Appendix A – List of Bridges/ Girders

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1	STSS	23	MGBU	G10	Steel Built-Up	N	1	42.4	-52.26	5.25		5.25		13	3	1912
2	STSS	23	MGBU	G11	Steel Built-Up	N	1	42.4	-52.26	5.25		7.5		13	3	1912
3	STSS	23	MGBU	G2	Steel Built-Up	N	1	42.4	-52.26	7.5		5.25		13	3	1912
4	STSS	23	MGBU	G3	Steel Built-Up	N	1	42.4	-52.26	5.25		5.25		13	3	1912
5	STSS	23	MGBU	G4	Steel Built-Up	N	1	42.4	-52.26	5.25		5.25		13	3	1912
6	STSS	24	MGBU	G10	Steel Built-Up	N	1	27	23.08	3.42		3.42		18	4	1912
7	STSS	24	MGBU	G3	Steel Built-Up	N	1	27	23.08	5.18		5.27		18	4	1912
8	STSS	24	MGBU	G4	Steel Built-Up	N	1	27	23.08	5.27		5.07		18	4	1912
9	STSS	24	MGBU	G5	Steel Built-Up	N	1	27	23.08	5.07		5.63		18	4	1912
10	STSS	24	MGBU	G6	Steel Built-Up	N	1	27	23.08	5.63		5.63		18	4	1912
11	STSS	24	MGBU	G7	Steel Built-Up	N	1	27	23.08	5.63		5.63		18	4	1912
12	STSS	24	MGBU	G8	Steel Built-Up	N	1	27	23.08	5.63		5.02		18	4	1912
13	STSS	24	MGBU	G9	Steel Built-Up	N	1	27	23.08	5.02		3.42		18	4	1912
14	STSS	25	MGBU	Member_1	Steel Built-Up	N	1	30	0	0.53	*	5.67		6	2	1934
15	STSS	25	MGBU	Member_2	Steel Built-Up	N	1	30	0	5.67		5.67		6	2	1934
16	STSS	25	MGBU	Member_5	Steel Built-Up	N	1	30	0	5.67		5.67		6	2	1934
17	STSS	26	MGSP	G2	Steel Plate	Y	1	36	0	5.33		5.33		15	4	2004
18	STSS	27	MGSP	G1	Steel Plate	Y	1	36.75	0	0.59	*	4.5		8	2	1928
19	STSS	27	MGSP	G2	Steel Plate	Y	1	36.75	0	4.5		4.5		8	2	1928
20	STSS	28	MGSP	G1	Steel Plate	Y	1	31.3	10	0.91	*	4.67		7	2	1936
21	STSS	28	MGSP	G2	Steel Plate	Y	1	31.3	10	4.67		4.67		7	2	1936
22	STSS	29	MGSP	G1	Steel Plate	Y	1	44.83	-45	0.92	*	6.33		6	2	1939
23	STSS	29	MGSP	G2	Steel Plate	Y	1	44.83	-45	6.33		6.33		6	2	1939
24	STSS	29	MGSP	G5	Steel Plate	Y	1	44.83	-45	6.33		6.33		6	2	1939
25	STSS	30	MGSP	G1	Steel Plate	N	1	31	-35	1.06	*	7.21		6	2	1941
26	STSS	30	MGSP	G2	Steel Plate	N	1	31	-35	7.21		7.21		6	2	1941
27	STSS	31	MGSP	G2	Steel Plate	Y	1	43.6	-35	4.63		4.63		9	3	1936
28	STSS	31	MGSP	G9	Steel Plate	Y	1	43.6	-35	4.63		1.66	*	9	3	1936

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
29	STSS	32	MGSP	G1	Steel Plate	N	1	31	-35	1.06	*	7.21		6	2	1941
30	STSS	32	MGSP	G2	Steel Plate	N	1	31	-35	7.21		7.21		6	2	1941
31	STSS	33	MGSP	Fascia_Girder_G1	Steel Plate	Y	1	44	0	1.33	*	5.34		6	2	1968
32	STSS	33	MGSP	Interior_Girder_G2	Steel Plate	Y	1	44	0	5.34		5.34		6	2	1968
33	STSS	34	MGRB	G1	Steel Rolled Beam	Y	1	43.17	30	3.08	*	4.25		9	3	1929
34	STSS	34	MGRB	G2	Steel Rolled Beam	Y	1	43.17	30	4.25		4		9	3	1929
35	STSS	34	MGRB	G5	Steel Rolled Beam	Y	1	43.17	30	4		4		9	3	1929
36	STSS	35	MGRB	G8	Steel Rolled Beam	N	1	37.67	0	2.79		1.23	*	8	2	1926
37	STSS	36	MGRB	G1	Steel Rolled Beam	Y	1	27	0	1.33	*	3.25		13	2	1900
38	STSS	36	MGRB	G2	Steel Rolled Beam	Y	1	27	0	3.25		2.75		13	2	1900
39	STSS	36	MGRB	G3	Steel Rolled Beam	Y	1	27	0	2.75		0.92		13	2	1900
40	STSS	36	MGRB	G4	Steel Rolled Beam	Y	1	27	0	0.92		3.75		13	2	1900
41	STSS	36	MGRB	G5	Steel Rolled Beam	Y	1	27	0	3.75		3.75		13	2	1900
42	STSS	37	MGRB	G1	Steel Rolled Beam	Y	1	22	0	0.42	*	3.21		7	1	1900
43	STSS	37	MGRB	G2	Steel Rolled Beam	Y	1	22	0	3.21		3.29		7	1	1900
44	STSS	37	MGRB	G3	Steel Rolled Beam	Y	1	22	0	3.29		3.29		7	1	1900
45	STSS	37	MGRB	G7	Steel Rolled Beam	Y	1	22	0	3.21		0.42	*	7	1	1900
46	STSS	38	MGRB	G1	Steel Rolled Beam	Y	1	27.7	-40	1.88	*	4.13		7	2	1900
47	STSS	38	MGRB	G2	Steel Rolled Beam	Y	1	27.7	-40	4.13		4.13		7	2	1900
48	STSS	39	MGRB	G1	Steel Rolled Beam	Y	1	30	0	0.88	*	3.5		18	3	1925
49	STSS	39	MGRB	G2	Steel Rolled Beam	Y	1	30	0	3.5		3.5		18	3	1925
50	STSS	39	MGRB	G3	Steel Rolled Beam	Y	1	30	0	3.5		3.5		18	3	1925
51	STSS	39	MGRB	G4	Steel Rolled Beam	Y	1	30	0	3.5		3.5		18	3	1925
52	STSS	39	MGRB	G5	Steel Rolled Beam	Y	1	30	0	3.5		3.5		18	3	1925
53	STSS	39	MGRB	G6	Steel Rolled Beam	Y	1	30	0	3.5		3.5		18	3	1925
54	STSS	40	MGRB	G1	Steel Rolled Beam	Y	1	34.33	-19.29	3.67	*	8.25		6	3	1902

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
55	STSS	40	MGRB	G2	Steel Rolled Beam	Y	1	34.33	-19.29	8.25		8.72		6	3	1902
56	STSS	40	MGRB	G3	Steel Rolled Beam	Y	1	34.33	-19.29	8.72		8.72		6	3	1902
57	STSS	40	MGRB	G4	Steel Rolled Beam	Y	1	34.33	-19.29	8.72		8.72		6	3	1902
58	STSS	40	MGRB	G5	Steel Rolled Beam	Y	1	34.33	-19.29	8.72		8.25		6	3	1902
59	STSS	40	MGRB	G6	Steel Rolled Beam	Y	1	34.33	-19.29	8.25		3.67	*	6	3	1902
60	STSS	41	MGRB	Fascia_Girder_G1	Steel Rolled Beam	Y	1	22	9	0.45	*	3.1		12	2	1907
61	STSS	41	MGRB	Fascia_Girder_G12	Steel Rolled Beam	Y	1	22	9	2.85		0.45	*	12	2	1907
62	STSS	41	MGRB	Interior_Girder_G6	Steel Rolled Beam	Y	1	22	9	3.1		2.85		12	2	1907
63	STSS	41	MGRB	Interior_Girder_G7	Steel Rolled Beam	Y	1	22	9	2.85		2.85		12	2	1907
64	STSS	41	MGRB	Interiro_Girder_G2	Steel Rolled Beam	Y	1	22	9	3.1		3.1		12	2	1907
65	STSS	42	MGRB	G1	Steel Rolled Beam	Y	1	48	0	1.08	*	6		7	2	1911
66	STSS	42	MGRB	G2	Steel Rolled Beam	Y	1	48	0	6		6		7	2	1911
67	STSS	42	MGRB	G3	Steel Rolled Beam	Y	1	48	0	6		6		7	2	1911
68	STSS	42	MGRB	G4	Steel Rolled Beam	Y	1	48	0	6		6		7	2	1911
69	STSS	42	MGRB	G5	Steel Rolled Beam	Y	1	48	0	6		6		7	2	1911
70	STSS	42	MGRB	G6	Steel Rolled Beam	Y	1	48	0	6		6		7	2	1911
71	STSS	42	MGRB	G7	Steel Rolled Beam	Y	1	48	0	6		1.08	*	7	2	1911
72	STSS	43	MGRB	G1	Steel Rolled Beam	N	1	36.67	30	0.38	*	6.42		4	1	1912
73	STSS	43	MGRB	G2	Steel Rolled Beam	N	1	36.67	30	6.42		6.42		4	1	1912
74	STSS	43	MGRB	G3	Steel Rolled Beam	N	1	36.67	30	6.42		6.42		4	1	1912
75	STSS	43	MGRB	G4	Steel Rolled Beam	N	1	36.67	30	6.42		0.37	*	4	1	1912
76	STSS	44	MGRB	3_-_Center	Steel Rolled Beam	Y	1	45.06	-45	6.75		6.75		5	2	1920
77	STSS	45	MGRB	G1	Steel Rolled Beam	Y	1	35	0	2.42	*	6.17		4	2	
78	STSS	45	MGRB	G2	Steel Rolled Beam	Y	1	35	0	6.17		6.17		4	2	
79	STSS	46	MGRB	G1	Steel Rolled Beam	Y	1	52.38	0	1.42	*	5.17		5	2	1920
80	STSS	46	MGRB	G2	Steel Rolled Beam	Y	1	52.38	0	5.17		5.17		5	2	1920
81	STSS	46	MGRB	G5	Steel Rolled Beam	Y	1	52.38	0	5.17		1.42	*	5	2	1920
82	STSS	47	MGRB	G1	Steel Rolled Beam	N	1	50.17	22	1.46	*	5.17		5	2	1921

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
83	STSS	47	MGRB	G2	Steel Rolled Beam	N	1	50.17	22	5.17		5.17		5	2	1921
84	STSS	48	MGRB	G1	Steel Rolled Beam	N	1	48.27	40	1.5	*	6		4	1	1930
85	STSS	48	MGRB	G2	Steel Rolled Beam	N	1	48.27	40	6		6		4	1	1930
86	STSS	49	MGRB	G1	Steel Rolled Beam	N	1	46.67	0	4.08	*	6.67		4	2	1922
87	STSS	49	MGRB	G2	Steel Rolled Beam	N	1	46.67	0	6.67		6.67		4	2	1922
88	STSS	49	MGRB	G3	Steel Rolled Beam	N	1	46.67	0	6.67		6.67		4	2	1922
89	STSS	49	MGRB	G4	Steel Rolled Beam	N	1	46.67	0	6.67		4.08	*	4	2	1922
90	STSS	50	MGRB	G1	Steel Rolled Beam	N	1	42.08	20	2.21	*	8.08		4	2	1922
91	STSS	50	MGRB	G2	Steel Rolled Beam	N	1	42.08	20	8.08		8.08		4	2	1922
92	STSS	51	MGRB	G1	Steel Rolled Beam	Y	1	45	0	0.75	*	4.33		7	2	1923
93	STSS	51	MGRB	G2	Steel Rolled Beam	Y	1	45	0	4.33		4.33		7	2	1923
94	STSS	52	MGRB	G1	Steel Rolled Beam	N	1	48.08	0	1.5	*	6		4	1	1932
95	STSS	52	MGRB	G2	Steel Rolled Beam	N	1	48.08	0	6		6		4	1	1932
96	STSS	53	MGRB	G1	Steel Rolled Beam	Y	1	38	0	0.63	*	4.75		8	2	1935
97	STSS	53	MGRB	G2	Steel Rolled Beam	Y	1	38	0	4.75		4.75		8	2	1935
98	STSS	53	MGRB	G3	Steel Rolled Beam	Y	1	38	0	4.75		4.75		8	2	1935
99	STSS	53	MGRB	G4	Steel Rolled Beam	Y	1	38	0	4.75		4.75		8	2	1935
100	STSS	53	MGRB	G5	Steel Rolled Beam	Y	1	38	0	4.75		4.75		8	2	1935
101	STSS	53	MGRB	G6	Steel Rolled Beam	Y	1	38	0	4.75		4.75		8	2	1935
102	STSS	53	MGRB	G7	Steel Rolled Beam	Y	1	38	0	4.75		4.75		8	2	1935
103	STSS	53	MGRB	G8	Steel Rolled Beam	Y	1	38	0	4.75		0.63	*	8	2	1935
104	STSS	54	MGRB	G1_Facia_Girder	Steel Rolled Beam	Y	1	40.3	30	0.83	*	4.5		8	2	1928
105	STSS	54	MGRB	G2_First_Interior_Girder	Steel Rolled Beam	Y	1	40.3	30	4.5		4.5		8	2	1928
106	STSS	54	MGRB	G8	Steel Rolled Beam	Y	1	40.3	30	4.5		0.83	*	8	2	1928
107	STSS	55	MGRB	G1	Steel Rolled Beam	N	1	51.67	0	2.5	*	6.67		4	2	1931
108	STSS	55	MGRB	G2	Steel Rolled Beam	N	1	51.67	0	6.67		6.67		4	2	1931
109	STSS	56	MGRB	G1	Steel Rolled Beam	N	1	48.42	-36.83	1.5	*	6		4	2	1931

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
110	STSS	56	MGRB	G2	Steel Rolled Beam	N	1	48.42	-36.83	6		6		4	2	1931
111	STSS	57	MGRB	G1	Steel Rolled Beam	Y	1	33	30	2.95	*	4.5		7	2	1931
112	STSS	57	MGRB	G4	Steel Rolled Beam	Y	1	33	30	4.5		4.5		7	2	1931
113	STSS	58	MGRB	G1	Steel Rolled Beam	Y	1	25.8	30	0.56	*	8.25		9	4	1931
114	STSS	58	MGRB	G2	Steel Rolled Beam	Y	1	25.8	30	8.25		8		9	4	1931
115	STSS	58	MGRB	G3	Steel Rolled Beam	Y	1	25.8	30	8		8		9	4	1931
116	STSS	58	MGRB	G4	Steel Rolled Beam	Y	1	25.8	30	8		8		9	4	1931
117	STSS	58	MGRB	G5	Steel Rolled Beam	Y	1	25.8	30	8		8		9	4	1931
118	STSS	58	MGRB	G6	Steel Rolled Beam	Y	1	25.8	30	8		8.25		9	4	1931
119	STSS	58	MGRB	G7	Steel Rolled Beam	Y	1	25.8	30	8.25		2.68		9	4	1931
120	STSS	58	MGRB	G8	Steel Rolled Beam	Y	1	25.8	30	2.68		7.71		9	4	1931
121	STSS	58	MGRB	G9	Steel Rolled Beam	Y	1	25.8	30	7.71		0.58	*	9	4	1931
122	STSS	59	MGRB	Member_1	Steel Rolled Beam	Y	1	34.42	0	2.14	*	4.94		8	2	1931
123	STSS	59	MGRB	Member_2	Steel Rolled Beam	Y	1	34.42	0	4.94		4.94		8	2	1931
124	STSS	60	MGRB	G1	Steel Rolled Beam	Y	1	25.86	30	0.75	*	8.25		9	4	1931
125	STSS	60	MGRB	G2	Steel Rolled Beam	Y	1	25.86	30	8.25		8		9	4	1931
126	STSS	60	MGRB	G3	Steel Rolled Beam	Y	1	25.86	30	8		8		9	4	1931
127	STSS	60	MGRB	G4	Steel Rolled Beam	Y	1	25.86	30	8		8		9	4	1931
128	STSS	60	MGRB	G5	Steel Rolled Beam	Y	1	25.86	30	8		8		9	4	1931
129	STSS	60	MGRB	G6	Steel Rolled Beam	Y	1	25.86	30	8		8.25		9	4	1931
130	STSS	60	MGRB	G7	Steel Rolled Beam	Y	1	25.86	30	8.25		2.71		9	4	1931
131	STSS	60	MGRB	G8	Steel Rolled Beam	Y	1	25.86	30	2.71		7.71		9	4	1931
132	STSS	60	MGRB	G9	Steel Rolled Beam	Y	1	25.86	30	7.71		0.75	*	9	4	1931
133	STSS	61	MGRB	G1	Steel Rolled Beam	N	1	51.5	-45	2.5	*	6.67		4	2	1932
134	STSS	61	MGRB	G2	Steel Rolled Beam	N	1	51.5	-45	6.67		6.67		4	2	1932
135	STSS	62	MGRB	G1	Steel Rolled Beam	N	1	48	-25	1.5	*	6		4	1	1932
136	STSS	62	MGRB	G2	Steel Rolled Beam	N	1	48	-25	6		6		4	1	1932
137	STSS	63	MGRB	G1	Steel Rolled Beam	N	1	46.67	-15	1.5	*	6		4	1	1932

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
138	STSS	63	MGRB	G2	Steel Rolled Beam	N	1	46.67	-15	6		6		4	1	1932
139	STSS	64	MGRB	G1	Steel Rolled Beam	N	1	28.52	0	1.5	*	6		4	1	1932
140	STSS	64	MGRB	G2	Steel Rolled Beam	N	1	28.52	0	6		6		4	1	1932
141	STSS	65	MGRB	G1	Steel Rolled Beam	N	1	48.81	-15	1.5	*	6		4	1	1932
142	STSS	65	MGRB	G2	Steel Rolled Beam	N	1	48.81	-15	6		6		4	1	1932
143	STSS	66	MGRB	G1	Steel Rolled Beam	Y	1	49.17	-40	2.17	*	4.19		13	4	1932
144	STSS	66	MGRB	G10	Steel Rolled Beam	Y	1	49.17	-40	4.19		6.02		13	4	1932
145	STSS	66	MGRB	G11	Steel Rolled Beam	Y	1	49.17	-40	6.02		6.02		13	4	1932
146	STSS	66	MGRB	G13	Steel Rolled Beam	Y	1	49.17	-40	6.02		2.17	*	13	4	1932
147	STSS	66	MGRB	G6	Steel Rolled Beam	Y	1	49.17	-40	4.19		4.19		13	4	1932
148	STSS	67	MGRB	G1_-_Left_Fascia	Steel Rolled Beam	Y	1	42	45	0.96	*	4.63		7	2	1936
149	STSS	67	MGRB	G2_-_First_Left_Interior	Steel Rolled Beam	Y	1	42	45	4.63		4.63		7	2	1936
150	STSS	68	MGRB	G1	Steel Rolled Beam	N	1	47.96	0	1.67	*	7.33		4	2	1937
151	STSS	68	MGRB	G2	Steel Rolled Beam	N	1	47.96	0	7.33		7.33		4	2	1937
152	STSS	69	MGRB	G1	Steel Rolled Beam	Y	1	52.25	0	1.01	*	5.33		6	2	1935
153	STSS	69	MGRB	G2	Steel Rolled Beam	Y	1	52.25	0	5.33		5.33		6	2	1935
154	STSS	70	MGRB	Member_1	Steel Rolled Beam	Y	1	34.6	15	0.75	*	3.2		7	1	1934
155	STSS	70	MGRB	Member_2	Steel Rolled Beam	Y	1	34.6	15	3.2		3.2		7	1	1934
156	STSS	70	MGRB	Member_3	Steel Rolled Beam	Y	1	34.6	15	3.2		3.2		7	1	1934
157	STSS	70	MGRB	Member_4	Steel Rolled Beam	Y	1	34.6	15	3.2		3.2		7	1	1934
158	STSS	70	MGRB	Member_7	Steel Rolled Beam	Y	1	34.6	15	3.2		0.75	*	7	1	1934
159	STSS	71	MGRB	G1	Steel Rolled Beam	N	1	43.5	0	0.83	*	2.42		7	2	1934
160	STSS	71	MGRB	G2	Steel Rolled Beam	Y	1	43.5	0	2.42		4.83		7	2	1934
161	STSS	71	MGRB	G3	Steel Rolled Beam	Y	1	43.5	0	4.83		4.83		7	2	1934
162	STSS	71	MGRB	G4	Steel Rolled Beam	Y	1	43.5	0	4.83		4.83		7	2	1934
163	STSS	72	MGRB	G1	Steel Rolled Beam	N	1	51.08	40	2.5	*	6.67		4	2	1935
164	STSS	72	MGRB	G2	Steel Rolled Beam	N	1	51.08	40	6.67		6.67		4	2	1935
165	STSS	73	MGRB	G1	Steel Rolled Beam	Y	1	50.88	-9.78	2.38	*	7.25		7	3	1935

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
166	STSS	74	MGRB	G1	Steel Rolled Beam	N	1	40.33	0	2	*	5.5		5	2	1939
167	STSS	74	MGRB	G2	Steel Rolled Beam	N	1	40.33	0	5.5		5.5		5	2	1939
168	STSS	75	MGRB	G1	Steel Rolled Beam	Y	1	32	24	0.03	*	3.91		11	3	1935
169	STSS	75	MGRB	G10	Steel Rolled Beam	Y	1	32	24	3.91		3.91		11	3	1935
170	STSS	75	MGRB	G11	Steel Rolled Beam	Y	1	32	24	3.91		0.03	*	11	3	1935
171	STSS	75	MGRB	G2	Steel Rolled Beam	Y	1	32	24	3.91		3.91		11	3	1935
172	STSS	75	MGRB	G3	Steel Rolled Beam	Y	1	32	24	3.91		3.91		11	3	1935
173	STSS	75	MGRB	G4	Steel Rolled Beam	Y	1	32	24	3.91		3.91		11	3	1935
174	STSS	75	MGRB	G5	Steel Rolled Beam	Y	1	32	24	3.91		3.91		11	3	1935
175	STSS	75	MGRB	G6	Steel Rolled Beam	Y	1	32	24	3.91		3.91		11	3	1935
176	STSS	75	MGRB	G7	Steel Rolled Beam	Y	1	32	24	3.91		3.91		11	3	1935
177	STSS	75	MGRB	G8	Steel Rolled Beam	Y	1	32	24	3.91		3.91		11	3	1935
178	STSS	75	MGRB	G9	Steel Rolled Beam	Y	1	32	24	3.91		3.91		11	3	1935
179	STSS	76	MGRB	G1	Steel Rolled Beam	N	1	40.09	-25	1.67	*	6		4	2	1936
180	STSS	76	MGRB	G2	Steel Rolled Beam	N	1	40.09	-25	6		6		4	2	1936
181	STSS	77	MGRB	G1_-_Left_Fascia	Steel Rolled Beam	Y	1	42	45	0.96	*	4.63		7	2	1936
182	STSS	77	MGRB	G2_-_First_Left_Interior	Steel Rolled Beam	Y	1	42	45	4.63		4.63		7	2	1936
183	STSS	78	MGRB	G2	Steel Rolled Beam	Y	1	51.92	10	4.13		4.13		7	2	1936
184	STSS	78	MGRB	G7	Steel Rolled Beam	Y	1	51.92	10	4.13		1.08	*	7	2	1936
185	STSS	79	MGRB	Fascia_Girder_G1	Steel Rolled Beam	Y	1	47.5	30	2.35	*	4.75		7	2	1936
186	STSS	79	MGRB	Interior_Girder_G2	Steel Rolled Beam	Y	1	47.5	30	4.75		4.5		7	2	1936
187	STSS	80	MGRB	G1	Steel Rolled Beam	N	1	34.04	0	1.67	*	6.67		4	2	1937
188	STSS	80	MGRB	G2	Steel Rolled Beam	N	1	34.04	0	6.67		6.67		4	2	1937
189	STSS	81	MGRB	G1	Steel Rolled Beam	Y	1	51.67	-35	3.33	*	6.67		4	2	1937
190	STSS	81	MGRB	G2	Steel Rolled Beam	Y	1	51.67	-35	6.67		6.67		4	2	1937
191	STSS	82	MGRB	G1	Steel Rolled Beam	Y	1	42.5	0	0.88	*	4.79		11	3	1937
192	STSS	82	MGRB	G2	Steel Rolled Beam	Y	1	42.5	0	4.79		4.79		11	3	1937
193	STSS	82	MGRB	G3	Steel Rolled Beam	Y	1	42.5	0	4.79		4.79		11	3	1937

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
194	STSS	83	MGRB	G1	Steel Rolled Beam	Y	1	41.67	0	3.33	*	6.67		4	2	1937
195	STSS	83	MGRB	G2	Steel Rolled Beam	Y	1	41.67	0	6.67		6.67		4	2	1937
196	STSS	83	MGRB	G3	Steel Rolled Beam	Y	1	41.67	0	6.67		6.67		4	2	1937
197	STSS	83	MGRB	G4	Steel Rolled Beam	Y	1	41.67	0	6.67		3.33	*	4	2	1937
198	STSS	84	MGRB	G1	Steel Rolled Beam	Y	1	40.19	-30	2.33	*	7.33		4	2	1938
199	STSS	84	MGRB	G2	Steel Rolled Beam	Y	1	40.19	-30	7.33		7.33		4	2	1938
200	STSS	85	MGRB	G1	Steel Rolled Beam	N	1	44.33	20	2	*	6.67		4	2	1939
201	STSS	85	MGRB	G2	Steel Rolled Beam	N	1	44.33	20	6.67		6.67		4	2	1939
202	STSS	86	MGRB	G1	Steel Rolled Beam	Y	1	47.96	-14.18	3.25	*	6.38		9	4	1938
203	STSS	86	MGRB	G2	Steel Rolled Beam	Y	1	47.96	-14.18	6.38		6.38		9	4	1938
204	STSS	86	MGRB	G3	Steel Rolled Beam	Y	1	47.96	-14.18	6.38		6.38		9	4	1938
205	STSS	86	MGRB	G4	Steel Rolled Beam	Y	1	47.96	-14.18	6.38		6.38		9	4	1938
206	STSS	86	MGRB	G5	Steel Rolled Beam	Y	1	47.96	-14.18	6.38		6.38		9	4	1938
207	STSS	86	MGRB	G6	Steel Rolled Beam	Y	1	47.96	-14.18	6.38		6.38		9	4	1938
208	STSS	86	MGRB	G7	Steel Rolled Beam	Y	1	47.96	-14.18	6.38		6.38		9	4	1938
209	STSS	86	MGRB	G8	Steel Rolled Beam	Y	1	47.96	-14.18	6.38		6.38		9	4	1938
210	STSS	86	MGRB	G9	Steel Rolled Beam	Y	1	47.96	-14.18	6.38		3.25	*	9	4	1938
211	STSS	87	MGRB	G1	Steel Rolled Beam	N	1	51.67	20	2	*	6		5	2	1939
212	STSS	87	MGRB	G2	Steel Rolled Beam	N	1	51.67	20	6		6		5	2	1939
213	STSS	88	MGRB	G1	Steel Rolled Beam	N	1	47.92	0	0.83	*	5.33		5	2	1939
214	STSS	88	MGRB	G2	Steel Rolled Beam	N	1	47.92	0	5.33		5.33		5	2	1939
215	STSS	89	MGRB	G1	Steel Rolled Beam	N	1	52	0	0.65	*	6.08		7	2	1939
216	STSS	89	MGRB	G2	Steel Rolled Beam	N	1	52	0	6.08		6.08		7	2	1939
217	STSS	89	MGRB	G6	Steel Rolled Beam	N	1	52	0	6.08		6.08		7	2	1939
218	STSS	89	MGRB	G7	Steel Rolled Beam	N	1	52	0	6.08		0.65	*	7	2	1939
219	STSS	90	MGRB	Fascia_Girder_G1	Steel Rolled Beam	N	1	38.8	-5	1.29	*	6.83		6	2	1939
220	STSS	90	MGRB	Fascia_Girder_G6	Steel Rolled Beam	N	1	38.8	-5	4.5		1.28	*	6	2	1939
221	STSS	90	MGRB	Interior_Girder_G2	Steel Rolled Beam	N	1	38.8	-5	6.83		6.83		6	2	1939

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
222	STSS	90	MGRB	Interior_Girder_G5	Steel Rolled Beam	N	1	38.8	-5	6.83		4.5		6	2	1939
223	STSS	91	MGRB	G1	Steel Rolled Beam	N	1	51.76	-10	2.5	*	8		4	2	1940
224	STSS	91	MGRB	G2	Steel Rolled Beam	N	1	51.76	-10	8		8		4	2	1940
225	STSS	92	MGRB	G1	Steel Rolled Beam	N	1	51.76	-10	2.5	*	8		4	2	1940
226	STSS	92	MGRB	G2	Steel Rolled Beam	N	1	51.76	-10	8		8		4	2	1940
227	STSS	92	MGRB	G3	Steel Rolled Beam	N	1	51.76	-10	8		8		4	2	1940
228	STSS	92	MGRB	G4	Steel Rolled Beam	N	1	51.76	-10	8		2.5	*	4	2	1940
229	STSS	93	MGRB	G1	Steel Rolled Beam	N	1	48.33	-30	2.08	*	5		5	2	1947
230	STSS	93	MGRB	G2	Steel Rolled Beam	N	1	48.33	-30	5		5		5	2	1947
231	STSS	94	MGRB	G1	Steel Rolled Beam	Y	1	45.33	-43.79	0.46	*	7.79		8	3	1942
232	STSS	94	MGRB	G2	Steel Rolled Beam	Y	1	45.33	-43.79	7.79		7.83		8	3	1942
233	STSS	94	MGRB	G3	Steel Rolled Beam	Y	1	45.33	-43.79	7.83		7.83		8	3	1942
234	STSS	95	MGRB	G1	Steel Rolled Beam	N	1	44.17	0	2.17	*	5.08		5	2	1949
235	STSS	95	MGRB	G3	Steel Rolled Beam	N	1	44.17	0	5.08		5.08		5	2	1949
236	STSS	96	MGRB	G1	Steel Rolled Beam	N	1	41.58	22	0.92	*	4.25		8	2	1940
237	STSS	96	MGRB	G2	Steel Rolled Beam	N	1	41.58	22	4.25		5.5		8	2	1940
238	STSS	96	MGRB	G3	Steel Rolled Beam	N	1	41.58	22	5.5		5.5		8	2	1940
239	STSS	96	MGRB	G4	Steel Rolled Beam	N	1	41.58	22	5.5		5.5		8	2	1940
240	STSS	97	MGRB	G1	Steel Rolled Beam	N	1	34.63	-30	2.08	*	6.67		4	2	1941
241	STSS	97	MGRB	G2	Steel Rolled Beam	N	1	34.63	-30	6.67		6.67		4	2	1941
242	STSS	98	MGRB	Fascia_Girder_G1	Steel Rolled Beam	N	1	43	0	0.5	*	3		8	2	1943
243	STSS	98	MGRB	Interior_Girder_G2	Steel Rolled Beam	N	1	43	0	3		3		8	2	1943
244	STSS	99	MGRB	G1	Steel Rolled Beam	N	1	48.17	0	2.17	*	6		3	1	1949
245	STSS	99	MGRB	G2	Steel Rolled Beam	N	1	48.17	0	6		6		3	1	1949
246	STSS	100	MGRB	G1	Steel Rolled Beam	N	1	41.44	30	2.13	*	5.5		6	2	1945
247	STSS	100	MGRB	G2	Steel Rolled Beam	N	1	41.44	30	5.5		5.5		6	2	1945
248	STSS	101	MGRB	3_-_Center	Steel Rolled Beam	N	1	41.25	0	6.75		6.75		5	2	1946
249	STSS	102	MGRB	G1	Steel Rolled Beam	N	1	49.88	0	2.17	*	6		4	2	1947

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
250	STSS	102	MGRB	G2	Steel Rolled Beam	N	1	49.88	0	6		6		4	2	1947
251	STSS	103	MGRB	G1	Steel Rolled Beam	N	1	48.18	45	2.08	*	5		5	2	1947
252	STSS	103	MGRB	G2	Steel Rolled Beam	N	1	48.18	45	5		5		5	2	1947
253	STSS	104	MGRB	G1	Steel Rolled Beam	N	1	43	0	0.73	*	4.85		11	3	1947
254	STSS	104	MGRB	G3	Steel Rolled Beam	N	1	43	0	4.85		4.85		11	3	1947
255	STSS	105	MGRB	G1	Steel Rolled Beam	Y	1	32.88	0	1.88	*	5.75		5	2	1947
256	STSS	105	MGRB	G2	Steel Rolled Beam	Y	1	32.88	0	5.75		5.75		5	2	1947
257	STSS	106	MGRB	G1	Steel Rolled Beam	N	1	40.33	23	2.08	*	6		4	2	1948
258	STSS	106	MGRB	G2	Steel Rolled Beam	N	1	40.33	23	6		6		4	2	1948
259	STSS	107	MGRB	G1	Steel Rolled Beam	N	1	33.92	10	2.17	*	6		4	2	1948
260	STSS	107	MGRB	G2	Steel Rolled Beam	N	1	33.92	10	6		6		4	2	1948
261	STSS	108	MGRB	G1	Steel Rolled Beam	N	1	46.31	-20	2.17	*	6		4	2	1948
262	STSS	108	MGRB	G2	Steel Rolled Beam	N	1	46.31	-20	6		6		4	2	1948
263	STSS	109	MGRB	G1	Steel Rolled Beam	N	1	50	35	2.17	*	5.08		5	2	1949
264	STSS	109	MGRB	G3	Steel Rolled Beam	N	1	50	35	5.08		5.08		5	2	1949
265	STSS	110	MGRB	G1	Steel Rolled Beam	Y	1	51.73	50	2.41	*	4.9		10	3	1949
266	STSS	110	MGRB	G2	Steel Rolled Beam	Y	1	51.73	50	4.9		4.9		10	3	1949
267	STSS	110	MGRB	G5	Steel Rolled Beam	Y	1	51.73	50	4.9		4.9		10	3	1949
268	STSS	110	MGRB	G9	Steel Rolled Beam	Y	1	51.73	50	4.9		4.9		10	3	1949
269	STSS	111	MGRB	G1	Steel Rolled Beam	N	1	50.17	0	2.17	*	6		4	2	1950
270	STSS	111	MGRB	G2	Steel Rolled Beam	N	1	50.17	0	6		6		4	2	1950
271	STSS	112	MGRB	G1	Steel Rolled Beam	N	1	28	0	3.46	*	5.5		4	2	1950
272	STSS	112	MGRB	G2	Steel Rolled Beam	N	1	28	0	5.5		5.5		4	2	1950
273	STSS	113	MGRB	G1	Steel Rolled Beam	Y	1	47.5	-45	2	*	8.5		5	2	1950
274	STSS	113	MGRB	G2	Steel Rolled Beam	Y	1	47.5	-45	8.5		8.5		5	2	1950
275	STSS	113	MGRB	G3	Steel Rolled Beam	Y	1	47.5	-45	8.5		8.5		5	2	1950
276	STSS	113	MGRB	G4	Steel Rolled Beam	Y	1	47.5	-45	8.5		8.5		5	2	1950
277	STSS	113	MGRB	G5	Steel Rolled Beam	Y	1	47.5	-45	8.5		2	*	5	2	1950

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
278	STSS	114	MGRB	G1	Steel Rolled Beam	N	1	31.5	0	0.28	*	3.21		8	2	1950
279	STSS	114	MGRB	G2	Steel Rolled Beam	N	1	31.5	0	3.21		3.19		8	2	1950
280	STSS	114	MGRB	G3	Steel Rolled Beam	N	1	31.5	0	3.19		3.17		8	2	1950
281	STSS	114	MGRB	G4	Steel Rolled Beam	N	1	31.5	0	3.17		3.17		8	2	1950
282	STSS	114	MGRB	G5	Steel Rolled Beam	N	1	31.5	0	3.17		3.17		8	2	1950
283	STSS	114	MGRB	G6	Steel Rolled Beam	N	1	31.5	0	3.17		3.17		8	2	1950
284	STSS	114	MGRB	G7	Steel Rolled Beam	N	1	31.5	0	3.17		3.25		8	2	1950
285	STSS	114	MGRB	G8	Steel Rolled Beam	N	1	31.5	0	3.25		0.29	*	8	2	1950
286	STSS	115	MGRB	G1	Steel Rolled Beam	Y	1	37.44	-13	0.97	*	5.86		8	3	1951
287	STSS	115	MGRB	G5	Steel Rolled Beam	Y	1	37.44	-13	5.86		5.86		8	3	1951
288	STSS	116	MGRB	G1	Steel Rolled Beam	N	1	30.23	-13	2.17	*	6		4	2	1952
289	STSS	116	MGRB	G2	Steel Rolled Beam	N	1	30.23	-13	6		6		4	2	1952
290	STSS	117	MGRB	Member_1	Steel Rolled Beam	Y	1	43	-3	2.5	*	7.84		6	3	1956
291	STSS	117	MGRB	Member_2	Steel Rolled Beam	Y	1	43	-3	7.84		7.84		6	3	1956
292	STSS	117	MGRB	Member_3	Steel Rolled Beam	Y	1	43	-3	7.84		7.84		6	3	1956
293	STSS	117	MGRB	Member_4	Steel Rolled Beam	Y	1	43	-3	7.84		7.84		6	3	1956
294	STSS	117	MGRB	Member_5	Steel Rolled Beam	Y	1	43	-3	7.84		7.84		6	3	1956
295	STSS	117	MGRB	Member_6	Steel Rolled Beam	Y	1	43	-3	7.84		2.5	*	6	3	1956
296	STSS	118	MGRB	G1	Steel Rolled Beam	N	1	50.08	0	2.17	*	6		4	2	1952
297	STSS	118	MGRB	G2	Steel Rolled Beam	N	1	50.08	0	6		6		4	2	1952
298	STSS	119	MGRB	G1	Steel Rolled Beam	Y	1	46.59	0.95	3	*	9		8	5	1958
299	STSS	119	MGRB	G2	Steel Rolled Beam	Y	1	46.59	0.95	9		9		8	5	1958
300	STSS	119	MGRB	G7	Steel Rolled Beam	Y	1	46.59	0.95	9		9		8	5	1958
301	STSS	119	MGRB	G8	Steel Rolled Beam	Y	1	46.59	0.95	9		2.5	*	8	5	1958
302	STSS	120	MGRB	G1	Steel Rolled Beam	Y	1	44	-15	2.5	*	4.98		8	2	1952
303	STSS	120	MGRB	G2	Steel Rolled Beam	Y	1	44	-15	4.98		6.42		8	2	1952
304	STSS	120	MGRB	G3	Steel Rolled Beam	Y	1	44	-15	6.42		6.42		8	2	1952
305	STSS	120	MGRB	G4	Steel Rolled Beam	Y	1	44	-15	6.42		6.42		8	2	1952

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
306	STSS	120	MGRB	G7	Steel Rolled Beam	Y	1	44	-15	6.42		6.19		8	2	1952
307	STSS	120	MGRB	G8	Steel Rolled Beam	Y	1	44	-15	6.19		1.25	*	8	2	1952
308	STSS	121	MGRB	G1	Steel Rolled Beam	Y	1	50.08	0	3.33	*	6		4	2	1952
309	STSS	121	MGRB	G2	Steel Rolled Beam	Y	1	50.08	0	6		6		4	2	1952
310	STSS	121	MGRB	G3	Steel Rolled Beam	Y	1	50.08	0	6		6		4	2	1952
311	STSS	121	MGRB	G4	Steel Rolled Beam	Y	1	50.08	0	6		3.33	*	4	2	1952
312	STSS	122	MGRB	Member_1	Steel Rolled Beam	Y	1	47	-1	3.19	*	7.34		8	4	1953
313	STSS	122	MGRB	Member_2	Steel Rolled Beam	Y	1	47	-1	7.34		7.34		8	4	1953
314	STSS	122	MGRB	Member_7	Steel Rolled Beam	Y	1	47	-1	7.34		7.34		8	4	1953
315	STSS	122	MGRB	Member_8	Steel Rolled Beam	Y	1	47	-1	7.34		3.19	*	8	4	1953
316	STSS	123	MGRB	G1	Steel Rolled Beam	N	1	50.06	0	2.17	*	6		4	2	1953
317	STSS	123	MGRB	G2	Steel Rolled Beam	N	1	50.06	0	6		6		4	2	1953
318	STSS	124	MGRB	G1	Steel Rolled Beam	N	1	43.77	30	2.33	*	6.67		4	2	1954
319	STSS	124	MGRB	G2	Steel Rolled Beam	N	1	43.77	30	6.67		6.67		4	2	1954
320	STSS	125	MGRB	G1	Steel Rolled Beam	N	1	33.91	15	2.83	*	8.67		4	2	1954
321	STSS	125	MGRB	G2	Steel Rolled Beam	N	1	33.91	15	8.67		8.67		4	2	1954
322	STSS	126	MGRB	Left_Fascia	Steel Rolled Beam	Y	1	46.25	25.38	0.81	*	5.38		10	3	1954
323	STSS	126	MGRB	Right_Fascia	Steel Rolled Beam	Y	1	46.25	25.38	5.38		0.81	*	10	3	1954
324	STSS	126	MGRB	Typical_Interior	Steel Rolled Beam	Y	1	46.25	25.38	5.38		5.38		10	3	1954
325	STSS	127	MGRB	Member_1	Steel Rolled Beam	Y	1	48.83	-16	2.58	*	7.33		8	4	1954
326	STSS	127	MGRB	Member_2	Steel Rolled Beam	Y	1	48.83	-16	7.33		7.33		8	4	1954
327	STSS	128	MGRB	Member_1	Steel Rolled Beam	Y	1	48.5	14	3.19	*	7.34		8	4	1954
328	STSS	128	MGRB	Member_2	Steel Rolled Beam	Y	1	48.5	14	7.34		7.34		8	4	1954
329	STSS	128	MGRB	Member_7	Steel Rolled Beam	Y	1	48.5	14	7.34		7.34		8	4	1954
330	STSS	128	MGRB	Member_8	Steel Rolled Beam	Y	1	48.5	14	7.34		3.19	*	8	4	1954
331	STSS	129	MGRB	Member_1	Steel Rolled Beam	Y	1	47.69	0	3	*	9		8	5	1954
332	STSS	129	MGRB	Member_2	Steel Rolled Beam	Y	1	47.69	0	9		9		8	5	1954
333	STSS	129	MGRB	Member_7	Steel Rolled Beam	Y	1	47.69	0	9		9		8	5	1954

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
334	STSS	129	MGRB	Member_8	Steel Rolled Beam	Y	1	47.69	0	9		2.5	*	8	5	1954
335	STSS	130	MGRB	G1	Steel Rolled Beam	Y	1	44.08	0	3.58	*	6		4	2	1955
336	STSS	130	MGRB	G2	Steel Rolled Beam	Y	1	44.08	0	6		6		4	2	1955
337	STSS	131	MGRB	G1	Steel Rolled Beam	Y	1	49.67	-35	3.58	*	6		4	2	1955
338	STSS	131	MGRB	G2	Steel Rolled Beam	Y	1	49.67	-35	6		6		4	2	1955
339	STSS	132	MGRB	G1	Steel Rolled Beam	N	1	40	0	4.04	*	4.17		5	2	1955
340	STSS	132	MGRB	G2	Steel Rolled Beam	N	1	40	0	4.17		4.17		5	2	1955
341	STSS	133	MGRB	Member_10	Steel Rolled Beam	Y	1	51.8	-15	7.25		7.25		8	4	1955
342	STSS	133	MGRB	Member_9	Steel Rolled Beam	Y	1	51.8	-15	2.88	*	7.25		8	4	1955
343	STSS	134	MGRB	G1	Steel Rolled Beam	Y	1	43.17	0	2.1	*	9.5		5	2	1956
344	STSS	134	MGRB	G2	Steel Rolled Beam	Y	1	43.17	0	9.5		9.5		5	2	1956
345	STSS	134	MGRB	G3	Steel Rolled Beam	Y	1	43.17	0	9.5		9.5		5	2	1956
346	STSS	134	MGRB	G4	Steel Rolled Beam	Y	1	43.17	0	9.5		9.5		5	2	1956
347	STSS	134	MGRB	G5	Steel Rolled Beam	Y	1	43.17	0	9.5		2.17	*	5	2	1956
348	STSS	135	MGRB	Beam_A	Steel Rolled Beam	Y	1	44.17	0	0.92	*	5.04		9	3	1957
349	STSS	135	MGRB	Beam_B	Steel Rolled Beam	Y	1	44.17	0	5.04		5.04		9	3	1957
350	STSS	135	MGRB	Beam_C	Steel Rolled Beam	Y	1	44.17	0	5.04		6		9	3	1957
351	STSS	135	MGRB	Beam_D	Steel Rolled Beam	Y	1	44.17	0	6		6		9	3	1957
352	STSS	135	MGRB	Beam_G	Steel Rolled Beam	Y	1	44.17	0	6		5.54		9	3	1957
353	STSS	135	MGRB	Beam_H	Steel Rolled Beam	Y	1	44.17	0	5.54		5.54		9	3	1957
354	STSS	135	MGRB	Beam_I	Steel Rolled Beam	Y	1	44.17	0	5.54		0.92	*	9	3	1957
355	STSS	136	MGRB	Beam_J	Steel Rolled Beam	Y	1	39.77	19.4	5.58		0.84	*	9	3	1957
356	STSS	136	MGRB	Beam_K	Steel Rolled Beam	Y	1	39.77	19.4	5.58		5.58		9	3	1957
357	STSS	136	MGRB	Beam_L	Steel Rolled Beam	Y	1	39.77	19.4	6		5.58		9	3	1957
358	STSS	136	MGRB	Beam_M	Steel Rolled Beam	Y	1	39.77	19.4	6		6		9	3	1957
359	STSS	136	MGRB	Beam_N	Steel Rolled Beam	Y	1	39.77	19.4	6		6		9	3	1957
360	STSS	136	MGRB	Beam_O	Steel Rolled Beam	Y	1	39.77	19.4	6		6		9	3	1957
361	STSS	136	MGRB	Beam_P	Steel Rolled Beam	Y	1	39.77	19.4	5.08		6		9	3	1957

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
362	STSS	136	MGRB	Beam_Q	Steel Rolled Beam	Y	1	39.77	19.4	5.08		5.08		9	3	1957
363	STSS	136	MGRB	Beam_R	Steel Rolled Beam	Y	1	39.77	19.4	0.83	*	5.08		9	3	1957
364	STSS	137	MGRB	2nd_N_Int	Steel Rolled Beam	N	1	43.92	0	6		6		6	2	1958
365	STSS	138	MGRB	G1	Steel Rolled Beam	N	1	32.67	0	1	*	8		4	2	1958
366	STSS	138	MGRB	G2	Steel Rolled Beam	N	1	32.67	0	8		8		4	2	1958
367	STSS	139	MGRB	G1	Steel Rolled Beam	N	1	49.98	10	2.17	*	6		4	2	1958
368	STSS	139	MGRB	G2	Steel Rolled Beam	N	1	49.98	10	6		6		4	2	1958
369	STSS	140	MGRB	G1	Steel Rolled Beam	Y	1	46.08	0	3.33	*	6		4	2	1959
370	STSS	140	MGRB	G2	Steel Rolled Beam	Y	1	46.08	0	6		6		4	2	1959
371	STSS	141	MGRB	G1	Steel Rolled Beam	Y	1	52.06	-0.73	3.35	*	9.67		4	2	1959
372	STSS	141	MGRB	G2	Steel Rolled Beam	Y	1	52.06	-0.73	9.67		9.67		4	2	1959
373	STSS	142	MGRB	G1	Steel Rolled Beam	Y	1	47.58	37.1	2.04	*	7		9	4	1959
374	STSS	142	MGRB	G2	Steel Rolled Beam	Y	1	47.58	37.1	7		7		9	4	1959
375	STSS	142	MGRB	G3	Steel Rolled Beam	Y	1	47.58	37.1	7		7		9	4	1959
376	STSS	142	MGRB	G4	Steel Rolled Beam	Y	1	47.58	37.1	7		7		9	4	1959
377	STSS	142	MGRB	G5	Steel Rolled Beam	Y	1	47.58	37.1	7		7		9	4	1959
378	STSS	142	MGRB	G6	Steel Rolled Beam	Y	1	47.58	37.1	7		7		9	4	1959
379	STSS	142	MGRB	G7	Steel Rolled Beam	Y	1	47.58	37.1	7		4.5		9	4	1959
380	STSS	142	MGRB	G8	Steel Rolled Beam	Y	1	47.58	37.1	4.5		6		9	4	1959
381	STSS	142	MGRB	G9	Steel Rolled Beam	Y	1	47.58	37.1	6		3.42	*	9	4	1959
382	STSS	143	MGRB	3_-_2nd_E_Int-x	Steel Rolled Beam	Y	1	35	0	7.17		7.17		8	4	1960
383	STSS	144	MGRB	G1	Steel Rolled Beam	N	1	26.08	-17	2.13	*	6		4	2	1960
384	STSS	144	MGRB	G2	Steel Rolled Beam	N	1	26.08	-17	6		6		4	2	1960
385	STSS	145	MGRB	G1	Steel Rolled Beam	N	1	50.08	-30	2.29	*	6.67		4	2	1960
386	STSS	145	MGRB	G2	Steel Rolled Beam	N	1	50.08	-30	6.67		6.67		4	2	1960
387	STSS	146	MGRB	Member_1	Steel Rolled Beam	N	1	34.67	-12	2.08	*	8.75		7	4	1953
388	STSS	146	MGRB	Member_2	Steel Rolled Beam	N	1	34.67	-12	8.75		8.75		7	4	1953
389	STSS	147	MGRB	G1	Steel Rolled Beam	Y	1	39	13	2.5	*	7.75		5	2	1960

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
390	STSS	147	MGRB	G2	Steel Rolled Beam	Y	1	39	13	7.75		7.75		5	2	1960
391	STSS	148	MGRB	Fascia_Girder_G1	Steel Rolled Beam	Y	1	49.1	19	1.87	*	7.38		7	3	1960
392	STSS	148	MGRB	Interior_Girder_G2	Steel Rolled Beam	Y	1	49.1	19	7.38		7.38		7	3	1960
393	STSS	149	MGRB	G1	Steel Rolled Beam	N	1	48.08	0	2.13	*	6		4	2	1961
394	STSS	149	MGRB	G2	Steel Rolled Beam	N	1	48.08	0	6		6		4	2	1961
395	STSS	150	MGRB	G1	Steel Rolled Beam	N	1	46.08	0	2.13	*	6.67		4	2	1961
396	STSS	150	MGRB	G2	Steel Rolled Beam	N	1	46.08	0	6.67		6.67		4	2	1961
397	STSS	151	MGRB	G1	Steel Rolled Beam	Y	1	39.79	-40	3.33	*	6		4	2	1962
398	STSS	151	MGRB	G2	Steel Rolled Beam	Y	1	39.79	-40	6		6		4	2	1962
399	STSS	152	MGRB	G1	Steel Rolled Beam	N	1	47.35	20.33	2.5	*	6.5		11	5	1962
400	STSS	152	MGRB	G10	Steel Rolled Beam	N	1	47.35	20.33	6.06		6.06		11	5	1962
401	STSS	152	MGRB	G11	Steel Rolled Beam	N	1	47.35	20.33	6.06		2.5	*	11	5	1962
402	STSS	152	MGRB	G2	Steel Rolled Beam	N	1	47.35	20.33	6.5		6.5		11	5	1962
403	STSS	152	MGRB	G3	Steel Rolled Beam	N	1	47.35	20.33	6.5		6.5		11	5	1962
404	STSS	152	MGRB	G4	Steel Rolled Beam	N	1	47.35	20.33	6.5		6.5		11	5	1962
405	STSS	152	MGRB	G5	Steel Rolled Beam	N	1	47.35	20.33	6.5		6.5		11	5	1962
406	STSS	152	MGRB	G6	Steel Rolled Beam	N	1	47.35	20.33	6.5		6		11	5	1962
407	STSS	152	MGRB	G7	Steel Rolled Beam	N	1	47.35	20.33	6		6.06		11	5	1962
408	STSS	152	MGRB	G8	Steel Rolled Beam	N	1	47.35	20.33	6.06		6.06		11	5	1962
409	STSS	152	MGRB	G9	Steel Rolled Beam	N	1	47.35	20.33	6.06		6.06		11	5	1962
410	STSS	153	MGRB	16_-_3rd_N_Int	Steel Rolled Beam	N	1	37	0	6.5		5.42		12	5	1963
411	STSS	154	MGRB	G1	Steel Rolled Beam	Y	1	48.42	-11	1.59	*	6		8	3	1963
412	STSS	154	MGRB	G2	Steel Rolled Beam	Y	1	48.42	-11	6		6		8	3	1963
413	STSS	154	MGRB	G5	Steel Rolled Beam	Y	1	48.42	-11	6		5.5		8	3	1963
414	STSS	154	MGRB	G6	Steel Rolled Beam	Y	1	48.42	-11	5.5		5.5		8	3	1963
415	STSS	154	MGRB	G8	Steel Rolled Beam	Y	1	48.42	-11	5.5		1.58	*	8	3	1963
416	STSS	155	MGRB	1W	Steel Rolled Beam	Y	1	51.92	-10.96	0.96	*	5.67		9	3	1963
417	STSS	155	MGRB	3W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		5.67		9	3	1963

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
418	STSS	155	MGRB	8W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		5.67		9	3	1963
419	STSS	155	MGRB	9W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		0.96	*	9	3	1963
420	STSS	156	MGRB	G1	Steel Rolled Beam	Y	1	43.73	-35	2.79	*	8		4	2	1964
421	STSS	156	MGRB	G2	Steel Rolled Beam	Y	1	43.73	-35	8		8		4	2	1964
422	STSS	157	MGRB	G1	Steel Rolled Beam	Y	1	48	15.19	1.5	*	8.5		8	4	1964
423	STSS	157	MGRB	G2	Steel Rolled Beam	Y	1	48	15.19	8.5		7.5		8	4	1964
424	STSS	157	MGRB	G3	Steel Rolled Beam	Y	1	48	15.19	7.5		7.5		8	4	1964
425	STSS	157	MGRB	G6	Steel Rolled Beam	Y	1	48	15.19	7.5		7.25		8	4	1964
426	STSS	157	MGRB	G7	Steel Rolled Beam	Y	1	48	15.19	7.25		7.25		8	4	1964
427	STSS	157	MGRB	G8	Steel Rolled Beam	Y	1	48	15.19	7.25		1.5	*	8	4	1964
428	STSS	158	MGRB	G1	Steel Rolled Beam	Y	1	48	15.19	1.5	*	7.25		8	4	1964
429	STSS	158	MGRB	G2	Steel Rolled Beam	Y	1	48	15.19	7.25		7.25		8	4	1964
430	STSS	158	MGRB	G3	Steel Rolled Beam	Y	1	48	15.19	7.25		7.5		8	4	1964
431	STSS	158	MGRB	G7	Steel Rolled Beam	Y	1	48	15.19	7.5		8.5		8	4	1964
432	STSS	158	MGRB	G8	Steel Rolled Beam	Y	1	48	15.19	8.5		1.5	*	8	4	1964
433	STSS	159	MGRB	G1	Steel Rolled Beam	Y	1	46.17	20	2.75	*	7.67		4	2	1965
434	STSS	159	MGRB	G2	Steel Rolled Beam	Y	1	46.17	20	7.67		7.67		4	2	1965
435	STSS	160	MGRB	G1	Steel Rolled Beam	N	1	32.5	0	0.75	*	3		9	2	1965
436	STSS	160	MGRB	G2	Steel Rolled Beam	N	1	32.5	0	3		3		9	2	1965
437	STSS	161	MGRB	G1	Steel Rolled Beam	N	1	47.96	15	2.17	*	6		4	1	1959
438	STSS	161	MGRB	G2	Steel Rolled Beam	N	1	47.96	15	6		6		4	1	1959
439	STSS	162	MGRB	G1	Steel Rolled Beam	Y	1	49.39	-20.24	3.12	*	7.04		10	4	1965
440	STSS	162	MGRB	G10	Steel Rolled Beam	Y	1	49.39	-20.24	4.83		0.66	*	10	4	1965
441	STSS	162	MGRB	G2	Steel Rolled Beam	Y	1	49.39	-20.24	7.04		7.04		10	4	1965
442	STSS	162	MGRB	G3	Steel Rolled Beam	Y	1	49.39	-20.24	7.04		7.04		10	4	1965
443	STSS	162	MGRB	G4	Steel Rolled Beam	Y	1	49.39	-20.24	7.04		7.04		10	4	1965
444	STSS	162	MGRB	G7	Steel Rolled Beam	Y	1	49.39	-20.24	7.04		4.83		10	4	1965
445	STSS	162	MGRB	G8	Steel Rolled Beam	Y	1	49.39	-20.24	4.83		4.83		10	4	1965

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
446	STSS	162	MGRB	G9	Steel Rolled Beam	Y	1	49.39	-20.24	4.83		4.83		10	4	1965
447	STSS	163	MGRB	G1	Steel Rolled Beam	Y	1	50.08	25	2.13	*	6.67		4	2	1961
448	STSS	163	MGRB	G2	Steel Rolled Beam	Y	1	50.08	25	6.67		6.67		4	2	1961
449	STSS	164	MGRB	G1	Steel Rolled Beam	N	1	49.85	-20	2.13	*	6		4	2	1961
450	STSS	164	MGRB	G2	Steel Rolled Beam	N	1	49.85	-20	6		6		4	2	1961
451	STSS	165	MGRB	G1	Steel Rolled Beam	N	1	40.17	-15	2.88	*	7.67		4	2	1966
452	STSS	165	MGRB	G2	Steel Rolled Beam	N	1	40.17	-15	7.67		7.67		4	2	1966
453	STSS	166	MGRB	G1	Steel Rolled Beam	Y	1	43.83	-30	3.38	*	7.33		4	2	1967
454	STSS	166	MGRB	G2	Steel Rolled Beam	Y	1	43.83	-30	7.33		7.33		4	2	1967
455	STSS	167	MGRB	G1	Steel Rolled Beam	Y	1	42.17	10	3.38	*	7.33		4	2	1968
456	STSS	167	MGRB	G2	Steel Rolled Beam	Y	1	42.17	10	7.33		7.33		4	2	1968
457	STSS	168	MGRB	G1	Steel Rolled Beam	Y	1	53	-29.47	1.33	*	8.5		8	4	1967
458	STSS	168	MGRB	G2	Steel Rolled Beam	Y	1	53	-29.47	8.5		7.5		8	4	1967
459	STSS	168	MGRB	G3	Steel Rolled Beam	Y	1	53	-29.47	7.5		7.5		8	4	1967
460	STSS	168	MGRB	G6	Steel Rolled Beam	Y	1	53	-29.47	7.5		7.25		8	4	1967
461	STSS	168	MGRB	G7	Steel Rolled Beam	Y	1	53	-29.47	7.25		7.25		8	4	1967
462	STSS	168	MGRB	G8	Steel Rolled Beam	Y	1	53	-29.47	7.25		1.33	*	8	4	1967
463	STSS	169	MGRB	G1	Steel Rolled Beam	Y	1	50	0	2.58	*	8		4	2	1968
464	STSS	169	MGRB	G2	Steel Rolled Beam	Y	1	50	0	8		8		4	2	1968
465	STSS	170	MGRB	G1	Steel Rolled Beam	Y	1	44.42	18.96	1.86	*	7.83		6	3	1968
466	STSS	170	MGRB	G2	Steel Rolled Beam	Y	1	44.42	18.96	7.83		7.83		6	3	1968
467	STSS	170	MGRB	G3	Steel Rolled Beam	Y	1	44.42	18.96	7.83		7.83		6	3	1968
468	STSS	170	MGRB	G4	Steel Rolled Beam	Y	1	44.42	18.96	7.83		7.83		6	3	1968
469	STSS	170	MGRB	G5	Steel Rolled Beam	Y	1	44.42	18.96	7.83		7.83		6	3	1968
470	STSS	170	MGRB	G6	Steel Rolled Beam	Y	1	44.42	18.96	7.83		1.86	*	6	3	1968
471	STSS	171	MGRB	G1	Steel Rolled Beam	Y	1	44.23	18.26	1.85	*	7.83		6	3	1968
472	STSS	171	MGRB	G2	Steel Rolled Beam	Y	1	44.23	18.26	7.83		7.83		6	3	1968
473	STSS	171	MGRB	G3	Steel Rolled Beam	Y	1	44.23	18.26	7.83		7.83		6	3	1968

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
474	STSS	171	MGRB	G4	Steel Rolled Beam	Y	1	44.23	18.26	7.83		7.83		6	3	1968
475	STSS	171	MGRB	G5	Steel Rolled Beam	Y	1	44.23	18.26	7.83		7.83		6	3	1968
476	STSS	171	MGRB	G6	Steel Rolled Beam	Y	1	44.23	18.26	7.83		1.85	*	6	3	1968
477	STSS	172	MGRB	G1	Steel Rolled Beam	Y	1	47.5	-17.1	1.15	*	8		6	3	1968
478	STSS	172	MGRB	G2	Steel Rolled Beam	Y	1	47.5	-17.1	8		8		6	3	1968
479	STSS	172	MGRB	G3	Steel Rolled Beam	Y	1	47.5	-17.1	8		8		6	3	1968
480	STSS	172	MGRB	G6	Steel Rolled Beam	Y	1	47.5	-17.1	8		1.15	*	6	3	1968
481	STSS	173	MGRB	4_-_3rd_N_Int	Steel Rolled Beam	N	1	37	0	6.5		5.42		12	5	1963
482	STSS	174	MGRB	G1	Steel Rolled Beam	Y	1	50.86	-30	1.71	*	7.25		6	3	1969
483	STSS	174	MGRB	G2	Steel Rolled Beam	Y	1	50.86	-30	7.25		7.25		6	3	1969
484	STSS	175	MGRB	G1	Steel Rolled Beam	Y	1	49.76	17	2.83	*	6.67		4	2	1962
485	STSS	175	MGRB	G2	Steel Rolled Beam	Y	1	49.76	17	6.67		6.67		4	2	1962
486	STSS	176	MGRB	G1	Steel Rolled Beam	Y	1	49.6	0	1.46	*	7.92		6	3	1970
487	STSS	176	MGRB	G2	Steel Rolled Beam	Y	1	49.6	0	7.92		7.92		6	3	1970
488	STSS	176	MGRB	G3	Steel Rolled Beam	Y	1	49.6	0	7.92		7.92		6	3	1970
489	STSS	177	MGRB	G1	Steel Rolled Beam	Y	1	50	0	1.46	*	7.92		6	3	1970
490	STSS	177	MGRB	G2	Steel Rolled Beam	Y	1	50	0	7.92		7.92		6	3	1970
491	STSS	178	MGRB	Fascia_Girder_G1	Steel Rolled Beam	N	1	51	30	1.25	*	4.25		7	2	1973
492	STSS	178	MGRB	Interior_Girder_G2	Steel Rolled Beam	N	1	51	30	4.25		5.08		7	2	1973
493	STSS	179	MGRB	G1	Steel Rolled Beam	Y	1	47.5	15	1.27	*	9.75		5	3	1969
494	STSS	179	MGRB	G2	Steel Rolled Beam	Y	1	47.5	15	9.75		9.75		5	3	1969
495	STSS	180	MGRB	G1	Steel Rolled Beam	Y	1	51.42	11	2	*	8.25		6	3	1972
496	STSS	180	MGRB	G2	Steel Rolled Beam	Y	1	51.42	11	8.25		8.25		6	3	1972
497	STSS	181	MGRB	G1	Steel Rolled Beam	N	1	52.83	0	3.5	*	7.96		4	2	1973
498	STSS	181	MGRB	G2	Steel Rolled Beam	N	1	52.83	0	7.96		7.96		4	2	1973
499	STSS	182	MGRB	G1	Steel Rolled Beam	Y	1	44.19	-15	3.33	*	6		4	2	1962
500	STSS	182	MGRB	G2	Steel Rolled Beam	Y	1	44.19	-15	6		6		4	2	1962
501	STSS	183	MGRB	G1	Steel Rolled Beam	Y	1	47.5	15	1.27	*	9.75		5	3	1969

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
502	STSS	183	MGRB	G2	Steel Rolled Beam	Y	1	47.5	15	9.75		9.75		5	3	1969
503	STSS	184	MGRB	G1	Steel Rolled Beam	N	1	29	10	0.5	*	5		8	2	1974
504	STSS	184	MGRB	G2	Steel Rolled Beam	N	1	29	10	5		5		8	2	1974
505	STSS	184	MGRB	G8	Steel Rolled Beam	N	1	29	10	5		0.5	*	8	2	1974
506	STSS	185	MGRB	G1	Steel Rolled Beam	Y	1	31.67	0	2.5	*	7.33		4	2	1974
507	STSS	185	MGRB	G2	Steel Rolled Beam	Y	1	31.67	0	7.33		7.33		4	2	1974
508	STSS	186	MGRB	G1	Steel Rolled Beam	Y	1	52.17	0	2.68	*	7.01		6	3	1975
509	STSS	186	MGRB	G2	Steel Rolled Beam	Y	1	52.17	0	7.01		7.01		6	3	1975
510	STSS	187	MGRB	G1	Steel Rolled Beam	Y	1	51.42	11	1.91	*	8.25		6	3	1972
511	STSS	187	MGRB	G2	Steel Rolled Beam	Y	1	51.42	11	8.25		8.25		6	3	1972
512	STSS	188	MGRB	G1	Steel Rolled Beam	N	1	47	30	0.33	*	3.66		9	2	1970
513	STSS	188	MGRB	G2	Steel Rolled Beam	N	1	47	30	3.66		3.67		9	2	1970
514	STSS	189	MGRB	Member_1	Steel Rolled Beam	Y	1	52.03	-10	0.79	*	5.43		7	2	1971
515	STSS	189	MGRB	Member_2	Steel Rolled Beam	Y	1	52.03	-10	5.43		5.43		7	2	1971
516	STSS	190	MGRB	Member_1	Steel Rolled Beam	N	1	52.7	0	0.43	*	1.58		11	1	1976
517	STSS	190	MGRB	Member_10	Steel Rolled Beam	N	1	52.7	0	1.98		1.58		11	1	1976
518	STSS	190	MGRB	Member_11	Steel Rolled Beam	N	1	52.7	0	1.58		0.43	*	11	1	1976
519	STSS	190	MGRB	Member_2	Steel Rolled Beam	N	1	52.7	0	1.58		1.98		11	1	1976
520	STSS	190	MGRB	Member_3	Steel Rolled Beam	N	1	52.7	0	1.98		1.98		11	1	1976
521	STSS	191	MGRB	Member_1	Steel Rolled Beam	N	1	48	0	0.37	*	1.58		13	2	1977
522	STSS	191	MGRB	Member_13	Steel Rolled Beam	N	1	48	0	1.58		0.37	*	13	2	1977
523	STSS	191	MGRB	Member_2	Steel Rolled Beam	N	1	48	0	1.58		2		13	2	1977
524	STSS	191	MGRB	Member_3	Steel Rolled Beam	N	1	48	0	2		2		13	2	1977
525	STSS	191	MGRB	Member_5	Steel Rolled Beam	N	1	48	0	2		2		13	2	1977
526	STSS	191	MGRB	Member_7	Steel Rolled Beam	N	1	48	0	2		2		13	2	1977
527	STSS	191	MGRB	Member_8	Steel Rolled Beam	N	1	48	0	2		2		13	2	1977
528	STSS	192	MGRB	G1	Steel Rolled Beam	N	1	48	35	2.5	*	7.5		5	2	1977
529	STSS	192	MGRB	G2	Steel Rolled Beam	N	1	48	35	7.5		7.5		5	2	1977

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
530	STSS	193	MGRB	G1	Steel Rolled Beam	N	1	31.88	-5.5	1.75	*	3.04		7	1	1978
531	STSS	193	MGRB	G2	Steel Rolled Beam	N	1	31.88	-5.5	3.04		5		7	1	1978
532	STSS	193	MGRB	G3	Steel Rolled Beam	N	1	31.88	-5.5	5		5		7	1	1978
533	STSS	194	MGRB	G1	Steel Rolled Beam	Y	1	40.17	0	2.13	*	6.67		4	2	1963
534	STSS	194	MGRB	G2	Steel Rolled Beam	Y	1	40.17	0	6.67		6.67		4	2	1963
535	STSS	195	MGRB	Member_1	Steel Rolled Beam	N	1	40.6	0	0.96	*	2.19		12	2	1979
536	STSS	195	MGRB	Member_10	Steel Rolled Beam	N	1	40.6	0	2.19		2.19		12	2	1979
537	STSS	195	MGRB	Member_12	Steel Rolled Beam	N	1	40.6	0	2.19		0.96	*	12	2	1979
538	STSS	195	MGRB	Member_2	Steel Rolled Beam	N	1	40.6	0	2.19		2.19		12	2	1979
539	STSS	195	MGRB	Member_6	Steel Rolled Beam	N	1	40.6	0	2.19		2.19		12	2	1979
540	STSS	195	MGRB	Member_8	Steel Rolled Beam	N	1	40.6	0	2.19		2.19		12	2	1979
541	STSS	196	MGRB	G1	Steel Rolled Beam	N	1	34	0	2	*	6.5		5	2	1979
542	STSS	196	MGRB	G2	Steel Rolled Beam	N	1	34	0	6.5		6.5		5	2	1979
543	STSS	197	MGRB	Member_1	Steel Rolled Beam	N	1	48.75	0	0.84	*	2.22		12	2	1980
544	STSS	197	MGRB	Member_2	Steel Rolled Beam	N	1	48.75	0	2.22		2.22		12	2	1980
545	STSS	197	MGRB	Member_8	Steel Rolled Beam	N	1	48.75	0	2.22		2.22		12	2	1980
546	STSS	198	MGRB	Member_1	Steel Rolled Beam	Y	1	48	11	2.03	*	8		5	2	1982
547	STSS	198	MGRB	Member_2	Steel Rolled Beam	Y	1	48	11	8		8		5	2	1982
548	STSS	199	MGRB	Member_1	Steel Rolled Beam	N	1	43.5	0	0.37	*	1.6		13	2	1980
549	STSS	199	MGRB	Member_2	Steel Rolled Beam	N	1	43.5	0	1.6		2		13	2	1980
550	STSS	199	MGRB	Member_3	Steel Rolled Beam	N	1	43.5	0	2		2		13	2	1980
551	STSS	199	MGRB	Member_5	Steel Rolled Beam	N	1	43.5	0	2		2		13	2	1980
552	STSS	199	MGRB	Member_6	Steel Rolled Beam	N	1	43.5	0	2		2		13	2	1980
553	STSS	199	MGRB	Member_7	Steel Rolled Beam	N	1	43.5	0	2		2		13	2	1980
554	STSS	200	MGRB	G1	Steel Rolled Beam	N	1	45	45	1	*	4		7	2	1986
555	STSS	200	MGRB	G2	Steel Rolled Beam	N	1	45	45	4		4		7	2	1986
556	STSS	201	MGRB	G1	Steel Rolled Beam	Y	1	40	0	2	*	4		7	2	1989
557	STSS	201	MGRB	G2	Steel Rolled Beam	Y	1	40	0	4		4		7	2	1989

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
558	STSS	202	MGRB	G1	Steel Rolled Beam	Y	1	31.68	36.41	2.5	*	8		6	2	1978
559	STSS	202	MGRB	G2	Steel Rolled Beam	Y	1	31.68	36.41	8		8		6	2	1978
560	STSS	202	MGRB	G3	Steel Rolled Beam	Y	1	31.68	36.41	8		8		6	2	1978
561	STSS	202	MGRB	G5	Steel Rolled Beam	Y	1	31.68	36.41	8		8		6	2	1978
562	STSS	203	MGRB	2_-_1st_W_Int	Steel Rolled Beam	Y	1	40	-26.58	9.5		9.5		5	3	1985
563	STSS	204	MGRB	Member_1	Steel Rolled Beam	N	1	43.2	-52	0.33	*	1.63		15	2	1983
564	STSS	204	MGRB	Member_2	Steel Rolled Beam	N	1	43.2	-52	1.63		2		15	2	1983
565	STSS	204	MGRB	Member_3	Steel Rolled Beam	N	1	43.2	-52	2		2		15	2	1983
566	STSS	205	MGRB	Fascia_Girder_G1	Steel Rolled Beam	Y	1	52	20	2.5	*	5.25		5	2	1985
567	STSS	205	MGRB	Interior_Girder_G2	Steel Rolled Beam	Y	1	52	20	5.25		5.25		5	2	1985
568	STSS	206	MGRB	Member_1	Steel Rolled Beam	N	1	39.7	-5	0.79	*	2.5		11	2	1986
569	STSS	206	MGRB	Member_2	Steel Rolled Beam	N	1	39.7	-5	2.5		2.5		11	2	1986
570	STSS	207	MGRB	G1	Steel Rolled Beam	Y	1	44.11	25	2.13	*	6.67		4	2	1963
571	STSS	207	MGRB	G2	Steel Rolled Beam	Y	1	44.11	25	6.67		6.67		4	2	1963
572	STSS	208	MGRB	Fascia_Girder_G1	Steel Rolled Beam	Y	1	48.75	0	2	*	5		7	2	1986
573	STSS	208	MGRB	Interior_Girder_G2	Steel Rolled Beam	Y	1	48.75	0	5		5		7	2	1986
574	STSS	209	MGRB	G1	Steel Rolled Beam	N	1	23.5	0	0.7	*	4		7	2	1988
575	STSS	209	MGRB	G2	Steel Rolled Beam	N	1	23.5	0	4		4		7	2	1988
576	STSS	210	MGRB	G2	Steel Rolled Beam	N	1	39	0	6.46		6.46		4	2	1988
577	STSS	211	MGRB	Member_1	Steel Rolled Beam	N	1	47.5	40	0.74	*	2.23		12	2	1983
578	STSS	211	MGRB	Member_2	Steel Rolled Beam	N	1	47.5	40	2.23		2.23		12	2	1983
579	STSS	212	MGRB	G1	Steel Rolled Beam	Y	1	50.02	30	2.79	*	7.33		4	2	1964
580	STSS	212	MGRB	G2	Steel Rolled Beam	Y	1	50.02	30	7.33		7.33		4	2	1964
581	STSS	213	MGRB	G1	Steel Rolled Beam	N	1	26.17	0	2.75	*	5		4	1	1989
582	STSS	213	MGRB	G2	Steel Rolled Beam	N	1	26.17	0	5		5		4	1	1989
583	STSS	214	MGRB	G1	Steel Rolled Beam	N	1	35	0	2.46	*	6.17		4	2	1989
584	STSS	214	MGRB	G2	Steel Rolled Beam	N	1	35	0	6.17		6.17		4	2	1989
585	STSS	215	MGRB	G1	Steel Rolled Beam	N	1	34.17	0	2.75	*	7.67		4	2	1965

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
586	STSS	215	MGRB	G2	Steel Rolled Beam	N	1	34.17	0	7.67		7.67		4	2	1965
587	STSS	216	MGRB	G1	Steel Rolled Beam	N	1	44.69	-20	2	*	4.67		5	2	1989
588	STSS	216	MGRB	G2	Steel Rolled Beam	N	1	44.69	-20	4.67		4.67		5	2	1989
589	STSS	216	MGRB	G3	Steel Rolled Beam	N	1	44.69	-20	4.67		4.67		5	2	1989
590	STSS	217	MGRB	G2	Steel Rolled Beam	Y	1	40.53	17	7.29		7.29		5	2	1990
591	STSS	218	MGRB	G1	Steel Rolled Beam	N	1	30.83	0	0.75	*	2.17		11	2	1990
592	STSS	218	MGRB	G2	Steel Rolled Beam	N	1	30.83	0	2.17		2.17		11	2	1990
593	STSS	219	MGRB	G1	Steel Rolled Beam	Y	1	49.73	20	2.79	*	7.33		4	2	1965
594	STSS	219	MGRB	G2	Steel Rolled Beam	Y	1	49.73	20	7.33		7.33		4	2	1965
595	STSS	220	MGRB	G1	Steel Rolled Beam	Y	1	44.17	0	3.25	*	8		4	2	1965
596	STSS	220	MGRB	G2	Steel Rolled Beam	Y	1	44.17	0	8		8		4	2	1965
597	STSS	221	MGRB	G10	Steel Rolled Beam	N	1	30.96	-7	6.83		8.28		11	4	1991
598	STSS	221	MGRB	G2	Steel Rolled Beam	N	1	30.96	-7	7.99		5.57		11	4	1991
599	STSS	221	MGRB	G5	Steel Rolled Beam	N	1	30.96	-7	5.57		6.83		11	4	1991
600	STSS	222	MGRB	G1	Steel Rolled Beam	N	1	51.6	-27	2.34	*	4.67		5	2	1991
601	STSS	222	MGRB	G2	Steel Rolled Beam	N	1	51.6	-27	4.67		4.67		5	2	1991
602	STSS	222	MGRB	G5	Steel Rolled Beam	N	1	51.6	-27	4.67		2.34	*	5	2	1991
603	STSS	223	MGRB	G1	Steel Rolled Beam	Y	1	34.17	0	3.38	*	7.33		4	2	1966
604	STSS	223	MGRB	G2	Steel Rolled Beam	Y	1	34.17	0	7.33		7.33		4	2	1966
605	STSS	224	MGRB	Member_1	Steel Rolled Beam	N	1	38.6	0	0.34	*	1.58		13	2	1968
606	STSS	224	MGRB	Member_13	Steel Rolled Beam	N	1	38.6	0	1.58		0.34	*	13	2	1968
607	STSS	224	MGRB	Member_2	Steel Rolled Beam	N	1	38.6	0	1.58		2		13	2	1968
608	STSS	224	MGRB	Member_3	Steel Rolled Beam	N	1	38.6	0	2		2		13	2	1968
609	STSS	224	MGRB	Member_5	Steel Rolled Beam	N	1	38.6	0	2		2		13	2	1968
610	STSS	224	MGRB	Member_9	Steel Rolled Beam	N	1	38.6	0	2		2		13	2	1968
611	STSS	225	MGRB	G1	Steel Rolled Beam	Y	1	36.41	-15	3.38	*	8		4	2	1967
612	STSS	225	MGRB	G2	Steel Rolled Beam	Y	1	36.41	-15	8		8		4	2	1967
613	STSS	226	MGRB	G1	Steel Rolled Beam	Y	1	43.67	0	1.25	*	7.03		6	2	1992

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
614	STSS	226	MGRB	G2	Steel Rolled Beam	Y	1	43.67	0	7.03		2.54		6	2	1992
615	STSS	227	MGRB	G1	Steel Rolled Beam	Y	1	48.42	-11	1.59	*	5.5		8	3	1963
616	STSS	227	MGRB	G2	Steel Rolled Beam	Y	1	48.42	-11	5.5		5.5		8	3	1963
617	STSS	227	MGRB	G4	Steel Rolled Beam	Y	1	48.42	-11	5.5		6		8	3	1963
618	STSS	227	MGRB	G5	Steel Rolled Beam	Y	1	48.42	-11	6		6		8	3	1963
619	STSS	227	MGRB	G8	Steel Rolled Beam	Y	1	48.42	-11	6		1.58	*	8	3	1963
620	STSS	228	MGRB	G1	Steel Rolled Beam	N	1	34.15	0	3.38	*	7.33		4	2	1966
621	STSS	228	MGRB	G2	Steel Rolled Beam	N	1	34.15	0	7.33		7.33		4	2	1966
622	STSS	229	MGRB	G1	Steel Rolled Beam	Y	1	52.57	9	1.58	*	6.58		9	4	1962
623	STSS	229	MGRB	G2	Steel Rolled Beam	Y	1	52.57	9	6.58		6.58		9	4	1962
624	STSS	229	MGRB	G3	Steel Rolled Beam	Y	1	52.57	9	6.58		6.58		9	4	1962
625	STSS	229	MGRB	G4	Steel Rolled Beam	Y	1	52.57	9	6.58		7.83		9	4	1962
626	STSS	229	MGRB	G5	Steel Rolled Beam	Y	1	52.57	9	7.83		7.83		9	4	1962
627	STSS	229	MGRB	G6	Steel Rolled Beam	Y	1	52.57	9	7.83		7.83		9	4	1962
628	STSS	229	MGRB	G7	Steel Rolled Beam	Y	1	52.57	9	7.83		7.83		9	4	1962
629	STSS	229	MGRB	G8	Steel Rolled Beam	Y	1	52.57	9	7.83		6.83		9	4	1962
630	STSS	229	MGRB	G9	Steel Rolled Beam	Y	1	52.57	9	6.83		1.83	*	9	4	1962
631	STSS	230	MGRB	G1	Steel Rolled Beam	N	1	52.31	-30	1	*	4		7	2	1994
632	STSS	230	MGRB	G2	Steel Rolled Beam	N	1	52.31	-30	4		4		7	2	1994
633	STSS	230	MGRB	G3	Steel Rolled Beam	N	1	52.31	-30	4		4		7	2	1994
634	STSS	230	MGRB	G4	Steel Rolled Beam	N	1	52.31	-30	4		4		7	2	1994
635	STSS	231	MGRB	G1	Steel Rolled Beam	Y	1	52.5	0	2.96	*	7.75		4	2	1961
636	STSS	231	MGRB	G2	Steel Rolled Beam	Y	1	52.5	0	7.75		7.75		4	2	1961
637	STSS	232	MGRB	G1	Steel Rolled Beam	N	1	41.75	-25	3.25	*	6.5		6	2	1995
638	STSS	232	MGRB	G2	Steel Rolled Beam	N	1	41.75	-25	6.5		6.5		6	2	1995
639	STSS	232	MGRB	G6	Steel Rolled Beam	N	1	41.75	-25	6.5		3.25	*	6	2	1995
640	STSS	233	MGRB	G1	Steel Rolled Beam	Y	1	24	-29	1.5	*	6		12	3	1995
641	STSS	233	MGRB	G10	Steel Rolled Beam	Y	1	24	-29	3.04		2		12	3	1995

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
642	STSS	233	MGRB	G11	Steel Rolled Beam	Y	1	24	-29	2		6		12	3	1995
643	STSS	233	MGRB	G12	Steel Rolled Beam	Y	1	24	-29	6		2.33	*	12	3	1995
644	STSS	233	MGRB	G2	Steel Rolled Beam	Y	1	24	-29	6		2		12	3	1995
645	STSS	233	MGRB	G3	Steel Rolled Beam	Y	1	24	-29	2		3.04		12	3	1995
646	STSS	233	MGRB	G4	Steel Rolled Beam	Y	1	24	-29	3.04		8		12	3	1995
647	STSS	233	MGRB	G5	Steel Rolled Beam	Y	1	24	-29	8		3.04		12	3	1995
648	STSS	233	MGRB	G6	Steel Rolled Beam	Y	1	24	-29	3.04		8		12	3	1995
649	STSS	233	MGRB	G7	Steel Rolled Beam	Y	1	24	-29	8		3.04		12	3	1995
650	STSS	233	MGRB	G8	Steel Rolled Beam	Y	1	24	-29	3.04		8		12	3	1995
651	STSS	233	MGRB	G9	Steel Rolled Beam	Y	1	24	-29	8		3.04		12	3	1995
652	STSS	234	MGRB	Member_1	Steel Rolled Beam	N	1	48.3	0	1.81	*	2.7		9	2	1996
653	STSS	234	MGRB	Member_2	Steel Rolled Beam	N	1	48.3	0	2.7		2.7		9	2	1996
654	STSS	235	MGRB	G1	Steel Rolled Beam	N	1	38.67	0	0.29	*	4.25		6	2	1967
655	STSS	235	MGRB	G2	Steel Rolled Beam	N	1	38.67	0	4.25		4.33		6	2	1967
656	STSS	236	MGRB	G1	Steel Rolled Beam	Y	1	42.17	10	3.38	*	7.33		4	2	1968
657	STSS	236	MGRB	G2	Steel Rolled Beam	Y	1	42.17	10	7.33		7.33		4	2	1968
658	STSS	237	MGRB	G1	Steel Rolled Beam	N	1	42.81	45	0.92	*	4		7	2	1998
659	STSS	237	MGRB	G2	Steel Rolled Beam	N	1	42.81	45	4		4		7	2	1998
660	STSS	237	MGRB	G5	Steel Rolled Beam	N	1	42.81	45	4		4		7	2	1998
661	STSS	238	MGRB	Fascia_Girder_G1	Steel Rolled Beam	Y	1	49	-26	2	*	5.5		5	2	1999
662	STSS	238	MGRB	Interior_Girder_G2	Steel Rolled Beam	Y	1	49	-26	5.5		5.5		5	2	1999
663	STSS	239	MGRB	G2	Steel Rolled Beam	Y	1	51.64	-5	5.58		5.58		8	3	2000
664	STSS	240	MGRB	Fascia_Girder_G1	Steel Rolled Beam	Y	1	48.5	-9.43	1.75	*	9.5		6	2	1968
665	STSS	240	MGRB	Interior_Girder_G2	Steel Rolled Beam	Y	1	48.5	-9.43	9.5		9.5		6	2	1968
666	STSS	241	MGRB	G1	Steel Rolled Beam	N	1	31.67	10	1.84	*	4.07		7	2	2001
667	STSS	241	MGRB	G2	Steel Rolled Beam	N	1	31.67	10	4.07		4.07		7	2	2001
668	STSS	242	MGRB	G1	Steel Rolled Beam	Y	1	50	20	2.48	*	5		6	2	2001
669	STSS	242	MGRB	G2	Steel Rolled Beam	Y	1	50	20	5		5		6	2	2001

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
670	STSS	243	MGRB	G1	Steel Rolled Beam	N	1	43.5	0	0.8	*	3.8		5	1	1963
671	STSS	243	MGRB	G2	Steel Rolled Beam	N	1	43.5	0	3.8		3.8		5	1	1963
672	STSS	244	MGRB	G2	Steel Rolled Beam	Y	1	37	0	7.33		7.33		15	5	2003
673	STSS	245	MGRB	G1	Steel Rolled Beam	Y	1	42.17	0	3.38	*	7.33		4	2	1967
674	STSS	245	MGRB	G2	Steel Rolled Beam	Y	1	42.17	0	7.33		7.33		4	2	1967
675	STSS	246	MGRB	G1	Steel Rolled Beam	Y	1	32.07	-11.33	3.33	*	6		4	2	2007
676	STSS	246	MGRB	G2	Steel Rolled Beam	Y	1	32.07	-11.33	6		6		4	2	2007
677	STSS	247	MGRB	G1	Steel Rolled Beam	N	1	50.12	-10	2.13	*	6		4	2	1961
678	STSS	247	MGRB	G2	Steel Rolled Beam	N	1	50.12	-10	6		6		4	2	1961
679	STSS	248	MGRB	1W	Steel Rolled Beam	Y	1	51.92	-10.96	0.96	*	5.67		9	3	1963
680	STSS	248	MGRB	2W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		5.67		9	3	1963
681	STSS	248	MGRB	3W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		5.67		9	3	1963
682	STSS	248	MGRB	4W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		5.67		9	3	1963
683	STSS	248	MGRB	5W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		5.67		9	3	1963
684	STSS	248	MGRB	6W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		5.67		9	3	1963
685	STSS	248	MGRB	7W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		5.67		9	3	1963
686	STSS	248	MGRB	8W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		5.67		9	3	1963
687	STSS	248	MGRB	9W	Steel Rolled Beam	Y	1	51.92	-10.96	5.67		0.96	*	9	3	1963
688	STSS	249	MGRB	G1	Steel Rolled Beam	N	1	46.85	0	0.46	*	3.08		11	2	2006
689	STSS	249	MGRB	G10	Steel Rolled Beam	N	1	46.85	0	3.16		3.02		11	2	2006
690	STSS	249	MGRB	G11	Steel Rolled Beam	N	1	46.85	0	3.02		0.46	*	11	2	2006
691	STSS	249	MGRB	G2	Steel Rolled Beam	N	1	46.85	0	3.08		3.02		11	2	2006
692	STSS	249	MGRB	G3	Steel Rolled Beam	N	1	46.85	0	3.02		3.25		11	2	2006
693	STSS	249	MGRB	G4	Steel Rolled Beam	N	1	46.85	0	3.25		3.06		11	2	2006
694	STSS	249	MGRB	G5	Steel Rolled Beam	N	1	46.85	0	3.06		3.05		11	2	2006
695	STSS	249	MGRB	G7	Steel Rolled Beam	N	1	46.85	0	3.06		3.01		11	2	2006
696	STSS	249	MGRB	G8	Steel Rolled Beam	N	1	46.85	0	3.01		3.17		11	2	2006
697	STSS	249	MGRB	G9	Steel Rolled Beam	N	1	46.85	0	3.17		3.16		11	2	2006

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
698	STSS	250	MGRB	G1	Steel Rolled Beam	Y	1	48.42	-11	1.59	*	5.5		8	3	1963
699	STSS	250	MGRB	G2	Steel Rolled Beam	Y	1	48.42	-11	5.5		5.5		8	3	1963
700	STSS	250	MGRB	G4	Steel Rolled Beam	Y	1	48.42	-11	5.5		6		8	3	1963
701	STSS	250	MGRB	G5	Steel Rolled Beam	Y	1	48.42	-11	6		6		8	3	1963
702	STSS	250	MGRB	G8	Steel Rolled Beam	Y	1	48.42	-11	6		1.58	*	8	3	1963
703	STSS	251	MGRB	G1	Steel Rolled Beam	Y	1	50.5	0	4	*	8.25		4	2	2007
704	STSS	251	MGRB	G2	Steel Rolled Beam	Y	1	50.5	0	8.25		8.25		4	2	2007
705	STSS	252	MGRB	G1	Steel Rolled Beam	Y	1	47	-15	3.33	*	6		4	2	2008
706	STSS	252	MGRB	G2	Steel Rolled Beam	Y	1	47	-15	6		6		4	2	2008
707	STSS	252	MGRB	G3	Steel Rolled Beam	Y	1	47	-15	6		6		4	2	2008
708	STSS	252	MGRB	G4	Steel Rolled Beam	Y	1	47	-15	6		3.33	*	4	2	2008
709	STSS	253	MGBU	Fascia	Steel Built-Up	Y	1	63.5	0	1.25	*	4.75		12	4	1930
710	STSS	253	MGBU	Typical_Interior	Steel Built-Up	Y	1	63.5	0	4.75		4.67		12	4	1930
711	STSS	254	MGRB	G1	Steel Rolled Beam	Y	1	70.33	0	2.33	*	6		5	2	1923
712	STSS	254	MGRB	G2	Steel Rolled Beam	Y	1	70.33	0	6		6		5	2	1923
713	STSS	255	MGBU	G1	Steel Built-Up	Y	1	80	0	2.39	*	7.33		4	2	1944
714	STSS	255	MGBU	G2	Steel Built-Up	Y	1	80	0	7.33		7.33		4	2	1944
715	STSS	257	MGRB	G1	Steel Rolled Beam	N	1	75.5	23.9	2.08	*	6		5	2	1932
716	STSS	257	MGRB	G2	Steel Rolled Beam	N	1	75.5	23.9	6		6		5	2	1932
717	STSS	258	MGBU	G1	Steel Built-Up	N	1	70	23	3.62	*	8.42		4	2	1941
718	STSS	258	MGBU	G2	Steel Built-Up	N	1	70	23	8.42		8.42		4	2	1941
719	STSS	258	MGBU	G4	Steel Built-Up	N	1	70	23	8.42		3.62	*	4	2	1941
720	STSS	259	MGSP	G1	Steel Plate	Y	1	82.33	0	2.5	*	8		4	2	1904
721	STSS	259	MGSP	G2	Steel Plate	Y	1	82.33	0	8		8		4	2	1904
722	STSS	260	MGSP	G1	Steel Plate	Y	1	85	50	3.75	*	9.5		4	2	1928
723	STSS	260	MGSP	G2	Steel Plate	Y	1	85	50	9.5		9.5		4	2	1928
724	STSS	260	MGSP	G3	Steel Plate	Y	1	85	50	9.5		9.5		4	2	1928
725	STSS	260	MGSP	G4	Steel Plate	Y	1	85	50	9.5		3.92	*	4	2	1928

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
726	STSS	261	MGSP	G1	Steel Plate	Y	1	73	0	3	*	6.5		6	3	1940
727	STSS	261	MGSP	G2	Steel Plate	Y	1	73	0	6.5		6.5		6	3	1940
728	STSS	261	MGSP	G3	Steel Plate	Y	1	73	0	6.5		6.5		6	3	1940
729	STSS	262	MGRB	G1	Steel Rolled Beam	N	1	79.17	0	2.17	*	6		4	2	1947
730	STSS	262	MGRB	G2	Steel Rolled Beam	N	1	79.17	0	6		6		4	2	1947
731	STSS	263	MGSP	G1	Steel Plate	Y	1	84	0	2.5	*	9		4	2	1964
732	STSS	263	MGSP	G2	Steel Plate	Y	1	84	0	9		9		4	2	1964
733	STSS	264	MGSP	Member_1	Steel Plate	N	1	54.4	5	0.7	*	6		5	2	1965
734	STSS	264	MGSP	Member_2	Steel Plate	N	1	54.4	5	6		6		5	2	1965
735	STSS	264	MGSP	Member_3	Steel Plate	N	1	54.4	5	6		6		5	2	1965
736	STSS	264	MGSP	Member_5	Steel Plate	N	1	54.4	5	6		0.7	*	5	2	1965
737	STSS	265	MGRB	G1	Steel Rolled Beam	N	1	69.17	0	2.17	*	6		3	1	1953
738	STSS	265	MGRB	G2	Steel Rolled Beam	N	1	69.17	0	6		6		3	1	1953
739	STSS	266	MGSP	Fascia_Girder_G1	Steel Plate	Y	1	83	-51.74	1.42	*	9.75		5	3	1965
740	STSS	266	MGSP	Interior_Girder_G2	Steel Plate	Y	1	83	-51.74	9.75		9.75		5	3	1965
741	STSS	267	MGSP	G1	Steel Plate	Y	1	63	37.09	1.38	*	3.5		11	2	
742	STSS	267	MGSP	G10	Steel Plate	Y	1	63	37.09	3.5		3.5		11	2	
743	STSS	267	MGSP	G11	Steel Plate	Y	1	63	37.09	3.5		1.38	*	11	2	
744	STSS	267	MGSP	G2	Steel Plate	Y	1	63	37.09	3.5		3.5		11	2	
745	STSS	268	MGSP	G1	Steel Plate	Y	1	82	24.14	1.6	*	8.52		7	4	1971
746	STSS	268	MGSP	G2	Steel Plate	Y	1	82	24.14	8.52		8.52		7	4	1971
747	STSS	268	MGSP	G3	Steel Plate	Y	1	82	24.14	8.52		8.52		7	4	1971
748	STSS	268	MGSP	G4	Steel Plate	Y	1	82	24.14	8.52		8.52		7	4	1971
749	STSS	268	MGSP	G5	Steel Plate	Y	1	82	24.14	8.52		8.52		7	4	1971
750	STSS	268	MGSP	G6	Steel Plate	Y	1	82	24.14	8.52		8.52		7	4	1971
751	STSS	268	MGSP	G7	Steel Plate	Y	1	82	24.14	8.52		1.6	*	7	4	1971
752	STSS	269	MGRB	G1	Steel Rolled Beam	N	1	73.89	0	2.17	*	6		4	2	1957
753	STSS	269	MGRB	G2	Steel Rolled Beam	N	1	73.89	0	6		6		4	2	1957

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
754	STSS	270	MGRB	G1	Steel Rolled Beam	N	1	73.52	45	2.17	*	6		4	2	1959
755	STSS	270	MGRB	G2	Steel Rolled Beam	N	1	73.52	45	6		6		4	2	1959
756	STSS	271	MGRB	G1	Steel Rolled Beam	N	1	60.04	0	2.13	*	6		4	2	1960
757	STSS	271	MGRB	G2	Steel Rolled Beam	N	1	60.04	0	6		6		4	2	1960
758	STSS	272	MGSP	G1	Steel Plate	Y	1	75	-35	3	*	9		5	3	1983
759	STSS	272	MGSP	G2	Steel Plate	Y	1	75	-35	9		9		5	3	1983
760	STSS	273	MGSP	G1	Steel Plate	Y	1	68	30	3.83	*	10.33		4	3	1983
761	STSS	273	MGSP	G2	Steel Plate	Y	1	68	30	10.33		10.33		4	3	1983
762	STSS	274	MGSP	Fascia_Girder_G1	Steel Plate	Y	1	82	0	4	*	8		5	2	1984
763	STSS	274	MGSP	Fascia_Girder_G5	Steel Plate	Y	1	82	0	8		4.5	*	5	2	1984
764	STSS	274	MGSP	Interior_Girder_G2	Steel Plate	Y	1	82	0	8		8		5	2	1984
765	STSS	274	MGSP	Interior_Girder_G4	Steel Plate	Y	1	82	0	8		8		5	2	1984
766	STSS	275	MGSP	G1	Steel Plate	Y	1	84.88	-24.86	2.54	*	9.54		5	3	1994
767	STSS	275	MGSP	G2	Steel Plate	Y	1	84.88	-24.86	9.54		9.54		5	3	1994
768	STSS	276	MGSP	G1	Steel Plate	Y	1	78.1	0	3.08	*	8		5	2	1987
769	STSS	276	MGSP	G2	Steel Plate	Y	1	78.1	0	8		8		5	2	1987
770	STSS	277	MGSP	Fascia_Girder_G1	Steel Plate	Y	1	80	0	2.08	*	10.5		4	2	1987
771	STSS	277	MGSP	Fascia_Girder_G4	Steel Plate	Y	1	80	0	10.5		2.12	*	4	2	1987
772	STSS	277	MGSP	Interior_Girder_G2	Steel Plate	Y	1	80	0	10.5		10.5		4	2	1987
773	STSS	277	MGSP	Interior_Girder_G3	Steel Plate	Y	1	80	0	10.5		10.5		4	2	1987
774	STSS	278	MGSP	Member_1	Steel Plate	Y	1	77	7	3	*	8		4	2	1990
775	STSS	278	MGSP	Member_2	Steel Plate	Y	1	77	7	8		8		4	2	1990
776	STSS	279	MGSP	Member_1	Steel Plate	Y	1	83.07	-5.67	2.37	*	5.91		7	4	1995
777	STSS	279	MGSP	Member_2	Steel Plate	Y	1	83.07	-5.67	5.91		5.91		7	4	1995
778	STSS	280	MGSP	G1	Steel Plate	Y	1	84.88	-24.86	2.54	*	9.54		5	3	1994
779	STSS	280	MGSP	G2	Steel Plate	Y	1	84.88	-24.86	9.54		9.54		5	3	1994
780	STSS	280	MGSP	G5	Steel Plate	Y	1	84.88	-24.86	9.54		2.54	*	5	3	1994
781	STSS	281	MGSP	Member_1	Steel Plate	Y	1	72.55	26.79	2.3	*	9.63		5	3	1995

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
782	STSS	281	MGSP	Member_2	Steel Plate	Y	1	72.55	26.79	9.63		9.63		5	3	1995
783	STSS	281	MGSP	Member_5	Steel Plate	Y	1	72.55	26.79	9.63		2.49	*	5	3	1995
784	STSS	282	MGSP	Fascia_Girder_G1	Steel Plate	Y	1	67	-10	3.25	*	7.38		5	2	1996
785	STSS	282	MGSP	Interior_Girder_G2	Steel Plate	Y	1	67	-10	7.38		7.38		5	2	1996
786	STSS	283	MGRB	G1	Steel Rolled Beam	N	1	58.48	25	2.17	*	6		4	1	1960
787	STSS	283	MGRB	G2	Steel Rolled Beam	N	1	58.48	25	6		6		4	1	1960
788	STSS	284	MGSP	G2_-_1st_W_Int_	Steel Plate	Y	1	78.74	0	5.91		5.91		6	2	2001
789	STSS	285	MGRB	G1	Steel Rolled Beam	N	1	69.08	0	2.29	*	6.67		4	2	1961
790	STSS	285	MGRB	G2	Steel Rolled Beam	N	1	69.08	0	6.67		6.67		4	2	1961
791	STSS	287	MGRB	Member_1	Steel Rolled Beam	Y	1	68.5	0	1.19	*	7.66		5	2	1930
792	STSS	287	MGRB	Member_2	Steel Rolled Beam	Y	1	68.5	0	7.66		7.66		5	2	1930
793	STSS	288	MGRB	G1	Steel Rolled Beam	Y	1	74.9	0	1.53	*	5.74		10	3	1932
794	STSS	288	MGRB	G2	Steel Rolled Beam	Y	1	74.9	0	5.74		2.99		10	3	1932
795	STSS	289	MGRB	G1	Steel Rolled Beam	N	1	58.08	0	1.21	*	4.5		9	2	1936
796	STSS	289	MGRB	G2	Steel Rolled Beam	N	1	58.08	0	4.5		4.5		9	2	1936
797	STSS	290	MGRB	Fascia_Steel_Girder_G1	Steel Rolled Beam	Y	1	69.25	-45	2.17	*	5.83		6	2	1939
798	STSS	290	MGRB	Interior_Steel_Girder_G2	Steel Rolled Beam	Y	1	69.25	-45	5.83		6		6	2	1939
799	STSS	291	MGRB	G1	Steel Rolled Beam	Y	1	71	0	1.5	*	6.25		8	5	1952
800	STSS	291	MGRB	G2	Steel Rolled Beam	Y	1	71	0	6.25		8.58		8	5	1952
801	STSS	291	MGRB	G3	Steel Rolled Beam	Y	1	71	0	8.58		8.58		8	5	1952
802	STSS	291	MGRB	G7	Steel Rolled Beam	Y	1	71	0	8.58		8.58		8	5	1952
803	STSS	291	MGRB	G8	Steel Rolled Beam	Y	1	71	0	8.58		2.75	*	8	5	1952
804	STSS	292	MGRB	G1	Steel Rolled Beam	N	1	62	0	1.25	*	6.75		5	2	1953
805	STSS	292	MGRB	G2	Steel Rolled Beam	N	1	62	0	6.75		6.75		5	2	1953
806	STSS	292	MGRB	G3	Steel Rolled Beam	N	1	62	0	6.75		6.75		5	2	1953
807	STSS	292	MGRB	G4	Steel Rolled Beam	N	1	62	0	6.75		6.75		5	2	1953

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
808	STSS	292	MGRB	G5	Steel Rolled Beam	N	1	62	0	6.75		1.25	*	5	2	1953
809	STSS	293	MGRB	Member_1	Steel Rolled Beam	Y	1	69.3	-46.6	3.21	*	7.25		8	4	1953
810	STSS	293	MGRB	Member_2	Steel Rolled Beam	Y	1	69.3	-46.6	7.25		7.25		8	4	1953
811	STSS	293	MGRB	Member_8	Steel Rolled Beam	Y	1	69.3	-46.6	7.25		2.5	*	8	4	1953
812	STSS	294	MGRB	Member_1	Steel Rolled Beam	Y	1	70.04	-5	2.63	*	7.25		8	3	1953
813	STSS	294	MGRB	Member_2	Steel Rolled Beam	Y	1	70.04	-5	7.25		7.25		8	3	1953
814	STSS	295	MGRB	G1	Steel Rolled Beam	Y	1	79	0	2.75	*	5.6		6	2	1939
815	STSS	295	MGRB	G2	Steel Rolled Beam	Y	1	79	0	5.6		5.6		6	2	1939
816	STSS	295	MGRB	G3	Steel Rolled Beam	Y	1	79	0	5.6		5.58		6	2	1939
817	STSS	296	MGRB	G1	Steel Rolled Beam	N	1	63.67	-20	2.17	*	6		4	1	1954
818	STSS	296	MGRB	G2	Steel Rolled Beam	N	1	63.67	-20	6		6		4	1	1954
819	STSS	297	MGRB	Member_1	Steel Rolled Beam	Y	1	65.42	-15.5	2.25	*	7.58		8	3	1952
820	STSS	297	MGRB	Member_2	Steel Rolled Beam	Y	1	65.42	-15.5	7.58		7.67		8	3	1952
821	STSS	297	MGRB	Member_3	Steel Rolled Beam	Y	1	65.42	-15.5	7.67		7.67		8	3	1952
822	STSS	297	MGRB	Member_7	Steel Rolled Beam	Y	1	65.42	-15.5	7.67		7.58		8	3	1952
823	STSS	297	MGRB	Member_8	Steel Rolled Beam	Y	1	65.42	-15.5	7.58		2.25	*	8	3	1952
824	STSS	298	MGRB	G1	Steel Rolled Beam	N	1	58.79	30	2.33	*	6.67		4	2	1955
825	STSS	298	MGRB	G2	Steel Rolled Beam	N	1	58.79	30	6.67		6.67		4	2	1955
826	STSS	299	MGRB	Member_1	Steel Rolled Beam	Y	1	53.5	22	2.87	*	7.25		8	4	1955
827	STSS	299	MGRB	Member_2	Steel Rolled Beam	Y	1	53.5	22	7.25		7.25		8	4	1955
828	STSS	300	MGRB	G1	Steel Rolled Beam	N	1	78.88	0	2.55	*	8		4	2	1955
829	STSS	300	MGRB	G2	Steel Rolled Beam	N	1	78.88	0	8		8		4	2	1955
830	STSS	301	MGRB	G1	Steel Rolled Beam	N	1	70.88	0	2.42	*	6.67		4	2	1955
831	STSS	301	MGRB	G2	Steel Rolled Beam	N	1	70.88	0	6.67		6.67		4	2	1955
832	STSS	302	MGRB	G1	Steel Rolled Beam	Y	1	63.67	25	2.13	*	6		4	2	1962
833	STSS	302	MGRB	G2	Steel Rolled Beam	Y	1	63.67	25	6		6		4	2	1962
834	STSS	303	MGRB	G1	Steel Rolled Beam	Y	1	54.17	0	2.13	*	6.67		4	2	1963
835	STSS	303	MGRB	G2	Steel Rolled Beam	Y	1	54.17	0	6.67		6.67		4	2	1963

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
836	STSS	304	MGRB	G2_-_1st_N_Int_	Steel Rolled Beam	N	1	55.67	32	7.92		7.92		5	2	1958
837	STSS	305	MGRB	G1	Steel Rolled Beam	N	1	82.83	0	2.17	*	4.5		5	2	1959
838	STSS	305	MGRB	G2	Steel Rolled Beam	N	1	82.83	0	4.5		4.5		5	2	1959
839	STSS	306	MGRB	6_-_4th_S_Int	Steel Rolled Beam	Y	1	78.7	-7.57	7		7		10	4	1960
840	STSS	307	MGRB	3_-_2nd_W_Int	Steel Rolled Beam	Y	1	59.98	-43.02	6		6		6	2	1960
841	STSS	308	MGRB	1_-_E_Fascia	Steel Rolled Beam	Y	1	71.83	-51.73	6		2.75	*	6	2	1960
842	STSS	308	MGRB	5_-_1st_W_Int	Steel Rolled Beam	Y	1	71.83	-51.73	6		6		6	2	1960
843	STSS	308	MGRB	6_-_W_Fascia	Steel Rolled Beam	Y	1	71.83	-51.73	2.75	*	6		6	2	1960
844	STSS	309	MGRB	G1	Steel Rolled Beam	Y	1	66.92	-20	1.09	*	6.25		6	2	1961
845	STSS	309	MGRB	G2	Steel Rolled Beam	Y	1	66.92	-20	6.25		6.25		6	2	1961
846	STSS	309	MGRB	G3	Steel Rolled Beam	Y	1	66.92	-20	6.25		6.25		6	2	1961
847	STSS	309	MGRB	G4	Steel Rolled Beam	Y	1	66.92	-20	6.25		6.25		6	2	1961
848	STSS	309	MGRB	G5	Steel Rolled Beam	Y	1	66.92	-20	6.25		6.25		6	2	1961
849	STSS	309	MGRB	G6	Steel Rolled Beam	Y	1	66.92	-20	6.25		1.08	*	6	2	1961
850	STSS	310	MGRB	G1	Steel Rolled Beam	Y	1	79.44	0	2.38	*	6.67		4	2	1961
851	STSS	310	MGRB	G2	Steel Rolled Beam	Y	1	79.44	0	6.67		6.67		4	2	1961
852	STSS	311	MGRB	G1__For_Level_II_Rating	Steel Rolled Beam	Y	1	58.35	-33	2.05	*	7.81		6	3	1961
853	STSS	312	MGRB	G1	Steel Rolled Beam	Y	1	63.79	30	2.13	*	6.67		4	2	1963
854	STSS	312	MGRB	G2	Steel Rolled Beam	Y	1	63.79	30	6.67		6.67		4	2	1963
855	STSS	313	MGRB	G1	Steel Rolled Beam	Y	1	60	0	1.38	*	7.79		5	2	1963
856	STSS	313	MGRB	G2	Steel Rolled Beam	Y	1	60	0	7.79		7.79		5	2	1963
857	STSS	314	MGRB	G1	Steel Rolled Beam	Y	1	84	0	3.08	*	7.75		9	5	1963
858	STSS	314	MGRB	G2	Steel Rolled Beam	Y	1	84	0	7.75		7.75		9	5	1963
859	STSS	314	MGRB	G3	Steel Rolled Beam	Y	1	84	0	7.75		7.75		9	5	1963
860	STSS	314	MGRB	G4	Steel Rolled Beam	Y	1	84	0	7.75		7.75		9	5	1963
861	STSS	314	MGRB	G5	Steel Rolled Beam	Y	1	84	0	7.75		7.75		9	5	1963
862	STSS	314	MGRB	G6	Steel Rolled Beam	Y	1	84	0	7.75		7.75		9	5	1963

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
863	STSS	314	MGRB	G7	Steel Rolled Beam	Y	1	84	0	7.75		7.75		9	5	1963
864	STSS	314	MGRB	G8	Steel Rolled Beam	Y	1	84	0	7.75		7.75		9	5	1963
865	STSS	314	MGRB	G9	Steel Rolled Beam	Y	1	84	0	7.75		2.42	*	9	5	1963
866	STSS	315	MGRB	G1	Steel Rolled Beam	Y	1	75.38	55.86	2.96	*	7.58		7	3	1963
867	STSS	315	MGRB	G2	Steel Rolled Beam	Y	1	75.38	55.86	7.58		7.58		7	3	1963
868	STSS	315	MGRB	G3	Steel Rolled Beam	Y	1	75.38	55.86	7.58		7.58		7	3	1963
869	STSS	315	MGRB	G4	Steel Rolled Beam	Y	1	75.38	55.86	7.58		7.58		7	3	1963
870	STSS	315	MGRB	G5	Steel Rolled Beam	Y	1	75.38	55.86	7.58		3.58		7	3	1963
871	STSS	315	MGRB	G6	Steel Rolled Beam	Y	1	75.38	55.86	3.58		5.25		7	3	1963
872	STSS	315	MGRB	G7	Steel Rolled Beam	Y	1	75.38	55.86	5.25		3.21	*	7	3	1963
873	STSS	317	MGRB	G1	Steel Rolled Beam	Y	1	84.31	-43.5	2.34	*	4.6		6	2	1964
874	STSS	317	MGRB	G3	Steel Rolled Beam	Y	1	84.31	-43.5	4.6		4.6		6	2	1964
875	STSS	317	MGRB	G6	Steel Rolled Beam	Y	1	84.31	-43.5	4.6		2.16	*	6	2	1964
876	STSS	318	MGRB	G1	Steel Rolled Beam	Y	1	76.17	-45.45	1.46	*	5.13		12	4	1964
877	STSS	318	MGRB	G12	Steel Rolled Beam	Y	1	76.17	-45.45	5.13		6.29	*	12	4	1964
878	STSS	318	MGRB	G3	Steel Rolled Beam	Y	1	76.17	-45.45	5.13		5.13		12	4	1964
879	STSS	319	MGRB	G1	Steel Rolled Beam	Y	1	79.26	-0.69	2.67	*	7.67		5	2	1964
880	STSS	319	MGRB	G2	Steel Rolled Beam	Y	1	79.26	-0.69	7.67		7.67		5	2	1964
881	STSS	319	MGRB	G3	Steel Rolled Beam	Y	1	79.26	-0.69	7.67		7.67		5	2	1964
882	STSS	319	MGRB	G4	Steel Rolled Beam	Y	1	79.26	-0.69	7.67		7.67		5	2	1964
883	STSS	319	MGRB	G5	Steel Rolled Beam	Y	1	79.26	-0.69	7.67		2	*	5	2	1964
884	STSS	320	MGRB	G1	Steel Rolled Beam	Y	1	65.64	11.38	1.99	*	8.6		6	3	1964
885	STSS	320	MGRB	G2	Steel Rolled Beam	Y	1	65.64	11.38	8.6		8.6		6	3	1964
886	STSS	320	MGRB	G3	Steel Rolled Beam	Y	1	65.64	11.38	8.6		8.6		6	3	1964
887	STSS	320	MGRB	G4	Steel Rolled Beam	Y	1	65.64	11.38	8.6		8.6		6	3	1964
888	STSS	320	MGRB	G5	Steel Rolled Beam	Y	1	65.64	11.38	8.6		8.6		6	3	1964
889	STSS	320	MGRB	G6	Steel Rolled Beam	Y	1	65.64	11.38	8.6		1.99	*	6	3	1964
890	STSS	321	MGRB	G1	Steel Rolled Beam	Y	1	63.92	15	2.75	*	7.67		4	2	1965

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
891	STSS	321	MGRB	G2	Steel Rolled Beam	Y	1	63.92	15	7.67		7.67		4	2	1965
892	STSS	322	MGRB	G1	Steel Rolled Beam	Y	1	53	-29.47	1.33	*	8.5		8	4	1967
893	STSS	322	MGRB	G2	Steel Rolled Beam	Y	1	53	-29.47	8.5		7.5		8	4	1967
894	STSS	322	MGRB	G3	Steel Rolled Beam	Y	1	53	-29.47	7.5		7.5		8	4	1967
895	STSS	322	MGRB	G6	Steel Rolled Beam	Y	1	53	-29.47	7.5		7.25		8	4	1967
896	STSS	322	MGRB	G7	Steel Rolled Beam	Y	1	53	-29.47	7.25		7.25		8	4	1967
897	STSS	322	MGRB	G8	Steel Rolled Beam	Y	1	53	-29.47	7.25		1.33	*	8	4	1967
898	STSS	323	MGRB	G1	Steel Rolled Beam	Y	1	79.95	0	1.71	*	7.25		6	3	1967
899	STSS	323	MGRB	G2	Steel Rolled Beam	Y	1	79.95	0	7.25		7.25		6	3	1967
900	STSS	324	MGRB	G1	Steel Rolled Beam	Y	1	78.63	25.75	2.58	*	8		4	2	1968
901	STSS	324	MGRB	G2	Steel Rolled Beam	Y	1	78.63	25.75	8		8		4	2	1968
902	STSS	325	MGRB	G1	Steel Rolled Beam	Y	1	68.68	19	1.5	*	6.5		5	2	1968
903	STSS	325	MGRB	G2	Steel Rolled Beam	Y	1	68.68	19	6.5		6.5		5	2	1968
904	STSS	326	MGRB	G1	Steel Rolled Beam	Y	1	66	25	3.33	*	6		9	4	2003
905	STSS	326	MGRB	G2	Steel Rolled Beam	Y	1	66	25	6		6		9	4	2003
906	STSS	327	MGRB	G1	Steel Rolled Beam	Y	1	81.17	0	2.58	*	8		9	5	1974
907	STSS	327	MGRB	G2	Steel Rolled Beam	Y	1	81.17	0	8		8		9	5	1974
908	STSS	328	MGRB	G1	Steel Rolled Beam	Y	1	70.5	35	2.41	*	6.69		7	2	1972
909	STSS	328	MGRB	G2	Steel Rolled Beam	Y	1	70.5	35	6.69		6.69		7	2	1972
910	STSS	329	MGRB	G1	Steel Rolled Beam	Y	1	75.75	0	2.54	*	7.08		6	3	1973
911	STSS	329	MGRB	G2	Steel Rolled Beam	Y	1	75.75	0	7.08		7.08		6	3	1973
912	STSS	330	MGRB	G1	Steel Rolled Beam	Y	1	80	0	3.88	*	7		6	3	1982
913	STSS	330	MGRB	G2	Steel Rolled Beam	Y	1	80	0	7		7		6	3	1982
914	STSS	331	MGRB	G1	Steel Rolled Beam	Y	1	81.68	0	3.3	*	7.08		6	3	1976
915	STSS	331	MGRB	G2	Steel Rolled Beam	Y	1	81.68	0	7.08		7.08		6	3	1976
916	STSS	332	MGRB	G1	Steel Rolled Beam	N	1	71.58	0	0.96	*	4.52		5	2	1979
917	STSS	332	MGRB	G2	Steel Rolled Beam	N	1	71.58	0	4.52		4.5		5	2	1979
918	STSS	332	MGRB	G5	Steel Rolled Beam	N	1	71.58	0	4.54		1.08	*	5	2	1979

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
919	STSS	333	MGRB	G1	Steel Rolled Beam	Y	1	81.68	0	3.38	*	7.88		7	4	1976
920	STSS	333	MGRB	G2	Steel Rolled Beam	Y	1	81.68	0	7.88		7.88		7	4	1976
921	STSS	334	MGRB	3_-_2nd_E_Int	Steel Rolled Beam	Y	1	66.67	0	7.5		7.5		6	3	1993
922	STSS	335	MGRB	3_-_2nd_N_Int-x	Steel Rolled Beam	Y	1	82.48	0	5.45		5.45		7	3	1998
923	STSS	336	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	Y	1	81.43	-4.9	6.75		6.75		11	5	2005
924	STSS	337	MGRB	G1	Steel Rolled Beam	Y	1	78.45	-40.71	2.54	*	5.5		11	3	2003
925	STSS	337	MGRB	G2	Steel Rolled Beam	Y	1	78.45	-40.71	5.5		5.5		11	3	2003
926	STSS	337	MGRB	G3	Steel Rolled Beam	Y	1	78.45	-40.71	5.5		5.5		11	3	2003
927	STSS	338	MGSP	G1	Steel Plate	Y	1	110	45	2.33	*	7.5		7	3	1959
928	STSS	338	MGSP	G2	Steel Plate	Y	1	110	45	7.5		7.5		7	3	1959
929	STSS	339	MGSP	Interior_Girder	Steel Plate	Y	1	109.88	42.29	6		6		10	4	1962
930	STSS	339	MGSP	Left_Fascia_Girder	Steel Plate	Y	1	109.88	42.29	2.5	*	7.5		10	4	1962
931	STSS	339	MGSP	Original_Fascia_Girder	Steel Plate	Y	1	109.88	42.29	7.5		6		10	4	1962
932	STSS	339	MGSP	Right_Fascia_Girder	Steel Plate	Y	1	109.88	42.29	6		2.25	*	10	4	1962
933	STSS	339	MGSP	Typical_Interior_Girder_at_Widening	Steel Plate	Y	1	109.88	42.29	7.5		7.5		10	4	1962
934	STSS	340	MGSP	3_-_2nd_N_Int_-_x	Steel Plate	Y	1	106.1	45	7.42		7.42		6	3	2008
935	STSS	341	MGSP	S11_-_2nd_N_Int-x	Steel Plate	Y	1	109.4	-40.43	5.7		5.7		8	3	1965
936	STSS	342	MGSP	G1	Steel Plate	Y	1	105.25	24.9	1.4	*	8.58		4	2	1968
937	STSS	342	MGSP	G2	Steel Plate	Y	1	105.25	24.9	8.58		8.58		4	2	1968
938	STSS	342	MGSP	G3	Steel Plate	Y	1	105.25	24.9	8.58		8.58		4	2	1968
939	STSS	342	MGSP	G4	Steel Plate	Y	1	105.25	24.9	8.58		1.4	*	4	2	1968
940	STSS	343	MGSP	Member_2	Steel Plate	Y	1	116.38	14.65	8		8		6	3	1972
941	STSS	344	MGSP	G1	Steel Plate	Y	1	100	28	1.58	*	8.17		6	3	1973
942	STSS	344	MGSP	G2	Steel Plate	Y	1	100	28	8.17		8.17		6	3	1973
943	STSS	345	MGSP	G1	Steel Plate	Y	1	100	0	3	*	9.5		5	3	1972
944	STSS	345	MGSP	G2	Steel Plate	Y	1	100	0	9.5		9.5		5	3	1972
945	STSS	346	MGSP	G1	Steel Plate	Y	1	109.58	0	2.79	*	7		6	3	1975

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
946	STSS	346	MGSP	G2	Steel Plate	Y	1	109.58	0	7		7		6	3	1975
947	STSS	347	MGSP	G1	Steel Plate	Y	1	109.58	0	2.79	*	7		6	3	1975
948	STSS	347	MGSP	G2	Steel Plate	Y	1	109.58	0	7		7		6	3	1975
949	STSS	348	MGSP	11_-_6th_NB_fr_S	Steel Plate	Y	1	109	34.04	7.67		7.67		8	4	1979
950	STSS	348	MGSP	15_-_2nd_NB_fr_S	Steel Plate	Y	1	109	34.04	7.67		7.67		8	4	1979
951	STSS	349	MGSP	G1	Steel Plate	Y	1	115	0	3.83	*	10.33		4	3	1980
952	STSS	349	MGSP	G2	Steel Plate	Y	1	115	0	10.33		10.33		4	3	1980
953	STSS	350	MGSP	Fascia_Grider	Steel Plate	Y	1	113.26	30	1.88	*	8		6	3	1972
954	STSS	350	MGSP	Interior_Girder	Steel Plate	Y	1	113.26	30	8		8		6	3	1972
955	STSS	351	MGSP	9_-_2nd_W_Int	Steel Plate	Y	1	105	-2.15	7.42		7.42		6	3	1988
956	STSS	352	MGSP	G1	Steel Plate	Y	1	112	15	2	*	6.5		7	3	1997
957	STSS	352	MGSP	G2	Steel Plate	Y	1	112	15	6.5		6.5		7	3	1997
958	STSS	353	MGSP	G1	Steel Plate	Y	1	110.56	-15.62	3.27	*	7.61		7	4	2000
959	STSS	353	MGSP	G2_Level_2	Steel Plate	Y	1	110.56	-15.62	7.61		7.61		7	4	2000
960	STSS	354	MGSP	Fascia_Girder	Steel Plate	Y	1	93	0	2.21	*	7.25		7	3	1983
961	STSS	354	MGSP	Interior_Girder	Steel Plate	Y	1	93	0	7.25		7.25		7	3	1983
962	STSS	355	MGBU	7_-_2nd_S_Int-x	Steel Built-Up	Y	1	100.5	-53	7		7		9	4	1958
963	STSS	356	MGBU	Typical_1st_Interior	Steel Built-Up	Y	1	99.48	39.45	5.37		5.37		12	4	1960
964	STSS	356	MGBU	Typical_Fascia	Steel Built-Up	Y	1	99.48	39.45	1.21	*	5.37		12	4	1960
965	STSS	356	MGBU	Typical_Interior	Steel Built-Up	Y	1	99.48	39.45	5.37		5.37		12	4	1960
966	STSS	357	MGBU	G1	Steel Built-Up	Y	1	110	0	1.5	*	6		5	2	1967
967	STSS	357	MGBU	G2	Steel Built-Up	Y	1	110	0	6		6		5	2	1967
968	STSS	358	MGRB	Member_1	Steel Rolled Beam	Y	1	90	-38.5	2.13	*	7.04		10	5	1953
969	STSS	358	MGRB	Member_10	Steel Rolled Beam	Y	1	90	-38.5	7.04		3	*	10	5	1953
970	STSS	358	MGRB	Member_2	Steel Rolled Beam	Y	1	90	-38.5	7.04		7.04		10	5	1953
971	STSS	359	MGRB	G1	Steel Plate	Y	1	115	-54.95	2.6	*	8.5		6	3	1961
972	STSS	359	MGRB	G2	Steel Plate	Y	1	115	-54.95	8.5		8.5		6	3	1961
973	STSS	359	MGRB	G3	Steel Plate	Y	1	115	-54.95	8.5		8.5		6	3	1961

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
974	STSS	359	MGRB	G4	Steel Plate	Y	1	115	-54.95	8.5		8.5		6	3	1961
975	STSS	359	MGRB	G5	Steel Plate	Y	1	115	-54.95	8.5		8.5		6	3	1961
976	STSS	359	MGRB	G6	Steel Plate	Y	1	115	-54.95	8.5		2.6	*	6	3	1961
977	STSS	360	MGRB	G1	Steel Plate	Y	1	100.52	59.6	2.61	*	8.18		6	3	1968
978	STSS	360	MGRB	G2	Steel Plate	Y	1	100.52	59.6	8.18		8.18		6	3	1968
979	STSS	360	MGRB	G3	Steel Plate	Y	1	100.52	59.6	8.18		8.18		6	3	1968
980	STSS	360	MGRB	G4	Steel Plate	Y	1	100.52	59.6	8.18		8.18		6	3	1968
981	STSS	360	MGRB	G5	Steel Plate	Y	1	100.52	59.6	8.18		8.18		6	3	1968
982	STSS	360	MGRB	G6	Steel Plate	Y	1	100.52	59.6	8.18		3.49	*	6	3	1968
983	STSS	361	MGRB	G1	Steel Rolled Beam	Y	1	93.11	0	2.71	*	7.08		10	5	1973
984	STSS	362	MGSP	Fascia_Girder	Steel Plate	Y	1	113.15	-41.58	2.17	*	6.75		7	3	1972
985	STSS	362	MGSP	Interior_Girder	Steel Plate	Y	1	113.15	-41.58	6.75		6.75		7	3	1972
986	STSS	363	MGRB	G1	Steel Plate	Y	1	109.58	0	2.79	*	7		6	3	1975
987	STSS	363	MGRB	G2	Steel Plate	Y	1	109.58	0	7		7		6	3	1975
988	STSS	364	MGRB	G1	Steel Rolled Beam	Y	1	89.44	-40.02	3.17	*	7.5		12	6	1987
989	STSS	364	MGRB	G2	Steel Rolled Beam	Y	1	89.44	-40.02	7.5		7.5		12	6	1987
990	STSS	365	MGRB	G1	Steel Rolled Beam	N	1	89	0	1	*	5.5		3	1	1991
991	STSS	365	MGRB	G2	Steel Rolled Beam	N	1	89	0	5.5		5.5		3	1	1991
992	STSS	365	MGRB	G3	Steel Rolled Beam	N	1	89	0	5.5		1	*	3	1	1991
993	STSS	366	MGRB	G1	Steel Rolled Beam	Y	1	100	0	2.42	*	6.83		12	5	1997
994	STSS	366	MGRB	G10	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997
995	STSS	366	MGRB	G11	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997
996	STSS	366	MGRB	G12	Steel Rolled Beam	Y	1	100	0	6.83		2.42	*	12	5	1997
997	STSS	366	MGRB	G2	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997
998	STSS	366	MGRB	G3	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997
999	STSS	366	MGRB	G4	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997
1000	STSS	366	MGRB	G5	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997
1001	STSS	366	MGRB	G6	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1002	STSS	366	MGRB	G7	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997
1003	STSS	366	MGRB	G8	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997
1004	STSS	366	MGRB	G9	Steel Rolled Beam	Y	1	100	0	6.83		6.83		12	5	1997
1005	STSS	367	MGSP	Member_1	Steel Plate	Y	1	138.59	-31.66	4.25	*	8.45		7	4	2000
1006	STSS	367	MGSP	Member_2	Steel Plate	Y	1	138.59	-31.66	8.45		8.45		7	4	2000
1007	STSS	368	MGSP	Left_Fascia_Girder	Steel Plate	Y	1	178.2	5.76	2.33	*	8.33		7	4	2003
1008	STSS	368	MGSP	Right_Fascia_Girder	Steel Plate	Y	1	178.2	5.76	8.33		1.37	*	7	4	2003
1009	STSS	368	MGSP	Typical_Interior_Girder	Steel Plate	Y	1	178.2	5.76	8.33		8.33		7	4	2003
1010	STSS	369	MGSP	Girder_A	Steel Plate	Y	1	136.85	-1.08	2	*	7.25		7	3	2005
1011	STSS	369	MGSP	Girder_B	Steel Plate	Y	1	136.85	-1.08	7.25		7.25		7	3	2005
1012	STSS	370	MGSP	G1	Steel Plate	Y	1	153.61	67.5	2.5	*	7.25		8	4	1974
1013	STSS	370	MGSP	G2	Steel Plate	Y	1	153.61	67.5	7.25		7.25		8	4	1974
1014	STSS	370	MGSP	G5	Steel Plate	Y	1	153.61	67.5	7.25		7.25		8	4	1974
1015	STSS	370	MGSP	G6	Steel Plate	Y	1	153.61	67.5	7.25		6.38		8	4	1974
1016	STSS	370	MGSP	G7	Steel Plate	Y	1	153.61	67.5	6.38		6.38		8	4	1974
1017	STSS	370	MGSP	G8	Steel Plate	Y	1	153.61	67.5	6.38		2.46	*	8	4	1974
1018	STSS	371	MGSP	Girder_L_(10S)	Steel Plate	Y	1	120	0	2.98	*	7.4		10	5	1988
1019	STSS	371	MGSP	Girder_Q_(6S)	Steel Plate	Y	1	120	0	7.4		7.4		10	5	1988
1020	STSS	371	MGSP	Girder_V_(1S)	Steel Plate	Y	1	120	0	7.4		3	*	10	5	1988
1021	STSS	372	MGSP	G2	Steel Plate	Y	1	163.38	45	8.5		8.5		4	2	1958
1022	STSS	373	MGSP	Girder_A	Steel Plate	Y	1	146.92	-30	2.25	*	6.5		8	3	2005
1023	STSS	373	MGSP	Girder_B	Steel Plate	Y	1	146.92	-30	6.5		6.5		8	3	2005
1024	STSS	374	MGSP	G1_-_span_length_150_75_ft	Steel Plate	Y	1	150.75	33.5	1.44	*	7.5		5	2	1967
1025	STSS	375	MGSP	Interior_Girder_G2	Steel Plate	Y	1	172.5	8.26	9.08		9.08		7	4	1971
1026	STSS	376	MGSP	G1	Steel Plate	Y	1	132.89	65	3.13	*	6.38		9	5	1974
1027	STSS	376	MGSP	G2	Steel Plate	Y	1	132.89	65	6.38		6.38		9	5	1974
1028	STSS	376	MGSP	G3	Steel Plate	Y	1	132.89	65	6.38		8.04		9	5	1974

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1029	STSS	376	MGSP	G4	Steel Plate	Y	1	132.89	65	8.04		8.04		9	5	1974
1030	STSS	376	MGSP	G9	Steel Plate	Y	1	132.89	65	8.04		1.83	*	9	5	1974
1031	STSS	377	MGSP	G2	Steel Plate	Y	1	169.83	58.51	9.5		9.5		5	3	1970
1032	STSS	377	MGSP	G3	Steel Plate	Y	1	169.83	58.51	9.5		9.5		5	3	1970
1033	STSS	378	MGSP	G10	Steel Plate	Y	1	140.3	13.5	8.25		8.25		11	6	1987
1034	STSS	378	MGSP	G11	Steel Plate	Y	1	140.3	13.5	8.25		2.04	*	11	6	1987
1035	STSS	378	MGSP	G8	Steel Plate	Y	1	140.3	13.5	8.25		8.25		11	6	1987
1036	STSS	379	MGSP	Member_1	Steel Plate	Y	1	212	23.55	2.21	*	10.25		12	9	1999
1037	STSS	379	MGSP	Member_2	Steel Plate	Y	1	212	23.55	10.25		10.25		12	9	1999
1038	STSS	380	MGSP	G1	Steel Plate	Y	1	126	0	2.96	*	9.75		6	4	2003
1039	STSS	380	MGSP	G2	Steel Plate	Y	1	126	0	9.75		9.75		6	4	2003
1040	STSS	381	MGSP	G1	Steel Plate	Y	1	204	-5	3.42	*	9.67		6	4	2006
1041	STSS	381	MGSP	G2	Steel Plate	Y	1	204	-5	9.67		9.67		6	4	2006
1042	PSSS	382	PSIB	Member_2	Prestressed I-Beam	Y	1	43.56	0	7		7		7	3	1956
1043	PSSS	383	PSIB	2nd_N_Int_	Prestressed I-Beam	Y	1	48.98	15	5.25		5.25		7	2	1959
1044	PSSS	384	PSIB	10_-_1st_S_Int-x	Prestressed I-Beam	Y	1	49	10.57	4.92		6.33		11	4	1959
1045	PSSS	385	PSIB	2_-_1st_N_Int-x	Prestressed I-Beam	Y	1	48	3.65	6.33		4.92		11	4	1959
1046	PSSS	386	PSIB	G1	Prestressed I-Beam	Y	1	42	0	2.75	*	6.5		7	3	1959
1047	PSSS	386	PSIB	G2	Prestressed I-Beam	Y	1	42	0	6.5		6.5		7	3	1959
1048	PSSS	386	PSIB	G3	Prestressed I-Beam	Y	1	42	0	6.5		6.5		7	3	1959
1049	PSSS	386	PSIB	G4	Prestressed I-Beam	Y	1	42	0	6.5		6.5		7	3	1959
1050	PSSS	387	PSIB	Beam_A	Prestressed I-Beam	Y	1	39.58	2.29	2.67	*	6.83		11	5	1960
1051	PSSS	387	PSIB	Beam_C	Prestressed I-Beam	Y	1	39.58	2.29	6.83		6.83		11	5	1960
1052	PSSS	387	PSIB	Beam_D	Prestressed I-Beam	Y	1	39.58	2.29	6.83		6		11	5	1960
1053	PSSS	387	PSIB	Beam_F	Prestressed I-Beam	Y	1	39.58	2.29	6		6		11	5	1960
1054	PSSS	387	PSIB	Beam_G	Prestressed I-Beam	Y	1	39.58	2.29	6		7		11	5	1960
1055	PSSS	387	PSIB	Beam_R	Prestressed I-Beam	Y	1	39.58	2.29	7		7		11	5	1960
1056	PSSS	387	PSIB	Beam_T	Prestressed I-Beam	Y	1	39.58	2.29	7		2.42	*	11	5	1960

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1057	PSSS	388	PSIB	G1	Prestressed I-Beam	Y	1	49	30	2	*	8		6	3	1960
1058	PSSS	388	PSIB	G2	Prestressed I-Beam	Y	1	49	30	8		8		6	3	1960
1059	PSSS	388	PSIB	G3	Prestressed I-Beam	Y	1	49	30	8		8		6	3	1960
1060	PSSS	389	PSIB	Beam_A	Prestressed I-Beam	Y	1	40.42	0	2.38	*	6		8	3	1961
1061	PSSS	389	PSIB	Beam_D	Prestressed I-Beam	Y	1	40.42	0	6		6		8	3	1961
1062	PSSS	390	PSIB	G1	Prestressed I-Beam	Y	1	51.08	3.5	2.25	*	5.71		18	7	1962
1063	PSSS	390	PSIB	G10	Prestressed I-Beam	Y	1	51.08	3.5	5.71		4.63		18	7	1962
1064	PSSS	390	PSIB	G11	Prestressed I-Beam	Y	1	51.08	3.5	4.63		5.58		18	7	1962
1065	PSSS	390	PSIB	G12	Prestressed I-Beam	Y	1	51.08	3.5	5.58		5.58		18	7	1962
1066	PSSS	390	PSIB	G2	Prestressed I-Beam	Y	1	51.08	3.5	5.71		5.71		18	7	1962
1067	PSSS	391	PSIB	G1	Prestressed I-Beam	Y	1	46.8	30.73	2.75	*	6.36		7	3	1963
1068	PSSS	391	PSIB	G4	Prestressed I-Beam	Y	1	46.8	30.73	6.36		6.36		7	3	1963
1069	PSSS	391	PSIB	G7	Prestressed I-Beam	Y	1	46.8	30.73	6.36		2	*	7	3	1963
1070	PSSS	392	PSIB	Member_1	Prestressed I-Beam	Y	1	48.67	30	2	*	6.75		5	2	1963
1071	PSSS	392	PSIB	Member_2	Prestressed I-Beam	Y	1	48.67	30	6.75		6.75		5	2	1963
1072	PSSS	393	PSIB	Member_1	Prestressed I-Beam	Y	1	43.67	0	2	*	6.75		5	2	1964
1073	PSSS	393	PSIB	Member_2	Prestressed I-Beam	Y	1	43.67	0	6.75		6.75		5	2	1964
1074	PSSS	394	PSIB	G1	Prestressed I-Beam	Y	1	46	0	3.25	*	7.5		6	3	1965
1075	PSSS	394	PSIB	G2	Prestressed I-Beam	Y	1	46	0	7.5		7.5		6	3	1965
1076	PSSS	394	PSIB	G3	Prestressed I-Beam	Y	1	46	0	7.5		7.5		6	3	1965
1077	PSSS	395	PSIB	G1	Prestressed I-Beam	Y	1	32.92	0	2.63	*	8		4	2	1967
1078	PSSS	395	PSIB	G2	Prestressed I-Beam	Y	1	32.92	0	8		8		4	2	1967
1079	PSSS	396	PSIB	G1	Prestressed I-Beam	Y	1	48.5	0	2.02	*	6.08		13	6	1967
1080	PSSS	396	PSIB	G10	Prestressed I-Beam	Y	1	48.5	0	5.96		5.96		13	6	1967
1081	PSSS	396	PSIB	G11	Prestressed I-Beam	Y	1	48.5	0	5.96		5.96		13	6	1967
1082	PSSS	396	PSIB	G12	Prestressed I-Beam	Y	1	48.5	0	5.96		6.08		13	6	1967
1083	PSSS	396	PSIB	G2	Prestressed I-Beam	Y	1	48.5	0	6.08		6.08		13	6	1967
1084	PSSS	396	PSIB	G3	Prestressed I-Beam	Y	1	48.5	0	6.08		6.08		13	6	1967

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1085	PSSS	396	PSIB	G4	Prestressed I-Beam	Y	1	48.5	0	6.08		6.08		13	6	1967
1086	PSSS	396	PSIB	G5	Prestressed I-Beam	Y	1	48.5	0	6.08		6.08		13	6	1967
1087	PSSS	396	PSIB	G7	Prestressed I-Beam	Y	1	48.5	0	6.08		5.96		13	6	1967
1088	PSSS	396	PSIB	G8	Prestressed I-Beam	Y	1	48.5	0	5.96		5.96		13	6	1967
1089	PSSS	397	PSIB	Member_1	Prestressed I-Beam	Y	1	38.5	0	2.75	*	8		6	3	1969
1090	PSSS	397	PSIB	Member_2	Prestressed I-Beam	Y	1	38.5	0	8		8		6	3	1969
1091	PSSS	398	PSIB	G2	Prestressed I-Beam	Y	1	31.17	0	8.25		8.25		10	5	1972
1092	PSSS	399	PSIB	G1	Prestressed I-Beam	Y	1	37.58	-15	2.33	*	9.17		9	5	1972
1093	PSSS	399	PSIB	G2	Prestressed I-Beam	Y	1	37.58	-15	9.17		9.17		9	5	1972
1094	PSSS	400	PSIB	Member_1	Prestressed I-Beam	Y	1	43.5	0	3.88	*	9.5		5	3	1972
1095	PSSS	400	PSIB	Member_2	Prestressed I-Beam	Y	1	43.5	0	9.5		9.5		5	3	1972
1096	PSSS	401	PSIB	G1	Prestressed I-Beam	Y	1	48.92	0	3.13	*	9		5	3	1973
1097	PSSS	401	PSIB	G2	Prestressed I-Beam	Y	1	48.92	0	9		9		5	3	1973
1098	PSSS	402	PSIB	Member_1	Prestressed I-Beam	Y	1	38.5	0	3.54	*	9.17		5	3	1975
1099	PSSS	402	PSIB	Member_2	Prestressed I-Beam	Y	1	38.5	0	9.17		9.17		5	3	1975
1100	PSSS	403	PSIB	9_-_2nd_E_Int	Prestressed I-Beam	Y	1	45.5	2.01	7.17		7.17		6	3	1978
1101	PSSS	404	PSIB	G1	Prestressed I-Beam	Y	1	32.63	0	3.38	*	8		4	2	1982
1102	PSSS	404	PSIB	G2	Prestressed I-Beam	Y	1	32.63	0	8		8		4	2	1982
1103	PSSS	405	PSIB	G1	Prestressed I-Beam	Y	1	32.63	0	3.38	*	8		4	2	1984
1104	PSSS	405	PSIB	G2	Prestressed I-Beam	Y	1	32.63	0	8		8		4	2	1984
1105	PSSS	406	PSIB	G1	Prestressed I-Beam	Y	1	31.25	0	2.21	*	7.25		7	3	1985
1106	PSSS	406	PSIB	G2	Prestressed I-Beam	Y	1	31.25	0	7.25		7.25		7	3	1985
1107	PSSS	407	PSIB	G1	Prestressed I-Beam	Y	1	33.74	30	3.38	*	7		5	2	1987
1108	PSSS	407	PSIB	G2	Prestressed I-Beam	Y	1	33.74	30	7		7		5	2	1987
1109	PSSS	408	PSIB	G1	Prestressed I-Beam	Y	1	39.88	0	3.38	*	6.67		4	2	1988
1110	PSSS	408	PSIB	G2	Prestressed I-Beam	Y	1	39.88	0	6.67		6.67		4	2	1988
1111	PSSS	409	PSIB	Member_1	Prestressed I-Beam	Y	1	38.25	0	2.88	*	8.75		8	5	1988
1112	PSSS	409	PSIB	Member_2	Prestressed I-Beam	Y	1	38.25	0	8.75		8.75		8	5	1988

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1113	PSSS	410	PSIB	G1	Prestressed I-Beam	Y	1	47.46	0	3.38	*	6.67		4	2	1990
1114	PSSS	410	PSIB	G2	Prestressed I-Beam	Y	1	47.46	0	6.67		6.67		4	2	1990
1115	PSSS	411	PSIB	G1	Prestressed I-Beam	Y	1	52.5	0	3.88	*	7		6	3	1990
1116	PSSS	411	PSIB	G2	Prestressed I-Beam	Y	1	52.5	0	7		7		6	3	1990
1117	PSSS	412	PSIB	G1	Prestressed I-Beam	Y	1	48.58	0	3.38	*	8		4	2	1991
1118	PSSS	412	PSIB	G2	Prestressed I-Beam	Y	1	48.58	0	8		8		4	2	1991
1119	PSSS	413	PSIB	G1	Prestressed I-Beam	Y	1	32.63	0	3.38	*	8		4	2	1992
1120	PSSS	413	PSIB	G2	Prestressed I-Beam	Y	1	32.63	0	8		8		4	2	1992
1121	PSSS	414	PSIB	G1	Prestressed I-Beam	Y	1	38.5	0	3.23	*	8.08		4	2	1993
1122	PSSS	414	PSIB	G2	Prestressed I-Beam	Y	1	38.5	0	8.08		8.08		4	2	1993
1123	PSSS	415	PSIB	G1	Prestressed I-Beam	Y	1	47.67	0	3.38	*	8		6	3	1993
1124	PSSS	415	PSIB	G2	Prestressed I-Beam	Y	1	47.67	0	8		8		6	3	1993
1125	PSSS	416	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	1	49.54	0	5.77		5.77		6	2	2001
1126	PSSS	417	PSIB	G2	Prestressed I-Beam	Y	1	47.83	0	6.58		6.58		7	3	2002
1127	PSSS	418	PSIB	G1	Prestressed I-Beam	Y	1	50.58	-35	3	*	7.17		5	2	2003
1128	PSSS	418	PSIB	G2	Prestressed I-Beam	Y	1	50.58	-35	7.17		7.17		5	2	2003
1129	PSSS	419	PSIB	4_-_1st_N_Int	Prestressed I-Beam	Y	1	47.25	0	8		8		6	3	2003
1130	PSSS	420	PSIB	G1	Prestressed I-Beam	Y	1	58.75	25	2.13	*	7.17		7	3	1985
1131	PSSS	420	PSIB	G3	Prestressed I-Beam	Y	1	58.75	25	7.17		7.17		7	3	1985
1132	PSSS	421	PSIB	Member_1	Prestressed I-Beam	Y	1	69.17	0	2.25	*	6		5	2	1957
1133	PSSS	421	PSIB	Member_2	Prestressed I-Beam	Y	1	69.17	0	6		6		5	2	1957
1134	PSSS	422	PSIB	4_-_3rd_S_Int	Prestressed I-Beam	Y	1	73.6	0	5.33		5.33		7	2	1958
1135	PSSS	422	PSIB	6_-_5th_S_Int	Prestressed I-Beam	Y	1	73.6	0	5.33		5.33		7	2	1958
1136	PSSS	423	PSIB	Member_1	Prestressed I-Beam	Y	1	58.5	0	2.33	*	6.58		5	2	1958
1137	PSSS	423	PSIB	Member_2	Prestressed I-Beam	Y	1	58.5	0	6.58		6.58		5	2	1958
1138	PSSS	424	PSIB	10_-_1st_S_Int	Prestressed I-Beam	Y	1	62.67	-18	4.92		6.33		11	4	1959
1139	PSSS	425	PSIB	4_-_3rd_N_Int-x	Prestressed I-Beam	Y	1	81.22	17.32	5.71		5.71		14	5	1959
1140	PSSS	426	PSIB	G1	Prestressed I-Beam	Y	1	73.5	-20.55	3	*	6.96		8	4	1959

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1141	PSSS	426	PSIB	G2	Prestressed I-Beam	Y	1	73.5	-20.55	6.96		6.96		8	4	1959
1142	PSSS	426	PSIB	G3	Prestressed I-Beam	Y	1	73.5	-20.55	6.96		7.4		8	4	1959
1143	PSSS	426	PSIB	G4	Prestressed I-Beam	Y	1	73.5	-20.55	7.4		7.4		8	4	1959
1144	PSSS	426	PSIB	G6	Prestressed I-Beam	Y	1	73.5	-20.55	7.4		7.4		8	4	1959
1145	PSSS	426	PSIB	G7	Prestressed I-Beam	Y	1	73.5	-20.55	7.4		7.4		8	4	1959
1146	PSSS	426	PSIB	G8	Prestressed I-Beam	Y	1	73.5	-20.55	7.4		2.96	*	8	4	1959
1147	PSSS	427	PSIB	2nd_E_Int	Prestressed I-Beam	Y	1	54.38	0	5.92		5.92		6	2	1960
1148	PSSS	428	PSIB	2_-_2nd_W_Int	Prestressed I-Beam	Y	1	71.67	20.12	6.17		6.17		10	4	1960
1149	PSSS	429	PSIB	8_-_N_(Median)_Fascia__	Prestressed I-Beam	Y	1	57.96	15	3.67	*	5.25		8	3	1960
1150	PSSS	430	PSIB	1A_-_N_(Outer)_Fascia__	Prestressed I-Beam	Y	1	57.96	15	4.75		2.92	*	8	3	1960
1151	PSSS	431	PSIB	G2	Prestressed I-Beam	Y	1	67.5	-16.37	8		8		4	2	1961
1152	PSSS	432	PSIB	20_-_2nd_W_Int-x	Prestressed I-Beam	Y	1	59.5	0	6.25		6.25		18	7	1962
1153	PSSS	433	PSIB	4_-_Centerline-x	Prestressed I-Beam	Y	1	77.67	39.25	5.08		5.08		7	2	1962
1154	PSSS	434	PSIB	G1	Prestressed I-Beam	Y	1	79.63	36	2.12	*	7.92		5	2	1984
1155	PSSS	434	PSIB	G2	Prestressed I-Beam	Y	1	79.63	36	7.92		7.92		5	2	1984
1156	PSSS	435	PSIB	Center	Prestressed I-Beam	Y	1	82.67	0	7		7		5	2	1963
1157	PSSS	436	PSIB	Member_1	Prestressed I-Beam	Y	1	67.17	7	3	*	6.75		5	2	1963
1158	PSSS	436	PSIB	Member_2	Prestressed I-Beam	Y	1	67.17	7	6.75		6.75		5	2	1963
1159	PSSS	436	PSIB	Member_5	Prestressed I-Beam	Y	1	67.17	7	6.75		3	*	5	2	1963
1160	PSSS	437	PSIB	G1	Prestressed I-Beam	Y	1	53.69	32	3.33	*	5.47		6	2	1965
1161	PSSS	437	PSIB	G2	Prestressed I-Beam	Y	1	53.69	32	5.47		5.47		6	2	1965
1162	PSSS	437	PSIB	G3	Prestressed I-Beam	Y	1	53.69	32	5.47		5.47		6	2	1965
1163	PSSS	438	PSIB	3_-_Center	Prestressed I-Beam	Y	1	63.92	0	7.5		7.5		5	2	1967
1164	PSSS	439	PSIB	3_-_Center	Prestressed I-Beam	Y	1	54.35	44.34	7.5		7.5		5	2	1967
1165	PSSS	440	PSIB	Member_1	Prestressed I-Beam	Y	1	58.04	0	3.63	*	7.75		6	3	1967
1166	PSSS	440	PSIB	Member_2	Prestressed I-Beam	Y	1	58.04	0	7.75		7.75		6	3	1967

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1167	PSSS	441	PSIB	G1	Prestressed I-Beam	Y	1	57.67	30	3.38	*	6.67		4	2	1968
1168	PSSS	441	PSIB	G2	Prestressed I-Beam	Y	1	57.67	30	6.67		6.67		4	2	1968
1169	PSSS	442	PSIB	G1	Prestressed I-Beam	Y	1	84	31.2	3.88	*	7.75		7	4	1969
1170	PSSS	442	PSIB	G2	Prestressed I-Beam	Y	1	84	31.2	7.75		7.75		7	4	1969
1171	PSSS	443	PSIB	G1	Prestressed I-Beam	Y	1	72	0	3.25	*	7.17		6	3	1969
1172	PSSS	443	PSIB	G2	Prestressed I-Beam	Y	1	72	0	7.17		7.17		6	3	1969
1173	PSSS	444	PSIB	G1	Prestressed I-Beam	Y	1	68	15.61	2.25	*	6.17		6	2	1969
1174	PSSS	444	PSIB	G2	Prestressed I-Beam	Y	1	68	15.61	6.17		6.17		6	2	1969
1175	PSSS	444	PSIB	G3	Prestressed I-Beam	Y	1	68	15.61	6.17		6.17		6	2	1969
1176	PSSS	444	PSIB	G6	Prestressed I-Beam	Y	1	68	15.61	6.17		1.92	*	6	2	1969
1177	PSSS	445	PSIB	G1	Prestressed I-Beam	Y	1	77.5	10	2.25	*	7.5		6	3	1970
1178	PSSS	445	PSIB	G2	Prestressed I-Beam	Y	1	77.5	10	7.5		7.5		6	3	1970
1179	PSSS	446	PSIB	Member_1	Prestressed I-Beam	Y	1	73.88	0	3.5	*	6.67		7	3	1970
1180	PSSS	446	PSIB	Member_2	Prestressed I-Beam	Y	1	73.88	0	6.67		6.67		7	3	1970
1181	PSSS	447	PSIB	G1	Prestressed I-Beam	Y	1	66	0	3.25	*	8		3	2	1972
1182	PSSS	447	PSIB	G2	Prestressed I-Beam	Y	1	66	0	8		8		3	2	1972
1183	PSSS	447	PSIB	G3	Prestressed I-Beam	Y	1	66	0	8		2.92	*	3	2	1972
1184	PSSS	448	PSIB	G1	Prestressed I-Beam	Y	1	72.78	-46.88	0.8	*	8		4	2	1972
1185	PSSS	448	PSIB	G2	Prestressed I-Beam	Y	1	72.78	-46.88	8		8		4	2	1972
1186	PSSS	448	PSIB	G4	Prestressed I-Beam	Y	1	72.78	-46.88	8		3.12	*	4	2	1972
1187	PSSS	449	PSIB	G4	Prestressed I-Beam	Y	1	58.13	0	6.92		6.92		8	4	1972
1188	PSSS	450	PSIB	G1	Prestressed I-Beam	Y	1	66.86	-51.84	2.68	*	6.83		4	2	1973
1189	PSSS	450	PSIB	G2	Prestressed I-Beam	Y	1	66.86	-51.84	6.83		6.83		4	2	1973
1190	PSSS	450	PSIB	G3	Prestressed I-Beam	Y	1	66.86	-51.84	6.83		6.83		4	2	1973
1191	PSSS	450	PSIB	G4	Prestressed I-Beam	Y	1	66.86	-51.84	6.83		2.68	*	4	2	1973
1192	PSSS	451	PSIB	G1	Prestressed I-Beam	Y	1	57.36	0	2.42	*	5.83		4	2	1973
1193	PSSS	451	PSIB	G2	Prestressed I-Beam	Y	1	57.36	0	5.83		5.83		4	2	1973
1194	PSSS	452	PSIB	Member_1	Prestressed I-Beam	Y	1	65	10	2	*	8		6	3	1974

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1195	PSSS	452	PSIB	Member_2	Prestressed I-Beam	Y	1	65	10	8		8		6	3	1974
1196	PSSS	453	PSIB	Member_1	Prestressed I-Beam	Y	1	65	10	2	*	8		6	3	1974
1197	PSSS	453	PSIB	Member_2	Prestressed I-Beam	Y	1	65	10	8		8		6	3	1974
1198	PSSS	454	PSIB	Member_1	Prestressed I-Beam	Y	1	61.19	34.71	2.88	*	7.33		7	3	1974
1199	PSSS	454	PSIB	Member_2	Prestressed I-Beam	Y	1	61.19	34.71	7.33		7.33		7	3	1974
1200	PSSS	455	PSIB	3_-_2nd_N_Int_	Prestressed I-Beam	Y	1	75	0	7.21		7.21		6	3	1975
1201	PSSS	456	PSIB	4_-_2nd_N_Int_	Prestressed I-Beam	Y	1	75	0	7.21		7.21		6	3	1976
1202	PSSS	457	PSIB	G1	Prestressed I-Beam	Y	1	64	0	2.04	*	7.6		4	2	1978
1203	PSSS	457	PSIB	G2	Prestressed I-Beam	Y	1	64	0	7.6		7.6		4	2	1978
1204	PSSS	458	PSIB	G1	Prestressed I-Beam	Y	1	78.58	0	3.5	*	7.08		10	5	1980
1205	PSSS	458	PSIB	G2	Prestressed I-Beam	Y	1	78.58	0	7.08		7.08		10	5	1980
1206	PSSS	459	PSIB	G1	Prestressed I-Beam	Y	1	60.83	-15	3.13	*	7.5		8	4	1981
1207	PSSS	459	PSIB	G2	Prestressed I-Beam	Y	1	60.83	-15	7.5		7.5		8	4	1981
1208	PSSS	460	PSIB	Member_1	Prestressed I-Beam	Y	1	63.25	0	3	*	9		5	3	1981
1209	PSSS	460	PSIB	Member_2	Prestressed I-Beam	Y	1	63.25	0	9		9		5	3	1981
1210	PSSS	461	PSIB	G1	Prestressed I-Beam	Y	1	58.5	0	3.13	*	7.5		8	4	1983
1211	PSSS	461	PSIB	G2	Prestressed I-Beam	Y	1	58.5	0	7.5		7.5		8	4	1983
1212	PSSS	462	PSIB	G1	Prestressed I-Beam	Y	1	67.66	0	3.38	*	8		6	3	1983
1213	PSSS	462	PSIB	G2	Prestressed I-Beam	Y	1	67.66	0	8		8		6	3	1983
1214	PSSS	463	PSIB	Member_1	Prestressed I-Beam	Y	1	73.25	0	3.33	*	8.25		5	3	1983
1215	PSSS	463	PSIB	Member_2	Prestressed I-Beam	Y	1	73.25	0	8.25		8.25		5	3	1983
1216	PSSS	464	PSIB	G1	Prestressed I-Beam	Y	1	65.33	0	3.38	*	8		4	2	1984
1217	PSSS	464	PSIB	G2	Prestressed I-Beam	Y	1	65.33	0	8		8		4	2	1984
1218	PSSS	465	PSIB	G2	Prestressed I-Beam	Y	1	85	-20	7.42		7.42		6	3	1984
1219	PSSS	466	PSIB	G2_-_1st_E_Int_	Prestressed I-Beam	Y	1	80.83	-22	6.5		6.5		6	3	1984
1220	PSSS	467	PSIB	G1	Prestressed I-Beam	Y	1	68.33	0	3.88	*	7		6	3	1985
1221	PSSS	467	PSIB	G2	Prestressed I-Beam	Y	1	68.33	0	7		7		6	3	1985
1222	PSSS	468	PSIB	G1	Prestressed I-Beam	Y	1	58.54	0	3.38	*	6.67		4	2	1985

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1223	PSSS	468	PSIB	G2	Prestressed I-Beam	Y	1	58.54	0	6.67		6.67		4	2	1985
1224	PSSS	469	PSIB	G1	Prestressed I-Beam	Y	1	58.75	25	2.13	*	7.17		7	3	1985
1225	PSSS	469	PSIB	G3	Prestressed I-Beam	Y	1	58.75	25	7.17		7.17		7	3	1985
1226	PSSS	470	PSIB	G1	Prestressed I-Beam	Y	1	78.23	29	3.88	*	7		6	3	1986
1227	PSSS	470	PSIB	G2	Prestressed I-Beam	Y	1	78.23	29	7		7		6	3	1986
1228	PSSS	471	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	1	69.19	-27	7.42		7.42		6	3	1986
1229	PSSS	472	PSIB	G1	Prestressed I-Beam	Y	1	54.08	0	3.88	*	7		6	3	1987
1230	PSSS	472	PSIB	G2	Prestressed I-Beam	Y	1	54.08	0	7		7		6	3	1987
1231	PSSS	473	PSIB	G1	Prestressed I-Beam	Y	1	68.5	0	3.38	*	8		4	2	1988
1232	PSSS	473	PSIB	G2	Prestressed I-Beam	Y	1	68.5	0	8		8		4	2	1988
1233	PSSS	474	PSIB	G1	Prestressed I-Beam	Y	1	73.33	0	3.88	*	7		6	3	1989
1234	PSSS	474	PSIB	G2	Prestressed I-Beam	Y	1	73.33	0	7		7		6	3	1989
1235	PSSS	475	PSIB	G1	Prestressed I-Beam	Y	1	78.5	0	3.38	*	8		4	2	1991
1236	PSSS	475	PSIB	G2	Prestressed I-Beam	Y	1	78.5	0	8		8		4	2	1991
1237	PSSS	476	PSIB	G6	Prestressed I-Beam	Y	1	62.83	0	0		6.75		4	2	1991
1238	PSSS	476	PSIB	GA	Prestressed I-Beam	Y	1	62.83	0	6.75		6.75		4	2	1991
1239	PSSS	476	PSIB	GC	Prestressed I-Beam	Y	1	62.83	0	6.75		3.25	*	4	2	1991
1240	PSSS	477	PSIB	G1	Prestressed I-Beam	Y	1	59.93	0	3.38	*	8		7	4	1992
1241	PSSS	477	PSIB	G2	Prestressed I-Beam	Y	1	59.93	0	8		8		7	4	1992
1242	PSSS	478	PSIB	Member_1	Prestressed I-Beam	Y	1	73.21	0	3	*	8.75		5	3	1993
1243	PSSS	478	PSIB	Member_2	Prestressed I-Beam	Y	1	73.21	0	8.75		8.75		5	3	1993
1244	PSSS	479	PSIB	G1	Prestressed I-Beam	Y	1	78.5	0	3.88	*	7		6	3	1994
1245	PSSS	479	PSIB	G2	Prestressed I-Beam	Y	1	78.5	0	7		7		6	3	1994
1246	PSSS	480	PSIB	Member_1	Prestressed I-Beam	Y	1	78.5	0	3.58	*	8.75		5	3	1994
1247	PSSS	480	PSIB	Member_2	Prestressed I-Beam	Y	1	78.5	0	8.75		8.75		5	3	1994
1248	PSSS	481	PSIB	G1	Prestressed I-Beam	Y	1	79.44	0	3.38	*	7.5		9	5	1995
1249	PSSS	481	PSIB	G2	Prestressed I-Beam	Y	1	79.44	0	7.5		7.5		9	5	1995
1250	PSSS	482	PSIB	G1	Prestressed I-Beam	Y	1	78	0	3.38	*	6.67		7	3	1997

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1251	PSSS	482	PSIB	G2	Prestressed I-Beam	Y	1	78	0	6.67		6.67		7	3	1997
1252	PSSS	483	PSIB	G2_-_1st_N_Int_	Prestressed I-Beam	Y	1	73	-22	6.17		6.17		7	3	1997
1253	PSSS	484	PSIB	G1	Prestressed I-Beam	Y	1	67.17	0	1.71	*	7.5		5	2	1997
1254	PSSS	484	PSIB	G2	Prestressed I-Beam	Y	1	67.17	0	7.5		7.5		5	2	1997
1255	PSSS	484	PSIB	G5	Prestressed I-Beam	Y	1	67.17	0	7.5		1.71	*	5	2	1997
1256	PSSS	485	PSIB	Beam_A	Prestressed I-Beam	Y	1	72.73	-30	2.5	*	8.17		10	6	1994
1257	PSSS	485	PSIB	Beam_C	Prestressed I-Beam	Y	1	72.73	-30	8.17		8.17		10	6	1994
1258	PSSS	486	PSIB	G1	Prestressed I-Beam	Y	1	73	0	3.29	*	6.75		10	5	1999
1259	PSSS	486	PSIB	G2	Prestressed I-Beam	Y	1	73	0	6.75		6.75		10	5	1999
1260	PSSS	487	PSIB	G1	Prestressed I-Beam	Y	1	66	0	3.25	*	8		3	2	1999
1261	PSSS	487	PSIB	G2	Prestressed I-Beam	Y	1	66	0	8		8		3	2	1999
1262	PSSS	487	PSIB	G3	Prestressed I-Beam	Y	1	66	0	8		2.92	*	3	2	1999
1263	PSSS	488	PSIB	3_-_2nd_E_Int	Prestressed I-Beam	Y	1	72.81	20	5.68		5.68		6	2	1999
1264	PSSS	489	PSIB	G1	Prestressed I-Beam	Y	1	85	20	3.33	*	9		5	3	2007
1265	PSSS	489	PSIB	G2	Prestressed I-Beam	Y	1	85	20	9		9		5	3	2007
1266	PSSS	490	PSIB	Fascia_PS_Concrete_I_Beam_G1	Prestressed I-Beam	Y	1	76	-30.42	4.23	*	5.74		5	2	2000
1267	PSSS	490	PSIB	Interior_PS_Concrete_I_Beam_G2	Prestressed I-Beam	Y	1	76	-30.42	5.74		5.74		5	2	2000
1268	PSSS	491	PSIB	G1	Prestressed I-Beam	Y	1	76.38	14.48	3	*	8.67		5	3	2007
1269	PSSS	491	PSIB	G2	Prestressed I-Beam	Y	1	76.38	14.48	8.67		8.67		5	3	2007
1270	PSSS	492	PSIB	G2	Prestressed I-Beam	Y	1	85	-9	6.25		6.25		7	3	2002
1271	PSSS	493	PSIB	G1	Prestressed I-Beam	Y	1	83	0	3.88	*	7.67		4	2	2003
1272	PSSS	493	PSIB	G2	Prestressed I-Beam	Y	1	83	0	7.67		7.67		4	2	2003
1273	PSSS	494	PSIB	G2	Prestressed I-Beam	Y	1	65	-30	7.83		7.83		9	5	2003
1274	PSSS	495	PSIB	Fascia__Type_IV_PCI	Prestressed I-Beam	Y	1	79.17	-1.96	2.71	*	8.42		6	3	2003
1275	PSSS	495	PSIB	Interior__Type_IV_PCI	Prestressed I-Beam	Y	1	79.17	-1.96	8.42		8.42		6	3	2003
1276	PSSS	496	PSIB	Fascia__Type_III_PC	Prestressed I-Beam	Y	1	74.47	8.57	2.58	*	8.42		6	3	2003

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
				I												
1277	PSSS	496	PSIB	Interior__Type_III_PCI	Prestressed I-Beam	Y	1	74.47	8.57	8.42		8.42		6	3	2003
1278	PSSS	497	PSIB	G11	Prestressed I-Beam	Y	1	66.67	0	9.33		3.58	*	11	7	2003
1279	PSSS	497	PSIB	G5	Prestressed I-Beam	Y	1	66.67	0	9.33		9.33		11	7	2003
1280	PSSS	498	PSIB	G1	Prestressed I-Beam	Y	1	82.75	-15	3.5	*	10.33		4	3	2003
1281	PSSS	498	PSIB	G2	Prestressed I-Beam	Y	1	82.75	-15	10.33		10.33		4	3	2003
1282	PSSS	498	PSIB	G3	Prestressed I-Beam	Y	1	82.75	-15	10.33		10.33		4	3	2003
1283	PSSS	498	PSIB	G4	Prestressed I-Beam	Y	1	82.75	-15	10.33		3.5	*	4	3	2003
1284	PSSS	499	PSIB	G2	Prestressed I-Beam	Y	1	67.5	0	6.67		6.67		6	2	2004
1285	PSSS	500	PSIB	G1	Prestressed I-Beam	Y	1	80.38	0	2.65	*	7.74		18	9	2004
1286	PSSS	500	PSIB	G2	Prestressed I-Beam	Y	1	80.38	0	7.74		7.74		18	9	2004
1287	PSSS	500	PSIB	G3	Prestressed I-Beam	Y	1	80.38	0	7.74		7.74		18	9	2004
1288	PSSS	501	PSIB	3_-_Center-x	Prestressed I-Beam	Y	1	83.16	-48.95	5.87		5.87		5	2	2005
1289	PSSS	502	PSIB	Typical_Fascia_Beam	Prestressed I-Beam	Y	1	53.33	0	2.17	*	4.75		10	3	2005
1290	PSSS	502	PSIB	Typical_Interior_Beam	Prestressed I-Beam	Y	1	53.33	0	4.75		4.75		10	3	2005
1291	PSSS	503	PSIB	G1	Prestressed I-Beam	Y	1	63.75	-7.73	2.83	*	8.5		11	7	2005
1292	PSSS	503	PSIB	G2	Prestressed I-Beam	Y	1	63.75	-7.73	8.5		8.5		11	7	2005
1293	PSSS	503	PSIB	G8	Prestressed I-Beam	Y	1	63.75	-7.73	8.5		8.5		11	7	2005
1294	PSSS	504	PSIB	Beam_A	Prestressed I-Beam	Y	1	106.38	-0.47	2.71	*	8		12	7	1957
1295	PSSS	504	PSIB	Beam_F	Prestressed I-Beam	Y	1	106.38	-0.47	8		8		12	7	1957
1296	PSSS	505	PSIB	2nd_W_Int	Prestressed I-Beam	Y	1	89.47	41.52	6		6		8	2	1958
1297	PSSS	506	PSIB	Typical_Fascia_Beam	Prestressed I-Beam	Y	1	98.83	45	2.04	*	8.17		8	4	1961
1298	PSSS	506	PSIB	Typical_Interior_Beam	Prestressed I-Beam	Y	1	98.83	45	8.17		8.17		8	4	1961
1299	PSSS	507	PSIB	G1	Prestressed I-Beam	Y	1	98.17	0	3.38	*	6.67		7	3	1994
1300	PSSS	507	PSIB	G2	Prestressed I-Beam	Y	1	98.17	0	6.67		6.67		7	3	1994
1301	PSSS	508	PSIB	Typical_Fascia_Beam	Prestressed I-Beam	Y	1	105.25	47.93	2.63	*	6		6	2	1964

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1302	PSSS	508	PSIB	Typical_Interior_Beam	Prestressed I-Beam	Y	1	105.25	47.93	6		6		6	2	1964
1303	PSSS	509	PSIB	Fascia__Type_III_PCI	Prestressed I-Beam	Y	1	89.67	-38.23	2.63	*	6		6	2	1964
1304	PSSS	509	PSIB	Interior__Type_III_PCI	Prestressed I-Beam	Y	1	89.67	-38.23	6		6		6	2	1964
1305	PSSS	510	PSIB	G1	Prestressed I-Beam	Y	1	100	34.38	3	*	6		7	3	1969
1306	PSSS	510	PSIB	G2	Prestressed I-Beam	Y	1	100	34.38	6		6		7	3	1969
1307	PSSS	511	PSIB	B6	Prestressed I-Beam	Y	1	92.12	-38.77	3.58	*	7.17		6	3	1969
1308	PSSS	512	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	1	85.92	0	7.21		7.21		6	3	1972
1309	PSSS	513	PSIB	Member_1	Prestressed I-Beam	Y	1	88.83	-31	2.89	*	8.17		8	5	1972
1310	PSSS	513	PSIB	Member_2	Prestressed I-Beam	Y	1	88.83	-31	8.17		8.17		8	5	1972
1311	PSSS	513	PSIB	Member_6	Prestressed I-Beam	Y	1	88.83	-31	8.17		8.17		8	5	1972
1312	PSSS	513	PSIB	Member_7	Prestressed I-Beam	Y	1	88.83	-31	8.17		8.17		8	5	1972
1313	PSSS	513	PSIB	Member_8	Prestressed I-Beam	Y	1	88.83	-31	8.17		2.82	*	8	5	1972
1314	PSSS	514	PSIB	G1	Prestressed I-Beam	Y	1	103	-11.7	1.5	*	5.13		9	3	1976
1315	PSSS	514	PSIB	G2	Prestressed I-Beam	Y	1	103	-11.7	5.13		5.13		9	3	1976
1316	PSSS	515	PSIB	G1	Prestressed I-Beam	Y	1	99	-27.26	1.5	*	6.6		6	2	1976
1317	PSSS	515	PSIB	G2	Prestressed I-Beam	Y	1	99	-27.26	6.6		6.6		6	2	1976
1318	PSSS	516	PSIB	G1	Prestressed I-Beam	Y	1	103	-31.68	1.5	*	5.13		9	3	1976
1319	PSSS	516	PSIB	G2	Prestressed I-Beam	Y	1	103	-31.68	5.13		5.13		9	3	1976
1320	PSSS	517	PSIB	3_-_2nd_N_Int	Prestressed I-Beam	Y	1	86.48	13	7.25		7.25		6	3	1979
1321	PSSS	518	PSIB	G2	Prestressed I-Beam	Y	1	87.83	16	7.42		7.42		6	3	1982
1322	PSSS	519	PSIB	G2	Prestressed I-Beam	Y	1	91.67	-25	5.33		5.33		8	3	1984
1323	PSSS	520	PSIB	Member_1	Prestressed I-Beam	Y	1	98.13	0	3.5	*	8.25		5	3	1984
1324	PSSS	520	PSIB	Member_2	Prestressed I-Beam	Y	1	98.13	0	8.25		8.25		5	3	1984
1325	PSSS	521	PSIB	G1	Prestressed I-Beam	Y	1	94.5	0	3.38	*	7.33		7	4	1985
1326	PSSS	521	PSIB	G2	Prestressed I-Beam	Y	1	94.5	0	7.33		7.33		7	4	1985
1327	PSSS	522	PSIB	Member_1	Prestressed I-Beam	Y	1	98.13	0	3.46	*	7.75		6	3	1987
1328	PSSS	522	PSIB	Member_2	Prestressed I-Beam	Y	1	98.13	0	7.75		7.75		6	3	1987

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1329	PSSS	523	PSIB	G1	Prestressed I-Beam	Y	1	89.92	-16.53	3.38	*	8		7	4	1988
1330	PSSS	523	PSIB	G2	Prestressed I-Beam	Y	1	89.92	-16.53	8		8		7	4	1988
1331	PSSS	524	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	1	89.71	0	6.17		6.17		7	3	1989
1332	PSSS	525	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	1	89.48	6	6.17		6.17		7	3	1989
1333	PSSS	526	PSIB	Fascia__Type_IV_PCI	Prestressed I-Beam	Y	1	94.73	12.91	2.33	*	6.08		8	3	1989
1334	PSSS	526	PSIB	Interior__Type_IV_PCI	Prestressed I-Beam	Y	1	94.73	12.91	6.08		6.08		8	3	1989
1335	PSSS	527	PSIB	Typical_Fascia_Beam	Prestressed I-Beam	Y	1	98.94	56.69	2.04	*	6.17		8	3	1989
1336	PSSS	527	PSIB	Typical_Interior_Beam	Prestressed I-Beam	Y	1	98.94	56.69	6.17		6.17		8	3	1989
1337	PSSS	528	PSIB	G1	Prestressed I-Beam	Y	1	93.83	-22.95	3.13	*	7.5		8	4	1990
1338	PSSS	528	PSIB	G2	Prestressed I-Beam	Y	1	93.83	-22.95	7.5		7.5		8	4	1990
1339	PSSS	529	PSIB	G1	Prestressed I-Beam	Y	1	98.5	0	1.75	*	7.81		5	2	1990
1340	PSSS	529	PSIB	G2	Prestressed I-Beam	Y	1	98.5	0	7.81		7.81		5	2	1990
1341	PSSS	530	PSIB	Member_1	Prestressed I-Beam	Y	1	98.67	0	2.96	*	7.25		6	3	1990
1342	PSSS	530	PSIB	Member_2	Prestressed I-Beam	Y	1	98.67	0	7.25		7.25		6	3	1990
1343	PSSS	531	PSIB	G2	Prestressed I-Beam	Y	1	93.28	30	6		6		6	2	1992
1344	PSSS	532	PSIB	Member_1	Prestressed I-Beam	Y	1	98.33	40.95	3.71	*	8.5		7	4	1992
1345	PSSS	532	PSIB	Member_2	Prestressed I-Beam	Y	1	98.33	40.95	8.5		8.5		7	4	1992
1346	PSSS	533	PSIB	Fifth_Interior_Beam_w_utility	Prestressed I-Beam	Y	1	115.92	1.72	8.67		8.67		7	3	1993
1347	PSSS	533	PSIB	First_Interior_Beam_w_utility	Prestressed I-Beam	Y	1	115.92	1.72	8.67		8.67		7	3	1993
1348	PSSS	533	PSIB	Left_Fascia_Beam	Prestressed I-Beam	Y	1	115.92	1.72	2.13	*	8.67		7	3	1993
1349	PSSS	533	PSIB	Right_Fascia_Beam	Prestressed I-Beam	Y	1	115.92	1.72	8.67		2.12	*	7	3	1993
1350	PSSS	533	PSIB	Typical_Interior_Beam	Prestressed I-Beam	Y	1	115.92	1.72	8.67		8.67		7	3	1993
1351	PSSS	534	PSIB	G1	Prestressed I-Beam	Y	1	97.33	0	4.38	*	8		6	2	2006
1352	PSSS	534	PSIB	G2	Prestressed I-Beam	Y	1	97.33	0	8		8		6	2	2006
1353	PSSS	535	PSIB	G1	Prestressed I-Beam	Y	1	102.5	42	2.17	*	8.58		6	3	1994

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1354	PSSS	535	PSIB	G2	Prestressed I-Beam	Y	1	102.5	42	8.58		8.58		6	3	1994
1355	PSSS	536	PSIB	G1	Prestressed I-Beam	Y	1	105.67	-23	3.88	*	7.67		4	2	1994
1356	PSSS	536	PSIB	G2	Prestressed I-Beam	Y	1	105.67	-23	7.67		7.67		4	2	1994
1357	PSSS	537	PSIB	3_-_2nd_N_Int	Prestressed I-Beam	Y	1	86.48	13	7.25		7.25		6	3	1979
1358	PSSS	538	PSIB	3A_-_2nd_N_Int	Prestressed I-Beam	Y	1	95.22	-21	6.17		6.17		7	3	1996
1359	PSSS	539	PSIB	Member_1	Prestressed I-Beam	Y	1	108.53	0	3.21	*	7.13		13	5	1999
1360	PSSS	539	PSIB	Member_2	Prestressed I-Beam	Y	1	108.53	0	7.13		7.13		13	5	1999
1361	PSSS	539	PSIB	Member_9	Prestressed I-Beam	Y	1	108.53	0	7.13		6.92		13	5	1999
1362	PSSS	540	PSIB	G2	Prestressed I-Beam	Y	1	91.67	-25	5.33		5.33		8	3	1984
1363	PSSS	541	PSIB	G1	Prestressed I-Beam	Y	1	116.17	0	3.38	*	8.25		9	5	2001
1364	PSSS	541	PSIB	G2	Prestressed I-Beam	Y	1	116.17	0	8.25		8.25		9	5	2001
1365	PSSS	542	PSIB	3_-_2nd_E_Int-x	Prestressed I-Beam	Y	1	85.5	0	6.42		6.42		6	2	2007
1366	PSSS	543	PSIB	Fascia_Girder	Prestressed I-Beam	Y	1	108.21	-31.02	2.5	*	6.03		10	4	2003
1367	PSSS	543	PSIB	Interior_Girder	Prestressed I-Beam	Y	1	108.21	-31.02	6.03		6.03		10	4	2003
1368	PSSS	544	PSIB	G1	Prestressed I-Beam	Y	1	89.33	-5	3.25	*	6.83		6	3	2008
1369	PSSS	544	PSIB	G2	Prestressed I-Beam	Y	1	89.33	-5	6.83		6.83		6	3	2008
1370	PSSS	545	PSIB	G1	Prestressed I-Beam	Y	1	116.52	-27.88	3.75	*	7.31		8	4	2004
1371	PSSS	545	PSIB	G2	Prestressed I-Beam	Y	1	116.52	-27.88	7.31		7.31		8	4	2004
1372	PSSS	546	PSIB	G1	Prestressed I-Beam	Y	1	112.5	15	3	*	8.67		5	3	2008
1373	PSSS	546	PSIB	G2	Prestressed I-Beam	Y	1	112.5	15	8.67		8.67		5	3	2008
1374	PSSS	547	PSIB	3_-_2nd_N_Int	Prestressed I-Beam	Y	1	95.13	-30	6.17		6.17		8	3	2007
1375	PSSS	547	PSIB	8_-_S_Fascia	Prestressed I-Beam	Y	1	95.13	-30	5.59		2.92	*	8	3	2007
1376	PSSS	548	PSIB	Member_1	Prestressed I-Beam	Y	1	98.5	0	2.33	*	7.5		6	3	1995
1377	PSSS	548	PSIB	Member_2	Prestressed I-Beam	Y	1	98.5	0	7.5		7.5		6	3	1995
1378	PSSS	549	PSIB	G3	Prestressed I-Beam	Y	1	90.85	19.41	10.58		10.58		4	3	2008
1379	PSSS	549	PSIB	G4	Prestressed I-Beam	Y	1	90.85	19.41	10.58		4.08	*	4	3	2008
1380	PSSS	550	PSIB	G1	Prestressed I-Beam	Y	1	130	0	3.38	*	8		4	2	
1381	PSSS	550	PSIB	G2	Prestressed I-Beam	Y	1	130	0	8		8		4	2	

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1382	PSSS	551	PSIB	G1	Prestressed I-Beam	Y	1	136	0	3.88	*	6.38		9	4	1995
1383	PSSS	551	PSIB	G2	Prestressed I-Beam	Y	1	136	0	6.38		6.38		9	4	1995
1384	PSSS	552	PSIB	G1	Prestressed I-Beam	Y	1	175	0	2.13	*	4.38		9	2	1983
1385	PSSS	552	PSIB	G2	Prestressed I-Beam	Y	1	175	0	4.38		4.38		9	2	1983
1386	PSSS	552	PSIB	G9	Prestressed I-Beam	Y	1	175	0	4.38		2.13	*	9	2	1983
1387	PSSS	553	PSIB	G1	Prestressed I-Beam	Y	1	143.15	-6.86	3.08	*	7.75		8	4	2008
1388	PSSS	553	PSIB	G2	Prestressed I-Beam	Y	1	143.15	-6.86	7.75		7.75		8	4	2008
1389	PSSS	554	PSIB	G1	Prestressed I-Beam	Y	1	138.25	0	4.13	*	5.58		14	6	1993
1390	PSSS	554	PSIB	G2	Prestressed I-Beam	Y	1	138.25	0	5.58		5.58		14	6	1993
1391	PSSS	555	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	1	133.13	16.88	5.83		5.83		13	6	1995
1392	PSSS	556	PSIB	G1	Prestressed I-Beam	Y	1	137.13	0	3.38	*	5.88		17	7	1995
1393	PSSS	556	PSIB	G2	Prestressed I-Beam	Y	1	137.13	0	5.88		5.88		17	7	1995
1394	PSSS	556	PSIB	G8	Prestressed I-Beam	Y	1	137.13	0	5.88		5.88		17	7	1995
1395	PSSS	556	PSIB	G9	Prestressed I-Beam	Y	1	137.13	0	5.88		5.88		17	7	1995
1396	PSSS	557	PSIB	G1	Prestressed I-Beam	Y	1	127.84	-38.19	3.88	*	7		6	3	1999
1397	PSSS	557	PSIB	G2	Prestressed I-Beam	Y	1	127.84	-38.19	7		7		6	3	1999
1398	PSSS	558	PSIB	Beam_A	Prestressed I-Beam	Y	1	132.28	-19.68	3.5	*	6.99		5	2	2000
1399	PSSS	558	PSIB	Beam_C	Prestressed I-Beam	Y	1	132.28	-19.68	6.99		6.99		5	2	2000
1400	PSSS	559	PSIB	Member_1	Prestressed I-Beam	Y	1	140.91	-17	3.79	*	8.2		5	3	2000
1401	PSSS	559	PSIB	Member_2	Prestressed I-Beam	Y	1	140.91	-17	8.2		8.2		5	3	2000
1402	PSSS	560	PSIB	G1	Prestressed I-Beam	Y	1	120.4	2.87	3.33	*	6.75		15	7	2008
1403	PSSS	560	PSIB	G3	Prestressed I-Beam	Y	1	120.4	2.87	6.75		6.75		15	7	2008
1404	PSSS	561	PSIB	G1	Prestressed I-Beam	Y	1	119.82	0	3.28	*	5.35		11	4	2004
1405	PSSS	561	PSIB	G2	Prestressed I-Beam	Y	1	119.82	0	5.35		5.35		11	4	2004
1406	PSSS	562	PSIB	G1	Prestressed I-Beam	Y	1	131.02	-22.5	3.04	*	5.29		17	7	2006
1407	PSSS	562	PSIB	G2	Prestressed I-Beam	Y	1	131.02	-22.5	5.29		5.29		17	7	2006
1408	PSSS	563	PSIB	G1	Prestressed I-Beam	Y	1	144.18	0.82	3.5	*	8.17		14	8	2008
1409	PSSS	563	PSIB	G3	Prestressed I-Beam	Y	1	144.18	0.82	8.17		8.17		14	8	2008

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1410	PSSS	564	PSIB	G1	Prestressed I-Beam	Y	1	38.33	0	3.38	*	8		4	2	2006
1411	PSSS	564	PSIB	G2	Prestressed I-Beam	Y	1	38.33	0	8		8		4	2	2006
1412	PSSS	565	PSIB	G1	Prestressed I-Beam	Y	1	37.59	30	3.38	*	8		4	2	2007
1413	PSSS	565	PSIB	G2	Prestressed I-Beam	Y	1	37.59	30	8		8		4	2	2007
1414	PSSS	566	PSIB	G2	Prestressed I-Beam	Y	1	45	0	5.83		5.83		6	2	2002
1415	PSSS	567	PSIB	G2	Prestressed I-Beam	Y	1	51.5	0	6.58		6.58		7	3	2003
1416	PSSS	568	PSIB	G2_-_1st_N_Int_	Prestressed I-Beam	Y	1	51.42	15	7.42		7.42		6	3	2007
1417	PSSS	569	PSIB	Typical_Fascia	Prestressed I-Beam	Y	1	28.33	0	2.5	*	9.25		6	4	1991
1418	PSSS	569	PSIB	Typical_Interior	Prestressed I-Beam	Y	1	28.33	0	9.25		9.25		6	4	1991
1419	PSSS	570	PSIB	G1	Prestressed I-Beam	Y	1	43.26	2.47	2.33	*	10		16	12	2008
1420	PSSS	570	PSIB	G2	Prestressed I-Beam	Y	1	43.26	2.47	10		10		16	12	2008
1421	PSSS	571	PSIB	G1	Prestressed I-Beam	Y	1	47.17	0	3.33	*	7.83		14	11	2008
1422	PSSS	571	PSIB	G2	Prestressed I-Beam	Y	1	47.17	0	7.83		10.67		14	11	2008
1423	PSSS	572	PSIB	Member_1	Prestressed I-Beam	Y	1	37.73	0	3.54	*	11.48		4	3	2000
1424	PSSS	572	PSIB	Member_2	Prestressed I-Beam	Y	1	37.73	0	11.48		11.48		4	3	2000
1425	PSSS	573	PSIB	G1	Prestressed I-Beam	Y	1	78.23	29	3.88	*	7		6	3	1986
1426	PSSS	573	PSIB	G2	Prestressed I-Beam	Y	1	78.23	29	7		7		6	3	1986
1427	PSSS	574	PSIB	G6	Prestressed I-Beam	Y	1	62.83	0	0		6.75		4	2	1991
1428	PSSS	574	PSIB	GA	Prestressed I-Beam	Y	1	62.83	0	6.75		6.75		4	2	1991
1429	PSSS	574	PSIB	GC	Prestressed I-Beam	Y	1	62.83	0	6.75		3.25	*	4	2	1991
1430	PSSS	575	PSIB	G1	Prestressed I-Beam	Y	1	78.55	0	3.88	*	7		6	3	1996
1431	PSSS	575	PSIB	G2	Prestressed I-Beam	Y	1	78.55	0	7		7		6	3	1996
1432	PSSS	576	PSIB	G1	Prestressed I-Beam	Y	1	78	0	3.38	*	6.67		7	3	1997
1433	PSSS	576	PSIB	G2	Prestressed I-Beam	Y	1	78	0	6.67		6.67		7	3	1997
1434	PSSS	577	PSIB	G1	Prestressed I-Beam	Y	1	60.71	0	2.88	*	5.67		22	8	2005
1435	PSSS	577	PSIB	G11	Prestressed I-Beam	Y	1	60.71	0	5.67		5.67		22	8	2005
1436	PSSS	577	PSIB	G2	Prestressed I-Beam	Y	1	60.71	0	5.67		5.67		22	8	2005
1437	PSSS	578	PSIB	9_-_2nd_W_Int	Prestressed I-Beam	Y	1	67.75	-30	7.33		7.33		6	3	1989

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1438	PSSS	579	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	1	77.17	-22	7.42		7.42		6	3	1989
1439	PSSS	580	PSIB	9_-_2nd_W_Int	Prestressed I-Beam	Y	1	72.33	-3	7.42		7.42		6	3	1989
1440	PSSS	581	PSIB	2_-_1st_E_Int	Prestressed I-Beam	Y	1	64.83	0	6.75		6.75		5	2	1990
1441	PSSS	582	PSIB	4_-_3rd_N_Int	Prestressed I-Beam	Y	1	71.19	18.36	6.92		6.92		10	5	2000
1442	PSSS	582	PSIB	9_-_1st_S_Int	Prestressed I-Beam	Y	1	71.19	18.36	6.92		6.92		10	5	2000
1443	PSSS	583	PSIB	3_-_2nd_N_Int	Prestressed I-Beam	Y	1	71.19	18.91	6.86		6.86		9	4	2000
1444	PSSS	584	PSIB	G2	Prestressed I-Beam	Y	1	82.81	0	7.28		7.28		6	3	2000
1445	PSSS	585	PSIB	3_-_2nd_E_Int-x	Prestressed I-Beam	Y	1	68.6	30	6.58		6.58		6	3	2008
1446	PSSS	586	PSIB	G1	Prestressed I-Beam	Y	1	58.75	25	2.13	*	7.17		7	3	1985
1447	PSSS	586	PSIB	G3	Prestressed I-Beam	Y	1	58.75	25	7.17		7.17		7	3	1985
1448	PSSS	587	PSIB	G10	Prestressed I-Beam	Y	1	74.46	-11.08	8.67		2.42	*	10	6	2005
1449	PSSS	587	PSIB	G9	Prestressed I-Beam	Y	1	74.46	-11.08	8.67		8.67		10	6	2005
1450	PSSS	588	PSIB	G2	Prestressed I-Beam	Y	1	59.36	-19.94	7.25		7.25		21	10	2005
1451	PSSS	588	PSIB	G3	Prestressed I-Beam	Y	1	59.36	-19.94	7.25		7.25		21	10	2005
1452	PSSS	589	PSIB	G1	Prestressed I-Beam	Y	1	72	-10	2.75	*	5.83		6	2	2006
1453	PSSS	589	PSIB	G2	Prestressed I-Beam	Y	1	72	-10	5.83		5.83		6	2	2006
1454	PSSS	590	PSIB	G1	Prestressed I-Beam	Y	1	72	0	3.25	*	7.17		6	3	1969
1455	PSSS	590	PSIB	G2	Prestressed I-Beam	Y	1	72	0	7.17		7.17		6	3	1969
1456	PSSS	591	PSIB	G1	Prestressed I-Beam	Y	1	77.5	10	2.25	*	7.5		6	3	1970
1457	PSSS	591	PSIB	G2	Prestressed I-Beam	Y	1	77.5	10	7.5		7.5		6	3	1970
1458	PSSS	592	PSIB	5_-_2nd_W_Int	Prestressed I-Beam	Y	1	89.71	0	6.17		6.17		7	3	1989
1459	PSSS	593	PSIB	7_-_N_(Median)_Fascia	Prestressed I-Beam	Y	1	101.5	0	3.92	*	7		6	3	1995
1460	PSSS	593	PSIB	8_-_1st_N_Int	Prestressed I-Beam	Y	1	101.5	0	7		7		6	3	1995
1461	PSSS	593	PSIB	9_-_2nd_N_Int	Prestressed I-Beam	Y	1	101.5	0	7		7		6	3	1995
1462	PSSS	594	PSIB	3_-_2nd_E_Int	Prestressed I-Beam	Y	1	100.32	-45	5.84		5.84		6	2	1999
1463	PSSS	595	PSIB	Typical_Fascia_Beam	Prestressed I-Beam	Y	1	108.5	-1.16	2	*	7.81		5	2	1990
1464	PSSS	595	PSIB	Typical_Interior_Beam	Prestressed I-Beam	Y	1	108.5	-1.16	7.81		7.81		5	2	1990

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1465	PSSS	596	PSIB	Fascia_Girder	Prestressed I-Beam	Y	1	100.25	0	2.71	*	5.59		9	3	1996
1466	PSSS	596	PSIB	Interior_Girder	Prestressed I-Beam	Y	1	100.25	0	5.59		5.59		9	3	1996
1467	PSSS	597	PSIB	Left_Fascia_Beam	Prestressed I-Beam	Y	1	109.96	0	2.19	*	6.08		9	3	1996
1468	PSSS	597	PSIB	Right_Fascia_Beam	Prestressed I-Beam	Y	1	109.96	0	6.08		2.19	*	9	3	1996
1469	PSSS	597	PSIB	Typical_Interior_Beam	Prestressed I-Beam	Y	1	109.96	0	6.08		6.08		9	3	1996
1470	PSSS	597	PSIB	Typical_Interior_Beam_w_utility	Prestressed I-Beam	Y	1	109.96	0	6.08		6.08		9	3	1996
1471	PSSS	598	PSIB	Fascia	Prestressed I-Beam	Y	1	101.83	0	2.63	*	10.42		5	3	1996
1472	PSSS	598	PSIB	Interior	Prestressed I-Beam	Y	1	101.83	0	10.42		10.42		5	3	1996
1473	PSSS	599	PSIB	B1	Prestressed I-Beam	Y	1	107.47	-13.99	2.5	*	6.18		13	6	2006
1474	PSSS	599	PSIB	B7	Prestressed I-Beam	Y	1	107.47	-13.99	6.18		6.18		13	6	2006
1475	PSSS	600	PSIB	G8	Prestressed I-Beam	Y	1	111.61	1.66	9.55		9.55		9	6	2001
1476	PSSS	600	PSIB	G9	Prestressed I-Beam	Y	1	111.61	1.66	9.55		4.25	*	9	6	2001
1477	PSSS	601	PSIB	G1	Prestressed I-Beam	Y	1	96	0	3.25	*	7		8	4	2005
1478	PSSS	601	PSIB	G3	Prestressed I-Beam	Y	1	96	0	7		7		8	4	2005
1479	PSSS	602	PSIB	G1	Prestressed I-Beam	Y	1	90	-20	3.08	*	8.17		4	2	2007
1480	PSSS	602	PSIB	G2	Prestressed I-Beam	Y	1	90	-20	8.17		8.17		4	2	2007
1481	PSSS	603	PSIB	G1	Prestressed I-Beam	Y	1	90	-15.84	3.46	*	10.58		4	3	2008
1482	PSSS	603	PSIB	G2	Prestressed I-Beam	Y	1	90	-15.84	10.58		10.58		4	3	2008
1483	PSSS	604	PSIB	G1	Prestressed I-Beam	Y	1	98	0	3	*	8.67		5	3	2009
1484	PSSS	604	PSIB	G2	Prestressed I-Beam	Y	1	98	0	8.67		8.67		5	3	2009
1485	PSSS	604	PSIB	G3	Prestressed I-Beam	Y	1	98	0	8.67		8.67		5	3	2009
1486	PSSS	605	PSIB	G1	Prestressed I-Beam	Y	1	100	23.2	3	*	6		7	3	1969
1487	PSSS	605	PSIB	G2	Prestressed I-Beam	Y	1	100	23.2	6		6		7	3	1969
1488	PSSS	606	PSIB	G1	Prestressed I-Beam	Y	1	90	17.93	3.58	*	7.5		7	3	1970
1489	PSSS	606	PSIB	G2	Prestressed I-Beam	Y	1	90	17.93	7.5		7.5		7	3	1970
1490	PSSS	606	PSIB	G3	Prestressed I-Beam	Y	1	90	17.93	7.5		7.5		7	3	1970
1491	PSSS	607	PSIB	G1	Prestressed I-Beam	Y	1	103	-31.68	1.5	*	5.13		9	3	1976

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1492	PSSS	607	PSIB	G2	Prestressed I-Beam	Y	1	103	-31.68	5.13		5.13		9	3	1976
1493	PSSS	608	PSIB	G1	Prestressed I-Beam	Y	1	108.42	0	1.58	*	6.67		4	1	1997
1494	PSSS	608	PSIB	G2	Prestressed I-Beam	Y	1	108.42	0	6.67		6.67		4	1	1997
1495	PSSS	608	PSIB	G4	Prestressed I-Beam	Y	1	108.42	0	6.67		1.58	*	4	1	1997
1496	PSSS	609	PSIB	G1	Prestressed I-Beam	Y	1	96.78	0	3.28	*	7.05		5	2	2002
1497	PSSS	609	PSIB	G2	Prestressed I-Beam	Y	1	96.78	0	7.05		7.05		5	2	2002
1498	PSSS	610	PSIB	Member_1	Prestressed I-Beam	Y	1	96.78	0	4.04	*	11.15		4	3	2003
1499	PSSS	610	PSIB	Member_2	Prestressed I-Beam	Y	1	96.78	0	11.15		11.15		4	3	2003
1500	PSSS	611	PSIB	G1	Prestressed I-Beam	Y	1	138.25	0	3.38	*	6		7	3	1998
1501	PSSS	611	PSIB	G2	Prestressed I-Beam	Y	1	138.25	0	6		6		7	3	1998
1502	PSSS	612	PSIB	G1	Prestressed I-Beam	Y	1	162.25	-60	2.9	*	5.54		12	5	2004
1503	PSSS	612	PSIB	G2	Prestressed I-Beam	Y	1	162.25	-60	5.54		5.54		12	5	2004
1504	PSSS	613	PSIB	G1	Prestressed I-Beam	Y	1	143.5	-2.84	2.75	*	8		14	8	2008
1505	PSSS	613	PSIB	G2	Prestressed I-Beam	Y	1	143.5	-2.84	8		8		14	8	2008
1506	PSSS	614	PSIB	G1	Prestressed I-Beam	Y	1	120	16.65	3	*	8.67		5	3	2008
1507	PSSS	614	PSIB	G2	Prestressed I-Beam	Y	1	120	16.65	8.67		8.67		5	3	2008
1508	PSSS	615	PSBX	G1	Prestressed Box Beam	N	1	43	-6.91	2.01	*	4.04		13	3	1975
1509	PSSS	615	PSBX	G2	Prestressed Box Beam	N	1	43	-6.91	4.04		4.04		13	3	1975
1510	PSSS	615	PSBX	G3	Prestressed Box Beam	N	1	43	-6.91	4.04		4.04		13	3	1975
1511	PSSS	616	PSBX	2_-_1st_W_Int	Prestressed Box Beam	N	1	30.38	0	4		4		22	7	1952
1512	PSSS	617	PSBX	G1	Prestressed Box Beam	N	1	43.21	0	1.71	*	3.04		16	3	1956
1513	PSSS	617	PSBX	G2	Prestressed Box Beam	N	1	43.21	0	3.04		3.04		16	3	1956
1514	PSSS	617	PSBX	G8	Prestressed Box Beam	N	1	43.21	0	3.04		3.04		16	3	1956
1515	PSSS	618	PSBX	G1	Prestressed Box Beam	N	1	47	20	1.45	*	2.75		13	2	1957
1516	PSSS	618	PSBX	G2	Prestressed Box Beam	N	1	47	20	2.75		3		13	2	1957
1517	PSSS	618	PSBX	G3	Prestressed Box Beam	N	1	47	20	3		3		13	2	1957
1518	PSSS	619	PSBX	7_-_6th_S_Int_(-2b)-y	Prestressed Box Beam	N	1	46.23	10	3		3		14	3	1977
1519	PSSS	620	PSBX	G1	Prestressed Box Beam	N	1	41	0	2	*	4		7	2	1959

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1520	PSSS	620	PSBX	G2	Prestressed Box Beam	N	1	41	0	4		4		7	2	1959
1521	PSSS	621	PSBX	G1	Prestressed Box Beam	N	1	47.25	-27.25	0.93	*	6.5		10	3	1960
1522	PSSS	621	PSBX	G2	Prestressed Box Beam	N	1	47.25	-27.25	6.5		4		10	3	1960
1523	PSSS	621	PSBX	G3	Prestressed Box Beam	N	1	47.25	-27.25	4		4		10	3	1960
1524	PSSS	622	PSBX	Fascia__21__PC_Box_Beam	Prestressed Box Beam	Y	1	44.13	0.59	3.28	*	6.6		10	5	1961
1525	PSSS	622	PSBX	Interior__21__PC_Box_Beam	Prestressed Box Beam	Y	1	44.13	0.59	6.6		6.6		10	5	1961
1526	PSSS	623	PSBX	G1	Prestressed Box Beam	N	1	39.29	0	2	*	4		6	2	1962
1527	PSSS	623	PSBX	G2	Prestressed Box Beam	N	1	39.29	0	4		3.5		6	2	1962
1528	PSSS	624	PSBX	G1_&_G7	Prestressed Box Beam	N	1	36.71	40	1.94	*	3.91		7	2	1962
1529	PSSS	624	PSBX	G2-G6	Prestressed Box Beam	N	1	36.71	40	3.91		3.91		7	2	1962
1530	PSSS	625	PSBX	1st_W_Int-x	Prestressed Box Beam	Y	1	28.32	28.33	4		4		10	3	1963
1531	PSSS	626	PSBX	G1	Prestressed Box Beam	N	1	43.26	-30	1.5	*	3.54		7	2	1963
1532	PSSS	626	PSBX	G2	Prestressed Box Beam	N	1	43.26	-30	3.54		4.04		7	2	1963
1533	PSSS	627	PSBX	G1	Prestressed Box Beam	N	1	47.99	15.08	1.94	*	3.91		11	3	1963
1534	PSSS	627	PSBX	G2	Prestressed Box Beam	N	1	47.99	15.08	3.91		3.91		11	3	1963
1535	PSSS	628	PSBX	1_-_E_Fascia_(-2b)	Prestressed Box Beam	N	1	46.17	-45	1.5	*	3		17	4	1964
1536	PSSS	628	PSBX	4_-_3rd_E_Int	Prestressed Box Beam	N	1	46.17	-45	3		3		17	4	1964
1537	PSSS	629	PSBX	Fascia__21__PC_Box_Beam	Prestressed Box Beam	Y	1	32.09	4.36	2.5	*	9.1		10	6	1964
1538	PSSS	629	PSBX	Interior__21__PC_Box_Beam	Prestressed Box Beam	Y	1	32.09	4.36	9.1		9.1		10	6	1964
1539	PSSS	630	PSBX	3rd_North_Int__Beam	Prestressed Box Beam	N	1	47.04	0	3		3		12	3	1965
1540	PSSS	631	PSBX	Fascia_3"_PS_Slab_G1	Prestressed Box Beam	N	1	36.5	0	1.52	*	3		15	3	1965
1541	PSSS	631	PSBX	G2	Prestressed Box Beam	N	1	36.5	0	3		3		15	3	1965
1542	PSSS	632	PSBX	Fascia_3"_PS_Slab_G1	Prestressed Box Beam	N	1	36.5	0	1.6	*	3		10	2	1965

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1543	PSSS	632	PSBX	Interior_3"_PS_Slab_G2	Prestressed Box Beam	N	1	36.5	0	3		3		10	2	1965
1544	PSSS	633	PSBX	11_-_1st_E_Int-x	Prestressed Box Beam	N	1	42.83	-30	3.5		4		12	3	1965
1545	PSSS	633	PSBX	12_-_E_Fascia	Prestressed Box Beam	N	1	42.83	-30	1.5	*	3.5		12	3	1965
1546	PSSS	634	PSBX	2_-_1st_E_Int-x	Prestressed Box Beam	N	1	30.83	0	3		3		15	3	1967
1547	PSSS	635	PSBX	Fascia_4"_PS_Concrete_Slab_G1	Prestressed Box Beam	N	1	41.5	0	2	*	4		8	2	1967
1548	PSSS	635	PSBX	Interior_4"_PS_Concrete_Slab_G2	Prestressed Box Beam	N	1	41.5	0	4		4		8	2	1967
1549	PSSS	636	PSBX	G1	Prestressed Box Beam	N	1	48	0	1.92	*	3		18	4	1969
1550	PSSS	636	PSBX	G2	Prestressed Box Beam	N	1	48	0	3		3		18	4	1969
1551	PSSS	637	PSBX	1st_N_Int	Prestressed Box Beam	N	1	31.83	0	3		3		11	2	1970
1552	PSSS	638	PSBX	2_-_1st_W_Int	Prestressed Box Beam	N	1	42.98	-10	3		3		10	2	1971
1553	PSSS	639	PSBX	1st_N_Int	Prestressed Box Beam	N	1	48.82	20	3		3		11	2	1971
1554	PSSS	640	PSBX	G2	Prestressed Box Beam	N	1	49.17	0	3		3		11	2	1971
1555	PSSS	641	PSBX	2_-_1st_S_Int	Prestressed Box Beam	N	1	32.66	30	4		4		8	2	1972
1556	PSSS	642	PSBX	Member_1	Prestressed Box Beam	N	1	43.88	-20	2	*	4.04		8	2	1973
1557	PSSS	642	PSBX	Member_2	Prestressed Box Beam	N	1	43.88	-20	4.04		4.04		8	2	1973
1558	PSSS	643	PSBX	1_-_W_Fascia	Prestressed Box Beam	N	1	35.26	-6.68	1.5	*	3		15	3	1974
1559	PSSS	643	PSBX	2_-_1st_W_Int	Prestressed Box Beam	N	1	35.26	-6.68	3		3		15	3	1974
1560	PSSS	644	PSBX	Member_1	Prestressed Box Beam	N	1	45.9	-20	2	*	4.07		8	2	1974
1561	PSSS	644	PSBX	Member_2	Prestressed Box Beam	N	1	45.9	-20	4.07		4.07		8	2	1974
1562	PSSS	645	PSBX	G1_-x	Prestressed Box Beam	N	1	48.73	0	1.5	*	3		11	2	1974
1563	PSSS	645	PSBX	G3	Prestressed Box Beam	N	1	48.73	0	3		3		11	2	1974
1564	PSSS	645	PSBX	G6	Prestressed Box Beam	N	1	48.73	0	3		3		11	2	1974
1565	PSSS	646	PSBX	1st_W_Int-x	Prestressed Box Beam	N	1	43.15	30	4		4		11	3	1975
1566	PSSS	646	PSBX	W_Fascia	Prestressed Box Beam	N	1	43.15	30	2	*	4		11	3	1975
1567	PSSS	647	PSBX	1st_W_Int	Prestressed Box Beam	N	1	36.49	7.33	4		4		10	3	1976
1568	PSSS	648	PSBX	G1	Prestressed Box Beam	Y	1	48	0	2.34	*	4.04		9	2	1978

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1569	PSSS	648	PSBX	G2	Prestressed Box Beam	Y	1	48	0	4.04		4.04		9	2	1978
1570	PSSS	649	PSBX	G2	Prestressed Box Beam	N	1	37.75	0	4		4		11	3	1978
1571	PSSS	650	PSBX	1_-_E_Fascia	Prestressed Box Beam	N	1	21.5	0	2	*	4		8	2	1979
1572	PSSS	650	PSBX	2_-_1st_E_Int	Prestressed Box Beam	N	1	21.5	0	4		4		8	2	1979
1573	PSSS	651	PSBX	G2	Prestressed Box Beam	N	1	46.33	0	3		3		11	2	1981
1574	PSSS	652	PSBX	3rd_East_Int__Beam	Prestressed Box Beam	N	1	41.51	0	3		3		12	3	1981
1575	PSSS	653	PSBX	Fascia_4"_PS_Concrete_Slab_G1	Prestressed Box Beam	Y	1	48.67	0	2.75	*	4		7	2	1985
1576	PSSS	653	PSBX	Interior_4"_PS_Concrete_Slab_G2	Prestressed Box Beam	Y	1	48.67	0	4		4		7	2	1985
1577	PSSS	654	PSBX	G1	Prestressed Box Beam	Y	1	43.93	35	1.5	*	4		7	2	1981
1578	PSSS	654	PSBX	G2	Prestressed Box Beam	Y	1	43.93	35	4		4.5		7	2	1981
1579	PSSS	654	PSBX	G3	Prestressed Box Beam	Y	1	43.93	35	4.5		4		7	2	1981
1580	PSSS	654	PSBX	G4	Prestressed Box Beam	Y	1	43.93	35	4		4		7	2	1981
1581	PSSS	654	PSBX	G5	Prestressed Box Beam	Y	1	43.93	35	4		3.5		7	2	1981
1582	PSSS	654	PSBX	G6	Prestressed Box Beam	Y	1	43.93	35	3.5		3		7	2	1981
1583	PSSS	654	PSBX	G7	Prestressed Box Beam	Y	1	43.93	35	3		1.5	*	7	2	1981
1584	PSSS	655	PSBX	2_-_1st_N_Int-x	Prestressed Box Beam	N	1	37.5	0	3		3		12	3	1982
1585	PSSS	656	PSBX	2nd_East_Int__Beam	Prestressed Box Beam	N	1	44.89	-45	4		4		8	2	1982
1586	PSSS	657	PSBX	3rd_W_Int_	Prestressed Box Beam	N	1	34.5	0	3		3		12	3	1982
1587	PSSS	658	PSBX	1st_E_Int-x	Prestressed Box Beam	N	1	39.33	0	4		3.5		11	3	1982
1588	PSSS	658	PSBX	E_Fascia	Prestressed Box Beam	N	1	39.33	0	2	*	4		11	3	1982
1589	PSSS	659	PSBX	Member_1	Prestressed Box Beam	Y	1	52	23	2.46	*	3.54		10	2	1982
1590	PSSS	659	PSBX	Member_2	Prestressed Box Beam	Y	1	52	23	3.54		3.04		10	2	1982
1591	PSSS	659	PSBX	Member_4	Prestressed Box Beam	Y	1	52	23	3.54		4.04		10	2	1982
1592	PSSS	660	PSBX	1st_N_Int	Prestressed Box Beam	N	1	38.46	-20	4		3.5		9	2	1983
1593	PSSS	660	PSBX	2nd_N_Int	Prestressed Box Beam	N	1	38.46	-20	3.5		3		9	2	1983
1594	PSSS	660	PSBX	3rd_N_Int	Prestressed Box Beam	N	1	38.46	-20	3		3		9	2	1983

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1595	PSSS	661	PSBX	G1	Prestressed Box Beam	Y	1	46	-16.75	2.33	*	4.02		10	2	1994
1596	PSSS	661	PSBX	G2	Prestressed Box Beam	Y	1	46	-16.75	4.02		4.02		10	2	1994
1597	PSSS	661	PSBX	G3	Prestressed Box Beam	Y	1	46	-16.75	4.02		4.02		10	2	1994
1598	PSSS	662	PSBX	Fascia_4"_PS_Concrete_Box_Beam_G1	Prestressed Box Beam	N	1	51.13	-35	2.11	*	4		6	2	1983
1599	PSSS	662	PSBX	Interior_4"_PS_Concrete_Box_Beam_G2	Prestressed Box Beam	N	1	51.13	-35	4		4		6	2	1983
1600	PSSS	663	PSBX	Member_1	Prestressed Box Beam	N	1	47.17	-23	1.5	*	3.04		10	2	1985
1601	PSSS	663	PSBX	Member_2	Prestressed Box Beam	N	1	47.17	-23	3.04		3.04		10	2	1985
1602	PSSS	664	PSBX	G1	Prestressed Box Beam	Y	1	44	21.75	2.33	*	4.04		14	4	1986
1603	PSSS	664	PSBX	G2	Prestressed Box Beam	Y	1	44	21.75	4.04		4.04		14	4	1986
1604	PSSS	664	PSBX	G7	Prestressed Box Beam	Y	1	44	21.75	3.54		3.04		14	4	1986
1605	PSSS	665	PSBX	1st_East_Int__Beam	Prestressed Box Beam	N	1	40.5	0	4		4		8	2	1987
1606	PSSS	666	PSBX	G1	Prestressed Box Beam	Y	1	36.71	40	1.5	*	3.13		15	3	1987
1607	PSSS	666	PSBX	G2	Prestressed Box Beam	Y	1	36.71	40	3.13		3.13		15	3	1987
1608	PSSS	667	PSBX	G1	Prestressed Box Beam	Y	1	33	25	2.13	*	3.04		9	2	1987
1609	PSSS	667	PSBX	G2	Prestressed Box Beam	Y	1	33	25	3.04		3.04		9	2	1987
1610	PSSS	668	PSBX	G1	Prestressed Box Beam	Y	1	49	0	2	*	4		10	3	1988
1611	PSSS	668	PSBX	G2	Prestressed Box Beam	Y	1	49	0	4		4		10	3	1988
1612	PSSS	669	PSBX	Fascia_4"_PS_Concrete_Slab_G1	Prestressed Box Beam	Y	1	50	0	2.46	*	4		7	2	1988
1613	PSSS	669	PSBX	Interior_4"_PS_Concrete_Slab_G2	Prestressed Box Beam	Y	1	50	0	4		4		7	2	1988
1614	PSSS	670	PSBX	Member_1	Prestressed Box Beam	Y	1	42	0	1.51	*	3.04		18	4	1989
1615	PSSS	670	PSBX	Member_2	Prestressed Box Beam	Y	1	42	0	3.04		3.04		18	4	1989
1616	PSSS	671	PSBX	Member_1	Prestressed Box Beam	N	1	50.6	-24	2	*	4.01		8	2	1990
1617	PSSS	671	PSBX	Member_2	Prestressed Box Beam	N	1	50.6	-24	4.01		4.01		8	2	1990
1618	PSSS	672	PSBX	G1	Prestressed Box Beam	Y	1	41.25	20.89	2.33	*	3.04		9	2	1990
1619	PSSS	672	PSBX	G2	Prestressed Box Beam	Y	1	41.25	20.89	3.04		3.04		9	2	1990

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1620	PSSS	672	PSBX	G8	Prestressed Box Beam	Y	1	41.25	20.89	3.04		3.04		9	2	1990
1621	PSSS	672	PSBX	G9	Prestressed Box Beam	Y	1	41.25	20.89	3.04		1.83	*	9	2	1990
1622	PSSS	673	PSBX	Member_1	Prestressed Box Beam	N	1	52.29	5	2	*	4.04		8	2	1991
1623	PSSS	673	PSBX	Member_2	Prestressed Box Beam	N	1	52.29	5	4.04		4.04		8	2	1991
1624	PSSS	674	PSBX	G1	Prestressed Box Beam	Y	1	47.33	0	2.38	*	4.04		7	2	1991
1625	PSSS	674	PSBX	G2	Prestressed Box Beam	Y	1	47.33	0	4.04		4.04		7	2	1991
1626	PSSS	675	PSBX	Fascia_4"_PS_Box_Beam_G1	Prestressed Box Beam	Y	1	49	-45	4	*	8		4	2	1991
1627	PSSS	675	PSBX	Interior_4"_PS_Box_Beam_G2	Prestressed Box Beam	Y	1	49	-45	8		8		4	2	1991
1628	PSSS	676	PSBX	G2	Prestressed Box Beam	Y	1	27.92	0	6.5		3.17		23	4	1994
1629	PSSS	676	PSBX	G3	Prestressed Box Beam	Y	1	27.92	0	3.17		3.17		23	4	1994
1630	PSSS	677	PSBX	G1	Prestressed Box Beam	N	1	36	-9.16	1.5	*	3.04		7	1	1994
1631	PSSS	677	PSBX	G2	Prestressed Box Beam	N	1	36	-9.16	3.04		3.04		7	1	1994
1632	PSSS	678	PSBX	7th_E_Int_(NBL)	Prestressed Box Beam	N	1	36.18	-20	4		4		34	9	1995
1633	PSSS	678	PSBX	E_Fascia	Prestressed Box Beam	N	1	36.18	-20	2	*	4		34	9	1995
1634	PSSS	679	PSBX	Fascia_3_ft_overhang	Prestressed Box Beam	Y	1	36.3	22.67	3	*	7.83		12	5	1995
1635	PSSS	679	PSBX	Interior_under_Sidewalk	Prestressed Box Beam	Y	1	36.3	22.67	7.83		7.83		12	5	1995
1636	PSSS	679	PSBX	Typical_Interior	Prestressed Box Beam	Y	1	36.3	22.67	7.83		7.83		12	5	1995
1637	PSSS	680	PSBX	Member_1	Prestressed Box Beam	N	1	40	0	2	*	4.04		8	2	1995
1638	PSSS	680	PSBX	Member_2	Prestressed Box Beam	N	1	40	0	4.04		4.04		8	2	1995
1639	PSSS	681	PSBX	Member_1	Prestressed Box Beam	Y	1	52.5	15	2	*	4.04		7	2	1995
1640	PSSS	681	PSBX	Member_2	Prestressed Box Beam	Y	1	52.5	15	4.04		4.06		7	2	1995
1641	PSSS	682	PSBX	Fascia_4"_PS_Concrete_Slab_G1	Prestressed Box Beam	Y	1	34.83	-14.5	2.5	*	4		7	2	1995
1642	PSSS	682	PSBX	Interior_3"_PS_Concrete_Slab_G3	Prestressed Box Beam	Y	1	34.83	-14.5	3.5		3		7	2	1995

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1643	PSSS	682	PSBX	Interior_3"_PS_Concrete_Slab_G4	Prestressed Box Beam	Y	1	34.83	-14.5	3		3		7	2	1995
1644	PSSS	682	PSBX	Interior_4"_PS_Concrete_Slab_G2	Prestressed Box Beam	Y	1	34.83	-14.5	4		3.5		7	2	1995
1645	PSSS	683	PSBX	G2	Prestressed Box Beam	N	1	43.38	0	4		4		9	3	1996
1646	PSSS	684	PSBX	G1	Prestressed Box Beam	Y	1	52	0	2.35	*	4.04		8	2	1996
1647	PSSS	684	PSBX	G2	Prestressed Box Beam	Y	1	52	0	4.04		4.04		8	2	1996
1648	PSSS	684	PSBX	G8	Prestressed Box Beam	Y	1	52	0	4.04		2.35	*	8	2	1996
1649	PSSS	685	PSBX	G1	Prestressed Box Beam	Y	1	40	0	2	*	4		8	2	1997
1650	PSSS	685	PSBX	G2	Prestressed Box Beam	Y	1	40	0	4		4		8	2	1997
1651	PSSS	686	PSBX	Bm_A_Fascia_6_55"_o_c__spa	Prestressed Box Beam	Y	1	38.67	10	3.79	*	6.56		9	5	1997
1652	PSSS	686	PSBX	Bm_B_-_1st_Interior_6_55"_o_c__spa	Prestressed Box Beam	Y	1	38.67	10	6.56		6.56		9	5	1997
1653	PSSS	686	PSBX	Bm_C_-_Interior_6_55"_o_c__spa	Prestressed Box Beam	Y	1	38.67	10	6.56		6.56		9	5	1997
1654	PSSS	686	PSBX	Bm_D_-_Interior_spa_6_55"_and_9_83"	Prestressed Box Beam	Y	1	38.67	10	6.56		9.83		9	5	1997
1655	PSSS	686	PSBX	Bm_E_-_Interior_9_83"_o_c__spa	Prestressed Box Beam	Y	1	38.67	10	9.83		9.83		9	5	1997
1656	PSSS	686	PSBX	Bm_J_-_Fascia_9_83"_spa	Prestressed Box Beam	Y	1	38.67	10	9.83		3.79	*	9	5	1997
1657	PSSS	687	PSBX	G1	Prestressed Box Beam	Y	1	48.06	0	2	*	4		8	2	1998
1658	PSSS	687	PSBX	G2	Prestressed Box Beam	Y	1	48.06	0	4		4		8	2	1998
1659	PSSS	688	PSBX	G1	Prestressed Box Beam	N	1	52	0	2.31	*	4.04		10	2	1998

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1660	PSSS	688	PSBX	G2	Prestressed Box Beam	N	1	52	0	4.04		4.04		10	2	1998
1661	PSSS	688	PSBX	G3	Prestressed Box Beam	N	1	52	0	4.04		4.04		10	2	1998
1662	PSSS	689	PSBX	G1	Prestressed Box Beam	Y	1	43.5	0	2.51	*	3.56		12	2	1998
1663	PSSS	689	PSBX	G2	Prestressed Box Beam	Y	1	43.5	0	3.56		3.56		12	2	1998
1664	PSSS	689	PSBX	G3	Prestressed Box Beam	Y	1	43.5	0	3.56		4.06		12	2	1998
1665	PSSS	689	PSBX	G4	Prestressed Box Beam	Y	1	43.5	0	4.06		4.06		12	2	1998
1666	PSSS	689	PSBX	G5	Prestressed Box Beam	Y	1	43.5	0	4.06		3.56		12	2	1998
1667	PSSS	689	PSBX	G6	Prestressed Box Beam	Y	1	43.5	0	3.56		3.56		12	2	1998
1668	PSSS	690	PSBX	Beam_A	Prestressed Box Beam	Y	1	44.7	11.36	1.5	*	3.13		27	4	1999
1669	PSSS	691	PSBX	Member_1	Prestressed Box Beam	N	1	51.39	-40	2	*	4.04		8	2	1999
1670	PSSS	691	PSBX	Member_2	Prestressed Box Beam	N	1	51.39	-40	4.04		4.04		8	2	1999
1671	PSSS	692	PSBX	1st_N_Int-x	Prestressed Box Beam	N	1	46.33	0	4		4		10	3	2001
1672	PSSS	693	PSBX	Fascia_4"_PS_Concrete_Box_Beam_G1	Prestressed Box Beam	Y	1	50.03	33	2.45	*	4		7	2	2001
1673	PSSS	693	PSBX	Interior_3"_PS_Concrete_Box_Beam_G3	Prestressed Box Beam	Y	1	50.03	33	3.5		3.5		7	2	2001
1674	PSSS	693	PSBX	Interior_4"_PS_Concrete_Box_Beam_G2	Prestressed Box Beam	Y	1	50.03	33	4		3.5		7	2	2001
1675	PSSS	693	PSBX	Interior_4"_PS_Concrete_Box_Beam_G4	Prestressed Box Beam	Y	1	50.03	33	3.5		3.5		7	2	2001
1676	PSSS	694	PSBX	G1	Prestressed Box Beam	Y	1	50	0	2	*	4		9	2	2004
1677	PSSS	694	PSBX	G2	Prestressed Box Beam	Y	1	50	0	4		4		9	2	2004
1678	PSSS	695	PSBX	Typical_Fascia	Prestressed Box Beam	Y	1	50.67	0	3.18	*	8.04		6	3	2005
1679	PSSS	695	PSBX	Typical_Interior	Prestressed Box Beam	Y	1	50.67	0	8.04		8.04		6	3	2005
1680	PSSS	696	PSBX	3rd_W_Int_	Prestressed Box Beam	N	1	51.17	0	3		3		11	2	2006
1681	PSSS	697	PSBX	4_-_3rd_W_Int_	Prestressed Box Beam	N	1	46.74	-6.68	4		4		9	3	2006
1682	PSSS	698	PSBX	2_-_1st_N_Int_-_x	Prestressed Box Beam	N	1	46.82	-27	3		3		11	2	2008
1683	PSSS	698	PSBX	G2	Prestressed Box Beam	N	1	47	-27	3		3		11	2	2008
1684	PSSS	699	PSBX	2_-_1st_E_Int-x	Prestressed Box Beam	N	1	50.93	45	3		3		11	2	2008

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1685	PSSS	700	PSBX	2_-_1st_E_Int_-_x	Prestressed Box Beam	N	1	41.67	0	3		3		18	3	2008
1686	PSSS	701	PSBX	G1	Prestressed Box Beam	N	1	66	-40	1.43	*	5.78		10	2	1959
1687	PSSS	701	PSBX	G10	Prestressed Box Beam	N	1	66	-40	5.78		1.43	*	10	2	1959
1688	PSSS	701	PSBX	G2	Prestressed Box Beam	N	1	66	-40	5.78		3.25		10	2	1959
1689	PSSS	701	PSBX	G3	Prestressed Box Beam	N	1	66	-40	3.25		3.25		10	2	1959
1690	PSSS	701	PSBX	G4	Prestressed Box Beam	N	1	66	-40	3.25		3.25		10	2	1959
1691	PSSS	701	PSBX	G9	Prestressed Box Beam	N	1	66	-40	3.25		5.78		10	2	1959
1692	PSSS	702	PSBX	G2	Prestressed Box Beam	Y	1	74.7	-28	4.75		3.17		13	2	1961
1693	PSSS	702	PSBX	G3	Prestressed Box Beam	Y	1	74.7	-28	3.17		3.17		13	2	1961
1694	PSSS	703	PSBX	G1	Prestressed Box Beam	N	1	72	-10	1.51	*	3.04		9	2	1961
1695	PSSS	703	PSBX	G2	Prestressed Box Beam	N	1	72	-10	3.04		3.04		9	2	1961
1696	PSSS	704	PSBX	2_-_1st_W_Int-x	Prestressed Box Beam	N	1	78.8	-29.49	3		3		22	4	1962
1697	PSSS	705	PSBX	5_-_4th_W_Int_(SR_8_10_3)-x	Prestressed Box Beam	N	1	65.5	0	3		3		16	2	1963
1698	PSSS	706	PSBX	G1	Prestressed Box Beam	N	1	72.15	21	1.83	*	3.04		13	3	1965
1699	PSSS	706	PSBX	G2	Prestressed Box Beam	Y	1	72.15	21	3.04		3.04		13	3	1965
1700	PSSS	707	PSBX	Typical_Fascia_Beam	Prestressed Box Beam	Y	1	71.25	-7.44	2.96	*	7.38		5	2	1966
1701	PSSS	707	PSBX	Typical_Interior_Beam	Prestressed Box Beam	Y	1	71.25	-7.44	7.38		7.38		5	2	1966
1702	PSSS	708	PSBX	G1	Prestressed Box Beam	N	1	55	0	1.5	*	3.04		5	1	1967
1703	PSSS	708	PSBX	G2	Prestressed Box Beam	N	1	55	0	3.04		3.04		5	1	1967
1704	PSSS	708	PSBX	G5	Prestressed Box Beam	N	1	55	0	3.04		1.5	*	5	1	1967
1705	PSSS	709	PSBX	G1	Prestressed Box Beam	N	1	57.5	25	1.92	*	3		18	4	1969
1706	PSSS	709	PSBX	G2	Prestressed Box Beam	N	1	57.5	25	3		3		18	4	1969
1707	PSSS	710	PSBX	G1	Prestressed Box Beam	Y	1	85	14.5	2.08	*	3.5		13	4	1976
1708	PSSS	710	PSBX	G2	Prestressed Box Beam	Y	1	85	14.5	3.5		4		13	4	1976
1709	PSSS	711	PSBX	1_N_Fascia	Prestressed Box Beam	N	1	67.89	0	1.5	*	3		16	4	1977
1710	PSSS	711	PSBX	2_-_1st_N_Int-x	Prestressed Box Beam	N	1	67.89	0	3		3		16	4	1977

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1711	PSSS	712	PSBX	G1	Prestressed Box Beam	N	1	75	0	1.54	*	3.08		16	3	1977
1712	PSSS	712	PSBX	G2	Prestressed Box Beam	N	1	75	0	3.08		3.08		16	3	1977
1713	PSSS	713	PSBX	1st_N_Int	Prestressed Box Beam	N	1	70	0	3		3		11	2	1978
1714	PSSS	714	PSBX	1_-_S_Fascia_-x	Prestressed Box Beam	N	1	76.83	-30	1.5	*	3		11	2	1979
1715	PSSS	714	PSBX	2_-_1st_S_Int	Prestressed Box Beam	N	1	76.83	-30	3		3		11	2	1979
1716	PSSS	715	PSBX	G1	Prestressed Box Beam	N	1	84.67	0	1.53	*	3.03		15	3	1979
1717	PSSS	715	PSBX	G2	Prestressed Box Beam	N	1	84.67	0	3.03		3.06		15	3	1979
1718	PSSS	716	PSBX	G1	Prestressed Box Beam	Y	1	83	45	1.83	*	3.6		15	4	1981
1719	PSSS	716	PSBX	G2	Prestressed Box Beam	Y	1	83	45	3.6		4.1		15	4	1981
1720	PSSS	716	PSBX	G3	Prestressed Box Beam	Y	1	83	45	4.1		4.1		15	4	1981
1721	PSSS	717	PSBX	4_-_3rd_N_Int	Prestressed Box Beam	N	1	61.07	29.63	3.5		4		11	3	1982
1722	PSSS	718	PSBX	3rd_W_Int_	Prestressed Box Beam	N	1	74.79	-15	3		3		12	2	1982
1723	PSSS	719	PSBX	Prestressed_Beam_1__left_fascia	Prestressed Box Beam	Y	1	84	-30	2.04	*	3.51		10	3	1982
1724	PSSS	719	PSBX	Prestressed_Beam_2	Prestressed Box Beam	Y	1	84	-30	3.51		4.01		10	3	1982
1725	PSSS	720	PSBX	B1_-_Left_Fascia_-_3"_prestressed	Prestressed Box Beam	Y	1	75	0	2.07	*	3.54		16	5	1983
1726	PSSS	720	PSBX	B2_-_4"_prestressed	Prestressed Box Beam	Y	1	75	0	3.54		4.04		16	5	1983
1727	PSSS	721	PSBX	G2	Prestressed Box Beam	N	1	78.33	0	3		3		10	2	1985
1728	PSSS	722	PSBX	G1	Prestressed Box Beam	N	1	81	0	2	*	5.06		12	4	1985
1729	PSSS	722	PSBX	G2	Prestressed Box Beam	N	1	81	0	5.06		4.13		12	4	1985
1730	PSSS	722	PSBX	G6	Prestressed Box Beam	N	1	81	0	4.13		4.13		12	4	1985
1731	PSSS	723	PSBX	G1	Prestressed Box Beam	N	1	74.25	45	2.38	*	3		15	3	1985
1732	PSSS	723	PSBX	G2	Prestressed Box Beam	N	1	74.25	45	3		3		15	3	1985
1733	PSSS	724	PSBX	Member_1	Prestressed Box Beam	Y	1	85	45	1.93	*	3.04		10	2	1985
1734	PSSS	724	PSBX	Member_2	Prestressed Box Beam	Y	1	85	45	3.04		3.04		10	2	1985
1735	PSSS	725	PSBX	G1	Prestressed Box Beam	Y	1	82	0	2.55	*	4		11	3	1985
1736	PSSS	725	PSBX	G2	Prestressed Box Beam	Y	1	82	0	4		4		11	3	1985

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1737	PSSS	725	PSBX	G6	Prestressed Box Beam	Y	1	82	0	4		4		11	3	1985
1738	PSSS	726	PSBX	G2	Prestressed Box Beam	N	1	62.25	6.5	3.5		4		11	3	1986
1739	PSSS	727	PSBX	Member_1	Prestressed Box Beam	N	1	77.64	45	2.5	*	4.05		7	2	1987
1740	PSSS	727	PSBX	Member_2	Prestressed Box Beam	N	1	77.64	45	4.05		4.05		7	2	1987
1741	PSSS	728	PSBX	Member_1	Prestressed Box Beam	N	1	74	-15	2	*	4.06		8	2	1989
1742	PSSS	728	PSBX	Member_2	Prestressed Box Beam	N	1	74	-15	4.06		4.06		8	2	1989
1743	PSSS	729	PSBX	G1	Prestressed Box Beam	N	1	70	-52	2.38	*	4.04		7	2	1990
1744	PSSS	729	PSBX	G2	Prestressed Box Beam	N	1	70	-52	4.04		4.04		7	2	1990
1745	PSSS	729	PSBX	G3	Prestressed Box Beam	N	1	70	-52	4.04		3.54		7	2	1990
1746	PSSS	729	PSBX	G4	Prestressed Box Beam	N	1	70	-52	3.54		3.04		7	2	1990
1747	PSSS	729	PSBX	G5	Prestressed Box Beam	N	1	70	-52	3.04		3.04		7	2	1990
1748	PSSS	729	PSBX	G6	Prestressed Box Beam	N	1	70	-52	3.04		3.54		7	2	1990
1749	PSSS	729	PSBX	G7	Prestressed Box Beam	N	1	70	-52	3.54		2.38	*	7	2	1990
1750	PSSS	730	PSBX	G1	Prestressed Box Beam	Y	1	82.67	41.56	2.5	*	4.73		25	8	1992
1751	PSSS	730	PSBX	G2	Prestressed Box Beam	Y	1	82.67	41.56	4.73		4.71		25	8	1992
1752	PSSS	730	PSBX	G3	Prestressed Box Beam	Y	1	82.67	41.56	4.71		4.68		25	8	1992
1753	PSSS	730	PSBX	G4	Prestressed Box Beam	Y	1	82.67	41.56	4.68		4.66		25	8	1992
1754	PSSS	731	PSBX	Member_1	Prestressed Box Beam	Y	1	70.83	0	1.63	*	3.13		20	5	1993
1755	PSSS	731	PSBX	Member_2	Prestressed Box Beam	Y	1	70.83	0	3.13		3.13		20	5	1993
1756	PSSS	732	PSBX	Member_1	Prestressed Box Beam	Y	1	71.26	16.45	1.63	*	3.13		20	5	1993
1757	PSSS	732	PSBX	Member_2	Prestressed Box Beam	Y	1	71.26	16.45	3.13		3.13		20	5	1993
1758	PSSS	733	PSBX	Member_1	Prestressed Box Beam	N	1	81.92	-15	2	*	4.06		8	2	1993
1759	PSSS	733	PSBX	Member_2	Prestressed Box Beam	N	1	81.92	-15	4.06		4.06		8	2	1993
1760	PSSS	734	PSBX	G1	Prestressed Box Beam	Y	1	64.33	25	2.84	*	4		10	2	1993
1761	PSSS	734	PSBX	G2	Prestressed Box Beam	Y	1	64.33	25	4		4		10	2	1993
1762	PSSS	735	PSBX	G1	Prestressed Box Beam	Y	1	85	-37	2.49	*	3.54		9	2	1993
1763	PSSS	735	PSBX	G2	Prestressed Box Beam	Y	1	85	-37	3.54		3.54		9	2	1993
1764	PSSS	735	PSBX	G3	Prestressed Box Beam	Y	1	85	-37	3.54		4.04		9	2	1993

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1765	PSSS	736	PSBX	Fascia	Prestressed Box Beam	Y	1	72.5	30	1.63	*	3.14		15	3	1994
1766	PSSS	736	PSBX	Typical_Interior	Prestressed Box Beam	Y	1	72.5	30	3.14		3.14		15	3	1994
1767	PSSS	737	PSBX	Fascia_4"_PS_Box_Beam_G1	Prestressed Box Beam	N	1	84	0	2.13	*	4		5	1	1994
1768	PSSS	737	PSBX	Interior_4"_PS_Box_Beam_G2	Prestressed Box Beam	N	1	84	0	4		4		5	1	1994
1769	PSSS	738	PSBX	G1	Prestressed Box Beam	Y	1	73	-9.75	2.25	*	4.06		5	1	1994
1770	PSSS	738	PSBX	G2	Prestressed Box Beam	Y	1	73	-9.75	4.06		4.06		5	1	1994
1771	PSSS	738	PSBX	G3	Prestressed Box Beam	Y	1	73	-9.75	4.06		4.06		5	1	1994
1772	PSSS	738	PSBX	G4	Prestressed Box Beam	Y	1	73	-9.75	4.06		4.6		5	1	1994
1773	PSSS	738	PSBX	G5	Prestressed Box Beam	Y	1	73	-9.75	4.6		2.5	*	5	1	1994
1774	PSSS	739	PSBX	G1	Prestressed Box Beam	Y	1	82	0	2.39	*	4.04		11	3	1996
1775	PSSS	739	PSBX	G2	Prestressed Box Beam	Y	1	82	0	4.04		4.04		11	3	1996
1776	PSSS	739	PSBX	G6	Prestressed Box Beam	Y	1	82	0	3.04		3.04		11	3	1996
1777	PSSS	740	PSBX	Fascia__27__PC_Box_Beam	Prestressed Box Beam	Y	1	57.27	0	3.28	*	6.92		6	3	1996
1778	PSSS	740	PSBX	Interior__27__PC_Box_Beam	Prestressed Box Beam	Y	1	57.27	0	6.92		6.92		6	3	1996
1779	PSSS	741	PSBX	G1	Prestressed Box Beam	Y	1	79.96	30.22	2.33	*	4.04		13	3	1996
1780	PSSS	741	PSBX	G2	Prestressed Box Beam	Y	1	79.96	30.22	4.04		3.54		13	3	1996
1781	PSSS	741	PSBX	G3	Prestressed Box Beam	Y	1	79.96	30.22	3.54		3.54		13	3	1996
1782	PSSS	741	PSBX	G4	Prestressed Box Beam	Y	1	79.96	30.22	3.54		3.54		13	3	1996
1783	PSSS	741	PSBX	G5	Prestressed Box Beam	Y	1	79.96	30.22	3.54		3.54		13	3	1996
1784	PSSS	741	PSBX	G6	Prestressed Box Beam	Y	1	79.96	30.22	3.54		3.54		13	3	1996
1785	PSSS	741	PSBX	G7	Prestressed Box Beam	Y	1	79.96	30.22	3.54		3.54		13	3	1996
1786	PSSS	742	PSBX	Fascia_4"_PS_Concrete_Box_Beam_G1	Prestressed Box Beam	Y	1	70	0	2.5	*	4		5	1	1998
1787	PSSS	742	PSBX	Interior_3"_PS_Concrete_Box_Beam_G3	Prestressed Box Beam	Y	1	70	0	3.5		3.5		5	1	1998

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1788	PSSS	742	PSBX	Interior_4"_PS_Concrete_Box_Beam_G2	Prestressed Box Beam	Y	1	70	0	4		3.5		5	1	1998
1789	PSSS	743	PSBX	Beam_A	Prestressed Box Beam	Y	1	60.37	0	1.59	*	3.13		15	3	2000
1790	PSSS	743	PSBX	Beam_B	Prestressed Box Beam	Y	1	60.37	0	3.13		3.13		15	3	2000
1791	PSSS	744	PSBX	G1	Prestressed Box Beam	Y	1	53.35	0	3.44	*	7.38		12	7	2000
1792	PSSS	744	PSBX	G2	Prestressed Box Beam	Y	1	53.35	0	7.38		7.38		12	7	2000
1793	PSSS	745	PSBX	Beam_A	Prestressed Box Beam	Y	1	83.64	-30	1.51	*	3.12		15	3	2000
1794	PSSS	745	PSBX	Beam_H	Prestressed Box Beam	Y	1	83.64	-30	3.12		3.12		15	3	2000
1795	PSSS	746	PSBX	G1	Prestressed Box Beam	Y	1	75.56	-30	2.13	*	4.13		12	3	2002
1796	PSSS	746	PSBX	G2	Prestressed Box Beam	Y	1	75.56	-30	4.13		4.13		12	3	2002
1797	PSSS	747	PSBX	Fascia_4"_PS_Concrete_Box_Beam_G1	Prestressed Box Beam	Y	1	82.51	-25	2.5	*	4		8	2	2003
1798	PSSS	747	PSBX	Interior_4"_PS_Concrete_Box_Beam_G2	Prestressed Box Beam	Y	1	82.51	-25	4		4		8	2	2003
1799	PSSS	748	PSBX	G2	Prestressed Box Beam	Y	1	66	-18	3.5		4		22	5	2004
1800	PSSS	748	PSBX	G3	Prestressed Box Beam	Y	1	66	-18	4		4		22	5	2004
1801	PSSS	749	PSBX	G1	Prestressed Box Beam	Y	1	69.23	30	2.33	*	3.6		11	3	2004
1802	PSSS	749	PSBX	G2	Prestressed Box Beam	Y	1	69.23	30	3.6		3.1		11	3	2004
1803	PSSS	749	PSBX	G5	Prestressed Box Beam	Y	1	69.23	30	3.6		4.1		11	3	2004
1804	PSSS	750	PSBX	G1	Prestressed Box Beam	Y	1	59.42	-35	1.5	*	3		50	12	2005
1805	PSSS	750	PSBX	G2	Prestressed Box Beam	Y	1	59.42	-35	3		3		50	12	2005
1806	PSSS	751	PSBX	2_-_1st_N_Int-x	Prestressed Box Beam	N	1	59.04	0	3		3		14	3	2008
1807	PSSS	752	PSBX	2_-_1st_E_Int-x	Prestressed Box Beam	N	1	74.88	-38.78	3		3		11	2	2008
1808	PSSS	753	PSBX	G1	Prestressed Box Beam	N	1	95	45	1.8	*	3		12	2	1973
1809	PSSS	753	PSBX	G2	Prestressed Box Beam	N	1	95	45	3		3		12	2	1973
1810	PSSS	754	PSBX	G1	Prestressed Box Beam	Y	1	98	0	2.33	*	4.04		9	2	1976
1811	PSSS	754	PSBX	G2	Prestressed Box Beam	Y	1	98	0	4.04		4.04		9	2	1976
1812	PSSS	755	PSBX	G1	Prestressed Box Beam	Y	1	100	-45	1.98	*	3.04		12	3	1978
1813	PSSS	755	PSBX	G12	Prestressed Box Beam	Y	1	100	-45	4.04		2.48	*	12	3	1978

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1814	PSSS	755	PSBX	G2	Prestressed Box Beam	Y	1	100	-45	3.04		3.54		12	3	1978
1815	PSSS	755	PSBX	G3	Prestressed Box Beam	Y	1	100	-45	3.54		4.04		12	3	1978
1816	PSSS	756	PSBX	Fascia_4"_PS_COnc rete_Box_Beam_G1	Prestressed Box Beam	Y	1	103	0	2.57	*	4		12	3	1978
1817	PSSS	756	PSBX	Interior_4"_PS_COnc rete_Box_Beam_G2	Prestressed Box Beam	Y	1	103	0	4		4		12	3	1978
1818	PSSS	757	PSBX	Fascia_3"_PS_Box_ Beam_G1	Prestressed Box Beam	Y	1	111	0	2.04	*	3		11	2	1978
1819	PSSS	757	PSBX	Interior_3"_PS_Box_ Beam_G2	Prestressed Box Beam	Y	1	111	0	3		3		11	2	1978
1820	PSSS	758	PSBX	Fascia_4"_PS_Box_ Beam_G1	Prestressed Box Beam	Y	1	98	-13.42	2.64	*	4		12	3	1981
1821	PSSS	758	PSBX	Interior_4"_PS_Box_ Beam_G2	Prestressed Box Beam	Y	1	98	-13.42	4		4		12	3	1981
1822	PSSS	759	PSBX	G1	Prestressed Box Beam	Y	1	90	-20	1.97	*	3.06		11	2	1985
1823	PSSS	759	PSBX	G2	Prestressed Box Beam	Y	1	90	-20	3.06		3.06		11	2	1985
1824	PSSS	760	PSBX	G1	Prestressed Box Beam	Y	1	99.83	0	1.71	*	3.13		22	4	1989
1825	PSSS	760	PSBX	G2	Prestressed Box Beam	Y	1	99.83	0	3.13		3.13		22	4	1989
1826	PSSS	760	PSBX	G3	Prestressed Box Beam	Y	1	99.83	0	3.13		3.81		22	4	1989
1827	PSSS	760	PSBX	G4	Prestressed Box Beam	Y	1	99.83	0	3.81		3.13		22	4	1989
1828	PSSS	760	PSBX	G5	Prestressed Box Beam	Y	1	99.83	0	3.13		3.13		22	4	1989
1829	PSSS	761	PSBX	G_1	Prestressed Box Beam	Y	1	90	13	2	*	4.05		16	4	1990
1830	PSSS	761	PSBX	G_2	Prestressed Box Beam	Y	1	90	13	4.05		4.05		16	4	1990
1831	PSSS	762	PSBX	Fascia_4"_PS_Concr ete_Box_Beam_G1	Prestressed Box Beam	Y	1	106	-10.5	2.54	*	4		7	2	1990
1832	PSSS	762	PSBX	Interior_4"_PS_Conc rete_Box_Beam_G2	Prestressed Box Beam	Y	1	106	-10.5	4		4		7	2	1990
1833	PSSS	763	PSBX	Member_1	Prestressed Box Beam	Y	1	97.92	0	1.5	*	3.13		25	6	1996
1834	PSSS	763	PSBX	Member_2	Prestressed Box Beam	Y	1	97.92	0	3.13		3.13		25	6	1996

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1835	PSSS	764	PSBX	Beam_A	Prestressed Box Beam	Y	1	111.21	-10.79	2.13	*	4.13		16	5	1998
1836	PSSS	764	PSBX	Beam_H	Prestressed Box Beam	Y	1	111.21	-10.79	4.13		4.13		16	5	1998
1837	PSSS	765	PSBX	Fascia_Girder	Prestressed Box Beam	Y	1	110.44	17.84	2.13	*	4.23		11	3	2002
1838	PSSS	765	PSBX	Interior_Girder	Prestressed Box Beam	Y	1	110.44	17.84	4.23		4.23		11	3	2002
1839	PSSS	766	PSBX	G1	Prestressed Box Beam	N	1	115	30	1.5	*	3.1		11	2	2004
1840	PSSS	766	PSBX	G2	Prestressed Box Beam	N	1	115	30	3.1		3.1		11	2	2004
1841	PSSS	767	PSBX	G1	Prestressed Box Beam	Y	1	101.71	0	2.33	*	4.06		9	2	2007
1842	PSSS	767	PSBX	G2	Prestressed Box Beam	Y	1	101.71	0	4.06		4.06		9	2	2007
1843	PSSS	768	PSBX	1st_N__Int_	Prestressed Box Beam	N	1	45.06	-34.5	4		4		8	2	1975
1844	PSSS	769	PSBX	G2	Prestressed Box Beam	N	1	40.15	-9.57	3		3		11	2	1975
1845	PSSS	770	PSBX	Member_1	Prestressed Box Beam	N	1	46.91	61	2	*	4.04		7	2	1988
1846	PSSS	770	PSBX	Member_2	Prestressed Box Beam	N	1	46.91	61	4.04		4.04		7	2	1988
1847	PSSS	771	PSBX	Fascia_4"_PS_Concrete_Box_Beam_G1	Prestressed Box Beam	Y	1	52	20	2.67	*	4		6	2	1993
1848	PSSS	771	PSBX	Interior_4"_PS_Concrete_Box_Beam_G2	Prestressed Box Beam	Y	1	52	20	4		4		6	2	1993
1849	PSSS	772	PSBX	G1	Prestressed Box Beam	Y	1	42	30	2	*	4.04		9	2	1994
1850	PSSS	772	PSBX	G2	Prestressed Box Beam	Y	1	42	30	4.04		4.04		9	2	1994
1851	PSSS	773	PSBX	G1	Prestressed Box Beam	N	1	36	-5	2.04	*	4.06		7	2	1995
1852	PSSS	773	PSBX	G2	Prestressed Box Beam	N	1	36	-5	4.06		4.06		7	2	1995
1853	PSSS	774	PSBX	Fascia__21__PC_Box_Beam	Prestressed Box Beam	Y	1	51.97	0	2.19	*	5.97		12	5	2000
1854	PSSS	774	PSBX	Interior__21__PC_Box_Beam	Prestressed Box Beam	Y	1	51.97	0	5.97		5.97		12	5	2000
1855	PSSS	775	PSBX	G1	Prestressed Box Beam	Y	1	50	15	2.58	*	4.05		7	2	2003
1856	PSSS	775	PSBX	G2	Prestressed Box Beam	Y	1	50	15	4.05		4.05		7	2	2003
1857	PSSS	775	PSBX	G4	Prestressed Box Beam	Y	1	50	15	4.05		4.05		7	2	2003
1858	PSSS	776	PSBX	2 - 1st_E_Int-x	Prestressed Box Beam	N	1	43.67	0	3		3		14	3	2008
1859	PSSS	777	PSBX	G1	Prestressed Box Beam	Y	1	56.8	13.98	3.08	*	4.04		7	2	1990

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1860	PSSS	777	PSBX	G2	Prestressed Box Beam	Y	1	56.8	13.98	4.04		4.04		7	2	1990
1861	PSSS	777	PSBX	G6	Prestressed Box Beam	Y	1	56.8	13.98	4.04		4.04		7	2	1990
1862	PSSS	777	PSBX	G7	Prestressed Box Beam	Y	1	56.8	13.98	4.04		2.5	*	7	2	1990
1863	PSSS	778	PSBX	G1	Prestressed Box Beam	Y	1	76	33.56	2.33	*	4.04		12	3	1991
1864	PSSS	778	PSBX	G2	Prestressed Box Beam	Y	1	76	33.56	4.04		4.04		12	3	1991
1865	PSSS	779	PSBX	Member_1	Prestressed Box Beam	Y	1	70.83	0	1.75	*	3.13		20	5	1993
1866	PSSS	779	PSBX	Member_2	Prestressed Box Beam	Y	1	70.83	0	3.13		3.13		20	5	1993
1867	PSSS	779	PSBX	Member_20	Prestressed Box Beam	Y	1	70.83	0	3.13		1.63	*	20	5	1993
1868	PSSS	780	PSBX	B1_Left_Fascia	Prestressed Box Beam	Y	1	84.02	42	2.38	*	4.04		11	3	1994
1869	PSSS	780	PSBX	B2	Prestressed Box Beam	Y	1	84.02	42	4.04		4.04		11	3	1994
1870	PSSS	780	PSBX	B6	Prestressed Box Beam	Y	1	84.02	42	3.04		3.04		11	3	1994
1871	PSSS	781	PSBX	Member_1	Prestressed Box Beam	Y	1	83	33.22	2.42	*	4.04		9	2	1995
1872	PSSS	781	PSBX	Member_2	Prestressed Box Beam	Y	1	83	33.22	4.04		4.04		9	2	1995
1873	PSSS	782	PSBX	G1	Prestressed Box Beam	Y	1	73.82	0	1.99	*	3.54		12	3	2000
1874	PSSS	782	PSBX	G10	Prestressed Box Beam	Y	1	73.82	0	4.04		4.04		12	3	2000
1875	PSSS	782	PSBX	G11	Prestressed Box Beam	Y	1	73.82	0	4.04		3.54		12	3	2000
1876	PSSS	782	PSBX	G12	Prestressed Box Beam	Y	1	73.82	0	3.54		1.99	*	12	3	2000
1877	PSSS	782	PSBX	G2	Prestressed Box Beam	Y	1	73.82	0	3.54		4.04		12	3	2000
1878	PSSS	782	PSBX	G3	Prestressed Box Beam	Y	1	73.82	0	4.04		4.04		12	3	2000
1879	PSSS	783	PSBX	G1	Prestressed Box Beam	Y	1	83.67	0	1.5	*	3.13		16	3	2002
1880	PSSS	783	PSBX	G2	Prestressed Box Beam	Y	1	83.67	0	3.13		3.13		16	3	2002
1881	PSSS	784	PSBX	G1	Prestressed Box Beam	Y	1	55.12	-15	2.33	*	4.05		7	2	2002
1882	PSSS	784	PSBX	G2	Prestressed Box Beam	Y	1	55.12	-15	4.05		4.05		7	2	2002
1883	PSSS	785	PSBX	Fascia_4"_PS_Concrete_Box_Beam_G1	Prestressed Box Beam	Y	1	107	0	2.63	*	4		10	2	1993
1884	PSSS	785	PSBX	Interior_4"_PS_Concrete_Box_Beam_G2	Prestressed Box Beam	Y	1	107	0	4		4		10	2	1993
1885	PSSS	786	PSBX	Fascia_4"_PS_Concrete_Box_Beam_G1	Prestressed Box Beam	Y	1	88.75	0	2.5	*	4		7	2	1999

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1886	PSSS	786	PSBX	Interior_3"_PS_Concrete_Box_Beam_G3	Prestressed Box Beam	Y	1	88.75	0	3.5		3		7	2	1999
1887	PSSS	786	PSBX	Interior_3"_PS_Concrete_Box_Beam_G4	Prestressed Box Beam	Y	1	88.75	0	3		3		7	2	1999
1888	PSSS	786	PSBX	Interior_4"_PS_Concrete_Box_Beam_G2	Prestressed Box Beam	Y	1	88.75	0	4		3.5		7	2	1999
1889	RCSS	787	RCTB	G1	RC T-Beam	N	1	31.25	0	1.75	*	6.5		4	1	1922
1890	RCSS	787	RCTB	G2	RC T-Beam	N	1	31.25	0	6.5		6.5		4	1	1922
1891	RCSS	788	RCTB	G1	RC T-Beam	N	1	30	0	1.75	*	6.5		4	2	1922
1892	RCSS	788	RCTB	G2	RC T-Beam	N	1	30	0	6.5		6.5		4	2	1922
1893	RCSS	789	RCTB	G1	RC T-Beam	N	1	36.25	0	1.92	*	6.5		4	1	1923
1894	RCSS	789	RCTB	G2	RC T-Beam	N	1	36.25	0	6.5		6.5		4	1	1923
1895	RCSS	790	RCTB	G2	RC T-Beam	N	1	24	0	5.67		5.67		5	2	1923
1896	RCSS	790	RCTB	G4	RC T-Beam	N	1	24	0	5.67		5.67		5	2	1923
1897	RCSS	791	RCTB	G1	RC T-Beam	N	1	26.46	0	2.35	*	7.9		4	2	1924
1898	RCSS	791	RCTB	G2	RC T-Beam	N	1	26.46	0	7.9		6.5		4	2	1924
1899	RCSS	791	RCTB	G3	RC T-Beam	N	1	26.46	0	6.5		7.9		4	2	1924
1900	RCSS	791	RCTB	G4	RC T-Beam	N	1	26.46	0	7.9		2.35	*	4	2	1924
1901	RCSS	792	RCTB	G1	RC T-Beam	N	1	31.25	0	1.75	*	6.5		4	1	1925
1902	RCSS	792	RCTB	G2	RC T-Beam	N	1	31.25	0	6.5		6.5		4	1	1925
1903	RCSS	793	RCTB	G1	RC T-Beam	N	1	39.25	0	1.38	*	5.06		5	2	1925
1904	RCSS	793	RCTB	G2	RC T-Beam	N	1	39.25	0	5.06		5.15		5	2	1925
1905	RCSS	793	RCTB	G3	RC T-Beam	N	1	39.25	0	5.15		5.15		5	2	1925
1906	RCSS	794	RCTB	G1	RC T-Beam	N	1	33.25	0	2.92	*	6.25		4	2	1925
1907	RCSS	794	RCTB	G2	RC T-Beam	N	1	33.25	0	6.25		6.33		4	2	1925
1908	RCSS	795	RCTB	G1	RC T-Beam	N	1	33.25	0	1.08	*	6.33		4	1	1925
1909	RCSS	795	RCTB	G2	RC T-Beam	N	1	33.25	0	6.33		6.33		4	1	1925
1910	RCSS	796	RCTB	G1	RC T-Beam	N	1	31.25	0	1.75	*	6.5		4	2	1926
1911	RCSS	796	RCTB	G2	RC T-Beam	N	1	31.25	0	6.5		6.5		4	2	1926

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1912	RCSS	797	RCTB	G1	RC T-Beam	N	1	36.25	0	3.13	*	5.18		6	2	1926
1913	RCSS	797	RCTB	G2	RC T-Beam	N	1	36.25	0	5.18		2.96		6	2	1926
1914	RCSS	798	RCTB	G2	RC T-Beam	N	1	27.67	0	6.02		5.63		12	4	1926
1915	RCSS	798	RCTB	G6	RC T-Beam	N	1	27.67	0	5.63		5.63		12	4	1926
1916	RCSS	799	RCTB	G1	RC T-Beam	N	1	32	20	0.75	*	4.75		8	2	1927
1917	RCSS	799	RCTB	G2	RC T-Beam	N	1	32	20	4.75		4.75		8	2	1927
1918	RCSS	799	RCTB	G3	RC T-Beam	N	1	32	20	4.75		4.75		8	2	1927
1919	RCSS	799	RCTB	G4	RC T-Beam	N	1	32	20	4.75		4.75		8	2	1927
1920	RCSS	800	RCTB	G1	RC T-Beam	N	1	36.25	0	2.5	*	6		4	2	1928
1921	RCSS	800	RCTB	G2	RC T-Beam	N	1	36.25	0	6		6		4	2	1928
1922	RCSS	801	RCTB	G1	RC T-Beam	N	1	27.25	0	1.13	*	5.06		5	2	1928
1923	RCSS	801	RCTB	G2	RC T-Beam	N	1	27.25	0	5.06		5.23		5	2	1928
1924	RCSS	801	RCTB	G3	RC T-Beam	N	1	27.25	0	5.23		5.23		5	2	1928
1925	RCSS	802	RCTB	G1	RC T-Beam	N	1	32.81	14	0.63	*	6		6	2	1936
1926	RCSS	802	RCTB	G2	RC T-Beam	N	1	32.81	14	6		6		6	2	1936
1927	RCSS	803	RCTB	G1	RC T-Beam	N	1	36.25	0	1.75	*	6.5		4	2	1929
1928	RCSS	803	RCTB	G2	RC T-Beam	N	1	36.25	0	6.5		6.5		4	2	1929
1929	RCSS	804	RCTB	G1	RC T-Beam	N	1	37	30	0.74	*	6.9		5	2	1929
1930	RCSS	804	RCTB	G2	RC T-Beam	N	1	37	30	6.9		6.87		5	2	1929
1931	RCSS	805	RCTB	G1	RC T-Beam	N	1	35.25	0	2.75	*	6.58		5	2	1930
1932	RCSS	805	RCTB	G2	RC T-Beam	N	1	35.25	0	6.58		5.83		5	2	1930
1933	RCSS	805	RCTB	G3	RC T-Beam	N	1	35.25	0	5.83		5.83		5	2	1930
1934	RCSS	805	RCTB	G5	RC T-Beam	N	1	35.25	0	5.83		2.75	*	5	2	1930
1935	RCSS	806	RCTB	G1	RC T-Beam	N	1	26.83	0	2.33	*	6.67		4	2	1938
1936	RCSS	806	RCTB	G2	RC T-Beam	N	1	26.83	0	6.67		6.67		4	2	1938
1937	RCSS	807	RCTB	G1	RC T-Beam	N	1	36.13	25	2.5	*	7.33		4	2	1931
1938	RCSS	807	RCTB	G2	RC T-Beam	N	1	36.13	25	7.33		7.33		4	2	1931
1939	RCSS	808	RCTB	G1	RC T-Beam	N	1	33.08	0	1.29	*	5.06		5	2	1931

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1940	RCSS	808	RCTB	G2	RC T-Beam	N	1	33.08	0	5.06		5.23		5	2	1931
1941	RCSS	808	RCTB	G3	RC T-Beam	N	1	33.08	0	5.23		5.23		5	2	1931
1942	RCSS	809	RCTB	G3	RC T-Beam	N	1	37.93	25	4.75		4.5		11	3	1931
1943	RCSS	809	RCTB	G4	RC T-Beam	N	1	37.93	25	4.5		4.5		11	3	1931
1944	RCSS	810	RCTB	G1	RC T-Beam	N	1	29.33	0	3.5	*	6		4	2	1932
1945	RCSS	810	RCTB	G2	RC T-Beam	N	1	29.33	0	6		6		4	2	1932
1946	RCSS	811	RCTB	G1	RC T-Beam	N	1	29.5	0	2.75	*	8.25		3	2	1934
1947	RCSS	811	RCTB	G2	RC T-Beam	N	1	29.5	0	8.25		8.25		3	2	1934
1948	RCSS	812	RCTB	G1	RC T-Beam	N	1	31.25	10	1.75	*	6.5		4	2	1935
1949	RCSS	812	RCTB	G2	RC T-Beam	N	1	31.25	10	6.5		6.5		4	2	1935
1950	RCSS	813	RCTB	G1	RC T-Beam	N	1	31.5	0	0.75	*	4.75		7	2	1938
1951	RCSS	813	RCTB	G2	RC T-Beam	N	1	31.5	0	4.75		4.5		7	2	1938
1952	RCSS	813	RCTB	G3	RC T-Beam	N	1	31.5	0	4.5		4.5		7	2	1938
1953	RCSS	814	RCTB	G1	RC T-Beam	N	1	27.5	0	1.54	*	7.67		10	5	1935
1954	RCSS	814	RCTB	G2	RC T-Beam	N	1	27.5	0	7.67		7.67		10	5	1935
1955	RCSS	814	RCTB	G3	RC T-Beam	N	1	27.5	0	7.67		7.67		10	5	1935
1956	RCSS	814	RCTB	G4	RC T-Beam	N	1	27.5	0	7.67		6.67		10	5	1935
1957	RCSS	814	RCTB	G5	RC T-Beam	N	1	27.5	0	6.67		6.67		10	5	1935
1958	RCSS	815	RCTB	G1	RC T-Beam	N	1	29.5	3.92	0.58	*	4.52		6	2	1935
1959	RCSS	815	RCTB	G2	RC T-Beam	N	1	29.5	3.92	4.52		6.32		6	2	1935
1960	RCSS	815	RCTB	G3	RC T-Beam	N	1	29.5	3.92	6.32		6.32		6	2	1935
1961	RCSS	816	RCTB	G1	RC T-Beam	N	1	31.5	0	0.75	*	4.75		7	2	1935
1962	RCSS	816	RCTB	G2	RC T-Beam	N	1	31.5	0	4.75		4.5		7	2	1935
1963	RCSS	816	RCTB	G3	RC T-Beam	N	1	31.5	0	4.5		4.5		7	2	1935
1964	RCSS	817	RCTB	G1	RC T-Beam	N	1	26.88	0	2.3	*	6.17		4	2	1947
1965	RCSS	817	RCTB	G2	RC T-Beam	N	1	26.88	0	6.17		6.17		4	2	1947
1966	RCSS	818	RCTB	G1	RC T-Beam	N	1	36.25	0	1.75	*	6.5		4	1	1936
1967	RCSS	818	RCTB	G2	RC T-Beam	N	1	36.25	0	6.5		6.5		4	1	1936

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1968	RCSS	819	RCTB	G1	RC T-Beam	N	1	25	39.07	1.25	*	7.08		7	3	1936
1969	RCSS	819	RCTB	G2	RC T-Beam	N	1	25	39.07	7.08		7.08		7	3	1936
1970	RCSS	820	RCTB	2nd_N_Int	RC T-Beam	N	1	36.5	0	6.5		6.5		7	3	1937
1971	RCSS	821	RCTB	G1	RC T-Beam	N	1	28.5	0	2.17	*	4.83		5	2	1938
1972	RCSS	821	RCTB	G2	RC T-Beam	N	1	28.5	0	4.83		4.83		5	2	1938
1973	RCSS	822	RCTB	G1	RC T-Beam	N	1	33	0	2.33	*	6.67		4	2	1938
1974	RCSS	822	RCTB	G2	RC T-Beam	N	1	33	0	6.67		6.67		4	2	1938
1975	RCSS	823	RCTB	G1	RC T-Beam	N	1	36.67	0	2.5	*	7.33		4	2	1939
1976	RCSS	823	RCTB	G2	RC T-Beam	N	1	36.67	0	7.33		7.33		4	2	1939
1977	RCSS	824	RCTB	G1	RC T-Beam	N	1	28.9	0	1.96	*	7.67		4	2	1940
1978	RCSS	824	RCTB	G2	RC T-Beam	N	1	28.9	0	7.67		7.67		4	2	1940
1979	RCSS	824	RCTB	G3	RC T-Beam	N	1	28.9	0	7.67		7.67		4	2	1940
1980	RCSS	824	RCTB	G4	RC T-Beam	N	1	28.9	0	7.67		1.96	*	4	2	1940
1981	RCSS	825	RCTB	G1	RC T-Beam	N	1	32.5	0	2.21	*	6.92		4	2	1940
1982	RCSS	825	RCTB	G2	RC T-Beam	N	1	32.5	0	6.92		6.92		4	2	1940
1983	RCSS	826	RCTB	G1	RC T-Beam	N	1	36.25	0	3.38	*	9.5		3	2	1941
1984	RCSS	826	RCTB	G2	RC T-Beam	N	1	36.25	0	9.5		9.5		3	2	1941
1985	RCSS	827	RCTB	G1	RC T-Beam	N	1	30.54	-30	3.38	*	9.5		3	2	1941
1986	RCSS	827	RCTB	G2	RC T-Beam	N	1	30.54	-30	9.5		9.5		3	2	1941
1987	RCSS	828	RCTB	G1	RC T-Beam	N	1	32.79	0	2.33	*	7.33		4	2	1947
1988	RCSS	828	RCTB	G2	RC T-Beam	N	1	32.79	0	7.33		7.33		4	2	1947
1989	RCSS	829	RCTB	G1	RC T-Beam	N	1	32.79	0	2.33	*	7.33		4	2	1947
1990	RCSS	829	RCTB	G2	RC T-Beam	N	1	32.79	0	7.33		7.33		4	2	1947
1991	RCSS	830	RCTB	G1	RC T-Beam	N	1	37.67	50	0.7	*	5.83		6	2	1950
1992	RCSS	830	RCTB	G2	RC T-Beam	N	1	37.67	50	5.83		6.04		6	2	1950
1993	RCSS	831	RCTB	G1	RC T-Beam	N	1	32.77	0	1.92	*	7		4	2	1948
1994	RCSS	831	RCTB	G2	RC T-Beam	N	1	32.77	0	7		7		4	2	1948
1995	RCSS	832	RCTB	G1	RC T-Beam	N	1	37.21	45	1.56	*	5.04		6	2	1950

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
1996	RCSS	832	RCTB	G2	RC T-Beam	N	1	37.21	45	5.04		5.04		6	2	1950
1997	RCSS	833	RCTB	G1	RC T-Beam	N	1	37	45	2.34	*	7.44		8	4	1951
1998	RCSS	833	RCTB	G2	RC T-Beam	N	1	37	45	7.44		7.44		8	4	1951
1999	RCSS	833	RCTB	G3	RC T-Beam	N	1	37	45	7.44		7.44		8	4	1951
2000	RCSS	833	RCTB	G4	RC T-Beam	N	1	37	45	7.44		7.44		8	4	1951
2001	RCSS	834	RCTB	G1	RC T-Beam	N	1	33.25	0	1.8	*	5.7		7	3	1951
2002	RCSS	834	RCTB	G2	RC T-Beam	N	1	33.25	0	5.7		5.6		7	3	1951
2003	RCSS	834	RCTB	G3	RC T-Beam	N	1	33.25	0	5.6		5.23		7	3	1951
2004	RCSS	834	RCTB	G4	RC T-Beam	N	1	33.25	0	5.23		5.23		7	3	1951
2005	RCSS	835	RCTB	G1	RC T-Beam	N	1	37	0	2.54	*	6.67		4	2	1952
2006	RCSS	835	RCTB	G2	RC T-Beam	N	1	37	0	6.67		6.67		4	2	1952
2007	RCSS	836	RCTB	G1	RC T-Beam	N	1	27.25	0	5	*	8.17		4	2	1953
2008	RCSS	836	RCTB	G2	RC T-Beam	N	1	27.25	0	8.17		8.17		4	2	1953
2009	RCSS	837	RCTB	G1	RC T-Beam	N	1	31	0	2.92	*	8.08		6	3	1954
2010	RCSS	837	RCTB	G2	RC T-Beam	N	1	31	0	8.08		8.08		6	3	1954
2011	RCSS	838	RCTB	G1	RC T-Beam	N	1	33	0	3.08	*	8.5		3	2	1954
2012	RCSS	838	RCTB	G2	RC T-Beam	N	1	33	0	8.5		8.5		3	2	1954
2013	RCSS	839	RCTB	G1	RC T-Beam	N	1	33	0	3.08	*	8.5		3	2	1954
2014	RCSS	839	RCTB	G2	RC T-Beam	N	1	33	0	8.5		8.5		3	2	1954
2015	RCSS	840	RCTB	G1	RC T-Beam	N	1	36.43	0	2.63	*	9		3	2	1956
2016	RCSS	840	RCTB	G2	RC T-Beam	N	1	36.43	0	9		9		3	2	1956
2017	RCSS	841	RCTB	G1	RC T-Beam	N	1	33	0	3.08	*	8.5		3	2	1956
2018	RCSS	841	RCTB	G2	RC T-Beam	N	1	33	0	8.5		8.5		3	2	1956
2019	RCSS	842	RCTB	G1	RC T-Beam	N	1	36.83	0	2.38	*	8		4	2	1956
2020	RCSS	842	RCTB	G2	RC T-Beam	N	1	36.83	0	8		8		4	2	1956
2021	RCSS	843	RCTB	G1	RC T-Beam	N	1	36.38	0	2.63	*	9		3	2	1958
2022	RCSS	843	RCTB	G2	RC T-Beam	N	1	36.38	0	9		9		3	2	1958
2023	RCSS	844	RCTB	G1	RC T-Beam	N	1	39	0	3.17	*	8.5		3	2	1958

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2024	RCSS	844	RCTB	G2	RC T-Beam	N	1	39	0	8.5		8.5		3	2	1958
2025	RCSS	845	RCTB	G1	RC T-Beam	N	1	33	0	2.5	*	8		4	2	1959
2026	RCSS	845	RCTB	G2	RC T-Beam	N	1	33	0	8		8		4	2	1959
2027	RCSS	846	RCTB	G1	RC T-Beam	N	1	33	0	2.5	*	8		4	2	1960
2028	RCSS	846	RCTB	G2	RC T-Beam	N	1	33	0	8		8		4	2	1960
2029	RCSS	847	RCTB	2nd_E_Int	RC T-Beam	N	1	37.9	37.75	6.75		6.75		7	3	1961
2030	RCSS	848	RCTB	G1	RC T-Beam	N	1	37.73	0	3.17	*	8.5		3	2	1961
2031	RCSS	848	RCTB	G2	RC T-Beam	N	1	37.73	0	8.5		8.5		3	2	1961
2032	RCSS	849	RCTB	G1	RC T-Beam	N	1	33	0	2.5	*	8		4	2	1962
2033	RCSS	849	RCTB	G2	RC T-Beam	N	1	33	0	8		8		4	2	1962
2034	RCSS	850	RCTB	G1	RC T-Beam	N	1	33	0	2.5	*	8		4	2	1964
2035	RCSS	850	RCTB	G2	RC T-Beam	N	1	33	0	8		8		4	2	1964
2036	RCSS	851	RCTB	G1	RC T-Beam	N	1	33	0	2.5	*	8		4	2	1964
2037	RCSS	851	RCTB	G2	RC T-Beam	N	1	33	0	8		8		4	2	1964
2038	RCSS	852	RCTB	G1	RC T-Beam	N	1	33.67	14	3.58	*	8.33		9	5	1964
2039	RCSS	852	RCTB	G2	RC T-Beam	N	1	33.67	14	8.33		8.33		9	5	1964
2040	RCSS	852	RCTB	G3	RC T-Beam	N	1	33.67	14	8.33		7.33		9	5	1964
2041	RCSS	852	RCTB	G4	RC T-Beam	N	1	33.67	14	7.33		7.33		9	5	1964
2042	RCSS	852	RCTB	G5	RC T-Beam	N	1	33.67	14	7.33		7.33		9	5	1964
2043	RCSS	852	RCTB	G7	RC T-Beam	N	1	33.67	14	7.33		7.33		9	5	1964
2044	RCSS	852	RCTB	G8	RC T-Beam	N	1	33.67	14	7.33		7.33		9	5	1964
2045	RCSS	852	RCTB	G9	RC T-Beam	N	1	33.67	14	7.33		3.67	*	9	5	1964
2046	RCSS	853	RCTB	2_-_1st_2nd_N_Int_Legs	RC T-Beam	N	1	33.25	0	3.38		3.75		7	2	1965
2047	RCSS	854	RCTB	G1	RC T-Beam	N	1	33	0	2.5	*	8		4	2	1966
2048	RCSS	854	RCTB	G2	RC T-Beam	N	1	33	0	8		8		4	2	1966
2049	RCSS	855	RCTB	G1	RC T-Beam	N	1	35	0	2.54	*	6.67		4	2	1968
2050	RCSS	855	RCTB	G2	RC T-Beam	N	1	35	0	6.67		6.67		4	2	1968

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2051	RCSS	856	RCTB	G1	RC T-Beam	N	1	33	0	3.5	*	7		6	3	1969
2052	RCSS	856	RCTB	G2	RC T-Beam	N	1	33	0	7		7		6	3	1969
2053	RCSS	857	RCTB	G1	RC T-Beam	N	1	33	0	3.08	*	8.5		3	2	1970
2054	RCSS	857	RCTB	G2	RC T-Beam	N	1	33	0	8.5		8.5		3	2	1970
2055	RCSS	858	RCTB	G1	RC T-Beam	N	1	39.04	24.65	1.88	*	8.25		6	3	1972
2056	RCSS	858	RCTB	G2	RC T-Beam	N	1	39.04	24.65	8.25		8.25		6	3	1972
2057	RCSS	859	RCTB	G1	RC T-Beam	N	1	32.83	0	2.38	*	8		4	2	1973
2058	RCSS	859	RCTB	G2	RC T-Beam	N	1	32.83	0	8		8		4	2	1973
2059	RCSS	860	RCTB	G1	RC T-Beam	N	1	33	0	3.5	*	7		6	3	1974
2060	RCSS	860	RCTB	G2	RC T-Beam	N	1	33	0	7		7		6	3	1974
2061	RCSS	861	RCTB	G1	RC T-Beam	N	1	32.88	0	2.71	*	7.83		7	4	1974
2062	RCSS	861	RCTB	G2	RC T-Beam	N	1	32.88	0	7.83		7.83		7	4	1974
2063	RCSS	862	RCTB	G1	RC T-Beam	N	1	31	0	3.5	*	7		6	3	1975
2064	RCSS	862	RCTB	G2	RC T-Beam	N	1	31	0	7		7		6	3	1975
2065	RCSS	862	RCTB	G3	RC T-Beam	N	1	31	0	7		7		6	3	1975
2066	RCSS	863	RCTB	G1	RC T-Beam	N	1	35.1	30	1.5	*	7		5	2	1975
2067	RCSS	863	RCTB	G2	RC T-Beam	N	1	35.1	30	7		7		5	2	1975
2068	RCSS	863	RCTB	G5	RC T-Beam	N	1	35.1	30	7		1.5	*	5	2	1975
2069	RCSS	864	RCTB	G1	RC T-Beam	N	1	32.75	0	2.76	*	7		6	3	1972
2070	RCSS	864	RCTB	G2	RC T-Beam	N	1	32.75	0	7		7		6	3	1972
2071	RCSS	864	RCTB	G6	RC T-Beam	N	1	32.75	0	7		1.63	*	6	3	1972
2072	RCSS	865	RCTB	G1	RC T-Beam	N	1	31	0	3.38	*	7.5		4	2	1964
2073	RCSS	865	RCTB	G2	RC T-Beam	N	1	31	0	7.5		7.5		4	2	1964
2074	RCSS	866	RCTB	G2_-_1st_S_Int_	RC T-Beam	N	1	29	0	8		8		6	3	1968
2075	RCSS	867	RCTB	1st_Int_Beam	RC T-Beam	N	1	41.19	0	7.67		7.67		3	1	1923
2076	RCSS	867	RCTB	2nd_Int_Beam	RC T-Beam	N	1	41.19	0	7.67		1.85	*	3	1	1923
2077	RCSS	868	RCTB	G1	RC T-Beam	N	1	46.25	0	1.75	*	6.5		4	2	1926
2078	RCSS	868	RCTB	G2	RC T-Beam	N	1	46.25	0	6.5		6.5		4	2	1926

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2079	RCSS	869	RCTB	G1	RC T-Beam	N	1	50.57	-30	1.75	*	6.5		4	1	1926
2080	RCSS	869	RCTB	G2	RC T-Beam	N	1	50.57	-30	6.5		6.5		4	1	1926
2081	RCSS	870	RCTB	G1	RC T-Beam	N	1	51.04	0	3.33	*	6.5		4	2	1926
2082	RCSS	870	RCTB	G2	RC T-Beam	N	1	51.04	0	6.5		6.5		4	2	1926
2083	RCSS	871	RCTB	G1	RC T-Beam	N	1	51.25	0	1.88	*	6.42		4	2	1927
2084	RCSS	871	RCTB	G2	RC T-Beam	N	1	51.25	0	6.42		6.42		4	2	1927
2085	RCSS	872	RCTB	G1	RC T-Beam	N	1	51.25	0	1.75	*	6.5		4	2	1928
2086	RCSS	872	RCTB	G2	RC T-Beam	N	1	51.25	0	6.5		6.5		4	2	1928
2087	RCSS	873	RCTB	G2	RC T-Beam	N	1	51.5	0	6.46		7.33		8	3	1931
2088	RCSS	873	RCTB	G3	RC T-Beam	N	1	51.5	0	7.33		7.42		8	3	1931
2089	RCSS	873	RCTB	G4	RC T-Beam	N	1	51.5	0	7.42		7.42		8	3	1931
2090	RCSS	874	RCTB	G1	RC T-Beam	N	1	50.74	30	2.38	*	6.75		4	2	1932
2091	RCSS	874	RCTB	G2	RC T-Beam	N	1	50.74	30	6.75		6.75		4	2	1932
2092	RCSS	875	RCTB	G1	RC T-Beam	N	1	48	45	0.88	*	6.21		7	3	1932
2093	RCSS	875	RCTB	G2	RC T-Beam	N	1	48	45	6.21		6.21		7	3	1932
2094	RCSS	876	RCTB	G1	RC T-Beam	N	1	39.71	0	2.92	*	6.33		7	3	1934
2095	RCSS	876	RCTB	G2	RC T-Beam	N	1	39.71	0	6.33		6.33		7	3	1934
2096	RCSS	877	RCTB	G1	RC T-Beam	N	1	51.67	35	3.75	*	6.33		9	4	1934
2097	RCSS	877	RCTB	G4	RC T-Beam	N	1	51.67	35	6.92		6.92		9	4	1934
2098	RCSS	878	RCTB	G1	RC T-Beam	N	1	56.5	0	3	*	5.67		4	2	1941
2099	RCSS	878	RCTB	G2	RC T-Beam	N	1	56.5	0	5.67		5.67		4	2	1941
2100	RCSS	879	RCTB	G1	RC T-Beam	N	1	50	0	0.92	*	6.04		7	2	1936
2101	RCSS	879	RCTB	G2	RC T-Beam	N	1	50	0	6.04		6.02		7	2	1936
2102	RCSS	879	RCTB	G3	RC T-Beam	N	1	50	0	6.02		6.02		7	2	1936
2103	RCSS	879	RCTB	G4	RC T-Beam	N	1	50	0	6.02		6.02		7	2	1936
2104	RCSS	879	RCTB	G7	RC T-Beam	N	1	50	0	6.04		0.92	*	7	2	1936
2105	RCSS	880	RCTB	G1	RC T-Beam	N	1	53.49	55	3.17	*	9.33		3	2	1937
2106	RCSS	880	RCTB	G2	RC T-Beam	N	1	53.49	55	9.33		9.33		3	2	1937

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2107	RCSS	881	RCTB	G1	RC T-Beam	N	1	41.25	0	2.63	*	7.25		4	2	1939
2108	RCSS	881	RCTB	G2	RC T-Beam	N	1	41.25	0	7.25		7.25		4	2	1939
2109	RCSS	881	RCTB	G3	RC T-Beam	N	1	41.25	0	7.25		7.25		4	2	1939
2110	RCSS	881	RCTB	G4	RC T-Beam	N	1	41.25	0	7.25		2.63	*	4	2	1939
2111	RCSS	882	RCTB	G1	RC T-Beam	N	1	56.4	-17.5	2.88	*	8		4	2	1941
2112	RCSS	882	RCTB	G2	RC T-Beam	N	1	56.4	-17.5	8		8		4	2	1941
2113	RCSS	883	RCTB	G1	RC T-Beam	N	1	56.5	0	3	*	5.67		4	2	1941
2114	RCSS	883	RCTB	G2	RC T-Beam	N	1	56.5	0	5.67		5.67		4	2	1941
2115	RCSS	884	RCTB	G1	RC T-Beam	N	1	56.5	0	3	*	5.67		4	2	1941
2116	RCSS	884	RCTB	G2	RC T-Beam	N	1	56.5	0	5.67		5.67		4	2	1941
2117	RCSS	885	RCTB	G1	RC T-Beam	N	1	41.5	0	4.92	*	6.83		4	2	1946
2118	RCSS	885	RCTB	G2	RC T-Beam	N	1	41.5	0	6.83		6.83		4	2	1946
2119	RCSS	886	RCTB	G1	RC T-Beam	N	1	56.25	0	2.88	*	8.92		3	2	1948
2120	RCSS	886	RCTB	G2	RC T-Beam	N	1	56.25	0	8.92		8.92		3	2	1948
2121	RCSS	887	RCTB	G1	RC T-Beam	N	1	60.69	35	1.54	*	7.08		3	1	1951
2122	RCSS	887	RCTB	G2	RC T-Beam	N	1	60.69	35	7.08		7.08		3	1	1951
2123	RCSS	888	RCTB	G2	RC T-Beam	N	1	61.25	0	8.92		8.92		3	2	1951
2124	RCSS	888	RCTB	G3	RC T-Beam	N	1	61.25	0	8.92		2.88	*	3	2	1951
2125	RCSS	889	RCTB	G1	RC T-Beam	N	1	56.27	0	2.88	*	8.92		3	2	1952
2126	RCSS	889	RCTB	G2	RC T-Beam	N	1	56.27	0	8.92		8.92		3	2	1952
2127	RCSS	890	RCTB	CL_Jt_Fascia	RC T-Beam	N	1	51.17	0	8.25		1.67	*	3	1	1954
2128	RCSS	891	RCTB	G1	RC T-Beam	N	1	53.18	-45	2.5	*	7.33		4	2	1957
2129	RCSS	891	RCTB	G2	RC T-Beam	N	1	53.18	-45	7.33		7.33		4	2	1957
2130	RCSS	891	RCTB	G4	RC T-Beam	N	1	53.18	-45	7.33		2.5	*	4	2	1957
2131	RCSS	892	RCTB	G1	RC T-Beam	N	1	56.25	17.57	3.75	*	8.04		4	2	1957
2132	RCSS	892	RCTB	G2	RC T-Beam	N	1	56.25	17.57	8.04		8.08		4	2	1957
2133	RCSS	893	RCTB	G1	RC T-Beam	N	1	60	20	2.63	*	9		3	2	1957
2134	RCSS	893	RCTB	G2	RC T-Beam	N	1	60	20	9		9		3	2	1957

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2135	RCSS	894	RCTB	G1	RC T-Beam	N	1	56.38	15	2.63	*	9		3	2	1958
2136	RCSS	894	RCTB	G2	RC T-Beam	N	1	56.38	15	9		9		3	2	1958
2137	RCSS	895	RCTB	G1	RC T-Beam	N	1	61.08	-20	2.63	*	9		3	2	1959
2138	RCSS	895	RCTB	G2	RC T-Beam	N	1	61.08	-20	9		9		3	2	1959
2139	RCSS	896	RCTB	G1	RC T-Beam	N	1	56.17	0	3.67	*	8.75		4	2	1960
2140	RCSS	896	RCTB	G2	RC T-Beam	N	1	56.17	0	8.75		8.75		4	2	1960
2141	RCSS	897	RCTB	6_-_1st_S_Int	RC T-Beam	N	1	43.25	43.16	7.75		7.75		7	3	1961
2142	RCSS	898	RCTB	G1	RC T-Beam	N	1	50.99	15	2.63	*	9		3	2	1961
2143	RCSS	898	RCTB	G2	RC T-Beam	N	1	50.99	15	9		9		3	2	1961
2144	RCSS	899	RCTB	G1	RC T-Beam	N	1	49	0	3.34	*	8.5		3	2	1962
2145	RCSS	899	RCTB	G2	RC T-Beam	N	1	49	0	8.5		8.5		3	2	1962
2146	RCSS	900	RCTB	G1	RC T-Beam	N	1	46.88	21.14	2.33	*	7.33		8	4	1962
2147	RCSS	900	RCTB	G2	RC T-Beam	N	1	46.88	21.14	7.33		7.33		8	4	1962
2148	RCSS	900	RCTB	G3	RC T-Beam	N	1	46.88	21.14	7.33		7.33		8	4	1962
2149	RCSS	900	RCTB	G4	RC T-Beam	N	1	46.88	21.14	7.33		7.33		8	4	1962
2150	RCSS	901	RCTB	G1	RC T-Beam	N	1	56.17	12.5	3.64	*	8.1		4	2	1963
2151	RCSS	901	RCTB	G2	RC T-Beam	N	1	56.17	12.5	8.1		8.1		4	2	1963
2152	RCSS	902	RCTB	G1	RC T-Beam	N	1	46.5	-25	2.25	*	8.25		7	3	1963
2153	RCSS	902	RCTB	G2	RC T-Beam	N	1	46.5	-25	8.25		8.25		7	3	1963
2154	RCSS	902	RCTB	G3	RC T-Beam	N	1	46.5	-25	8.25		8.25		7	3	1963
2155	RCSS	903	RCTB	G1	RC T-Beam	N	1	59.83	0	2.67	*	6.67		4	2	1964
2156	RCSS	903	RCTB	G2	RC T-Beam	N	1	59.83	0	6.67		6.58		4	2	1964
2157	RCSS	904	RCTB	G1	RC T-Beam	N	1	41.17	0	2.63	*	9		3	2	1965
2158	RCSS	904	RCTB	G2	RC T-Beam	N	1	41.17	0	9		9		3	2	1965
2159	RCSS	905	RCTB	G1	RC T-Beam	N	1	46.48	20	2.71	*	3.92		6	2	1968
2160	RCSS	905	RCTB	G3	RC T-Beam	N	1	46.48	20	6.5		6.5		6	2	1968
2161	RCSS	906	RCTB	G1	RC T-Beam	N	1	42	0	2	*	8		4	2	1973
2162	RCSS	906	RCTB	G2	RC T-Beam	N	1	42	0	8		8		4	2	1973

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2163	RCSS	907	RCTB	G1	RC T-Beam	N	1	56.35	0	2.63	*	9		3	2	1958
2164	RCSS	907	RCTB	G2	RC T-Beam	N	1	56.35	0	9		9		3	2	1958
2165	RCSS	908	RCTB	G1	RC T-Beam	N	1	51.83	22	3.58	*	8.13		4	2	1958
2166	RCSS	908	RCTB	G2	RC T-Beam	N	1	51.83	22	8.13		8.17		4	2	1958
2167	RCSS	909	RCTB	G1	RC T-Beam	N	1	47	15	1.42	*	6.5		5	2	1959
2168	RCSS	909	RCTB	G2	RC T-Beam	N	1	47	15	6.5		6.5		5	2	1959
2169	RCSS	909	RCTB	G3	RC T-Beam	N	1	47	15	6.5		6.5		5	2	1959
2170	RCSS	910	RCTB	G1	RC T-Beam	N	1	51.83	0	2.63	*	9		3	2	1959
2171	RCSS	910	RCTB	G2	RC T-Beam	N	1	51.83	0	9		9		3	2	1959
2172	RCSS	911	RCTB	G1	RC T-Beam	N	1	56.38	0	2.63	*	9		3	2	1959
2173	RCSS	911	RCTB	G2	RC T-Beam	N	1	56.38	0	9		9		3	2	1959
2174	RCSS	912	RCTB	G1	RC T-Beam	N	1	61.17	0	2.63	*	9		3	2	1959
2175	RCSS	912	RCTB	G2	RC T-Beam	N	1	61.17	0	9		9		3	2	1959
2176	RCSS	913	RCTB	G1	RC T-Beam	N	1	46.17	0	3.42	*	8.25		4	2	1959
2177	RCSS	913	RCTB	G2	RC T-Beam	N	1	46.17	0	8.25		8.25		4	2	1959
2178	RCSS	914	RCTB	G1	RC T-Beam	N	1	55.95	15	2.63	*	9		3	2	1959
2179	RCSS	914	RCTB	G2	RC T-Beam	N	1	55.95	15	9		9		3	2	1959
2180	RCSS	915	RCTB	G1	RC T-Beam	N	1	56.17	0	3.67	*	8.75		4	2	1960
2181	RCSS	915	RCTB	G2	RC T-Beam	N	1	56.17	0	8.75		8.75		4	2	1960
2182	RCSS	916	RCTB	G1	RC T-Beam	N	1	46.25	0	3.13	*	9.33		5	3	1961
2183	RCSS	916	RCTB	G2	RC T-Beam	N	1	46.25	0	9.33		9.33		5	3	1961
2184	RCSS	917	RCSL	Span_1	RC Slab	Y	1	25	0	336		336		5	3	1919
2185	RCSS	918	RCSL	G1-Original_Portion	RC Slab	Y	1	22	0	12		12		5	3	1920
2186	RCSS	919	RCSL	G1	RC Slab	Y	1	24.46	0	12		12		5	3	1920
2187	RCSS	920	RCSL	G1	RC Slab	Y	1	25	0	12		12		5	3	1920
2188	RCSS	921	RCSL	G1-Original_Portion	RC Slab	Y	1	21	0	12		12		5	3	1921
2189	RCSS	922	RCSL	Reinforced_Concrete_Slab	RC Slab	Y	1	23	0	12		12		5	3	1922

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2190	RCSS	923	RCSL	Typical_Slab_Member	RC Slab	Y	1	22.85	0	12		12			3	1923
2191	RCSS	924	RCSL	12__Slab_Strip	RC Slab	Y	1	29.42	0	12		12			3	1924
2192	RCSS	925	RCSL	Slab_1	RC Slab	Y	1	21.16	0	270		270			3	1924
2193	RCSS	926	RCSL	Slab_1	RC Slab	Y	1	25.25	0	316.38		316.38			3	1925
2194	RCSS	927	RCSL	Slab	RC Slab	Y	1	25.58	0	399		399			3	1927
2195	RCSS	928	RCSL	Reinforced_Concrete_Slab	RC Slab	Y	1	25.5	0	12		12			3	1927
2196	RCSS	929	RCSL	Slab_1	RC Slab	Y	1	25.42	0	276		276			3	1929
2197	RCSS	930	RCSL	Slab_1	RC Slab	Y	1	20.59	0	276		276			3	1930
2198	RCSS	931	RCSL	Span_1	RC Slab	Y	1	25.55	0	12		12			3	1930
2199	RCSS	932	RCSL	Concrete_Section_G1	RC Slab	Y	1	20	0	12		12			3	1930
2200	RCSS	933	RCSL	Slab_1	RC Slab	Y	1	21	0	300		300			3	1932
2201	RCSS	934	RCSL	12__RC_Slab	RC Slab	Y	1	25.58	0	12		12			3	1933
2202	RCSS	935	RCSL	Typical_Slab_Member	RC Slab	Y	1	25.55	0	12		12			3	1934
2203	RCSS	936	RCSL	Reinforced_Concrete_Slab	RC Slab	Y	1	25.29	0	12		12			3	1935
2204	RCSS	937	RCSL	typical_12__section	RC Slab	Y	1	23.5	0	12		12			3	1935
2205	RCSS	938	RCSL	Alternative__1	RC Slab	Y	1	23.5	0	12		12			3	1936
2206	RCSS	939	RCSL	Typical_Slab_Member	RC Slab	Y	1	26	0	12		12			3	1937
2207	RCSS	940	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	26.5	0	12		12			3	1938
2208	RCSS	941	RCSL	Slab_1	RC Slab	Y	1	21.5	0	324		324			3	1938
2209	RCSS	942	RCSL	RC_Slab	RC Slab	Y	1	25.5	0	12		12			3	1938
2210	RCSS	943	RCSL	G1	RC Slab	Y	1	26.5	0	12		12			3	1938
2211	RCSS	944	RCSL	Typ__1-ft_slab_section	RC Slab	Y	1	25.5	0	12		12			3	1939
2212	RCSS	945	RCSL	1-ft_Typ__Slab	RC Slab	Y	1	26.1	0	12		12			3	1939
2213	RCSS	946	RCSL	typical_slab_member	RC Slab	Y	1	23.67	0	12		12			3	1939
2214	RCSS	947	RCSL	Typical_Slab_Section	RC Slab	Y	1	26	0	12		12			3	1939

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2215	RCSS	948	RCSL	G1	RC Slab	Y	1	30	0	34		34			3	1940
2216	RCSS	949	RCSL	typical_12__section	RC Slab	Y	1	26	0	12		12			3	1940
2217	RCSS	950	RCSL	Typical_Slab_Member	RC Slab	Y	1	26.25	0	12		12			3	1940
2218	RCSS	951	RCSL	G1	RC Slab	Y	1	21.3	0	12		12			3	1943
2219	RCSS	952	RCSL	Slab_1	RC Slab	Y	1	22	0	381		381			3	1947
2220	RCSS	953	RCSL	Typical_Slab_Member	RC Slab	Y	1	27.54	0	12		12			3	1949
2221	RCSS	954	RCSL	G1	RC Slab	Y	1	28.2	0	12		12			3	1949
2222	RCSS	955	RCSL	typical_12__section	RC Slab	Y	1	25.5	0	12		12			3	1949
2223	RCSS	956	RCSL	Typical_Slab_Member	RC Slab	Y	1	21.5	0	12		12			3	1949
2224	RCSS	957	RCSL	Concrete_Slab_G1	RC Slab	Y	1	29	0	352		352			3	1949
2225	RCSS	958	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	23.38	0	12		12			3	1950
2226	RCSS	959	RCSL	Member_1	RC Slab	Y	1	26.5	0	36		36			3	1952
2227	RCSS	960	RCSL	12__Int_Slab_Strip_(Widening)-x	RC Slab	Y	1	28.53	0	12		12			3	1953
2228	RCSS	961	RCSL	Concrete_Slab_Member	RC Slab	Y	1	25	0	12		12			3	1953
2229	RCSS	962	RCSL	12__RC_Slab_Section	RC Slab	Y	1	30	0	12		12			3	1954
2230	RCSS	963	RCSL	RC_Slab	RC Slab	Y	1	28.75	0	12		12			3	1954
2231	RCSS	964	RCSL	12__Slab_Strip	RC Slab	Y	1	21.5	0	12		12			3	1956
2232	RCSS	965	RCSL	12__Concrete_Section	RC Slab	Y	1	27	0	12		12			3	1957
2233	RCSS	966	RCSL	Concrete_Section_G1	RC Slab	Y	1	22	0	12		12			3	1958
2234	RCSS	967	RCSL	12__Int__Slab_Strip	RC Slab	Y	1	26.75	0	12		12			3	1959
2235	RCSS	968	RCSL	12__Int_Slab_Strip_(M)	RC Slab	Y	1	25.17	0	12		12			3	1959
2236	RCSS	969	RCSL	Concrete_Slab_Section_G1	RC Slab	Y	1	26.5	0	12		12			3	1959
2237	RCSS	970	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	29.28	0	12		12			3	1960
2238	RCSS	971	RCSL	12__Int__Slab_Strip	RC Slab	Y	1	26.75	0	12		12			3	1959

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2239	RCSS	972	RCSL	Typical_Slab_Section	RC Slab	Y	1	27.5	0	12		12			3	1963
2240	RCSS	973	RCSL	12__RC_Slab_Sectio n	RC Slab	Y	1	23.33	0	12		12			3	1965
2241	RCSS	974	RCSL	12__Int__Slab_Strip	RC Slab	Y	1	25	0	12		12			3	1965
2242	RCSS	975	RCSL	12__Int__Strip	RC Slab	Y	1	27.09	0	12		12			3	1966
2243	RCSS	976	RCSL	12__Int__Strip	RC Slab	Y	1	27.09	0	12		12			3	1966
2244	RCSS	977	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	20.75	0	12		12			3	1967
2245	RCSS	978	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	20.75	0	12		12			3	1967
2246	RCSS	979	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	21.88	0	12		12			3	1967
2247	RCSS	980	RCSL	25"_RC__SLAB_SP AN	RC Slab	Y	1	24	0	12		12			3	1967
2248	RCSS	981	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	23.54	0	12		12			3	1968
2249	RCSS	982	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	23.54	0	12		12			3	1968
2250	RCSS	983	RCSL	S01	RC Slab	Y	1	27.55	0	12		12			3	1974
2251	RCSS	984	RCSL	S01	RC Slab	Y	1	20.78	0	12		12			3	1974
2252	RCSS	985	RCSL	G1	RC Slab	Y	1	21.7	0	12		12			3	1977
2253	RCSS	986	RCSL	Exterior_Reinforced_ Concrete_Slab	RC Slab	Y	1	21.83	0	48		48			3	1985
2254	RCSS	987	RCSL	Precast_reinforced_c oncrete_slab_(l...	RC Slab	Y	1	24	0	12		12			3	1986
2255	RCSS	988	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	25	0	12		12			3	1987
2256	RCSS	989	RCSL	beam_1	RC Slab	Y	1	28.5	0	72		72			3	1990
2257	RCSS	990	RCSL	12__Int_Slab_Strip	RC Slab	Y	1	22.75	0	12		12			3	1995
2258	RCSS	991	RCSL	Slab_Line_-_Interior	RC Slab	Y	1	21.88	0	82		82			3	1998
2259	RCSS	992	RCSL	Slab	RC Slab	Y	1	24.67	0	12.01		12.01			3	1999
2260	RCSS	993	RCSL	Slab	RC Slab	Y	1	25.98	0	12.01		12.01			3	1999
2261	RCSS	994	RCSL	Slab	RC Slab	Y	1	21	0	12.01		12.01			3	1999
2262	RCSS	995	RCSL	12__Int__Slab_Strip	RC Slab	Y	1	27.01	0	12		12			3	2005
2263	RCSS	996	RCSL	G1	RC Slab	Y	1	25.17	0	72		72			3	2008
2264	RCSS	997	RCSL	Typical_4_ft_section	RC Slab	Y	1	37.83	0	48		48			3	1928

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2265	RCSS	998	RCSL	Slab_2	RC Slab	Y	1	31	0	324		324			3	1932
2266	RCSS	999	RCSL	Slab_Member	RC Slab	Y	1	41.58	0	12		12			3	1946
2267	RCSS	1000	RCSL	typical_slab_member	RC Slab	Y	1	41.5	0	12		12			3	1947
2268	RCSS	1001	RCSL	Reinforced_Concrete_Slab	RC Slab	Y	1	36.5	0	12		12			3	1950
2269	RCSS	1002	RCSL	12__Int__Slab_Strip	RC Slab	Y	1	33.6	0	12		12			3	1955
2270	RCSS	1003	RCSL	Reinforced_Concrete_Slab	RC Slab	Y	1	31.5	0	12		12			3	1957
2271	RCSS	1004	RCSL	12__Int__Slab_Strip	RC Slab	Y	1	31.04	0	12		12			3	1963
2272	RCSS	1005	RCSL	S01	RC Slab	Y	1	35.5	0	12		12			3	1973
2273	RCSS	1006	RCSL	12__Int__Strip	RC Slab	Y	1	32.28	0	12		12			3	1974
2274	RCSS	1007	RCSL	S01	RC Slab	Y	1	32	0	12		12			3	1977
2275	RCSS	1008	RCSL	S01	RC Slab	Y	1	32	0	12		12			3	1985
2276	RCSS	1009	RCSL	S01	RC Slab	Y	1	36.77	0	12		12			3	1985
2277	RCSS	1010	RCSL	One_Foot_Width	RC Slab	Y	1	36.9	0	12		12			3	1988
2278	RCSS	1011	RCSL	Slab	RC Slab	Y	1	38.53	0	896		896			3	1998
2279	RCSS	1012	RCSL	Slab_Line_-_Fascia	RC Slab	Y	1	32.75	0	62.44		62.44			3	1998
2280	RCSS	1013	RCSL	Slab_Line	RC Slab	Y	1	37.63	0	55.59		55.59			3	2001
2281	RCSS	1014	RCSL	Slab_Line_-_Interior	RC Slab	Y	1	42.59	0	51		51			3	2001
2282	RCSS	1015	RCSL	Slab_Line	RC Slab	Y	1	37.63	0	55.59		55.59			3	2003
2283	STMS	1016	MGRB	Fascia_Girder	Steel Rolled Beam	Y	2	54.35|54.35	-15	2.03	*	7.09		7	3	1931
2284	STMS	1016	MGRB	Interior_Girder	Steel Rolled Beam	Y	2	54.35|54.35	-15	7.09		7.09		7	3	1931
2285	STMS	1017	MGRB	G1	Steel Rolled Beam	N	2	22.00|22.00	0	1.55	*	5.42		5	2	1940
2286	STMS	1017	MGRB	G2	Steel Rolled Beam	N	2	22.00|22.00	0	5.42		5.42		5	2	1940
2287	STMS	1018	MGRB	G1	Steel Rolled Beam	Y	2	69.60|69.60	-30	3	*	6		5	2	1940
2288	STMS	1018	MGRB	G2	Steel Rolled Beam	Y	2	69.60|69.60	-30	6		6		5	2	1940
2289	STMS	1019	MGRB	G1	Steel Rolled Beam	N	2	30.00|30.00	0	0.38	*	3.75		4	1	1948
2290	STMS	1019	MGRB	G2	Steel Rolled Beam	N	2	30.00|30.00	0	3.75		3.75		4	1	1948

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2291	STMS	1020	MGRB	3_-_2nd_E_Int-x	Steel Rolled Beam	N	2	64.17|64.17	-45	6		6		6	2	1952
2292	STMS	1021	MGRB	4_-_2nd_S_Int-x	Steel Rolled Beam	N	2	46.58|46.58	35	6.33		6.33		6	2	1955
2293	STMS	1022	MGRB	12_-_W_Fascia	Steel Rolled Beam	N	2	69.15|69.15	-32.61	1.08	*	6.08		12	4	1957
2294	STMS	1022	MGRB	3_-_2nd_E_Int-x	Steel Rolled Beam	N	2	69.15|69.15	-32.61	6.08		6.08		12	4	1957
2295	STMS	1023	MGRB	G1	Steel Rolled Beam	N	2	75.00|75.00	0	2.29	*	6		4	2	1958
2296	STMS	1023	MGRB	G2	Steel Rolled Beam	N	2	75.00|75.00	0	6		6		4	2	1958
2297	STMS	1024	MGRB	Member_1	Steel Rolled Beam	Y	2	81.21|79.21	45	3	*	6		5	2	1960
2298	STMS	1025	MGRB	12_-_2nd_N_Int	Steel Rolled Beam	Y	2	82.88|82.88	0	6.47		6.47		14	5	1965
2299	STMS	1026	MGRB	G1	Steel Rolled Beam	Y	2	49.75|81.77	18.57	2.16	*	6.22		6	2	1965
2300	STMS	1026	MGRB	G2	Steel Rolled Beam	Y	2	49.75|81.77	18.57	6.22		6.22		6	2	1965
2301	STMS	1027	MGRB	5_-_2nd_E_Int	Steel Rolled Beam	N	2	33.33|33.33	0	6.75		6.75		7	3	1967
2302	STMS	1028	MGRB	G3	Steel Rolled Beam	Y	2	45.52|82.24	-44	6		6		6	2	1968
2303	STMS	1028	MGRB	G6	Steel Rolled Beam	Y	2	45.52|82.24	-44	6		2.46	*	6	2	1968
2304	STMS	1029	MGRB	3_-_2nd_W_Int	Steel Rolled Beam	Y	2	51.00|51.00	0	7.54		7.54		14	6	1975
2305	STMS	1030	MGRB	Member_1	Steel Rolled Beam	Y	2	66.13|66.13	-16	2.25	*	8.83		4	2	1954
2306	STMS	1030	MGRB	Member_2	Steel Rolled Beam	Y	2	66.13|66.13	-16	8.83		8.83		4	2	1954
2307	STMS	1030	MGRB	Member_4	Steel Rolled Beam	Y	2	66.13|66.13	-16	8.83		2.25	*	4	2	1954
2308	STMS	1031	MGRB	Member_1	Steel Rolled Beam	Y	2	76.00|76.00	-46.89	3.67	*	9.67		5	3	1981
2309	STMS	1031	MGRB	Member_2	Steel Rolled Beam	Y	2	76.00|76.00	-46.89	9.67		9.67		5	3	1981
2310	STMS	1032	MGRB	3_-_Center	Steel Rolled Beam	N	2	51.42|51.35	-4.83	6.53		6.53		5	2	1982
2311	STMS	1032	MGRB	4_-_W_Int	Steel Rolled Beam	N	2	51.42|51.35	-4.83	6.53		6.53		5	2	1982
2312	STMS	1033	MGRB	G1	Steel Rolled Beam	Y	2	25.42|25.42	0	2.88	*	3		8	2	1988
2313	STMS	1033	MGRB	G2	Steel Rolled Beam	Y	2	25.42|25.42	0	3		3		8	2	1988
2314	STMS	1034	MGRB	G1	Steel Rolled Beam	Y	2	65.62|65.62	0	2.48	*	6.23		7	3	2003
2315	STMS	1034	MGRB	G2	Steel Rolled Beam	Y	2	65.62|65.62	0	6.23		6.23		7	3	2003
2316	STMS	1034	MGRB	G3	Steel Rolled Beam	Y	2	65.62|65.62	0	6.23		6.23		7	3	2003
2317	STMS	1035	MGRB	3_-_2nd_N_Int_-x	Steel Rolled Beam	Y	2	62.83|62.83	50	5.83		5.83		6	2	2007
2318	STMS	1036	MGSP	9_-_2nd_N_Int_	Steel Plate	N	2	81.00|81.00	28	7.21		7.21		6	3	1975

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2319	STMS	1037	MGSP	G1	Steel Plate	Y	2	82.83|82.83	-29.42	3	*	8.5		9	5	1979
2320	STMS	1037	MGSP	G2	Steel Plate	Y	2	82.83|82.83	-29.42	8.5		8.5		9	5	1979
2321	STMS	1037	MGSP	G9	Steel Plate	Y	2	82.83|82.83	-29.42	8.5		3	*	9	5	1979
2322	STMS	1038	MGSP	3_-_2nd_N_Int-x	Steel Plate	Y	2	82.00|82.00	0	7.29		7.29		8	3	1991
2323	STMS	1038	MGSP	8_-_7th_N_Int-x	Steel Plate	Y	2	82.00|82.00	0	7.29		1.46	*	8	3	1991
2324	STMS	1039	MGSP	G1	Steel Plate	Y	2	82.59|83.38	8.7	2.83	*	7.5		4	2	1992
2325	STMS	1039	MGSP	G2	Steel Plate	Y	2	82.59|83.38	8.7	7.5		7.5		4	2	1992
2326	STMS	1039	MGSP	G3	Steel Plate	Y	2	82.59|83.38	8.7	7.5		7.5		4	2	1992
2327	STMS	1039	MGSP	G4	Steel Plate	Y	2	82.59|83.38	8.7	7.5		3	*	4	2	1992
2328	STMS	1040	MGSP	G1	Steel Plate	Y	2	69.00|69.00	-30	2.13	*	7.75		5	2	1998
2329	STMS	1040	MGSP	G2	Steel Plate	Y	2	69.00|69.00	-30	7.75		7.75		5	2	1998
2330	STMS	1041	MGSP	Member_1	Steel Plate	Y	2	148.80|108.80	33	2.5	*	7		5	2	1953
2331	STMS	1041	MGSP	Member_2	Steel Plate	Y	2	148.80|108.80	33	7		7		5	2	1953
2332	STMS	1042	MGSP	Fascia_Girder	Steel Plate	Y	2	109.50|51.31	-42.03	2.17	*	6.5		8	3	1964
2333	STMS	1042	MGSP	Interior_Girder	Steel Plate	Y	2	109.50|51.31	-42.03	6.5		6.5		8	3	1964
2334	STMS	1043	MGSP	3-2nd_W_Int	Steel Plate	Y	2	118.67|136.58	-45.23	6.5		6.5		10	3	1965
2335	STMS	1044	MGSP	3_-_2nd_N_Int-x	Steel Plate	Y	2	121.25|121.25	18.46	8		8		12	6	1968
2336	STMS	1045	MGSP	G1	Steel Plate	Y	2	107.00|107.00	-8.93	4.08	*	9.25		7	4	1969
2337	STMS	1045	MGSP	G2	Steel Plate	Y	2	107.00|107.00	-8.93	9.25		9.25		7	4	1969
2338	STMS	1045	MGSP	G7	Steel Plate	Y	2	107.00|107.00	-8.93	9.25		4.09	*	7	4	1969
2339	STMS	1046	MGSP	G1	Steel Plate	Y	2	129.00|114.00	-17.5	3	*	10		9	6	1981
2340	STMS	1046	MGSP	G2	Steel Plate	Y	2	129.00|114.00	-17.5	10		10		9	6	1981
2341	STMS	1046	MGSP	G5	Steel Plate	Y	2	129.00|114.00	-17.5	10		10		9	6	1981
2342	STMS	1047	MGSP	Typical_Interior_Beam	Steel Plate	Y	2	152.83|152.83	-60	8.17		8.17		10	5	1972
2343	STMS	1048	MGSP	Fascia_Girder_G1	Steel Plate	Y	2	149.00|166.00	-58.58	3	*	7.33		4	2	1972
2344	STMS	1048	MGSP	Interior_Girder_G2	Steel Plate	Y	2	149.00|166.00	-58.58	7.33		7.33		4	2	1972
2345	STMS	1049	MGSP	Fascia_Girder	Steel Plate	Y	2	58.09|146.83	-54.48	2.06	*	10		10	7	1975
2346	STMS	1049	MGSP	Interior_Girder	Steel Plate	Y	2	58.09|146.83	-54.48	10		10		10	7	1975

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2347	STMS	1050	MGSP	G1	Steel Plate	Y	2	110.00|120.01	15	3.38	*	9		5	3	1975
2348	STMS	1050	MGSP	G2	Steel Plate	Y	2	110.00|120.01	15	9		9		5	3	1975
2349	STMS	1051	MGSP	G1	Steel Plate	Y	2	106.79|106.79	18.09	2.92	*	8		11	6	1977
2350	STMS	1051	MGSP	G2	Steel Plate	Y	2	106.79|106.79	18.09	8		8		11	6	1977
2351	STMS	1051	MGSP	G4	Steel Plate	Y	2	106.79|106.79	18.09	8		8		11	6	1977
2352	STMS	1052	MGSP	G1	Steel Plate	Y	2	114.00|114.00	0	3.46	*	8.08		6	3	1977
2353	STMS	1052	MGSP	G2	Steel Plate	Y	2	114.00|114.00	0	8.08		8.08		6	3	1977
2354	STMS	1053	MGSP	Member_1	Steel Plate	Y	2	102.00|132.00	8	2.4	*	10.2		7	5	1982
2355	STMS	1053	MGSP	Member_2	Steel Plate	Y	2	102.00|132.00	8	10.2		10.2		7	5	1982
2356	STMS	1054	MGSP	G1	Steel Plate	Y	2	91.19|91.32	12.5	3.63	*	8.75		10	6	1978
2357	STMS	1054	MGSP	G2	Steel Plate	Y	2	91.19|91.32	12.5	8.75		8.75		10	6	1978
2358	STMS	1054	MGSP	G4	Steel Plate	Y	2	91.19|91.32	12.5	8.75		8.75		10	6	1978
2359	STMS	1055	MGSP	G1	Steel Plate	Y	2	113.00|108.00	1.67	3.33	*	8.67		8	5	1979
2360	STMS	1055	MGSP	G2	Steel Plate	Y	2	113.00|108.00	1.67	8.67		8.67		8	5	1979
2361	STMS	1056	MGSP	Fascia_Girder_G1	Steel Plate	Y	2	189.00|189.00	9.66	3.05	*	9.75		7	4	1979
2362	STMS	1056	MGSP	Interior_Girder_G2	Steel Plate	Y	2	189.00|189.00	9.66	9.75		9.75		7	4	1979
2363	STMS	1057	MGSP	G1	Steel Plate	Y	2	104.00|104.00	0	2.92	*	9.5		5	3	1981
2364	STMS	1057	MGSP	G2	Steel Plate	Y	2	104.00|104.00	0	9.5		9.5		5	3	1981
2365	STMS	1058	MGSP	G1	Steel Plate	Y	2	102.17|102.17	4.25	2.92	*	8.5		9	5	1981
2366	STMS	1058	MGSP	G2	Steel Plate	Y	2	102.17|102.17	4.25	8.5		8.5		9	5	1981
2367	STMS	1058	MGSP	G4	Steel Plate	Y	2	102.17|102.17	4.25	8.5		8.5		9	5	1981
2368	STMS	1059	MGSP	G1	Steel Plate	Y	2	116.98|116.98	-2.61	3.42	*	9.25		5	3	1981
2369	STMS	1059	MGSP	G2	Steel Plate	Y	2	116.98|116.98	-2.61	9.25		9.25		5	3	1981
2370	STMS	1060	MGSP	G1	Steel Plate	Y	2	116.98|116.98	-1.11	3.42	*	9.25		5	3	1981
2371	STMS	1060	MGSP	G2	Steel Plate	Y	2	116.98|116.98	-1.11	9.25		9.25		5	3	1981
2372	STMS	1061	MGSP	G1	Steel Plate	Y	2	126.25|126.25	3.15	2.92	*	8		7	4	1983
2373	STMS	1061	MGSP	G2	Steel Plate	Y	2	126.25|126.25	3.15	8		8		7	4	1983
2374	STMS	1062	MGSP	G1	Steel Plate	Y	2	118.50|118.50	30	2.92	*	8.5		9	5	1986

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2375	STMS	1062	MGSP	G2	Steel Plate	Y	2	118.50|118.50	30	8.5		8.5		9	5	1986
2376	STMS	1062	MGSP	G4	Steel Plate	Y	2	118.50|118.50	30	8.5		8.5		9	5	1986
2377	STMS	1063	MGSP	G1	Steel Plate	Y	2	98.00|98.00	0	2.92	*	8.5		9	5	1987
2378	STMS	1063	MGSP	G2	Steel Plate	Y	2	98.00|98.00	0	8.5		8.5		9	5	1987
2379	STMS	1064	MGSP	G1	Steel Plate	Y	2	99.17|89.17	3.22	2.92	*	8		8	4	1992
2380	STMS	1064	MGSP	G2	Steel Plate	Y	2	99.17|89.17	3.22	8		8		8	4	1992
2381	STMS	1064	MGSP	G8	Steel Plate	Y	2	99.17|89.17	3.22	8		2.92	*	8	4	1992
2382	STMS	1065	MGSP	G1	Steel Plate	Y	2	100.75|108.75	-29.12	2.92	*	8.67		4	2	1992
2383	STMS	1065	MGSP	G2	Steel Plate	Y	2	100.75|108.75	-29.12	8.67		8.67		4	2	1992
2384	STMS	1065	MGSP	G3	Steel Plate	Y	2	100.75|108.75	-29.12	8.67		8.67		4	2	1992
2385	STMS	1065	MGSP	G4	Steel Plate	Y	2	100.75|108.75	-29.12	8.67		2.92	*	4	2	1992
2386	STMS	1066	MGSP	G1	Steel Plate	Y	2	97.83|97.83	29.66	2.92	*	8.67		4	2	1992
2387	STMS	1066	MGSP	G2	Steel Plate	Y	2	97.83|97.83	29.66	8.67		8.67		4	2	1992
2388	STMS	1066	MGSP	G3	Steel Plate	Y	2	97.83|97.83	29.66	8.67		8.67		4	2	1992
2389	STMS	1066	MGSP	G4	Steel Plate	Y	2	97.83|97.83	29.66	8.67		2.92	*	4	2	1992
2390	STMS	1067	MGSP	G1	Steel Plate	Y	2	111.00|140.00	0	3.13	*	7.75		4	2	1994
2391	STMS	1067	MGSP	G2	Steel Plate	Y	2	111.00|140.00	0	7.75		7.75		4	2	1994
2392	STMS	1068	MGSP	Member_1	Steel Plate	Y	2	189.00|134.00	-30	2.29	*	8.5		5	2	1994
2393	STMS	1068	MGSP	Member_2	Steel Plate	Y	2	189.00|134.00	-30	8.5		8.5		5	2	1994
2394	STMS	1069	MGSP	G1	Steel Plate	Y	2	129.05|129.05	31.43	3.38	*	8		6	3	1984
2395	STMS	1069	MGSP	G2	Steel Plate	Y	2	129.05|129.05	31.43	8		8		6	3	1984
2396	STMS	1070	MGSP	Fascia_Girder_G1	Steel Plate	Y	2	111.00|126.00	37.5	3	*	8.5		5	3	1985
2397	STMS	1070	MGSP	Interior_Girder_G2	Steel Plate	Y	2	111.00|126.00	37.5	8.5		8.5		5	3	1985
2398	STMS	1071	MGSP	1_-_W_(Outer)_Fascia	Steel Plate	Y	2	157.81|157.81	-21.71	2.92	*	6.5		7	3	2005
2399	STMS	1071	MGSP	2_-_1st_W_Int	Steel Plate	Y	2	157.81|157.81	-21.71	6.5		6.5		7	3	2005
2400	STMS	1071	MGSP	3_-_2nd_W_Int	Steel Plate	Y	2	157.81|157.81	-21.71	6.5		6.5		7	3	2005
2401	STMS	1072	MGSP	G1	Steel Plate	Y	2	172.50|172.50	0	3	*	7.5		5	2	1987
2402	STMS	1072	MGSP	G2	Steel Plate	Y	2	172.50|172.50	0	7.5		7.5		5	2	1987

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2403	STMS	1072	MGSP	G3	Steel Plate	Y	2	172.50|172.50	0	7.5		7.5		5	2	1987
2404	STMS	1073	MGSP	G1	Steel Plate	Y	2	161.00|141.00	0	2.13	*	7.67		6	3	1991
2405	STMS	1073	MGSP	G2	Steel Plate	Y	2	161.00|141.00	0	7.67		7.67		6	3	1991
2406	STMS	1073	MGSP	G3	Steel Plate	Y	2	161.00|141.00	0	7.67		7.67		6	3	1991
2407	STMS	1074	MGSP	Fascia_Steel_Girder_G1	Steel Plate	Y	2	193.57|193.57	-27.3	3.1	*	7.84		5	2	2006
2408	STMS	1074	MGSP	Interior_Steel_Girder_G2	Steel Plate	Y	2	193.57|193.57	-27.3	7.84		7.84		5	2	2006
2409	STMS	1074	MGSP	Interior_Steel_Girder_G3	Steel Plate	Y	2	193.57|193.57	-27.3	7.84		7.84		5	2	2006
2410	STMS	1075	MGSP	G1	Steel Plate	Y	2	116.00|116.00	-43	2.29	*	7		4	2	1992
2411	STMS	1075	MGSP	G2	Steel Plate	Y	2	116.00|116.00	-43	7		7		4	2	1992
2412	STMS	1076	MGRB	2_-_N_Int	Steel Rolled Beam	Y	3	45.35|41.20|45.35	-14.75	7.25		7.25		5	2	1934
2413	STMS	1077	MGRB	2_-_1st_E_Int-x	Steel Rolled Beam	Y	3	28.83|36.33|28.83	0	7.92		6.67		7	3	1938
2414	STMS	1078	MGRB	G1	Steel Rolled Beam	N	3	50.00|80.00|50.00	0	2.08	*	6.67		4	2	1948
2415	STMS	1078	MGRB	G2	Steel Rolled Beam	N	3	50.00|80.00|50.00	0	6.67		6.67		4	2	1948
2416	STMS	1079	MGRB	G1	Steel Rolled Beam	Y	3	36.00|72.00|36.00	15	1.25	*	7.25		9	4	1946
2417	STMS	1079	MGRB	G2	Steel Rolled Beam	Y	3	36.00|72.00|36.00	15	7.25		7.25		9	4	1946
2418	STMS	1080	MGRB	2_-_1st_S_Int	Steel Rolled Beam	N	3	36.25|46.00|36.25	0	6		6		6	2	1948
2419	STMS	1081	MGRB	2nd_E_Int	Steel Rolled Beam	N	3	65.00|81.50|65.00	-28	5.63		5.63		7	2	1951
2420	STMS	1081	MGRB	W_(Outer)_Fascia	Steel Rolled Beam	N	3	65.00|81.50|65.00	-28	5.63		0.83	*	7	2	1951
2421	STMS	1082	MGRB	G1	Steel Rolled Beam	Y	3	52.00|65.00|52.00	-19.92	1.92	*	8.75		7	4	1956
2422	STMS	1082	MGRB	G2	Steel Rolled Beam	Y	3	52.00|65.00|52.00	-19.92	8.75		8.75		7	4	1956
2423	STMS	1082	MGRB	G3	Steel Rolled Beam	Y	3	52.00|65.00|52.00	-19.92	8.75		8.75		7	4	1956
2424	STMS	1083	MGRB	Member_1	Steel Rolled Beam	Y	3	53.83|54.33|53.83	-45	3	*	6		5	2	1953
2425	STMS	1083	MGRB	Member_2	Steel Rolled Beam	Y	3	53.83|54.33|53.83	-45	6		7		5	2	1953
2426	STMS	1084	MGRB	G1	Steel Rolled Beam	Y	3	79.08|81.98|79.08	-50	1.46	*	5.54		7	2	1954
2427	STMS	1084	MGRB	G2	Steel Rolled Beam	Y	3	79.08|81.98|79.08	-50	5.54		5.54		7	2	1954
2428	STMS	1085	MGRB	A_-	Steel Rolled Beam	N	3	35.75|45.00|35.75	2.35	2.83	*	4.96		7	3	1954

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
				_E_(Outer)_Fascia												
2429	STMS	1085	MGRB	C_-_2nd_E_Int	Steel Rolled Beam	N	3	35.75|45.00|35.75	2.35	6.25		6.25		7	3	1954
2430	STMS	1086	MGRB	G1	Steel Rolled Beam	N	3	60.00|75.00|60.00	15	2.17	*	6		4	2	1954
2431	STMS	1086	MGRB	G2	Steel Rolled Beam	N	3	60.00|75.00|60.00	15	6		6		4	2	1954
2432	STMS	1087	MGRB	G1	Steel Rolled Beam	Y	3	60.00|70.00|60.00	-35	3.33	*	6		4	2	1954
2433	STMS	1087	MGRB	G2	Steel Rolled Beam	Y	3	60.00|70.00|60.00	-35	6		6		4	2	1954
2434	STMS	1087	MGRB	G3	Steel Rolled Beam	Y	3	60.00|70.00|60.00	-35	6		6		4	2	1954
2435	STMS	1087	MGRB	G4	Steel Rolled Beam	Y	3	60.00|70.00|60.00	-35	6		3.33	*	4	2	1954
2436	STMS	1088	MGRB	Member_1	Steel Rolled Beam	Y	3	63.00|63.50|63.00	12	2.5	*	8.25		5	3	1954
2437	STMS	1088	MGRB	Member_2	Steel Rolled Beam	Y	3	63.00|63.50|63.00	12	8.25		8.25		5	3	1954
2438	STMS	1088	MGRB	Member_5	Steel Rolled Beam	Y	3	63.00|63.50|63.00	12	8.25		2.5	*	5	3	1954
2439	STMS	1089	MGRB	G1_Fascia	Steel Rolled Beam	Y	3	44.00|60.00|44.00	15	2.54	*	7.5		8	4	1954
2440	STMS	1089	MGRB	G2_-_Interior	Steel Rolled Beam	Y	3	44.00|60.00|44.00	15	7.5		7.5		8	4	1954
2441	STMS	1090	MGRB	G2	Steel Rolled Beam	Y	3	58.83|68.83|58.83	0	6.58		6.58		6	3	1957
2442	STMS	1091	MGRB	1_-_N_Fascia	Steel Rolled Beam	N	3	57.25|66.92|57.25	0	1.38	*	6.58		6	2	1957
2443	STMS	1091	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	N	3	57.25|66.92|57.25	0	6.58		6.58		6	2	1957
2444	STMS	1092	MGRB	G1	Steel Rolled Beam	N	3	70.00|85.00|70.00	15	2.79	*	6.5		5	2	1958
2445	STMS	1092	MGRB	G2	Steel Rolled Beam	N	3	70.00|85.00|70.00	15	6.5		6.5		5	2	1958
2446	STMS	1093	MGRB	1_-_E_(Median)_Fascia	Steel Rolled Beam	Y	3	40.58|69.17|40.58	2.07	2.83	*	6.83		9	3	1960
2447	STMS	1093	MGRB	2_-_1st_E_Int	Steel Rolled Beam	Y	3	40.58|69.17|40.58	2.07	6.83		6.83		9	3	1960
2448	STMS	1094	MGRB	1W_-_E_(Median)_Fascia	Steel Rolled Beam	N	3	47.25|55.33|47.25	1.88	1.83	*	6.75		7	2	1960
2449	STMS	1094	MGRB	3W_-_2nd_E_Int	Steel Rolled Beam	N	3	47.25|55.33|47.25	1.88	6.75		6.75		7	2	1960
2450	STMS	1095	MGRB	G1_-_N_Fascia	Steel Rolled Beam	Y	3	42.00|67.00|42.00	0	3.13	*	7.5		5	2	1960
2451	STMS	1095	MGRB	G2_-_1st_N_Int_	Steel Rolled Beam	Y	3	42.00|67.00|42.00	0	7.5		7.5		5	2	1960
2452	STMS	1096	MGRB	2nd_N_Int	Steel Rolled Beam	N	3	41.92|53.33|33.92	20.39	5		5		9	3	1961
2453	STMS	1096	MGRB	3rd_S_Int	Steel Rolled Beam	N	3	41.92|53.33|33.92	20.39	6.28		6.28		9	3	1961
2454	STMS	1097	MGRB	7_-_1st_N_Int	Steel Rolled Beam	Y	3	33.08|49.17|33.08	-19	9		9		5	3	1961

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2455	STMS	1098	MGRB	G1	Steel Rolled Beam	N	3	65.00|80.00|65.00	0	2.13	*	6		4	2	1961
2456	STMS	1098	MGRB	G2	Steel Rolled Beam	N	3	65.00|80.00|65.00	0	6		6		4	2	1961
2457	STMS	1099	MGRB	1_-_E_Fascia	Steel Rolled Beam	Y	3	55.25|68.75|55.25	20.22	1.88	*	7.58		10	5	1962
2458	STMS	1099	MGRB	3_-_2nd_E_Int	Steel Rolled Beam	Y	3	55.25|68.75|55.25	20.22	7.58		7.58		10	5	1962
2459	STMS	1100	MGRB	10_-_2nd_N_Int	Steel Rolled Beam	Y	3	50.00|58.50|50.00	20.37	6		6		7	3	1962
2460	STMS	1100	MGRB	8_-_N_Fascia	Steel Rolled Beam	Y	3	50.00|58.50|50.00	20.37	2.79	*	5.34		7	3	1962
2461	STMS	1101	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	N	3	45.17|52.92|45.17	0	5		5		9	3	1964
2462	STMS	1102	MGRB	3_-_2nd_W_Int-x	Steel Rolled Beam	Y	3	60.25|75.50|60.25	-56.5	6.58		6.58		6	3	1964
2463	STMS	1103	MGRB	1_-_W_Fascia	Steel Rolled Beam	Y	3	46.53|80.59|46.60	28.3	2.42	*	6.33		7	3	1965
2464	STMS	1103	MGRB	3_-_2nd_W_Int	Steel Rolled Beam	Y	3	46.53|80.59|46.60	28.3	6.33		6.33		7	3	1965
2465	STMS	1104	MGRB	G1	Steel Rolled Beam	Y	3	47.52|77.58|52.27	-43.8	1.46	*	6.58		10	5	1965
2466	STMS	1104	MGRB	G2	Steel Rolled Beam	Y	3	47.52|77.58|52.27	-43.8	6.58		6.58		10	5	1965
2467	STMS	1105	MGRB	1_-_N_Fascia	Steel Rolled Beam	Y	3	61.00|83.50|61.00	46.64	2.92	*	7.5		7	4	1966
2468	STMS	1105	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	Y	3	61.00|83.50|61.00	46.64	7.5		7.5		7	4	1966
2469	STMS	1106	MGRB	G1	Steel Rolled Beam	Y	3	60.00|80.00|60.00	0	3.38	*	9.33		4	2	1966
2470	STMS	1106	MGRB	G2	Steel Rolled Beam	Y	3	60.00|80.00|60.00	0	9.33		9.33		4	2	1966
2471	STMS	1107	MGRB	3"_-_2nd_S_Int	Steel Rolled Beam	N	3	35.83|42.00|35.83	-26.5	6.33		6.33		7	3	1967
2472	STMS	1108	MGRB	3_-_2nd_E_Int	Steel Rolled Beam	N	3	50.92|67.50|50.92	0	6.33		6.33		7	3	1967
2473	STMS	1109	MGRB	G1	Steel Rolled Beam	N	3	60.00|80.00|60.00	0	2.46	*	7.25		6	3	1967
2474	STMS	1109	MGRB	G2	Steel Rolled Beam	N	3	60.00|80.00|60.00	0	7.25		7.25		6	3	1967
2475	STMS	1110	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	N	3	60.33|75.33|60.33	45.65	6.67		6.67		6	2	1968
2476	STMS	1111	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	N	3	64.25|82.33|64.25	0	7.21		7.21		6	3	1969
2477	STMS	1112	MGRB	G1	Steel Rolled Beam	Y	3	55.00|71.00|55.00	55	3.38	*	8.5		5	3	1971
2478	STMS	1112	MGRB	G2	Steel Rolled Beam	Y	3	55.00|71.00|55.00	55	8.5		8.5		5	3	1971
2479	STMS	1113	MGRB	1_-_W_Fascia	Steel Rolled Beam	N	3	40.08|47.25|40.08	10	2.71	*	7.25		6	3	1972
2480	STMS	1113	MGRB	3_-_2nd_W_Int	Steel Rolled Beam	N	3	40.08|47.25|40.08	10	7.25		7.25		6	3	1972
2481	STMS	1114	MGRB	G1	Steel Rolled Beam	Y	3	50.00|76.00|64.00	-55.33	2.5	*	9.25		5	2	1974
2482	STMS	1114	MGRB	G2	Steel Rolled Beam	Y	3	50.00|76.00|64.00	-55.33	9.25		9.25		5	2	1974

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2483	STMS	1114	MGRB	G3	Steel Rolled Beam	Y	3	50.00|76.00|64.00	-55.33	9.25		9.25		5	2	1974
2484	STMS	1115	MGRB	1_-_N_(Outer)_Fascia	Steel Rolled Beam	Y	3	43.00|83.25|46.75	7.58	1.83	*	6.25		9	4	1973
2485	STMS	1115	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	Y	3	43.00|83.25|46.75	7.58	6.25		6.25		9	4	1973
2486	STMS	1116	MGRB	G1	Steel Rolled Beam	Y	3	59.14|80.11|59.10	0	2.71	*	7.58		11	6	1974
2487	STMS	1116	MGRB	G2	Steel Rolled Beam	Y	3	59.14|80.11|59.10	0	7.58		7.58		11	6	1974
2488	STMS	1117	MGRB	G1	Steel Rolled Beam	N	3	50.00|60.00|50.00	-45	2.71	*	7		6	3	1974
2489	STMS	1117	MGRB	G2	Steel Rolled Beam	N	3	50.00|60.00|50.00	-45	7		7		6	3	1974
2490	STMS	1118	MGRB	G1	Steel Rolled Beam	N	3	45.59|76.01|48.59	5	2.67	*	7.88		7	4	1975
2491	STMS	1118	MGRB	G2	Steel Rolled Beam	N	3	45.59|76.01|48.59	5	7.88		7.88		7	4	1975
2492	STMS	1119	MGRB	7_-_N_(Median)_Fascia	Steel Rolled Beam	N	3	42.00|49.42|42.00	0	2.71	*	7.25		6	3	1976
2493	STMS	1119	MGRB	9_-_2nd_N_Int_	Steel Rolled Beam	N	3	42.00|49.42|42.00	0	7.25		7.25		6	3	1976
2494	STMS	1120	MGRB	1_-_W_Fascia	Steel Rolled Beam	N	3	44.92|52.58|44.92	0	2.71	*	7.25		6	3	1977
2495	STMS	1120	MGRB	3_-_2nd_W_Int	Steel Rolled Beam	N	3	44.92|52.58|44.92	0	7.25		7.25		6	3	1977
2496	STMS	1121	MGRB	Fascia_Girder_G1	Steel Rolled Beam	Y	3	59.00|77.00|59.00	-20	4	*	10		5	3	1978
2497	STMS	1121	MGRB	Interior_Girder_G2	Steel Rolled Beam	Y	3	59.00|77.00|59.00	-20	10		10		5	3	1978
2498	STMS	1122	MGRB	G1	Steel Rolled Beam	Y	3	45.00|65.00|45.00	24.17	2.26	*	7.24		8	5	1983
2499	STMS	1122	MGRB	G2	Steel Rolled Beam	Y	3	45.00|65.00|45.00	24.17	7.24		8.75		8	5	1983
2500	STMS	1122	MGRB	G3	Steel Rolled Beam	Y	3	45.00|65.00|45.00	24.17	8.75		8.75		8	5	1983
2501	STMS	1123	MGRB	G1	Steel Rolled Beam	Y	3	53.00|62.00|53.00	0	3.08	*	7.25		5	2	1984
2502	STMS	1123	MGRB	G2	Steel Rolled Beam	Y	3	53.00|62.00|53.00	0	7.25		7.25		5	2	1984
2503	STMS	1124	MGRB	7_-_W_(Median)_Fascia	Steel Rolled Beam	Y	3	42.07|54.17|41.97	9.55	2.88	*	7.42		6	3	1986
2504	STMS	1124	MGRB	9_-_2nd_W_Int	Steel Rolled Beam	Y	3	42.07|54.17|41.97	9.55	7.42		7.42		6	3	1986
2505	STMS	1125	MGRB	3_-_2nd_W_Int	Steel Rolled Beam	Y	3	41.33|50.00|41.33	0	7.5		7.5		6	3	1988
2506	STMS	1126	MGRB	G1	Steel Rolled Beam	Y	3	40.00|49.00|40.00	-30	3.29	*	7.5		5	2	1990
2507	STMS	1126	MGRB	G2	Steel Rolled Beam	Y	3	40.00|49.00|40.00	-30	7.5		7.5		5	2	1990
2508	STMS	1127	MGRB	1_-_E_Fascia	Steel Rolled Beam	Y	3	58.01|84.00|58.01	-26.97	2.67	*	7.5		6	3	1993
2509	STMS	1127	MGRB	3_-_2nd_E_Int	Steel Rolled Beam	Y	3	58.01|84.00|58.01	-26.97	7.5		7.5		6	3	1993

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2510	STMS	1128	MGRB	G1	Steel Rolled Beam	Y	3	59.33|74.33|59.33	0	3.83	*	10.33		4	3	1995
2511	STMS	1128	MGRB	G2	Steel Rolled Beam	Y	3	59.33|74.33|59.33	0	10.33		10.33		4	3	1995
2512	STMS	1129	MGRB	G1	Steel Rolled Beam	Y	3	75.09|82.00|75.09	29	2.75	*	5.67		5	2	2005
2513	STMS	1129	MGRB	G2	Steel Rolled Beam	Y	3	75.09|82.00|75.09	29	5.67		5.67		5	2	2005
2514	STMS	1129	MGRB	G3	Steel Rolled Beam	Y	3	75.09|82.00|75.09	29	5.67		5.67		5	2	2005
2515	STMS	1130	MGRB	1_-_E_Fascia	Steel Rolled Beam	Y	3	42.00|76.83|42.00	22.42	2.63	*	5.92		6	2	2006
2516	STMS	1130	MGRB	3_-_2nd_E_Int	Steel Rolled Beam	Y	3	42.00|76.83|42.00	22.42	5.92		5.92		6	2	2006
2517	STMS	1131	MGSP	G2_-_1st_E_Int_	Steel Plate	N	3	140.58|179.83|140.58	0	7.71		7.71		10	4	1956
2518	STMS	1131	MGSP	G3_-_2nd_E_Int_	Steel Plate	N	3	140.58|179.83|140.58	0	7.71		7.71		10	4	1956
2519	STMS	1132	MGSP	26A_-_1st_W_Int-x	Steel Plate	Y	3	81.25|120.38|81.25	51.46	6.21		6.18		12	5	1958
2520	STMS	1132	MGSP	26B_-_W_(Outer)_Fascia	Steel Plate	Y	3	81.25|120.38|81.25	51.46	2.83	*	6.21		12	5	1958
2521	STMS	1133	MGSP	G1	Steel Plate	N	3	90.00|180.00|90.00	-45	1.5	*	8.5		5	2	1958
2522	STMS	1133	MGSP	G2	Steel Plate	Y	3	90.00|180.00|90.00	-45	8.5		7.5		5	2	1958
2523	STMS	1133	MGSP	G3	Steel Plate	Y	3	90.00|180.00|90.00	-45	7.5		7.5		5	2	1958
2524	STMS	1134	MGSP	1_-_N_(Outer)_Fascia	Steel Plate	Y	3	82.47|146.78|82.47	-42.8	2.69	*	8.14		7	4	1959
2525	STMS	1134	MGSP	3_-_2nd_N_Int_	Steel Plate	Y	3	82.47|146.78|82.47	-42.8	8.14		8.14		7	4	1959
2526	STMS	1135	MGSP	G1	Steel Plate	N	3	125.00|150.00|125.00	30	2.29	*	8		4	2	1960
2527	STMS	1135	MGSP	G2	Steel Plate	N	3	125.00|150.00|125.00	30	8		8		4	2	1960
2528	STMS	1136	MGSP	G1	Steel Plate	Y	3	103.00|140.00|103.00	30	2.13	*	7.75		11	6	1960
2529	STMS	1136	MGSP	G2	Steel Plate	Y	3	103.00|140.00|103.00	30	7.75		7.75		11	6	1960

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2530	STMS	1137	MGSP	G1	Steel Plate	Y	3	107.00|141.00|107.00	0	2.63	*	9.5		3	2	1961
2531	STMS	1137	MGSP	G2	Steel Plate	Y	3	107.00|141.00|107.00	0	9.5		9.5		3	2	1961
2532	STMS	1138	MGSP	8_-_1st_N_Int	Steel Plate	Y	3	60.17|134.47|86.08	-11.92	7.75		7.75		9	5	1962
2533	STMS	1139	MGSP	3_-_5th_W_Int-x	Steel Plate	Y	3	147.50|220.00|147.50	17	7.17		7.17		8	3	1964
2534	STMS	1139	MGSP	G3_-_W_Fascia	Steel Plate	Y	3	147.50|220.00|147.50	17	2.49	*	6.23		8	3	1964
2535	STMS	1140	MGSP	7_-_7th_S_Int-x	Steel Plate	Y	3	193.44|223.00|156.84	-18.69	8.08		8.08		10	5	1964
2536	STMS	1140	MGSP	GS-1_-_S_(Outer)_Fascia	Steel Plate	Y	3	193.44|223.00|156.84	-18.69	2.95	*	7.58		10	5	1964
2537	STMS	1141	MGSP	5_-_2nd_W_Int	Steel Plate	Y	3	107.08|267.83|112.00	-8.3	8.92		8.92		7	4	1966
2538	STMS	1141	MGSP	7_-_W_(Outer)_Fascia	Steel Plate	Y	3	107.08|267.83|112.00	-8.3	2.25	*	8.92		7	4	1966
2539	STMS	1142	MGSP	G1	Steel Plate	Y	3	136.13|177.65|136.10	-49.33	2.95	*	6.85		7	3	1967
2540	STMS	1142	MGSP	G2	Steel Plate	Y	3	136.13|177.65|136.10	-49.33	6.85		6.85		7	3	1967
2541	STMS	1143	MGSP	G1	Steel Plate	Y	3	111.33|135.00|111.33	0	2	*	7		7	3	1967
2542	STMS	1143	MGSP	G2	Steel Plate	Y	3	111.33|135.00|111.33	0	7		7		7	3	1967
2543	STMS	1144	MGSP	G1	Steel Plate	Y	3	163.91|221.00|163.91	-10.52	3.36	*	9.29		4	2	1969
2544	STMS	1144	MGSP	G2	Steel Plate	Y	3	163.91|221.00|163.91	-10.52	9.29		9.29		4	2	1969

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2545	STMS	1144	MGSP	G4	Steel Plate	Y	3	163.91|221.00|163.91	-10.52	9.29		2.76	*	4	2	1969
2546	STMS	1145	MGSP	10_-_2nd_N_Int	Steel Plate	Y	3	65.50|133.50|56.00	43.66	7.33		7.33		10	5	1970
2547	STMS	1145	MGSP	8_-_N_Fascia_@_Ramp	Steel Plate	Y	3	65.50|133.50|56.00	43.66	2.96	*	4.5		10	5	1970
2548	STMS	1146	MGSP	G1	Steel Plate	Y	3	96.00|125.00|96.00	-15.41	4.21	*	8.75		6	3	1970
2549	STMS	1146	MGSP	G2	Steel Plate	Y	3	96.00|125.00|96.00	-15.41	8.75		8.75		6	3	1970
2550	STMS	1147	MGSP	G1	Steel Plate	Y	3	106.00|138.00|106.00	-45	3.13	*	9		5	3	1972
2551	STMS	1147	MGSP	G2	Steel Plate	Y	3	106.00|138.00|106.00	-45	9		9		5	3	1972
2552	STMS	1148	MGSP	G1	Steel Plate	Y	3	90.00|114.94|90.00	-20	3.38	*	8.5		5	3	1972
2553	STMS	1148	MGSP	G2	Steel Plate	Y	3	90.00|114.94|90.00	-20	8.5		8.5		5	3	1972
2554	STMS	1149	MGSP	G1	Steel Plate	N	3	86.29|142.02|85.95	0	1.5	*	8.04		18	10	1972
2555	STMS	1149	MGSP	G2	Steel Plate	N	3	86.29|142.02|85.95	0	8.04		8.04		18	10	1972
2556	STMS	1150	MGSP	1_-_W_Fascia	Steel Plate	Y	3	95.00|121.00|95.00	-22	2.71	*	7.25		6	3	1974
2557	STMS	1150	MGSP	3_-_2nd_W_Int	Steel Plate	Y	3	95.00|121.00|95.00	-22	7.25		7.25		6	3	1974
2558	STMS	1151	MGSP	G1	Steel Plate	Y	3	80.00|120.00|80.00	0	3.38	*	8		4	2	1976
2559	STMS	1151	MGSP	G2	Steel Plate	Y	3	80.00|120.00|80.00	0	8		8		4	2	1976
2560	STMS	1152	MGSP	G1	Steel Plate	Y	3	87.08|114.00|74.08	0	3.25	*	7.63		11	6	1977
2561	STMS	1152	MGSP	G2	Steel Plate	Y	3	87.08|114.00|74.08	0	7.63		7.63		11	6	1977
2562	STMS	1153	MGSP	G1	Steel Plate	Y	3	140.00|180.00|140.00	0	3.88	*	8.75		5	3	1980
2563	STMS	1153	MGSP	G2	Steel Plate	Y	3	140.00|180.00|140.00	0	8.75		8.75		5	3	1980
2564	STMS	1154	MGSP	G1	Steel Plate	Y	3	78.50|116.50|106.00	57	3.92	*	9		5	3	1987
2565	STMS	1154	MGSP	G2	Steel Plate	Y	3	78.50|116.50|106.00	57	9		9		5	3	1987
2566	STMS	1154	MGSP	G3	Steel Plate	Y	3	78.50|116.50|106.0	57	9		9		5	3	1987

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
								0								
2567	STMS	1155	MGSP	1_-_W_(Outer)_Fascia	Steel Plate	Y	3	122.00|153.31|122.00	-37	3.08	*	8.83		7	4	1987
2568	STMS	1155	MGSP	2_-_1st_W_Int	Steel Plate	Y	3	122.00|153.31|122.00	-37	8.83		8.83		7	4	1987
2569	STMS	1156	MGSP	G1	Steel Plate	Y	3	68.45|98.56|68.34	-45.79	3.92	*	9		5	3	1989
2570	STMS	1156	MGSP	G2	Steel Plate	Y	3	68.45|98.56|68.34	-45.79	9		9		5	3	1989
2571	STMS	1156	MGSP	G3	Steel Plate	Y	3	68.45|98.56|68.34	-45.79	9		9		5	3	1989
2572	STMS	1157	MGSP	1_-_E_Fascia	Steel Plate	Y	3	94.00|120.00|94.00	38	3.5	*	9		4	2	1982
2573	STMS	1157	MGSP	2_-_E_Int	Steel Plate	Y	3	94.00|120.00|94.00	38	9		9		4	2	1982
2574	STMS	1158	MGSP	Fascia_Girder_G1_W__Utilities	Steel Plate	Y	3	104.85|158.45|104.85	0	2.29	*	8		5	2	1993
2575	STMS	1158	MGSP	Interior_Girder_G2_W__Utilities	Steel Plate	Y	3	104.85|158.45|104.85	0	8		8		5	2	1993
2576	STMS	1159	MGSP	G1_-_N_Fascia	Steel Plate	Y	3	29.00|165.17|29.00	0	3.08	*	6.75		5	2	1990
2577	STMS	1159	MGSP	G2_-_1st_N_Int_	Steel Plate	Y	3	29.00|165.17|29.00	0	6.75		6.75		5	2	1990
2578	STMS	1160	MGSP	G1	Steel Plate	Y	3	98.43|180.45|131.23	0	3.26	*	8.86		5	3	1998
2579	STMS	1160	MGSP	G2	Steel Plate	Y	3	98.43|180.45|131.23	0	8.86		8.86		5	3	1998
2580	STMS	1161	MGSP	G1	Steel Plate	Y	3	176.00|203.00|197.00	-30	2.92	*	9.25		7	4	1998
2581	STMS	1161	MGSP	G2	Steel Plate	Y	3	176.00|203.00|197.00	-30	9.25		9.25		7	4	1998
2582	STMS	1161	MGSP	G3	Steel Plate	Y	3	176.00|203.00|197.00	-30	9.25		9.25		7	4	1998
2583	STMS	1162	MGSP	G1	Steel Plate	Y	3	188.50|273.00|188.50	0	5.08	*	12.75		7	6	1999
2584	STMS	1162	MGSP	G2	Steel Plate	Y	3	188.50|273.00|188.50	0	12.75		12.75		7	6	1999

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2585	STMS	1163	MGSP	G1_-_W_Fascia	Steel Plate	Y	3	146.52|219.82|146.52	0	3.61	*	7.55		12	6	2005
2586	STMS	1163	MGSP	G3_-_2nd_W_Int	Steel Plate	Y	3	146.52|219.82|146.52	0	7.55		7.55		12	6	2005
2587	STMS	1164	MGSP	N_11_-_1st_N_Int-x	Steel Plate	Y	3	52.49|109.91|52.49	0	8.86		8.86		12	8	2006
2588	STMS	1164	MGSP	N_12_-_N_Fascia	Steel Plate	Y	3	52.49|109.91|52.49	0	2.79	*	8.86		12	8	2006
2589	STMS	1165	MGSP	1_-_N_Fascia	Steel Plate	Y	3	29.25|166.50|29.25	0	2.92	*	9		8	4	1991
2590	STMS	1165	MGSP	2_-_1st_N_Int-x	Steel Plate	Y	3	29.25|166.50|29.25	0	9		9		8	4	1991
2591	STMS	1166	MGRB	9_-_3rd_N_Int-x	Steel Rolled Beam	N	4	48.50|61.00|61.00|48.50	0	6		6		12	4	1949
2592	STMS	1167	MGRB	G1	Steel Rolled Beam	N	4	60.00|70.00|70.00|60.00	0	2.33	*	6.67		4	2	1949
2593	STMS	1167	MGRB	G2	Steel Rolled Beam	N	4	60.00|70.00|70.00|60.00	0	6.67		6.67		4	2	1949
2594	STMS	1168	MGRB	Member_1	Steel Rolled Beam	Y	4	37.70|65.80|65.80|42.90	-3	2.5	*	9.5		5	3	1953
2595	STMS	1168	MGRB	Member_2	Steel Rolled Beam	Y	4	37.70|65.80|65.80|42.90	-3	9.5		9.5		5	3	1953
2596	STMS	1169	MGRB	G1	Steel Rolled Beam	N	4	42.00|55.00|55.00|42.00	0	2.83	*	8.67		4	2	1955
2597	STMS	1169	MGRB	G2	Steel Rolled Beam	N	4	42.00|55.00|55.00|42.00	0	8.67		8.67		4	2	1955
2598	STMS	1170	MGRB	6_-_2nd_S_Int-x	Steel Rolled Beam	N	4	50.00|65.00|65.00|50.00	37.08	6.25		6.25		8	3	1956
2599	STMS	1171	MGRB	G1	Steel Rolled Beam	Y	4	68.00|80.00|80.00|56.00	41.45	2.83	*	7		6	3	1956
2600	STMS	1171	MGRB	G2	Steel Rolled Beam	Y	4	68.00|80.00|80.00|56.00	41.45	7		7		6	3	1956

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2601	STMS	1172	MGRB	G1	Steel Rolled Beam	Y	4	56.00|68.00|68.00|56.00	-35.21	3.42	*	7.46		5	2	1956
2602	STMS	1172	MGRB	G2	Steel Rolled Beam	Y	4	56.00|68.00|68.00|56.00	-35.21	7.46		7.46		5	2	1956
2603	STMS	1173	MGRB	G2_-_1st_S_Int_	Steel Rolled Beam	N	4	61.00|78.00|78.00|61.00	0	6.33		6.33		6	2	1957
2604	STMS	1174	MGRB	G1	Steel Rolled Beam	N	4	42.00|56.00|56.00|42.00	0	1.79	*	7.67		4	2	1958
2605	STMS	1174	MGRB	G2	Steel Rolled Beam	N	4	42.00|56.00|56.00|42.00	0	7.67		7.67		4	2	1958
2606	STMS	1175	MGRB	G1	Steel Rolled Beam	N	4	60.00|75.00|75.00|60.00	10	2.13	*	6		4	2	1960
2607	STMS	1175	MGRB	G2	Steel Rolled Beam	N	4	60.00|75.00|75.00|60.00	10	6		6		4	2	1960
2608	STMS	1176	MGRB	16_-_2nd_W_Int	Steel Rolled Beam	Y	4	50.58|73.08|73.08|40.17	1.4	8.5		8.5		9	5	1961
2609	STMS	1177	MGRB	G1	Steel Rolled Beam	Y	4	65.00|83.00|83.00|65.00	0	2.29	*	7.33		4	2	1961
2610	STMS	1177	MGRB	G2	Steel Rolled Beam	Y	4	65.00|83.00|83.00|65.00	0	7.33		7.33		4	2	1961
2611	STMS	1178	MGRB	G1	Steel Rolled Beam	Y	4	57.00|76.00|76.00|57.00	-30	3.33	*	8.67		4	2	1966
2612	STMS	1178	MGRB	G2	Steel Rolled Beam	Y	4	57.00|76.00|76.00|57.00	-30	8.67		8.67		4	2	1966
2613	STMS	1179	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	N	4	56.50|81.00|81.00|52.50	-42.5	6.79		6.79		6	3	1962
2614	STMS	1180	MGRB	G1	Steel Rolled Beam	Y	4	48.00|70.00|70.00|48.00	0	2.79	*	9.33		4	2	1963

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2615	STMS	1180	MGRB	G2	Steel Rolled Beam	Y	4	48.00|70.00|70.00|48.00	0	9.33		9.33		4	2	1963
2616	STMS	1181	MGRB	19_-_1st_W_Int	Steel Rolled Beam	Y	4	50.00|60.00|60.00|50.00	8.11	6.79		6.25		11	5	1964
2617	STMS	1182	MGRB	9_-_2nd_E_Int	Steel Rolled Beam	N	4	66.25|85.00|84.00|65.50	-35	6.42		6.42		6	2	1965
2618	STMS	1183	MGRB	9_-_2nd_S_Int	Steel Rolled Beam	Y	4	44.42|59.58|59.58|46.42	30.65	6.25		6.25		11	4	1966
2619	STMS	1184	MGRB	BMS-6_-_3rd_N_Int_	Steel Rolled Beam	Y	4	44.33|84.42|84.42|44.33	-6.76	6.5		6.5		9	4	1966
2620	STMS	1185	MGRB	2_-_1st_E_Int-x	Steel Rolled Beam	N	4	38.92|71.33|71.33|49.50	10	6.5		6.5		5	2	1967
2621	STMS	1186	MGRB	3_-_2nd_E_Int	Steel Rolled Beam	Y	4	38.50|42.67|42.67|38.50	1	7.25		7.25		7	3	1968
2622	STMS	1187	MGRB	G1	Steel Rolled Beam	Y	4	55.00|71.00|55.00|33.00	23.5	3.38	*	8.5		5	3	1968
2623	STMS	1187	MGRB	G2	Steel Rolled Beam	Y	4	55.00|71.00|55.00|33.00	23.5	8.5		8.5		5	3	1968
2624	STMS	1188	MGRB	2_-_1st_N_Int-x	Steel Rolled Beam	N	4	47.71|81.17|81.17|47.71	30.05	7		7		9	4	1969
2625	STMS	1189	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	Y	4	48.67|78.04|78.04|48.67	-3	7.58		7.58		6	3	1974
2626	STMS	1190	MGRB	G1	Steel Rolled Beam	Y	4	42.00|65.01|65.01|45.00	20	3.38	*	8		6	3	1975
2627	STMS	1190	MGRB	G2	Steel Rolled Beam	Y	4	42.00|65.01|65.01|45.00	20	8		8		6	3	1975
2628	STMS	1191	MGRB	3_-_2nd_S_Int	Steel Rolled Beam	Y	4	43.00|51.25|51.25|43.00	0	6.67		6.67		7	3	1977

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2629	STMS	1192	MGRB	4_-_3rd_E_Int_	Steel Rolled Beam	Y	4	38.96|70.25|58.25|43.96	1.09	7.33		7.33		7	3	1978
2630	STMS	1193	MGRB	G1	Steel Rolled Beam	Y	4	35.50|76.00|76.00|32.50	0	3.38	*	8		6	3	1977
2631	STMS	1193	MGRB	G2	Steel Rolled Beam	Y	4	35.50|76.00|76.00|32.50	0	8		8		6	3	1977
2632	STMS	1194	MGRB	3_-_2nd_N_Int	Steel Rolled Beam	Y	4	55.75|66.42|66.42|55.75	0	7.42		7.42		6	3	1986
2633	STMS	1195	MGRB	G1	Steel Rolled Beam	Y	4	50.00|73.00|73.00|64.00	41.75	3	*	8.67		5	3	2003
2634	STMS	1195	MGRB	G2	Steel Rolled Beam	Y	4	50.00|73.00|73.00|64.00	41.75	8.67		8.67		5	3	2003
2635	STMS	1196	MGRB	G1	Steel Rolled Beam	Y	4	101.00|90.00|90.00|87.50	47.79	2.33	*	7		5	2	1952
2636	STMS	1196	MGRB	G2	Steel Rolled Beam	Y	4	101.00|90.00|90.00|87.50	47.79	7		7		5	2	1952
2637	STMS	1197	MGRB	G3	Steel Rolled Beam	Y	4	67.50|100.50|100.50|67.50	0	6.25		6.25		12	3	1955
2638	STMS	1198	MGRB	G3	Steel Rolled Beam	Y	4	64.75|100.50|100.50|64.75	0	6.38		6.38		14	5	1956
2639	STMS	1199	MGRB	G2_-_1st_N_Int_	Steel Rolled Beam	Y	4	81.00|104.00|104.00|81.00	42	5.88		5.88		6	2	1958
2640	STMS	1200	MGRB	G1	Steel Rolled Beam	N	4	75.00|90.00|90.00|75.00	0	2.17	*	6		4	1	1958
2641	STMS	1200	MGRB	G2	Steel Rolled Beam	N	4	75.00|90.00|90.00|75.00	0	6		6		4	1	1958
2642	STMS	1201	MGSP	4_-_3rd_E_Int	Steel Plate	Y	4	48.42|88.50|88.50|44.67	14.11	7.26		7.26		8	4	1961

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2643	STMS	1202	MGSP	5_-_1st_S_Int	Steel Plate	Y	4	103.95|117.86|106.29|80.54	59.67	7.21		7.21		6	3	1963
2644	STMS	1203	MGSP	10_-_2nd_N_Int	Steel Plate	Y	4	91.29|117.00|117.00|91.29	58.4	8.17		8.17		10	6	1964
2645	STMS	1204	MGSP	Fascia_Girder_G1	Steel Plate	Y	4	90.00|120.00|120.00|90.00	-45	1.5	*	8.75		4	2	1964
2646	STMS	1204	MGSP	Interior_Girder_G2	Steel Plate	Y	4	90.00|120.00|120.00|90.00	-45	8.75		8.83		4	2	1964
2647	STMS	1205	MGSP	G1	Steel Plate	Y	4	115.00|150.00|150.00|115.00	10	2.75	*	7.67		4	2	1965
2648	STMS	1205	MGSP	G2	Steel Plate	Y	4	115.00|150.00|150.00|115.00	10	7.67		7.67		4	2	1965
2649	STMS	1206	MGSP	3_-_Center-x	Steel Plate	N	4	78.00|132.50|132.50|78.00	0	8		8		5	2	1967
2650	STMS	1207	MGSP	3_-_2nd_N_Int_	Steel Plate	Y	4	71.25|114.25|114.25|87.75	16.18	8		8		9	5	1968
2651	STMS	1208	MGSP	G1	Steel Plate	Y	4	38.00|105.00|105.00|69.00	35.1	3.38	*	8.5		5	3	1969
2652	STMS	1208	MGSP	G2	Steel Plate	Y	4	38.00|105.00|105.00|69.00	35.1	8.5		8.5		5	3	1969
2653	STMS	1209	MGSP	G1	Steel Plate	Y	4	33.00|86.00|86.00|33.00	0	3.38	*	8		6	3	1969
2654	STMS	1209	MGSP	G2	Steel Plate	Y	4	33.00|86.00|86.00|33.00	0	8		8		6	3	1969
2655	STMS	1210	MGSP	G1	Steel Plate	Y	4	51.00|121.00|121.00|68.00	52.68	3.38	*	9		5	3	1969
2656	STMS	1210	MGSP	G2	Steel Plate	Y	4	51.00|121.00|121.00|68.00	52.68	9		9		5	3	1969

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2657	STMS	1211	MGSP	G1	Steel Plate	Y	4	54.01|132.02|132.02|49.01	-49.52	3.38	*	8		6	3	1969
2658	STMS	1212	MGSP	3_-_2nd_N_Int	Steel Plate	Y	4	66.00|87.17|122.25|84.17	-44.95	6.08		6.08		7	3	1970
2659	STMS	1213	MGSP	G1	Steel Plate	Y	4	61.00|139.00|139.00|49.00	-52.07	3.38	*	8		4	2	1970
2660	STMS	1213	MGSP	G2	Steel Plate	Y	4	61.00|139.00|139.00|49.00	-52.07	8		8		4	2	1970
2661	STMS	1214	MGSP	G1	Steel Plate	Y	4	110.25|155.00|155.00|110.25	0	4.5	*	11.67		4	3	1971
2662	STMS	1214	MGSP	G2	Steel Plate	Y	4	110.25|155.00|155.00|110.25	0	11.67		11.67		4	3	1971
2663	STMS	1215	MGSP	G1	Steel Plate	Y	4	53.00|104.00|104.00|41.00	35	3.38	*	7.5		5	2	1972
2664	STMS	1215	MGSP	G2	Steel Plate	Y	4	53.00|104.00|104.00|41.00	35	7.5		7.5		5	2	1972
2665	STMS	1216	MGSP	G1	Steel Plate	Y	4	45.50|112.00|112.00|45.50	-40	3.38	*	8		6	3	1974
2666	STMS	1216	MGSP	G2	Steel Plate	Y	4	45.50|112.00|112.00|45.50	-40	8		8		6	3	1974
2667	STMS	1217	MGSP	G3	Steel Plate	Y	4	135.00|165.00|165.00|135.00	0	9.75		9.75		5	3	1975
2668	STMS	1218	MGSP	G1	Steel Plate	Y	4	95.00|115.00|115.00|95.00	-60	3	*	9.5		5	3	1976
2669	STMS	1218	MGSP	G2	Steel Plate	Y	4	95.00|115.00|115.00|95.00	-60	9.5		9.5		5	3	1976
2670	STMS	1219	MGSP	G1	Steel Plate	Y	4	95.00|115.00|115.00|95.00	-60	3	*	9.5		5	3	1976

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2671	STMS	1219	MGSP	G2	Steel Plate	Y	4	95.00|115.00|115.00|95.00	-60	9.5		9.5		5	3	1976
2672	STMS	1220	MGSP	G1	Steel Plate	Y	4	44.20|92.00|92.00|37.20	20	3.38	*	8		12	7	1977
2673	STMS	1220	MGSP	G10	Steel Plate	Y	4	44.20|92.00|92.00|37.20	20	7.83		7.83		12	7	1977
2674	STMS	1221	MGSP	G1	Steel Plate	Y	4	75.00|135.00|135.00|105.00	0	3.66	*	8.67		5	2	1980
2675	STMS	1221	MGSP	G2	Steel Plate	Y	4	75.00|135.00|135.00|105.00	0	8.67		8.67		5	2	1980
2676	STMS	1222	MGSP	Member_1	Steel Plate	Y	4	131.00|167.00|167.00|131.00	53	3.5	*	9.67		4	2	1981
2677	STMS	1222	MGSP	Member_2	Steel Plate	Y	4	131.00|167.00|167.00|131.00	53	9.67		9.67		4	2	1981
2678	STMS	1223	MGSP	G1	Steel Plate	Y	4	48.00|123.00|123.00|53.00	-45.53	3.33	*	10		5	3	1983
2679	STMS	1223	MGSP	G2	Steel Plate	Y	4	48.00|123.00|123.00|53.00	-45.53	10		10		5	3	1983
2680	STMS	1224	MGSP	G1	Steel Plate	Y	4	125.00|150.00|125.00|72.00	-30	3.08	*	8.83		5	3	1984
2681	STMS	1224	MGSP	G2	Steel Plate	Y	4	125.00|150.00|125.00|72.00	-30	8.83		8.83		5	3	1984
2682	STMS	1225	MGSP	2_-_1st_W_Int	Steel Plate	Y	4	139.75|160.00|120.00|106.25	23.44	8.08		8.08		9	5	1987
2683	STMS	1226	MGSP	11_-_1st_W_Int	Steel Plate	Y	4	139.75|160.00|120.00|106.25	23.44	8.08		8.08		9	5	1987
2684	STMS	1227	MGSP	G1	Steel Plate	Y	4	79.96|172.09|172.11|57.15	60	3.75	*	9.5		5	3	1990

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Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2685	STMS	1227	MGSP	G2	Steel Plate	Y	4	79.96|172.09|172.11|57.15	60	9.5		9.5		5	3	1990
2686	STMS	1228	MGSP	G1	Steel Plate	Y	4	70.01|110.01|150.01|110.01	0	3.75	*	9.5		5	3	1991
2687	STMS	1228	MGSP	G2	Steel Plate	Y	4	70.01|110.01|150.01|110.01	0	9.5		9.5		5	3	1991
2688	STMS	1229	MGSP	Fascia_Grider	Steel Plate	Y	4	76.73|201.71|201.71|76.73	-65.08	2.13	*	9		8	5	1995
2689	STMS	1229	MGSP	Interior_Girder	Steel Plate	Y	4	76.73|201.71|201.71|76.73	-65.08	9		9		8	5	1995
2690	STMS	1230	MGSP	G3	Steel Plate	Y	4	120.00|120.00|120.00|120.00	0	9.25		9.25		7	3	1998
2691	STMS	1230	MGSP	G6	Steel Plate	Y	4	120.00|120.00|120.00|120.00	0	9.25		9.25		7	3	1998
2692	STMS	1231	MGSP	Fascia_Girder_G1	Steel Plate	Y	4	130.00|250.00|250.00|215.00	-5.79	3	*	10		9	5	1998
2693	STMS	1231	MGSP	Interior_Girder_G4	Steel Plate	Y	4	130.00|250.00|250.00|215.00	-5.79	10		10		9	5	1998
2694	STMS	1232	MGSP	Fascia_Girder_G1	Steel Plate	Y	4	114.83|225.72|225.72|135.73	0	3.94	*	8.53		8	4	2004
2695	STMS	1232	MGSP	Interior_Girder_G2	Steel Plate	Y	4	114.83|225.72|225.72|135.73	0	8.53		8.53		8	4	2004
2696	STMS	1233	MGSP	5_-_1st_W_Int	Steel Plate	Y	4	130.17|157.38|190.50|233.17	0	7.25		7.25		6	3	2006
2697	STMS	1234	MGSP	G1	Steel Plate	Y	4	138.21|185.00|143.00|138.21	55	3	*	8.17		5	3	2006
2698	STMS	1234	MGSP	G2	Steel Plate	Y	4	138.21|185.00|143.00|138.21	55	8.17		8.17		5	3	2006

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Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2699	STMS	1235	MGSP	G11	Steel Plate	Y	4	133.53|167.00|137.00|88.53	-57.72	7.83		3.33	*	11	6	2006
2700	STMS	1235	MGSP	G2	Steel Plate	Y	4	133.53|167.00|137.00|88.53	-57.72	7.83		7.83		11	6	2006
2701	RCMS	1236	RCSL	Slab	RC Slab	Y	3	25.00|25.00|25.00	0	357		357		11	3	1946
2702	RCMS	1237	RCSL	Slab	RC Slab	Y	3	25.08|25.00|25.08	0	357		357		11	3	1946
2703	RCMS	1238	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	20.00|26.21|20.00	0	276		276		11	3	1947
2704	RCMS	1239	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	21.75|27.00|21.75	0	281		281		11	3	1947
2705	RCMS	1240	RCSL	G01	RC Slab	Y	3	22.00|27.50|22.00	0	12		12		11	3	1949
2706	RCMS	1241	RCSL	Slab_1	RC Slab	Y	3	19.72|26.00|19.72	0	339		339		11	3	1949
2707	RCMS	1242	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	33.17|39.00|33.17	0	387		387		11	3	1951
2708	RCMS	1243	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	26.00|26.00|26.00	0	283		283		11	3	1952
2709	RCMS	1244	RCSL	Slab	RC Slab	Y	3	25.00|25.00|25.00	0	387		387		11	3	1952
2710	RCMS	1245	RCSL	Slab_1	RC Slab	Y	3	31.75|32.50|31.75	0	474		474		11	3	1952
2711	RCMS	1246	RCSL	12__RC_Slab_Section	RC Slab	Y	3	23.00|28.67|23.00	0	12		12		11	3	1953
2712	RCMS	1247	RCSL	Solid_Slab	RC Slab	Y	3	29.50|29.50|29.50	0	288		288		11	3	1954
2713	RCMS	1248	RCSL	Slab	RC Slab	Y	3	22.49|22.50|22.49	0	368		368			3	1954
2714	RCMS	1249	RCSL	S01	RC Slab	Y	3	26.00|32.50|26.00	0	12		12			3	1955
2715	RCMS	1250	RCSL	Slab_1	RC Slab	Y	3	32.25|32.50|32.25	0	380		380			3	1956
2716	RCMS	1251	RCSL	12__Int__Slab_Strip	RC Slab	Y	3	26.33|32.83|26.33	0	12		12			3	1957
2717	RCMS	1252	RCSL	12__Int__Strip	RC Slab	Y	3	27.88|36.50|27.88	0	12		12			3	1959
2718	RCMS	1253	RCSL	Slab	RC Slab	Y	3	27.83|33.97|27.87	0	306		306			3	1960
2719	RCMS	1254	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	26.53|34.06|26.53	0	306		306			3	1960
2720	RCMS	1255	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	27.79|27.81|27.79	0	354		354			3	1960
2721	RCMS	1256	RCSL	Slab	RC Slab	Y	3	37.52|37.50|37.52	0	379		379			3	1960

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Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2722	RCMS	1257	RCSL	Slab_1	RC Slab	Y	3	27.50|27.50|27.50	0	319		319			3	1961
2723	RCMS	1258	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	32.50|32.50|32.50	0	379		379			3	1962
2724	RCMS	1259	RCSL	RC-Slab	RC Slab	Y	3	21.50|26.82|21.50	0	12		12			3	1963
2725	RCMS	1260	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	30.75|39.75|30.75	0	12		12			3	1963
2726	RCMS	1261	RCSL	G01	RC Slab	Y	3	27.71|34.64|27.71	0	12		12			3	1964
2727	RCMS	1262	RCSL	12__Int__Slab_Strip	RC Slab	Y	3	24.34|31.33|24.34	0	12		12			3	1964
2728	RCMS	1263	RCSL	12__Int__Slab_Strip	RC Slab	Y	3	31.25|38.92|31.25	0	12		12			3	1965
2729	RCMS	1264	RCSL	12__Wide_Int__Slab_Strip	RC Slab	Y	3	31.25|39.00|31.25	0	12		12			3	1966
2730	RCMS	1265	RCSL	12__Int__Slab_Strip	RC Slab	Y	3	26.11|34.08|26.11	0	12		12			3	1967
2731	RCMS	1266	RCSL	Slab_1	RC Slab	Y	3	31.75|39.00|31.75	0	417		417			3	1967
2732	RCMS	1267	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	27.75|34.75|27.75	0	12		12			3	1968
2733	RCMS	1268	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	27.33|34.08|27.33	0	12		12			3	1968
2734	RCMS	1269	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	22.00|28.00|22.00	0	489		489			3	1969
2735	RCMS	1270	RCSL	S01	RC Slab	Y	3	32.00|40.00|32.00	0	12		12			3	1971
2736	RCMS	1271	RCSL	Slab_1	RC Slab	Y	3	21.27|26.00|21.28	0	416		416			3	1971
2737	RCMS	1272	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	27.25|34.00|27.25	0	369		369			3	1971
2738	RCMS	1273	RCSL	Slab_1	RC Slab	Y	3	25.00|36.00|25.00	0	513		513			3	1972
2739	RCMS	1274	RCSL	12__Int__Strip	RC Slab	Y	3	30.25|37.83|30.25	0	12		12			3	1974
2740	RCMS	1275	RCSL	12__Int__Strip	RC Slab	Y	3	27.42|35.58|27.42	0	12		12			3	1974
2741	RCMS	1276	RCSL	12__Int__Strip	RC Slab	Y	3	29.14|37.92|29.14	0	12		12			3	1974
2742	RCMS	1277	RCSL	12__Int__Slab_Strip	RC Slab	Y	3	28.59|36.00|28.59	0	12		12			3	1975
2743	RCMS	1278	RCSL	Slab_1	RC Slab	Y	3	30.00|39.00|30.00	0	507		507			3	1975
2744	RCMS	1279	RCSL	Slab	RC Slab	Y	3	32.00|40.00|32.00	0	448		448			3	1976
2745	RCMS	1280	RCSL	Slab	RC Slab	Y	3	26.00|33.00|26.00	0	513		513			3	1976
2746	RCMS	1281	RCSL	Slab_1	RC Slab	Y	3	23.00|31.00|23.00	0	448		448			3	1977
2747	RCMS	1282	RCSL	G01	RC Slab	Y	3	21.45|26.81|21.45	0	12		12			3	1981

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2748	RCMS	1283	RCSL	G01	RC Slab	Y	3	21.45|26.81|21.45	0	12		12			3	1981
2749	RCMS	1284	RCSL	G01	RC Slab	Y	3	29.00|36.25|29.00	0	12		12			3	1982
2750	RCMS	1285	RCSL	G01	RC Slab	Y	3	30.00|37.50|30.00	0	12		12			3	1983
2751	RCMS	1286	RCSL	G01	RC Slab	Y	3	32.00|40.00|32.00	0	12		12			3	1984
2752	RCMS	1287	RCSL	G01	RC Slab	Y	3	28.00|35.00|28.00	0	12		12			3	1984
2753	RCMS	1288	RCSL	S01	RC Slab	Y	3	30.00|37.50|30.00	0	12		12			3	1985
2754	RCMS	1289	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	25.00|35.00|25.00	0	426		426			3	1985
2755	RCMS	1290	RCSL	Slab_span_1-3	RC Slab	Y	3	20.25|20.00|20.25	0	59.52		59.52			3	1985
2756	RCMS	1291	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	25.00|25.00|25.00	0	498		498			3	1986
2757	RCMS	1292	RCSL	S01	RC Slab	Y	3	21.21|26.52|21.21	0	12		12			3	1987
2758	RCMS	1293	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	30.25|37.17|30.25	0	12		12			3	1987
2759	RCMS	1294	RCSL	G01	RC Slab	Y	3	27.25|34.06|27.25	0	12		12			3	1988
2760	RCMS	1295	RCSL	S01	RC Slab	Y	3	27.00|33.75|27.00	0	12		12			3	1989
2761	RCMS	1296	RCSL	12__Int__Strip	RC Slab	Y	3	27.83|37.04|35.48	0	12		12			3	1990
2762	RCMS	1297	RCSL	S01	RC Slab	Y	3	32.00|40.00|32.00	0	12		12			3	1994
2763	RCMS	1298	RCSL	S01	RC Slab	Y	3	31.00|38.75|31.00	0	12		12			3	1995
2764	RCMS	1299	RCSL	12__Interior_Slab_Strip	RC Slab	Y	3	24.17|25.00|24.17	0	12		12			3	1995
2765	RCMS	1300	RCSL	Typ__slab_member	RC Slab	Y	3	31.09|37.73|30.94	0	12.01		12.01			3	1999
2766	RCMS	1301	RCSL	Slab	RC Slab	Y	3	20.50|20.50|20.50	0	12		12			3	2003
2767	RCMS	1302	RCSL	3_SPAN_SLAB_BRIDGE	RC Slab	Y	3	26.69|33.46|26.69	0	39.37		39.37			3	2003
2768	RCMS	1303	RCSL	Interior_1_ft__Strip	RC Slab	Y	3	29.75|37.00|29.75	0	12		12			3	2004
2769	RCMS	1304	RCSL	12__Int__Slab_Strip	RC Slab	Y	3	21.88|29.50|21.88	0	12		12			3	2007
2770	RCMS	1305	RCSL	12__Int__Slab_Strip	RC Slab	Y	3	32.16|37.00|32.16	0	12		12			3	2007
2771	RCMS	1306	RCSL	Continuous_Solid_Slab	RC Slab	Y	3	34.20|40.31|34.20	0	354		354			3	1958
2772	RCMS	1307	RCSL	Slab_1	RC Slab	Y	3	42.50|42.50|42.50	0	379		379			3	1958

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Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2773	RCMS	1308	RCSL	12__Int__Slab_Strip	RC Slab	Y	3	33.09|42.99|33.09	0	12		12			3	1959
2774	RCMS	1309	RCSL	12__Int__Strip	RC Slab	Y	3	36.50|47.50|36.50	0	12		12			3	1959
2775	RCMS	1310	RCSL	Slab_1	RC Slab	Y	3	31.00|45.00|31.00	0	379		379			3	1961
2776	RCMS	1311	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	35.00|44.00|32.00	0	12		12			3	1962
2777	RCMS	1312	RCSL	RC-Slab_(Haunched)	RC Slab	Y	3	33.25|43.17|33.25	0	12		12			3	1963
2778	RCMS	1313	RCSL	12__Int__Slab_Strip	RC Slab	Y	3	33.58|43.67|33.58	0	12		12			3	1963
2779	RCMS	1314	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	33.00|41.25|33.00	0	12		12			3	1963
2780	RCMS	1315	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	34.00|44.25|34.00	0	12		12			3	1963
2781	RCMS	1316	RCSL	Member_Alternative_1	RC Slab	Y	3	32.75|40.34|39.03	0	426		426			3	1963
2782	RCMS	1317	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	35.75|46.50|35.75	0	12		12			3	1965
2783	RCMS	1318	RCSL	Slab	RC Slab	Y	3	32.00|42.00|32.00	0	489		489			3	1967
2784	RCMS	1319	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	33.00|41.25|33.00	0	12		12			3	1968
2785	RCMS	1320	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	33.00|41.50|33.00	0	12		12			3	1968
2786	RCMS	1321	RCSL	Slab	RC Slab	Y	3	35.00|46.00|35.00	0	489		489			3	1968
2787	RCMS	1322	RCSL	12__Int__Strip	RC Slab	Y	3	34.75|45.08|34.75	0	12		12			3	1969
2788	RCMS	1323	RCSL	G01	RC Slab	Y	3	42.00|52.00|42.00	0	12		12			3	1970
2789	RCMS	1324	RCSL	G01	RC Slab	Y	3	32.36|40.45|32.36	0	12		12			3	1971
2790	RCMS	1325	RCSL	Interior_12__Strip_Section	RC Slab	Y	3	33.79|43.93|33.79	0	12		12			3	1973
2791	RCMS	1326	RCSL	12__Int__Strip	RC Slab	Y	3	30.67|40.25|30.67	0	12		12			3	1975
2792	RCMS	1327	RCSL	G01	RC Slab	Y	3	40.00|50.00|40.00	0	12		12			3	1976
2793	RCMS	1328	RCSL	G01	RC Slab	Y	3	35.02|47.92|35.02	0	12		12			3	1976
2794	RCMS	1329	RCSL	Slab_1	RC Slab	Y	3	31.00|44.00|31.00	0	448		448			3	1977
2795	RCMS	1330	RCSL	Slab	RC Slab	Y	3	33.00|43.00|33.00	0	513		513			3	1981
2796	RCMS	1331	RCSL	G01	RC Slab	Y	3	41.00|52.50|39.28	0	12		12			3	1982
2797	RCMS	1332	RCSL	G01	RC Slab	Y	3	34.00|42.50|34.00	0	12		12			3	1982
2798	RCMS	1333	RCSL	Slab	RC Slab	Y	3	36.00|44.00|36.00	0	505		505			3	1983
2799	RCMS	1334	RCSL	S01	RC Slab	Y	3	34.00|42.50|34.00	0	12		12			3	1985

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2800	RCMS	1335	RCSL	15__RC_Slab	RC Slab	Y	3	34.50|44.50|34.50	0	12		12			3	1988
2801	RCMS	1336	RCSL	S01	RC Slab	Y	3	35.25|44.00|35.25	0	12		12			3	1995
2802	RCMS	1337	RCSL	RC_Slab	RC Slab	Y	3	37.73|42.65|37.73	0	39.37		39.37			3	2003
2803	RCMS	1338	RCSL	Slab_Bridge_Member	RC Slab	Y	3	42.42|53.00|42.42	0	12		12			3	2004
2804	RCMS	1339	RCSL	12__Slab_Strip	RC Slab	Y	3	38.08|45.83|38.08	0	12		12			3	2005
2805	RCMS	1340	RCSL	12__Int_Slab_Strip	RC Slab	Y	3	39.46|50.00|39.46	0	12		12			3	2006
2806	PSMS	1341	PSIB	G1	Prestressed I-Beam	Y	2	64.33|64.33	31.48	1.92	*	4.75		9	3	1967
2807	PSMS	1341	PSIB	G2	Prestressed I-Beam	Y	2	64.33|64.33	31.48	4.75		4.75		9	3	1967
2808	PSMS	1342	PSIB	3_-_2nd_S_Int_	Prestressed I-Beam	Y	2	42.83|42.83	-32	7.21		7.21		6	3	1971
2809	PSMS	1343	PSIB	G1	Prestressed I-Beam	Y	2	60.88|60.88	26.69	3	*	7		4	2	1971
2810	PSMS	1343	PSIB	G2	Prestressed I-Beam	Y	2	60.88|60.88	26.69	7		7		4	2	1971
2811	PSMS	1344	PSIB	G1	Prestressed I-Beam	Y	2	70.88|70.88	-39.5	3.25	*	7.5		6	3	1972
2812	PSMS	1344	PSIB	G2	Prestressed I-Beam	Y	2	70.88|70.88	-39.5	7.5		7.5		6	3	1972
2813	PSMS	1345	PSIB	3_-_2nd_N_Int-x	Prestressed I-Beam	Y	2	63.75|63.75	0	7.25		7.25		6	3	1974
2814	PSMS	1346	PSIB	3_-_2nd_W_Int-x	Prestressed I-Beam	Y	2	64.75|64.75	-20	7.21		7.21		6	3	1979
2815	PSMS	1347	PSIB	G2	Prestressed I-Beam	Y	2	73.50|73.50	-23	9		9		5	3	1986
2816	PSMS	1348	PSIB	3_-_2nd_S_Int	Prestressed I-Beam	Y	2	74.42|74.42	-23.5	7.38		7.38		6	3	1986
2817	PSMS	1349	PSIB	G1	Prestressed I-Beam	Y	2	82.30|82.30	15	3.13	*	9.75		4	2	1986
2818	PSMS	1349	PSIB	G2	Prestressed I-Beam	Y	2	82.30|82.30	15	9.75		9.75		4	2	1986
2819	PSMS	1350	PSIB	9_-_2nd_S_Int	Prestressed I-Beam	Y	2	74.42|74.42	-23.5	7		7		8	4	1987
2820	PSMS	1351	PSIB	G2	Prestressed I-Beam	Y	2	64.00|56.00	45	5.83		5.83		6	2	1988
2821	PSMS	1352	PSIB	G2	Prestressed I-Beam	Y	2	74.75|74.75	0	6.63		6.63		6	3	1990
2822	PSMS	1353	PSIB	G2_-_1st_E_Int_	Prestressed I-Beam	Y	2	49.25|69.25	0	7.25		7.25		5	2	1991
2823	PSMS	1354	PSIB	G1	Prestressed I-Beam	Y	2	73.29|77.29	3	3.08	*	8.83		5	3	1991
2824	PSMS	1354	PSIB	G2	Prestressed I-Beam	Y	2	73.29|77.29	3	8.83		8.83		5	3	1991
2825	PSMS	1355	PSIB	G1	Prestressed I-Beam	Y	2	61.48|61.48	12	3.5	*	9.33		7	2	1991
2826	PSMS	1355	PSIB	G2	Prestressed I-Beam	Y	2	61.48|61.48	12	9.33		9.33		7	2	1991
2827	PSMS	1356	PSIB	G1	Prestressed I-Beam	Y	2	52.23|52.26	-25	3.25	*	7.75		5	2	1991

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2828	PSMS	1356	PSIB	G2	Prestressed I-Beam	Y	2	52.23|52.26	-25	7.75		7.75		5	2	1991
2829	PSMS	1357	PSIB	10_-_2nd_W_Int	Prestressed I-Beam	Y	2	80.70|80.70	15.73	7.42		7.42		6	3	1994
2830	PSMS	1358	PSIB	G1	Prestressed I-Beam	Y	2	61.56|61.56	10	3.12	*	8.96		5	3	1996
2831	PSMS	1358	PSIB	G2	Prestressed I-Beam	Y	2	61.56|61.56	10	8.96		8.96		5	3	1996
2832	PSMS	1359	PSIB	G1	Prestressed I-Beam	Y	2	83.35|83.35	0	3.18	*	8.46		23	15	1999
2833	PSMS	1359	PSIB	G2	Prestressed I-Beam	Y	2	83.35|83.35	0	8.46		8.46		23	15	1999
2834	PSMS	1360	PSIB	G1	Prestressed I-Beam	Y	2	64.21|64.21	0	3.83	*	9.75		5	3	2002
2835	PSMS	1360	PSIB	G2	Prestressed I-Beam	Y	2	64.21|64.21	0	9.75		9.75		5	3	2002
2836	PSMS	1361	PSIB	G1	Prestressed I-Beam	Y	2	75.38|75.38	0	3.5	*	8.92		5	3	2003
2837	PSMS	1361	PSIB	G2	Prestressed I-Beam	Y	2	75.38|75.38	0	8.92		8.92		5	3	2003
2838	PSMS	1362	PSIB	G2	Prestressed I-Beam	Y	2	81.63|71.82	0	7.84		7.84		8	4	2003
2839	PSMS	1362	PSIB	G4	Prestressed I-Beam	Y	2	81.63|71.82	0	7.84		5.08		8	4	2003
2840	PSMS	1363	PSIB	G1	Prestressed I-Beam	Y	2	52.83|52.83	-3.29	3	*	9.33		6	4	2006
2841	PSMS	1363	PSIB	G2	Prestressed I-Beam	Y	2	52.83|52.83	-3.29	9.33		9.33		6	4	2006
2842	PSMS	1364	PSIB	G1	Prestressed I-Beam	Y	2	82.41|82.41	-10.04	3.44	*	8.2		7	3	2006
2843	PSMS	1364	PSIB	G2	Prestressed I-Beam	Y	2	82.41|82.41	-10.04	8.2		8.2		7	3	2006
2844	PSMS	1365	PSIB	G1	Prestressed I-Beam	Y	2	78.75|75.25	22.74	3.08	*	10.5		5	2	2008
2845	PSMS	1365	PSIB	G2	Prestressed I-Beam	Y	2	78.75|75.25	22.74	10.5		10.5		5	2	2008
2846	PSMS	1366	PSIB	G1	Prestressed I-Beam	Y	2	95.88|95.88	29.36	3.25	*	7.5		6	3	1972
2847	PSMS	1366	PSIB	G2	Prestressed I-Beam	Y	2	95.88|95.88	29.36	7.5		7.5		6	3	1972
2848	PSMS	1367	PSIB	3_-_2nd_N_Int-x	Prestressed I-Beam	Y	2	101.00|95.00	-22.07	6.17		6.17		7	3	1994
2849	PSMS	1368	PSIB	G1	Prestressed I-Beam	Y	2	92.13|90.13	-10	3.5	*	7.5		8	4	1995
2850	PSMS	1368	PSIB	G2	Prestressed I-Beam	Y	2	92.13|90.13	-10	7.5		7.5		8	4	1995
2851	PSMS	1369	PSIB	9_-_2nd_N_Int	Prestressed I-Beam	Y	2	98.59|98.59	0	7.35		7.35		6	3	1998
2852	PSMS	1370	PSIB	G1	Prestressed I-Beam	Y	2	115.33|115.33	8.38	3.33	*	9.5		9	6	2002
2853	PSMS	1370	PSIB	G2	Prestressed I-Beam	Y	2	115.33|115.33	8.38	9.5		9.5		9	6	2002
2854	PSMS	1371	PSIB	1_-_W_(Outer)_Fascia	Prestressed I-Beam	Y	2	85.46|77.59	14.81	3.12	*	7.87		6	3	2001
2855	PSMS	1371	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	2	85.46|77.59	14.81	7.87		7.87		6	3	2001

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2856	PSMS	1372	PSIB	G1	Prestressed I-Beam	Y	2	93.50|93.50	26.75	3.95	*	8.53		5	3	2001
2857	PSMS	1372	PSIB	G2	Prestressed I-Beam	Y	2	93.50|93.50	26.75	8.53		8.53		5	3	2001
2858	PSMS	1373	PSIB	G1	Prestressed I-Beam	Y	2	103.35|106.63	0	3.36	*	7.58		8	4	2002
2859	PSMS	1373	PSIB	G2	Prestressed I-Beam	Y	2	103.35|106.63	0	7.58		7.58		8	4	2002
2860	PSMS	1374	PSIB	G1	Prestressed I-Beam	Y	2	100.80|109.00	-3.17	3.51	*	8.46		7	4	2002
2861	PSMS	1374	PSIB	G2	Prestressed I-Beam	Y	2	100.80|109.00	-3.17	8.46		8.46		7	4	2002
2862	PSMS	1375	PSIB	G2	Prestressed I-Beam	Y	2	91.63|80.25	9.89	6.66		6.66		11	5	2003
2863	PSMS	1376	PSIB	G11	Prestressed I-Beam	Y	2	109.00|104.50	0	7.33		7.33		12	5	2003
2864	PSMS	1376	PSIB	G2	Prestressed I-Beam	Y	2	109.00|104.50	0	7.25		7.33		12	5	2003
2865	PSMS	1377	PSIB	G2	Prestressed I-Beam	Y	2	119.09|119.09	-10	5.58		5.58		12	4	2003
2866	PSMS	1377	PSIB	G3	Prestressed I-Beam	Y	2	119.09|119.09	-10	5.58		6.23		12	4	2003
2867	PSMS	1378	PSIB	Typical_Fascia_Girder	Prestressed I-Beam	Y	2	116.54|116.54	35	2.42	*	8.42		6	3	2003
2868	PSMS	1378	PSIB	Typical_Interior_Girder	Prestressed I-Beam	Y	2	116.54|116.54	35	8.42		8.42		6	3	2003
2869	PSMS	1379	PSIB	G2	Prestressed I-Beam	Y	2	116.97|101.47	12	5.83		5.83		6	2	2004
2870	PSMS	1380	PSIB	G1	Prestressed I-Beam	Y	2	90.00|90.00	-40	3.58	*	9.17		4	2	2004
2871	PSMS	1380	PSIB	G2	Prestressed I-Beam	Y	2	90.00|90.00	-40	9.17		9.17		4	2	2004
2872	PSMS	1381	PSIB	G1	Prestressed I-Beam	Y	2	119.13|119.13	0	3.33	*	9		5	3	2004
2873	PSMS	1381	PSIB	G2	Prestressed I-Beam	Y	2	119.13|119.13	0	9		9		5	3	2004
2874	PSMS	1382	PSIB	9_-_6th_W_Int_	Prestressed I-Beam	Y	2	92.03|114.99	0	8.37		8.37		9	5	2005
2875	PSMS	1383	PSIB	1_-_8th_E_Int_	Prestressed I-Beam	Y	2	95.54|95.54	-6.92	6.56		6.56		8	3	2005
2876	PSMS	1384	PSIB	3_-_2nd_E_Int_	Prestressed I-Beam	Y	2	92.03|114.99	0	8.86		8.86		7	4	2006
2877	PSMS	1385	PSIB	5_-_4th_N_Int-x	Prestressed I-Beam	Y	2	108.50|108.50	0	6.67		6.67		14	6	2007
2878	PSMS	1386	PSIB	G5	Prestressed I-Beam	Y	2	111.46|111.46	-52.32	8.5		8.5		6	3	2007
2879	PSMS	1386	PSIB	G6	Prestressed I-Beam	Y	2	111.46|111.46	-52.32	8.5		3.79	*	6	3	2007
2880	PSMS	1387	PSIB	G1	Prestressed I-Beam	Y	2	134.21|123.21	-9.24	4.33	*	10		3	2	2007
2881	PSMS	1387	PSIB	G2	Prestressed I-Beam	Y	2	134.21|123.21	-9.24	10		10		3	2	2007
2882	PSMS	1388	PSIB	G2_-_1st_N_Int_	Prestressed I-Beam	Y	2	92.75|92.75	0	5.75		5.75		6	2	2008

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2883	PSMS	1389	PSIB	G1	Prestressed I-Beam	Y	2	109.68|107.42	-25.52	2.46	*	7.25		6	2	2008
2884	PSMS	1389	PSIB	G3	Prestressed I-Beam	Y	2	109.68|107.42	-25.52	7.25		7.25		6	2	2008
2885	PSMS	1390	PSIB	G1	Prestressed I-Beam	Y	2	68.13|102.13	0	3.42	*	9.17		6	4	2005
2886	PSMS	1390	PSIB	G2	Prestressed I-Beam	Y	2	68.13|102.13	0	9.17		9.17		6	4	2005
2887	PSMS	1390	PSIB	G3	Prestressed I-Beam	Y	2	68.13|102.13	0	9.17		9.17		6	4	2005
2888	PSMS	1390	PSIB	G4	Prestressed I-Beam	Y	2	68.13|102.13	0	9.17		9.17		6	4	2005
2889	PSMS	1390	PSIB	G5	Prestressed I-Beam	Y	2	68.13|102.13	0	9.17		9.17		6	4	2005
2890	PSMS	1390	PSIB	G6	Prestressed I-Beam	Y	2	68.13|102.13	0	9.17		3.42	*	6	4	2005
2891	PSMS	1391	PSIB	BMN_3_-_2nd_N_Int_	Prestressed I-Beam	Y	3	39.69|51.50|39.69	-15	7.46		7.46		6	3	1958
2892	PSMS	1392	PSIB	10_-_1st_S_Int	Prestressed I-Beam	Y	3	57.54|49.33|57.54	42.82	6.75		6.75		11	5	1959
2893	PSMS	1393	PSIB	3_-_2nd_N_Int	Prestressed I-Beam	Y	3	54.33|69.01|54.33	-3.79	7.38		7.38		10	5	1963
2894	PSMS	1394	PSIB	3_-_2nd_E_Int-x	Prestressed I-Beam	Y	3	68.50|69.33|68.50	14.68	6.33		6.33		6	2	1965
2895	PSMS	1395	PSIB	3_-_2nd_S_Int	Prestressed I-Beam	Y	3	51.67|68.33|51.67	40	6.33		6.33		7	3	1965
2896	PSMS	1396	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	3	46.67|47.50|46.67	-4.49	7.25		7.25		6	3	1966
2897	PSMS	1397	PSIB	3_-_2nd_N_Int	Prestressed I-Beam	Y	3	51.33|52.25|51.33	-20	7.42		7.42		6	3	1968
2898	PSMS	1398	PSIB	4_-_2nd_S_Int	Prestressed I-Beam	Y	3	63.58|64.42|63.58	0	7.21		7.21		6	3	1968
2899	PSMS	1399	PSIB	5_-_2nd_W_Int	Prestressed I-Beam	Y	3	51.25|58.63|51.25	-23	6.33		6.33		7	3	1968
2900	PSMS	1400	PSIB	3_-_2nd_N_Int_	Prestressed I-Beam	Y	3	51.92|52.75|51.92	0	7.21		7.21		6	3	1968
2901	PSMS	1401	PSIB	G1	Prestressed I-Beam	Y	3	42.00|42.00|42.00	0	3.38	*	8.5		5	3	1969
2902	PSMS	1401	PSIB	G2	Prestressed I-Beam	Y	3	42.00|42.00|42.00	0	8.5		8.5		5	3	1969
2903	PSMS	1402	PSIB	G1	Prestressed I-Beam	Y	3	35.00|35.00|35.00	0	3.38	*	8.5		5	3	1970
2904	PSMS	1402	PSIB	G2	Prestressed I-Beam	Y	3	35.00|35.00|35.00	0	8.5		8.5		5	3	1970
2905	PSMS	1403	PSIB	3_-_2nd_E_Int	Prestressed I-Beam	Y	3	57.33|58.17|57.33	0	7.67		7.67		6	3	1971
2906	PSMS	1404	PSIB	9_-_2nd_E_Int	Prestressed I-Beam	Y	3	31.75|47.50|26.83	8.78	7.17		7.17		6	3	1971
2907	PSMS	1405	PSIB	4_-_2nd_E_Int	Prestressed I-Beam	Y	3	50.83|51.67|50.83	-18.99	7.21		7.21		6	3	1971
2908	PSMS	1406	PSIB	G1	Prestressed I-Beam	Y	3	59.29|60.00|59.29	-20	3.38	*	7.5		5	2	1972
2909	PSMS	1406	PSIB	G2	Prestressed I-Beam	Y	3	59.29|60.00|59.29	-20	7.5		7.5		5	2	1972
2910	PSMS	1407	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	3	66.54|67.50|66.54	0	6.5		6.5		9	4	1973

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2911	PSMS	1408	PSIB	3_-_2nd_E_Int	Prestressed I-Beam	Y	3	62.71|63.67|62.71	-30	7.21		7.21		6	3	1973
2912	PSMS	1409	PSIB	9_-_2nd_N_Int-x	Prestressed I-Beam	Y	3	29.00|48.00|29.00	0	7.21		7.21		6	3	1972
2913	PSMS	1410	PSIB	3_-_2nd_N_Int-x	Prestressed I-Beam	Y	3	55.17|56.00|55.17	0	7.58		7.58		6	3	1974
2914	PSMS	1411	PSIB	G1	Prestressed I-Beam	Y	3	41.29|55.00|41.29	40	3.38	*	8		6	3	1974
2915	PSMS	1411	PSIB	G2	Prestressed I-Beam	Y	3	41.29|55.00|41.29	40	8		8		6	3	1974
2916	PSMS	1412	PSIB	9_-_2nd_N_Int-x	Prestressed I-Beam	Y	3	50.75|51.58|50.75	8.32	7.21		7.21		6	3	1976
2917	PSMS	1413	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	3	51.17|65.33|51.17	-9.25	7.21		7.21		6	3	1977
2918	PSMS	1414	PSIB	G1	Prestressed I-Beam	Y	3	66.33|67.67|66.33	28.03	3.38	*	8		6	3	1976
2919	PSMS	1414	PSIB	G2	Prestressed I-Beam	Y	3	66.33|67.67|66.33	28.03	8		8		6	3	1976
2920	PSMS	1415	PSIB	G1	Prestressed I-Beam	Y	3	69.23|71.00|69.23	-45	3.46	*	8.08		6	3	1977
2921	PSMS	1415	PSIB	G2	Prestressed I-Beam	Y	3	69.23|71.00|69.23	-45	8.08		8.08		6	3	1977
2922	PSMS	1416	PSIB	G1	Prestressed I-Beam	Y	3	50.29|65.00|50.29	-15	3.38	*	9		5	3	1978
2923	PSMS	1416	PSIB	G2	Prestressed I-Beam	Y	3	50.29|65.00|50.29	-15	9		9		5	3	1978
2924	PSMS	1417	PSIB	G1	Prestressed I-Beam	Y	3	68.21|68.92|68.21	-35	3.67	*	8		6	3	1978
2925	PSMS	1417	PSIB	G2	Prestressed I-Beam	Y	3	68.21|68.92|68.21	-35	8		8		6	3	1978
2926	PSMS	1418	PSIB	G2	Prestressed I-Beam	Y	3	69.29|70.00|69.29	22.53	9		9		5	3	1978
2927	PSMS	1419	PSIB	G2	Prestressed I-Beam	Y	3	61.67|62.63|62.17	-55	8.08		8.08		6	3	1979
2928	PSMS	1420	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	3	51.50|57.33|49.50	0	7.21		7.21		6	3	1981
2929	PSMS	1421	PSIB	3_-_2nd_N_Int-x	Prestressed I-Beam	Y	3	52.13|53.21|52.13	0	6.75		6.75		7	3	1981
2930	PSMS	1422	PSIB	G2	Prestressed I-Beam	Y	3	54.25|55.00|54.25	32	8.08		8.08		6	3	1981
2931	PSMS	1423	PSIB	G2	Prestressed I-Beam	Y	3	57.00|64.67|63.00	0	7.29		7.29		5	2	1982
2932	PSMS	1424	PSIB	G2	Prestressed I-Beam	Y	3	57.29|58.00|57.29	-20	8.08		8.08		6	3	1983
2933	PSMS	1425	PSIB	G2	Prestressed I-Beam	Y	3	65.25|66.00|58.29	42	9		9		5	3	1983
2934	PSMS	1426	PSIB	G2	Prestressed I-Beam	Y	3	61.50|62.33|61.50	20	9.25		9.25		5	3	1984
2935	PSMS	1427	PSIB	G2	Prestressed I-Beam	Y	3	43.29|64.00|34.29	0	9		9		5	3	1983
2936	PSMS	1428	PSIB	G2	Prestressed I-Beam	Y	3	57.29|70.00|57.29	20	8.83		8.83		5	3	1983
2937	PSMS	1429	PSIB	G1	Prestressed I-Beam	Y	3	64.75|80.00|64.75	32	3.08	*	8.83		5	3	1983
2938	PSMS	1429	PSIB	G2	Prestressed I-Beam	Y	3	64.75|80.00|64.75	32	8.83		8.83		5	3	1983

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2939	PSMS	1430	PSIB	3_-_Centerline-x	Prestressed I-Beam	Y	3	79.50|73.58|50.00	22.5	7.25		7.25		5	2	1984
2940	PSMS	1431	PSIB	9_-_2nd_N_Int	Prestressed I-Beam	Y	3	45.67|45.67|45.67	-50	7.42		7.42		6	3	1986
2941	PSMS	1432	PSIB	G2	Prestressed I-Beam	Y	3	74.29|75.00|74.29	10	8.08		8.08		6	3	1985
2942	PSMS	1433	PSIB	C_-_Centerline-x	Prestressed I-Beam	Y	3	71.71|72.75|71.71	0	7.25		7.25		5	2	1986
2943	PSMS	1434	PSIB	G2	Prestressed I-Beam	Y	3	65.30|66.00|65.30	-40	8.33		8.33		4	2	1987
2944	PSMS	1435	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	3	48.50|49.50|48.50	0	7.42		7.42		6	3	1988
2945	PSMS	1436	PSIB	G2	Prestressed I-Beam	Y	3	79.29|80.00|79.29	0	7.75		7.75		4	2	1988
2946	PSMS	1437	PSIB	G2	Prestressed I-Beam	Y	3	55.25|56.00|55.25	-15	8.83		8.83		5	3	1988
2947	PSMS	1438	PSIB	2_-_1st_S_Int	Prestressed I-Beam	Y	3	63.08|63.83|63.08	0	6.17		6.17		7	3	1989
2948	PSMS	1439	PSIB	G2_-_1st_N_Int_	Prestressed I-Beam	Y	3	48.25|49.25|48.25	-30	7.42		7.42		6	3	1990
2949	PSMS	1440	PSIB	G2	Prestressed I-Beam	Y	3	54.32|78.04|54.32	0	9.33		9.33		6	4	1990
2950	PSMS	1441	PSIB	G2	Prestressed I-Beam	Y	3	62.25|63.00|62.25	15	8.83		8.83		5	3	1990
2951	PSMS	1442	PSIB	G2	Prestressed I-Beam	Y	3	40.25|48.00|40.25	30	8.83		8.83		5	3	1990
2952	PSMS	1443	PSIB	G2	Prestressed I-Beam	Y	3	82.13|83.00|82.13	-30	8.83		8.83		5	3	1990
2953	PSMS	1444	PSIB	G3	Prestressed I-Beam	Y	3	58.21|59.00|58.21	25	9.5		9.5		7	5	1990
2954	PSMS	1444	PSIB	G7	Prestressed I-Beam	Y	3	58.21|59.00|58.21	25	9.5		3.75	*	7	5	1990
2955	PSMS	1445	PSIB	G2	Prestressed I-Beam	Y	3	47.20|55.00|47.20	31.38	7		7		6	3	1990
2956	PSMS	1446	PSIB	G2	Prestressed I-Beam	Y	3	60.29|80.00|60.29	0	8.83		8.83		5	3	1991
2957	PSMS	1447	PSIB	G2	Prestressed I-Beam	Y	3	78.14|78.69|77.97	28	9.5		9.5		8	5	1992
2958	PSMS	1448	PSIB	G2	Prestressed I-Beam	Y	3	56.00|78.00|56.00	-35.5	8.83		8.83		5	3	1992
2959	PSMS	1449	PSIB	G2	Prestressed I-Beam	Y	3	69.13|69.88|69.13	11	8.83		8.83		5	3	1993
2960	PSMS	1450	PSIB	G2	Prestressed I-Beam	Y	3	76.17|77.00|76.97	0	8.94		8.94		5	3	1993
2961	PSMS	1451	PSIB	G2	Prestressed I-Beam	Y	3	63.13|63.96|59.92	17.34	8.83		8.83		5	3	1995
2962	PSMS	1452	PSIB	G2	Prestressed I-Beam	Y	3	68.00|71.06|58.17	-4.85	8.83		8.83		7	4	1995
2963	PSMS	1453	PSIB	G2	Prestressed I-Beam	Y	3	60.25|63.00|62.06	0	8.75		8.75		5	3	1995
2964	PSMS	1454	PSIB	G1	Prestressed I-Beam	Y	3	74.72|75.46|74.72	0	3.12	*	8.96		5	3	1996
2965	PSMS	1454	PSIB	G2	Prestressed I-Beam	Y	3	74.72|75.46|74.72	0	8.96		8.96		5	3	1996
2966	PSMS	1455	PSIB	G1	Prestressed I-Beam	Y	3	57.85|64.78|59.16	-29.01	3.88	*	7.83		7	4	1996

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2967	PSMS	1455	PSIB	G2	Prestressed I-Beam	Y	3	57.85|64.78|59.16	-29.01	7.83		7.83		7	4	1996
2968	PSMS	1456	PSIB	G2	Prestressed I-Beam	Y	3	58.91|59.68|58.90	0	8.83		8.83		5	3	1997
2969	PSMS	1457	PSIB	G2	Prestressed I-Beam	Y	3	49.28|70.11|49.78	-7.51	7.83		7.83		7	4	1997
2970	PSMS	1458	PSIB	G2_-_1st_W_Int_	Prestressed I-Beam	Y	3	64.44|78.17|64.44	22	6.43		6.43		6	3	1998
2971	PSMS	1459	PSIB	G2	Prestressed I-Beam	Y	3	61.81|68.90|61.81	-35	9.58		9.58		5	3	1998
2972	PSMS	1460	PSIB	G2	Prestressed I-Beam	Y	3	41.95|42.65|41.95	30	9.58		9.58		5	3	1998
2973	PSMS	1461	PSIB	G1	Prestressed I-Beam	Y	3	78.32|79.03|78.32	45	3.08	*	8.83		5	3	1998
2974	PSMS	1461	PSIB	G2	Prestressed I-Beam	Y	3	78.32|79.03|78.32	45	8.83		8.83		5	3	1998
2975	PSMS	1462	PSIB	G2	Prestressed I-Beam	Y	3	59.21|60.00|59.21	0	7.75		7.75		5	2	1998
2976	PSMS	1463	PSIB	5_-_Center	Prestressed I-Beam	Y	3	54.38|69.14|54.38	-4.63	7.45		8.53		9	5	1999
2977	PSMS	1464	PSIB	G1	Prestressed I-Beam	Y	3	60.25|63.00|62.06	0	3.88	*	8.75		5	3	1997
2978	PSMS	1464	PSIB	G2	Prestressed I-Beam	Y	3	60.25|63.00|62.06	0	8.75		8.75		5	3	1997
2979	PSMS	1465	PSIB	3_-_2nd_E_Int	Prestressed I-Beam	Y	3	59.00|68.00|59.00	0	6		6		6	2	2001
2980	PSMS	1466	PSIB	G2_-_1st_N_Int_	Prestressed I-Beam	Y	3	28.79|33.75|28.79	20	6.63		6.63		6	3	2001
2981	PSMS	1467	PSIB	G2	Prestressed I-Beam	Y	3	44.25|45.00|44.25	-35	9		9		5	3	2001
2982	PSMS	1468	PSIB	1_-_W_Fascia	Prestressed I-Beam	Y	3	30.91|67.59|30.91	0	2.79	*	5.77		6	2	2001
2983	PSMS	1468	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	3	30.91|67.59|30.91	0	5.77		5.77		6	2	2001
2984	PSMS	1469	PSIB	G1	Prestressed I-Beam	Y	3	70.29|71.00|70.29	-15	3.33	*	8.5		9	6	2001
2985	PSMS	1469	PSIB	G2	Prestressed I-Beam	Y	3	70.29|71.00|70.29	-15	8.5		8.5		9	6	2001
2986	PSMS	1470	PSIB	G2	Prestressed I-Beam	Y	3	45.88|59.00|45.88	0	8.92		8.92		5	3	2002
2987	PSMS	1471	PSIB	10_-_2nd_N_Int	Prestressed I-Beam	Y	3	78.33|79.25|78.33	0	6.83		6.83		7	3	2002
2988	PSMS	1472	PSIB	G2	Prestressed I-Beam	Y	3	59.29|60.00|59.29	-10	7.5		7.5		4	2	2002
2989	PSMS	1473	PSIB	G2	Prestressed I-Beam	Y	3	61.25|62.00|61.25	-40	9.17		9.17		4	2	2002
2990	PSMS	1474	PSIB	G2_-_1st_N_Int_	Prestressed I-Beam	Y	3	61.22|75.49|61.22	60	7.02		7.02		7	3	2003
2991	PSMS	1475	PSIB	G2_-_1st_N_Int_	Prestressed I-Beam	Y	3	40.52|41.14|40.52	-28	5.97		5.97		6	2	2001
2992	PSMS	1476	PSIB	G2_-_1st_W_Int_	Prestressed I-Beam	Y	3	46.06|74.53|46.06	-24.34	6.56		6.56		6	3	2003
2993	PSMS	1477	PSIB	3_-_2nd_N_Int	Prestressed I-Beam	Y	3	52.72|65.62|52.72	0	6.27		6.27		20	9	2003
2994	PSMS	1478	PSIB	G1	Prestressed I-Beam	Y	3	70.03|84.04|70.03	-40	3.33	*	9		5	3	2003

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
2995	PSMS	1478	PSIB	G2	Prestressed I-Beam	Y	3	70.03|84.04|70.03	-40	9		9		5	3	2003
2996	PSMS	1479	PSIB	G2	Prestressed I-Beam	Y	3	44.25|50.00|44.25	-25	7.5		7.5		4	2	2003
2997	PSMS	1480	PSIB	G2	Prestressed I-Beam	Y	3	50.25|80.00|79.25	35	8.17		8.17		5	3	2003
2998	PSMS	1481	PSIB	10_-_2nd_W_Int_	Prestressed I-Beam	Y	3	92.42|93.17|92.17	-56.07	6		6		7	3	1976
2999	PSMS	1482	PSIB	G3	Prestressed I-Beam	Y	3	74.13|63.75|85.21	0	8		8		10	5	1980
3000	PSMS	1483	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	3	73.31|95.37|71.67	25.47	5.71		5.71		9	4	2005
3001	PSMS	1484	PSIB	G2	Prestressed I-Beam	Y	3	67.29|86.00|67.29	-25	7.75		7.75		4	2	1984
3002	PSMS	1485	PSIB	G2	Prestressed I-Beam	Y	3	34.29|88.00|38.29	5	8.08		8.08		6	3	1984
3003	PSMS	1486	PSIB	G2	Prestressed I-Beam	Y	3	79.29|92.00|79.29	10	7.83		7.83		6	3	1985
3004	PSMS	1487	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	3	74.30|96.78|74.30	25.47	5.56		5.56		16	7	2006
3005	PSMS	1488	PSIB	S_3_-_2nd_N_Int	Prestressed I-Beam	Y	3	43.62|90.22|43.62	0	8.53		8.53		13	8	2006
3006	PSMS	1489	PSIB	G2	Prestressed I-Beam	Y	3	93.96|95.00|93.73	-7	7.33		7.33		6	3	1986
3007	PSMS	1490	PSIB	G1	Prestressed I-Beam	Y	3	80.29|88.00|80.29	15	3.13	*	7.75		4	2	1986
3008	PSMS	1490	PSIB	G2	Prestressed I-Beam	Y	3	80.29|88.00|80.29	15	7.75		7.75		4	2	1986
3009	PSMS	1491	PSIB	G2	Prestressed I-Beam	Y	3	64.96|89.92|64.96	0	6.67		6.67		4	2	1987
3010	PSMS	1492	PSIB	G2	Prestressed I-Beam	Y	3	47.29|93.00|47.29	-20	7.83		7.83		6	3	1987
3011	PSMS	1493	PSIB	3_-_2nd_N_Int	Prestressed I-Beam	Y	3	95.33|95.00|95.33	15	7.42		7.42		6	3	1988
3012	PSMS	1494	PSIB	G2	Prestressed I-Beam	Y	3	55.25|88.00|55.25	0	9.5		9.5		5	3	1988
3013	PSMS	1495	PSIB	G2	Prestressed I-Beam	Y	3	75.29|86.00|75.29	0	8.83		8.83		5	3	1989
3014	PSMS	1496	PSIB	G2	Prestressed I-Beam	Y	3	92.13|93.00|92.13	-13	8.33		8.33		5	3	1992
3015	PSMS	1497	PSIB	G2	Prestressed I-Beam	Y	3	64.00|90.25|63.92	50	5.92		5.92		5	2	1992
3016	PSMS	1498	PSIB	G2	Prestressed I-Beam	Y	3	64.15|85.04|64.21	-24.89	9.33		9.33		4	2	1992
3017	PSMS	1499	PSIB	G2	Prestressed I-Beam	Y	3	99.08|100.00|98.83	15	8.83		8.83		5	3	1993
3018	PSMS	1500	PSIB	G2	Prestressed I-Beam	Y	3	90.08|91.00|90.08	-45	8.83		8.83		5	3	1993
3019	PSMS	1501	PSIB	G3	Prestressed I-Beam	Y	3	85.21|118.00|88.21	-27	9.75		9.75		6	4	1994
3020	PSMS	1502	PSIB	G2	Prestressed I-Beam	Y	3	62.29|86.00|62.29	0	7.75		7.75		5	2	1994
3021	PSMS	1503	PSIB	G3	Prestressed I-Beam	Y	3	84.71|111.96|86.22	-15	10.17		10.17		7	5	1994
3022	PSMS	1504	PSIB	G4	Prestressed I-Beam	Y	3	85.21|118.00|88.21	-27	9.75		9.75		6	4	1994

Appendix A – List of Girders used for analysis/rating comparisons

Girder #	Bridge Material	Bridge ID(3)	Bridge Type(4)	Girder Description(5)	Cross Section	Comp (Y/N)	Num Spans	Span Length(s) (ft)	Skew angle	Left Girder spacing (ft)		Right Girder spacing (ft)		Num Girders	Num Lanes	Year Built
3023	PSMS	1505	PSIB	G2	Prestressed I-Beam	Y	3	123.13|124.00|123.13	0	7.5		7.5		5	2	1995
3024	PSMS	1506	PSIB	G2	Prestressed I-Beam	Y	3	64.85|91.80|64.85	0	8.96		8.96		5	3	1996
3025	PSMS	1507	PSIB	G2	Prestressed I-Beam	Y	3	92.57|94.24|92.61	45.45	8.46		8.46		5	3	1999
3026	PSMS	1508	PSIB	G2	Prestressed I-Beam	Y	3	91.27|92.84|91.15	45	8.46		8.46		5	3	1999
3027	PSMS	1509	PSIB	G1	Prestressed I-Beam	Y	3	96.08|119.81|96.08	25	3.12	*	8.46		5	3	1999
3028	PSMS	1509	PSIB	G2	Prestressed I-Beam	Y	3	96.08|119.81|96.08	25	8.46		8.46		5	3	1999
3029	PSMS	1510	PSIB	G2	Prestressed I-Beam	Y	3	47.39|88.94|47.39	0	8.53		8.53		5	4	2000
3030	PSMS	1511	PSIB	G2	Prestressed I-Beam	Y	3	114.33|120.50|114.33	35	7.33		7.33		6	3	2002
3031	PSMS	1512	PSIB	G2	Prestressed I-Beam	Y	3	71.25|85.01|71.27	0	9		9		5	3	2002
3032	PSMS	1513	PSIB	3_-_2nd_N_Int	Prestressed I-Beam	Y	3	42.98|92.42|42.98	-30	6.01		6.01		7	3	2003
3033	PSMS	1514	PSIB	G2	Prestressed I-Beam	Y	3	77.23|88.00|77.23	10	7.42		7.42		6	3	2004
3034	PSMS	1515	PSIB	G2	Prestressed I-Beam	Y	3	103.27|111.00|103.27	30	8.67		8.67		5	3	2004
3035	PSMS	1516	PSIB	G2	Prestressed I-Beam	Y	3	108.34|110.00|108.34	25	9.17		9.17		4	2	2004
3036	PSMS	1517	PSIB	G2	Prestressed I-Beam	Y	3	72.00|90.00|72.00	-20	9		9		5	3	2004
3037	PSMS	1518	PSIB	3_-_2nd_W_Int	Prestressed I-Beam	Y	3	115.66|116.67|115.66	5	7.25		7.25		6	3	2005
3038	PSMS	1519	PSIB	G1	Prestressed I-Beam	Y	3	89.75|100.00|89.75	0	3.33	*	9		5	3	2005
3039	PSMS	1519	PSIB	G2	Prestressed I-Beam	Y	3	89.75|100.00|89.75	0	9		9		5	3	2005
3040	PSMS	1520	PSIB	G2	Prestressed I-Beam	Y	3	125.00|131.50|95.50	0	5.83		5.83		6	2	2006
3041	PSMS	1521	PSIB	G2	Prestressed I-Beam	Y	3	66.29|126.00|66.29	29.67	8.67		8.67		5	3	2006
3042	PSMS	1522	PSIB	G2	Prestressed I-Beam	Y	3	48.00|92.00|48.00	24.2	8.67		8.67		5	3	2006
3043	PSMS	1523	PSIB	G2	Prestressed I-Beam	Y	3	109.21|110.00|109.21	-25	8.67		8.67		5	3	2006

B Simple Span Steel Girder Bridges

B.1 Interior Composite Girders

The results for the girders in this subset are shown in the following sections. Four graphs are shown for each ratio or comparison that was made. The graphs show the same data but are plotted versus varying criteria. The criteria include year of construction, tributary width, skew angle, and span length. All live loads are distributed according to the appropriate distribution factors from the LFR and LRFD specifications. The LFR distribution factors are manually input by the user in Virtis; as such these values may or may not be correct.

B.1.1 Dead Loads

B.1.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure B-1, with the exception of one case the ratio of DC1 moments (self-weight, dead loads on non-composite section) are very close to 1.0. Those that are slightly below 1.0 are caused by the moment being obtained at the four-tenths point for LFR while the LRFR moment is calculated at midspan. RIO determines the location of the critical rating factor and then uses this location to obtain the moments due to dead and live loads. Figure B-1 shows one girder where the ratio of DC1 moments is 1.6. The reason for this is that the LFR critical section is at the eight-tenths point while the LRFR critical section is at midspan. This is caused by the thickness of the bottom flange changing at this location (and also the two-tenths point).

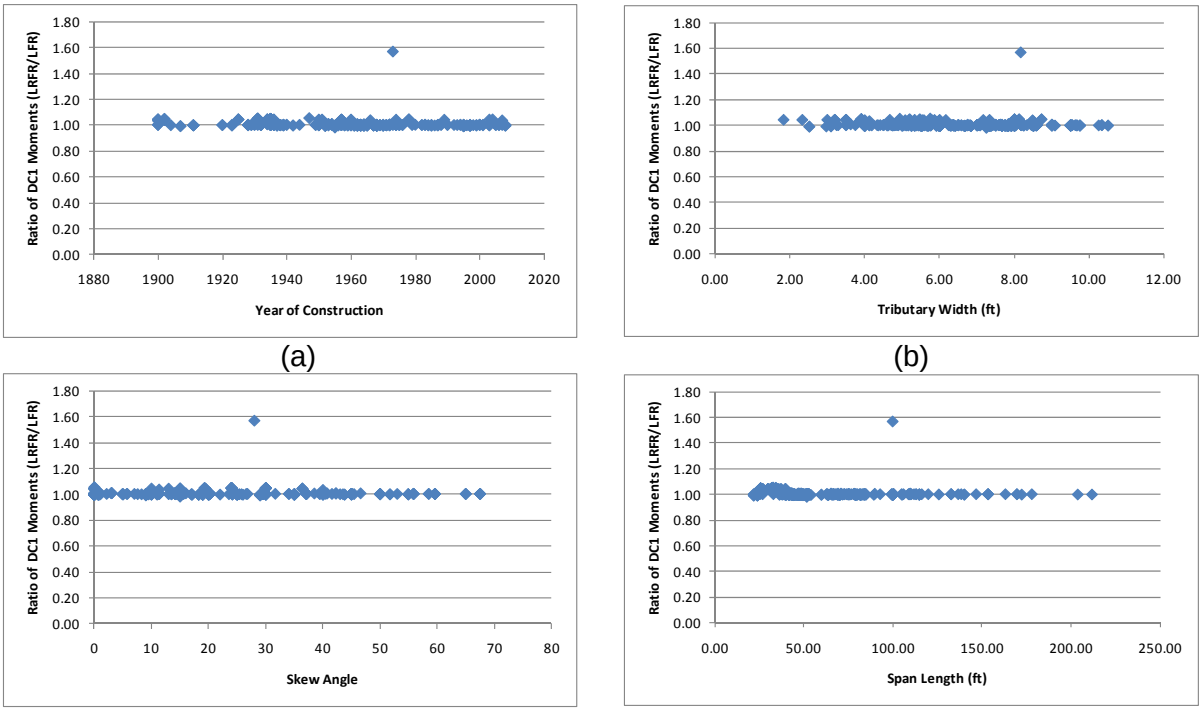


Figure B-1: Ratio of DC1 LRFR Moment to DC1 LFR Moment (unfactored loads)

Figure B-2 shows that there is more variation in the loads applied to the composite section (DC2 and DW loads). The variation is a result of some dead load moments not being output in the NCHRP 12-50 Process results. In most cases, the results are very close to 1.0.

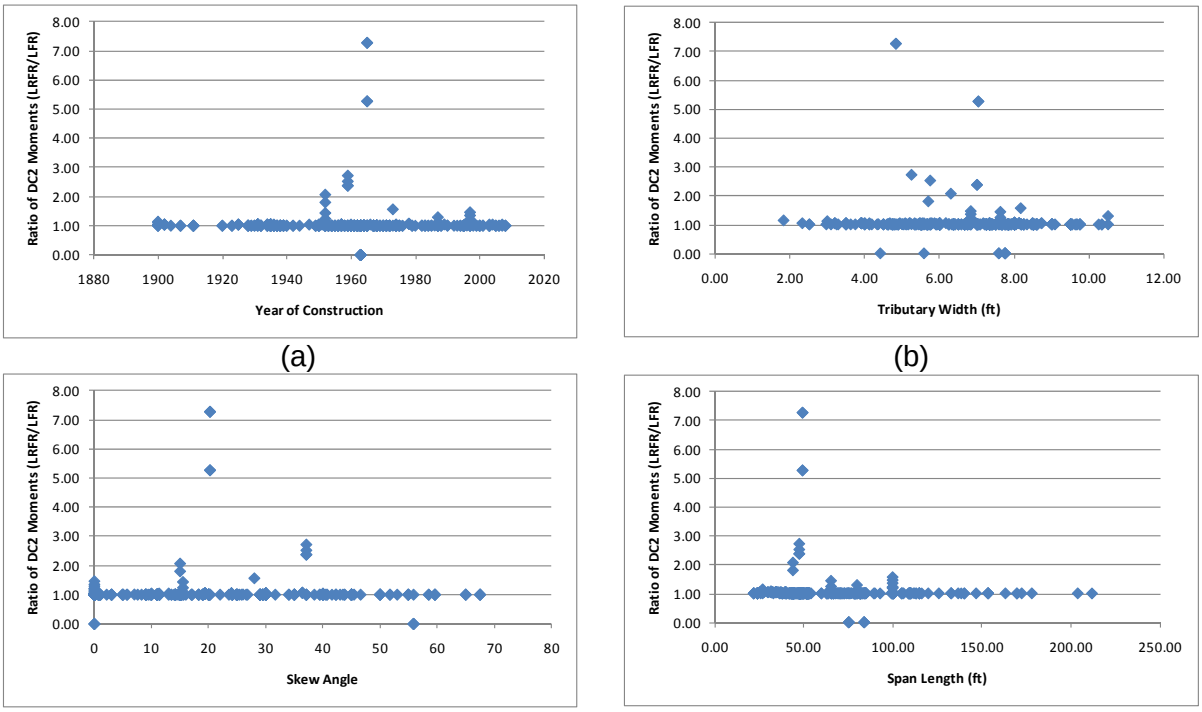
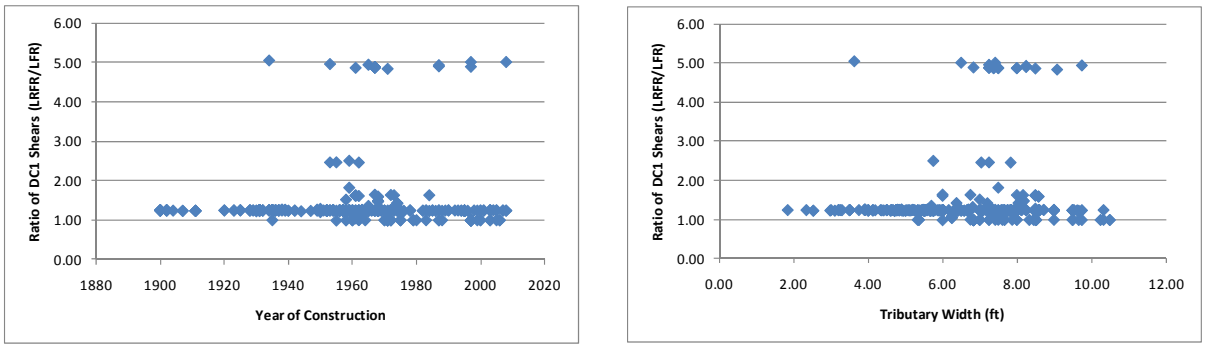
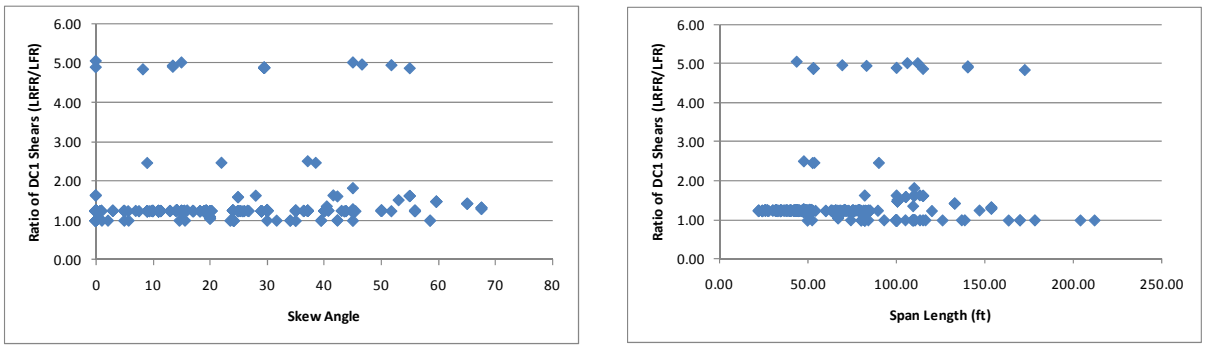


Figure B-2: Ratio of DC2 LRFR Moment to DC2 LFR Moment (unfactored loads)

B.1.1.2 Shear

Figure B-3 below shows that for most girders the LRFR DC1 shear is 125% of the LFR DC1 shear. This is a result of BRASS not always calculating a rating factor for shear at the support for LFR. The result was typically that the LFR rating was then calculated at either the one-tenth or nine-tenths point along the span. This would correspond to a 25% increase in dead load shear for simple spans (DC1 is a uniform load with maximum shear at the ends of the span and zero shear at midspan) when comparing LRFR to LFR.

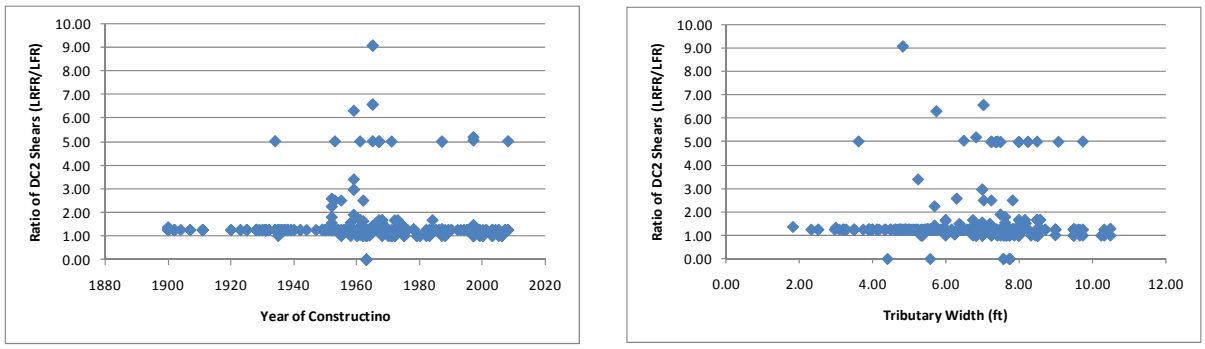




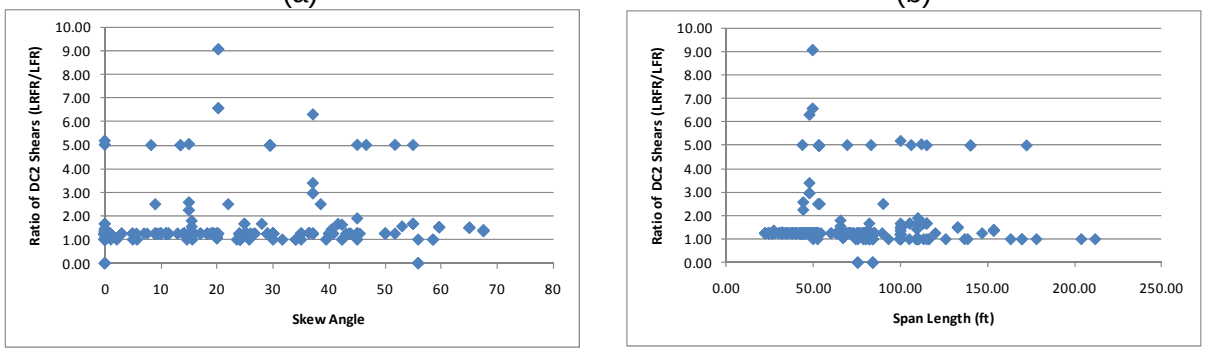
(c) (d)

Figure B-3: Ratio of DC1 LRFR Shear to DC1 LFR Shear (unfactored loads)

Figure B-4 shows the same trend as Figure B-3 in that the LRFR shear for the majority of girders is 125% of the LFR shear for DC2 loads. There is also more variation within the DC2 and DW loads than in the DC1 loads.



(a) (b)



(c) (d)

Figure B-4: Ratio of DC2 LRFR Shear to DC2 LFR Shear (unfactored loads)

B.1.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure B-5. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

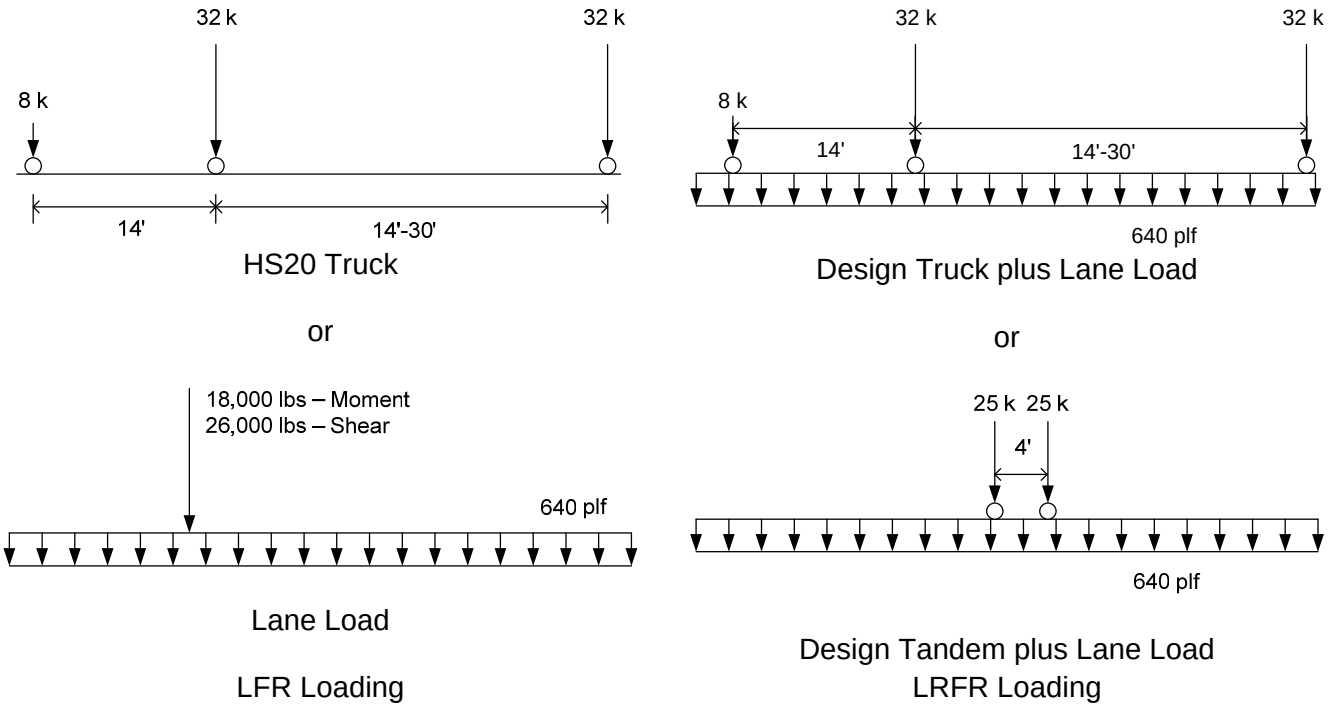
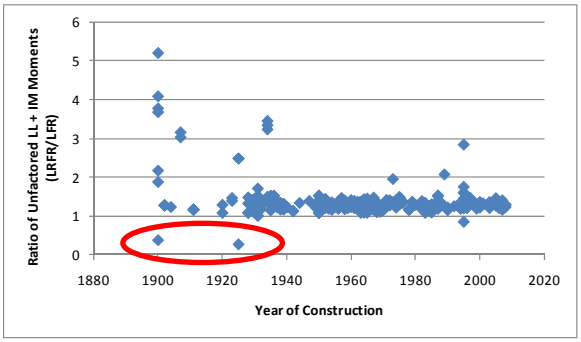


Figure B-5: Vehicle Loadings and Load Factors

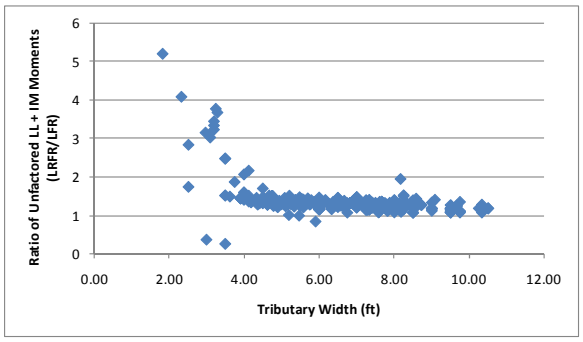
B.1.2.1 Moment

B.1.2.1.1 Live Loads

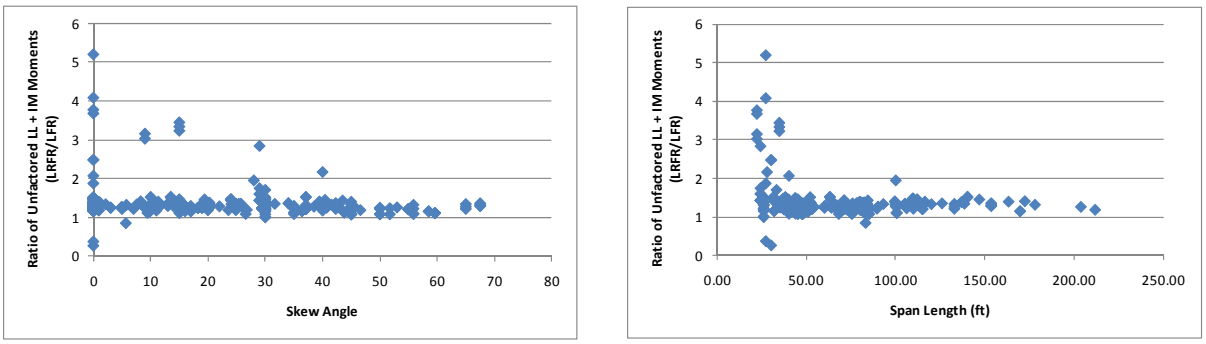
Figure B-6 shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is approximately 1.33 for most of the girders within this subset. The two circled points are of concern though as the moment because the HL-93 loading is expected to be larger than the HS-20 loading. Large differences that are not shared by other bridges with similar parameters is thought to indicate either a unique feature in the subject bridge that can be determined by reviewing the geometry and configuration of the bridge or an error in the input file.



(a)



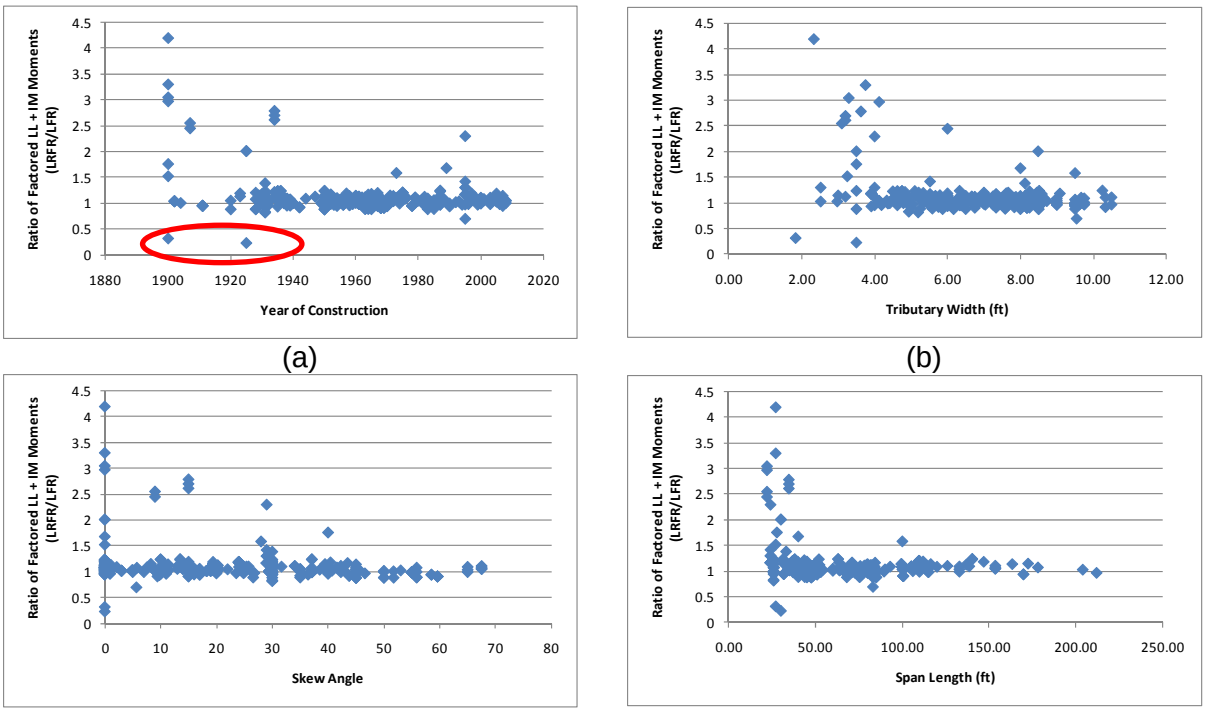
(b)



(c) (d)

Figure B-6: Ratio of Unfactored Live Load plus Impact Moments for Design Vehicle (LRFR/LFR)

The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-7 shows that the results have shifted down and are close to 1.0 for most cases.



(a) (b)

(c) (d)

Figure B-7: Ratio of Factored Live Load plus Impact Moments for Design Vehicle (LRFR/LFR)

Generally, the comparisons of the applied loads indicated that with the exception of bridges having special features, the calculated values seem to be in line with what is expected, i.e. unfactored dead loads are the same and unfactored HL-93 load is higher than the HS20-44 load with the difference in live loads decreasing when the loads are factored. Bridge special features resulting in significant differences in values include small girder spacing, presence of sidewalks, and thick decks. The girder with a ratio of factored live load in Figure B-7 is G4 from Figure B-8. This girder has a deck thickness greater than the range of applicability for the LRFD distribution factor equation and the lever rule is used to calculate the distribution factor. The distribution factor for LRFD is 0.06 lanes, while the LFR

distribution factor is 0.64 wheel lines. Additionally this girder is under the sidewalk, which is not accounted for in the LFR distribution factor but is accounted for in the application of the lever rule.

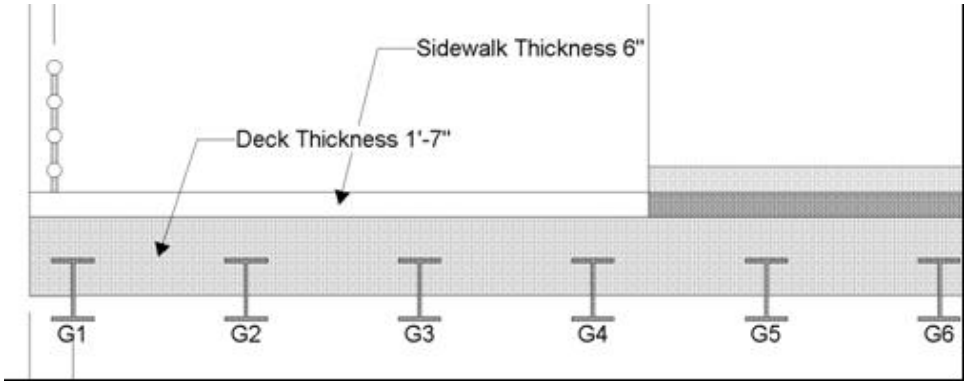


Figure B-8: Bridge with ratio of factored live load = 0.2

Another feature that was encountered was a bridge with a large variation in skew angle. This bridge was removed from the set as the goal is to look at typical bridges, while this bridge is clearly atypical. Figure B-9 shows a plan view of this bridge.

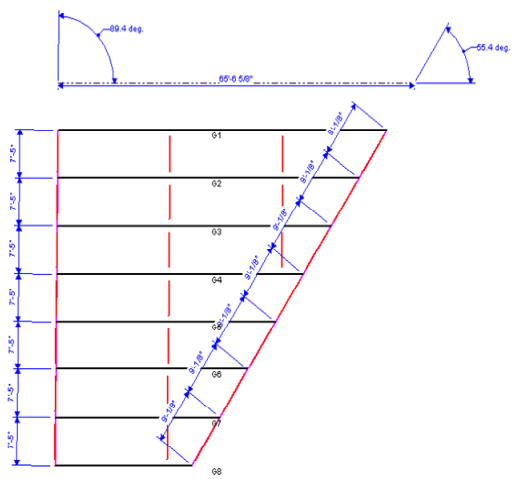
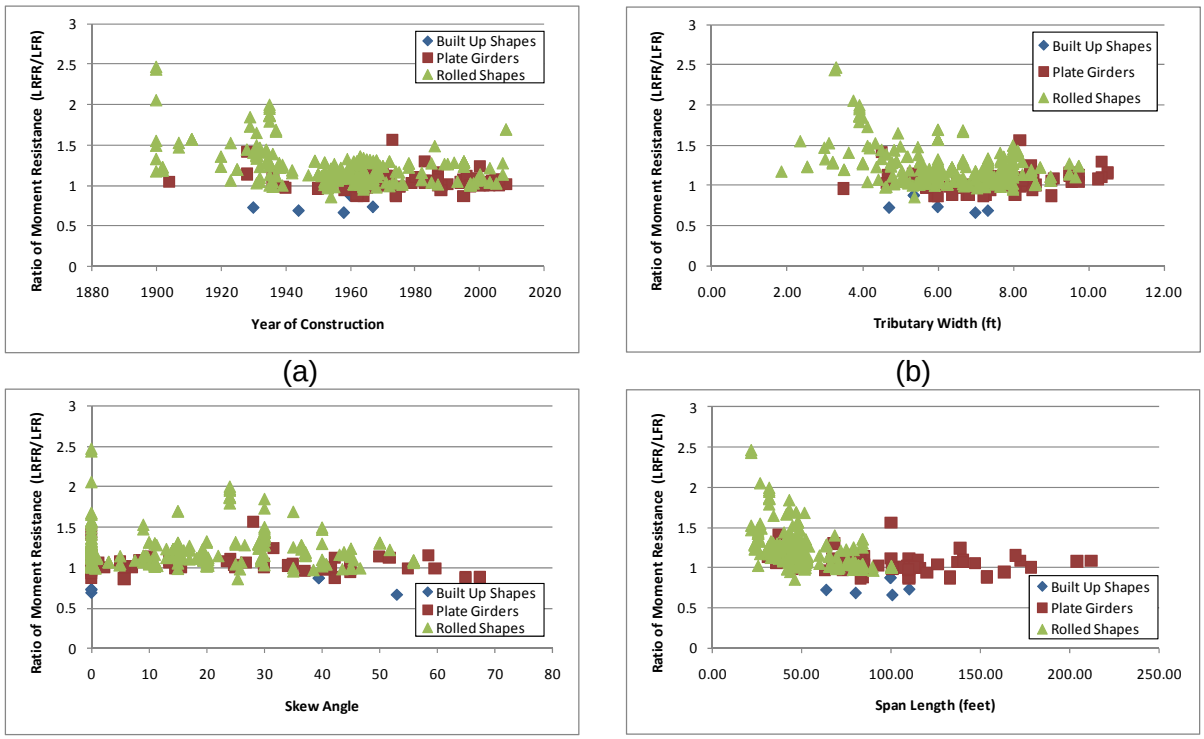


Figure B-9: Bridge with large variation in skew angle

B.1.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods of rating. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance after extracting all other terms of the equation from the BRASS output. Figure B-10 shows that the ratio of resistance is generally between 0.75 and 1.25. The ratios above 0.75 are either plate girders or rolled shapes, while those less than 0.75 are built up cross sections. Built-up shapes typically have higher resistance using LFR than when using LRFR. Rolled shapes and plate girders are more likely to have higher LRFR resistance than LFR resistance, though there are some exceptions shown in Figure B-10.



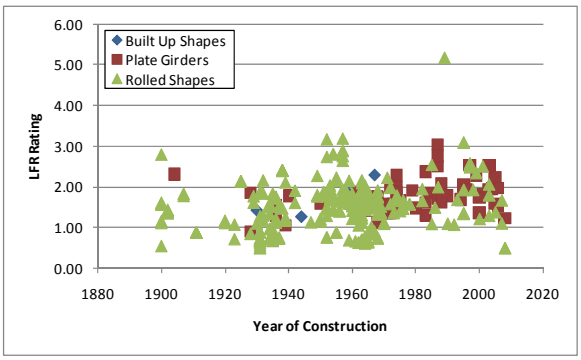
(a) (b)

(c) (d)

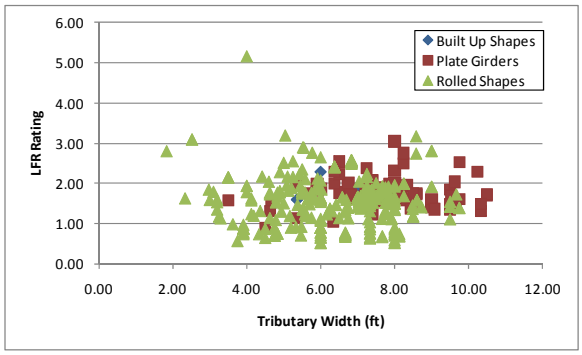
Figure B-10: Ratio of factored Moment Resistance (LRFR/LFR)

B.1.2.1.3 Rating Factors

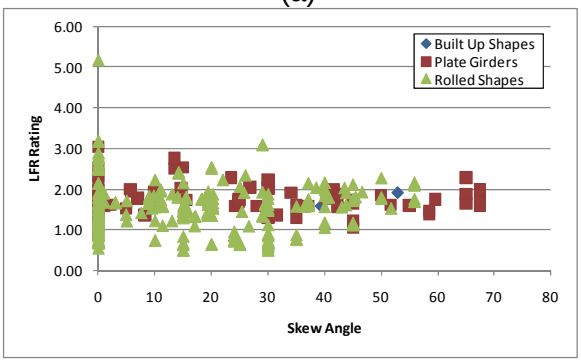
After comparing the loads and resistances to verify that those results seemed appropriate, the actual rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (432 girders) did not have inventory rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 70 girders with LFR ratings less than 1.0, 54 girders with LRFR ratings less than 1.0, and 41 girders where both the LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower rating factors. The results for this subset indicate that more girders had inventory ratings less than 1.0 for LFR than LRFR. In addition, the LRFR rating was greater than the LFR rating for two-thirds of the girders in this subset. This indicates that while the rating factor of some bridges dropped when they were rated using LRFR as compared to the LFR, overall the rating factors have actually improved for this subset of bridges considered in these comparisons. Figure B-11 and Figure B-12 show the LFR rating factors and LRFR rating factors, respectively.



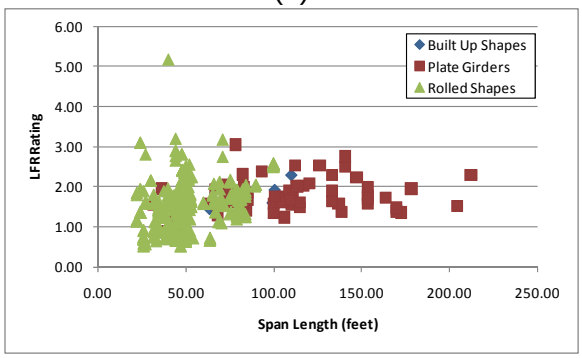
(a)



(b)

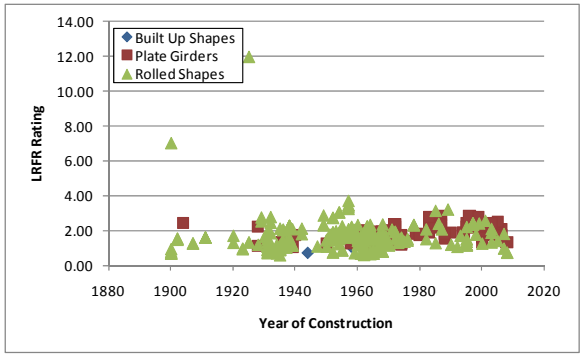


(c)

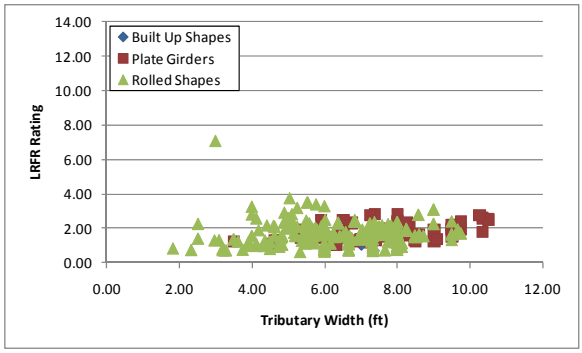


(d)

Figure B-11: LFR Flexure Rating Factors for HS-20 Vehicle



(a)



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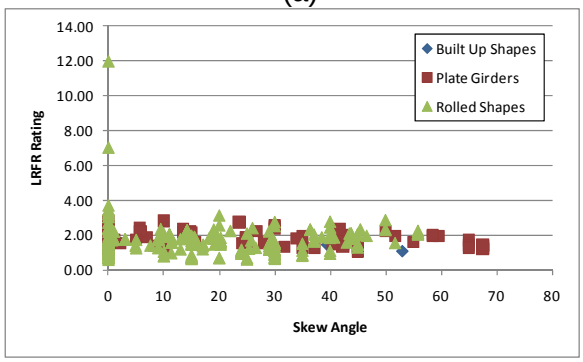
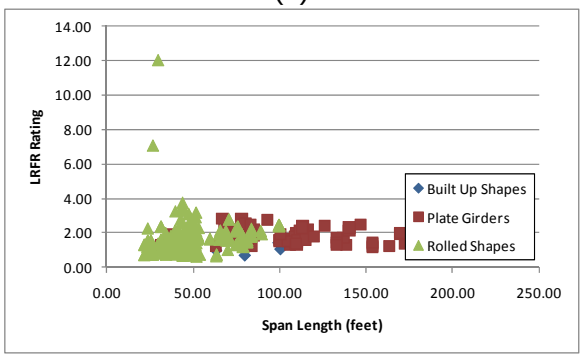


(c)



(d)

Figure B-12: LRFR Flexure Rating Factors for HL-93 Design Load

B.1.2.1.4 Rating Factor Comparisons

The LRFR rating factor was then divided by the LFR rating factor to determine if there were any trends in the data. This is shown in Figure B-13. The results show more scatter for short span lengths but the results generally approach one for longer spans. For the results graphed versus tributary width, the LFR Rating is larger for small tributary widths (small girder spacing) as signified by the smaller LRFR/LFR rating ratio. The ratio increases to be over 1.0 for larger tributary widths signifying larger rating factors for LRFR than for LFR. Built-up cross-sections have larger LFR ratings compared to LRFR rating as the ratio is close to 0.5. This is likely a result of the resistance being larger for LFR than for LRFR.

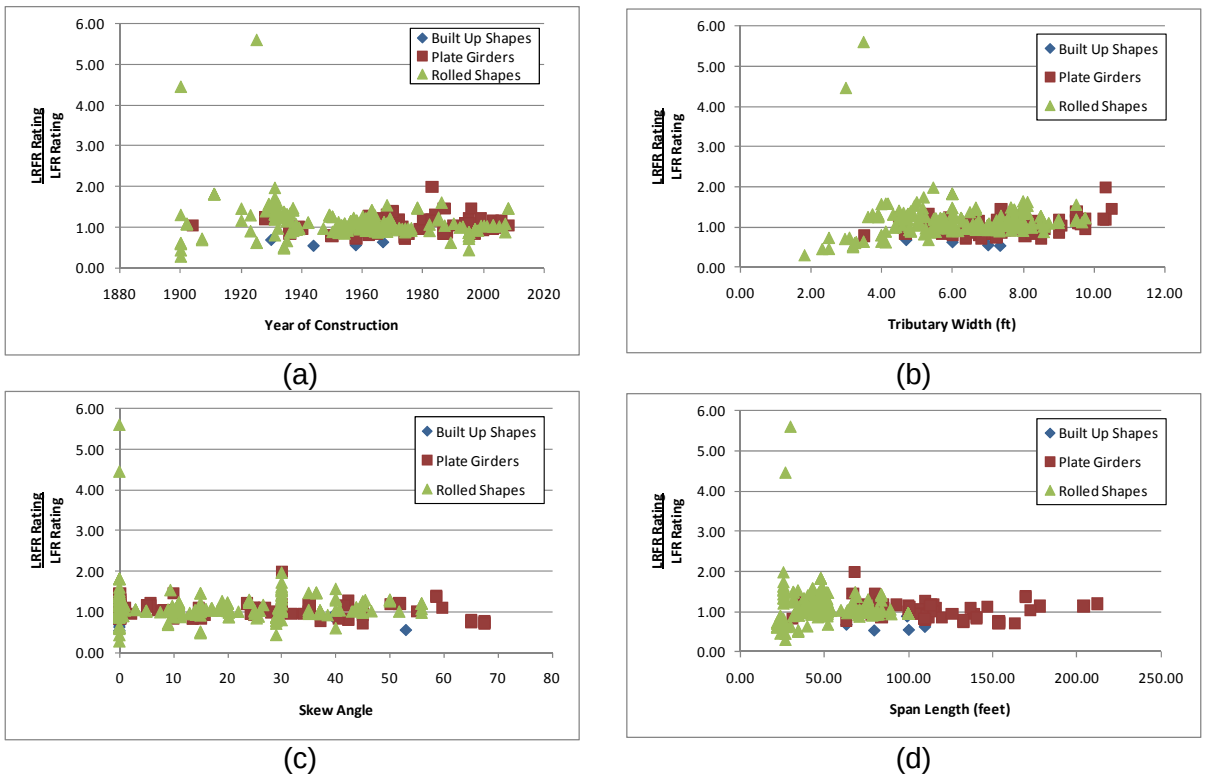


Figure B-13: Ratio of Flexure LRFR Rating to LFR Rating for Design Vehicles

Figure B-14 shows how the ratio of LRFR rating to LFR rating varies for the girders with a LRFR rating less than 1.0. For most girders with an LRFR rating less than 1.0, the LRFR rating is greater than the LFR rating. The remaining girders would required a reduction in live load of 30 to 60% to return the LRFR rating to a value similar to the LFR rating.

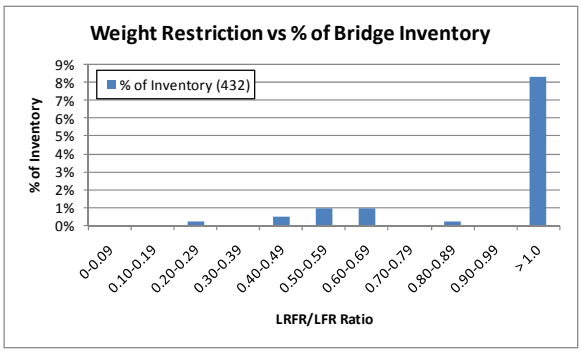


Figure B-14: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

B.1.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure B-15 shows that most girders in this subset have a reliability index higher than that assumed in the development of the LRFR rating at this loading level. This result is encouraging because while some girders may have ratings less than 1.0 they still provide the level of reliability assumed in the LRFR rating, i.e. 3.5. The required level of reliability is higher because of the time frame used in the development of the rating manual. The superstructure element will have higher reliability for a time frame of 5 years as used in the MBE compared to 75 years used in the LRFD Design Specification.

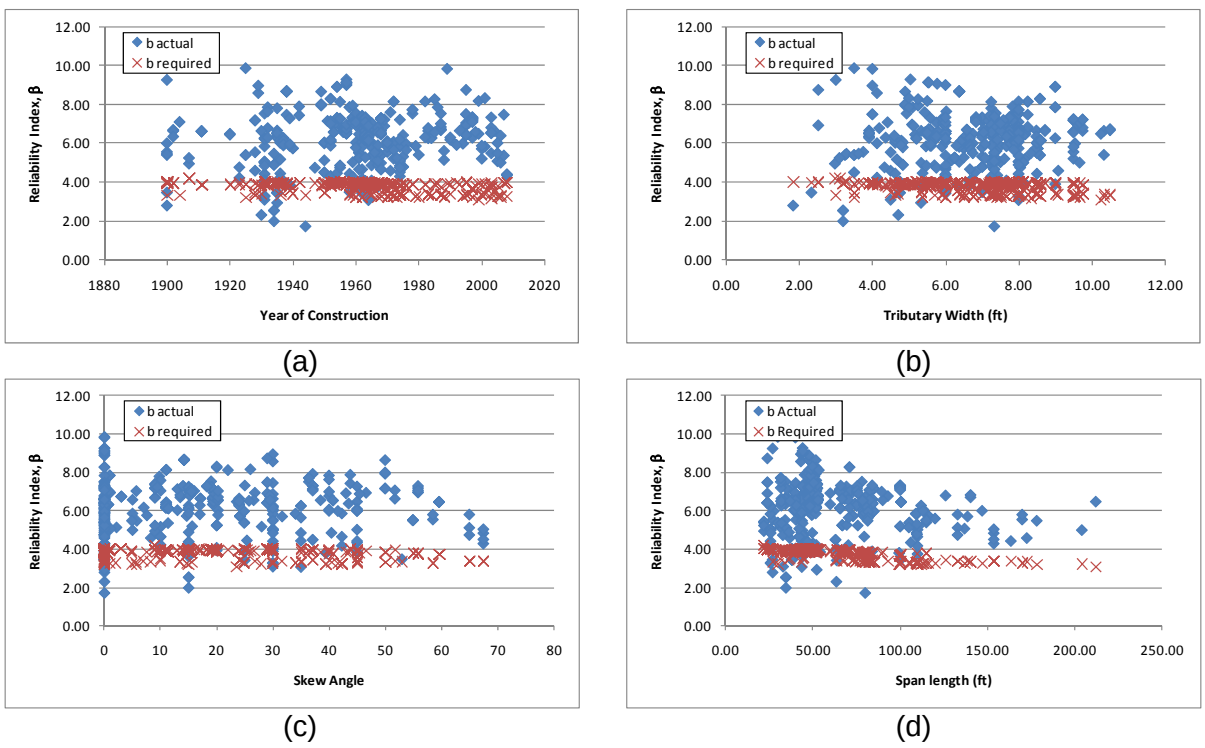


Figure B-15: Reliability Indices for Flexure for HL-93 Design Load

Figure B-16 shows the actual reliability index, based upon the resistance of the cross-section, versus the calculated LRFR rating factor. From this figure, it can be seen that an LRFR rating factor of 1.0 corresponds to a girder with a reliability index of approximately 3.5. This indicates that the design live load factor results in the level of reliability expected at the inventory level.

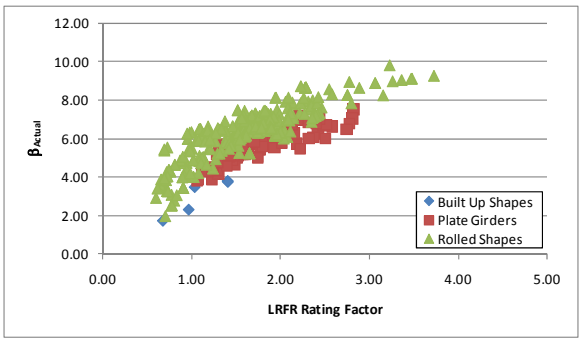


Figure B-16: Reliability Index versus LRFR Rating Factor

B.1.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is steel, simple span interior girders with composite concrete decks.

B.1.2.2.1 Live Loads

Figure B-17 shows that the ratio of unfactored LRFR live load shear to unfactored LFR live load shear is typically between 1.25 and 2.0. There are two outliers for which the LFR shear is significantly larger than the LRFR shear. These two girders correspond to those that were discussed as outliers for moment (see Figure B-6 and Figure B-7). The large difference in live loads for the outliers is again caused by the difference in how special features, such as sidewalks, were considered in the determination of the distribution factors in the two methods.

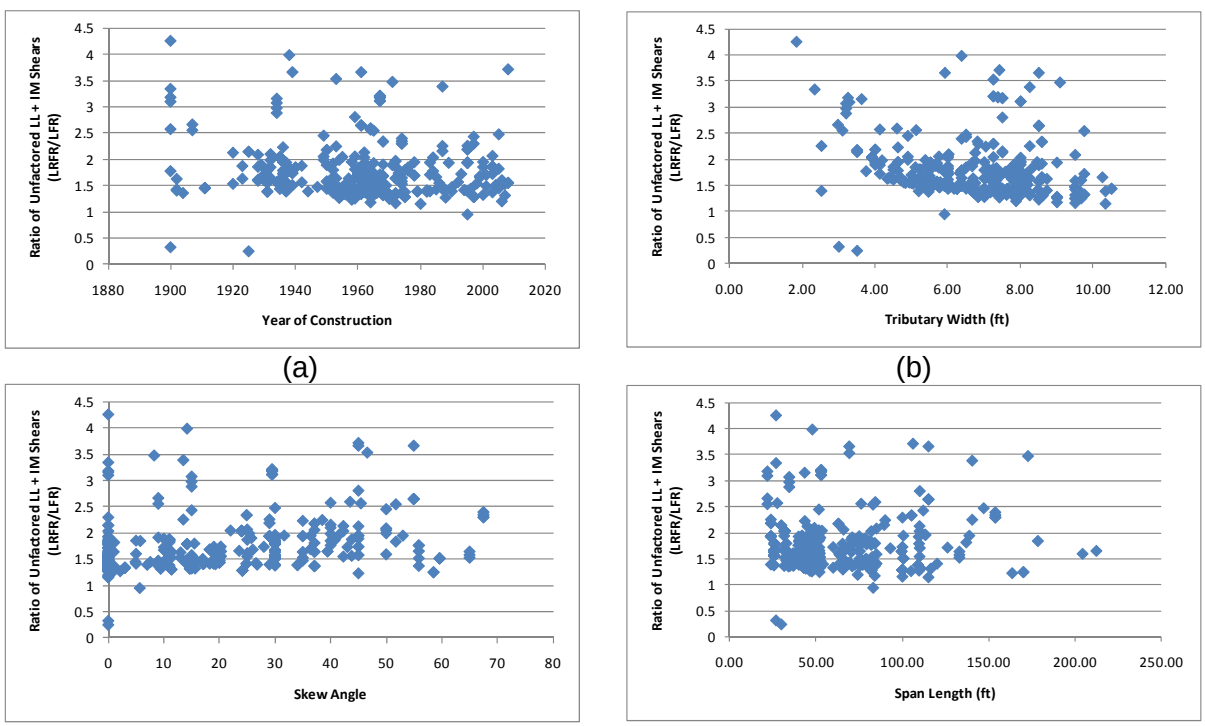


Figure B-17: Ratio of Unfactored Live Load plus Impact Shears for Design Vehicles (LRFR/LFR)

The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor

equation for an inventory rating. Figure B-18 shows that the ratio of factored live load shears has decreased and is between 1.0 and 1.5 for most cases.

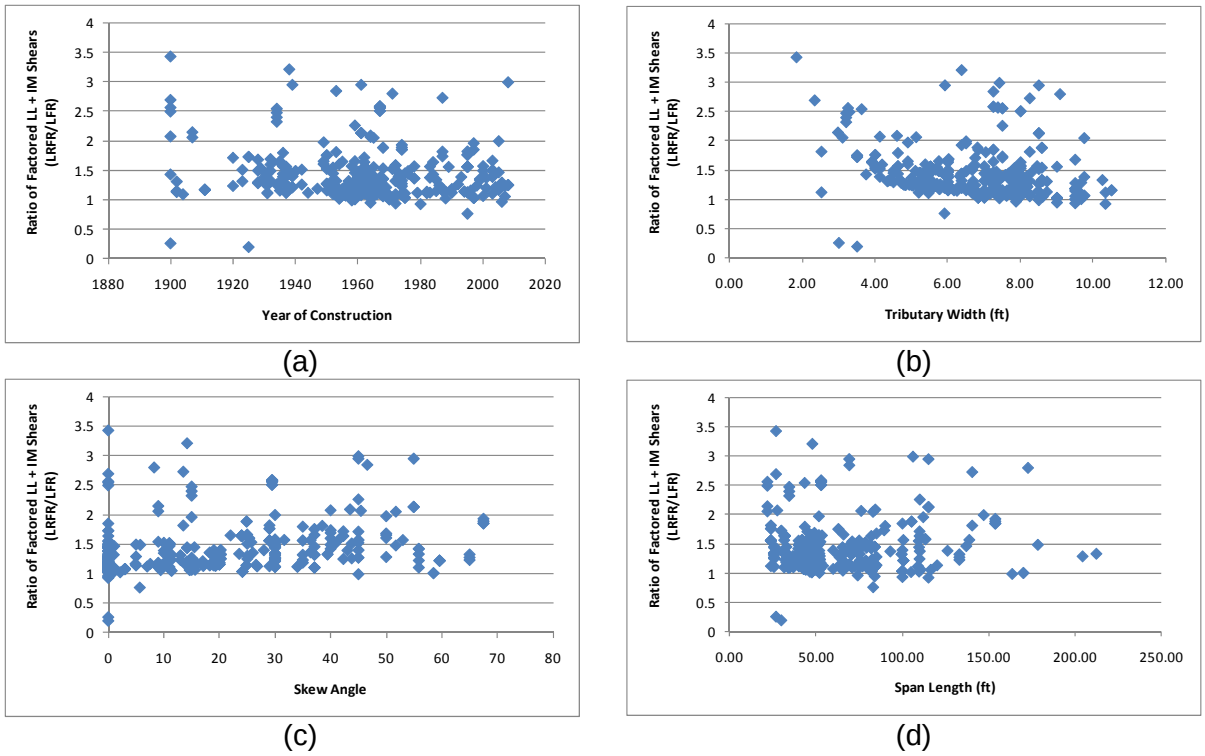
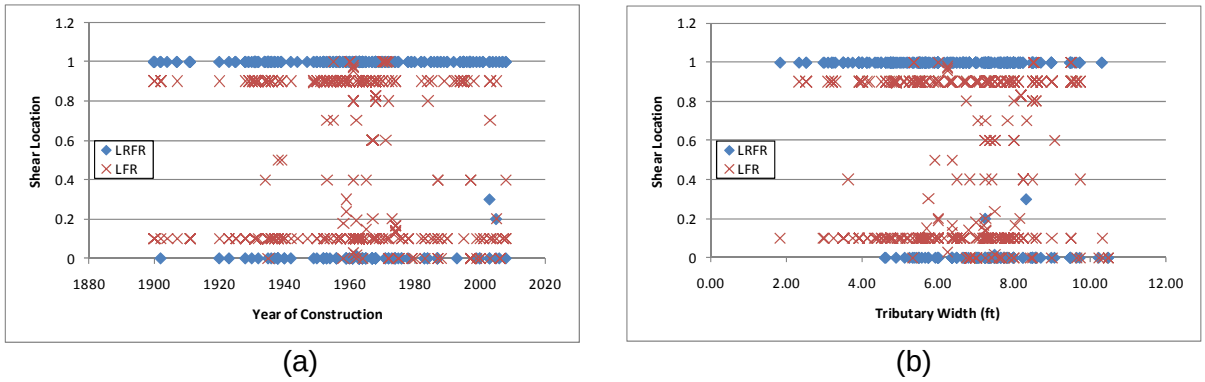
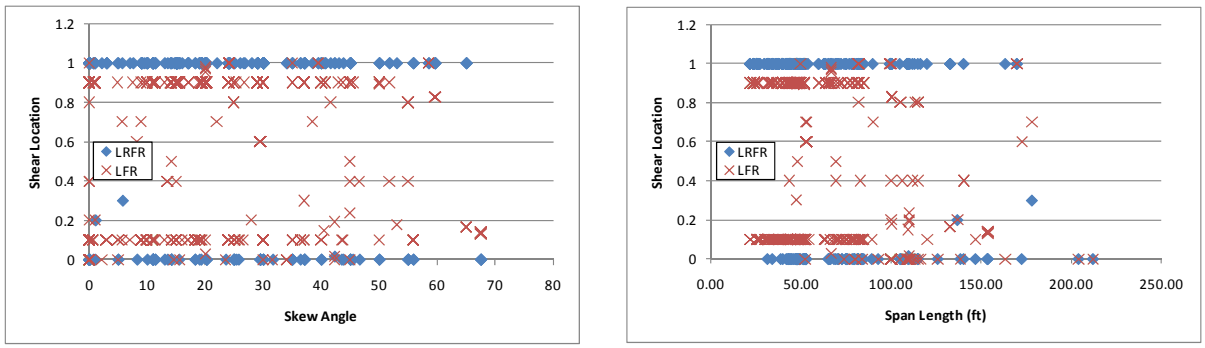


Figure B-18: Ratio of Factored Live Load plus Impact Shears for Design Vehicles (LRFR/LFR)

As shown in Figure B-19, the location of the critical section for shear rating for most girders is the end of the span and at the one tenth point for the LRFR and LFR ratings, respectively. The difference in the factored shears shown in Figure B-18 was exacerbated by the difference in the critical section for shear rating. Figure B-19 also shows that there are many girders where the LFR critical location is near the middle of the span instead of the end. The remaining graphs in this section consider all girders; the graphs in the following section, B.1.2.3, consider only those girders where the critical location was at the support or the one- or nine-tenths points.



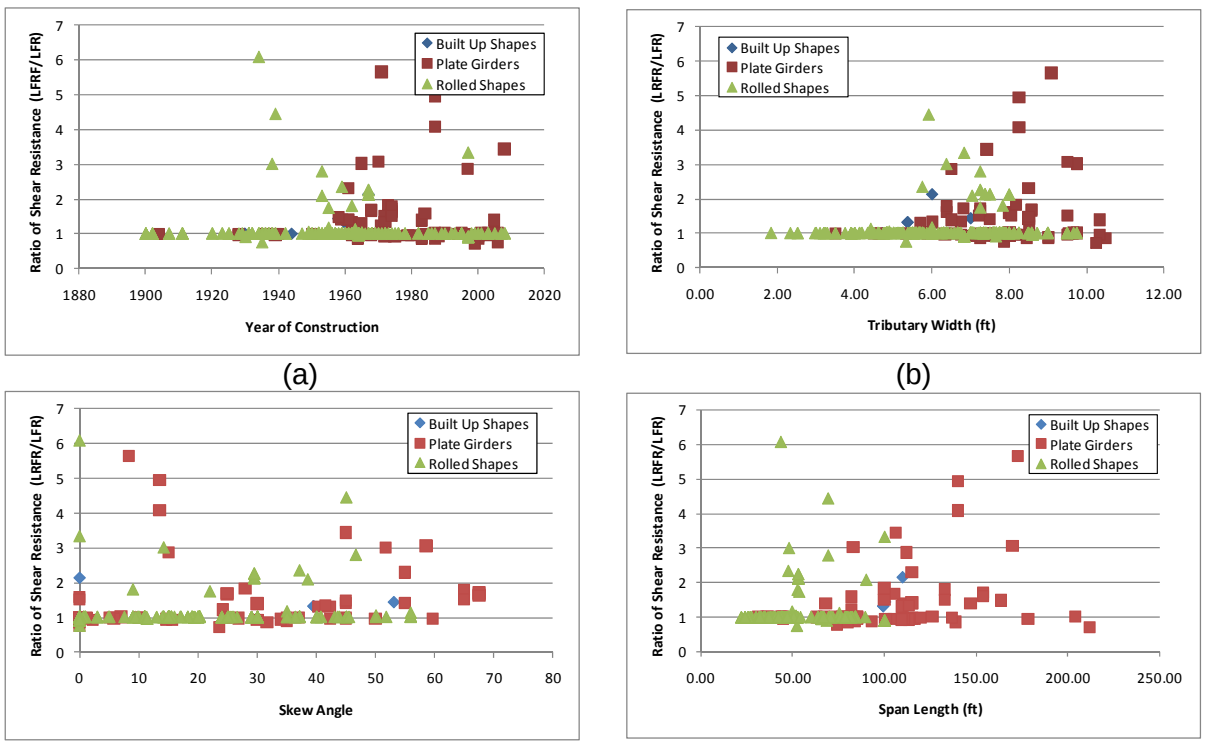


(c) (d)

Figure B-19: Graph of critical shear location for Design Vehicles

B.1.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure B-20 shows that the ratio of resistance is generally between 1.0 and 2.0. The shear resistance of rolled shapes was typically very close to 1.0, with plate girders more likely to have higher LRFR resistances than LFR resistances.



(a) (b)

(c) (d)

Figure B-20: Ratio of factored Shear Resistance (LRFR/LFR)

B.1.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results seemed appropriate, the actual rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 0 girders with LFR ratings less than 1.0 and 49 girders with LRFR ratings less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. In addition, the LFR rating was greater than the LRFR rating for 98% of the girders in this subset. Figure B-21 and Figure B-22 show the LFR rating factors and LRFR rating factors, respectively.

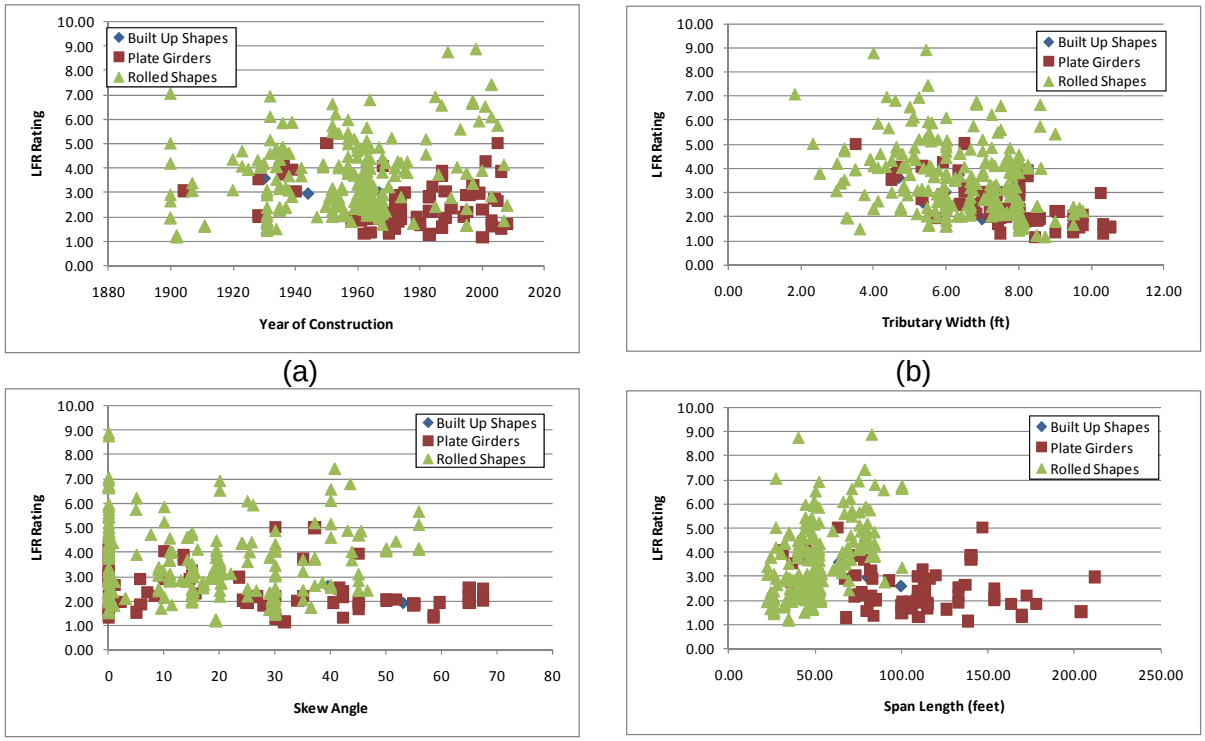
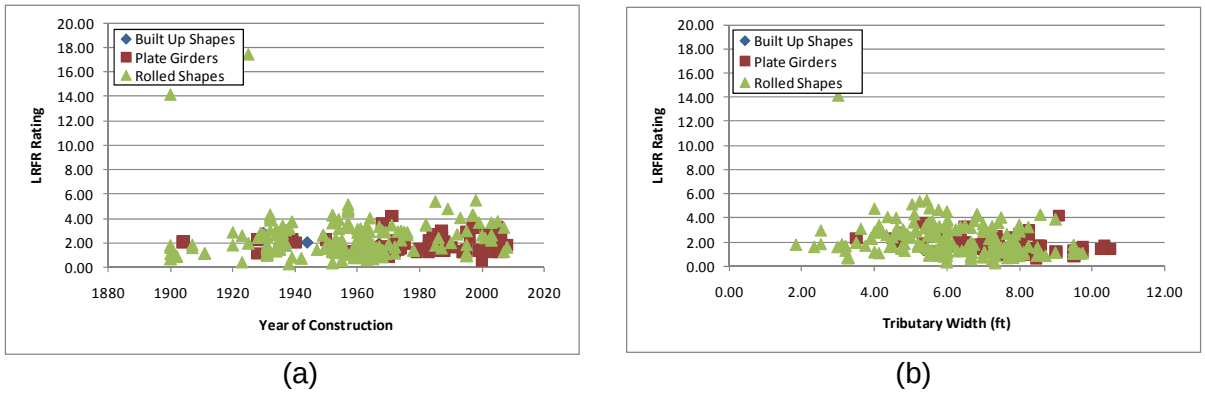
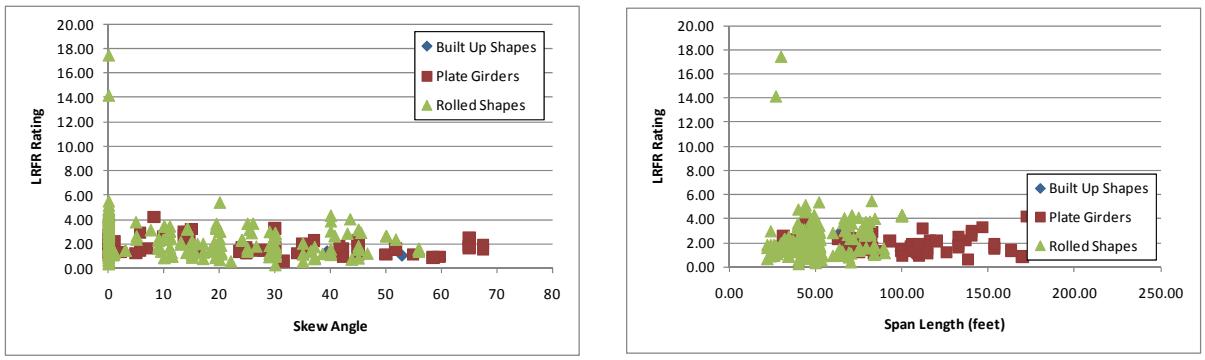


Figure B-21: LFR Shear Rating Factors for HS-20 Loading

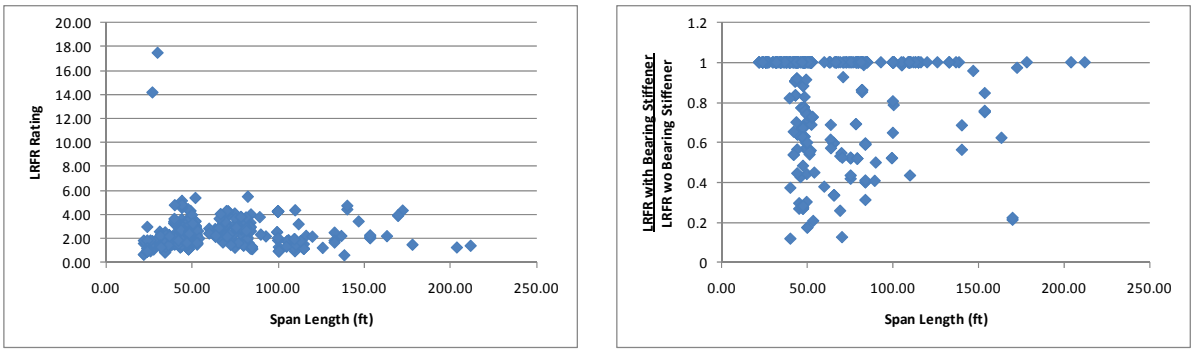




(c) (d)

Figure B-22: LRFR Shear Rating Factors for HL-93 Design Vehicle

Figure B-23a shows the LRFR shear ratings when the bearing stiffener rating is ignored. The figure shows that girders have higher ratings for spans less than 100 feet. Ignoring the bearing stiffener rating, resulted in 30 fewer girders having ratings less than 1.0 than when it was included. Most of these girders are less than 100 feet in span length. Figure B-23b shows the ratio of LRFR rating including the bearing stiffener rating divided by the LRFR rating when the bearing stiffener is ignored. Figure B-23b shows that most of the girders that are affected by the bearing stiffener rating are less than 100 feet in span length and a significant portion is less than 50 feet. 36% of the girders have lower LRFR rating when the bearing stiffener rating is included than when it is excluded.

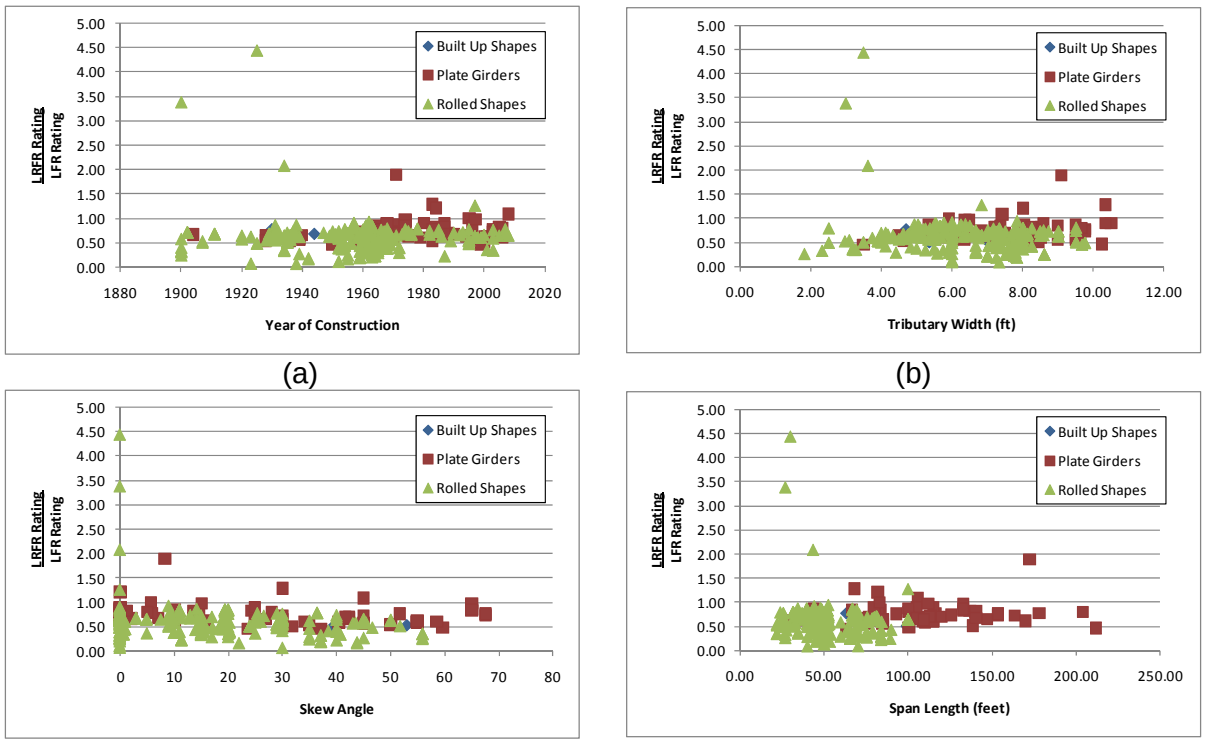


(a) (b)

Figure B-23: Effect of Bearing Stiffener Rating on LRFR Shear Rating

B.1.2.2.4 Rating Factor Comparisons

Figure B-24 shows the ratio of the LRFR rating to the LFR rating. The results show that the LRFR rating is typically around one-half the LFR rating. There are very few cases where the LRFR rating is greater than the LFR rating, and two of these are where there is a sidewalk present and the live load reaching the girder is significantly smaller for LRFR than for LFR. The results shown below rate using the current MBE and considers the bearing stiffener rating, which was found to control 36% of the girders in this subset. This is one reason for the significantly lower LRFR ratings.



(a) (b) (c) (d)

Figure B-24: Ratio of Shear LRFR Rating to LFR Rating for Design Vehicles

Figure B-25 shows the distribution of LRFR/LFR rating factor ratio for those girders with an LRFR rating factor less than 1.0. The figure shows that for most girders, a significant reduction in loads would be required to raise the LRFR rating to the LFR rating. Most of these girders are controlled by the bearing stiffener rating criteria.

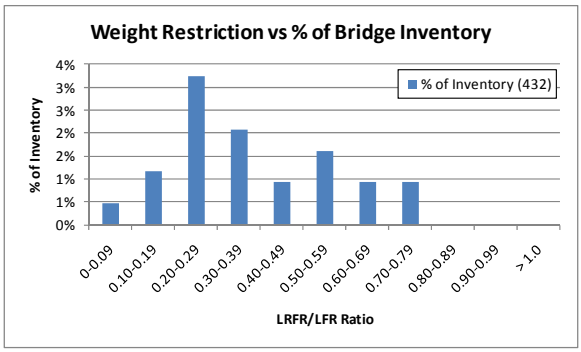


Figure B-25: Distribution of LRFR/LFR Ratio for girders with LRFR Rating Factor less than 1.0

B.1.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure B-26 shows that most girders in this subset have the level of reliability assumed in the LRFD Specifications (reliability index of 3.5). This result is encouraging because while the girder may rate at less than 1.0 the structure is still providing the required level of reliability. The reason there appear to be two levels of required reliability is due to the different statistical parameters used for rolled and built-up shapes and for welded plate girders.

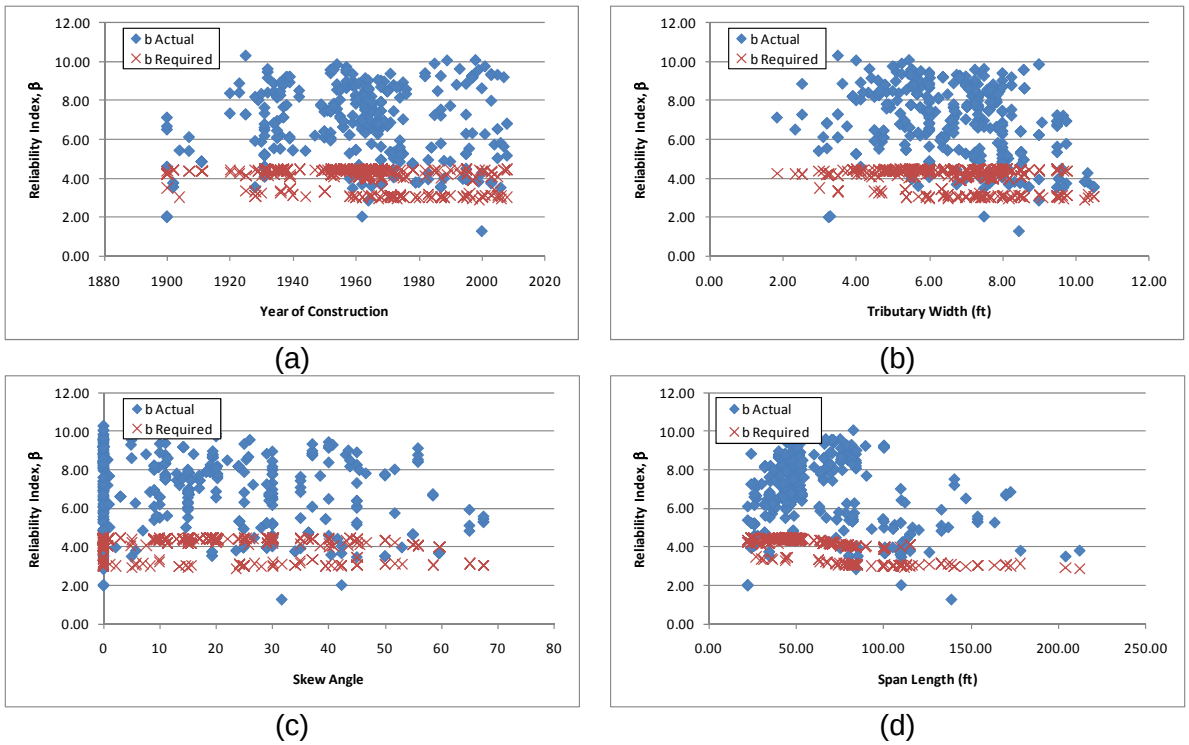


Figure B-26: Shear Reliability Indices for HL-93 loading

Figure B-27 compares the actual reliability index, based upon the resistance of the cross-section, and the calculated LRFR rating factor. If the live load factor is properly calibrated, then a girder with a rating factor of 1.0 would have a reliability index of 1.75 for the design load. Ignoring the first red square above 1.0, the graph indicates that a LRFR rating factor of 1.0 would have a reliability index of 3.5.

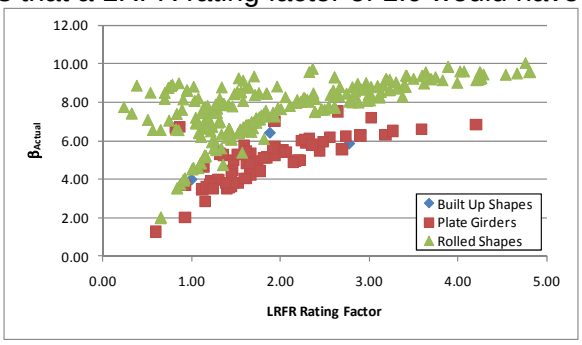


Figure B-27: Reliability Index versus LRFR Rating Factor

B.1.2.3 Shear-Corrected

Close examination of the BRASS output for shear ratings revealed the following problems that complicated the comparisons:

- Shear ratings for LFR and LRFR are not at the same location
- For LRFR Rating, BRASS checks ratings for both web shear and bearing stiffener resistance. The controlling shear resistance is taken as the controlling value of the bearing stiffener rating and the web shear rating. For LFR rating, only web shear is considered.

To better compare the ratings from the two methods, the following was utilized:

- To normalize the analysis, only the girders where the LRFR and LFR controlling shear rating were at the end and at the one- or nine-tenths point, respectively. The LFR shears were

increased by a factor of 1.25 to determine the approximate value of the end shear of the simple spans using the values calculated at the one- or nine-tenths point.

- The LFR resistance at the end of the span was assumed equal to that calculated at the one- or nine-tenths point. For plate girders and built-up girders, assuming that the shear resistance at the end and at the tenth point is equal implies that tension field action is considered at the support.

Incorporating these assumptions eliminated 166 girders from 432 girders originally in the subset. The following figures are based on the 266 remaining girders.

B.1.2.3.1 Live Load

Figure B-28 shows that the ratio of unfactored shear is typically between 1.0 and 2.5. There are two low outliers which correspond to the same girders that were discussed as outliers for moment (see Figure B-6 and Figure B-7). The large difference in live loads for the outliers is again caused by the difference in the application of the distribution factor equations between LFR and LRFR methods for bridges with special features such as sidewalks.

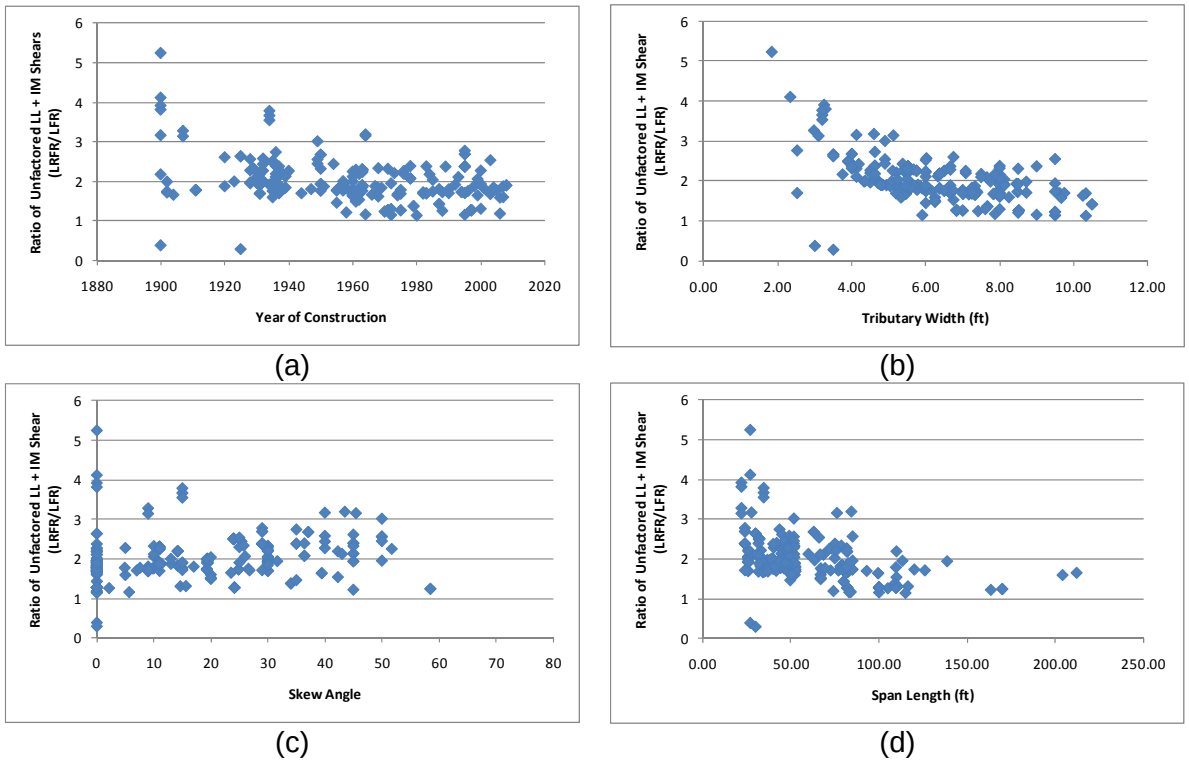


Figure B-28: Ratio of Unfactored Live Load plus Impact Shear for Design Vehicles (LRFR/LFR)

The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-29 shows that the ratio of factored live load shears has increased and is between 1.0 and 1.5 for most cases.

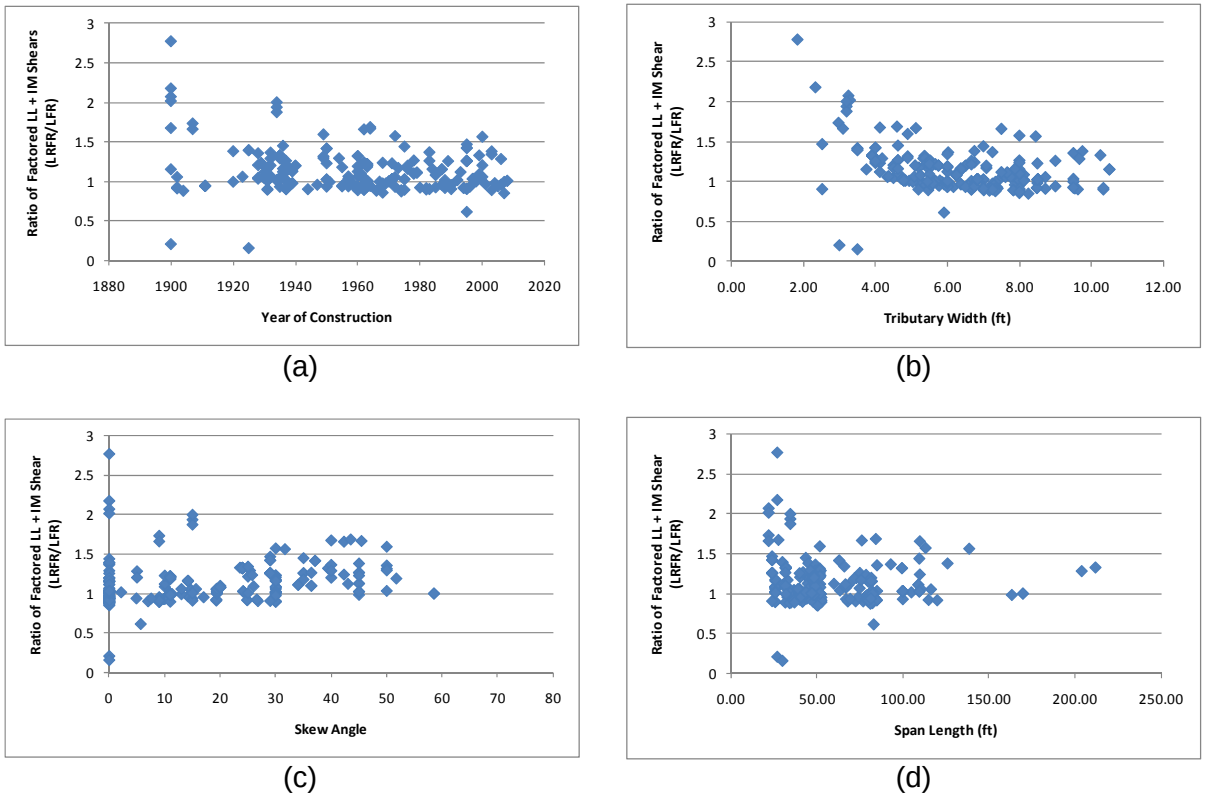
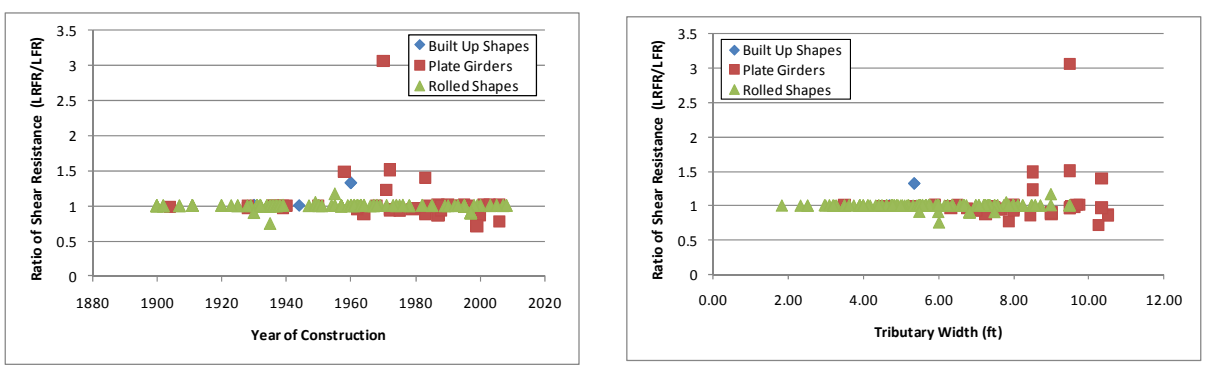
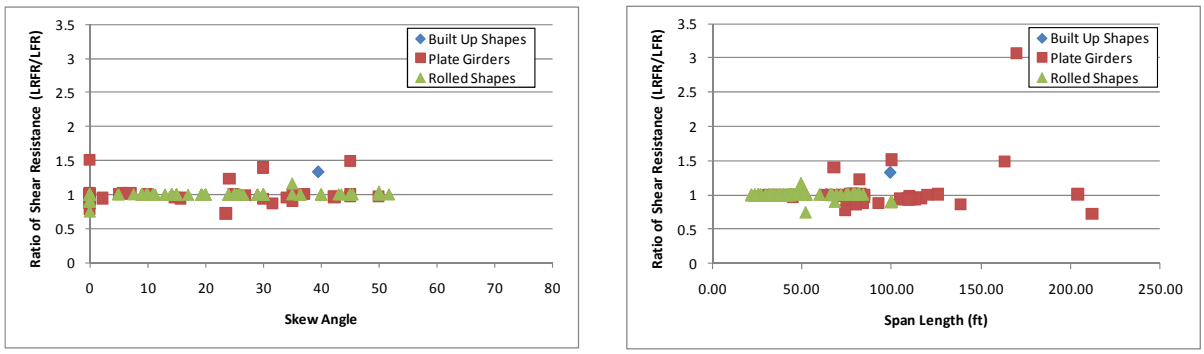


Figure B-29: Ratio of Factored Live Load plus Impact Shear for Design Vehicles (LRFR/LFR)

B.1.2.3.2 Resistance

The resistances used in this comparison (see Figure B-30) are the same as those shown in the previous section. It was assumed that the stiffener spacing remained constant between the support and the one-tenth point and that tension field action was considered in the end panel; therefore the shear resistance would remain the same. Figure B-30 shows that the range of resistance ratios has been significantly reduced by removing the girders with critical locations away from the support.



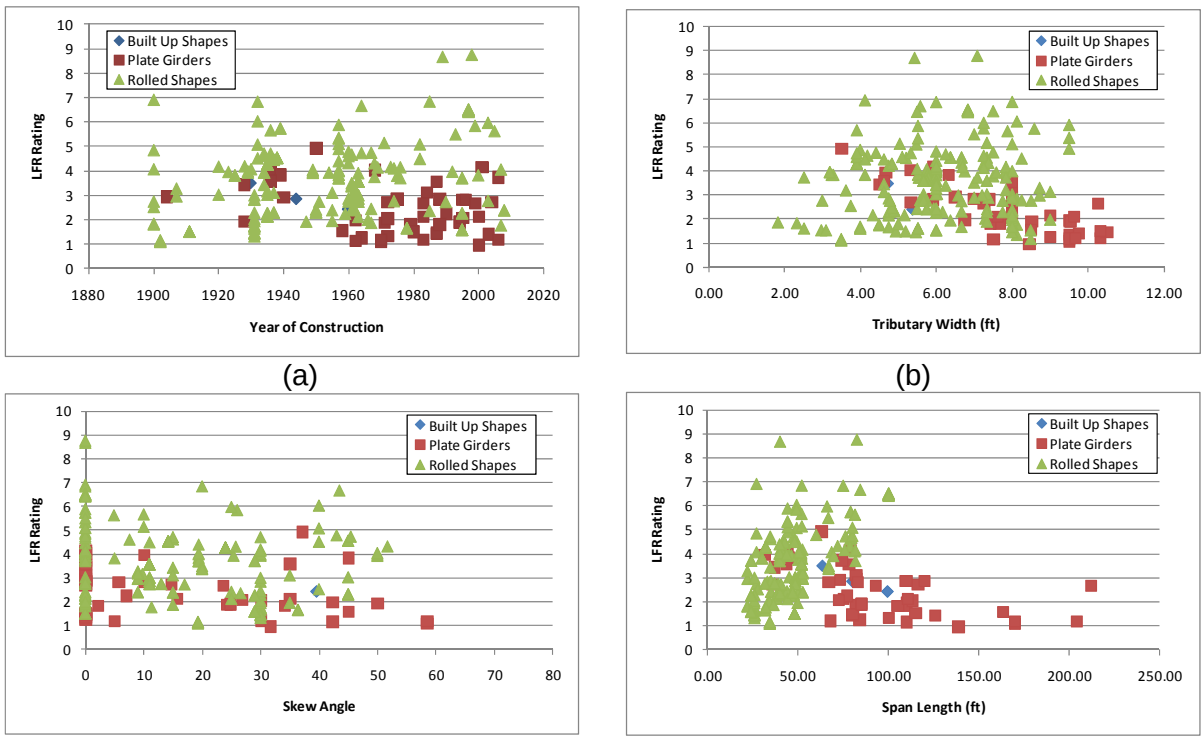


(c) (d)

Figure B-30: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.2.3.3 Rating Factors

The LFR rating factors were calculated using the loads from the one- or nine-tenths point multiplied by 1.25 such that they would approximate the shear at the support. The LFR rating factors are shown in Figure B-31.



(a) (b)

(c) (d)

Figure B-31: LFR Shear Rating Factors for HS-20 Loading

The LRFR rating factors are calculated at the support and are used as obtained from BRASS. The LRFR rating factors are shown in Figure B-32.

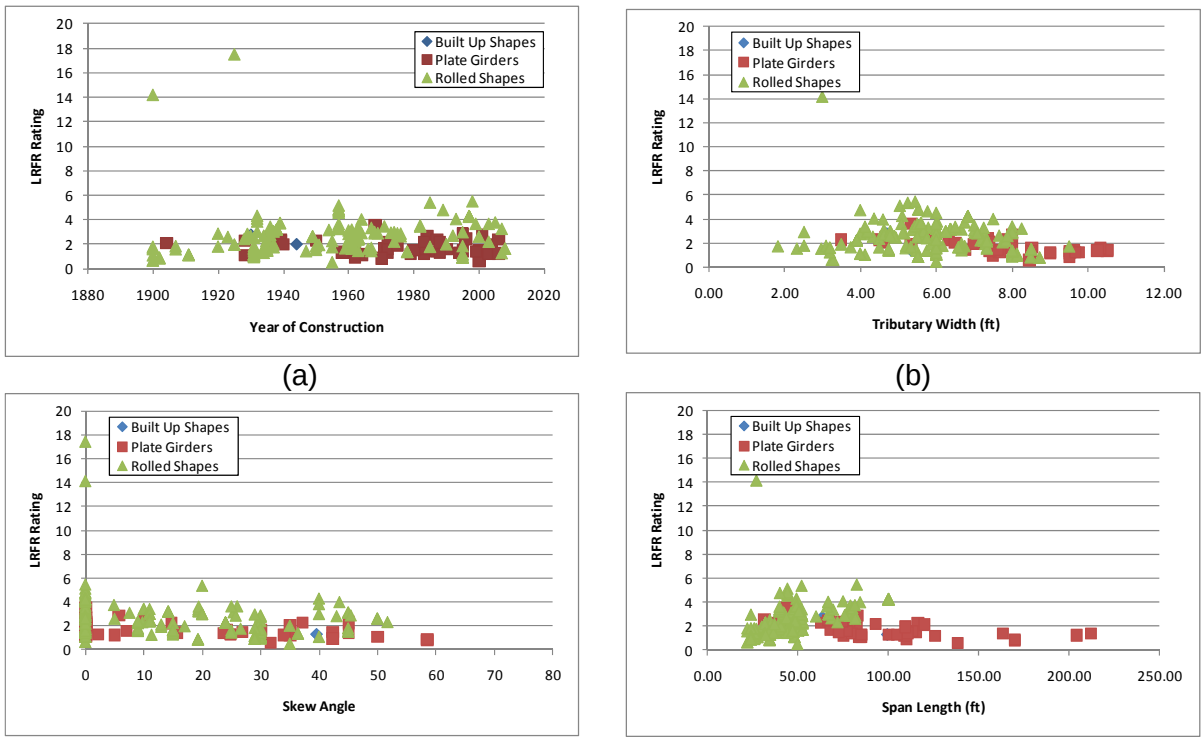
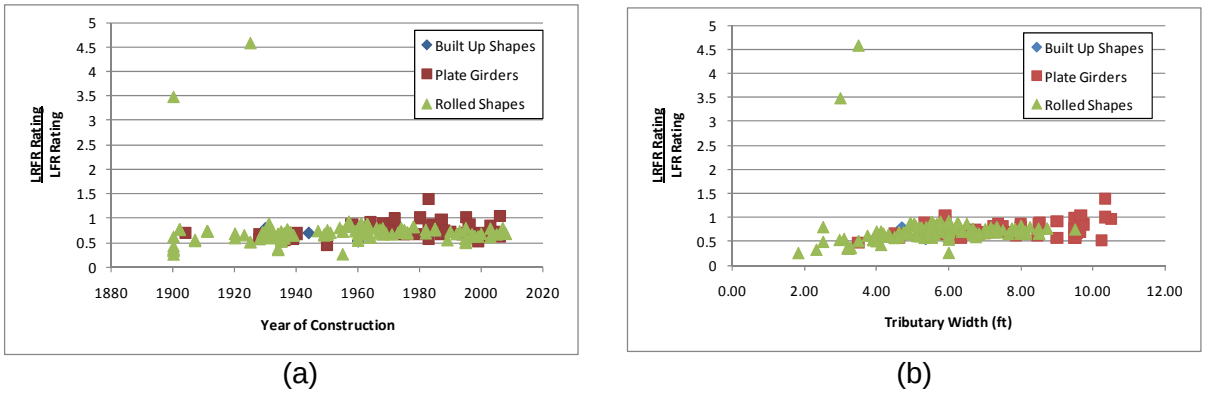
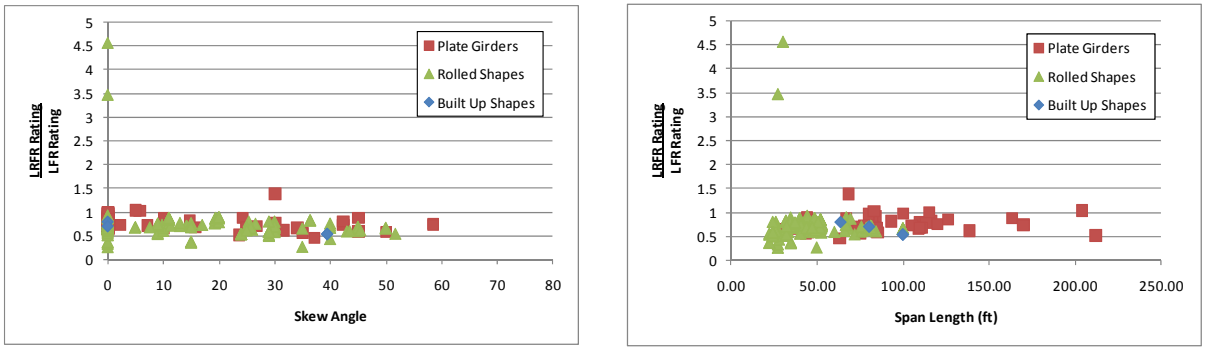


Figure B-32: LRFR Shear Rating Factors for HL-93 Loading

B.1.2.3.4 Rating Factor Comparison

After calculating the LFR rating factor at the support, the two rating factors were compared by dividing the LRFR rating by the LFR rating. The results of this comparison are shown in Figure B-33. The results show that most ratios are between 0.5 and 1.0, but almost always less than 1.0. Rolled shapes generally have smaller ratios while plate girders generally have larger ratios.



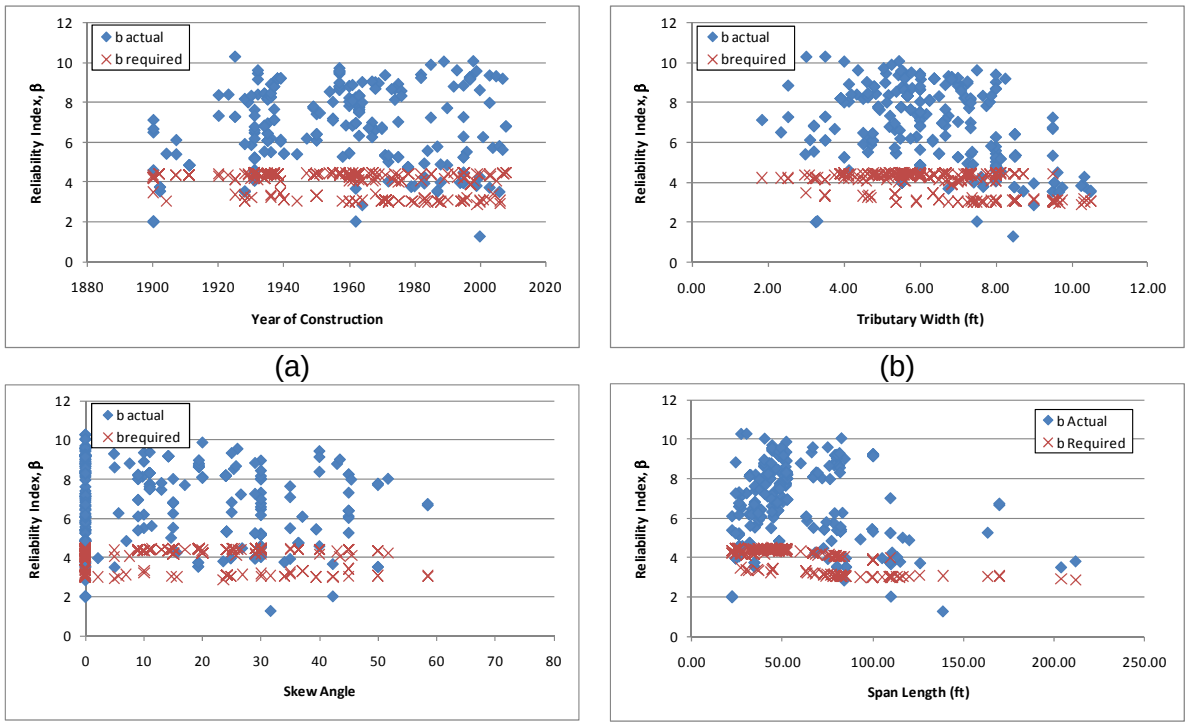


(c) (d)

Figure B-33: Ratio of LRFR Shear Rating Factor to LFR Rating Factor for Design Vehicles

B.1.2.3.5 Reliability Indices

The reliability indices shown in Figure B-34 are the same as those shown above in Figure B-26. The reliability indices shown in Figure B-26 will not change because the LRFR location is assumed to remain the same. There may be fewer girders that appear to not have the required level of reliability when compared to Figure B-26.



(a) (b)

(c) (d)

Figure B-34: Reliability Indices for Design Vehicles

B.1.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-35. The applicable load factors for these vehicles are 1.30 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

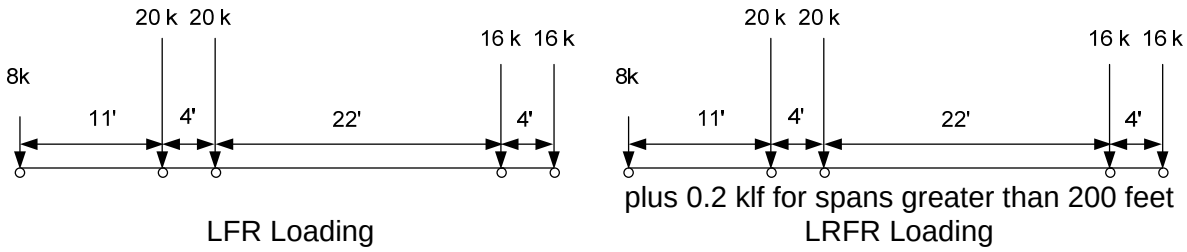


Figure B-35: Vehicle Loadings and Load Factors

B.1.3.1 Moment

The following section contains the results for interior, composite steel girders within simple span bridges for the DE-07 Vehicle.

B.1.3.1.1 Live Loads

The results in Figure B-36 show that the LFR moment is similar to those for LRFR, with approximately equal numbers having higher LFR loads or higher LRFR loads. As with the design vehicle, there are several outliers due to the presence of a side walk on the bridge. The unfactored moments for LRFR are 75 to 125% of the LFR moments.

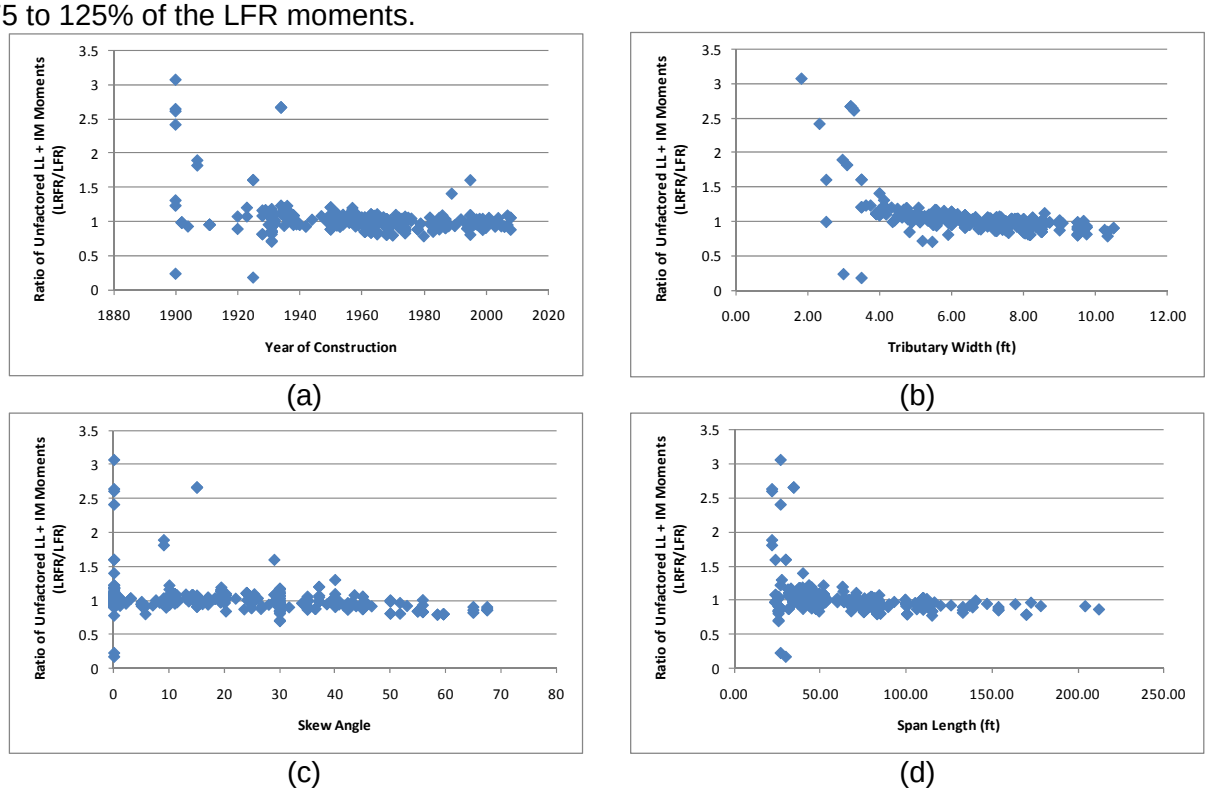


Figure B-36: Ratio of Unfactored Live Load plus Impact Moments for DE-07 Vehicle (LRFR/LFR)

The ratio of factored live loads is also compared. The LFR live load is factored by 1.30 which corresponds to an operating rating while the LRFR live load is factored by 1.6 for a routine permit rating. The results are shown in Figure B-37. The LRFR factored loads are 100 to 150% of the LFR factored loads.

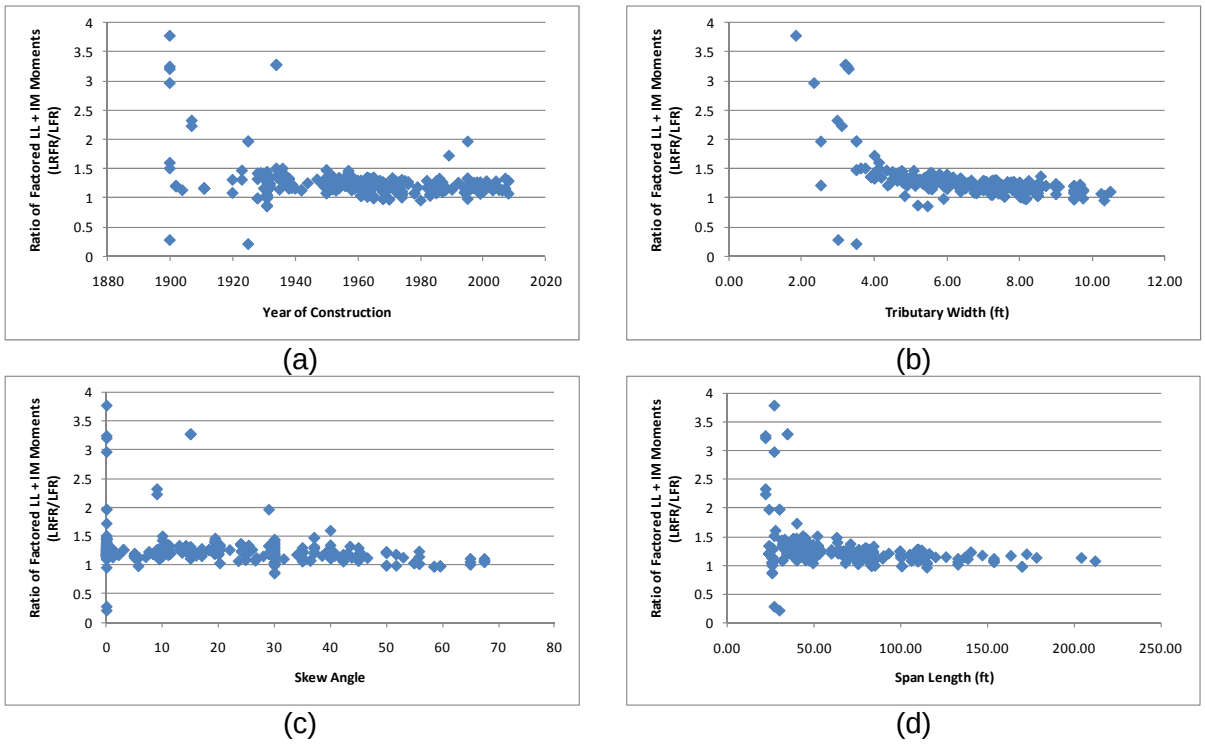
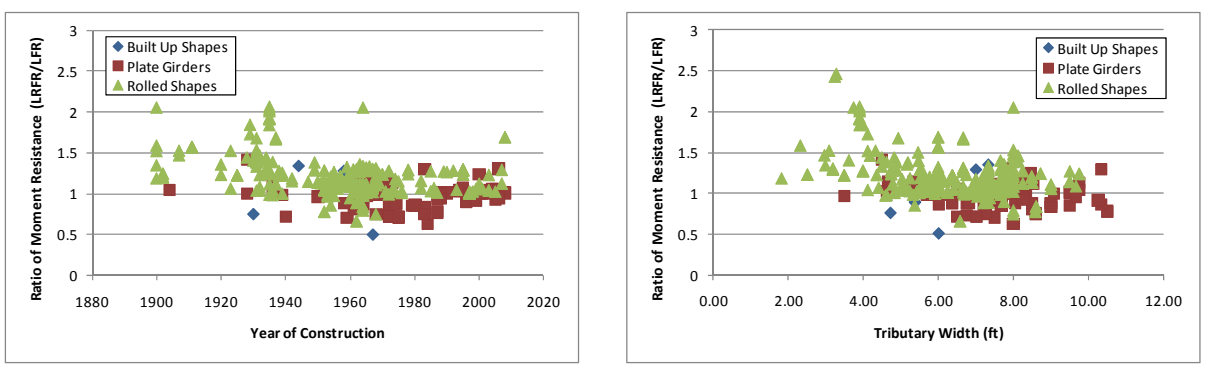
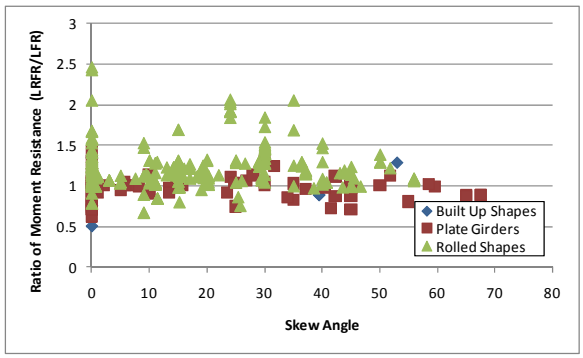


Figure B-37: Ratio of Factored Live Load plus Impact Moments for DE-07 Vehicle (LRFR/LFR)

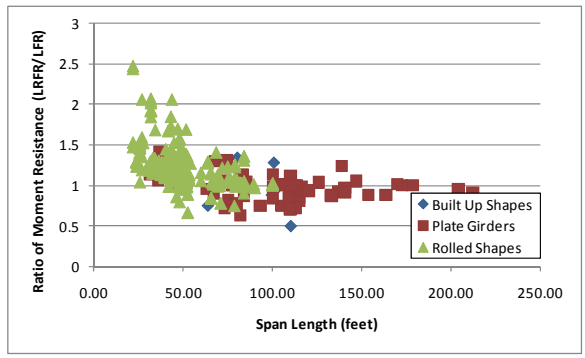
B.1.3.1.2 Resistances

After comparing the unfactored and factored live loads, the next step was to look at the resistance. Figure B-38 shows the resistances computed for LRFR are typically greater than the LFR resistance for rolled shapes. Plate girders generally have higher LFR resistance than LRFR resistance as shown in Figure B-38. The LRFR resistance is typically 75 to 150% of the LFR resistance.





(c)

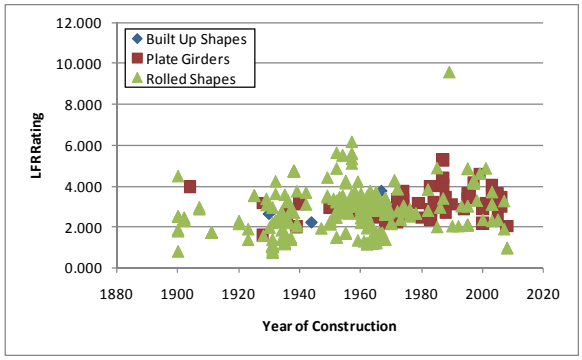


(d)

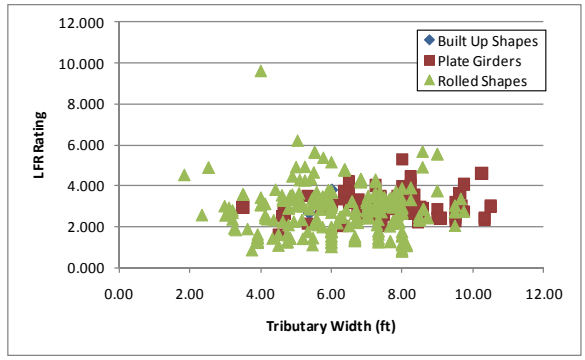
Figure B-38: Ratio of factored Moment Resistance (LRFR/LFR)

B.1.3.1.3 Rating Factors

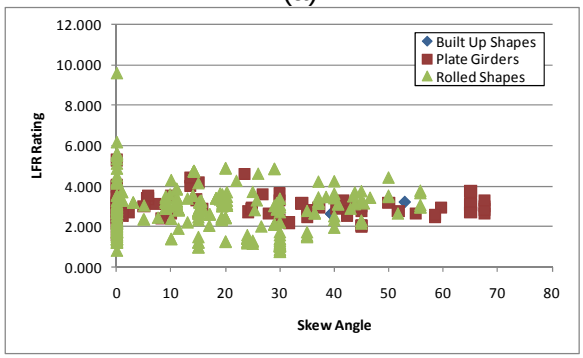
After verifying that the factored loads and resistances were similar the rating factors were examined. Figure B-39 and Figure B-40 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are six girders with an LFR rating less than 1.0, 28 girders with an LRFR rating less than 1.0, and five girders where both ratings are less than 1.0. Those girders that had LRFR ratings less than 1.0 typically had routine permit ratings greater than 0.8. Those with LFR ratings less than 1.0 typically had operating ratings less than 0.9. The LFR operating rating is greater than the LRFR routine permit rating for 89% of the girders in this subset. This indicates that while the ratings have dropped for a significant number of girders between the LFR and LRFR methodologies, a similar number have ratings less than 1.0.



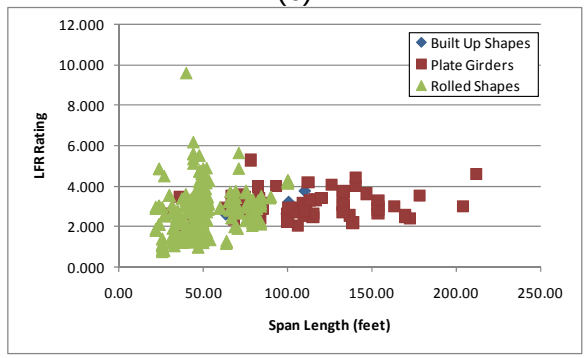
(a)



(b)



(c)



(d)

Figure B-39: LFR Rating Factors for DE-07 Vehicle

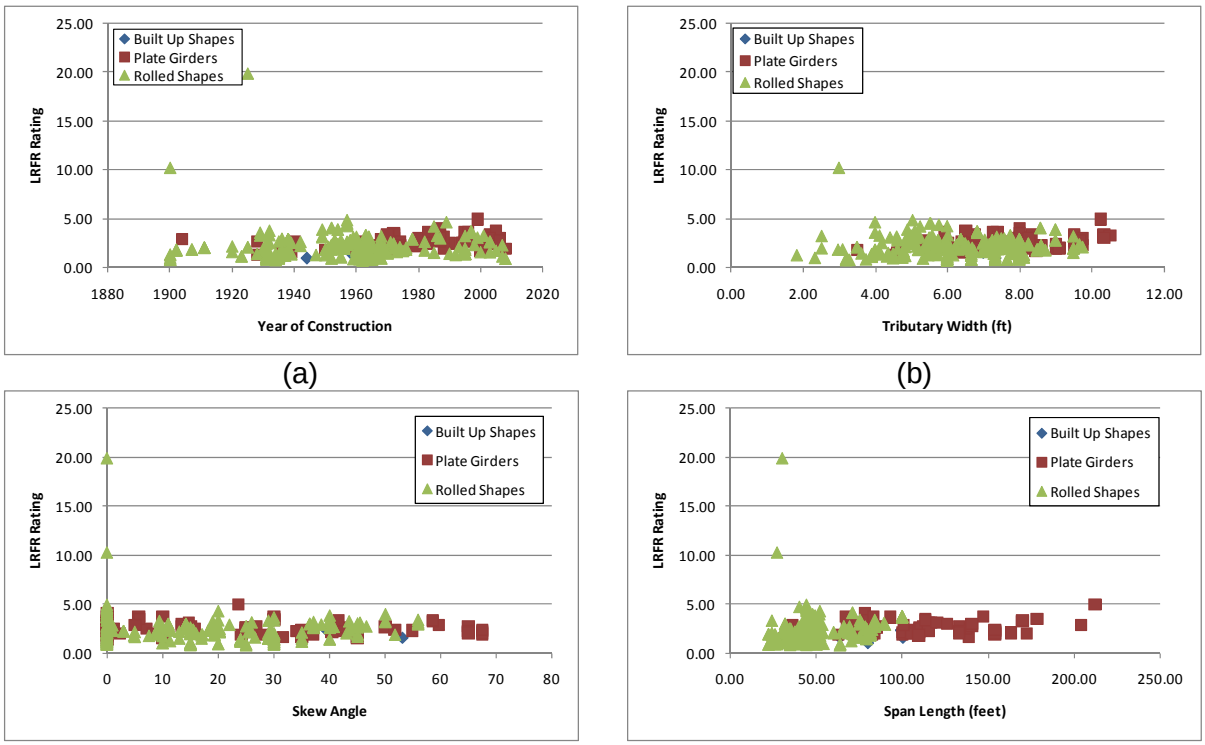
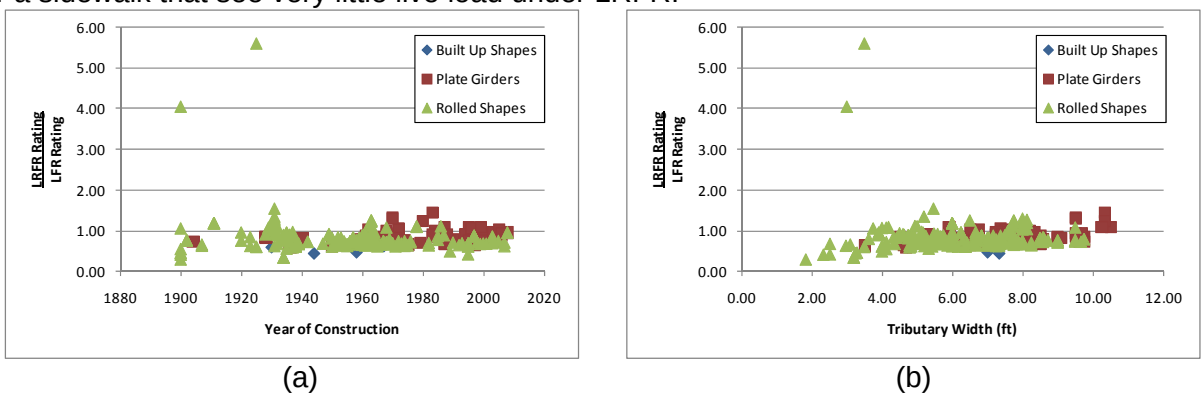
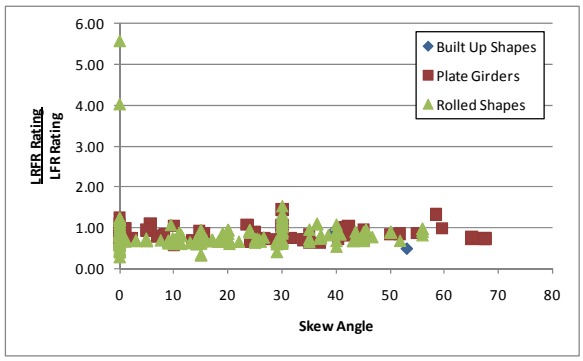


Figure B-40: LRFR Rating Factors for DE-07 Vehicle

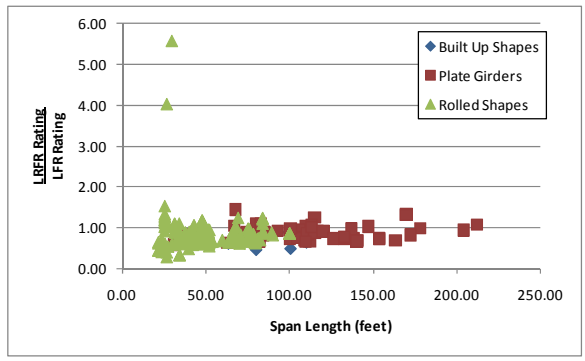
B.1.3.1.4 Rating Factor Comparisons

Figure B-41 shows the ratio of LRFR to LFR rating. The ratio is generally between 0.5 and 1.5 with most between 0.5 and 1.0. This indicates that the LFR rating is greater than the LRF rating as shown in Figure B-39 and Figure B-40. There are several outliers, which as mentioned previously are girders under a sidewalk that see very little live load under LRFR.





(c)

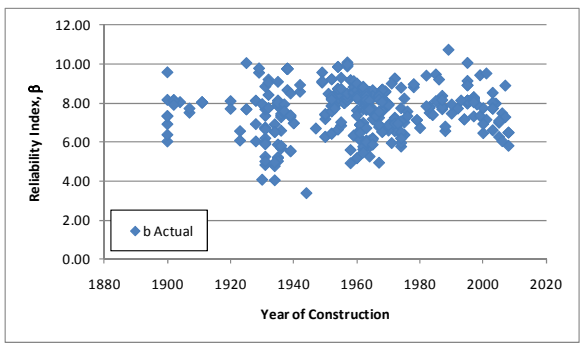


(d)

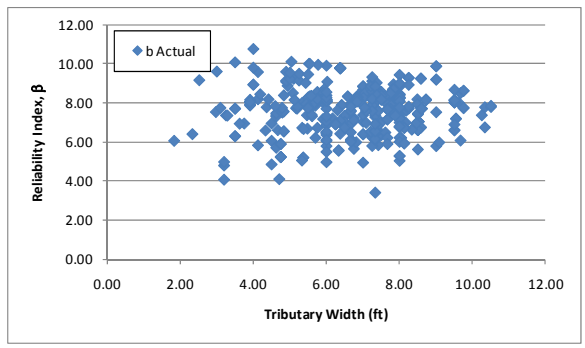
Figure B-41: Ratio of LRFR Flexure rating to LFR Flexure rating for DE-07 Vehicle

B.1.3.1.5 Reliability Indices

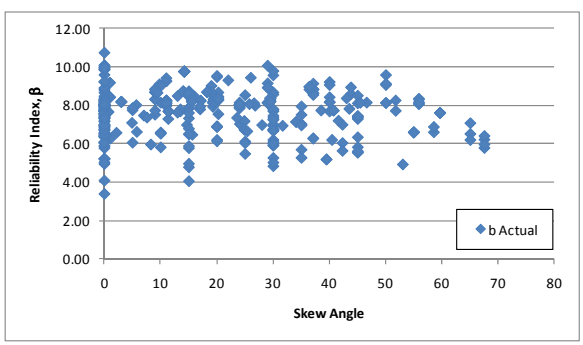
The reliability index was calculated for this subset of girders. Figure B-42 shows that no girders have a reliability index based upon girder strength that is less than the reliability index of 2.5 assumed for routine permit vehicles in the MBE.



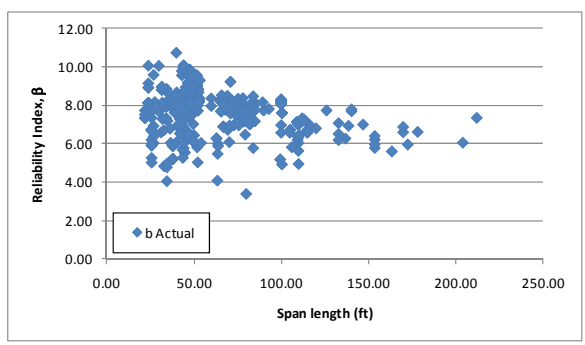
(a)



(b)



(c)



(d)

Figure B-42: Flexural Reliability Indices for DE-07 Vehicle

Figure B-43 shows the actual reliability index, based on existing resistance of member, versus the calculated LRFR rating factor. The level of reliability assumed for a routine permit vehicle is 2.5; the figure shows that girders having a rating factor of 1.0 generally have a reliability index greater than 4. This suggests that a reduced live load factor could be used and still get the expected level of reliability.

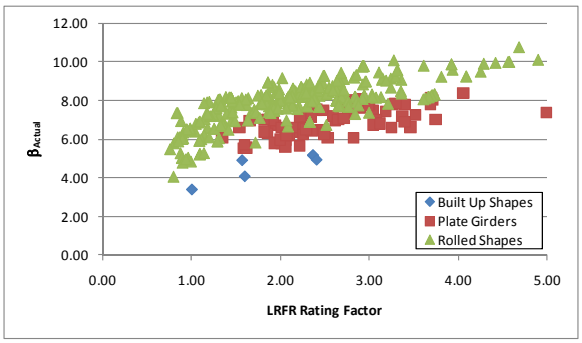


Figure B-43: Reliability Index versus LRFR RatingFactor

B.1.3.2 Shear

The results in this section consider the data as obtained from BRASS. This section does not account for the variation in critical location.

B.1.3.2.1 Live Loads

The ratios of unfactored and factored live loads were calculated and are shown in Figure B-44 and Figure B-45, respectively. The LRFR shear is typically 120-150% of the LFR shear for unfactored loads and 150-200% of the LFR shear for factored loads. Since it is expected that the ratio of live load shears would be nearer to 1.0 the critical shear location is plotted. The critical shear locations are shown in Figure B-46; the LFR location is typically at the one- or nine-tenths point with the LRFR location typically at the support. This is will cause the live load shear ratios to be higher than expected. Again there are several low outliers caused by the presence of a sidewalk and the application of the distribution factors.

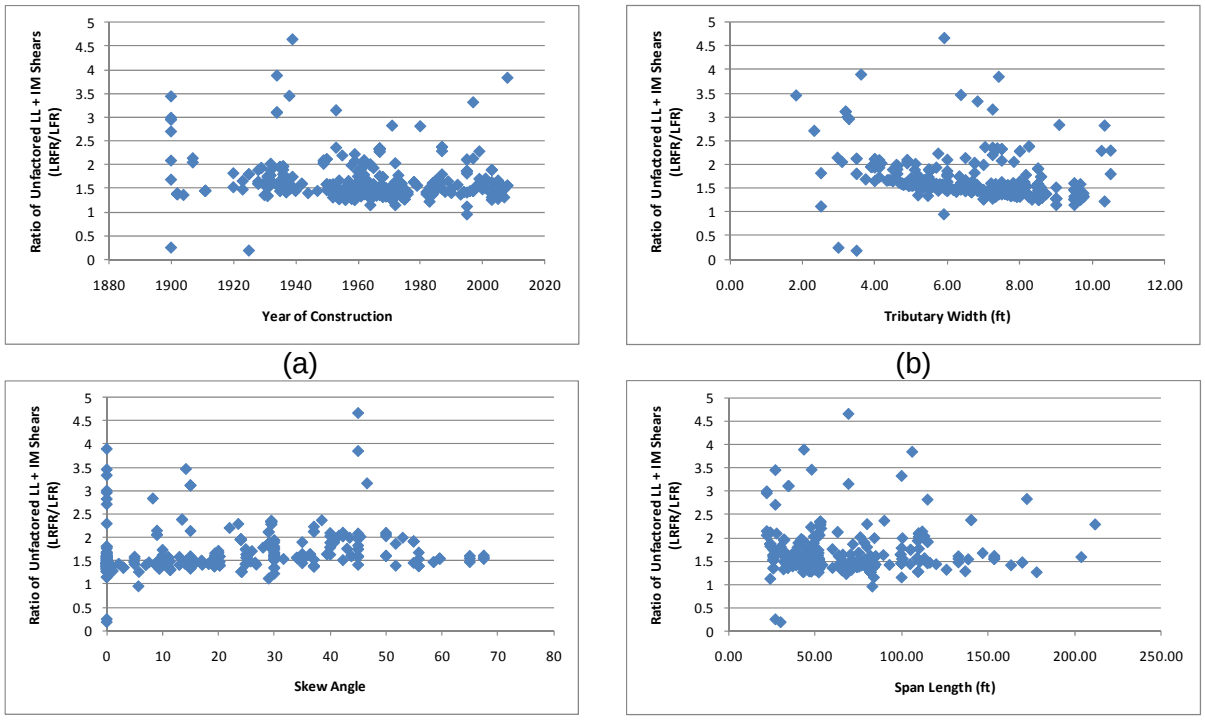
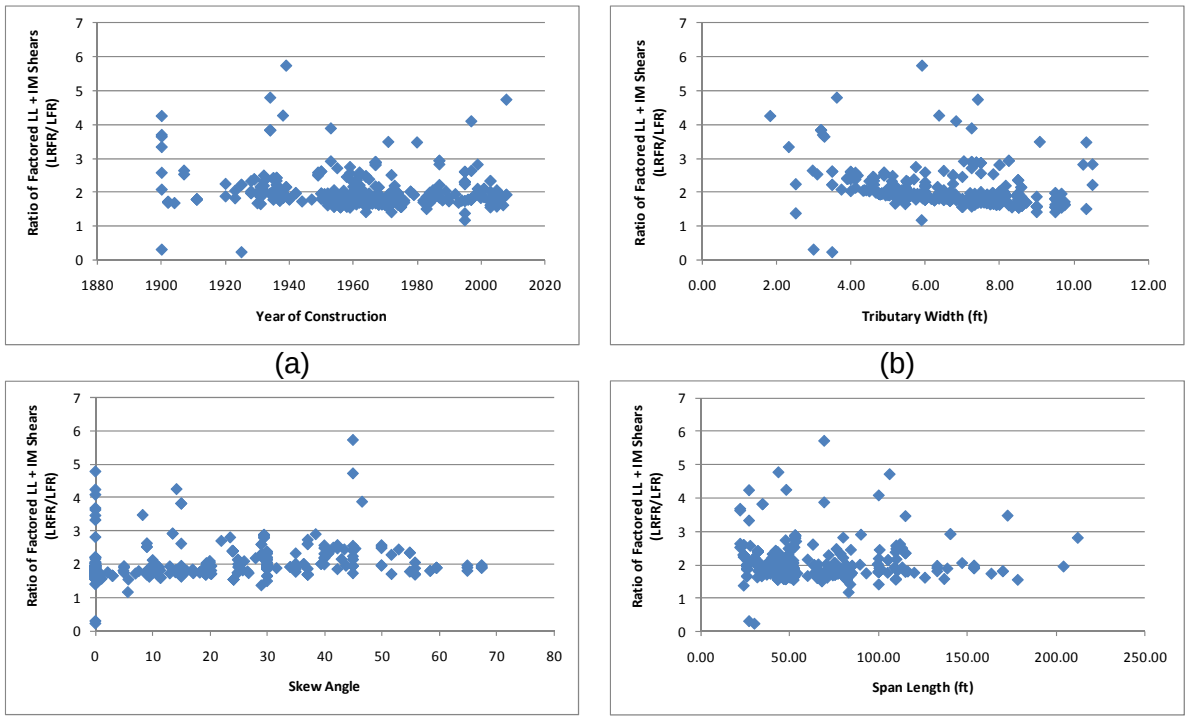
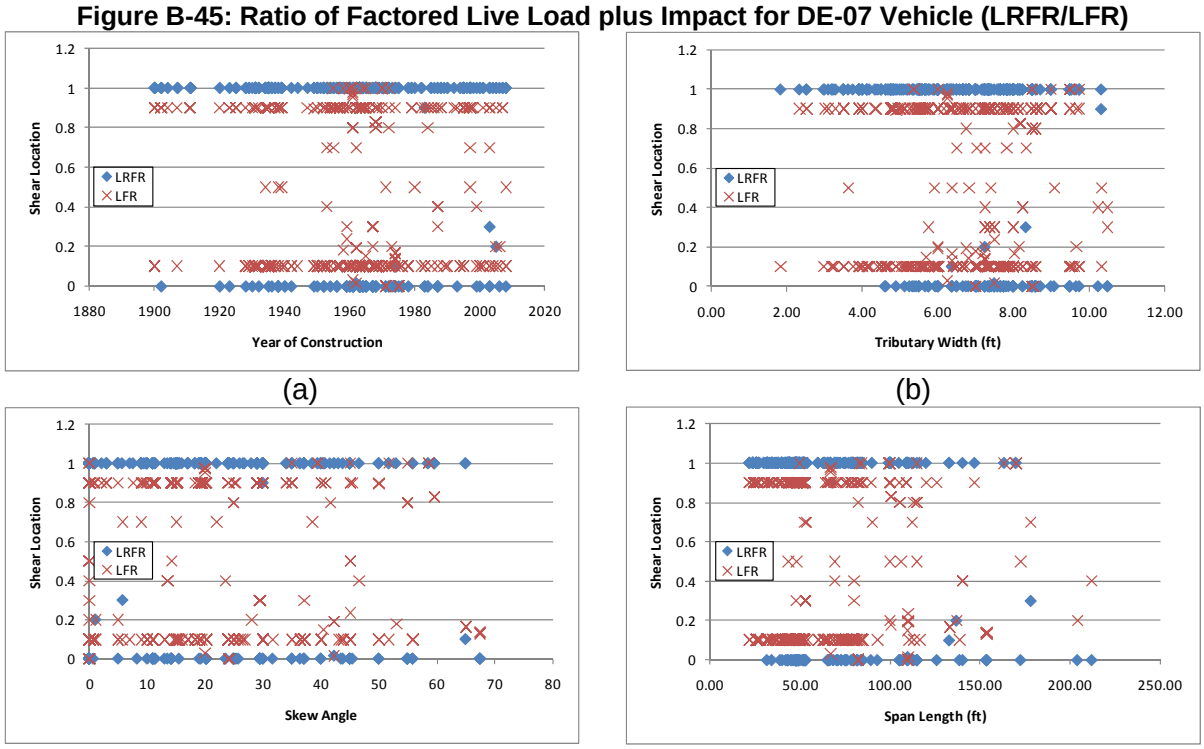


Figure B-44: Ratio of Unfactored Live Load plus Impact for DE-07 Vehicle (LRFR/LFR)



(a) (b) (c) (d)

Figure B-45: Ratio of Factored Live Load plus Impact for DE-07 Vehicle (LRFR/LFR)



(a) (b) (c) (d)

Figure B-46: Critical shear location for DE-07 Vehicle

B.1.3.2.2 Resistances

After verifying that the live loads are comparable between methods, the next step was to verify that the shear resistance was comparable. For most girders, shown in Figure B-47, the ratio of shear

resistance was close to 1.0 but there are several where the ratio is greater than 1.0 or less than 1.0. This may be caused by the critical locations varying by more than one-tenth of the span length. The stiffener spacing is not likely to change between the support and one-tenth point but the spacing may change as the critical location moves away from the support. The resistance at the support may vary due to the LRFR portion of the MBE not allowing tension field action from being considered in the shear resistance.

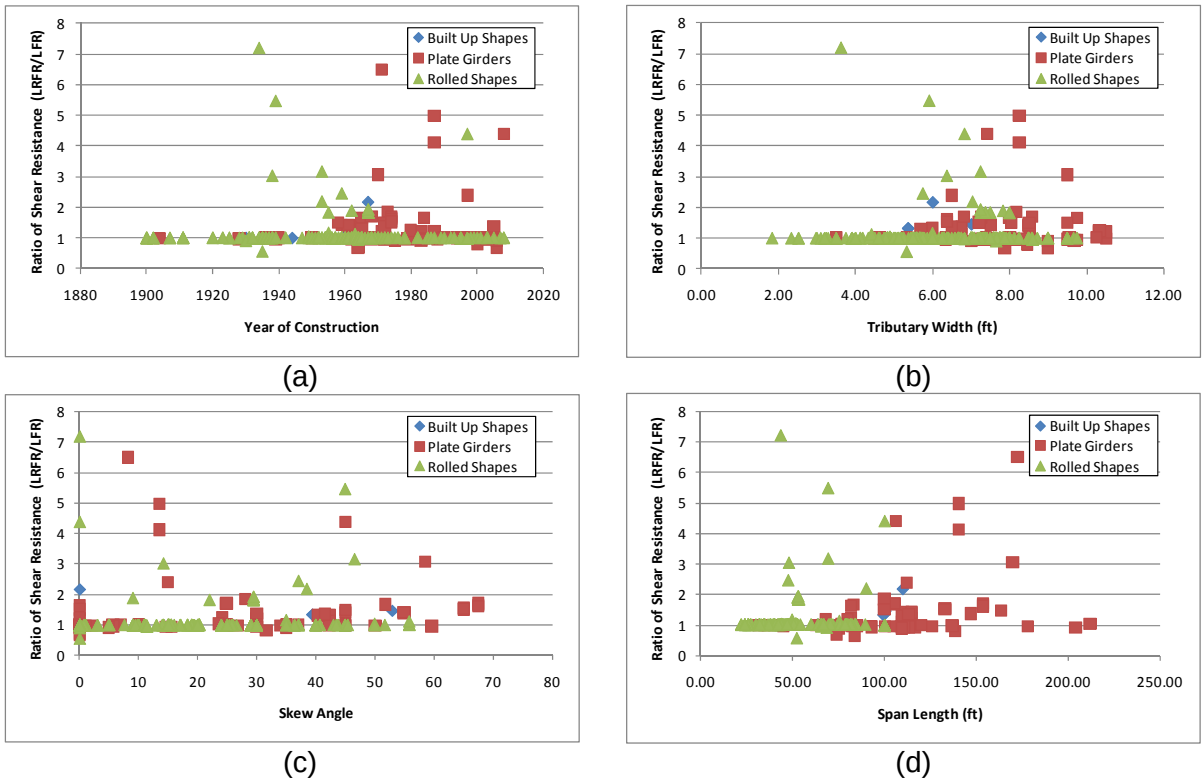
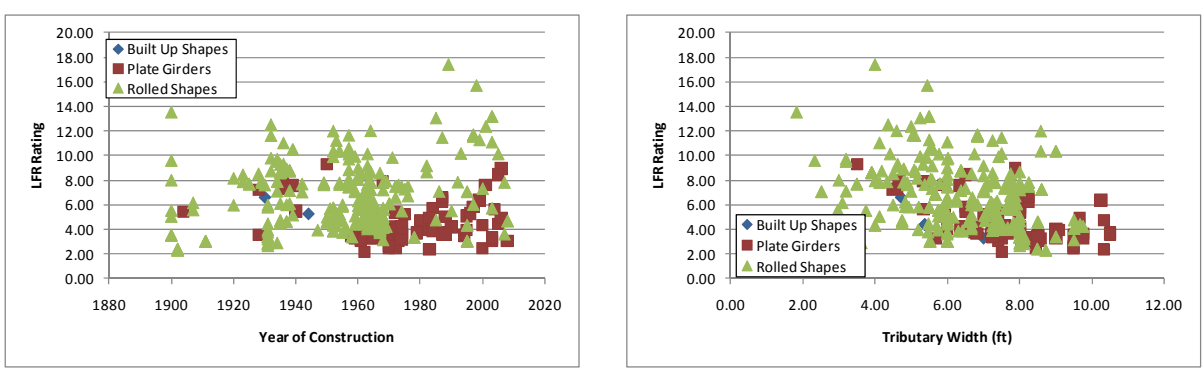


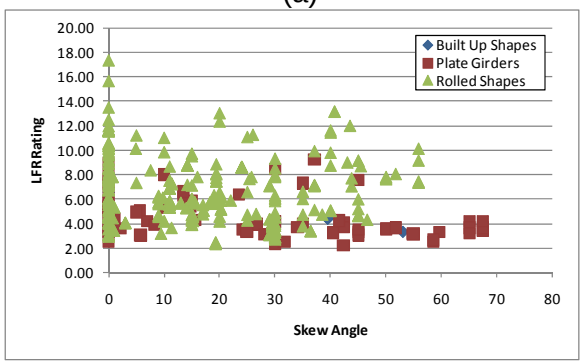
Figure B-47: Ratio of factored Shear Resistance (LRFR/LFR)

B.1.3.2.3 Rating Factors

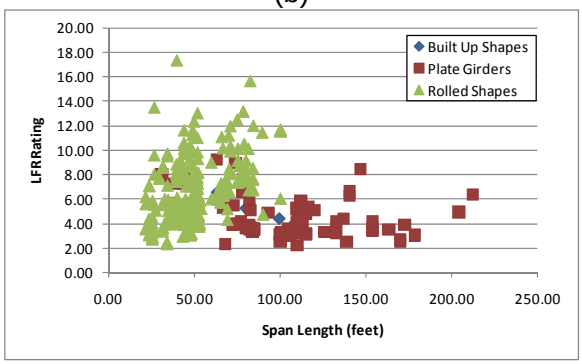
After examining the results for the resistance and also for the live loads, the actual rating factors were examined. For shear, there are zero girders that have an LFR rating factor less than 1.0 and 11 girders with an LRFR rating factor less than 1.0. In this situation, there are no problems caused by rating the bridges using the LRFR methodology even though they may not have been designed with the LRFD Design Specification. The LFR Rating is greater than the LRFR rating for 98% of the girders in this subset. Figure B-48 and Figure B-49 show the LFR and LRFR ratings, respectively.



(a)

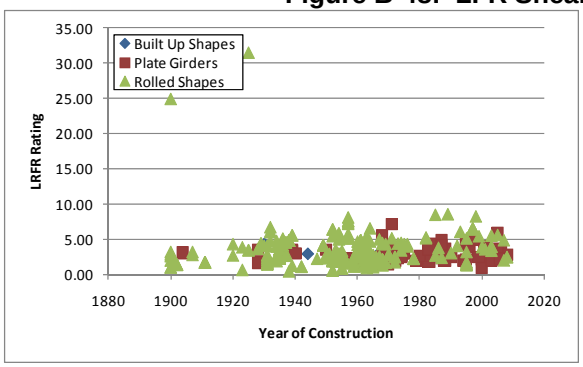


(b)

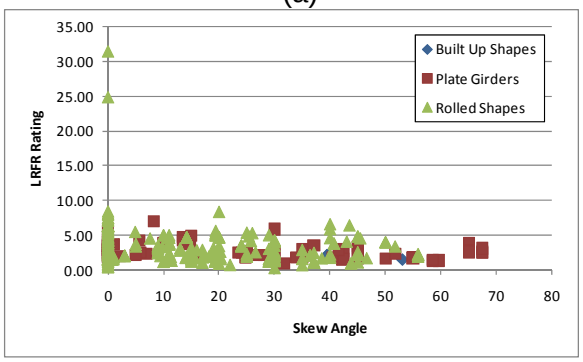


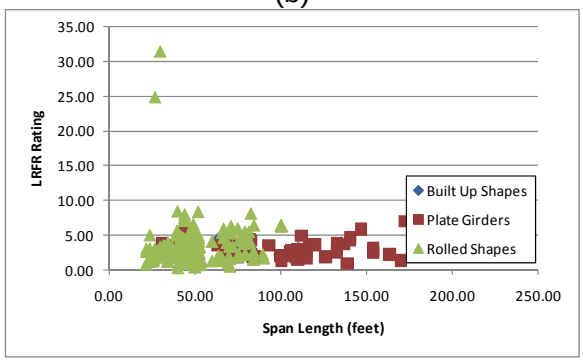
(c) (d)

Figure B-48: LFR Shear Ratings for DE-07 Vehicle



(a) (b)



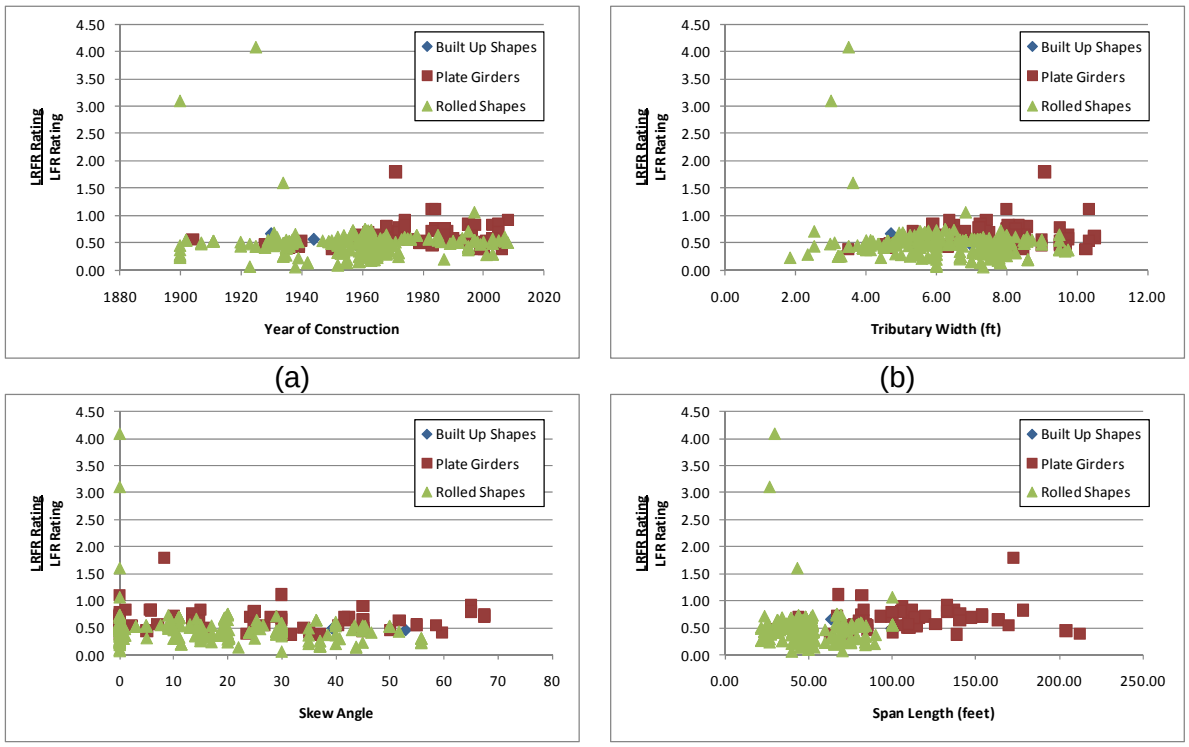


(c) (d)

Figure B-49: LRFR Shear Ratings for DE-07 Vehicle

B.1.3.2.4 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of the LRFR Rating to the LFR Rating. Figure B-50 shows the ratio of rating factors. Figure B-50 shows that the ratio is generally between 0.25 and 1.0, with rolled shapes generally between 0.25 and 0.75. Plate girders are generally between 0.5 and 1.0.

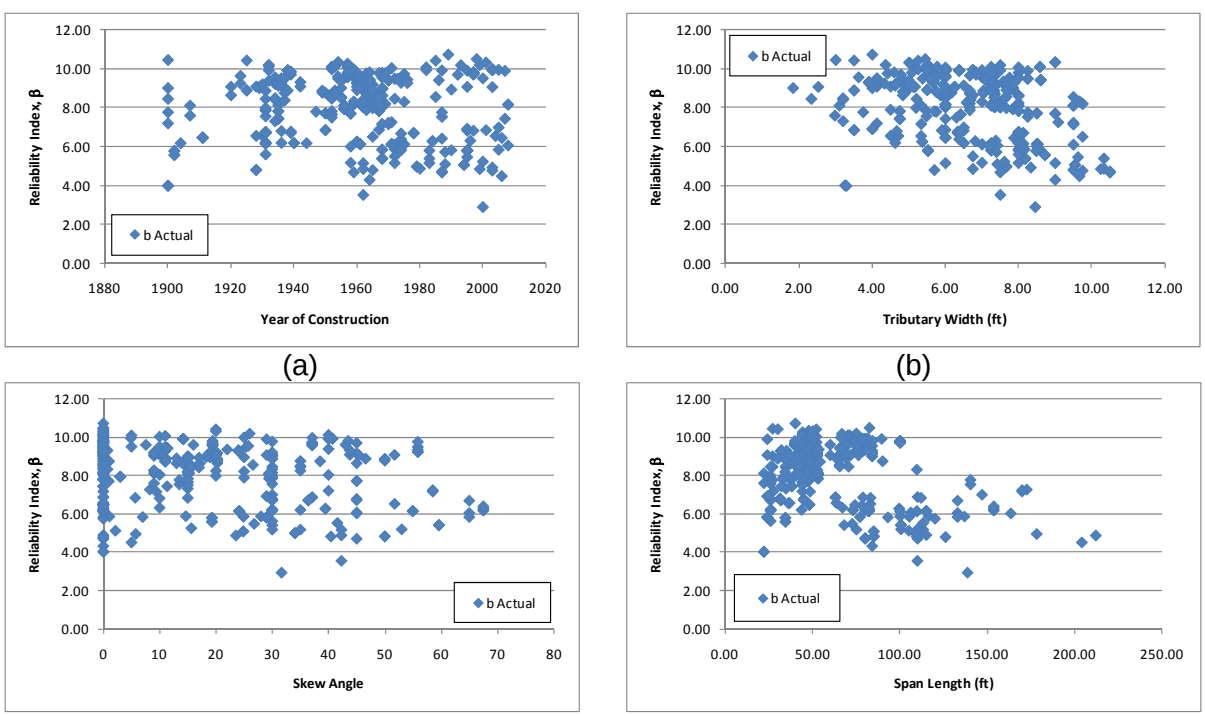


(a) (b) (c) (d)

Figure B-50: Ratio of LRFR Shear Rating to LFR Shear Rating for DE-07 Vehicle

B.1.3.2.5 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the reliability index of 2.5 assumed for routine permit vehicles in the development of the MBE as shown in Figure B-51. There are two girders with a reliability index of less than 4.0.



(a) (b)

(c) (d)

Figure B-51: Shear Reliability Indices for DE-07 Vehicle

Figure B-52 shows the reliability index based upon girder strength plotted versus the LRFR rating factor. The figure shows that a girder with a rating factor of 1.0 has a reliability index of at least 3.0 and possibly higher because of the limited number of data points with LRFR rating close to 1.0. It is also obvious in this figure that the statistical parameters vary between different girder types as the plate girders are significantly lower than the rolled shapes.

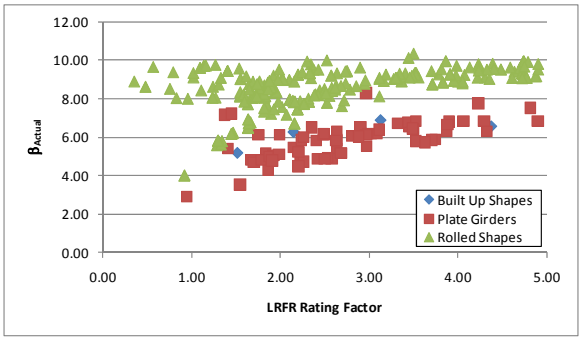


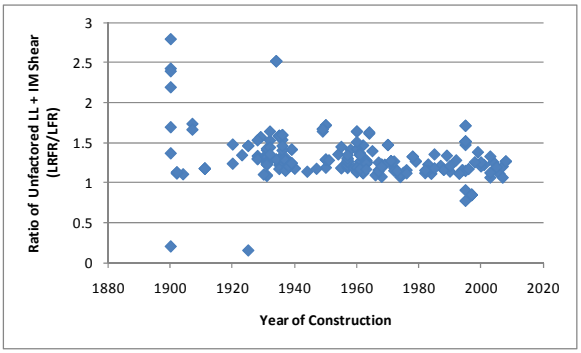
Figure B-52: Reliability Index versus LRFR Rating Factor

B.1.3.3 Shear-Corrected

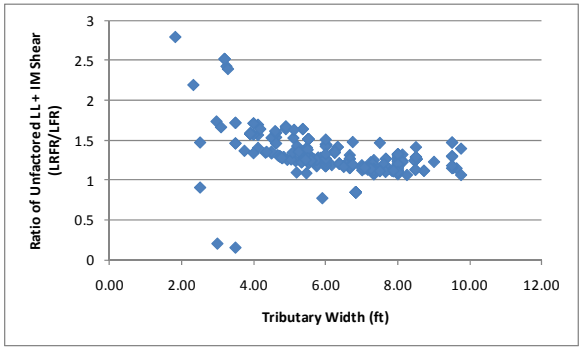
This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.3.3.1 Live Load

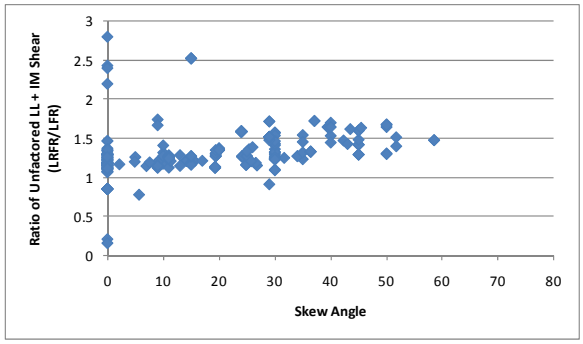
Figure B-53 and Figure B-54 show the ratio of unfactored and factored live load plus impact shear for those girders with critical locations at the either the support or one-tenth of the span away from the support. The LRFR unfactored shear is approximately 100-150% of the LFR unfactored shear, when factored the LRFR live load shear is approximately 1.5 times the LFR live load shear. This is an improvement over that shown in the previous section as the unfactored load ratio is closer to 1.0, which is what would be expected.



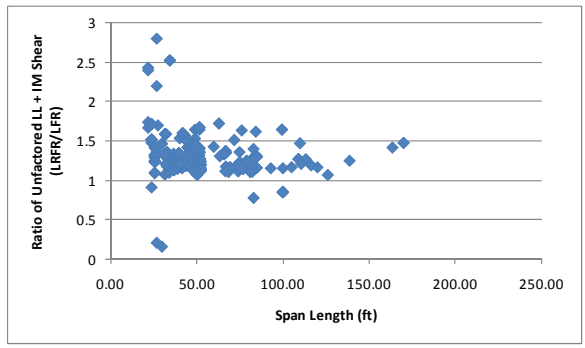
(a)



(b)

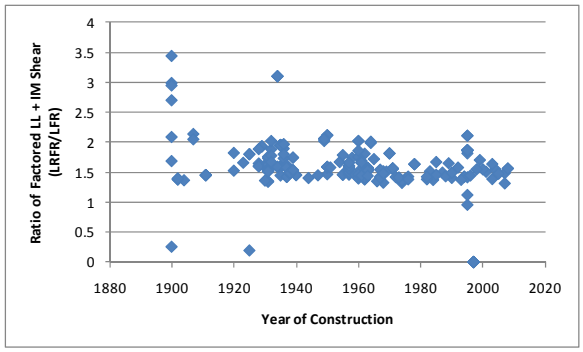


(c)

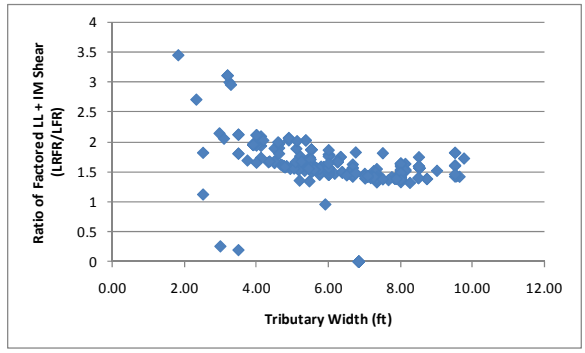


(d)

Figure B-53: Ratio of Unfactored Live Load plus Impact Shear for DE-07 Vehicle (LRFR/LFR)



(a)



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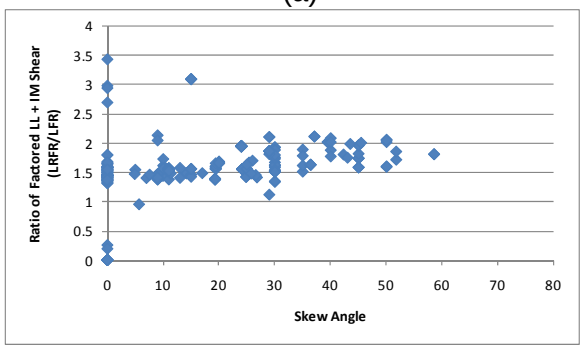

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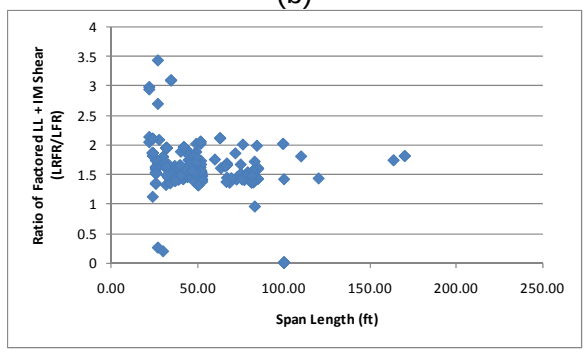
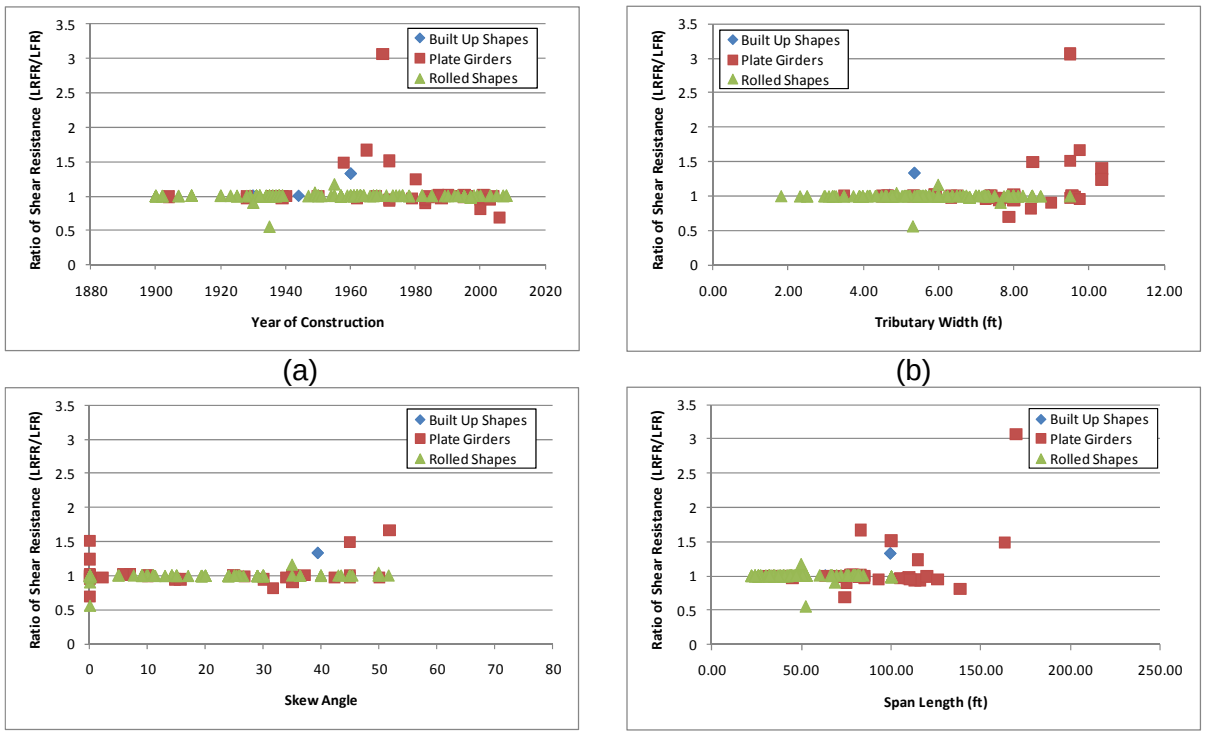


(d)

Figure B-54: Ratio of Factored Live Load plus Impact for DE-07 Vehicle (LRFR/LFR)

B.1.3.3.2 Resistance

The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was greater than 1.0 have been eliminated by considering only those close to the support and where the stiffener spacing was likely to be the same. The ratio of shear resistance is shown in Figure B-55.



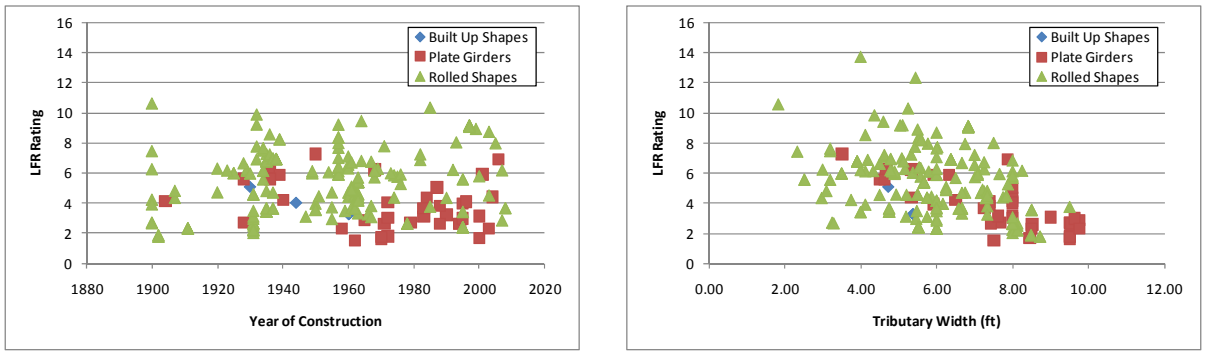
(a) (b)

(c) (d)

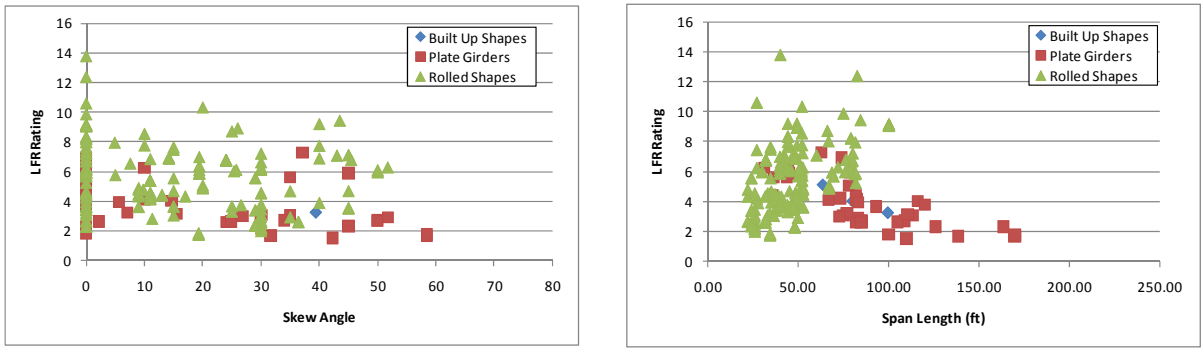
Figure B-55: Ratio of factored Shear Resistance (LRFR/LFR)

B.1.3.3.3 Rating Factors

After verifying that the live load shears and shear resistances are similar, the next step was to examine the rating factors. Figure B-56 and Figure B-57 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of the eliminated girders were plate girders where it is likely that the stiffener spacing would vary along the span length.

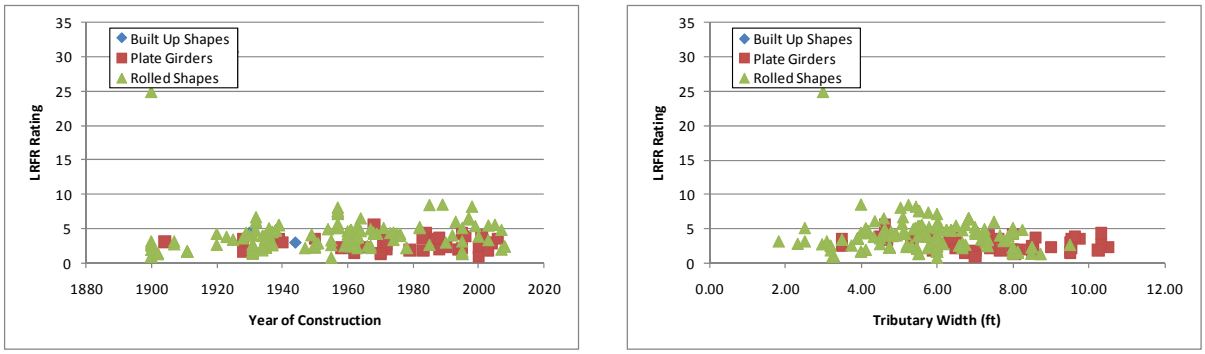


(a) (b)

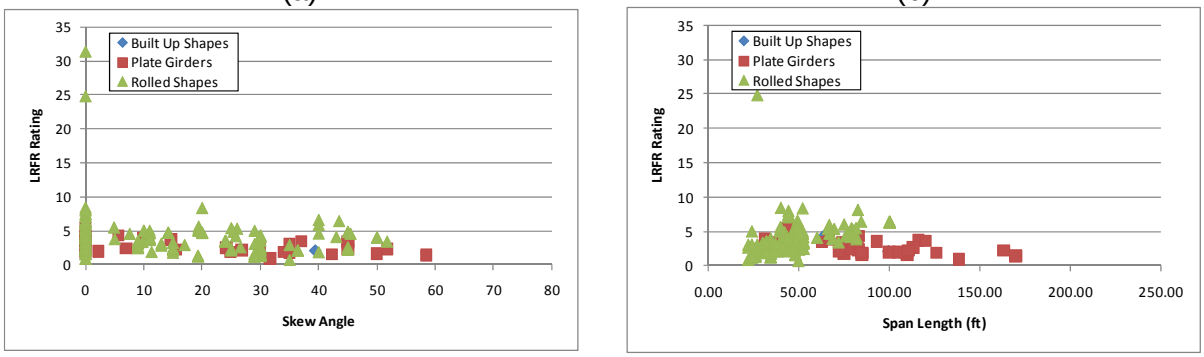


(c) (d)

Figure B-56: LFR Shear Rating Factors for DE-07 Vehicle



(a) (b)



(c) (d)

Figure B-57: LRFR Shear Rating Factors for DE-07 Vehicle

B.1.3.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio of the LRFR rating factor to the LFR rating factor. Figure B-58 shows the results of this comparison. The results show that the LRFR rating is typically 50 to 75% of the LFR rating after recalculating the rating at the support. Plate girders are more likely to have a ratio of ratings closer to 1.0 then rolled shapes.

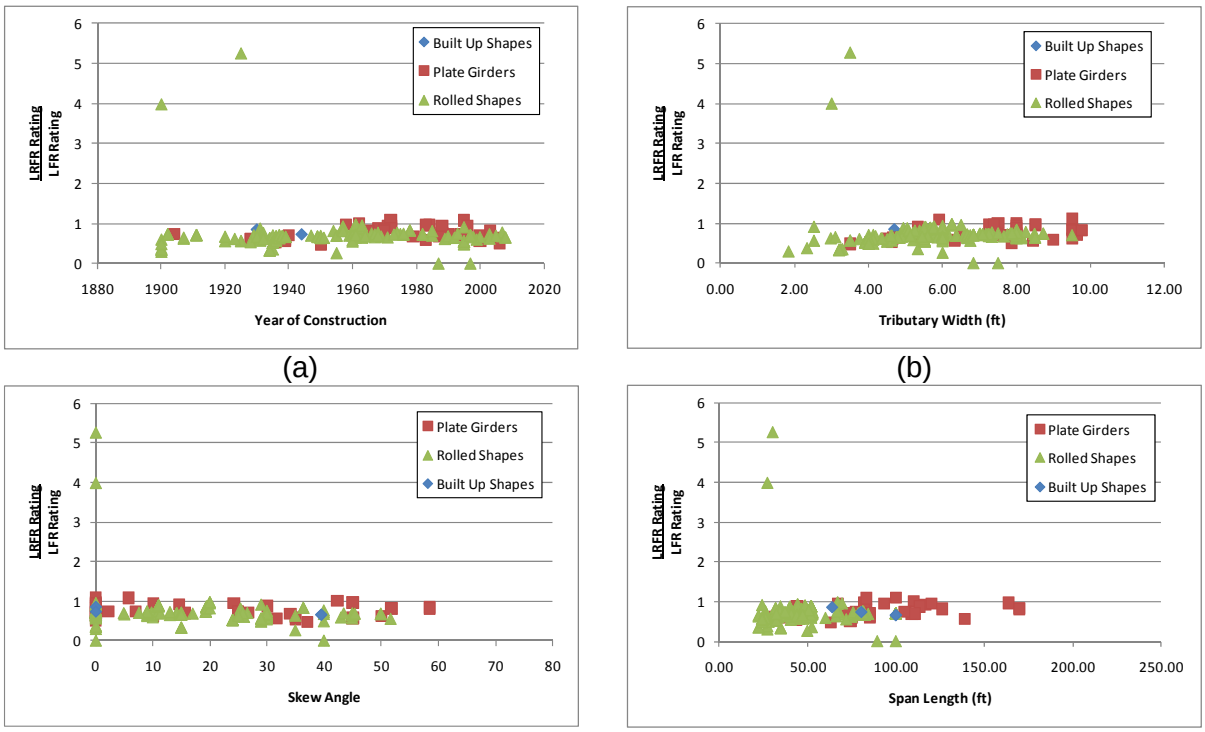
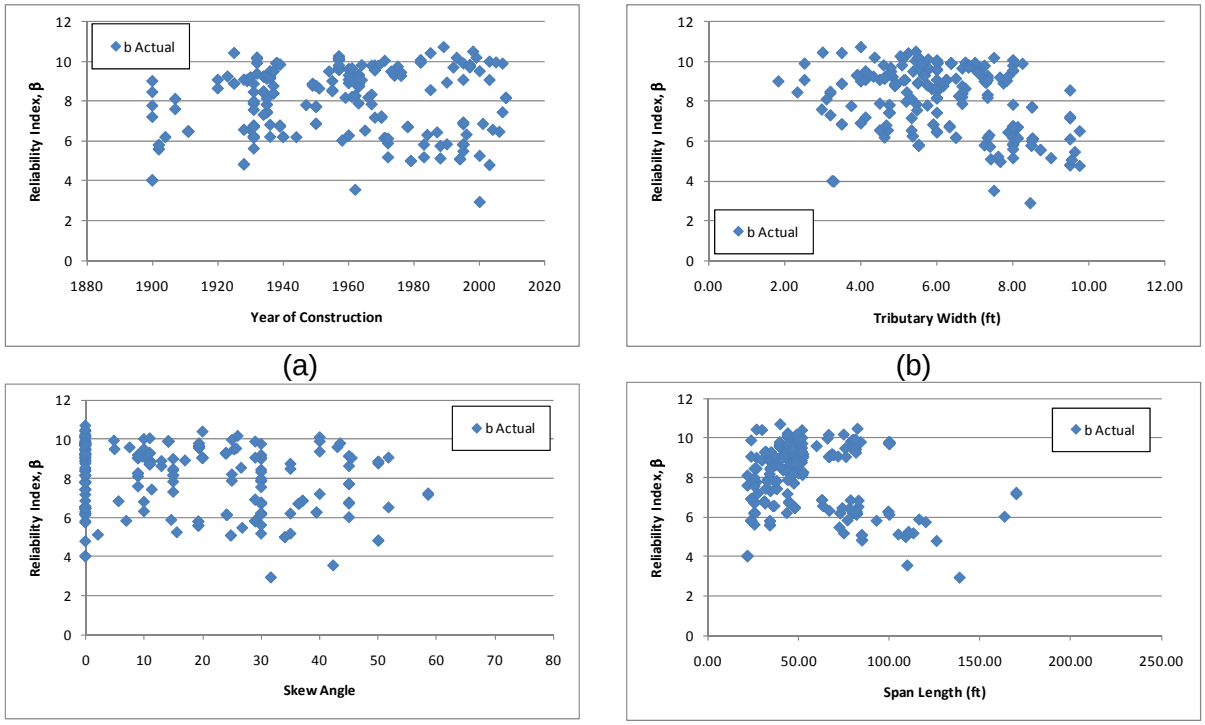


Figure B-58: Ratio of LRFR Shear Rating to LFR Shear Rating for DE-07 Vehicle

B.1.3.3.5 Reliability Indices

The reliability indices shown in Figure B-59 are the same as those shown in Figure B-51. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 2.5. The reliability index remains the same as calculated previously because the LRFR location did not move.



(c) (d)

Figure B-59: Shear Reliability Indices for DE-07 Vehicle

B.1.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-60. The applicable load factors for these vehicles are 1.30 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

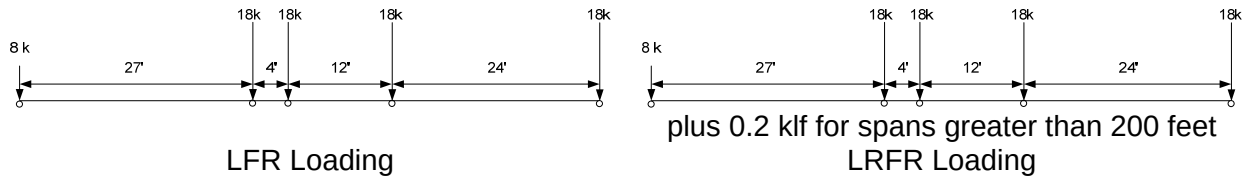
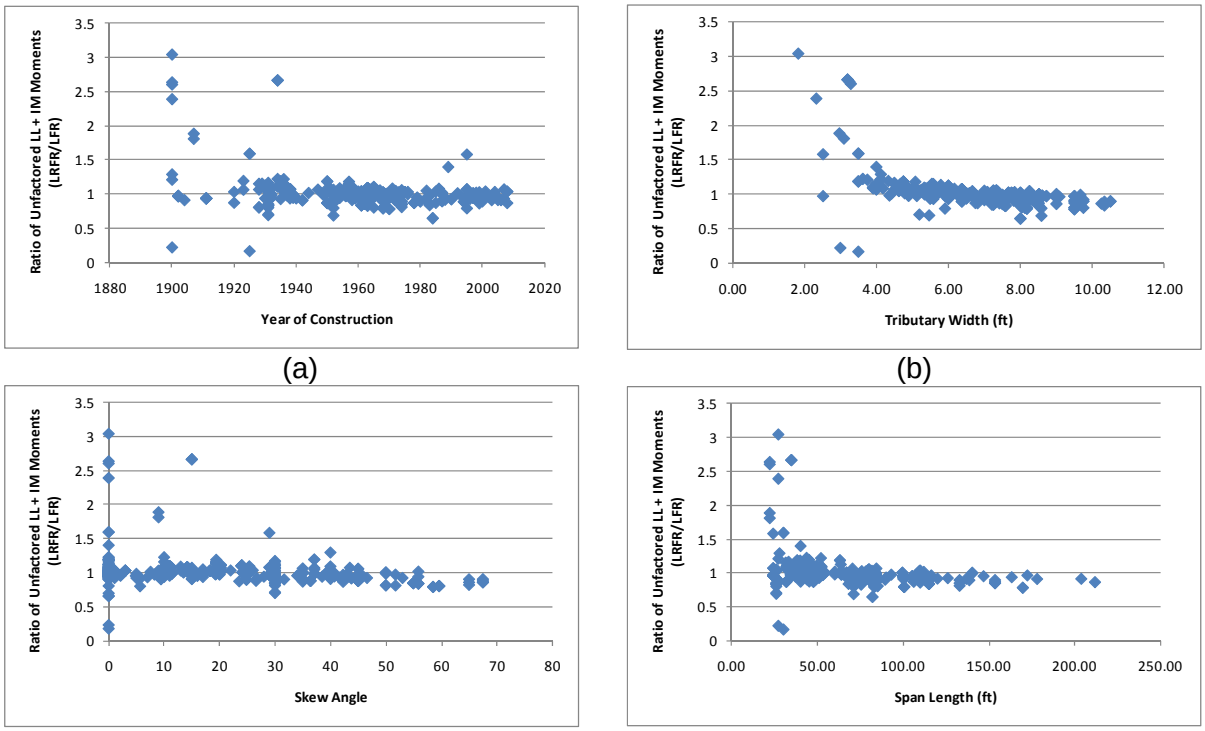


Figure B-60: Vehicle Loadings and Load Factors

B.1.4.1 Moment

B.1.4.1.1 Live Loads

Figure B-61 shows that the unfactored LFR live loads are typically greater than the unfactored LRFR live loads; unfactored LRFR live load is typically 75-125% of the unfactored LFR live load. Girders that are narrowly spaced tend to have LRFR loads greater than LFR loads (Figure B-61b); this is likely caused by differences in the distribution factor. The narrow girder spacing will result in the LRFR distribution factor being calculated using the lever rule while the LFR distribution factor will be either S/4.5 or S/5.5. Figure B-61d shows that there is more variation in live load for spans less than 50 feet in length than for longer spans.

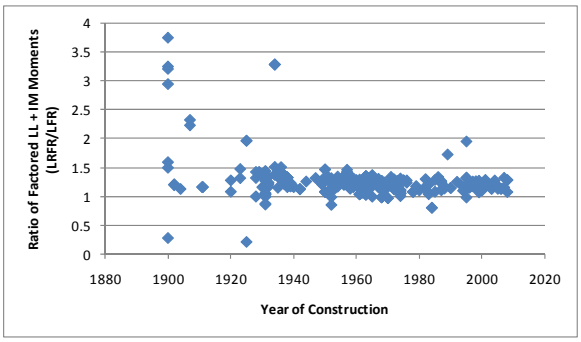


(a) (b)

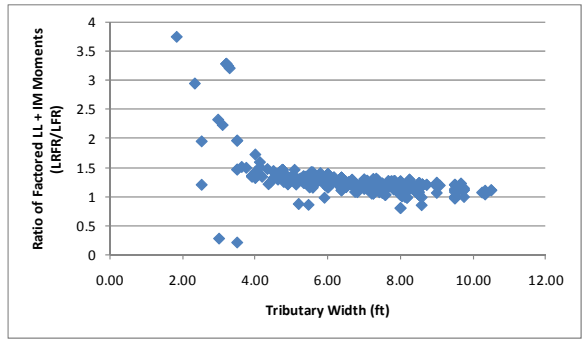
(c) (d)

Figure B-61: Ratio of Unfactored Live Load plus Impact Moment for FL-04 Vehicle (LRFR/LFR)

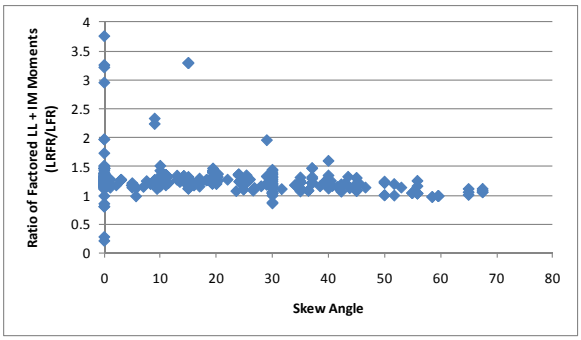
Figure B-62 shows the ratio of factored live loads, the results are the same except that they have now shifted up due to the application of the load factors which are 1.3 for LFR and 1.6 for LRFR. The ratio of factored live loads is now between 1.0 and 1.5.



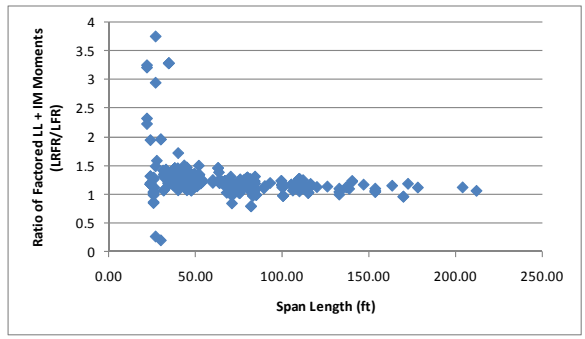
(a)



(b)



(c)

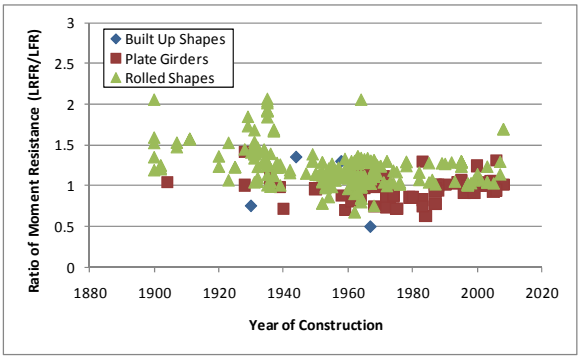


(d)

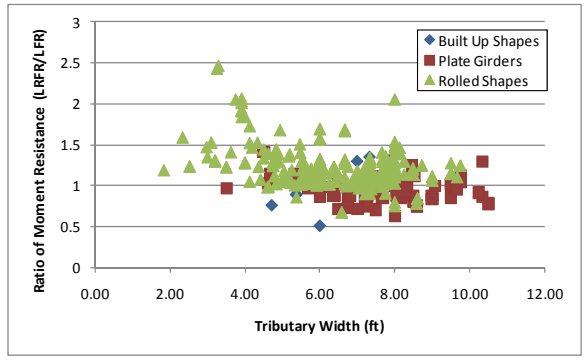
Figure B-62: Ratio of Factored Live Load plus Impact Moment for FL-04 Vehicle (LRFR/LFR)

B.1.4.1.2 Resistances

Figure B-63 shows the ratio of moment resistances. The ratios are generally between 0.75 and 1.5 with plate girders having larger LFR resistance than LRFR resistance. Rolled shapes are more likely to have higher LRFR resistance than LFR resistance.



(a)



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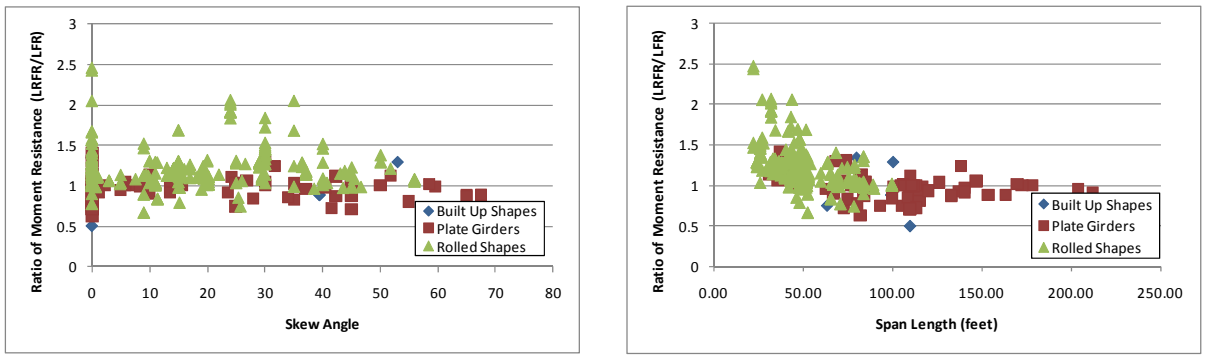
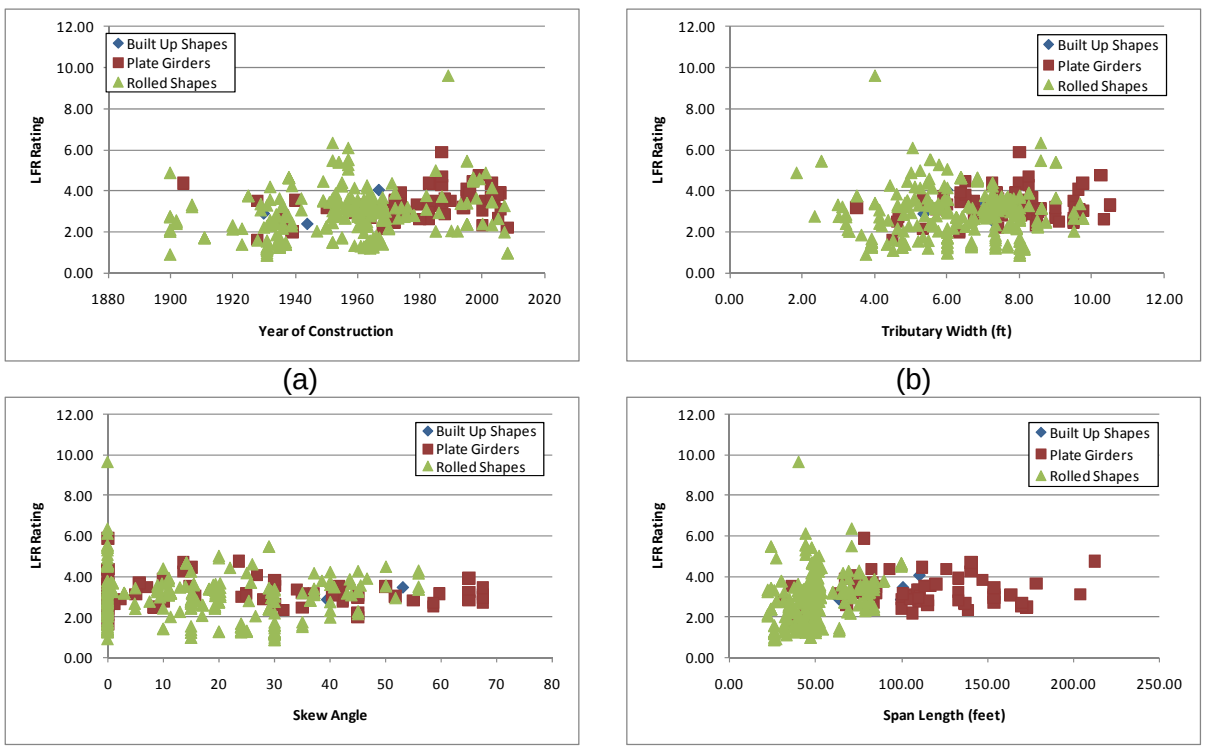


(c) (d)

Figure B-63: Ratio of Factored Moment Resistances (LRFR/LFR)

B.1.4.1.3 Rating Factors

Figure B-64 and Figure B-65 show the rating factors calculated by BRASS; the LFR ratings are operating ratings while the LRFR ratings are routine permit ratings. There are six girders that have LFR ratings less than 1.0, 27 girders with LRFR ratings less than 1.0, and five girders where both LFR and LRFR ratings less than 1.0. Additionally 89% of the girders have LFR ratings greater than LRFR ratings. A majority of girders had lower ratings when switching to LRFR but it is important to note that there are still very few that don't have a satisfactory rating. Figure B-64d and Figure B-65d also show that the lower ratings tend to correspond to shorter span lengths



(a) (b)

(c) (d)

Figure B-64: LFR Moment Rating Factor for FL-04 Vehicle

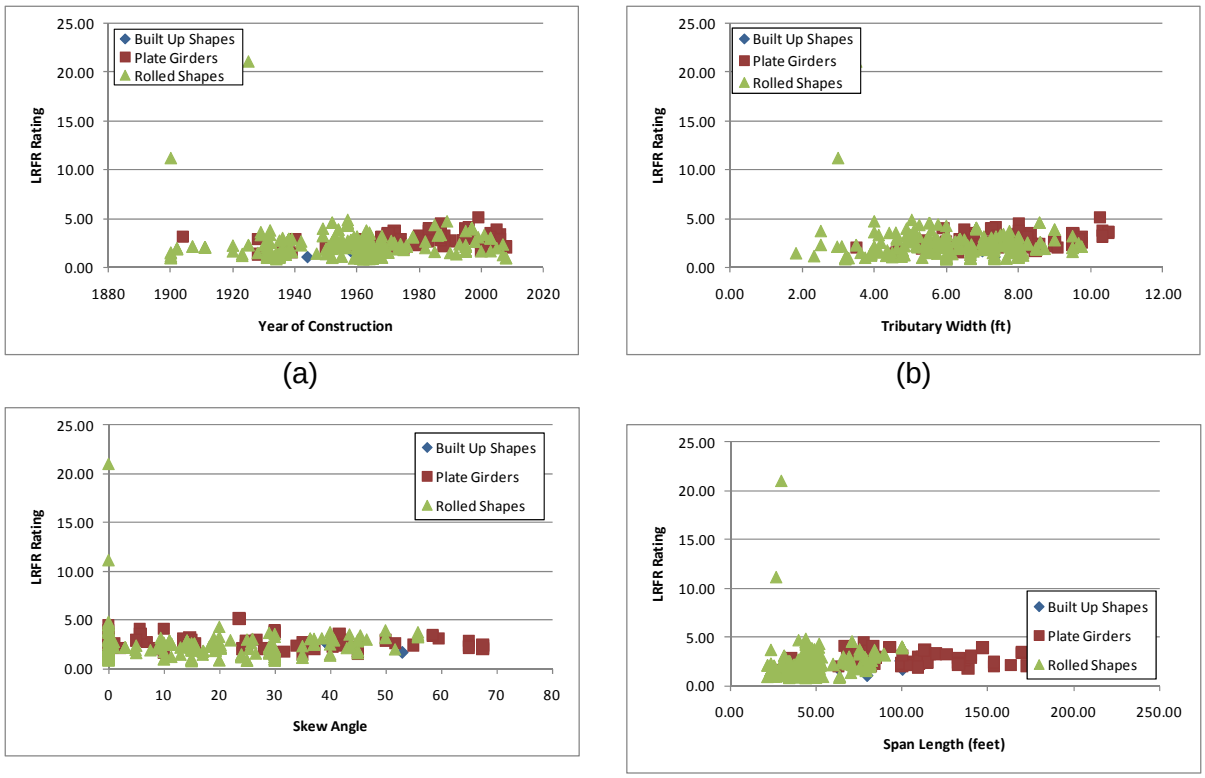
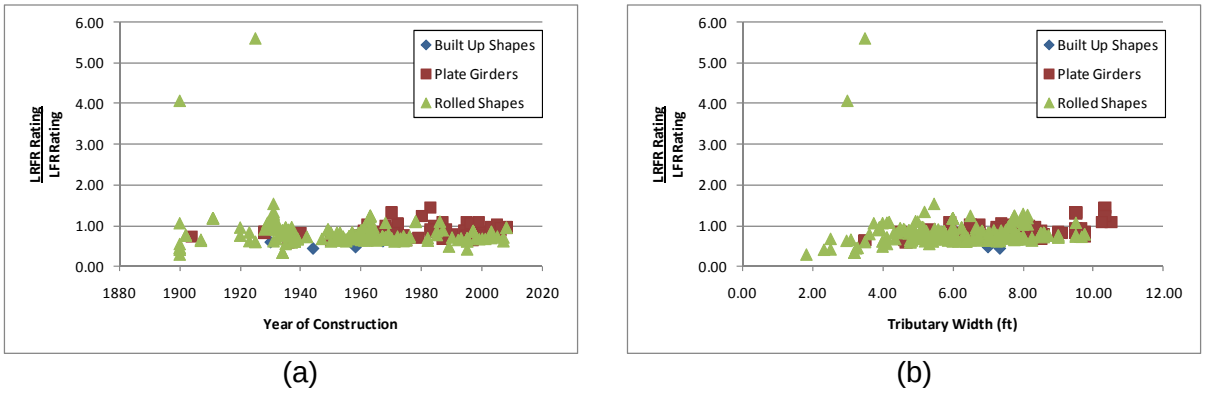
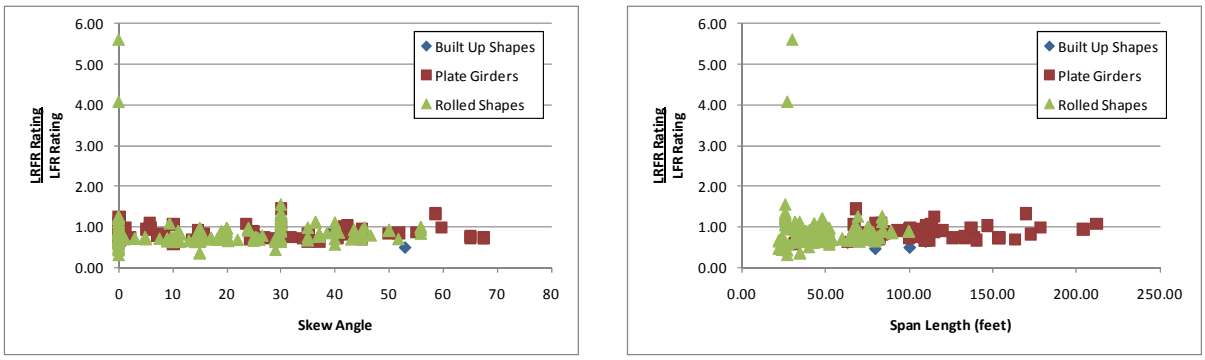


Figure B-65: LRFR Moment Rating Factors for FL-04 Vehicle

B.1.4.1.4 Rating Factor Comparisons

Figure B-66 shows a comparison of the LRFR rating to the LFR rating. The ratio is generally between 0.5 and 1.0, with rolled shapes tending to have lower ratios.



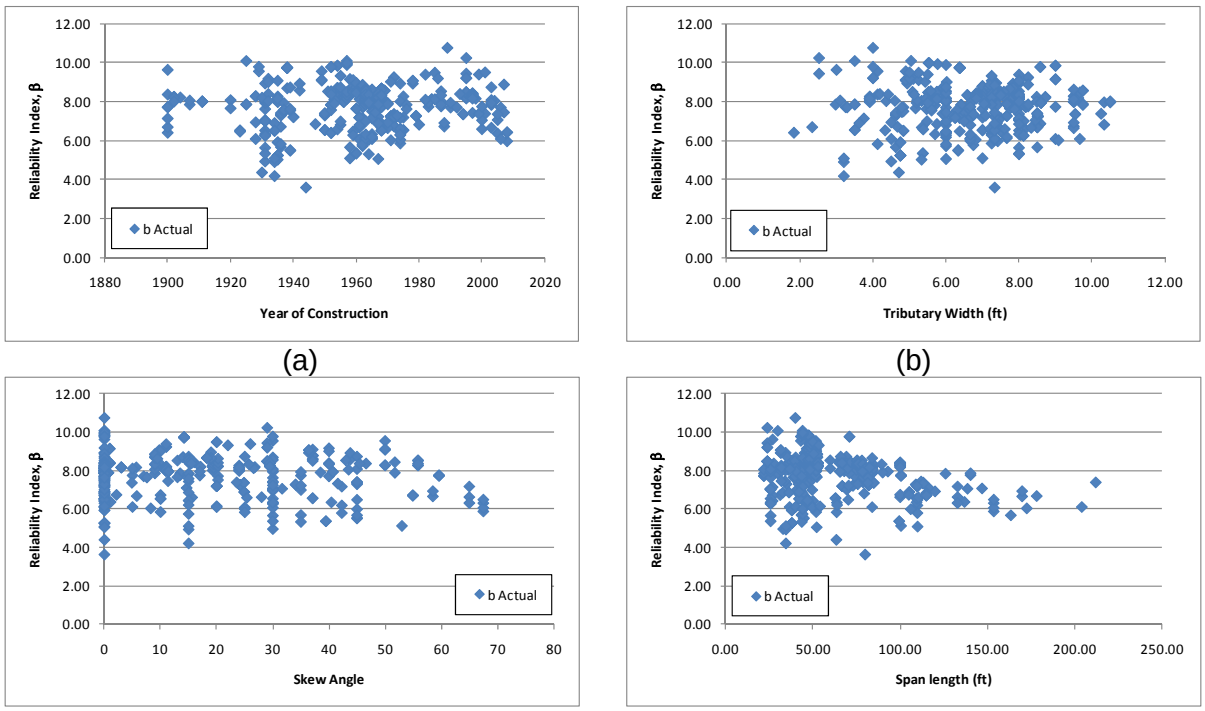


(c) (d)

Figure B-66: Ratio of LRFR Moment Rating to LFR Moment Rating for FL-04 Vehicle

B.1.4.1.5 Reliability Indices

Figure B-67 shows the actual reliability index and for this vehicle the assumed level of reliability is 2.5. All girders have a level of reliability exceeding that which is assumed in the MBE.



(a) (b)

(c) (d)

Figure B-67: Flexural Reliability Indices for FL-04 Vehicle

Figure B-68 shows the actual reliability index plotted versus the LRFR rating factor. The figure shows that a girder with a rating factor of 1.0 has a reliability index of approximately 4. It is expected that a girder with a LRFR rating factor of 1.0 would have a reliability index near 2.5. This indicates that the live load factor could be reduced.

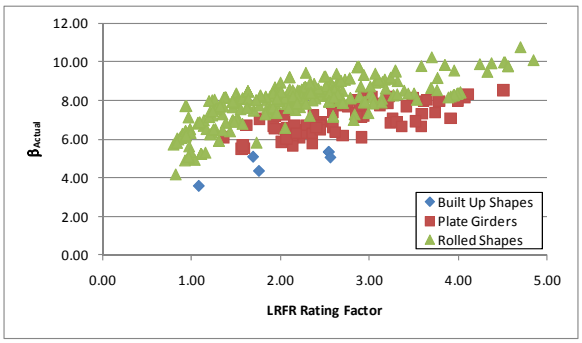


Figure B-68: Reliability Index versus LRFR Rating Factor

B.1.4.2 Shear

B.1.4.2.1 Live Loads

Figure B-69 and Figure B-70 show the ratios for unfactored and factored loads, respectively. Figure B-71 shows the critical location for shear; the LFR critical location is typically at one-tenth of the span length from the support while the LRFR critical location is typically at the support. The LRFR shears are almost exclusively greater than the LFR shears. The ratio of unfactored live loads is generally between 1.25 and 1.75, while the ratio of factored loads is between 1.5 and 2.0. The load factors used are 1.3 for LFR and 1.6 for LRFR. Figure B-69c and Figure B-70c show a slight increase in live load ratios as the skew angle increases; this is expected because LRFR considers skew while LFR does not.

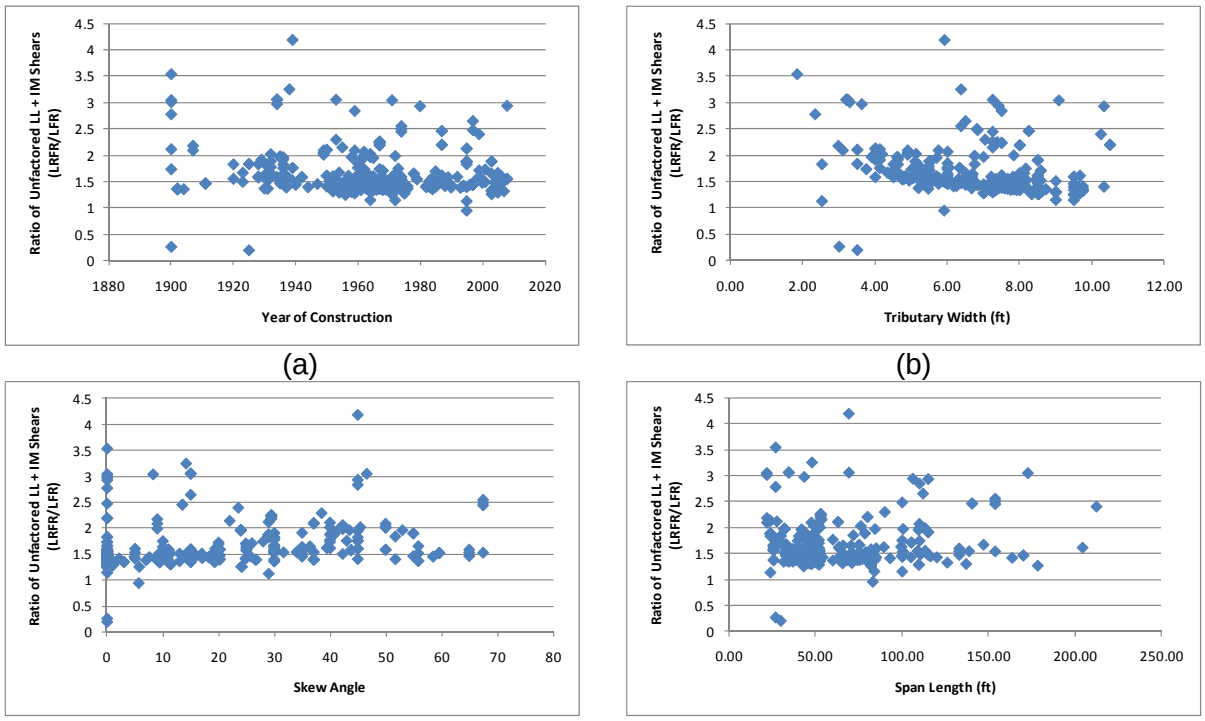


Figure B-69: Ratio of Unfactored Live Load plus Impact Shear for FL-04 Vehicle (LRFR/LFR)

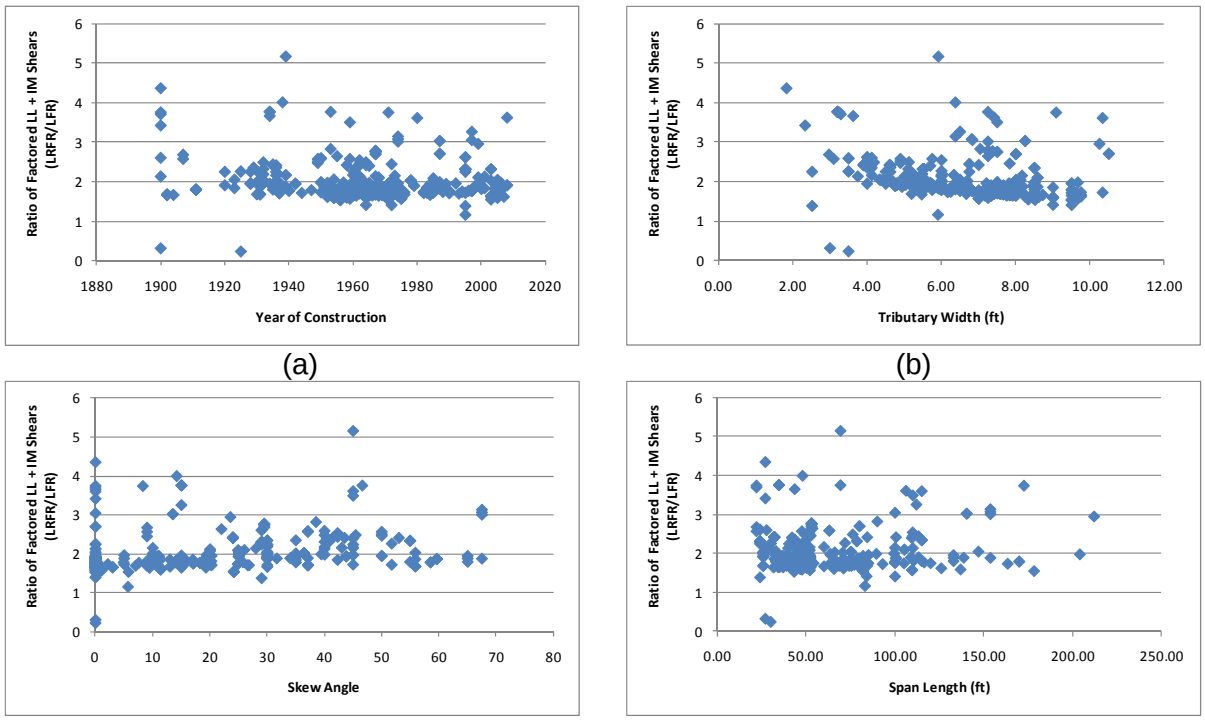


Figure B-70: Ratio of Factored Live Load plus Impact Shear for FL-04 Vehicle (LRFR/LFR)

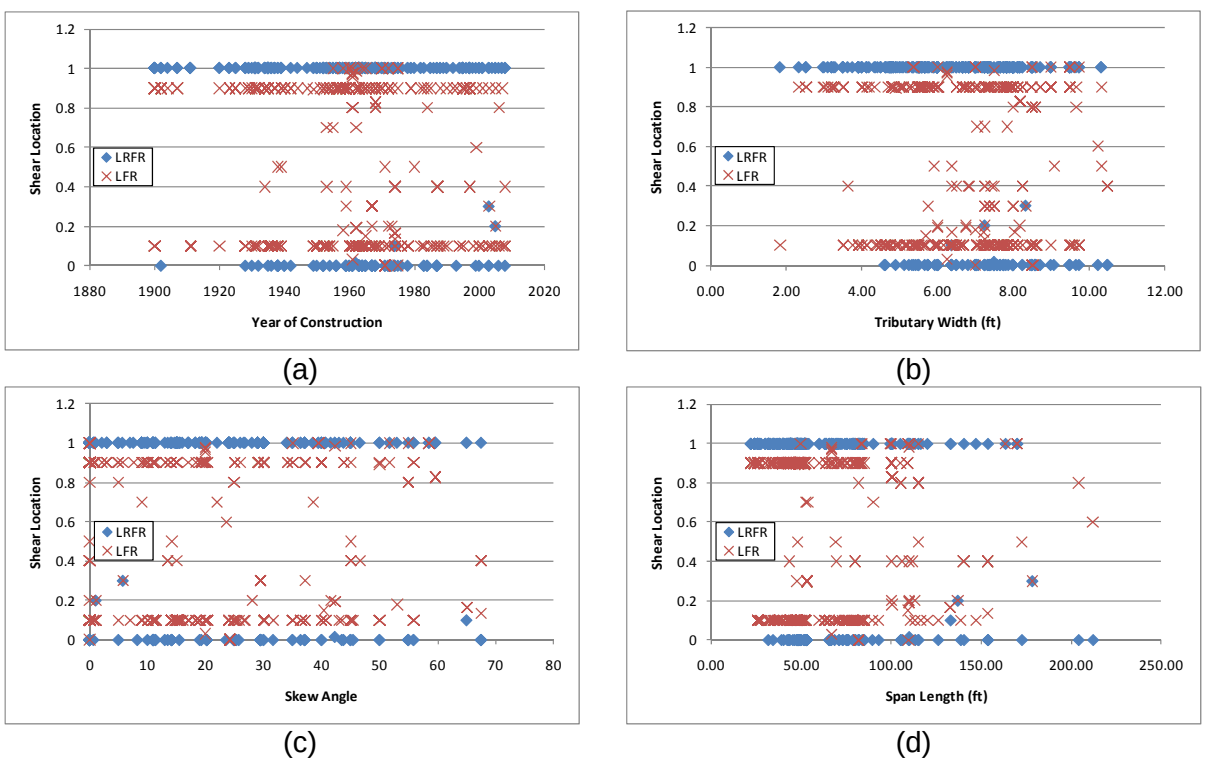


Figure B-71: Critical Shear Location for FL-04 Vehicle

B.1.4.2.2 Resistances

Figure B-72 shows the ratio of factored shear resistance. There are a number of girders where the shear resistance for LRFR is significantly greater than for LFR. These girders are removed in the next section (B.1.4.2.3) where only girders with the critical location at the support or one-tenth point are considered.

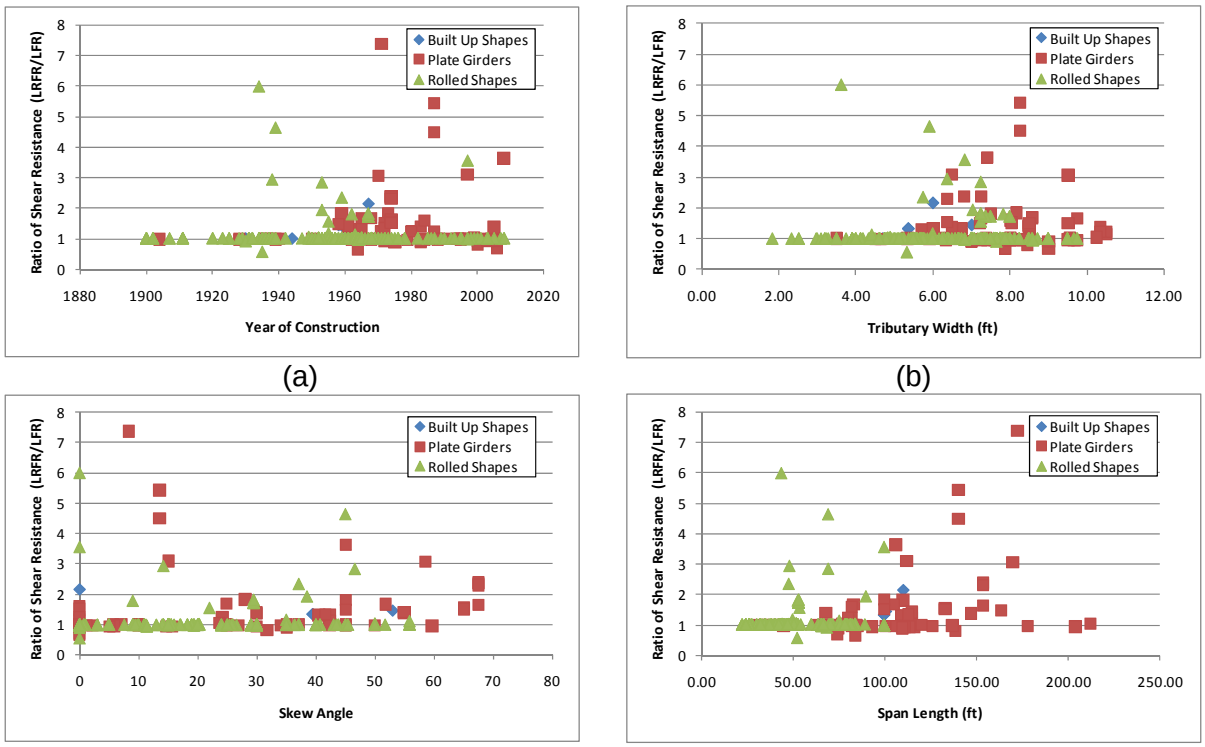
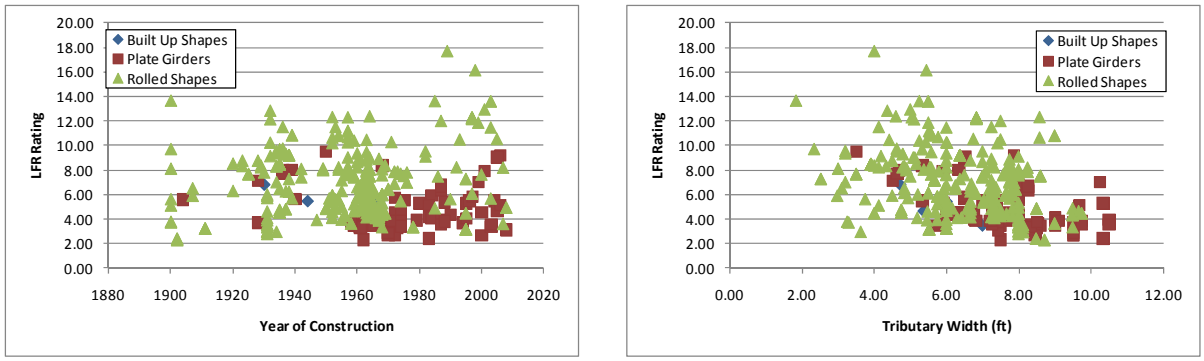
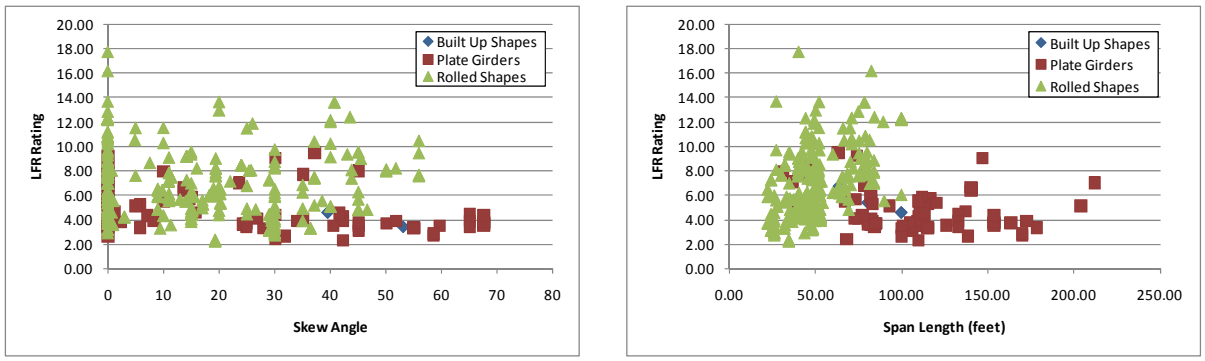


Figure B-72: Ratio of factored shear resistance (LRFR/LFR)

B.1.4.2.3 Rating Factors

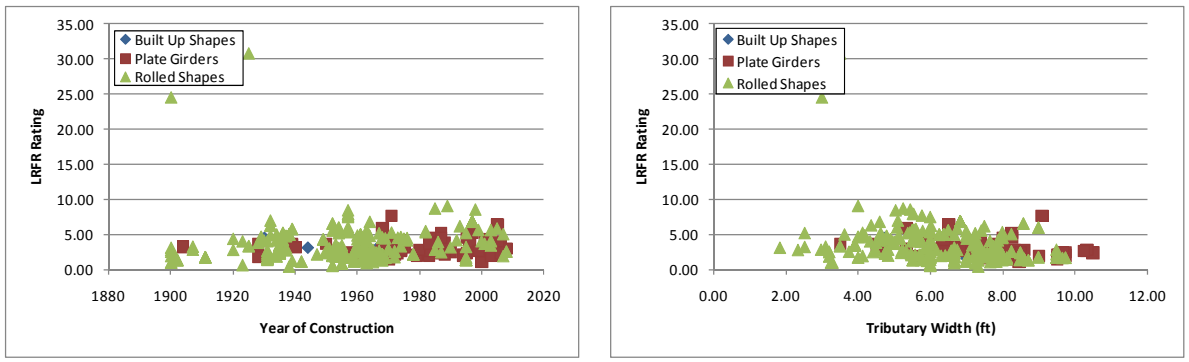
Figure B-73 and Figure B-74 show the LFR and LRFR rating factors respectively. The LFR ratings tend to have less scatter as the span length increases (Figure B-73d); this is not noticed in the LRFR ratings. There are no girders with an LFR rating less than 1.0 and nine girders with an LRFR rating less than 1.0, and 98% of the girders have LFR ratings greater than LRFR ratings. The reduction in LRFR shear rating may be partially a result of the bearing stiffener rating controlling as well as the factored LRFR live load is approximately two times larger than the factored LFR live load.



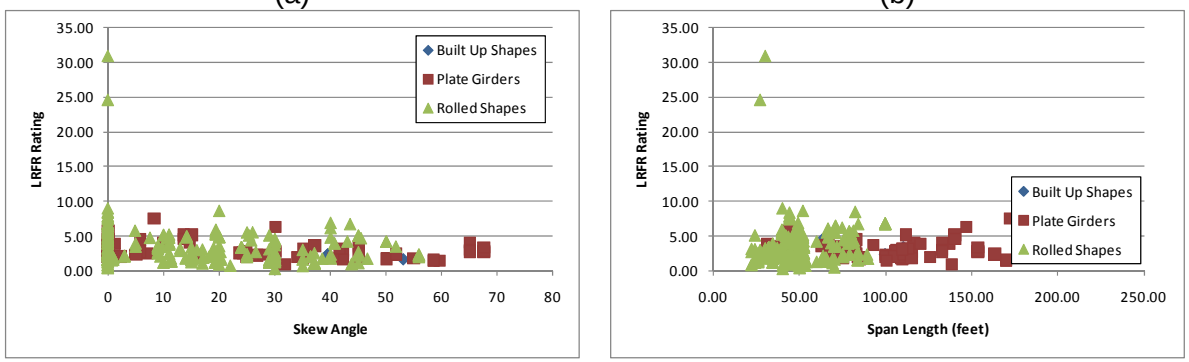


(c) (d)

Figure B-73: LFR Shear Rating Factors for FL-04 Vehicle



(a) (b)

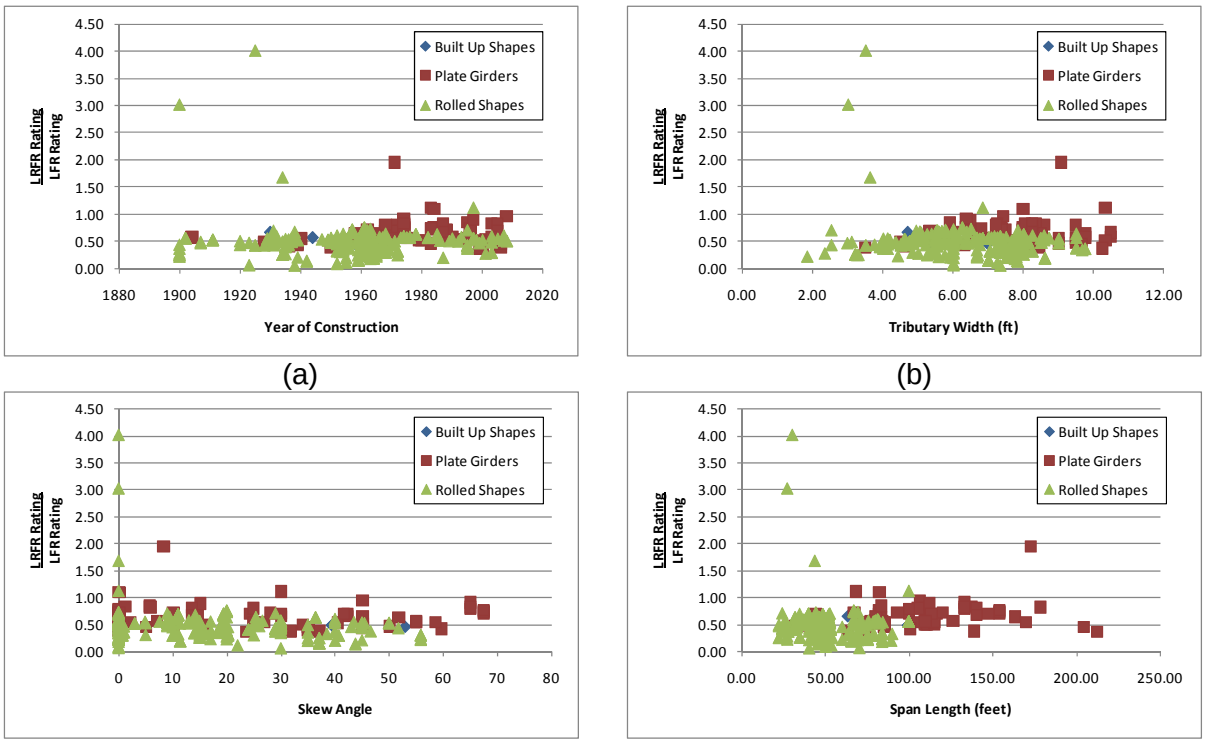


(c) (d)

Figure B-74: LRFR Shear Rating Factors for FL-04 Vehicle

B.1.4.2.4 Rating Factor Comparisons

Figure B-75 shows the ratio of rating factors, LRFR divided by LFR. In almost all cases, the LFR rating is greater than the LRFR rating. Rolled shapes typically have a LRFR rating of 75% of the LFR rating or less, while plate girders are generally between 0.5 and 1.0.



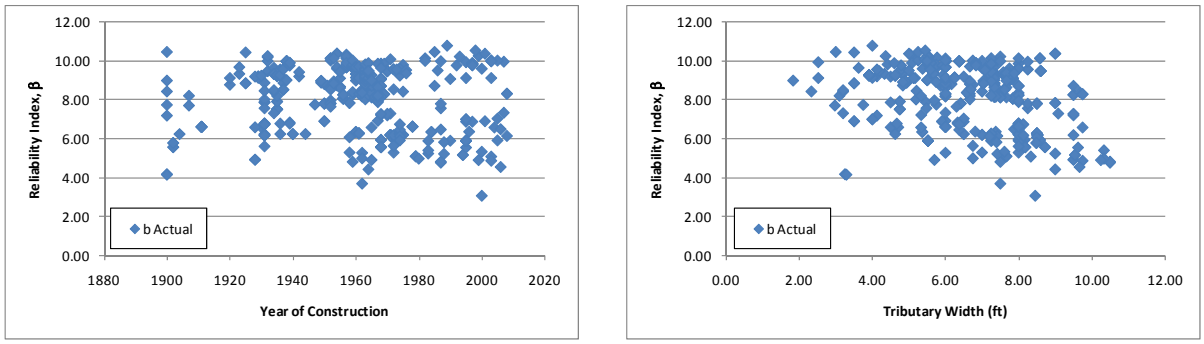
(a) (b)

(c) (d)

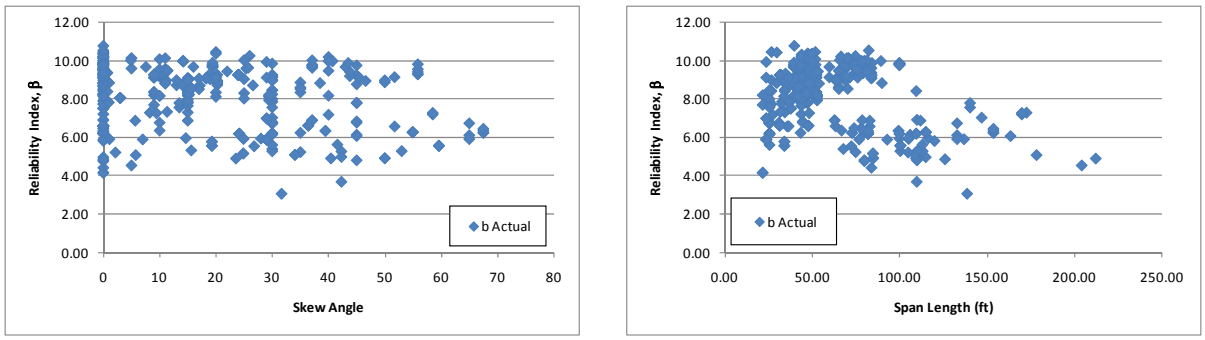
Figure B-75: Ratio of LRFR Shear Rating to LFR Shear Rating for FL-04 Vehicle

B.1.4.2.5 Reliability Indices

Figure B-76 shows the reliability indices that were calculated. The level of reliability assumed in the development of the MBE is 2.5 for a routine permit vehicle. There is significant scatter in the actual reliability index, with Figure B-76b shows more scatter with increasing tributary width and Figure B-76d having more scatter with shorter spans.



(a) (b)



(c) (d)

Figure B-76: Shear Reliability Indices for FL-04 Vehicle

Figure B-77 shows the actual reliability index versus the LRFR rating factor. The figure shows that for a rating factor of 1.0 the expected actual reliability index will be at least 3 and possibly higher. This indicates that lower live load factors could be used and still obtain the required level of reliability.

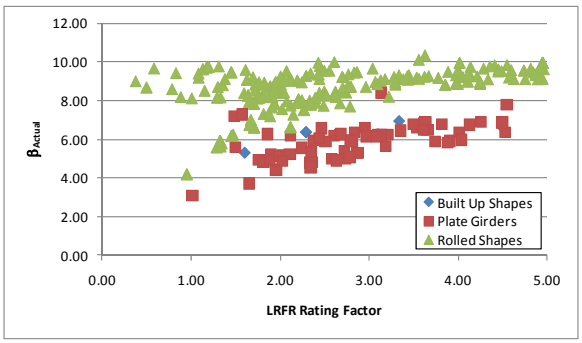


Figure B-77: Reliability Index versus LRFR Rating Factor

B.1.4.3 Shear-Corrected

This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.4.3.1 Live Load

Figure B-78 and Figure B-79 show the ratio of unfactored and factored live load plus impact shear for those girders with critical locations at the either the support or one-tenth of the span away from the support. The LRFR unfactored shear is between 1.0 and 1.5 times the LFR unfactored shear, when factored the LRFR live load shear is 1.25 to 2.0 times the LFR live load shear. This shows that the live loads are more similar when they are taken at the same location but the LRFR live load is still significantly larger than the LFR live load.

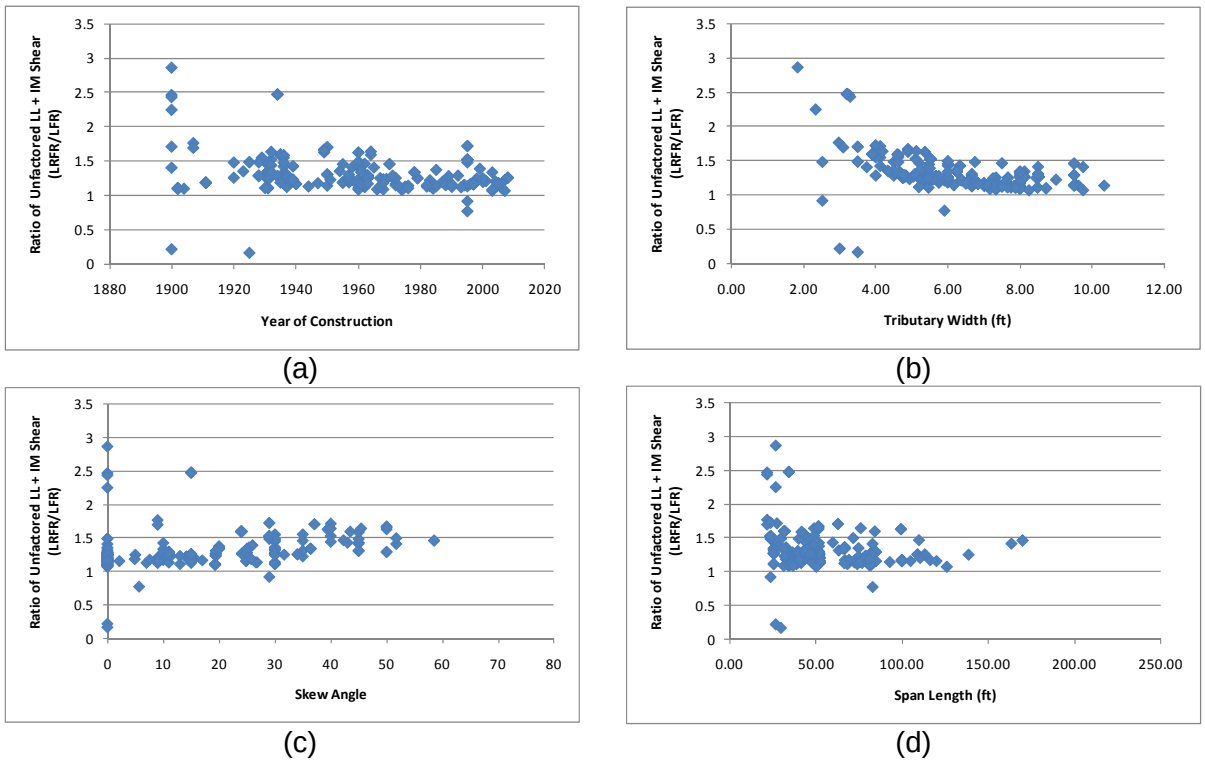


Figure B-78: Ratio of Unfactored Live Load plus Impact Shear for FL-04 Vehicle (LRFR/LFR)

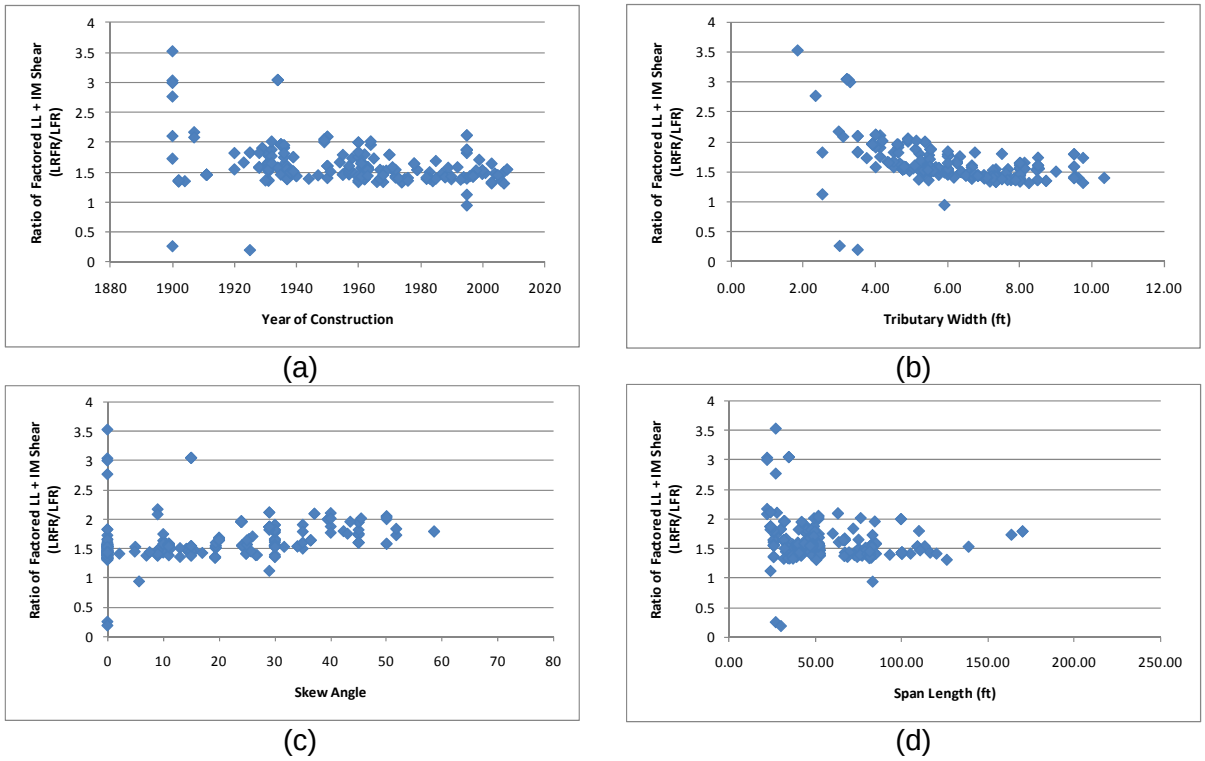
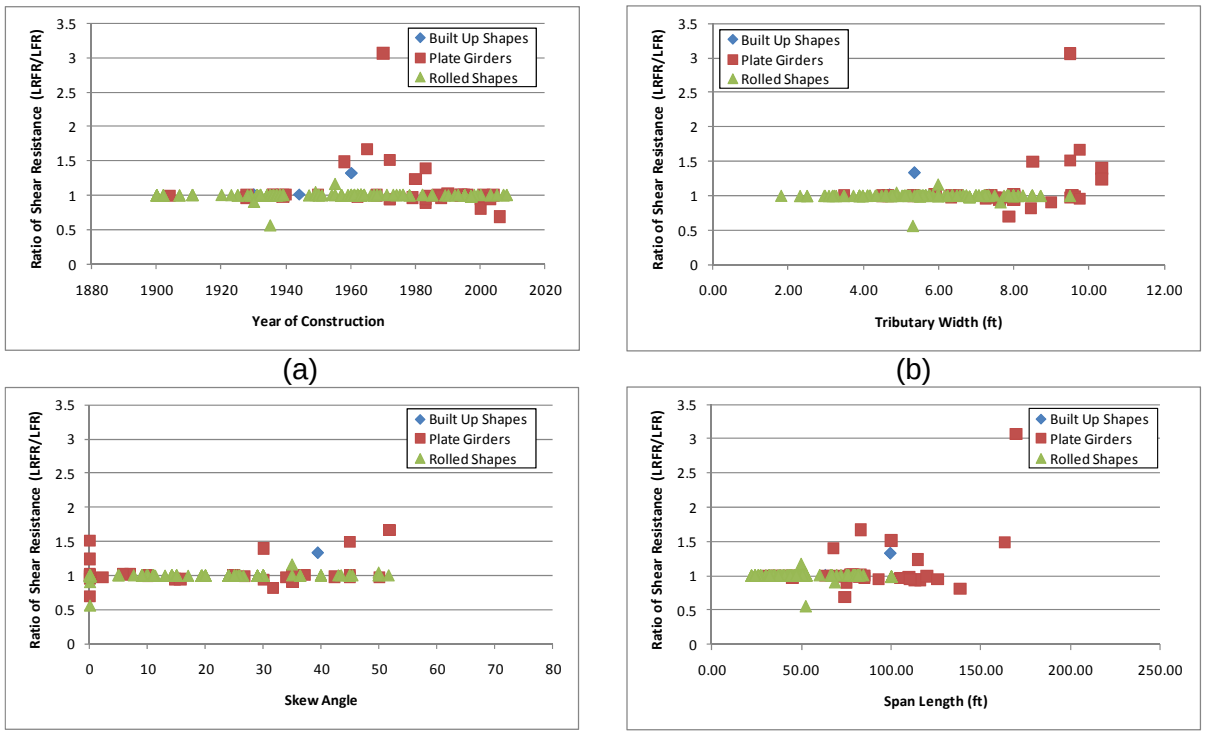


Figure B-79: Ratio of Factored Live Load plus Impact Shear for FL-04 Vehicle (LRFR/LFR)

B.1.4.3.2 Resistance

The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was greater than 1.0 have been eliminated by considering only those close to the support and where the stiffener spacing was likely to be the same. The ratio of shear resistance is shown in Figure B-80.



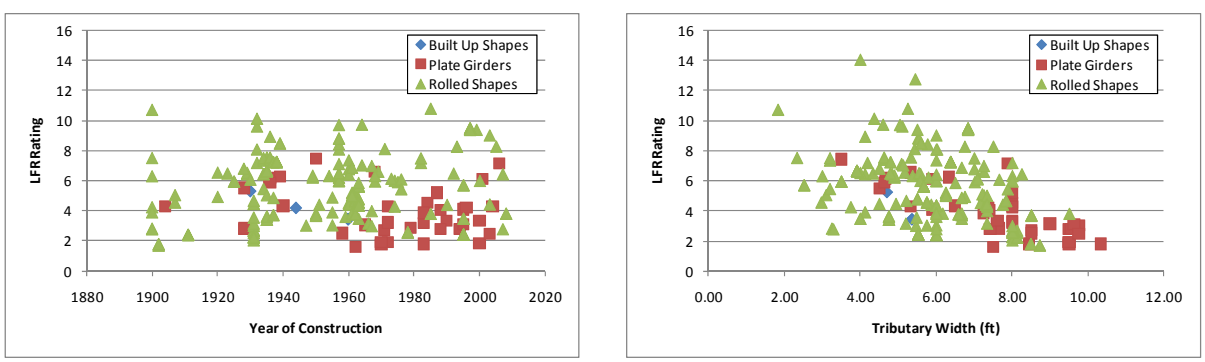
(a) (b)

(c) (d)

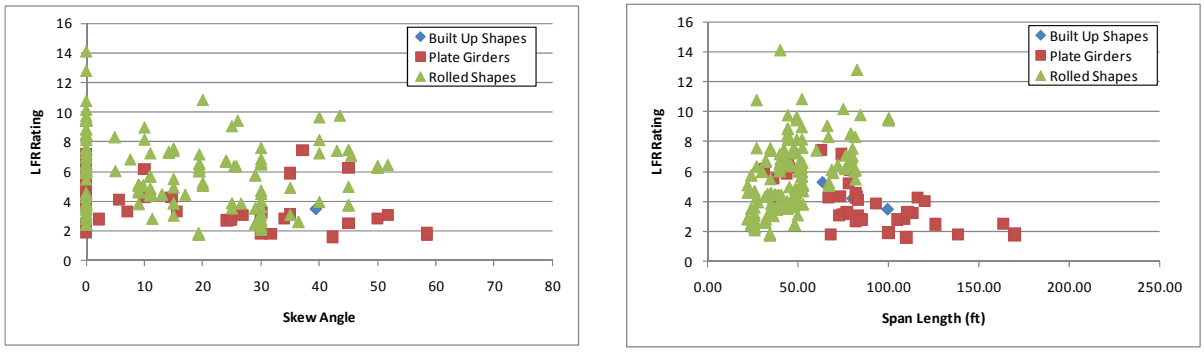
Figure B-80: Ratio of Factored Shear Resistance

B.1.4.3.3 Rating Factors

After verifying that the live load shears and shear resistances are similar, the next step was to examine the rating factors. Figure B-81 and Figure B-82 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where it is likely that the stiffeners are present and their spacing may vary along the span length.

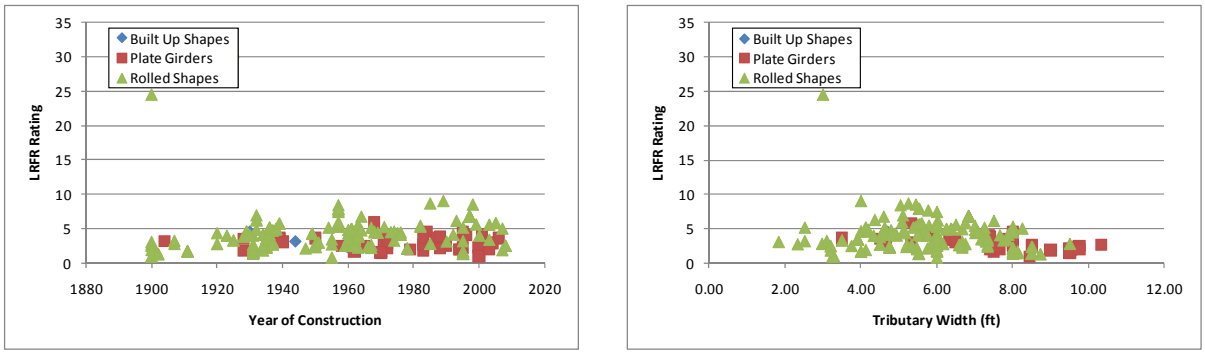


(a) (b)

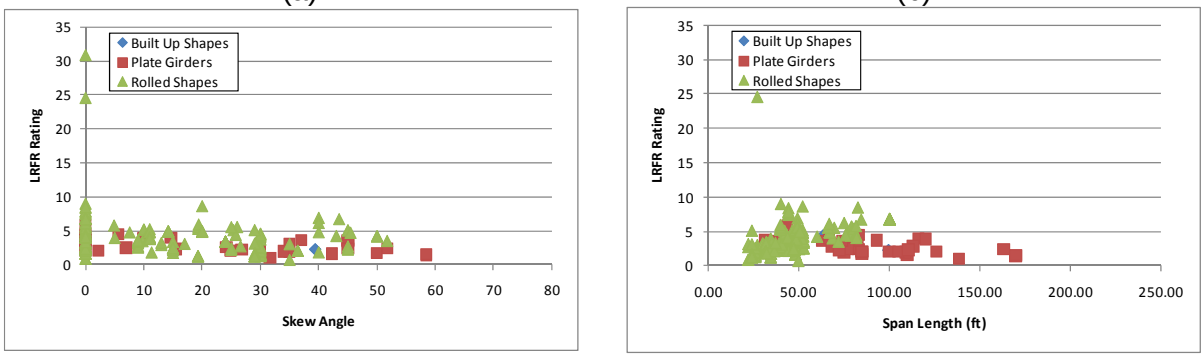


(c) (d)

Figure B-81: LFR Shear Rating Factor for FL-04 Vehicle



(a) (b)

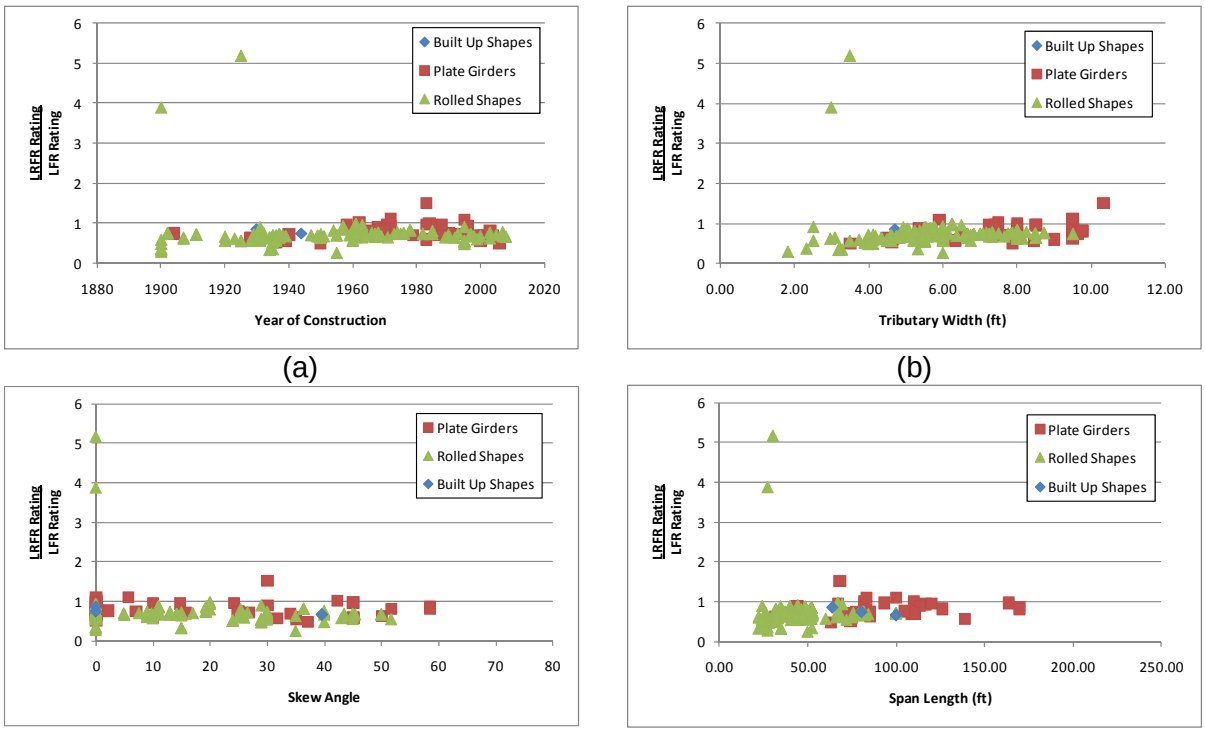


(c) (d)

Figure B-82: LRFR Shear Rating Factor for FL-04 Vehicle

B.1.4.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio of the LRFR rating factor to the LFR rating factor. Figure B-83 shows the results of this comparison. The results show that the LFR rating is typically greater than the LRFR rating after recalculating the rating at the support. The LFR rating being larger than the LRFR rating is a result of the LRFR live load being larger and reducing the rating.



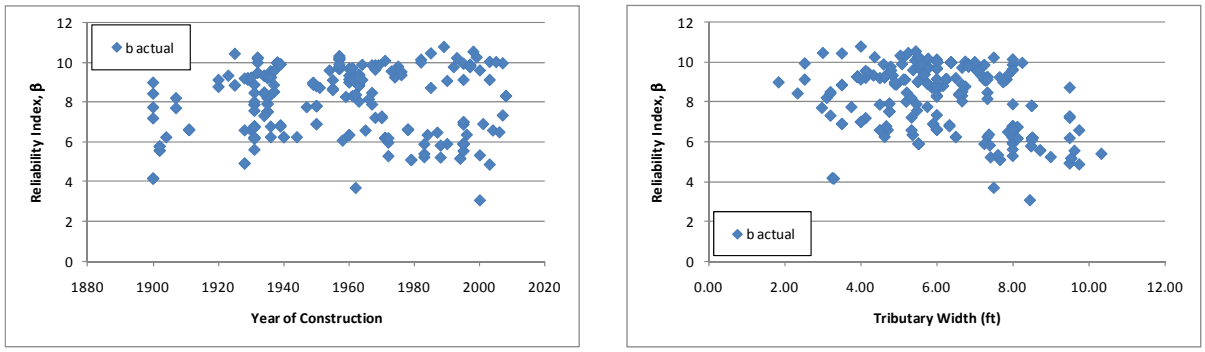
(a) (b)

(c) (d)

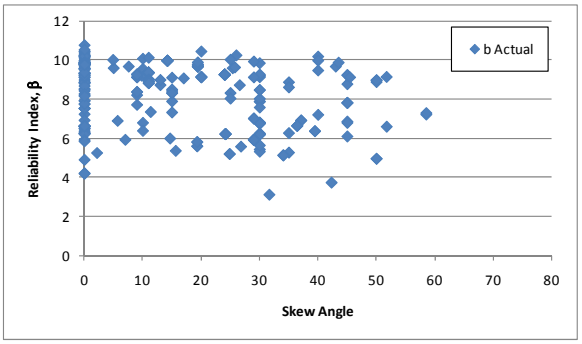
Figure B-83: Ratio of LRFR Shear Rating to LFR Shear Rating for FL-04 Vehicle

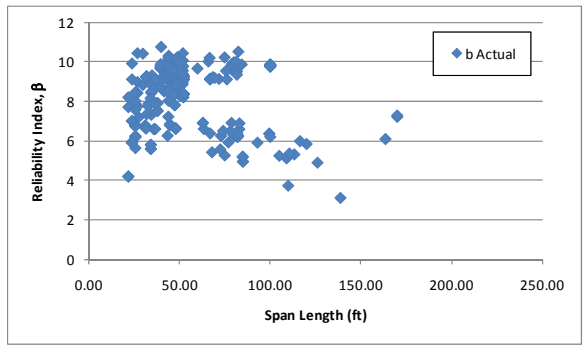
B.1.4.3.5 Reliability Indices

The reliability indices shown in Figure B-84 are the same as those shown in Figure B-76. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 2.5. The reliability index remains the same as calculated previously because the LRFR location did not move.



(a) (b)





(c) (d)

Figure B-84: Shear Reliability Indices for FL-04 Vehicle

B.1.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-85. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

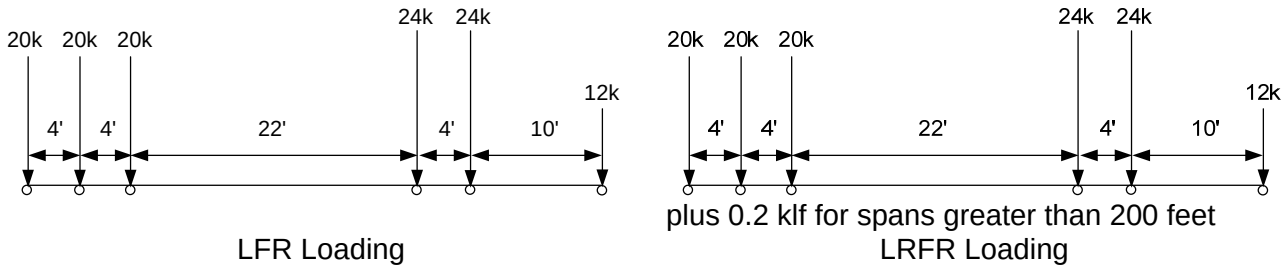
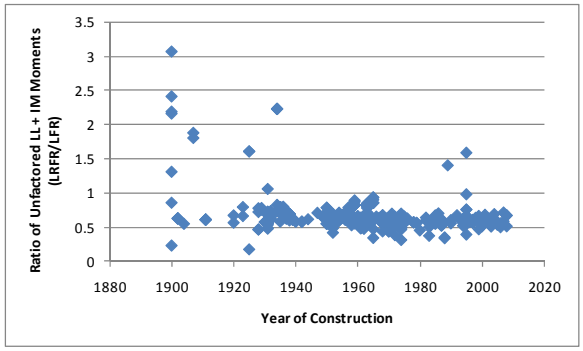


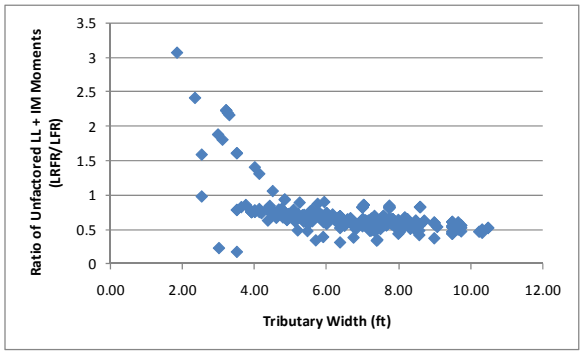
Figure B-85: Vehicle Loadings and Load Factors

B.1.5.1 Moment

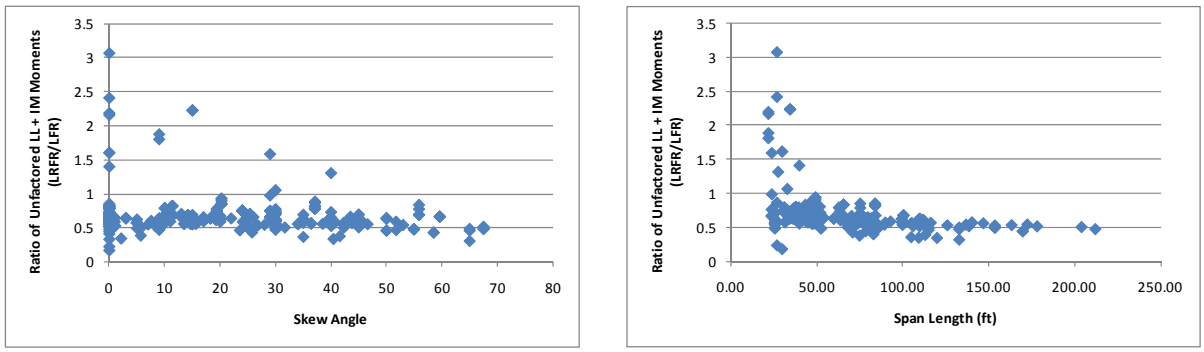
B.1.5.1.1 Live Loads

Figure B-86 and Figure B-87 shows the ratios of unfactored and factored live load plus impact moments for the IL-01 vehicle. The LFR moments due to live load plus impact are typically greater than the LRFR moments, for both the factored and unfactored case. The unfactored ratio is typically around 0.50 and 0.80, while the factored ratio is between 0.60 and 0.9. The live load factors used are 1.40 for LRFR and 1.30 for LFR.



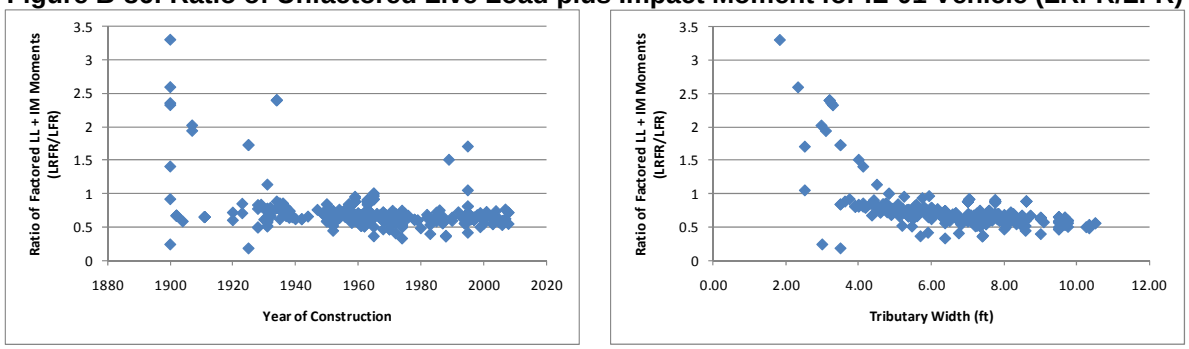


(a) (b)

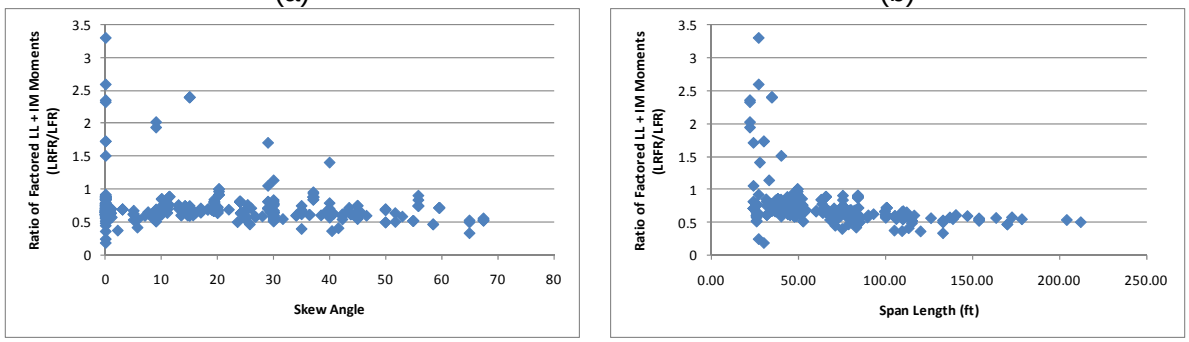


(c) (d)

Figure B-86: Ratio of Unfactored Live Load plus Impact Moment for IL-01 Vehicle (LRFR/LFR)



(a) (b)

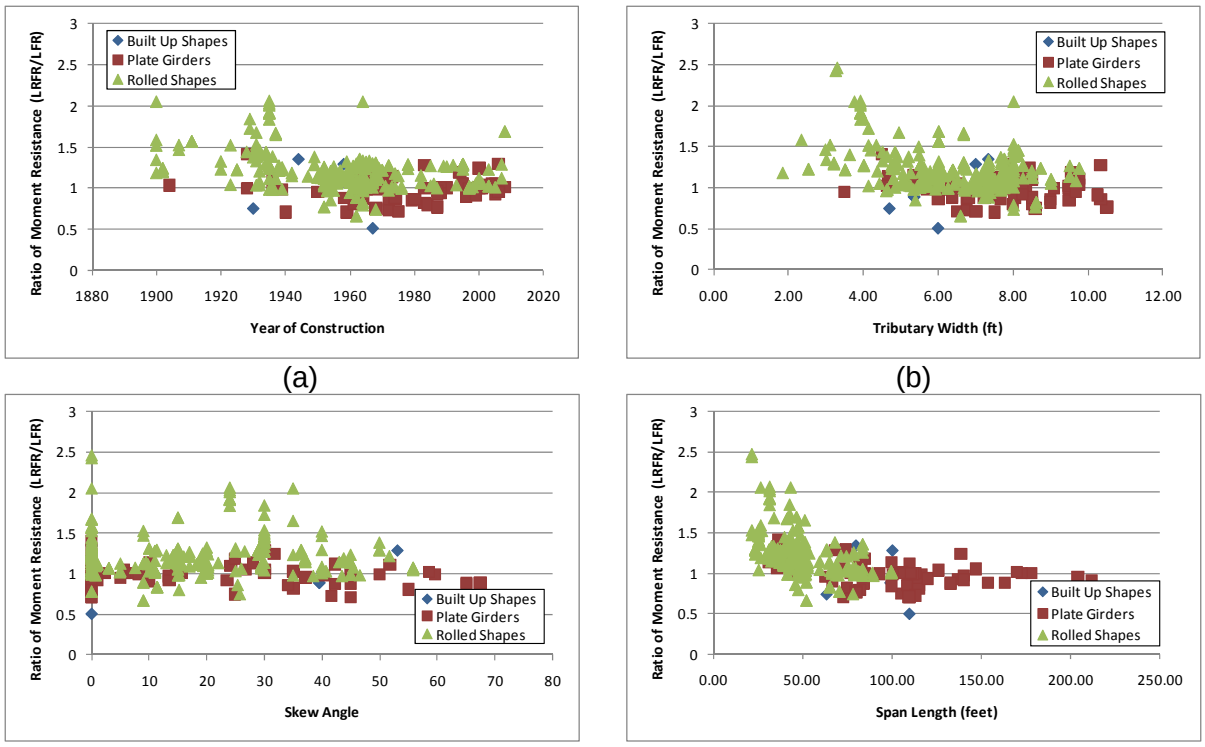


(c) (d)

Figure B-87: Ratio of Factored Live Load plus Impact Moment for IL-01 Vehicle (LRFR/LFR)

B.1.5.1.2 Resistances

Figure B-88 shows the ratio of the factored moment resistances. The strength does not appear to be affected by the skew as may be expected if designed using the LRFD Design Specification because of the additional load due to the skew. Rolled shapes are more likely to have higher LRFR resistance than LFR resistance while plate girders show that the LFR resistance is typically greater than the LRFR resistance.



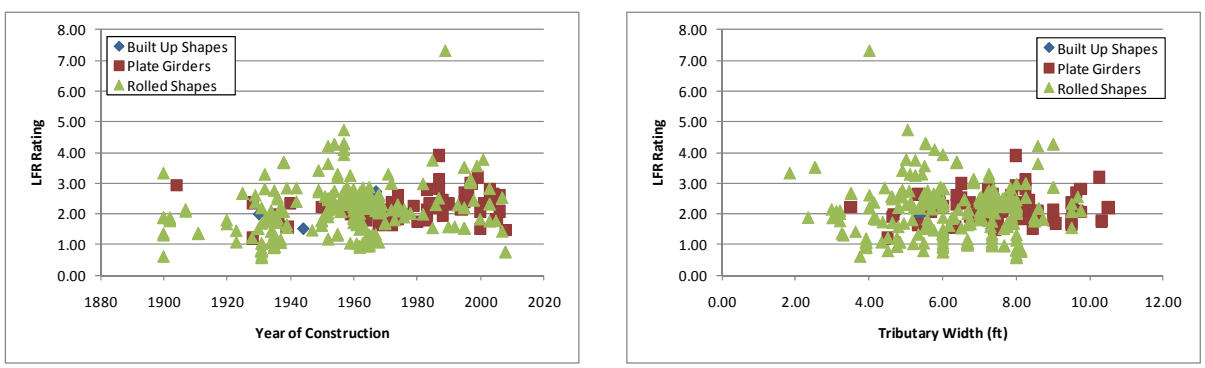
(a) (b)

(c) (d)

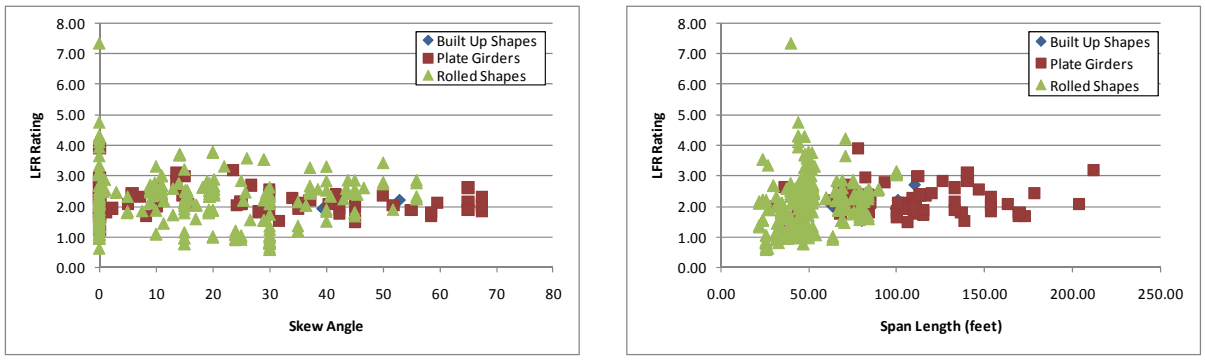
Figure B-88: Ratio of Moment Resistance (LRFR/LFR)

B.1.5.1.3 Rating Factors

Figure B-89 and Figure B-90 present the LFR and LRFR ratings from BRASS, respectively. There are 29 girders with an LFR rating less than 1.0, nine girders with an LRFR rating less than 1.0, and three girders where both ratings are less than 1.0. Ignoring the outliers, the two methods provide similar scatter with the LRFR rating shifted up from the LFR rating. The increase in rating is expected due to the reduced LRFR live load.

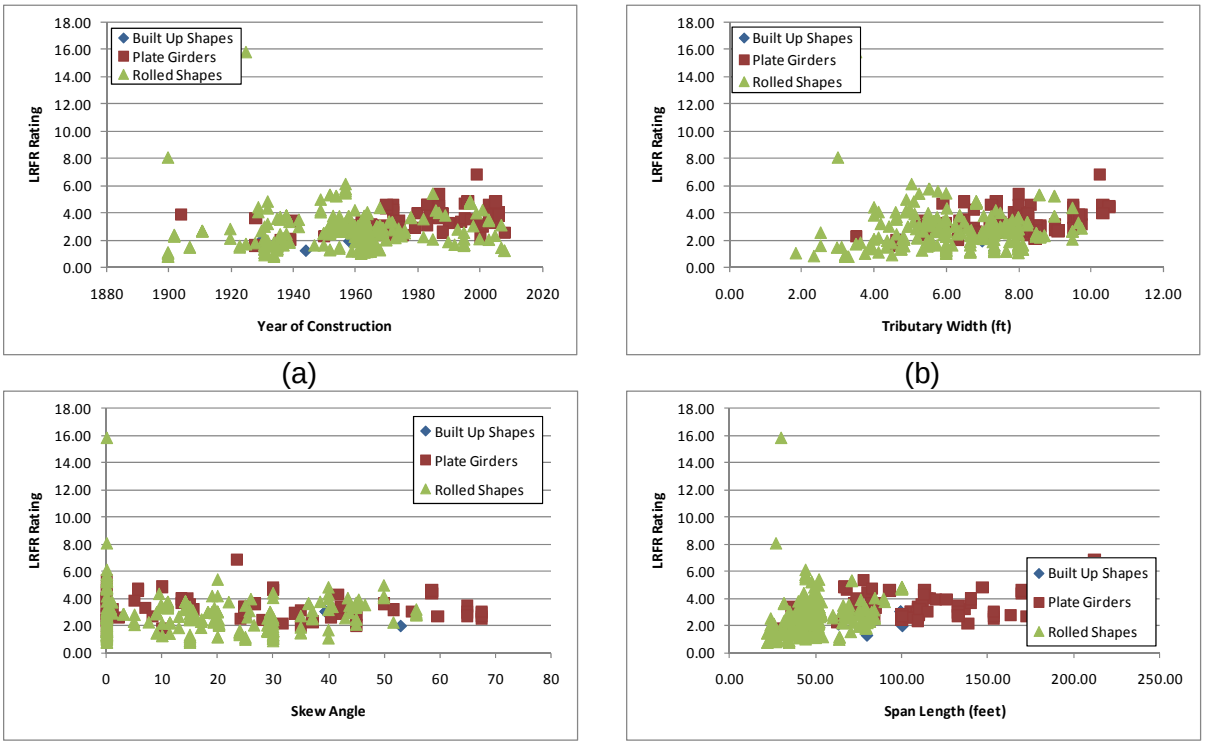


(a) (b)



(c) (d)

Figure B-89: LFR Moment Rating Factor for IL-01 Vehicle



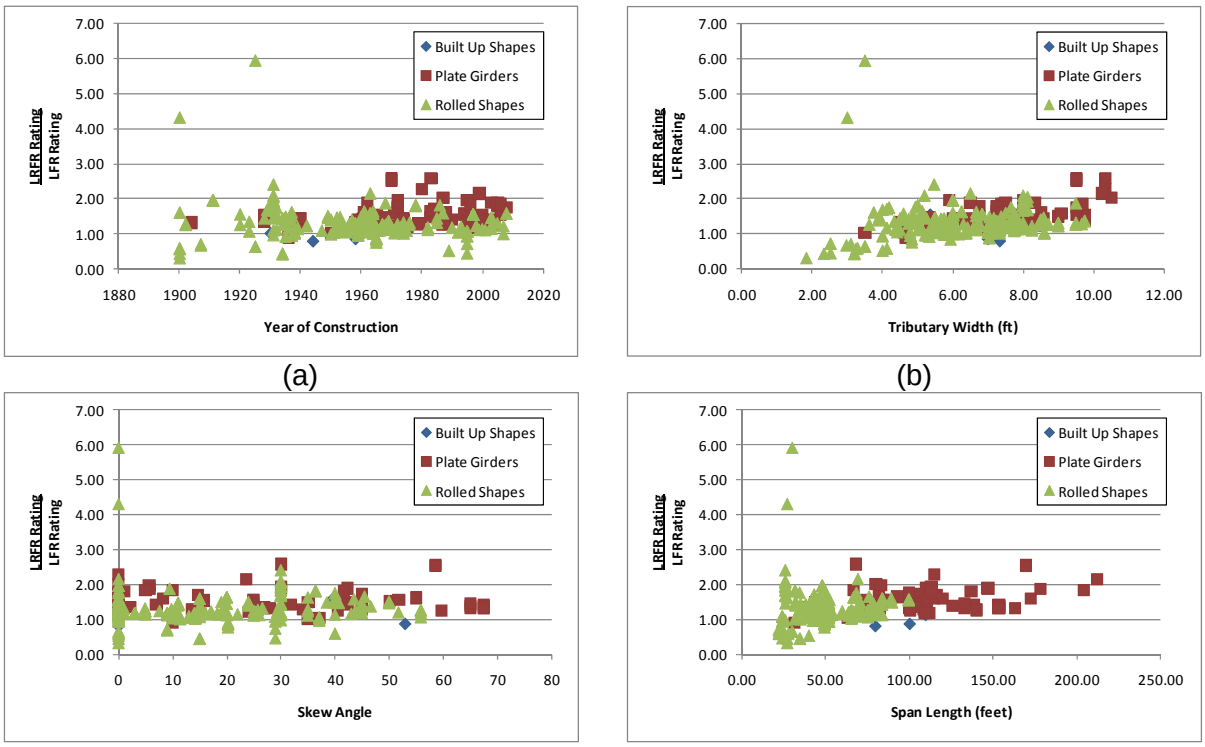
(a) (b)

(c) (d)

Figure B-90: LRFR Moment Rating Factor for IL-01 Vehicle

B.1.5.1.4 Rating Factor Comparisons

Figure B-91 shows that with for most girders, the LRFR rating is greater than the LFR rating. Eight percent of girders in this subset have an LFR rating that is greater than the LRFR rating. The girders with higher LFR ratings generally have closely spaced girders and short span lengths. Plate girders generally have ratios above 1.0.



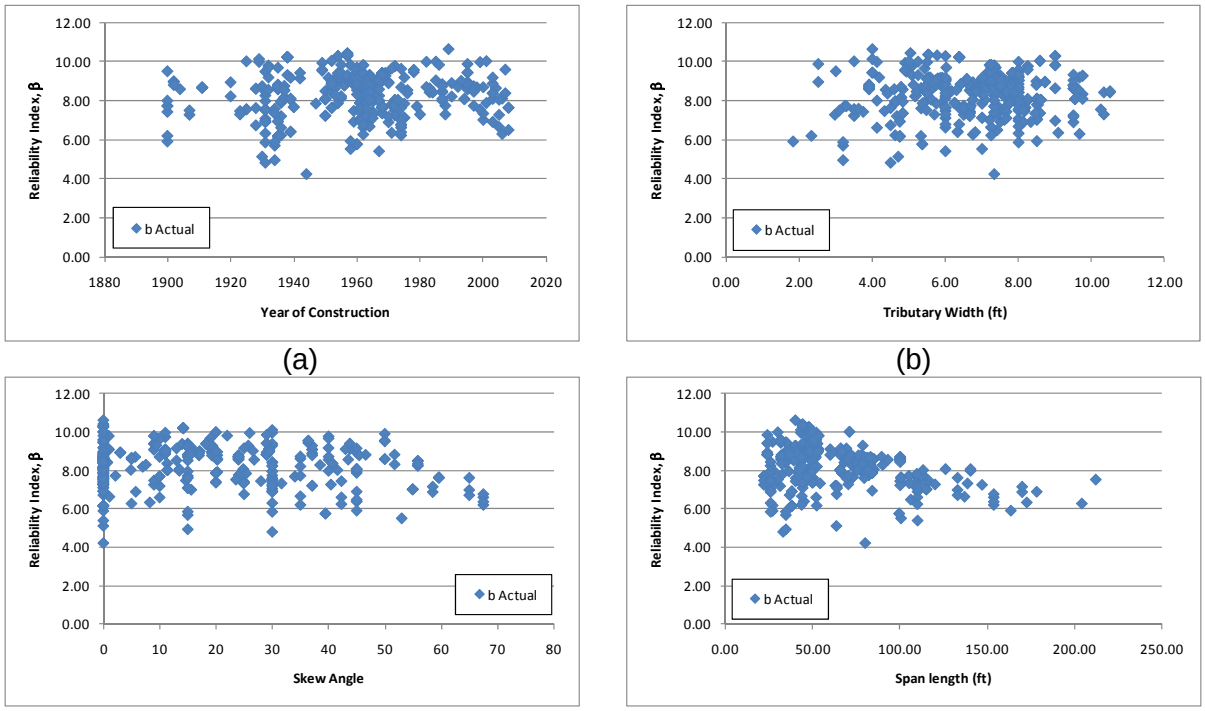
(a) (b)

(c) (d)

Figure B-91: Ratio of LRFR Moment Rating to LFR Moment Rating for IL-01 Vehicle

B.1.5.1.5 Reliability Indices

Figure B-92 presents the reliability index as calculated based upon the resistance of the cross-section. The reliability index for a special permit vehicle used in the development of the MBE is 3.5. This higher value as assumed to limit the loads applied to the structure.



(a) (b)

(c) (d)

Figure B-92: Flexural Reliability Indices for IL-01 Vehicle

Figure B-93 shows the actual reliability index versus the LRFR rating factor. A girder having a LRFR rating of 1.0 would be expected to have a reliability index above 4.0, while a reliability index of 3.5 is what the MBE is calibrated to provide for special permit vehicles. This indicates that a lower live load factor may be possible for these vehicles.

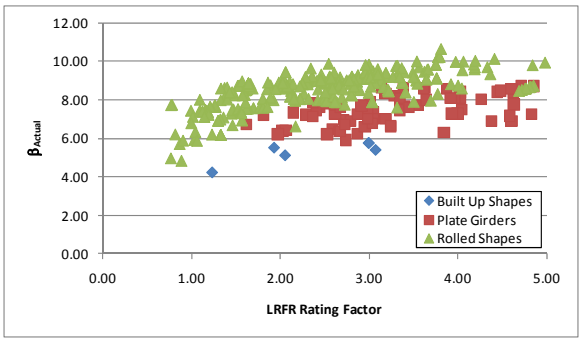
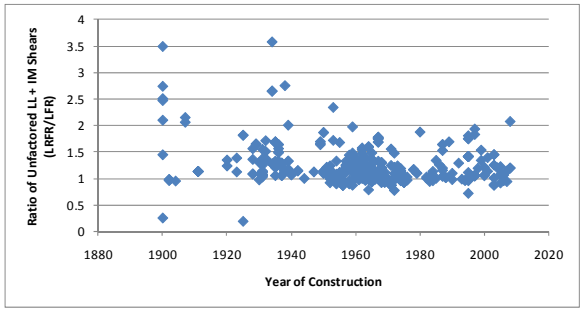


Figure B-93: Reliability Index versus LRFR Rating Factor

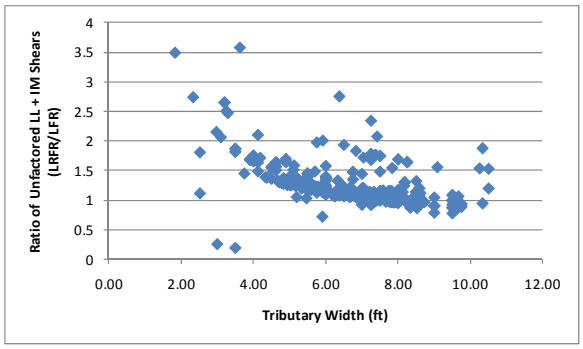
B.1.5.2 Shear

B.1.5.2.1 Live Loads

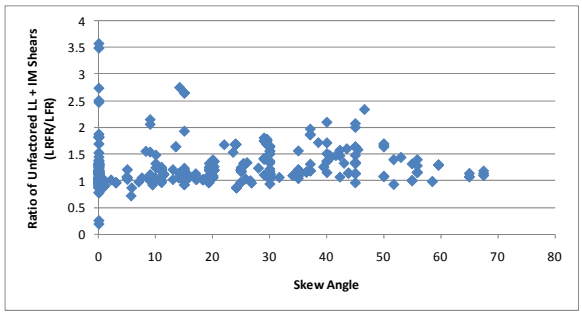
Figure B-94 and Figure B-95 show the ratios of unfactored and factored live load plus impact shear, respectively. The ratio of unfactored loads is generally between 0.8 and 1.50 and is between 1.0 and 1.75 when the loads are factored. Figure B-94c and Figure B-95c show that the ratio increases with increasing skew; this is expected as the LRFD Design Specification increases the load distributed to each girder because of the skew while the Standard Specification does not consider the effect of skew. Figure B-96 shows where the critical shear rating occurred for each girder. The LFR location is typically away from the support while the LRFR location is typically at the support.



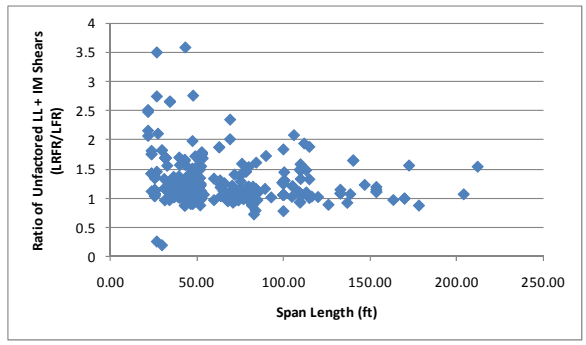
(a)



(b)

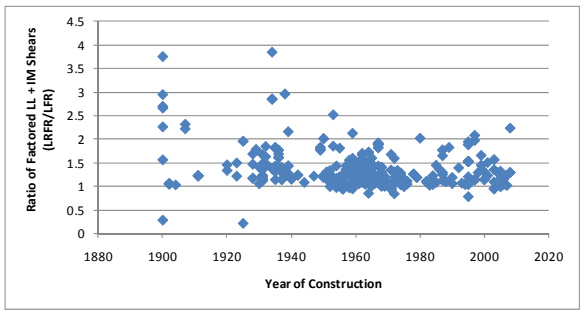


(c)

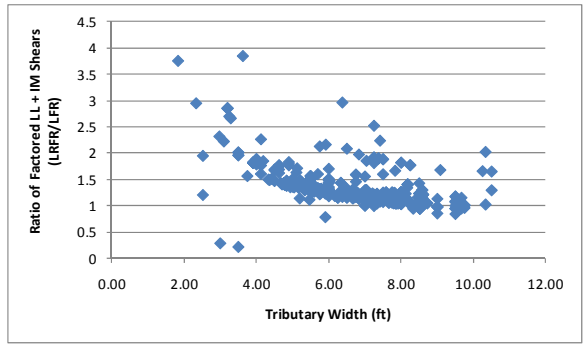


(d)

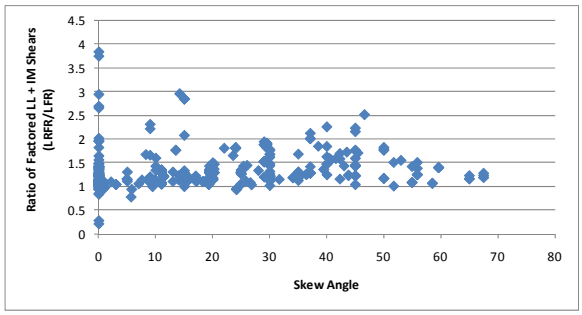
Figure B-94: Ratio of Unfactored Live Load plus Impact Shear for IL-01 Vehicle (LRFR/LFR)



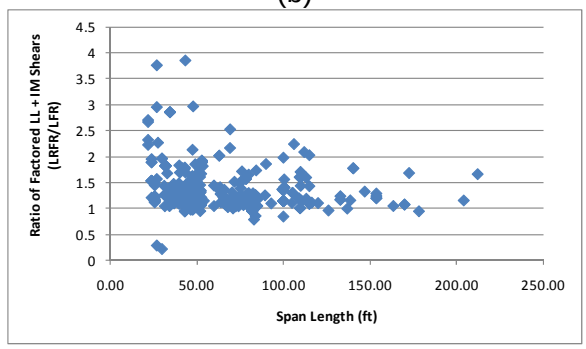
(a)



(b)

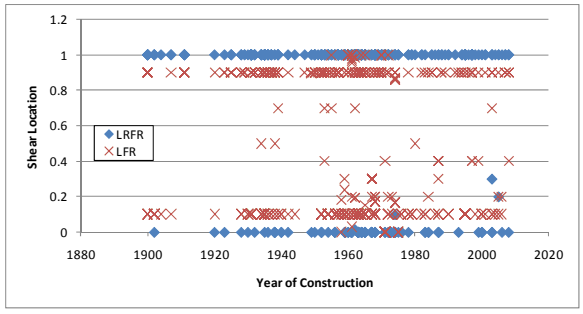


(c)

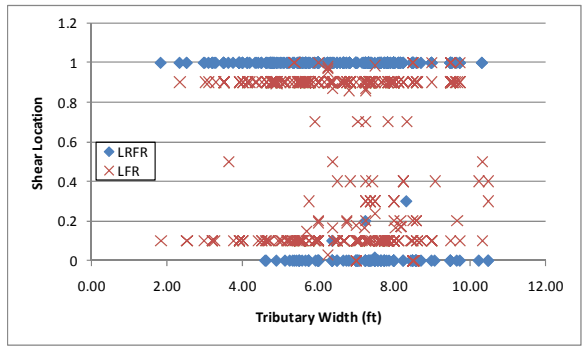


(d)

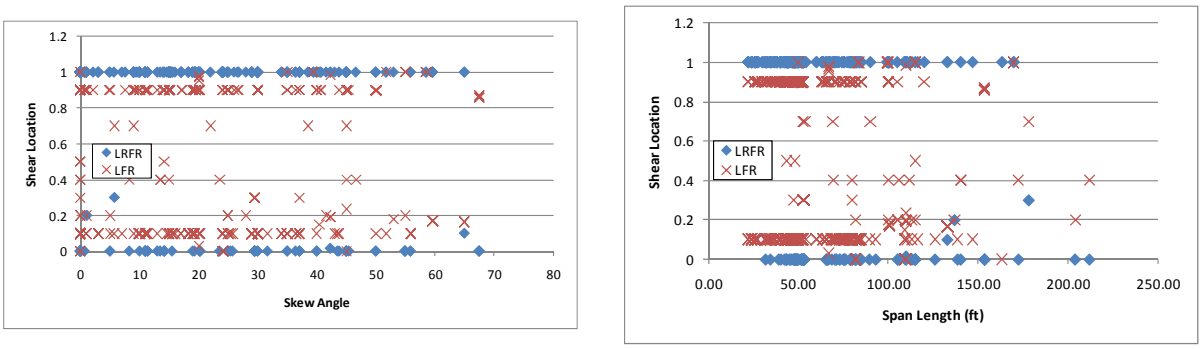
Figure B-95: Ratio of Factored Live Load plus Impact Shear for IL-01 Vehicle (LRFR/LFR)



(a)



(b)

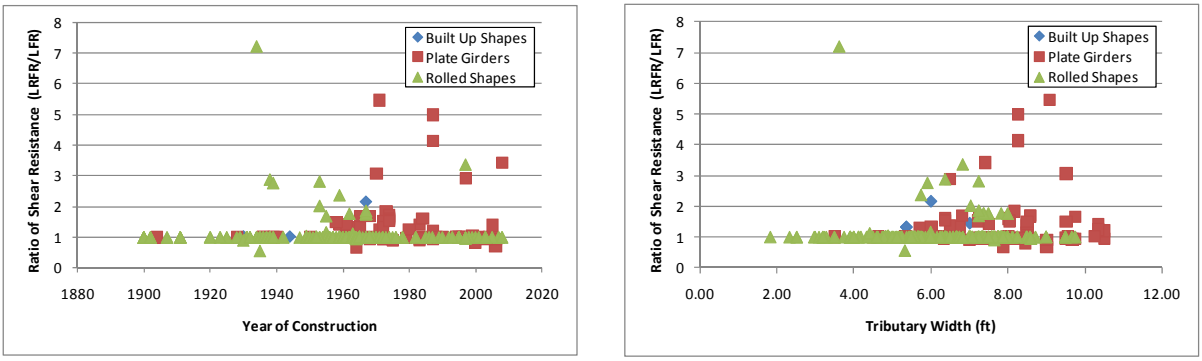


(c) (d)

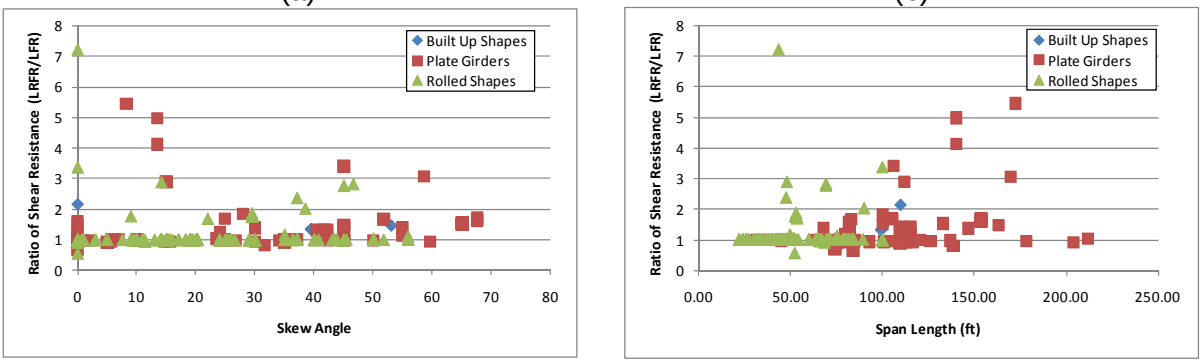
Figure B-96: Critical Shear Location for IL-01 Vehicle

B.1.5.2.2 Resistances

Figure B-97 shows the ratio of factored shear resistances. The ratio is generally close to 1.0, with most of the scatter being eliminated by removing those girders where the critical shear location varies significantly (Section B.1.5.3.2).



(a) (b)



(c) (d)

Figure B-97: Ratio of Factored Shear Resistances (LRFR/LFR)

B.1.5.2.3 Rating Factors

Figure B-98 and Figure B-99 present the ratings as calculated by BRASS for LFR and LRFR, respectively. The LFR Ratings tend to decrease with increasing tributary width and increasing span length (Figure B-98b and d). There is also less scatter in the LFR rating with increasing span length (Figure B-98d), no such observations can be made for the LRFR rating. There are zero girders with an LFR rating of less than 1.0 and nine girders with an LRFR rating less than 1.0. Additionally, 82% of the girders have LFR Ratings greater than the LRFR rating.

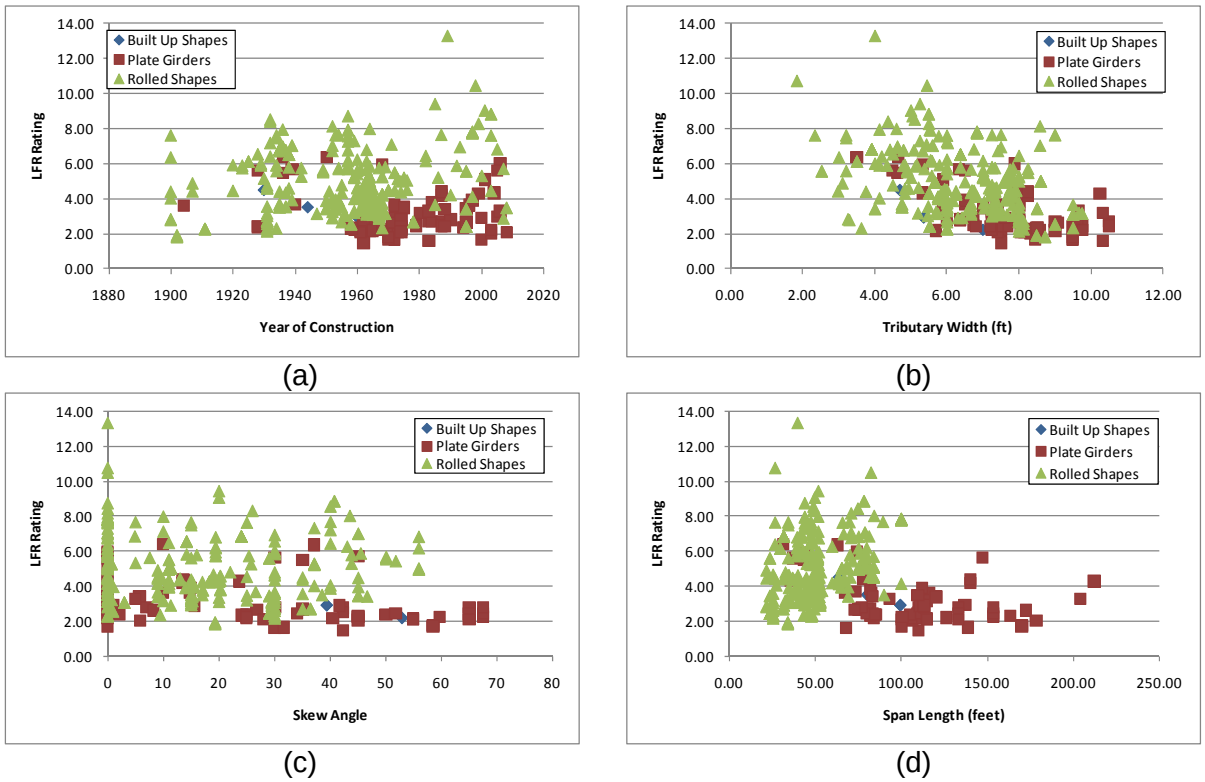


Figure B-98: LFR Shear Rating Factors for IL-01 Vehicle

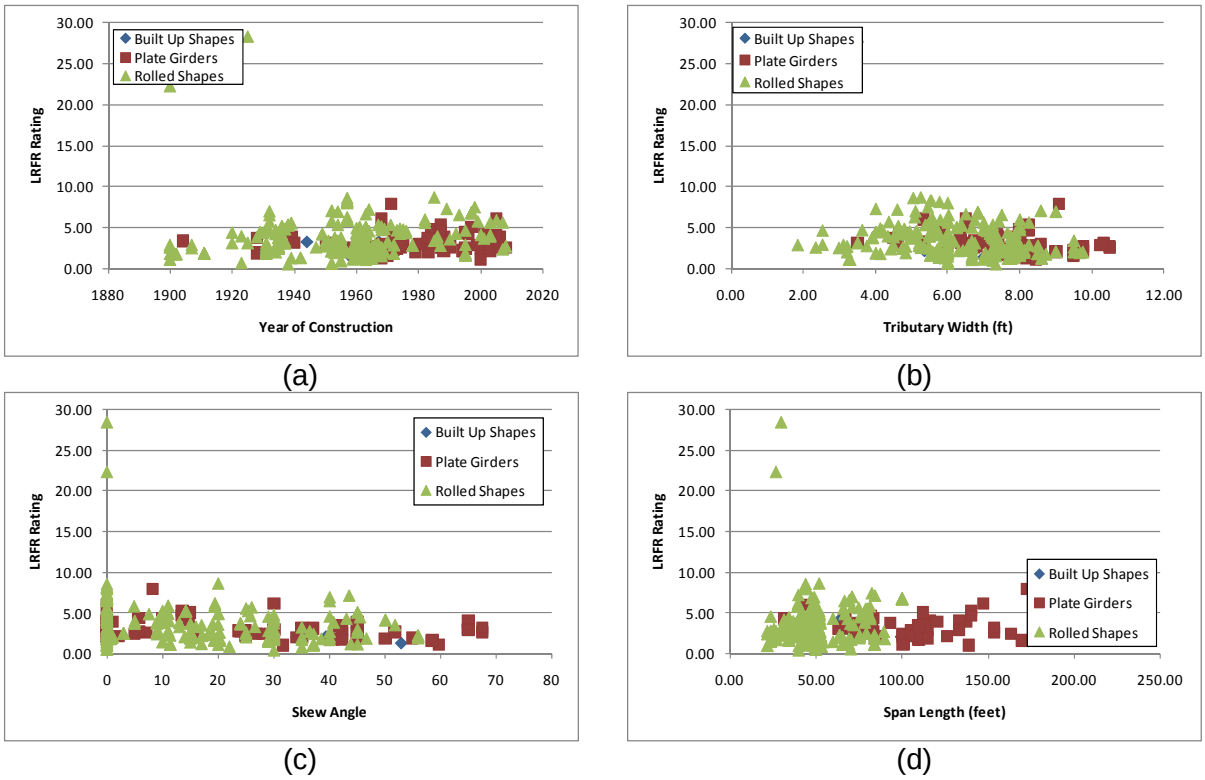
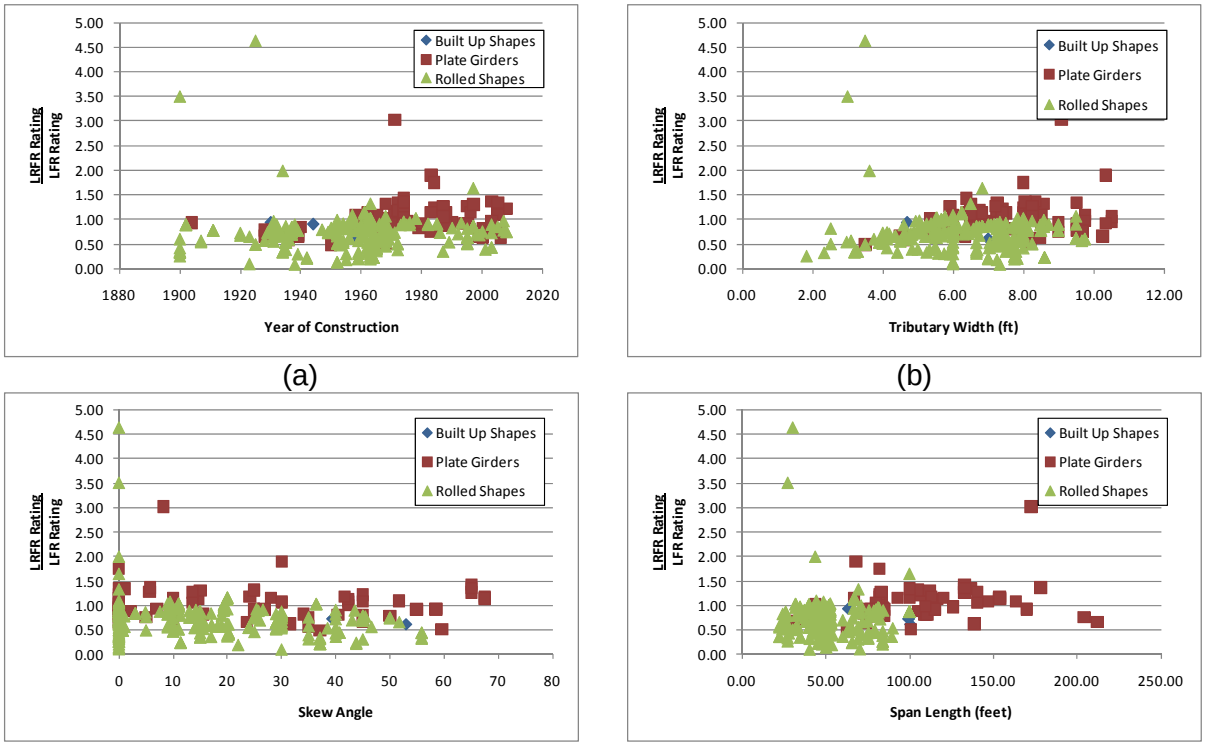


Figure B-99: LRFR Shear Rating Factors for IL-01 Vehicle

B.1.5.2.4 Rating Factor Comparisons

Figure B-100 shows the ratio of LRFR rating to LFR rating. The ratio tends to increase with increasing tributary width and increasing span length. Plate girders are more likely to have LRFR ratings higher than the corresponding LFR rating. With the exception of plate girders, the ratio is generally less than 1.0 for the other types of steel girders.

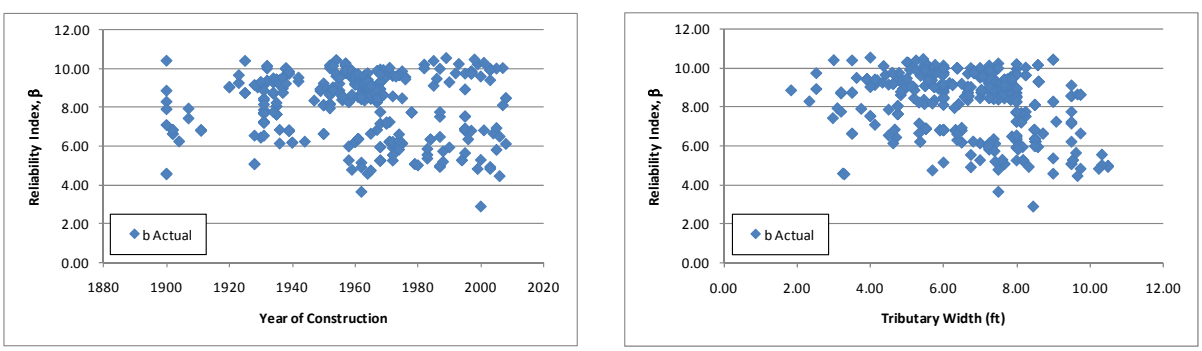


(a) (b) (c) (d)

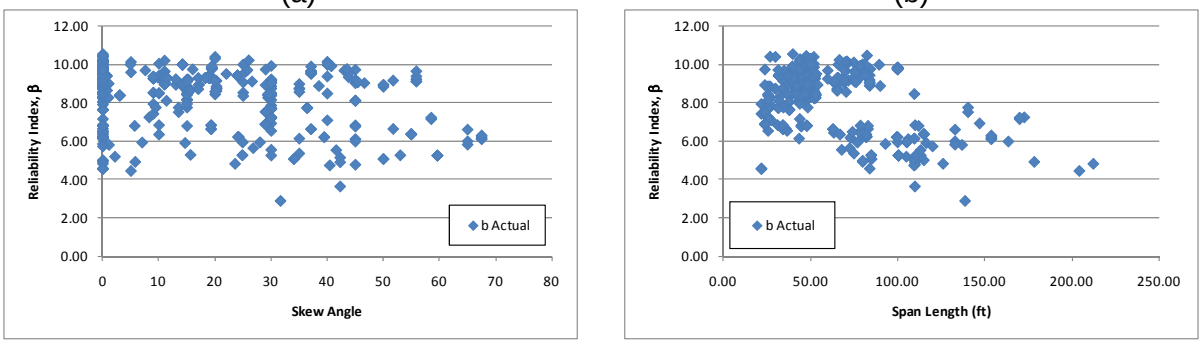
Figure B-100: Ratio of LRFR Shear Rating to LFR Shear Rating for IL-01 Vehicle

B.1.5.2.5 Reliability Indices

Figure B-101 shows the reliability indices as calculated based upon the strength of the section. The required level of reliability is 3.5 for this vehicle. There is one girder where the actual reliability index is less than the required and also several cases where they are very similar. Based on the figure there is no clear relationship between the horizontal axis and those that are close to the required value. One bridge was constructed in 1900 while another was constructed in 2000, the tributary width varies from slightly more than three feet to more than eight feet, and span length varies from less than 50 feet to almost 140 feet.



(a) (b)



(c) (d)

Figure B-101: Shear Reliability Indices for IL-01 Vehicle

Figure B-102 shows the actual reliability index plotted agains the LRFR rating factor for the IL-01 vehicle. The figure shows that a girder with a rating factor of 1.0 is expected to have a reliability index of between 2.5 and 3.0. This is less than the value used in the MBE of 3.5.

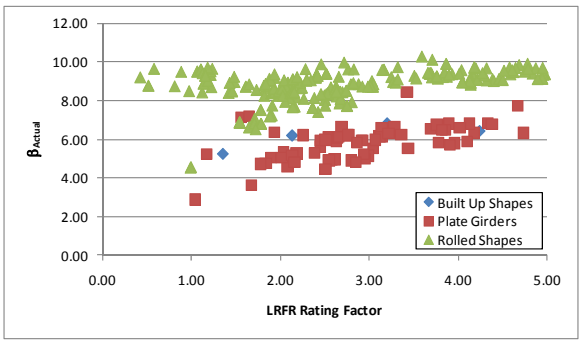


Figure B-102: Shear Reliability Index versus LRFR Shear Rating Factor for IL-01 Vehicle

B.1.5.3 Shear-Corrected

This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.5.3.1 Live Load

Figure B-103 and Figure B-104 show the ratio of unfactored and factored live load shear that have been modified to move those calculated at the one-tenth (or nine-tenths) point for LFR back to the support. Figure B-103 shows that there is less scatter with increasing span lengths and that the LRFR shear is generally greater than the LFR shear. The ratio is generally between 0.75 and 1.0 for unfactored loads and shifts up to 0.8 to 1.2 when factored.

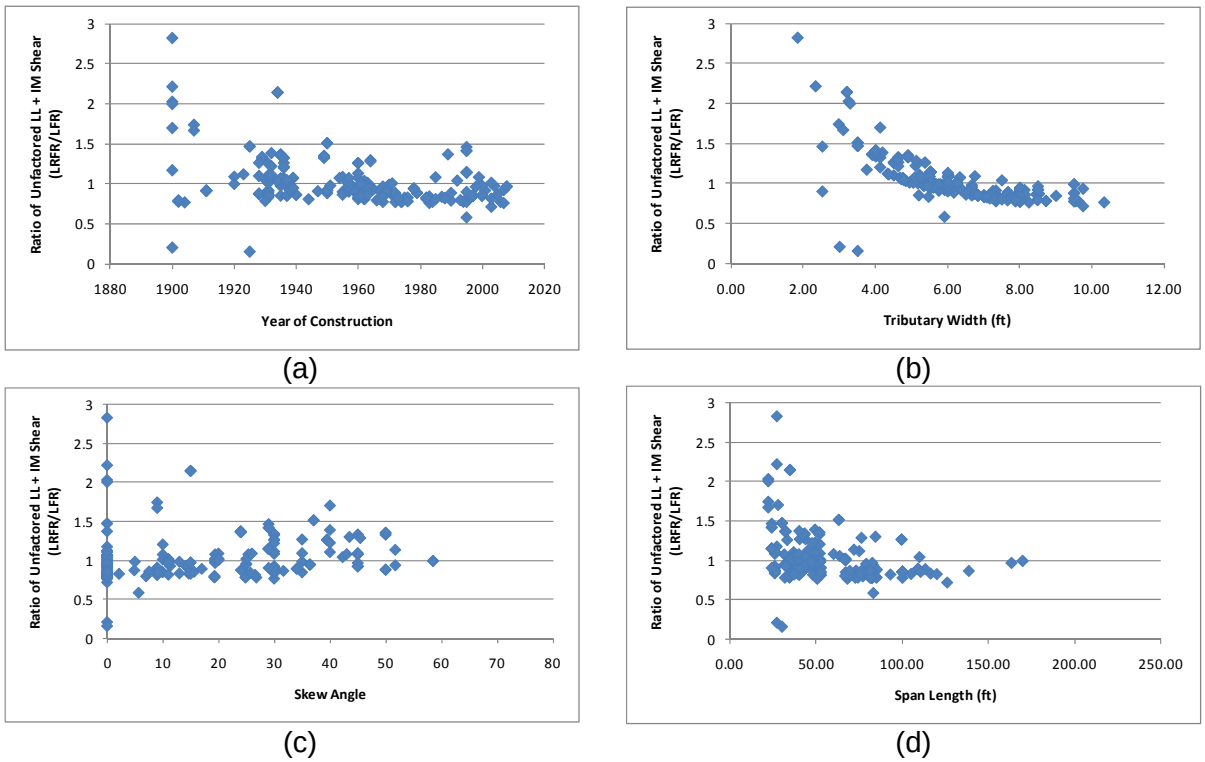


Figure B-103: Ratio of Unfactored Live Load plus Impact Shear for IL-01 Vehicle (LRFR/LFR)

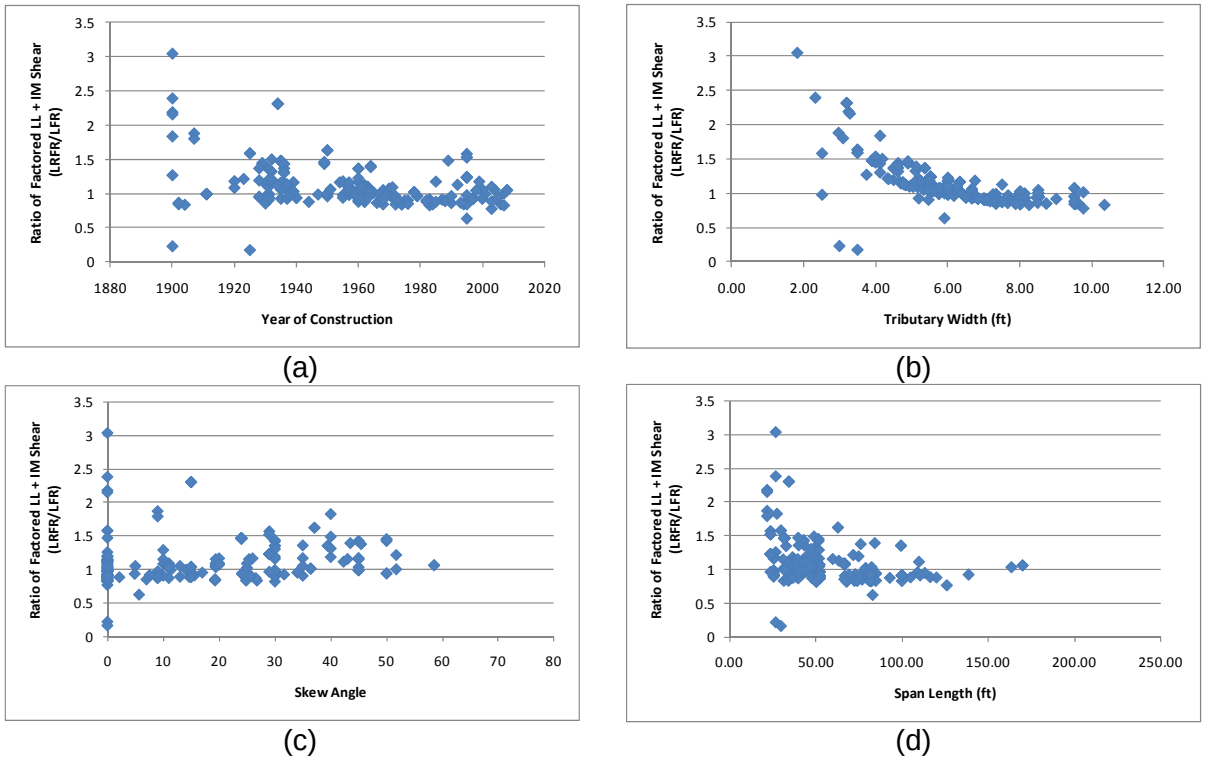
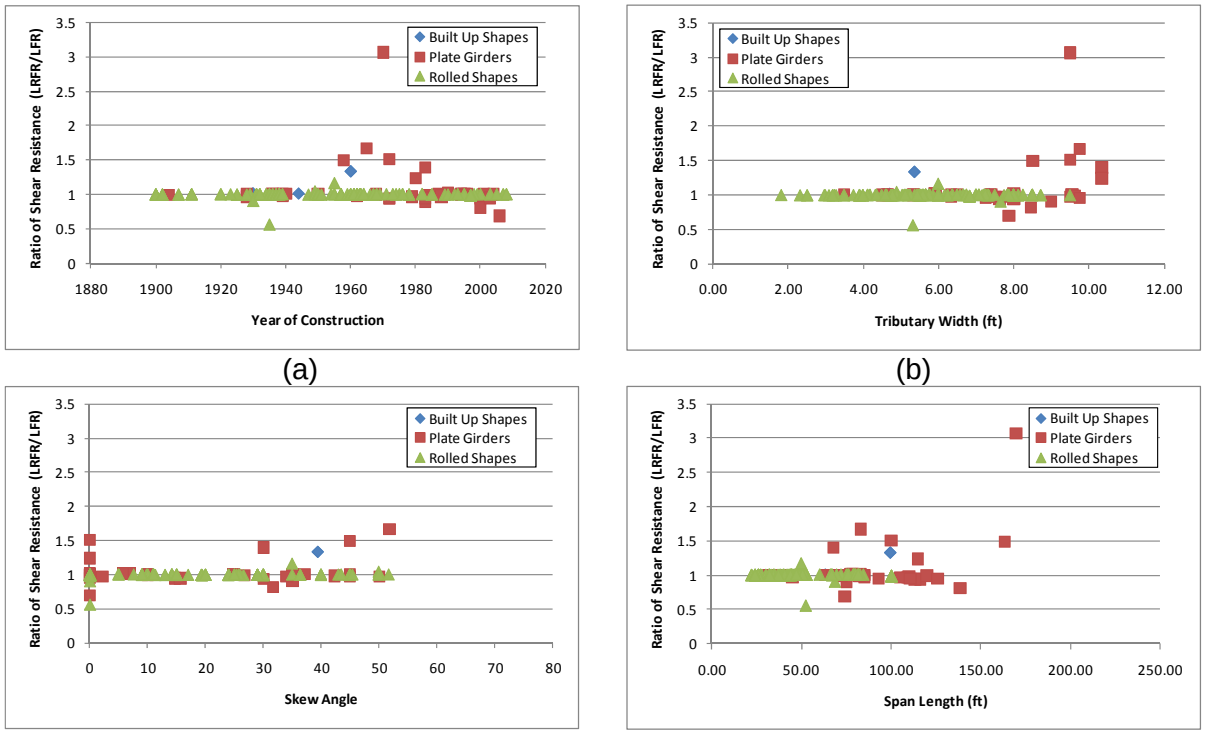


Figure B-104: Ratio of Factored Live Load plus Impact Shear for IL-01 Vehicle (LRFR/LFR)

B.1.5.3.2 Resistance

Figure B-105 shows the ratio of factored shear resistance; a significant portion of the scatter has been removed by considering only those girders where the critical location is at the support or within one-tenth of the support. As expected the shear resistance is generally very close to 1.0.



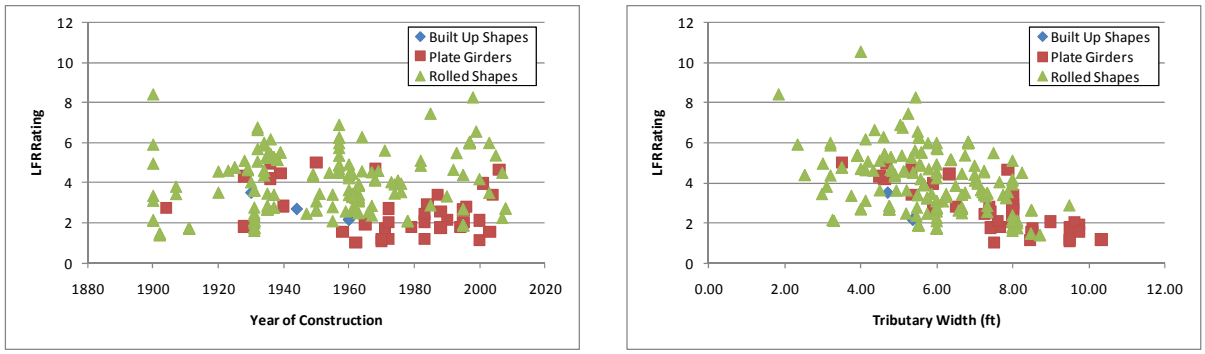
(a) (b)

(c) (d)

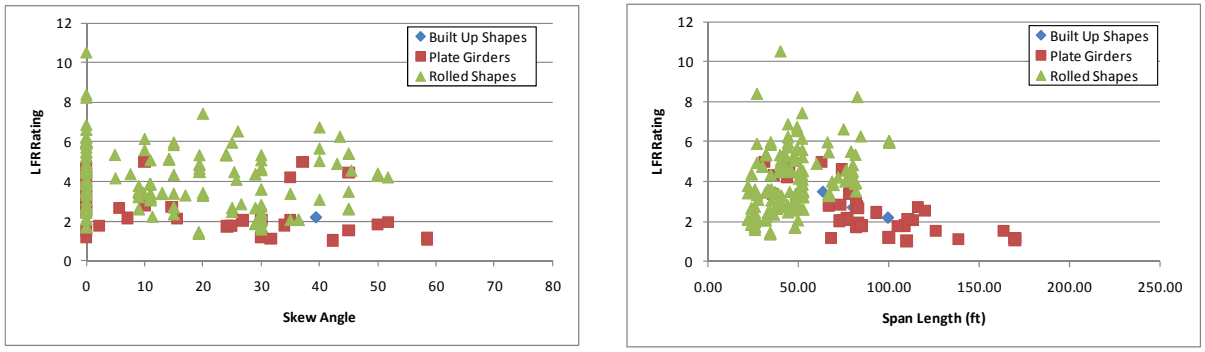
Figure B-105: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.5.3.3 Rating Factors

After verifying that the live load shears and shear resistances are similar, the next step was to examine the rating factors. Figure B-106 and Figure B-107 show the rating factors, the LFR ratings that were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where it is likely that the stiffener spacing would vary along the span length. The LFR ratings are also reduced compared to those shown in B.1.5.2.3 which is expected because the applied loads have increased and the resistance remained the same.

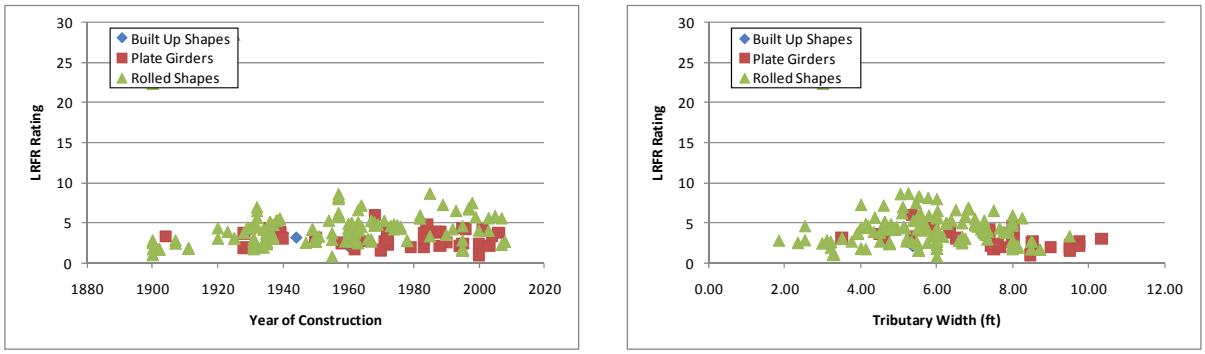


(a) (b)

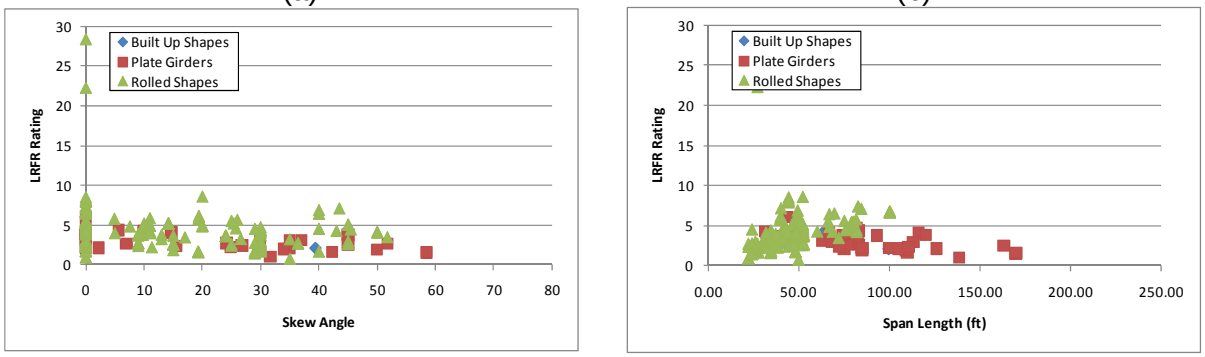


(c) (d)

Figure B-106: LFR Shear Rating Factor for IL-01 Vehicle



(a) (b)

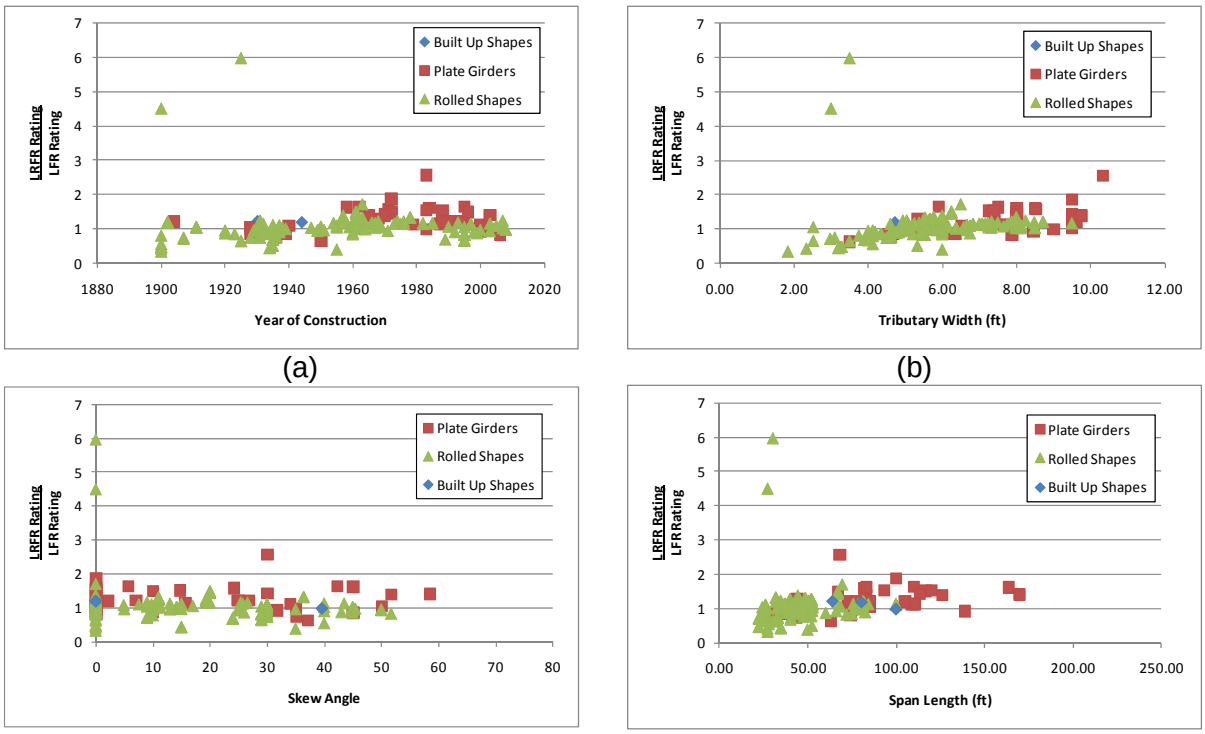


(c) (d)

Figure B-107: LRFR Shear Rating Factor for IL-01 Vehicle

B.1.5.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio between the LRFR rating factor and the LFR rating factor. Figure B-108 shows the results of this comparison. The results show that the LRFR rating is typically greater than the LFR rating after recalculating the rating at the support for a significant number of girders. Plate girders are more likely to have ratios above 1.0, with some rolled shapes also having ratios greater than 1.0. Closely spaced girders in short spans are more likely to have higher LFR ratings than LRFR ratings.



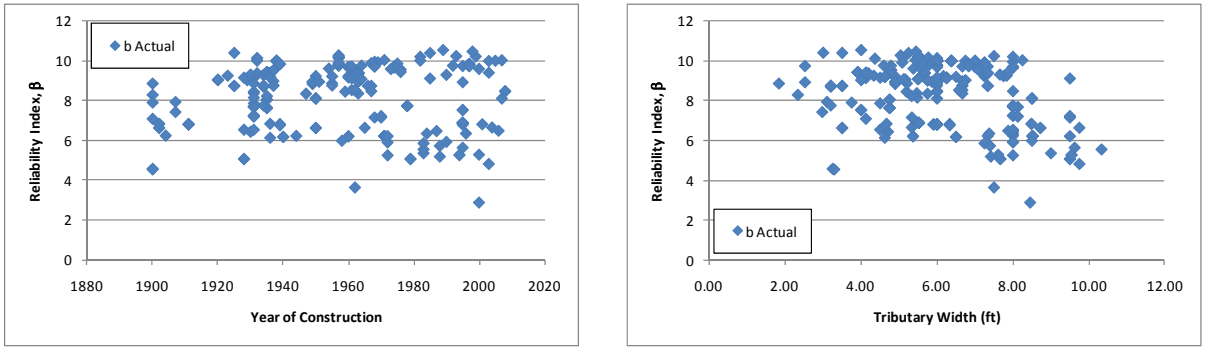
(a) (b)

(c) (d)

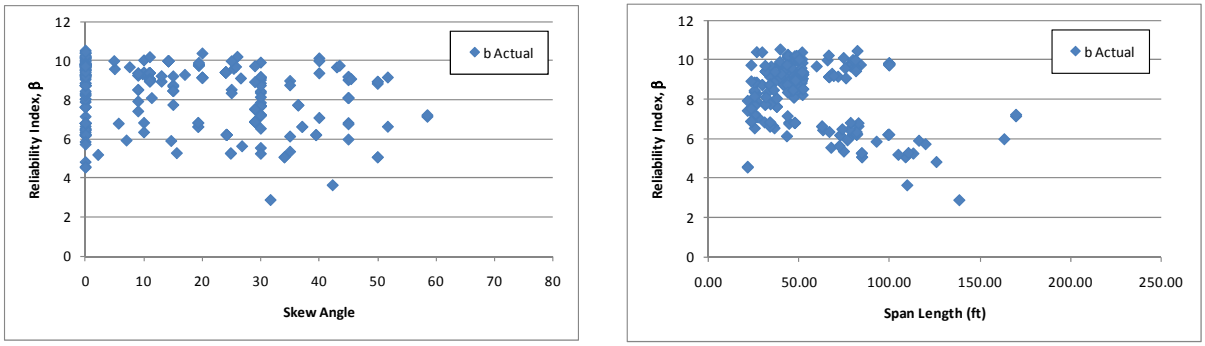
Figure B-108: Ratio of LRFR Shear Rating to LFR Shear Rating for IL-01 Vehicle

B.1.5.3.5 Reliability Indices

The reliability indices shown in Figure B-109 are the same as those shown in Figure B-101. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 2.5. The reliability index remains the same as calculated previously because the LRFR location did not move.



(a) (b)



(c) (d)

Figure B-109: Shear Reliability Indices for IL-01 Vehicle

B.1.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-110. The applicable load factors for these vehicles are 1.30 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

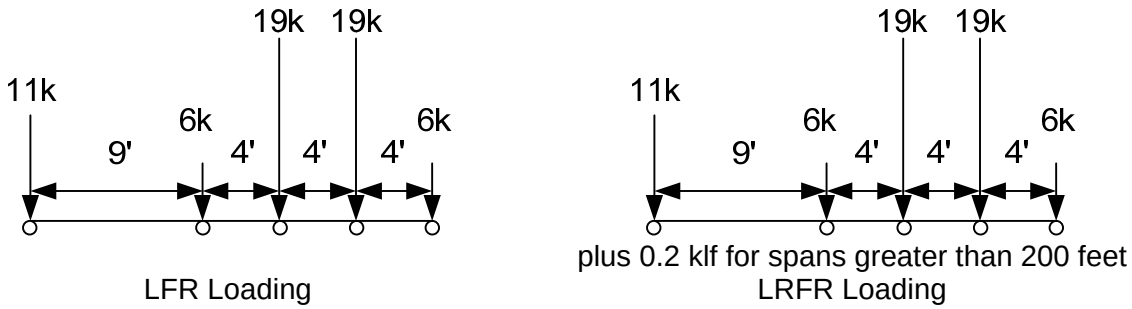
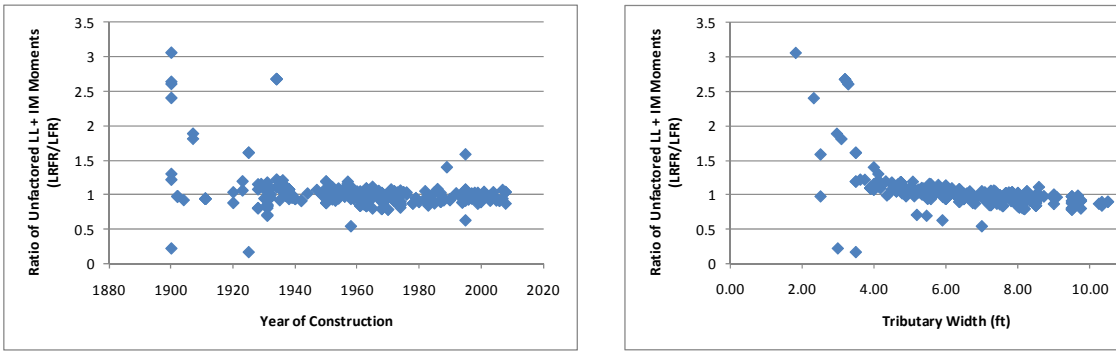


Figure B-110: Vehicle Loadings and Load Factors

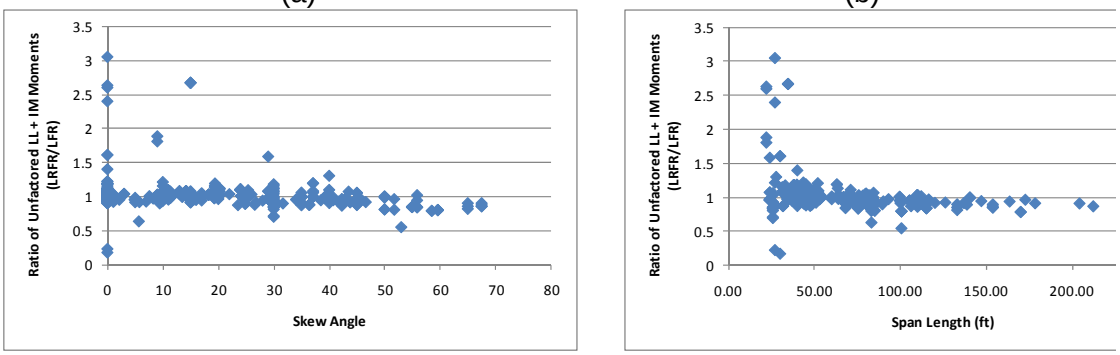
B.1.6.1 Moment

B.1.6.1.1 Live Loads

Figure B-111 and Figure B-112 shows the ratios of unfactored and factored live load plus impact moments for the NC-21 vehicle. The ratio, LRFR divided by LFR, of unfactored momentis generally between 0.75 and 1.25 with the ratio of factored moments increasing to 1.0 and 1.50 due to the difference in load factor.

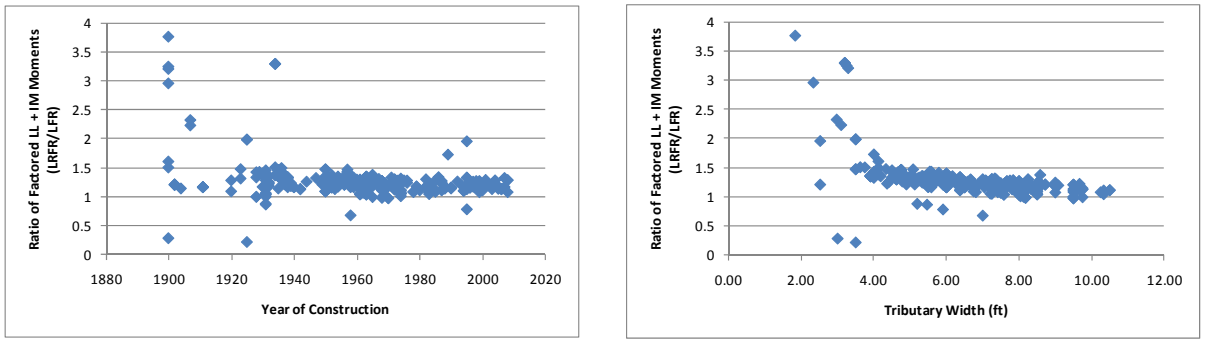


(a) (b)

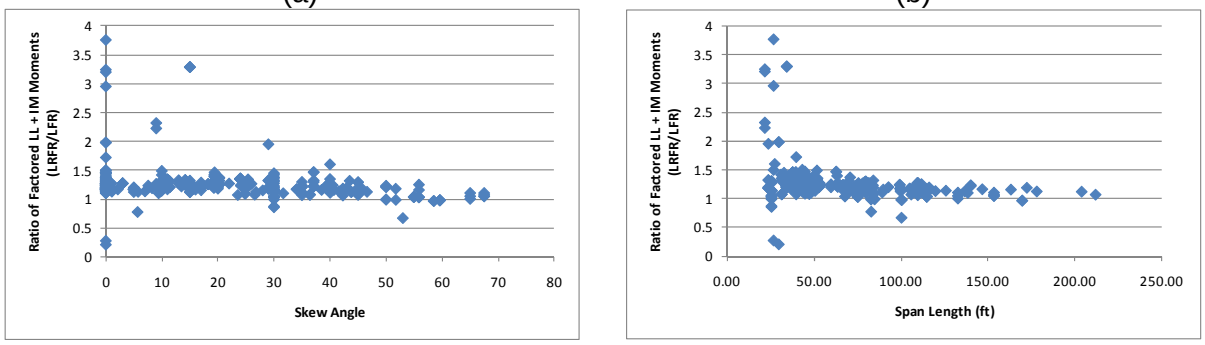


(c) (d)

Figure B-111: Ratio of Unfactored Live Load plus Impact Moment for NC-21 Vehicle (LRFR/LFR)



(a) (b)



(c) (d)

Figure B-112: Ratio of Factored Live Load plus Impact Moment for NC-21 Vehicle (LRFR/LFR)

B.1.6.1.2 Resistances

Figure B-113 shows the ratio of the factored moment resistances, LRFR divided by LFR. The ratio is generally greater than 1.0 for rolled shapes, while for plate girders and built-up shapes the LFR resistance is greater than the LRFR resistance. The ratio of rolled shapes is between 1.0 and 1.5, with the ratio for plate girders between 0.5 and 1.0.

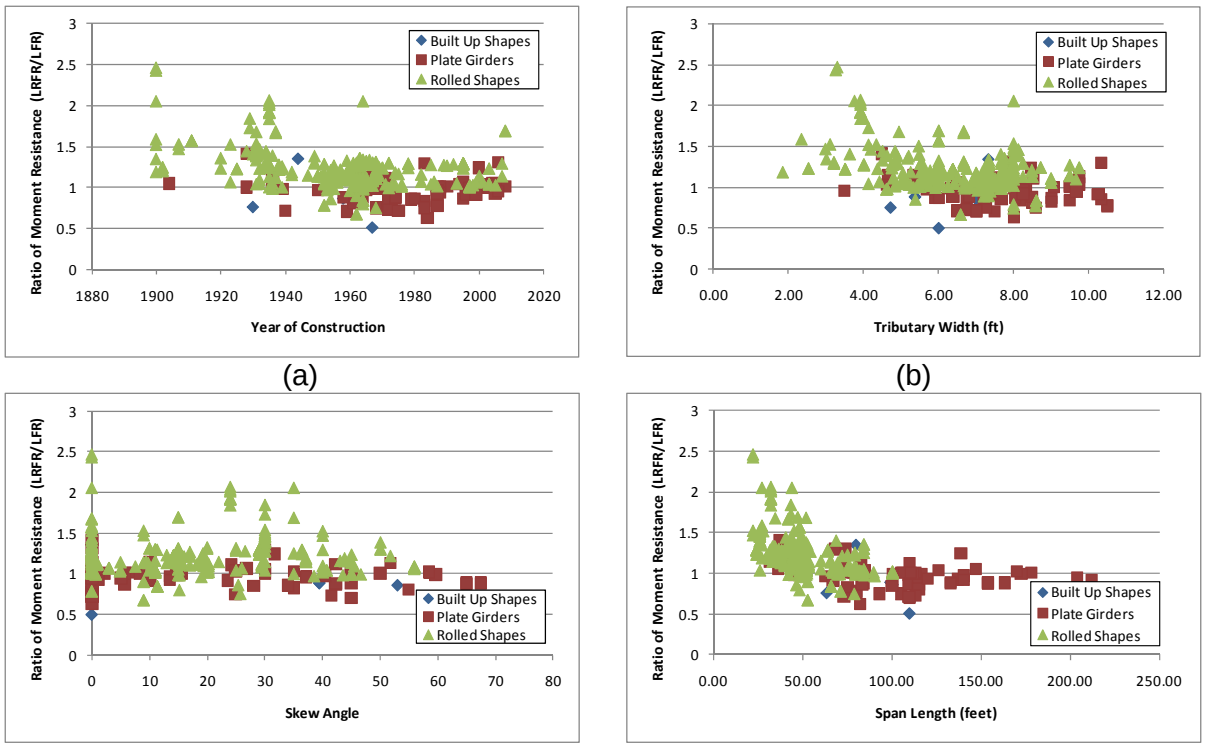
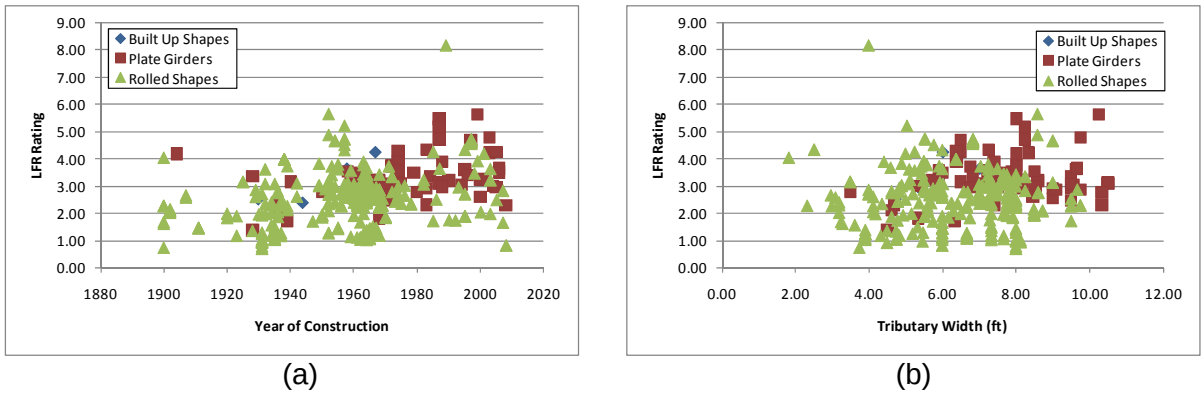
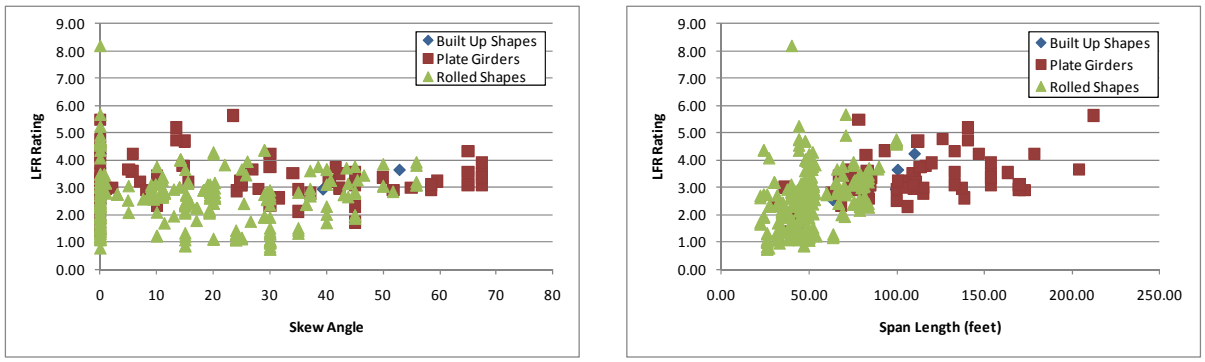


Figure B-113: Ratio of Factored Moment Resistance (LRFR/LFR)

B.1.6.1.3 Rating Factors

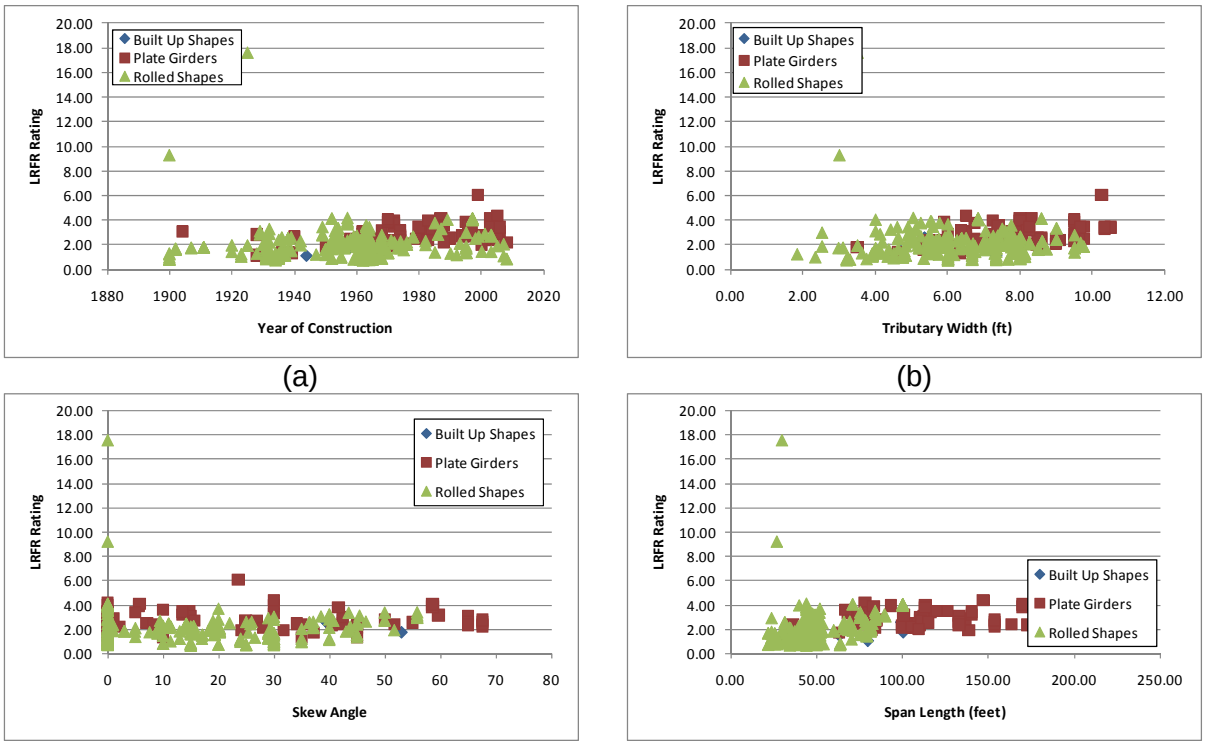
Figure B-114 and Figure B-115 present the LFR and LRFR ratings from BRASS, respectively. There are 12 girders with an LFR rating less than 1.0, 41 girders with an LRFR rating less than 1.0, and 8 girders where both ratings are less than 1.0. Ignoring the outliers, the two methods provide similar scatter with the LRFR rating shifted down from the LFR rating due to higher live loads.





(c) (d)

Figure B-114: LFR Flexure Rating Factors for NC-21 Vehicle



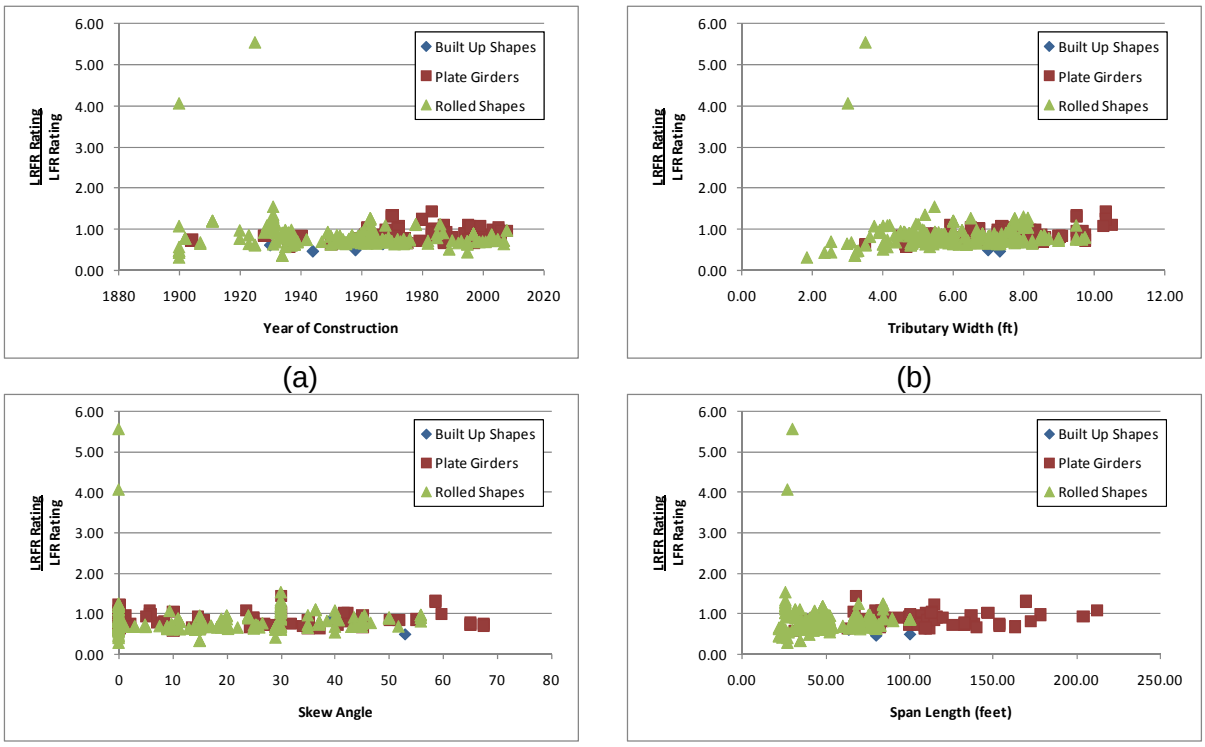
(a) (b)

(c) (d)

Figure B-115: LRFR Flexure Rating Factors for NC-21 Vehicle

B.1.6.1.4 Rating Factor Comparisons

Figure B-116 shows that ratio of LRFR rating to LFR rating is generally between 0.5 and 1.0, with several girders being above 1.0. Figure B-116b shows that for narrow girder spacing the LFR rating is higher than the LRFR rating, while for large girder spacing the ratio increases. 89% of the girders for this vehicle have an LFR rating greater than the LRFR rating.



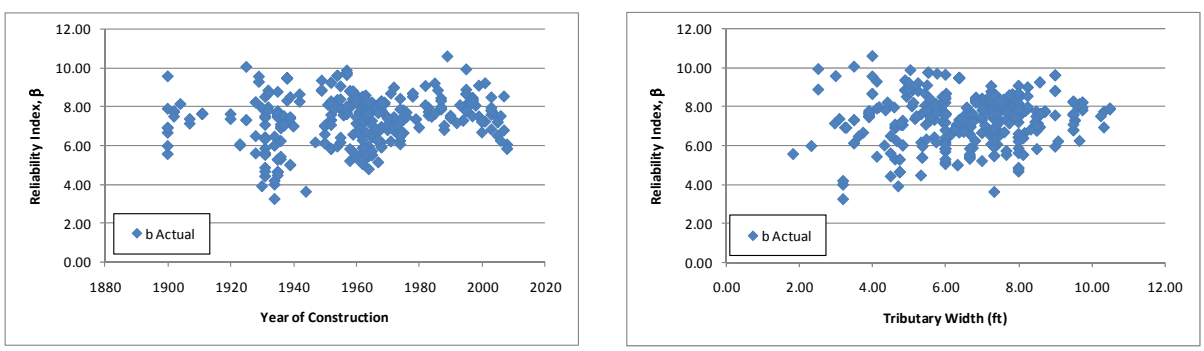
(a) (b)

(c) (d)

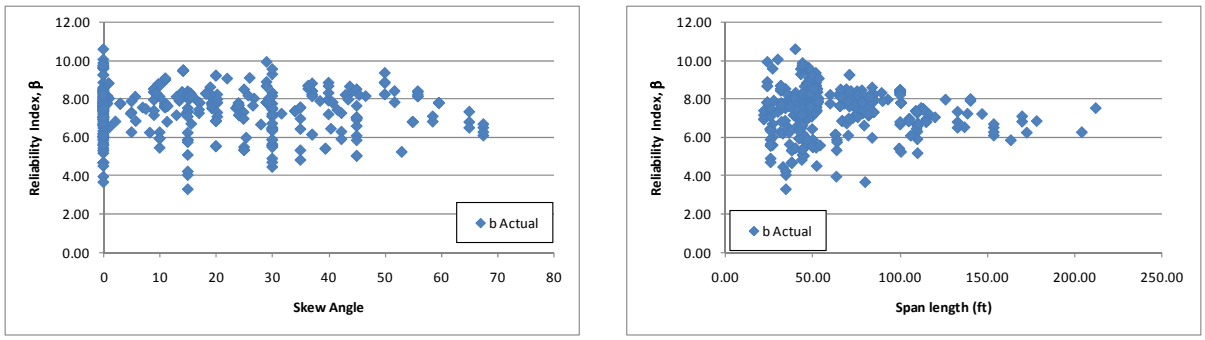
Figure B-116: Ratio of LRFR Flexure Rating to LFR Flexure Rating for NC-21 Vehicle

B.1.6.1.5 Reliability Indices

Figure B-117 presents the reliability indices as calculated. There is one girder where the actual reliability index is very close to the required reliability index. This girder is relatively old (~65 years or more), with fairly narrow girder spacing (under four feet), and have span lengths under 50 feet. The required reliability index increases with span length and tributary width.



(a) (b)



(c) (d)

Figure B-117: Flexural Reliability Indices for NC-21 Vehicle

Figure B-118 shows the actual reliability index plotted against the LRFR rating factor for the NC-21 vehicle. This figure shows that a girder with a passing rating is expected to have a reliability index greater than 4. The level of reliability for this vehicle, assumed to be a routine permit vehicle, is 2.5. This indicates that a lower load factor could be used and maintain the expected level of reliability.

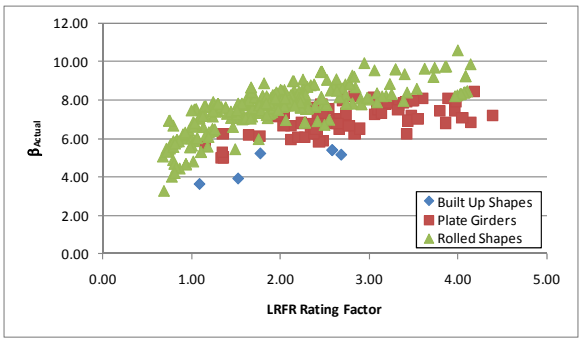
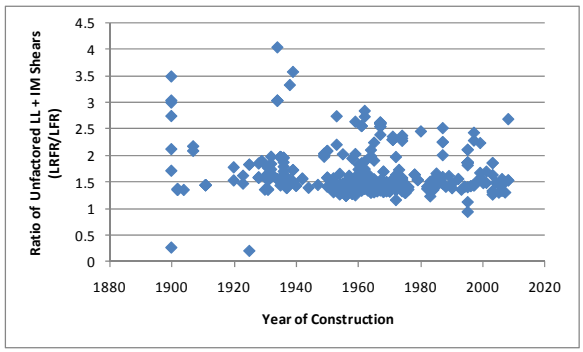


Figure B-118: Flexure Reliability Index vs. LRFR Flexure Rating for NC-21 Vehicle

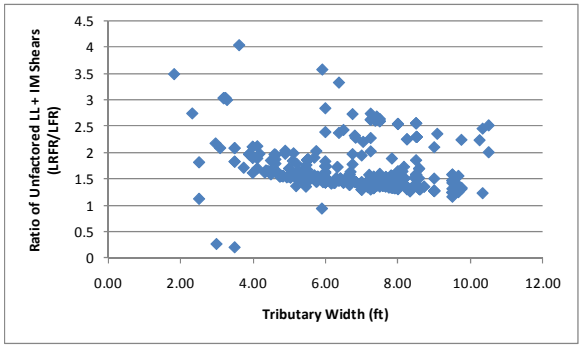
B.1.6.2 Shear

B.1.6.2.1 Live Loads

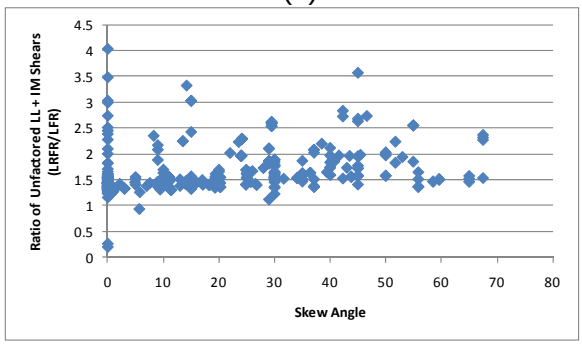
Figure B-119 and Figure B-120 show the ratios of unfactored and factored live load plus impact shear (LRFR divided by LFR), respectively. The ratio of unfactored loads is generally betweem 1.25 and 1.75 and is typically greater than 1.5 when the loads are factored. This is likely a result of the distribution factors as the LRFD equations limit the girder spacing to greater than 3.5 feet, while the LFR distribution factors are applicable to any girder spacing. Figure B-119c and Figure B-120c show that the ratio increases with larger skew angles; this is expected as the LRFD Specification increases the load distributed to each girder because of the skew while the LFR Specification does not consider the effect of skew. Figure B-121 shows where the critical shear rating occurred for each girder. The LFR location is typically away from the support while the LRFD location is typically at the support.



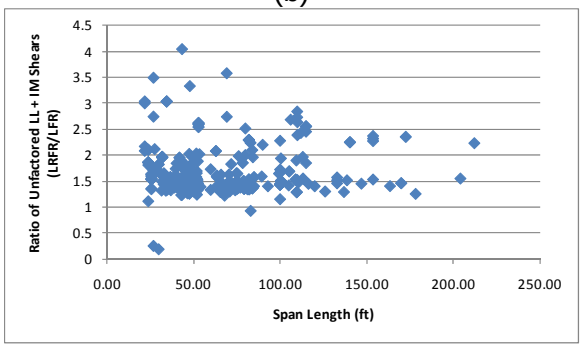
(a)



(b)

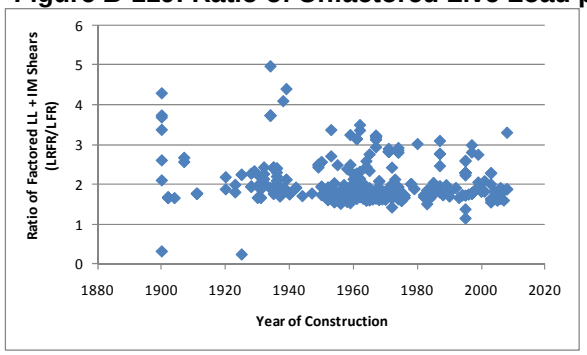


(c)

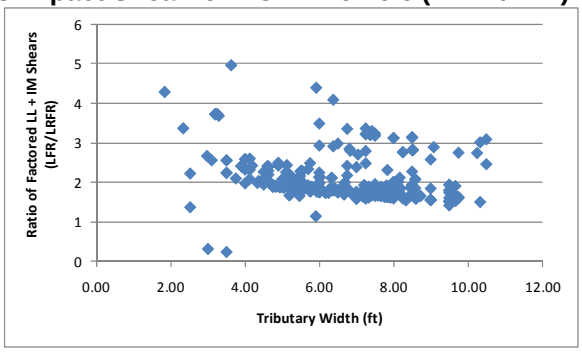


(d)

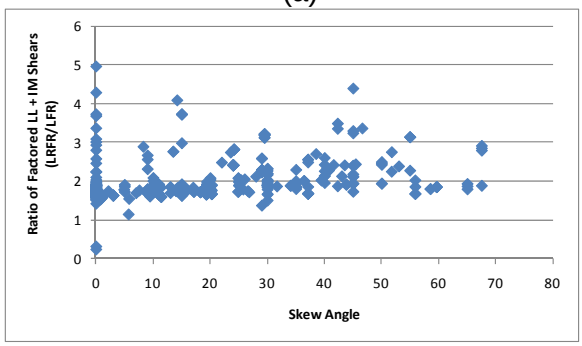
Figure B-119: Ratio of Unfactored Live Load plus Impact Shear for NC-21 Vehicle (LRFR/LFR)



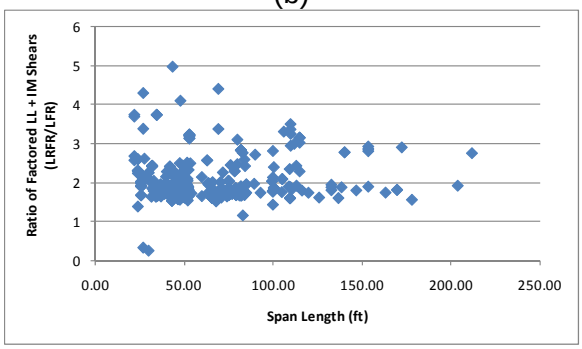
(a)



(b)



(c)



(d)

Figure B-120: Ratio of Factored Live Load plus Impact Shear for NC-21 Vehicle (LRFR/LFR)

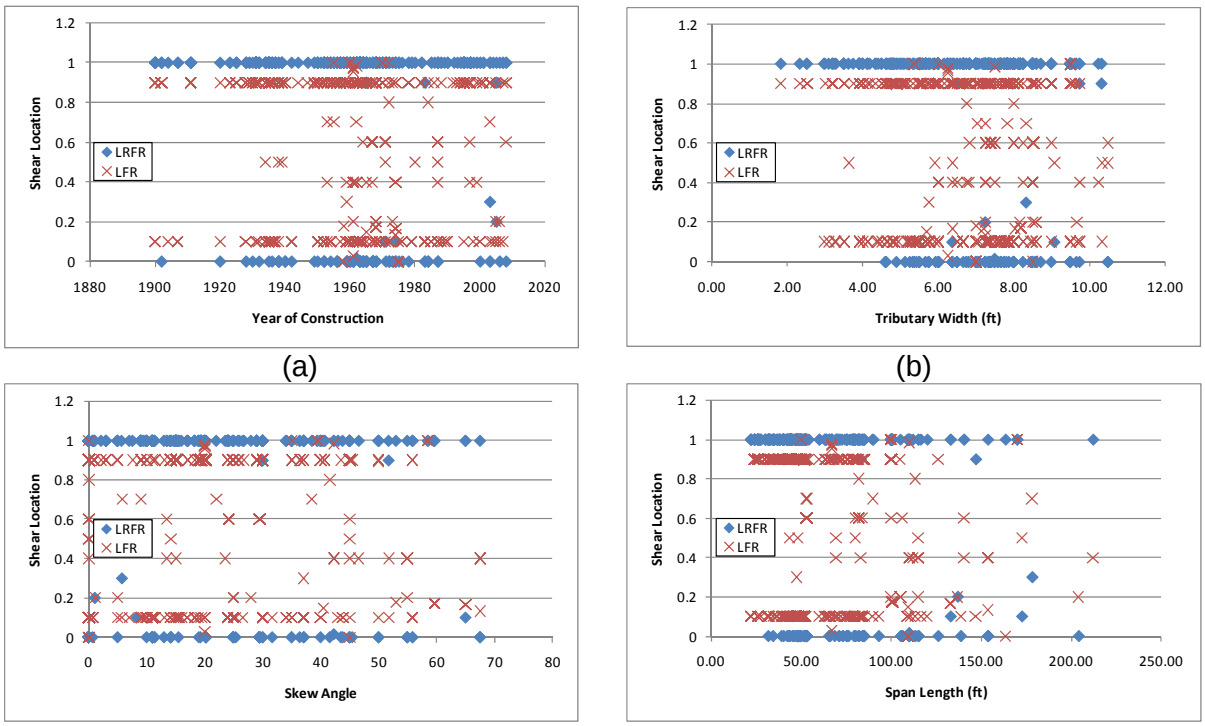
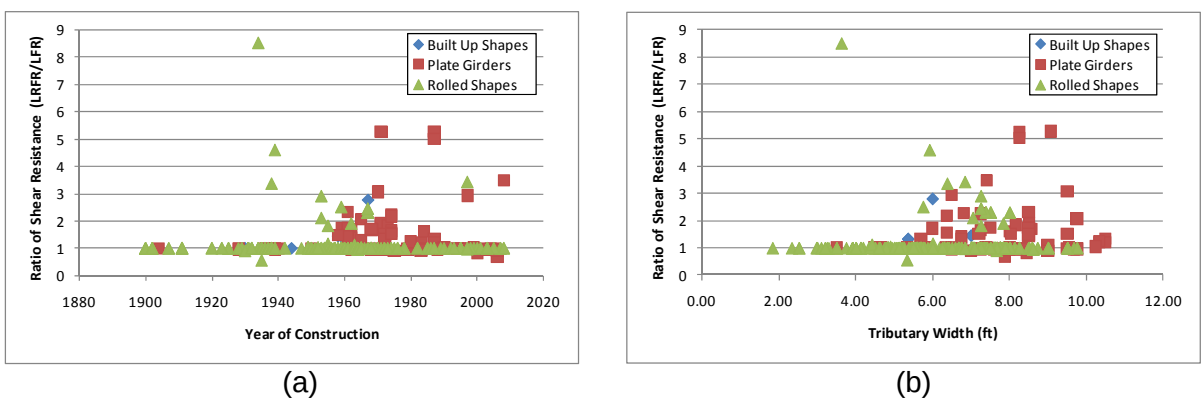
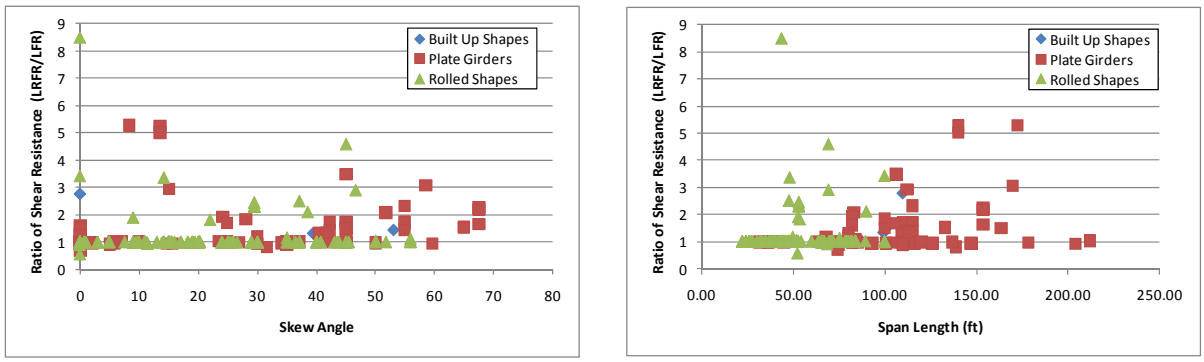


Figure B-121: Critical Shear Location for NC-21 Vehicle

B.1.6.2.2 Resistances

Figure B-122 shows the ratio of factored shear resistances, LRFR divided by LFR. The ratio is generally close to 1.0; with most of the scatter being eliminated by removing those girders where the critical shear location varies significantly (Section B.1.6.3.2). Figure B-122 shows that a large number of girders where the ratio of shear resistance is greater than 1.0 are plate girders.



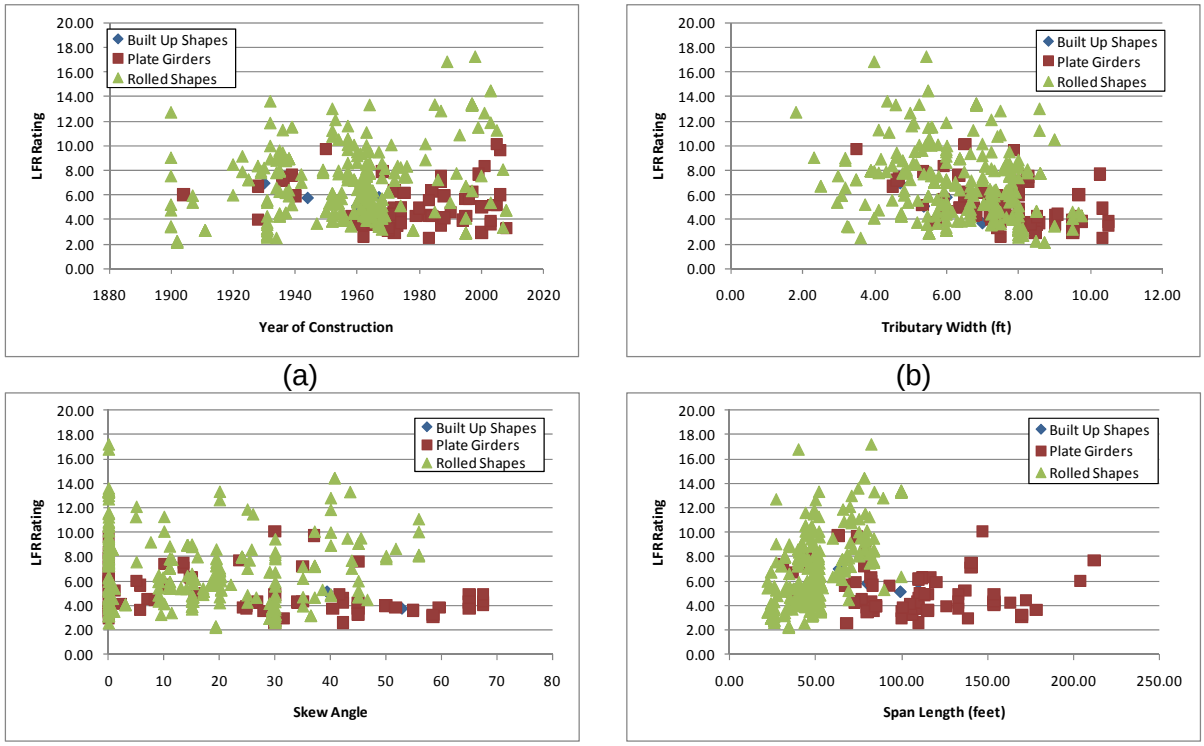


(c) (d)

Figure B-122: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.6.2.3 Rating Factors

Figure B-123 and Figure B-124 present the ratings as calculated by BRASS for LFR and LRFR, respectively. There are zero girders with an LFR rating of less than 1.0 and ten girders with an LRFR rating less than 1.0. Additionally, 98% of the girders have LFR Ratings greater than the LRFR rating.



(a) (b)

(c) (d)

Figure B-123: LFR Shear Rating Factor for NC-21 Vehicle

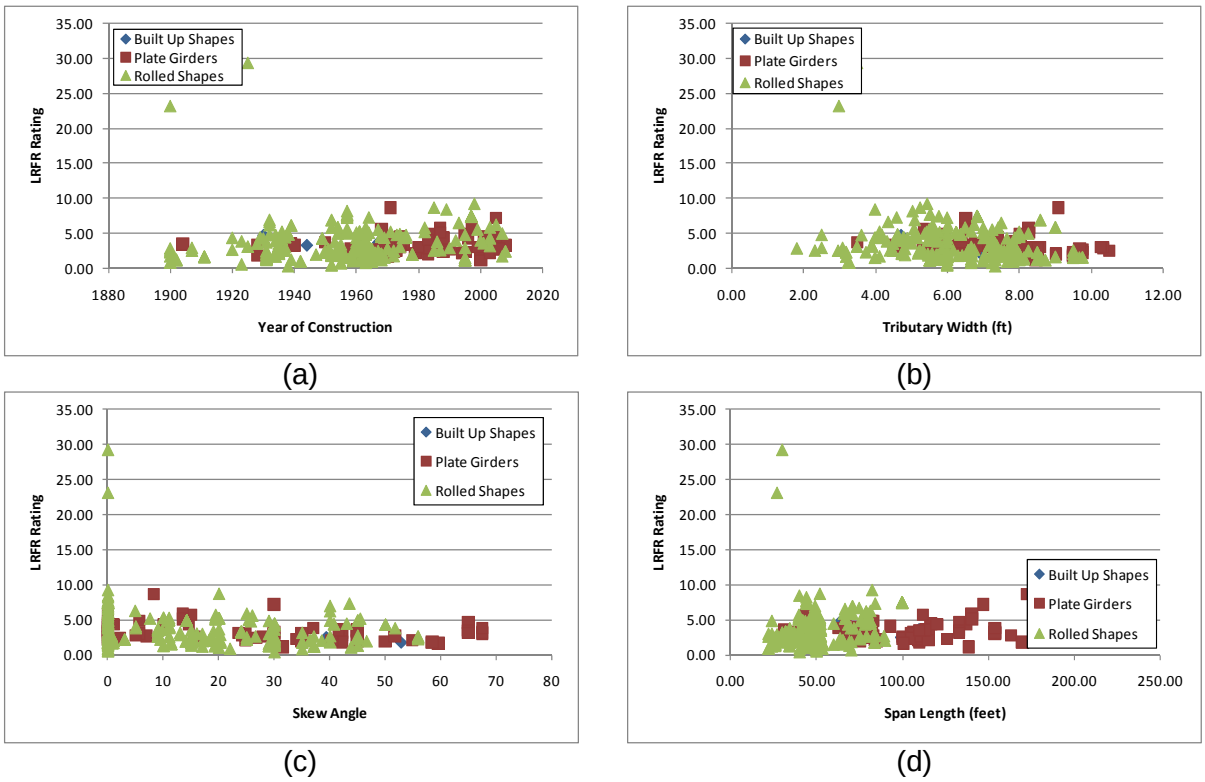
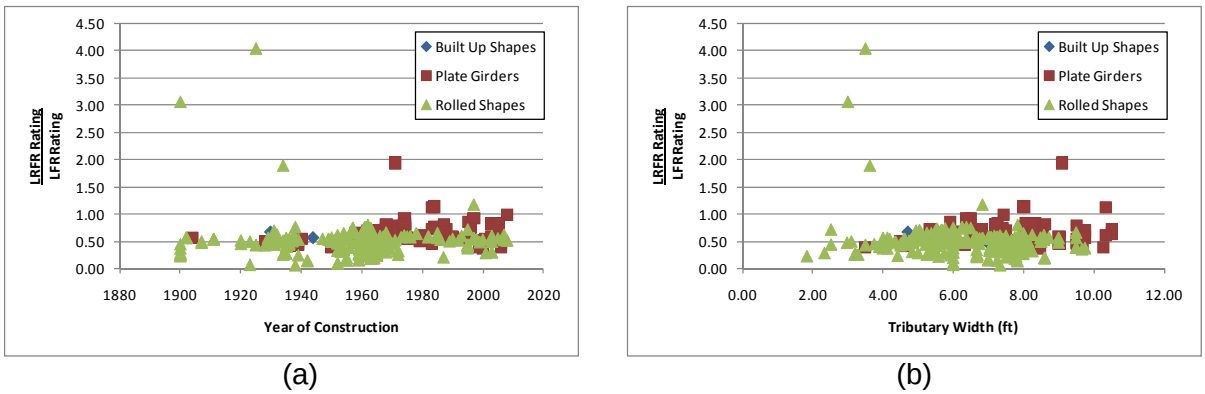
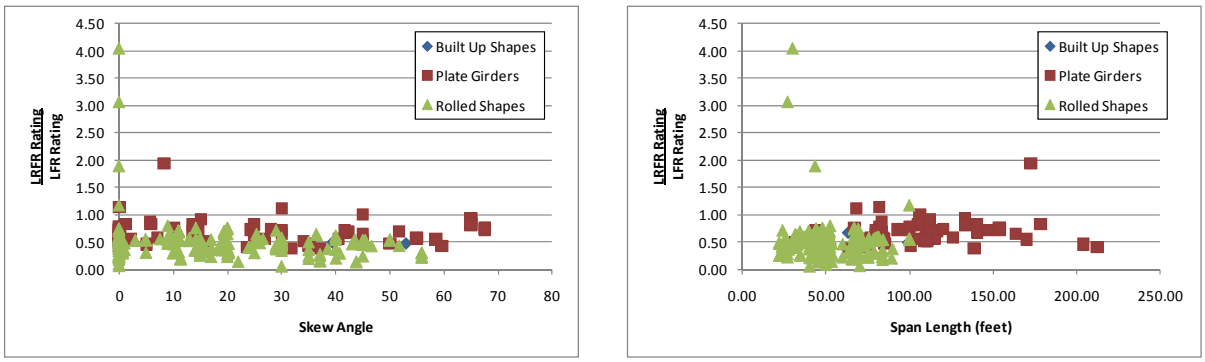


Figure B-124: LRFR Shear Rating Factor for NC-21 Vehicle

B.1.6.2.4 Rating Factor Comparisons

Figure B-125 shows the ratio of LRFR rating factor to LFR rating factor. The ratio is generally less than 1.0 with plate girders having LRFR ratings that are closer to the LFR rating. The ratio of ratings for plate girders is generally between 0.5 and 1.0, while rolled shapes are generally less than 0.75.



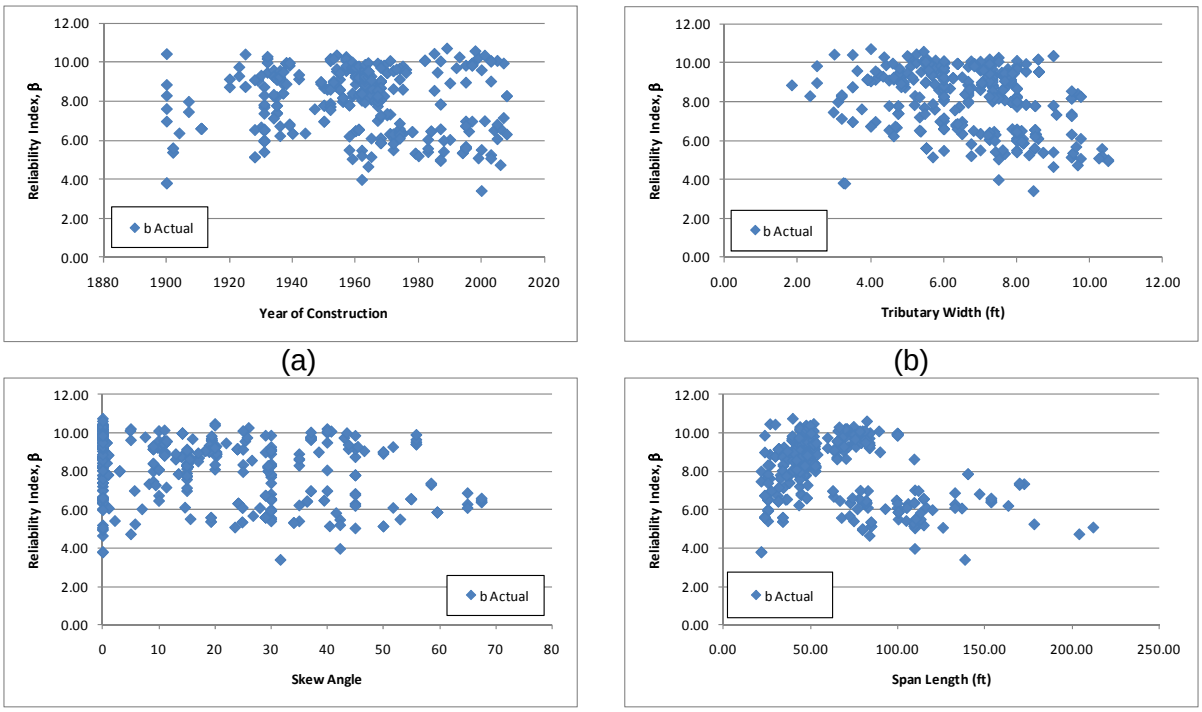


(c) (d)

Figure B-125: Ratio of LRFR Shear Rating to LFR Shear Rating for NC-21 Vehicle (LRFR/LFR)

B.1.6.2.5 Reliability Indices

Figure B-126 shows the reliability indices as calculated based upon the strength of the section and also based upon the applied loads. There is one girder where the actual reliability index is approaching the required reliability index. Based on the figure there is no clear relationship between the horizontal axis and those that are close to the required value. The bridge of concern is of significant age, with narrow girder spacing, and very short.



(a) (b)

(c) (d)

Figure B-126: Shear Reliability Indices for NC-21 Vehicle

Figure B-127 shows the reliability index plotted agains the LRFR rating for shear caused by the NC-21 vehicle. The figure shows that a girder passing the rating (at least 1.0) is expected to have a reliability index of approximately 4.0. This indicates that a lower load factor could be used and the expected level of reliability of 2.5 would be maintained.

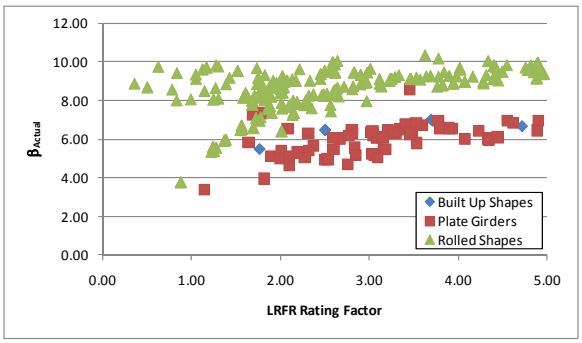


Figure B-127: Shear Reliability Index vs. LRFR Shear Rating for NC-21 Vehicle

B.1.6.3 Shear-Corrected

This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.6.3.1 Live Load

Figure B-128 and Figure B-129 show the ratio of unfactored and factored live load plus impact shear for those girders with critical locations at the either the support or one-tenth of the span away from the support. The LRFR unfactored shear is 100 to 150% of the LFR unfactored shear, when factored the LRFR live load shears increase to between 125 and 175% of the LFR live load shears. Moving the LFR location back to the support results in shears that are more similar.

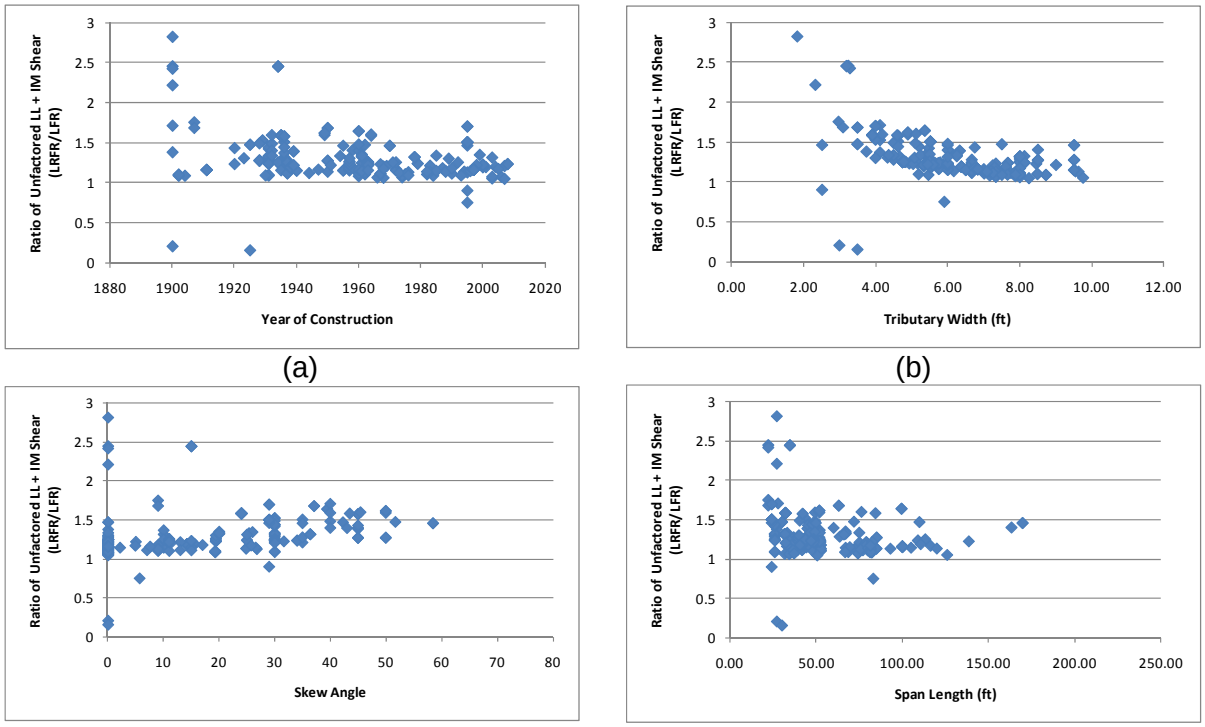


Figure B-128: Ratio of Unfactored Live Load plus Impact Shear for NC-21 Vehicle (LRFR/LFR)

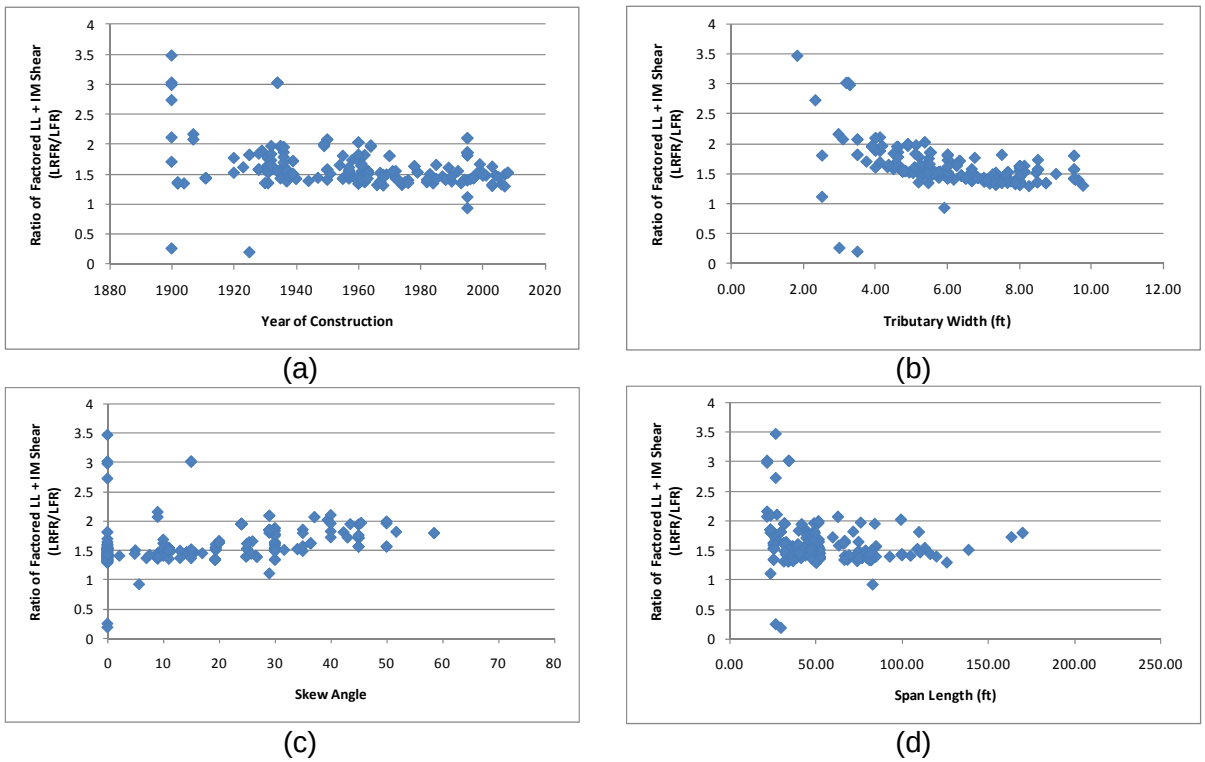
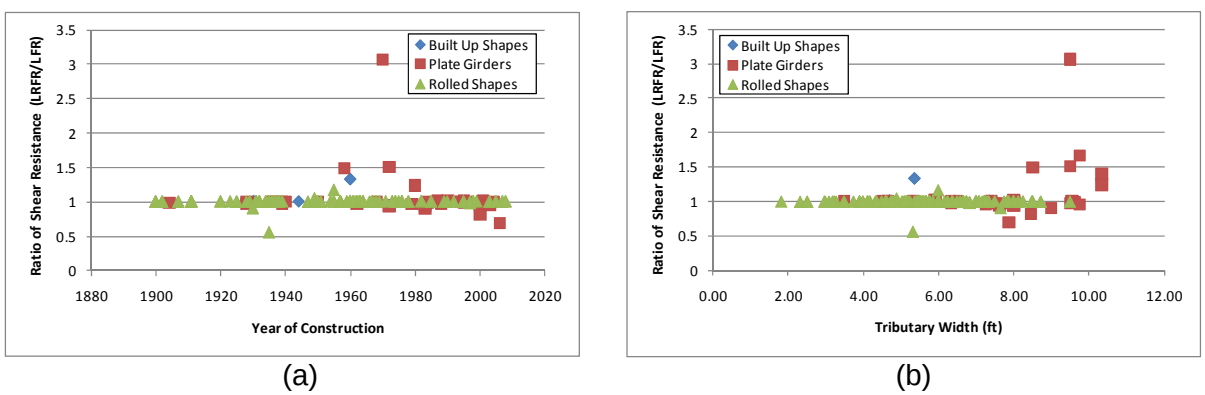
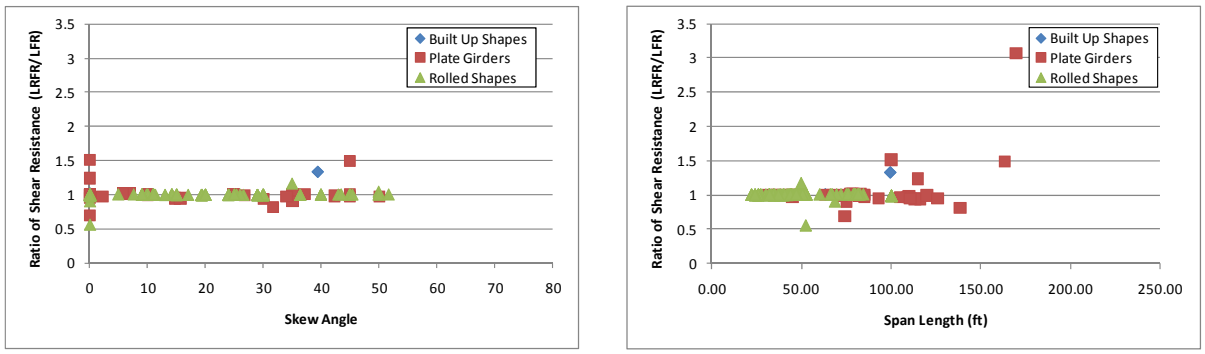


Figure B-129: Ratio of Factored Live Load plus Impact Shear for NC-21 Vehicle (LRFR/LFR)

B.1.6.3.2 Resistance

The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was greater than 1.0 have been eliminated by considering only those close to the support and where the stiffener spacing was likely to be the same. The ratio of shear resistance, LRFR divided by LFR, is shown in Figure B-130.



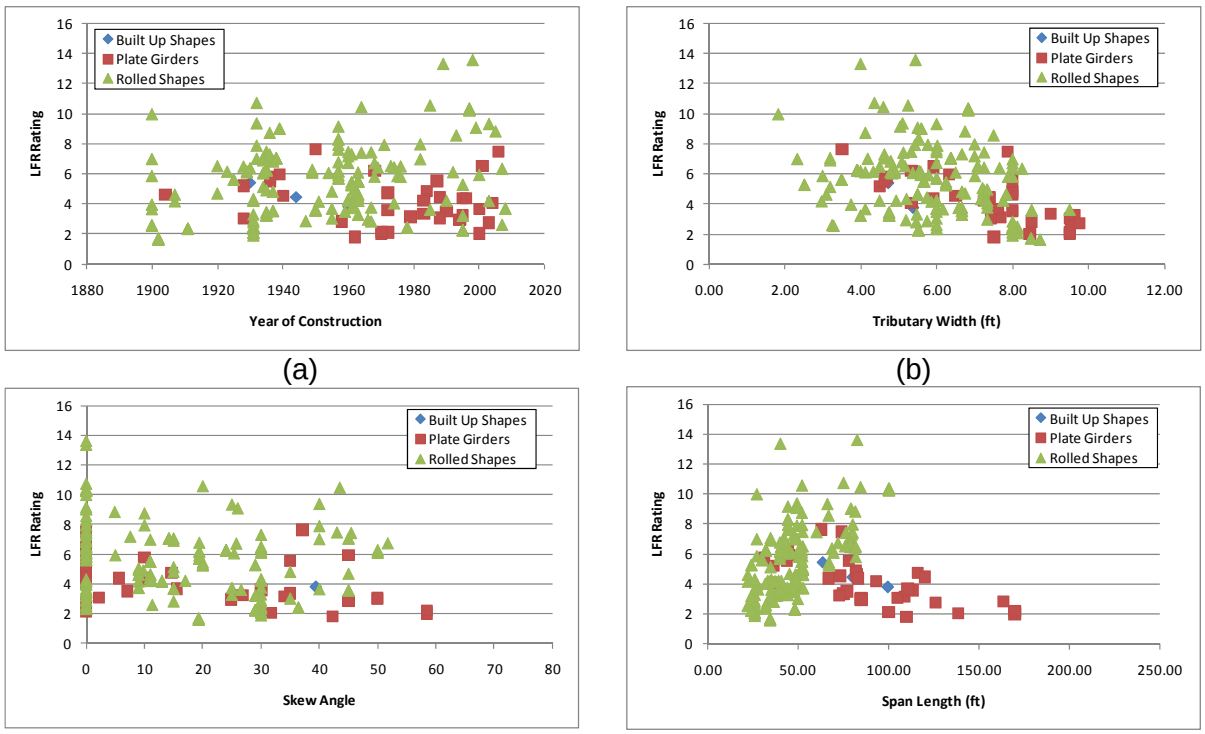


(c) (d)

Figure B-130: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.6.3.3 Rating Factors

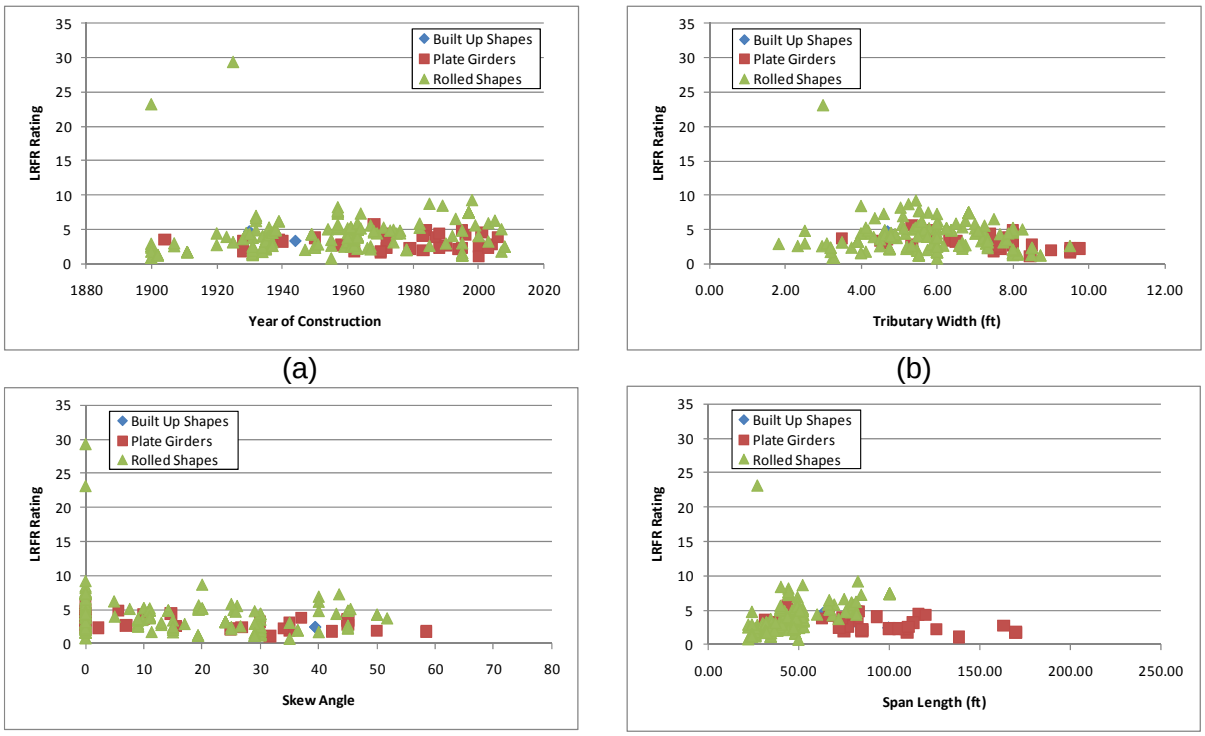
After verifying that the live load shears and shear resistances are similar, the next step was to examine the rating factors. Figure B-131 and Figure B-132 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where it is likely that the stiffener spacing would vary along the span length.



(a) (b)

(c) (d)

Figure B-131: LFR Shear Rating Factor for NC-21 Vehicle



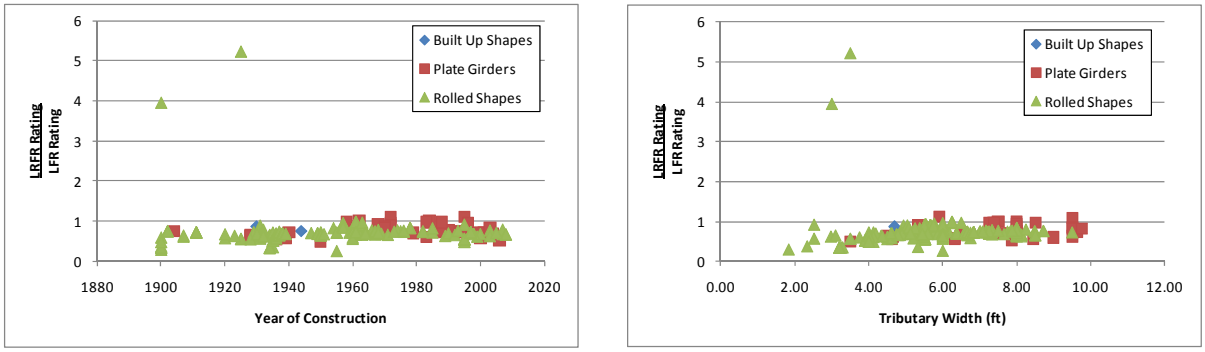
(a) (b)

(c) (d)

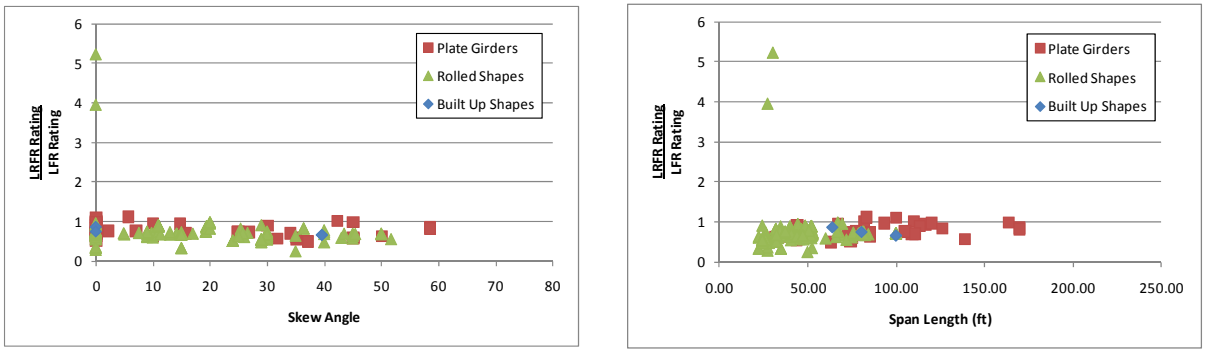
Figure B-132: LRFR Shear Rating Factor for NC-21 Vehicle

B.1.6.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio of the LRFR rating factor to the LFR rating factor. Figure B-133 shows the results of this comparison. The results show that the LFR rating is typically greater than the LRFR rating after recalculating the rating at the support. The LRFR rating is between 50 and 100% of the LFR rating for most girders with several outliers present.



(a) (b)

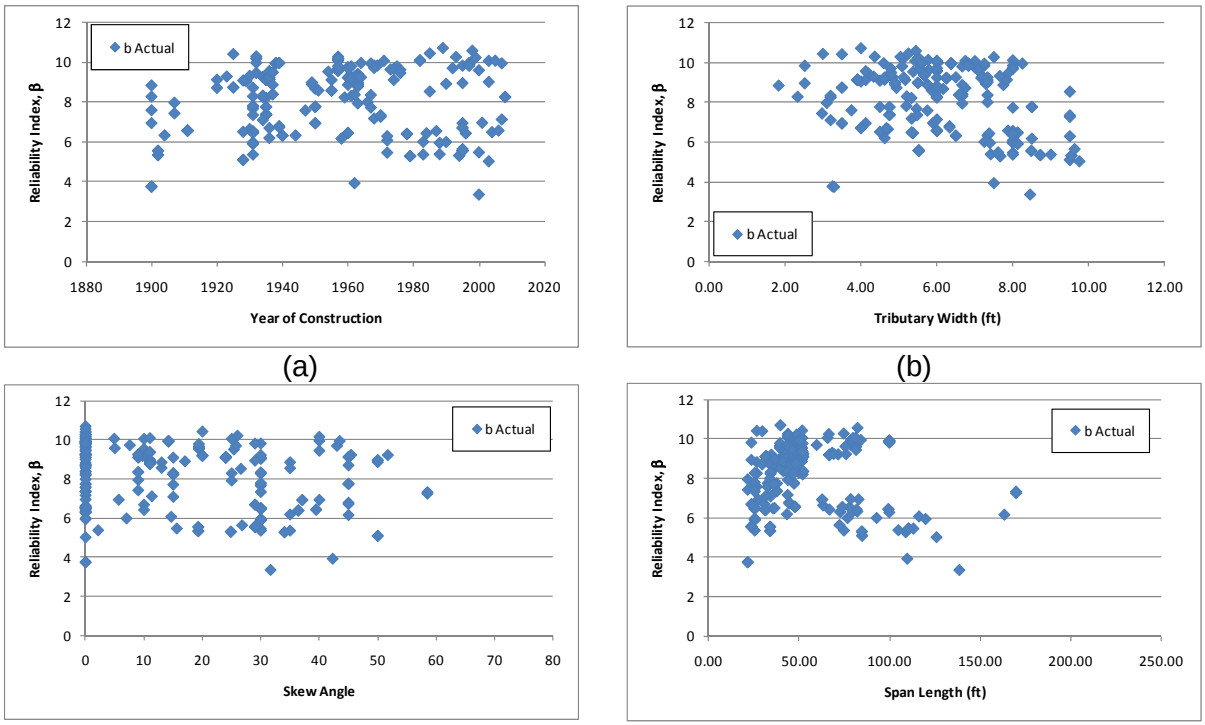


(c) (d)

Figure B-133: Ratio of LRFR Shear Rating to LFR Shear Rating for NC-21 Vehicle

B.1.6.3.5 Reliability Indices

The reliability indices shown in Figure B-134 are the same as those shown in Figure B-126. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 2.5. The reliability index remains the same as calculated previously because the LRFR location did not move.



(a) (b)

(c) (d)

Figure B-134: Shear Reliability Indices for NC-21 Vehicle

B.1.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-135. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

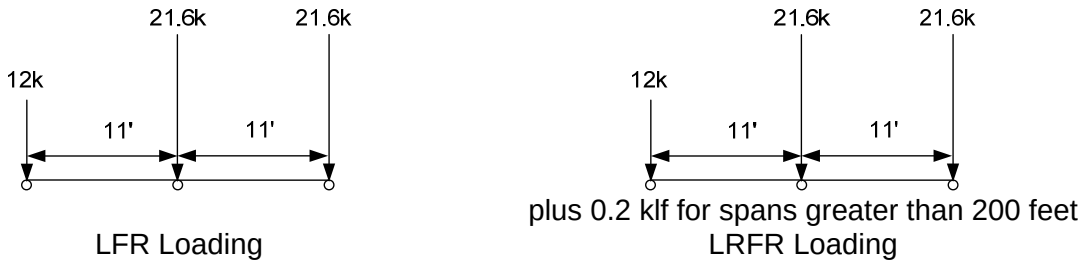


Figure B-135: Vehicle Loadings and Load Factors

B.1.7.1 Moment

B.1.7.1.1 Live Loads

Figure B-136 and Figure B-137 shows the ratios of unfactored and factored live load plus impact moments for the NM-04 vehicle. The LFR moments due to live load plus impact are typically greater than the LRFR moments, for unfactored case. The ratio of unfactored loads is typically between 0.75 and 1.25. This ratio increases to 1.0 to 1.50 when factored loads are considered. The increase is due to the LRFR load factor (1.6) being larger than the LFR load factor (1.3). The ratio tends to decrease with increasing tributary width (Figure B-136b and Figure B-137b), while there is less scatter for increasing span lengths (Figure B-136d and Figure B-137d).

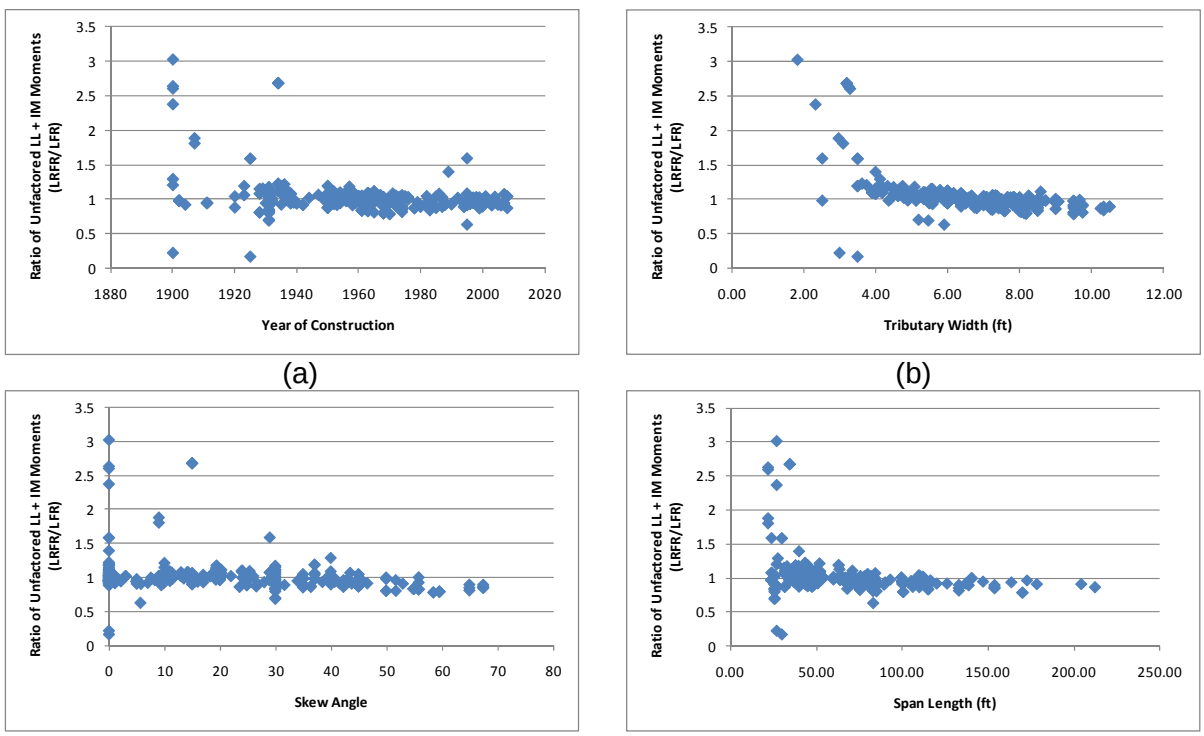


Figure B-136: Ratio of Unfactored Live Load plus Impact Moment for NM-04 Vehicle (LRFR/LFR)

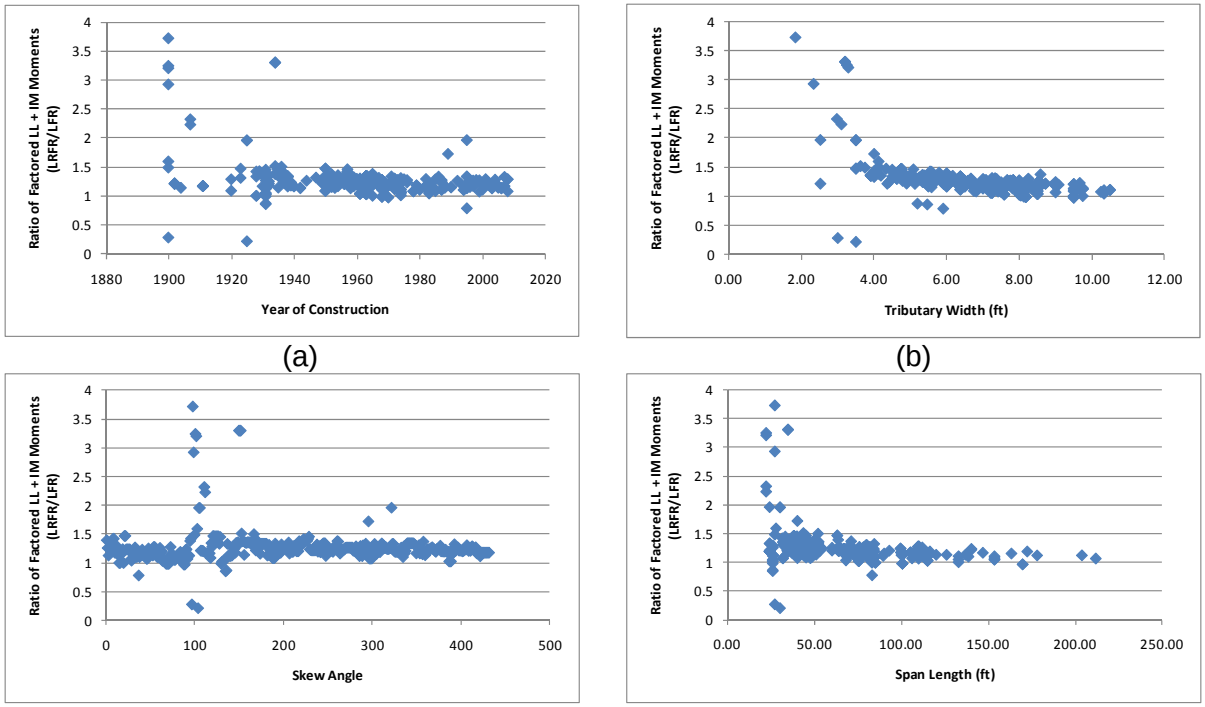
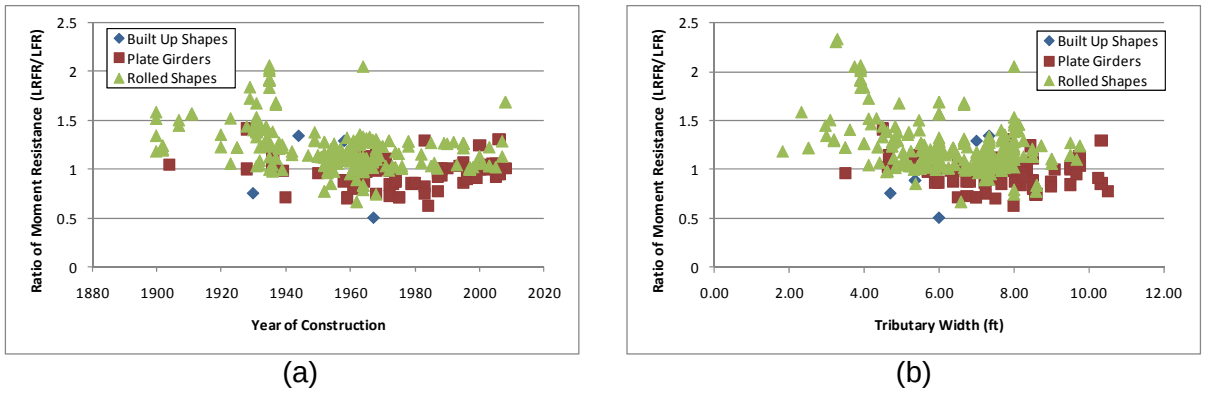
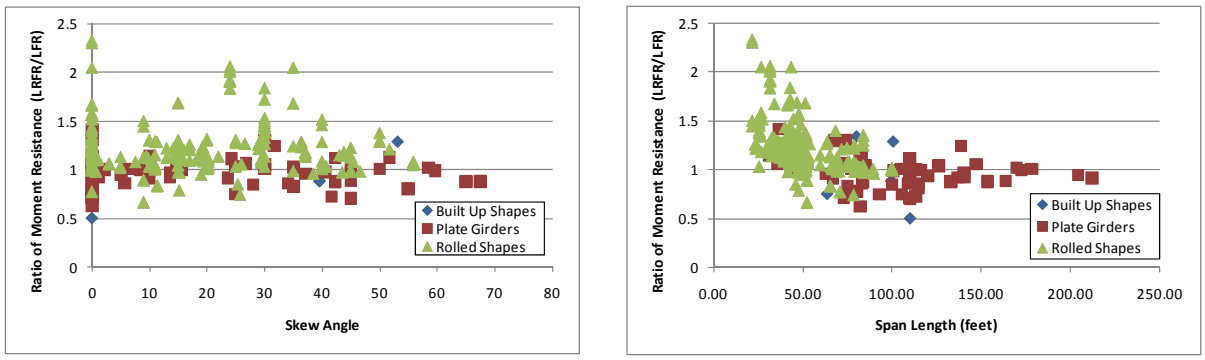


Figure B-137: Ratio of Factored Live Load plus Impact Moment for NM-04 Vehicle (LRFR/LFR)

B.1.7.1.2 Resistances

Figure B-138 shows the ratio of the factored moment resistances. Rolled shapes are more likely to have higher LRFR resistance than LFR resistance while plate girders show that the LFR resistance is greater than the LRFR resistance. The ratio is generally between 1.0 and 1.5 for rolled shapes and between 0.6 and 1.0 for plate girders. Built-up shapes do not consistently have one method providing higher resistance than the other method.



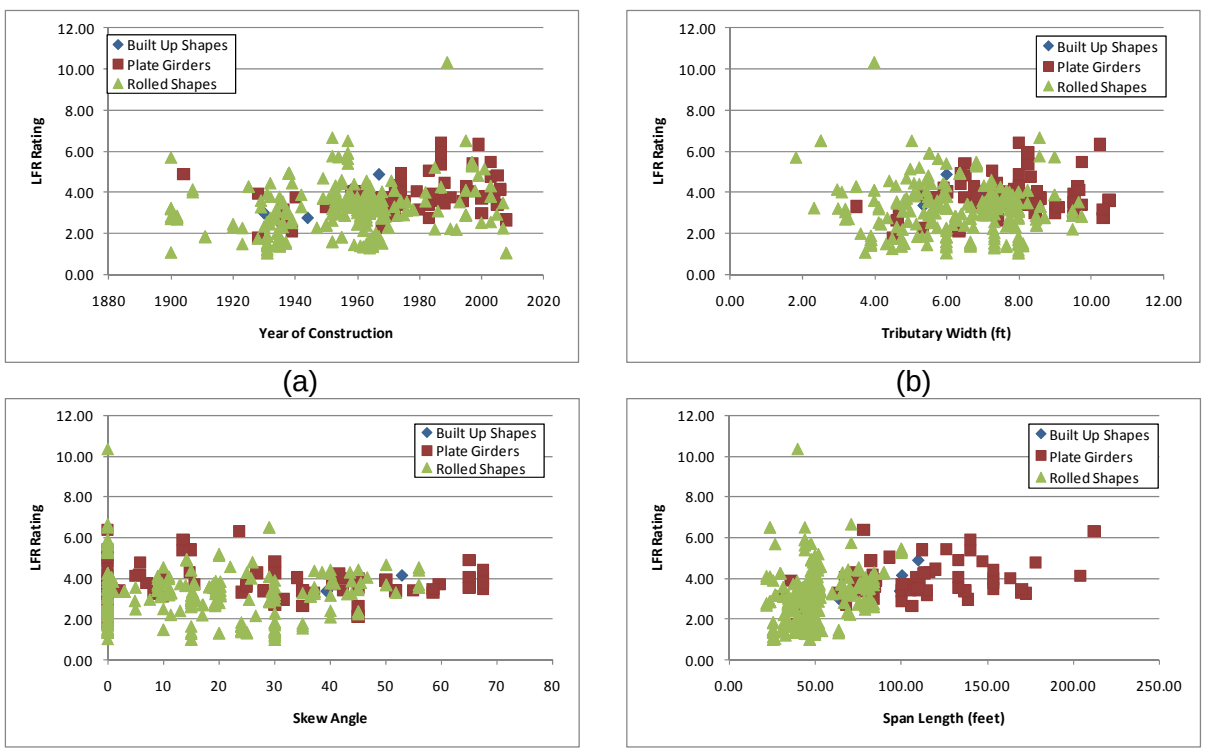


(c) (d)

Figure B-138: Ratio of Factored Moment Resistance (LRFR/LFR)

B.1.7.1.3 Rating Factors

Figure B-139 and Figure B-140 present the LFR and LRFR ratings from BRASS, respectively. There are zero girders with an LFR rating less than 1.0, 14 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Ignoring the outliers, the two methods provide similar scatter with the LRFR rating shifted down from the LFR rating. The LRFR rating shifts down due to the increase in live load shown in Figure B-137.



(a) (b)

(c) (d)

Figure B-139: LFR Flexure Rating Factor for NM-04 Vehicle

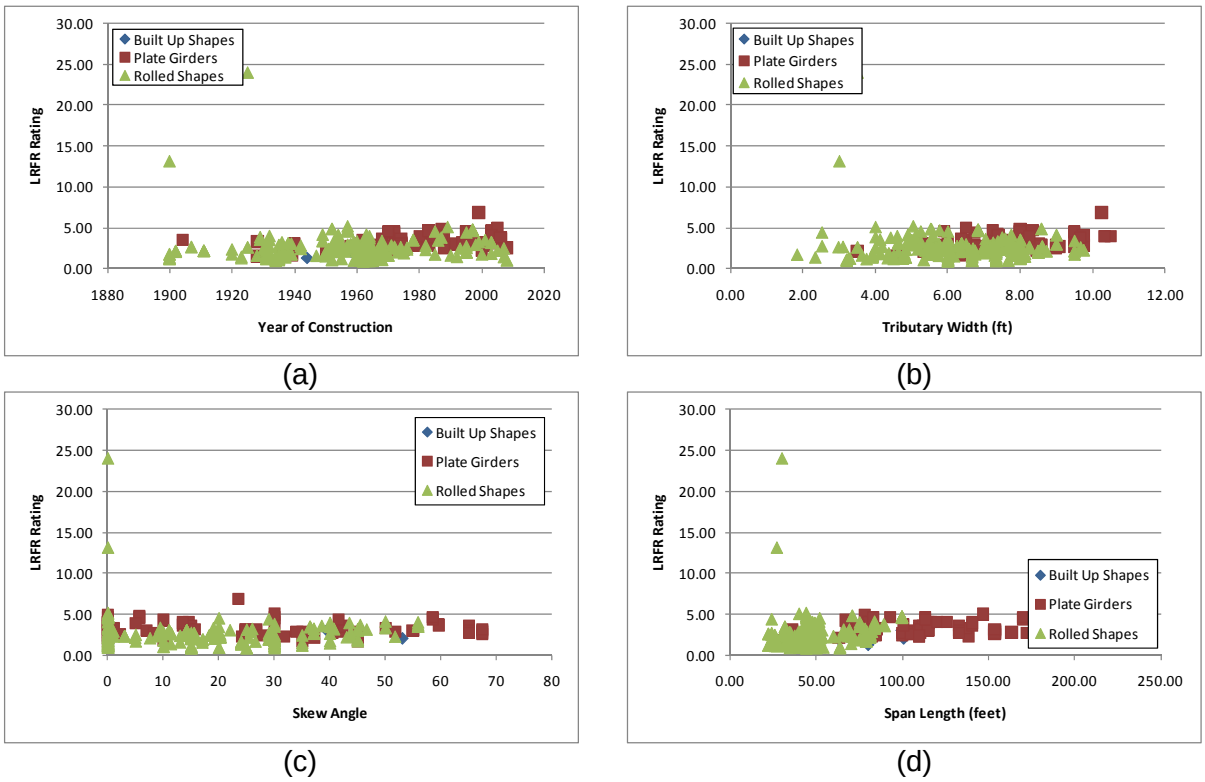
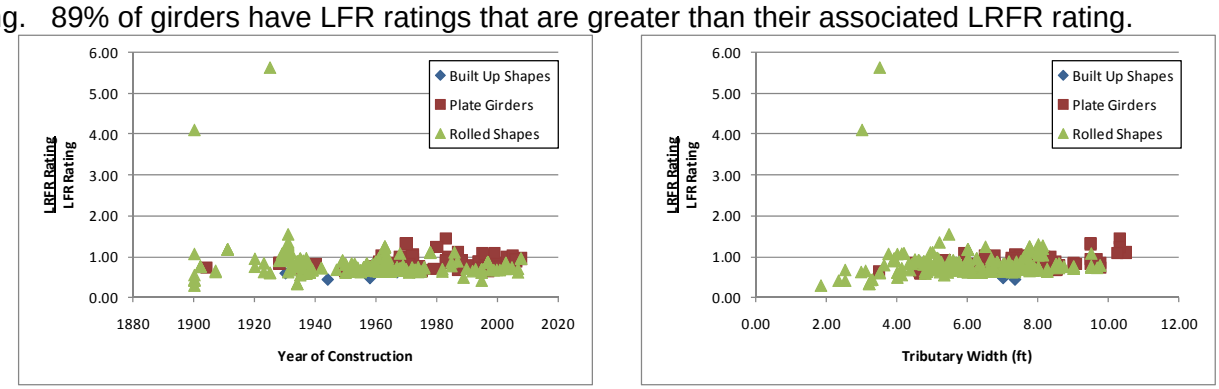
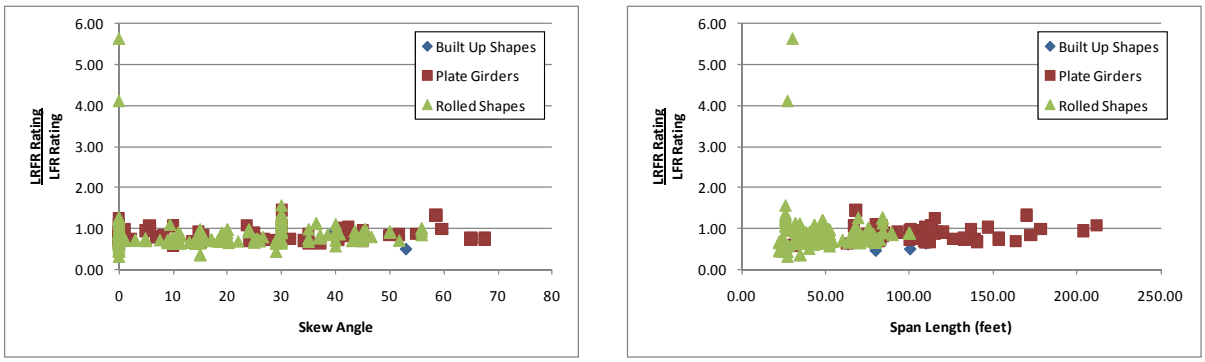


Figure B-140: LRFR Flexure Rating Factor for NM-04 Vehicle

B.1.7.1.4 Rating Factor Comparisons

Figure B-141 shows that the ratio of LRFR rating to LFR rating is generally less than 1.0. Rolled shapes are more likely to have higher a LFR rating than LRFR rating, with plate girders having ratings that are more similar between methods. The scatter decreases with increasing span length (Figure B-141d). Figure B-141b shows that for narrow girder spacing the LFR rating is higher than the LRFR rating. 89% of girders have LFR ratings that are greater than their associated LRFR rating.



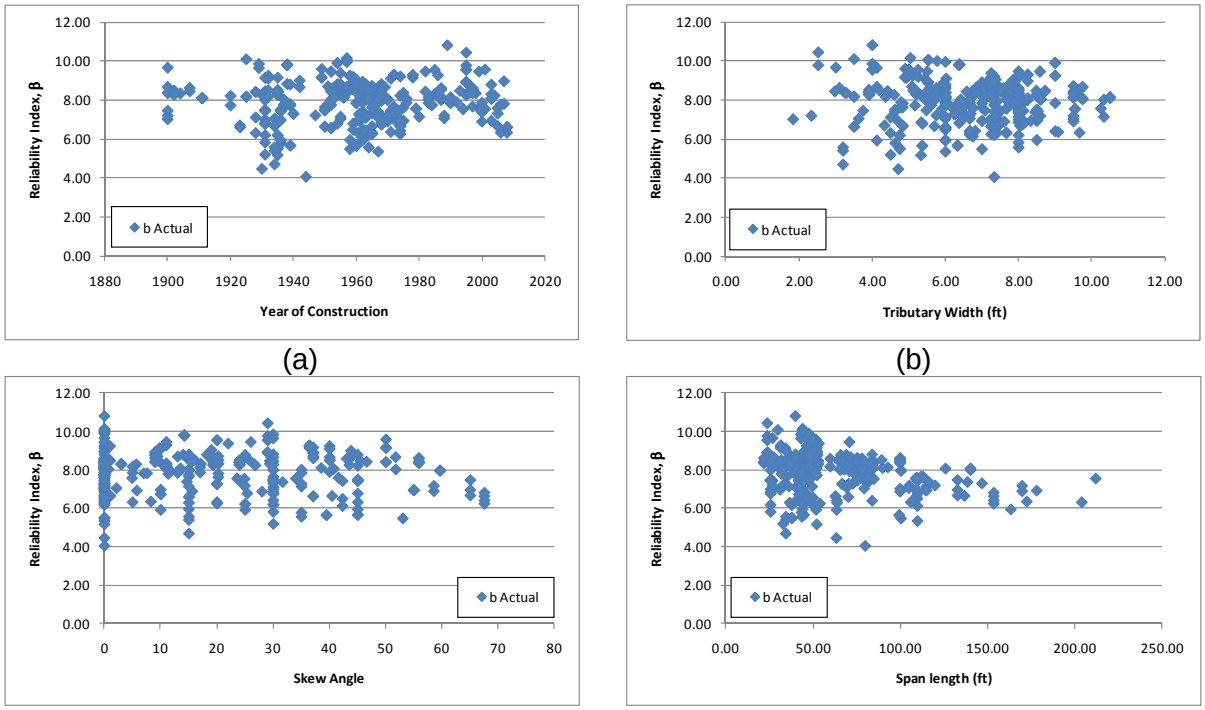


(c) (d)

Figure B-141: Ratio of LRFR Flexure Rating to LFR Flexure Rating for NM-04 Vehicle

B.1.7.1.5 Reliability Indices

Figure B-142 presents the reliability indices as calculated. The required reliability index was assumed to be 2.5 in the development of the MBE for routine permit vehicles. The actual reliability index tends to have less scatter with increasing tributary width and span lengths.



(a) (b)

(c) (d)

Figure B-142: Flexure Reliability Indices for NM-04 Vehicle

Figure B-143 shows the flexure reliability index calculated based upon the resistance of the section against the LRFR rating factor. The figure shows that a girder having a passing rating would have a reliability index of approximately 5. This is significantly larger than the value assumed in the MBE of 2.5 for a routine permit vehicle.

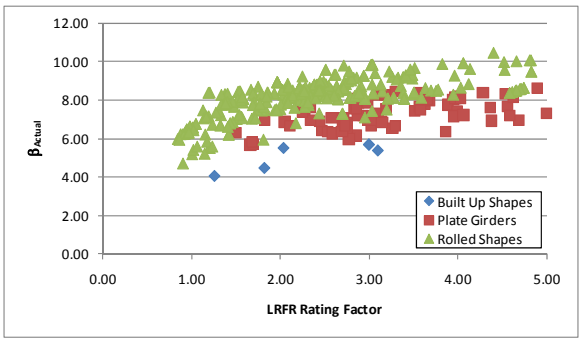


Figure B-143: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

B.1.7.2 Shear

B.1.7.2.1 Live Loads

Figure B-144 and Figure B-145 show the ratios, LRFR to LFR, of unfactored and factored live load plus impact shear, respectively. The ratio of unfactored loads is generally between 1.25 and 1.75 and between 1.5 and 2.25 when the loads are factored. The ratio of live loads decreases with increasing tributary width and is likely a result of the distribution factors as the LRFD equations limit the girder spacing to greater than 3.5 feet, while the LFR distribution factors are applicable to any girder spacing. Figure B-144c and Figure B-145c show that the ratio increases with increasing skew; this is expected though as the LRFD Specification increases the load distributed to each girder because of the skew while the LFR Specification does not consider the effect of skew. Figure B-146 shows where the critical shear rating occurred for each girder. The LFR location is typically away from the support while the LRFD location is typically at the support.

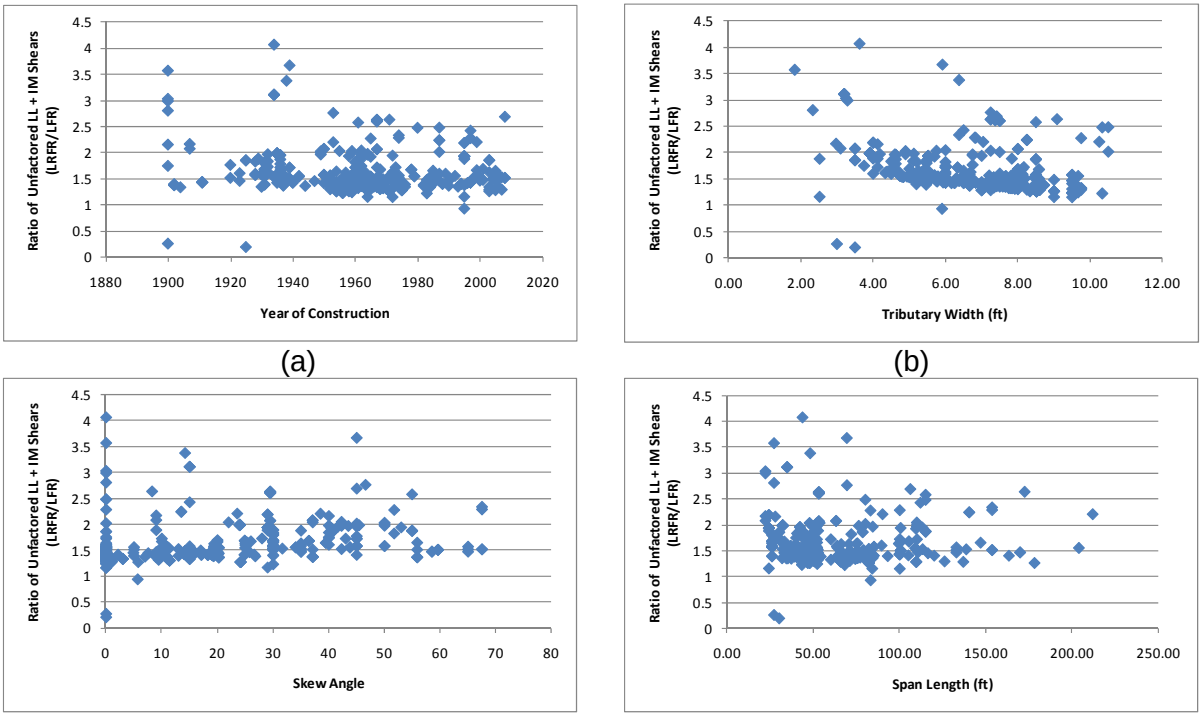
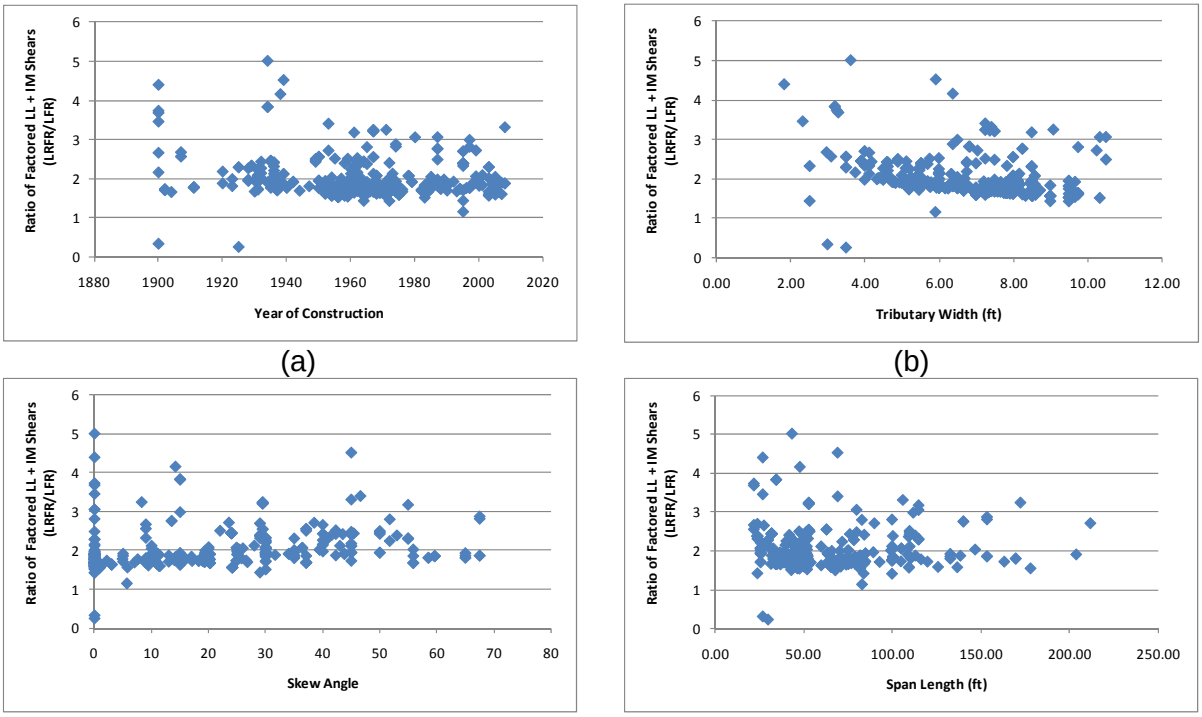


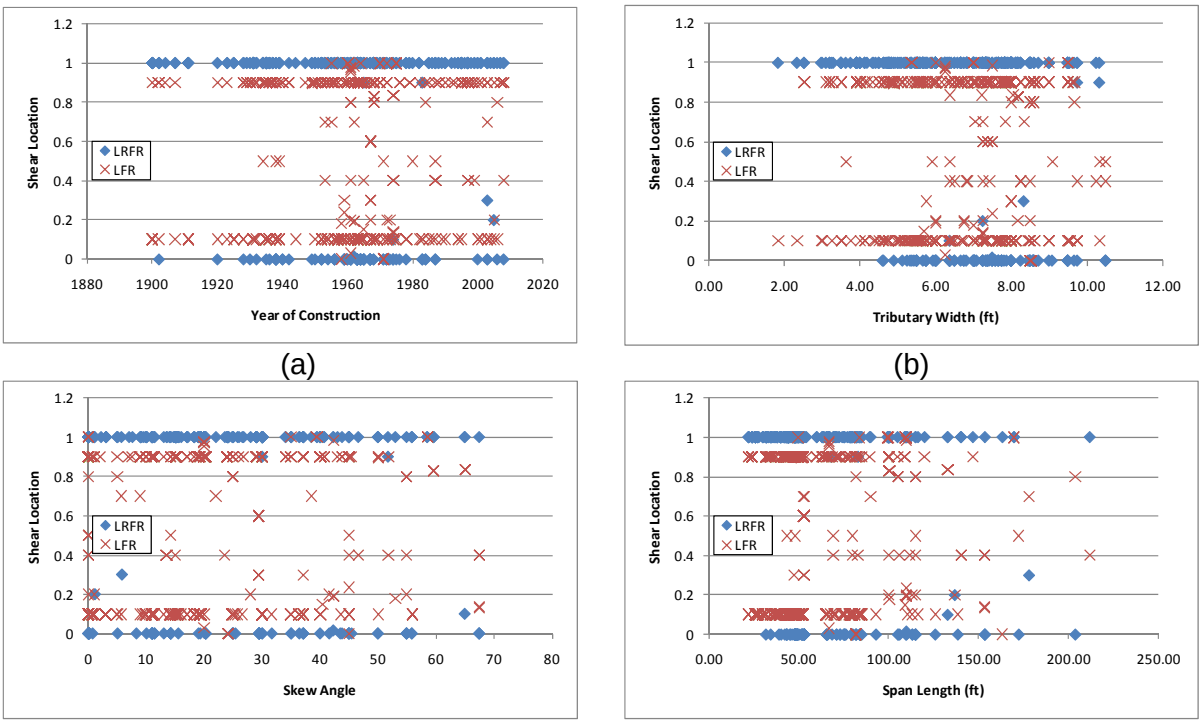
Figure B-144: Ratio of Unfactored Live Load plus Impact Shear for NM-04 Vehicle (LRFR/LFR)



(a) (b)

(c) (d)

Figure B-145: Ratio of Factored Live Load plus Impact Shear for NM-04 Vehicle (LRFR/LFR)



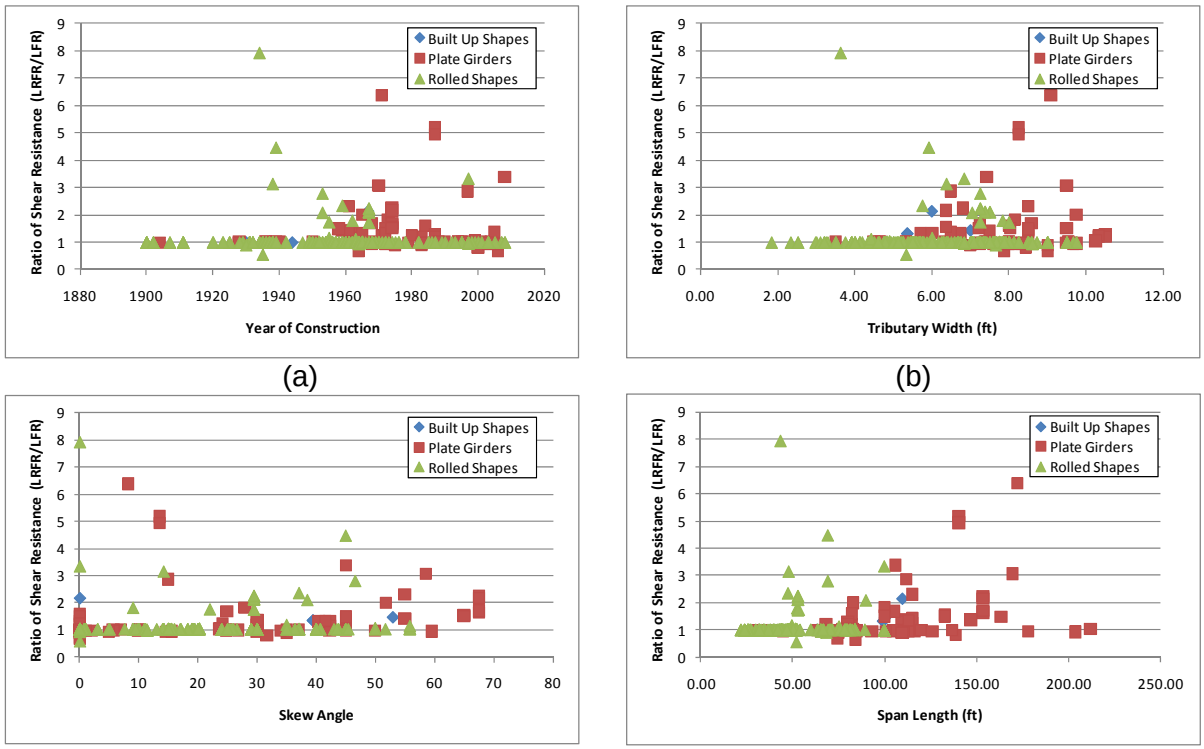
(a) (b)

(c) (d)

Figure B-146: Critical Shear Location for NM-04 Vehicle

B.1.7.2.2 Resistances

Figure B-147 shows the ratio of factored shear resistances, LRFR divided by LFR. The ratio is generally close to 1.0 with most of the scatter being eliminated by removing those girders where the critical shear location varies significantly (Section B.1.7.3.2). Figure B-147 shows that plate girders are more likely to be affected by the location of the shear rating.



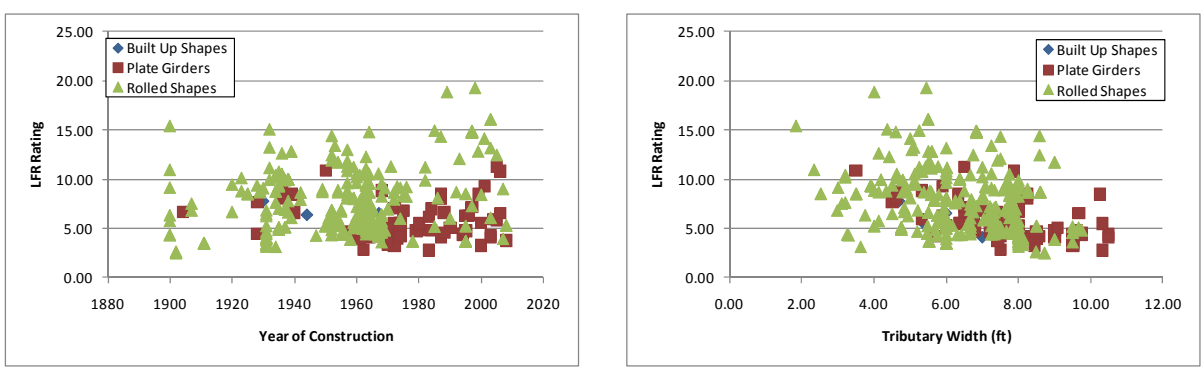
(a) (b)

(c) (d)

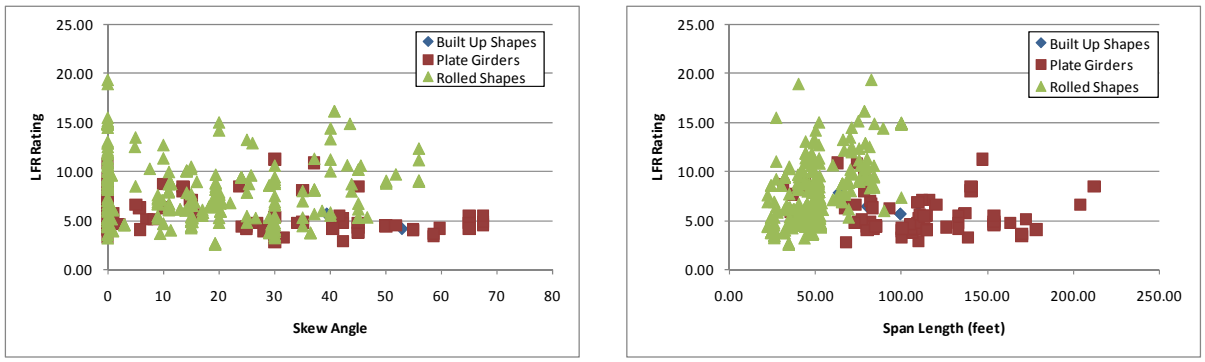
Figure B-147: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.7.2.3 Rating Factors

Figure B-148 and Figure B-149 present the ratings as calculated by BRASS for LFR and LRFR, respectively. The LFR Ratings tend to decrease with increasing tributary width and increasing span length (Figure B-148b and d). There is also less scatter with increasing span length (Figure B-148d). There are zero girders with an LFR rating of less than 1.0 and seven girders with an LRFR rating less than 1.0. Additionally, 98% of the girders have LFR Ratings greater than the LRFR rating.

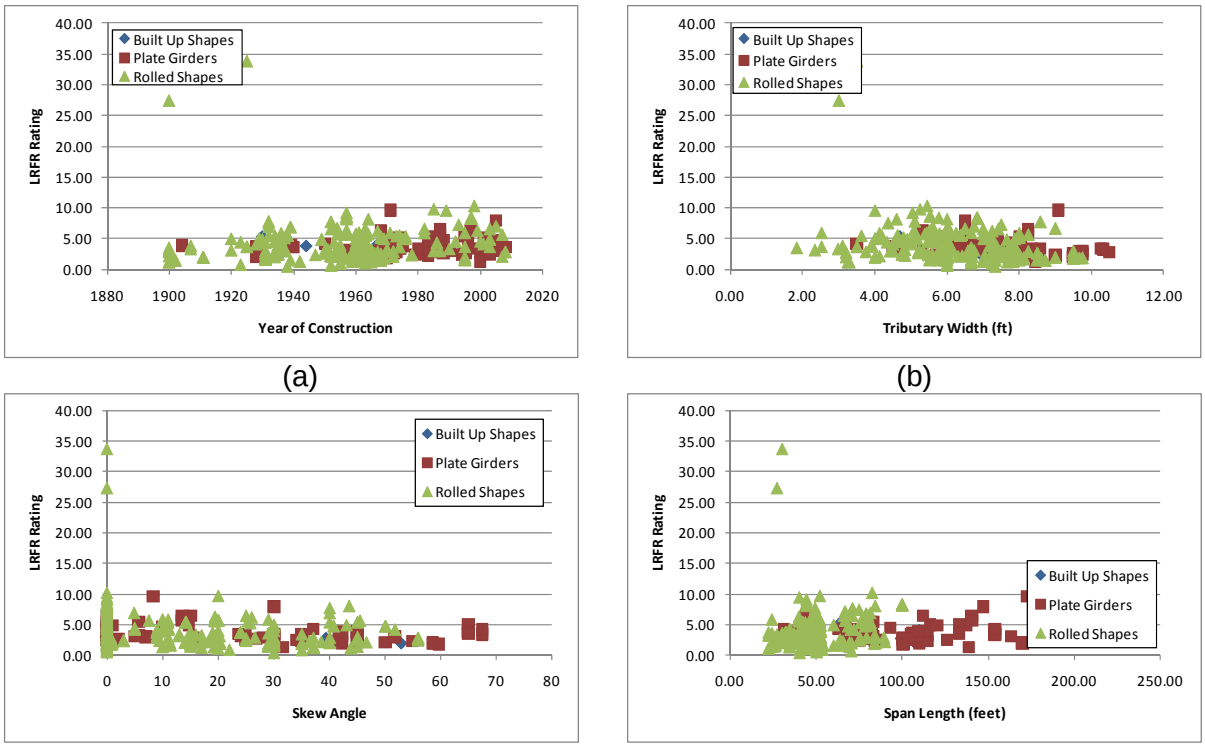


(a) (b)



(c) (d)

Figure B-148: LFR Shear Rating Factor for NM-04 Vehicle



(a) (b)

(c) (d)

Figure B-149: LRFR Shear Rating Factor for NM-04 Vehicle

B.1.7.2.4 Rating Factor Comparisons

Figure B-150 shows the ratio of LRFR rating factor divided by LFR rating factor. The ratio is generally less than 1.0, with rolled shapes generally having a ratio less than 0.75. Plate girders are generally between 0.5 and 1.0, with several above 1.0.

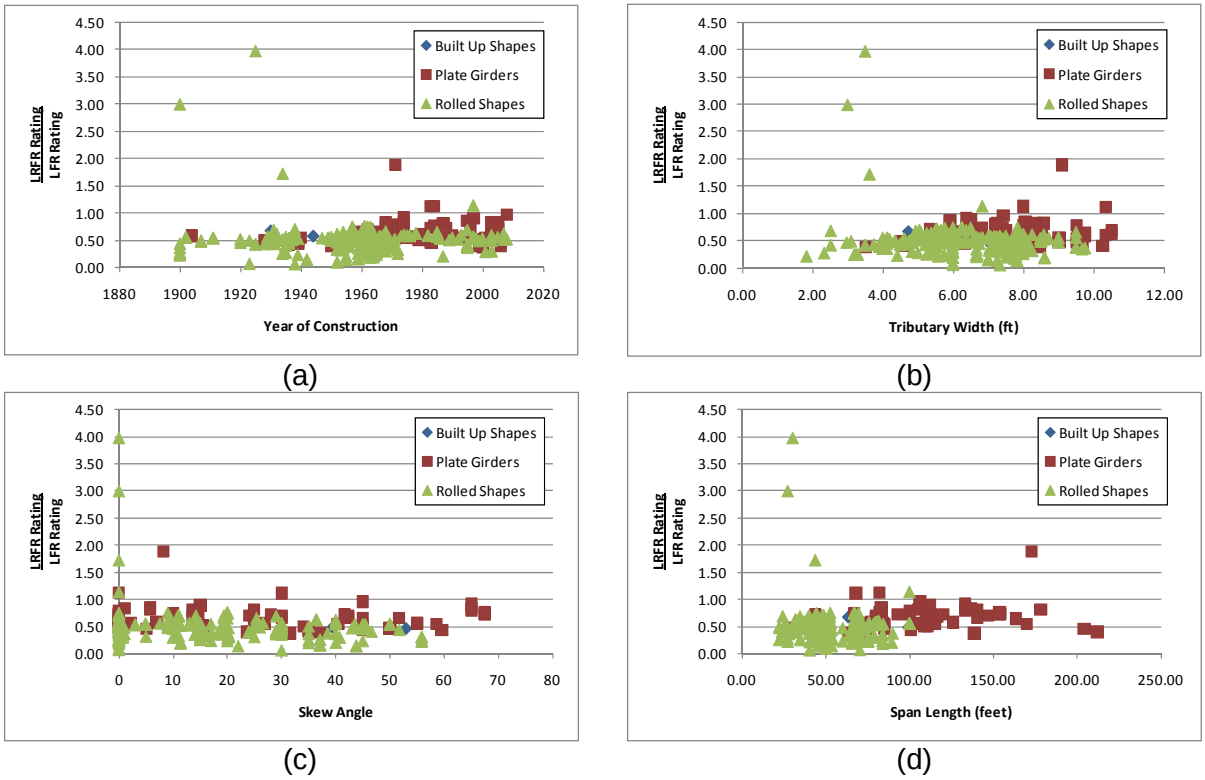
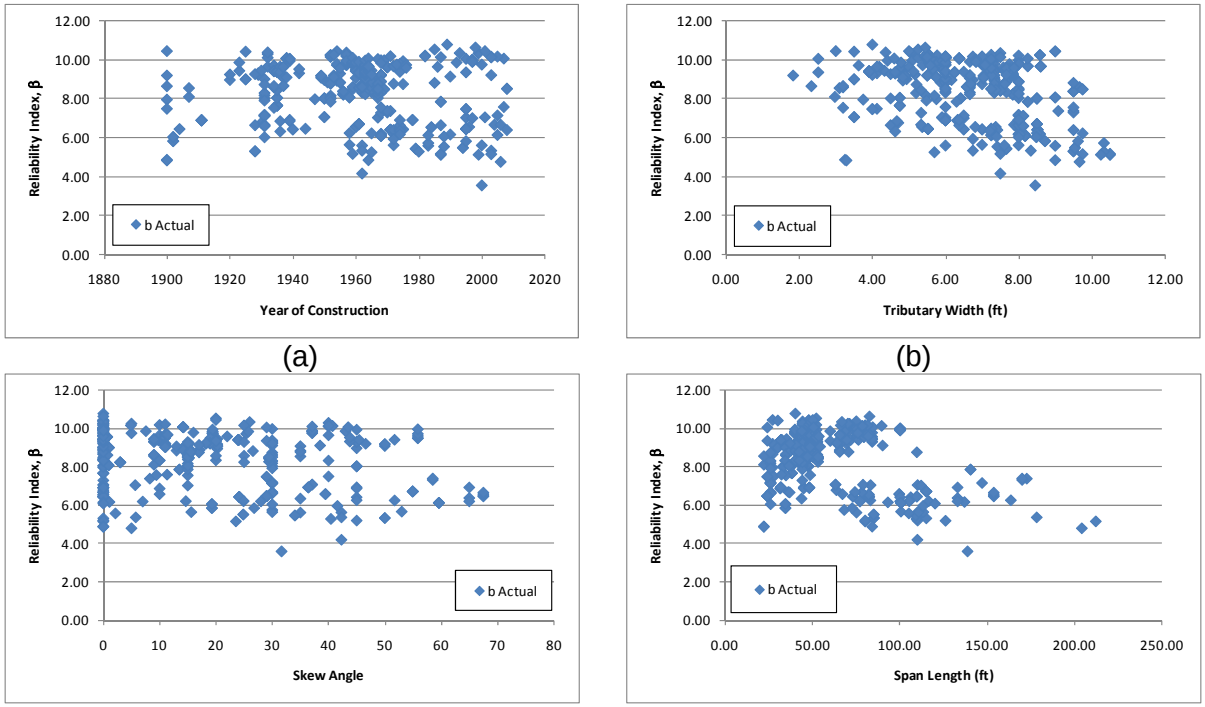


Figure B-150: Ratio of LRFR Shear Rating to LFR Shear Rating for NM-04 Vehicle

B.1.7.2.5 Reliability Indices

Figure B-151 shows the reliability index as calculated based upon the strength of the section. There are no girders approaching the reliability index of 2.5 assumed in the development of the MBE. There tends to be more scatter with increasing tributary width.



(c) (d)

Figure B-151: Shear Reliability Indices for NM-04 Vehicle

Figure B-152 shows the actual reliability index plotted against the LRFR rating factor for shear. The figure indicates that a girder with a passing rating is expected to have a reliability index of approximately 4.0. Since the required level of reliability is 2.5 for a routine permit vehicle, the live load factor could be reduced and still maintain the required level of reliability.

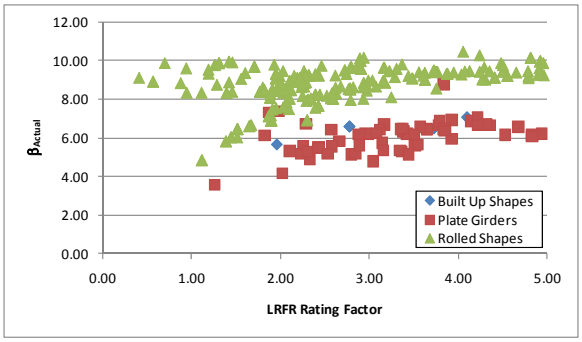


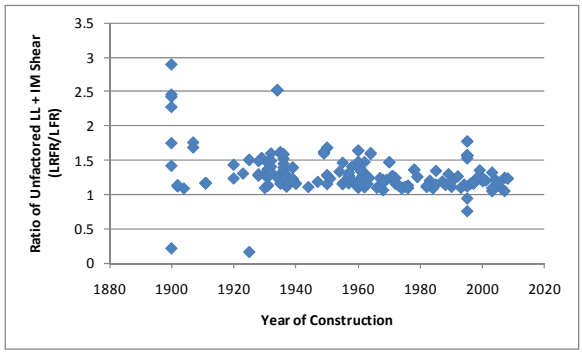
Figure B-152: Shear Reliability Index vs. LRFR Shear Rating for NM-04 Vehicle

B.1.7.3 Shear-Corrected

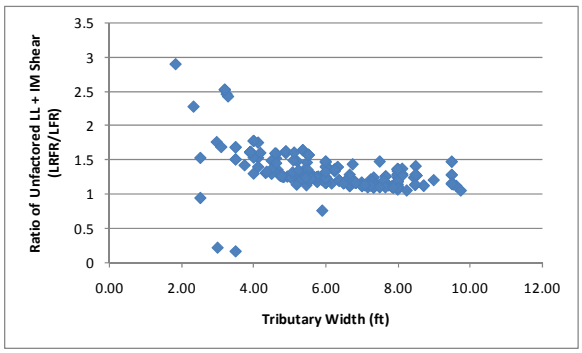
This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.7.3.1 Live Load

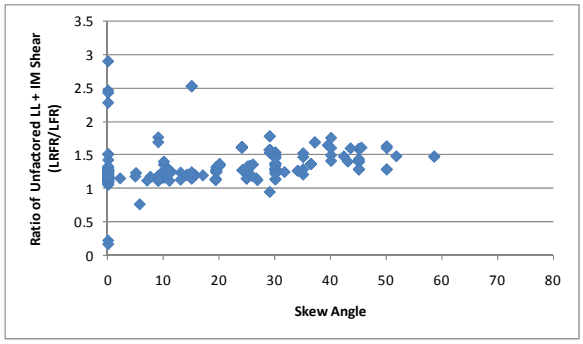
Figure B-153 and Figure B-154 show the ratio, LRFR to LFR, of unfactored and factored live load plus impact shear for those girders with critical locations at the either the support or one-tenth of the span away from the support. The LRFR unfactored shear is generally 100 to 150% of the LFR unfactored shear, when factored the LRFR live load shears are between 125 and 175% of the LFR live load shears. The live loads are similar when taking them at the same location, but the LRFR live loads still remain significantly larger than the LFR live loads.



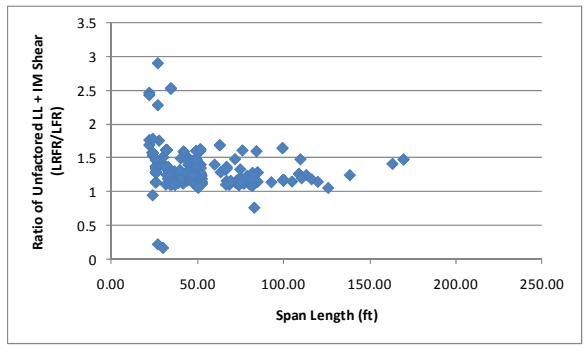
(a)



(b)

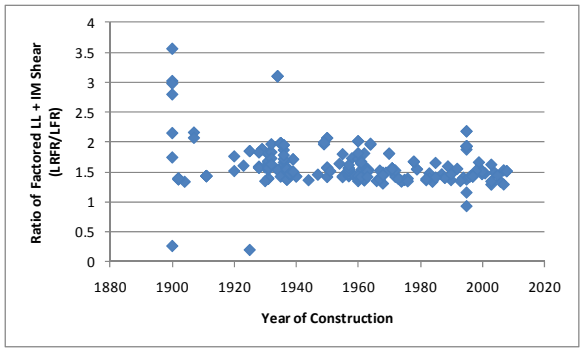


(c)

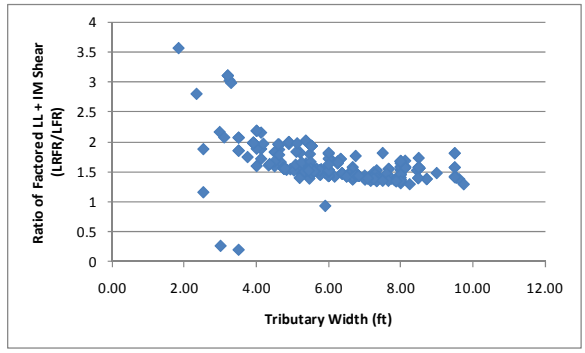


(d)

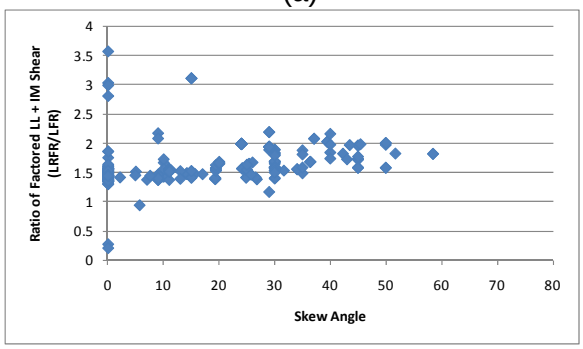
Figure B-153: Ratio of Unfactored Live Load plus Impact Shear for NM-04 Vehicle (LRFR/LFR)



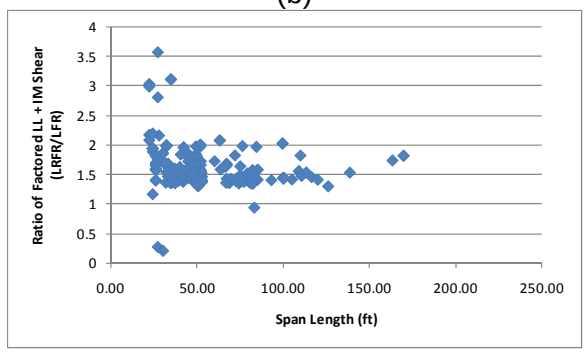
(a)



(b)



(c)

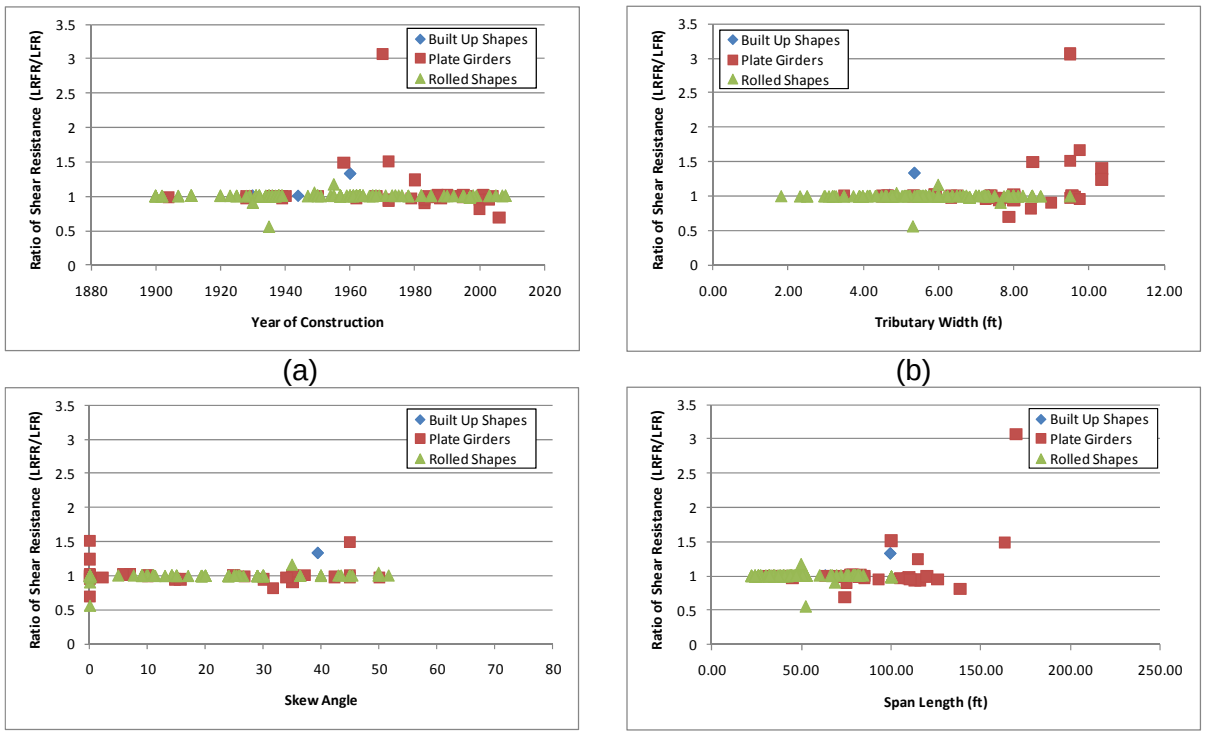


(d)

Figure B-154: Ratio of Factored Live Load plus Impact Shear for NM-04 Vehicle (LRFR/LFR)

B.1.7.3.2 Resistance

The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was greater than 1.0 have been eliminated by considering only those close to the support. The ratio of shear resistance (LRFR divided by LFR) is shown in Figure B-155.



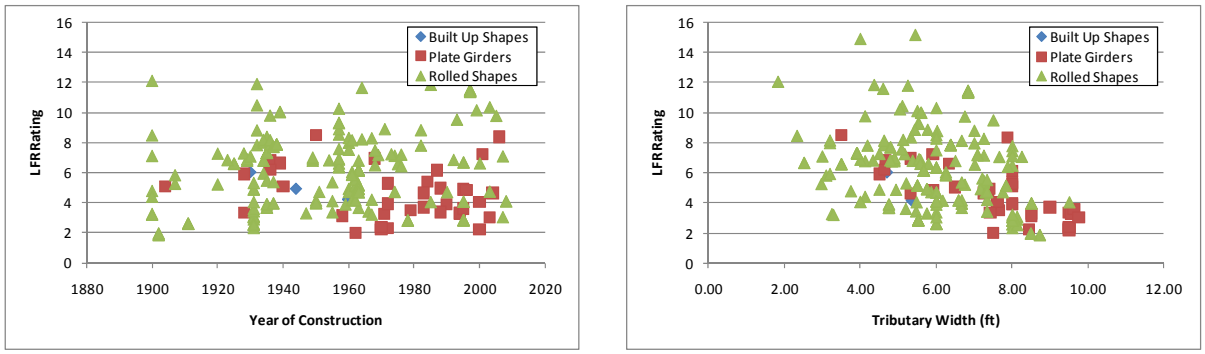
(a) (b)

(c) (d)

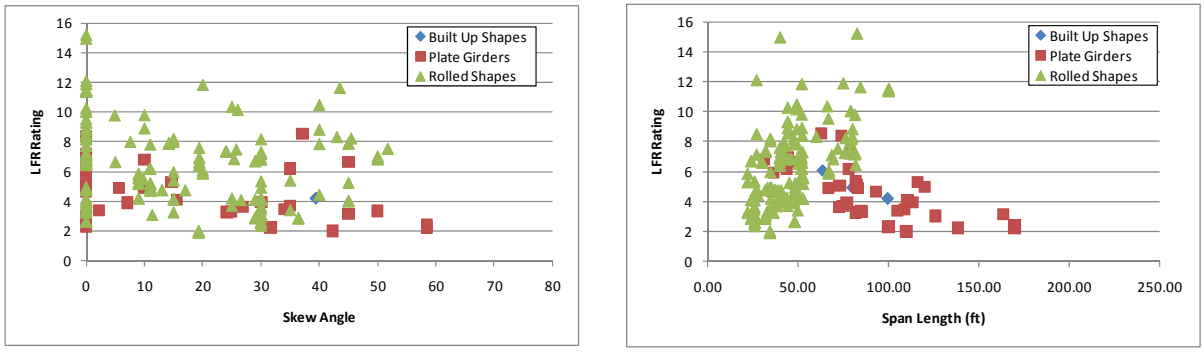
Figure B-155: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.7.3.3 Rating Factors

After determining the LFR loads at the support and the shear resistances are similar, the next step was to calculate the LFR rating and compare the rating factors. Figure B-156 and Figure B-157 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where it is likely that the stiffener spacing would vary along the span length. Significant variation still exists in the LFR ratings with similar variation also occurring in the LRFR ratings.

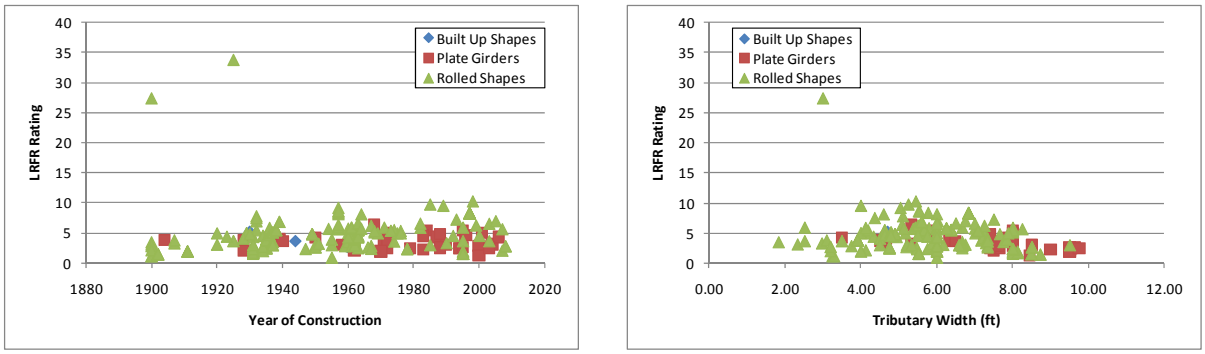


(a) (b)

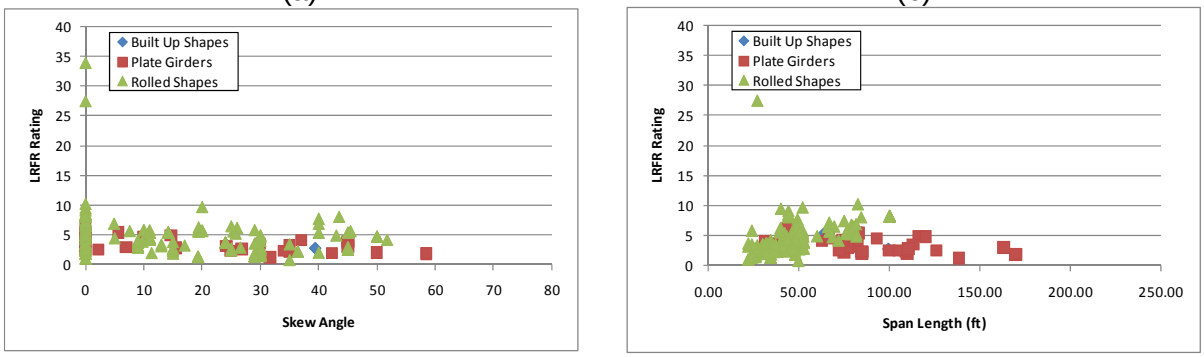


(c) (d)

Figure B-156: LFR Shear Rating Factor for NM-04 Vehicle



(a) (b)



(c) (d)

Figure B-157: LRFR Shear Rating Factor for NM-04 Vehicle

B.1.7.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio of the LRFR rating factor to the LFR rating factor. Figure B-158 shows the results of this comparison. The results show that the LFR rating remains greater than the LRFR rating after recalculating the rating at the support. The ratio is generally between 0.5 and 1.0 for all girder types.

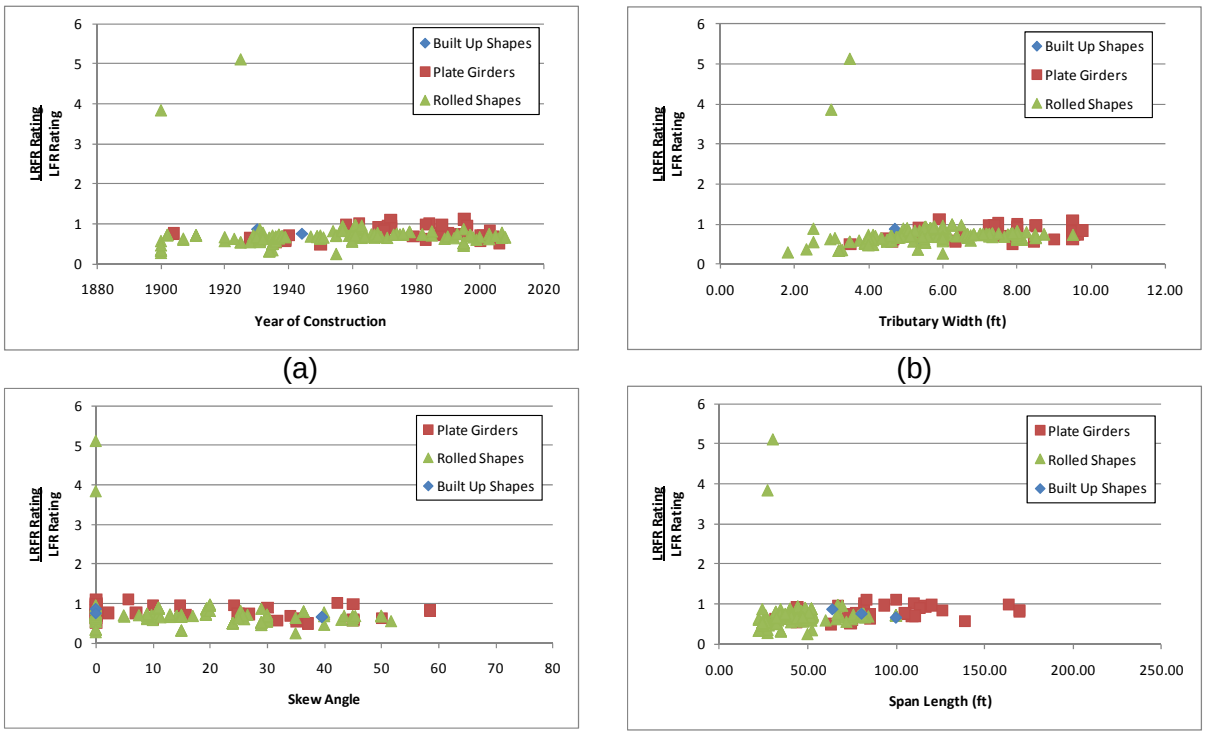
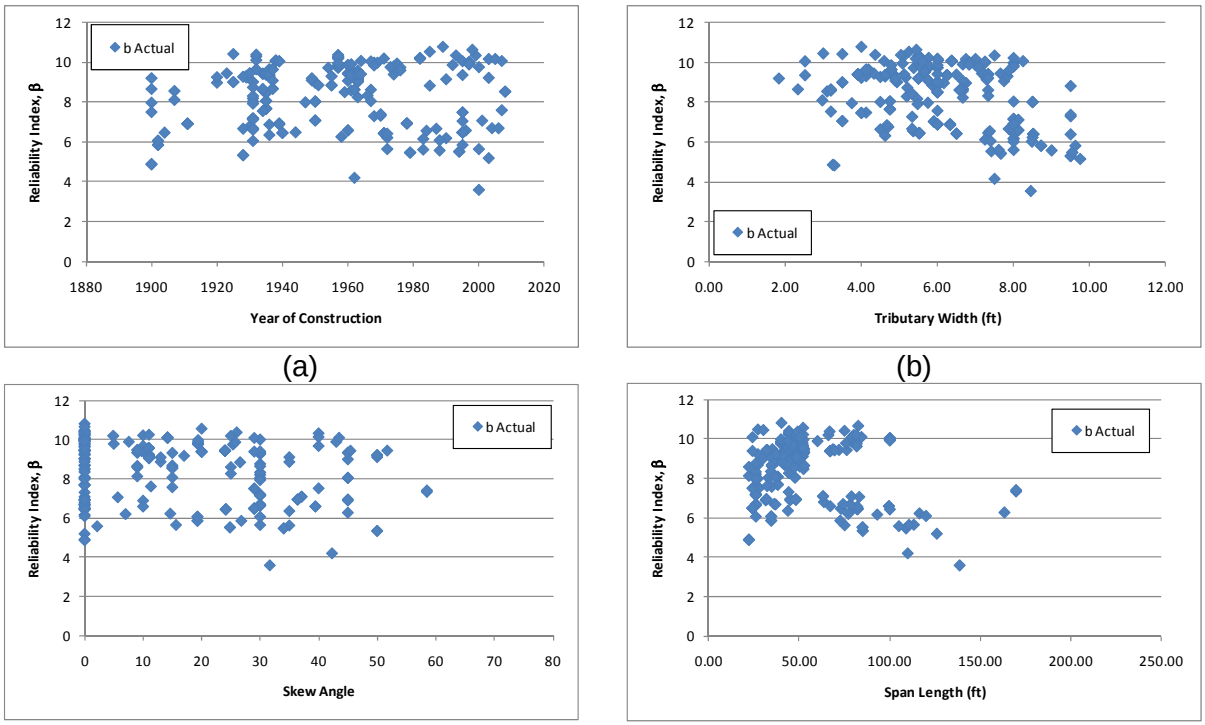


Figure B-158: Ratio of LRFR Shear Rating to LFR Shear Rating for NM-04 Vehicle

B.1.7.3.5 Reliability Indices

The reliability indices shown in Figure B-159 are the same as those shown in Figure B-151. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 2.5. The reliability index remains the same as calculated previously because the LRFR location did not move.

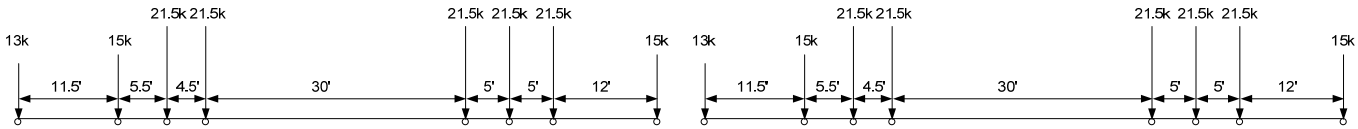


(c) (d)

Figure B-159: Shear Reliability Indices for NM-04 Vehicle

B.1.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-160. The applicable load factors for these vehicles are 1.30 and 1.40 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

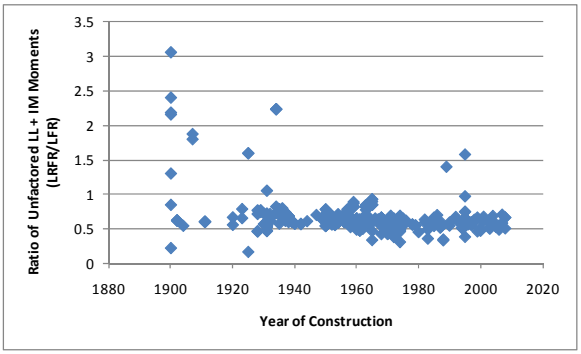
LFR Loading LRFR Loading

Figure B-160: Vehicle Loadings and Load Factors

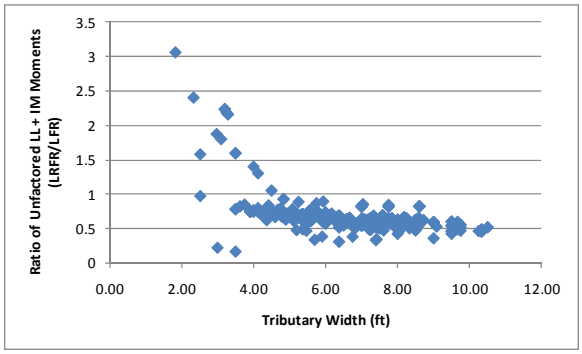
B.1.8.1 Moment

B.1.8.1.1 Live Loads

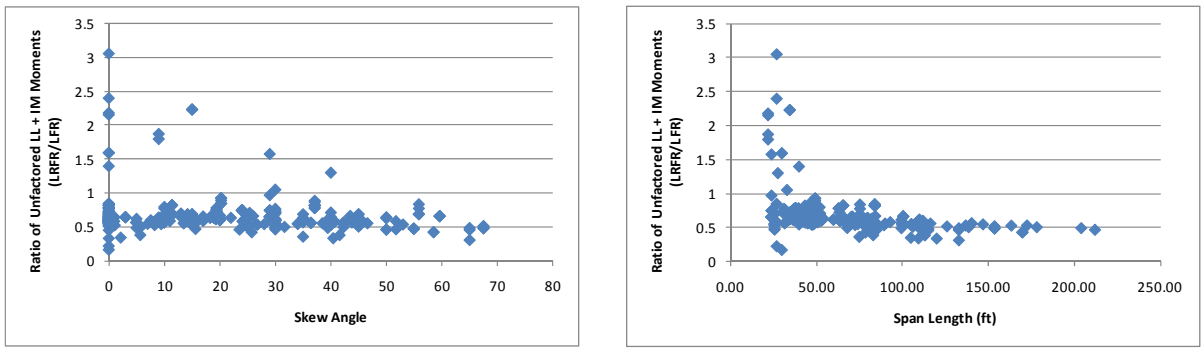
Figure B-161 and Figure B-162 shows the ratios of unfactored and factored live load plus impact moments for the OR-06 vehicle. The LFR moments due to live load plus impact are typically greater than the LRFR moments, for both the factored and unfactored case. The ratio of unfactored loads is generally between 0.5 and 0.75 while the ratio of factored loads has increased slightly. The ratio tends to decrease slightly with increasing tributary width (Figure B-161b and Figure B-162b), while there is less scatter for increasing span lengths (Figure B-161d and Figure B-162d).



(a)

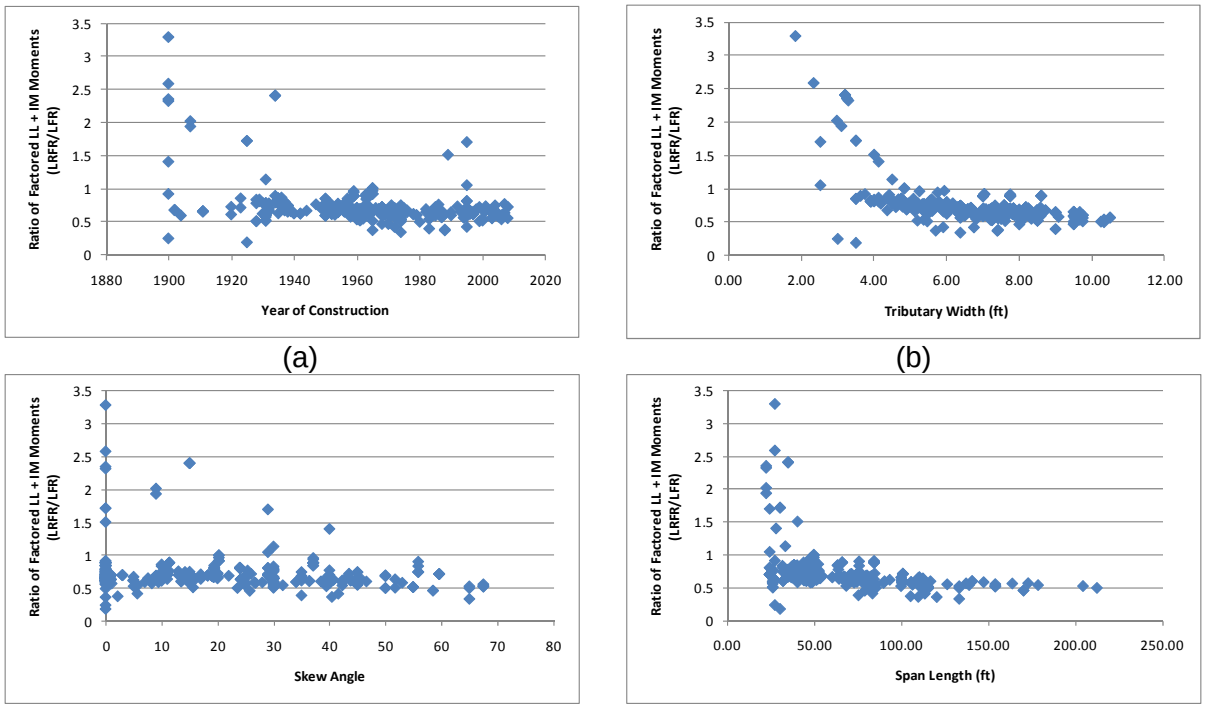


(b)



(c) (d)

Figure B-161: Ratio of Unfactored Live Load plus Impact Moment for OR-06 Vehicle (LRFR/LFR)



(a) (b)

(c) (d)

Figure B-162: Ratio of Factored Live Load plus Impact Moment for OR-06 Vehicle (LRFR/LFR)

B.1.8.1.2 Resistances

Figure B-163 shows the ratio of the factored moment resistances. Rolled shapes typically have higher resistance for LRFR than for LFR while plate girders appear to typically have higher LFR resistance. The resistance ratio for rolled shapes generally between 1.0 and 1.5 while for plate girders it is between 0.6 and 1.0.

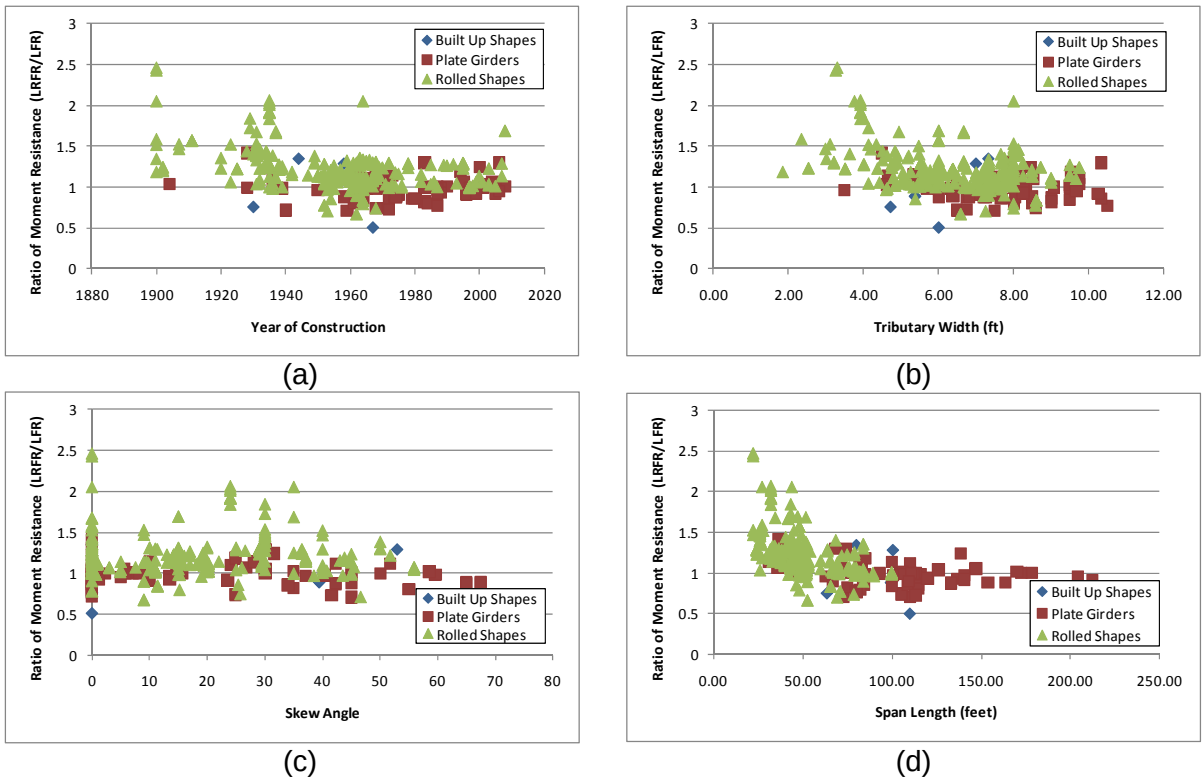
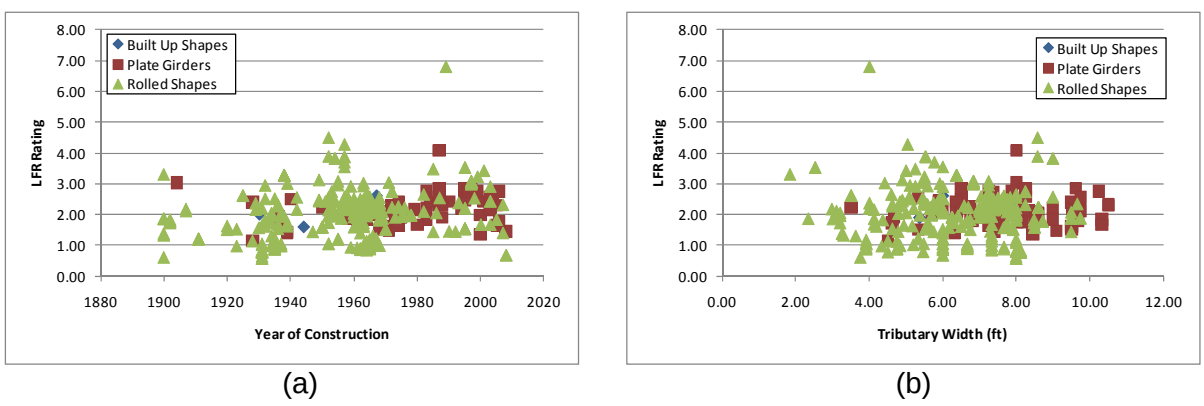
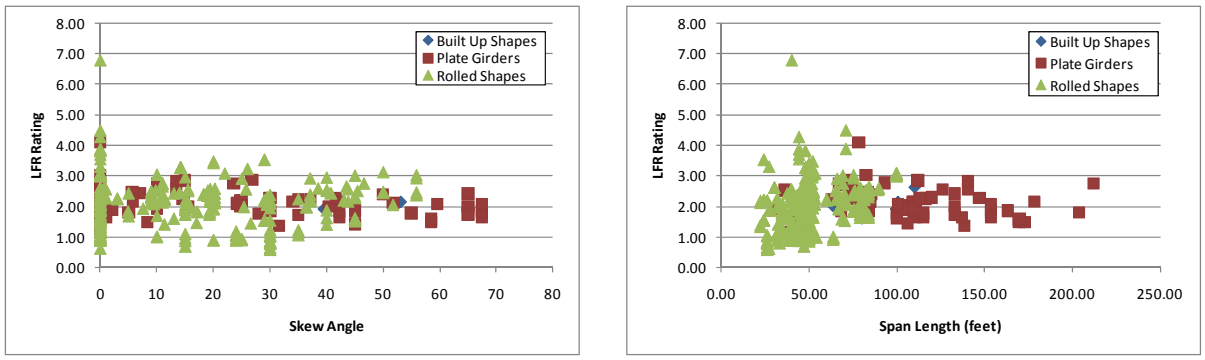


Figure B-163: Ratio of Factored Moment Resistance (LRFR/LFR)

B.1.8.1.3 Rating Factors

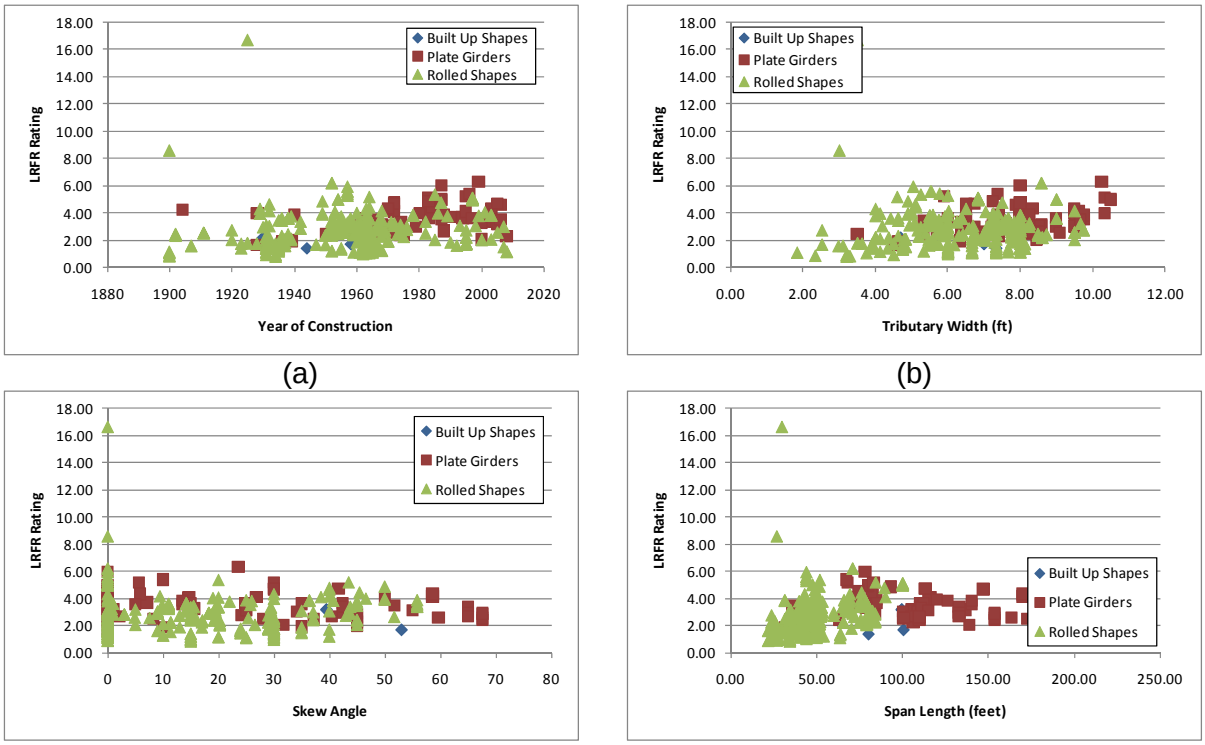
Figure B-164 and Figure B-165 present the LFR and LRFR ratings calculated by BRASS, respectively. There are 41 girders with an LFR rating less than 1.0, 8 girders with an LRFR rating less than 1.0, and 2 girders where both ratings are less than 1.0. Ignoring the outliers, the two methods provide similar scatter with the LRFR rating shifted up from the LFR rating.





(c) (d)

Figure B-164: LFR Flexure Rating Factor for OR-06 Vehicle



(a) (b)

(c) (d)

Figure B-165: LRFR Flexure Rating Factor for OR-06 Vehicle

B.1.8.1.4 Rating Factor Comparisons

Figure B-166 show the ratio of LRFR rating factor to LFR rating factor is generally above 1.0; seven percent of girders have higher LFR ratings than LRFR ratings. The scatter decreases with increasing span length (Figure B-166d). Figure B-166b shows that for narrow girder spacing the LFR rating is higher than the LRFR rating, while for large girder spacing the LRFR rating is greater. The increase in rating is due to LRFR considering only one lane loaded and ignoring the 1.2 multiple presence factor in the distribution factor.

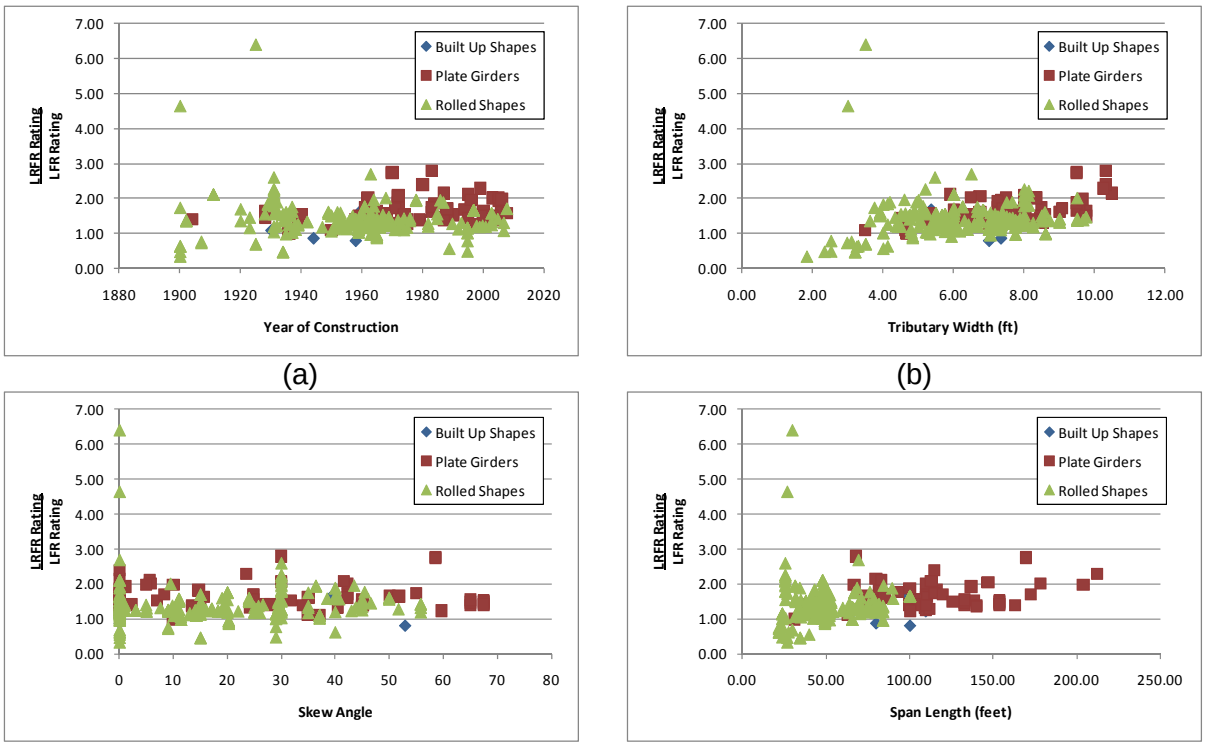


Figure B-166: Ratio of LRFR Flexure Rating to LFR Flexure Rating for OR-06 Vehicle

B.1.8.1.5 Reliability Indices

Figure B-167 presents the actual reliability index. The reliability index for all girders is greater than that assumed in the development of the MBE for special permit vehicles of 3.5.

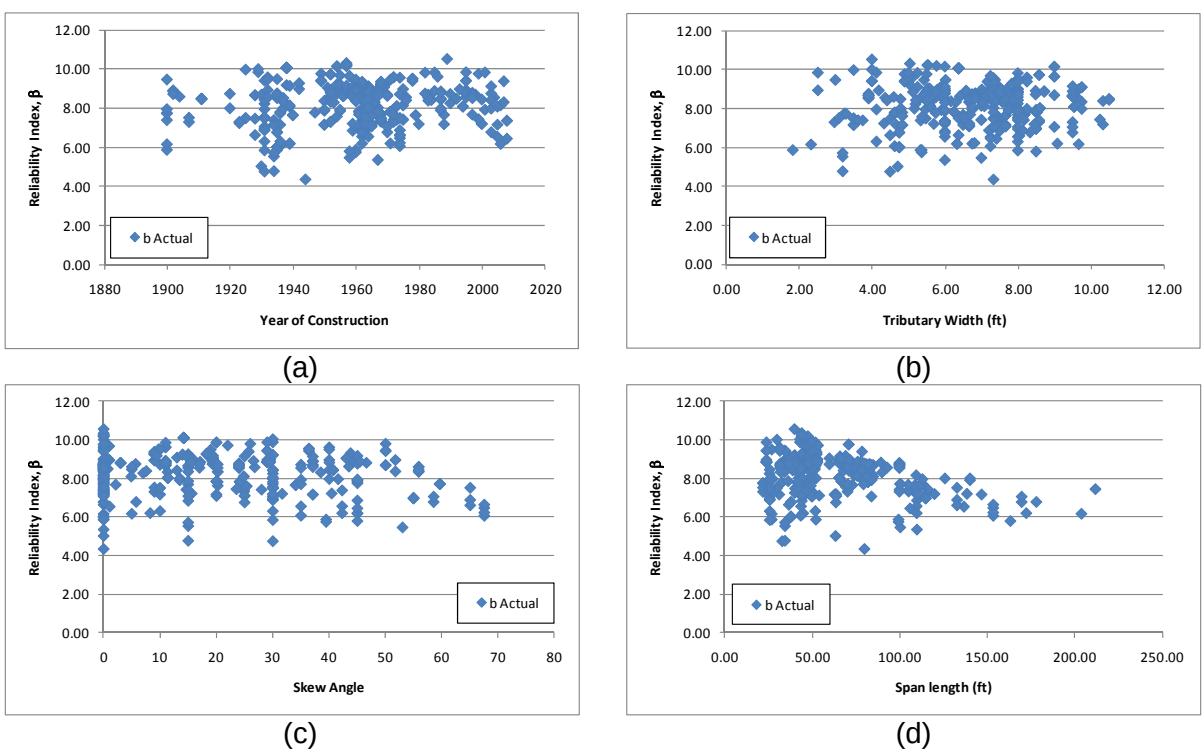


Figure B-167: Flexure Reliability Indices for OR-06 Vehicle

Figure B-168 shows the reliability index plotted agains the LRFR rating factor for the OR-06 Vehicle. This vehicle is considered a special permit vehicle for the purposes of this research and is expected to have a reliability index of 3.5. The figure shows that a girder with a rating of 1.0 will have a reliability index of approximately 4.5. This indicates that the live load factor could be reduced and would maintain the expected level of reliability.

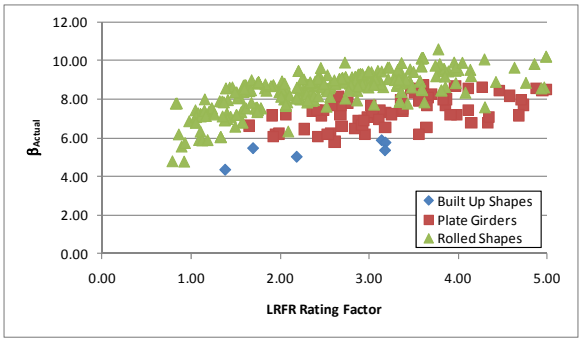
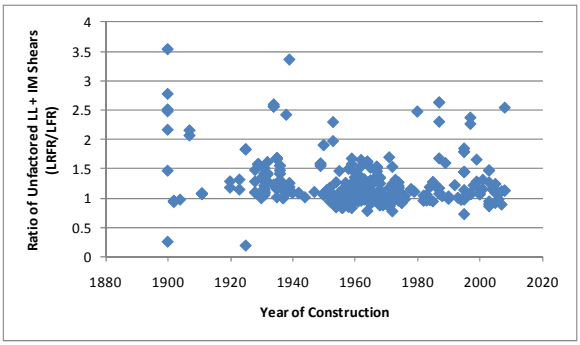


Figure B-168: Flexure Reliabilty Index vs LRFR Flexure Rating for OR-06 Vehicle

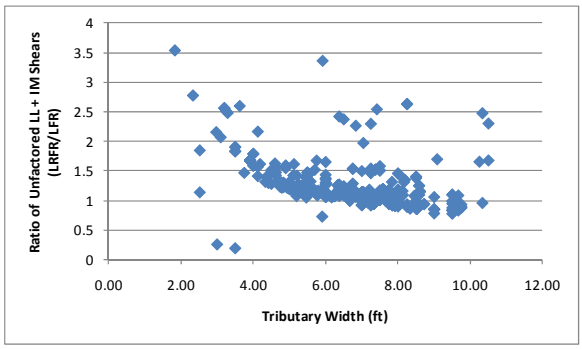
B.1.8.2 Shear

B.1.8.2.1 Live Loads

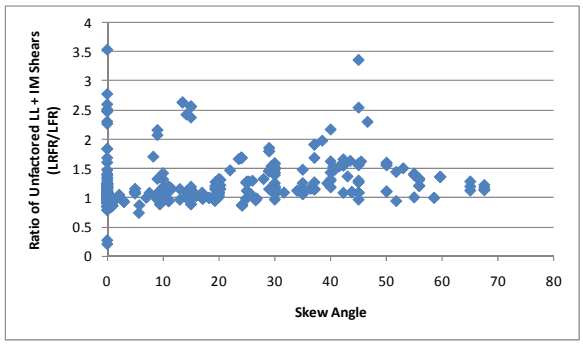
Figure B-169 and Figure B-170 show the ratios of unfactored and factored live load plus impact shear, respectively. The ratio of unfactored LRFR loads to LFR loads is generally between 0.8 and 1.5 and is between 0.9 and 1.6 when the loads are factored, and decrease with increasing tributary width (Figure B-169b and Figure B-170b). This is likely a result of the distribution factors as the LRFD equations limit the girder spacing to greater than 3.5 feet, while the LFR distribution factors are applicable to any girder spacing. Figure B-169c and Figure B-170c show that the ratio increases with larger skew angles; this is an expected result though as the LRFD Specification increases the load distributed to each girder because of the skew while the LFR Specification does not consider the effect of skew. Figure B-171 shows where the critical shear rating occurred for each girder. The LFR location is typically away from the support while the LRFD location is typically at the support.



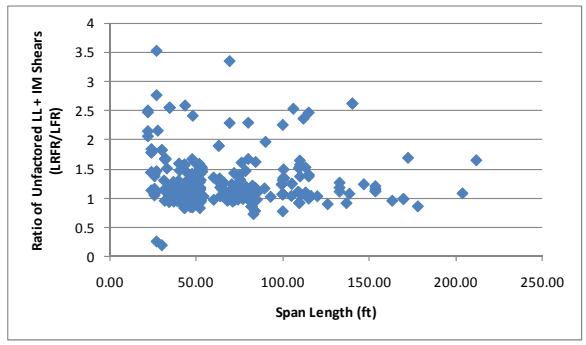
(a)



(b)

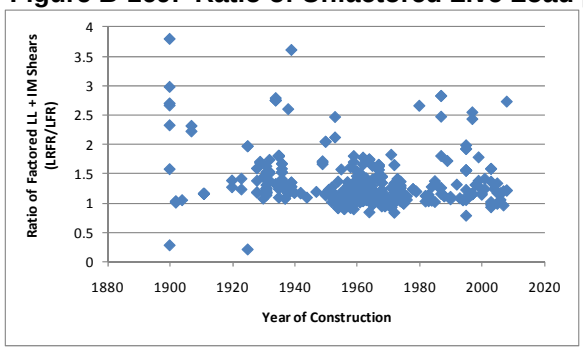


(c)

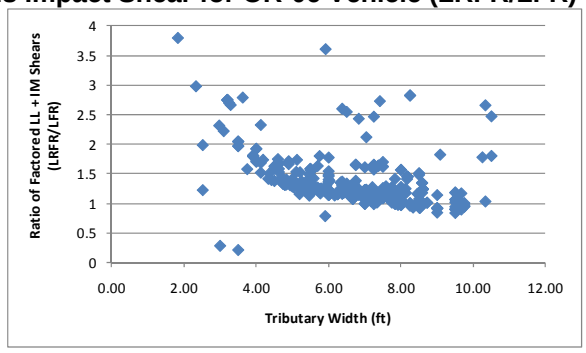


(d)

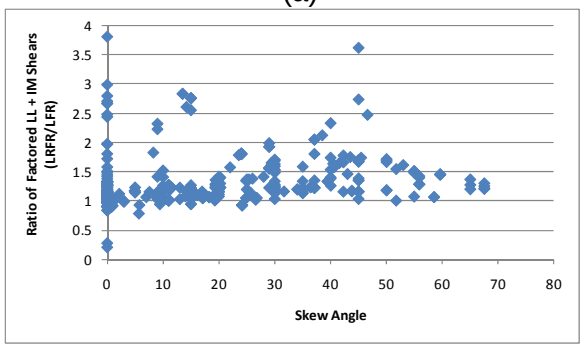
Figure B-169: Ratio of Unfactored Live Load plus Impact Shear for OR-06 Vehicle (LRFR/LFR)



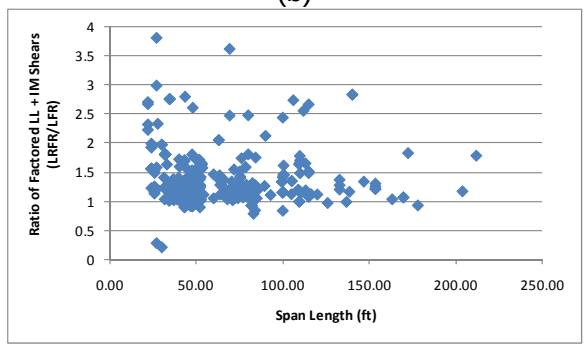
(a)



(b)

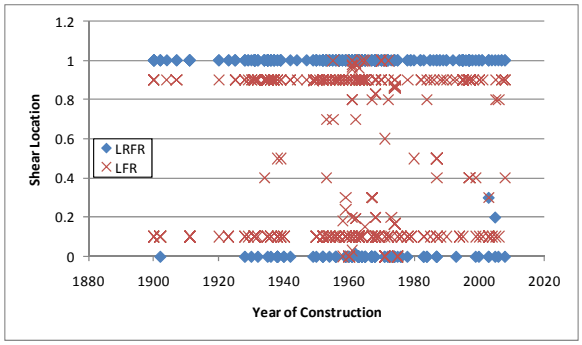


(c)

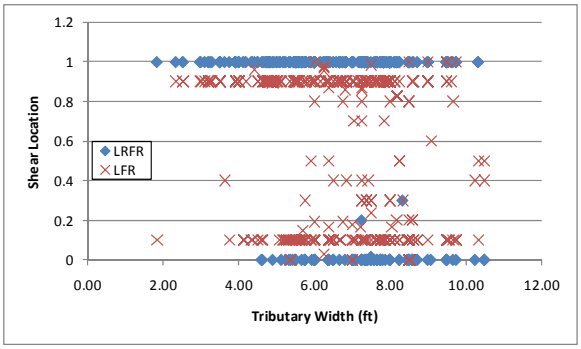


(d)

Figure B-170: Ratio of Factored Live Load plus Impact Shear for OR-06 Vehicle (LRFR/LFR)



(a)



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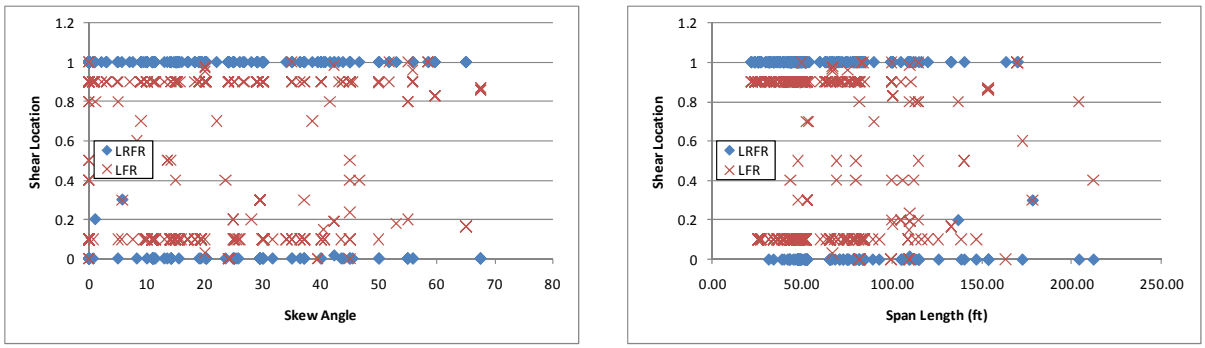
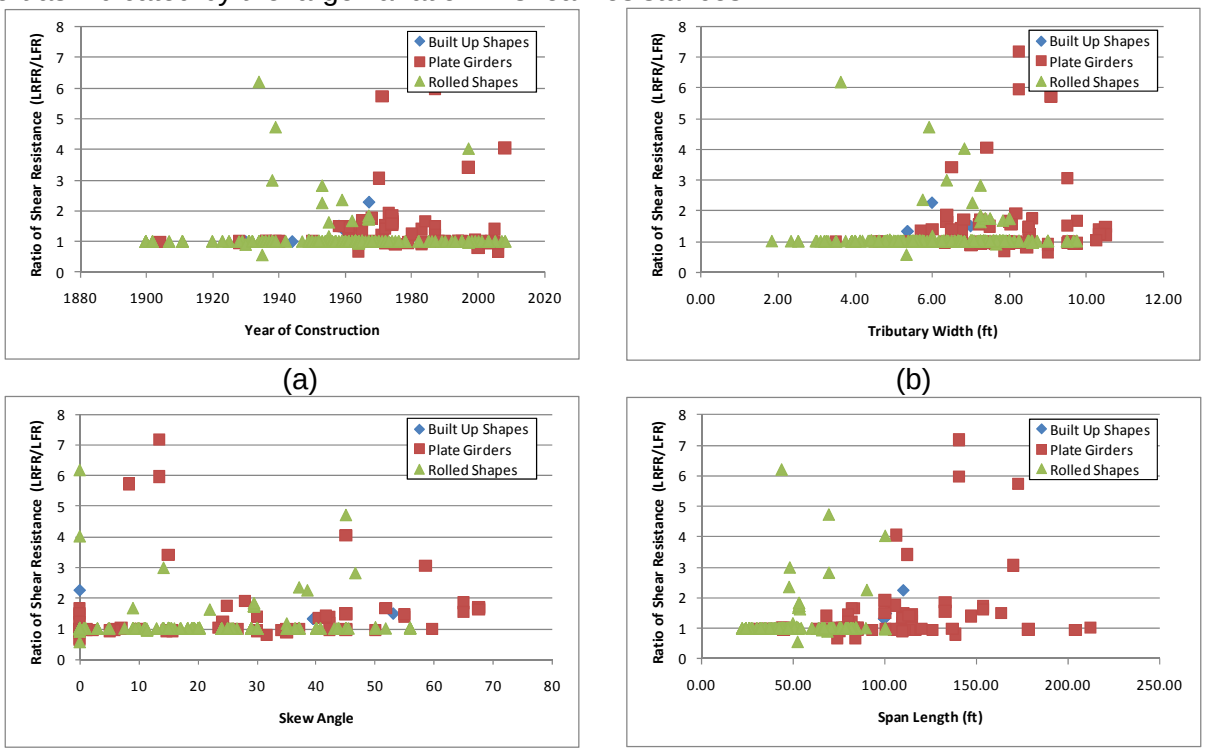


(c) (d)

Figure B-171: Critical Shear Location for OR-06 Vehicle

B.1.8.2.2 Resistances

Figure B-172 shows the ratio of factored shear resistances. The ratio is generally close to 1.0, with most of the scatter being eliminated by removing those girders where the critical shear location varies significantly (Section B.1.8.3.2). Plate girders are more likely to have a critical location away from the support as indicated by the large variation in shear resistances.



(a) (b)

(c) (d)

Figure B-172: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.8.2.3 Rating Factors

Figure B-173 and Figure B-174 present the ratings as calculated by BRASS for LFR and LRFR, respectively. The LFR Ratings tend to decrease with increasing tributary width and increasing span length (Figure B-173b and d). There is also less scatter with increasing span length (Figure B-173d). Figure B-174b also shows that there is less scatter with larger tributary widths. There are zero girders with an LFR rating of less than 1.0 and nine girders with an LRFR rating less than 1.0. Additionally, 80% of the girders have LFR Ratings greater than the LRFR rating.

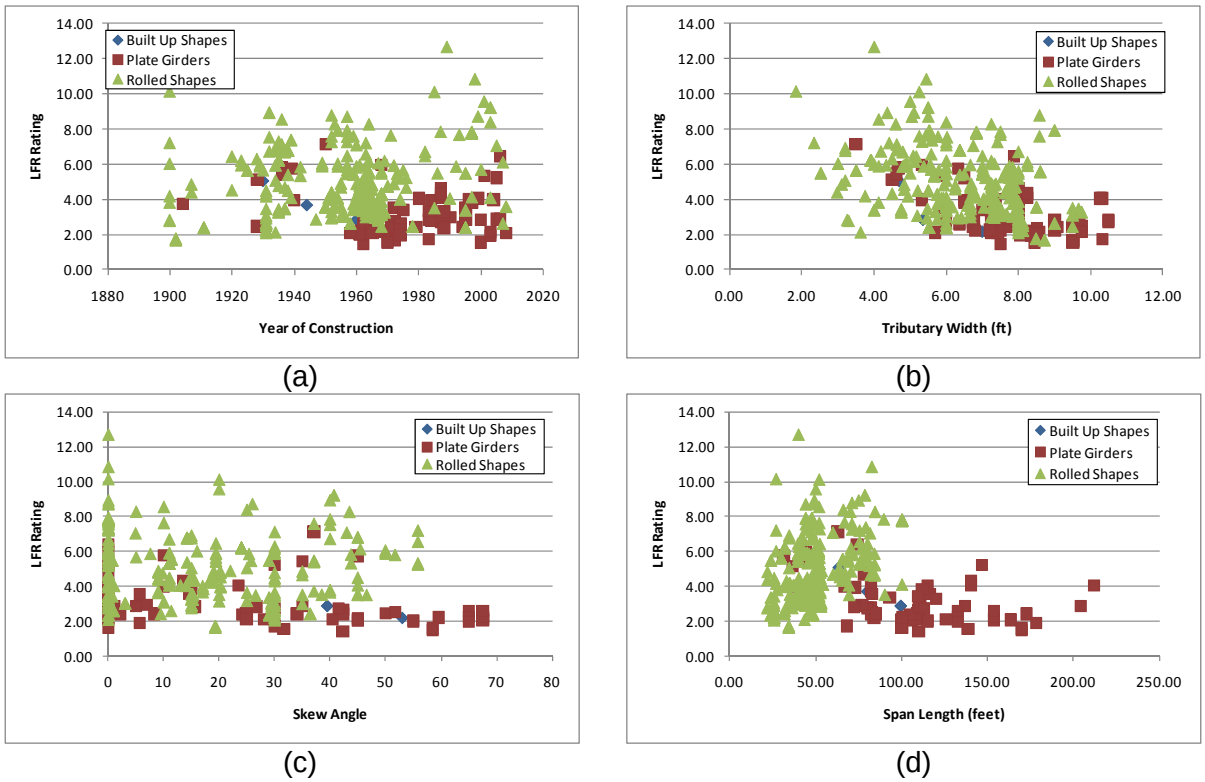


Figure B-173: LFR Shear Rating Factor for OR-06 Vehicle

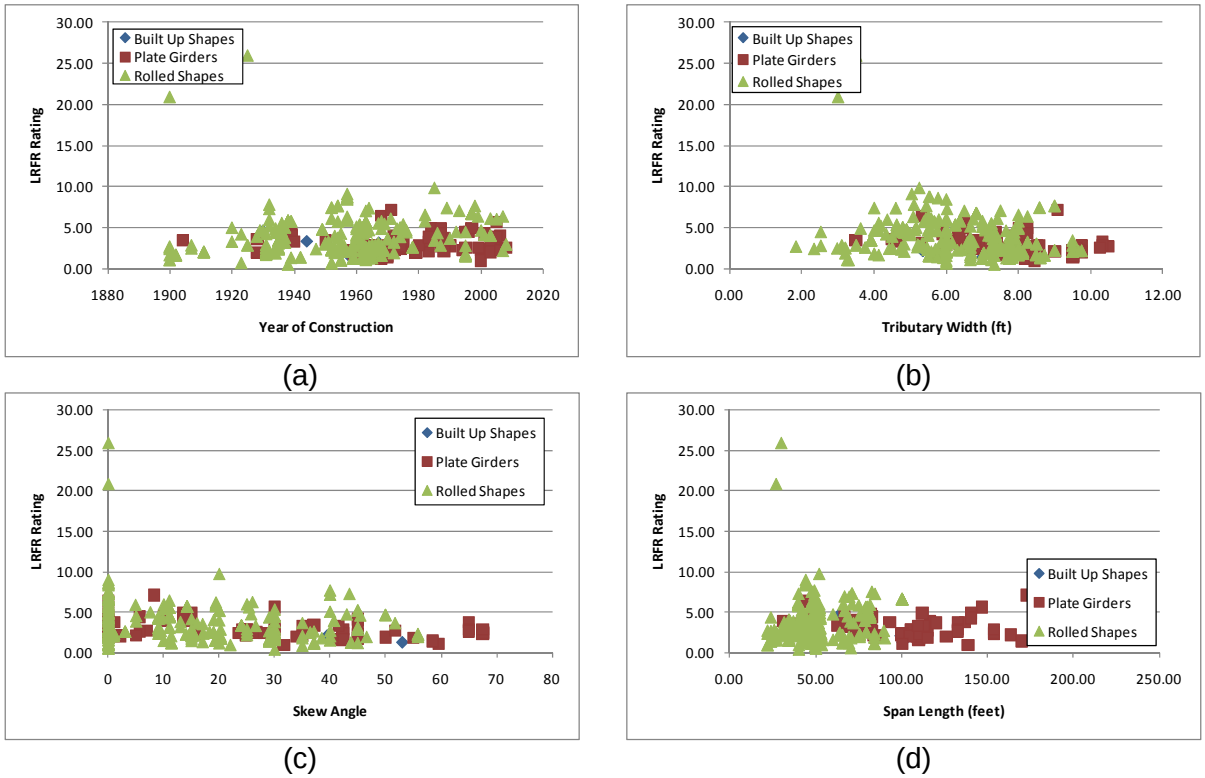
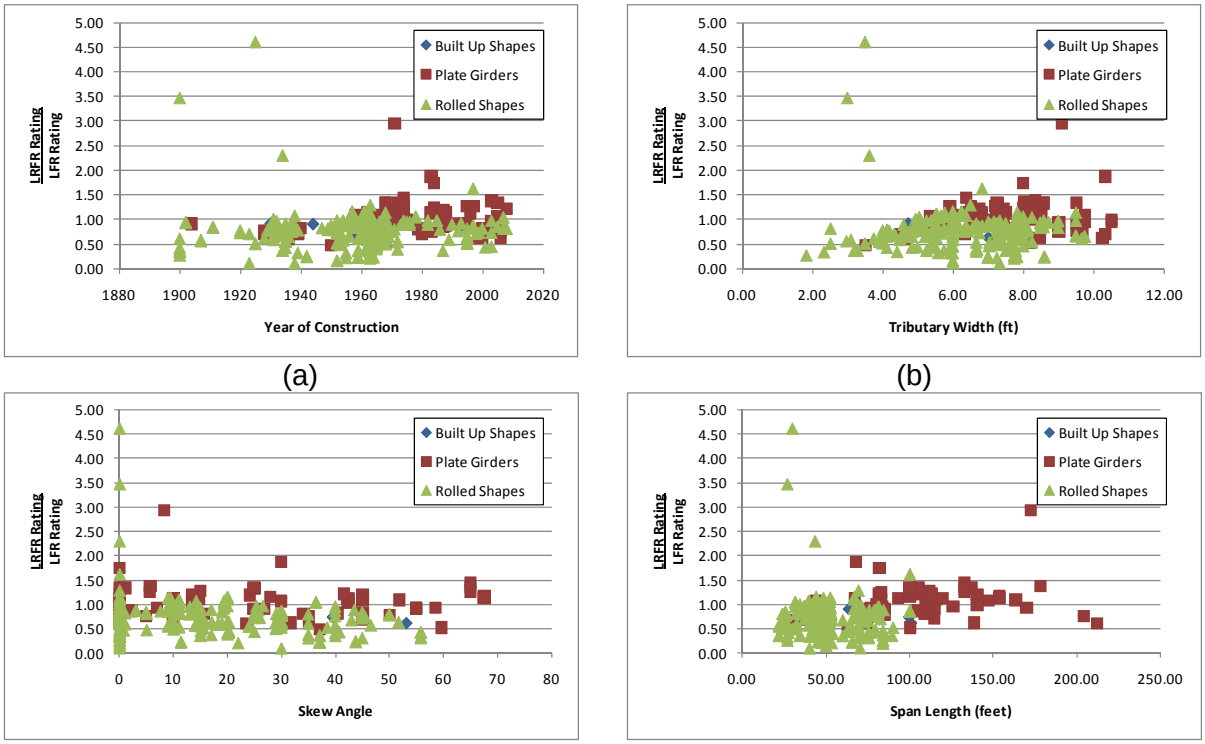


Figure B-174: LRFR Shear Rating Factor for OR-06 Vehicle

B.1.8.2.4 Rating Factor Comparisons

Figure B-175 shows the ratio of LRFR rating factor to LFR rating factor. The ratio tends to increase with increasing tributary width and increasing span length. The LRFR rating is generally less than the LFR rating for rolled shapes, while for plate girders it is more likely that the LRFR rating will be greater than the LFR rating.



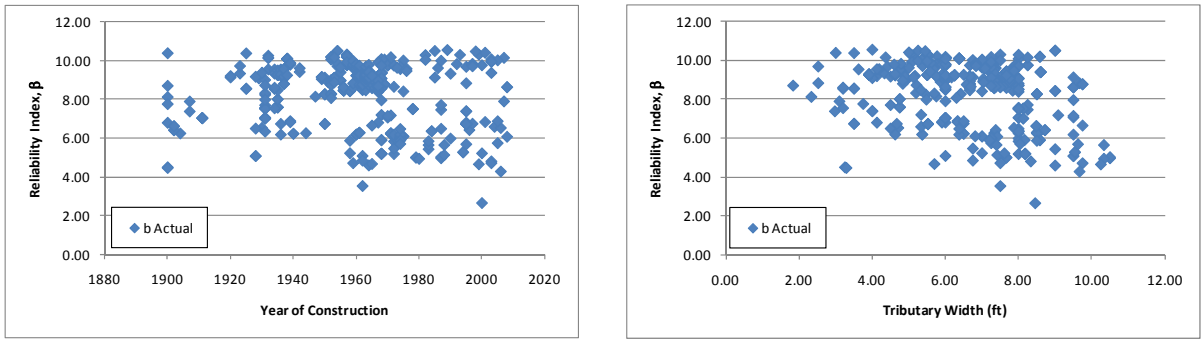
(a) (b)

(c) (d)

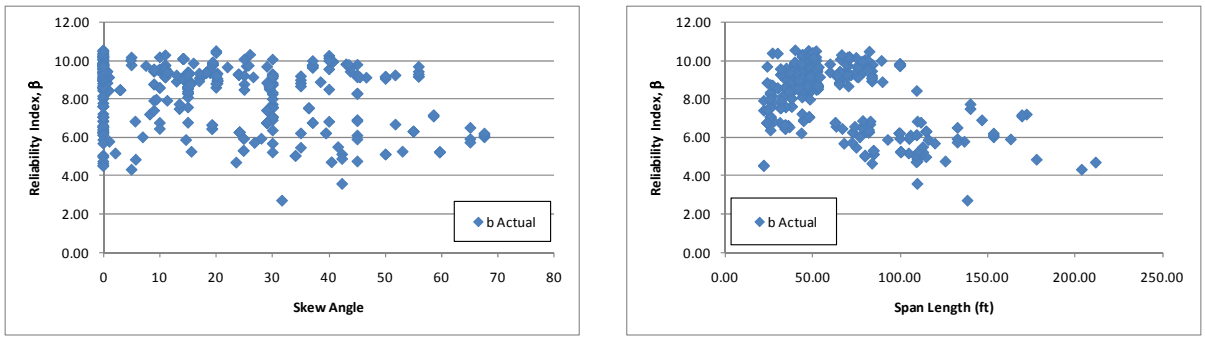
Figure B-175: Ratio of LRFR Shear Rating to LFR Shear Rating for OR-06 Vehicle

B.1.8.2.5 Reliability Indices

Figure B-176 shows the reliability index as calculated based upon the strength of the section. There is one girder where the actual reliability index is less than the required level of 3.5 and one that is close to this value. The characteristics of these girders vary and provide no clear insight into why they have a low reliability index.



(a) (b)



(c) (d)

Figure B-176: Shear Reliability Indices for OR-06 Vehicle

Figure B-177 shows the reliability index plotted agains the LRFR rating factor. This figure shows that for a rating factor of 1.0, the expected reliability is between 2.5 and 4.5 depending on the type of girder. Rolled shapes have higher reliability than plate girders for the same rating factor. This is expected because rolled shapes are more consistent because they are manufactured within certain tolerances.

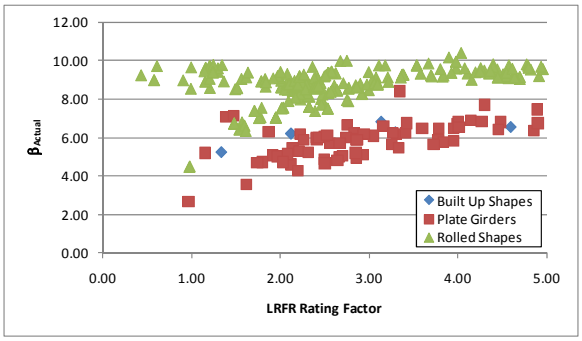


Figure B-177: Shear Reliability Index vs. LRFR Shear Rating for OR-06 Vehicle

B.1.8.3 Shear-Corrected

This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.8.3.1 Live Load

Figure B-178 and Figure B-179 show the ratio of unfactored and factored live load plus impact shear (LRFR divided by LFR) for those girders with critical locations at the either the support or one-tenth of the span away from the support. The LRFR unfactored shear is 70 to 125% of the LFR unfactored shear with the ratio of factored loads increasing to above 80%. This shows that the live loads are very similar when they are taken at the same location.

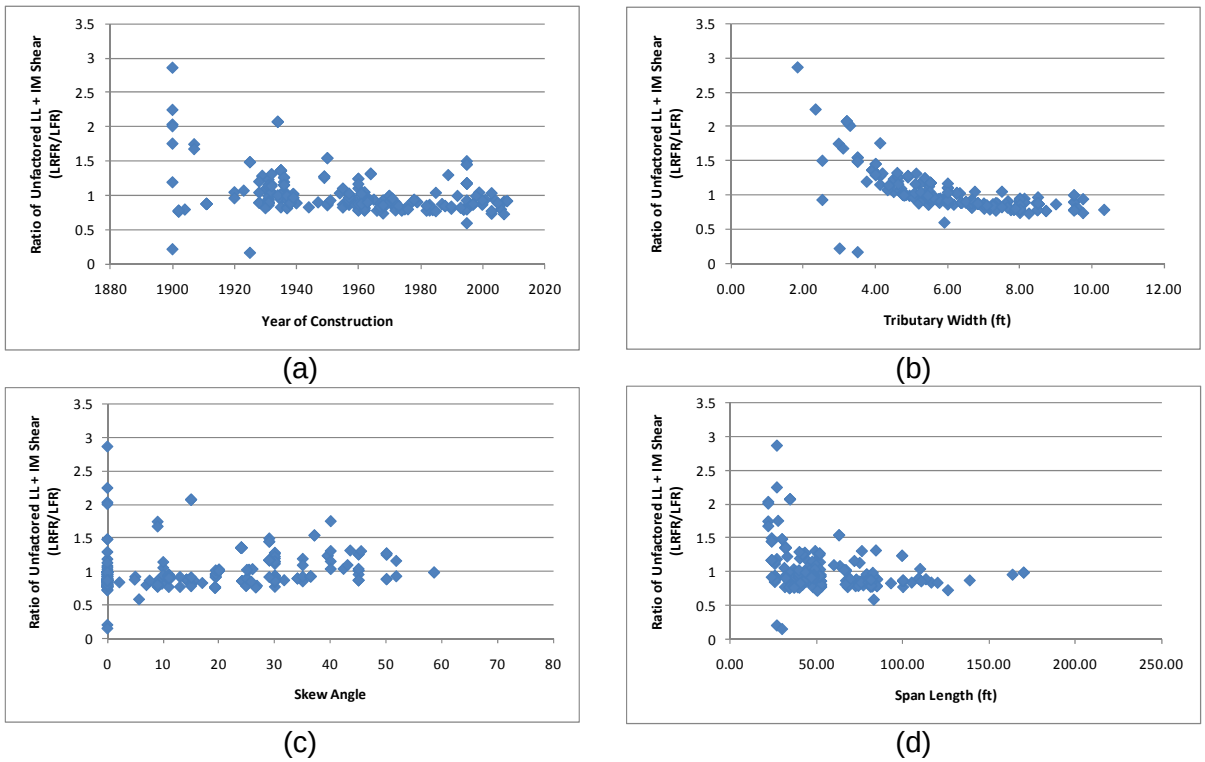


Figure B-178: Ratio of Unfactored Live Load plus Impact Shear for OR-06 Vehicle (LRFR/LFR)

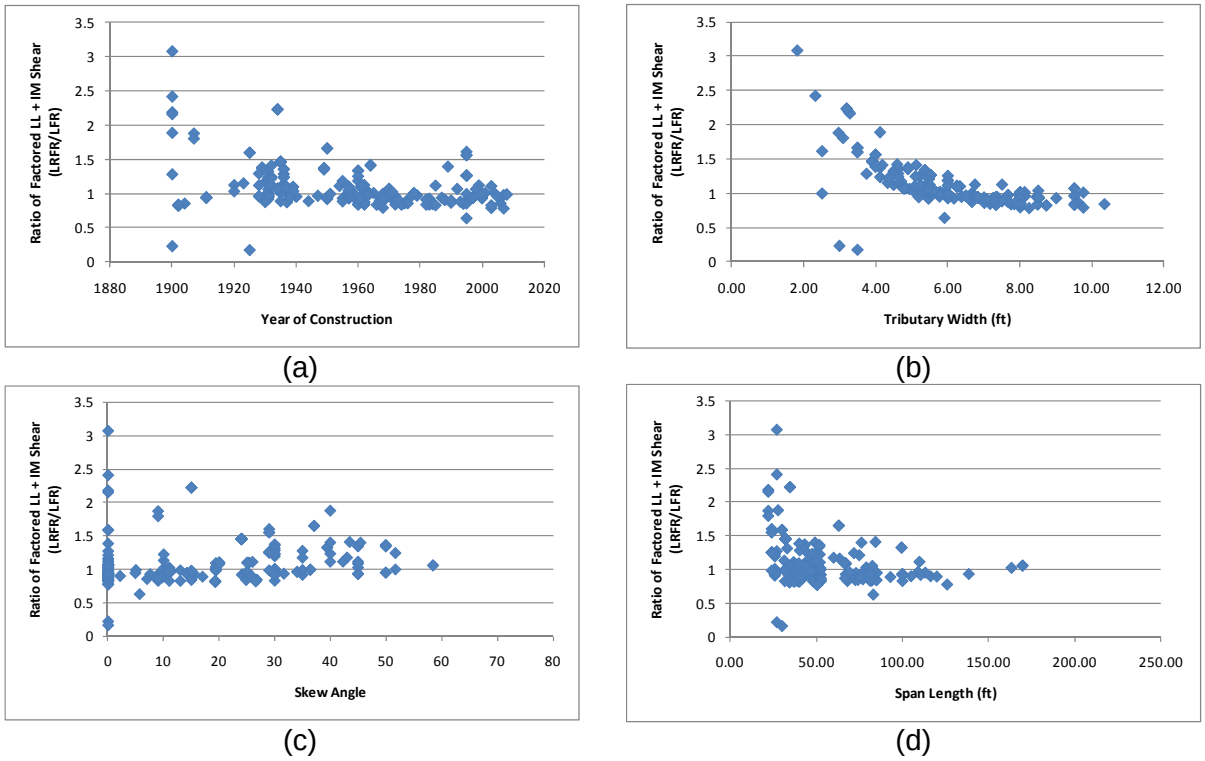


Figure B-179: Ratio of Factored Live Load plus Impact Shear for OR-06 Vehicle (LRFR/LFR)

B.1.8.3.2 Resistance

The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was less than 1.0 have been eliminated by considering only those close to the support and where the stiffener spacing was likely to be the same. The ratio of LRFR shear resistance to LFR shear resistance is shown in Figure B-180.

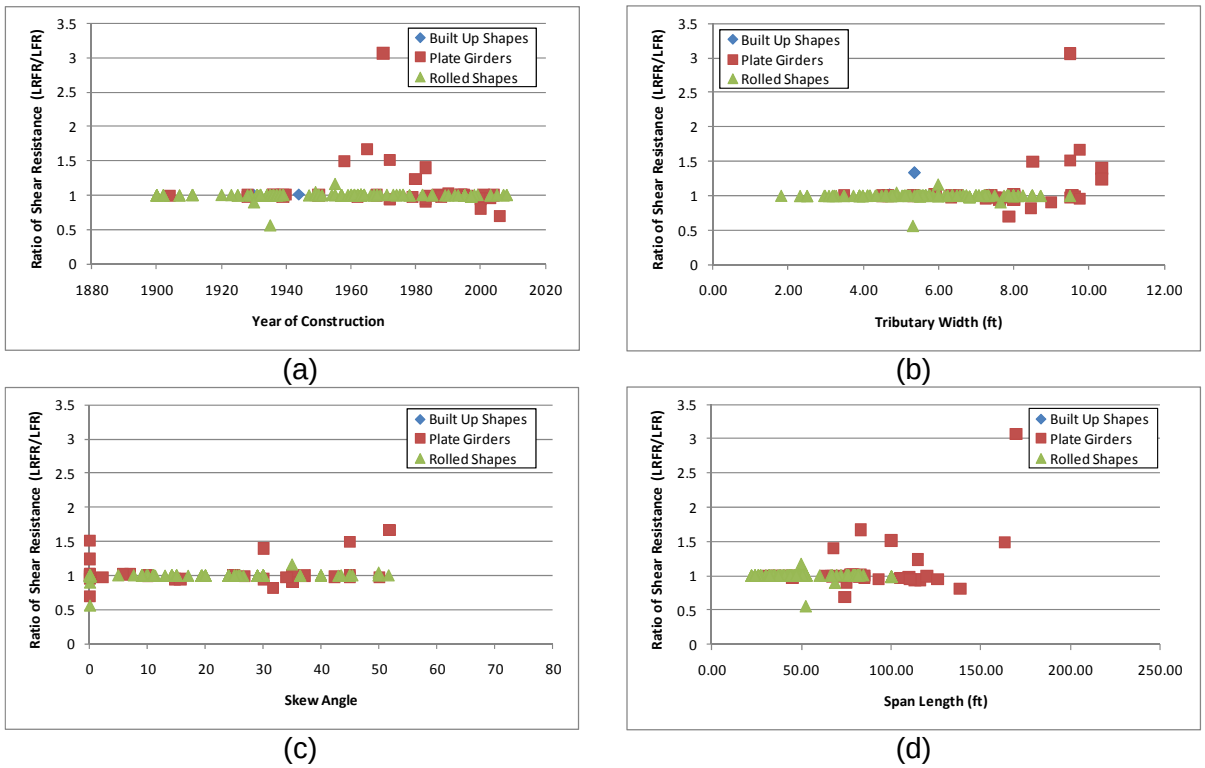
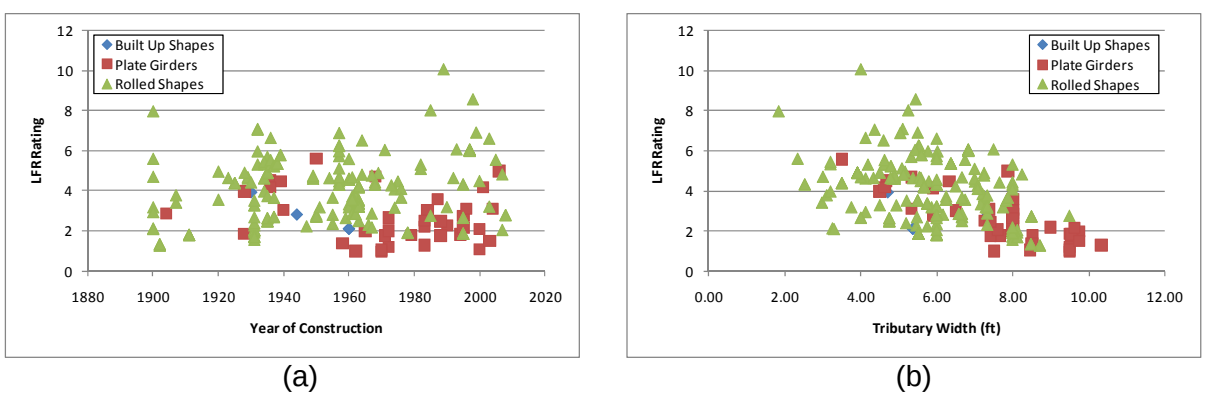
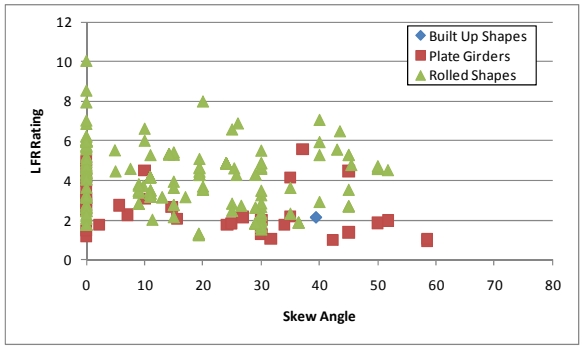


Figure B-180: Ratio of Factored Shear Resistance (LRFR/LFR)

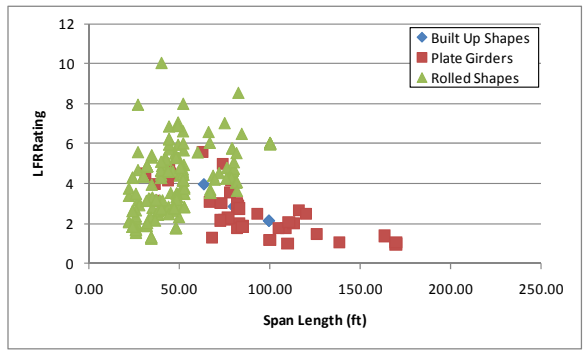
B.1.8.3.3 Rating Factors

After verifying that the live load shears and shear resistances were reasonable, the next step was to examine the rating factors. Figure B-181 and Figure B-182 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where it is likely that the stiffener spacing would vary along the span length.



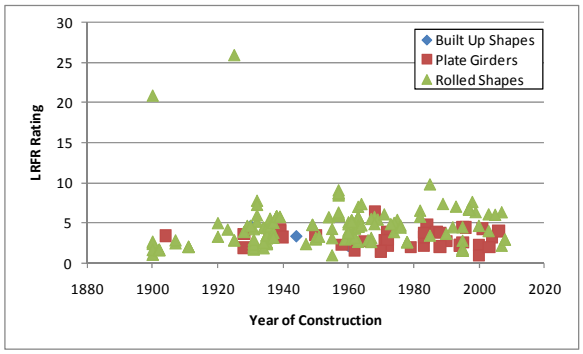


(c)

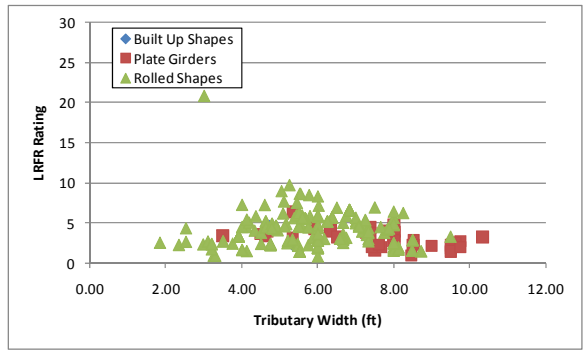


(d)

Figure B-181: LFR Shear Rating Factors for OR-06 Vehicle

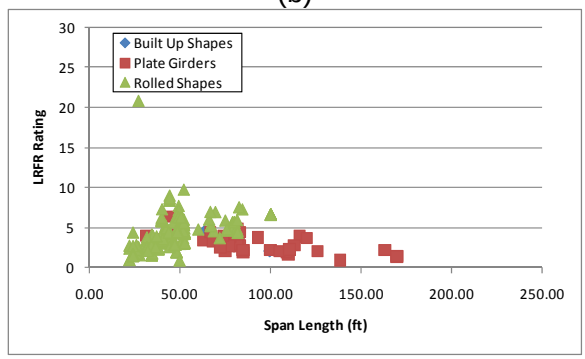


(a)



(b)

(c)

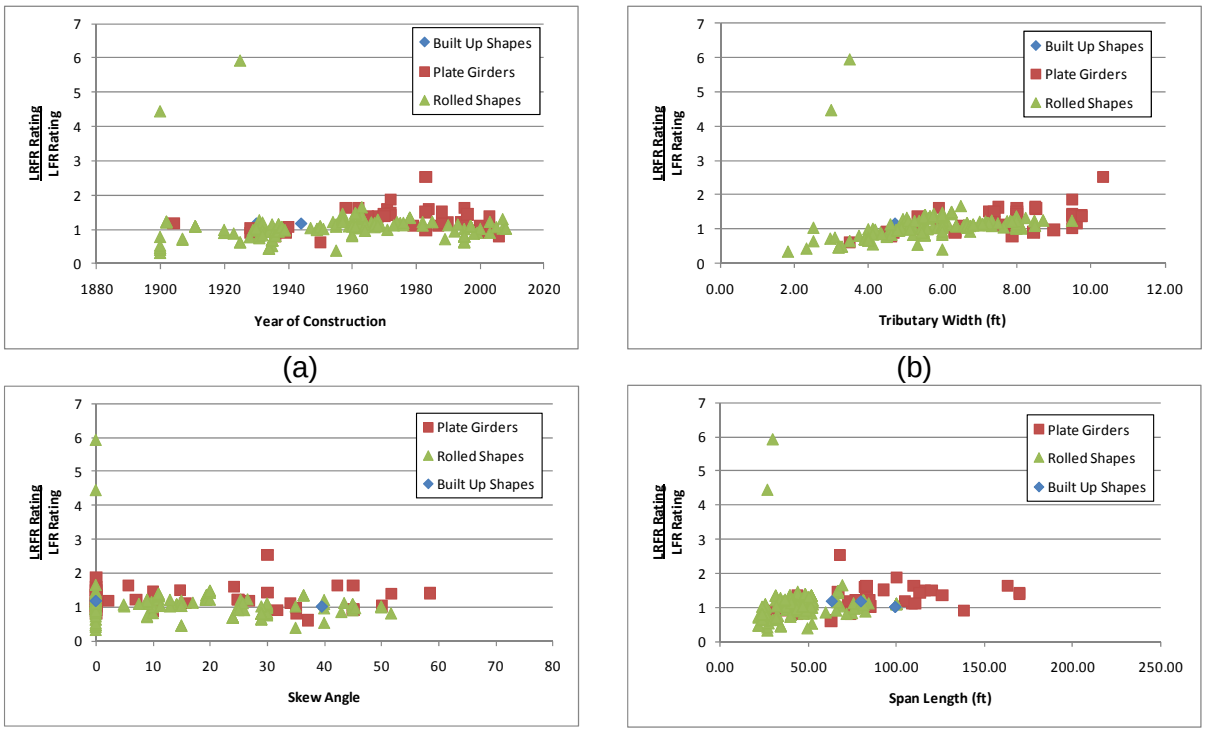


(d)

Figure B-182: LRFR Shear Rating Factor for OR-06 Vehicle

B.1.8.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio of the LRFR rating factor to the LFR rating factor. Figure B-183 shows the results of this comparison. The results show that the ratio is typically above 1.0 for plate girders and generally between 0.5 and 1.5 for rolled shapes. Built-up shapes are typically very close to 1.0.



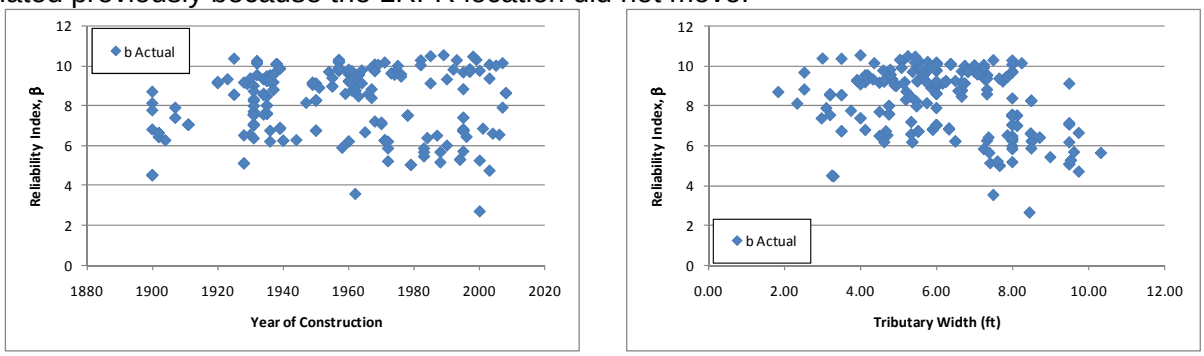
(a) (b)

(c) (d)

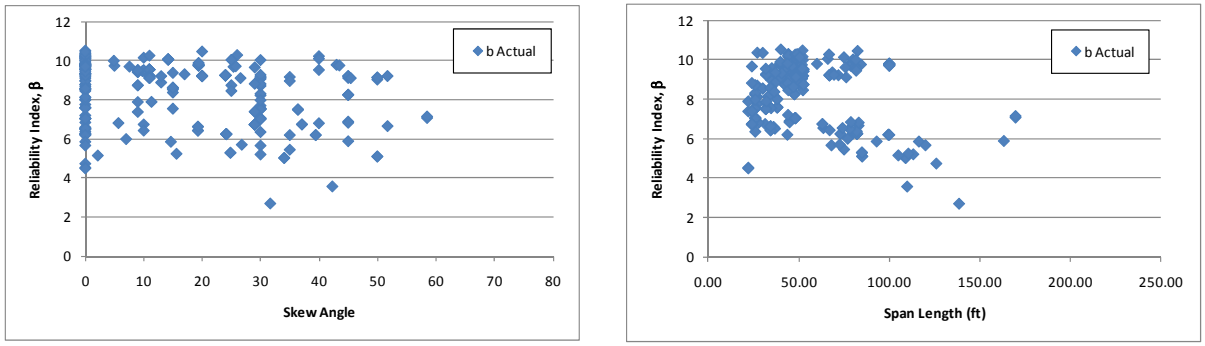
Figure B-183: Ratio of LRFR Shear Rating to LFR Shear Rating

B.1.8.3.5 Reliability Indices

The reliability indices shown in Figure B-184 are the same as those shown in Figure B-176. The reliability index is above the value assumed in the development of the MBE for all except two girders. The required value is 3.5 for special permit vehicles. The reliability index remains the same as calculated previously because the LRFR location did not move.



(a) (b)



(c) (d)

Figure B-184: Shear Reliability Indices for OR-06 Vehicle

B.1.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-185. The applicable load factors for this vehicle are 1.30 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

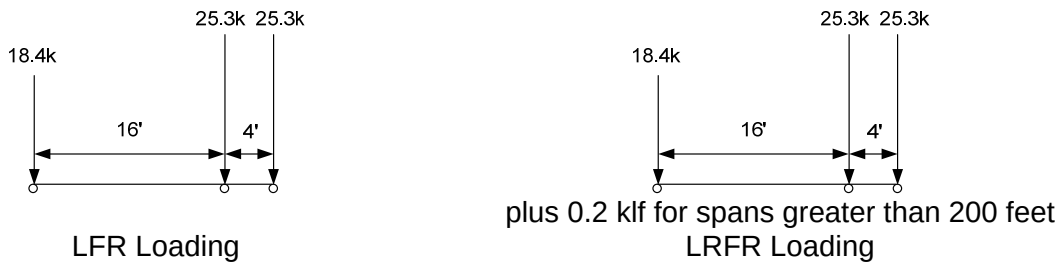
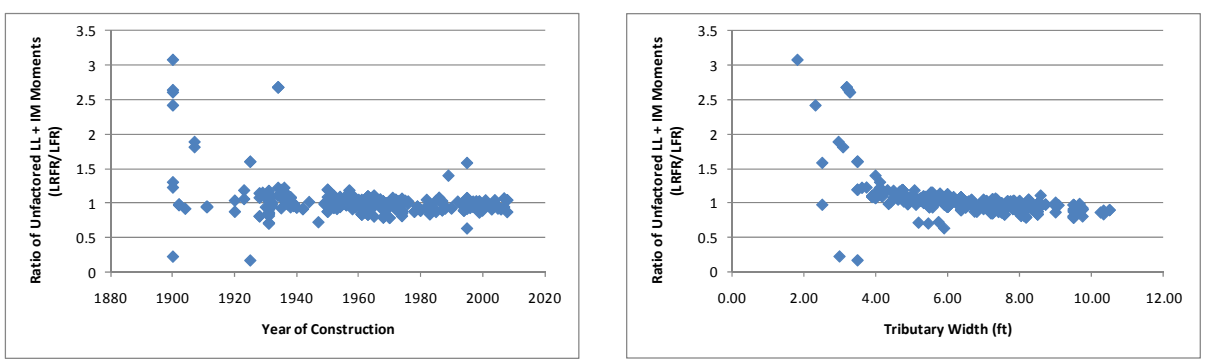


Figure B-185: Vehicle Loadings and Load Factors

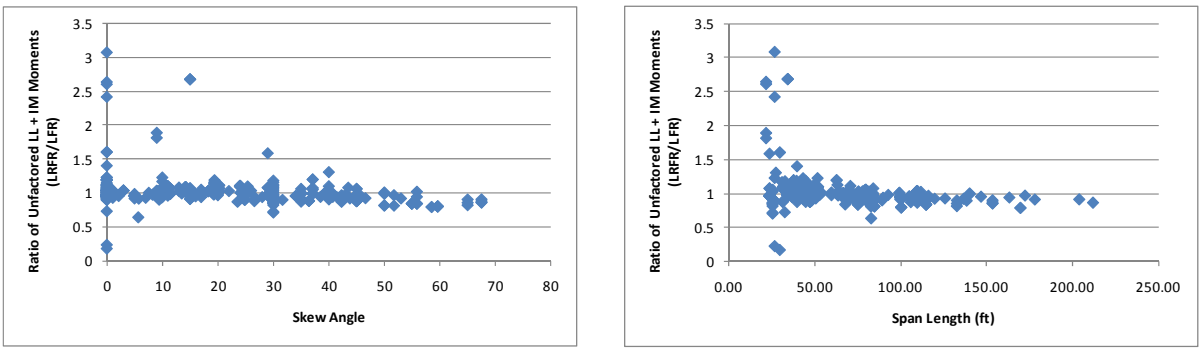
B.1.9.1 Moment

B.1.9.1.1 Live Loads

Figure B-186 and Figure B-187 shows the ratios of unfactored and factored live load plus impact moments (LRFR divided by LFR) for the TX-04 vehicle. The LRFR moments due to live load plus impact are between 75 and 125% of the LFR moments for the unfactored case and increase to 100 to 150% of the LFR moments when factored.. The ratio tends to decrease with increasing tributary width (Figure B-186b and Figure B-187b), while there is less scatter for increasing span lengths (Figure B-186d and Figure B-187d).

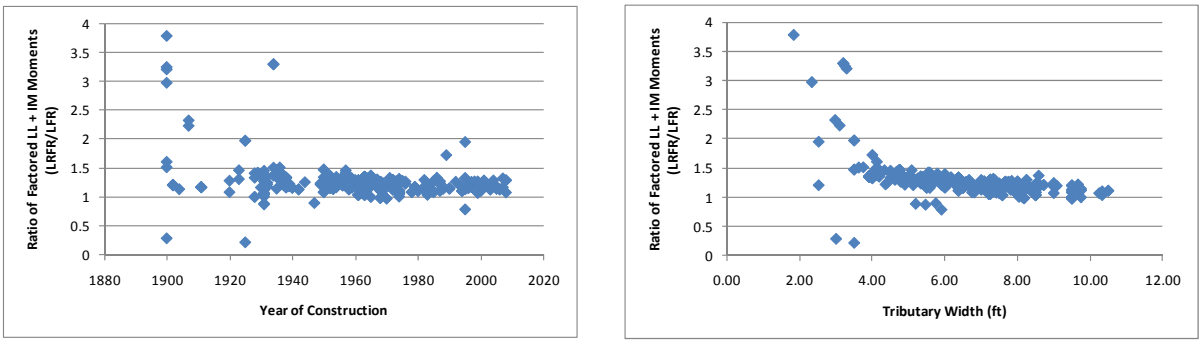


(a) (b)

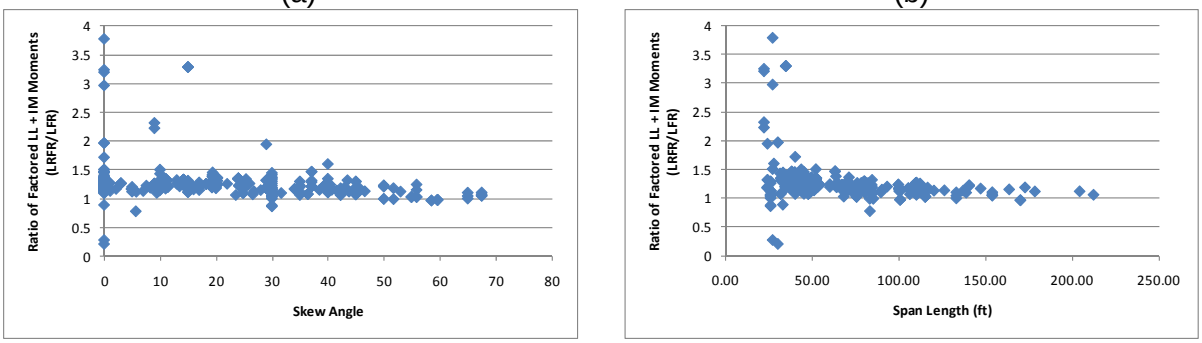


(c) (d)

Figure B-186: Ratio of Unfactored Live Load plus Impact Moment for TX-04 Vehicle (LRFR/LFR)



(a) (b)



(c) (d)

Figure B-187: Ratio of Factored Live Load plus Impact Moment for TX-04 Vehicle (LRFR/LFR)

B.1.9.1.2 Resistances

Figure B-188 shows the ratio of the factored moment resistances, LRFR divided by LFR. The ratio of resistance is generally above 1.0 for rolled shapes and less than 1.0 for plate girders. Built-up shapes do not typically have resistance that is higher or lower for a specific method.

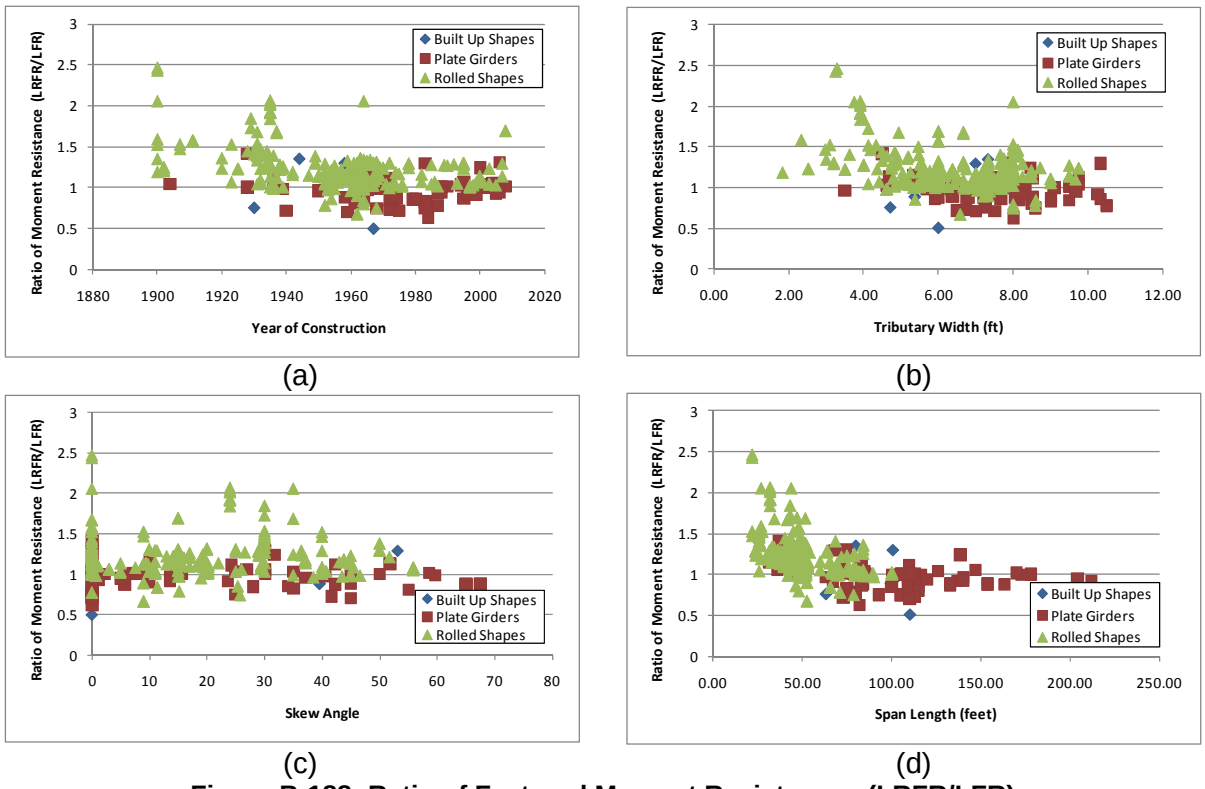
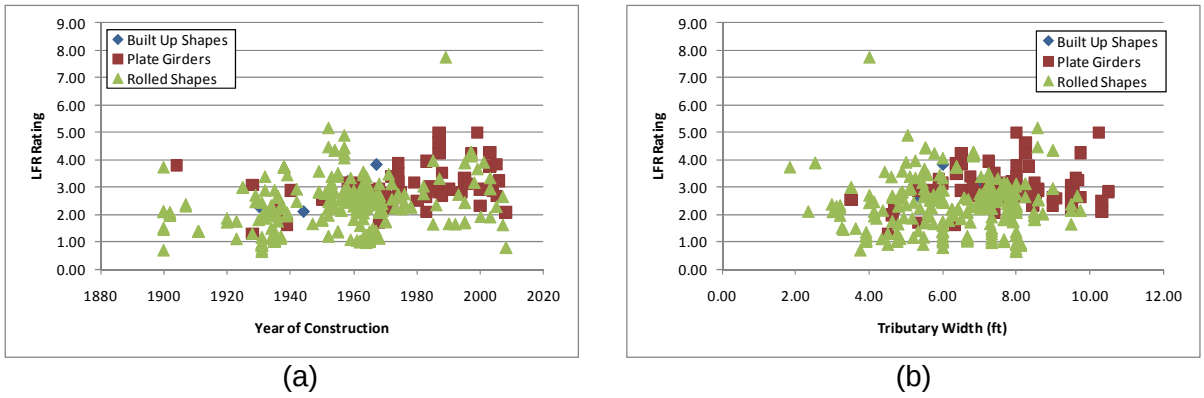
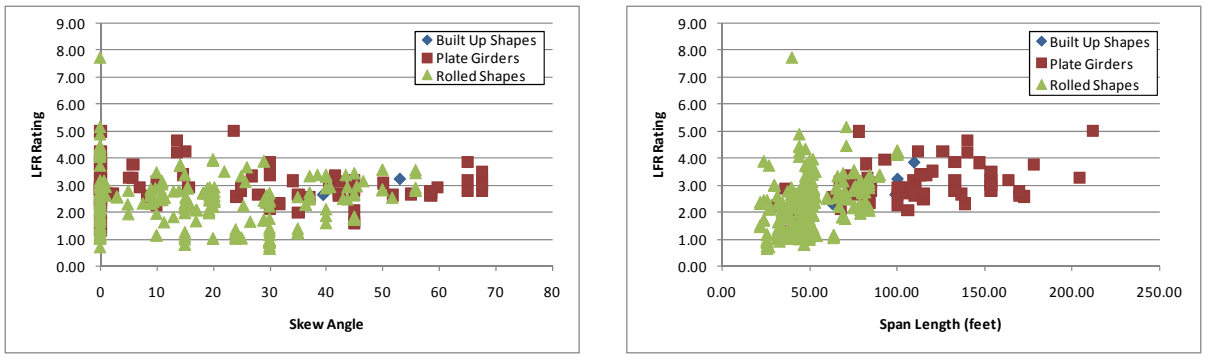


Figure B-188: Ratio of Factored Moment Resistances (LRFR/LFR)

B.1.9.1.3 Rating Factors

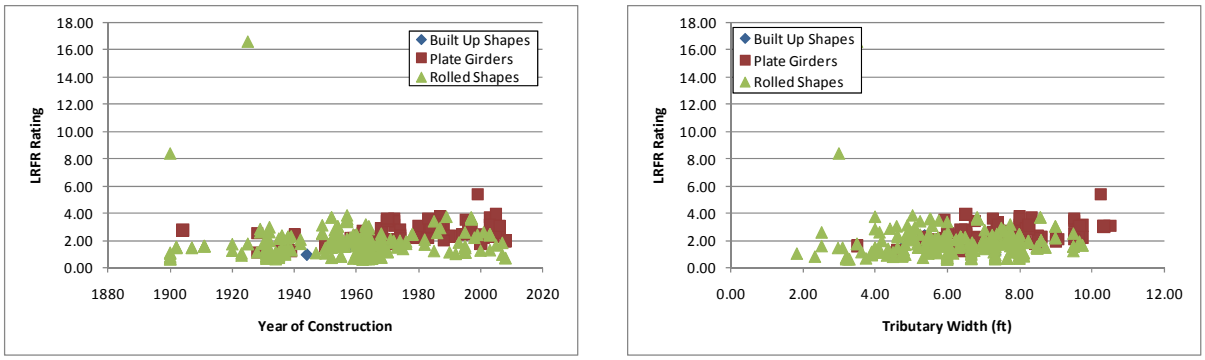
Figure B-189 and Figure B-190 present the LFR and LRFR ratings from BRASS, respectively. There are 18 girders with an LFR rating less than 1.0, 52 girders with an LRFR rating less than 1.0, and 13 girders where both ratings are less than 1.0. Ignoring the outliers, the two methods provide similar scatter with the LRFR rating shifted down from the LFR rating.



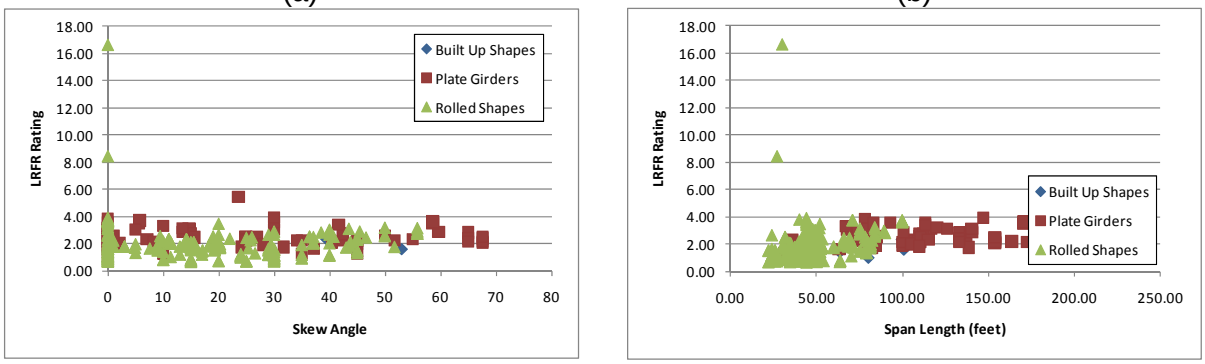


(c) (d)

Figure B-189: LFR Flexure Ratings for TX-04 Vehicle



(a) (b)



(c) (d)

Figure B-190: LRFR Flexure Ratings for TX-04 Vehicle

B.1.9.1.4 Rating Factor Comparisons

Figure B-191 shows the ratio of LRFR rating to LFR rating. This ratio is generally less than 1.0 for all girder types but above 0.5 for most girders. The scatter decreases with increasing span length (Figure B-191d). Figure B-191b shows that for narrow girder spacing the LFR rating is significantly higher than the LRFR rating, while for large girder spacing the ratings are similar. 88% of girders have LFR ratings greater than their associated LRFR rating.

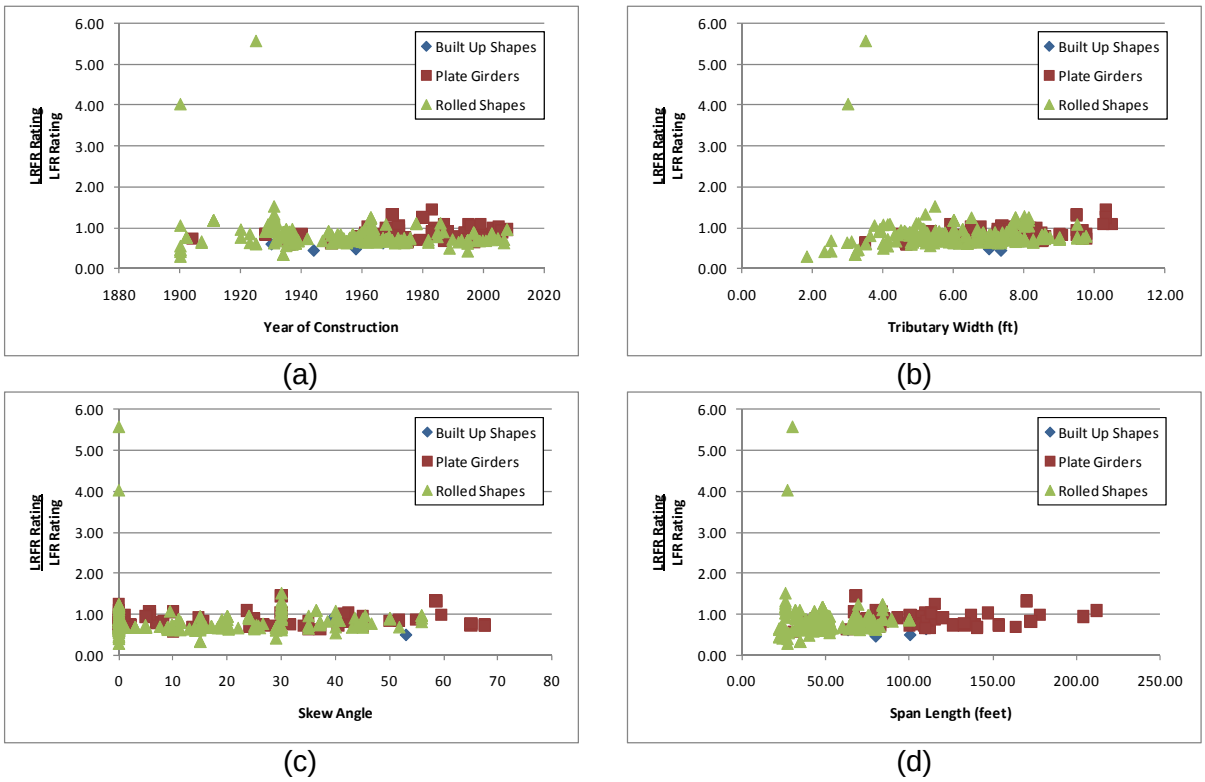
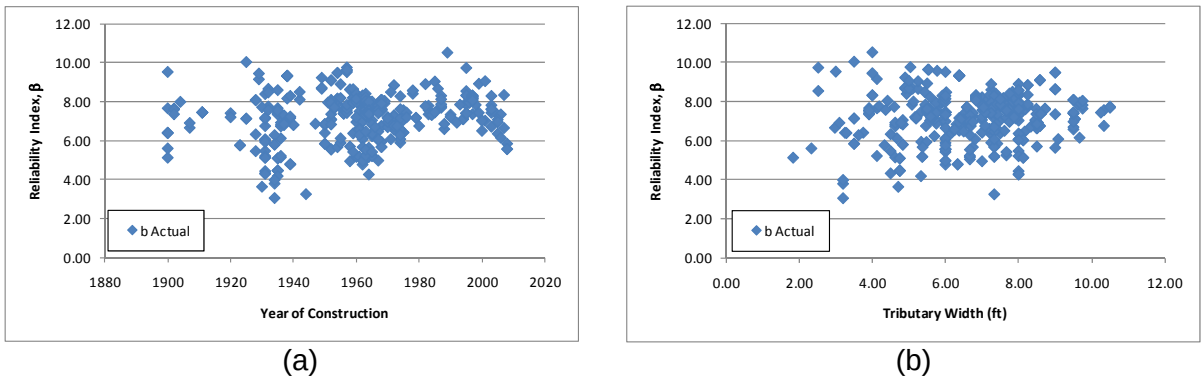
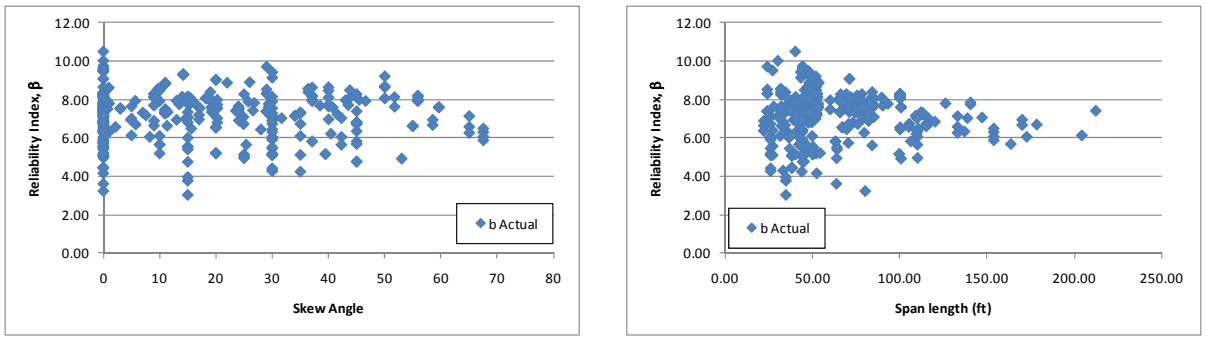


Figure B-191: Ratio of LRFR Flexure Rating to LFR Flexure Rating for TX-04 Vehicle

B.1.9.1.5 Reliability Indices

Figure B-192 presents the actual reliability index as calculated. There is one girder where the actual reliability index is approaching the required reliability index of 2.5. This girder is in a relatively old bridge (~65 years or more), with narrow girder spacing (under four feet), and have span lengths under 50 feet.





(c) (d)

Figure B-192: Flexure Reliability Indices for TX-04 Vehicle

Figure B-193 shows the actual reliability index plotted against the LRFR rating factor. A girder with a passing rating typically has a reliability index greater than three and in most cases above 4.5. The required level of reliability for the TX-04 vehicle, treated as a routine permit vehicle, is 2.5. Therefore, a reduced live load factor could be used and maintain the level of reliability obtained.

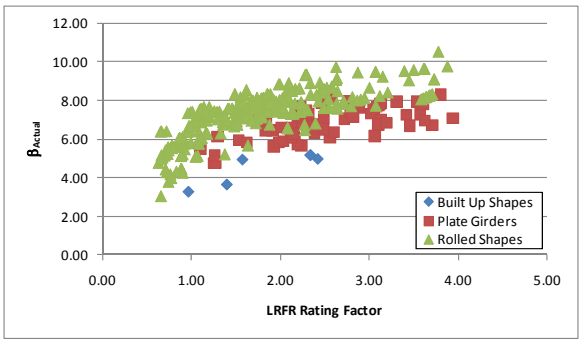


Figure B-193: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

B.1.9.2 Shear

B.1.9.2.1 Live Loads

Figure B-194 and Figure B-195 show the ratios of unfactored and factored live load plus impact shear (LRFR divided by LFR), respectively. The ratio of unfactored loads is generally greater than 1.0 and is generally greater than 1.5 when the loads are factored, and decrease with increasing tributary width (Figure B-194b and Figure B-195b). This is likely a result of the distribution factors as the LRFD equations limit the girder spacing to greater than 3.5 feet, while the LFR distribution factors are applicable to any girder spacing. Figure B-194c and Figure B-195c show that the ratio increases with increasing skew; this is an expected result as the LRFD Specification increases the load distributed to each girder because of the skew while the LFR Specification does not consider the effect of skew. Figure B-196 shows where the critical shear rating occurred for each girder. The LFR location is typically away from the support while the LRFD location is typically at the support.

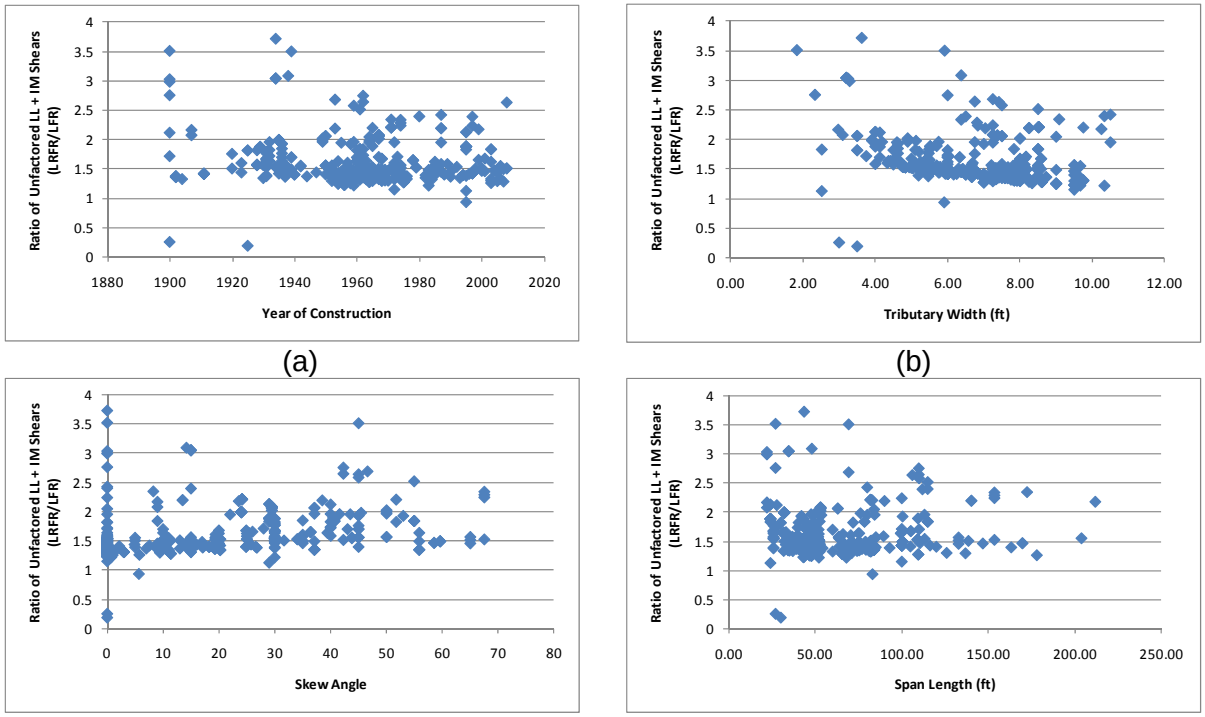


Figure B-194: Ratio of Unfactored Live Load plus Impact Shear for TX-04 Vehicle (LRFR/LFR)

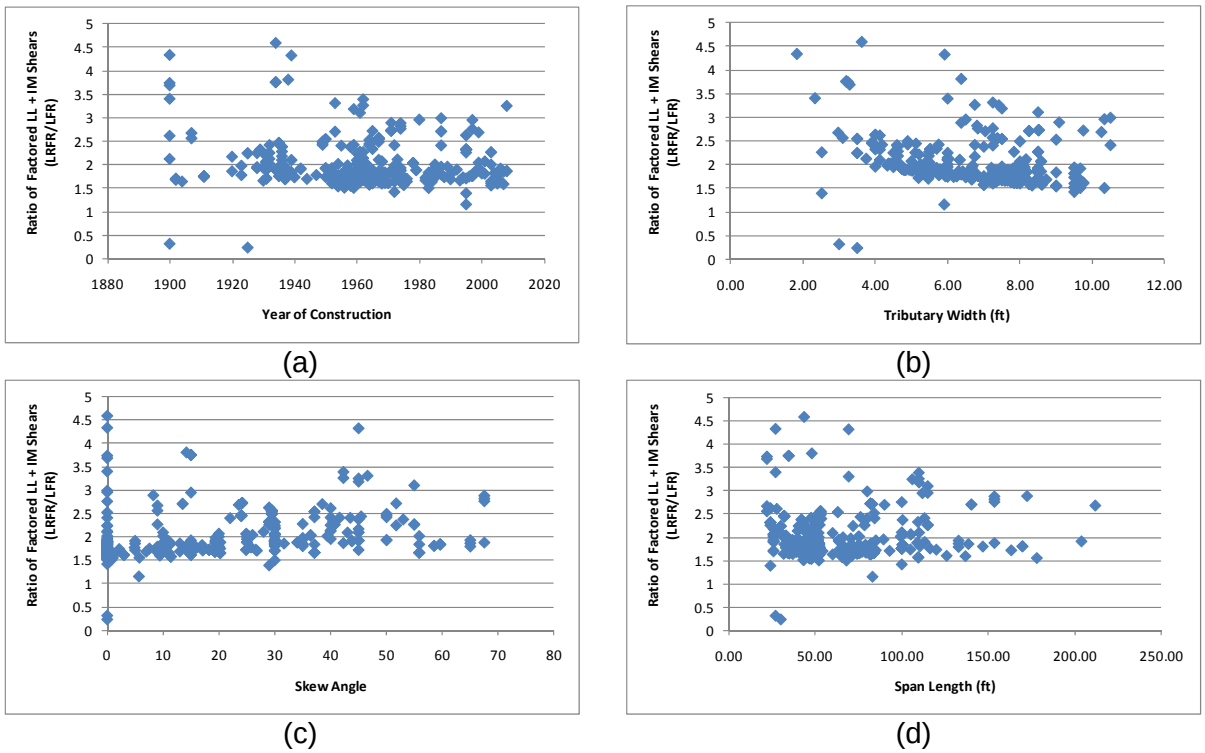


Figure B-195: Ratio of Factored Live Load plus Impact Shear for TX-04 Vehicle (LRFR/LFR)

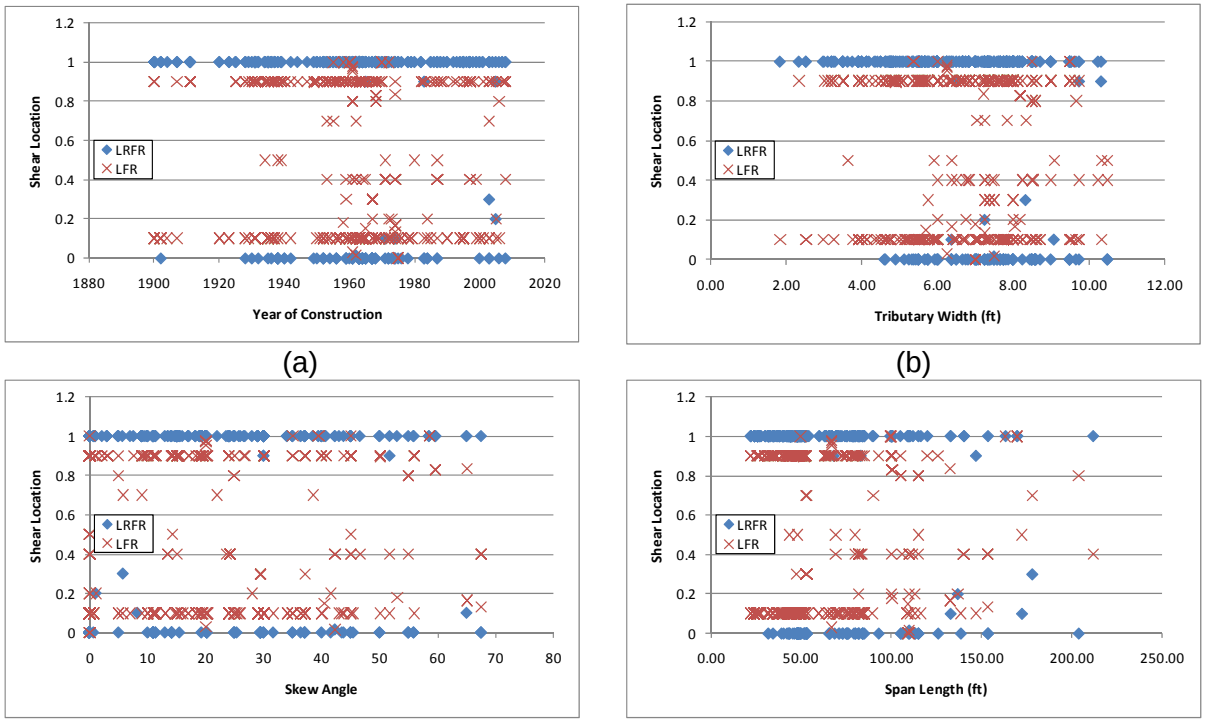
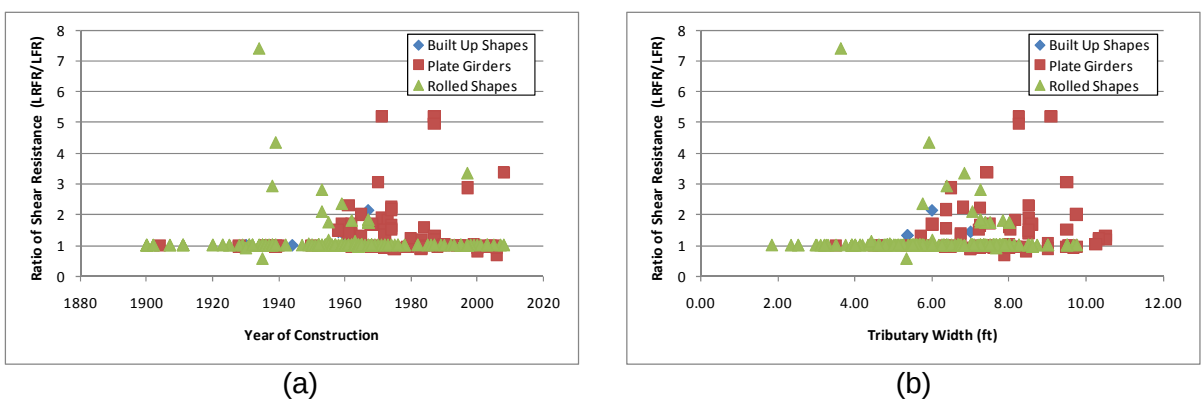
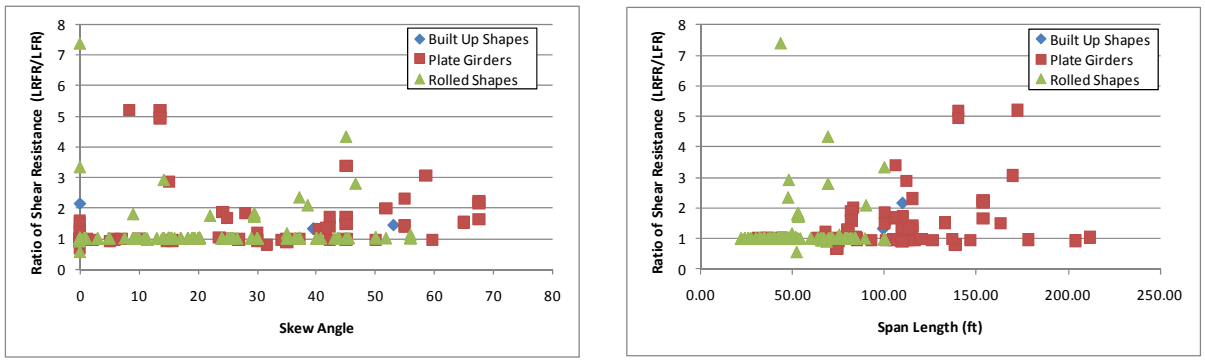


Figure B-196: Critical Shear Location for TX-04 Vehicle

B.1.9.2.2 Resistances

Figure B-197 shows the ratio of factored shear resistances. The ratio is generally close to 1.0, with most of the scatter being plate girders which will be removed when considering those girders only at the support or one- or nine-tenths point (Section B.1.9.3.2).



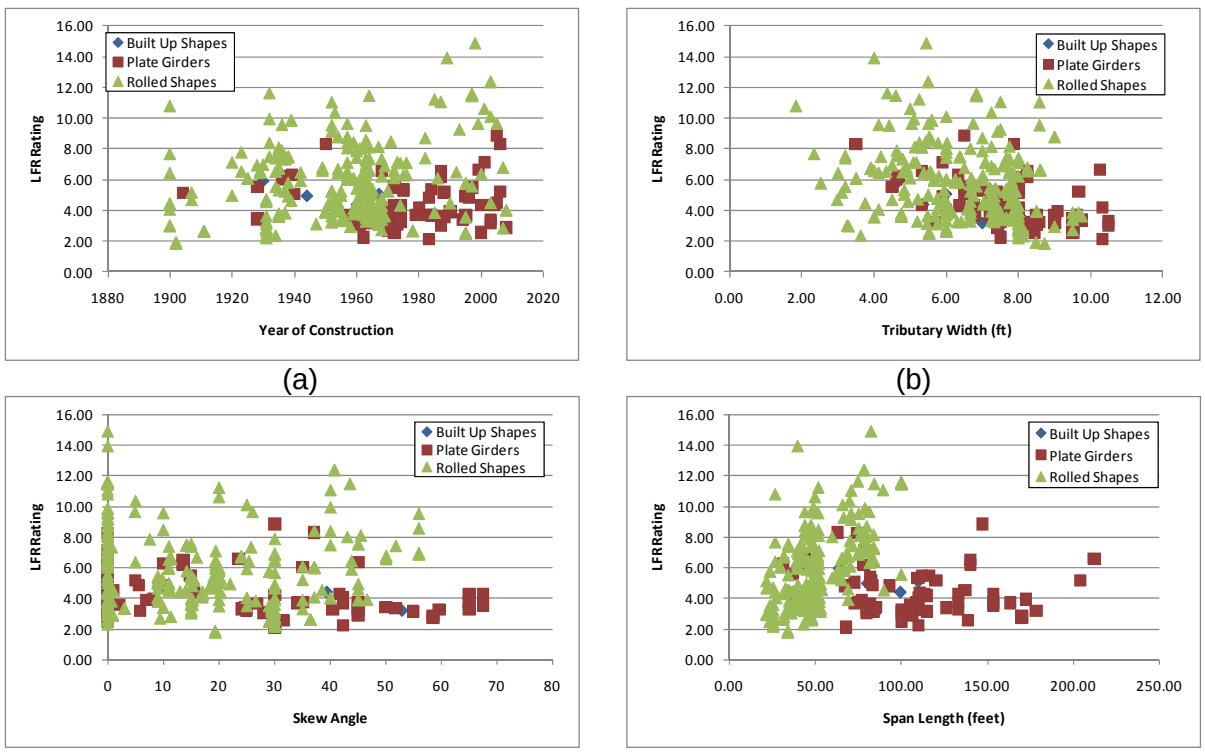


(c) (d)

Figure B-197: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.9.2.3 Rating Factors

Figure B-198 and Figure B-199 present the ratings as calculated by BRASS for LFR and LRFR, respectively. The LFR Ratings tend to decrease with increasing tributary width and increasing span length (Figure B-198b and d). There is also less scatter with increasing span length (Figure B-198d). There are zero girders with an LFR rating of less than 1.0 and 19 girders with an LRFR rating less than 1.0. Additionally, 98% of the girders have LFR Ratings greater than the LRFR rating. The LRFR ratings are shifted down significantly from the LFR ratings; this is a result of the larger live loads calculated for LRFR.



(a) (b)

(c) (d)

Figure B-198: LFR Shear Ratings for TX-04 Vehicle

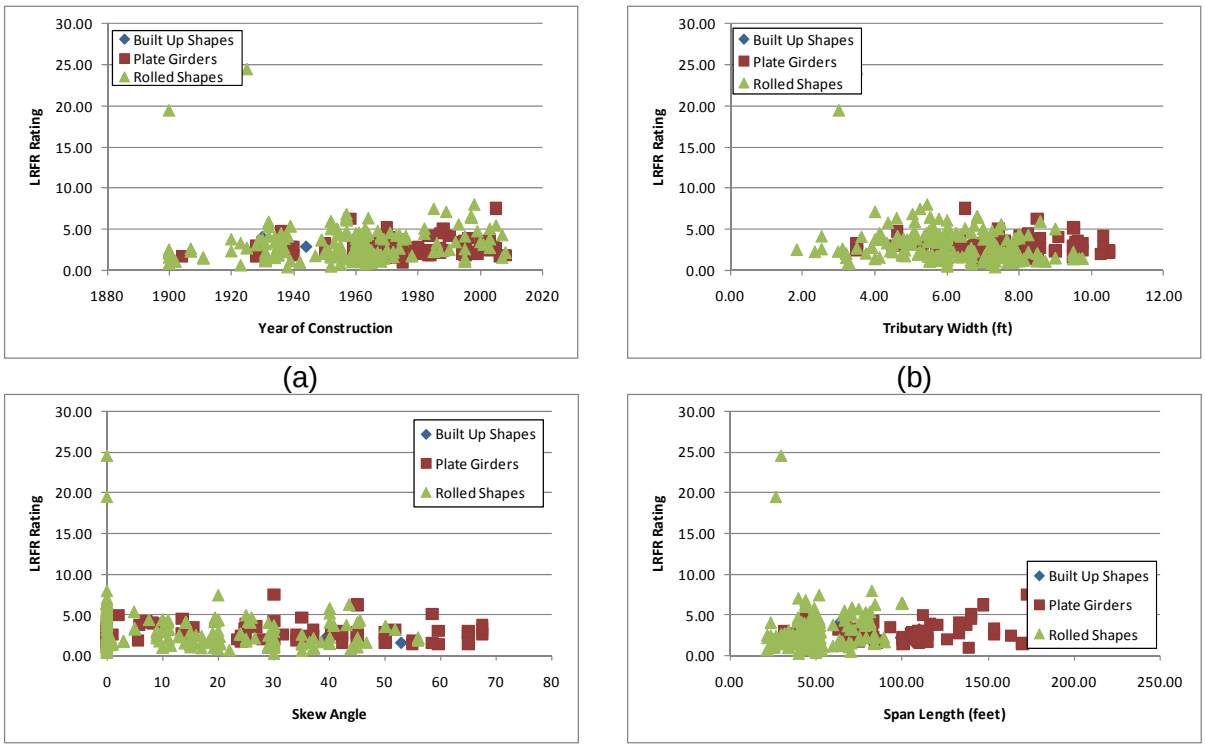
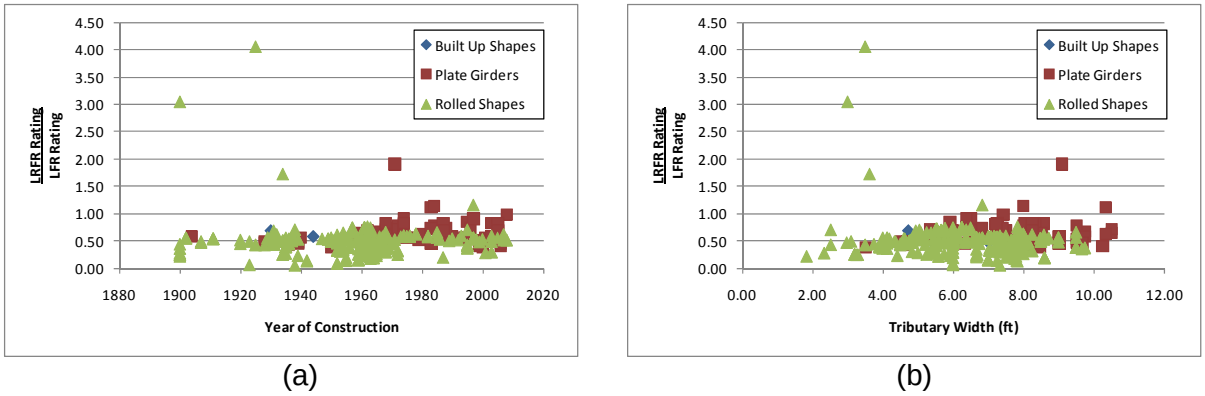
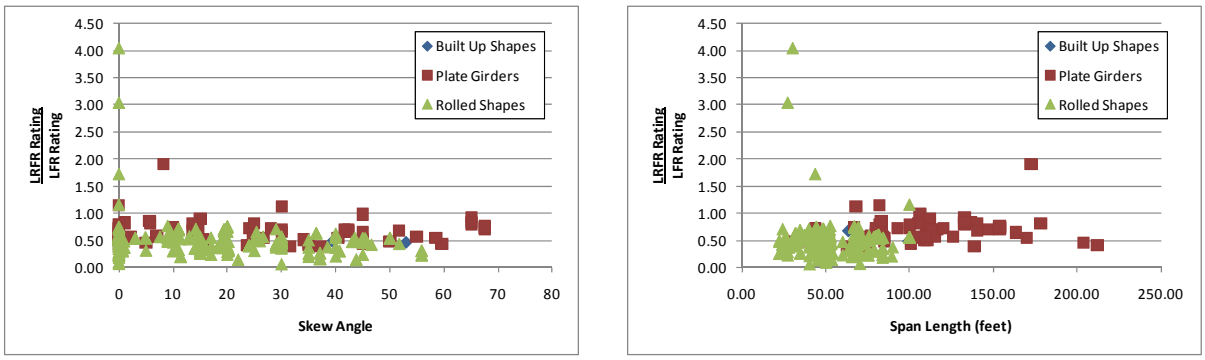


Figure B-199: LRFR Shear Ratings for TX-04 Vehicle

B.1.9.2.4 Rating Factor Comparisons

Figure B-200 shows the ratio of the LRFR rating to the LFR rating. With the exception of several girders, almost all have higher LFR ratings than LRFR ratings. Plate girders typically have a higher ratio of ratings than rolled shapes.



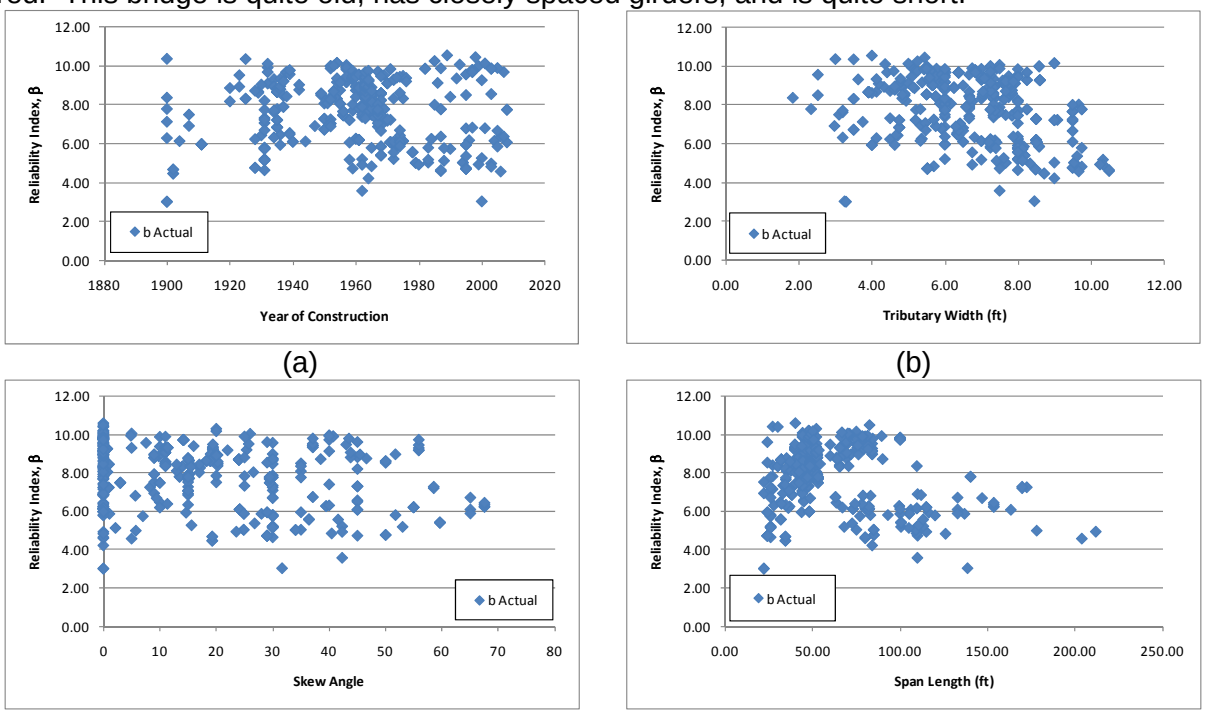


(c) (d)

Figure B-200: Ratio of LRFR Shear Rating to LFR Shear Rating for TX-04 Vehicle

B.1.9.2.5 Reliability Indices

Figure B-201 shows the reliability indices as calculated based upon the strength of the section and also based upon the applied loads. There is one girder where the actual reliability index is very similar required. This bridge is quite old, has closely spaced girders, and is quite short.



(a) (b)

(c) (d)

Figure B-201: Shear Reliability Indices for TX-04 Vehicle

Figure B-202 shows the actual reliability index for shear plotted versus the LRFR shear rating. The figure shows that a girder with a passing rating will have a reliability index of approximately three for plate girders and greater than four for rolled shapes. These reliability indices exceed the value required by the MBE of 2.5. The girders with high reliability indices but low ratings are girders controlled by the bearing stiffener rating.

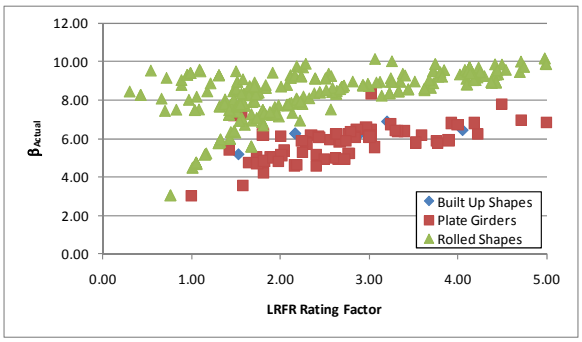


Figure B-202: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

B.1.9.3 Shear-Corrected

This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.9.3.1 Live Load

Figure B-203 and Figure B-204 show the ratio of unfactored and factored live load plus impact shear for those girders with critical locations either at the support or one-tenth of the span away from the support. The LRFR unfactored shear is 1.0 to 1.5 times the LFR unfactored shear, when factored the LRFR live load shear is at least 1.25 times the LFR live load shear. As expected, the live load shears are more similar when considering the same location.

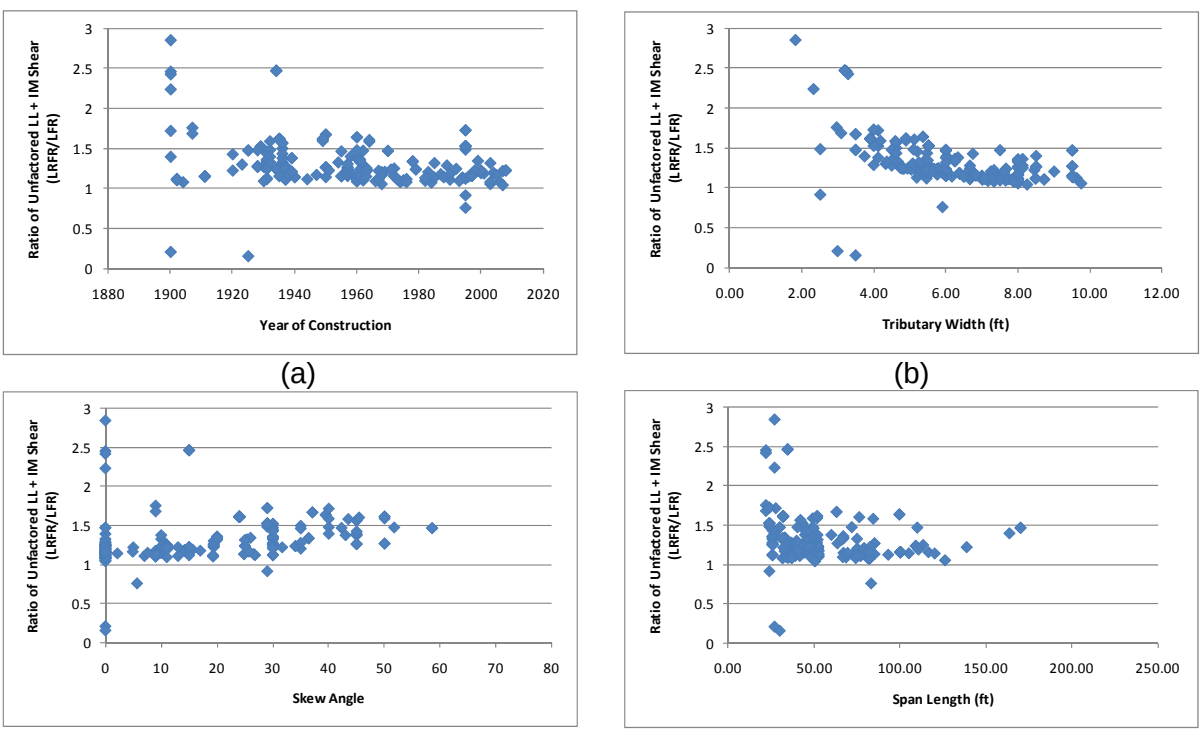


Figure B-203: Ratio of Unfactored Live Load plus Impact Shear for TX-04 Vehicle (LRFR/LFR)

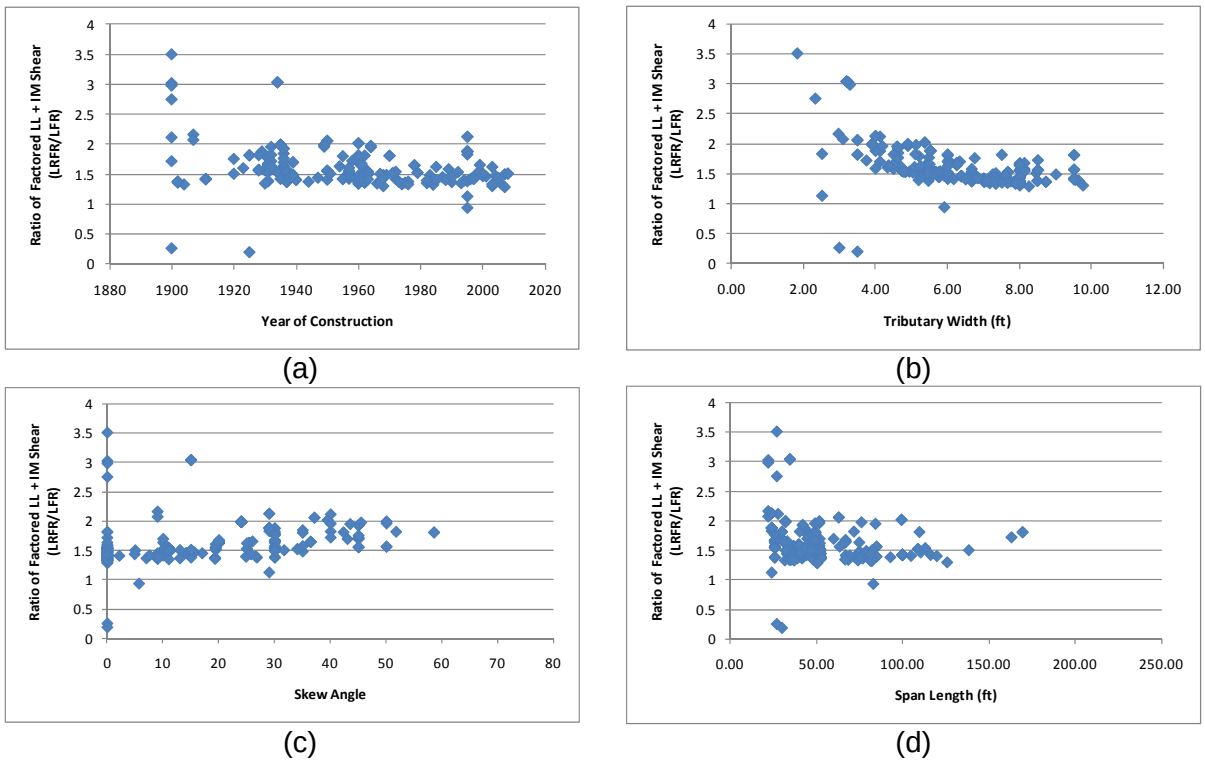
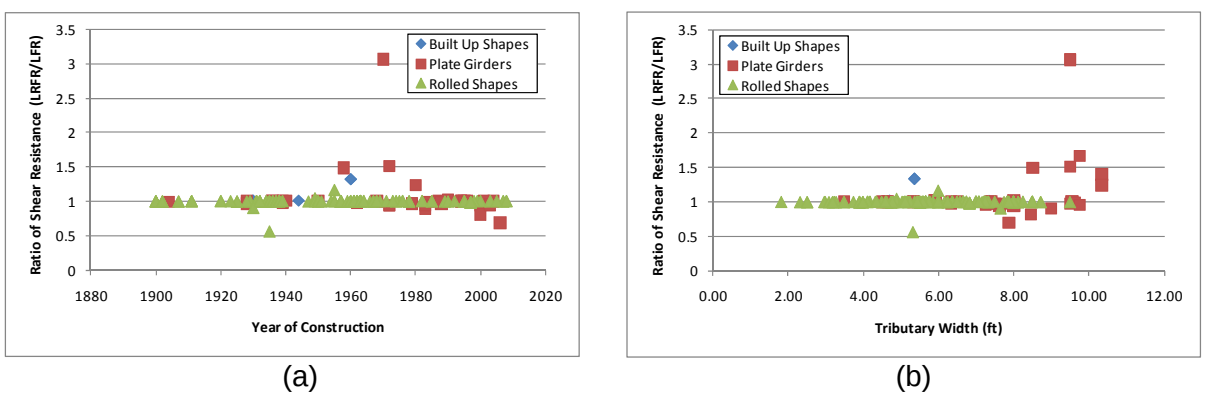
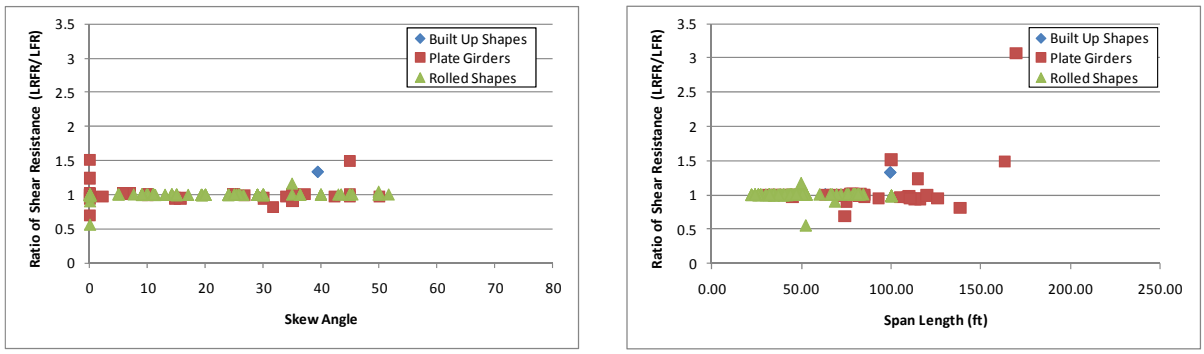


Figure B-204: Ratio of Factored Live Load plus Impact Shear for TX-04 Vehicle (LRFR/LFR)

B.1.9.3.2 Resistance

The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was greater than 1.0 have been eliminated by considering only those at or near the support and where the stiffener spacing was likely to be the same. The ratio of shear resistance is shown in Figure B-205.



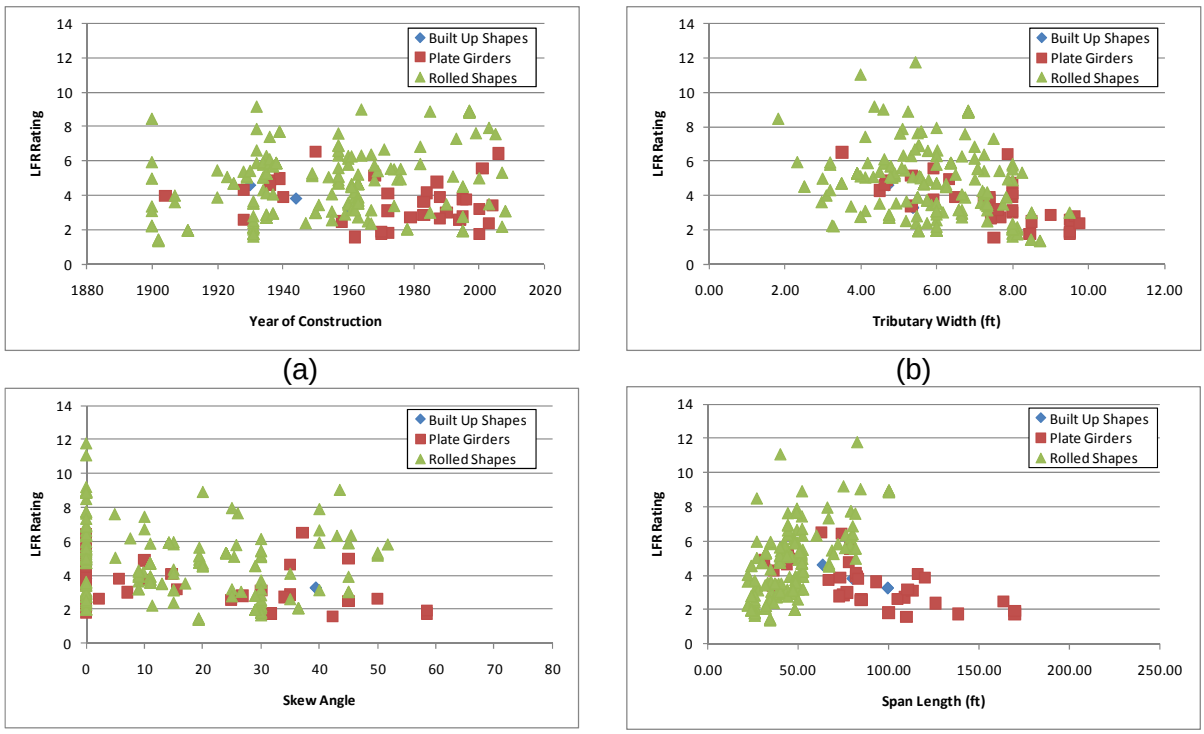


(c) (d)

Figure B-205: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.9.3.3 Rating Factors

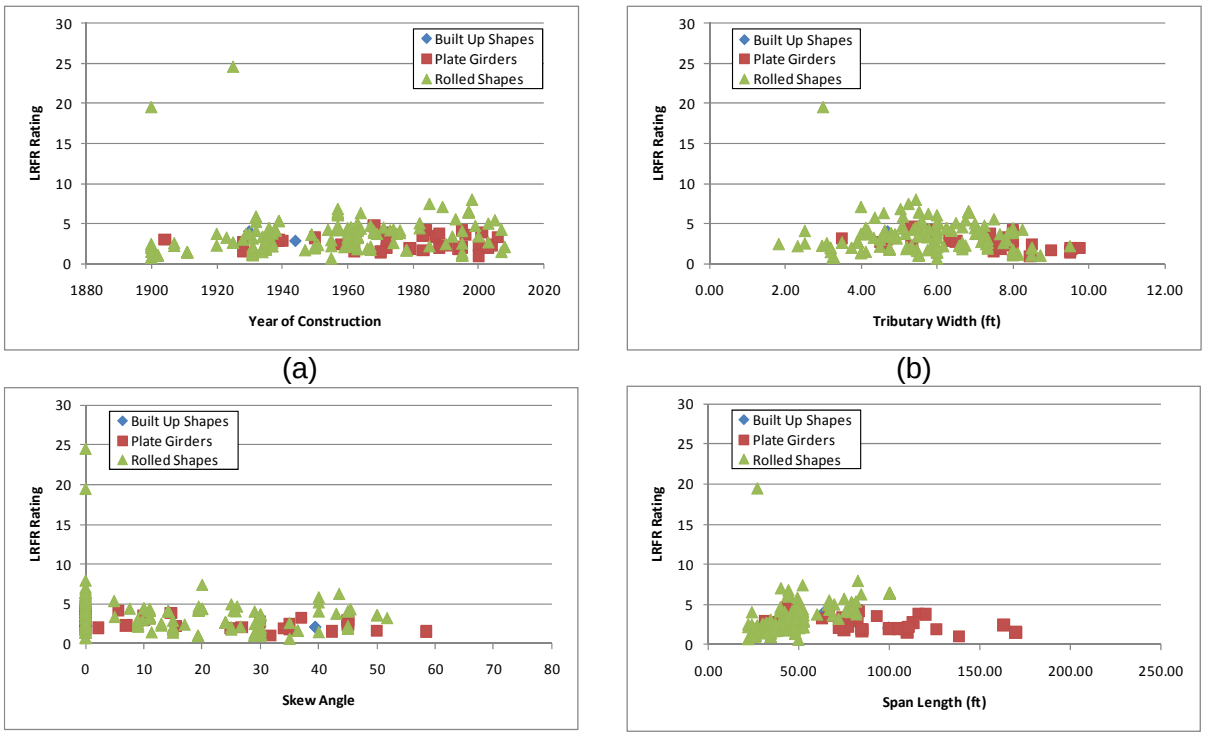
After verifying that the live load shears and shear resistances were reasoanble, the next step was to compare the rating factors. Figure B-206 and Figure B-207 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where it is likely that the shear resistance would vary along the length.



(a) (b)

(c) (d)

Figure B-206: LFR Shear Ratings for TX-04 Vehicle



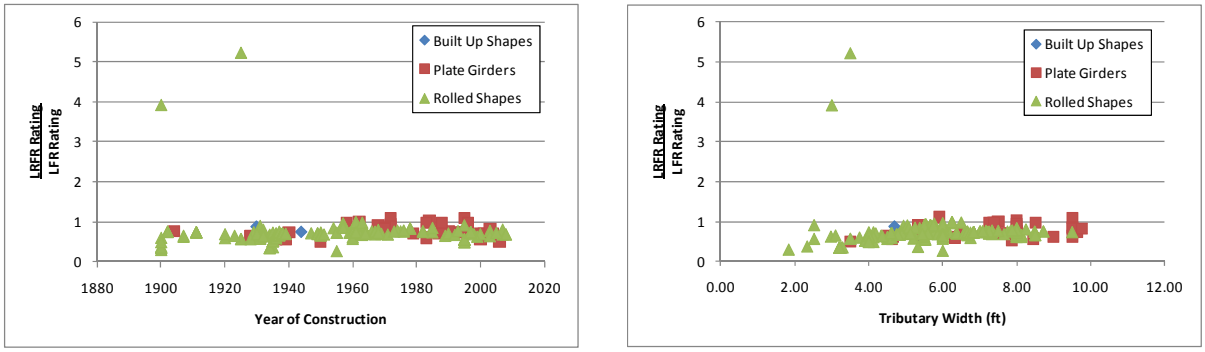
(a) (b)

(c) (d)

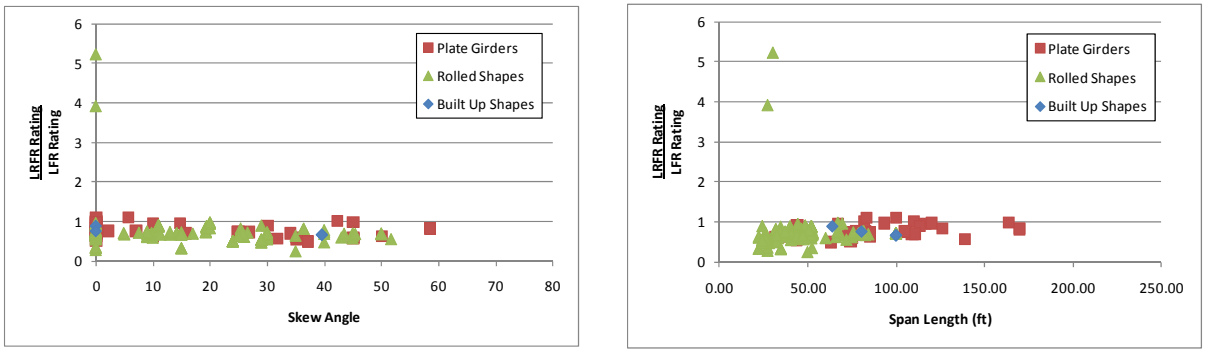
Figure B-207: LRFR Shear Ratings for TX-04 Vehicle

B.1.9.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio of the LRFR rating factor to the LFR rating factor. Figure B-208 shows the results of this comparison. The results show that the LFR rating is typically greater than the LRFR rating after recalculating the rating at the support. While the LFR rating is still greater, the ratio has shifted up and is closer to 1.0 than in the previous section where it was near 0.5.



(a) (b)

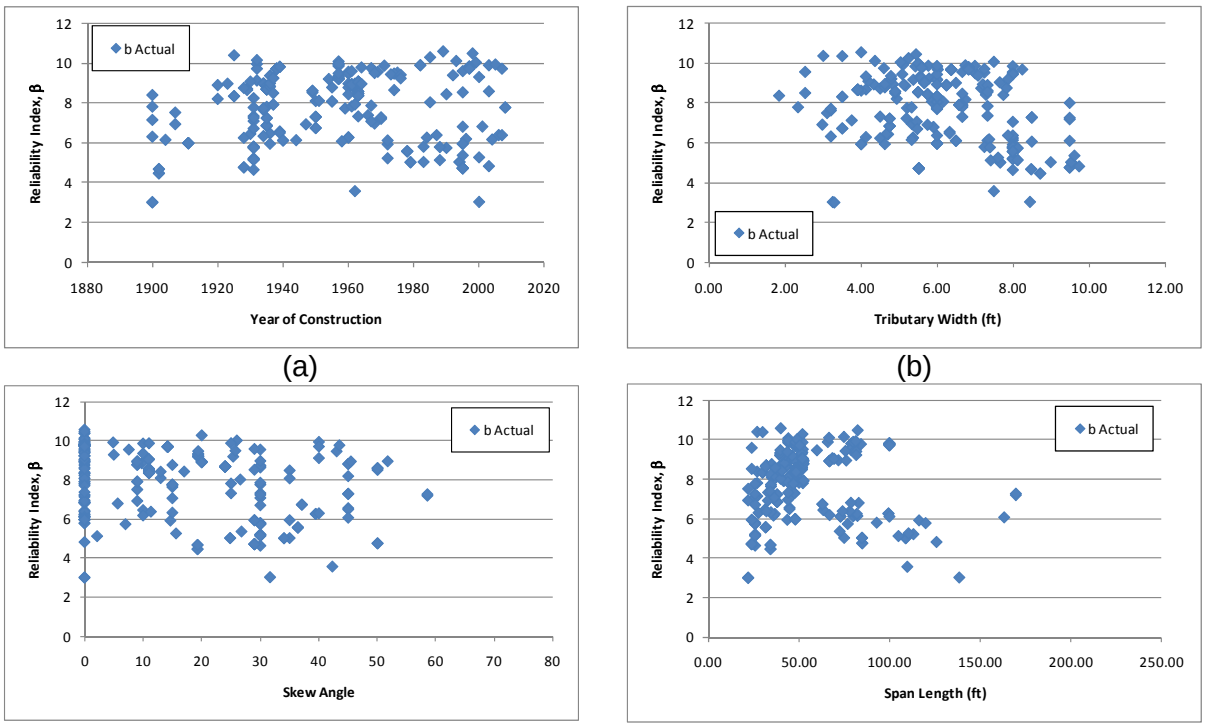


(c) (d)

Figure B-208: Ratio of LRFR Shear Rating to LFR Shear Rating for TX-04 Vehicle

B.1.9.3.5 Reliability Indices

The reliability indices shown in Figure B-209 are the same as those shown in Figure B-201. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 2.5. The reliability index remains the same as calculated previously because the LRFR location did not move.



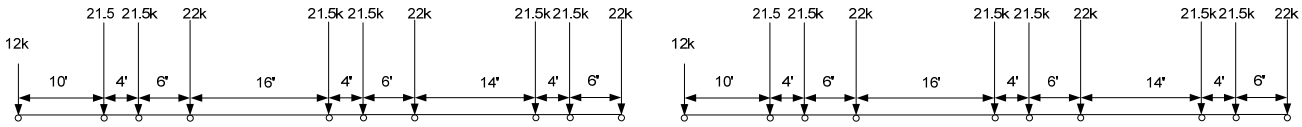
(a) (b)

(c) (d)

Figure B-209: Shear Reliability Indices for TX-04 Vehicle

B.1.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-210. The applicable load factors for this vehicle are 1.3 and 1.40 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading

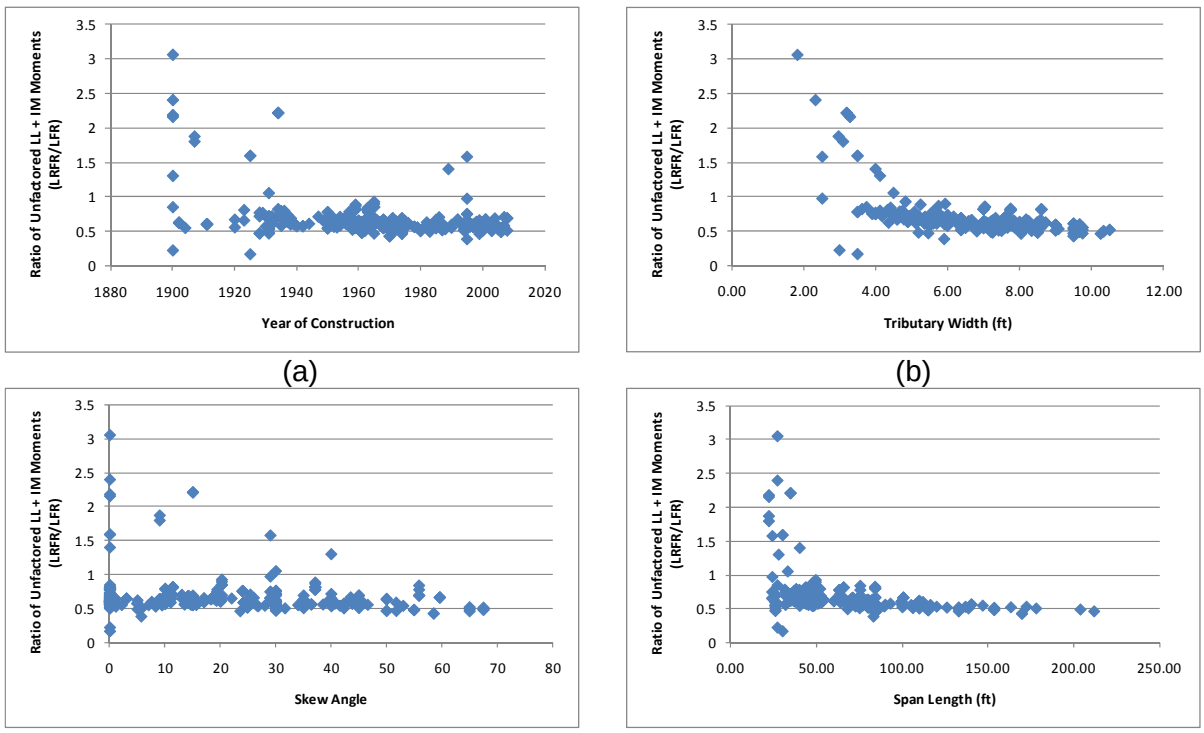
plus 0.2 klf for spans greater than 200 feet
LRFR Loading

Figure B-210: Vehicle Loadings and Load Factors

B.1.10.1 Moment

B.1.10.1.1 Live Loads

Figure B-211 and Figure B-212 shows the ratios of unfactored and factored live load plus impact moments (LRFR divided by LFR) for the WA-02 vehicle. The LRFR moments due to live load plus impact are typically smaller than the LFR moments, for both the factored and unfactored case. Unfactored LRFR loads are typically 50 to 75% of the LFR load and for factored loads the ratio has shifted up slightly. The ratio tends to decrease with increasing tributary width (Figure B-211b and Figure B-212b), while there is less scatter for increasing span lengths (Figure B-211d and Figure B-212d).



(a) (b) (c) (d)

Figure B-211: Ratio of Unfactored Live Load plus Impact Moment for WA-02 Vehicle (LRFR/LFR)

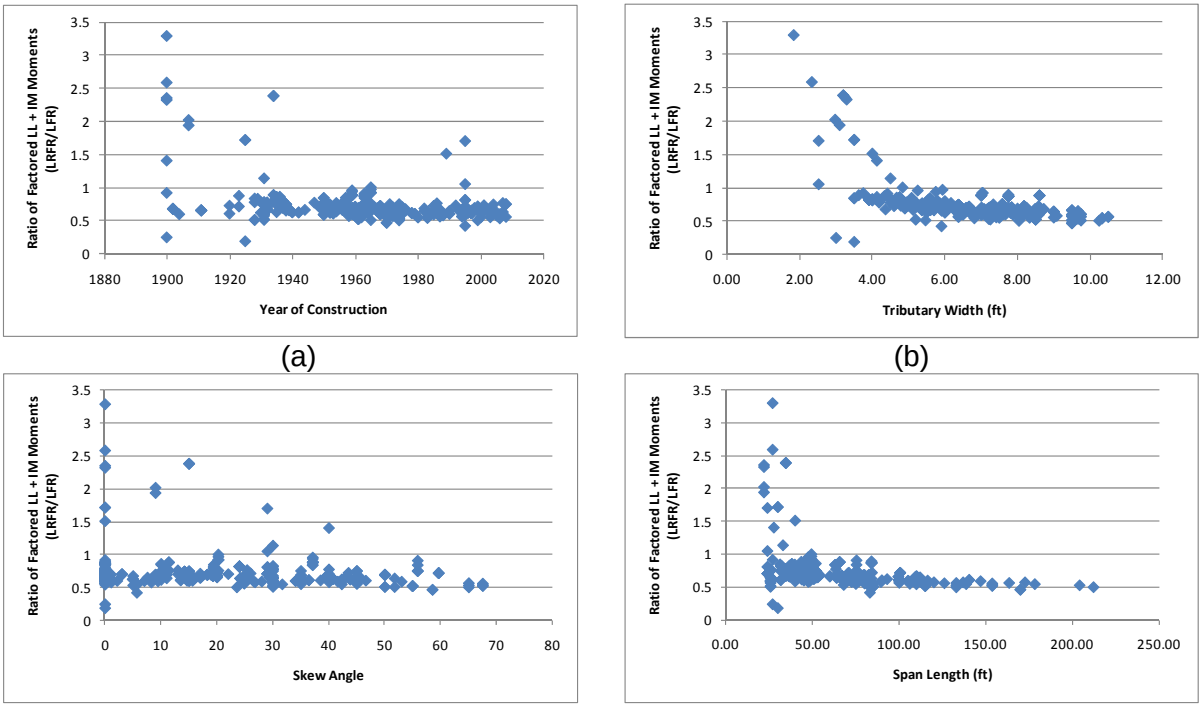


Figure B-212: Ratio of Factored Live Load plus Impact Moment for WA-02 Vehicle (LRFR/LFR)

B.1.10.1.2 Resistances

Figure B-213 shows the ratio of the factored moment resistances, LRFR resistance to LFR resistance. The ratio is generally above 1.0 for rolled shapes and less than 1.0 for plate girders.

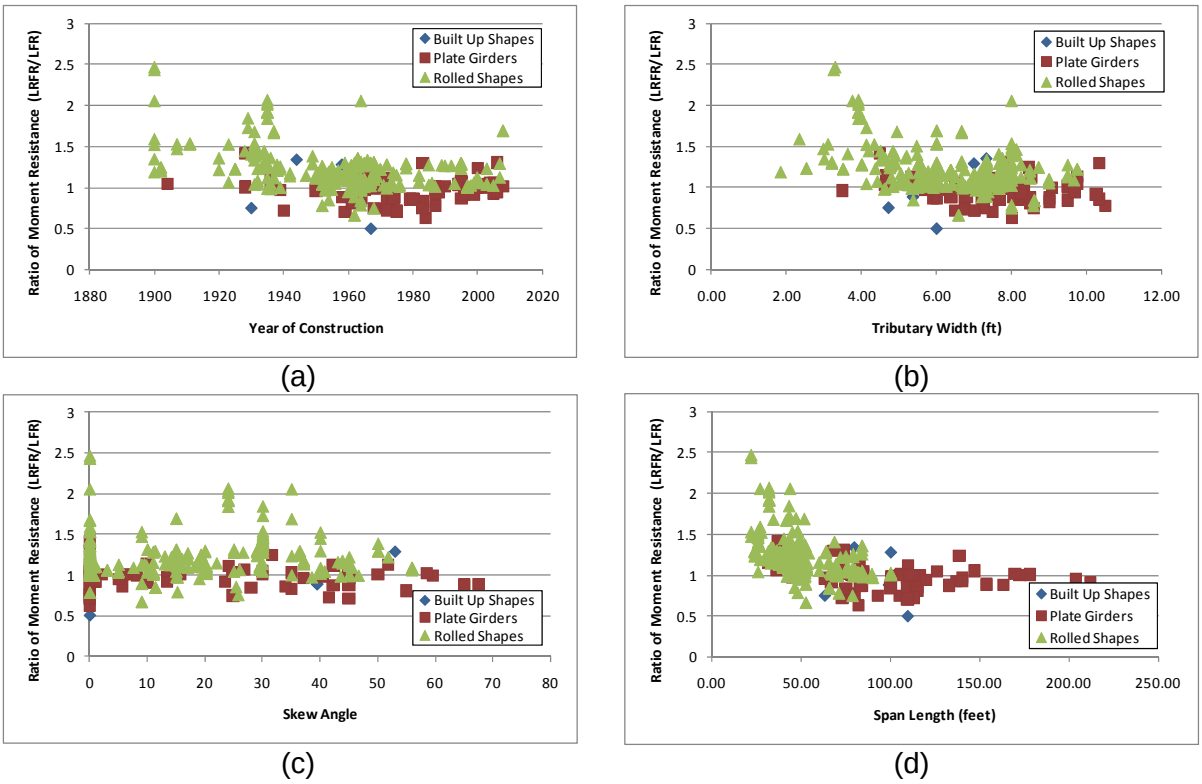


Figure B-213: Ratio of Factored Moment Resistance (LRFR/LFR)

B.1.10.1.3 Rating Factors

Figure B-214 and Figure B-215 present the LFR and LRFR ratings from BRASS, respectively. There are 47 girders with an LFR rating less than 1.0, 24 girders with an LRFR rating less than 1.0, and 16 girders where both ratings are less than 1.0. Ignoring the outliers, the two methods provide similar scatter with the LRFR rating shifted up slightly from the LFR rating.

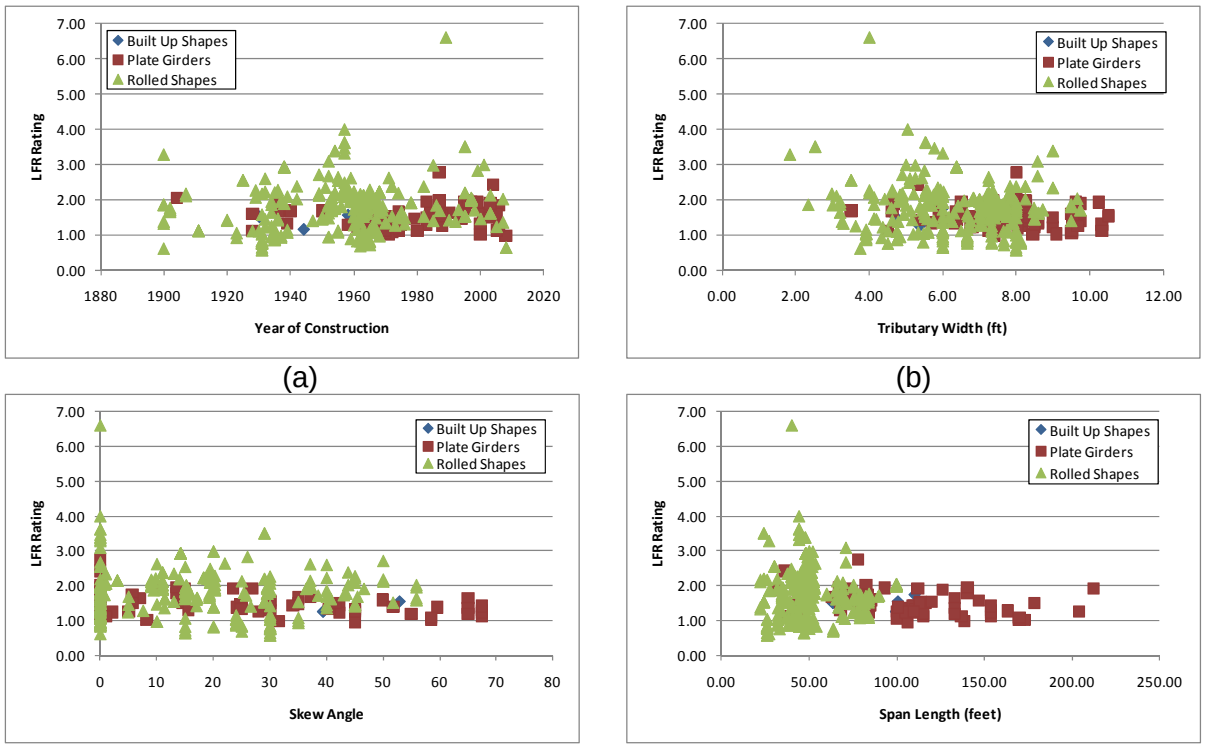
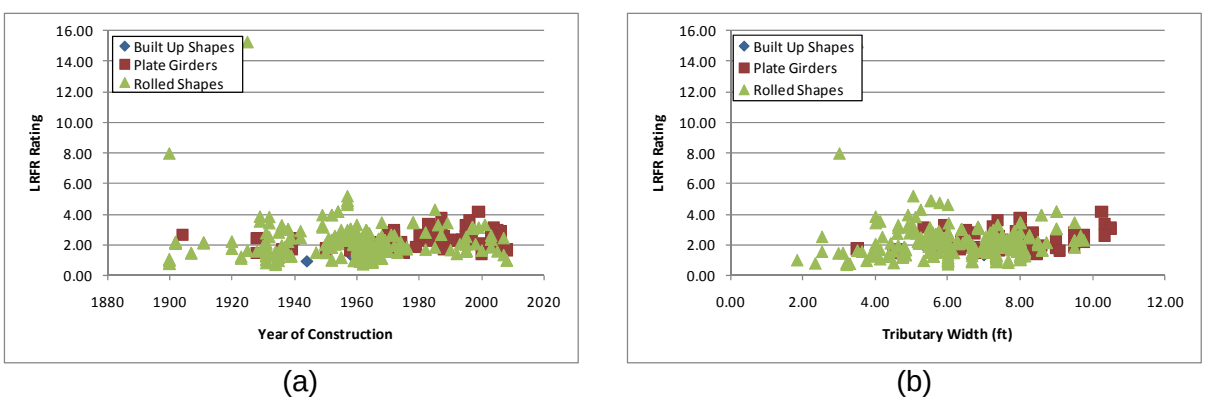
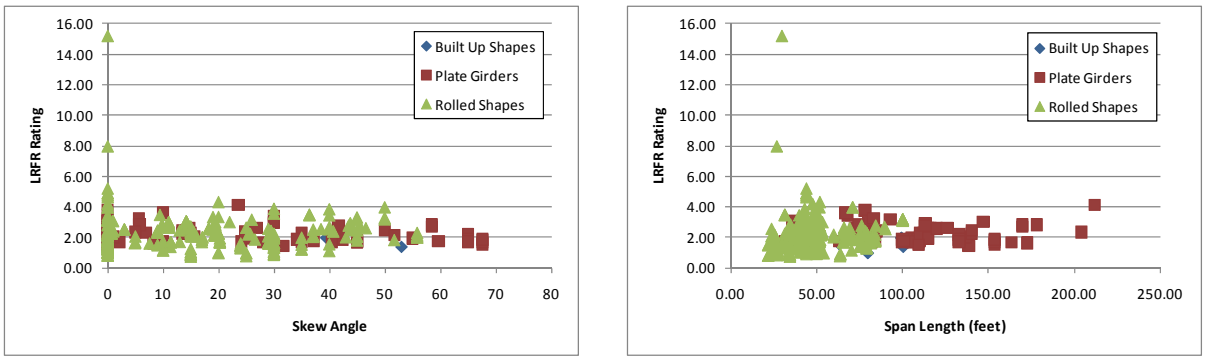


Figure B-214: LFR Flexure Ratings for WA-02 Vehicle



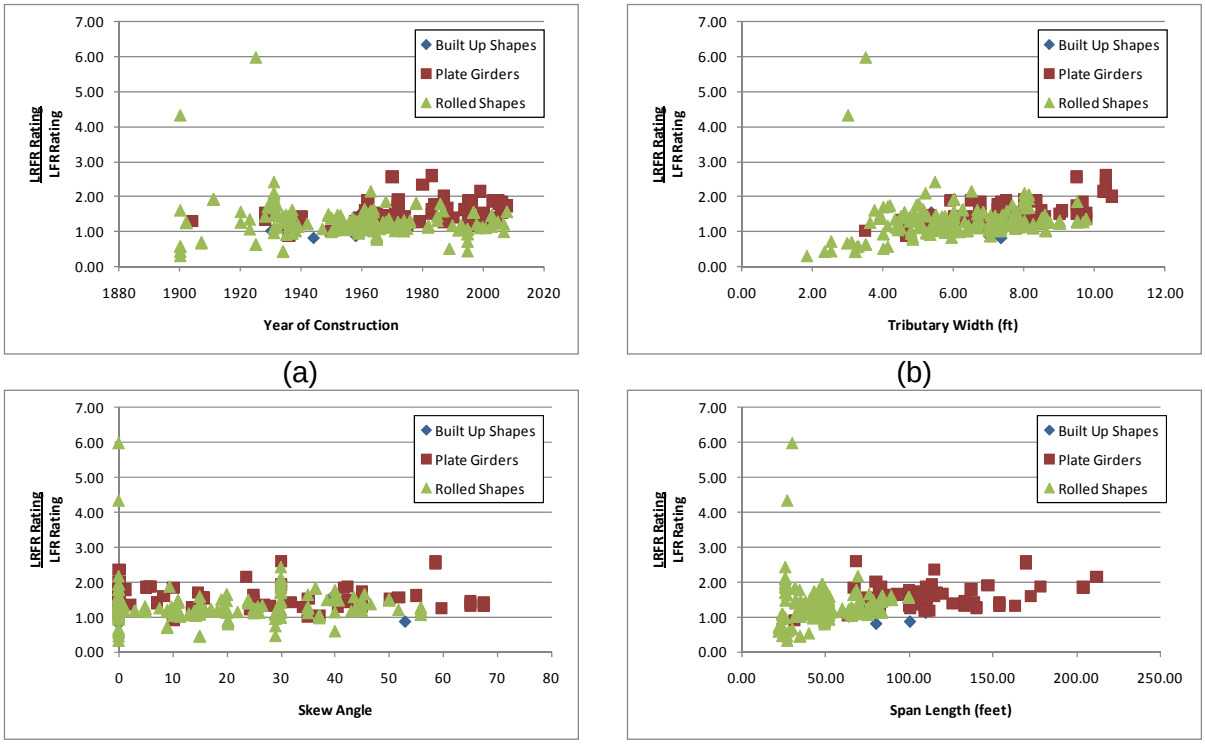


(c) (d)

Figure B-215: LRFR Flexure Ratings for WA-02 Vehicle

B.1.10.1.4 Rating Factor Comparisons

Figure B-216 shows that the ratio of LRFR rating to LFR rating is generally greater than 1.0; only 8% of girders have LFR ratings greater than the LRFR rating. Figure B-216b shows that for narrow girder spacing the LFR rating is higher than the LRFR rating, while for large girder spacing the LRFR rating is greater. Most girders with higher LFR ratings are rolled shapes with plate girders having a ratio above 1.0. The built-up shapes are very close to 1.0.



(a) (b)

(c) (d)

Figure B-216: Ratio of LRFR Flexure Rating to LFR Flexure Rating for WA-02 Vehicle

B.1.10.1.5 Reliability Indices

Figure B-217 presents the actual reliability indices as calculated. There is one girder where the actual reliability index is very close to the required reliability index of 3.5. Most girders have a reliability index of greater than four.

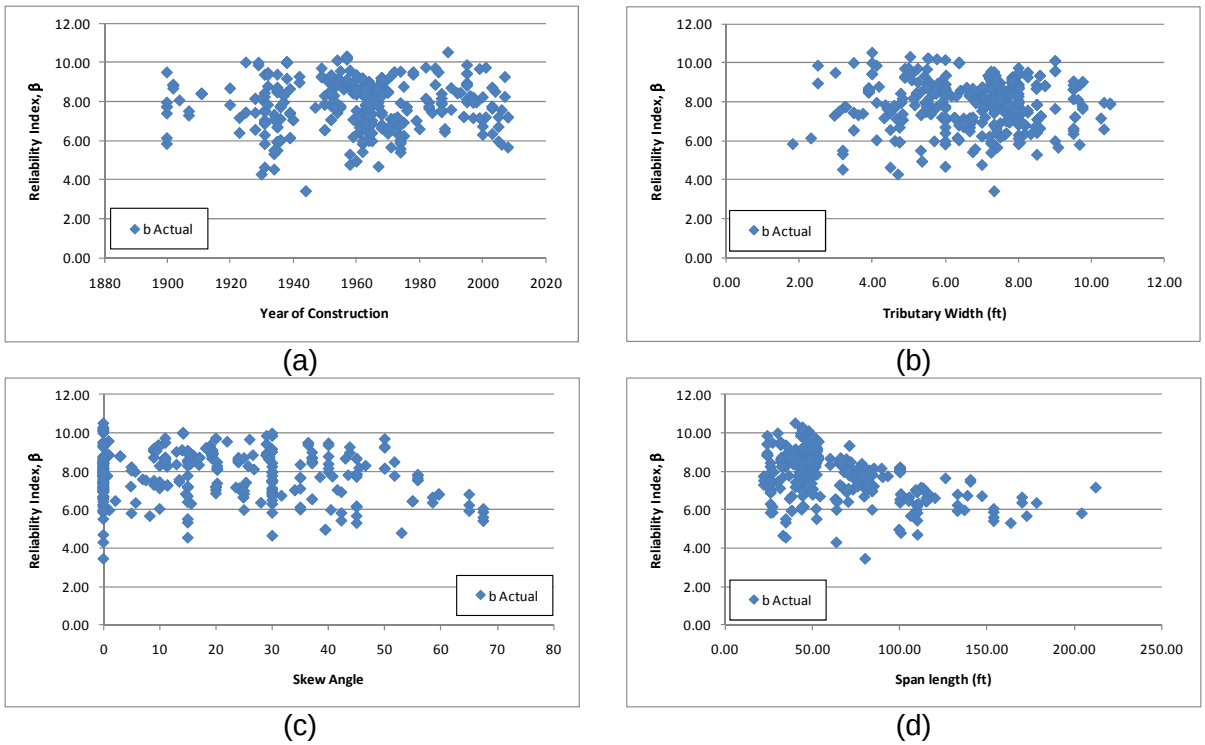


Figure B-217: Flexure Reliability Indices for WA-02 Vehicle

Figure B-218 shows the actual flexure reliability plotted agains the LRFR flexure rating. The figure shows that girders with a passing rating are expected to have a reliability index of at least 3.5 and likely above 5 for rolled shapes and plate girders. This indicates that a reduction in the live load factor may be possible.

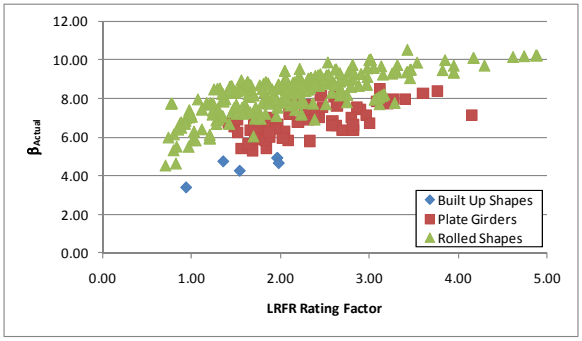


Figure B-218: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

B.1.10.2 Shear

B.1.10.2.1 Live Loads

Figure B-219 and Figure B-220 show the ratios of unfactored and factored live load plus impact shear (LRFR divided by LFR), respectively. The ratio of unfactored loads is between 0.75 and 1.5 and between 1.0 and 1.75 for factored loads, and decrease with increasing tributary width (Figure B-219b and Figure B-220b). This is likely a result of the distribution factors as the LRFD equations limit the girder spacing to greater than 3.5 feet, while the LFR distribution factors are applicable to any girder spacing. Figure B-219c and Figure B-220c show that the ratio increases with increasing skew; this is an expected result as the LRFD Specification increases the load distributed to each girder because of the skew while the LFR Specification does not consider the effect of skew. Figure B-221 shows where

the critical shear rating occurred for each girder. The LFR location is typically away from the support while the LRFD location is typically at the support.

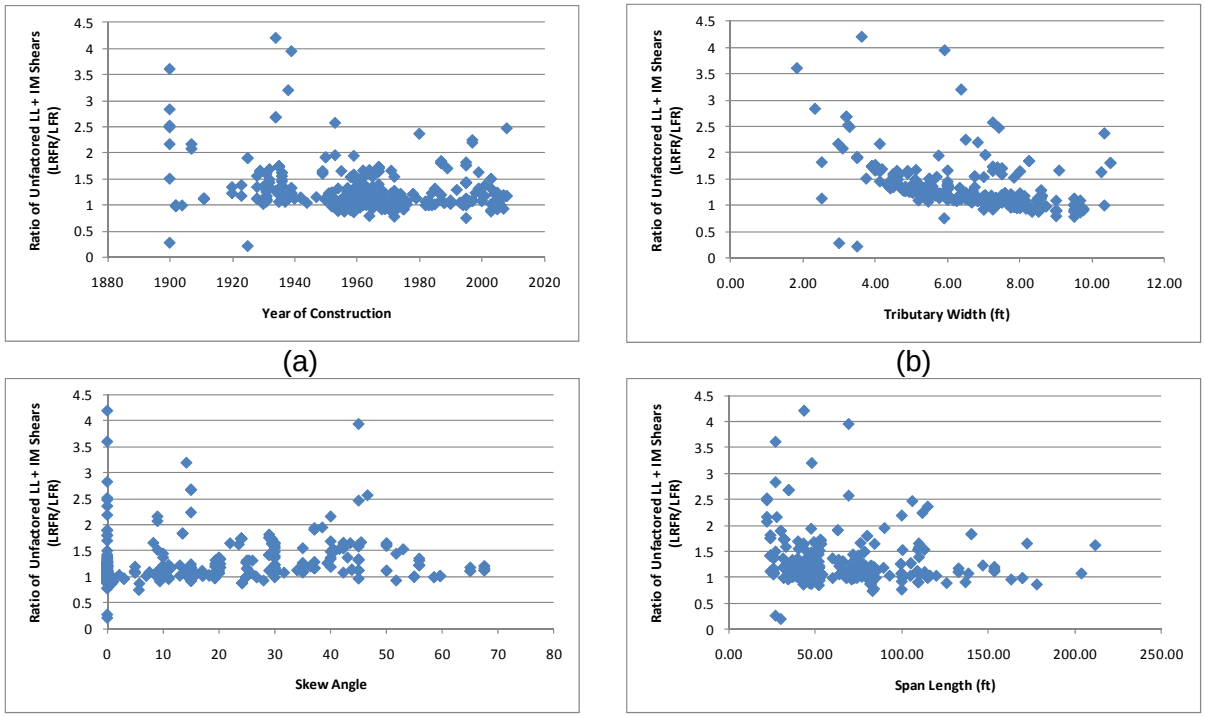


Figure B-219: Ratio of Unfactored Live Load plus Impact Shear for WA-02 Vehicle (LRFR/LFR)

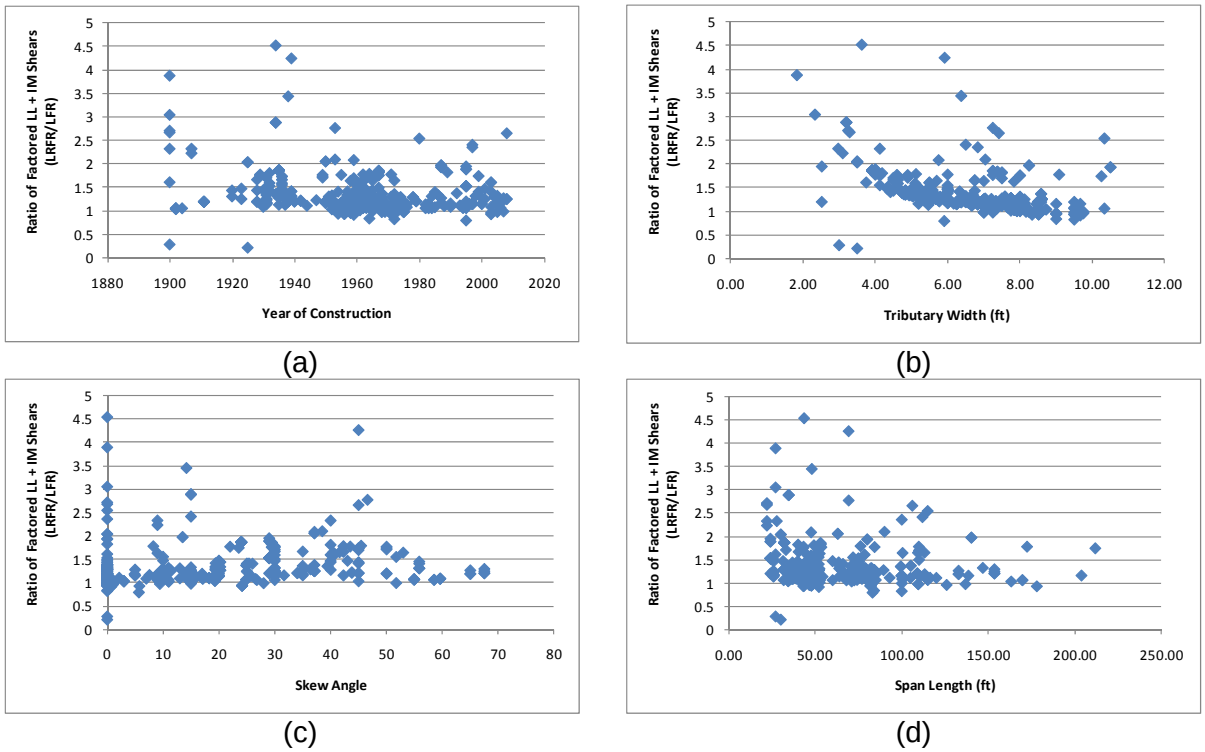


Figure B-220: Ratio of Factored Live Load plus Impact Shear for WA-02 Vehicle (LRFR/LFR)

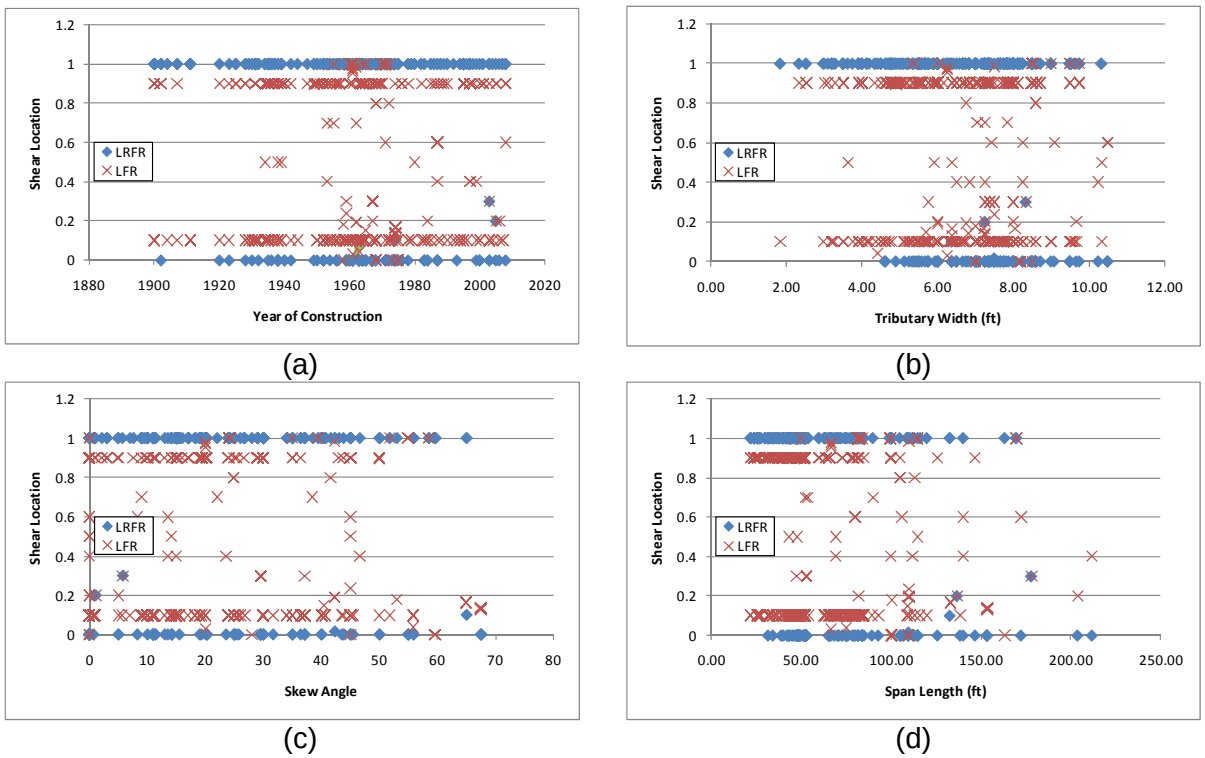
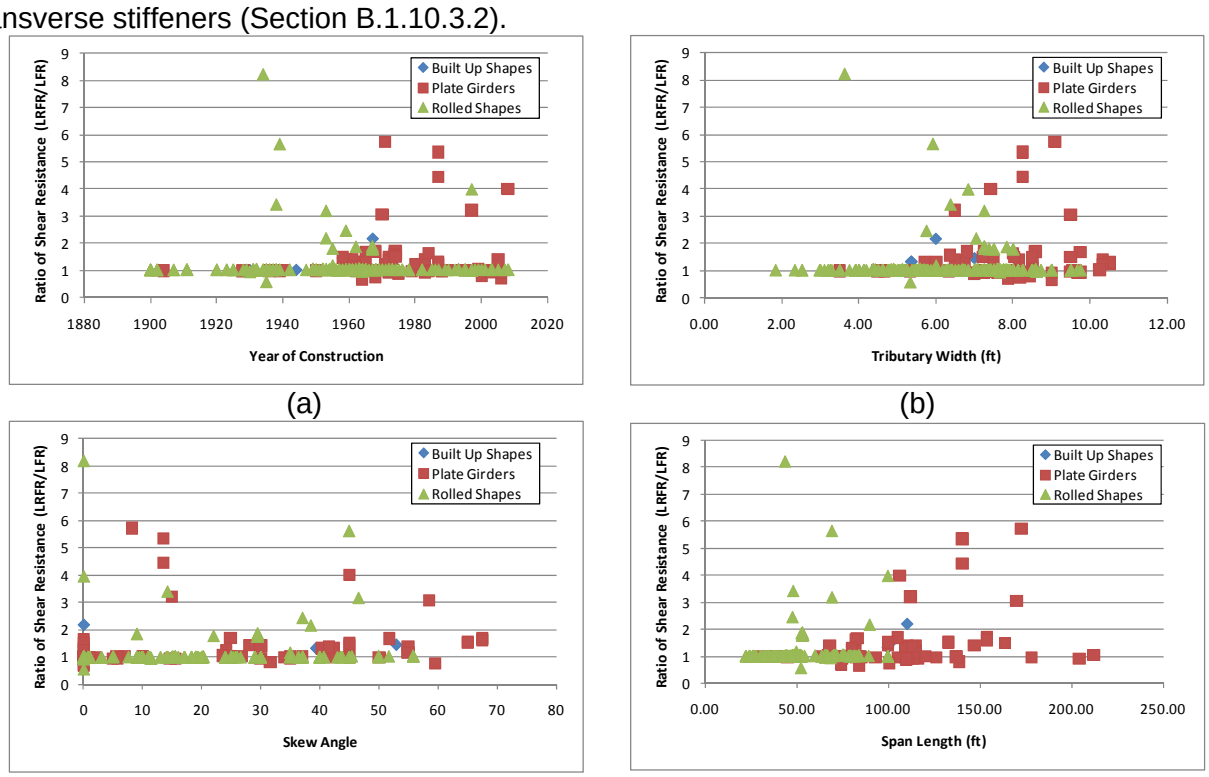


Figure B-221: Critical Shear Location for WA-02 Vehicle

B.1.10.2.2 Resistances

Figure B-222 shows the ratio of factored shear resistances. The ratio is generally close to 1.0, with most of the scatter a result of plate girders where the shear resistance would be affected by the spacing of transverse stiffeners (Section B.1.10.3.2).

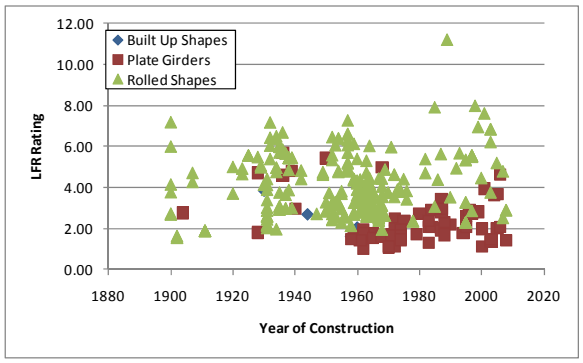


(c) (d)

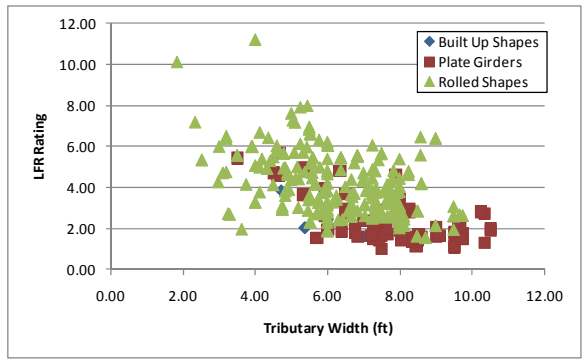
Figure B-222: Ratio of Factored Shear Resistances (LRFR/LFR)

B.1.10.2.3 Rating Factors

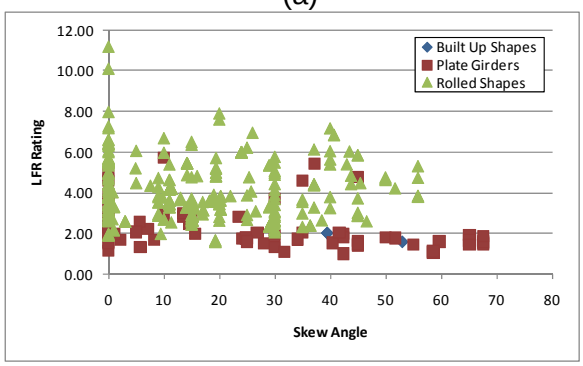
Figure B-223 and Figure B-224 present the ratings as calculated by BRASS for LFR and LRFR, respectively. The LFR Ratings tend to decrease with increasing tributary width and increasing span length (Figure B-223b and d). There is also less scatter with increasing span length (Figure B-223d). There are zero girders with an LFR rating of less than 1.0 and 31 girders with an LRFR rating less than 1.0. Additionally, 82% of the girders have LFR Ratings greater than the LRFR rating.



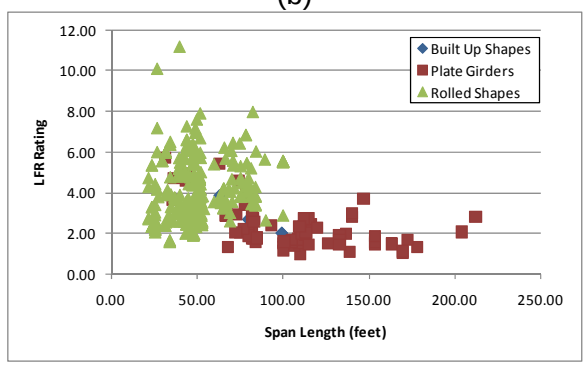
(a)



(b)

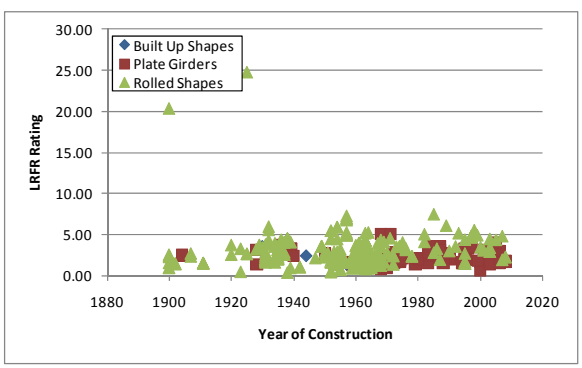


(c)

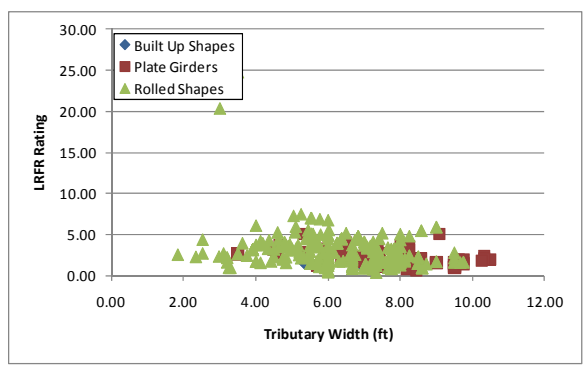


(d)

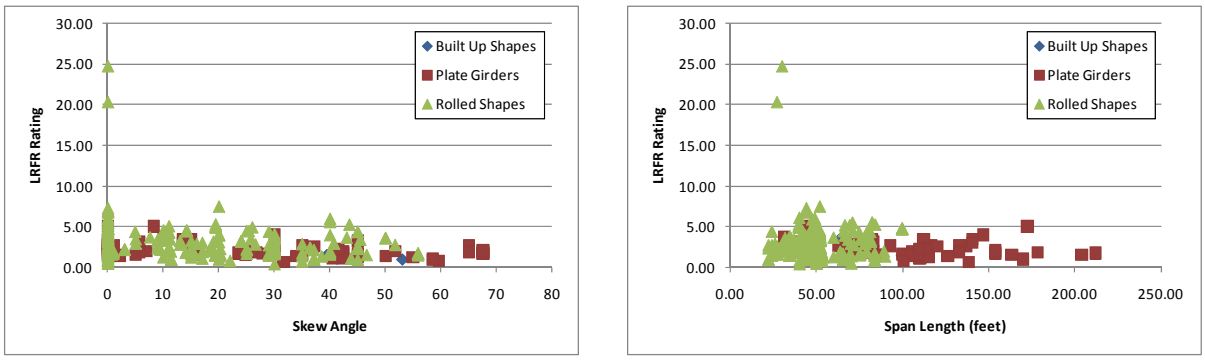
Figure B-223: LFR Shear Ratings for WA-02 Vehicle



(a)



(b)

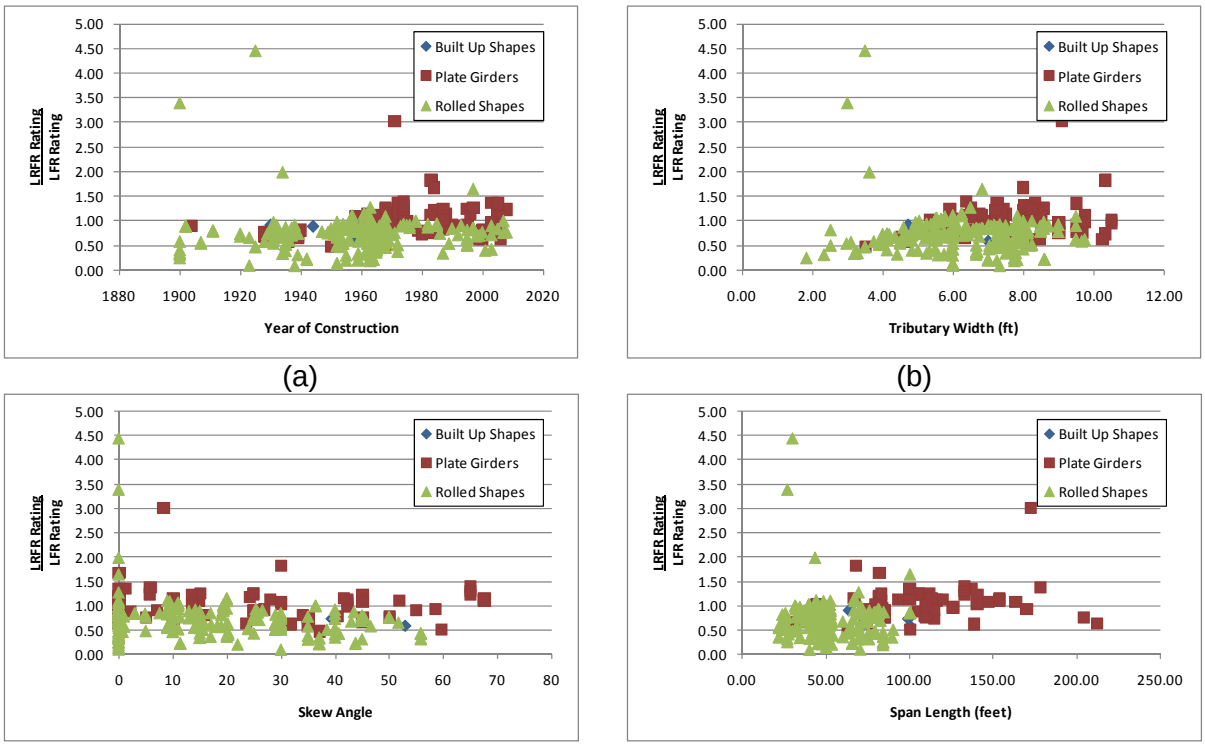


(c) (d)

Figure B-224: LRFR Shear Ratings for WA-02 Vehicle

B.1.10.2.4 Rating Factor Comparisons

Figure B-225 shows the ratio (LRFR to LFR) of the rating factors. Rolled shapes typically have higher LFR ratings than LRFR ratings, while plate girders appear to have higher LRFR ratings than LFR ratings. Shorter span lengths appear to be more likely to have higher LFR ratings than LRFR ratings (Figure B-225d).



(a) (b)

(c) (d)

Figure B-225: Ratio of LRFR Shear Rating to LFR Shear Rating for WA-02 Vehicle

B.1.10.2.5 Reliability Indices

Figure B-226 shows the actual reliability indices as calculated based upon the strength of the section. The required level of reliability for this vehicle, a special permit vehicle, is 3.5. There are at least two girders where the actual reliability index is less than the required and also several cases where they are very similar.

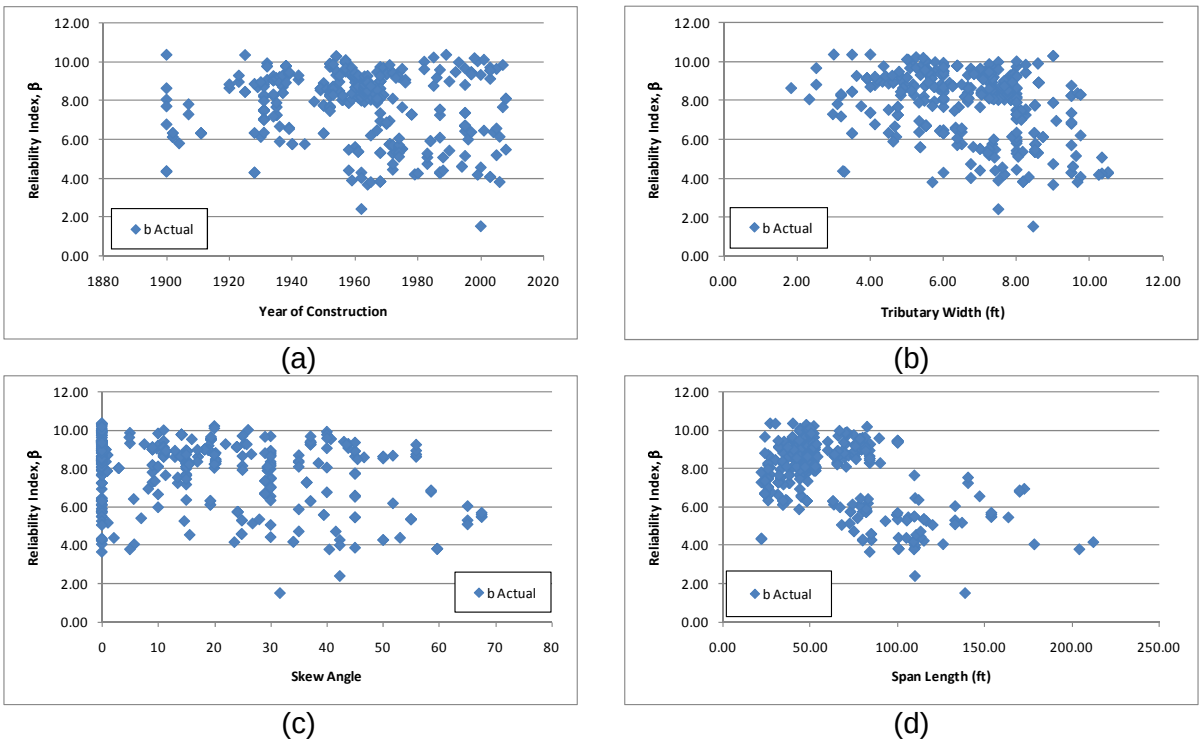


Figure B-226: Shear Reliability Indices for WA-02 Vehicle

Figure B-227 shows the actual shear reliability index plotted against the LRFR shear rating for the WA-02 vehicle. The figure indicates that the reliability index expected for a girder with a rating factor of 1.0 is approximately 3 for plate girders and 4 for rolled shapes. The required level of reliability for this special permit vehicle is 3.5. This indicates that there may be a need to increase the live load factor but since these are lowest girders, not the middle of the plate girders, the need to increase the live load factor is small.

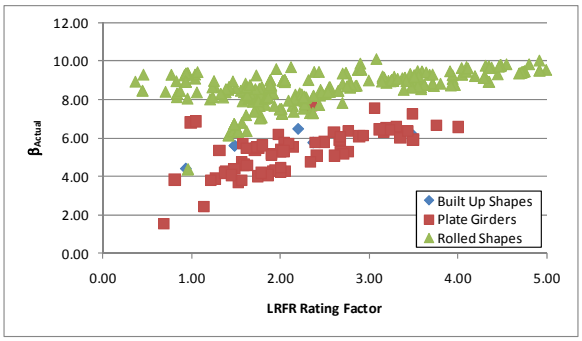


Figure B-227: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

B.1.10.3 Shear-Corrected

This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.10.3.1 Live Load

Figure B-228 and Figure B-229 show the ratio of unfactored and factored live load plus impact shear (LRFR to LFR) for those girders with critical locations at the either the support or one-tenth of the span

away from the support. The LRFR unfactored shear is 75 to 110% of the LFR unfactored shear and when factored the live load shear ratio increases slightly to between 0.8 and 1.2. Considering the same location, the live loads are more similar.

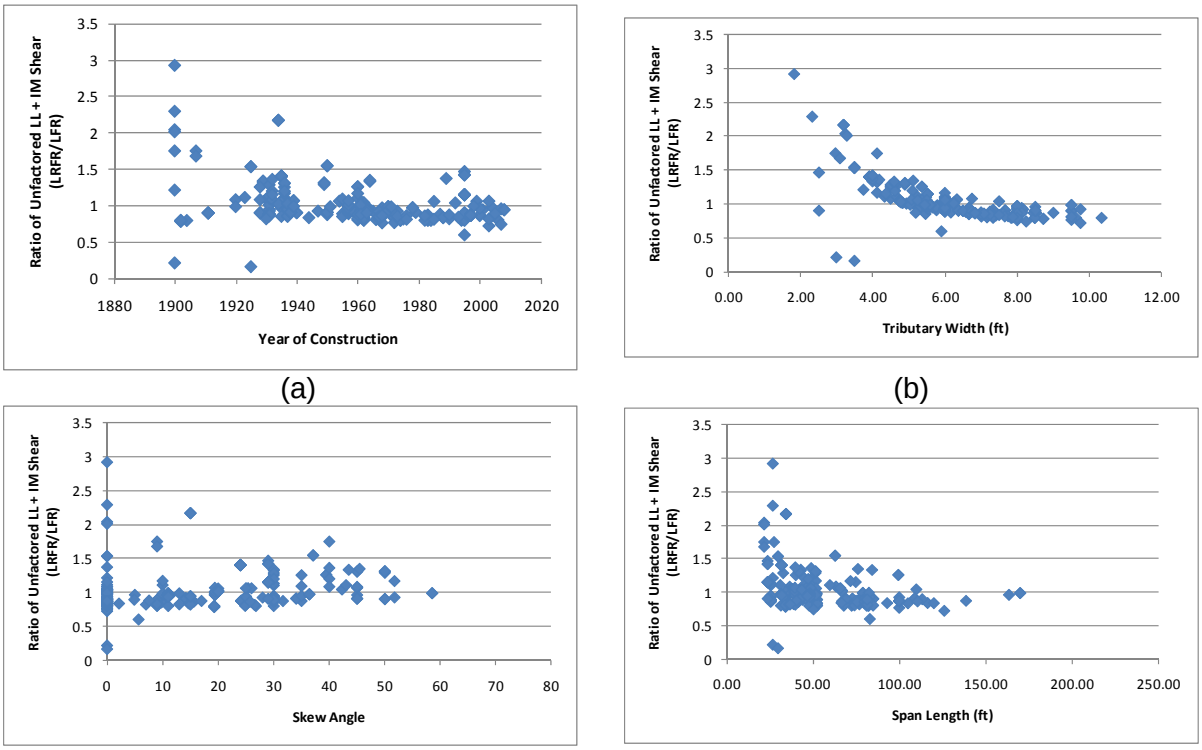
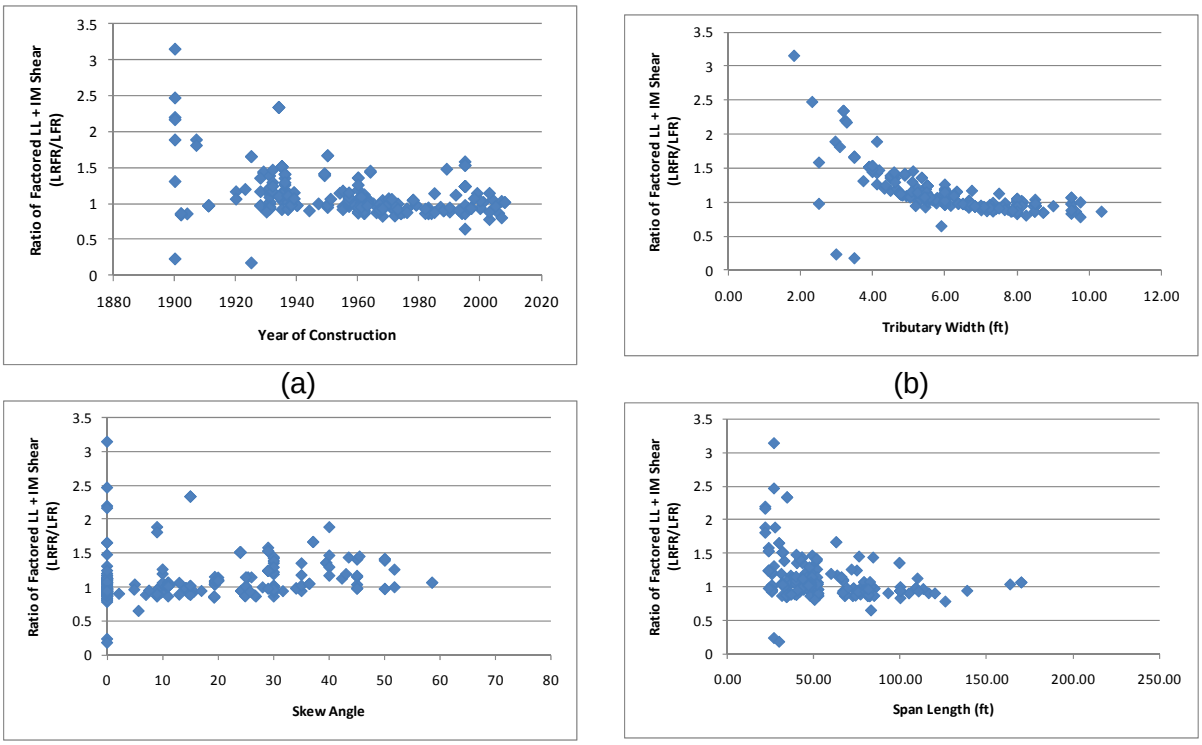


Figure B-228: Ratio of Unfactored Live Load plus Impact Shear for WA-02 Vehicle (LRFR/LFR)

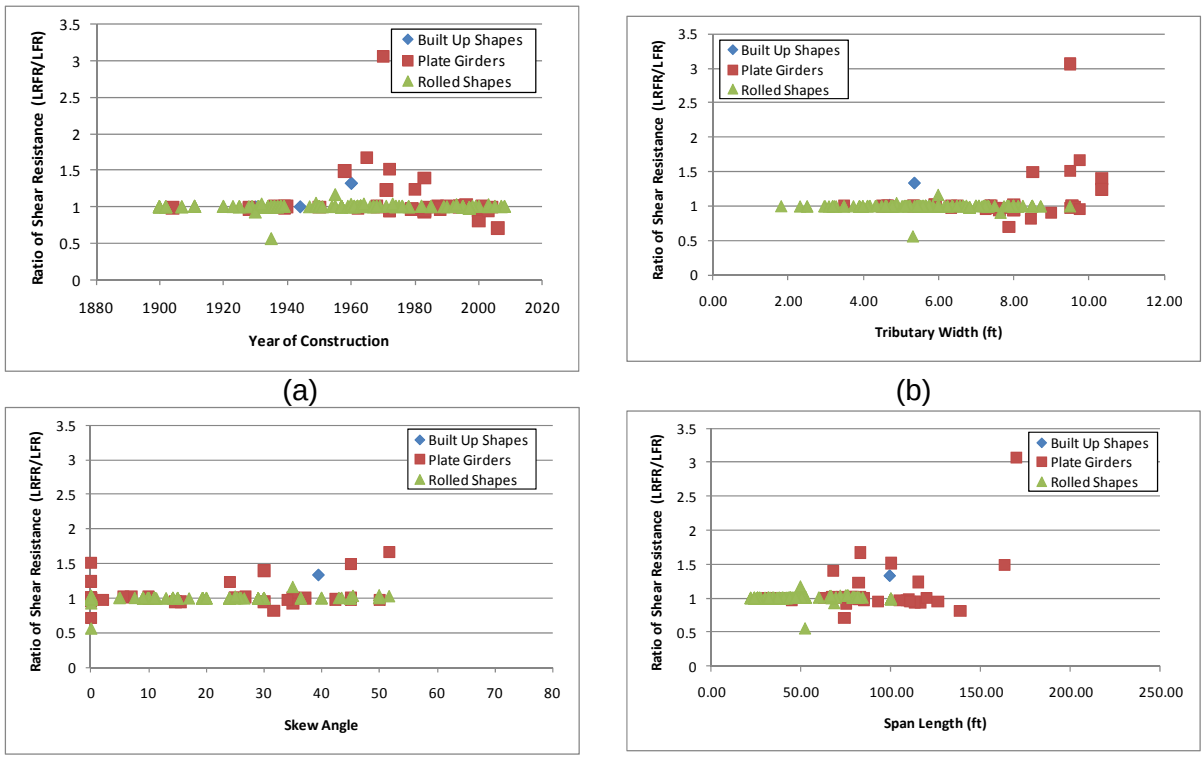


(c) (d)

Figure B-229: Ratio of Factored Live Load plus Impact Shear for WA-02 Vehicle (LRFR/LFR)

B.1.10.3.2 Resistance

The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was greater than 1.0 have been eliminated by considering only those near the support. The ratio of shear resistance is shown in Figure B-230.



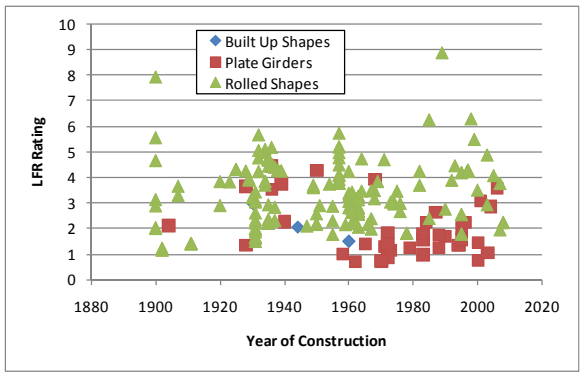
(a) (b)

(c) (d)

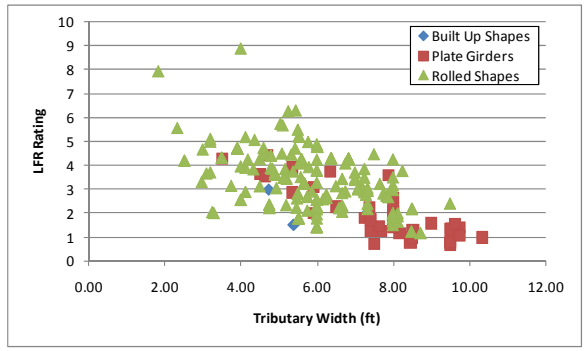
Figure B-230: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.10.3.3 Rating Factors

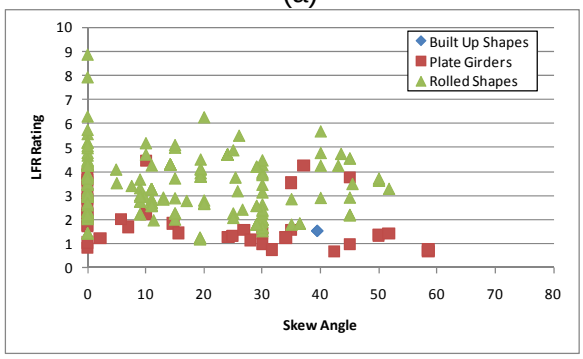
After verifying that the live load shears and shear resistances are reasonable, the next step was to compare the rating factors. Figure B-231 and Figure B-232 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where it is likely that the shear resistance would vary along the span length.



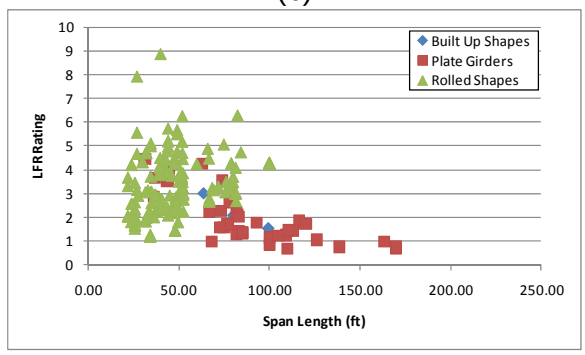
(a)



(b)

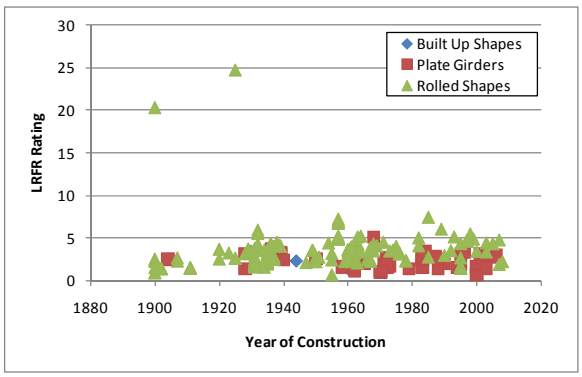


(c)

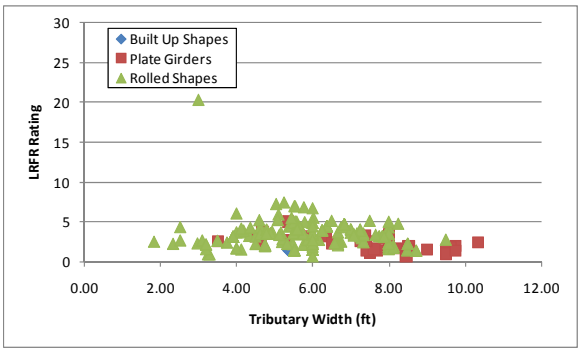


(d)

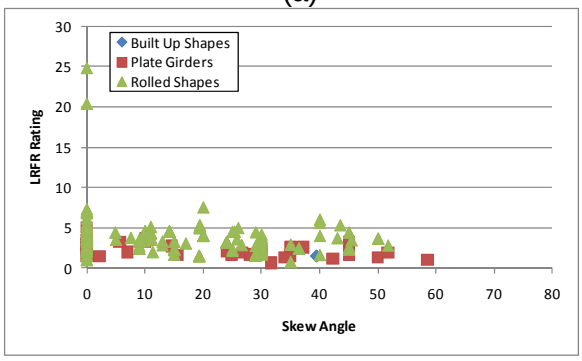
Figure B-231: LFR Shear Rating Factor for WA-02 Vehicle



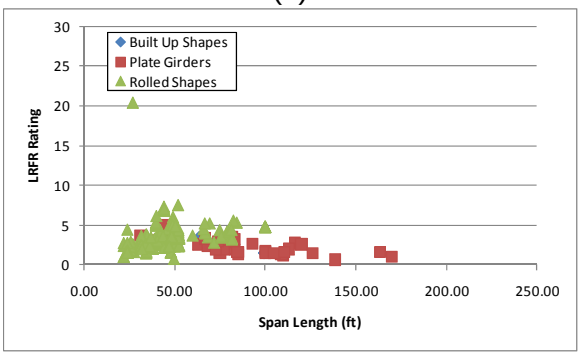
(a)



(b)



(c)



(d)

Figure B-232: LRFR Shear Rating Factor for WA-02 Vehicle

B.1.10.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio between the LRFR rating factor and the LFR rating factor. Figure B-233 shows the results of this comparison. The results show that the LFR rating is greater than the LRFR rating for rolled shapes that are closely spaced. Rolled shapes with larger spacings and plate girders are more likely to have higher LRFR ratings than LFR ratings.

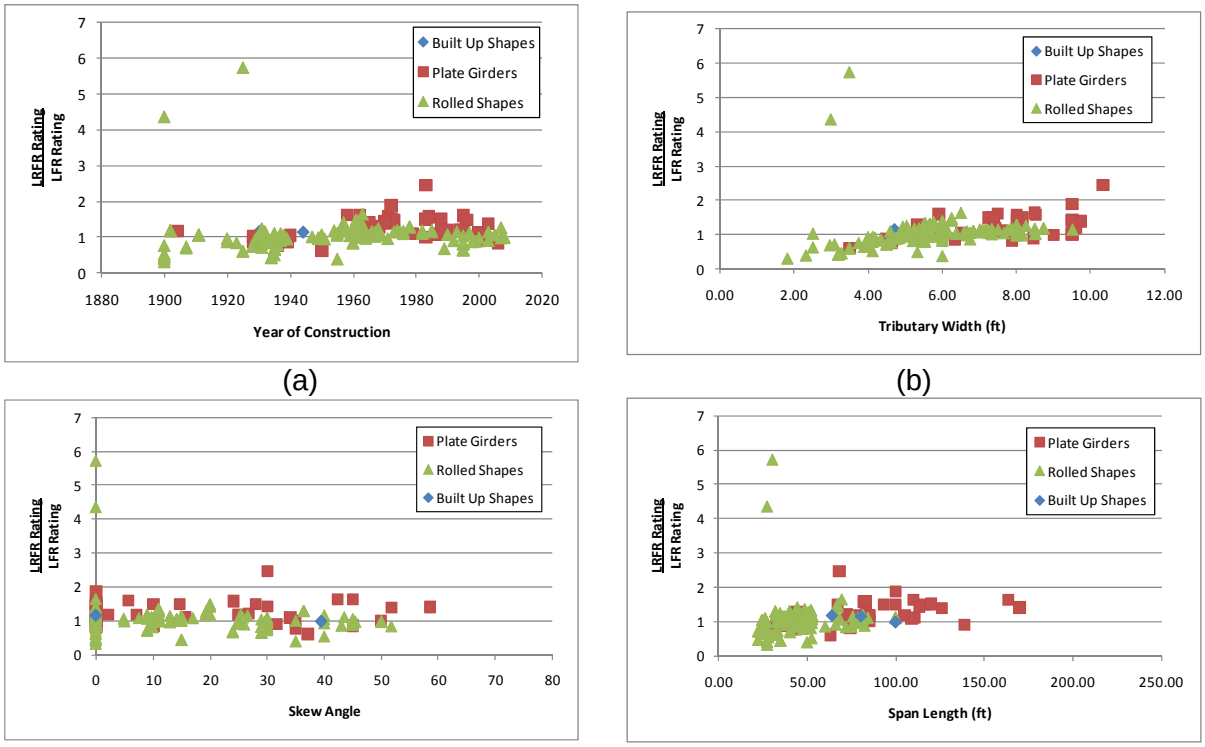
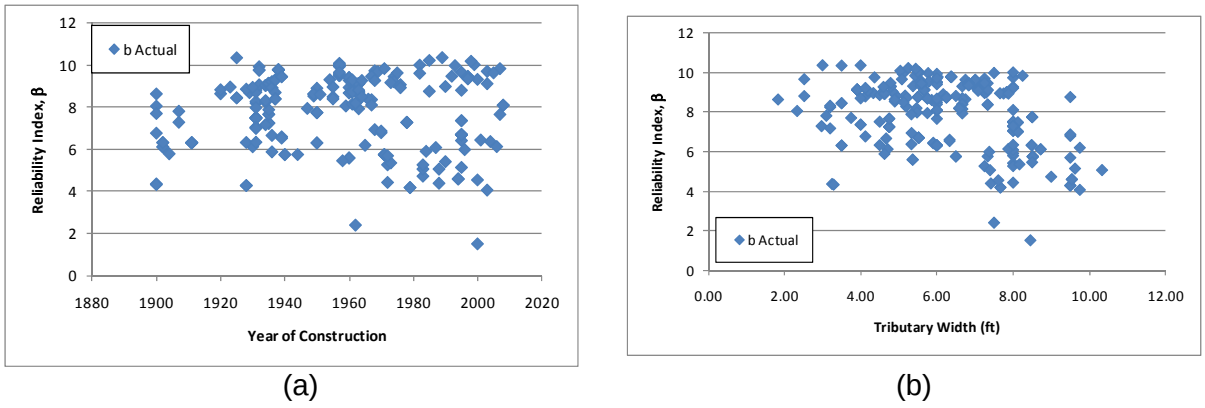
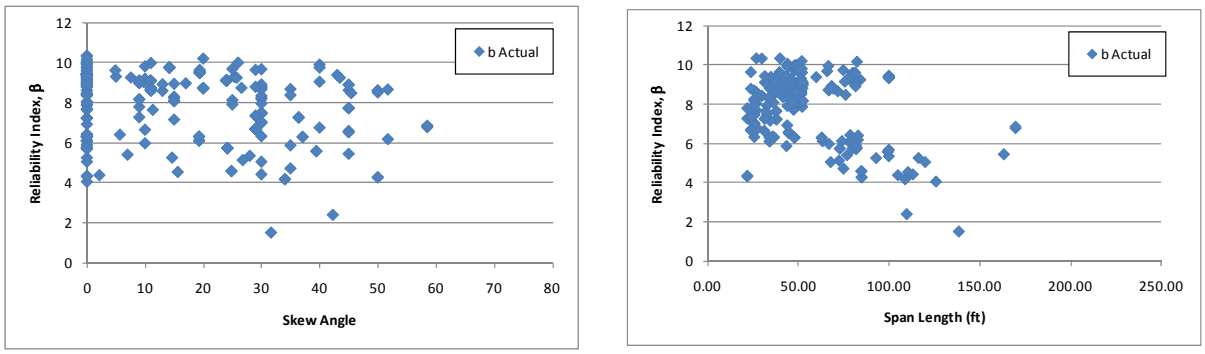


Figure B-233: Ratio of LRFR Shear Rating to LFR Shear Rating for WA-02 Vehicle

B.1.10.3.5 Reliability Indices

The reliability indices shown in Figure B-234 are the same as those shown in Figure B-226. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 3.5. The reliability index remains the same as calculated previously because the LRFR location did not move.





(c) (d)

Figure B-234: Shear Reliability Indices for WA-02 Vehicle

B.1.11 AASHTO Type 3 Vehicle

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-235. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

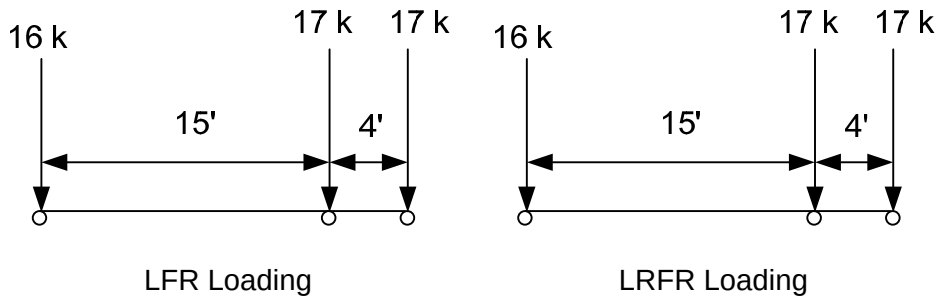


Figure B-235: Vehicle Loadings and Load Factors

B.1.11.1 Moment

B.1.11.1.1 Live Loads

Figure B-236 and Figure B-237 show the ratio (LRFR divided by LFR) of unfactored and factored live load plus impact moments for the AASHTO Type 3 vehicle. The LFR moments due to live load plus impact are typically greater than the LRFR moments, for both the factored and unfactored case. For the unfactored loads, the ratio is generally between 0.75 and 1.25. The ratio increases to between 1.0 and 1.5 when the load factors are applied. The ratio tends to decrease with increasing tributary width (Figure B-236b and Figure B-237b), while there is less scatter for increasing span lengths (Figure B-236d and Figure B-237d).

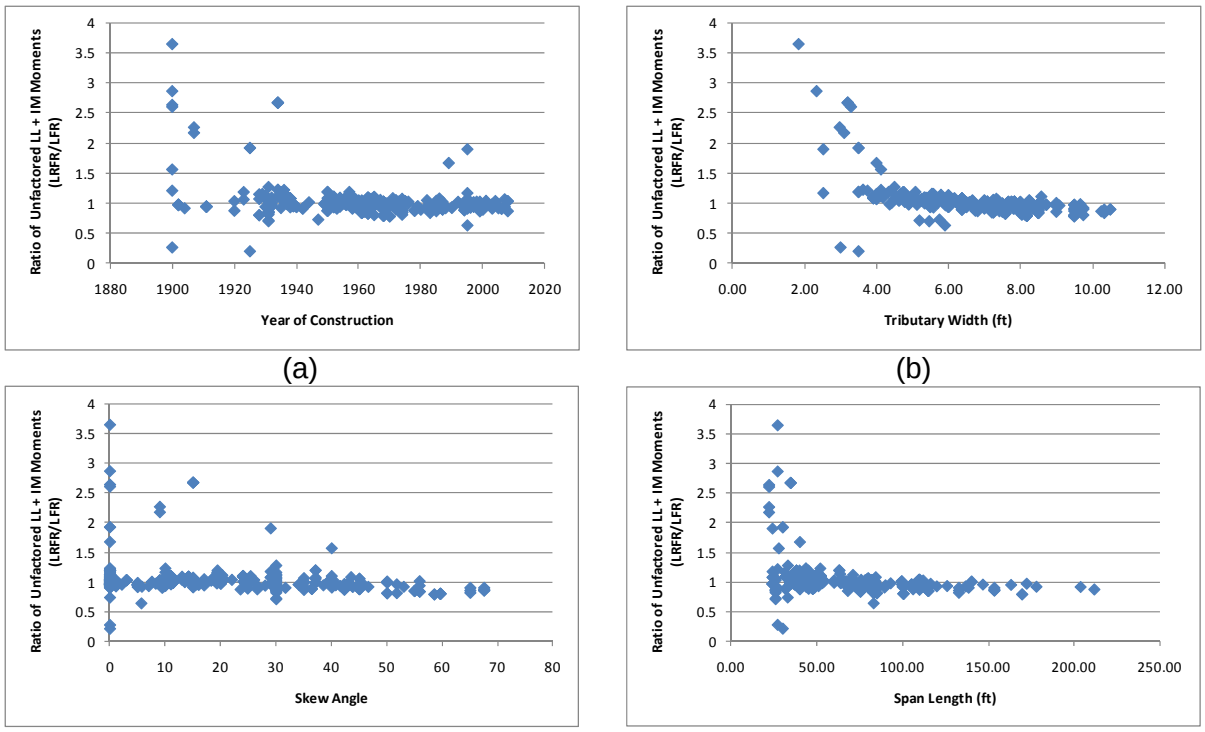


Figure B-236: Ratio of Unfactored Live Load plus Impact Moment for AASHTO Type 3 Vehicle (LRFR/LFR)

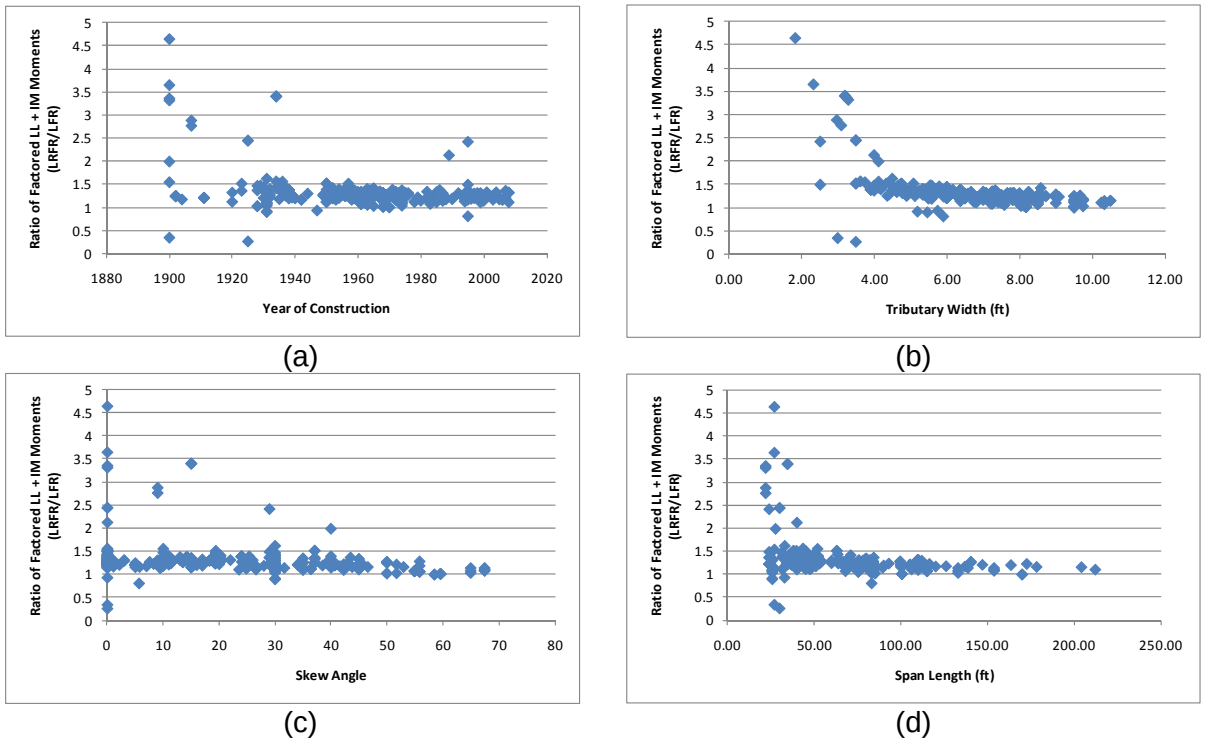


Figure B-237: Ratio of Factored Live Load plus Impact Moment for AASHTO Type 3 Vehicle (LRFR/LFR)

B.1.11.1.2 Resistances

Figure B-238 shows the ratio of the factored moment resistances, LRFR to LFR. Rolled shapes typically have higher resistance for LRFR than for LFR while plate girders exhibit the opposite trend.

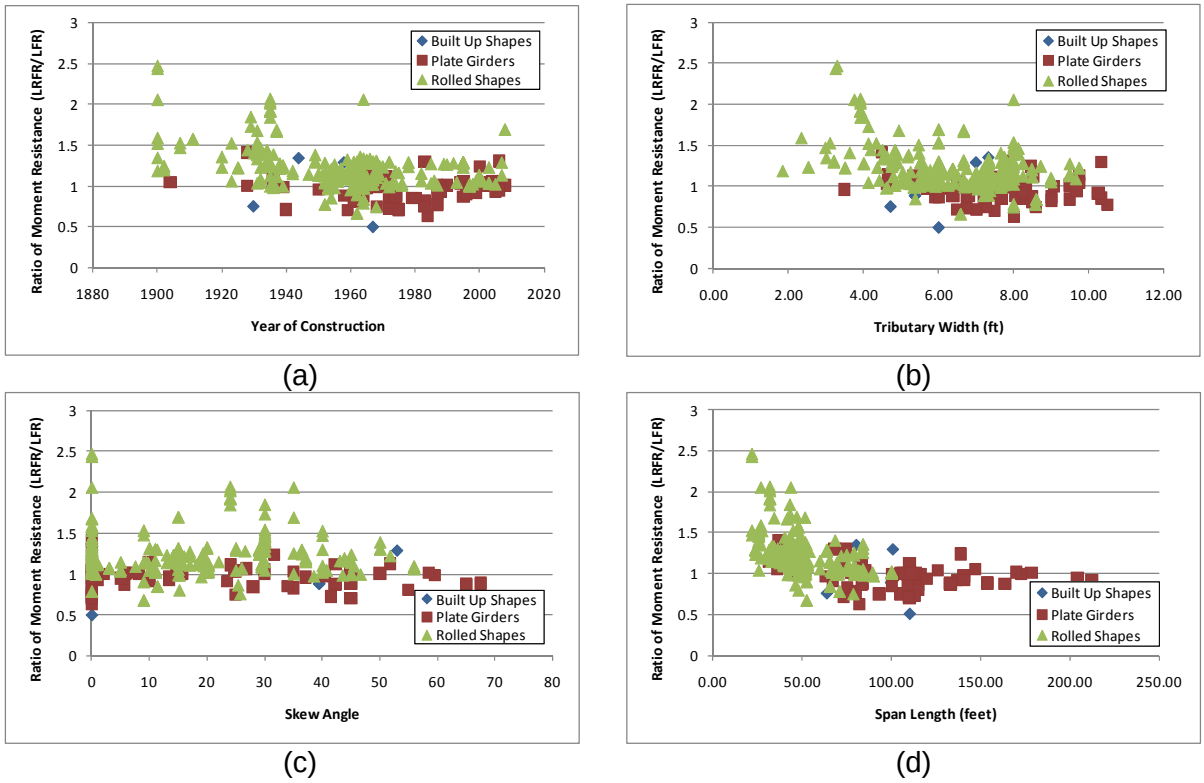
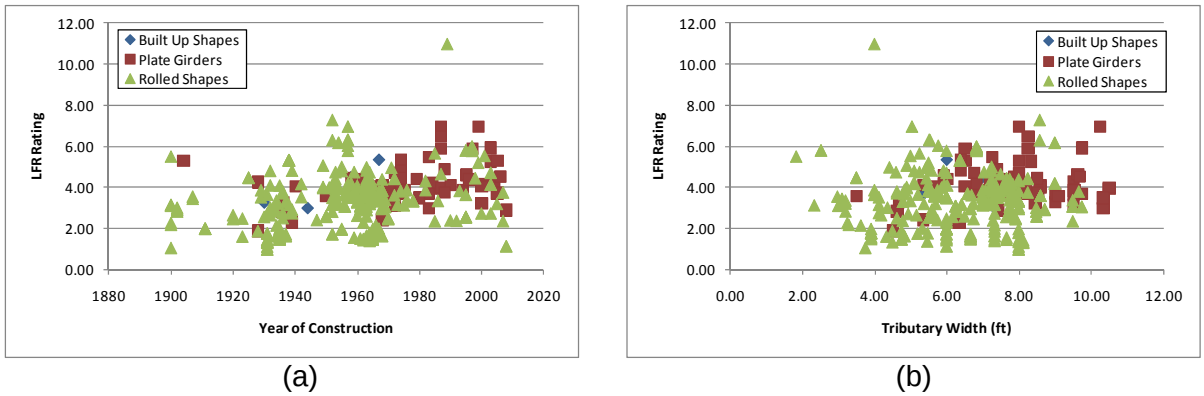
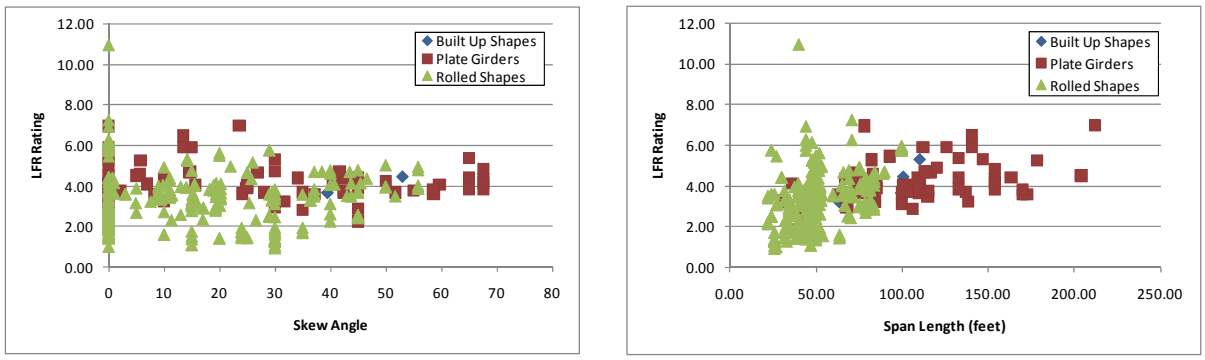


Figure B-238: Ratio of Factored Moment Resistance (LRFR/LFR)

B.1.11.1.3 Rating Factors

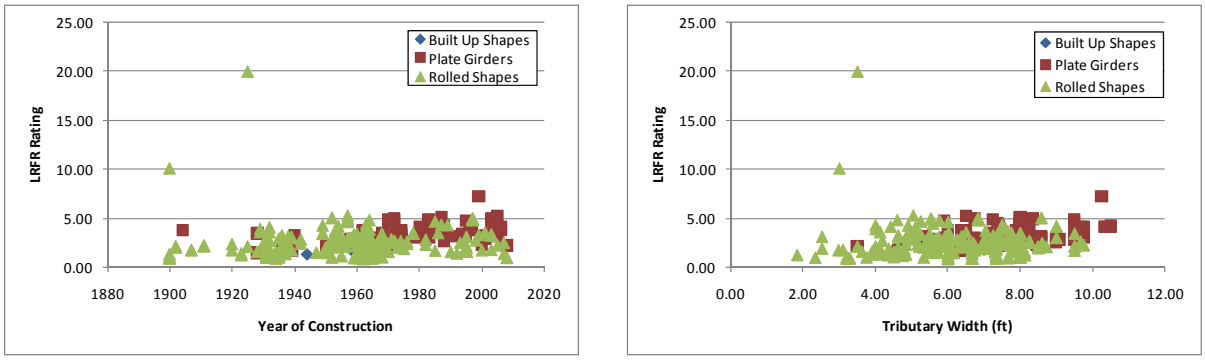
Figure B-239 and Figure B-240 present the LFR and LRFR ratings from BRASS, respectively. There are two girders with an LFR rating less than 1.0, twelve girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Ignoring the outliers, the two methods provide similar scatter with the LRFR rating shifted down from the LFR rating.



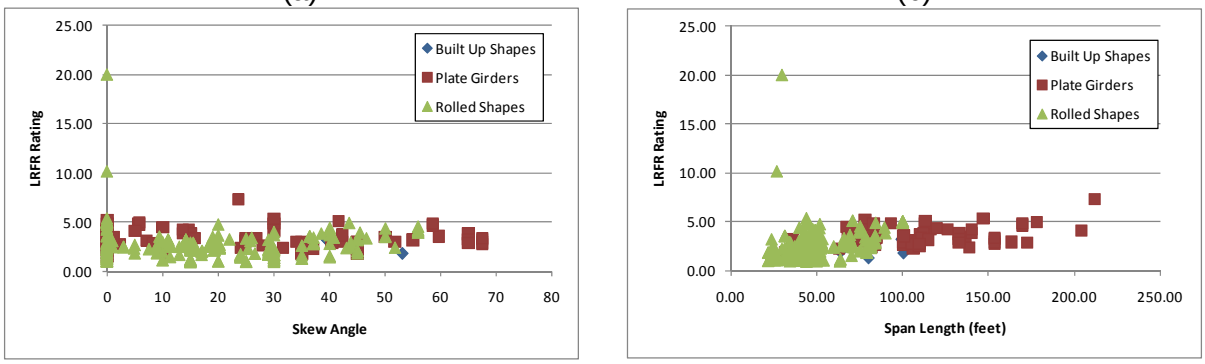


(c) (d)

Figure B-239: LFR Flexure Ratings for AASHTO Type 3 Vehicle



(a) (b)



(c) (d)

Figure B-240: LRFR Flexure Ratings for AASHTO Type 3 Vehicle

B.1.11.1.4 Rating Factor Comparisons

Figure B-241 shows that the ratio of rating factors, LRFR to LFR, is generally less than 1.0. 90% of LRFR ratings are less than the LFR rating for the same girder. The ratio is generally between 0.5 and 1.0, with closely spaced girders having slightly lower ratios. The ratio is not significantly affected by the type of girder, except that the closely spaced girders are typically rolled shapes and these have lower ratios.

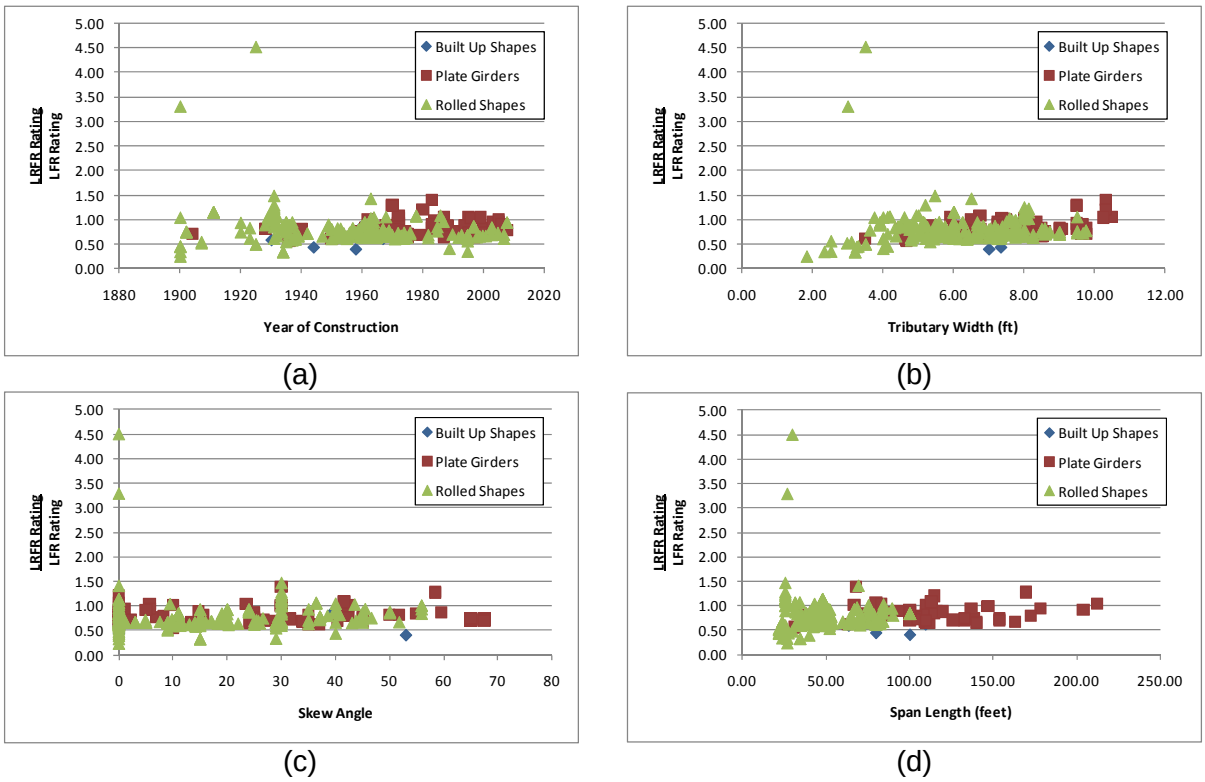
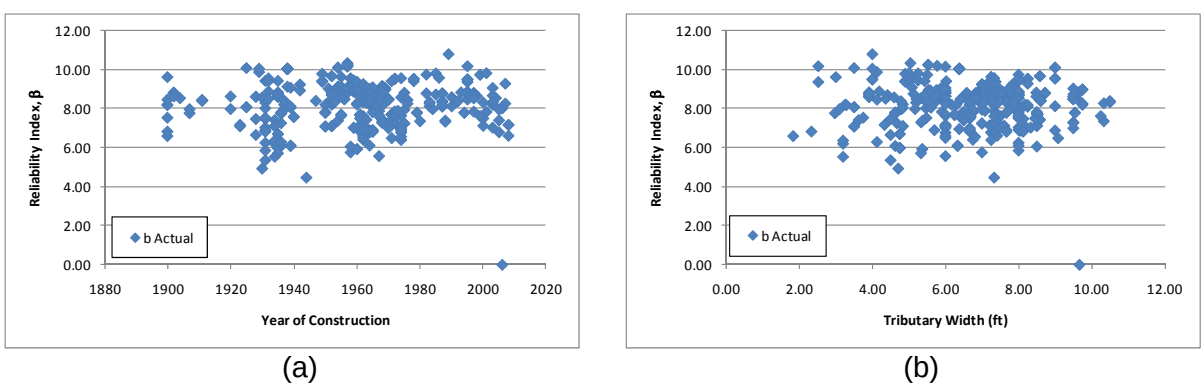
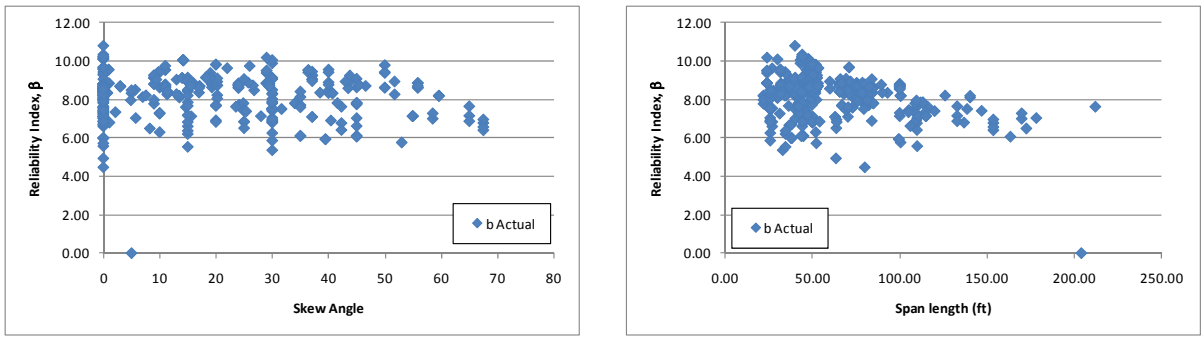


Figure B-241: Ratio of LRFR Flexure Rating to LFR Flexure Rating for AASHTO Type 3 Vehicle

B.1.11.1.5 Reliability Indices

Figure B-242 presents the reliability indices as calculated. The required reliability index for the AASHTO Legal Vehicles is 2.5, which all girders exceed except for one. The reliability index decreases with larger skew angles and longer span lengths. This is expected because the mean loads increase with increasing skew and span length.





(c) (d)

Figure B-242: Flexure Reliability Indices for AASHTO Type 3 Vehicle

Figure B-243 shows the actual reliability index plotted versus the LRFR rating factor for the AASHTO Type 3 truck. A girder passing rating will have a reliability index of at least four as shown in the figure. The required reliability index for the AASHTO Legal Loads is 2.5, which is exceeded with the current load factors. Therefore, the live load factors could be reduced and the level of reliability maintained.

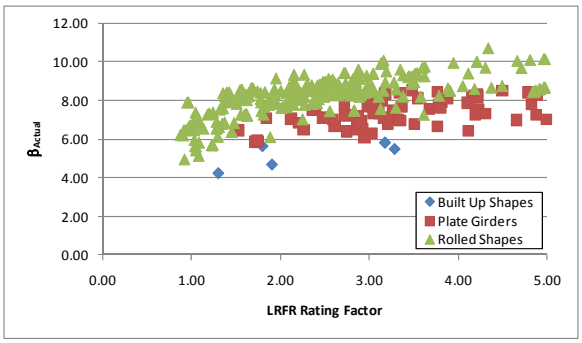


Figure B-243: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

B.1.11.2 Shear

B.1.11.2.1 Live Loads

Figure B-244 and Figure B-245 show the ratio, LRFR to LFR, of unfactored and factored live load plus impact shear, respectively. The ratio of unfactored loads is generally between 1.0 and 1.5 and increases to between 1.5 and 2.0 for factored loads, and decrease with increasing tributary width (Figure B-244b and Figure B-245b). This is likely a result of the distribution factors as the LRFD equations limit the girder spacing to greater than 3.5 feet, while the LFR distribution factors are applicable to any girder spacing. Figure B-244c and Figure B-245c show that the ratio increases with increasing skew; this is an expected result as the LRFD Design Specification increases the load distributed to each girder because of the skew while the LFR Specification does not consider the effect of skew. Figure B-246 shows where the critical shear rating occurred for each girder. The LFR location is typically away from the support while the LRFR location is typically at the support.

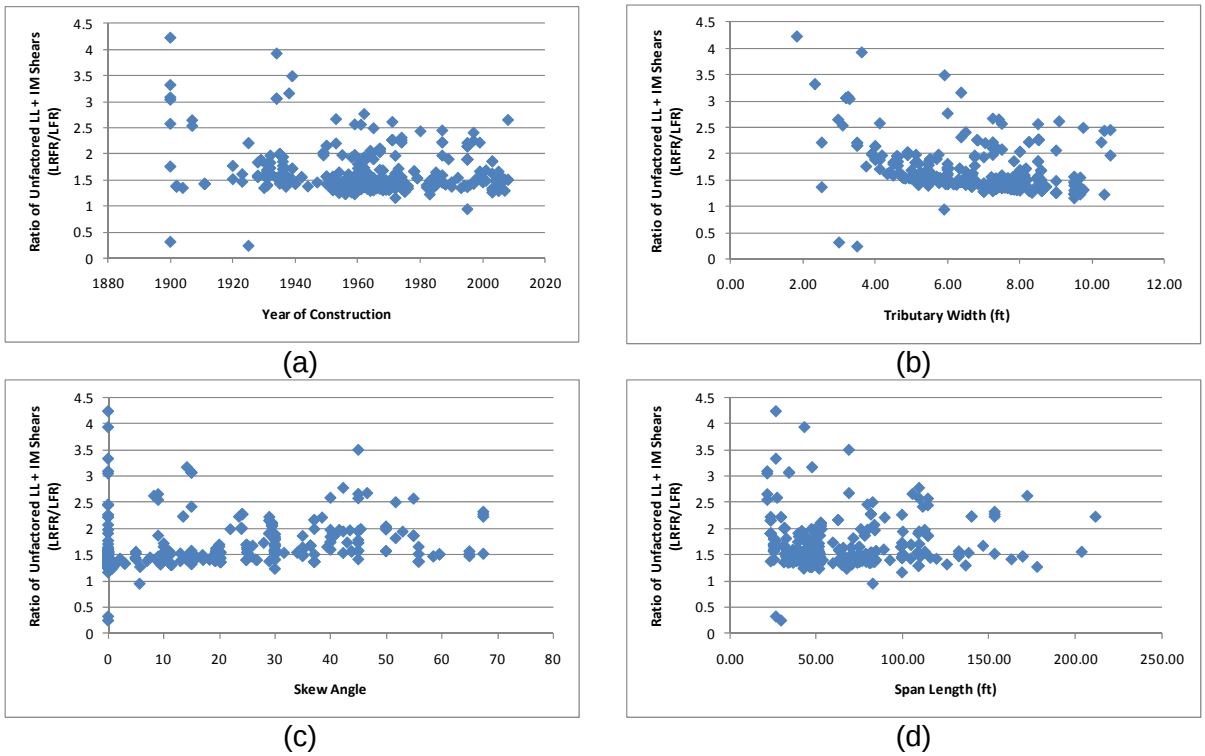


Figure B-244: Ratio of Unfactored Live Load plus Impact Shear for AASHTO Type 3 Vehicle (LRFR/LFR)

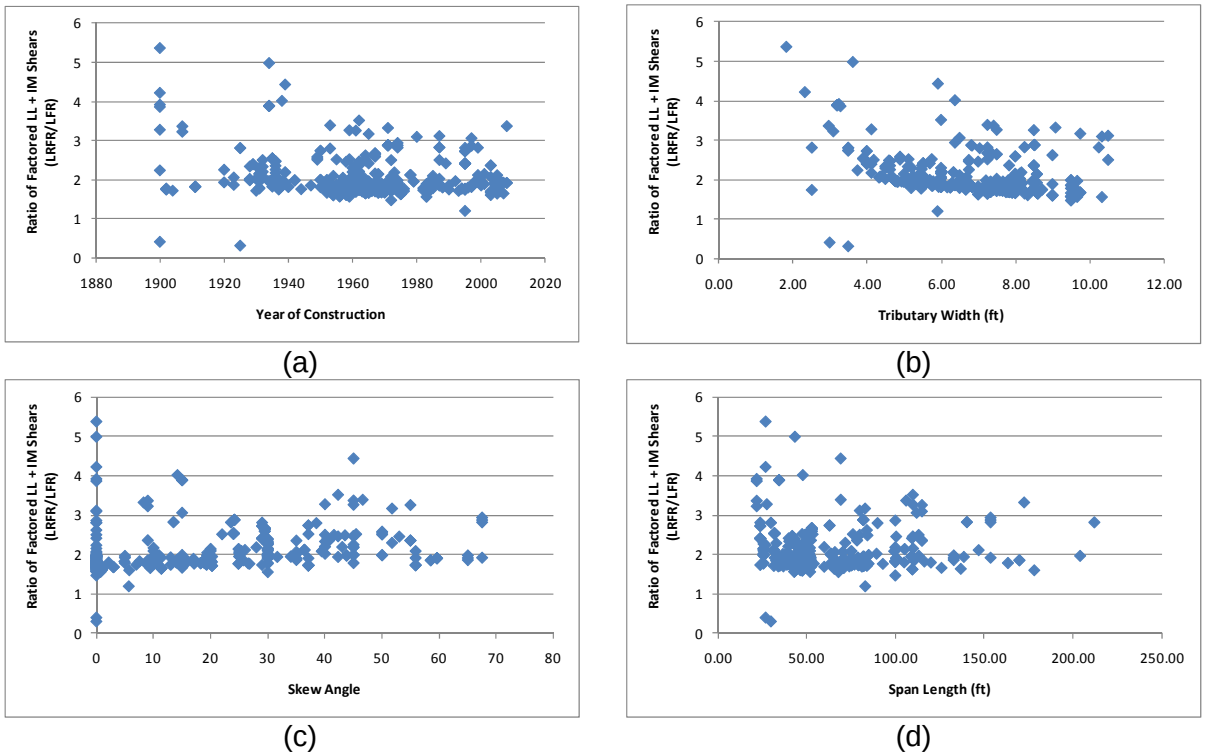


Figure B-245: Ratio of Factored Live Load plus Impact Shear for AASHTO Type 3 Vehicle (LRFR/LFR)

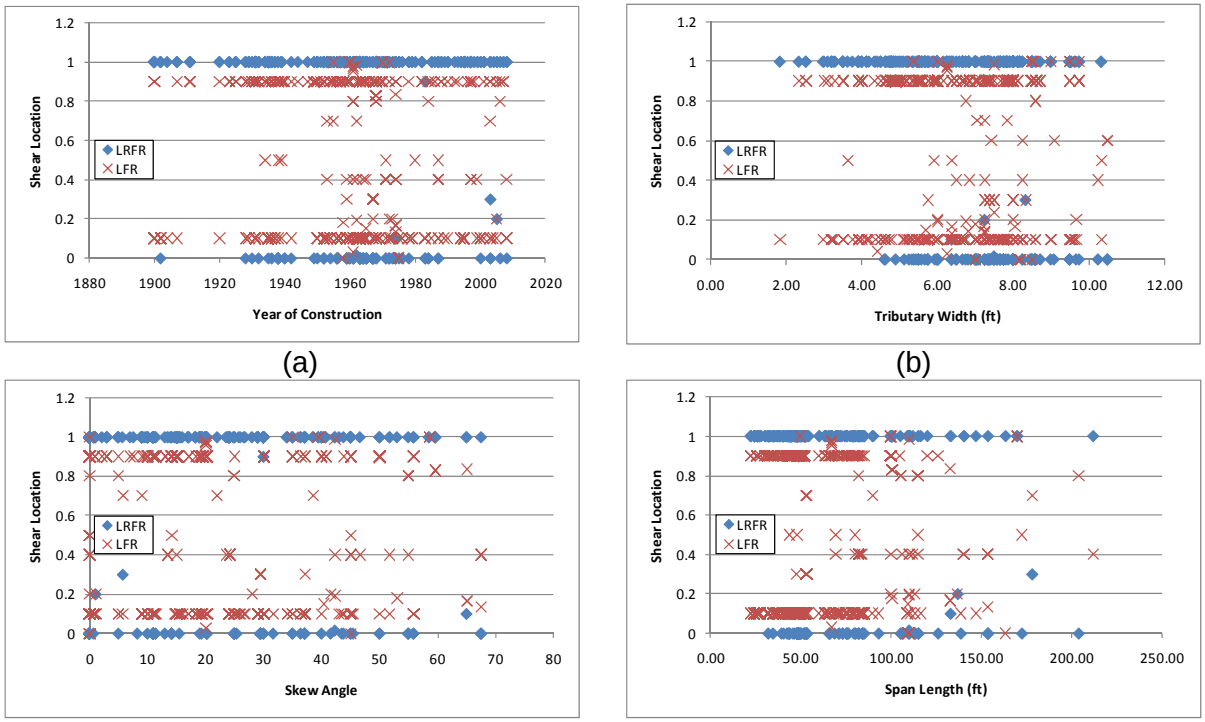
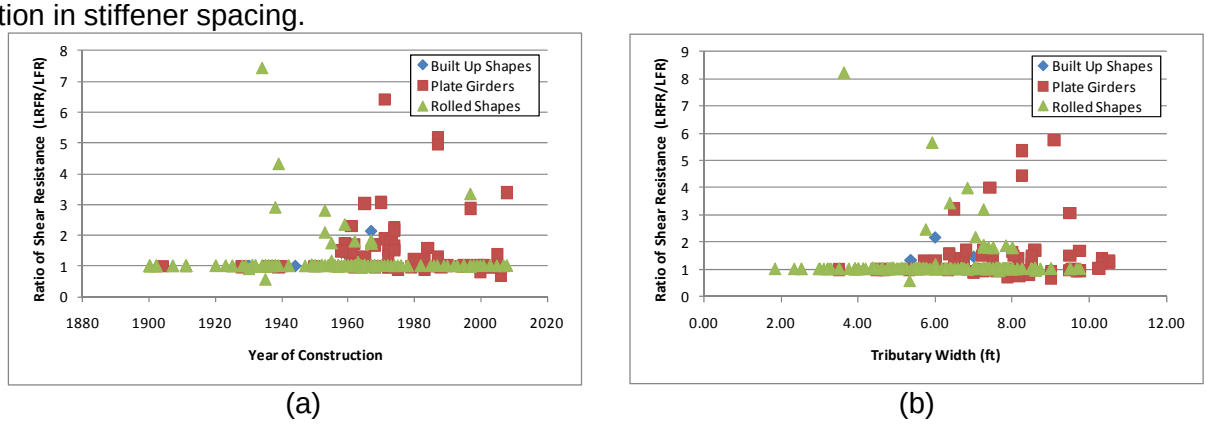
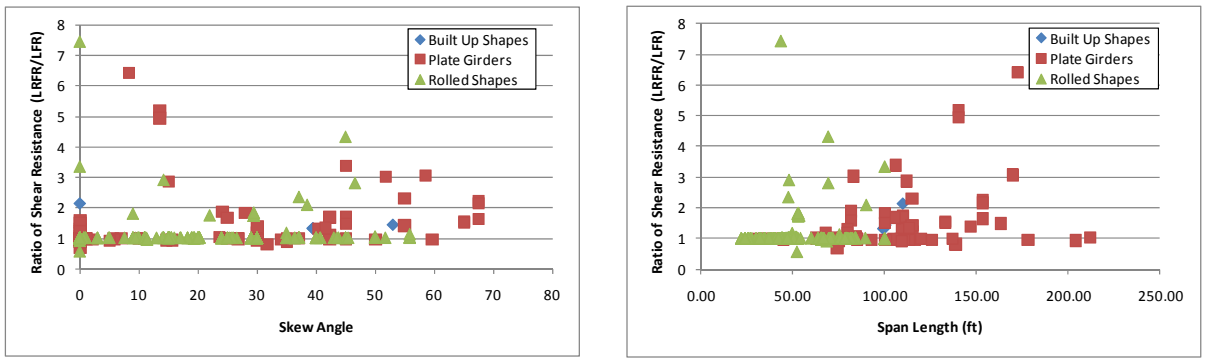


Figure B-246: Critical Shear Location for AASHTO Type 3 Vehicle

B.1.11.2.2 Resistances

Figure B-247 shows the ratio of factored shear resistances. The ratio is generally close to 1.0, with most of the scatter being eliminated by removing those girders where the critical shear location varies significantly (Section B.1.10.3.2). Almost all rolled shapes have a resistance ratio of 1.0, while plate girders have more variation. This variation results from the different locations and also from the variation in stiffener spacing.



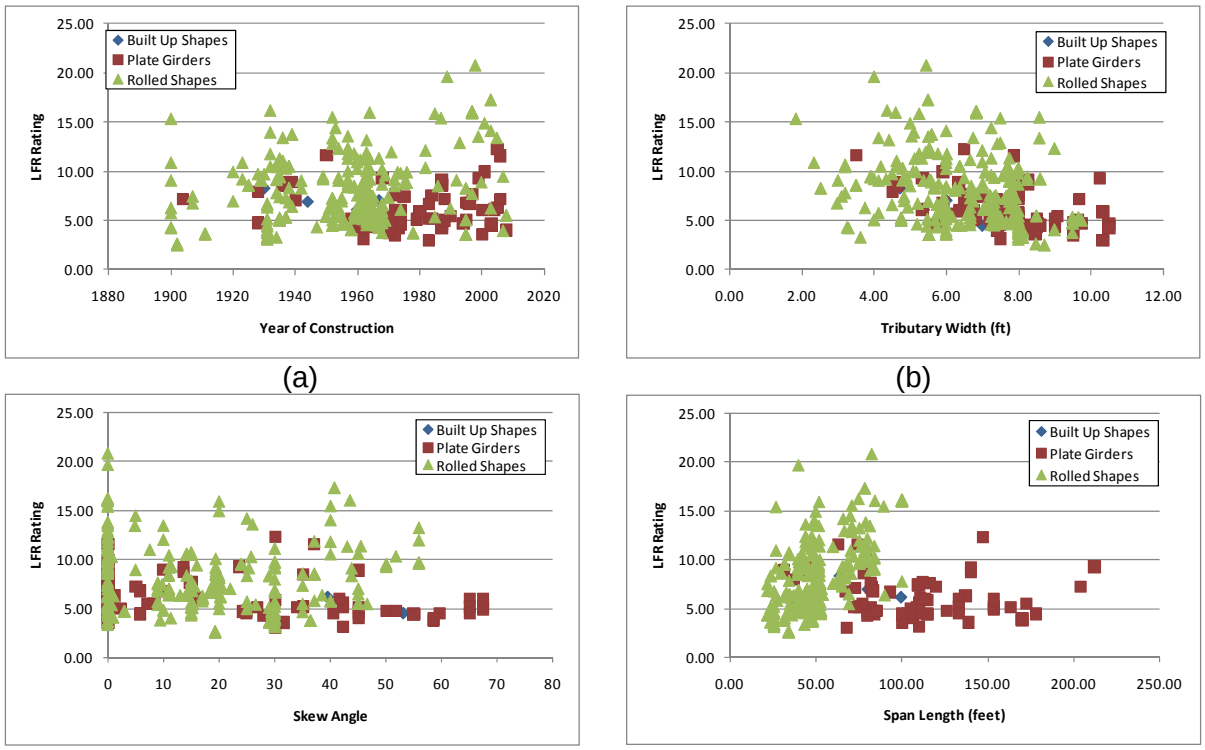


(c) (d)

Figure B-247: Ratio of Factored Shear Resistances (LRFR/LFR)

B.1.11.2.3 Rating Factors

Figure B-248 and Figure B-249 present the ratings as calculated by BRASS for LFR and LRFR, respectively. The LFR Ratings tend to decrease with increasing tributary width and increasing span length (Figure B-248b and d). There is also less scatter with increasing span length (Figure B-248d). There are zero girders with an LFR rating of less than 1.0 and seven girders with an LRFR rating less than 1.0. Additionally, 98% of the girders have LFR Ratings greater than the LRFR rating.



(a) (b)

(c) (d)

Figure B-248: LFR Shear Ratings for AASHTO Type 3 Vehicle

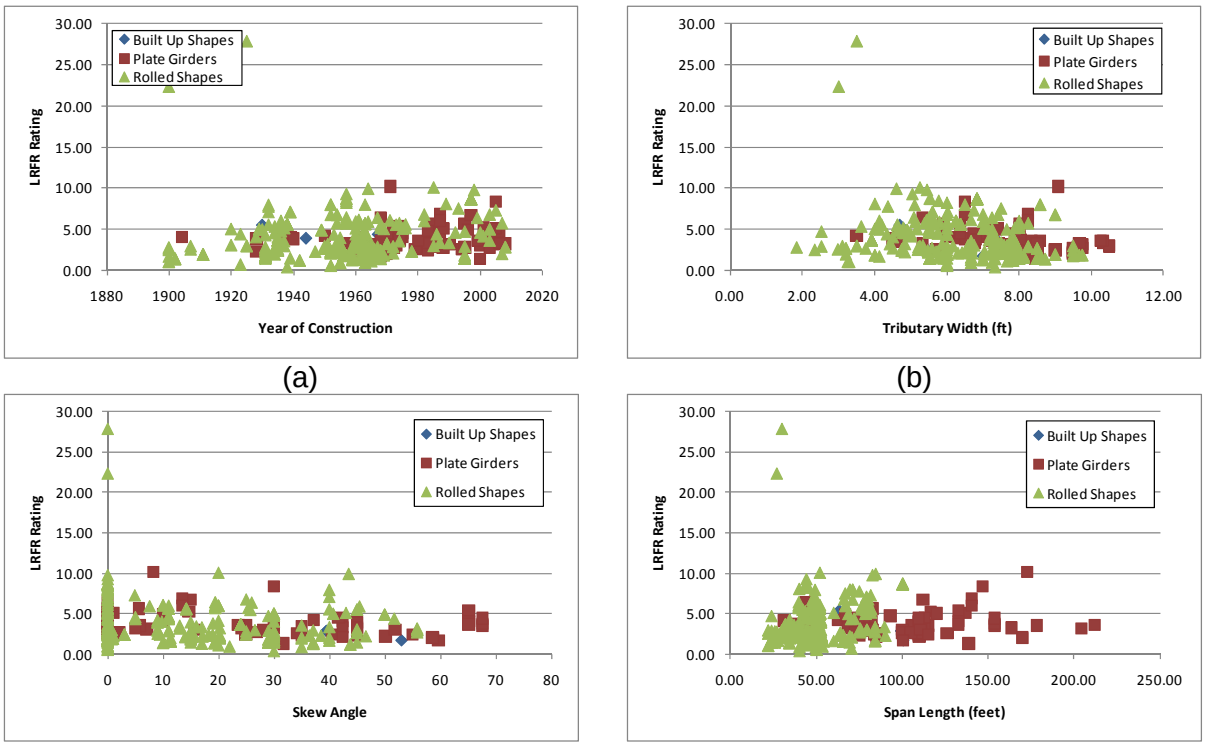
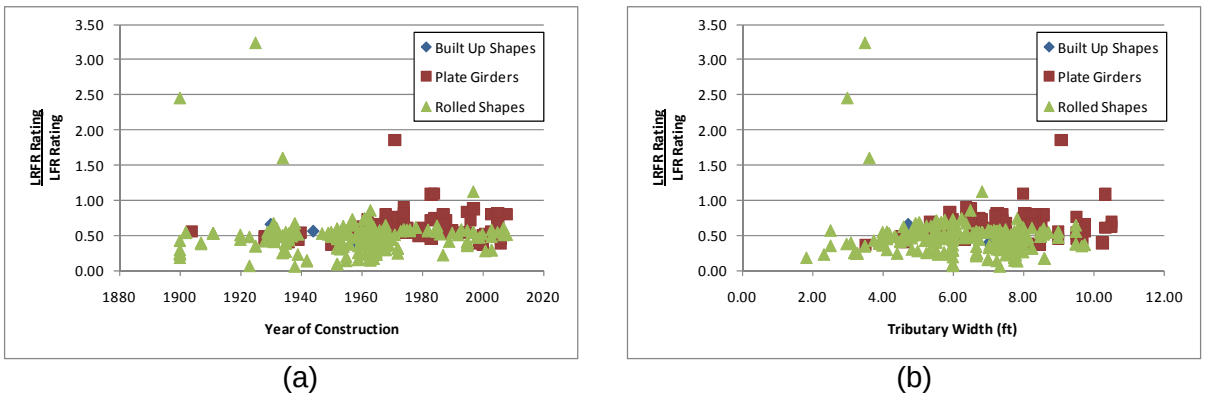
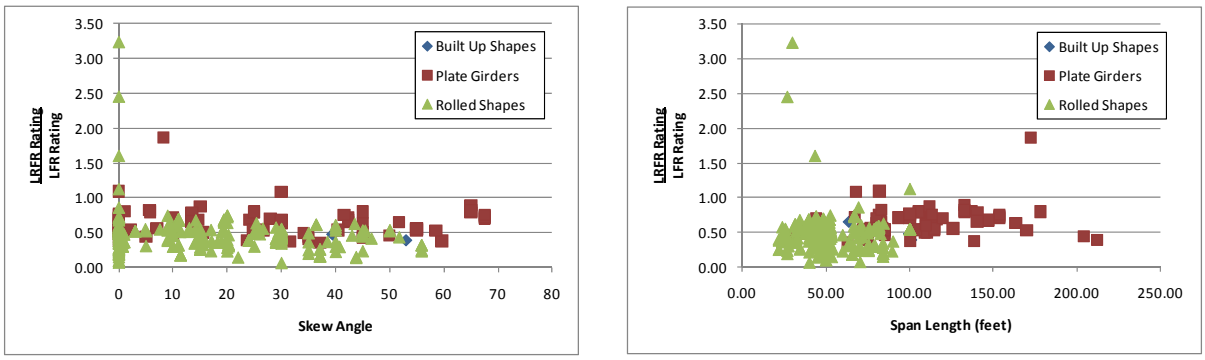


Figure B-249: LRFR Shear Ratings for AASHTO Type 3 Vehicle

B.1.11.2.4 Rating Factor Comparisons

Figure B-250 present the ratio of LRFR rating factor to LFR rating factor. The ratio of ratings is generally less than 1.0 with rolled shapes typically less than 0.5 while for plate girders the ratio is generally between 0.5 and 1.0.



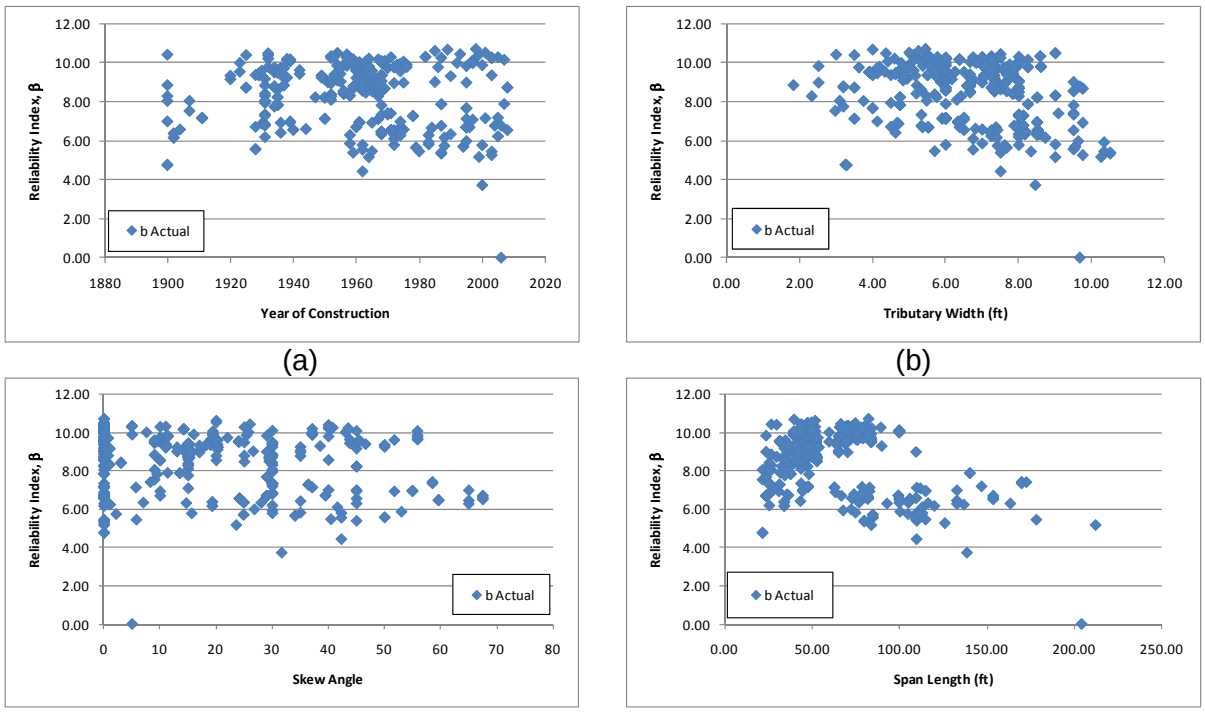


(c) (d)

Figure B-250: Ratio of LRFR Shear Rating to LFR Shear Rating for AASHTO Type 3 Vehicle

B.1.11.2.5 Reliability Indices

Figure B-251 shows the reliability indices as calculated based upon the strength of the section. The reliability index assumed in the MBE development is 2.5, which with the exception of one girder is met. The reliability index has no clear trends based upon the criteria which it was plotted against.



(a) (b)

(c) (d)

Figure B-251: Shear Reliability Indices for AASHTO Type 3 Vehicle

Figure B-252 shows the actual shear reliability index plotted against the LRFR shear rating. The figure shows that a girder with a rating factor of 1.0 is expected to have a reliability index of at least 3.5, which is greater than the required value of 2.5 for the AASHTO Type 3 vehicle. This indicates that a lower live load factor could be used without affecting the reliability.

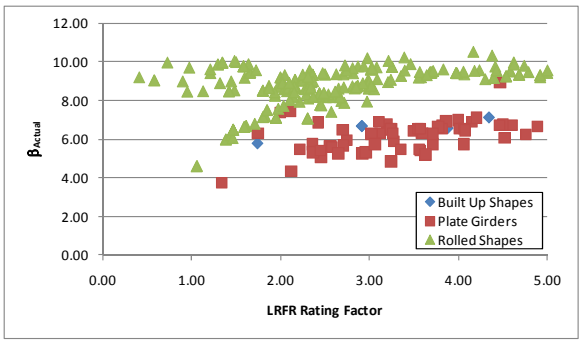


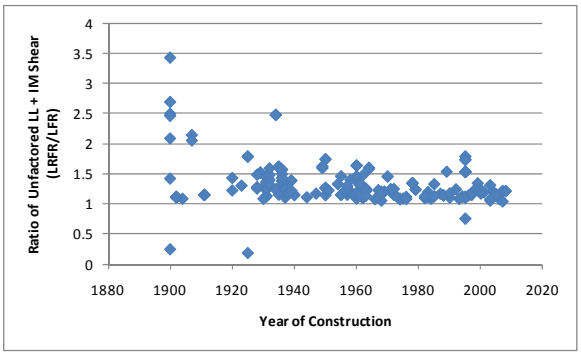
Figure B-252: Shear Reliability Index vs LRFR Shear Rating

B.1.11.3 Shear-Corrected

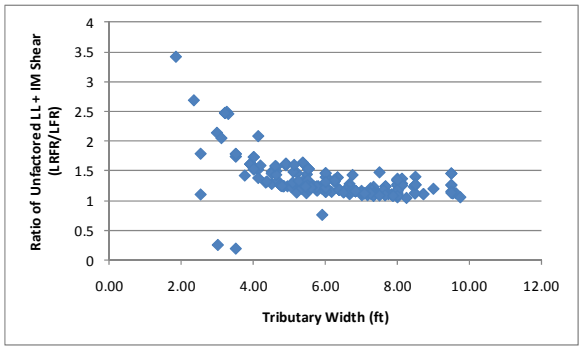
This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.11.3.1 Live Load

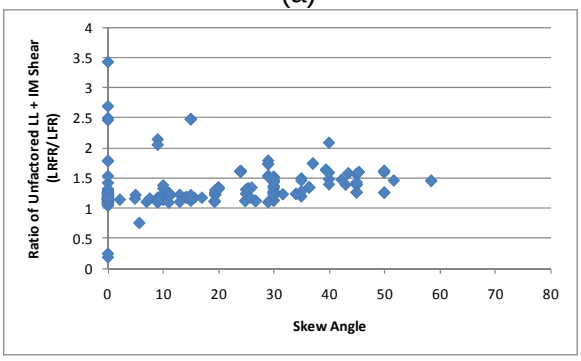
Figure B-253 and Figure B-254 show the ratio of unfactored and factored live load plus impact shear for those girders with critical locations at the either the support or one-tenth of the span away from the support. The unfactored LRFR live load shear is typically 1.0 to 1.5 times the unfactored LFR live load shear. The ratio of factored loads increases to the range of 1.3 to 2.0, due to the difference in live load factors. The ratio has been reduced from the previous section where the loads were taken from different locations.



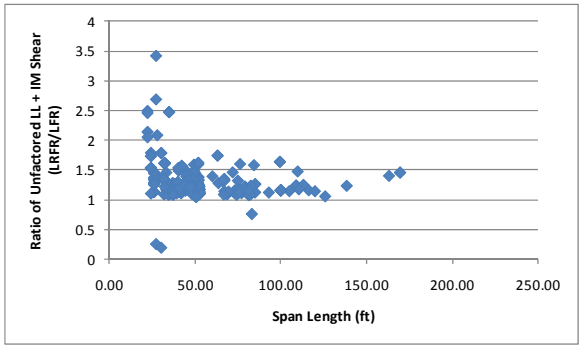
(a)



(b)

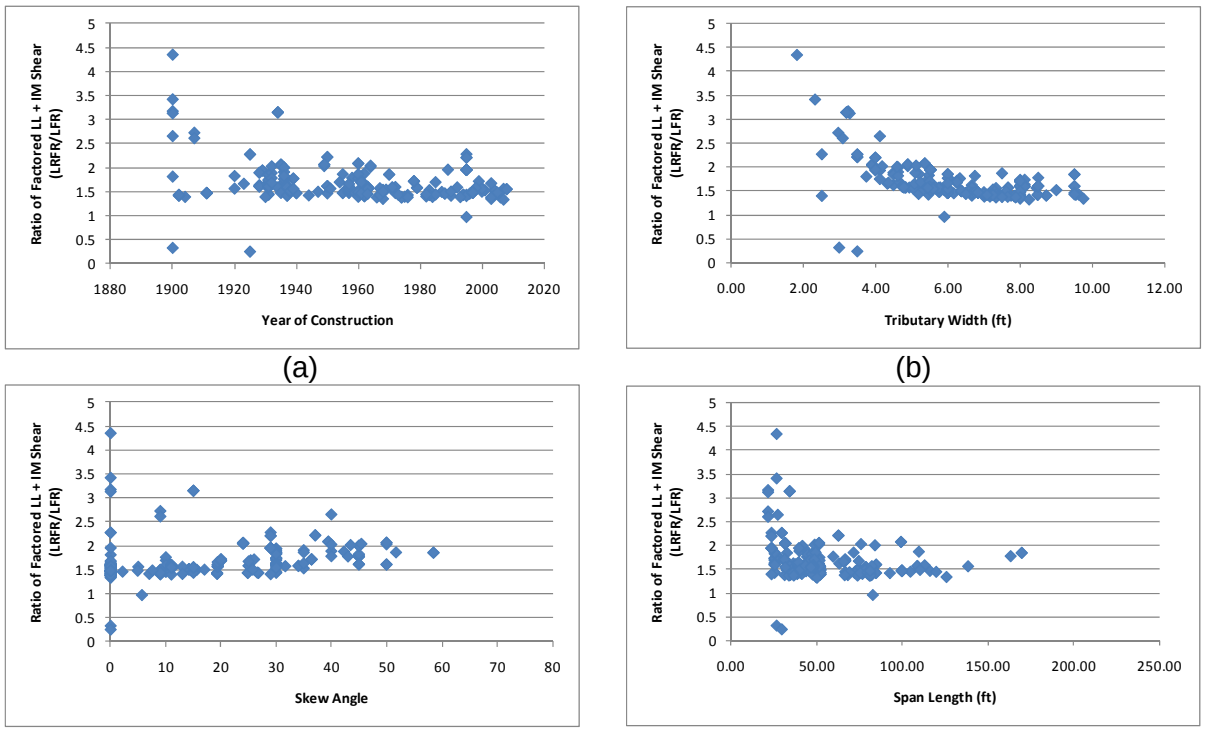


(c)



(d)

Figure B-253: Ratio of Unfactored Live Load plus Impact Shear for AASHTO Type 3 Vehicle (LRFR/LFR)



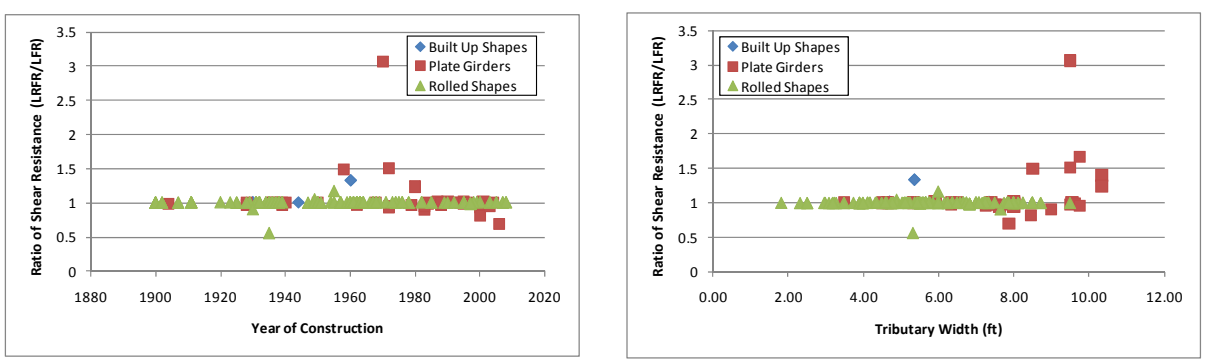
(a) (b)

(c) (d)

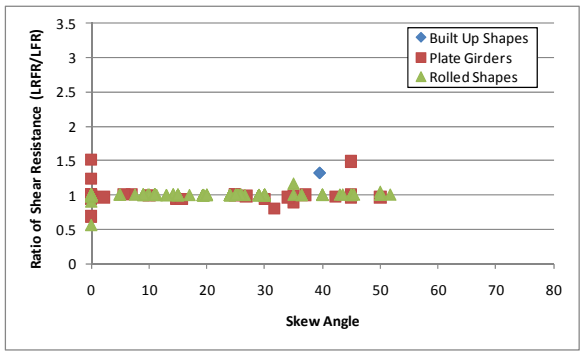
Figure B-254: Ratio of Factored Live Load plus Impact Shear for AASHTO Type 3 Vehicle (LRFR/LFR)

B.1.11.3.2 Resistance

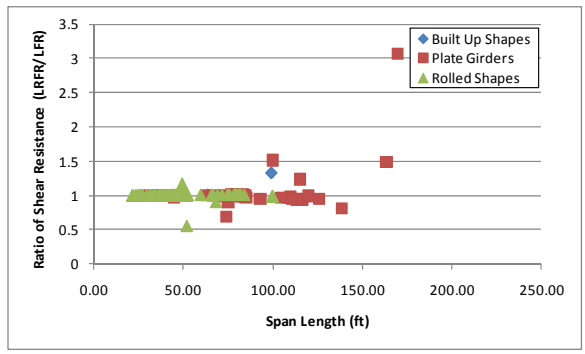
The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was less than 1.0 have been eliminated by considering only those near the support. The ratio of shear resistance is shown in Figure B-255.



(a) (b)



(c)

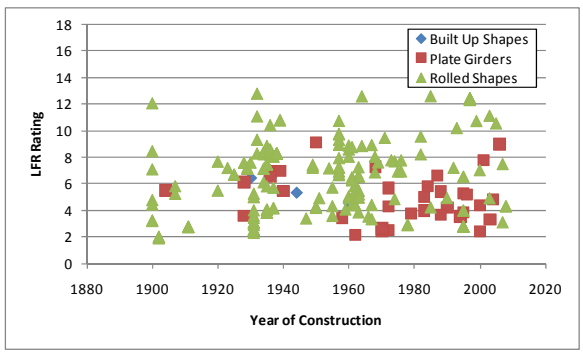


(d)

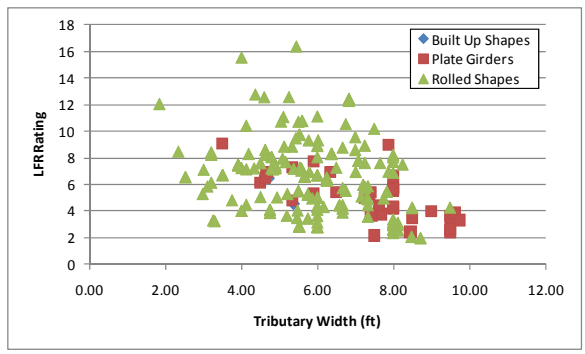
Figure B-255: Ratio of Factored Shear Resistance

B.1.11.3.3 Rating Factors

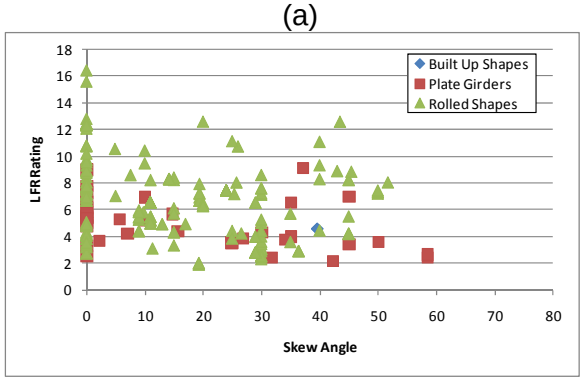
After verifying that the live load shears and shear resistances were reasonable, the next step was to compare the rating factors. Figure B-256 and Figure B-257 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where the shear resistance would vary along the span length.



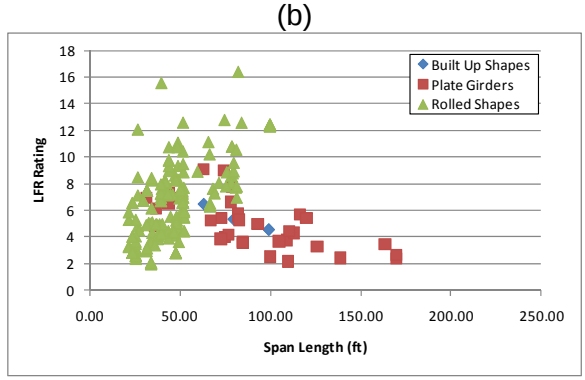
(a)



(b)

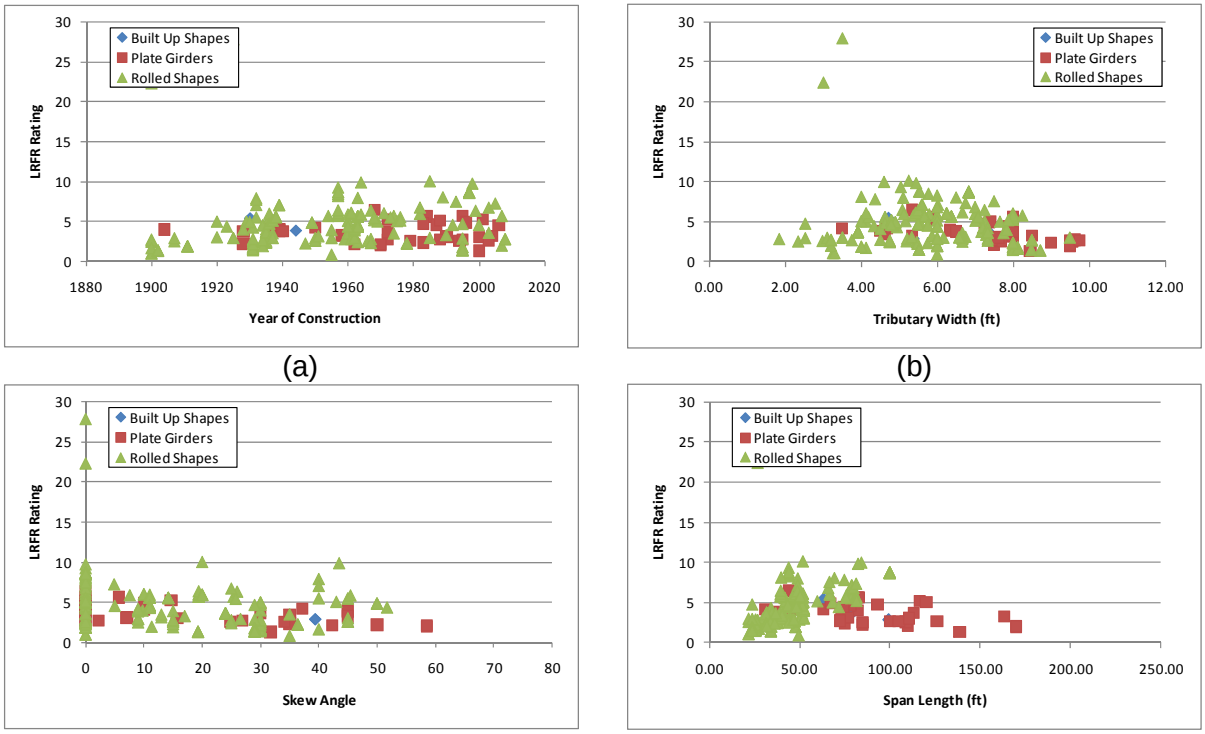


(c)



(d)

Figure B-256: LFR Shear Rating Factor for AASHTO Type 3 Vehicle



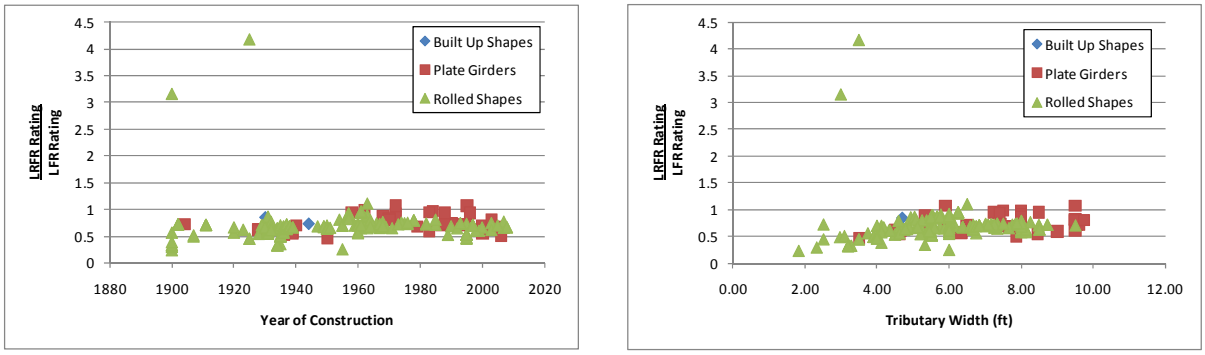
(a) (b)

(c) (d)

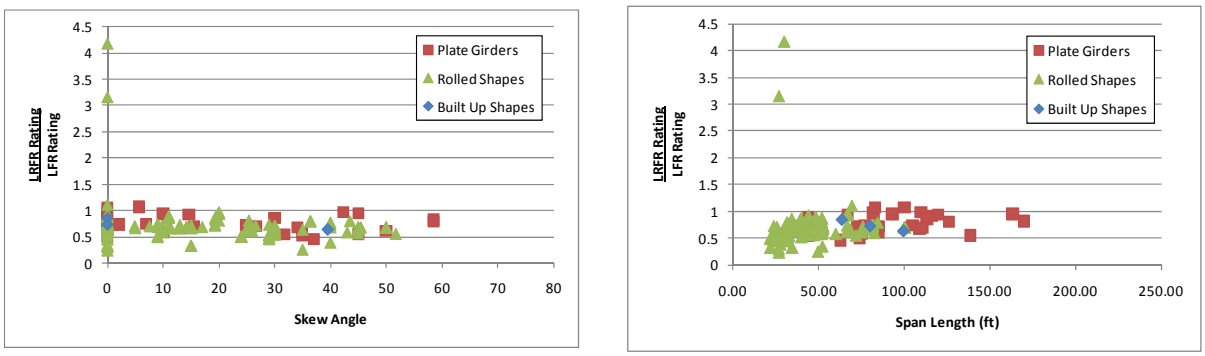
Figure B-257: LRFR Shear Rating Factor for AASHTO Type 3 Vehicle

B.1.11.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio of the LRFR rating factor to the LFR rating factor. Figure B-258 shows the results of this comparison. The results show that the LFR rating is typically greater than the LRFR rating. While the LFR rating is still greater than LRFR rating, the ratio has increased slightly with more girders having a ratio greater than 0.5.



(a) (b)

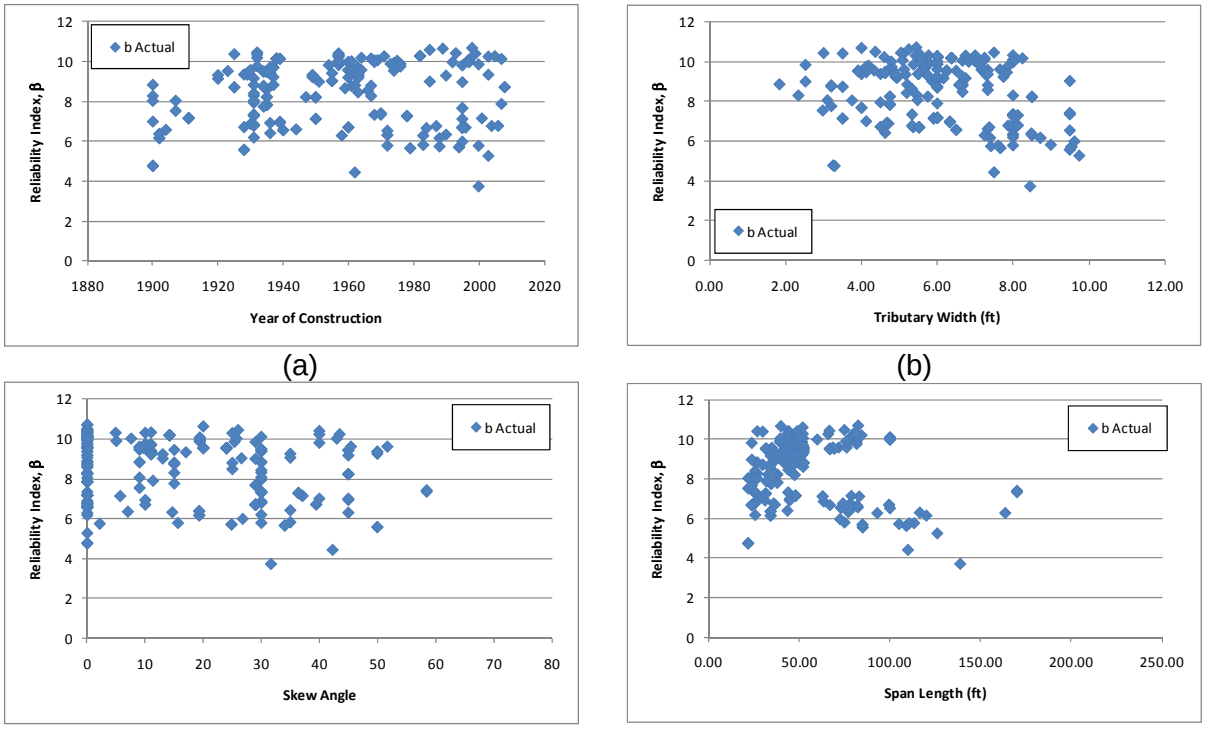


(c) (d)

Figure B-258: Ratio of LRFR Shear Rating to LFR Shear Rating for AASHTO Type 3 Vehicle

B.1.11.3.5 Reliability Indices

The reliability indices shown in Figure B-259 are the same as those shown in Figure B-251. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 2.5. The reliability index remains the same as calculated previously because the LRFR location did not move.



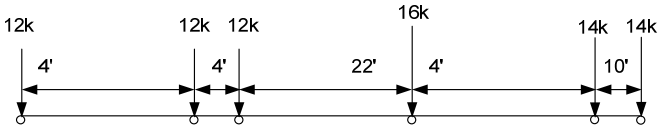
(a) (b)

(c) (d)

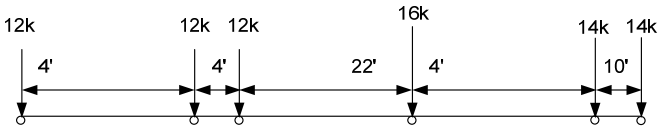
Figure B-259: Shear Reliability Indices for AASHTO Type 3 Vehicle

B.1.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-260. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.



LFR Loading



for spans greater than 200 feet, use 75% of this vehicle combined with a 0.2 klf lane load

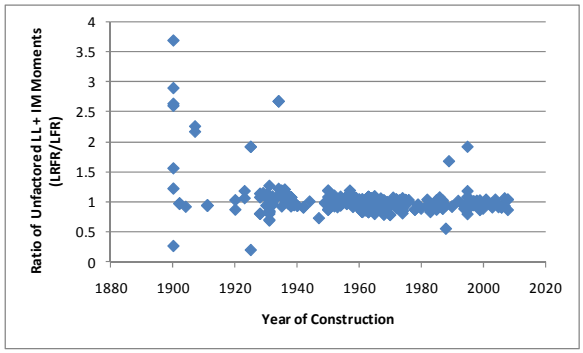
LRFR Loading

Figure B-260: Vehicle Loadings and Load Factors

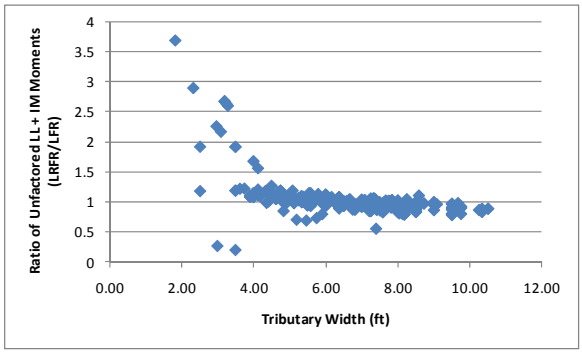
B.1.12.1 Moment

B.1.12.1.1 Live Loads

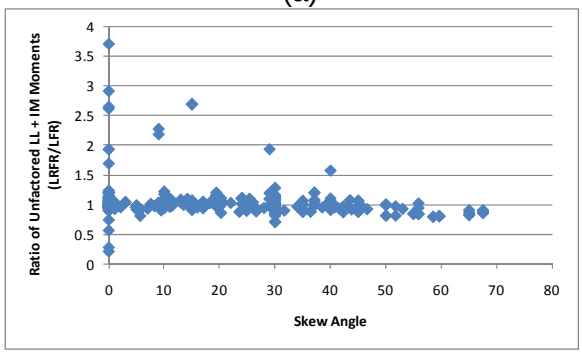
Figure B-261 and Figure B-262 shows the ratios of unfactored and factored live load plus impact moments for the Type 3-3 vehicle; the ratio is LRFR moment divided by LFR moment. The LRFR moments due to live load plus impact are typically around 75-125% of the LFR moments, for the unfactored case. For the factored loads, the LRFR live load increased to 100 to 150% of the LFR live load. The ratio tends to decrease with increasing tributary width (Figure B-261b and Figure B-262b), while there is less scatter for increasing span lengths (Figure B-261d and Figure B-262d).



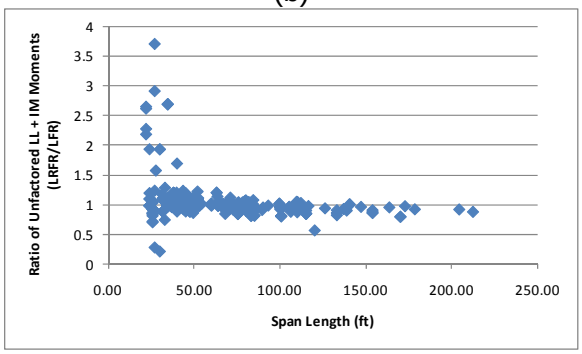
(a)



(b)



(c)



(d)

Figure B-261: Ratio of Unfactored Live Load plus Impact Moment for Type 3-3 Vehicle (LRFR/LFR)

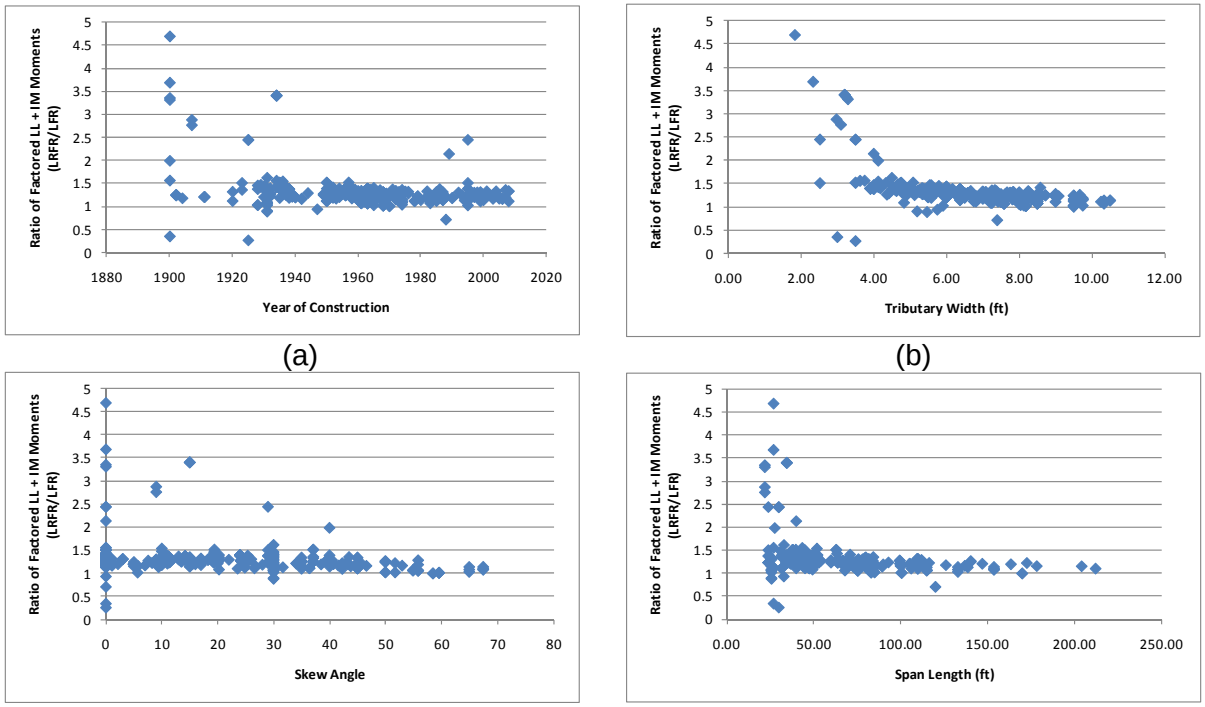


Figure B-262: Ratio of Factored Live Load plus Impact Moment for Type 3-3 Vehicle (LRFR/LFR)

B.1.12.1.2 Resistances

Figure B-263 shows the ratio of the factored moment resistances. The ratio of resistance is generally above 1.0 for rolled shapes and less than 1.0 for plate girders. Built-up shapes do not typically have resistance that is higher or lower for a specific method.

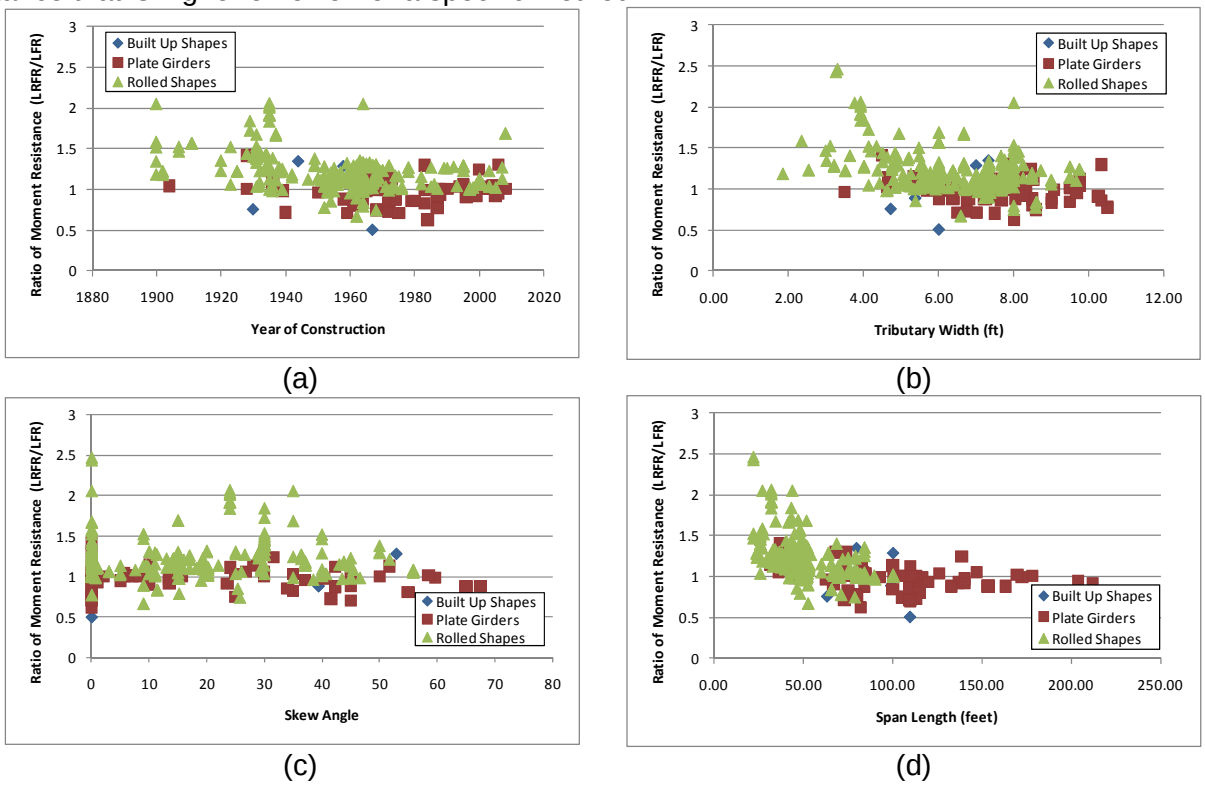


Figure B-263: Ratio of Factored Moment Resistance (LRFR/LFR)

B.1.12.1.3 Rating Factors

Figure B-264 and Figure B-265 present the LFR and LRFR ratings from BRASS, respectively. There are zero girders with an LFR rating less than 1.0, one girder with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Ignoring the outliers, the two methods provide similar scatter with the LRFR rating shifted down from the LFR rating.

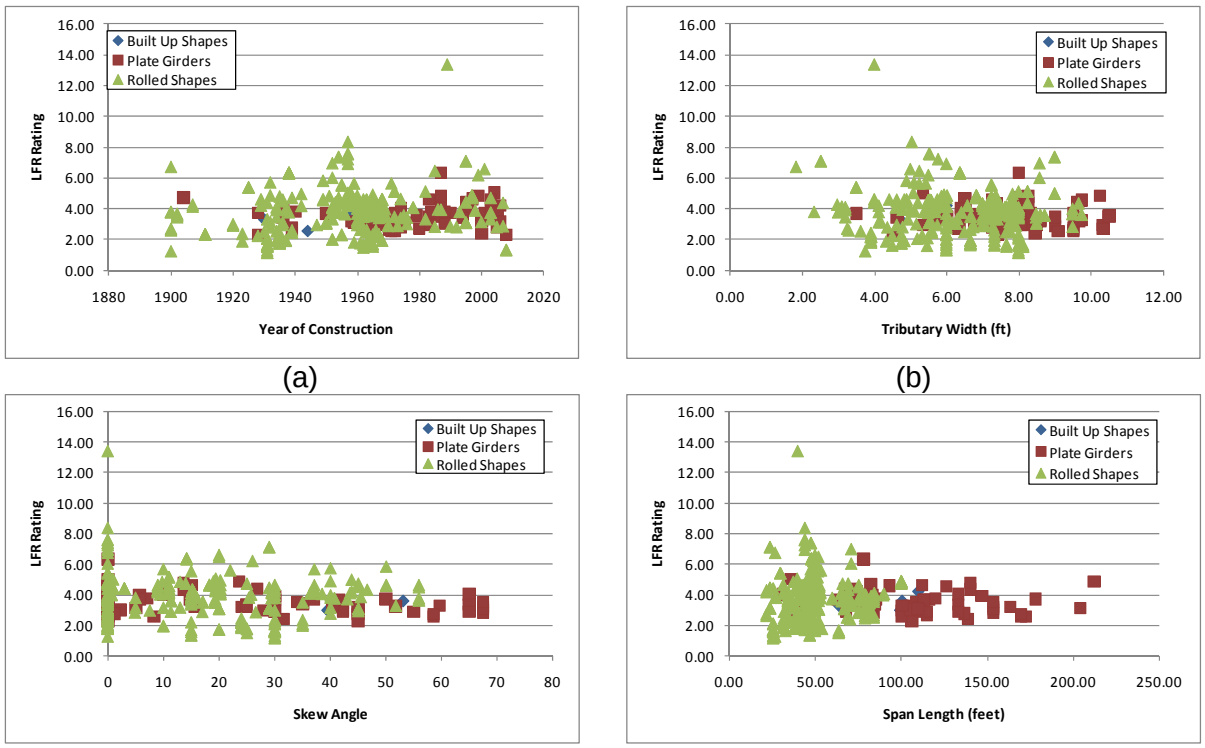
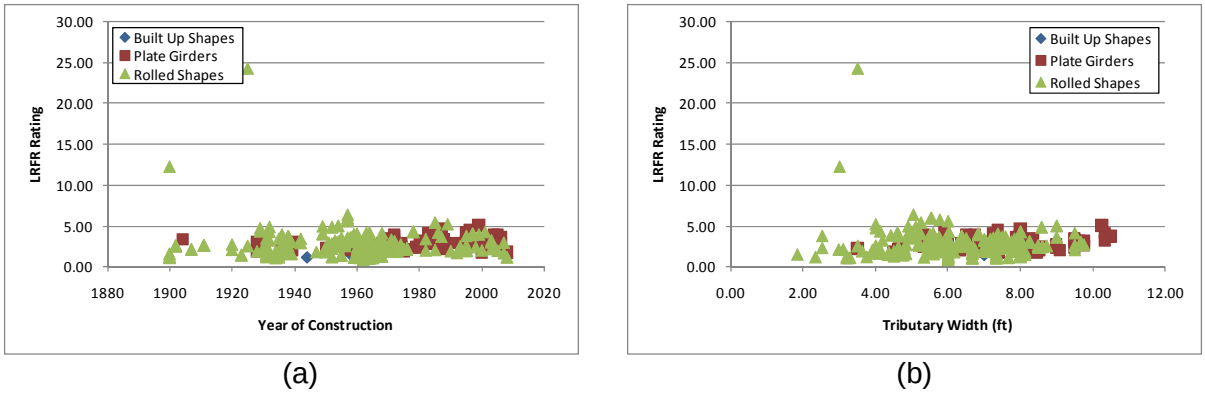
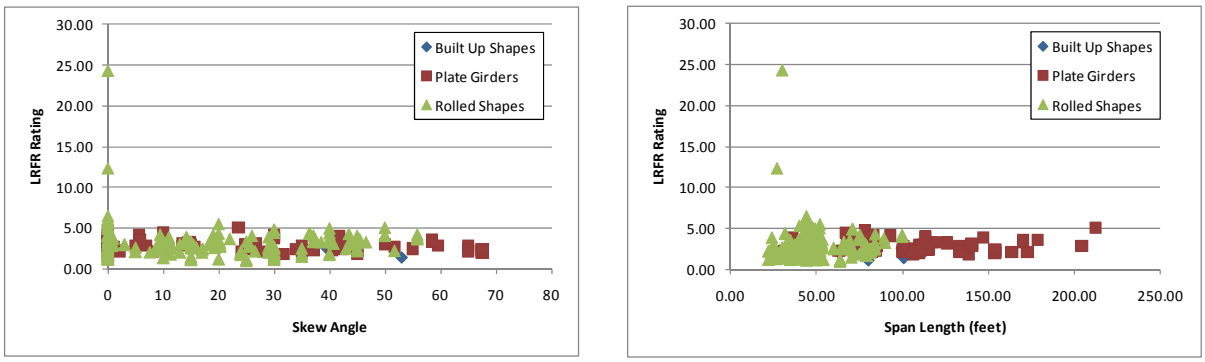


Figure B-264: LFR Flexure Ratings for Type 3-3 Vehicle



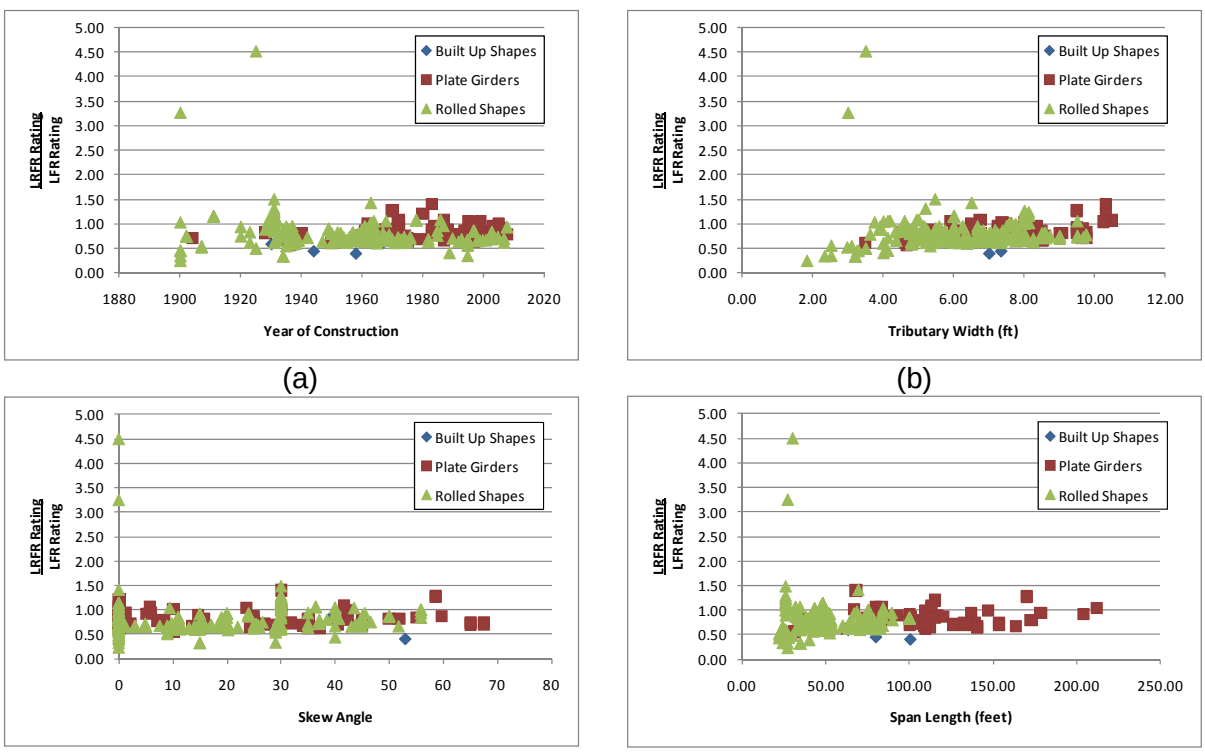


(c) (d)

Figure B-265: LRFR Flexure Ratings for Type 3-3 Vehicle

B.1.12.1.4 Rating Factor Comparisons

Figure B-266 shows that for most girders (90%) the ratio of ratings (LRFR to LFR) is between 0.5 and 1.0, with several greater than 1.0. There are also two outliers present; these outliers are girders located underneath a sidewalk. Closely spaced, short span rolled girders are likely to have LFR ratings significantly higher than the LRFR rating.



(a) (b)

(c) (d)

Figure B-266: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Type 3-3 Vehicle

B.1.12.1.5 Reliability Indices

Figure B-267 presents the reliability indices based on cross-section resistance. The reliability indices are greater than 2.5 assumed in the development of the MBE. The reliability index decreases with increasing span length but does not seem to be affected by any of the other criteria.

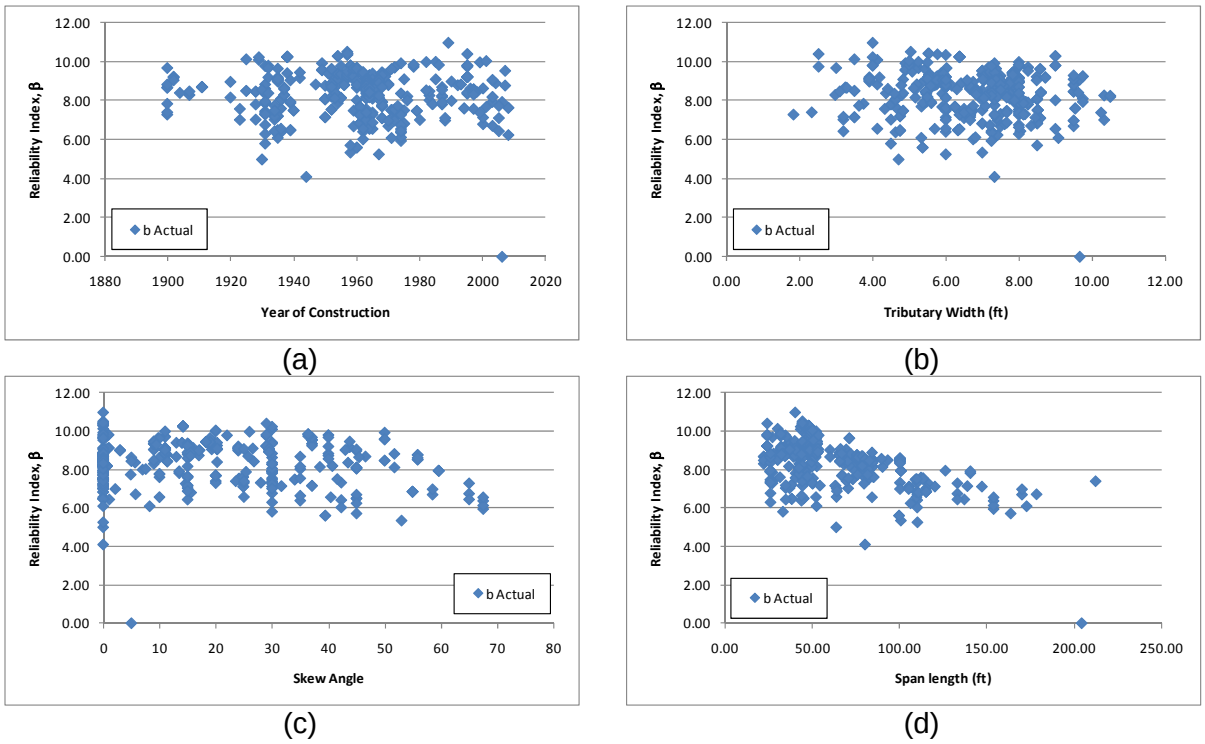


Figure B-267: Flexure Reliability Indices for Type 3-3 Vehicle

Figure B-268 shows the actual reliability index for flexure plotted against the LRFR flexure rating. The figure shows that girders passing rating have a reliability index higher than that assumed in the development of the MBE, which is 2.5 for the AASHTO Legal Vehicles. The live load factor could be reduced and still achieve the required level of reliability.

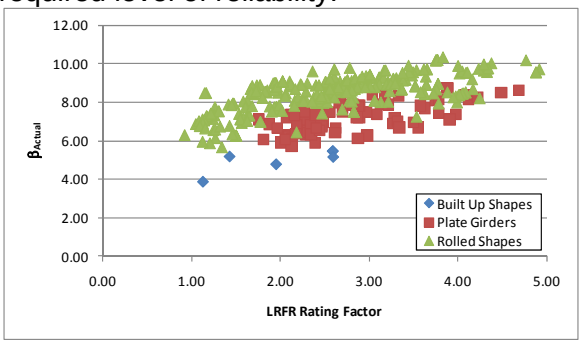


Figure B-268: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

B.1.12.2 Shear

B.1.12.2.1 Live Loads

Figure B-269 and Figure B-270 show the ratios of unfactored and factored live load plus impact shear, LRFR to LFR, respectively. The ratio of unfactored loads is about 1.5 and approaches 2.0 when the loads are factored, and decrease with increasing tributary width (Figure B-269b and Figure B-270b). This is likely a result of the distribution factors as the LRFD equations limit the girder spacing to greater than 3.5 feet, while the LFR distribution factors are applicable to any girder spacing. Figure B-269c and Figure B-270c shows that the ratio decreases with increasing skew; this is an expected result as the LRFD Specification increases the load distributed to each girder because of the skew while the

Standard Specification does not consider the effect of skew. Figure B-271 shows where the critical shear rating occurred for each girder. The LFR location is typically away from the support while the LRFD location is typically at the support.

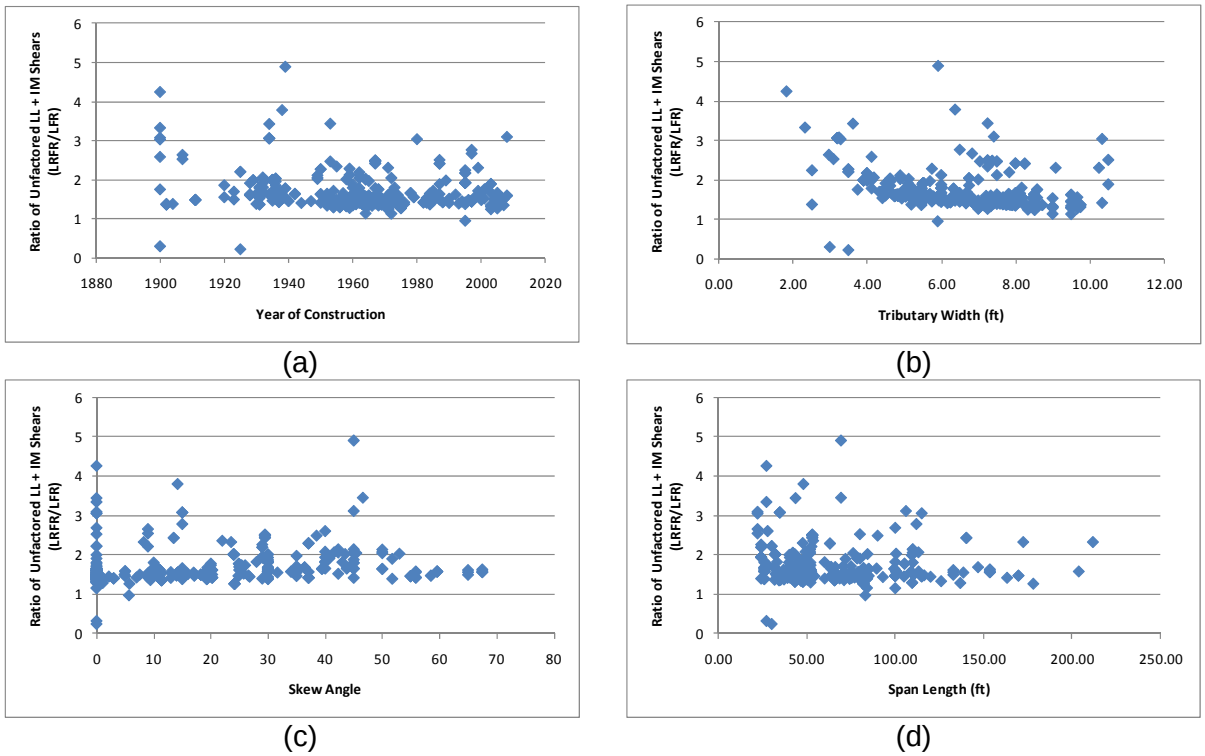


Figure B-269: Ratio of Unfactored Live Load plus Impact Shear for Type 3-3 Vehicle (LRFR/LFR)

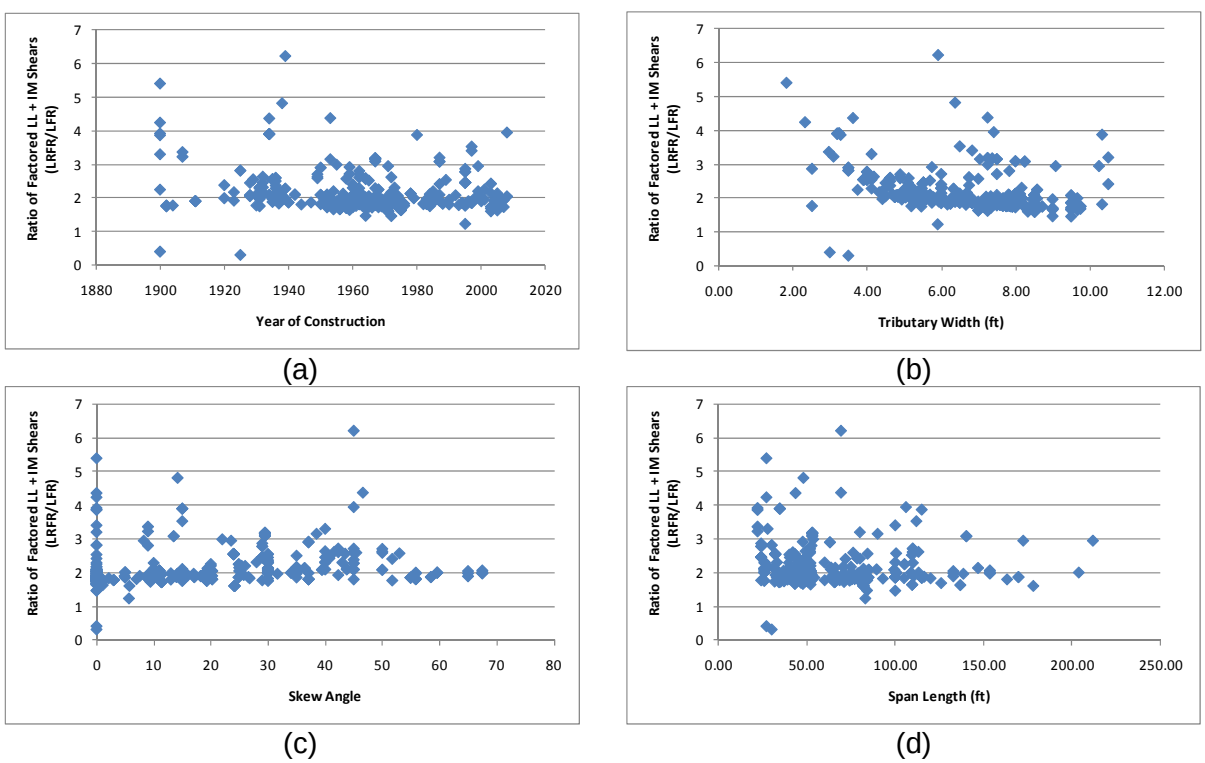


Figure B-270: Ratio of Factored Live Load plus Impact Shear for Type 3-3 Vehicle (LRFR/LFR)

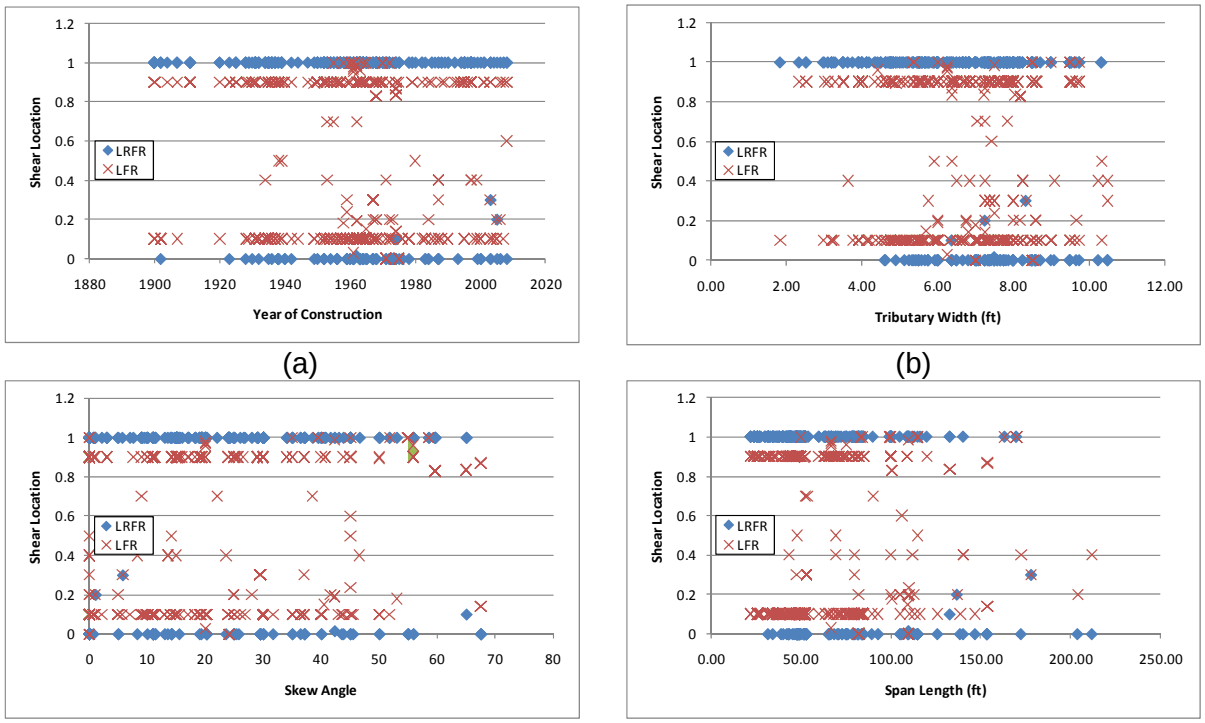
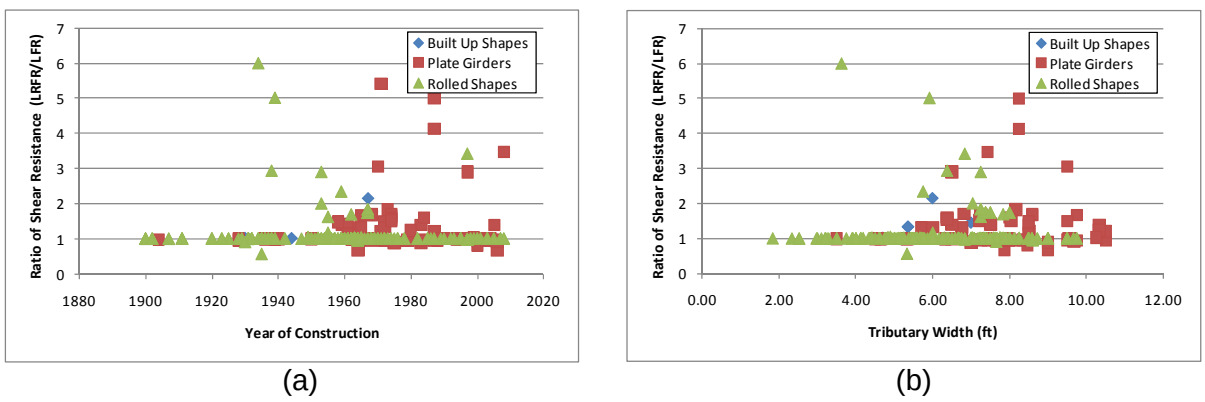
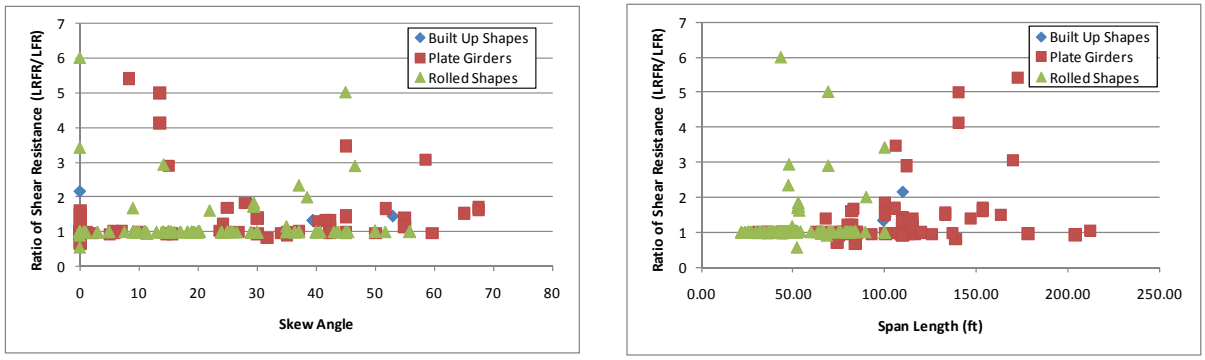


Figure B-271: Critical Shear Location for Type 3-3 Vehicle

B.1.12.2.2 Resistances

Figure B-272 shows the ratio of factored shear resistances. The ratio is generally close to 1.0, with most of the scatter existing in plate girders where the shear resistance may vary with location on the span (Section B.1.10.3.2).



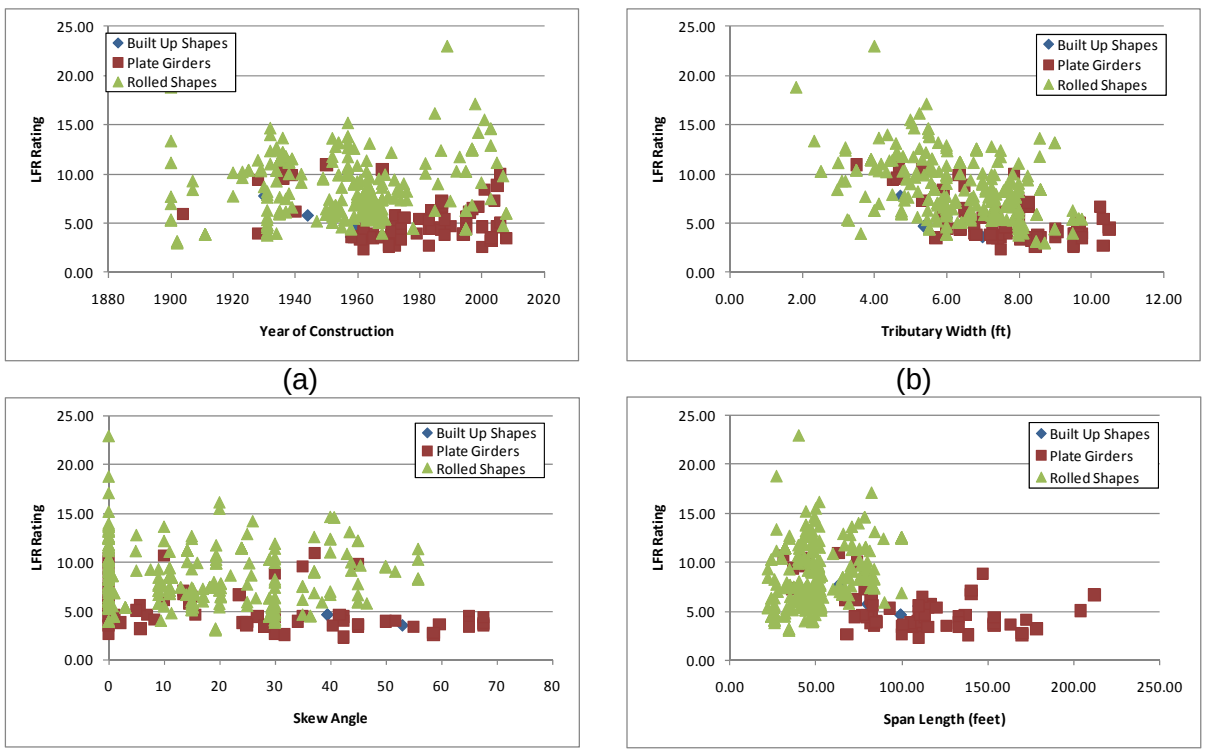


(c) (d)

Figure B-272: Ratio of Factored Shear Resistances (LRFR/LFR)

B.1.12.2.3 Rating Factors

Figure B-273 and Figure B-274 present the ratings as calculated by BRASS for LFR and LRFR, respectively. The LFR Ratings tend to decrease with increasing tributary width and increasing span length (Figure B-273b and d). There is also less scatter with increasing span length (Figure B-273d). Figure B-274b also shows that there is less scatter with larger tributary widths. There are zero girders with an LFR rating of less than 1.0 and seven girders with an LRFR rating less than 1.0. Additionally, 99% of the girders have LFR Ratings greater than the LRFR rating.



(a) (b)

(c) (d)

Figure B-273: LFR Shear Ratings for Type 3-3 Vehicle

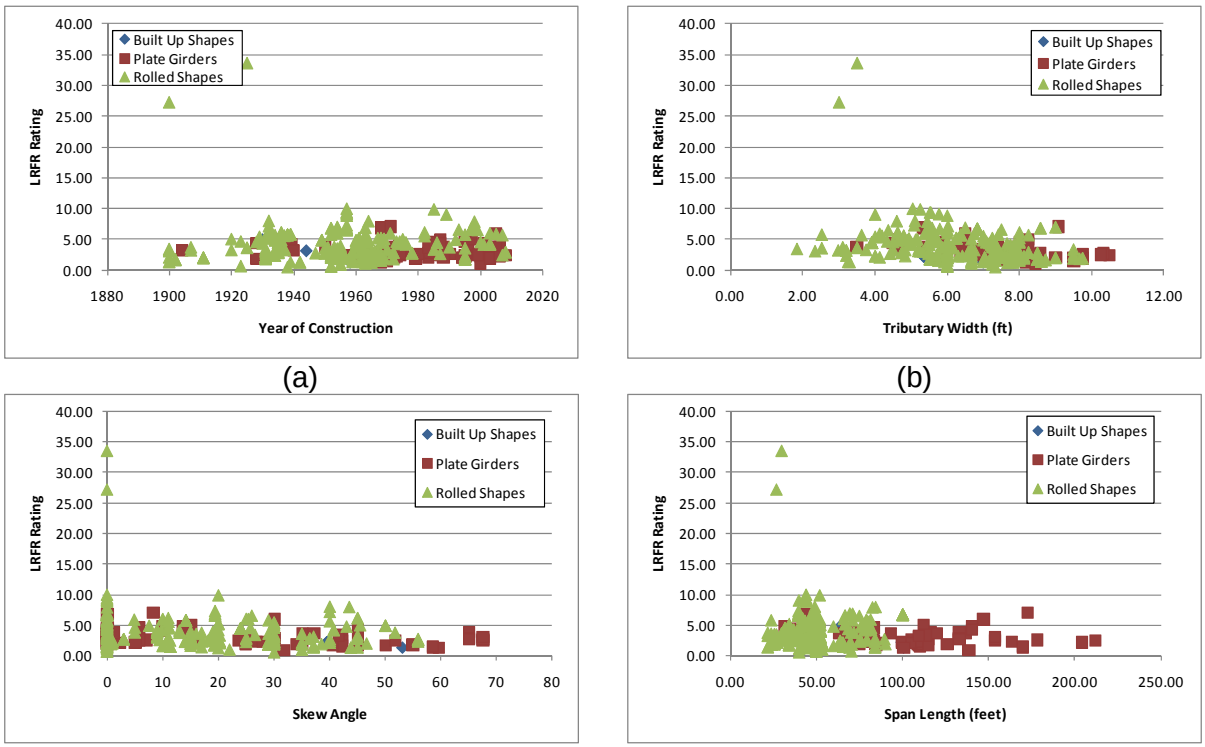
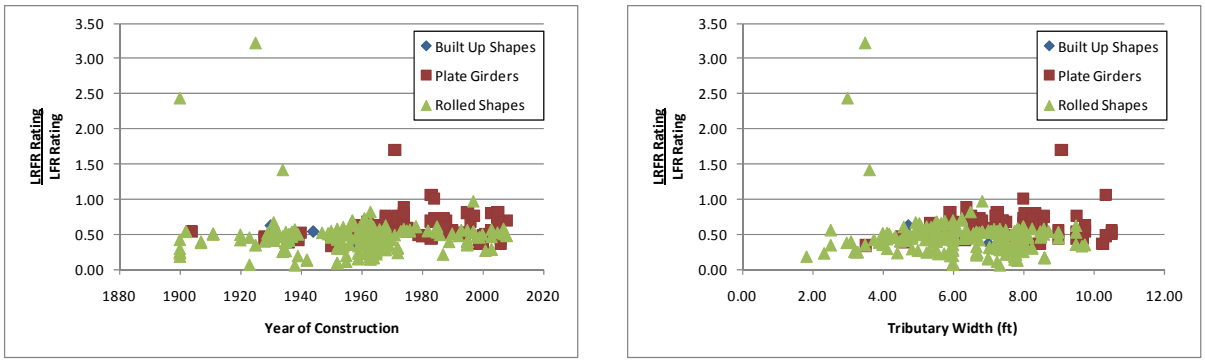
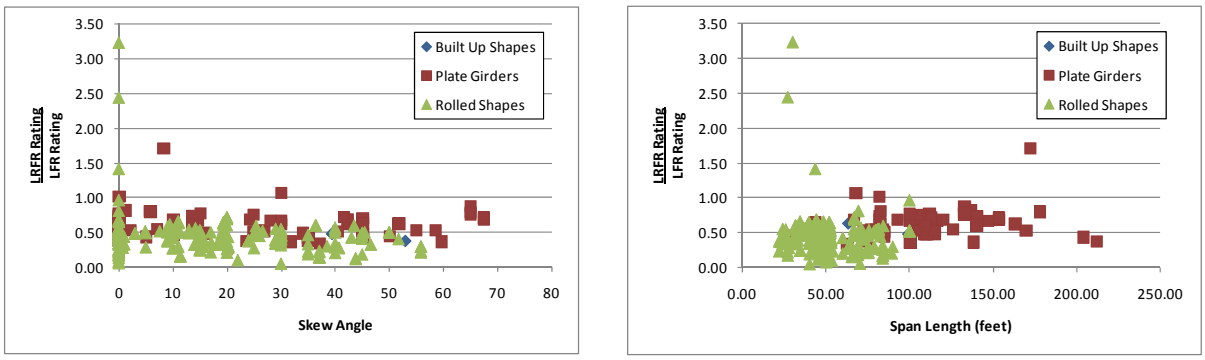


Figure B-274: LRFR Shear Ratings for Type 3-3 Vehicle

B.1.12.2.4 Rating Factor Comparisons

Figure B-275 shows the ratio of LRFR rating factor to LFR rating factor. The ratio is typically less than one, with rolled shapes generally having the smaller ratios. Previous vehicles showed that closely spaced girders were more likely to have higher LFR ratings; the Type 3-3 vehicle shows that girders with spacings of 6 to 8 feet also have higher than expected LFR ratings. Plate girders generally have a ratio greater than 0.5. The reduction in rating factor is partially due to the increase in live load shown above.



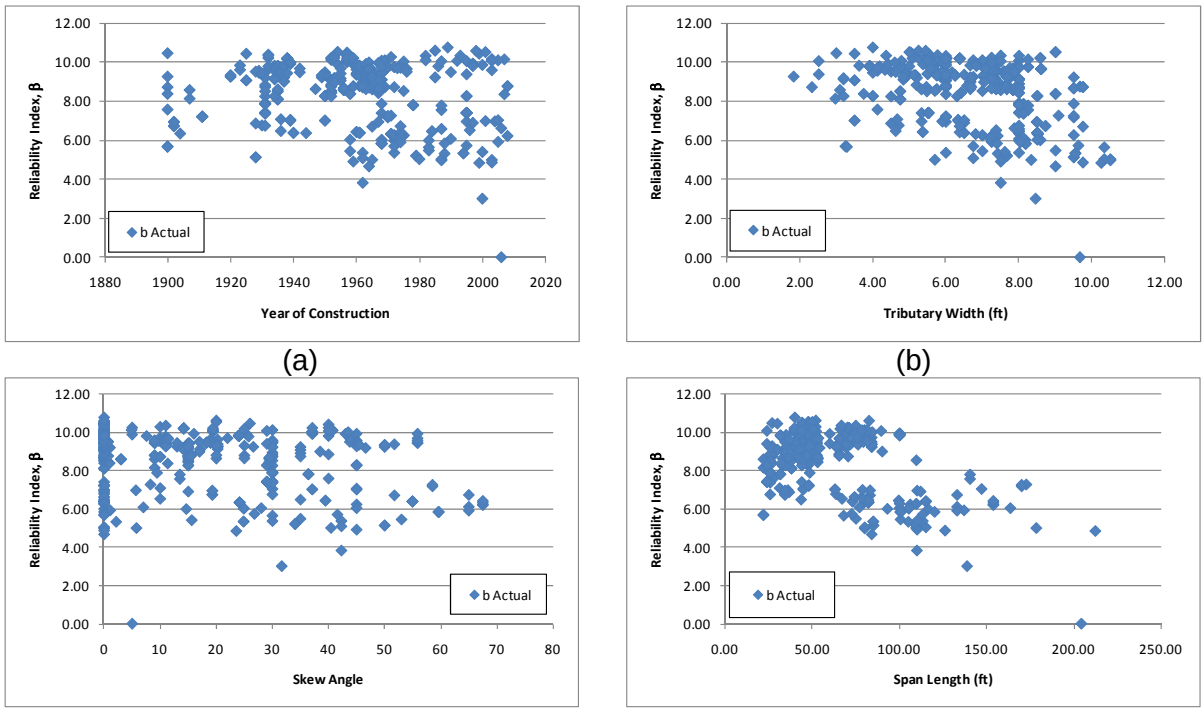


(c) (d)

Figure B-275: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3-3 Vehicle

B.1.12.2.5 Reliability Indices

Figure B-276 shows the reliability indices as calculated based upon the resistance of the section. For the Type 3-3 vehicle, there is one girder with a reliability index of approximately 3.0 which is close to the value assumed in the development of the MBE of 2.5. There also appears to be more scatter as the tributary width increases for the Type 3-3 vehicle.



(a) (b)

(c) (d)

Figure B-276: Shear Reliability Indices for Type 3-3 Vehicle

Figure B-277 shows the actual reliability index for shear plotted agains the LRFR shear rating. The expected level of reliability for plate girders with a rating of one is approximately 3 and for rolled shapes is approximately 4. This indicates that a slight reduction in the live load factor may be possible and still achieve the required level of reliability which is 2.5 for the AASHTO Type 3-3 truck.

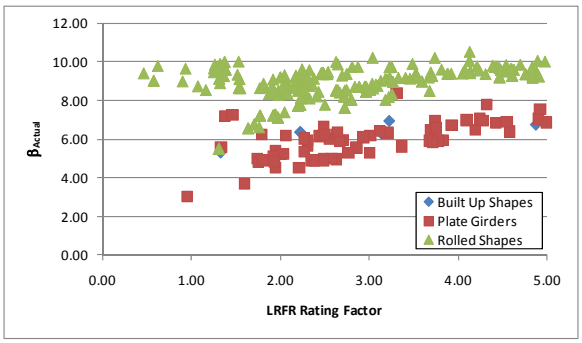


Figure B-277: Shear Reliability Index vs LRFR Shear Rating for Type 3-3 Vehicle

B.1.12.3 Shear-Corrected

This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.12.3.1 Live Load

Figure B-278 and Figure B-279 show the ratio of unfactored and factored LRFR live load plus impact moment to LFR live load plus impact moment, respectively. The unfactored LRFR loads are typically 100 to 150% of the unfactored loads. The unfactored loads are significantly larger for closesly spaced girders. The factored LRFR loads are typically 150 to 200% of the factored LFR loads.

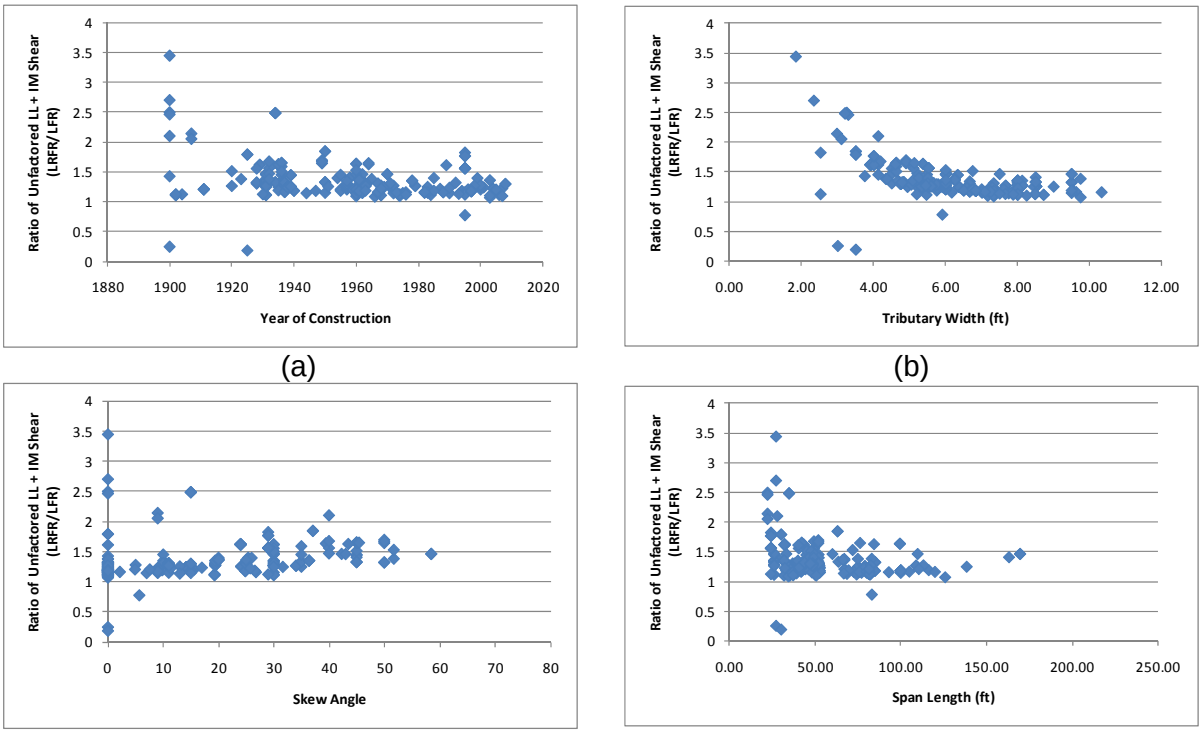


Figure B-278: Ratio of Unfactored Live Load plus Impact Shear for Type 3-3 Vehicle (LRFR/LFR)

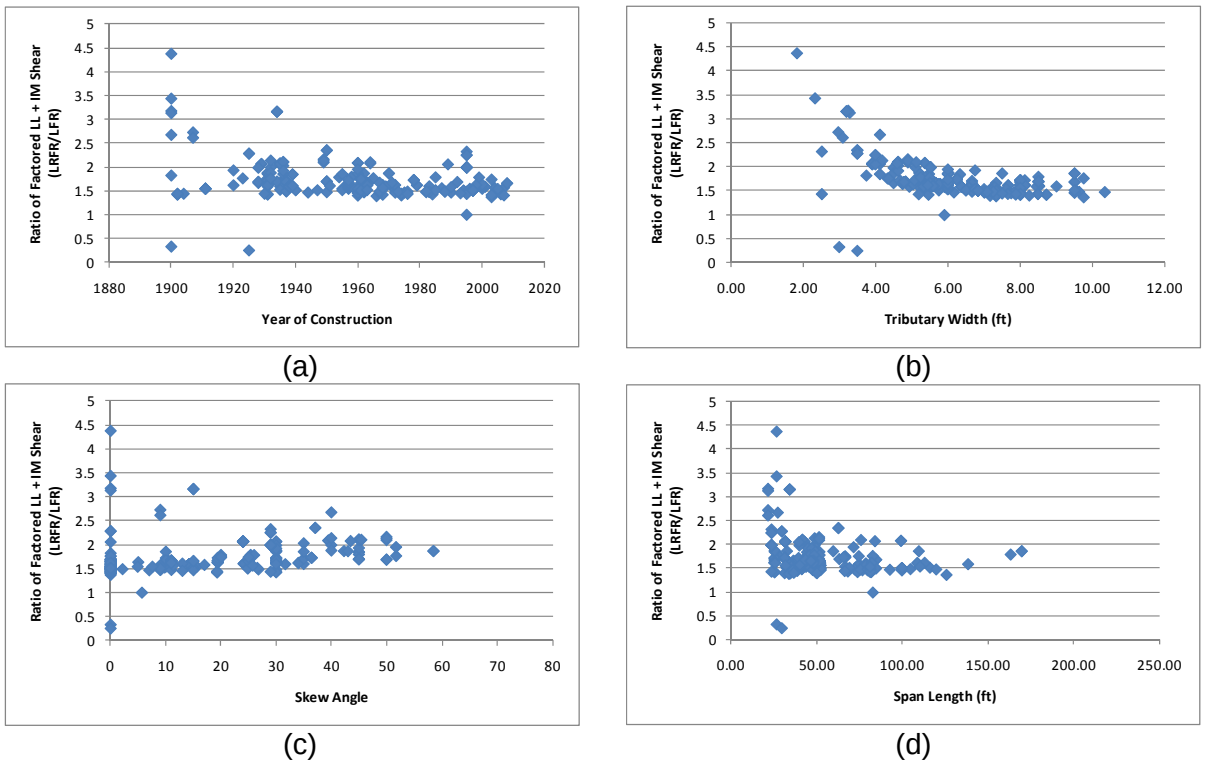
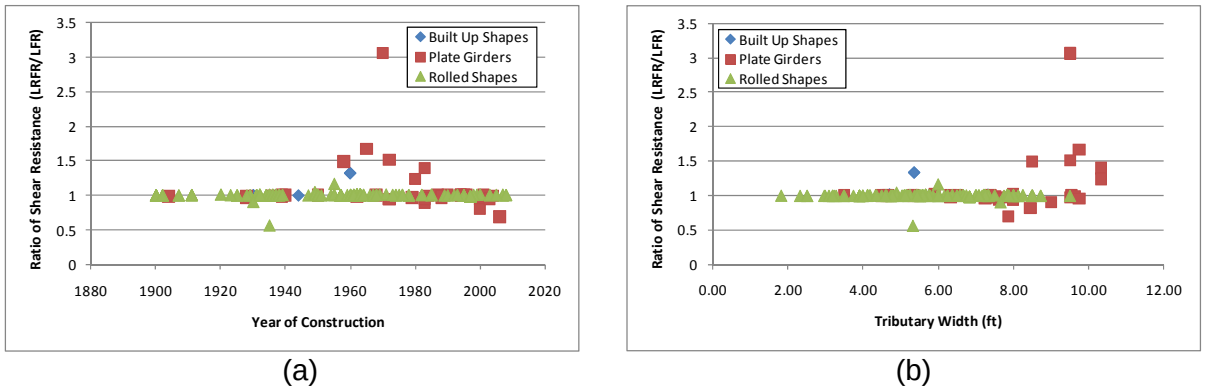
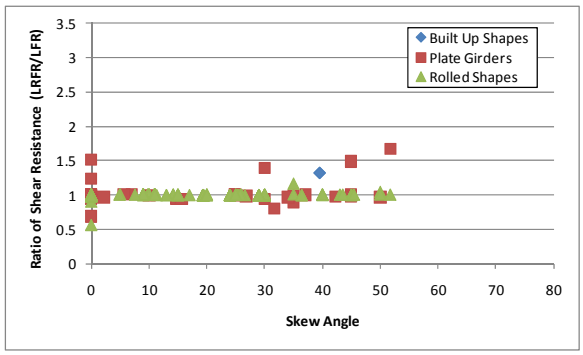


Figure B-279: Ratio of Factored Live Load plus Impact Shear for Type 3-3 Vehicle (LRFR/LFR)

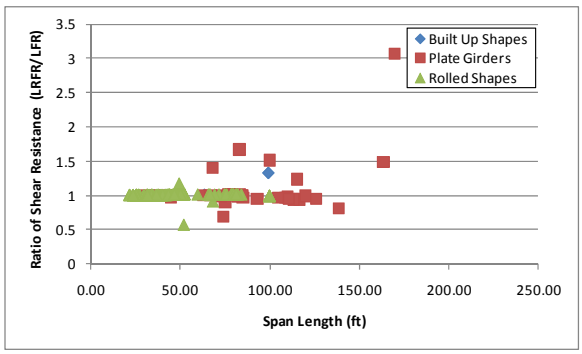
B.1.12.3.2 Resistance

The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was greater than 1.0 have been eliminated by considering only those near the support. The ratio of shear resistance is shown in Figure B-280. Most of those that were eliminated were plate girders; the shear strength is likely to vary for plate girders depending upon location.





(c)

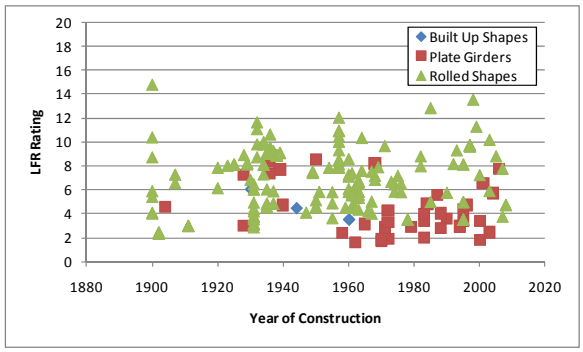


(d)

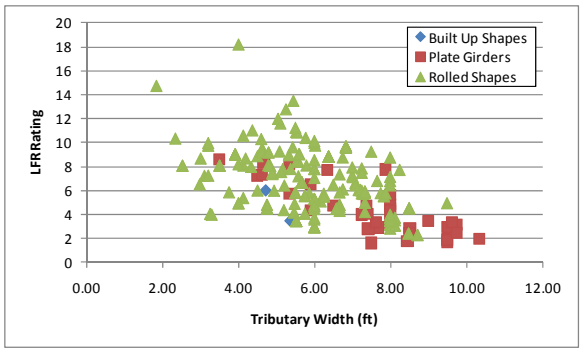
Figure B-280: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.12.3.3 Rating Factors

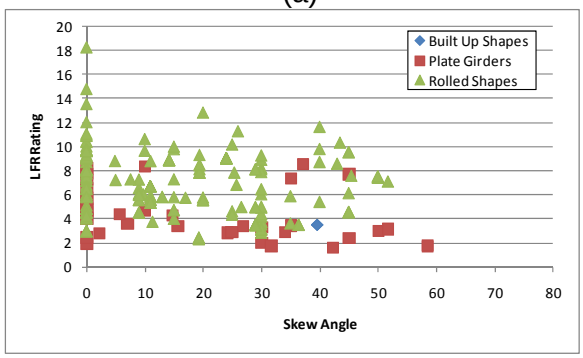
After verifying that the live load shears and shear resistances were reasonable, the next step was to examine the rating factors. Figure B-281 and Figure B-282 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where it is likely that the shear strength varied along the span length.



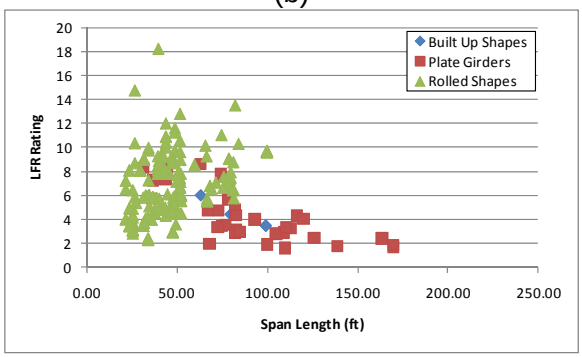
(a)



(b)

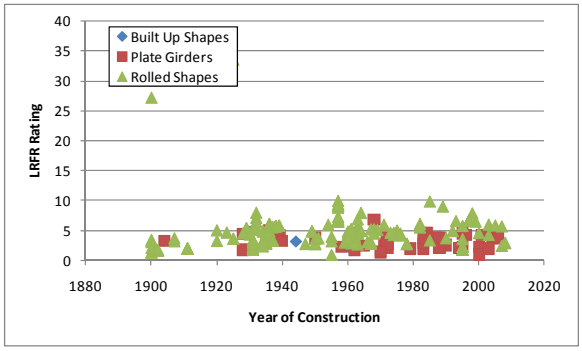


(c)

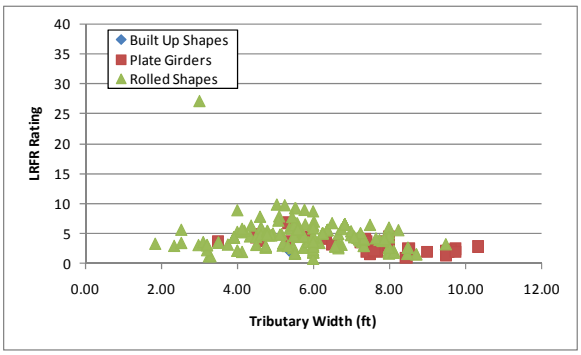


(d)

Figure B-281: LFR Shear Rating Factor for Type 3-3 Vehicle



(a)



(b)

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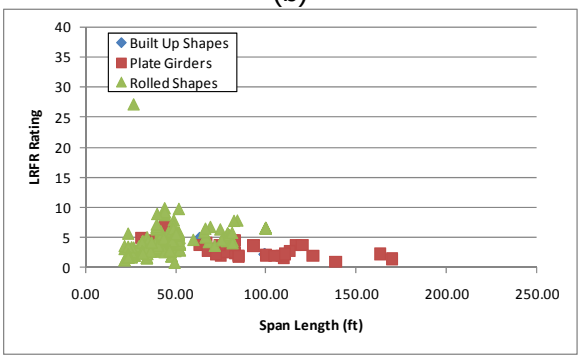
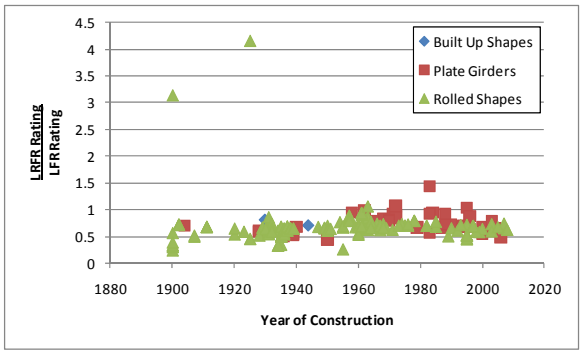


(d)

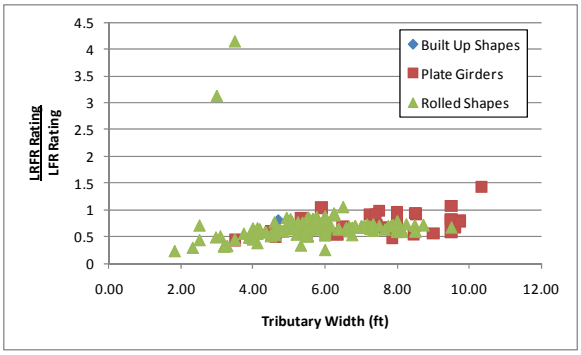
Figure B-282: LRFR Shear Rating Factor for Type 3-3 Vehicle

B.1.12.3.4 Rating Factor Comparison

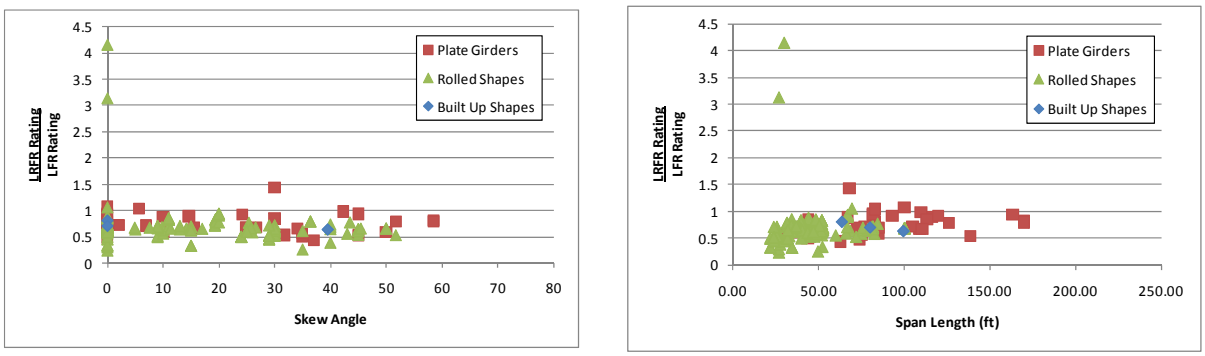
The rating factors are then compared by looking at the ratio of the LRFR rating factor to the LFR rating factor. Figure B-283 shows the results of this comparison. The results show that the LFR rating is typically greater than the LRFR rating for all girder types.



(a)



(b)

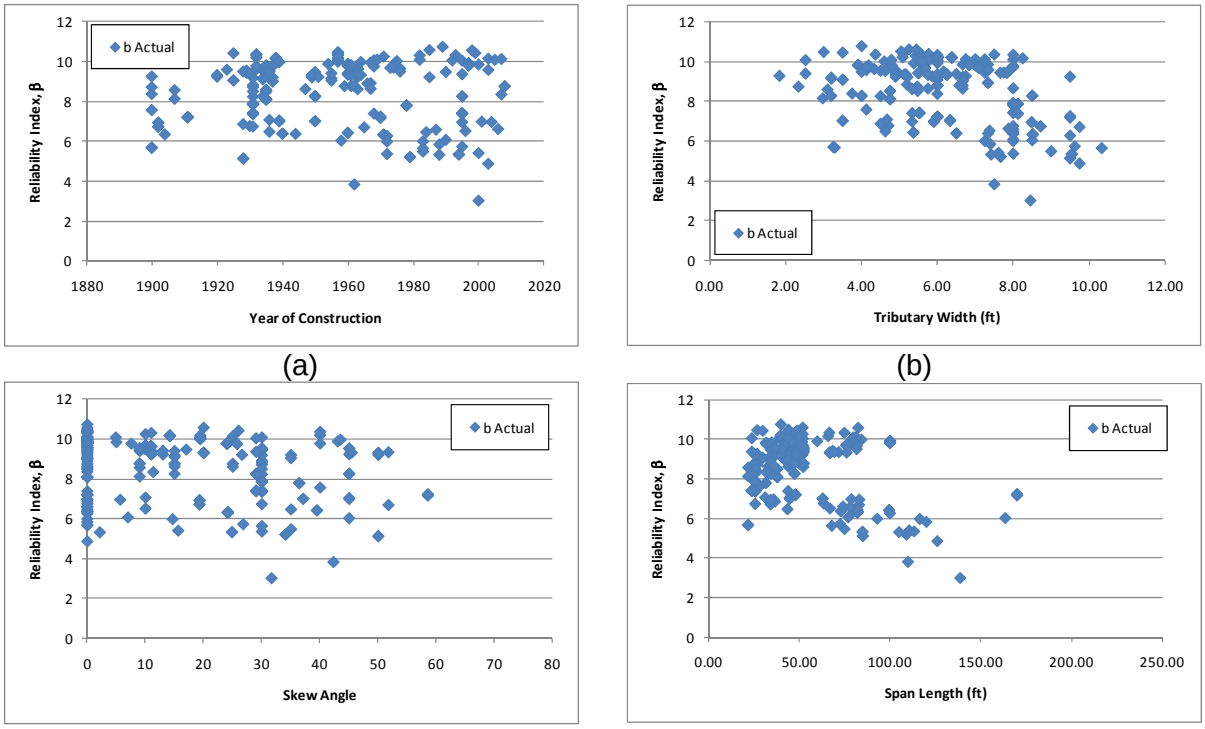


(c) (d)

Figure B-283: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3-3 Vehicle

B.1.12.3.5 Reliability Indices

The reliability indices shown in Figure B-284 are the same as those shown in Figure B-276. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 2.5. The reliability index remains the same as calculated previously because the LRFR location did not move.



(a) (b)

(c) (d)

Figure B-284: Shear Reliability Indices for Type 3-3 Vehicle

B.1.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-285. The applicable load factors for this vehicle are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

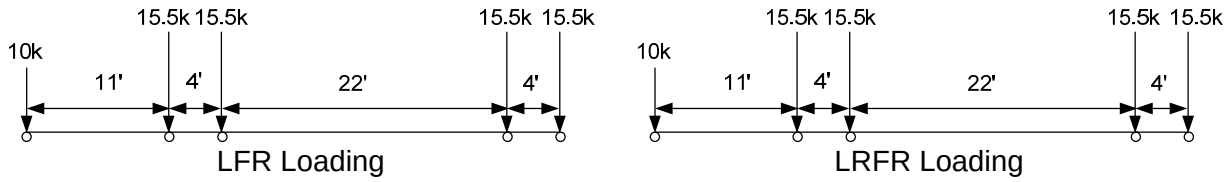


Figure B-285: Vehicle Loadings and Load Factors

B.1.13.1 Moment

B.1.13.1.1 Live Loads

Figure B-286 and Figure B-287 shows the ratio (LRFR to LFR) of unfactored and factored live load plus impact moments for the Type 3S2 vehicle. The LFR moments due to live load plus impact are typically greater than the LRFR moments, for both the factored and unfactored case. The ratio tends to decrease with increasing tributary width (Figure B-286b and Figure B-287b), while there is less scatter for increasing span lengths (Figure B-286d and Figure B-287d). The ratio of unfactored loads is generally between 0.75 and 1.25 with the ratio of factored loads increasing to between 1.0 and 1.5.

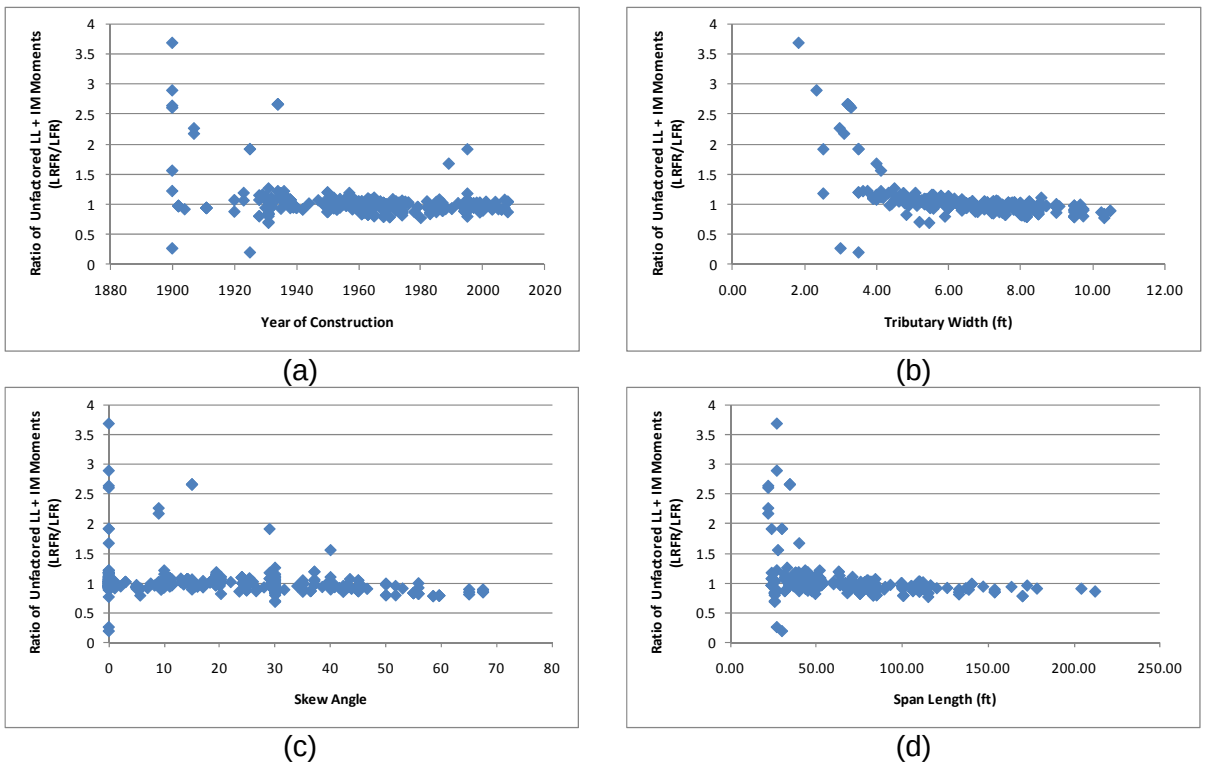


Figure B-286: Ratio of Unfactored Live Load plus Impact Moment for Type 3S2 Vehicle (LRFR/LFR)

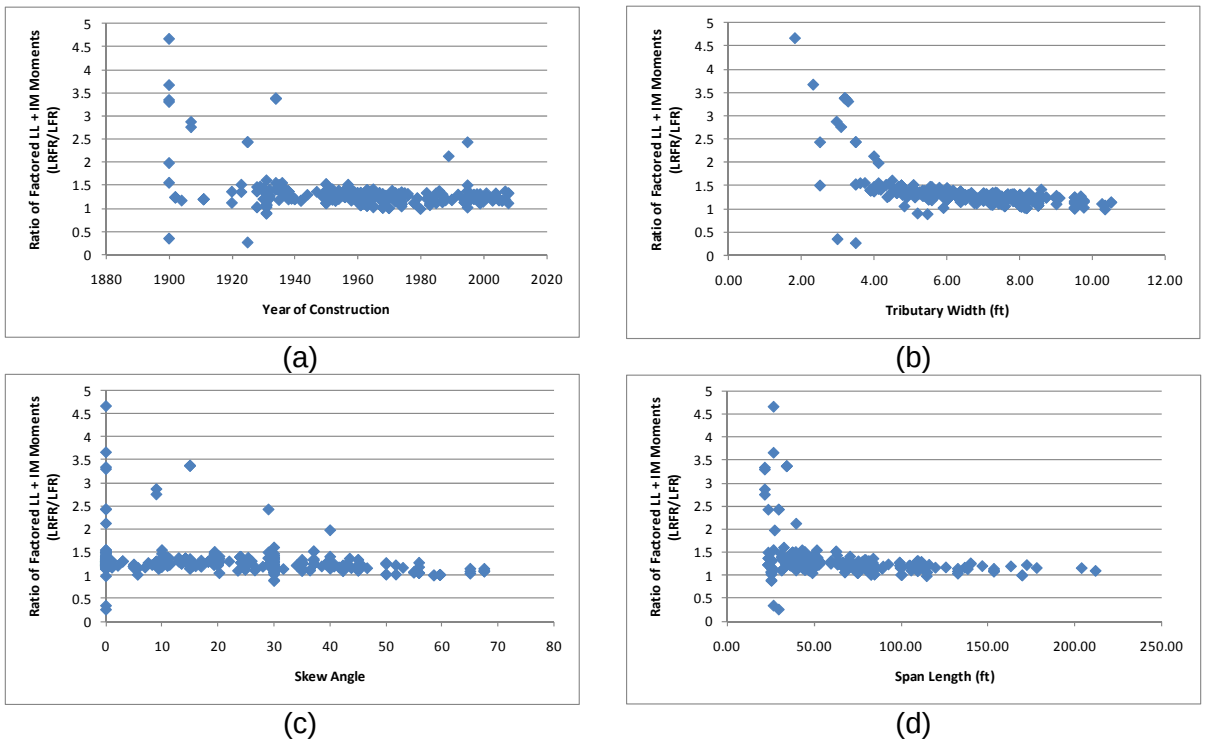
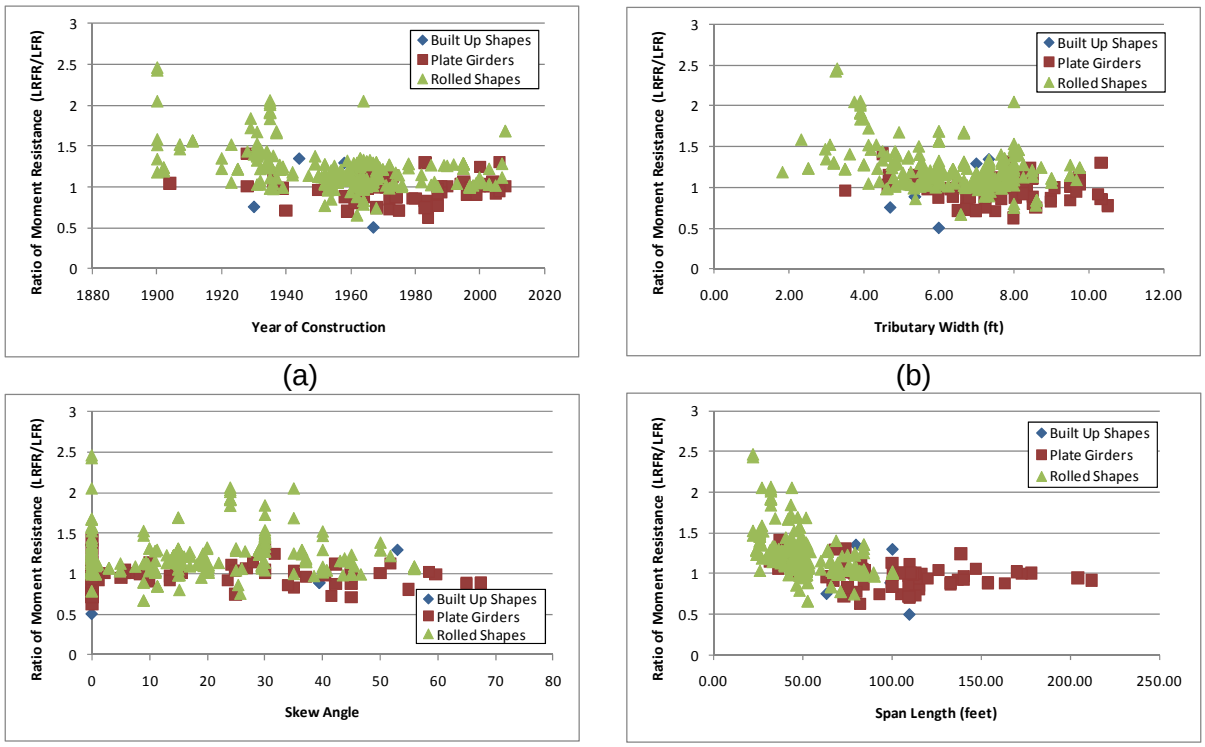


Figure B-287: Ratio of Factored Live Load plus Impact Moment for Type 3S2 Vehicle (LRFR/LFR)

B.1.13.1.2 Resistances

Figure B-288 shows the ratio of the factored moment resistances. The ratio of resistance is generally above 1.0 for rolled shapes and less than 1.0 for plate girders. Built-up shapes do not typically have resistance that is higher or lower for a specific method.

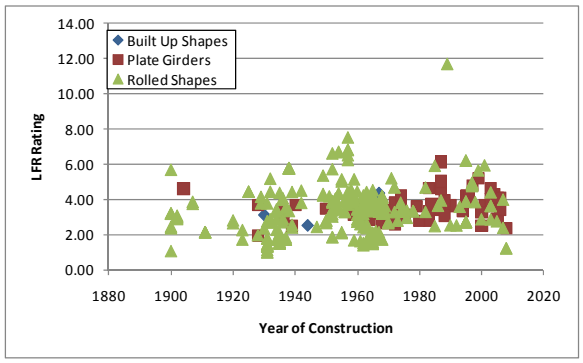


(c) (d)

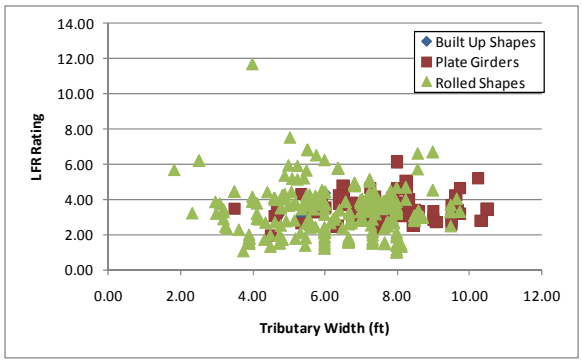
Figure B-288: Ratio of Factored Moment Resistance (LRFR/LFR)

B.1.13.1.3 Rating Factors

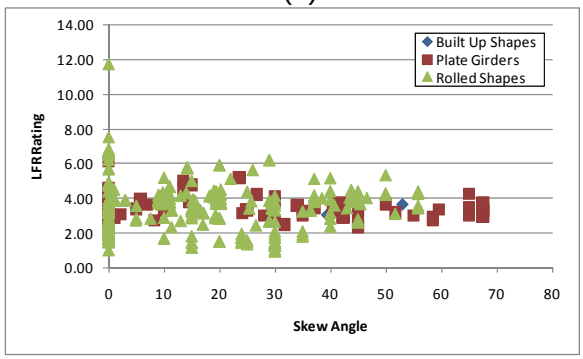
Figure B-289 and Figure B-290 present the LFR and LRFR ratings from BRASS, respectively. There are two girders with an LFR rating less than 1.0, four girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Ignoring the outliers, the two methods provide similar scatter with the LRFR rating shifted down from the LFR rating.



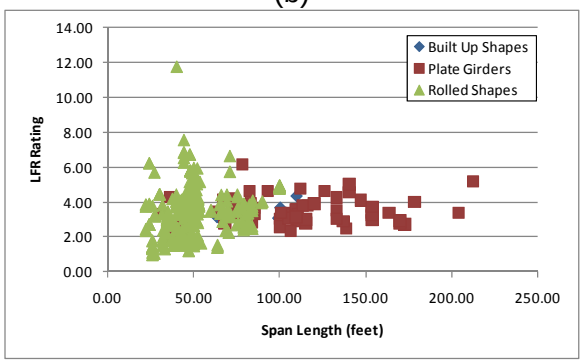
(a)



(b)

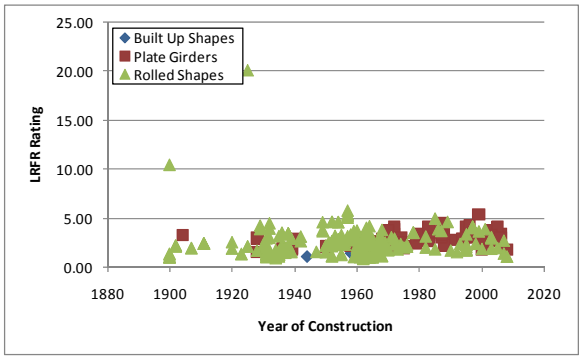


(c)



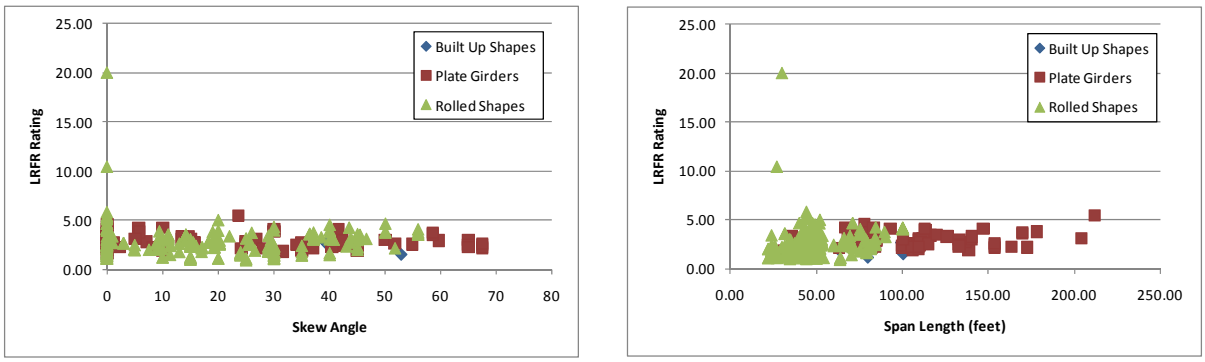
(d)

Figure B-289: LFR Flexure Ratings for Type 3S2 Vehicle



(a)

(b)

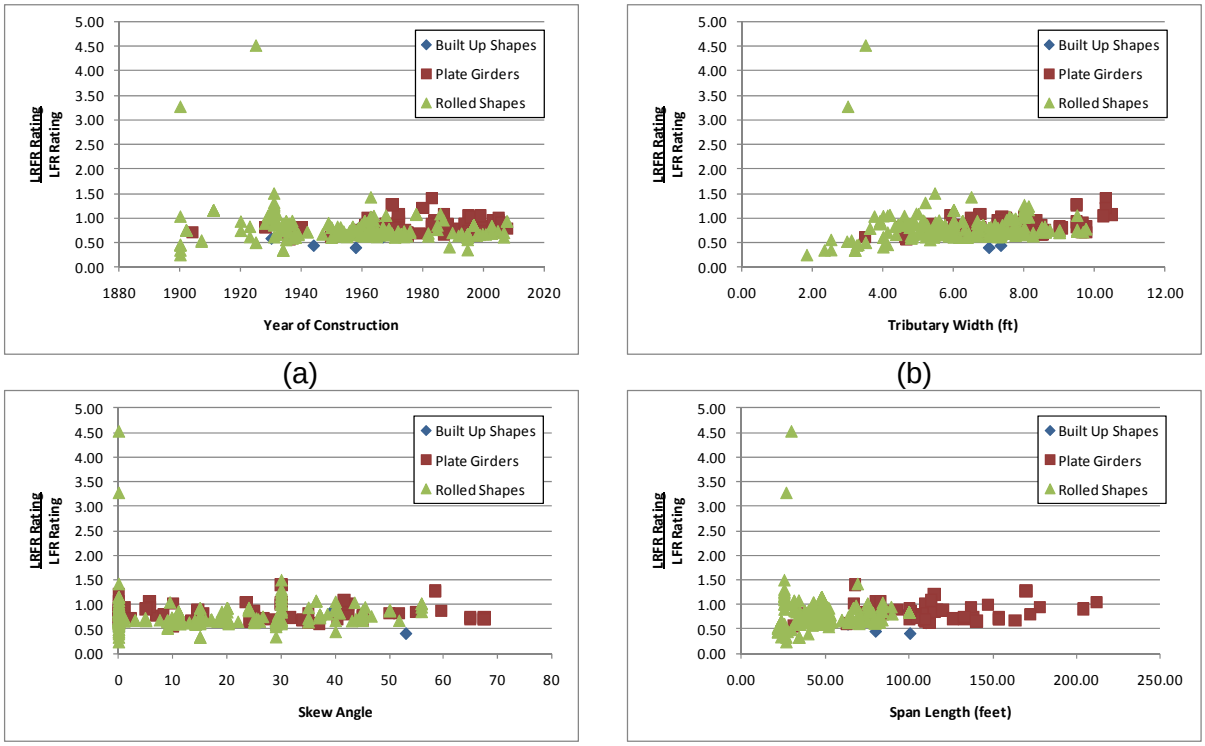


(c) (d)

Figure B-290: LRFR Flexure Ratings for WA-02 Vehicle

B.1.13.1.4 Rating Factor Comparisons

Figure B-291 shows the ratio between LRFR rating and LFR rating. Most girders (89%) have a LRFR rating that is less than the LFR rating. The ratio is typically between 0.5 and 1.0, with closely spaced girders having smaller ratios.



(a) (b)

(c) (d)

Figure B-291: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Type 3S2 Vehicle

B.1.13.1.5 Reliability Indices

Figure B-292 presents the reliability indices based upon the cross-section resistance. The lowest reliability index (excluding the one at zero) is 4.0, which is significantly greater than the level assumed in the development of the MBE which was 2.5.

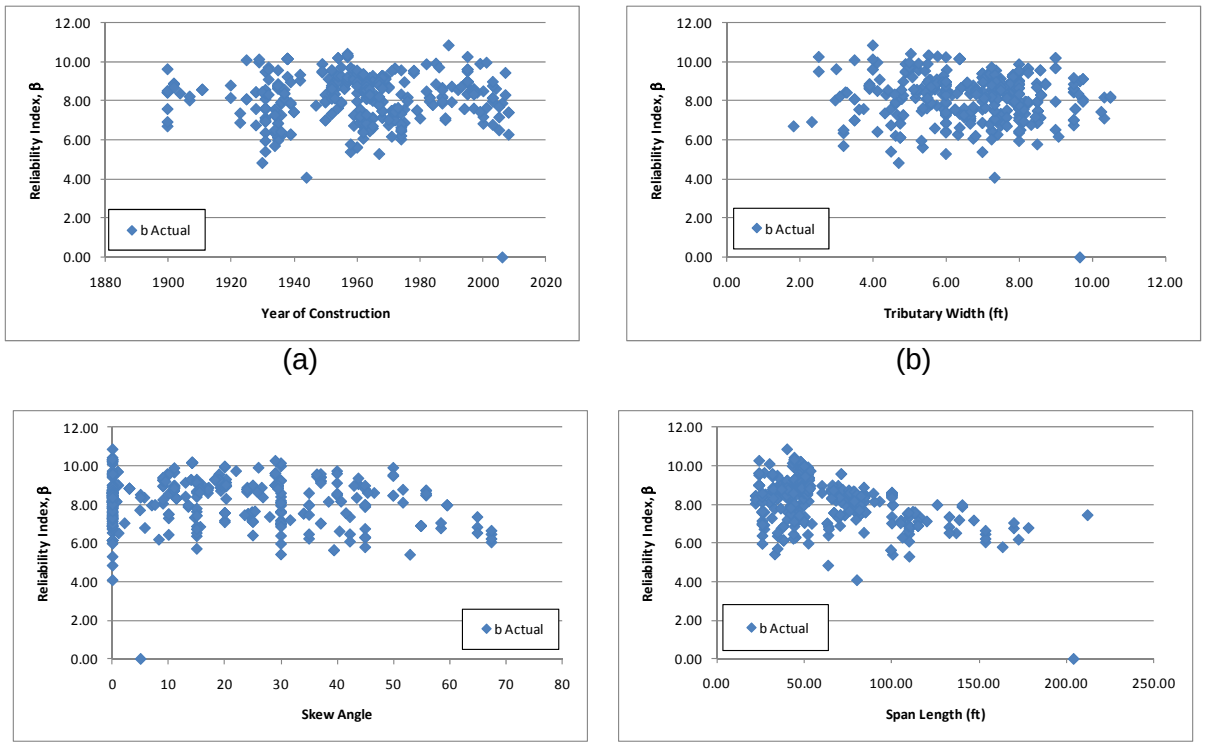


Figure B-292: Flexure Reliability Indices for Type 3S2 Vehicle

Figure B-293 shows the actual flexure reliability plotted against the LRFR flexure rating factor. Figure B-293 shows that for rolled shapes having a rating of 1.0, the reliability index will be at least 5 and for built-up shapes the reliability index will be at least 3.5. These values exceed the required value of 2.5 for the AASHTO Legal Loads and suggest that the live load factors could be reduced.

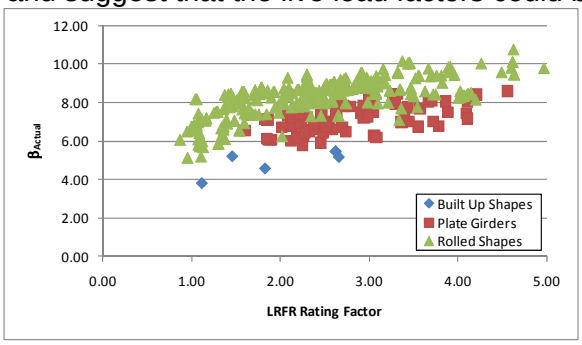


Figure B-293: Flexure Reliability Index vs LRFR Flexure Rating for Type 3S2 Vehicle

B.1.13.2 Shear

B.1.13.2.1 Live Loads

Figure B-294 and Figure B-295 show the ratios of unfactored and factored live load plus impact shear (LRFR divided by LFR), respectively. The ratio of unfactored loads is between 1.25 and 1.5 and between 1.5 and 2.0 for factored loads. The ratio decreases with increasing tributary width (Figure B-294b and Figure B-295b). This is likely a result of the distribution factors as the LRFD equations limit the girder spacing to greater than 3.5 feet, while the LFR distribution factors are applicable to any girder spacing. Figure B-294c and Figure B-295c show that the ratio increases with increasing skew; this is an expected result as the LRFD Design Specification increases the load distributed to each girder

because of the skew while the LFR Specification does not consider the effect of skew. Figure B-296 shows where the critical shear rating occurred for each girder. The LFR location is typically away from the support while the LRFD location is typically at the support.

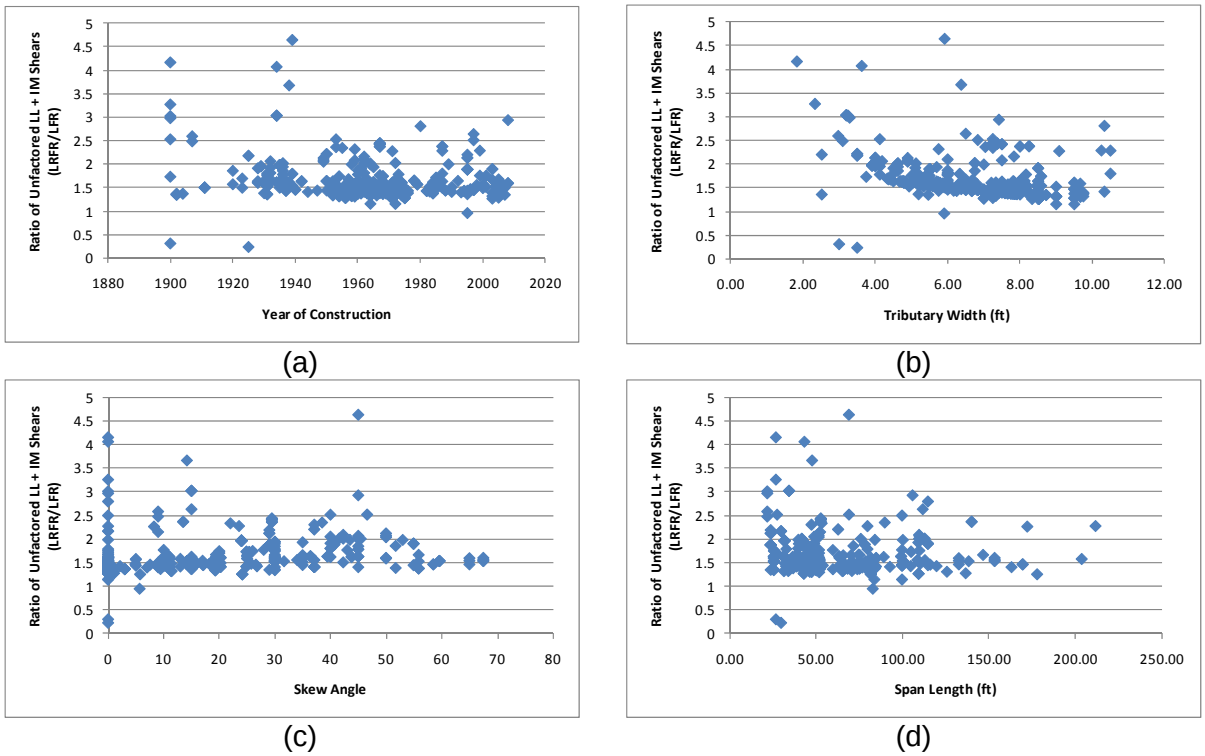


Figure B-294: Ratio of Unfactored Live Load plus Impact Shear for Type 3S2 Vehicle (LRFR/LFR)

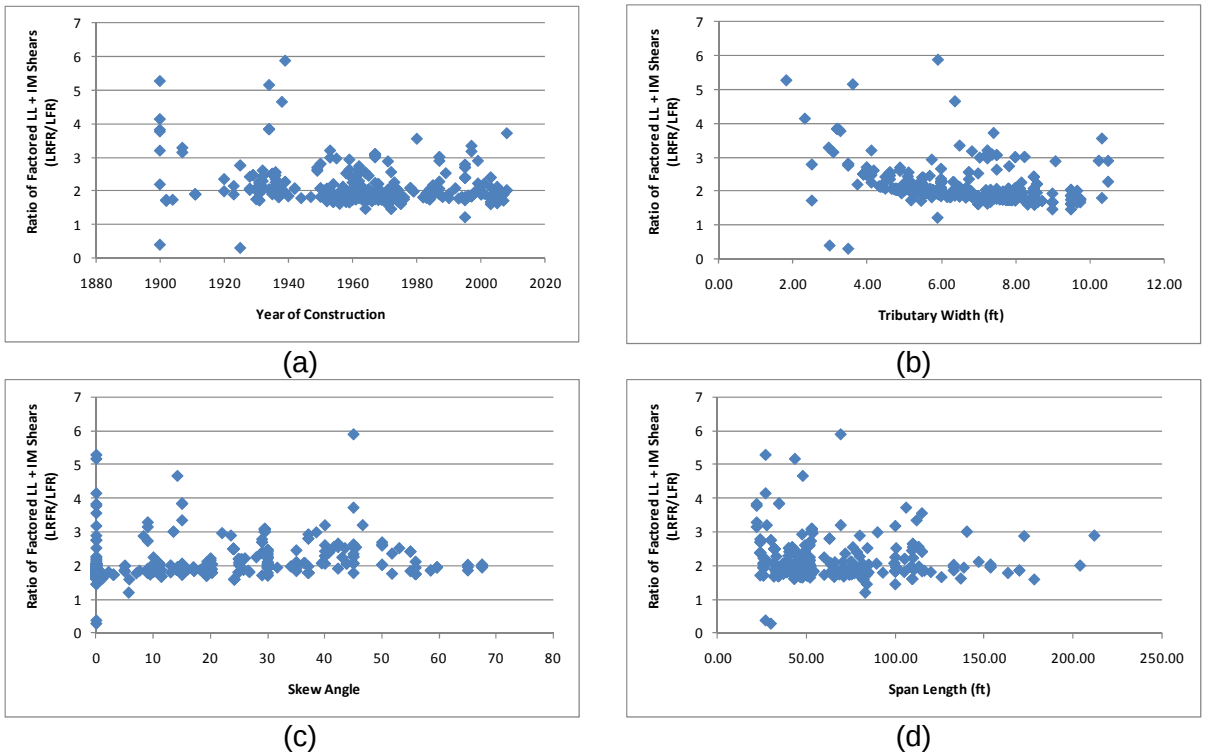


Figure B-295: Ratio of Factored Live Load plus Impact Shear for Type 3S2 Vehicle (LRFR/LFR)

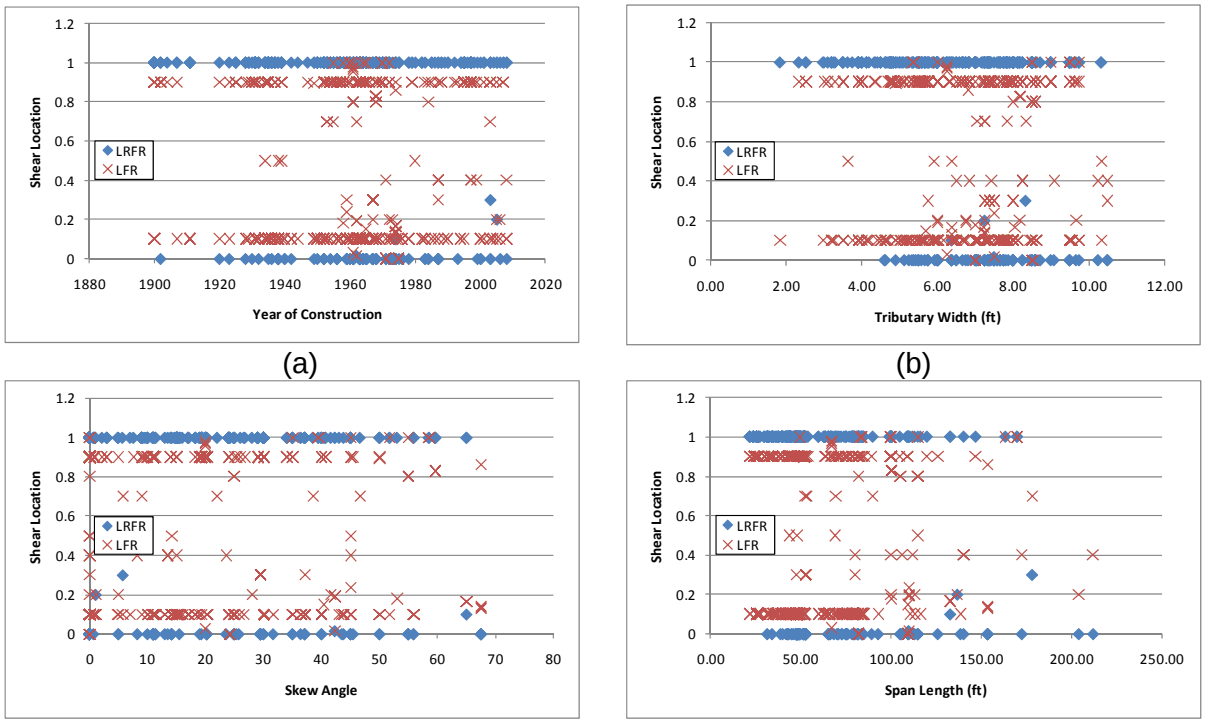
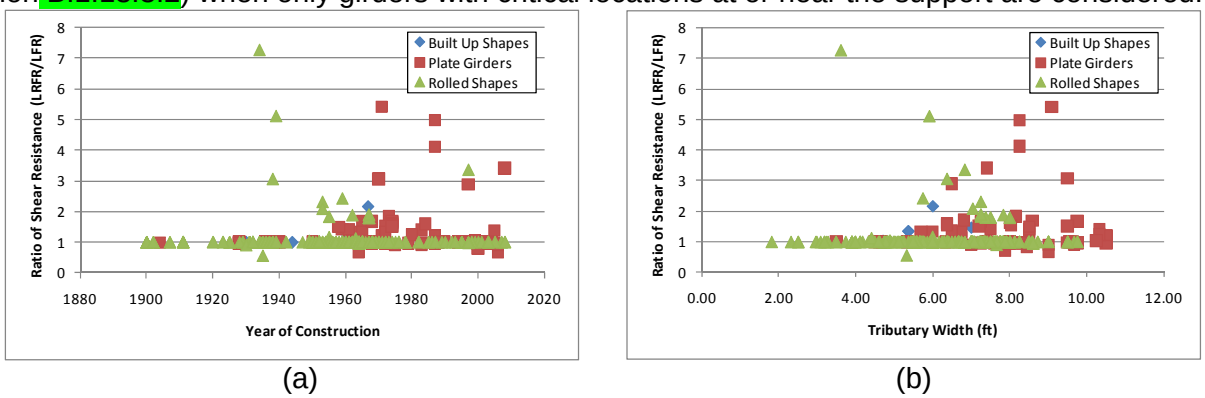
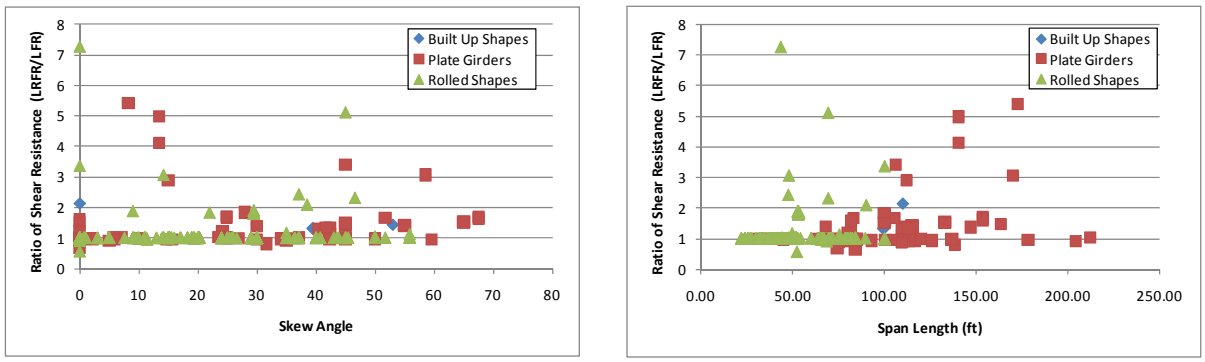


Figure B-296: Critical Shear Location for Type 3S2 Vehicle

B.1.13.2.2 Resistances

Figure B-297 shows the ratio of factored shear resistances. The ratio is generally close to 1.0, with most of the scatter due to plate girders. The resistance has less scatter in the following section (Section B.1.13.3.2) when only girders with critical locations at or near the support are considered.



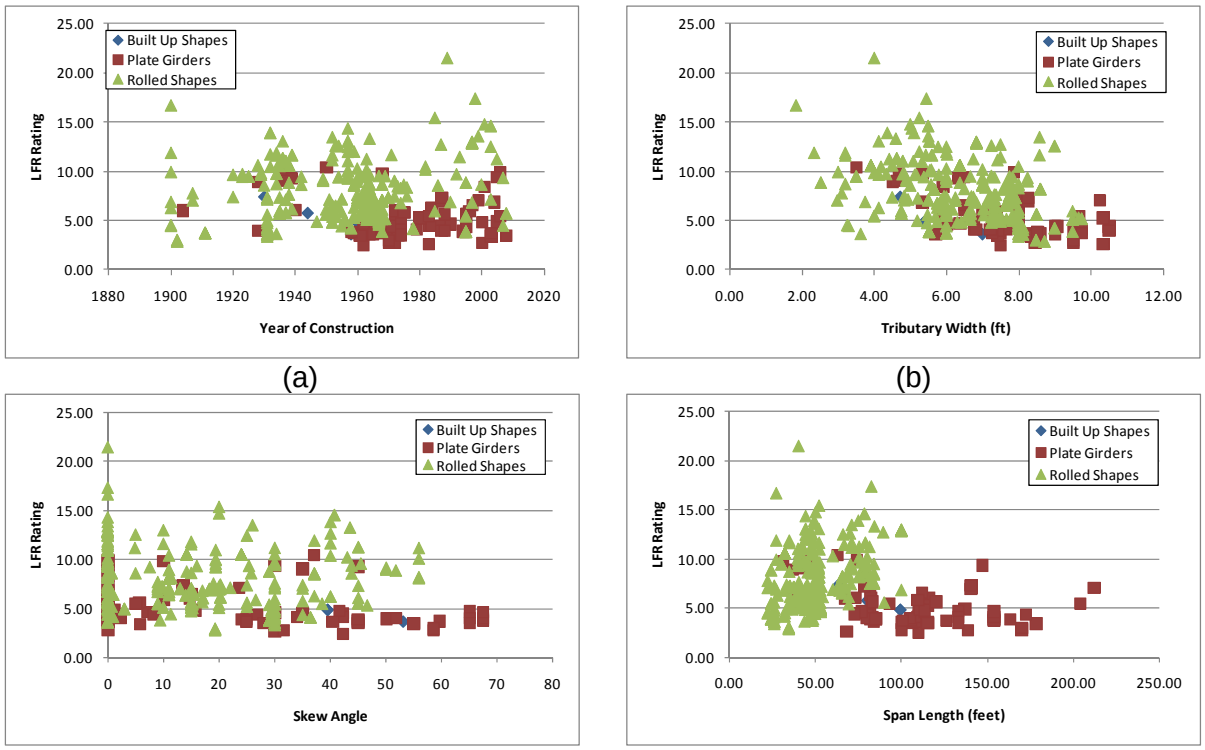


(c) (d)

Figure B-297: Ratio of Factored Shear Resistances (LRFR/LFR)

B.1.13.2.3 Rating Factors

Figure B-298 and Figure B-299 present the ratings as calculated by BRASS for LFR and LRFR, respectively. The LFR Ratings tend to decrease with increasing tributary width and increasing span length (Figure B-298b and d). There is also less scatter with increasing span length (Figure B-298d). There are zero girders with an LFR rating of less than 1.0 and seven girders with an LRFR rating less than 1.0. Additionally, 98% of the girders have LFR Ratings greater than the LRFR rating.



(a) (b)

(c) (d)

Figure B-298: LFR Shear Ratings for Type 3S2 Vehicle

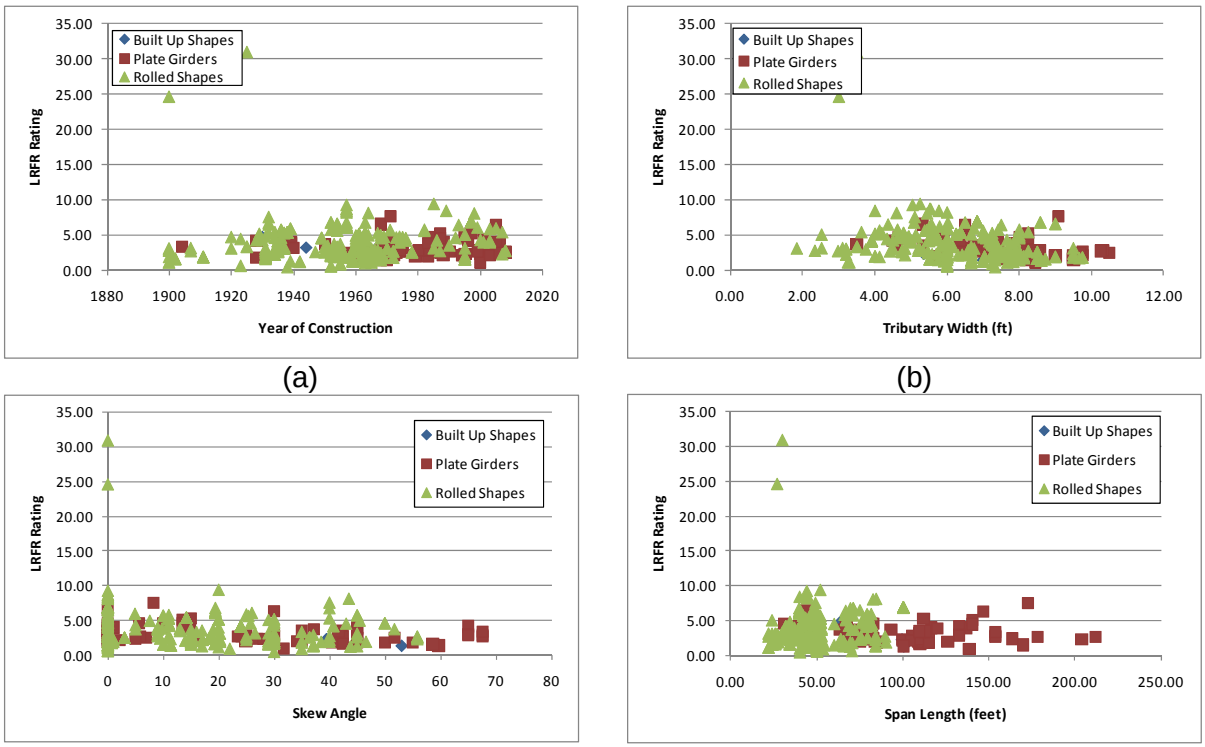
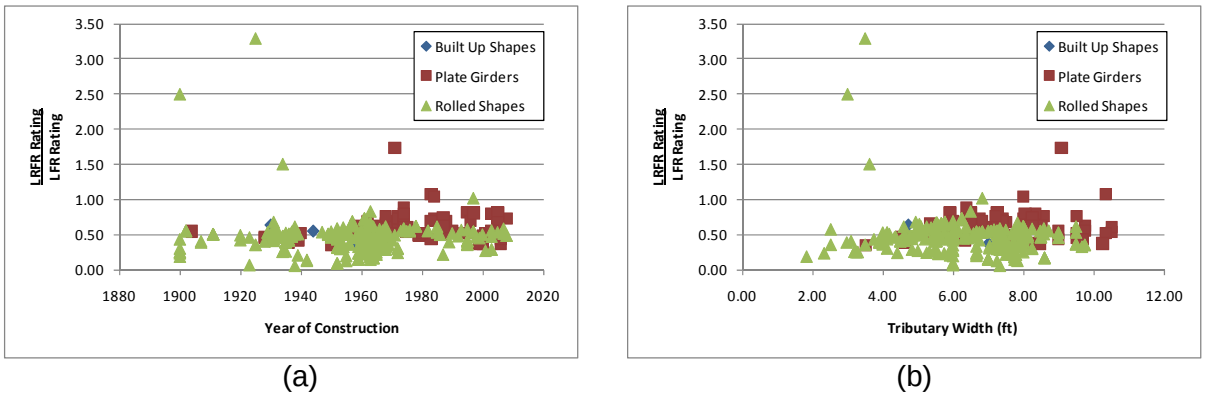
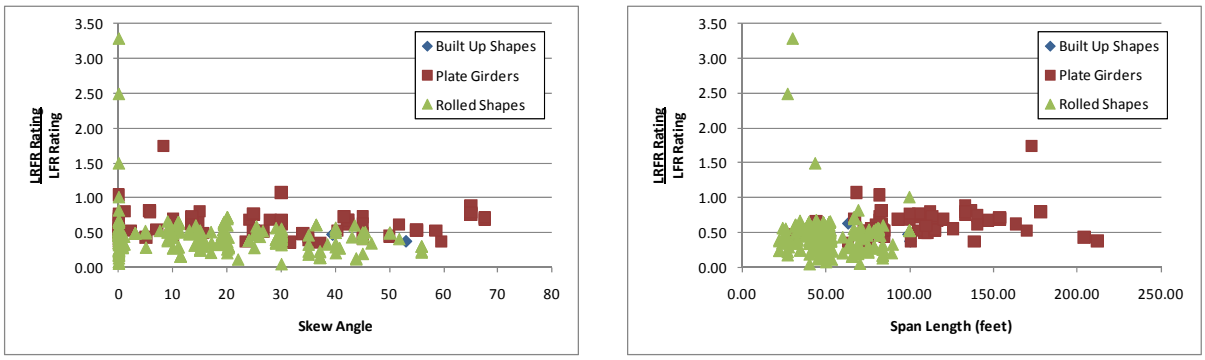


Figure B-299: LRFR Shear Ratings for Type 3S2 Vehicle

B.1.13.2.4 Rating Factor Comparisons

Figure B-300 shows the ratio of LRFR rating factor to LFR rating factor. Girders typically have higher LFR ratings than LRFR ratings for all types of girders. Plate girders have higher ratios of ratings but do not typically have LRFR ratings greater than the LFR rating. Rolled shapes with tributary widths of six to eight feet, in addition to those with tributary widths of less than four feet, have lower ratios for this vehicle than for others.



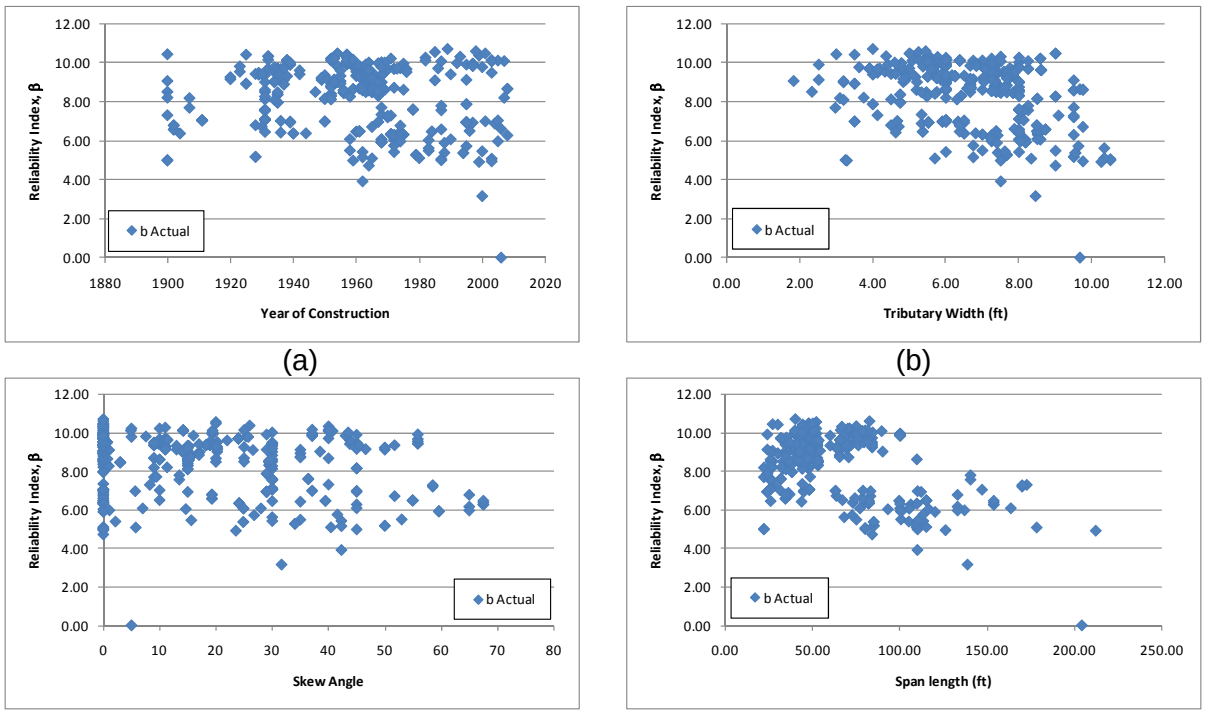


(c) (d)

Figure B-300: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3S2 Vehicle

B.1.13.2.5 Reliability Indices

Figure B-301 shows the reliability indices calculated based upon cross-section resistance. The reliability indices are generally scattered for all criteria, but there appears to be more scatter for larger tributary widths than for smaller tributary widths.



(a) (b)

(c) (d)

Figure B-301: Shear Reliability Indices for Type 3S2 Vehicle

Figure B-302 shows the actual shear reliability index versus the LRFR shear rating. The figure indicates that girders with passing ratings have reliability indices greater than the value of 2.5 assumed in the development of the MBE for the AASHTO Legal Loads. Reducing the live load factors will limit the number of girders with inadequate ratings while maintaining the required level of reliability.

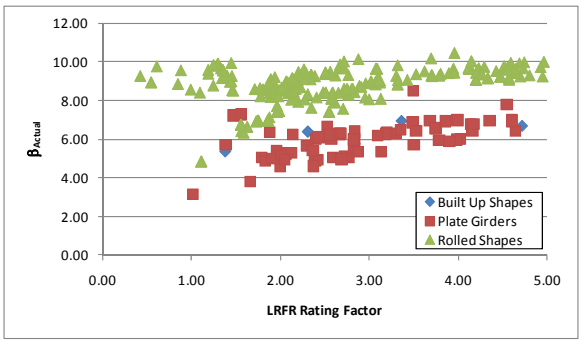


Figure B-302: Shear Reliability Index vs LRFR Shear Rating for Type 3S2 Vehicle

B.1.13.3 Shear-Corrected

This section shows the results when only considering those girders where the critical shear section was at the support or at the one- or nine-tenths point. The shears at the one- or nine-tenths point were multiplied by 1.25 to approximate what the value is at the support.

B.1.13.3.1 Live Load

Figure B-303 and Figure B-304 show the ratio of unfactored and factored live load plus impact shear for those girders with critical locations at the either the support or one-tenth of the span away from the support. The ratio is that of LRFR shear to LFR shear, and the unfactored LRFR shear is between 1.0 and 1.5 times that of the LFR shear. When factored the ratio increases to between 1.5 and 2.0 times the LFR shear.

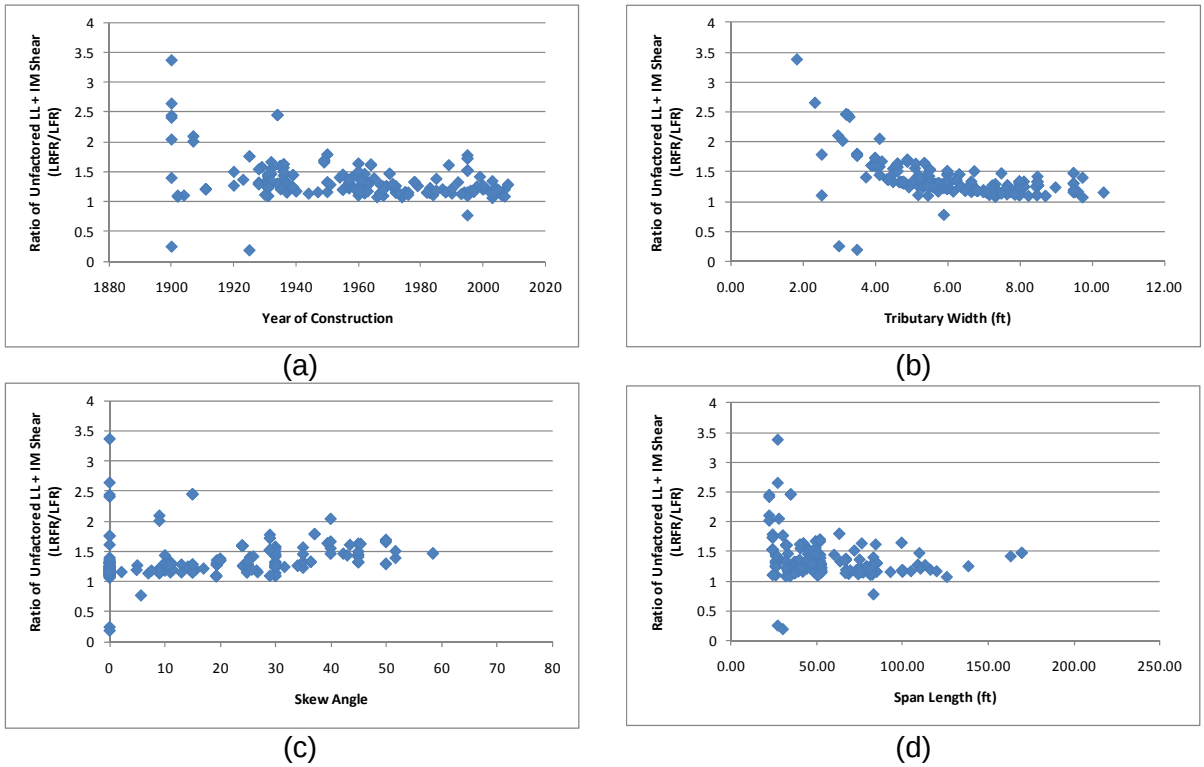
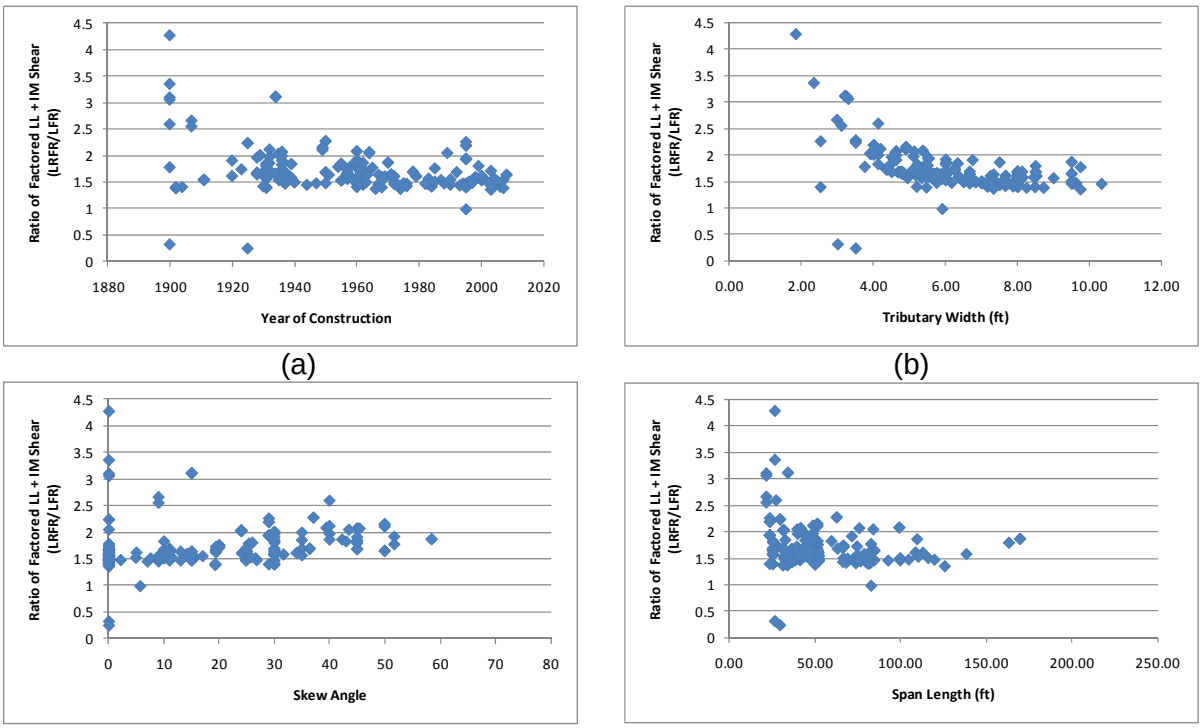


Figure B-303: Ratio of Unfactored Live Load plus Impact Shear for Type 3S2 Vehicle (LRFR/LFR)



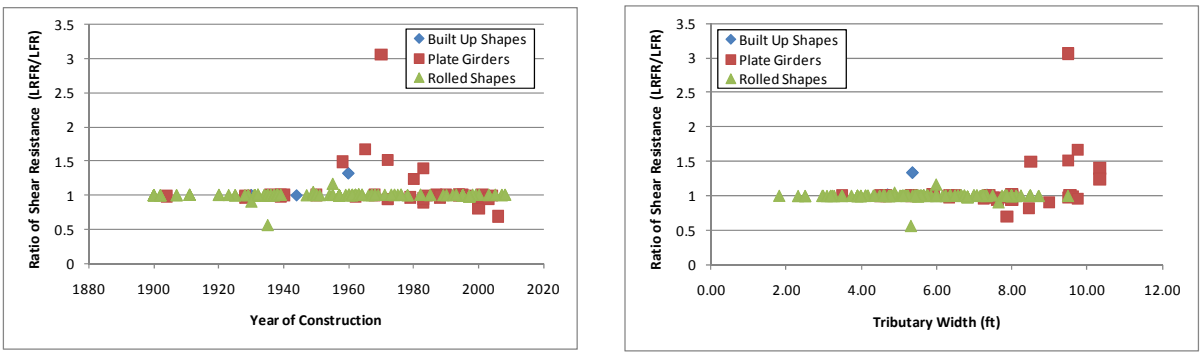
(a) (b)

(c) (d)

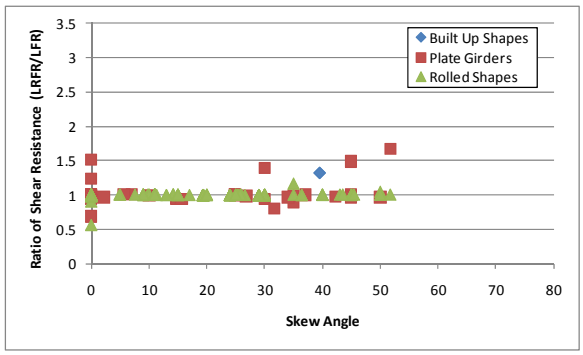
Figure B-304: Ratio of Factored Live Load plus Impact Shear for Type 3S2 Vehicle (LRFR/LFR)

B.1.13.3.2 Resistance

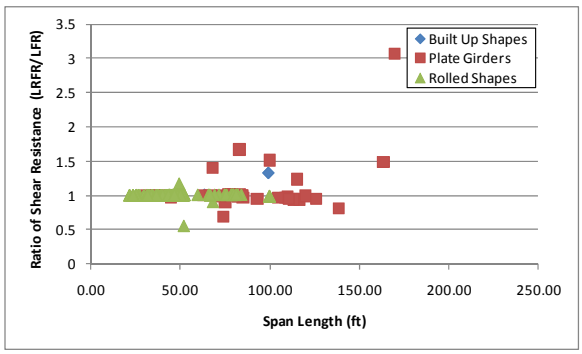
The shear resistance was compared next and the results show that the ratio of resistances is very close to 1.0. A significant number of the girders where the resistance ratio was greater than 1.0 have been eliminated by considering only those near the support. The ratio of shear resistance is shown in Figure B-305.



(a) (b)



(c)

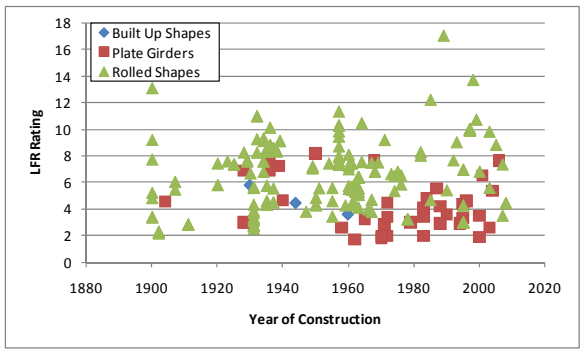


(d)

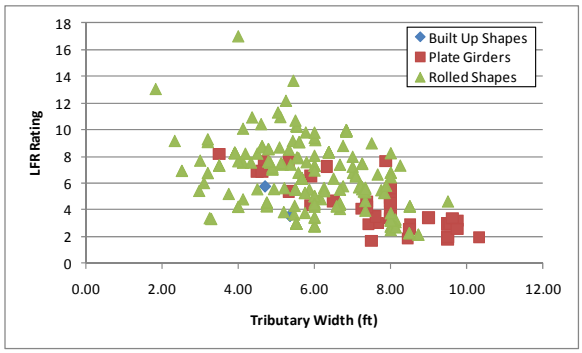
Figure B-305: Ratio of Factored Shear Resistance (LRFR/LFR)

B.1.13.3.3 Rating Factors

After verifying that the live load shears and shear resistances were reasonable, the next step was to compare the rating factors. Figure B-306 and Figure B-307 show the rating factors, the LFR ratings were calculated using the resistance and the increased dead and live loads while the LRFR ratings were typically at the support and were used as calculated by BRASS. The figures show that a large number of those girders that were eliminated are plate girders where it is possible that the shear resistance would vary with location.



(a)



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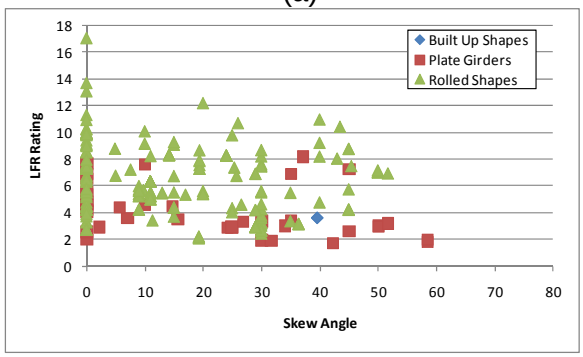
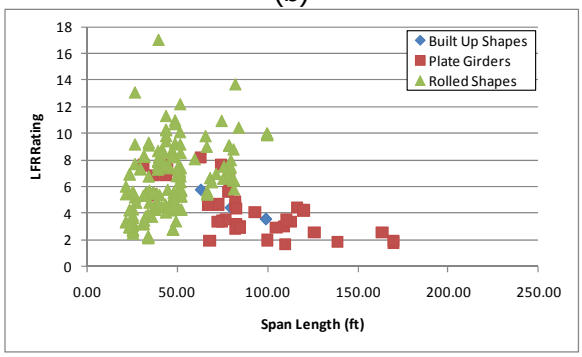


(c)



(d)

Figure B-306: LFR Shear Rating Factor for Type 3S2 Vehicle

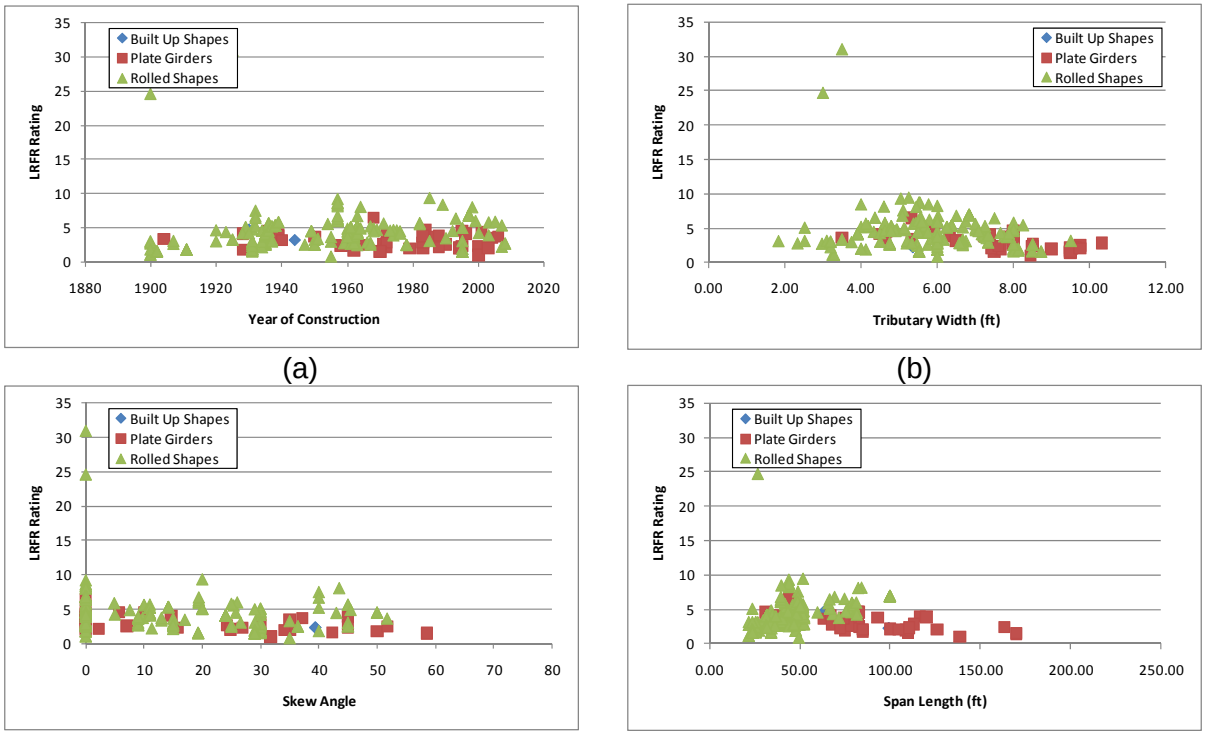
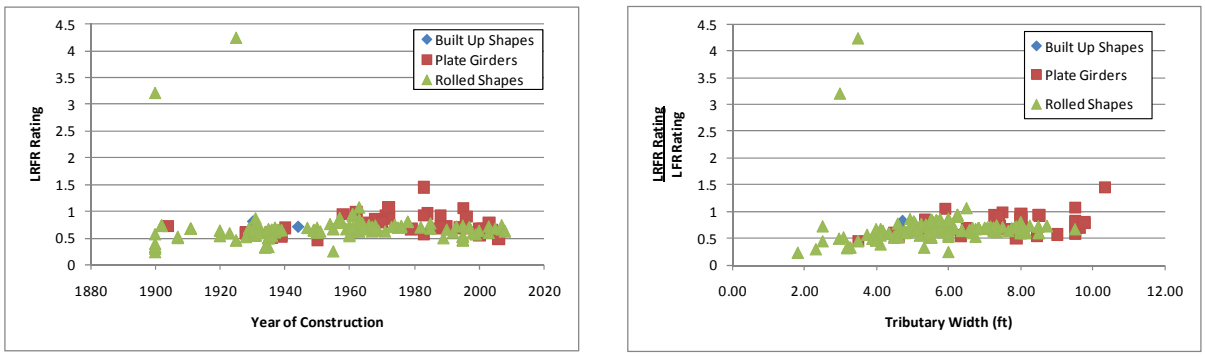
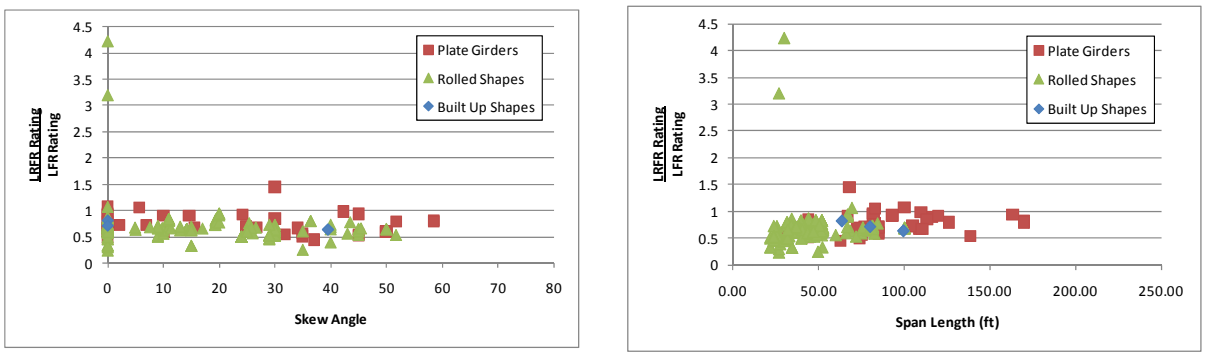


Figure B-307: LRFR Shear Rating Factor for Type 3S2 Vehicle

B.1.13.3.4 Rating Factor Comparison

The rating factors are then compared by looking at the ratio between the LRFR rating factor and the LFR rating factor. Figure B-308 shows the results of this comparison. The results show that the LFR rating is typically greater than the LRFR rating. Most of the girders with tributary widths between six and eight feet were girders where the critical location varied and were removed from this comparison. The ratio has increased slightly but the LRFR rating is still less than the LFR rating.



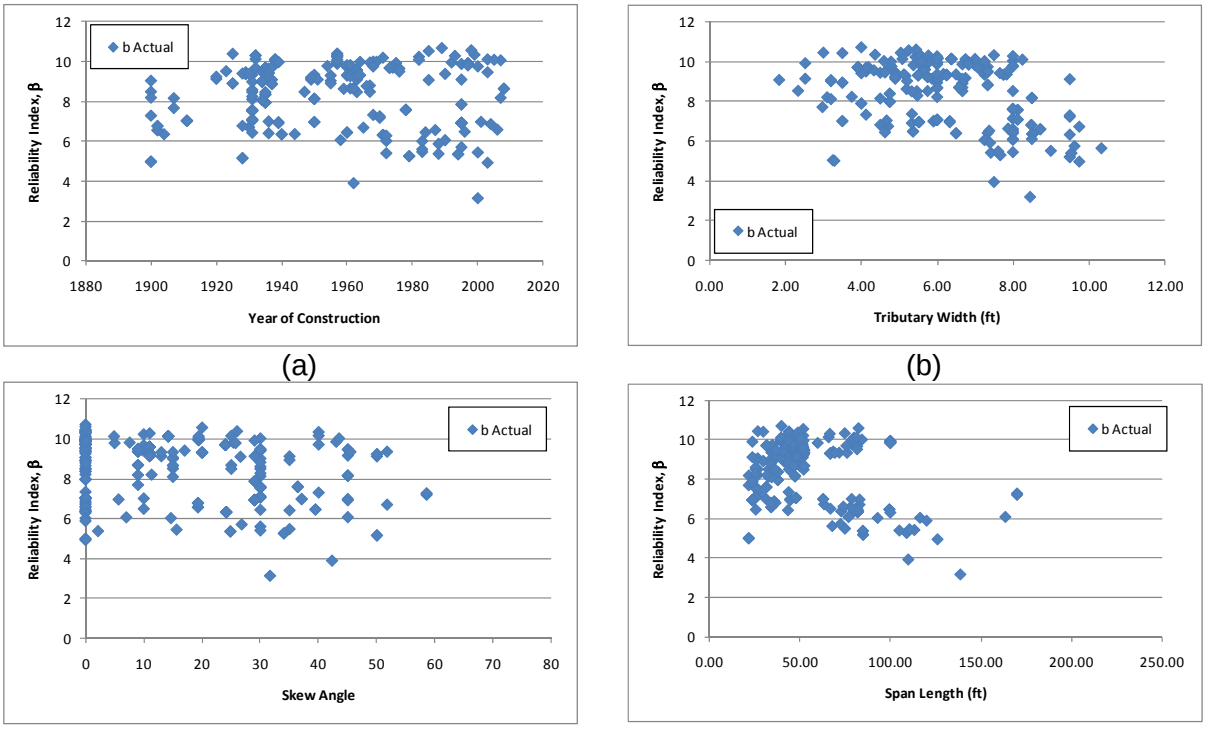


(c) (d)

Figure B-308: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3S2 Vehicle

B.1.13.3.5 Reliability Indices

The reliability indices shown in Figure B-309 are the same as those shown in Figure B-301. The reliability indices shown are above the value assumed in the development of the MBE, which is a value of 2.5. The reliability index remains the same as calculated previously because the LRFR location did not move.



(a) (b)

(c) (d)

Figure B-309: Shear Reliability Indices for Type 3S2 Vehicle

B.1.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table B-1 shows the results for the moment ratings. For the design vehicle a similar number of girders have ratings less than 1.0 for either method. For the other vehicles investigated, the number of girders varied significantly depending on the vehicle, but overall a similar number had LFR ratings that were greater than the LRFR ratings.

Table B-1: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	432	70	6	6	29	12	0	41	18	47	2	0	2
LRFR Rating less than 1.0		54	28	27	9	41	14	8	52	24	12	1	4
LFR and LRFR Rating less than 1.0		41	5	5	3	8	0	2	13	16	0	0	0
% with LFR RF greater than LRFR RF		32	89	89	8	89	89	7	88	8	90	90	89

B.1.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table B-2 shows the results for the shear ratings.

Table B-2: Shear Rating Factor Results for All 12 Vehicles

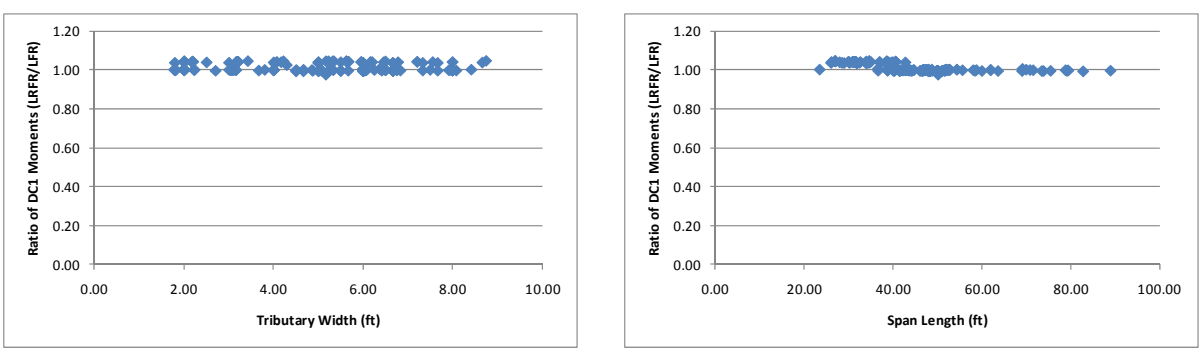
	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	432	0	0	0	0	0	0	0	0	0	0	0	0
LRFR Rating less than 1.0		49	11	9	9	10	7	9	19	31	7	7	7
LFR and LRFR Rating less than 1.0		0	0	0	0	0	0	0	0	0	0	0	0
% with LFR RF greater than LRFR RF		98	98	98	82	98	98	80	98	82	98	99	98

B.2 Interior Non-Composite Girders

B.2.1 Dead Loads

B.2.1.1 Moment

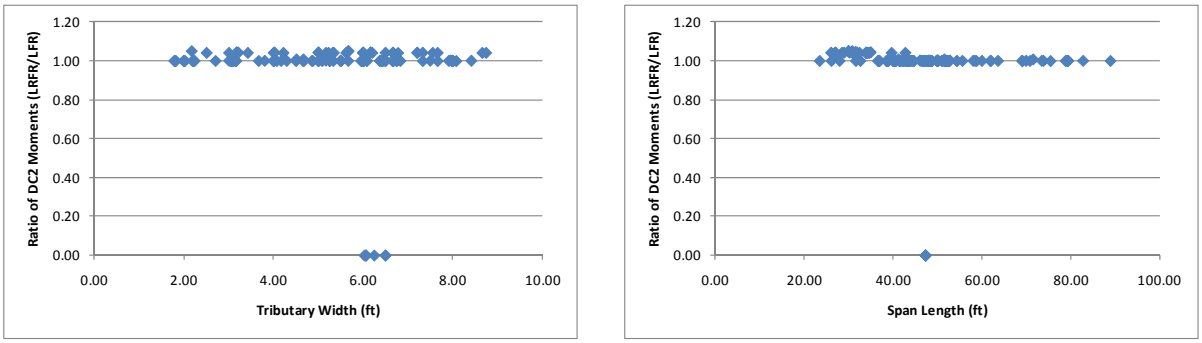
The first set of graphs show the results that were obtained for flexure. As shown in Figure B-310, with the ratio of DC1 moments (self-weight, dead loads on non-composite section) are very close to 1.0. Those that are slightly above 1.0 are caused by the moment being obtained at the four-tenths point for LFR while the LRFR moment is calculated at midspan.



(a) (b)

Figure B-310: Ratio of DC1 LRFR Moment to DC1 LFR Moment (unfactored loads)

Figure B-311 shows that there is little variation in the DC2 and DW loads. There are several above 1.0 which are a result of the LRFR critical location being at midspan and the LFR critical location being at the four-tenths point.

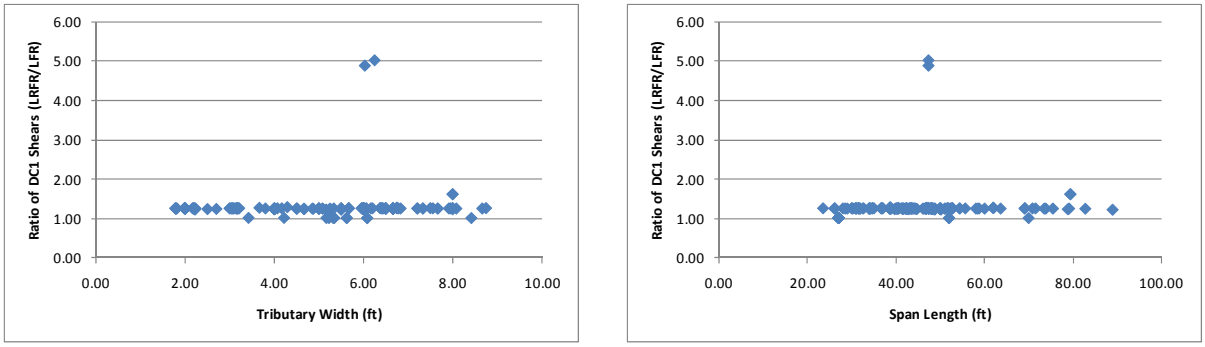


(a) (b)

Figure B-311: Ratio of DC2 and DW LRFR Moment to DC2 and DW LFR Moment (unfactored loads)

B.2.1.2 Shear

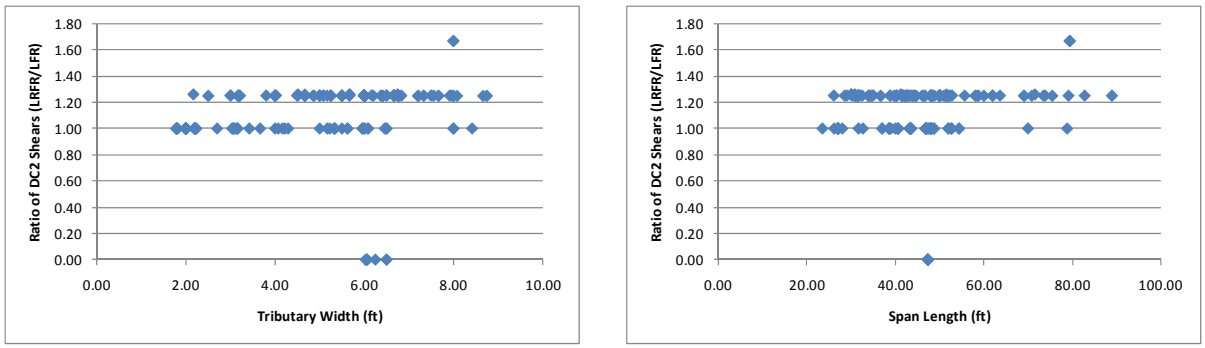
Figure B-312 below shows that for most girders the LRFR DC1 shear is 125% of the LFR DC1 shear. This is a result of BRASS not always calculating a rating factor for shear at the support for LFR; to get around this an option in RIO was created to ignore zero shear ratings. The result was typically that the LFR rating was taken at either the one-tenth or nine-tenths point along the span. This would correspond to a 25% increase in dead load shear since all the results compiled so far are for simple spans and DC1 is a uniform load.



(a) (b)

Figure B-312: Ratio of DC1 LRFR Shear to DC1 LFR Shear (unfactored loads)

Figure B-313 shows the same trend as Figure B-312 in that the LRFR shear for the majority of girders is 125% of the LFR shear for DC2 and DW loads. The ratios at 1.0 for the DC2 and DW loads are cases where both the LFR and LRFR shear was zero.



(a) (b)

Figure B-313: Ratio of DC2 LRFR Shear to DC2 LFR Shear (unfactored loads)

B.2.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure B-314. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

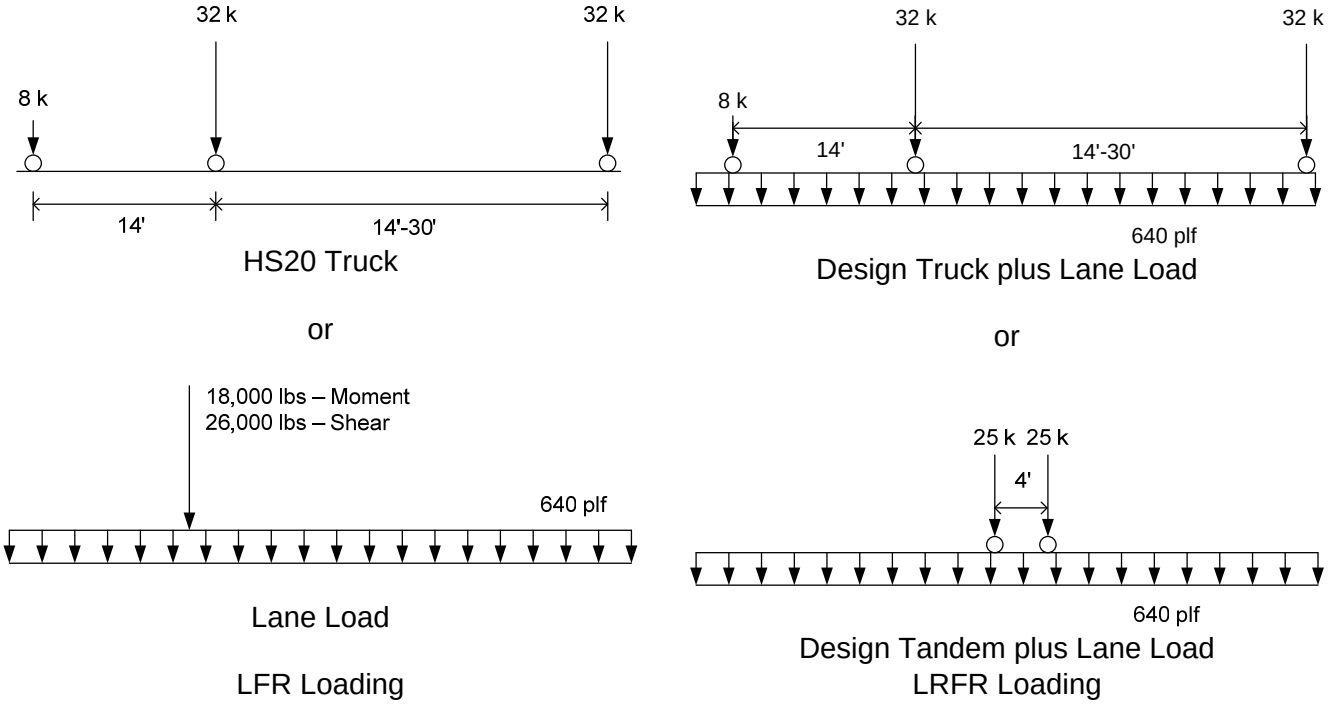
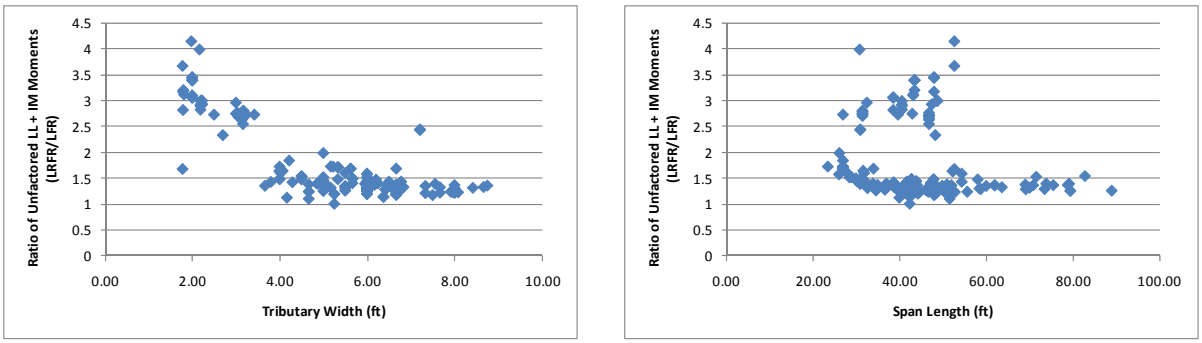


Figure B-314: Vehicle Loadings and Load Factors

B.2.2.1 Moment

B.2.2.1.1 Live Loads

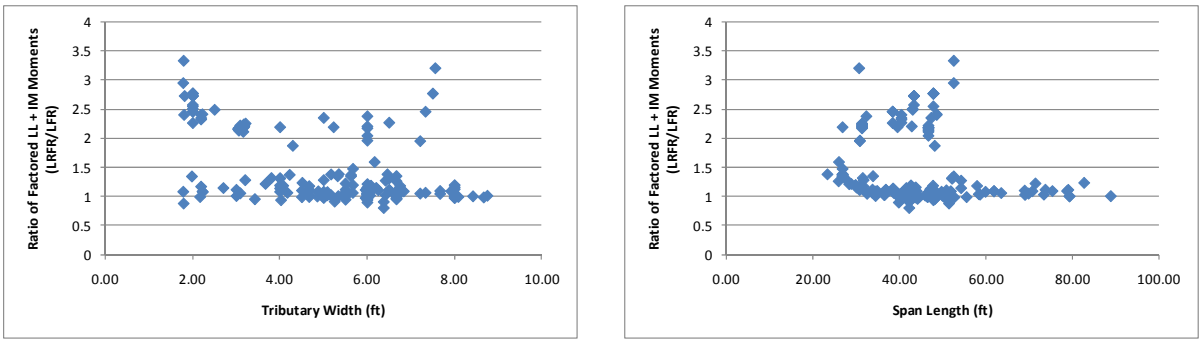
Figure B-315 shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is approximately 1.3 for most of the girders within this subset. The ratio of unfactored live loads tends to increase with decreasing tributary width. This also occurs to some extent when looking at the results for the span length. The LRFR live loads for short spans with narrow girder spacing are larger than for longer spans with wider girder spacing.



(a) (b)

Figure B-315: Ratio of Unfactored Live Load plus Impact Moments for Design Vehicles (LRFR/LFR)

The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-316 shows that the results have shifted down and are between 1.0 and 1.5 for most cases.



(a) (b)

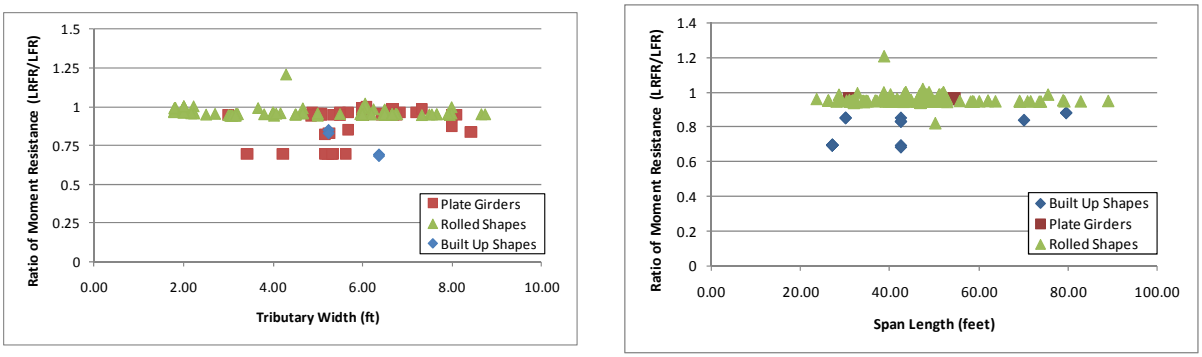
Figure B-316: Ratio of Factored Live Load plus Impact Moments for Design Vehicles (LRFR/LFR)

While there appear to be trends in the data, the fact that a subset of the LRFR loads is significantly greater than the LFR loads for some girders is reason for concern. Further investigation was conducted into the distribution factors used in the analysis for several girders. What was found was the possibility that some of these bridges have timber decks that are input as concrete in the Virtis file. This was discovered by dividing the girder spacing by the distribution factor to determine the denominator of the S-over equation. In several cases it came out be exactly what is in the Standard Specification for timber decks on steel girders. BRASS would calculate the LRFR distribution factors

using the equations in Table 4.6.2.2.2b-1 for moment and Table 4.6.2.2.3a-1 for shear for a concrete deck on steel girders.

B.2.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure B-317 shows that the ratio of resistance is slightly below 1.0 for most girders, with several approaching 0.75.

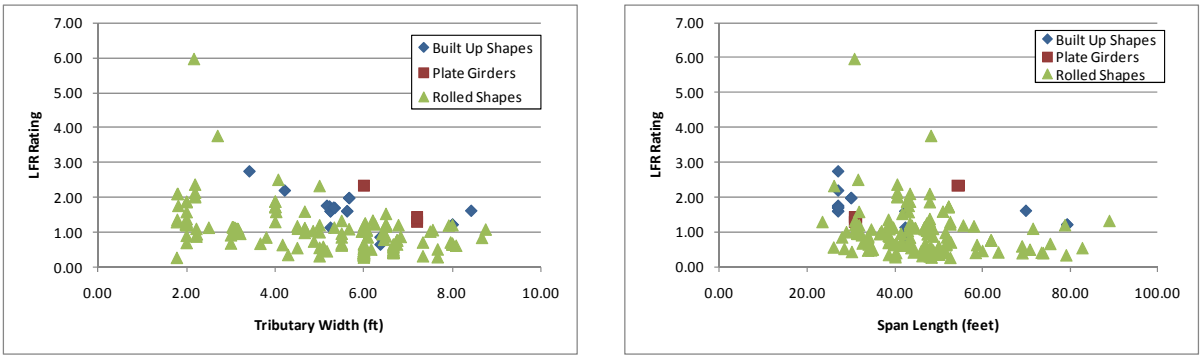


(a) (b)

Figure B-317: Ratio of factored Moment Resistance (LRFR/LFR)

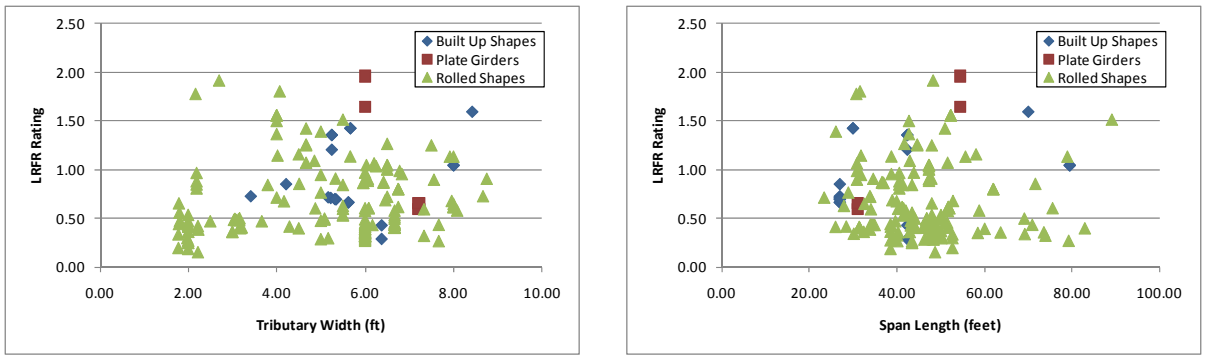
B.2.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results seemed reasonable, the actual rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (193 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 101 girders with LFR ratings less than 1.0, 155 girders with LRFR ratings less than 1.0, and 90 girders where both the LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower rating factors. Figure B-318 and Figure B-319 show the LFR rating factors and LRFR rating factors, respectively.



(a) (b)

Figure B-318: LFR Flexure Rating Factors for Design Vehicles

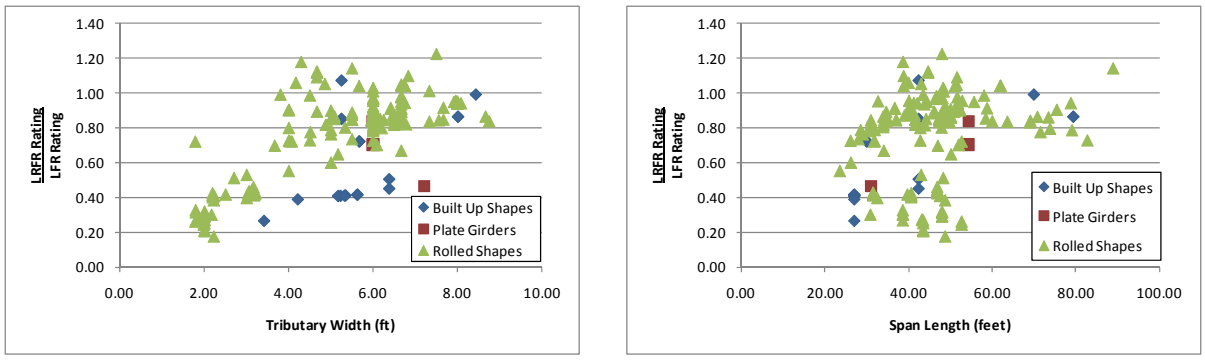


(a) (b)

Figure B-319: LRFR Flexure Rating Factors for Design Vehicles

B.2.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR divided by LFR, is shown in Figure B-320. The results indicated that 90% of the girders in this set have LFR ratings greater than LRFR ratings. Tributary widths greater than four feet generally have higher ratios than those with tributary widths less than four feet, which is indicative of LFR having higher ratings for narrow girder spacing. There is significant scatter for span lengths less than 60 feet but there is no clear trend with regards to the span length.



(a) (b)

Figure B-320: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Vehicles

Figure B-321 shows the variation of the ratio between LRFR rating and LFR rating for those girders with an LRFR rating less than 1.0. The figure shows that most girders with an LRFR rating that is less than 1.0 have an LRFR rating that is at least 70% of the LFR rating. Most of the girders that are not at least 70% of the LFR rating are between 20 and 50% of the LFR rating.

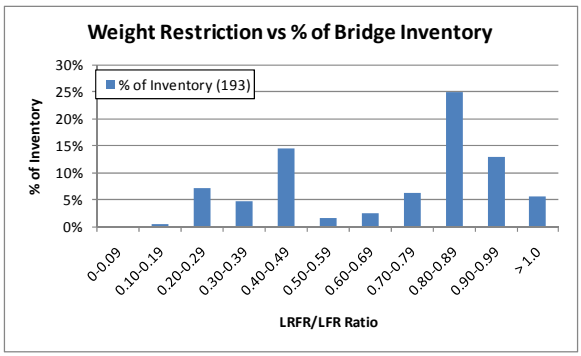
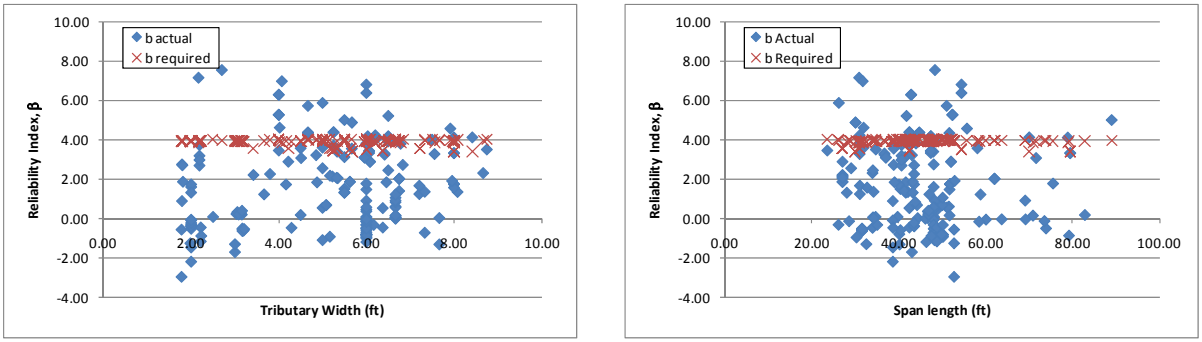


Figure B-321: Distribution of LRR/LFR Ratio for Girders with LRFR Rating less than 1.0

B.2.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure B-322 shows that a significant number of girders have a reliability index lower than that assumed in the development of the MBE at the inventory level. This is concerning but it also agrees with the calculated LRFR rating factors as they are generally less than 1.0. There are 136 girders with required level of reliability greater than the existing level of reliability.



(a) (b)

Figure B-322: Flexure Reliability Indices for Design Vehicles

Figure B-323 shows the reliability index versus the LRFR rating for this set of girders. The figure shows that for a girder passing the LRFR rating, the reliability index for flexure would be approximately 4.0. This value is also shown in Figure B-322 as the required beta. It is expected that this value would be approximately 3.5 but the MBE utilizes a time span of 5 years instead of the 75 years used in the AASHTO LRFD Design Specifications and therefore results in higher reliability.

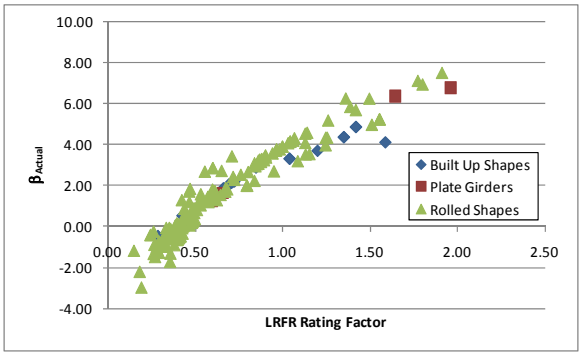


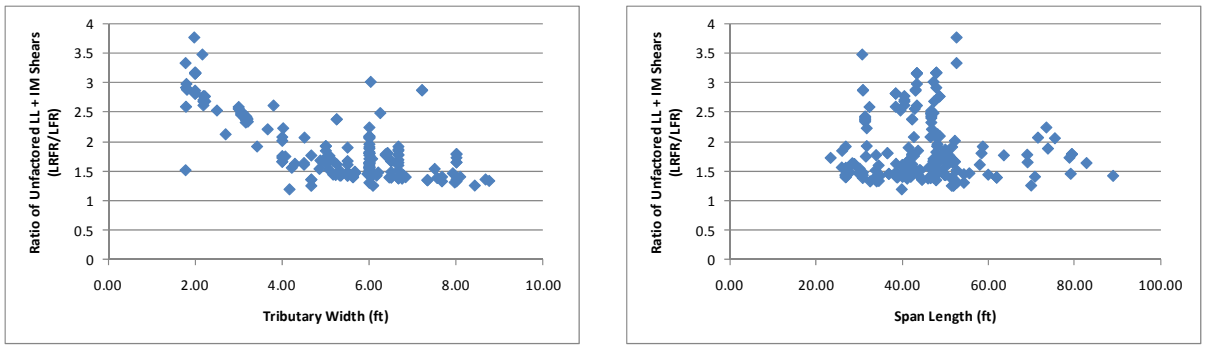
Figure B-323: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Vehicle

B.2.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is steel, simple span interior girders with non-composite concrete decks.

B.2.2.2.1 Live Loads

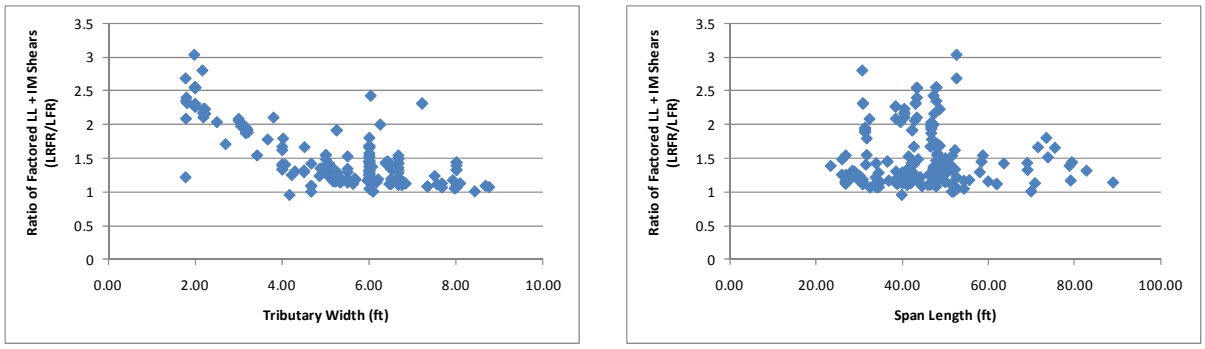
Figure B-324 shows that the ratio of unfactored shear varies significantly from 1.25 to 3.75. The ratio decreases with increasing tributary width but no trends are noted with the span length.



(a) (b)

Figure B-324: Ratio of Unfactored Live Load plus Impact Shears for Design Vehicles (LRFR/LFR)

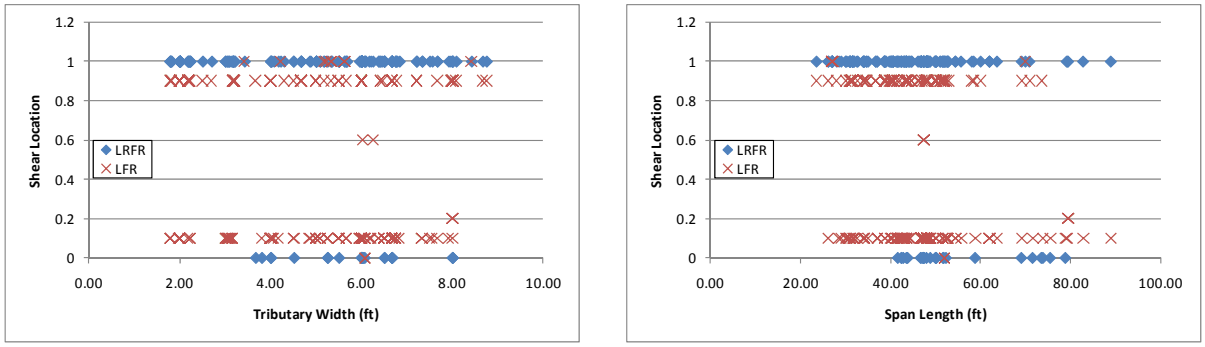
The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-325 shows that the ratio of factored live load shears has decreased and is generally between 1.0 and 3.0 for most cases.



(a) (b)

Figure B-325: Ratio of Factored Live Load plus Impact Shears for Design Vehicles (LRFR/LFR)

As shown in Figure B-326, the location of the critical section for shear rating for most girders is the end of the span and at the one tenth point for the LRFR and LFR ratings, respectively. The variation in the factored shears shown in Figure B-325 was exacerbated by the difference in the critical section for shear rating.

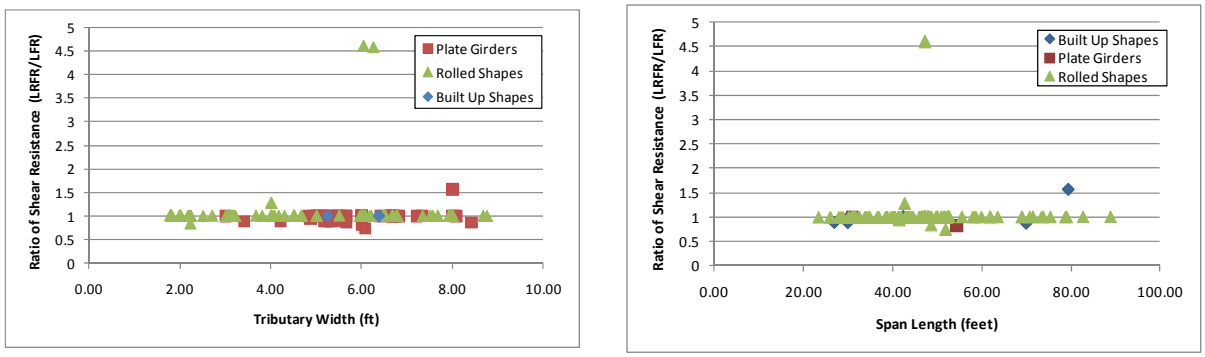


(a) (b)

Figure B-326: Graph of critical shear location for Design Vehicles

B.2.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure B-327 shows that the ratio of resistance is generally around 1.0. There are two girders with an LRFR resistance 4.5 times larger than the LFR resistance; these are the two girders shown in Figure B-326 with an LFR critical location at 0.6.

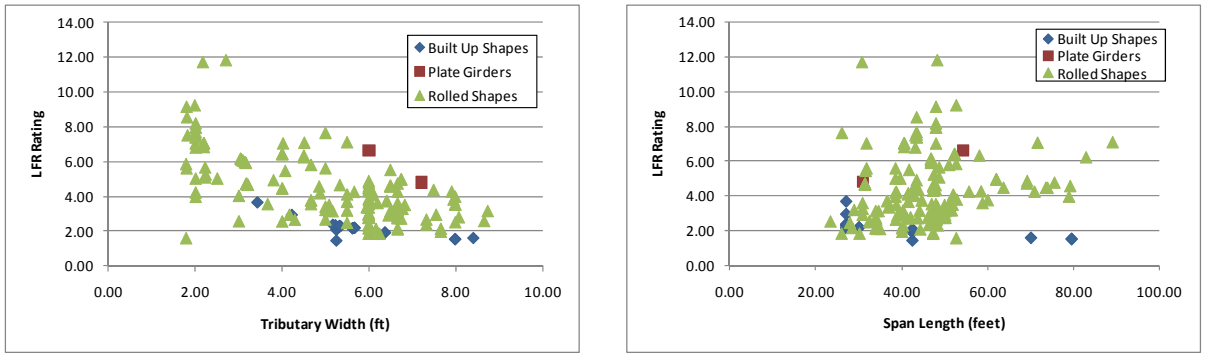


(a) (b)

Figure B-327: Ratio of factored Shear Resistance (LRFR/LFR)

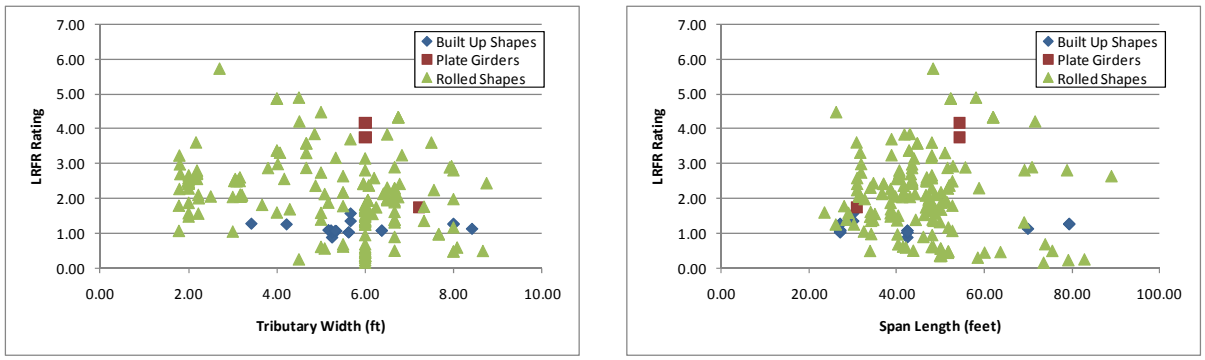
B.2.2.2.3 Rating Factors

After comparing the loads and resistances to verify that the results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 0 girders with LFR ratings less than 1.0 and 29 girder with LRFR ratings less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. In addition, the LFR rating was greater than the LRFR rating for 100% of the girders in this subset. Figure B-328 and Figure B-329 show the LFR rating factors and LRFR rating factors, respectively. The LFR rating tends to decrease with increasing tributary width while the LFR rating versus span length shows no general trends. Neither graph for the LRFR ratings show any trends.



(a) (b)

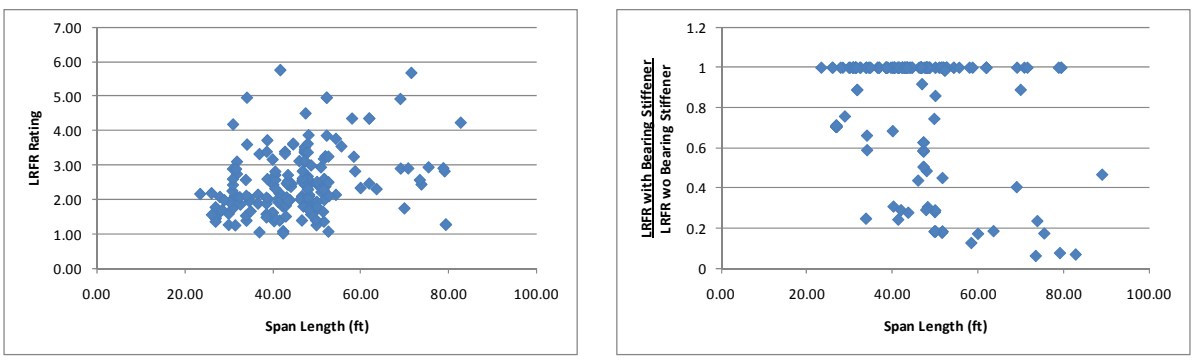
Figure B-328: LFR Shear Rating Factors for Design Vehicles



(a) (b)

Figure B-329: LRFR Shear Rating Factors for Design Vehicles

Figure B-330a shows the LRFR shear ratings when the bearing stiffener is ignored. When compared to Figure B-329b, there are now very few girders with ratings less than 1.0. In fact 28 fewer girders have LRFR ratings less than 1.0 when ignoring the bearing stiffener rating. Figure B-330b shows the ratio of LRFR rating including the bearing stiffener rating divided by the LRFR rating ignoring the bearing stiffener rating. Most girders have ratings of 1.0, but those that don't are less than 1.0 and most are less than 50 feet in span length. 31% of girders have lower LRFR ratings when the bearing stiffener rating is included than when it is excluded.

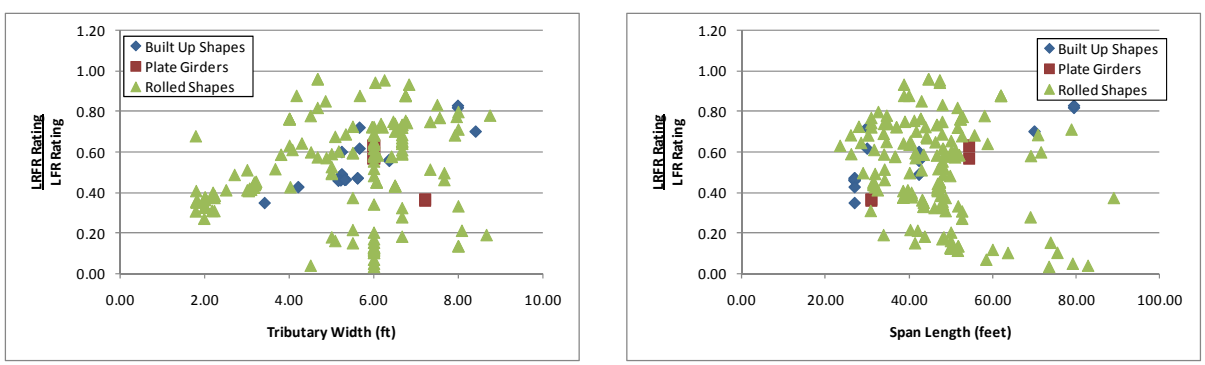


(a) (b)

Figure B-330: Effect of Bearing Stiffener on LRFR Shear Rating

B.2.2.2.4 Rating Factor Comparisons

Figure B-331 shows the ratio of the LRFR rating to the LFR rating. The results show that the LRFR rating is always less than the LFR rating. Most girders have an LRFR rating that is at least 40% of the LFR rating. The ratio of ratings increases with tributary width but there are no trends in the span length.



(a) (b)

Figure B-331: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Vehicles

Figure B-332 shows that most girders with an LRFR rating less than 1.0 have ratings that are significantly lower than their corresponding LFR rating. All girders with LRFR ratings less than 1.0 have ratings that are less than 70% of the LFR rating, with most being under 20%. The rating for these girders is controlled by the bearing stiffener rating for LRFR.

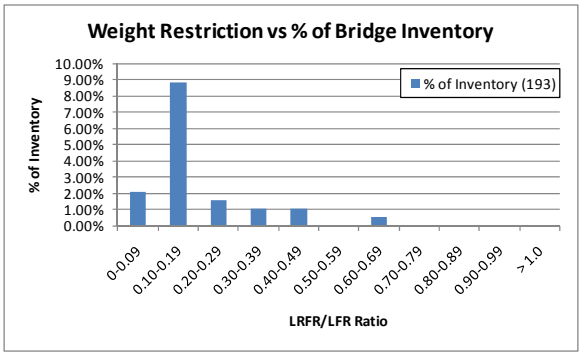
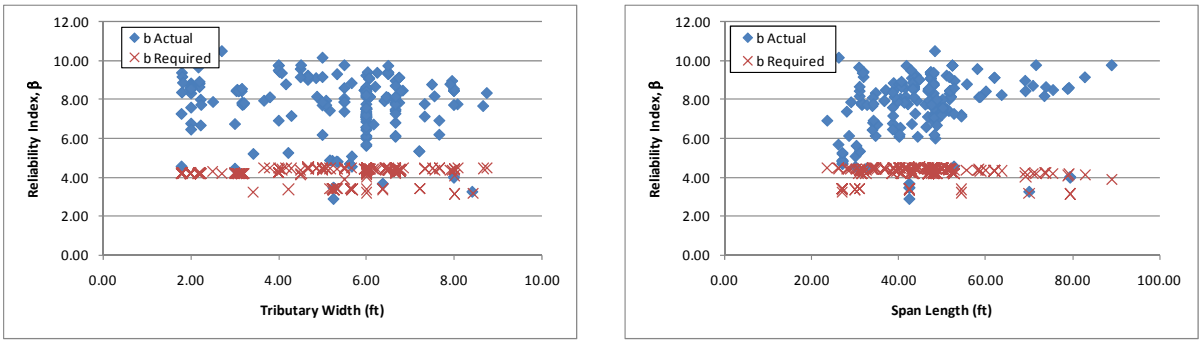


Figure B-332: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

B.2.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure B-333 shows that most girders have a reliability index for shear greater than the required level (reliability index of 3.5).



(a) (b)

Figure B-333: Shear Reliability Indices for Design Vehicles

Figure B-334 shows the reliability index plotted agains the LRFR rating for shear caused by the HL-93 loading. The figure shows that a girder with a rating factor of 1.0 will have a reliability index of approximately 4.0. The points with low ratings but high reliability are those girders that are controlled by the bearing stiffener rating. The reliability index is artificially high because it is based upon the shear strength of the web, not the strength of the bearing stiffener.

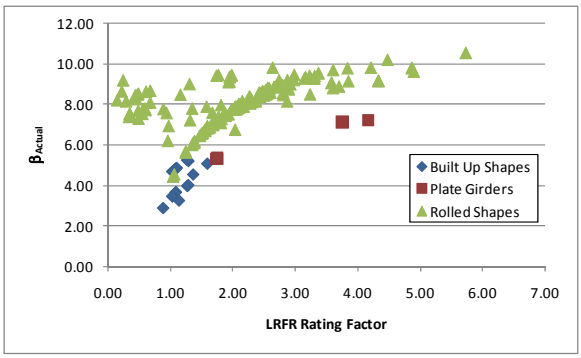


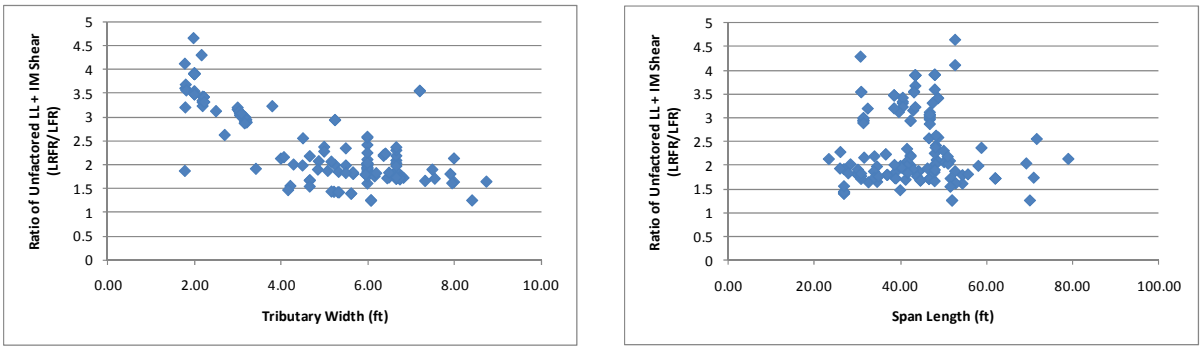
Figure B-334: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

B.2.2.3 Shear-Corrected

Since a significant number of the simple span girders had the critical shear location for LFR at either the one- or nine-tenths point, the results for these locations were multiplied by 1.25 to approximate the results at the support. The following graphs show the results of this effort.

B.2.2.3.1 Live Load

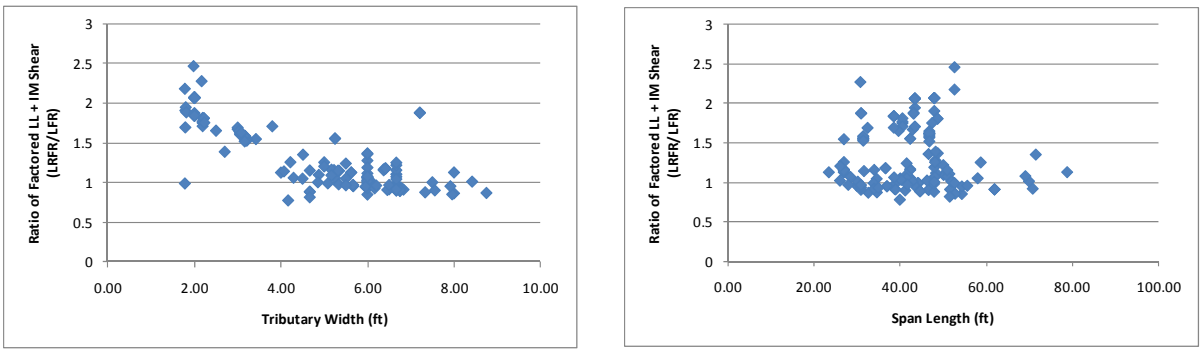
Figure B-335 shows that the ratio of unfactored shear has increased from the previous section and is in the range of 1.5 to 2.5 for most girders. Narrowly spaced girders are more likely to have higher LRFR shears than LFR shears.



(a) (b)

Figure B-335: Ratio of Unfactored Live Load plus Impact Shear for Design Vehicles (LRFR/LFR)

The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-336 shows that the ratio of factored live load shears has decreased and is between 0.8 and 1.25 for most cases with closely spaced girders having ratios greater than 1.5.

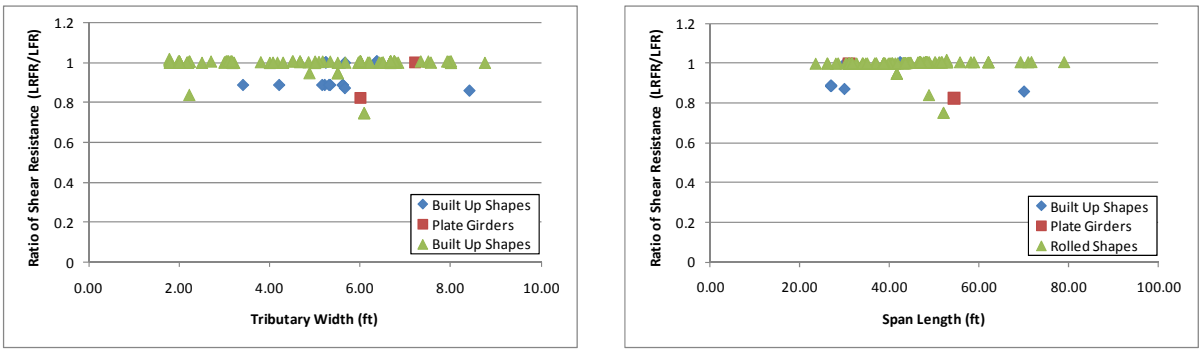


(a) (b)

Figure B-336: Ratio of Factored Live Load plus Impact Shear for Design Vehicles (LRFR/LFR)

B.2.2.3.2 Resistance

The resistances used in this comparison (see Figure B-337) are the same as those shown in the previous section. It was assumed that the shear resistance would remain the same between the support and one-tenth point; this may not be the case for plate girders where tension field action in the end panel may or may not be considered in the shear resistance.

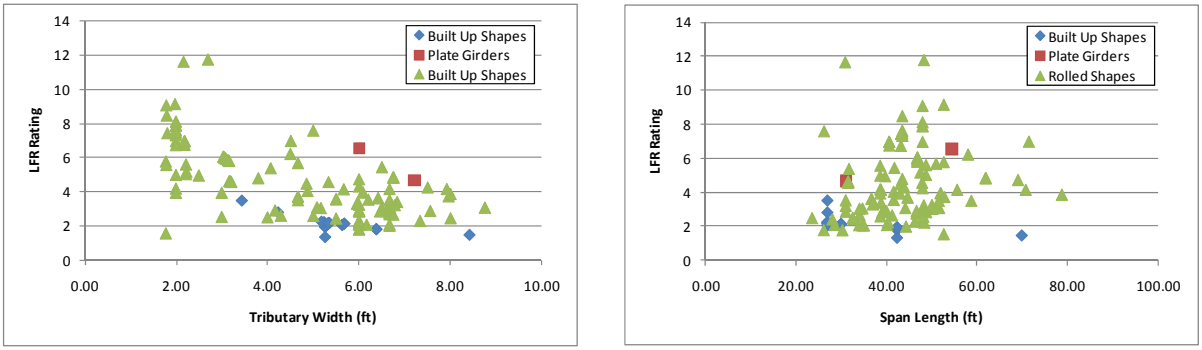


(a) (b)

Figure B-337: Ratio of factored Shear Resistance (LRFR/LFR)

B.2.2.3.3 Rating Factors

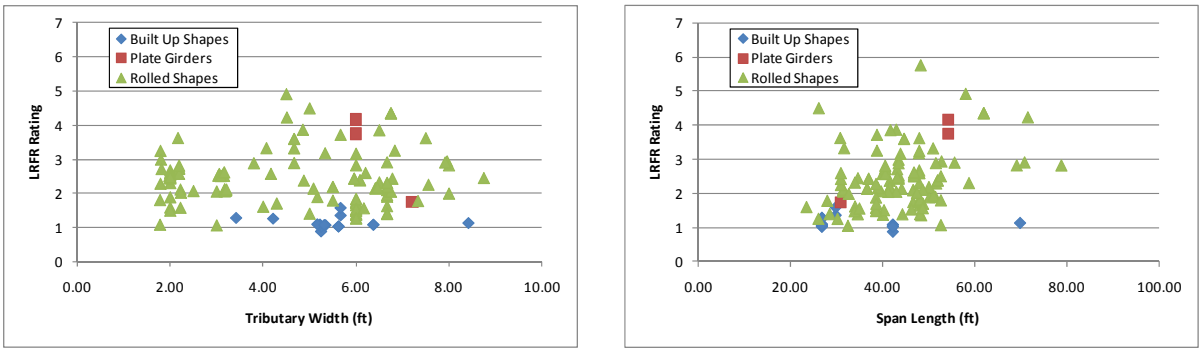
The LFR rating factors were calculated using the loads from the one- or nine-tenths point multiplied by 1.25 such that they would approximate the shear at the support. The LFR rating factors are shown in Figure B-338.



(a) (b)

Figure B-338: LFR Shear Rating Factors for Design Vehicles

The LRFR rating factors are calculated at the support and are used as obtained from BRASS. The LRFR rating factors are shown in Figure B-339.

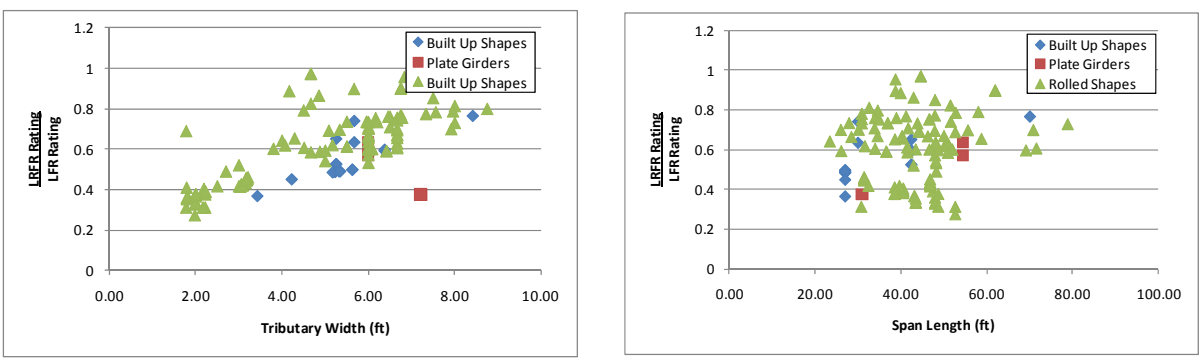


(a) (b)

Figure B-339: LRFR Shear Rating Factors for Design Vehicles

B.2.2.3.4 Rating Factor Comparison

After calculating the LFR rating factor at the support, the two rating factors were compared by dividing the LRFR rating by the LFR rating. The results of this comparison are shown in Figure B-340. Figure B-340 shows that most of the girders that were removed by considering only those near the support had low LRFR ratings. Also taking the LFR rating to be at the support, shifted the ratio of ratings up slightly.

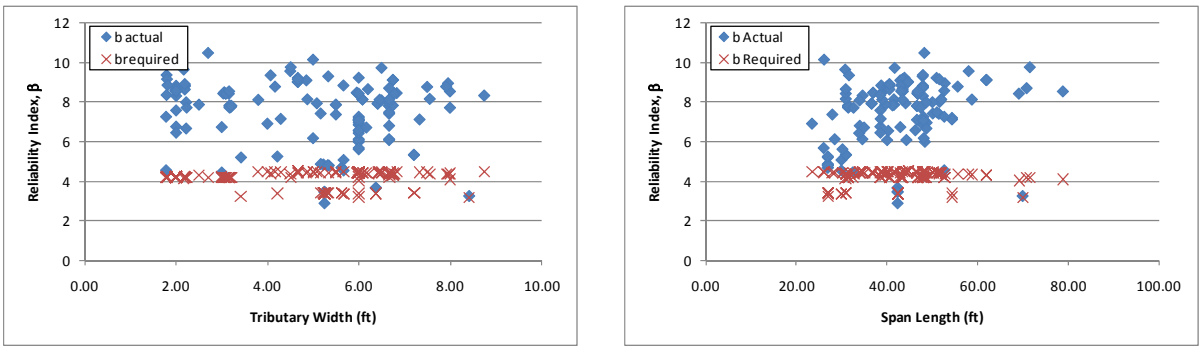


(a) (b)

Figure B-340: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Vehicles

B.2.2.3.5 Reliability Indices

The reliability indices shown in Figure B-341 are the same as those shown above in Figure B-333. The actual reliability index would decrease because the mean total load will increase, while the required reliability index would increase because the increase in mean total load is less than the increase in the mean factored load. This could possibly cause more girders to have a reliability index less than the code required value. There are several girders that do not have the required level of reliability; these girders do not have any identifying characteristics with regards to span length or tributary width.



(a) (b)

Figure B-341: Shear Reliability Indices for Design Vehicles

B.2.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-342. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

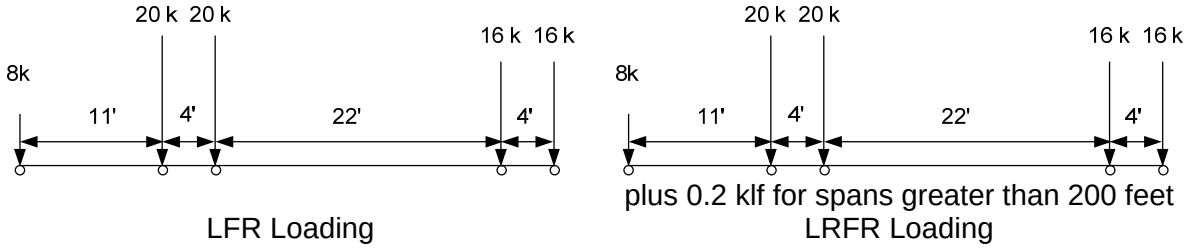


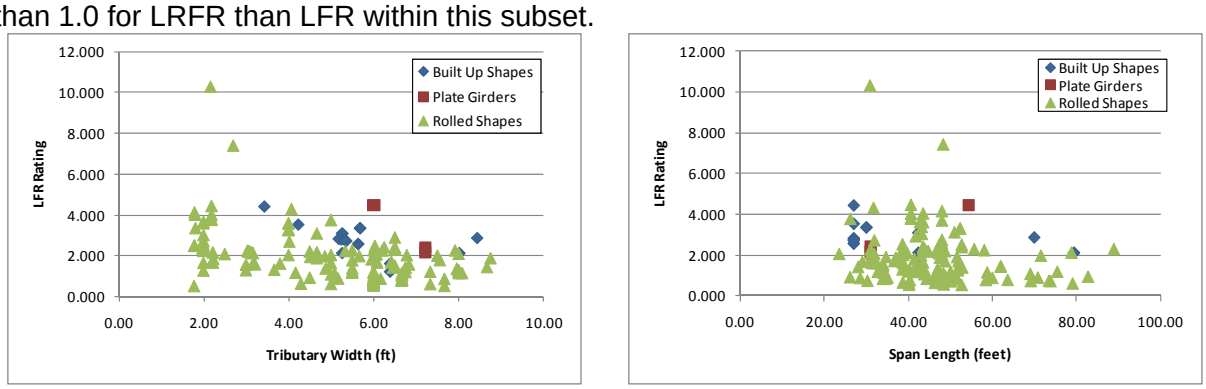
Figure B-342: Vehicle Loadings and Load Factors

B.2.3.1 Moment

The following section contains the flexure results for interior, non-composite steel girders within simple span bridges for the DE-07 Vehicle.

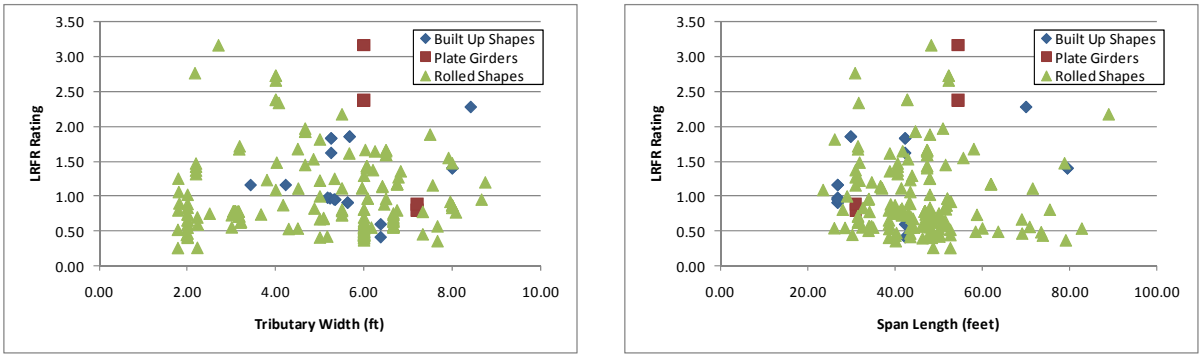
B.2.3.1.1 Rating Factors

Figure B-343 and Figure B-344 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 47 girders with an LFR rating less than 1.0, 121 girders with an LRFR rating less than 1.0, and 47 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 99% of the girders in this subset. Significantly more girders have ratings less than 1.0 for LRFR than LFR within this subset.



(a) (b)

Figure B-343: LFR Flexure Rating Factors for DE-07 Vehicle

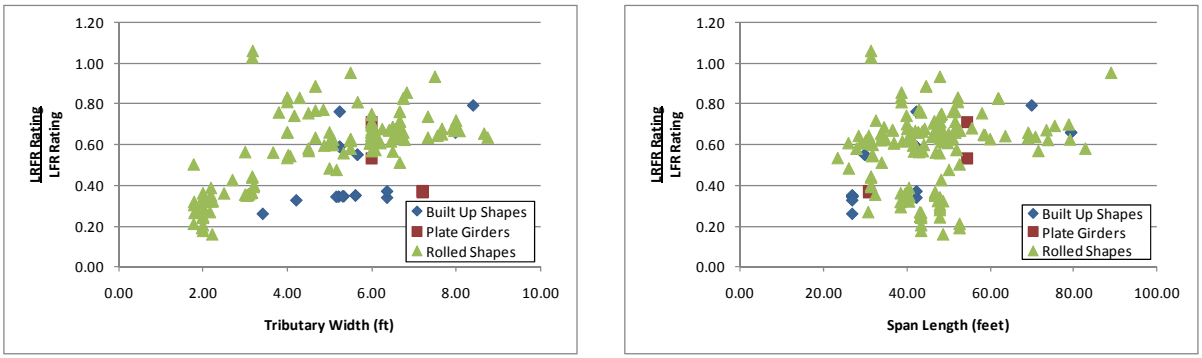


(a) (b)

Figure B-344: LRFR Flexure Rating Factors for DE-07 Vehicle

B.2.3.1.2 Rating Factor Comparisons

Figure B-345 shows the ratio of LRFR rating to LFR rating. Values greater than 1 indicate girders where the LRFR rating is greater than the LFR rating. This occurs with very few girders, with a majority of the girders clustered between 0.60 and 0.80. Bridges with narrowly spaced girders, approximately 2 feet, have higher LFR ratings than those with wider spacing.

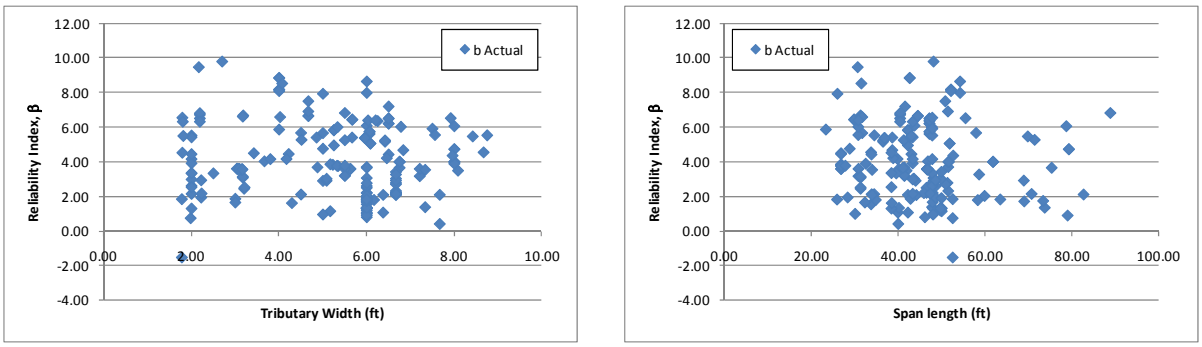


(a) (b)

Figure B-345: LRFR Flexure Rating divided by LFR Flexure Rating for DE-07 Vehicle

B.2.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-346 shows that there are a significant number of girders where the reliability index based on the section capacity is less than that assumed in the development of the MBE. The required level of reliability for routine permit vehicles is 2.5.



(a) (b)

Figure B-346: Flexure Reliability Indices for DE-07 Vehicle

Figure B-347 shows the reliability index plotted against the LRFR rating factor for the DE-07 vehicle. The figure shows that girders passing rating will have a reliability index of approximately 4.0 which is above the value of 2.5 used in the development of the MBE. This indicates that the live load factors currently in the MBE could be reduced to bring the expected level of reliability closer to the target of 2.5 for routine permit vehicles.

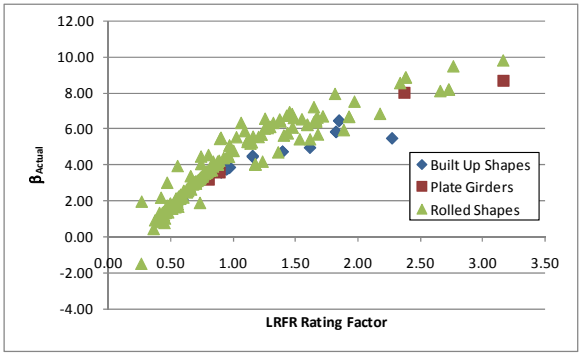


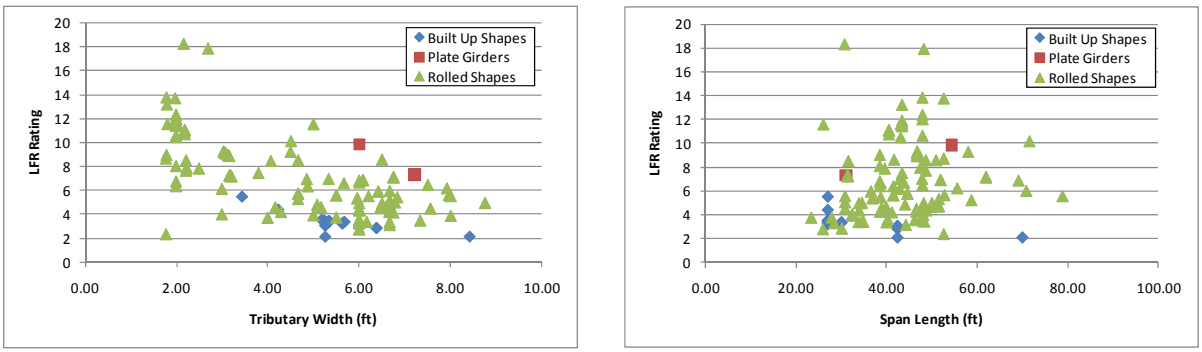
Figure B-347: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

B.2.3.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

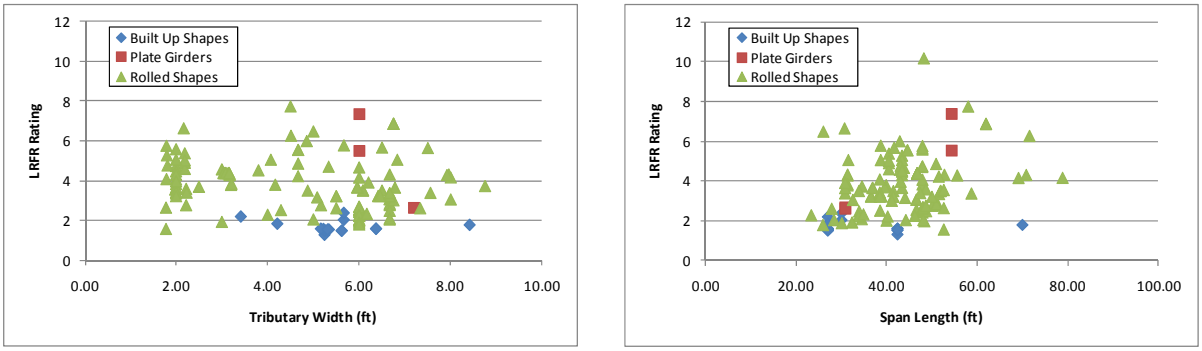
B.2.3.2.1 Rating Factors

For shear, there are no girders that have an LFR rating factor less than 1.0 and 22 girders with an LRFR rating factor less than 1.0. In this situation, 11% of the girders are affected by switching from LFR to LRFR. Most of these girders are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 99% of the girders in this subset. Figure B-348 and Figure B-349 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-348: LFR Shear Ratings for DE-07 Vehicle

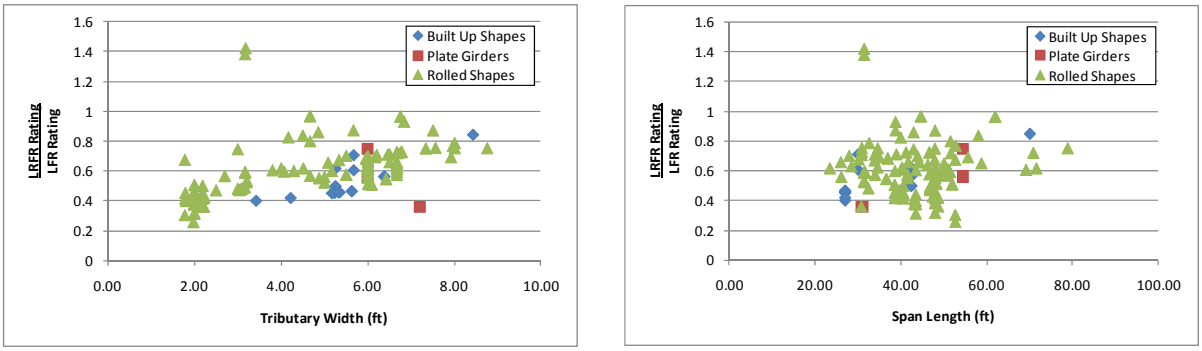


(a) (b)

Figure B-349: LRFR Shear Ratings for DE-07 Vehicle

B.2.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of rating factors. Figure B-350 shows the ratio of rating factors. The ratio increases slightly with increasing tributary width, but for most girders the ratio is between 0.4 and 0.8.

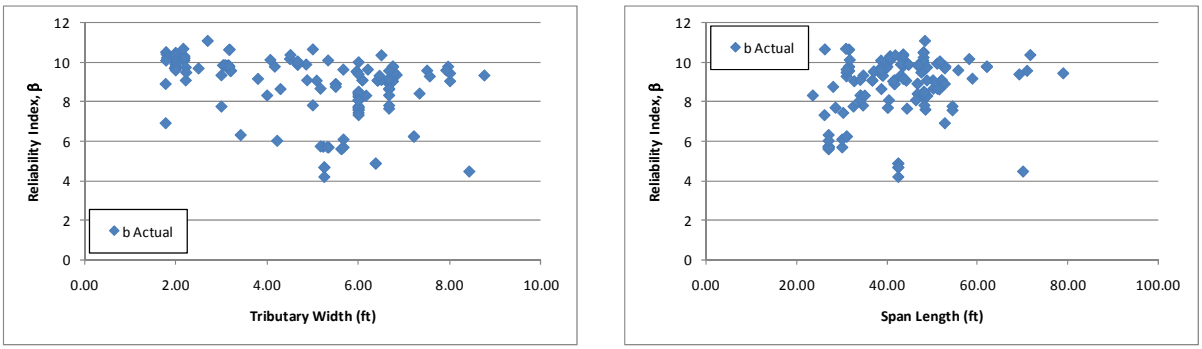


(a) (b)

Figure B-350: Ratio of LRFR Shear Rating to LFR Shear Rating for DE-07 Vehicle

B.2.3.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than that assumed in the MBE for all girders as shown in Figure B-351.



(a) (b)

Figure B-351: Shear Reliability Indices for DE-07 Vehicle

Figure B-352 shows the reliability index plotted against the LRFR rating for shear caused by the DE-07 vehicle. The figure shows that girders passing rating have a reliability index of approximately 4.0. This is above the reliability index used in the development of the MBE for routine permit vehicles, which is 2.5. The live load factors could be reduced and achieve the level of reliability expected. The diata points with high reliability but low ratings are girders where the rating was controlled by the bearing stiffener. The reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

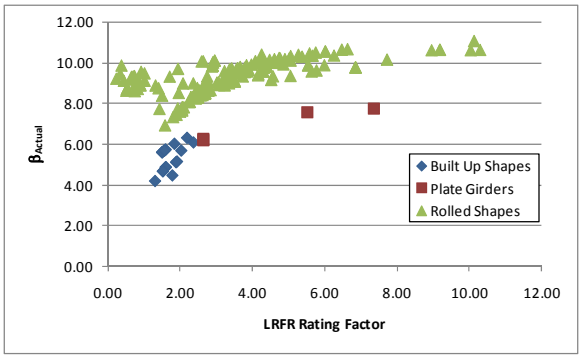


Figure B-352: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

B.2.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-353. The applicable load factors for this vehicle are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

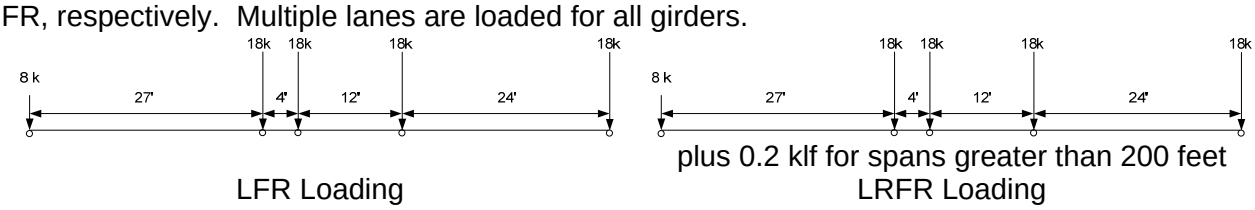


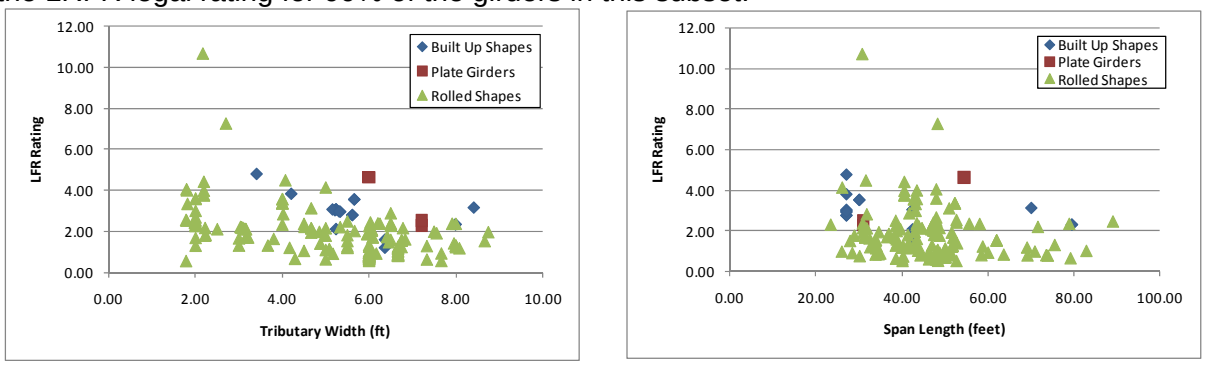
Figure B-353: Vehicle Loadings and Load Factors

B.2.4.1 Moment

The following section contains the flexure results for interior, non-composite steel girders within simple span bridges for the FL-04 Vehicle.

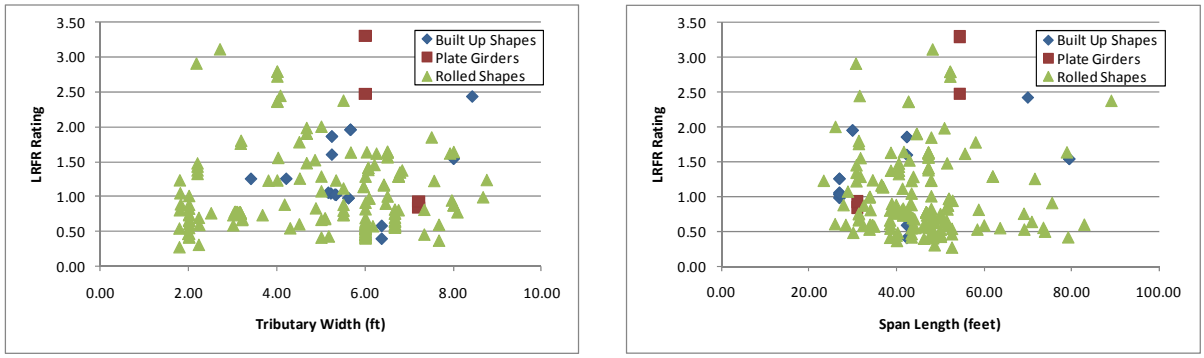
B.2.4.1.1 Rating Factors

Figure B-354 and Figure B-355 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 46 girders with an LFR rating less than 1.0, 117 girders with an LRFR rating less than 1.0, and 46 girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 99% of the girders in this subset.



(a) (b)

Figure B-354: LFR Flexure Rating Factors for FL-04 Vehicle

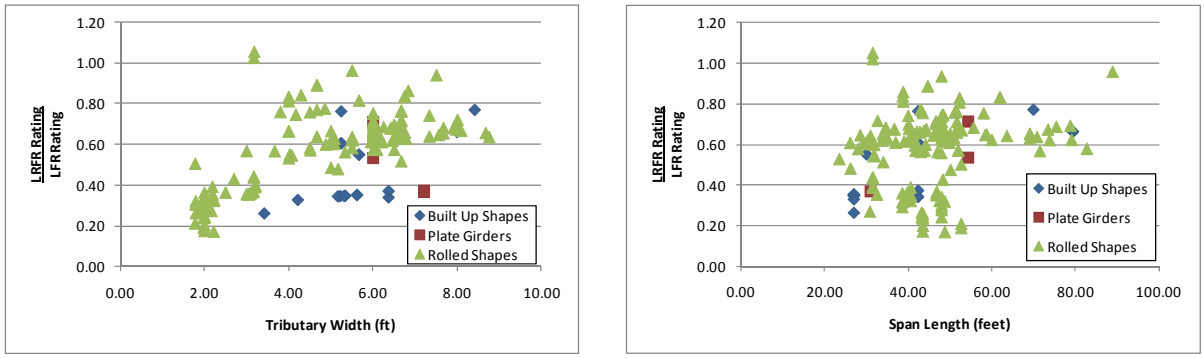


(a) (b)

Figure B-355: LRFR Flexure Rating Factors for FL-04 Vehicle

B.2.4.1.2 Rating Factor Comparisons

Figure B-356 show the ratio of the LRFR rating divided by the LFR rating. Values greater than 1 indicate LRFR ratings greater than the LFR rating. Most of the ratios are between 0.6 and 0.8, with closely spaced rolled shapes having ratios between 0.2 and 0.4.

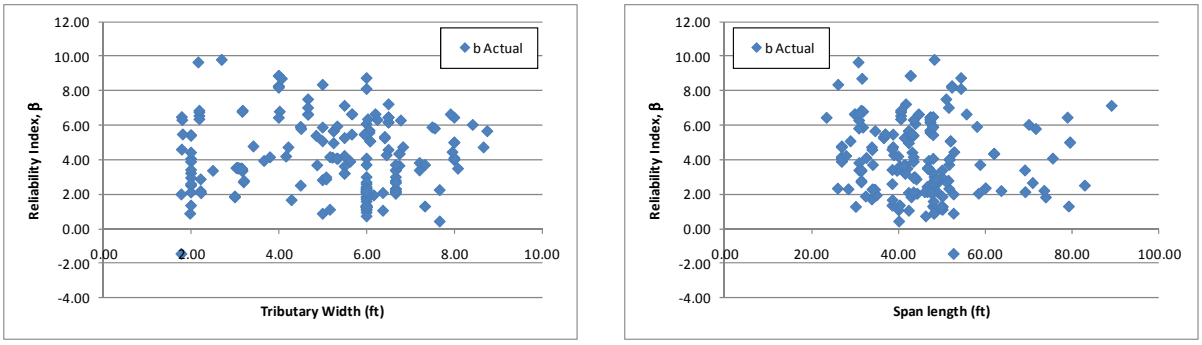


(a) (b)

Figure B-356: LRFR Flexure Rating divided by LFR Flexure Rating for FL-04 Vehicle

B.2.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-357 shows a large number of girders have reliability indices based upon existing section capacity that is less than the 2.5 that is assumed in the development of the MBE. Most of these girders have short span lengths but the tributary width varies significantly.



(a) (b)

Figure B-357: Flexure Reliability Indices for FL-04 Vehicle

Figure B-358 shows the reliability index versus LRFR rating for flexure caused by FL-04 vehicle. The figure shows that a girder passing rating will have a reliability index of approximately 3.5. This is above the value of 2.5 required for routine permit vehicles. This indicates that the live load factor in the MBE could be reduced and achieve the required level of reliability.

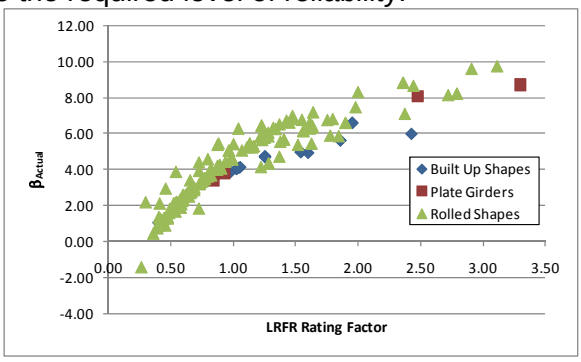


Figure B-358: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

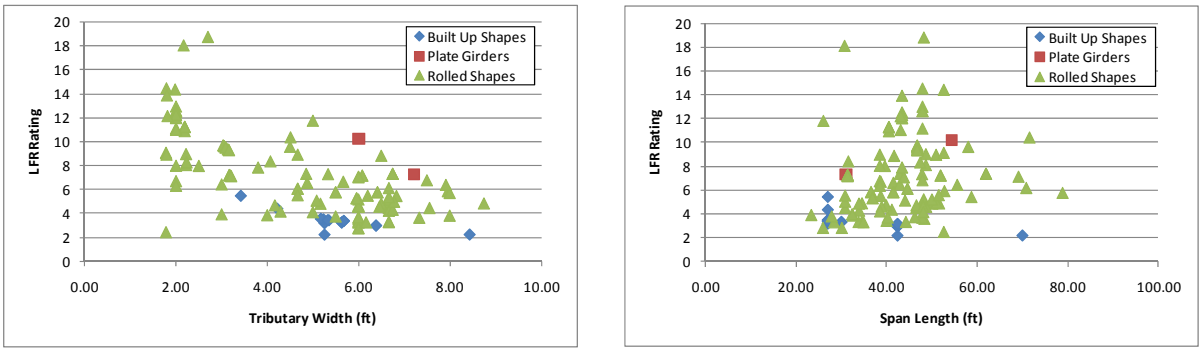
B.2.4.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

B.2.4.2.1 Rating Factors

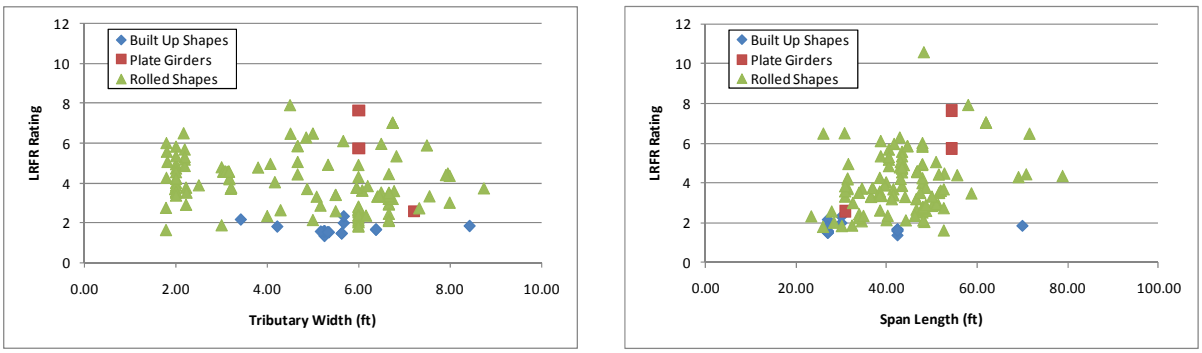
For shear, there are no girders that have an LFR rating factor less than 1.0 and 22 girders with an LRFR rating factorless than 1.0. In this situation, 11% of the girders are affected by switching from LFR to LRFR. These 22 girders are cases where the bearing stiffener controlled the rating. The LFR Rating is greater than the LRFR rating for 99% of the girders in this subset. Figure B-359 and Figure B-360 show the LFR and LRFR ratings, respectively. The LFR ratings tend to decrease with increasing

tributary widths and increasing span lengths. The LRFR ratings do not appear to be affected by either tributary width or span length.



(a) (b)

Figure B-359: LFR Shear Ratings for FL-04 Vehicle

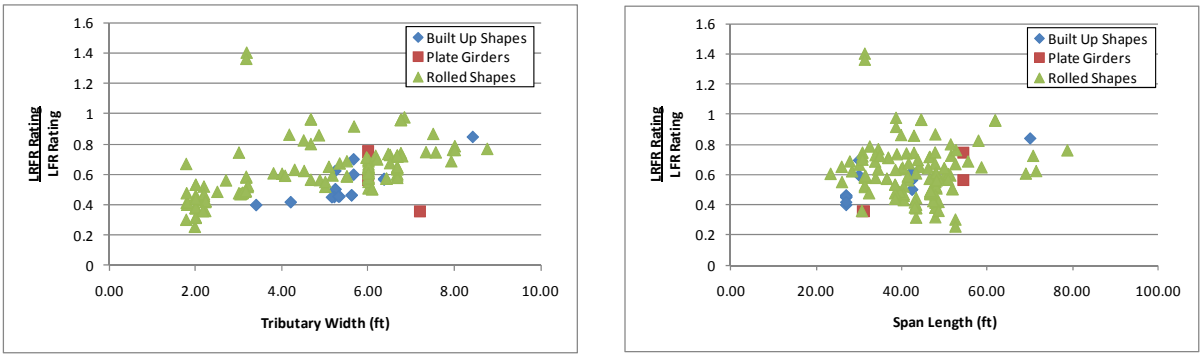


(a) (b)

Figure B-360: LRFR Shear Ratings for FL-04 Vehicle

B.2.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR rating to LFR rating. Figure B-361 shows the comparison of rating factors. Figure B-361 shows that in most cases the ratio is between 0.4 and 0.8

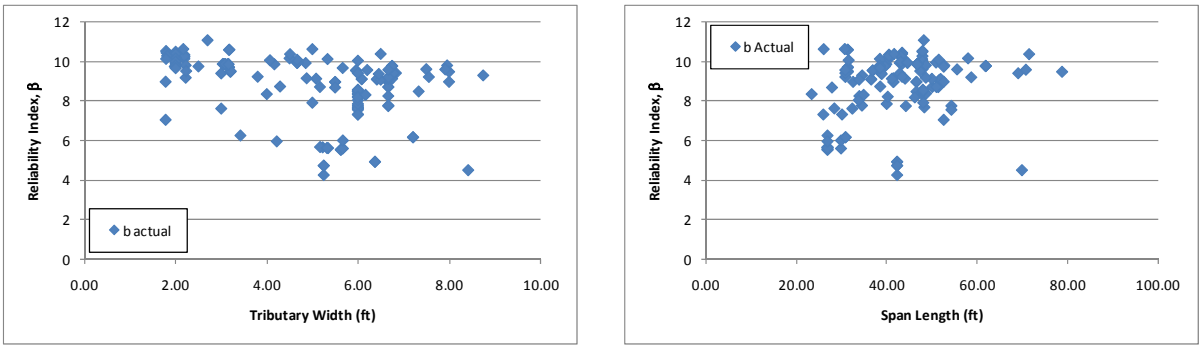


(a) (b)

Figure B-361: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

B.2.4.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the reliability index assumed in the development of the MBE for all girders as shown in Figure B-362.



(a) (b)

Figure B-362: Shear Reliability Indices for FL-04 Vehicle

Figure B-363 shows the reliability index plotted against the LRFR rating factor for shear caused by the FL-04 vehicle. The figure shows that girders passing rating will have a reliability index of approximately 4.0 for built up shapes and approximately 5.5 for rolled shapes. These values are significantly larger than the value of 2.5 used in the development of the MBE. This indicates that the live load factors in the MBE are conservative and could be reduced and provide the required level of reliability.

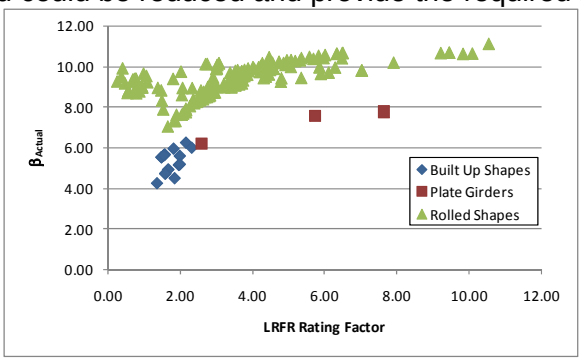


Figure B-363: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

B.2.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-364. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

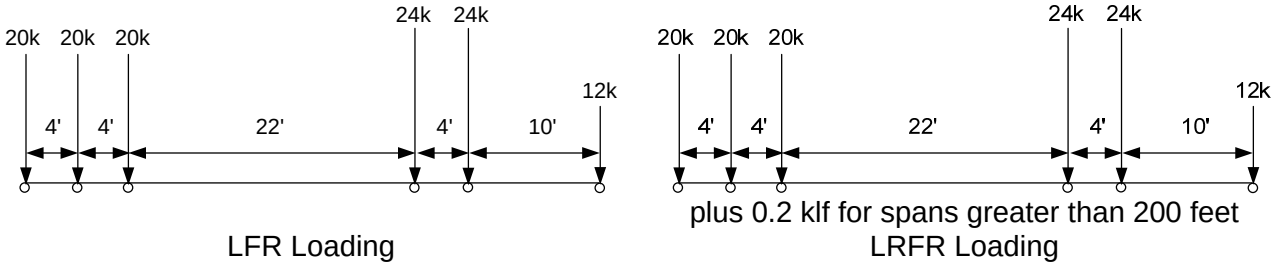


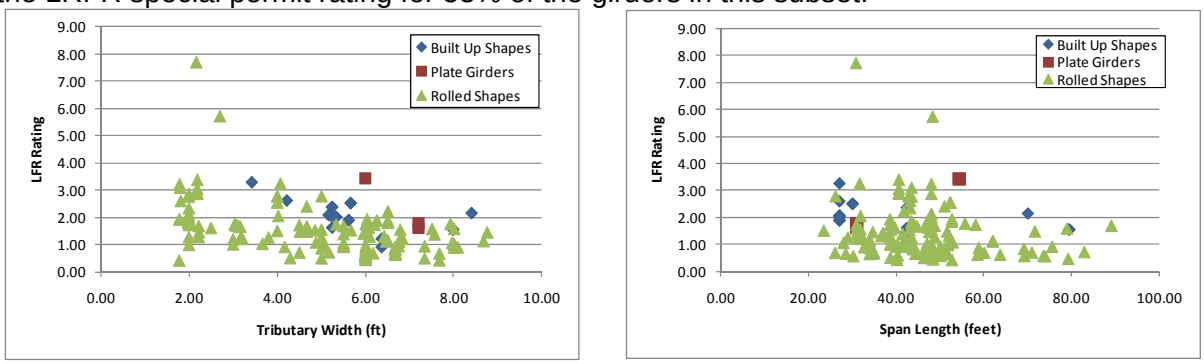
Figure B-364: Vehicle Loadings and Load Factors

B.2.5.1 Moment

The following section contains the results for interior, non-composite steel girders within simple span bridges for the IL-01 Vehicle.

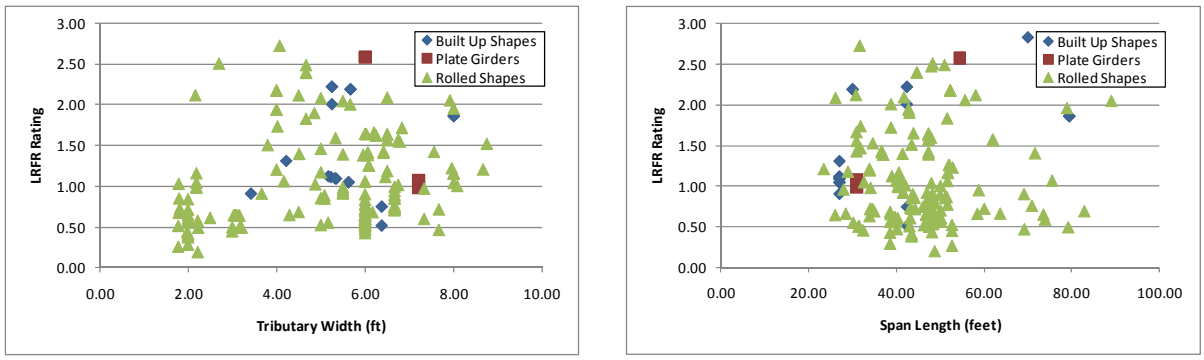
B.2.5.1.1 Rating Factors

Figure B-365 and Figure B-366 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 72 girders with an LFR rating less than 1.0, 105 girders with an LRFR rating less than 1.0, and 63 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 53% of the girders in this subset.



(a) (b)

Figure B-365: LFR Flexure Rating Factors for IL-01 Vehicle

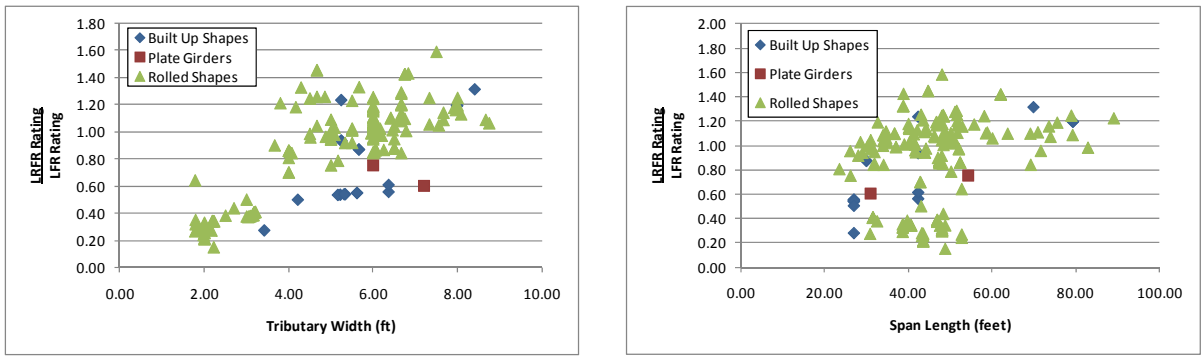


(a) (b)

Figure B-366: LRFR Flexure Rating Factors for IL-01 Vehicle

B.2.5.1.2 Rating Factor Comparisons

Figure B-367 shows the ratio of the LRFR rating to the LFR ratings. Values greater than 1.0 indicate LRFR ratings are greater than LFR ratings. Most of the ratios are between 0.8 and 1.2. Closely spaced girders are more likely to have an LFR rating significantly higher than the LRFR rating.

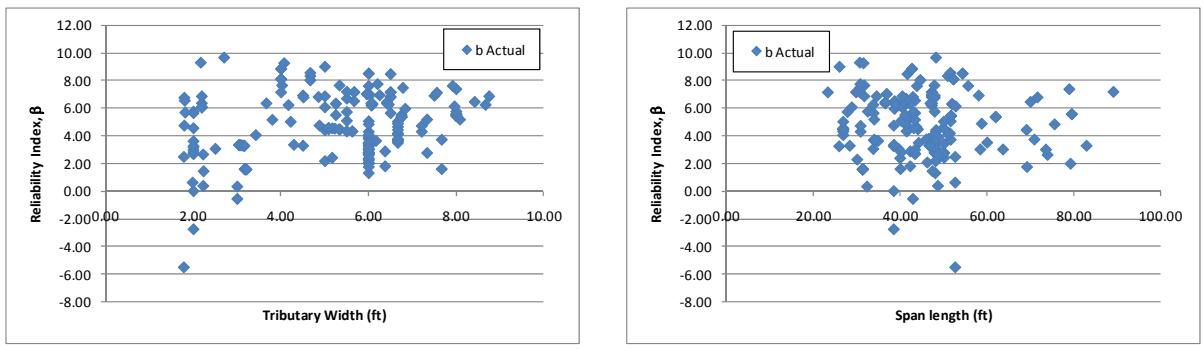


(a) (b)

Figure B-367: LRFR Flexure Rating divided by LFR Flexure Rating for IL-01 Vehicle

B.2.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-368 shows that a significant number of girders have a reliability index less than that assumed in the development of the MBE, which for special permit vehicles is 3.5. These girders tend to be shorter spans but there are several longer spans that also do not have the required level of reliability.



(a) (b)

Figure B-368: Flexure Reliability Indices for IL-01 Vehicle

Figure B-369 shows the reliability index plotted against the LRFR rating factor for moment caused by the IL-01 vehicle. The figure shows that a girder passing rating will have a reliability index of approximately 4 which is greater than the value of 3.5 used in the development of the MBE. This indicates that the LRFR live load factors could be reduced slightly and bring the reliability index back to the target reliability index.

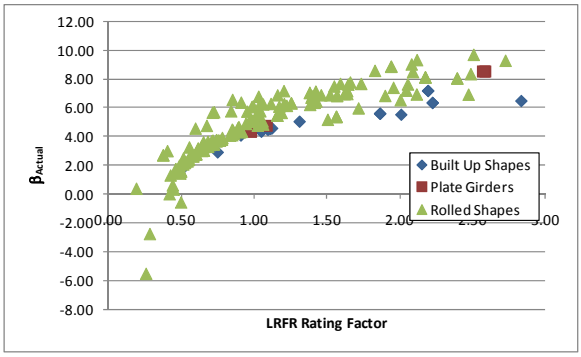


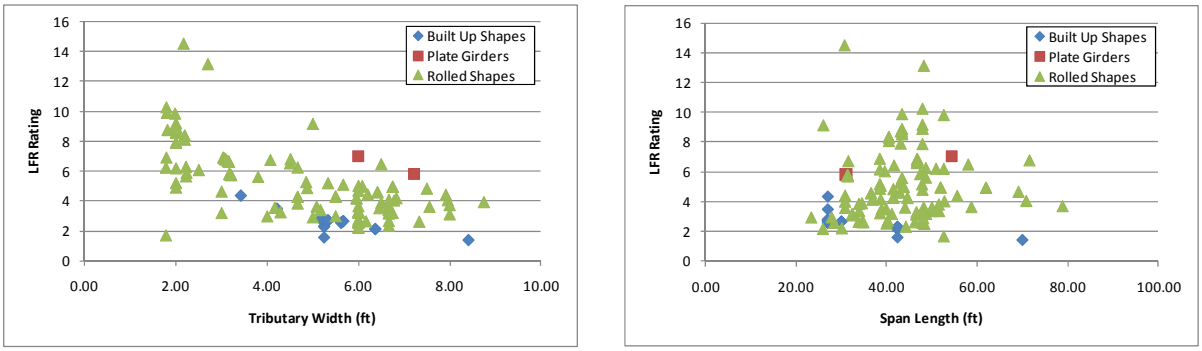
Figure B-369: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

B.2.5.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

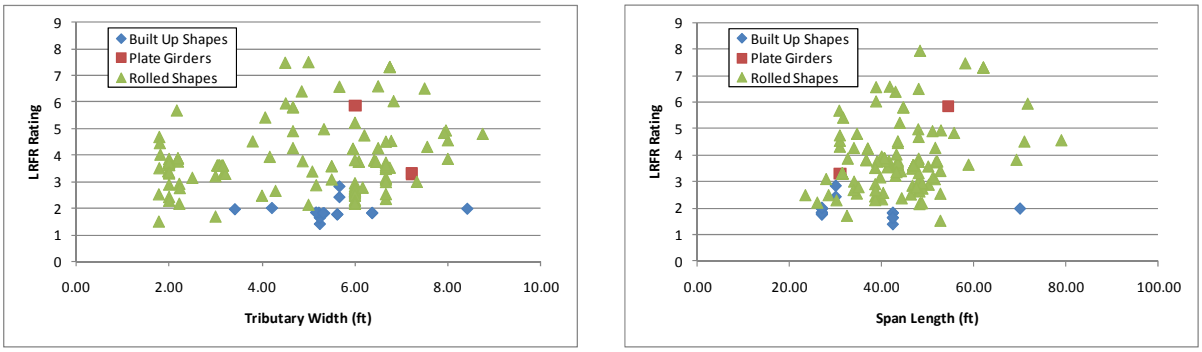
B.2.5.2.1 Rating Factors

For shear, there are no girders that have LFR rating factors less than 1.0 and 20 girders that have LRFR rating factors less than 1.0. In this situation, 10% of girders are affected by rating the bridges using the LRFR methodology even though they may have been designed with the Standard Specification. The LFR Rating is greater than the LRFR rating for 94% of the girders in this subset. Figure B-370 and Figure B-371 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-370: LFR Shear Ratings for IL-01 Vehicle

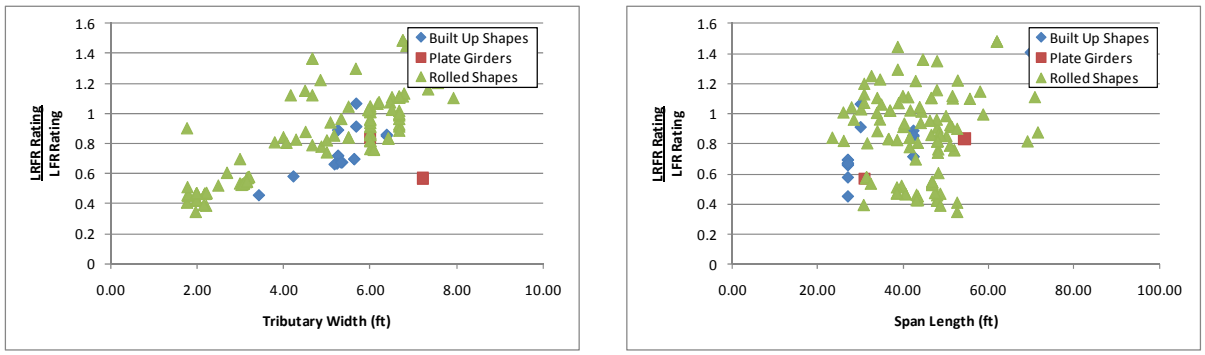


(a) (b)

Figure B-371: LRFR Shear Ratings for IL-01 Vehicle

B.2.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of the LRFR Rating to the LFR Rating. Figure B-372 shows the comparison of rating factors. The ratio increases with increasing tributary width and is typically above 0.8 for tributary widths greater than four feet. The distribution of the ratio versus the span length shows no clear trends.

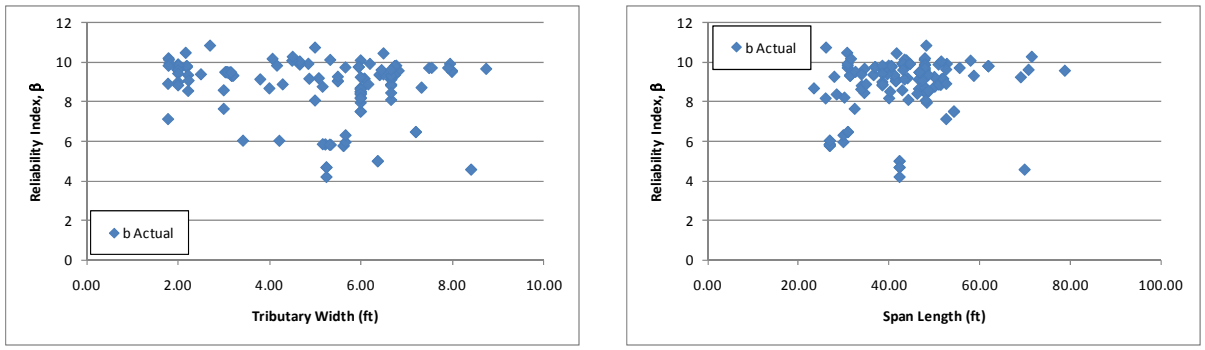


(a) (b)

Figure B-372: LRFR Shear Rating divided by LFR Shar Rating for IL-01 Vehicle

B.2.5.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the level assumed in the development of the MBE, that is 3.5, as shown in Figure B-373.



(a) (b)

Figure B-373: Shear Reliability Indices for IL-01 Vehicle

Figure B-374 shows the reliability index plotted against the LRFR rating factor for shear caused by the IL-01 vehicle. The figure shows that for built up shapes passing rating a reliability index of 3.5 will be obtained while for rolled shapes the value is approximately 6.0. This indicates that for shear the live load factors currently in the MBE produce the target reliability index of 3.5 for this vehicle. The girders with low ratings but high reliability are controlled by the bearing stiffener rating; the reliability index is calculated based upon the web shear resistance not the bearing stiffener resistance.

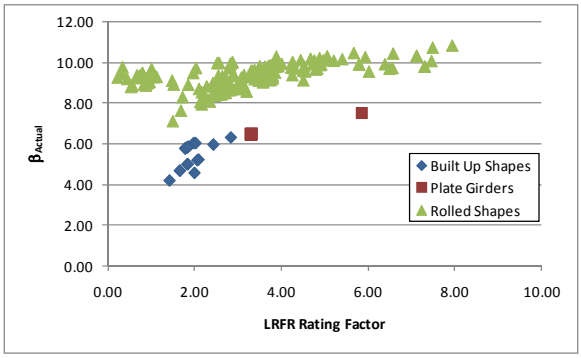


Figure B-374: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

B.2.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-375. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

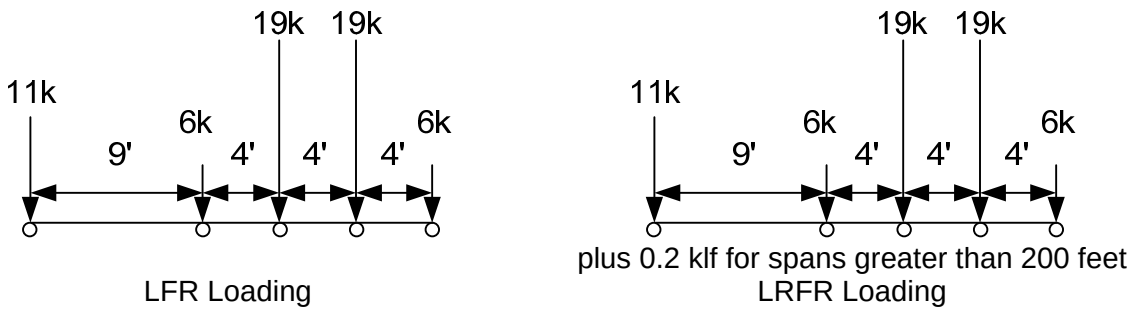


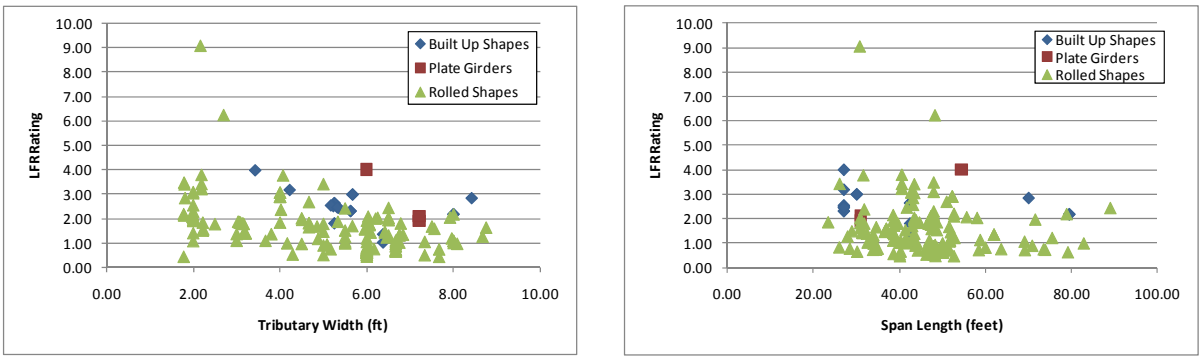
Figure B-375: Vehicle Loadings and Load Factors

B.2.6.1 Moment

The following section contains the results for interior, non-composite steel girders within simple span bridges for the NC-21 Vehicle.

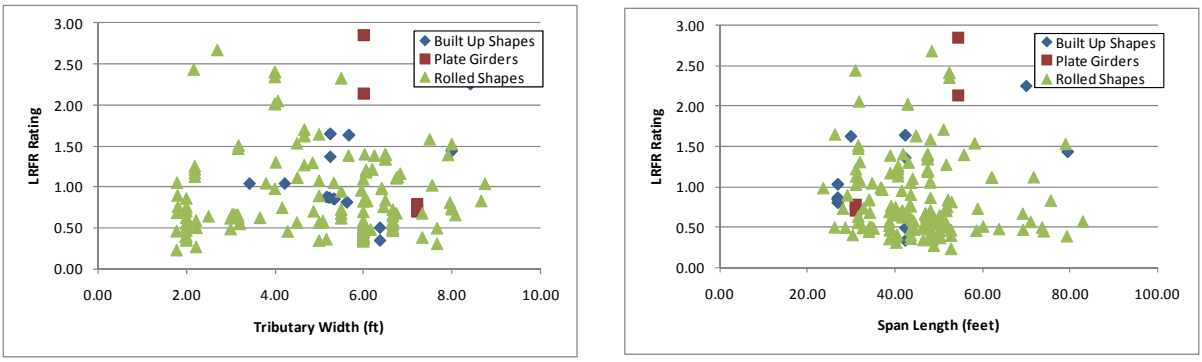
B.2.6.1.1 Rating Factors

Figure B-376 and Figure B-377 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 55 girders with an LFR rating less than 1.0, 130 girders with an LRFR rating less than 1.0, and 55 girders where both ratings are less than 1.0.



(a) (b)

Figure B-376: LFR Flexure Rating Factors for NC-21 Vehicle

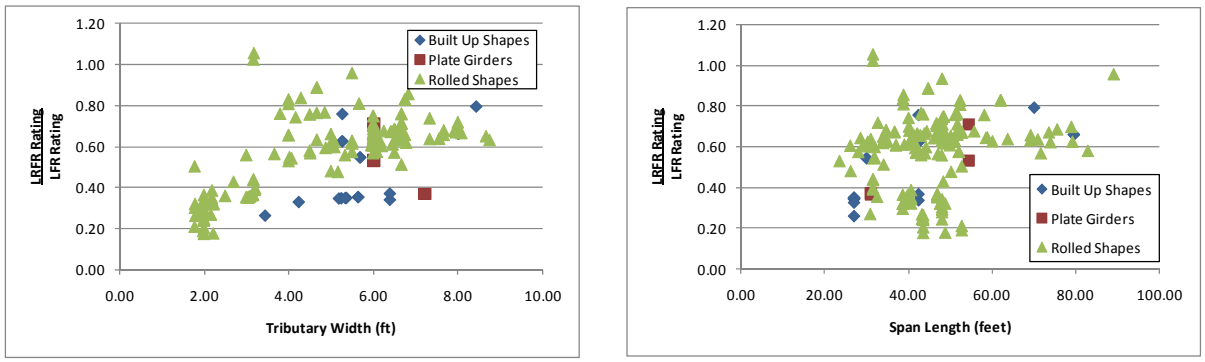


(a) (b)

Figure B-377: LRFR Flexure Rating Factors for NC-21 Vehicle

B.2.6.1.2 Rating Factor Comparisons

Figure B-378 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate that the LRFR rating is greater than the LFR rating. For this subset of bridges, almost all girders have LFR ratings greater than LRFR ratings. As mentioned previously for other vehicles, closely spaced rolled shapes are likely to have LFR ratings that are significantly greater than the LRFR rating.

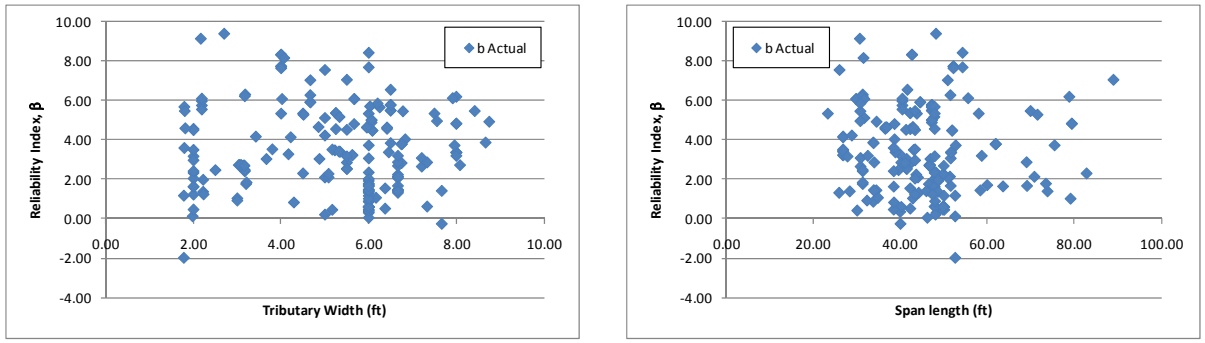


(a) (b)

Figure B-378: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

B.2.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-379 shows there are many girders with reliability indices less than that required assumed in the development of the MBE, that is 2.5. Most of these girders are in shorter span bridges but there are several at longer span lengths.



(a) (b)

Figure B-379: Flexure Reliability Indices for NC-21 Vehicle

Figure B-380 shows the reliability index plotted against the LRFR rating for moment caused by the NC-21 vehicle. The figure shows that a girder passing rating will have a reliability index above 4.0. This indicates that the LRFR live load factors could be reduced to bring the reliability index of a girder passing rating down to the target reliability index of 2.5.

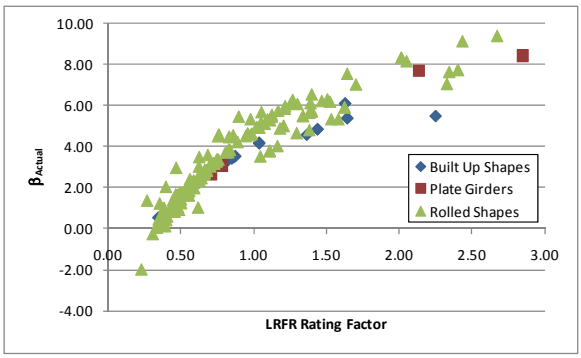


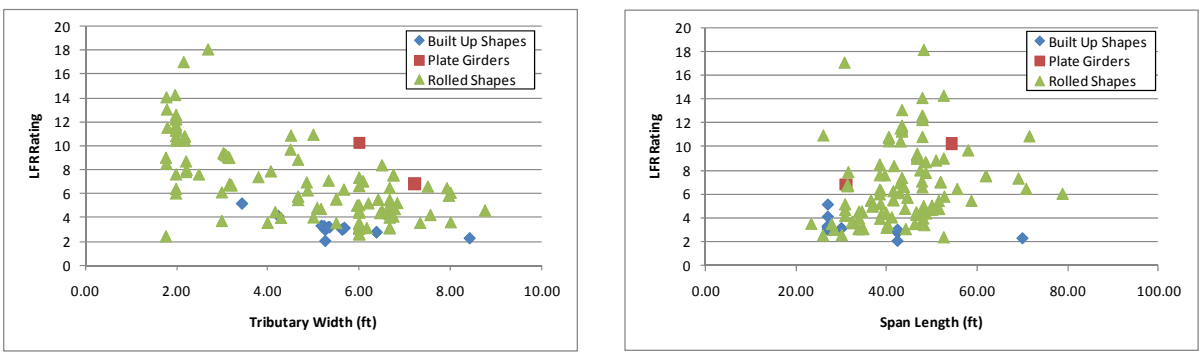
Figure B-380: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

B.2.6.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

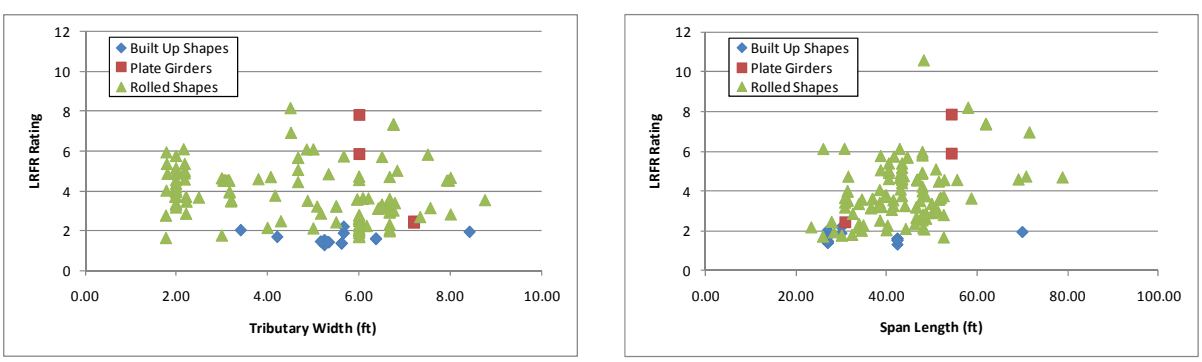
B.2.6.2.1 Rating Factors

For shear, there are no girders that have LFR rating factors less than 1.0 and 22 girders that have LRFR rating factors less than 1.0. For shear, 11% of the girders in this subset are affected by rating the bridges using the LRFR methodology The LFR Rating is greater than the LRFR rating for 99% of the girders in this subset. Figure B-381 and Figure B-382 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-381: LFR Shear Ratings for NC-21 Vehicle

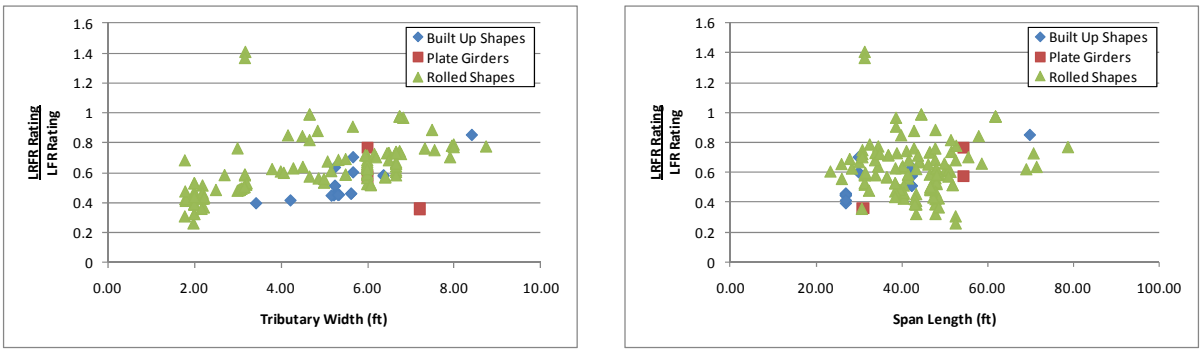


(a) (b)

Figure B-382: LRFR Shear Ratings for NC-21 Vehicle

B.2.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR rating to LFR rating. Figure B-383 shows this ratio of rating factors. The ratio is generally between 0.4 and 0.8, with several lower than and several higher than this range. The ratio tends to increase with larger tributary widths.

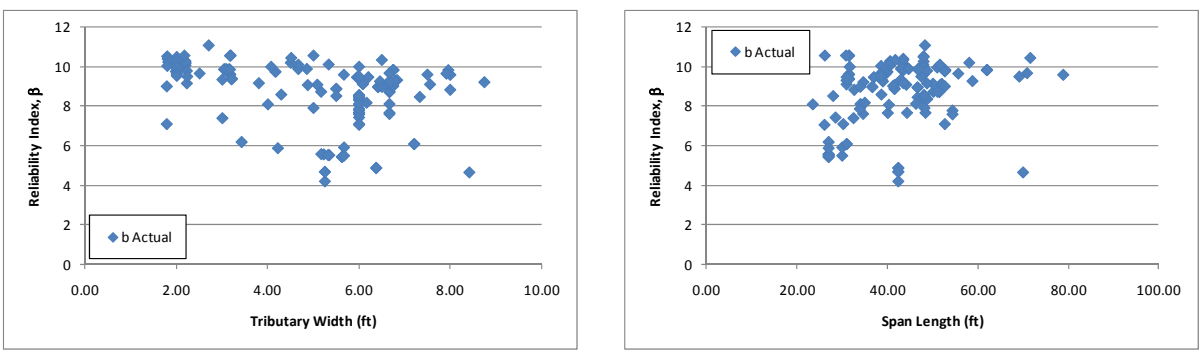


(a) (b)

Figure B-383: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

B.2.6.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the value of 2.5 assumed in the development of the MBE as shown in Figure B-384.



(a) (b)

Figure B-384: Shear Reliability Indices for NC-21 Vehicle

Figure B-385 shows the reliability index versus the LRFR rating factor for shear caused by the NC-21 vehicle. The figure shows that a girder passing rating will have a reliability index above the target level of 2.5 used for routine permit vehicles. This indicates that the live load factors in the MBE can be reduced. The current load factors result in girders passing rating having reliability indices above 4.0. The girders with low ratings and high reliability are those controlled by the bearing stiffener rating; the resistance used in the calculation of the reliability index is that of the web shear not of the bearing stiffener.

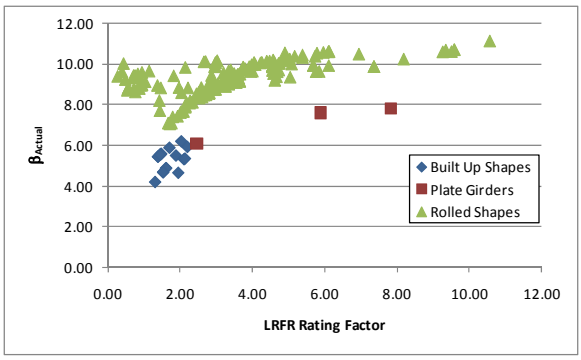


Figure B-385: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

B.2.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-386. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

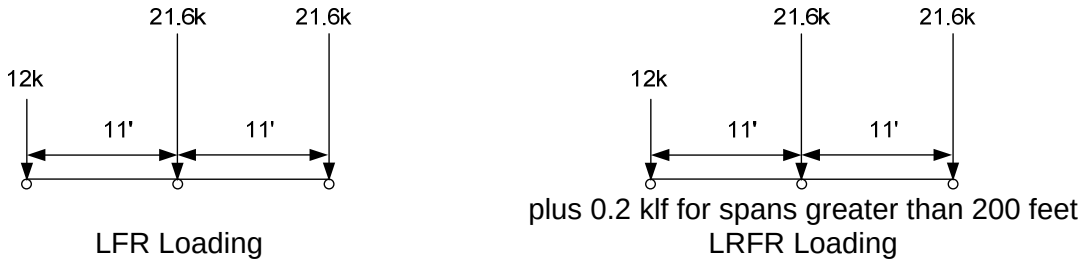


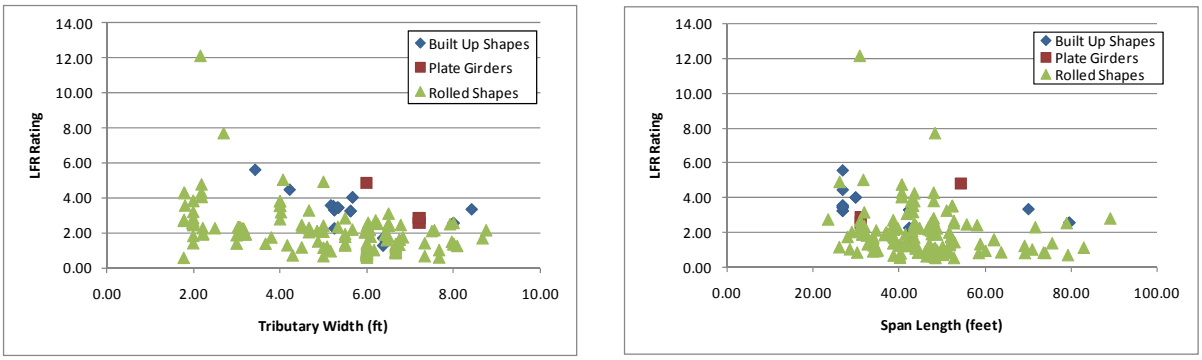
Figure B-386: Vehicle Loadings and Load Factors

B.2.7.1 Moment

The following section contains the results for interior, non-composite steel girders within simple span bridges for the NM-04 Vehicle.

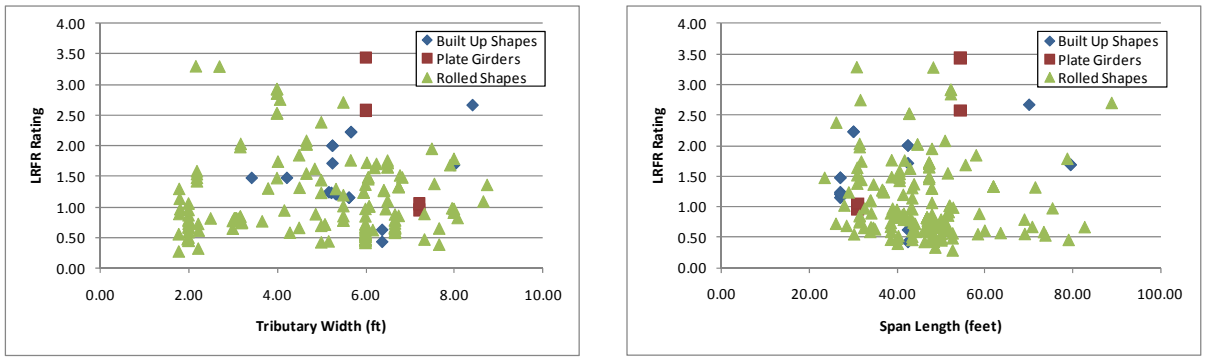
B.2.7.1.1 Rating Factors

Figure B-387 and Figure B-388 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 43 girders with an LFR rating less than 1.0, 109 girders with an LRFR rating less than 1.0, and 43 girders where both ratings are less than 1.0.



(a) (b)

Figure B-387: LFR Flexure Rating Factors for NM-04 Vehicle

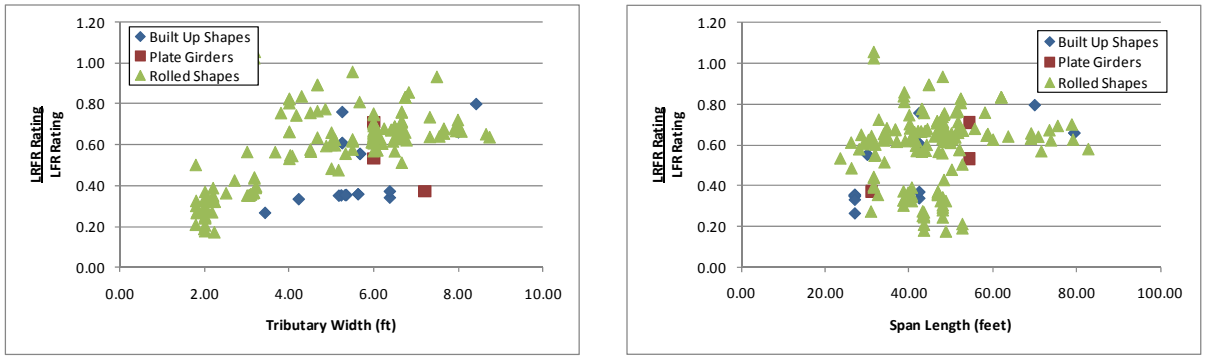


(a) (b)

Figure B-388: LRFR Flexure Rating Factors for NM-04 Vehicle

B.2.7.1.2 Rating Factor Comparisons

Figure B-389 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate an LRFR rating greater than the LFR rating. Most ratios are between 0.6 and 0.8 (LFR rating is generally 1.25 to 1.67 times greater than LRFR rating). Girders with larger tributary widths typically have higher ratios while all span lengths have similar ratios.

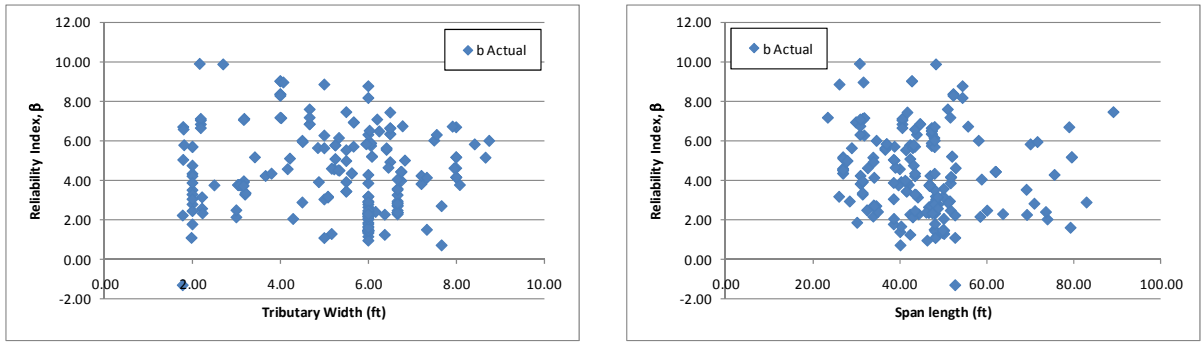


(a) (b)

Figure B-389: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

B.2.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-390 shows that there are fewer girders for this vehicle that do not have level of reliability assumed in the development of the MBE. This is likely a result of this vehicle not having either a tandem or tridem (three axles closely spaced) set of axles.



(a) (b)

Figure B-390: Flexure Reliability Indices for NM-04 Vehicle

Figure B-391 shows the reliability index plotted against the LRFR rating for moment due to the NM-04 vehicle. The figure shows that a girder passing rating will have a reliability index of approximately 4.0 while the target reliability index is 2.5. This indicates that the LRFR live load factors could be reduced such that the reliability index moves closer to the target value.

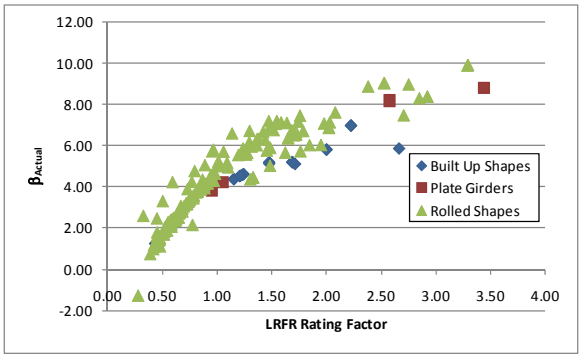


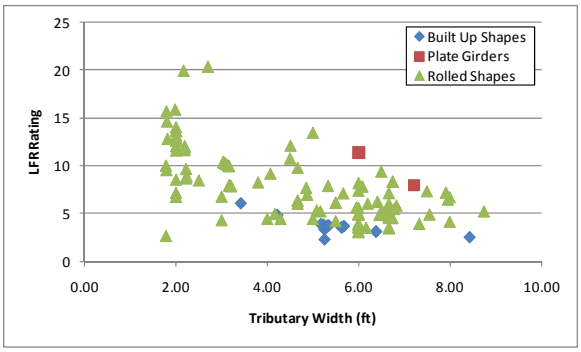
Figure B-391: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

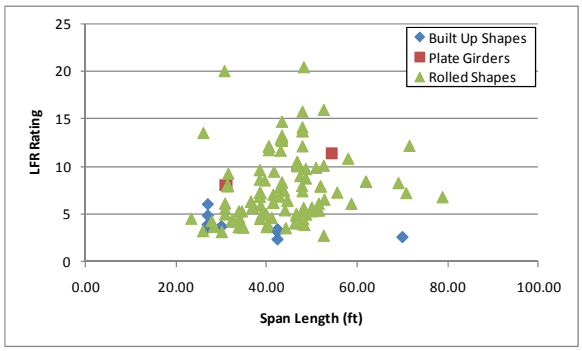
B.2.7.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

B.2.7.2.1 Rating Factors

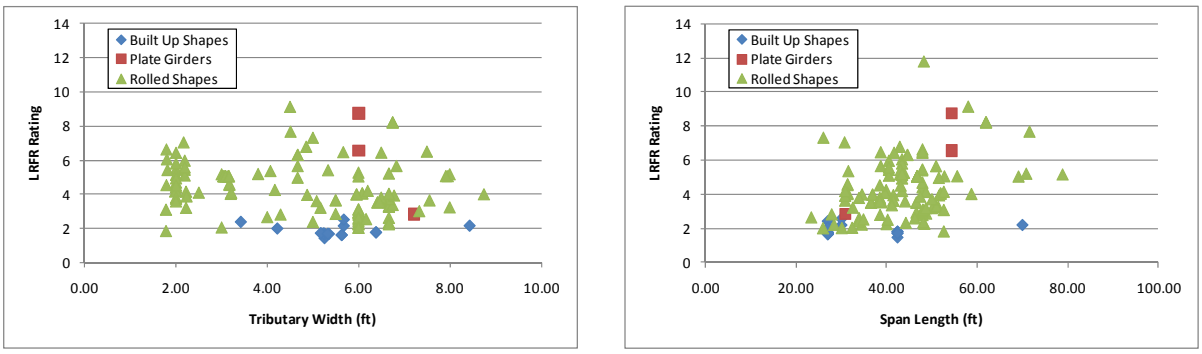
For shear, there are no girders that have LFR rating factors less than 1.0 and 19 girders that have have an LRFR rating factor less than 1.0. In this situation, 10% of girders are affected by rating the bridges using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 99% of the girders in this subset. Figure B-392 and Figure B-393 show the LFR and LRFR ratings, respectively.





(a) (b)

Figure B-392: LFR Shear Ratings for NM-04 Vehicle

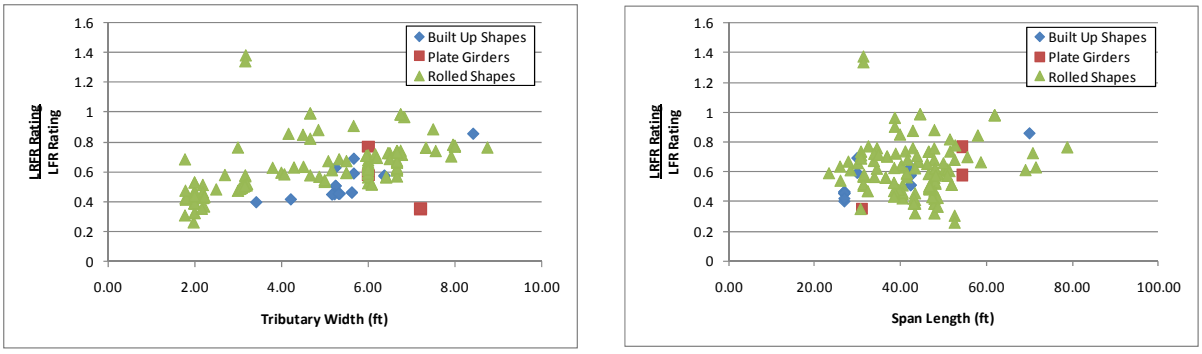


(a) (b)

Figure B-393: LRFR Shear Ratings for NM-04 Vehicle

B.2.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of the LRFR Rating to the LFR rating. Figure B-394 shows the comparison of rating factors. The ratio is generally between 0.4 and 0.8. The ratio increases with larger tributary widths but not as significantly as shown for other vehicles.

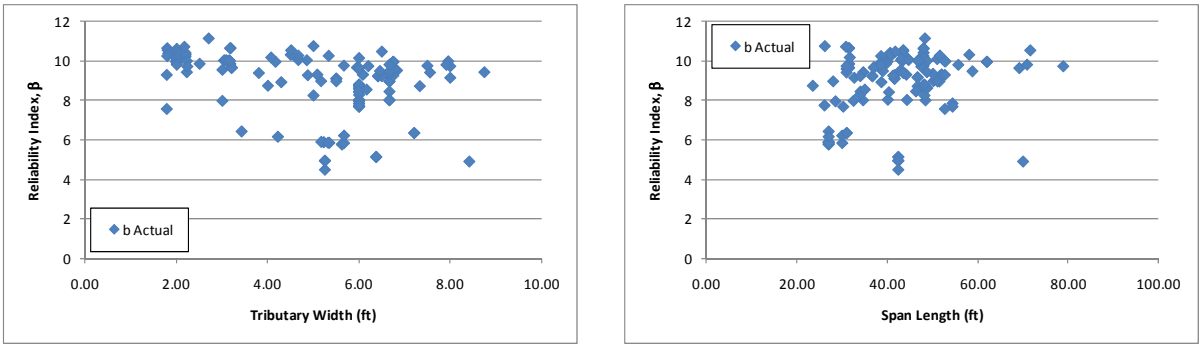


(a) (b)

Figure B-394: LRFR Shear rating divided by LFR Shear rating for NM-04 Vehicle

B.2.7.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the value of 2.5 assumed in the development of the MBE as shown in Figure B-395.



(a) (b)

Figure B-395: Shear Reliability Indices for NM-04 Vehicle

Figure B-396 shows the reliability index plotted against the LRFR rating for shear due to the NM-04 vehicle. The figure shows that girders passing rating will have a reliability index of approximately 4.0 while the target reliability is 2.5. This indicates that the live load factors could be reduced, thereby increasing the rating and reducing the reliability index towards the target value for girders that will pass rating. The girders with low ratings and high reliability are those controlled by the bearing stiffener rating; the reliability index calculation utilizes the web shear resistance not the bearing stiffener resistance.

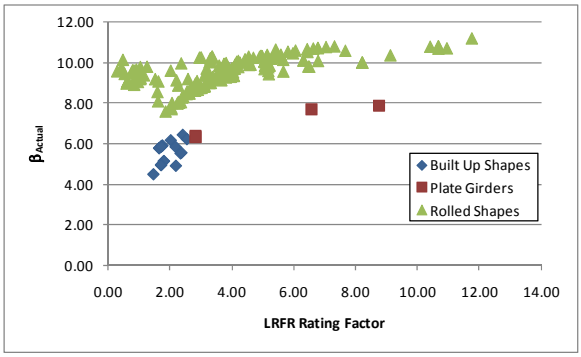


Figure B-396: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

B.2.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-397. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

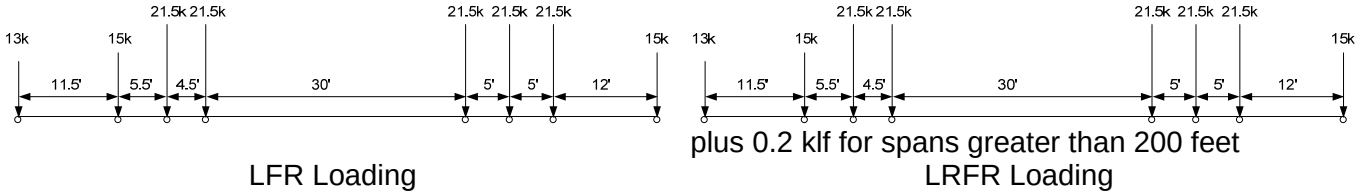


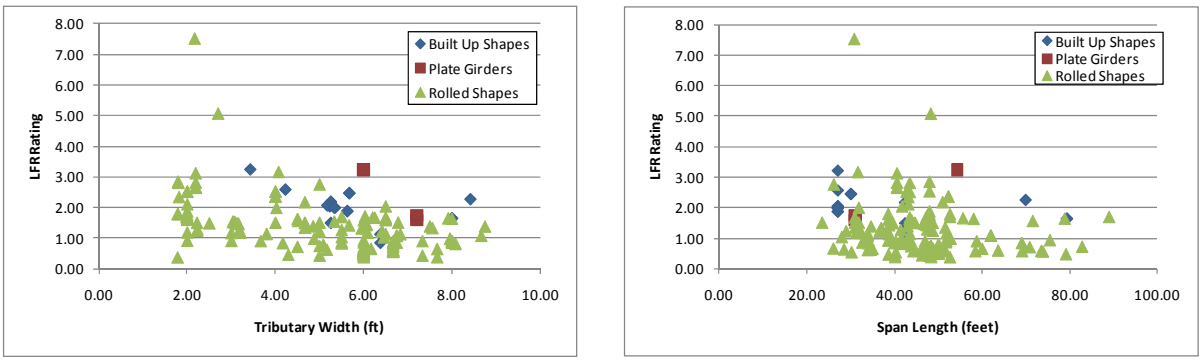
Figure B-397: Vehicle Loadings and Load Factors

B.2.8.1 Moment

The following section contains the results for interior, non-composite steel girders within simple span bridges for the OR-06 Vehicle.

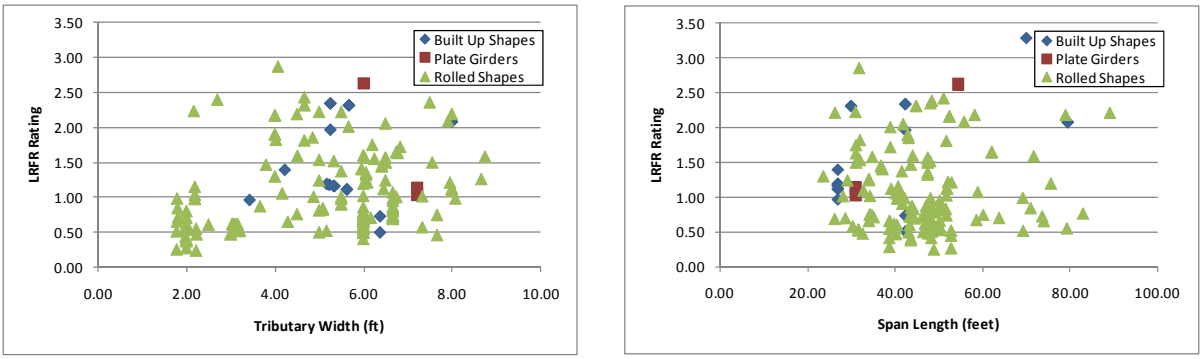
B.2.8.1.1 Rating Factors

Figure B-398 and Figure B-399 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 75 girders with an LFR rating less than 1.0, 103 girders with an LRFR rating less than 1.0, and 63 girders where both ratings are less than 1.0. There are no clear trends as to which girders have ratings above or below 1.0.



(a) (b)

Figure B-398: LFR Flexure Rating Factors for OR-06 Vehicle

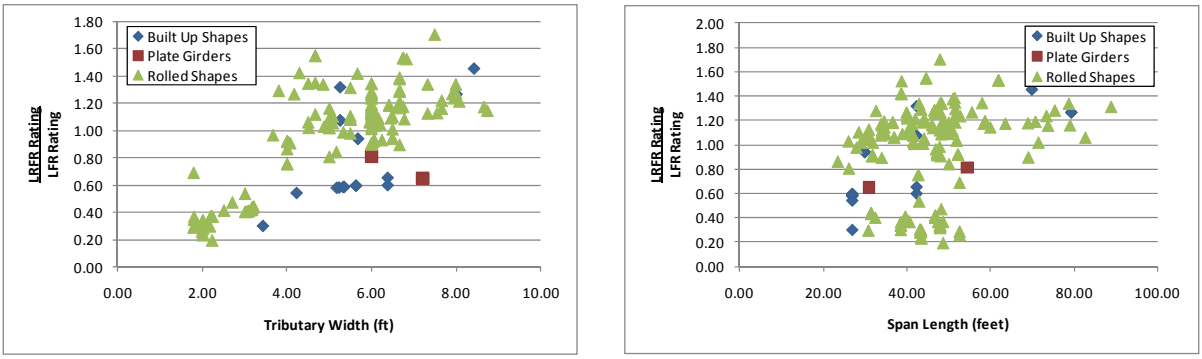


(a) (b)

Figure B-399: LRFR Flexure Rating Factors for OR-06 Vehicle

B.2.8.1.2 Rating Factor Comparisons

Figure B-400 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate that the LRFR rating is greater than the LFR rating. Those girders with small ratios tend to have narrow girder spacings and be of shorter span lengths. 55% of the girders have LRFR ratings that are higher then the associated LFR rating. The ratio for a majority of girders is between 1.0 and 1.4. The increase in ratings is partially a result of using a single lane loaded without multiple presence.

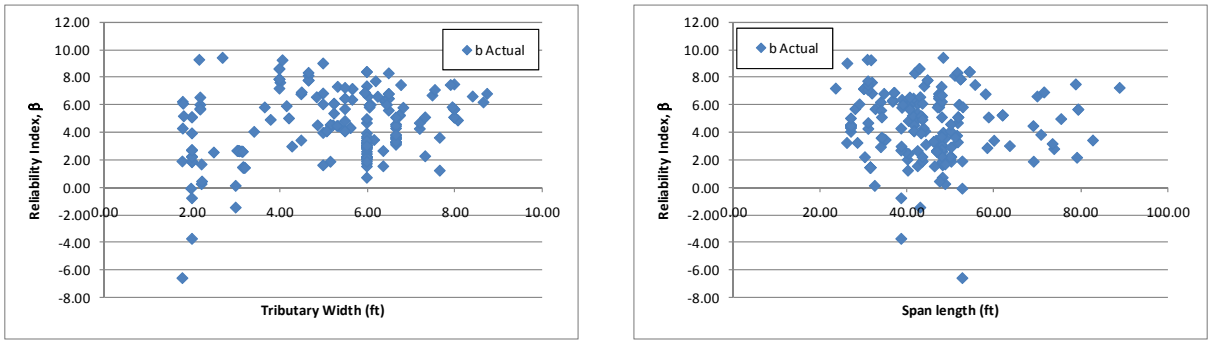


(a) (b)

Figure B-400: Ratio of LRFR Flexure Rating to LFR Flexure Rating for OR-06 Vehicle

B.2.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-401 shows that there are a significant number of girders with a reliability index less than 3.5. These girders tend to have shorter spans.



(a) (b)

Figure B-401: Flexure Reliability Indices for OR-06 Vehicle

Figure B-402 shows the reliability index plotted against the LRFR rating for moment caused by the OR-06 vehicle. The figure shows that girders with a passing rating will have a reliability index of approximately 4.0 which is higher than the target reliability of 3.5. This indicates that the LRFR load factor could be reduced to bring a girder passing rating to have the target level of reliability.

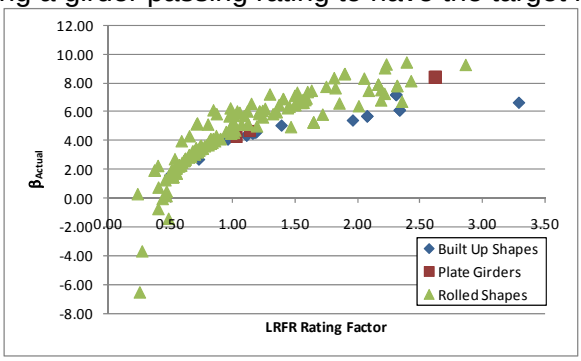


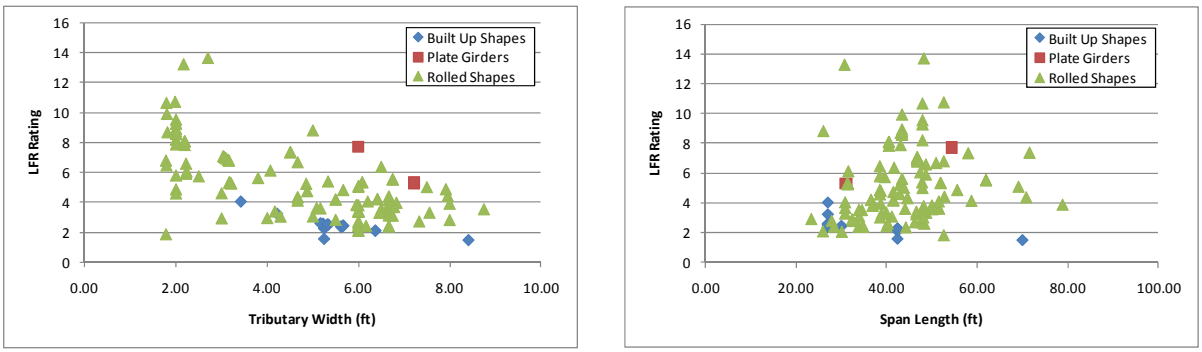
Figure B-402: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

B.2.8.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

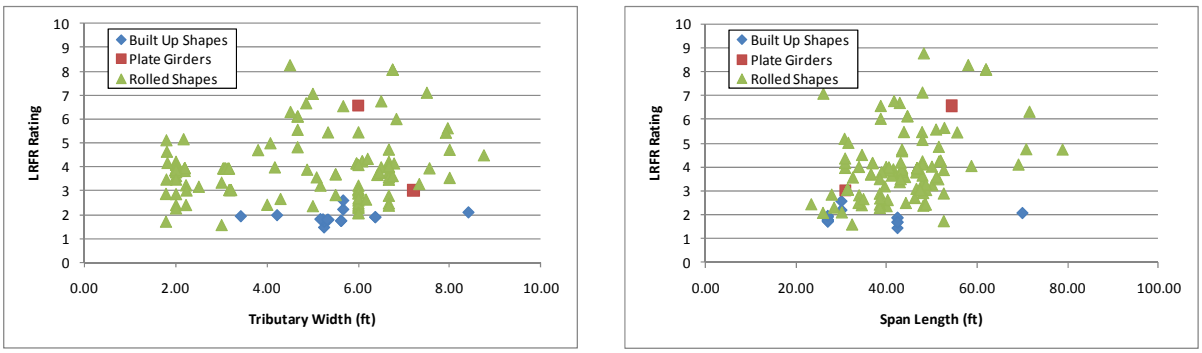
B.2.8.2.1 Rating Factors

For shear, there are 18 girders that have an LRFR rating factors less than 1.0 and no girders for LFR. In this situation, 9% of girders are affected by rating the bridges using the LRFR methodology even though they may not have been designed with the LRFD Design Specification. The LFR Rating is greater than the LRFR rating for 91% of the girders in this subset, but yet does not cause any to have a rating less than 1.0. Figure B-403 and Figure B-404 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-403: LFR Shear Ratings for OR-06 Vehicle

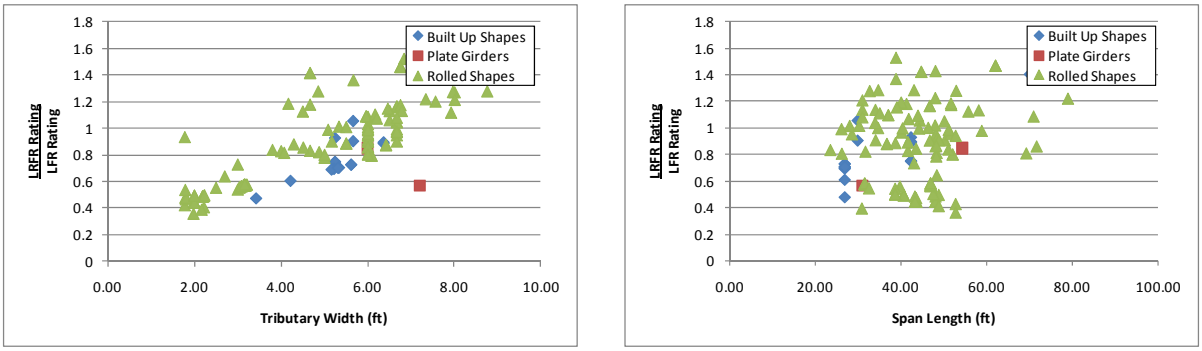


(a) (b)

Figure B-404: LRFR Shear Ratings for OR-06 Vehicle

B.2.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR rating to LFR rating. Figure B-405 shows the comparison of rating factors. The ratio tends to be in the range of 0.8 to 1.2 for girders having tributary widths greater than four feet. The ratio tends to increase with increasing tributary widths.

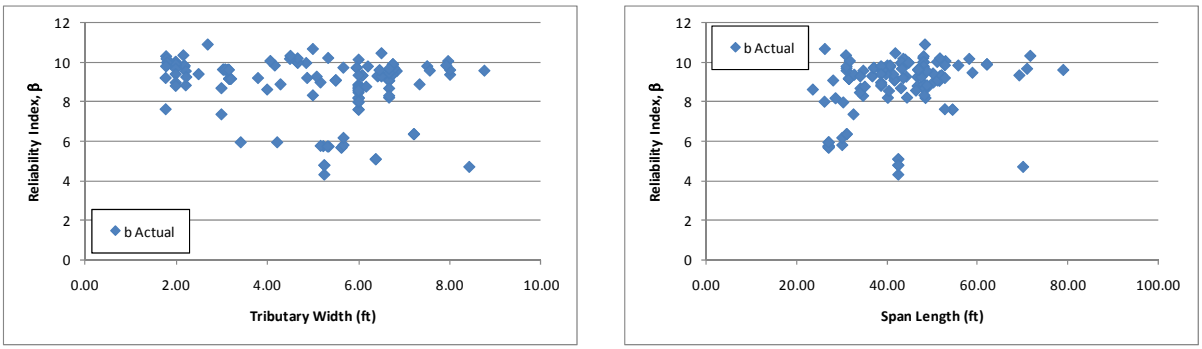


(a) (b)

Figure B-405: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

B.2.8.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than value of 3.5 assumed in the development of the MBE as shown in Figure B-406. For this particular vehicle the reliability index based upon section capacity has shifted down compared to other vehicles shown.



(a) (b)

Figure B-406: Shear Reliability Indices for OR-06 Vehicle

Figure B-407 shows the reliability index plotted against the LRFR rating for shear caused by the OR-06 vehicle. The figure shows that girders passing rating will have a reliability index greater than the target value of 3.5. This indicates that the LRFR live load factors could be reduced and achieve the target reliability index. The data points with low ratings and high reliability are those controlled by the bearing stiffener rating; the reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

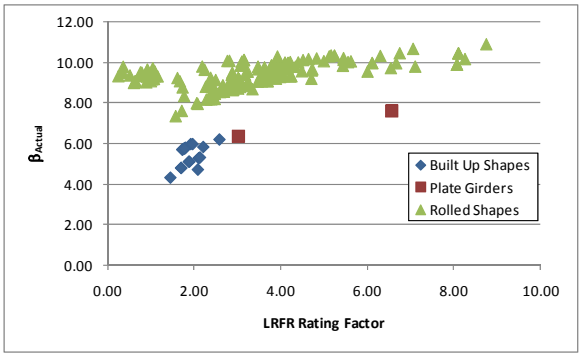


Figure B-407: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

B.2.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-408. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

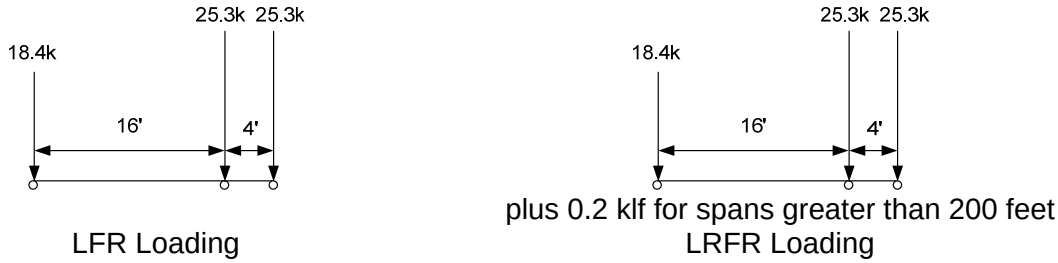


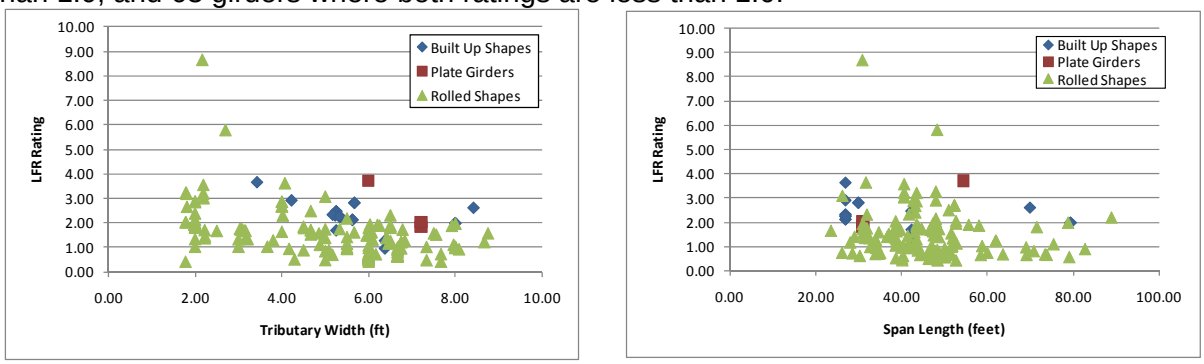
Figure B-408: Vehicle Loadings and Load Factors

B.2.9.1 Moment

The following section contains the results for interior, non-composite steel girders within simple span bridges for the TX-04 Vehicle.

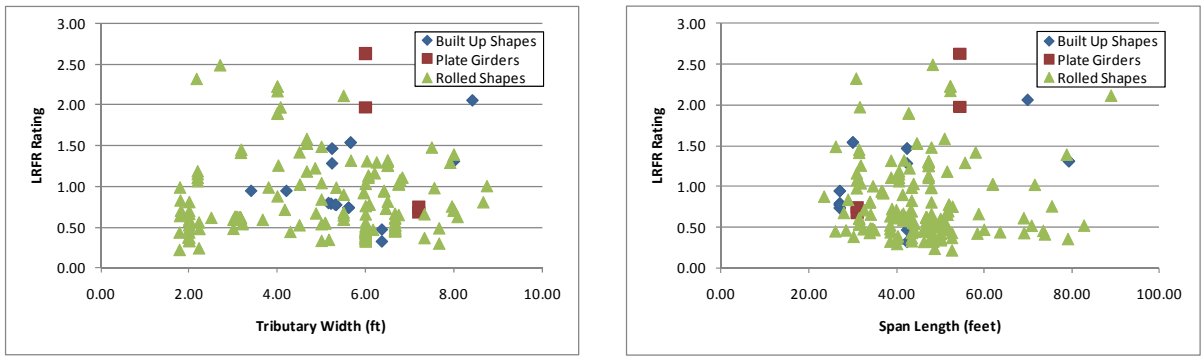
B.2.9.1.1 Rating Factors

Figure B-409 and Figure B-410 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 63 girders with an LFR rating less than 1.0, 136 girders with an LRFR rating less than 1.0, and 63 girders where both ratings are less than 1.0.



(a) (b)

Figure B-409: LFR Flexure Rating Factors for TX-04 Vehicle

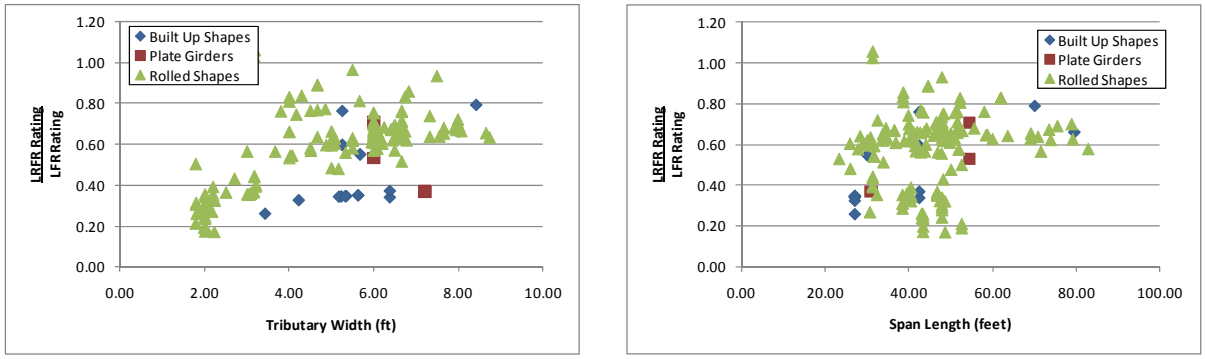


(a) (b)

Figure B-410: LRFR Flexure Rating Factors for TX-04 Vehicle

B.2.9.1.2 Rating Factor Comparisons

Figure B-411 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate an LRFR rating greater than the LFR rating. The ratio is generally between 0.6 and 0.8, with those rolled shapes having ratios less than 0.6 generally being closely spaced. 99% of girders for this vehicle have an LFR rating that is greater than the LRFR rating.

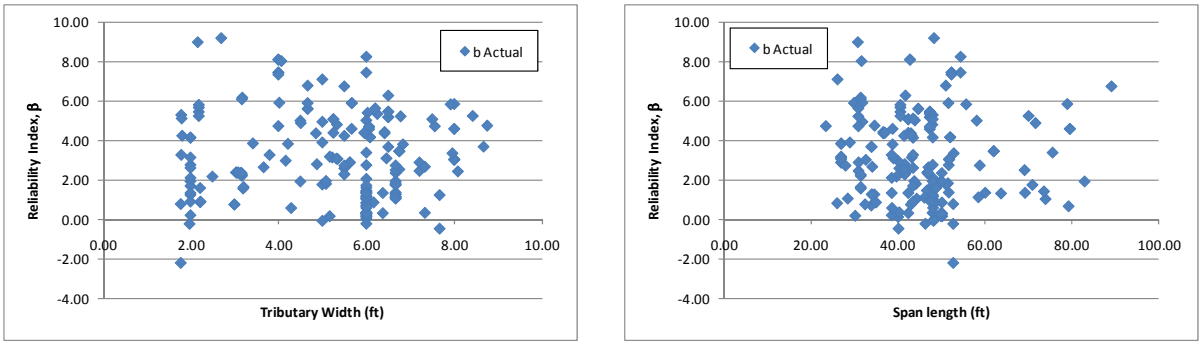


(a) (b)

Figure B-411: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

B.2.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-412 shows that many girders do not have the assumed reliability level of 2.5. In some cases, the reliability index of the section is negative indicating that the applied moments are significantly larger than the sections' moment resistance.



(a) (b)

Figure B-412: Flexure Reliability Indices for TX-04 Vehicle

Figure B-413 shows the reliability index plotted against the LRFR rating factor for moment caused by the TX-04 vehicle. The figure indicates that a girder passing rating will have a reliability index above 4 while the target reliability index is 2.5. This indicates that the reliability index could be reduced to the target level by decreasing the load factor.

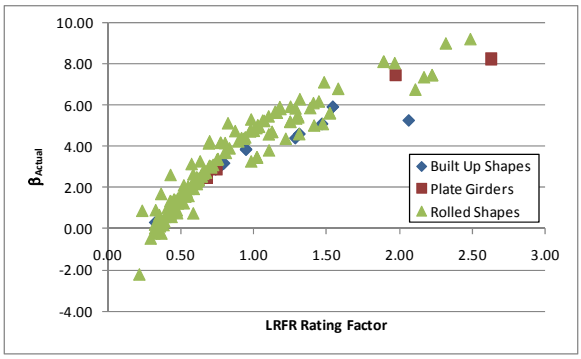


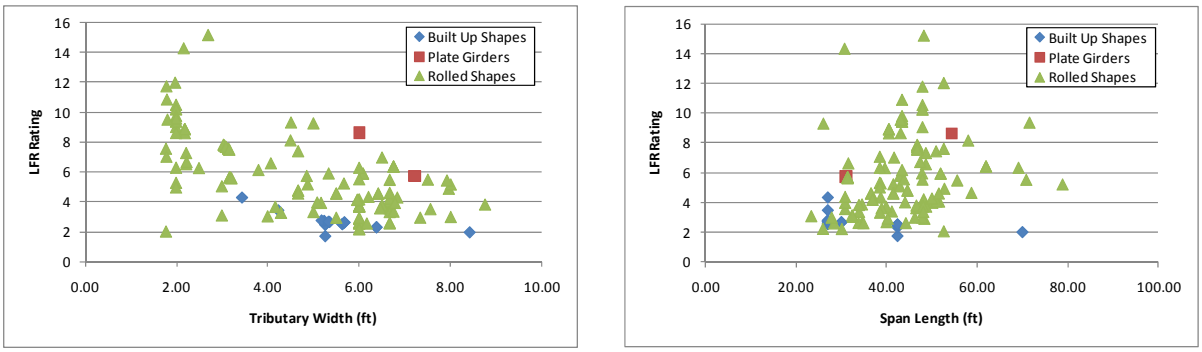
Figure B-413: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

B.2.9.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

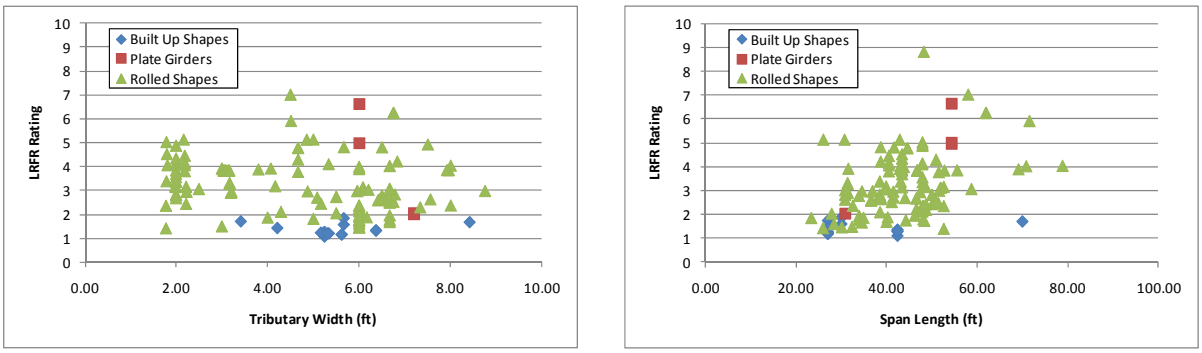
B.2.9.2.1 Rating Factors

For shear, there are 24 girders that have LRFR rating factors less than 1.0 and no girders that have an LFR rating factor less than 1.0. In this situation, 12% of girders are affected by rating the bridges using the LRFR methodology even though the girders may have been designed with the Standard Specification. The LFR Rating is greater than the LRFR rating for 99% of the girders in this subset. Figure B-414 and Figure B-415 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-414: LFR Shear Ratings for TX-04 Vehicle

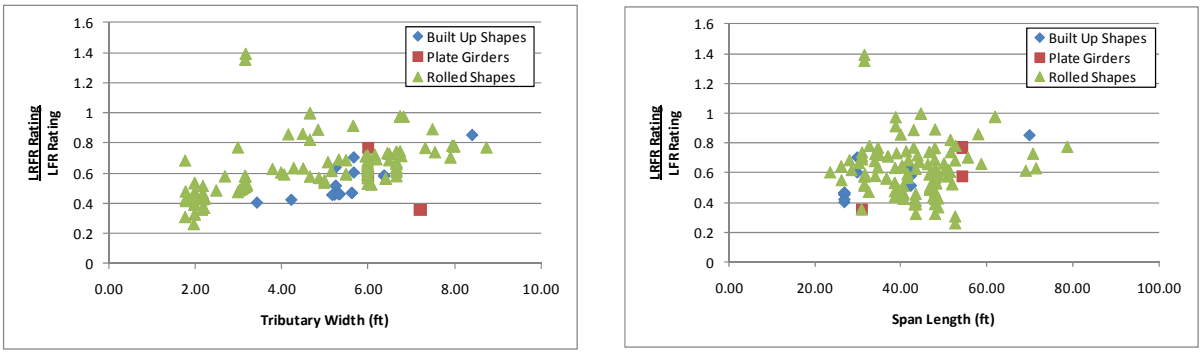


(a) (b)

Figure B-415: LRFR Shear Ratings for TX-04 Vehicle

B.2.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of the LRFR rating to the LFR rating. Figure B-416 shows the comparison of rating factors. The ratio is generally between 0.4 and 0.8 for the shear rating, indicating the LFR rating is larger than the LFR rating. The ratio increases slightly with increasing tributary width but remains relatively constant with increasing span lengths.

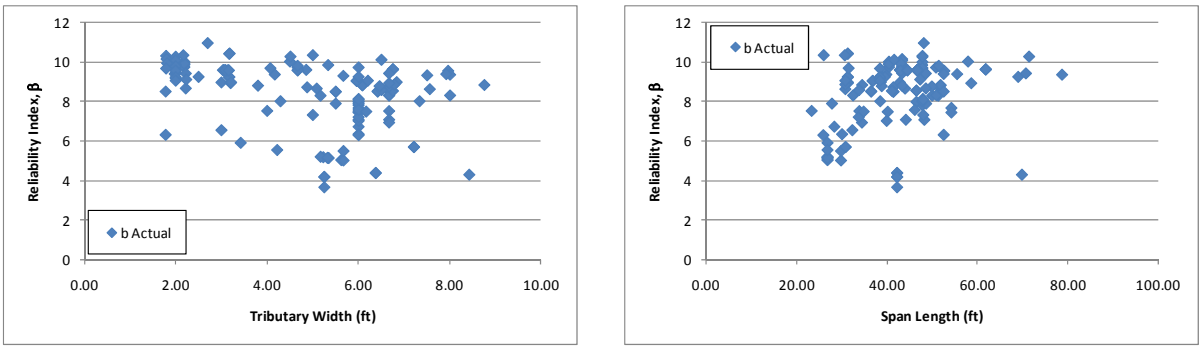


(a) (b)

Figure B-416: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

B.2.9.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the value of 2.5 assumed in the development of the MBE as shown in Figure B-417.



(a) (b)

Figure B-417: Shear Reliability Indices for TX-04 Vehicle

Figure B-418 shows the reliability index plotted against the LRFR rating for shear caused by the TX-04 vehicle. The figure indicates that girders passing rating will have a reliability index greater than the target level of 2.5 used for routine permit vehicles. The reliability index could be reduced to the target by reducing the LRFR live load factor. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating; the reliability is calculated using the web shear resistance not the bearing stiffener resistance.

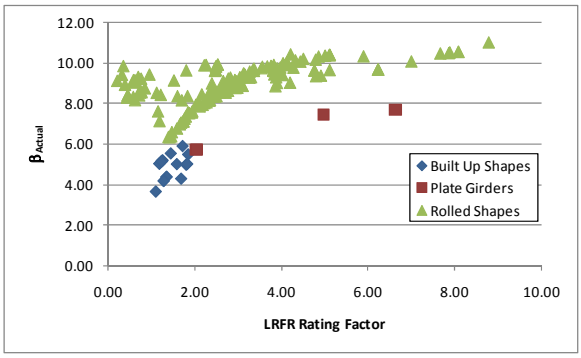
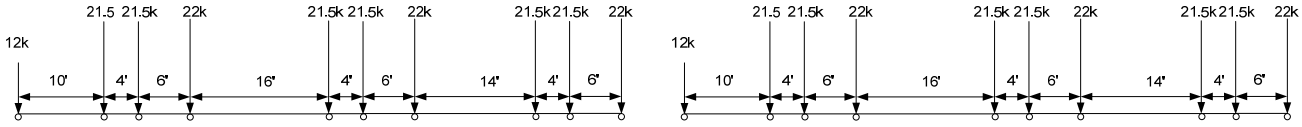


Figure B-418: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

B.2.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-419. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

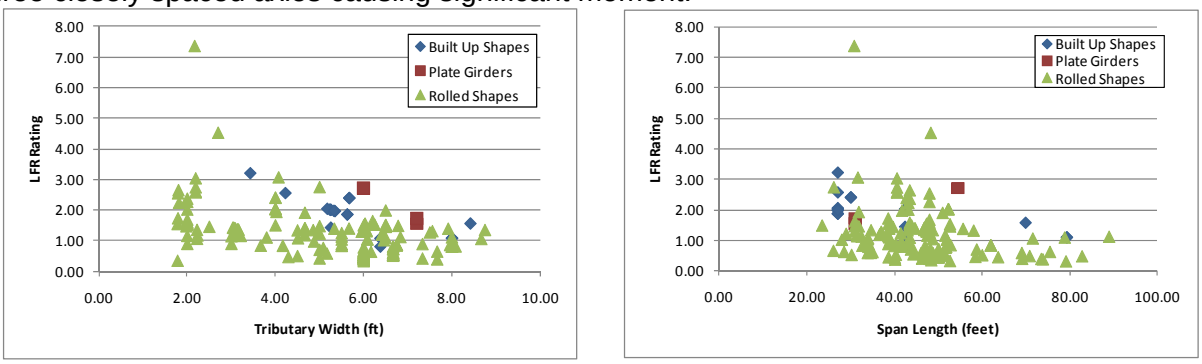
Figure B-419: Vehicle Loadings and Load Factors

B.2.10.1 Moment

The following section contains the results for interior, non-composite steel girders within simple span bridges for the WA-02 Vehicle.

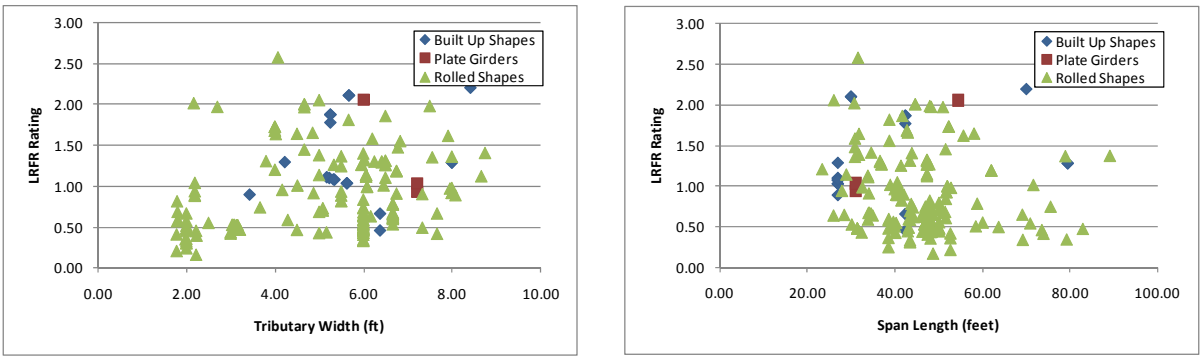
B.2.10.1.1 Rating Factors

Figure B-420 and Figure B-421 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 79 girders with an LFR rating less than 1.0, 120 girders with an LRFR rating less than 1.0, and 75 girders where both ratings are less than 1.0. There are a significant number of girders that do not have satisfactory ratings for both methods for this vehicle. This is likely caused by the three closely spaced axles causing significant moment.



(a) (b)

Figure B-420: LFR Flexure Rating Factors for WA-02 Vehicle

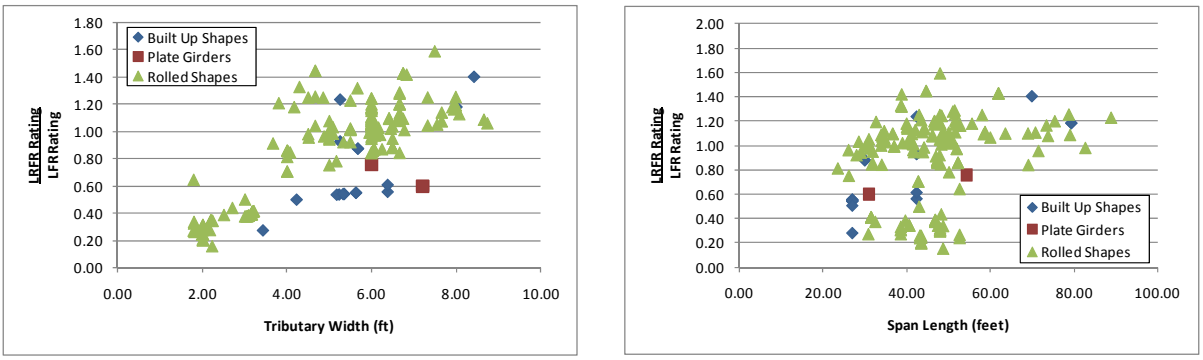


(a) (b)

Figure B-421: LRFR Flexure Rating Factors for WA-02 Vehicle

B.2.10.1.2 Rating Factor Comparisons

Figure B-422 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate an LRFR rating greater than the LFR rating. The ratio is generally between 0.8 and 1.2 with those having smaller ratios generally having closely spaced girders. 46% of the girders in this group have an LRFR rating that is greater than the LFR rating.

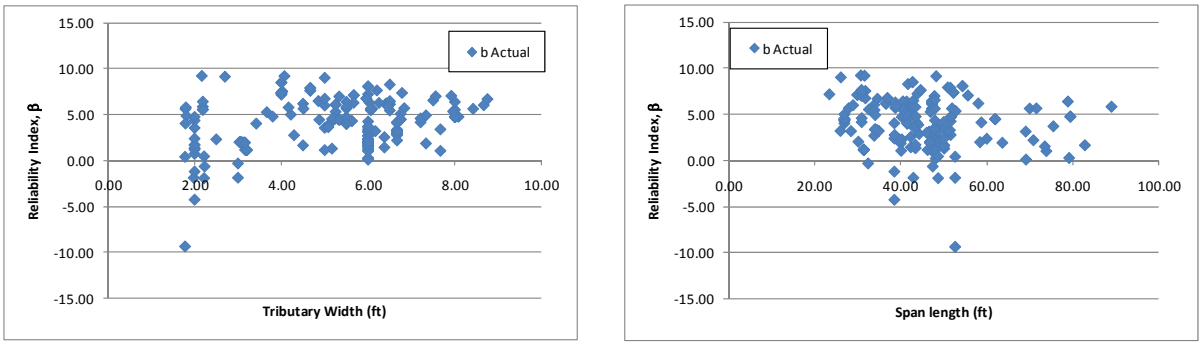


(a) (b)

Figure B-422: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

B.2.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-423 shows that a large number of girders do not have the expected level of reliability.



(a) (b)

Figure B-423: Flexure Reliability Indices for WA-02 Vehicle

Figure B-424 shows the reliability index versus the LRFR rating for flexure due to the WA-02 vehicle. The figure shows that girders passing rating have a reliability index of approximately 4.0. This is slightly higher than the target value of 3.5 used in the development of the MBE. A slight reduction in the LRFR live load factors would bring the reliability index back to the target level of 3.5.

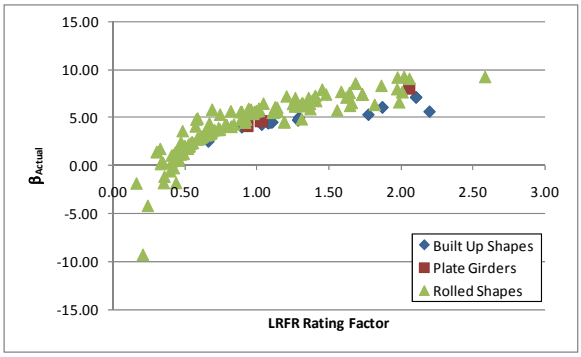


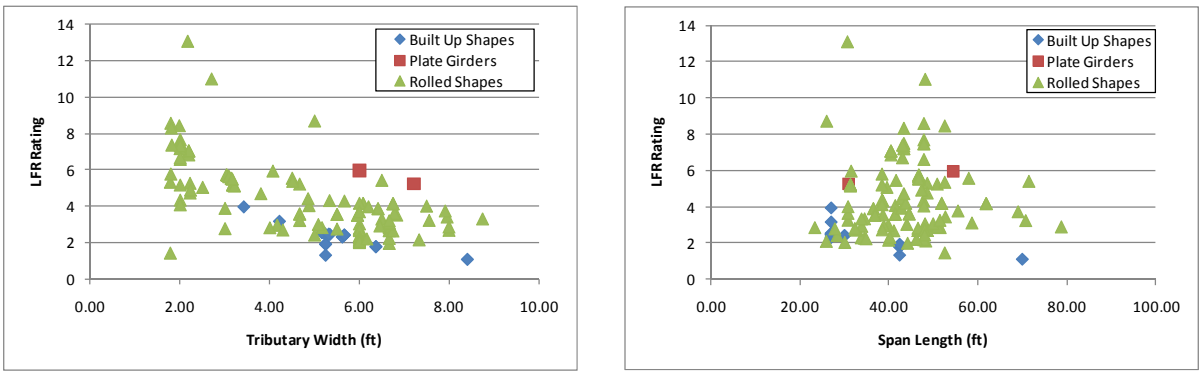
Figure B-424: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

B.2.10.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

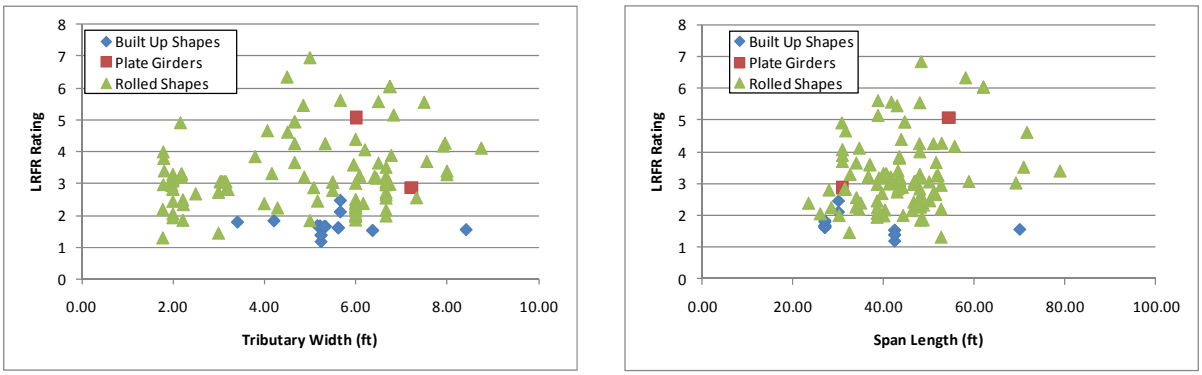
B.2.10.2.1 Rating Factors

For shear, there are 24 girders that has a rating factor less than 1.0 for the LRFR method. In this situation, 24 girders were affected by the switch from rating using the LFR method to the LRFR method. The LFR Rating is greater than the LRFR rating for 94% of the girders in this subset. Figure B-425 and Figure B-426 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-425: LFR Shear Ratings for WA-02 Vehicle

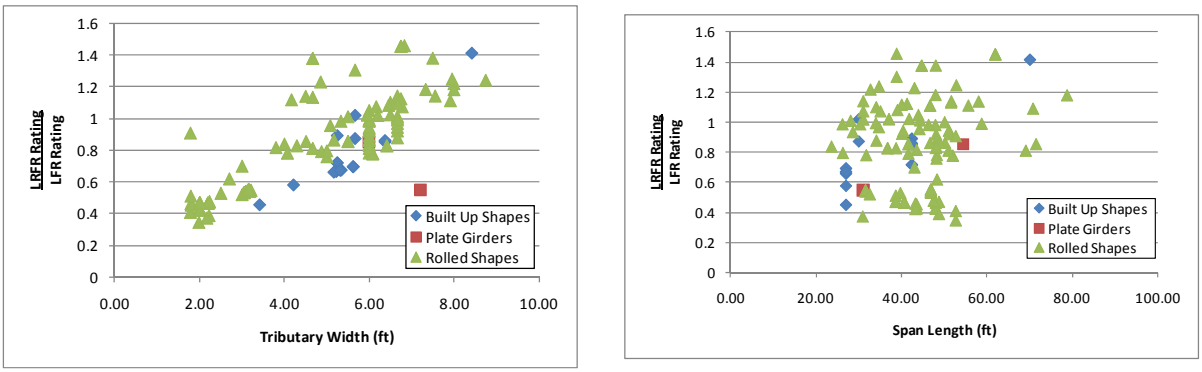


(a) (b)

Figure B-426: LRFR Shear Ratings for WA-02 Vehicle

B.2.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-427 shows the comparison of rating factors. The ratio is generally between 0.8 and 1.2 for this vehicle and girder subset. The LRFR ratings are likely higher because of the loading condition assumed in the MBE, a single lane is loaded without multiple presence included in the distribution factor.

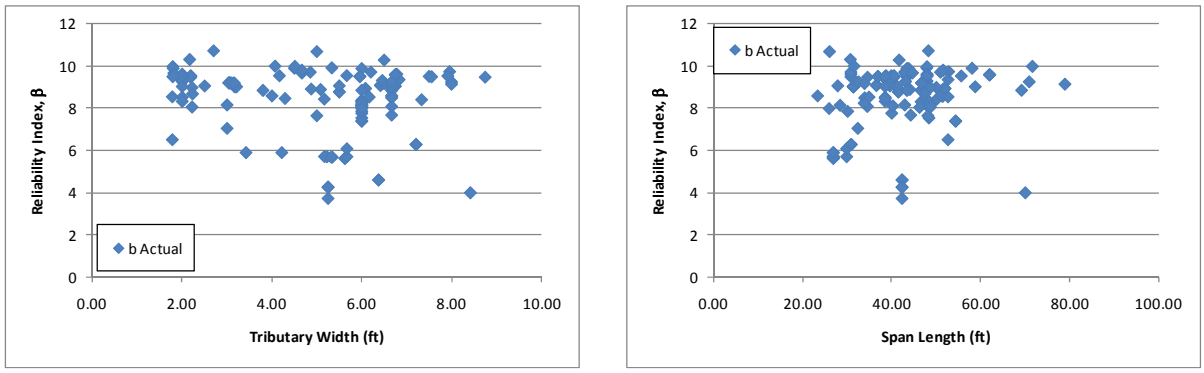


(a) (b)

Figure B-427: Ratio of LRFR Shear Rating to LFR Shear Rating for WA-02 Vehicle

B.2.10.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index assumed in the development of the MBE is 3.5 The actual reliability index is greater than that assumed in the development of the MBE as shown in Figure B-428. There are several girders where the reliability index is approaching the required value. These girders generally have short spans but have a variety of tributary widths.



(a) (b)

Figure B-428: Shear Reliability Indices for WA-02 Vehicle

Figure B-429 shows the reliability index plotted against the LRFR rating for shear caused by the WA-02 vehicle. The live load factors currently in the MBE result in girders passing rating having a reliability index of 3.5 for built up shapes and 5.0 for rolled shapes. For this vehicle, the current live load factors produce the target level of reliability assumed in the development of the MBE. The girders with high reliability and low ratings are those controlled by the bearing stiffener; the reliability index is calculated using the web shear resistance and not the bearing stiffener resistance.

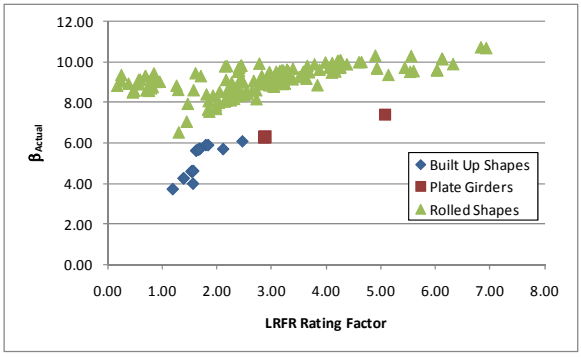


Figure B-429: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

B.2.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-430. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

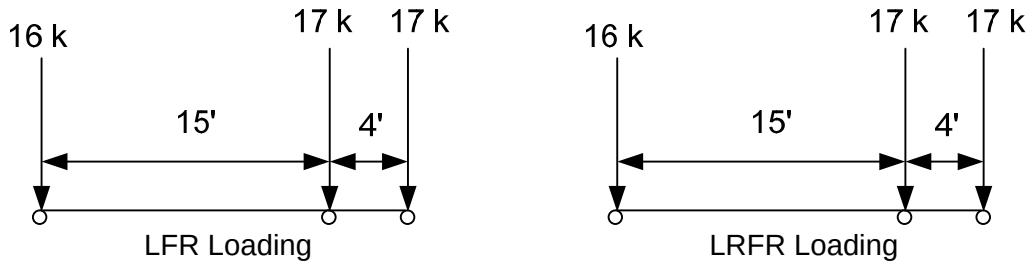


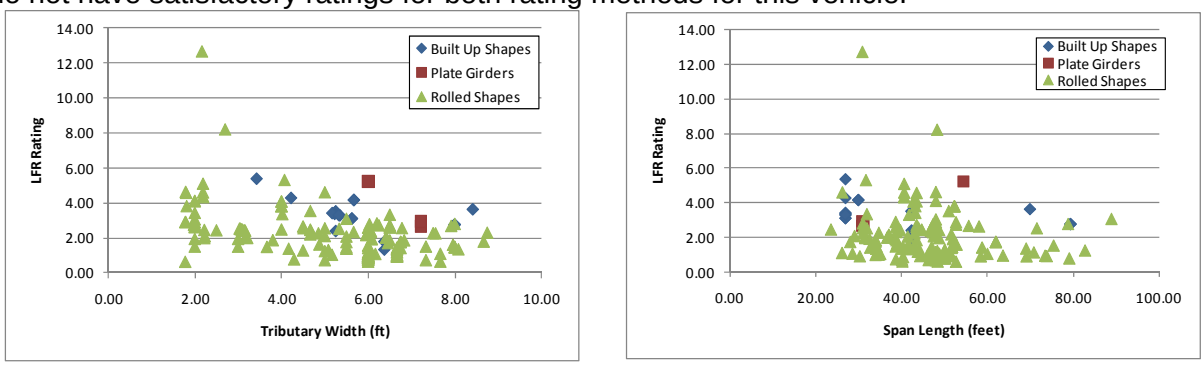
Figure B-430: Vehicle Loadings and Load Factors

B.2.11.1 Moment

The following section contains the results for interior, non-composite steel girders within simple span bridges for the Type 3 Vehicle.

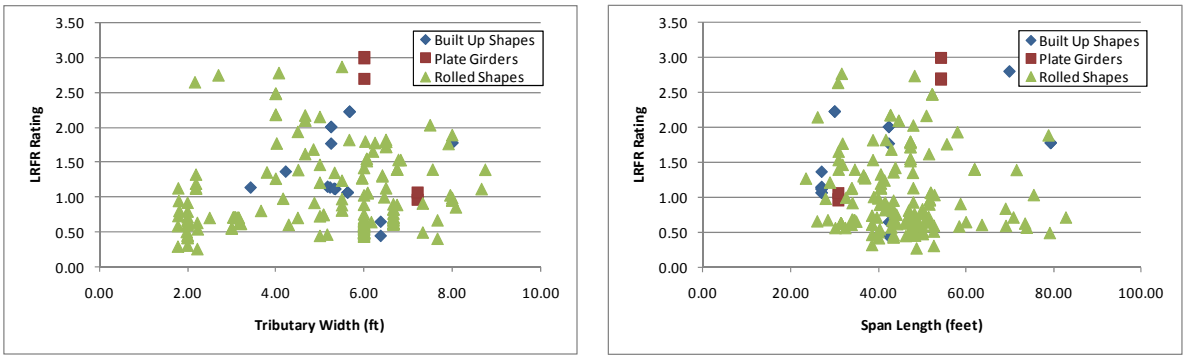
B.2.11.1.1 Rating Factors

Figure B-431 and Figure B-432 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 36 girders with an LFR rating less than 1.0, 112 girders with an LRFR rating less than 1.0, and 36 girders where both ratings are less than 1.0. There are a large number of girders that do not have satisfactory ratings for both rating methods for this vehicle.



(a) (b)

Figure B-431: LFR Flexure Rating Factors for Type 3 Vehicle



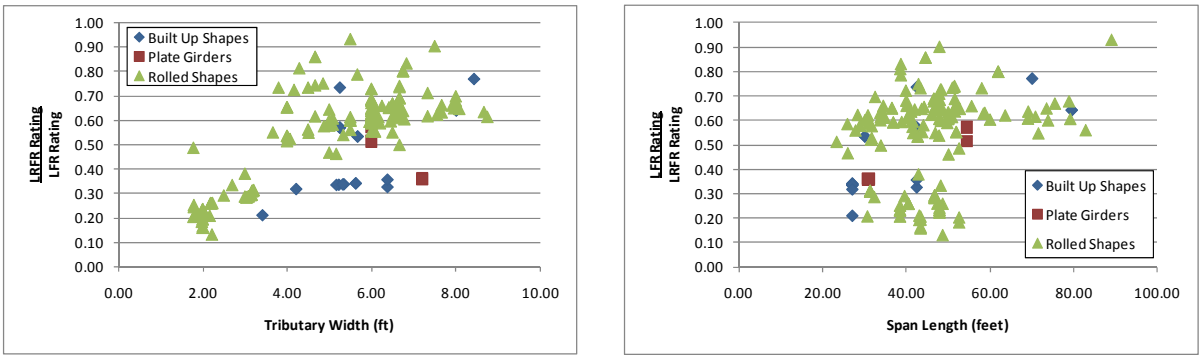
(a) (b)

Figure B-432: LRFR Flexure Rating Factors for Type 3 Vehicle

B.2.11.1.2 Rating Factor Comparisons

Figure B-433 show the ratio of LRFR rating to LFR rating. Figure B-422 shows that there are no girders that have an LRFR rating greater than the LFR rating. The ratio is generally between 0.5 and 0.7 with

those having smaller ratios generally having closely spaced girders. All girders have a higher LFR rating than LRFR rating for this vehicle.

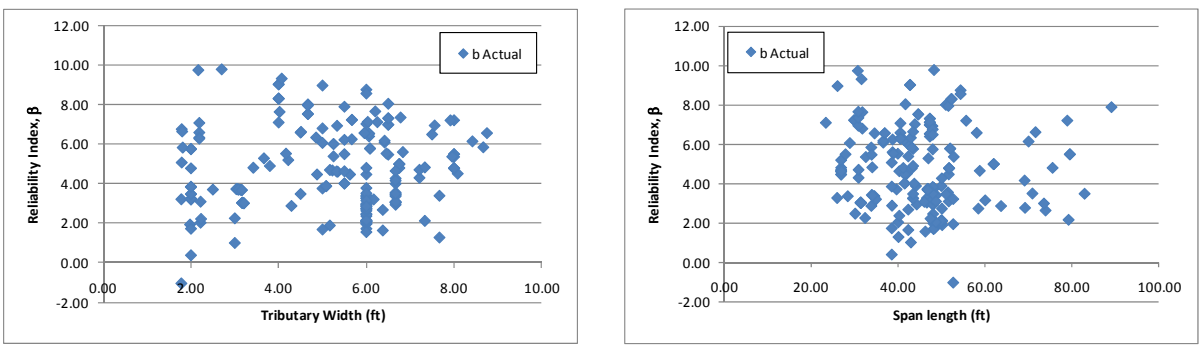


(a) (b)

Figure B-433: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

B.2.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-434 shows that a large number of girders have a reliability index less than the 2.5 assumed in the development of the MBE. These girders have varying tributary widths and span lengths.



(a) (b)

Figure B-434: Flexure Reliability Indices for Type 3 Vehicle

Figure B-435 shows the reliability index plotted against the LRFR rating for moment due to the AASHTO Type 3 truck. The figure shows that girders passing rating have a reliability index of 4 which is above the target reliability of 2.5. Reducing the LRFR live load factors would bring the reliability index of a girder passing rating closer to the target level of 2.5.

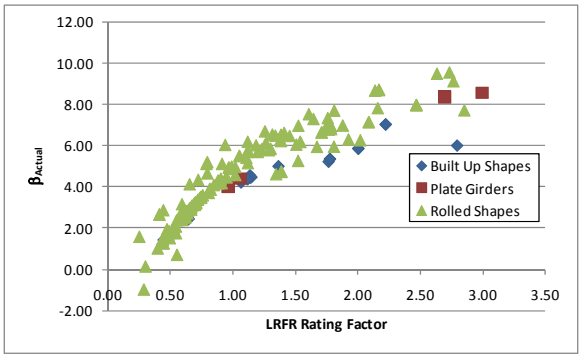


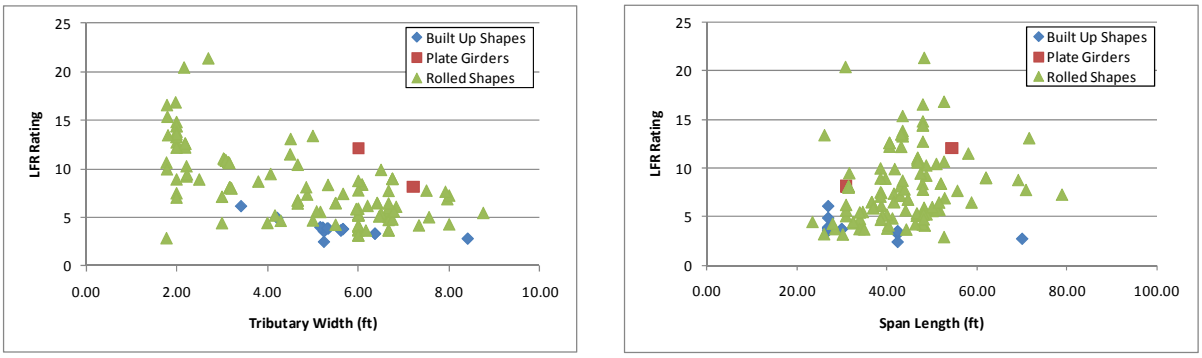
Figure B-435: Flexure Reliability Index vs LRFR Flexure Rating for Type 3 Vehicle

B.2.11.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

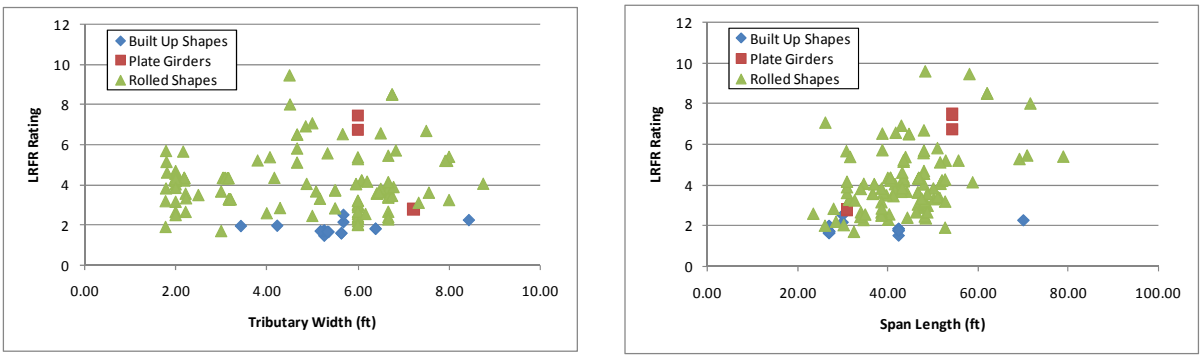
B.2.11.2.1 Rating Factors

For shear, there are are 18 girders that have a rating factor less than 1.0 for the LRFR method. In this situation, 18 girders were affected by the switch from rating using the LFR method to the LRFR method. The LFR Rating is greater than the LRFR rating for 100% of the girders in this subset. Figure B-436 and Figure B-437 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-436: LFR Shear Ratings for Type 3 Vehicle

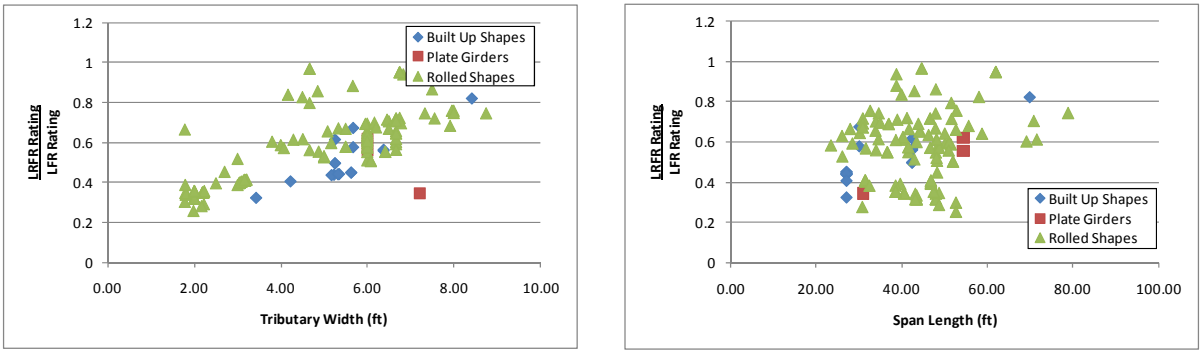


(a) (b)

Figure B-437: LRFR Shear Ratings for Type 3 Vehicle

B.2.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-438 shows the comparison of rating factors. The ratio is generally between 0.4 and 0.8 and no girders have an LRFR rating greater than the LFR rating. The ratio tends to increases with tributary widths but is not affected by the span length.

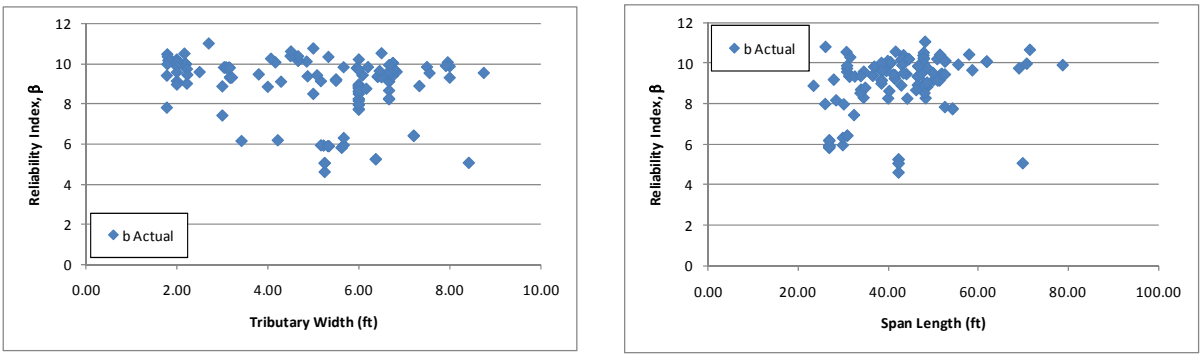


(a) (b)

Figure B-438: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3 Vehicle

B.2.11.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the reliability index of 2.5 assumed in the development of the MBE for all girders as shown in Figure B-439. Most girders have reliability indices much larger than 2.5.



(a) (b)

Figure B-439: Shear Reliability Indices for Type 3 Vehicle

Figure B-440 shows the reliability index plotted against the LRFR rating factor for shear caused by the AASHTO Type 3 truck. The figure shows that girders passing rating have reliability indices above the target value of 2.5. This indicates that the LRFR live load factors could be reduced and result in girders passing rating having reliability near the target value. The girders with low ratings and high reliability are those controlled by the bearing stiffener rating; the reliability is calculated using the web shear resistance not the the bearing stiffener resistance.

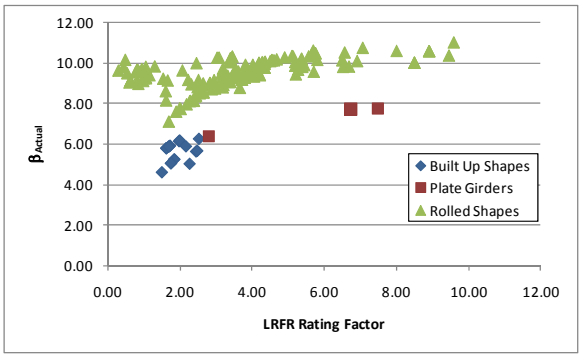


Figure B-440: Shear Reliability Index vs LRFR Shear Rating for Type 3 Vehicle

B.2.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-441. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

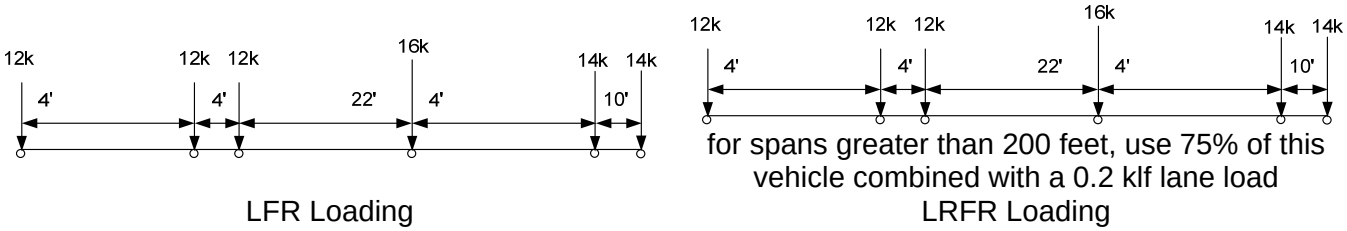


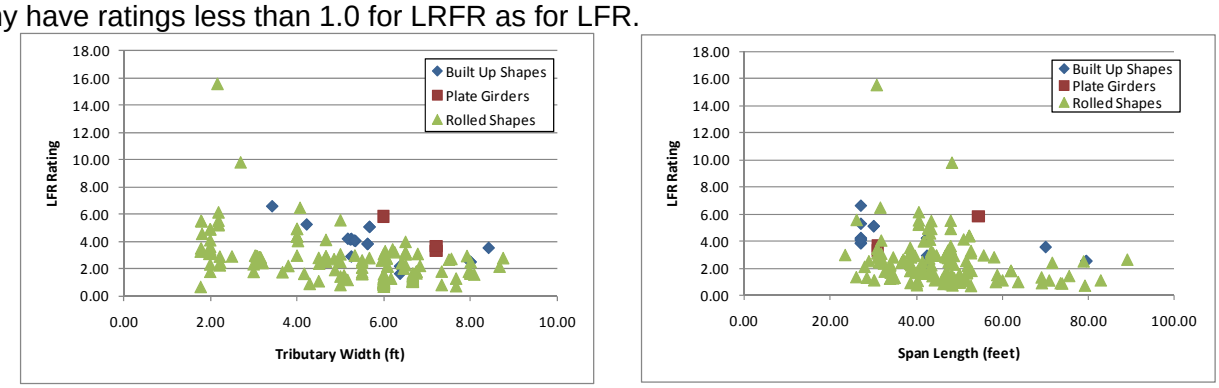
Figure B-441: Vehicle Loadings and Load Factors

B.2.12.1 Moment

The following section contains the results for interior, non-composite steel girders within simple span bridges for the Type 3-3 Vehicle.

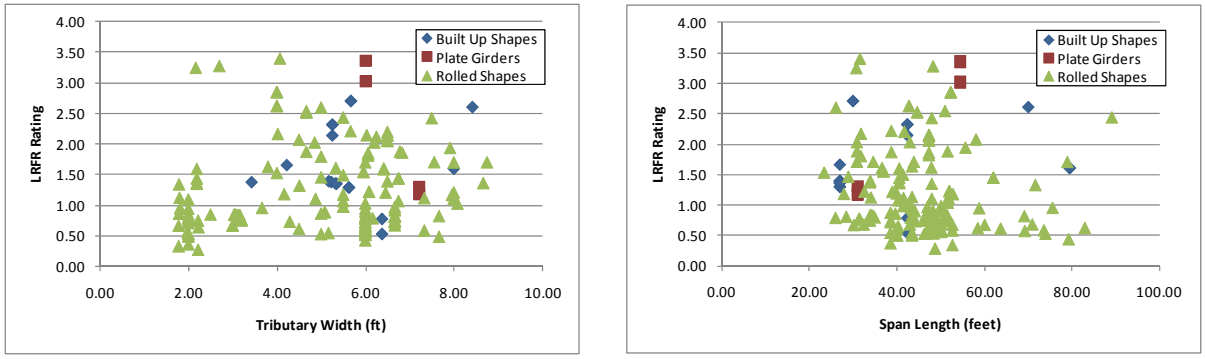
B.2.12.1.1 Rating Factors

Figure B-442 and Figure B-443 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 21 girders with an LFR rating less than 1.0, 97 girders with an LRFR rating less than 1.0, and 21 girders where both ratings are less than 1.0. There is a large number of girders that do not have satisfactory ratings for both rating methods for this vehicle but nearly five times as many have ratings less than 1.0 for LRFR as for LFR.



(a) (b)

Figure B-442: LFR Flexure Rating Factors for Type 3-3 Vehicle

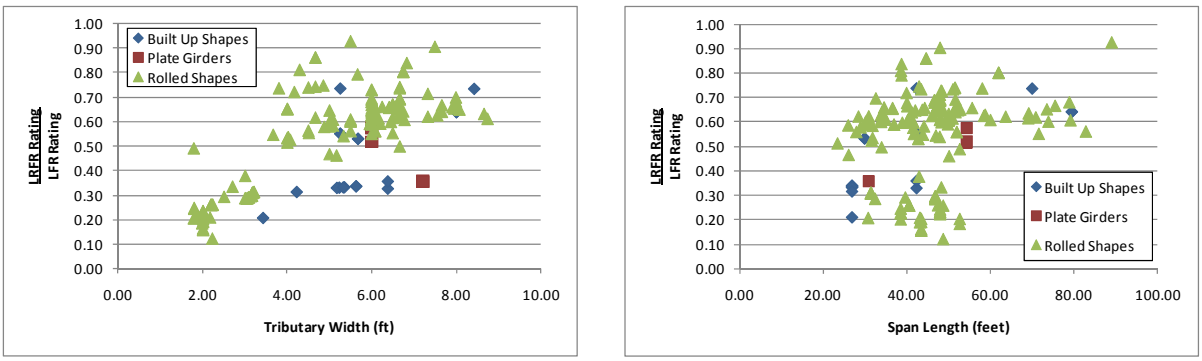


(a) (b)

Figure B-443: LRFR Flexure Rating Factors for Type 3-3 Vehicle

B.2.12.1.2 Rating Factor Comparisons

Figure B-444 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate an LRFR rating greater than the LFR rating, which for this vehicle there are no girders where this occurs. The ratio is generally between 0.5 and 0.7 with those having smaller ratios generally being closely spaced rolled shapes. The LFR rating is greater than the LRFR rating for all girders in this subset.

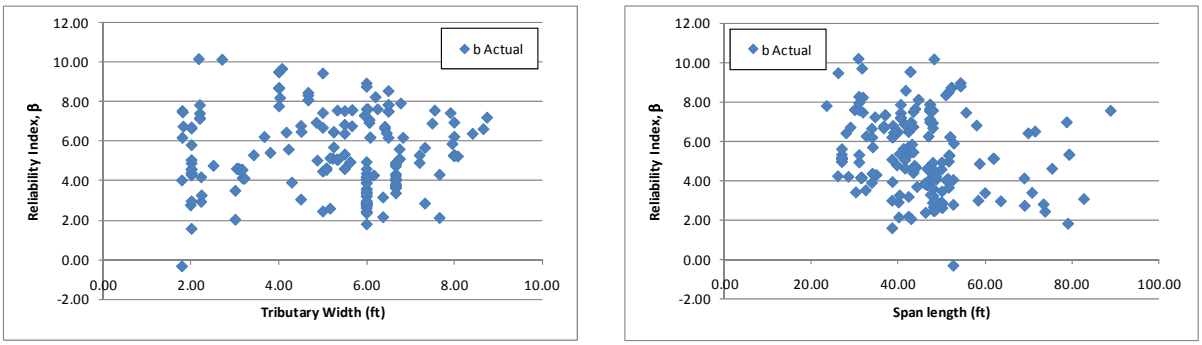


(a) (b)

Figure B-444: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

B.2.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-445 shows that several girders have a reliability index less than the 2.5 assumed in the development of the MBE.



(a) (b)

Figure B-445: Flexure Reliability Indices for Type 3-3 Vehicle

Figure B-446 shows the reliability index plotted versus the LRFR rating for moment caused by the AASHTO Type 3-3 Truck. The figure shows that girders passing rating have a reliability index of 4.0 which is above the target reliability of 2.5. The live load factors could be reduced such that girders passing rating have a reliability index of approximately 2.5.

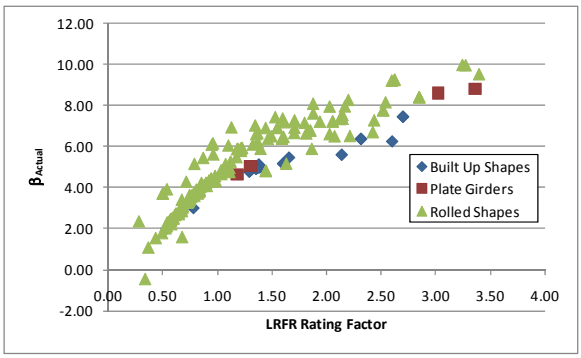


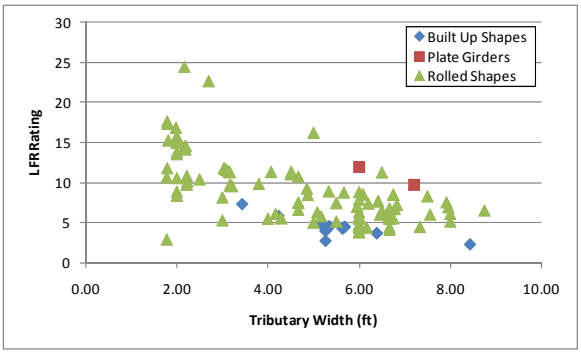
Figure B-446: Flexure Reliability Index vs LRFR Flexure Rating for Type 3-3 Truck

B.2.12.2 Shear

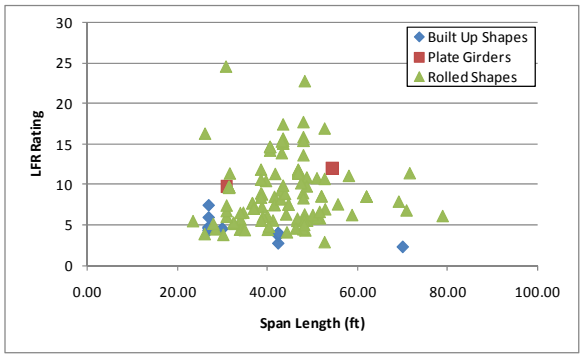
The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

B.2.12.2.1 Rating Factors

For shear, there are are 18 girders that have a rating factor less than 1.0 for the LRFR method. In this situation, 9% of girders were affected by switching from rating using the LFR method to the LRFR method. The LFR Rating is greater than the LRFR rating for 100% of the girders in this subset. Figure B-447 and Figure B-448 show the LFR and LRFR ratings, respectively.

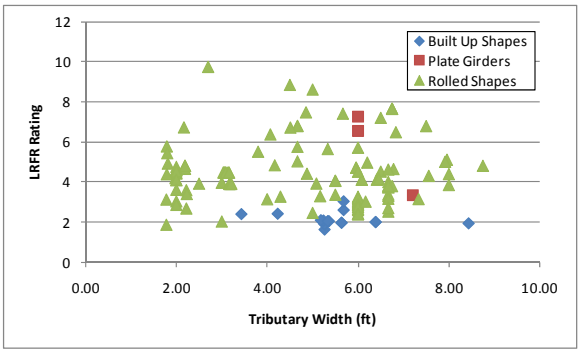


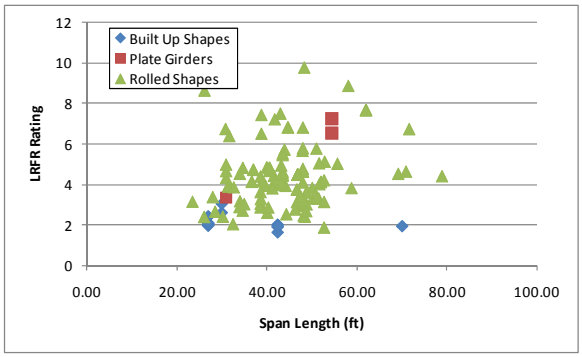
(a)



(b)

Figure B-447: LFR Shear Ratings for Type 3-3 Vehicle



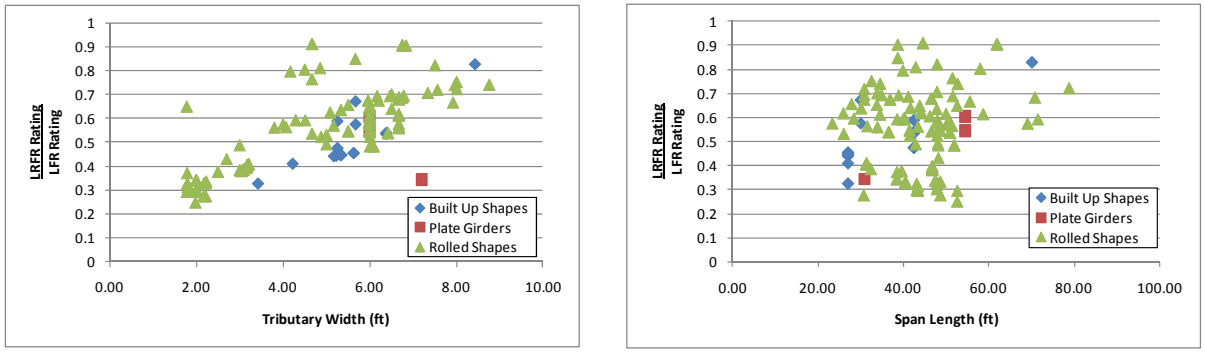


(a) (b)

Figure B-448: LRFR Shear Ratings for Type 3-3 Vehicle

B.2.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-449 shows this comparison of rating factors. The ratio is generally between 0.5 and 0.7. The ratio increases with increasing tributary width but there are no girders that produce an LRFR rating greater than the LFR rating.

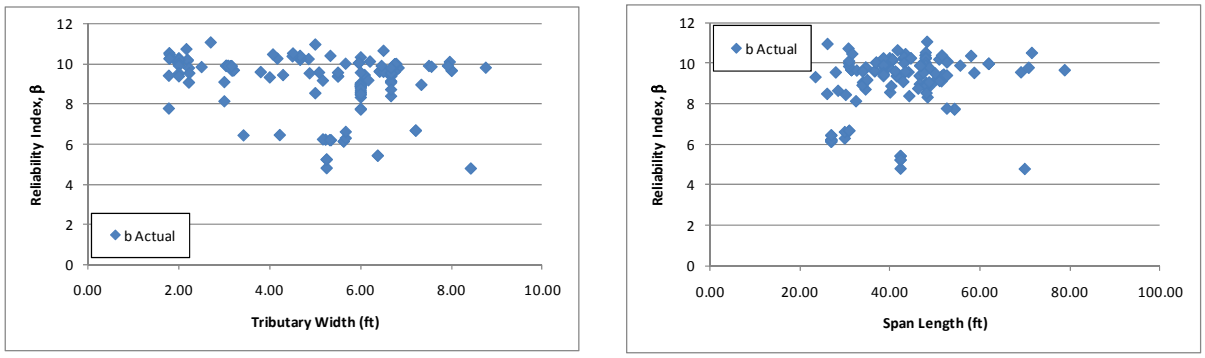


(a) (b)

Figure B-449: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3-3 Vehicle

B.2.12.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index of 2.5 for all girders as shown in Figure B-450.



(a) (b)

Figure B-450: Shear Reliability Indices for Type 3-3 Vehicle

Figure B-451 shows the reliability index plotted against the LRFR rating for shear due to the AASHTO Type 3-3 Truck. The figure shows that girders passing rating have reliability indices higher than the target reliability of 2.5. Reducing the LRFR live load factors would result in the girders passing rating having a reliability index nearer the target reliability. The girders with high reliability and low rating are those controlled by the bearing stiffener rating; the reliability is calculated using the web shear resistance not the bearing stiffener resistance.

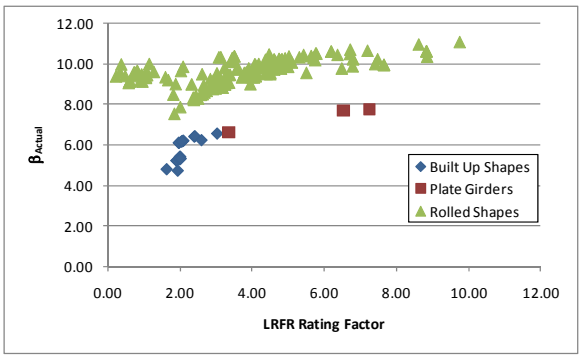


Figure B-451: Shear Reliability Index vs LRFR Shear Rating for Type 3-3 Truck

B.2.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-452. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

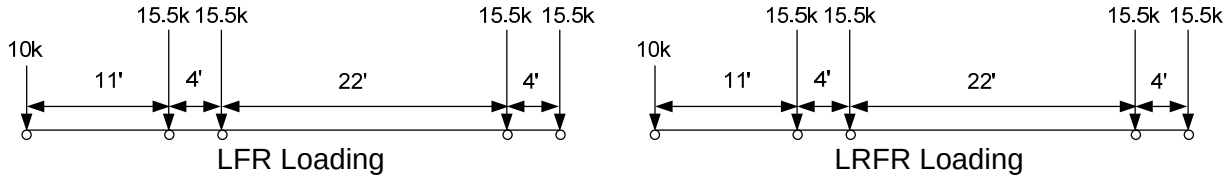


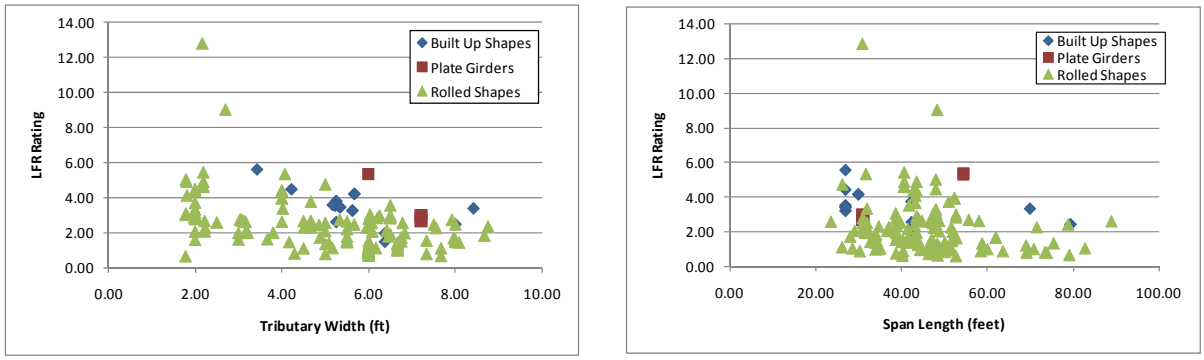
Figure B-452: Vehicle Loadings and Load Factors

B.2.13.1 Moment

The following section contains the results for interior, non-composite steel girders within simple span bridges for the Type 3S2 Vehicle.

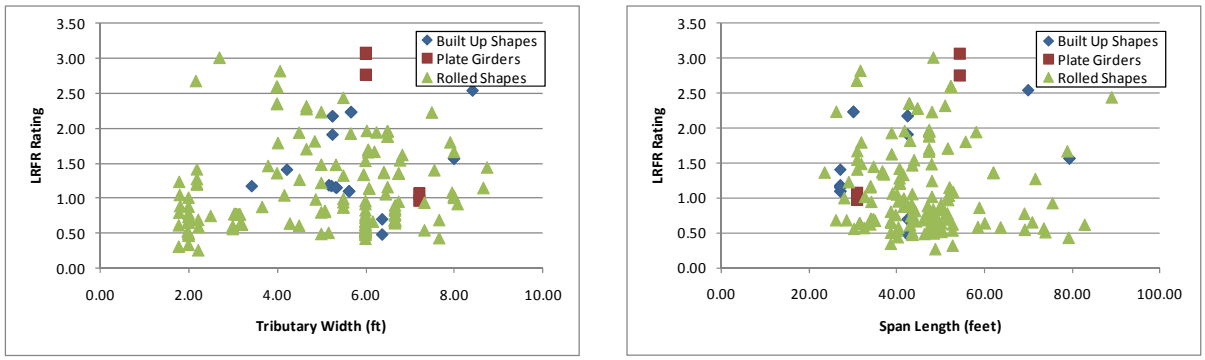
B.2.13.1.1 Rating Factors

Figure B-453 and Figure B-454 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 30 girders with an LFR rating less than 1.0, 105 girders with an LRFR rating less than 1.0, and 30 girders where both ratings are less than 1.0. There are a significant number of girders that do not have satisfactory ratings for both methods for this vehicle but there are three times as many girders having an LRFR rating less than 1.0 as LFR rating less than 1.0.



(a) (b)

Figure B-453: LFR Flexure Rating Factors for Type 3S2 Vehicle

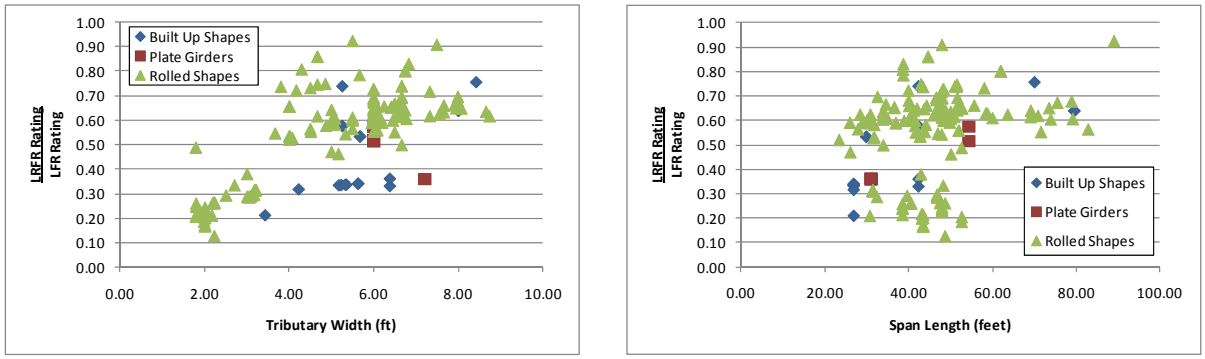


(a) (b)

Figure B-454: LRFR Flexure Rating Factors for Type 3S2 Vehicle

B.2.13.1.2 Rating Factor Comparisons

Figure B-455 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0, of which none exist for this vehicle, indicate an LRFR rating greater than the LFR rating. The ratio is generally between 0.5 and 0.7 with those having smaller ratios generally being closely spaced rolled shapes. All girders have an LFR rating greater than LRFR rating.

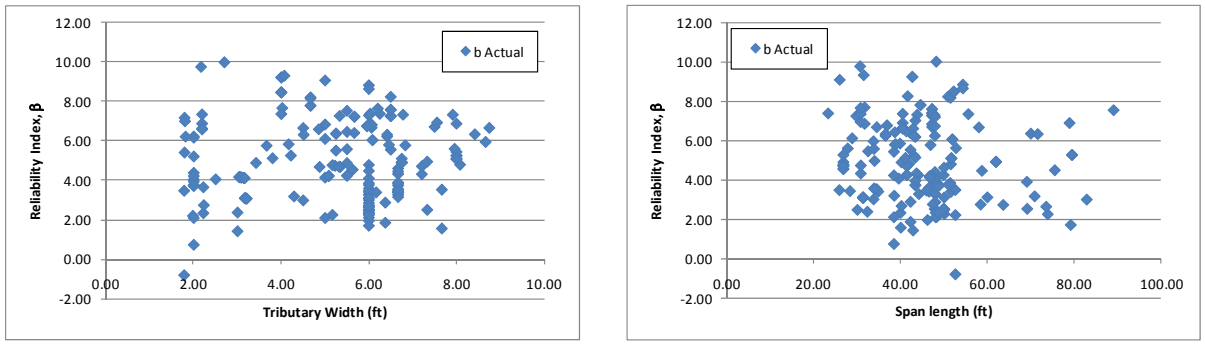


(a) (b)

Figure B-455: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

B.2.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-456 shows that a number of girders have a reliability index less than 2.5.



(a) (b)

Figure B-456: Flexure Reliability Indices for Type 3S2 Vehicle

Figure B-457 shows the reliability index plotted against the LRFR rating for moment caused by the AASHTO Type 3S2 Truck. The figure shows that girders passing rating have reliability indices of at least 4.0 which is greater than the target reliability of 2.5. The LRFR live load factors could be reduced which would reduce the reliability index of the girders passing rating to the target reliability of 2.5.

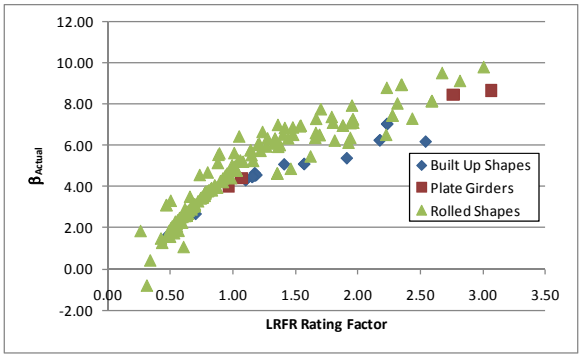


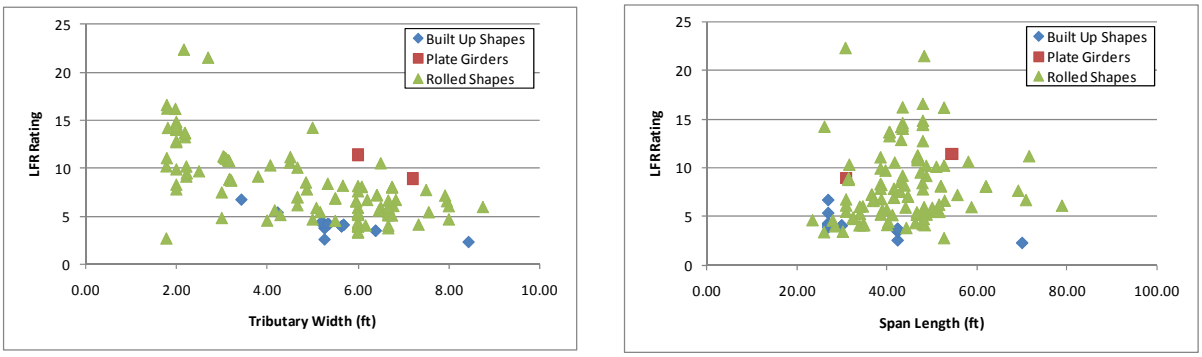
Figure B-457: Flexure Reliability Index vs LRFR flexure Rating for Type 3S2 Truck

B.2.13.2 Shear

The figures presented in the following section have been corrected to account for the different locations between LFR and LRFR. The number of girders with ratings less than 1.0 utilizes all girders not just those at the same location and with the same controlling rating factor. For this reason, the figure may show no girders with a rating less than 1.0 but the text may indicate that there are girders with LRFR ratings less than 1.0

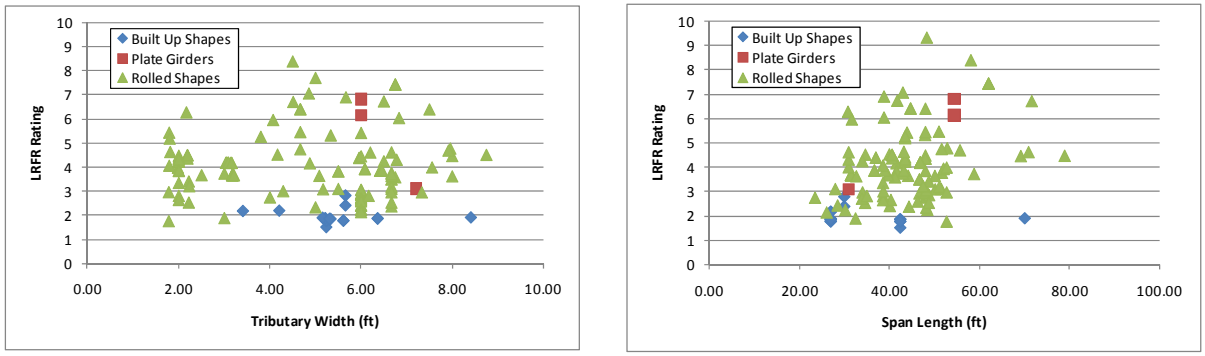
B.2.13.2.1 Rating Factors

For shear, there are 18 girders that have a rating factor less than 1.0 for the LRFR method. In this situation, 18 girders were affected by the switch from rating using the LFR method to the LRFR method. The LFR Rating is greater than the LRFR rating for 100% of the girders in this subset. Figure B-458 and Figure B-459 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-458: LFR Shear Ratings for Type 3S2 Vehicle

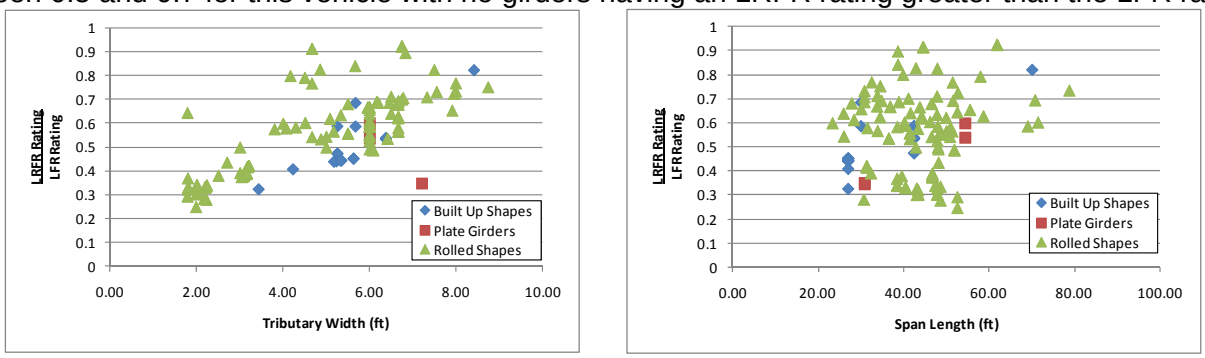


(a) (b)

Figure B-459: LRFR Shear Ratings for Type 3S2 Vehicle

B.2.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-460 shows the comparison of rating factors. The ratio is generally between 0.5 and 0.7 for this vehicle with no girders having an LRFR rating greater than the LFR rating.

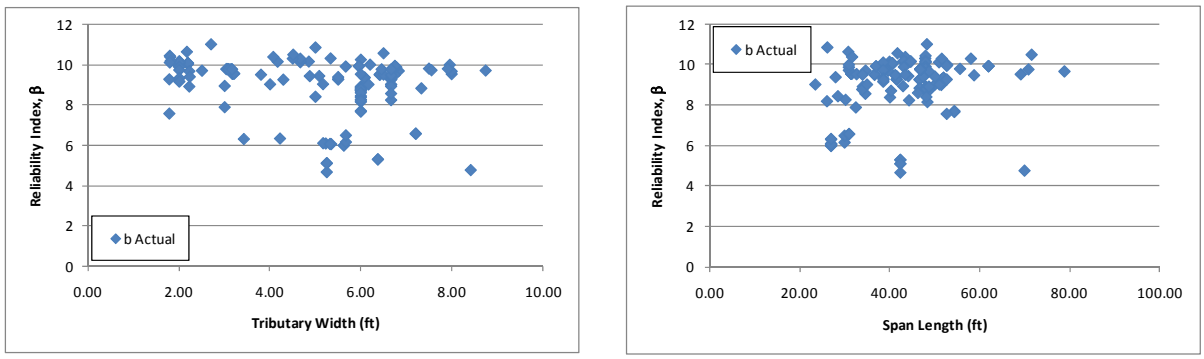


(a) (b)

Figure B-460: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3S2 Vehicle

B.2.13.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required value of 3.5 for all girders as shown in Figure B-461.



(a) (b)

Figure B-461: Shear Reliability Indices for Type 3S2 Vehicle

Figure B-462 shows the reliability index plotted against the LRFR rating for shear due to the AASHTO Type 3S2 truck. The figure shows that girders passing rating have a reliability index above the target

reliability of 2.5. This indicates that the live load factors could be reduced. This would result in girders passing rating to have reliability indices near the target reliability index of 2.5. The girders with high reliability and low ratings are controlled by the bearing stiffener rating; the reliability is calculated using the web shear resistance not the bearing stiffener resistance.

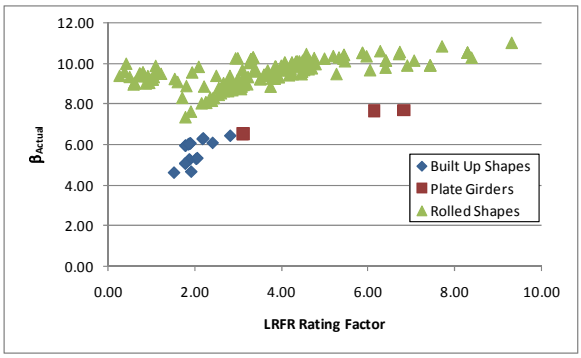


Figure B-462: Shear Reliability Index vs LRFR Shear Rating for Type 3S2 Truck

B.2.14 Moment – Rating Statistics

The number of girders in this subset that do not have ratings greater than 1.0 for LFR ratings, LRFR ratings, and both ratings for all nine vehicles that were investigated are shown in
Table B-3. The table shows that there are a significant number of girders for all of the vehicles that have ratings less than 1.0. The LRFR rating resulted in more girders not having satisfactory ratings but there are a significant number that also did not have satisfactory LFR ratings.

Table B-3: Flexure Rating Factor Results for All 12 vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	193	101	47	46	72	55	43	75	63	79	36	21	30
LRFR Rating less than 1.0		155	121	117	105	130	109	103	136	120	112	97	105
LFR and LRFR Rating less than 1.0		90	47	46	63	55	43	63	63	75	36	21	30
% with LFR RF greater than LRFR RF		90	99	99	53	99	99	45	99	54	100	100	100

B.2.15 Shear – Rating Statistics

The number of girders in this subset that do not have ratings greater than 1.0 for LFR ratings, LRFR ratings, and both ratings for all twelve vehicles that were investigated are shown in Table B-4. The table shows that at most 15% of girders do not have satisfactory ratings, and the LFR rating is greater than the LRFR rating at least 90% of the time for all vehicles. The number of girders that have LRFR ratings less than 1.0 is reduced when considering only those at the same location and controlled by the same rating criteria.

Table B-4: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2

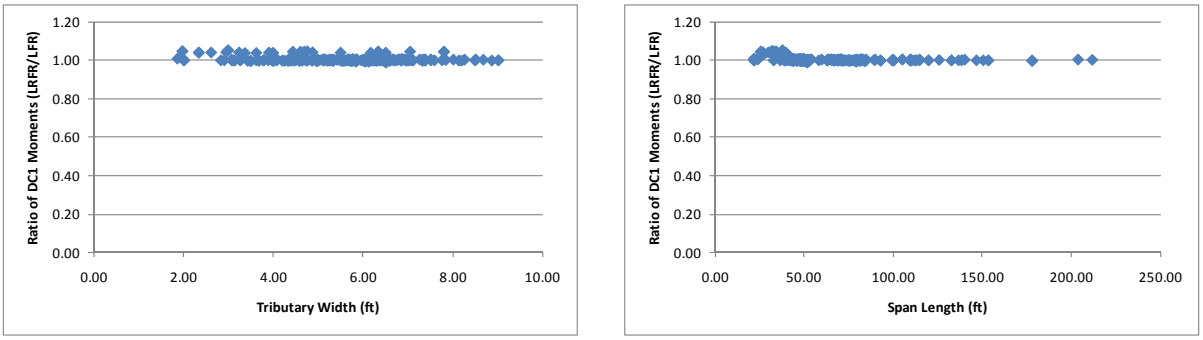
LFR Rating less than 1.0	193	0	0	0	0	0	0	0	0	0	0	0	0
LRFR Rating less than 1.0		29	22	22	20	22	19	18	24	24	18	18	18
LFR and LRFR Rating less than 1.0		0	0	0	0	0	0	0	0	0	0	0	0
% with LFR RF greater than LRFR RF		100	99	99	94	99	99	91	99	94	100	100	100

B.3 Exterior Composite Girders

B.3.1 Dead Loads

B.3.1.1 Moment

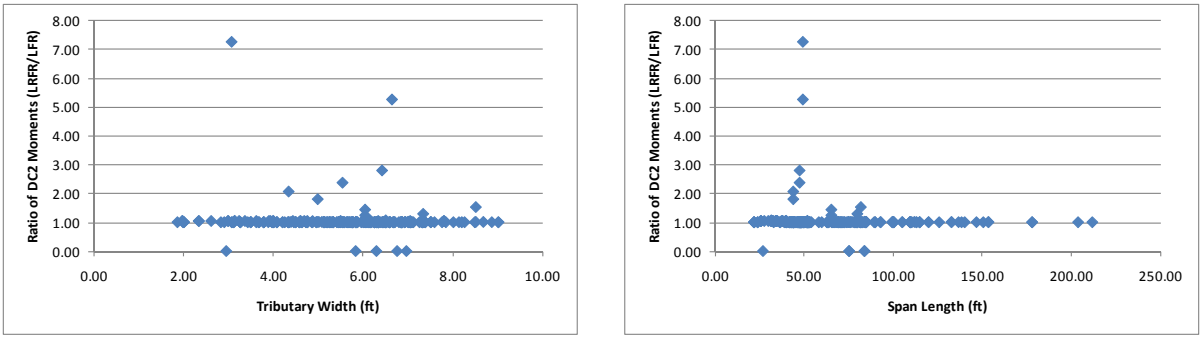
The first set of graphs show the results that were obtained for flexure. As shown in Figure B-463, the ratio of unfactored DC1 moments (self-weight, dead loads on non-composite section) is very close to 1.0. Those that are slightly above 1.0 are caused by the moment being obtained at the four-tenths point for LFR while the LRFR moment is calculated at midspan. RIO determines the location of the critical rating factor and then uses this location to obtain the moments due to dead and live loads.



(a) (b)

Figure B-463: Ratio of DC1 LRFR Moment to DC1 LFR Moment (unfactored loads)

Figure B-464 shows that there is more variation in the loads applied to the composite section (DC2 and DW loads). In most cases, the results are very close to 1.0 with those being significantly different likely caused by variation in the critical location.

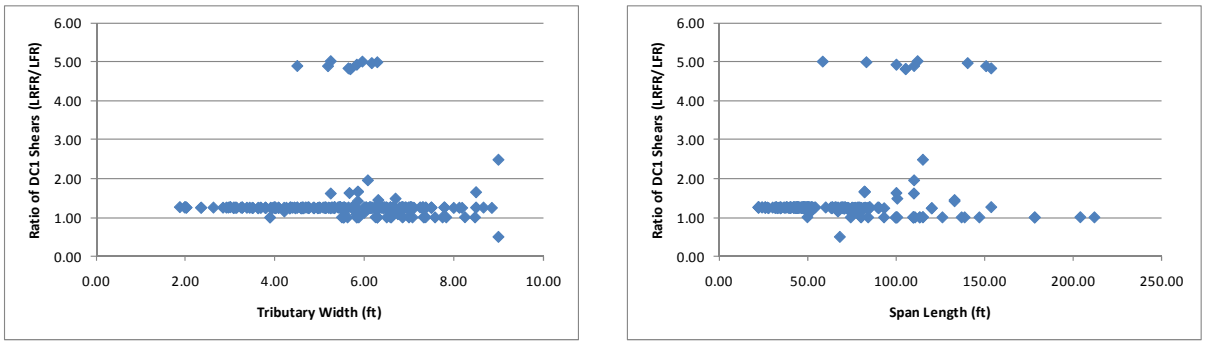


(a) (b)

Figure B-464: Ratio of DC2 LRFR Moment to DC2 LFR Moment (unfactored loads)

B.3.1.2 Shear

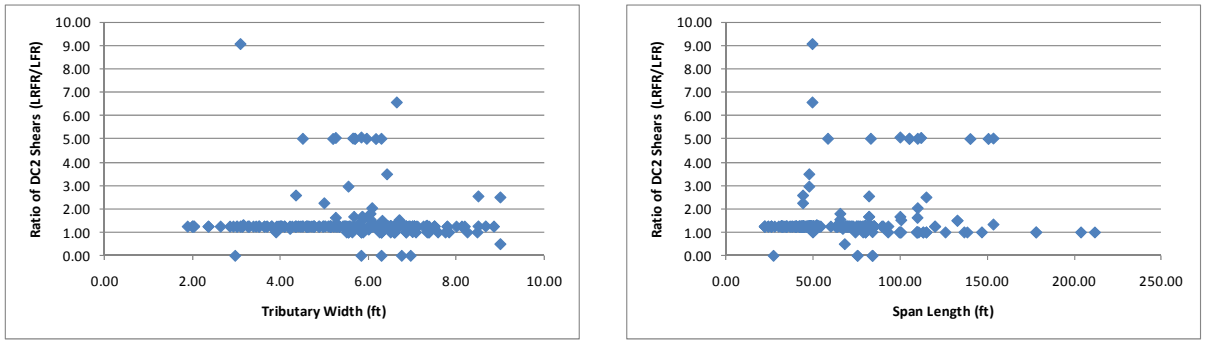
Figure B-465 below shows that for most girders the LRFR DC1 shear is 125% of the LFR DC1 shear. This is a result of BRASS not always calculating a rating factor for shear at the support for LFR; to get around this an option in RIO was created to ignore zero shear ratings. The result was typically that the LFR rating was then taken at either the one-tenth or nine-tenths point along the span. This would correspond to a 25% increase in dead load shear since all the results compiled so far are for simple spans and DC1 is a uniform load. There are also several other girders where the critical location varies as indicated by the data points at 2.5 and 5.0.



(a) (b)

Figure B-465: Ratio of DC1 LRFR Shear to DC1 LFR Shear (unfactored loads)

Figure B-466 shows the same trend as Figure B-465 in that the LRFR shear for the majority of girders is 125% of the LFR shear for DC2 loads. The ratios at 1.0 for the DC2 loads may be cases where both the LFR and LRFR shear was zero. There is also more variation within the DC2 and DW loads than in the DC1 loads.



(a) (b)

Figure B-466: Ratio of DC2 LFR Shear to DC2 LRFR Shear (unfactored loads)

B.3.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure B-467. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

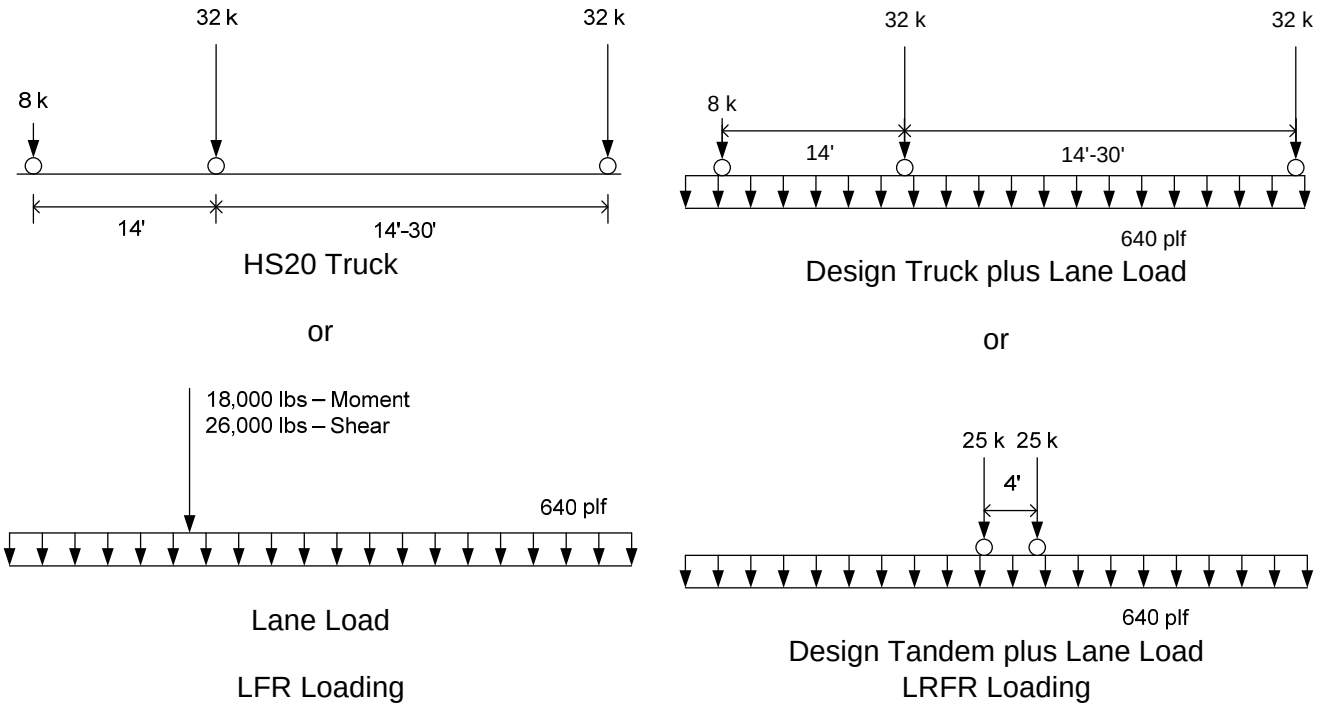
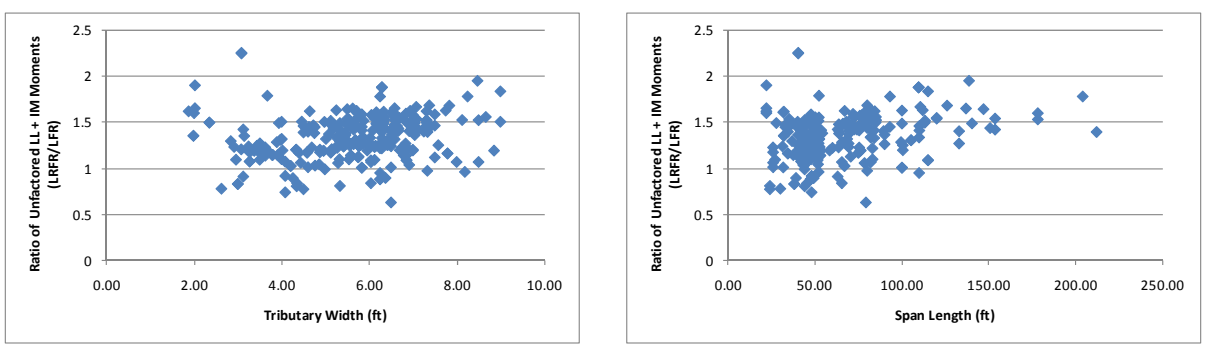


Figure B-467: Vehicle Loadings and Load Factors

B.3.2.1 Moment

B.3.2.1.1 Live Loads

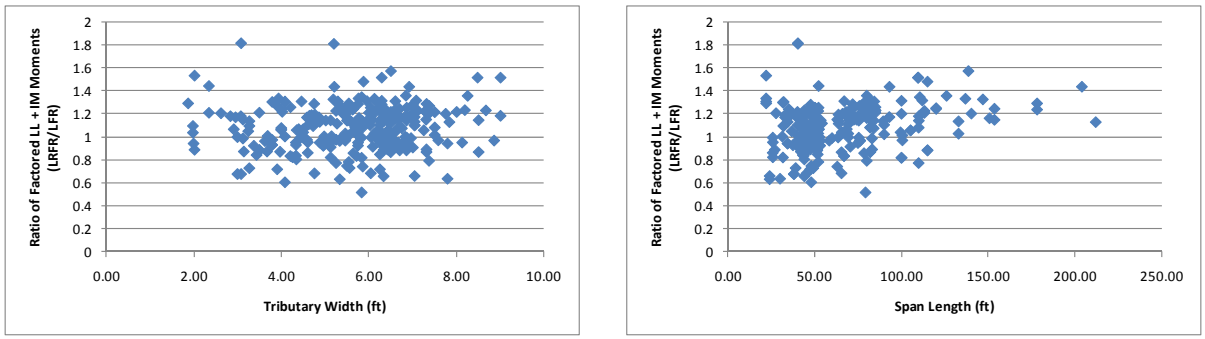
Figure B-468 shows a plot of the unfactored live load moment caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is approximately between 1.0 and 1.5 for most of the girders within this subset. The LRFR live load is generally greater than the LFR live load for most girders for all values of span length and tributary width.



(a) (b)

Figure B-468: Ratio of Unfactored Live Load plus Impact Moments for Design Vehicles (LRFR/LFR)

The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-469 shows that the results have shifted down and are close to 1.0 for most cases.

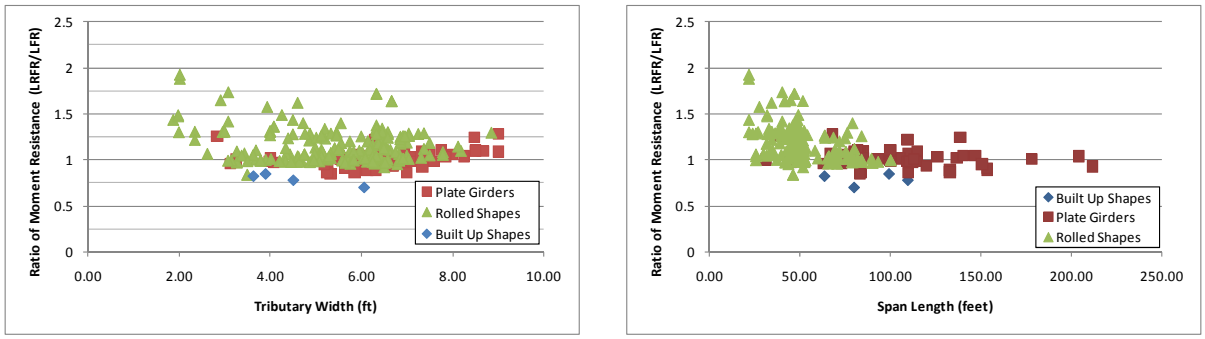


(a) (b)

Figure B-469: Ratio of Factored Live Load plus Impact Moments for Design Vehicles (LRFR/LFR)

B.3.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure B-470 shows that the ratio of resistance is generally between 1.0 and 1.5. Rolled shapes and welded plate girders typically have LRFR resistance greater than LFR resistance while built up shapes generally have higher LFR resistance than LRFR resistance.

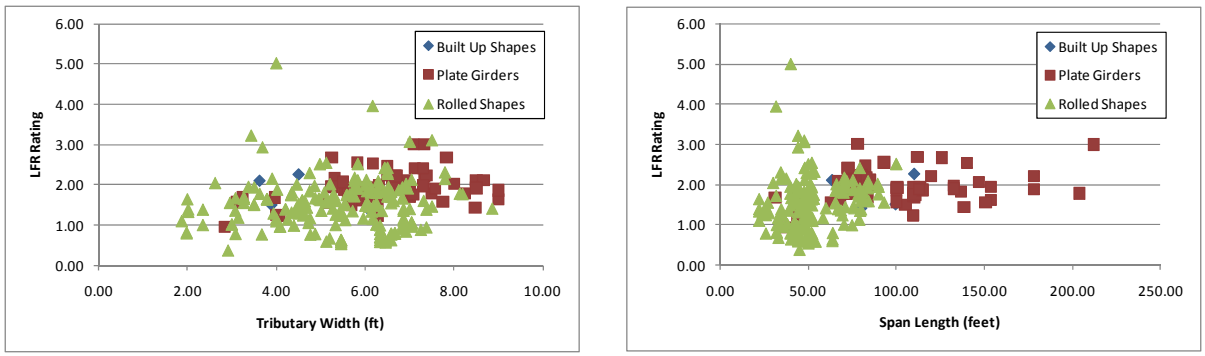


(a) (b)

Figure B-470: Ratio of factored Moment Resistance (LRFR/LFR)

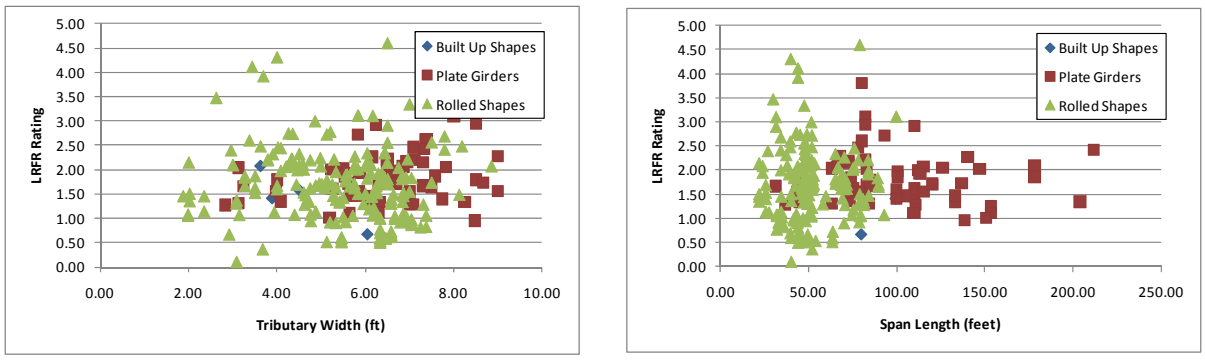
B.3.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (279 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 41 girders with LFR ratings less than 1.0, 41 girders with LRFR ratings less than 1.0, and 31 girders where both ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower rating factors. In this case, there are actually fewer girders with ratings less than 1.0 for LRFR than LFR. Figure B-471 and Figure B-472 show the LFR rating factors and LRFR rating factors, respectively.



(a) (b)

Figure B-471: LFR Flexure Rating Factors for HS-20 Loading

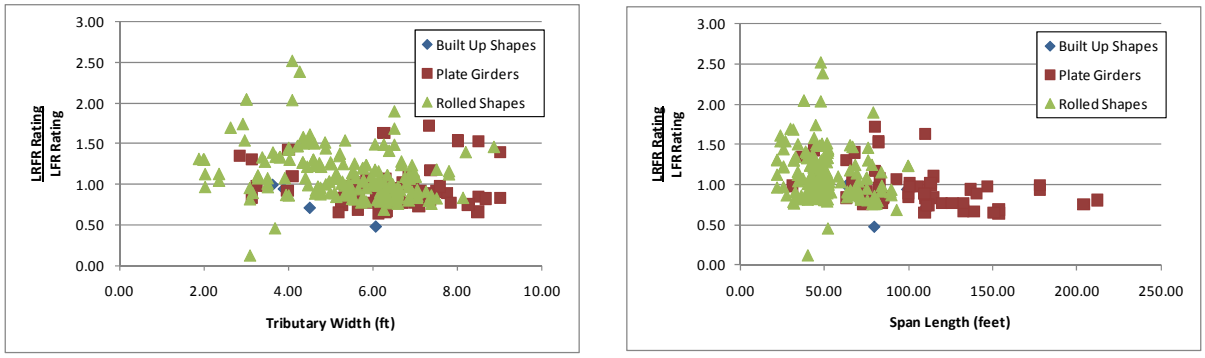


(a) (b)

Figure B-472: LRFR Flexure Rating Factors for HL-93 Loading

B.3.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR divided by LFR, is shown in Figure B-473. The results indicated that 50% of the girders in this set have LFR ratings greater than LRFR ratings. The ratio of ratings is generally between 0.75 and 1.5 for rolled shapes and between 0.5 and 1.0 for plate girders. Built up shapes are generally less than 1.0.



(a) (b)

Figure B-473: Ratio of LRFR Flexure Rating to LFR Flexure Rating

Figure B-474 shows the the percentage of girders in this group that have LRFR ratings less than 1.0 and what the ratio of LRFR to LFR ratings are. The figure shows that for most girders with ratings less than 1.0, the LRFR rating is greater than 80% of the LFR rating including a portion that have LRFR ratings greater than the LFR rating.

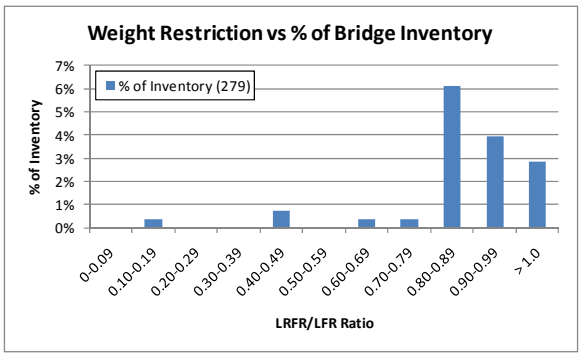
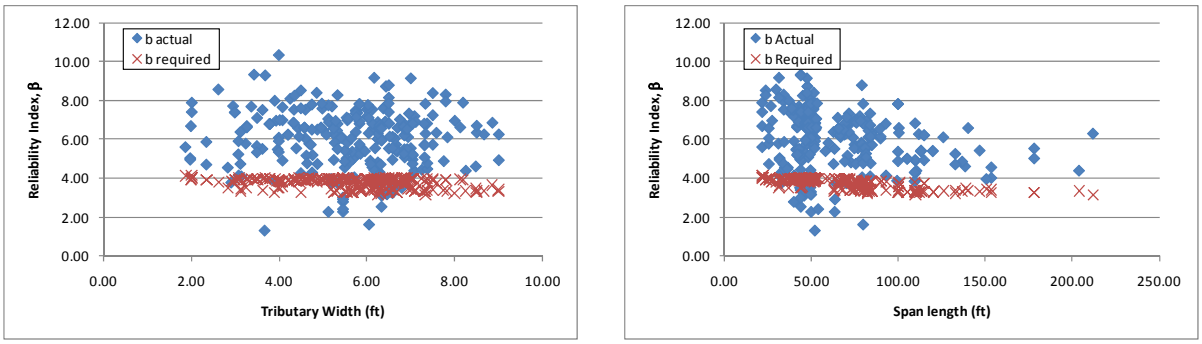


Figure B-474: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

B.3.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure B-475 shows that several girders have a reliability index lower than that assumed in the development of the MBE at the Design Load Inventory level.



(a) (b)

Figure B-475: Flexure Reliability Indices for HL-93 Loading

Figure B-476 shows the reliability index plotted against the LRFR rating factor for moment caused by the HL-93 Design Loading. The figure shows that girders passing rating have a reliability index of approximately 4.0 which is above the target value of 3.5.

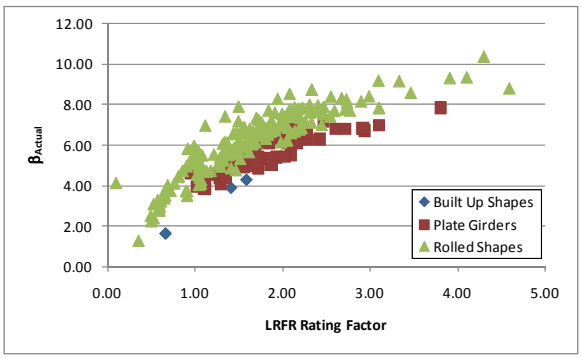


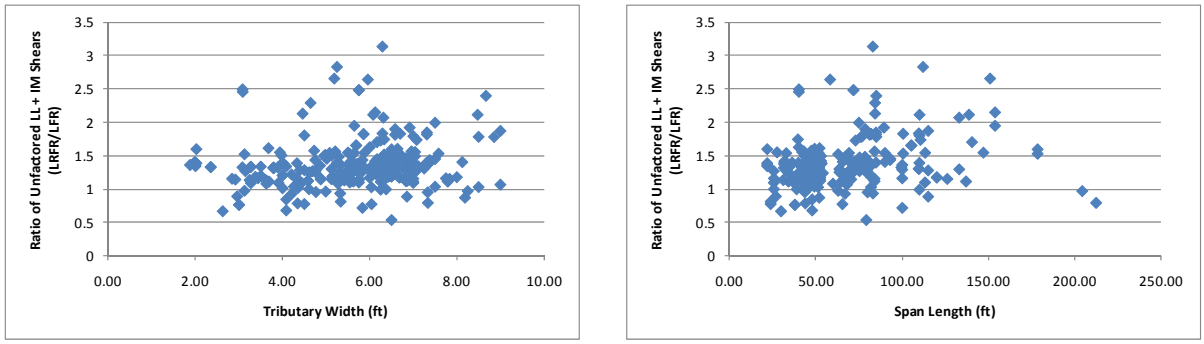
Figure B-476: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Loading

B.3.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is steel, simple span exterior girders with composite concrete decks.

B.3.2.2.1 Live Loads

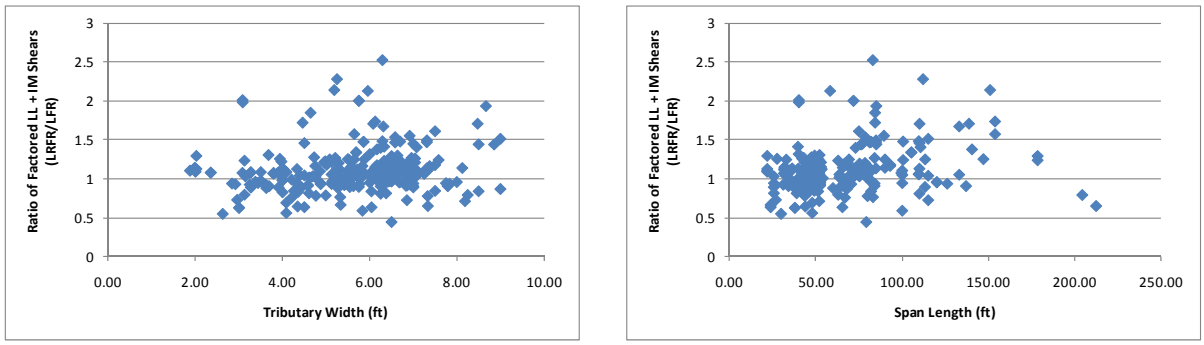
Figure B-477 shows that the ratio of unfactored shear varies significantly. There are no apparent trends but a significant number of girders have a ratio between 1.0 and 1.5.



(a) (b)

Figure B-477: Ratio of Unfactored Live Load plus Impact Shears for Design Vehicles (LRFR/LFR)

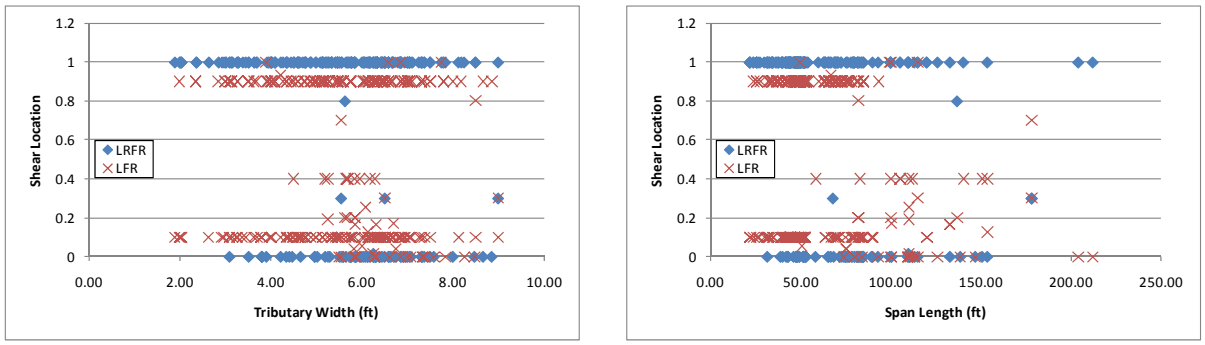
The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-478 shows that the ratio of factored live load shears has decreased and is generally between 0.75 and 1.25 for most cases. This is a large difference which is not easily explained except that almost all LFR results are at one-tenth of the span length from the support.



(a) (b)

Figure B-478: Ratio of Factored Live Load plus Impact Shears for Design Vehicles (LRFR/LFR)

As shown in Figure B-479, the location of the critical section for shear in most girders is the end of the span and at the one tenth point for the LRFR and LFR ratings, respectively. The difference in the factored shears shown in Figure B-478 may have been affected by the difference in the critical section for shear rating.

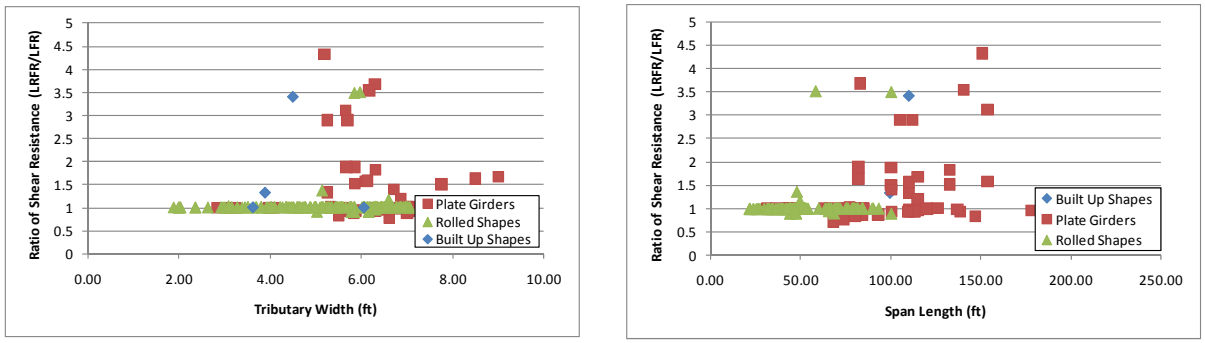


(a) (b)

Figure B-479: Graph of critical shear location for Design Vehicles

B.3.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure B-480 shows that the ratio of resistance is generally around 1.0. There are a number of girders where the LRFR resistance is significantly larger than the LFR resistance; these points are girders where the LFR critical section is out near the middle of the span as shown in Figure B-479.

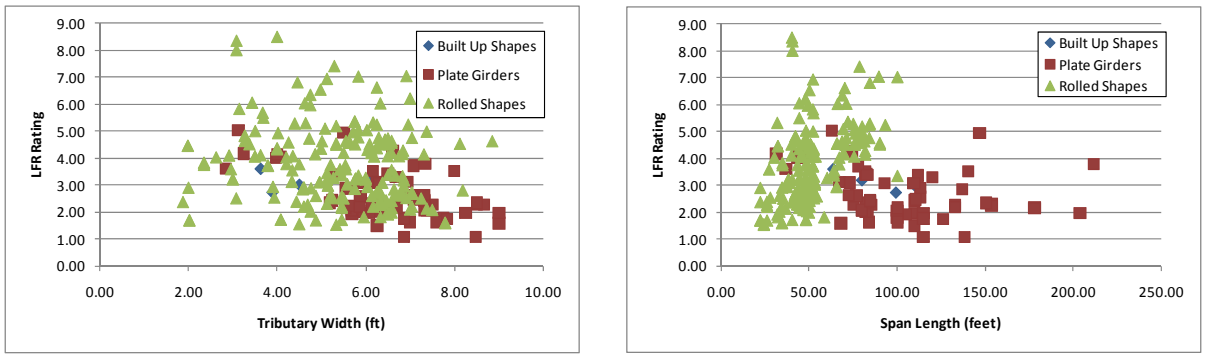


(a) (b)

Figure B-480: Ratio of factored Shear Resistance (LRFR/LFR)

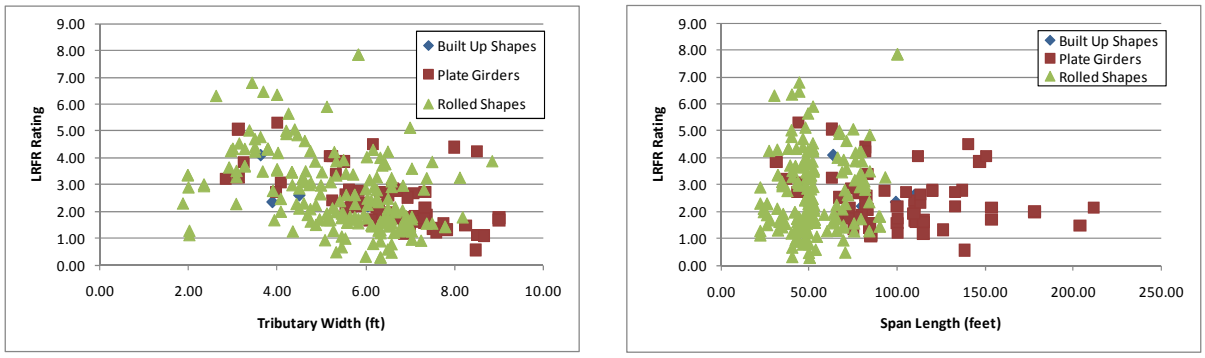
B.3.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 0 girders with LFR ratings less than 1.0 and 15 girder with LRFR ratings less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. The LFR rating was greater than the LRFR rating for 80% of the girders in this subset. Figure B-481 and Figure B-482 show the LFR rating factors and LRFR rating factors, respectively. The LFR rating tends to decrease with increasing tributary width while the LFR rating versus span length shows no general trends. The same is true for the LRFR rating graphs.



(a) (b)

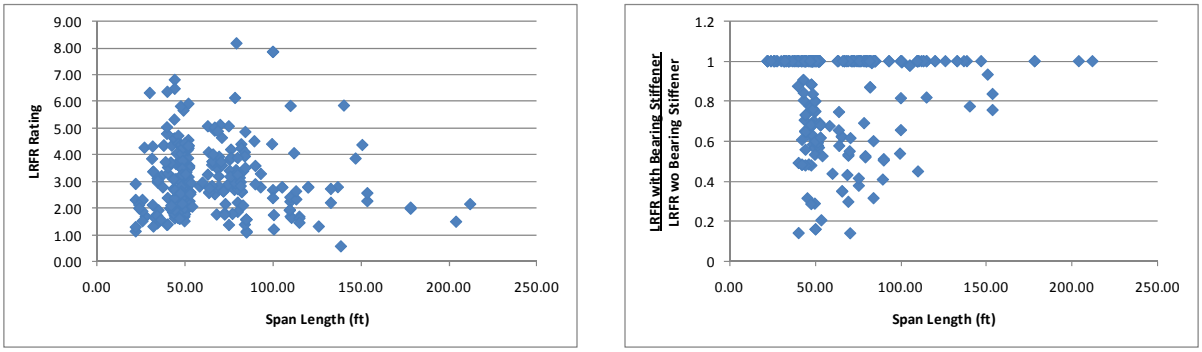
Figure B-481: LFR Shear Rating Factors for HS-20 Loading



(a) (b)

Figure B-482: LRFR Shear Rating Factors for HL-93 Loading

Figure B-483a shows the LRFR ratings when the bearing stiffener rating is ignored. The figure shows that many of girders with spans near 50 feet with ratings less than 1.0 now have higher ratings than shown in Figure B-482b. Ignoring the bearing stiffener rating resulted in 14 fewer girders having ratings less than 1.0 than when the rating was included. Figure B-483b shows the LRFR rating including the bearing stiffener divided by the LRFR rating ignoring the bearing stiffener. Most girders have LRFR ratings including the bearing stiffener that are between 40 and 80% of the LRFR rating when the bearing stiffener is ignored. This figure also shows that most of the affected girders are shorter spans. 37% of girders are controlled for shear by the bearing stiffener rating.

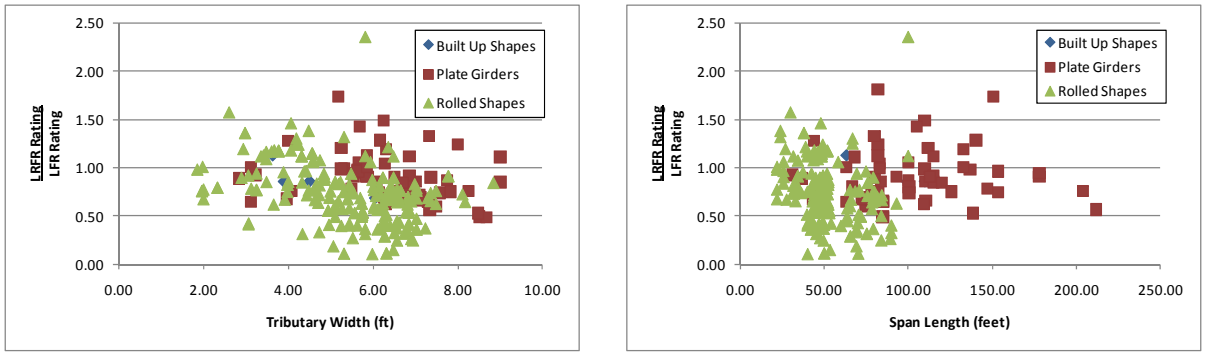


(a) (b)

Figure B-483: Effect of Bearing Stiffener Rating on LRFR Shear Ratings

B.3.2.2.4 Rating Factor Comparisons

Figure B-484 shows the ratio of the LRFR rating to the LFR rating. The results show that the LRFR rating is typically between 50% and 100% of the LFR rating. The LRFR rating is greater than the LFR rating for 20% of the girders in this group.



(a) (b)

Figure B-484: Ratio of LRFR Shear Rating to LFR Shear Rating

Figure B-485 shows the the percentage of girders in this group that have LRFR ratings less than 1.0 and what the ratio of LRFR to LFR ratings are. The figure shows that for most girders with ratings less than 1.0, the LRFR rating is less than 40% of the LFR rating. The low ratios are due to the bearing stiffener controlling the rating and having significantly less capacity than in LFR.

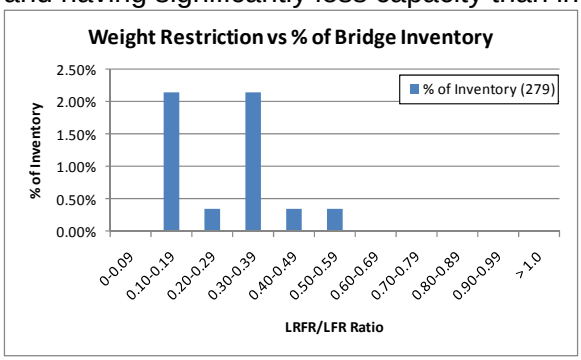
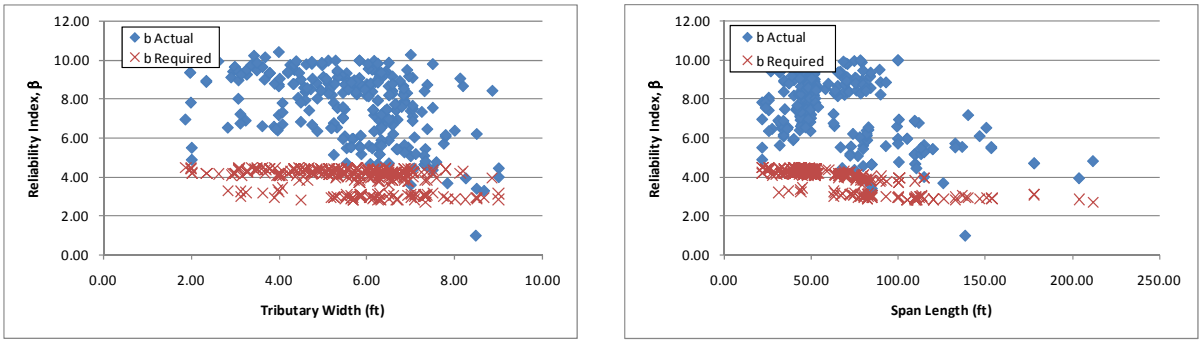


Figure B-485: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

B.3.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure B-486 shows several girders do not have a reliability index for shear greater than the required level of 3.5. Figure B-486 shows that those girders with larger tributary widths have lower levels of reliability than those with moderate tributary widths.



(a) (b)

Figure B-486: Shear Reliability Indices for HL-93 Design Vehicle

Figure B-487 shows the reliability index plotted against the LRFR rating factor for shear due to the HL-93 Design Vehicle. The figure shows that girders with a rating above 1.0 have a reliability index of approximately 3.5. This indicates that LRFR live load factors in the MBE produce the target level of reliability.

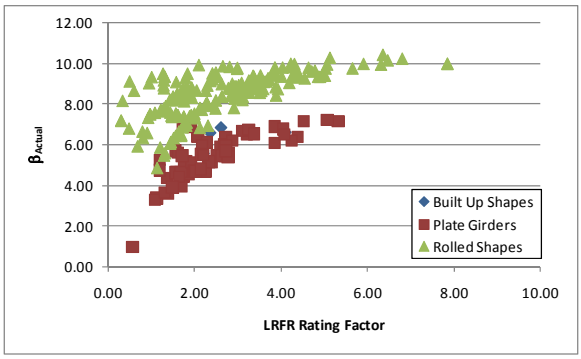


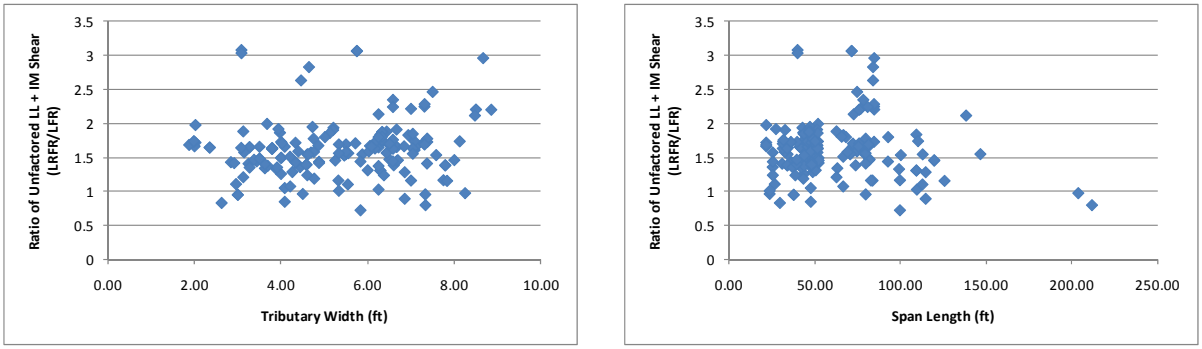
Figure B-487: Shear Reliability Index vs LRFR Shear Rating for HL-93 Design Vehicle

B.3.2.3 Shear-Corrected

Since a significant number of the simple span girders had the critical shear location for LFR at either the one- or nine-tenths point, the results were multiplied by 1.25 to approximate the results at the support. The following graphs show the results of this effort.

B.3.2.3.1 Live Load

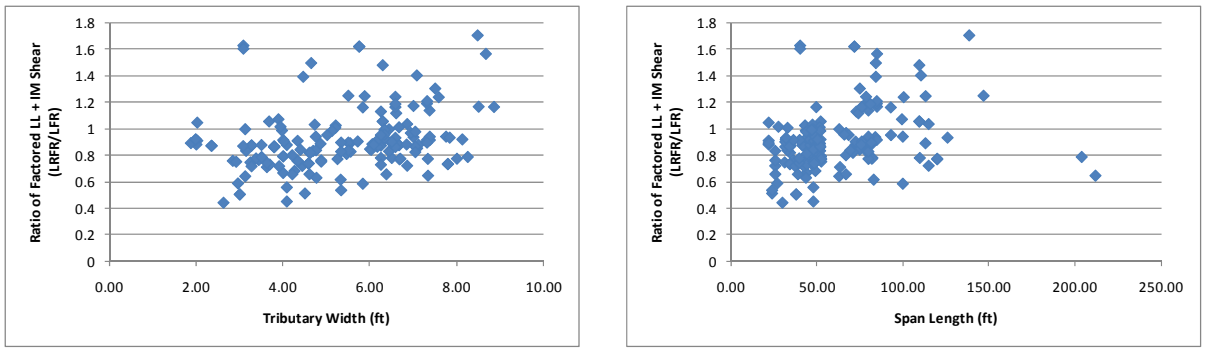
Figure B-488 shows that the ratio of unfactored shear has increased from the previous section and is now in the range of 1.0 and 2.0.



(a) (b)

Figure B-488: Ratio of Unfactored Live Load plus Impact Shear for Design Vehicles (LRFR/LFR)

The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-489 shows that the ratio of factored live load shears has decreased and is between 0.6 and 1.0 for most cases.

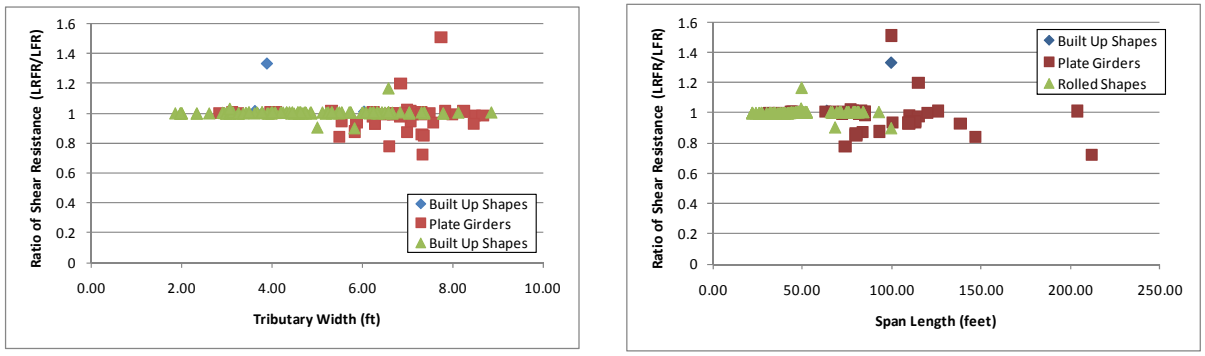


(a) (b)

Figure B-489: Ratio of Factored Live Load plus Impact Shear for Design Vehicles (LRFR/LFR)

B.3.2.3.2 Resistance

The resistances used in this comparison (see Figure B-490) are the same as those shown in the previous section. It was assumed that the resistance would be the same at the support as for the one-tenth point for LFR. This assumption may not be completely correct because stiffener spacing may have changed and tension field action may not be incorporated in determining the resistance at the support. Since most of the data points are near one, the assumption seems to provide a reasonable solution.

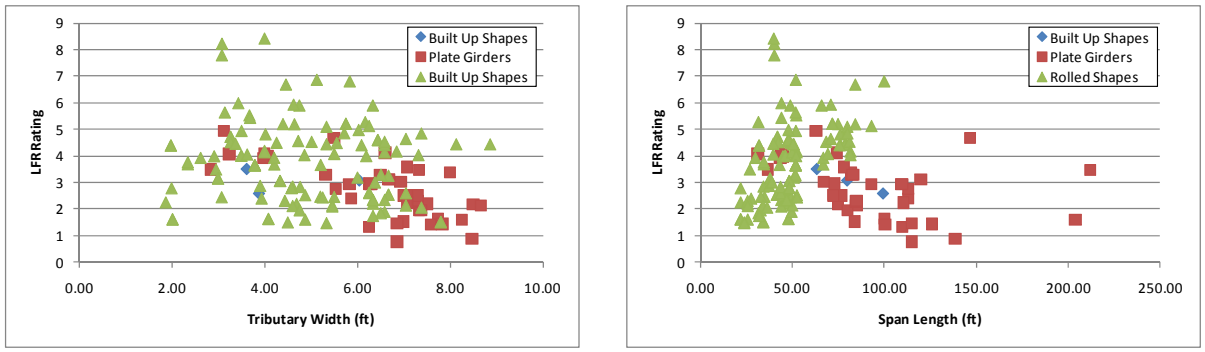


(a) (b)

Figure B-490: Ratio of factored Shear Resistance (LRFR/LFR)

B.3.2.3.3 Rating Factors

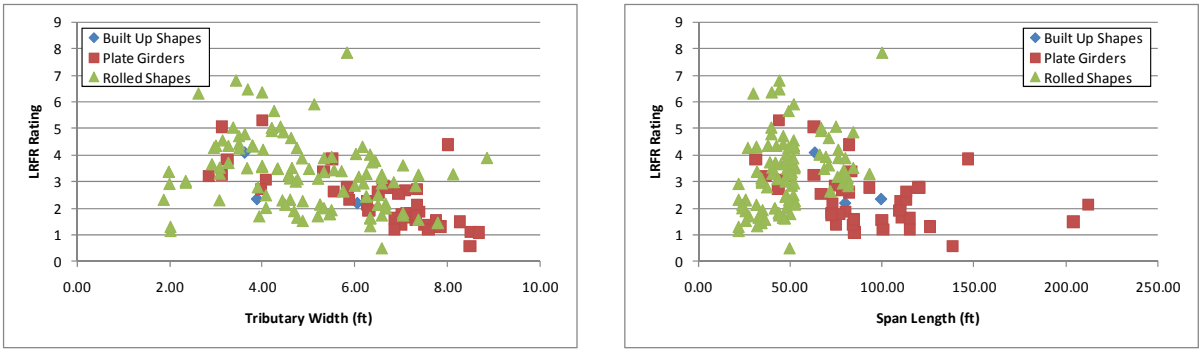
The LFR rating factors were calculated using the loads from the one- or nine-tenths point multiplied by 1.25 such that they would approximate the shear at the support. The LFR rating factors are shown in Figure B-491.



(a) (b)

Figure B-491: LFR Shear Rating Factors for HS-20 Loading

The LRFR rating factors are calculated at the support and are used as obtained from BRASS. The LRFR rating factors are shown in Figure B-492.

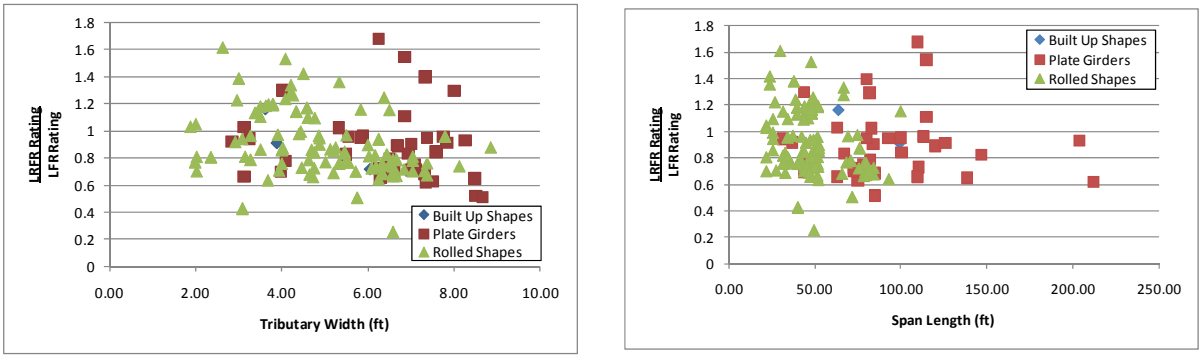


(a) (b)

Figure B-492: LRFR Shear Rating Factors for HL-93 Loading

B.3.2.3.4 Rating Factor Comparison

After calculating the LFR rating at the support, the two rating factors were compared by dividing the LRFR rating by the LFR rating. The results of this comparison are shown in Figure B-493. The LRFR rating is typically 60 to 120% of the LFR rating factor.

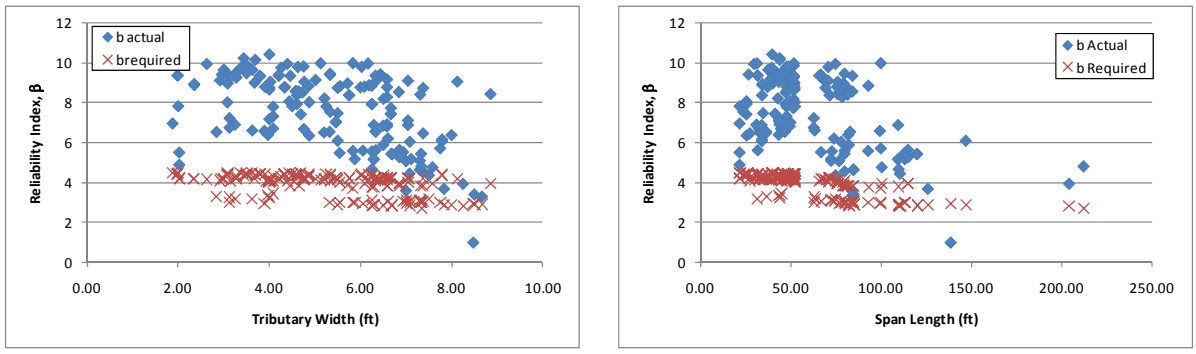


(a) (b)

Figure B-493: LRFR Shear Rating divided by LFR Shear Rating

B.3.2.3.5 Reliability Indices

The reliability indices shown in Figure B-494 are the same as those shown above in Figure B-486. The actual reliability index would decrease because the mean total load will increase, while the required reliability index would increase because the increase in mean total load is less than the increase in the mean factored load. This would possibly cause more girders to have a reliability index less than the code required value.



(a) (b)

Figure B-494: Reliability Indices

B.3.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-495. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

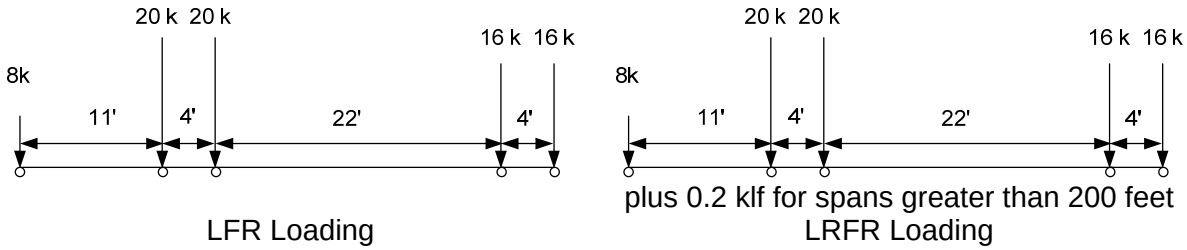


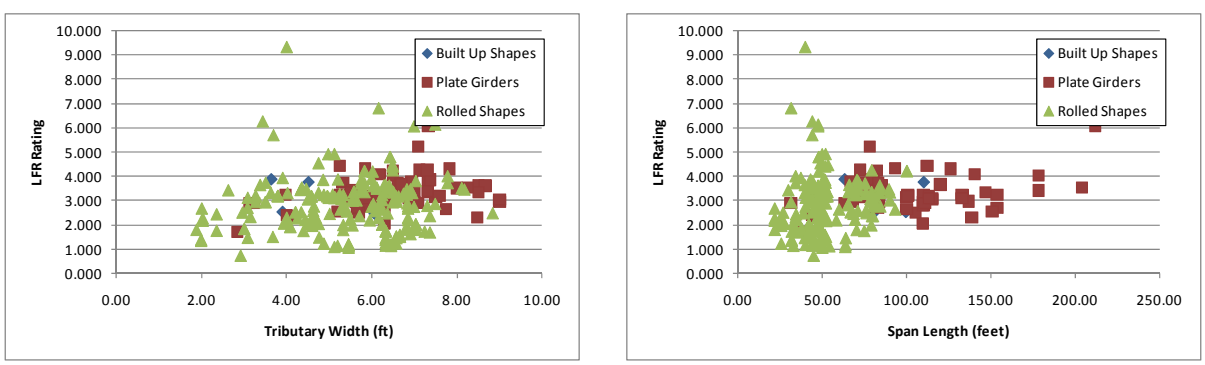
Figure B-495: Vehicle Loadings and Load Factors

B.3.3.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the DE-07 Vehicle.

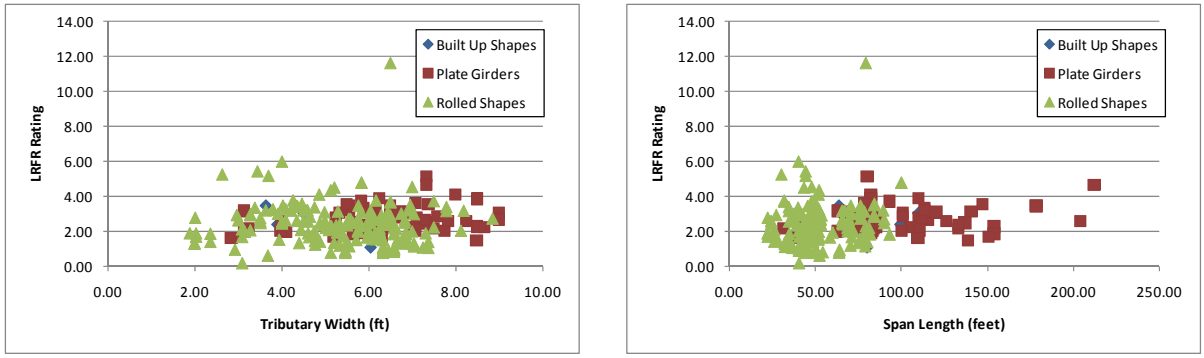
B.3.3.1.1 Rating Factors

Figure B-496 and Figure B-497 show the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 19 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0.



(a) (b)

Figure B-496: LFR Flexure Rating Factors for DE-07 Vehicle

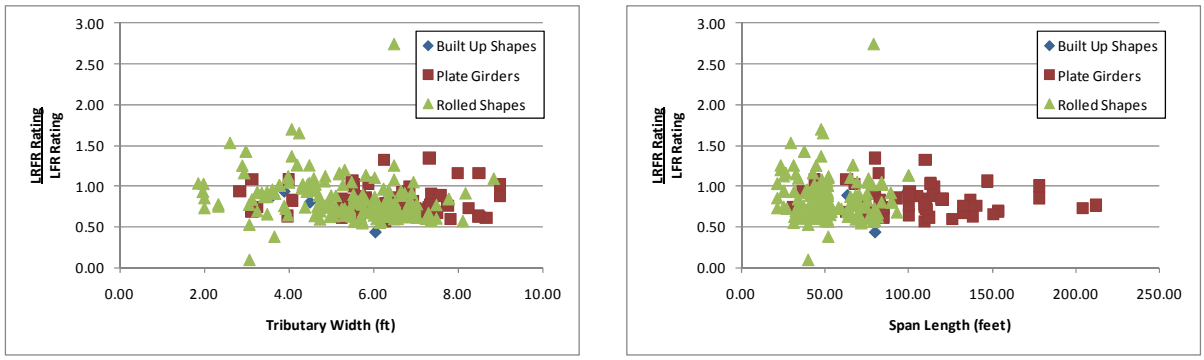


(a) (b)

Figure B-497: LRFR Flexure Rating Factors for DE-07 Vehicle

B.3.3.1.2 Rating Factor Comparisons

Figure B-498 shows the ratio between the LFR and LRFR ratings. Values greater than 1.0 indicate that the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.0, but there are no clear trends in the data. 82% of the girders in this subset have LFR ratings greater than LRFR ratings.

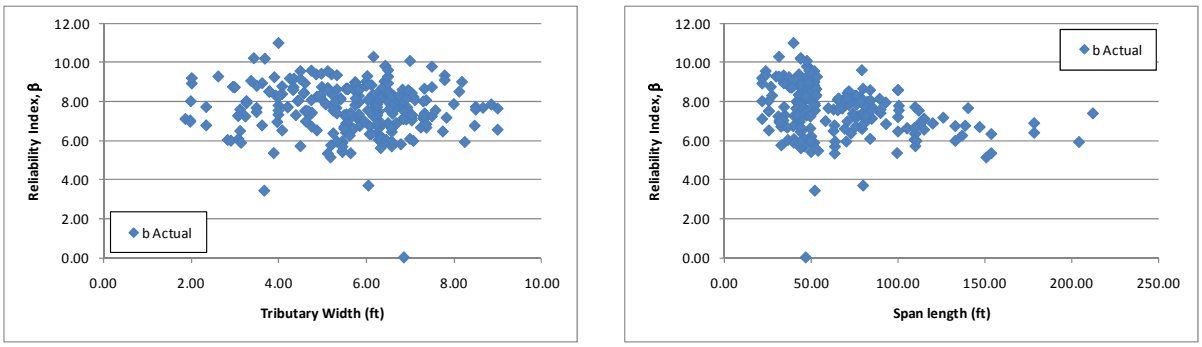


(a) (b)

Figure B-498: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

B.3.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-499 shows that no girders have a reliability index based upon girder strength that is less than the reliability index of 2.5 assumed in the development of the MBE. This is encouraging because these girders maintain the code required level of reliability even if they do not have ratings greater than 1.0.



(a) (b)

Figure B-499: Flexure Reliability Indices for DE-07 Vehicle

Figure B-500 shows the reliability index plotted against the LRFR rating factor for moment due to the DE-07 vehicle. The figure shows that the reliability index for girders passing rating is above the target level of 2.5. For rolled shapes, the reliability index is approximately 6.0. This indicates that the live load factor could be reduced and bring the reliability of girders passing rating closer to the target value.

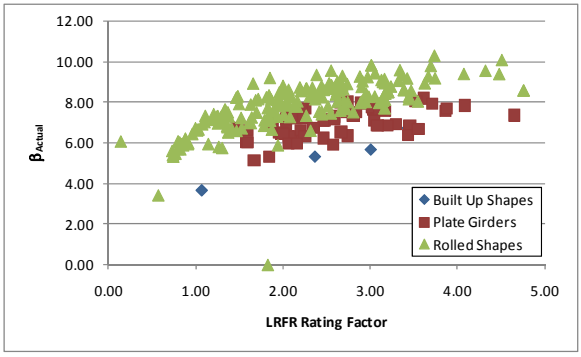


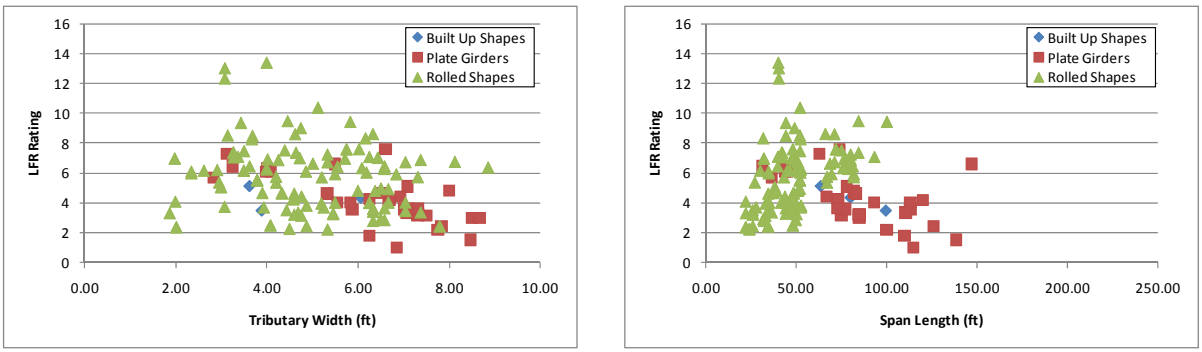
Figure B-500: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

B.3.3.2 Shear

The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

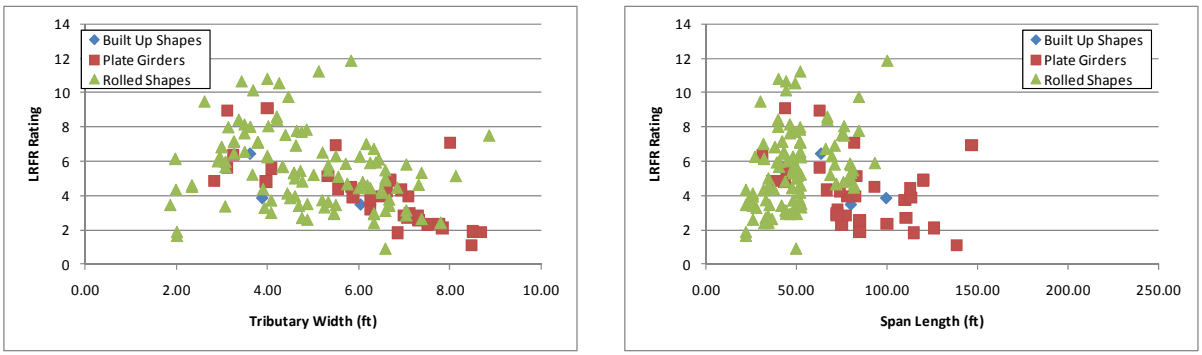
B.3.3.2.1 Rating Factors

For shear, there are five girders that have an LRFR rating factor less than 1.0. In this situation, less than 2% of girders by rating the bridges using the LRFR methodology even though they may have been designed with the Standard Specification. The LFR Rating is greater than the LRFR rating for 88% of the girders in this subset. Figure B-501 and Figure B-502 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-501: LFR Shear Ratings for DE-07 Vehicle

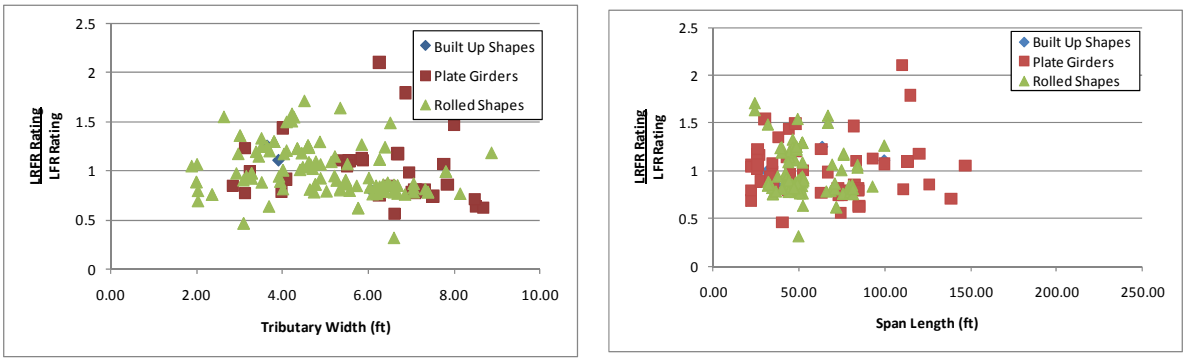


(a) (b)

Figure B-502: LRFR Shear Ratings for DE-07 Vehicle

B.3.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR rating divided by the LFR rating. Figure B-503 shows the comparison of rating factors. The ratio is generally between 0.75 and 1.25, with approximately equal numbers above and below 1.

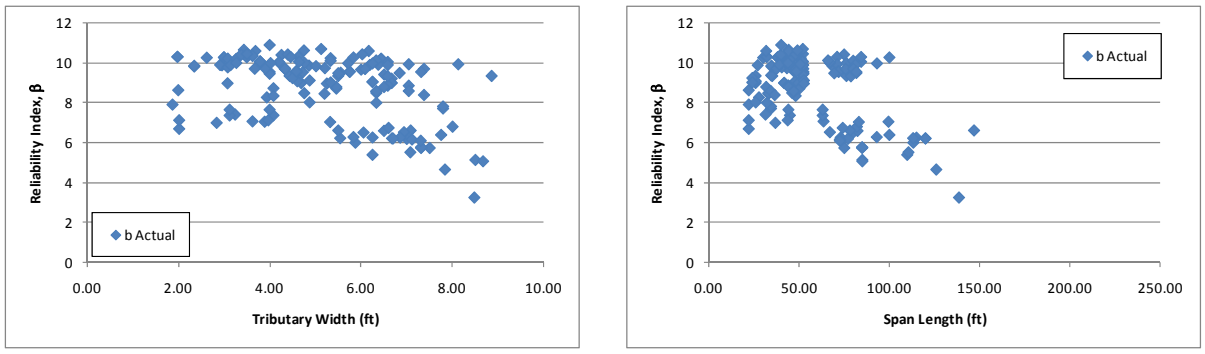


(a) (b)

Figure B-503: LRFR Shear Rating divided by LFR Shar Rating for DE-07 Vehicle

B.3.3.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all girders as shown in Figure B-504.



(a) (b)

Figure B-504: Shear Reliability Indices for DE-07 Vehicle

Figure B-505 shows the reliability index plotted agains the LRFR rating factor for shear due to the DE-07 Vehicle. The figure shows that girders passing rating have reliability indices greater than the target reliability of 2.5. The LRFR live load factors could be reduced and the reliability of those passing rating would be reduced to a value closer to the target value of 2.5.

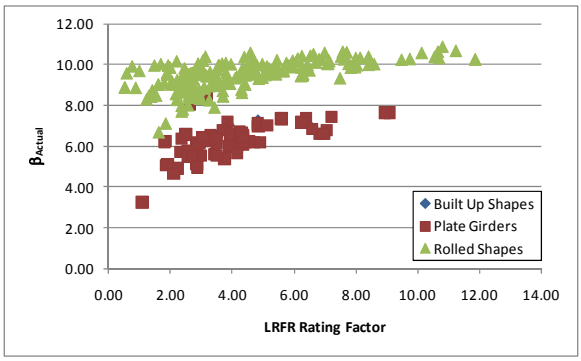
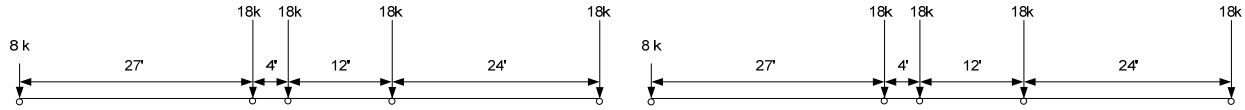


Figure B-505: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

B.3.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-467. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading

plus 0.2 klf for spans greater than 200 feet

LRFR Loading

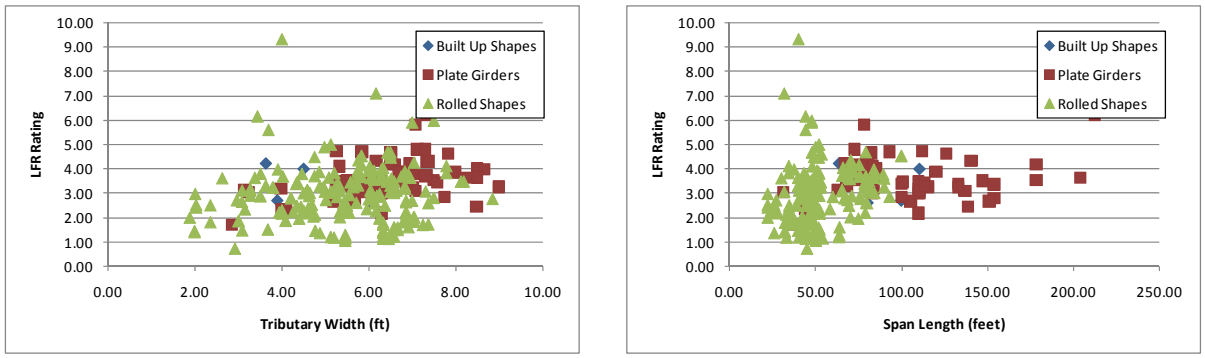
Figure B-506: Vehicle Loadings and Load Factors

B.3.4.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the FL-04 Vehicle.

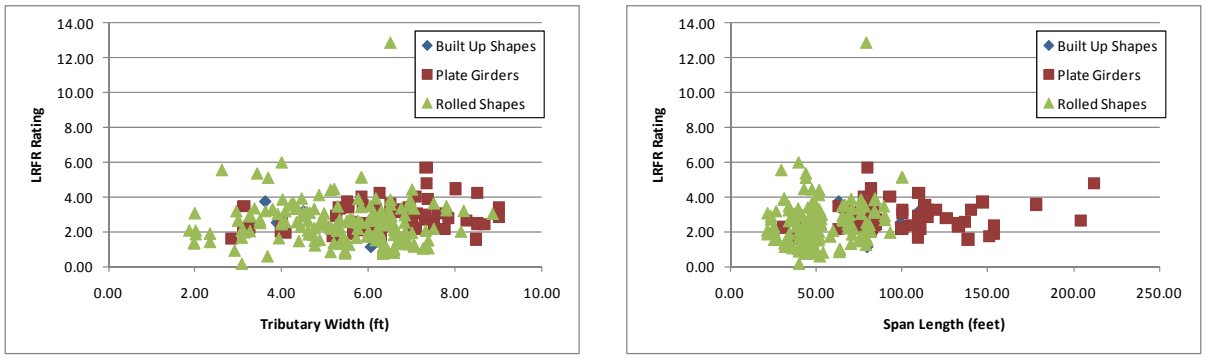
B.3.4.1.1 Rating Factors

Figure B-507 and Figure B-508 show the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 20 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 82% of the girders in this subset.



(a) (b)

Figure B-507: LFR Flexure Rating Factors for FL-04 Vehicle

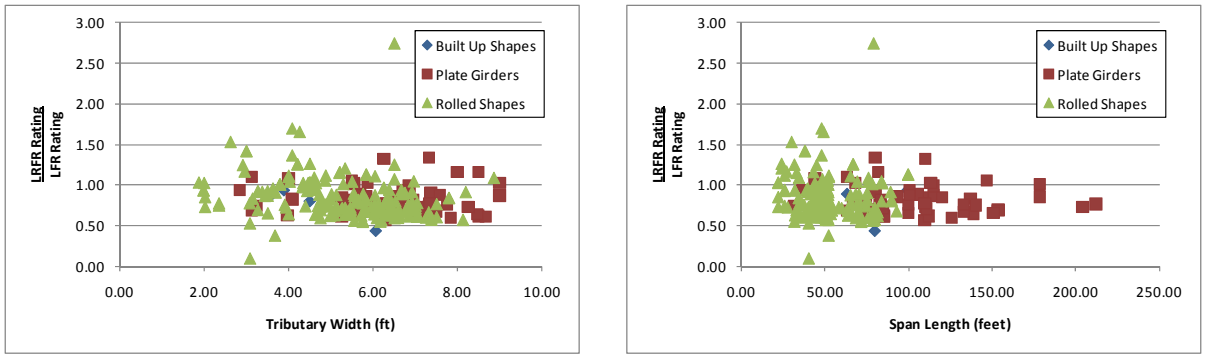


(a) (b)

Figure B-508: LRFR Flexure Rating Factors for FL-04 Vehicle

B.3.4.1.2 Rating Factor Comparisons

Figure B-509 show the ratio of LRFR rating to LFR ratings. Values greater than one indicate the LRFR rating is greater than the LFR rating. The graph shows that for most girders that the ratio is between 0.5 and 1.0. 18% of the girders have an LRFR rating greater than the LFR rating.

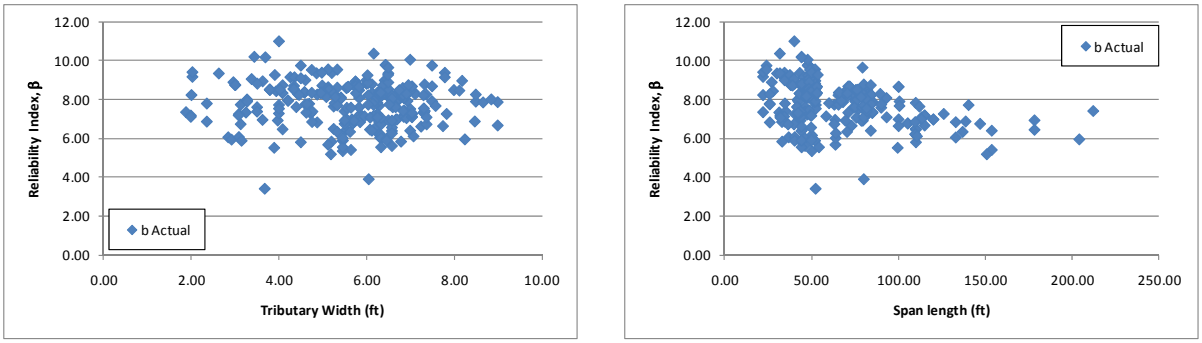


(a) (b)

Figure B-509: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

B.3.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-510 shows that no girders have a reliability index based upon girder strength that is less than the reliability index based upon the applied loads. This is encouraging because these girders maintain the code required level of reliability even though they have ratings less than 1.0.



(a) (b)

Figure B-510: Flexure Reliability Indices for FL-04 Vehicle

Figure B-511 shows the reliability index plotted against the LRFR rating factor for shear caused by the FL-04 vehicle. The figure shows that girders passing rating have reliability indices of at least 4 which is above the target reliability of 2.5. This indicates that utilizing lower load factors would result in girders passing rating and having a reliability index near 2.5.

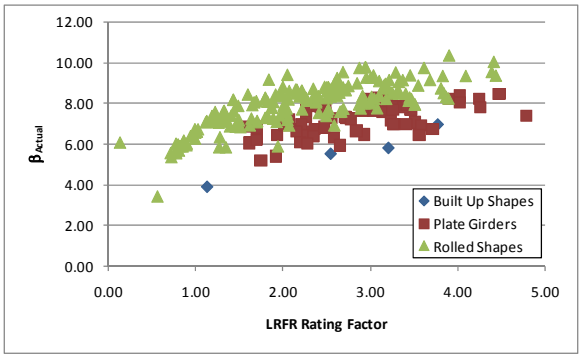


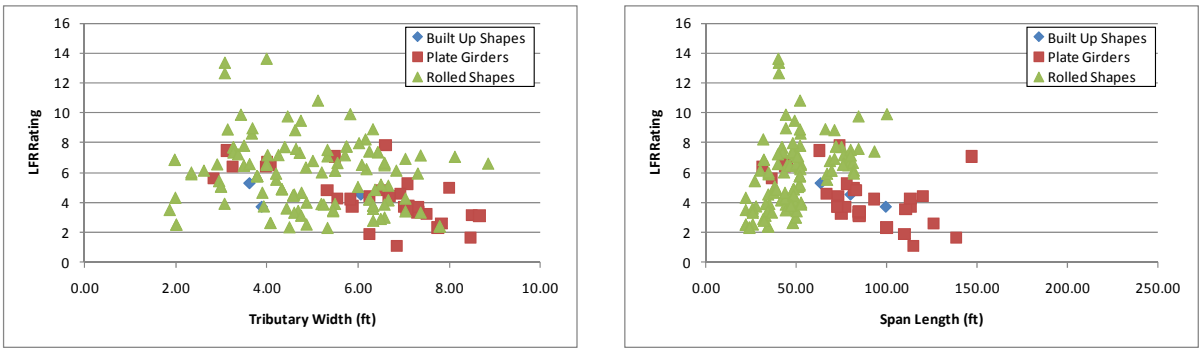
Figure B-511: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

B.3.4.2 Shear

The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

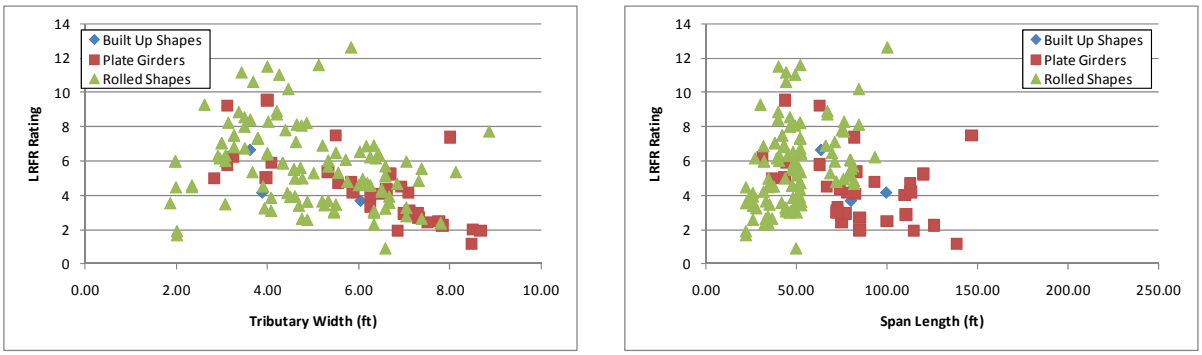
B.3.4.2.1 Rating Factors

For shear, there are five girders that have LRFR rating factors less than 1.0. In this situation, less than 2% of girders are affected by rating the bridges using the LRFR methodology even though they may have been designed with the Standard Specification. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure B-512 and Figure B-513 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-512: LFR Shear Ratings for FL-04 Vehicle

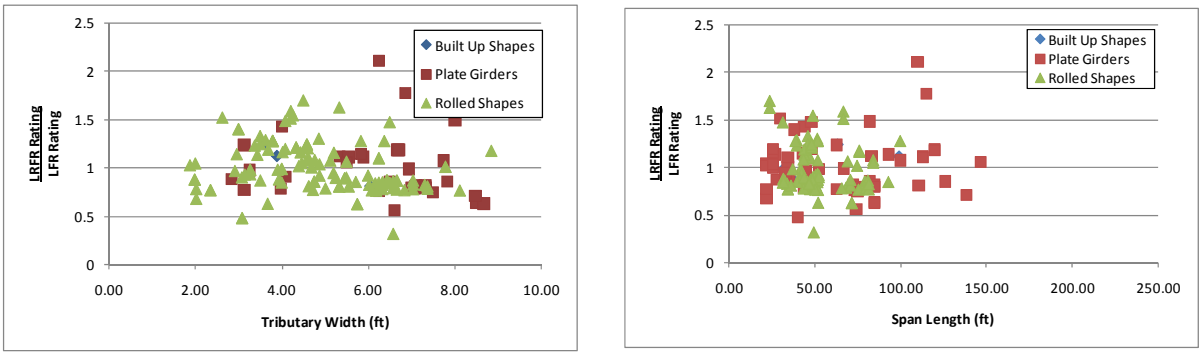


(a) (b)

Figure B-513: LRFR Shear Ratings for FL-04 Vehicle

B.3.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-514 show this comparison of rating factors. For shear, the ratio of rating factors is generally between 0.75 and 1.25.

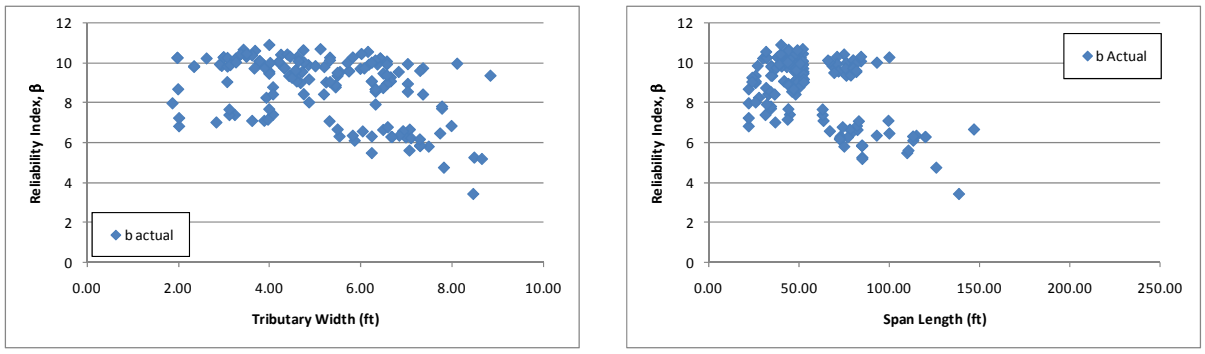


(a) (b)

Figure B-514: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

B.3.4.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all girders as shown in Figure B-515.



(a) (b)

Figure B-515: Shear Reliability Indices for FL-04 Vehicle

Figure B-516 shows the reliability index plotted against the LRFR rating factor for shear due to the FL-04 vehicle. The figure shows that girders passing rating have reliability indices greater than the target value of 2.5. This indicates that lower live load factors could be used for LRFR than what is in the MBE.

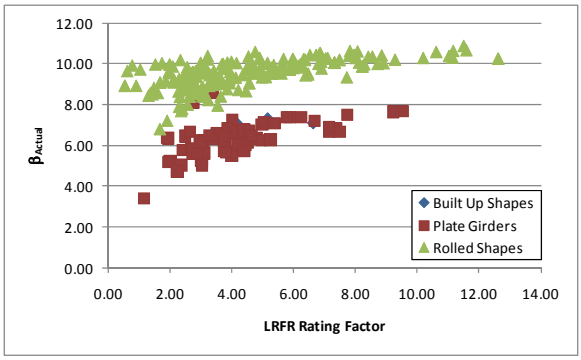


Figure B-516: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

B.3.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-467. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

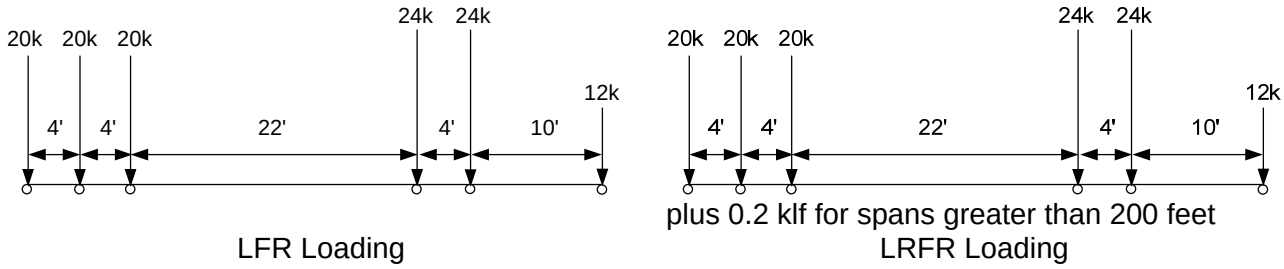


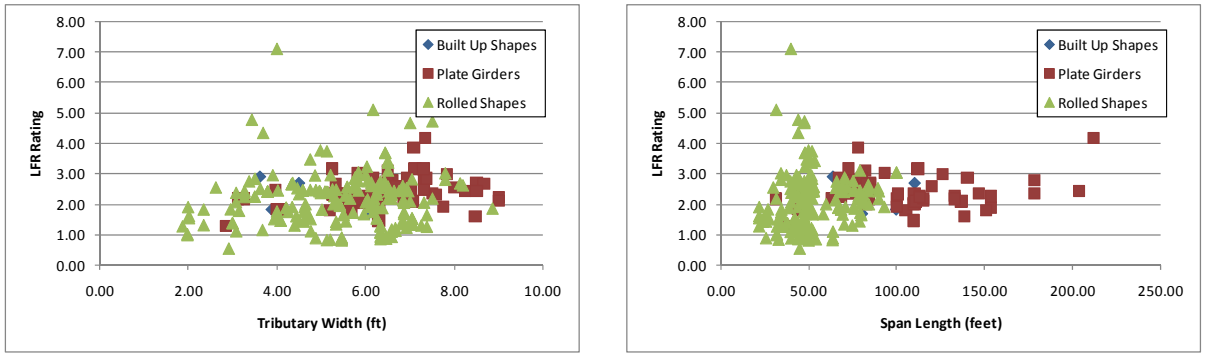
Figure B-517: Vehicle Loadings and Load Factors

B.3.5.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the IL-01 Vehicle.

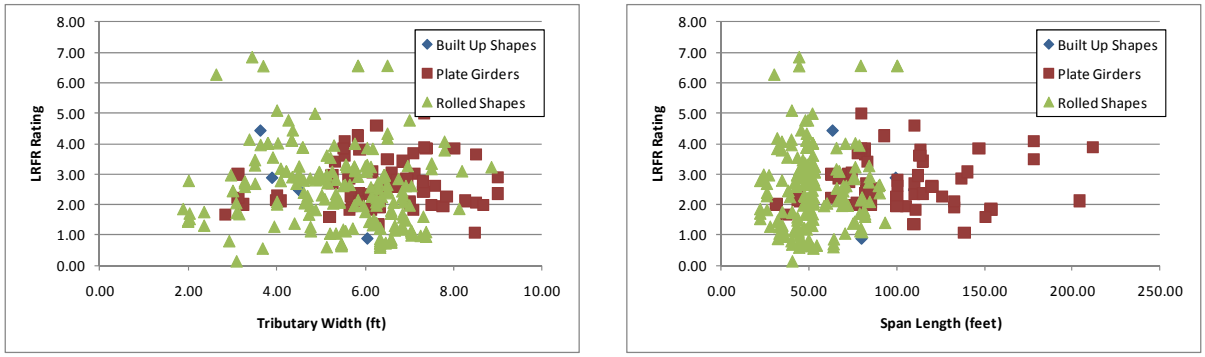
B.3.5.1.1 Rating Factors

Figure B-518 and Figure B-519 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 14 girders with an LFR rating less than 1.0, 25 girders with an LRFR rating less than 1.0, and 12 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 42% of the girders in this subset.



(a) (b)

Figure B-518: LFR Flexure Rating Factors for IL-01 Vehicle

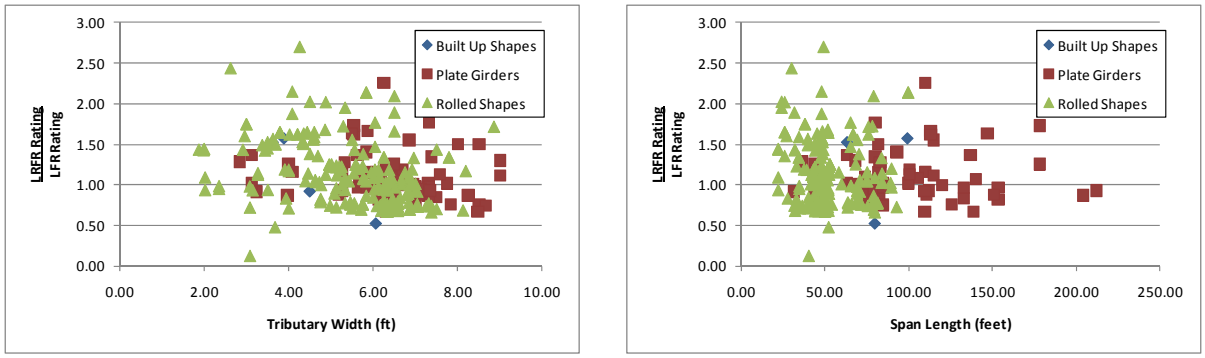


(a) (b)

Figure B-519: LRFR Flexure Rating Factors for IL-01 Vehicle

B.3.5.1.2 Rating Factor Comparisons

Figure B-520 shows the ratio of LRFR to LFR ratings. Values greater than one indicate the LRFR ratings is greater than the LFR rating. There are no clear trends and most ratios are greater than 0.5 with 58% having LRFR ratings greater than LFR ratings.

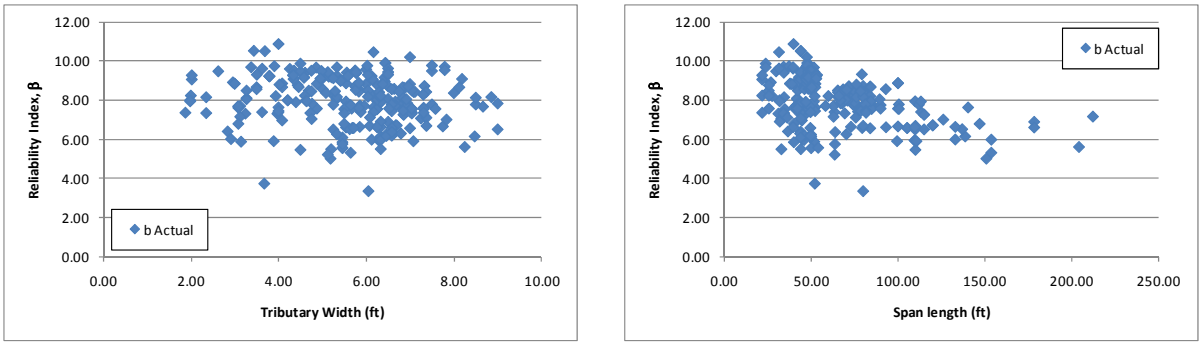


(a) (b)

Figure B-520: Ratio of LRFR Flexure Rating to LFR Flexure Rating for IL-01 Vehicle

B.3.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-521 shows several girders have a reliability index based upon girder strength that is very close to the target reliability of 3.5. There are no obvious characteristics about these two girders that would set them apart from the others.



(a) (b)

Figure B-521: Flexure Reliability Indices for IL-01 Vehicle

Figure B-522 shows the reliability index plotted against the LRFR rating for moment due to the IL-01 Vehicle. The figure shows that girders passing rating have reliability indices greater than the target of 3.5. This indicates that the LRFR live load factors could be reduced to a level where girders passing rating would have a reliability index near 3.5.

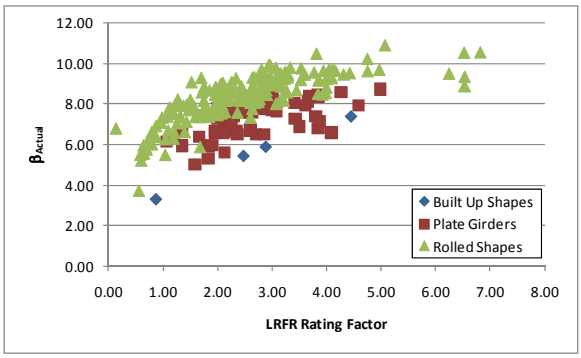


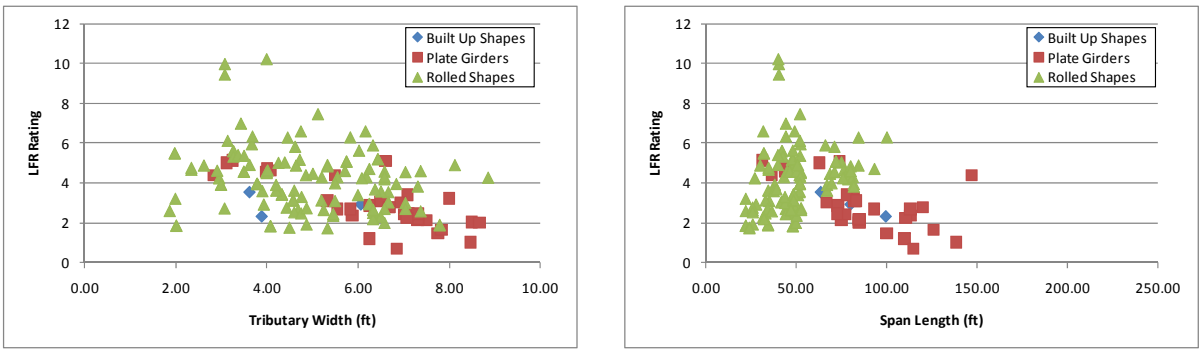
Figure B-522: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

B.3.5.2 Shear

The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

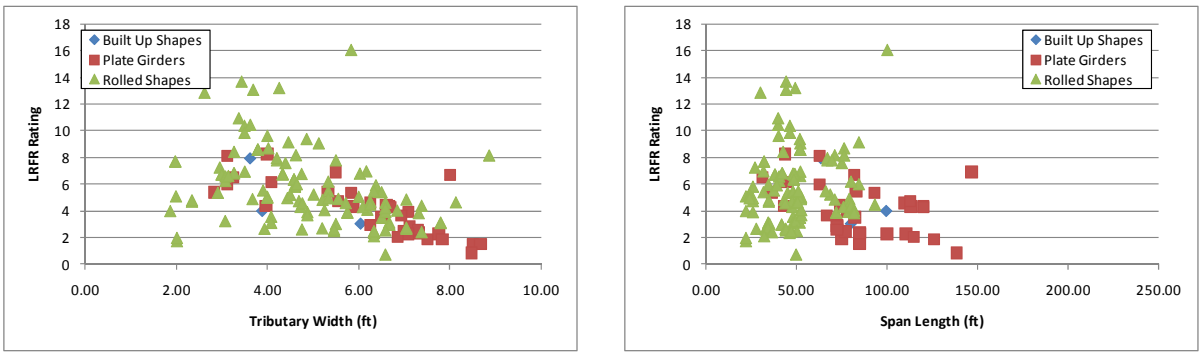
B.3.5.2.1 Rating Factors

For shear, there are seven girders with an LRFR rating factor less than 1.0 while there are no girders with an LFR rating less than 1.0. The LFR Rating is greater than the LRFR rating for 61% of the girders in this subset. Figure B-523 and Figure B-524 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-523: LFR Shear Ratings for IL-01 Vehicle

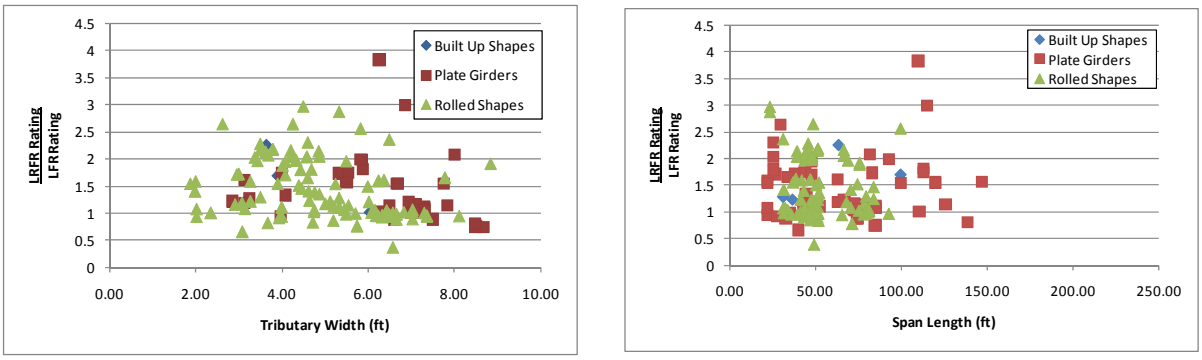


(a) (b)

Figure B-524: LRFR Shear Ratings for IL-01 Vehicle

B.3.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-525 shows the comparison of rating factors. The ratio is generally between 0.75 and 1.5.

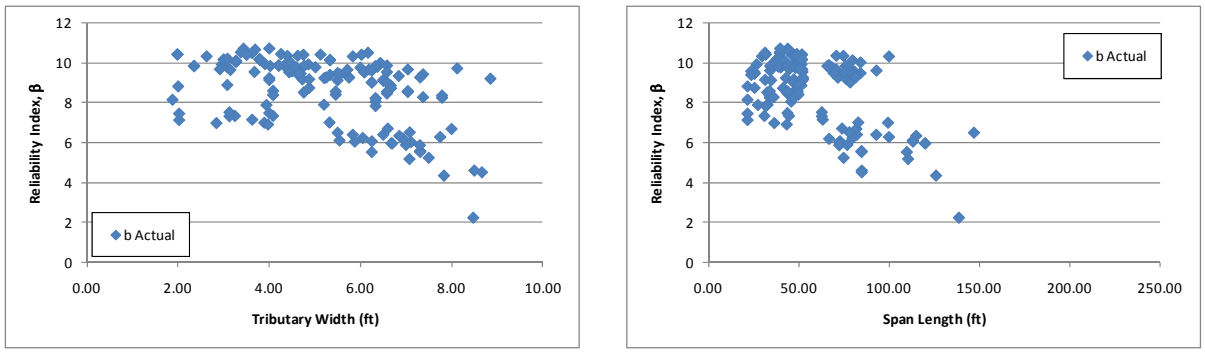


(a) (b)

Figure B-525: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

B.3.5.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all but one girder as shown in Figure B-526.



(a) (b)

Figure B-526: Shear Reliability Indices for IL-01 Vehicle

Figure B-527 shows the reliability index plotted against the LRFR rating for shear due to the IL-01 vehicle. The figure shows that girders passing rating will have reliability indices of approximately 3.5 which is the target value for this vehicle. This indicates that for this vehicle, the current LRFR live load factors produce the expected level of reliability.

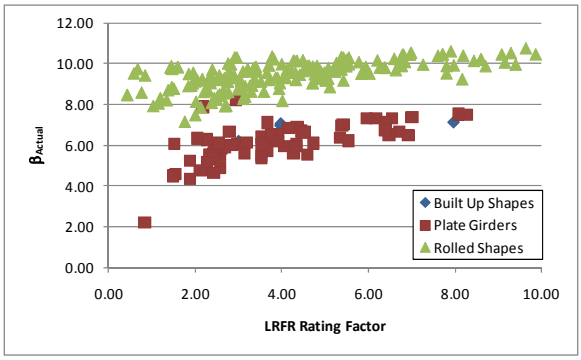


Figure B-527: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

B.3.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-467. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

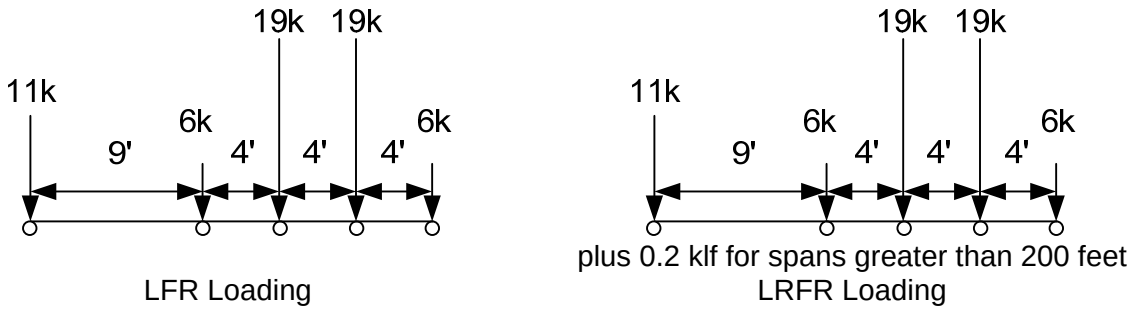


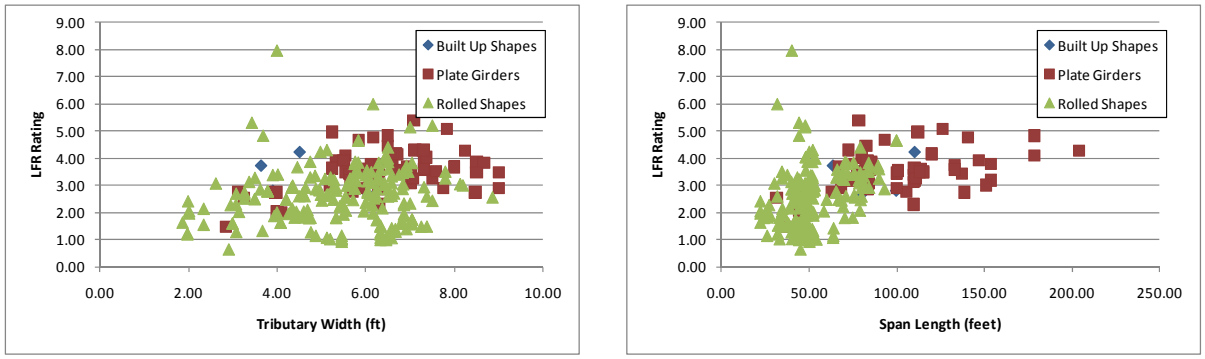
Figure B-528: Vehicle Loadings and Load Factors

B.3.6.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the NC-21 Vehicle.

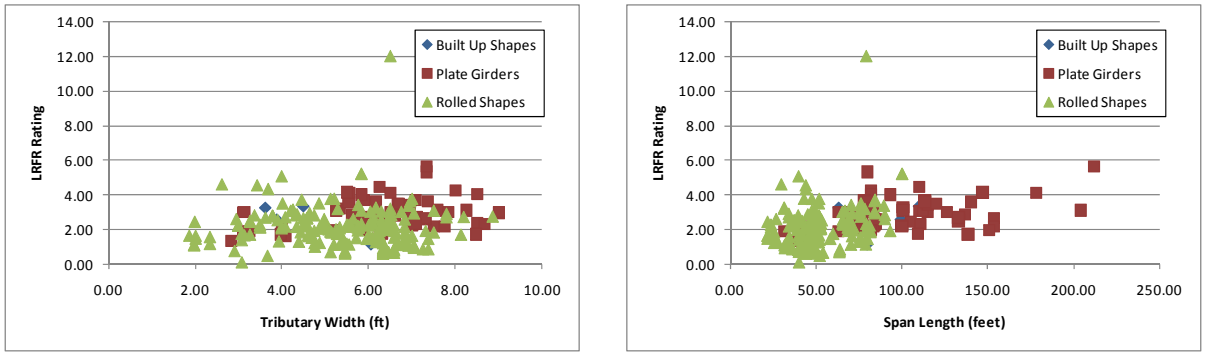
B.3.6.1.1 Rating Factors

Figure B-529 and Figure B-530 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are six girders with an LFR rating less than 1.0, 24 girders with an LRFR rating less than 1.0, and five girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 82% of the girders in this subset.



(a) (b)

Figure B-529: LFR Flexure Rating Factors for NC-21 Vehicle

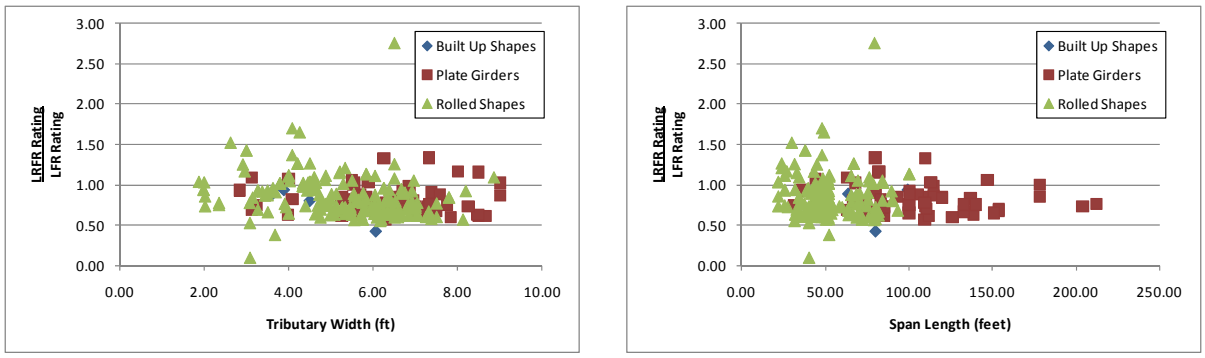


(a) (b)

Figure B-530: LRFR Flexure Rating Factors for NC-21 Vehicle

B.3.6.1.2 Rating Factor Comparisons

Figure B-531 shows the ratio of LRFR rating to LFR rating. Values greater than one indicate the LRFR rating is greater than the LFR rating. The ratio is between 0.5 and 1.0 for most girders in this group. The LRFR rating is greater than the LFR rating for 18% of the girders.

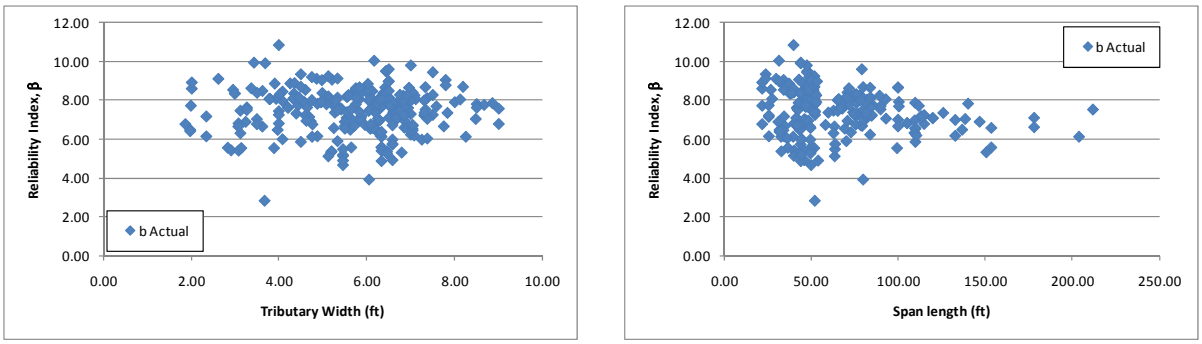


(a) (b)

Figure B-531: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

B.3.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-532 shows that no girders have a reliability index based upon girder strength that is less than the reliability index based upon the applied loads, with one girder being very close.



(a) (b)

Figure B-532: Flexure Reliability Indices for NC-21 Vehicle

Figure B-533 shows the reliability index plotted against the LRFR rating factor for moment caused by the NC-21 vehicle. The figure shows that girders passing rating for this vehicle have reliability indices of approximately 3.5 or higher which is above the target reliability of 2.5. This indicates that lower LRFR live load factors could be used and the target reliability would still be achieved.

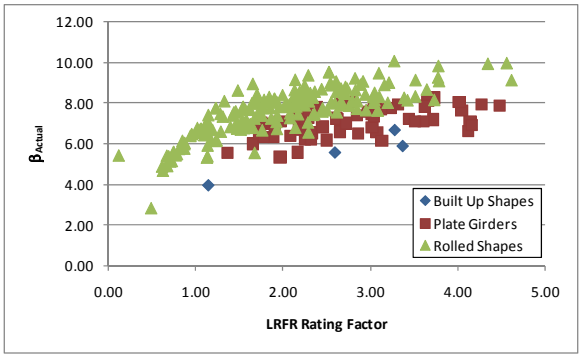


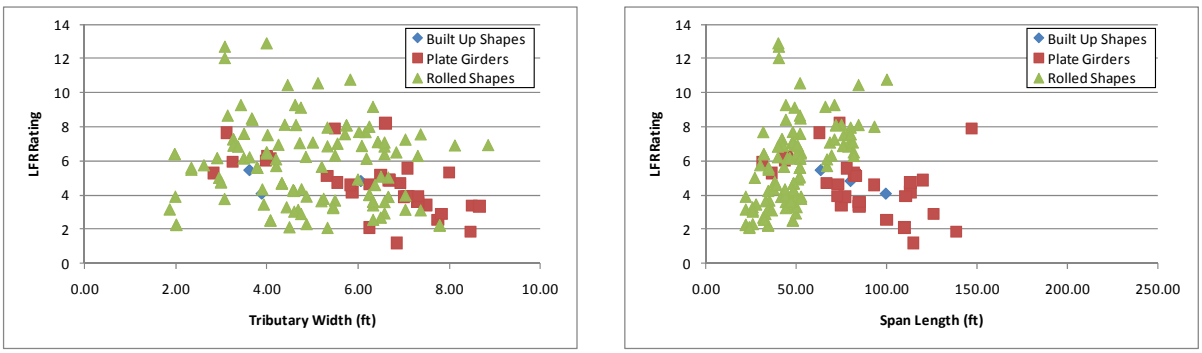
Figure B-533: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

B.3.6.2 Shear

The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

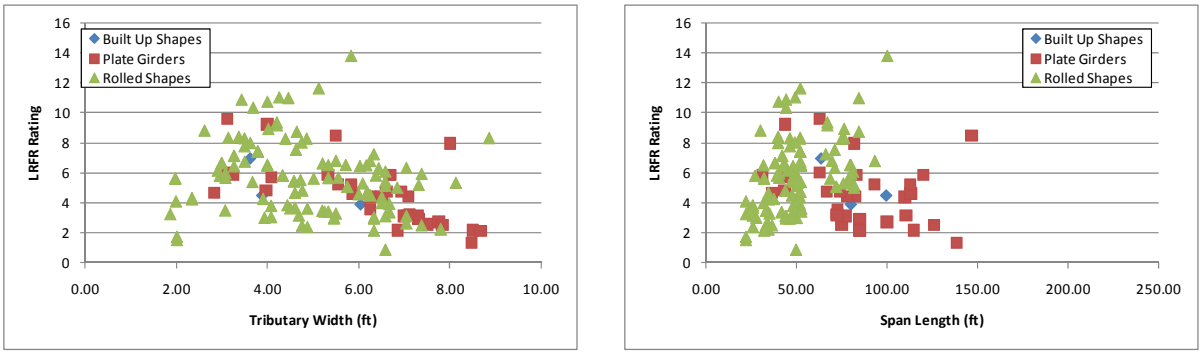
B.3.6.2.1 Rating Factors

For shear, there are five girders that have LRFR rating factors less than 1.0. In this situation, less than 2% of girders are affected by rating the bridges using the LRFR methodology even though they may have been designed with the Standard Specification. The LFR Rating is greater than the LRFR rating for 87% of the girders in this subset. Figure B-534 and Figure B-535 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-534: LFR Shear Ratings for NC-21 Vehicle

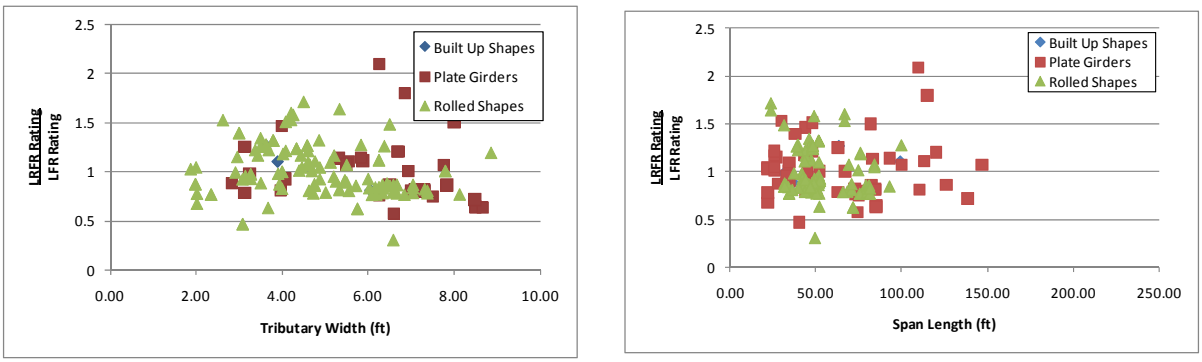


(a) (b)

Figure B-535: LRFR Shear Ratings for NC-21 Vehicle

B.3.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure B-536 shows the comparison of rating factors. The ratio is generally between 0.75 and 1.25.

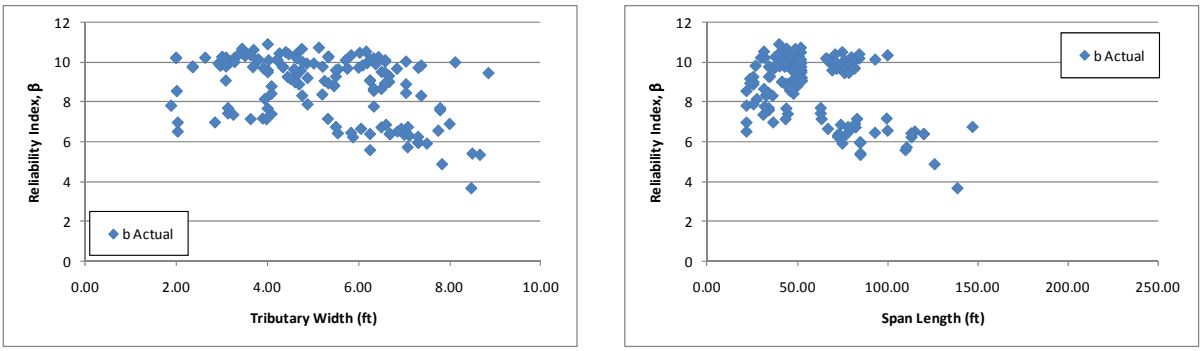


(a) (b)

Figure B-536: Ratio of LRFR Shear Rating to LFR Shear Rating for NC-21 Vehicle

B.3.6.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all girders as shown in Figure B-537.



(a) (b)

Figure B-537: Shear Reliability Indices for NC-21 Vehicle

Figure B-538 shows the reliability index plotted versus the LRFR rating factor for shear caused by the NC-21 vehicle. The figure shows that the reliability index for girders passing rating is above the target value of 2.5 and is approximately 4.0. Reducing the LRFR live load factor would result in more girders passing the rating while still maintaining the target reliability level.

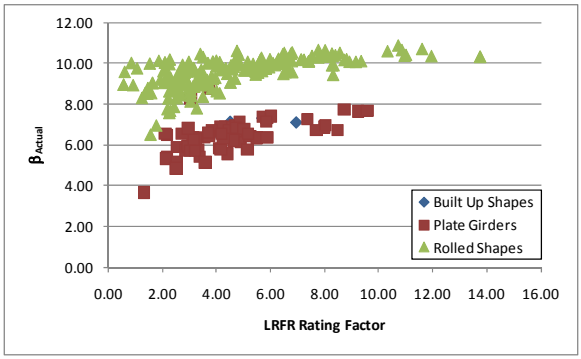


Figure B-538: Shear Reliabilty Index vs LRFR Shear Rating for NC-21 Vehicle

B.3.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-467. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

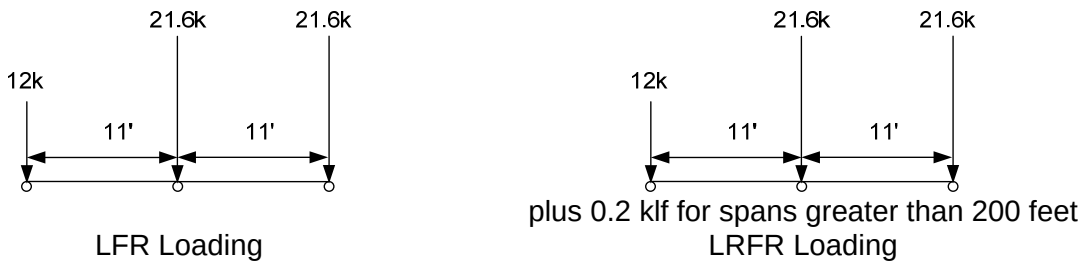


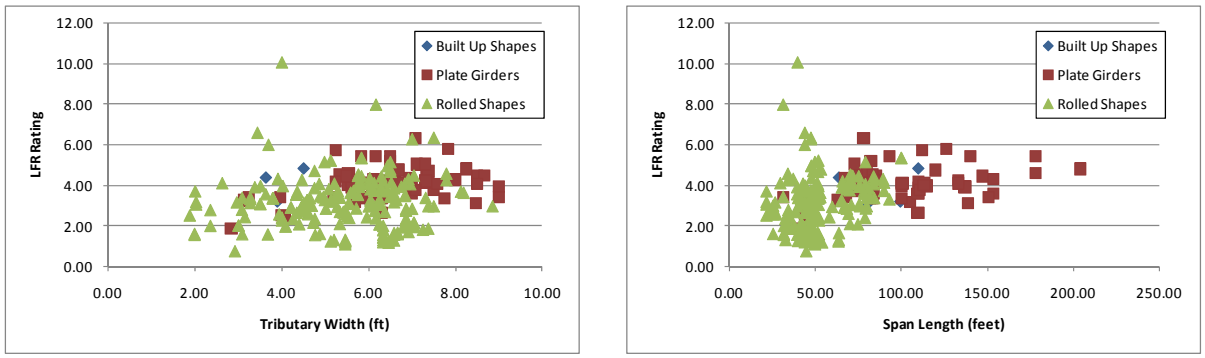
Figure B-539: Vehicle Loadings and Load Factors

B.3.7.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the NM-04 Vehicle.

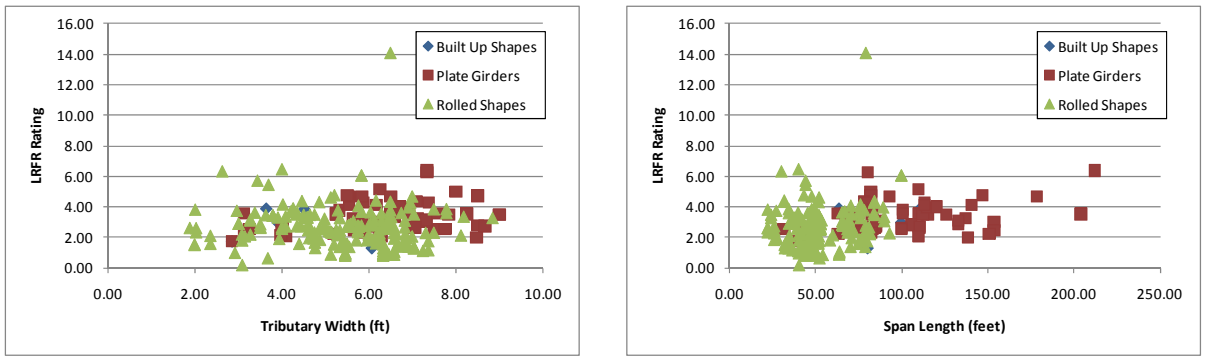
B.3.7.1.1 Rating Factors

Figure B-540 and Figure B-541 show the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 16 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 81% of the girders in this subset.



(a) (b)

Figure B-540: LFR Flexure Rating Factors for NM-04 Vehicle

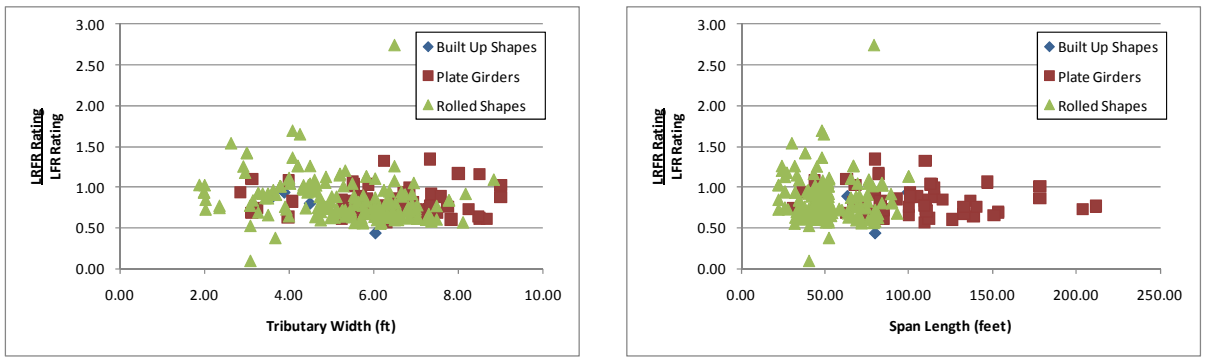


(a) (b)

Figure B-541: LRFR Flexure Rating Factors for NM-04 Vehicle

B.3.7.1.2 Rating Factor Comparisons

Figure B-542 shows the ratio between LRFR ratings and LFR ratings. Values greater than one indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.0 with several greater than 1.5. The LRFR rating is greater than the LFR rating for 19% of the girders in this group.

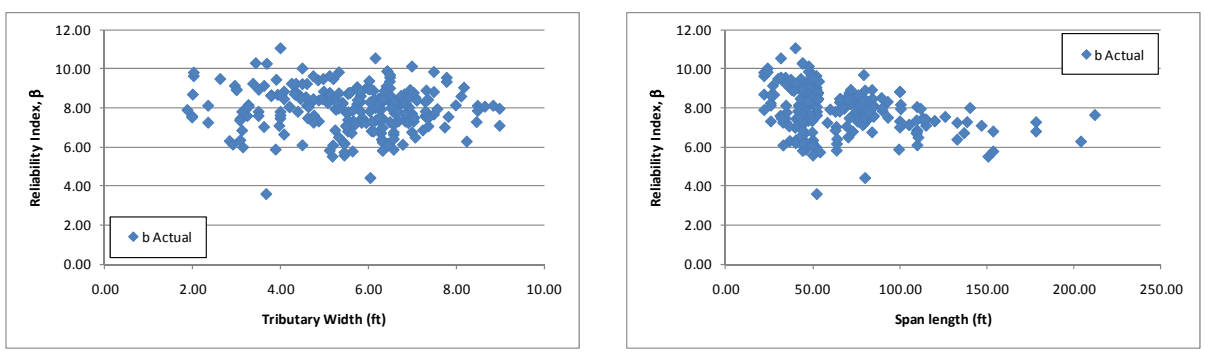


(a) (b)

Figure B-542: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

B.3.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-543 shows that no girders have a reliability index based upon girder strength that is less than the reliability index based upon the applied loads.



(a) (b)

Figure B-543: Flexure Reliability Indices for NM-04 Vehicle

Figure B-544 shows the reliability index plotted against the LRFR rating factor for moment due to the NM-04 vehicle. The figure shows that for girders passing rating the reliability index is approximately 4 for built up shapes and approaching 6 for rolled shapes. The reliability index is greater than the target value of 2.5, indicating that the LRFR live load factors could be reduced and maintain the target reliability.

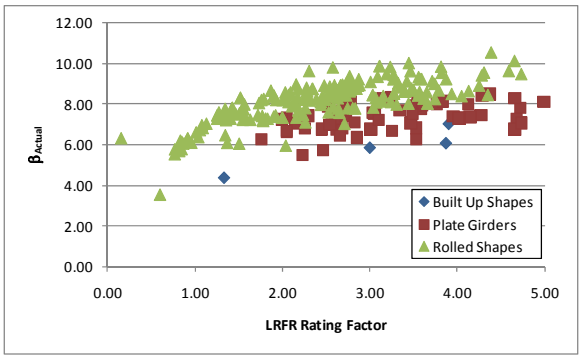


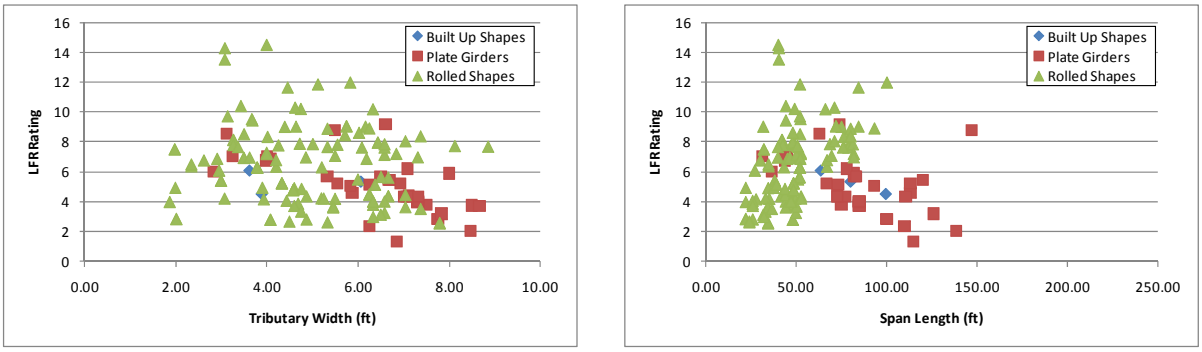
Figure B-544: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

B.3.7.2 Shear

The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

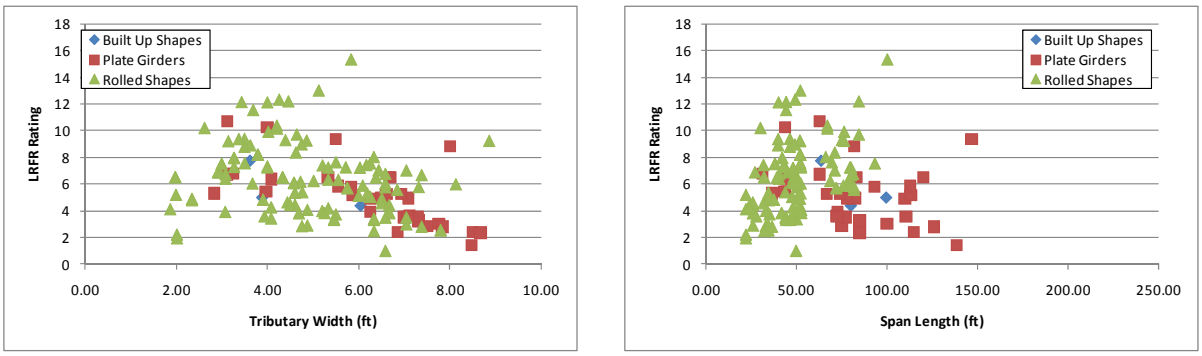
B.3.7.2.1 Rating Factors

For shear, there are four girders that have LRFR rating factors less than 1.0. In this situation, less than 1.5% of girders are affected by rating the bridges using the LRFR methodology even though they may have been designed with the Standard Specification. The LFR Rating is greater than the LRFR rating for 88% of the girders in this subset. Figure B-545 and Figure B-546 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-545: LFR Shear Ratings for NM-04 Vehicle

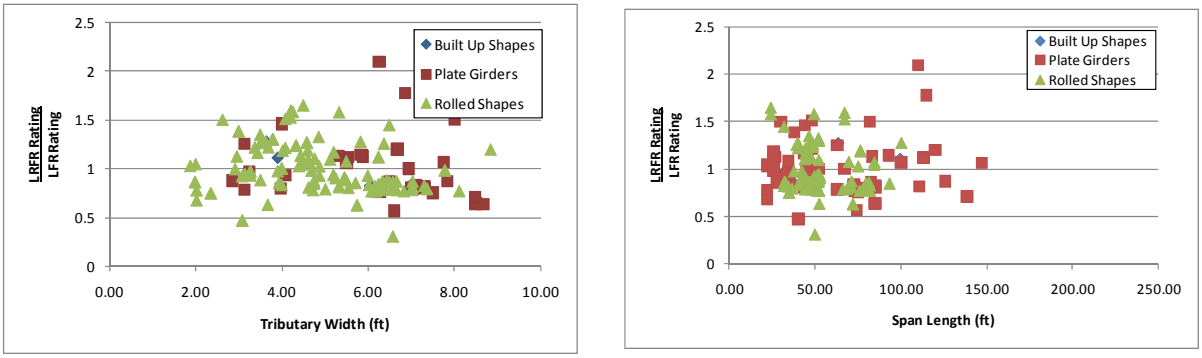


(a) (b)

Figure B-546: LRFR Shear Ratings for NM-04 Vehicle

B.3.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by plotting the ratio of LRFR Rating to LFR Rating. Figure B-547 shows the comparison of rating factors. The ratio is generally between 0.75 and 1.25.

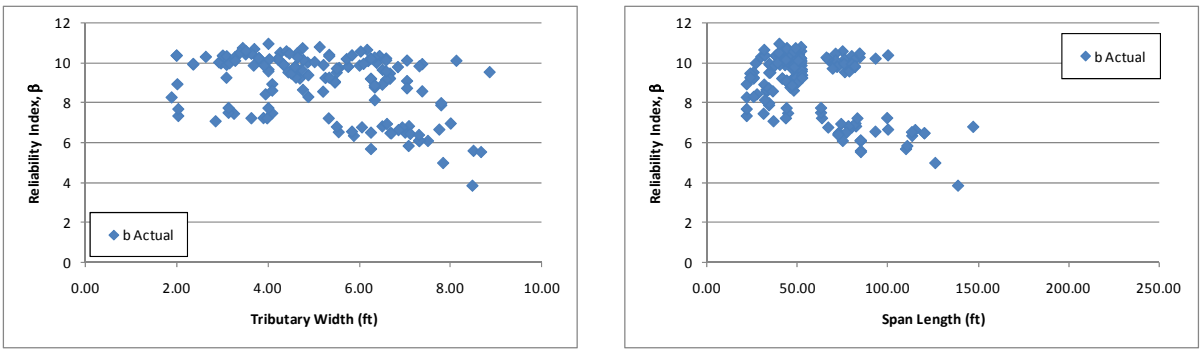


(a) (b)

Figure B-547: Ratio of LRFR Shear Rating to LFR Shear Rating for NM-04 Vehicle

B.3.7.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all girders as shown in Figure B-548.



(a) (b)

Figure B-548: Shear Reliability Indices for NM-04 Vehicle

Figure B-549 shows the reliability index plotted against the LRFR rating for shear due to the NM-04 Vehicle. The figure shows that girders passing the rating have reliability indices significantly greater than the target reliability of 2.5. This indicates that lower LRFR live load factors could be used to reduce the number of girders failing the rating while maintaining the target level of reliability.

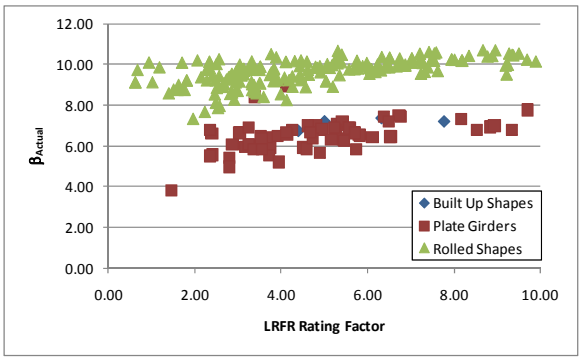


Figure B-549: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

B.3.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-467. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

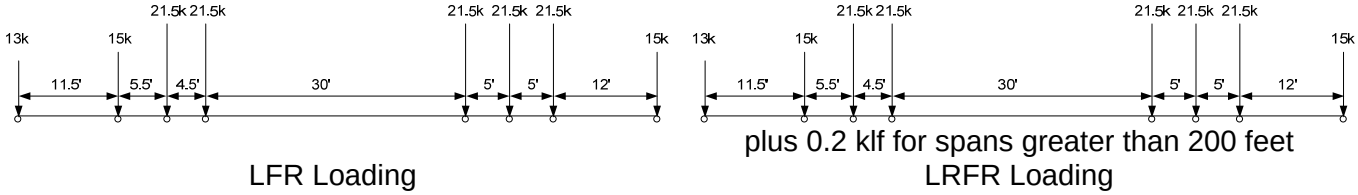


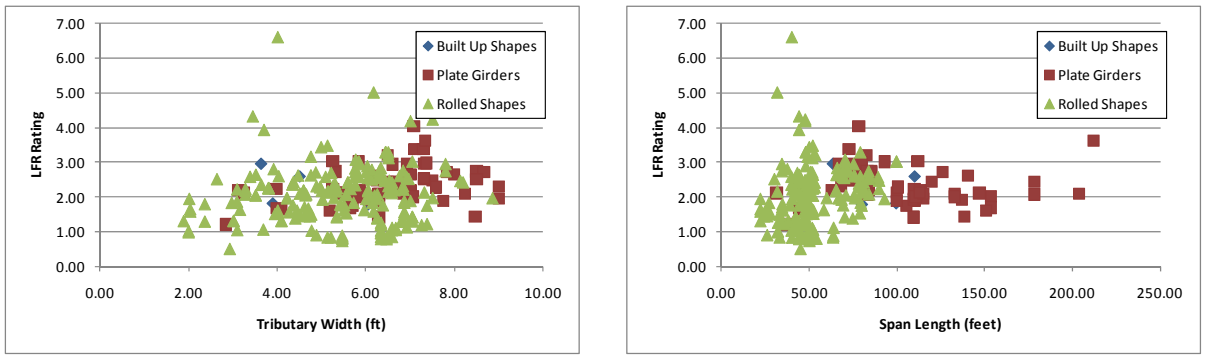
Figure B-550: Vehicle Loadings and Load Factors

B.3.8.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the OR-06 Vehicle.

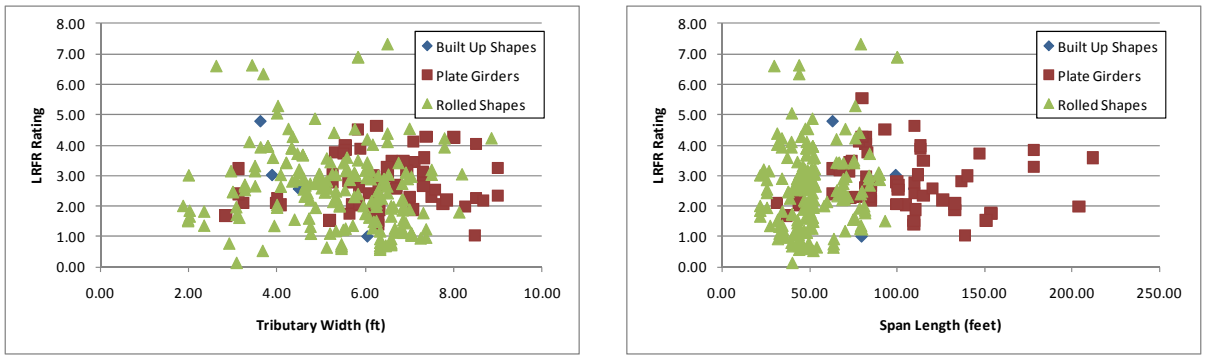
B.3.8.1.1 Rating Factors

Figure B-551 and Figure B-552 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 17 girders with an LFR rating less than 1.0, 24 girders with an LRFR rating less than 1.0, and 14 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 34% of the girders in this subset.



(a) (b)

Figure B-551: LFR Flexure Rating Factors for OR-06 Vehicle

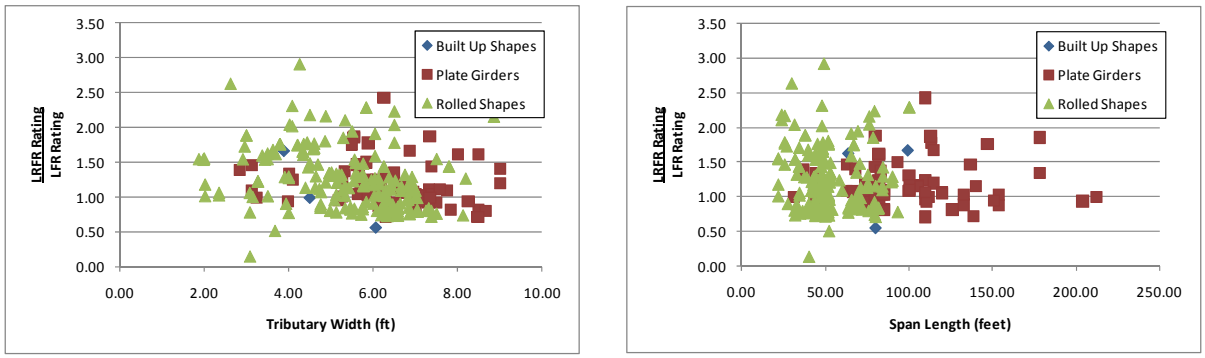


(a) (b)

Figure B-552: LRFR Flexure Rating Factors for OR-06 Vehicle

B.3.8.1.2 Rating Factor Comparisons

Figure B-553 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.7 and 1.5. 66% of the girders in this group have an LRFR rating that is greater than the LFR rating.

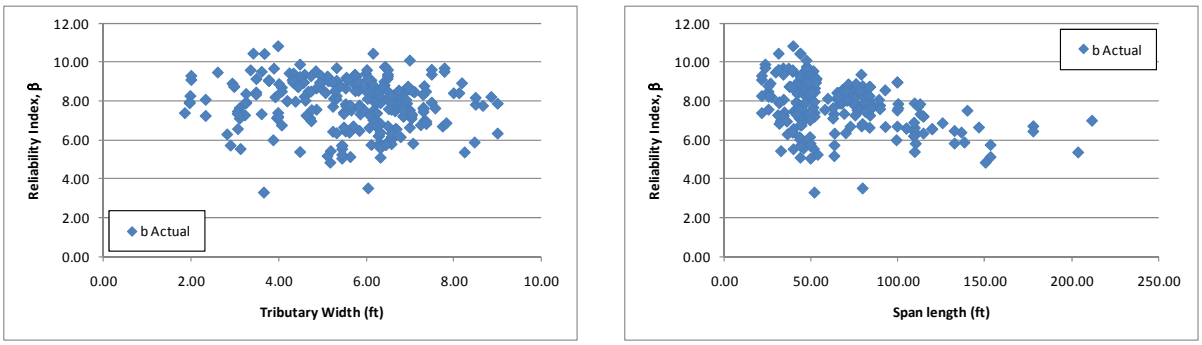


(a) (b)

Figure B-553: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

B.3.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-554 shows that one girder may have a reliability index less than that required. There are also several girders with reliability indices lower than most of the girders. These generally are girders with spans less than 100 feet.



(a) (b)

Figure B-554: Flexure Reliability Indices for OR-06 Vehicle

Figure B-555 shows the reliability index plotted against the LRFR rating for moment caused by the OR-06 vehicle. The figure shows that for girders passing rating, most have a reliability index significantly above the target reliability of 3.5. There are several that are lower and near the target reliability but most girders are higher indicating that the LRFR live load factors could be reduced.

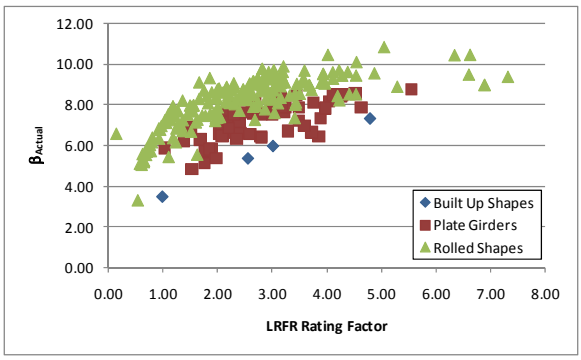


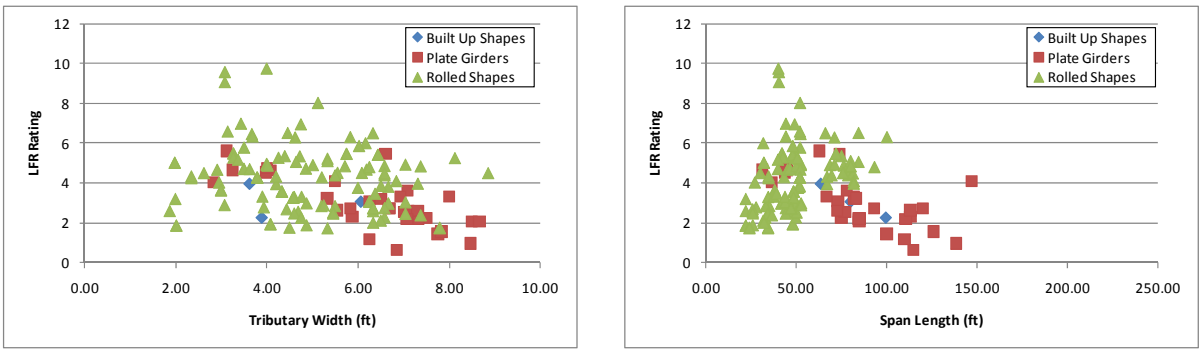
Figure B-555: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

B.3.8.2 Shear

The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

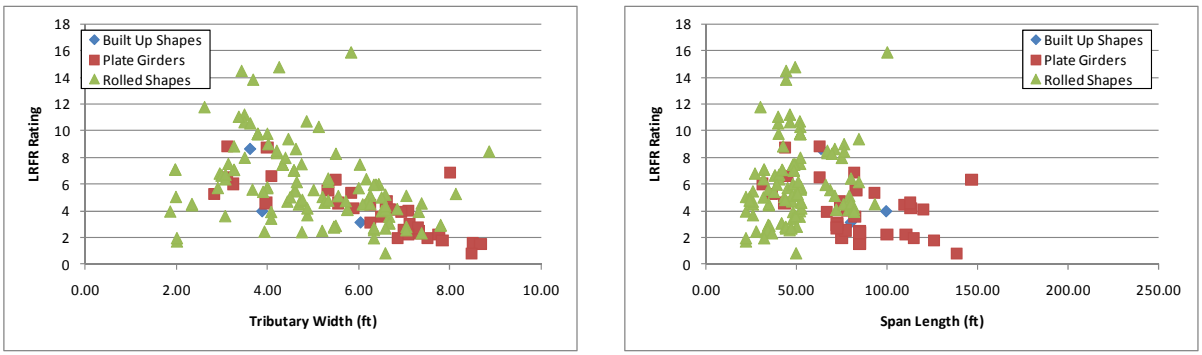
B.3.8.2.1 Rating Factors

For shear, there are seven girders that have a rating factor less than 1.0 for the LRFR method, there are no girders with ratings less than 1.0 for LFR. In this situation, only seven girders were affected by rating the bridges using the LRFR methodology even though they were designed with the Standard Specification. The LFR Rating is greater than the LRFR rating for 59% of the girders in this subset. Figure B-556 and Figure B-557 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-556: LFR Shear Ratings for OR-06 Vehicle

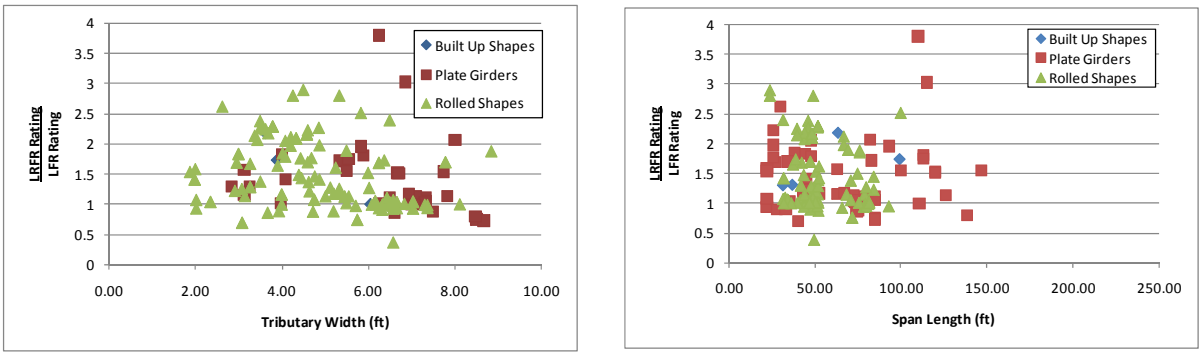


(a) (b)

Figure B-557: LRFR Shear Ratings for OR-06 Vehicle

B.3.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-558 shows the comparison of rating factors. The ratio is generally between 0.7 and 2.0.

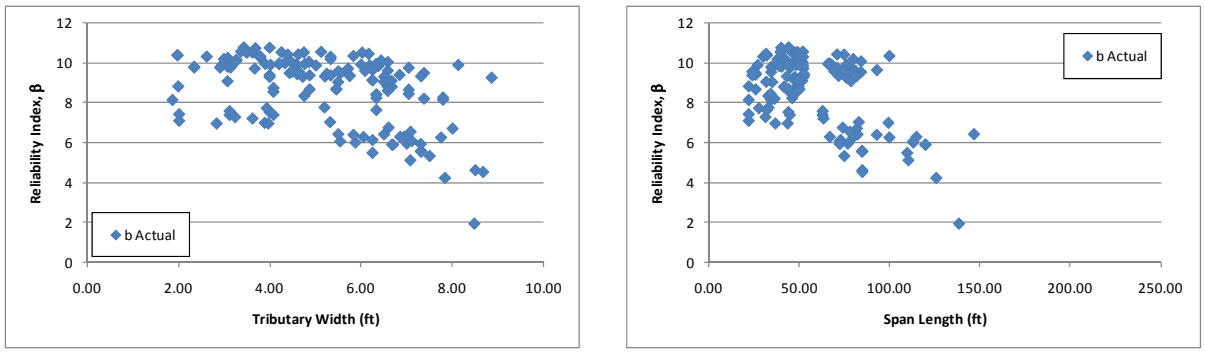


(a) (b)

Figure B-558: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

B.3.8.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all but one girder as shown in Figure B-559. This girder has a large tributary width for an exterior girder, allowing more dead load and live load to be applied.



(a) (b)

Figure B-559: Shear Reliability Indices for OR-06 Vehicle

Figure B-560 shows the reliability index plotted against the LRFR rating factor for shear due to the OR-06 vehicle. The figure shows that most girders with a passing rating have a reliability index greater than 4 which is greater than the target reliability of 3.5. This indicates that a reduction in live load factors would result in more girders passing rating while still maintaining an adequate level of reliability.

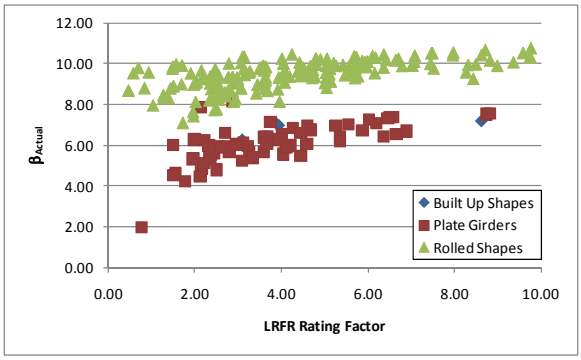


Figure B-560: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

B.3.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-467. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

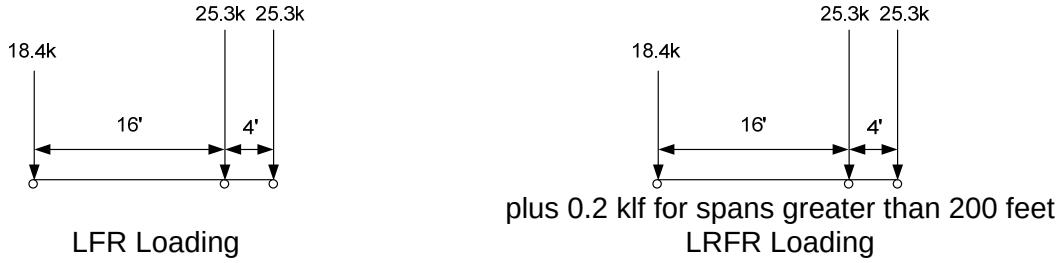


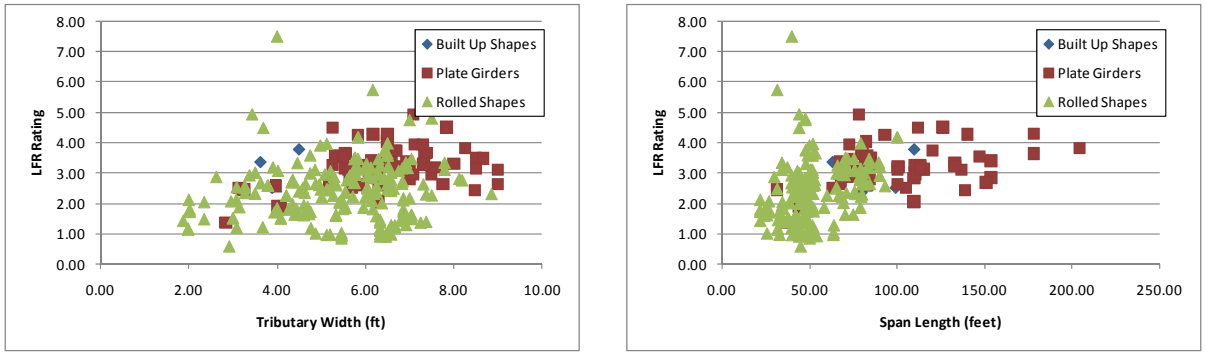
Figure B-561: Vehicle Loadings and Load Factors

B.3.9.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the TX-04 Vehicle.

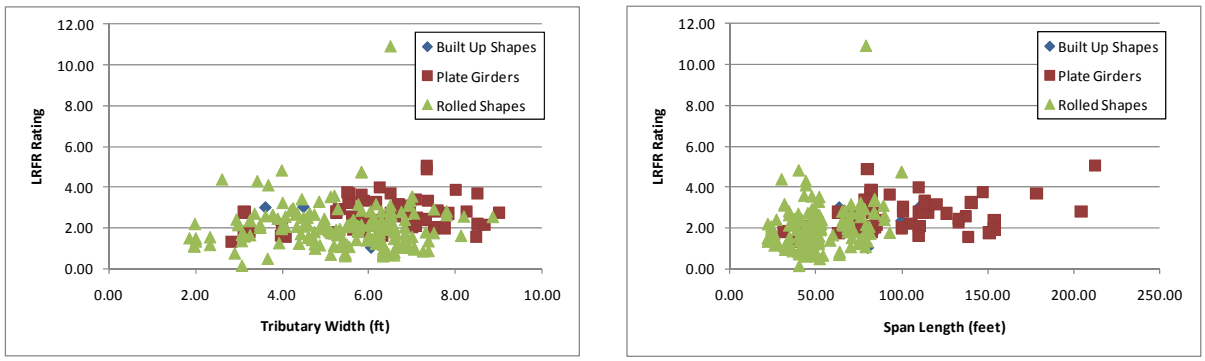
B.3.9.1.1 Rating Factors

Figure B-562 and Figure B-563 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 13 girders with an LFR rating less than 1.0, 29 girders with an LRFR rating less than 1.0, and 11 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 82% of the girders in this subset. Those girders with ratings less than 1.0 generally have spans less than 75 feet.



(a) (b)

Figure B-562: LFR Flexure Rating Factors for TX-04 Vehicle

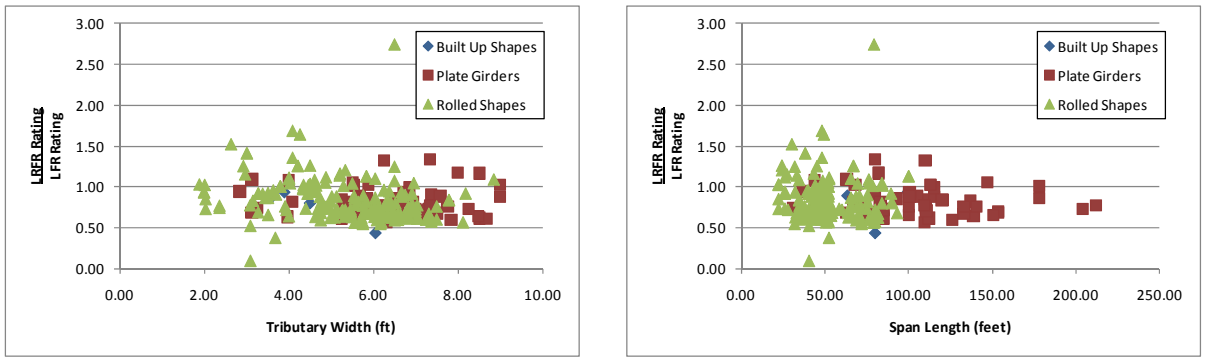


(a) (b)

Figure B-563: LRFR Flexure Rating Factors for TX-04 Vehicle

B.3.9.1.2 Rating Factor Comparisons

Figure B-564 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.0. The LRFR rating is greater than the LFR rating for 18% of the girders in this group.

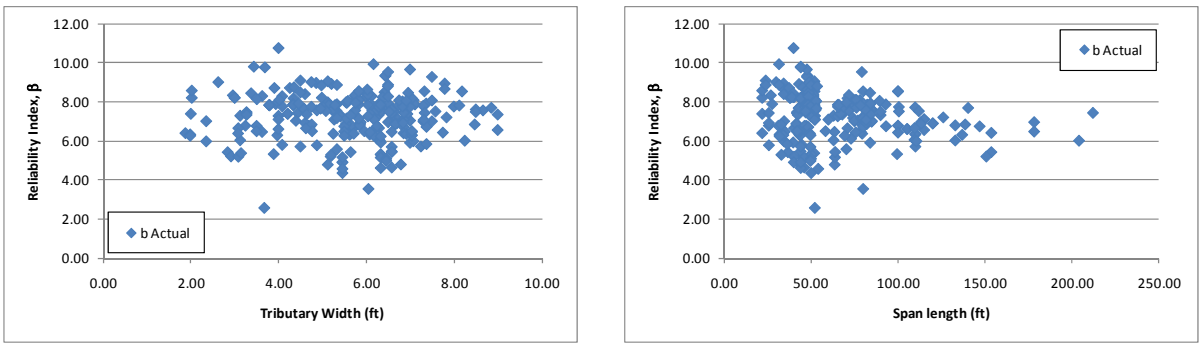


(a) (b)

Figure B-564: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

B.3.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-565 shows that no girders have a reliability index based upon girder strength that is less than that assumed in the development of the MBE.



(a) (b)

Figure B-565: Flexure Reliability Indices for TX-04 Vehicle

Figure B-566 shows the reliability index plotted versus the LRFR rating factor for moment due to the TX-04 vehicle. The figure shows that girders passing rating have a reliability index of at least 3.5 which is greater than the target reliability of 2.5. This indicates that reducing the LRFR live load factors would result in girders with a rating of 1.0 having a reliability index close to the target reliability level.

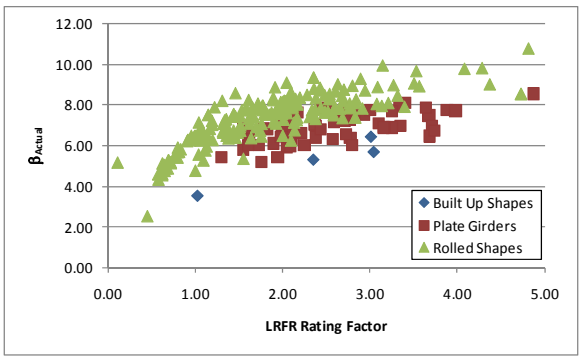


Figure B-566: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

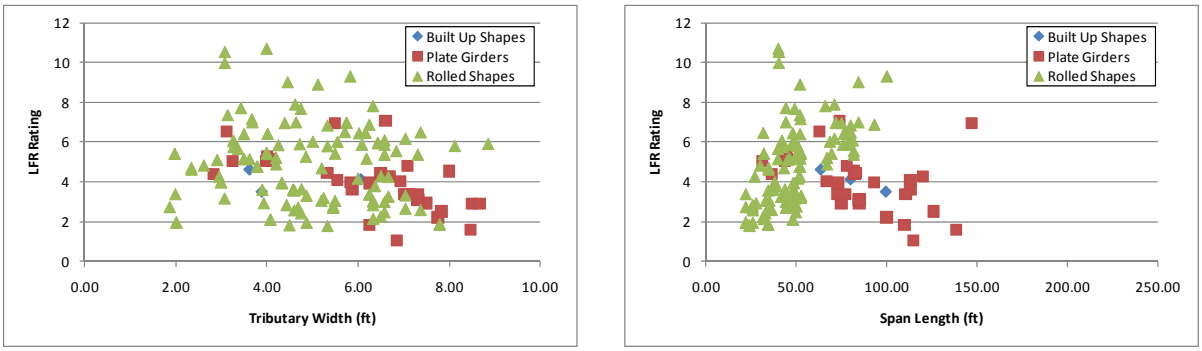
B.3.9.2 Shear

The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

B.3.9.2.1 Rating Factors

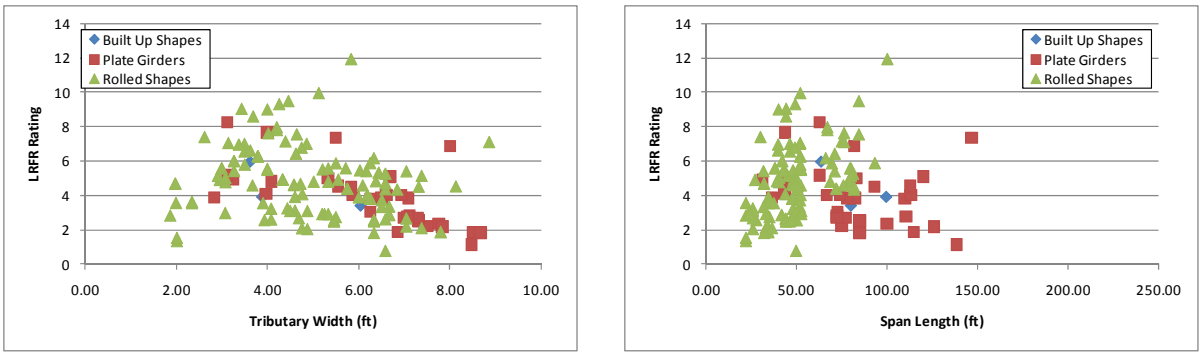
For shear, there are six girders that have LRFR rating factors less than 1.0. In this situation, 2% of girders are affected by rating the bridges using the LRFR methodology even though they may have been designed with the Standard Specification. The LFR Rating is greater than the LRFR rating for

86% of the girders in this subset. Figure B-567 and Figure B-568 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-567: LFR Shear Ratings for TX-04 Vehicle

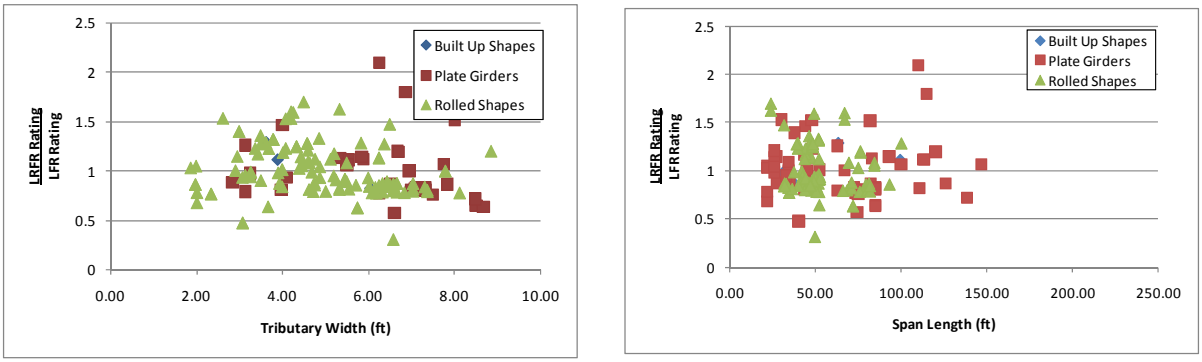


(a) (b)

Figure B-568: LRFR Shear Ratings for TX-04 Vehicle

B.3.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating divided by LFR Rating. Figure B-569 shows this comparison. The ratio is generally between 0.7 and 1.25. The LFR rating is greater than the LRFR rating for 86% of girders.

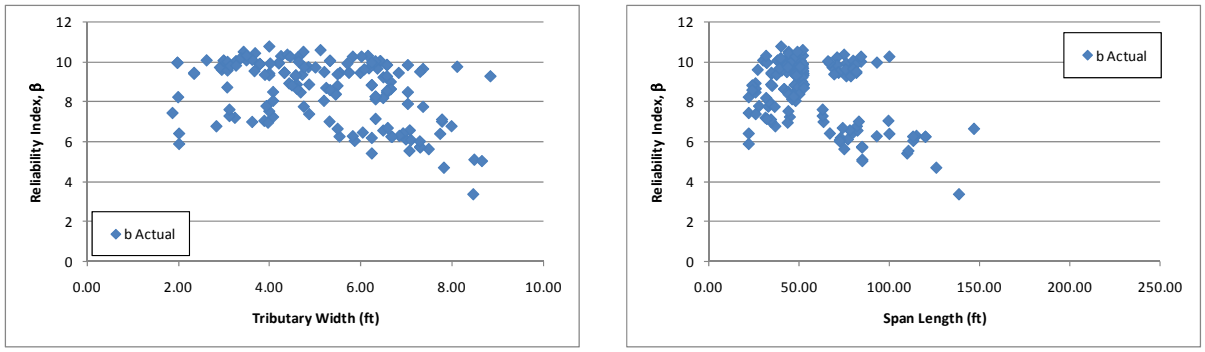


(a) (b)

Figure B-569: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

B.3.9.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all girders as shown in Figure B-570.



(a) (b)

Figure B-570: Shear Reliability Indices for TX-04 Vehicle

Figure B-571 shows the reliability index plotted against the LRFR rating for shear caused by the TX-04 vehicle. The figure shows that girders passing rating have reliability indices of at 3.25 which is above the target value of 2.5. Reducing the live load factors would shift the graph to the right; therefore more girders would pass rating and those that just pass the rating would have reliability indices closer to the target value of 2.5.

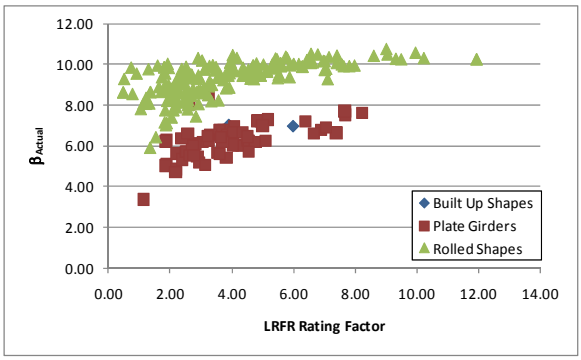
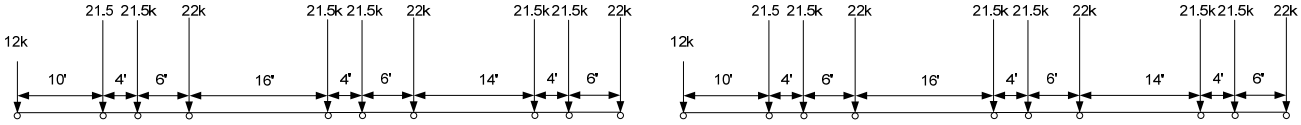


Figure B-571: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

B.3.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-467. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading

plus 0.2 klf for spans greater than 200 feet

LRFR Loading

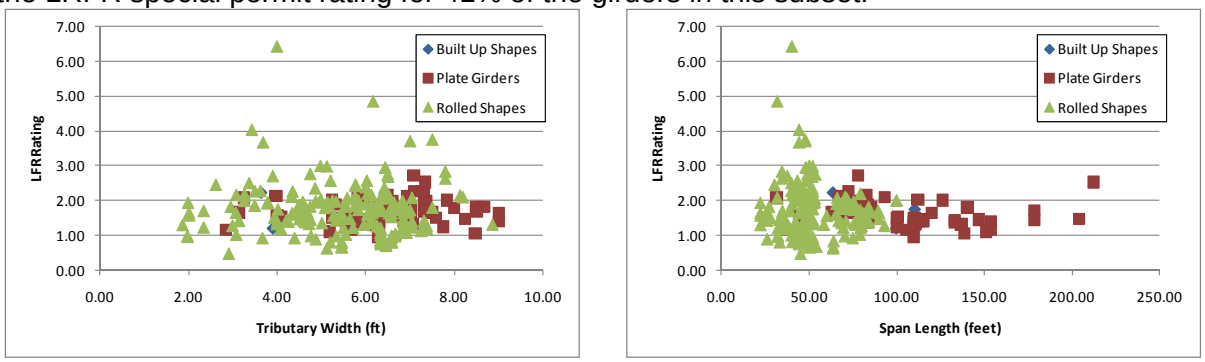
Figure B-572: Vehicle Loadings and Load Factors

B.3.10.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the WA-02 Vehicle.

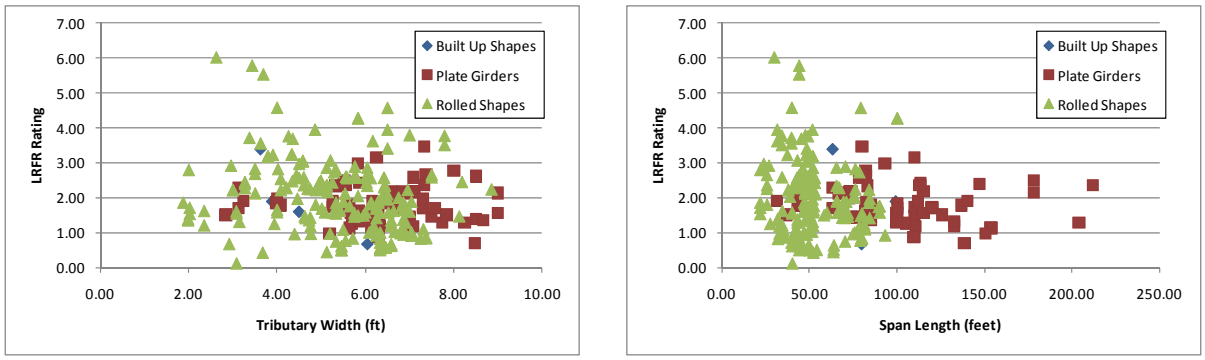
B.3.10.1.1 Rating Factors

Figure B-573 and Figure B-574 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 28 girders with an LFR rating less than 1.0, 41 girders with an LRFR rating less than 1.0, and 24 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 41% of the girders in this subset.



(a) (b)

Figure B-573: LFR Flexure Rating Factors for WA-02 Vehicle

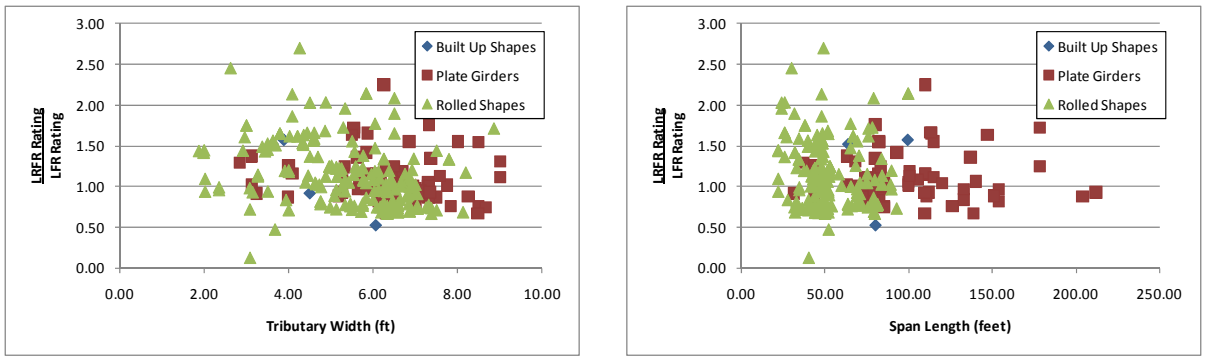


(a) (b)

Figure B-574: LRFR Flexure Rating Factors for WA-02 Vehicle

B.3.10.1.2 Rating Factor Comparisons

Figure B-575 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 1.5. The LRFR rating is greater than the LFR rating for 59% of the girders in this group.

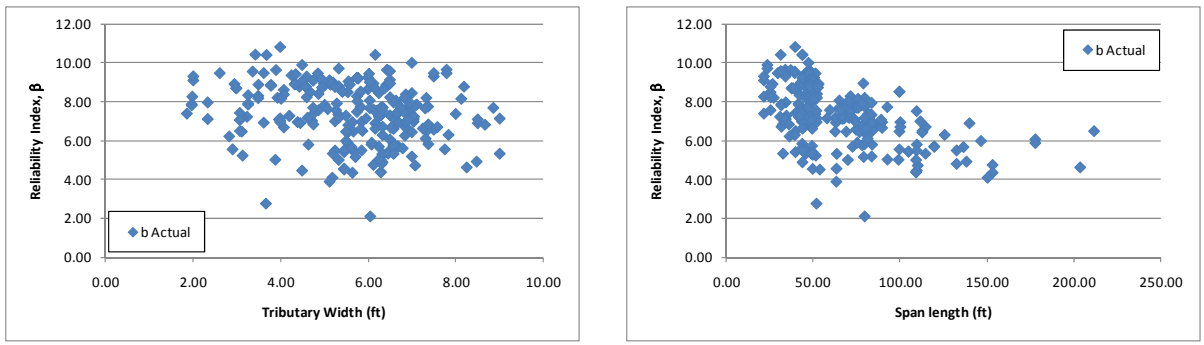


(a) (b)

Figure B-575: Ratio of LRFR Flexure Rating to LFR Flexure Rating for WA-02 Vehicle

B.3.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-576 shows that a handful of girders have a reliability index based upon girder strength that is less than that assumed in the development of the MBE. These are generally shorter spans with varying tributary widths.



(a) (b)

Figure B-576: Flexure Reliability Indices for WA-02 Vehicle

Figure B-577 shows the reliability index plotted against the LRFR rating for moment caused by the WA-02 Vehicle. The figure shows that girders with a rating of 1.0 have a reliability index of at least 4 which is slightly above the target reliability of 3.5. This indicates that a slight reduction in LRFR live load factors is possible; this will increase the number of girders passing the rating while maintaining the target level of reliability.

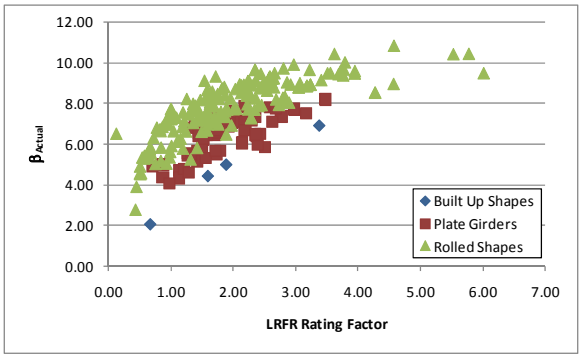


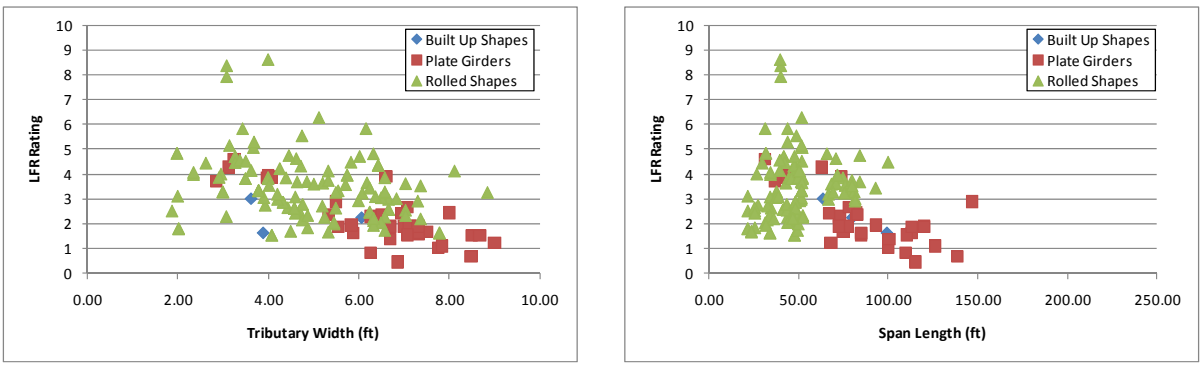
Figure B-577: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

B.3.10.2 Shear

The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

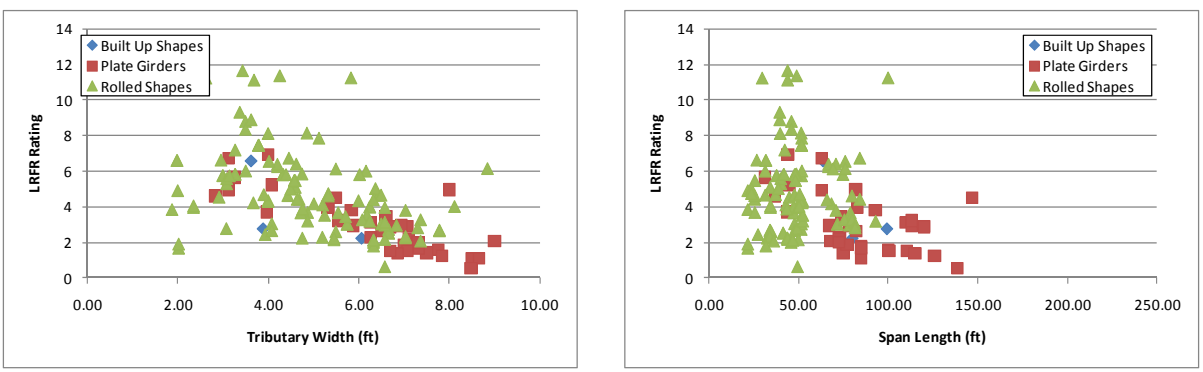
B.3.10.2.1 Rating Factors

For shear, there are nine girders that have LRFR rating factors less than 1.0 and one girder with LFR ratings less than 1.0. Very few girders (3%) were affected by rating the bridges using the LRFR methodology even though they were not necessarily designed with the LRFD Design Specification. The LFR Rating is greater than the LRFR rating for 63% of the girders in this subset. Figure B-578 and Figure B-579 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-578: LFR Shear Ratings for WA-02 Vehicle

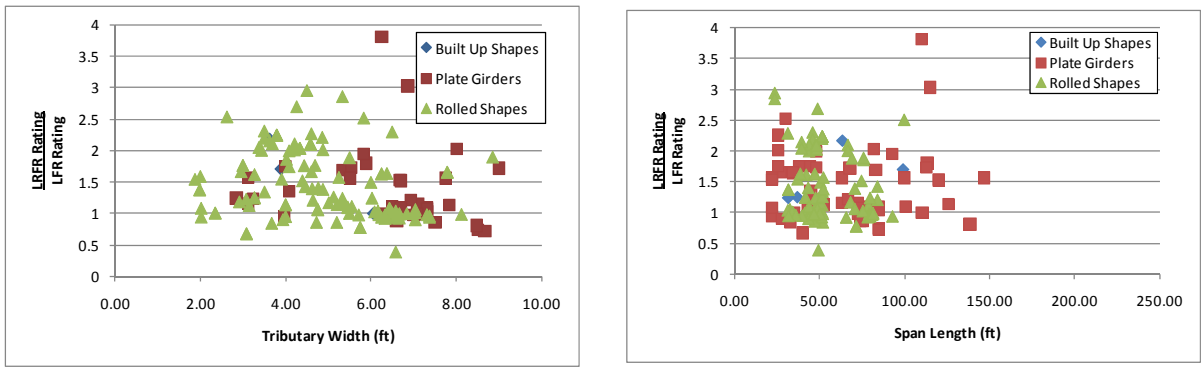


(a) (b)

Figure B-579: LRFR Shear Ratings for WA-02 Vehicle

B.3.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-580 shows the comparison of rating factors. The ratio is generally between 0.7 and 1.2. 37% of girders have LRFR ratings greater than the LFR rating.

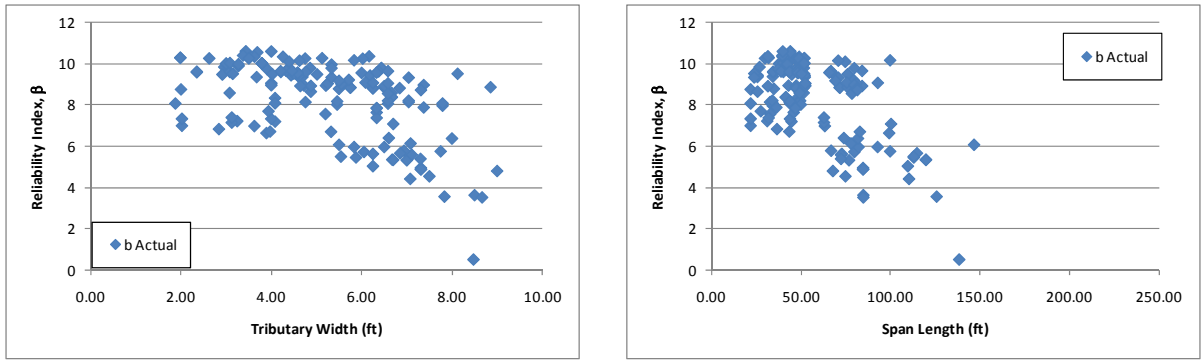


(a) (b)

Figure B-580: Ratio of LRFR Shear Rating to LFR Shear Rating for WA-02 Vehicle

B.3.10.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all girders as shown in Figure B-581, but there are two girders where the indices are very similar.



(a) (b)

Figure B-581: Shear Reliability Indices for WA-02 Vehicle

Figure B-582 shows the reliability index plotted against the LRFR rating factor for shear caused by the WA-02 vehicle. The figure shows that girders passing rating have a reliability index of at 3.5 which is the target reliability for this vehicle. This indicates that for shear, the current live load factors in the MBE provided the target reliability.

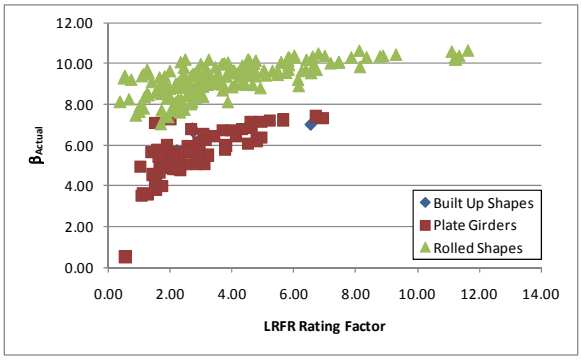


Figure B-582: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

B.3.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-467. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

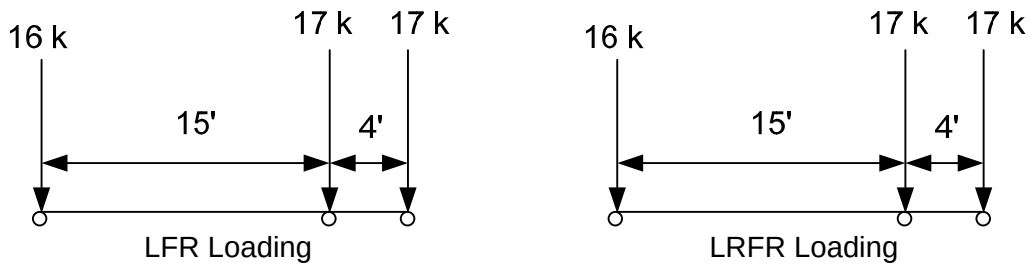


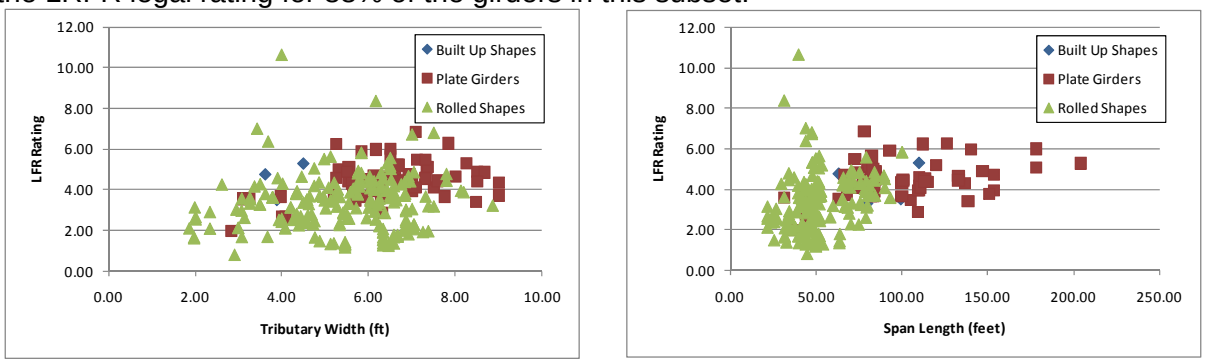
Figure B-583: Vehicle Loadings and Load Factors

B.3.11.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the Type 3 Vehicle.

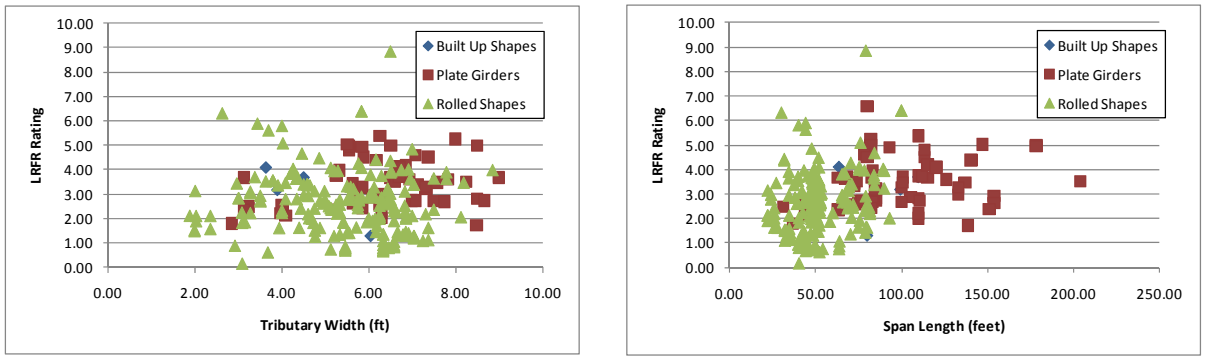
B.3.11.1.1 Rating Factors

Figure B-584 and Figure B-585 show the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 19 girders with an LRFR rating less than 1.0, and 1 girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 88% of the girders in this subset.



(a) (b)

Figure B-584: LFR Flexure Rating Factors for Type 3 Vehicle

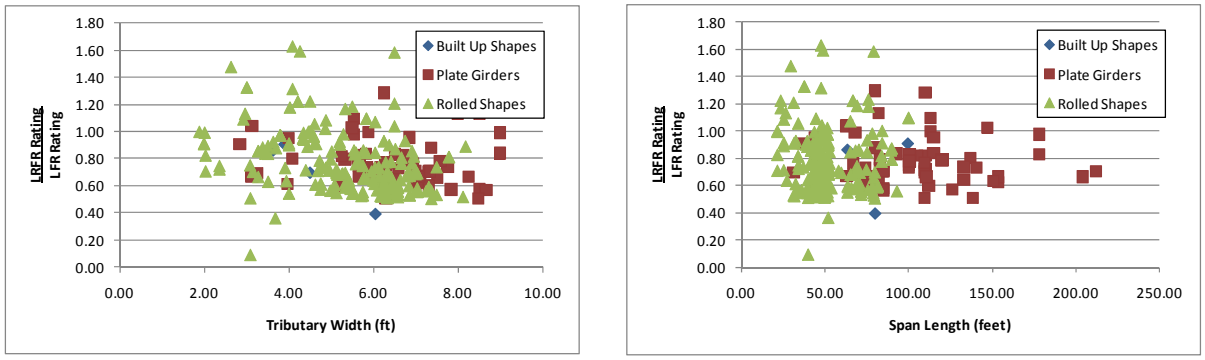


(a) (b)

Figure B-585: LRFR Flexure Rating Factors for Type 3 Vehicle

B.3.11.1.2 Rating Factor Comparisons

Figure B-586 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.0. 12% of girders have an LRFR rating greater than the LFR rating for this group.

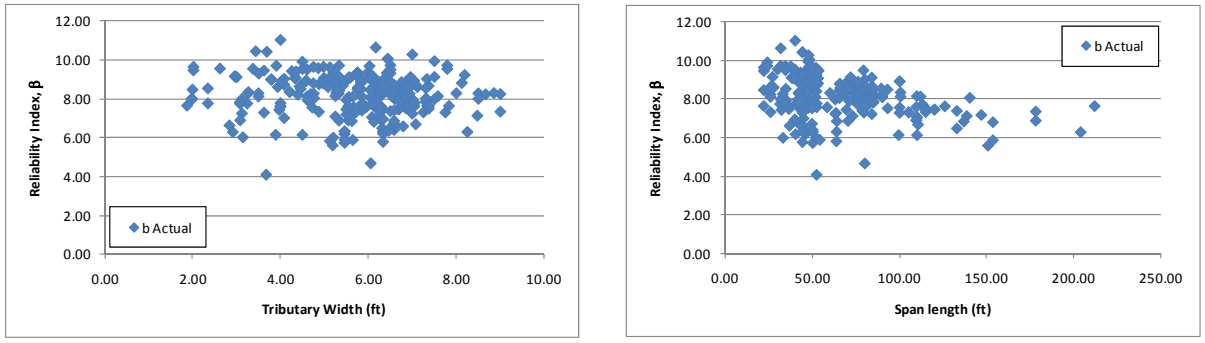


(a) (b)

Figure B-586: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Type 3 Vehicle

B.3.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-587 shows that no girders have a reliability index based upon girder strength that is less than the value of 2.5 used in the development of the MBE.



(a) (b)

Figure B-587: Flexure Reliability Indices for Type 3 Vehicle

Figure B-588 shows the reliability index plotted against the LRFR rating factor for moment caused by the AASHTO Type 3 Truck. The figure shows that girders with a rating factor of 1.0 typically have a reliability index greater than 4.0 which is greater than the target reliability of 2.5. The LRFR live load factors could be reduced increasing the rating factor associated with a specific reliability index.

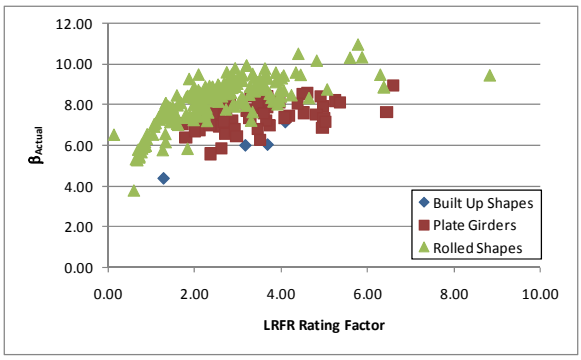


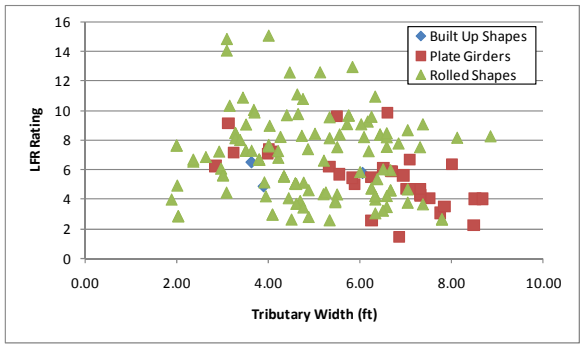
Figure B-588: Flexure Reliability Index vs LRFR Flexure Rating for Type 3 Vehicle

B.3.11.2 Shear

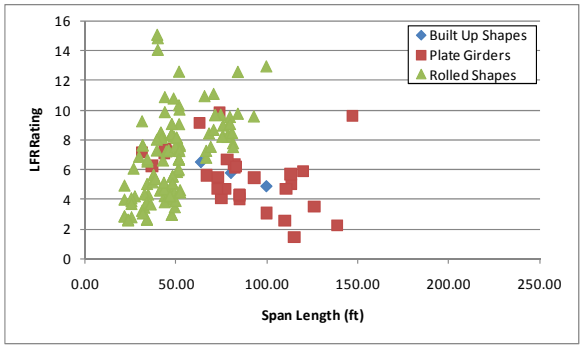
The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

B.3.11.2.1 Rating Factors

For shear, there are five girders that have LRFR rating factors less than 1.0 and no girders with LFR ratings less than 1.0. Five girders were affected by rating the bridges using the LRFR methodology even though they were not necessarily designed with the LRFD Design Specification. The LFR Rating is greater than the LRFR rating for 88% of the girders in this subset. Figure B-589 and Figure B-590 show the LFR and LRFR ratings, respectively.

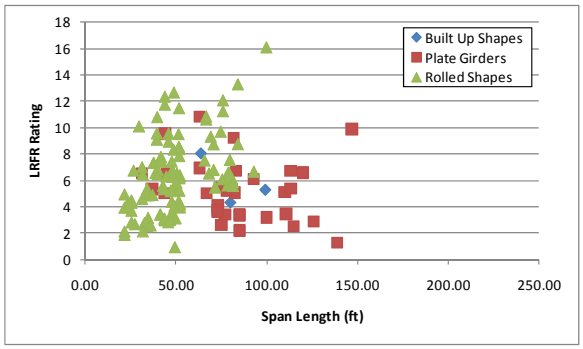


(a)



(b)

Figure B-589: LFR Shear Ratings for Type 3 Vehicle

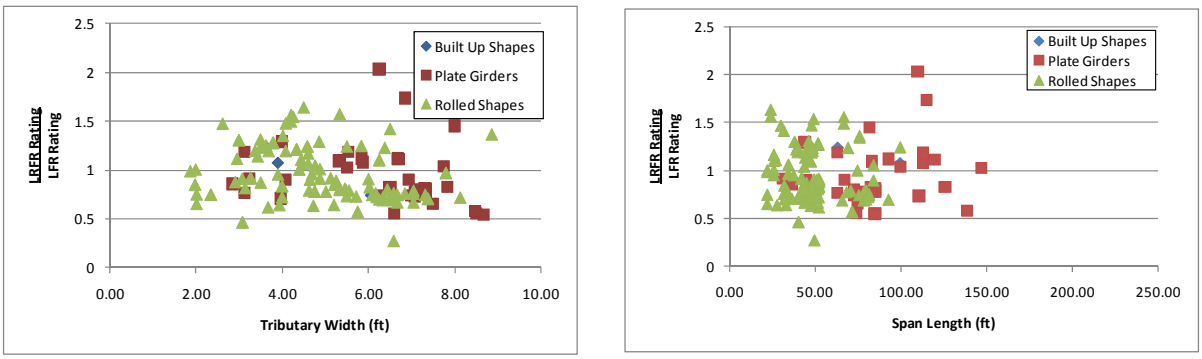


(a) (b)

Figure B-590: LRFR Shear Ratings for Type 3 Vehicle

B.3.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-591 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.25. The LRFR rating is greater than the LFR rating for 12% of girders in this group.

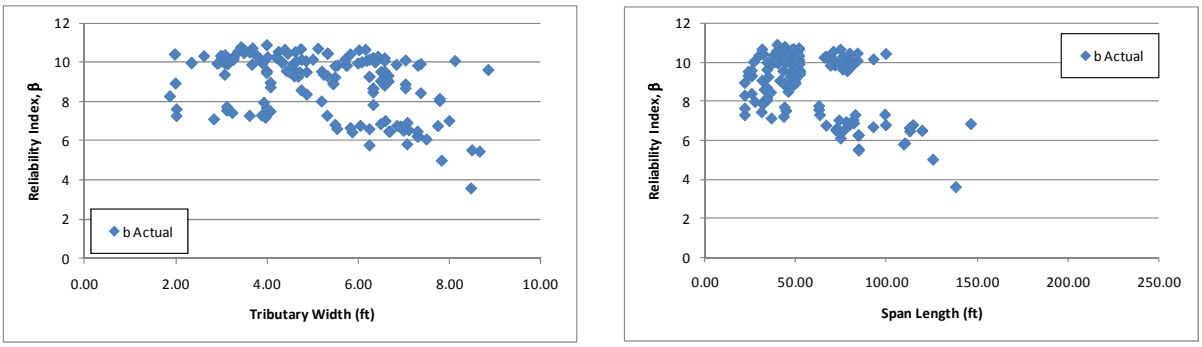


(a) (b)

Figure B-591: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3 Vehicle

B.3.11.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the level of reliability assumed in the development of the MBE for all girders as shown in Figure B-592. The level of reliability assumed in the development of the MBE is 2.5.



(a) (b)

Figure B-592: Shear Reliability Indices for Type 3 Vehicle

Figure B-593 shows the reliability index plotted against the LRFR rating factor for shear due to the AASHTO Type 3 vehicle. The figure shows that girders passing rating typically have reliability indices greater than the target reliability of 2.5. This indicates that the LRFR live load factors could be reduced because girders just passing the rating would be expected to have reliability similar to the target value.

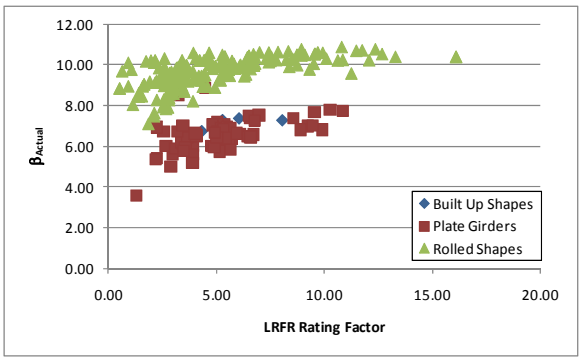


Figure B-593: Shear Reliability Index vs LRFR Shear Rating for Type 3 Vehicle

B.3.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-594. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

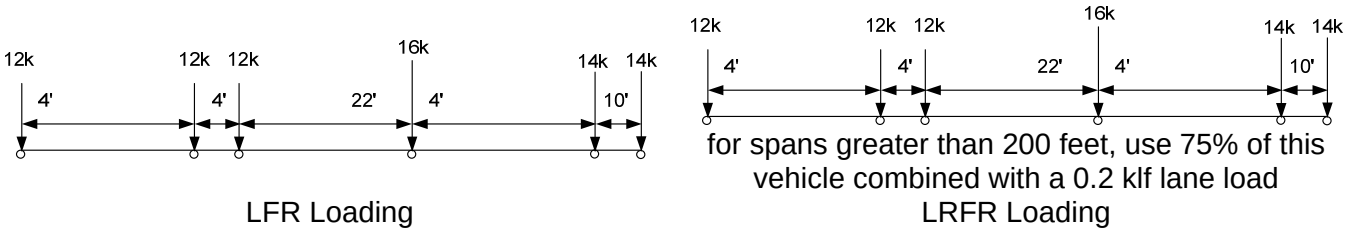


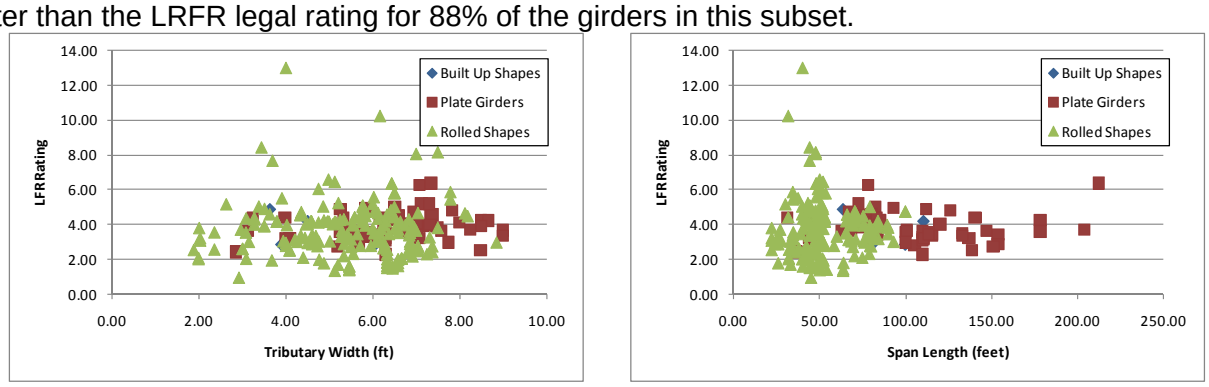
Figure B-594: Vehicle Loadings and Load Factors

B.3.12.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the Type 3-3 Vehicle.

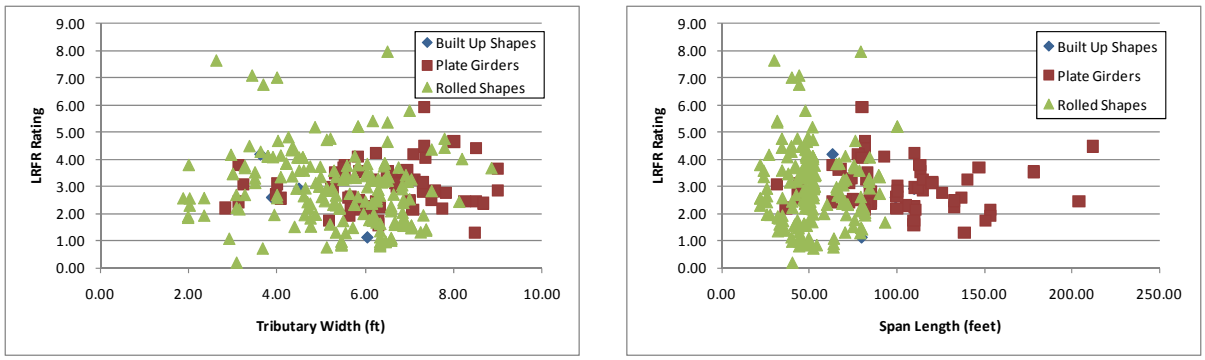
B.3.12.1.1 Rating Factors

Figure B-595 and Figure B-596 show the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 15 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 88% of the girders in this subset.



(a) (b)

Figure B-595: LFR Flexure Rating Factors for Type 3-3 Vehicle

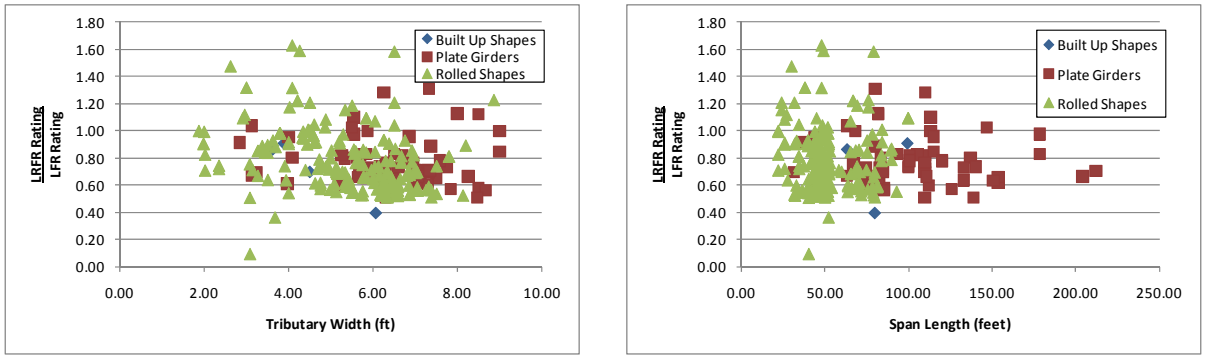


(a) (b)

Figure B-596: LRFR Flexure Rating Factors for Type 3-3 Vehicle

B.3.12.1.2 Rating Factor Comparisons

Figure B-597 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.0. 12% of girders have an LRFR rating that is greater than the LFR rating.

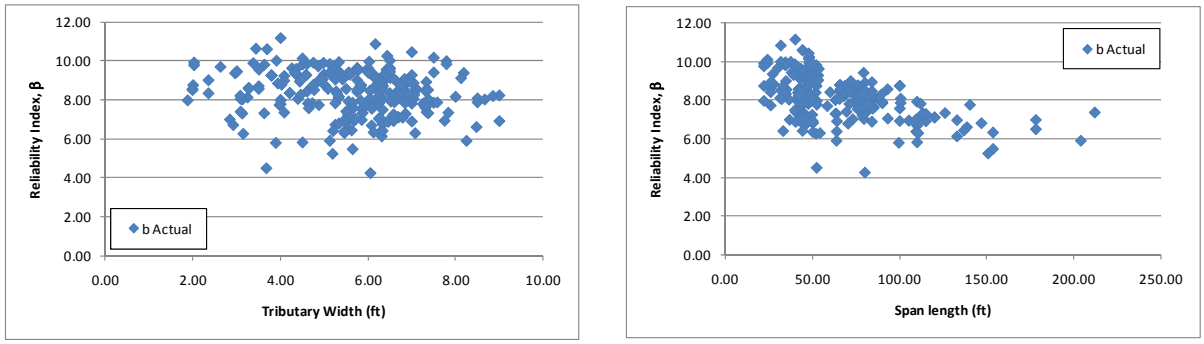


(a) (b)

Figure B-597: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Type 3-3 Vehicle

B.3.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-598 shows that all girders have a reliability index greater than the 2.5 considered in the development of the MBE.



(a) (b)

Figure B-598: Flexure Reliability Indices for Type 3-3 Vehicle

Figure B-599 shows the reliability index plotted against the LRFR rating for moment caused by the AASHTO Type 3-3 vehicle. The figure shows that girders with LRFR ratings above 1.0 typically have a reliability index of 4.0 or higher. The target reliability for the AASHTO Legal loads is 2.5. The LRFR live load factors could be reduced such that the girders with ratings of 1.0 have a reliability index of approximately 2.5.

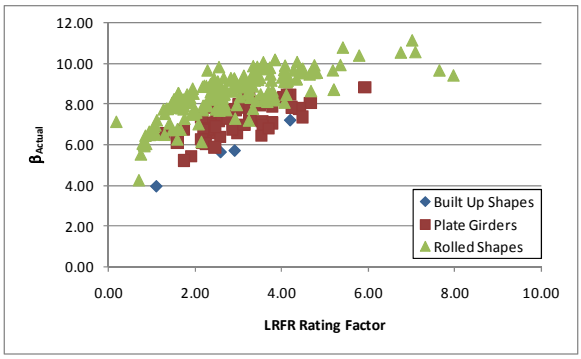


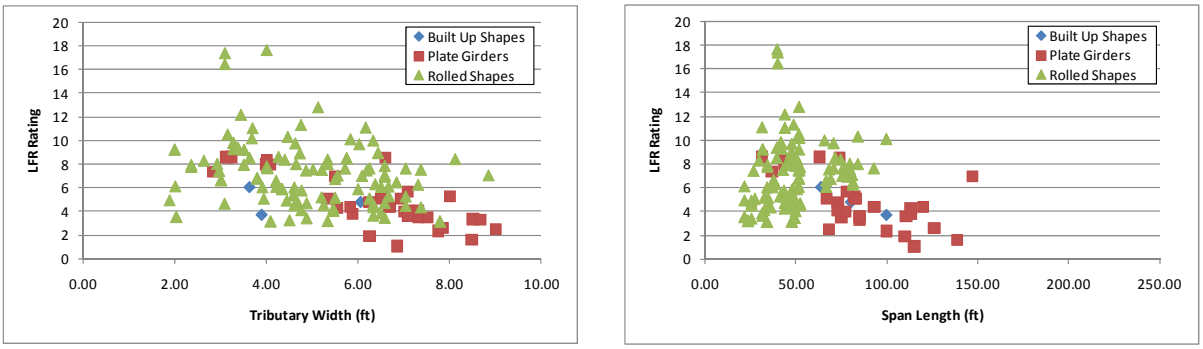
Figure B-599: Flexure Reliability Index vs LRFR Flexure Rating for Type 3-3 Vehicle

B.3.12.2 Shear

The results shown in the following section have been corrected to consider only those girders with critical locations at the support or one-tenth of the span length from the support and the same controlling rating criteria. The number of girders with ratings less than 1.0 considers all possible girders. For this reason, the text may indicate that there are girders with ratings less than 1.0 and the figures indicate otherwise.

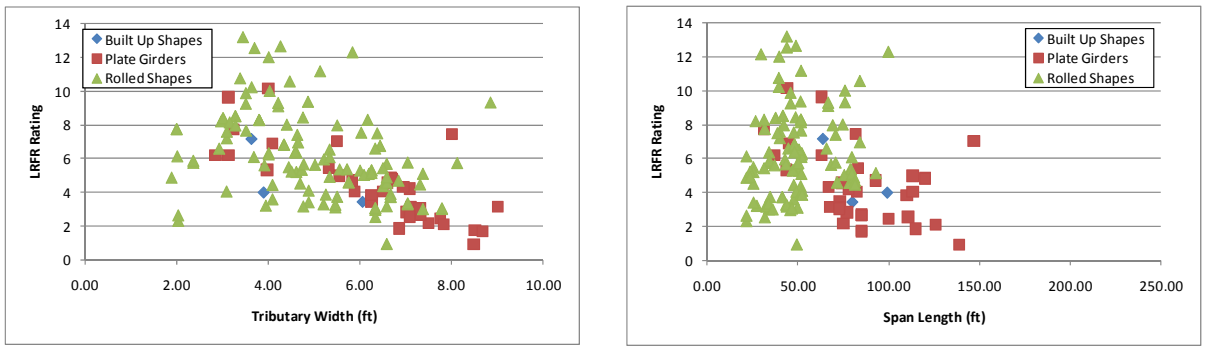
B.3.12.2.1 Rating Factors

For shear, there are six girders that have LRFR rating factors less than 1.0 and no girders with LFR ratings less than 1.0. Very few (2%) girders were affected by rating the bridges using the LRFR methodology even though they were not necessarily designed with the LRFD Design Specification. The LFR Rating is greater than the LRFR rating for 92% of the girders in this subset. Figure B-600 and Figure B-601 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-600: LFR Shear Ratings for Type 3-3 Vehicle

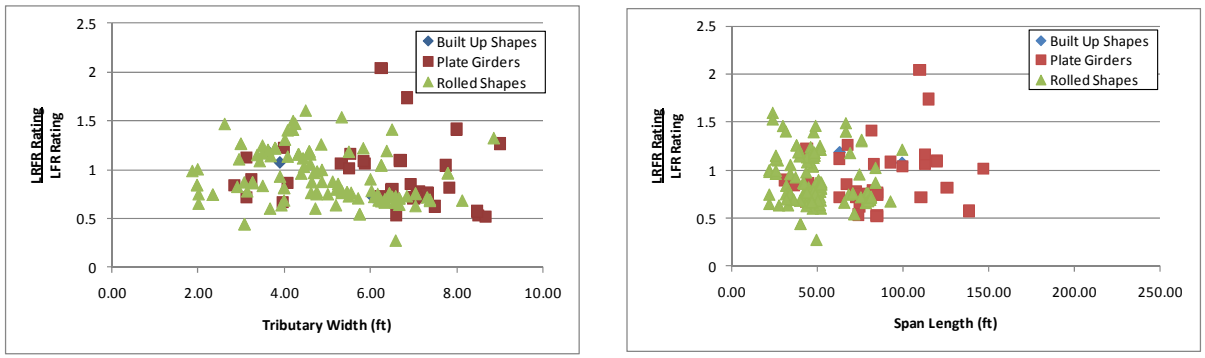


(a) (b)

Figure B-601: LRFR Shear Ratings for Type 3-3 Vehicle

B.3.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-602 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.25. 8% of the girders in this group have a higher LRFR rating than LFR rating.

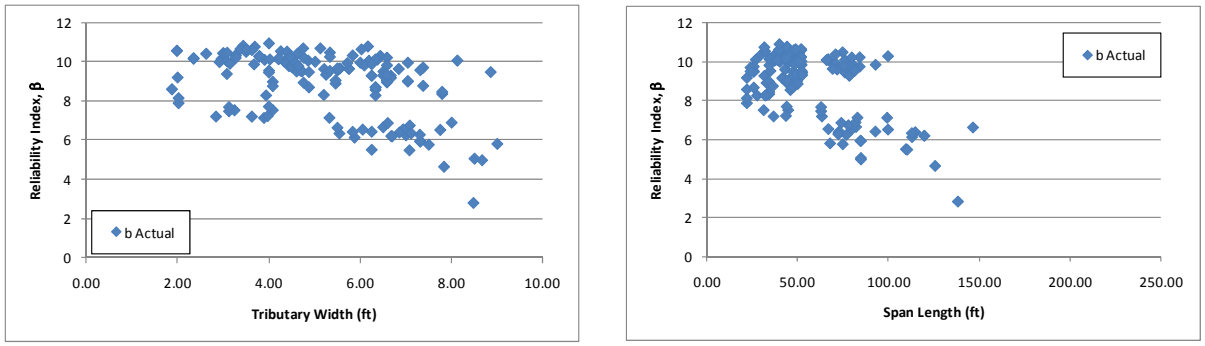


(a) (b)

Figure B-602: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3-3 Vehicle

B.3.12.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than value of 2.5 assumed in the development of the MBE for all girders as shown in Figure B-603, but there is one girder approaching the required value.



(a) (b)

Figure B-603: Shear Reliability Indices for Type 3-3 Vehicle

Figure B-604 shows the reliability index plotted against the LRFR rating for shear due to the AASHTO Type 3-3 truck. The figure shows that most girders with ratings less than 1.0 have reliability indices above the target value of 2.5. Reducing the LRFR live load factors would increase the ratings and result in girders having rating of 1.0 having reliability indices near 2.5.

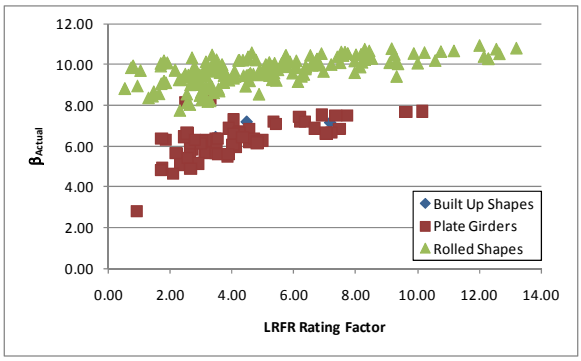


Figure B-604: Shear Reliability Index vs LRFR Shear Rating for Type 3-3 Truck

B.3.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-605. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

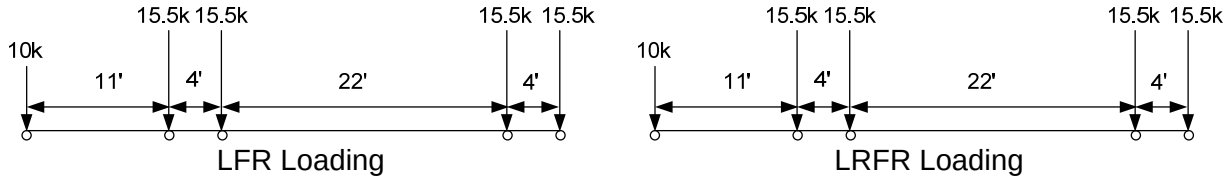


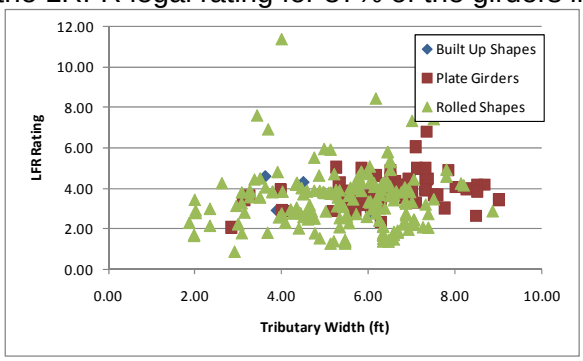
Figure B-605: Vehicle Loadings and Load Factors

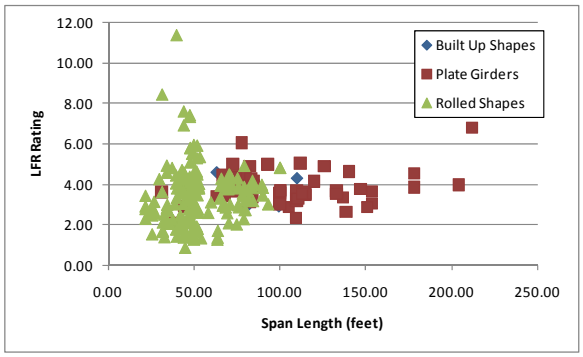
B.3.13.1 Moment

The following section contains the results for exterior, composite steel girders within simple span bridges for the Type 3S2 Vehicle.

B.3.13.1.1 Rating Factors

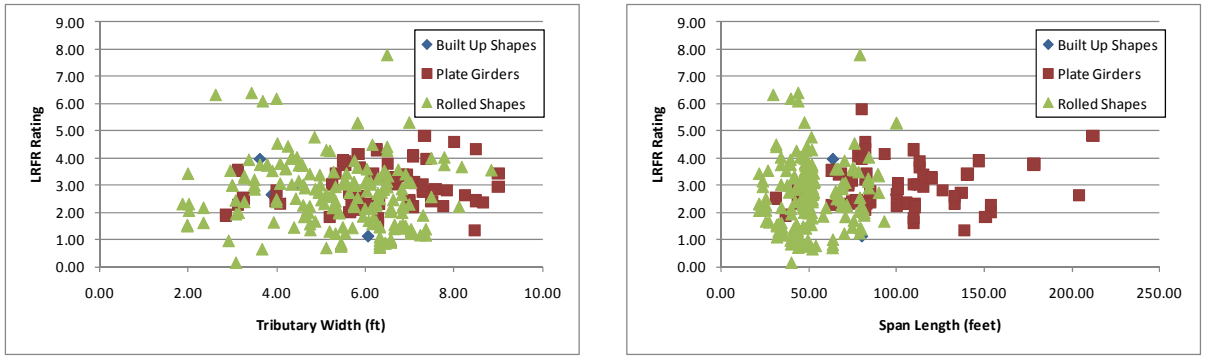
Figure B-606 and Figure B-607 show the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 19 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 87% of the girders in this subset.





(a) (b)

Figure B-606: LFR Flexure Rating Factors for WA-02 Vehicle

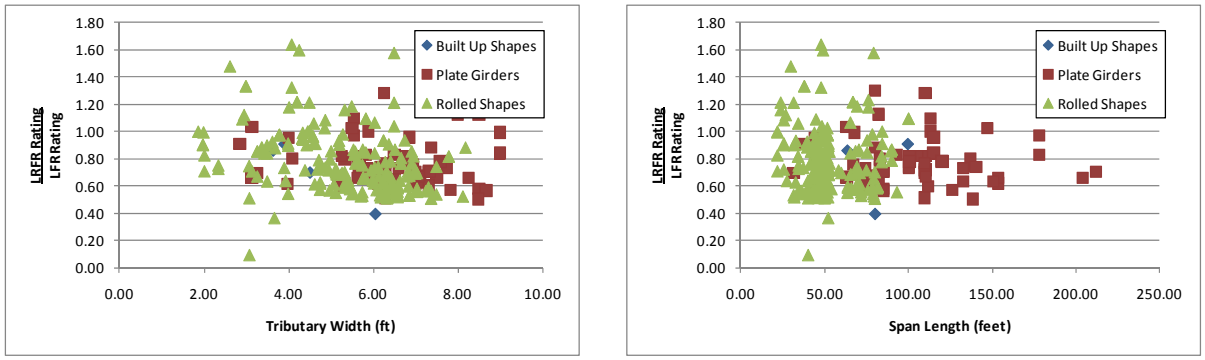


(a) (b)

Figure B-607: LRFR Flexure Rating Factors for WA-02 Vehicle

B.3.13.1.2 Rating Factor Comparisons

Figure B-608 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.0; 13% of girders have an LRFR rating greater than the LFR rating.

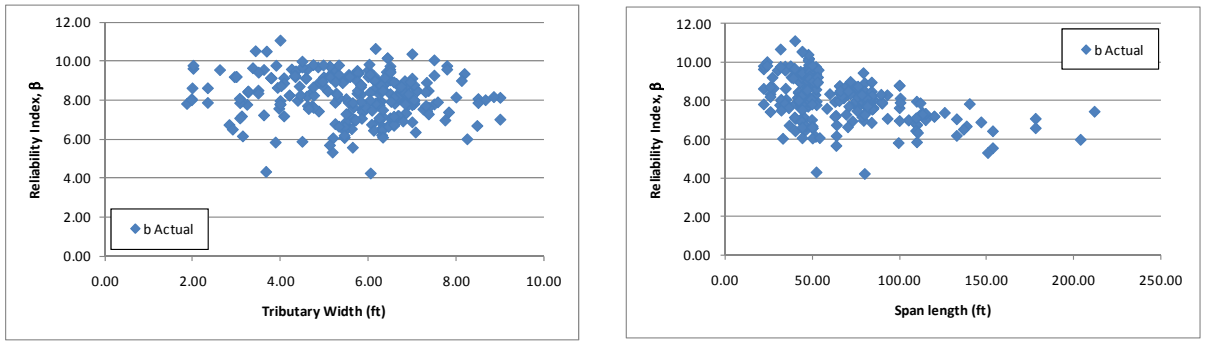


(a) (b)

Figure B-608: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Type 3S2 Vehicle

B.3.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-609 shows that all girders have the level of reliability assumed in the development of the MBE. The level assumed in the development of the MBE for legal loads is the traditional Operating level of 2.5.



(a) (b)

Figure B-609: Flexure Reliability Indices for Type 3S2 Vehicle

Figure B-610 shows the reliability index plotted against the LRFR rating for moment due to the AASHTO Type 3S2 truck. The figure shows that girders passing rating typically have reliability indices above the target reliability of 2.5. This indicates that the live load factor could be reduced, resulting in girders passing rating with reliability indices closer to the target reliability.

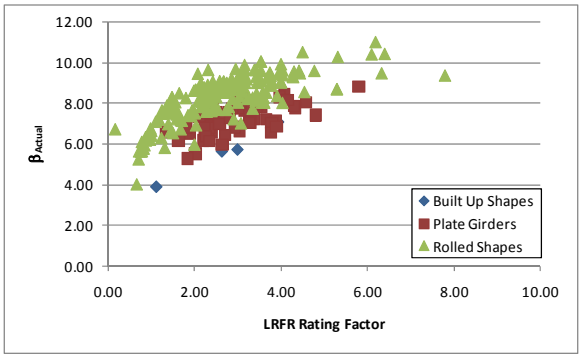
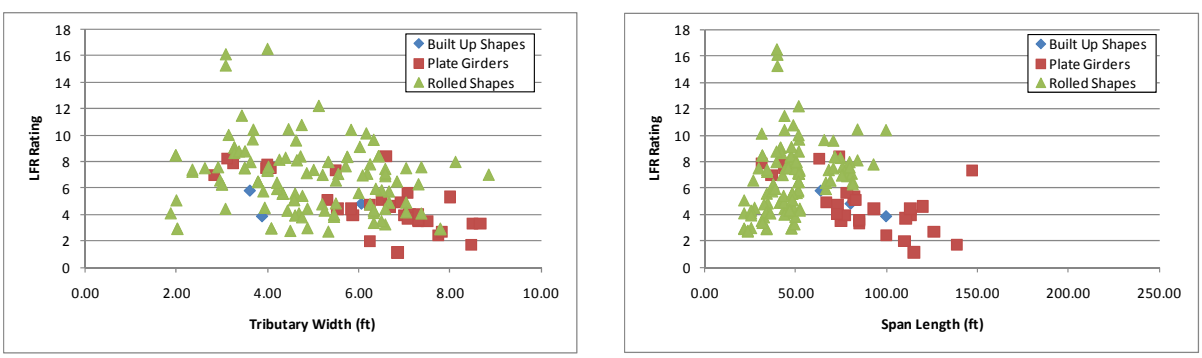


Figure B-610: Flexure Reliability Index vs LRFR Flexure Rating for Type 3S2 truck

B.3.13.2 Shear

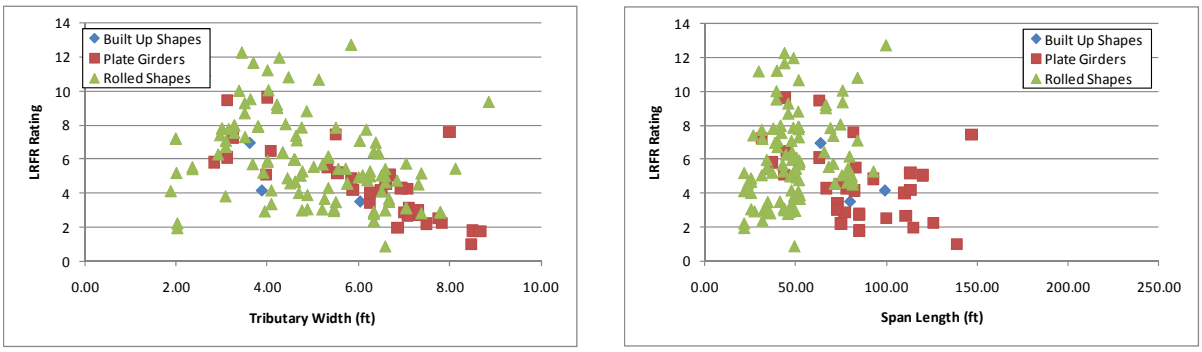
B.3.13.2.1 Rating Factors

For shear, there are seven girders that have LRFR rating factors less than 1.0 and no girders with LFR ratings less than 1.0. 2.5% of girders were affected by rating the bridges using the LRFR methodology even though they were not necessarily designed with the LRFD Design Specification. The LFR Rating is greater than the LRFR rating for 92% of the girders in this subset. Figure B-611 and Figure B-612 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-611: LFR Shear Ratings for Type 3S2 Vehicle

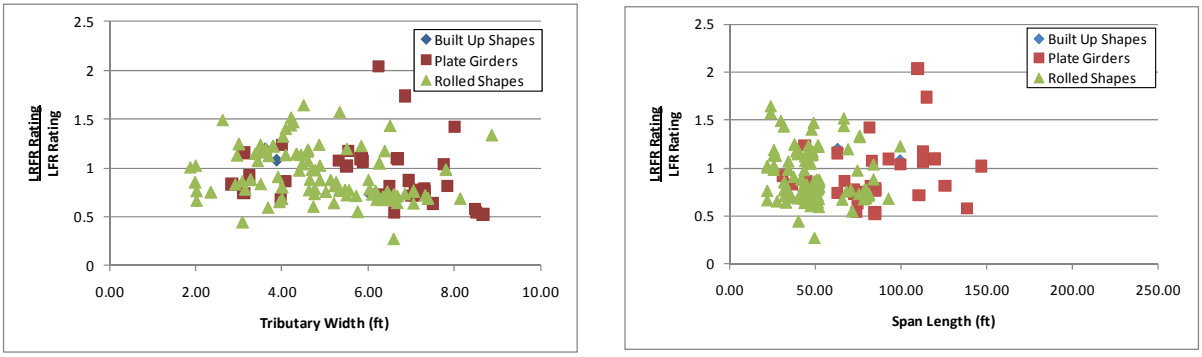


(a) (b)

Figure B-612: LRFR Shear Ratings for Type 3S2 Vehicle

B.3.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by examining the ratio of LRFR Rating to LFR Rating. Figure B-613 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.25.

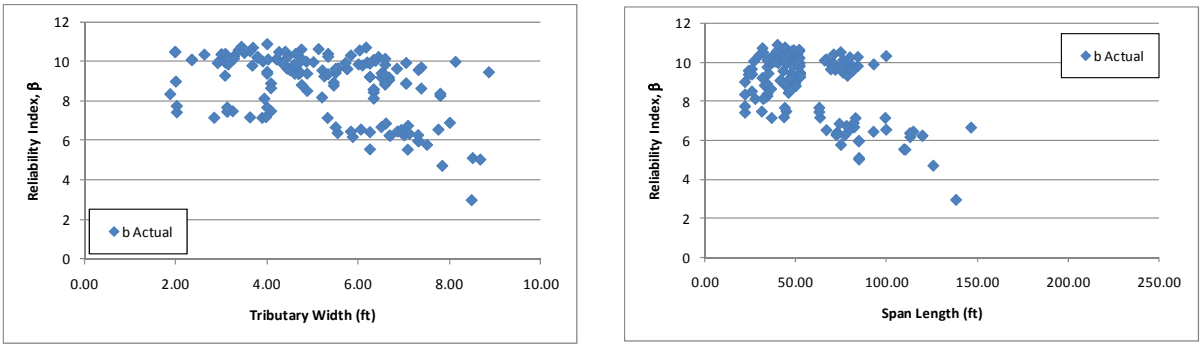


(a) (b)

Figure B-613: Ratio of LRFR Shear Rating to LFR Shear Rating for Type 3S2 Vehicle

B.3.13.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index of 2.5 for all girders as shown in Figure B-614, but there is one girder where the indices are similar.



(a) (b)

Figure B-614: Shear Reliability Indices for Type 3S2 Vehicle

Figure B-615 shows the reliability index plotted against the LRFR rating for shear due to the AASHTO Type 3S2 Truck. The figure shows girders passing rating typically have reliability indices greater than the target reliability of 2.5. Reducing the LRFR live load factor will shift the data to the right such that the reliability is near 2.5 for a rating of 1.0.

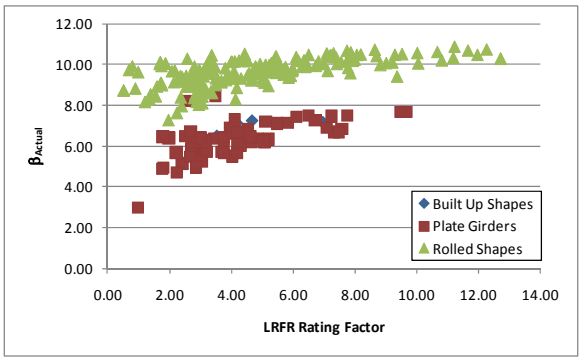


Figure B-615: Shear Reliability Index vs LRFR Shear Rating for Type 3S2 vehicle

B.3.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both.

Table B-5 shows the results for the moment ratings. For the design vehicle a similar number of girders have ratings less than 1.0 for either method. For the other vehicles investigated, the number of girders varied significantly depending on the vehicle, but overall a similar percentage of girders had LFR ratings that were greater than the LRFR ratings for the routine permit vehicles and legal vehicles. The special permit vehicles had significantly more girders with LRFR ratings greater than LFR ratings.

Table B-5: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	279	41	1	1	14	6	1	17	13	28	1	1	1
LRFR Rating less than 1.0		41	19	20	25	24	16	24	29	41	19	15	19
LFR and LRFR Rating less than 1.0		31	1	1	12	5	1	14	11	24	1	0	1
% with LFR RF greater than LRFR RF		50	82	82	42	82	81	34	82	41	88	88	87

B.3.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table B-6 shows the results for the shear ratings. There were very few girders that had LFR ratings less than 1.0, and for LRFR there were a similar number of girders for all vehicles that had ratings less than 1.0.

Table B-6: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	279	0	0	0	0	0	0	0	0	1	0	0	0
LRFR Rating less than 1.0		15	5	5	7	5	4	7	6	9	5	6	7

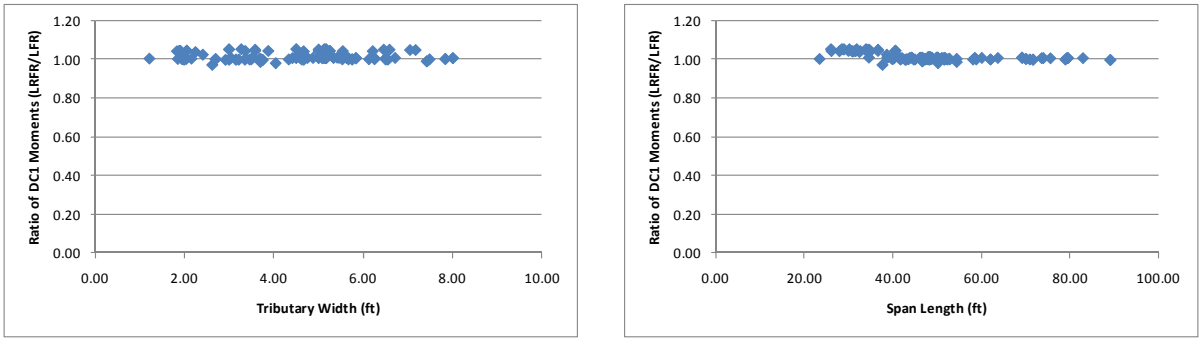
LFR and LRFR Rating less than 1.0		0	0	0	0	0	0	0	0	0	0	0	0
% with LFR RF greater than LRFR RF		80	88	85	61	87	88	59	86	63	88	92	92

B.4 Exterior Non-composite Girders

B.4.1 Dead Loads

B.4.1.1 Moment

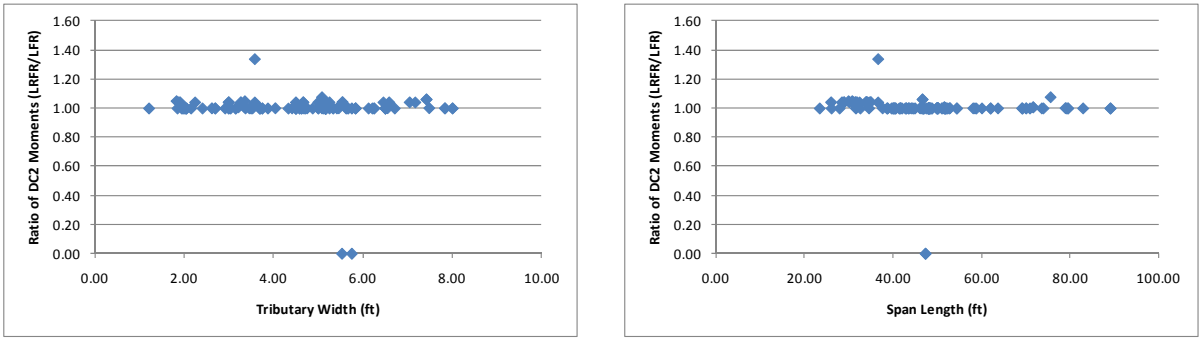
The first set of graphs show the results that were obtained for flexure. As shown in Figure B-616, the ratio of unfactored DC1 moments (self-weight, dead loads on non-composite section) are very close to 1.0. Those that are slightly above 1.0 are caused by the moment being obtained at the four-tenths point for LFR while the LRFR moment is calculated at midspan. RIO determines the location of the critical rating factor and then uses this location to obtain the moments due to dead and live loads.



(a) (b)

Figure B-616: Ratio of DC1 LRFR Moment to DC1 LFR Moment (unfactored loads)

Figure B-617 shows that there is slightly more variation in the long-term dead loads applied to the section after placement of the deck (DC2 and DW loads). Most girders have a ratio of between 1.0 and 1.05, with two girders having a ratio of 0 and one girder having a ratio of 1.35.



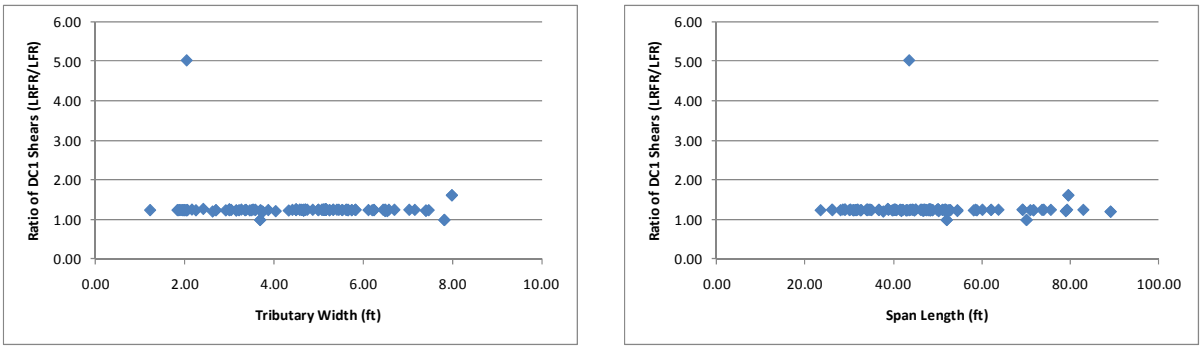
(a) (b)

Figure B-617: Ratio of DC2 LRFR Moment to DC2 LFR Moment (unfactored loads)

B.4.1.2 Shear

Figure B-618 below shows that for most girders the LRFR DC1 shear is 125% of the LFR DC1 shear. This is a result of BRASS not always calculating a rating factor for shear at the support for LFR; to get around this an option in RIO was created to ignore zero shear ratings. The result was typically that the LFR rating was then taken at either the one-tenth or nine-tenths point along the span. This would

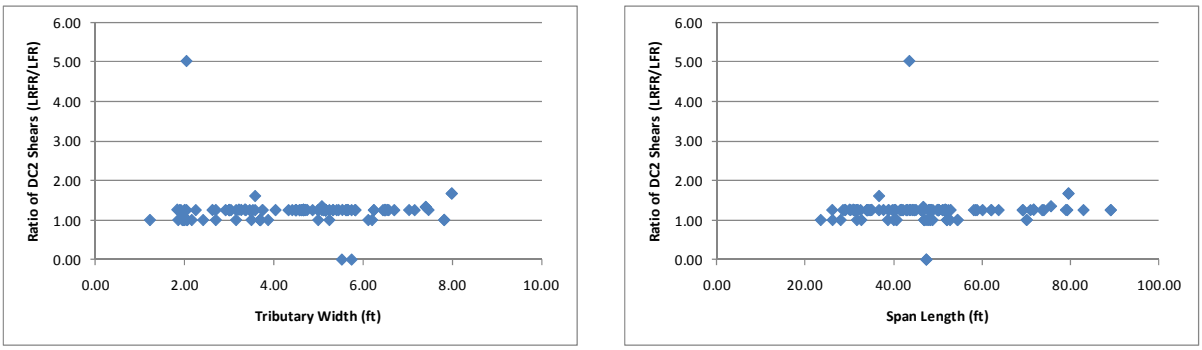
correspond to a 25% increase in dead load shear since all the results compiled so far are for simple spans and DC1 is a uniform load.



(a) (b)

Figure B-618: Ratio of DC1 LRFR Shear to DC1 LFR Shear (unfactored loads)

Figure B-619 shows the same trend as Figure B-618 in that the LRFR shear for the majority of girders is 125% of the LRFR shear for DC2 and DW loads. There are more girders where the ratio is 1.0 because the DC2 and DW load for both LFR and LRFR were zero. There is also more variation within the DC2 and DW loads than in the DC1 loads.

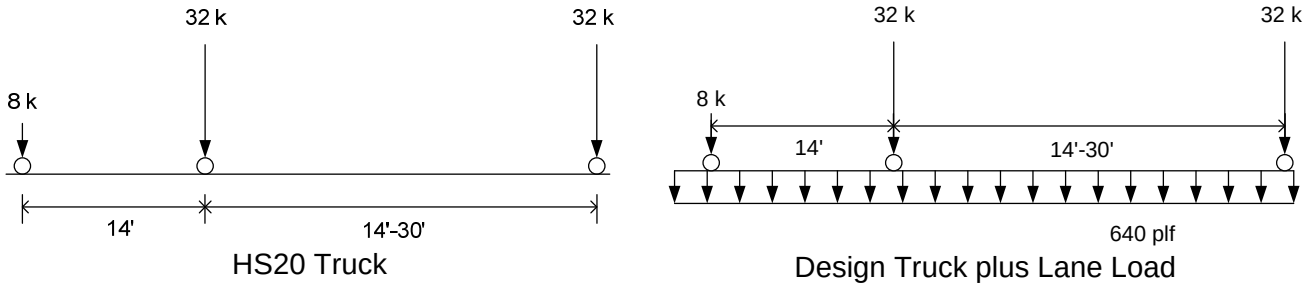


(a) (b)

Figure B-619: Ratio of DC2 LFR Shear to DC2 LRFR Shear (unfactored loads)

B.4.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure B-620. The load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.



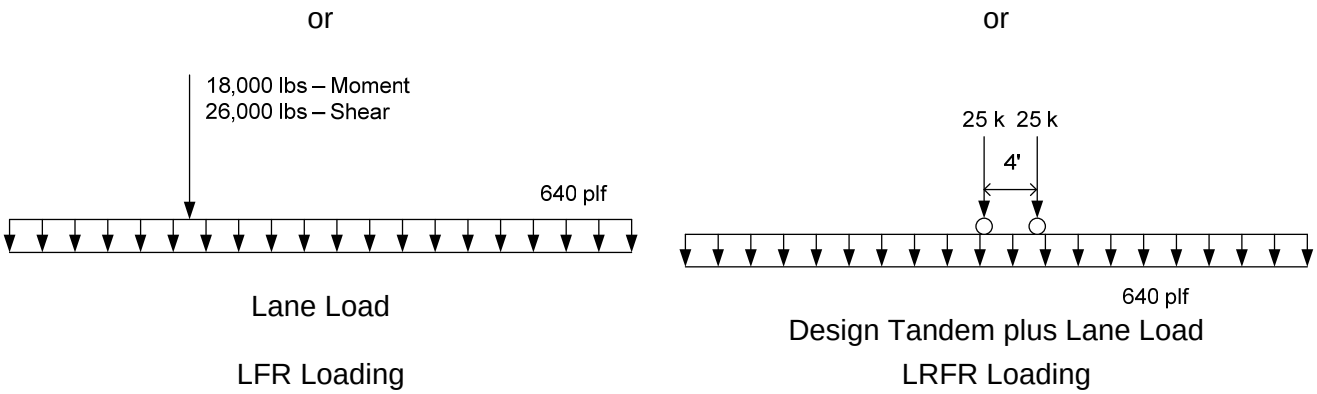
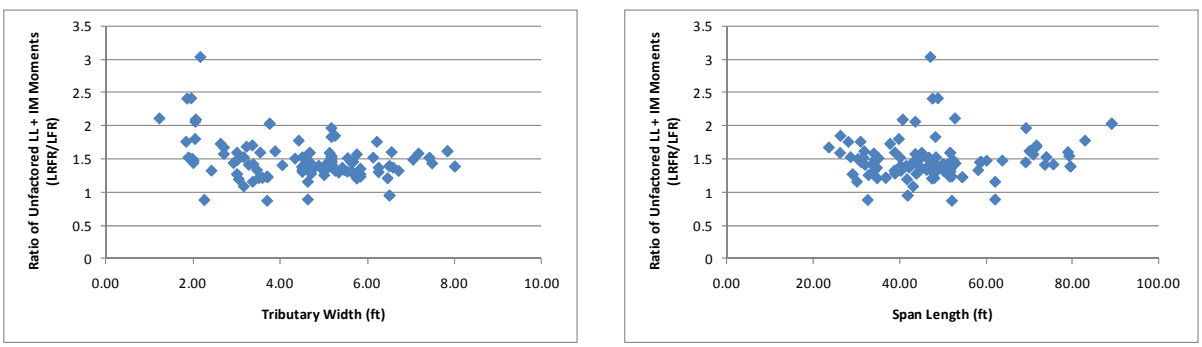


Figure B-620: Vehicle Loadings and Load Factors

B.4.2.1 Moment

B.4.2.1.1 Live Loads

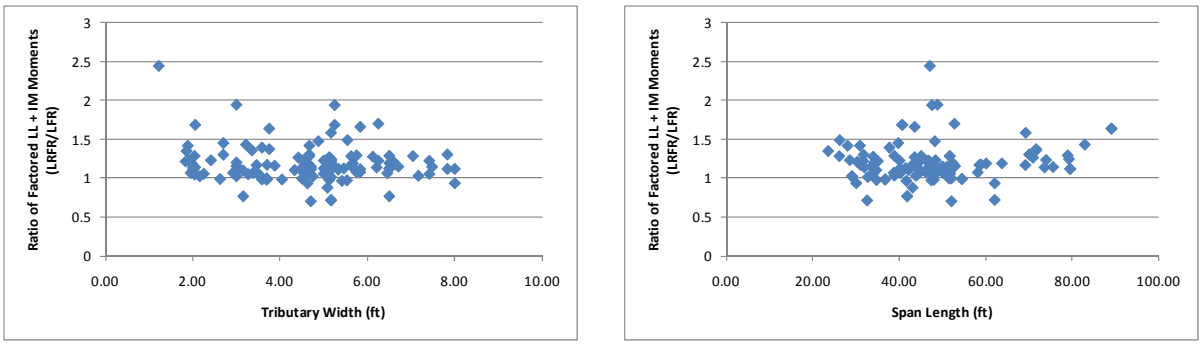
Figure B-621 shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is approximately 1.3 for most of the girders within this subset.



(a) (b)

Figure B-621: Ratio of Unfactored Live Load plus Impact Moments for Design Vehicle (LRFR/LFR)

The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-622 shows that the results have shifted down and are close to 1.0 for most cases.



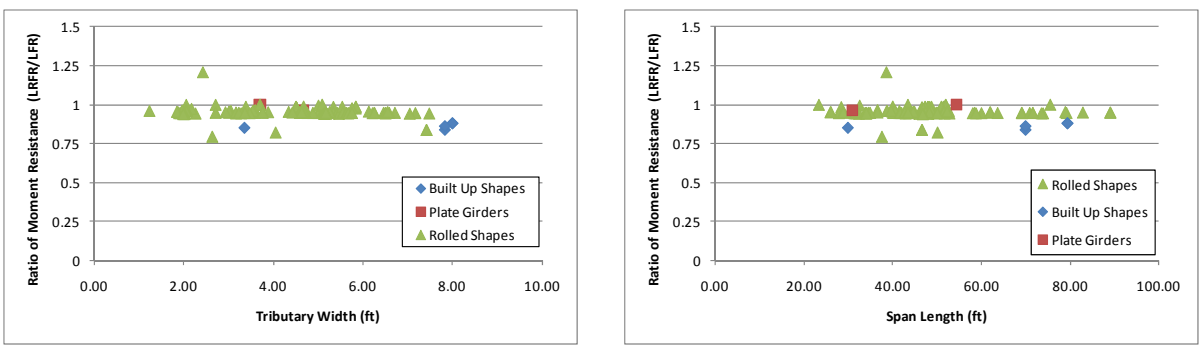
(a) (b)

Figure B-622: Ratio of Factored Live Load plus Impact Moments for Design Vehicle (LRFR/LFR)

While there appear to be trends in the data, the fact that a subset of the LRFR loads is significantly greater than the LFR loads is reason for concern. In several cases, further investigation was conducted into the distribution factors used in the analysis. What was found was the possibility that some of these bridges have timber decks that are being modeled as concrete. This was discovered by dividing the girder spacing by the distribution factor to determine the denominator of the S-over equation. In several cases it came out be exactly what is in the Standard Specification for timber decks on steel girders. BRASS would calculate the LRFR distribution factors using the equations in Table 4.6.2.2.2d-1 for moment and Table 4.6.2.2.3b-1 for shear for a concrete deck on steel girders.

B.4.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure B-623 shows that the ratio of resistance is generally below 1.0.



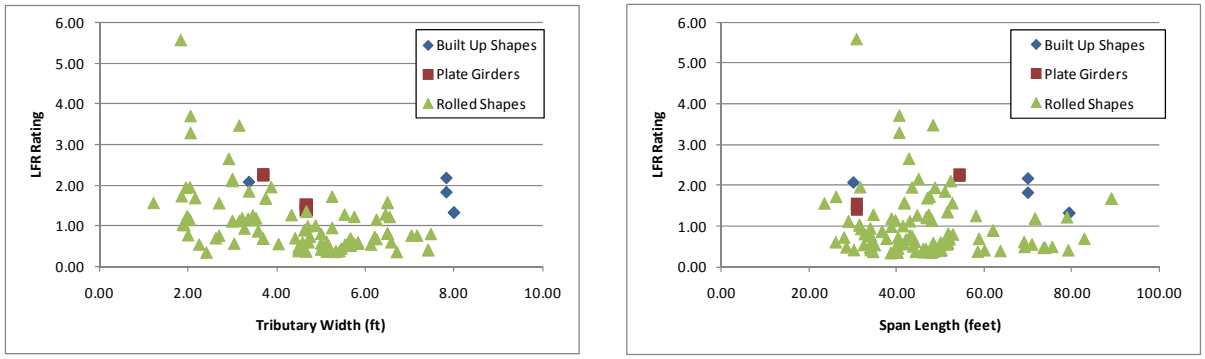
(a) (b)

Figure B-623: Ratio of factored Moment Resistance (LRFR/LFR)

B.4.2.1.3 Rating Factors

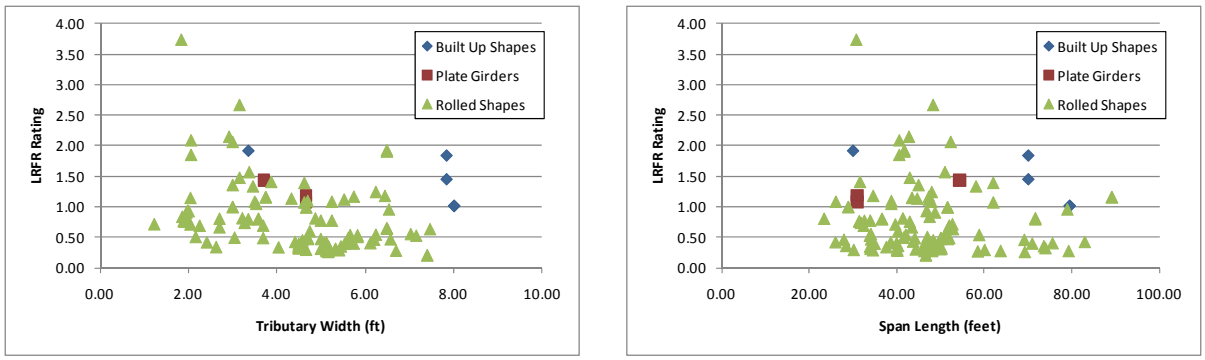
After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (133 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 83 girders with LFR ratings less than 1.0, 95 girders with LRFR ratings less than 1.0, and 80 girders where both the LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. For the design vehicles, a similar number of girders do not have a satisfactory rating for either method. Figure B-624 and Figure B-625

show the LFR rating factors and LRFR rating factors, respectively. Built up shapes and plate girders always have ratings for both methods greater than 1.0 for the design vehicle.



(a) (b)

Figure B-624: LFR Flexure Rating Factors for HS-20 Loading

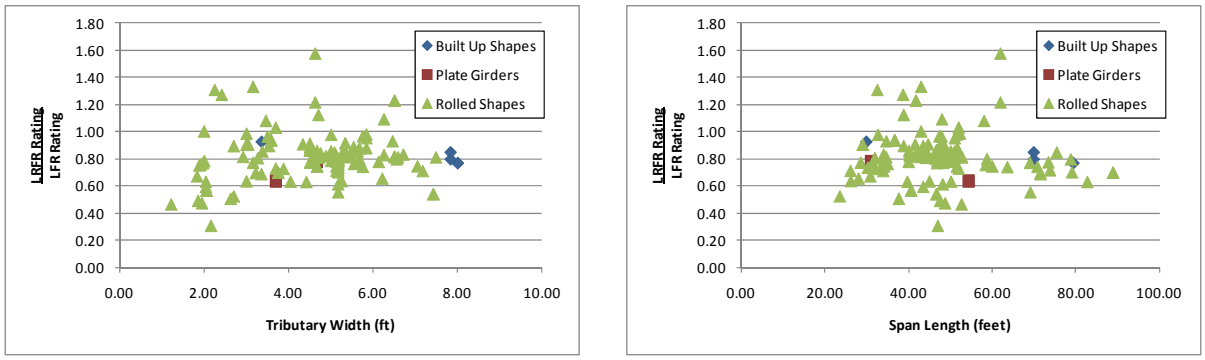


(a) (b)

Figure B-625: LRFR Flexure Rating Factors for HL-93 Loading

B.4.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure B-626. The results indicated that 91% of the girders in this set have LFR ratings greater than LRFR ratings, with most girders having an LRFR rating that is 60-100% of the LFR rating. The only type of girder that had LRFR ratings greater than LFR ratings are rolled shapes.



(a) (b)

Figure B-626: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Vehicles

Figure B-627 shows how girders with ratings less than 1.0 are distributed according to the ratio of LRFR rating to LFR rating. The figure shows that most girders with LRFR ratings less than 1.0 have LRFR ratings that are between 20 and 50% of the corresponding LFR rating. There are several girders with LRFR rating greater than the LFR rating. This figure indicates that switching from LFR to LRFR for non-composite girders will significantly impact the ratings and posting loads.

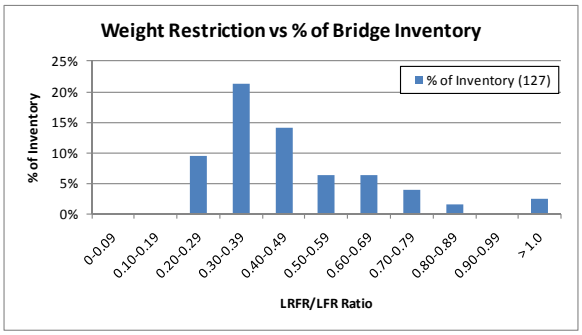
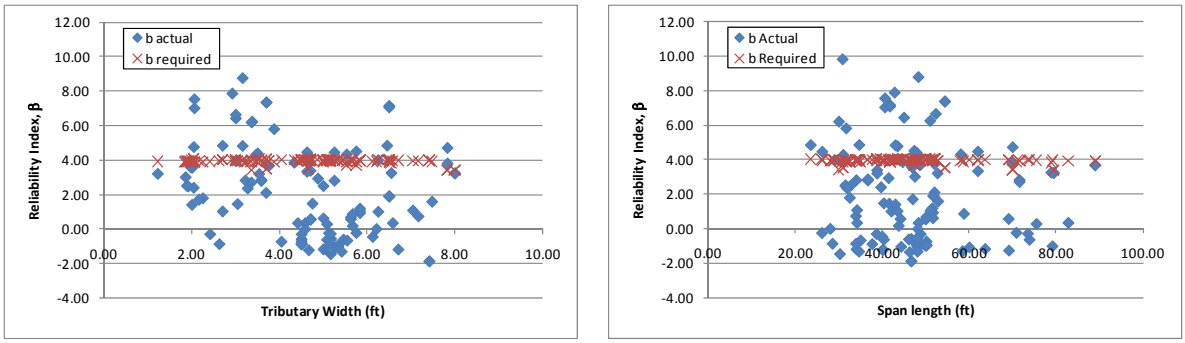


Figure B-627: Distribution of LRFR/LFR Ratio of Girders with LRFR Rating less than 1.0

B.4.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure B-628 shows that a significant number of girders have a reliability index lower than that calculated using the current load factors and applied loads.



(a) (b)

Figure B-628: Flexure Reliability Indices for HL-93 Loading

Figure B-629 shows the reliability index plotted against the LRFR rating factor for moments caused by the HL-93 design load. The figure shows that girders with ratings of 1.0 or above had reliability indices of approximately 3.5. This is the target reliability for the design load at the inventory level.

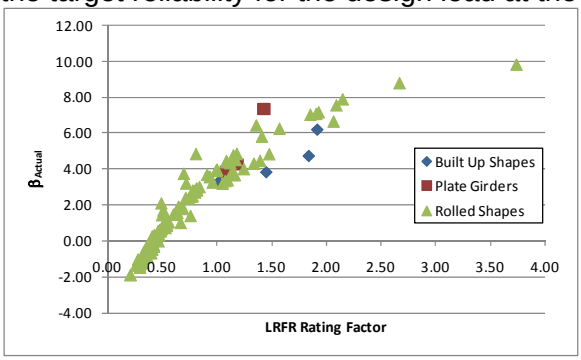


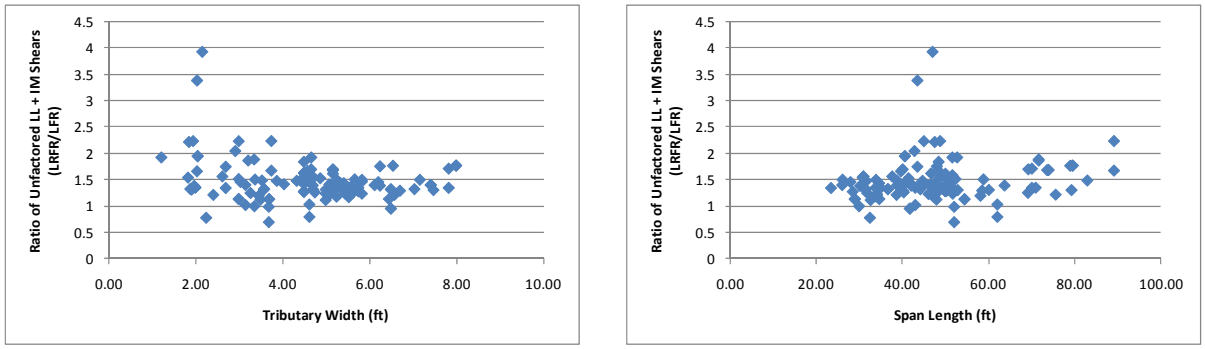
Figure B-629: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Design Load

B.4.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is steel, simple span exterior girders with non-composite concrete (and occasionally timber) decks.

B.4.2.2.1 Live Loads

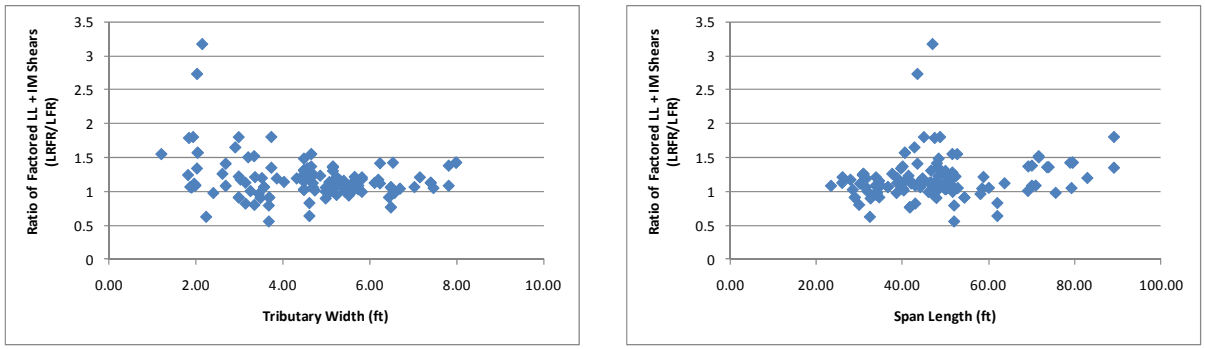
Figure B-630 shows that the ratio of unfactored live load shear varies from 1.0 to 1.7, with some ratios approaching four. This indicates that the unfactored LRFR live load shear is typically greater than the unfactored LFR live load shear.



(a) (b)

Figure B-630: Ratio of Unfactored Live Load plus Impact Shears for Design Vehicle (LRFR/LFR)

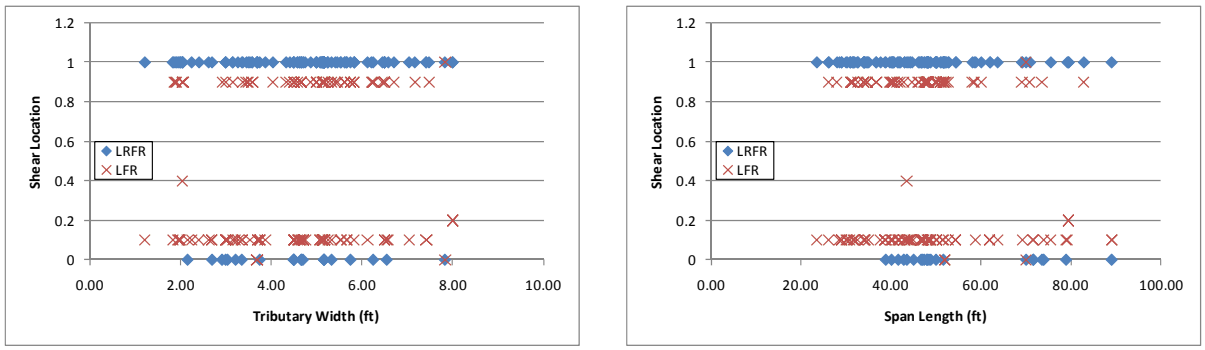
The next step was to compare the factored live loads. This was done by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-631 shows that the ratio of factored live load shears has decreased and is generally between 1.0 and 1.25 for most cases.



(a) (b)

Figure B-631: Ratio of Factored Live Load plus Impact Shears for Design Vehicle (LRFR/LFR)

As shown in Figure B-632, the location of the critical section for shear rating for most girders is the end of the span and at the one tenth point for the LRFR and LFR ratings, respectively. The variation in the factored shears shown in Figure B-631 was exacerbated by the difference in the critical section for shear rating.

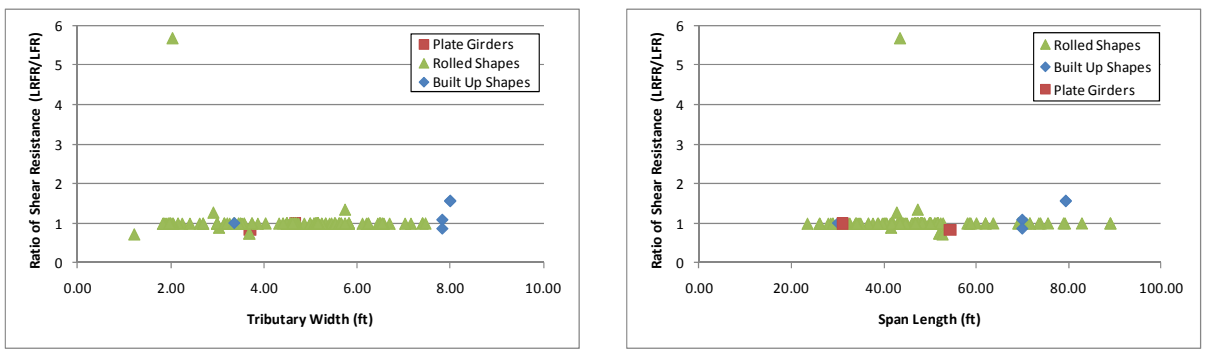


(a) (b)

Figure B-632: Graph of critical shear location for Design Vehicle

B.4.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure B-633 shows that the ratio of resistance is generally around 1.0. The data point near six is the girder with the LFR critical location at the four-tenths point.

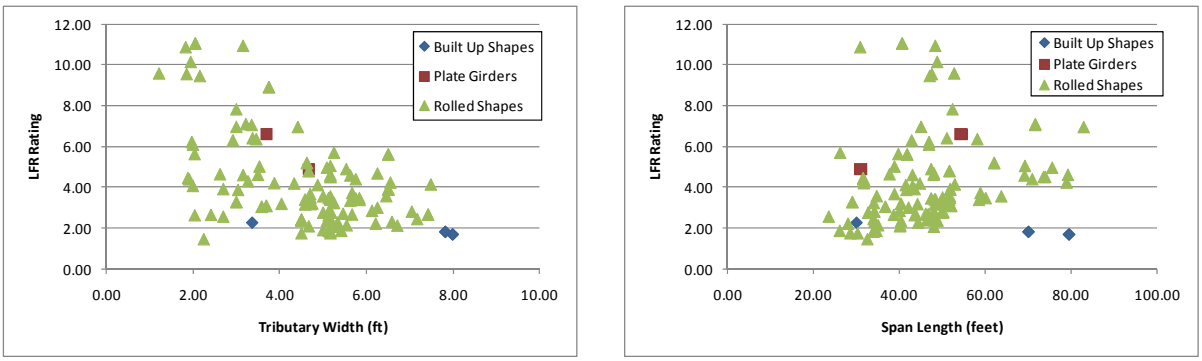


(a) (b)

Figure B-633: Ratio of factored Shear Resistance (LRFR/LFR)

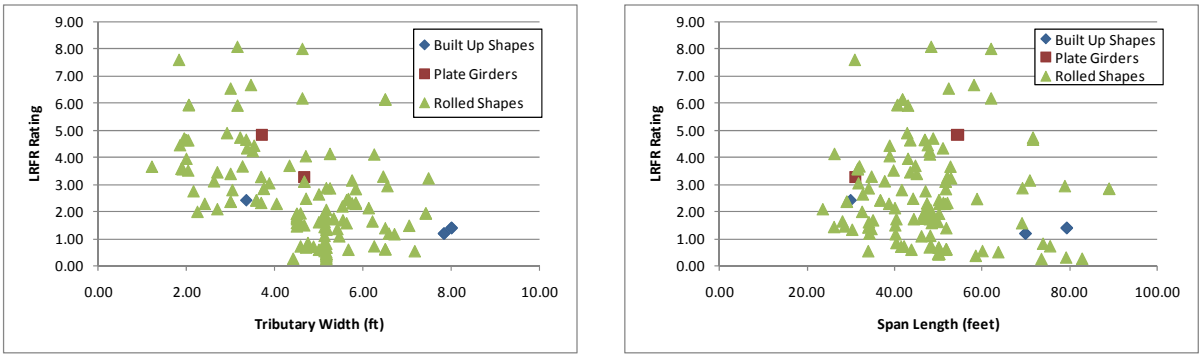
B.4.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the actual rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are zero girders with LFR ratings less than 1.0 and 24 girders with LRFR ratings less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. This is not the case for this subset of bridges. In addition, the LFR rating was greater than the LRFR rating for 92% of the girders in this subset. Figure B-634 and Figure B-635 show the LFR rating factors and LRFR rating factors, respectively. The LFR rating tends to decrease with increasing tributary width and has increasing scatter with increasing span length.



(a) (b)

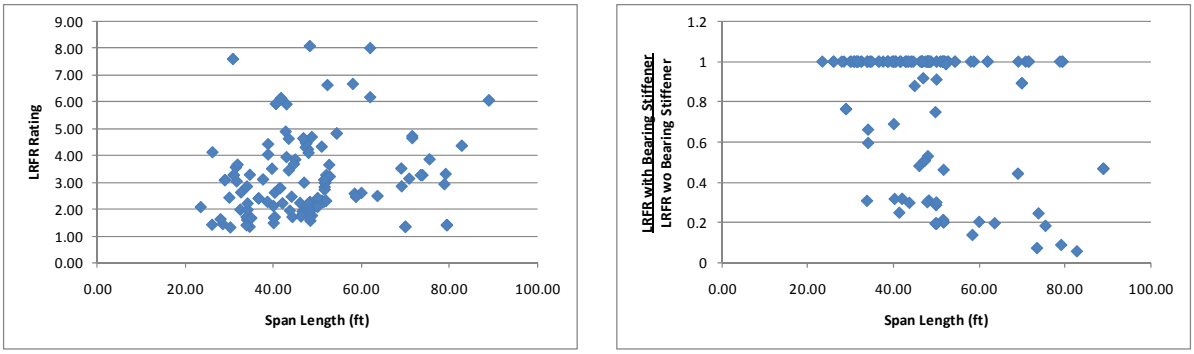
Figure B-634: LFR Shear Rating Factors for HS-20 Loading



(a) (b)

Figure B-635: LRFR Shear Rating Factors for HL-93 Loading

Figure B-636a shows the LRFR ratings when the bearing stiffener rating is ignored. Comparing to Figure B-635b, there are no girders with ratings less than 1.0. Ignoring the bearing stiffener rating eliminates the 24 girders which previously had LRFR ratings less than 1.0. Figure B-636b shows the ratio of LRFR rating including the bearing stiffener rating divided by the LRFR rating excluding the bearing stiffener rating. The reduction in rating when including the bearing stiffener rating is significant with most ratings reduced by 50%. One-third of girders are controlled by the bearing stiffener rating.

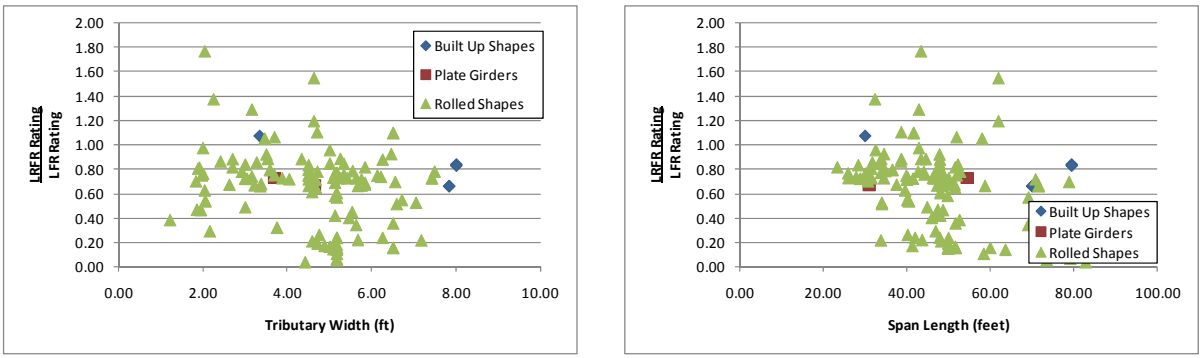


(a) (b)

Figure B-636: Effect of Bearing Stiffener Rating on LRFR Ratings

B.4.2.2.4 Rating Factor Comparisons

Figure B-637 shows the ratio of the LRFR rating to the LFR rating. The results show that the LRFR rating is typically around 60 to 90% of the LFR rating. There are few cases where the LRFR rating is greater than the LFR rating.



(a) (b)

Figure B-637: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Vehicle

Figure B-638 shows that there are no girders with LRFR ratings less than 1.0 for shear due to the design vehicle. Even though the LRFR rating is significantly smaller than the LFR rating in some cases, it is not less than 1.0.

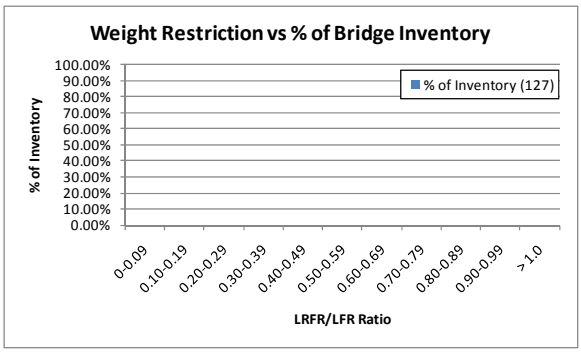
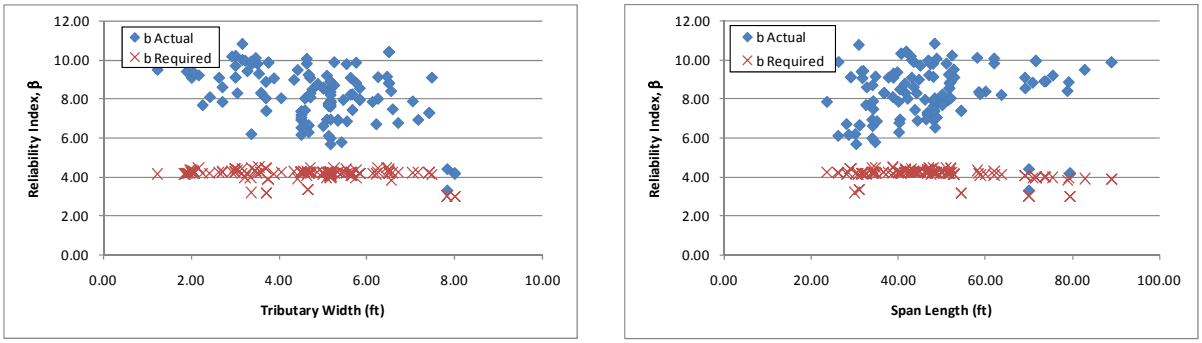


Figure B-638: Distribution of LRFR/LFR ratios for Girders with LRFR Ratings less than 1.0

B.4.2.2.5 Reliability Indices

The next plot was that of the reliability indices. Figure B-639 shows that most girders have a reliability index for shear greater than the required level. There are three girders with reliability indices approaching the required level; these girders have large tributary widths (8 feet) for exterior girders.



(a) (b)

Figure B-639: Shear Reliability Indices for HL-93 Loading

Figure B-640 shows the reliability index plotted against the LRFR rating factor for shear due to the HL-93 Design Load. The figure shows that girders having ratings of 1.0 have a reliability index of approximately 3.5. This is the target level for the design vehicle and inventory ratings.

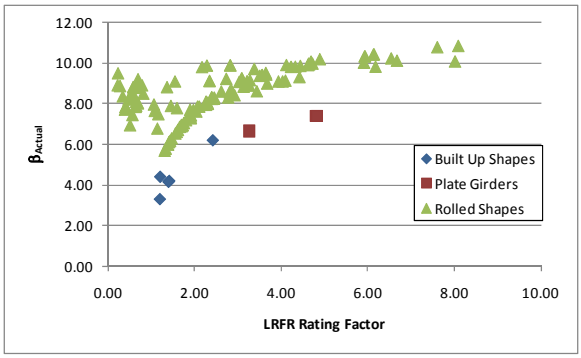


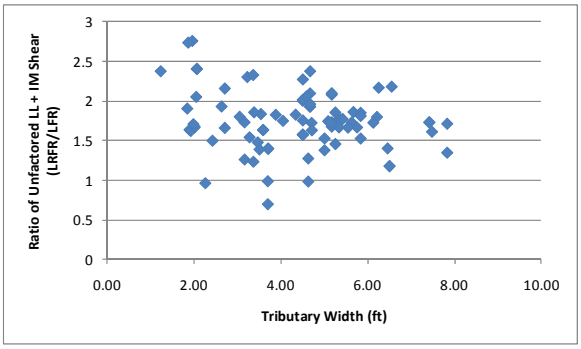
Figure B-640: Shear Reliability Index vs LRFR Shear Rating for HL-93 Design Load

B.4.2.3 Shear-Corrected

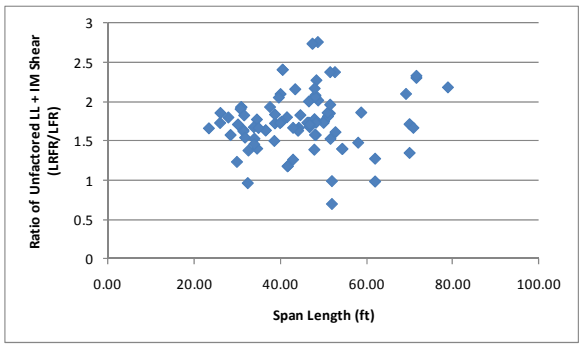
Since a significant number of the simple span girders had the critical shear location for LFR at either the one- or nine-tenths point, the dead and live loads were multiplied by 1.25 to approximate the results at the support. The following graphs show the results of this effort.

B.4.2.3.1 Live Load

Figure B-641 shows that the ratio of unfactored shear has increased from the previous section and is generally in the range of 1.5 to 2.0. This indicates that the LRFR live load produces significantly more shear than the LFR live load.



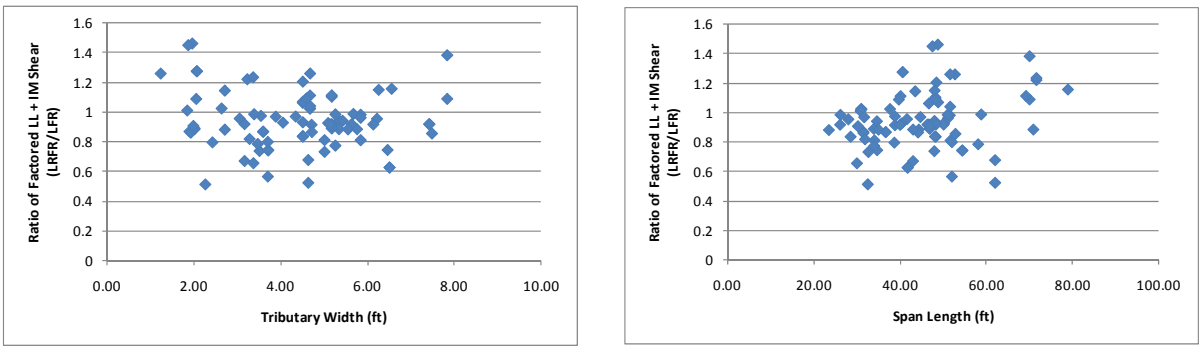
(a)



(b)

Figure B-641: Ratio of Unfactored Live Load plus Impact Shear for Design Vehicle (LRFR/LFR)

The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure B-642 shows that the ratio of factored live load shears has decreased and is between 0.8 and 1.0 for most girders.

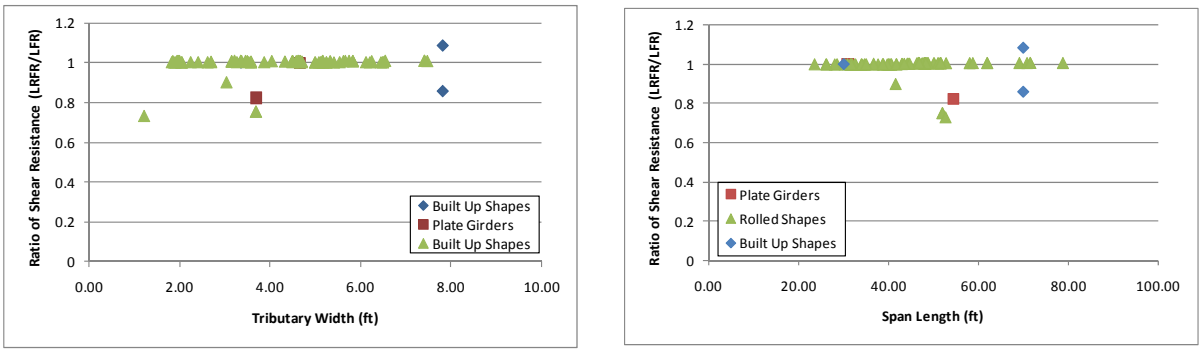


(a) (b)

Figure B-642: Ratio of Factored Live Load plus Impact Shear for Design Vehicle (LRFR/LFR)

B.4.2.3.2 Resistance

The resistances used in this comparison (see Figure B-643) are the same as those shown in the previous section. It was assumed that the resistance would not change between the support and the tenth-point; this assumption may not be valid due to tension field action being used for interior panels but not being allowed for end panels. As shown in Figure B-643, the assumption appears to be reasonable as there are few girders that are not 1.0.

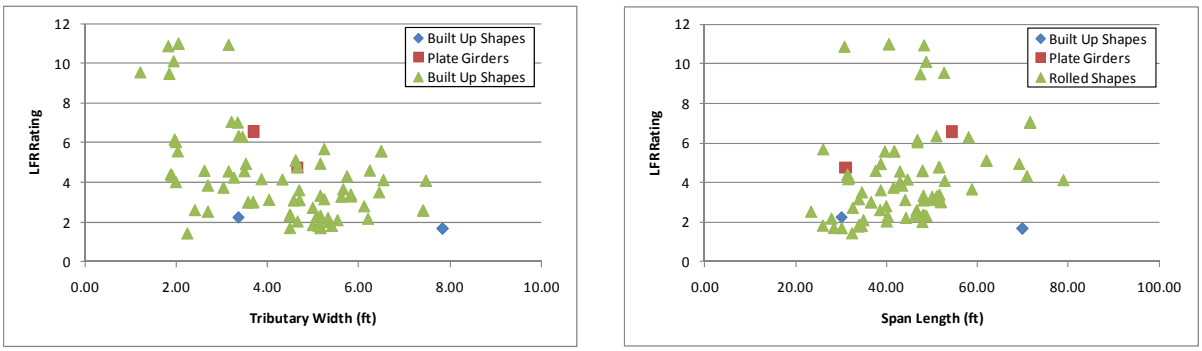


(a) (b)

Figure B-643: Ratio of factored Shear Resistance (LRFR/LFR)

B.4.2.3.3 Rating Factors

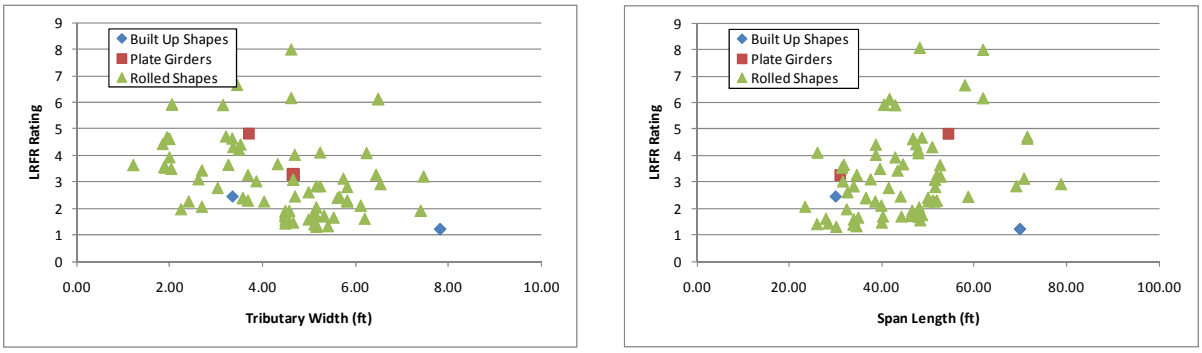
The LFR rating factors were calculated using the loads from the one- or nine-tenths point multiplied by 1.25 such that they would approximate the shear at the support. The LFR rating factors are shown in Figure B-644.



(a) (b)

Figure B-644: LFR Shear Rating Factors for HS-20 Loading

The LRFR rating factors are calculated at the support and are used as obtained from BRASS. The LRFR rating factors are shown in Figure B-645.

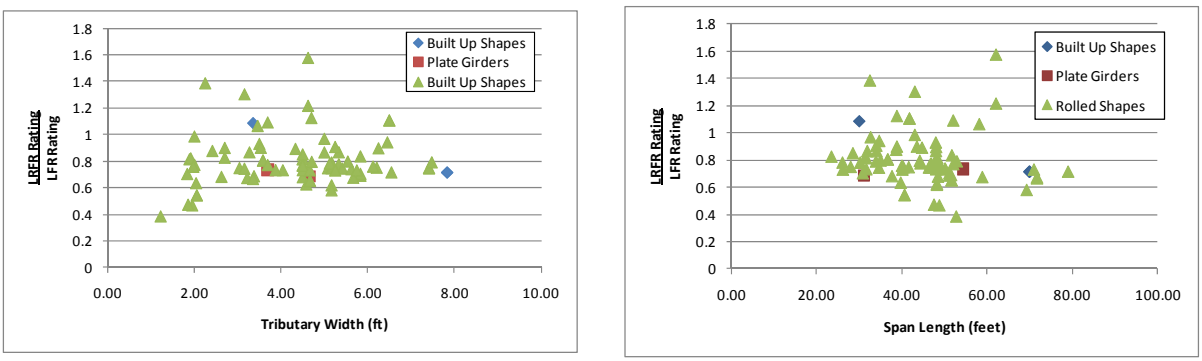


(a) (b)

Figure B-645: LRFR Shear Rating Factors for HL-93 Loading

B.4.2.3.4 Rating Factor Comparison

The after calculating the LFR rating factor at the support, the two rating factors were compared by dividing the LRFR rating by the LFR rating. The results of this comparison are shown in Figure B-646. The results are similar to those calculated with the results at the different locations. Most girders have an LRFR rating that is 60 to 90% of the LFR rating.

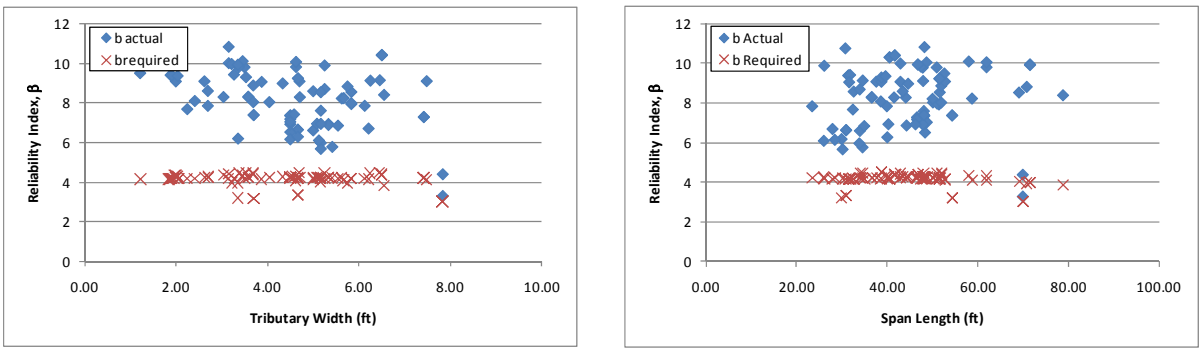


(a) (b)

Figure B-646: LRFR Shear rating divided by LFR Shear rating for Design Vehicle

B.4.2.3.5 Reliability Indices

The reliability indices shown in Figure B-647 are the same as those shown above in Figure B-639. The actual reliability index would decrease because the mean total load will increase, while the required reliability index would increase because the increase in mean total load is less than the increase in the mean factored load. This would possibly cause more girders to have a reliability index less than the code required value.



(a) (b)

Figure B-647: Shear Reliability Indices for HL-93 Loading

B.4.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-648. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

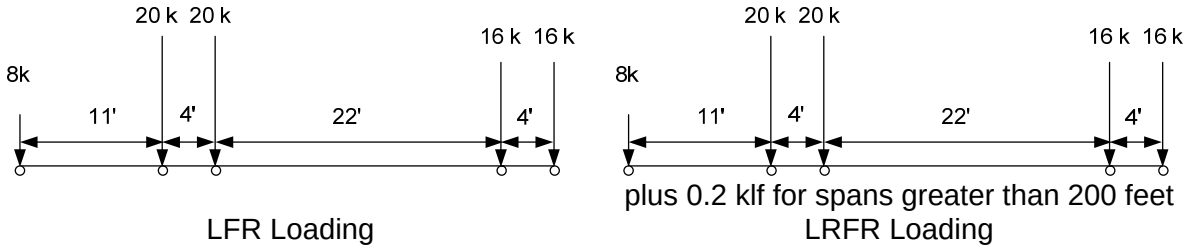


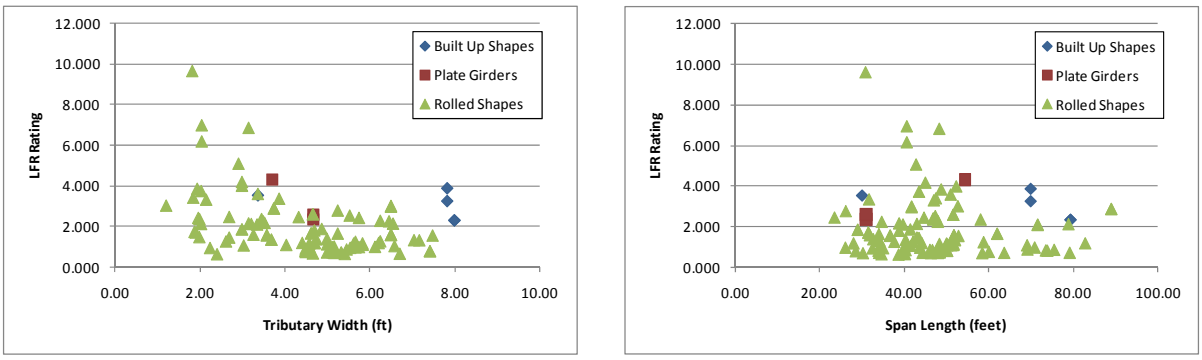
Figure B-648: Vehicle Loadings and Load Factors

B.4.3.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the DE-07 Vehicle.

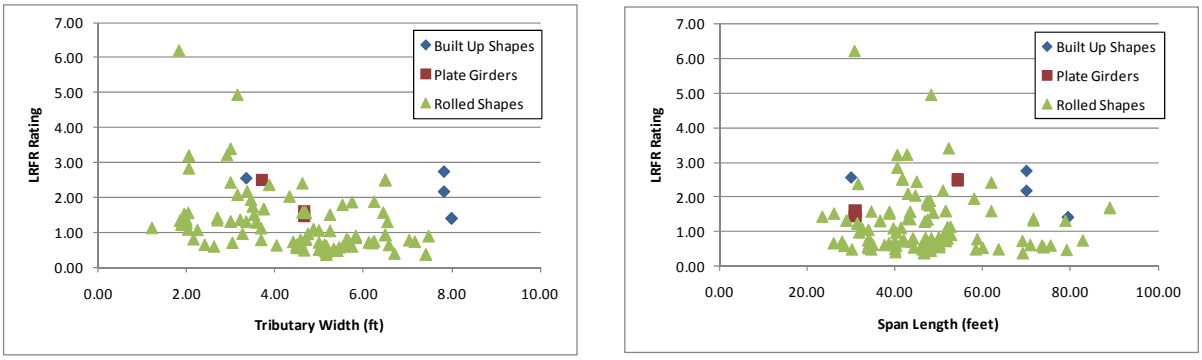
B.4.3.1.1 Rating Factors

Figure B-649 and Figure B-650 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 46 girders with an LFR rating less than 1.0, 72 girders with an LRFR rating less than 1.0, and 45 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 98% of the girders in this subset.



(a) (b)

Figure B-649: LFR Flexure Rating Factors for DE-07 Vehicle

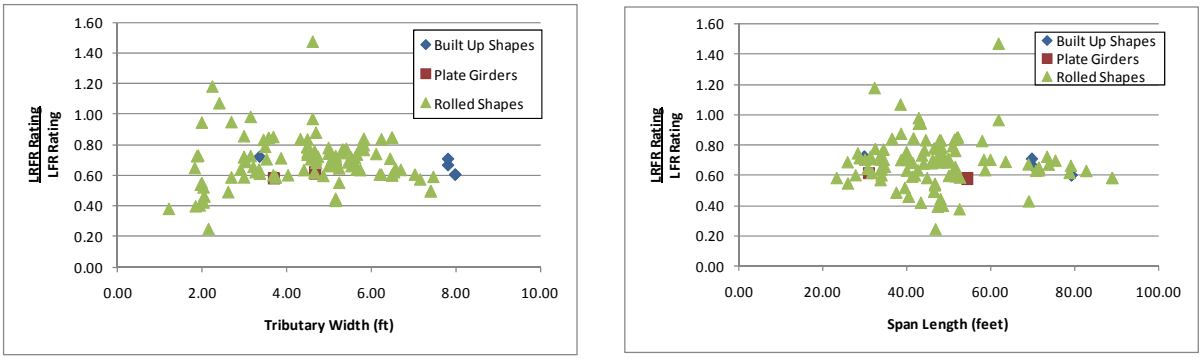


(a) (b)

Figure B-650: LRFR Flexure Rating Factors for DE-07 Vehicle

B.4.3.1.2 Rating Factor Comparisons

Figure B-651 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.6 to 0.8 with near 1.0. 98% of girders have LFR ratings higher than the LRFR ratings.

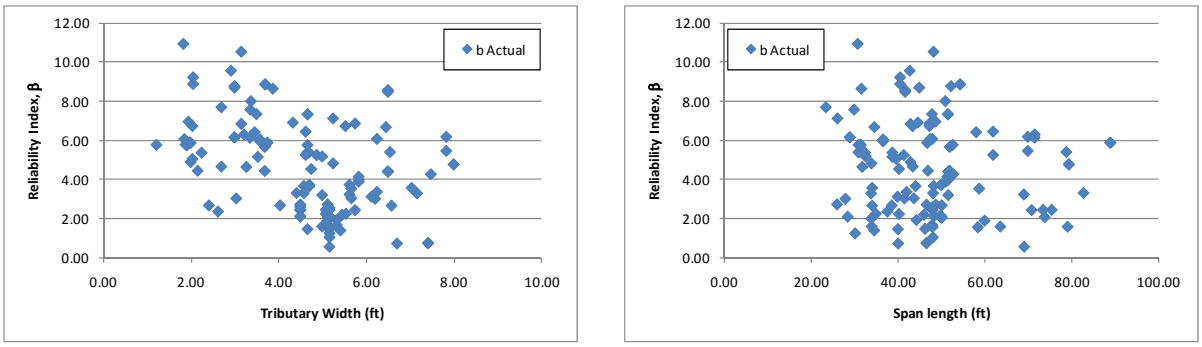


(a) (b)

Figure B-651: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

B.4.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-652 shows that a portion of the girders have a reliability index based upon girder strength that is less than the assumed value of 2.5 used in the the development of the MBE. This indicates that the girders with ratings less than 1.0 may also not have the code required level of reliability.



(a) (b)

Figure B-652: Flexure Reliability Indices for DE-07 Vehicle

Figure B-653 shows the reliability index plotted against the LRFR rating for moment caused by the DE-07 vehicle. The figure shows that girders with rating factors greater than 1.0 have reliability indices greater than 4.0. This is greater than the target reliability of 2.5 for routine permit vehicles. Reducing the LRFR live load factor would result in girders with ratings of 1.0 having a reliability index of approximately 2.5.

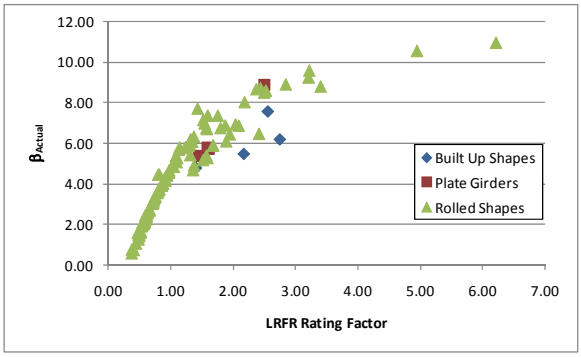


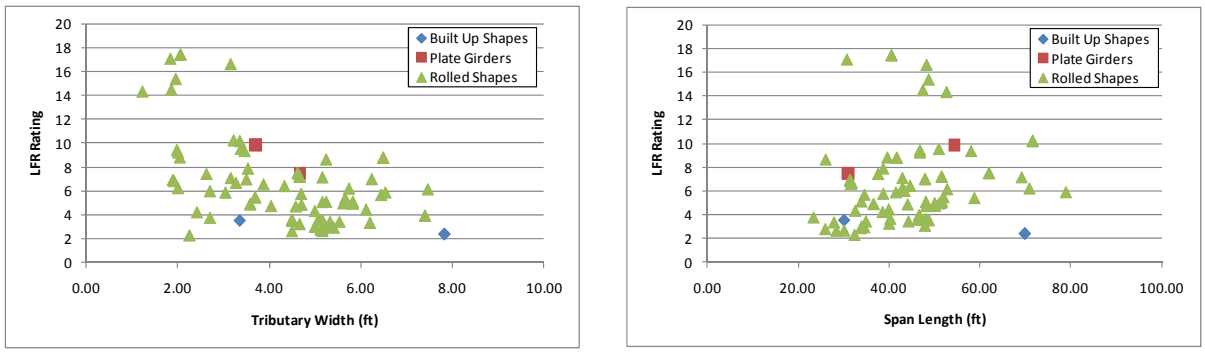
Figure B-653: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

B.4.3.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0, these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

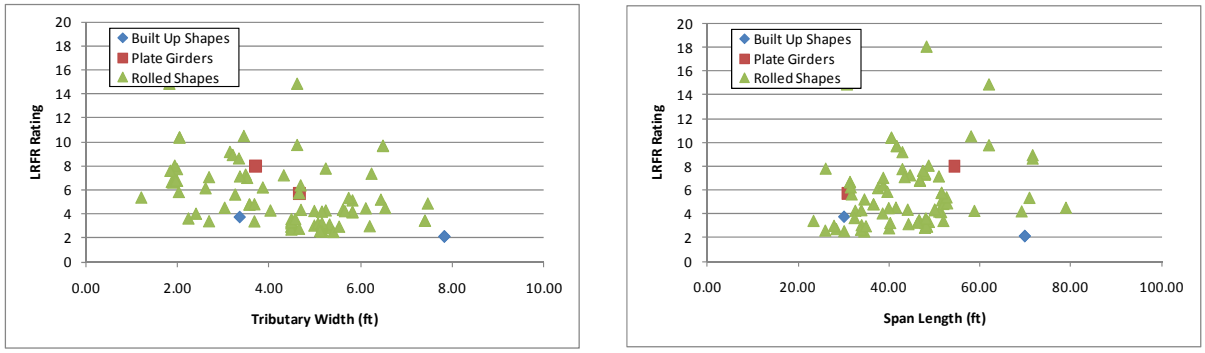
B.4.3.2.1 Rating Factors

For shear, there are 14 girders that have rating factors less than 1.0 for LRFR and zero girders for LFR. In this situation, 10.5% of girders are affected by rating using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 96% of the girders in this subset. Figure B-654 and Figure B-655 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-654: LFR Shear Ratings for DE-07 Vehicle

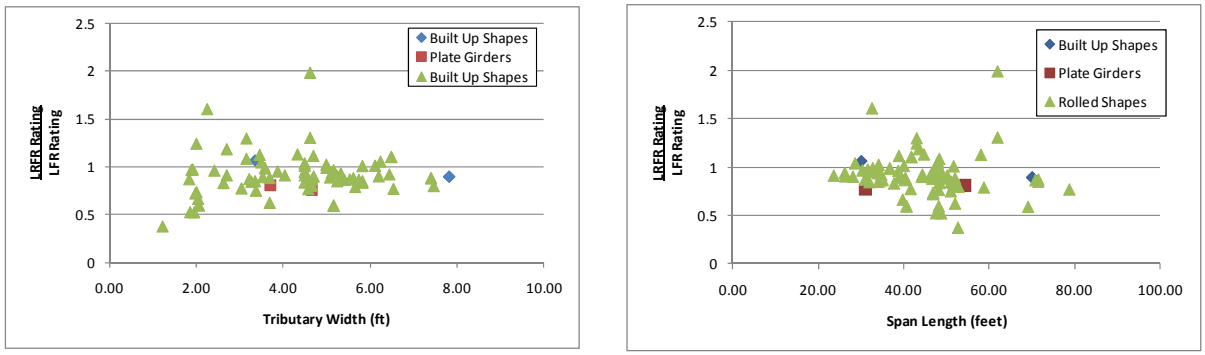


(a) (b)

Figure B-655: LRFR Shear Ratings for DE-07 Vehicle

B.4.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure B-656 show the comparison of rating factors. The ratio is generally between 0.75 and 1.0, which is generally better than what was seen for other groups. 96% of girders have higher LFR ratings than LRFR ratings for this group.

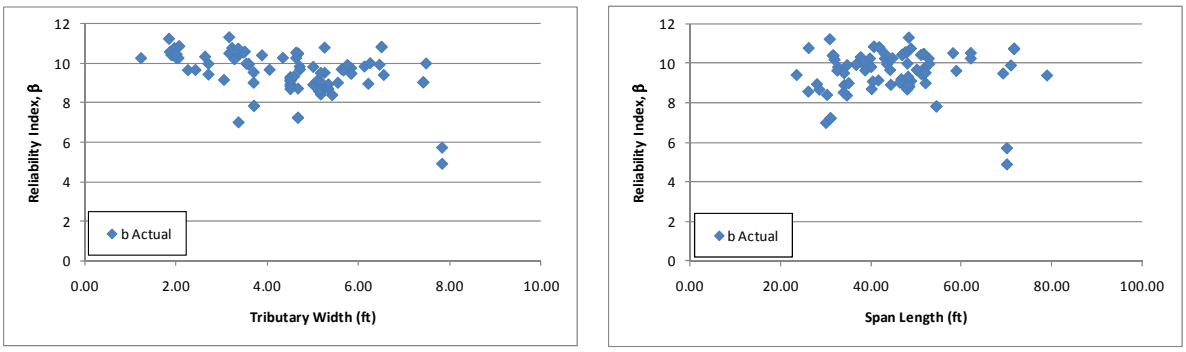


(a) (b)

Figure B-656: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

B.4.3.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index shown in Figure B-657 is greater than the assumed value of 2.5 used in the development of the MBE.



(a) (b)

Figure B-657: Shear Reliability Indices for DE-07 Vehicle

Figure B-658 shows the reliability index plotted against the LRFR rating for shear from the DE-07 vehicle. The figure shows that girders passing rating typically have reliability indices of greater than 3.5. This value is greater than the target reliability index of 2.5. Reducing the LRFR live load factors would result in girders passing the rating and having a reliability index near the target value. The girders with low ratings and high reliability are controlled by the bearing stiffener rating; the reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

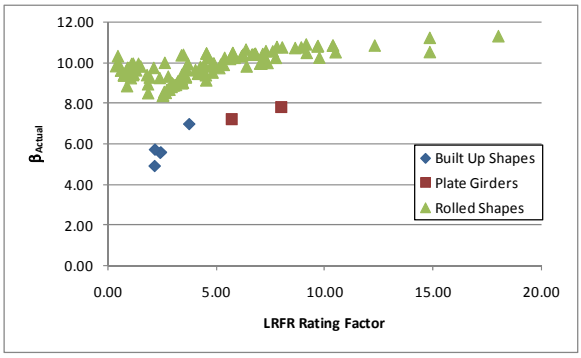


Figure B-658: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

B.4.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-659. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

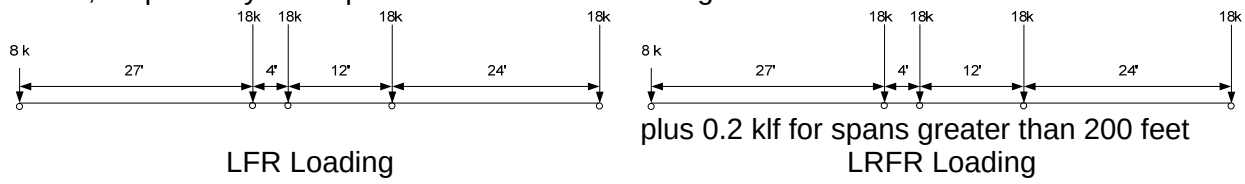


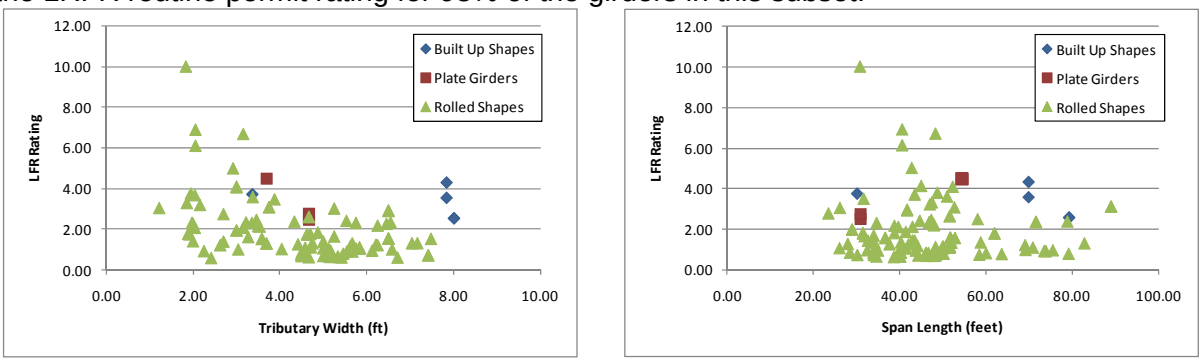
Figure B-659: Vehicle Loadings and Load Factors

B.4.4.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the FL-04 Vehicle.

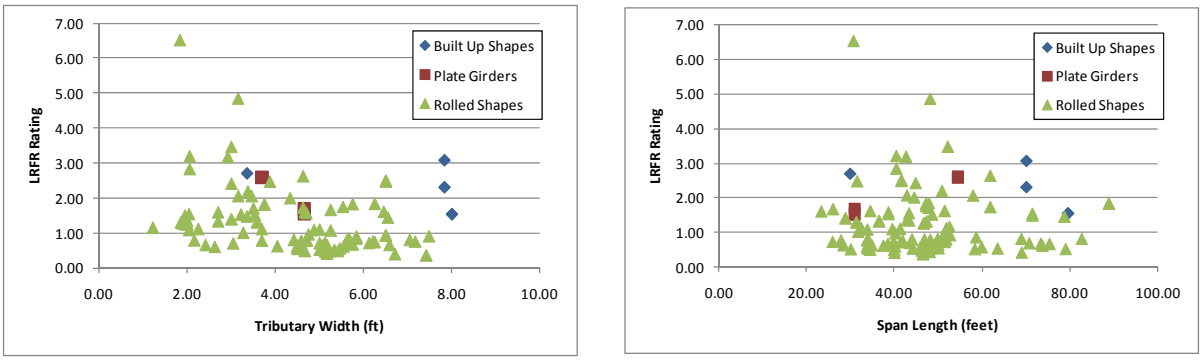
B.4.4.1.1 Rating Factors

Figure B-660 and Figure B-661 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 44 girders with an LFR rating less than 1.0, 71 girders with an LRFR rating less than 1.0, and 43 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 98% of the girders in this subset.



(a) (b)

Figure B-660: LFR Flexure Rating Factors for FL-04 Vehicle

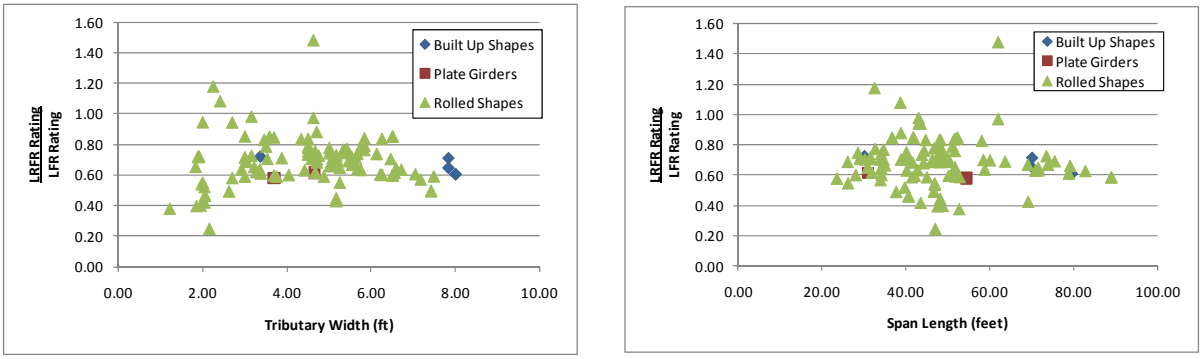


(a) (b)

Figure B-661: LRFR Flexure Rating Factors for FL-04 Vehicle

B.4.4.1.2 Rating Factor Comparisons

Figure B-662 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. Most girders have an LRFR rating that is 60 to 80% of the LFR rating. 98% of girders in this group have an LFR rating that is greater than the LRFR rating.

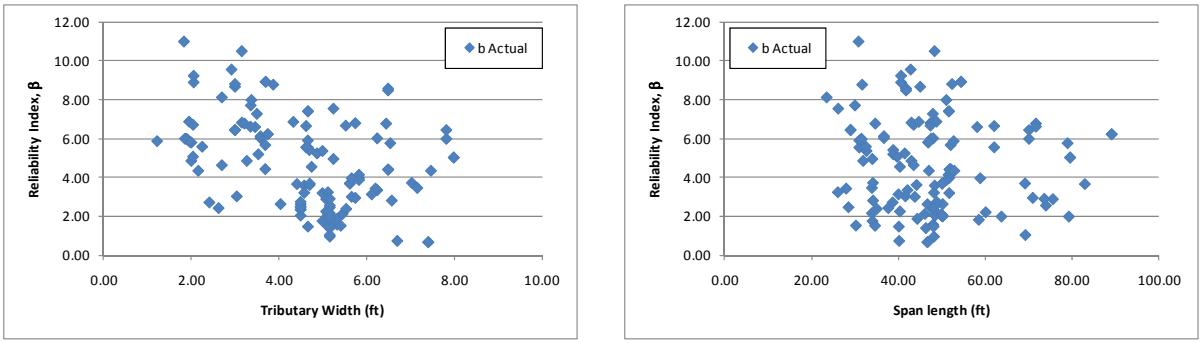


(a) (b)

Figure B-662: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

B.4.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-663 shows that a number of girders have an actual reliability index that is less than that used in the development of the MBE. The reliability index used to develop the MBE for routine permit vehicles is 2.5.



(a) (b)

Figure B-663: Flexure Reliability Indices for FL-04 Vehicle

Figure B-664 shows the reliability index plotted against the LRFR rating for moment caused by the FL-04 vehicle. The figure shows that girders passing rating have reliability indices of approximately 4.0 which is higher than the target value of 2.5. Reducing the LRFR live load factor would shift the graph to the right on the horizontal axis, such that the reliability index for a girder rating at 1.0 would be approximately 2.5.

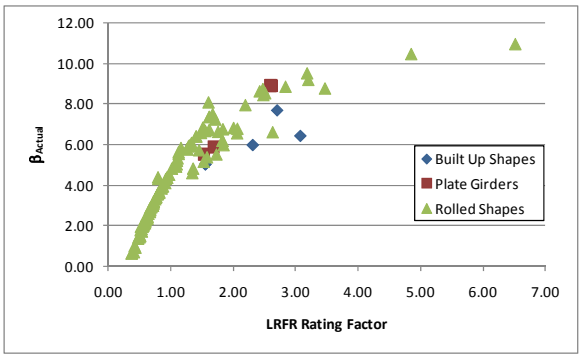


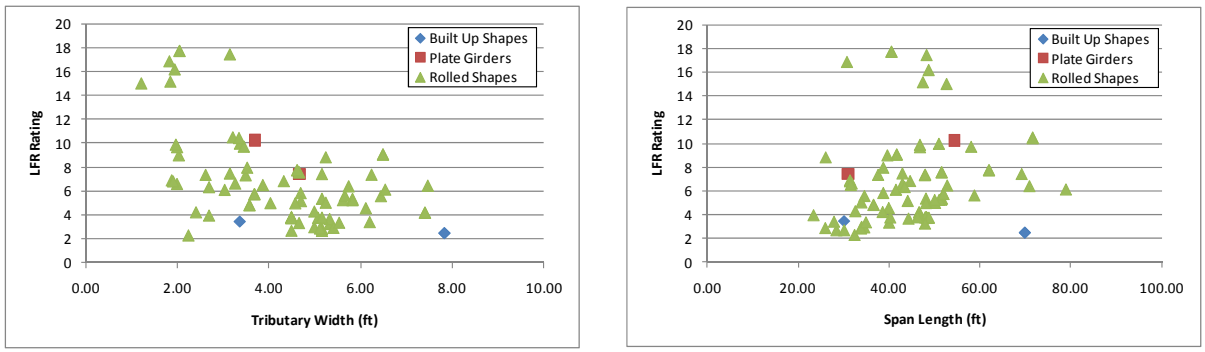
Figure B-664: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

B.4.4.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0, these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

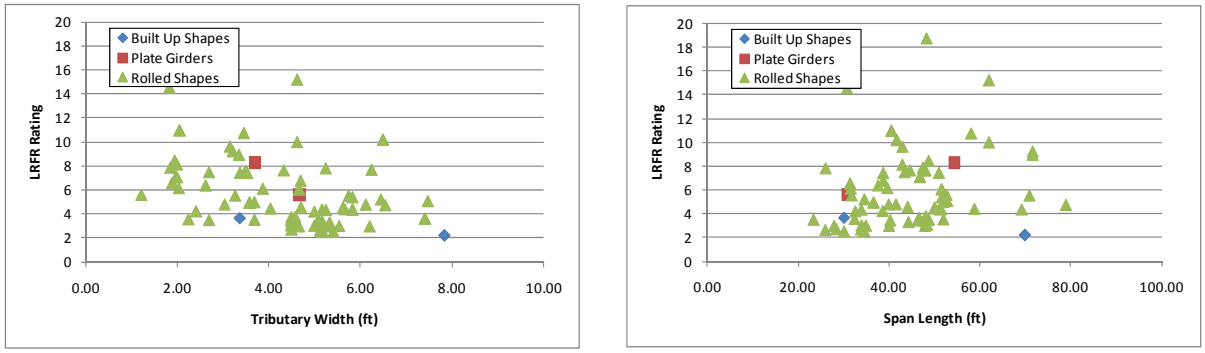
B.4.4.2.1 Rating Factors

For shear, there are 12 girders that have rating factors less than 1.0 for LRFR while no girders have a ratings less than 1.0 for LFR. In this situation, 9.0% of girders are affected by rating using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 96% of the girders in this subset. Figure B-665 and Figure B-666 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-665: LFR Shear Ratings for FL-04 Vehicle

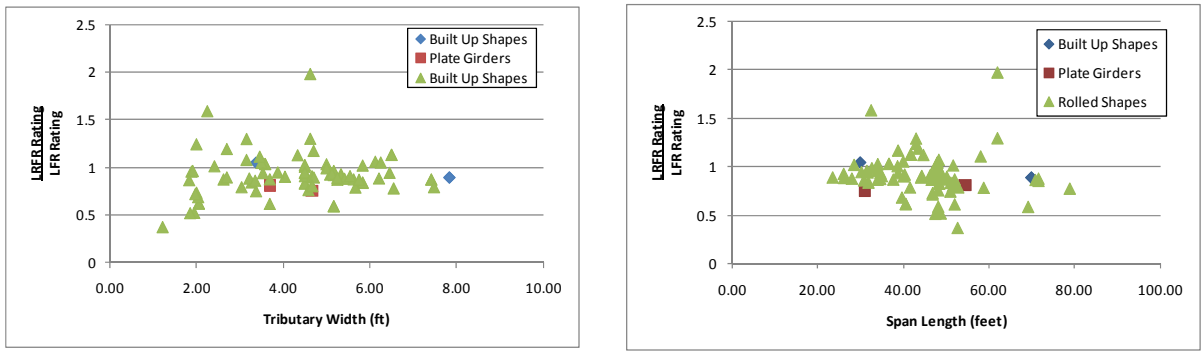


(a) (b)

Figure B-666: LRFR Shear Ratings for FL-04 Vehicle

B.4.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure B-667 shows the comparison of rating factors. The LRFR rating is generally between 70 and 100% of the LFR rating. 96% of girders in this group have higher LFR ratings than LRFR ratings.

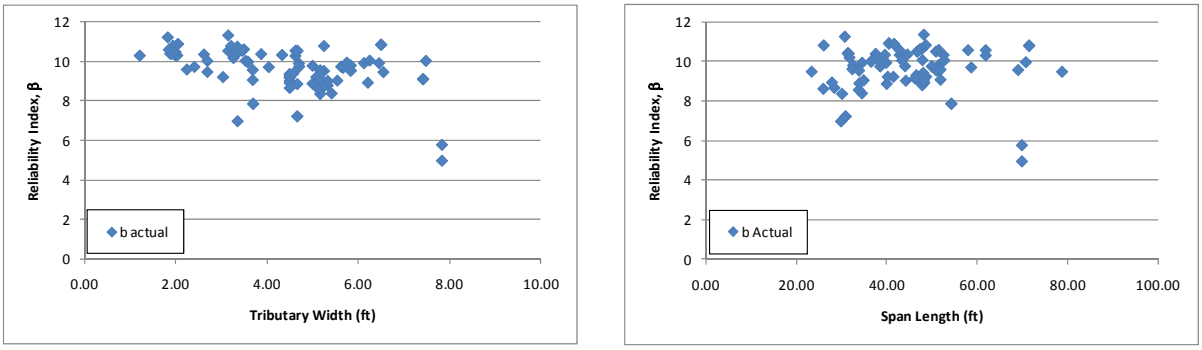


(a) (b)

Figure B-667: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

B.4.4.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index shown in Figure B-668 is greater than the value of 2.5 used in the development of the MBE for routine permit vehicles.



(a) (b)

Figure B-668: Shear Reliability Indices for FL-04 Vehicle

Figure B-669 shows the reliability index plotted against the LRFR rating for shear due to the FL-04 Vehicle. The figure shows that girders passing rating have reliability indices greater than the target value of 2.5. Reducing the live load factor would reduce the reliability index for girders having a rating of 1.0. The girders with high reliability and lower ratings are those controlled by the bearing stiffener rating; the reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

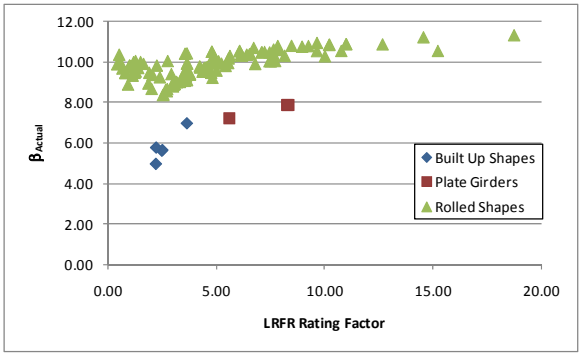


Figure B-669: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

B.4.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-670. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

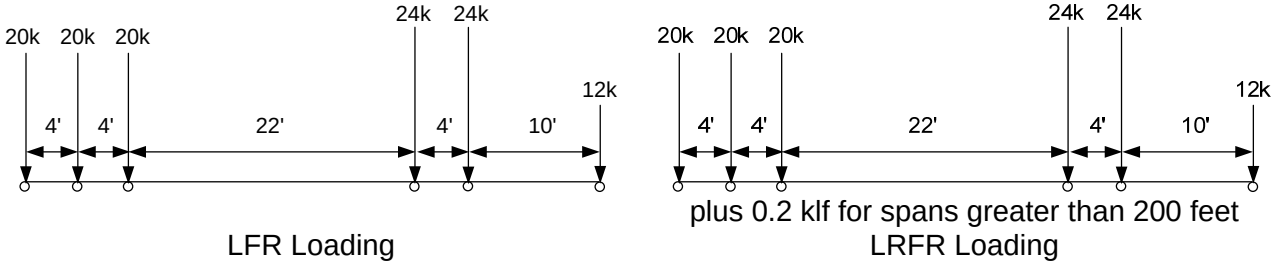


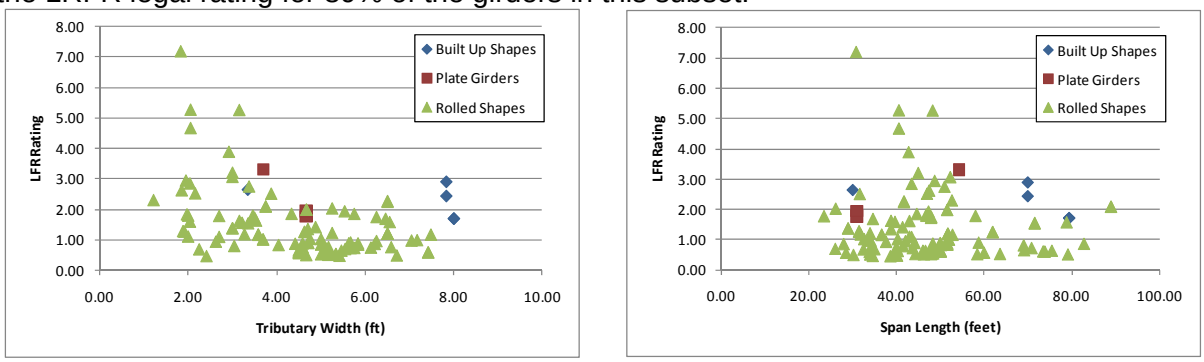
Figure B-670: Vehicle Loadings and Load Factors

B.4.5.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the IL-01 Vehicle.

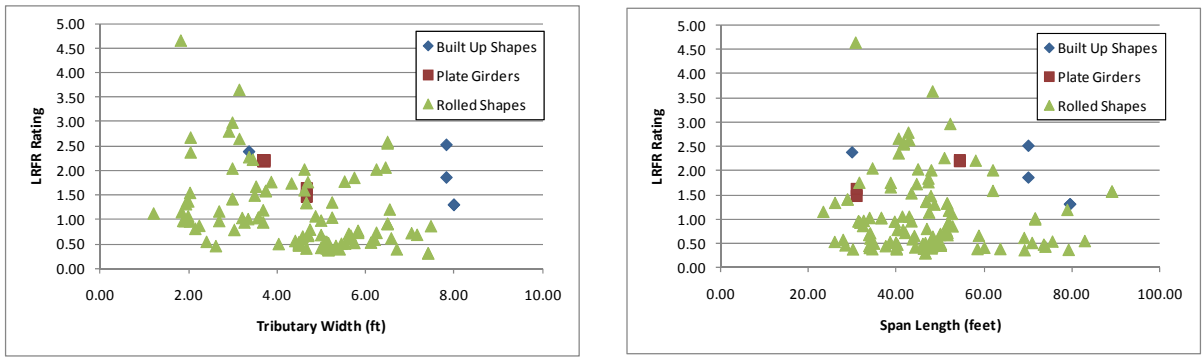
B.4.5.1.1 Rating Factors

Figure B-671 and Figure B-672 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 65 girders with an LFR rating less than 1.0, 78 girders with an LRFR rating less than 1.0, and 65 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 89% of the girders in this subset.



(a) (b)

Figure B-671: LFR Flexure Rating Factors for IL-01 Vehicle

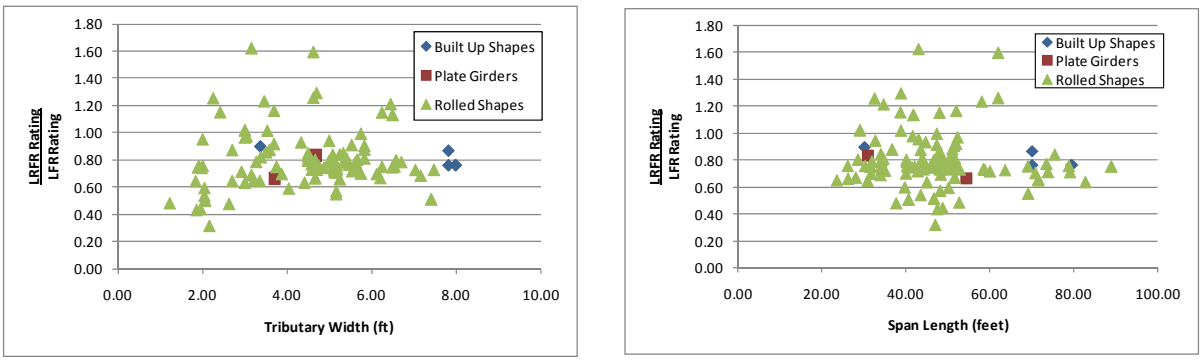


(a) (b)

Figure B-672: LRFR Flexure Rating Factors for IL-01 Vehicle

B.4.5.1.2 Rating Factor Comparisons

Figure B-673 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is typically 60 to 80% of the LFR rating; 89% of girders have LFR ratings greater than LRFR ratings.

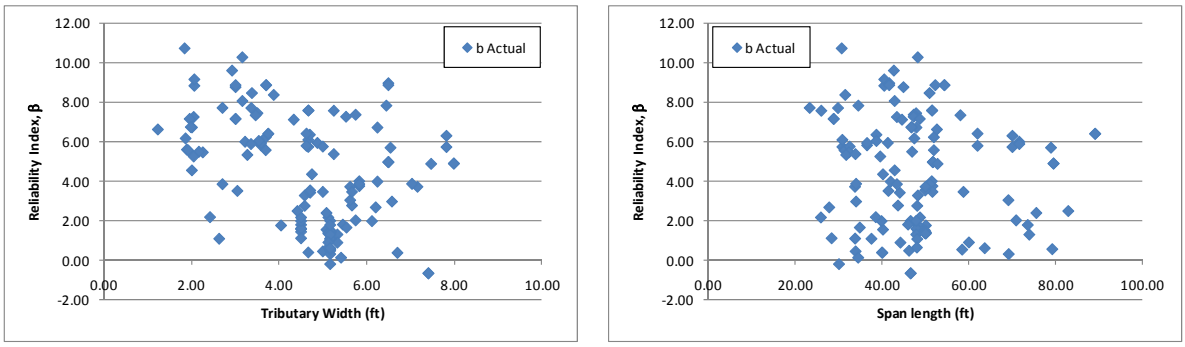


(a) (b)

Figure B-673: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

B.4.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-674 shows that a portion of the girders have a reliability index based upon girder strength that is less than the value of 3.5 assumed in the development of the MBE. Most of the girders that do not have the required level of reliability have larger tributary widths.



(a) (b)

Figure B-674: Flexure Reliability Indices for IL-01 Vehicle

Figure B-675 shows the reliability index plotted against the LRFR rating for moment due to the IL-01 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index between 4.0 and 6.0, which is greater than the target reliability of 3.5. This indicates that the LRFR live load factors could be reduced. This would reduce the reliability index of a girder passing rating to approximately the target reliability of 3.5.

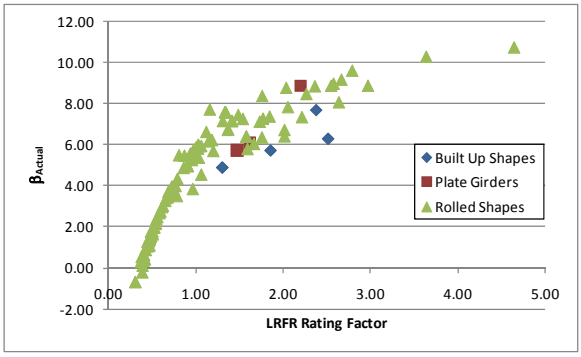


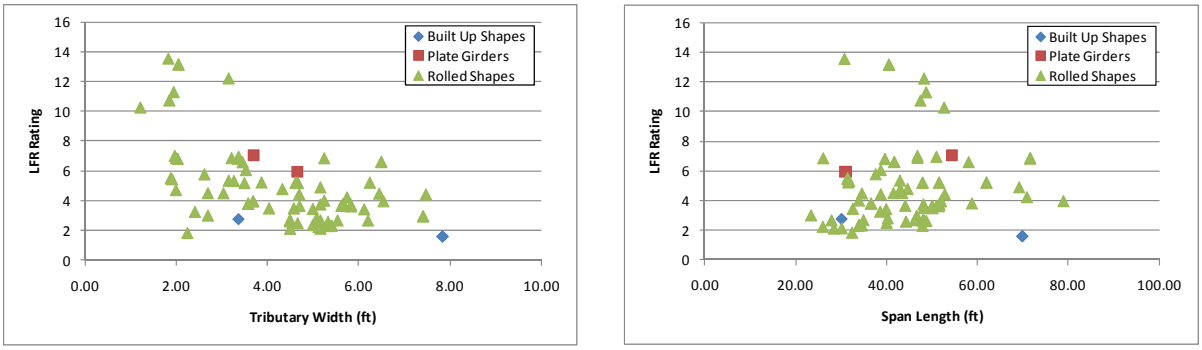
Figure B-675: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

B.4.5.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0, these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

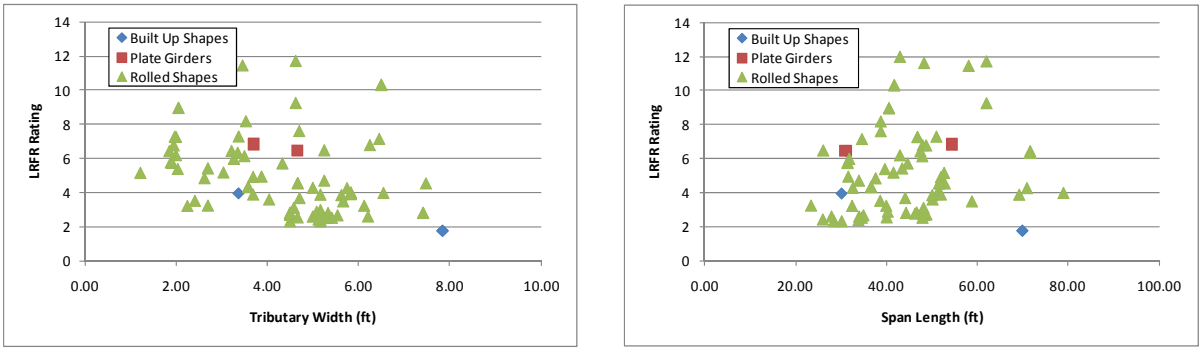
B.4.5.2.1 Rating Factors

For shear, there are 18 girders that have LRFR rating factors less than 1.0 and zero girders with LFR rating factors less than 1.0. In this situation, 13.5% of girders are affected by rating using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 89% of the girders in this subset. Figure B-676 and Figure B-677 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-676: LFR Shear Ratings for IL-01 Vehicle

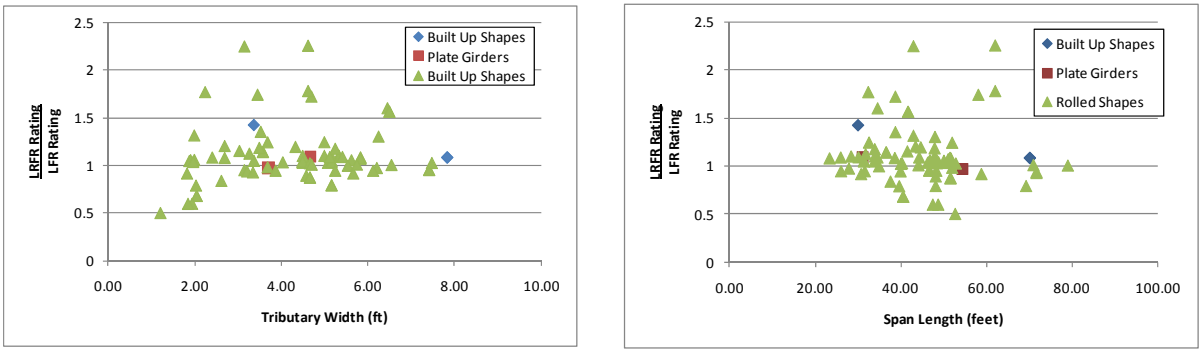


(a) (b)

Figure B-677: LRFR Shear Ratings for IL-01 Vehicle

B.4.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure B-678 shows the comparison of rating factors. The ratio is generally between 0.9 and 1.1, with the lowest ratios being from girders that are closely spaced. The LFR rating is greater than the LRFR rating for 89% of the girders. The LRFR rating is higher than the LFR rating because of the single lane loaded without multiple presence loading applied for LRFR.

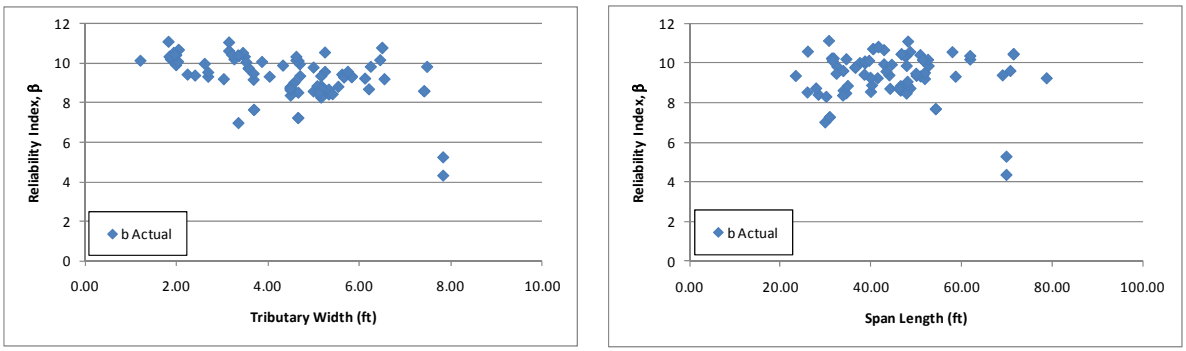


(a) (b)

Figure B-678: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

B.4.5.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the the assumed value of 3.5 for all girders as shown in Figure B-679.



(a) (b)

Figure B-679: Shear Reliability Indices for IL-01 Vehicle

Figure B-680 shows the reliability index plotted against the LRFR rating for shear due to the IL-01 vehicle. The figures shows that girders passing the rating, excluding those controlled by the bearing stiffener, have reliability indices greater than the target value of 3.5. This indicates that the LRFR live load factors could be reduced. The girders controlled by the bearing stiffener rating have low ratings and high reliability; the high reliability is a result of using the web shear resistance instead of the bearing stiffener resistance in the calculation.

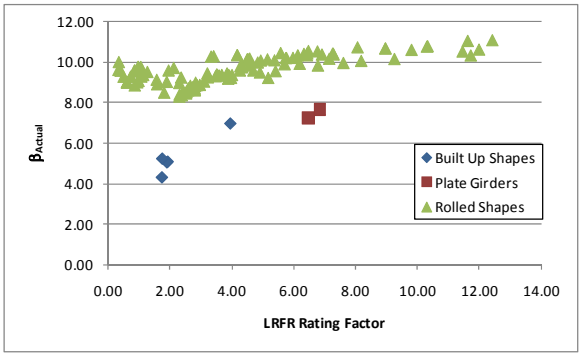


Figure B-680: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

B.4.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-681. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

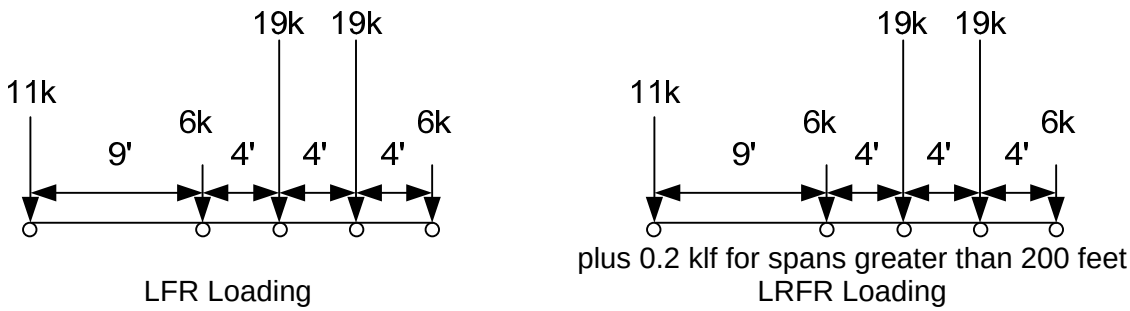


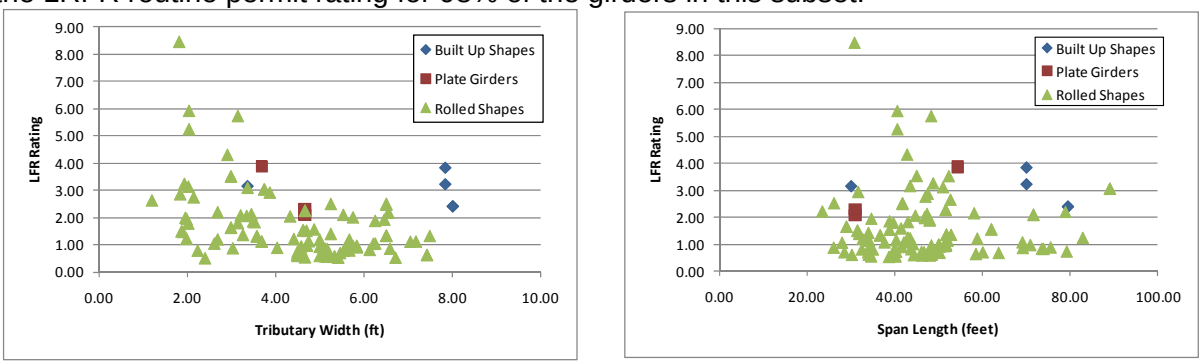
Figure B-681: Vehicle Loadings and Load Factors

B.4.6.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the NC-21 Vehicle.

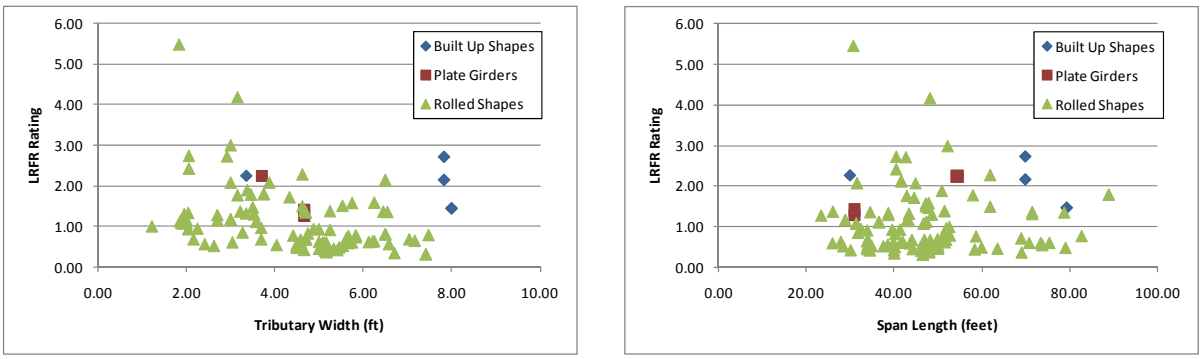
B.4.6.1.1 Rating Factors

Figure B-682 and Figure B-683 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 57 girders with an LFR rating less than 1.0, 78 girders with an LRFR rating less than 1.0, and 57 girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 98% of the girders in this subset.



(a) (b)

Figure B-682: LFR Flexure Rating Factors for NC-21 Vehicle

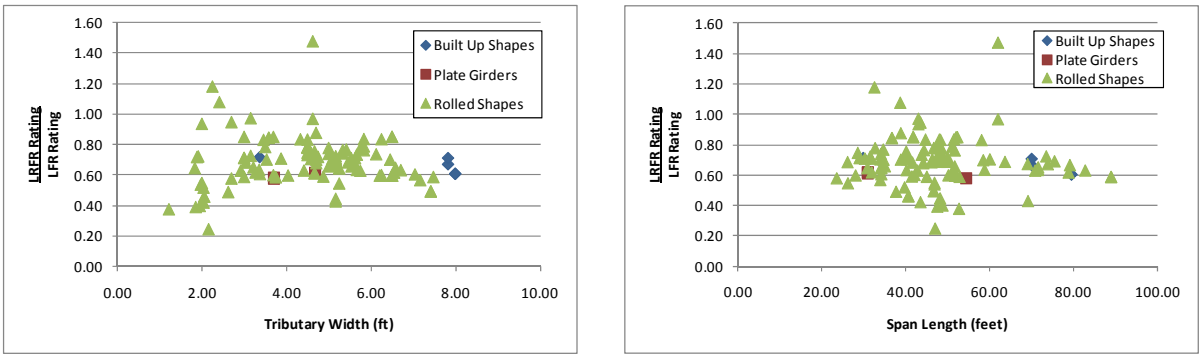


(a) (b)

Figure B-683: LRFR Flexure Rating Factors for NC-21 Vehicle

B.4.6.1.2 Rating Factor Comparisons

Figure B-684 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8 for this vehicle, with the lowest ratings corresponding to girders with narrow girder spacing. The LFR rating is greater than the LRFR rating for 98% of the girders in this group.

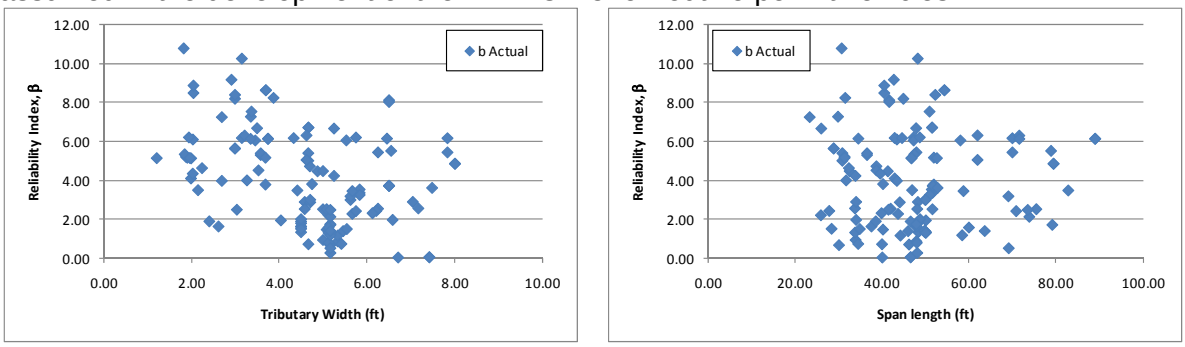


(a) (b)

Figure B-684: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

B.4.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-685 shows that some girders have an actual reliability index that is less than that assumed in the development of the MBE. The value assumed in the development of the MBE is 2.5 for routine permit vehicles.



(a) (b)

Figure B-685: Flexure Reliability Indices for NC-21 Vehicle

Figure B-686 shows the reliability index plotted against the LRFR rating for moment due to the NC-21 Vehicle. The figure shows that girders with a rating of 1.0 have reliability indices in the range of 4.0 to 5.0, significantly higher than the target reliability of 2.5 used for routine permit vehicles. The LRFR live load factors could be reduced to bring the reliability index of a girder with a rating of 1.0 closer to the target reliability of 2.5.

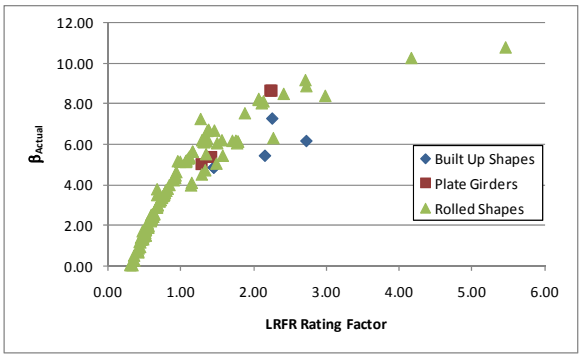


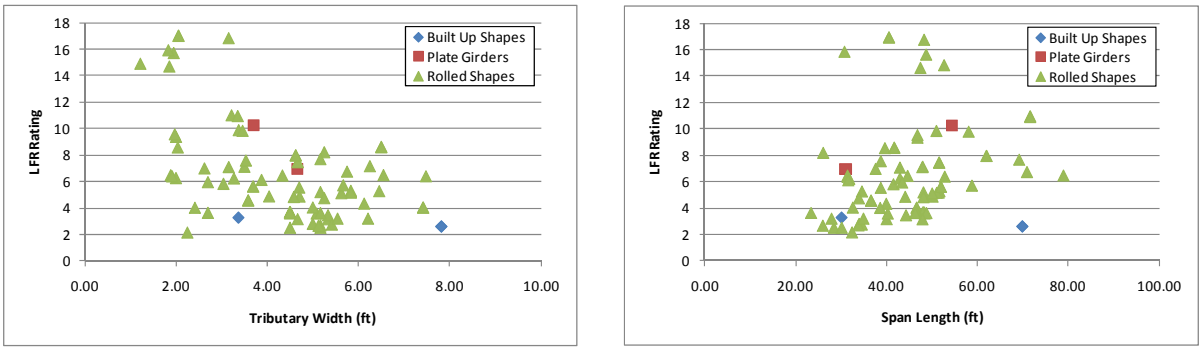
Figure B-686: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

B.4.6.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0; these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

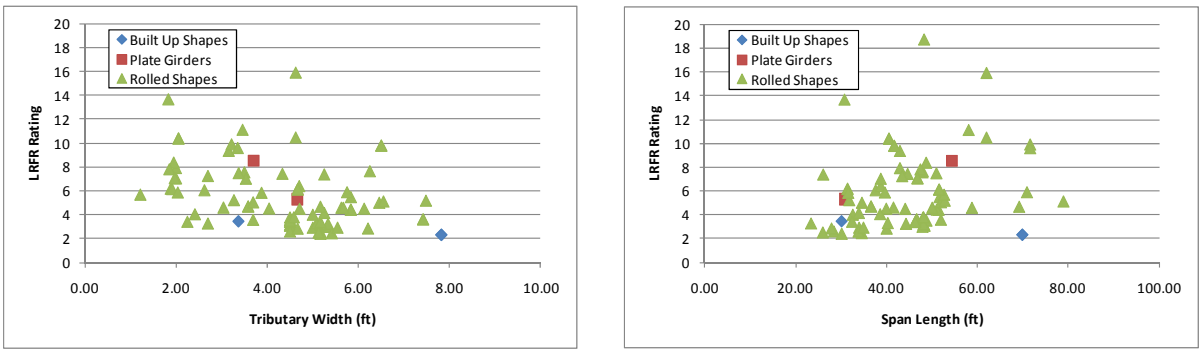
B.4.6.2.1 Rating Factors

For shear, there are 12 girders that have LRFR rating factors less than 1.0 and zero girders that have an LFR rating less than 1.0. In this situation, 9.0% of girders are affected by rating using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 95% of the girders in this subset. Figure B-687 and Figure B-688 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-687: LFR Shear Ratings for NC-21 Vehicle

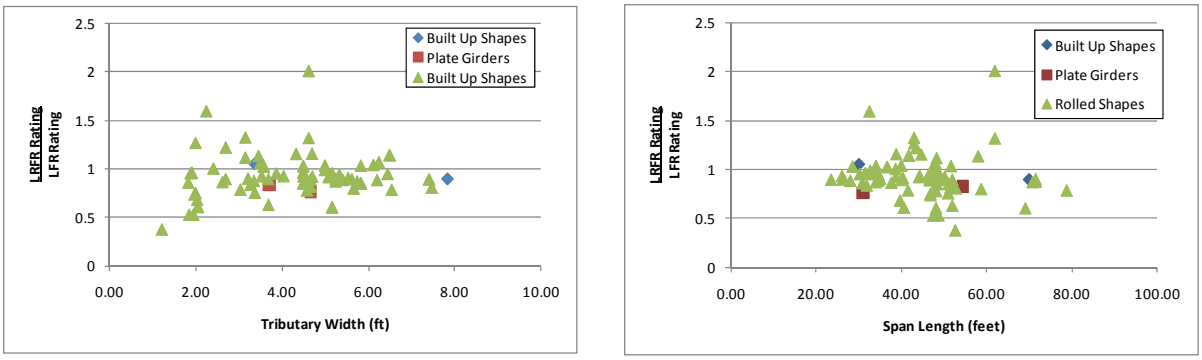


(a) (b)

Figure B-688: LRFR Shear Ratings for NC-21 Vehicle

B.4.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure B-689 shows the comparison of rating factors. The LRFR rating is between 75 and 100% of the LFR rating for most girders. The LFR rating is greater than the LRFR rating for 95% of girders in this group.

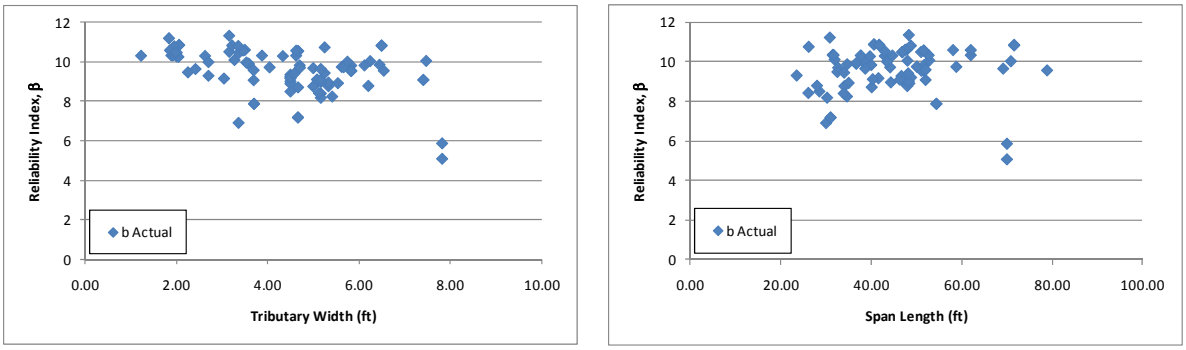


(a) (b)

Figure B-689: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

B.4.6.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index shown in Figure B-690 is greater than the value of 2.5 used in the development of the MBE for all girders.



(a) (b)

Figure B-690: Shear Reliability Indices for NC-21 Vehicle

Figure B-691 shows the reliability index plotted against the LRFR rating for shear due to the NC-21 Vehicle. The figure shows that girders passing rating have reliability indices larger than the target reliability index of 2.5. Reducing the LRFR live load factors would shift the graph to the right such that girders would pass rating and have a reliability index close to the target value. The girders with high reliability and low ratings are controlled by the bearing stiffener rating; the reliability index calculation uses the web shear resistance instead of the bearing stiffener resistance.

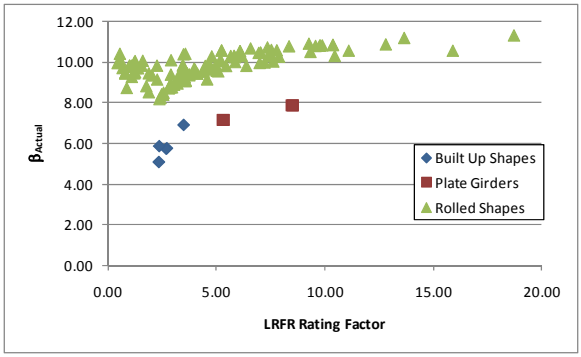


Figure B-691: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

B.4.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-692. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

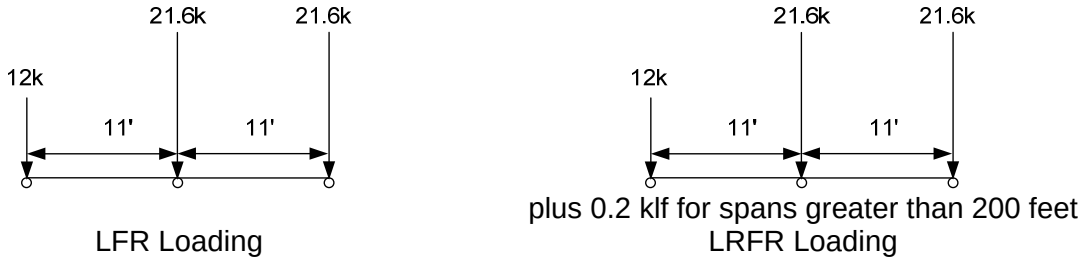


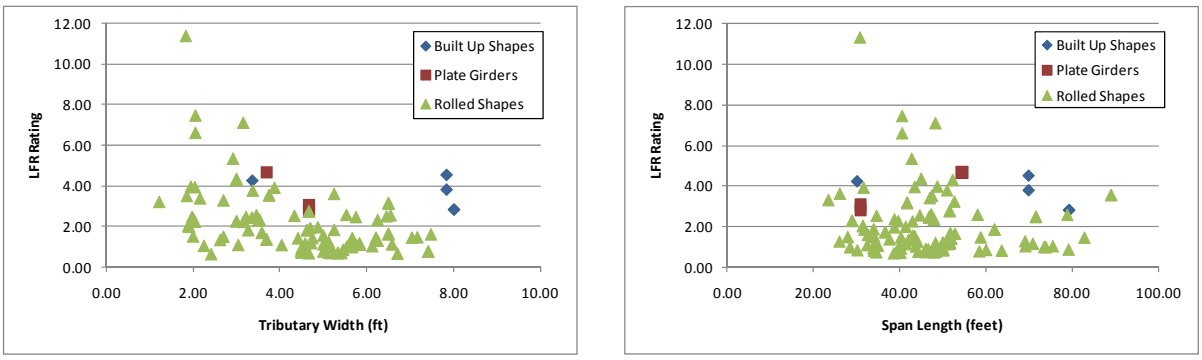
Figure B-692: Vehicle Loadings and Load Factors

B.4.7.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the NM-04 Vehicle.

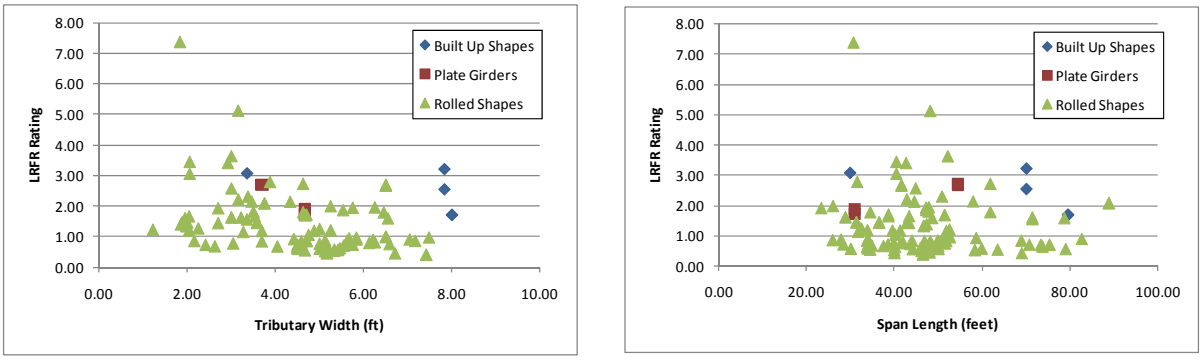
B.4.7.1.1 Rating Factors

Figure B-693 and Figure B-694 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 36 girders with an LFR rating less than 1.0, 70 girders with an LRFR rating less than 1.0, and 36 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 98% of the girders in this subset.



(a) (b)

Figure B-693: LFR Flexure Rating Factors for NM-04 Vehicle

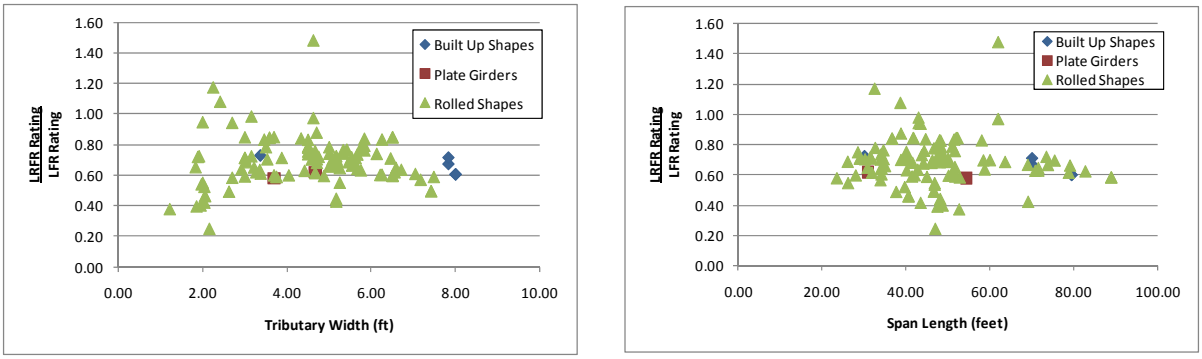


(a) (b)

Figure B-694: LRFR Flexure Rating Factors for NM-04 Vehicle

B.4.7.1.2 Rating Factor Comparisons

Figure B-695 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is typically 60 to 80% of the LFR rating for this group with three girders having LRFR ratings greater than the LFR rating. The LFR rating is greater than the LRFR rating for 98% of the girders in this group.

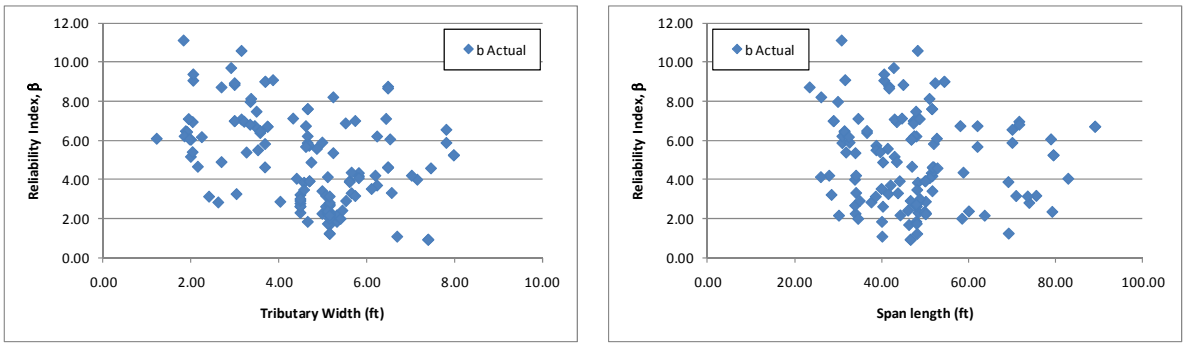


(a) (b)

Figure B-695: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

B.4.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-696 shows that a number of girders have an actual reliability index based upon girder strength that is less than the value of 2.5 assumed in the development of the MBE for routine permit vehicles.



(a) (b)

Figure B-696: Flexure Reliability Indices for NM-04 Vehicle

Figure B-697 shows the reliability index plotted against the LRFR rating for moment due to the NM-04 vehicle. The figure shows that girders with a rating of 1.0 have reliability indices of approximately 4.5, significantly higher than the target reliability of 2.5. This indicates that the LRFR live load factors could be reduced; resulting in more girders passing rating but still having the target level of reliability.

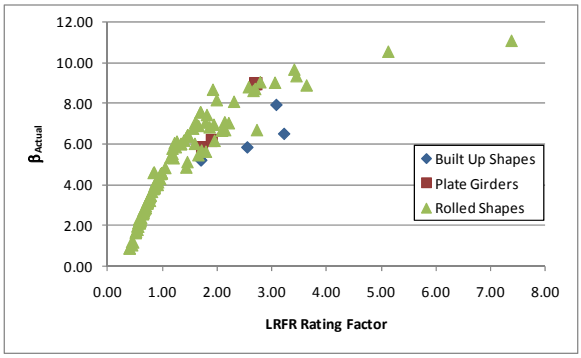


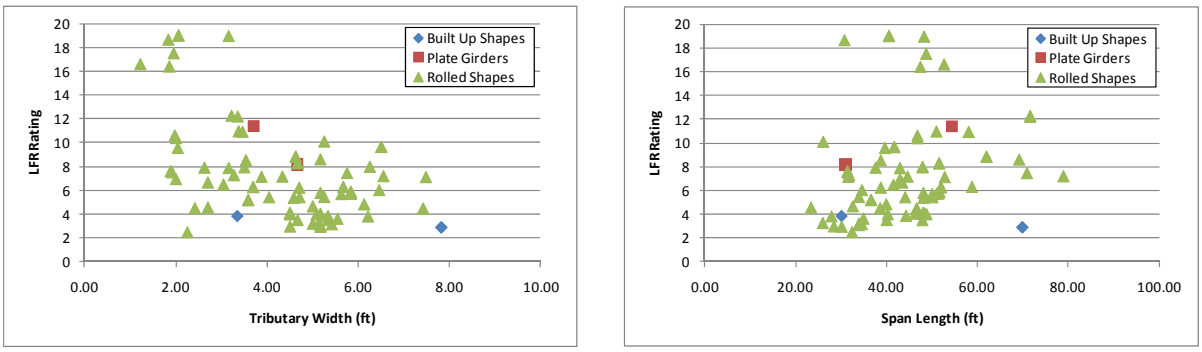
Figure B-697: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

B.4.7.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0, these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

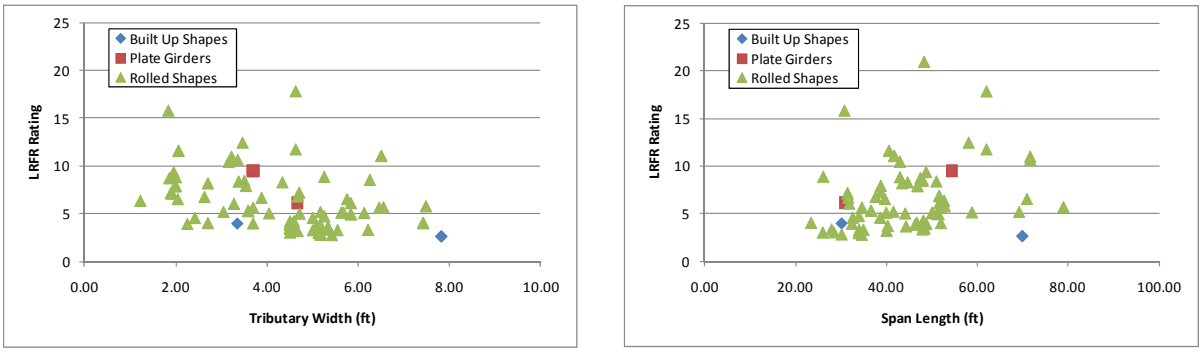
B.4.7.2.1 Rating Factors

For shear, there are nine girders that have LRFR rating factors less than 1.0 and zero girders that have LFR rating factors less than 1.0. In this situation, 6.8% of girders are affected by rating using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 95% of the girders in this subset. Figure B-698 and Figure B-699 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-698: LFR Shear Ratings for NM-04 Vehicle

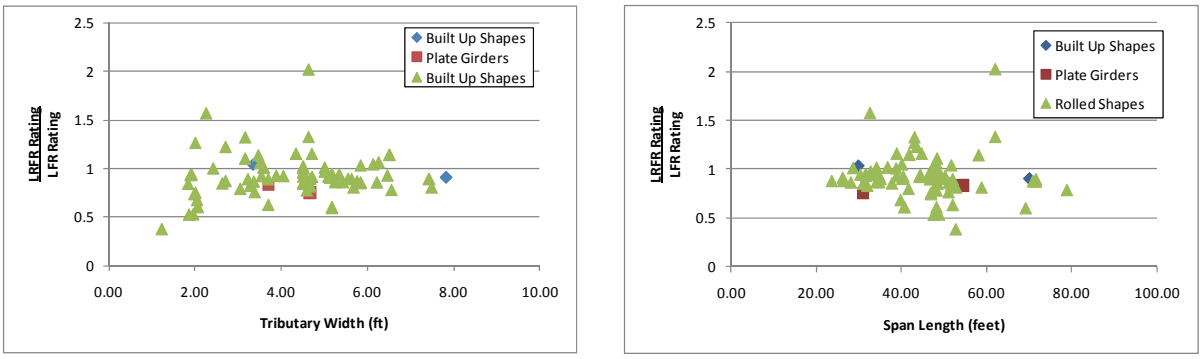


(a) (b)

Figure B-699: LRFR Shear Ratings for NM-04 Vehicle

B.4.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure B-700 show the comparison of rating factors. The LRFR rating is typically 70 to 100% of the LFR rating. The LFR rating is greater than the LRFR rating for 95% of girders in this group.

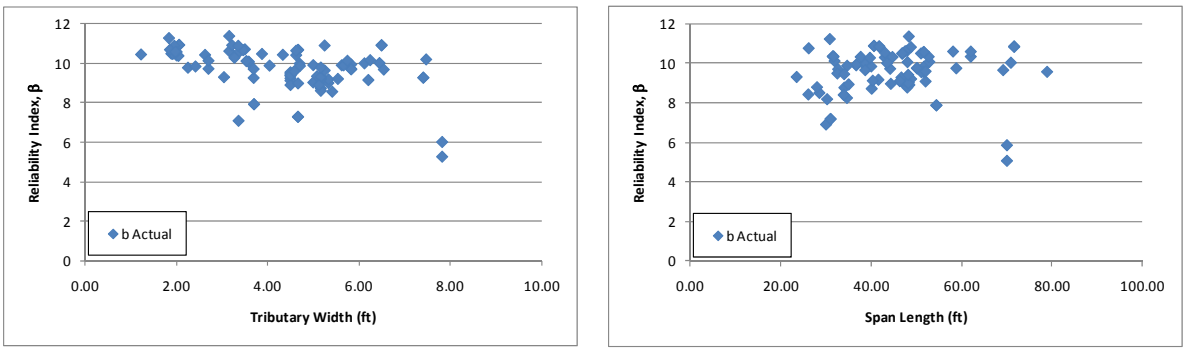


(a) (b)

Figure B-700: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

B.4.7.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index shown in Figure B-701 is greater than the value of 2.5 used in the development of the MBE.



(a) (b)

Figure B-701: Shear Reliability Indices for NM-04 Vehicle

Figure B-702 shows the reliability index plotted against the LRFR rating factor for shear due to the NM-04 vehicle. The figure shows that girders with a passing rating have reliability indices greater than the target reliability of 2.5. This suggests that the LRFR live load factors could be reduced resulting in more girders passing the rating and still having the target level of reliability. The girders with low rating and high reliability are controlled by the bearing stiffener rating; the reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

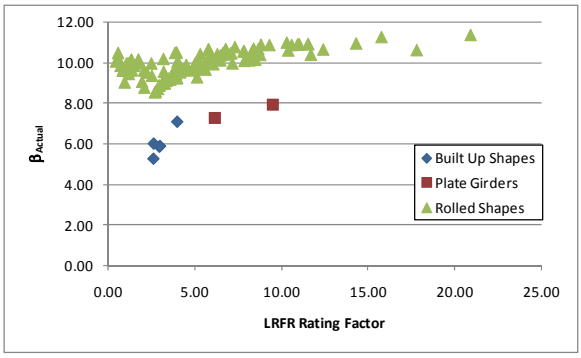
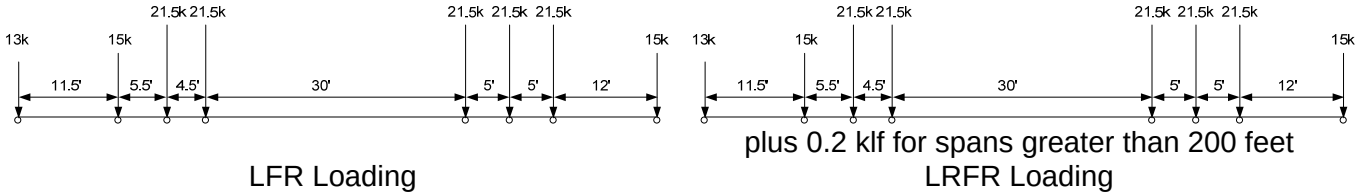


Figure B-702: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

B.4.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-703. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

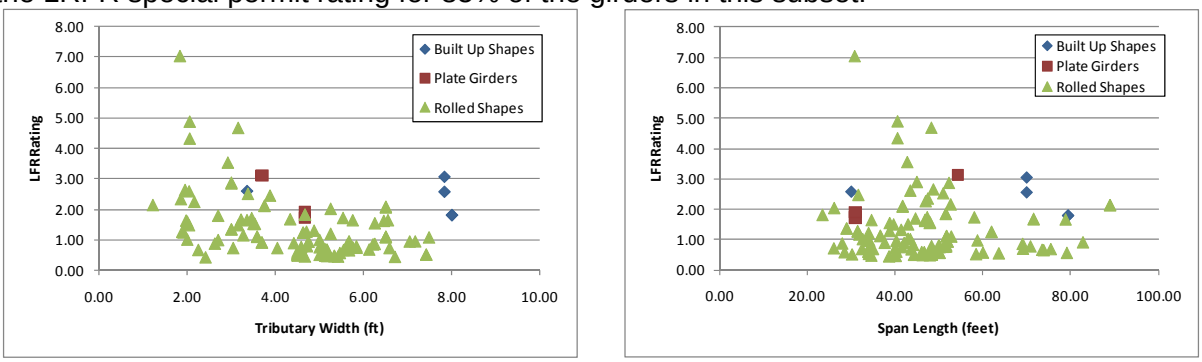
Figure B-703: Vehicle Loadings and Load Factors

B.4.8.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the OR-06 Vehicle.

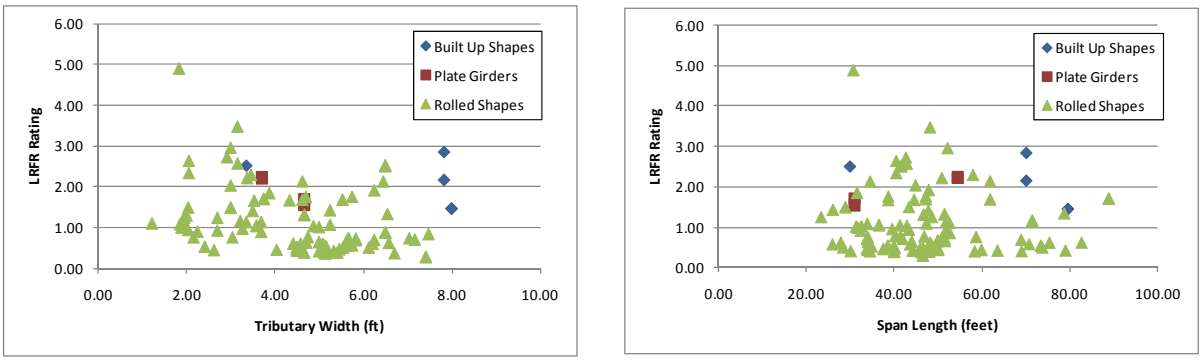
B.4.8.1.1 Rating Factors

Figure B-704 and Figure B-705 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 68 girders with an LFR rating less than 1.0, 75 girders with an LRFR rating less than 1.0, and 67 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 85% of the girders in this subset.



(a) (b)

Figure B-704: LFR Flexure Rating Factors for OR-06 Vehicle

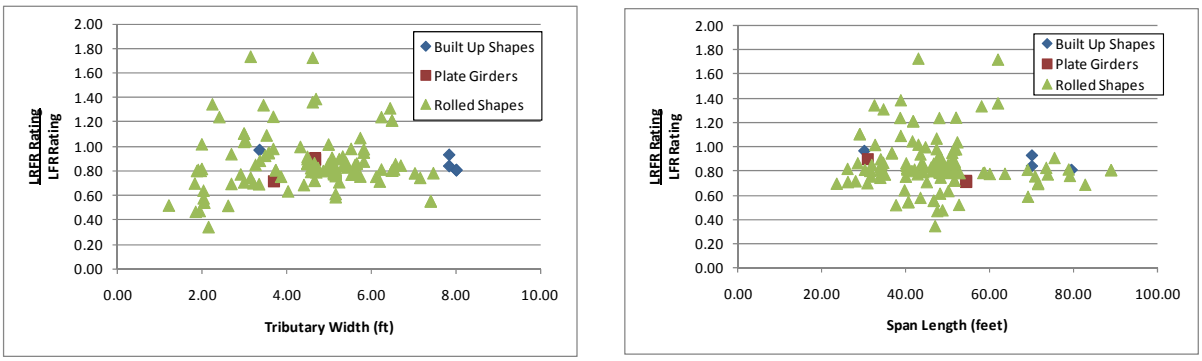


(a) (b)

Figure B-705: LRFR Flexure Rating Factors for OR-06 Vehicle

B.4.8.1.2 Rating Factor Comparisons

Figure B-706 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is typically 70 to 100% of the LFR rating. 85% of girders have an LFR rating that is greater than the LRFR rating.

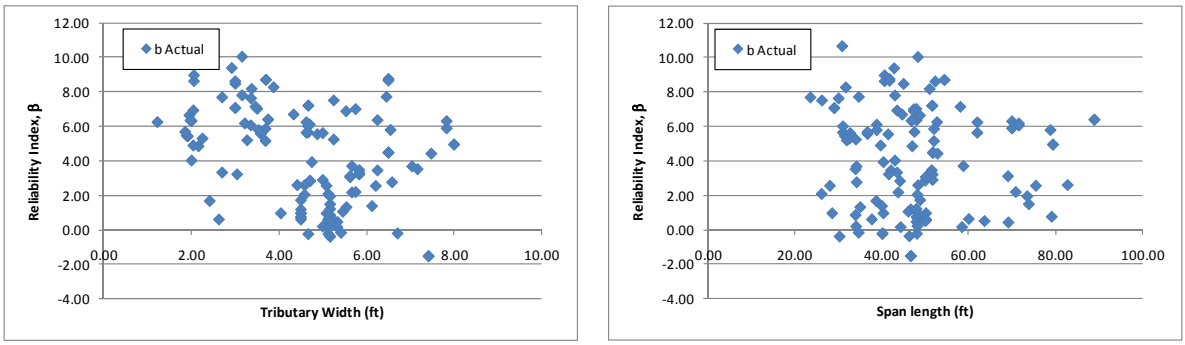


(a) (b)

Figure B-706: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

B.4.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-707 shows a large number of girders have a reliability index based upon girder strength that is less than the value of 3.5 used in the development of the MBE. These girders tend to be of shorter spans (but not always) and have larger overhangs and girder spacing.



(a) (b)

Figure B-707: Flexure Reliability Indices for OR-06 Vehicle

Figure B-708 shows the reliability index plotted against the LRFR rating for moment due to the OR-06 Vehicle.The figure shows that girders with a rating of 1.0 have reliability indices of at least 4.0 and often greater than 5. This suggests that the LRFR live load factors could be reduced; this would decrease the number of girders failing the rating and result in girders passing the rating have reliability indices near the target value of 3.5.

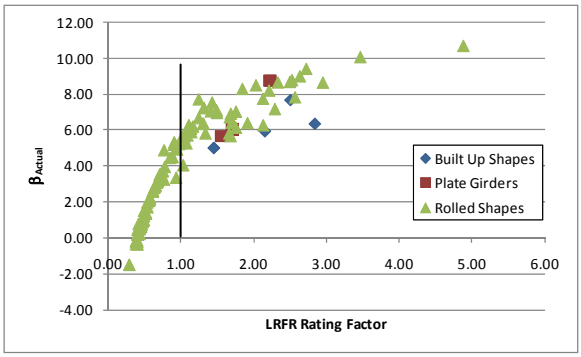


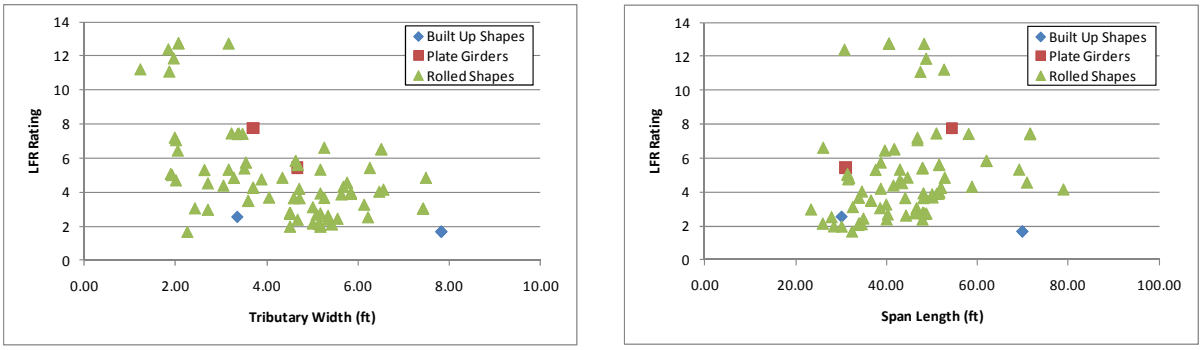
Figure B-708: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

B.4.8.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0, these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

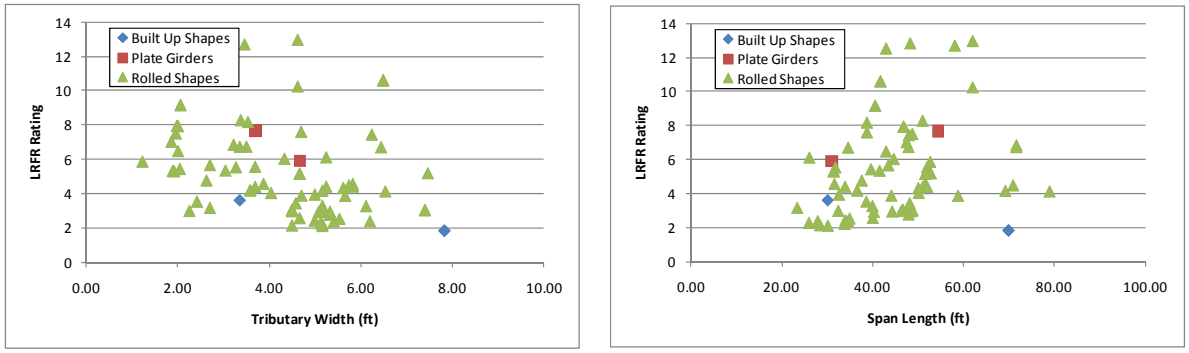
B.4.8.2.1 Rating Factors

For shear, there are 14 girders that have LRFR rating factors less than 1.0 and zero girders that have LFR ratings less than 1.0. In this situation, 10.5% of girders are affected by rating the bridges using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 89% of the girders in this subset. Figure B-709 and Figure B-710 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-709: LFR Shear Ratings for OR-06 Vehicle

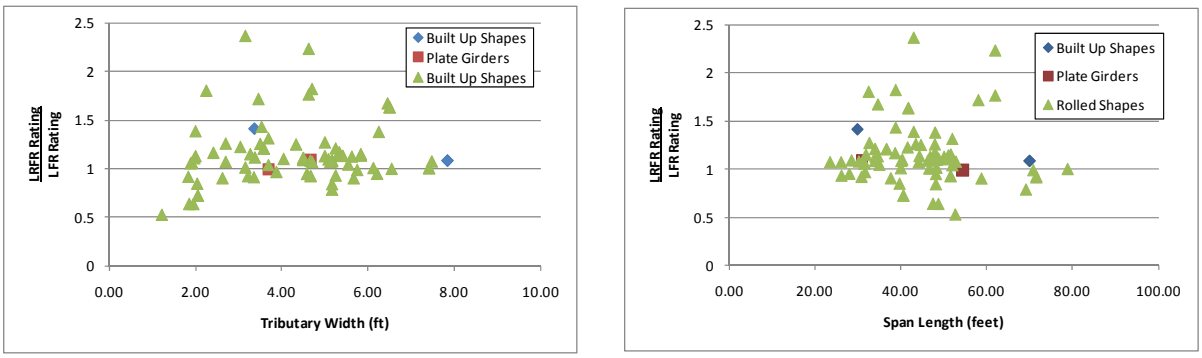


(a) (b)

Figure B-710: LRFR Shear Ratings for OR-06 Vehicle

B.4.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure B-711 shows the comparison of rating factors. The LRFR rating is typically 100 to 125% of the LFR rating for this vehicle and group of bridges. This is a result of the LRFR loading consisting of a single lane without multiple presence included.

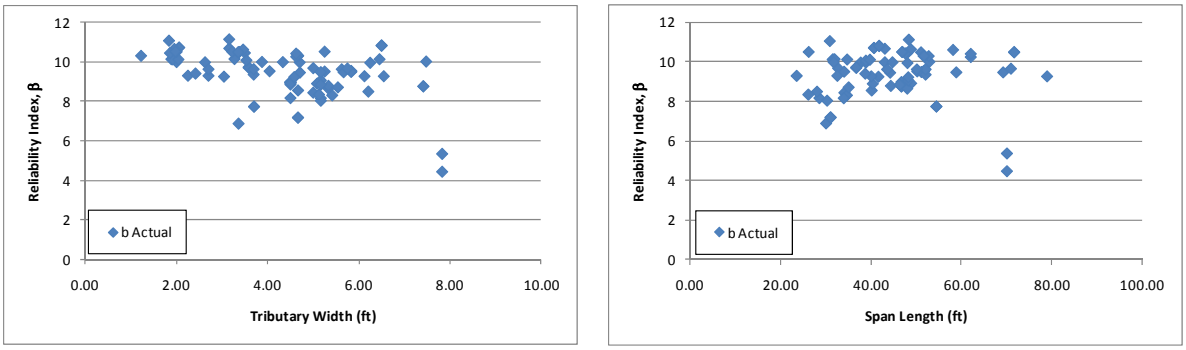


(a) (b)

Figure B-711: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

B.4.8.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index shown in Figure B-712 is greater than the reliability index of 3.5 used in the development of the MBE for special permit vehicles.



(a) (b)

Figure B-712: Shear Reliability Indices for OR-06 Vehicle

Figure B-713 shows the reliability index plotted against the LRFR rating factor for shear due to the OR-06 vehicle. The figure shows that girders with satisfactory ratings have reliability indices exceeding the target value of 3.5. This suggests that reducing the LRFR live load factors would result in girders passing the rating and have reliability indices near the target reliability.

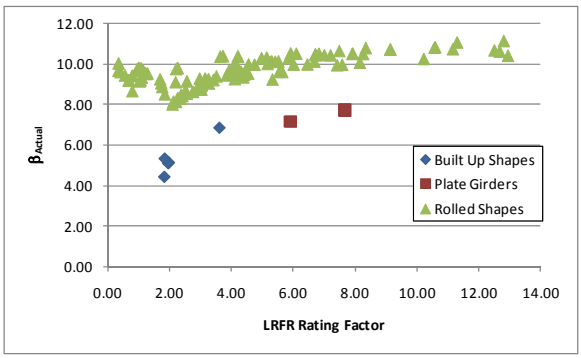


Figure B-713: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

B.4.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-714. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

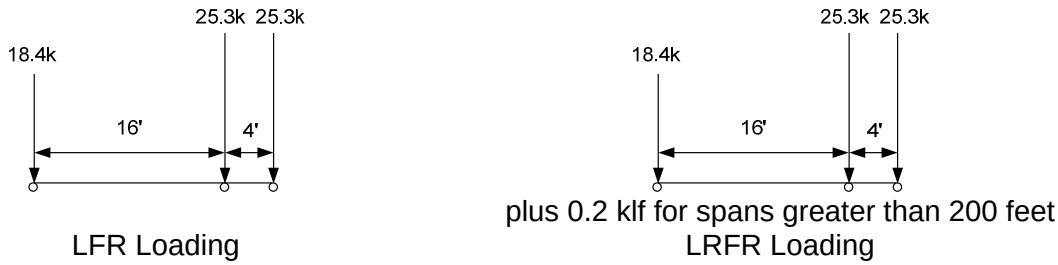


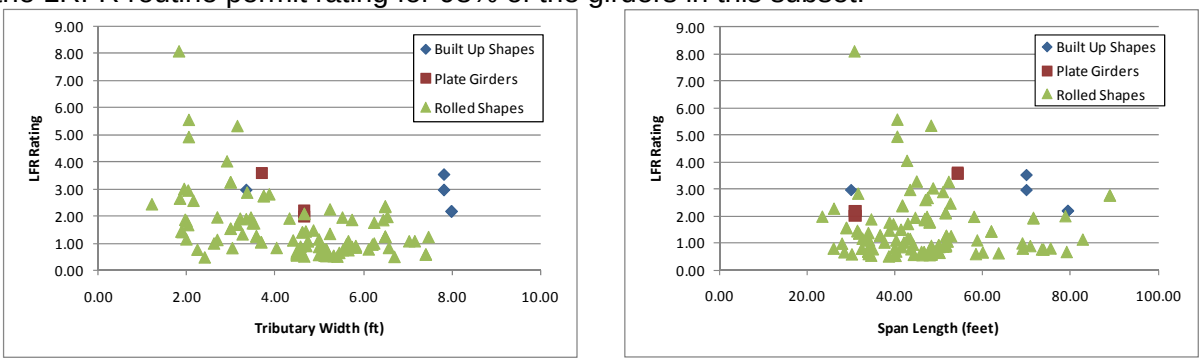
Figure B-714: Vehicle Loadings and Load Factors

B.4.9.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the TX-04 Vehicle.

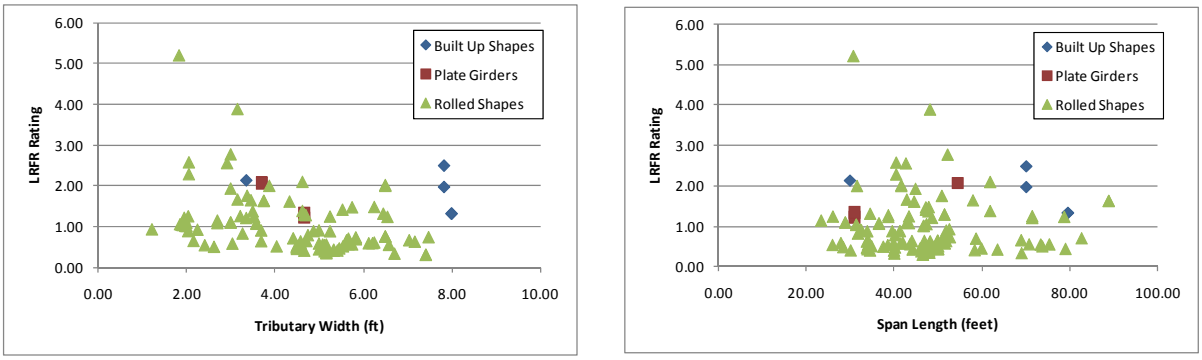
B.4.9.1.1 Rating Factors

Figure B-715 and Figure B-716 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 59 girders with an LFR rating less than 1.0, 79 girders with an LRFR rating less than 1.0, and 59 girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 98% of the girders in this subset.



(a) (b)

Figure B-715: LFR Flexure Rating Factors for TX-04 Vehicle

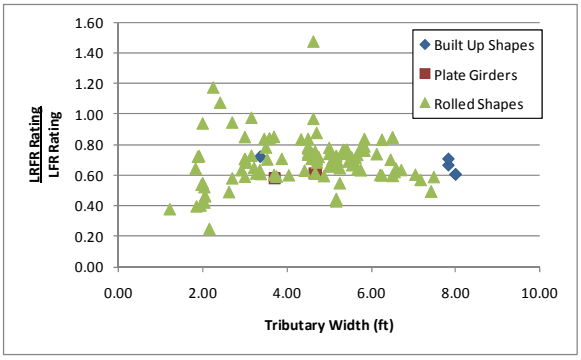


(a) (b)

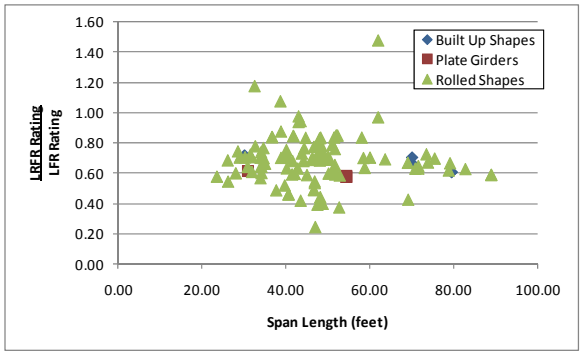
Figure B-716: LRFR Flexure Rating Factors for TX-04 Vehicle

B.4.9.1.2 Rating Factor Comparisons

Figure B-717 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is generally 60 to 80% of the LFR rating for the girders in this group with this vehicle. The LFR rating is greater than the LRFR rating for 98% of the girders in this group.



(a)

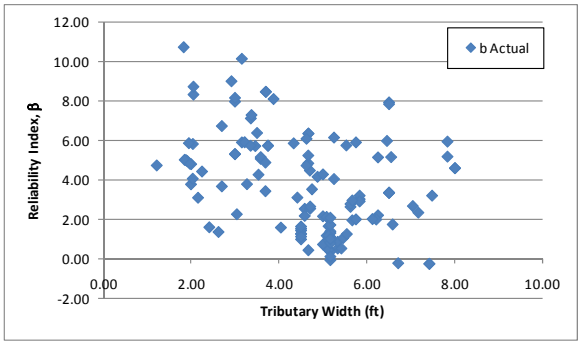


(b)

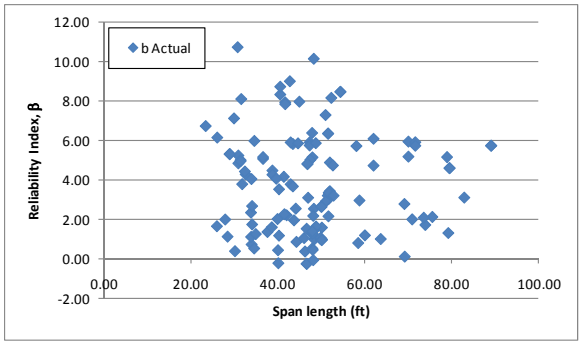
Figure B-717: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

B.4.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-718 shows a number of girders have an actual reliability index less than the value of 2.5 assumed for routine permit vehicles in the MBE.



(a)



(b)

Figure B-718: Flexure Reliability Indices for TX-04 Vehicle

Figure B-719 shows the reliability index plotted against the LRFR rating for moment caused by the TX-04 vehicle. The figure shows that girders with ratings of 1.0 typically have reliability indices greater than 4.0 and often closer to 5.0. This is significantly higher than the target reliability of 2.5 for routine permit vehicles. This suggests that reducing the LRFR live load factors will result in girders with rating factors of 1.0 having a reliability index nearer the target reliability of 2.5.

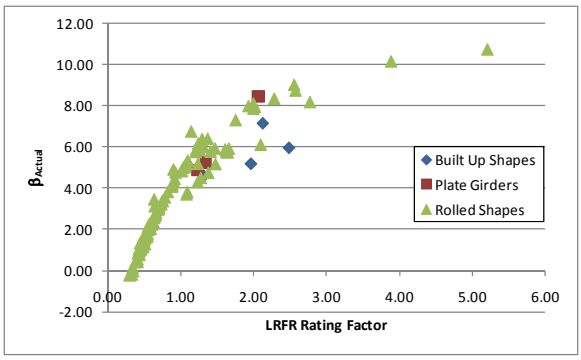


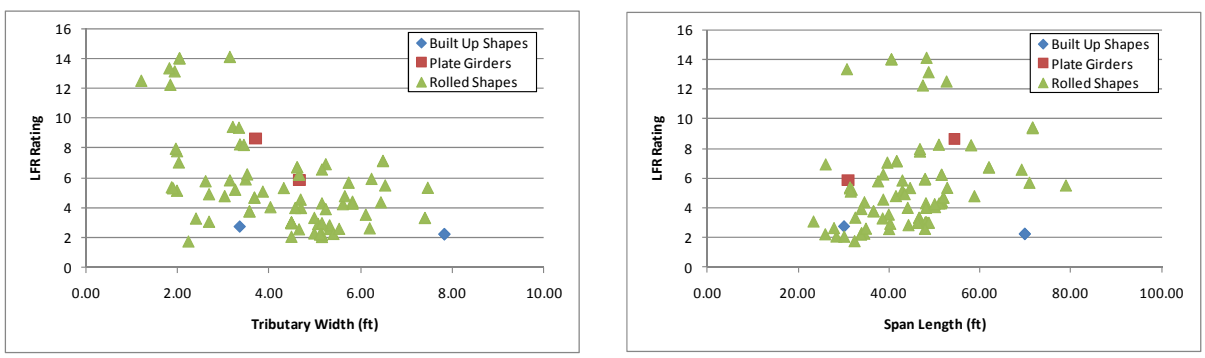
Figure B-719: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

B.4.9.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0, these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

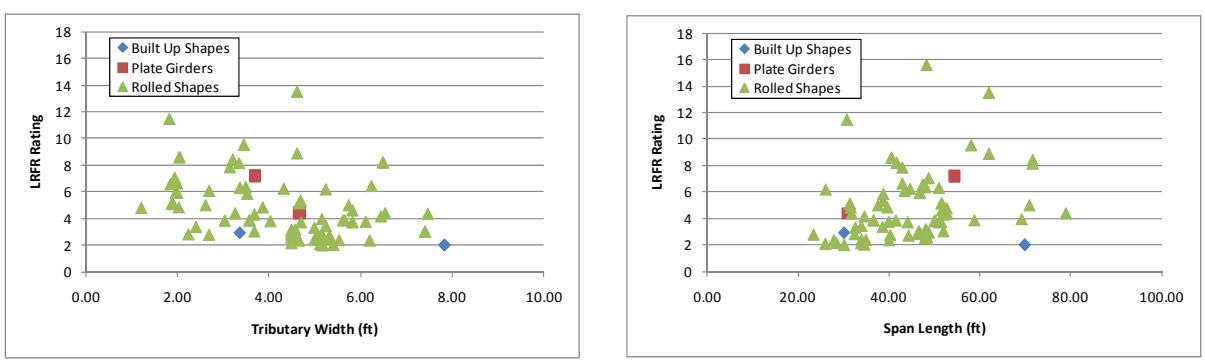
B.4.9.2.1 Rating Factors

For shear, there are 17 girders that have LRFR rating factors less than 1.0 and zero girders with LFR ratings less than 1.0. In this situation, 12.8% of girders are affected by rating the bridges using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 95% of the girders in this subset. Figure B-720 and Figure B-721 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-720: LFR Shear Ratings for TX-04 Vehicle

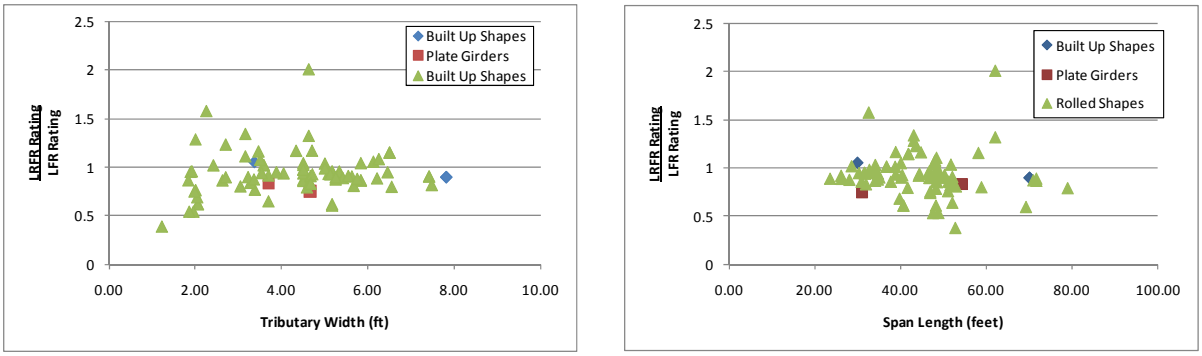


(a) (b)

Figure B-721: LRFR Shear Ratings for TX-04 Vehicle

B.4.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure B-722 shows the comparison of rating factors. The LRFR rating is generally 70 to 100% of the LFR rating for the girders in this group. The LFR rating is greater than the LRFR rating for 95% of the girders.

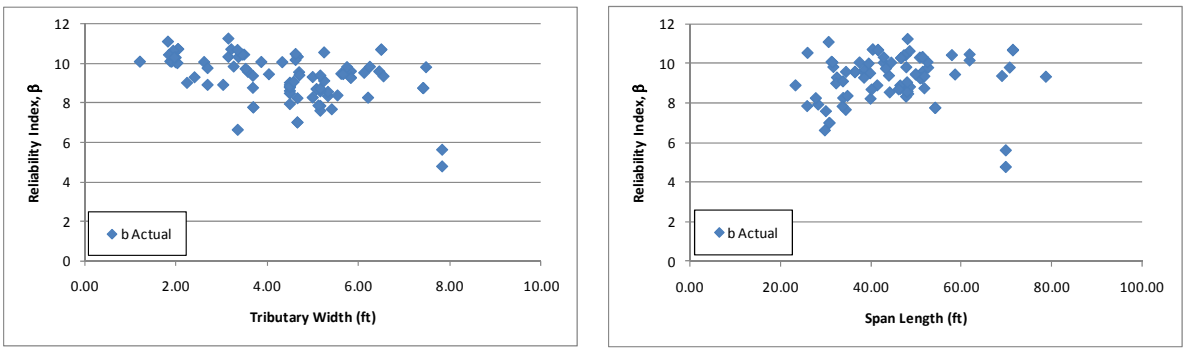


(a) (b)

Figure B-722: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

B.4.9.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index shown in Figure B-723 is greater than the value of 2.5 used for routine permit vehicles in the development of the MBE.



(a) (b)

Figure B-723: Shear Reliability Indices for TX-04 Vehicle

Figure B-724 shows the reliability index plotted against the LRFR rating for shear for the TX-04 vehicle. The figure shows that girders with passing ratings have reliability indices in excess of the target reliability of 2.5. Reducing the LRFR live load factors would result in girders having reliability indices near the target value while still having rating above 1.0. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating; the reliability index is calculated based upon the web shear resistance not the bearing stiffener resistance.

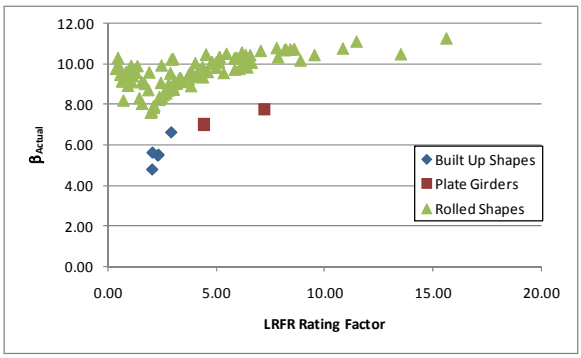


Figure B-724: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

B.4.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-725. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

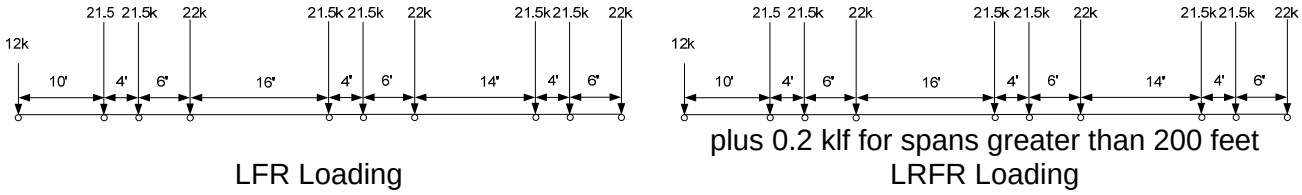


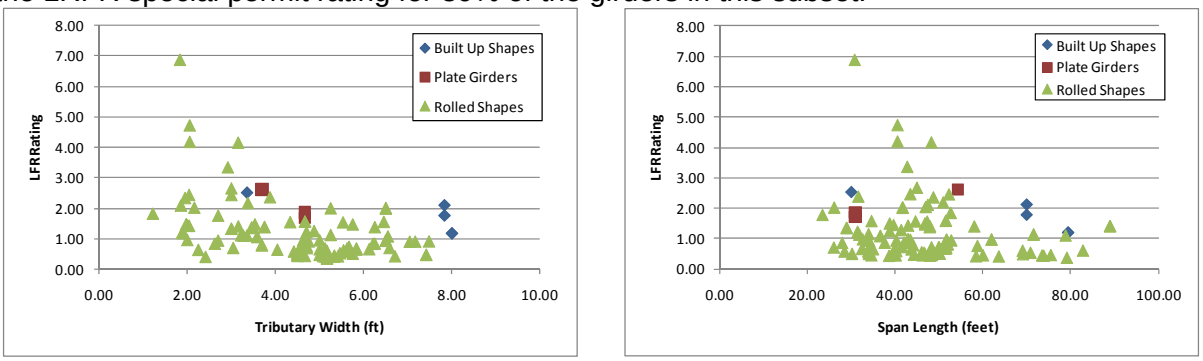
Figure B-725: Vehicle Loadings and Load Factors

B.4.10.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the WA-02 Vehicle.

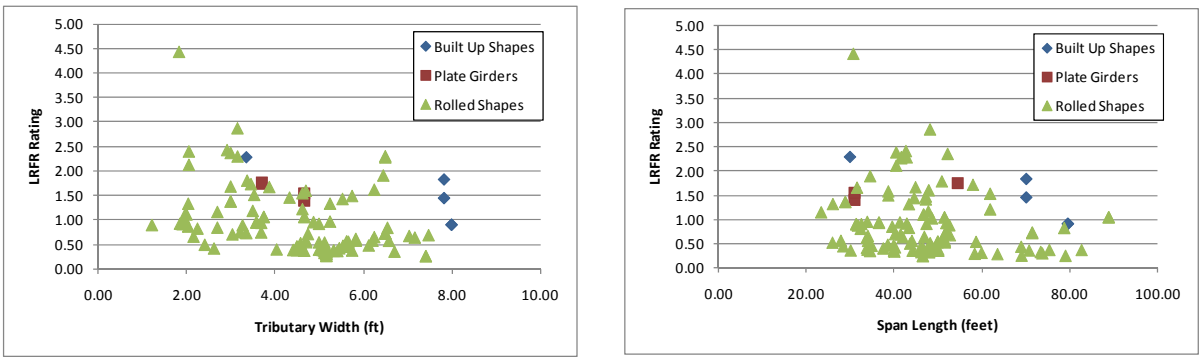
B.4.10.1.1 Rating Factors

Figure B-726 and Figure B-727 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 77 girders with an LFR rating less than 1.0, 91 girders with an LRFR rating less than 1.0, and 75 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 89% of the girders in this subset.



(a) (b)

Figure B-726: LFR Flexure Rating Factors for WA-02 Vehicles

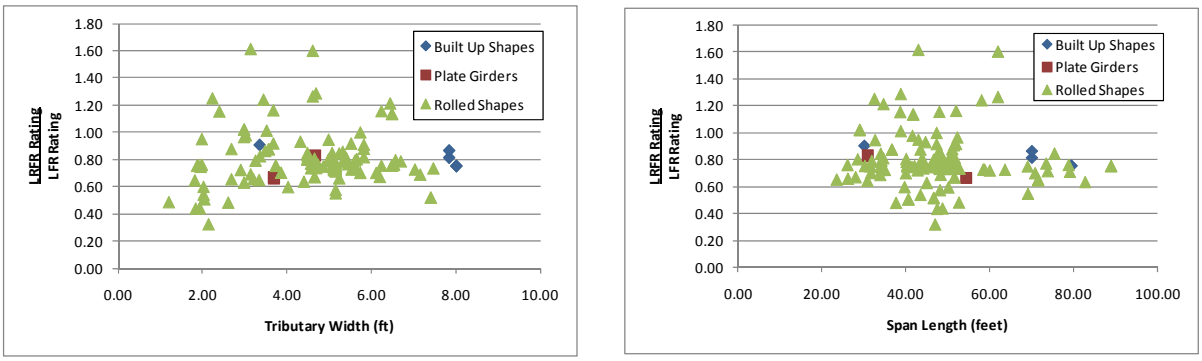


(a) (b)

Figure B-727: LRFR Flexure Rating Factors for WA-02 Vehicles

B.4.10.1.2 Rating Factor Comparisons

Figure B-728 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is benerally between 70 and 100% of the LFR rating for this vehicle. The LFR rating is greater than the LRFR rating for 89% of the girders in this group.

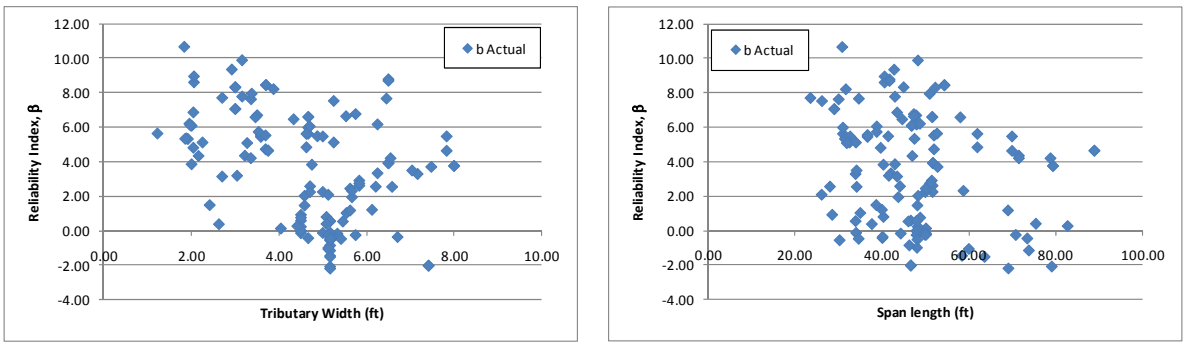


(a) (b)

Figure B-728: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicles

B.4.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-729 shows that a number of girders have a reliability index based upon girder strength that is less than the value of 3.5 used in the development of the MBE.



(a) (b)

Figure B-729: Flexure Reliability Indices for WA-02 Vehicles

Figure B-730 shows the reliability index plotted against the LRFR rating for moment due to the WA-02 vehicle. The figure shows that girders with ratings of 1.0 have reliability indices varying from approximately 4.0 to 6.0, above the target reliability of 3.5 for special permit vehicles. This suggests that the LRFR live load factors could be reduced resulting in girders having ratings of 1.0 and reliability indices near 3.5.

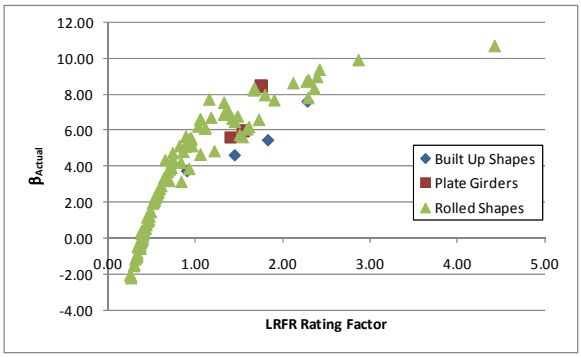


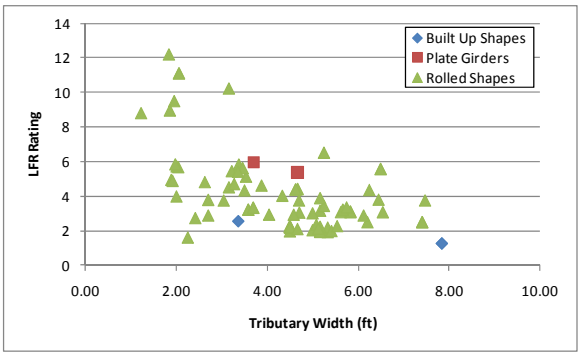
Figure B-730: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

B.4.10.2 Shear

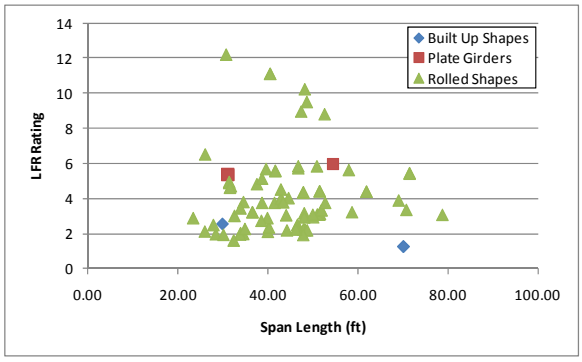
The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0, these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

B.4.10.2.1 Rating Factors

For shear, there are 23 girders that have LRFR rating factors less than 1.0 and zero girders with LFR rating factors less than 1.0. In this situation, 17.3% of girders are affected by rating the bridges using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 89% of the girders in this subset. Figure B-731 and Figure B-732 show the LFR and LRFR ratings, respectively.

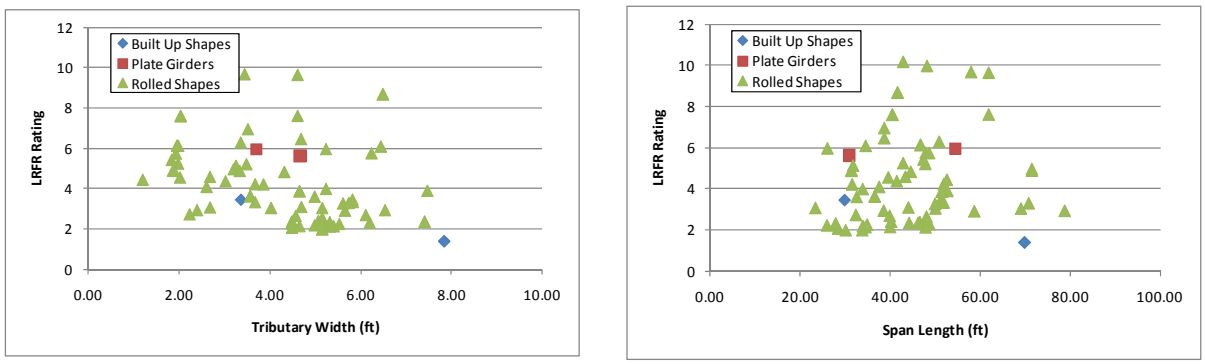


(a)



(b)

Figure B-731: LFR Shear Ratings for WA-02 Vehicles

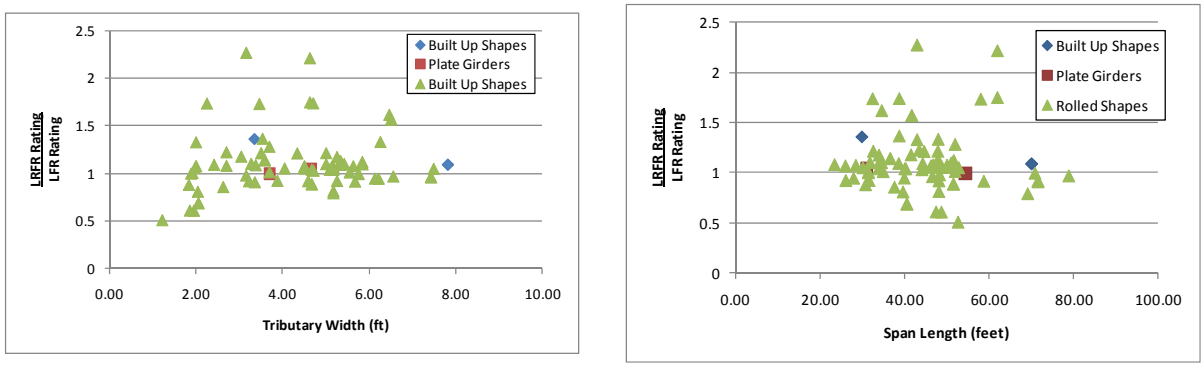


(a) (b)

Figure B-732: LRFR Shear Ratings for WA-02 Vehicles

B.4.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure B-733 show the comparison of rating factors. The LRFR rating is generally between 90 and 120% of the LFR rating. The LRFR rating is higher due to the loading required by the MBE of a single lane loaded without multiple presence included. The LFR rating is greater than the LRFR rating for 89% of the girders in this group.

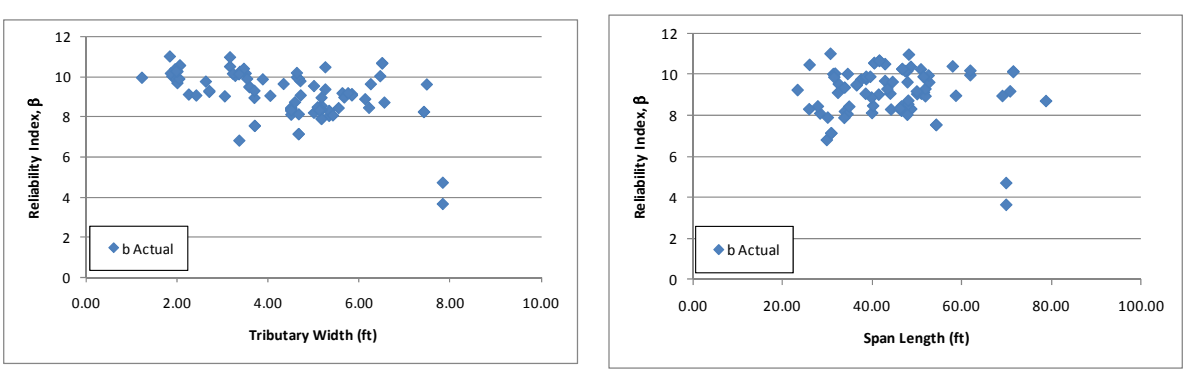


(a) (b)

Figure B-733: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicles

B.4.10.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all girders as shown in Figure B-734.



(a) (b)

Figure B-734: Shear Reliability Indices for WA-02 Vehicles

Figure B-735 shows the reliability index plotted against the LRFR rating for shear due to the WA-02 vehicle. The figure shows that girders with ratings near 1.0 have ratings near the target reliability index of 3.5. Rolled shapes have reliability indices that significantly exceed the target reliability. The LRFR live load factors currently result in a reliability index close to the target value. Girders with high reliability and lower ratings are controlled by the bearing stiffener rating; the reliability is calculated using the web shear resistance not the bearing stiffener resistance.

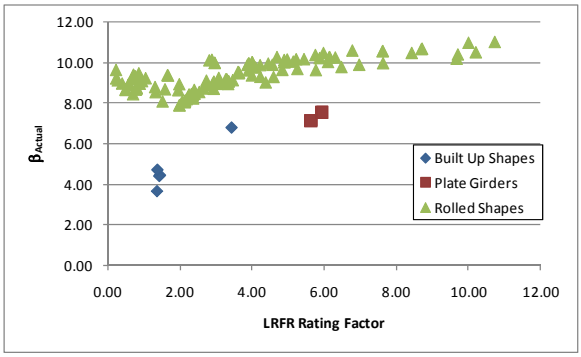


Figure B-735: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

B.4.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-736. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

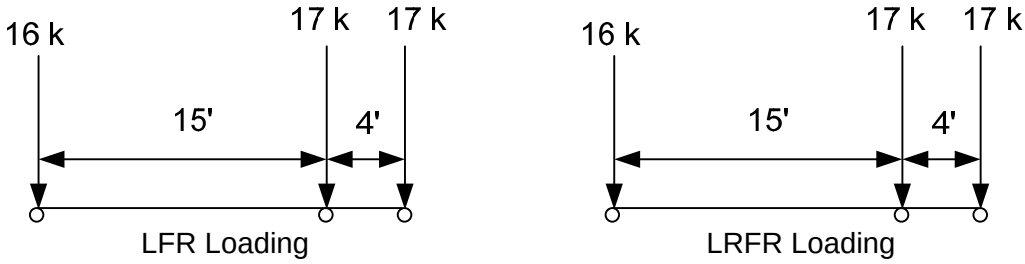


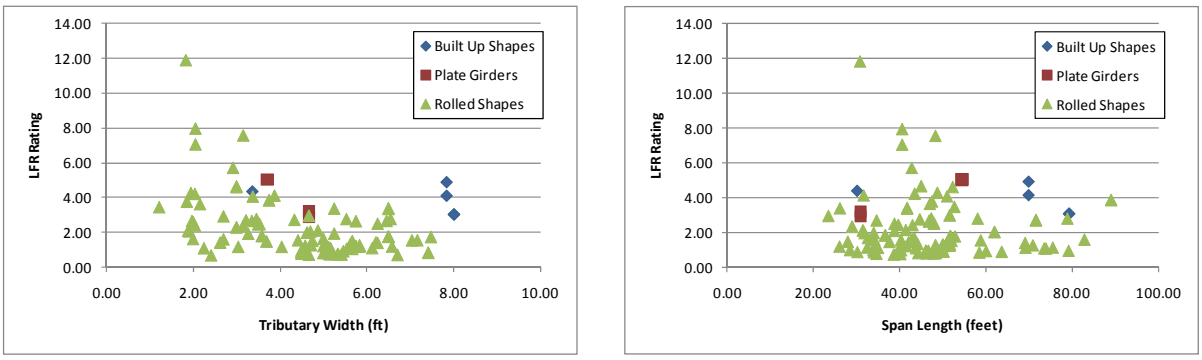
Figure B-736: Vehicle Loadings and Load Factors

B.4.11.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the Type 3 Vehicle.

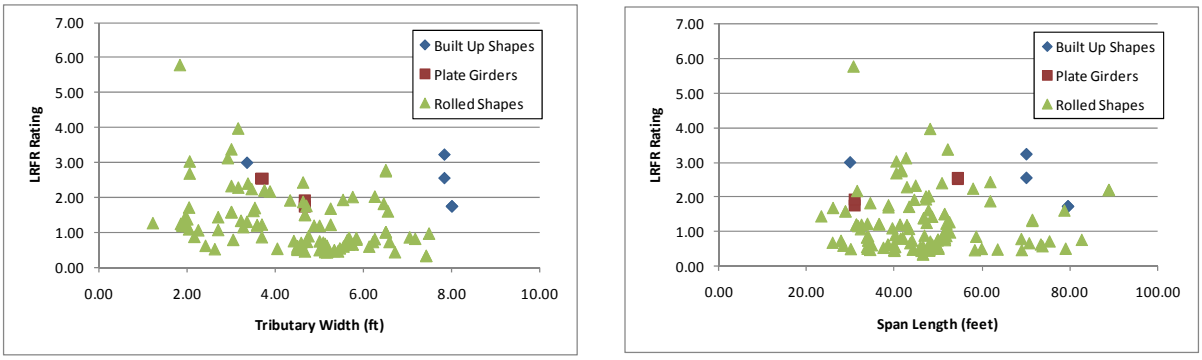
B.4.11.1.1 Rating Factors

Figure B-737 and Figure B-738 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 33 girders with an LFR rating less than 1.0, 68 girders with an LRFR rating less than 1.0, and 33 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 99% of the girders in this subset.



(a) (b)

Figure B-737: LFR Flexure Rating Factors for Type 3 Vehicles

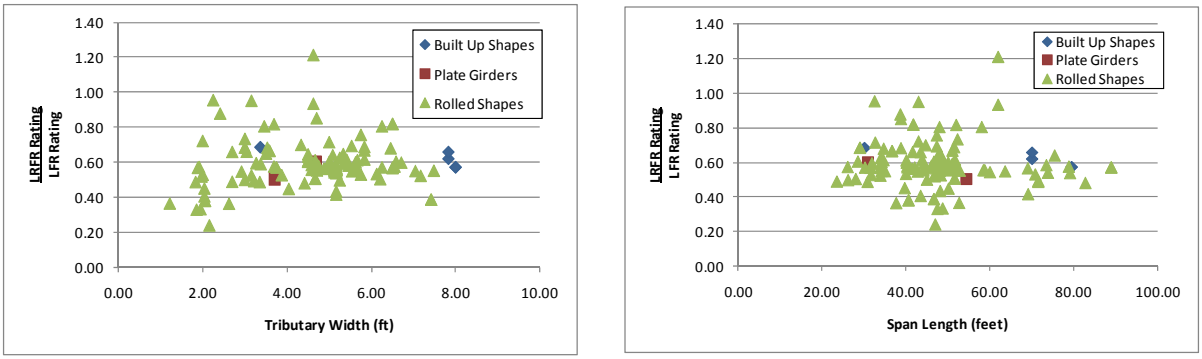


(a) (b)

Figure B-738: LRFR Flexure Rating Factors for Type 3 Vehicles

B.4.11.1.2 Rating Factor Comparisons

Figure B-739 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is generally between 50 and 70% of the LFR rating. The LFR rating is greater than the LRFR rating for 99% of the girders in this group.

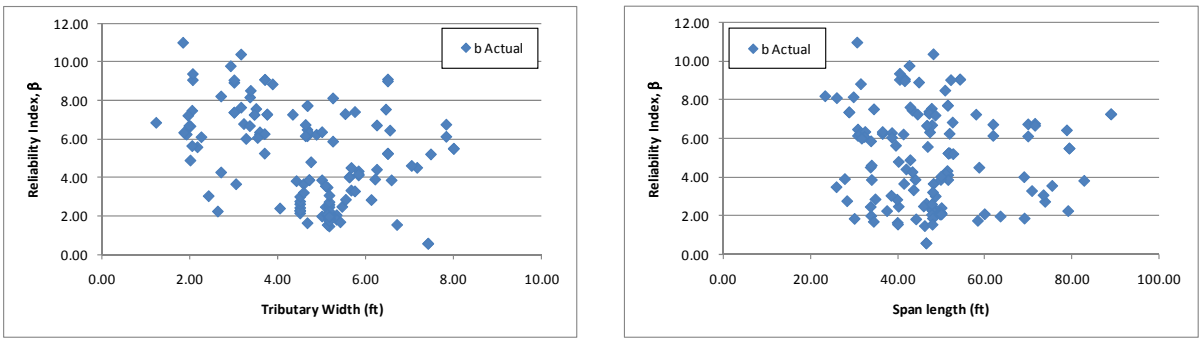


(a) (b)

Figure B-739: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicles

B.4.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-740 shows that a number of girders have a reliability index based upon the existing condition of the girder that is less than the value of 2.5 used in the development of the MBE.



(a) (b)

Figure B-740: Flexure Reliability Indices for Type 3 Vehicles

Figure B-741 shows the reliability index plotted against the LRFR rating factor for moment due to the AASHTO Type 3 Truck. The figure shows that girders having ratings of 1.0 have reliability indices of approximately 4.0 which is greater than the target reliability of 2.5. This indicates that by reducing the LRFR live load factors, girders having a rating of 1.0 will have a reliability index near the target value of 2.5.

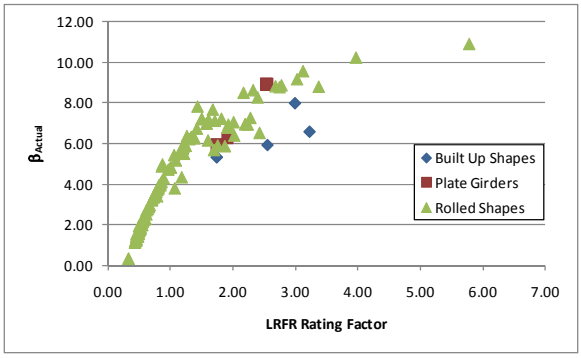


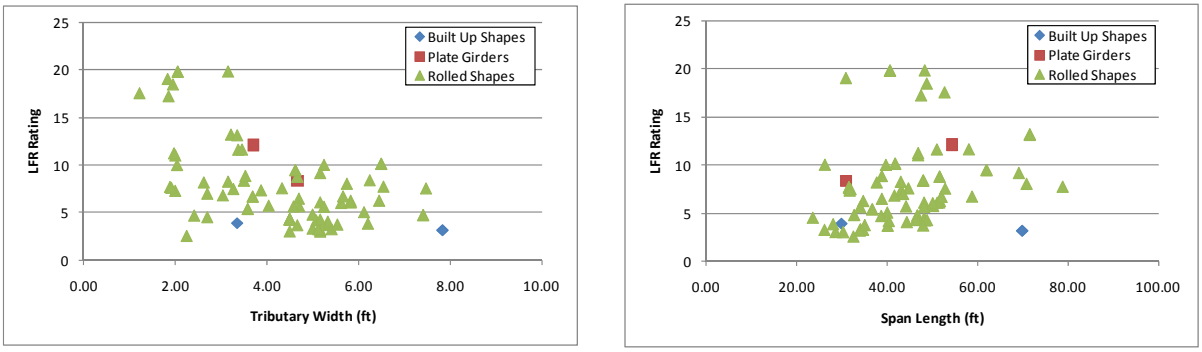
Figure B-741: Flexure Reliability Index vs LRFR Flexure Rating for Type 3 Vehicle

B.4.11.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0; these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

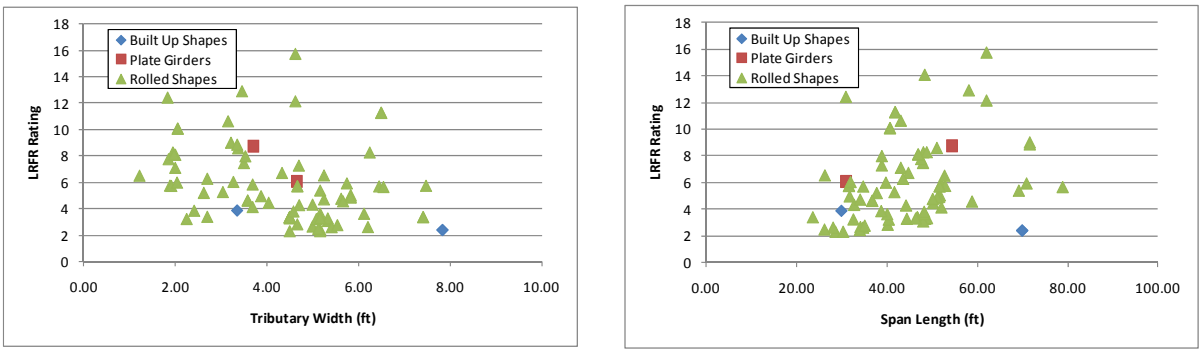
B.4.11.2.1 Rating Factors

For shear, there are 11 girders that have LRFR rating factors less than 1.0 and zero girders with LFR rating factors less than 1.0. In this situation, 8.3% of girders are affected by rating using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 96% of the girders in this subset. Figure B-742 and Figure B-743 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-742: LFR Shear Ratings for Type 3 Vehicles

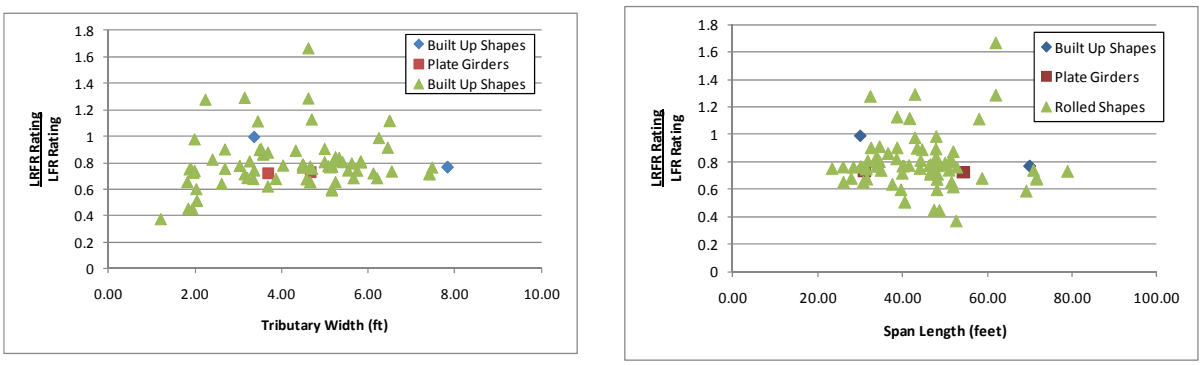


(a) (b)

Figure B-743: LRFR Shear Ratings for Type 3 Vehicles

B.4.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure B-744 shows the comparison of rating factors. The LRFR rating is between 60 and 80% of the LFR rating for most girders in this group. The LFR rating is greater than the LRFR rating for 96% of the girders.

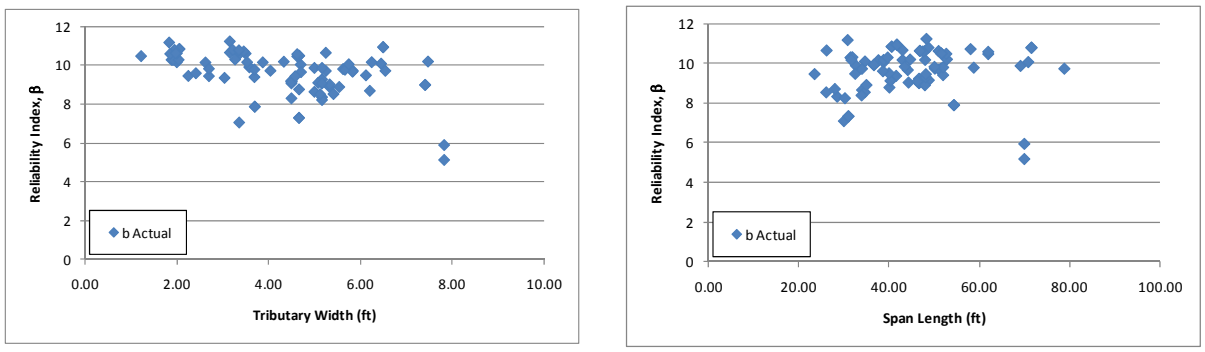


(a) (b)

Figure B-744: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicles

B.4.11.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index shown in Figure B-745 is greater than the value of 2.5 used in the development of the MBE for legal loads.



(a) (b)

Figure B-745: Shear Reliability Indices for Type 3 Vehicles

Figure B-746 shows the reliability index plotted against the LRFR rating for shear due to the AASHTO Type 3 vehicle. The figure shows that girders with ratings greater than 1.0 have reliability indices significantly greater than the target value of 2.5. Reducing the LRFR live load factors will increase the rating and result in girders having a reliability near the target value when they meet the rating criteria.

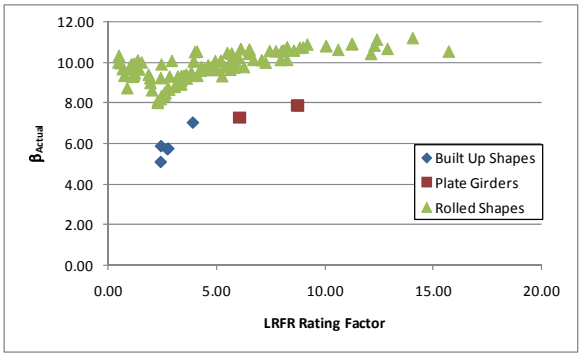


Figure B-746: Shear Reliability Index vs LRFR Shear Rating for Type 3 Vehicle

B.4.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-747. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

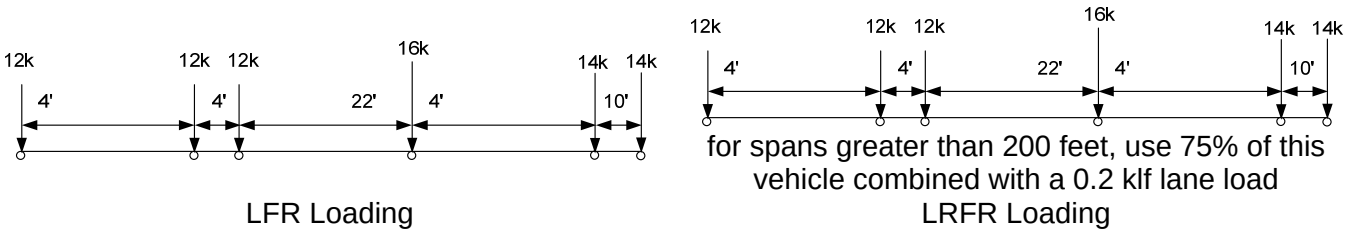


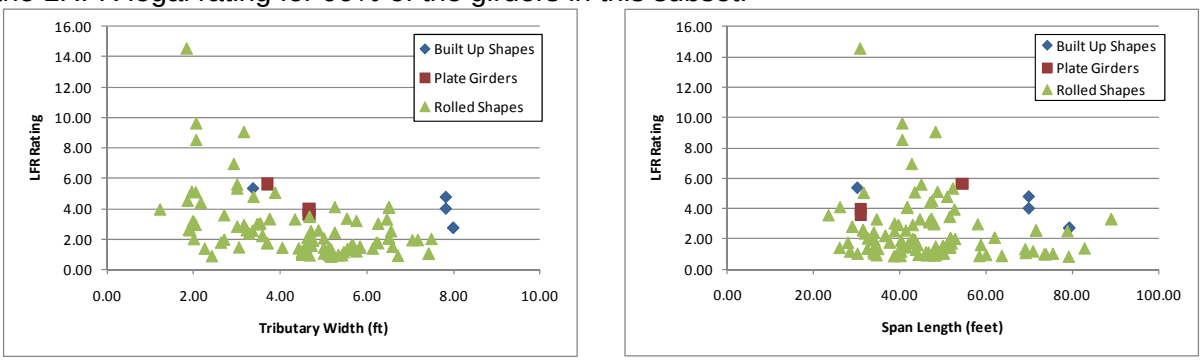
Figure B-747: Vehicle Loadings and Load Factors

B.4.12.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the Type 3-3 Vehicle.

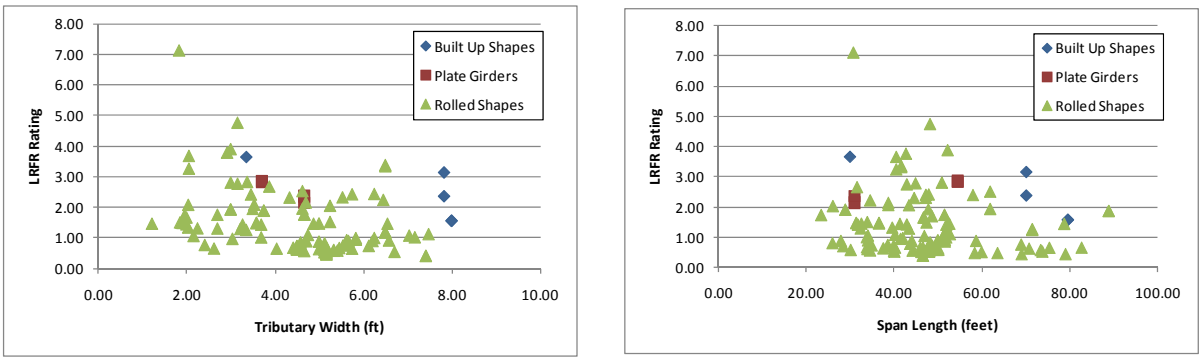
B.4.12.1.1 Rating Factors

Figure B-748 and Figure B-749 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 15 girders with an LFR rating less than 1.0, 62 girders with an LRFR rating less than 1.0, and 15 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 99% of the girders in this subset.



(a) (b)

Figure B-748: LFR Flexure Rating Factors for Type 3-3 Vehicles

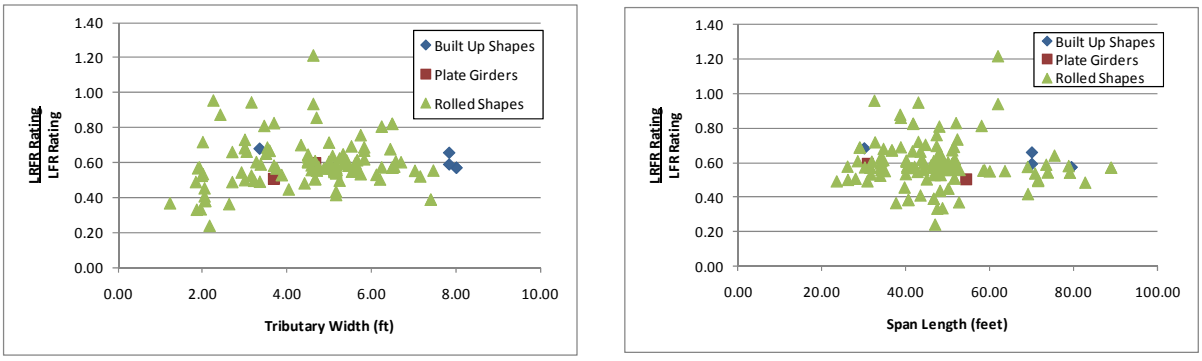


(a) (b)

Figure B-749: LRFR Flexure Rating Factors for Type 3-3 Vehicles

B.4.12.1.2 Rating Factor Comparisons

Figure B-750 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is between 50 and 70% of the LFR rating for most girders. The LFR rating is greater than the LRFR rating for 99% of girders.

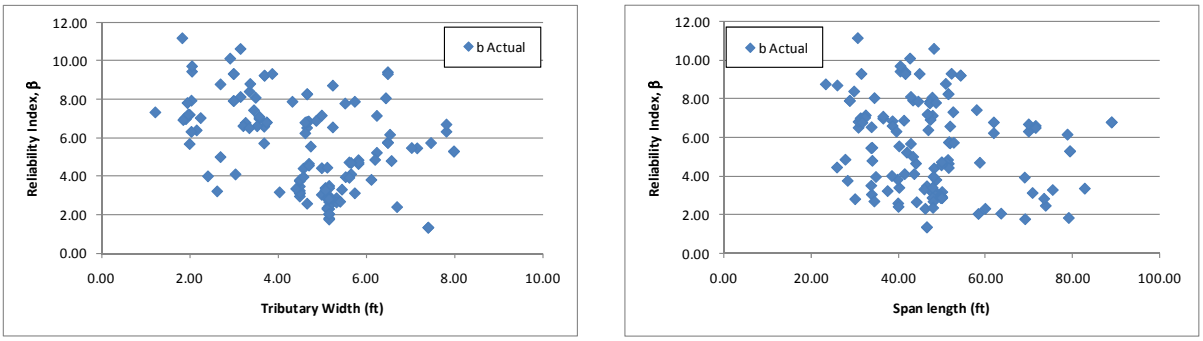


(a) (b)

Figure B-750: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicles

B.4.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-751 shows that a number of girders have a reliability index based upon existing girder strength less than the value of 2.5 used in the development of the MBE.



(a) (b)

Figure B-751: Flexure Reliability Indices for Type 3-3 Vehicles

Figure B-752 shows the reliability index plotted against the LRFR rating for moment due to the AASHTO Type 3-3 Truck. The figure shows that girders with a rating of 1.0 have a reliability index of approximately 4.0 which is significantly higher than the target reliability of 2.5. Reducing the LRFR live load factors will result in girders with ratings of 1.0 and reliability indices near the target value of 2.5.

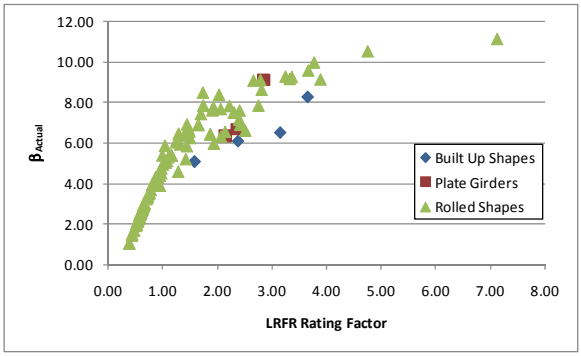


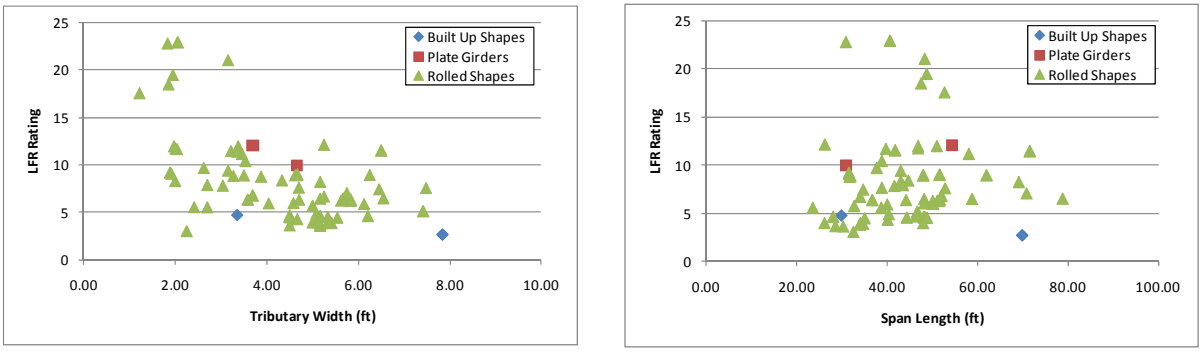
Figure B-752: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Vehicle

B.4.12.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0, these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

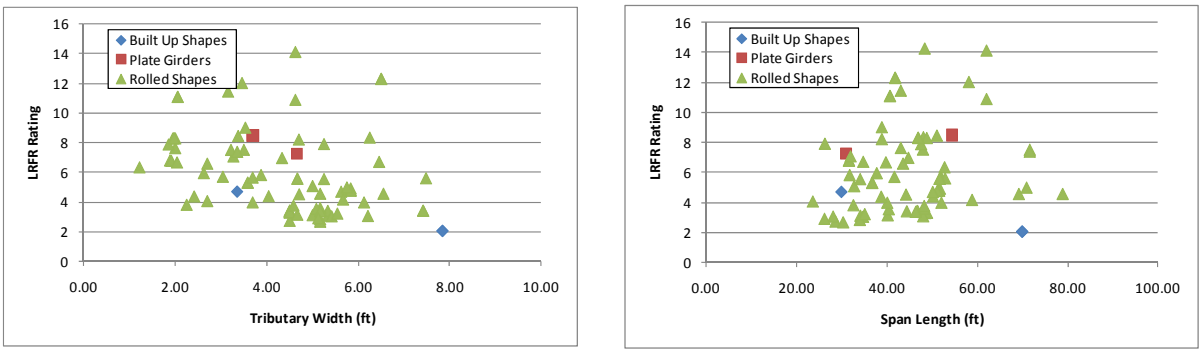
B.4.12.2.1 Rating Factors

For shear, there are 10 girders that have LRFR rating factors less than 1.0 and zero girders with an LFR rating less than 1.0. In this situation, 7.5% of girders are affectedby rating using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 98% of the girders in this subset. Figure B-753 and Figure B-754 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-753: LFR Shear Ratings for Type 3-3 Vehicles

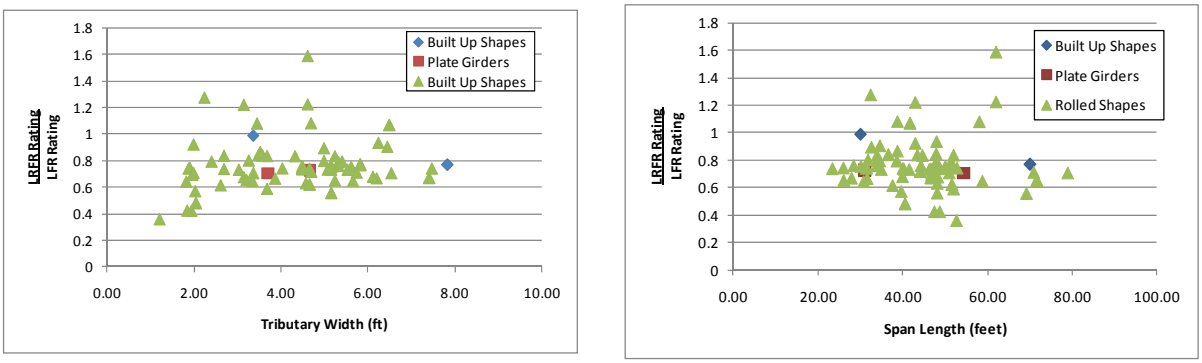


(a) (b)

Figure B-754: LRFR Shear Ratings for Type 3-3 Vehicles

B.4.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure B-755 show the comparison of rating factors. The LRFR rating is typically 60 to 90% of the LFR rating and 98% of girders have an LFR rating greater than LRFR rating.

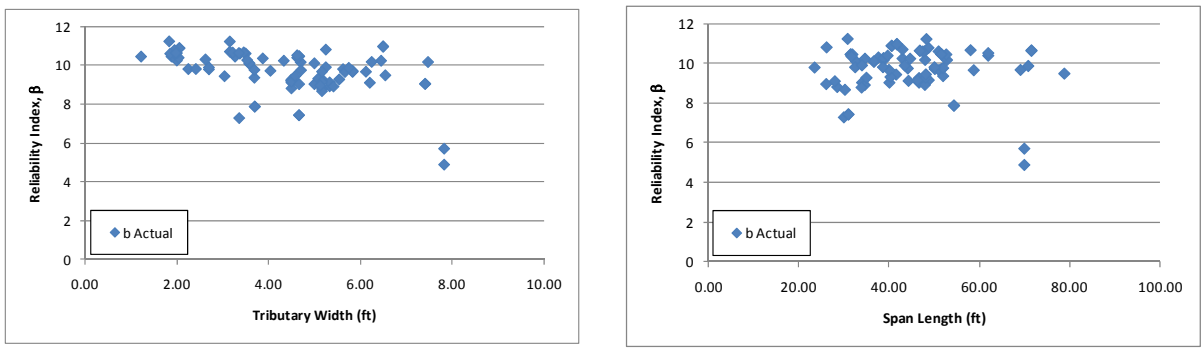


(a) (b)

Figure B-755: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicles

B.4.12.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index shown in Figure B-756 is greater than the target value of 2.5 used in the development of the MBE for legal loads.



(a) (b)

Figure B-756: Shear Reliability Indices for Type 3-3 Vehicles

Figure B-757 shows the reliability index plotted against the LRFR rating factor for shear for the AASHTO Type 3-3 vehicle. The figure shows that the reliability index is greater than the target value for all girders with ratings less than 1.0. Reducing the LRFR live load factors would result in girders having ratings near 1.0 and reliability indices near 2.5. The girders with high reliability and low ratings are controlled by the bearing stiffener rating; the reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

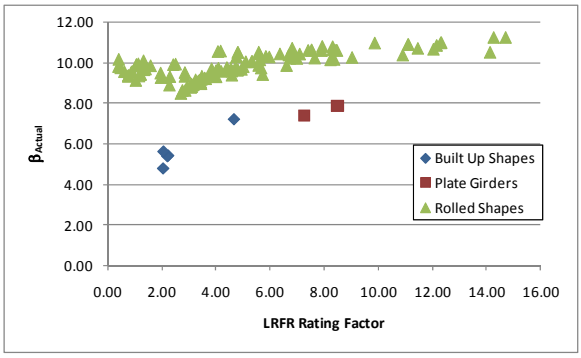


Figure B-757: Shear Reliability Index vs LRFR Shear Rating for Type 3-3 Vehicle

B.4.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure B-758. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

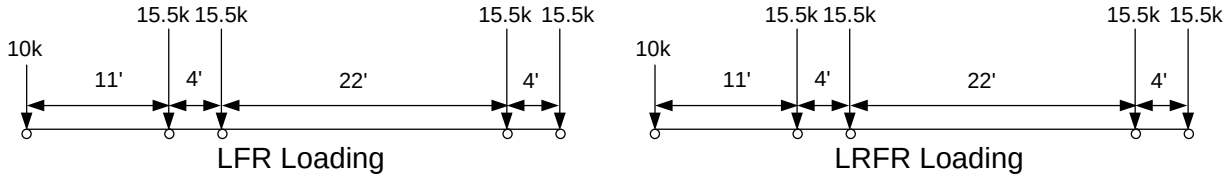


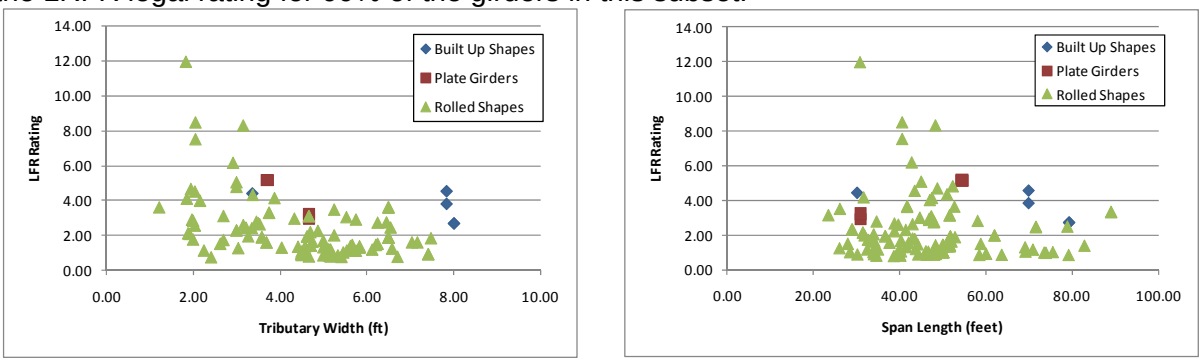
Figure B-758: Vehicle Loadings and Load Factors

B.4.13.1 Moment

The following section contains the results for exterior, non-composite steel girders within simple span bridges for the Type 3S2 Vehicle.

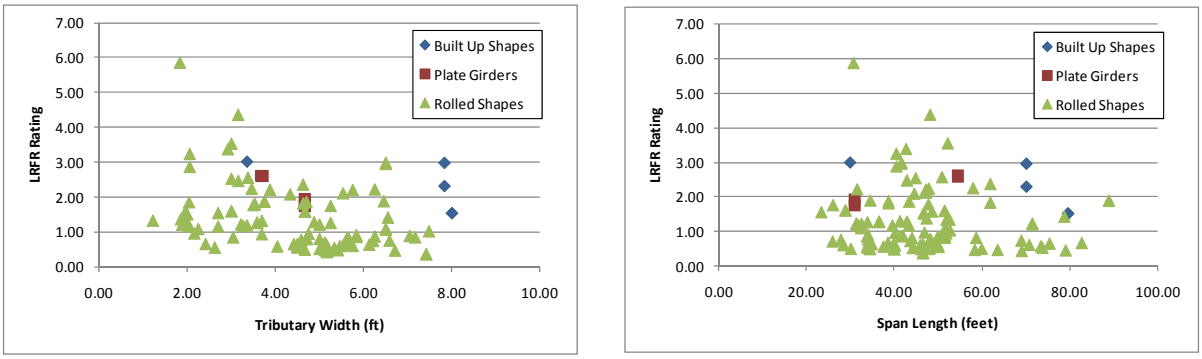
B.4.13.1.1 Rating Factors

Figure B-759 and Figure B-760 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 32 girders with an LFR rating less than 1.0, 67 girders with an LRFR rating less than 1.0, and 32 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 99% of the girders in this subset.



(a) (b)

Figure B-759: LFR Flexure Rating Factors for Type 3S2 Vehicles

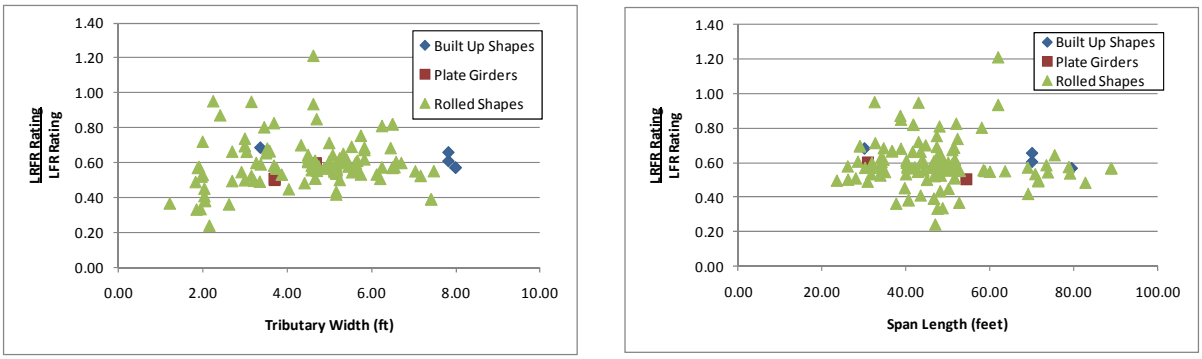


(a) (b)

Figure B-760: LRFR Flexure Rating Factors for Type 3S2 Vehicles

B.4.13.1.2 Rating Factor Comparisons

Figure B-761 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is typically between 50 and 70% of the LFR rating for the girders in this subset. The LFR rating is greater than the LRFR rating for 99% of the girders.

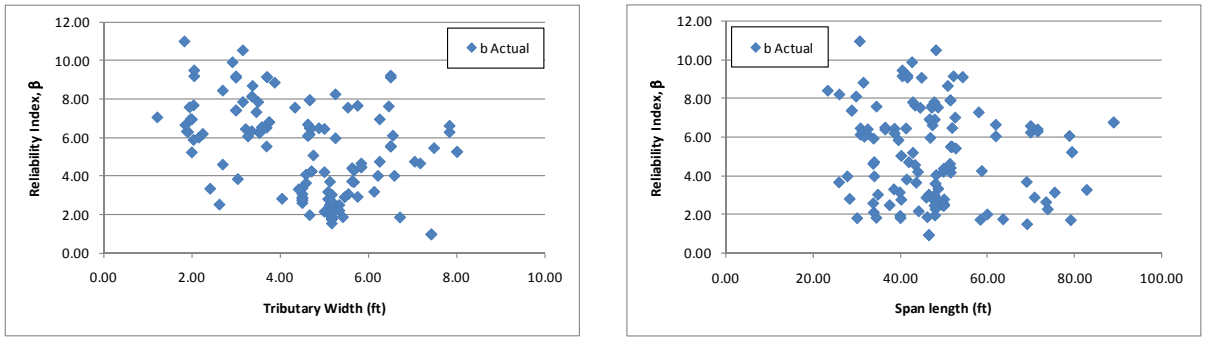


(a) (b)

Figure B-761: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicles

B.4.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure B-762 shows that a number of girders have a reliability index based upon existing girder strength that is less than the value of 2.5 used in the development of the MBE for legal loads.



(a) (b)

Figure B-762: Flexure Reliability Indices for Type 3S2 Vehicles

Figure B-763 shows the reliability index plotted against the LRFR rating due to moment from the AASHTO Type 3S2 Truck. The figure shows that girders with ratings of 1.0 have reliability indices of 4.0, which is significantly greater than the targer reliability of 2.5. The reliability index of a girder with a rating of 1.0 can be decreased by decreasing the LRFR live load factor.

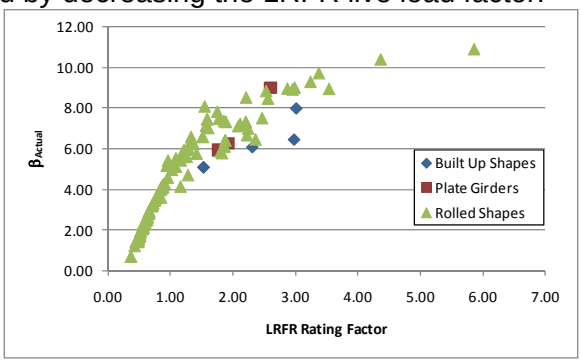


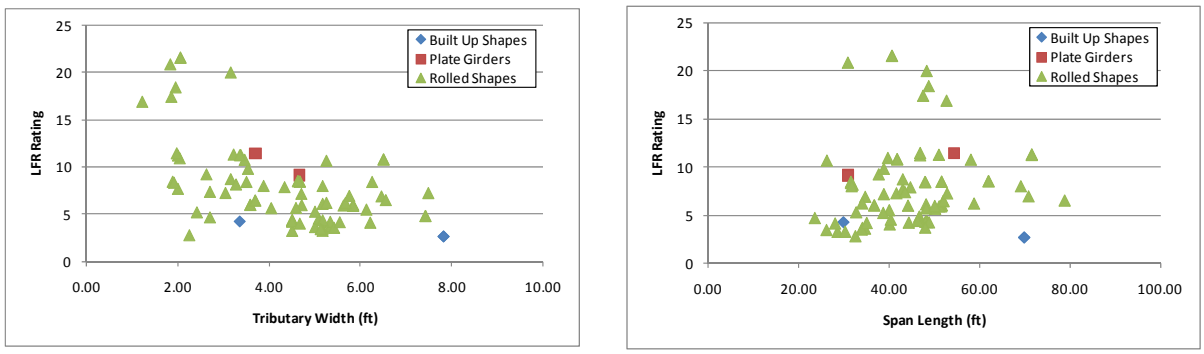
Figure B-763: Flexure Reliability Index vs LRFR Flexure Rating for Type 3S2 Vehicle

B.4.13.2 Shear

The results in this section have been modified to move the LFR rating to the support. The exception is the number of girders with ratings less than 1.0, these numbers consider all girders in this group. For this reason, the text may indicate that there are a number of girders with ratings less than 1.0 but the figures will show no points below 1.0.

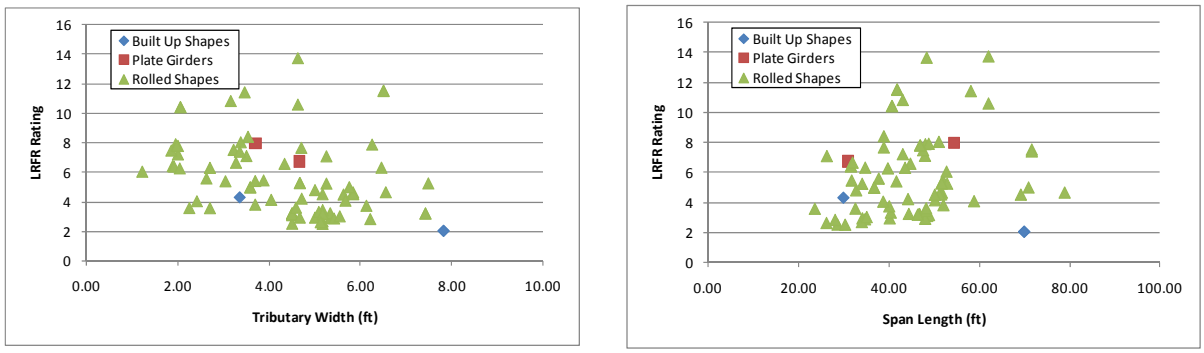
B.4.13.2.1 Rating Factors

For shear, there are 13 girders that have LRFR rating factors less than 1.0 and zero girders for LFR with ratings less than 1.0. In this situation, 9.8% of girders were affected by rating using the LRFR methodology. The LFR Rating is greater than the LRFR rating for 98% of the girders in this subset. Figure B-764 and Figure B-765 show the LFR and LRFR ratings, respectively.



(a) (b)

Figure B-764: LFR Shear Ratings for Type 3S2 Vehicles

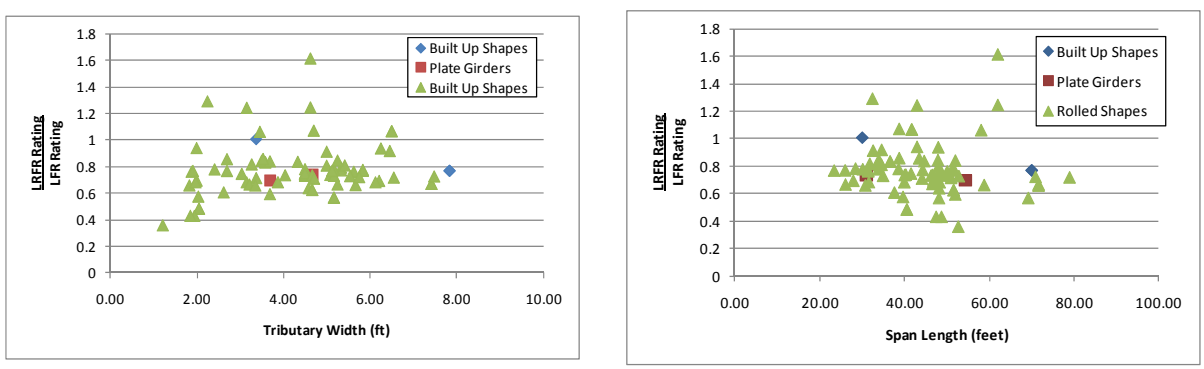


(a) (b)

Figure B-765: LRFR Shear Ratings for Type 3S2 Vehicles

B.4.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure B-766 show the comparison of rating factors. The ratio is generally between 0.6 and 0.8. The LFR rating is greater than the LRFR rating for 98% of girders in this subset.

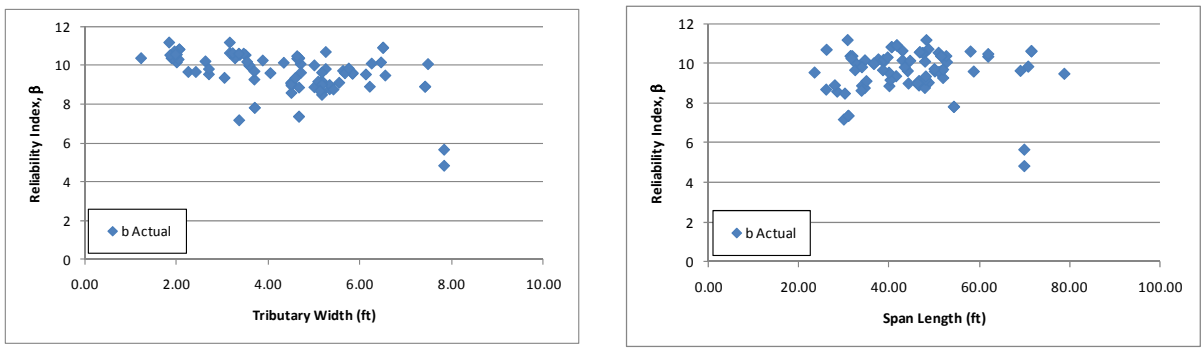


(a) (b)

Figure B-766: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicles

B.4.13.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index shown in Figure B-767 is greater than the value of 2.5 used in the development of the MBE.



(a) (b)

Figure B-767: Shear Reliability Indices for Type 3S2 Vehicles

Figure B-768 shows the reliability index plotted against the LRFR shear rating for the AASHTO Type 3S2 Truck. The figure shows that girders with satisfactory ratings typically have reliability indices significantly higher than the target reliability of 2.5. The girders with high reliability and low ratings are controlled by the bearing stiffener rating; the reliability index is calculated using the web shear resistance not the bearing stiffener resistance. Reducing the LRFR live load factors will reduce the reliability index associated with a LRFR rating factor of 1.0.

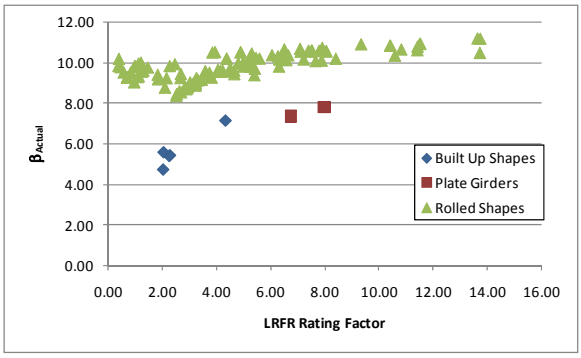


Figure B-768: Shear Reliability Index vs LRFR Shear Rating for Type 3S2 Truck

B.4.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table B-7 shows the results for the moment ratings. For the design vehicle a similar number of girders for each method have ratings less than 1.0. For the special permit vehicles, a larger number of girders had LFR ratings less than 1.0 than for the routine permit vehicles. The number of girders with LRFR ratings less than 1.0 was similar for all vehicle types, except for the WA-02 vehicle which is significantly heavier than the other vehicles. The AASHTO Legal vehicles result in the fewest girders with LFR ratings less than 1.0.

Table B-7: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	133	83	46	44	65	57	36	68	59	77	33	15	32
LRFR Rating less than 1.0		95	72	71	78	78	70	75	79	91	68	62	67
LFR and LRFR Rating less than 1.0		80	45	43	65	57	36	67	59	75	33	15	32
% with LFR RF greater than LRFR RF		91	98	98	89	98	98	85	98	89	99	99	99

B.4.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table B-8 shows the results for the shear ratings. The LFR shear ratings for all vehicles are greater than 1.0. All vehicles resulted in some girders having LRFR ratings less than 1.0; it was determined that these girders are controlled by the bearing stiffener rating. The number of girders does not depend upon the type of vehicle as similar numbers are obtained for legal vehicles and special permit vehicles.

Table B-8: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	133	0	0	0	0	0	0	0	0	0	0	0	0
LRFR Rating less than 1.0		24	14	12	18	12	9	14	17	23	11	10	13
LFR and LRFR Rating less than 1.0		0	0	0	0	0	0	0	0	0	0	0	0
% with LFR RF greater than LRFR RF		92	96	96	89	95	95	89	95	89	96	98	98

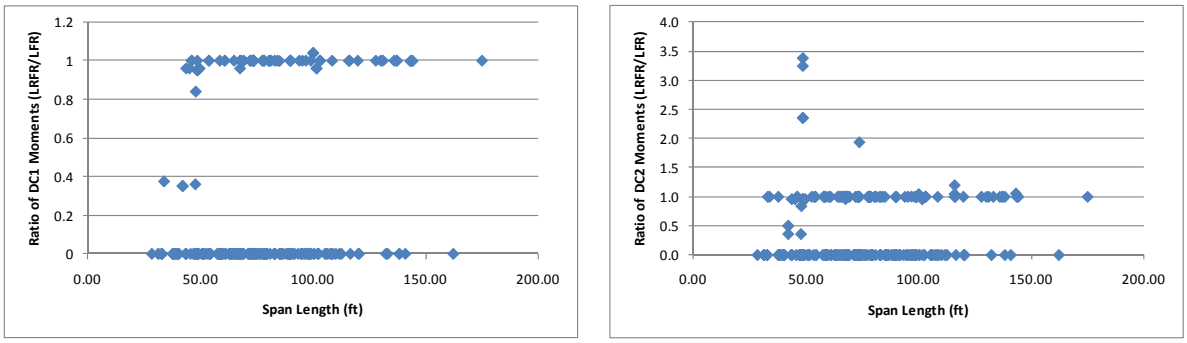
C Simple Span Prestressed I Girder Bridges

C.1 Interior Composite Girders

C.1.1 Dead Loads

C.1.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure C-1a, the ratios of unfactored DC1 moments (self-weight, dead loads on non-composite section) are very close to 1.0. Figure C-1b shows that there is more variation in the loads applied to the composite section (DC2 and DW loads). Both graphs show that there are a large number of girders where the ratio of LRFR dead load moments divided by LFR dead load moments is zero. These are girders where the critical section for LRFR was at the support due to the longitudinal steel requirement of AASHTO LRFD 5.8.3.5 controlling the rating.

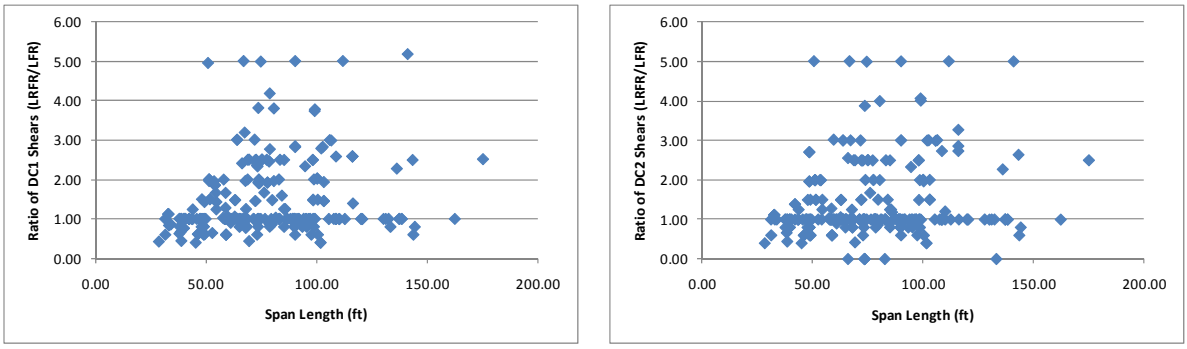


(a) (b)

Figure C-1: Ratios of DC1 and DC2 Moment LRFR/LFR (unfactored loads)

C.1.1.2 Shear

Figure C-2a shows that numerous girders have a ratio of DC1 shear close to 1.0, but there are also many where the ratio is either above or below 1.0. This is a mostly due to the variation of the critical section for shear. Figure C-2b is similar to Figure C-2a in that the LFR shear is similar to the LRFR shear.



(a) (b)

Figure C-2: Ratios of DC1 and DC2 Shear LRFR/LFR (unfactored loads)

C.1.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure C-3. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

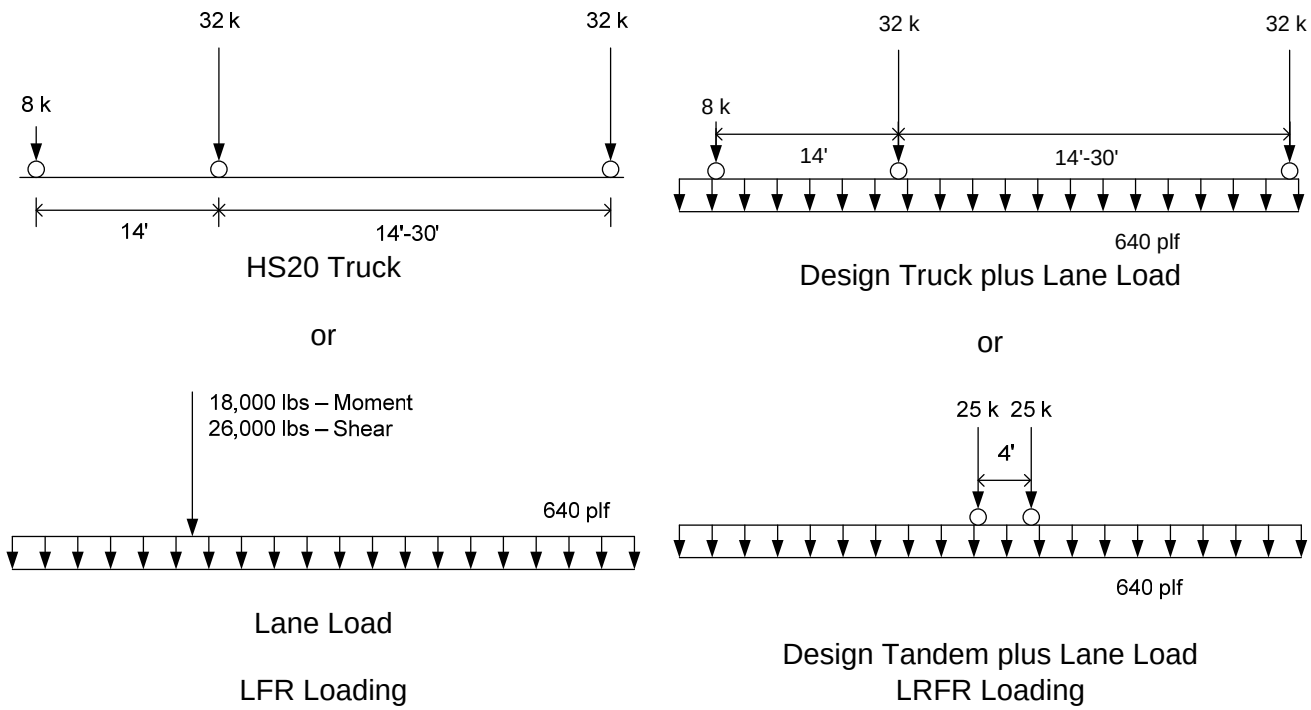
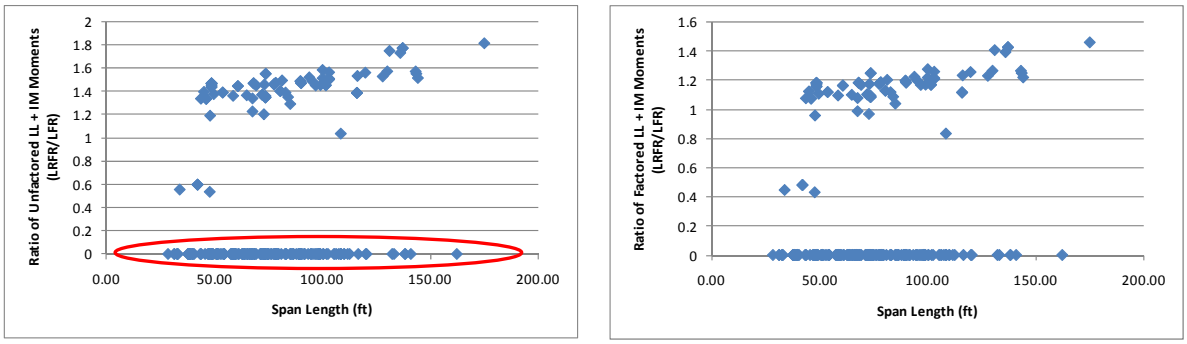


Figure C-3: Vehicle Loadings and Load Factors

C.1.2.1 Moment

C.1.2.1.1 Live Loads

Figure C-4a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.2 and 1.6 for most of the girders within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure C-4b shows that the results have shifted down and are between 1.0 and 1.4 for most cases. The data points circled in Figure C-4a are those controlled by the longitudinal steel requirement of AASHTO LRFD 5.8.3.5; this rating criteria controls for 211 girders of the 274 girders in this group..



(a) (b)

Figure C-4: Ratios of Unfactored and Factored Live Load plus Impact Moments for Design Vehicles (LRFR/LFR)

C.1.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure C-5 shows that the ratio of LRFR resistance to LFR resistance is generally between 1.0 and 1.25. The increase is due to the reduction in prestress losses between the LFR and LRFR methods. The girders between 0 and 0.25 correspond to those circled in Figure C-4a; the LRFR moment resistance at the support is compared to the LFR moment resistance at midspan.

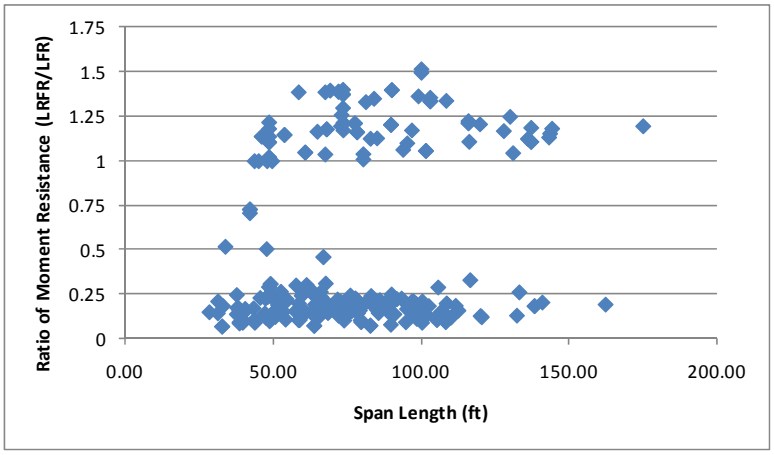
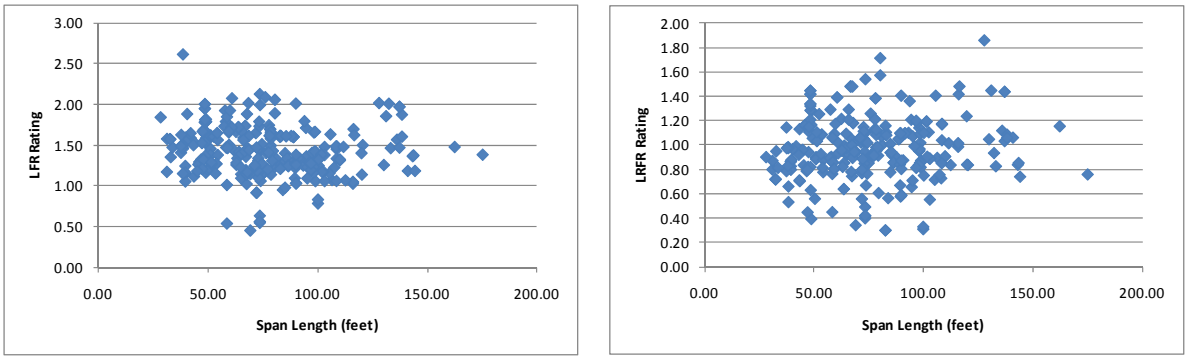


Figure C-5: Ratio of factored Moment Resistance (LRFR/LFR)

C.1.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (274 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 12 girders with LFR ratings less than 1.0, 159 girders with LRFR ratings less than 1.0, and 12 girders where both the LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD

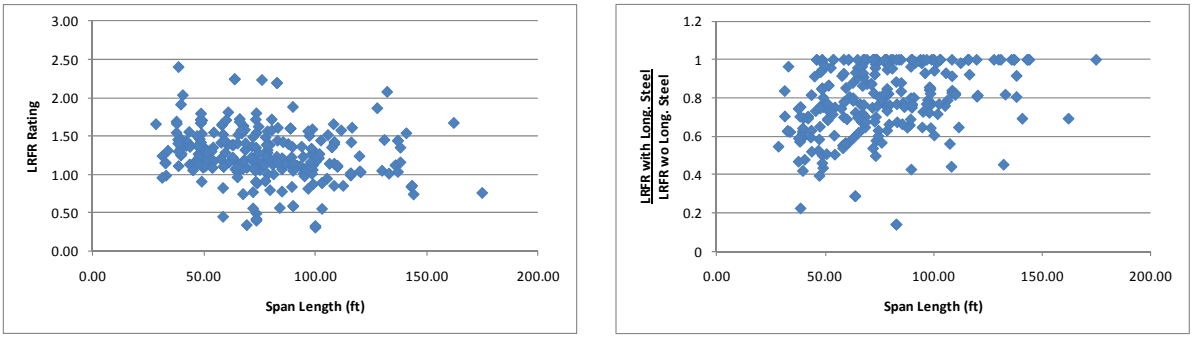
specification, is that they would produce significantly lower rating factors. Figure C-6 shows the LFR rating factors and LRFR rating factors.



(a) (b)

Figure C-6: LFR and LRFR Flexure Rating Factors for HS-20 and HL-93 Loadings

Figure C-7a shows the LRFR ratings when the longitudinal steel rating is ignored. Ignoring this check eliminates 119 of the girders with LRFR ratings less than 1.0. Figure C-7b shows the ratio of LRFR rating including the longitudinal steel rating divided by the LRFR rating ignoring the longitudinal steel rating. 77% of girders have higher LRFR ratings when the longitudinal steel check is ignored. The LRFR rating including the longitudinal steel rating is typically 40-90% of the LRFR rating when the longitudinal steel is not included.



(a) (b)

Figure C-7: Effect of Longitudinal Steel Rating on LRFR Rating

C.1.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure C-8. The results indicated that 100% of the girders in this set have LFR ratings greater than LRFR ratings.

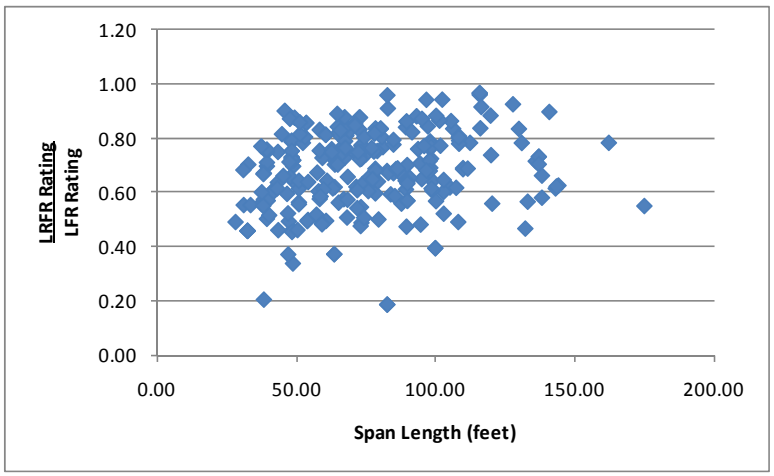


Figure C-8: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Vehicles

Figure C-9 shows the distribution of the ratio of LRFR/LFR ratings for girders with LRFR ratings less than 1.0. The figure shows that most girders with LRFR ratings less than 1.0 have an allowable truck weight that is at least 50% of the LFR allowable truck weight. This figure utilizes the rating factors for the longitudinal steel reinforcement so the LRFR ratings are expected to be significantly lower than the LFR ratings.

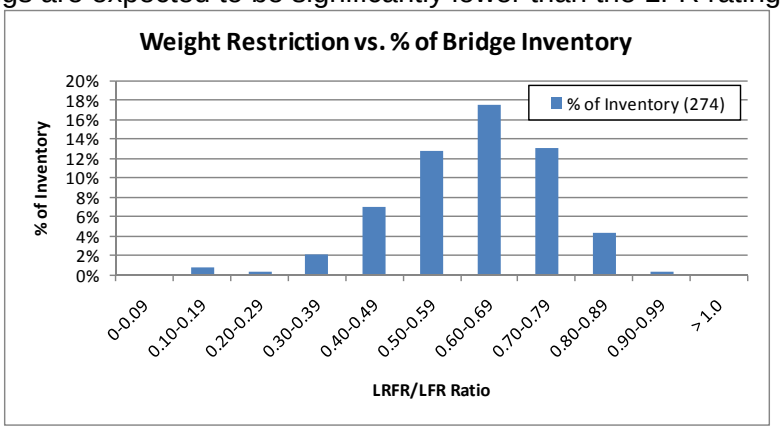


Figure C-9: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

C.1.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure C-10 shows that three girders have a reliability index lower than that assumed in the development of the MBE at this loading level. The girders controlled by the longitudinal steel requirement have an actual reliability index of 15.50 and a required reliability index shown as zero.

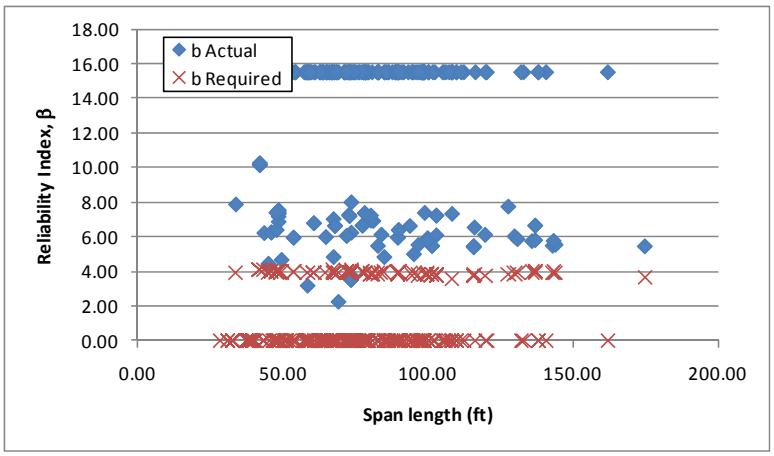


Figure C-10: Flexure Reliability Indices for HL-93 Loading

Figure C-11 shows the reliability index plotted against the LRFR rating for moment caused by the HL-93 Design Vehicle. The figure shows that girders with a rating of 1.0 have a reliability index of 4.0. Girders with ratings less than 1.0 have reliability indices ranging from 2.0 to 8.0. The figure also shows that girders controlled by the AASHTO LRFD 5.8.3.5 have the same reliability independent of the rating; this is because all the loads that go into the reliability index calculation are zero.

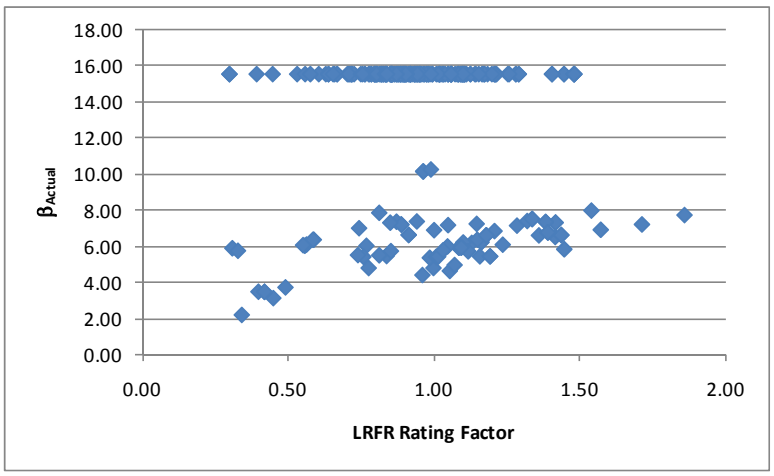


Figure C-11: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Vehicle

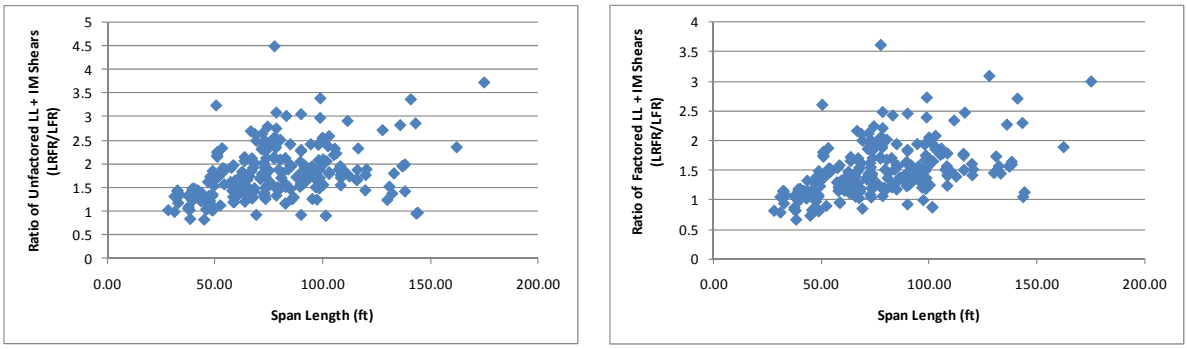
C.1.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is prestressed concrete I-beam, simple span interior girders with composite concrete decks.

C.1.2.2.1 Live Loads

Figure C-12a shows that the ratio of unfactored shear varies significantly, with most girders between 1.0 and 2.5, with some ratios less than 1.0 and others greater than 3.0. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure C-12b

shows that the ratio of factored live load shears has decreased and is generally between 0.75 and 2.0 for most cases.



(a) (b)

Figure C-12: Ratios of Unfactored and Factored Live Load plus Impact Shears for Design Vehicles (LFR/LRFR)

As shown in Figure C-13, the location of the critical section for varies significantly for most girders in this subset. The difference in the factored shears shown in Figure C-12 was caused in part by the difference in the critical section for shear rating.

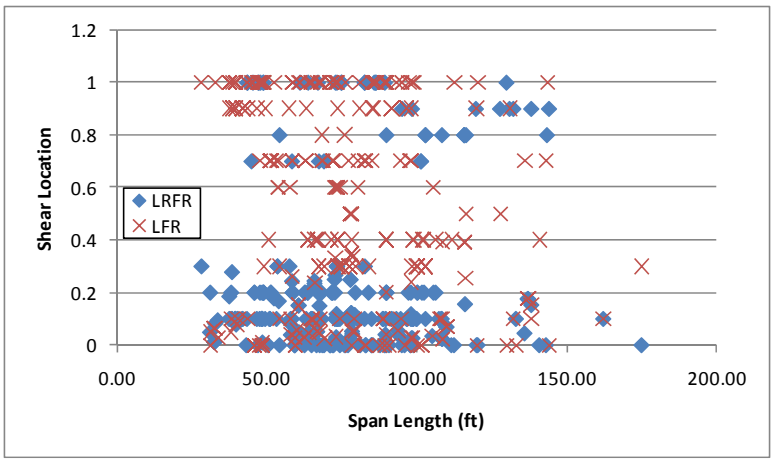


Figure C-13: Graph of critical shear location for Design Vehicles

C.1.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure C-14 shows that the ratio of resistance is generally greater than 1.0 (LRFR resistance is greater than LFR resistance). The LRFR shear resistance is expected to be greater than the LFR shear resistance due to the increase in applied load.

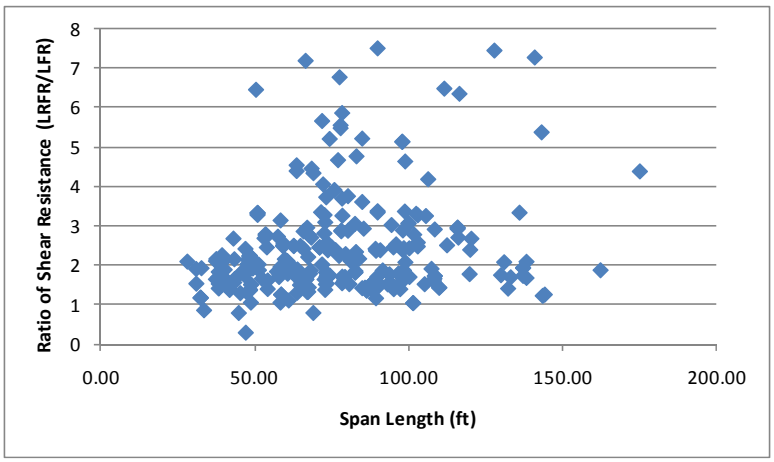
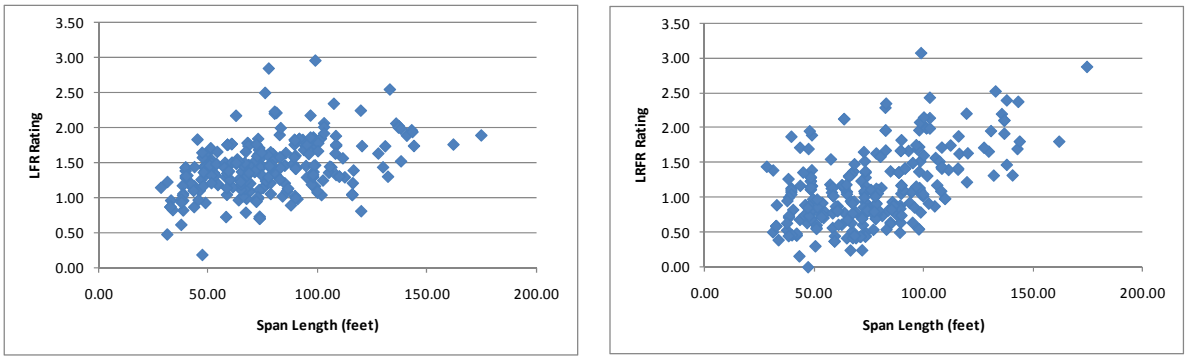


Figure C-14: Ratio of factored Shear Resistance (LRFR/LFR)

C.1.2.2.3 Rating Factors

After comparing the loads and resistances to verify that the results were reasonable, the actual rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 30 girders with LFR ratings less than 1.0, 127 girders with LRFR ratings less than 1.0, and 26 girders where both LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. For this subset, there are significant number girders that have shear ratings less than 1.0 for LRFR. The year of construction was checked to see if there was any trend associated with this variable, and the year does not appear to affect the rating. In fact, some girders constructed in the last decade have ratings lower than those constructed 50 years ago. In addition, the LFR rating was greater than the LRFR rating for 80% of the girders in this subset. Figure C-15 shows the LFR rating factors and LRFR rating factors. The LFR rating tends to increase with increasing span length, with LRFR showing the same trend.



(a) (b)

Figure C-15: LFR and LRFR Shear Rating Factors for HS-20 and HL-93 Loadings

C.1.2.2.4 Rating Factor Comparisons

Figure C-16 shows the ratio of the LRFR rating to the LFR rating. There are a number of girders with LRFR ratings greater than LFR ratings, but this is only 20% of the girders in the set. There are no obvious trends when it comes to this comparison.

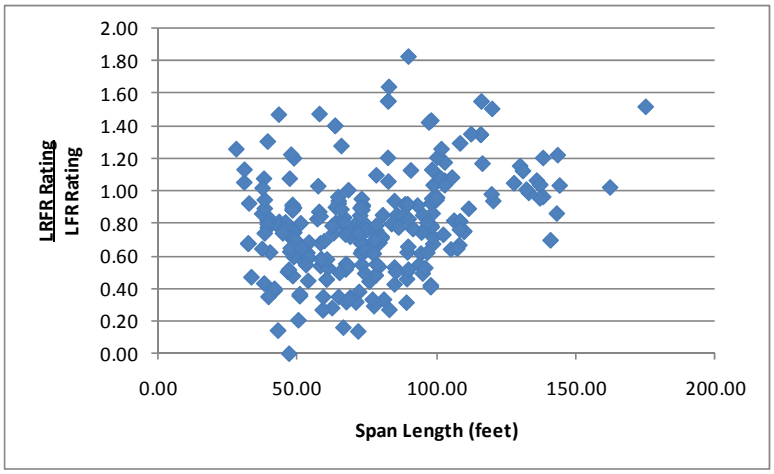


Figure C-16: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Vehicles

Figure C-17 shows the distribution of the ratio between LRFR and LFR ratings for the HL-93 Design Load. The figure shows that most girders with LRFR ratings less than 1.0 also have significantly lower LRFR ratings. Most girders would have an allowable LRFR weight that is less than 70% of the LFR weight. This is a significant reduction in the allowable load on the bridge. There are several girders where the LRFR rating is higher than the LFR rating as indicated by the bar in the greater than 1.0 segment.

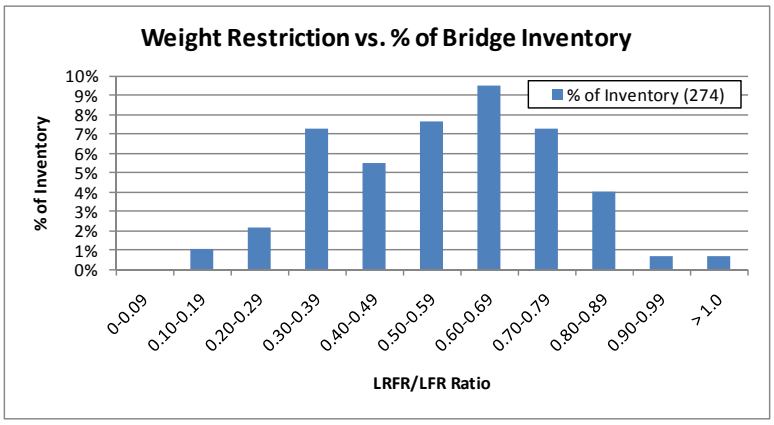


Figure C-17: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

C.1.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure C-18 shows that most of the girders have a reliability index for shear greater than the required level. The girders that do not have the required level of reliability are generally of lengths less than 75 feet. In several cases, the actual reliability index is less than zero, indicating the applied loads are significantly larger than the section resistance. This may also be caused by the shear reinforcement not being input into the model.

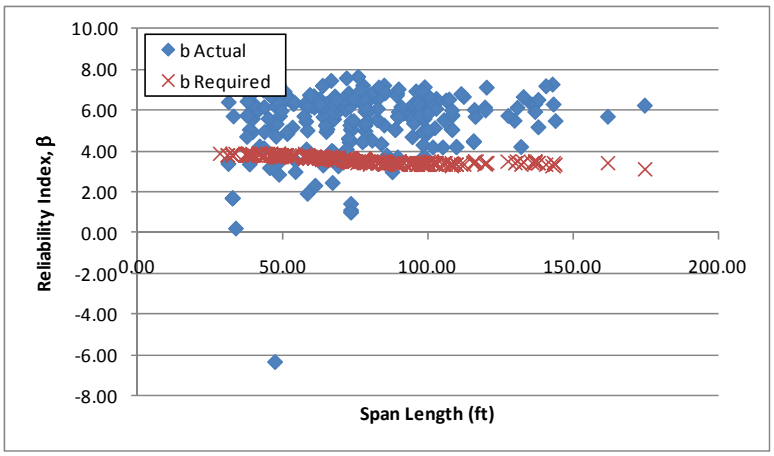


Figure C-18: Shear Reliability Indices for HL-93 Loading

Figure C-19 shows the reliability index plotted against the LRFR rating for shear due to the HL-93 vehicle. The figure shows that girders with an LRFR rating of 1.0 have reliability indices of at least 4.0. Girders exist where the LRFR rating is low and the reliability index is high; the reliability index is high because it is calculated using the shear resistance instead of the shear friction resistance used in determining the rating.

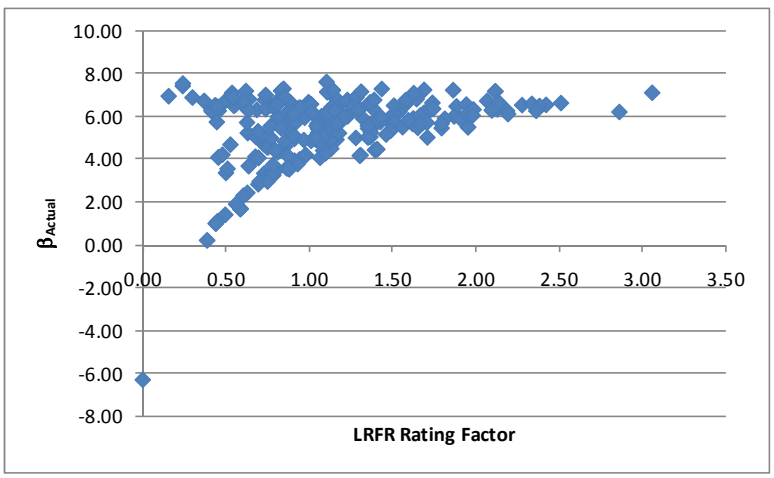
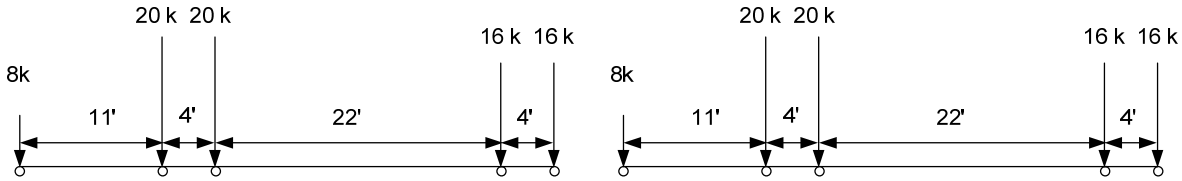


Figure C-19: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

C.1.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-20. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

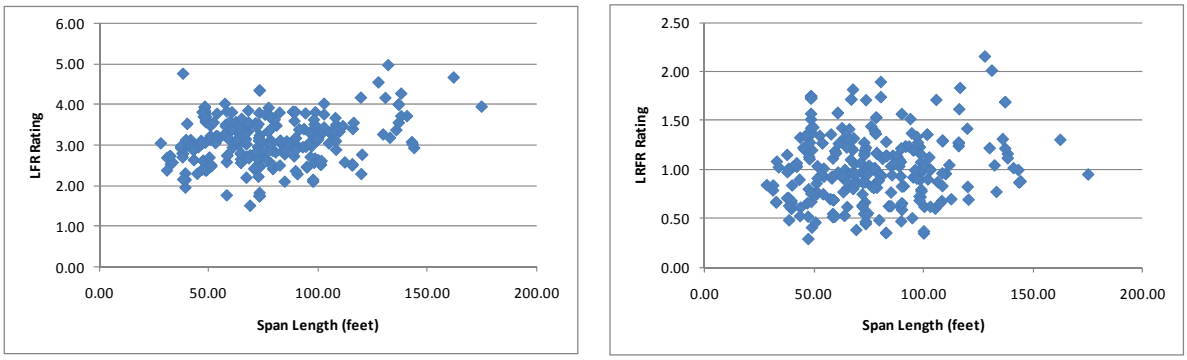
Figure C-20: Vehicle Loadings and Load Factors

C.1.3.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the DE-07 Vehicle.

C.1.3.1.1 Rating Factors

Figure C-21 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 141 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for all girders in this subset. Of the 141 girders with an LRFR rating less than 1.0, 118 are controlled by rating the longitudinal steel reinforcement near the support.



(a) (b)

Figure C-21: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure C-22 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 60% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0.

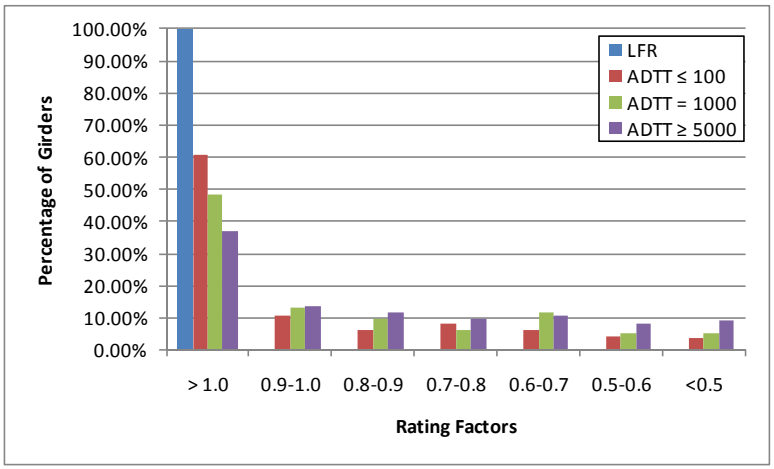


Figure C-22: Flexure Ratings for Different ADTTs in MBE

C.1.3.1.2 Rating Factor Comparisons

Figure C-23 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. All girders have higher LFR ratings than LRFR ratings and the ratio of ratings is between 0.2 and 0.5 for most girders. The reduction in live load is significant when switching from LFR to LRFR.

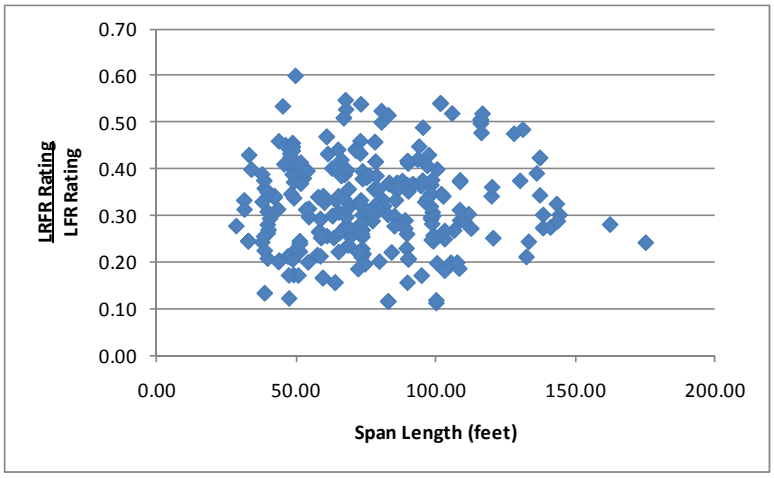


Figure C-23: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

C.1.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-24 shows that all girders have a reliability index based upon girder strength that is greater than the target reliability index of 2.5 used in the development of the MBE.

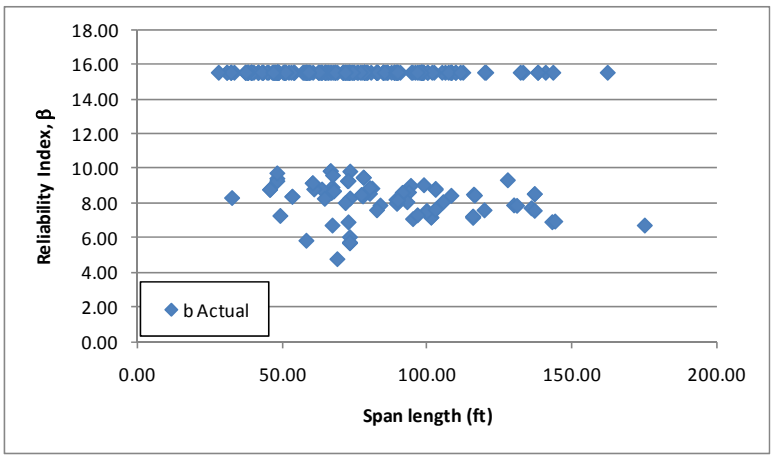


Figure C-24: Flexure Reliability Indices for DE-07 Vehicle

Figure C-25 shows the reliability index plotted against the LRFR rating factor for moment due to the DE-07 vehicle. The reliability index for a girder passing rating is greater than the target reliability index of 2.5 for routine permit vehicles. This indicates that the LRFR live load factors could be reduced and still maintain the target level of reliability.

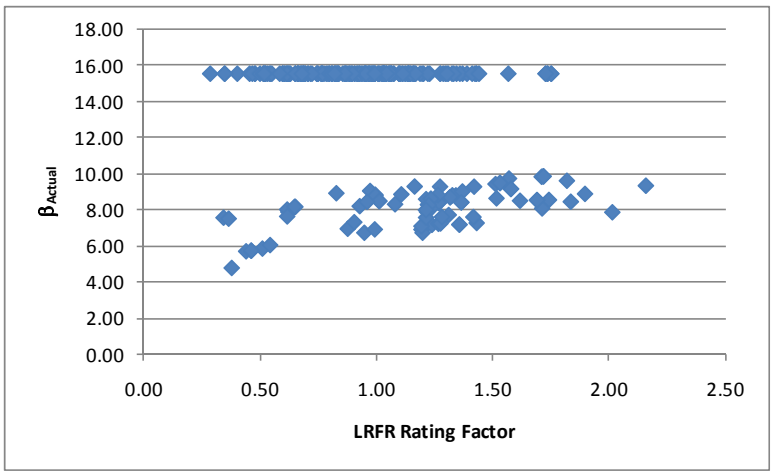
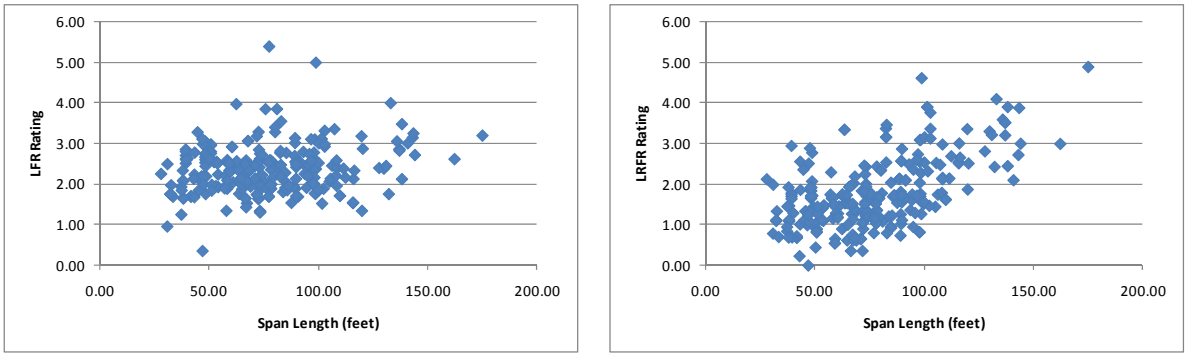


Figure C-25: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

C.1.3.2 Shear

C.1.3.2.1 Rating Factors

For shear, there are two girders that have rating factors less than 1.0 for LFR, 40 girders for LRFR, and 2 girders where both LFR and LRFR are less than 1.0. The LRFR rating results in more girders not having satisfactory ratings, indicating that increase in shear resistance does not offset the increase in live load over the LFR method. The LFR Rating is greater than the LRFR rating for 80% of the girders in this subset. Figure C-26 show the LFR and LRFR ratings.



(a) (b)

Figure C-26: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure C-27 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, 90% of girders will have an LRFR rating above 1.0 while almost all girders will have an LFR rating greater than 1.0.

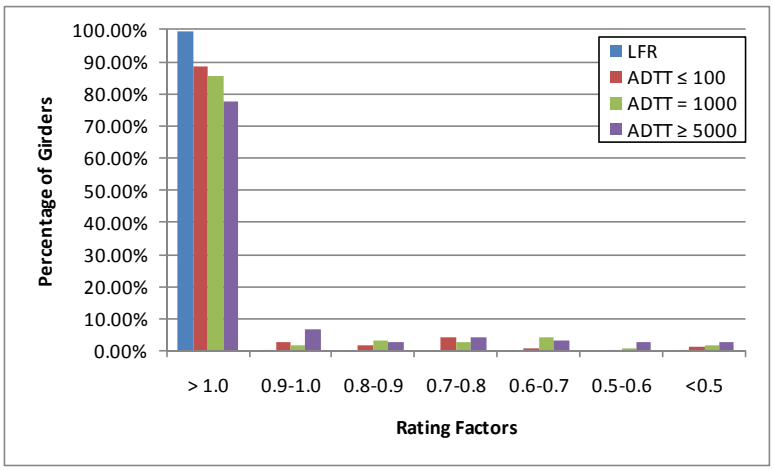


Figure C-27: Shear Ratings for Different ADTTs in MBE

C.1.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure C-28 show the comparison of rating factors. The ratio is generally less than 1.0, with longer spans more likely to have a ratio greater than 1.0.

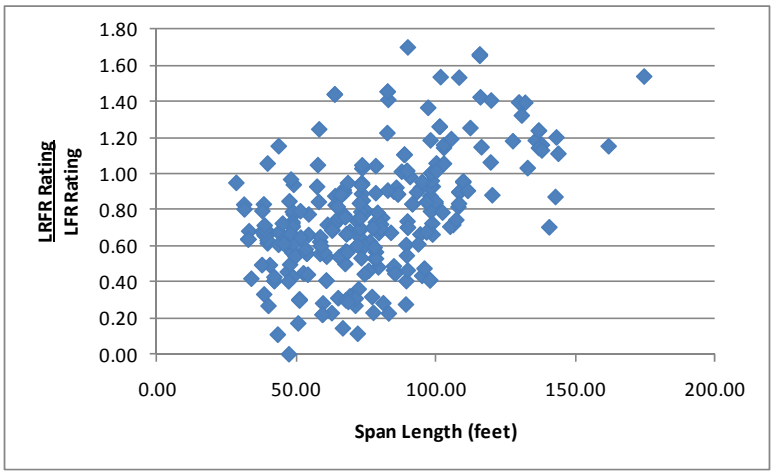


Figure C-28: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

C.1.3.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders except for one as shown in

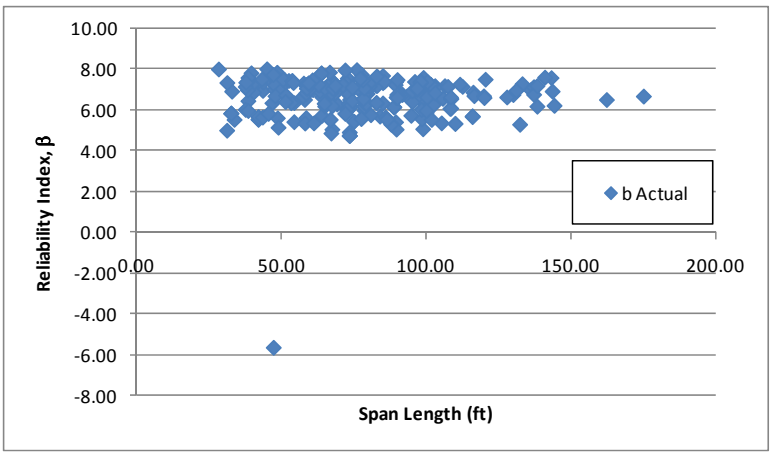


Figure C-29. The girder with a reliability index of -6 does not have properly defined shear reinforcement which reduces the shear resistance significantly.

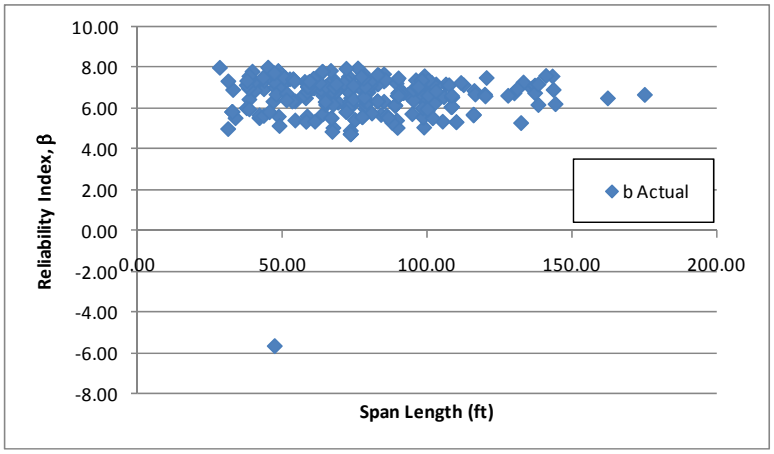


Figure C-29: Shear Reliability Indices for DE-07 Vehicle

Figure C-30 shows the reliability index plotted against the LRFR rating for shear due to the DE-07 vehicle. The figure shows that girders with an LRFR rating of 1.0 have a reliability index of approximately 4.0 which is greater than the target reliability of 2.5. This indicates that the target reliability could be maintained while reducing the LRFR live load factors. A number of girders have high reliability and low ratings; these ratings are controlled by shear friction but the reliability index is calculated using the shear resistance not the shear friction resistance.

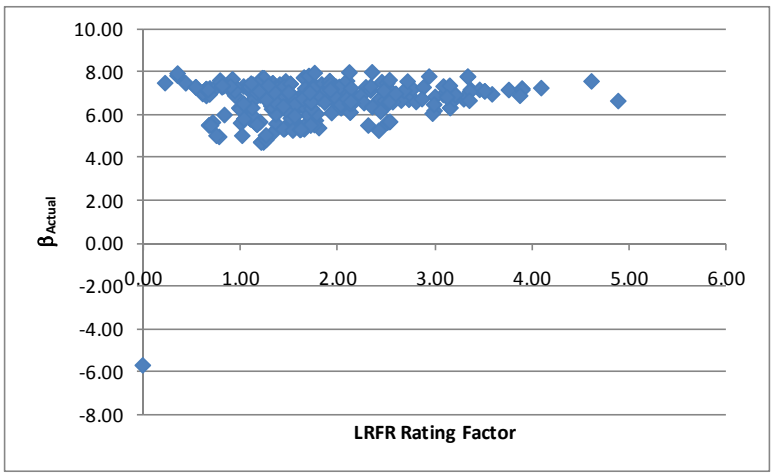
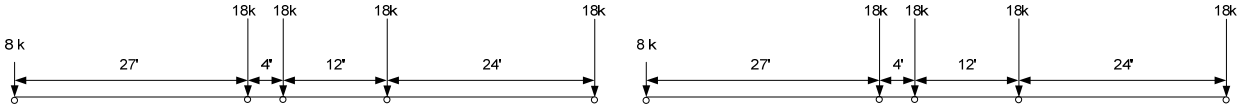


Figure C-30: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

C.1.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-31. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

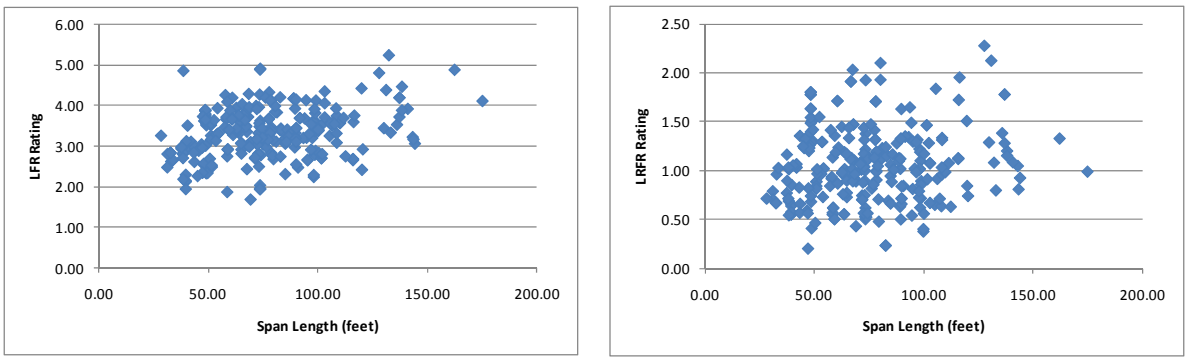
Figure C-31: Vehicle Loadings and Load Factors

C.1.4.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the FL-04 Vehicle.

C.1.4.1.1 Rating Factors

Figure C-32 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 125 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. Of the 125 girders with an LRFR rating less than 1.0, 108 are controlled by the longitudinal steel requirement of AASHTO LRFD 5.8.3.5.



(a) (b)

Figure C-32: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure C-33 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 65% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0.

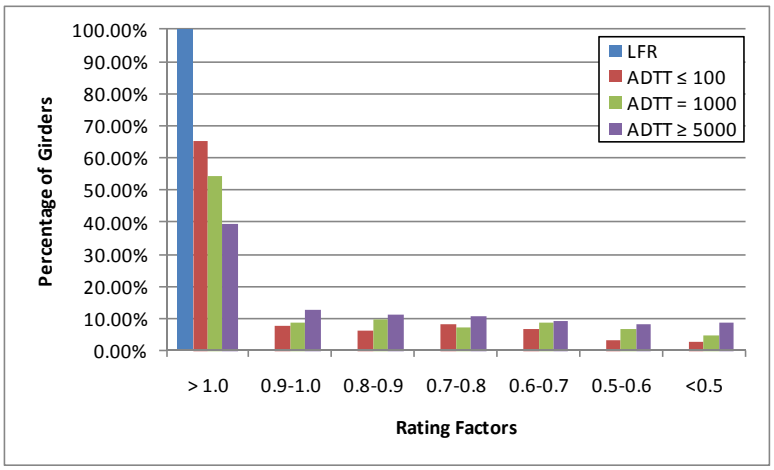


Figure C-33: Flexure Ratings for Various ADTTs in MBE

C.1.4.1.2 Rating Factor Comparisons

Figure C-34 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating, which for this vehicle there are no girders with LRFR ratings greater than LFR ratings The LRFR rating is typically 20 to 40% of the LFR rating. The signficnant reduction is partially caused by the LRFR rating for the longitudinal steel reinforcement being considered.

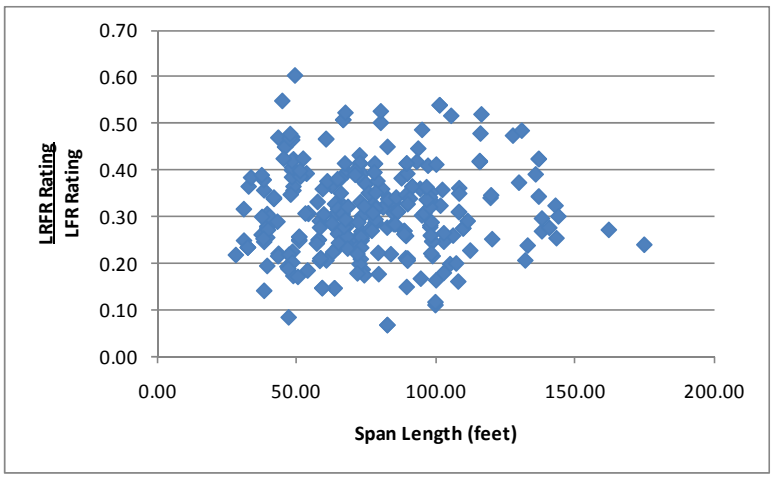


Figure C-34: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

C.1.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders.

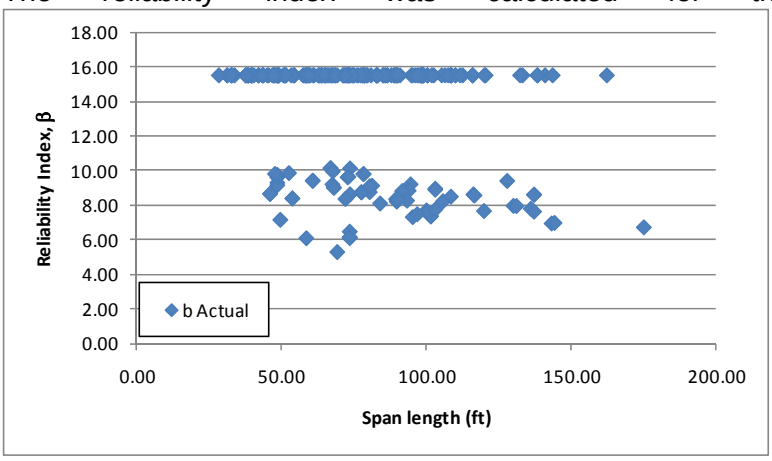


Figure C-35 shows that all girders have a reliability index based upon girder strength that is greater than the target reliability index of 2.5 for routine permit vehicles. The girders at 15.5 are those controlled by the rating of the longitudinal reinforcement.

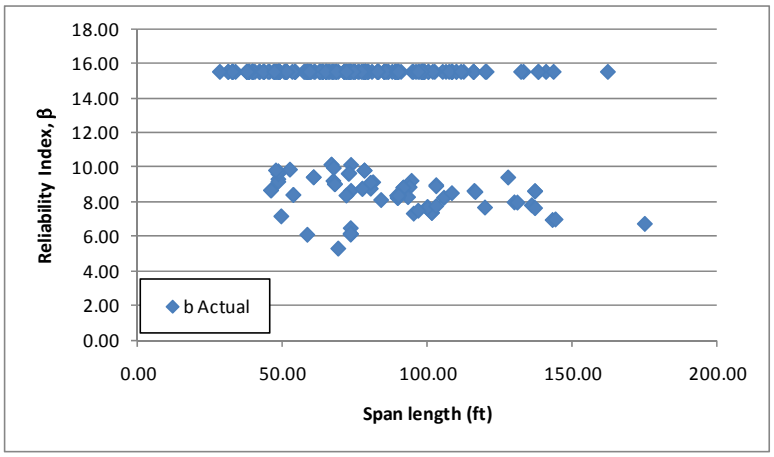


Figure C-35: Flexure Reliability Indices for FL-04 Vehicle

Figure C-36 shows the reliability index plotted against the LRFR rating for moment due to the FL-04 vehicle. The figure shows that girders passing rating, ignoring those that are controlled by the longitudinal reinforcement, have a reliability index above 6.0. This is above the target reliability of 2.5 for routine permit vehicles. This indicates that the reliability could be maintained using live load factors lower than those currently in the MBE.

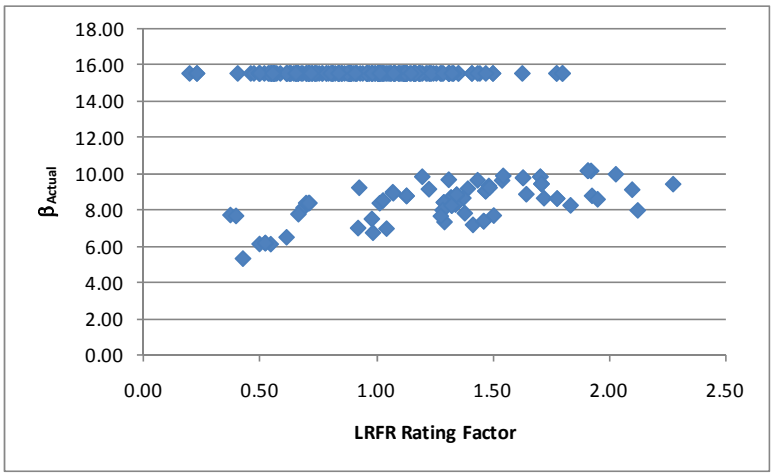
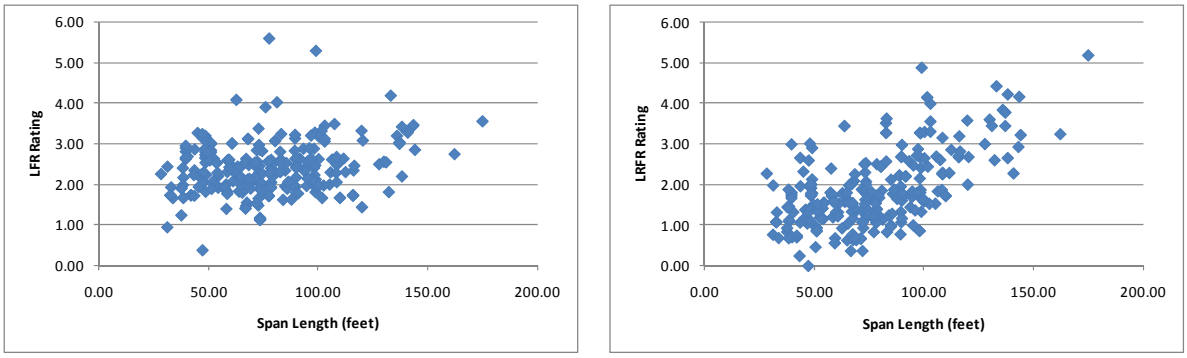


Figure C-36: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

C.1.4.2 Shear

C.1.4.2.1 Rating Factors

For shear, there are two girders that have LFR rating factors less than 1.0, 39 girders with LRFR ratings less than 1.0, and 2 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure C-37 show the LFR and LRFR ratings. The LFR ratings remain fairly constant with increasing span lengths while the LRFR ratings increase with increasing span length.



(a) (b)

Figure C-37: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure C-38 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, less than 90% of girders will have an LRFR rating above 1.0 while almost all girders will have an LFR rating greater than 1.0.

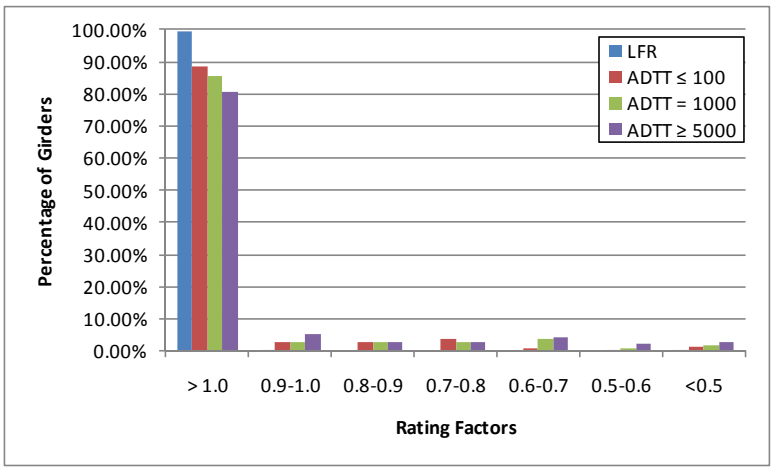


Figure C-38: Shear Ratings for Various ADTTs in MBE

C.1.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-39 shows the comparison of rating factors. The ratio is generally between 0.4 and 1.0, with the ratio increasing for longer span lengths. The LFR rating is greater than the LRFR rating for 76% of the girders.

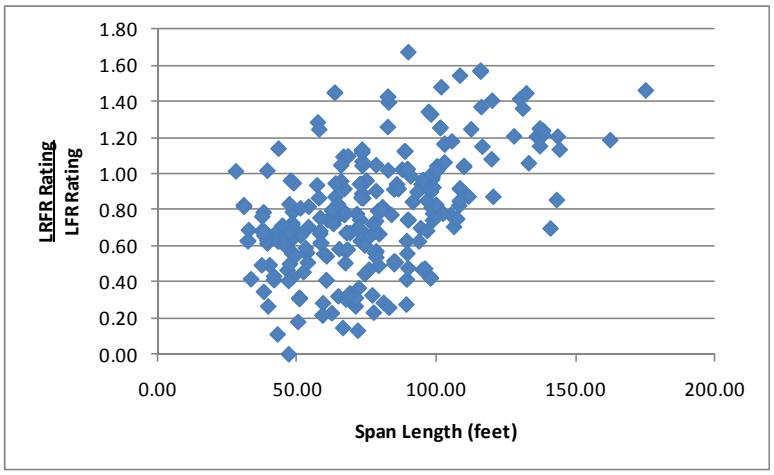


Figure C-39: LRFR Shear Rating divided by LFR Shear Rating FL-04 Vehicle

C.1.4.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all but one girder as shown in Figure C-40

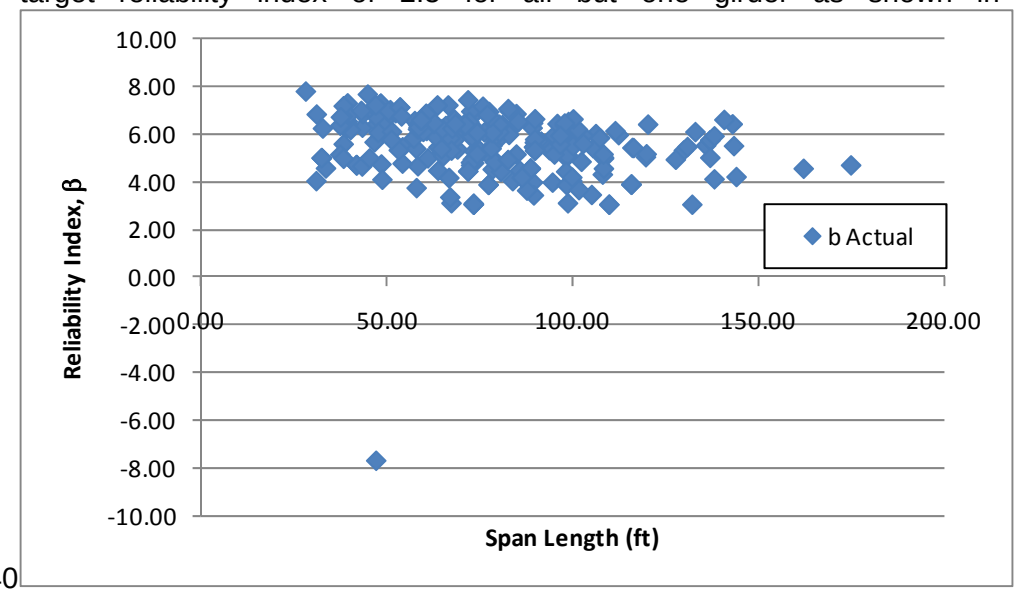


Figure C-40. This is the same girder mentioned for the previous vehicle where the shear reinforcement is not input correctly.

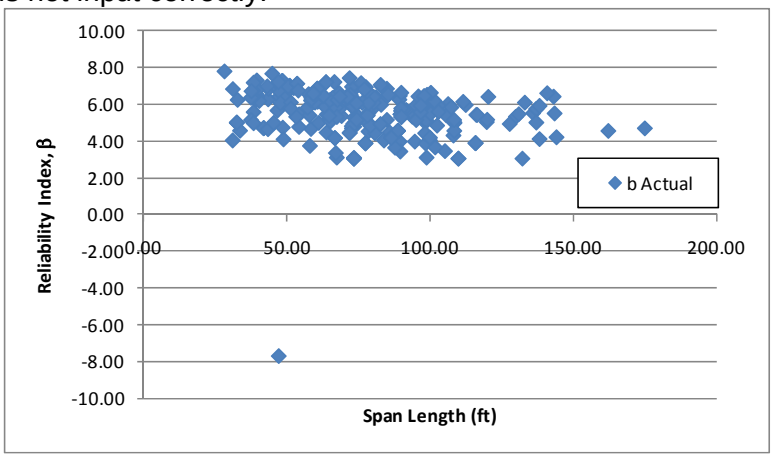


Figure C-40: Shear Reliability Indices for FL-04 Vehicle

Figure C-41 shows the reliability index plotted against the LRFR rating for shear caused by the FL-04 vehicle. The figure shows that girders passing rating have a reliability index of approximately 3.0 which is near the target reliability of 2.5. This indicates that the target reliability could be obtained by reducing the LRFR live load factors. Several girders have high reliability and low ratings; these girders are controlled by the shear friction rating but the reliability index is calculated using the LRFR shear resistance.

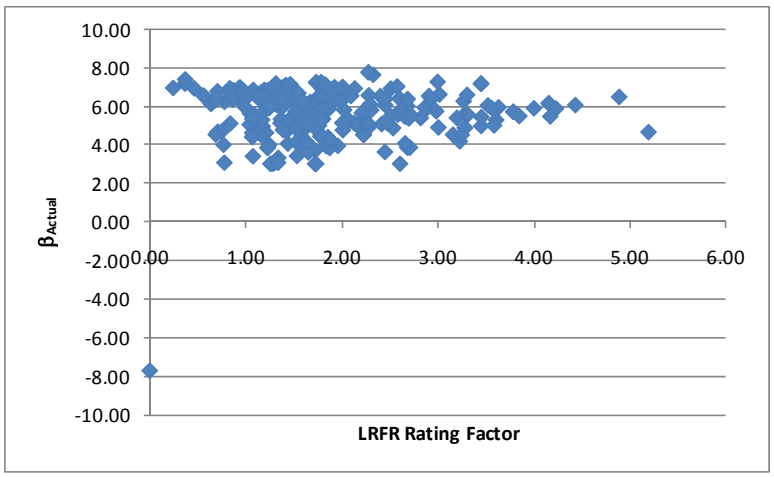


Figure C-41: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

C.1.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-42. The applicable load factors for these vehicles are 1.3 and 1.40 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

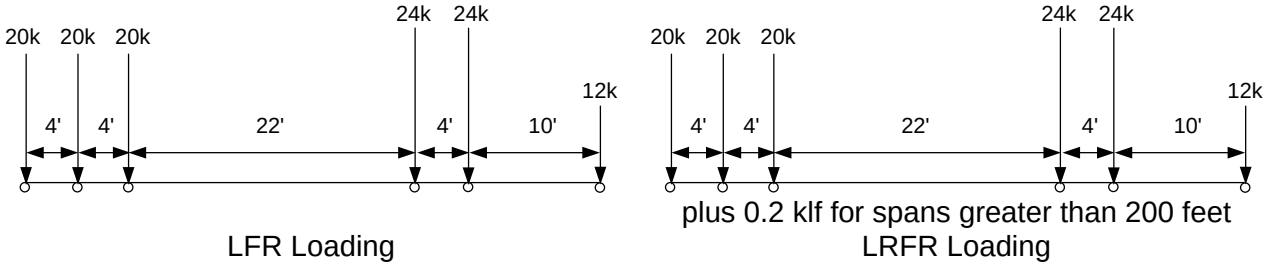


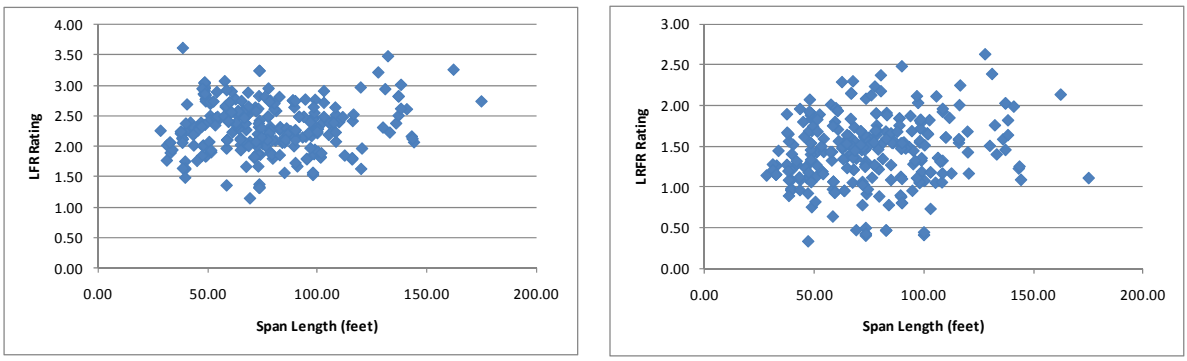
Figure C-42: Vehicle Loadings and Load Factors

C.1.5.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the IL-01 Vehicle.

C.1.5.1.1 Rating Factors

Figure C-43 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 35 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 100% of the girders in this subset. The LRFR ratings for the IL-01 vehicle are higher than those shown for other vehicles because the IL-01 vehicle is treated as a special permit vehicle which uses lower load factors and one lane of live load without the 1.2 multiple presence factor.



(a) (b)

Figure C-43: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure C-44 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is not as significant for the special permit vehicles; using an the multiple crossing with an ADTT of 5000, 70% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0.

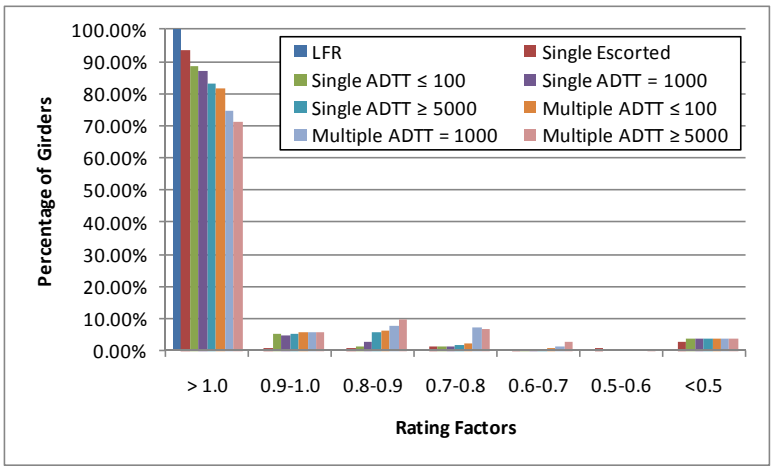


Figure C-44: Flexure Ratings for Different ADTTs in MBE

C.1.5.1.2 Rating Factor Comparisons

Figure C-45 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.8. The figure shows that the LFR rating is greater than the LRFR rating for all girders for the IL-01 vehicle.

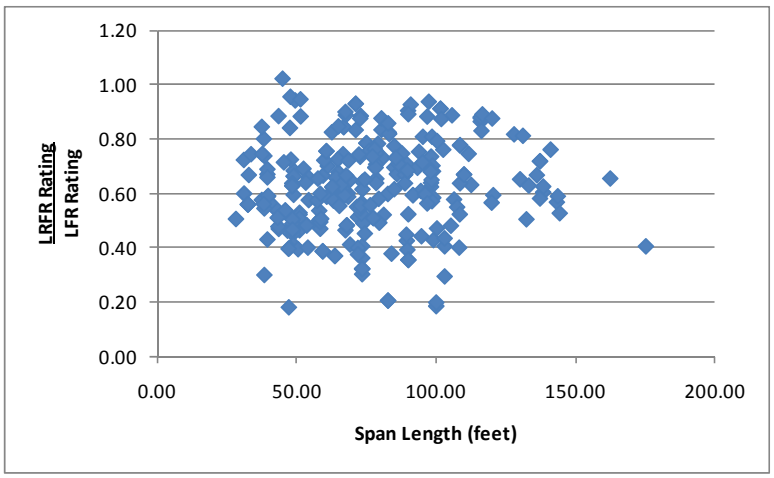


Figure C-45: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

C.1.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-46 shows that none of the girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index is generally between 8 and 10 for most span lengths.

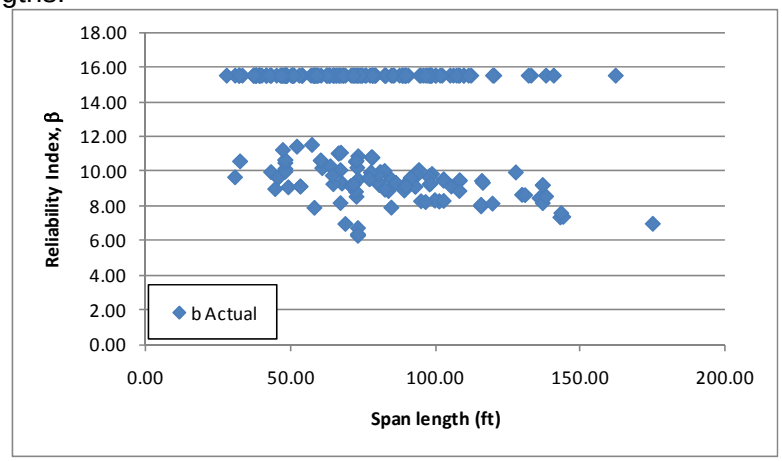


Figure C-46: Flexure Reliability Indices for IL-01 Vehicle

Figure C-47 shows the reliability index plotted against the LRFR rating for moment caused by the IL-01 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index greater than 6.0. This is significantly larger than the target reliability index of 3.5 used in the development of the MBE. This indicates that the target reliability can be obtained using lower load factors than those currently in the MBE.

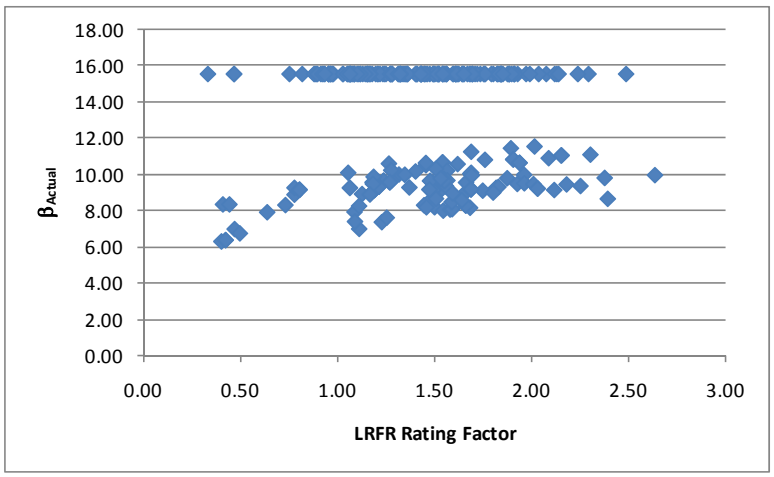
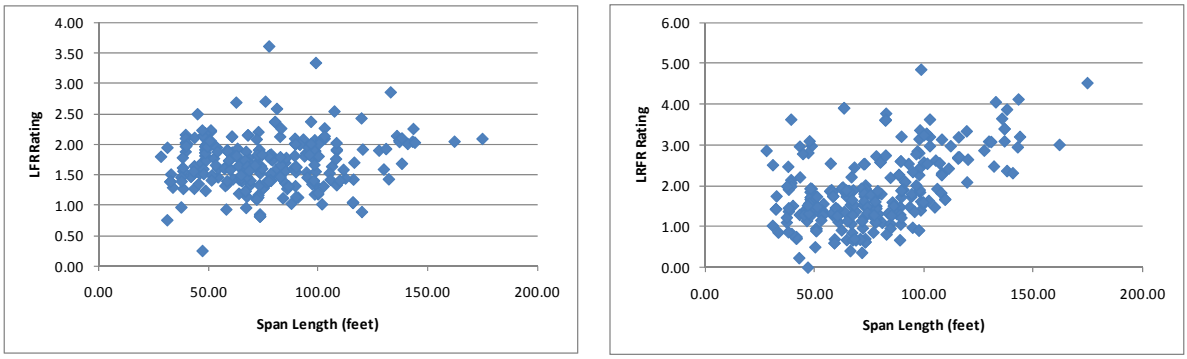


Figure C-47: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

C.1.5.2 Shear

C.1.5.2.1 Rating Factors

For shear, there are 10 girders that have LFR rating factors less than 1.0, 39 girders with LRFR ratings less than 1.0, and 5 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 42% of the girders in this subset. Figure C-48 shows the LFR and LRFR ratings. The LFR rating is generally between 1.0 and 2.0 for all span lengths, while for LRFR the rating tends to increase with increasing span length.



(a) (b)

Figure C-48: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure C-49 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is less significant; using the worst case load factor, multiple trips with an ADTT of 5000, over 70% of the girders will still have an LRFR rating above 1.0. The LFR rating is above 1.0 for approximately 95% of the girders.

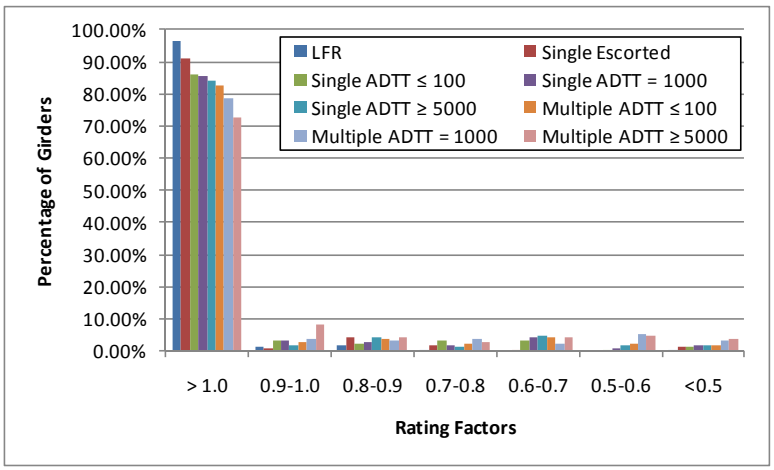


Figure C-49: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

C.1.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-50 shows the comparison of rating factors. The LRFR rating is greater than the LFR rating for 58% of the girders in this group. This is shown in the figure below as most data points are above 1.0.

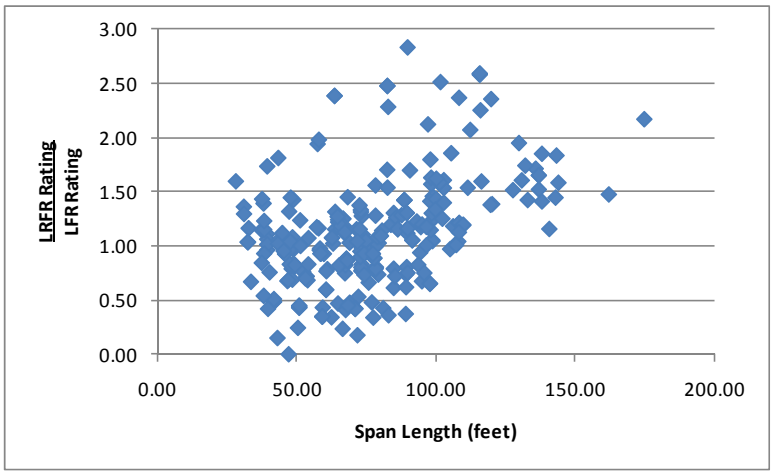


Figure C-50: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

C.1.5.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 3.5 for most girders as shown in Figure C-51. The girder with a reliability index of -18 is the one that does not have properly defined shear reinforcement. There are also several girders where the actual reliability index is similar to the target value of 3.5.

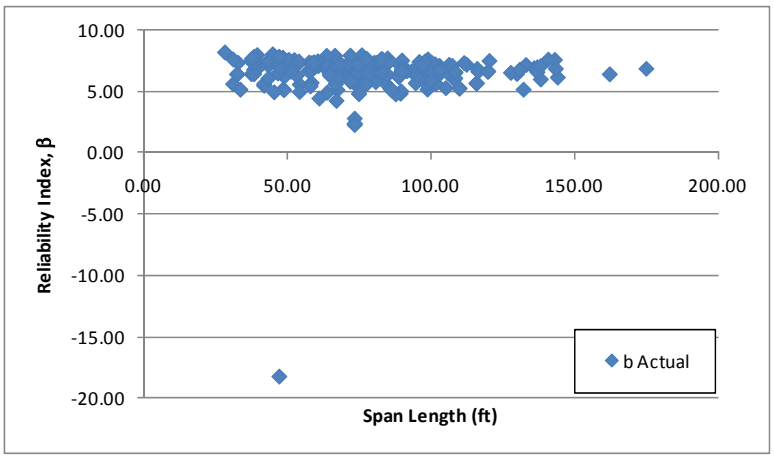


Figure C-51: Shear Reliability Indices for IL-01 Vehicle

Figure C-52 shows the reliability index plotted against the LRFR rating for shear due to the IL-01 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index of approximately 4.0. This indicates that the target reliability could be maintained while using lower LRFR live load factors. A number of girders have high reliability and low ratings; the ratings are controlled by shear friction but the reliability index is calculated using the shear resistance.

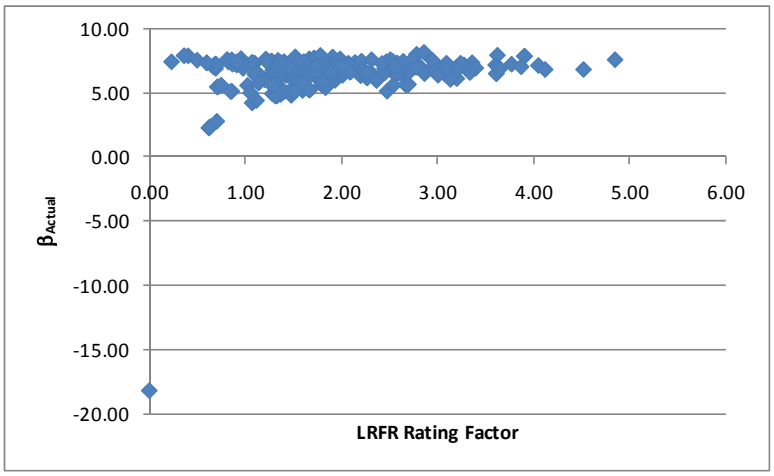


Figure C-52: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

C.1.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-53. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

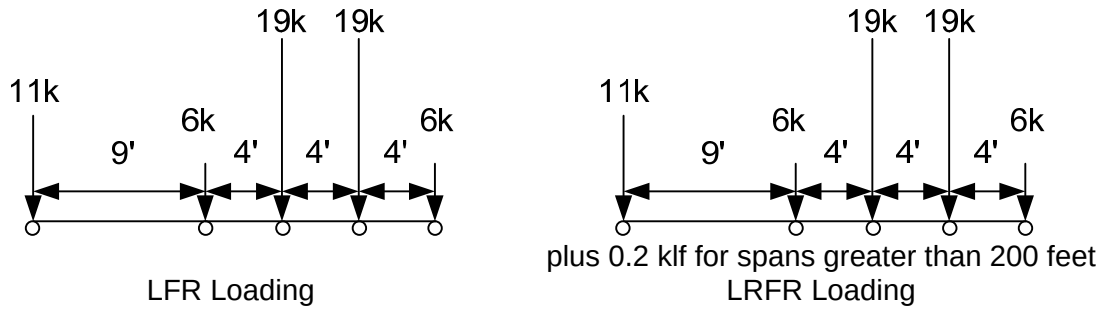


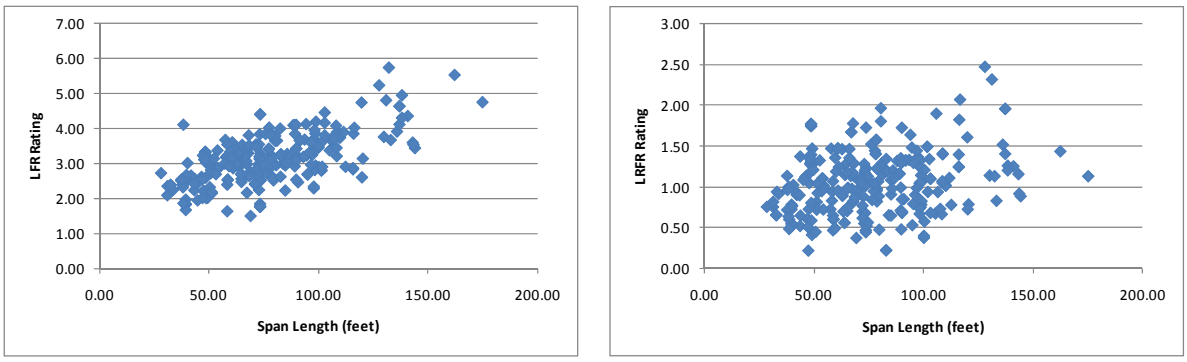
Figure C-53: Vehicle Loadings and Load Factors

C.1.6.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the NC-21 Vehicle.

C.1.6.1.1 Rating Factors

Figure C-54 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 126 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating increases with increasing span length while the LRFR rating increases slightly with increasing span length. Of the 126 girders with LRFR ratings less than 1.0, 109 are controlled by the longitudinal reinforcement rating.



(a) (b)

Figure C-54: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure C-55 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 65% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. For an ADTT of 5000, the number of girders in each category below 1.0 is similar.

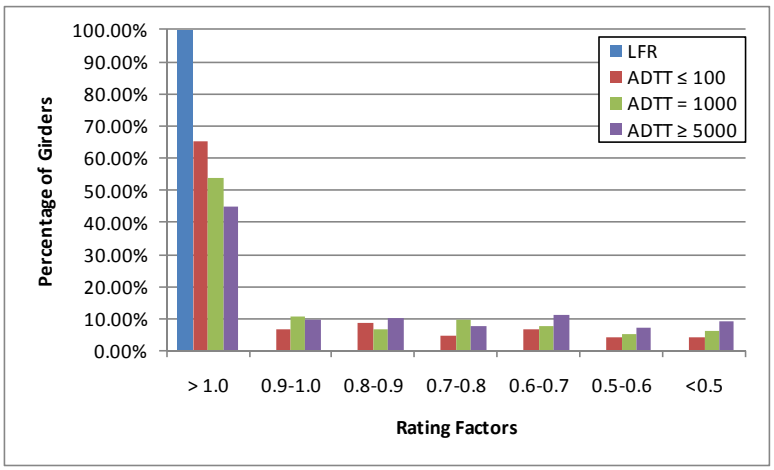


Figure C-55: Flexure Ratings for Various ADTTs in MBE for NC-21 Vehicle

C.1.6.1.2 Rating Factor Comparisons

Figure C-56 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6 for this vehicle and no girders with an LRFR rating greater than the LFR rating.

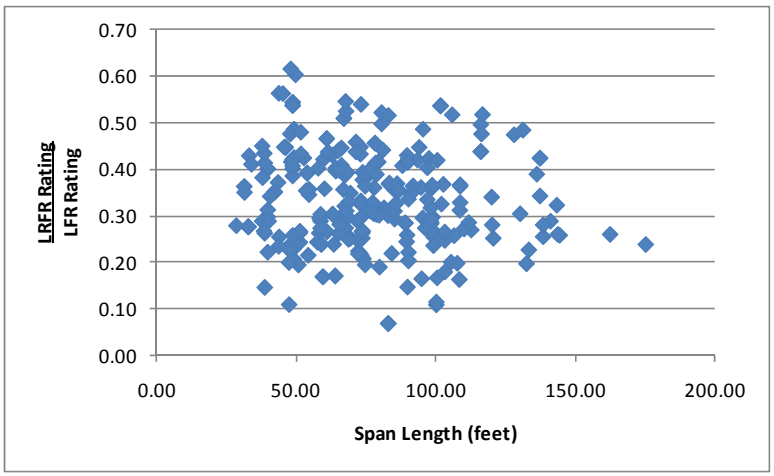


Figure C-56: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

C.1.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-57 shows that none of the girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5 used for routine permit vehicles.

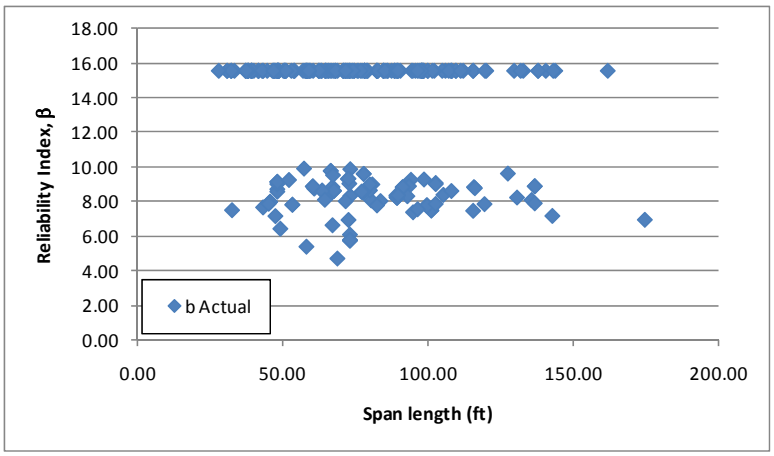


Figure C-57: Flexure Reliability Indices for NC-21 Vehicle

Figure C-58 shows the reliability index plotted against the LRFR rating for moment due to the NC-21 vehicle. The figure shows that for girders with a rating of 1.0, a reliability index between 5.0 and 6.0 is expected. This is significantly greater than the target reliability of 2.5; the target reliability can be maintained using reduced LRFR live load factors.

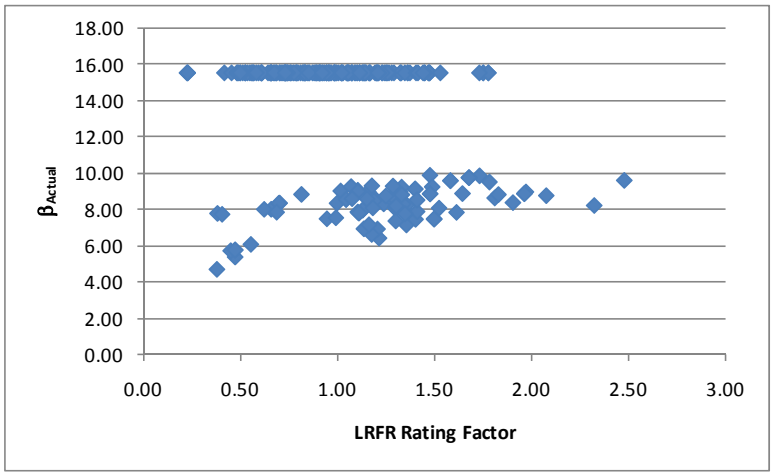
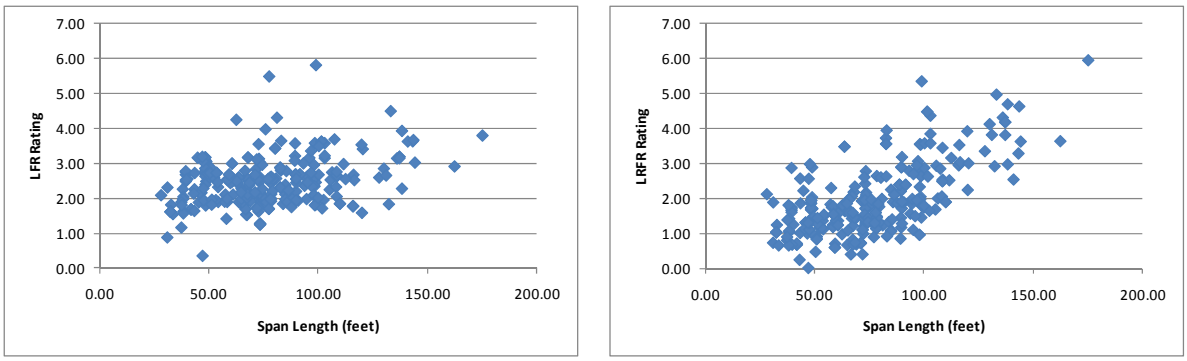


Figure C-58: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

C.1.6.2 Shear

C.1.6.2.1 Rating Factors

For shear, there are two girders that have LFR rating factors less than 1.0, 37 girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 75% of the girders in this subset. Figure C-59 shows the LFR and LRFR ratings. The LRFR rating increases with increasing span length while the LFR ratings tend to stay fairly constant with span length.



(a) (b)

Figure C-59: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure C-60 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is most significant when an ADTT of 5,000 is used as 20% more girders will have ratings less than 1.0.

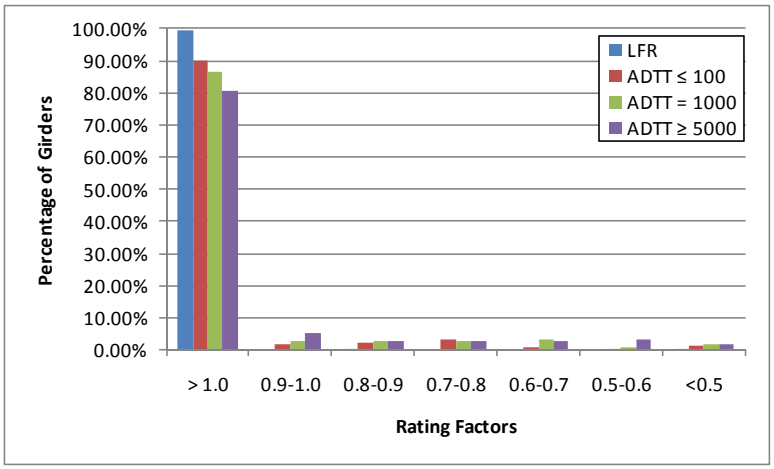


Figure C-60: Shear Ratings for Various ADTTs in MBE

C.1.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-61 shows the comparison of rating factors. The ratio is generally between 0.4 and 1.2. Longer span girders are more likely to have an LRFR rating greater than the LFR rating.

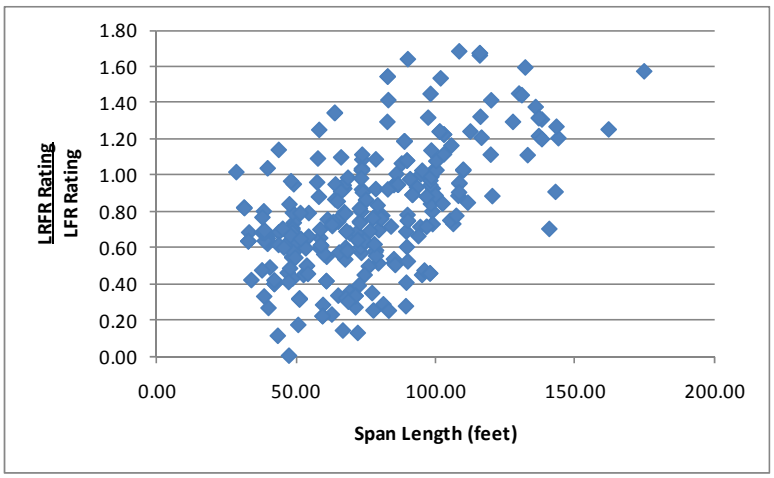


Figure C-61: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

C.1.6.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the required reliability index for all but one girder as shown in Figure C-62. This girder does not have properly defined shear reinforcement in the input file. The lack of shear reinforcement reduces the resistance significantly. Most girders have a reliability index between 6.0 and 8.0.

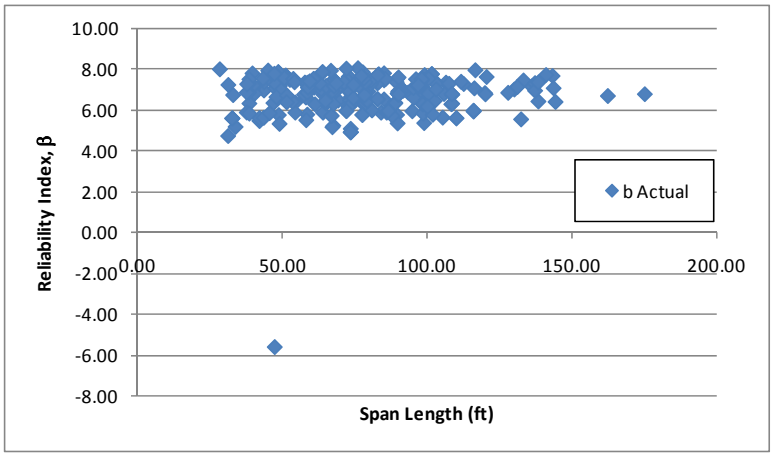


Figure C-62: Shear Reliability Indices for NC-21 Vehicle

Figure C-63 shows the reliability index plotted against the LRFR rating for shear due to the NC-21 vehicle. The figure shows that girders with LRFR ratings of 1.0 are likely to have reliability indices that are near 4.0. This is greater than the target reliability of 2.5 used in the development of the MBE. The target reliability could be obtained by using LRFR live load factors smaller than those currently in the MBE. Girders with high reliability and low rating are controlled by the shear friction rating while the reliability index is calculated using the LRFR shear resistance.

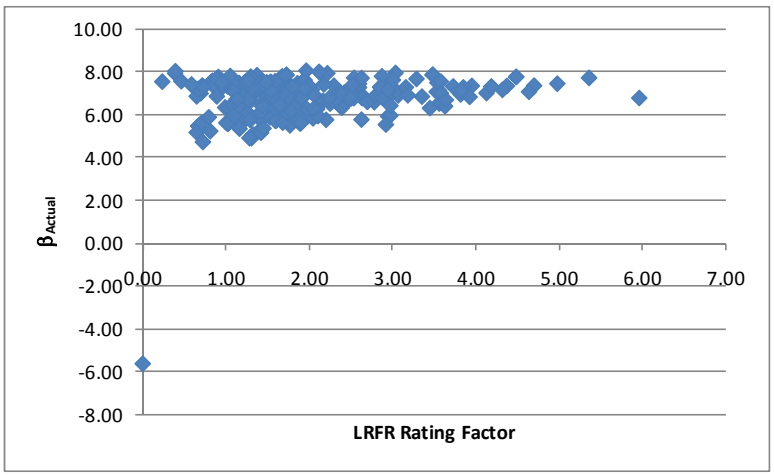


Figure C-63: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

C.1.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-64. The applicable load factors for these vehicles are 1.30 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

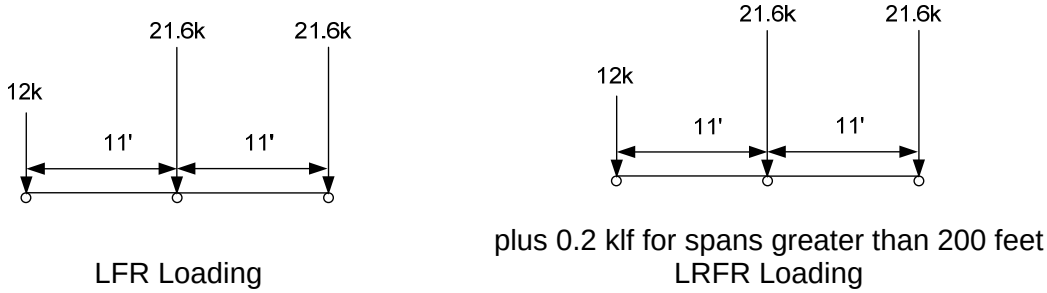


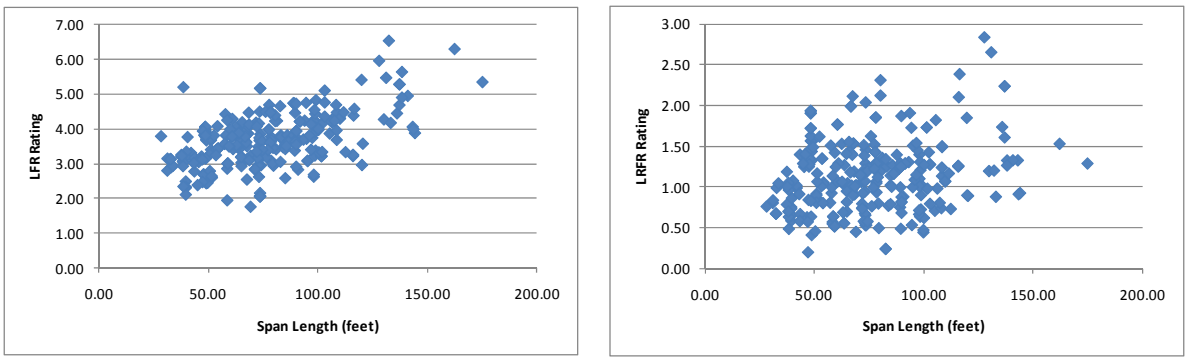
Figure C-64: Vehicle Loadings and Load Factors

C.1.7.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the NM-04 Vehicle.

C.1.7.1.1 Rating Factors

Figure C-65 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 109 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating tends to increase with increasing span length while the LRFR rating remains fairly constant with span length. Of the 109 girders with an LRFR rating less than 1.0, 95 are controlled by the rating of the longitudinal steel reinforcement.



(a) (b)

Figure C-65: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure C-66 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 70% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The number of girders with ratings less than 1.0 is distributed almost equally within each range of ratings.

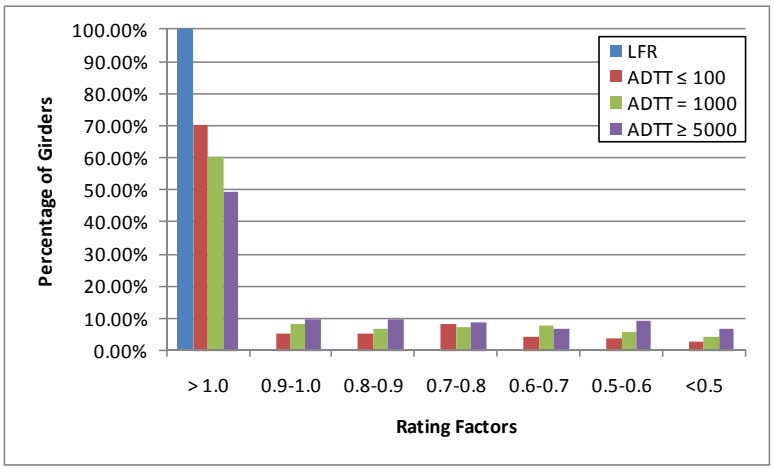


Figure C-66: Flexure Rating for Various ADTTs in MBE for NM-04 Vehicle

C.1.7.1.2 Rating Factor Comparisons

Figure C-67 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.4, with no girders having LRFR ratings greater than the LFR rating.

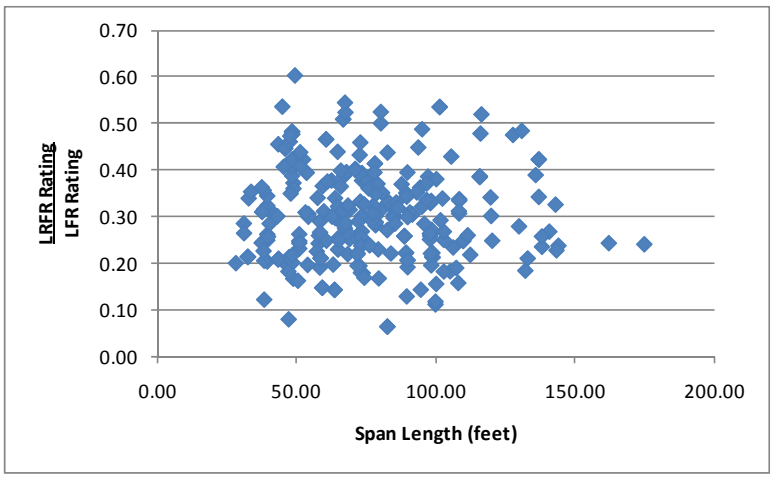


Figure C-67: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

C.1.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-68 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index.

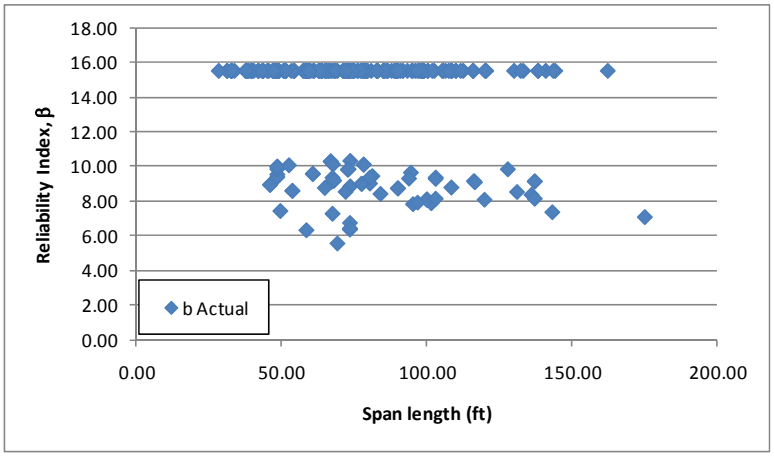


Figure C-68: Flexure Reliability Indices for NM-04 Vehicle

Figure C-69 shows the reliability index plotted against the LRFR rating factor for moment caused by the NM-04 Vehicle. The figure shows that girders with a rating of 1.0 will have a reliability index of approximately 6.0. This indicates that the target reliability could be obtained using LRFR live load factors lower than those currently in the MBE.

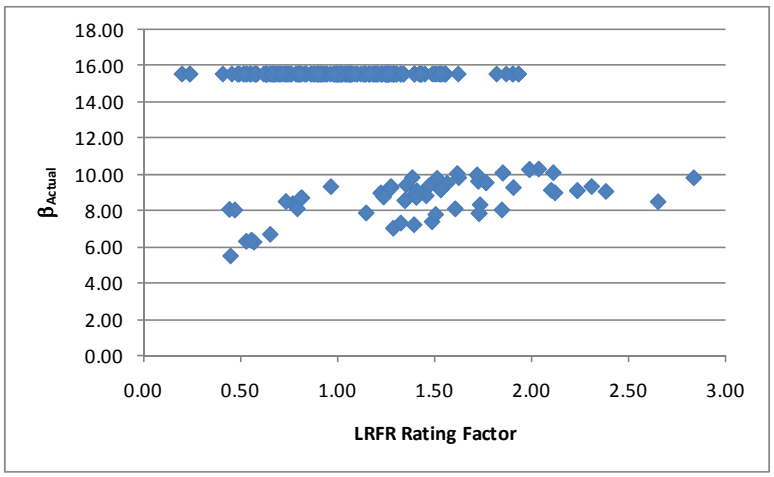
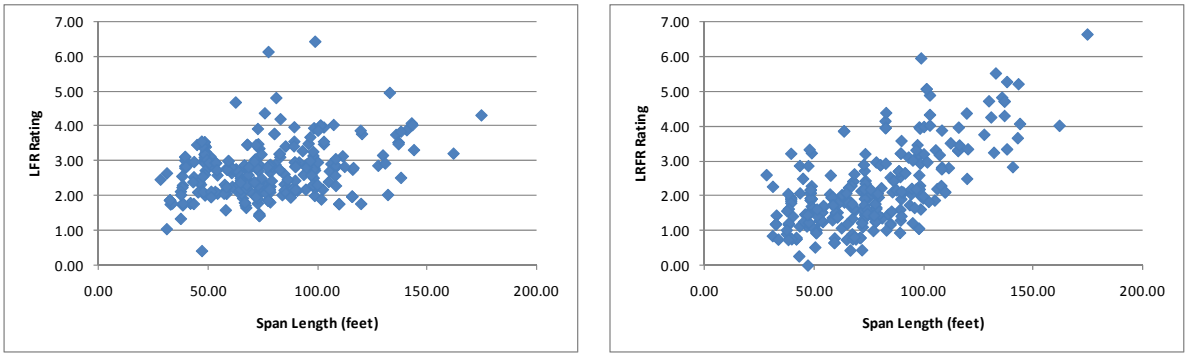


Figure C-69: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

C.1.7.2 Shear

C.1.7.2.1 Rating Factors

For shear, there is one girder that has an LFR rating factor less than 1.0, 28 girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 73% of the girders in this subset. Figure C-70 shows the LFR and LRFR ratings. The LFR rating remains fairly constant with increasing span length while the LRFR rating increases with increasing span length.



(a) (b)

Figure C-70: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure C-71 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is not as significant for shear; using an ADTT of 5,000, only 15% of girders will have an LRFR rating below 1.0.

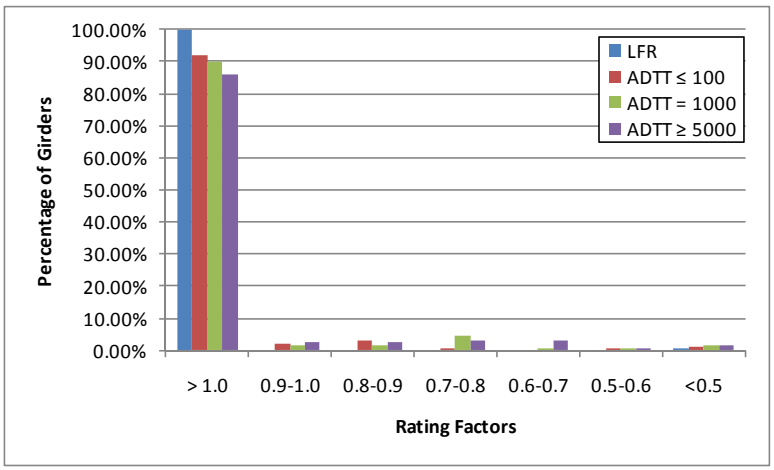


Figure C-71: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

C.1.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure C-72 show the comparison of rating factors. The ratio is generally between 0.4 and 1.0. Longer spans are more likely to have LRFR ratings greater than shorter spans.

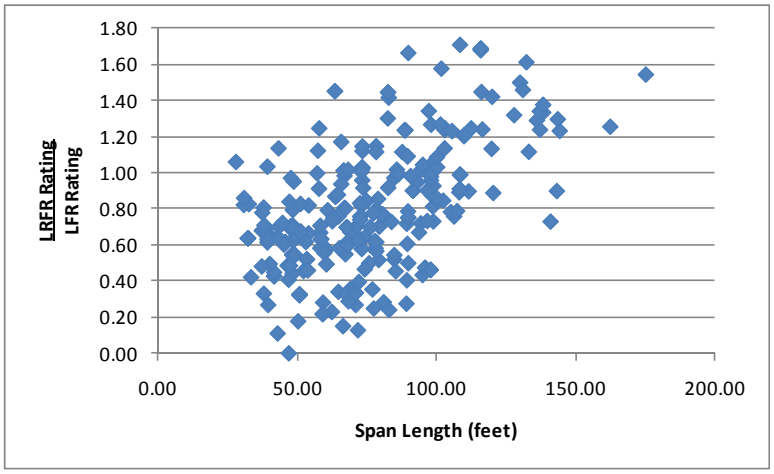


Figure C-72: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

C.1.7.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index for all but one girder as shown in Figure C-73. The girder with a negative reliability index does not have properly defined shear reinforcement as mentioned previously for other vehicles.

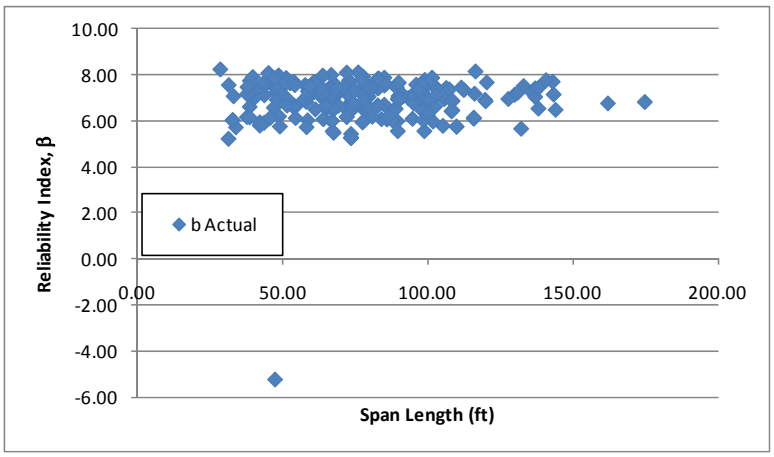


Figure C-73: Shear Reliability Indices for NM-04 Vehicle

Figure C-74 shows the reliability index plotted against the LRFR rating for shear caused by the NM-04 Vehicle. The figure shows that girders with a rating of 1.0 have reliability indices greater than 4.0; the target reliability for this vehicle assumed to be a routine permit vehicle is 2.5. This indicates that the target reliability could be maintained and reduced live load factors used for LRFR. A number of girders have high reliability and low ratings; these girders are controlled by the shear friction rating while the reliability index is calculated using the shear resistance.

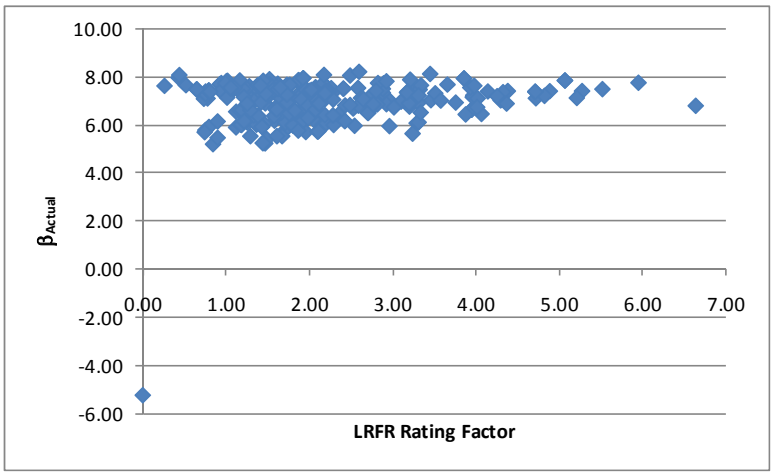
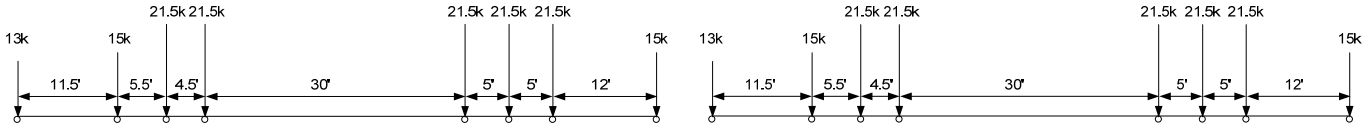


Figure C-74: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

C.1.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-75. The applicable load factors for these vehicles are 1.3 and 1.40 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

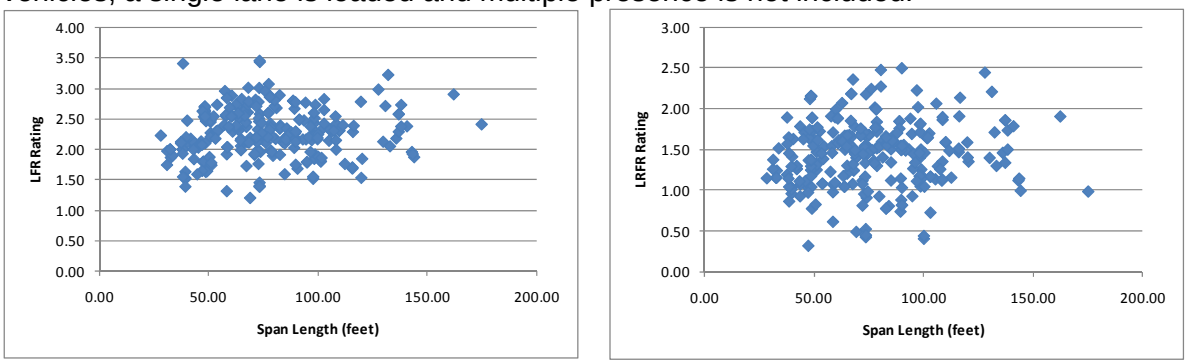
Figure C-75: Vehicle Loadings and Load Factors

C.1.8.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the OR-06 Vehicle.

C.1.8.1.1 Rating Factors

Figure C-76 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 32 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating is generally within the same range for all span lengths; the LRFR rating also remains constant for this case. 17 of the 32 girders with an LRFR rating less than 1.0 are controlled by the longitudinal steel requirement. The increase in rating factor is attributed to the reduction in live load considered for special permit vehicles; a single lane is loaded and multiple presence is not included.



(a) (b)

Figure C-76: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure C-77 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious because more girders have LRFR ratings less than 1.0. The effect for the special permit vehicles is not as significant as for the routine permit vehicles. For the worst case loading, a multiple trip permit with an ADTT of 5,000, 30% of girders will have LRFR ratings less than 1.0.

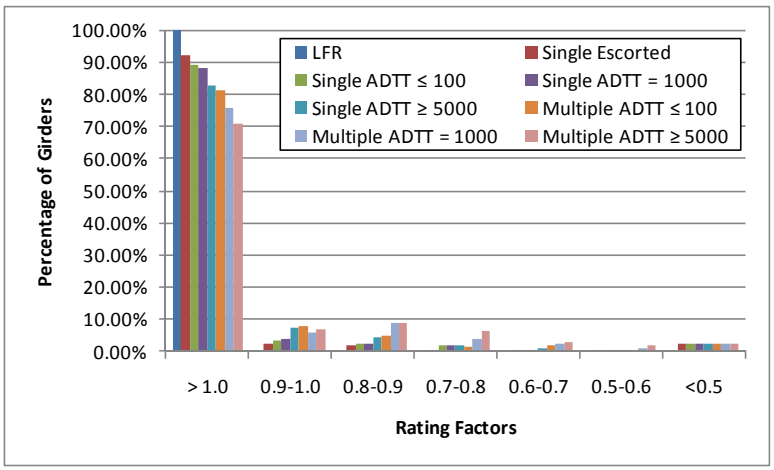


Figure C-77: Flexure Rating for Various ADTTs in MBE

C.1.8.1.2 Rating Factor Comparisons

Figure C-78 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.8.

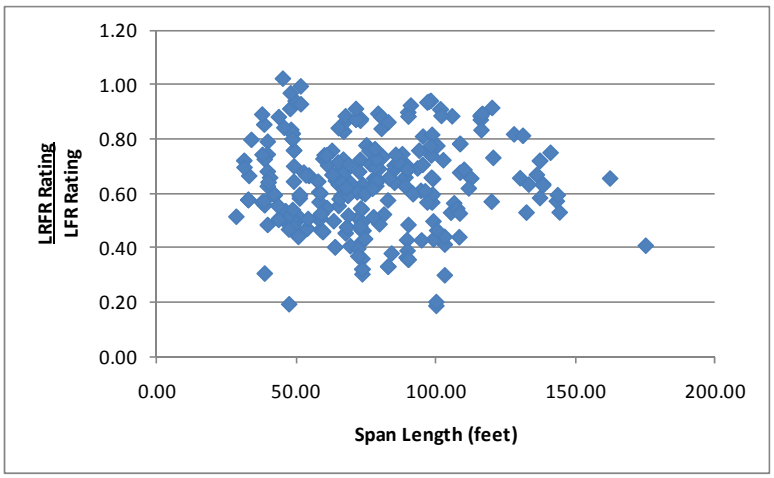


Figure C-78: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

C.1.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-79 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index.

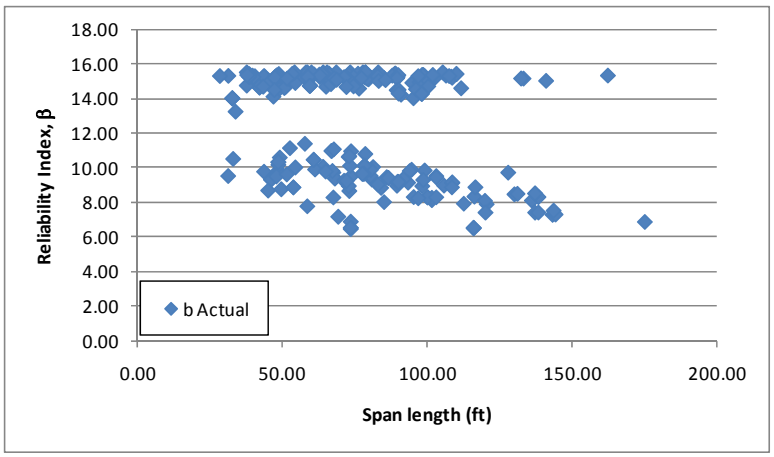


Figure C-79: Flexure Reliability Indices for OR-06 Vehicle

Figure C-80 shows the reliability index plotted against the LRFR rating for moment caused by the OR-06 truck. The figure shows that girders with a rating of 1.0 the reliability index is expected to be between 4.0 and 6.0. The expected reliability index is greater than the target reliability index of 3.5 for special permit vehicles. This indicates that the target reliability can be maintained while using live load factors that are lower than those currently in the MBE.

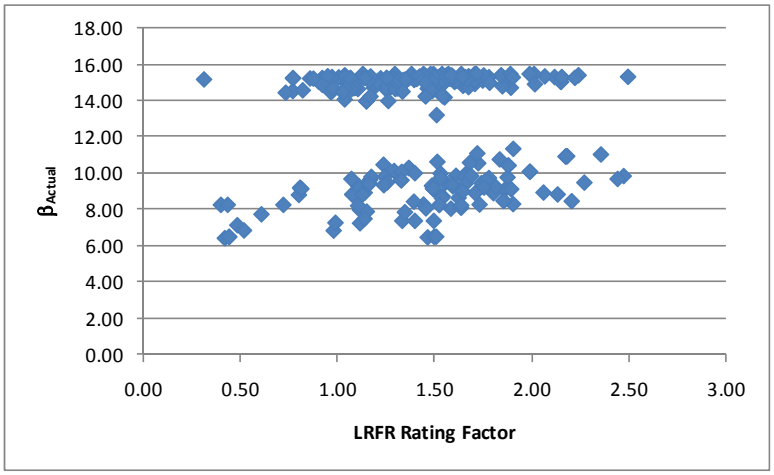
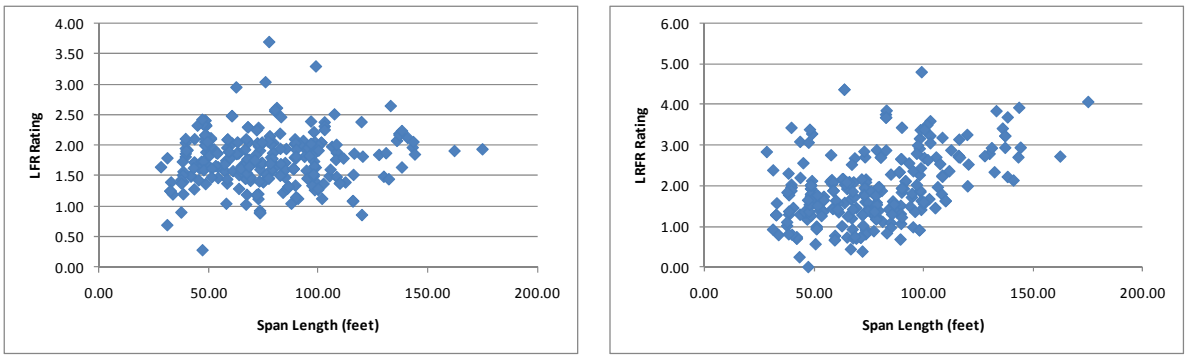


Figure C-80: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

C.1.8.2 Shear

C.1.8.2.1 Rating Factors

For shear, there are eight girders that have LFR rating factors less than 1.0, 38 girders have LRFR ratings less than 1.0, and six girders have both ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 42% of the girders in this subset. Figure C-81 shows the LFR and LRFR ratings. The LFR rating does not increase or decrease with increasing span lengths while the LRFR rating increases with increasing span lengths. Fewer girders have LRFR ratings less than 1.0 due to the configuration of the live load used in the MBE for special permit vehicles. The live load is a single lane loaded and does not include the 1.2 multiple presence factor.



(a) (b)

Figure C-81: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure C-82 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph but not as significant as for the routine permit vehicles. The worst loading situation, multiple trip permit with an ADTT of 5,000, causes less than 25% of the girders to have LRFR ratings less than 1.0. The percentage of girders with LRFR ratings less than 1.0 increases with the different types of permit and ADTT.

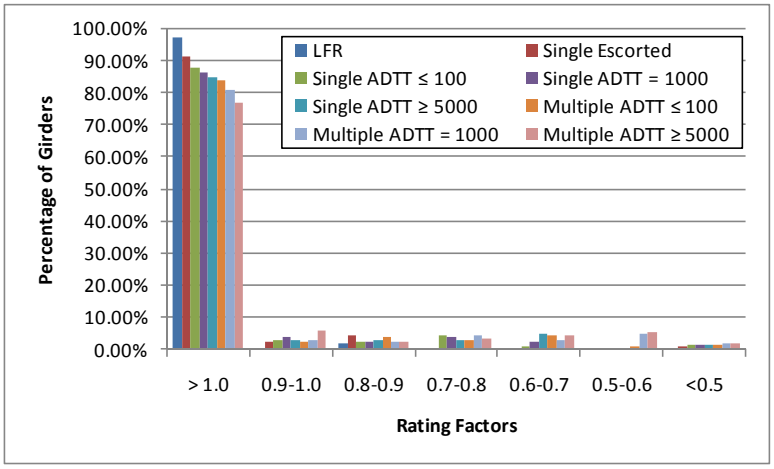


Figure C-82: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

C.1.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-83 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5 for this set of girders with this vehicle. Longer spans are more likely to have LRFR ratings greater than LFR rating. The LRFR rating is greater than the LFR rating for 58% of the girders for this vehicle.

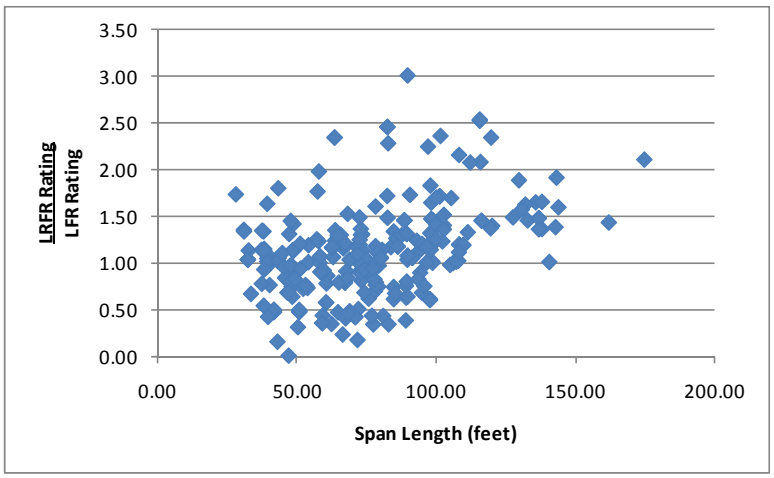


Figure C-83: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

C.1.8.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index for all but a few girders as shown in Figure C-84. The girder with a reliability index of -16 does not have properly defined shear reinforcement. There are also several girders with reliability indices close to the target reliability of 3.5.

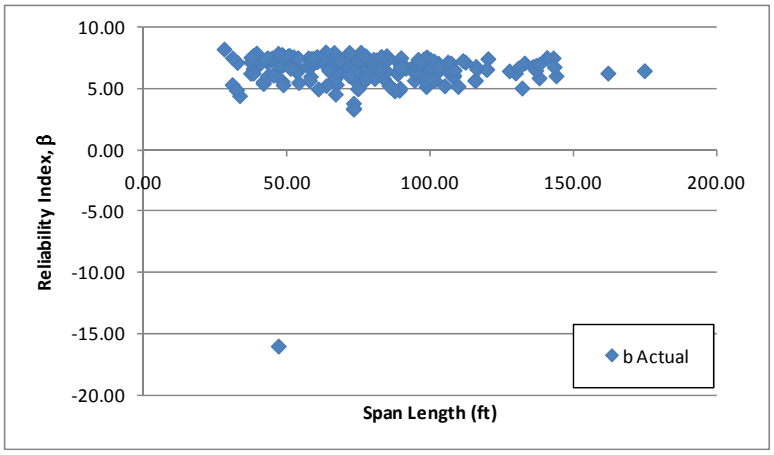


Figure C-84: Shear Reliability Indices for OR-06 Vehicle

Figure C-85 shows the reliability index plotted against the LRFR rating factor for shear due to the OR-06 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index of approximately 3.5, the target value used in the development of the MBE. For this combination of girders and vehicle, the reliability of a girder passing rating is near the target reliability indicating that the live load factors are adequate.

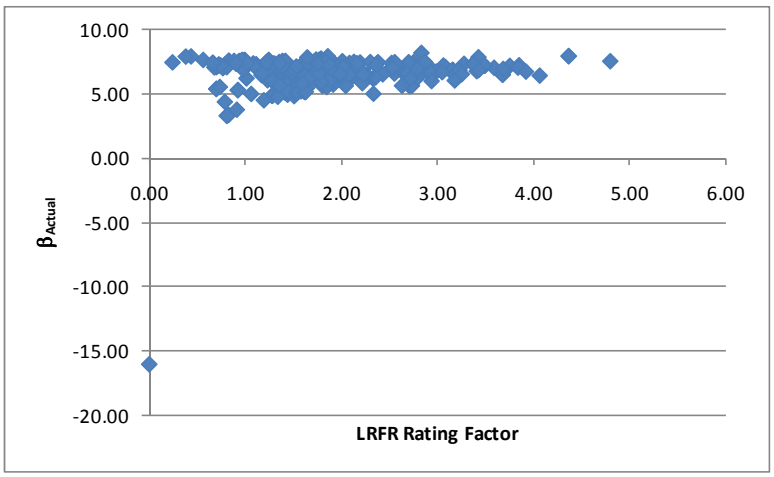


Figure C-85: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

C.1.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-86. The applicable load factors for these vehicles are 1.3 and 1. for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

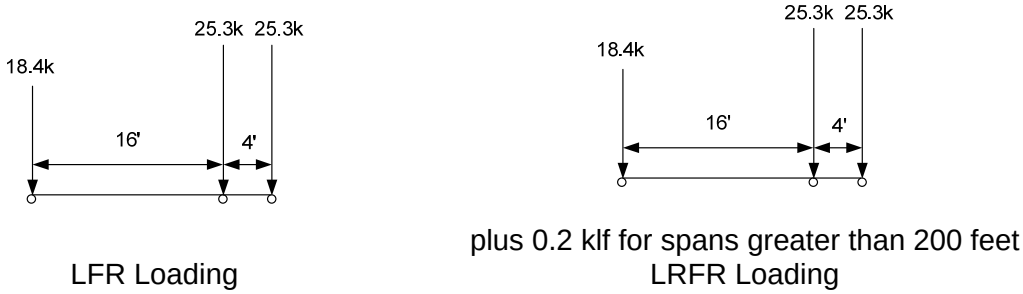


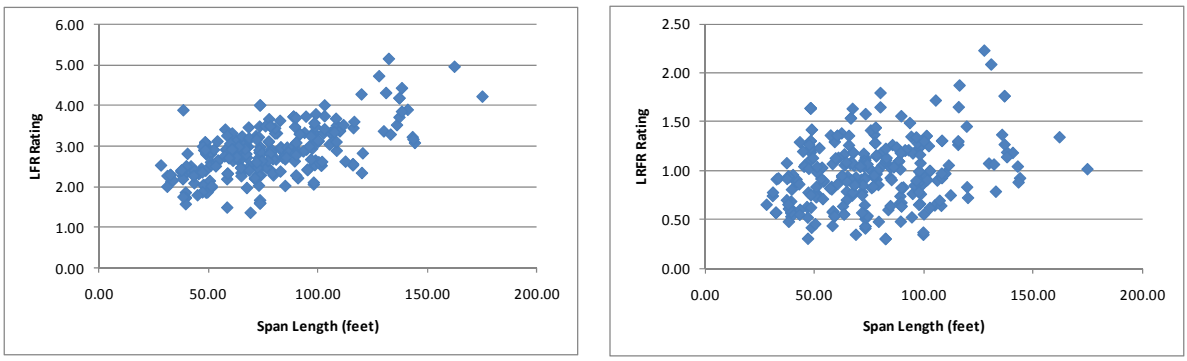
Figure C-86: Vehicle Loadings and Load Factors

C.1.9.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the TX-04 Vehicle.

C.1.9.1.1 Rating Factors

Figure C-87 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 144 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating increases with increasing span length and the LRFR rating remains fairly constant with increasing span length. Of the 144 girders with an LRFR rating less than 1.0, 119 are controlled by the longitudinal steel reinforcement rating.



(a) (b)

Figure C-87: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure C-88 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 60% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The number of girders in each category of ratings is similar for those with ratings less than 1.0.

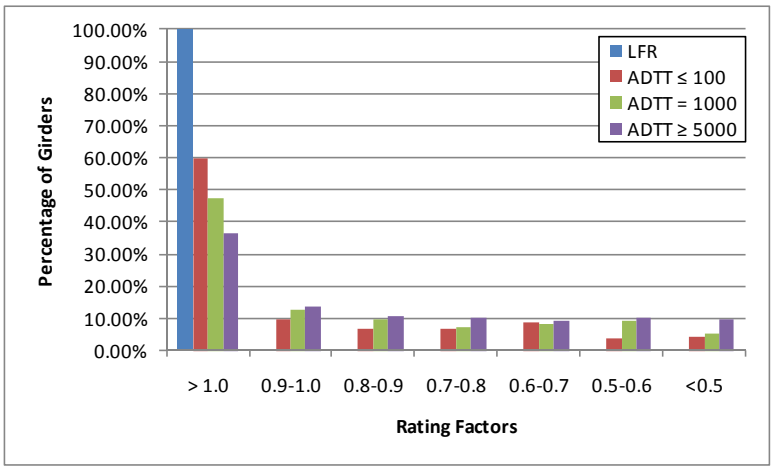


Figure C-88: Flexure Rating for Various ADTT in MBE for TX-04 Vehicle

C.1.9.1.2 Rating Factor Comparisons

Figure C-89 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. There are no clear trends in the data, but the LRFR rating is generally 20 to 50% of the LFR rating. The rating of the longitudinal steel reinforcement reduces the ratio of rating factors.

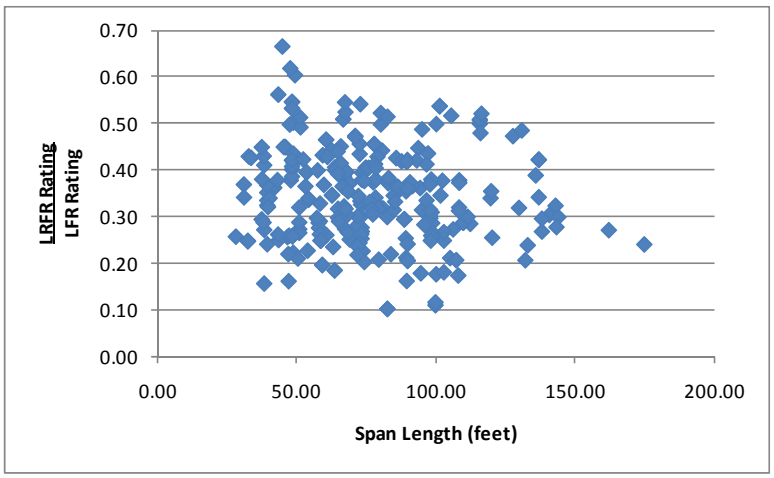


Figure C-89: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

C.1.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-90 shows no girders that have a reliability index based upon girder strength that is less than the target reliability index of 2.5. Most girders have a reliability index between 6.0 and 10.0, with those controlled by the longitudinal steel reinforcement at 15.5.

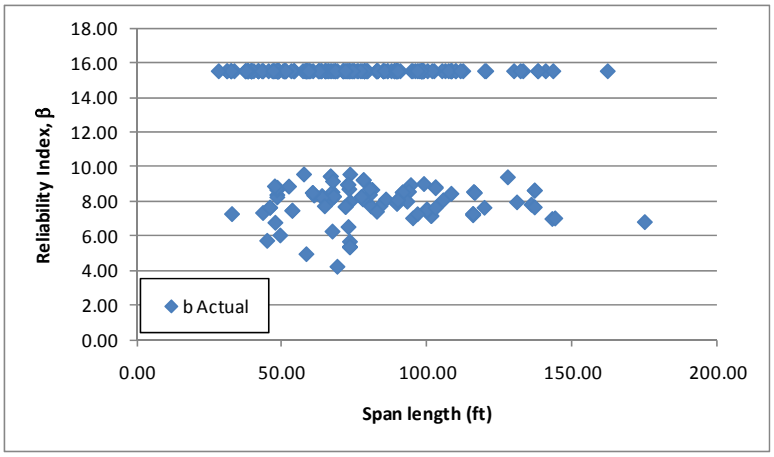


Figure C-90: Flexure Reliability Indices for TX-04 Vehicle

Figure C-91 shows the reliability index plotted against the LRFR rating factor for moment caused by the TX-04 vehicle. The figure shows that girders with a rating of 1.0 have reliability indices of at least 4.0 and typically higher. The target reliability index for the TX-04 vehicle is 2.5. This indicates that the live load factors for LRFR could be reduced and the target reliability would be maintained.

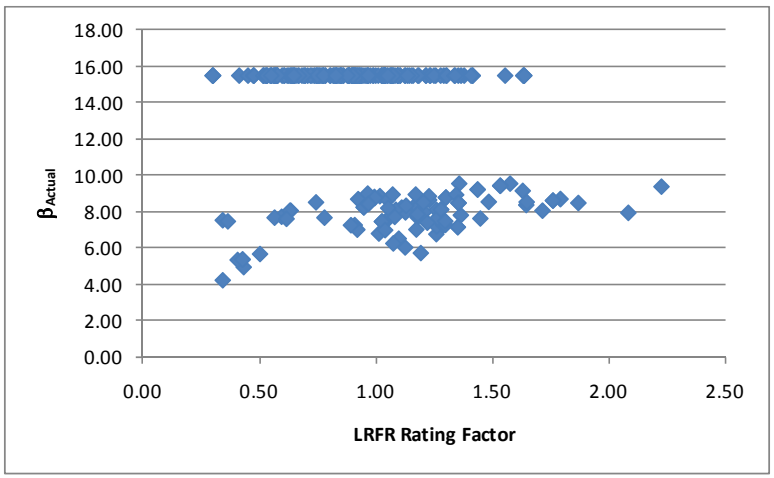
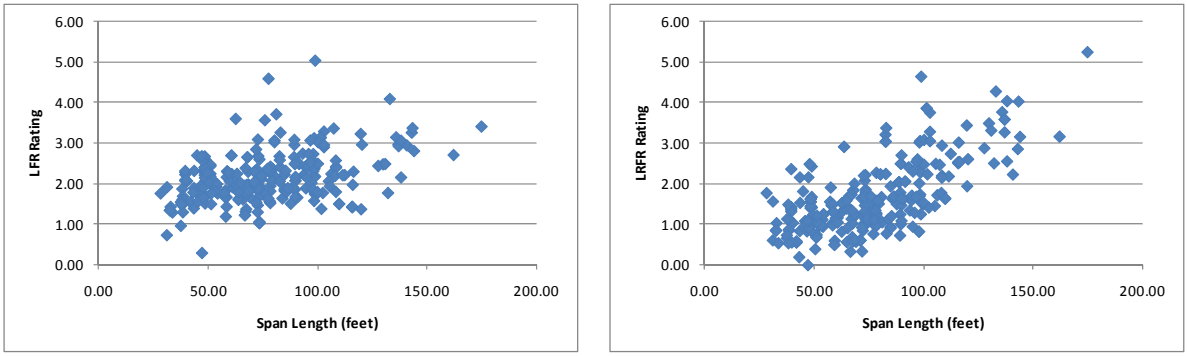


Figure C-91: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

C.1.9.2 Shear

C.1.9.2.1 Rating Factors

For shear, there are three girders that have LFR rating factors less than 1.0, 60 girders with LRFR ratings less than 1.0, and three girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 77% of the girders in this subset. Figure C-92 shows the LFR and LRFR ratings. Both ratings appear to increase with increasing lengths, with the LRFR rating increasing more.



(a) (b)

Figure C-92: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure C-93 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, 85% of girders will have an LRFR rating above 1.0 while most girders will have an LFR rating greater than 1.0. For the worst case loading, ADTT of 5,000, approximately 30% of girders will have LRFR ratings less than 1.0. Of the 30% of girders with LRFR ratings less than 1.0, approximately one-third will have ratings between 0.9 and 1.0.

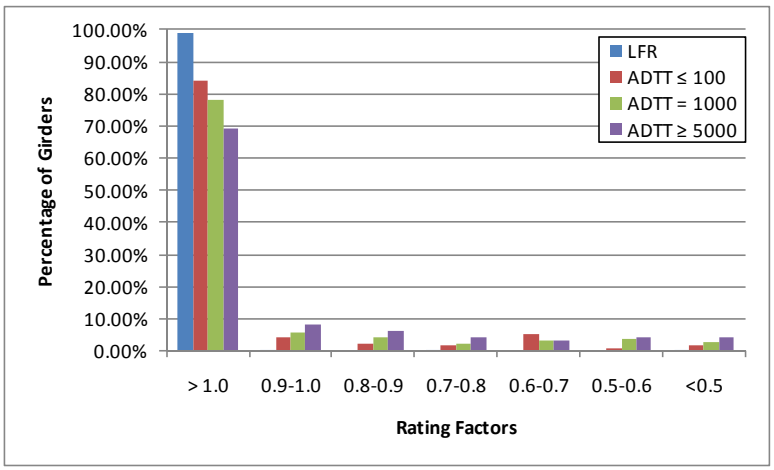


Figure C-93: Shear Ratings for Various ADTTs in MBE for TX-04

C.1.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure C-94 shows the comparison of rating factors. The ratio is generally between 0.2 and 1.0 for shear. 23% of girders have LRFR ratings greater than the LFR ratings.

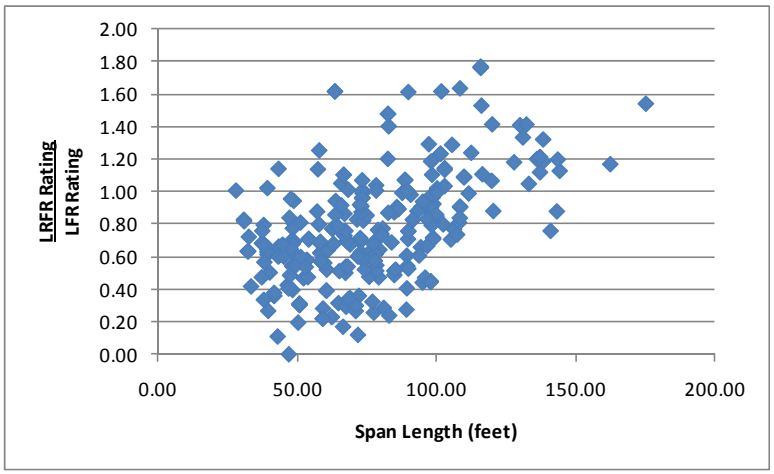


Figure C-94: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

C.1.9.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index for all but one girder as shown in Figure C-95. Most girders have reliability indices for shear between 4.0 and 8.0, above the target reliability of 2.5 for routine permit vehicles.

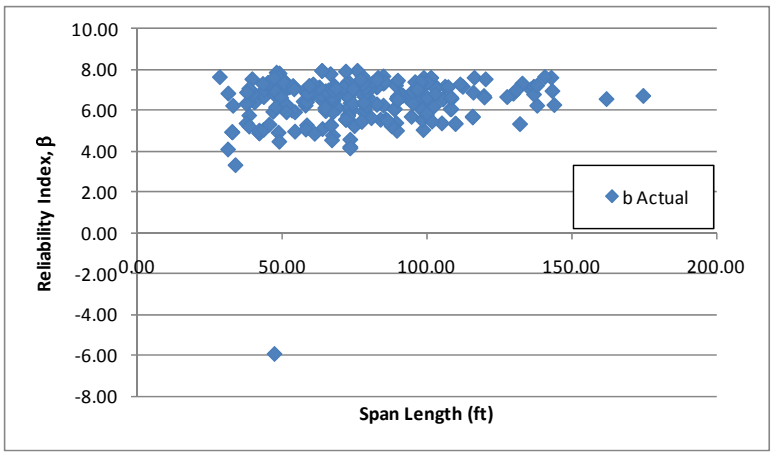


Figure C-95: Shear Reliability Indices for TX-04 Vehicle

Figure C-96 shows the reliability index plotted against the LRFR rating factor for shear caused by the TX-04 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index that is at least 4.0; the target reliability index is 2.5. This indicates that the target reliability can be maintained while using lower load factors. Girders with high reliability and low ratings are typically controlled by the shear friction rating and the reliability index is calculated using the shear resistance.

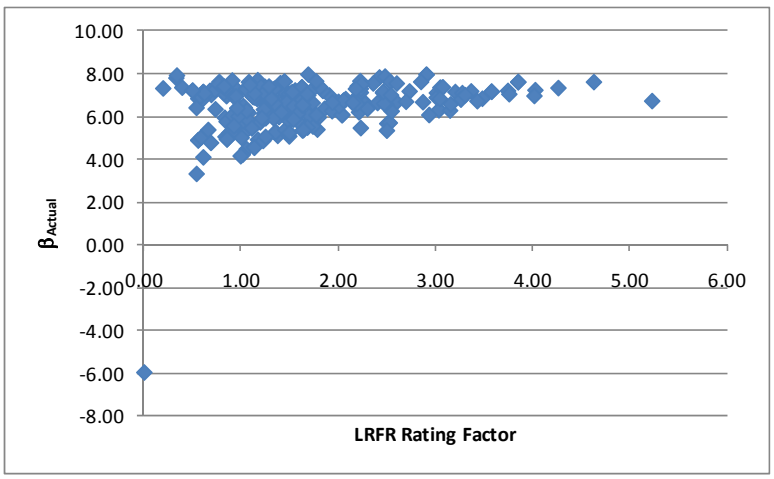
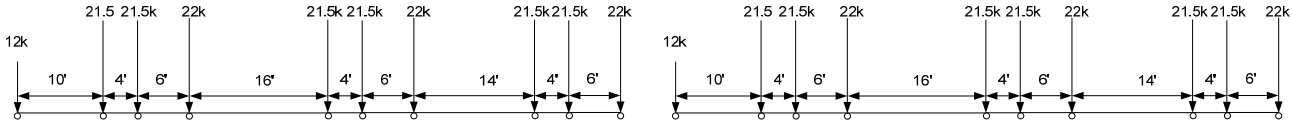


Figure C-96: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

C.1.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-97. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

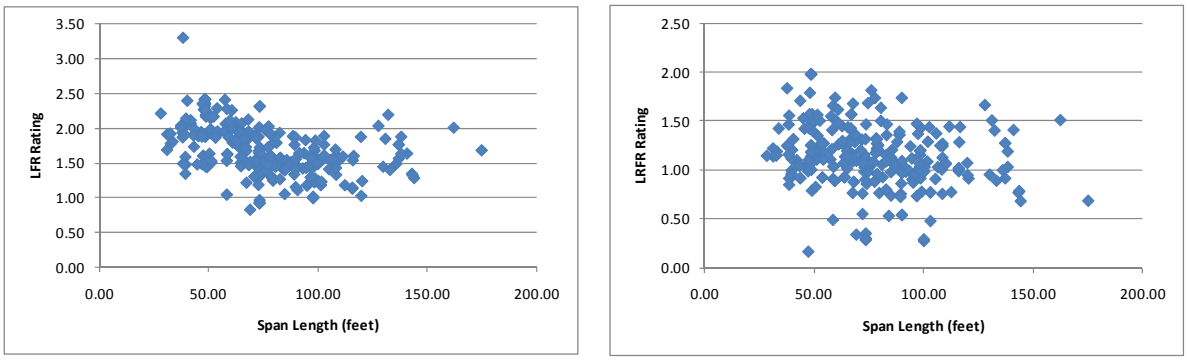
Figure C-97: Vehicle Loadings and Load Factors

C.1.10.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the WA-02 Vehicle.

C.1.10.1.1 Rating Factors

Figure C-98 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are six girders with an LFR rating less than 1.0, 84 girders with an LRFR rating less than 1.0, and five girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 98% of the girders in this subset. Both ratings for this vehicle decrease with increasing span length. This is possibly due to the axle configuration of this vehicle, as longer spans would allow more axles to influence the rating. Of the 84 girders with LRFR ratings less than 1.0, 25 are controlled by the rating of the longitudinal steel reinforcement.



(a) (b)

Figure C-98: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure C-99 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; for a single trip, escorted vehicle, 75% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. For the best case situation, an escorted vehicle not allowed to mix with traffic, 25% of girders will have LRFR ratings less than 1.0. For the worse case situation, multiple trip permits allowed to mix with traffic on a route with ADTT of 5,000, 50% of girders have ratings less than 1.0.

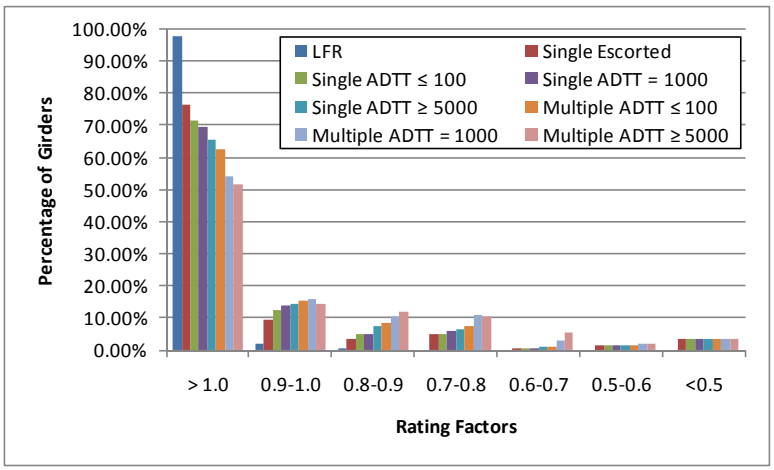


Figure C-99: Flexure Ratings for Various ADTTs in MBE for WA-02 Vehicle

C.1.10.1.2 Rating Factor Comparisons

Figure C-100 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating which is true for 2% of the girders in this group. The ratio is generally between 0.4 and 1.0.

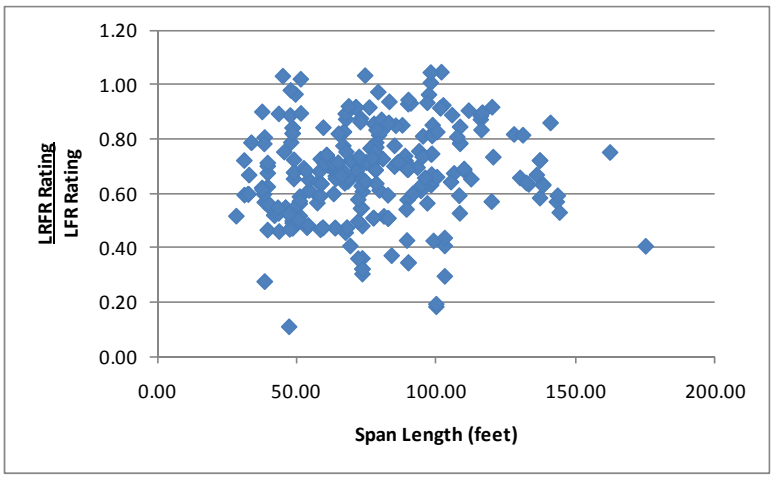


Figure C-100: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicles

C.1.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-101 shows no girders with a reliability index less than the target reliability. The reliability index based on section strength is also decreasing with increasing span length, for the other vehicles it remained relatively constant with increasing span length.

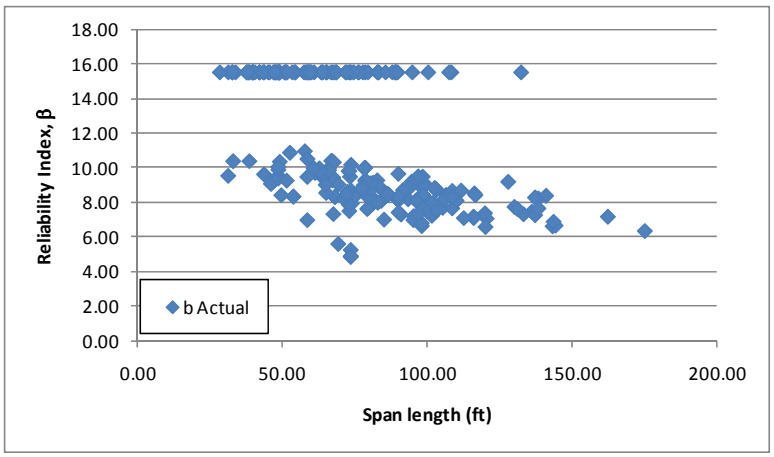


Figure C-101: Flexure Reliability Indices for WA-02 Vehicles

Figure C-102 shows the reliability index plotted against the LRFR rating for flexure due to the WA-02 vehicle. The figure shows that girders with ratings above 1.0 have reliability indices greater than 6.0 and girders with ratings less than 0.5 have reliability indices greater than 4.0, greater than the target reliability of 3.5. This indicates the target reliability could be maintained while using lower live load factors for LRFR.

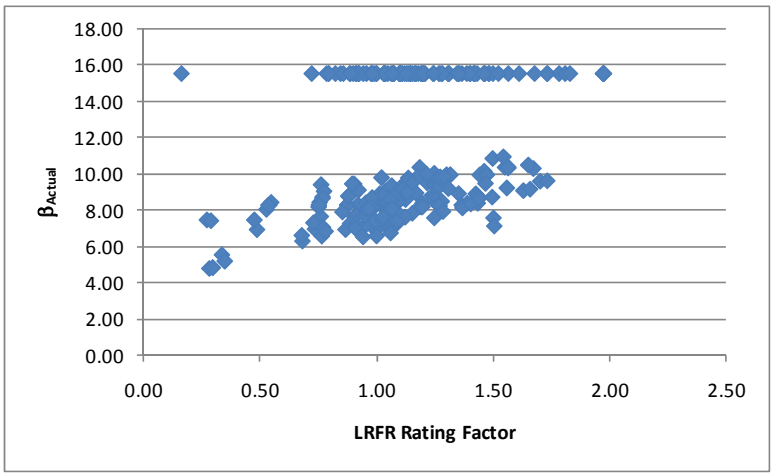
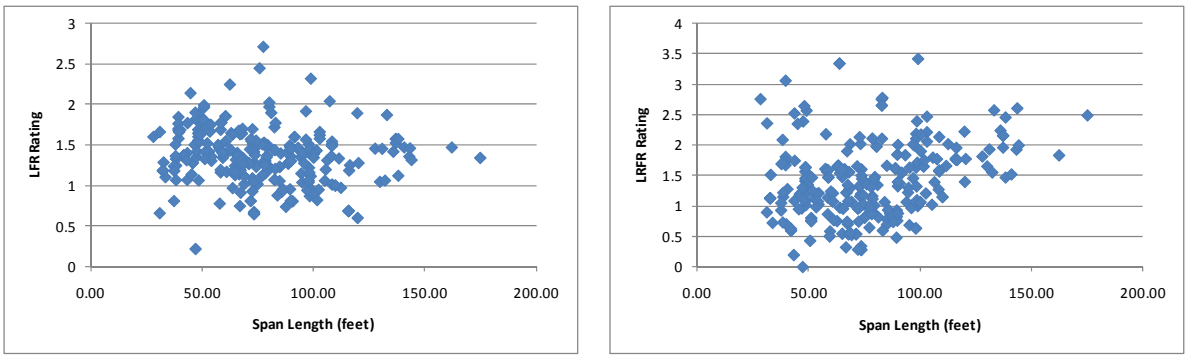


Figure C-102: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

C.1.10.2 Shear

C.1.10.2.1 Rating Factors

For shear, there are 36 girders with LFR rating factors less than 1.0, 74 girders with LRFR ratings less than 1.0, and 18 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 51% of the girders in this subset. Figure C-103 shows the LFR and LRFR ratings. LFR ratings tend to decrease with increasing span while LRFR ratings tend to increase with increasing span length. Higher LRFR ratings for this vehicle are expected because a single lane loaded without multiple presence is the prescribed loading in the MBE.



(a) (b)

Figure C-103: LFR and LRFR Shear Ratings for WA-02 Vehicles

Figure C-104 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; for a multiple trip permit allowed to mix with traffic and an ADTT of 5,000, approximately 50% of girders will have an LRFR rating above 1.0 while 85% of girders will have an LFR rating greater than 1.0.

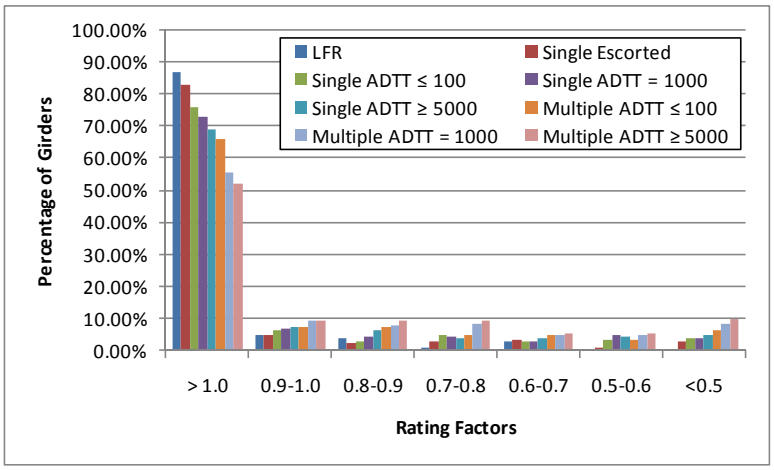


Figure C-104: Shear Rating for Various ADTTs in MBE for WA-02 Vehicle

C.1.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-105 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5. The LRFR rating is greater than the LFR rating for 49% of the girders in this group.

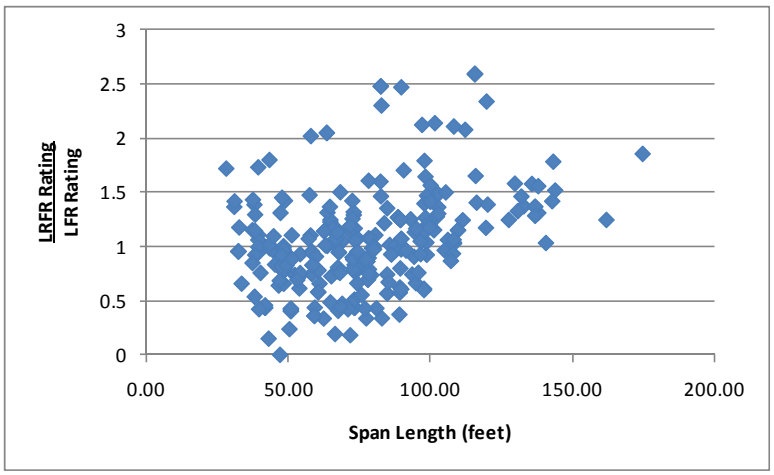


Figure C-105: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicles

C.1.10.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index for approximately eight girders as shown in Figure C-106. Three of the eight girders have negative reliability indices which indicates that the applied loads are greater than the resistances, two of these are actual cases where the loads exceed the resistance and one is a case where the resistance does not include shear reinforcement.

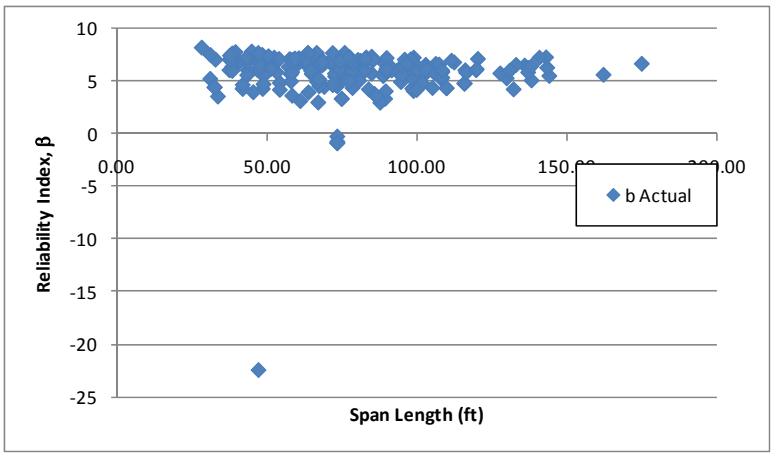


Figure C-106: Shear Reliability Indices for WA-02 Vehicles

Figure C-107 shows the reliability index plotted against the LRFR rating factor for shear due to the WA-02 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index near the target of 3.5. This indicates that the current live load factors produce the target level of reliability and do not need to be adjusted unless the target reliability is changed.

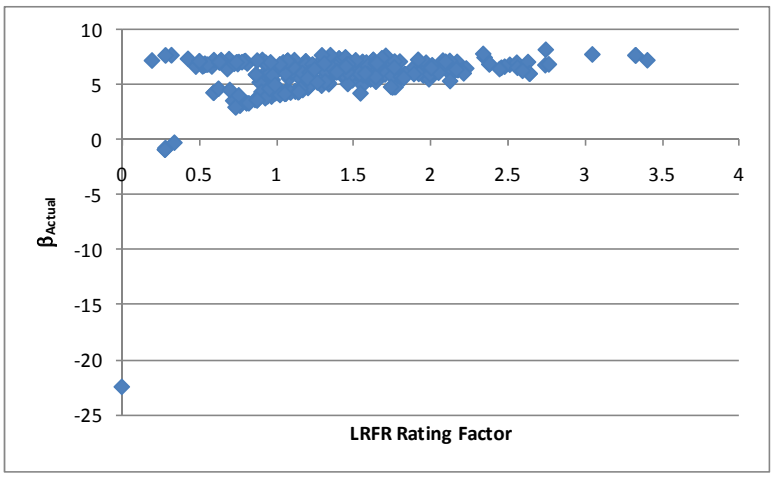


Figure C-107: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

C.1.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-108. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

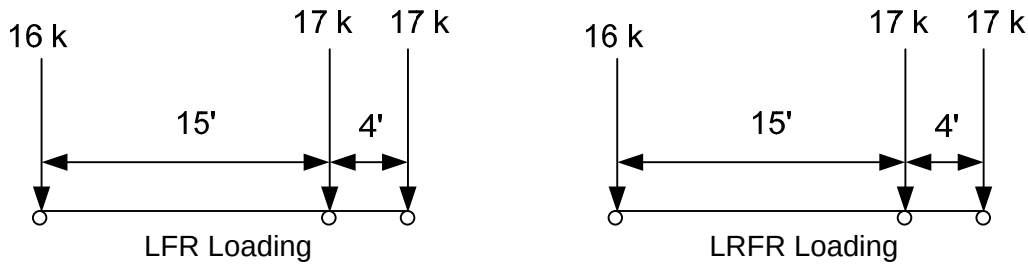


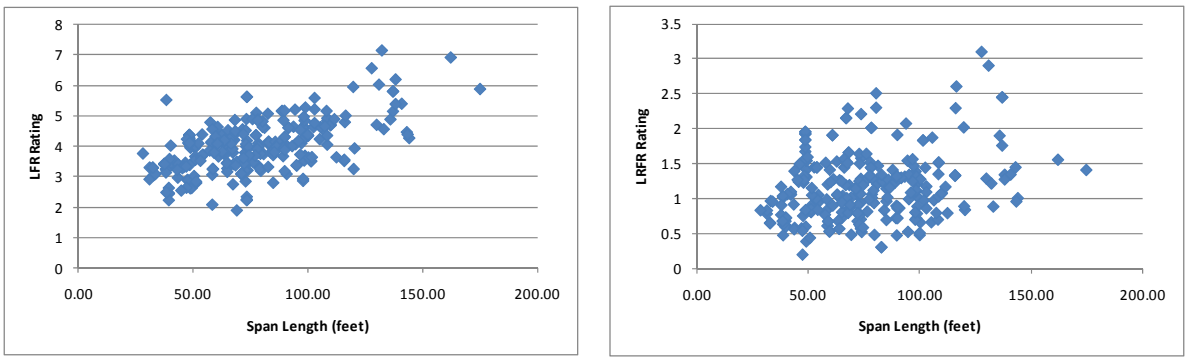
Figure C-108: Vehicle Loadings and Load Factors

C.1.11.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the Type 3 Vehicle.

C.1.11.1.1 Rating Factors

Figure C-109 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 110 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. Of the 110 girders with LRFR ratings less than 1.0, 97 are controlled by the longitudinal steel reinforcement rating.



(a) (b)

Figure C-109: LFR and LRFR Flexure Rating Factors for Type 3 Vehicles

Figure C-110 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, 70% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The girders with ratings less than 1.0 are distributed evenly between the different rating categories.

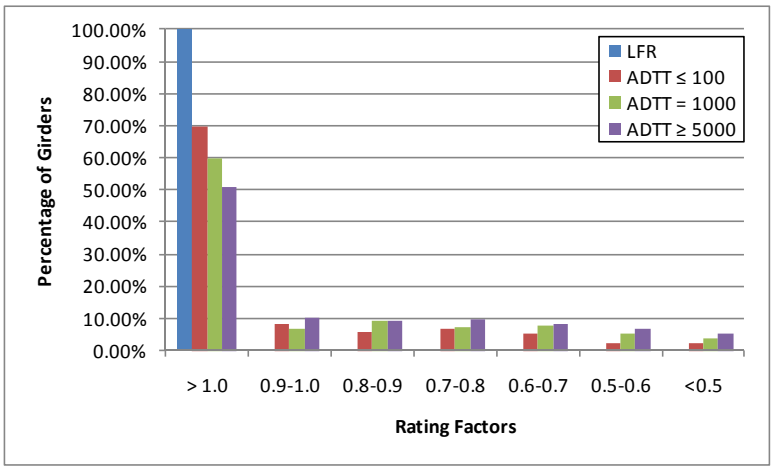


Figure C-110: Flexure Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

C.1.11.1.2 Rating Factor Comparisons

Figure C-111 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.1 and 0.4 with no girders having an LRFR rating greater than the LFR rating.

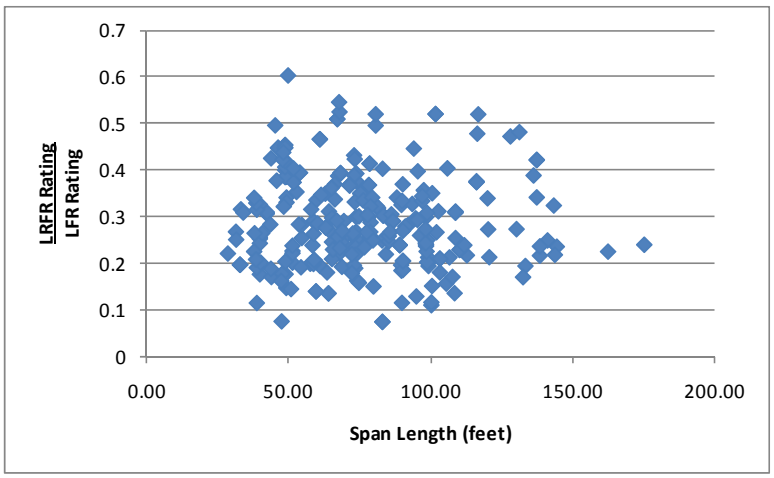


Figure C-111: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicles

C.1.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-112 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index.

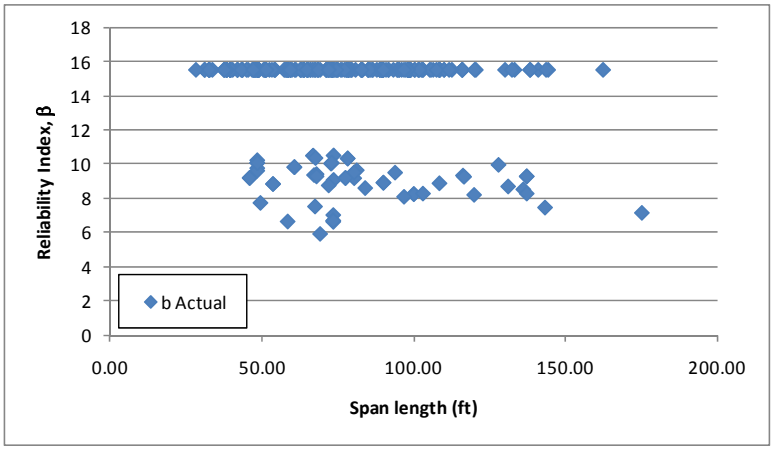


Figure C-112: Flexure Reliability Indices for Type 3 Vehicles

Figure C-113 shows the reliability index plotted against the LRFR rating for moment due to the AASHTO Type 3 vehicle. The figure shows that girders with a passing rating have a reliability index above 5 which is significantly larger than the target reliability of 2.5. This indicates the target reliability can be obtained using lower LRFR live load factors than those currently in the MBE.

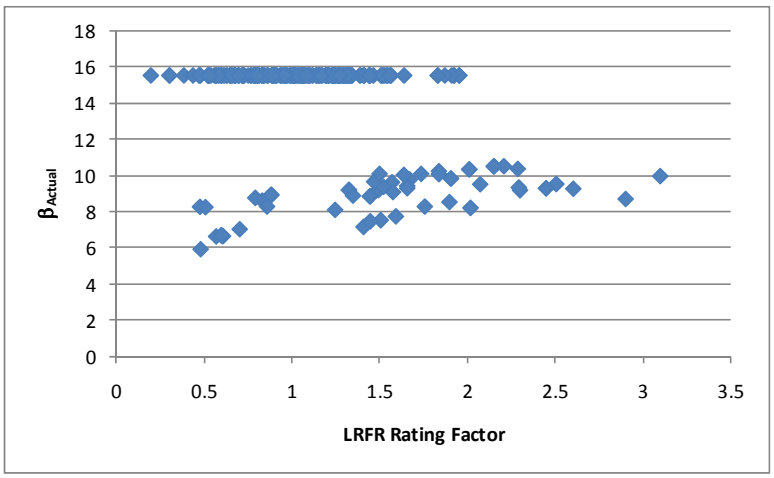
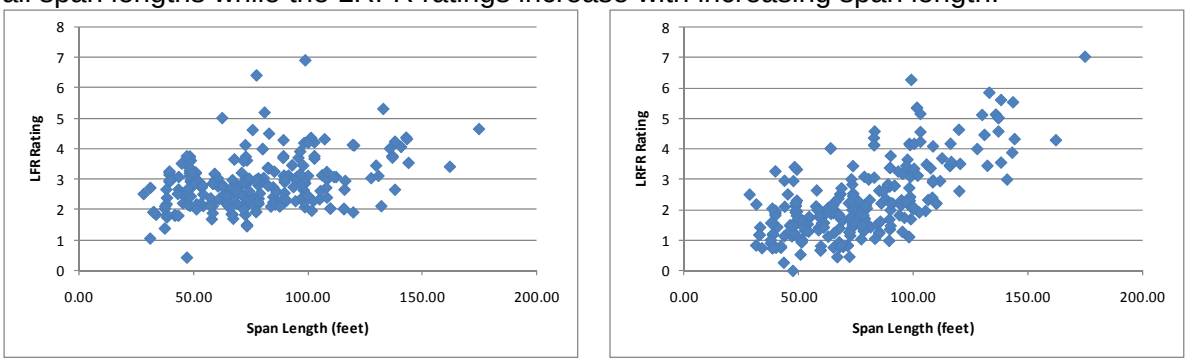


Figure C-113: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

C.1.11.2 Shear

C.1.11.2.1 Rating Factors

For shear, there is one girder with an LFR rating factor less than 1.0, 27 girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 74% of the girders in this subset. Figure C-114 shows the LFR and LRFR ratings. The LFR ratings remain between 2 and 3 for all span lengths while the LRFR ratings increase with increasing span length.



(a) (b)

Figure C-114: LFR and LRFR Shear Ratings for Type 3 Vehicles

Figure C-115 shows the distribution of shear ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, 92% of girders will have an LRFR rating above 1.0 and all girders will have an LFR rating greater than 1.0. The effect of the different load factors for different ADTTs is not as significant for shear as for moment. An ADTT of 5,000 results in slightly more than 10% of girders having LRFR shear ratings less than 1.0.

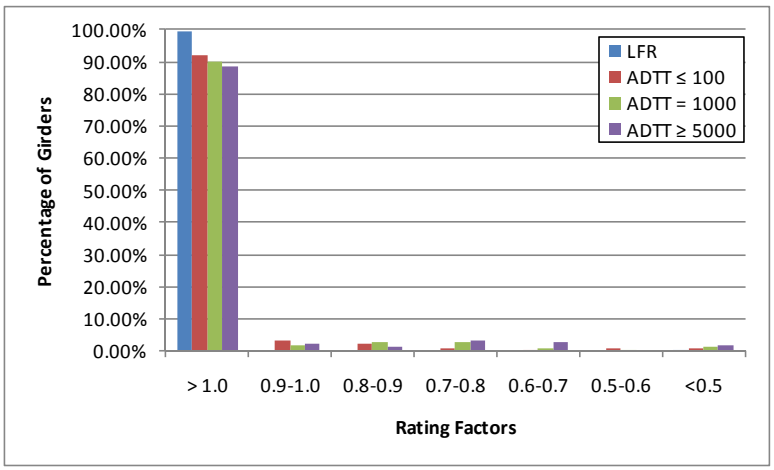


Figure C-115: Shear Rating for Various ADTTs in MBE for AASHTO Type 3 Truck

C.1.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-116 show the comparison of rating factors. The ratio is generally between 0.4 and 1.0 with significant scatter.

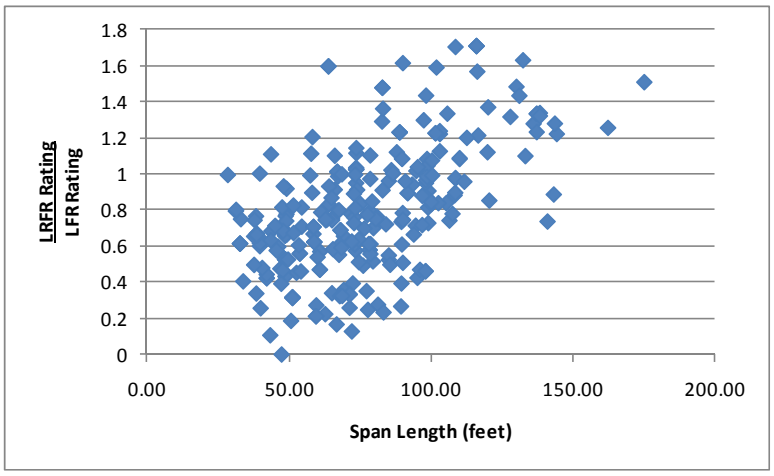


Figure C-116: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicles

C.1.11.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index for one girder as shown in Figure C-117. The reliability index is between 6 and 8 for most girders; the target reliability index is 2.5.

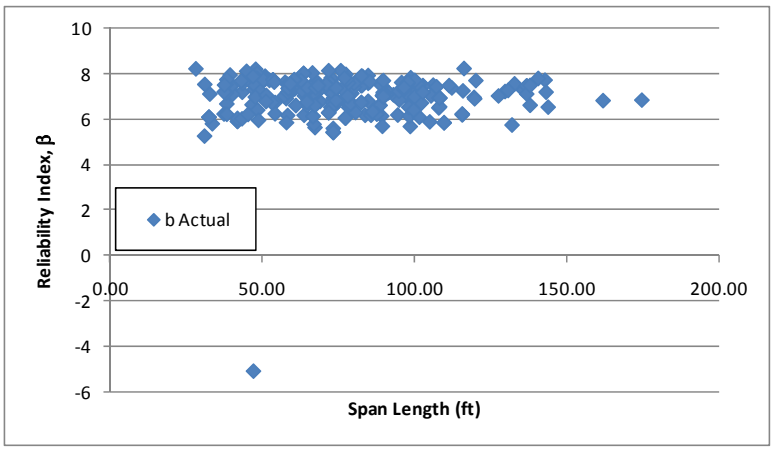


Figure C-117: Shear Reliability Indices for WA-02 Vehicles

Figure C-118 shows the reliability index plotted against the LRFR rating for shear due to the AASHTO Type 3 Vehicle. The figure shows that girders with ratings above 1.0 have reliability indices greater than 5.0. This indicates the target reliability could be obtained using live load factors that are lower than those currently in the MBE.

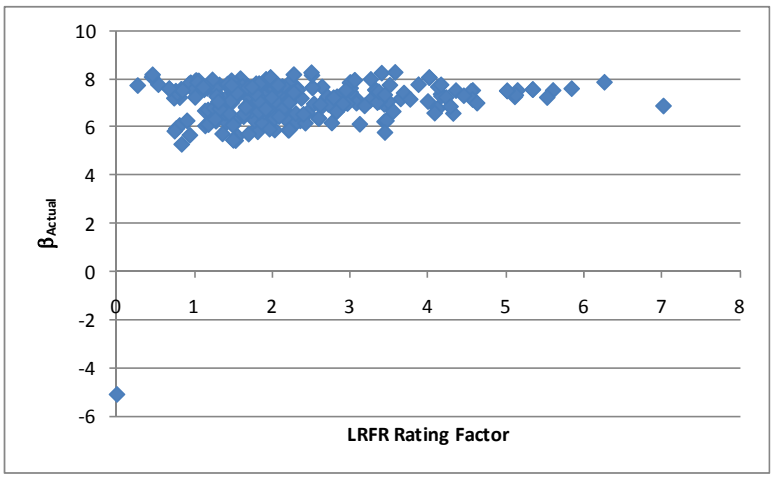


Figure C-118: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Vehicle

C.1.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-119. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

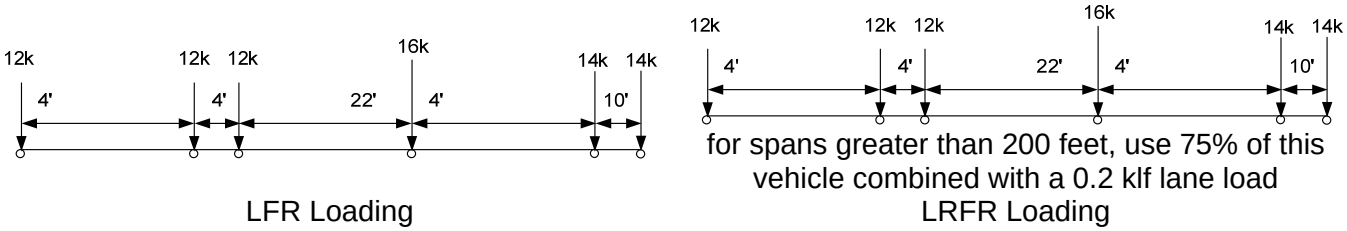


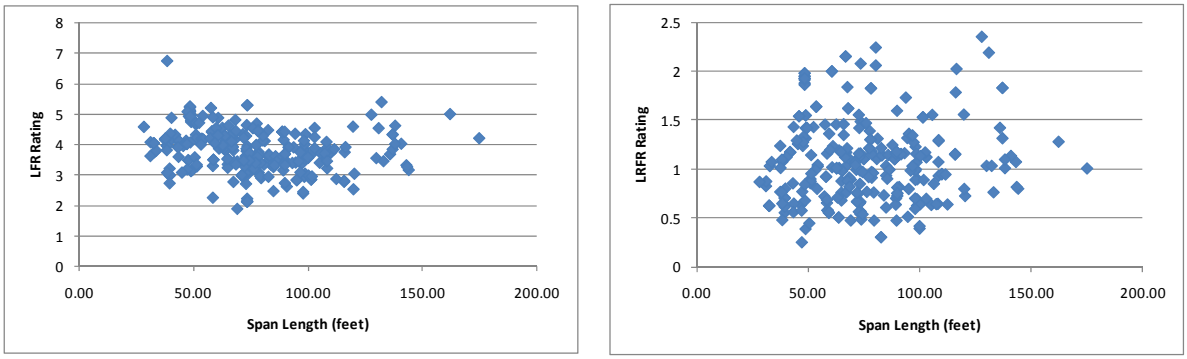
Figure C-119: Vehicle Loadings and Load Factors

C.1.12.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the Type 3-3 Vehicle.

C.1.12.1.1 Rating Factors

Figure C-120 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 128 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. Of the 128 girders with an LRFR rating less than 1.0, 115 are controlled by the rating of the longitudinal steel reinforcement.



(a) (b)

Figure C-120: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicles

Figure C-121 shows the distribution of moment ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, less than 70% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. An ADTT of 5,000, results in over half of the girders having LRFR ratings less than 1.0.

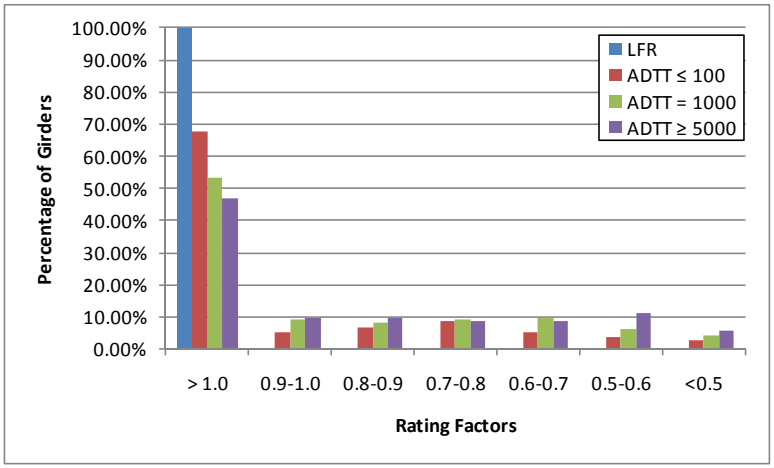


Figure C-121: Flexure Rating for Various ADTTs in MBE for AASHTO Type 3-3 Truck

C.1.12.1.2 Rating Factor Comparisons

Figure C-122 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating, which does not occur for any girders in this group for the AASHTO Type 3-3 vehicle. The ratio is generally between 0.1 and 0.4.

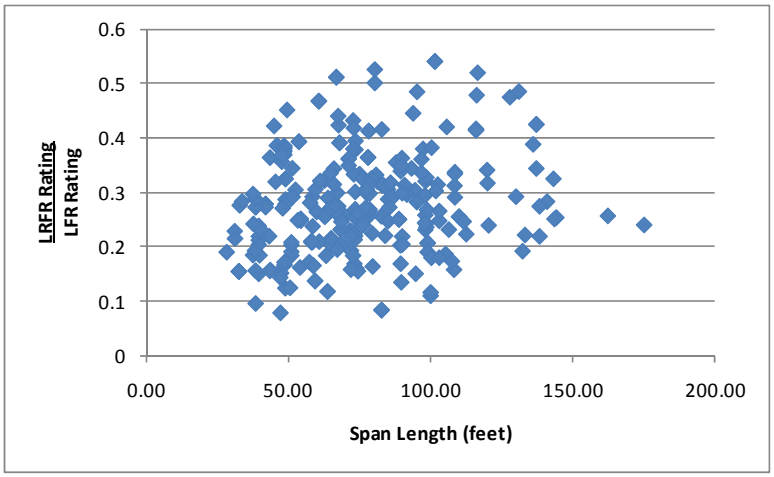


Figure C-122: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicles

C.1.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-123 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index.

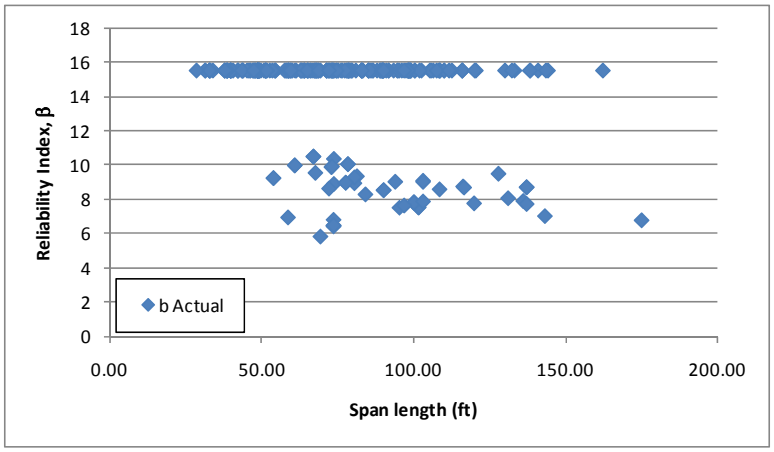


Figure C-123: Flexure Reliability Indices for Type 3-3 Vehicles

Figure C-124 shows the reliability index plotted against the LRFR rating for flexure caused by the AASHTO Type 3-3 Vehicle. The figure shows that a girder with a passing rating has a reliability index above 6, significantly larger than the target reliability of 2.5. This indicates the target reliability can be obtained by using live load factors that are less than those currently in the MBE.

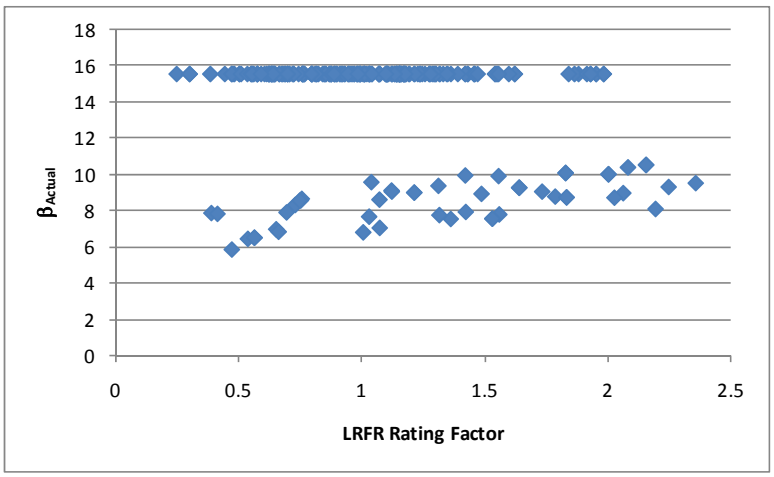
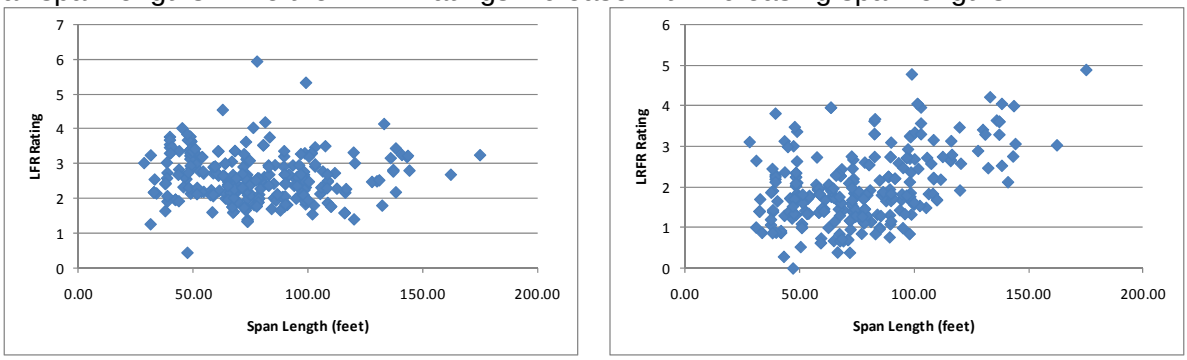


Figure C-124: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Vehicle

C.1.12.2 Shear

C.1.12.2.1 Rating Factors

For shear, there is one girder with an LFR rating factor less than 1.0, 33 girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 77% of the girders in this subset. Figure C-125 shows the LFR and LRFR ratings. LFR ratings are generally between 2 and 3 for all span lengths while the LRFR ratings increase with increasing span lengths.



(a) (b)

Figure C-125: LFR and LRFR Shear Ratings for Type 3-3 Vehicles

Figure C-126 shows the distribution of shear ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs as expected due to the increasing live load factors. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, about 8% of girders have LRFR ratings less than 1.0 for an ADTT of 100. This increases to approximately 15% of girders when an ADTT of 5,000 is used.

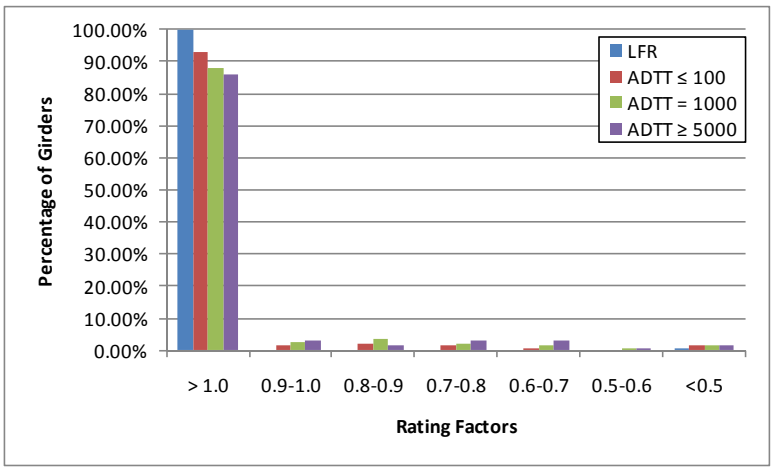


Figure C-126: Shear Rating for Various ADTTs in MBE for AASHTO Tye 3-3 Truck

C.1.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-127 show the comparison of rating factors. The ratio is less than one for 77% of the girders. The girders with LRFR ratings greater than LFR ratings are generally spans greater than 100 feet.

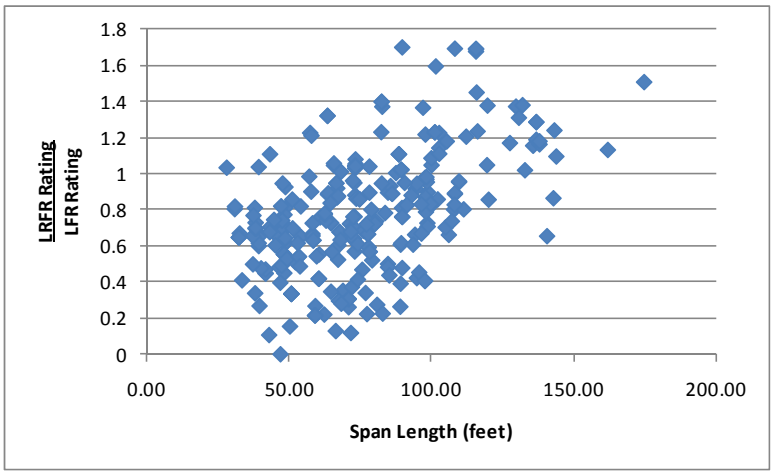


Figure C-127: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicles

C.1.12.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index for all but one girder as shown in Figure C-128. The reliability index is between 5 and 8 for most girders, higher than the target reliability of 2.5.

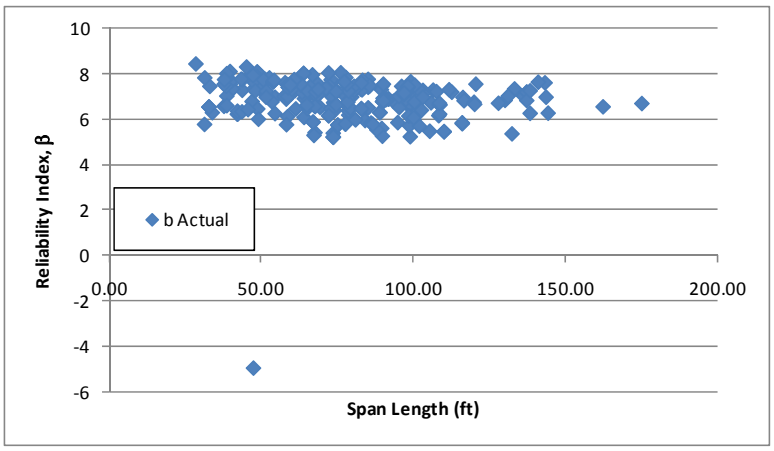


Figure C-128: Shear Reliability Indices for Type 3-3 Vehicles

Figure C-129 shows the reliability index plotted against the LRFR rating for shear due to the AASHTO Type 3-3 Vehicle. The figure shows that for girders with a rating of 1.0, the reliability index will be above 5.0. This indicates the target reliability can be obtained using live load factors less than those currently in the MBE. There are several girders with high reliability and lower ratings; these critical rating is for shear friction while the reliability index is calculated using the shear resistance.

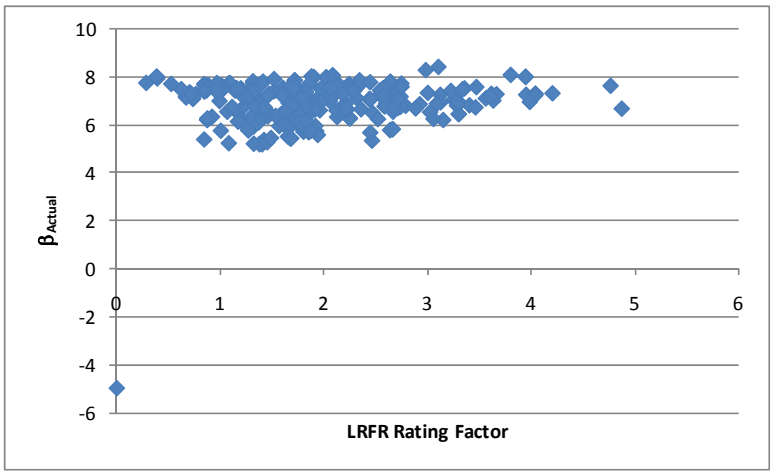


Figure C-129: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Vehicle

C.1.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-130. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

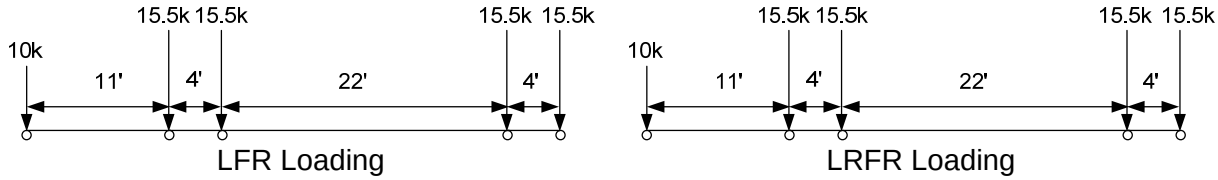


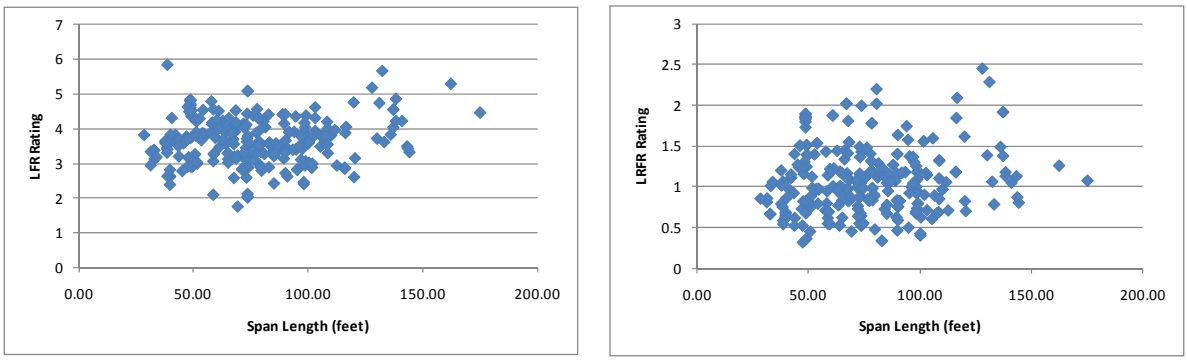
Figure C-130: Vehicle Loadings and Load Factors

C.1.13.1 Moment

The following section contains the results for interior, composite prestressed I girders within simple span bridges for the Type 3S2 Vehicle.

C.1.13.1.1 Rating Factors

Figure C-131 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 131 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating is typically between 3 and 4.5 while the LRFR rating is typically between 0.5 and 1.5. Of the 131 girders with LRFR rating less than 1.0, 117 were controlled by the longitudinal steel reinforcement rating.



(a) (b)

Figure C-131: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicles

Figure C-132 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs and increasing live load factors. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, more than 30% of girders have an LRFR rating less 1.0 while all girders will have an LFR rating greater than 1.0. Over 50% of girders have an LRFR rating less than 1.0 for an ADTT of 5,000 which corresponds to the highest load factors.

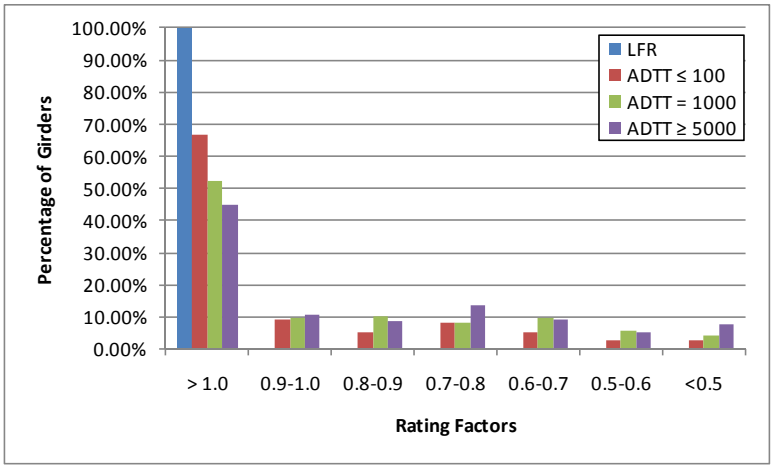


Figure C-132: Flexure Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Vehicle

C.1.13.1.2 Rating Factor Comparisons

Figure C-133 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating; no girders in this group have LRFR rating greater than the LFR rating. The ratio is generally between 0.1 and 0.4.

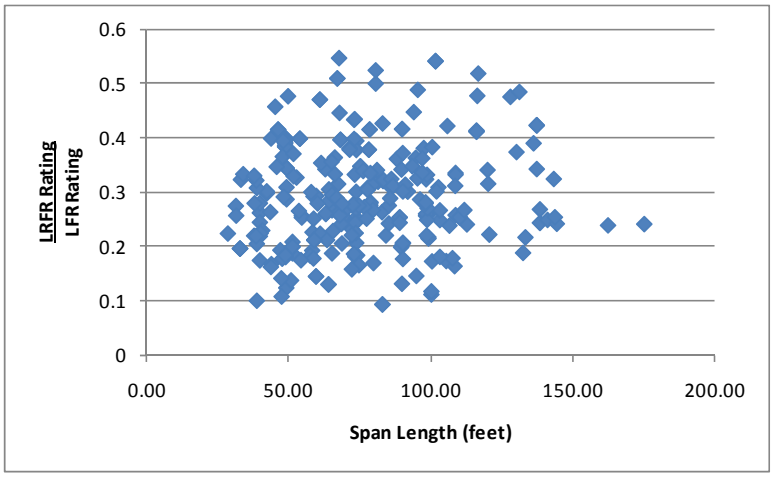


Figure C-133: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicles

C.1.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-134 shows no girders have a reliability index based upon girder strength that is less than the target reliability index. The reliability index for most girders is between 6 and 10.

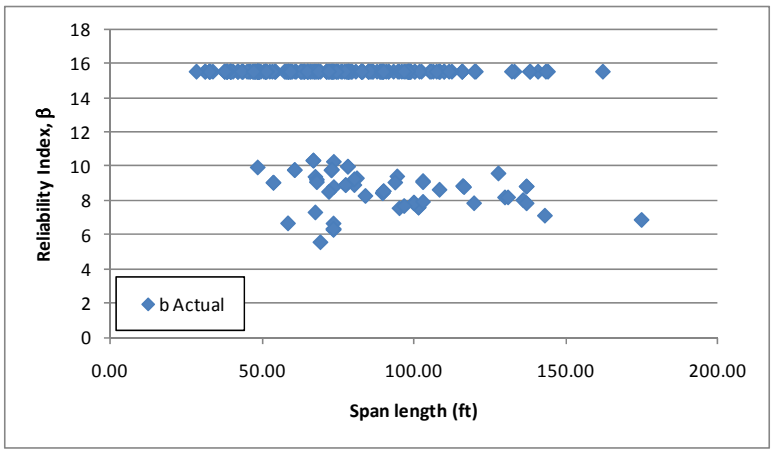


Figure C-134: Flexure Reliability Indices for Type 3S2 Vehicles

Figure C-135 shows the reliability index plotted against the LRFR rating factor for moment caused by the AASHTO Type 3S2 truck. The figure shows that a girder passing rating will have a reliability index above five; the target reliability index is 2.5 for the AASHTO Legal loads. This indicates the target reliability can be obtained using live load factors lower than those currently in the MBE.

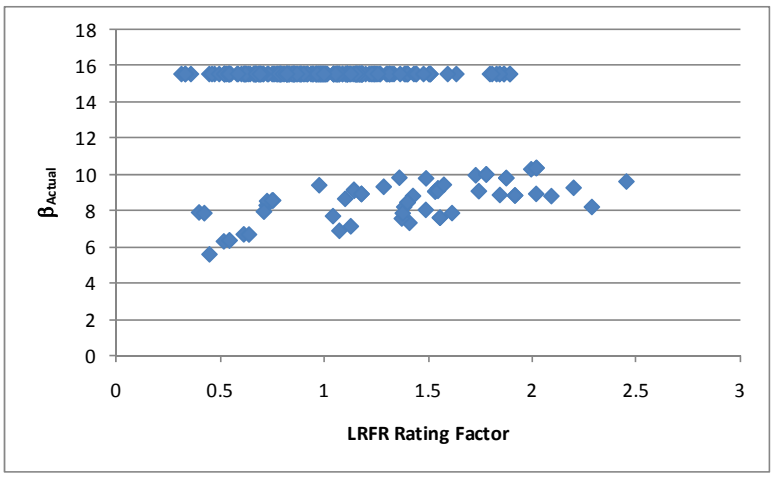
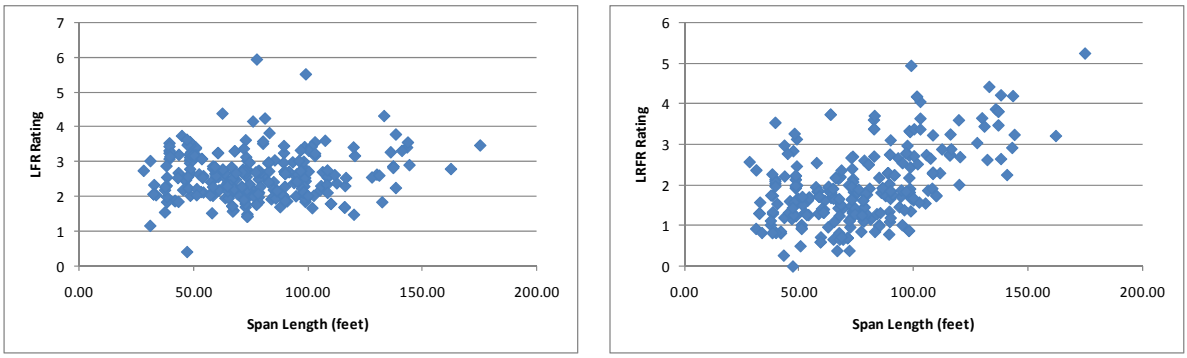


Figure C-135: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 vehicle

C.1.13.2 Shear

C.1.13.2.1 Rating Factors

For shear, there is one girder with an LFR rating factors less than 1.0, 33 girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 80% of the girders in this subset. Figure C-136 shows the LFR and LRFR ratings.



(a) (b)

Figure C-136: LFR and LRFR Shear Ratings for Type 3S2 Vehicles

Figure C-137 shows the distribution of shear ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The lowest ADTT results in about 8% of girders having an LRFR rating that is less than 1.0. This increases to approximately 14% of girders when an ADTT of 5,000 is used.

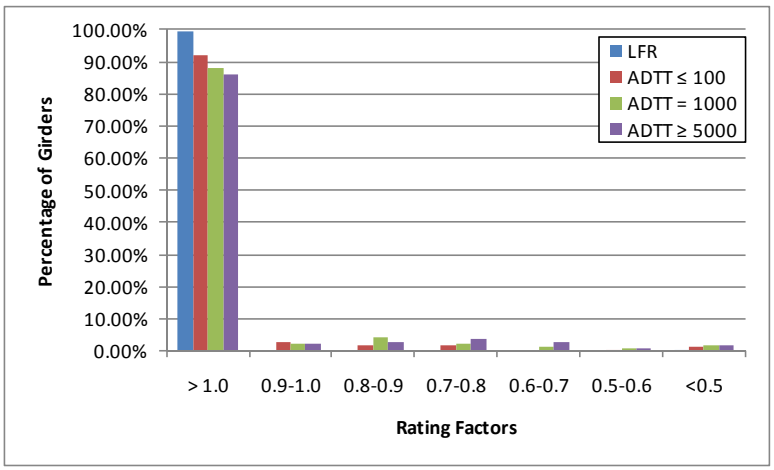


Figure C-137: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

C.1.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-138 show the comparison of rating factors. The ratio is generally between 0.4 and 1.0. 20% of the girders in this group have LRFR ratings greater than the LFR rating.

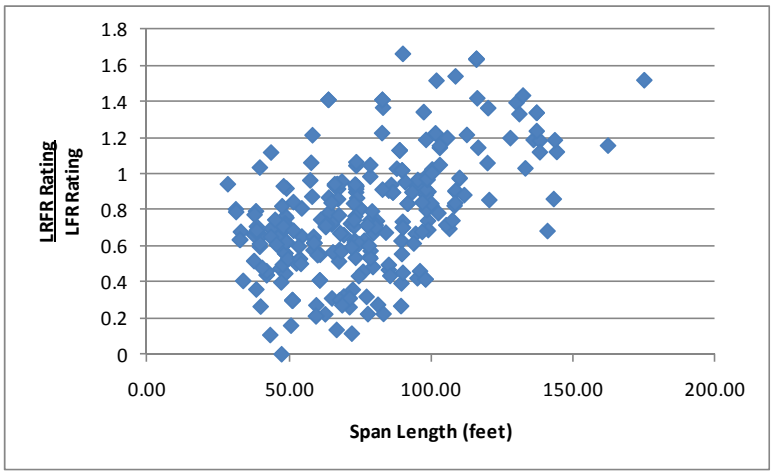


Figure C-138: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicles

C.1.13.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index for one girder as shown in Figure C-139. The reliability index is between 5.0 and 8.0 for most girders in this group.

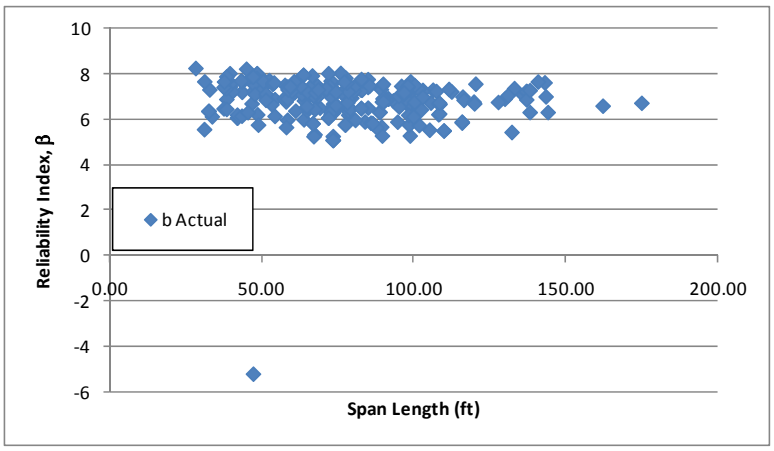


Figure C-139: Shear Reliability Indices for Type 3S2 Vehicles

Figure C-140 shows the reliability index plotted against the LRFR Rating for shear due to the AASHTO Type 3S2 legal truck. The figure shows that girders with a rating factor of 1.0 will have a reliability index above the target value of 2.5. This indicates the target reliability can be obtained using live load factors reduced from those in the current MBE.

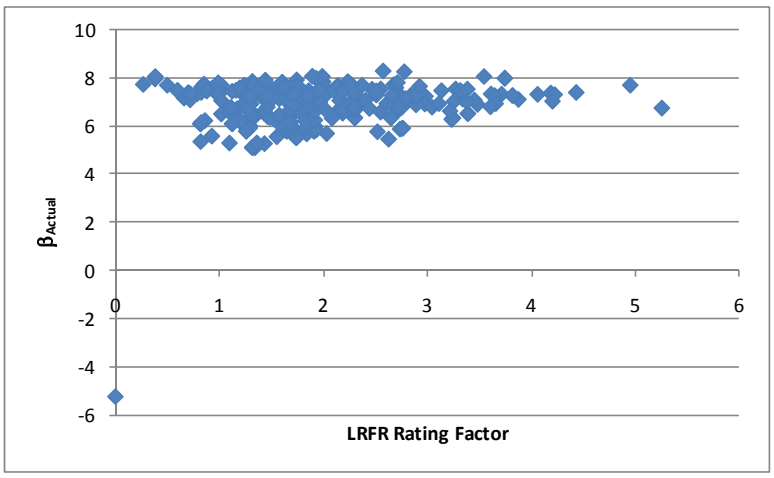


Figure C-140: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

C.1.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table C-1 shows the results for the moment ratings. For the design vehicle significantly more girders have ratings less than 1.0 for LRFR than for LFR. For the other vehicles investigated, the number of girders varied significantly depending on the vehicle, but overall a similar percentage had LFR ratings that were greater than the LRFR ratings. An additional row is shown indicating the number of girders controlled by the longitudinal steel requirements and having an LRFR rating less than 1.0. With the exception of the WA-02 vehicle, most girders with LRFR ratings less than 1.0 were controlled by the requirements of AASHTO LRFD 5.8.3.5. The girders with LRFR ratings less than 1.0 and not controlled by the longitudinal steel rating are controlled by the Service III Limit State, limiting the tension stress in the bottom of the beam.

Table C-1: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	274	12	0	0	0	0	0	0	0	6	0	0	0
LRFR Rating less than 1.0		159	141	125	35	126	109	32	144	84	110	128	131
LFR and LRFR Rating less than 1.0		12	0	0	0	0	0	0	0	5	0	0	0
% with LFR RF greater than LRFR RF		100	100	100	100	100	100	100	100	98	100	100	100
Controlled by AASHTO LRFD 5.8.3.5 and LRFR Rating less than 1.0		131	118	108	22	109	95	17	119	25	97	115	117
LRFR Rating less than 1.0 and controlled by service limit state		18	23	17	13	17	14	15	25	59	13	13	14

C.1.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table C-2 shows the results for the shear ratings. Few girders had LFR ratings less than 1.0 for routine permit and legal trucks. Special permits and the design vehicle produced more girders with LFR ratings less than 1.0. With the exception of the design vehicle, TX-04, and WA-02, the number of girders with LRFR ratings less than 1.0 were very similar between different truck types.

Table C-2: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	274	30	2	2	10	2	1	8	3	36	1	1	1
LRFR Rating less than 1.0		127	40	39	39	37	28	38	60	74	27	33	33
LFR and LRFR Rating less than 1.0		26	2	2	5	2	1	6	3	18	1	1	1
% with LFR RF greater than LRFR RF		80	80	76	42	75	73	42	77	51	74	77	80

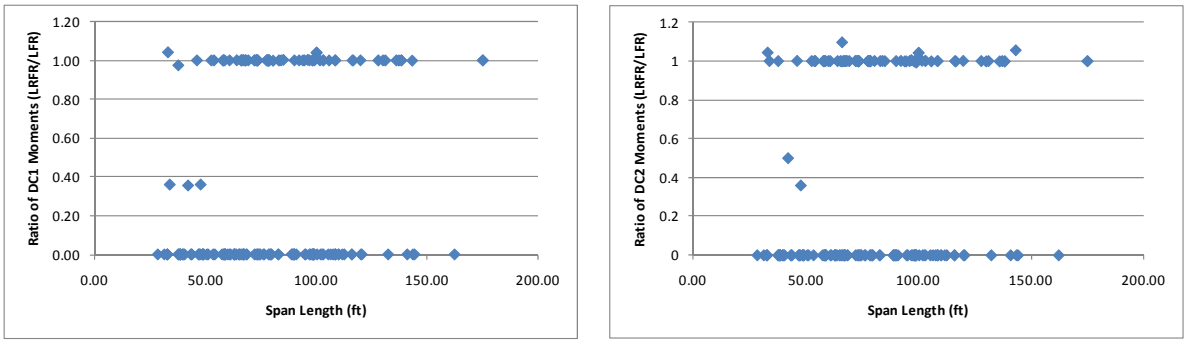
C.2 Exterior Composite Girders

C.2.1 Dead Loads

C.2.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure C-141a, the ratio of unfactored DC1 moments (self-weight, dead loads on composite section) is very close to 1.0 for all girders. Figure C-141b shows that there is

similar variation in the loads applied to the composite section (DC2 and DW loads). The figure also shows that a significant number of exterior girders where the ratio of dead loads is zero.

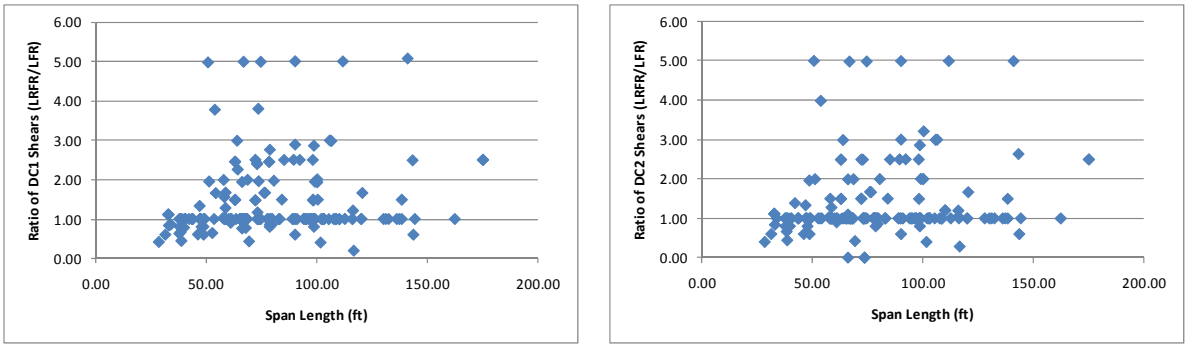


(a) (b)

Figure C-141: Ratios of DC1 and DC2 Moment (unfactored loads LRFR/LFR)

C.2.1.2 Shear

Figure C-142a shows that numerous girders have a ratio of DC1 shear close to 1.0, but there are also many where the ratio is either above or below 1.0. This is a mostly due to the variation of the critical section for shear. Figure C-142b shows the same trend as Figure C-142a in that the LFR shear is similar to the LRFR shear.



(a) (b)

Figure C-142: Ratios of DC1 and DC2 Shear (unfactored loads LRFR/LFR)

C.2.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure C-143. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

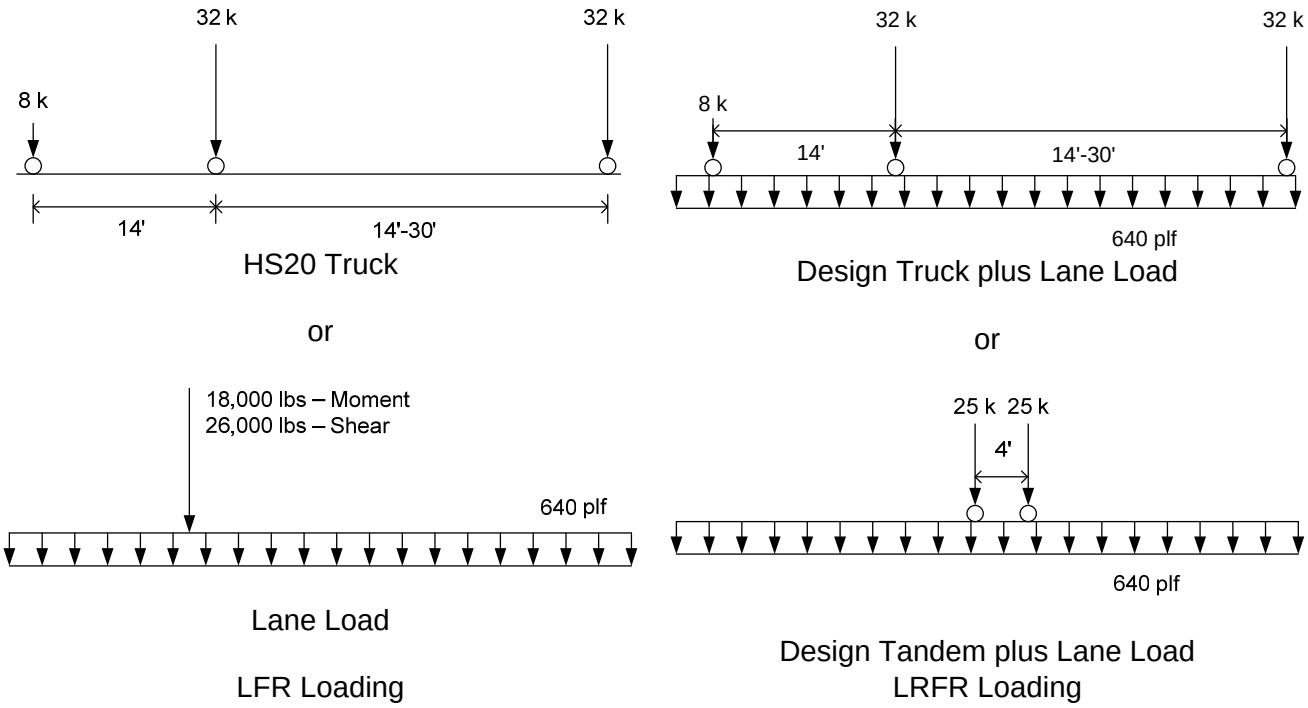
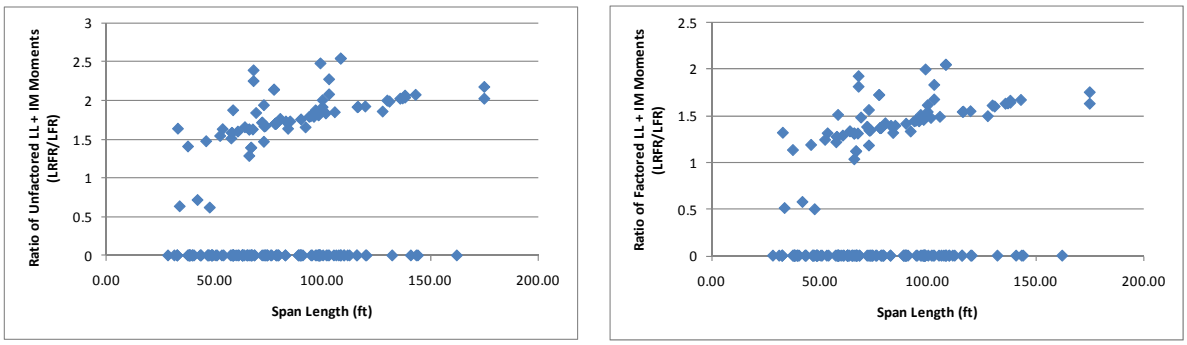


Figure C-143: Vehicle Loadings and Load Factors

C.2.2.1 Moment

C.2.2.1.1 Live Loads

Figure C-144a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.5 and 2.0 for most of the girders within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure C-144b shows that the results have shifted down and are between 1.1 and 1.7 for most cases. Also shown are a significant number of girders where the ratio of live load is zero; these are girders controlled by rating the longitudinal steel in the girder where the critical section is at the support.



(a) (b)

Figure C-144: Ratios of Unfactored and Factored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

C.2.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure C-145 shows that the ratio of resistance is generally between 1.0 and 1. 5 for girders not controlled by the longitudinal steel requirement. The increase in resistance is due to the reduction in prestress losses accompanying the switch from LFR to LRFR. For those girders controlled by the longitudinal steel requirement, the ratio is between 0 and 0.25.

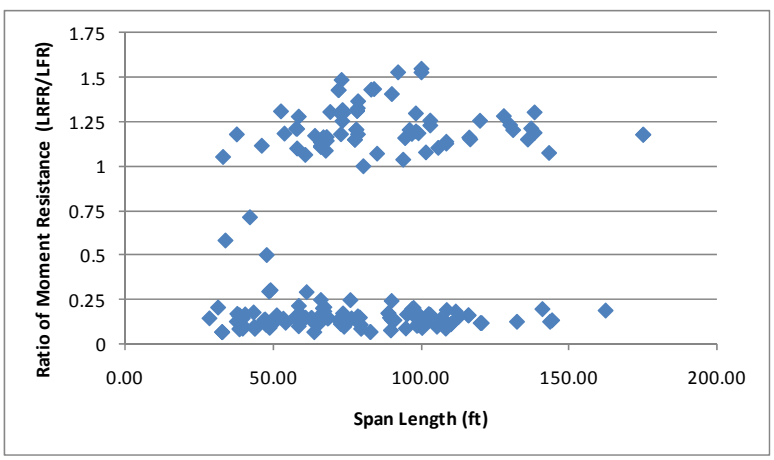
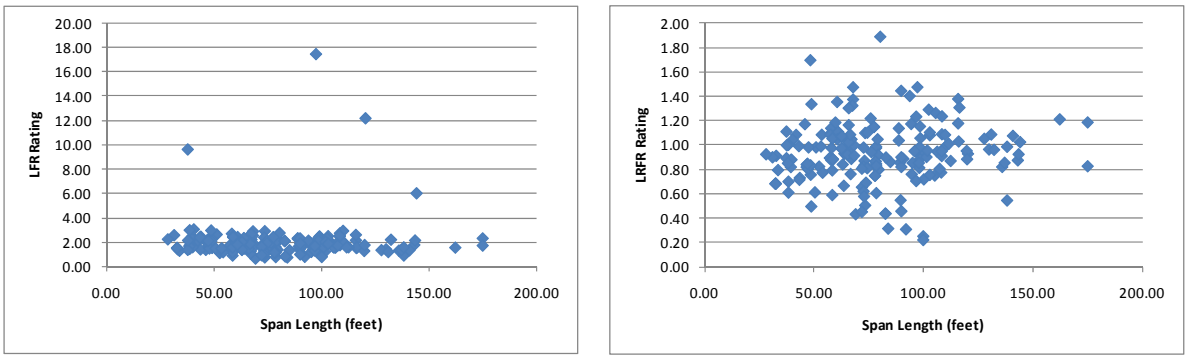


Figure C-145: Ratio of factored Moment Resistance (LRFR/LFR)

C.2.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (193 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 13 girders with LFR ratings less than 1.0, 130 girders with LRFR ratings less than 1.0, and 13 girders where both the LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. Figure C-146 shows the LFR rating factors and LRFR rating factors, respectively. Of the 130 girders with

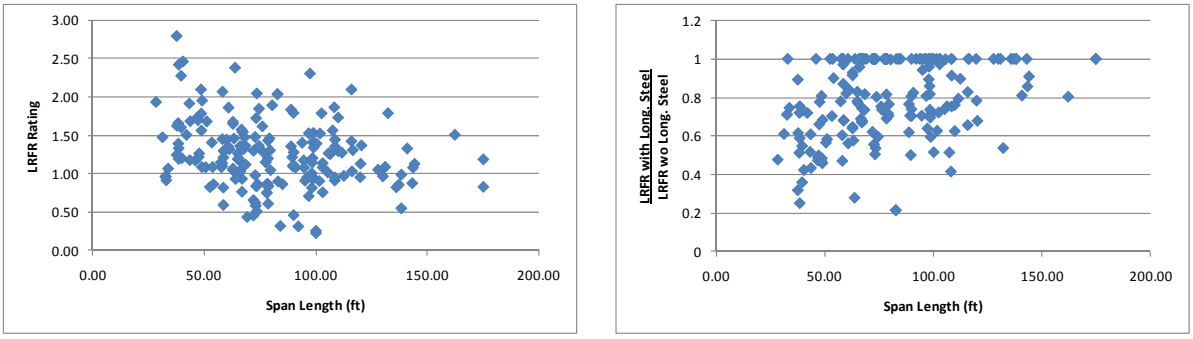
LRFR ratings less than 1.0, 84 were controlled by the longitudinal steel requirement of AASHTO LRFD 5.8.3.5.



(a) (b)

Figure C-146: LFR and LRFR Flexure Rating Factors for HS-20 and HL-93 Loadings

Figure C-147a shows the LRFR ratings when the longitudinal steel rating is ignored. Ignoring the longitudinal steel rating causes 75 fewer girders having LRFR ratings less than 1.0. The ratings for shorter spans have increased when compared to Figure C-146b. Figure C-147b shows the ratio of the LRFR rating including the longitudinal steel divided by the LRFR rating ignoring the longitudinal steel rating. The ratings including the longitudinal steel rating are between 40 and 80% of the rating when ignoring the longitudinal steel rating. 65% of girders have higher ratings when the longitudinal steel rating is ignored.



(a) (b)

Figure C-147: Effect of Longitudinal Steel on LRFR Rating

C.2.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure C-148. The results indicated that 99% of the girders in this set have LFR ratings greater than LRFR ratings. Most girders have a ratio between 0.4 and 0.8.

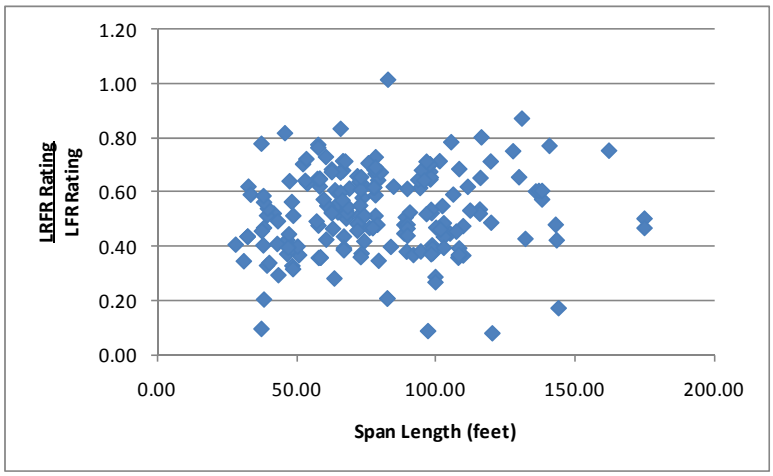


Figure C-148: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Vehicles

Figure C-149 shows the distribution of LRFR rating divided by LFR rating. The figure shows that most girders have a ratio below 0.7, indicating that the allowable truck load for LRFR would be smaller than that for LFR.

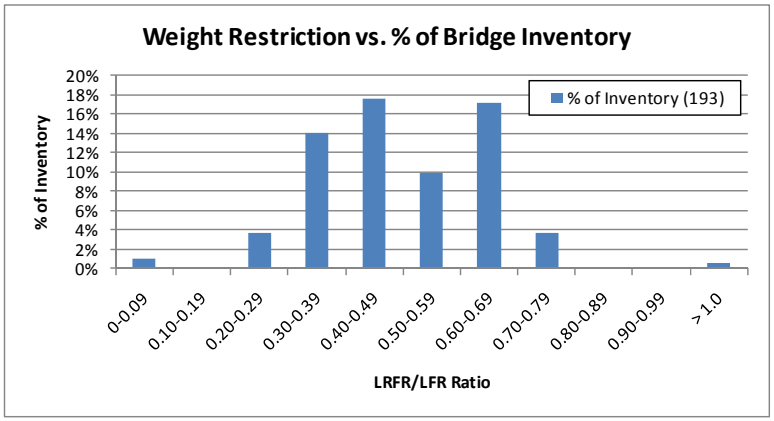


Figure C-149: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

C.2.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure C-150 shows four girders have a reliability index lower than target reliability in the development of the LRFR Rating Specification at this loading level. The required reliability index is based upon a 75 year time frame since it corresponds to the Design Level reliability and is slightly above 3.5 because the load factors were increased by 10% for conservatism.

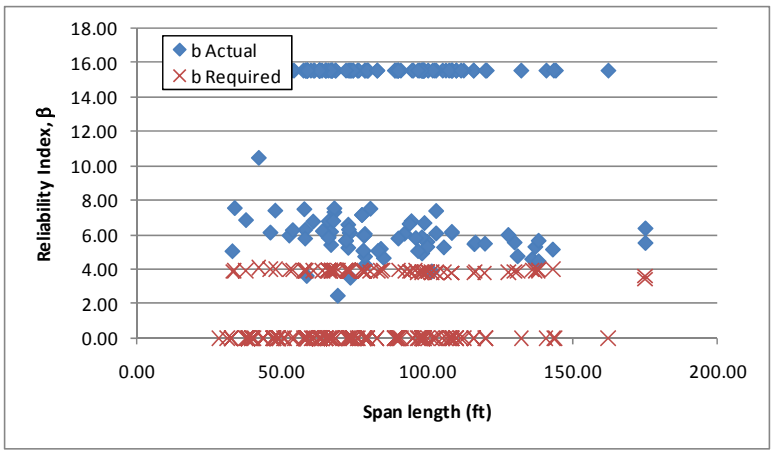


Figure C-150: Flexure Reliability Indices for HL-93 Loading

Figure C-151 shows the reliability index plotted against the LRFR rating for moment caused by the HL-93 Design Load. The figure shows that girders passing the design rating have ratings above 4.0. This is expected because the actual live load factor determined in the calibration of the design specification was 1.6 but was increased to be conservative.

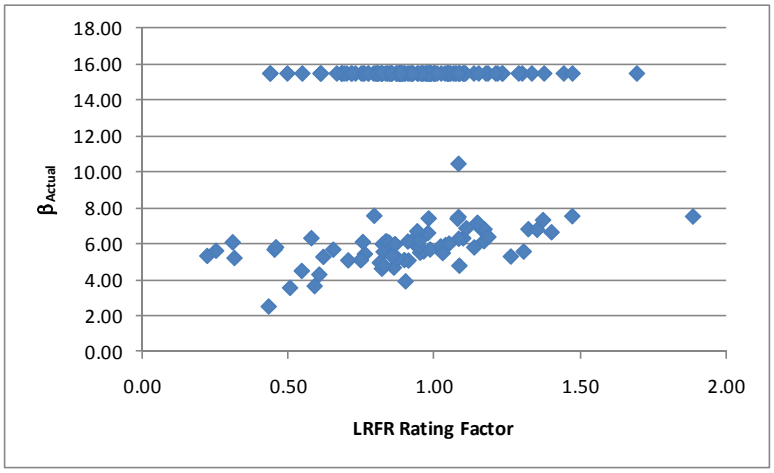


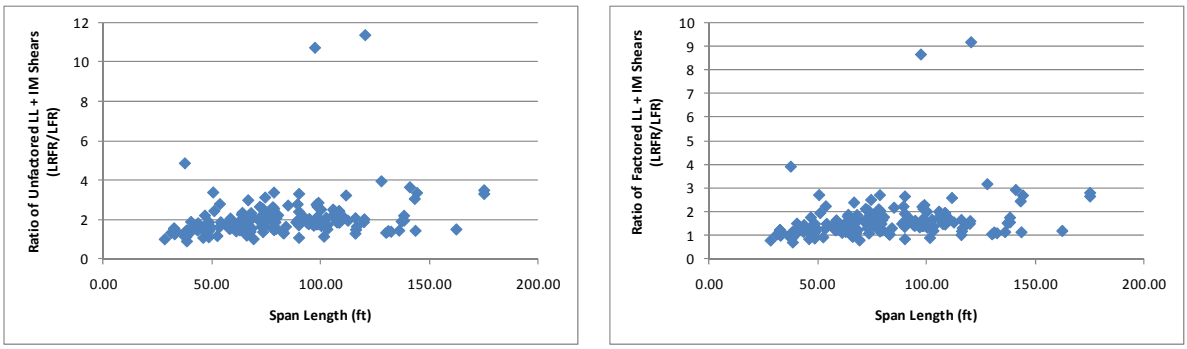
Figure C-151: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Loading

C.2.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is prestressed concrete I-beam, simple span exterior girders with composite concrete decks.

C.2.2.2.1 Live Loads

Figure C-152a shows that the ratio of unfactored shear varies significantly, with most girders between 1.0 to 2.5. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure C-152b shows that the ratio of factored live load shears has decreased and is generally between 1.0 and 2.0 for most cases.



(a) (b)

Figure C-152: Ratio of Unfactored and Factored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

As shown in Figure C-153, the location of the critical section for varies significantly for most girders in this subset. The variation in the factored shears shown in Figure C-152 was exaggerated by the difference in the critical section for shear rating.

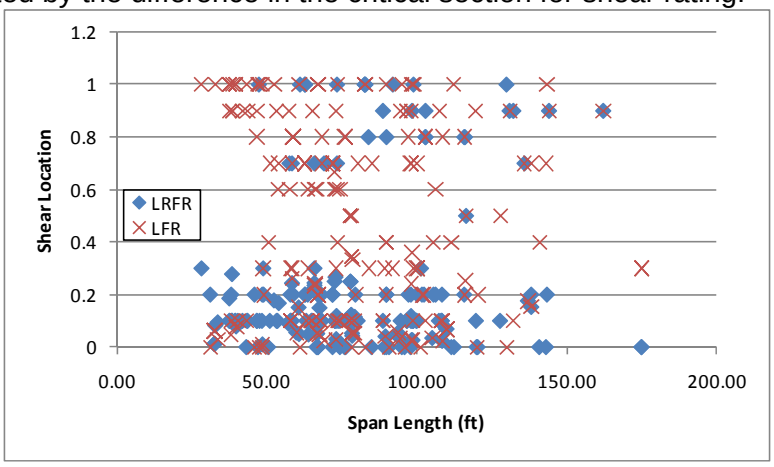


Figure C-153: Graph of critical shear location for Design Loadings

C.2.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure C-154 shows that the ratio of resistance is generally greater than 1.0 (LRFR resistance is greater than LFR resistance). It is expected that most of the resistances will not be the same because of the variation in the critical location shown in Figure C-153 and the different shear reinforcement spacing along the length of the beam.

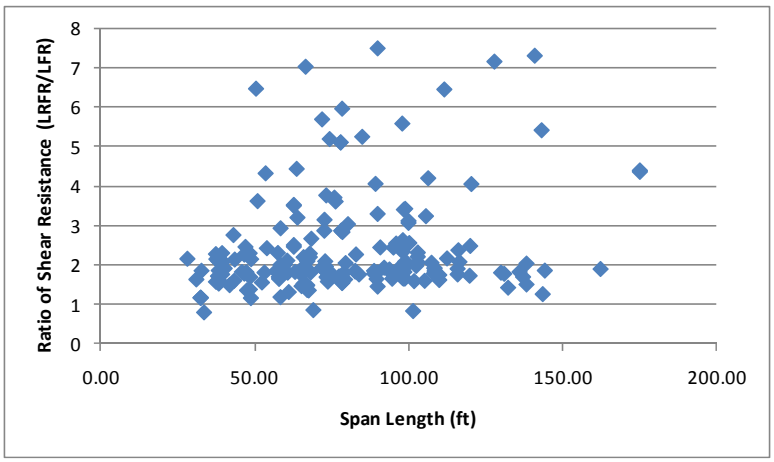
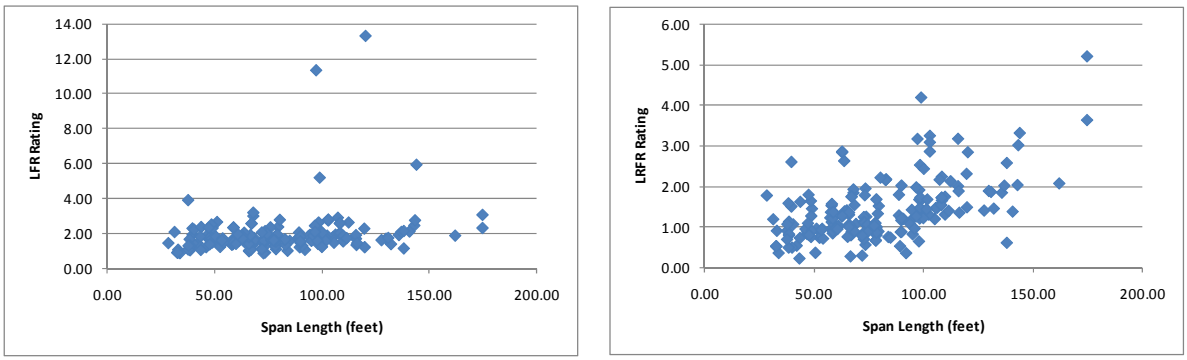


Figure C-154: Ratio of factored Shear Resistance (LFR/LRFR)

C.2.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 9 girders with LFR ratings less than 1.0, 66 girders with LRFR ratings less than 1.0, and 7 girders where both LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. For this subset, there is a significant number of girders that have shear ratings less than 1.0 for LRFR. In addition, the LFR rating was greater than the LRFR rating for 82% of the girders in this subset. Figure C-155 shows the LFR rating factors and LRFR rating factors. The LFR rating tends to increase with increasing span length, with LRFR showing the same trend.



(a) (b)

Figure C-155: LFR and LRFR Shear Rating Factors for HS-20 and HL-93 Loadings

C.2.2.2.4 Rating Factor Comparisons

Figure C-156 shows the ratio of the LRFR rating to the LFR rating. There are a number of girders with LRFR ratings greater than LFR ratings, but this is only 18% of the girders in the set. The ratio tends to increase with increasing span lengths.

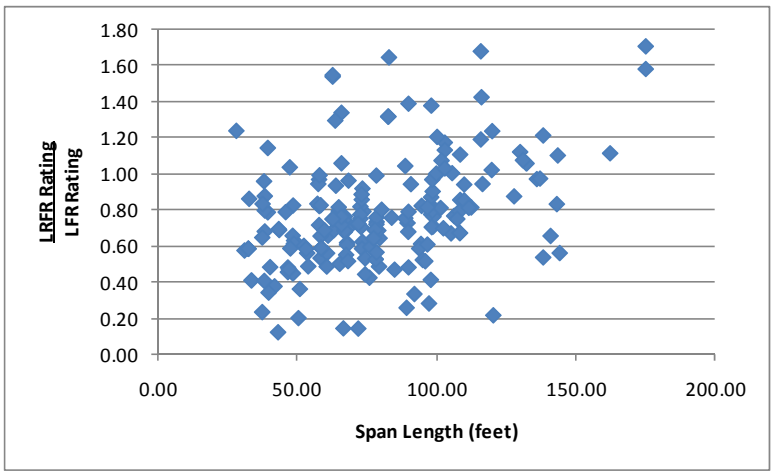


Figure C-156: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure C-157 shows what percentage of the LFR rating the LRFR rating is for girders with LRFR ratings less than 1.0. The figure shows that most girders have LRFR ratings less than 80% of the LFR rating. This is a significant reduction in load carrying capacity as compared to LFR.

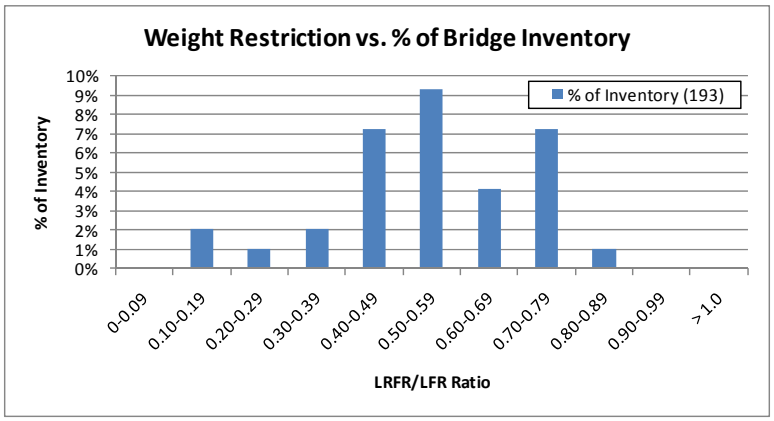


Figure C-157: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

C.2.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure C-158 shows that most girders have a reliability index for shear greater than the target level indicated by the red "x". The girders that do not have the required level of reliability are generally less than 100 feet in length.

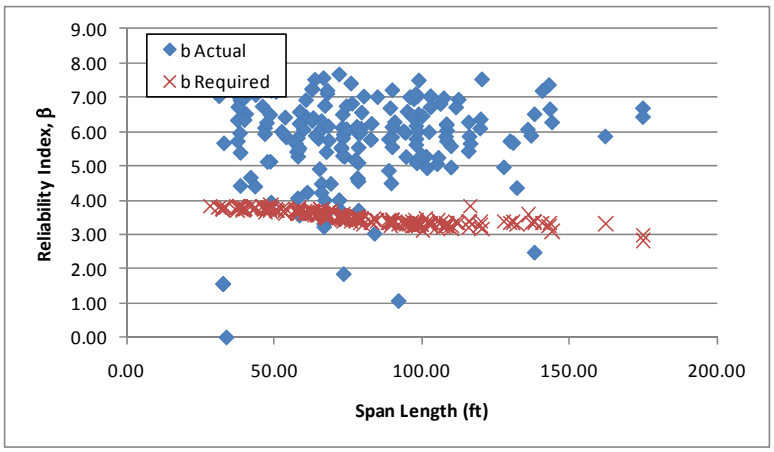


Figure C-158: Shear Reliability Indices for HL-93 Loading

Figure C-159 shows the reliability index plotted against the LRFR rating for shear caused by the HL-93 design loading. The figure shows that girders passing rating have reliability indices of approximately 4.0; similar to the target value of 3.5. Girders with high reliability and low ratings are controlled by shear friction rating and the reliability index is calculated using the shear resistance of the cross-section.

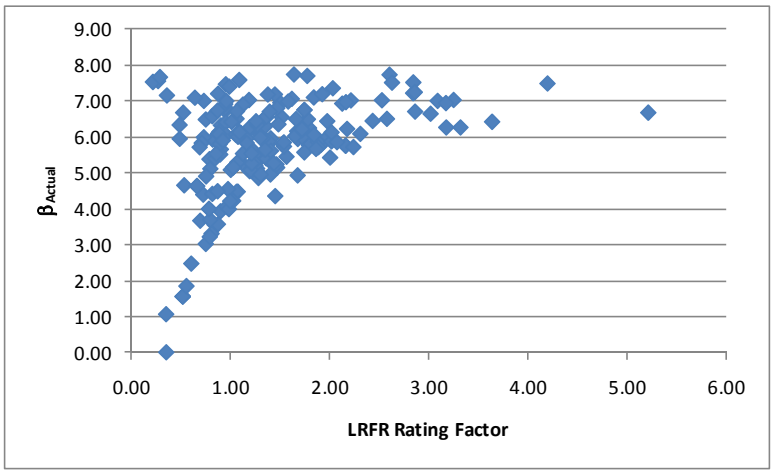
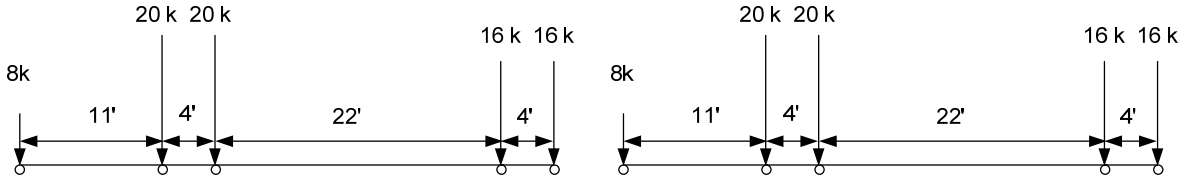


Figure C-159: Shear Reliability Index vs LRFR Shear Rating for HL-93 Design Load

C.2.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-160. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

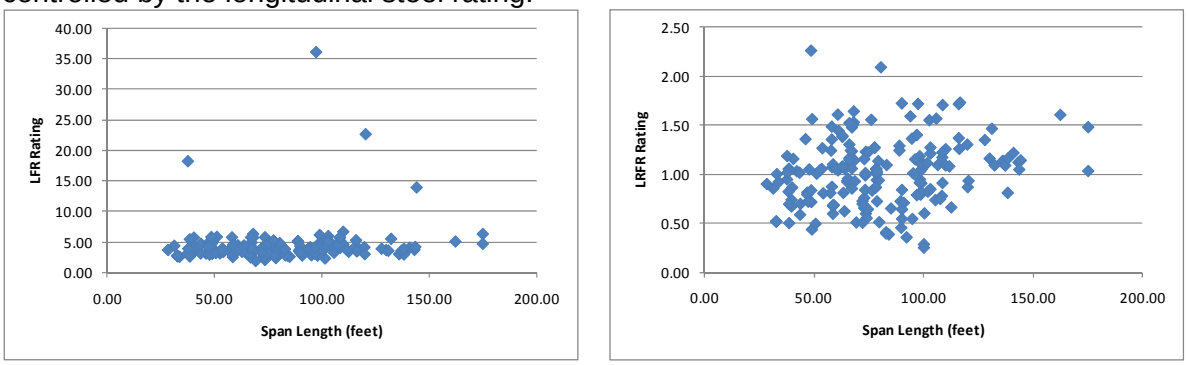
Figure C-160: Vehicle Loadings and Load Factors

C.2.3.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the DE-07 Vehicle.

C.2.3.1.1 Rating Factors

Figure C-161 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 90 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for all girders in this subset. The LFR ratings are between 2 and 5 for most girders while the LRFR ratings are between 0.5 and 1.5. Of the 90 girders with LRFR ratings less than 1.0, 69 are controlled by the longitudinal steel rating.



(a) (b)

Figure C-161: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure C-162 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 60% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 40% when an ADTT of 5,000 is used.

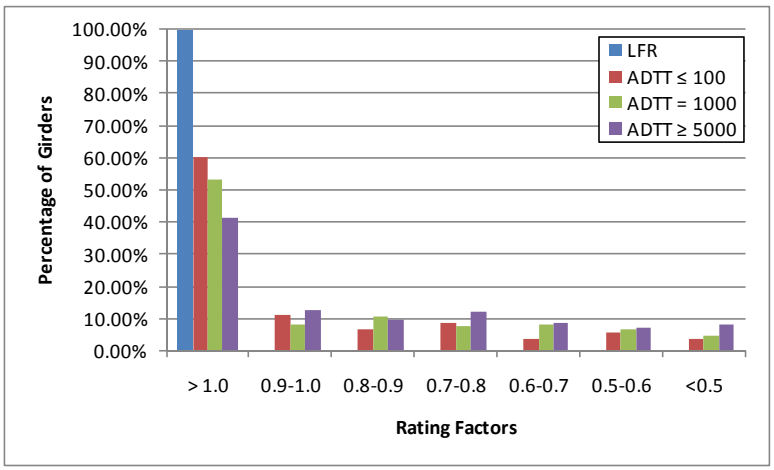


Figure C-162: Flexure Ratings for Various ADTTs in MBE for DE-07 Vehicle

C.2.3.1.2 Rating Factor Comparisons

Figure C-163 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.1 to 0.4. The low ratios are not a complete surprise because the longitudinal steel requirement was not present in the Standard Specification and existing girders most likely do not have adequate mild steel reinforcement to carry the additional shear.

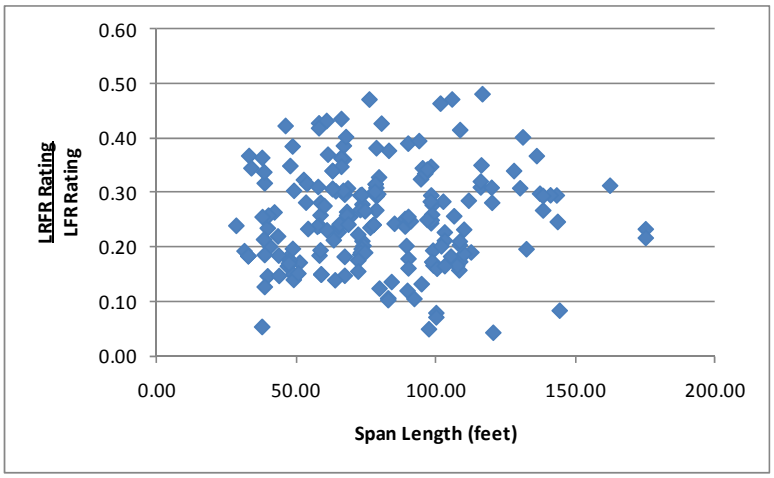


Figure C-163: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

C.2.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-164 shows that all girders have a reliability index based upon girder strength that is greater than the target reliability index of 2.5.

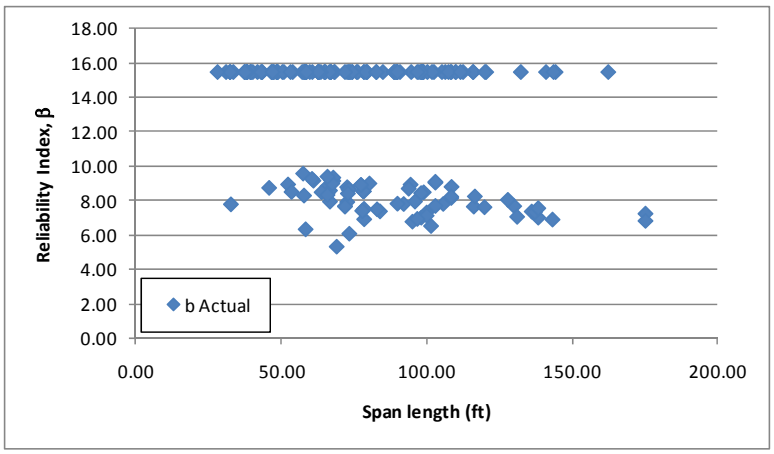


Figure C-164: Flexure Reliability Indices for DE-07 Vehicle

Figure C-165 shows the reliability index plotted against the LRFR rating for flexure due to the DE-07 vehicle. The figure shows that girders with a passing rating, neglecting those controlled by the longitudinal reinforcement, have a reliability index of at least six. This indicates the target reliability can be achieved while using lower live load factors than currently in the MBE.

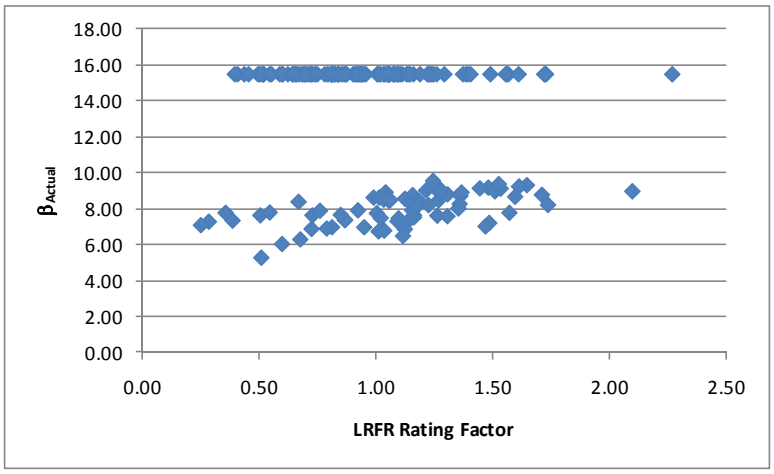
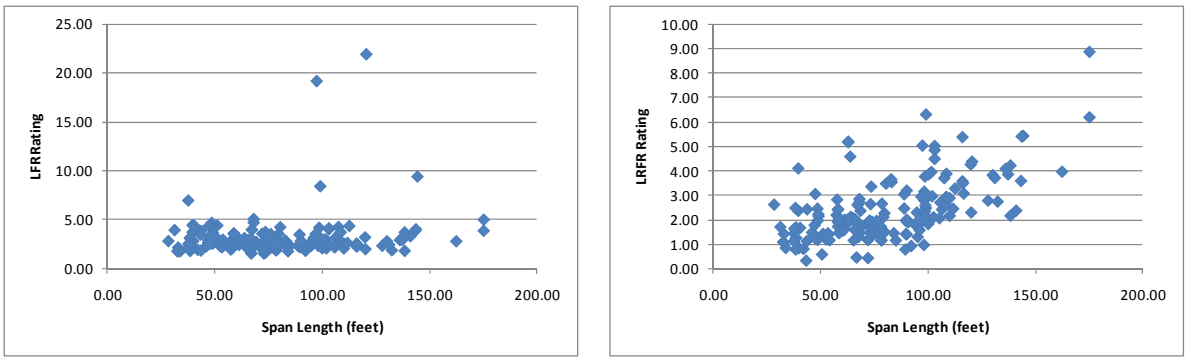


Figure C-165: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

C.2.3.2 Shear

C.2.3.2.1 Rating Factors

For shear, there are zero girders that have rating factors less than 1.0 for LFR, 11 girders for LRFR, and zero girders where both LFR and LRFR are less than 1.0. The LRFR rating results in more girders not having satisfactory ratings The LFR Rating is greater than the LRFR rating for 78% of the girders in this subset. Figure C-166 show the LFR and LRFR ratings. The LRFR ratings increase with increasing span length while the LFR ratings remain within the same range for all span lengths.



(a) (b)

Figure C-166: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure C-167 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is not as significant for shear as it was for moment; using an ADTT of 100, 95% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 92% when an ADTT of 5,000 is used.

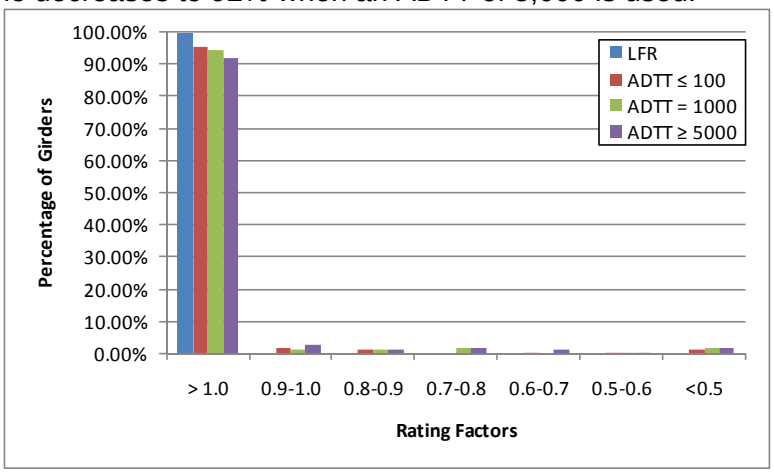


Figure C-167: Shear Rating for Various ADTTs in MBE for DE-07 Vehicle

C.2.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure C-168 shows the comparison of rating factors. The ratio is generally less than 1.0, with longer spans being the most likely to have a ratio greater than 1.0. 22% of the girders in this group have LRFR ratings greater than the LFR rating.

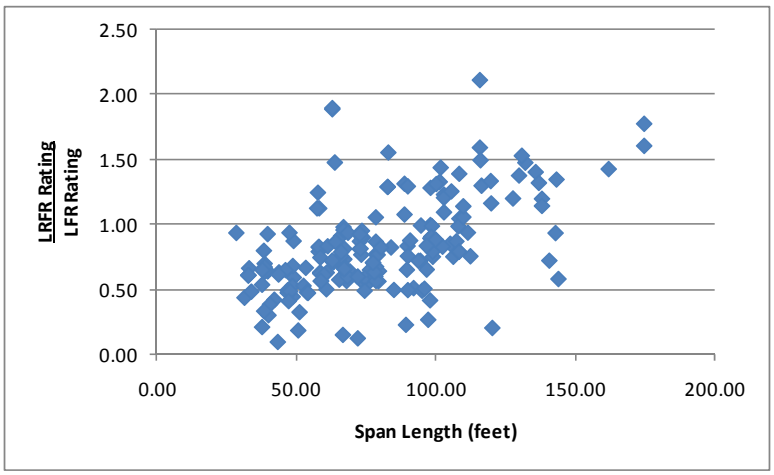


Figure C-168: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

C.2.3.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure C-169. The girder where the reliability index is low does not have properly defined shear reinforcement. The reliability index is between 6.0 and 8.0 for most cases.

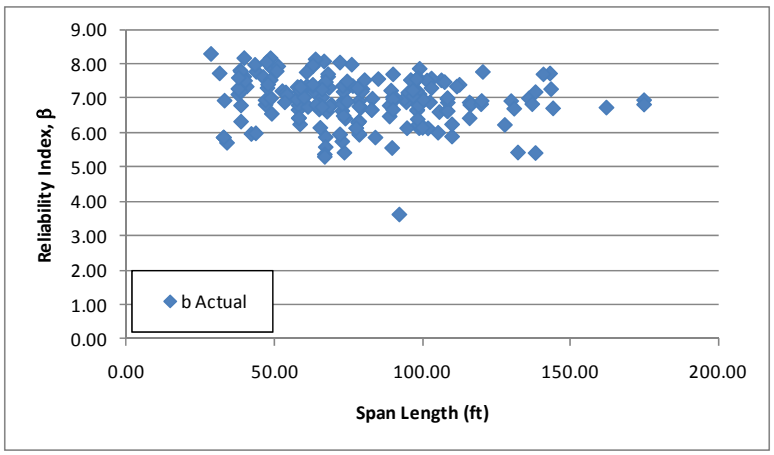


Figure C-169: Shear Reliability Indices for DE-07 Vehicle

Figure C-170 shows the reliability index plotted against the LRFR rating factor for shear due to the DE-07 vehicle. The figure shows that girders with a rating factor of 1.0 have reliability indices in excess of the target reliability of 2.5. This indicates the target reliability can be achieved while using load factors less than those in the current MBE for live load.

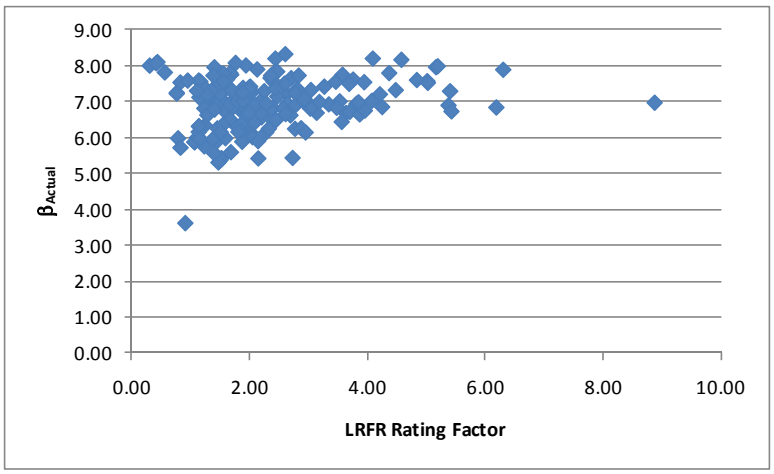
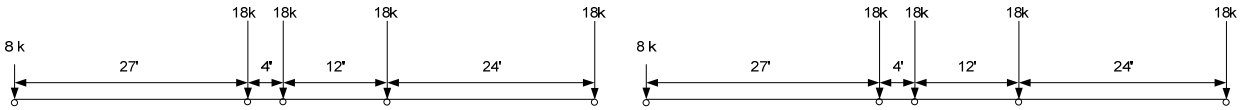


Figure C-170: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

C.2.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-171. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

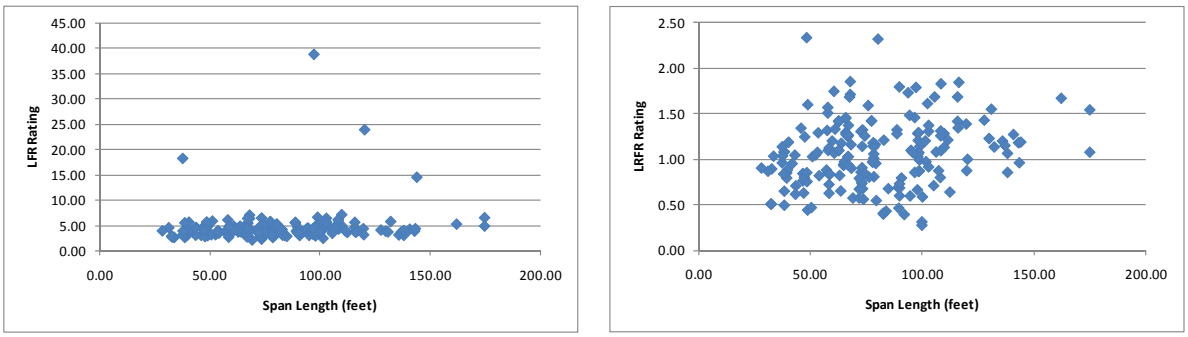
Figure C-171: Vehicle Loadings and Load Factors

C.2.4.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the FL-04 Vehicle.

C.2.4.1.1 Rating Factors

Figure C-172 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 87 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. Of the 87 girders with LRFR ratings less than 1.0, 70 are controlled by the longitudinal steel requirement. LFR ratings are between 2.5 and 5 while LRFR ratings are between 0.5 and 1.5 for most girders.



(a) (b)

Figure C-172: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure C-173 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, approximately 63% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 43% when an ADTT of 5,000 is used.

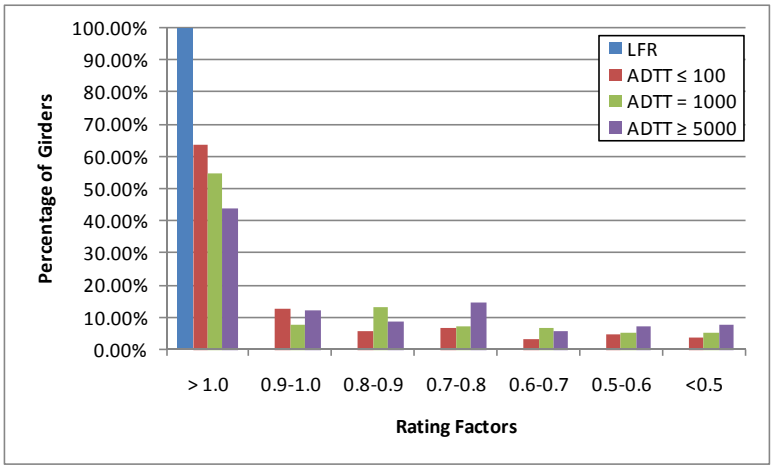


Figure C-173: Flexure Ratings for Various ADTTs in MBE for FL-04 Vehicle

C.2.4.1.2 Rating Factor Comparisons

Figure C-174 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. As mentioned before there are no girders with an LRFR rating greater than the LFR rating. The LRFR rating is typically 10 to 30% of the LFR rating.

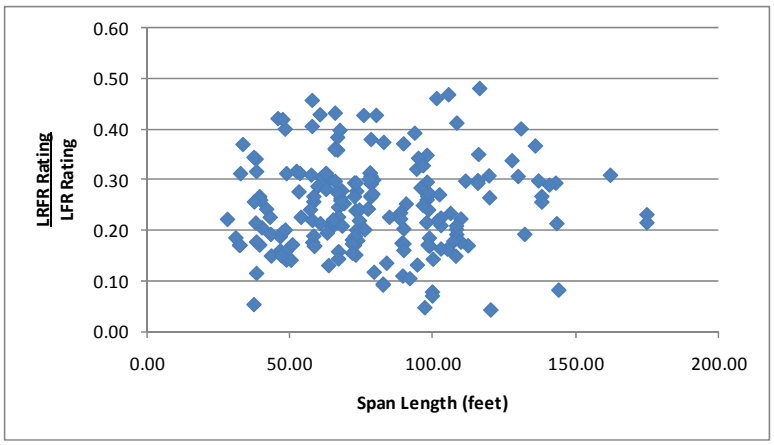


Figure C-174: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

C.2.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-175 shows that all girders have a reliability index based upon girder strength that is greater than the target reliability index of 2.5.

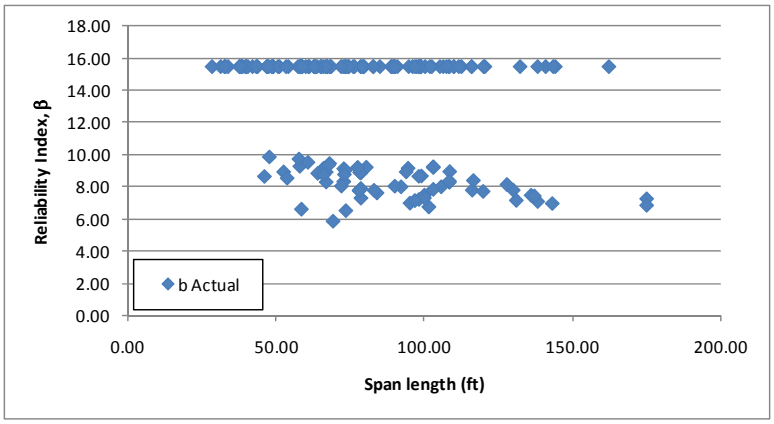


Figure C-175: Flexure Reliability Indices for FL-04 Vehicle

Figure C-176 shows the reliability index plotted against the LRFR rating factor for moment due to the FL-04 vehicle. The figure shows that girders with low rating have reliability indices significantly higher than the target reliability of 2.5, neglecting those controlled by the longitudinal steel requirement (beta = 15.5). This suggests that the live load factors can be reduced and maintain the target reliability.

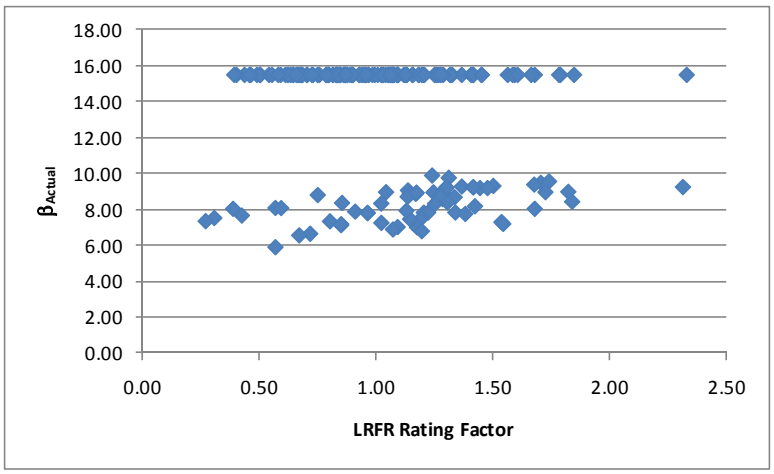
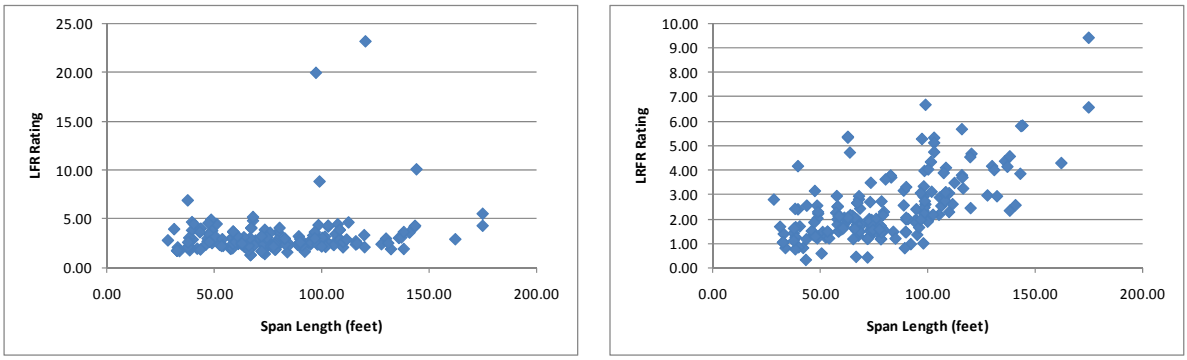


Figure C-176: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

C.2.4.2 Shear

C.2.4.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, 10 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 73% of the girders in this subset. Figure C-177 shows the LFR and LRFR ratings. The LFR ratings remain fairly constant with increasing span lengths while the LRFR ratings increase with increasing span length.



(a) (b)

Figure C-177: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure C-178 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is not as significant for shear as for moment; using an ADTT of 100, about 95% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 92% when an ADTT of 5,000 is used. This is not a significant reduction in girders rating less than 1.0 even for the worst case loading with an ADTT of 5,000.

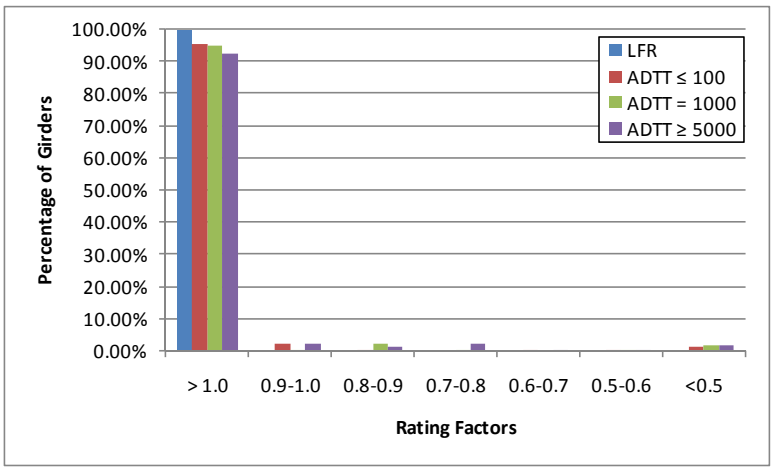


Figure C-178: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

C.2.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-179 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with the ratio increasing for longer span lengths.

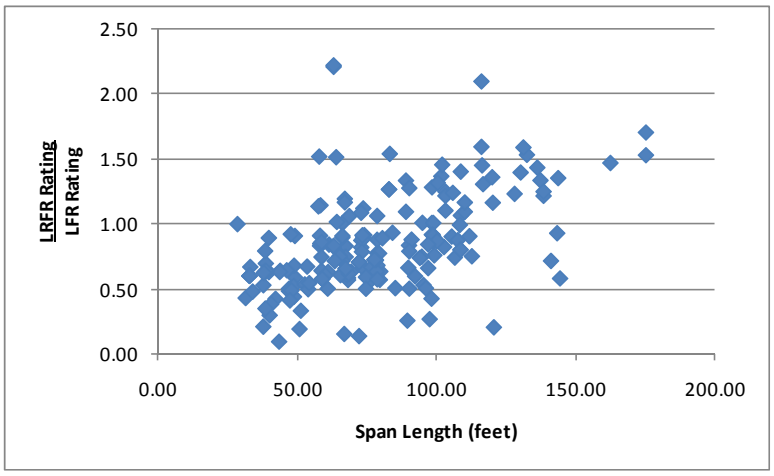


Figure C-179: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

C.2.4.2.3 Reliability Indices

The reliability indices were calculated. The actual reliability index is greater than the target reliability index for all but one girder as shown in Figure C-180. This girder does not have properly defined shear reinforcement in the input file.

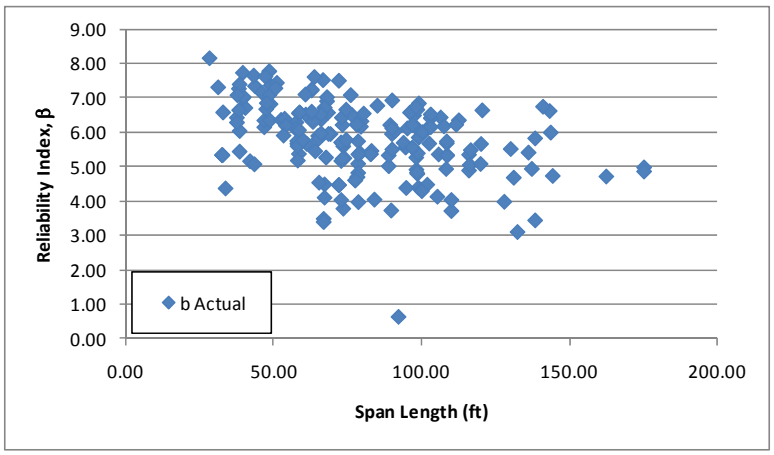


Figure C-180: Shear Reliability Indices for FL-04 Vehicle

Figure C-181 shows the reliability index plotted against the LRFR rating for shear due to the FL-04 vehicle. The figure shows that girders with rating factors of 1.0 typically have a reliability index above 3.0, slightly above the target of 2.5. There are several girders with low ratings and high reliability; these are girders where the LRFR rating is controlled by the shear friction rating and the reliability index is calculated using the shear resistance.

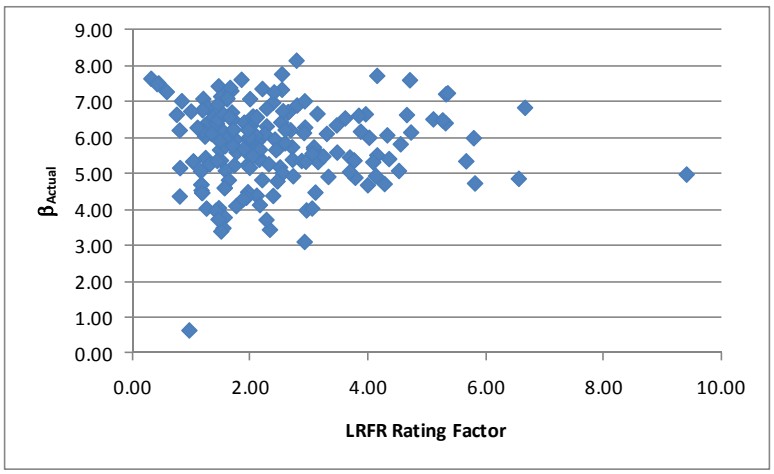


Figure C-181: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

C.2.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-182. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

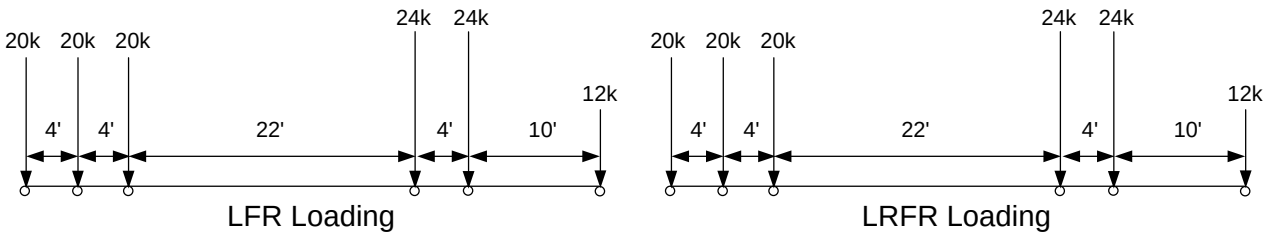


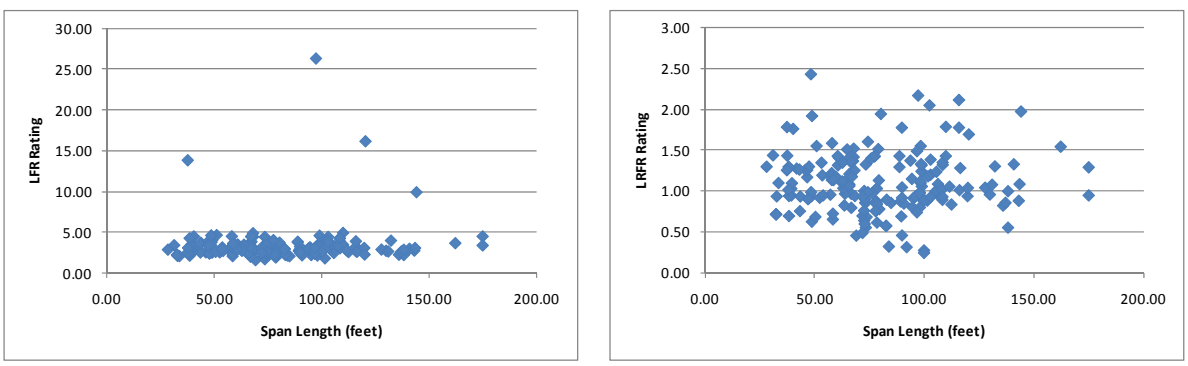
Figure C-182: Vehicle Loadings and Load Factors

C.2.5.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the IL-01 Vehicle.

C.2.5.1.1 Rating Factors

Figure C-183 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 85 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. Of the 85 girders with LRFR ratings less than 1.0, 36 are controlled by the longitudinal steel reinforcement rating.



(a) (b)

Figure C-183: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure C-184 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; for a single trip, escorted permit vehicle, less than 70% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to approximately 35% when an ADTT of 5,000 is used.

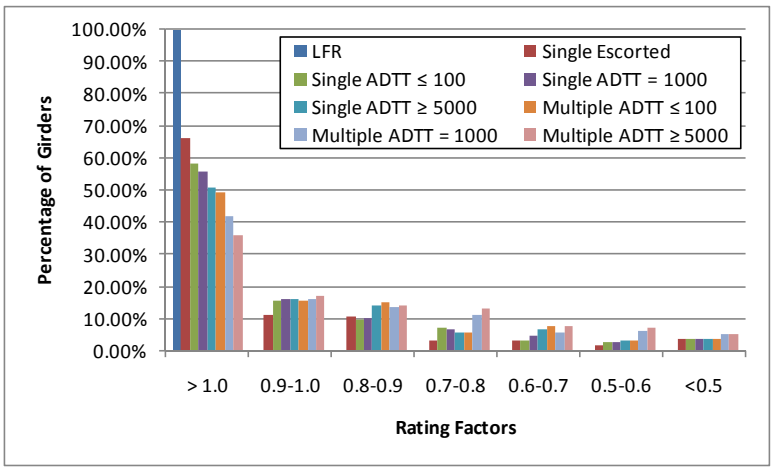


Figure C-184: Flexure Rating for Various ADTTs in MBE for IL-01 Vehicle

C.2.5.1.2 Rating Factor Comparisons

Figure C-185 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.5, with the lower ratios generally coming from longer spans. There are no girders with an LRFR rating greater than the LFR rating.

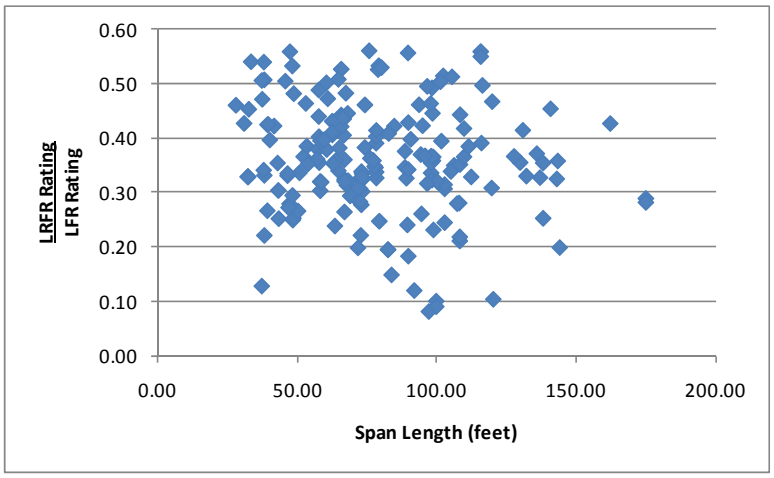


Figure C-185: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

C.2.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-186 shows that none of the girders have a reliability index based upon girder strength that is less than the target reliability of 3.5. The reliability index is generally between 6 and 10 for most span lengths, with shorter spans generally having higher indices.

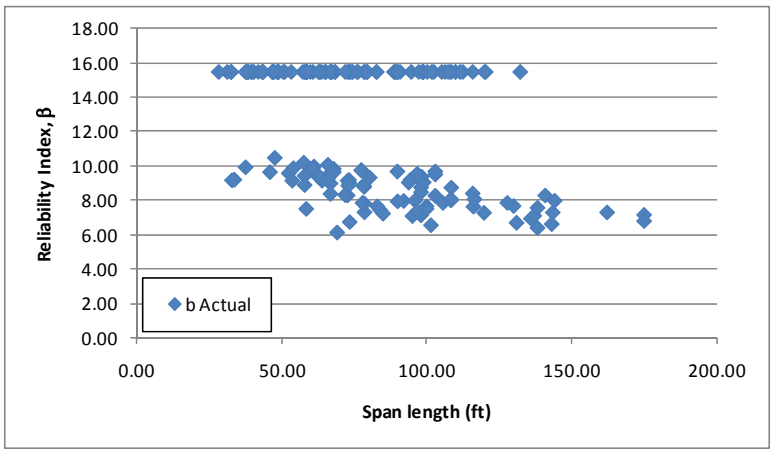


Figure C-186: Flexure Reliability Indices for IL-01 Vehicle

Figure C-187 shows the reliability index plotted against the LRFR rating factor for moment caused by the IL-01 Vehicle. The figure shows that all girders have a reliability index of 6.0, even those with a rating factor of 0.25. This level of reliability is above the target reliability of 3.5 for special permit vehicles assumed in the development of the MBE. This suggests that the target reliability could be achieved while using lower load factors that currently in the MBE for live load.

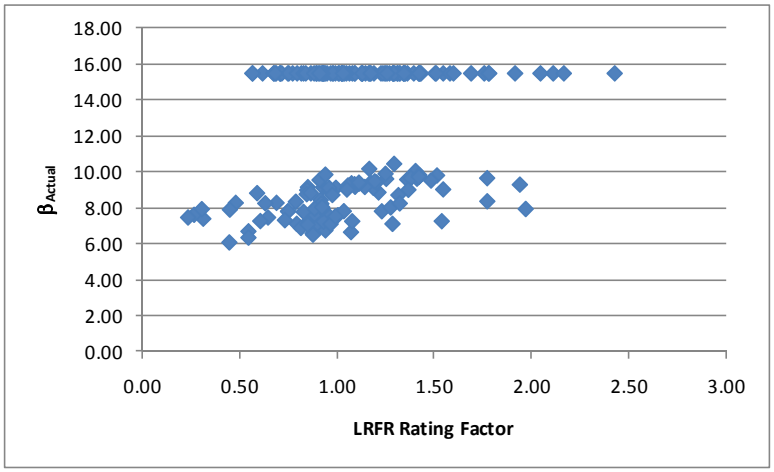
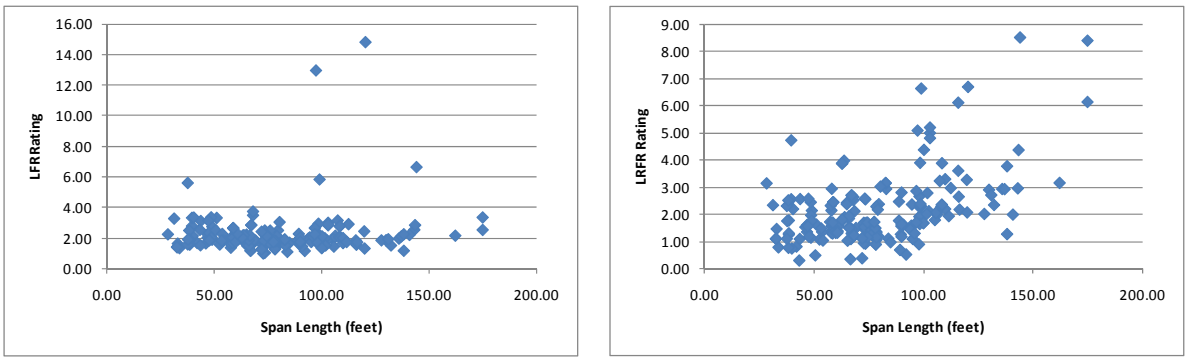


Figure C-187: Flexure Reliablity Index vs LRFR Flexure Rating for IL-01 Vehicle

C.2.5.2 Shear

C.2.5.2.1 Rating Factors

For shear, there is one girder that has an LFR rating factor less than 1.0, 16 girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 60% of the girders in this subset. Figure C-188 shows the LFR and LRFR ratings. The LFR rating is generally between 1.0 and 3.0 for all span lengths, while for LRFR the rating tends to increase with increasing span length but also is mostlye between 1.0 and 3.0.



(a) (b)

Figure C-188: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure C-189 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is not as significant for shear as for moment. For the worst case, multiple trip permit allowed to mix with other traffic and an ADTT of 5,000, approximately 25% of girders will have an LRFR rating less than 1.0. A single trip, escorted permit will have approximately 5% of girders with LRFR ratings less than 1.0.

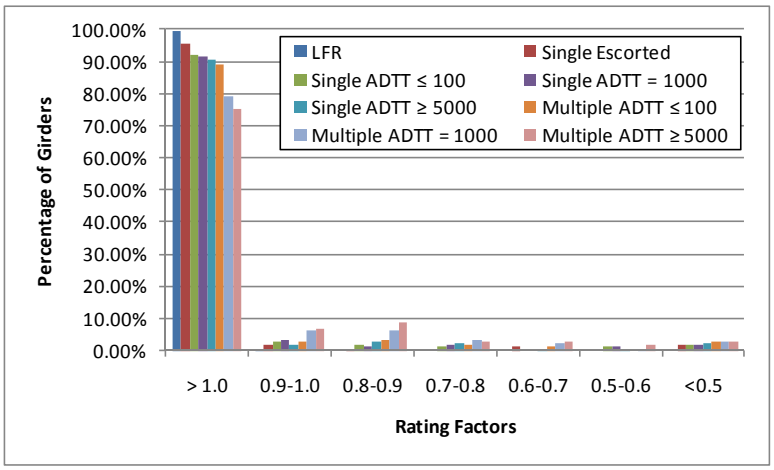


Figure C-189: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

C.2.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-190 shows the comparison of rating factors. The ratio is generally less than 1.0 but longer girders tend to have an LRFR rating greater than the associated LFR rating.

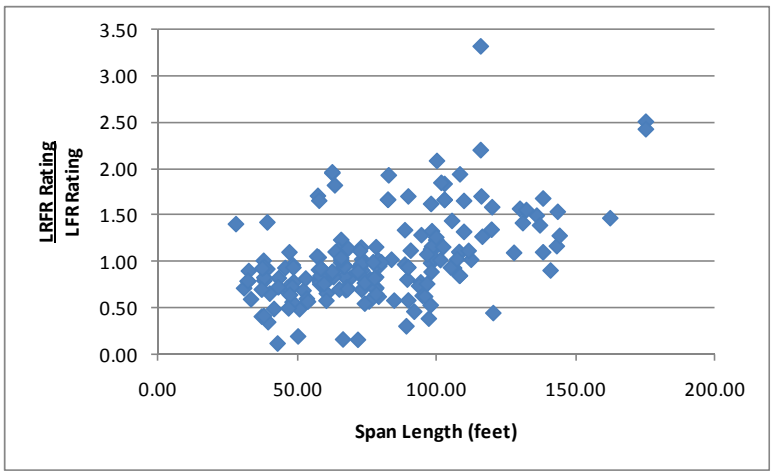


Figure C-190: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

C.2.5.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 3.5 for most girders as shown in Figure C-191. It is likely that the one girder with a reliability index less than the target does not have properly defined shear reinforcement.

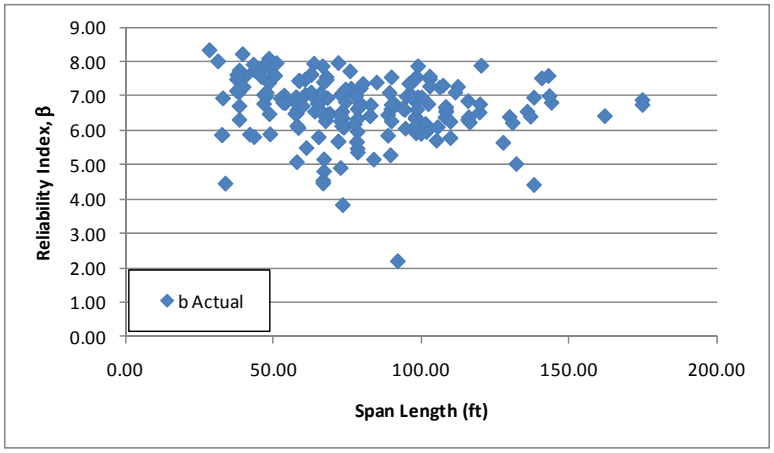


Figure C-191: Shear Reliability Indices for IL-01 Vehicle

Figure C-192 shows the reliability index plotted against the LRFR rating for shear due to the IL-01 vehicle. The figure indicates that the live load factors currently in the MBE produce a level of reliability similar to the target value of 3.5.

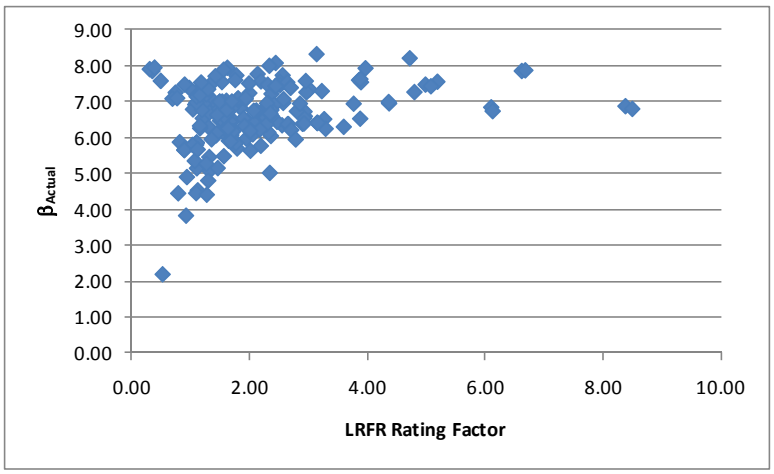


Figure C-192: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

C.2.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-193. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

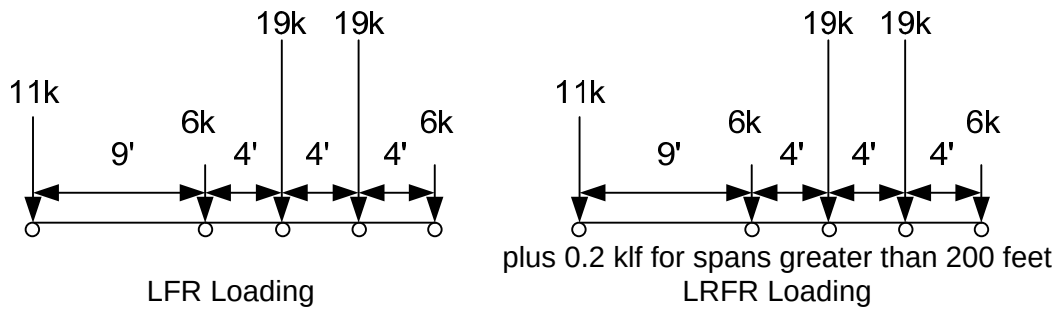


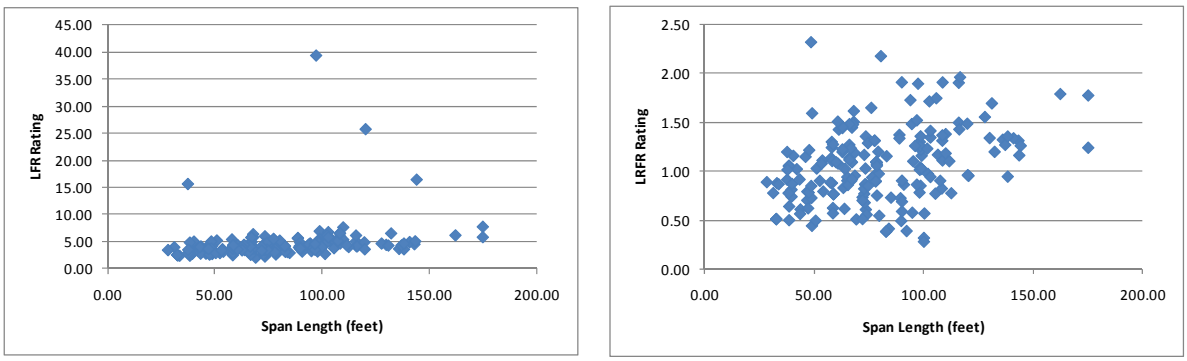
Figure C-193: Vehicle Loadings and Load Factors

C.2.6.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the NC-21 Vehicle.

C.2.6.1.1 Rating Factors

Figure C-194 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 88 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating increases with increasing span length while the LRFR rating remains fairly constant but increases slightly with increasing span length. The LFR rating is typically between 2 and 6 while the LRFR rating is typically between 0.5 and 1.5. Of the 88 girders with an LRFR rating less than 1.0, 67 are controlled by the longitudinal steel rating.



(a) (b)

Figure C-194: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure C-195 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 62% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 45% when an ADTT of 5,000 is used.

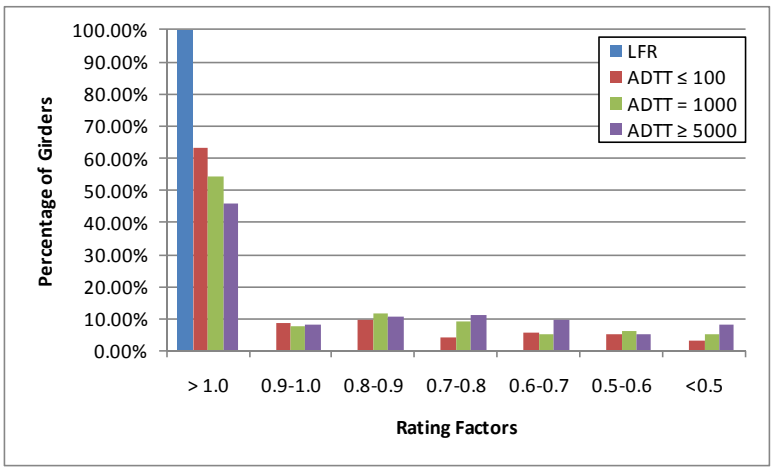


Figure C-195: Flexure Rating for Various ADTTs in MBE for NC-21 Vehicle

C.2.6.1.2 Rating Factor Comparisons

Figure C-196 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.1 and 0.4 for this vehicle. There are no girders with an LRFR rating greater than the LFR rating for this group of girders.

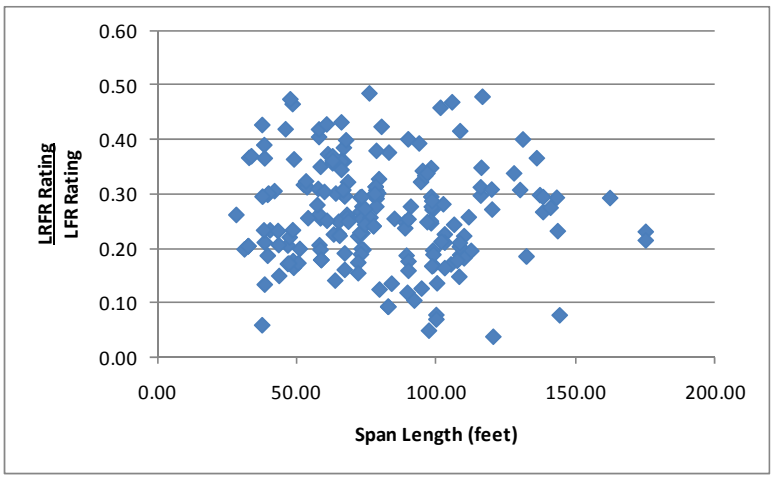


Figure C-196: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

C.2.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-197 shows that none of the girders have a reliability index based upon girder strength that is less than the target reliability index. The reliability index is between 7 and 10 for most girders, neglecting those controlled by the longitudinal reinforcement with a reliability index of 15.5.

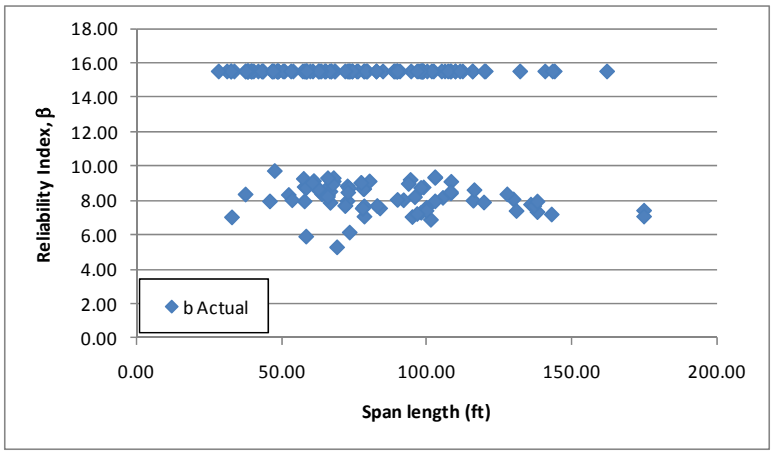


Figure C-197: Flexure Reliability Indices for NC-21 Vehicle

Figure C-198 shows the reliability index plotted against the LRFR rating for moment due to the NC-21 vehicle. The figure shows girders with insufficient ratings having reliability indices greater than 6, much higher than the target reliability of 2.5 for routine permit vehicles. This suggests that lower live load factors than those currently in the MBE may be possible.

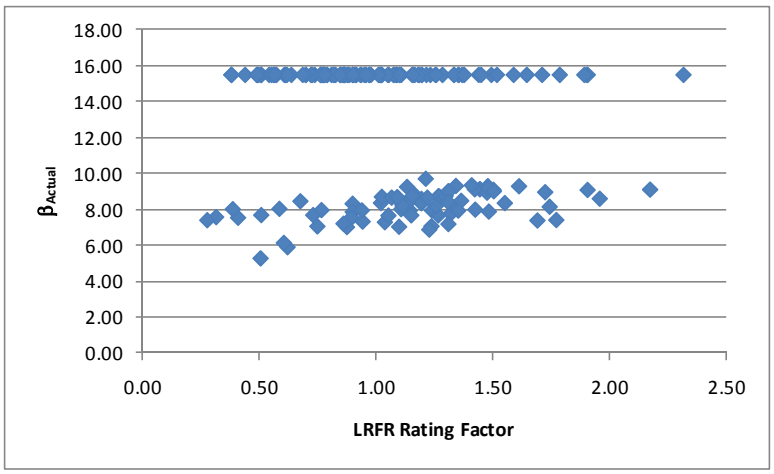
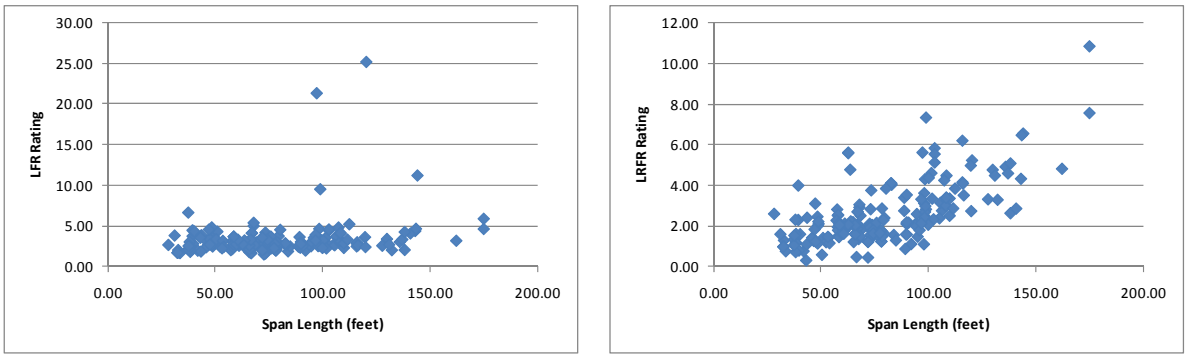


Figure C-198: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

C.2.6.2 Shear

C.2.6.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, twelve girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 73% of the girders in this subset. Figure C-199 show the LFR and LRFR ratings. The LRFR rating increases with increasing span length while the LFR ratings tend to remain constant with span length.



(a) (b)

Figure C-199: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure C-200 Figure C-162shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is minor for shear; using an ADTT of 100, 95% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The worst case scenario with an ADTT of 5,000 has less than 10% of girders with LRFR ratings less than 1.0.

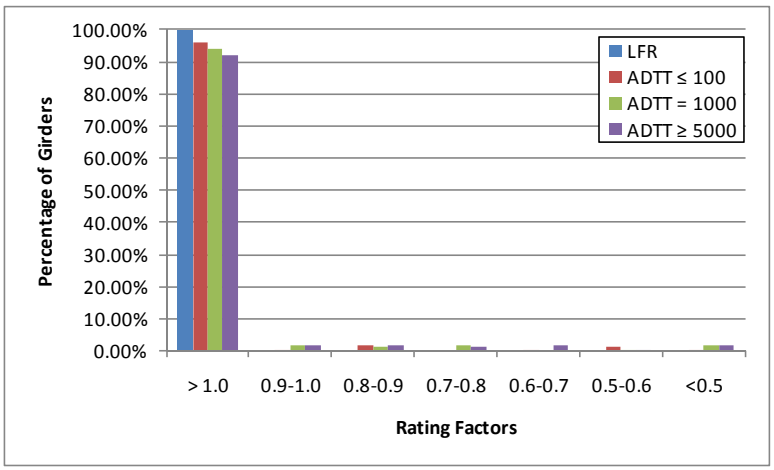


Figure C-200: Shear Rating for Various ADTTs in MBE for NC-21 Vehicle

C.2.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-201 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5. Longer span girders are more likely to have an LRFR rating greater than the LFR rating. The figure shows a number of girders with LRFR rating greater than LFR rating; 27% of the girders have an LRFR rating greater than the LFR rating.

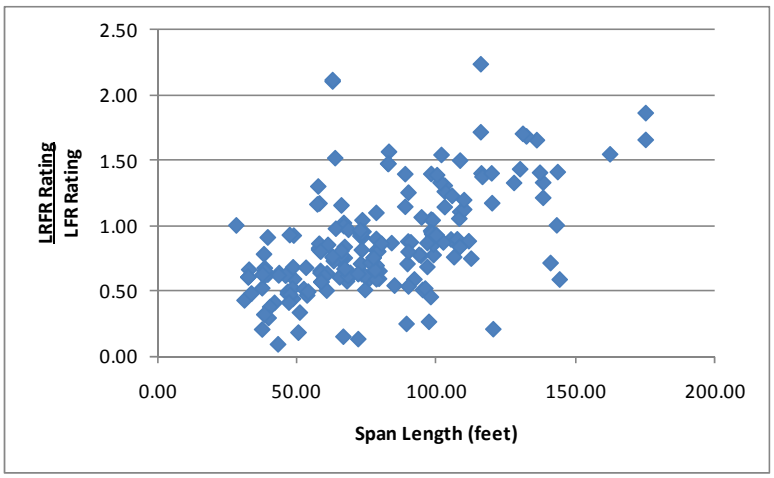


Figure C-201: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

C.2.6.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index for all girders as shown in Figure C-202. Most girders have a reliability index between 6.0 and 8.0 with one as low as 4.0. The target reliability index for the NC-21 vehicle is 2.5.

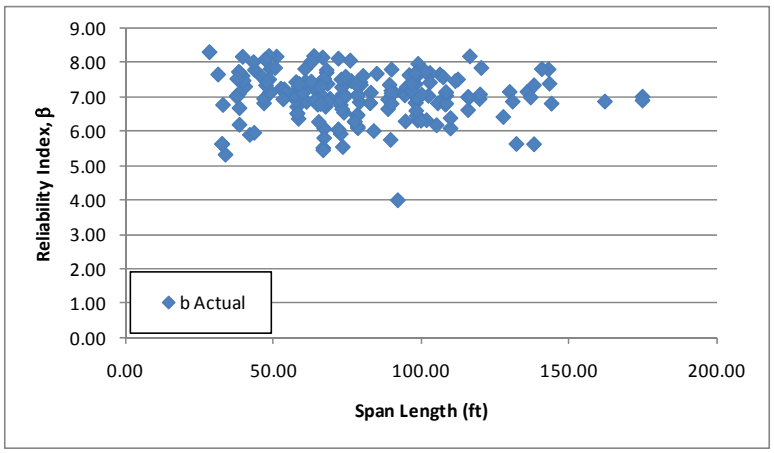


Figure C-202: Shear Reliability Indices for NC-21 Vehicle

Figure C-203 shows the reliability index plotted against the LRFR rating for shear due to the NC-21 vehicle. The figure shows that girders with passing ratings have reliability significantly higher than the target reliability of 2.5. This suggests that the use of lower live load factors than those currently in the MBE is possible.

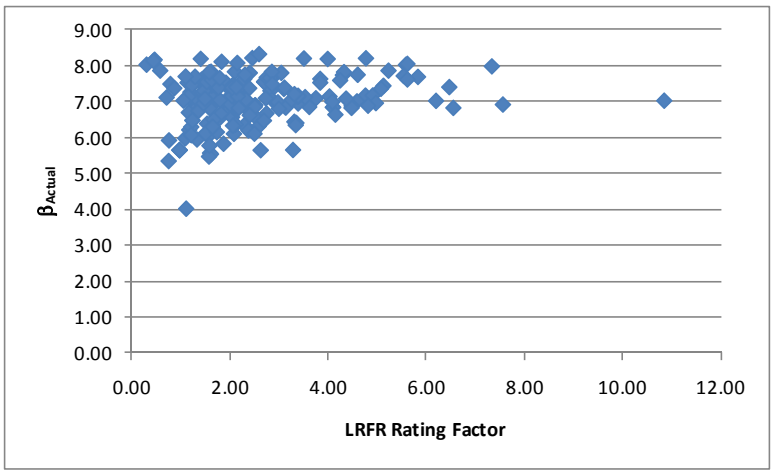


Figure C-203: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

C.2.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-204. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

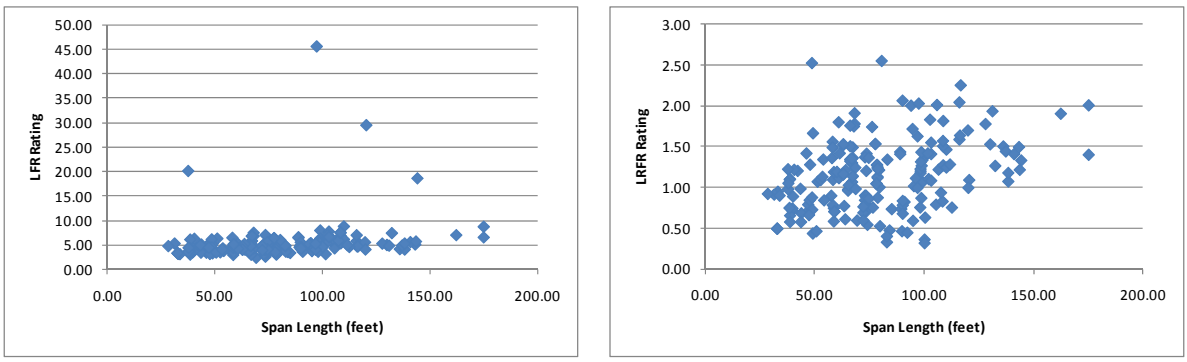
Figure C-204: Vehicle Loadings and Load Factors

C.2.7.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the NM-04 Vehicle.

C.2.7.1.1 Rating Factors

Figure C-205 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 76 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The ratings for both methods appear to increase slightly with increasing span lengths. The LFR ratings are typically between 2.5 and 7.5 while the LRFR ratings are typically between 0.5 and 1.50. Of the 76 girders with LRFR ratings less than 1.0, the longitudinal steel reinforcement rating controls the rating for 63 girders.



(a) (b)

Figure C-205: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure C-206 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, less than 70% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one drops to approximately 53% when an ADTT of 5,000 is used.

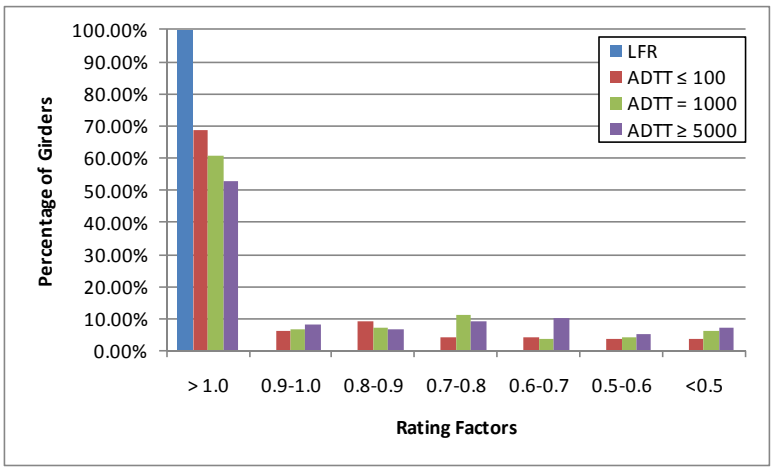


Figure C-206: Flexure Ratings for Various ADTTs in MBE for NM-04 Vehicle

C.2.7.1.2 Rating Factor Comparisons

Figure C-207 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.1 and 0.4, with no girders having LRFR ratings greater than the LFR rating.

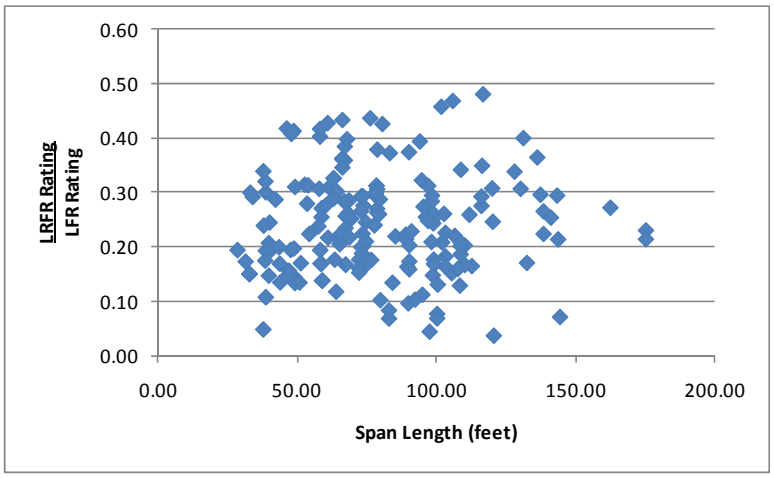


Figure C-207: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

C.2.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-208 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index. The figure shows the reliability index is between 8 and 10 for girders not controlled by the longitudinal steel requirement.

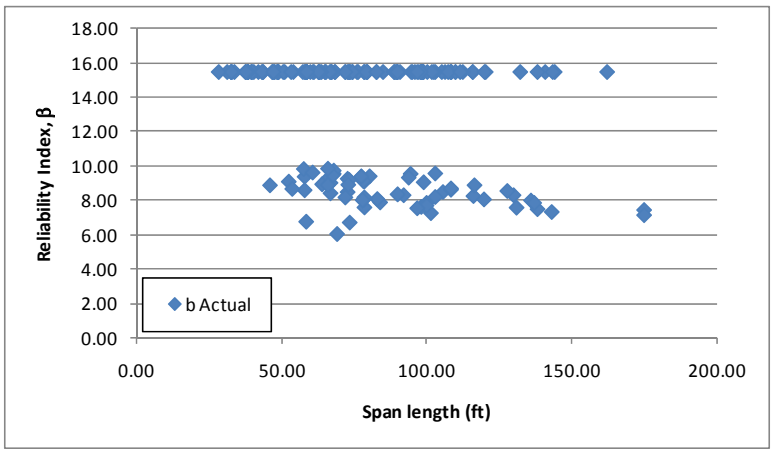


Figure C-208: Flexure Reliability Indices for NM-04 Vehicle

Figure C-209 shows the reliability index plotted against the LRFR rating factor for flexure due to the NM-04 vehicle. The figure shows that girders with low ratings have high reliability indices. This suggests that the target reliability of 2.5 could be achieved using load factors less than those currently in the MBE.

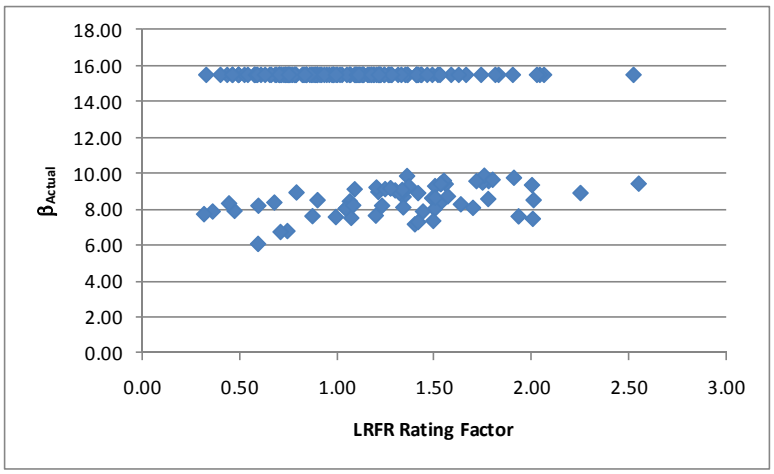
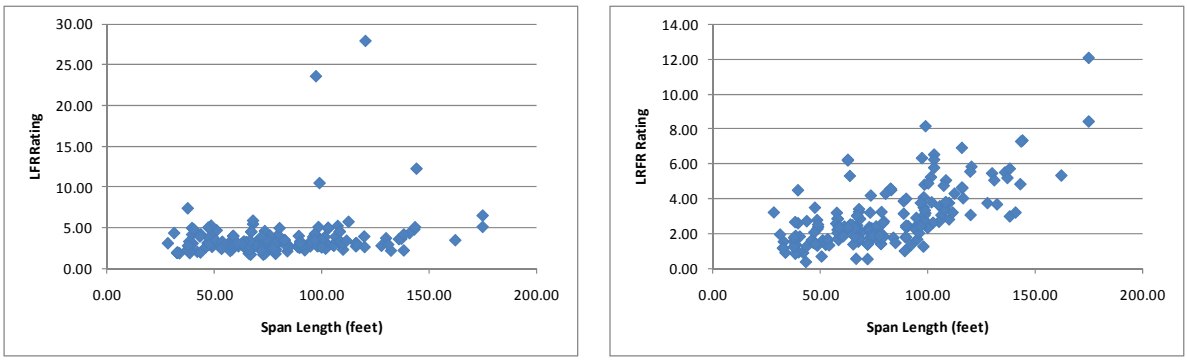


Figure C-209: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

C.2.7.2 Shear

C.2.7.2.1 Rating Factors

For shear, there are zero girders that have an LFR rating factor less than 1.0, 9 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 72% of the girders in this subset. Figure C-210 shows the LFR and LRFR ratings. The LFR rating remains fairly constant with increasing span length while the LRFR rating increases with increasing span length.



(a) (b)

Figure C-210: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure C-211 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is not as significant for shear as it was for moment. Approximately 95% of girders have LRFR ratings greater than 1.0 for an ADTT of 5,000. 97% of girders have LRFR ratings greater than 1.0 for an ADTT of 100.

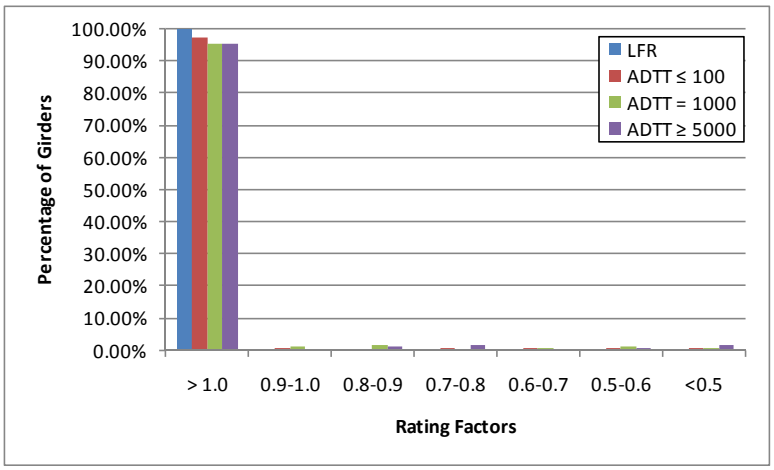


Figure C-211: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

C.2.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure C-212 show the comparison of rating factors. The ratio is generally between 0.5 and 1.0, with 28% of the girders above 1.0 (indicative of LRFR ratings higher than LFR ratings). Longer spans are more likely to have LRFR ratings greater than shorter spans.

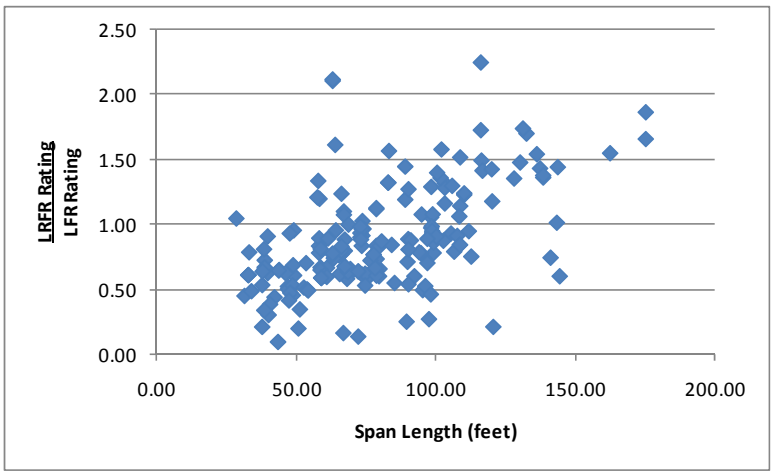


Figure C-212: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

C.2.7.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure C-213. The reliability index is between 6.0 and 8.0 for most girders in this group.

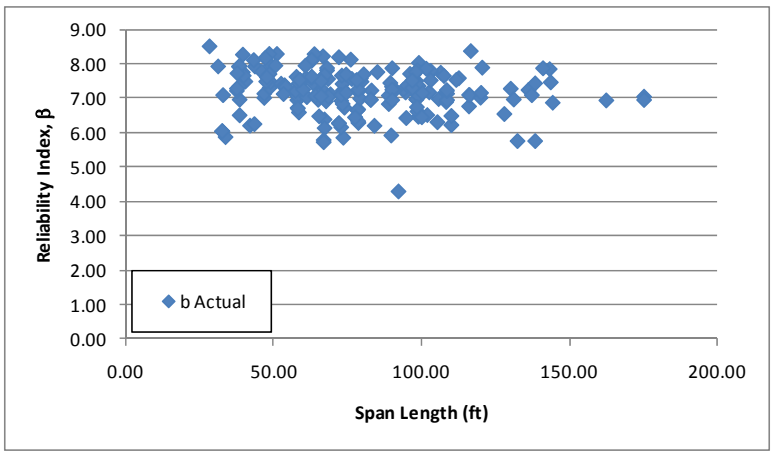


Figure C-213: Shear Reliability Indices for NM-04 Vehicle

Figure C-214 shows the reliability index plotted against the LRFR rating for shear due to the NM-04 vehicle. The figure shows that all girders have a reliability index greater than the target value of 2.5 and is close to 6.0 for girders with a rating of 1.0. This suggests that the live load factors could be reduced to something lower than those currently in the MBE and still achieve the target level of reliability.

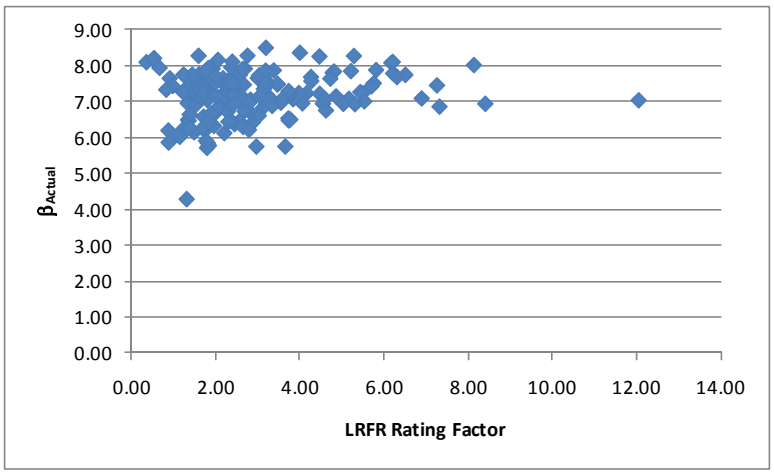
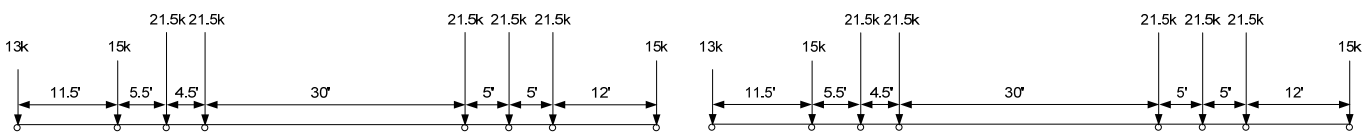


Figure C-214: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

C.2.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-215. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

Figure C-215: Vehicle Loadings and Load Factors

C.2.8.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the OR-06 Vehicle.

C.2.8.1.1 Rating Factors

Figure C-216 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 93 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating is generally between 2.0 and 5.0 for all span lengths; the LRFR rating also remains between 0.5 and 1.5 for most girders. 42 of the 93 girders with LRFR Ratings less than 1.0 are controlled by the longitudinal steel reinforcement rating.

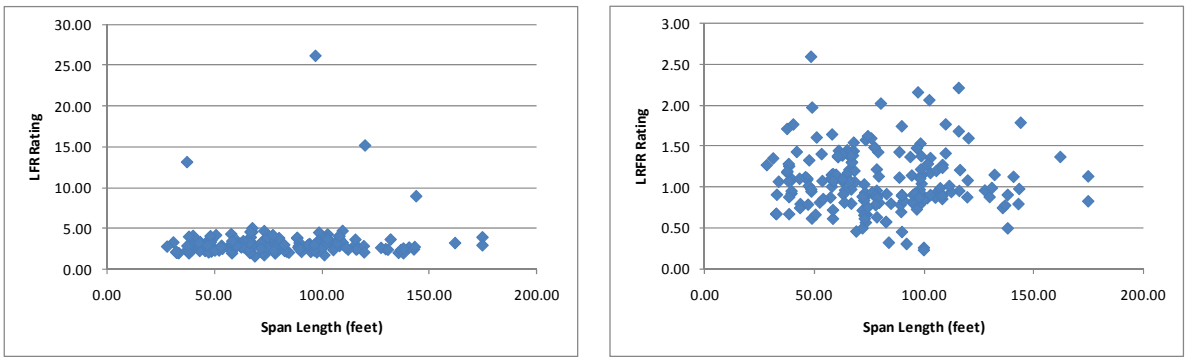


Figure C-216: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure C-217 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 63% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 36% for a multiple trip permit allowed to mix with traffic on a route with an ADTT of 5,000.

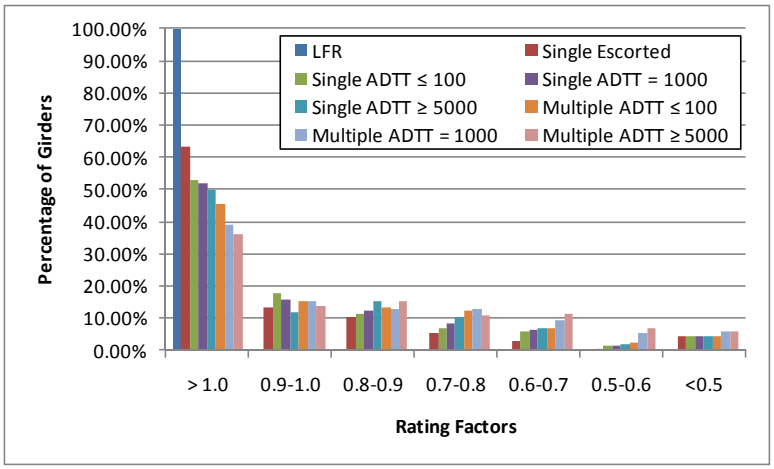


Figure C-217: Flexure Rating for Various ADTTs in MBE for OR-06 Vehicle

C.2.8.1.2 Rating Factor Comparisons

Figure C-218 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6, with no girders having an LRFR rating greater than the LFR rating.

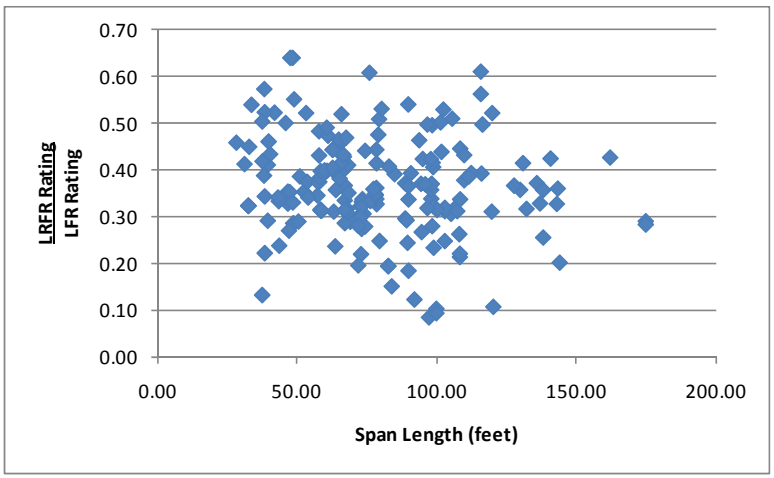


Figure C-218: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

C.2.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-219 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index is between 6 and 10 for most girders not controlled by the longitudinal steel reinforcement rating.

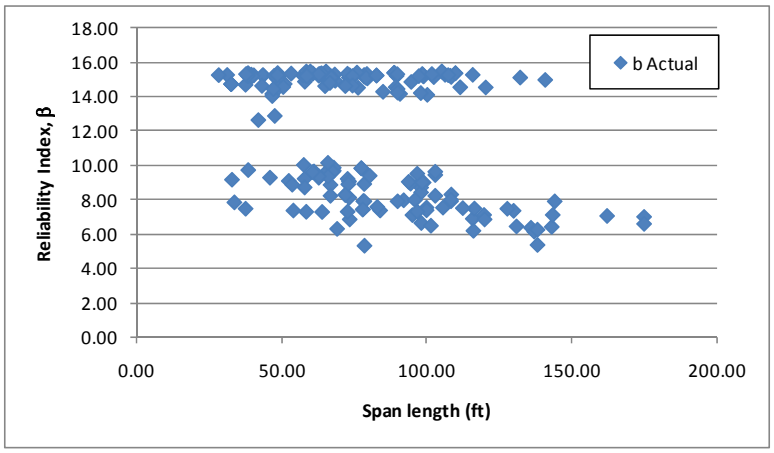


Figure C-219: Flexure Reliability Indices for OR-06 Vehicle

Figure C-220 shows the reliability index plotted against the LRFR rating factor for moment due to the OR-06 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index of at least 6 which is much greater than the target reliability of 3.5 for special permit vehicles. This indicates that lower live load factors may be possible for use in the MBE.

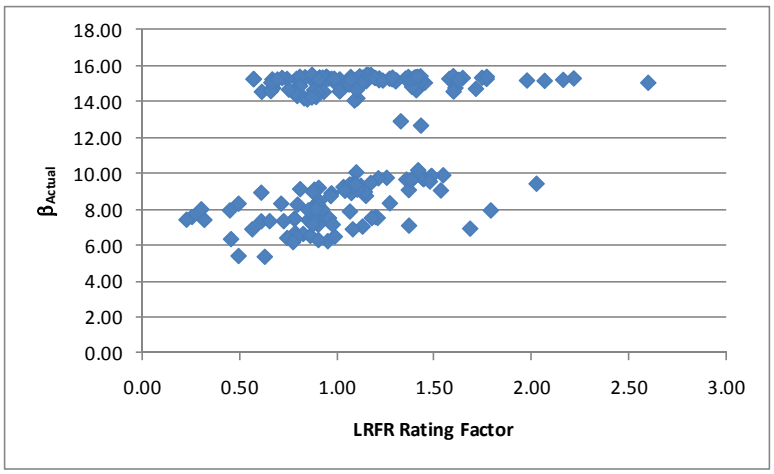
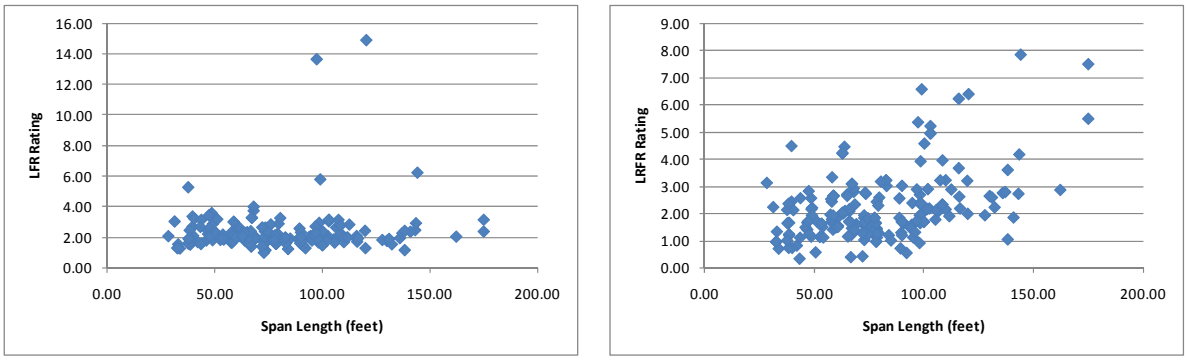


Figure C-220: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

C.2.8.2 Shear

C.2.8.2.1 Rating Factors

For shear, there is one girder that has an LFR rating factors less than 1.0, 16 girders have LRFR ratings less than 1.0, and zero girders have both ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 58% of the girders in this subset. Figure C-221 shows the LFR and LRFR ratings. The LFR rating does not increase or decrease with increasing span lengths while the LRFR rating increases with increasing span lengths.



(a) (b)

Figure C-221: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure C-222 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with different permit types and increasing ADTTs. The effect of switching from LFR to LRFR is not as significant for shear as it was for moment. The reduction in girders with LRFR ratings greater than 1.0 was less than 10% for most LRFR permit types, except for the multiple trip permits for ADTTs of 1000 and 5000. For these two permit types, between 20 and 25% of girders have ratings less than 1.0.

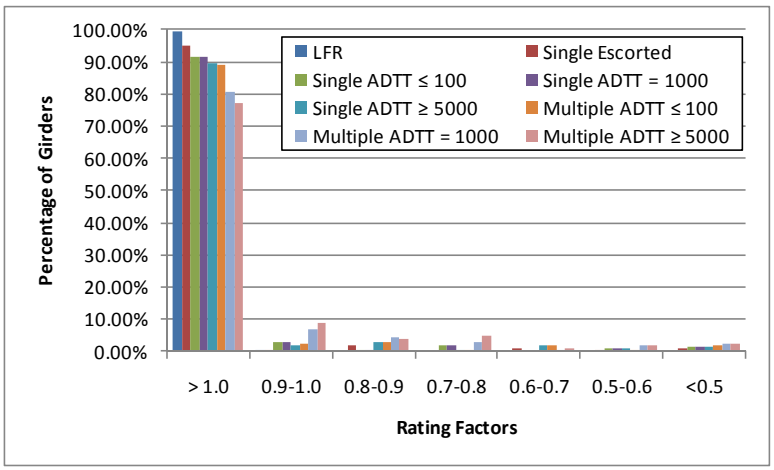


Figure C-222: Shear Rating for Various ADTTs in MBE for OR-06 Vehicle

C.2.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure C-223 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5 for this set of girders with this vehicle. Longer spans are more likely to have LRFR ratings greater than LFR rating. 42% of girders have LRFR ratings greater than the LFR rating.

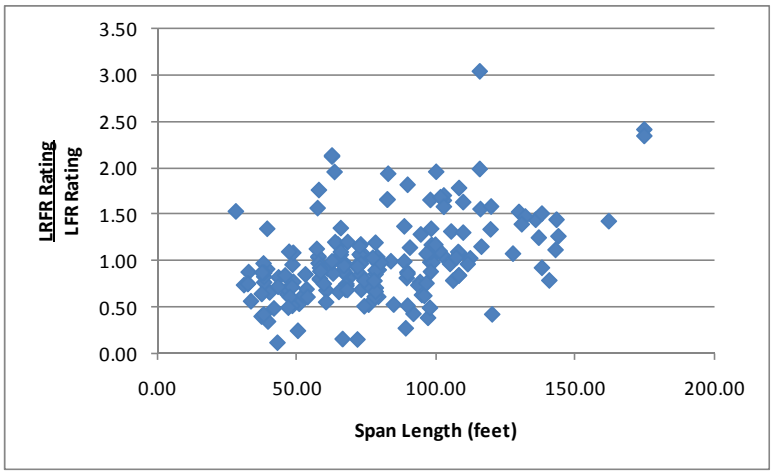


Figure C-223: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

C.2.8.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 3.5 for all but two girders as shown in Figure C-224. The reliability index is between 6 and 8 for most girders.

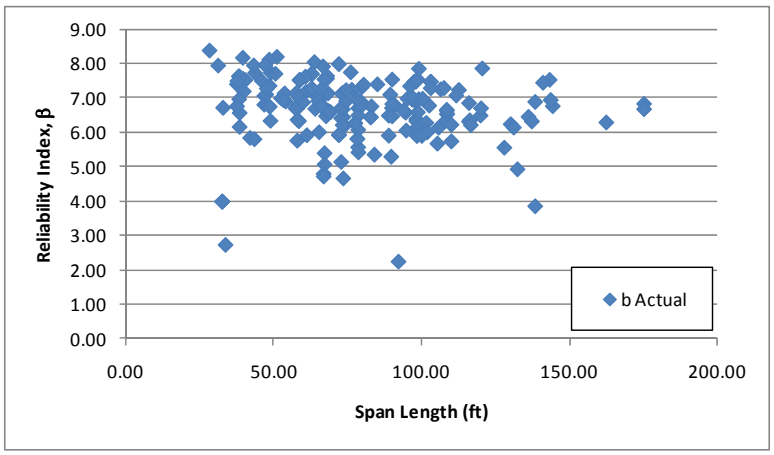


Figure C-224: Shear Reliability Indices for OR-06 Vehicle

Figure C-225 shows the reliability index plotted against the LRFR rating for shear due to the OR-06 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index between 3.5 and 4.0. This indicates that the current MBE live load factors produce the target level of reliability.

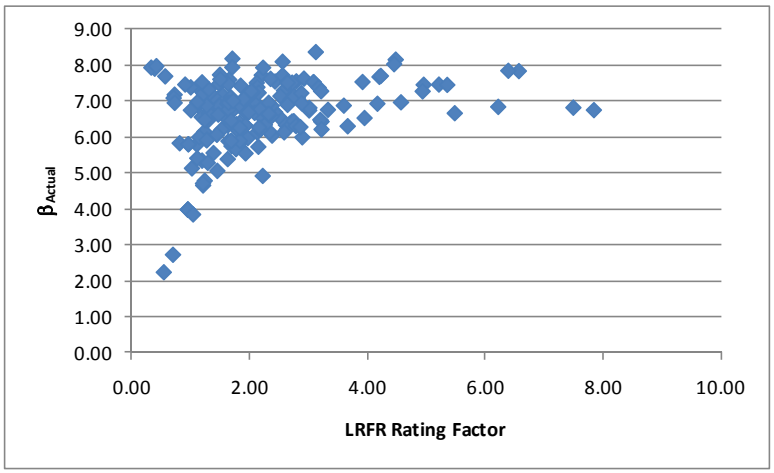
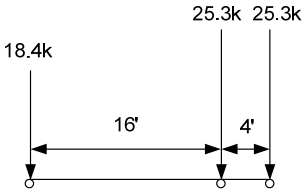


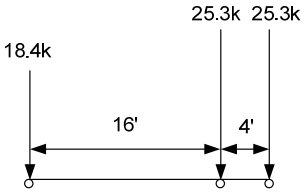
Figure C-225; Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

C.2.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-226. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet
LRFR Loading

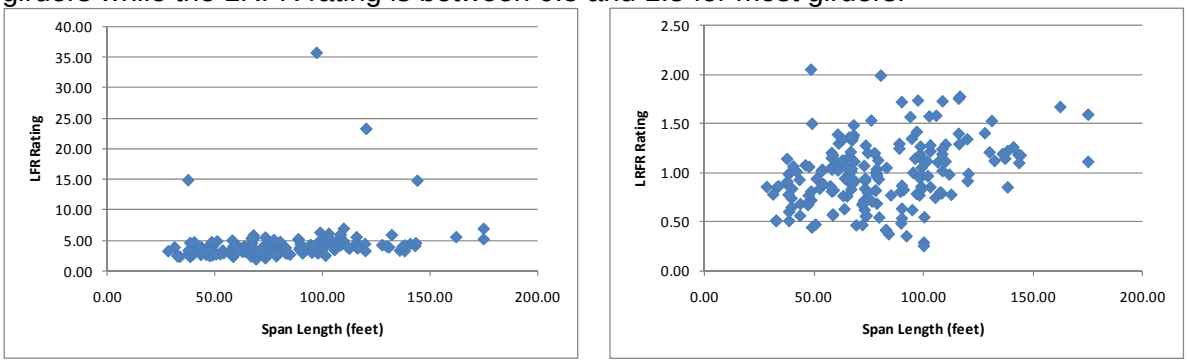
Figure C-226: Vehicle Loadings and Load Factors

C.2.9.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the TX-04 Vehicle.

C.2.9.1.1 Rating Factors

Figure C-227 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 102 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. Of the 102 girders with an LRFR rating less than 1.0, 71 are controlled by the longitudinal steel requirement rating. The LFR rating is between 2 and 5 for most girders while the LRFR rating is between 0.5 and 1.5 for most girders.



(a) (b)

Figure C-227: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure C-228 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 55% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 38% when an ADTT of 5,000 is used.

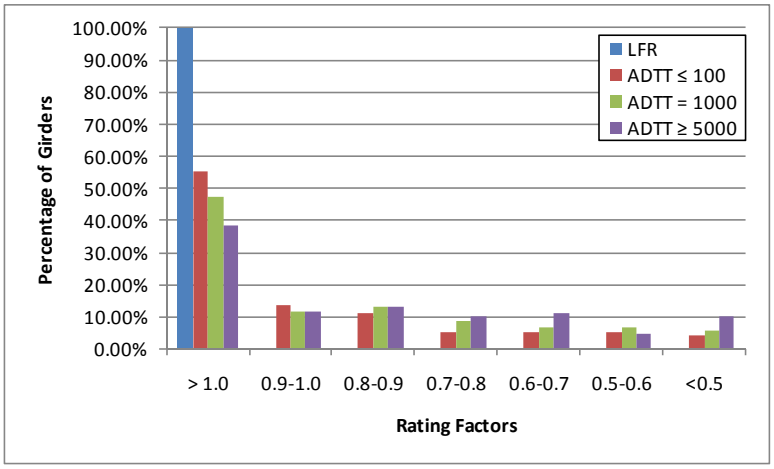


Figure C-228: Flexure Ratings for Various ADTTs in MBE for TX-04 Vehicle

C.2.9.1.2 Rating Factor Comparisons

Figure C-229 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is generally 10 to 40% of the LFR rating, with no girders having an LRFR rating greater than the LFR rating.

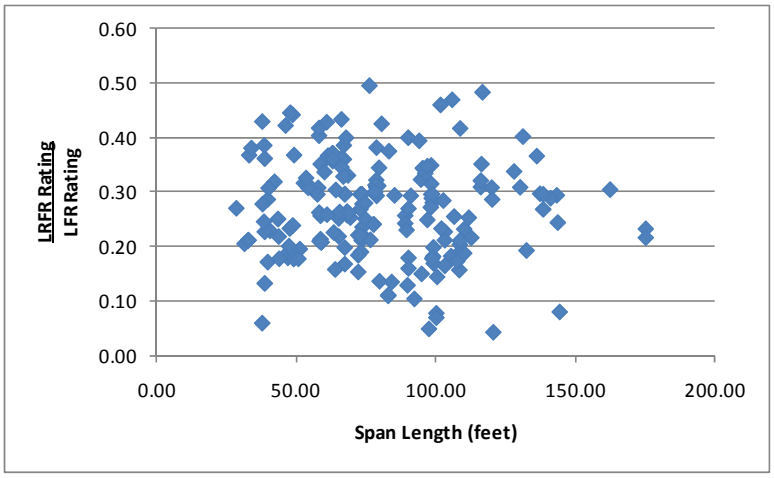


Figure C-229: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

C.2.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-230 shows no girders that have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between 6 and 10 for most girders with several below 6.

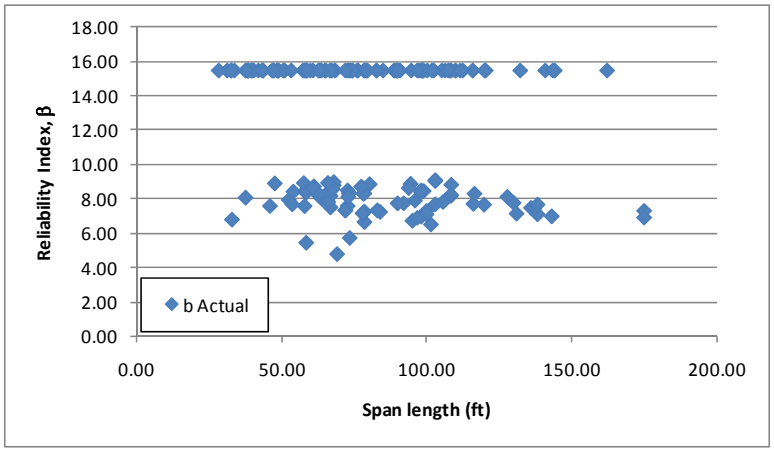


Figure C-230: Flexure Reliability Indices for TX-04 Vehicle

Figure C-231 shows the reliability index as a function of the LRFR rating for moment caused by the TX-04 vehicle. The figure shows that for girders with an LRFR rating of 1.0, the reliability index is at least 6.0. This is significantly higher than the target reliability of 2.5. This indicates the target reliability can be maintained while reducing the LRFR live load factors.

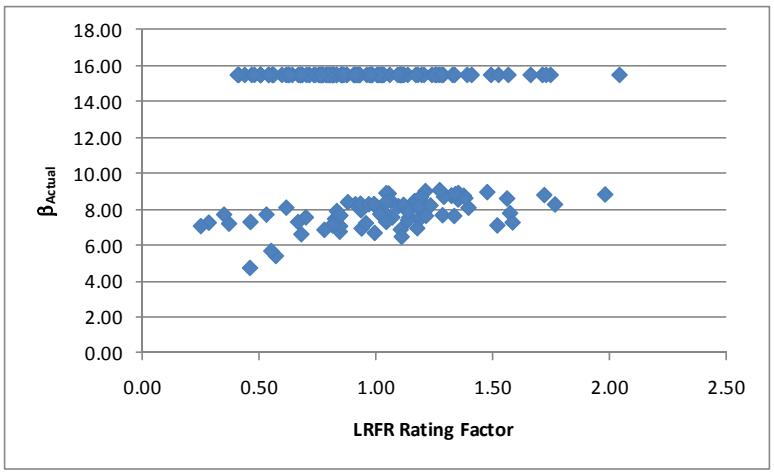
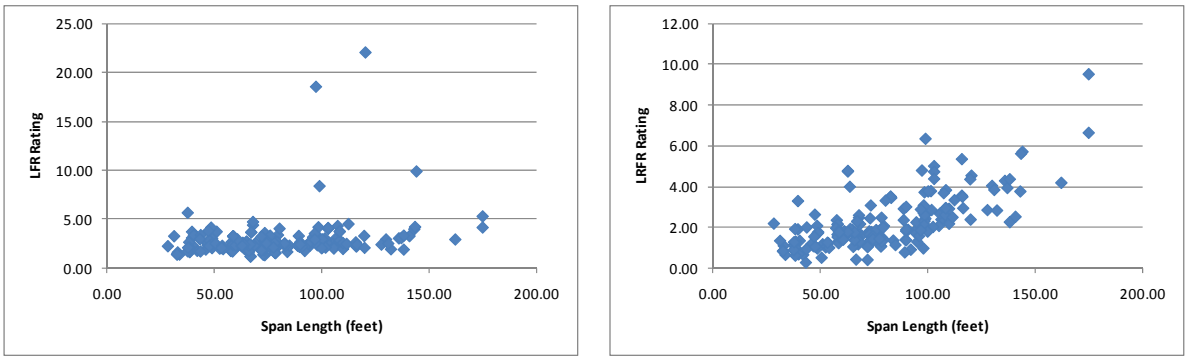


Figure C-231: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

C.2.9.2 Shear

C.2.9.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, 20 girders with LRFR ratings less than 1.0 and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 75% of the girders in this subset. Figure C-232 show the LFR and LRFR ratings, respectively. Both ratings appear to increase with increasing lengths, with the LRFR rating increasing more.



(a) (b)

Figure C-232: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure C-233 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious but not as significant as for moment; using an ADTT of 100, 94% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to only 85% when an ADTT of 5,000 is used.

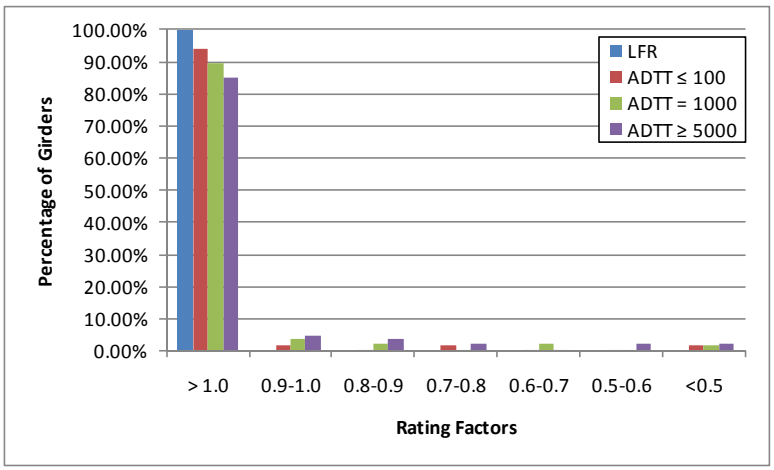


Figure C-233: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

C.2.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure C-234 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5 for shear.

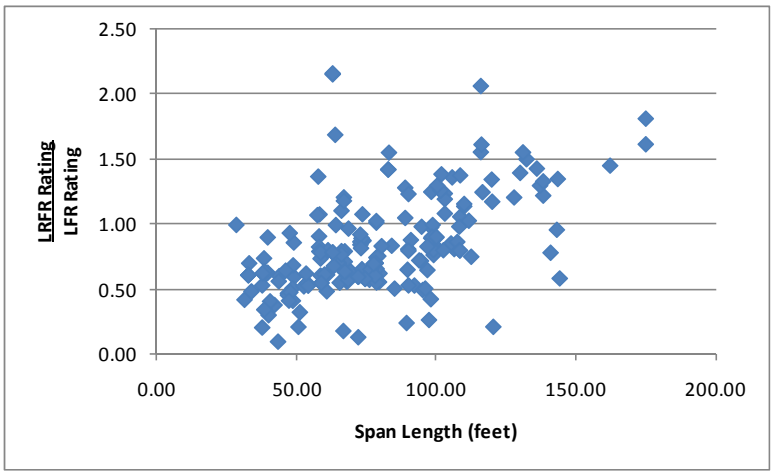


Figure C-234: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

C.2.9.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure C-235. The reliability index is between 6 and 8 for most girders with two less than 4.0.

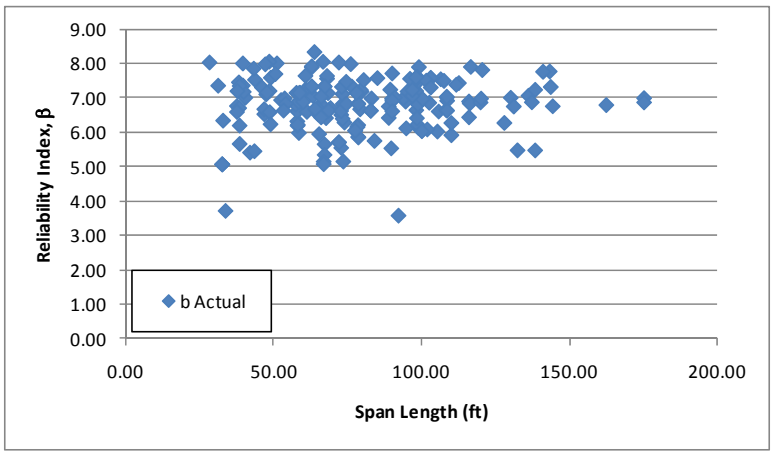


Figure C-235: Shear Reliability Indices for TX-04 Vehicle

Figure C-236 shows the reliability index as a function of the LRFR rating for shear due to the TX-04 vehicle. The reliability index for a girder passing rating is above the target reliability of 2.5. This indicates that reducing the live load factors for LRFR will reduce the reliability of a girder passing rating to a level nearer the target reliability.

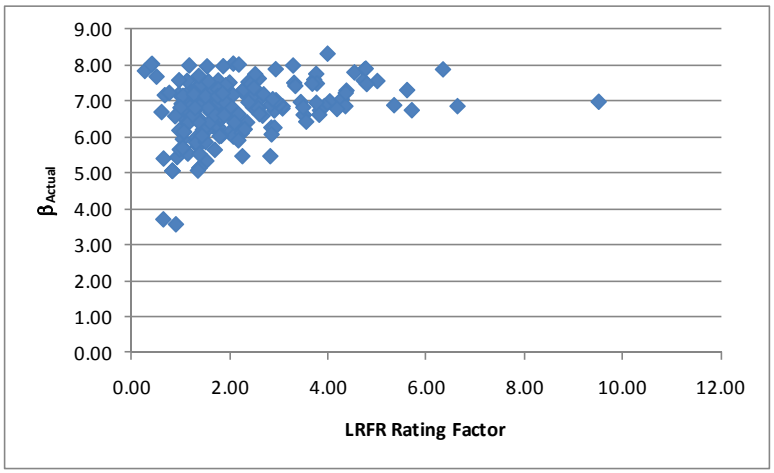
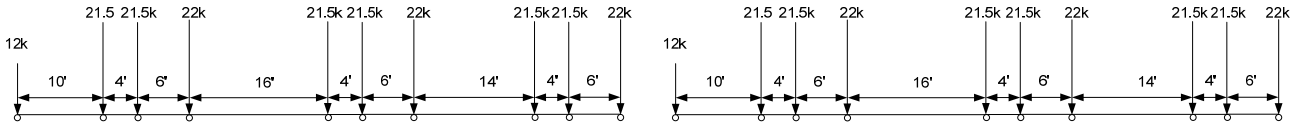


Figure C-236: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

C.2.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-237. The applicable load factors for these vehicles are 1.3 and 1.40 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading

plus 0.2 klf for spans greater than 200 feet
LRFR Loading

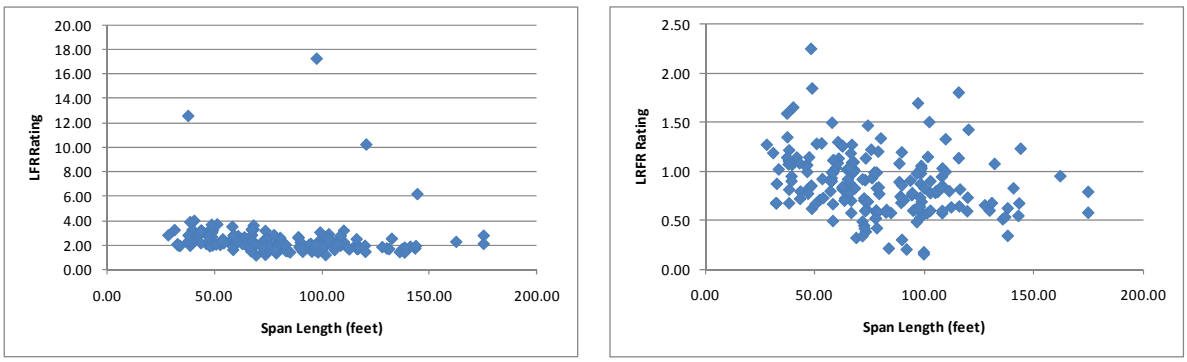
Figure C-237: Vehicle Loadings and Load Factors

C.2.10.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the WA-02 Vehicle.

C.2.10.1.1 Rating Factors

Figure C-238 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 132 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Of the 132 girders with an LRFR rating less than 1.0, 34 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 100% of the girders in this subset. Both ratings for this vehicle decrease with increasing span length. This is possibly due to the axle configuration of this vehicle, as longer spans would allow more axles to influence the rating.



(a) (b)

Figure C-238: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure C-239 shows the distribution of ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is significant for the WA-02 Vehicle; for an escorted permit vehicle, only 38% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one is reduced to 17% when the WA-02 vehicle is treated as a multiple trip permit allowed to mix with other traffic and an ADTT of 5,000. Switching to LRFR from LFR is going to have a very significant effect on the ratings but some of these girders are controlled by the longitudinal steel rating which is typically low.

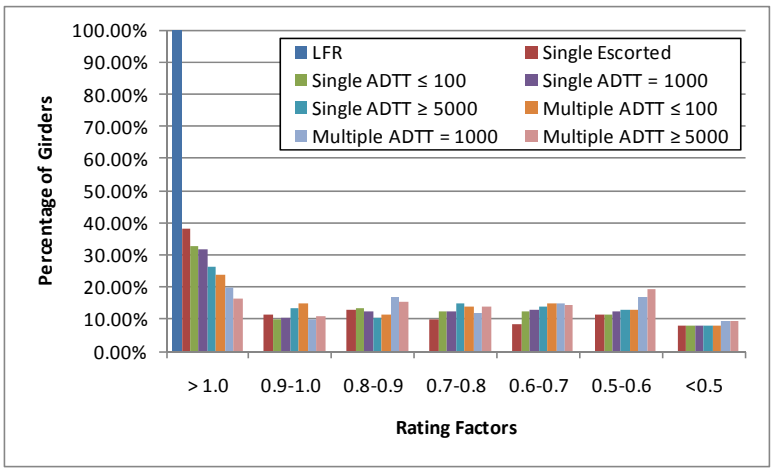


Figure C-239: Flexure Ratings for Various ADTTs in MBE for WA-02 Vehicle

C.2.10.1.2 Rating Factor Comparisons

Figure C-240 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6.

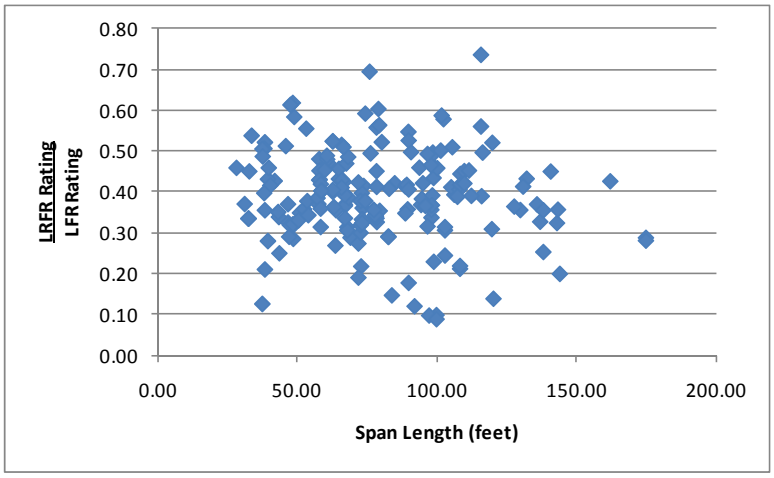


Figure C-240: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

C.2.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-241 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index. The reliability index decreases with increasing span lengths; this is likely because the longer spans allow more axles of this vehicle on the bridge and increase the moment.

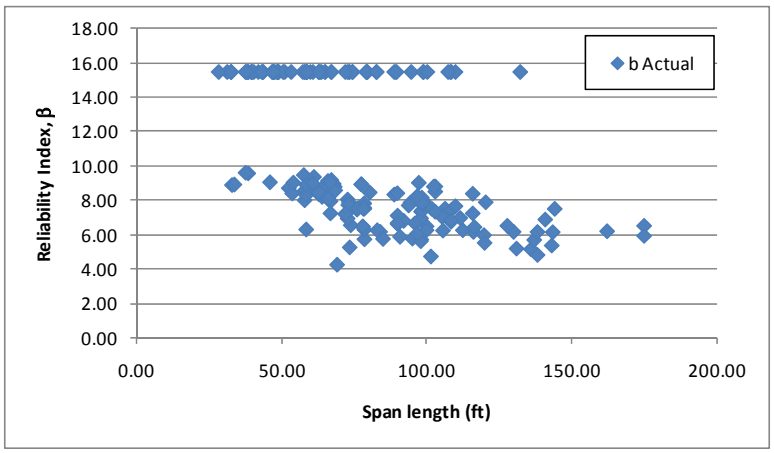


Figure C-241: Flexure Reliability Indices for WA-02 Vehicle

Figure C-242 shows the reliability index as a function of the LRFR rating factor for moment due to the WA-02 vehicle. The figure shows the reliability increases as the load factor increases but the reliability index is significantly greater than the target reliability of 3.5 for a rating factor of 1.0. This indicates that the target reliability is achieved for girders with low ratings; the live load factor could be reduced and the target reliability achieved.

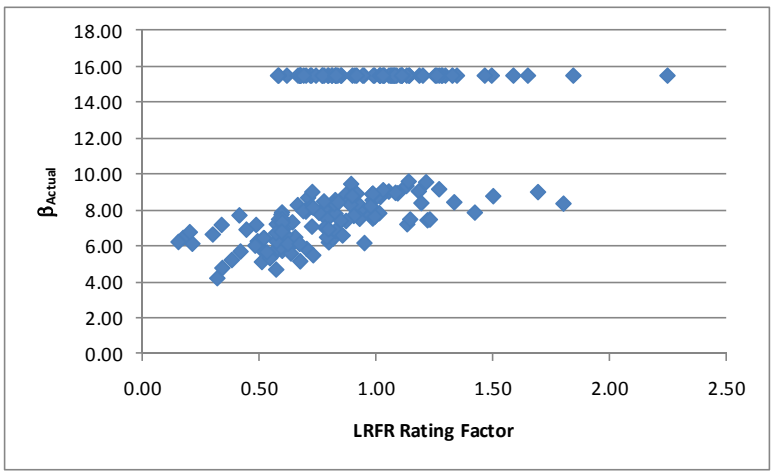
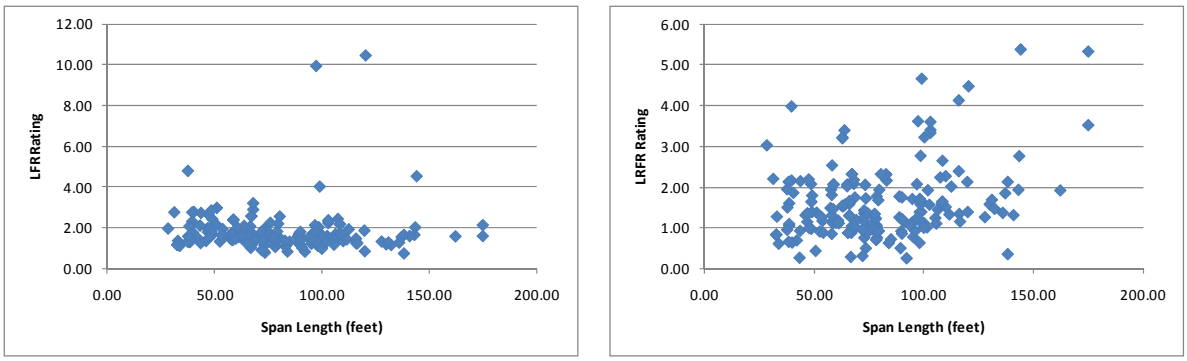


Figure C-242: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

C.2.10.2 Shear

C.2.10.2.1 Rating Factors

For shear, there are eight girders with LFR rating factors less than 1.0, 45 girders with LRFR ratings less than 1.0, and seven girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 69% of the girders in this subset. Figure C-243 shows the LFR and LRFR ratings. The LFR rating is typically between 1.0 and 3.0 while the LRFR rating is generally between 0.5 and 2.0.



(a) (b)

Figure C-243: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure C-244 shows the distribution of shear ratings for the different permit types and ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; 10% of girders have LRFR ratings less than 1.0 for the single trip, escorted case which uses a load factor of 1.15. 45% of girders have LRFR ratings less than 1.0 for the multiple trip permit allowed to mix with other vehicles and ADTT of 5,000.

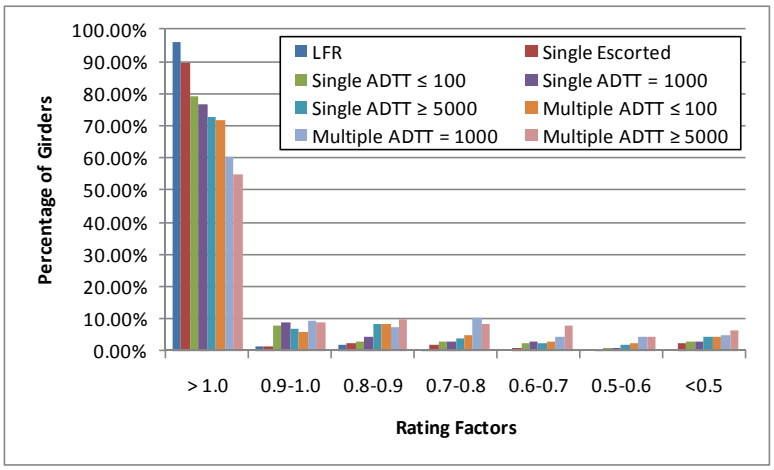


Figure C-244: Shear Rating for Various ADTTs in MBE for WA-02 Vehicle

C.2.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-245 shows the comparison of rating factors. The ratio is between 0.5 and 1.0 for most girders. 31% of girders have an LRFR rating greater than the LFR rating; these girders are indicated by data points above 1.0.

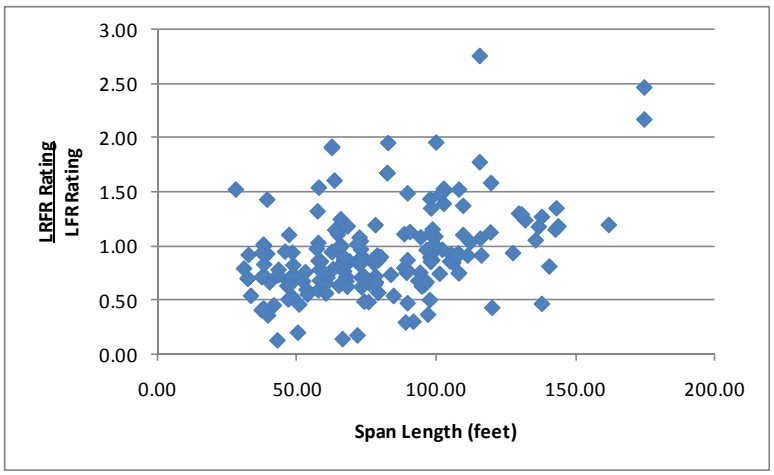


Figure C-245: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

C.2.10.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 3.5 for nine girders as shown in Figure C-246. The reliability index decreases with increasing span lengths; this is a result of the longer spans allowing more axles to be on the bridge and increasing the applied loads.

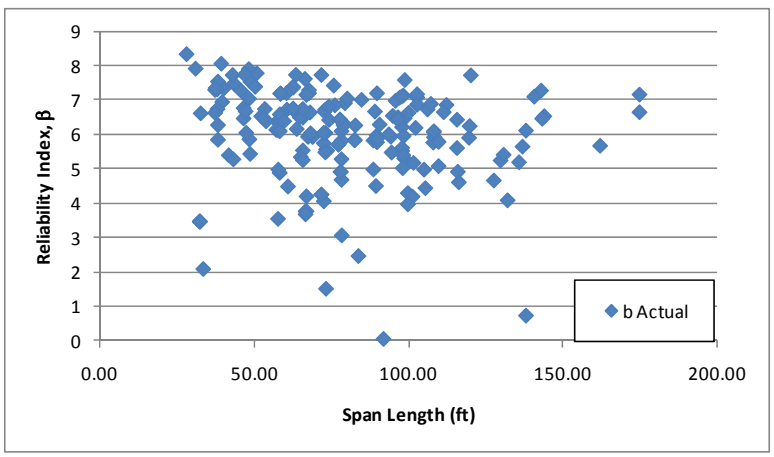


Figure C-246: Shear Reliability Indices for WA-02 Vehicle

Figure C-247 shows the reliability index as a function of the LRFR rating factor for shear due to the WA-02 vehicle. The figure shows that the reliability index for a girder passing rating is approximately 4.0 which is slightly greater than the target reliability of 3.5. The live load factors could be reduced such that a girder passing rating would have the target reliability of 3.5. Girders with high reliability and a low rating may be controlled by the shear friction rating while the LRFR shear resistance is used to calculate the reliability index.

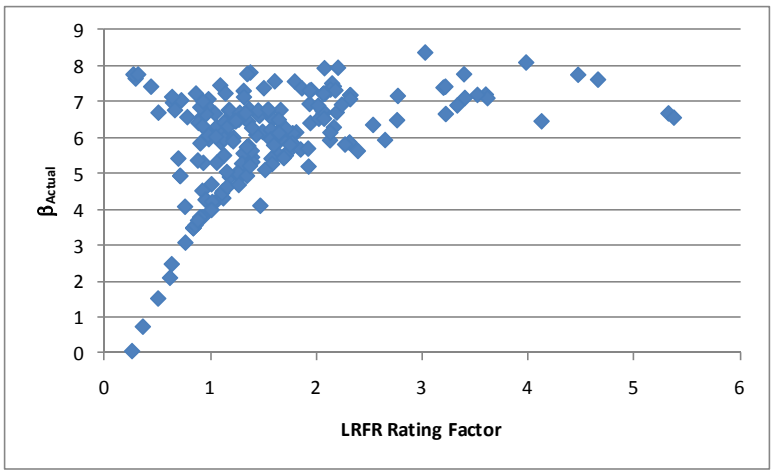


Figure C-247: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

C.2.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-248. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

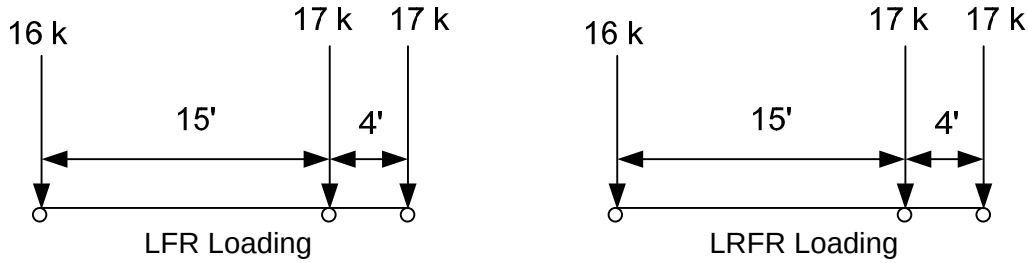


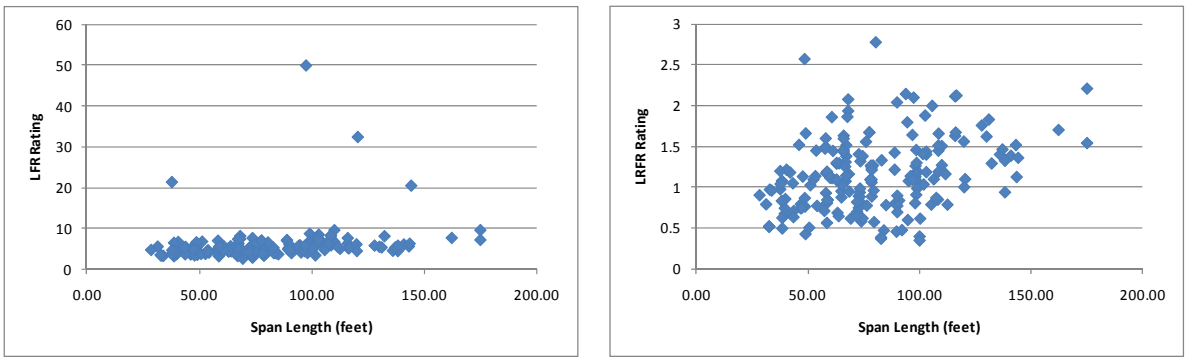
Figure C-248: Vehicle Loadings and Load Factors

C.2.11.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the Type 3 Vehicle.

C.2.11.1.1 Rating Factors

Figure C-249 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 78 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Of the 78 girders with LRFR ratings less than 1.0, 65 are controlled by the longitudinal steel requirement of AASHTO LRFD 5.8.3.5.The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LRFR rating is between 0.5 and 1.5 for most girders while the LFR rating is between 3.0 and 6.0 for most girders.



(a) (b)

Figure C-249: LFR and LRFR Flexure Rating Factors for Type 3 Vehicles

Figure C-250 shows the distribution of moment ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, about 70% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 54% when an ADTT of 5,000 is used.

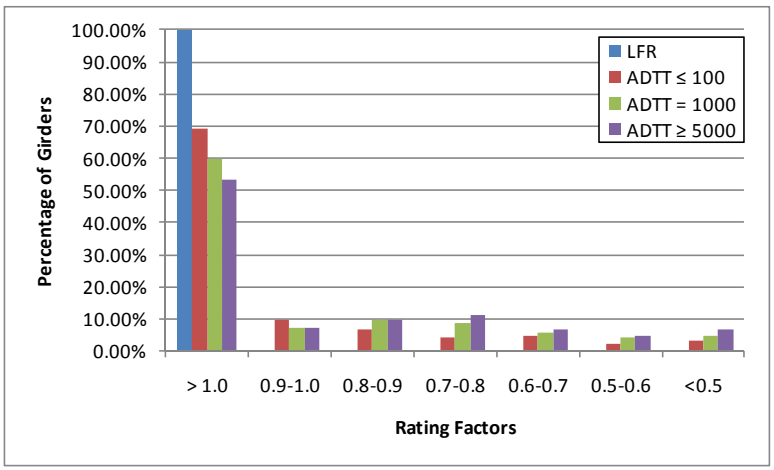


Figure C-250: Flexure Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

C.2.11.1.2 Rating Factor Comparisons

Figure C-251 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating which for this vehicle does not occur. The ratio is less than 0.45 for all girders.

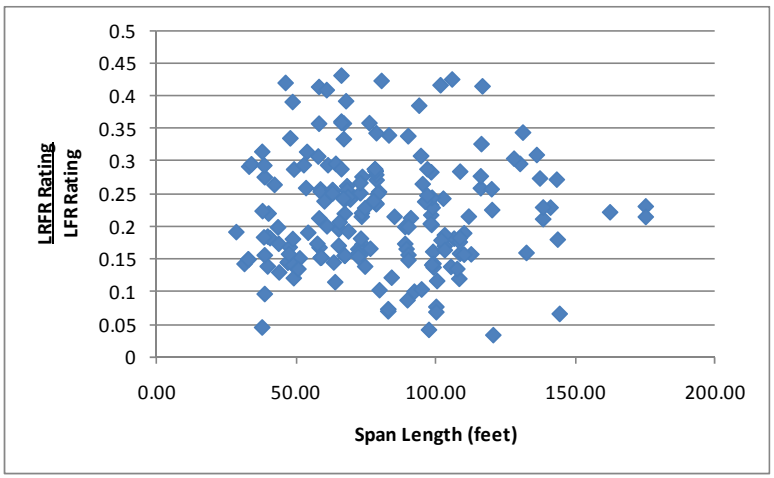


Figure C-251: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicles

C.2.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-252 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between 7 and 10 for most girders not controlled by the longitudinal steel reinforcement rating.

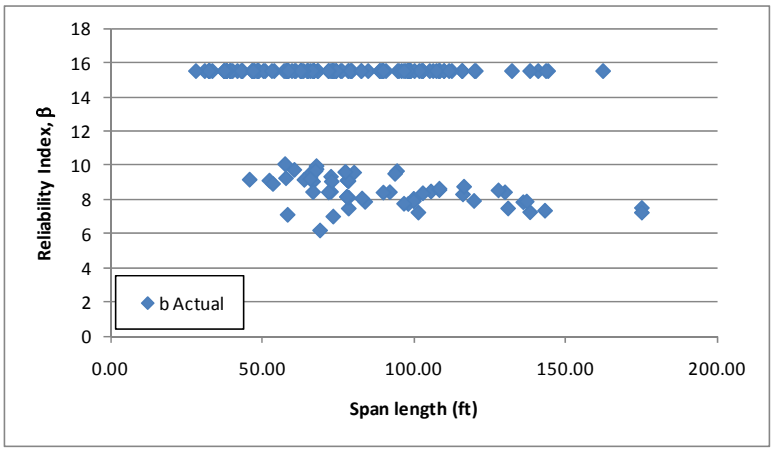


Figure C-252: Flexure Reliability Indices for Type 3 Vehicles

Figure C-253 shows the reliability index as a function of the LRFR rating for moment due to the AASHTO Type 3 Vehicle. The figure shows that the reliability index increases as the LRFR rating increases. Girders with a LRFR rating have reliability indices greater than the target reliability of 2.5. This indicates that the live load factors are higher than required and lower live load factors could be used.

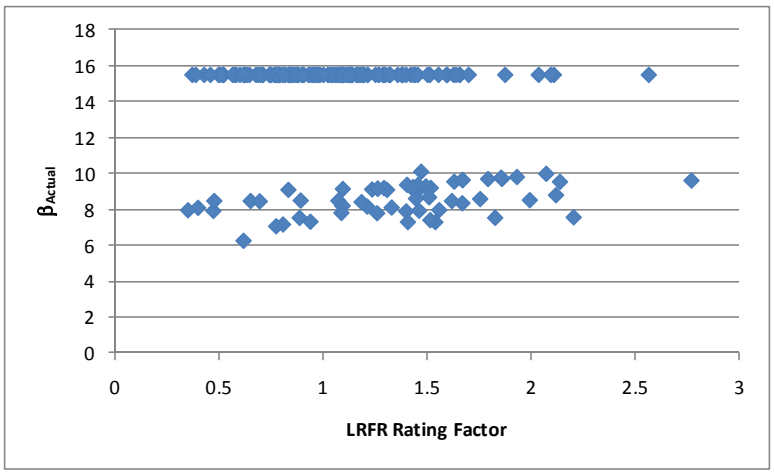
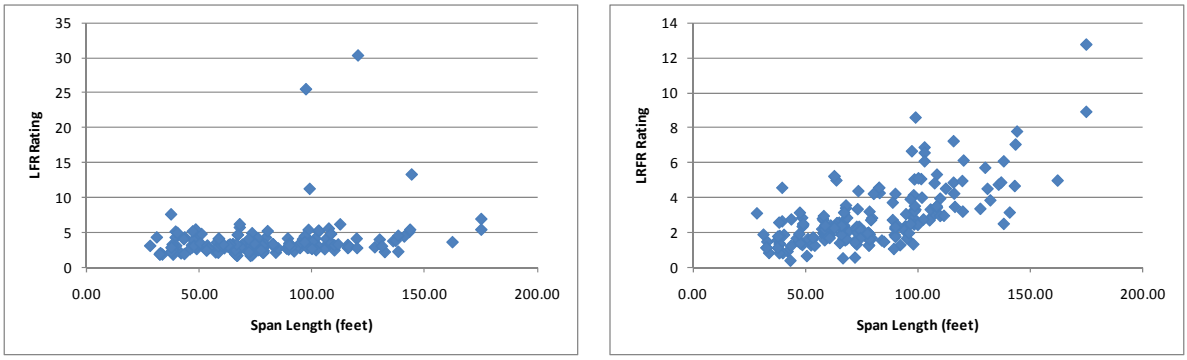


Figure C-253: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Vehicle

C.2.11.2 Shear

C.2.11.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, eight girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 77% of the girders in this subset. Figure C-254 shows the LFR and LRFR ratings. LFR ratings are constant with increasing length while LRFR ratings tend to increase with increasing span length. The LFR ratings are generally less than five while the LRFR ratings are generally less than four.



(a) (b)

Figure C-254: LFR and LRFR Shear Ratings for Type 3 Vehicles

Figure C-255 shows the distribution of shear ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is clear in this graph but is not extremely large. For an ADTT of 5,000, only 5% of girders have ratings less than 1.0. Most of these girders have ratings that are between 0.7 and 0.8 or less than 0.5.

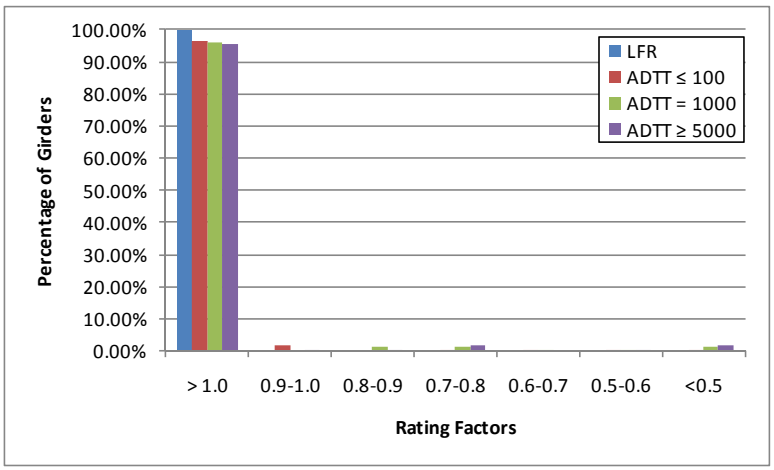


Figure C-255: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

C.2.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-256 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with 23% of girders having LRFR ratings greater than the LFR rating.

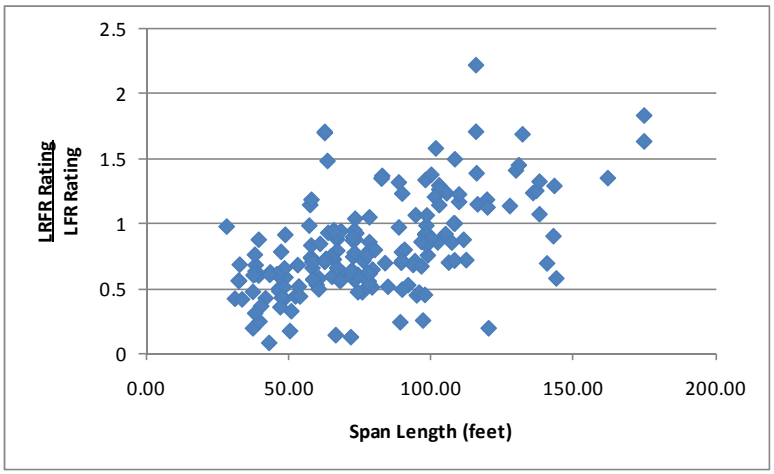


Figure C-256: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicles

C.2.11.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for no girders as shown in Figure C-257. The reliability index is between 6 and 8 for most girders.

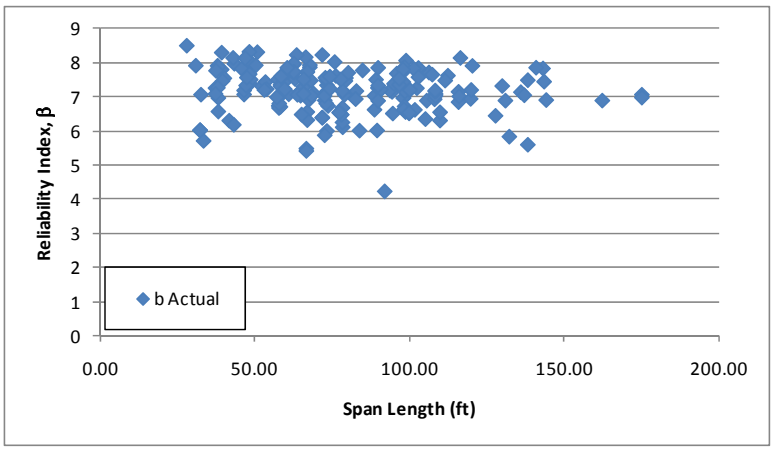


Figure C-257: Shear Reliability Indices for Type 3 Vehicles

Figure C-258 shows the reliability index plotted against the LRFR rating for shear due to the AASHTO Type 3 truck. The figure shows that all girders have a reliability index greater than the target of 2.5. Girders with high reliability and low ratings are controlled by the rating for shear friction and the reliability index is calculated using the LRFR shear resistance. It may be possible to reduce the live load factors and bring the reliability of a girder passing rating nearer to the target reliability.

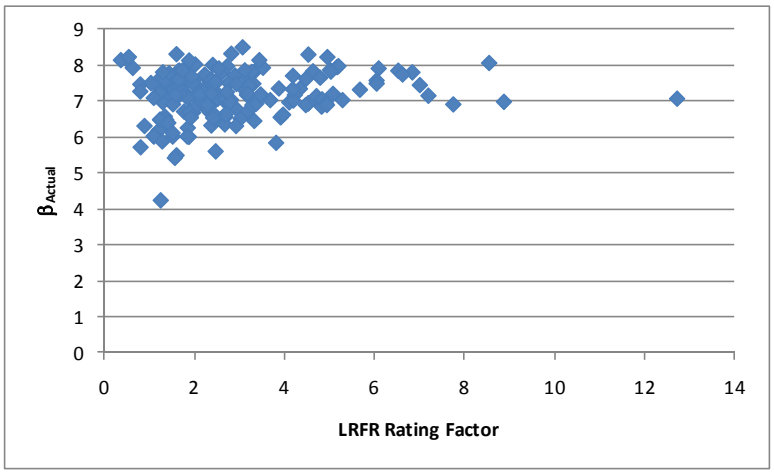


Figure C-258: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

C.2.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-259. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

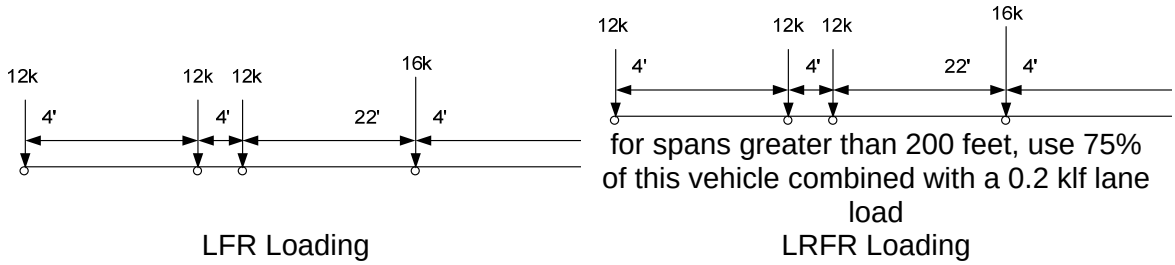


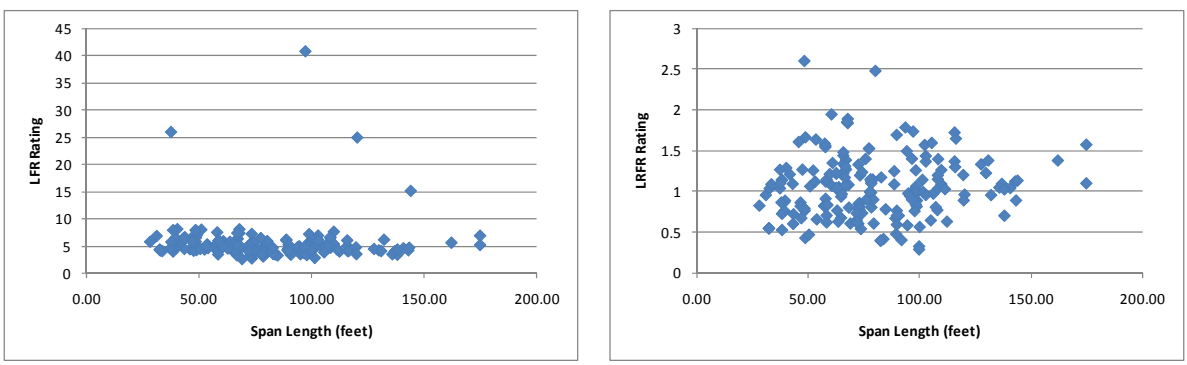
Figure C-259: Vehicle Loadings and Load Factors

C.2.12.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the Type 3-3 Vehicle.

C.2.12.1.1 Rating Factors

Figure C-260 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 94 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Of the 94 girders with an LRFR rating less than 1.0, 78 are controlled by the longitudinal steel requirements of AASHTO LRFD 5.8.3.5. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR ratings are between three and eight for most girders while the LRFR ratings are between 0.5 and 1.5 for most girders.



(a) (b)

Figure C-260: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicles

Figure C-261 shows the distribution of moment ratings for the different ADTTs in the MBE. The figure shows that more girders have lower ratings with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, 65% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 42% when an ADTT of 5,000 is used.

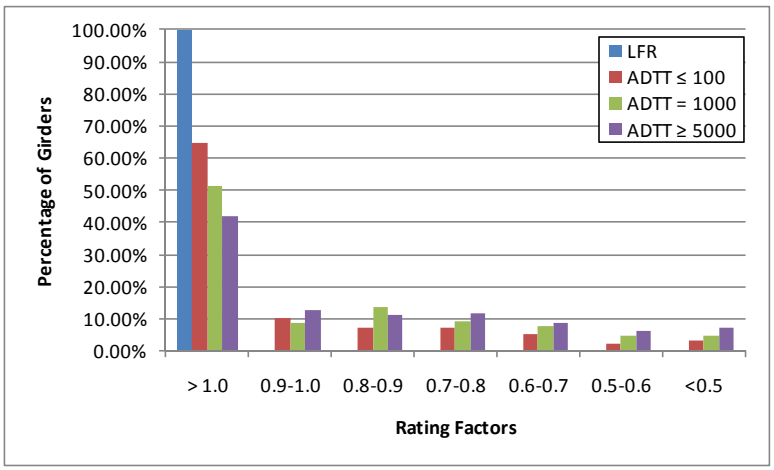


Figure C-261: Flexure Rating for Various ADTTs in MBE for AASHTO Type 3-3 Truck

C.2.12.1.2 Rating Factor Comparisons

Figure C-262 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating which does not occur for any girders. The ratio is less than 0.45 for all girders with some girders as low as 0.04.

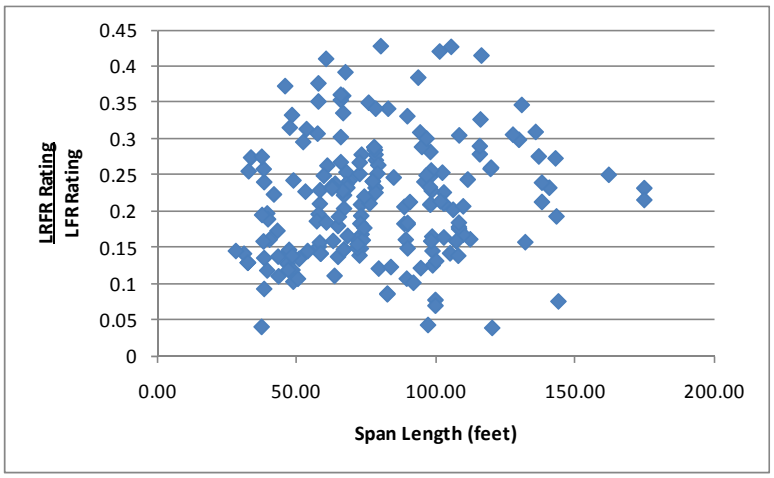


Figure C-262: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicles

C.2.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-263 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index. The reliability index is between six and ten for most girders not controlled by the longitudinal steel rating.

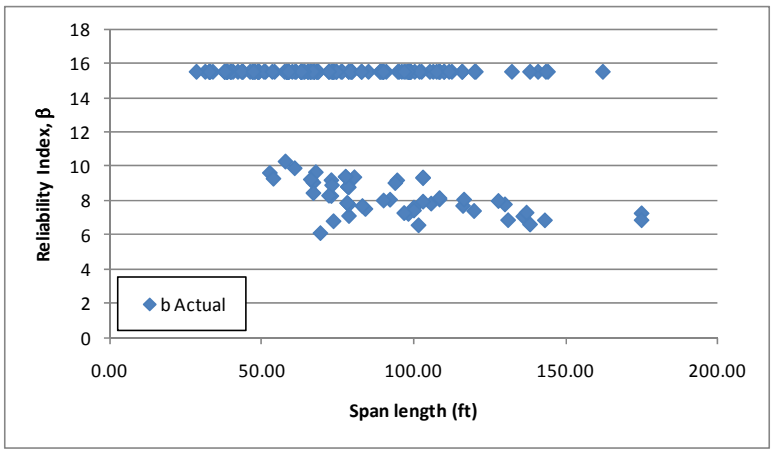


Figure C-263: Flexure Reliability Indices for Type 3-3 Vehicles

Figure C-264 shows the reliability index plotted against the LRFR rating factor for shear due to the AASHTO Type 3-3 Truck. The target reliability index of 2.5 is exceeded for all girders; the minimum reliability index is approximately six. The fact that the target reliability is exceeded for all girders, even those with ratings less than 0.5, indicate that the live load factors can be reduced and maintain the target level of reliability.

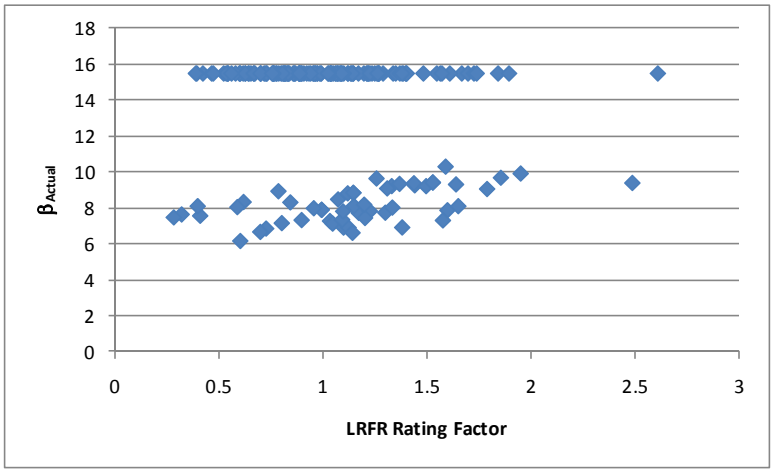
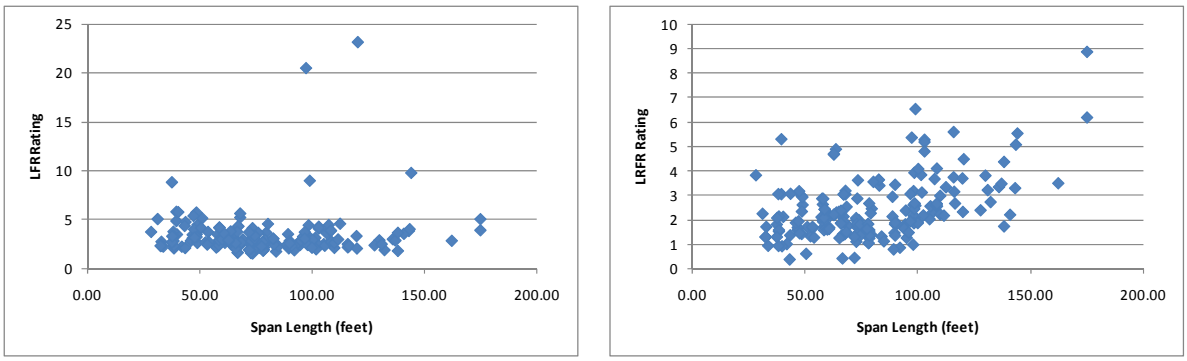


Figure C-264: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

C.2.12.2 Shear

C.2.12.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, 10 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 78% of the girders in this subset. Figure C-265 shows the LFR and LRFR ratings. The LFR ratings are between 2 and 5 for most girders while the LRFR rating is between 1 and 3.



(a) (b)

Figure C-265: LFR and LRFR Shear Ratings for Type 3-3 Vehicles

Figure C-266 shows the distribution of shear ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious but not as significant in this graph as it was for moment; using an ADTT of 100, only 3% of girders will have an LRFR rating below 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 93% when an ADTT of 5,000 is used.

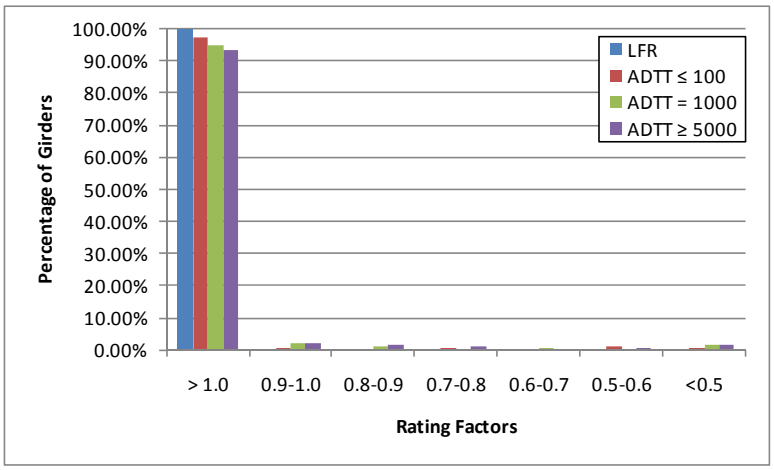


Figure C-266: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

C.2.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-267 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5. 22% of girders have an LRFR rating greater than the LFR rating.

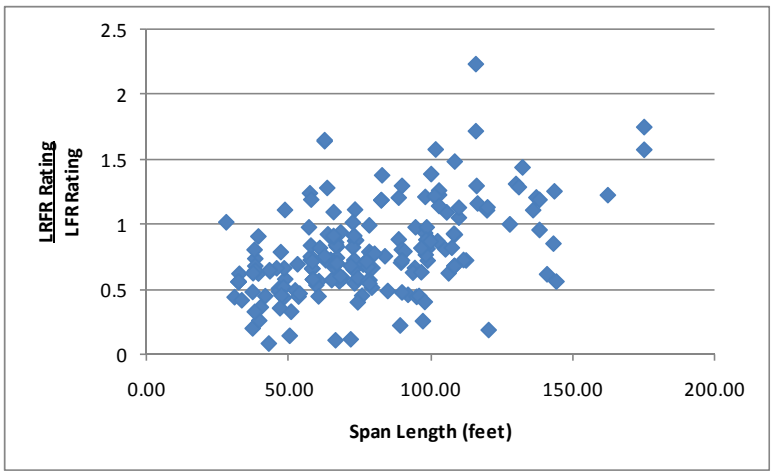


Figure C-267: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicles

C.2.12.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for no girders as shown in Figure C-268. The reliability index is between six and eight for most girders with the lowest reliability index being 3.5.

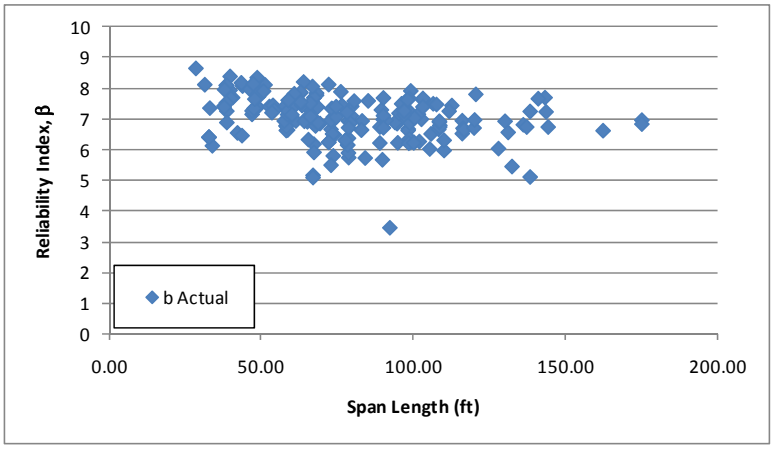


Figure C-268: Shear Reliability Indices for Type 3-3 Vehicles

Figure C-269 shows the reliability index plotted against the LRFR rating factor for shear due to the AASHTO Type 3-3 Truck. The figure shows that the reliability index increases with increasing rating factors. The figure also shows that girders with a rating of 1.0 have a reliability index much larger than the target reliability of 2.5. This indicates that reducing the live load factors may be a reasonable solution for bringing the reliability index closer to the target value for a girder passing rating.

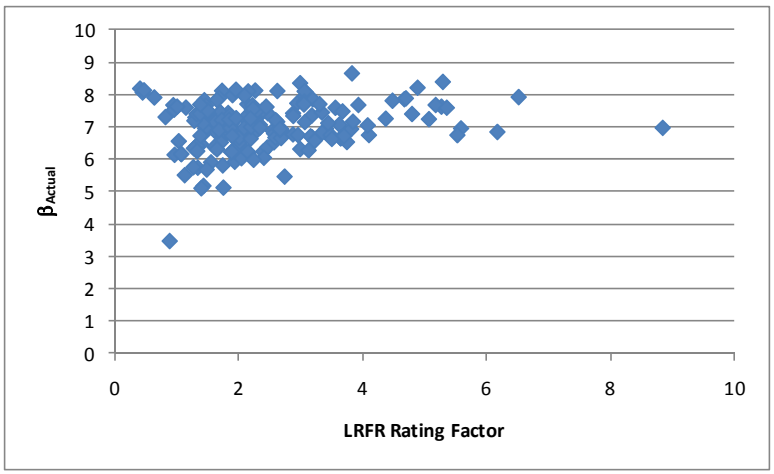


Figure C-269: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

C.2.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure C-270. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

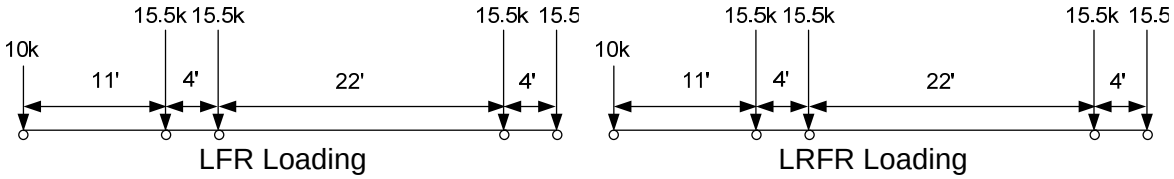


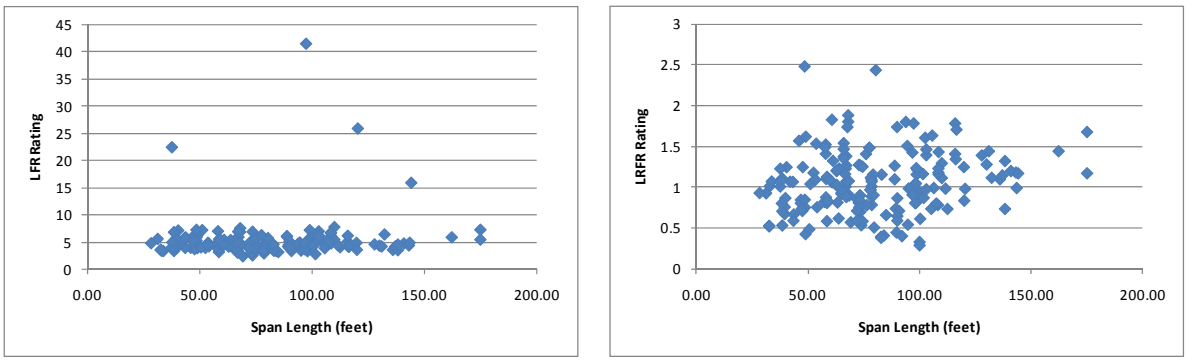
Figure C-270: Vehicle Loadings and Load Factors

C.2.13.1 Moment

The following section contains the results for exterior, composite prestressed I girders within simple span bridges for the AASHTO Type 3S2 Vehicle.

C.2.13.1.1 Rating Factors

Figure C-271 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 92 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Of the 92 girders with LRFR ratings less than 1.0, 74 are controlled by the longitudinal steel requirement of AASHTO LRFD 5.8.3.5. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating is between 3 and 8 while the LRFR rating is between 0.5 and 1.5 for most girders in this group.



(a) (b)

Figure C-271: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicles

Figure C-272 shows the distribution of flexure ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious in this graph; using an ADTT of 100, only 65% of girders will have an LRFR rating above 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 44% when an ADTT of 5,000 is used.

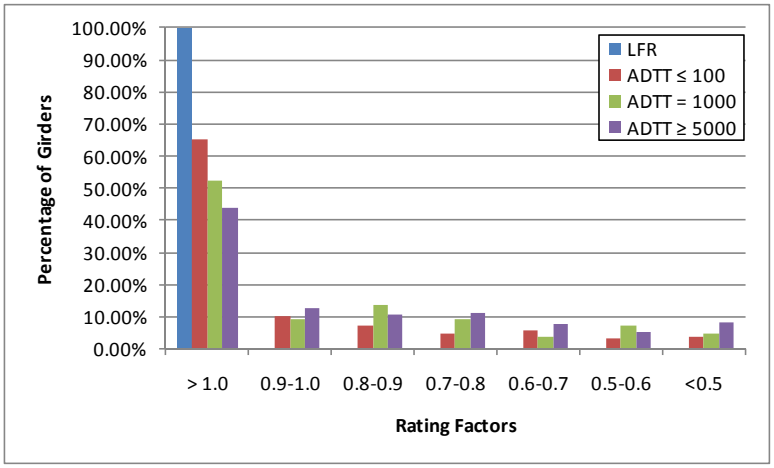


Figure C-272: Flexure Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

C.2.13.1.2 Rating Factor Comparisons

Figure C-273 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating which does not occur for the girders in this group. The ratio is less than 0.45 for all girders in this group.

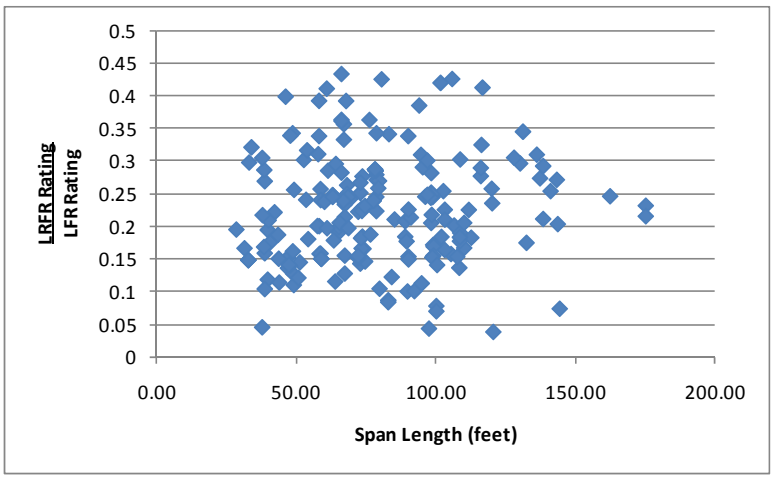


Figure C-273: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicles

C.2.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure C-274 shows that no girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between six and ten for most girders not controlled by the longitudinal steel requirement of AASHTO LRFD 5.8.3.5.

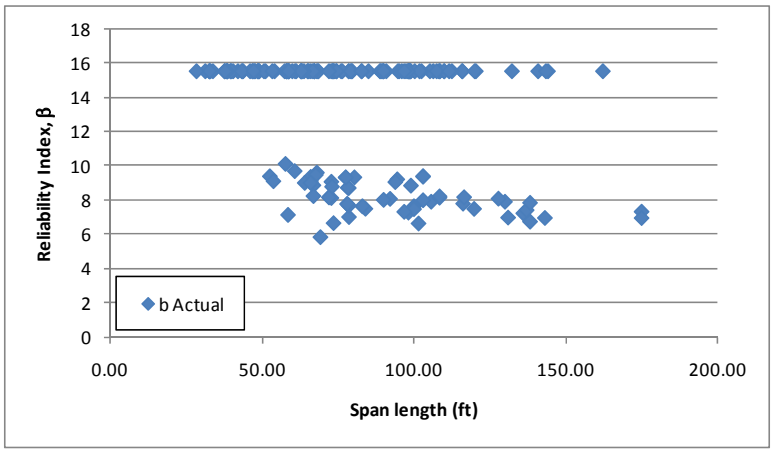


Figure C-274: Flexure Reliability Indices for Type 3S2 Vehicles

Figure C-275 shows the reliability index plotted against the LRFR rating for moment due to the AASHTO Type 3S2 Truck. The figure shows that the reliability increases with increasing rating. The target reliability of 2.5 is exceeded by a significant margin for all girders. This indicates that the target reliability would be maintained for girders with low ratings, therefore the live load factors could be reduced and the target reliability would be maintained.

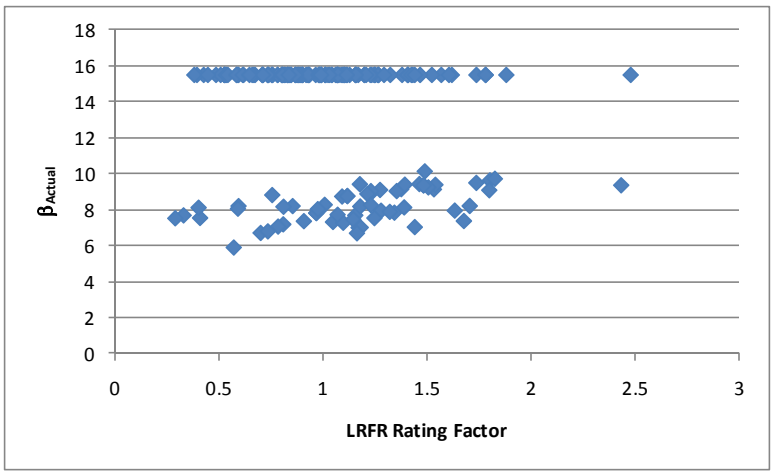
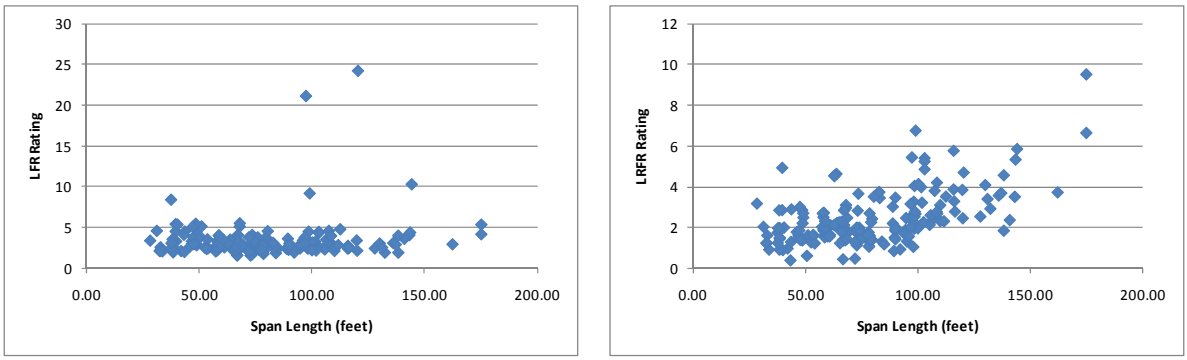


Figure C-275: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

C.2.13.2 Shear

C.2.13.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, ten girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 80% of the girders in this subset. Figure C-276 shows the LFR and LRFR ratings. LFR ratings are between two and five while LRFR ratings are between one and four for most cases.



(a) (b)

Figure C-276: LFR and LRFR Shear Ratings for Type 3S2 Vehicles

Figure C-277 shows the distribution of shear ratings for the different ADTTs in the MBE. The figure shows that more girders have lower rating with increasing ADTTs. The effect of switching from LFR to LRFR is obvious but not as significant in this graph as for the moment; using an ADTT of 100, only 3% of girders will have an LRFR rating below 1.0 while all girders will have an LFR rating greater than 1.0. The percentage of girders with LRFR ratings greater than one decreases to 95% when an ADTT of 5,000 is used.

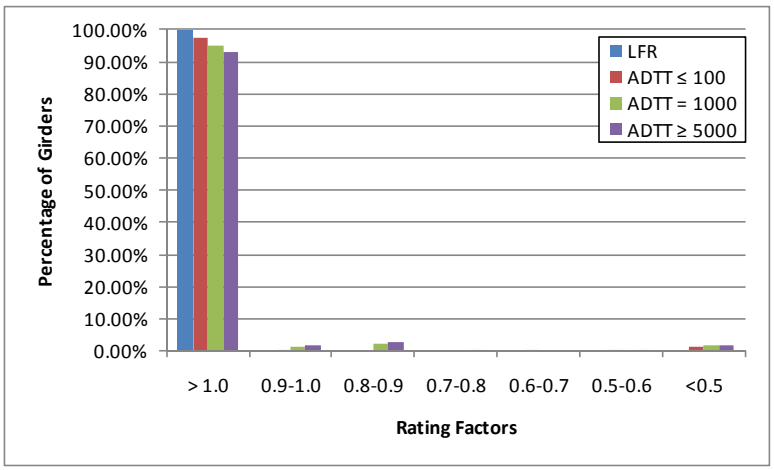


Figure C-277: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

C.2.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure C-278 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5. 20% of the girders have an LRFR rating greater than the LFR rating.

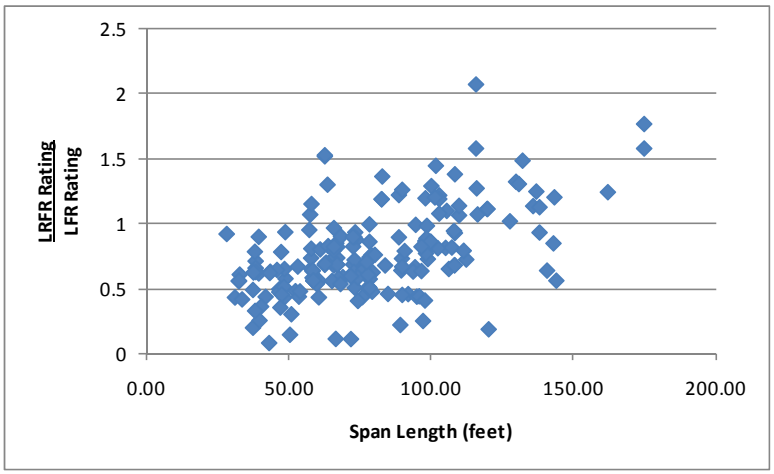


Figure C-278: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicles

C.2.13.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for no girders as shown in Figure C-279. The reliability index is between six and eight for most girders.

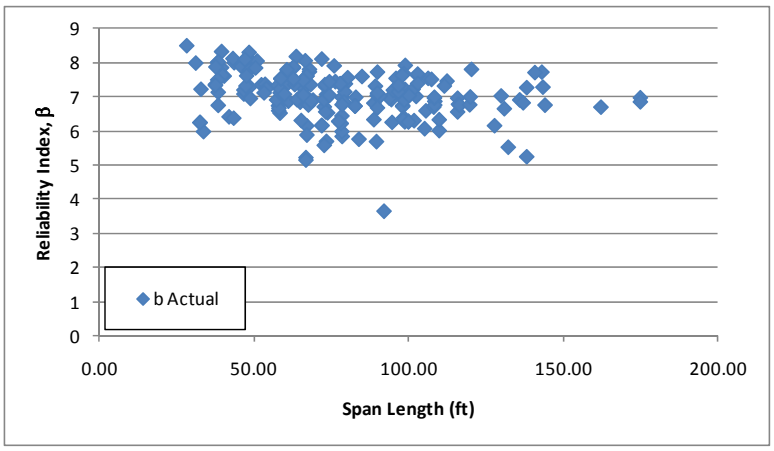


Figure C-279: Shear Reliability Indices for Type 3S2 Vehicles

Figure C-280 shows the reliability index plotted against the LRFR rating for shear due to the AASHTO Type 3S2 Truck. The figure shows that all girders have a reliability index exceeding the target reliability of 2.5. Some of the girders with high reliability and low ratings are controlled by the shear friction rating but the reliability index is calculated using the LRFR shear resistance.

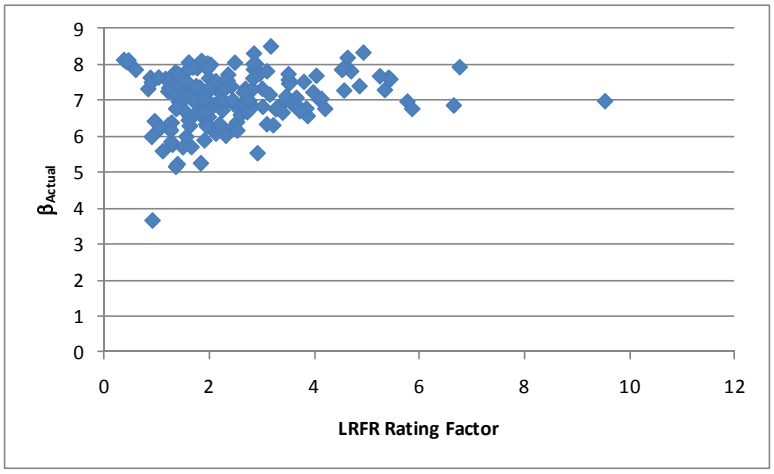


Figure C-280: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

C.2.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table C-3 shows the results for the moment ratings. For all twelve vehicles, there are very few girders with an LFR rating less than 1.0 and at least 40% of girders had LRFR ratings less than 1.0. The LFR rating exceeded the LRFR rating for all girders for all vehicles. An additional row has been added to the table to indicate how many girders were controlled by the longitudinal steel requirements of AASHTO LRFD 5.8.3.5. The percentage of girders with LRFR ratings less than 1.0 controlled by the requirements of AASHTO LRFD 5.8.3.5 varied from a minimum 26% for the WA-02 vehicle to 83% for the AASHTO Type 3 Truck. The girders with LRFR ratings less than 1.0 and not controlled by the longitudinal steel rating, are controlled by the tension in the bottom of the beam, corresponding to the Service III Limit State.

Table C-3: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	193	13	0	0	0	0	0	0	0	0	0	0	0
LRFR Rating less than 1.0		130	90	87	85	88	76	93	102	132	78	94	92
LFR and LRFR Rating less than 1.0		13	0	0	0	0	0	0	0	0	0	0	0
% with LFR RF greater than LRFR RF		99	100	100	100	100	100	100	100	100	100	100	100
LRFR rating less than 1.0 and controlled by AASHTO LRFD 5.8.3.5		84	69	70	36	67	63	42	71	34	65	78	74
LRFR Rating less than 1.0 and controlled by service limit state		46	21	17	49	21	13	51	31	98	13	16	18

C.2.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table C-4 shows the results for the shear ratings. The design vehicle and special permit vehicles cause some girders to have LFR ratings less than 1.0 and generally have the most girders with LRFR ratings less than 1.0. Routine permit and legal vehicles cause no bridges to have LFR ratings less than 1.0 and generally cause few girders to have LRFR ratings less than 1.0. The percentage of girders with LFR ratings greater than LRFR ratings is vehicle dependent due to the shear resistance being a function of V_u/M_u. The live load factors also affect the percentage of girders for each vehicle as the vehicles with higher load factors have higher percentages of girders with the LFR rating greater than LRFR rating.

Table C-4: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	193	9	0	0	1	0	0	1	0	8	0	0	0
LRFR Rating less than 1.0		66	11	10	16	12	9	16	20	45	8	10	10
LFR and LRFR Rating less than 1.0		7	0	0	1	0	0	0	0	7	0	0	0
% with LFR RF greater than LRFR RF		82	78	73	60	73	72	58	75	69	77	78	80

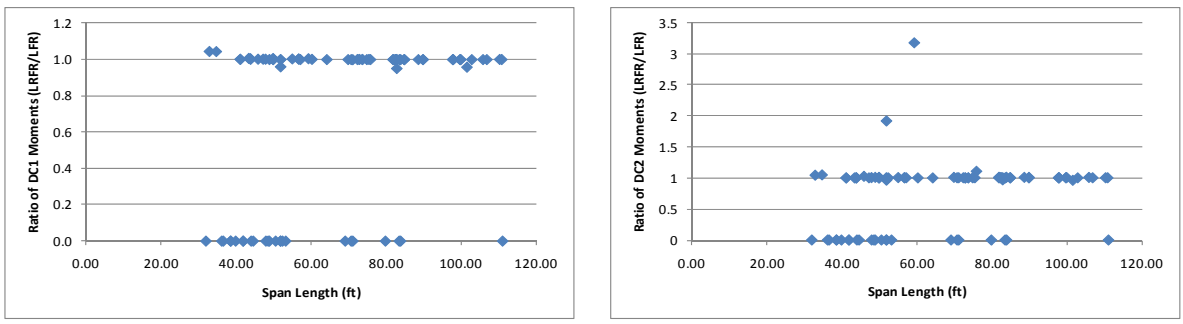
D Simple Span Prestressed Box Girder Bridges

D.1 Exterior Composite Girders

D.1.1 Dead Loads

D.1.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure D-1a, the ratios of unfactored DC1 moments, LRFR divided by LFR, (self-weight, dead loads on non-composite section) are very close to 1.0. Those that are slightly above below 1.0 are caused by one moment being obtained at the four-tenths point and the other at midspan. The data points at zero are girders where the LRFR critical rating was the longitudinal steel requirement from AASHTO LRFD 5.8.3.5. This occurs at the support; these are simple span girders so the moments are zero at the support. Figure D-1b shows that with the exception of two girders, the DC2 and DW moments are the same or zero for those controlled by AASHTO LRFD 5.8.3.5.

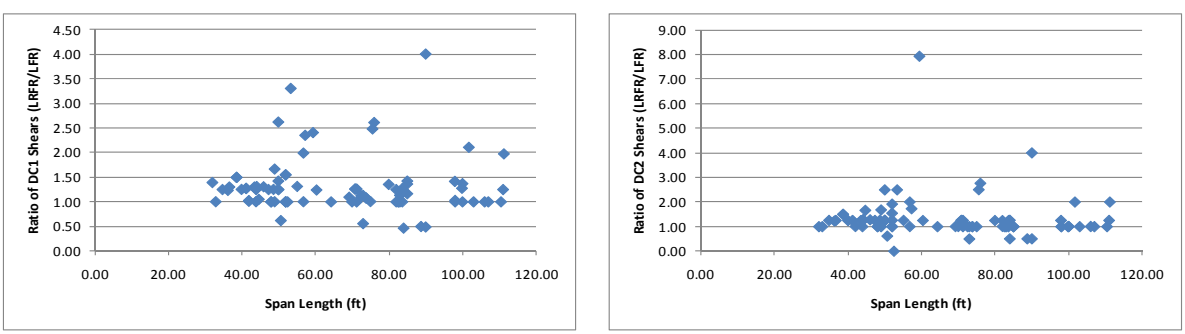


(a) (b)

Figure D-1: Ratios of DC1 and DC2 Moment (unfactored loads, LRFR/LFR)

D.1.1.2 Shear

Figure D-2a shows that many girders have a ratio of LRFR DC1 shear to LFR DC1 shear of either 1.0 or 1.25. There are also girders where the ratio of dead load shear is not close to 1.0; this is due to the variation of the critical section for shear. Figure D-2b shows the same trend as Figure D-2a in that the LFR shear is similar to the LRFR shear for the DC2 and DW shears.



(a) (b)

Figure D-2: Ratios of DC1 and DC2 Shear (unfactored loads, LRFR/LFR)

D.1.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure D-3. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

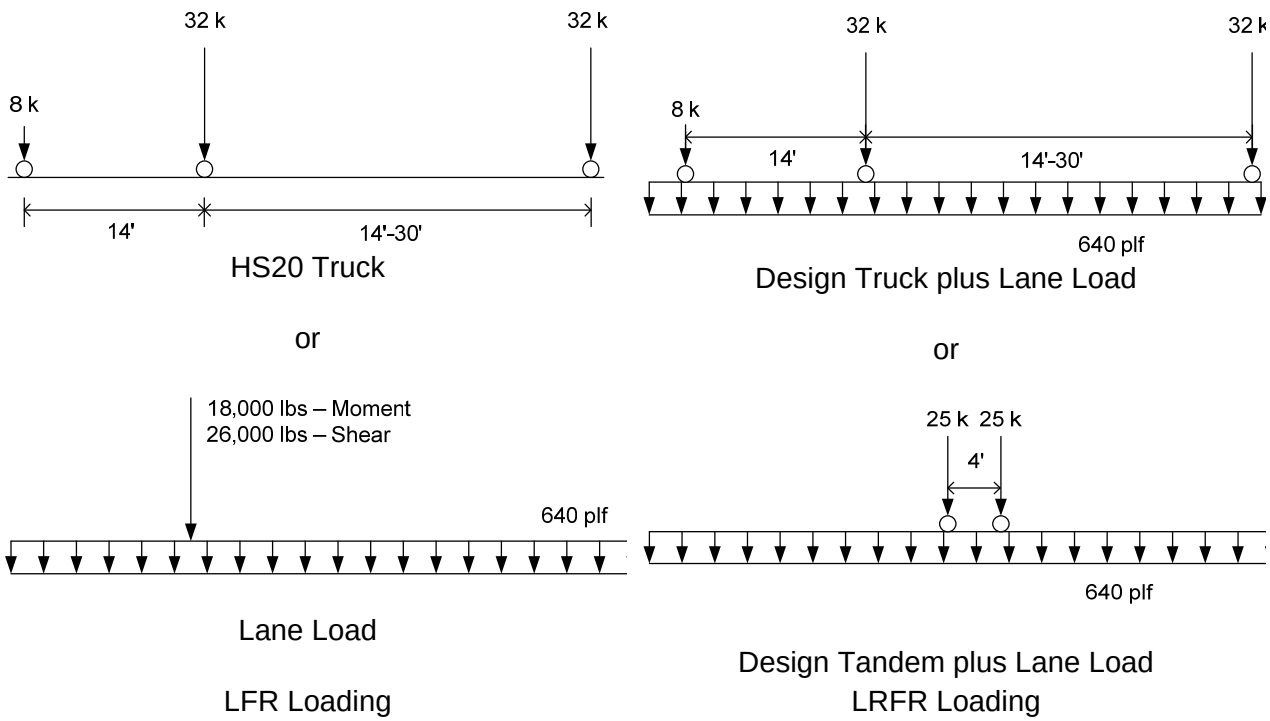
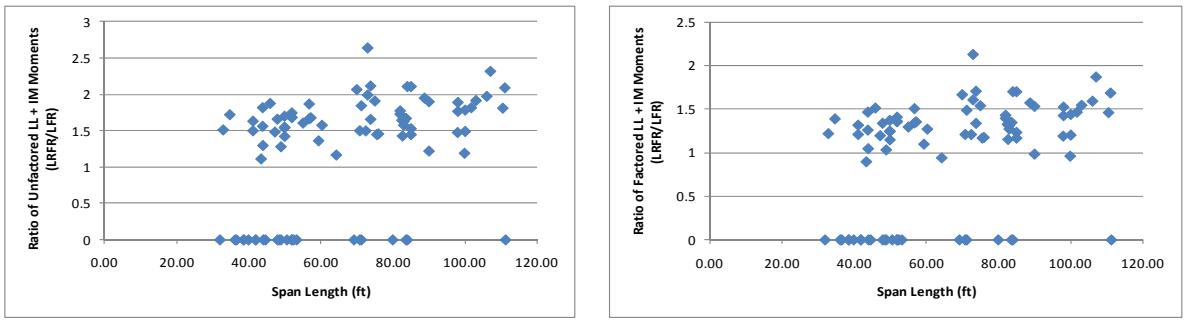


Figure D-3: Vehicle Loadings and Load Factors

D.1.2.1 Moment

D.1.2.1.1 Live Loads

Figure D-4a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.0 and 2.0 for most of the girders within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure D-4b shows that the results have shifted down and are between 1.0 and 2.0 for most cases.



(a) (b)

Figure D-4: Ratio of Unfactored and Factored Live Load plus Impact Moments for Design Vehicle (LRFR/LFR)

D.1.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure D-5 shows that the ratio of resistance is generally between 1.0 and 1.25. The increased resistance for LRFR is due to the reduction in prestress losses. There are also a number of girders where the resistance ratios are between 0 and 0.25. These are the girders where the LRFR rating is controlled by the longitudinal steel requirement near the support.

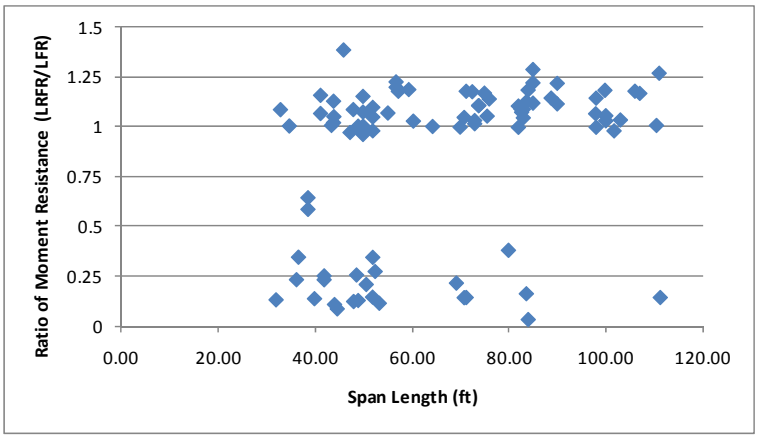
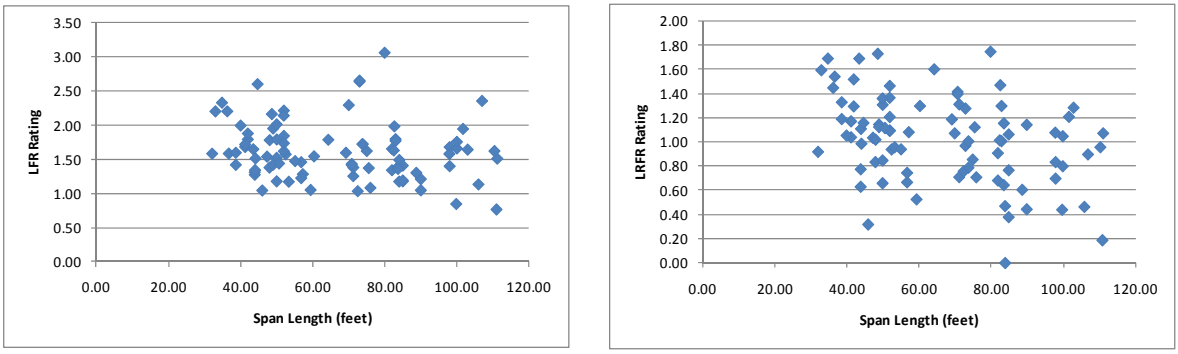


Figure D-5: Ratio of factored Moment Resistance (LFR/LRFR)

D.1.2.1.3 Rating Factors

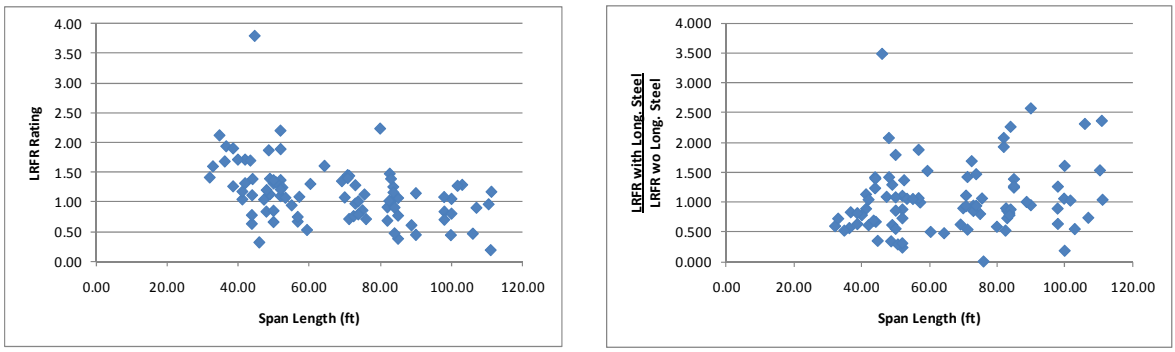
After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (88 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 2 girders with LFR ratings less than 1.0, 37 girders with LRFR ratings less than 1.0, and 2 girders where both the LFR and LRFR ratings are less than 1.0. Six of the 37 girders with LRFR ratings less than 1.0 are controlled by the check of AASHTO LRFD 5.8.3.5. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. For this set of girders, a large number of girders do not have satisfactory ratings for LRFR while very few do for the LFR method. Figure D-6 shows the LFR rating factors and LRFR rating factors.



(a) (b)

Figure D-6: LFR and LRFR Flexure Rating Factor for HS-20 and HL-93 Loadings

Figure D-7a shows the LRFR ratings when the longitudinal steel rating is not included. The effect of not including this rating is small and eliminates five girders with ratings less than 1.0. Figure D-7b shows the ratio of LRFR rating including longitudinal steel divided by the LRFR rating ignoring the longitudinal rating. 55% of girders have lower ratings when the longitudinal steel is considered than when it is ignored.



(a) (b)

Figure D-7: Effect of Longitudinal Steel on LRFR Rating

D.1.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure D-8. The results indicated that 99% of the girders in this set have LFR ratings greater than LRFR ratings. Girders with shorter spans tend to have higher ratios of rating factors.

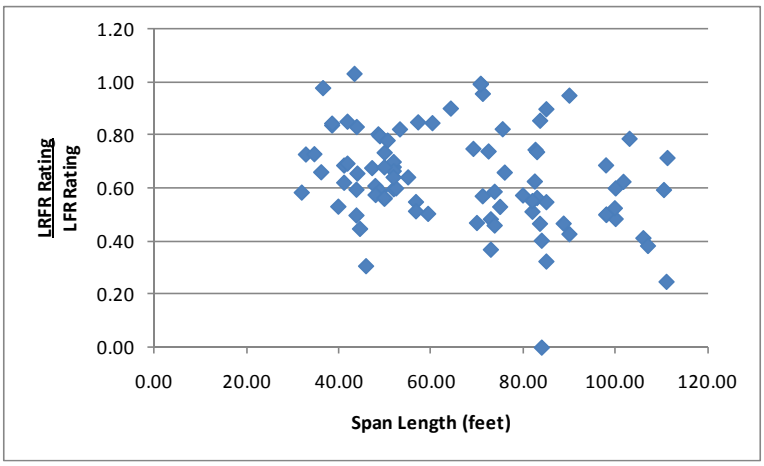


Figure D-8: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Vehicle

Figure D-9 shows the distribution of LRFR/LFR ratio for girders with LRFR ratings less than 1.0. Most girders with LRFR ratings less than 1.0 have an LRFR rating factor that is less than 60% of the LFR rating. This is a significant reduction that occurs when switching from LFR to LRFR.

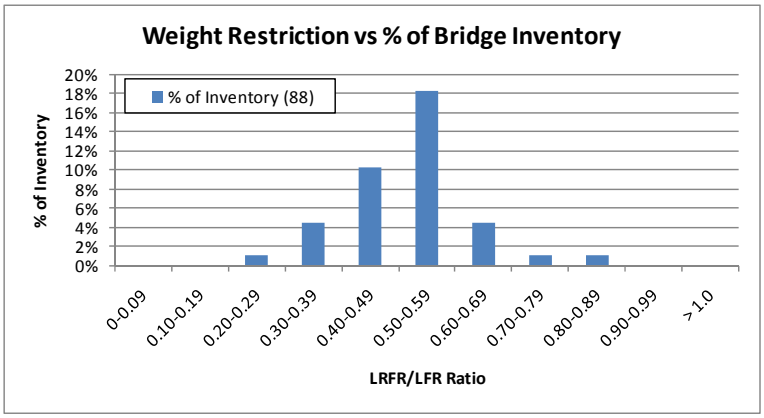


Figure D-9: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

D.1.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure D-10 shows that eight girders have a reliability index higher than that assumed in the development of the LRFR Rating Specification. The target reliability is 3.5 for the design vehicle; the figure shows that the target is closer to 4.0, this is because the live load factor was originally 1.6 but increased to 1.75 to be conservative.

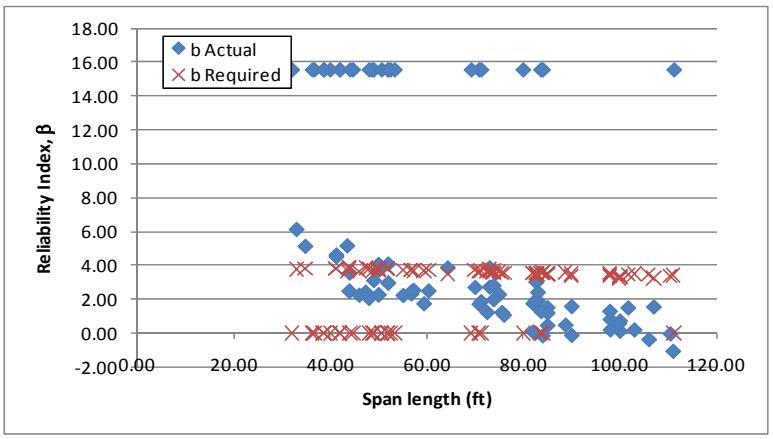


Figure D-10: Flexure Reliability Indices for HL-93 Loading

Figure D-11 shows the reliability index plotted against the LRFR rating factor for moment caused by the design load. The figure shows that most girders have a reliability index less than the target reliability and those with a passing rating have a reliability index between 2 and 3 (using the middle of the scatter).

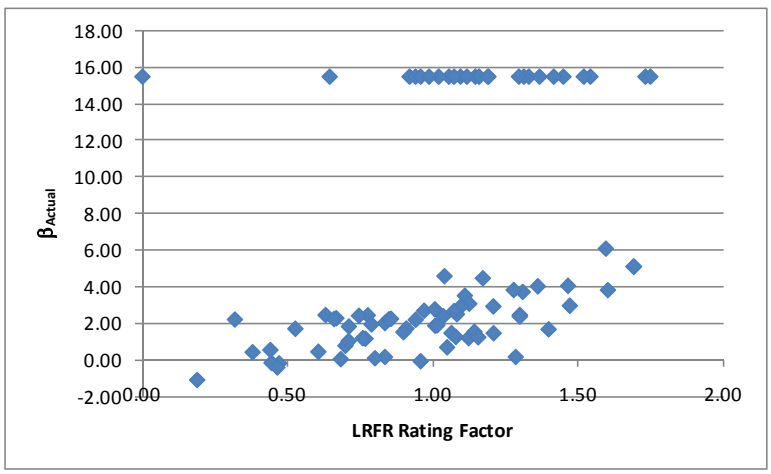


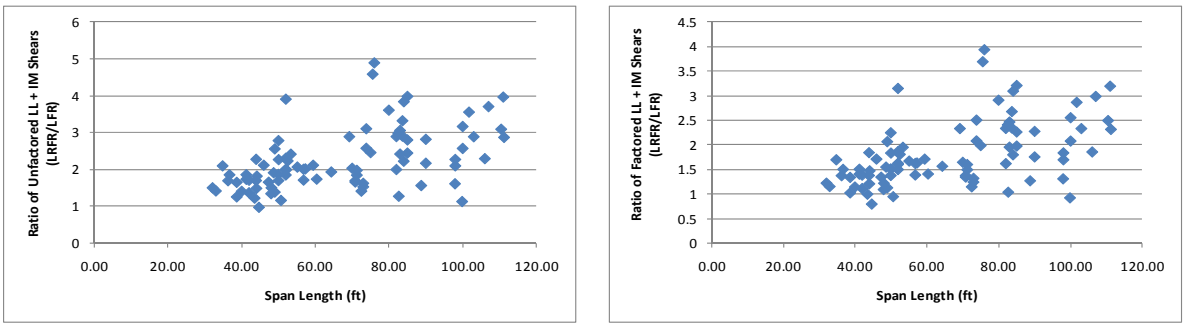
Figure D-11: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Loading

D.1.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is prestressed concrete box girders, simple span exterior girders with composite concrete decks.

D.1.2.2.1 Live Loads

Figure D-12a shows that the ratio of unfactored shear varies significantly, with most girders between 1.0 to 3.0, Longer girders have higher ratios of Live Load plus Impact than shorter girders, this is likely a result of the uniform lane load component of the HL-93 design load. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure D-12b shows that the ratio of factored live load shears has decreased and is generally between 1.0 and 2,0 for most girders.



(a) (b)

Figure D-12: Ratios of Unfactored and Factored Live Load plus Impact Shears for Design Vehicle (LRFR/LFR)

As shown in Figure D-13, the location of the critical section for varies for most girders in this subset. The difference in the factored shears shown in Figure D-12 was exacerbated by the difference in the critical section for shear rating.

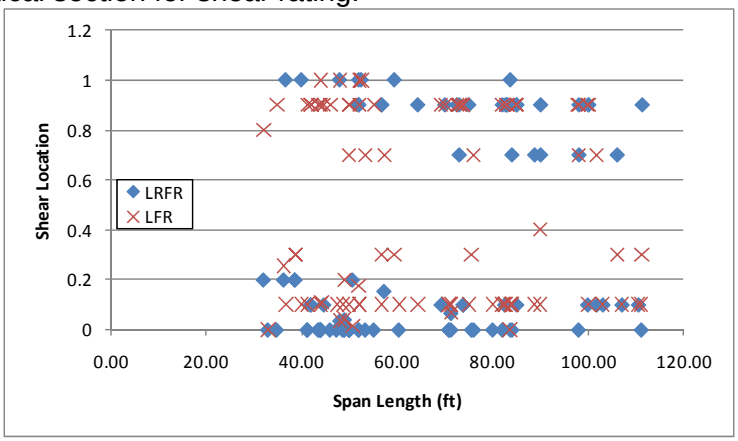


Figure D-13: Graph of critical shear location for Design Vehicle

D.1.2.2.2 Resistance

The next step was to verify that the resistances were reasonable two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure D-14 shows that the ratio of resistance is generally between 1.0 and 2.5, with some higher (LRFR resistance is greater than LFR resistance). The girders with large ratios are likely girders where the critical locations were different between methods. The shear strength depends on the shear reinforcement spacing which varies along the span.

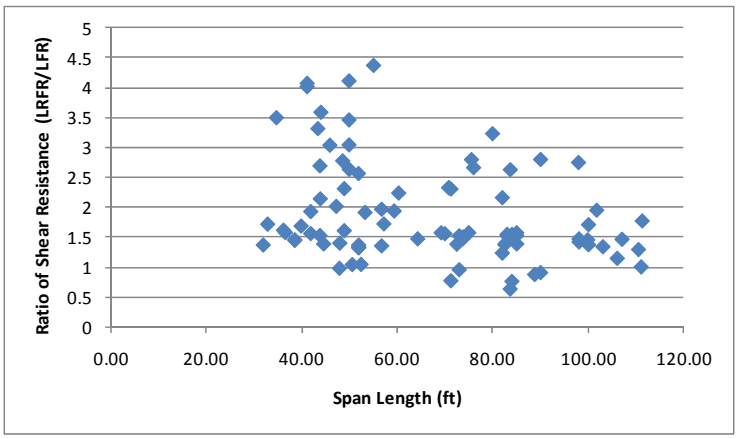
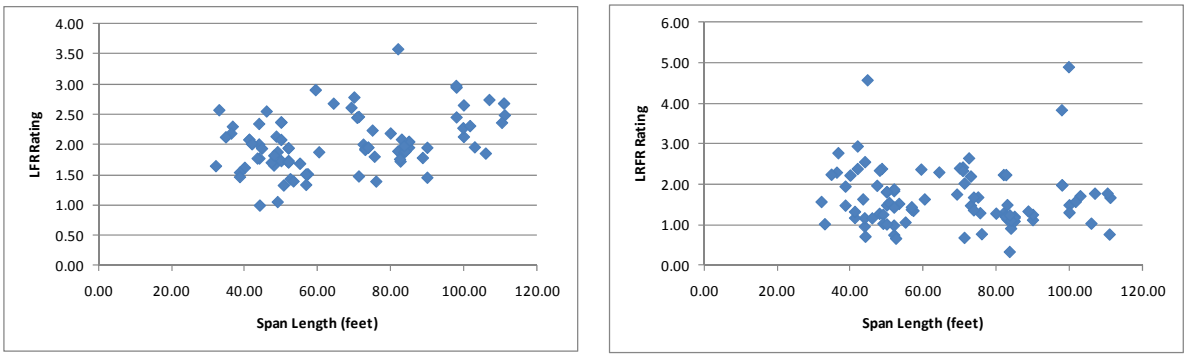


Figure D-14: Ratio of factored Shear Resistance (LRFR/LFR)

D.1.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there is one girder with LFR rating less than 1.0, 11 girders with LRFR ratings less than 1.0, and one girder where both LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. The LFR rating was greater than the LRFR rating for 76% of the girders in this subset. Figure D-15 shows the LFR rating factors and LRFR rating factors. The LFR rating tends to increase with increasing span length, with LRFR remaining relatively constant. The LFR rating is between 1.0 and 2.5 for most girders with the LRFR ratings also in the same range of 1.0 to 2.5.



(a) (b)

Figure D-15: LFR and LRFR Shear Rating Factors for HS-20 and HL-93 Loadings

D.1.2.2.4 Rating Factor Comparisons

Figure D-16 shows the ratio of the LRFR rating to the LFR rating. There are a number of girders with LRFR ratings greater than LFR ratings, but this is about 25% of the girders in the set. The LFR rating increases the LRFR rating does with span length, therefore the ratio decreases with increasing span lengths. Short spans are typically between 0.5 and 1.5 while longer spans are between 0.5 and 1.0.

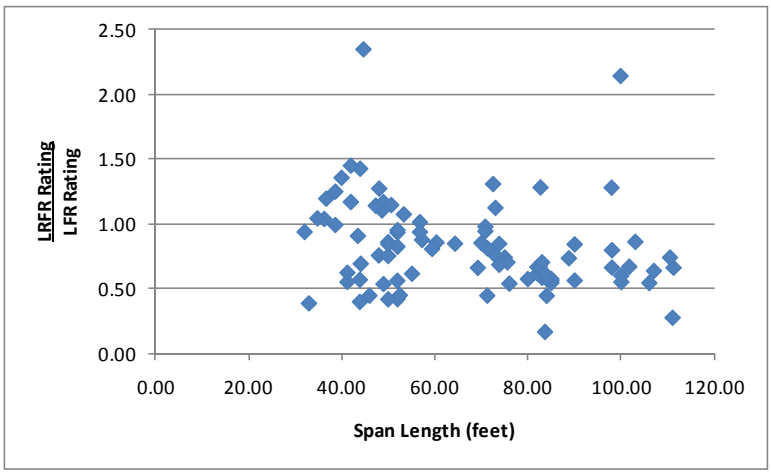


Figure D-16: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Vehicle

Figure D-17 shows the distribution of LRFR/LFR ratio for girders with LRFR ratings less than 1.0. The figure shows that all girders with ratings less than 1.0 have LRFR ratings that are less than 70% of the LFR rating. This is a reduction of at least 30% by switching from LFR to LRFR. The graph does not consider girders whether the LFR rating is less than 1.0 only those with LRFR ratings less than 1.0; some girders may have LFR ratings less than 1.0.

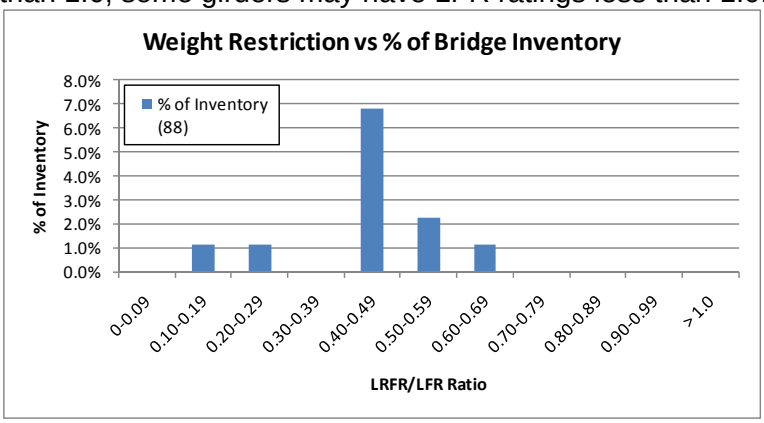


Figure D-17: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

D.1.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure D-18 shows that all but six girders have a reliability index for shear greater than the required level. The girders that do not have the required level of reliability are of varying lengths. In several cases, the reliability index based on the section capacity is less than zero, indicating that either the applied loads are significantly larger than the section resistance or the shear reinforcement was not included in the model.

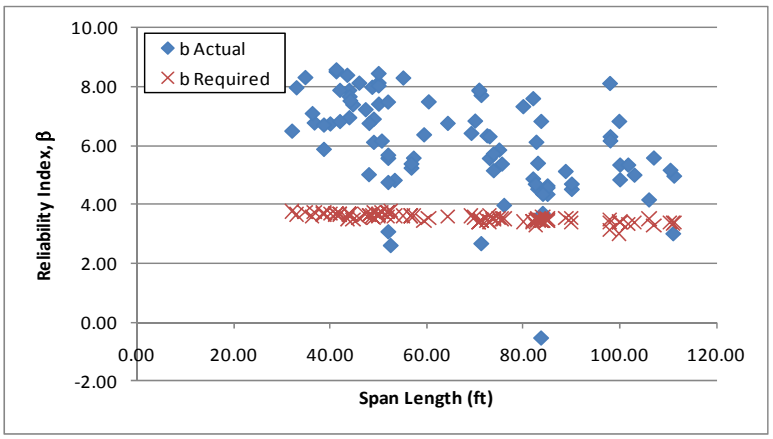


Figure D-18: Shear Reliability Indices for HL-93 Loading

Figure D-19 shows the reliability index plotted against the LRFR rating for shear due to the HL-93 Design Load. The figure shows that girders with a rating of 1.0 have a reliability index of approximately 4.0 which is near the required value shown in Figure D-18. As mentioned for flexure, the original live load factor was determined to be 1.6 but was increased to 1.75 for conservatism this explains the increase in reliability from the expected value of 3.5 to a value closer to 4.0.

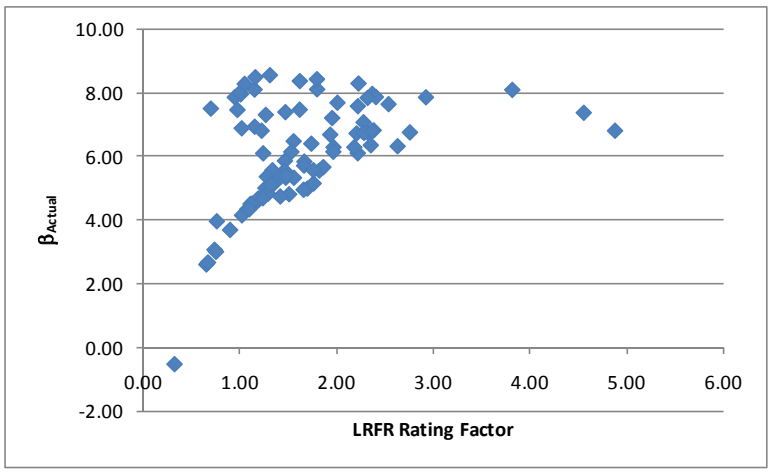
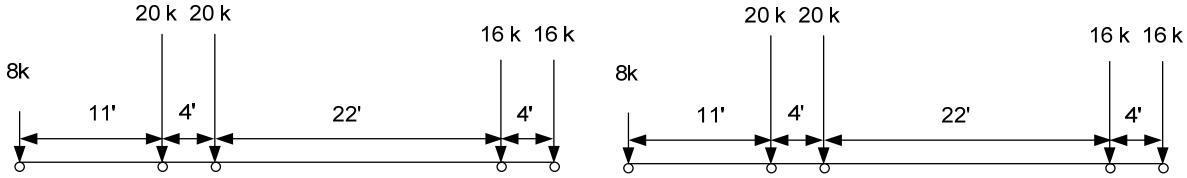


Figure D-19: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

D.1.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-20. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading

plus 0.2 klf for spans greater than 200 feet
LRFR Loading

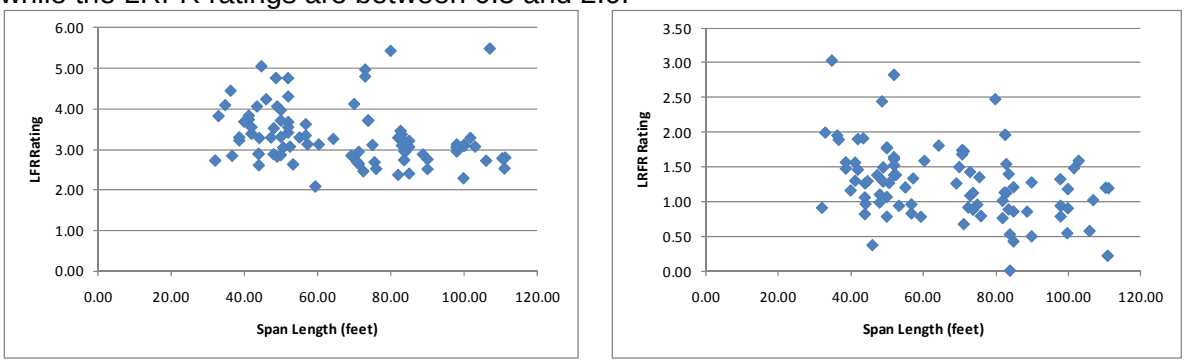
Figure D-20: Vehicle Loadings and Load Factors

D.1.3.1 Moment

The following section contains the results for exterior, composite prestressed box girders within simple span bridges for the DE-07 Vehicle.

D.1.3.1.1 Rating Factors

Figure D-21 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 29 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Six of the 29 girders with LRFR ratings less than 1.0 are controlled by the criteria of AASHTO LRFD 5.8.3.5. The LFR operating rating is greater than the LRFR permit rating for 98% of the girders in this subset. Longer spans typically have lower ratings than shorter spans. The LFR ratings are generally between 2 and 5 while the LRFR ratings are between 0.5 and 2.0.



(a) (b)

Figure D-21: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure D-22 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows a significant number of girders will be negatively affected by switching from LFR to LRFR. 30% of girders will have LRFR ratings less than 1.0 for the lowest traffic level of ADTT = 100. For ADTT = 1,000 and 5,000, more than 30% of girders have LRFR ratings less than 1.0.

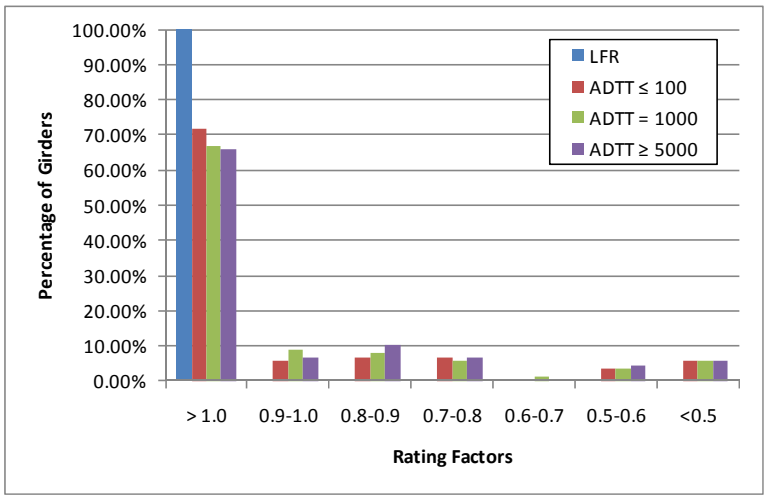


Figure D-22: Flexure Ratings for Various ADTTs in MBE for DE-07 Vehicle

D.1.3.1.2 Rating Factor Comparisons

Figure D-23 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.2 to 0.6. The ratio decreases slightly with increasing span lengths.

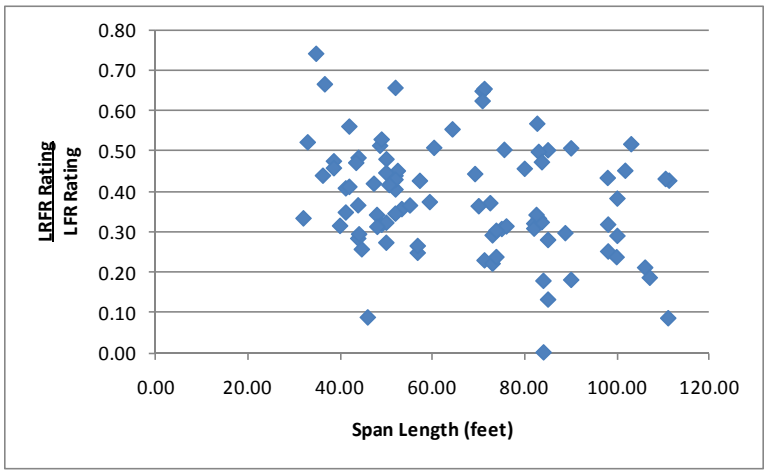


Figure D-23: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

D.1.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-24 shows that a quarter of the girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is above six for girders less than forty feet in length and decreases to less than two for girders greater than eighty feet in length.

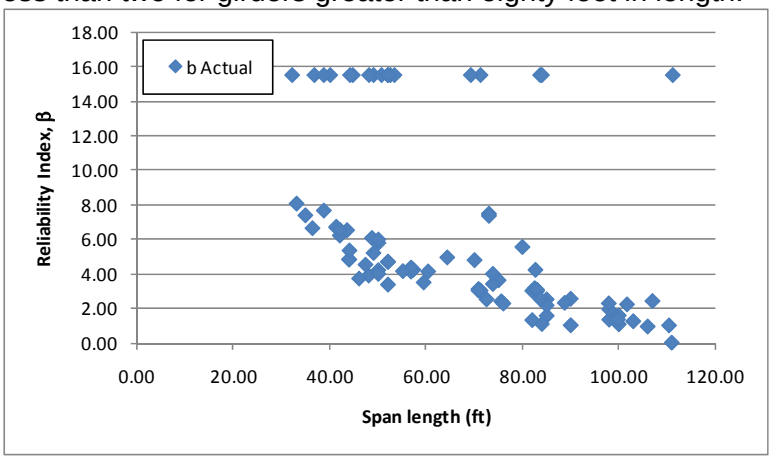


Figure D-24: Flexure Reliability Indices for DE-07 Vehicle

Figure D-25 shows the reliability index plotted against the LRFR rating factor for flexure due to the DE-07 vehicle. The figure shows that girders exist with passing ratings and low reliability. The target reliability index of 2.5 is exceeded for girders with ratings of 1.0 if the middle of the data is used but if the bottom edge of the data is used the target reliability is not achieved.

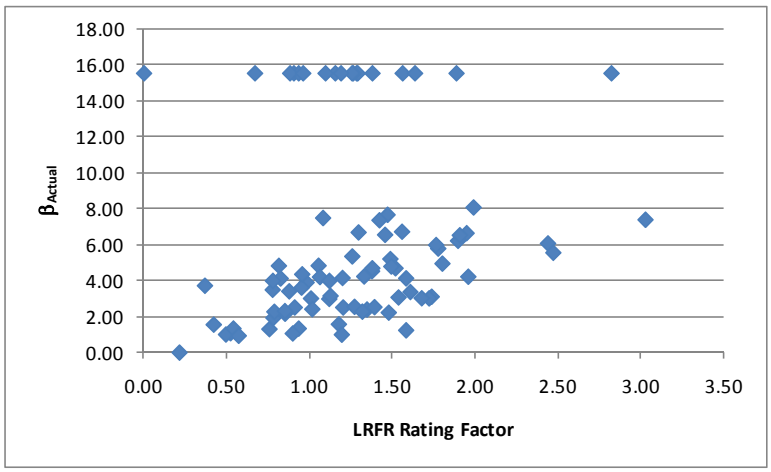
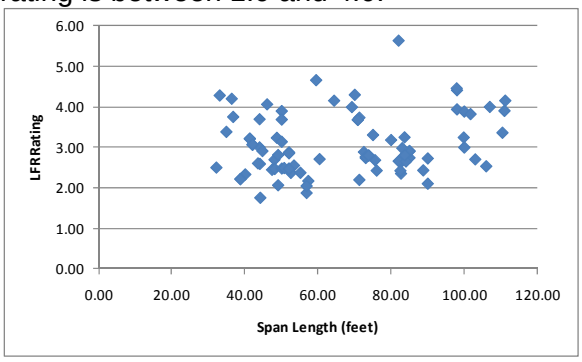


Figure D-25: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

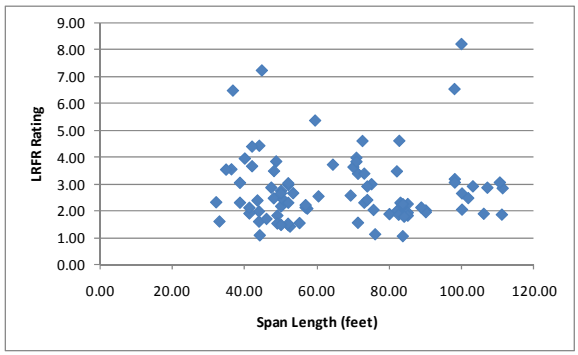
D.1.3.2 Shear

D.1.3.2.1 Rating Factors

For shear, there are zero girders with a rating less than 1.0 for either method. The LFR rating is greater than the LRFR rating for 69% of the girders in this subset. Figure D-26 shows the LFR and LRFR ratings. The LFR rating is between 2.0 and 4.0 for most girders while the LRFR rating is between 1.0 and 4.0.



(a)



(b)

Figure D-26: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure D-27 shows the distribution of LRFR shear ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows a small number of girders will be negatively affected by switching from LFR to LRFR. 2% of girders will have LRFR ratings less than 1.0 for the ADTT = 5,000. Zero girders have LRFR ratings less than 1.0 for ADTT = 100 and ADTT = 1,000.

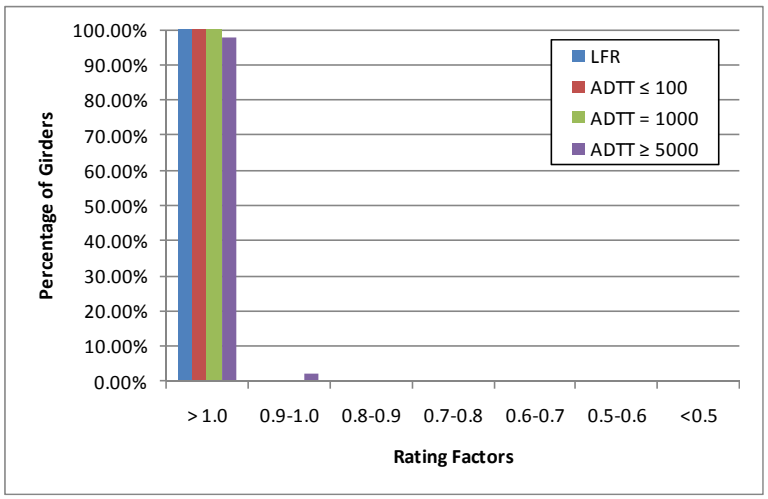


Figure D-27: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

D.1.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure D-28 shows the comparison of rating factors. Approximately 30% of the girders have ratios greater than 1.0; these are typically girders with shorter spans. Longer spans typically have greater LFR ratings, this results in a lower ratio as shown in the figure. The ratio of ratings is typically between 0.5 and 1.0 with shorter girders also having ratios between 1.0 and 1.5.

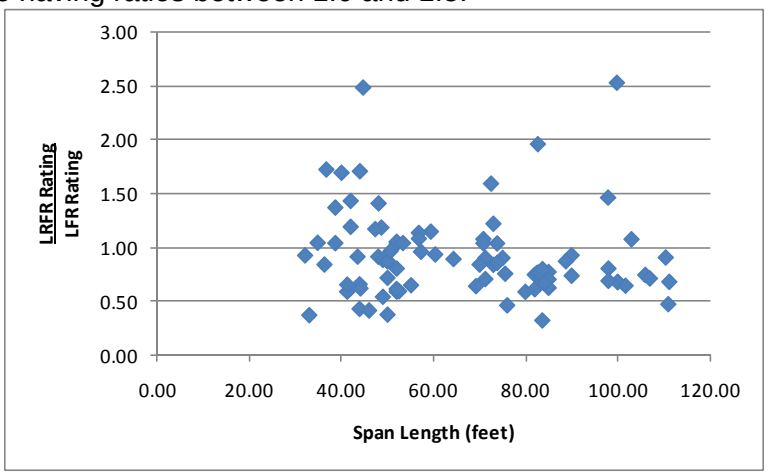


Figure D-28: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

D.1.3.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-29. The reliability index based on section resistance decreases with increasing span length. The reliability index is between six and nine for this group of girders. The lower reliability index corresponds to longer spans and higher reliability index corresponds to shorter spans.

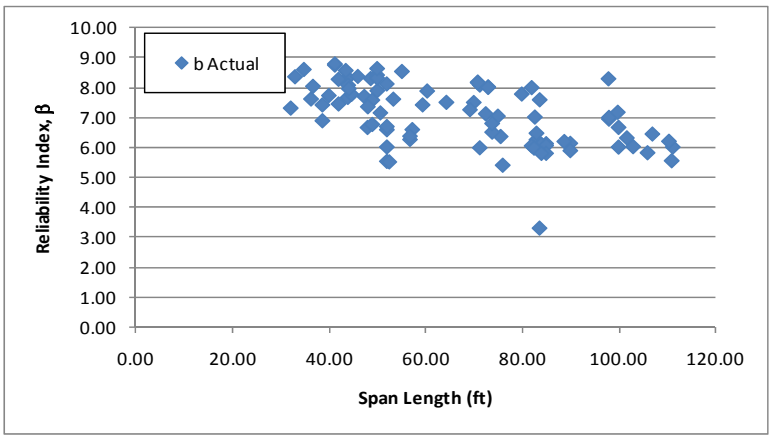


Figure D-29: Shear Reliability Indices for DE-07 Vehicle

Figure D-30 shows the reliability index plotted against the LRFR rating for shear due to the DE-07 vehicle. The figure shows that the girder with the lowest reliability, approximately 3.25, has a rating above 1.0. The reliability for most girders is above 5.0 which is well above the target reliability of 2.5. This suggests that for shear lower load factors can be used and maintain the target reliability.

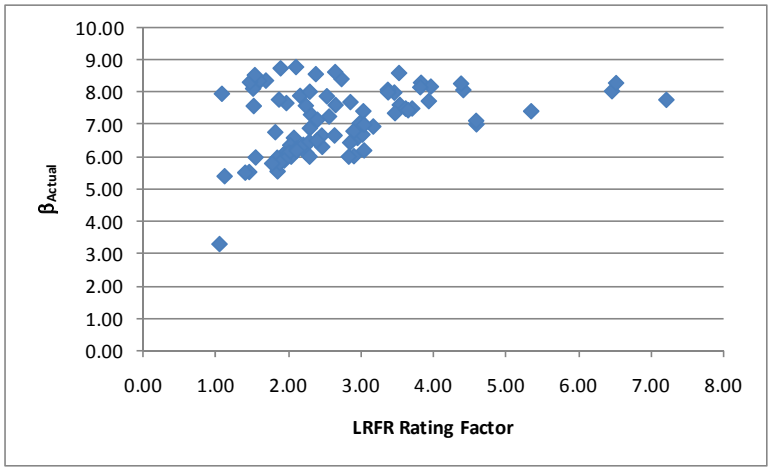


Figure D-30: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

D.1.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-31. The applicable load factors for this vehicle are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

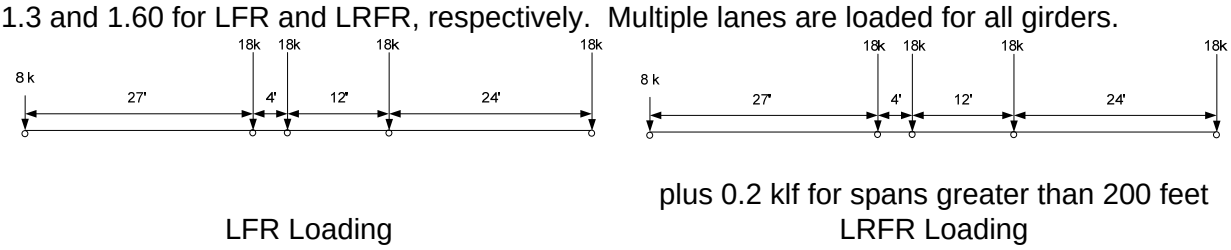


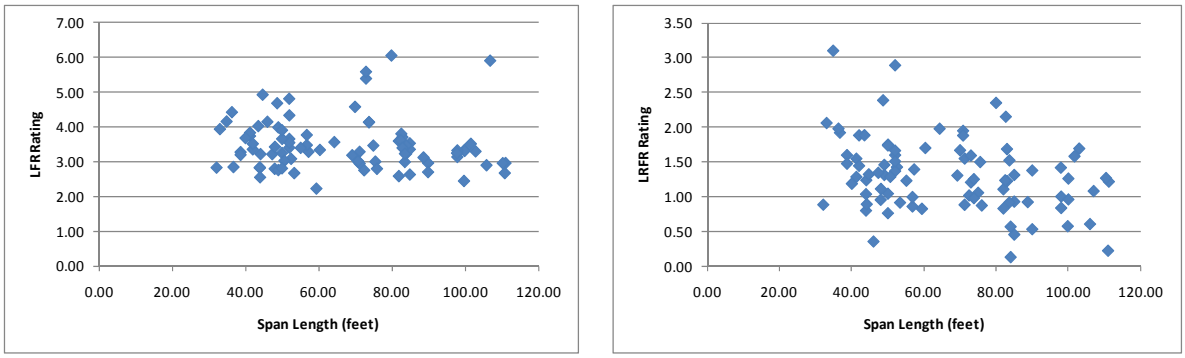
Figure D-31: Vehicle Loadings and Load Factors

D.1.4.1 Moment

The following section contains the results for exterior, composite prestressed box girders within simple span bridges for the FL-04 Vehicle.

D.1.4.1.1 Rating Factors

Figure D-32 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 26 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 98% of the girders in this subset. Both ratings decrease with increasing span length, with the LRFR rating having a larger decrease than the LFR rating. 20% of the girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel requirements of AASHTO LRFD 5.8.3.5.



(a) (b)

Figure D-32: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure D-33 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows a significant number of girders will be negatively affected by switching from LFR to LRFR. 25% of girders will have LRFR ratings less than 1.0 for the lowest traffic level of ADTT = 100. For ADTT = 1,000 and 5,000, 30% and 31% of girders have LRFR ratings less than 1.0, respectively.

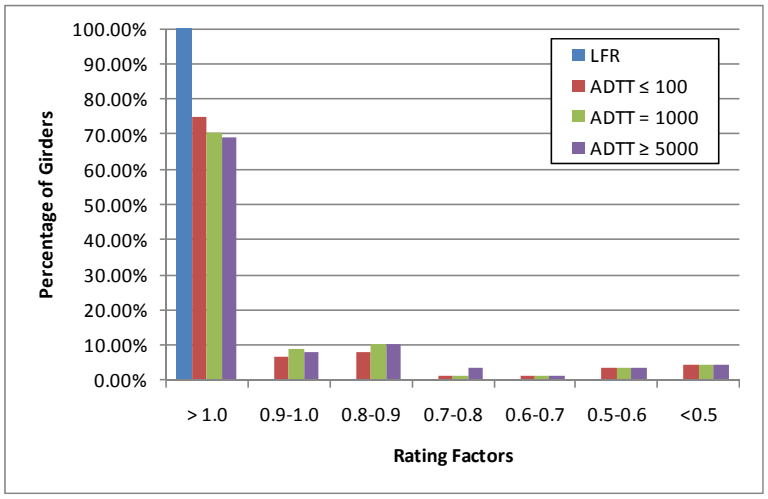


Figure D-33: Flexure Ratings for Various ADTTs in MBE for FL-04 Vehicle

D.1.4.1.2 Rating Factor Comparisons

Figure D-34 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. There are zero girders with LRFR ratings greater than LFR rating. The LRFR rating is typically 20 to 60% of the LFR rating, with shorter spans having higher ratios of ratings.

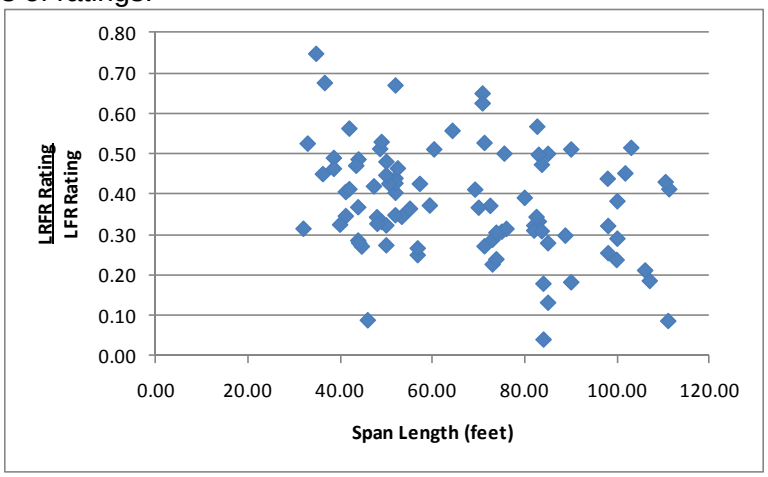


Figure D-34: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

D.1.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-35 shows that 17 girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The actual reliability index decreases with increasing span length.

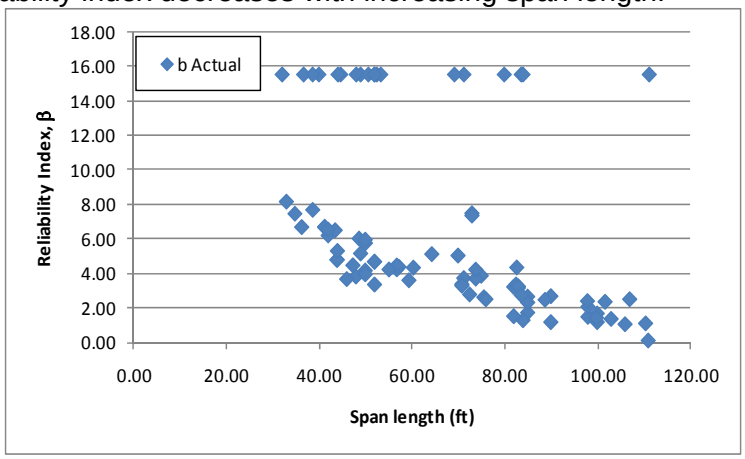


Figure D-35: Flexure Reliability Indices for FL-04 Vehicle

Figure D-36 shows the reliability index plotted against the LRFR rating factor for moment due to the FL-04 vehicle. The figure shows that the average reliability index for a girder with a rating of 1.0 is between 3.0 and 3.5, above the target reliability of 2.5. This indicates the target reliability can be maintained but lower live load factors could be used.

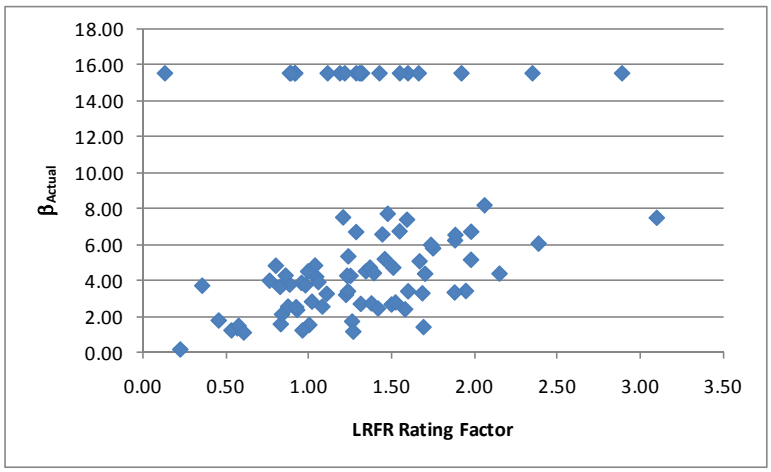
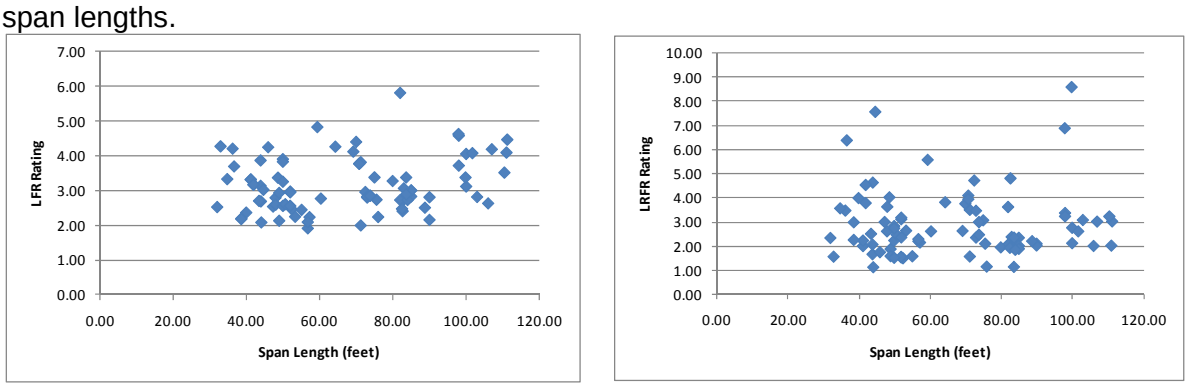


Figure D-36: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

D.1.4.2 Shear

D.1.4.2.1 Rating Factors

For shear, there are no girders with either an LFR rating or LRFR rating less than 1.0 for shear. The LFR Rating is greater than the LRFR rating for 69% of the girders in this subset. Figure D-37 shows the LFR and LRFR ratings, respectively. The LFR ratings are generally between 2.0 and 4.0 for all span lengths while the LRFR ratings are generally between 1.0 and 4.0 for all span lengths.



(a) (b)

Figure D-37: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure D-38 shows the distribution of LRFR shear ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows zero girders will be negatively affected by switching from LFR to LRFR.

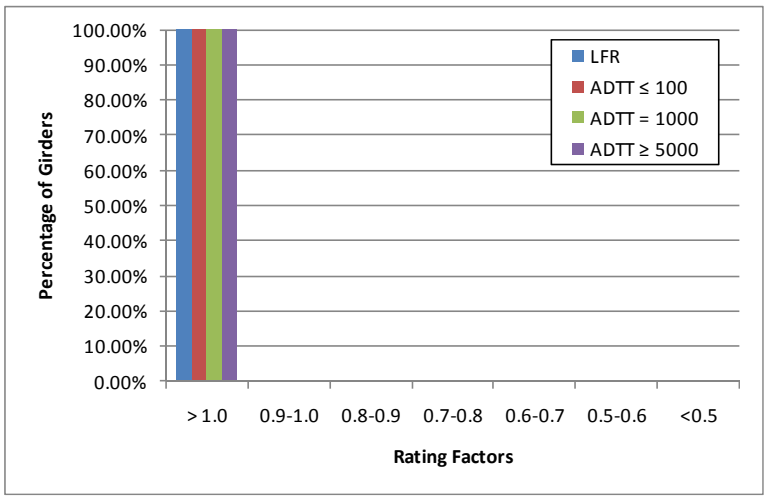


Figure D-38: Shear Rating for Various ADTTs in MBE for FL-04 Vehicle

D.1.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-39 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with the ratio decreasing for longer span lengths. 31% of girders in this group have LRFR ratings that are greater than the LFR rating.

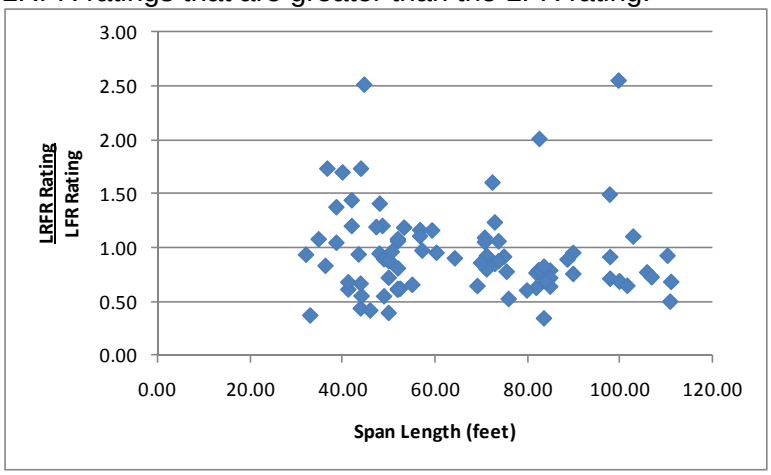


Figure D-39: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

D.1.4.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-40. There is one girder where reliability index is low. The shear reinforcement is most likely not defined in the file for this bridge.

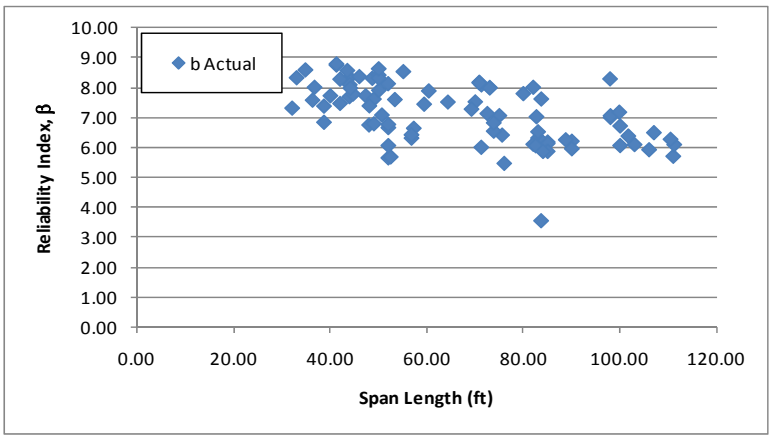


Figure D-40: Shear Reliability Indices for FL-04 Vehicle

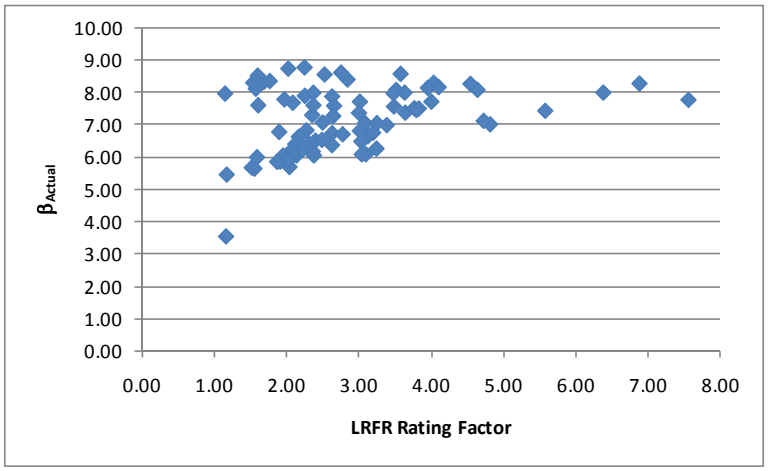


Figure D-41: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

D.1.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-42. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

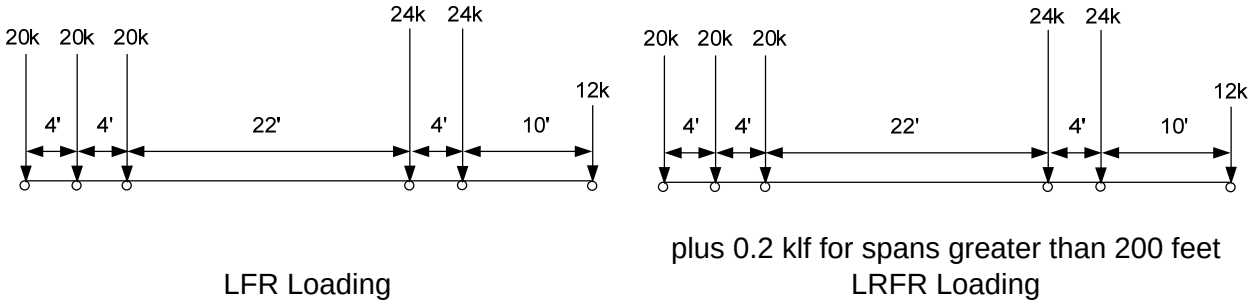


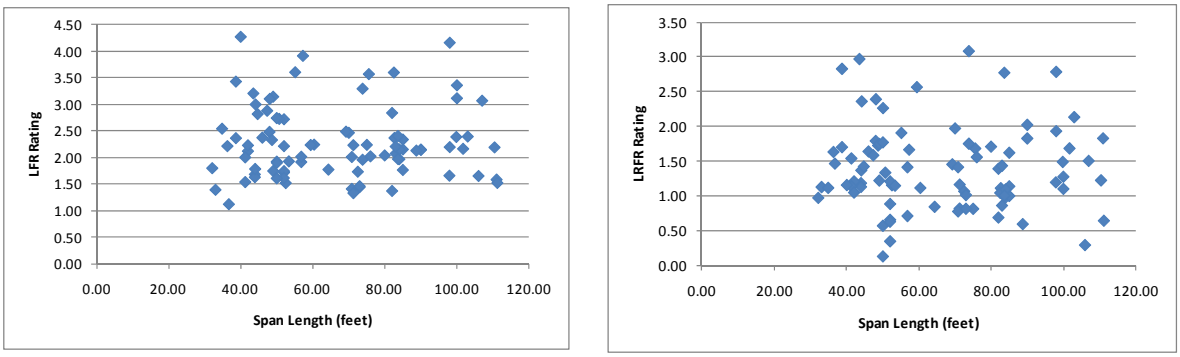
Figure D-42: Vehicle Loadings and Load Factors

D.1.5.1 Moment

The following section contains the results for exterior, composite prestressed box girders within simple span bridges for the IL-01 Vehicle.

D.1.5.1.1 Rating Factors

Figure D-43 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 20 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 94% of the girders in this subset. The both ratings tend to decrease with increasing span length. None of the girders with LRFR ratings less than 1.0 were controlled by longitudinal steel requirements of AASHTO LRFD 5.8.3.5.



(a) (b)

Figure D-43: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure D-44 shows the distribution of LRFR moment ratings for the different permit categories in the MBE for special permit vehicles. The figure shows that a significant number of girders will be negatively affected by switching from LFR to LRFR. 23% of girders will have LRFR ratings less than 1.0 for the first three special permit categories, 24% for the fourth and fifth categories, and 25% for the last two categories. All girders have LFR ratings greater than 1.0.

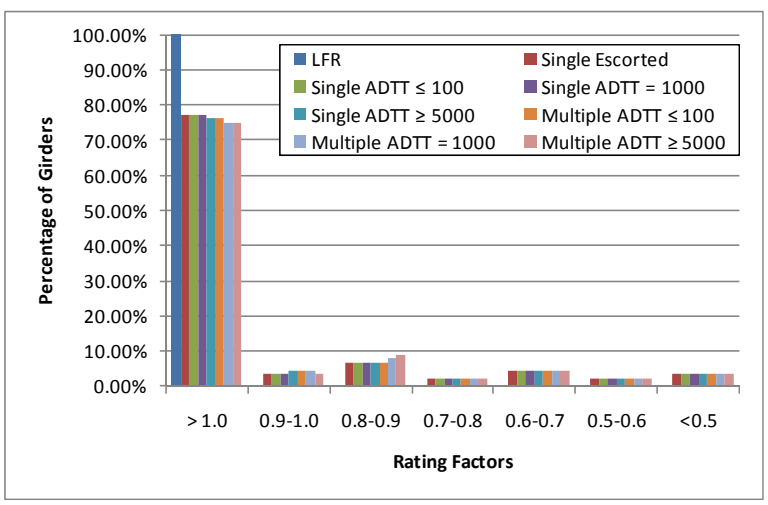


Figure D-44: Flexure Rating for Various ADTTs in MBE for IL-01 Vehicle

D.1.5.1.2 Rating Factor Comparisons

Figure D-45 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.8,with five girders having LRFR ratings greater than the LFR rating.

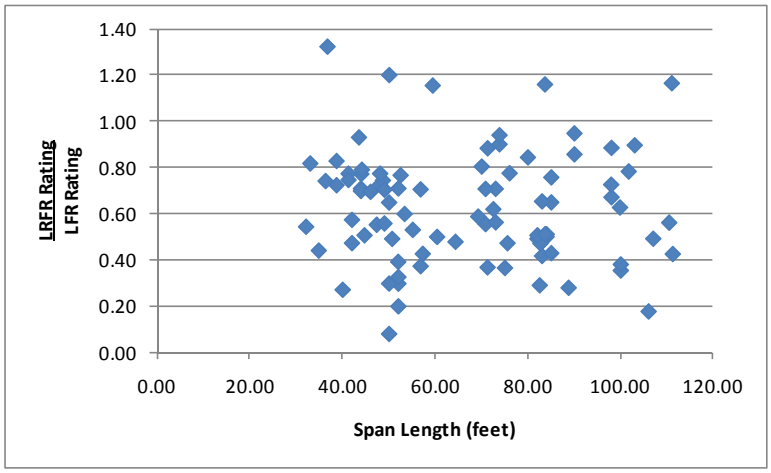


Figure D-45: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

D.1.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-46 shows that 18 girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index for longer spans is less than that of the shorter spans.

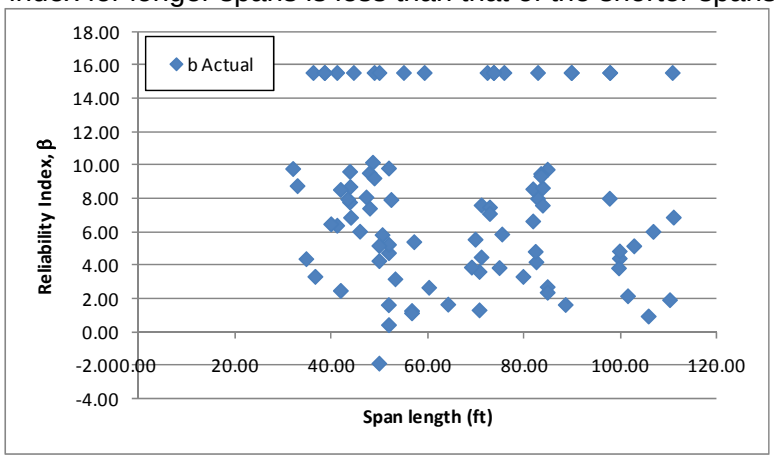


Figure D-46: Flexure Reliability Indices for IL-01 Vehicle

Figure D-47 shows the reliability index plotted against the LRFR rating for moment caused by the IL-01 vehicle. The reliability index for girders with a rating of 1.0 is approximately 5 at the middle of the scatter. This is above the target reliability index of 3.5. Lower live load factors may be used to bring the average reliability of a girder passing rating nearer to the target reliability.

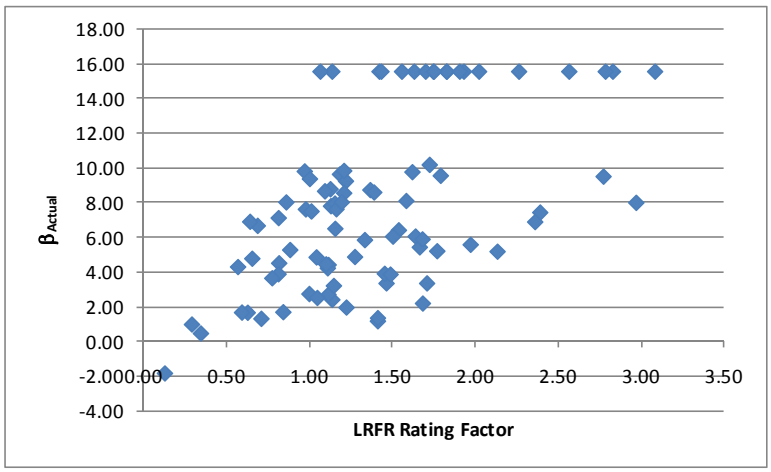
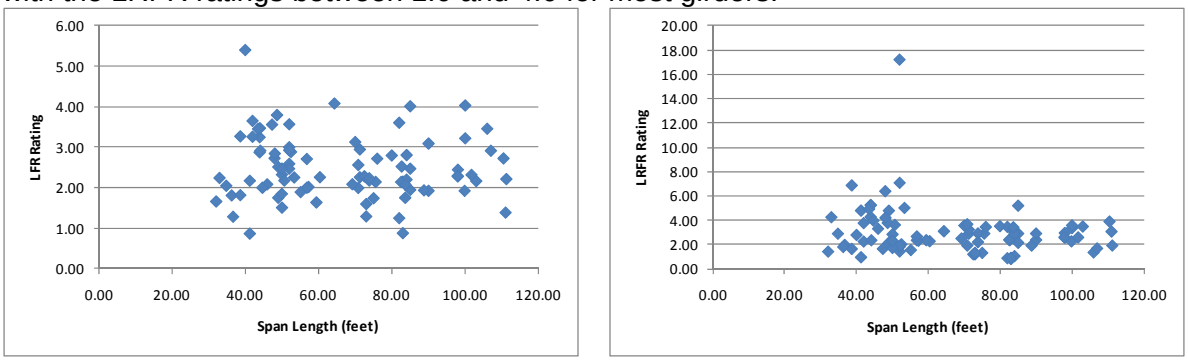


Figure D-47: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

D.1.5.2 Shear

D.1.5.2.1 Rating Factors

For shear, there are two girders that have LFR rating factors less than 1.0, four girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 42% of the girders in this subset. Figure D-48 shows the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 3.0 for all span lengths with the LRFR ratings between 1.0 and 4.0 for most girders.



(a) (b)

Figure D-48: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure D-49 shows the distribution of LRFR shear ratings for the different ADTT categories in the MBE for special permit vehicles. The figure shows a generally small number of girders will be negatively affected by switching from LFR to LRFR. 1% of girders have an LRFR single escorted rating greater than the LFR rating. Most permit types though have between 5 and 12% of girders with LRFR ratings less than 1.0. The multiple trip permit with an ADTT = 5,000 has the most girders with LRFR ratings less than 1.0.

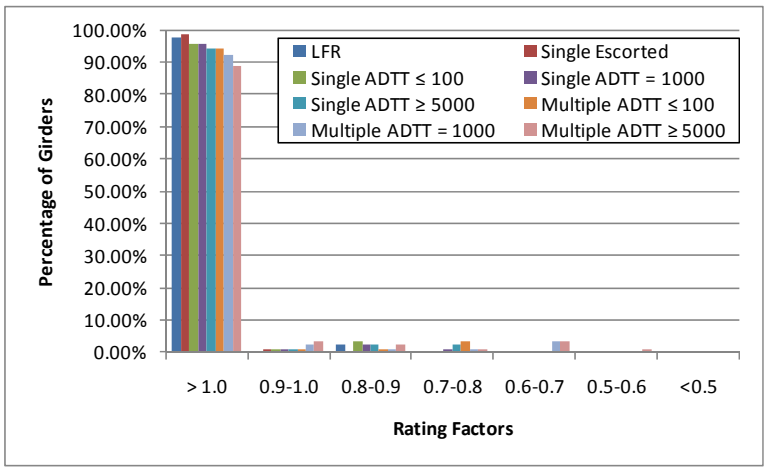


Figure D-49: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

D.1.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-50 shows the comparison of rating factors. The ratio is greater than 1.0 for most girders under 60 feet while girders longer than 60 feet are split equally above and below 1.0.

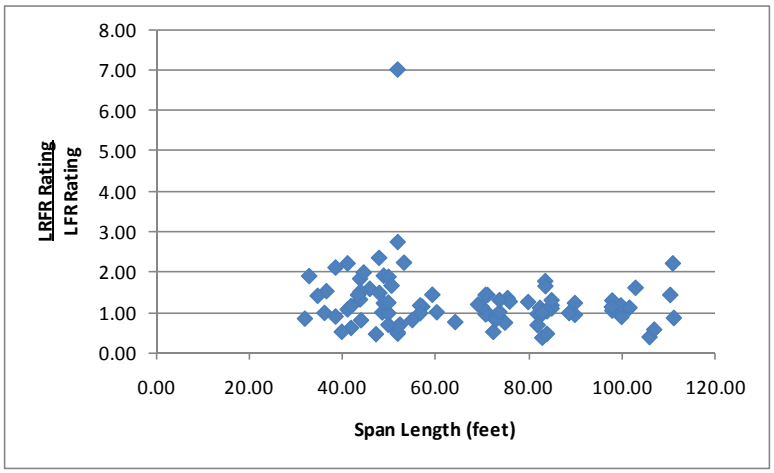


Figure D-50: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

D.1.5.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index for all but two girders as shown in Figure D-51. The reliability index is between six and nine for most girders with several girders being less than five.

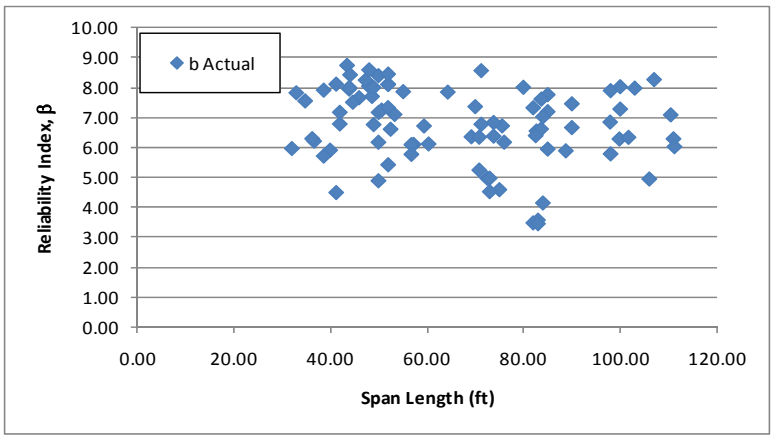


Figure D-51: Shear Reliability Indices for IL-01 Vehicle

Figure D-52 shows the reliability index plotted against the LRFR rating for shear due to the IL-01 Vehicle. The figure shows that girders with a passing rating have a reliability index very close to 3.5, the target reliability index. This indicates that the current load factors in the MBE for special permits provide the target level of reliability.

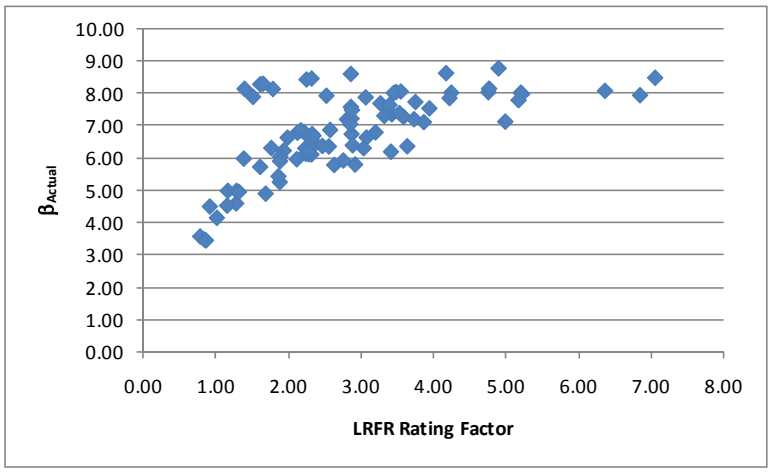
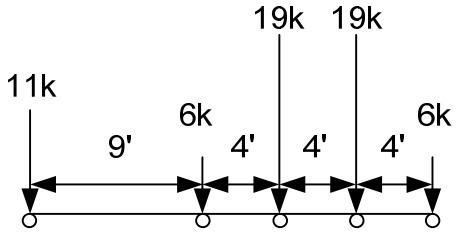


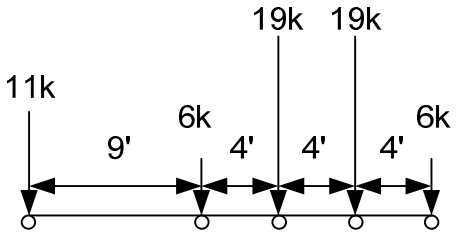
Figure D-52: Shear Reliabilty Index vs LRFR Shear Rating for IL-01 Vehicle

D.1.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-53. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet

LRFR Loading

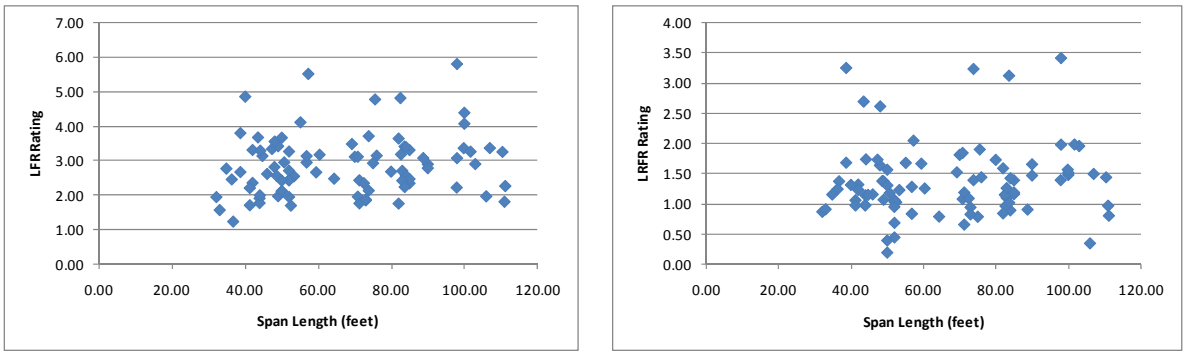
Figure D-53: Vehicle Loadings and Load Factors

D.1.6.1 Moment

The following section contains the results for exterior, composite prestressed box girders within simple span bridges for the NC-21 Vehicle.

D.1.6.1.1 Rating Factors

Figure D-54 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 23 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. The LFR rating remains relatively constant with increasing span length while the LRFR rating remains fairly constant but decreases slightly with increasing span length. Only one of the 23 girders with LRFR ratings less than 1.0 is controlled by the longitudinal steel requirement of AASHTO LRFD 5.8.3.5.



(a) (b)

Figure D-54: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure D-55 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows a significant number of girders will be negatively affected by switching from LFR to LRFR. 25% of girders will have LRFR ratings less than 1.0 for an ADTT = 100, with a maximum of 27% of girders having an LRFR rating less than 1.0 for ADTT = 5,000. All girders have LFR ratings greater than 1.0.

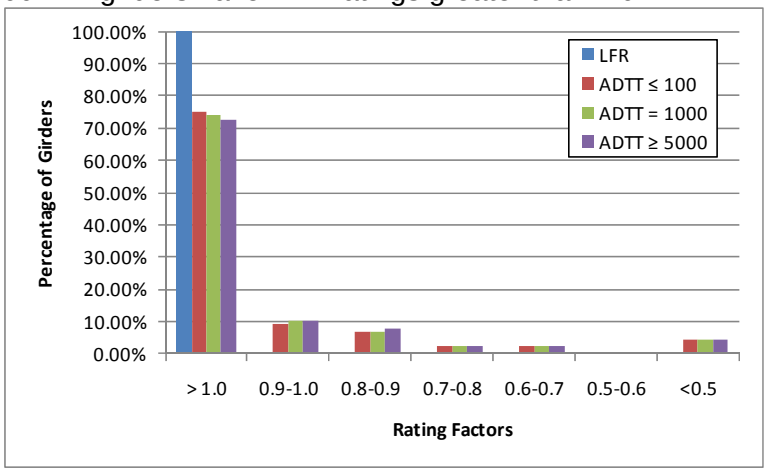


Figure D-55: Flexure Rating for Various ADTTs in MBE for NC-21 Vehicle

D.1.6.1.2 Rating Factor Comparisons

Figure D-56 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating; there is one girder with an LRFR rating greater than the LFR rating in this group. The ratio is generally between 0.2 and 0.6 for this vehicle.

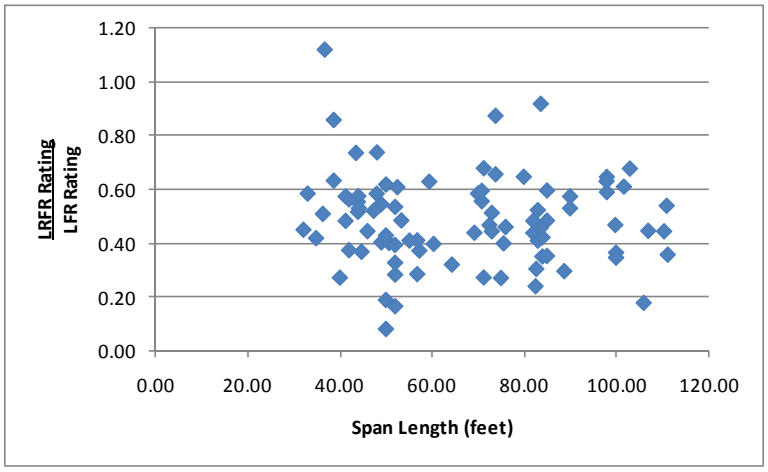


Figure D-56: LRFR Shear rating divided by LFR Shear rating for NC-21 Vehicle

D.1.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-57 shows that eleven girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index varies widely for girders of the same length but is typically between two and eight.

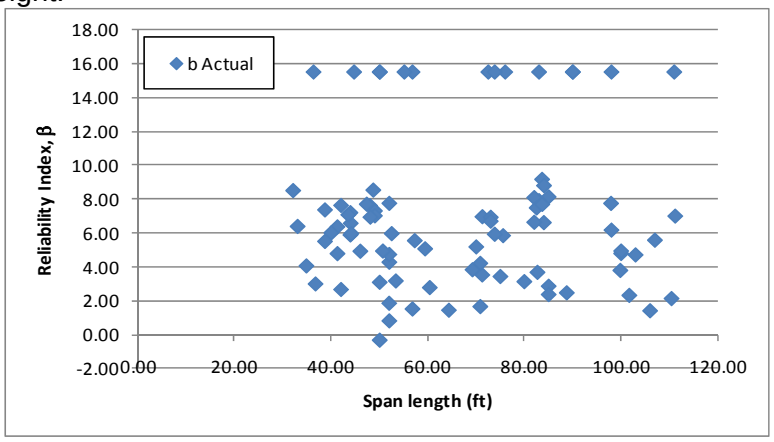


Figure D-57: Flexure Reliability Indices for NC-21 Vehicle

Figure D-58 shows the reliability index plotted against the LRFR rating for moment due to the NC-21 vehicle. The figure shows the average reliability index for girders passing rating to be approximately 4.0 which is above the target reliability index of 2.5. This indicates the target reliability can be obtained using lower LRFR live load factors.

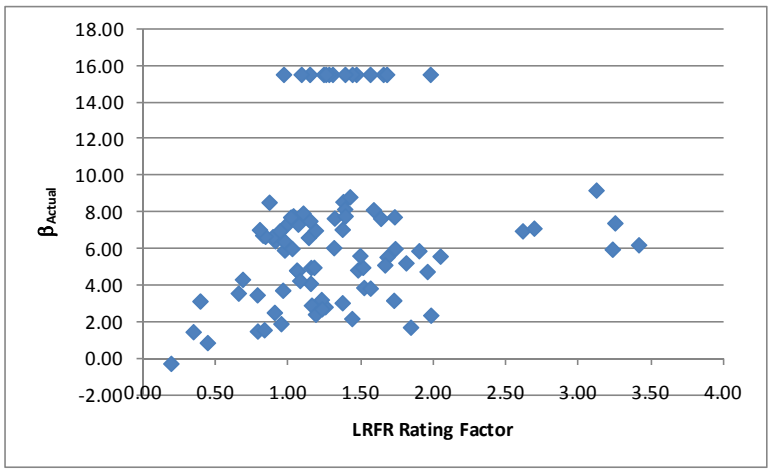
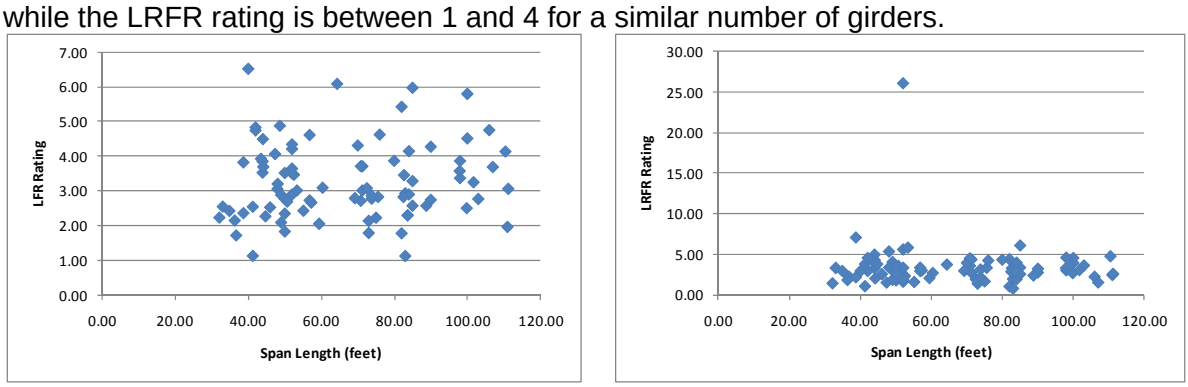


Figure D-58: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

D.1.6.2 Shear

D.1.6.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, one girder with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 55% of the girders in this subset. Figure D-59 shows the LFR and LRFR ratings, respectively. The LFR rating is between 2 and 5 for most girders while the LRFR rating is between 1 and 4 for a similar number of girders.



(a) (b)

Figure D-59: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure D-60 shows the distribution of LRFR shear ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows a small number of girders will be negatively affected by switching from LFR to LRFR. Less than 4% of girders will have LRFR ratings less than 1.0 for the for all traffic levels. All girders have LFR ratings greater than 1.0.

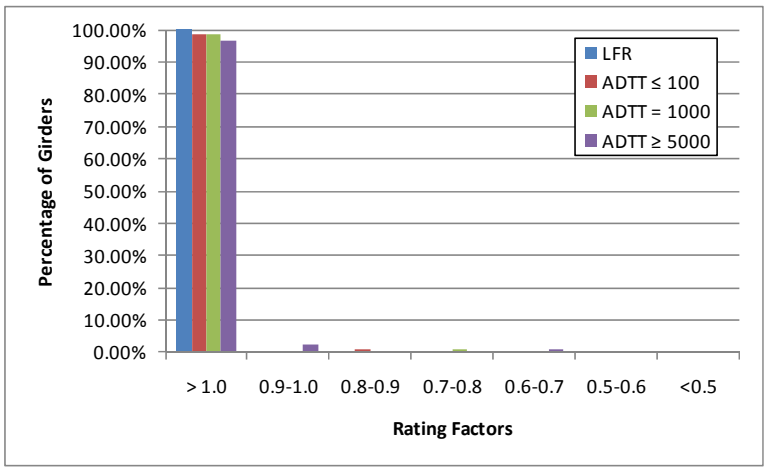


Figure D-60: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

D.1.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-61 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5. Shorter span girders are the most likely to have an LRFR rating greater than the LFR rating.

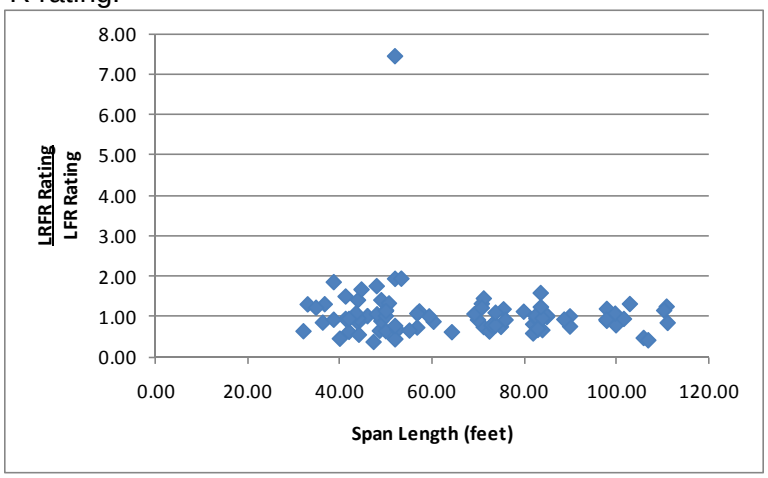


Figure D-61: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

D.1.6.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-62. The reliability index is between six and nine for most girders with two girders having a reliability index less than five.

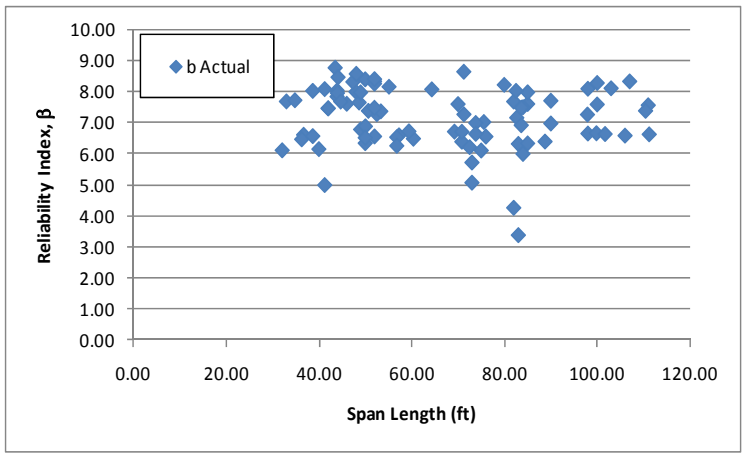


Figure D-62: Shear Reliability Indices for NC-21 Vehicle

Figure D-63 shows the reliability index plotted against the LRFR rating factor for shear due to the NC-21 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index between three and four which is greater than the target reliability of 2.5. This indicates the target reliability index can be achieved while using lower live load factors than currently in the MBE.

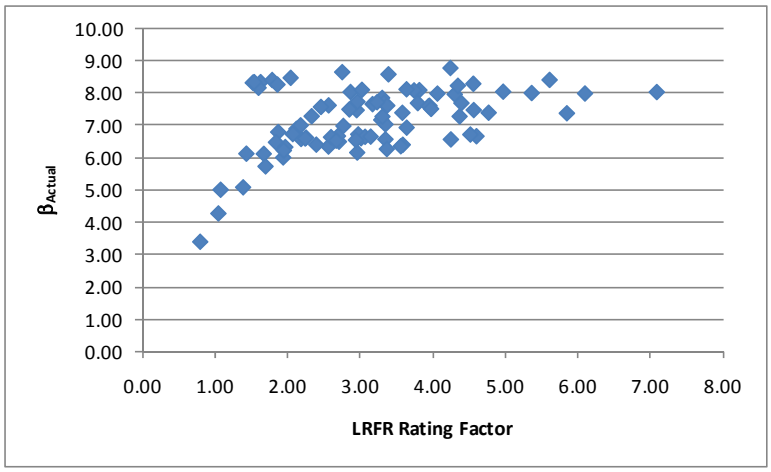


Figure D-63: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

D.1.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-64. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

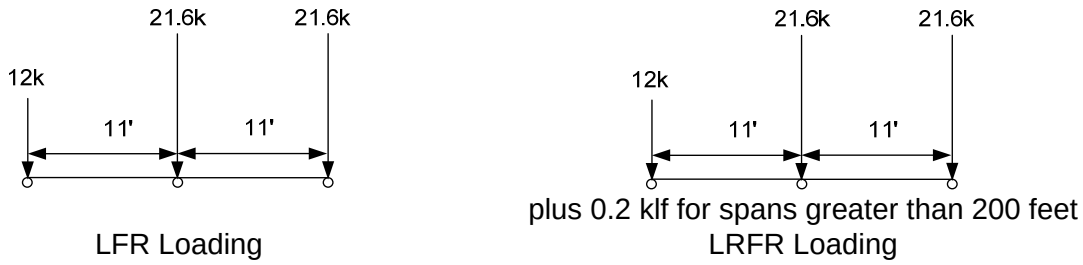


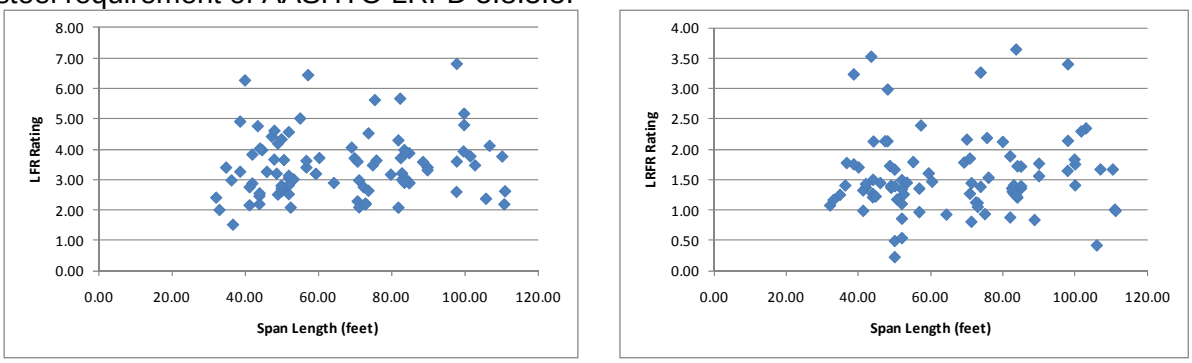
Figure D-64: Vehicle Loadings and Load Factors

D.1.7.1 Moment

The following section contains the results for exterior, composite prestressed box girders within simple span bridges for the NM-04 Vehicle.

D.1.7.1.1 Rating Factors

Figure D-65 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 13 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. The LFR rating is between two and five for most girders while the LRFR rating is typically between 1.0 and 2.0. One of the thirteen girders with an LRFR rating less than 1.0 was controlled by the longitudinal steel requirement of AASHTO LRFD 5.8.3.5.



(a) (b)

Figure D-65: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure D-66 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows a number of girders will be negatively affected by switching from LFR to LRFR. 14% of girders will have LRFR ratings less than 1.0 for an ADTT = 100; this will increase to 17% for ADTT = 5,000. All girders have LFR ratings greater than 1.0.

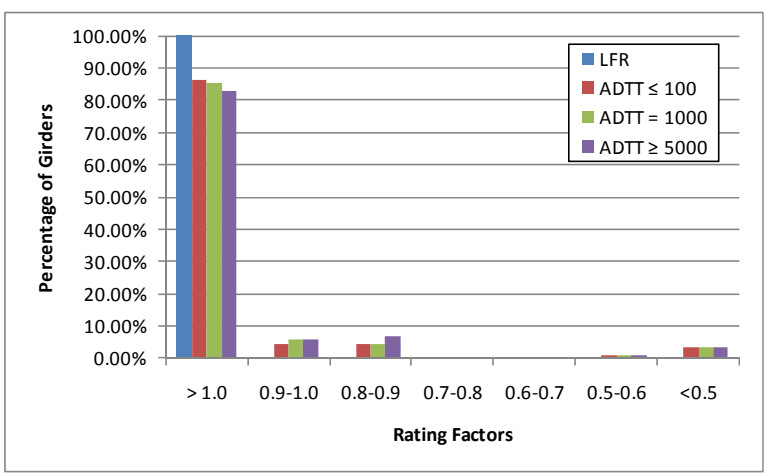


Figure D-66: Flexure Ratings for Various ADTTs in MBE for NM-04 Vehicle

D.1.7.1.2 Rating Factor Comparisons

Figure D-67 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6, with one girder having a LRFR rating greater than the LFR rating.

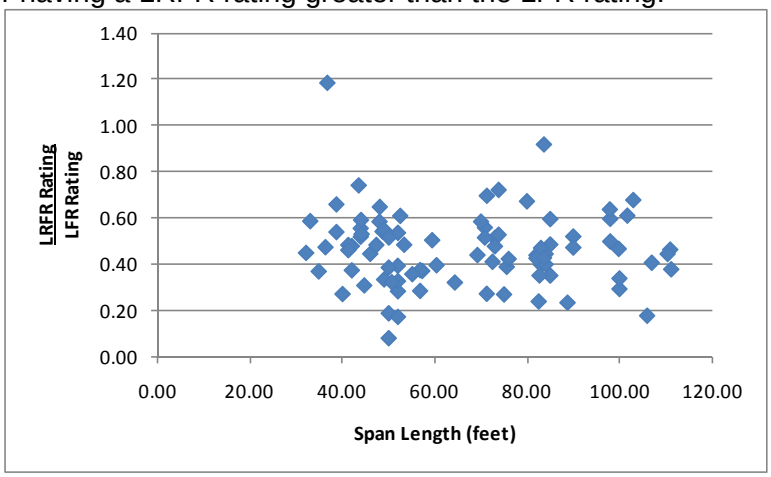


Figure D-67: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

D.1.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-68 shows that nine girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index for moment is scattered between two and ten for most girders.

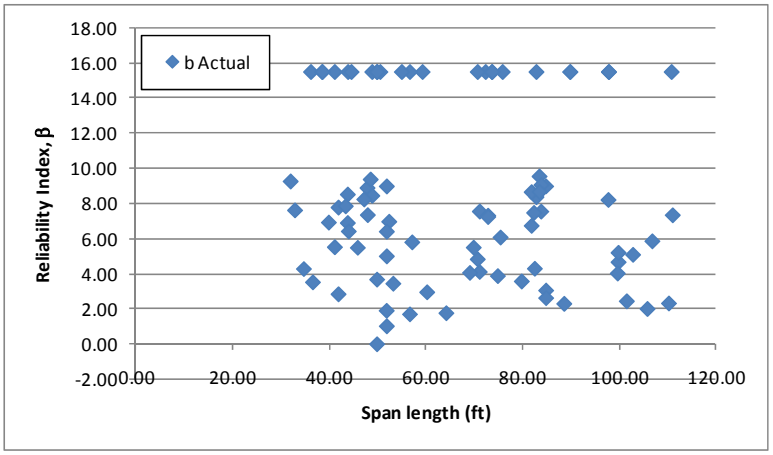


Figure D-68: Flexure Reliability Indices for NM-04 Vehicle

Figure D-69 shows the reliability index plotted against the LRFR rating for moment due to the NM-04 vehicle. The figure shows that for girders with a rating close to 1.0, the reliability varies from two to seven with the average reliability being about 4.5. This is above the target reliability of 2.5 indicating the target reliability can be achieved using load factors lower than those currently in the MBE.

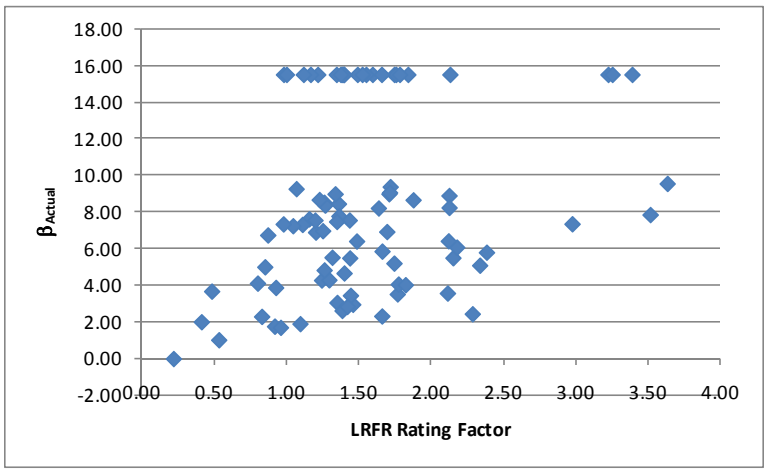
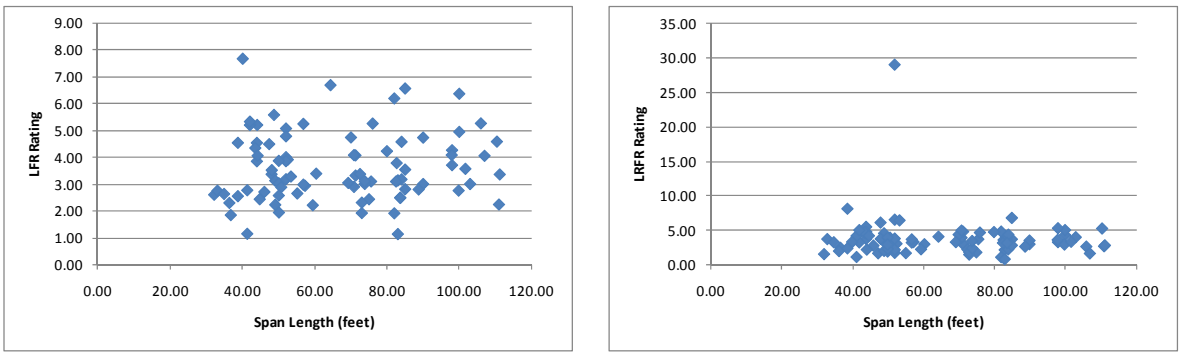


Figure D-69: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

D.1.7.2 Shear

D.1.7.2.1 Rating Factors

For shear, there is one girder with an LRFR shear rating less than 1.0. The LFR Rating is greater than the LRFR rating for 52% of the girders in this subset. Figure D-70 shows the LFR and LRFR ratings. The LFR ratings are between two and five for most girders while LRFR ratings are between one and five for most girders.



(a) (b)

Figure D-70: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure D-71 shows the distribution of LRFR shear ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows a small number of girders will be negatively affected by switching from LFR to LRFR. A maximum of 2% of girders will have LRFR ratings less than 1.0 for the for all traffic levels. All girders have LFR ratings greater than 1.0.

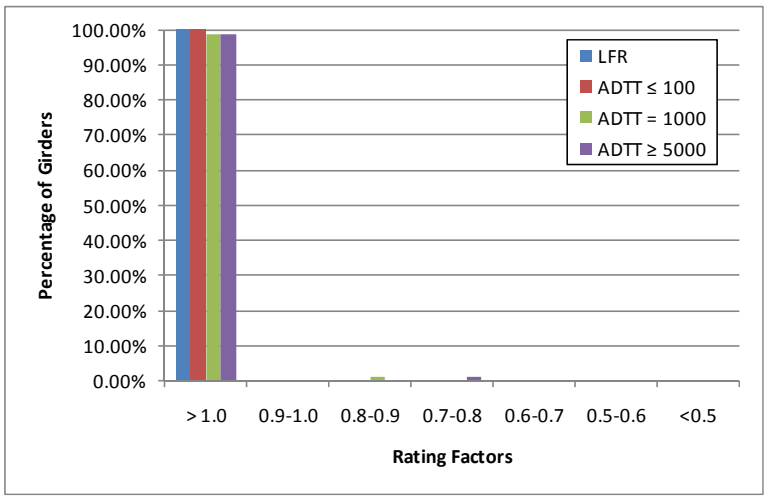


Figure D-71: Shear Rating for Various ADTTs in MBE for NM-04 Vehicle

D.1.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-72shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0 with shorter spans are more likely to have LRFR ratings greater than LFR ratings.

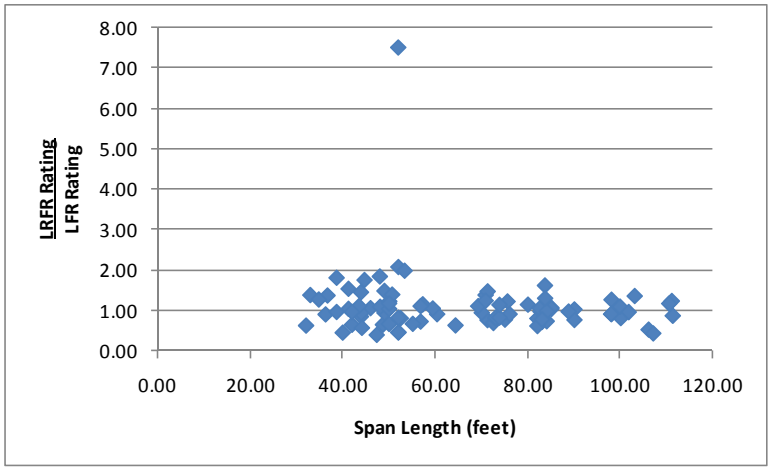


Figure D-72: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

D.1.7.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-73. The reliability index is between six and nine for most girders with several outside this range.

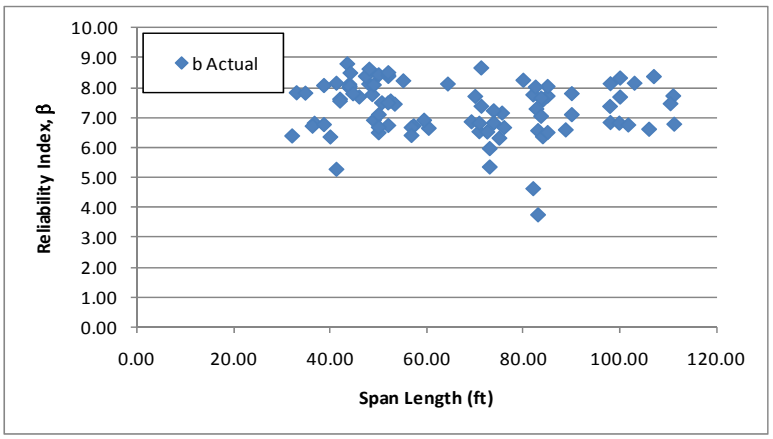


Figure D-73: Shear Reliability Indices for NM-04 Vehicle

Figure D-74 shows the shear reliability index plotted against the LRFR shear rating for the NM-04 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index above 3.5. The target reliability for this vehicle is 2.5. This indicates that lower live load factors could be used and the target reliability achieved.

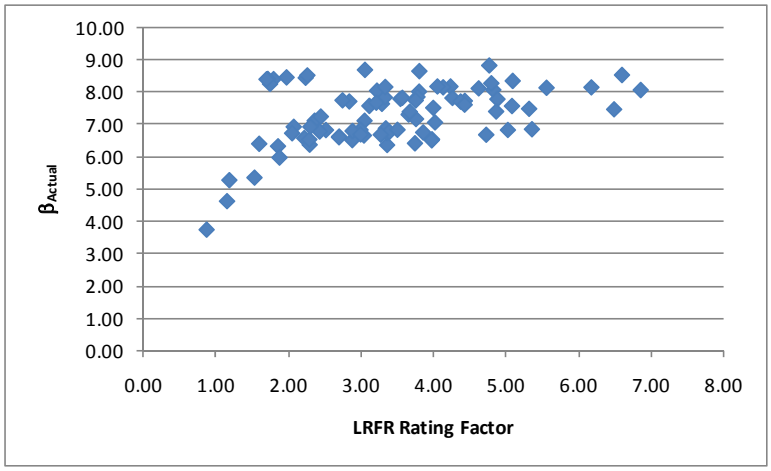
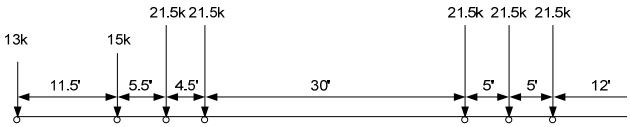


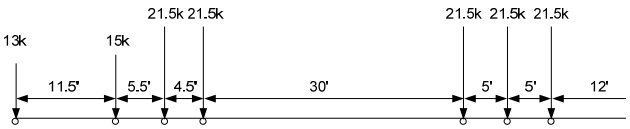
Figure D-74: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

D.1.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-75. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading



plus 0.2 klf for spans greater than 200 feet
LRFR Loading

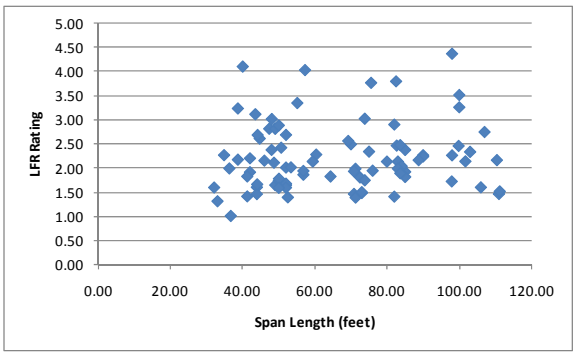
Figure D-75: Vehicle Loadings and Load Factors

D.1.8.1 Moment

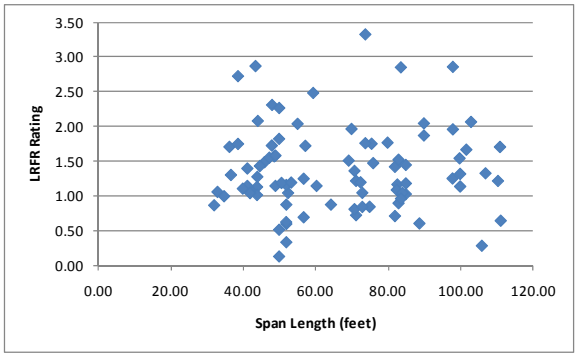
The following section contains the results for exterior, composite prestressed box girders within simple span bridges for the OR-06 Vehicle.

D.1.8.1.1 Rating Factors

Figure D-76 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 20 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 92% of the girders in this subset. The LFR ratings are between 1.5 and 2.5 for most girders while the LRFR rating is typically between 1.0 and 2.0.



(a)



(b)

Figure D-76: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure D-77 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for special permit vehicles. The figure shows a number of girders will be negatively affected by switching from LFR to LRFR. 23% of girders will have LRFR ratings less than 1.0 for the first five LRFR permit categories; this will increase to 25% for the last two LRFR permit categories. 99% of girders have an LFR rating greater than 1.0.

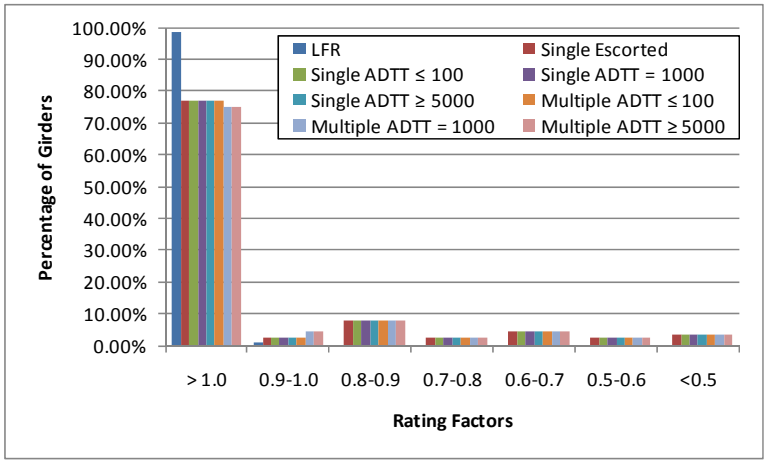


Figure D-77: Flexure Rating for Various ADTTs in MBE for OR-06 Vehicle

D.1.8.1.2 Rating Factor Comparisons

Figure D-78 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating which occurs for eight percent of girders with this vehicle. The ratio is generally between 0.2 and 0.8.

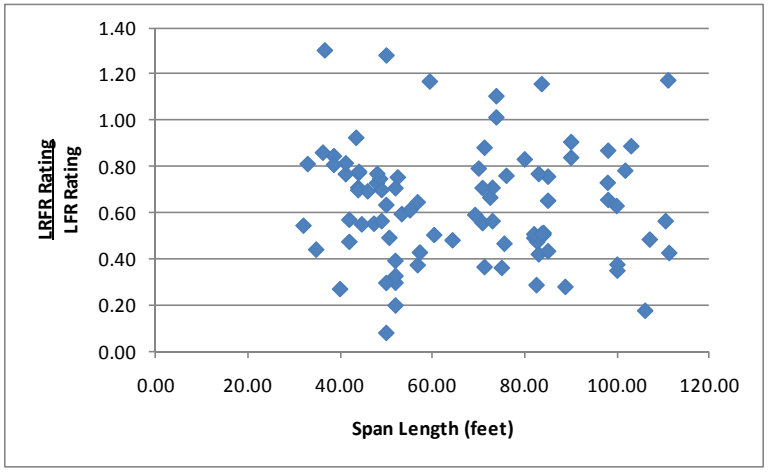


Figure D-78: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

D.1.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-79 shows that 19 girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index for this combination of truck and girders varies widely between zero and ten for all different span lengths.

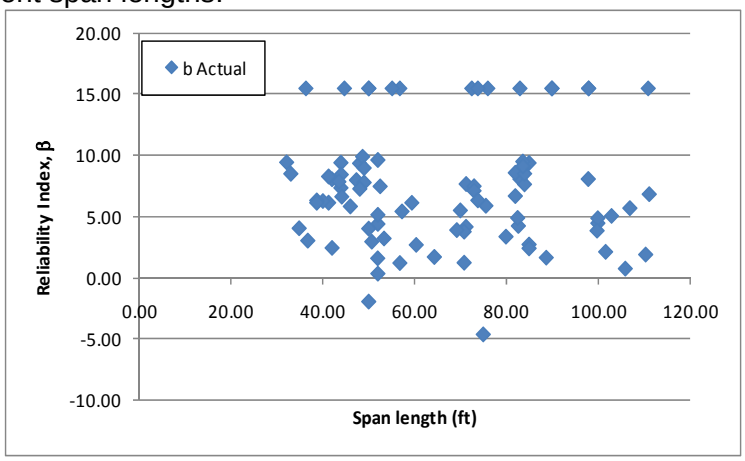


Figure D-79: Flexure Reliability Indices for OR-06 Vehicle

Figure D-80 shows the reliability index plotted against the LRFR rating for moment due to the OR-06 vehicle. The target reliability index is 3.5, and the average reliability index for girders with a rating of 1.0 is approximately six, well above the target. This indicates that for some girders the current load factors do not provide the target reliability while for other girders they do provide the target reliability.

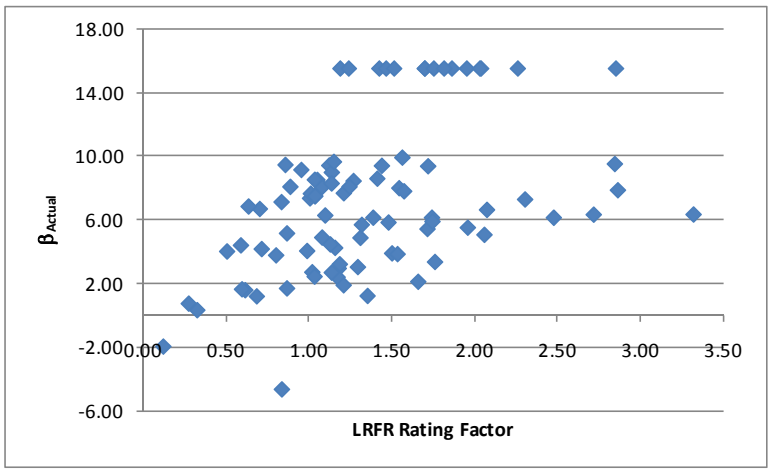
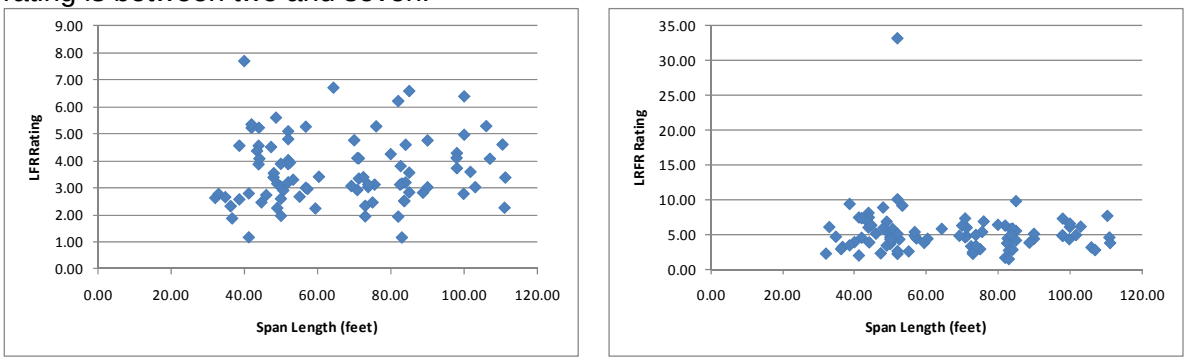


Figure D-80: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

D.1.8.2 Shear

D.1.8.2.1 Rating Factors

For shear, there are no girders with ratings less than 1.0 for either method. The LFR Rating is greater than the LRFR rating for 17% of the girders in this subset. Figure D-81 shows the LFR and LRFR ratings. The LFR rating is between two and five for most girders while the LRFR rating is between two and seven.



(a) (b)

Figure D-81: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure D-82 shows the distribution of LRFR shear ratings for the different ADTT categories in the MBE for special permit vehicles. The figure shows that all girders have LRFR ratings greater than 1.0 for all permit categories. No girders are negatively affected by switching to LRFR.

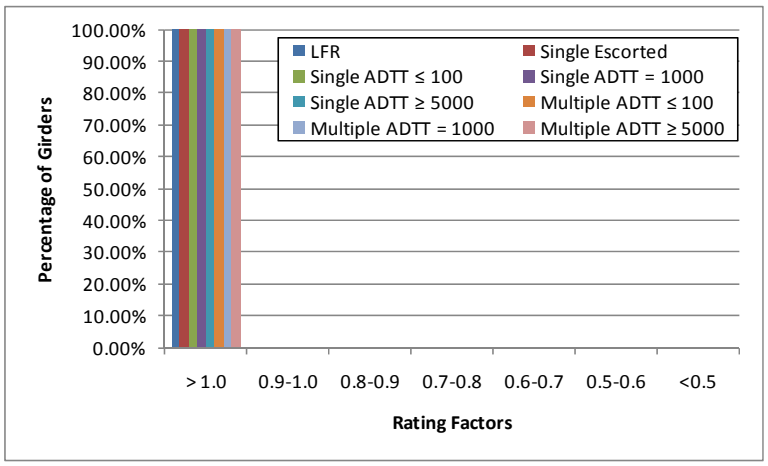


Figure D-82: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicles

D.1.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-83 shows the comparison of rating factors. The ratio is generally between 1.0 and 2.0 for this set of girders with this vehicle. Spans under 60 feet are more likely to have LRFR ratings that are twice as large as the LFR ratings than spans longer than 60 feet.

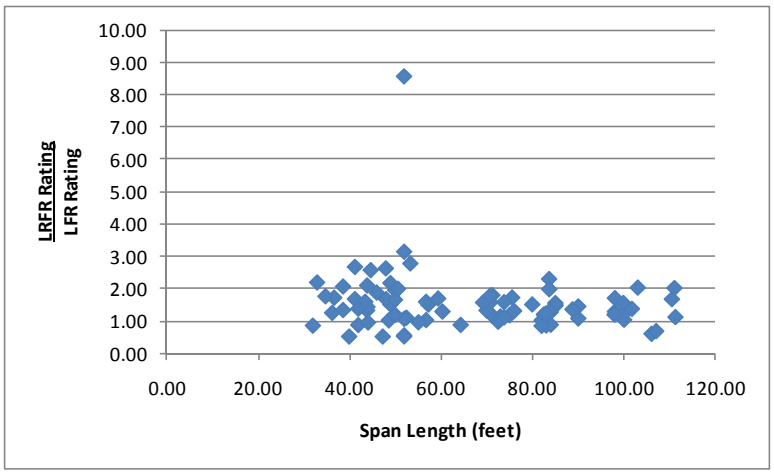


Figure D-83: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

D.1.8.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 3.5 for all girders as shown in Figure D-84. The reliability index is between six and nine for most girders when this vehicle is used.

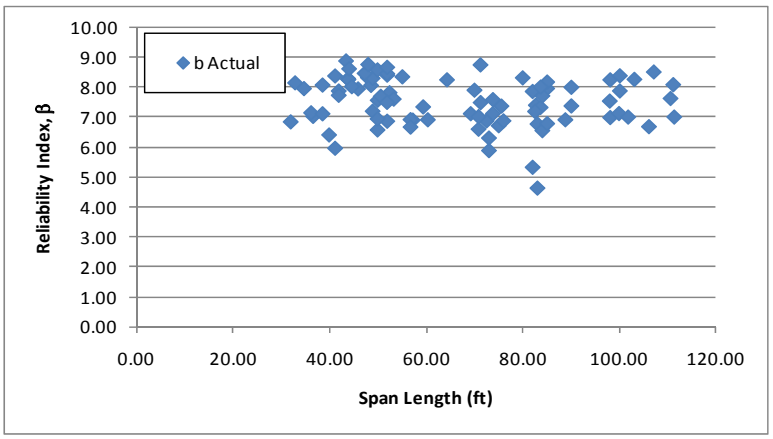


Figure D-84: Shear Reliability Indices for OR-06 Vehicle

Figure D-85 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The reliability index for a girder with a rating of 1.0 is expected to be very close to the target reliability. This indicates that the live load factors currently in the MBE provide the target level of reliability and do not need to be modified.

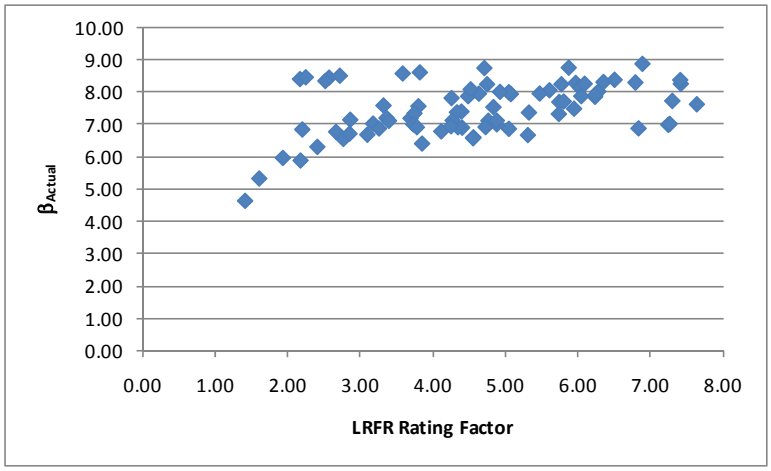
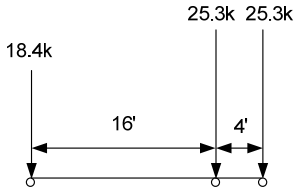


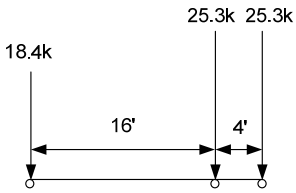
Figure D-85: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

D.1.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-86. The applicable load factors for these vehicles are 1.3 and 1.60 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet
LRFR Loading

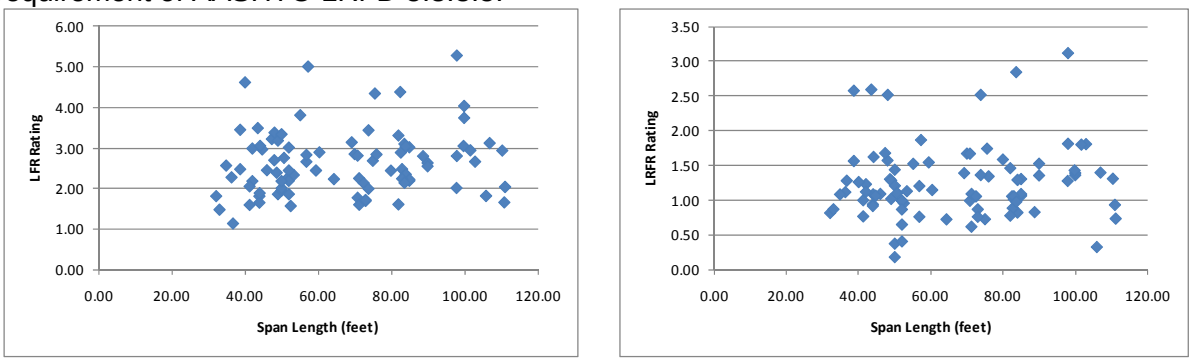
Figure D-86: Vehicle Loadings and Load Factors

D.1.9.1 Moment

The following section contains the results for exterior, composite prestressed box girders within simple span bridges for the TX-04 Vehicle.

D.1.9.1.1 Rating Factors

Figure D-87 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 29 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 99% of the girders in this subset. The LFR rating is between 1.5 and 3.0 for most girders while the LRFR rating is between 0.75 and 1.5. 7% of the girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel requirement of AASHTO LRFD 5.8.3.5.



(a) (b)

Figure D-87: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure D-88 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows a number of girders will be negatively affected by switching from LFR to LRFR. 32% of girders will have LRFR ratings less than 1.0 for ADTT = 100; this increases to 37.5% for ADTT = 5,000.

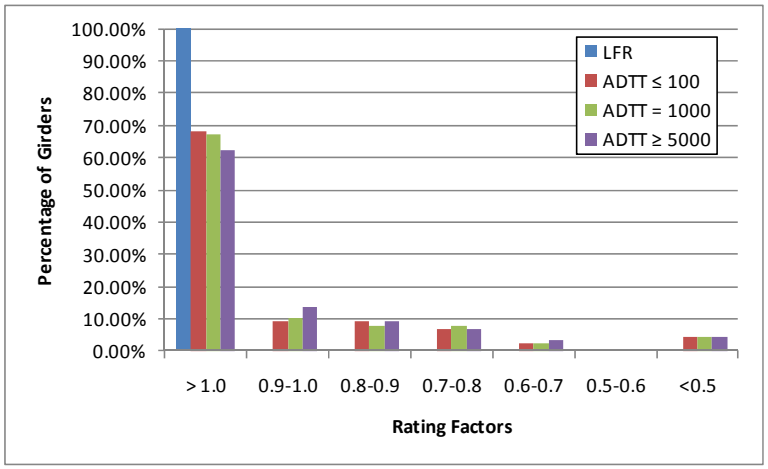


Figure D-88: Flexure Ratings for Various ADTTs in MBE for TX-04 Vehicle

D.1.9.1.2 Rating Factor Comparisons

Figure D-89 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating which is true for one girder. The LRFR rating is generally 20 to 80% of the LFR rating.

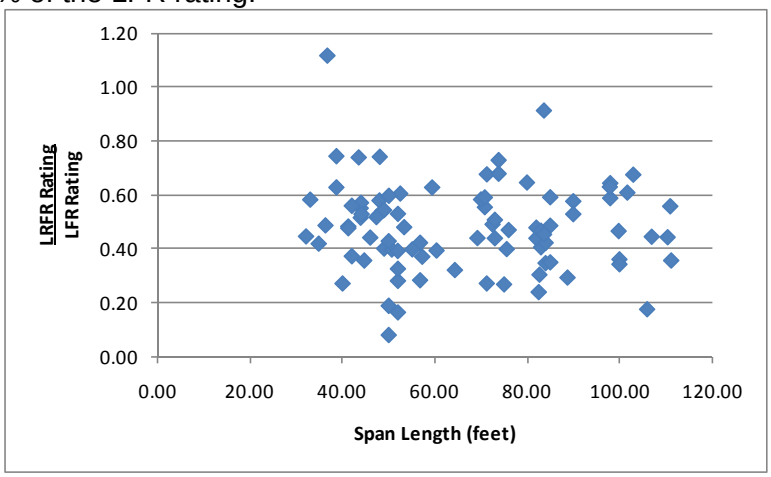


Figure D-89: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

D.1.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-90 shows twelve girders that have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index varies between zero and eight for girders of all span lengths.

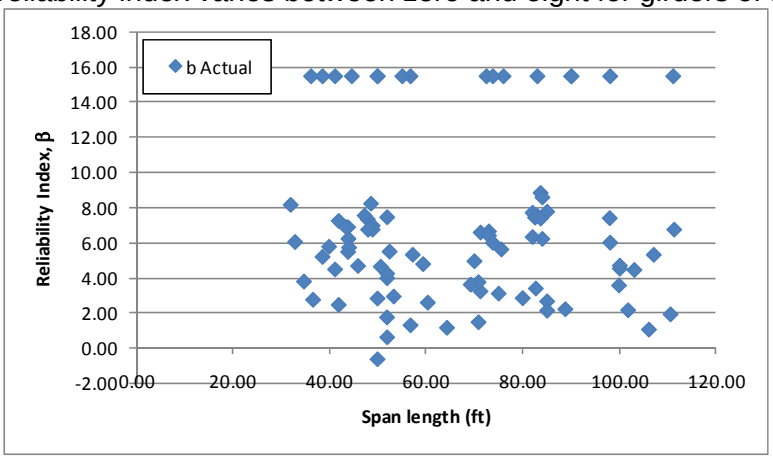


Figure D-90: Flexure Reliability Indices for TX-04 Vehicle

Figure D-91 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The figure shows that girders with a rating near one have reliability indices ranging from 2.0 to 8.0 with an average reliability of approximately five. This is above the target reliability of 2.5 and indicates that the live load factors are conservative and can possibly be reduced.

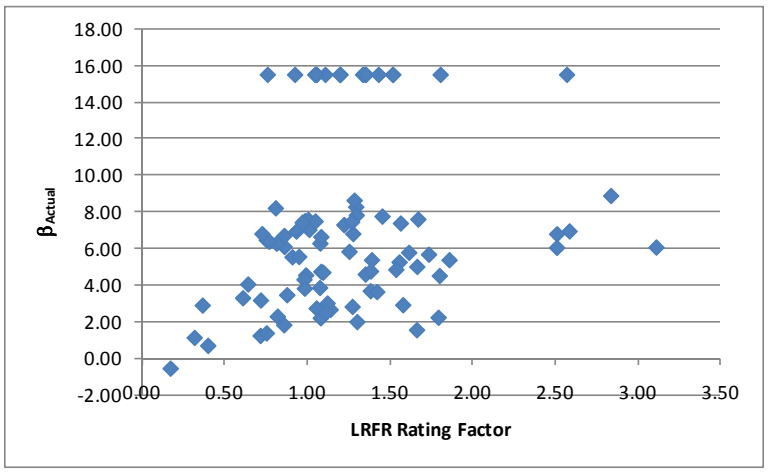
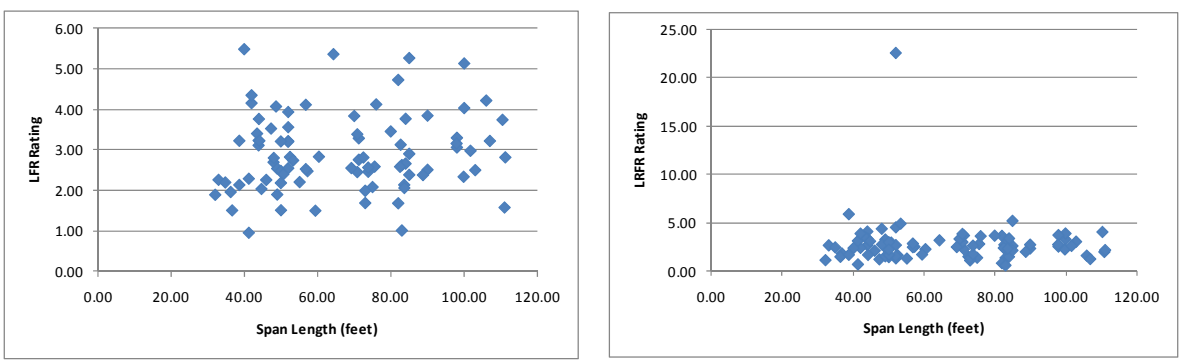


Figure D-91: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

D.1.9.2 Shear

D.1.9.2.1 Rating Factors

For shear, there is one girder with an LFR rating less than 1.0, three girders that have LRFR ratings less than 1.0, and one girder with both ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 66% of the girders in this subset. Figure D-92 shows the LFR and LRFR ratings. The LFR rating is between two and four and the LRFR rating is between one and four. .



(a) (b)

Figure D-92: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure D-93 shows the distribution of LRFR shear ratings for the different ADTT categories in the MBE for routine permit vehicles. The figure shows a number of girders will be negatively affected by switching from LFR to LRFR. 4% of girders are affected for all ADTT categories for the LRFR ratings. 1% of girders have LFR ratings that are less than 1.0.

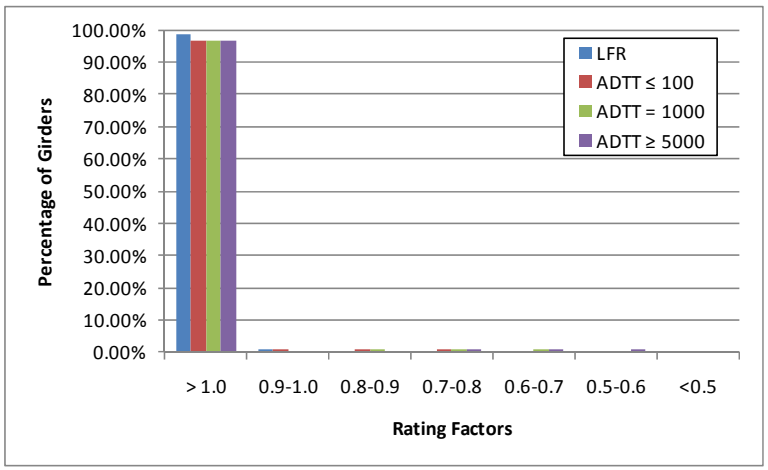


Figure D-93: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

D.1.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-94 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0 for shear, with lower ratios generally being for girders of longer span.

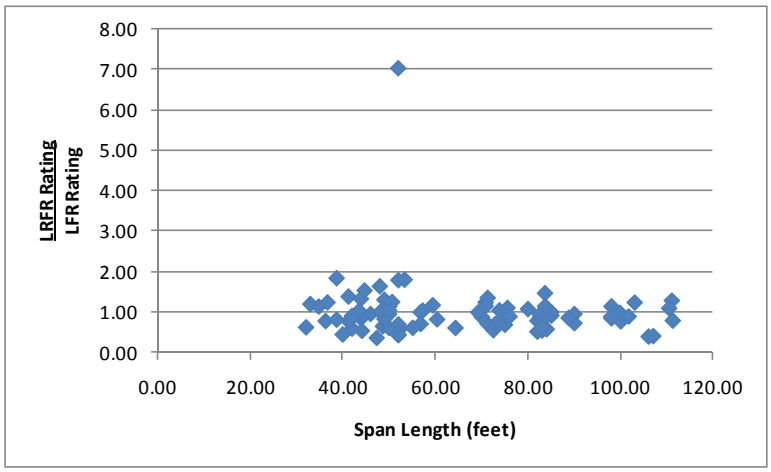


Figure D-94: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

D.1.9.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index for all girders as shown in Figure D-95. This girder likely does not have properly defined shear reinforcement resulting in low shear resistance.

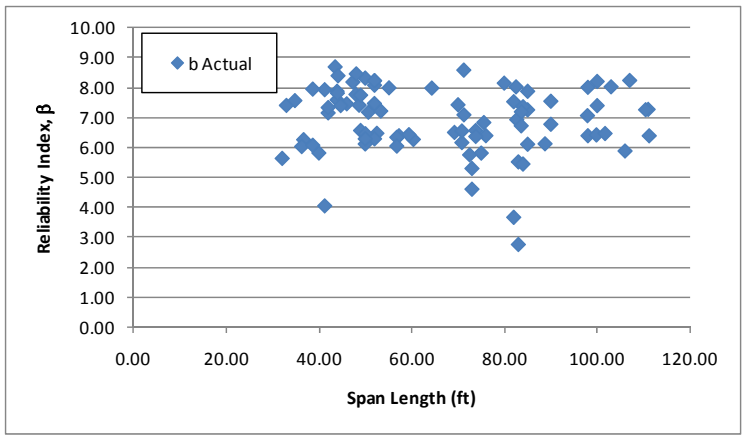


Figure D-95: Shear Reliability Indices for TX-04 Vehicle

Figure D-96 shows the shear reliability index plotted against the LRFR shear rating factor for the TX-04 vehicle. The figure shows that a girder with a passing rating will have a reliability index of approximately 4.0 above the target reliability of 2.5. This indicates that the current live load factors are conservative and can be reduced.

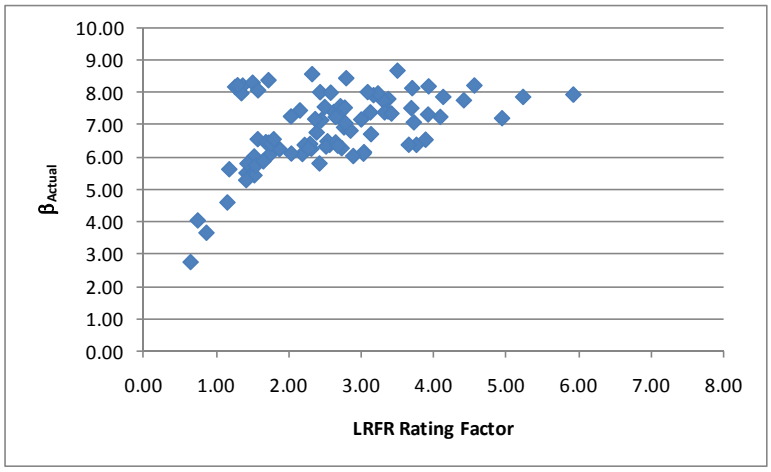
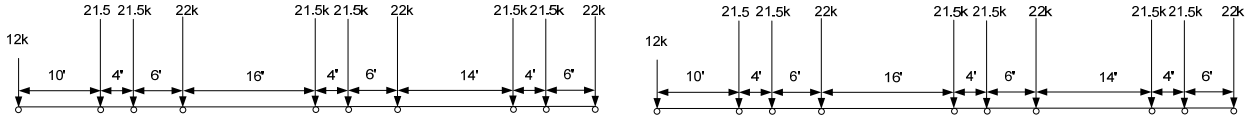


Figure D-96: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

D.1.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-97. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

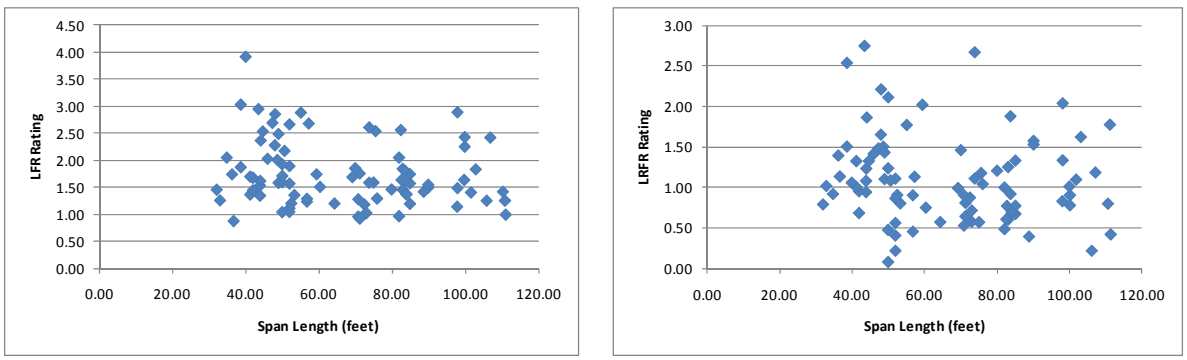
Figure D-97: Vehicle Loadings and Load Factors

D.1.10.1 Moment

The following section contains the results for exterior, composite prestressed box girders within simple span bridges for the WA-02 Vehicle.

D.1.10.1.1 Rating Factors

Figure D-98 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are five girders with an LFR rating less than 1.0, 42 girders with an LRFR rating less than 1.0, and four girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 92% of the girders in this subset. The LFR rating is between one and three for spans less than 60 feet and between one and two for spans greater than 60 feet. The LRFR rating is between 0.5 and 2.0 for most girders. All 42 girders with LRFR ratings less than 1.0 were controlled by a rating criteria other than checking the force in the longitudinal steel reinforcement near the support as required in AASHTO LRFD 5.8.3.5.



(a) (b)

Figure D-98: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure D-99 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for special permit vehicles. The figure shows a number of girders will be negatively affected by switching from LFR to LRFR. 48% of girders will have LRFR ratings less than 1.0 for the first three LRFR permit categories; this will increase to 51% for the last two LRFR permit categories. 94% of girders have an LFR rating greater than 1.0.

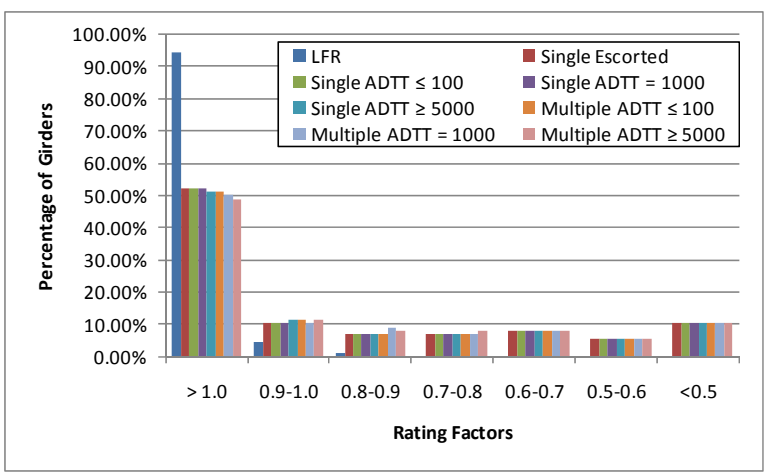


Figure D-99: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

D.1.10.1.2 Rating Factor Comparisons

Figure D-100 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating which occurs for 8% of the girders in this group. The ratio is generally between 0.2 and 0.8 for most girders.

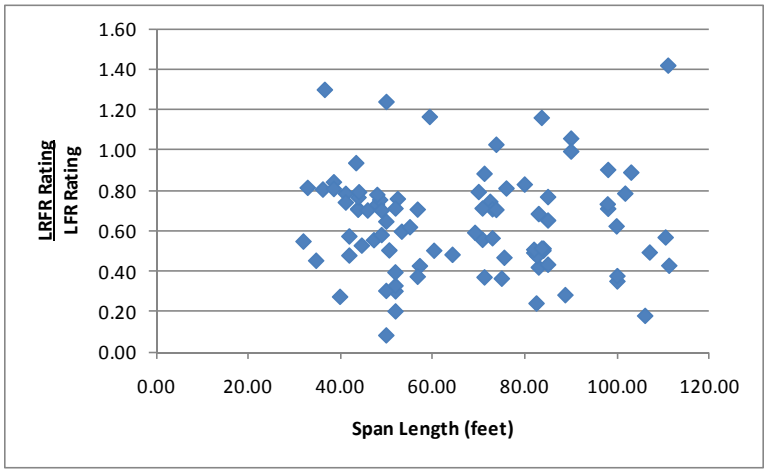


Figure D-100: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

D.1.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-101 shows that at 27 girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index varies significantly for girders with similar spans. As an example for spans near 50 feet in length, the reliability index varies from -5 to 10.

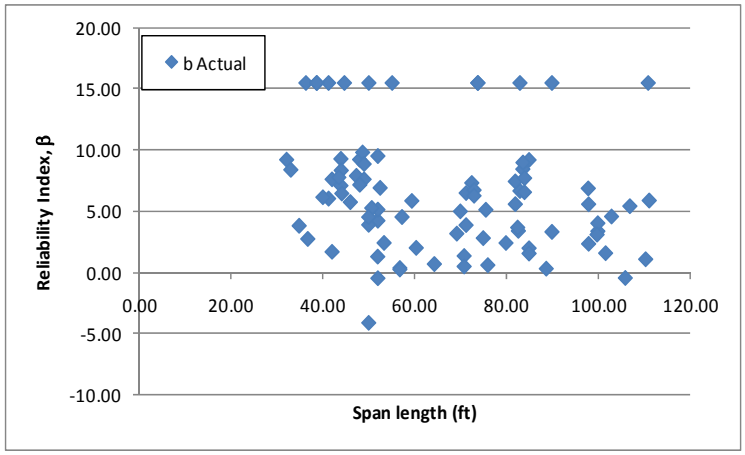


Figure D-101: Flexure Reliability Indices for WA-02 Vehicle

Figure D-102 shows the moment reliability index plotted against the LRFR moment rating for the WA-02 vehicle. The figure shows that girders with ratings near 1.0 have widely varying reliability indices, from zero to 10. The average reliability index is close to 5.0, which is above the target reliability of 3.5. This indicates that lower live load factors could be used but girders with low reliability would then have higher rating factors but still have low reliability.

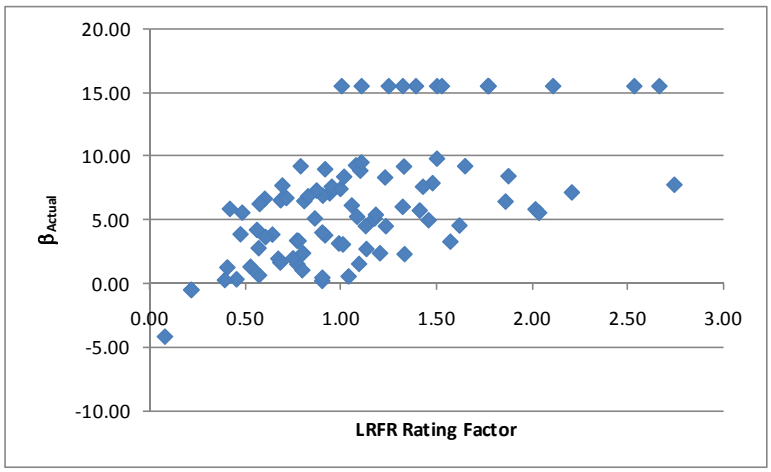
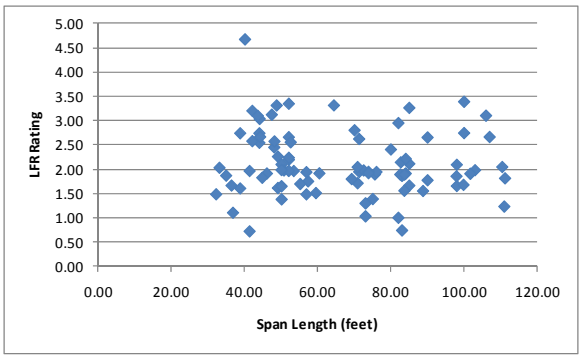


Figure D-102: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

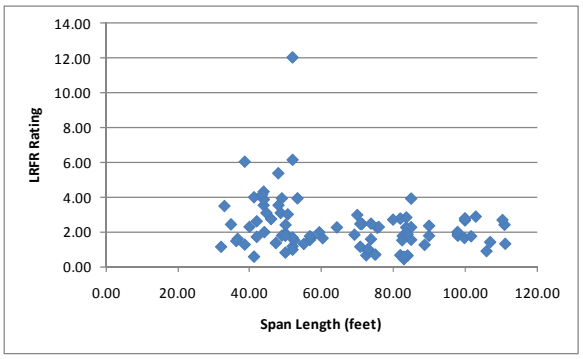
D.1.10.2 Shear

D.1.10.2.1 Rating Factors

For shear, there are three girders with LFR rating factors less than 1.0, eleven girders with LRFR ratings less than 1.0, and three girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 52% of the girders in this subset. Figure D-103 shows the LFR and LRFR ratings. LFR ratings are between 1.5 and 3.5 for most girders while the LRFR ratings are between 1.0 and 4.0 for most girders.



(a)



(b)

Figure D-103: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure D-104 shows the distribution of LRFR shear ratings for the different ADTT categories in the MBE for special permit vehicles. The figure shows a number of girders will be negatively affected by switching from LFR to LRFR. 22% of girders will be affected in the worst case corresponding to a multiple trip permit vehicle with an ADTT = 5,000. Fewer girders are affected for the other permit types. 3.4% of girders have LFR ratings that are less than 1.0.

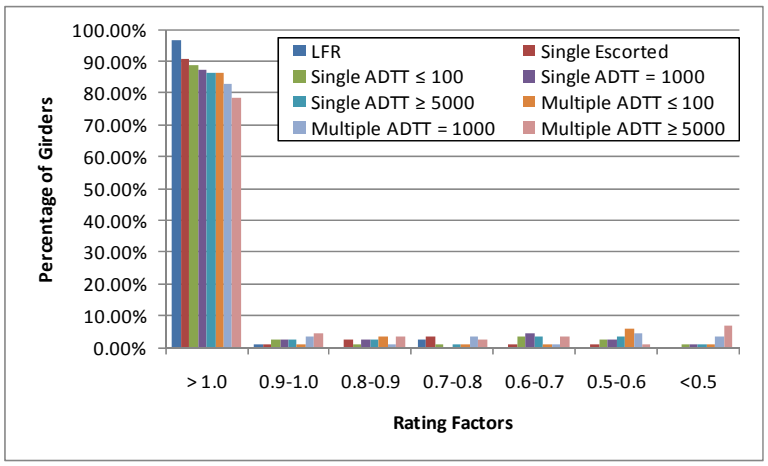


Figure D-104: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

D.1.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-105 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0, with shorter spans more likely to have LRFR ratings greater than LFR ratings.

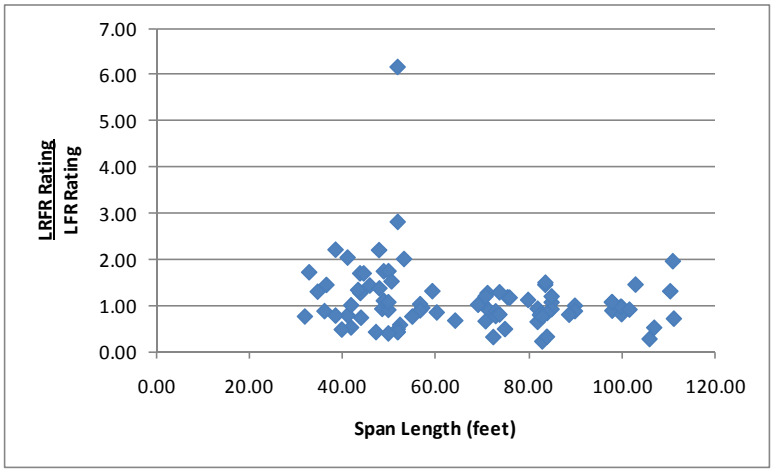


Figure D-105: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

D.1.10.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index for eleven girders as shown in Figure D-106. The target reliability index for the WA-02 vehicle is 3.5. The reliability index for most girders is between four and eight.

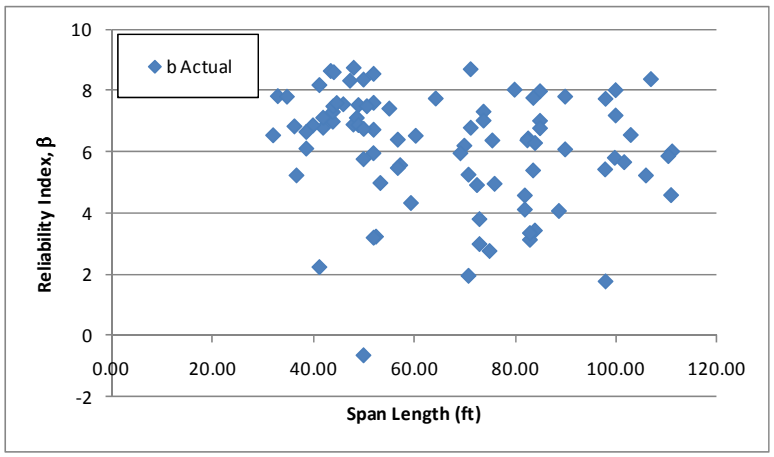


Figure D-106: Shear Reliability Indices for WA-02 Vehicle

Figure D-107 shows the reliability index plotted against the LRFR rating for shear due to the WA-02 truck. The figure shows that the reliability index for girders with a rating close to one varies from two to eight. The average reliability index for these girders is approximately five which is greater than the target reliability of 3.5. This indicates that the live load factors currently in the MBE may be overly conservative.

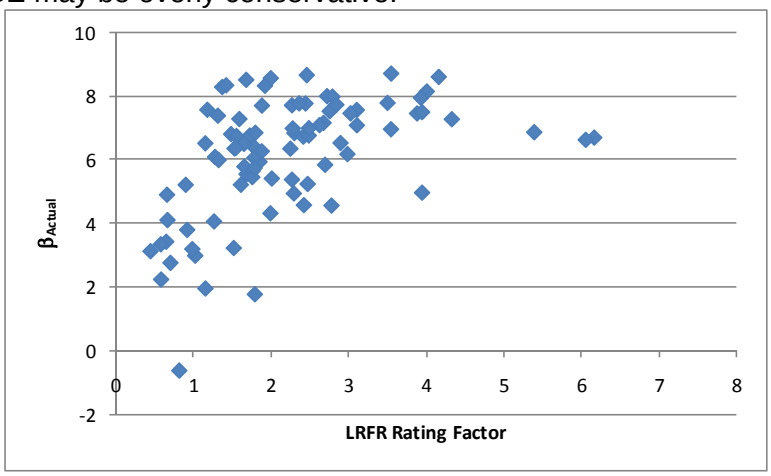


Figure D-107: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

D.1.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-108. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

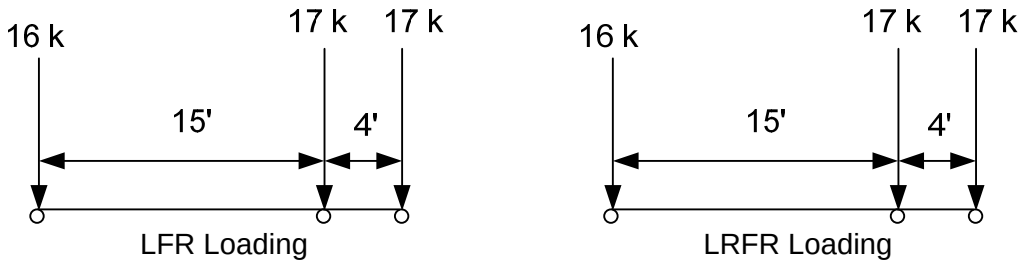
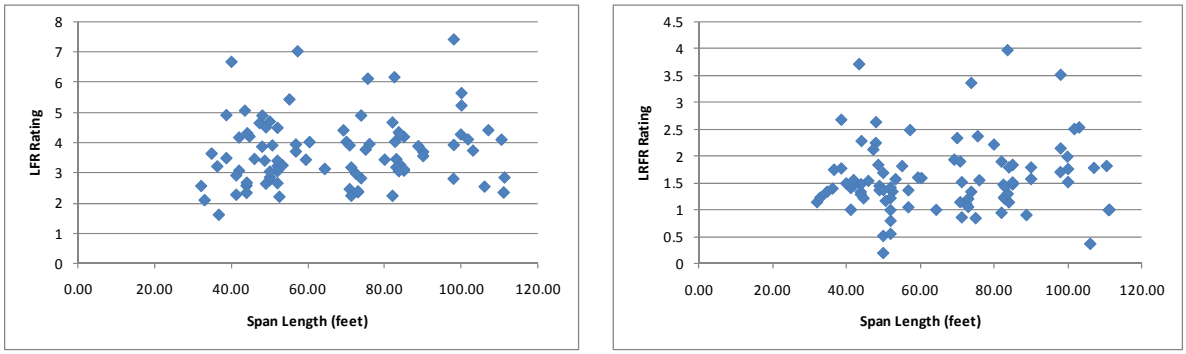


Figure D-108: Vehicle Loadings and Load Factors

D.1.11.1 Moment

D.1.11.1.1 Rating Factors

Figure D-109 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 10 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 99% of the girders in this subset. The LFR rating is typically between 2.0 and 5.0 while the LRFR rating is typically between 0.5 and 2.5.



(a) (b)

Figure D-109: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure D-110 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for legal vehicles. The figure shows a number of girders will be negatively affected by switching from LFR to LRFR. 9% of girders are affected for ADTT = 100, while 12.5% of girders are affected for ADTT = 5,000. All girders have LFR ratings greater than 1.0.

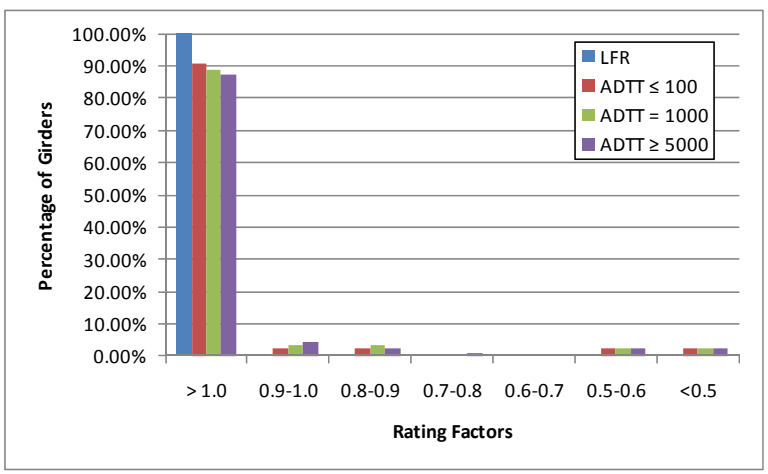


Figure D-110: Flexure Rating for Various ADTT in MBE for AASHTO Type 3 Truck

D.1.11.1.2 Rating Factor Comparisons

Figure D-111 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating which occurs for one girder with this vehicle. The ratio is generally between 0.2 and 0.6, with all span lengths having similar ratios.

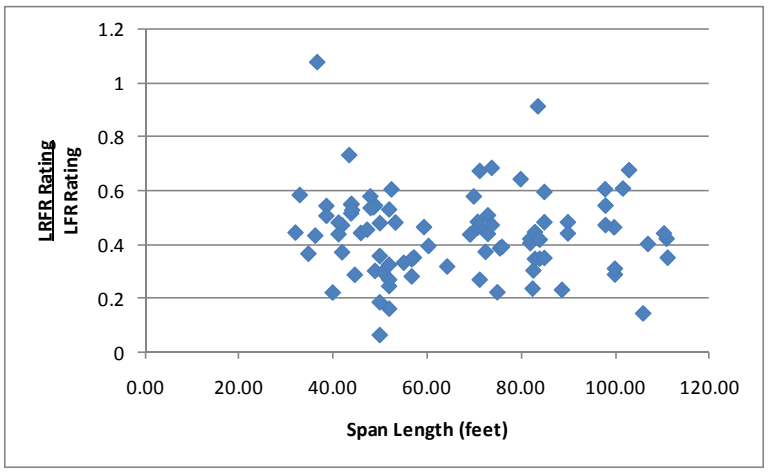


Figure D-111: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

D.1.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-112 shows that nine girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index varies significantly between girders with similar span lengths.

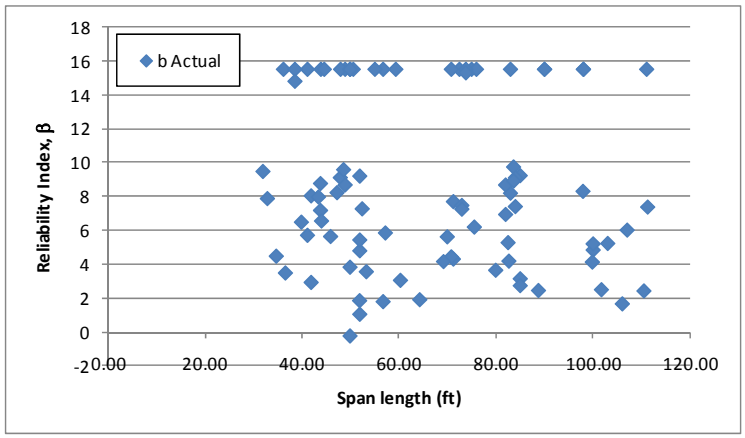


Figure D-112: Flexure Reliability Indices for Type 3 Vehicle

Figure D-113 shows the moment reliability index plotted against the LRFR moment rating for the AASHTO Type 3 truck. The figure shows that girders with an LRFR rating of 1.0 have a reliability index varying from 2.0 to almost 8.0. The average reliability index for these girders is approximately 5.0, above the target reliability of 2.5. This suggests that the live load factors could be reduce to bring the average reliability nearer the target reliability of 2.5.

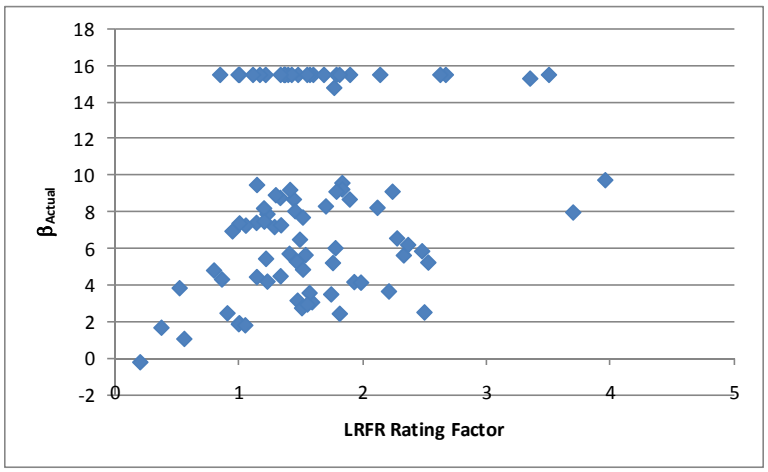
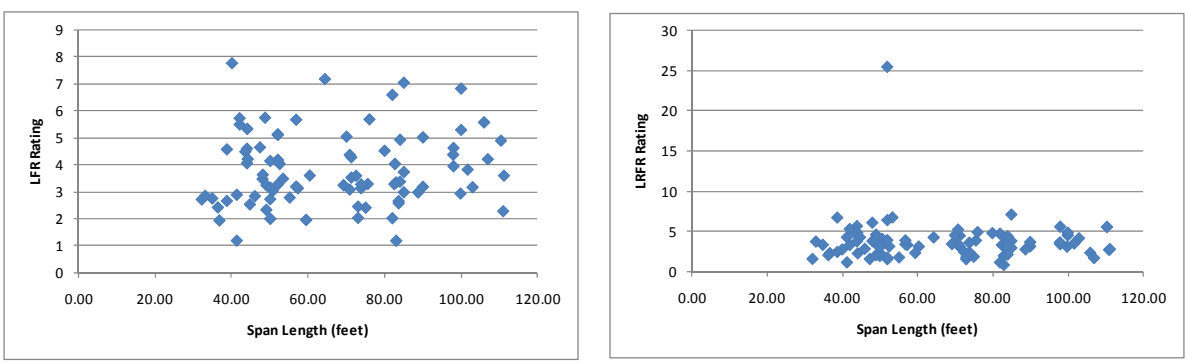


Figure D-113: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

D.1.11.2 Shear

D.1.11.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, one girder with LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 53% of the girders in this subset. Figure D-114 shows the LFR and LRFR ratings. The LFR ratings are between two and six for most girders while the LRFR ratings are between one and five.



(a) (b)

Figure D-114: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure D-115 shows the distribution of LRFR shear ratings for the different ADTT categories in the MBE for legal vehicles. The figure shows few girders will be negatively affected by switching from LFR to LRFR. 1% of girders are affected for ADTT = 1,000 and ADTT = 5,000. All girders have LFR ratings greater than 1.0.

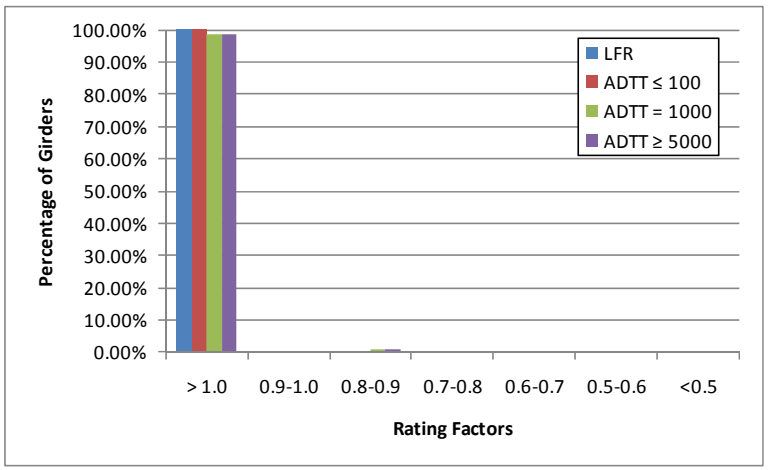


Figure D-115: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

D.1.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-116 show the comparison of rating factors. The ratio is generally between 0.5 and 2.0, with shorter spans generally having higher ratios. 47% of the girders in this group have LRFR ratings greater than the LFR rating when using the AASHTO Type 3 truck.

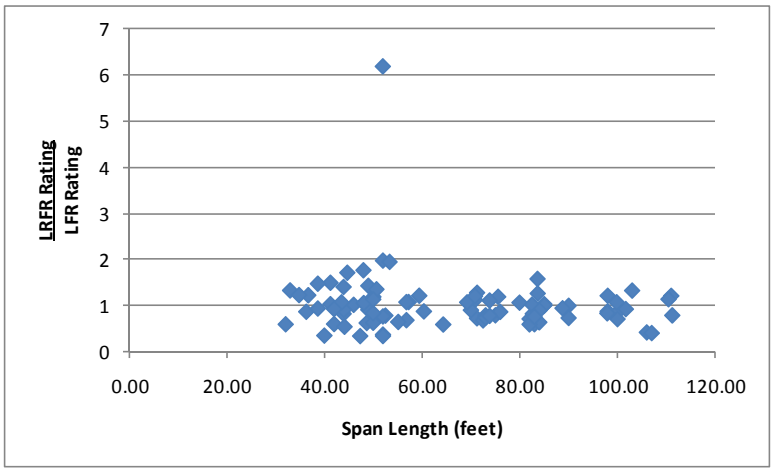


Figure D-116: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

D.1.11.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure D-117. The reliability index is between six and nine for most girders.

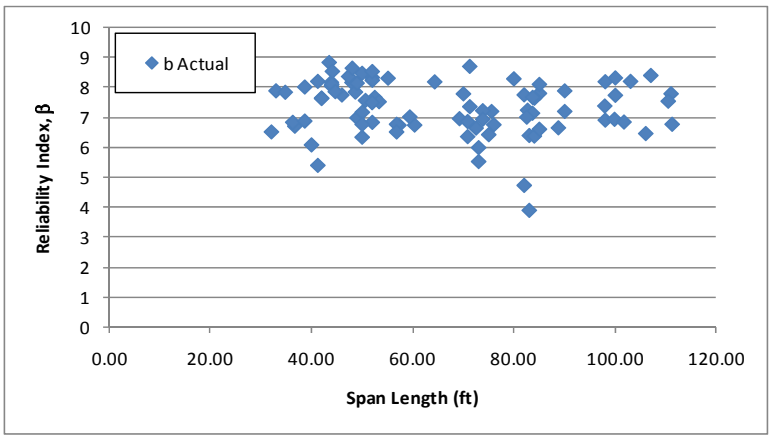


Figure D-117: Shear Reliability Indices for Type 3 Vehicle

Figure D-118 shows the shear reliability index plotted against the LRFR shear rating for the AASHTO Type 3 Truck. The figure shows that girders with a rating of 1.0 have a reliability index above four which is above the target reliability of 2.5. This indicates that the target reliability can be achieved while using load factors that have been reduced from those currently in the MBE.

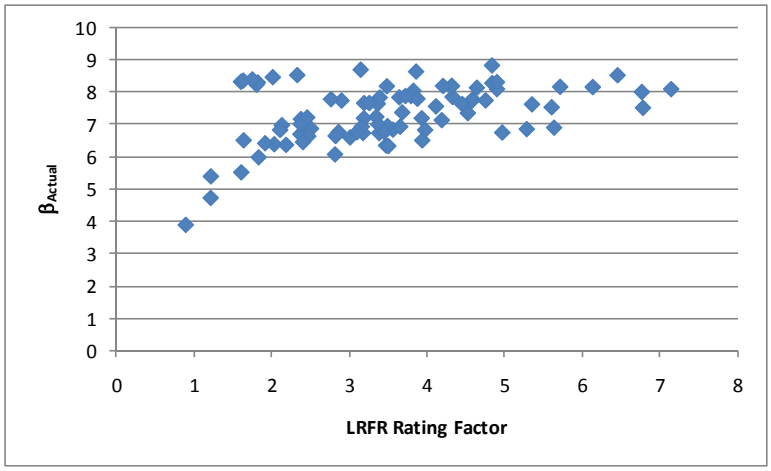


Figure D-118: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

D.1.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-119. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

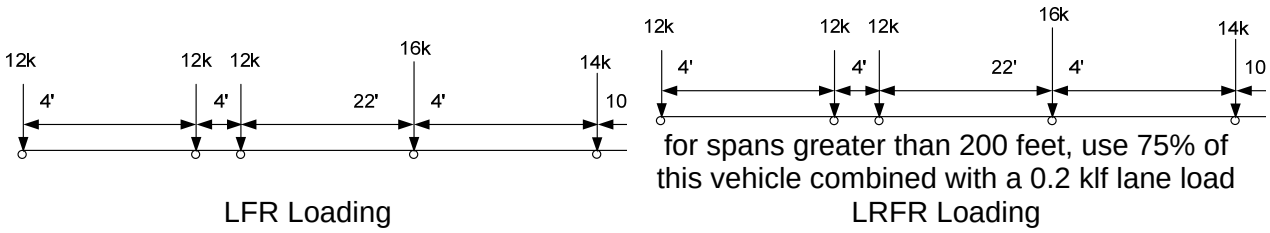


Figure D-119: Vehicle Loadings and Load Factors

D.1.12.1 Moment

D.1.12.1.1 Rating Factors

Figure D-120 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 13 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. The LFR rating is between two and four for most girders while the LRFR rating is between 0.5 and 2.0. 15% of girders with LRFR ratings less than 1.0 were controlled by the rating of the longitudinal steel reinforcement criterion.

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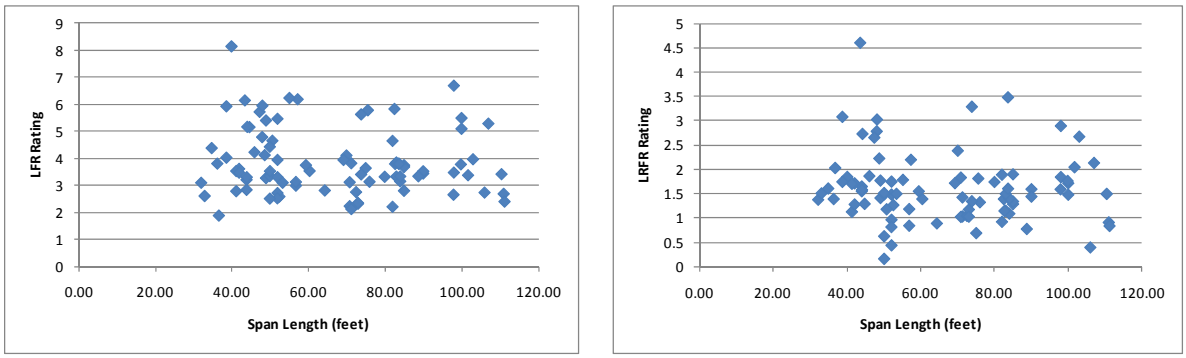


(a) (b)

Figure D-120: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure D-121 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for legal vehicles. The figure shows a number of girders will be negatively affected by switching from LFR to LRFR. 14% of girders are affected for ADTT = 100, while 16% of girders are affected for ADTT = 5,000. All girders have LFR ratings that are greater than 1.0.

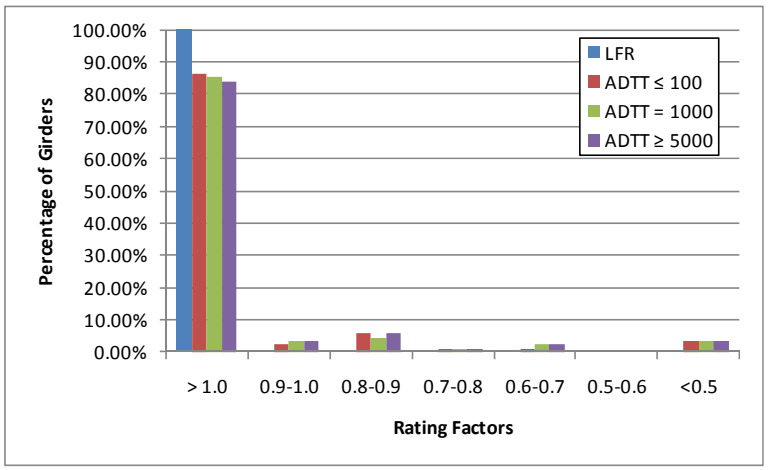


Figure D-121: Flexure Rating for Various ADTTs in MBE for AASHTO Type 3-3 Truck

D.1.12.1.2 Rating Factor Comparisons

Figure D-122 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating, which occurs for one girder in this group. The ratio is generally between 0.2 and 0.6 for girders of all span lengths.

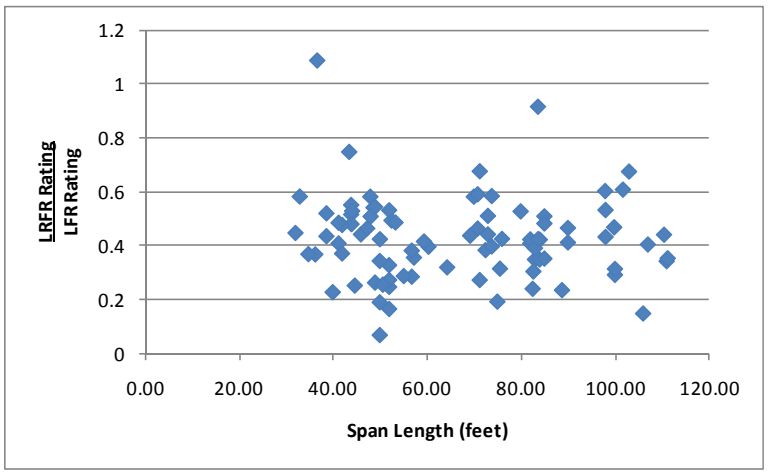


Figure D-122: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

D.1.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-123 shows that ten girders have a reliability index based upon girder strength that is less than the target reliability index. The reliability index varies widely for girders with similar span lengths. As an example look at the girders with a span length of 80 feet, the lowest reliability is four and the highest reliability is ten.

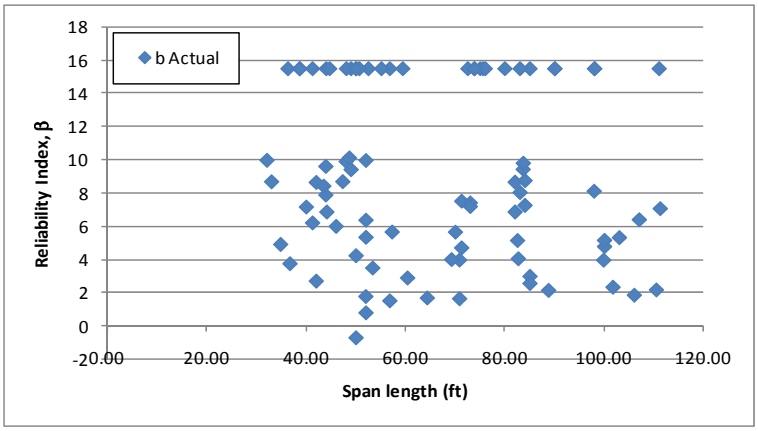


Figure D-123: Flexure Reliability Indices for Type 3-3 Vehicle

Figure D-124 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The figure shows that the reliability index varies from four to seven for girders with a rating factor of 1.0. These are above the target reliability of 2.5 indicating that lower live load factors can be used in the MBE than those currently present.

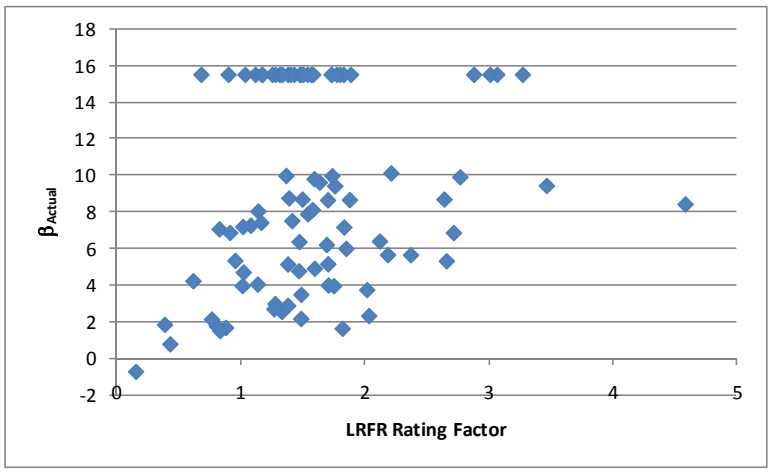
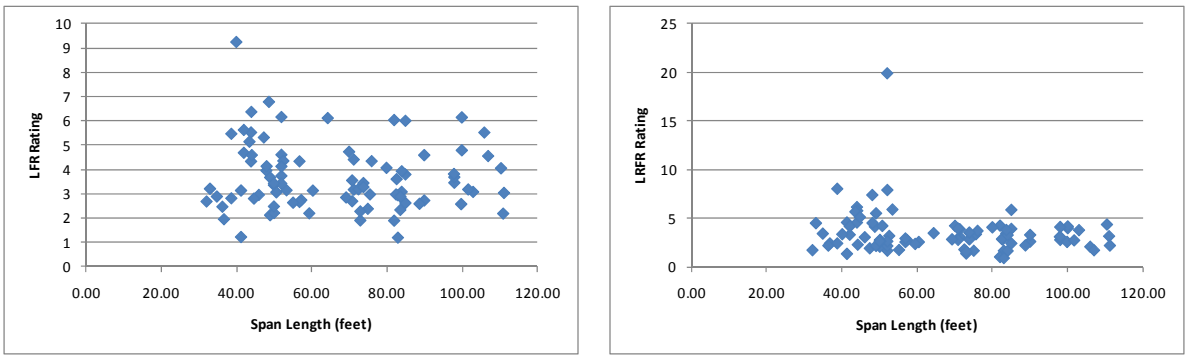


Figure D-124: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

D.1.12.2 Shear

D.1.12.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, one girder with LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 58% of the girders in this subset. Figure D-125 shows the LFR and LRFR ratings. The LFR and LRFR ratings are between two and five for most girders.



(a) (b)

Figure D-125: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure D-126 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for legal vehicles. The figure shows few girders will be negatively affected by switching from LFR to LRFR. 0% of girders are affected for ADTT = 100, while 2.3% of girders are affected for ADTT = 5,000. All girders have LFR ratings greater than 1.0.

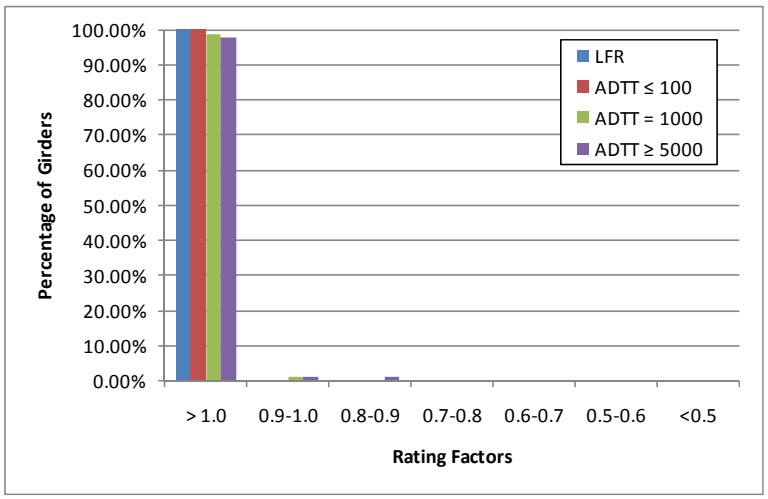


Figure D-126: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

D.1.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-127 show the comparison of rating factors. The ratio is generally between 0.5 and 2.0, with shorter spans generally having higher ratios. 42% of the girders have LRFR ratings greater than LFR ratings as shown in the figure.

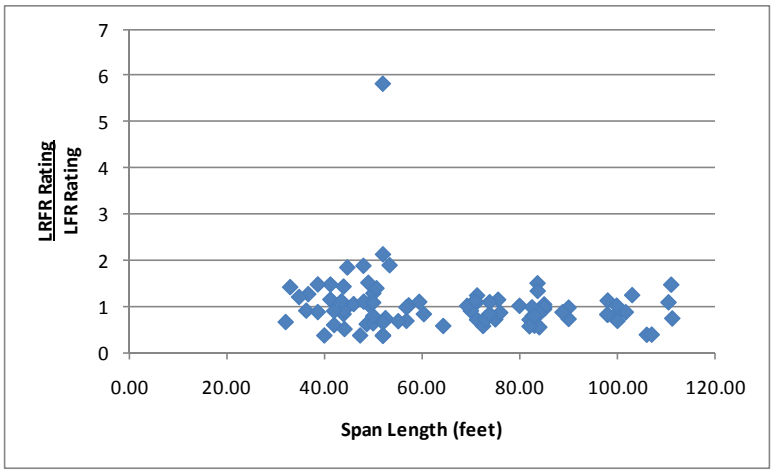


Figure D-127: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

D.1.12.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the required reliability index for zero girders as shown in Figure D-128. The reliability index is between six and nine for most girders with two below five.

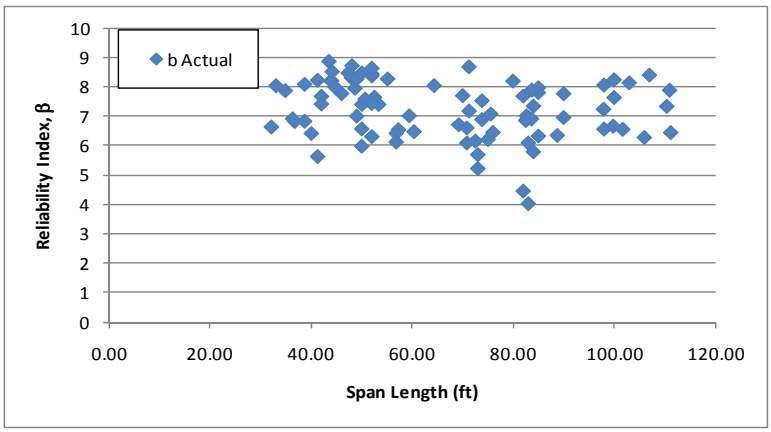


Figure D-128: Shear Reliability Indices for Type 3-3 Vehicle

Figure D-129 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 truck. The figure shows that girders with ratings of 1.0 have reliability indices of approximately 4.0 which is greater than the target reliability of 2.5. This indicates that lower load factors can be used and maintain the target reliability.

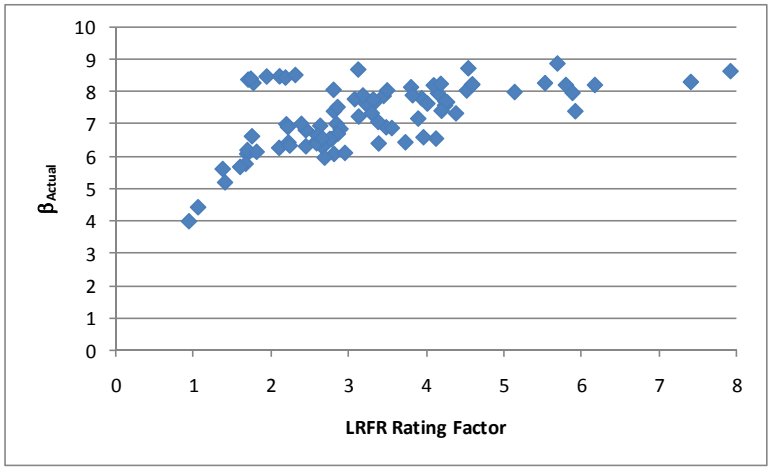


Figure D-129: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

D.1.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-130. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

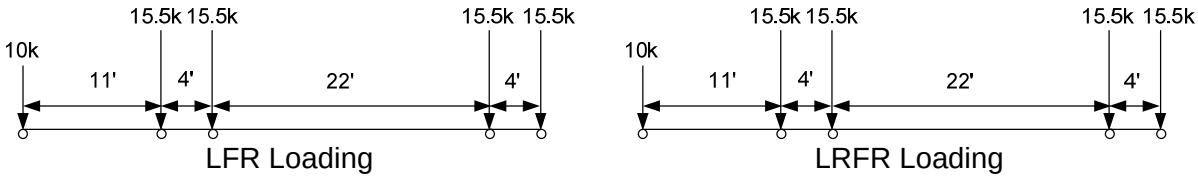
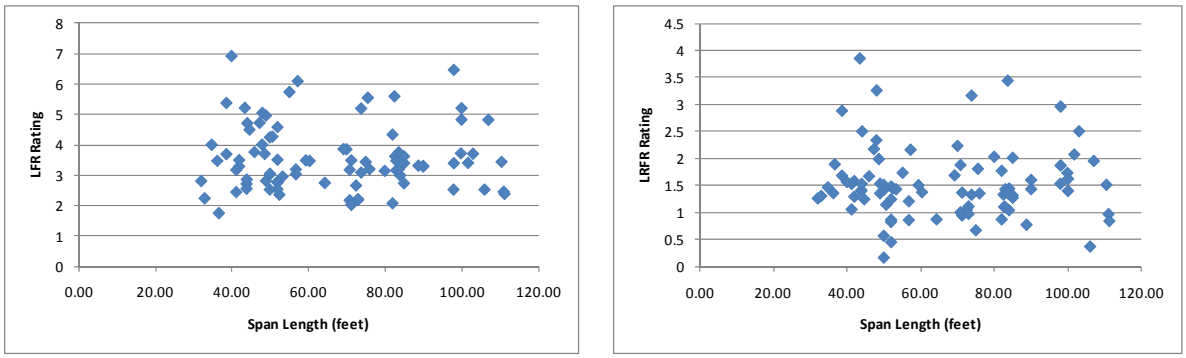


Figure D-130: Vehicle Loadings and Load Factors

D.1.13.1 Moment

D.1.13.1.1 Rating Factors

Figure D-131 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 15 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. The LFR rating is between two and five for most girders while the LRFR rating is between one and 2.5. 13% of girders with LRFR ratings less than 1.0 are controlled by the rating of the longitudinal reinforcement.



(a) (b)

Figure D-131: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure D-132 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for legal vehicles. The figure shows a number of girders will be negatively affected by switching from LFR to LRFR. 16% of girders are affected for ADTT = 100, while 19.3% of girders are affected for ADTT = 5,000. All girders have LFR ratings greater than 1.0.

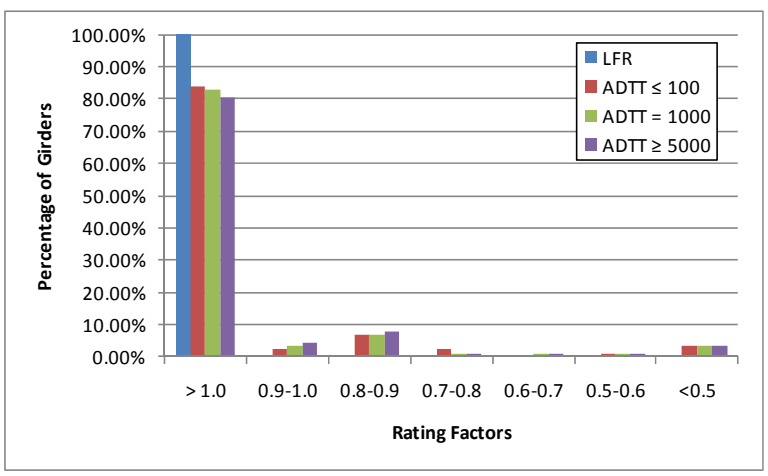


Figure D-132: Flexure Rating for Various ADTTs in MBE for AASHTO Type 3S2 Truck

D.1.13.1.2 Rating Factor Comparisons

Figure D-133 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating; this occurs for one girder in this group. The ratio is between 0.2 and 0.6 for most girders.

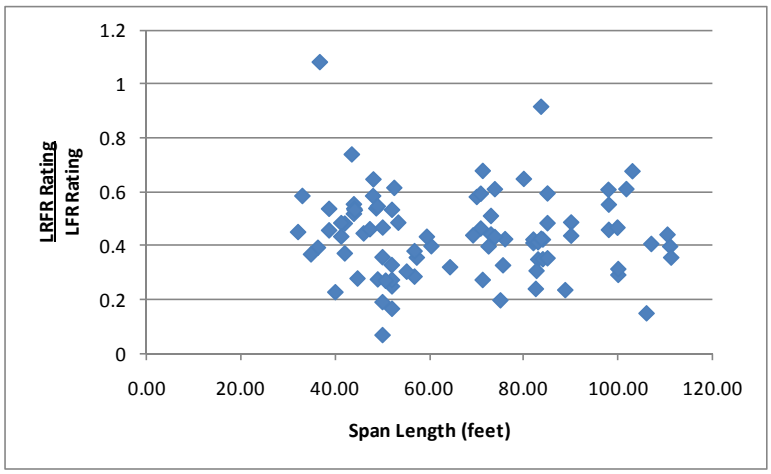


Figure D-133: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

D.1.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-134 shows that ten girders have a reliability index based upon girder strength that is less than the target reliability index. The reliability index varies widely between girders with similar span lengths. The reliability index is between two and ten with most girders not having the target level of reliability being under 80 feet in length.

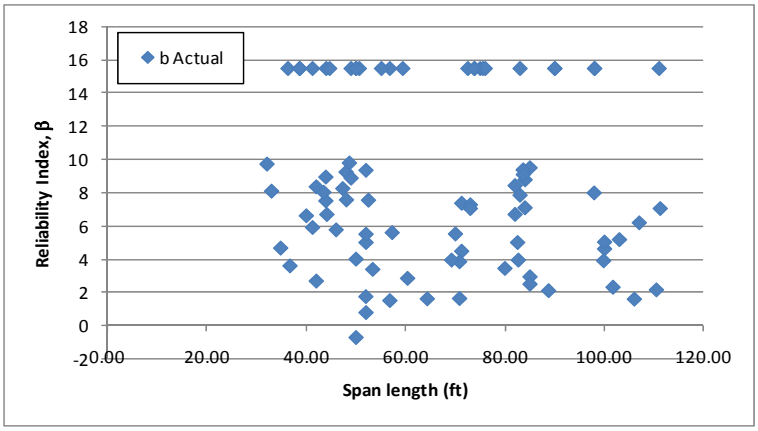


Figure D-134: Flexure Reliability Indices for Type 3S2 Vehicle

Figure D-135 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 truck. The figure shows that the reliability index for a girder with a rating of 1.0 varies from four to eight, taking the average reliability index to be in the middle of the scatter the average reliability index is around 5.0. This is above the target reliability of 2.5. This indicates that reducing the live load factors would shift the data points to the right and reduce the average reliability index for girders with a rating of 1.0.

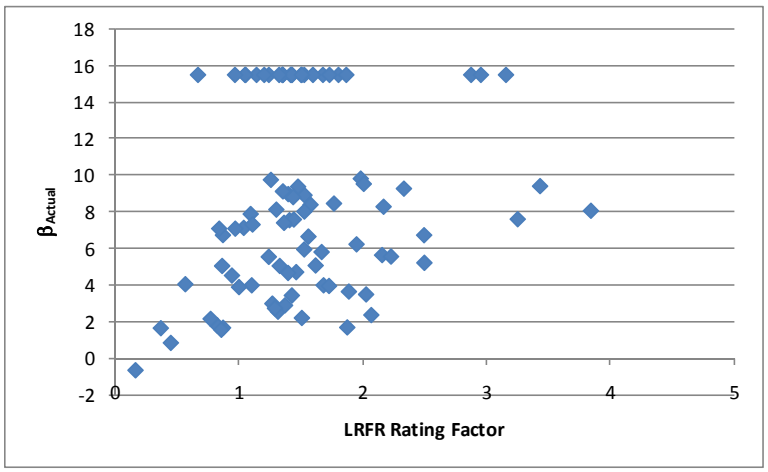
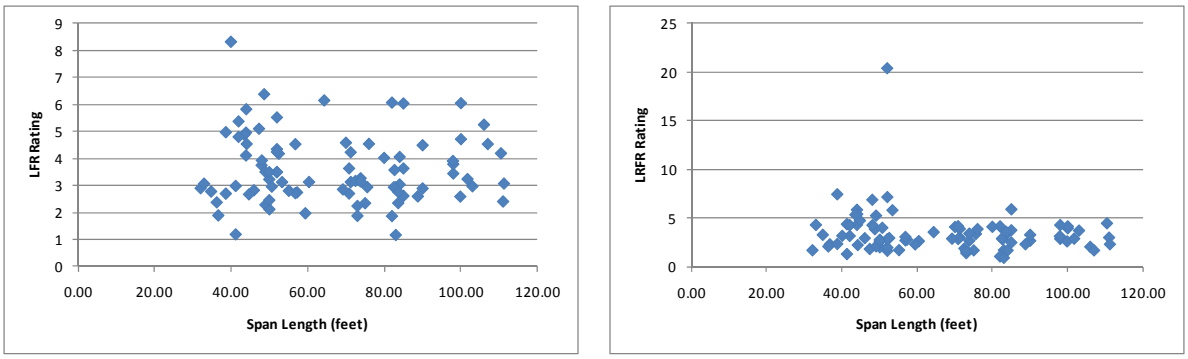


Figure D-135: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

D.1.13.2 Shear

D.1.13.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, one girder with LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 59% of the girders in this subset. Figure D-136 shows the LFR and LRFR ratings. The LFR rating is between two and five for most girders while the LRFR rating is between one and five for most girders.



(a) (b)

Figure D-136: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure D-137 shows the distribution of LRFR moment ratings for the different ADTT categories in the MBE for legal vehicles. The figure shows few girders will be negatively affected by switching from LFR to LRFR. 0% of girders are affected for ADTT = 100, while 2.3% of girders are affected for ADTT = 5,000. All girders have LFR ratings greater than 1.0.

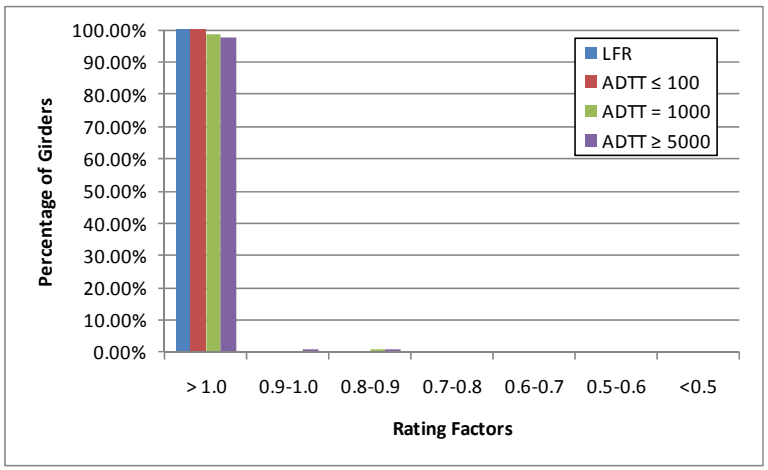


Figure D-137: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

D.1.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-138 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0, with 41% of girders having LRFR ratings higher than the LFR rating. Most girders with a ratio greater than one are spans that are less than 60 feet in length.

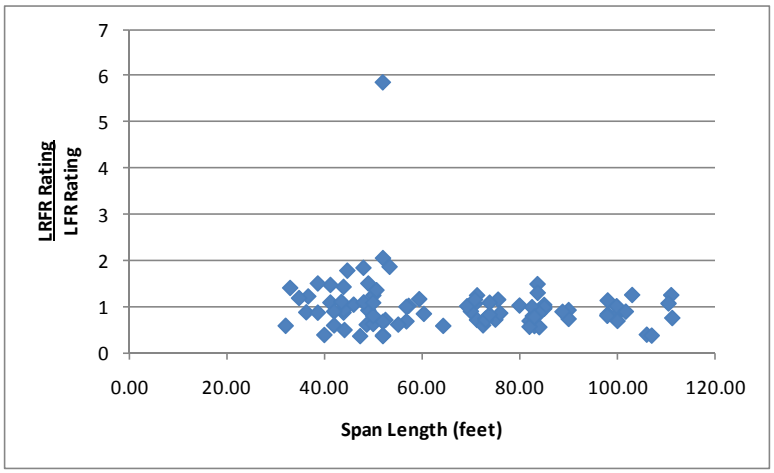


Figure D-138: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

D.1.13.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for approximately zero girders as shown in Figure D-139. The reliability index is between six and nine for most girders.

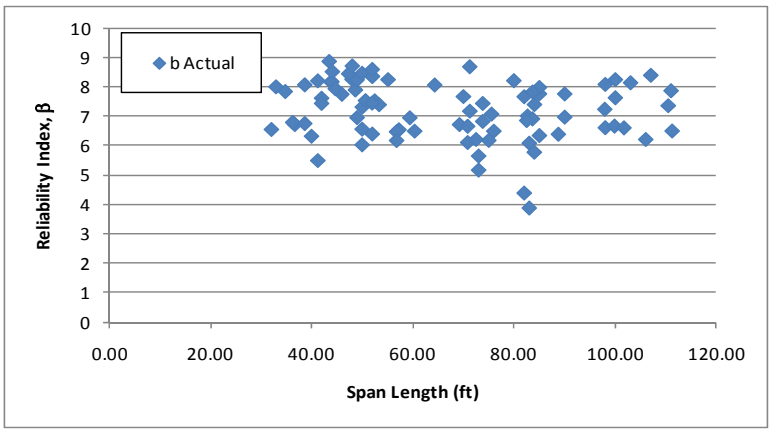


Figure D-139: Shear Reliability Indices for Type 3S2 Vehicle

Figure D-140 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 truck. The figure shows the reliability index for a girder with a rating of 1.0 is near four, greater than the target reliability of 2.5. This indicates the target reliability can be achieved using live load factors that are lower than those currently in the MBE.

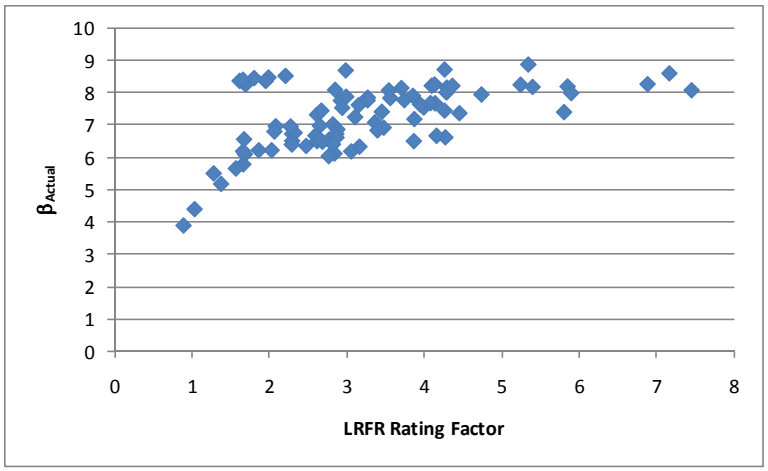


Figure D-140: Shear Reliability Index vs LRFR Shear Rating for AASHTO TYpe 3S2 Vehicle

D.1.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table D-1 shows the results for the moment ratings. All design and permit vehicles except NM-04 have significantly more girders with ratings less than 1.0 for LRFR than for LFR. For the legal vehicles and NM-04, fewer girders had ratings less than 1.0 than for the other vehicles. The percentage of girders with higher LFR ratings than LRFR ratings was similar for the design, routine permit, and legal vehicles. The special permit vehicles had more girders with LRFR ratings greater than the LFR rating, this is likely due to the loading configuration. An additional row is added to the table to indicate the number of girders controlled by the rating of the longitudinal steel and at most 20% of the girders with ratings less than 1.0 are controlled by this criterion. Most girders with LRFR ratings less than 1.0 are controlled by the Service III limit state for tension at the bottom of the beam.

Table D-1: Flexure Rating Factor Results for All 9 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	88	2	0	0	0	0	0	3	0	5	0	0	0
LRFR Rating less than 1.0		37	29	26	20	23	13	26	29	42	10	13	15
LFR and LRFR Rating less than 1.0		2	0	0	0	0	0	0	0	4	0	0	0
% with LFR RF greater than LRFR RF		99	98	98	94	98	98	94	98	92	99	99	99
Girders controlled by AASHTO LRFD 5.8.3.5 Rating and LRFR rating less than 1.0		6	6	5	0	1	1	0	2	0	2	2	2
LRFR Rating less than 1.0 and controlled by service limit state		31	23	21	20	22	12	20	27	42	8	11	13

D.1.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table D-2 shows the results for the shear ratings. LFR ratings were greater than 1.0, for most girders and vehicle combinations. There were three girders for the NM-04 and WA-02 vehicles with ratings less than one and several girders for other vehicles with ratings less than 1.0. The percentage of girders with LFR ratings greater than LRFR ratings seems to depend on the vehicle, which is expected because the LRFR shear strength equation uses the ratio of V_u/M_u. The special permit vehicles have more girders with LRFR ratings that are greater than the LFR ratings.

Table D-2: Shear Rating Factor Results for All 9 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	88	1	0	0	2	0	3	0	1	3	0	0	0
LRFR Rating less than 1.0		11	0	0	4	1	0	0	3	11	1	1	1
LFR and LRFR Rating less than 1.0		1	0	0	2	0	0	0	1	3	0	0	0
% with LFR RF greater than LRFR RF		76	68	68	42	55	60	52	65	52	53	58	59

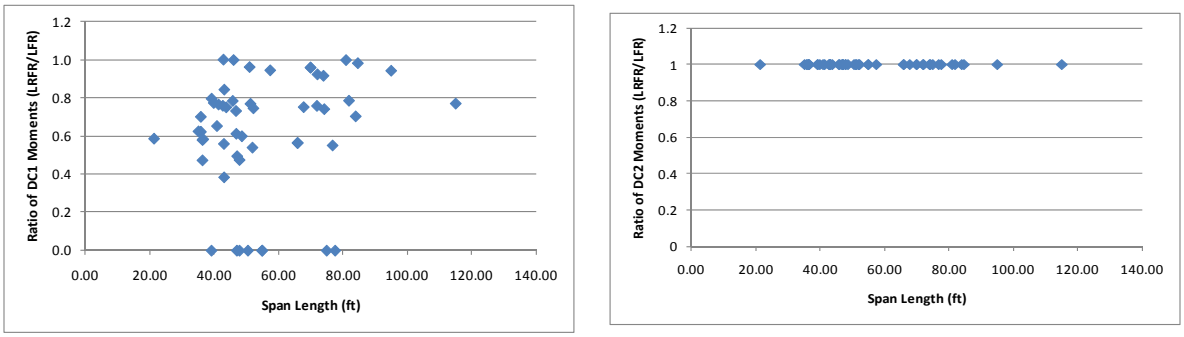
D.2 Exterior Non-Composite Girders

D.2.1 Dead Loads

D.2.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure D-141a, the ratio of unfactored DC1 moments (self-weight, dead loads on non-composite section) varies significantly for this group. There are several girders close to one while others are between 0.4 and 0.8 and some are zero. Figure D-141b shows that the DC2 and DW loads

are equal between methods for all vehicles, this is likely because both have no DC2 or DW loads and the ratio of zero divided by zero was set equal to 1.0.

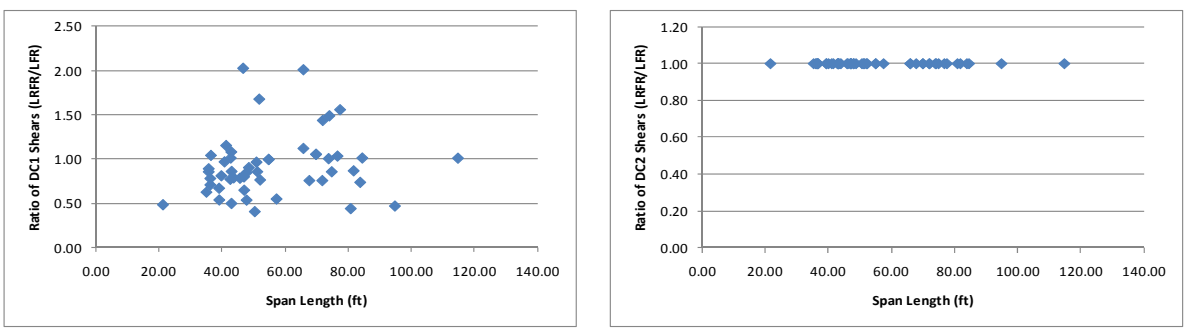


(a) (b)

Figure D-141: Ratios of DC1 and DC2 Moment (unfactored loads LRFR/LFR)

D.2.1.2 Shear

Figure D-142a shows a few girders have a ratio of DC1 shear of 1.0, but most girders have a ratio that is either above or below 1.0. This is mostly due to the variation of the critical section for shear. Figure D-142b shows the same trend as Figure D-141b in that the LFR shear is the same as the LRFR shear. Again, this is likely a result of the ratio of zero divided by zero being set equal to 1.0.



(a) (b)

Figure D-142: Ratios of DC1 and DC2 Shears (unfactored loads LRFR/LFR)

D.2.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure D-143. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

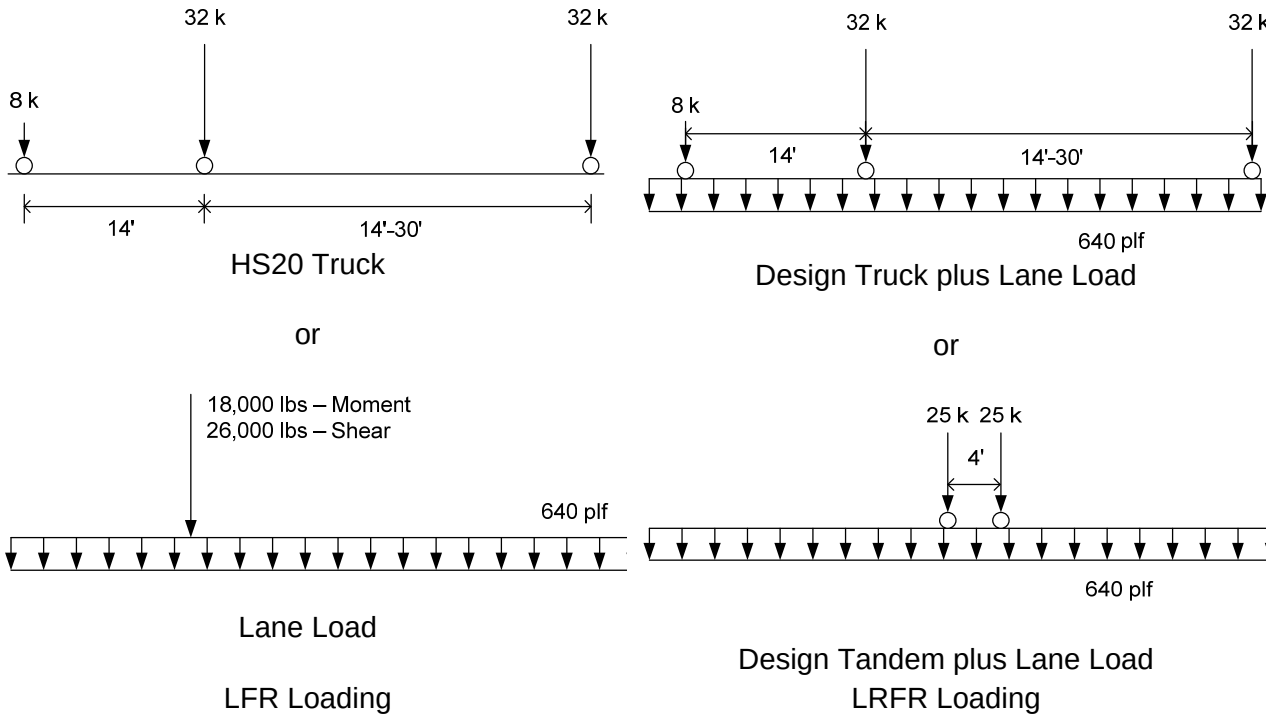
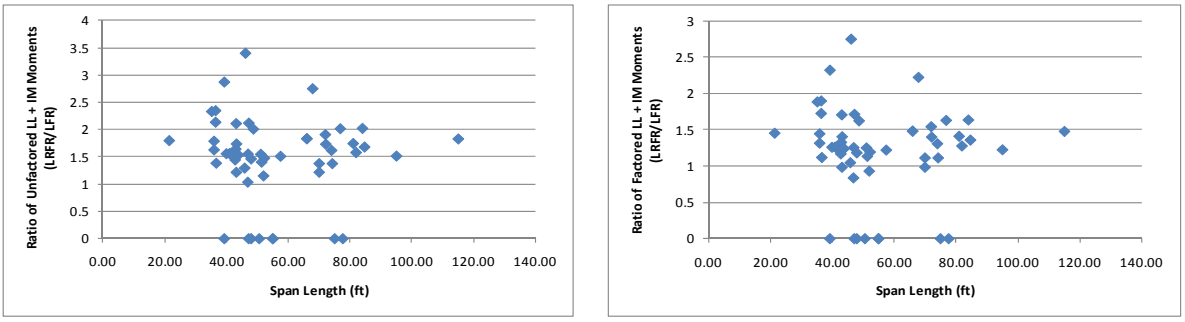


Figure D-143: Vehicle Loadings and Load Factors

D.2.2.1 Moment

D.2.2.1.1 Live Loads

Figure D-144a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between one and two for most of the girders within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure D-144b shows that the results have shifted down and are between 1.0 and 1.5 for most cases. The girders at zero are controlled by rating the criteria of AASHTO LRFD 5.8.3.5 at the support where the moment is zero.



(a) (b)

Figure D-144: Ratio of Unfactored and Factored Live Load plus Impact Moments for HS-20 and HL-93 Loadings, respectively (LRFR/LFR)

D.2.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure D-145 shows that the ratio of resistance is generally between 1.0 and 1.25. The increased resistance for LRFR is due to the reduction in prestress losses. There are also several girders with an LRFR resistance less than the one quarter of the LFR resistance, these girders are controlled by the longitudinal steel requirements of AASHTO LRFD 5.8.3.5 at the support.

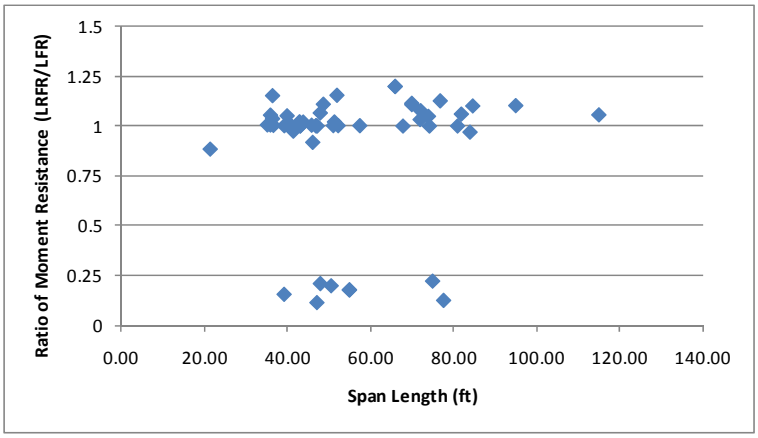
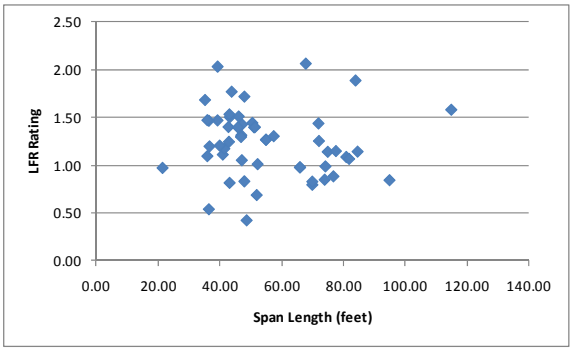


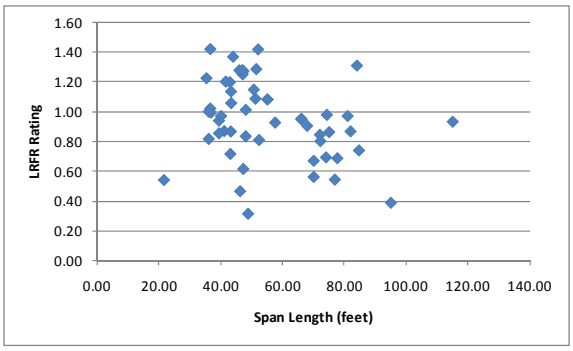
Figure D-145: Ratio of factored Moment Resistance (LFR/LRFR)

D.2.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (53 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 14 girders with LFR ratings less than 1.0, 32 girders with LRFR ratings less than 1.0, and 11 girders where both the LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. This concern is verified within this set of girders. Figure D-146 shows the LFR rating factors and LRFR rating factors. The LFR ratings are greater than 1.0 for most girders while the LRFR ratings are less than 1.4 for all girders. Twelve of the 32 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.



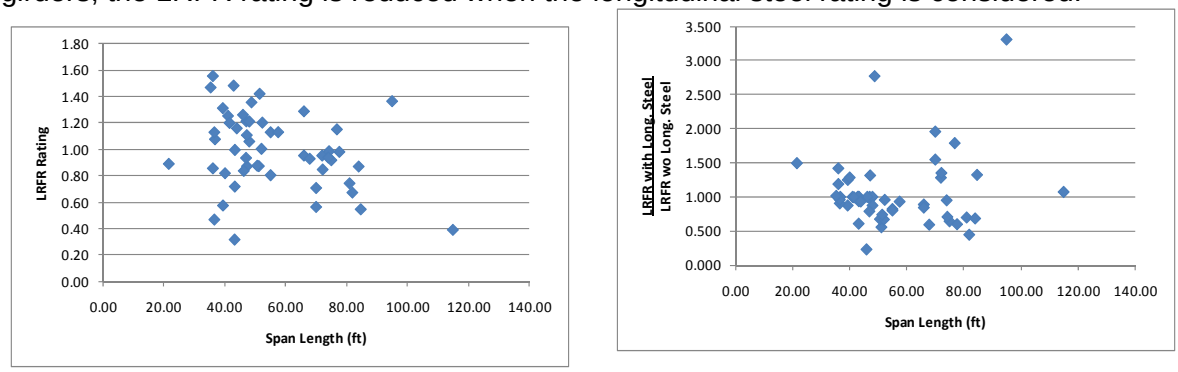
(a)



(b)

Figure D-146: LFR and LRFR Flexure Rating Factors for HS-20 and HL-93 Loading

Figure D-147a shows the LRFR ratings when the longitudinal steel rating is ignored. Figure D-147b shows the ratio of LRFR rating including the longitudinal steel rating divided by the LRFR rating when the longitudinal steel rating is ignored. The figure shows that for 55% of the girders, the LRFR rating is reduced when the longitudinal steel rating is considered.



(a) (b)

Figure D-147: Effect of Longitudinal Steel Rating on LRFR Rating

D.2.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure D-148. The results indicated that 91% of the girders in this set have LFR ratings greater than LRFR ratings. Most ratios are between 0.5 and 1.0, indicating the LFR rating is between one and two times the LRFR rating.

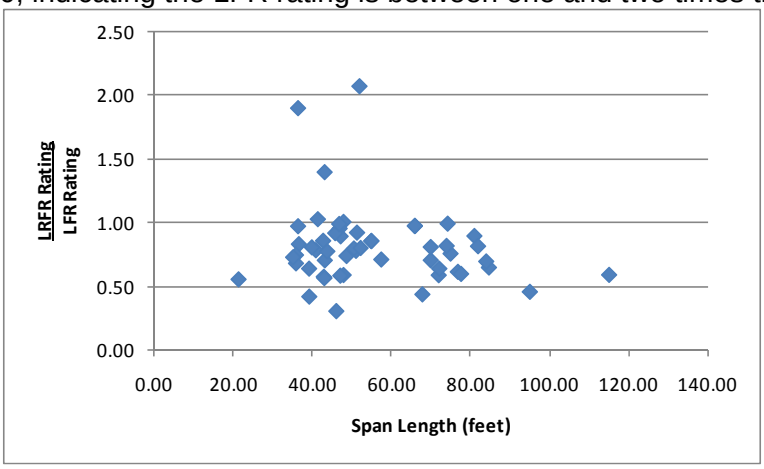


Figure D-148: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Vehicle

Figure D-149 shows the distribution of the LRFR/LFR rating ratio for girders with LRFR ratings less than 1.0. The figure shows that the LRFR rating is significantly smaller than the LFR rating for some girders while for others they are similar. The figure indicates what percentage of the LFR live load would be allowed on the bridge for LRFR.

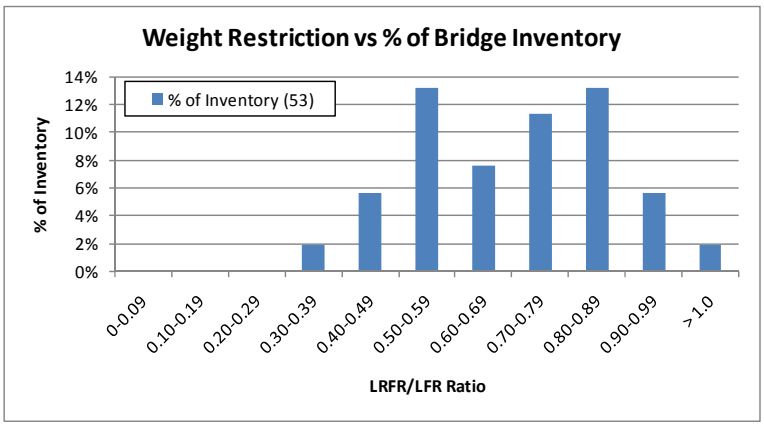


Figure D-149: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

D.2.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure D-150 shows that five girders have a reliability index lower than that assumed in the development of the LRFR Rating Specification at this loading level. These girders generally are of spans under 80 feet in length. The reliability index is between four and eight for most girders.

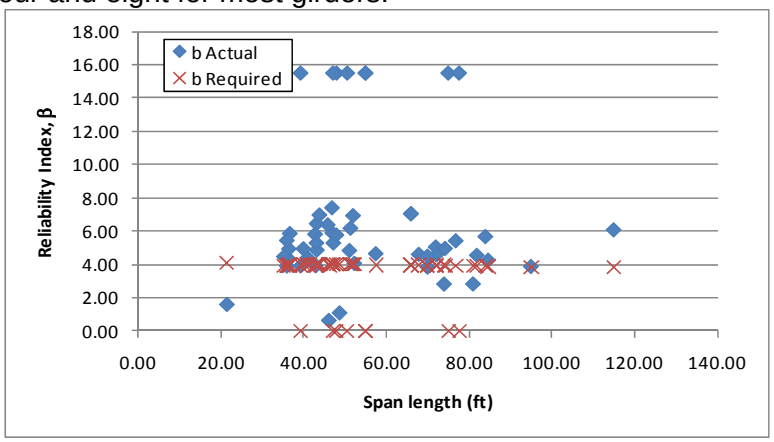


Figure D-150: Flexure Reliability Indices for HL-93 Loading

Figure D-151 shows the reliability index for moment plotted against the LRFR Design Inventory rating for the HL-93 Design Load. The figure shows that girders with a rating of 1.0 have a reliability index of at least four. This is the same value shown in Figure D-150 for beta required.

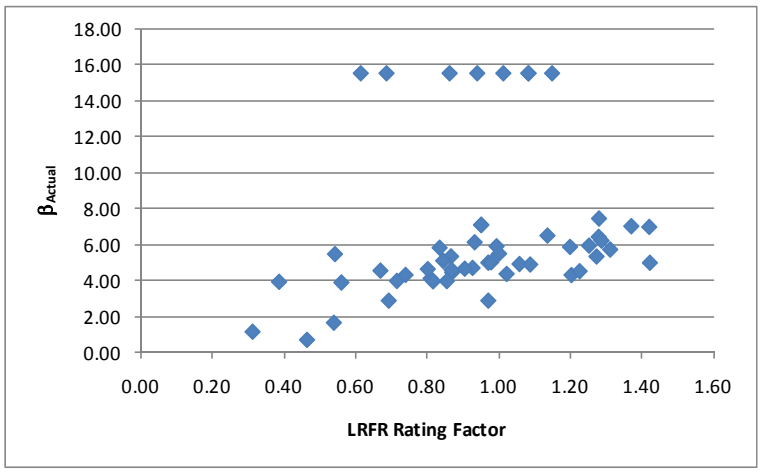


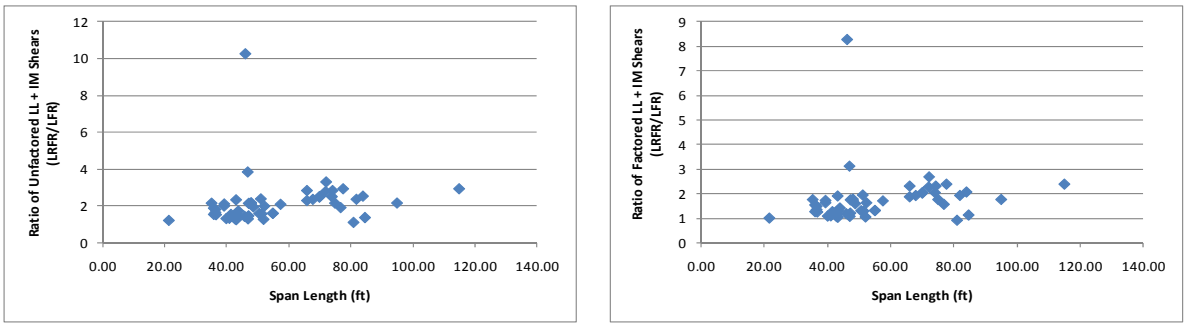
Figure D-151: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Loading

D.2.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment; that is exterior, non-composite, prestressed concrete box girders from simple span bridges.

D.2.2.2.1 Live Loads

Figure D-152a shows that the ratio of unfactored shear varies significantly, with most girders between 1.5 to 2.5. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure D-152b shows that the ratio of factored live load shears has decreased and is generally between 1.0 and 2.0 for most cases.



(a) (b)

Figure D-152: Ratio of Unfactored and Factored Live Load plus Impact Shears for HS-20 and HL-93 Loading, respectively (LRFR/LFR)

As shown in Figure D-153, the location of the critical section for varies for some girders in this subset. The difference in the factored shears shown in Figure D-152 was likely exacerbated by the difference in the critical section for shear rating.

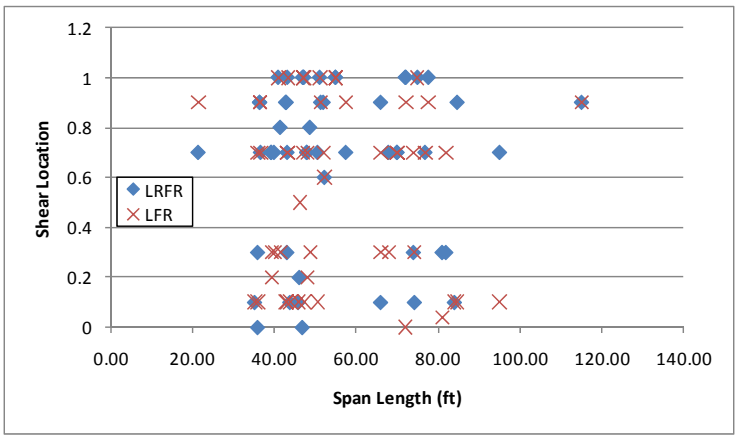


Figure D-153: Graph of critical shear location for HS-20 and HL-93 loadings

D.2.2.2.2 Resistance

The next step was to verify that the resistances were reasonably similar between LFR and LRFR. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure D-154 shows that the ratio of resistance varies significantly from 0.7 to 2. The LRFR resistance is greater than LFR resistance for most girders but there is a significant number that have higher LFR resistance.

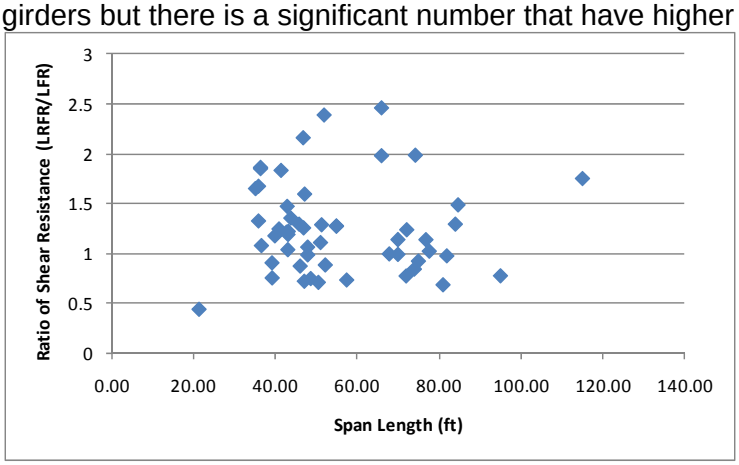
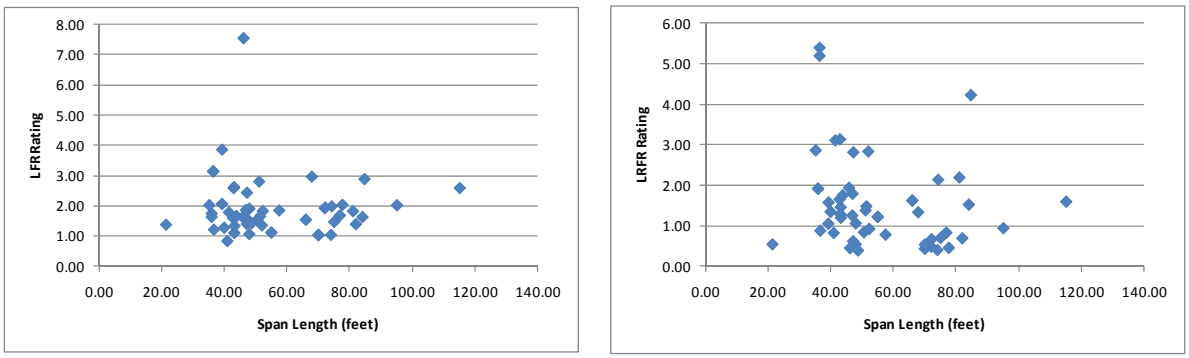


Figure D-154: Ratio of factored Shear Resistance for Design Vehicles (LFR/LRFR)

D.2.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there is one girder with LFR ratings less than 1.0, 20 girders with LRFR ratings less than 1.0, and one girder where both LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. For this subset, there is a significant number of girders that have shear ratings less than 1.0 for LRFR. In addition, the LFR rating was greater than the LRFR rating for 58% of the girders in this subset. Figure D-155 shows the LFR rating factors and LRFR rating factors. The LFR rating is between one and two for most girders while the LRFR rating has more scatter and varies from 0.4 to 2.0.



(a) (b)

Figure D-155: LFR and LRFR Shear Rating Factors for HS-20 and HL-93 Loadings

D.2.2.2.4 Rating Factor Comparisons

Figure D-156 shows the ratio of the LRFR rating to the LFR rating. 42% of the girders in this set have LRFR ratings greater than LFR ratings. This is shown in the figure below. There is significant scatter in the ratios calculated for these girders with many less than 0.5 while a similar number are above 1.0.

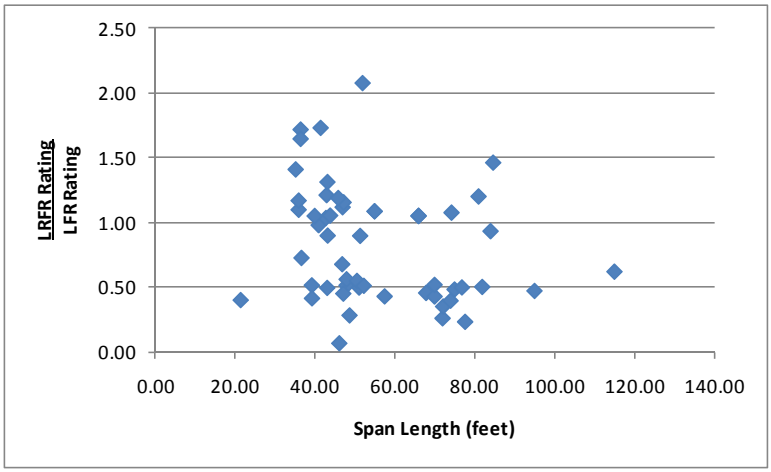


Figure D-156: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Vehicle

Figure D-157 shows the distribution of the LRFR/LFR ratio for the girders in this group with LRFR ratings less than 1.0. Most girders with LRFR ratings less than 1.0 have an LRFR rating that is between 20 and 60% of the LFR rating. This indicates that the live load allowed on the bridge for LRFR will be significantly reduced from that allowed for LFR.

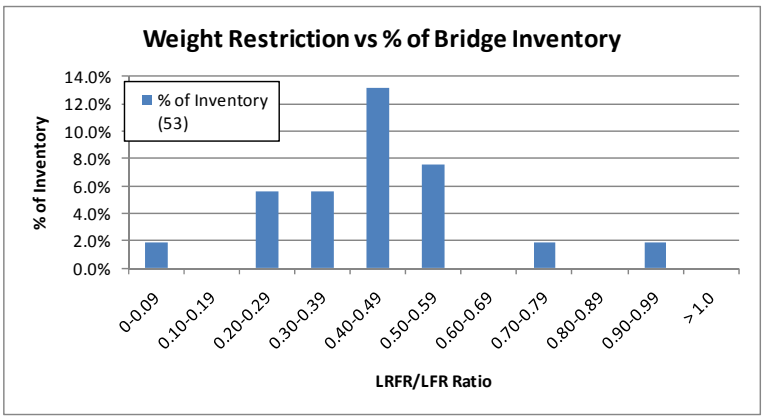


Figure D-157: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

D.2.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure D-158 shows that 14 girders have a reliability index for shear less than the required level. The girders that do not have the required level of reliability are generally less than 100 feet in length. The girders with reliability higher than the required value have a reliability index between four and seven.

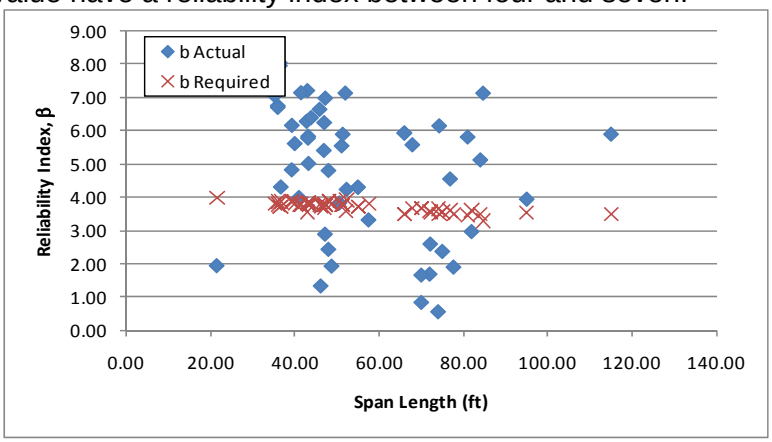


Figure D-158: Shear Reliability Indices for HL-93 Loading

Figure D-159 shows the reliability index for shear plotted against the LRFR Inventory shear rating for the HL-93 Design Load. The figure shows that girders with a rating of 1.0 have a reliability index of approximately 4 which is very similar to the beta required value shown in Figure D-158.

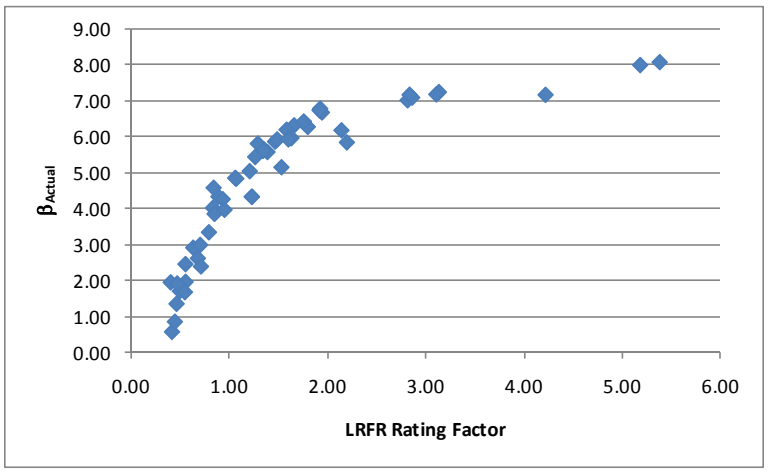


Figure D-159: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

D.2.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-160. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

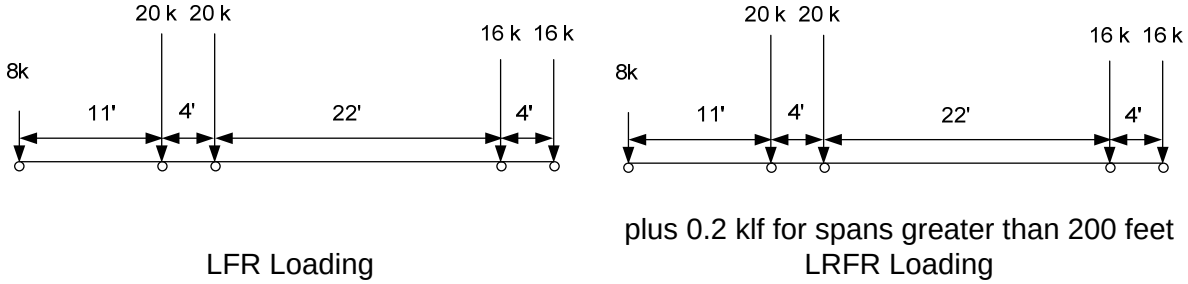


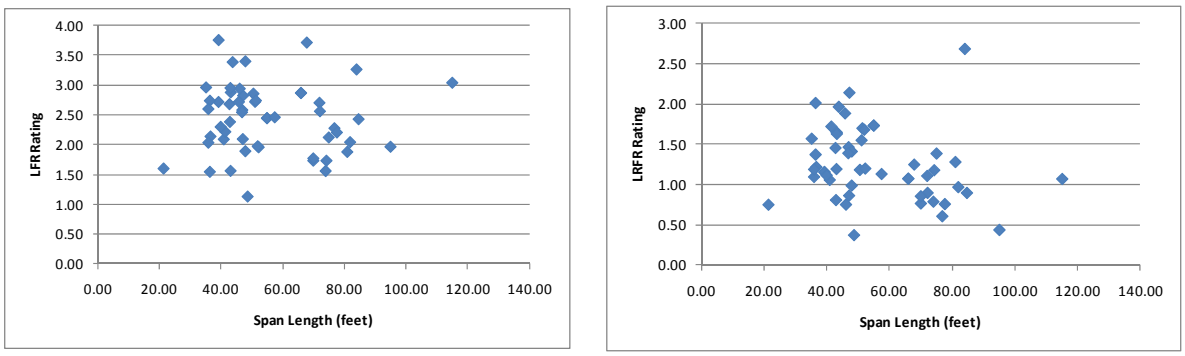
Figure D-160: Vehicle Loadings and Load Factors

D.2.3.1 Moment

The following section contains the results for exterior, non-composite prestressed box girders within simple span bridges for the DE-07 Vehicle.

D.2.3.1.1 Rating Factors

Figure D-161 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 15 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. Two of the 15 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 98% of girders in this subset. The LFR rating is generally greater than 1.5 while the LRFR rating is typically between 0.5 and 2.0.



(a) (b)

Figure D-161: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure D-162 shows the percentage of girders in each category of rating for the different ADTT categories in the MBE for the DE-07, a routine permit vehicle. 28% of girders have ratings less than 1.0 for all ADTT categories. In general, more girders have lower ratings as the ADTT increases. All girders have LFR ratings greater than 1.0. Switching to LRFR causes a significant number of girders to have ratings less than 1.0.

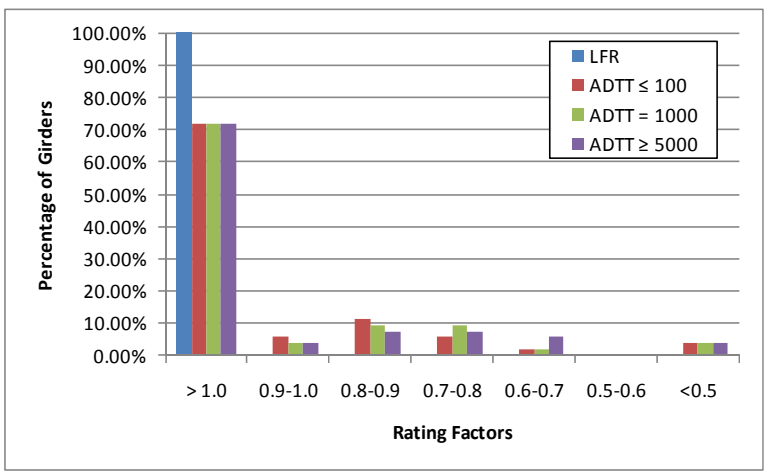


Figure D-162: Moment Rating for Various ADTTs in MBE for DE-07 Vehicle

D.2.3.1.2 Rating Factor Comparisons

Figure D-163 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating, which occurs for one girder in this group. The ratio generally decreases with longer span lengths with significant scatter for those girders between 40 and 50 feet. The ratio is between 0.2 and 0.8 for most girders.

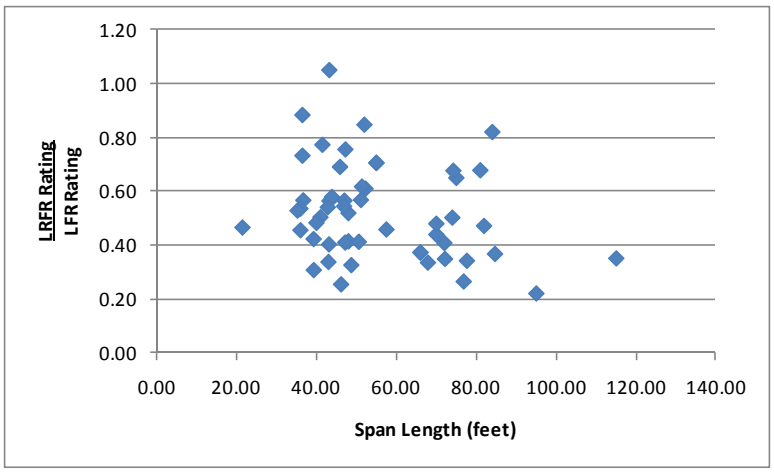


Figure D-163: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

D.2.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-164 shows that all girders have a reliability index based upon girder strength that is greater than the target reliability index of 2.5. The reliability index is between six and ten for most girders.

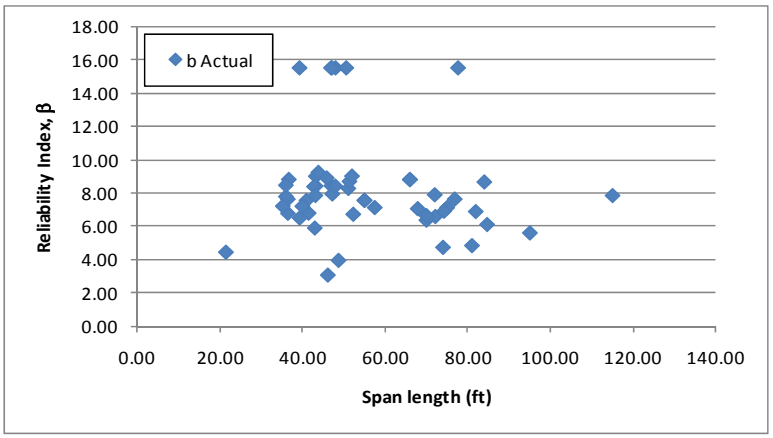


Figure D-164: Flexure Reliability Indices for DE-07 Vehicle

Figure D-165 shows the reliability index for moment plotted against the LRFR routine permit moment rating for the DE-07 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index greater than six far exceeding the target reliability of 2.5. This indicates the target reliability can be achieved while using load factors for live load that are less than those currently in the MBE.

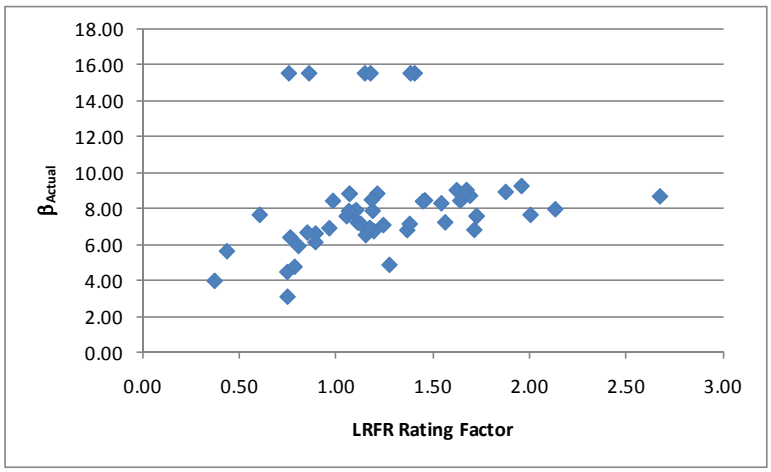
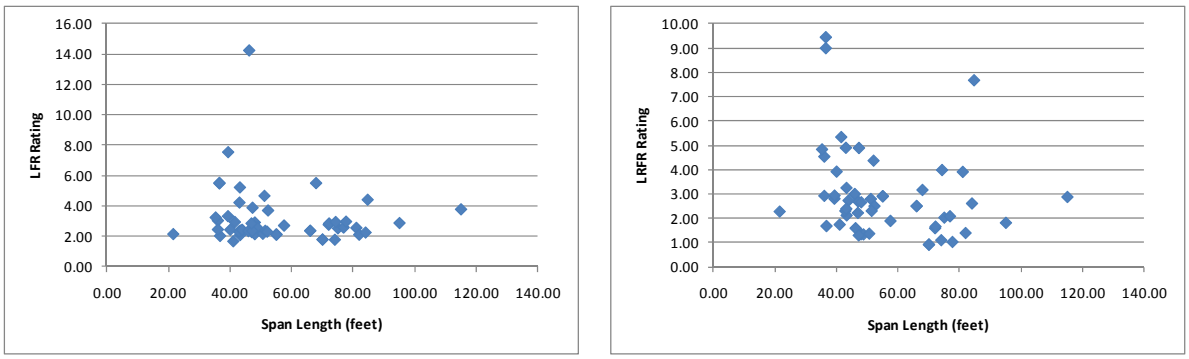


Figure D-165: Flexure Reliability Index vs LRFR Moment Rating for DE-07 Vehicle

D.2.3.2 Shear

D.2.3.2.1 Rating Factors

For shear, there are two girders with LRFR ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 53% of the girders in this subset. Figure D-166 shows the LFR and LRFR ratings. The LFR ratings are between two and four for most girders while the LRFR ratings are between one and three four most girders.



(a) (b)

Figure D-166: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure D-167 shows the shear ratings corresponding to the different ADTT categories in the MBE for a routine permit vehicle. ADTT = 100 causes zero girders to have LRFR shear ratings less than 1.0; ADTT = 5,000 causes 7.5% of girders to have LRFR shear ratings less than 1.0. Switching to LRFR from LFR does not cause a significant number of girders to have ratings less than 1.0.

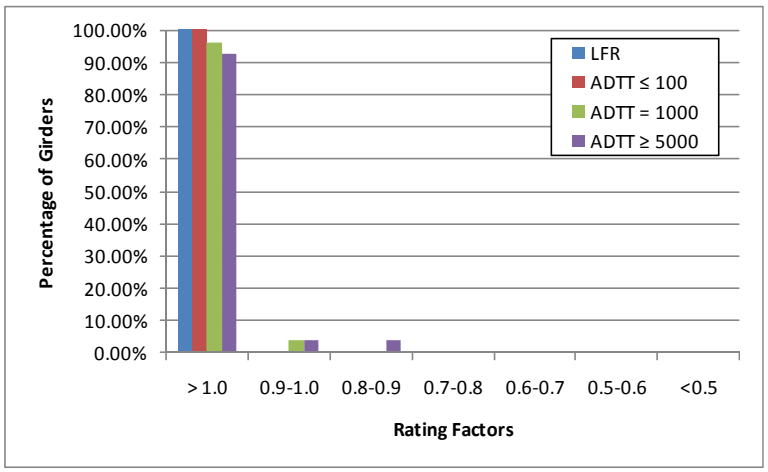


Figure D-167: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

D.2.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure D-168 shows the comparison of rating factors. The number of girders with LFR rating greater than LRFR rating is about half of the girders in this subset. Most girders have a ratio of LRFR rating to LFR rating between 0.5 and 2.0.

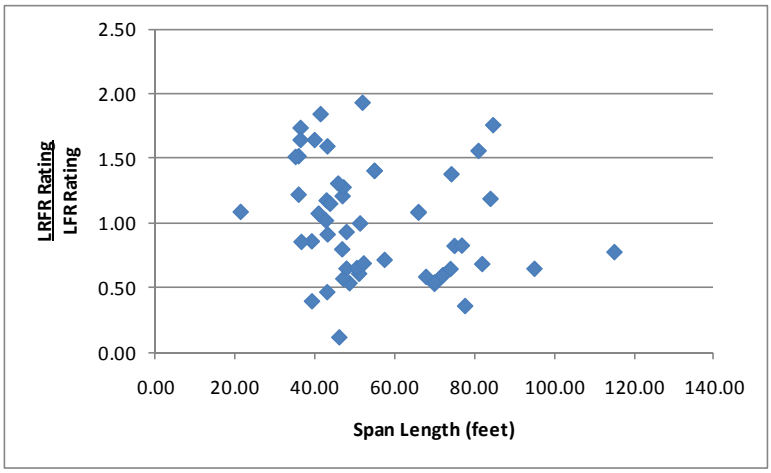


Figure D-168: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

D.2.3.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-169. The reliability index is between five and eight for most girders, well above the target reliability of 2.5.

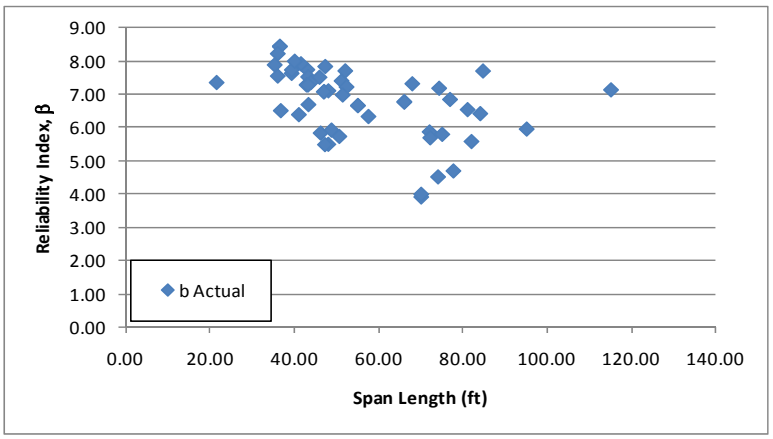


Figure D-169: Shear Reliability Indices for DE-07 Vehicle

Figure D-170 shows the shear reliability index plotted against the LRFR shear rating for the DE-07 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index of approximately four, exceeding the target of 2.5. This suggests the target reliability can be achieved while using lower live load factors than those currently present in the MBE.

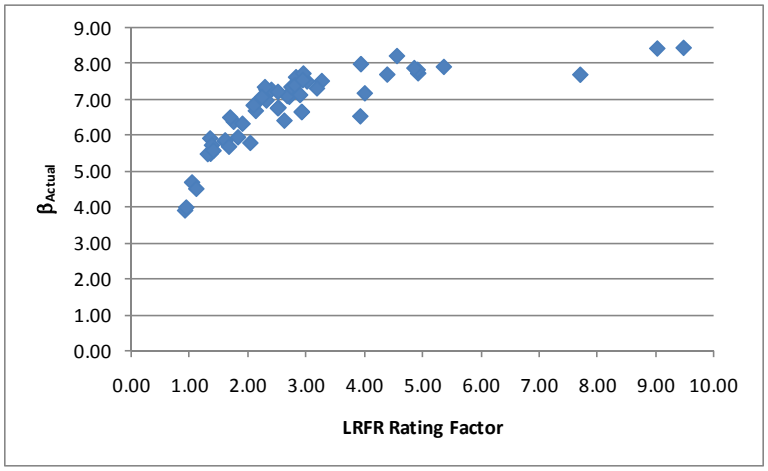
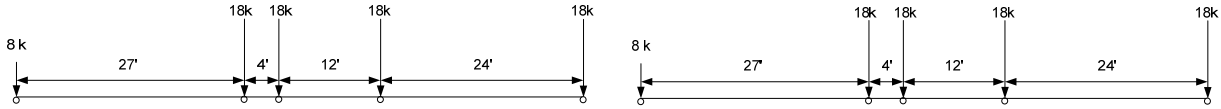


Figure D-170: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

D.2.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-171. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

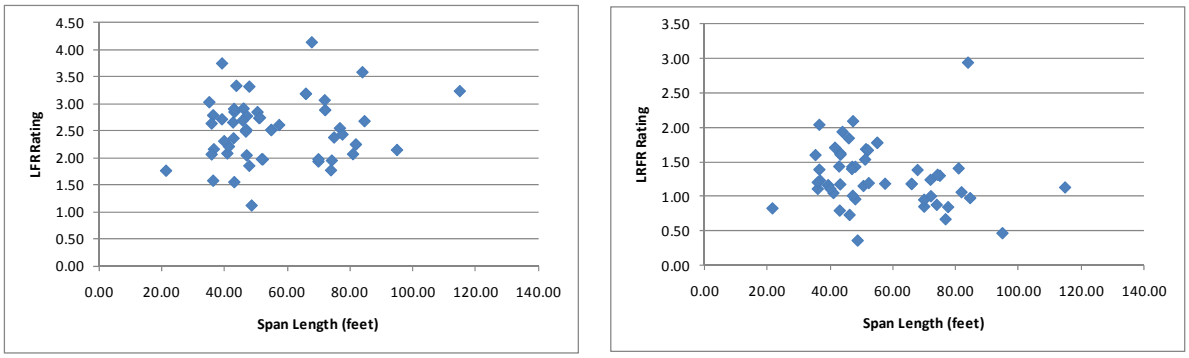
Figure D-171: Vehicle Loadings and Load Factors

D.2.4.1 Moment

The following section contains the results for exterior, non-composite prestressed box girders used in simple span bridges for the FL-04 Vehicle.

D.2.4.1.1 Rating Factors

Figure D-172 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 12 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 98% of the girders in this subset. One of the twelve girders with LRFR ratings less than 1.0 is controlled by the longitudinal steel rating. The LFR rating is between 1.5 and 3.0 for most girders while the LRFR rating is between 0.5 and 2.0 for most girders.



(a) (b)

Figure D-172: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure D-173 shows the percentage of girders in each category for the various ADTTs in the MBE for routine permit vehicles. 23% of girders have LRFR moment ratings less than 1.0 for all ADTTs. The number of girders with low ratings remains the same with increasing ADTT but generally shifts to lower ratings. Switching to LRFR causes a significant number of girders to have ratings less than 1.0, as all girders have LFR ratings greater than 1.0.

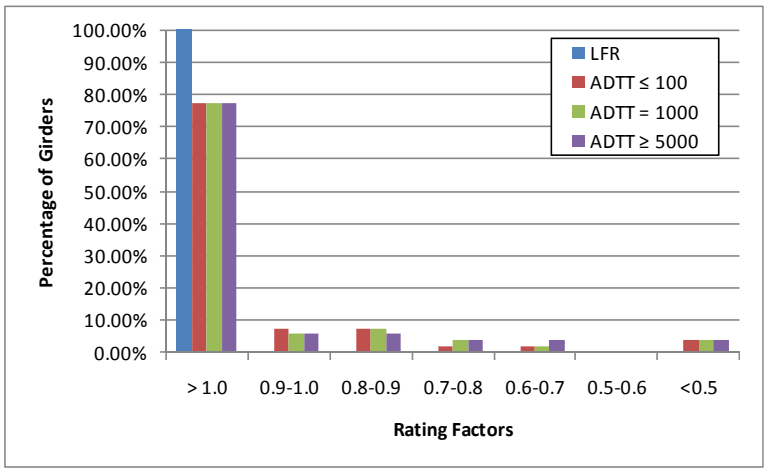


Figure D-173: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

D.2.4.1.2 Rating Factor Comparisons

Figure D-174 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. As mentioned before there is one girder with an LRFR rating greater than the LFR rating. The LRFR rating is typically 30 to 60% of the LFR rating.

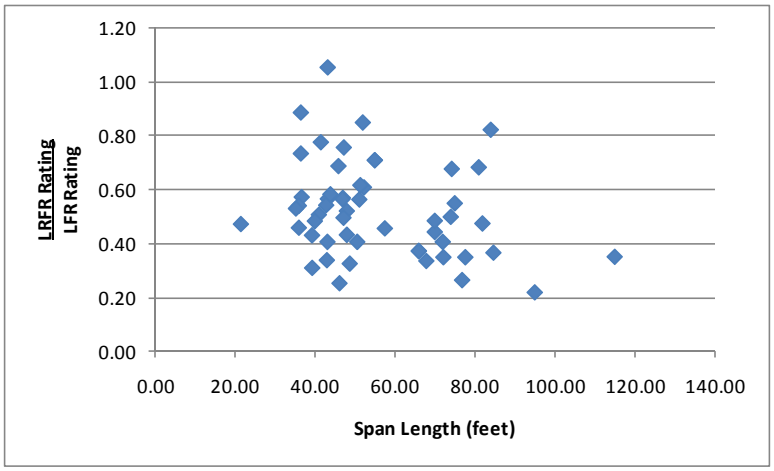


Figure D-174: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

D.2.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-175 shows that all girders have a reliability index based upon girder strength that is greater than the target reliability index of 2.5. The reliability index is between six and ten for most girders.

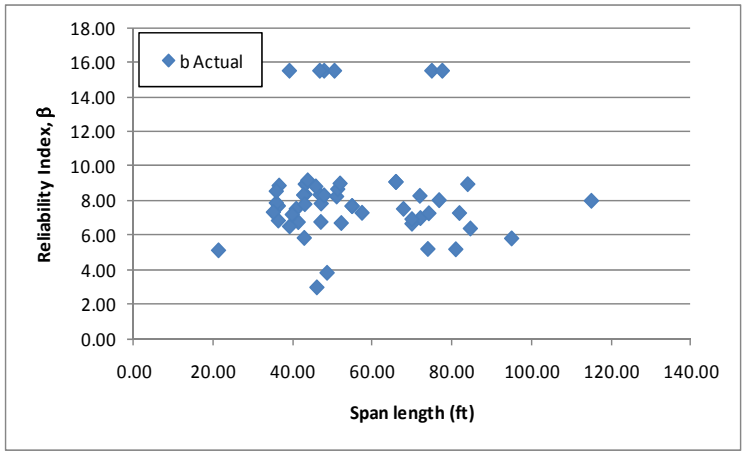


Figure D-175: Flexure Reliability Indices for FL-04 Vehicle

Figure D-176 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index that is greater than six, well above the target reliability of 2.5. This indicates the target reliability can be achieved using lower live load factors than those currently in the MBE.

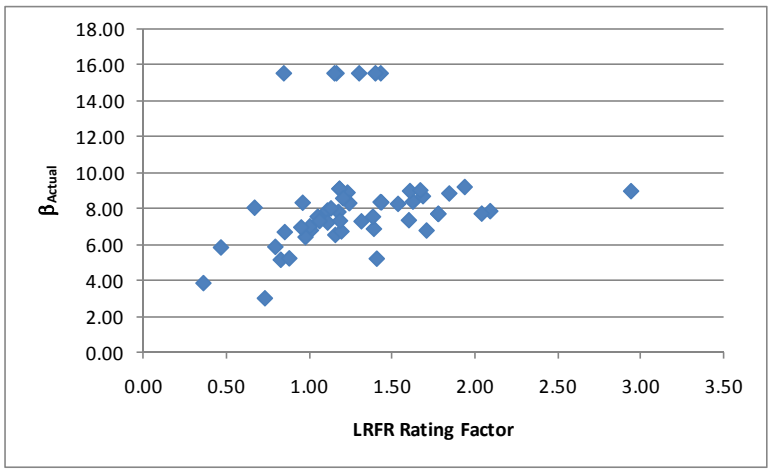
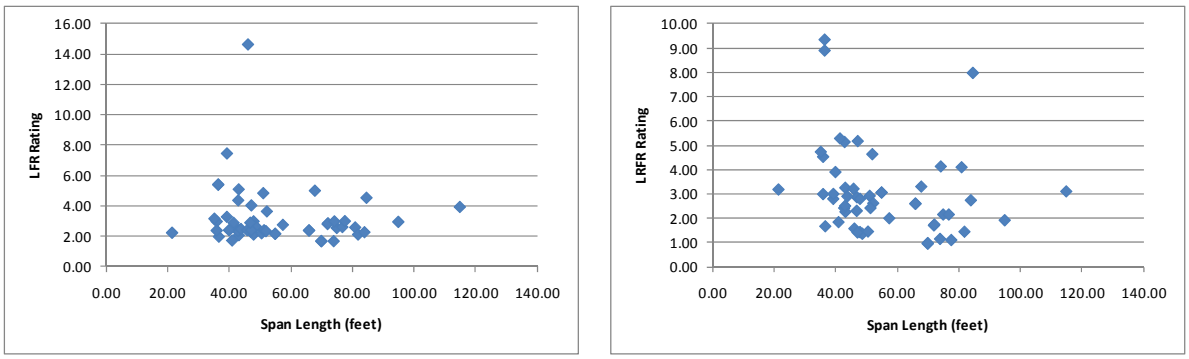


Figure D-176: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

D.2.4.2 Shear

D.2.4.2.1 Rating Factors

For shear, there are two girders with LRFR ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 51% of the girders in this subset. Figure D-177 shows the LFR and LRFR ratings, respectively. The LFR rating is between two and five for most girders while the LRFR rating is between one and five for most girders.



(a) (b)

Figure D-177: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure D-178 shows the percentage of girders in each rating category for shear. All girders have LRFR ratings greater than 1.0 for ADTT = 100. 3% and 5% of girders have LRFR ratings less than one for ADTTs of 1,000 and 5,000, respectively. All girders have LRFR ratings above 0.8. Few girders are affected by the switch to LRFR from LFR; all girders have LFR ratings greater than 1.0.

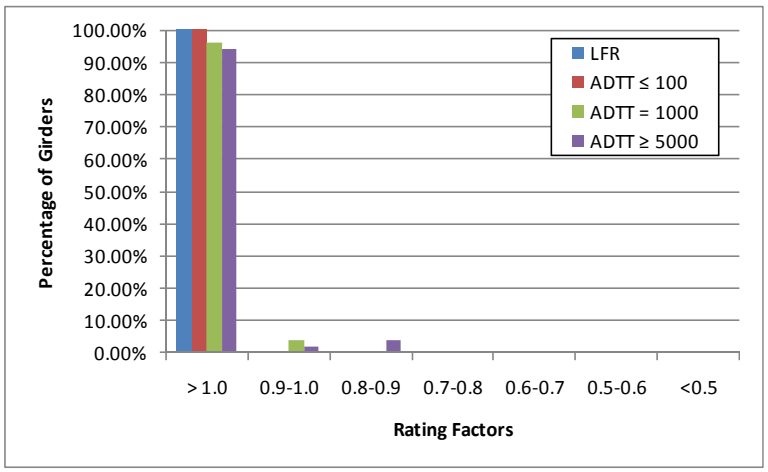


Figure D-178: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

D.2.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-179 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with the ratio decreasing for longer span lengths.

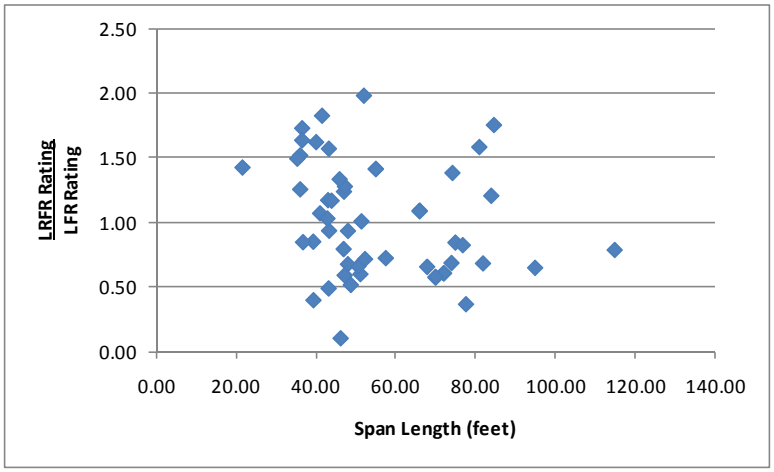


Figure D-179: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

D.2.4.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-180. The reliability index is greater than five for most girders in this group for this vehicle.

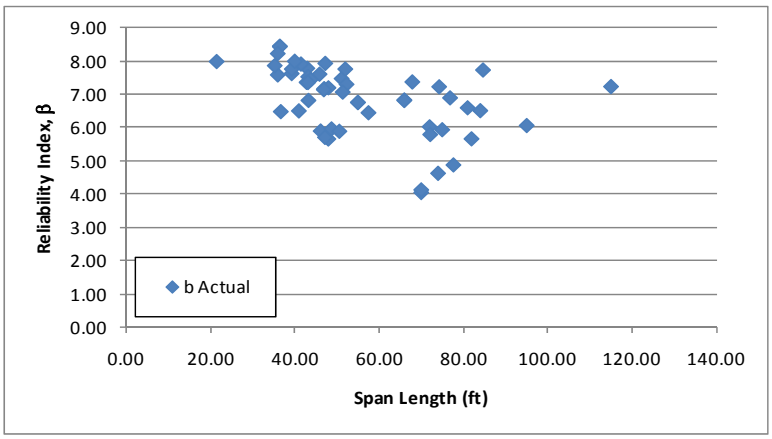


Figure D-180: Shear Reliability Indices for FL-04 Vehicle

Figure D-181 shows the shear reliability index plotted against the LRFR shear rating for the FL-04 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index of approximately four. The target reliability index is 2.5; this indicates the target reliability can be obtained while using LRFR live load factors less than those currently in the MBE. The load factors can be reduced to a level that produces a reliability index close to the target value while producing a rating of 1.0.

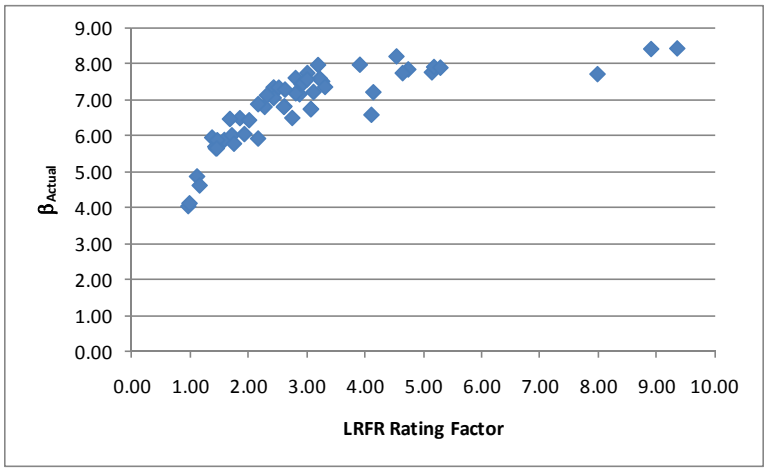
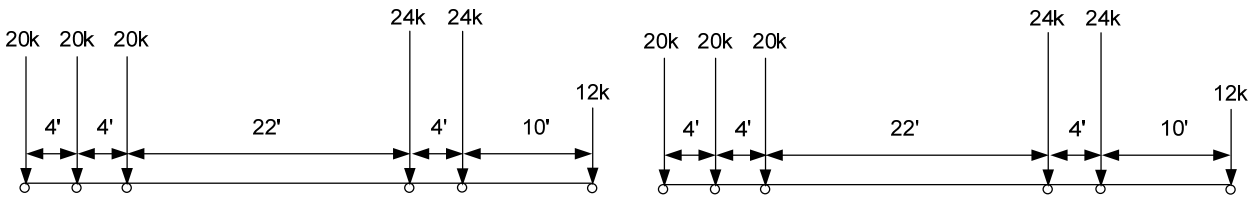


Figure D-181: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

D.2.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-182. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

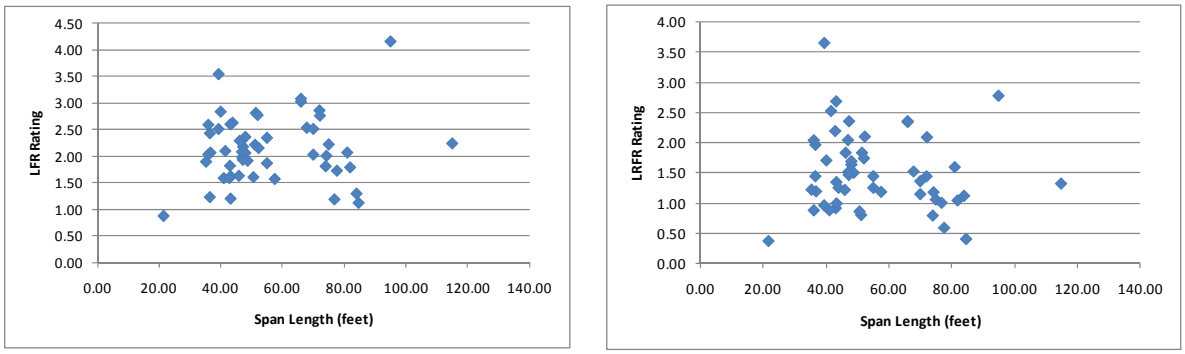
Figure D-182: Vehicle Loadings and Load Factors

D.2.5.1 Moment

The following section contains the results for exterior, non-composite prestressed box girders within simple span bridges for the IL-01 Vehicle.

D.2.5.1.1 Rating Factors

Figure D-183 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 11 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 87% of the girders in this subset. Two of the eleven girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR rating is between 1.5 and 3.0 for most girders while the LRFR rating is between 1.0 and 2.5.



(a) (b)

Figure D-183: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure D-184 shows the percentage of moment ratings in each rating category for the IL-01 vehicle. 17% of girders have LRFR ratings less than 1.0 when the vehicle is treated as an escorted permit vehicle and 24.5% of girders have LRFR ratings less than 1.0 when the vehicle is treated as a multiple trip permit with an ADTT of 5,000. The increase in girders having ratings less than 1.0 is expected due to the increase in the live load factor. 98% of girders have LFR ratings greater than 1.0.

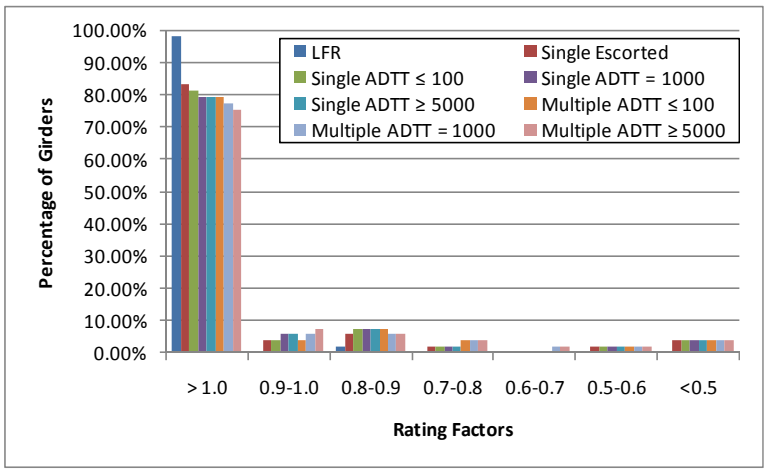


Figure D-184: Moment Ratings for Various ADTTs in MBE for IL-01

D.2.5.1.2 Rating Factor Comparisons

Figure D-185 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating, which occurs for 13% of the girders for this vehicle. The ratio is generally between 0.4 and 0.8, with lower ratios generally for longer spans.

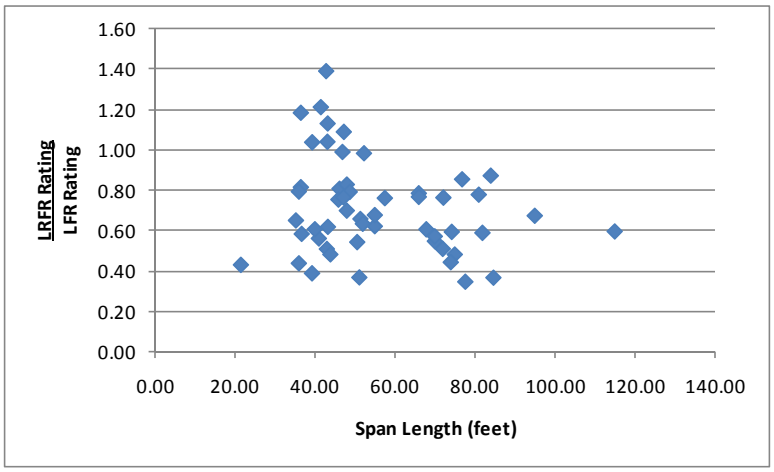


Figure D-185: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

D.2.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-186 shows that seven girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. There is significant scatter in the reliability index with most girders between six and ten.

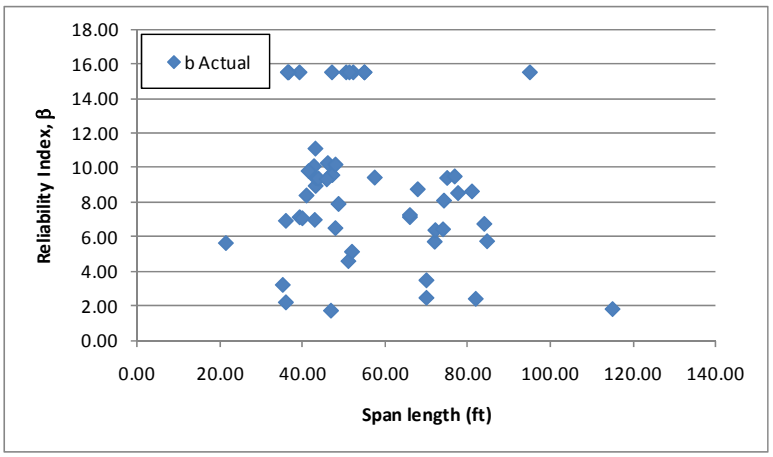


Figure D-186: Flexure Reliability Indices for IL-01 Vehicle

Figure D-187 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The figure shows the reliability index for a girder with a rating near one varies from two to ten. The reliability index exceeds the target value for most girders with a rating above 1.0. This indicates that reducing the live load factors is possible while maintaining the target level of reliability.

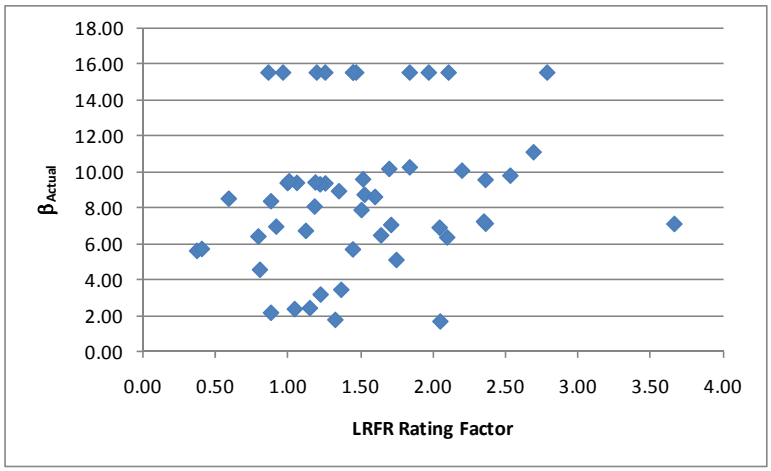
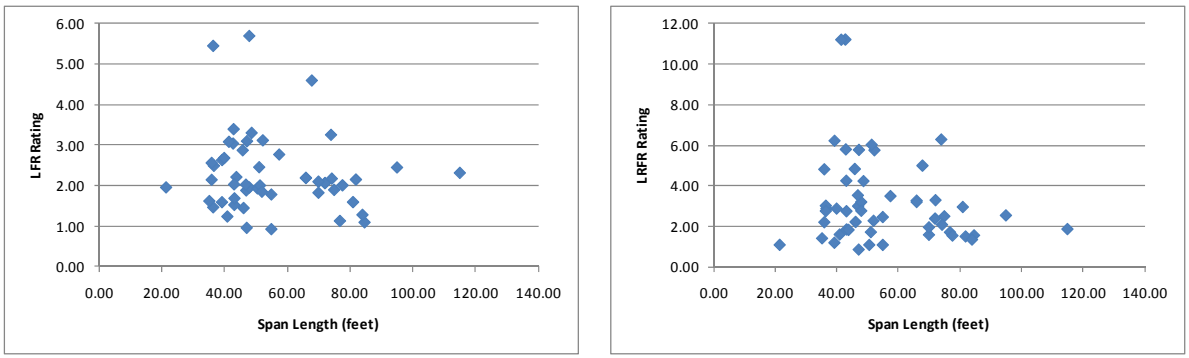


Figure D-187: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

D.2.5.2 Shear

D.2.5.2.1 Rating Factors

For shear, there are two girders that have an LFR rating factor less than 1.0, one girder with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 26% of the girders in this subset. Figure D-188 shows the LFR and LRFR ratings. The LFR rating is generally between 1.0 and 3.0 for all span lengths, while the LRFR rating is between one and five for most girders.



(a) (b)

Figure D-188: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure D-189 shows the percentage of girders with shear ratings in each category. The first three LRFR categories have more girders with passing ratings than LFR. For the worst case permit and loading combination, multiple trip with ADTT = 5,000, less than 10% of girders have LRFR ratings less than 1.0. Most girders with LRFR ratings less than 1.0 have shear ratings greater than 0.8. 96% of girders have LFR ratings that are greater than 1.0.

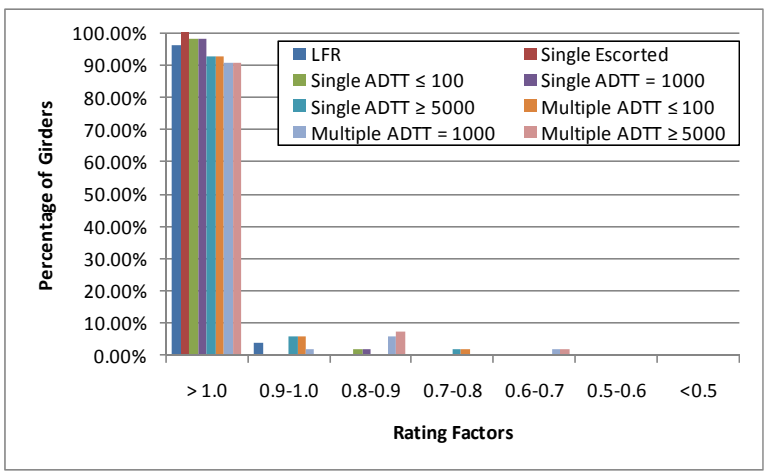


Figure D-189: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

D.2.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-190 shows the comparison of rating factors. As mentioned before, 64% of the girders have LRFR ratings greater than LFR ratings with girders of short span lengths having higher ratios of ratings. The ratio is between 0.5 and 2.0 for most girders.

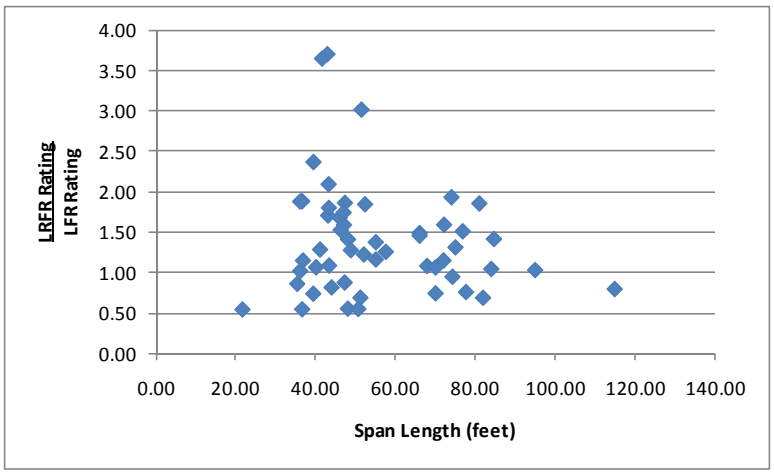


Figure D-190: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

D.2.5.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 3.5 for all but one girder as shown in Figure D-191. The reliability index is between six and nine for most girders.

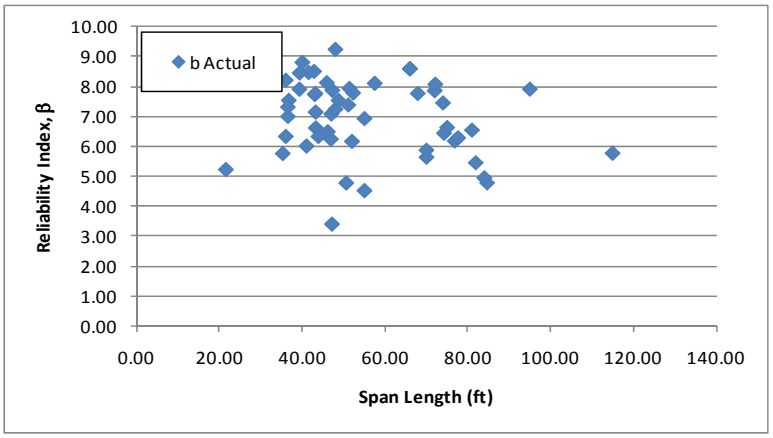


Figure D-191: Shear Reliability Indices for IL-01 Vehicle

Figure D-192 shows the shear reliability index plotted against the LRFR shear rating for the IL-01 vehicle. The figure shows that a girder with a rating of 1.0 has a reliability index near 3.5. This is the target reliability for the IL-01 vehicle being treated as a special permit vehicle. The live load factors in the MBE provide the target level of reliability.

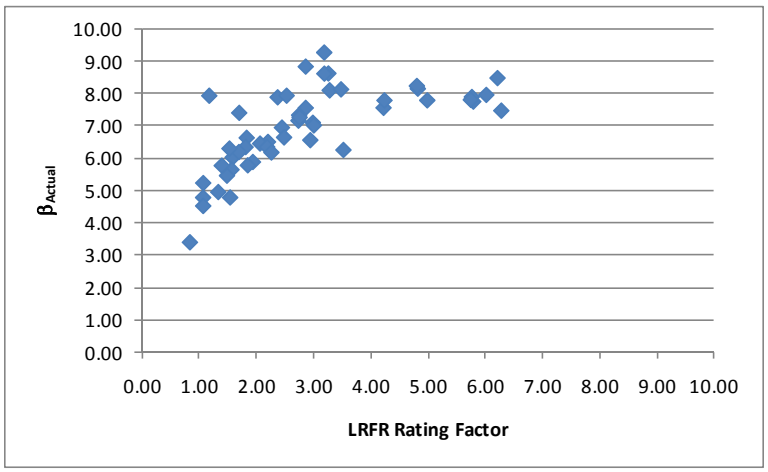


Figure D-192: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

D.2.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-193. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

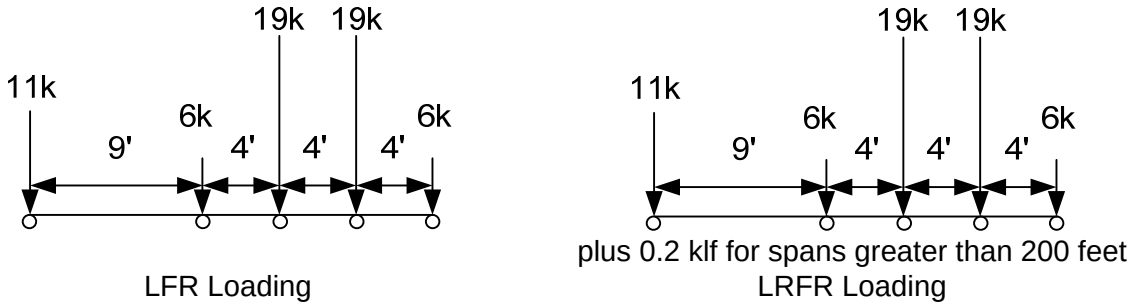


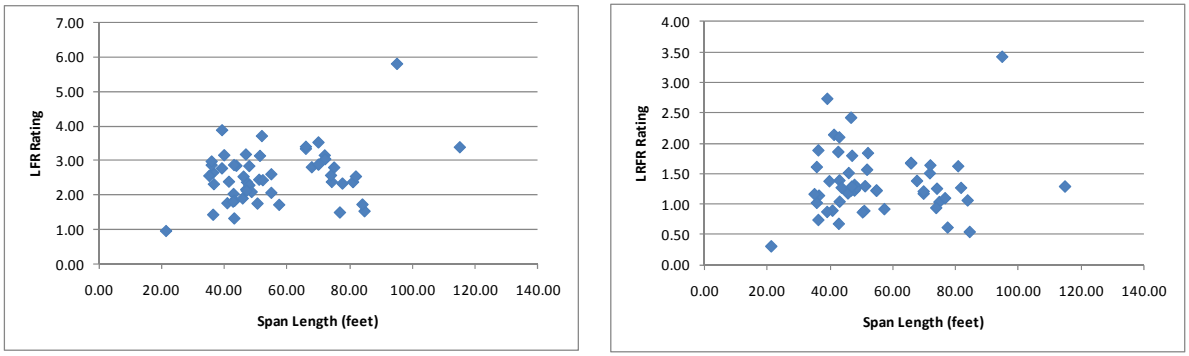
Figure D-193: Vehicle Loadings and Load Factors

D.2.6.1 Moment

The following section contains the results for exterior, non-composite prestressed box girders within simple span bridges for the NC-21 Vehicle.

D.2.6.1.1 Rating Factors

Figure D-194 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 11 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 96% of the girders in this subset. The LFR rating is between one and three for most girders while the LRFR rating is between 0.5 and 2.5 for most girders. Two of the eleven girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.



(a) (b)

Figure D-194: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure D-195 shows the percentage of girders with moment ratings in each category. Approximately 21% of girders have LRFR ratings less than 1.0 for the different ADTT categories in the MBE. Most girders with LRFR ratings less than 1.0 have ratings that are above 0.8. 98% of girders have LFR ratings greater than 1.0.

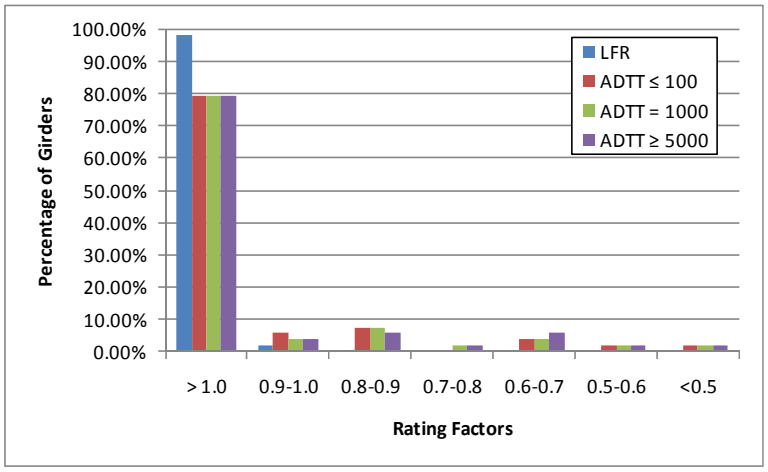


Figure D-195: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

D.2.6.1.2 Rating Factor Comparisons

Figure D-196 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating; this occurs for two girders as shown in the figure. The ratio is generally between 0.3 and 0.8 for this vehicle.

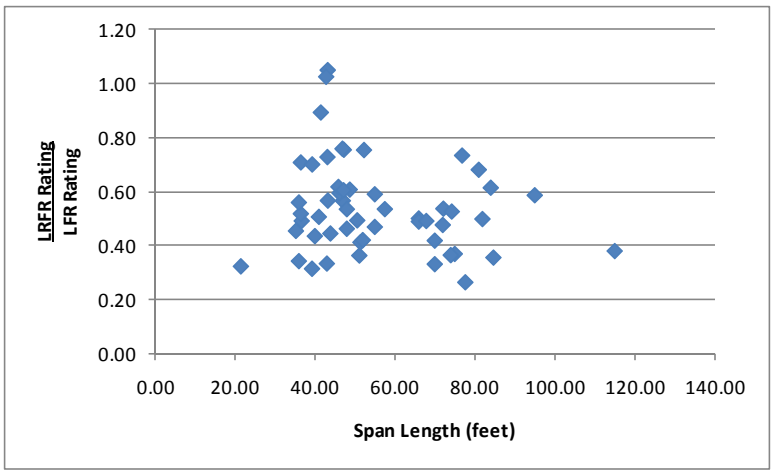


Figure D-196: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

D.2.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-197 shows that four girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The figure shows that the actual reliability index varies but is between four and ten for most girders.

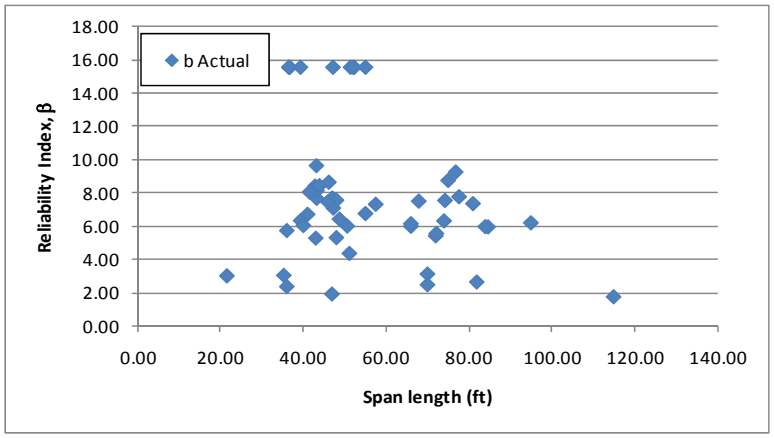


Figure D-197: Flexure Reliability Indices for NC-21 Vehicle

Figure D-198 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index that varies between two and nine. The average reliability index is greater than the target reliability of 2.5. This indicates the target reliability can be obtained using lower LRFR live load factors.

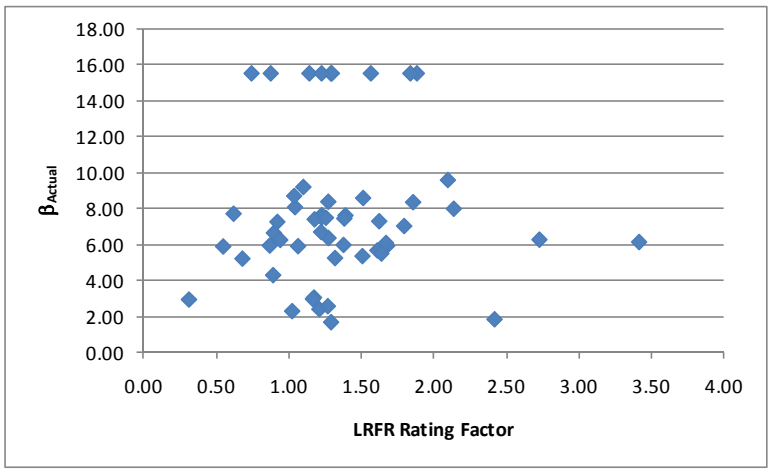
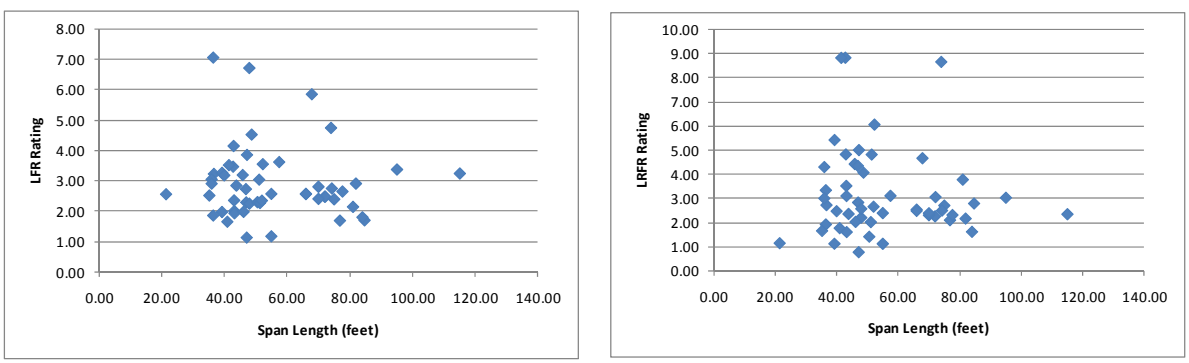


Figure D-198: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

D.2.6.2 Shear

D.2.6.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, one girder with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 53% of the girders in this subset. Figure D-199 shows the LFR and LRFR ratings. The LRFR ratings are between one and four while the LFR ratings are between 1.5 and 4 for most girders.



(a) (b)

Figure D-199: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure D-200 shows the percentage of girders with shear ratings in each category. 5.7% of girders have LRFR ratings less than 1.0 for an ADTT of at least 5,000. For shear, switching from LFR to LRFR does not cause a significant number of girders to fail the rating. For ADTTs of 100 and 1,000, 1.9% of girders have LRFR shear ratings less than 1.0. All girders have LFR ratings that are greater than 1.0.

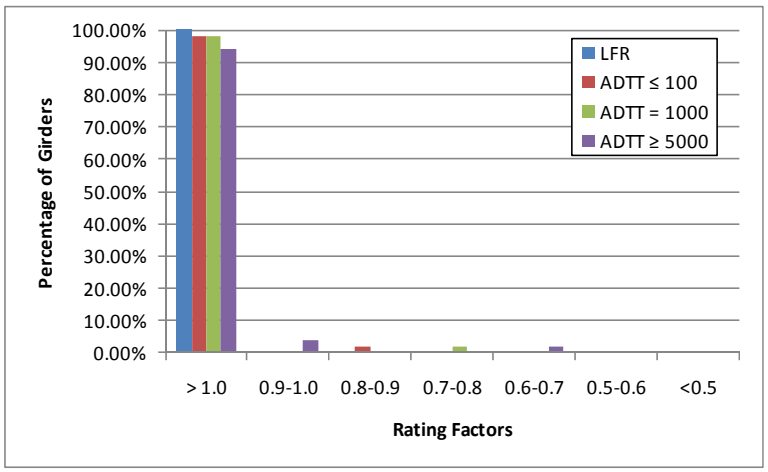


Figure D-200: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

D.2.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-201 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.75. Shorter span girders are more likely to have an LRFR rating greater than the LFR rating. 47% of girders have LRFR ratings greater than the LFR ratings.

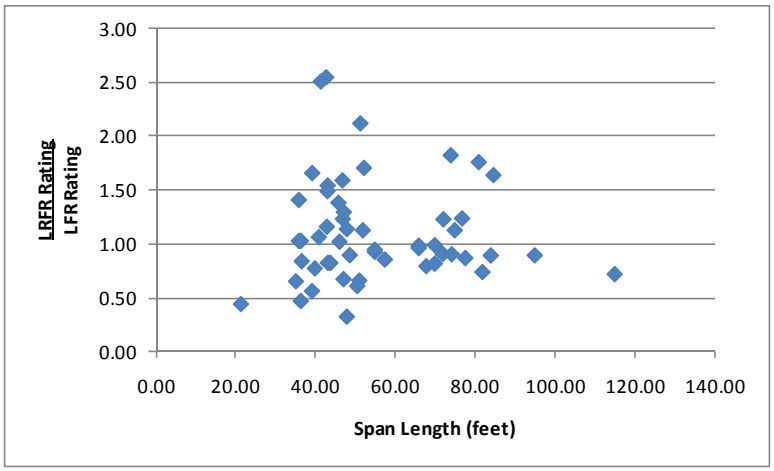


Figure D-201: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

D.2.6.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-202. The reliability index is between six and nine for most girders.

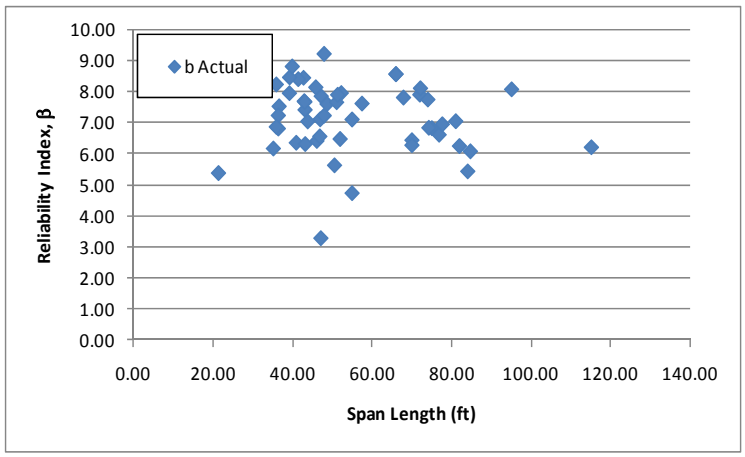


Figure D-202: Shear Reliability Indices for NC-21 Vehicle

Figure D-203 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 vehicle. The figure shows that the reliability index corresponding to a rating factor of 1.0 is approximately 4.0, above the target reliability of 2.5. This indicates the target reliability can be achieved while using lower load factors than currently in the MBE.

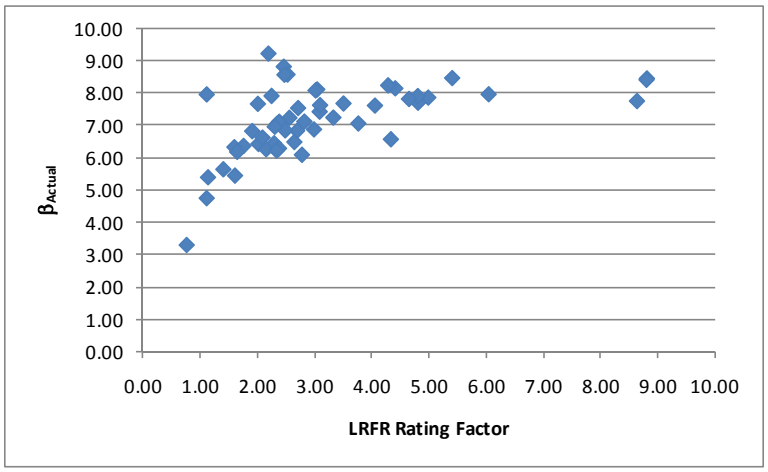


Figure D-203: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

D.2.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-204. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

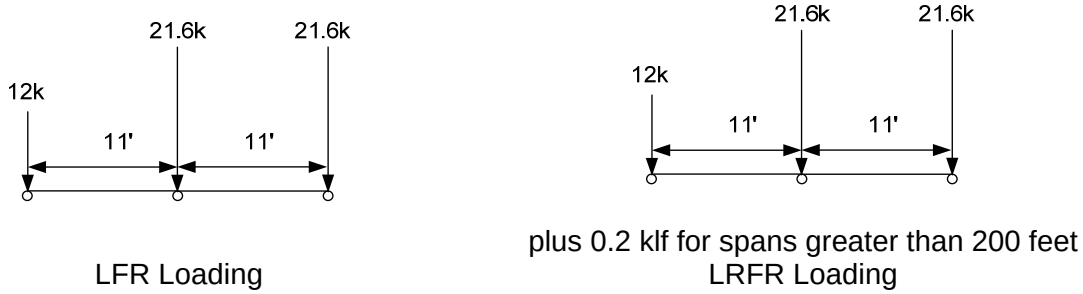


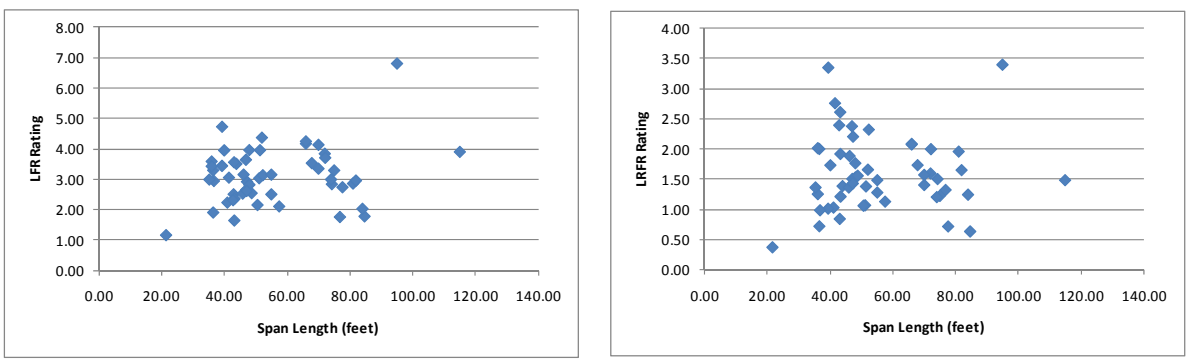
Figure D-204: Vehicle Loadings and Load Factors

D.2.7.1 Moment

The following section contains the results for exterior, non-composite prestressed box girders within simple span bridges for the NM-04 Vehicle.

D.2.7.1.1 Rating Factors

Figure D-205 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, six girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 96% of the girders in this subset. The LFR ratings are between two and four while the LRFR ratings are between 1.0 and 2.0 for most girders. Two of the six girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating from AASHTO LRFD 5.8.3.5.



(a) (b)

Figure D-205: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure D-206 shows the percentage of girders with moment ratings in each rating category. 9.4% of girders are affected by the switch from LFR to LRFR for an ADTT of 100. This increases to 13.3% for an ADTT of 5,000. All girders have LFR ratings greater than 1.0. The number of girders affected by switching to LRFR from LFR is not a significant portion of the girders.

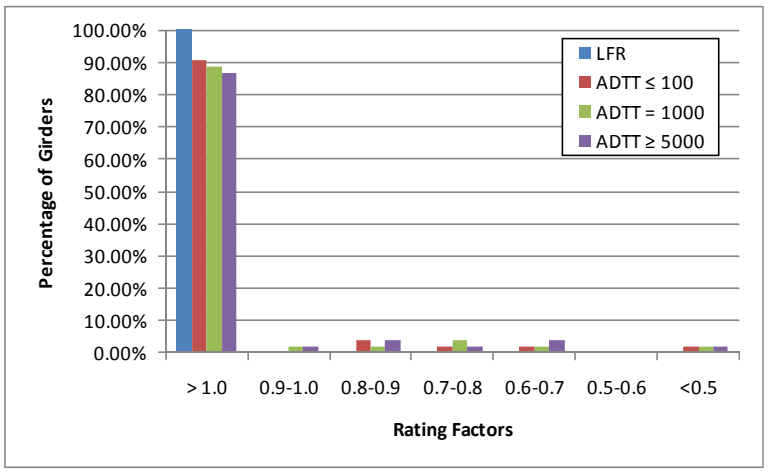


Figure D-206: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

D.2.7.1.2 Rating Factor Comparisons

Figure D-207 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.3 and 0.8, with two girders having LRFR ratings greater than the LFR rating.

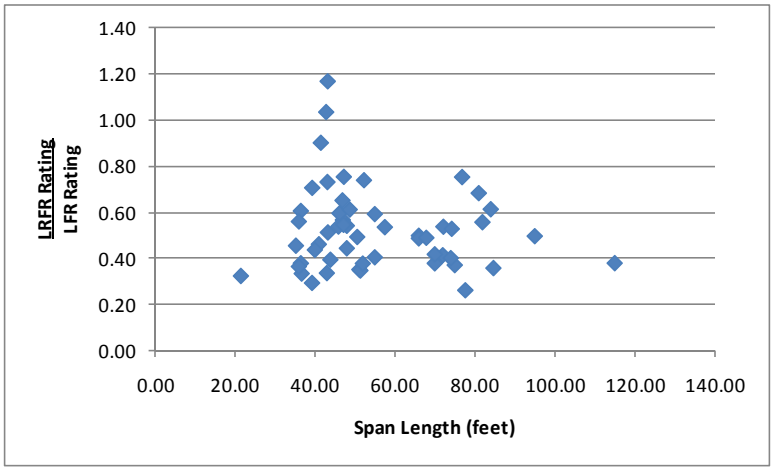


Figure D-207: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

D.2.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-208 shows that one girder has a reliability index based upon girder strength that is less than the target reliability index of 2.5, with several girders having a reliability index close to the target reliability.

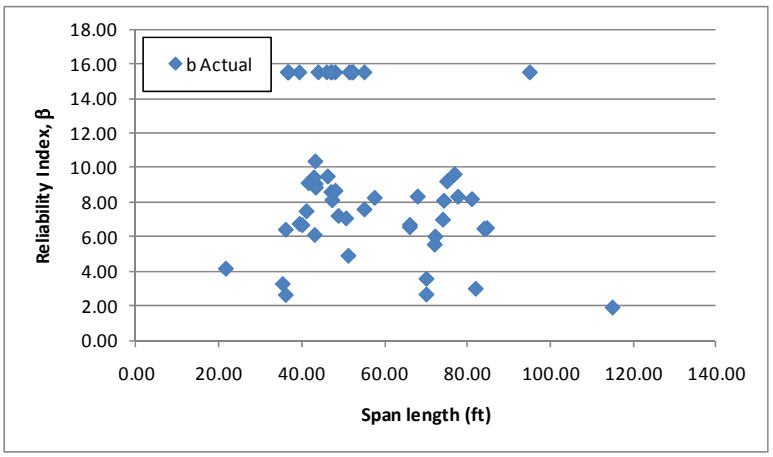


Figure D-208: Flexure Reliability Indices for NM-04 Vehicle

Figure D-209 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The figure shows the reliability index associated with a rating of 1.0 are above the target level of reliability while girders with a rating above 1.0 have the lowest reliability indices. The target reliability can be achieved by reducing the live load factors but the girders with the lowest reliability would have higher ratings.

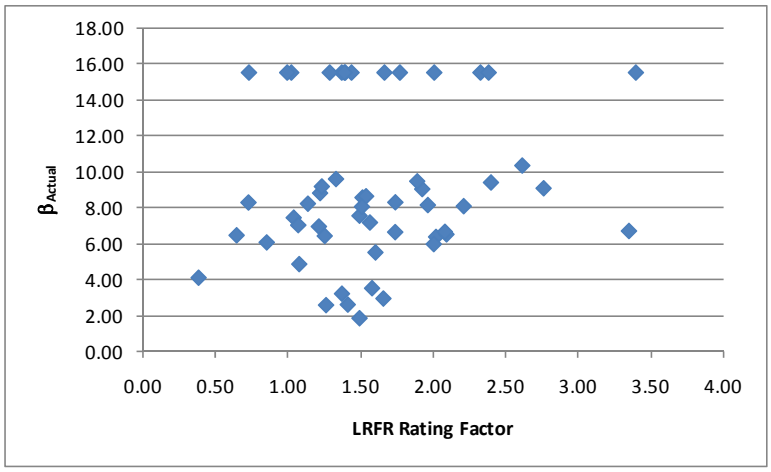
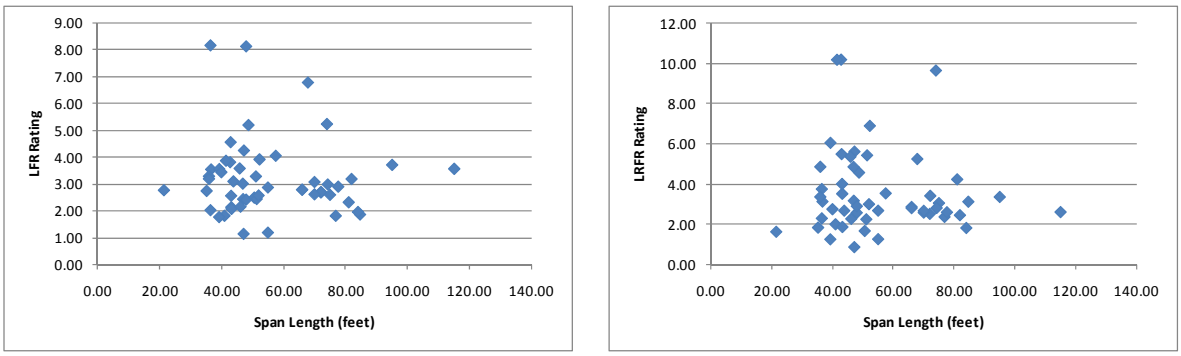


Figure D-209: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

D.2.7.2 Shear

D.2.7.2.1 Rating Factors

For shear, there is one girder with an LRFR rating less than 1.0.. The LFR Rating is greater than the LRFR rating for 47% of the girders in this subset. Figure D-210 shows the LFR and LRFR ratings. The LFR and LRFR ratings are between two and four for most girders.



(a) (b)

Figure D-210: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure D-211 shows the percentage of girders with shear ratings in each rating category for the NM-04 vehicle. The figure shows that 1.9% of girders are affected by switching from LFR to LRFR. The girders that are affected are in a lower rating category for each increase in ADTT. Very few girders are affected by switching from LFR to LRFR; all girders have an LRFR rating that is greater than 1.0.

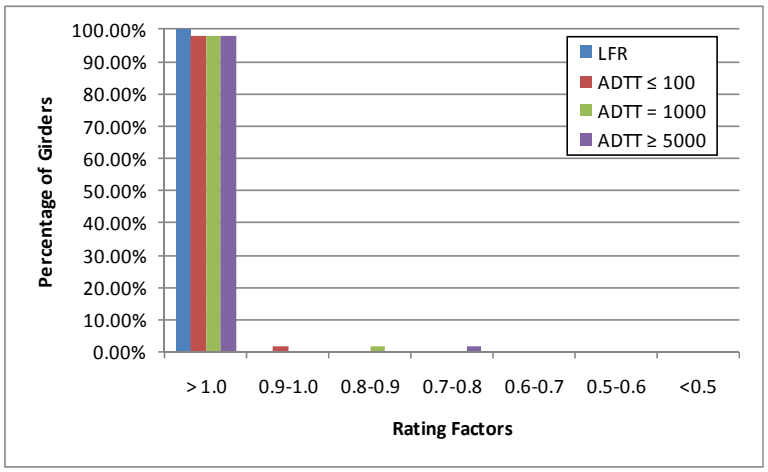


Figure D-211: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

D.2.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-212 show the comparison of rating factors. The ratio is generally between 0.5 and 1.75. Shorter spans are more likely to have LRFR ratings greater than shorter spans with 53% of the girders having LRFR ratings greater than the LFR rating.

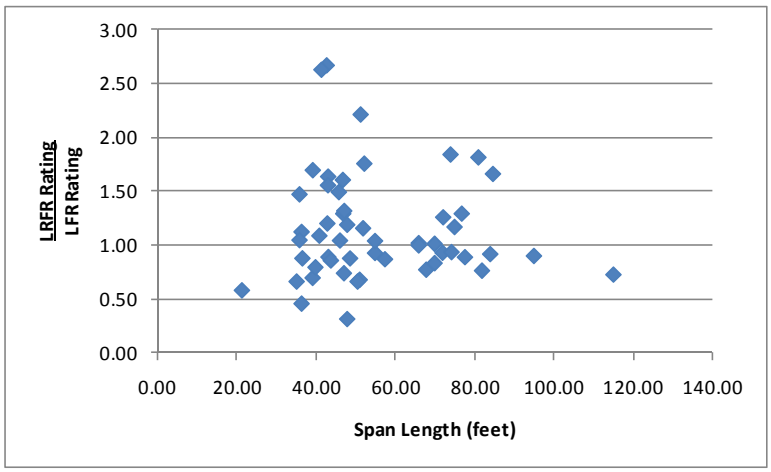


Figure D-212: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

D.2.7.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-213. The reliability index appears to decrease is between six and nine for most girders.

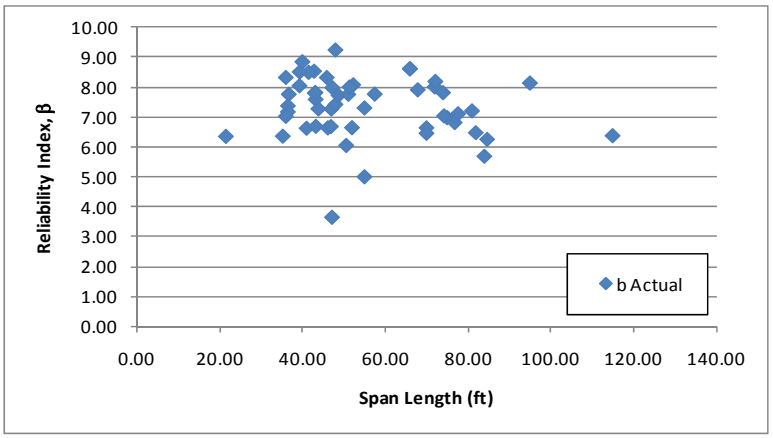


Figure D-213: Shear Reliability Indices for NM-04 Vehicle

Figure D-214 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. The figure shows that a girder with a rating of 1.0 has a reliability index of approximately 3.5 to 4.0. This indicates the target reliability of 2.5 could be achieved using load factors lower than those currently in the MBE.

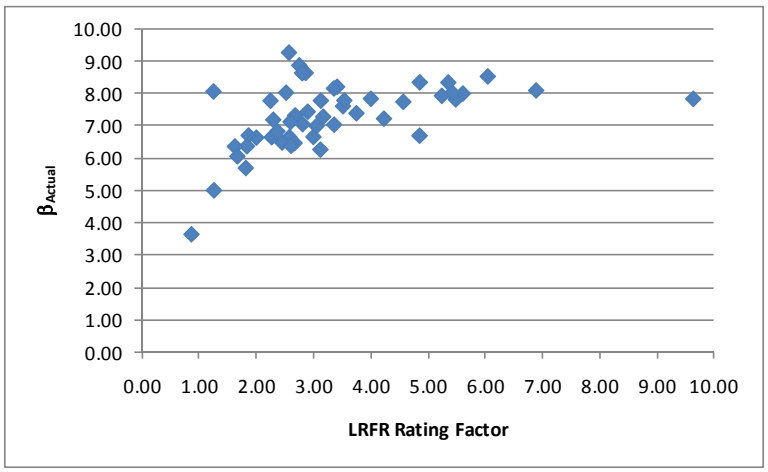
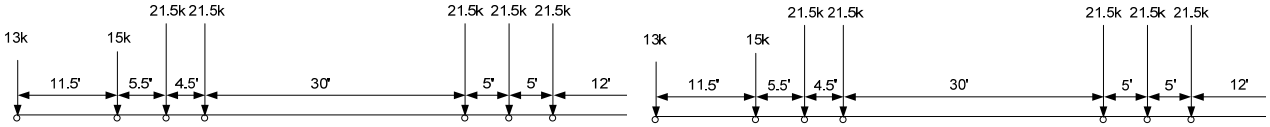


Figure D-214: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

D.2.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-215. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

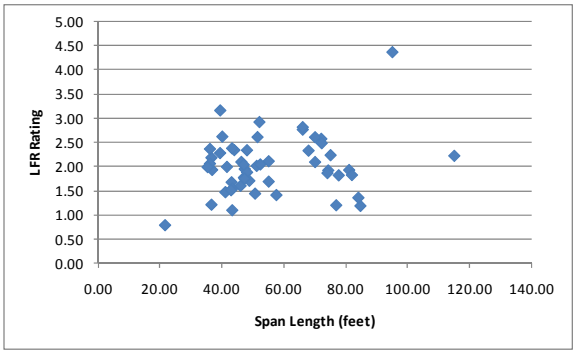
Figure D-215: Vehicle Loadings and Load Factors

D.2.8.1 Moment

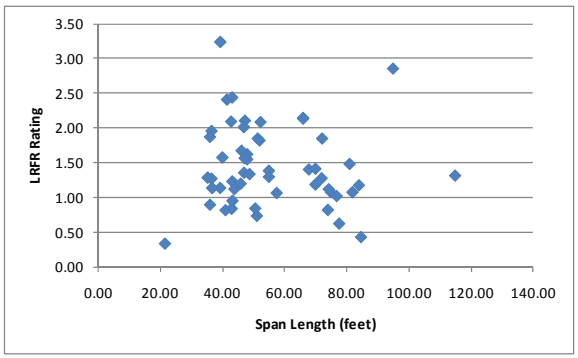
The following section contains the results for exterior, non-composite prestressed box girders within simple span bridges for the OR-06 Vehicle.

D.2.8.1.1 Rating Factors

Figure D-216 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, ten girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 85% of the girders in this subset. The LFR rating is generally between 1.0 and 2.0 for all span lengths; the LRFR rating is between 0.75 and 1.75 for most girders.



(a)



(b)

Figure D-216: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure D-217 shows the percentage of girders with moment ratings in each rating category for the OR-06 vehicle. This vehicle is treated as a special permit vehicle. The percentage of girders with LRFR ratings less than 1.0 varies from 18.9% for permit categories of single escorted to multiple trips with an ADTT of 100 and increases to 22.6% for multiple trips with ADTT of 5,000. Approximately 20% of girders are negatively affected by the switch from LFR to LRFR; this is a significant portion of the girders. 98% of girders have LFR ratings greater than 1.0.

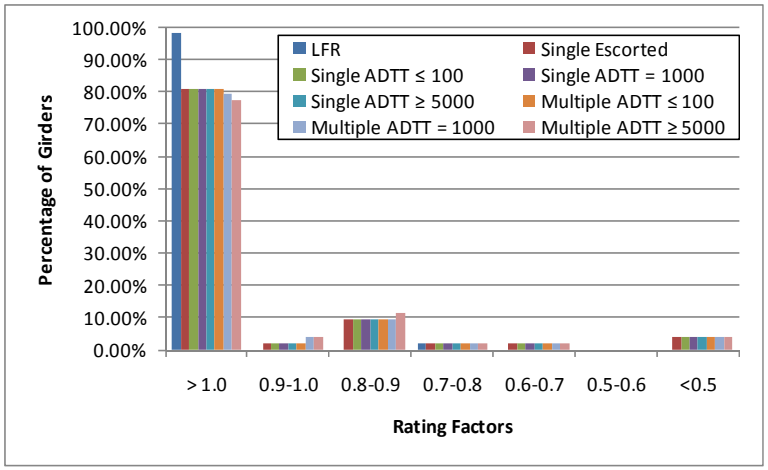


Figure D-217: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

D.2.8.1.2 Rating Factor Comparisons

Figure D-218 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating which occurs for eight girders in this group. The ratio is generally between 0.4 and 0.8 for girders less than one and between 1.0 and 1.2 for those greater than 1.0.

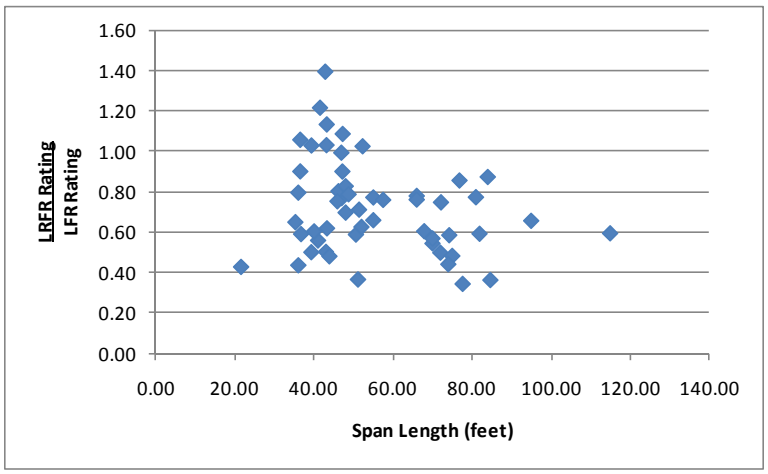


Figure D-218: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

D.2.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-219 shows that eight girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The target reliability index is between six and ten for most girders in this group.

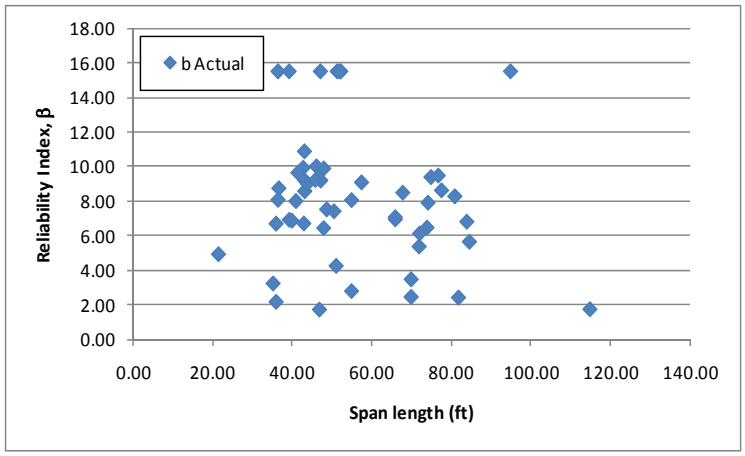


Figure D-219: Flexure Reliability Indices for OR-06 Vehicle

Figure D-220 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 vehicle. The figure indicates that girders with a rating of 1.0 have widely varying reliability indices. The reliability index varies from two which is below the target of 3.5 to almost 10 which is significantly higher than the target reliability. The average reliability index is above the target reliability index when looking at the girders clustered between four and ten. The reliability could be brought nearer to the target reliability by decreasing the live load factor in the MBE for LRFR.

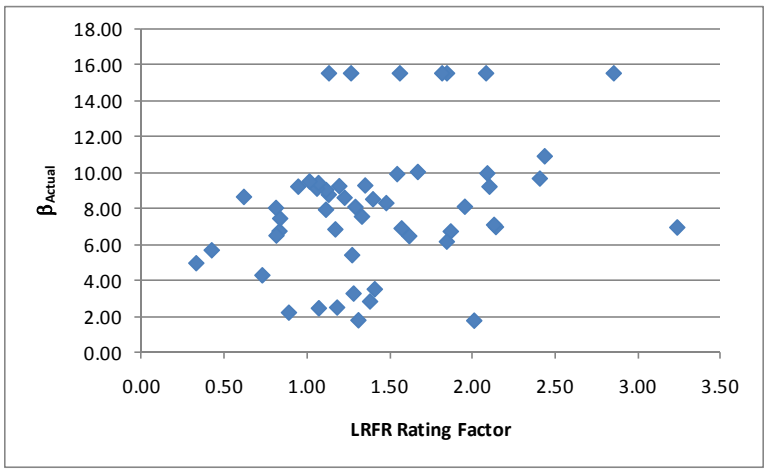
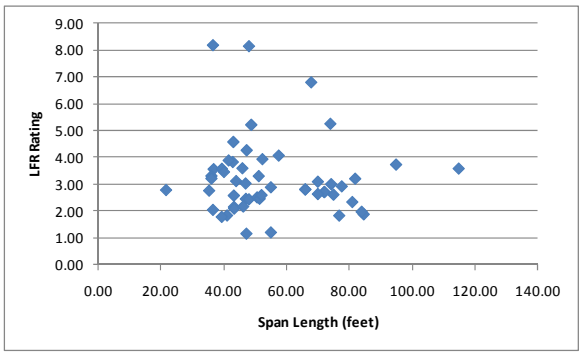


Figure D-220: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

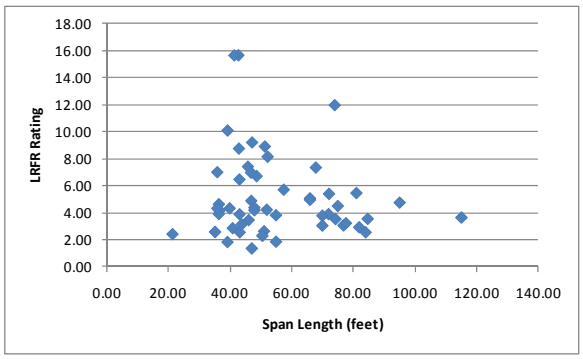
D.2.8.2 Shear

D.2.8.2.1 Rating Factors

For shear, there are zero girders with either an LFR or LRFR rating less than 1.0. The LFR Rating is greater than the LRFR rating for 15% of the girders in this subset. Figure D-221 shows the LFR and LRFR ratings. The LFR rating is between two and four while the LRFR rating is between two and eight for most girders.



(a)



(b)

Figure D-221: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure D-222 shows the percentage of girders with shear ratings in each rating category for the OR-06 vehicle. The figure shows that all girders for all permit types have LRFR ratings greater than 1.0. All girders also have LFR ratings greater than 1.0. No girders are affected by the switch from LFR to LRFR for shear.

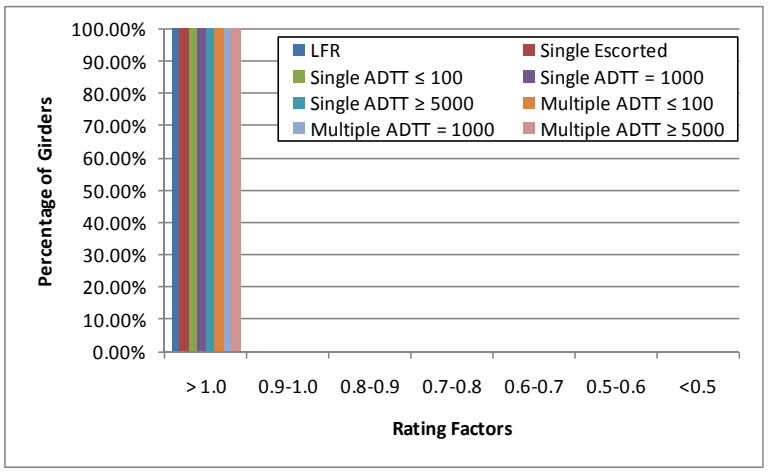


Figure D-222: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

D.2.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-223 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.5 for this set of girders. 85% of girders have LRFR ratings greater than LFR rating.

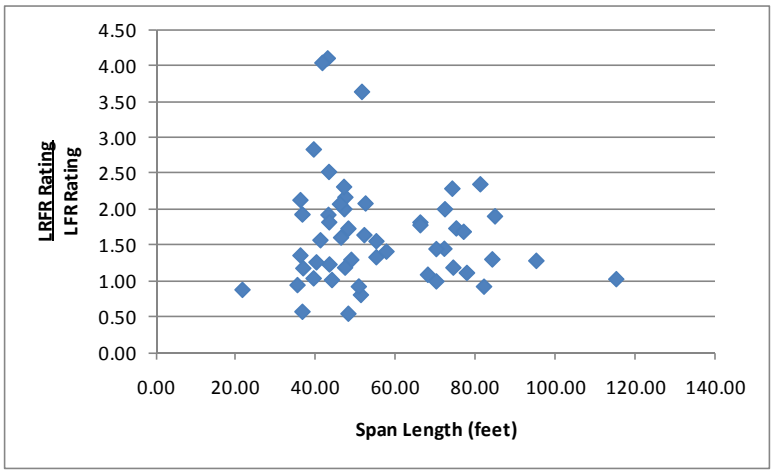


Figure D-223: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

D.2.8.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 3.5 for all girders as shown in Figure D-224. The reliability index is between six and nin e for most girders.

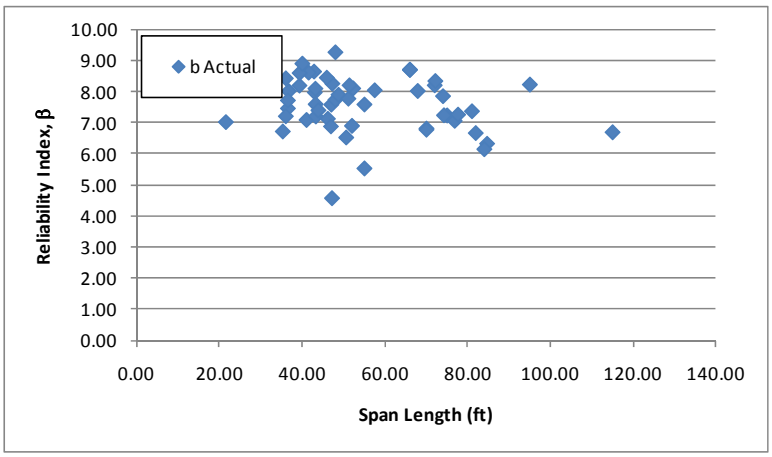


Figure D-224: Shear Reliability Indices for OR-06 Vehicle

Figure D-225 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The figure shows that the reliability index associated with a rating of 1.0 is greater than the target reliability of 3.5. This indicates the target reliability can be achieved and lower live load factors be used than those currently in the MBE.

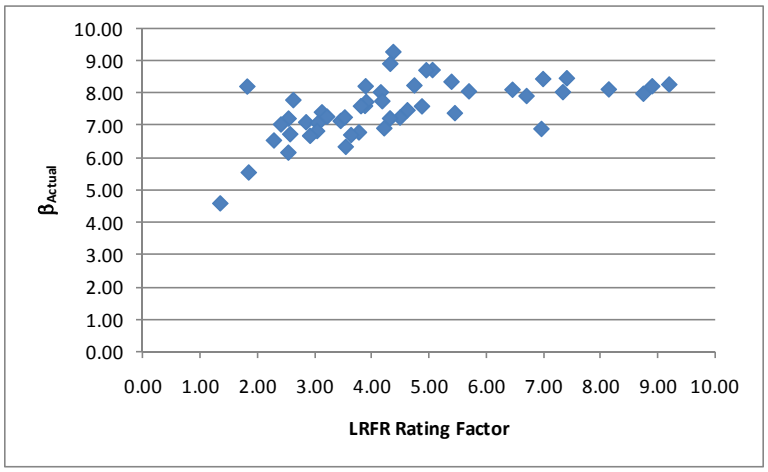
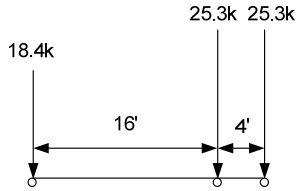


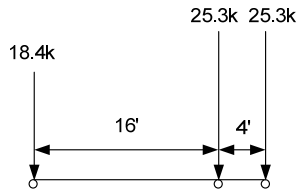
Figure D-225: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

D.2.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-226. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet

LRFR Loading

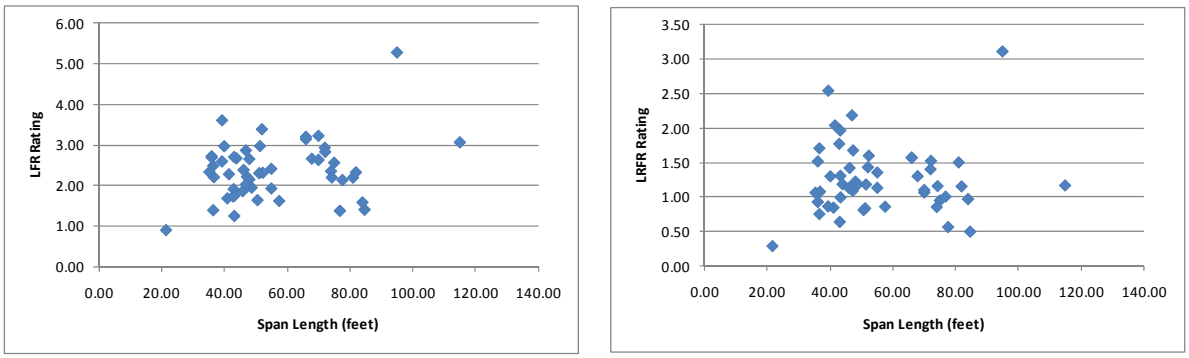
Figure D-226: Vehicle Loadings and Load Factors

D.2.9.1 Moment

The following section contains the results for exterior, non-composite prestressed box girders within simple span bridges for the TX-04 Vehicle.

D.2.9.1.1 Rating Factors

Figure D-227 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 15 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 96% of the girders in this subset. The LFR rating is between 1.5 and 3.0 for most girders while the LRFR rating is between 0.5 and 1.5 for most girders. Two of the fifteen girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.



(a) (b)

Figure D-227: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure D-228 shows the percentage of girders with moment ratings in each rating categories. Approximately 72% of girders have LRFR ratings greater than 1.0 for ADTTs of 100 and 1,000. This decreases to 68% of girders for an ADTT of 5,000. This is a significant number (28-32%) of girders affected by switching from LFR to LRFR. 98% of girders have LFR ratings greater than 1.0.

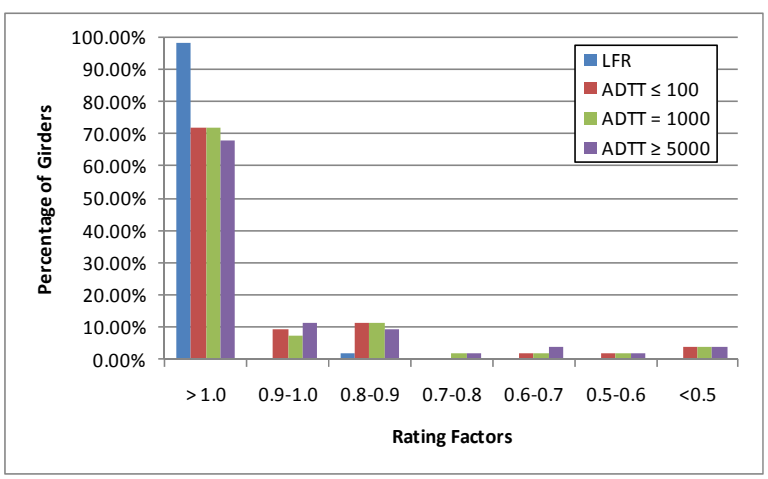


Figure D-228: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

D.2.9.1.2 Rating Factor Comparisons

Figure D-229 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating which is true for two girders in this group. The LRFR rating is generally 30 to 60% of the LFR rating, with shorter spans generally having higher ratios.

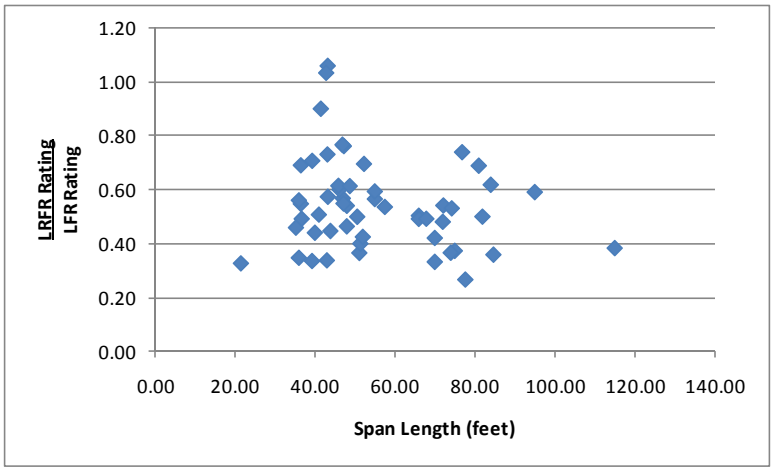


Figure D-229: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

D.2.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-230 shows five girders that have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between four and nine for most girders in this group.

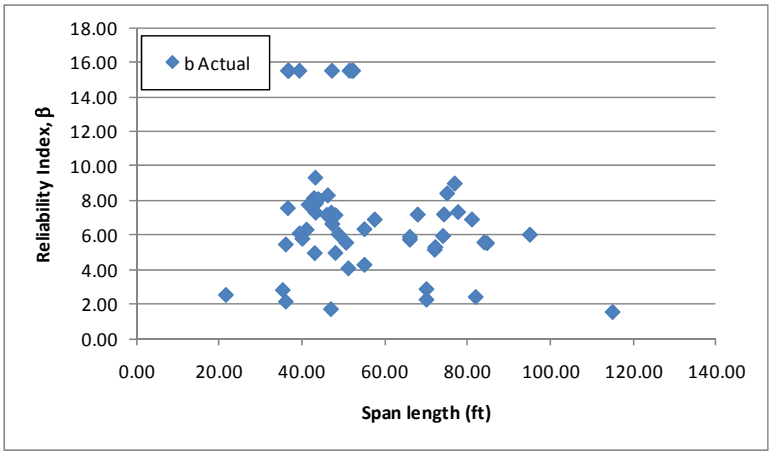


Figure D-230: Flexure Reliability Indices for TX-04 Vehicle

Figure D-231 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The figure shows that the reliability index for girders having ratings closer to 1.0 vary from two to nine. Ignoring the high and low data results, the average reliability index is approximately six, well above the target reliability of 2.5. This indicates the target reliability can be maintained for most girders while using reduced live load factors.

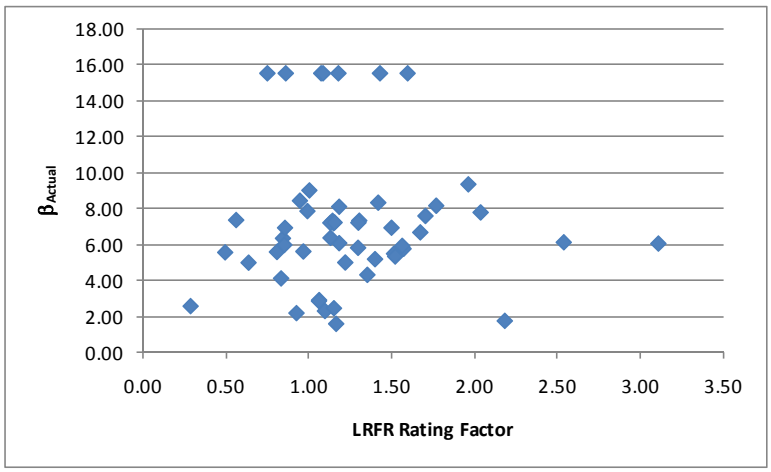
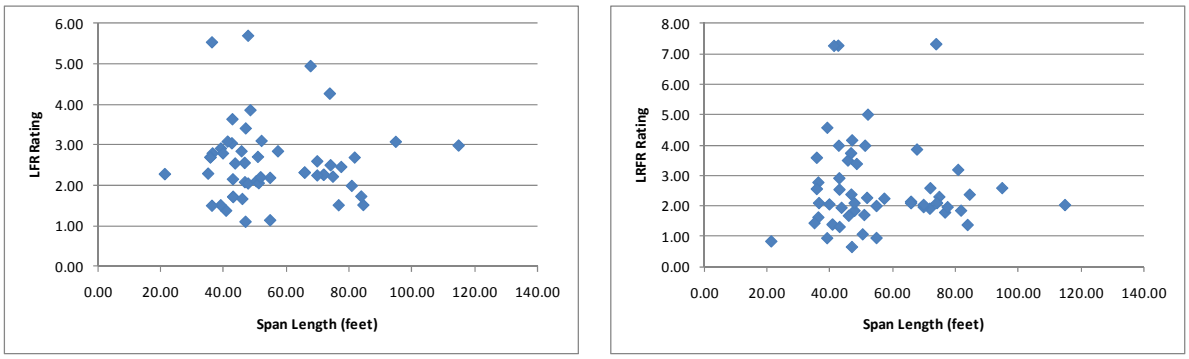


Figure D-231: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

D.2.9.2 Shear

D.2.9.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, four girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 55% of the girders in this subset. Figure D-232 shows the LFR and LRFR ratings, respectively. The LFR rating is between 1.5 and 3.0 for most girders while the LRFR rating is between 1.0 and 3.0.



(a) (b)

Figure D-232: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure D-233 shows the percentage of girders with shear ratings in each category for the TX-04 vehicle. The figure shows that the number of girders with LRFR ratings less than 1.0 increases with increasing ADTT. 3.8% of girders have LRFR ratings less than 1.0 for an ADTT of 100 while 9.4% of girders have LRFR ratings less than 1.0 for an ADTT of 5,000. Less than 10% of girders are affected by switching from LFR to LRFR for shear. All girders have LRFR ratings greater than 1.0.

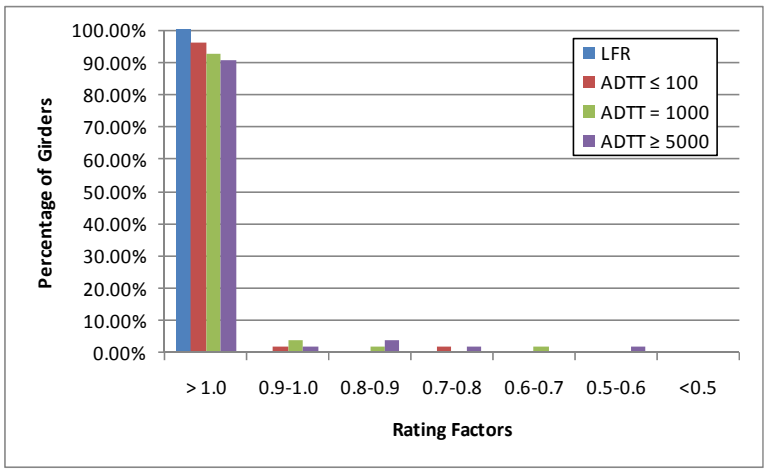


Figure D-233: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

D.2.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-234 shows the comparison of rating factors. The ratio is between 0.5 and 1.5.

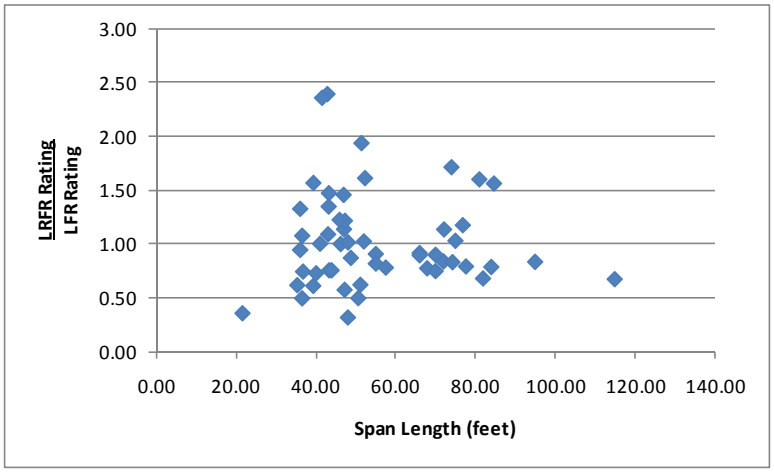


Figure D-234: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

D.2.9.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-235. The reliability index for most girders is between six and nine.

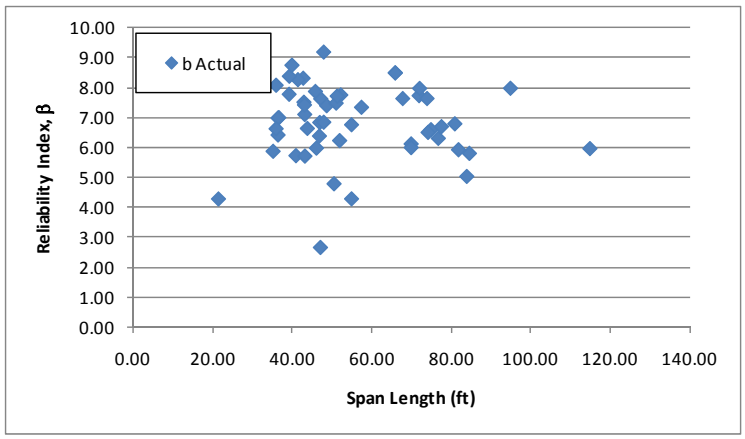


Figure D-235: Shear Reliability Indices for TX-04 Vehicle

Figure D-236 shows the reliability index for shear plotted against the LRFR rating for shear for the TX-04 Vehicle. The figure shows that girders with a rating factor of 1.0 have a reliability index near 4.0. This exceeds the target reliability of 2.5. This indicates the target reliability can be achieved using LRFR live load factors that are less than those currently in the MBE for routine permit vehicles.

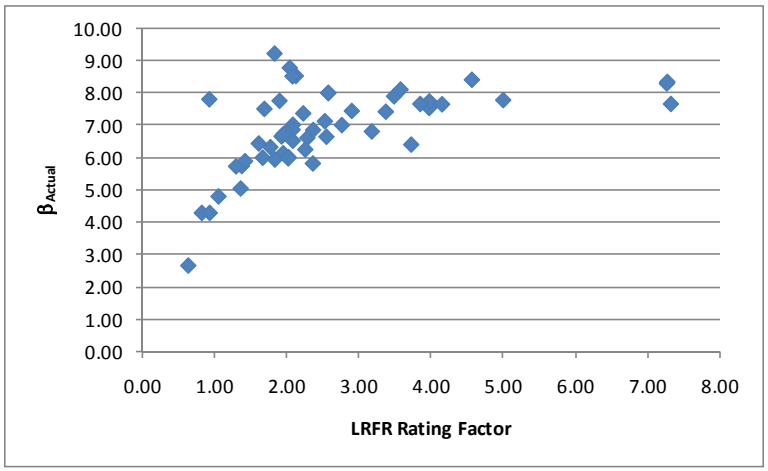
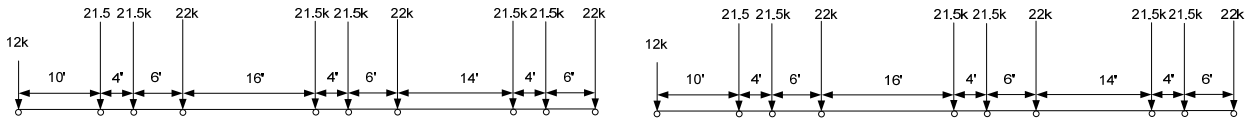


Figure D-236: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

D.2.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-237. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

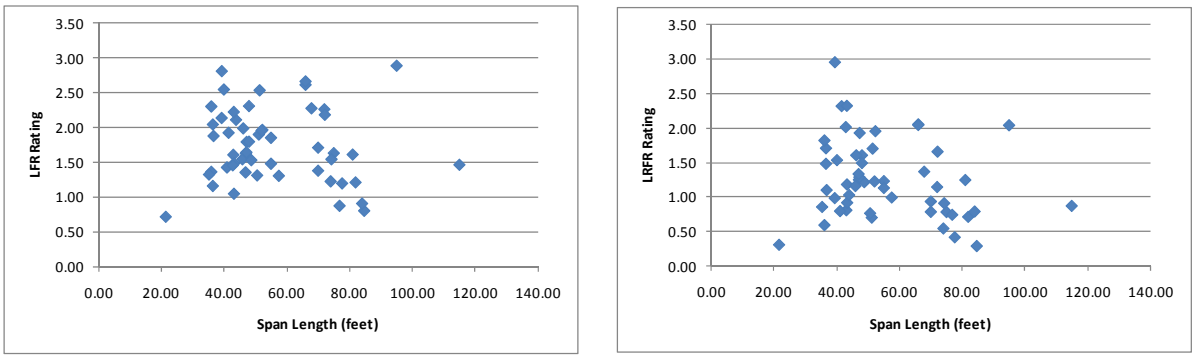
Figure D-237: Vehicle Loadings and Load Factors

D.2.10.1 Moment

The following section contains the results for exterior, non-composite prestressed box girders within simple span bridges for the WA-02 Vehicle.

D.2.10.1.1 Rating Factors

Figure D-238 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are four girders with an LFR rating less than 1.0, 21 girders with an LRFR rating less than 1.0, and four girders where both ratings are less than 1.0. There are two girders where the LRFR rating is controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 87% of the girders in this subset. The LFR ratings are between 1.0 and 2.5 for most girders while the LRFR ratings are between 0.5 and 2.0.



(a) (b)

Figure D-238: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure D-239 shows the percentage of girders with moment ratings in each rating category for the WA-02 Vehicle. The figure shows that the 62.3% of girders have LRFR ratings greater than 1.0 for the first two LRFR permit types, single escorted and single mixed with traffic with an ADTT of 100. The percentage of girders decreases to 56.6% for multiple trip permits with an ADTT of 5,000. A significant number of girders (~30%) are affected by the switch from LFR to LRFR, as approximately 8.5% of girders have LFR ratings that are less than 1.0.

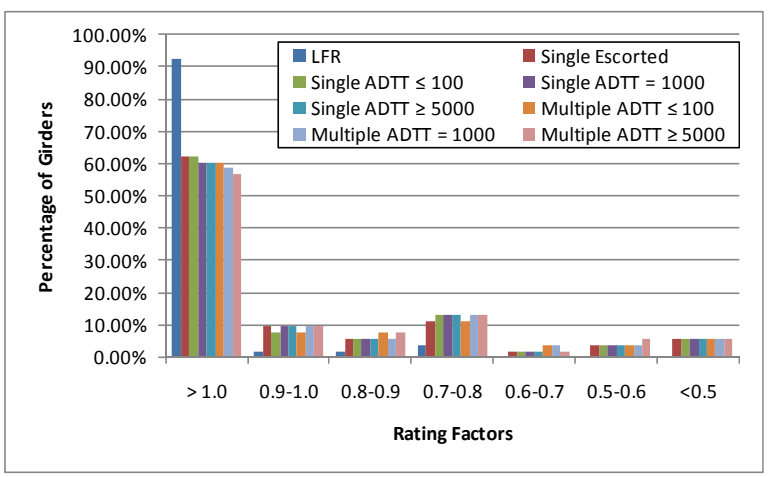


Figure D-239: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

D.2.10.1.2 Rating Factor Comparisons

Figure D-240 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating which occurs for seven girders in this group. The ratio is generally between 0.4 and 0.8 or above 1.0.

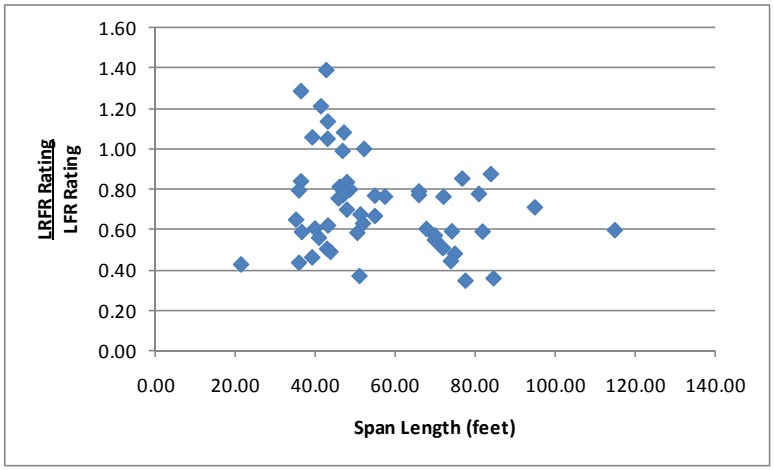


Figure D-240: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

D.2.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-241 shows that seven girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index decreases with increasing span length and is between six and ten for most girders. The girders with reliability indices below the target values are of varying span lengths.

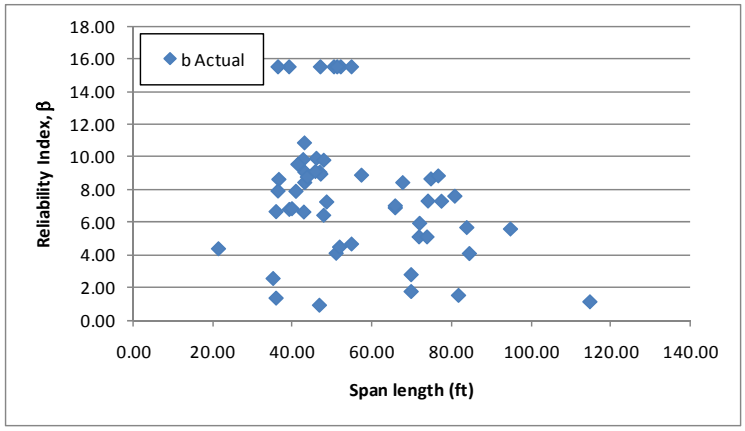


Figure D-241: Flexure Reliability Indices for WA-02 Vehicle

Figure D-242 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 vehicle. The figure shows that girders with rating factors of 1.0 have widely varying reliability indices. The reliability index exceeds the target reliability for most girders with ratings greater than one as well as many with ratings less than one. This indicates that for most girders the live load factors can be reduced and maintain the target reliability level.

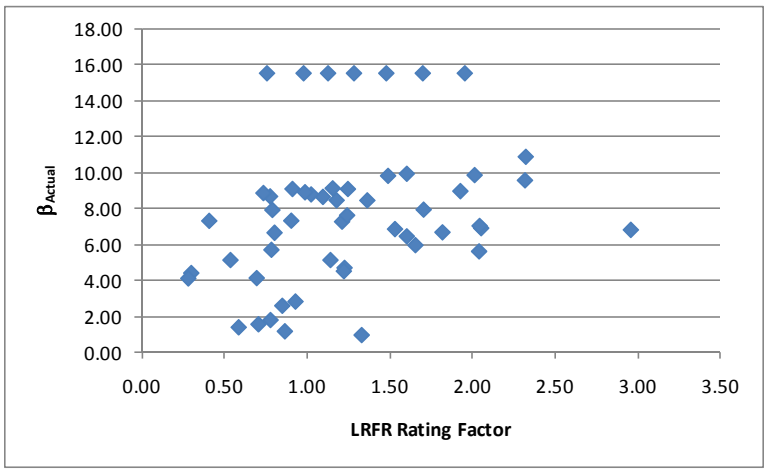
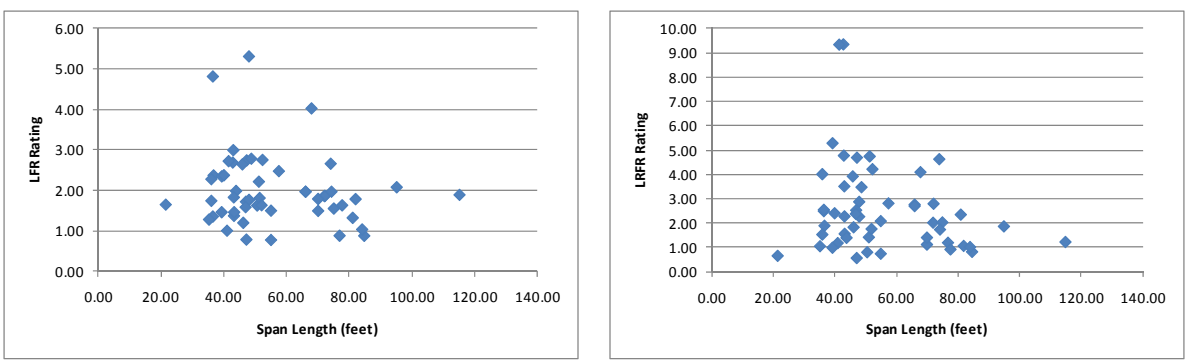


Figure D-242: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

D.2.10.2 Shear

D.2.10.2.1 Rating Factors

For shear, there are four girders with LFR rating factors less than 1.0, seven girders with LRFR ratings less than 1.0, and three girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 40% of the girders in this subset. Figure D-243 shows the LFR and LRFR ratings. The LFR ratings are between one and three for most girders while the LRFR ratings are also between one and three but with more above three.



(a) (b)

Figure D-243: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure D-244 shows the percentage of girders with shear ratings in each rating range for the WA-02 vehicle. The percentage of girders with LRFR ratings greater than 1.0 is 92.5% for a single trip, escorted permit truck and drops to 73.6% of girders for a multiple trip permit with an ADTT of 5,000. This is a significant number of girders for the worst permit category. 92.5% of girders have LFR ratings greater than 1.0.

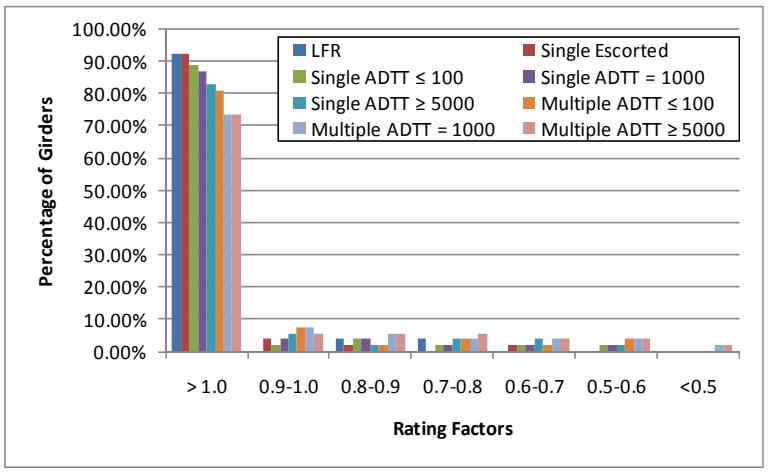


Figure D-244: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

D.2.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-245 shows the comparison of rating factors. The ratio varies between 0.5 and 2.0 with 60% of the girders having higher LRFR ratings than LFR ratings. The ratio is generally higher for short spans and decreases with increasing span lengths.

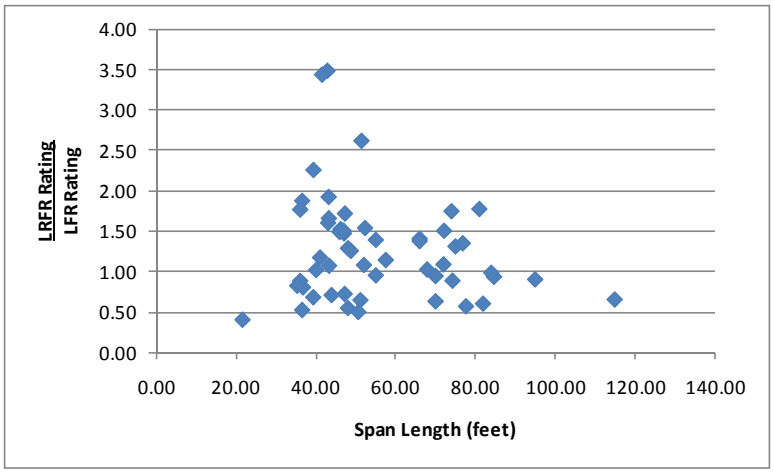


Figure D-245: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

D.2.10.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 3.5 for one girder as shown in Figure D-246. The reliability index is between six and nine for girders with spans under 60 feet and decreases for to between four and six for girders of longer spans.

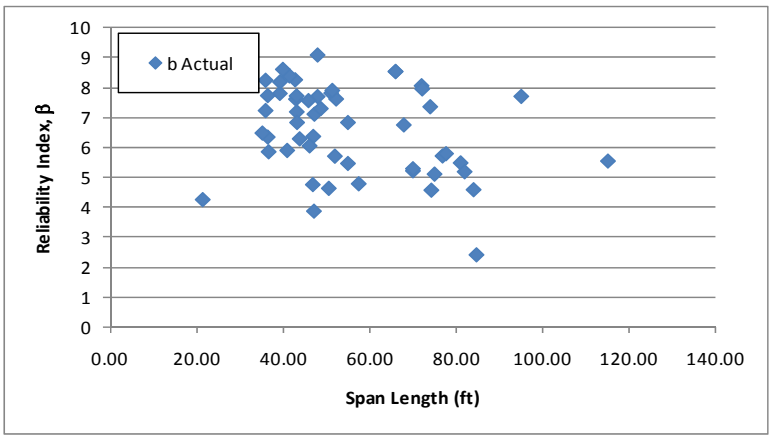


Figure D-246: Shear Reliability Indices for WA-02 Vehicle

Figure D-247 shows the reliability index for shear plotted against the LRFR shear rating for the WA-02 vehicle. The figure shows that girders with ratings of 1.0 have reliability indices of approximately 4.5. This is above the target value of 3.5, indicating the target reliability can be maintained while reducing the live load factor in the MBE.

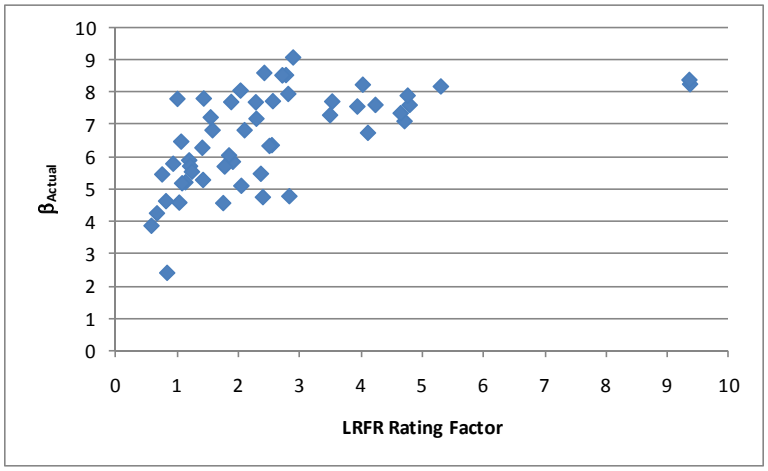


Figure D-247: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

D.2.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-248. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

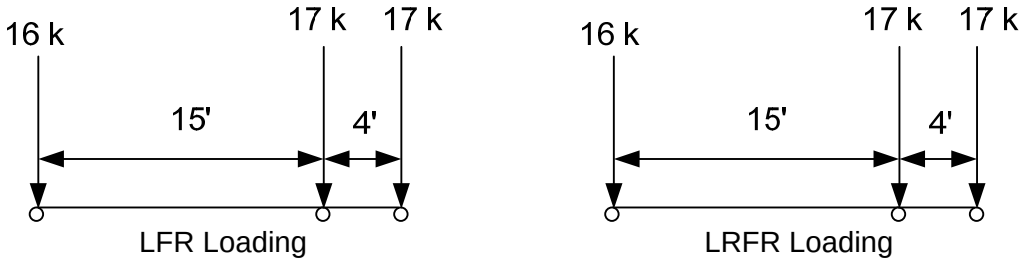
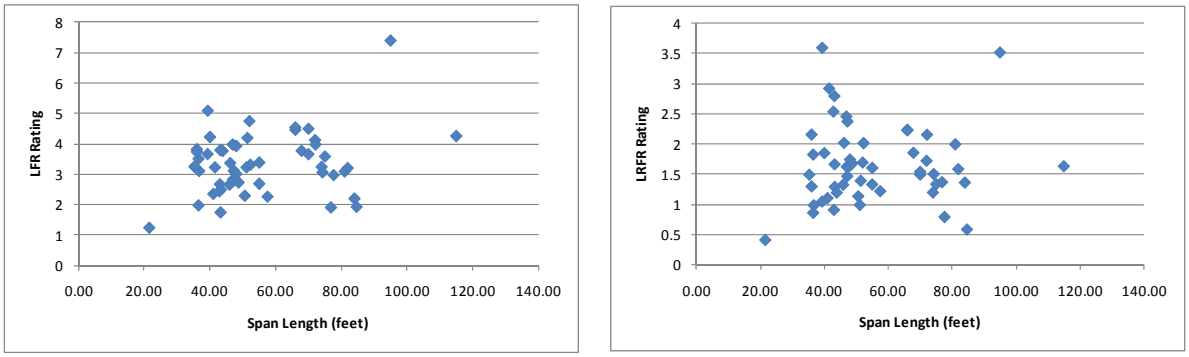


Figure D-248: Vehicle Loadings and Load Factors

D.2.11.1 Moment

D.2.11.1.1 Rating Factors

Figure D-249 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, seven girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 98% of the girders in this subset. Two girders of those with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR ratings are generally between 2 and 5 while the LRFR rating is between 1 and 2.5.



(a) (b)

Figure D-249: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure D-250 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3 Truck. The percentage of girders rating greater than 1.0 ranges from 90.6% for an ADTT of 100 to 84.9% for an ADTT of 5,000, at most about 15% of girders will be affected by the switch from LFR to LRFR. 5.7% of the girders with ratings less than 1.0 for ADTT of 5,000 have ratings between 0.9 and 1.0. 100% of girders have an LFR rating greater than 1.0.

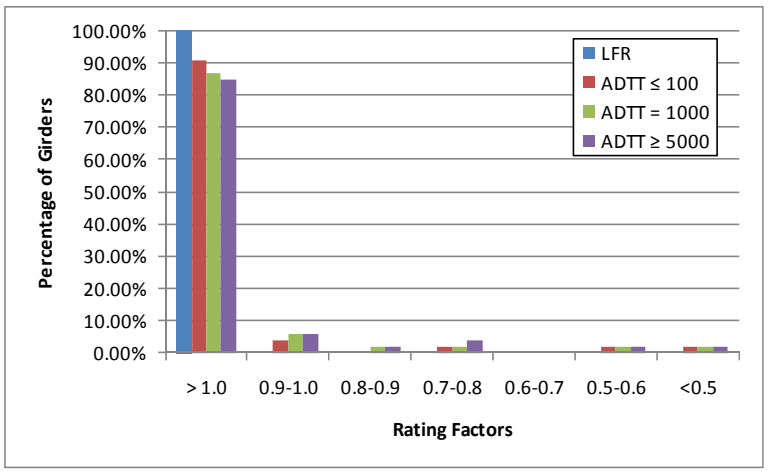


Figure D-250: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

D.2.11.1.2 Rating Factor Comparisons

Figure D-251 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating, which occurs for one girder. The ratio is generally between 0.3 and 0.6, with longer span girders having lower ratios.

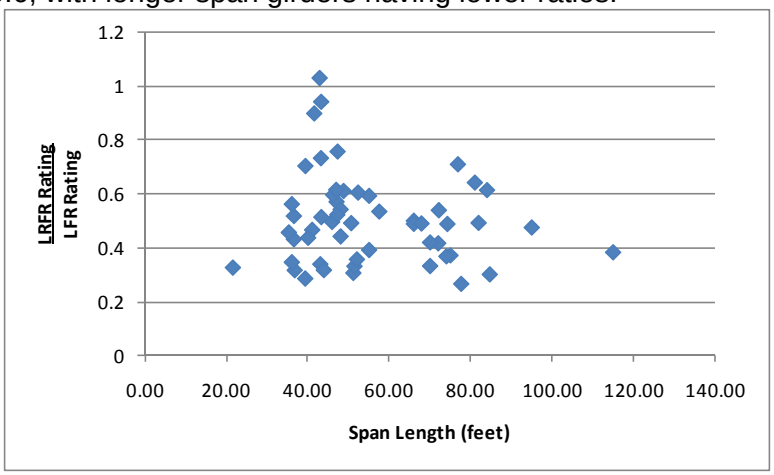


Figure D-251: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

D.2.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-252 shows that one girder has a reliability index based upon girder strength that is less than the target reliability index. The reliability index varies significantly with span length. Girders with 40 foot spans have reliability indices ranging from six to ten.

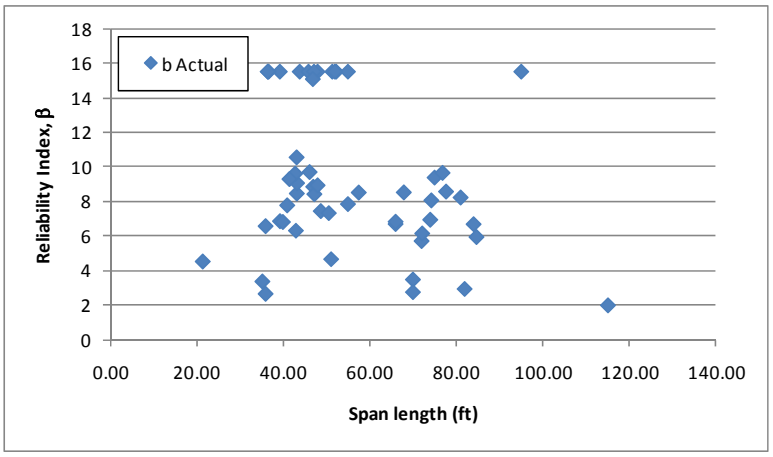


Figure D-252: Flexure Reliability Indices for Type 3 Vehicle

Figure D-253 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 truck. The figure shows that girders with reliability indices near the target reliability of 2.5 have ratings above 1.0 while girders with ratings less than one have reliability indices above four. Ignoring the girders with low reliability and high ratings, the average reliability index is approximately six. This indicates that lower live load factors than those currently in the MBE may be used and maintain the target level of reliability.

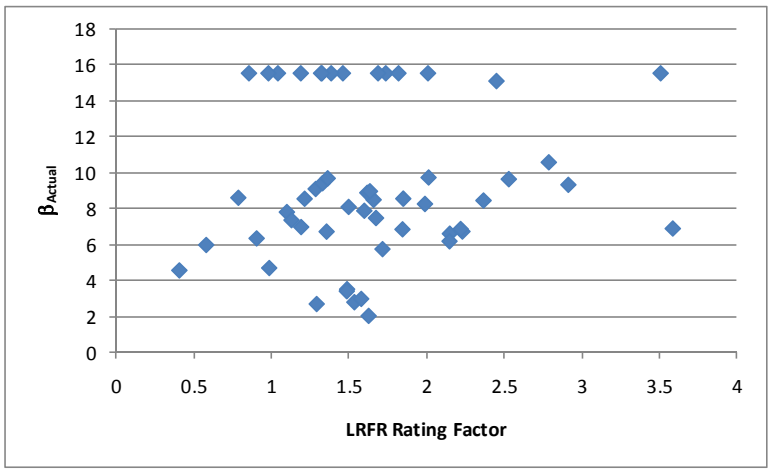
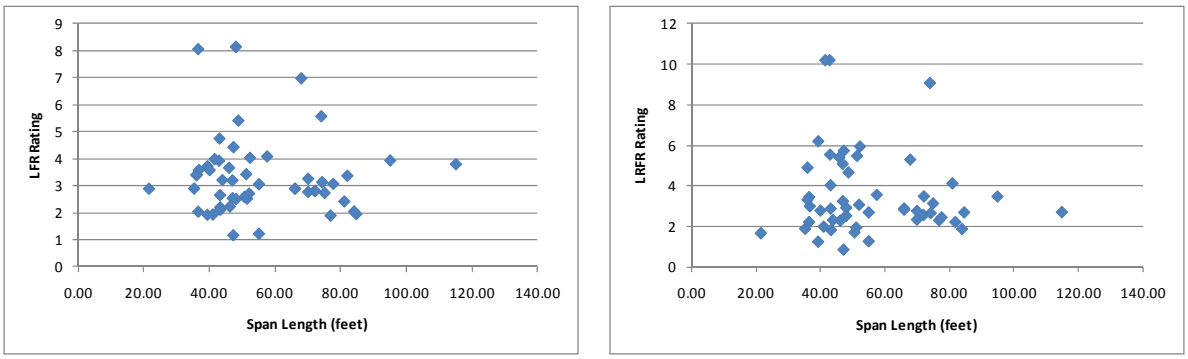


Figure D-253: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

D.2.11.2 Shear

D.2.11.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, one girder with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 49% of the girders in this subset. Figure D-254 shows the LFR and LRFR ratings. The LFR and LRFR ratings are between two and four for most girders.



(a) (b)

Figure D-254: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure D-255 shows the percentage of trucks with shear ratings in each rating range for the AASHTO Type 3 Truck. 100% of girders have ratings greater than 1.0 for LFR and for LRFR with an ADTT of 100. 98.1% of girders have LRFR ratings greater than 1.0 for ADTT of 1,000 and 5,000. Very few girders are affected by the switch to LRFR from LFR for shear for the AASHTO Type 3 Truck.

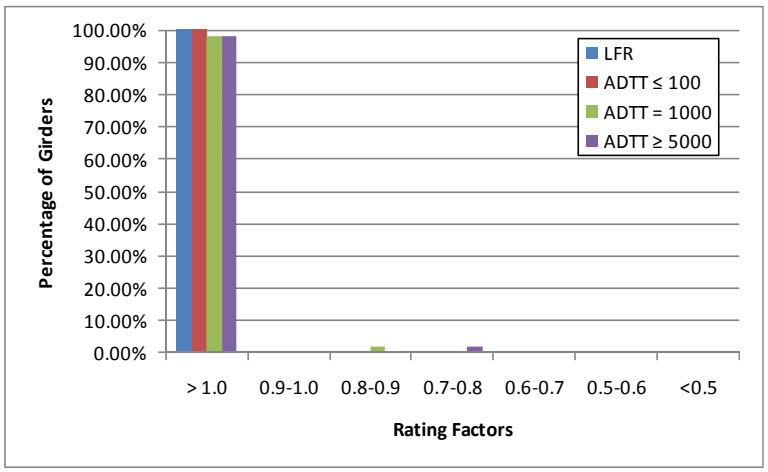


Figure D-255: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

D.2.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-256 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with shorter spans generally having higher ratios. 51% of girders have LRFR ratings that exceed the LFR rating.

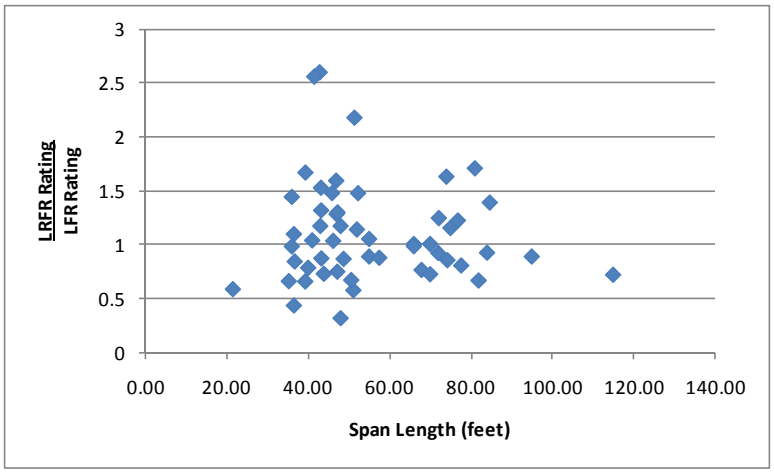


Figure D-256: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

D.2.11.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure D-257. The figure shows that most girders have reliability indices between six and nine.

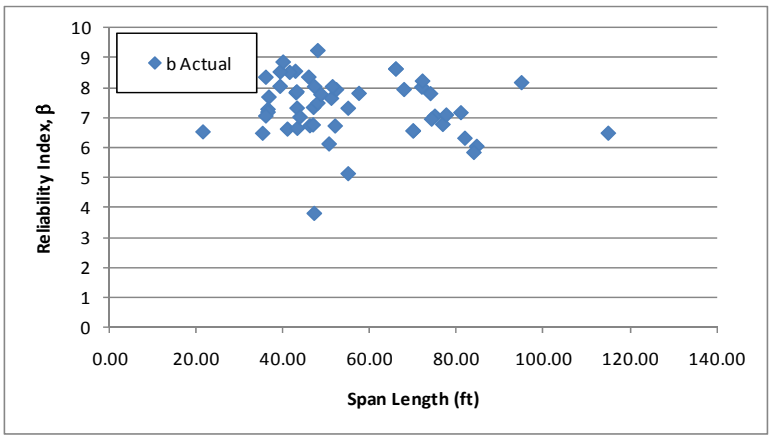


Figure D-257: Shear Reliability Indices for Type 3 Vehicle

Figure D-258 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 truck. The figure shows that girders with a rating of 1.0 have reliability indices above 3.5 which is above the target reliability of 2.5. This indicates that the LRFR live load factors can be reduced and maintain the target level of reliability.

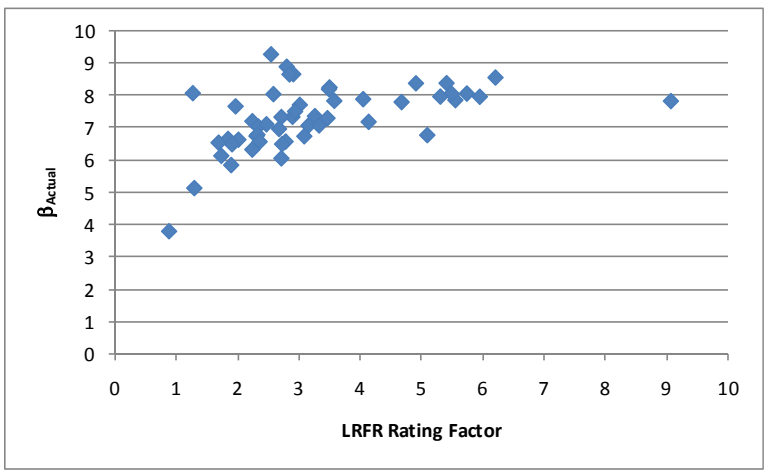


Figure D-258: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

D.2.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-259. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

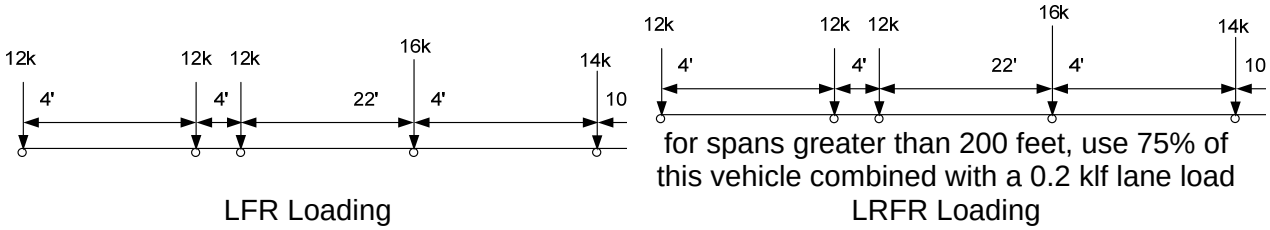
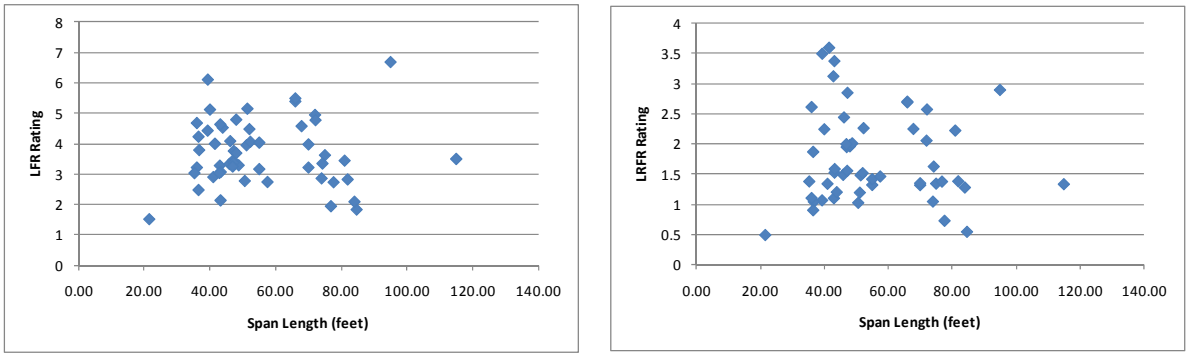


Figure D-259: Vehicle Loadings and Load Factors

D.2.12.1 Moment

D.2.12.1.1 Rating Factors

Figure D-260 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, four girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 98% of the girders in this subset. The LFR rating is between two and five for most girders while the LRFR rating is between one and there for most girders. One girder is controlled by the LRFR rating criteria for the longitudinal steel at the support.



(a) (b)

Figure D-260: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure D-261 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3-3 Truck. All girders have LFR ratings greater than 1.0 for the AASHTO Type 3-3 Truck. 5.6% of girders have LRFR ratings less than 1.0 for an ADTT of 100 and increases to 13.2% of girders for an ADTT of 5,000. Less than 10% of girders will be affected by the switch from LFR to LRFR for ADTTs less than 1,000.

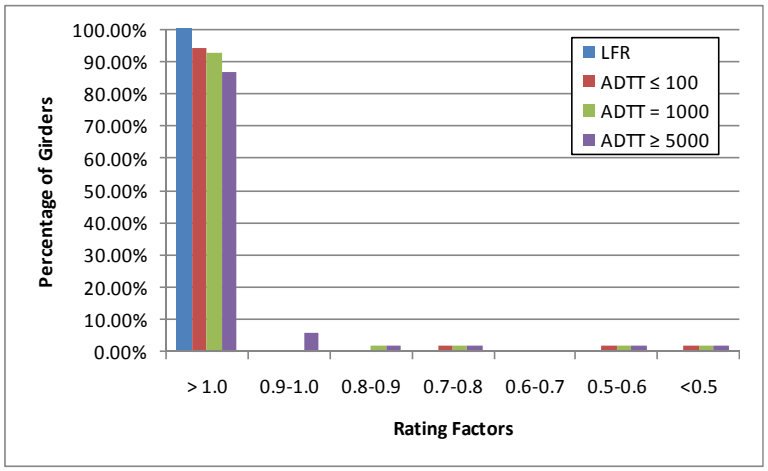


Figure D-261: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

D.2.12.1.2 Rating Factor Comparisons

Figure D-262 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0, which occurs for one girder, indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6, with longer span girders having lower ratios.

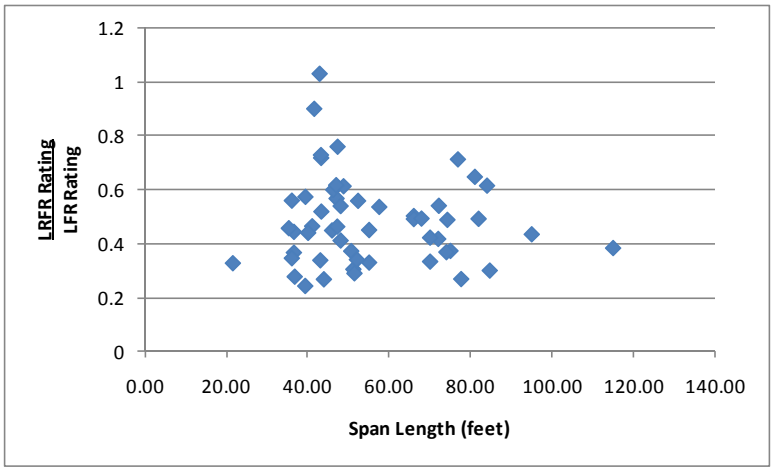


Figure D-262: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

D.2.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-263 shows that two girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between six and 10 for most girders.

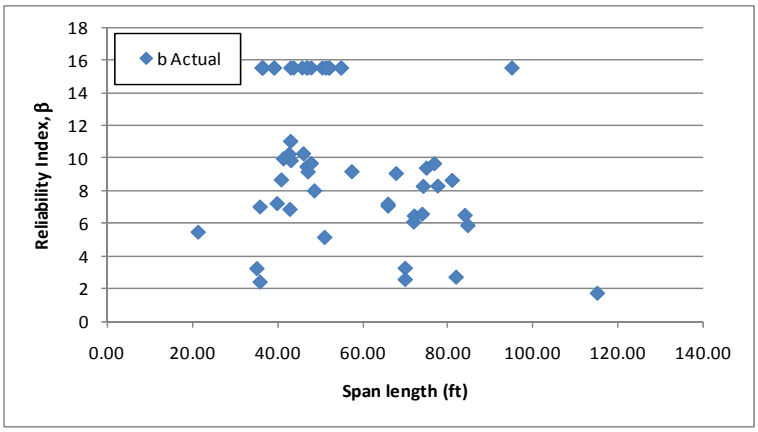


Figure D-263: Flexure Reliability Indices for Type 3-3 Vehicle

Figure D-264shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 truck. The figure shows that girders with ratings near 1.0 have reliability indices that vary from two to six. The average reliability is approximately four which is above the target reliability of 2.5. This indicates the target reliability can be maintained while lowering the live load factors in the MBE.

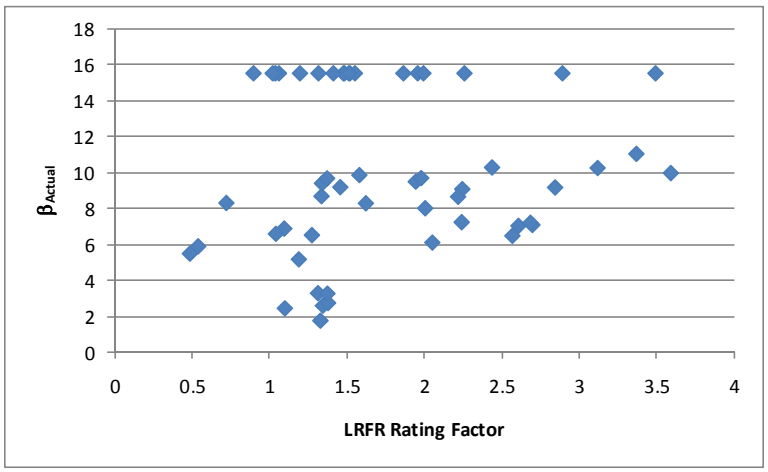
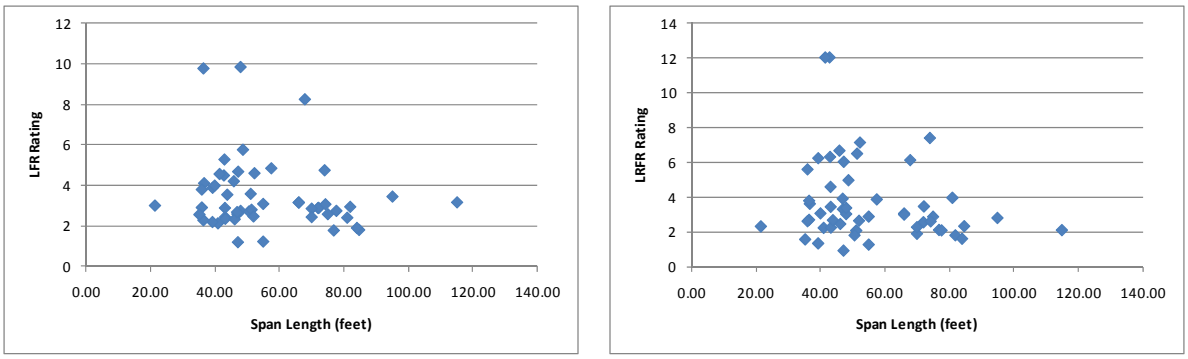


Figure D-264: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

D.2.12.2 Shear

D.2.12.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, one girder with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 53% of the girders in this subset. Figure D-265 shows the LFR and LRFR ratings. Both LFR and LRFR ratings are between two and four for most girders with some scattered higher.



(a) (b)

Figure D-265: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure D-266 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3-3 Truck. 100% of girders have LFR ratings and LRFR ratings for ADTT of 100 greater than 1.0. 1.9% of girders have LRFR ratings less than 1.0 for ADTTs of 1,000 and 5,000. Very few girders are affected by the switch from LFR to LRFR for shear.

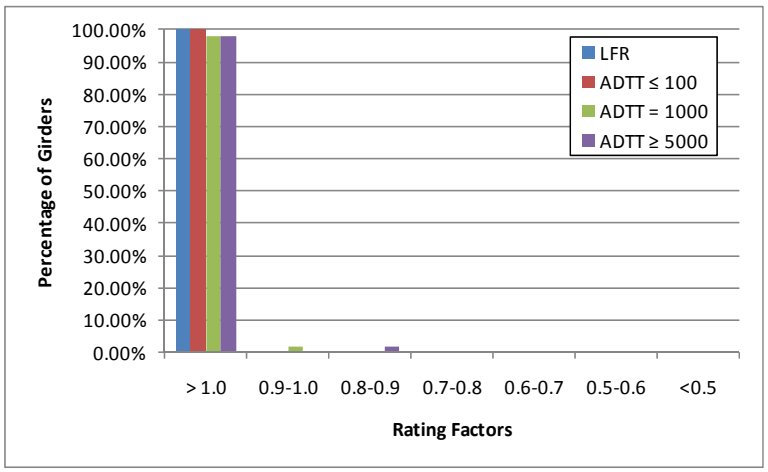


Figure D-266: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

D.2.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-267 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5.

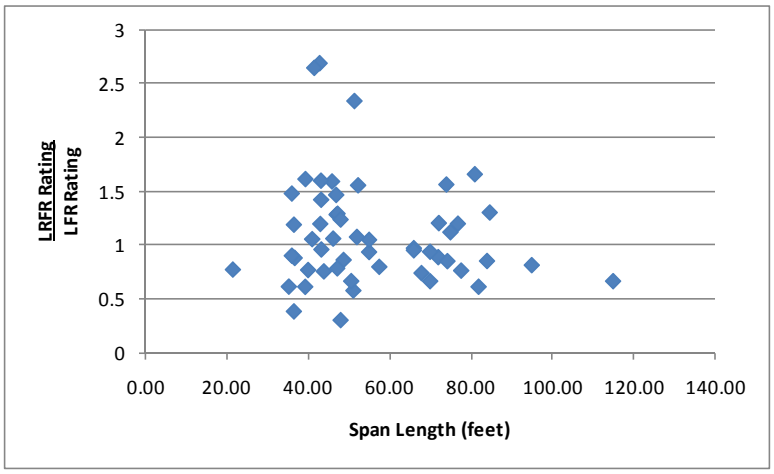


Figure D-267: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

D.2.12.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index for zero girders as shown in Figure D-268. The reliability index for most girders is between six and nine, well above the target reliability of 2.5.

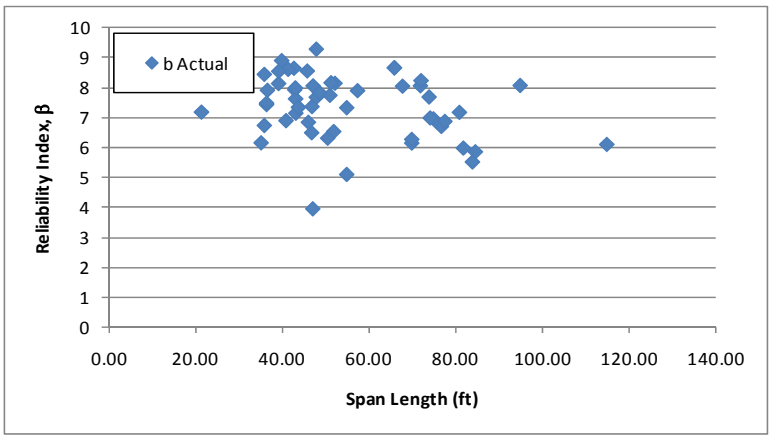


Figure D-268: Shear Reliability Indices for Type 3-3 Vehicle

Figure D-269 shows the reliability index for shear plotted against the LRFR rating for shear due to the AASHTO Type 3-3 Truck. The figure shows the reliability index for girders with a rating near one is approximately four. This exceeds the target reliability of 2.5. The reliability exceeding the target reliability indicates that lower live load factors can be used to obtain the target reliability.

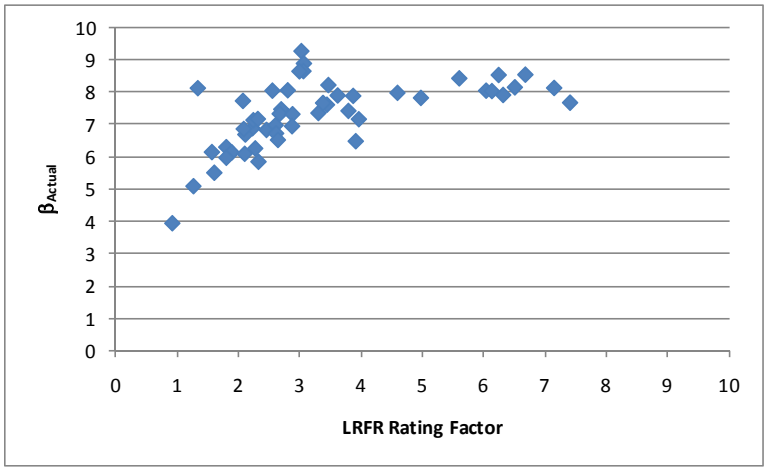


Figure D-269: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

D.2.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-270. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

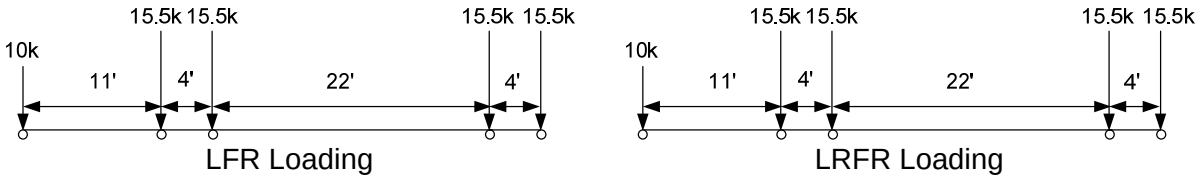
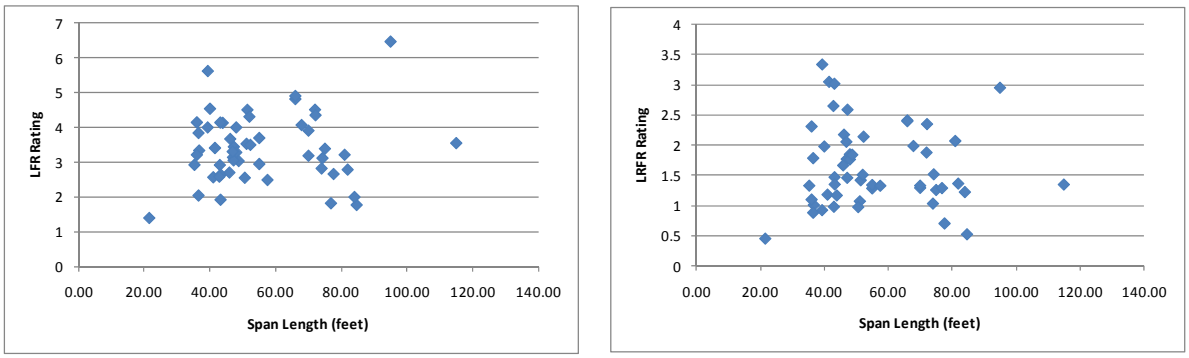


Figure D-270: Vehicle Loadings and Load Factors

D.2.13.1 Moment

D.2.13.1.1 Rating Factors

Figure D-271 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, seven girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 98% of the girders in this subset. The LFR ratings are between two and five for most girders while the LRFR rating is between one and three for most girders. Three of the seven girders with LRFR ratings less than one are controlled by the longitudinal steel rating.



(a) (b)

Figure D-271: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure D-272 shows the percentage of girders with ratings in each rating range for the AASHTO Type 3S2 Truck. 7.5% of girders have LRFR ratings less than 1.0 for an ADTT of 100 and 15.1% of girders have an LRFR rating less than 1.0 for ADTT of 5,000. This indicates that the ratings will be negatively affected by the switch from LFR to LRFR; most girders will not be affected. 100% of girders have LFR ratings greater than 1.0.

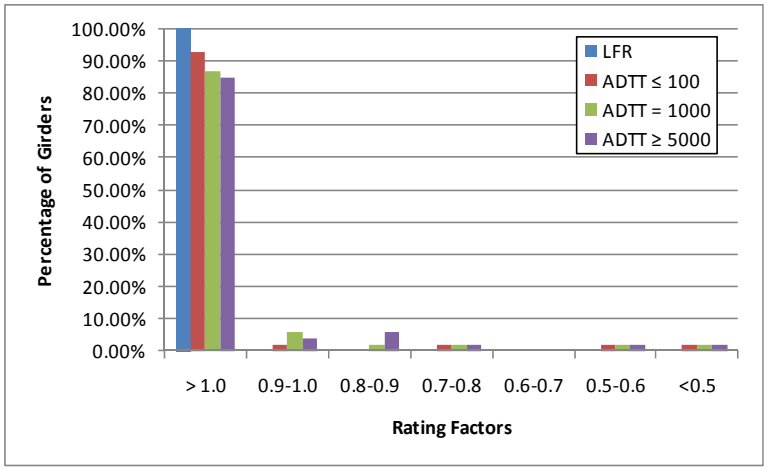


Figure D-272: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

D.2.13.1.2 Rating Factor Comparisons

Figure D-273 shows the ratio of LRFR rating to LFR rating. One girder has an LRFR rating higher than the LFR rating, indicated by the data point above 1.0. The ratio is generally between 0.2 and 0.6.

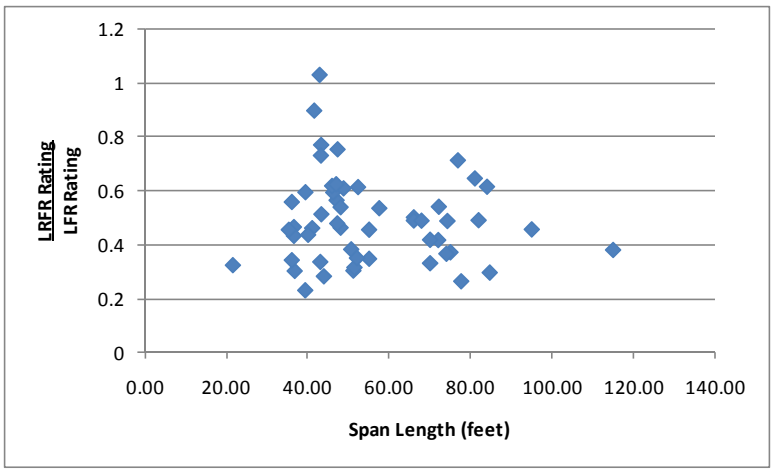


Figure D-273: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

D.2.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-274 shows that three girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between six and ten for most girders.

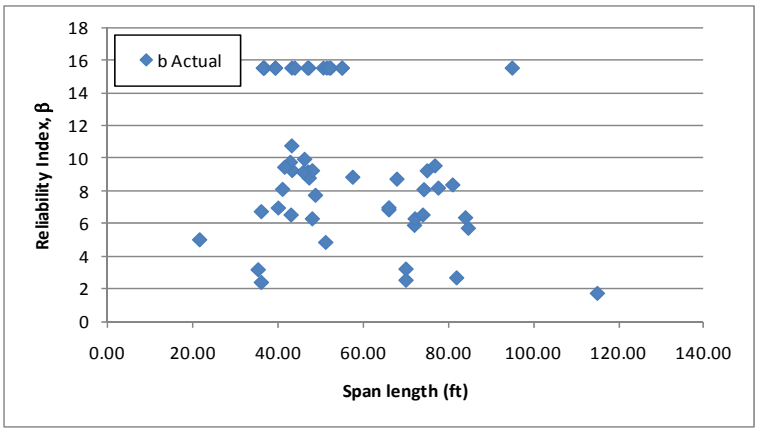


Figure D-274: Flexure Reliability Indices for Type 3S2 Vehicle

Figure D-275 shows the moment reliability index plotted against the LRFR moment rating for the AASHTO Type 3S2 truck. The figure shows that girders with ratings of 1.0 typically have the target reliability of 2.5. The average reliability index is between four and six, exceeding the target reliability of 2.5. This indicates the target reliability can be maintained using live load factors lower than the currently in the MBE.

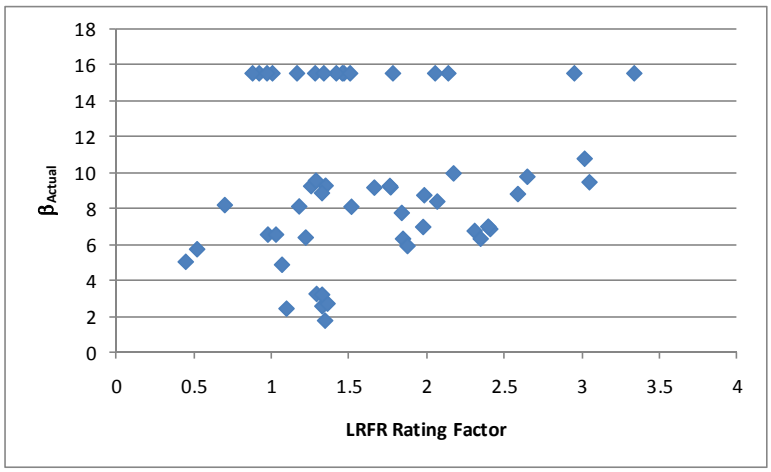
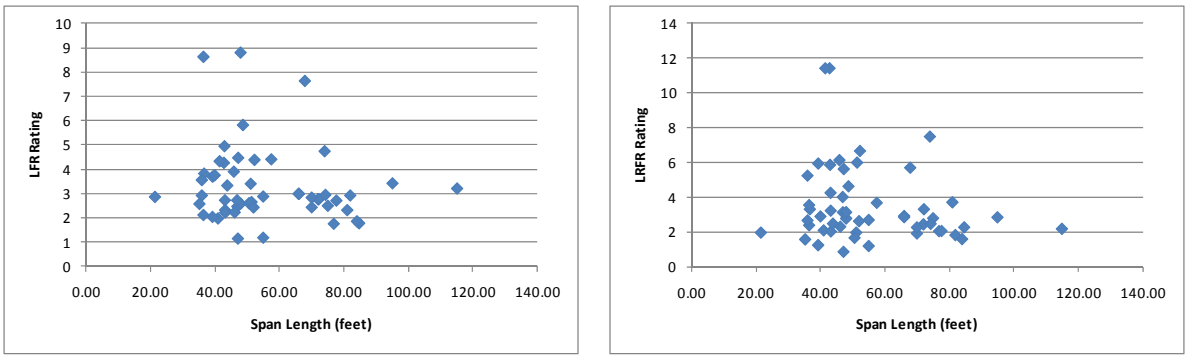


Figure D-275: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Vehicle

D.2.13.2 Shear

D.2.13.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, one girder with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 53% of the girders in this subset. Figure D-276 shows the LFR and LRFR ratings. The LFR ratings are between 2.0 and 4.5 for most girders while the LRFR ratings are between 2.0 and 6.0 for most girders.



(a) (b)

Figure D-276: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure D-277 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 Truck. All girders have ratings greater than 1.0 for LFR and LRFR for an ADTT of 100. 98.1% of girders have LRFR ratings greater than 1.0 for ADTTs of 1000 and 5000. Very few girders will be negative affected by the switch from LFR to LRFR.

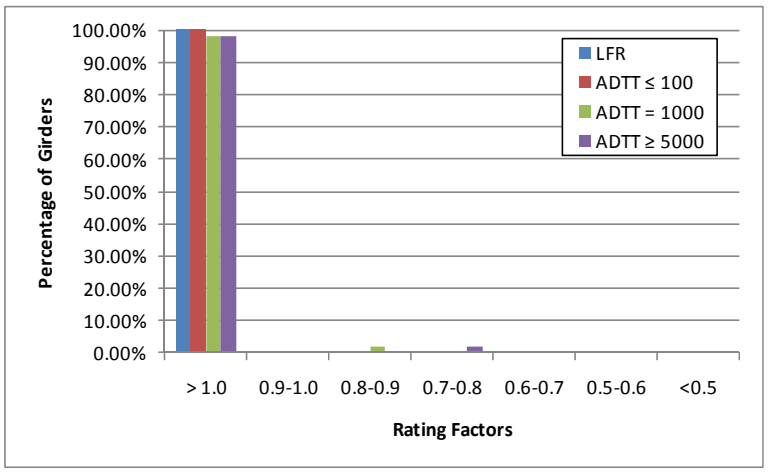


Figure D-277: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

D.2.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-278 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with shorter spans generally having higher ratios.

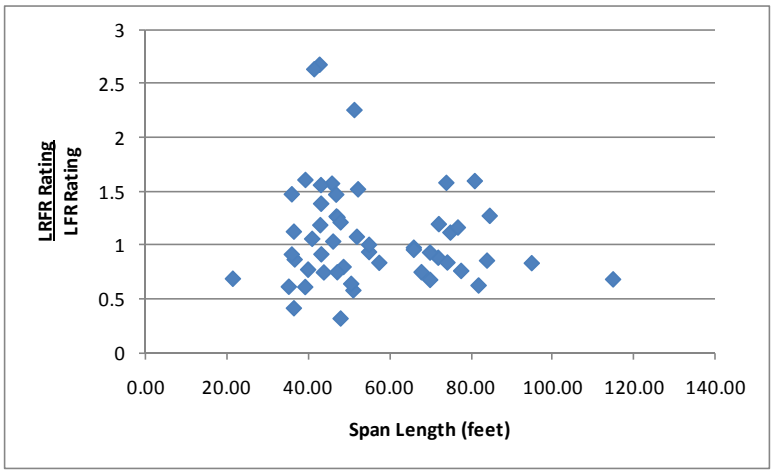


Figure D-278: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

D.2.13.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index for zero girders as shown in Figure D-279. The reliability index for most girders is between six and nine.

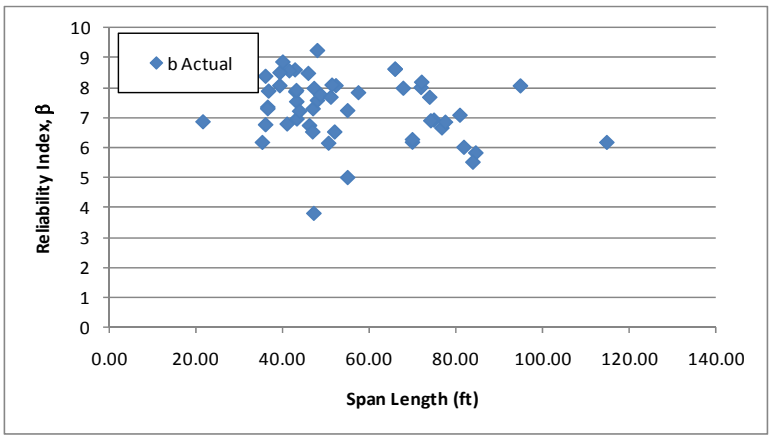


Figure D-279: Shear Reliability Indices for Type 3S2 Vehicle

Figure D-280 shows the reliability index for shear plotted against the LRFR rating for shear due to the AASHTO Type 3S2 truck. The reliability index for girders with ratings of 1.0 is approximately four, above the target reliability of 2.5. This indicates the target reliability can be obtained with load factors lower than those currently in the MBE.

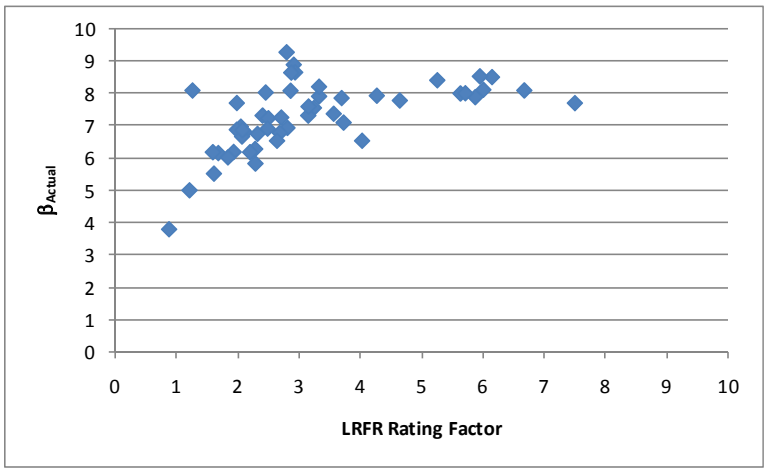


Figure D-280: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

D.2.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table D-3 shows the results for the moment ratings. For the design vehicle two times as many girders have ratings less than 1.0 for LRFR than for LFR. For the other vehicles investigated, the number of girders varied depending on the vehicle, but overall all vehicles have more girders with lower ratings for LRFR than for LFR. The heavy vehicles, the design vehicle and the special permit vehicles, have more girders with LRFR ratings that are greater than the LFR ratings. The routine permit vehicles and legal vehicles have similar numbers of girders with LRFR ratings greater than the LFR rating. The table also shows how many girders with LRFR ratings less than 1.0 are controlled by different rating criteria; the Service III limit state which limits the tensile stress in the bottom of the girder controls most ratings. If the Service III limit state does not control and the LRFR rating is less than 1.0, the longitudinal steel rating controls.

Table D-3: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	53	14	0	0	1	1	0	1	1	4	0	0	0
LRFR Rating less than 1.0		32	15	12	11	11	6	10	15	21	7	4	7
LFR and LRFR Rating less than 1.0		11	0	0	1	1	0	1	1	4	0	0	0
% with LFR RF greater than LRFR RF		91	98	98	87	96	96	85	96	87	98	98	98
Girders controlled by longitudinal steel rating and LRFR Rating less than 1.0		12	2	1	2	2	2	0	2	2	2	1	3
LRFR Rating less than 1.0 and controlled by service limit state		19	12	10	9	9	4	10	13	19	5	3	4

D.2.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table D-4 shows the results for the shear ratings. The routine permit vehicles except for NM-04 and the legal vehicles produced no girders that have LFR ratings less than 1. The design vehicle and special permit vehicles, except for OR-06, caused several girders to have LFR ratings less than 1.0. The percentage of girders with LFR ratings greater than LRFR ratings depends on the type vehicle, which is expected because the LRFR shear strength equation uses the ratio of V_u/M_u.

Table D-4: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	53	1	0	0	2	0	0	0	0	4	0	0	0
LRFR Rating less than 1.0		20	2	2	1	1	1	0	4	7	1	1	1
LFR and LRFR Rating less than 1.0		1	0	0	1	0	0	0	0	3	0	0	0
% with LFR RF greater than LRFR RF		58	53	51	26	53	47	15	55	40	49	53	53

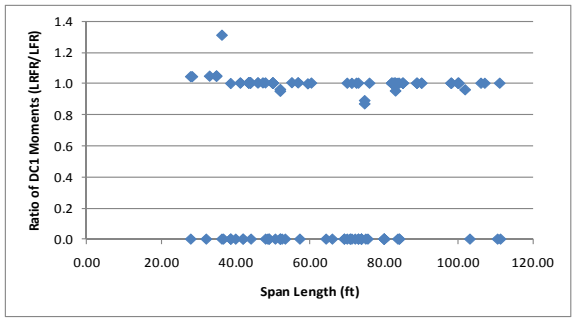
D.3 Interior Composite Girders

D.3.1 Dead Loads

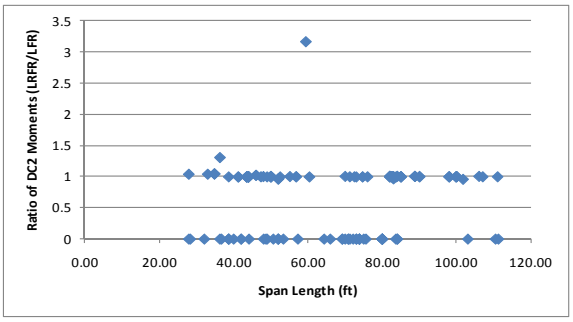
D.3.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure D-281a, the ratio of unfactored DC1 moments (self-weight, dead loads on composite section) is very close to one or zero. Those that are slightly above 1.0 are caused by the moment being obtained at the four-tenths point for LFR while the LRFR moment is calculated at midspan.

Figure D-281b shows that there is a small amount of variation in the loads applied to the composite section (DC2 and DW loads), with the exception of the two girders near 1.3, one girder near 3.1, and numerous girders at zero. The girders with ratios of dead load moments are due to the LRFR critical section being at the support for moment. This is due the LRFR rating of the longitudinal steel reinforcement at the support. The critical number of lanes loaded was utilized for the design vehicles.



(a)

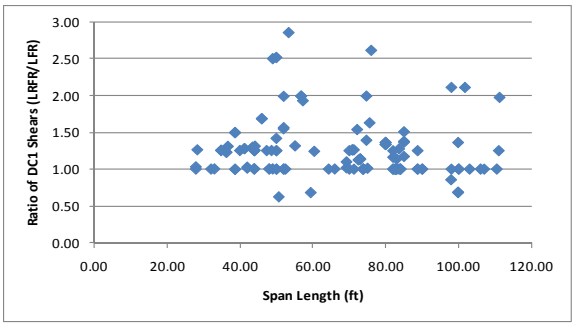


(b)

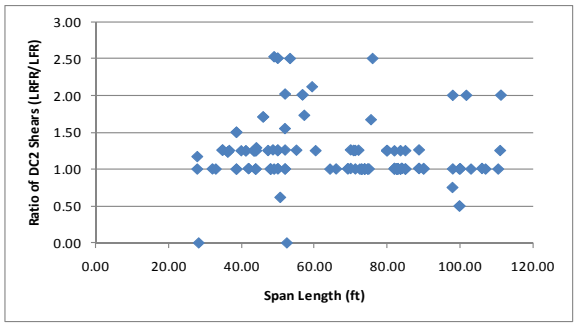
Figure D-281: Ratios of DC1 and DC2 Moments (unfactored loads LRFR/LFR)

D.3.1.2 Shear

Figure D-282a shows that numerous girders have a ratio of DC1 shear close to 1.0, but there are also many where the ratio is above 1.0. This is due to the variation of the critical section for shear. Figure D-282b shows the same trend as Figure D-282a in that the LFR shear is similar to the LRFR shear. The values at 1.25 indicate the LRFR critical section is at the support while the LFR critical section was at one tenth of the span length from the support.



(a)



(b)

Figure D-282: Ratios of DC1 and DC2 Shears (unfactored loads)

D.3.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure D-283. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively.

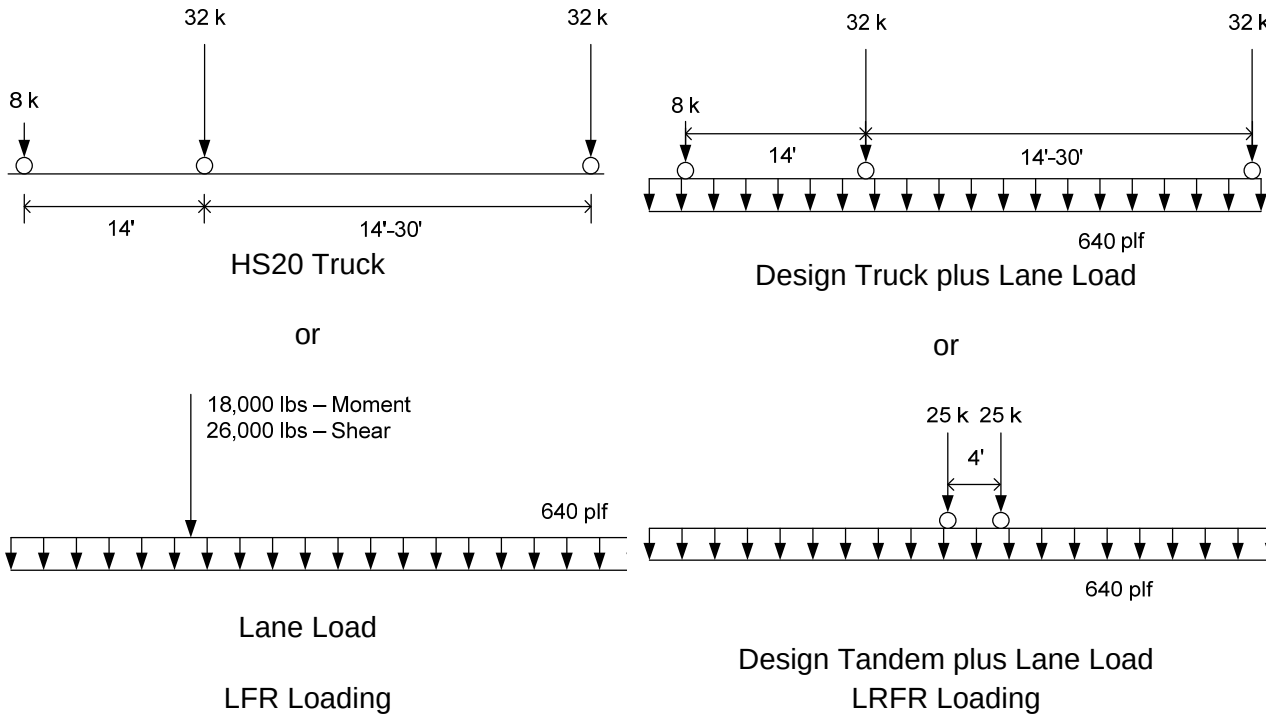
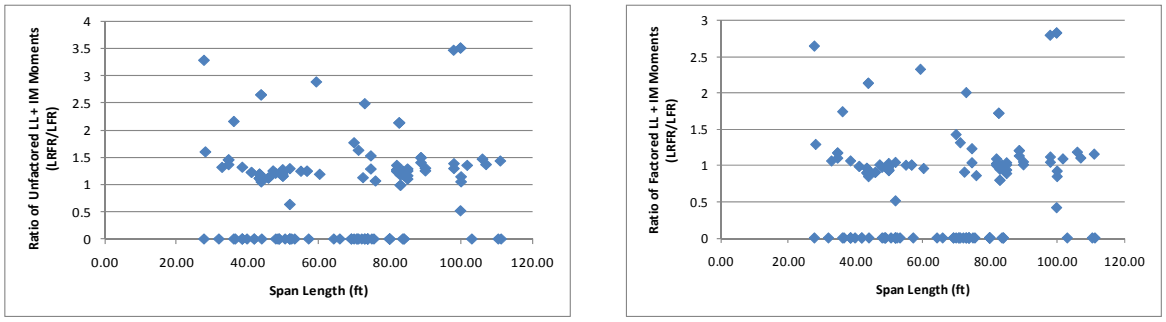


Figure D-283: Vehicle Loadings and Load Factors

D.3.2.1 Moment

D.3.2.1.1 Live Loads

Figure D-284a shows a plot of the unfactored live load moments caused by the the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by HS-20 Design load (the controlling of the truck or lane load) . The graph shows that the ratio of unfactored live loads is between 1.0 and 1.5 for most girders within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure D-284b shows that the results have shifted down and are very close to 1.0.



(a) (b)

Figure D-284: Ratio of Unfactored and Factored Live Load plus Impact Moments for HS-20 and HL-93 Loadings, respectively (LRFR/LFR)

D.3.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure D-285 shows that the ratio of resistance is generally between 1.0 and 1.25. The increased resistance for LRFR is due to the reduction in prestress losses. A large number of girders show that their LRFR resistance is one-quarter of the LFR resistance; these are the girders where the critical location is at the support for LRFR and near midspan for LFR.

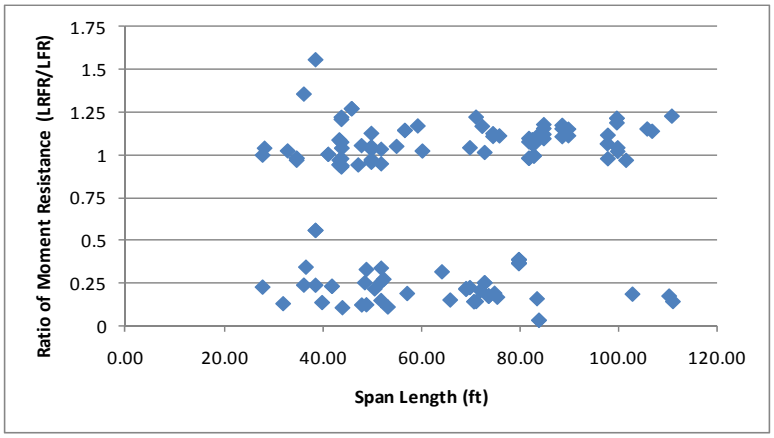
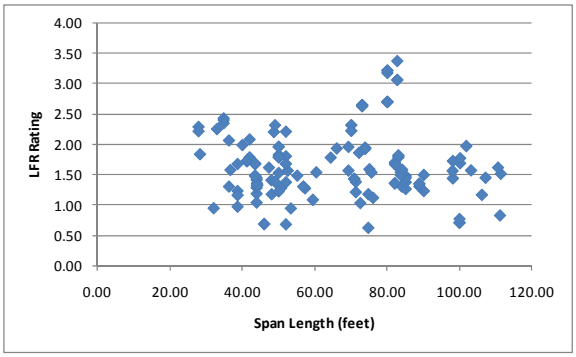


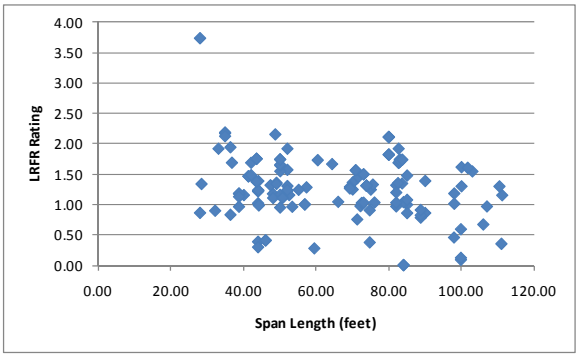
Figure D-285: Ratio of factored Moment Resistance (LFR/LRFR)

D.3.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (132 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 11 girders with LFR ratings less than 1.0, 34 girders with LRFR ratings less than 1.0, and 10 girders where both the LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. Figure D-286 shows the LFR rating factors and LRFR rating factors. The ratings for both methods are similar in that most girders have ratings between one and two, though the low LRFR ratings are lower than the LFR ratings. Six of the 34 girders with ratings less than 1.0 are controlled by the rating of the longitudinal steel reinforcement.



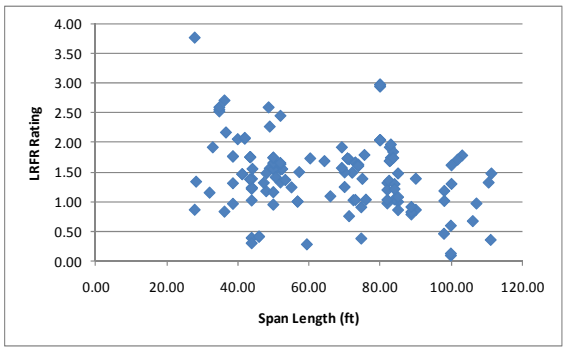
(a)



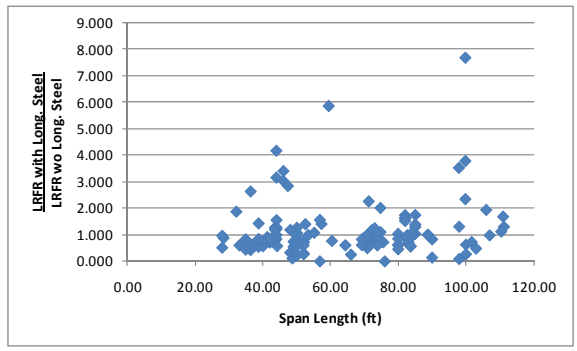
(b)

Figure D-286: LFR and LRFR Flexure Rating Factors for HS-20 and HL-93 Loading, respectively

Figure D-287a shows the LRFR rating when the longitudinal steel rating is ignored. When compared to Figure D-286b, it is obvious that some ratings have increased. Figure D-287b shows the ratio of the LRFR rating including the longitudinal steel rating divided by the LRFR rating ignoring the longitudinal steel rating. The figure shows that 61% of girders have higher LRFR ratings when the longitudinal steel rating is ignored. Six girders have ratings greater than 1.0 when the longitudinal steel rating is ignored that had ratings less than 1.0 when the longitudinal steel check was included.



(a)



(b)

Figure D-287: Effect of Longitudinal Steel Rating on LRFR Rating

D.3.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure D-288. The results indicate that 89% of the girders in this set have LFR ratings greater than LRFR ratings. The ratio is generally between 0.6 and 1.0.

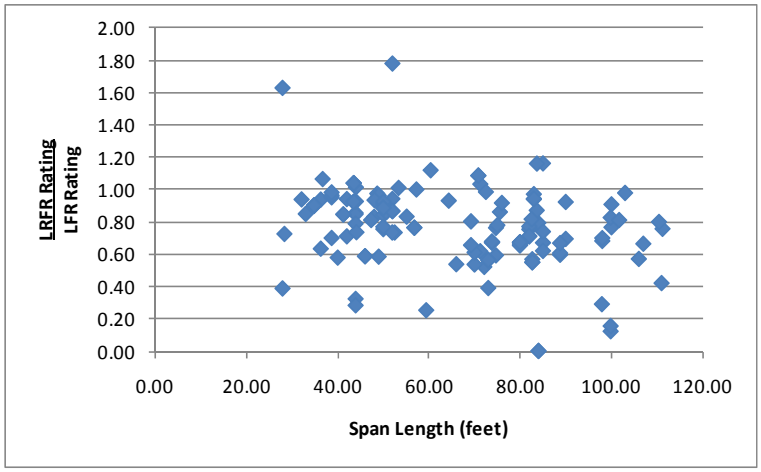


Figure D-288: Ratio of LRFR Flexure Rating to LFR Flexure Rating

Figure D-289 shows the percentage of girders in each category of LRFR/LFR ratio for the girders with LRFR ratings less than 1.0. The figure shows that most girders with LRFR ratings less than one have an LRFR rating that is between 50 and 90% of the LFR rating. The figure can be used to roughly approximate the reduction in live load that can be carried by the bridge.

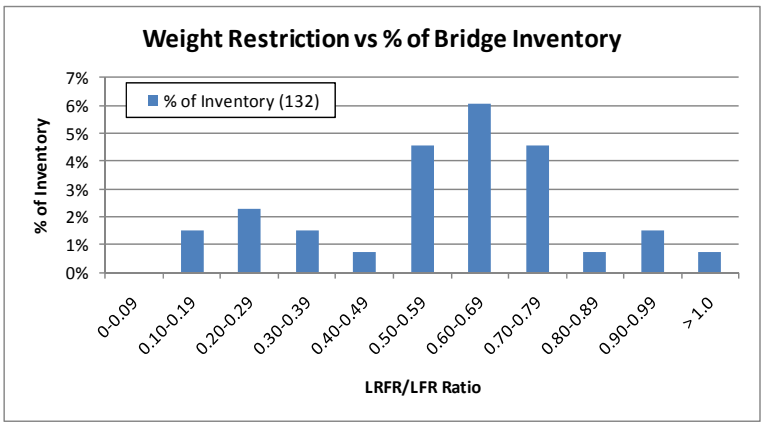


Figure D-289: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

D.3.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure D-290 shows that 52 girders have a reliability index lower than that assumed in the development of the LRFR Rating Specification at the inventory level. For the girders with the actual reliability index greater than the required, the reliability index decreases with increasing span length.

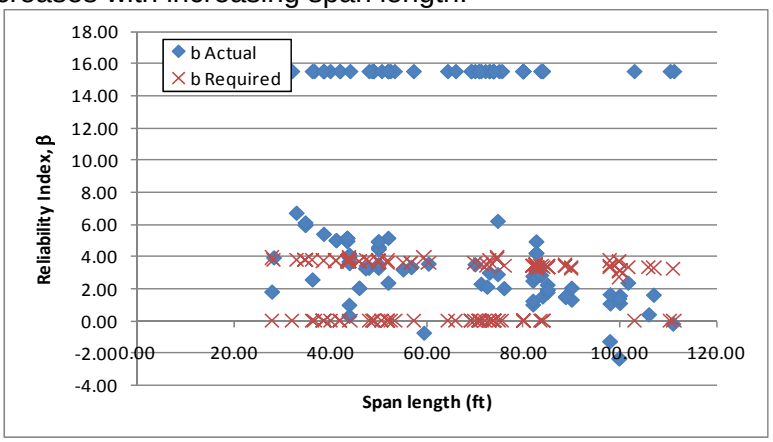


Figure D-290: Flexure Reliability Indices for HL-93 Loading

Figure D-291 shows the reliability index for moment plotted against the LRFR moment rating for the LRFD Design vehicle. The figure shows that the reliability increases with the LRFR rating. The figure shows that girders with a rating of 1.0 have a reliability index of approximately 2.5 or 3, less than the value of 3.5 inherent in the LRFD Design Specifications.

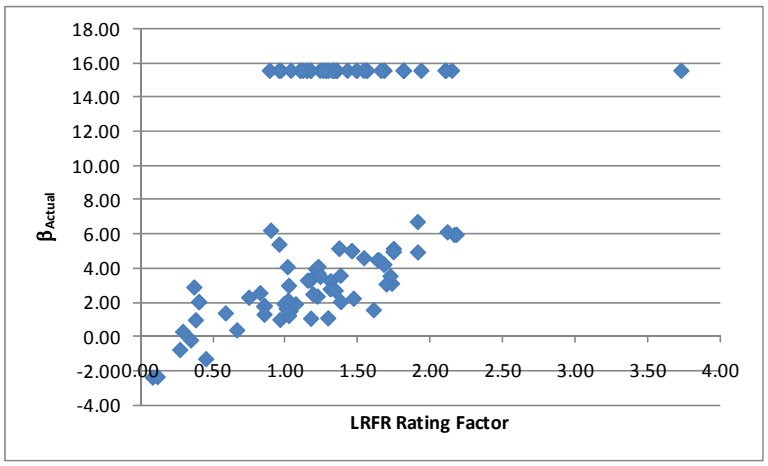


Figure D-291: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Loading

D.3.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is interior simple span prestressed concrete box girders with composite concrete decks.

D.3.2.2.1 Live Loads

Figure D-292a shows that the ratio of unfactored shear varies significantly, with most girders between 1.0 and 2.5, with some outside this range. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure D-292b shows that the ratio of factored live load shears has decreased and is generally between 0.9 and 2.0 for most cases. The ratio of live loads increases with increasing span length; this is due to the presence of the uniform lane load in the HL-93 design loading as compared to the design loading in the Standard Specification. The variation in critical location also affects the variation in the live load ratio.

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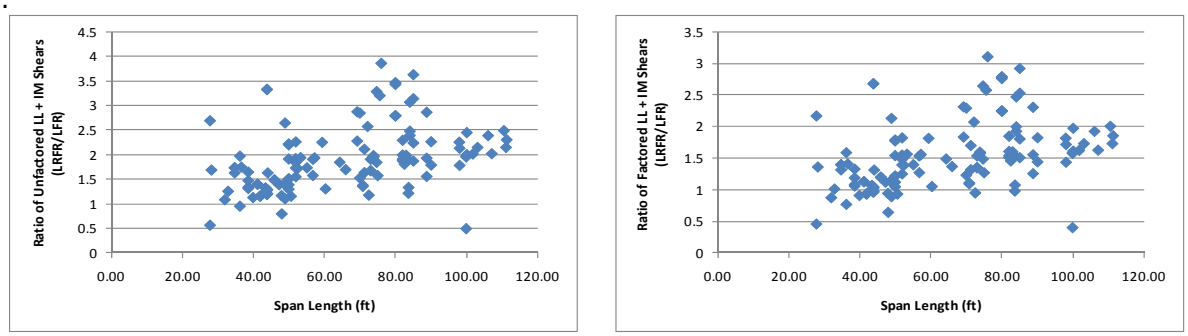


(a) (b)

Figure D-292: Ratio of Unfactored and Factored Live Load plus Impact Shears for HS-20 and HL-93 Loading, respectively (LRFR/LFR)

As shown in Figure D-293, the location of the critical section for varies significantly for most girders in this subset. The variation in the factored shear shown in Figure D-292 was affected by the difference in the critical section for shear rating.

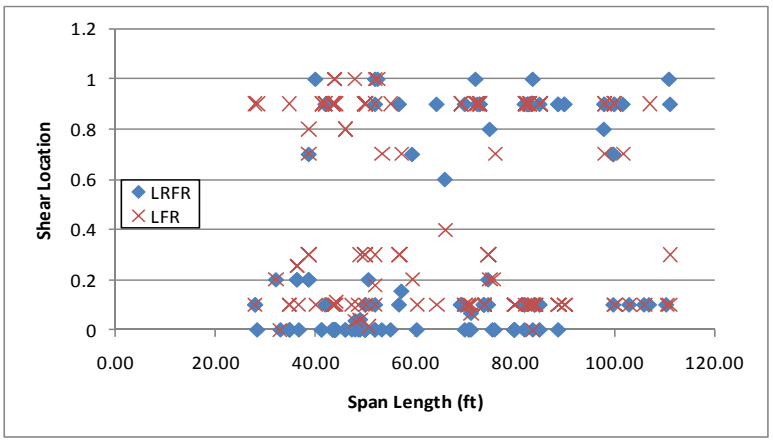


Figure D-293: Graph of critical shear location for HS-20 and HL-93 Loadings

D.3.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure D-294 shows that the ratio of resistance is generally greater than 1.0 (LRFR resistance is greater than LFR resistance) with most between 1.0 and 3.0.

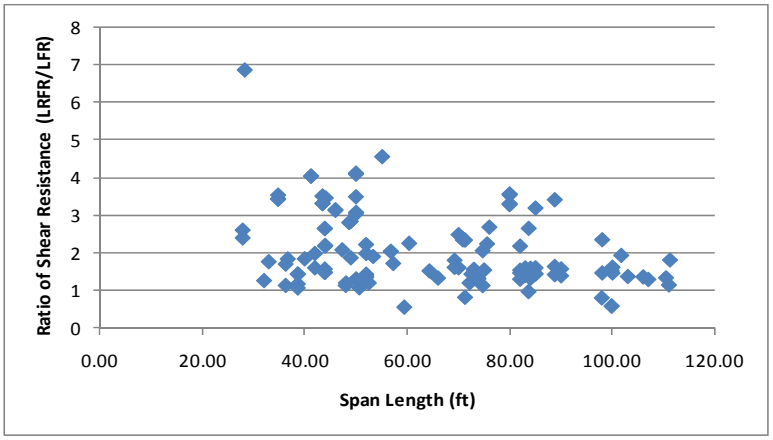
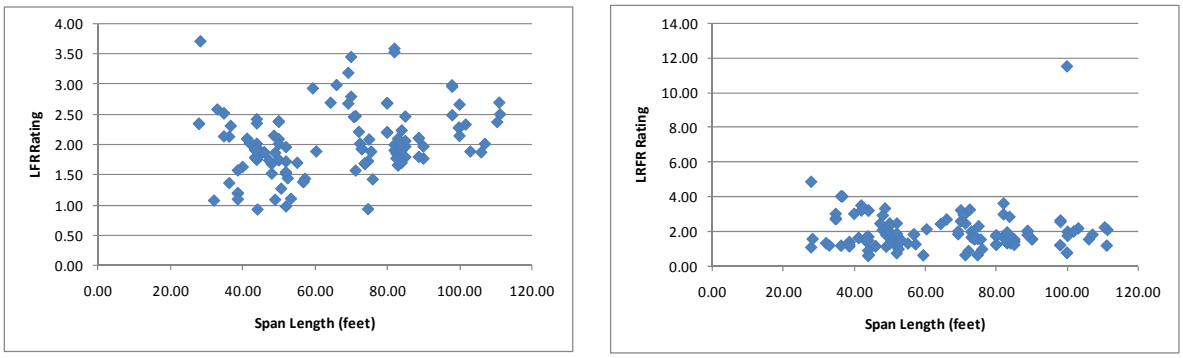


Figure D-294: Ratio of factored Shear Resistance (LFR/LRFR)

D.3.2.2.3 Rating Factors

After comparing the loads and resistances to verify that the results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are three girders with LFR ratings less than 1.0, 11 girders with LRFR ratings less than 1.0, and two girders where both LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. For this subset, there is a small percentage (8%) of girders that have shear ratings less than 1.0 for LRFR. The LFR rating was greater than the LRFR rating for 67% of the girders in this subset. Figure D-295 shows the LFR rating factors and LRFR rating factors. The LFR

rating is between one and three for most girders while the LRFR rating is also between one and three for most girders.



(a) (b)

Figure D-295: LFR and LRFR Shear Rating Factors for HS-20 and HL-93 Loadings, respectively

D.3.2.2.4 Rating Factor Comparisons

Figure D-296 shows the ratio of the LRFR rating to the LFR rating. Almost 33% of the girders in this subset have LRFR ratings that are higher than their associated LFR rating. The ratio tends to decrease with increasing span lengths. The ratio is between 0.5 and 2.0 for most girders.

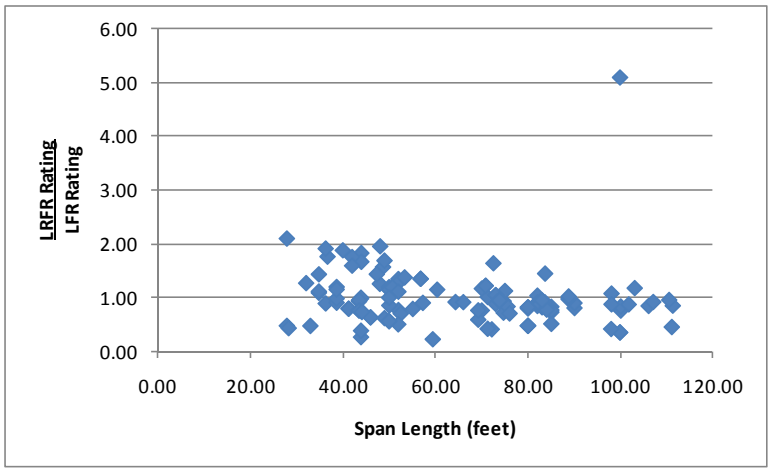


Figure D-296: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Vehicles

Figure D-297 shows the percentage of girders affected by switching from LFR to LRFR and the effect on rating that will occur. The figure shows that most girders with LRFR ratings less than 1.0 will have an LRFR rating that is less than 60% of the LFR rating.

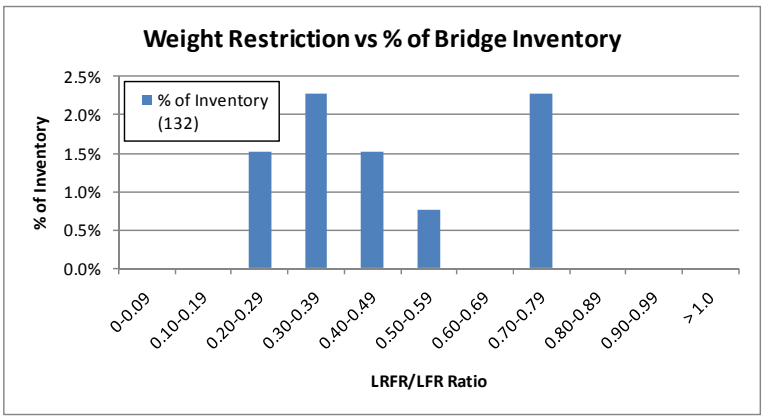


Figure D-297: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

D.3.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure D-298 shows all but five girders have a reliability index for shear greater than the required level. The reliability index for most girders is above five but decreases with increasing span lengths.

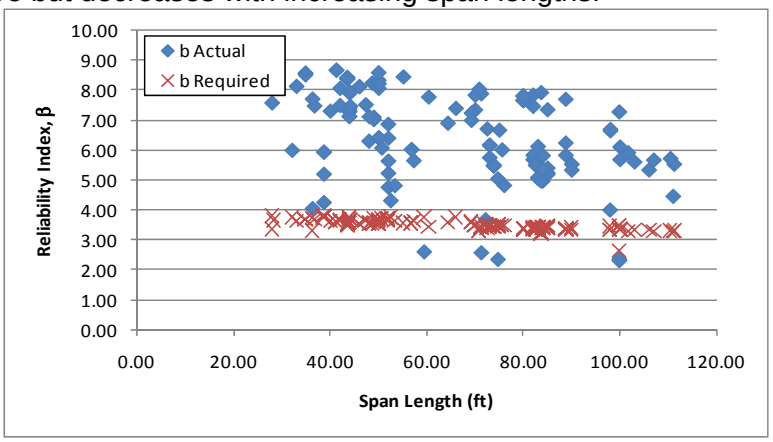


Figure D-298: Shear Reliability Indices for HL-93 Loading

Figure D-299 shows the shear reliability index plotted against the LRFR shear rating for the design loading. The figure shows that the reliability index for a girder with a rating of one is approximately four. This value is similar to the value of 3.5 inherent in the LRFD Design Specifications.

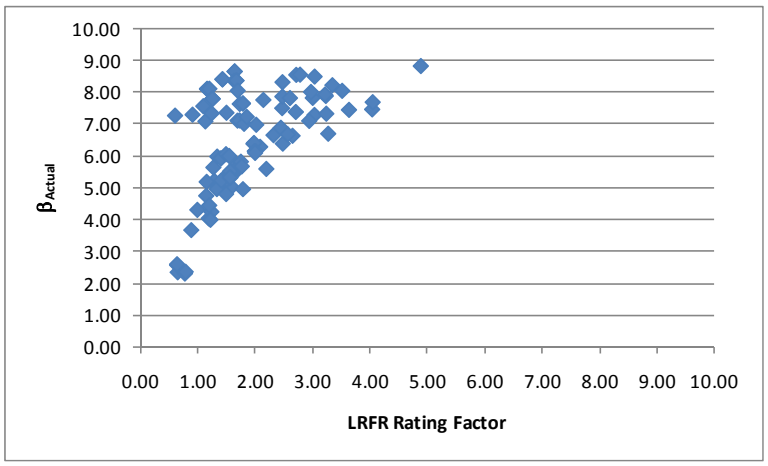


Figure D-299: Shear Reliability Index vs LRFR Shear Rating for Design Loading

D.3.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-300. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

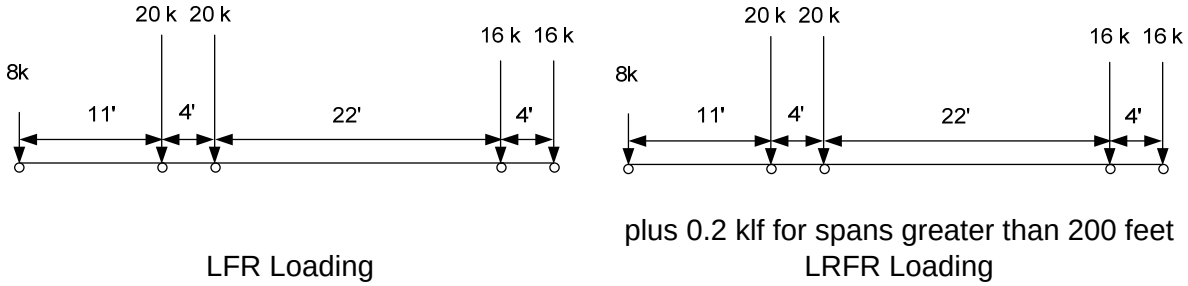


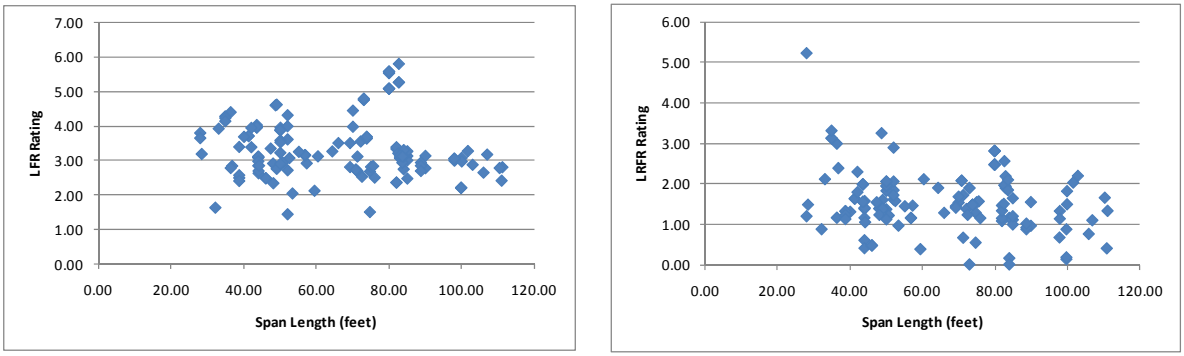
Figure D-300: Vehicle Loadings and Load Factors

D.3.3.1 Moment

The following section contains the results for interior, composite prestressed box girders within simple span bridges for the DE-07 Vehicle.

D.3.3.1.1 Rating Factors

Figure D-301 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 21 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 98% of the girders in this subset. The LFR ratings are between two and four for most girders while the LRFR rating is between one and two for most girders. This shows that a reduction in rating is expected when switching from LFR to LRFR. Five of the twenty-one girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.



(a) (b)

Figure D-301: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure D-302 shows the percentage of girders with moment ratings in each rating range for the DE-07 Vehicle. 15.5% of girders will have ratings less than 1.0 for an LRFR rating with an ADTT of 100. This increases to 16.7% for LRFR ratings with an ADTT of 5,000. Less than 20% of girders are affected by the switch from LFR to LRFR. All girders have LFR ratings greater than 1.0 for the DE-07 Vehicle.

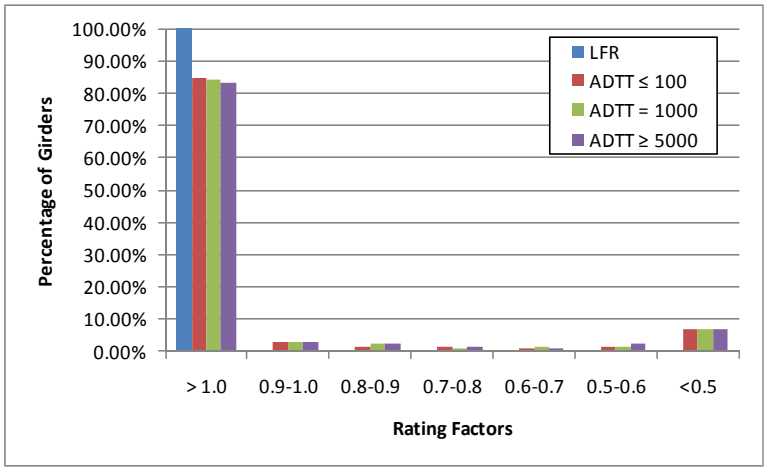


Figure D-302: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

D.3.3.1.2 Rating Factor Comparisons

Figure D-303 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating which occurs for two girders in this group. The ratio is generally in the range of 0.3 to 0.7, with lower ratios generally corresponding to longer span lengths.

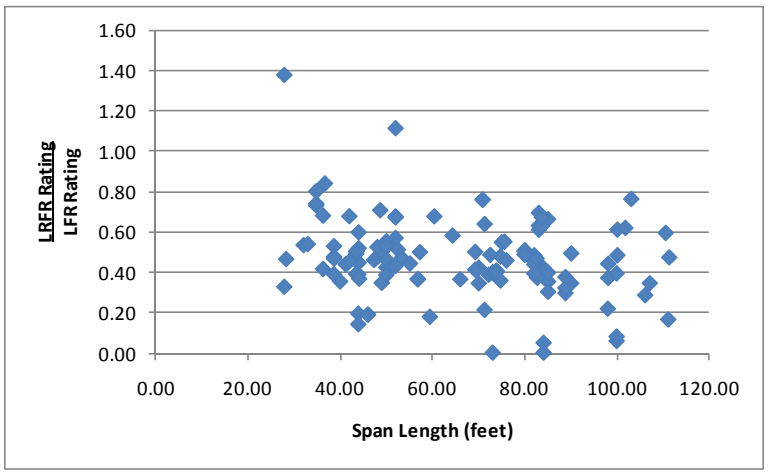


Figure D-303: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

D.3.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-304 shows that 18 girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index decreases with increasing span lengths.

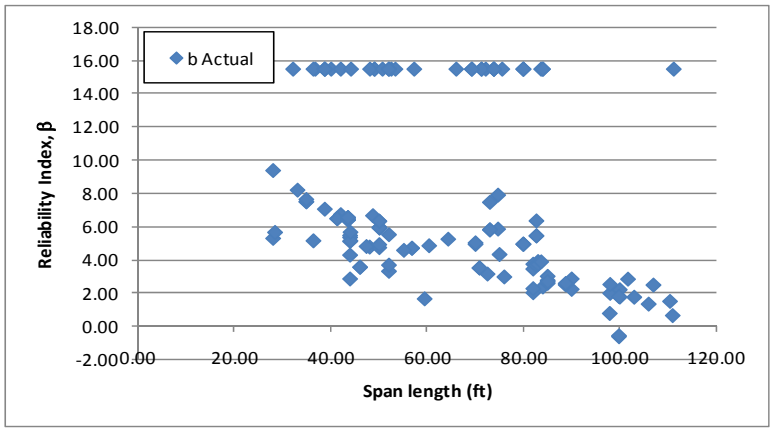


Figure D-304: Flexure Reliability Indices for DE-07 Vehicle

Figure D-305 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 vehicle. The figure shows that the reliability index increases with increasing LRFR ratings. The figure shows that the target reliability index of 2.5 is very similar to the value for girders with a rating of 1.0. This indicates that the live load factors currently in the MBE for routine permit vehicles result in the target reliability for this vehicle.

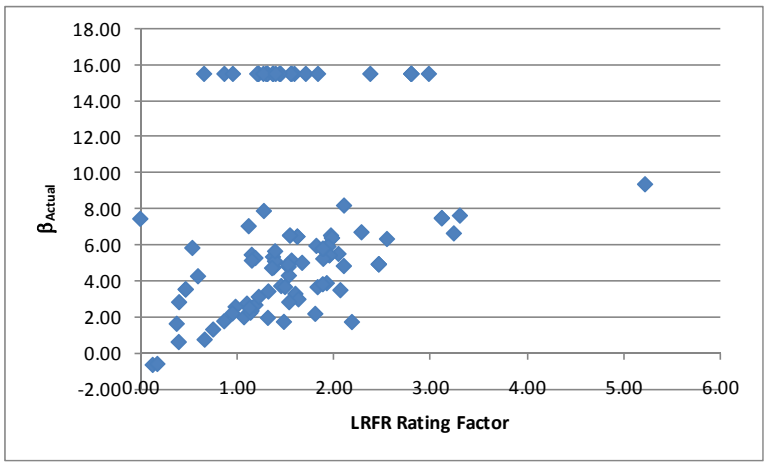
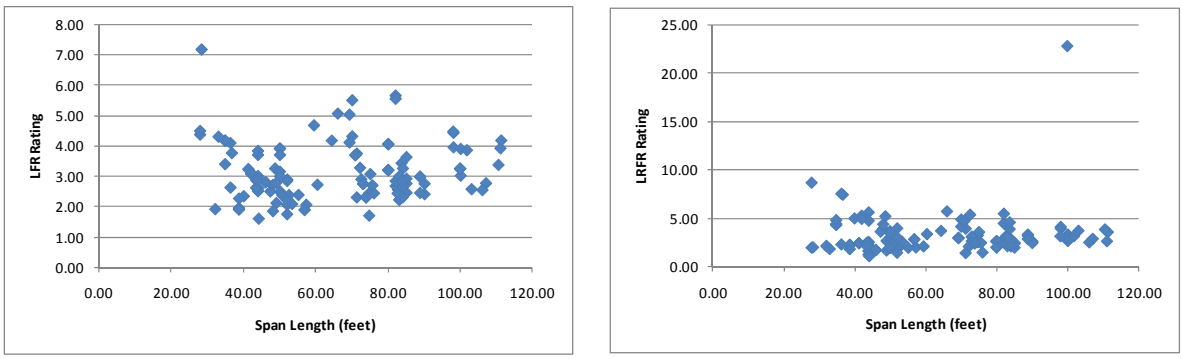


Figure D-305: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 vehicle

D.3.3.2 Shear

D.3.3.2.1 Rating Factors

For shear, there are zero girders with ratings less than 1.0 for either method. The LFR Rating is greater than the LRFR rating for 52% of the girders in this subset. Figure D-306 shows the LFR and LRFR ratings. The LFR ratings are between two and four for most girders while the LRFR ratings are between one and six for most girders.



(a) (b)

Figure D-306: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure D-307 shows the percentage of girders with shear ratings in each rating range. All girders have ratings greater than 1.0 except for the ADTT = 5,000 case where less than 1% of girders have an LRFR rating less than 1.0. Very few girders are affected by the switch from LFR to LRFR; the girders that are affected have ratings between 0.9 and 1.0.

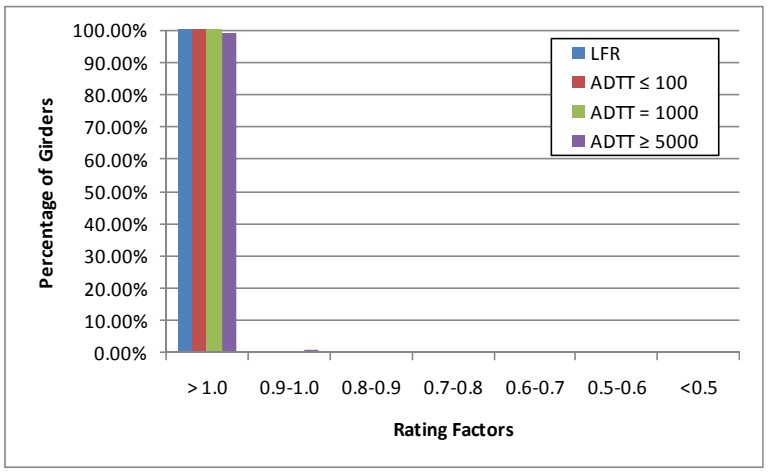


Figure D-307: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

D.3.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure D-308 show the comparison of rating factors. The ratio is greater than 1.0 for 48% of the girders, with shorter spans more likely to have a ratio greater than 1.0.

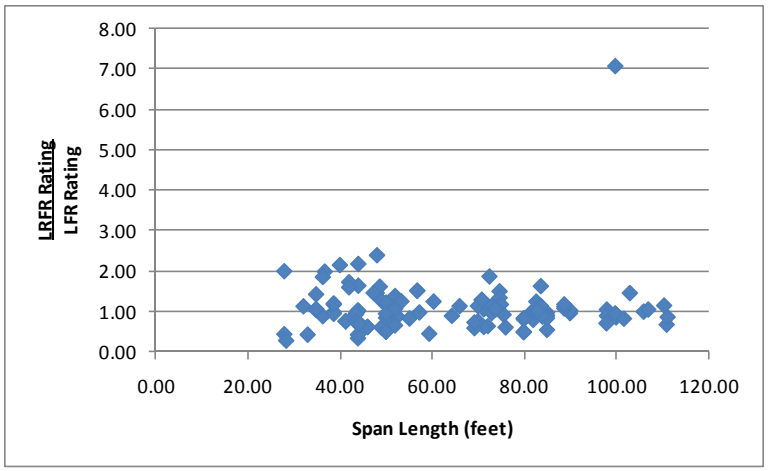


Figure D-308: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

D.3.3.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-309. The reliability index decreases with increasing span length but does not result in any girders not having the target reliability.

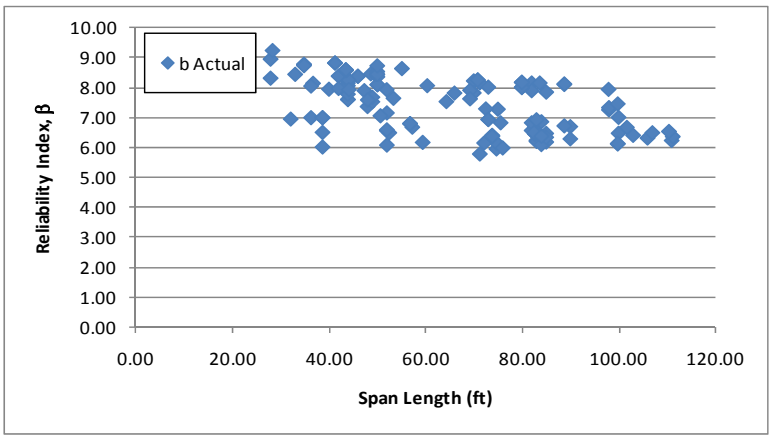


Figure D-309: Shear Reliability Indices for DE-07 Vehicle

Figure D-310 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 Vehicle. The figure shows that girders with ratings greater than 1.0 have reliability indices exceeding six. This suggests that the current live load factors are too conservative and may result in girders rating less than 1.0 that exceed the target reliability of 2.5.

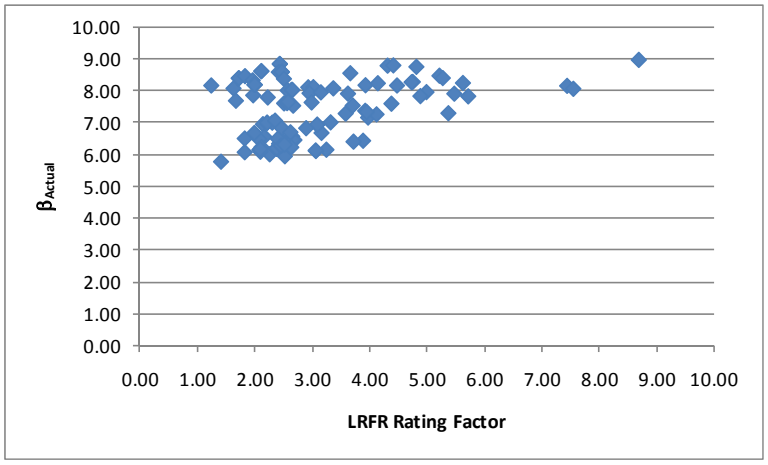
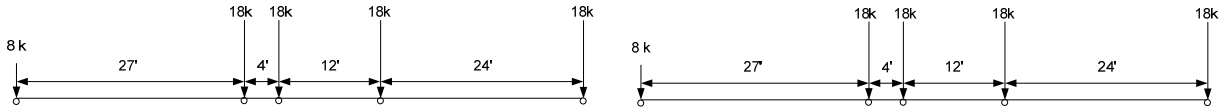


Figure D-310: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

D.3.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-311. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

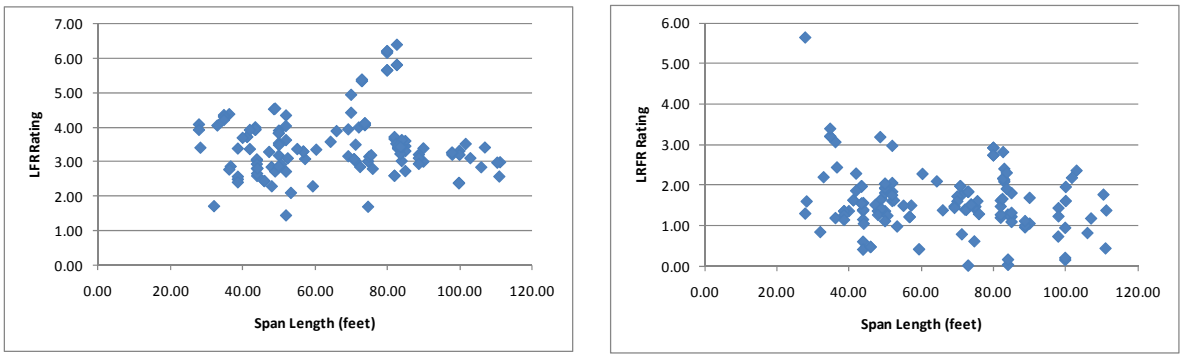
Figure D-311: Vehicle Loadings and Load Factors

D.3.4.1 Moment

The following section contains the results for interior, composite prestressed box girders within simple span bridges for the FL-04 Vehicle.

D.3.4.1.1 Rating Factors

Figure D-312 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 19 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 98% of the girders in this subset. The LFR ratings are between two and four for most girders while the LRFR ratings are between one and two for most girders. Five of the nineteen girders with LRFR ratings less than one are controlled by the longitudinal reinforcement rating.



(a) (b)

Figure D-312: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure D-313 shows the percentage of girders with moment ratings in each rating range for the FL-04 Vehicle. Approximately 85% of girders have LRFR ratings greater than 1.0 for all ADTT values. 40% of the girders with LRFR ratings less than 1.0 have ratings less than 0.5. While a small portion of the girders are affected by the switch from LFR to LRFR, most of those girders are significantly affected by this switch. 100% of girders have LFR ratings greater than 1.0.

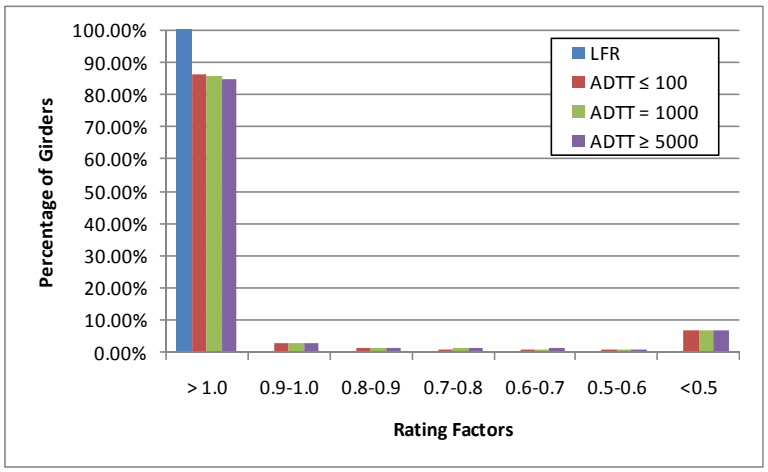


Figure D-313: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

D.3.4.1.2 Rating Factor Comparisons

Figure D-314 shows the ratio of LRFR rating to LFR rating. Two girders have LRFR ratings greater than the LFR rating. The LRFR rating is typically 30 to 70% of the LFR rating. Longer spans generally have greater LFR ratings than LRFR ratings.

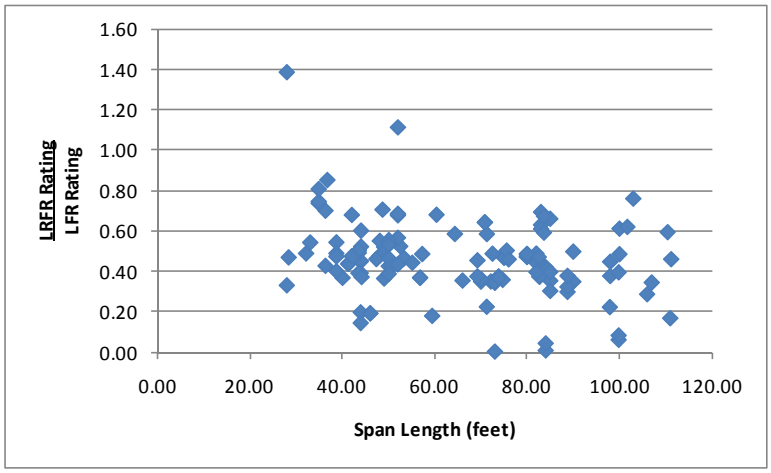


Figure D-314: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

D.3.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-315 shows that 16 girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index decreases with increasing span lengths.

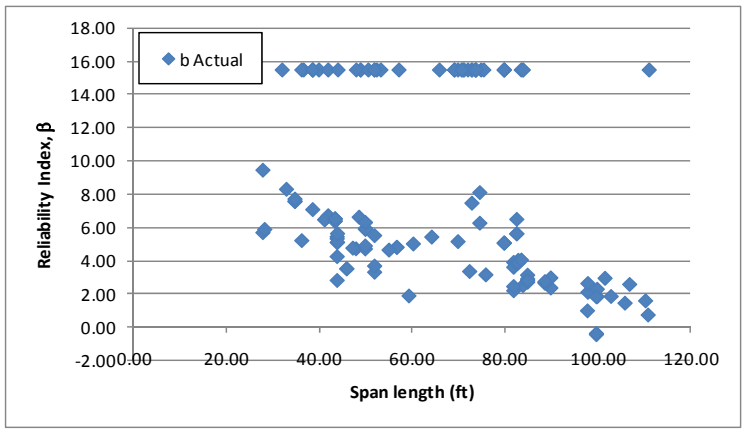


Figure D-315: Flexure Reliability Indices for FL-04 Vehicle

Figure D-316 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 vehicle. The figure shows that the reliability index for girders with a rating of 1.0 is close to 2.0 or 2.5. This is near the target of 2.5, indicating that the current live load factors produce the target level of reliability.

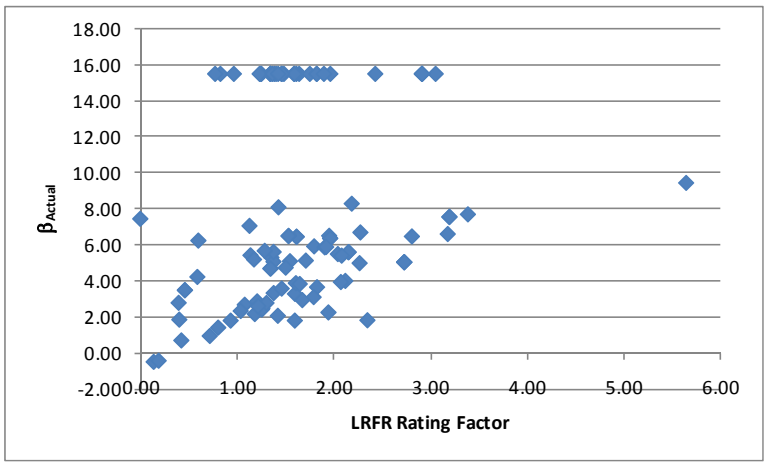
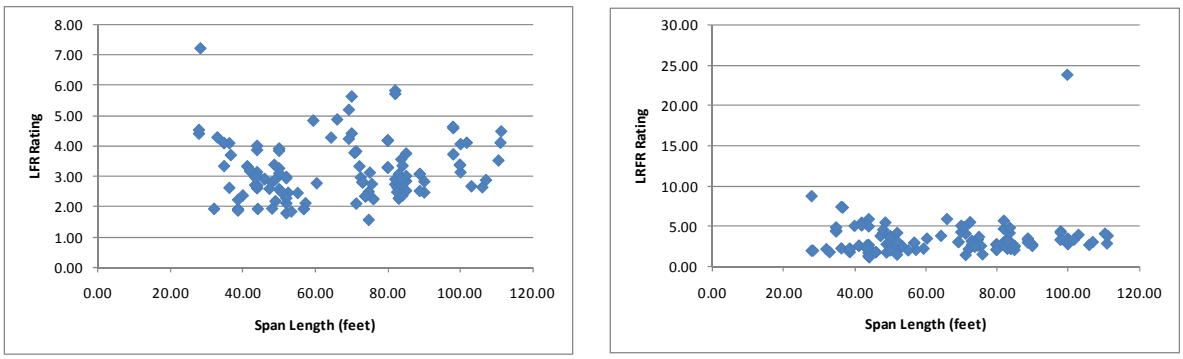


Figure D-316: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

D.3.4.2 Shear

D.3.4.2.1 Rating Factors

For shear, there are zero girders with a rating less than 1.0 for either method. The LFR Rating is greater than the LRFR rating for 49% of the girders in this subset. Figure D-317 shows the LFR and LRFR ratings. The LFR ratings are between two and four for most girders while the LRFR ratings are between one and five for most girders.



(a) (b)

Figure D-317: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure D-318 shows the percentage of girders with shear ratings in each rating category for the FL-04 vehicle. All girders have ratings greater than 1.0 for all ratings. No girders are affected by the switch to LRFR such that they have a rating less than 1.0.

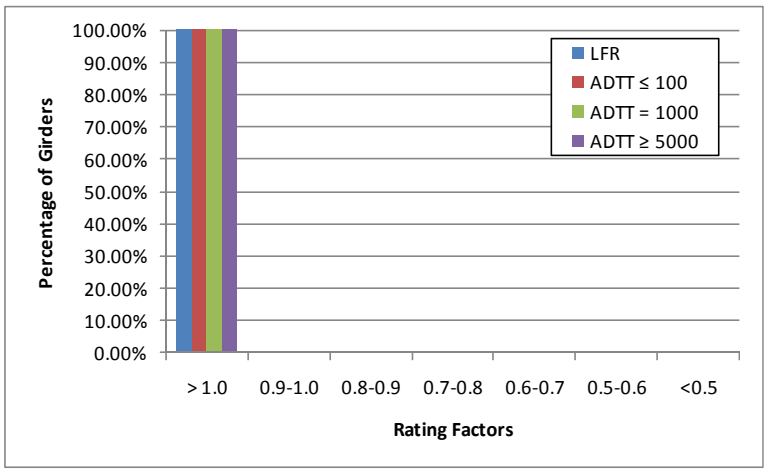


Figure D-318: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

D.3.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-319 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0, with the ratio decreasing for longer span lengths. 51% of the girders have LRFR ratings that are higher than the LFR rating.

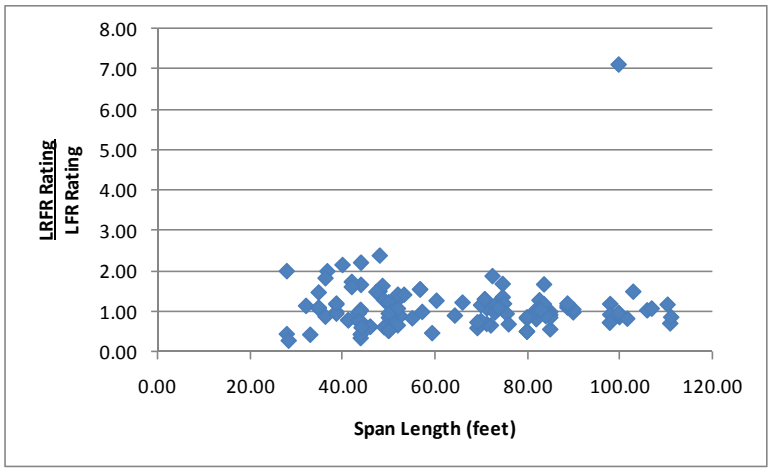


Figure D-319: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

D.3.4.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-320. The actual reliability index decreases with increasing span length and is between six and nine for most girders.

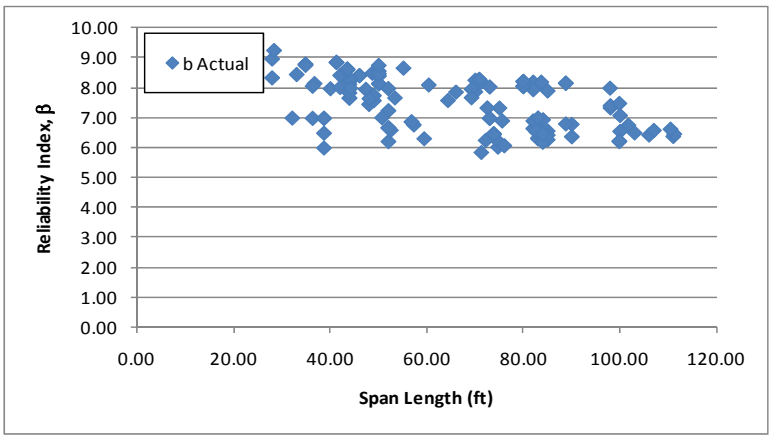


Figure D-320: Shear Reliability Indices for FL-04 Vehicle

Figure D-321 shows the shear reliability index plotted against the LRFR shear rating for the FL-04 vehicle. The figure shows that all girders have reliability indices which significantly exceed the target reliability even for girders with ratings near 1.0. This indicates that reducing the live load factors in the MBE may be overly conservative.

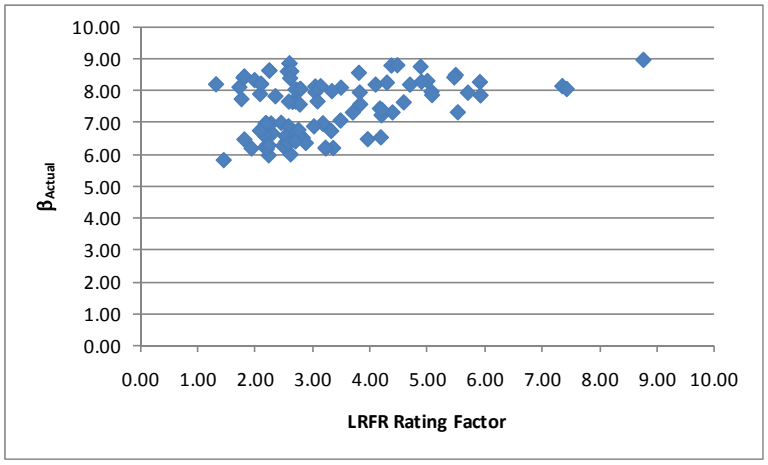


Figure D-321: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

D.3.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-322. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

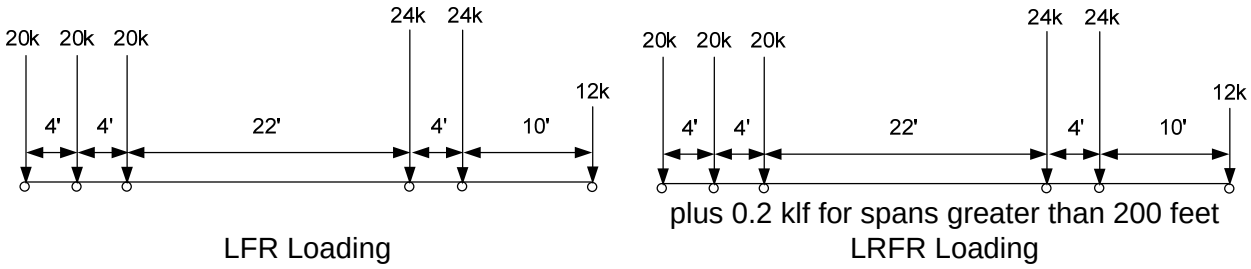


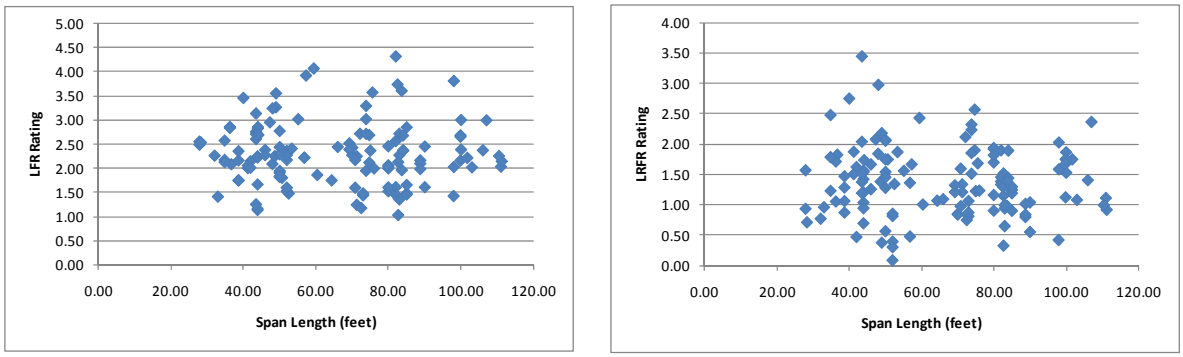
Figure D-322: Vehicle Loadings and Load Factors

D.3.5.1 Moment

The following section contains the results for interior, composite prestressed box girders within simple span bridges for the IL-01 Vehicle.

D.3.5.1.1 Rating Factors

Figure D-323 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 35 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 97% of the girders in this subset. The LFR ratings are between 1.5 and 3.0 for most girders while the LRFR ratings are between 0.5 and 2.0 for most girders. Two of the 35 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.



(a) (b)

Figure D-323: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure D-324 shows the percentage of girders with moment ratings in each rating category for the IL-01 vehicle, treated as a special permit vehicle. 25% of girders have LRFR ratings less than 1.0 for a single, escorted permit vehicle. This increases to 29.5% for multiple trip permits with an ADTT of 5,000. The number of girders with ratings less than 1.0 does not increase significantly between the various LRFR permit types. Most girders with LRFR ratings less than 1.0 have ratings between 0.8 and 1.0. All girders have LFR ratings greater than 1.0.

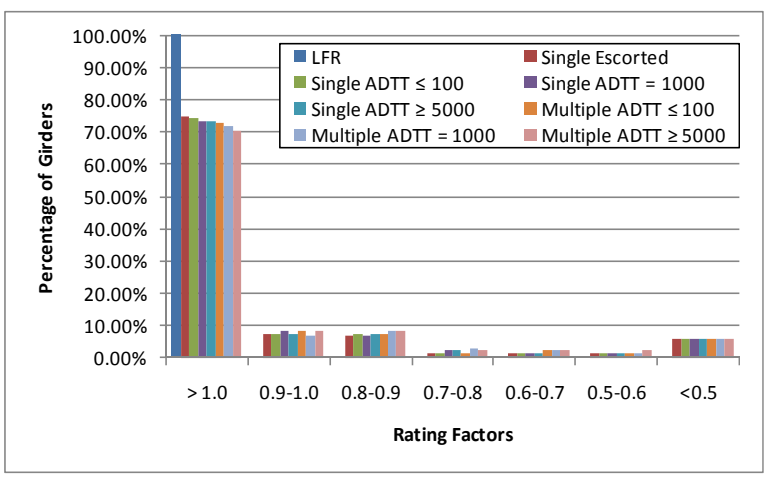


Figure D-324: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

D.3.5.1.2 Rating Factor Comparisons

Figure D-325 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.3 and 1.0. Four girders have an LRFR rating that is greater than the LFR rating.

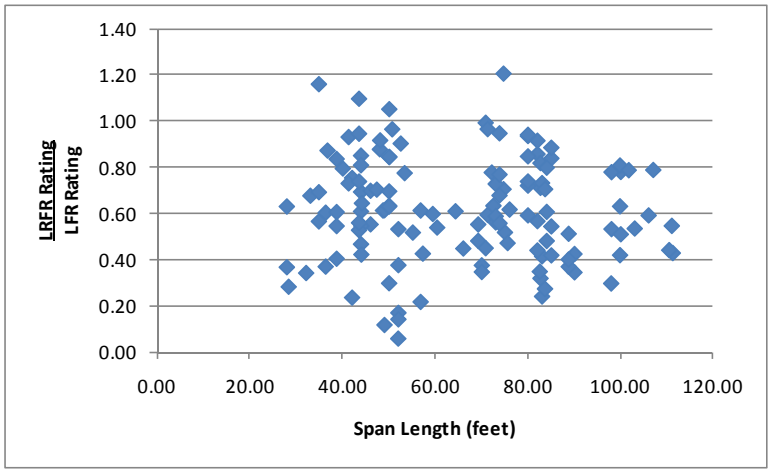


Figure D-325: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

D.3.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-326 shows that 29 girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index is varies between two and ten for the girders in this group.

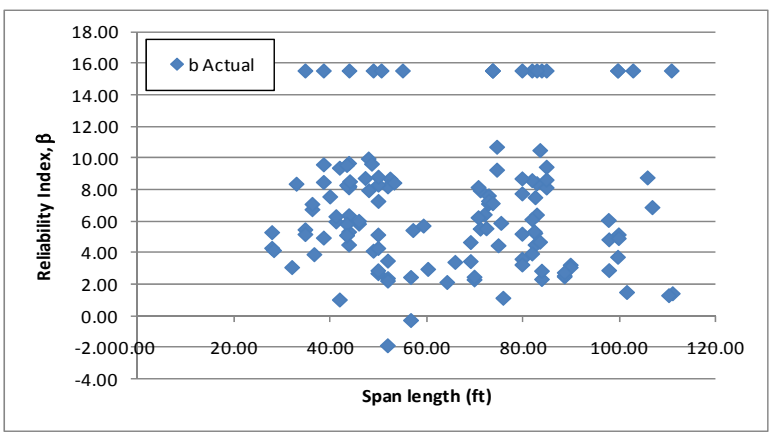


Figure D-326: Flexure Reliability Indices for IL-01 Vehicle

Figure D-327 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 Vehicle. The figure shows that the average reliability index for girders with a rating of one is near five, exceeding the target level of reliability of 3.5. This indicates that the live load factors in the MBE may be reduced and yet able to provide the target level of reliability.

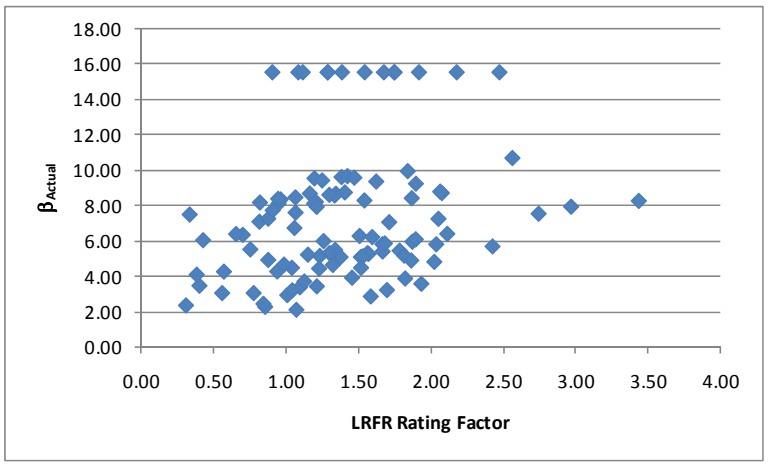
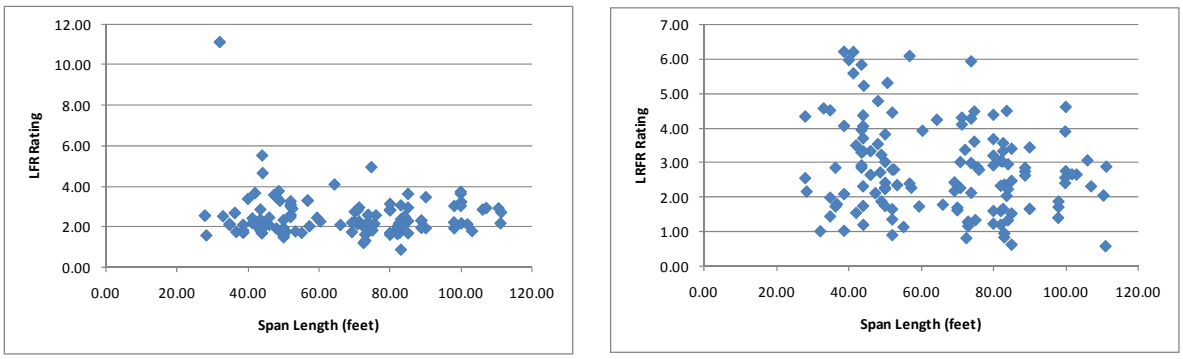


Figure D-327: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

D.3.5.2 Shear

D.3.5.2.1 Rating Factors

For shear, there is one girder that has an LFR rating factor less than 1.0, six girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 41% of the girders in this subset. Figure D-328 shows the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 3.0 for all span lengths, while the LRFR rating is between one and five for all span lengths.



(a) (b)

Figure D-328: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure D-329 shows the percentage of girders with shear ratings in each rating range for the IL-01 vehicle. The percentage of girders with LRFR ratings less than 1.0 varies from 1.5% for a single trip, escorted vehicle to 11.4% for a multi-trip permit vehicle and an ADTT of 5,000. Less than 1% of girders have an LFR rating less than 1.0; most girders are not significantly affected by the switch from LFR to LRFR.

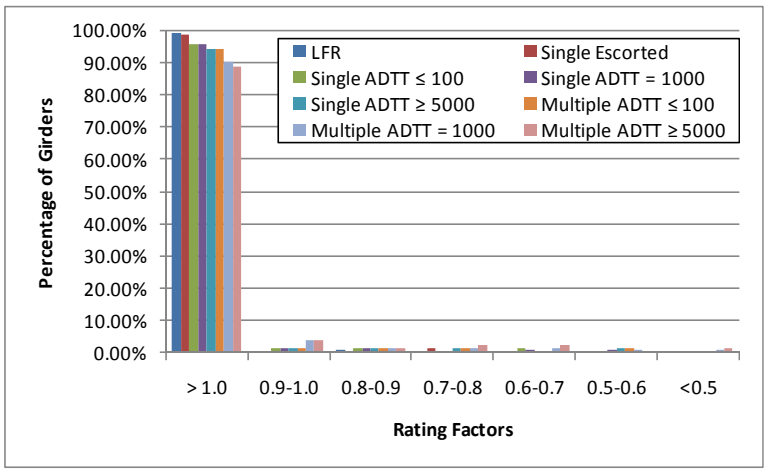


Figure D-329: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

D.3.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-330 shows the comparison of rating factors. The ratio is less than 1.0 about 40% of the time. Longer girders tend to have an LFR rating greater than the associated LRFR rating.

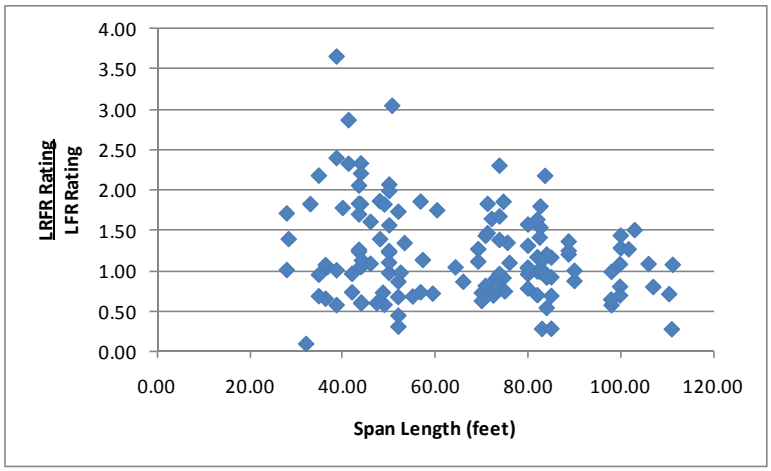


Figure D-330: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

D.3.5.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 3.5 for all but three girders as shown in Figure D-331. The reliability index tends to decrease slightly with increasing span length. The reliability index is greater than five for most girders.

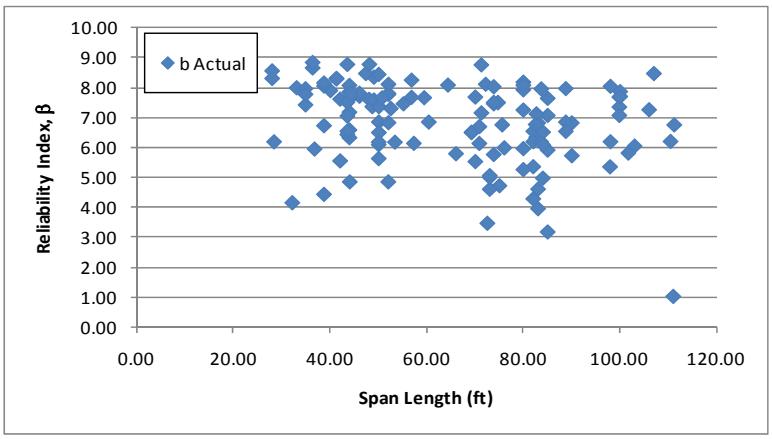


Figure D-331: Shear Reliability Indices for IL-01 Vehicle

Figure D-332 shows the shear reliability index plotted against the LRFR shear rating for the IL-01 vehicle. The figure shows that girders with a rating of one have a reliability index that is approximately four. This exceeds the target reliability of 3.5 for this vehicle. The reliability index exceeding the target indicates that the live load factors could be reduced such that the reliability index for a girder with a rating of 1.0 is nearer the target reliability.

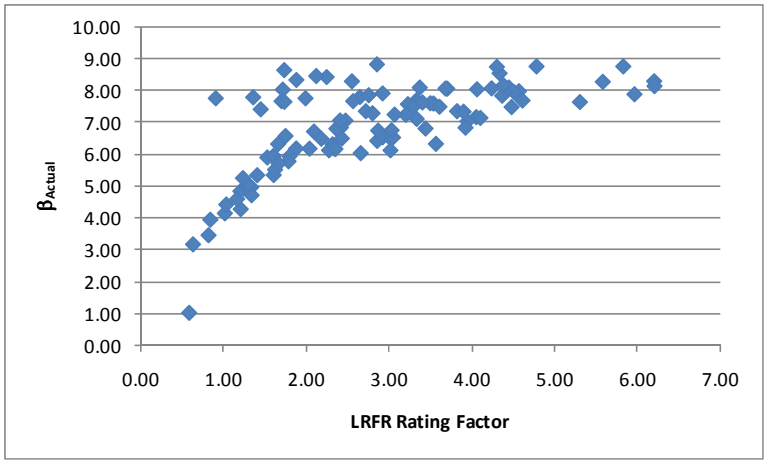


Figure D-332: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

D.3.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-333. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

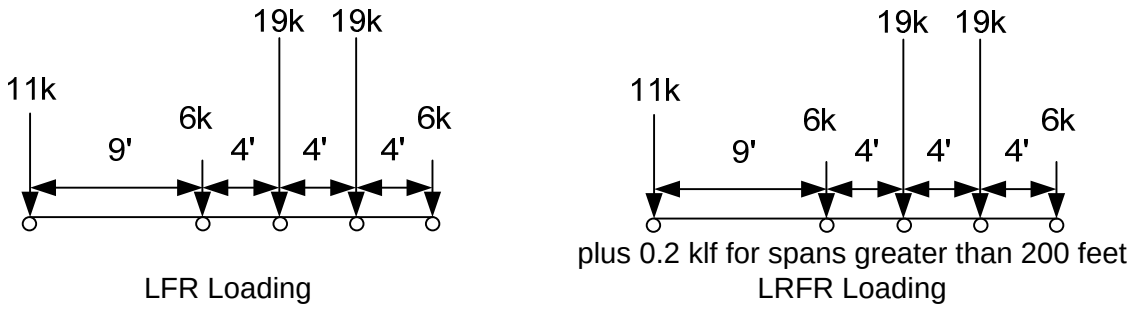


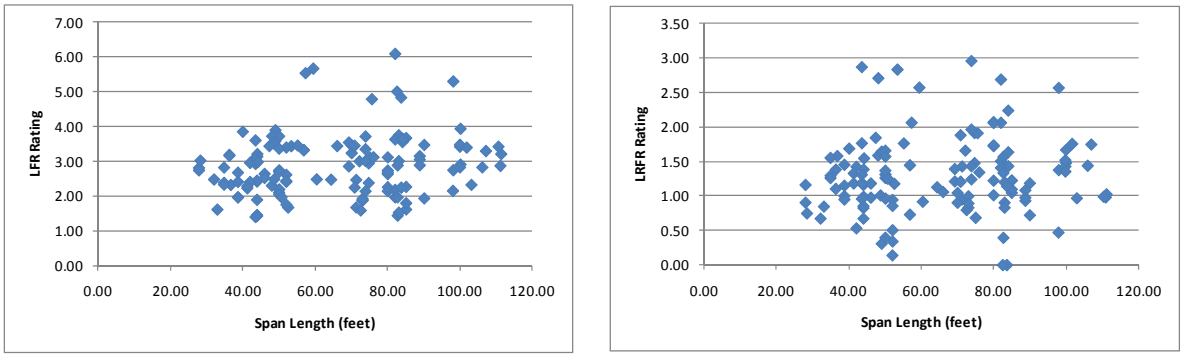
Figure D-333: Vehicle Loadings and Load Factors

D.3.6.1 Moment

The following section contains the results for interior, composite prestressed box girders within simple span bridges for the NC-21 Vehicle.

D.3.6.1.1 Rating Factors

Figure D-334 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 40 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating is between 1.5 and 4 for most girders while the LRFR rating is between 0.5 and 2 for most girders. Four of the forty girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.



(a) (b)

Figure D-334: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure D-335 shows the percentage of girders with moment ratings in each rating range for the NC-21 Vehicle. 30% of girders have LRFR ratings less than 1.0 for all LRFR ADTT values. A significant number of girders are affected by the switch from LFR to LRFR for all ADTT values. 100% of girders have LFR ratings that are greater than 1.0.

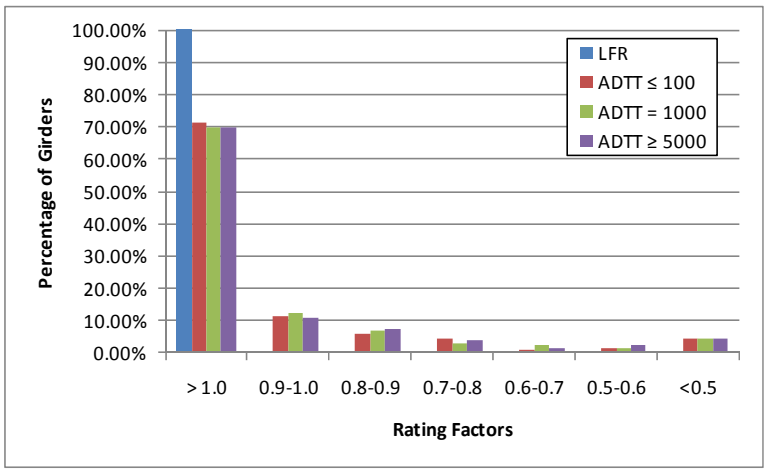


Figure D-335: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

D.3.6.1.2 Rating Factor Comparisons

Figure D-336 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.3 and 0.7 for this vehicle. There are no girders with this vehicle that have an LRFR rating greater than the LFR rating.

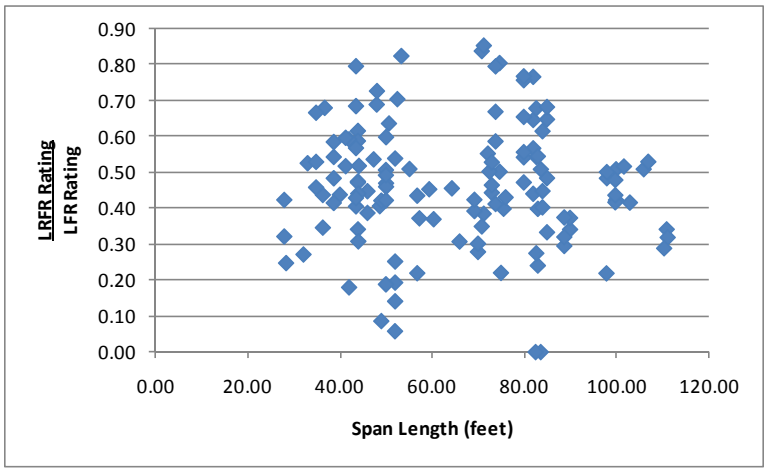


Figure D-336: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

D.3.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-337 shows that 15 girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between two and eight for most girders.

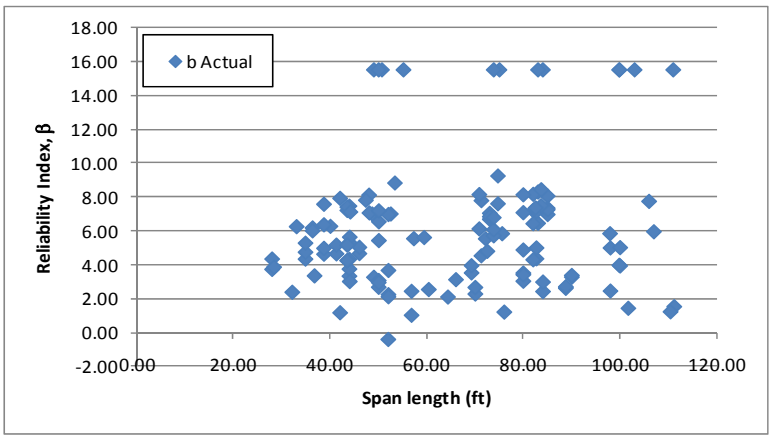


Figure D-337: Flexure Reliability Indices for NC-21 Vehicle

Figure D-338 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 vehicle. The figure shows that the average reliability index for a girder with a rating of 1.0 is approximately 5. This exceeds the target value of 2.5, indicating that lower load factors can be used and the target reliability will still be achieved.

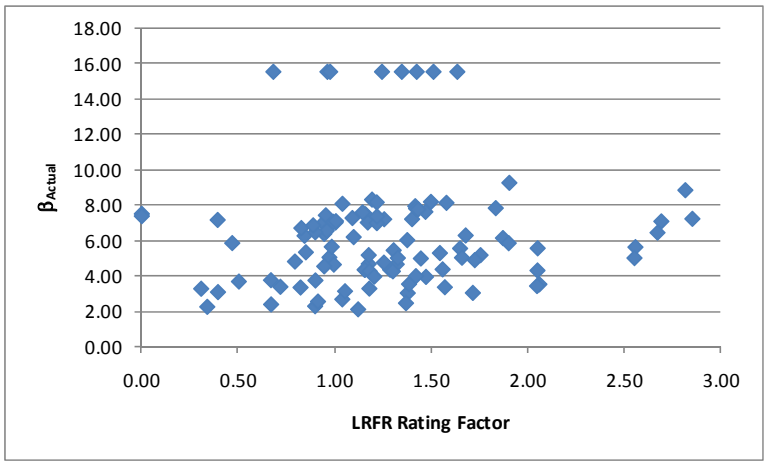
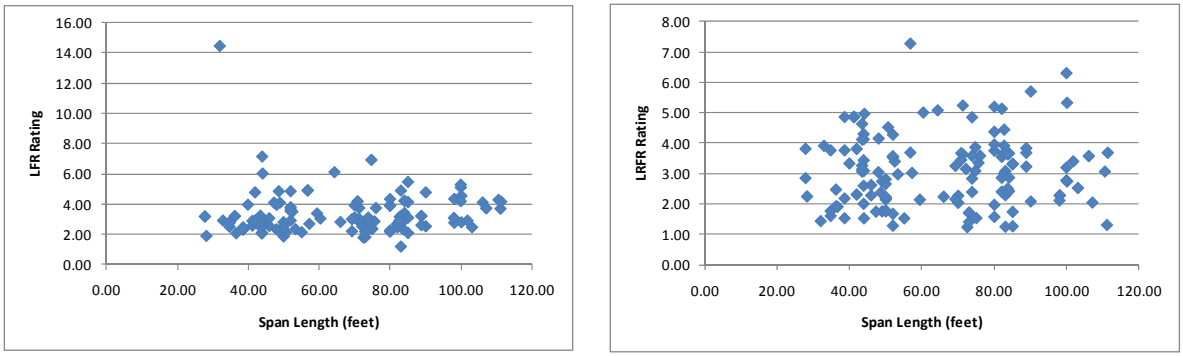


Figure D-338: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

D.3.6.2 Shear

D.3.6.2.1 Rating Factors

For shear, there are zero girders with a rating less than 1.0 for either LFR or LRFR. The LFR Rating is greater than the LRFR rating for 55% of the girders in this subset. Figure D-339 shows the LFR and LRFR ratings. The LFR rating is between two and four for most girders while the LRFR rating is between 1.5 and four for most girders.



(a) (b)

Figure D-339: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure D-340 shows the percentage of girders with shear ratings in each rating range for the NC-21 vehicle. All girders have ratings greater than 1.0 for LFR and all LRFR ADTT values. Shear ratings are not affected by the switch to LRFR from LFR.

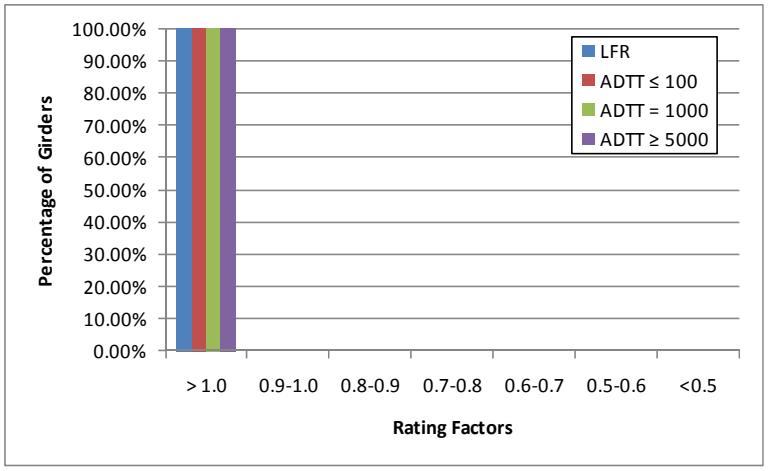


Figure D-340: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

D.3.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-341 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5. Shorter spans are more likely to have an LRFR rating greater than the LFR rating. 45% of girders have an LRFR rating that is greater than the LFR rating.

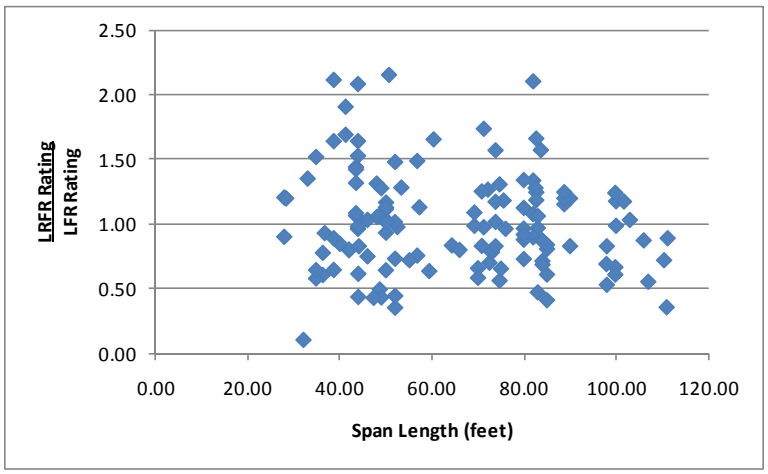


Figure D-341: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

D.3.6.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-342. The reliability index also decreases with increasing span length. The reliability index is between six and nine for most girders.

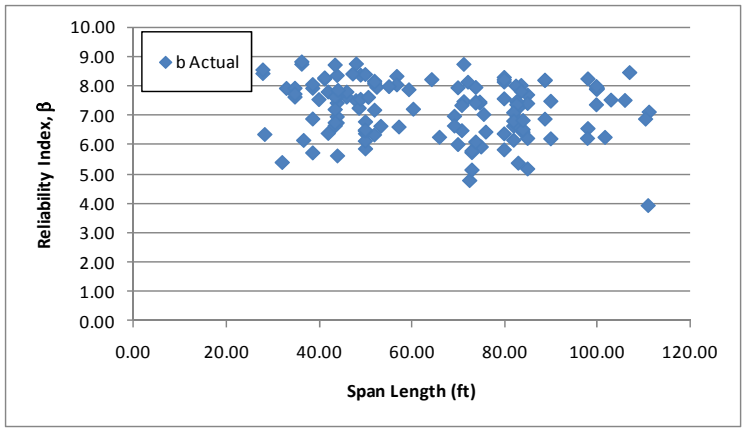


Figure D-342: Shear Reliability Indices for NC-21 Vehicle

Figure D-343 shows the reliability index for shear plotted against the LRFR rating factor for shear due to the NC-21 vehicle. The reliability index of a girder with a rating near one is near four which exceeds the target reliability of 2.5. This indicates that the live load factors in the MBE can be reduced and provide the target reliability.

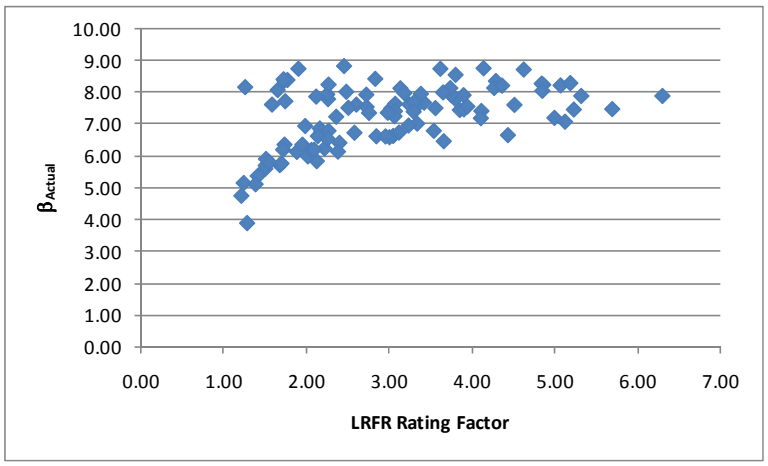


Figure D-343: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicles

D.3.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-344. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

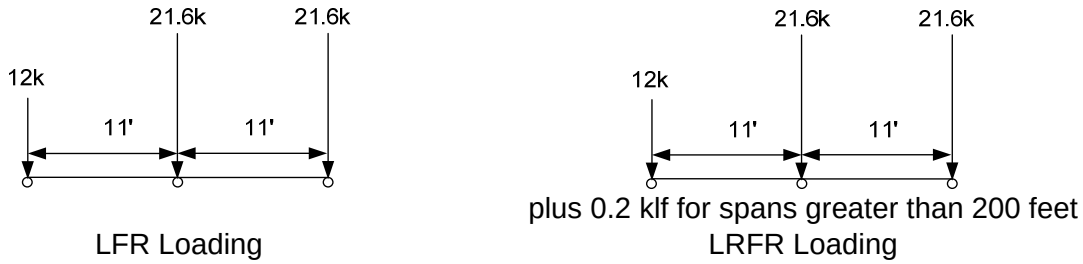


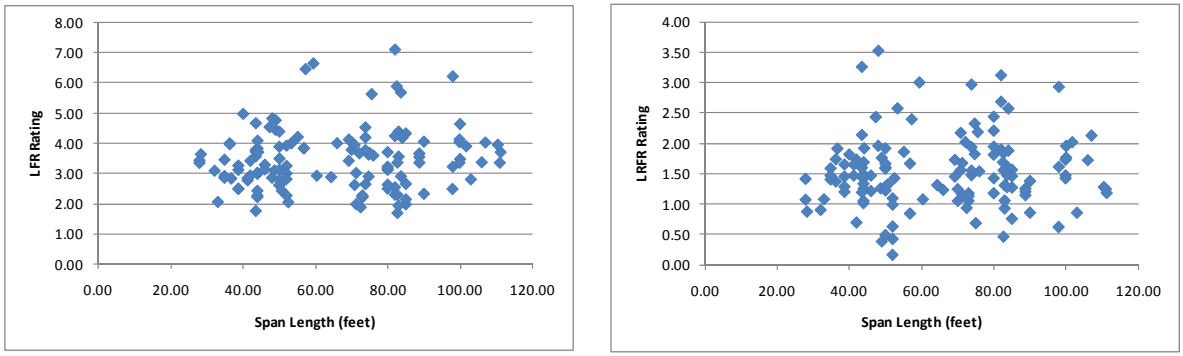
Figure D-344: Vehicle Loadings and Load Factors

D.3.7.1 Moment

The following section contains the results for interior, composite prestressed box girders within simple span bridges for the NM-04 Vehicle.

D.3.7.1.1 Rating Factors

Figure D-345 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 18 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is between two and five for most girders while the LRFR rating is between 0.5 and 2.5 for most girders. Four of the girders with LRFR ratings less than 1.0 were controlled by the longitudinal steel rating.



(a) (b)

Figure D-345: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure D-346 shows the percentage of girders with moment ratings in each rating category for the NM-04 Vehicle. Approximately 87% of girders have LRFR ratings less than 1.0 for all ADTT values. This indicates that 13% of girders are affected by switching from LFR to LRFR for moment. All girders have LFR ratings greater than 1.0.

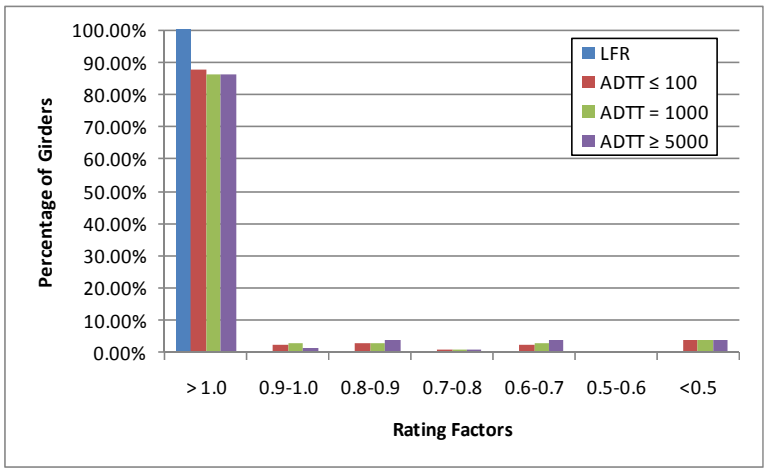


Figure D-346: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

D.3.7.1.2 Rating Factor Comparisons

Figure D-347 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating, which for this vehicle no girders have LRFR ratings greater than the LFR ratings. The ratio is generally between 0.3 and 0.7, with zero girders having LRFR ratings greater than the LFR rating.

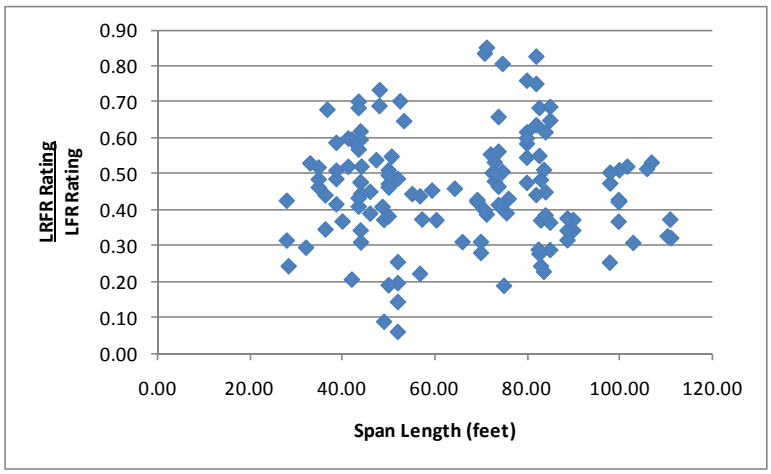


Figure D-347: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

D.3.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-348 shows that 10 girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between two and nine for most girders in this group.

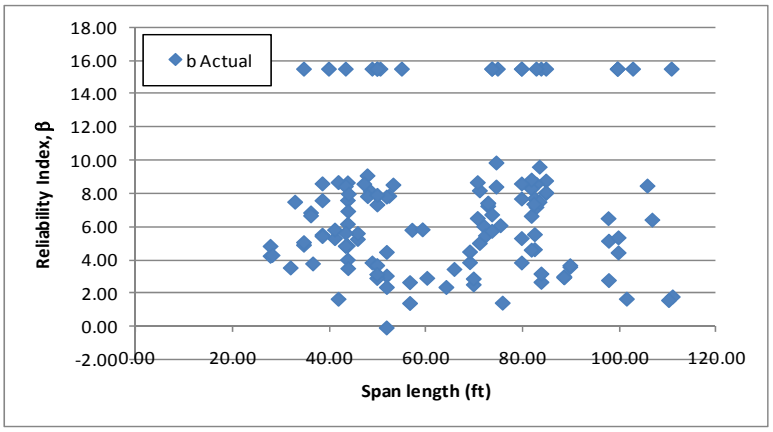


Figure D-348: Flexure Reliability Indices for NM-04 Vehicle

Figure D-349 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The figure shows that girders with a rating of 1.0 have reliability indices that vary from two to eight, providing an average of approximately 5. This exceeds the target reliability index of 2.5 and indicates the live load factors in the MBE may be overly conservative.

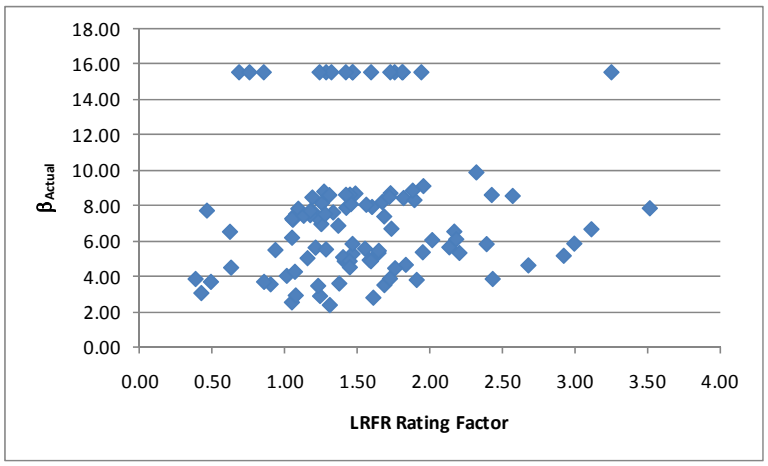
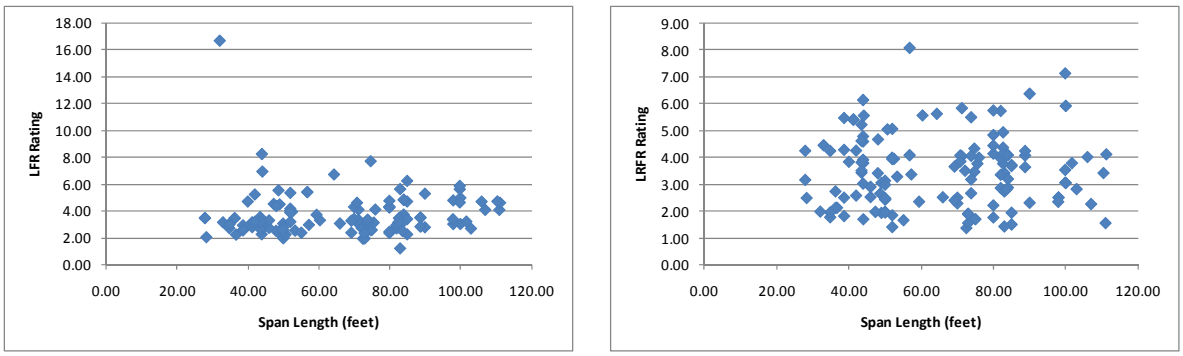


Figure D-349: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

D.3.7.2 Shear

D.3.7.2.1 Rating Factors

For shear, there are no girders that have ratings less than 1.0 for either LFR or LRFR method. The LFR Rating is greater than the LRFR rating for 51% of the girders in this subset. Figure D-350 shows the LFR and LRFR ratings. Both methods appear to result in slightly higher ratings for increasing span length. The LFR ratings are between two and five for most girders while the LRFR ratings are between two and six for most girders.



(a) (b)

Figure D-350: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure D-351 shows the percentage of girders with shear ratings in each rating range for the NM-04 vehicle. There are no girders that are affected by switching from LFR to LRFR for the shear rating of prestressed boxes with composite decks.

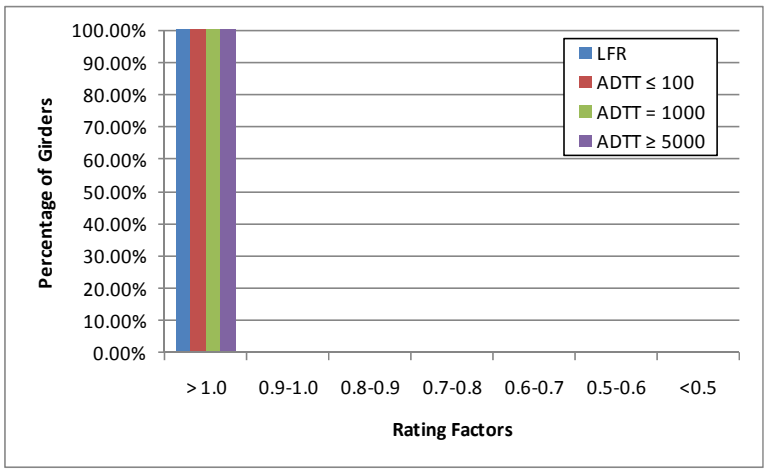


Figure D-351: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

D.3.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-352 show the comparison of rating factors. The ratio is generally between 0.5 and 2.0. Longer spans have less scatter in the data than shorter spans; 49% of the girders have LRFR ratings greater than the LFR Ratings for this vehicle.

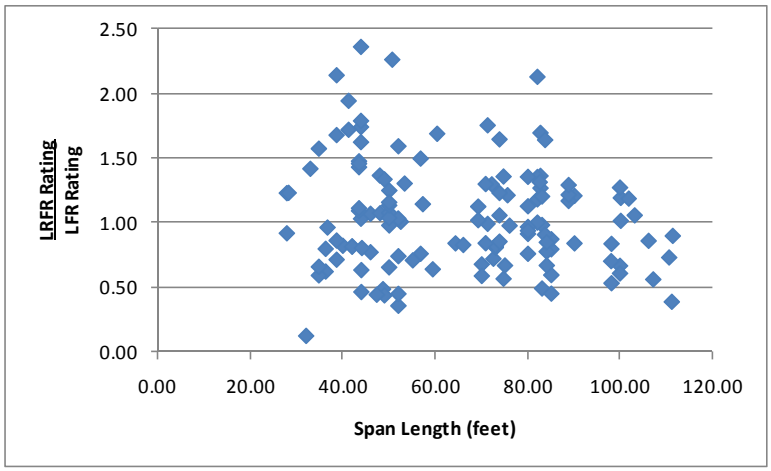


Figure D-352: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

D.3.7.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-353. The reliability index decreases with increasing span length and is between six and nine for most girders

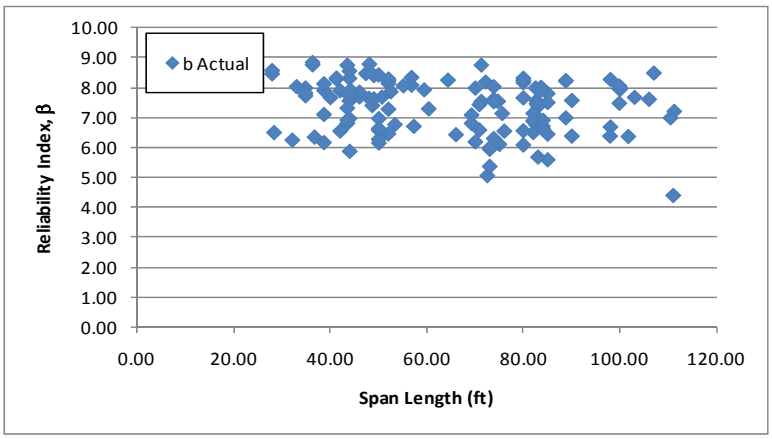


Figure D-353: Shear Reliability Indices for NM-04 Vehicle

Figure D-354 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. This figure shows that girders with ratings of one would have a reliability that would be near four, exceeding the target value of 2.5. This indicates that the live load factors in the MBE may be overly conservative.

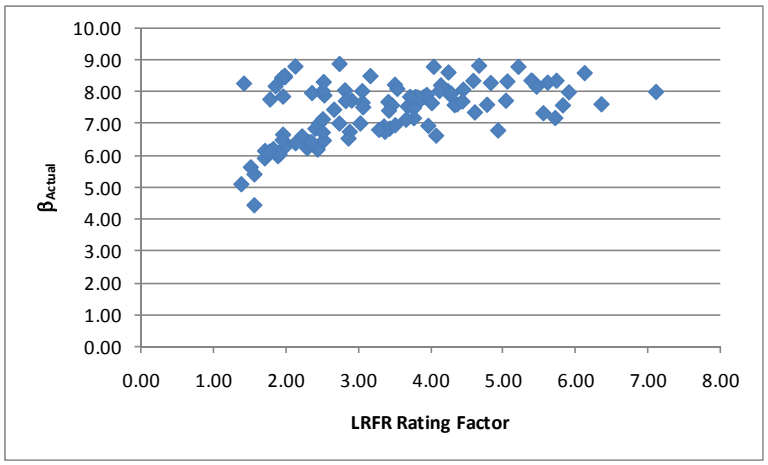
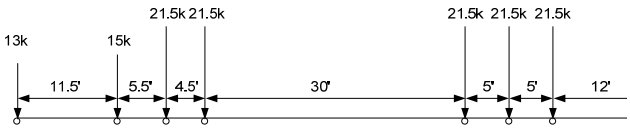


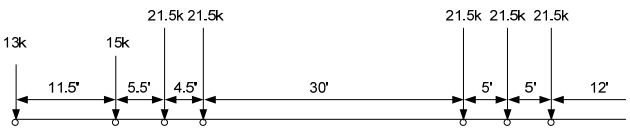
Figure D-354: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

D.3.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-355. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading



plus 0.2 klf for spans greater than 200 feet

LRFR Loading

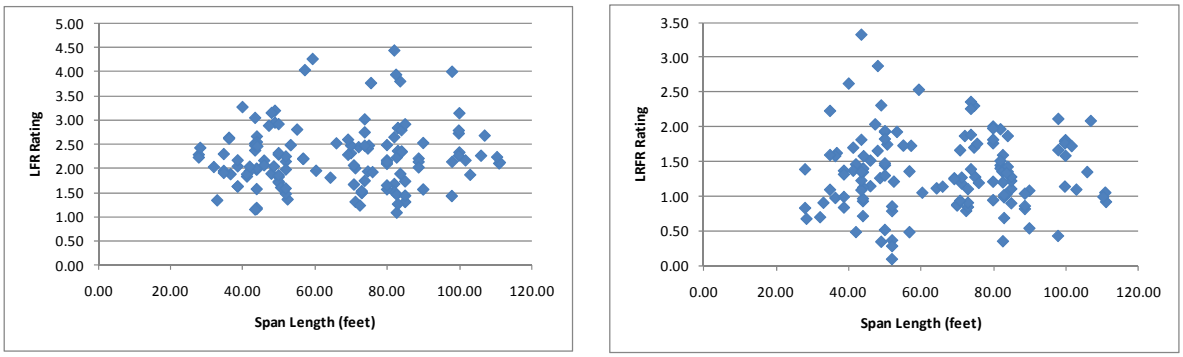
Figure D-355: Vehicle Loadings and Load Factors

D.3.8.1 Moment

The following section contains the results for interior, composite prestressed box girders within simple span bridges for the OR-06 Vehicle.

D.3.8.1.1 Rating Factors

Figure D-356 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 36 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. One of the thirty-six girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR permit rating for 95% of the girders in this subset. The LFR rating is between 1.5 and 3.0 for most girders while the LRFR rating is between 0.75 and 2.0 for most girders.



(a) (b)

Figure D-356: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure D-357 shows the percentage of girders with moment ratings in each rating range for the OR-06 vehicle, a special permit vehicle. Between 26.5 and 29.5% of girders have LRFR ratings less than 1.0. When treated as a single trip, escorted permit vehicle the fewest number of girders are affected while a multi-trip permit with an ADTT of 5,000 affects the most girders. A significant number of girders (over 25%) are affected by the switch from LFR to LRFR for the OR-06 Vehicle. All girders have LFR ratings greater than 1.0.

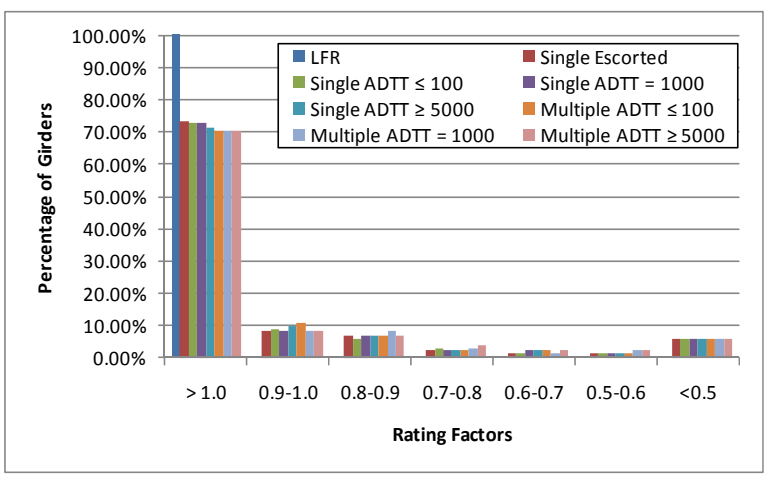


Figure D-357: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

D.3.8.1.2 Rating Factor Comparisons

Figure D-358 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.8. Six girders have LRFR ratings that exceed the LFR rating.

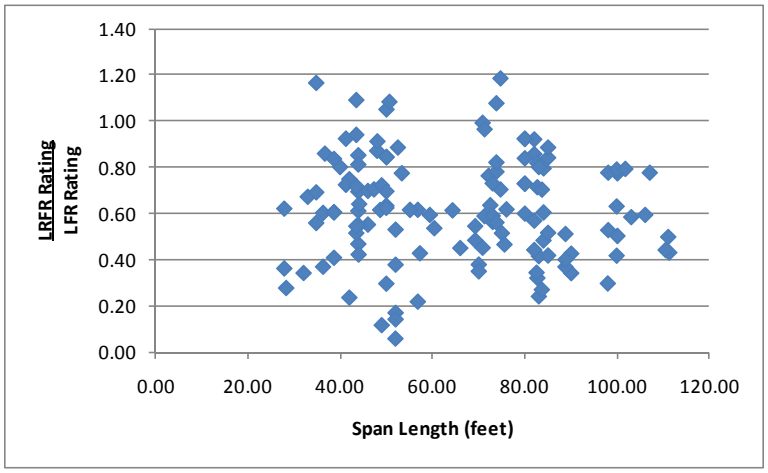


Figure D-358: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

D.3.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-359 shows that 31 girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index is between two and ten for most girders.

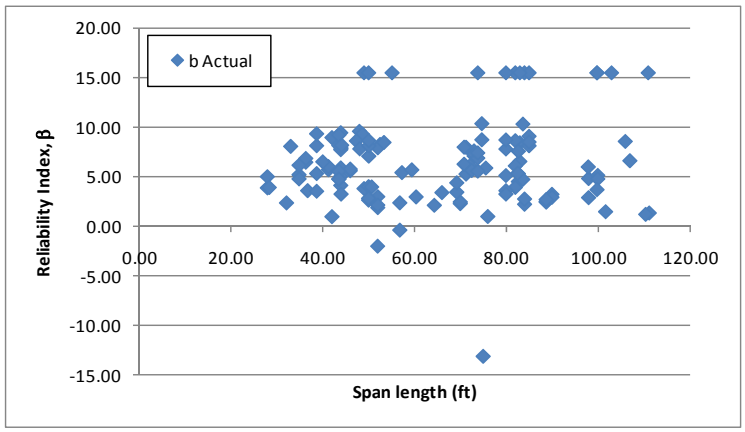


Figure D-359: Flexure Reliability Indices for OR-06 Vehicle

Figure D-360 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 vehicle. The figure shows that the average reliability index for a girder with a rating of 1.0 is approximately 5. This exceeds the target value of 3.5, indicating the live load factors in the MBE may be overly conservative.

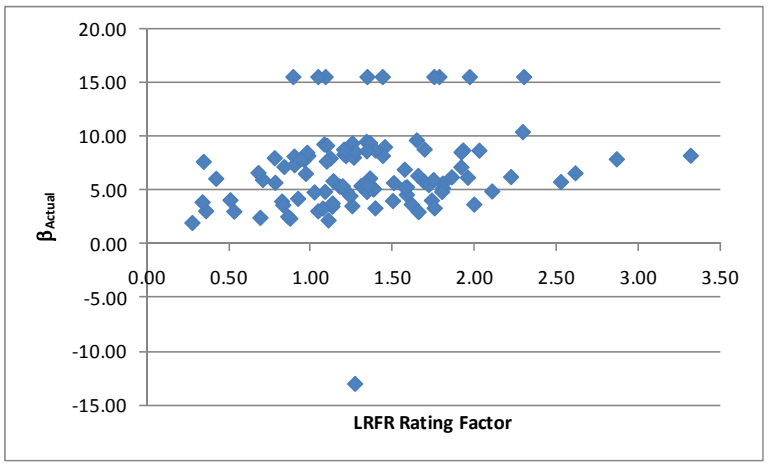
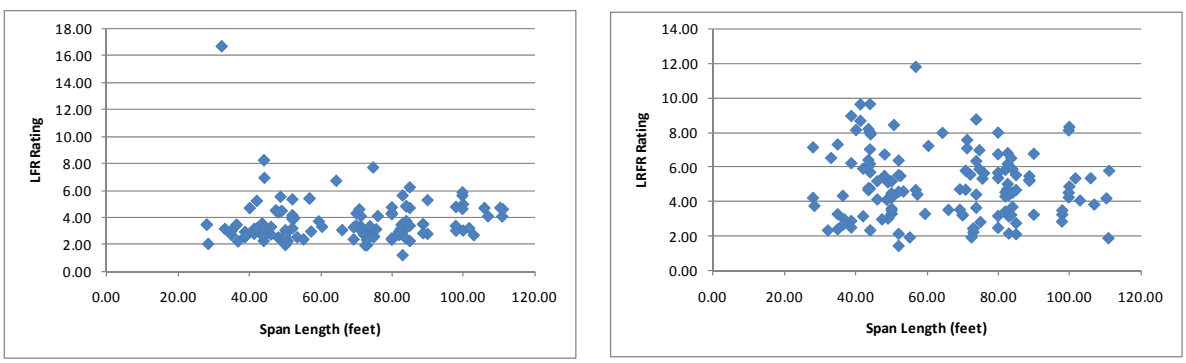


Figure D-360: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

D.3.8.2 Shear

D.3.8.2.1 Rating Factors

For shear, there are zero girders that have an LFR or LRFR rating factor less than 1.0. The LFR Rating is greater than the LRFR rating for 24% of the girders in this subset. Figure D-361 shows the LFR and LRFR ratings. The LFR ratings are between two and six for most girders while the LRFR ratings are between two and eight for most girders.



(a) (b)

Figure D-361: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure D-362 shows the percentage of girders with shear ratings less in each rating category for the OR-06 vehicle. The figure shows that all girders have ratings greater than 1.0 for all seven LRFR permit and ADTT combinations. All girders also have LFR ratings greater than 1.0.

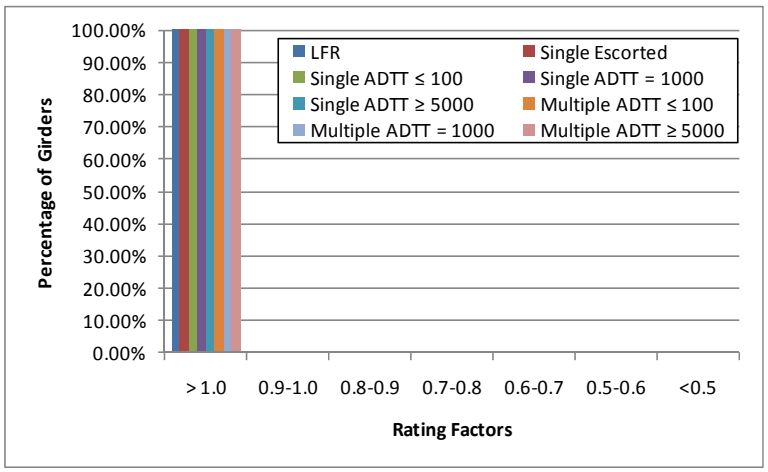


Figure D-362: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

D.3.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-363 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.5 for this set of girders with this vehicle. 76% of girders have LRFR rating that is greater than the LFR rating.

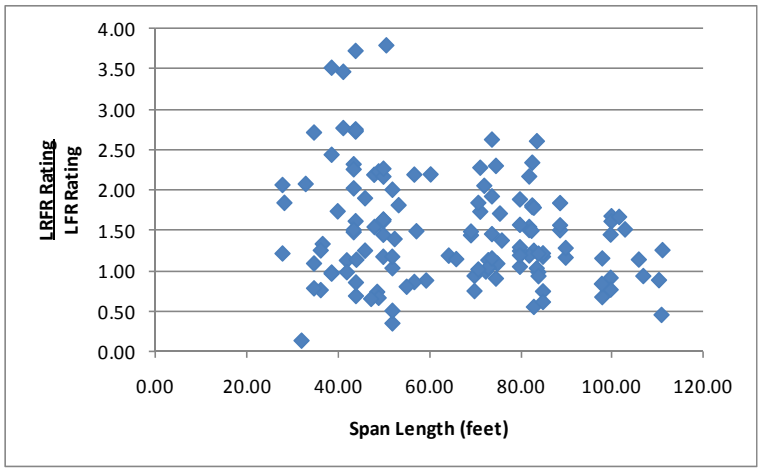


Figure D-363: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

D.3.8.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 3.5 for all girders as shown in Figure D-364. The reliability index decreases with increasing span lengths and is between six and nine for most girders.

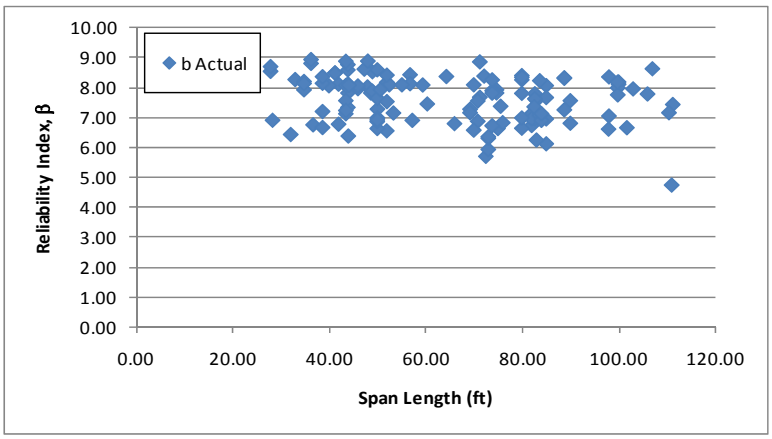


Figure D-364: Shear Reliability Indices for OR-06 Vehicle

Figure D-365 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The figure shows that girders with ratings above 1.0 have reliability indices of approximately 4.5 which exceed the target value of 3.5. This indicates that the live load factors in the MBE may be overly conservative.

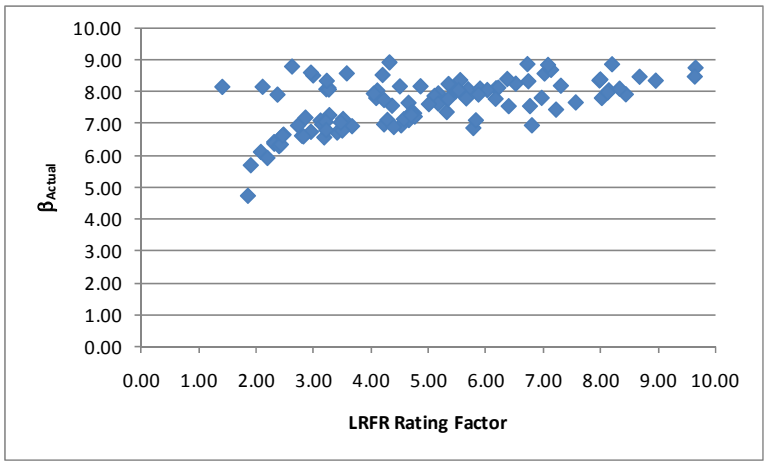


Figure D-365: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

D.3.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-366. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

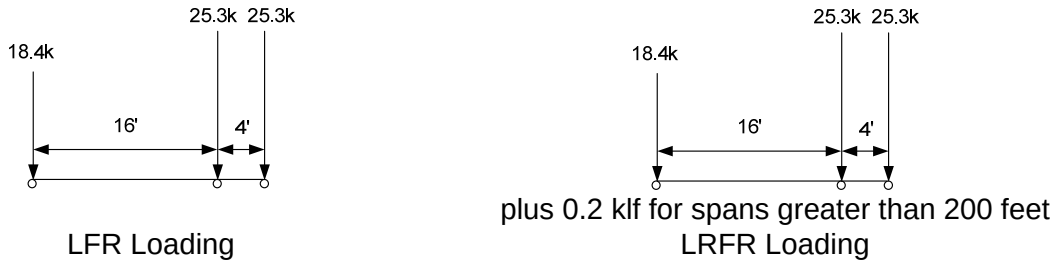


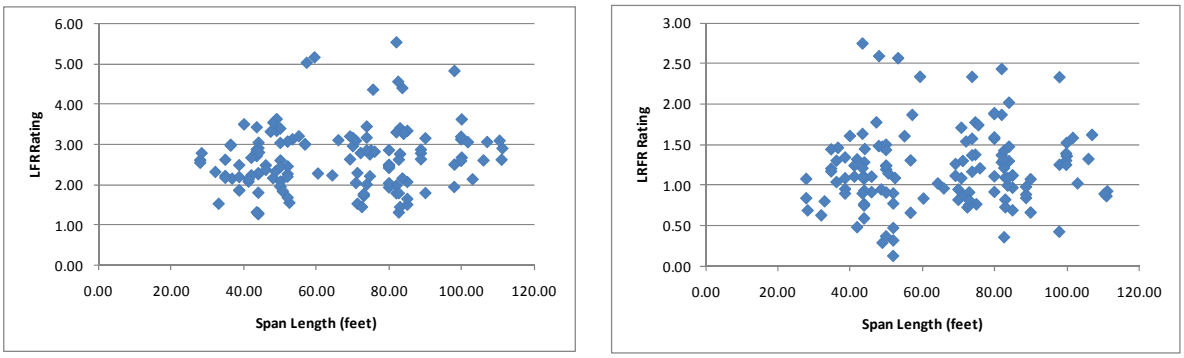
Figure D-366: Vehicle Loadings and Load Factors

D.3.9.1 Moment

The following section contains the results for interior, composite prestressed box girders within simple span bridges for the TX-04 Vehicle.

D.3.9.1.1 Rating Factors

Figure D-367 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 48 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating is between 1.5 and 3.0 for most girders while the LRFR rating is between 0.5 and 1.5 for most girders. Three of the 48 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.



(a) (b)

Figure D-367: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure D-368 shows the percentage of girders with moment ratings in each rating range for the TX-04 vehicle. Approximately 37% of girders have LRFR ratings less than 1.0 for all ADTT values. This is a significant number of girders that are affected by the switch from LFR to LRFR. Approximately half of these girders have ratings between 0.8 and 1.0. All girders have LFR ratings greater than 1.0 for moment.

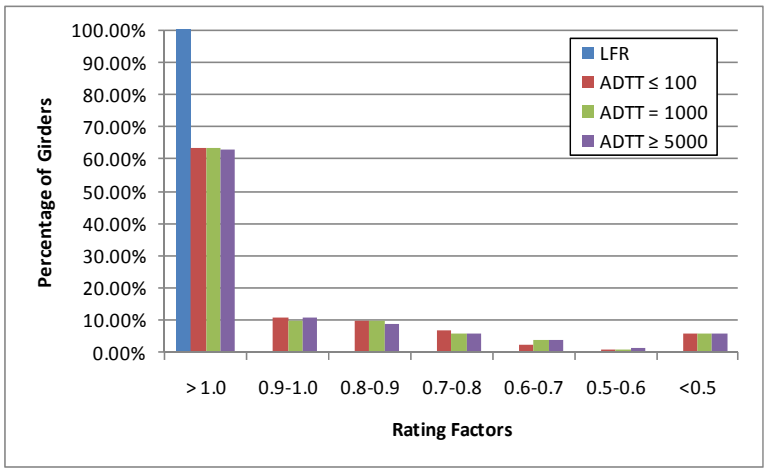


Figure D-368: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

D.3.9.1.2 Rating Factor Comparisons

Figure D-369 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio tends to decrease with an increase in span length; the LRFR rating is generally 30 to 70% of the LFR rating. No girders have an LRFR rating that is greater than the LFR rating for this vehicle.

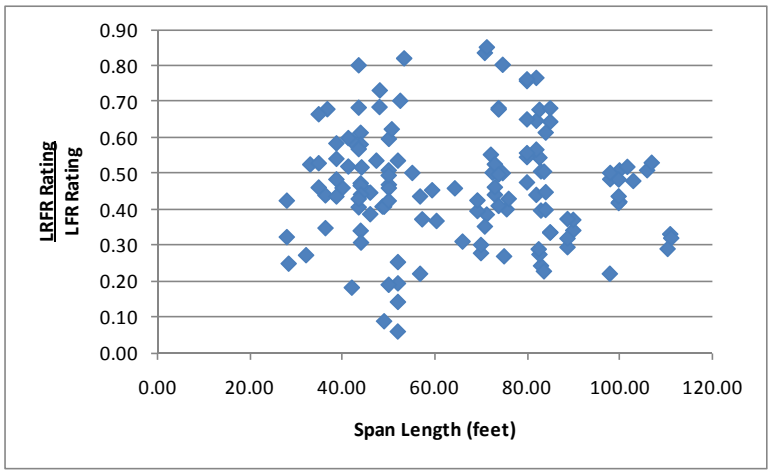


Figure D-369: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

D.3.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-370 shows 19 girders that have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between two and eight for most girders in this group.

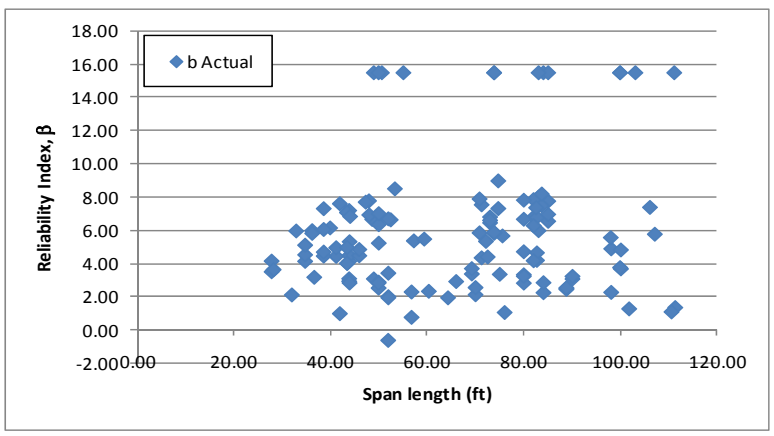


Figure D-370: Flexure Reliability Indices for TX-04 Vehicle

Figure D-371 shows the reliability index for moment plotted against the LRFR moment rating factor for the TX-04 vehicle. The figure shows that girders with a rating of 1.0 have reliability indices that vary from 2 to 8 providing an average reliability index of approximately 5, exceeding the target reliability of 2.5. This indicates that the LRFR live load factors may be overly conservative as currently used.

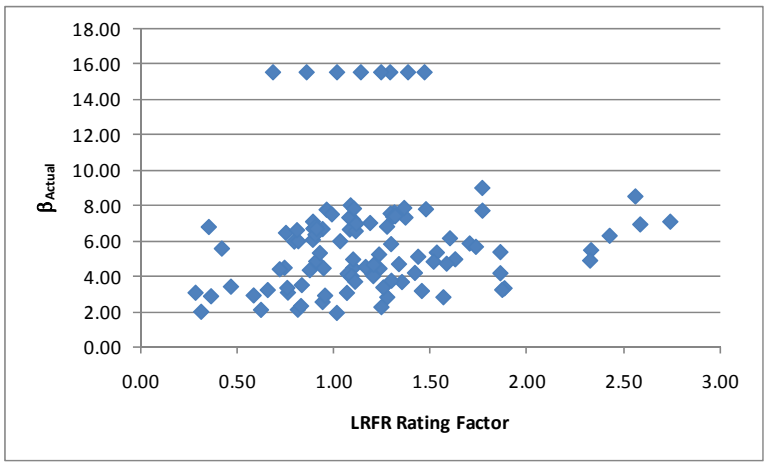
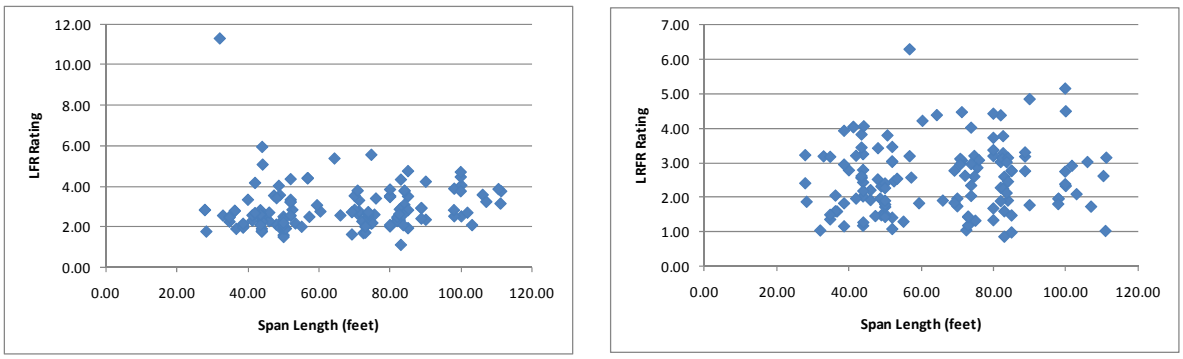


Figure D-371: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

D.3.9.2 Shear

D.3.9.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, two girders with LRFR ratings less than 1.0 and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 61% of the girders in this subset. Figure D-372 shows the LFR and LRFR ratings. The LFR rating is between two and four for most girders while the LRFR rating is between one and four for most girders.



(a) (b)

Figure D-372: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure D-373 shows the percentage of girders with shear ratings in each rating range for the TX-04 vehicle. The figure shows that less than 5% of girders are affected by the switch from LFR to LRFR for the worst LRFR category with an ADTT of 5,000. Less than 1% of girders have LRFR ratings less than 1.0 for an ADTT of 100, and less than 2% for an ADTT of 1,000. Very few girders are affected by the switch from LFR to LRFR; all girders have LFR ratings greater than 1.0.

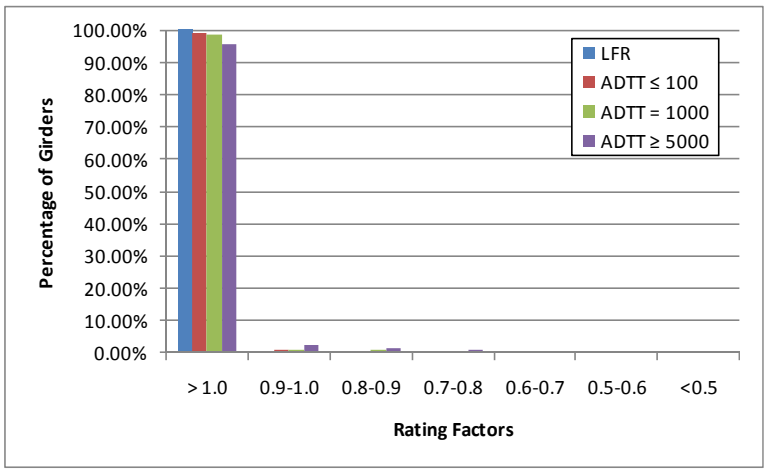


Figure D-373: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

D.3.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-374 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5 for shear with less scatter in the data for longer spans. The LRFR rating is greater that the LFR rating for 39% of the girders in this group.

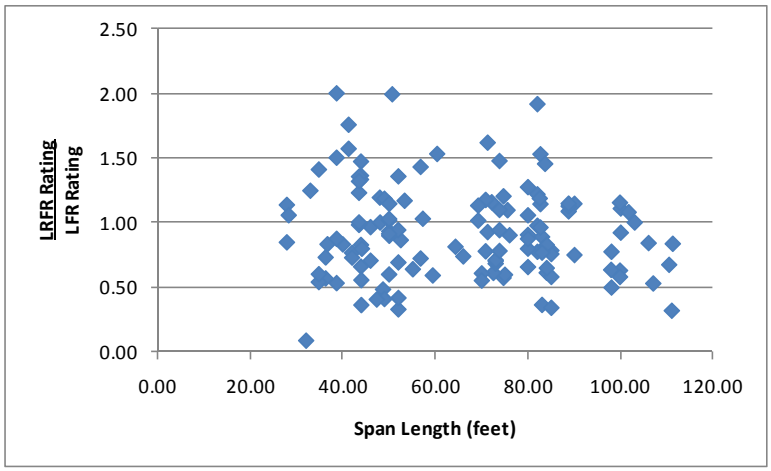


Figure D-374: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

D.3.9.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure D-375. The actual reliability index decreases with increasing span lengths and is between five and nine for most girders.

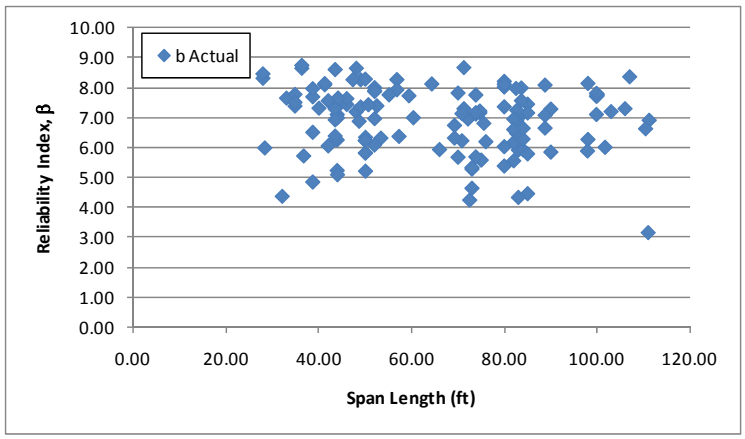


Figure D-375: Shear Reliability Indices for TX-04 Vehicle

Figure D-376 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The figure shows that girders with a rating of 1.0 have a reliability index between 3 and 4.5, this exceeds the target reliability of 2.5. This indicates that the live load factors in the MBE may be overly conservative.

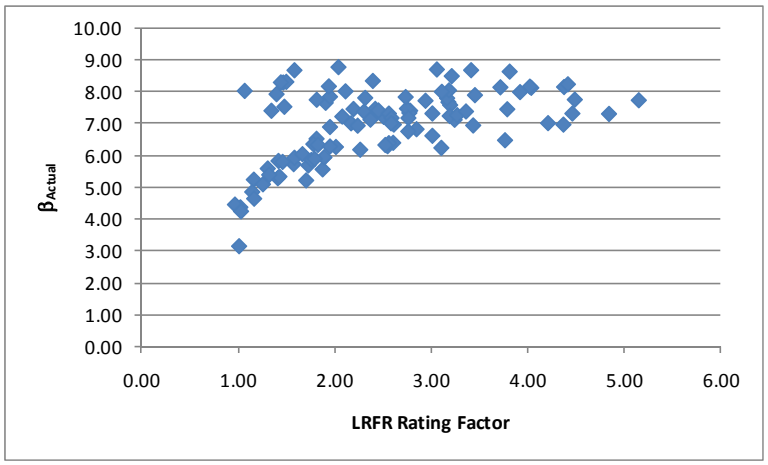
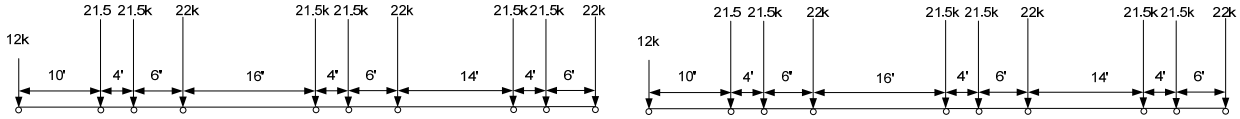


Figure D-376: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

D.3.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-377. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

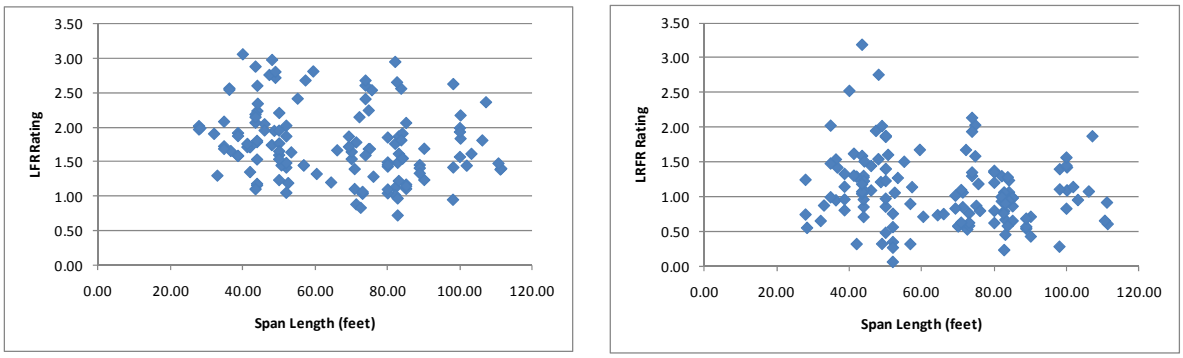
Figure D-377: Vehicle Loadings and Load Factors

D.3.10.1 Moment

The following section contains the results for interior, composite prestressed box girders within simple span bridges for the WA-02 Vehicle.

D.3.10.1.1 Rating Factors

Figure D-378 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are five girders with an LFR rating less than 1.0, 65 girders with an LRFR rating less than 1.0, and five girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 96% of the girders in this subset. The LFR ratings are typically between 1 and 2.5 while the LRFR ratings are typically between 0.5 and 1.5. Three of sixty five girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.



(a) (b)

Figure D-378: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure D-379 shows the percentage of girders with moment ratings in each rating range for the WA-02 vehicle. The figure shows approximately 50% of girders have ratings less than 1.0 for LRFR, independent of permit type and ADTT. This is a significant portion of the girders affected by switching from LFR to LRFR. 96% of girders have LFR ratings greater than 1.0 for moment.

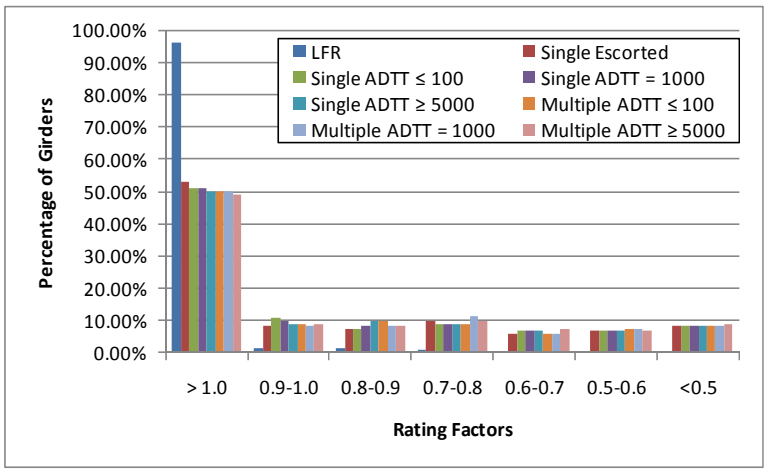


Figure D-379: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

D.3.10.1.2 Rating Factor Comparisons

Figure D-380 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.9. 4% of girders have LRFR ratings that exceed the LFR rating.

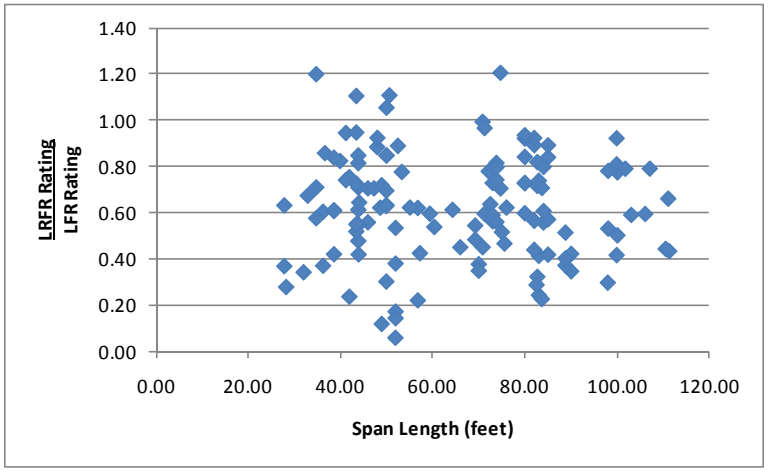


Figure D-380: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

D.3.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-381 shows that 37 girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index for most girders is between two and ten.

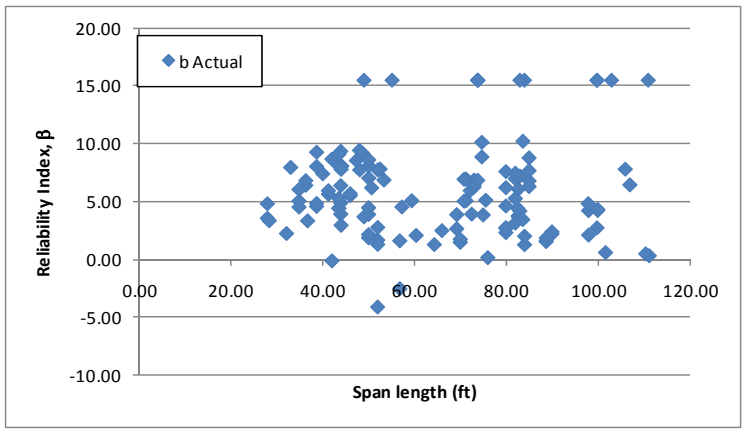


Figure D-381: Flexure Reliability Indices for WA-02 Vehicle

Figure D-382 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 vehicle. The figure shows that the average reliability index for girders with ratings near 1.0 is near six, exceeding the target value of 3.5. This indicates that the LRFR live load factors may be overly conservative.

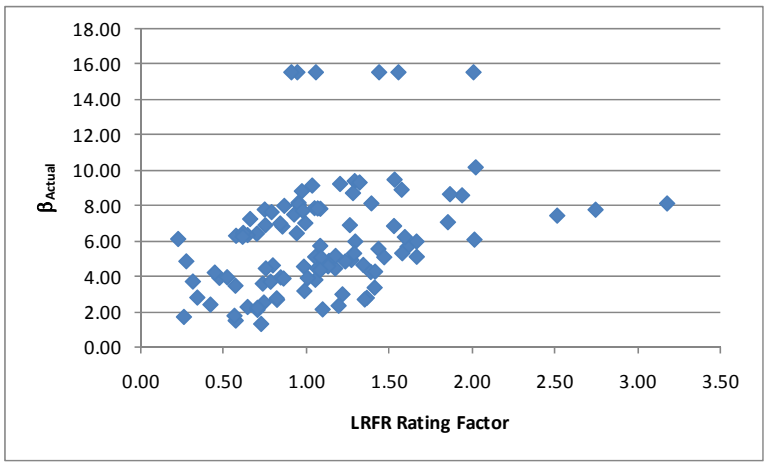
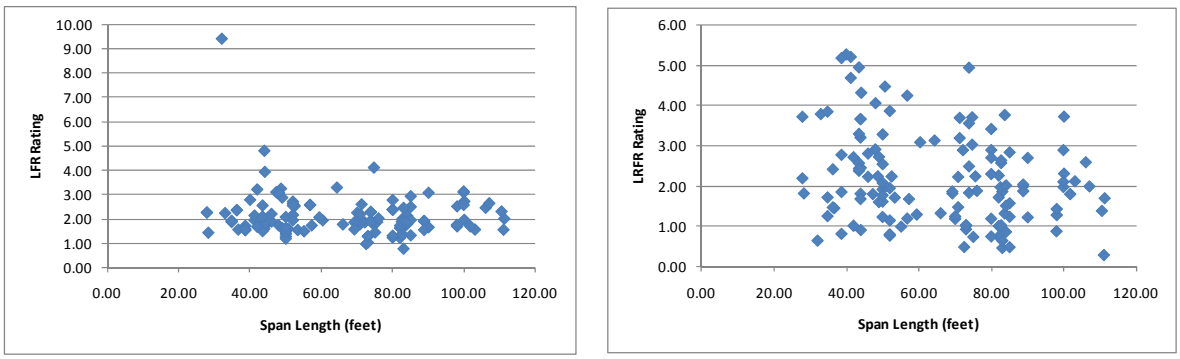


Figure D-382: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

D.3.10.2 Shear

D.3.10.2.1 Rating Factors

For shear, there are two girders with LFR rating less than 1.0, 17 girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 52% of the girders in this subset. Figure D-383 shows the LFR and LRFR ratings. The LFR ratings are between one and three for most girders while the LRFR ratings are between one and four.



(a) (b)

Figure D-383: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure D-384 shows the percentage of girders with shear ratings in each rating range for the WA-02 vehicle. The percentage of girders with ratings greater than 1.0 varies from 74.2% to 90.9% for multi-trip, ADTT of 5,000 permits to single, escorted permits. A significant number of girders are affected for the multi-trip permit with an ADTT of 5,000 while significantly fewer girders are affected when the truck is treated as a single trip, escorted permit. 98.5% of girders have LFR ratings greater than 1.0.

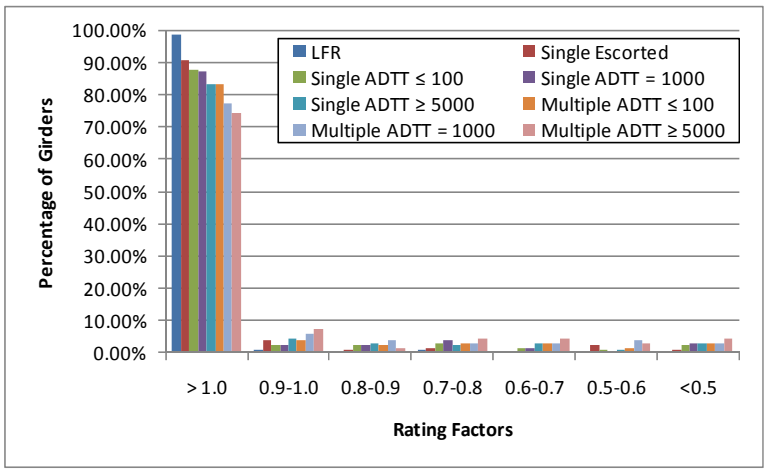


Figure D-384: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

D.3.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-385 show the comparison of rating factors. The ratio is generally between 0.5 and 2.0. Shorter spans typically have higher ratios of ratings than longer spans. 48% of girder have LRFR ratings that exceed the LFR rating.

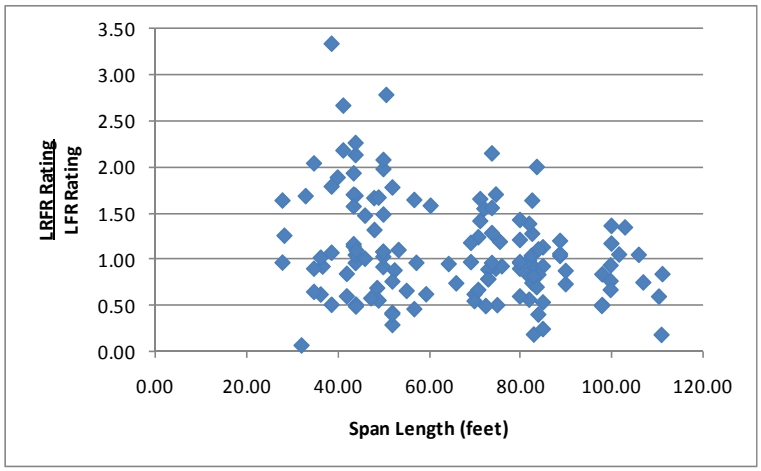


Figure D-385: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

D.3.10.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 3.5 for 15 girders as shown in Figure D-386. The reliability index generally decreases with increasing span lengths and is between five and eight for most girders.

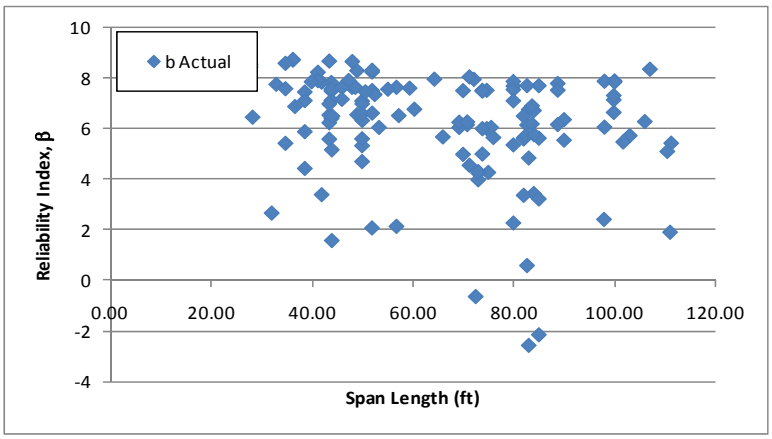


Figure D-386: Shear Reliability Indices for WA-02 Vehicle

Figure D-387 shows the reliability index for shear plotted against the LRFR rating for moment due to the WA-02 vehicle. The figure shows that girders with ratings near one have reliability indices of approximately four. This exceeds the target reliability of 3.5 indicating that the current load factors may be slightly over-conservative.

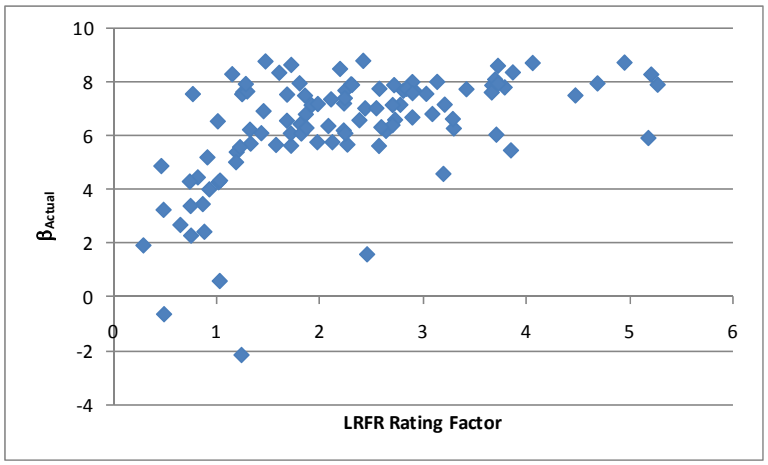


Figure D-387: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

D.3.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-388. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

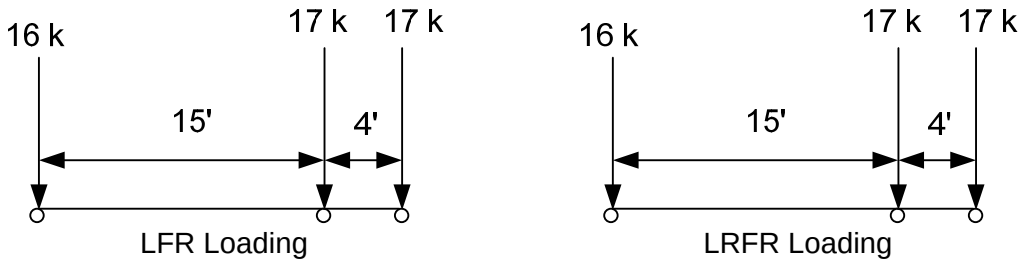
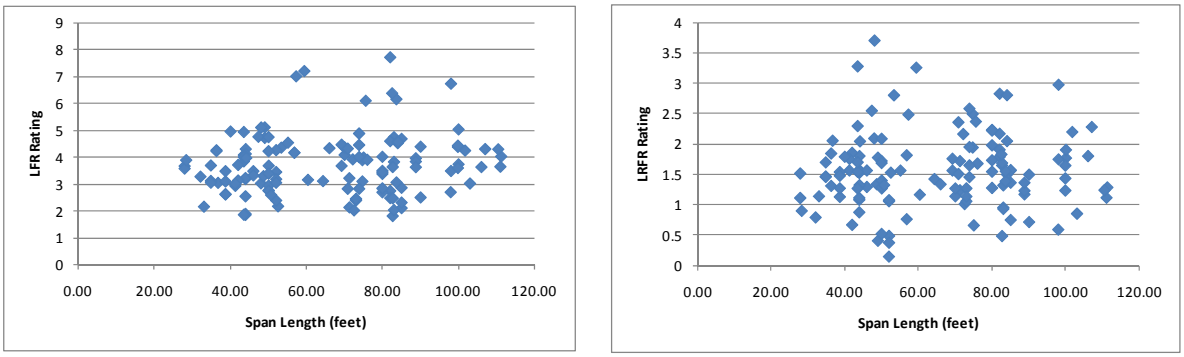


Figure D-388: Vehicle Loadings and Load Factors

D.3.11.1 Moment

D.3.11.1.1 Rating Factors

Figure D-389 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 18 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. Four of the eighteen girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR rating is between two and five for most girders while the LRFR rating is between 0.5 and 2.5.



(a) (b)

Figure D-389: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure D-390 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3 Truck. The LFR ratings are all greater than 1.0 while the LRFR ratings are greater than 1.0 for 87% of the girders. The number of girders affected by the switch from LFR to LRFR is not extremely significant but approximately one-quarter of those with LRFR ratings less than 1.0 have ratings less than 0.5.

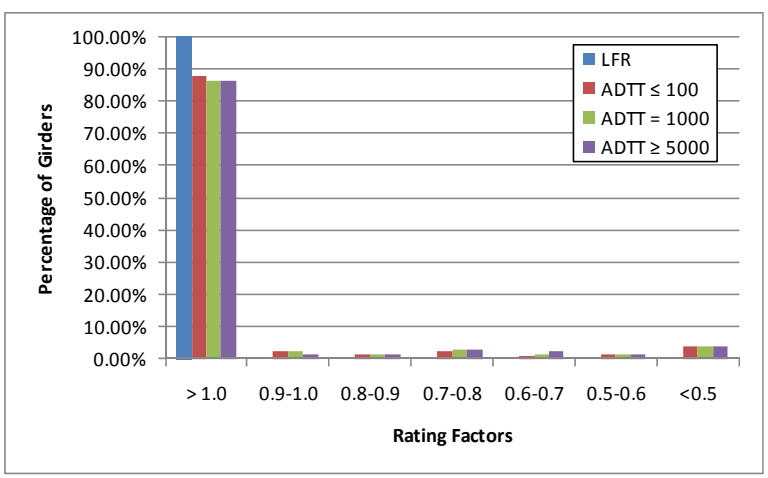


Figure D-390: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

D.3.11.1.2 Rating Factor Comparisons

Figure D-391 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6; no girders have an LRFR rating that exceeds the LFR rating.

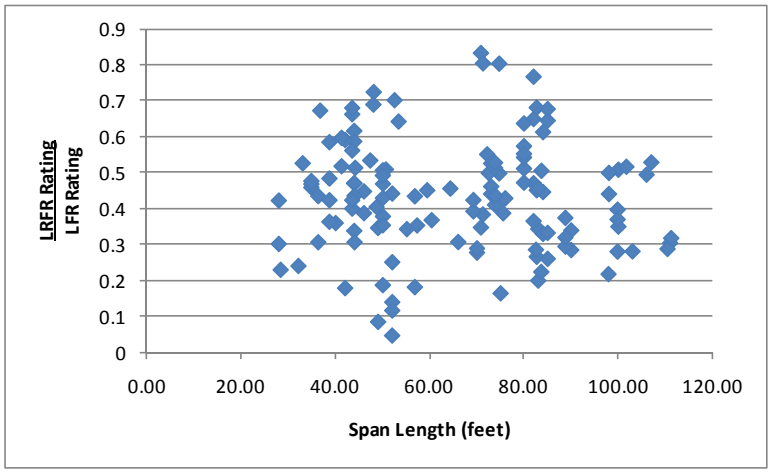


Figure D-391: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

D.3.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-392 shows that nine girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index varies between two and ten for most girders.

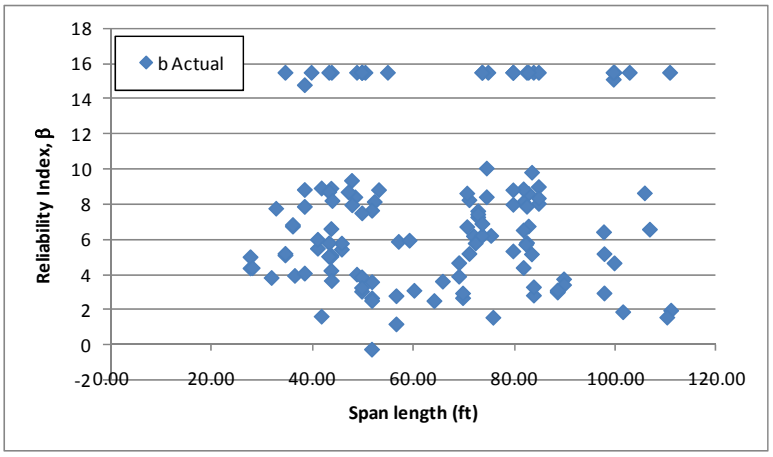


Figure D-392: Flexure Reliability Indices for Type 3 Vehicle

Figure D-393 shows the flexure reliability index plotted against the LRFR moment rating for the AASHTO Type 3 truck. The figure shows that the reliability index corresponding to a girder with a rating of 1.0 is approximately four. This exceeds the target reliability of 2.5 and indicates that the live load factors in the MBE may be over conservative.

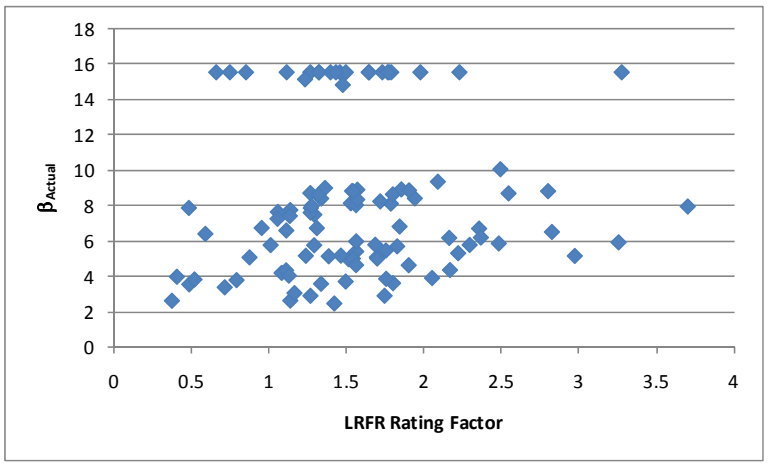
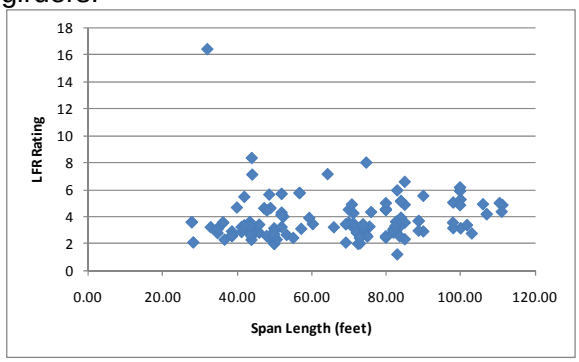


Figure D-393: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

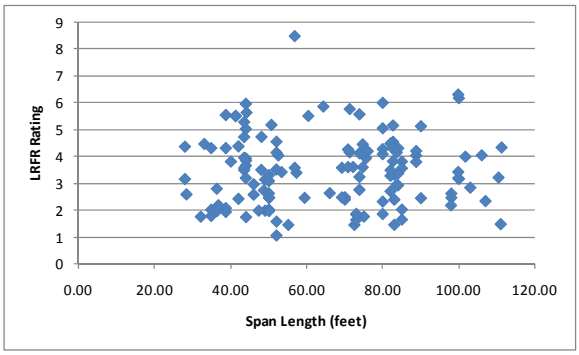
D.3.11.2 Shear

D.3.11.2.1 Rating Factors

For shear, there are zero girders for both LFR and LRFR that have ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 52% of the girders in this subset. Figure D-394 shows the LFR and LRFR ratings. LFR and LRFR ratings are between two and six for most girders.



(a)



(b)

Figure D-394: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure D-395 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3 Truck. All girders have ratings greater than 1.0 for LFR and for LRFR with ADTTs of 100 and 1,000. Less than 1% of girders have LRFR ratings less than 1.0 for an ADTT of 5,000. Most girders are not affected by the switch from LFR to LRFR.

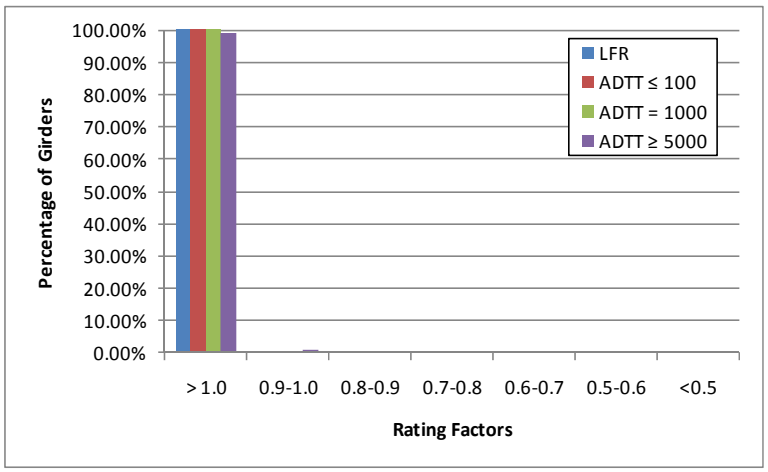


Figure D-395: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

D.3.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-396 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with shorter spans generally having higher ratios. 48% of girders have LRFR ratings that exceed the LFR rating.

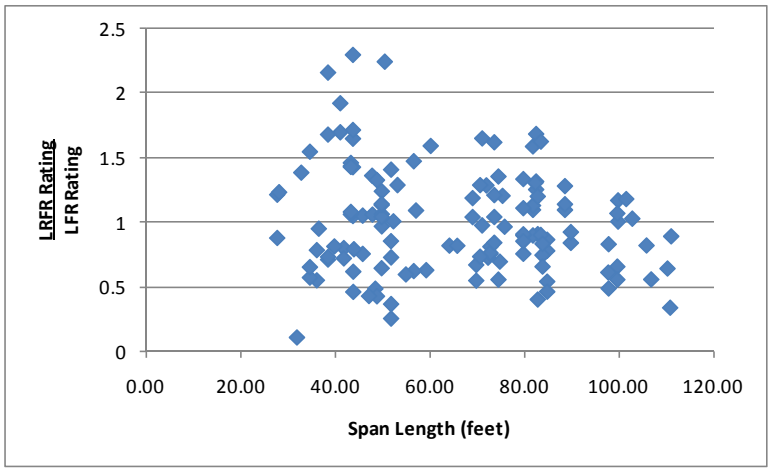


Figure D-396: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

D.3.11.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure D-397. The reliability index is between six and nine for most girders.

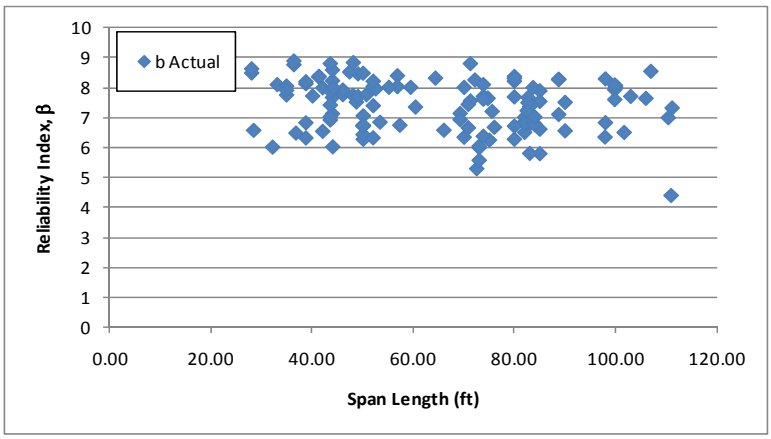


Figure D-397: Shear Reliability Indices for Type 3 Vehicle

Figure D-398 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 truck. The figure shows that the reliability index for a girder with a rating of 1.0 will exceed the target reliability index of 2.5. This indicates that the live load factors in the MBE may be overly conservative.

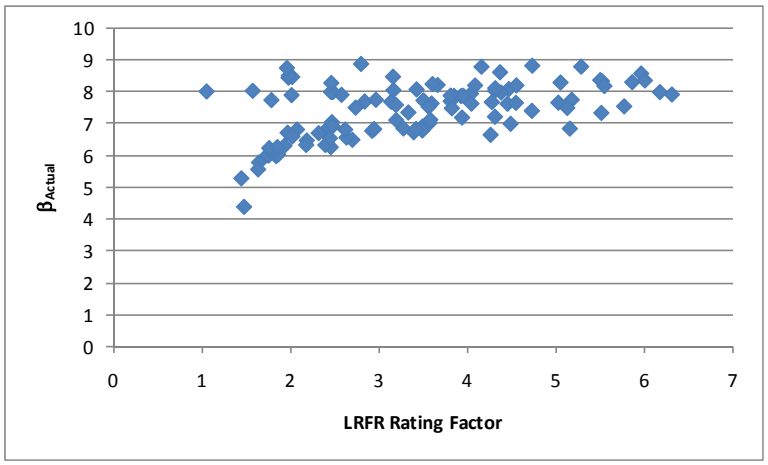


Figure D-398: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

D.3.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-399. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

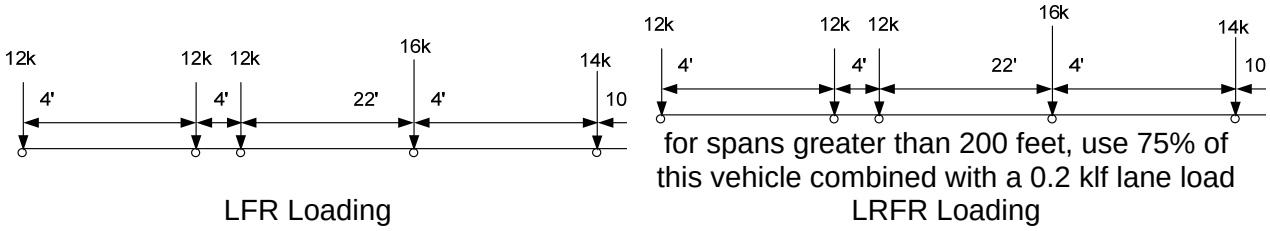
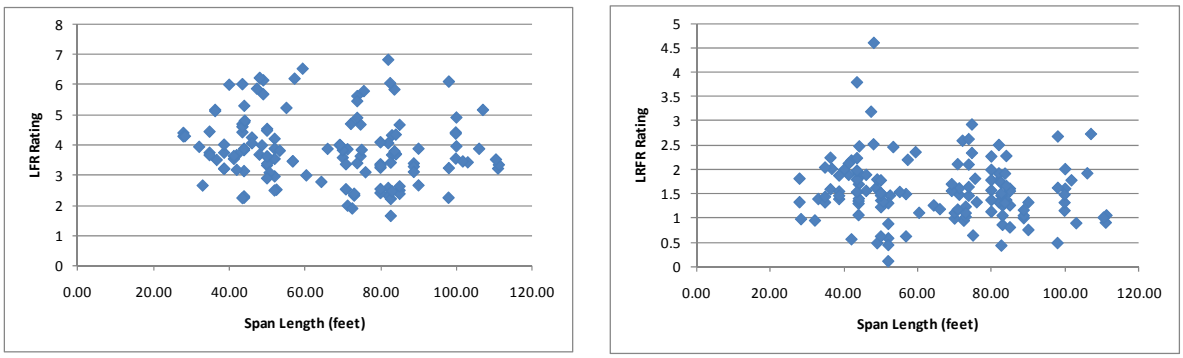


Figure D-399: Vehicle Loadings and Load Factors

D.3.12.1 Moment

D.3.12.1.1 Rating Factors

Figure D-400 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 20 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating is between 2.5 and 5 for most girders while the LRFR rating is between 1.0 and 2.5 for most girders. Four of the twenty girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.



(a) (b)

Figure D-400: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure D-401 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3-3 Truck. Approximately 85% of girders have LRFR ratings greater than 1.0 for all ADTT values. This indicates that about 15% of girders are negatively affected by switching from LFR to LRFR. All girders have LFR ratings greater than 1.0 for the AASHTO Type 3-3 Truck.

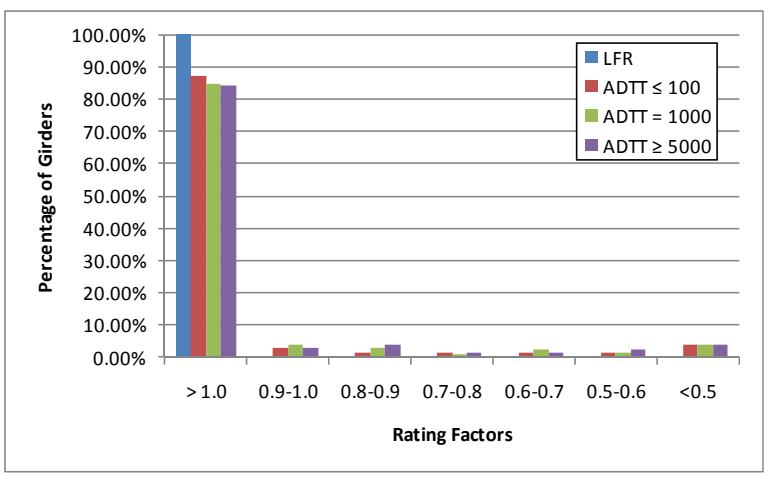


Figure D-401: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

D.3.12.1.2 Rating Factor Comparisons

Figure D-402 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6. No girders have LRFR ratings greater than the LFR ratings for moment due to the Type 3-3 vehicle.

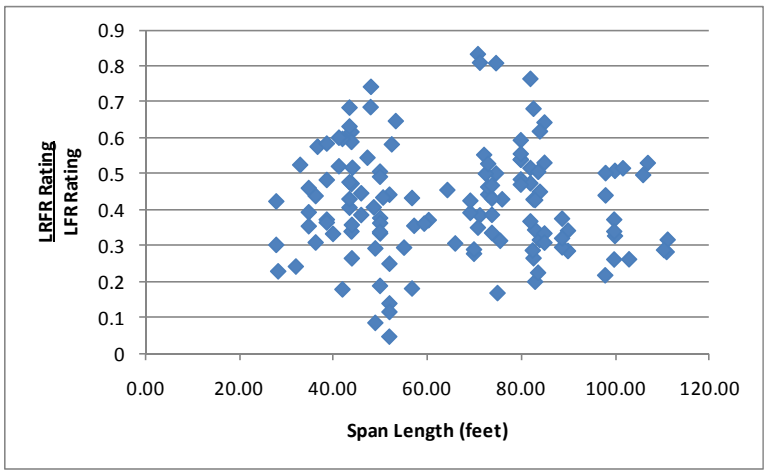


Figure D-402: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

D.3.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-403 shows that twelve girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index varies from two to ten for most girders.

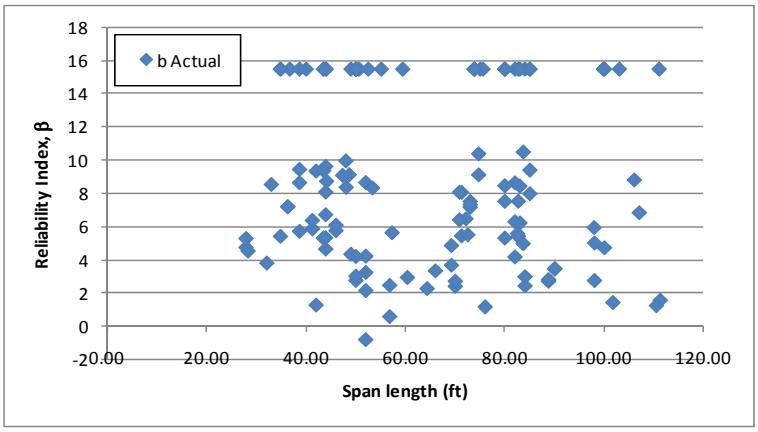


Figure D-403: Flexure Reliability Indices for Type 3-3 Vehicle

Figure D-404 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The figure shows that for girders with ratings near 1.0 the reliability index will be approximately four. This is greater than the target reliability of 2.5, indicating the LRFR live load factors may be over-conservative.

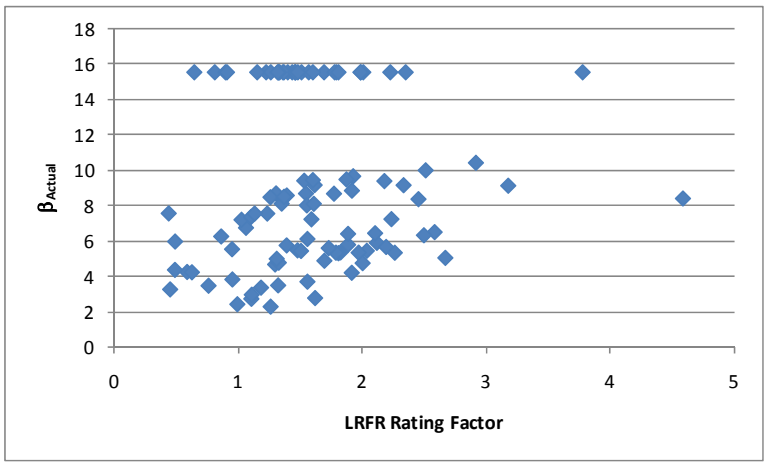
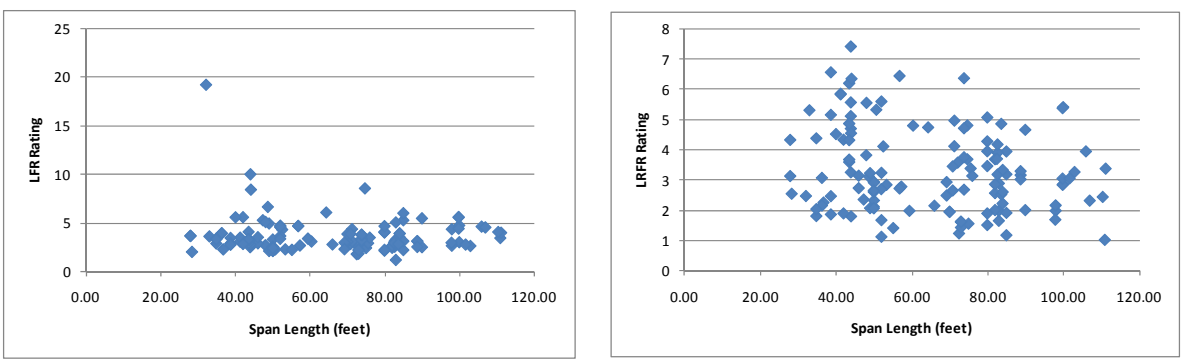


Figure D-404: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

D.3.12.2 Shear

D.3.12.2.1 Rating Factors

For shear, there are zero girders with LFR or LRFR rating factors less than 1.0. The LFR Rating is greater than the LRFR rating for 57% of the girders in this subset. Figure D-405 shows the LFR and LRFR ratings. The LFR ratings are between two and five while the LRFR ratings are between one and five for most girders.



(a) (b)

Figure D-405: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure D-406 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3-3 Truck. With the exception of the ADTT = 5,000 category, all girders have LRFR and LFR ratings greater than 1.0. For the ADTT = 5,000 category, less than 1% of girders have an LRFR rating less than 1.0.

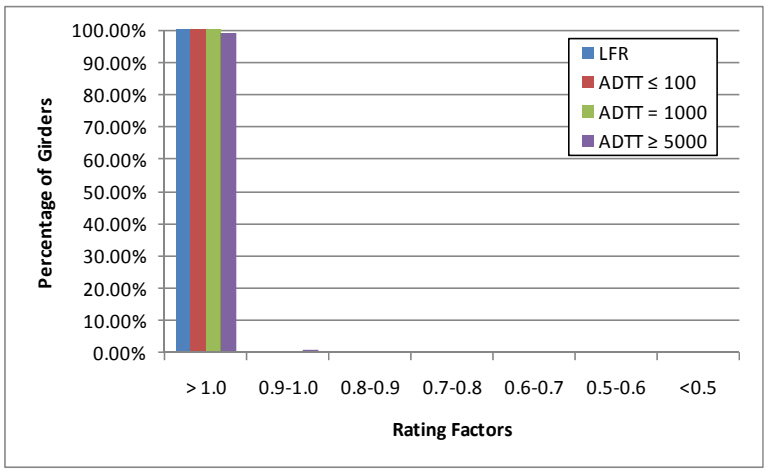


Figure D-406: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

D.3.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-407 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with shorter spans generally having higher ratios.

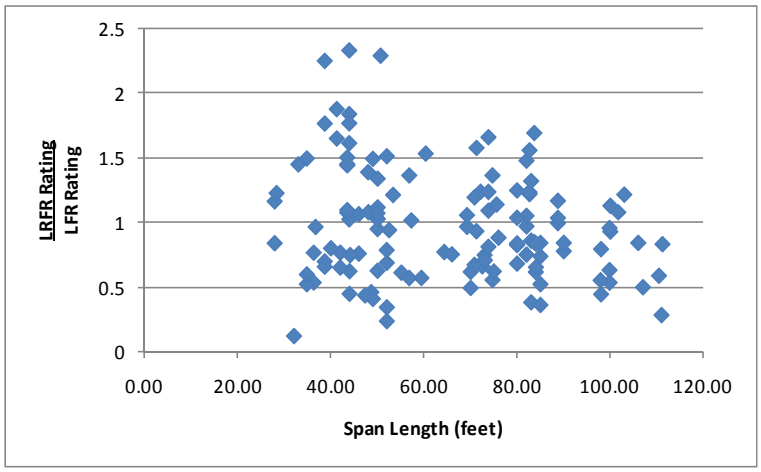


Figure D-407: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

D.3.12.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the required reliability index for approximately 8 girders as shown in Figure D-408.

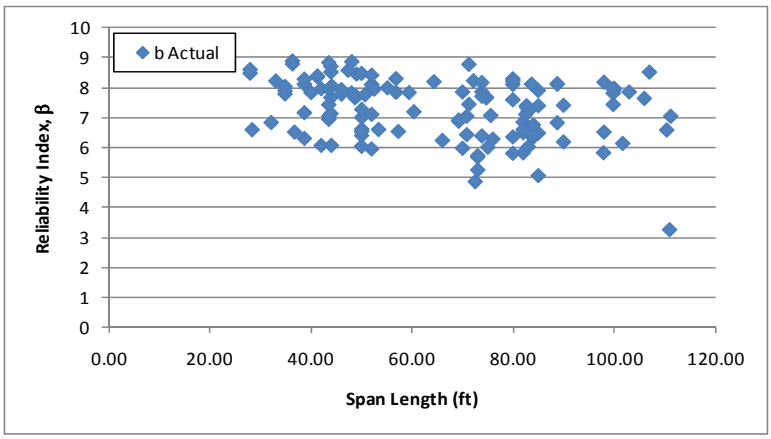


Figure D-408: Shear Reliability Indices for Type 3-3 Vehicle

Figure D-409 shows the reliability index for shear plotted against the LRFR shear rating factor for the AASHTO Type 3-3 Truck. The figure shows that girders with ratings near one have reliability indices of approximately 3.25, higher than the target reliability of 2.5. This indicates that live load factors in the MBE may be slightly over conservative.

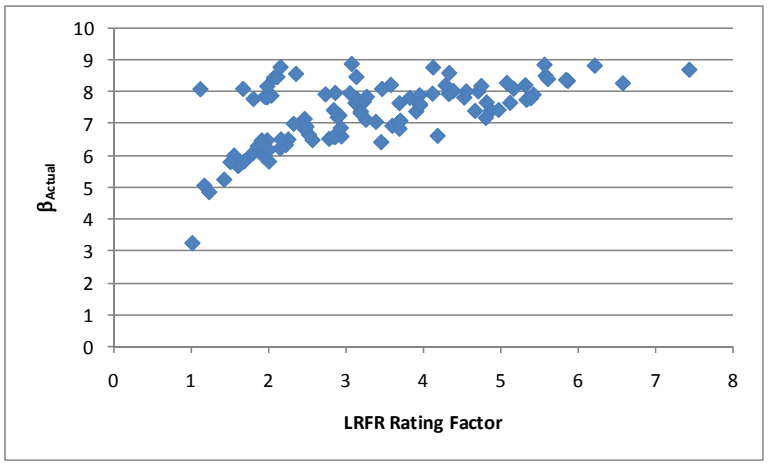


Figure D-409: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

D.3.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-410. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

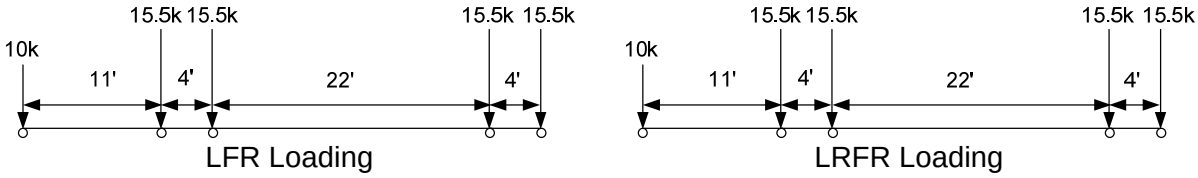
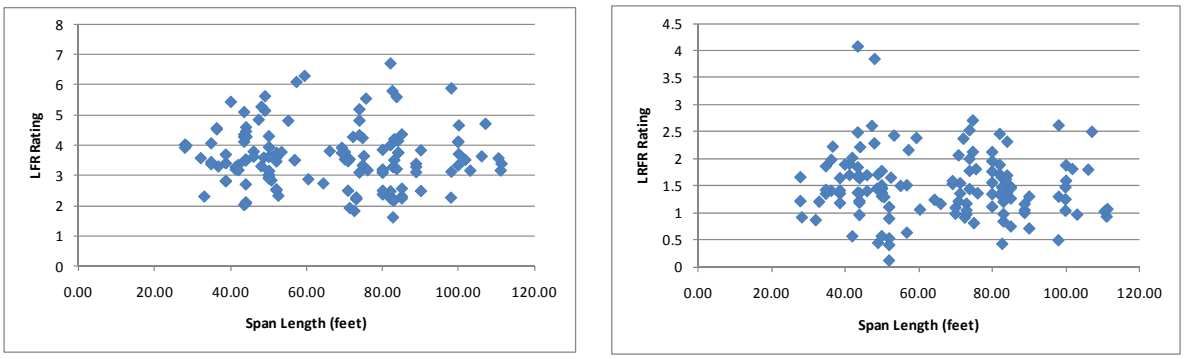


Figure D-410: Vehicle Loadings and Load Factors

D.3.13.1 Moment

D.3.13.1.1 Rating Factors

Figure D-411 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 24 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. Five of the twenty four girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR ratings are between two and five for most girders while the LRFR rating is between 0.5 and 2.0.



(a) (b)

Figure D-411: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure D-412 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3S2 Truck. Between 81 and 85% of girders have LRFR ratings greater than 1.0 for the various LRFR ADTT values. Approximately one-third to one-quarter of the girders with LRFR ratings less than 1.0, have ratings between 0.9 and 1.0. All girders have LFR ratings greater than 1.0.

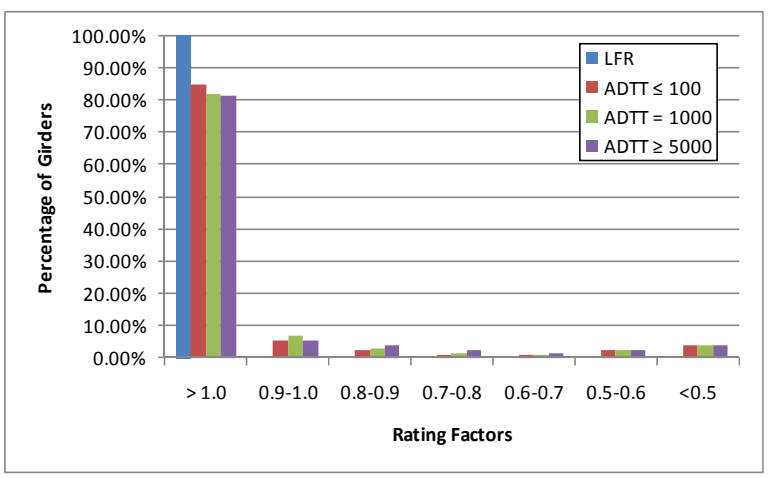


Figure D-412: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

D.3.13.1.2 Rating Factor Comparisons

Figure D-413 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6. All girders have LFR ratings that exceed the LRFR ratings.

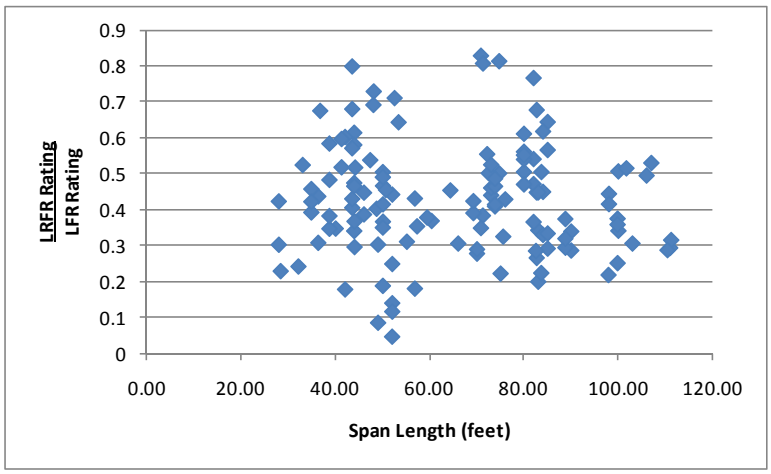


Figure D-413: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

D.3.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-414 shows that twelve girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between two and ten for most girders.

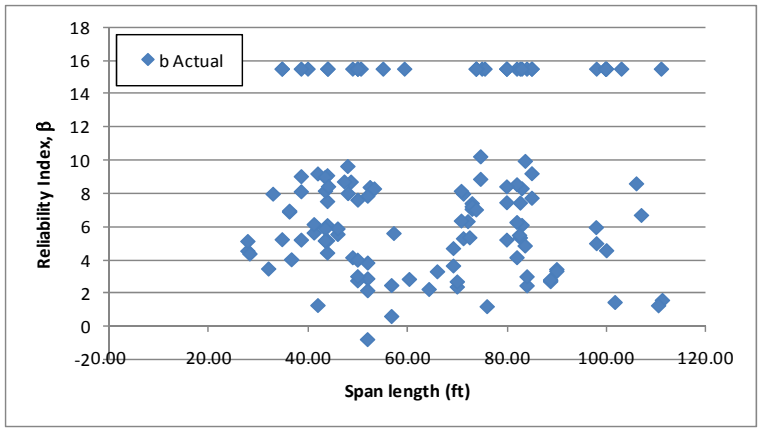


Figure D-414: Flexure Reliability Indices for Type 3S2 Vehicle

Figure D-415 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 truck. The reliability index increases with increasing LRFR ratings. An LRFR rating of 1.0 corresponds to a reliability index between 2.5 and 7.0. This may indicate that the LRFR live load factors are over-conservative as the target reliability index of 2.5 is exceeded for most girders.

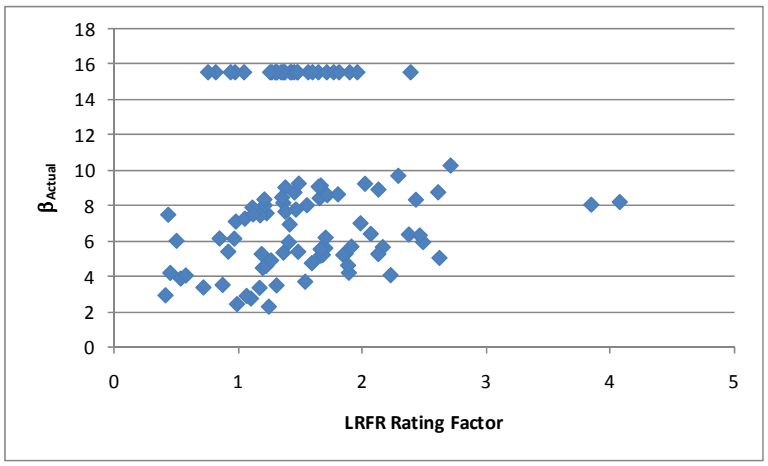
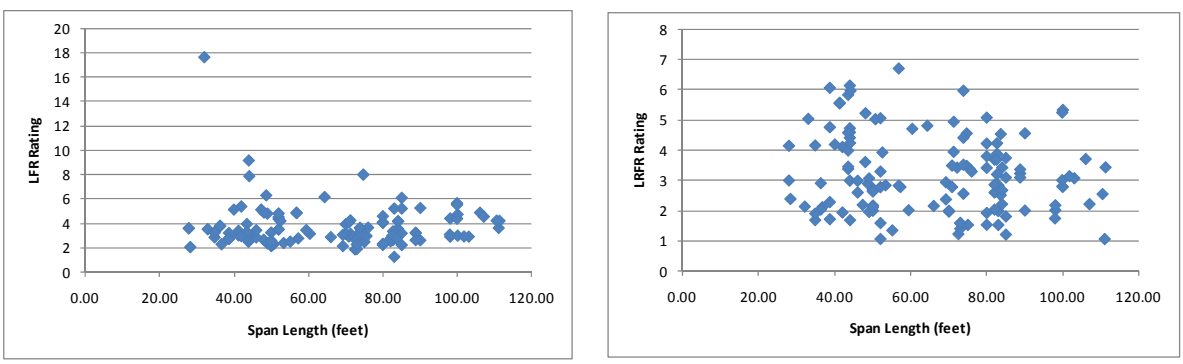


Figure D-415: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

D.3.13.2 Shear

D.3.13.2.1 Rating Factors

For shear, there are zero girders with LFR or LRFR rating factors less than 1.0. The LFR Rating is greater than the LRFR rating for 58% of the girders in this subset. Figure D-416 shows the LFR and LRFR ratings. LFR ratings are between two and six for most girders while the LRFR ratings are between one and six.



(a) (b)

Figure D-416: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure D-417 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 Truck. 1.5% of girders have an LRFR rating less than 1.0 when an ADTT of 5,000 is assumed. All other LRFR ratings and the LFR ratings are greater than 1.0 for all girders.

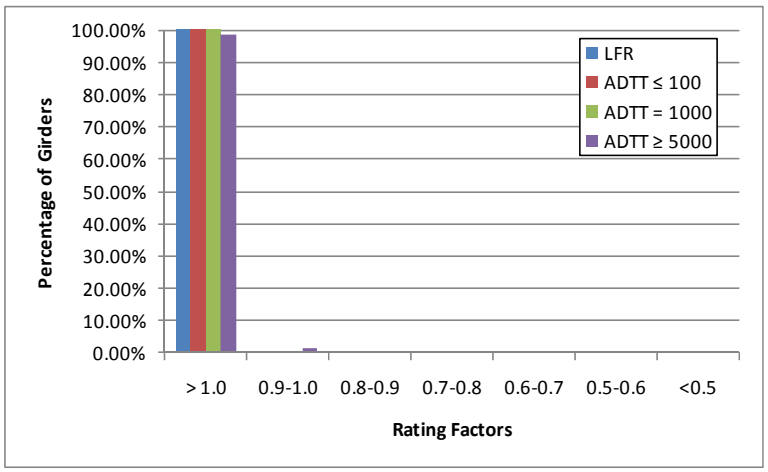


Figure D-417: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

D.3.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-418 show the comparison of rating factors. The ratio is generally between 0.5 and 2.0. 42% of girders have LRFR ratings that exceed the LFR rating.

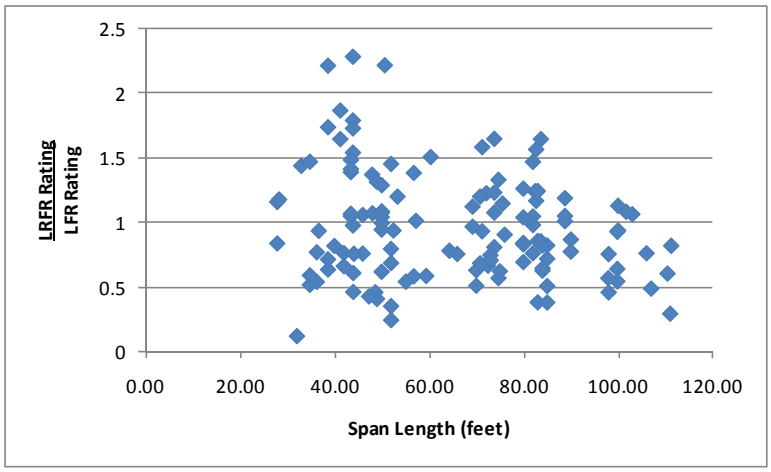


Figure D-418: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

D.3.13.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure D-419. The reliability index is between six and nine for most girders.

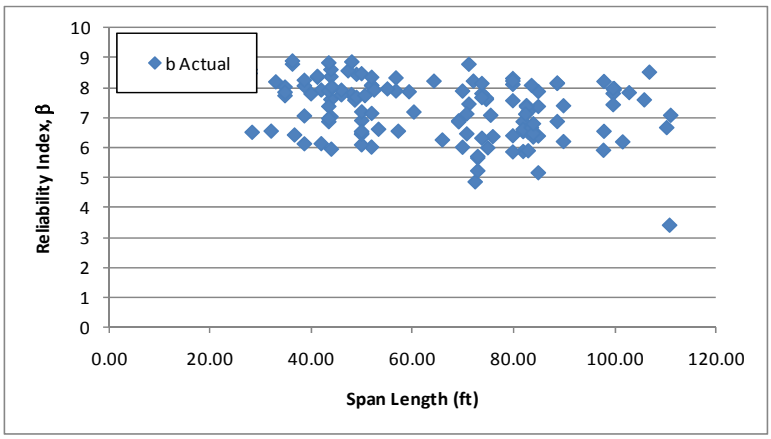


Figure D-419: Shear Reliability Indices for Type 3S2 Vehicle

Figure D-420 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 truck. The figure shows that girders with ratings near one have reliability indices between 3.25 and 5.0. The target reliability is 2.5, which is exceeded significantly and indicates that the live load factors in the MBE may be over-conservative.

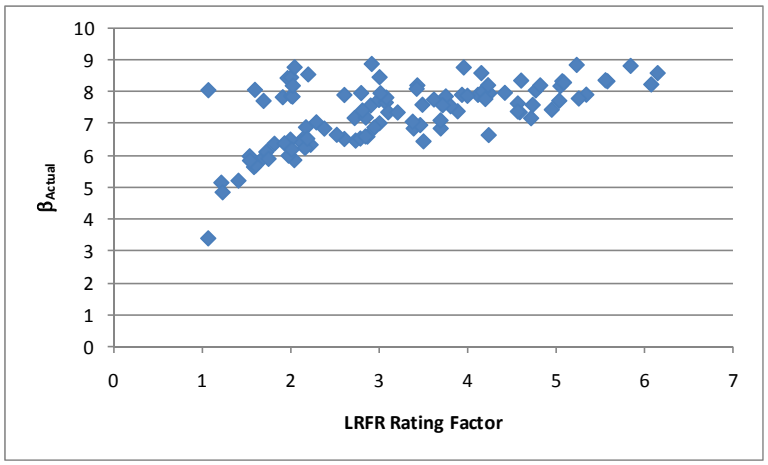


Figure D-420: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

D.3.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table D-5 shows the results for the moment ratings. The design vehicle and the heaviest special permit vehicles cause at most eleven girders to have LFR ratings less than 1.0. For the other vehicles investigated, very few girders had ratings less than 1.0 for LFR. For LRFR ratings, the number of girders with ratings less than one varies from 18 to 65 depending on the vehicle. The number of girders controlled by the longitudinal steel rating and having an LRFR rating less than one compose less than 5% of the total number of girders. Most girders with ratings less than 1.0 are controlled by the Service III limit state which limits the tensile stress at the bottom of the girder.

Table D-5: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	132	11	0	0	0	0	0	0	0	5	0	0	0
LRFR Rating less than 1.0		34	21	19	35	40	18	36	48	65	18	20	24
LFR and LRFR Rating less than 1.0		10	0	0	0	0	0	0	0	5	0	0	0
% with LFR RF greater than LRFR RF		89	98	98	97	100	100	95	100	96	100	100	100
Girders controlled by longitudinal steel and have LRFR rating less than 1.0		6	5	5	2	4	4	1	3	3	4	4	5
LRFR Rating less than 1.0 and controlled by service limit state		28	16	14	32	35	13	34	44	61	13	15	18

D.3.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table D-6 shows the results for the shear ratings. The design vehicle, the special permit vehicle except for OR-06, and NM-04 are the only trucks that cause LFR ratings less than 1.0. For LRFR the same trucks except for NM-04 have girders with ratings less than 1.0. The percentage of girders with LFR ratings greater than LRFR ratings seems to depend on the vehicle, which is expected because the LRFR shear strength equation uses the ratio of V_u/M_u.

Table D-6: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	132	3	0	0	1	0	0	0	0	2	0	0	0
LRFR Rating less than 1.0		11	0	0	6	0	0	0	2	17	0	0	0
LFR and LRFR Rating less than 1.0		2	0	0	1	0	0	0	0	2	0	0	0
% with LFR RF greater than LRFR RF		67	52	49	41	55	51	24	61	52	52	57	58

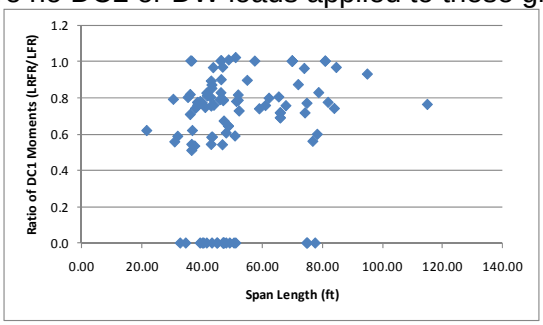
D.4 Interior Non-Composite Girders

D.4.1 Dead Loads

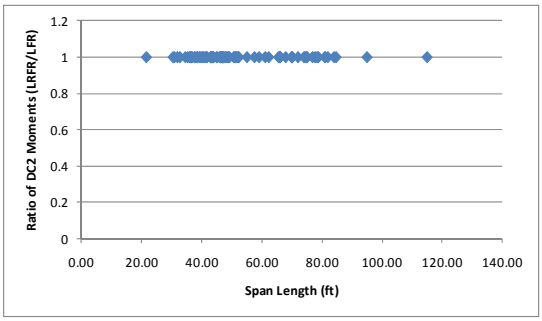
D.4.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure D-421a, the ratio of unfactored DC1 moments (self-weight, dead loads on non-composite section) there is a significant amount of variation in the ratio of DC1 loads. There typically should be little variation in the dead loads unless the critical location is different. The critical

locations are plotted for this set of girders and many of the LRFR locations vary from the LFR location. Figure D-421b shows that there is no variation in DC2 moments, this is because there are no DC2 or DW loads applied to these girders.



(a)

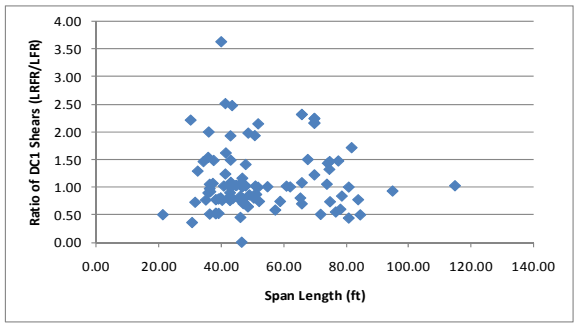


(b)

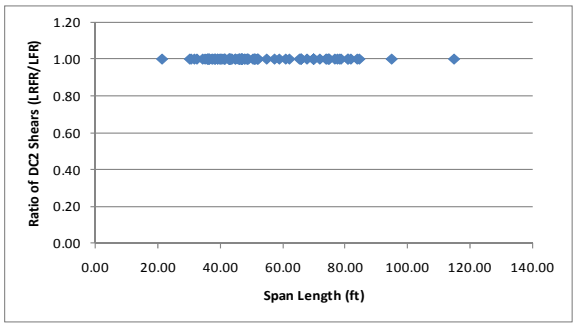
Figure D-421: Ratios of DC1 and DC2 Moments (unfactored loads LRFR/LFR)

D.4.1.2 Shear

Figure D-422a shows that there is also significant scatter in the ratio of DC1 shears. Some scatter is expected in the shear due to the critical section being at different locations. Figure D-422b shows that there is no variation in DC2 and DW loads; in all cases there are no DC2 loads applied to the cross section.



(a)



(b)

Figure D-422: Ratios of DC1 and DC2 Shears (unfactored loads LRFR/LFR)

D.4.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure D-423. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

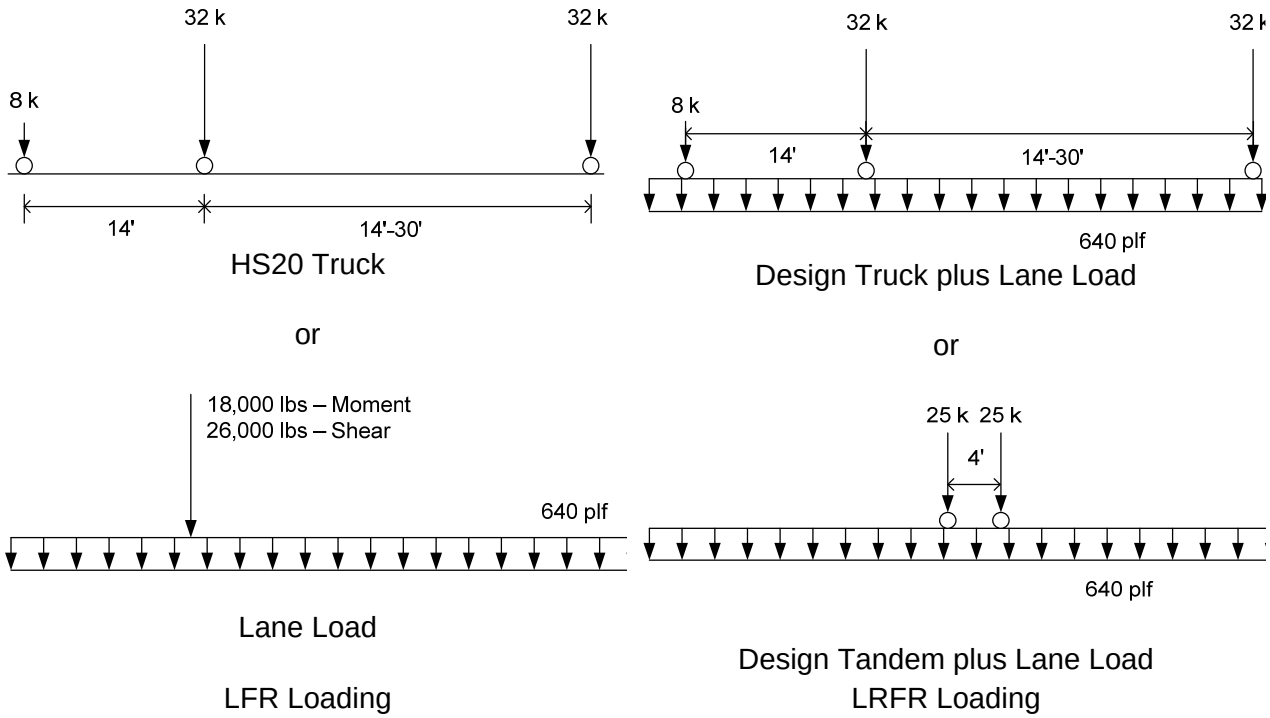
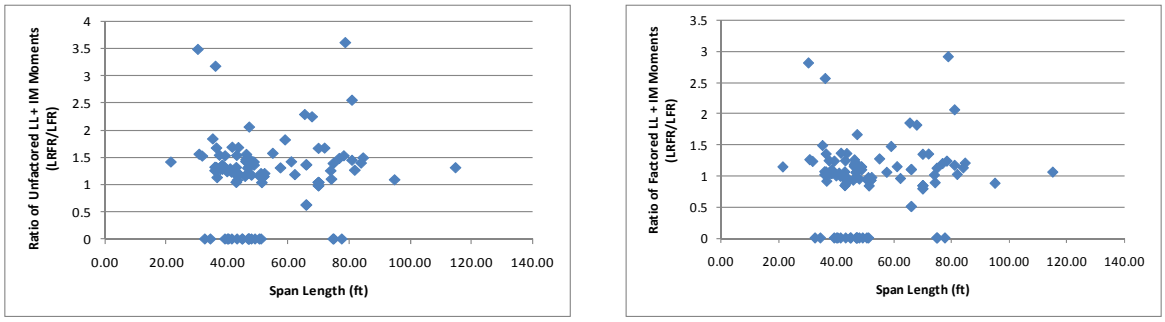


Figure D-423: Vehicle Loadings and Load Factors

D.4.2.1 Moment

D.4.2.1.1 Live Loads

Figure D-424a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.0 and 1.75 for most of the girders within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure D-424b shows that the results have shifted down and are between 0.9 and 1.4 for most cases.



(a) (b)

Figure D-424: Ratio of Unfactored and Factored Live Load plus Impact Moments for Design Vehicles (LRFR/LFR)

D.4.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure D-425 shows that the ratio of resistance is very close to 1.0 for most girders. The increased resistance for LRFR is due to the reduction in prestress losses. The data points near 0.25 are the girders that are controlled by the LRFR rating of the longitudinal steel.

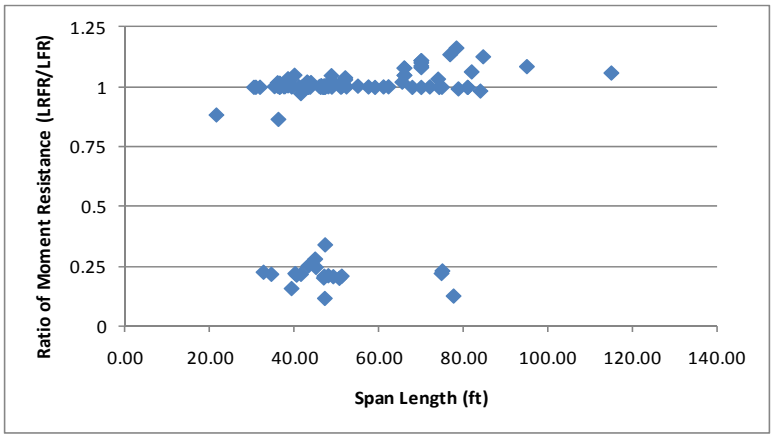
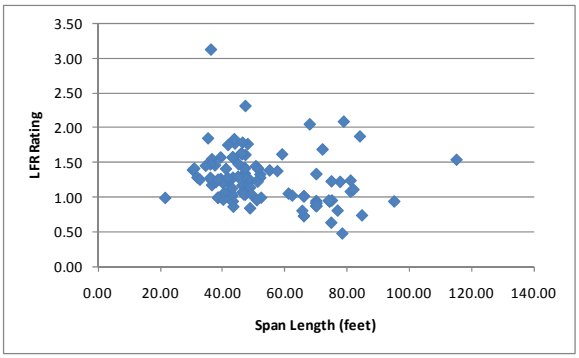


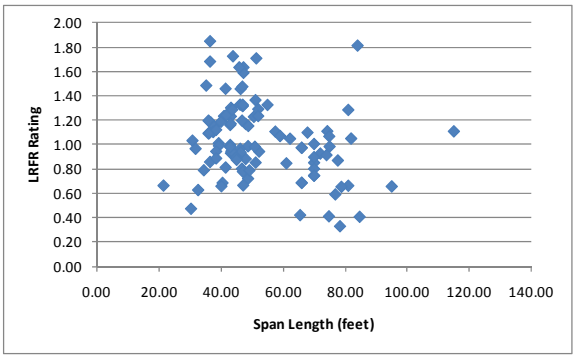
Figure D-425: Ratio of factored Moment Resistance (LRFR/LFR)

D.4.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (104 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 26 girders with LFR ratings less than 1.0, 53 girders with LRFR ratings less than 1.0, and 25 girders where both the LFR and LRFR ratings are less than 1.0. Thirty one of the 53 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. Figure D-426 shows the LFR rating factors and LRFR rating factors. The LFR rating is between 1.0 and 2.0 while the LRFR rating is between 0.8 and 1.4.



(a)

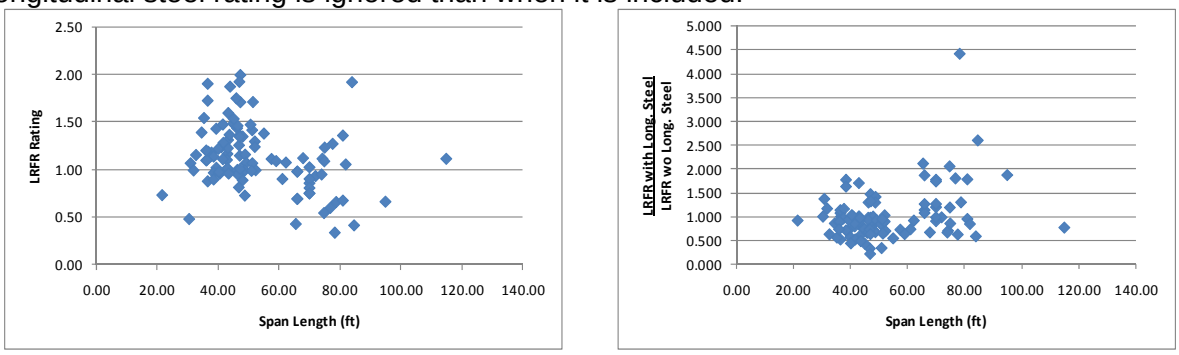


(b)

Figure D-426: LFR and LRFR Flexure Rating Factors for HS-20 and HL-93 Loadings

Figure D-427a shows the LRFR rating factor when the longitudinal steel rating is ignored. There are 14 fewer girders with LRFR ratings less than 1.0 when the longitudinal steel rating is ignored. Figure D-427b shows the ratio of the LRFR rating including the longitudinal steel rating

divided by the LRFR rating where the longitudinal steel rating is ignored. The figure shows that many girders have a ratio less than 1.0. 63.5% of girders have higher LRFR ratings when the longitudinal steel rating is ignored than when it is included.



(a) (b)

Figure D-427: LFR and LRFR Flexure Rating Factors for HS-20 and HL-93 Loadings

D.4.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure D-428. The results indicated that 85% of the girders in this set have LFR ratings greater than LRFR ratings. The ratio of ratings is between 0.6 and 0.8 for most girders.

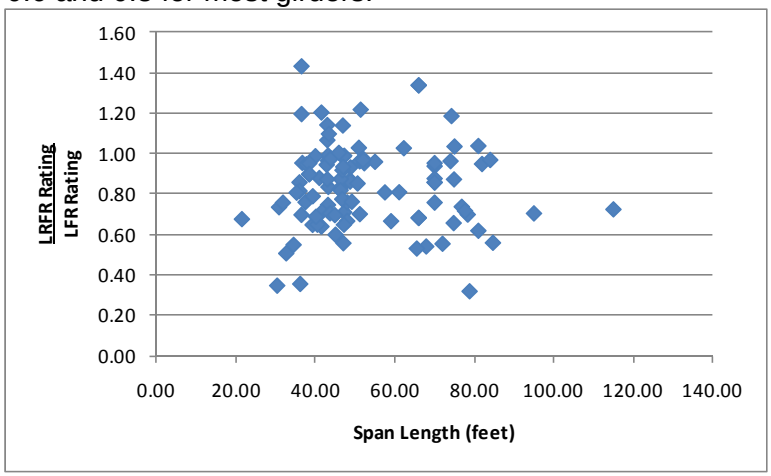


Figure D-428: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Vehicle

Figure D-429 shows the percentage of girders with LRFR ratings less than 1.0 in each group. The figure shows that most girders with LRFR ratings less than 1.0 have LRFR ratings that are greater than 50% of the LFR rating, there are also girders with LRFR ratings greater than the LFR rating. The graph provides an estimate of the reduction in allowable weight for the design vehicle.

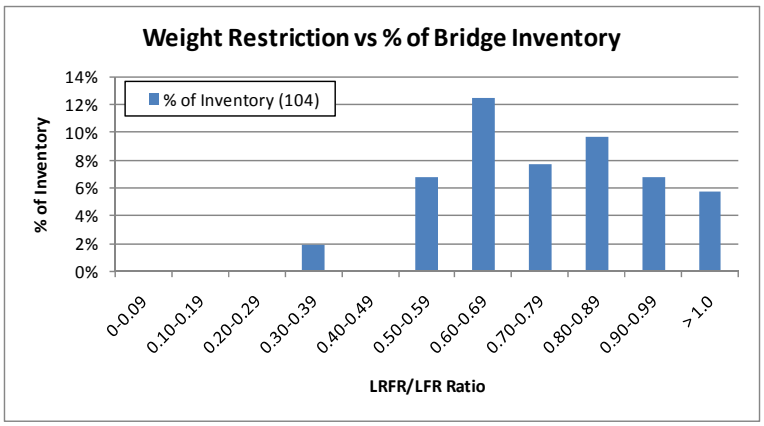


Figure D-429: Distribution of LRFR/LFR Ratios for Girders with LRFR Ratings less than 1.0

D.4.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure D-430 shows that five girders have a reliability index lower than that assumed in the development of the LRFR Rating Specification at this loading level. For the two girders with reliability indices less than 1.0, the live load (including impact) utilizes a significant portion of the section capacity.

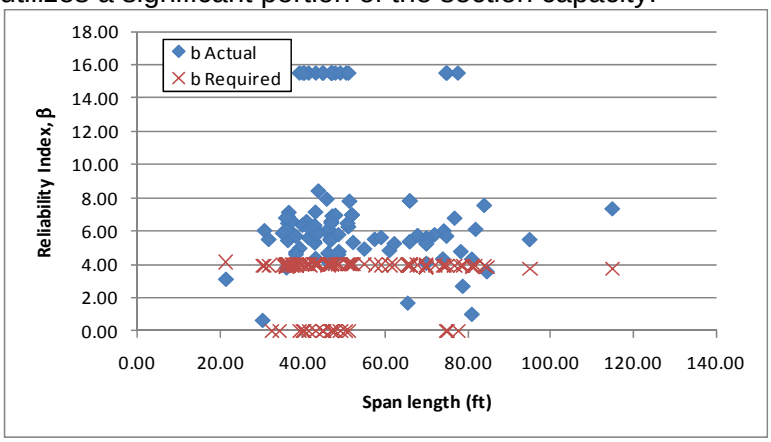


Figure D-430: Flexure Reliability Indices for HL-93 Loading

Figure D-431 shows that the reliability index is near four for girders with LRFR ratings of 1.0. This is similar to what is shown in Figure D-430 where beta required is 4.0. This indicates that the live load factors provide the target level of reliability.

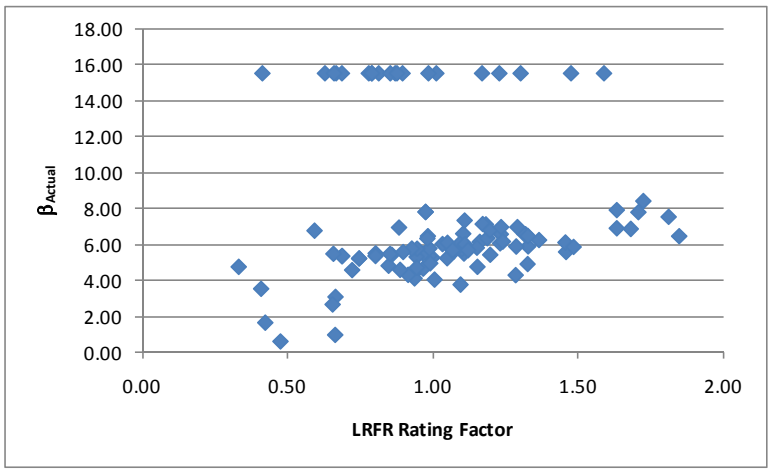


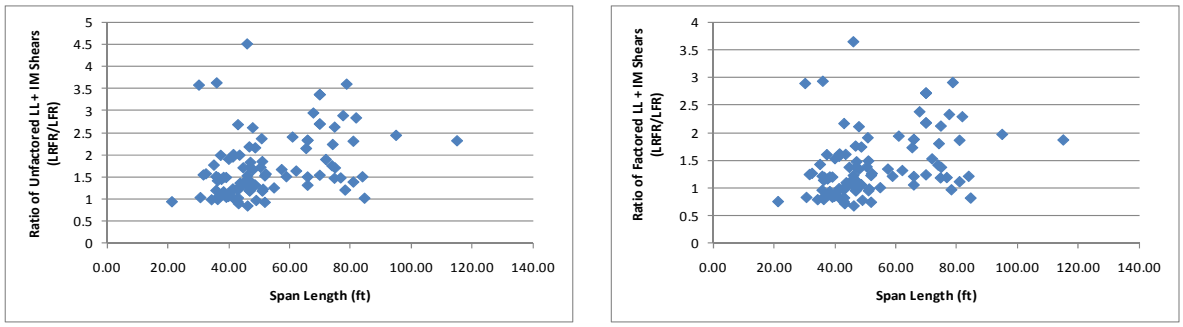
Figure D-431: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Design Load

D.4.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is interior prestressed concrete box girders with no cast in place concrete decks in simple span bridges.

D.4.2.2.1 Live Loads

Figure D-432a shows that the ratio of unfactored shear varies significantly, with most girders between 1.0 and 2.0, with some ratios greater than 2.0. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure D-432b shows that the ratio of factored live load shears has decreased and is generally between 0.75 and 1.5 for most cases.



(a) (b)

Figure D-432: Ratio of Unfactored and Factored Live Load plus Impact Shears for Design Vehicles (LRFR/LFR)

As shown in Figure D-433, the location of the critical section for shear varies for most girders in this subset. The difference in the factored shears shown in Figure D-432 may have been affected by the difference in the critical section for shear rating.

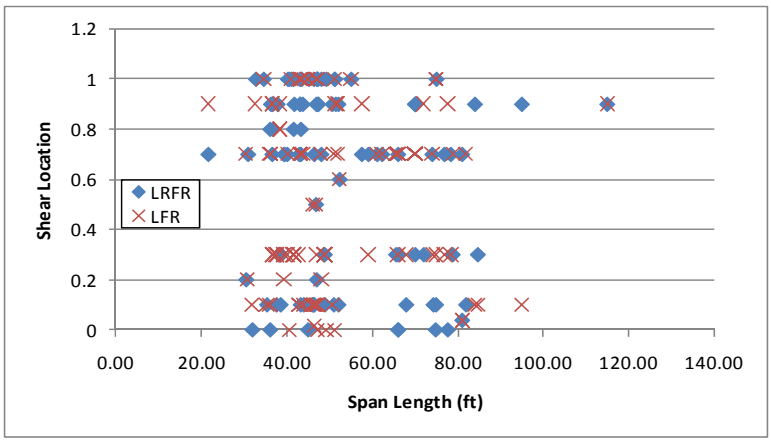


Figure D-433: Graph of critical shear location for Design Loadings

D.4.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure D-434 shows that the ratio of resistance is generally greater than 1.0 (LRFR resistance is greater than LFR resistance). Due to the variation in critical location, the variation in shear resistance is not unexpected because of the different shear reinforcement spacing used throughout the span.

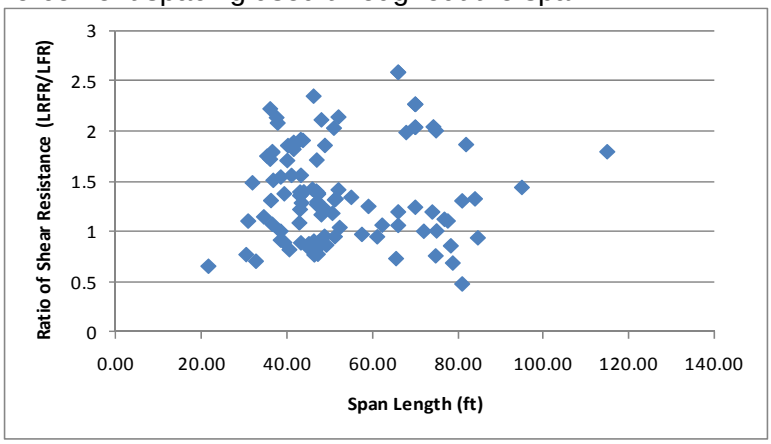
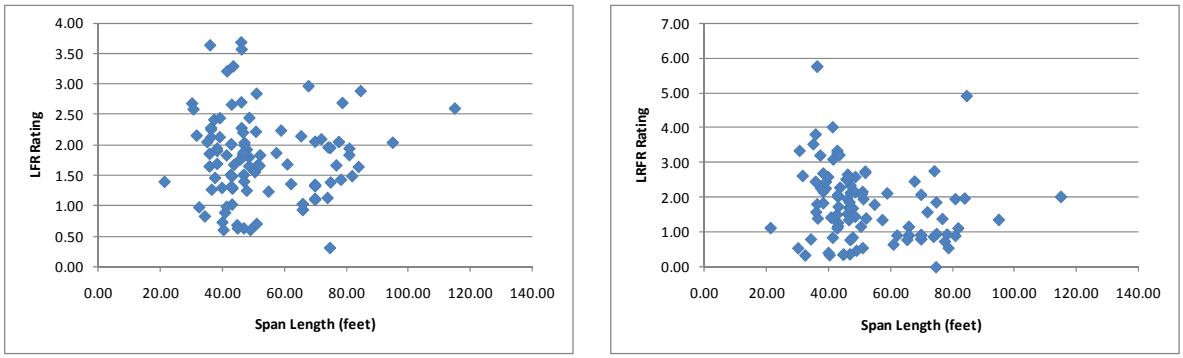


Figure D-434: Ratio of factored Shear Resistance (LRFR/LFR)

D.4.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 14 girders with LFR ratings less than 1.0, 30 girders with LRFR ratings less than 1.0, and 11 girders where both LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. For this subset, one third of the girders have shear ratings less than 1.0 for LRFR. The LFR rating was greater than the LRFR rating for 58% of the girders in this subset. Figure D-435

shows the LFR rating factors and LRFR rating factors. The LFR rating is between 0.5 and 2.5 while the LRFR rating is between 0.5 and 3.0 for most girders.



(a) (b)

Figure D-435: LFR and LRFR Shear Rating Factors for Design Loadings

D.4.2.2.4 Rating Factor Comparisons

Figure D-436 shows the ratio of the LRFR rating to the LFR rating. Slightly more than 40% of the girders have LRFR ratings greater than LFR ratings. The ratio is between 0.5 and 1.5 and decreases with increasing span lengths.

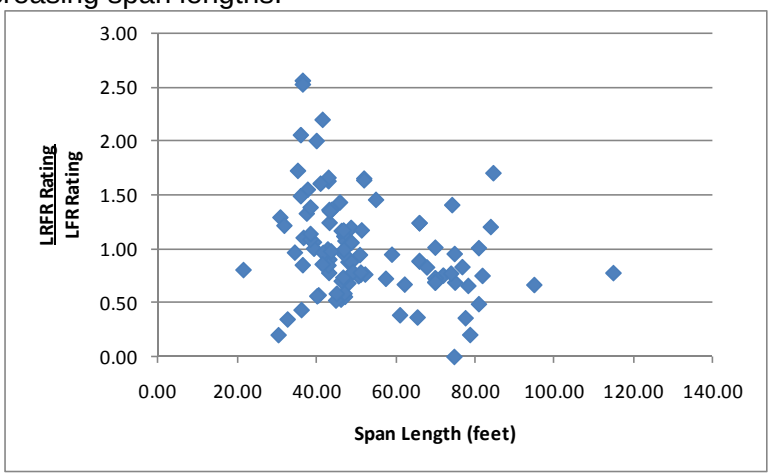


Figure D-436: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure D-437 shows the percentage of girders in each category as a percent of the total number of girders in this group. The figure shows that most girders with LRFR ratings less than 1.0 have LRFR ratings greater than 50% of the LFR rating. The figure provides an estimate of the reduction in load required to have the LRFR rating be at the LFR level as well as shows how much the girders with ratings less than one will be affected.

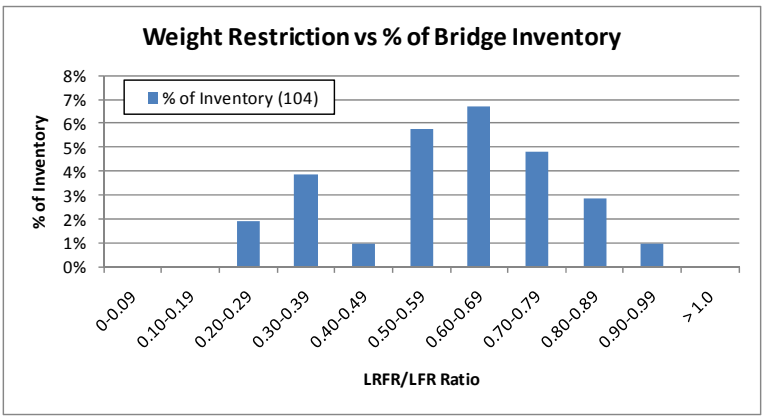


Figure D-437: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

D.4.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure D-438 shows that 15 girders have a reliability index for shear less than the required level. The girders that do not have the required level of reliability are less than 100 feet. In one case, the reliability index based on the section capacity is less than zero, indicating the applied loads are significantly larger than the shear resistance. This may be indicative of the bridge file not being correct (shear reinforcement is not defined or defined incorrectly). The reliability index for most girders is between six and eight.

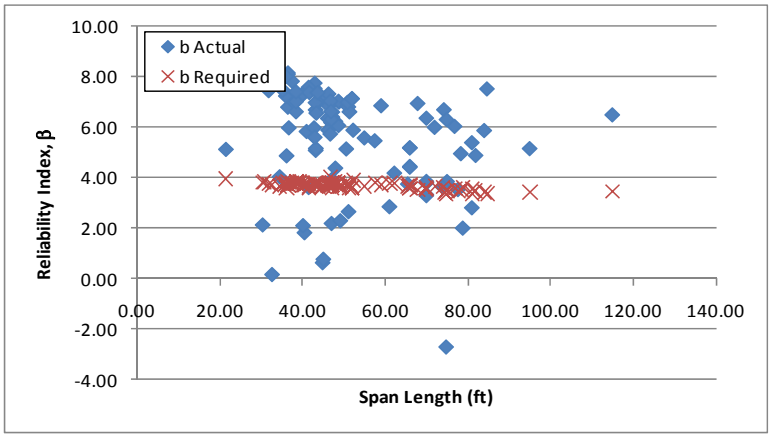


Figure D-438: Shear Reliability Indices for HL-93 Loading

Figure D-439 shows the reliability index for shear plotted against the LRFR shear rating for the design vehicle. The figure shows that girders with ratinge near one have reliability indices greater than 3.5 inherent in the LRFD Design Specifications.

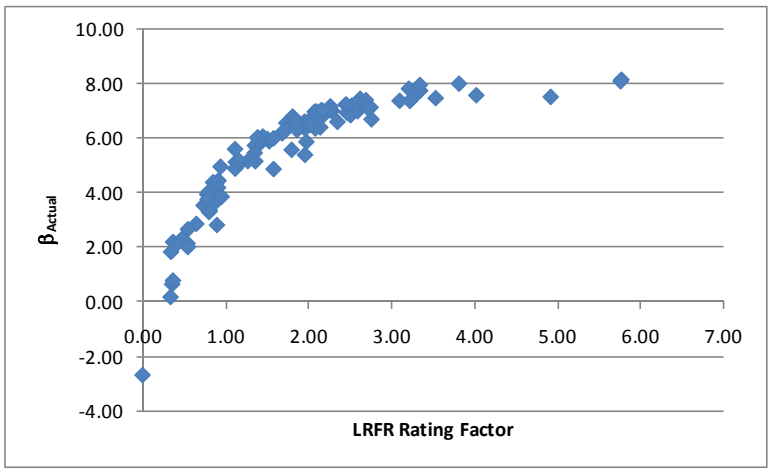


Figure D-439: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

D.4.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-440. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

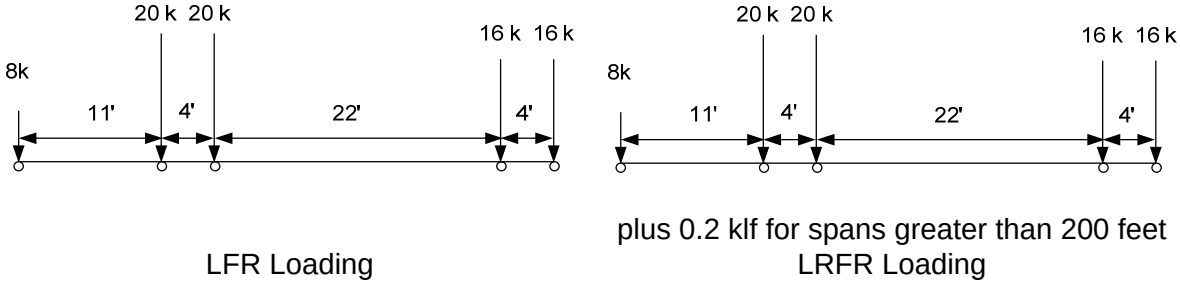


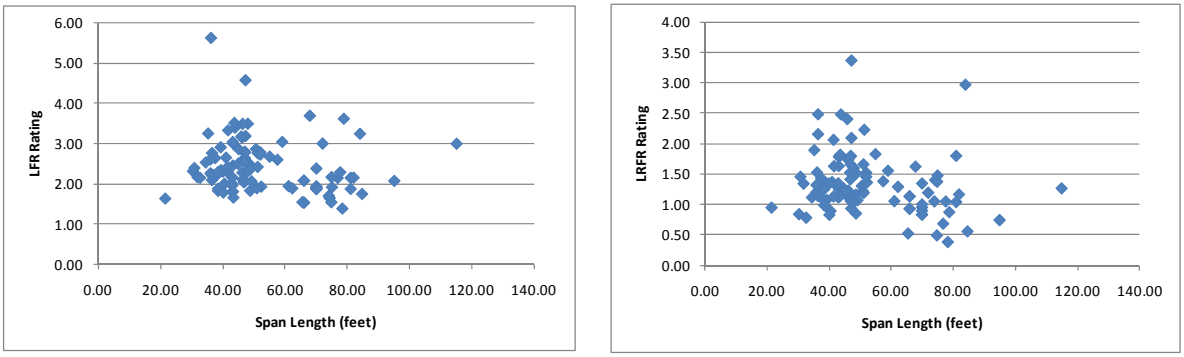
Figure D-440: Vehicle Loadings and Load Factors

D.4.3.1 Moment

The following section contains the results for interior, non-composite prestressed box girders within simple span bridges for the DE-07 Vehicle.

D.4.3.1.1 Rating Factors

Figure D-441 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 21 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. Five of the twenty one girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR ratings are between 1.5 and 3.0 for most cases while the LRFR ratings are between 1.0 and 2.0.



(a) (b)

Figure D-441: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure D-442 shows the percentage of girders with moment ratings in each rating range for the DE-07 Vehicle. The LRFR ratings are greater than 1.0 for between 75 and 82% of the girders, with the lower percentage corresponding to a higher ADTT. This is a significant number of girders affected by the switch from LFR to LRFR, though most girders affected have ratings between 0.8 and 1.0. All girders have LFR ratings greater than 1.0.

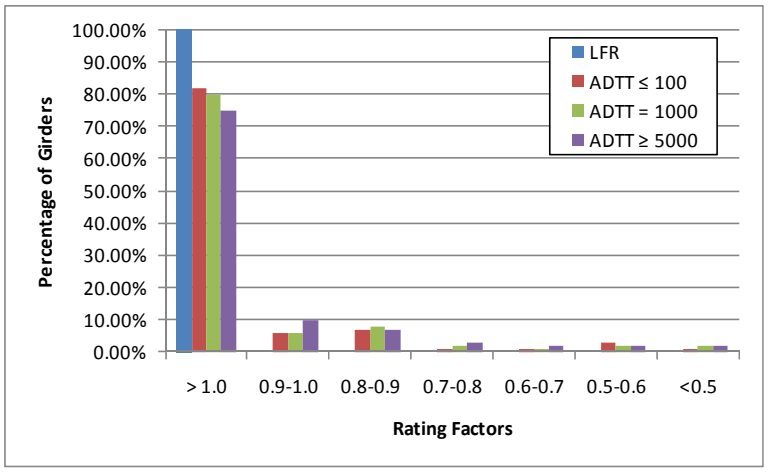


Figure D-442: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

D.4.3.1.2 Rating Factor Comparisons

Figure D-443 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.4 to 0.7, with lower ratios generally corresponding to longer span lengths. One girder exists for this vehicle where the LRFR rating is higher than the LFR rating.

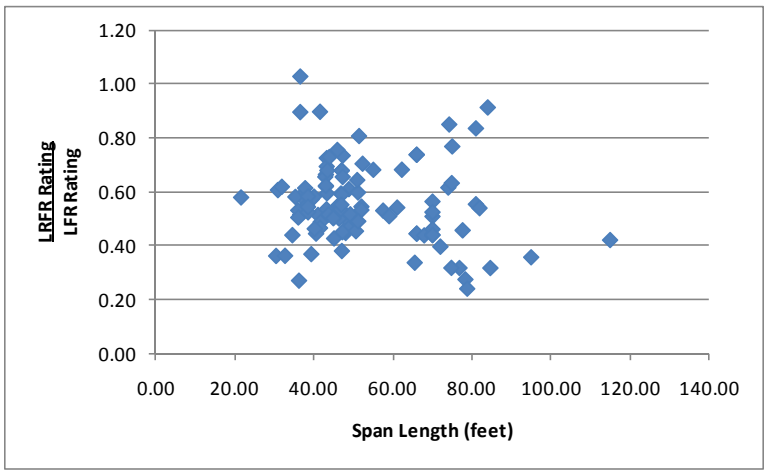


Figure D-443: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

D.4.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-444 shows that all girders have a reliability index based upon section strength that is greater than the target reliability index of 2.5. The reliability index is between six and ten for most girders.

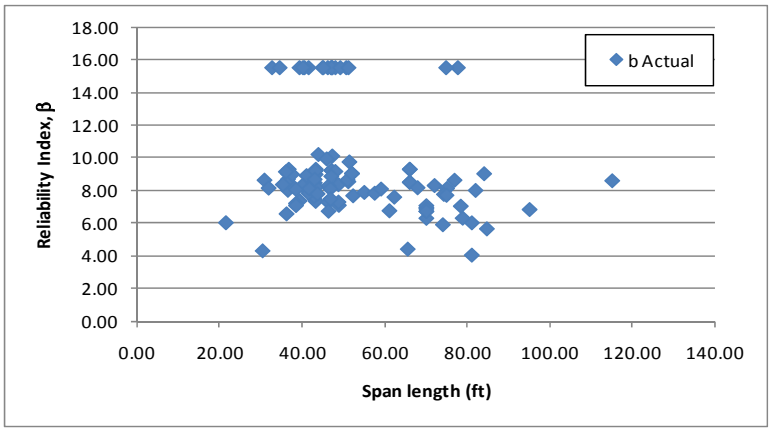


Figure D-444: Flexure Reliability Indices for DE-07 Vehicle

Figure D-445 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 vehicle. The figure shows that the reliability index for a girder with a rating near one is above six, exceeding the target reliability of 2.5. This indicates that the load factors in the MBE may be over-conservative and could be reduced.

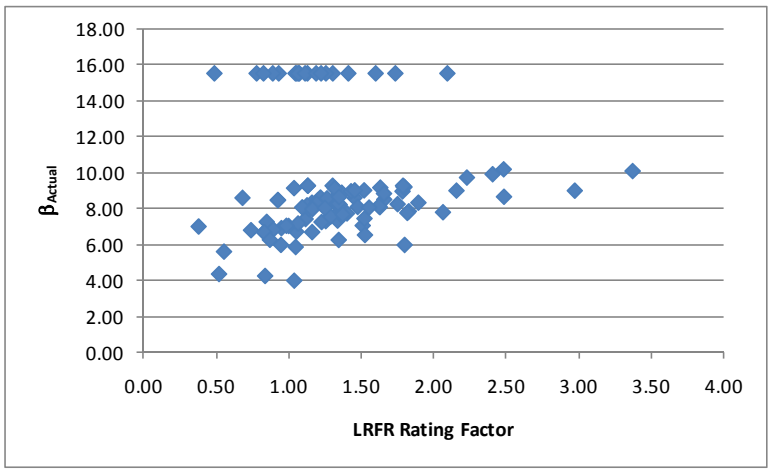
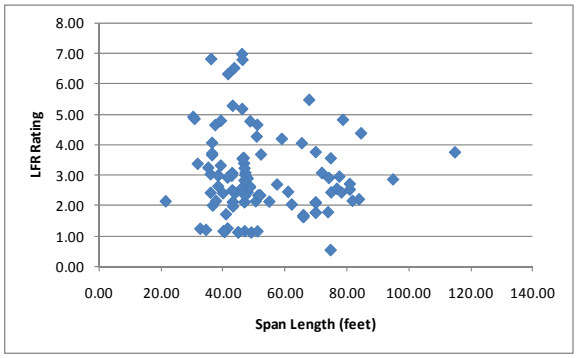


Figure D-445: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

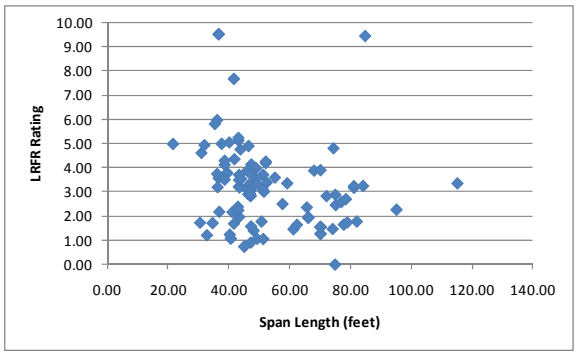
D.4.3.2 Shear

D.4.3.2.1 Rating Factors

For shear, there is one girder that has a rating factor less than 1.0 for LFR, four girders for LRFR, and one girder where both LFR and LRFR are less than 1.0. The LFR Rating is greater than the LRFR rating for 47% of the girders in this subset. Figure D-446 shows the LFR and LRFR ratings. The LFR rating is between two and four for most girders while the LRFR rating is between one and four.



(a)



(b)

Figure D-446: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure D-447 shows the percentage of girders with shear ratings within each rating range for the DE-07 vehicle. Between 2.9 and 6.7% of girders have LRFR ratings less than 1.0 for the DE-07 vehicle. The higher percentage of girders corresponds to higher LRFR ADTTs. Approximately 1% of girders have LFR ratings that are less than 1.0. Approximately 6% of girders will be negative affected by the switch from LFR to LRFR for the worst case loading of ADTT = 5,000.

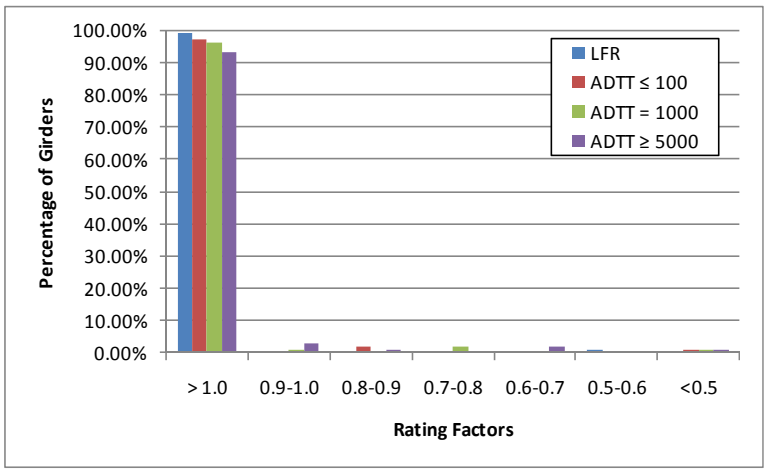


Figure D-447: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

D.4.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure D-448 show the comparison of rating factors. The ratio is greater than 1.0 for 53% of the girders. The ratio is between 0.5 and 2.0 for most girders.

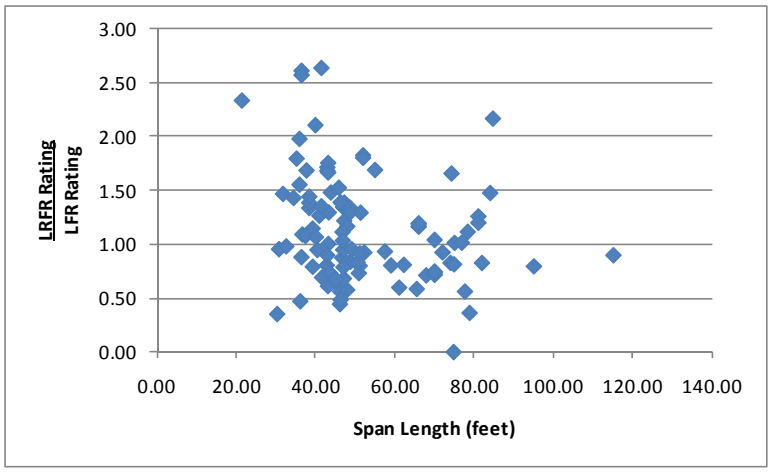


Figure D-448: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

D.4.3.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all but one girder as shown in Figure D-449. The girder where the two reliability indices are close (and also the one that is between zero and one) is likely caused by the shear reinforcement not being input correctly. The reliability index is between five and nine for most girders.

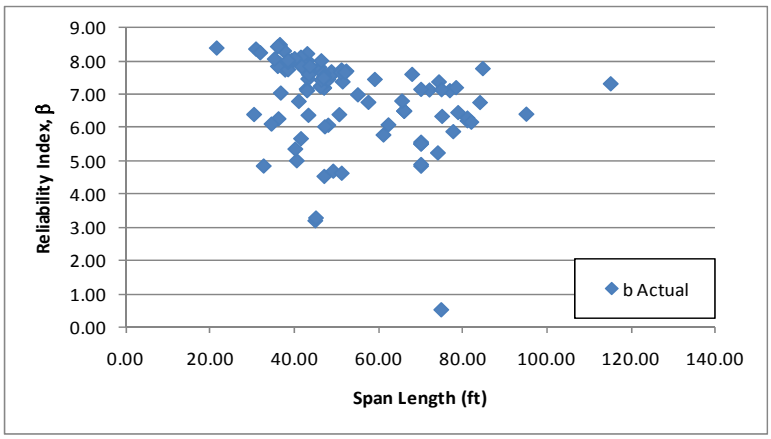


Figure D-449: Shear Reliability Indices for DE-07 Vehicle

Figure D-450 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 vehicle. The figure shows that a girder passing rating has a reliability index around 4.5, exceeding the target reliability of 2.5. This indicates that the live load factors in the MBE may be over-conservative and can be reduced.

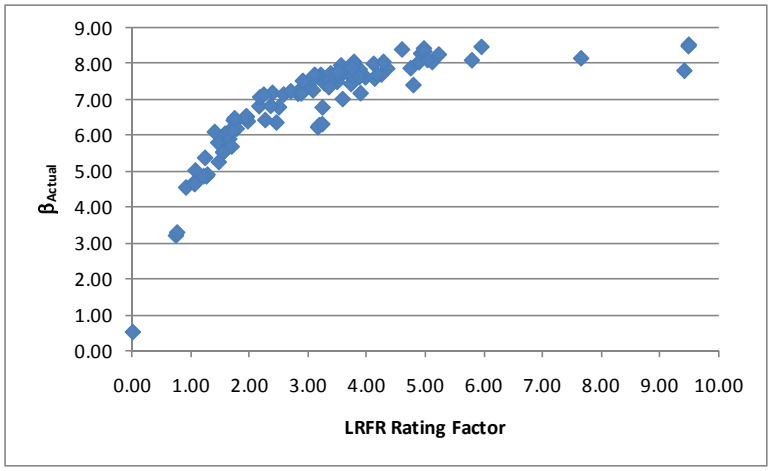
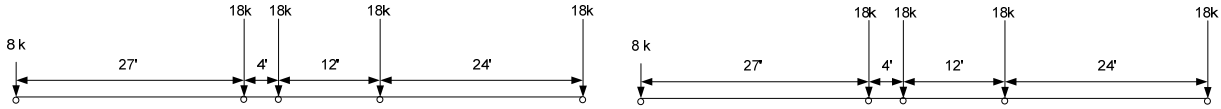


Figure D-450: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

D.4.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-451. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

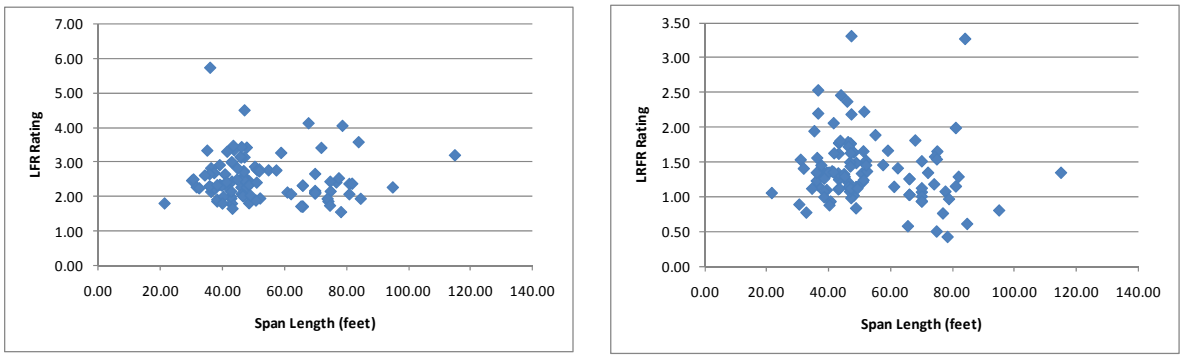
Figure D-451: Vehicle Loadings and Load Factors

D.4.4.1 Moment

The following section contains the results for interior, non-composite prestressed box girders within simple span bridges for the FL-04 Vehicle.

D.4.4.1.1 Rating Factors

Figure D-452 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 16 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. Five of the sixteen girders with LRFR ratings less than 1.0 are controlled by longitudinal steel rating at the support. The LFR ratings are between 1.75 and 3.5 while the LRFR ratings are between 1.0 and 2.0 for most girders.



(a) (b)

Figure D-452: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure D-453 shows the percentage of girders with moment ratings in each rating range for the FL-04 Vehicle. The percentage of girders with ratings greater than 1.0 ranges from 79.8 to 87.5%, with lower percentages corresponding to higher ADTTs for LRFR. At most one-fifth of girders will be affected by the switch from LFR to LRFR as all girders have LFR ratings greater than 1.0.

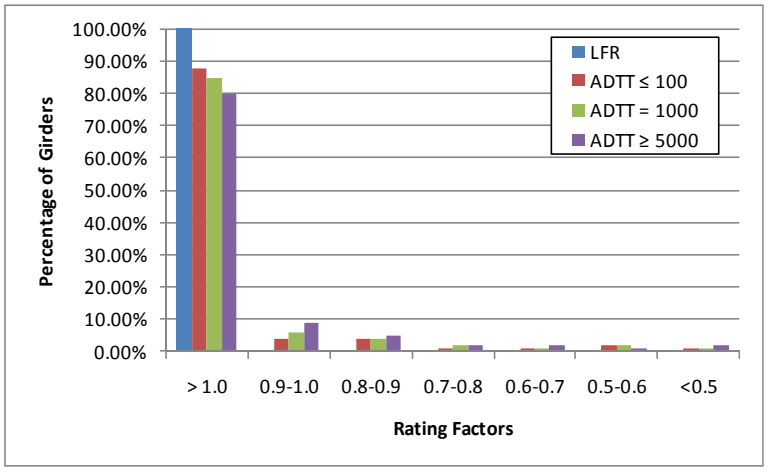


Figure D-453: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

D.4.4.1.2 Rating Factor Comparisons

Figure D-454 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. As mentioned before there are very few (1) with an LRFR rating greater than the LFR rating. The LRFR rating is typically 40 to 70% of the LFR rating.

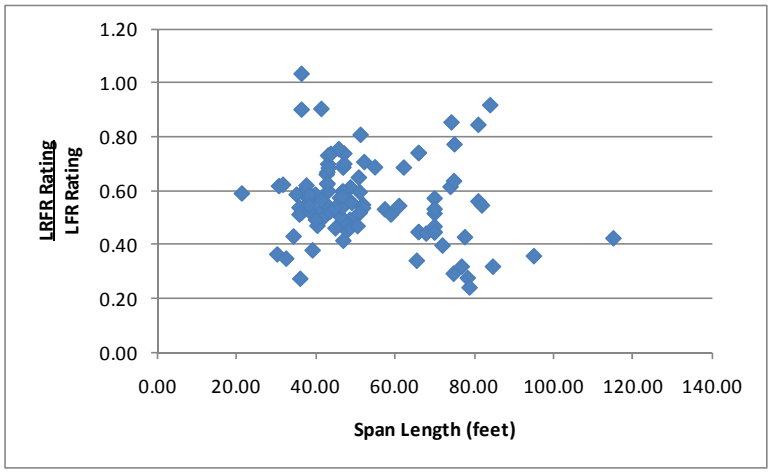


Figure D-454: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

D.4.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-455 shows that all girders have a reliability index based upon girder strength that is greater than the target reliability index of 2.5. The reliability index is between six and ten for most girders with several approaching four.

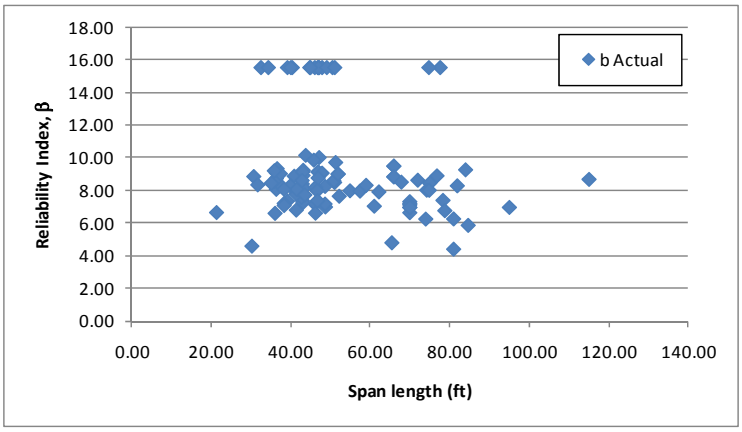


Figure D-455: Flexure Reliability Indices for FL-04 Vehicle

Figure D-456 shows the reliability index for moment plotted against the LRFR flexure rating for the FL-04 vehicle. The reliability index for most girders with ratings above 1.0 is above six, above the target reliability of 2.5. This indicates that the current load factors in the MBE are over-conservative.

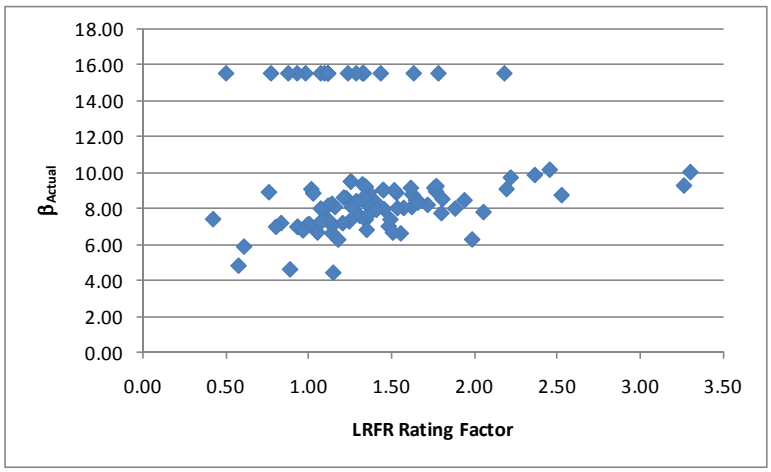
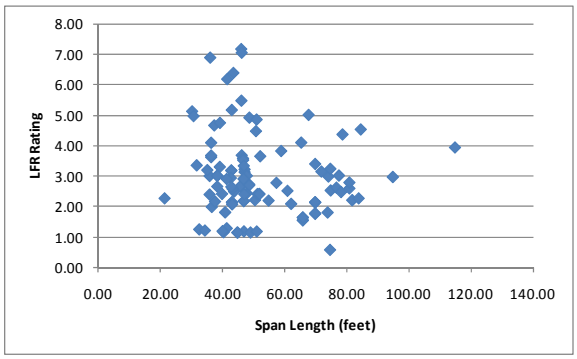


Figure D-456: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

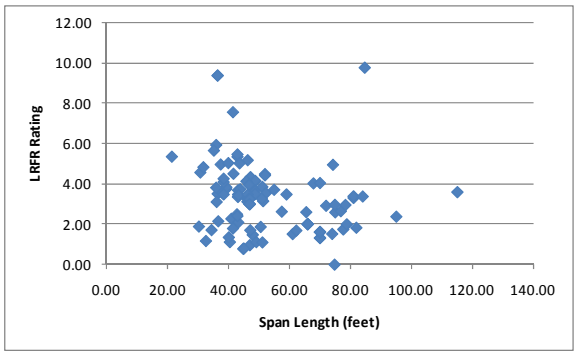
D.4.4.2 Shear

D.4.4.2.1 Rating Factors

For shear, there is one girder that has an LFR rating factor less than 1.0, four girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 47% of the girders in this subset. Figure D-457 shows the LFR and LRFR ratings. The LFR ratings are between two and four for most girders while the LRFR ratings are between one and five for most girders.



(a)



(b)

Figure D-457: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure D-458 shows the percentage of girders with shear ratings in each rating range for the FL-04 vehicle. 6.7% of girders have ratings less than 1.0 for the worst LRFR condition with an ADTT of 5,000. 1% of girders have LFR ratings less than 1.0; approximately 6% of girders will be affected negatively by the switch from LFR to LRFR. This is not a significant number of girders.

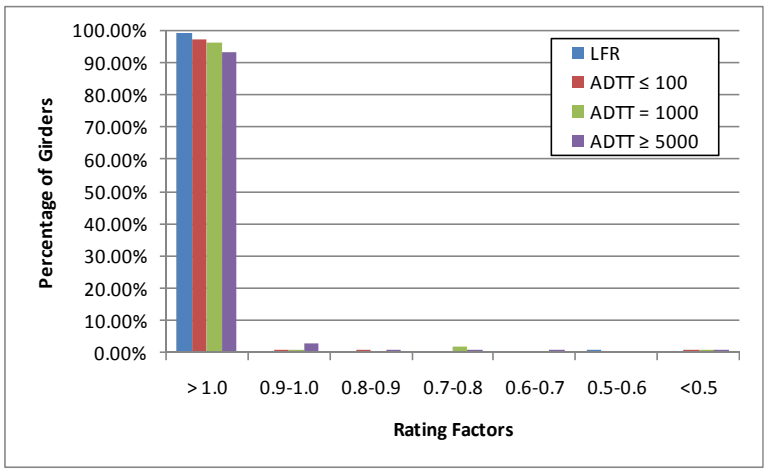


Figure D-458: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

D.4.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-459 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with the ratio decreasing for longer span lengths. 53% of girders have an LRFR rating that exceeds the LFR rating.

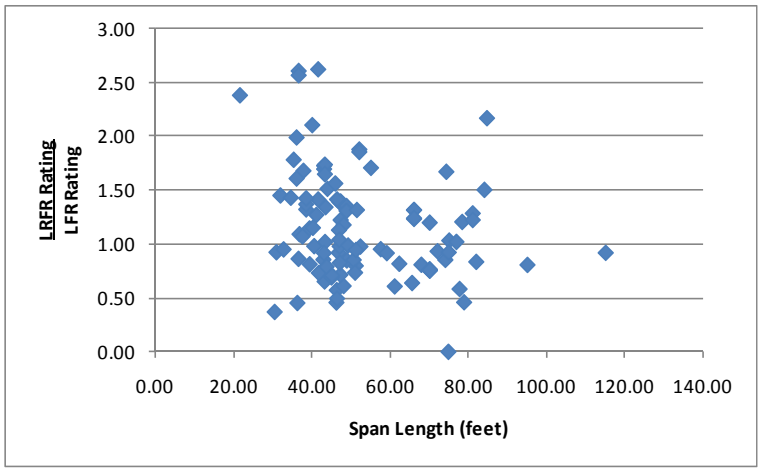


Figure D-459: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

D.4.4.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all but one girder as shown in Figure D-460. The reliability index is between six and nine for most girders.

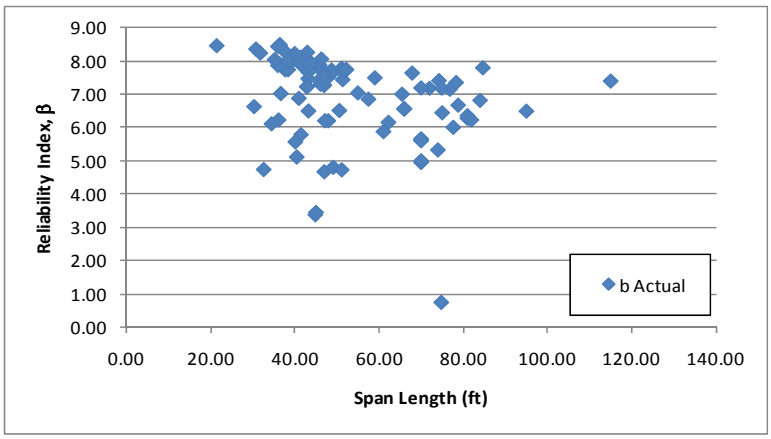


Figure D-460: Shear Reliability Indices for FL-04 Vehicle

Figure D-461 shows the reliability index for shear plotted against the LRFR shear for the FL-04 Vehicle. The reliability index for a girder passing rating is approximately 4.5, exceeding the target reliability of 2.5. This indicates that the live load factors currently in the MBE are over-conservative.

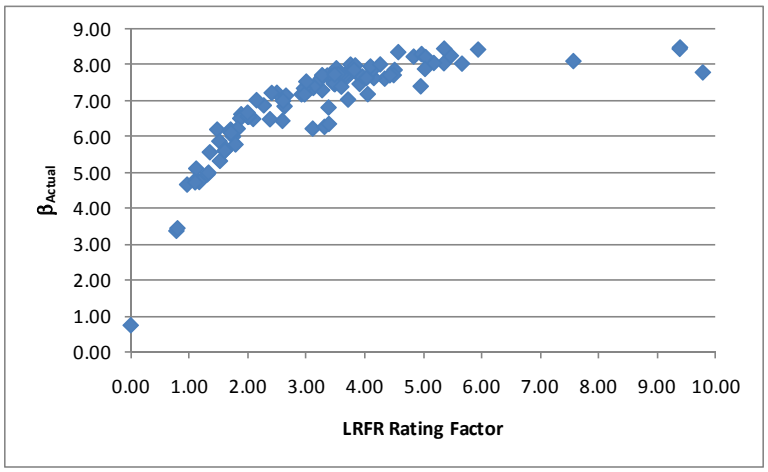
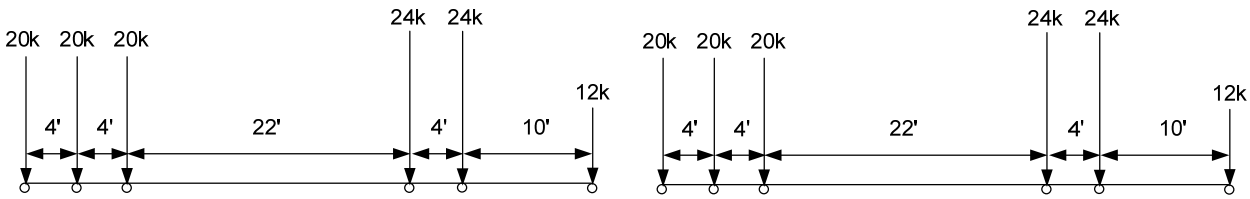


Figure D-461: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

D.4.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-462. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading

plus 0.2 klf for spans greater than 200 feet
LRFR Loading

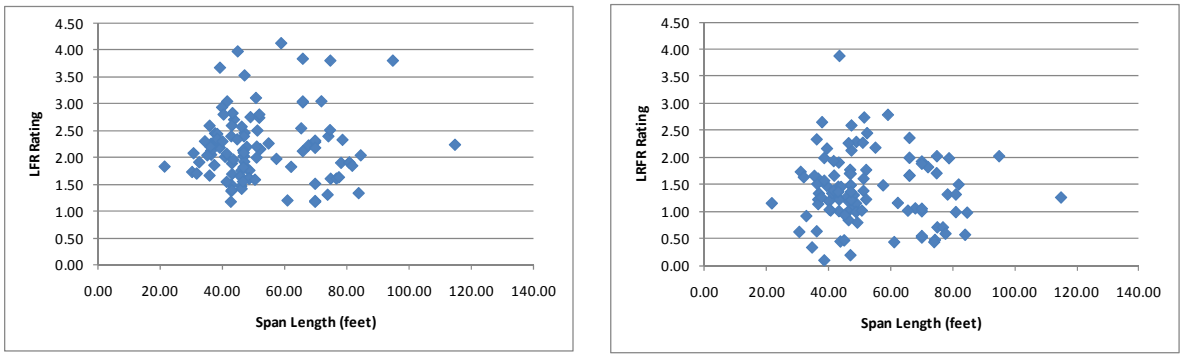
Figure D-462: Vehicle Loadings and Load Factors

D.4.5.1 Moment

The following section contains the results for interior, non-composite prestressed box girders within simple span bridges for the IL-01 Vehicle.

D.4.5.1.1 Rating Factors

Figure D-463 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 23 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 93% of the girders in this subset. Five of the twenty three girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR ratings are between 1.5 and 3.0 for most girders while the LRFR rating is between 1.0 and 2.0 for most girders.



(a) (b)

Figure D-463: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure D-464 shows the percentage of girders with moment ratings in each rating range for the IL-01 vehicle. The percentage of girders with ratings greater than 1.0 varies with the type of permit. 72.1% of girders have ratings greater than 1.0 for a multi-trip permit with ADTT of 5,000 while 78.9% of girders have ratings greater than 1.0 for a single trip, escorted permit. At least 20% of girders are affected by the switch from LFR to LRFR, independent of the type of LRFR permit used. All girders have LFR ratings greater than 1.0.

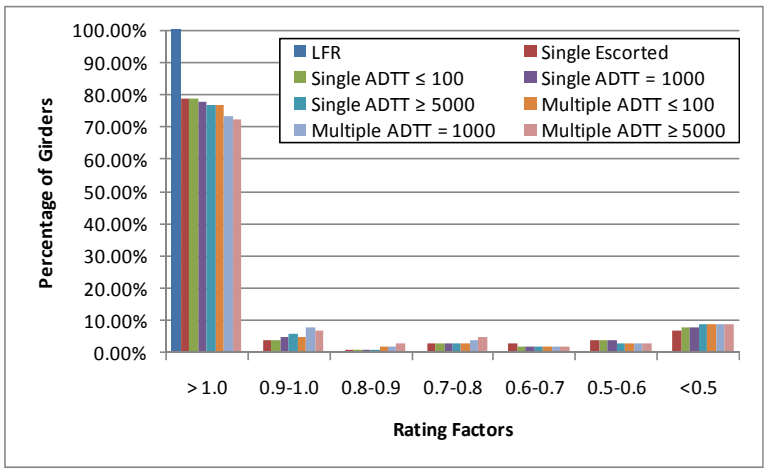


Figure D-464: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

D.4.5.1.2 Rating Factor Comparisons

Figure D-465 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.8, with the lower ratios generally coming from girders with longer spans. 7% of the girders have LRFR ratings exceeding the LFR rating for this vehicle.

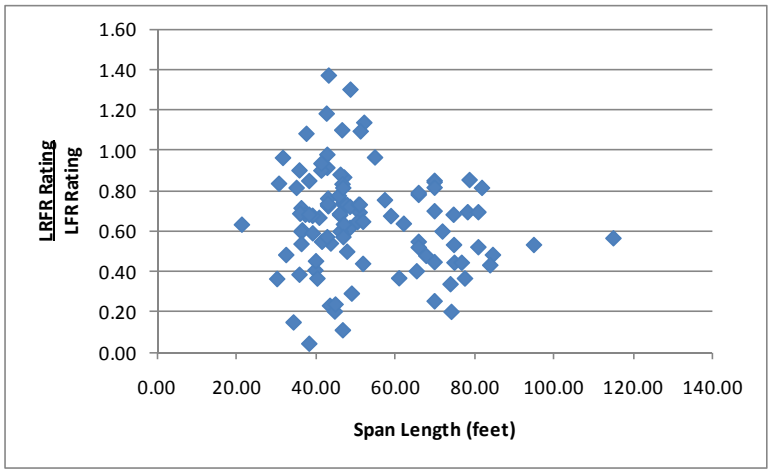


Figure D-465: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

D.4.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-466 shows that 13 girders have an actual reliability index that is less than the target reliability index of 3.5. The reliability index is between two and ten for most girders.

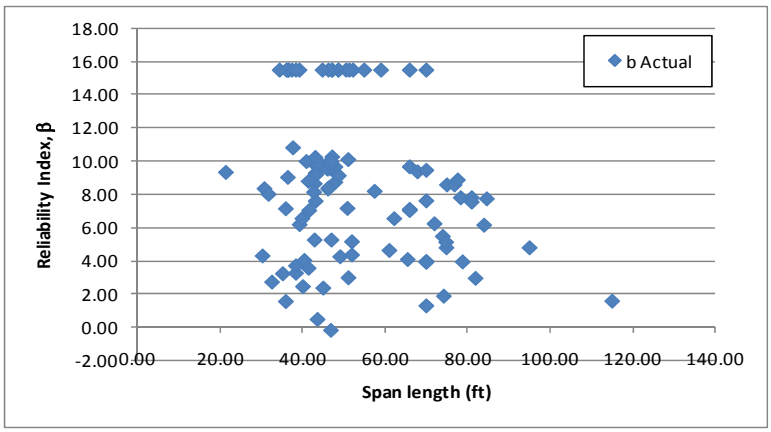


Figure D-466: Flexure Reliability Indices for IL-01 Vehicle

Figure D-467 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The figure shows that the reliability index for girders with ratings near 1.0 vary from 2.5 to 10 with more between six and ten then less than four. This suggests that for the average girder the reliability index will be greater than the target reliability index of 3.5. This indicates that the LRFR live load factors currently in use are over-conservative.

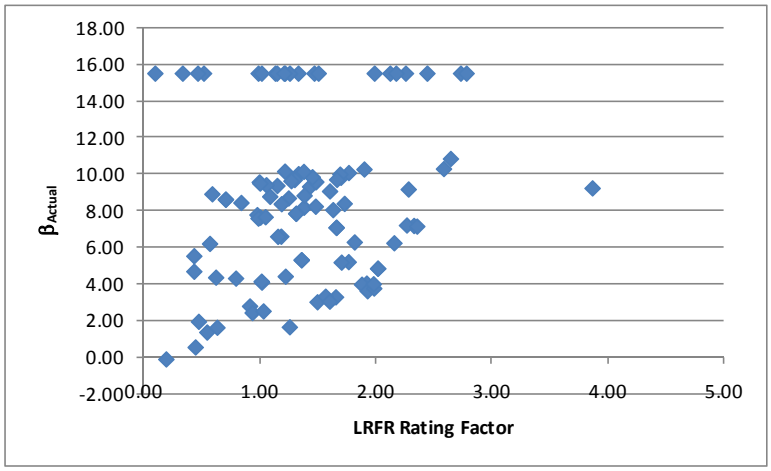
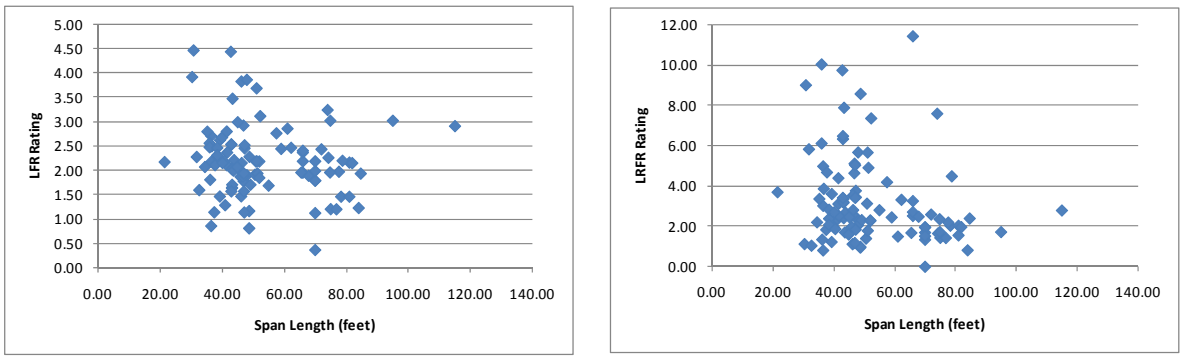


Figure D-467: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

D.4.5.2 Shear

D.4.5.2.1 Rating Factors

For shear, there are three girders that have LFR rating factors less than 1.0, five girders with LRFR ratings less than 1.0, and three girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 29% of the girders in this subset. Figure D-468 shows the LFR and LRFR ratings. The LFR ratings are between 1.5 and 3 while the LRFR ratings are between one and four for most girders.



(a) (b)

Figure D-468: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure D-469 shows the percentage of girders with shear ratings in each rating range for the IL-01 vehicle. A maximum of 9.6% of girders have LRFR ratings less than 1.0 for ADTTs of 1,000 and 5,000 and multi-trip permits. This percentage is reduced to 2.9% of girders for LFR and single trip, escorted permits. At most, 7% of girders will be affected by the switch from LFR to LRFR for the IL-01 vehicle.

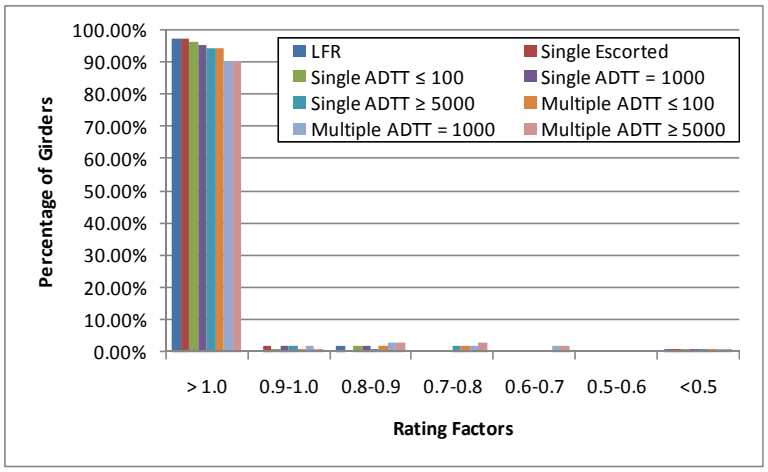


Figure D-469: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

D.4.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-470 shows the comparison of rating factors. 71% of the girders have higher LRFR ratings that LFR ratings; these girders are typically shorter spans. The ratio of ratings is between 0.5 and 2.5 for most girders.

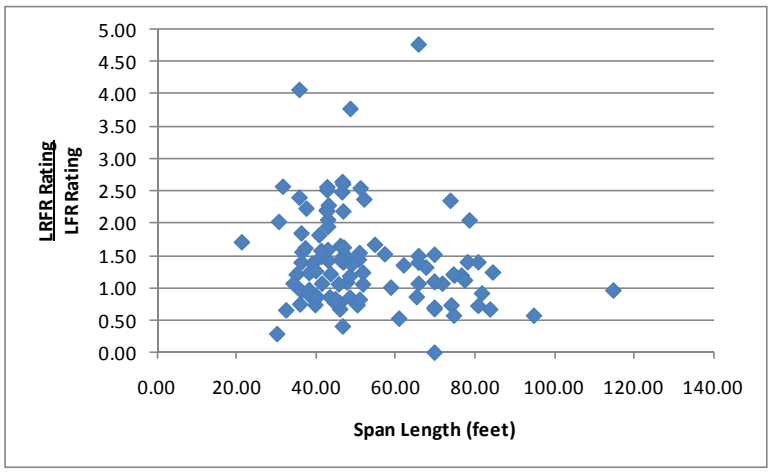


Figure D-470: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

D.4.5.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index for all but two girders as shown in Figure D-471. The reliability index is between six and nine for most girders with those not in this range below this six

.

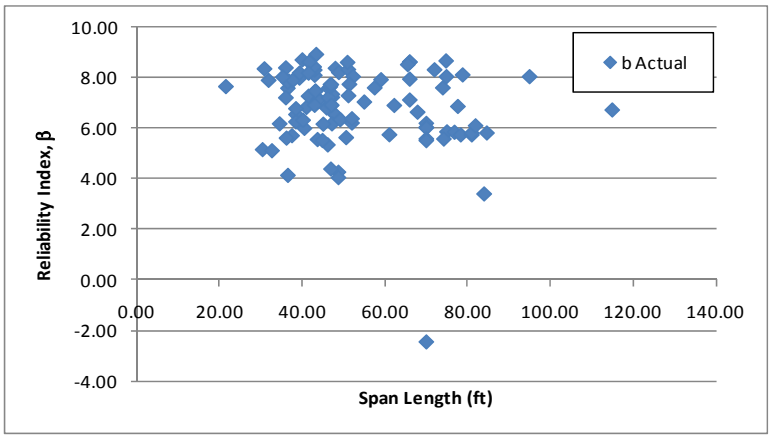


Figure D-471: Shear Reliability Indices for IL-01 Vehicle

Figure D-472 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 vehicle. The figure shows that girders with ratings of 1.0 have reliability indices of approximately 4.5, higher than the target reliability of 3.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

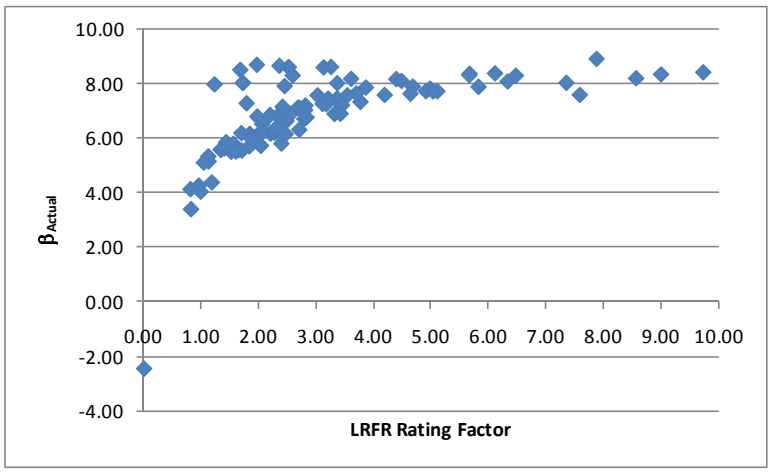


Figure D-472: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

D.4.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-473. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

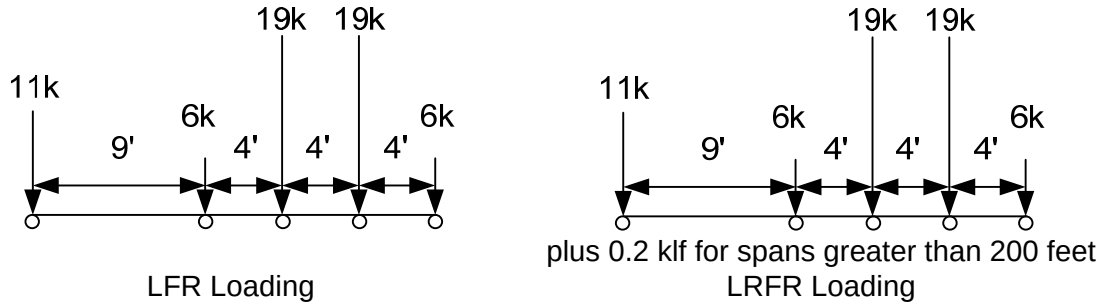


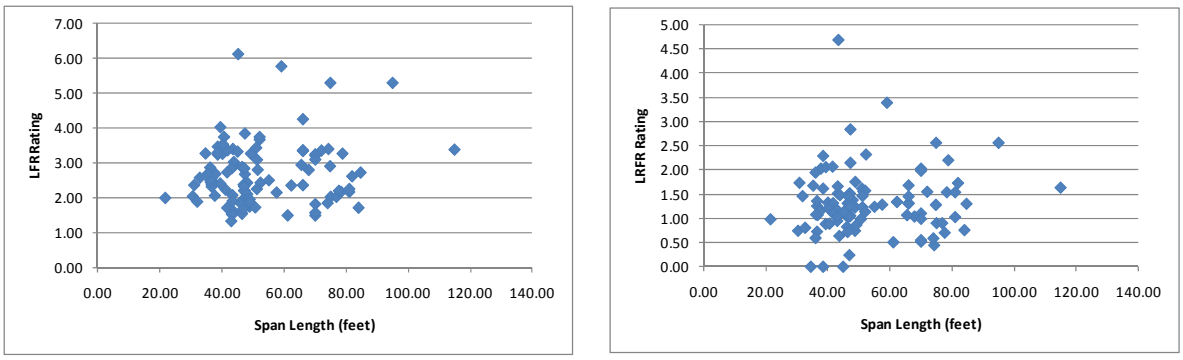
Figure D-473: Vehicle Loadings and Load Factors

D.4.6.1 Moment

The following section contains the results for interior, non-composite prestressed box girders within simple span bridges for the NC-21 Vehicle.

D.4.6.1.1 Rating Factors

Figure D-474 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 28 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. Seven of the twenty eight girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR rating is between 1.5 and 4 while the LRFR ratings are between 0.5 and 2.0.



(a) (b)

Figure D-474: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure D-475 shows the percentage of girders with moment ratings in each range of ratings for the NC-21 Vehicle. Between 26 and 30% of girders have LRFR ratings less than 1.0, with higher percentages corresponding to higher ADTTs. This is a significant number of girders affected by the switch from LFR to LRFR. All girders have LFR ratings greater than 1.0.

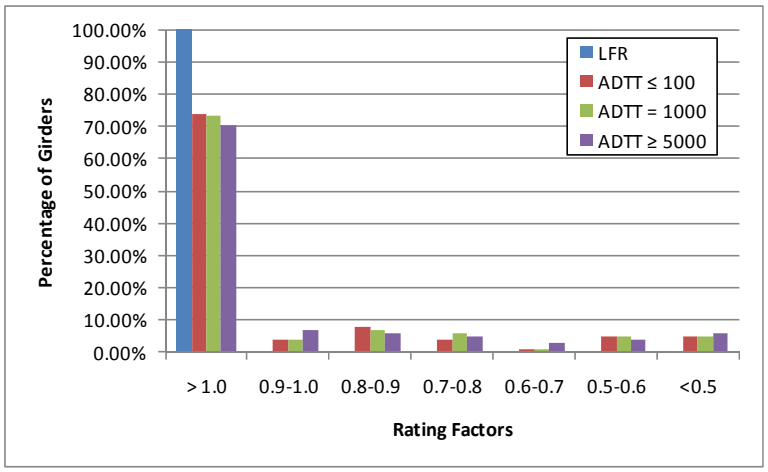


Figure D-475: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

D.4.6.1.2 Rating Factor Comparisons

Figure D-476 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating with only one girder having an LRFR rating that is greater than the LFR rating. The ratio is generally between 0.2 and 0.8 for this vehicle, with the lower ratios corresponding to girders with longer spans.

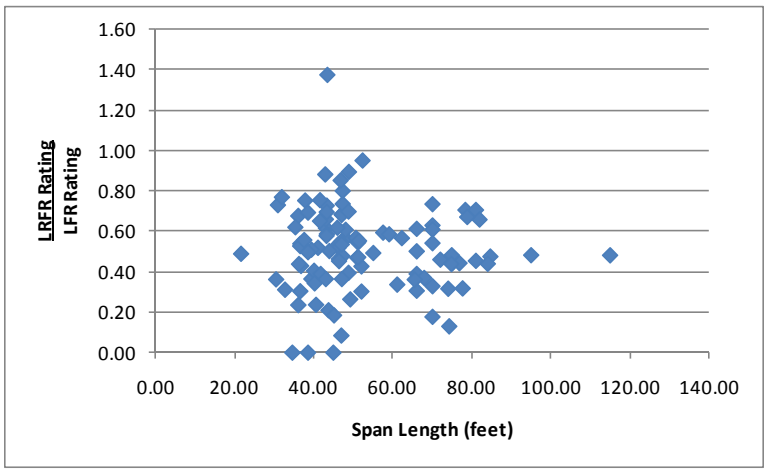


Figure D-476: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

D.4.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-477 shows that seven girders have a reliability index based upon girder strength that is less than the target reliability index based of 2.5. The reliability index for most girders is between two and ten.

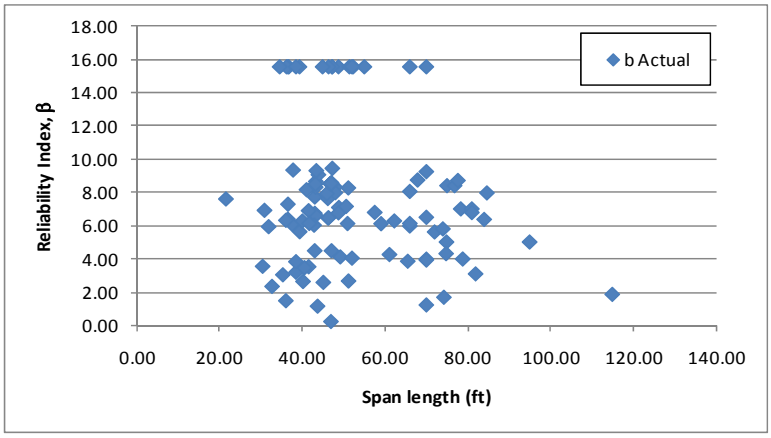


Figure D-477: Flexure Reliability Indices for NC-21 Vehicle

Figure D-478 shows the reliability index for moment against the LRFR flexure rating for the NC-21 Vehicle. The reliability index for a girder with a rating of 1.0 is varies from four to nine, with an average near five. This exceeds the target reliability of 2.5, indicating that the current live load factors in the MBE are over- conservative and can be reduced.

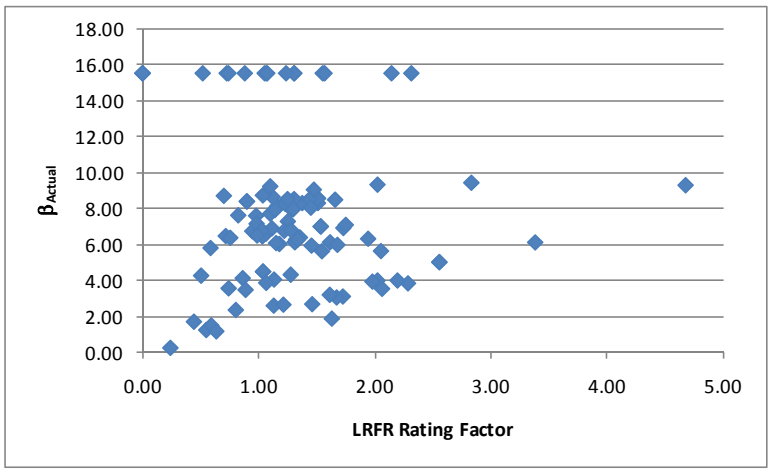
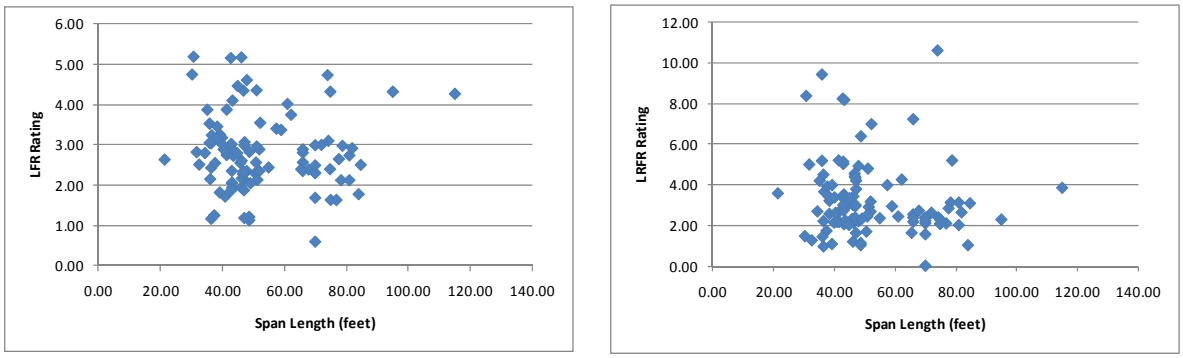


Figure D-478: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

D.4.6.2 Shear

D.4.6.2.1 Rating Factors

For shear, there is one girder that has an LFR rating factor less than 1.0, two girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 43% of the girders in this subset. Figure D-479 shows the LFR and LRFR ratings, respectively. The LFR ratings are between 1.5 and 4 while the LRFR ratings are between one and four.



(a) (b)

Figure D-479: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure D-480 shows the percentage of girders with shear ratings in each rating range for the NC-21 vehicle. Between one and six percent of girders have LRFR ratings less than 1.0. Higher percentages of girders with ratings less than 1.0 correspond to higher ADTTs. One percent of girders have an LFR rating less than 1.0 for shear. At most, 5% of girders are affected by the switch to LRFR from LFR and most have ratings between 0.9 and 1.0.

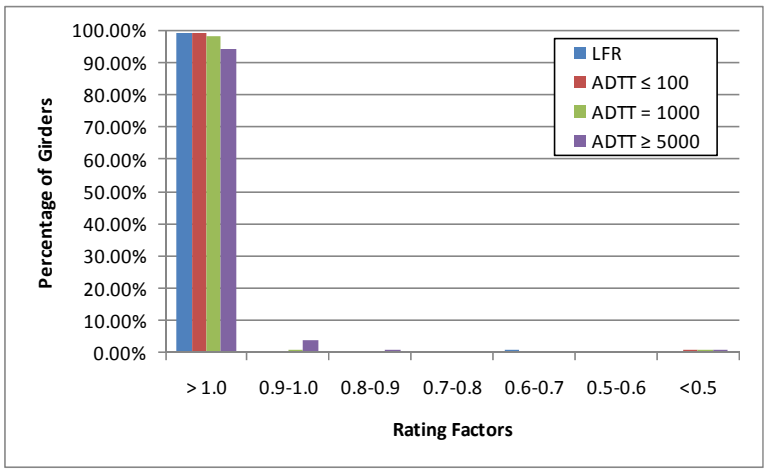


Figure D-480: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

D.4.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-481 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0. Longer span girders are the most likely to have an LRFR rating smaller than the LFR rating.

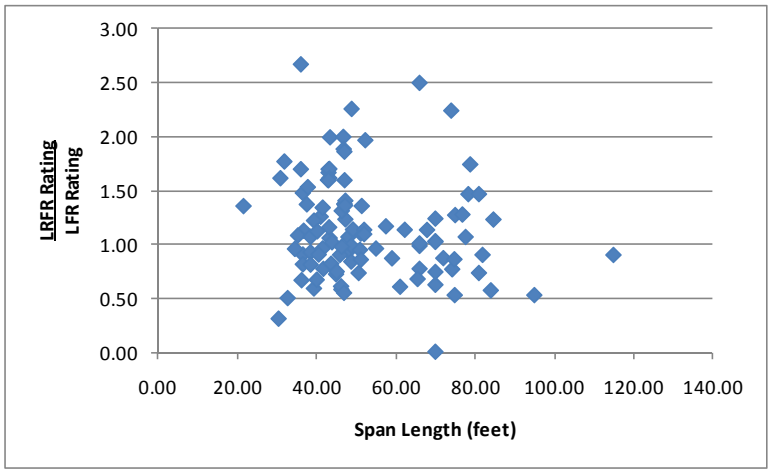


Figure D-481: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

D.4.6.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all but one girder as shown in Figure D-482. The reliability index is between six and nine for most girders.

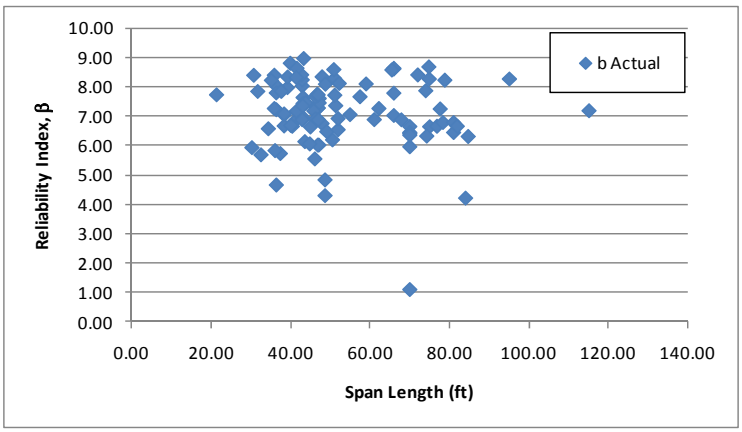


Figure D-482: Shear Reliability Indices for NC-21 Vehicle

Figure D-483 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 Vehicle. The figure shows that girders with ratings near one have reliability indices between four and five which exceeds the target reliability of 2.5. This indicates that the live load factors currently in the MBE are over-conservative and can be reduced.

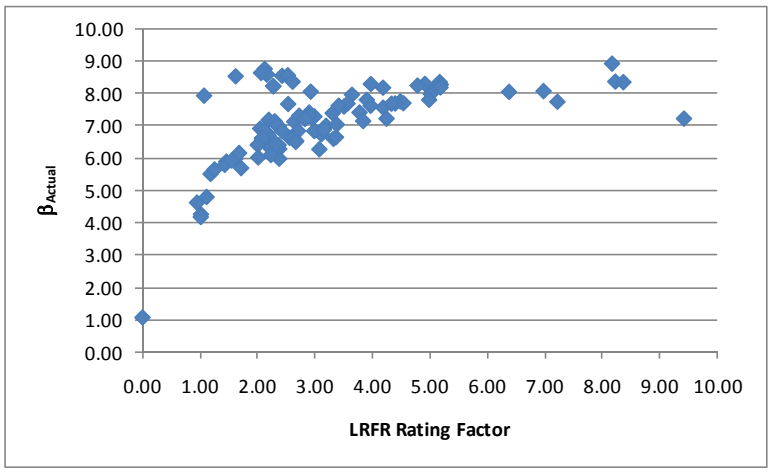


Figure D-483: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

D.4.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-484. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

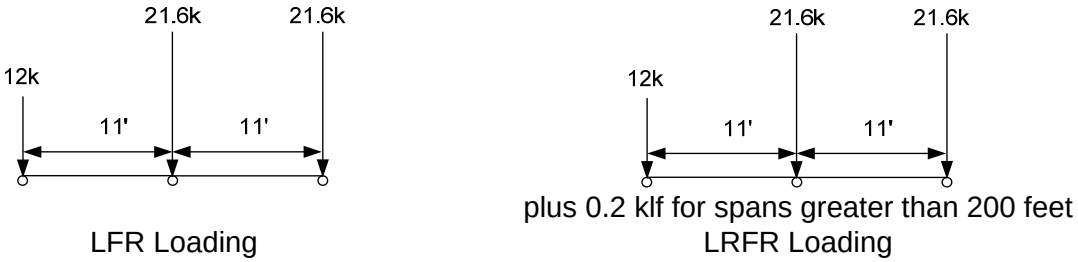


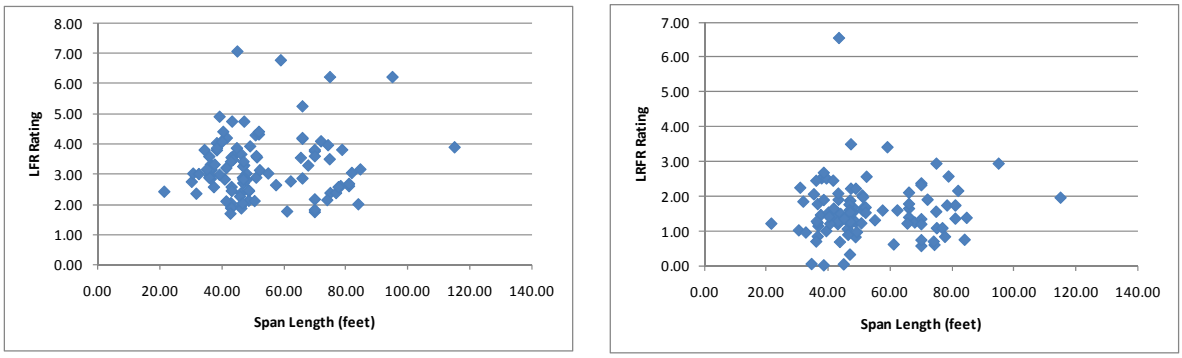
Figure D-484: Vehicle Loadings and Load Factors

D.4.7.1 Moment

The following section contains the results for interior, non-composite prestressed box girders within simple span bridges for the NM-04 Vehicle.

D.4.7.1.1 Rating Factors

Figure D-485 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 19 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 99% of the girders in this subset. Seven of the nineteen girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR ratings are between two and five while the LRFR ratings are between one and three.



(a) (b)

Figure D-485: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure D-486 shows the percentage of girders with moment ratings in each rating range for NM-04 vehicle. Between 17.3 and 19.3 percent of girders have LRFR ratings less than 1.0. This is a significant number of girders with ratings less than 1.0 for LRFR when LFR has no girders with ratings less than 1.0.

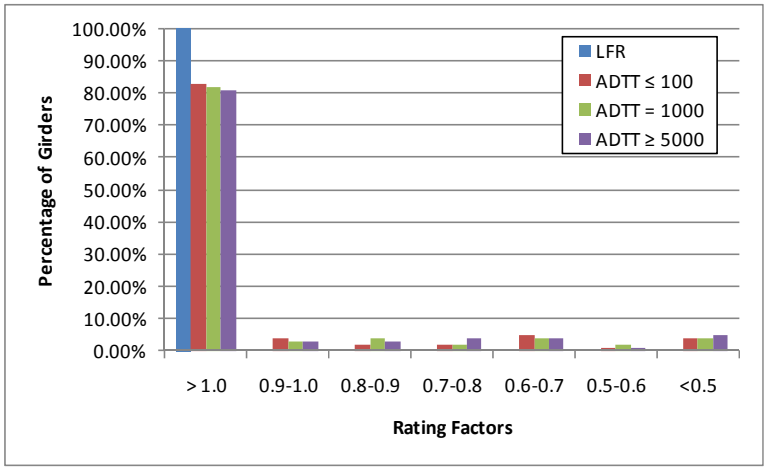


Figure D-486: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

D.4.7.1.2 Rating Factor Comparisons

Figure D-487 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and

0.8, with one girder having LRFR ratings greater than the LFR rating. Shorter spans are more likely to have similar ratings than the longer spans shown in the graph.

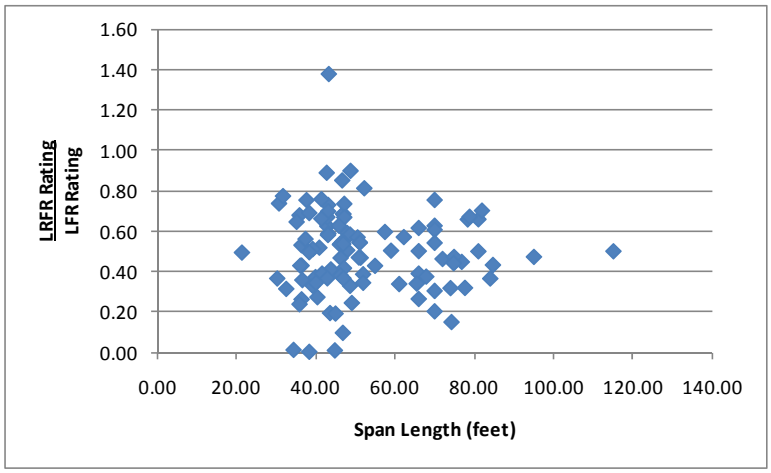


Figure D-487: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

D.4.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-488 shows that six girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between two and ten for most girders.

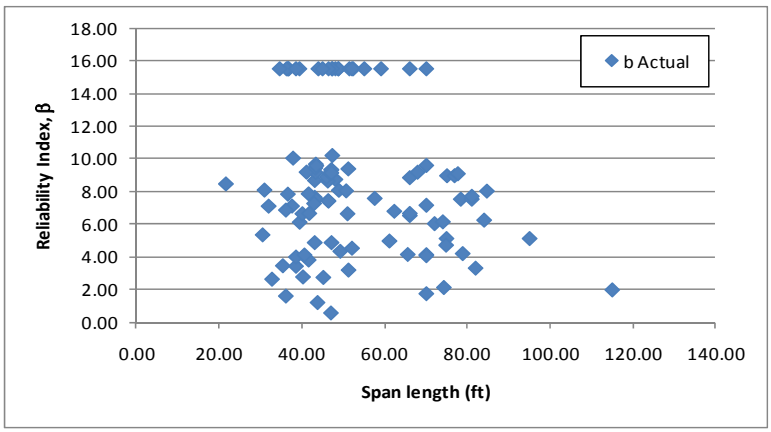


Figure D-488: Flexure Reliability Indices for NM-04 Vehicle

Figure D-489 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 Vehicle. The figure shows that the reliability index for a girder with a rating of 1.0 is between 2.5 and 9.0. Most of the reliability indices are greater than 2.5 which suggest that an average girder will have a reliability index greater than 2.5, which is the target reliability. This indicates that the current LRFR live load factors are over-conservative and can be reduced.

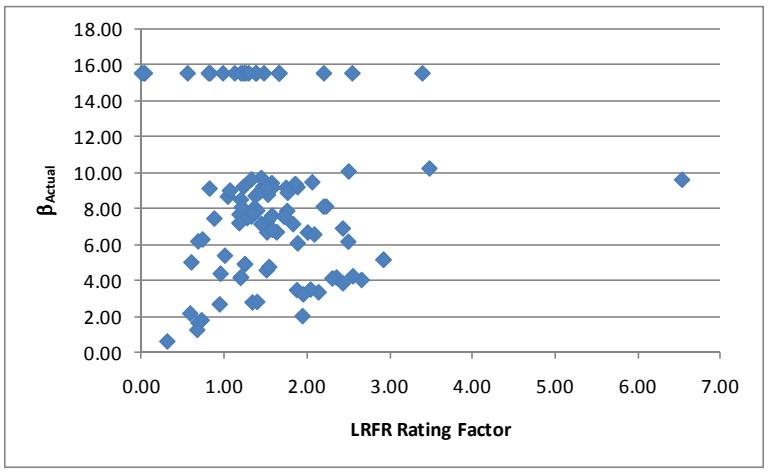
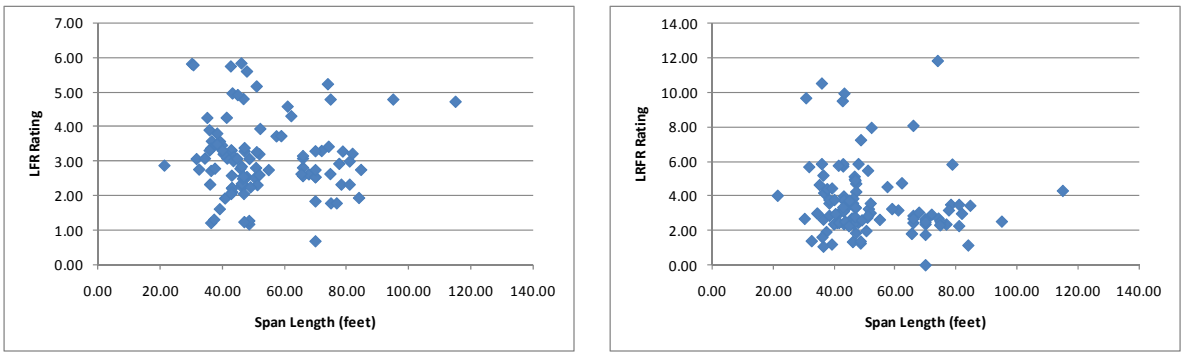


Figure D-489: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

D.4.7.2 Shear

D.4.7.2.1 Rating Factors

For shear, there are zero girders with a rating less than 1.0 for either method. The LFR Rating is greater than the LRFR rating for 39% of the girders in this subset. Figure D-490 shows the LFR and LRFR ratings, respectively. The LFR Rating is between two and four for most girders with some above five. The LRFR rating is between two and six for most girders.



(a) (b)

Figure D-490: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure D-491 shows the percentage of girders with shear ratings in each rating range for the NM0-04 vehicle. 1% of girders have LRFR ratings less than 1.0 for LFR, ADTT of 100, and ADTT of 1,000. 2% of girders have LRFR ratings less than 1.0 for an LRFR rating with ADTT of 5,000. Very few girders are affected by the switch from LFR to LRFR for shear.

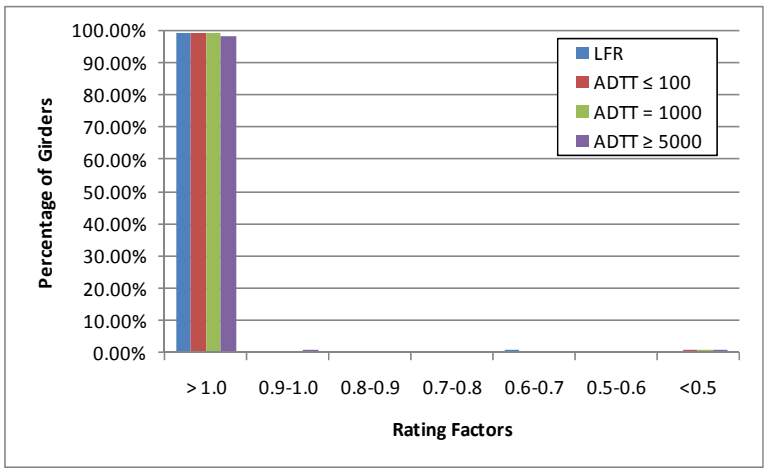


Figure D-491: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

D.4.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-492 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0. Shorter spans are more likely to have LRFR ratings greater than longer spans.

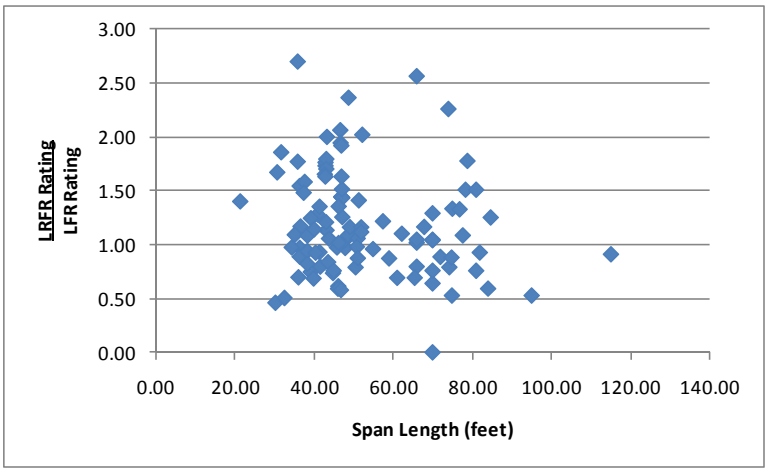


Figure D-492: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

D.4.7.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all but one girder as shown in Figure D-493. The actual reliability index is between six and nine for most girders.

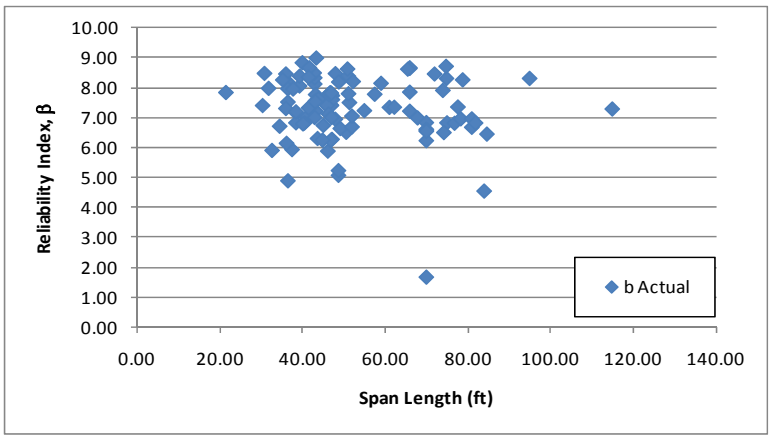


Figure D-493: Shear Reliability Indices for NM-04 Vehicle

Figure D-494 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 Vehicle. The figure shows that a girder with a rating factor of 1.0 will have a reliability index of approximately 4.0. This is greater than the target reliability of 2.5; this indicates that the current live load factors in the MBE are over-conservative and can be reduced.

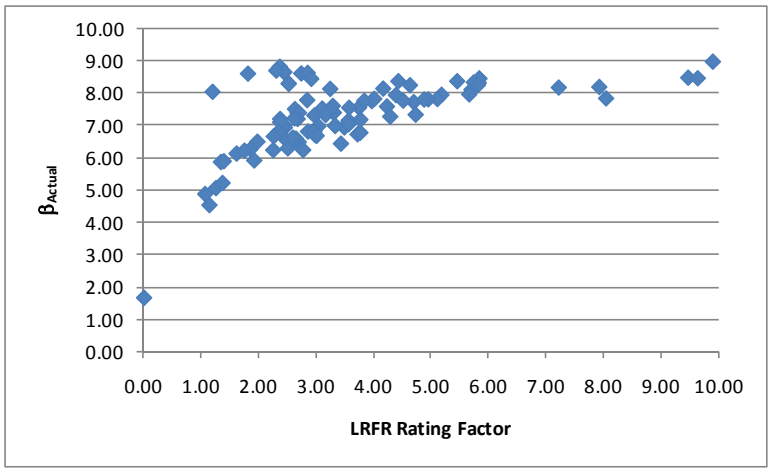
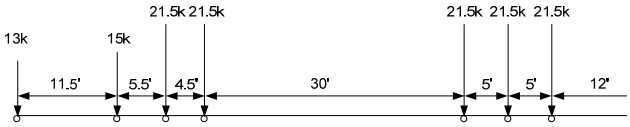


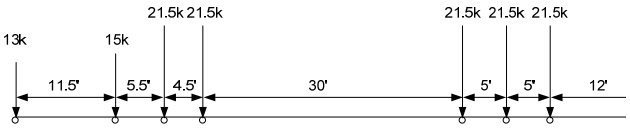
Figure D-494: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

D.4.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-495. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading



plus 0.2 klf for spans greater than 200 feet
LRFR Loading

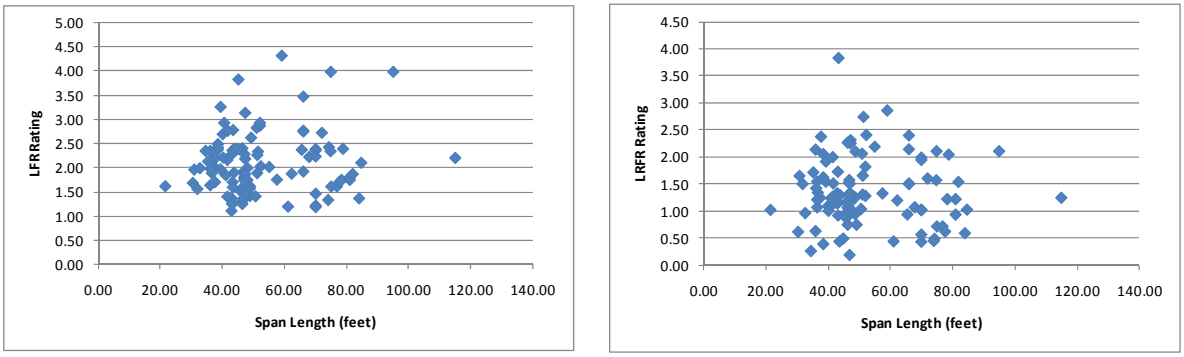
Figure D-495: Vehicle Loadings and Load Factors

D.4.8.1 Moment

The following section contains the results for interior, non-composite prestressed box girders within simple span bridges for the OR-06 Vehicle.

D.4.8.1.1 Rating Factors

Figure D-496 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 26 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 91% of the girders in this subset. Five of the 26 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR rating is between 1.0 and 2.5 while the LRFR rating is between one and two.



(a) (b)

Figure D-496: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure D-497 shows the percentage of girders with moment ratings in each rating range for the OR-06 vehicle. Between 24.0 and 28.9% of girders have LRFR ratings less than 1.0 with the highest percentage being for the multi-trip permits. This is a significant number of girders affected by the switch from LFR to LRFR; all girders have LFR ratings that are greater than 1.0.

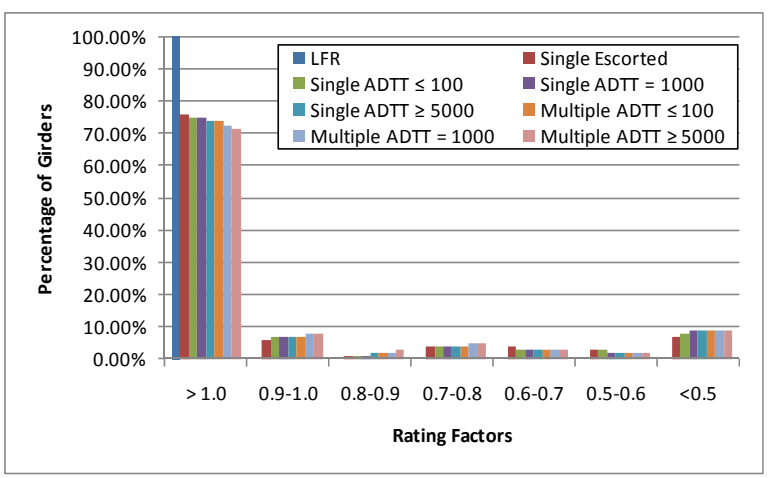


Figure D-497: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

D.4.8.1.2 Rating Factor Comparisons

Figure D-498 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.8, with nine girders having LRFR ratings greater than the LFR rating.

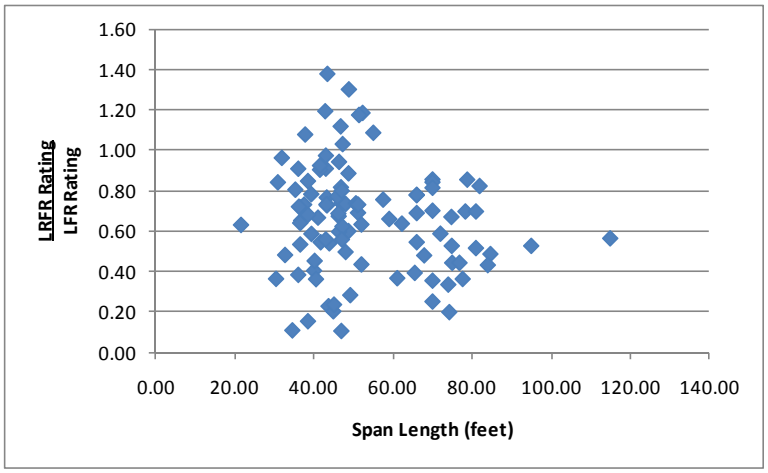


Figure D-498: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

D.4.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-499 shows that thirteen girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5 for this vehicle.

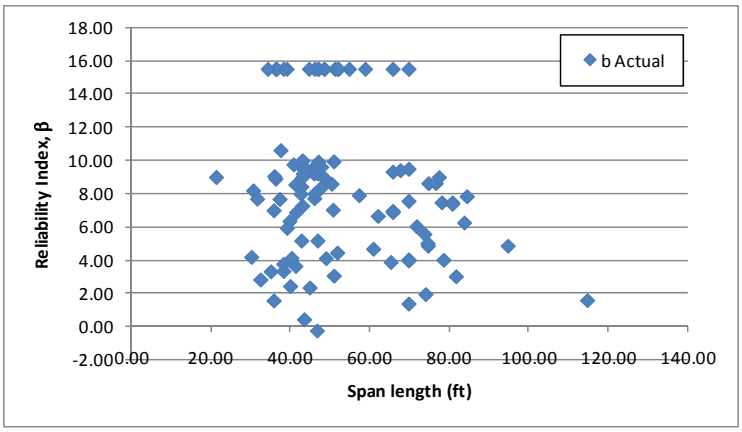


Figure D-499: Flexure Reliability Indices for OR-06 Vehicle

Figure D-500 shows the reliability index for moment plotted against the LRFR flexure rating for the OR-06 Vehicle. Girders with an LRFR rating of 1.0 have reliability indices ranging from 2.25 to 9 with most girders between four and nine. This indicates that the average reliability index will be greater than the target reliability of 3.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

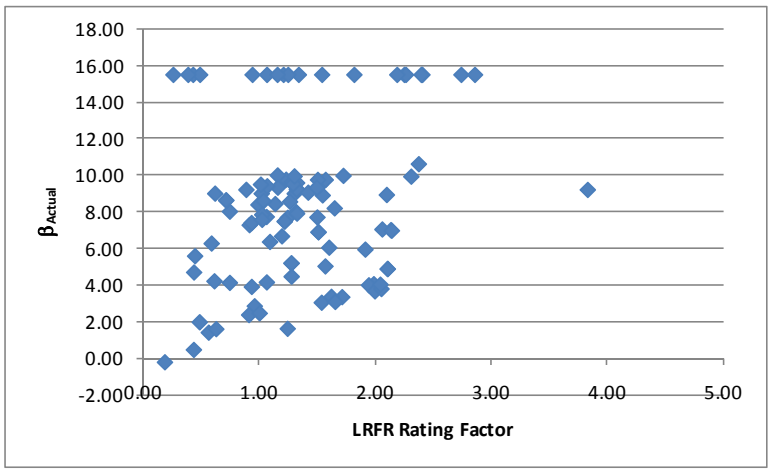
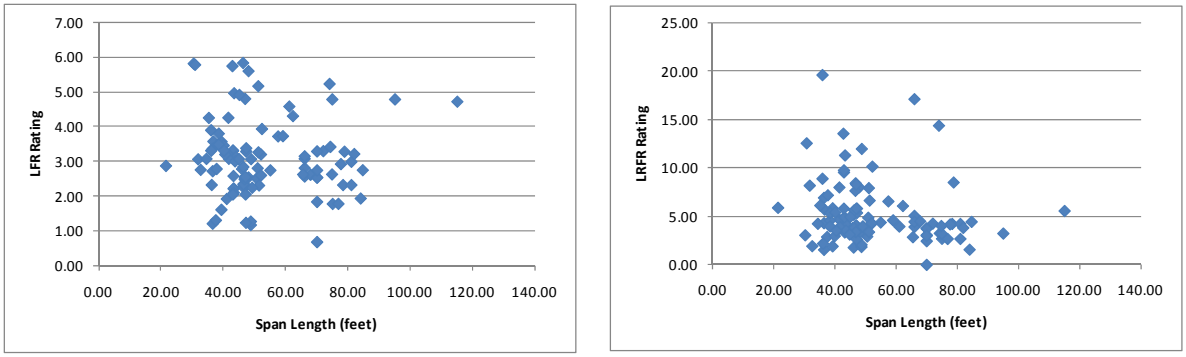


Figure D-500: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

D.4.8.2 Shear

D.4.8.2.1 Rating Factors

For shear, there is one girder that has both LFR and LRFR ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 15% of the girders in this subset. Figure D-501 shows the LFR and LRFR ratings. The LFR rating is between two and four for most girders while the LRFR ratings are between one and six for most girders.



(a) (b)

Figure D-501: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure D-502 shows the percentage of girders with shear ratings in each rating range for the OR-06 vehicle. The figure shows that 99% of girders have ratings greater than 1.0 for LFR and for all LRFR permit types. The one percent of girders with ratings less than 1.0 is generally less than 0.5. Very few girders are affected by the switch from LFR to LRFR.

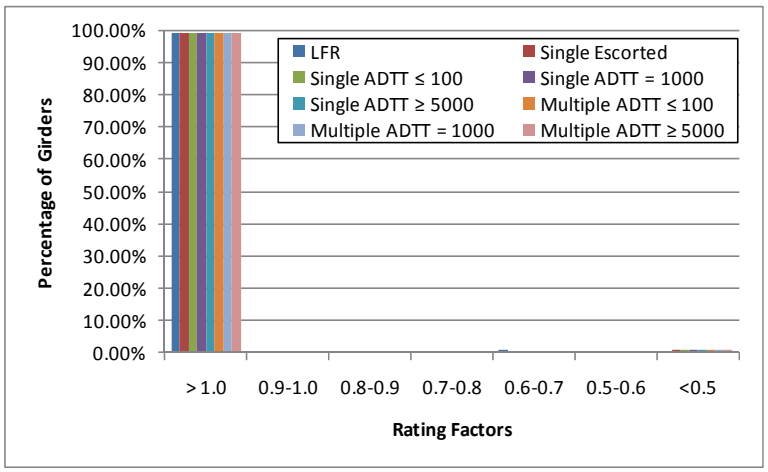


Figure D-502: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

D.4.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-503 shows the comparison of rating factors. The ratio is generally between one and two for this set of girders with this vehicle. Short spans are more likely to have LRFR ratings greater than LFR rating and higher ratios.

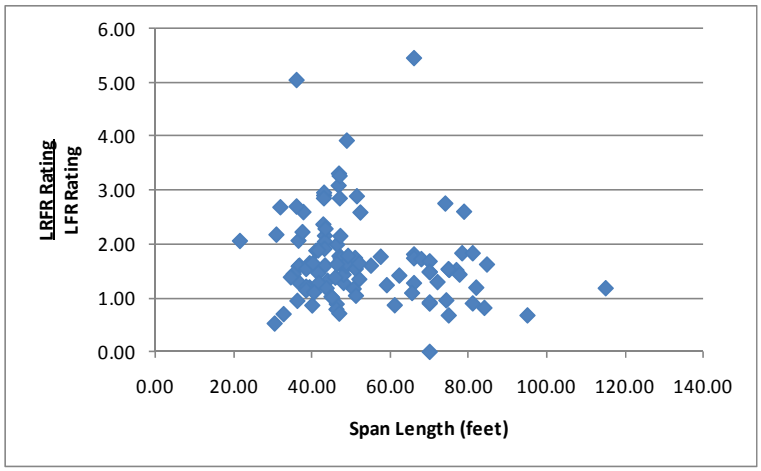


Figure D-503: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

D.4.8.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index for all but one girder as shown in Figure D-504. This girder likely does not have properly define shear reinforcement. The reliability index is between six and nine for most girders in this group.

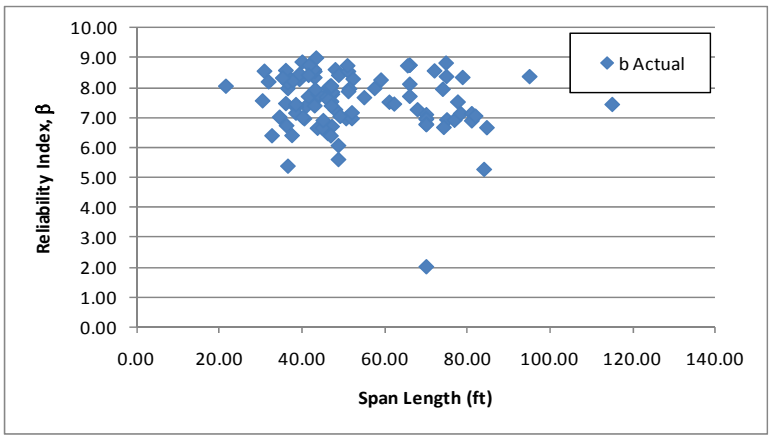


Figure D-504: Shear Reliability Indices for OR-06 Vehicle

Figure D-505 shows the shear reliability index plotted against the LRFR shear rating for the OR-06 vehicle. The figure shows that girders with a rating factor of 1.0 have reliability indices near 4.0. This is above the target reliability index of 3.5; the current live load factors are over-conservative for this vehicle.

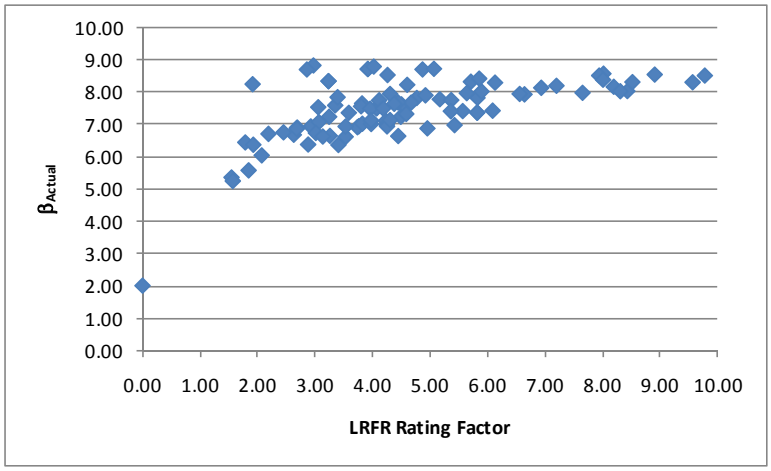
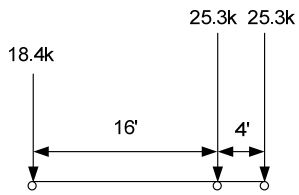


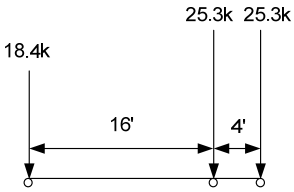
Figure D-505: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

D.4.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-506. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet
LRFR Loading

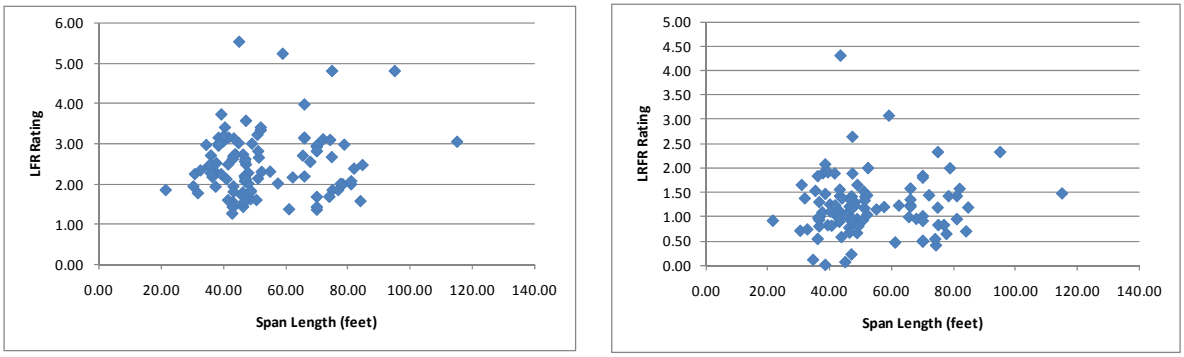
Figure D-506: Vehicle Loadings and Load Factors

D.4.9.1 Moment

The following section contains the results for interior, non-composite prestressed box girders within simple span bridges for the TX-04 Vehicle.

D.4.9.1.1 Rating Factors

Figure D-507 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 40 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. Twelve of the forty girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR rating is between one and three while the LRFR rating is between 0.5 and 2.0.



(a) (b)

Figure D-507: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure D-508 shows the percentage of girders with moment ratings in each rating range for the TX-04 vehicle. The figure shows that 35 to 40% of girders have LRFR ratings less than 1.0. This is a significant number of girders with LRFR ratings less than 1.0 when all girders have LFR ratings that are greater than 1.0. Approximately one-quarter of those with LRFR ratings less than 1.0 have ratings between 0.9 and 1.0.

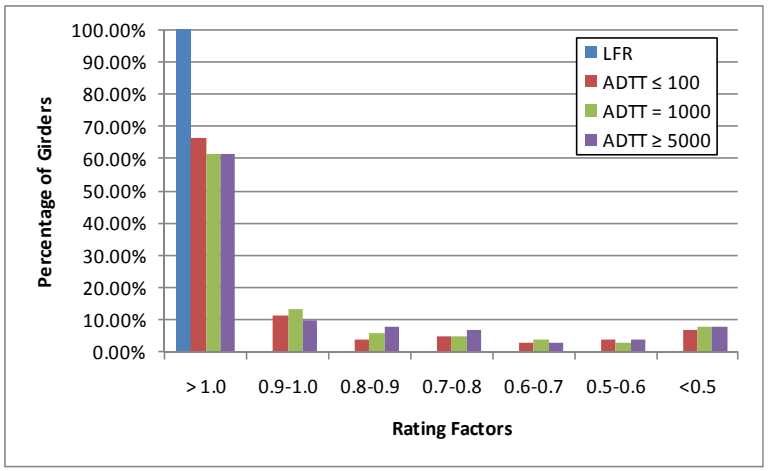


Figure D-508: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

D.4.9.1.2 Rating Factor Comparisons

Figure D-509 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is generally 20 to 80% of the LFR rating, with short spans having LRFR ratings nearer to the LFR rating. One girder has an LRFR rating that exceeds the LFR rating.

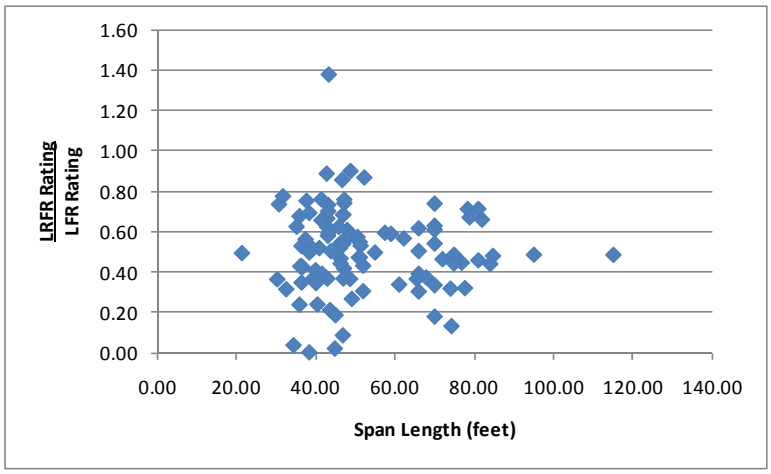


Figure D-509: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

D.4.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-510 shows ten girders having a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index for most girders is between two and nine.

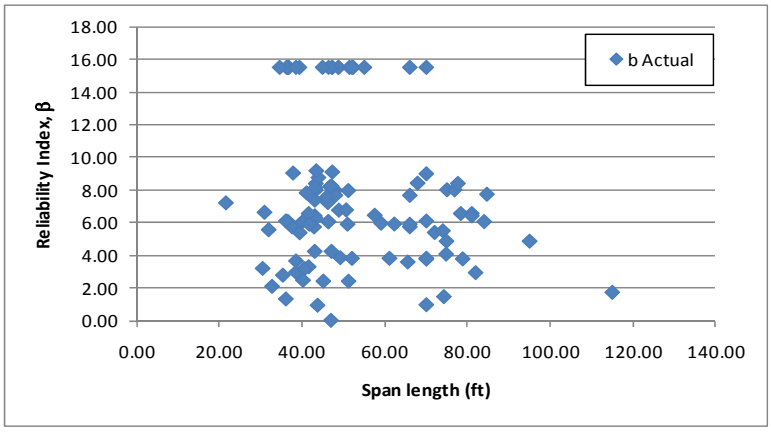


Figure D-510: Flexure Reliability Indices for TX-04 Vehicle

Figure D-511 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The figure shows that girders with rating factors of 1.0 have reliability indices ranging from 2.0 to 8.0. The average reliability is above the target reliability of 2.5 indicating the LRFR live load factors are over-conservative and can possibly be reduced.

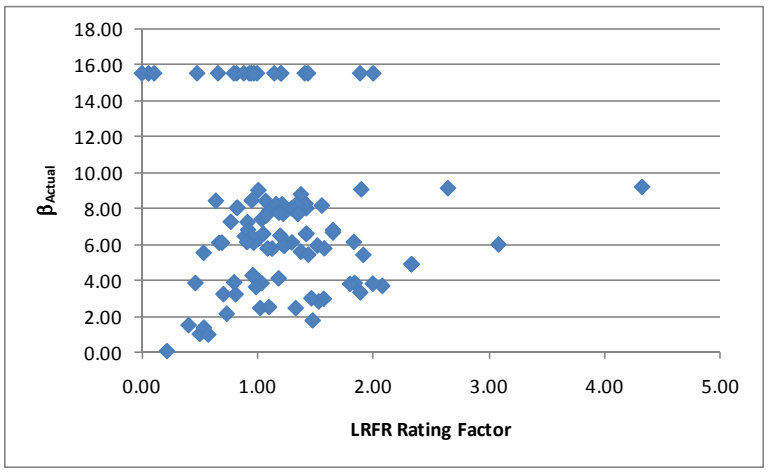
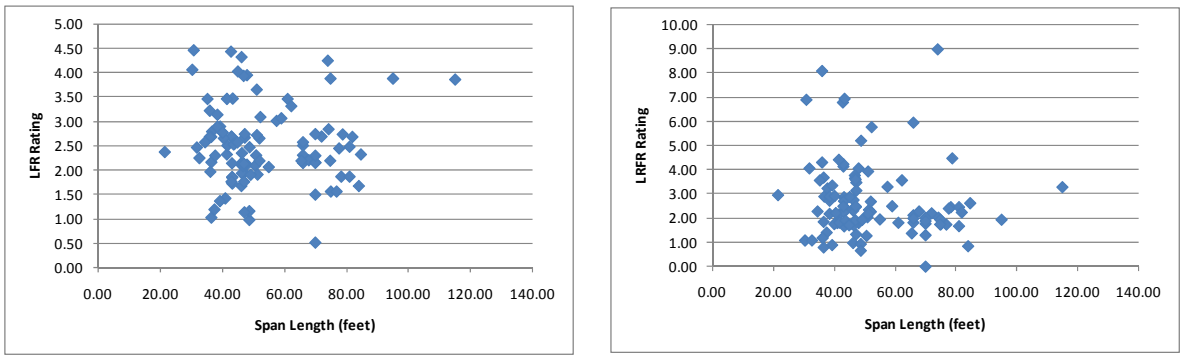


Figure D-511: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

D.4.9.2 Shear

D.4.9.2.1 Rating Factors

For shear, there are two girders that have LFR rating factors less than 1.0, seven girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 50% of the girders in this subset. Figure D-512 shows the LFR and LRFR ratings. Most of the LFR ratings are above 1.5 while most of the LRFR ratings are between one and four.



(a) (b)

Figure D-512: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure D-513 shows the percentage of girders with shear ratings in each rating range for the TX-04 vehicle. Less than 10% of girders have LRFR ratings less than 1.0 for the highest ADTT category. 98% of girders have LFR ratings that are greater than 1.0; this indicates that less than 7% of girders are affected by the switch from LFR to LRFR.

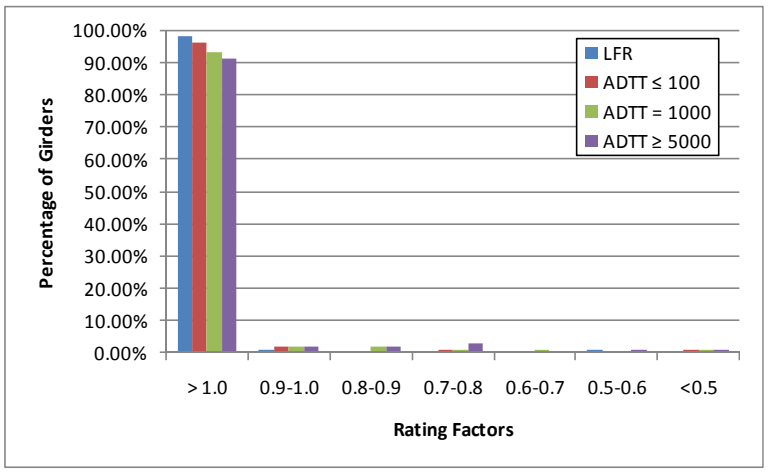


Figure D-513: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

D.4.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure D-514 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5 for shear. The ratio decreases (LFR rating is greater than LRFR rating) for increasing span lengths. 50% of the girders have LRFR ratings greater than the LFR rating.

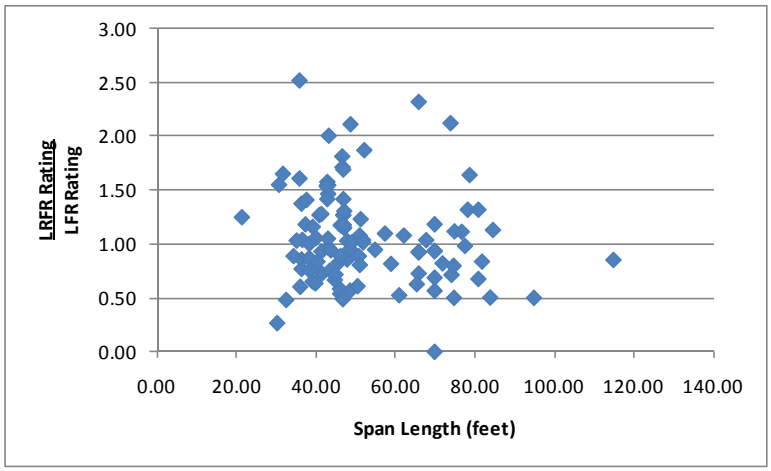


Figure D-514: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

D.4.9.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is greater than the target reliability index of 2.5 for all but one girder as shown in Figure D-515. The reliability index is between six and nine for most girders. The girder with a reliability index near zero likely does not have properly defined shear reinforcement.

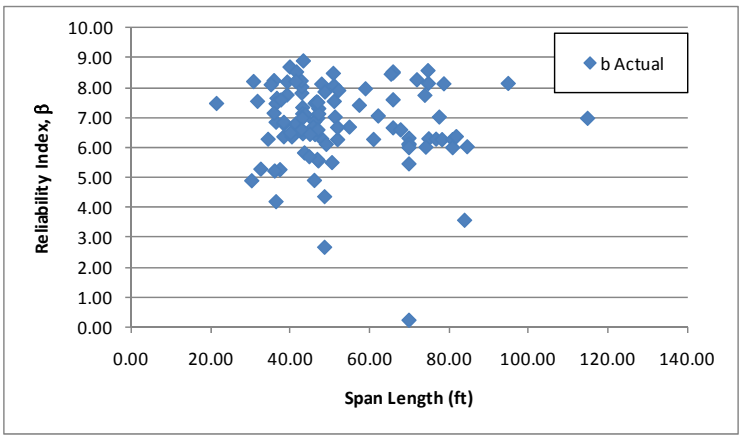


Figure D-515: Shear Reliability Indices for TX-04 Vehicle

Figure D-516 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The figure shows that girders with a rating of 1.0 have reliability indices near four, above the target reliability of 2.5. This indicates that the live load factors currently in the MBE are over-conservative.

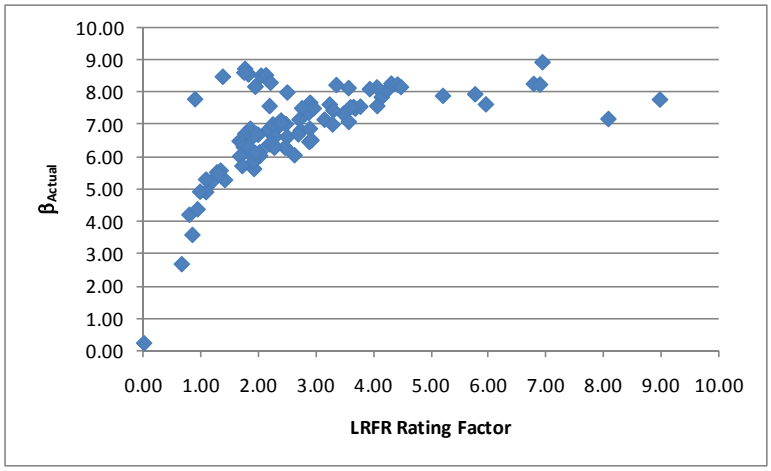
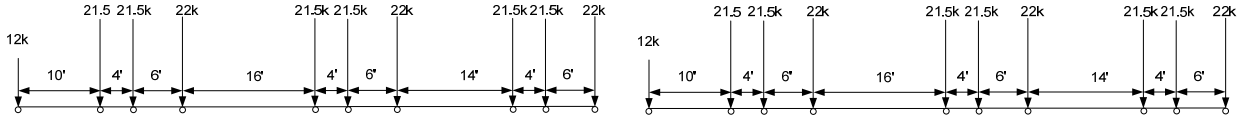


Figure D-516: Shear Reliability Index vs LRFR Shear Rating Factor for TX-04 Vehicle

D.4.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-517. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

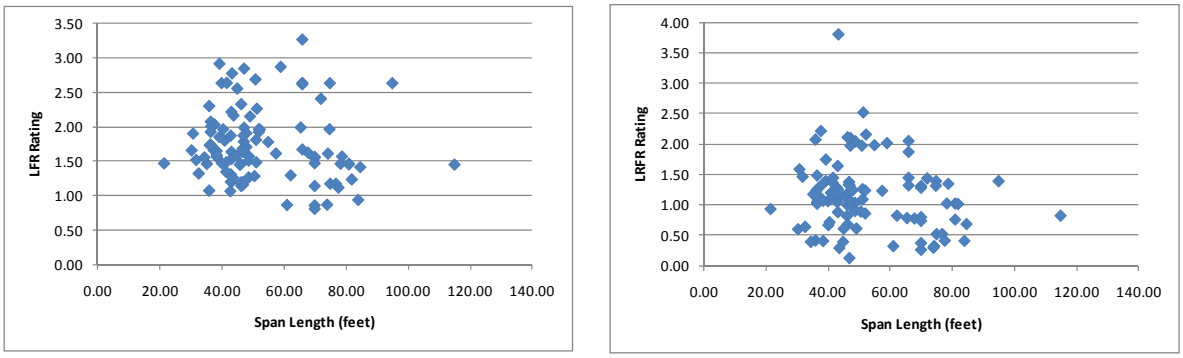
Figure D-517: Vehicle Loadings and Load Factors

D.4.10.1 Moment

The following section contains the results for interior, non-composite prestressed box girders within simple span bridges for the WA-02 Vehicle.

D.4.10.1.1 Rating Factors

Figure D-518 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are five girders with an LFR rating less than 1.0, 38 girders with an LRFR rating less than 1.0, and five girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 92% of the girders in this subset. Six of the 38 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR ratings are mostly above 1.0while the LRFR ratings are between 0.5 and 1.5 for most girders.



(a) (b)

Figure D-518: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure D-519 shows the percentage of girders with moment ratings in each rating range for the WA-02 vehicle. Between 35 and 42% of girders have LRFR moment ratings that are less than 1.0, with the percentage increasing with the ADTT and number of trips allowed with the permit. 4.8% of girders have LFR ratings less than 1.0. This indicates that a significant number of girders will be affected by the switch from LFR to LRFR. A significant portion of the girders with ratings less than 1.0 have ratings less than 0.5.

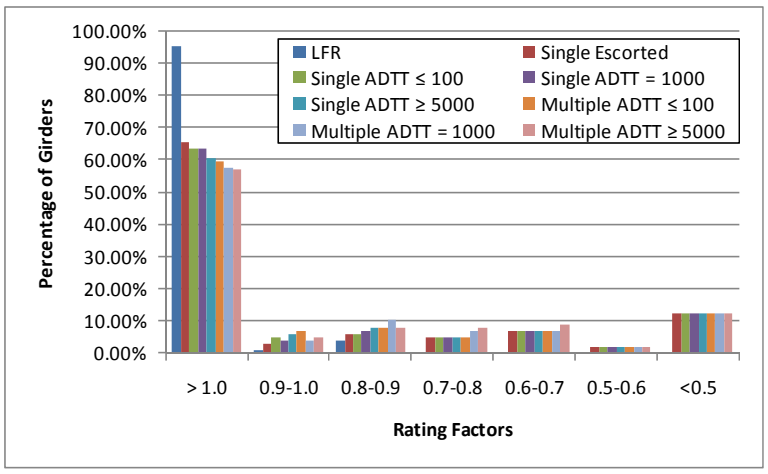


Figure D-519: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

D.4.10.1.2 Rating Factor Comparisons

Figure D-520 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.8, with eight girders having LRFR ratings greater than the LFR rating.

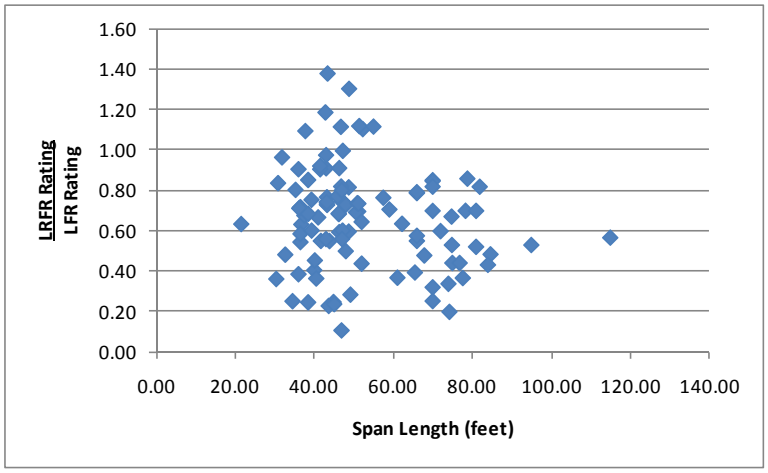


Figure D-520: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

D.4.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-521 shows that 21 girders have a reliability index based upon girder strength that is less than the target reliability index of 3.5. The reliability index is between two and ten for most girders in this group.

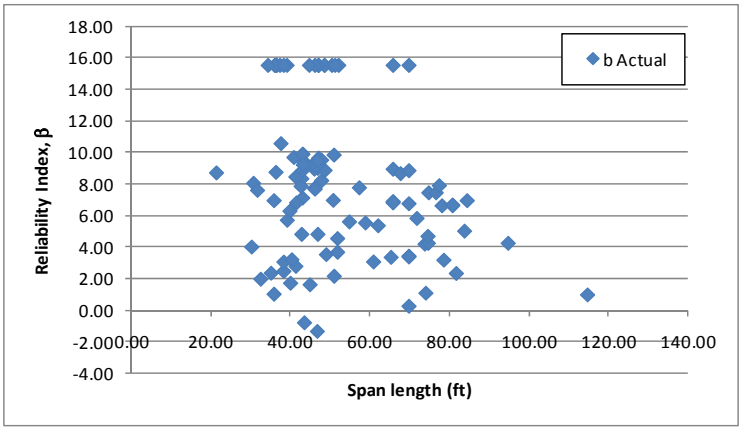


Figure D-521: Flexure Reliability Indices for WA-02 Vehicle

Figure D-522 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 vehicle. The reliability index varies from 2.0 to 9.0 for girders with LRFR ratings of 1.0. The average reliability index is above the target reliability of 3.5. This indicates that the LRFR live load factors are over-conservative and can be reduced.

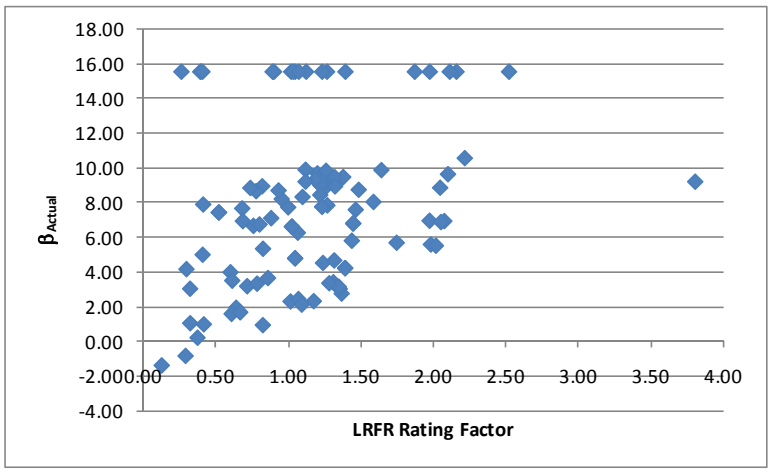
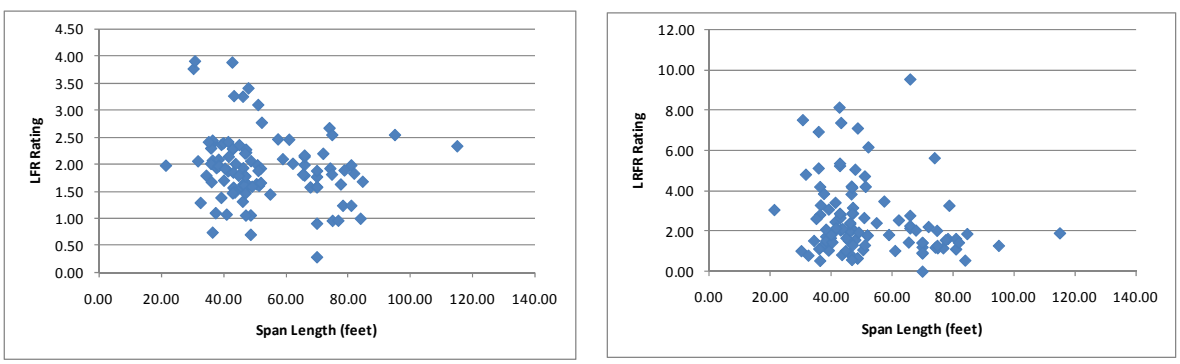


Figure D-522: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

D.4.10.2 Shear

D.4.10.2.1 Rating Factors

For shear, there are seven girders with LFR rating factors less than 1.0, eleven girders with LRFR ratings less than 1.0, and four girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 38% of the girders in this subset. Figure D-523 shows the LFR and LRFR ratings. The LFR rating is between one and 2.5 for most girders while the LRFR rating is between 0.5 and 4.0 for most girders.



(a) (b)

Figure D-523: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure D-524 shows the percentage of girders with shear ratings in each rating range for the different permit types for LRFR and for LFR. 6.7% of girders have LFR ratings less than 1.0. 7.7 to 26% of girders have LRFR ratings less than 1.0 depending on the type of permit and ADTT used in determining the rating. At most, an additional 20% of girders will be affected by the switch from LFR to LRFR.

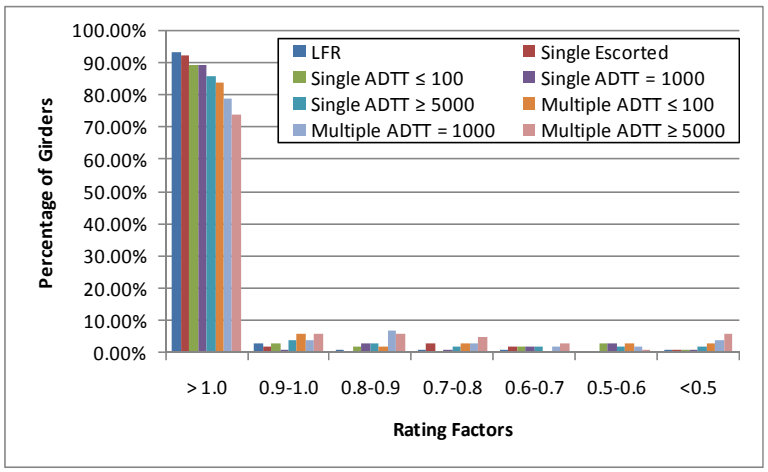


Figure D-524: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

D.4.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-525 show the comparison of rating factors. The ratio is generally between 0.5 and 2.0. Short spans are more likely to have LRFR ratings be greater than the LFR rating 62% of girders have an LRFR rating that exceeds the LFR rating.

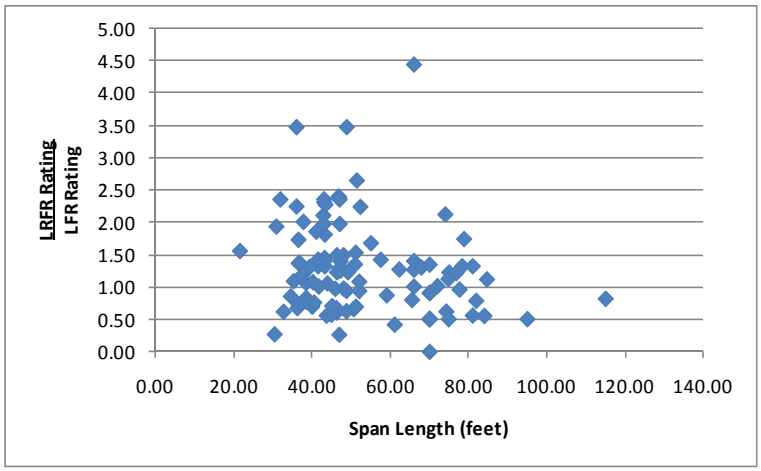


Figure D-525: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

D.4.10.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 3.5 for 11 girders as shown in Figure D-526.

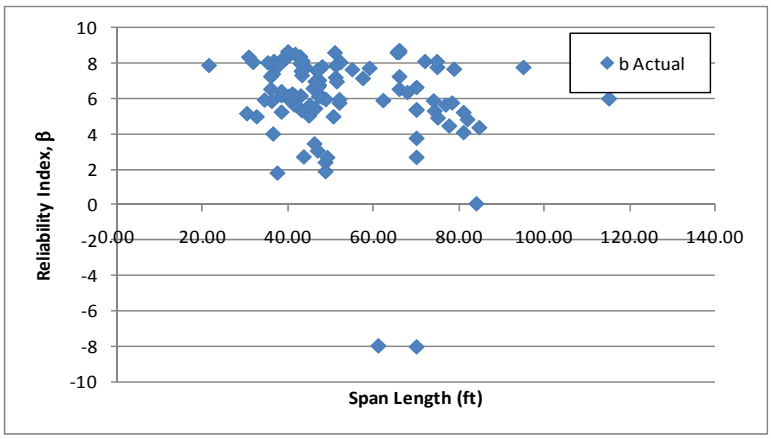


Figure D-526: Shear Reliability Indices for WA-02 Vehicle

Figure D-527 shows the reliability index for shear plotted against the LRFR shear rating for the WA-02 Vehicle. The figure shows that girders with a rating of 1.0 have reliability in the range of 2.5 to 5 with the average reliability index around 3.5. This is the target reliability for this vehicle. This indicates the current live load factors in the MBE provide the target level of reliability.

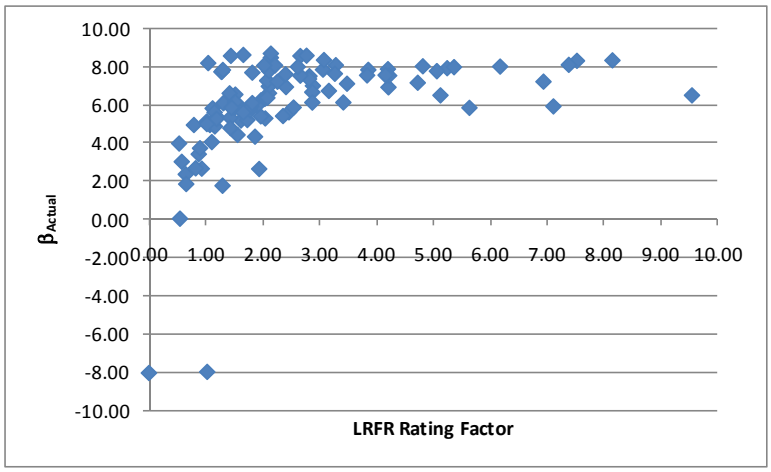


Figure D-527: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

D.4.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-528. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

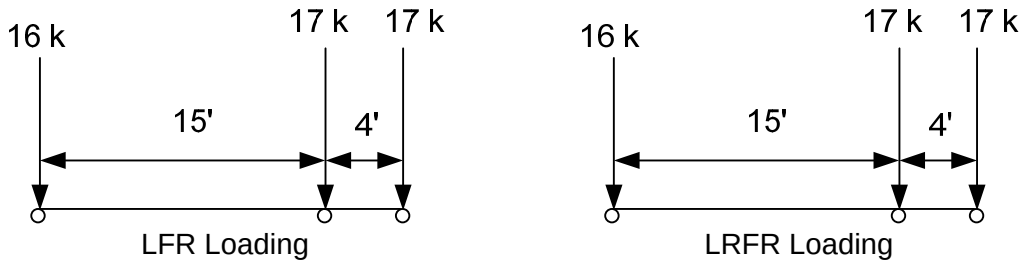
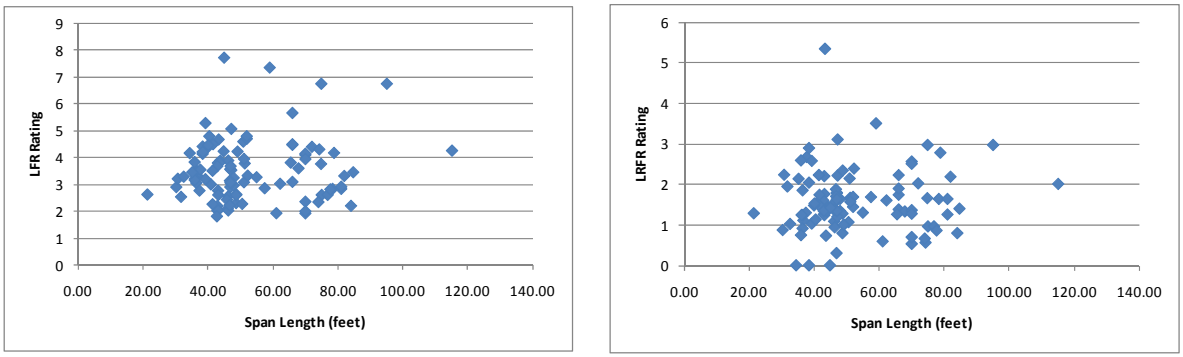


Figure D-528: Vehicle Loadings and Load Factors

D.4.11.1 Moment

D.4.11.1.1 Rating Factors

Figure D-529 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 19 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. Six of the nineteen girders with LRFR rating less than one are controlled by the longitudinal steel rating. The LFR rating is above two for most girders while the LRFR rating is between 1.0 and 2.5 for most girders.



(a) (b)

Figure D-529: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure D-530 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3 Truck. Between 17.3 and 20.2% of girders have LRFR ratings less than 1.0 for the AASHTO Type 3 truck. The percentage of girders with LRFR rating ratings less than 1.0 is not significantly affected by the ADTT used. All girders have LFR ratings greater than 1.0. This indicates that about 20% of girders will be negative affected by the switch to LFR from LRFR.

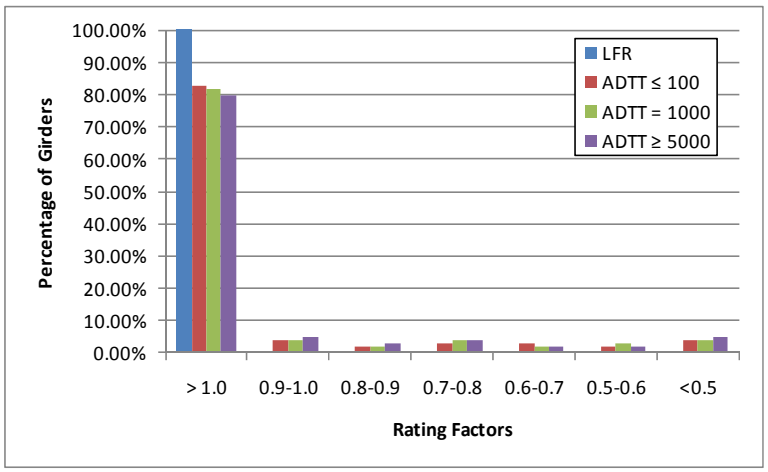


Figure D-530: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

D.4.11.1.2 Rating Factor Comparisons

Figure D-531 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.7, with one girder having an LRFR rating that is greater than the LFR rating.

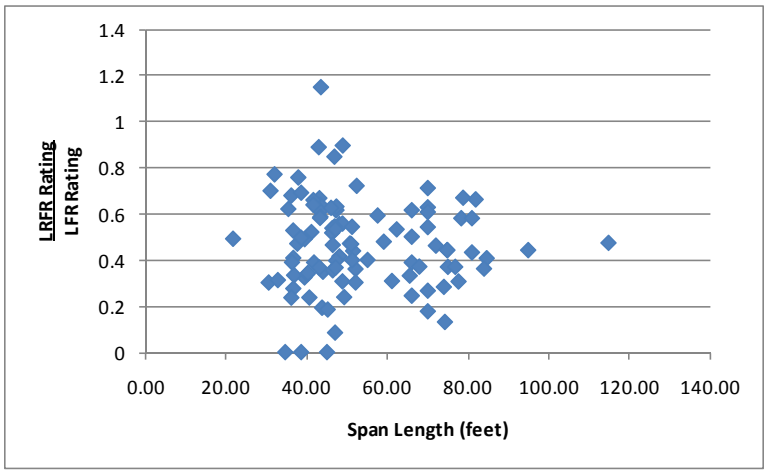


Figure D-531: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

D.4.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-532 shows that six girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index based is between two and ten for most girders.

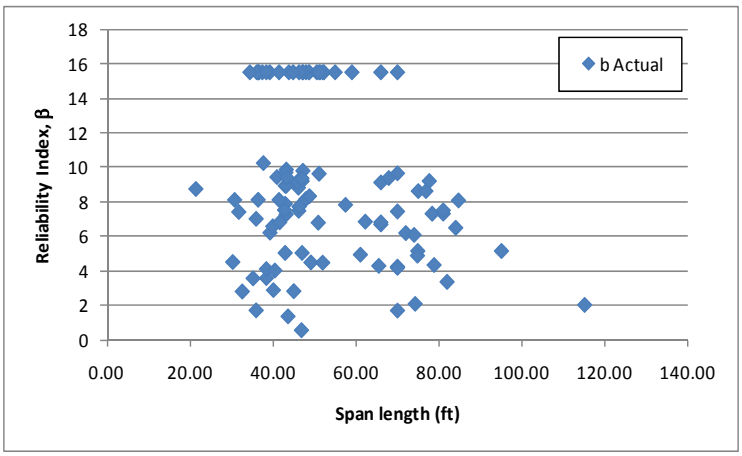


Figure D-532: Flexure Reliability Indices for Type 3 Vehicle

Figure D-533 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 truck. The figure shows that girders with ratings near one have a reliability index ranging from 2.75 to 9; the average reliability is above the target reliability of 2.5. This indicates that the current live load factors in the MBE are over-conservative and can be reduced.

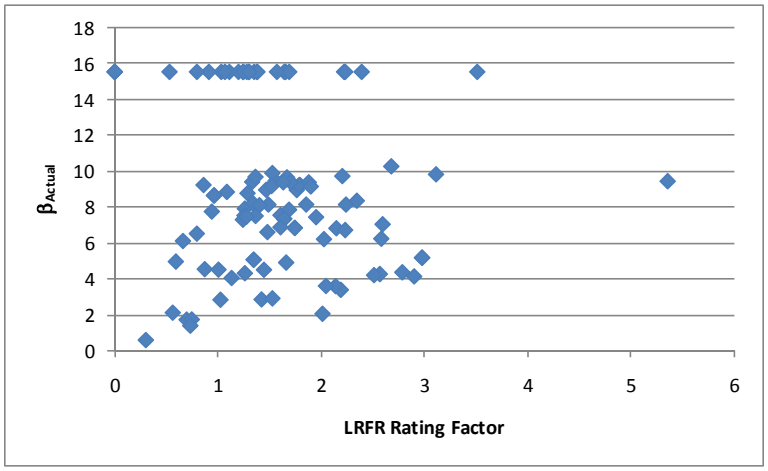
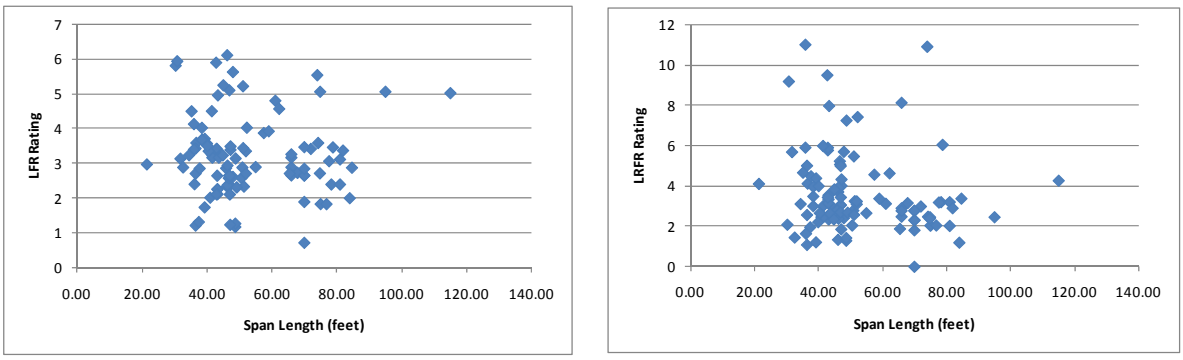


Figure D-533: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

D.4.11.2 Shear

D.4.11.2.1 Rating Factors

For shear, there is one girder with both LFR and LRFR ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 41% of the girders in this subset. Figure D-534 shows the LFR and LRFR ratings. The LFR rating is between two and four for most girders while the LRFR rating is between two and six for most girders.



(a) (b)

Figure D-534: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure D-535 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3 Truck. 1% of girders have ratings less than 1.0 for LFR and for LRFR with ADTTs of 100 and 1,000. 2% of girders have ratings less than 1.0 for LRFR with an ADTT of 5,000. Very few girders are affected by the switch from LFR to LRFR, independent of ADTT.

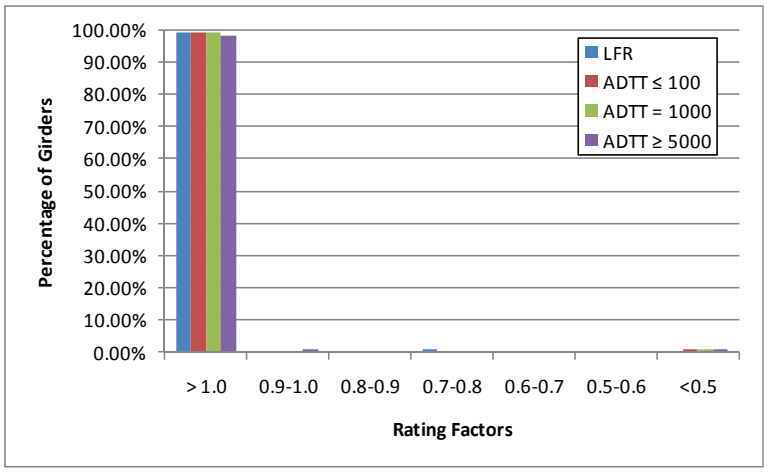


Figure D-535: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

D.4.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-536 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5, with shorter spans generally having higher ratios. The LRFR rating is greater than the LFR rating for 59% of the girders for this vehicle.

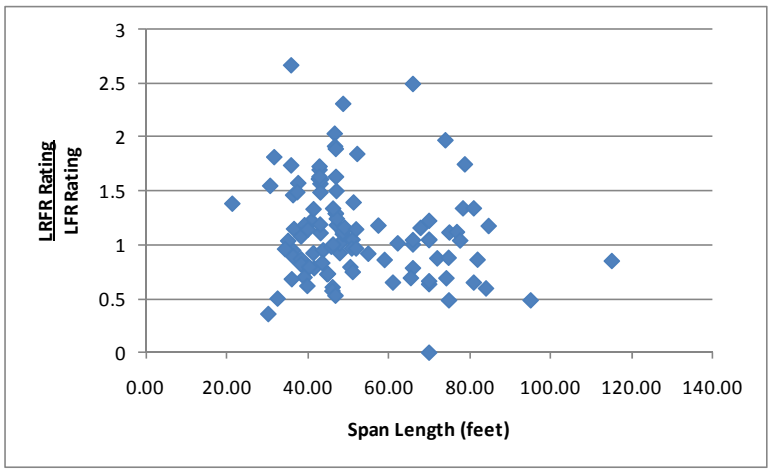


Figure D-536: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

D.4.11.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for one girder as shown in Figure D-537. The reliability index is between six and nine for most girders.

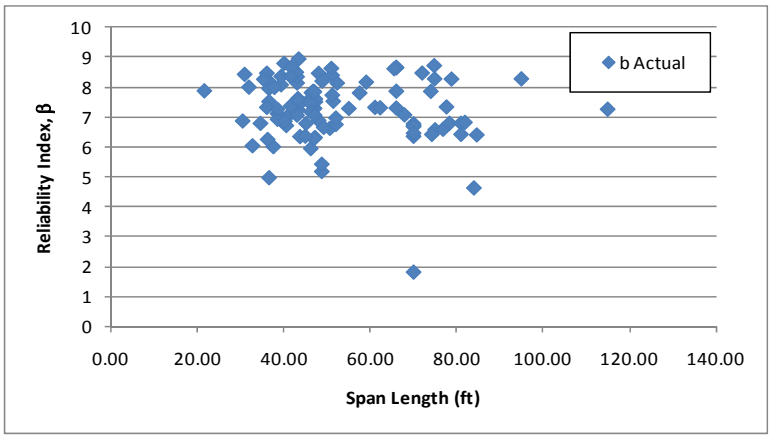


Figure D-537: Shear Reliability Indices for Type 3 Vehicle

Figure D-538 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 Truck. The figure shows that the reliability index associated with a rating of 1.0 is greater than four; the target reliability is 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

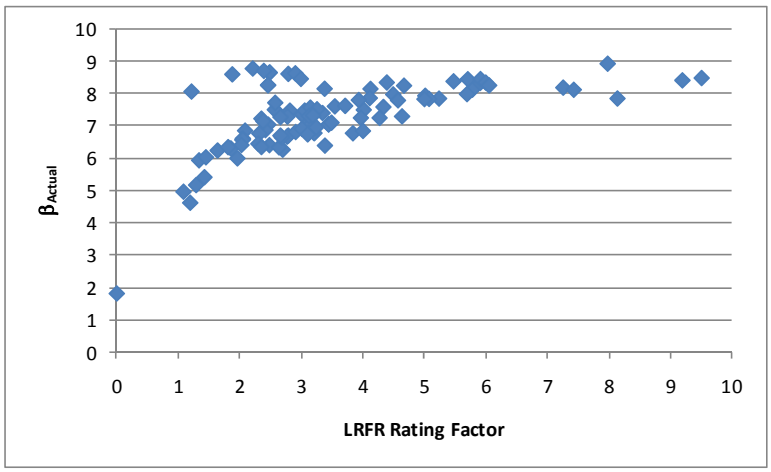


Figure D-538: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

D.4.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-539. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

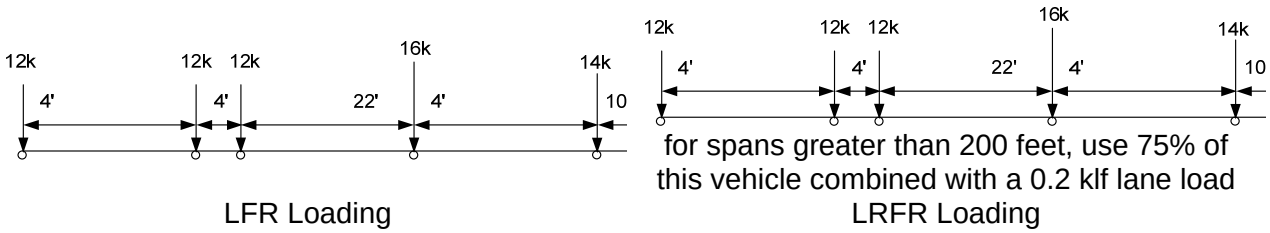
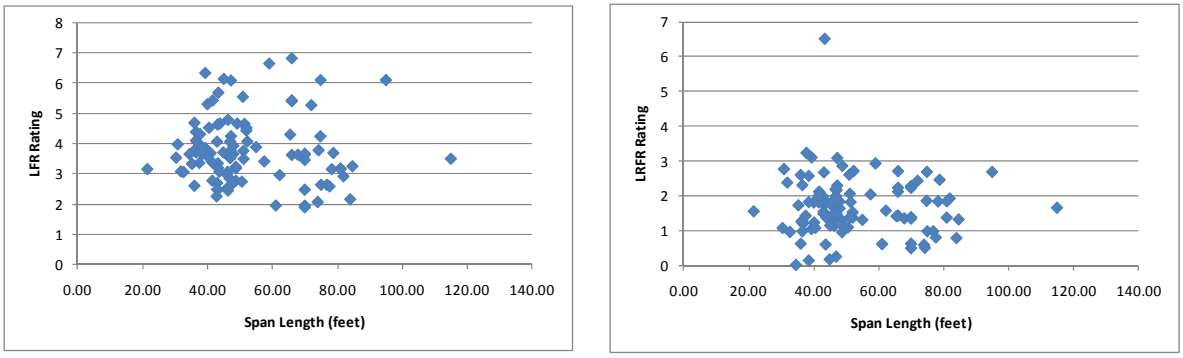


Figure D-539: Vehicle Loadings and Load Factors

D.4.12.1 Moment

D.4.12.1.1 Rating Factors

Figure D-540 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 18 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 99% of the girders in this subset. Six of the eighteen girders with LRFR ratings less than one are controlled by the longitudinal steel rating. The LFR rating is above two for almost all girders while the LRFR rating is between 0.5 and 3.0 for most girders.



(a) (b)

Figure D-540: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure D-541 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3-3 Truck. Between 15.4 and 19.2% of girders have LRFR ratings less than 1.0, with the higher percentage corresponding to an ADTT of 5,000. All girders have LFR ratings greater than 1.0. This indicates that at least 15% of girders will be negative affected by the switch to LRFR from LFR.

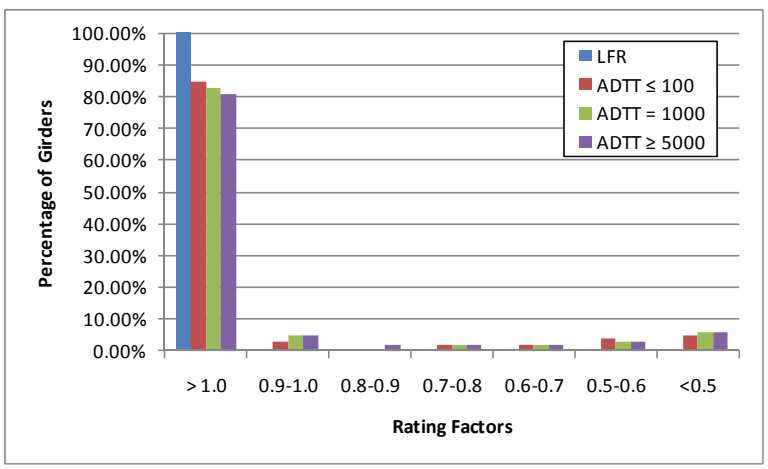


Figure D-541: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

D.4.12.1.2 Rating Factor Comparisons

Figure D-542 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6, with one girder having an LRFR rating greater than the LFR rating.

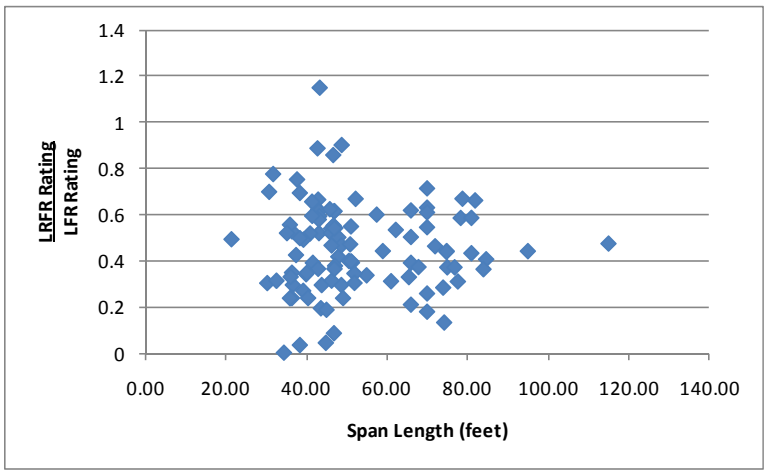


Figure D-542: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

D.4.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-543 shows that six girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between three and ten for most girders.

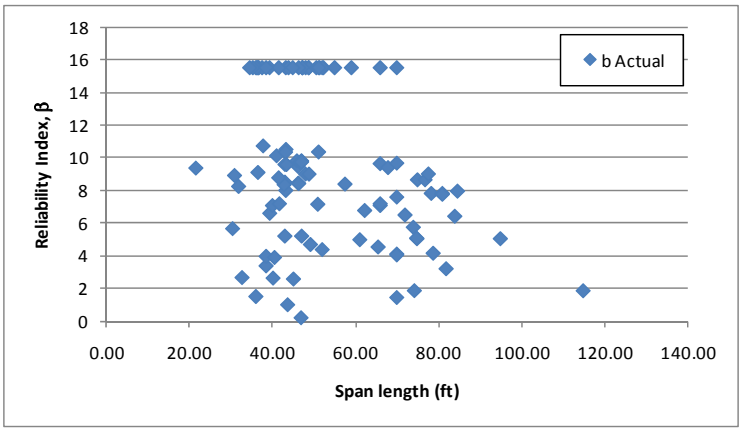


Figure D-543: Flexure Reliability Indices for Type 3-3 Vehicle

Figure D-544 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 truck. The figure shows the reliability index for a girder with a rating of 1.0 varies from 2.5 to 8.5; the average reliability exceeds the target reliability of 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

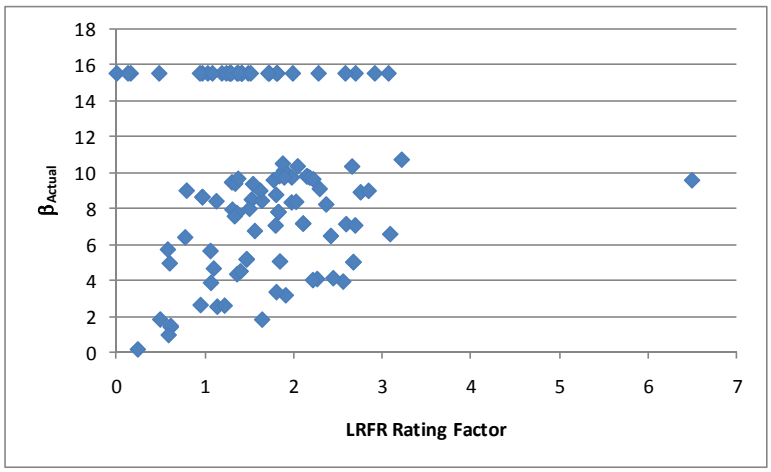
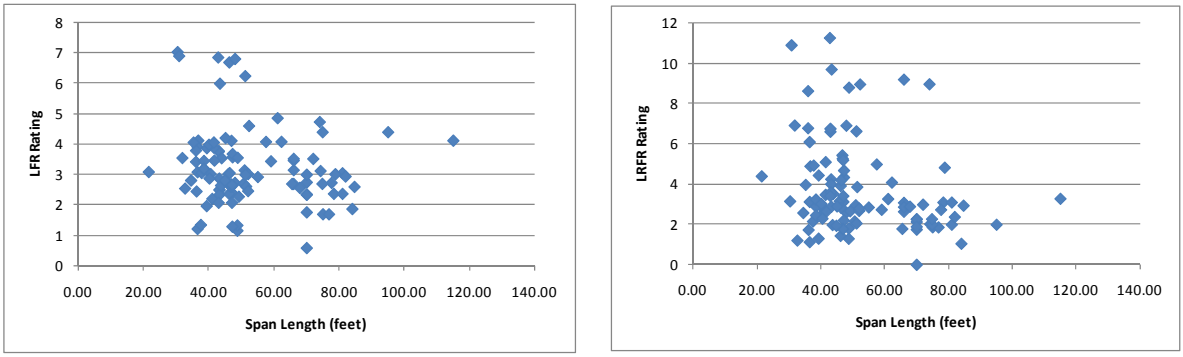


Figure D-544: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

D.4.12.2 Shear

D.4.12.2.1 Rating Factors

For shear, there is one girder with both LFR and LRFR ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 45% of the girders in this subset. Figure D-545 shows the LFR and LRFR ratings. Most LFR ratings are between two and four while most LRFR ratings are between 1.5 and 5.



(a) (b)

Figure D-545: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure D-546 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3-3 Truck. Less than 2% of girders have ratings less than 1.0 for an LRFR rating with an ADTT of 5,000. This indicates that very few girders are affected by the switch from LFR to LRFR.

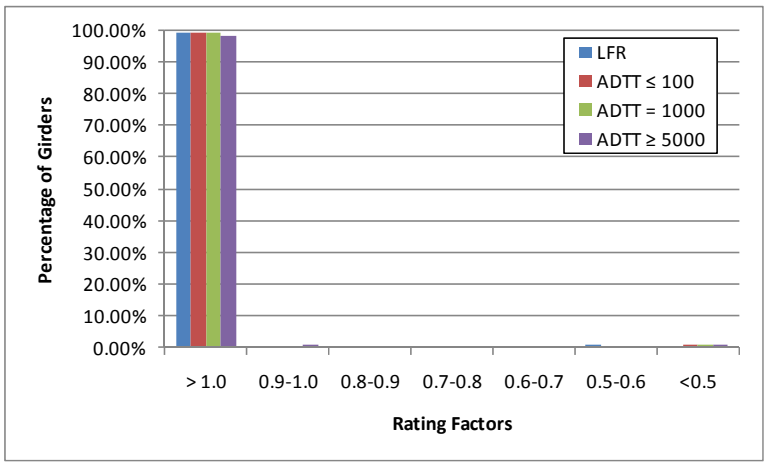


Figure D-546: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

D.4.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-547 show the comparison of rating factors. The ratio is generally between 0.5 and 2.0, with 55% of girders having an LRFR rating that is greater than the LFR rating.

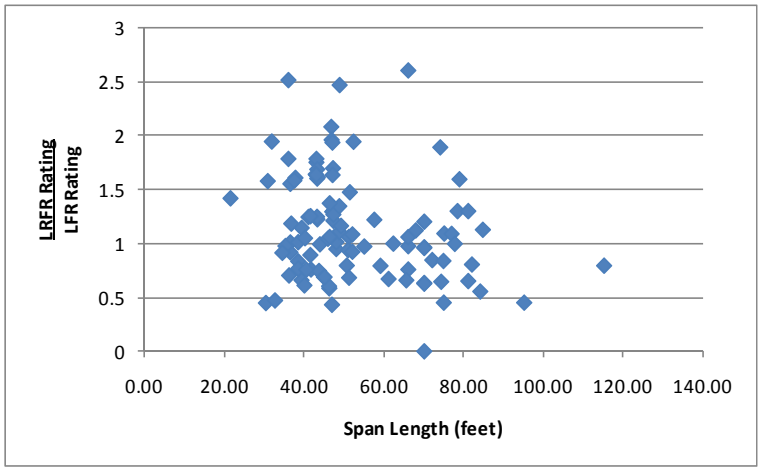


Figure D-547: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

D.4.12.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability index of 2.5 for one girder as shown in Figure D-548. The reliability index is between six and nine for most girders well above the target reliability of 2.5.

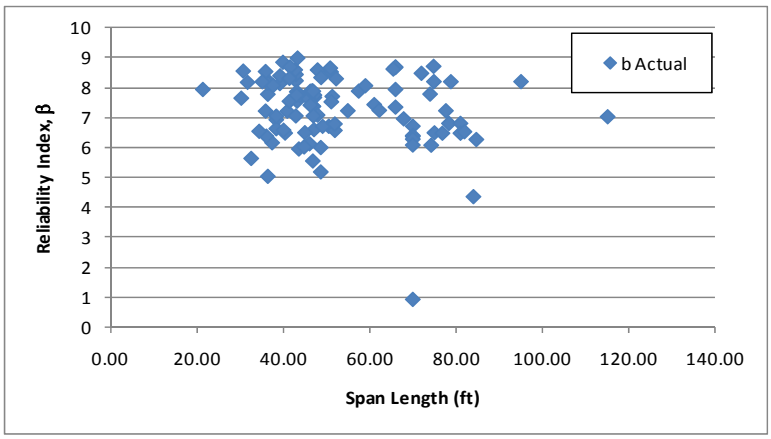


Figure D-548: Shear Reliability Indices for Type 3-3 Vehicle

Figure D-549 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 truck. The figure shows that girders with ratings near one have reliability indices near four, above the target reliability of 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

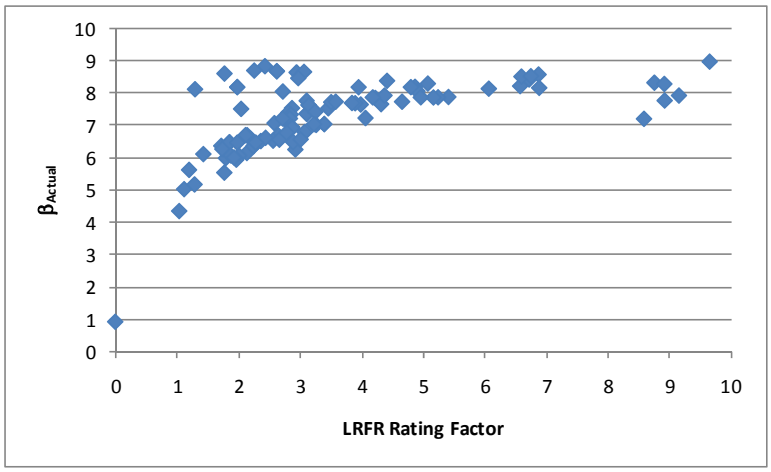


Figure D-549: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Vehicle

D.4.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure D-550. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

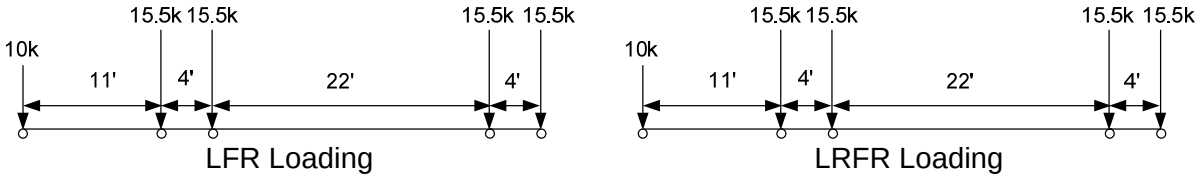
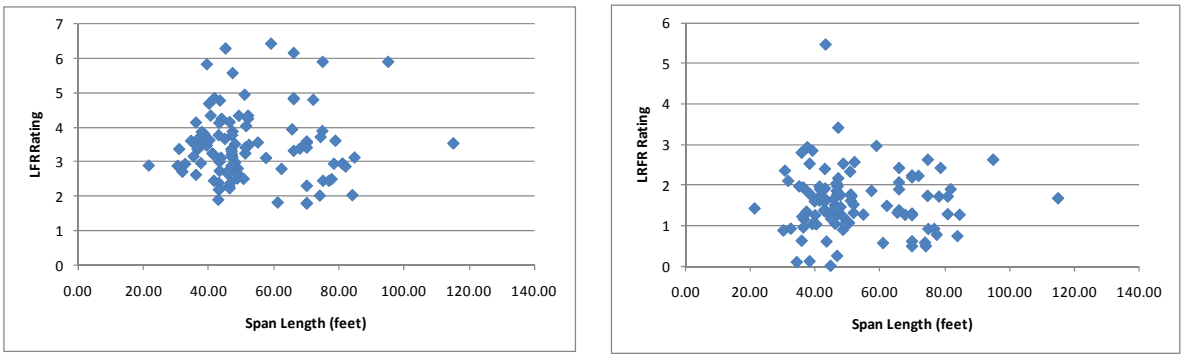


Figure D-550: Vehicle Loadings and Load Factors

D.4.13.1 Moment

D.4.13.1.1 Rating Factors

Figure D-551 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 19 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 99% of the girders in this subset. Six of the nineteen girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR rating is greater than two for most girders while most LRFR ratings are between one and three.



(a) (b)

Figure D-551: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure D-552 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3S2 truck. Between 16.3 and 20.2% of girders have LRFR ratings less than 1.0 with higher percentages corresponding to higher ADTTs. All girders have LFR ratings greater than 1.0. The switch from LFR to LRFR will negatively affect at least 15% of the girders.

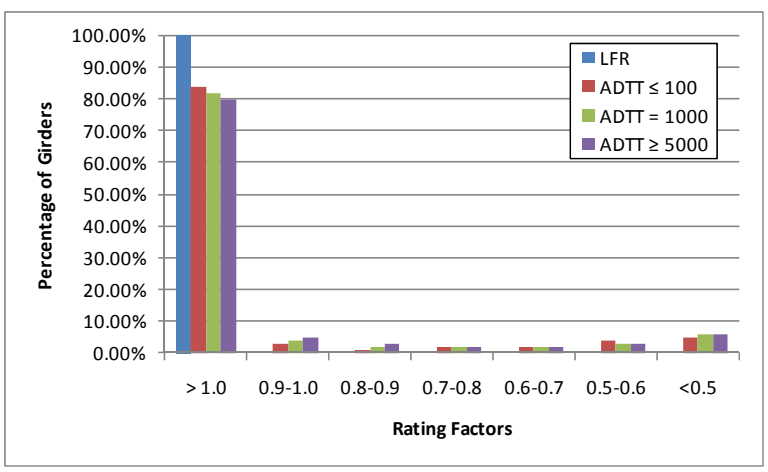


Figure D-552: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

D.4.13.1.2 Rating Factor Comparisons

Figure D-553 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6, with longer span girders having lower ratios. One girder has an LRFR rating that is greater than the LFR rating for this vehicle.

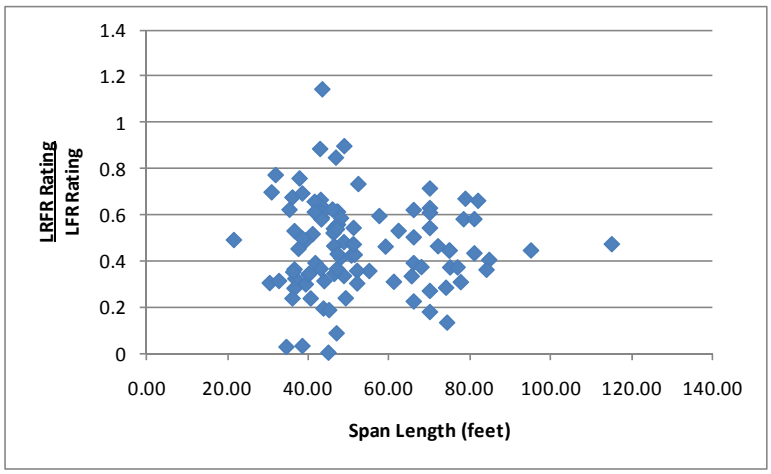


Figure D-553: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

D.4.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure D-554 shows that six girders have a reliability index based upon girder strength that is less than the target reliability index of 2.5. The reliability index is between two and ten for most girders in this group.

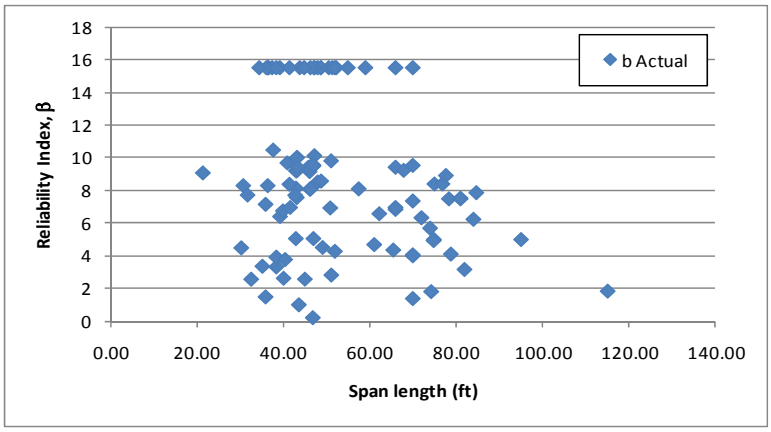


Figure D-554: Flexure Reliability Indices for Type 3S2 Vehicle

Figure D-555 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 truck. The figure shows that the reliability index for a girder with a rating of 1.0 is between 2.5 and 8.0; the average reliability is higher than the target reliability of 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

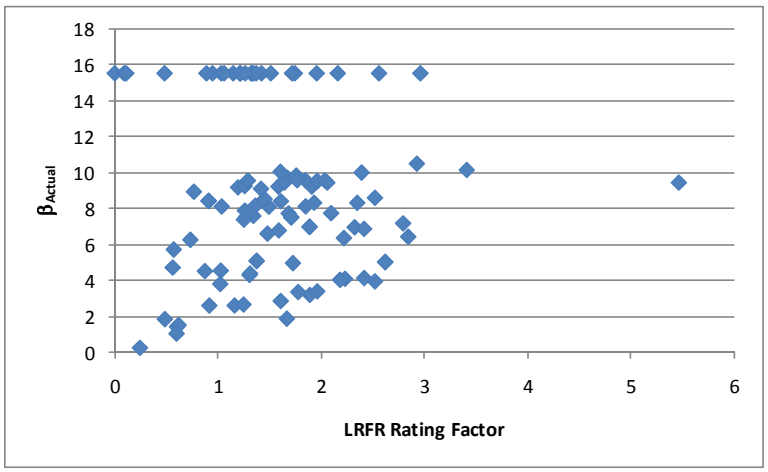
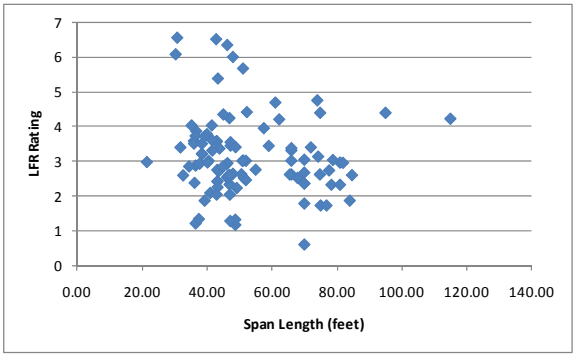


Figure D-555: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

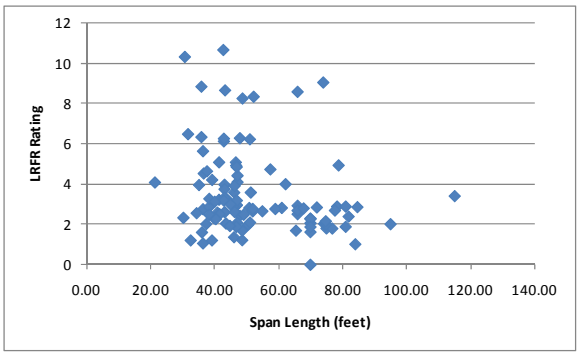
D.4.13.2 Shear

D.4.13.2.1 Rating Factors

For shear, there is one girder with LFR and LRFR ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 47% of the girders in this subset. Figure D-556 shows the LFR and LRFR ratings. The LFR ratings are mostly above two while the LRFR ratings are mostly above one.



(a)



(b)

Figure D-556: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure D-557 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 truck. Less than 3% of girders have LRFR ratings less than 1.0 for an ADTT of 5,000. This indicates that very few girders are affected by the switch from LFR to LRFR for shear.

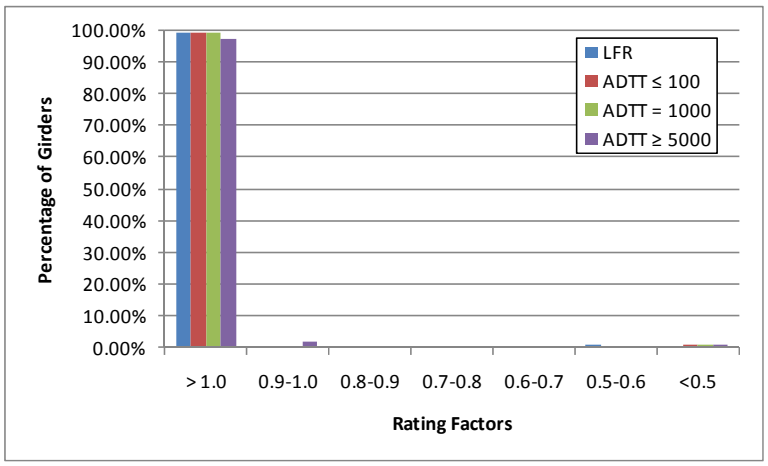


Figure D-557: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

D.4.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure D-558 show the comparison of rating factors. The ratio is generally between 0.5 and 2.0, with shorter spans generally having higher ratios. 53% of girders have an LRFR rating that is greater than the LFR rating for shear.

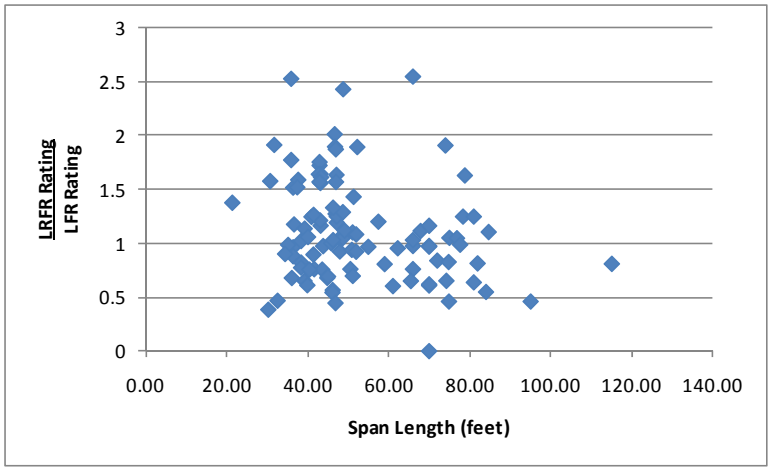


Figure D-558: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

D.4.13.2.3 Reliability Indices

The reliability indices were also calculated. The actual reliability index is less than the target reliability of 2.5 index for one girder as shown in Figure D-559. The figure shows that the reliability index for most girders is between six and nine. The girder with a reliability index near one likely does not have properly defined shear reinforcement.

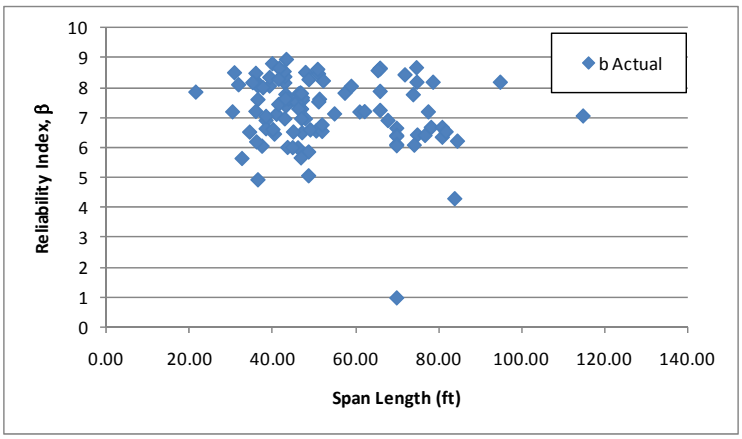


Figure D-559: Shear Reliability Indices for Type 3S2 Vehicle

Figure D-560 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 vehicle. The figure shows that the reliability index for a girder with a rating of 1.0 is approximately 4.0 above the target reliability of 2.5. This indicates that the live load factors in the MBE are overly conservative and can be reduced.

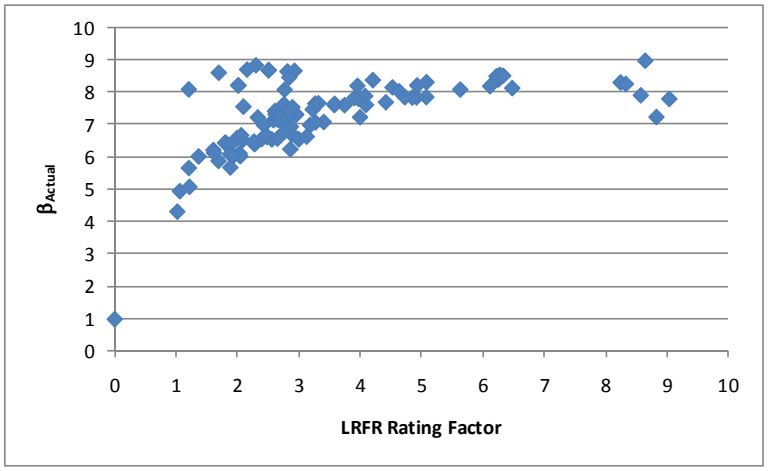


Figure D-560: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

D.4.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table D-7 shows the results for the moment ratings. The design vehicle and heaviest of the special permit vehicles resulted in girders having LFR ratings less than 1.0. All vehicles resulted in some girders having LRFR ratings less than 1.0, with routine permit and legal vehicles generally having the fewest girders and special permit and design vehicles having the most. An additional row has been added to Table D-7 to show the number of girders with LRFR ratings less than 1.0 controlled by the longitudinal steel rating. Typically between 20 and 60% of the girders with ratings less than 1.0 are controlled by the longitudinal steel rating. The girders with LRFR ratings less than 1.0 and not controlled by the longitudinal steel rating are typically controlled by the Service III limit state limiting the tensile stress in the bottom of the beam.

Table D-7: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	104	26	0	0	0	0	0	0	0	5	0	0	0
LRFR Rating less than 1.0		53	21	16	23	28	19	26	40	38	19	18	19
LFR and LRFR Rating less than 1.0		25	0	0	0	0	0	0	0	5	0	0	0
% with LFR RF greater than LRFR RF		85	99	99	93	99	99	91	99	92	99	99	99
Girders with LRFR Rating less than one and controlled by longitudinal steel rating		31	5	5	5	7	7	5	12	6	6	6	6
LRFR Rating less than 1.0 and controlled by service limit state		20	16	11	18	21	12	21	28	32	13	12	13

D.4.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table D-8 shows the results for the shear ratings. All vehicles utilized in this analysis resulted in girders having ratings less than 1.0 for both methods. The number of girders varied between vehicles but at least one girder was always affected. The percentage of girders with LFR ratings greater than LRFR ratings seems to depend on the vehicle, which is expected because the LRFR shear strength equation uses the ratio of V_u/M_u. Special permit vehicles generally had more girders with LRFR ratings that were higher than the LFR ratings this is because of the loading configuration specified in the MBE.

Table D-8: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	104	14	1	1	3	1	20	1	2	7	1	1	1
LRFR Rating less than 1.0		30	4	4	5	2	0	1	7	11	1	1	1
LFR and LRFR Rating less than 1.0		11	1	1	3	1	0	1	2	4	1	1	1
% with LFR RF greater than LRFR RF		58	47	47	29	43	35	15	50	38	41	45	47

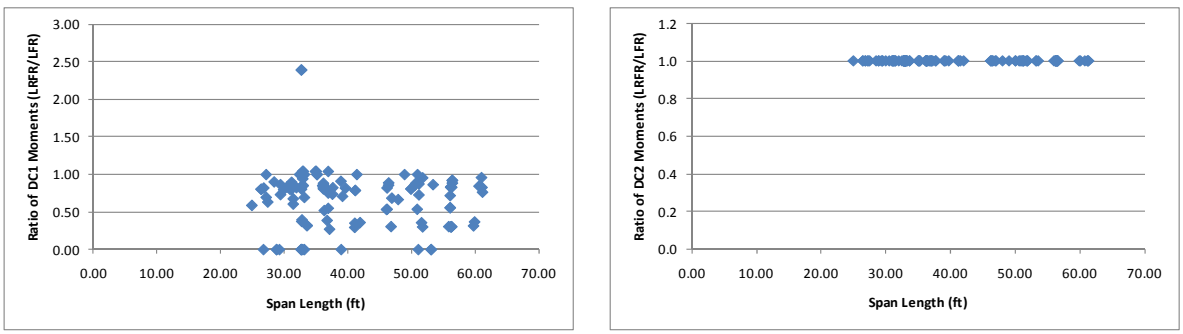
E Simple Span Reinforced Concrete T-Beam Bridges

E.1 Exterior Girders

E.1.1 Dead Loads

E.1.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure E-1a, the ratios of unfactored DC1 moments (self-weight, dead loads on composite section) are generally around 0.8 or 1. Those that are slightly above 1.0 are caused by the moment being obtained at the four-tenths point for LFR while the LRFR moment is calculated at midspan. There are several data points indicating the rating of DC1 moments is zero; these are girders where the critical LRFR location is at a support and the moment is zero. Figure E-1b shows that the DC2 LRFR loads are the same as the DC2 LFR loads. In most cases both are zero and the ratio of zeros was set equal to 1.0.

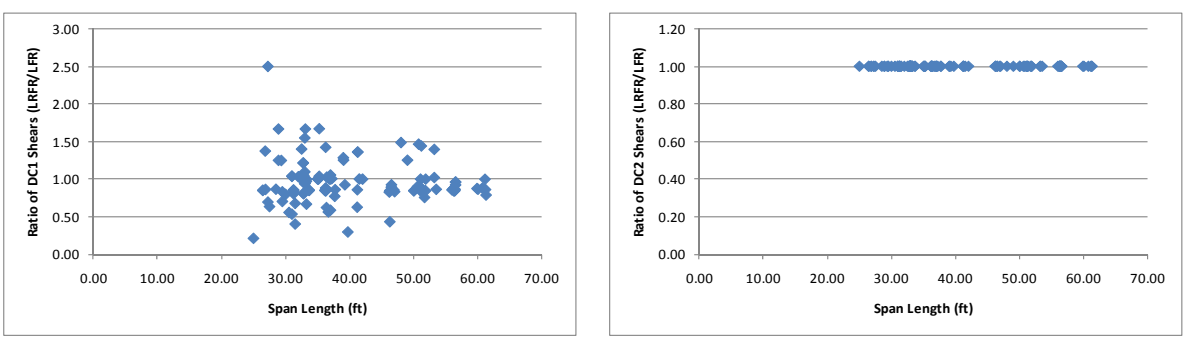


(a) (b)

Figure E-1: Ratios of DC1 and DC2 and DW Moment (unfactored loads LRFR/LFR)

E.1.1.2 Shear

Figure E-2a shows that numerous girders have a ratio of DC1 shear close to 1.0, but there are also many where the ratio is either above or below 1.0. This is a mostly due to the variation of the critical section for shear. Figure E-2b shows that the DC2 and DW shears are the same for LFR and LRFR. In most cases both of are zero, and the ratio of zeros was set equal to 1.0.



(a) (b)

Figure E-2: Ratio of DC1 and DC2 and DW Shear (unfactored loads LRFR/LFR)

E.1.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure E-3. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

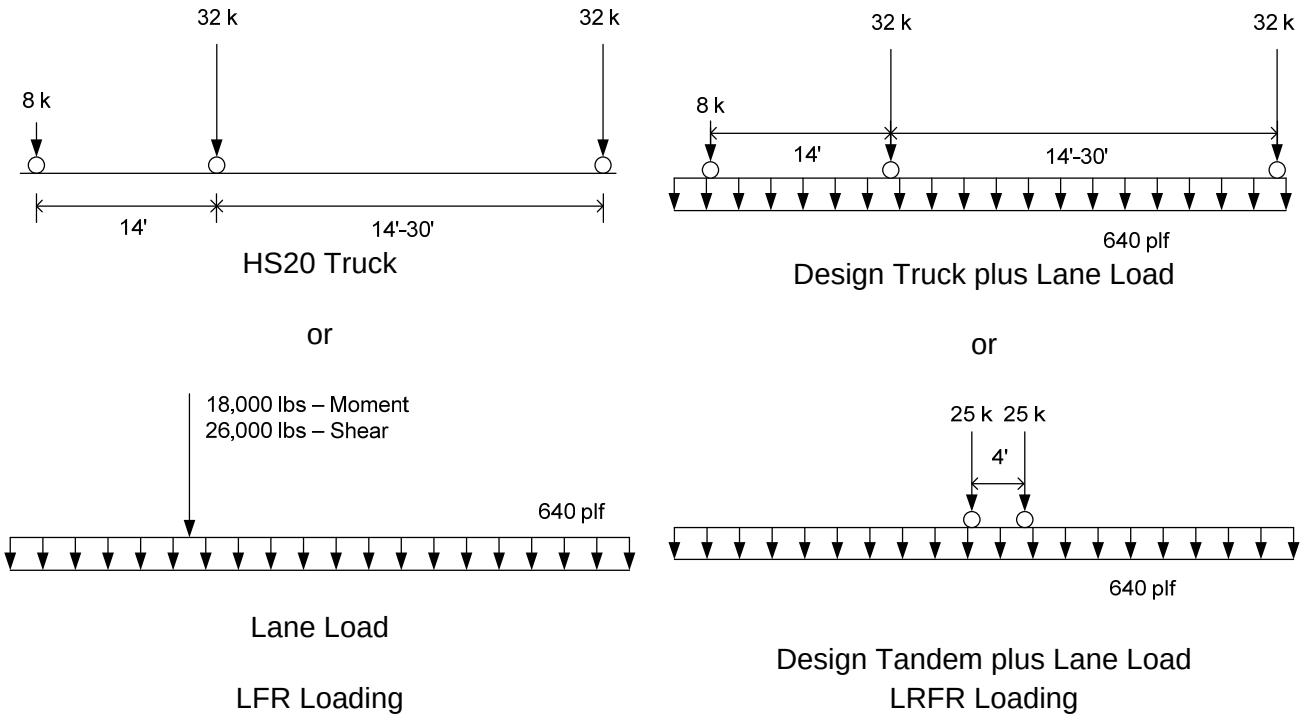
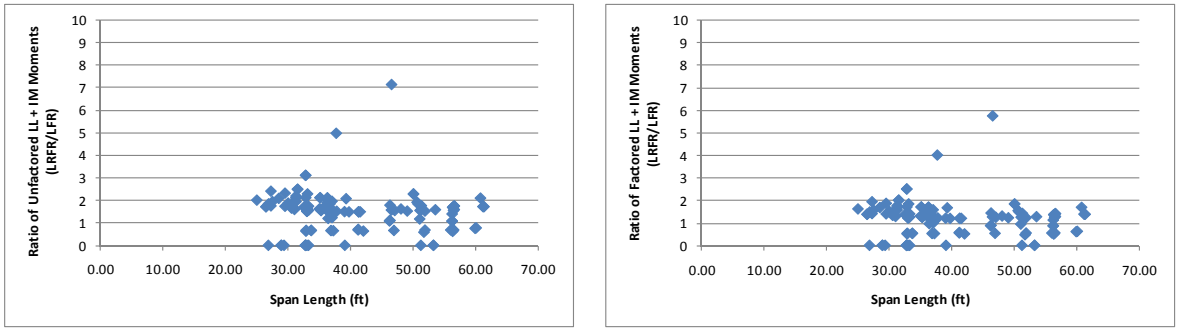


Figure E-3: Vehicle Loadings and Load Factors

E.1.2.1 Moment

E.1.2.1.1 Live Loads

Figure E-4a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.5 and 2.5 for most of the girders within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure E-4b shows that the results have shifted down and are between 1.25 and 1.75 for most cases.



(a) (b)

Figure E-4: Ratios of Unfactored and Factored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

E.1.2.1.2 Resistance

The next step was to verify that the factored resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure E-5 shows that the ratio of resistance is 1.0 for most girders with clusters of girders near 0.5 and 0.1. The girders near 0.5 and 0.1 have varying critical locations between LFR and LRFR.

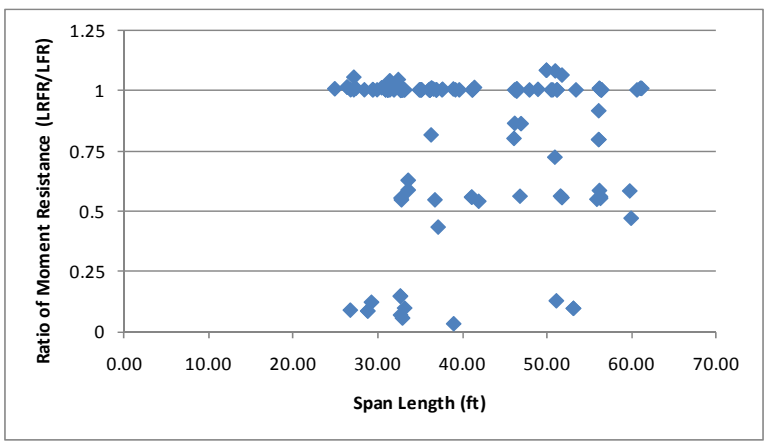
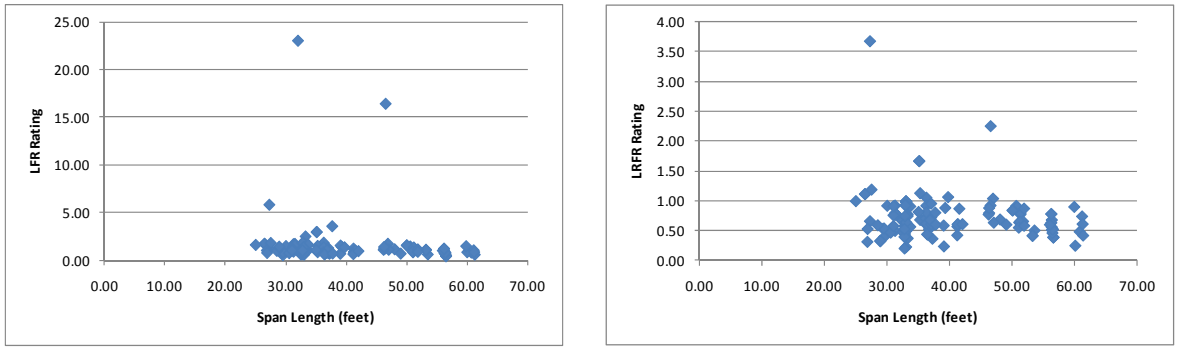


Figure E-5: Ratio of factored Moment Resistance (LRFR/LFR)

E.1.2.1.3 Rating Factors

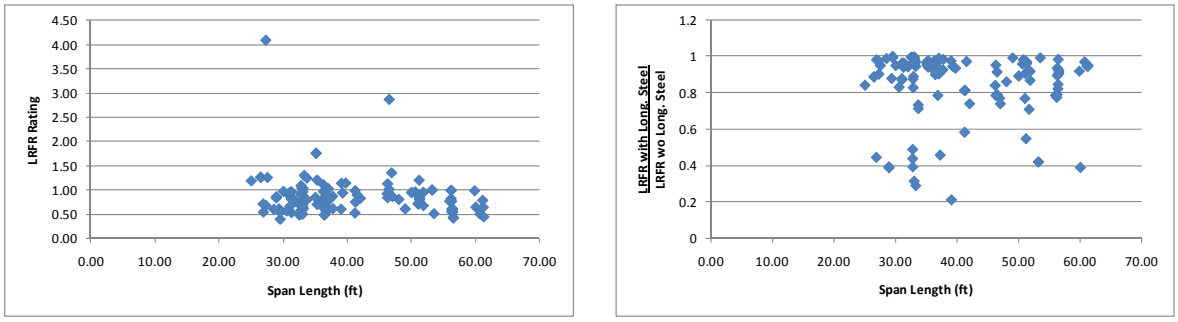
After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (130 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 48 girders with LFR ratings less than 1.0, 119 girders with LRFR ratings less than 1.0, and 48 girders where both the LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. Figure E-6 shows the LFR rating factors and LRFR rating factors. The LFR rating is between 0.5 and two for most girders while the LRFR ratings are mostly less than 1.0. Of the 119 girders with LRFR ratings less than 1.0, 116 are controlled by the longitudinal steel rating.



(a) (b)

Figure E-6: LFR and LRFR Flexure Rating Factors for Design Loadings

Figure E-7a shows the LRFR rating factors when the longitudinal steel rating is ignored. The figure shows that many girders with ratings less than 0.5 have been eliminated when compared to Figure E-6b. Sixteen fewer girders have ratings less than 1.0 when the longitudinal steel rating is ignored. Figure E-7b shows the ratio of the LRFR rating including the longitudinal steel rating divided by the LRFR rating excluding the longitudinal steel rating. 99% of girders have higher ratings when the longitudinal steel rating is ignored. Most of the ratios are between 0.8 and 1.0.



(a) (b)

Figure E-7: Effect of Longitudinal Steel Rating on LRFR Rating

E.1.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure E-8. The results indicated that 100% of the girders in this set have LFR ratings greater than LRFR ratings. The LRFR ratings are typically between 50 and 80% of the LFR rating for all span lengths.

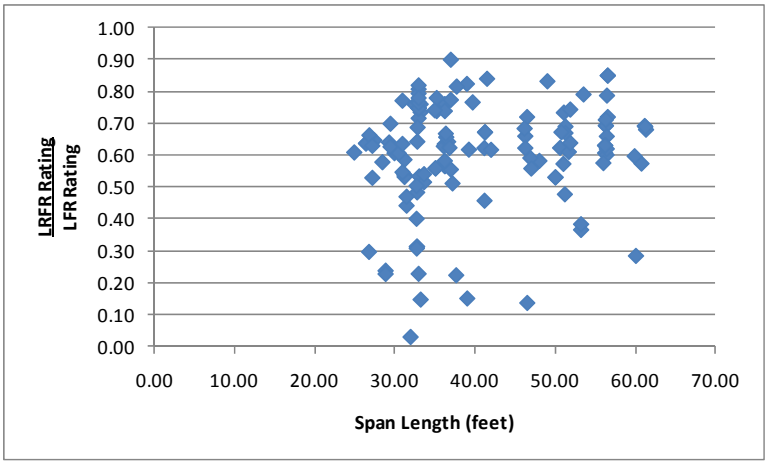


Figure E-8: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure E-9 shows the percentage of girders with an LRFR rating less than 1.0 in each category. The figure shows that 30% of the girders with LRFR ratings less than one have an LRFR rating that is between 60 and 69% of the LFR rating. The figure also provides an estimate of how many girders will be affected by switching to LRFR from LFR and the reduction in live load capacity.

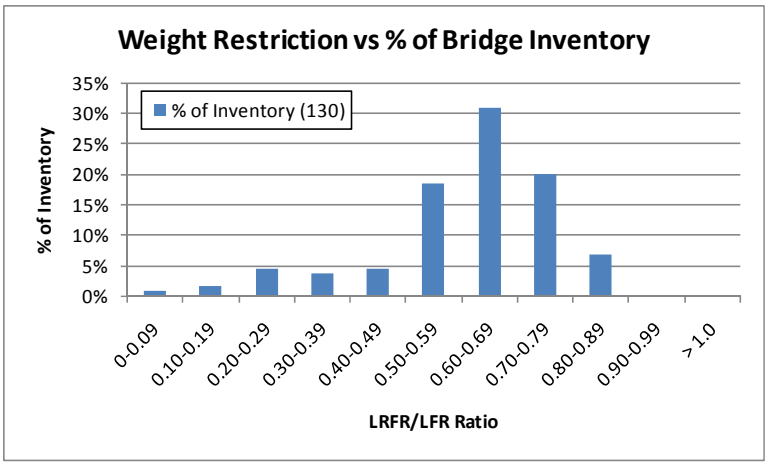


Figure E-9: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

E.1.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure E-10 shows 46 girders do not have the target reliability of 3.5 inherent in the AASHTO LRFD Design Specifications. Most of these girders have spans less than 40 feet but there are a number that are between 50 and 60 feet. The reliability index for most girders is less than six.

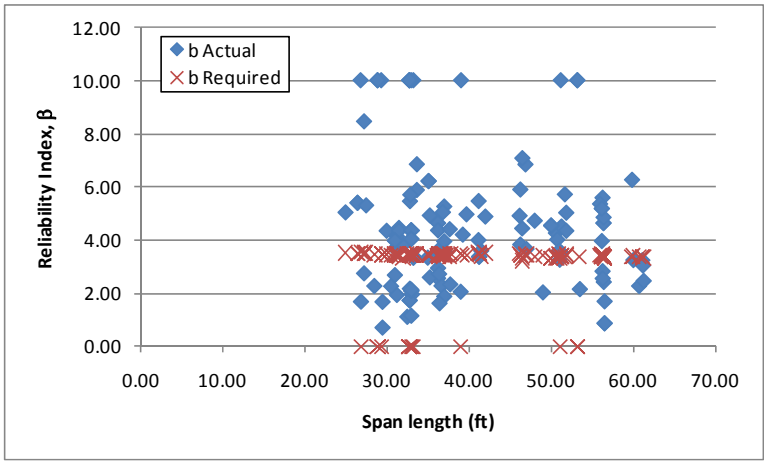


Figure E-10: Flexure Reliability Indices for HL-93 Loading

Figure E-11 shows the reliability index for moment plotted against the LRFR moment rating for the design vehicle. The figure shows the reliability increases with increasing LRFR ratings. The figure shows that girders with an LRFR rating of 1.0 have a reliability index of approximately four; this is higher than the target reliability of 3.5 but is expected because the live load factors used in the design inventory rating are higher than what was actually determined in the calibration.

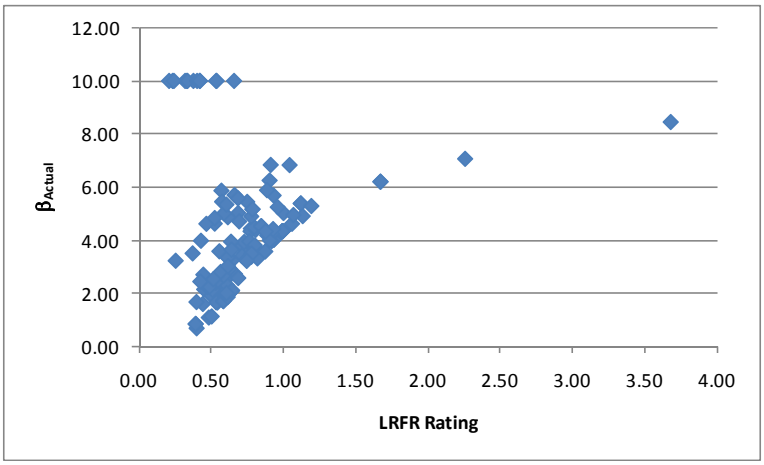


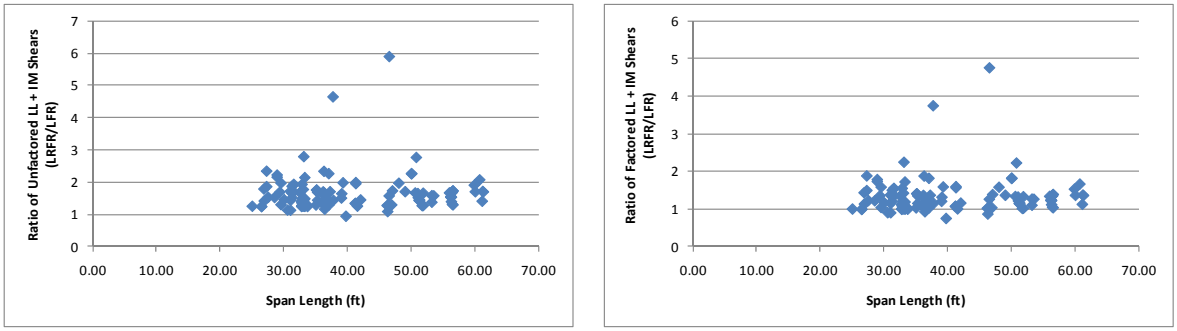
Figure E-11: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Design Load

E.1.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is reinforced concrete tee-beam, simple span exterior girders.

E.1.2.2.1 Live Loads

Figure E-12a shows that the ratio of unfactored shear varies significantly, with most girders between 1.0 and 2.0. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure E-12b shows that the ratio of factored live load shears has decreased and is generally between 0.8 and 1.6 for most cases.



(a) (b)

Figure E-12: Ratio of Unfactored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

As shown in Figure E-13, the location of the critical section varies for most girders in this subset. The factored shears shown in Figure E-12 are scattered due to the difference in the critical section for shear rating.

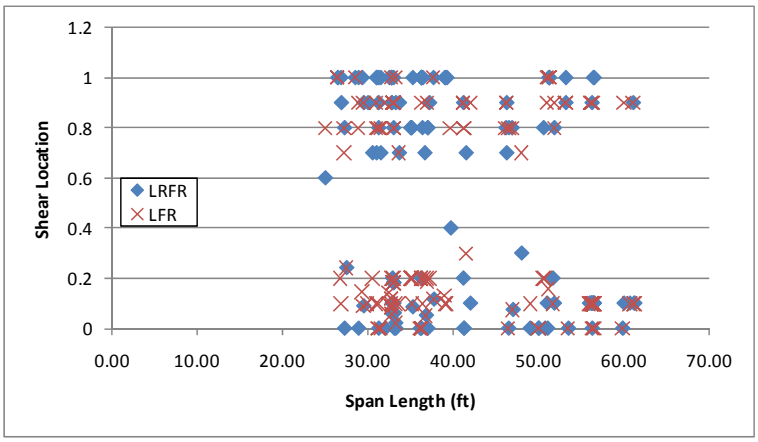


Figure E-13: Graph of critical shear location for Design Loadings

E.1.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure E-14 shows that the ratio of resistance is generally greater than 1.0 (LRFR resistance is greater than LFR resistance).

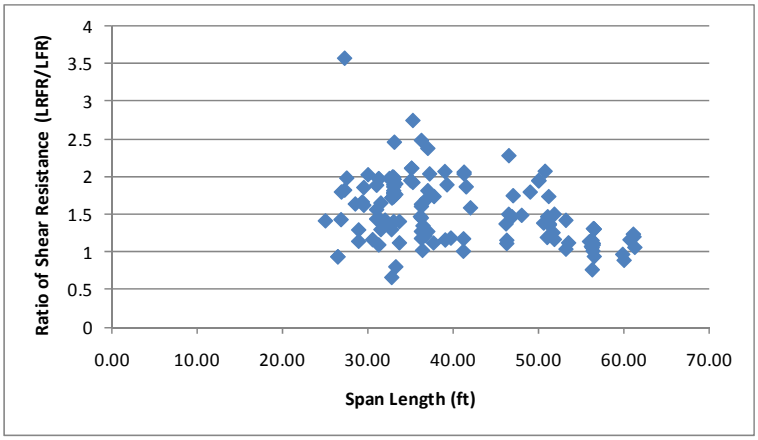
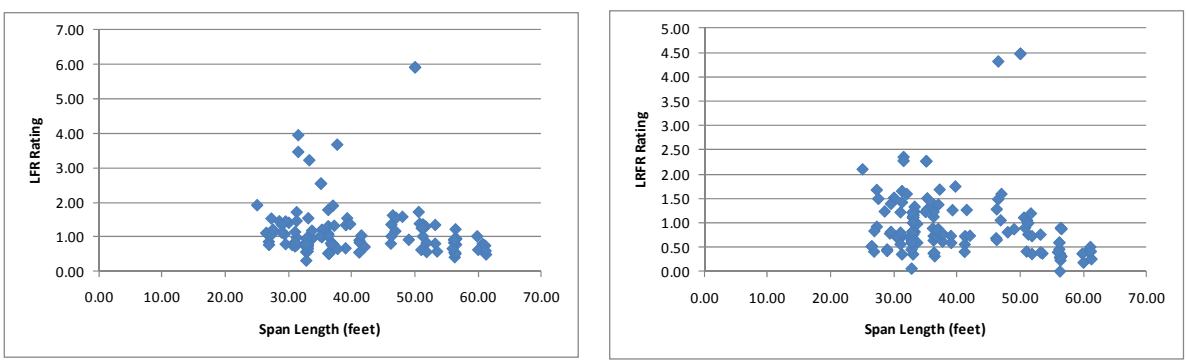


Figure E-14: Ratio of factored Shear Resistance (LRFR/LFR)

E.1.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 72 girders with LFR ratings less than 1.0, 82 girders with LRFR ratings less than 1.0, and 61 girders where both LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. For this subset, 63% of girders have shear ratings less than 1.0 for LRFR. The LFR rating was greater than the LRFR rating for 69% of the girders in this subset. Figure E-15 shows the LFR rating factors and LRFR rating factors. The LFR rating is between 0.5 and 2 for most girders, there were several outliers, one at fourteen and another at 52 that were removed from the graph showing the LFR ratings. The LRFR rating is between 0.5 and 2 for most girders.



(a) (b)

Figure E-15: LFR and LRFR Shear Rating Factors for Design Loadings

E.1.2.2.4 Rating Factor Comparisons

Figure E-16 shows the ratio of the LRFR rating to the LFR rating. About 30% of the girders in this subset have LRFR ratings greater than LFR ratings. The ratio of ratings tends to decrease with increasing span lengths, and spans less than 40 feet are more likely to have LRFR ratings greater than LFR ratings.

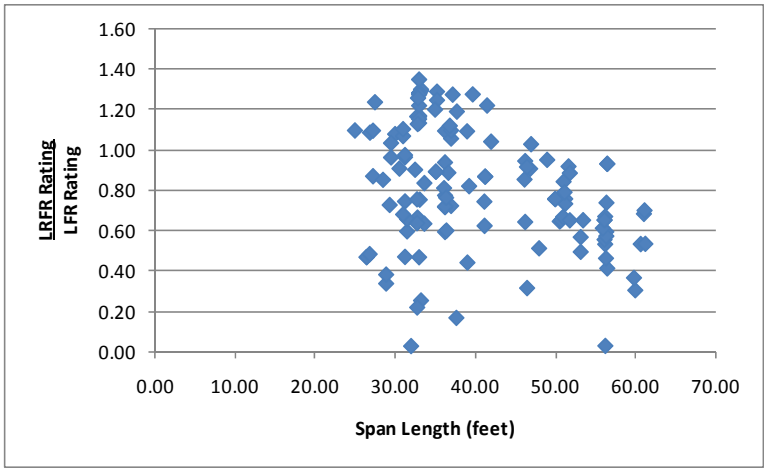


Figure E-16: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure E-17 shows the percentage of girders with ratings less than 1.0 in each category of LRFR/LFR ratio. The figure shows that 12% of the total girders in this group have LRFR ratings that are greater than the LFR rating. The figure provides an estimation of the number of girders that will be affected by switching from LFR to LRFR and the effect on the allowable truck weight.

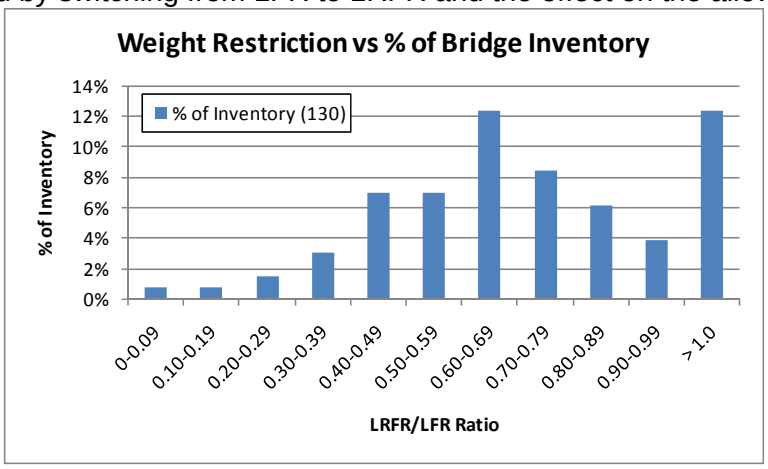


Figure E-17: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

E.1.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure E-18 shows that 66 girders do not have a reliability index for shear greater than the target reliability of 3.5 inherent in the AASHTO LRFD Design Specifications. These girders are of varying lengths. In several cases, the reliability index based on the section capacity is less than zero, indicating the applied loads are significantly larger than the section resistance. This may also be indicative of shear reinforcement not being input or being input incorrectly. The reliability index for most girders is less than six.

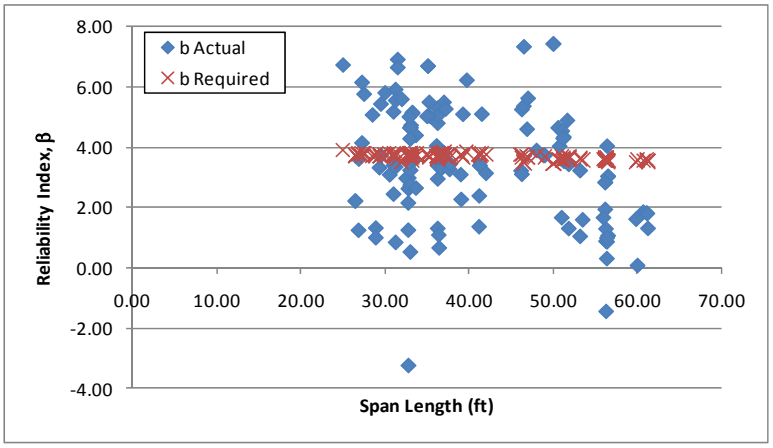


Figure E-18: Shear Reliability Indices for HL-93 Loading

Figure E-19 shows the reliability index for shear plotted against the LRFR shear rating for the HL-93 design load. The figure shows that the reliability index for a girder with a rating of 1.0 is approximately four. This is not an unexpected result because the live load factors determined in the calibration of the Design Specification were increased to be conservative.

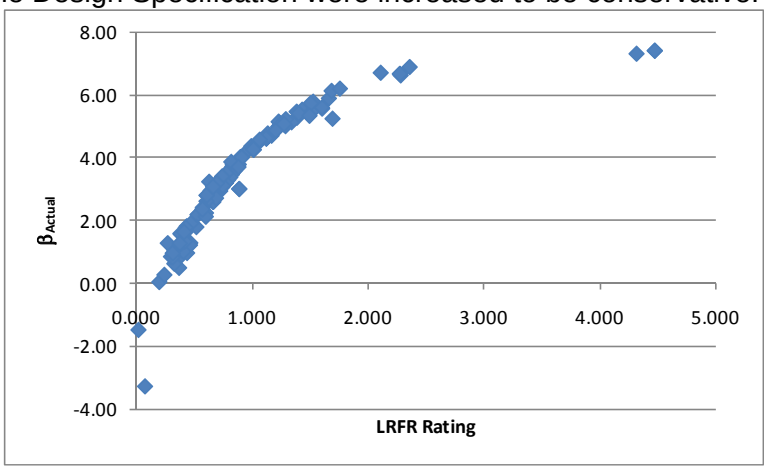
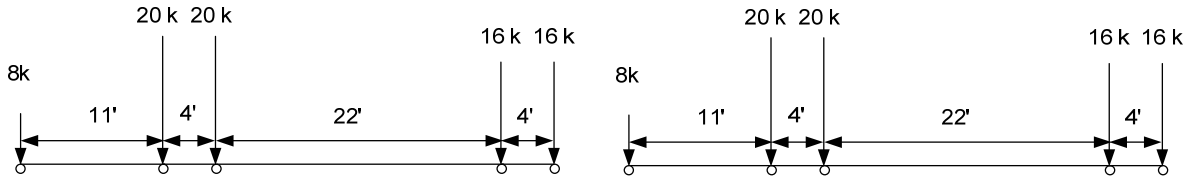


Figure E-19: Shear Reliability Index vs LRFR Shear Rating for HL-93 Design Load

E.1.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-20. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.



LFR Loading

plus 0.2 klf for spans greater than 200 feet
LRFR Loading

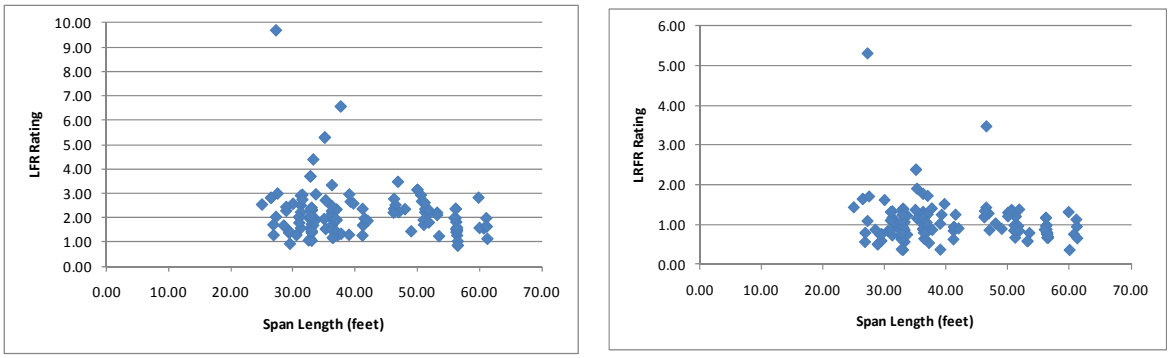
Figure E-20: Vehicle Loadings and Load Factors

E.1.3.1 Moment

The following section contains the results for exterior reinforced concrete tee-beam girders within simple span bridges for the DE-07 Vehicle.

E.1.3.1.1 Rating Factors

Figure E-21 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are three girders with an LFR rating less than 1.0, 66 girders with an LRFR rating less than 1.0, and three girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. All of the girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR ratings are between one and three for most girders; the vertical axis on the graph was reduced and eliminated two girders with ratings between 30 and 40. The LRFR rating is between 0.5 and 1.5.



(a) (b)

Figure E-21: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure E-22 shows the percentage of girders with moment ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 61% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 38.5% of girders when the ADTT is greater than 5,000. 98% of girders have LFR ratings greater than 1.0. Approximately 40% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 60% when the highest ADTT is considered.

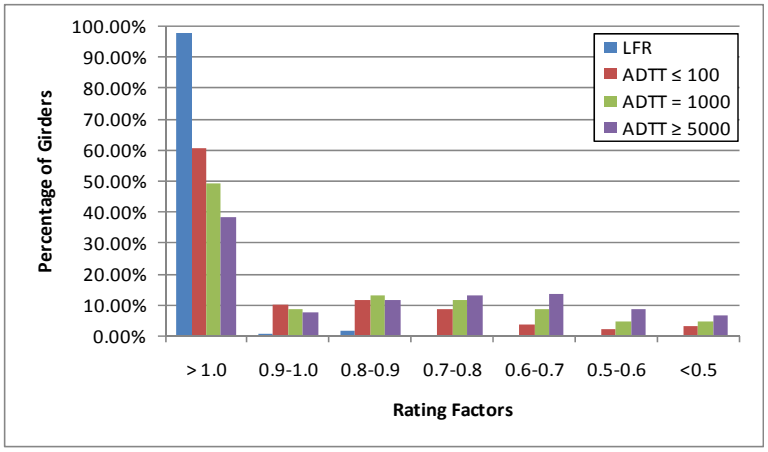


Figure E-22: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

E.1.3.1.2 Rating Factor Comparisons

Figure E-23 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.4 to 0.7. Zero girders have LRFR ratings higher than the LFR ratings; girders with the lowest ratios tend to be under forty feet in length.

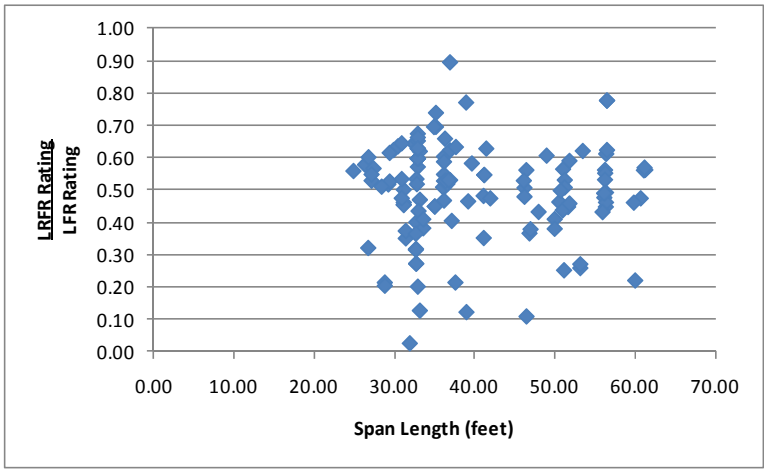


Figure E-23: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

E.1.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-24 shows that all but two girders have a reliability index that is greater than the target reliability index of 2.5. The reliability index is between four and eight for most girders.

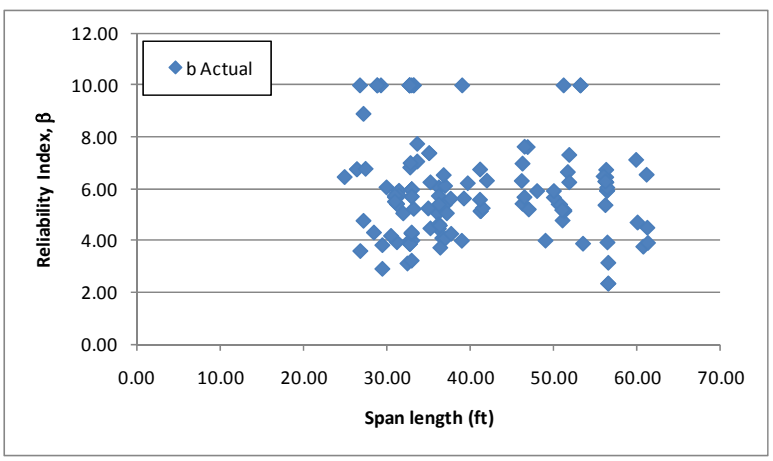


Figure E-24: Flexure Reliability Indices for DE-07 Vehicle

Figure E-25 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 vehicle. The figure shows the reliability index corresponding to an LRFR rating of 1.0 is at least 4.0. The average reliability index is greater than the target reliability of 2.5 indicating the LRFR live load factors are over-conservative and can be reduced.

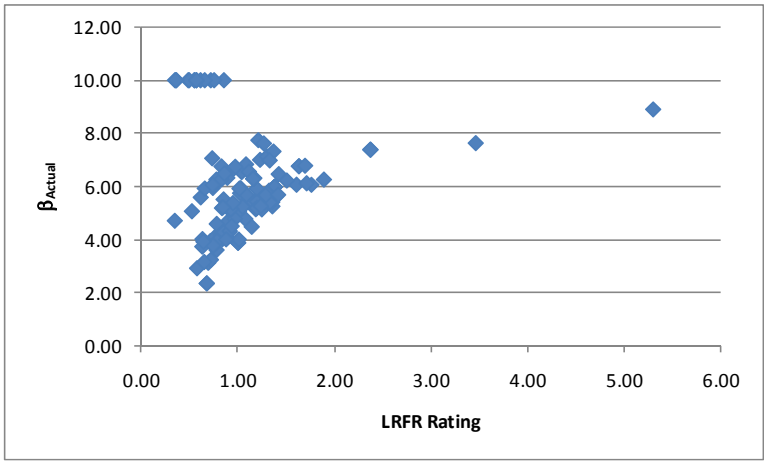
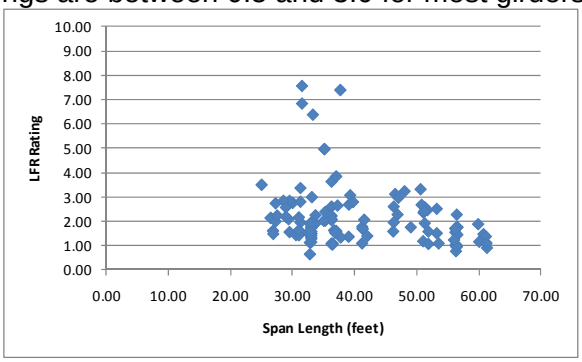


Figure E-25: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

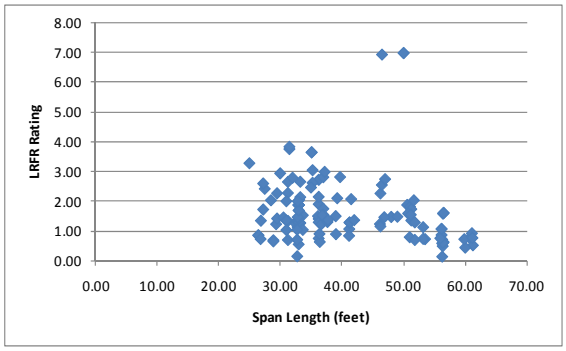
E.1.3.2 Shear

E.1.3.2.1 Rating Factors

For shear, there are six girders that have rating factors less than 1.0 for LFR, 33 girders for LRFR, and six girders where both LFR and LRFR are less than 1.0. The LFR Rating is greater than the LRFR rating for 78% of the girders in this subset. Figure E-26 shows the LFR and LRFR ratings. The LFR ratings are between one and three for most girders. Three outliers were removed from the LFR rating graph; they had ratings of 12, 27, and 103. The LRFR ratings are between 0.5 and 3.0 for most girders.



(a)



(b)

Figure E-26: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure E-27 shows the percentage of girders with shear ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 77% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 70% of girders when the ADTT is greater than 5,000. 95% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to 25% when the highest ADTT is considered.

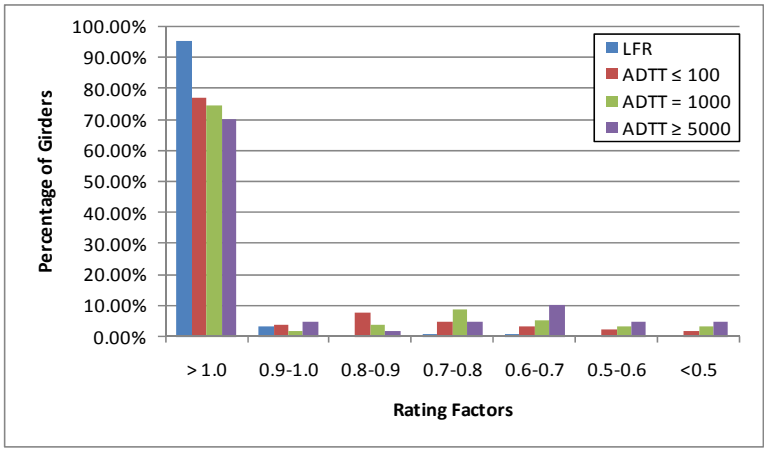


Figure E-27: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

E.1.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure E-28 shows the comparison of rating factors. The ratio is less than 1.0 for 78% of the girders, with spans under 45 feet being the most likely to have an LRFR rating greater than an LFR rating.

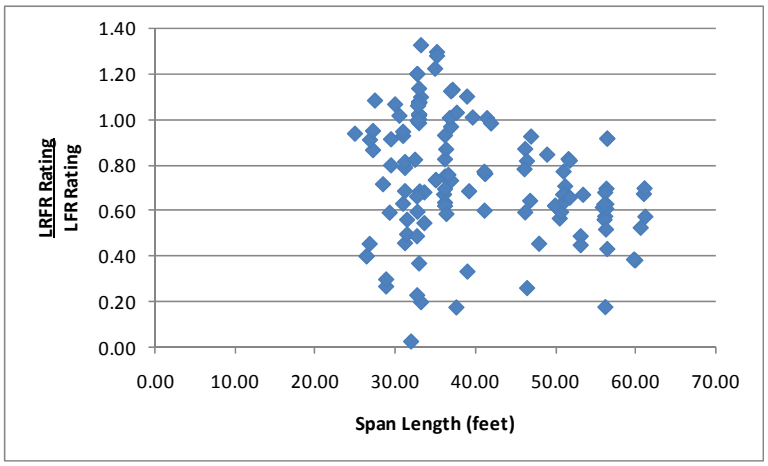


Figure E-28: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

E.1.3.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but five girders as shown in Figure E-29. The most likely reason for this is that the shear reinforcement is not input or input incorrectly. The reliability index is between two and seven for most girders.

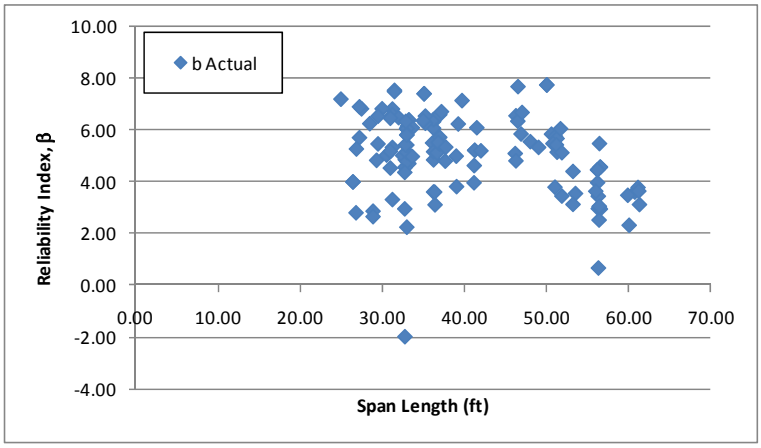


Figure E-29: Shear Reliability Indices for DE-07 Vehicle

Figure E-30 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 vehicle. The figure shows that girders with a rating of 1.0 have reliability indices of approximately four, above the target reliability of 2.5. This indicates that the live load factors in the MBE may be over conservative and can be reduced. Reducing the live load factors will increase the number of girders passing the rating as well as bring the reliability index closer to the target reliability for girders passing the rating.

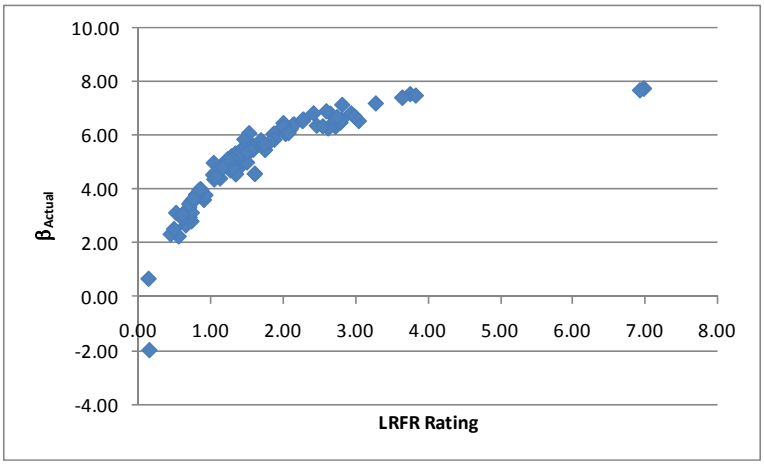
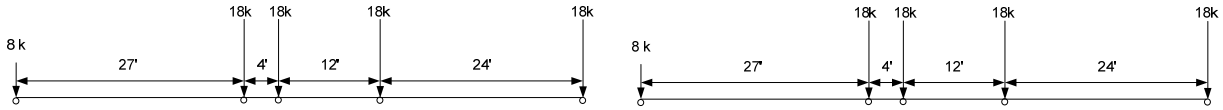


Figure E-30: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

E.1.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-31. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.



LFR Loading

plus 0.2 klf for spans greater than 200 feet
LRFR Loading

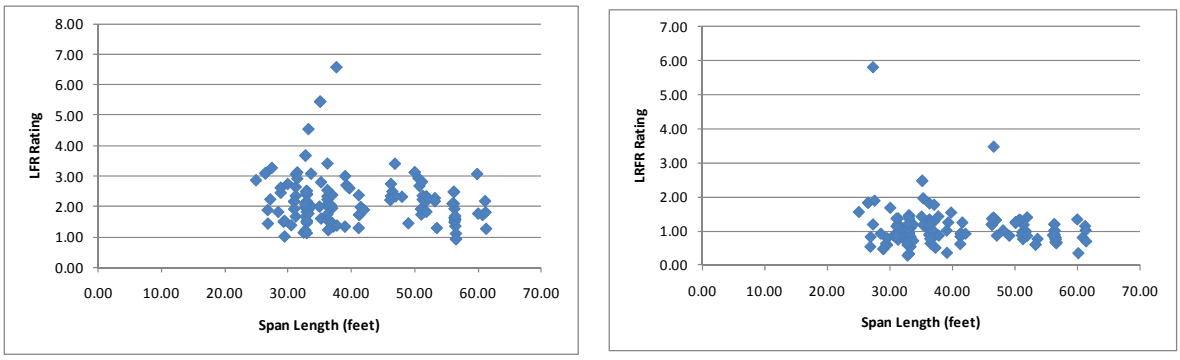
Figure E-31: Vehicle Loadings and Load Factors

E.1.4.1 Moment

The following section contains the results for exterior, reinforced concrete tee-beams within simple span bridges for the FL-04 Vehicle.

E.1.4.1.1 Rating Factors

Figure E-32 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are three girders with an LFR rating less than 1.0, 63 girders with an LRFR rating less than 1.0, and three girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. All girders with LRFR ratings less than 1.0 were controlled by the longitudinal steel rating. The LFR ratings are between one and three; three outliers were removed they had values of 11, 32 and 40. The LRFR ratings are between 0.5 and 1.5 for most girders.



(a) (b)

Figure E-32: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure E-33 shows the percentage of girders with moment ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 67% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 41.5% of girders when the ADTT is greater than 5,000. 98% of girders have LFR ratings greater than 1.0. Approximately 30% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to approximately 55% when the highest ADTT is considered.

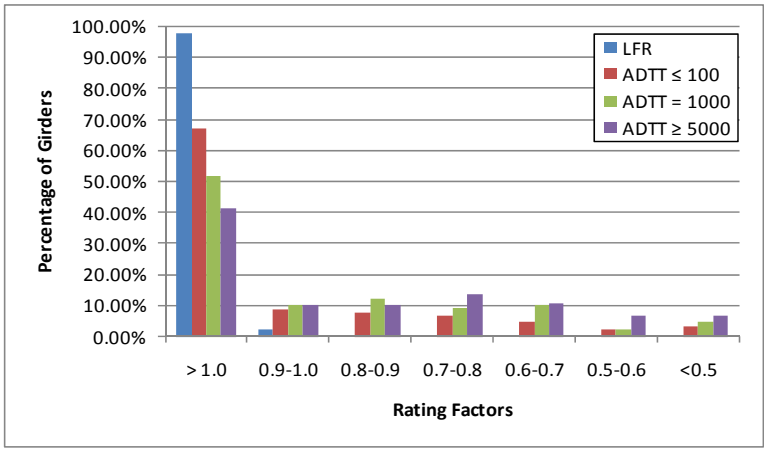


Figure E-33: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

E.1.4.1.2 Rating Factor Comparisons

Figure E-34 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. There are zero girders with an LRFR rating greater than the LFR rating. The LRFR rating is typically 40 to 60% of the LFR rating.

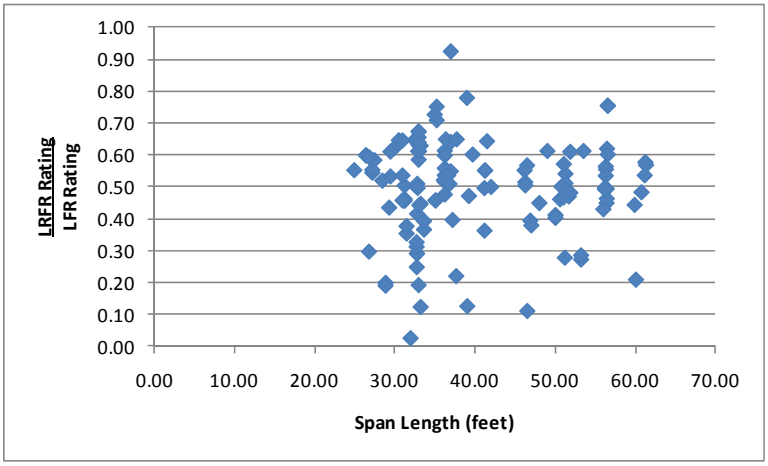


Figure E-34: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

E.1.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-35 shows that all girders have a reliability index greater than the target reliability index of 2.5. The reliability indices are between four and eight for most girders, well above the target reliability of 2.5.

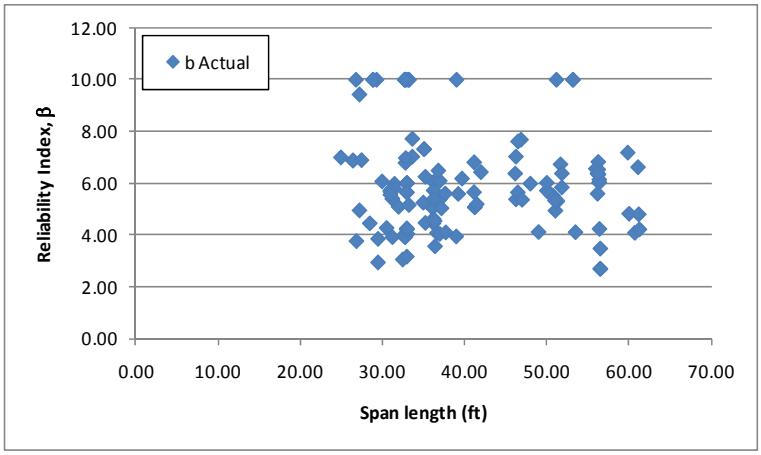


Figure E-35: Flexure Reliability Indices for FL-04 Vehicle

Figure E-36 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 Vehicle. The figure shows that the average reliability index for a girder with a rating of 1.0 is approximately 5.0, greater than the target reliability of 2.5. This indicates that the LRFR live load factors are over-conservative and can be reduced.

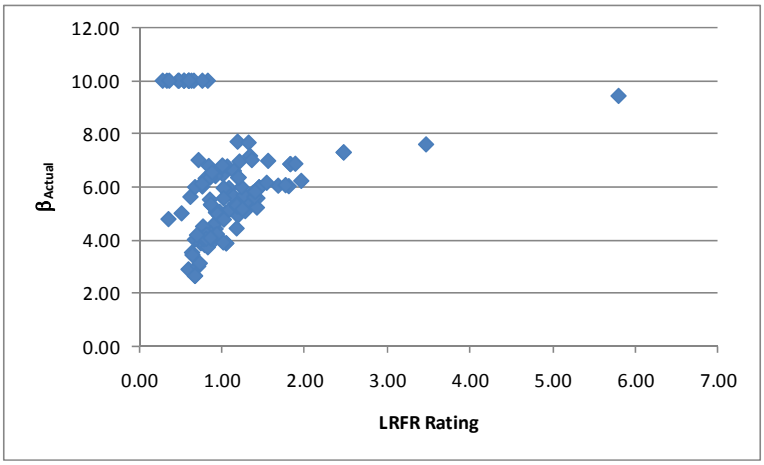
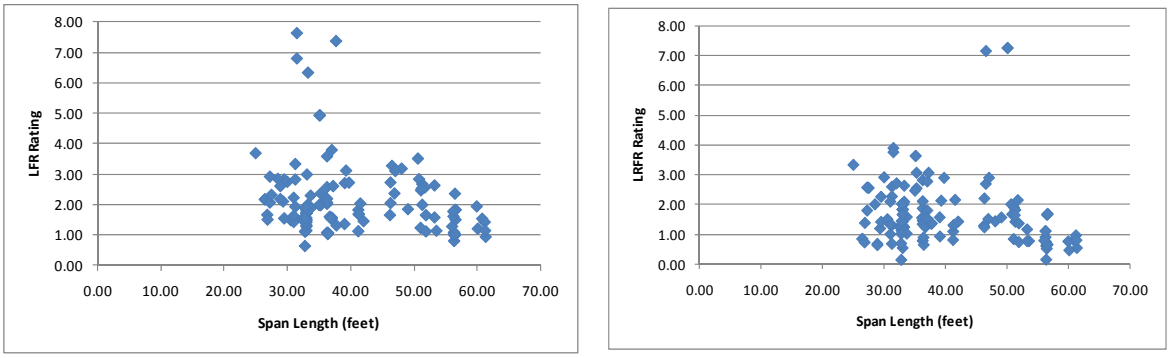


Figure E-36: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

E.1.4.2 Shear

E.1.4.2.1 Rating Factors

For shear, there are five girders that have LFR rating factors less than 1.0, 33 girders with LRFR ratings less than 1.0, and five girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 78% of the girders in this subset. Figure E-37 shows the LFR and LRFR ratings. The LFR rating is between one and three for most girders while the LRFR ratings are between 0.5 and 3. Three outliers were removed from the LFR rating graph, these ratings were 12, 28, and 102.



(a) (b)

Figure E-37: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure E-38 shows the percentage of girders with shear ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 78% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 69% of girders when the ADTT is greater than 5,000. 96% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 30% when the highest ADTT is considered.

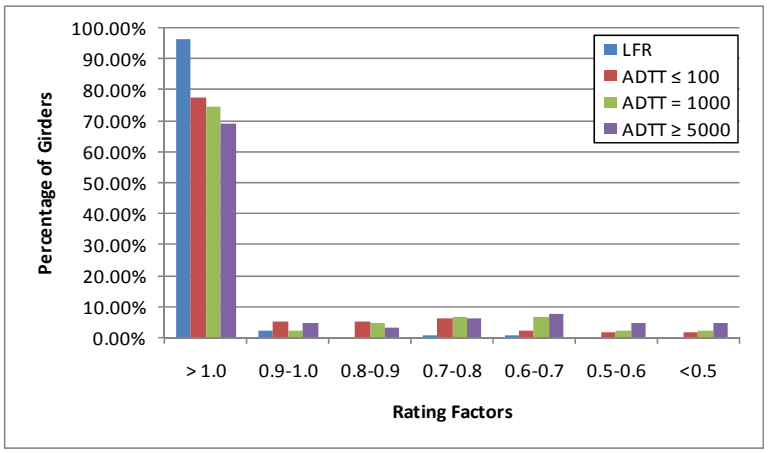


Figure E-38: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

E.1.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-39 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2, with the ratio decreasing for longer span lengths. 22% of the girders in this group have LRFR ratings that exceed the LFR rating.

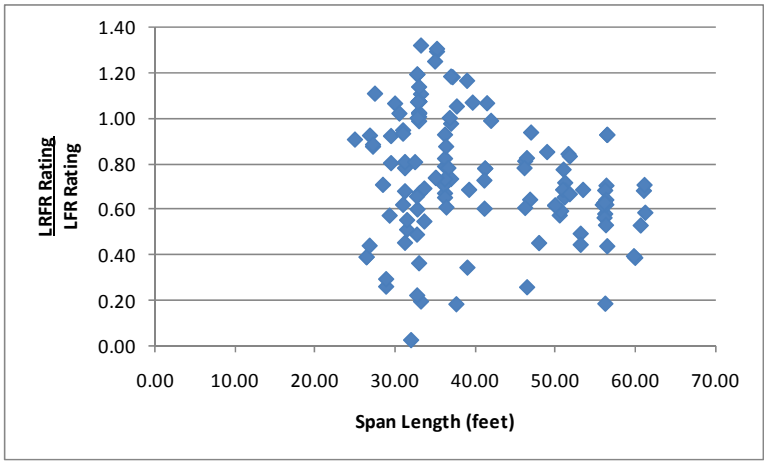


Figure E-39: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

E.1.4.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 except for four girders as shown in Figure E-40. These girders likely have shear reinforcement that was not input or input incorrectly resulting in the very low shear resistances. The reliability index is between two and seven for most girders.

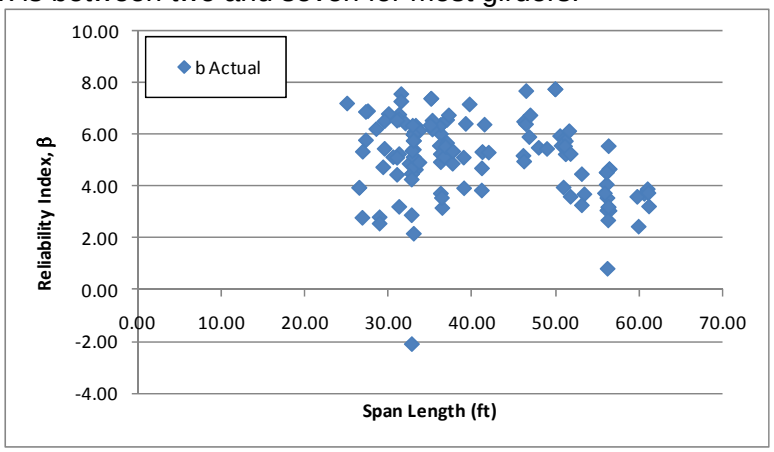


Figure E-40: Shear Reliability Indices for FL-04 Vehicle

Figure E-41 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 vehicle. The figure shows that the average reliability index for a girder with a rating of 1.0 is approximately 4.5, higher than the target value of 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

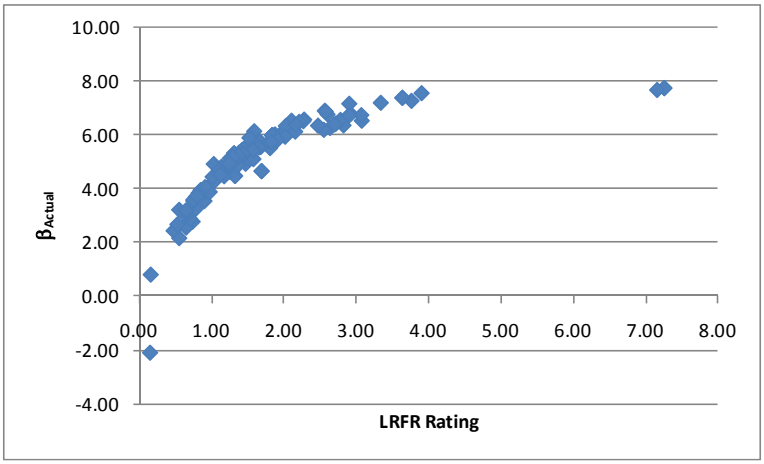


Figure E-41: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

E.1.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-42. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases multiple lanes may control.

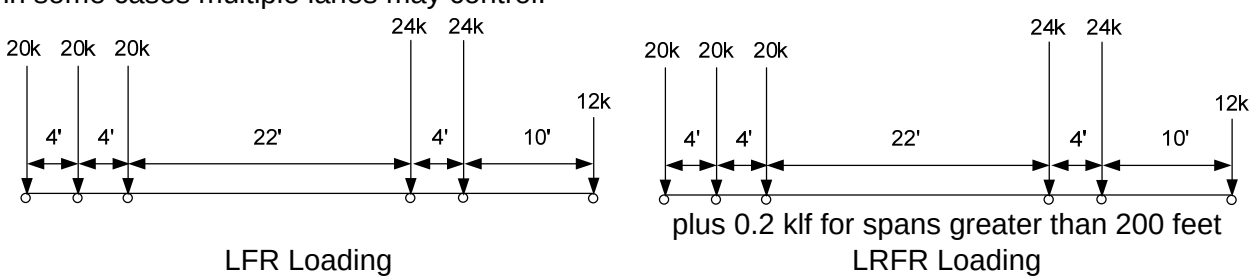


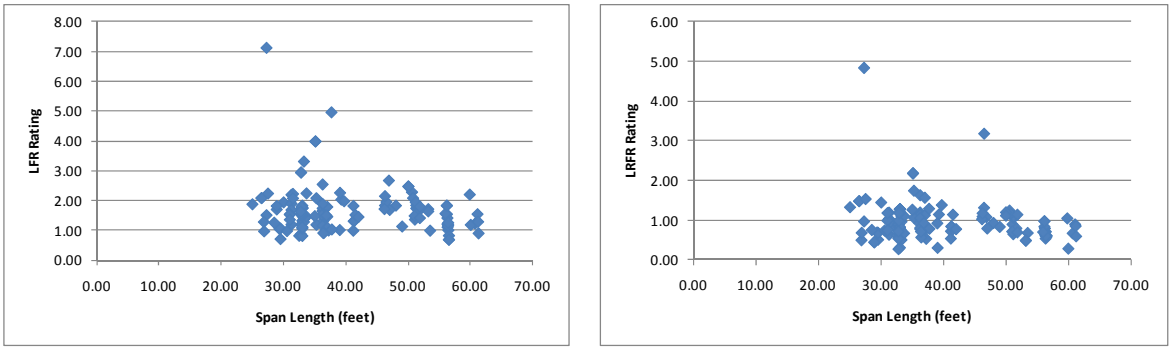
Figure E-42: Vehicle Loadings and Load Factors

E.1.5.1 Moment

The following section contains the results for exterior, reinforced concrete tee-beams within simple span bridges for the IL-01 Vehicle.

E.1.5.1.1 Rating Factors

Figure E-43 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 16 girders with an LFR rating less than 1.0, 81 girders with an LRFR rating less than 1.0, and 16 girders where both ratings are less than 1.0. All 81 girders with LRFR ratings less than 1.0 were controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 99% of the girders in this subset. The LFR ratings are between one and two for most girders; two outliers were removed with values of 25 and 29. The LRFR rating is between 0.5 and 1.5 for most girders.



(a) (b)

Figure E-43: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure E-44 shows the percentage of girders with moment ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 56% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit. This decreases to 10% of girders when a multi-trip permit and ADTT greater than 5,000. 88% of girders have LFR ratings greater than 1.0. Approximately 30% more girders have LRFR ratings less than 1.0 when a single escorted permit is considered; this increases to almost 80% when a multi-trip permit with ADTT greater than 5,000 is considered.

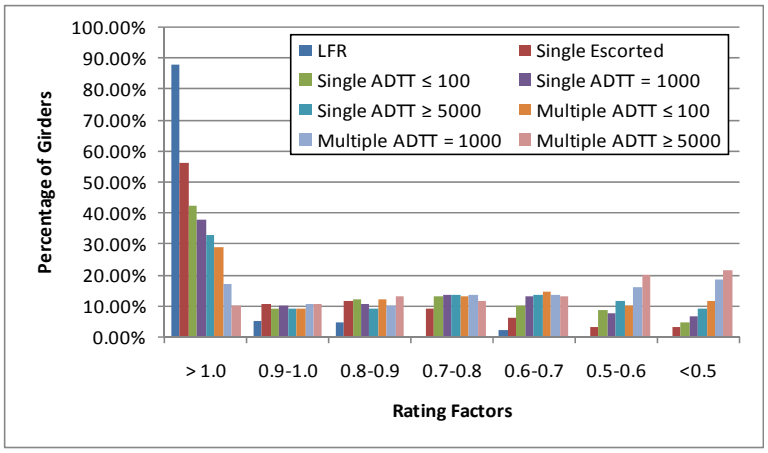


Figure E-44: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

E.1.5.1.2 Rating Factor Comparisons

Figure E-45 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.8, with the ratio generally within the same range for all span lengths. There are several that are outside this range of values, these correspond to those outliers shown above for the rating factors. There is one girder with an LRFR rating greater than the LFR rating.

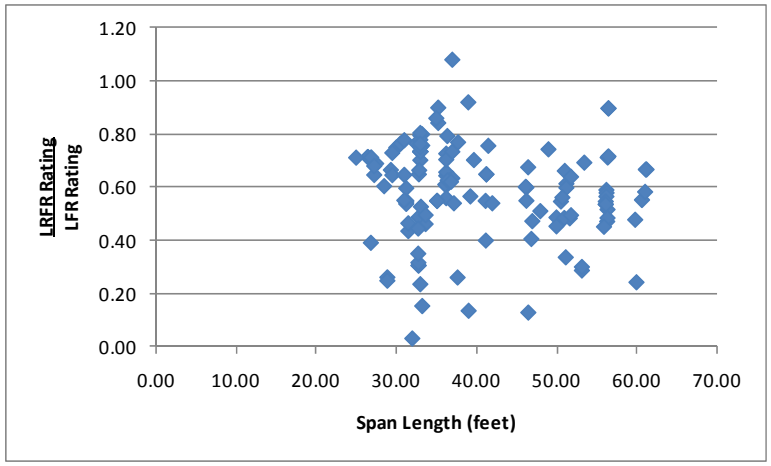


Figure E-45: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

E.1.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-46 shows that five girders have a reliability index less than the target reliability index of 3.5. The reliability index is between four and eight for most girders with longer span girders having the lower reliability indexes.

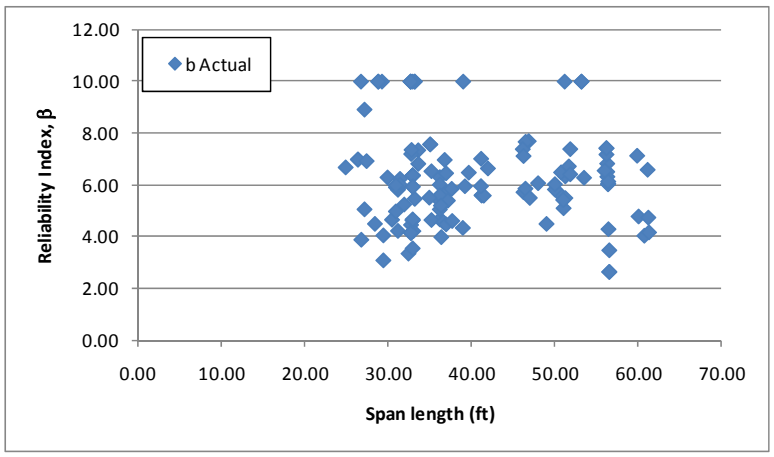


Figure E-46: Flexure Reliability Indices for IL-01 Vehicle

Figure E-47 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The figure shows that the average reliability index for girders with a rating of 1.0 is approximately 5.5. This exceeds the target reliability of 3.5. The average reliability exceeding the target reliability indicates that the live load factors in the MBE are over-conservative and can be reduced.

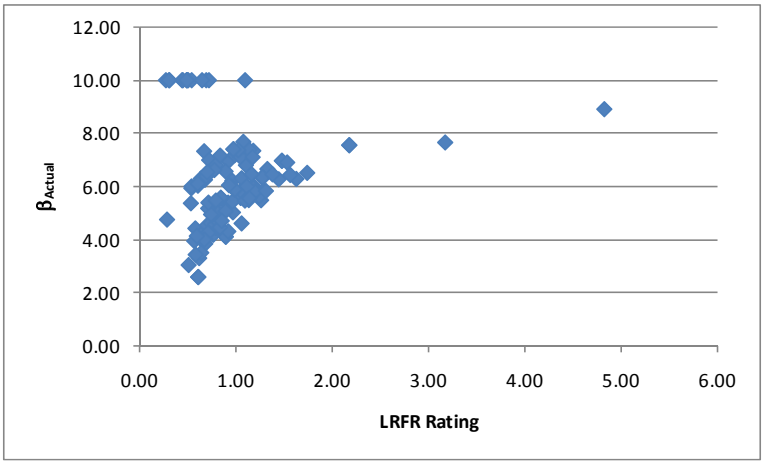
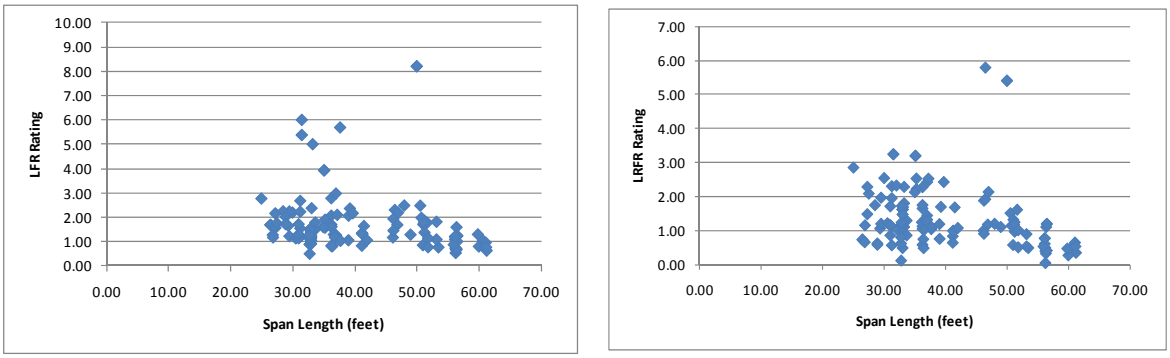


Figure E-47: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

E.1.5.2 Shear

E.1.5.2.1 Rating Factors

For shear, there are 22 girders that have LFR rating factors less than 1.0, 48 girders with LRFR ratings less than 1.0, and 20 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 72% of the girders in this subset. Figure E-48 shows the LFR and LRFR ratings. The LFR rating is between 1.0 and 2.5 for most girders; two outliers were removed with ratings of 20 and 82. The LRFR rating is between 0.5 and 2.5 for most girders.



(a) (b)

Figure E-48: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure E-49 shows the percentage of girders with shear ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 72% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 36.2% of girders for a multiple trip permit with an ADTT of 5,000. 83% of girders have LFR ratings greater than 1.0. Approximately 10% more girders have LRFR ratings less than 1.0 when the single trip, escorted permit is considered; this increases to almost 50% when a multi-trip permit with ADTT of 5,000 is considered.

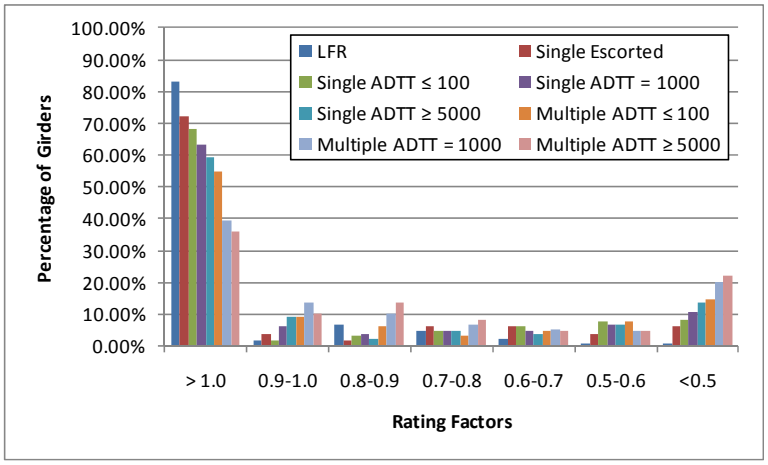


Figure E-49: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

E.1.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-50 shows the comparison of rating factors. The ratio is less than 1.0 for 72% of the girders with longer girders tending to have an LRFR rating smaller than the associated LFR rating.

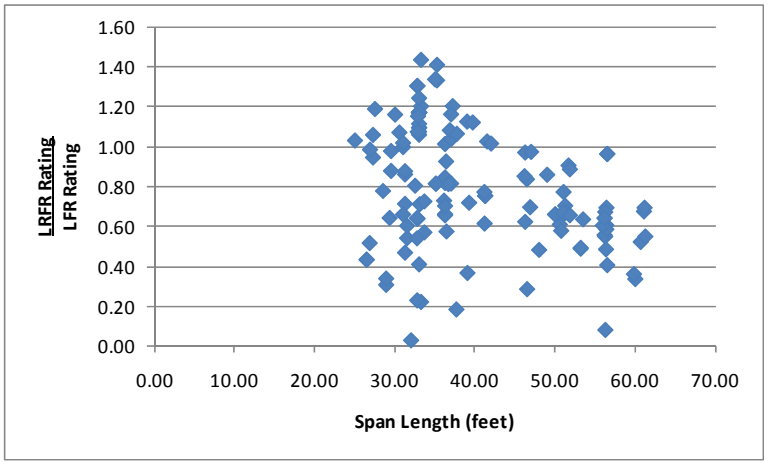


Figure E-50: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

E.1.5.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for 28 girders as shown in Figure E-51. The figure shows that the reliability index is between two and eight, with most of the girders less than four being less than the target reliability of 3.5.

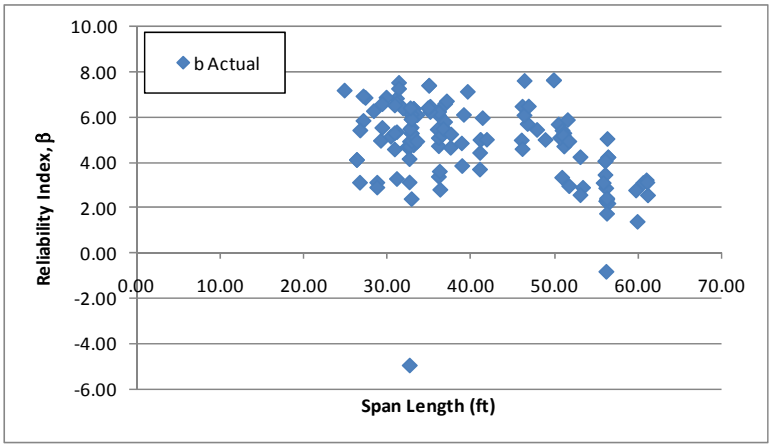


Figure E-51: Shear Reliability Indices for IL-01 Vehicle

Figure E-52 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 vehicle. This figure shows that the average reliability index for a girder with a rating of 1.0 is approximately 5.0. This exceeds the target reliability of 3.5 and indicates that the live load factors currently in the MBE are over-conservative and can be reduced.

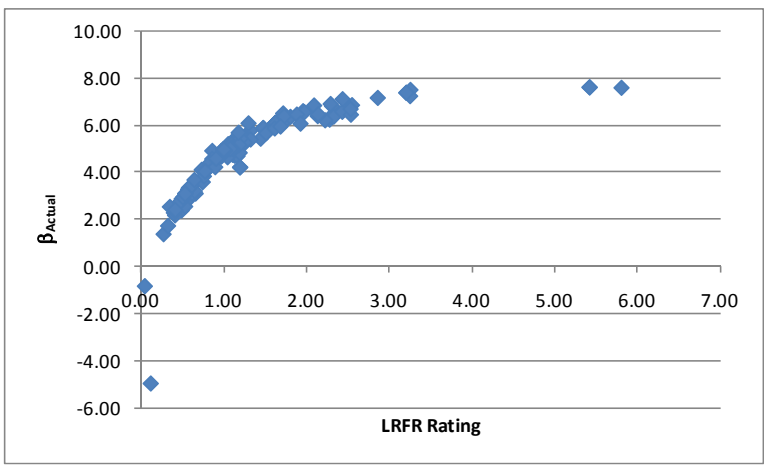
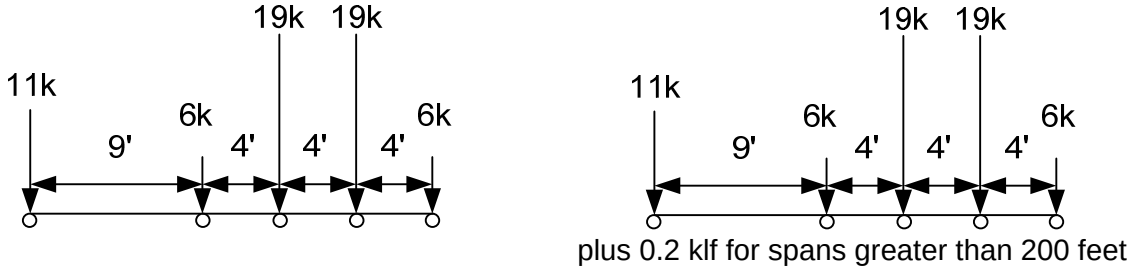


Figure E-52: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

E.1.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-53. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.



LFR Loading LRFR Loading

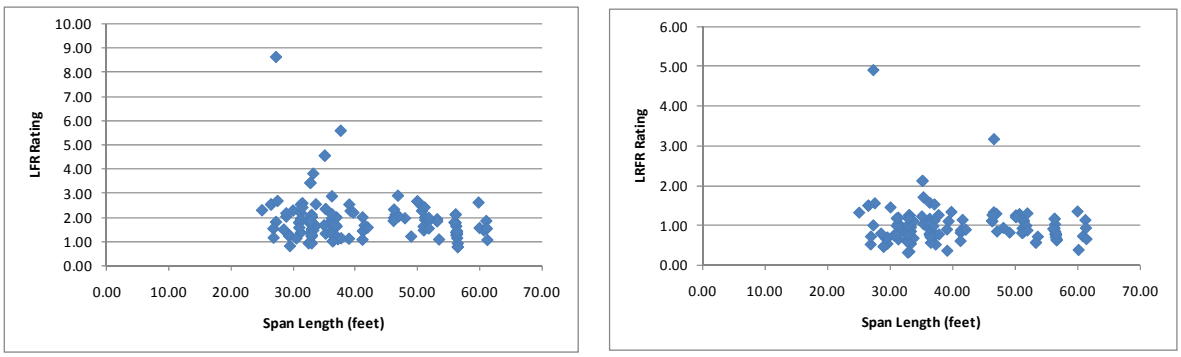
Figure E-53: Vehicle Loadings and Load Factors

E.1.6.1 Moment

The following section contains the results for exterior, reinforced concrete tee beams within simple span bridges for the NC-21 Vehicle.

E.1.6.1.1 Rating Factors

Figure E-54 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are six girders with an LFR rating less than 1.0, 76 girders with an LRFR rating less than 1.0, and six girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. All girders with an LRFR rating less than 1.0 are controlled by the longitudinal steel rating. The LFR rating is between one and three for most girders; two outliers were removed with values of 27 and 34. The LRFR rating is between 0.5 and 1.5 for most girders.



(a) (b)

Figure E-54: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure E-55 shows the percentage of girders with moment ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 55% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 30% of girders when the ADTT is greater than 5,000. 95% of girders have LFR ratings greater than 1.0. Approximately 40% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 65% when the highest ADTT is considered.

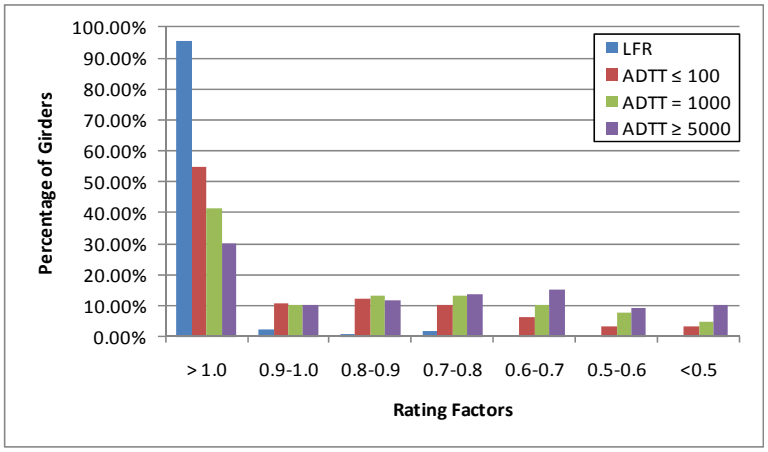


Figure E-55: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

E.1.6.1.2 Rating Factor Comparisons

Figure E-56 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.7 for this vehicle, with the ratio remaining relatively constant with varying span length. No girders have an LRFR rating greater than the LFR rating for this vehicle.

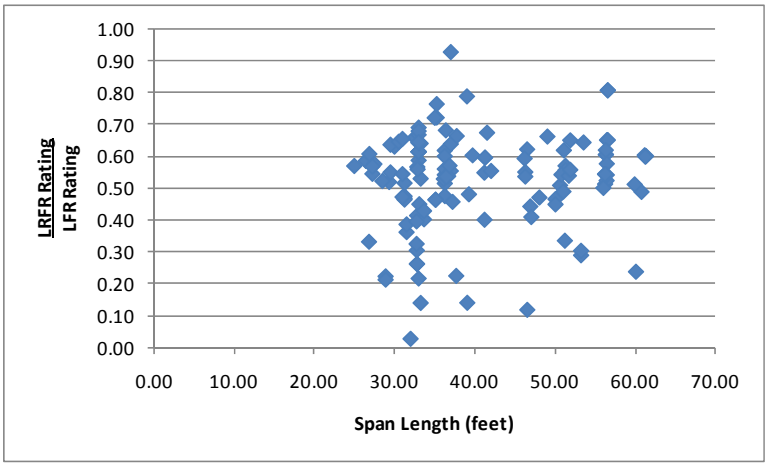


Figure E-56: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

E.1.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-57 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index varies and is between two and seven for most girders.

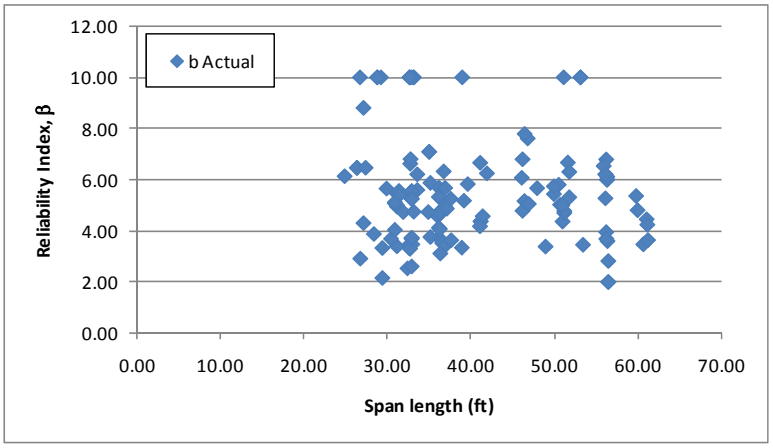


Figure E-57: Flexure Reliability Indices for NC-21 Vehicle

Figure E-58 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 Vehicle. The average reliability index for girders with a rating of 1.0 is approximated to be 4.75, exceeding the target reliability of 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

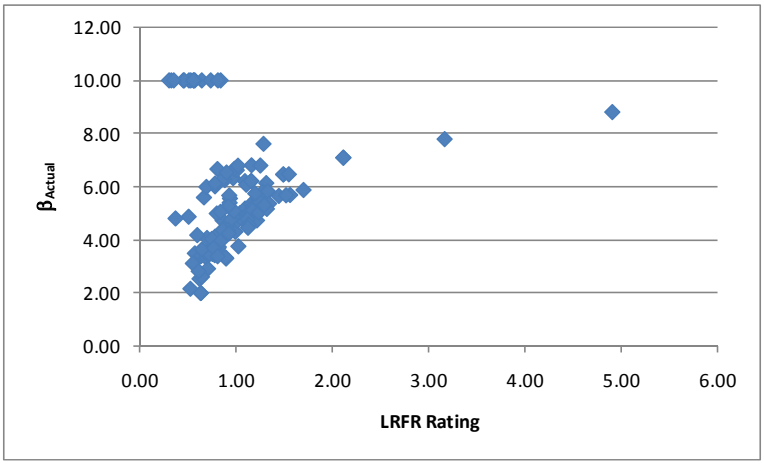
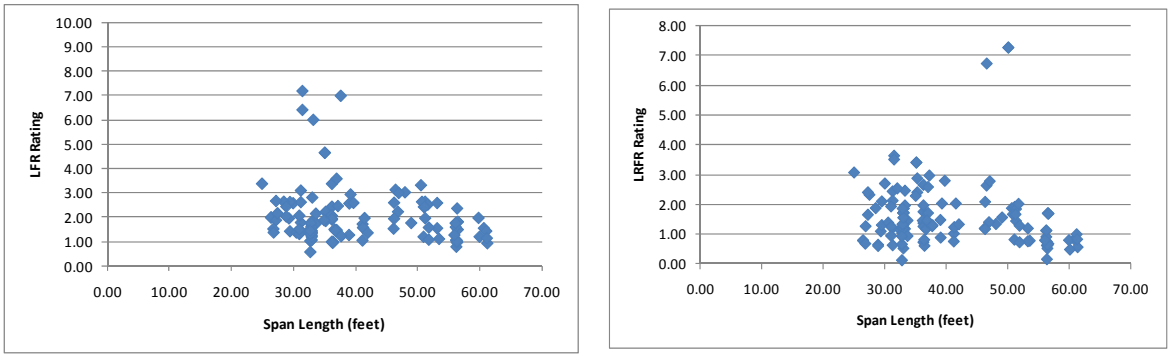


Figure E-58: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

E.1.6.2 Shear

E.1.6.2.1 Rating Factors

For shear, there are six girders that have LFR rating factors less than 1.0, 36 girders with LRFR ratings less than 1.0, and 6 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 82% of the girders in this subset. Figure E-59 shows the LFR and LRFR ratings. The LFR ratings are between one and three for most girders; two outliers were removed with values of 26 and 96. The LRFR ratings are between 0.5 and 3.0 for most girders.



(a) (b)

Figure E-59: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure E-60 shows the percentage of girders with shear ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 77% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 68% of girders when the ADTT is greater than 5,000. 95% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 30% when the highest ADTT is considered.

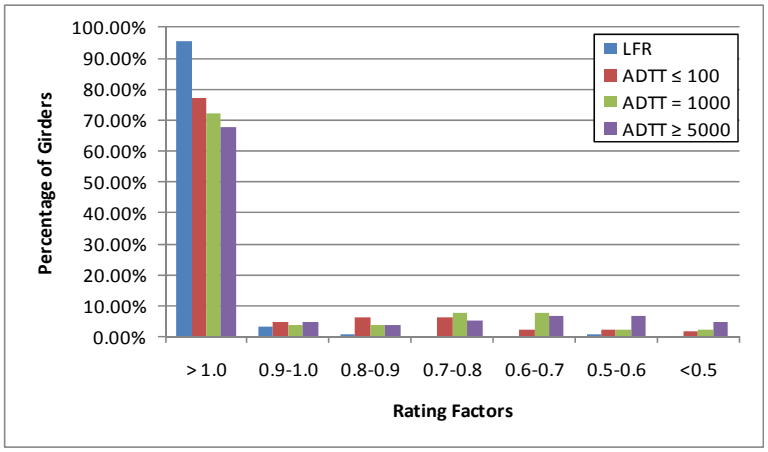


Figure E-60: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

E.1.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-61 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2. Short span girders are more likely to have an LRFR rating greater than the LFR rating, with 18% of girders having LRFR ratings greater than the LFR rating.

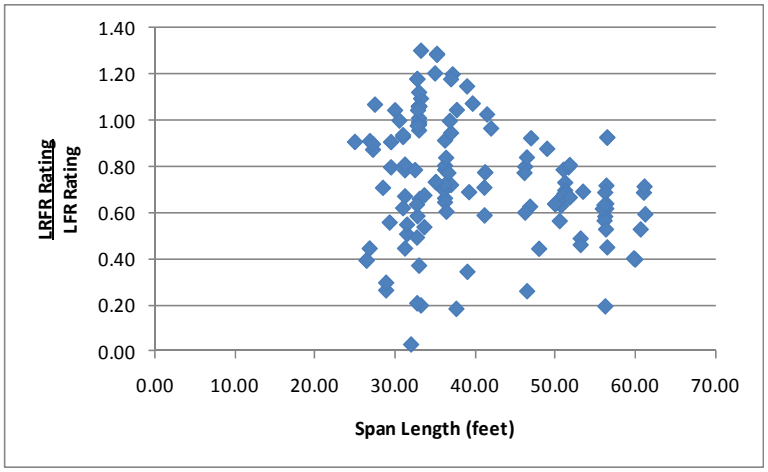


Figure E-61: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

E.1.6.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but five girders as shown in Figure E-62. The girder with negative reliability and the girder with a reliability index of one likely do not have properly defined shear reinforcement.

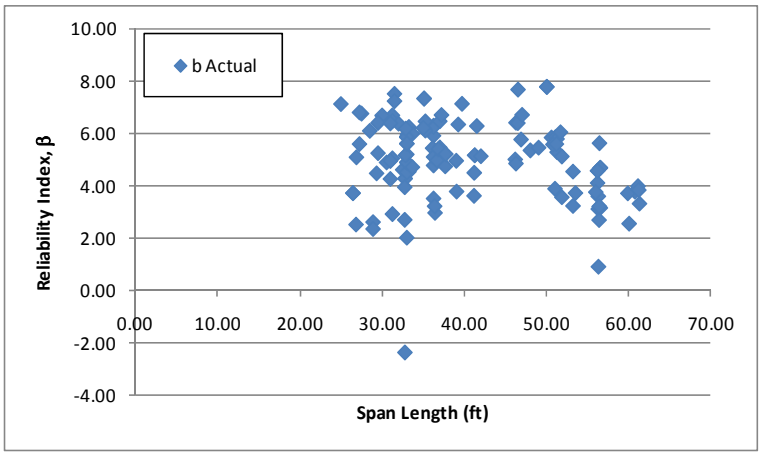


Figure E-62: Shear Reliability Indices for NC-21 Vehicle

Figure E-63 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 vehicle. The average reliability for a girder with a rating of 1.0 is approximately 4.25, exceeding the target reliability of 2.5. This indicates that the current live load factors in the MBE are over-conservative and can be reduced.

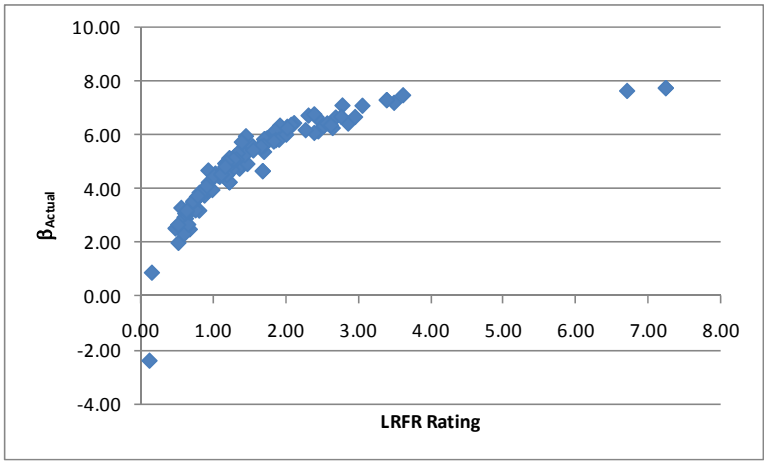


Figure E-63: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

E.1.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-64. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.

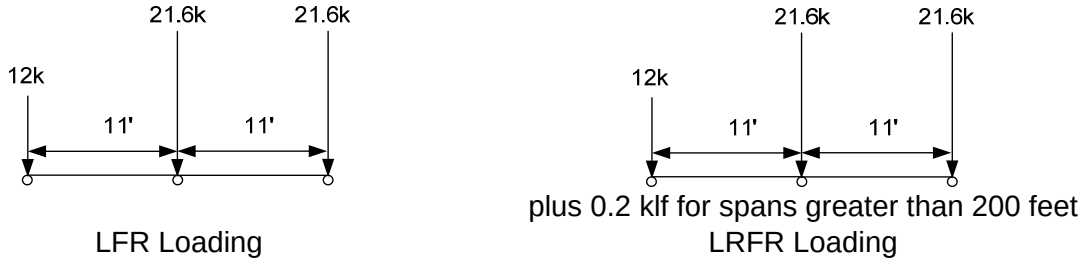


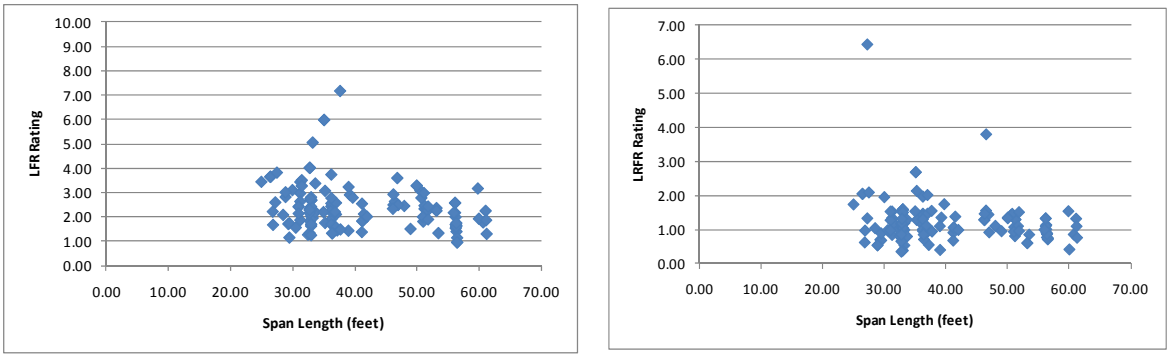
Figure E-64: Vehicle Loadings and Load Factors

E.1.7.1 Moment

The following section contains the results for exterior, reinforced concrete tee beams within simple span bridges for the NM-04 Vehicle.

E.1.7.1.1 Rating Factors

Figure E-65 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are two girders with an LFR rating less than 1.0, 54 girders with an LRFR rating less than 1.0, and two girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR ratings are between one and three for most girders; several outliers with values of 12, 33, and 45 were removed from the rating graph. The LRFR rating is between 0.5 and 2.0 for most girders. All 54 girders with LRFR ratings less than 1.0 were controlled by the longitudinal steel rating.



(a) (b)

Figure E-65: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure E-66 shows the percentage of girders with moment ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 74% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 48% of girders when the ADTT is greater than 5,000. 98% of girders have LFR ratings greater than 1.0. Approximately 25% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 50% when the highest ADTT is considered.

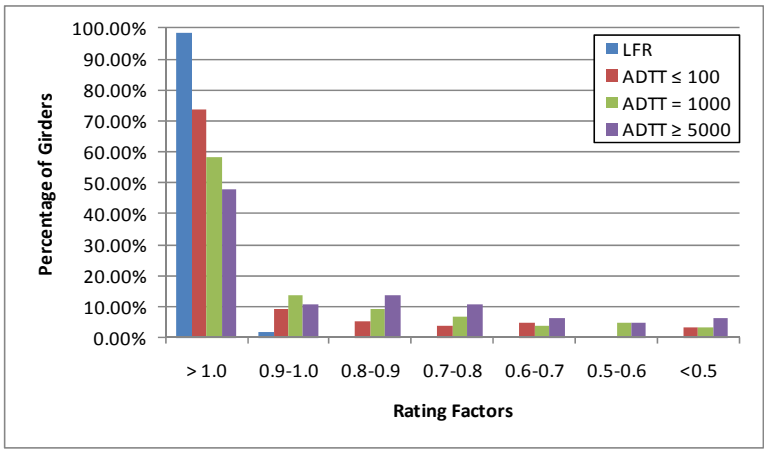


Figure E-66: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

E.1.7.1.2 Rating Factor Comparisons

Figure E-67 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.6, with zero girders having an LRFR rating greater than the LFR rating. The ratio remains relatively constant for all span lengths.

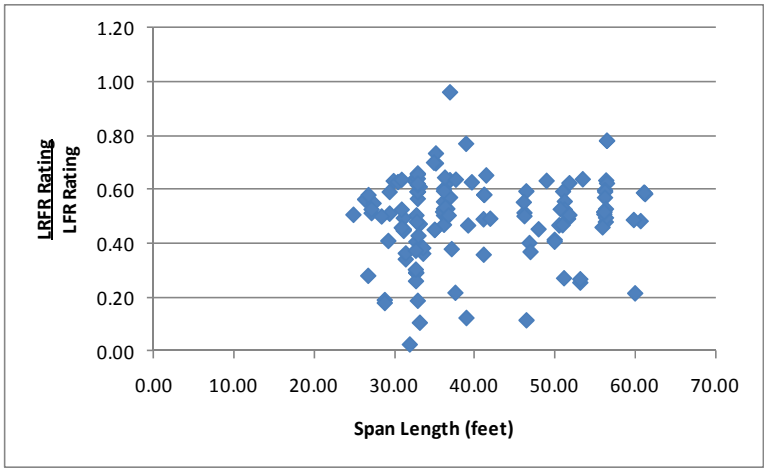


Figure E-67: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

E.1.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-68 shows that no girders have a reliability index less than the target reliability index of 2.5. The reliability index is between four and eight for most girders.

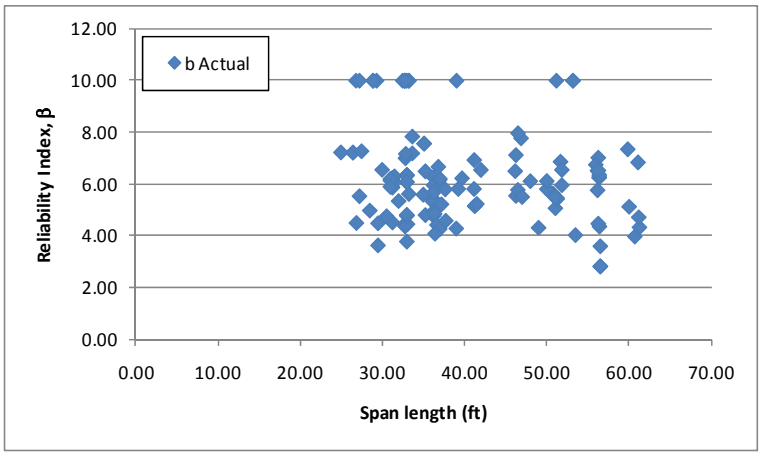


Figure E-68: Flexure Reliability Indices for NM-04 Vehicle

Figure E-69 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The average reliability index for a girder with a rating of 1.0 is approximated as 5.5, above the target reliability of 2.5. This indicates the LRFR live load factors are over-conservative and can be reduced.

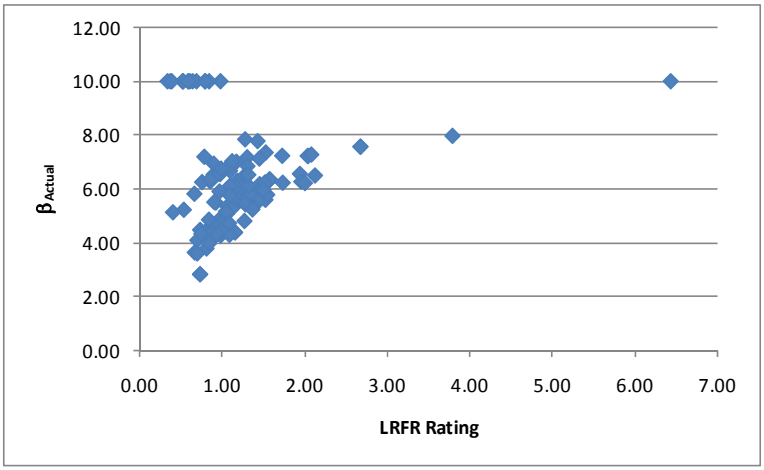
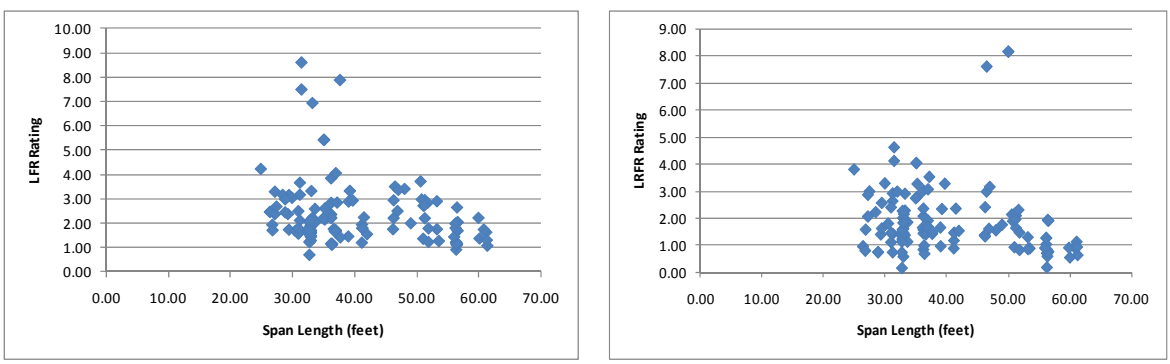


Figure E-69: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

E.1.7.2 Shear

E.1.7.2.1 Rating Factors

For shear, there are two girders that have an LFR rating factor less than 1.0, 30 girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 75% of the girders in this subset. Figure E-70 shows the LFR and LRFR ratings. The LFR rating is between one and three for most girders, three outliers were removed with values of 13, 29 and 112. The LRFR rating is between 0.5 and 3.0 for most girders.



(a) (b)

Figure E-70: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure E-71 shows the percentage of girders with shear ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 85% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 75.4% of girders when the ADTT is greater than 5,000. 98% of girders have LFR ratings greater than 1.0. Approximately 15% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 25% when the highest ADTT is considered.

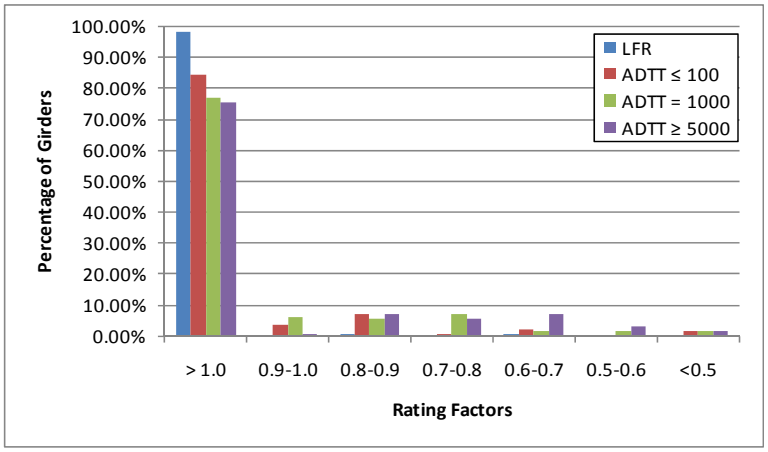


Figure E-71: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

E.1.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure E-72 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2 with 25% of girders having an LRFR rating greater than the LFR rating.

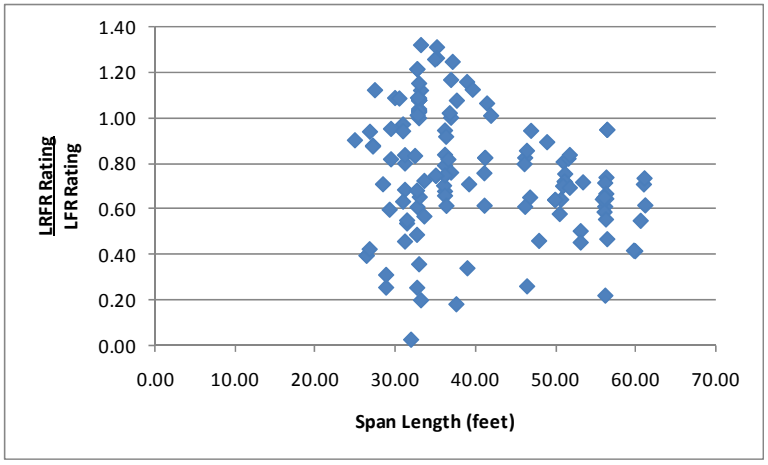


Figure E-72: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

E.1.7.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but three girders as shown in Figure E-73. The reliability index is between three and eight for most girders. The girder with a negative reliability index likely does not have properly defined shear reinforcement.

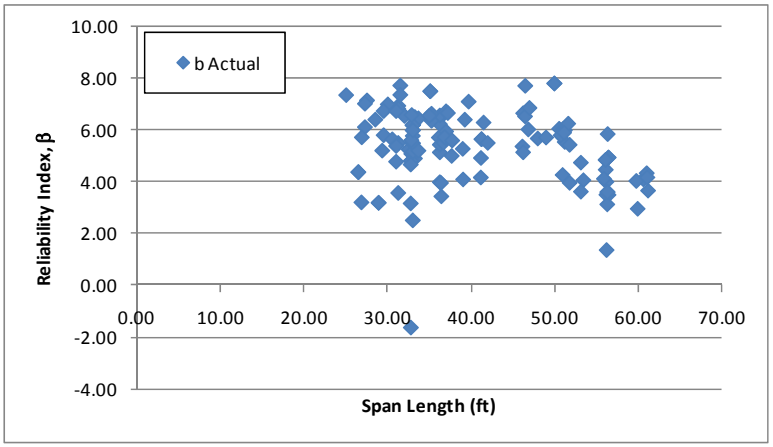


Figure E-73: Shear Reliability Indices for NM-04 Vehicle

Figure E-74 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. The average reliability index for a girder with a rating of 1.0 is approximately 4.25, greater than the target reliability of 2.5. The average reliability index exceeding the target reliability index suggests that the live load factors are over-conservative and can be reduced.

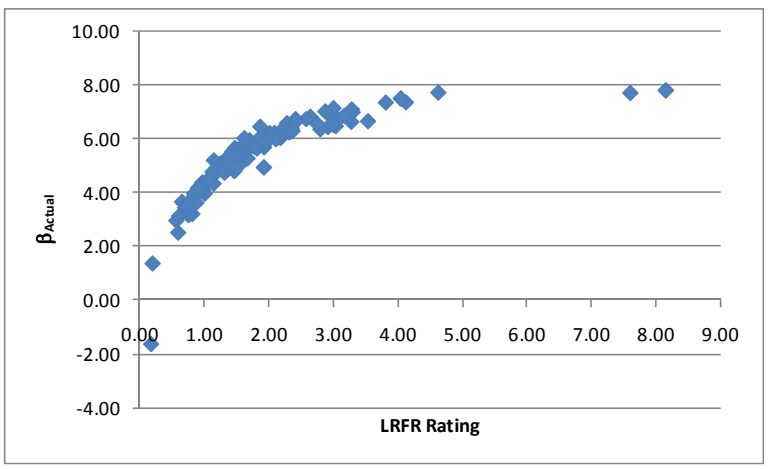


Figure E-74: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

E.1.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-75. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases multiple lanes may control.

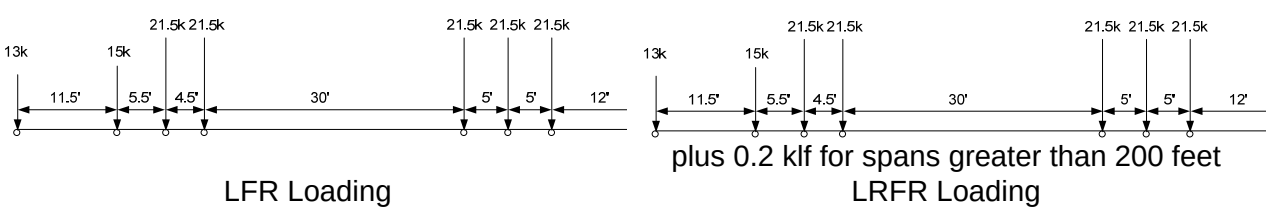


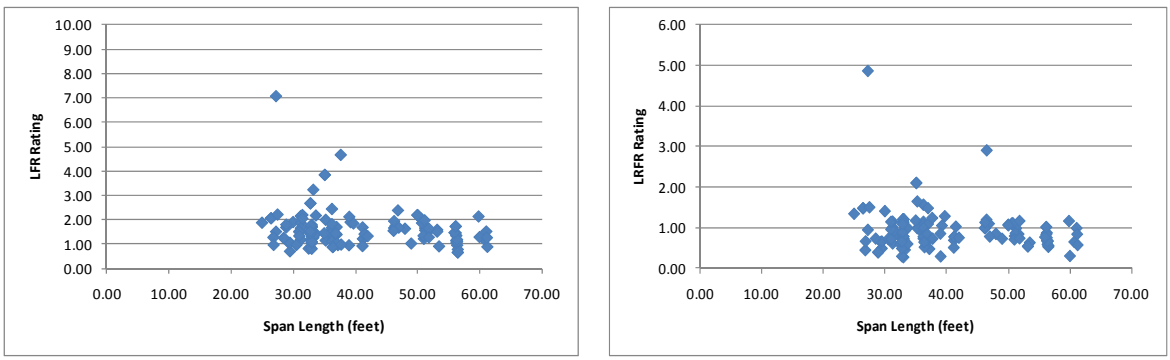
Figure E-75: Vehicle Loadings and Load Factors

E.1.8.1 Moment

The following section contains the results for exterior, reinforced concrete tee beams within simple span bridges for the OR-06 Vehicle.

E.1.8.1.1 Rating Factors

Figure E-76 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 18 girders with an LFR rating less than 1.0, 82 girders with an LRFR rating less than 1.0, and 18 girders where both ratings are less than 1.0. All 82 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 99% of the girders in this subset. The LFR rating is within the range of 1 to 2; two outliers were removed from the graph with values of 22 and 28. The LRFR rating is between 0.5 and 1.25 for most girders.



(a) (b)

Figure E-76: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure E-77 shows the percentage of girders with moment ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 55% of girders have LRFR ratings greater than 1.0 for the single trip, escorted category. This decreases to 9.2% of girders for a multi-trip permit with an ADTT of at least 5,000. 86% of girders have LFR ratings greater than 1.0. Approximately 30% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 80% when the highest ADTT is considered.

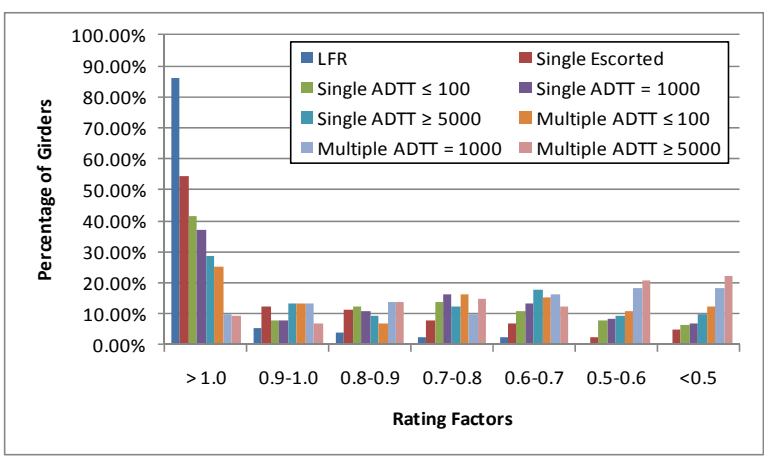


Figure E-77: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

E.1.8.1.2 Rating Factor Comparisons

Figure E-78 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating; this occurs for one girder. The ratio is generally between 0.4 and 0.8.

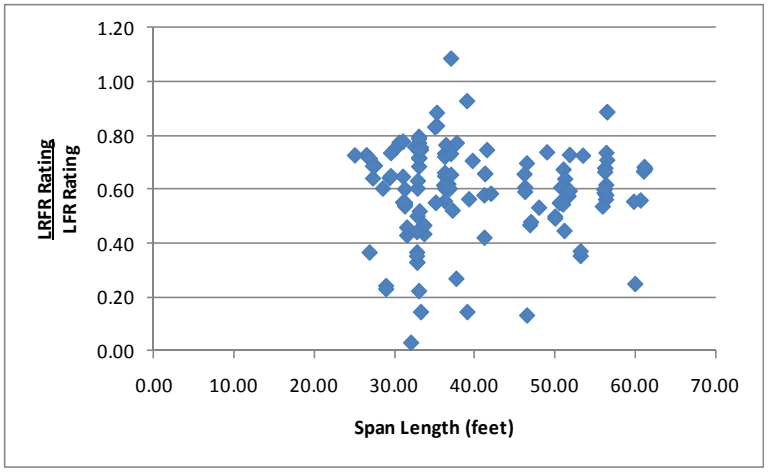


Figure E-78: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

E.1.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-79 shows that four girders have a reliability index less than the target reliability index of 3.5. The reliability index is between four and eight for most girders.

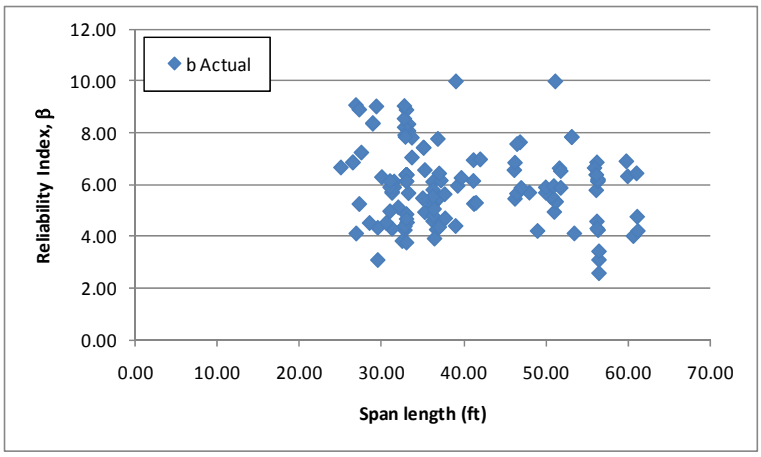


Figure E-79: Flexure Reliability Indices for OR-06 Vehicle

Figure E-80 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 vehicle. The average reliability index for a girder with an LRFR rating of 1.0 is approximately 5.5, exceeding the target reliability index of 3.5. This indicates the live load factors in the MBE are over-conservative and can be reduced.

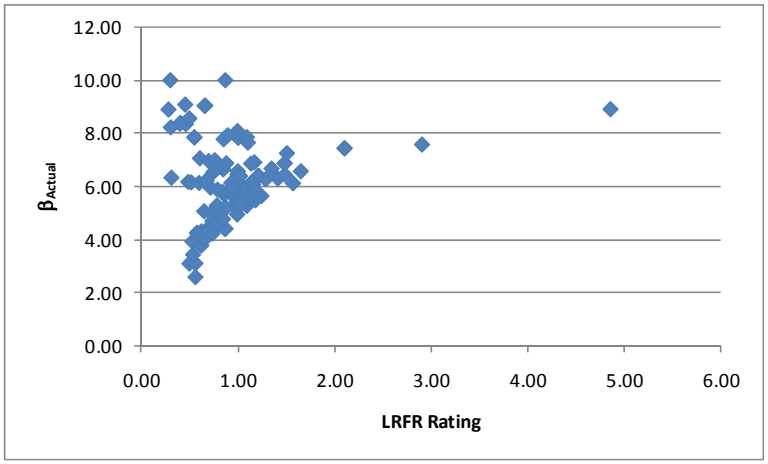
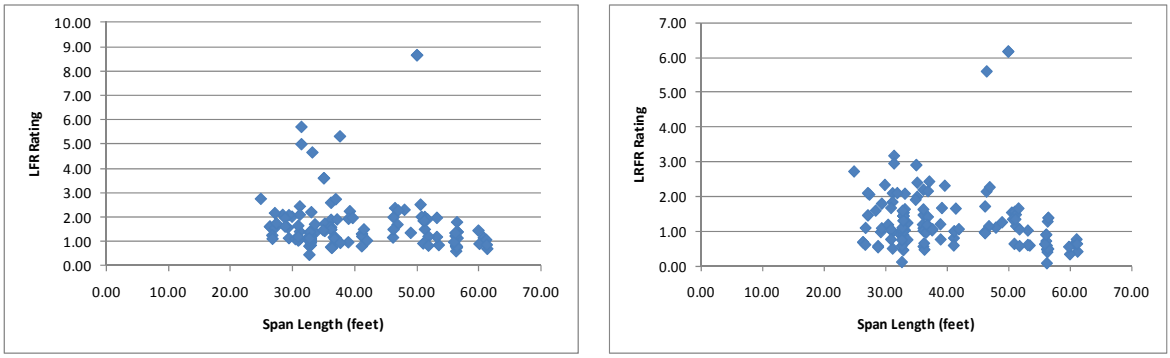


Figure E-80: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

E.1.8.2 Shear

E.1.8.2.1 Rating Factors

For shear, there are 25 girders that have LFR rating factors less than 1.0, 51 girders have LRFR ratings less than 1.0, and 21 girders have both ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 73% of the girders in this subset. Figure E-81 shows the LFR and LRFR ratings. The LFR rating is between one and two for most girders with two girders eliminated as outliers. The outliers had values of 20 and 75. The LRFR rating is between 0.5 and 2.0 for most girders.



(a) (b)

Figure E-81: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure E-82 shows the percentage of girders with shear ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 71% of girders have LRFR ratings greater than 1.0 for the single trip, escorted category. This decreases to 39.2% of girders for a multi-trip permit with an ADTT of at least 5,000. 81% of girders have LFR ratings greater than 1.0. Approximately 10% more girders have LRFR ratings less than 1.0 when a single trip, escorted permit is considered; this increases to 40% when a multi-trip permit with an ADTT of 5,000 is considered.

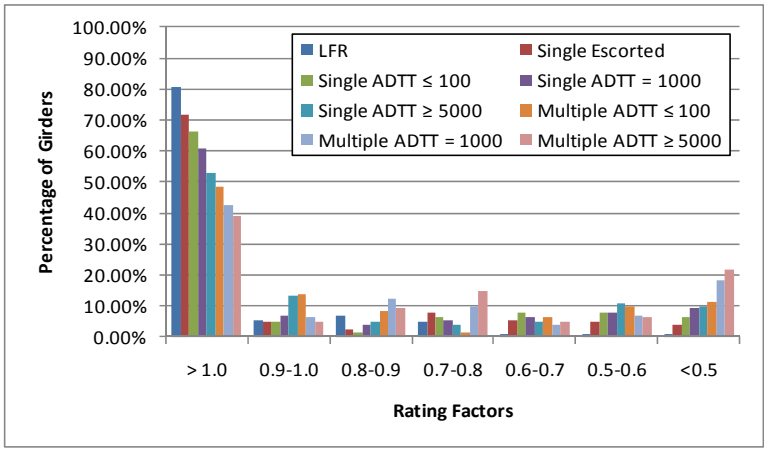


Figure E-82: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

E.1.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure E-83 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2 for this set of girders with this vehicle. 27% of girders have LRFR ratings that exceed the LFR rating for this vehicle.

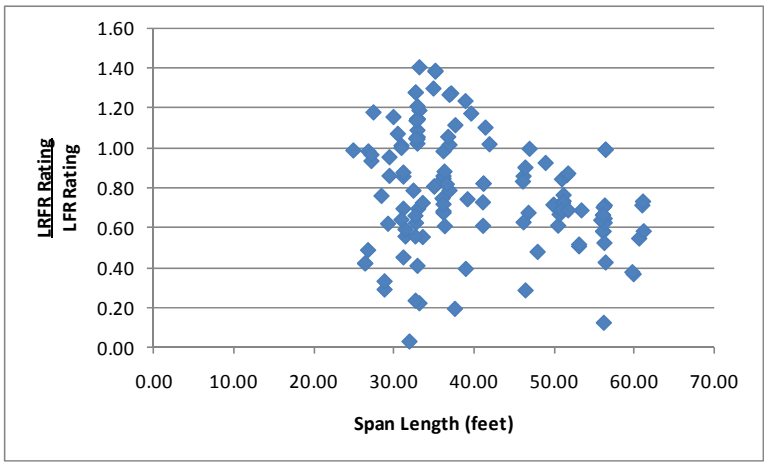


Figure E-83: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

E.1.8.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for 25 girders as shown in Figure E-84. The number of girders not having the target reliability index is likely due to the heavy weight of this truck. The reliability index for most girders is between four and eight.

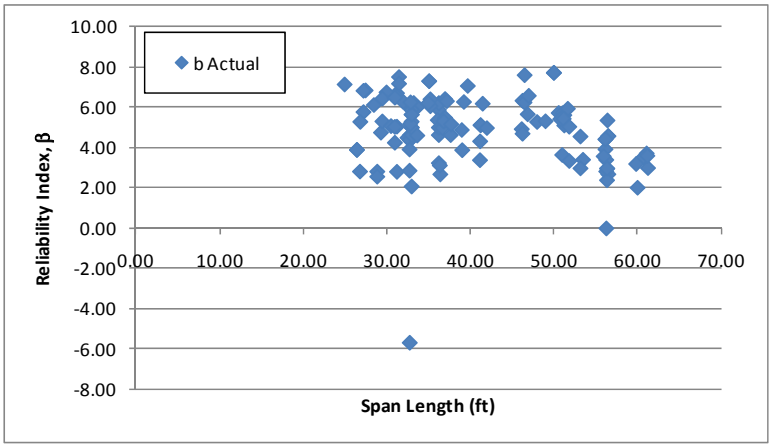


Figure E-84: Shear Reliability Indices for OR-06 Vehicle

Figure E-85 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The average reliability index for girders with a rating of 1.0 is approximately 4.75. This exceeds the target reliability of 3.5 and indicates that the live load factors in the MBE are over-conservative and can be reduced.

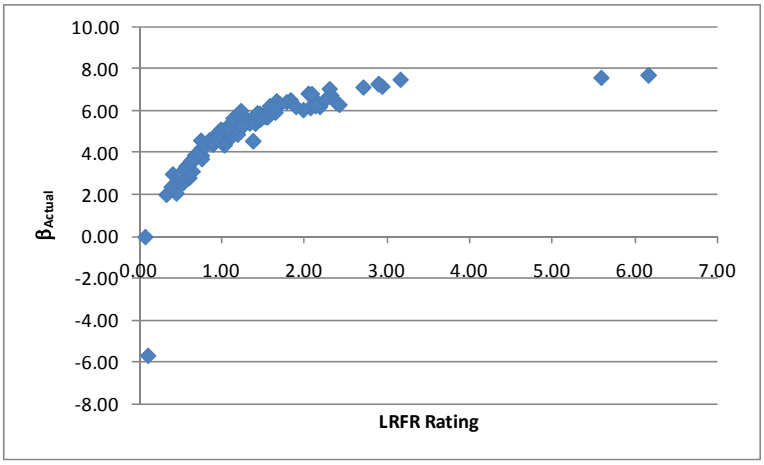
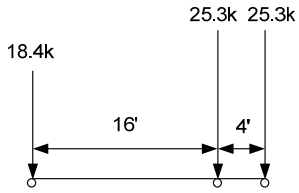


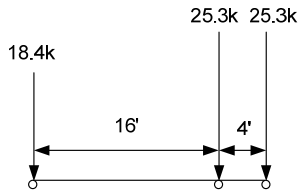
Figure E-85: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

E.1.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-86. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.



LFR Loading



plus 0.2 klf for spans greater than 200 feet

LRFR Loading

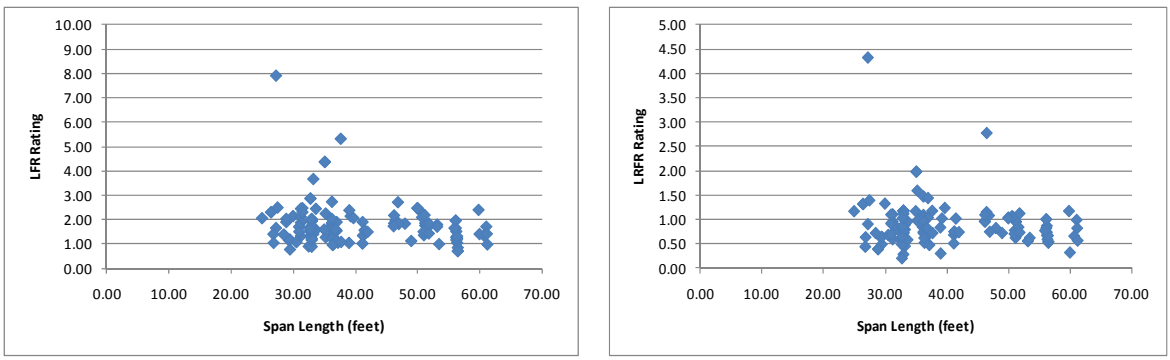
Figure E-86: Vehicle Loadings and Load Factors

E.1.9.1 Moment

The following section contains the results for exterior, reinforced concrete tee beams within simple span bridges for the TX-04 Vehicle.

E.1.9.1.1 Rating Factors

Figure E-87 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are ten girders with an LFR rating less than 1.0, 90 girders with an LRFR rating less than 1.0, and ten girders where both ratings are less than 1.0. All girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is between one and two for most girders with two outliers removed. The outliers had LFR ratings of 25 and 32. The LRFR ratings are between 0.5 and 1.5 for most girders in this group.



(a) (b)

Figure E-87: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure E-88 shows the percentage of girders with moment ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 43.1% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 17.7% of girders when the ADTT is greater than 5,000. 92% of girders have LFR ratings greater than 1.0. Approximately 50% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 75% when the highest ADTT is considered.

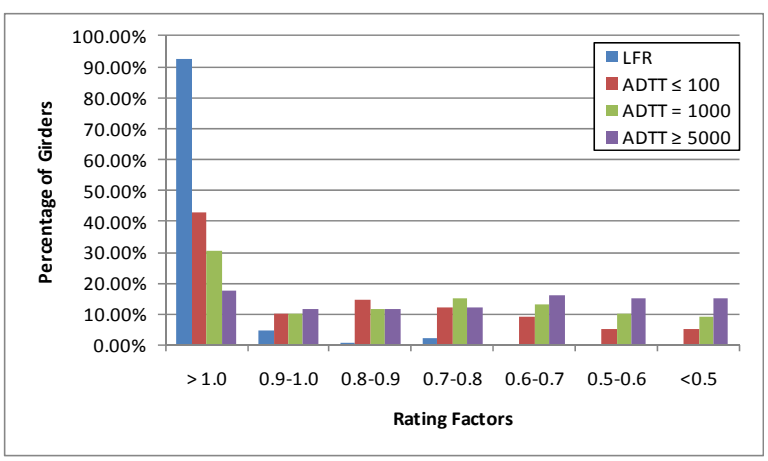


Figure E-88: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

E.1.9.1.2 Rating Factor Comparisons

Figure E-89 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is generally 40 to 60% of the LFR rating. No girders have an LRFR rating that exceeds the LFR rating for this vehicle.

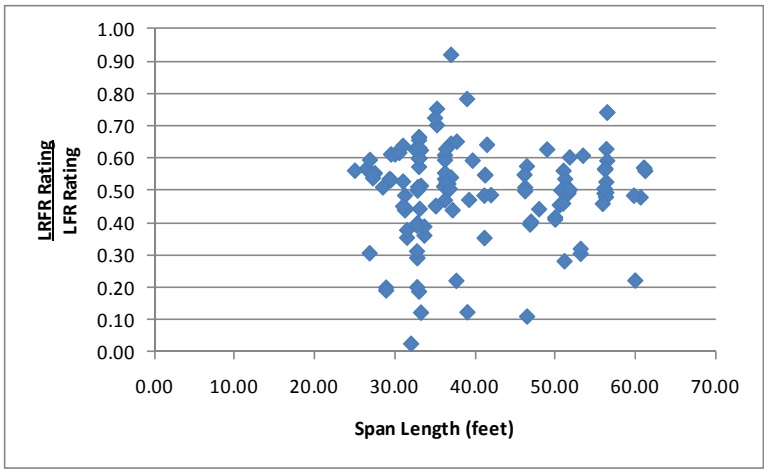


Figure E-89: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

E.1.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-90 shows five girders have a reliability index less than the target reliability index of 2.5. Most girders have a reliability index between three and seven, greater than the target reliability of 2.5.

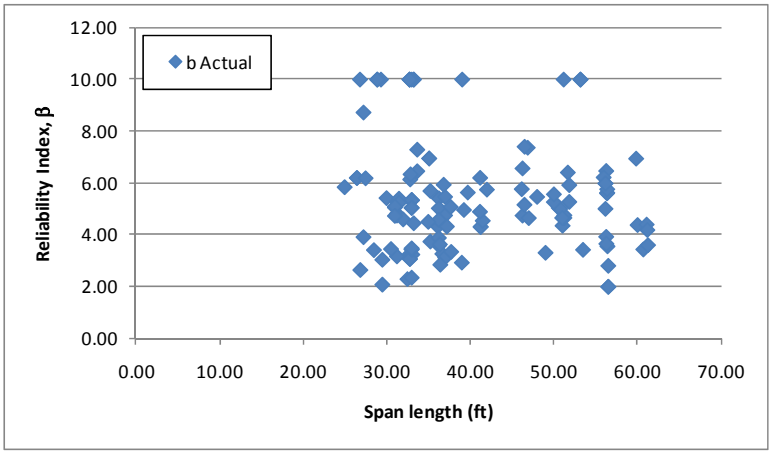


Figure E-90: Flexure Reliability Indices for TX-04 Vehicle

Figure E-91 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The average reliability index for girders with a rating of 1.0 is approximated as 5.0. The average reliability index is greater than the target reliability index of 2.5 and indicates that the live load factors in the MBE are over-conservative and can be reduced.

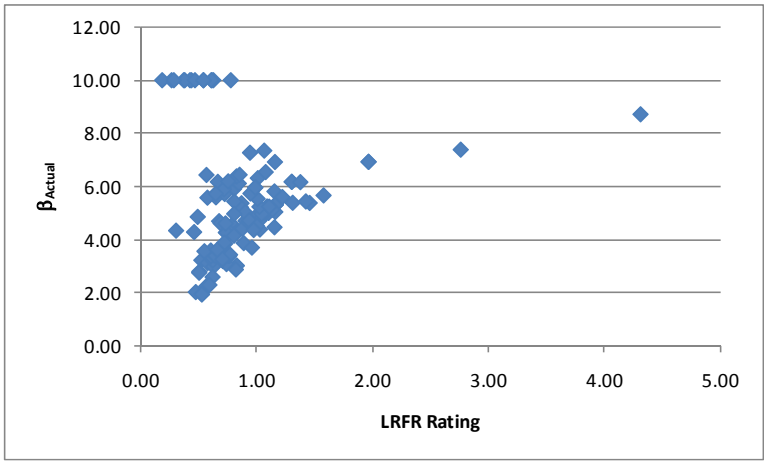
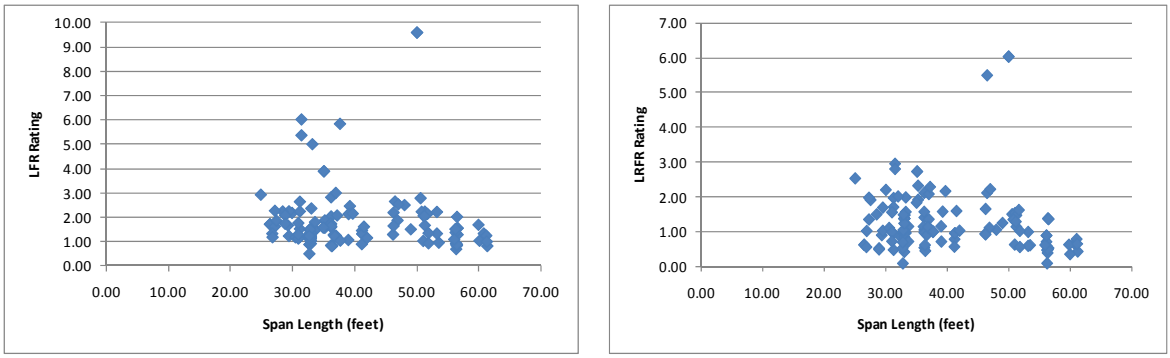


Figure E-91: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

E.1.9.2 Shear

E.1.9.2.1 Rating Factors

For shear, there are 18 girders that have LFR rating factors less than 1.0, 56 girders with LRFR ratings less than 1.0 and 18 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 83% of the girders in this subset. Figure E-92 shows the LFR and LRFR ratings. The LFR rating is between one and three for most girders with two outliers at 22 and 81 that were removed. The LRFR rating is between 0.5 and 2.0 for most girders.



(a) (b)

Figure E-92: LFR and LRFR Shear Ratings

Figure E-93 shows the percentage of girders with shear ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 69% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 46.9% of girders when the ADTT is greater than 5,000. 86% of girders have LFR ratings greater than 1.0. Approximately 15% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 40% when the highest ADTT is considered.

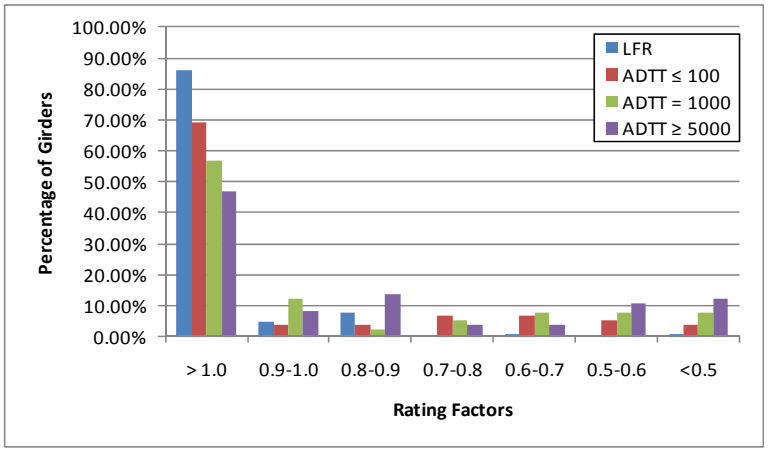


Figure E-93: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

E.1.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure E-94 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2 for shear. Shorter spans generally have higher ratios of ratings, indicating that they have higher LRFR ratings than LFR ratings. 17% of girders have LRFR ratings greater than the LFR rating for this vehicle.

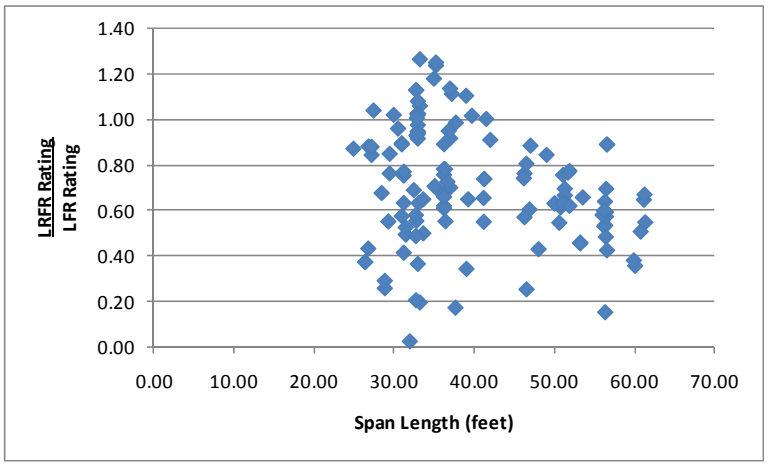


Figure E-94: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

E.1.9.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for 16 girders as shown in Figure E-95. The reliability index for most girders is between four and seven. Girders that do not have the target reliability may not have properly defined shear reinforcement or may not have enough shear reinforcement to resist the loads from this vehicle.

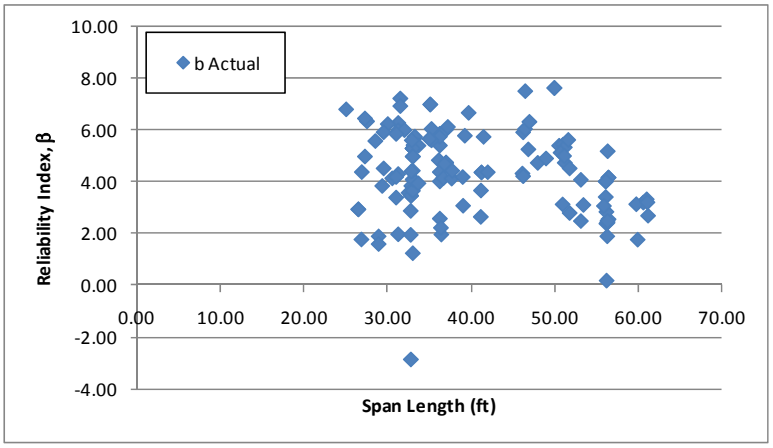


Figure E-95: Shear Reliability Indices for TX-04 Vehicle

Figure E-96 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The average reliability index for girders with ratings of 1.0 is approximately 4.0. The target reliability index for this truck is 2.5, indicating that the LRFR live load factors are over-conservative and can be reduced.

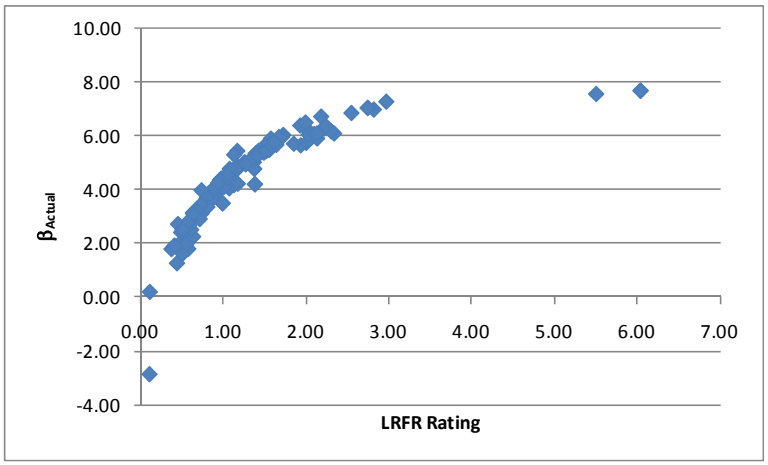
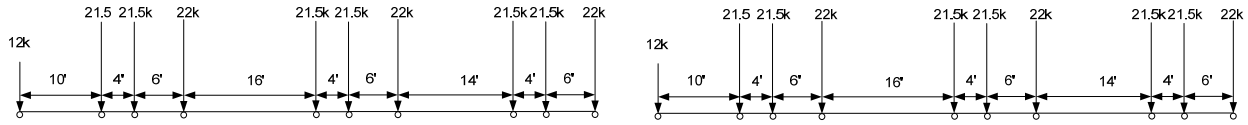


Figure E-96: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

E.1.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-97. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases multiple lanes may control.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

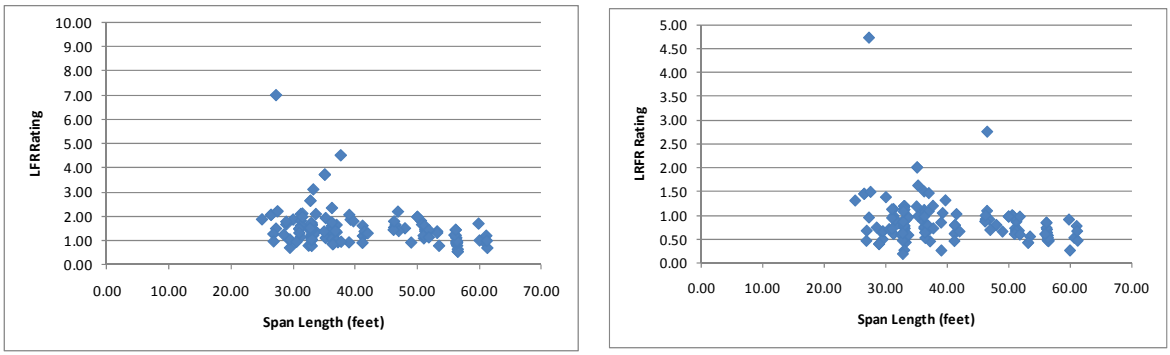
Figure E-97: Vehicle Loadings and Load Factors

E.1.10.1 Moment

The following section contains the results for exterior, reinforced concrete tee beams within simple span bridges for the WA-02 Vehicle.

E.1.10.1.1 Rating Factors

Figure E-98 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 29 girders with an LFR rating less than 1.0, 98 girders with an LRFR rating less than 1.0, and 29 girders where both ratings are less than 1.0. 97 of the 98 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 99% of the girders in this subset. The LFR rating is between one and two for most girders with two outliers with values of 20 and 27 removed from the graph. The LRFR rating is between 0.5 and 1.5 for most girders.



(a) (b)

Figure E-98: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure E-99 shows the percentage of girders with moment ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 48% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 8.5% of girders for a multi-trip permit with an ADTT greater than 5,000. 78% of girders have LFR ratings greater than 1.0. Approximately 30% more girders have LRFR ratings less than 1.0 when a single trip, escorted permit is considered; this increases to almost 70% when a multi-trip permit with an ADTT greater than 5,000 is considered.

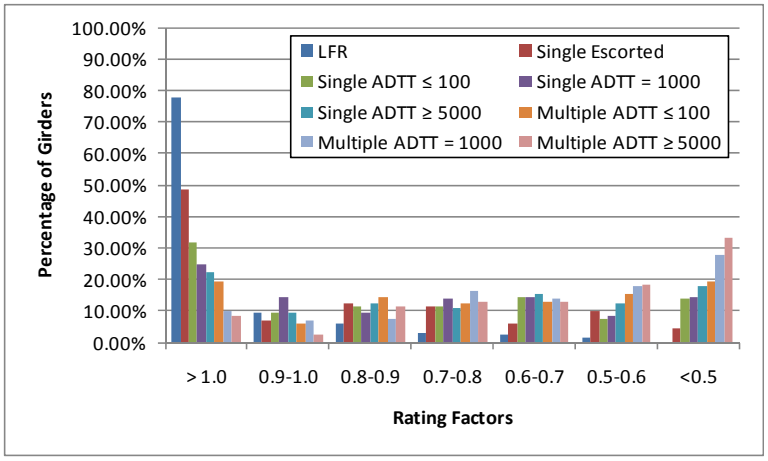


Figure E-99: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

E.1.10.1.2 Rating Factor Comparisons

Figure E-100 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating which occurs for one girder with this vehicle. The ratio is generally between 0.4 and 0.8.

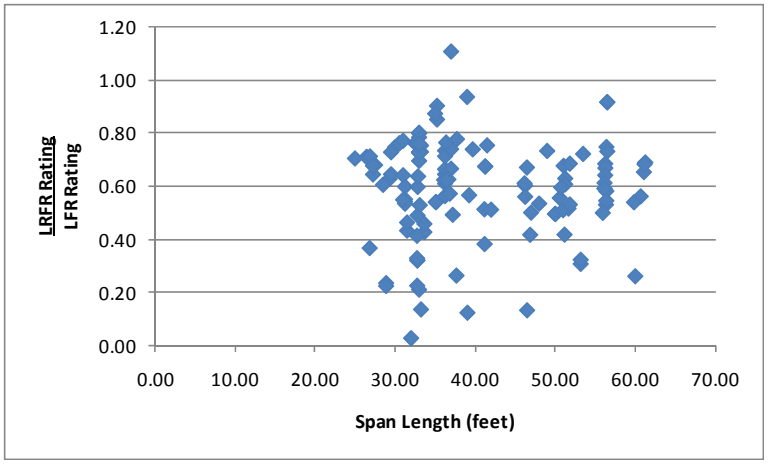


Figure E-100: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

E.1.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-101 shows 19 girders have a reliability index less than the target reliability index of 3.5. Girders with the target reliability have a reliability index that is between four and seven.

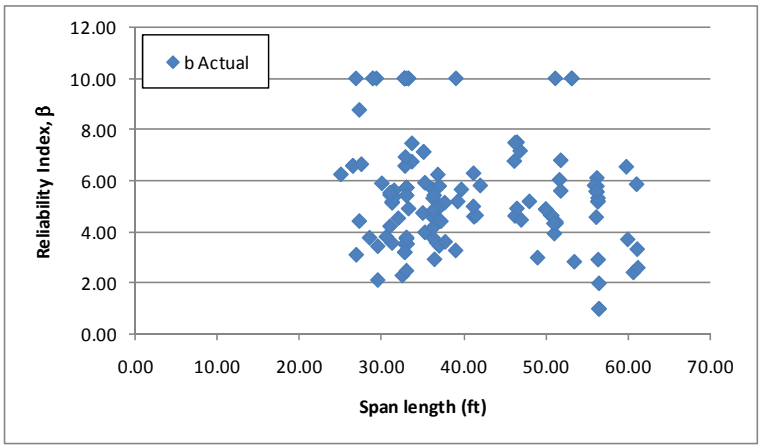


Figure E-101: Flexure Reliability Indices for WA-02 Vehicle

Figure E-102 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 vehicle. The average reliability index for girders with ratings of 1.0 is estimated to be 5.0 exceeding the target reliability of 3.5. This indicates the LRFR live load factors are over-conservative and can be reduced.

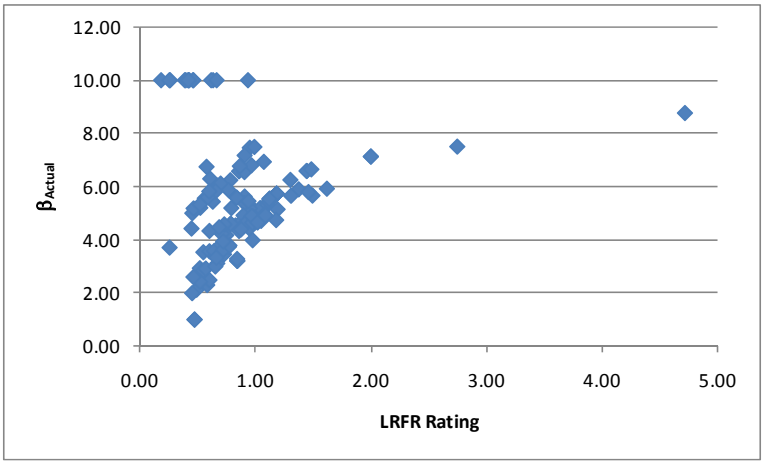
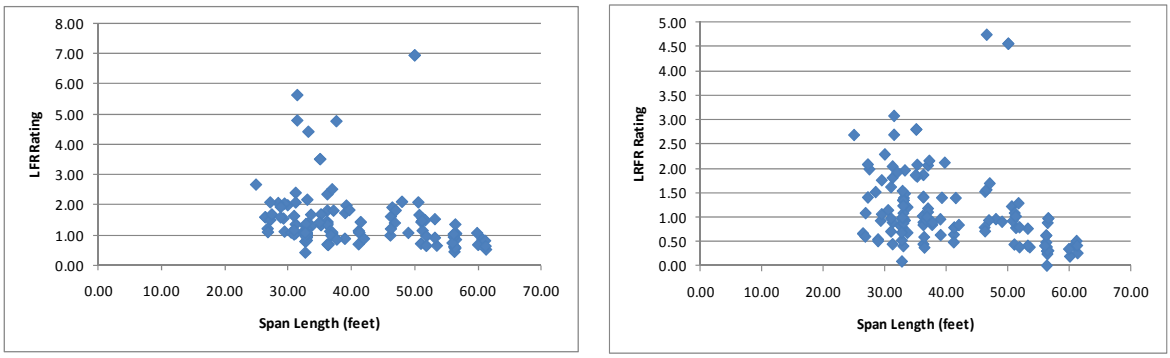


Figure E-102: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

E.1.10.2 Shear

E.1.10.2.1 Rating Factors

For shear, there are 36 girders with LFR rating factors less than 1.0, 71 girders with LRFR ratings less than 1.0, and 34 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 75% of the girders in this subset. Figure E-103 shows the LFR and LRFR ratings. The LFR rating is between 0.5 and 2.0 for most girders, two outliers with values of 17 and 72 were removed. The LRFR rating is also between 0.5 and 2.0 for most girders.



(a) (b)

Figure E-103: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure E-104 shows the percentage of girders with shear ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 64% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 32.3% of girders when a multi-trip permit with ADTT greater than 5,000. 72% of girders have LFR ratings greater than 1.0. Approximately 8% more girders have LRFR ratings less than 1.0 when a single trip, escorted permit is considered, this increases to almost 40% when the multi-trip permit with ADTT of 5,000 is considered.

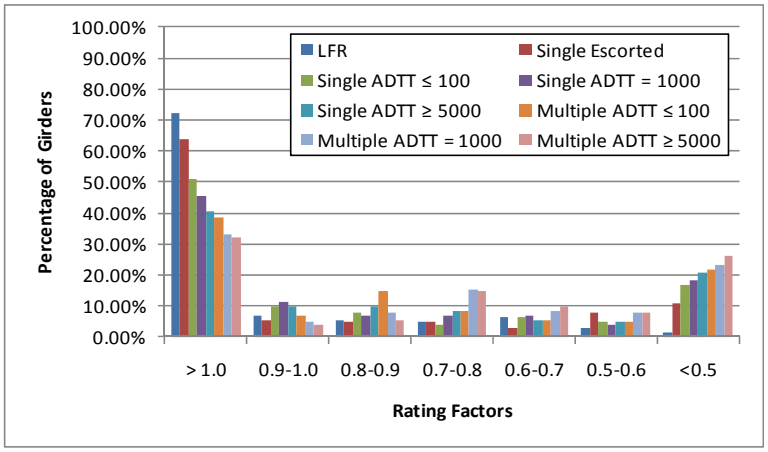


Figure E-104: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

E.1.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-105 show the comparison of rating factors. The ratio is generally between 0.5 and 1.2, with higher ratios for short spans and lower ratios for long spans. 25% of girders have LRFR ratings greater than the LFR ratings.

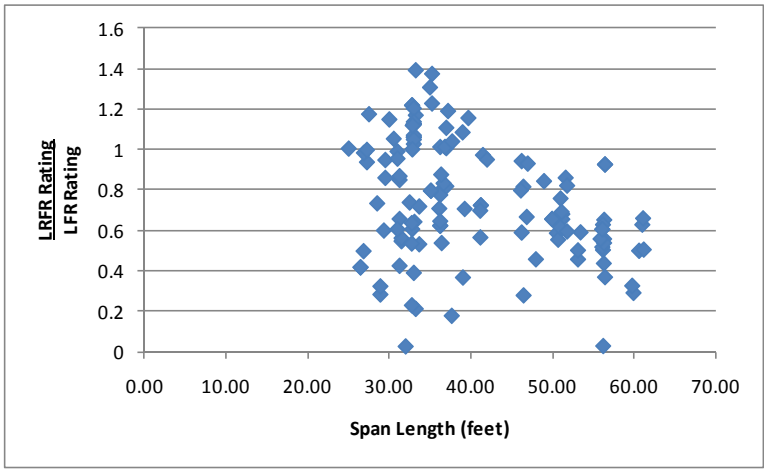


Figure E-105: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

E.1.10.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for 53 girders as shown in Figure E-106. The large number of girders that do not have the target reliability is partially caused by the weight of the truck. This truck is the heaviest of the 12 used in the study. Girders having the target reliability typically have reliability indexes between four and seven.

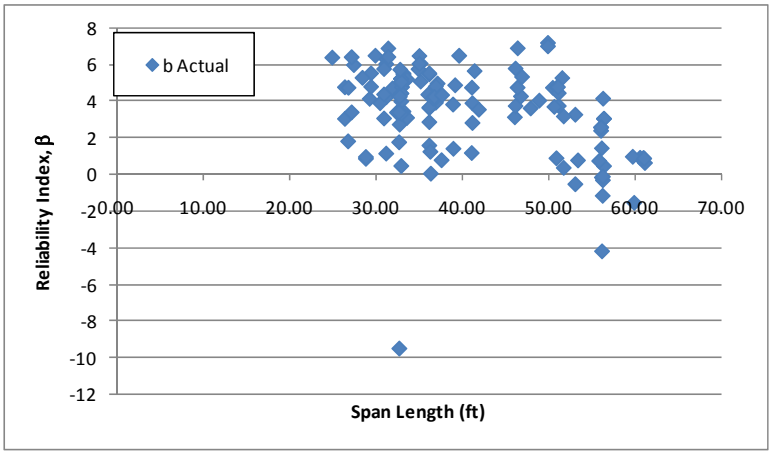


Figure E-106: Shear Reliability Indices for WA-02 Vehicle

Figure E-107 shows the reliability index for shear plotted against the LRFR shear rating for the WA-02 Vehicle. The average reliability index for girders with a rating of 1.0 is approximately 4.0, slightly above the target reliability of 3.5. The average reliability exceeding the target reliability indicates that the live load factors in the MBE are over-conservative and can be reduced.

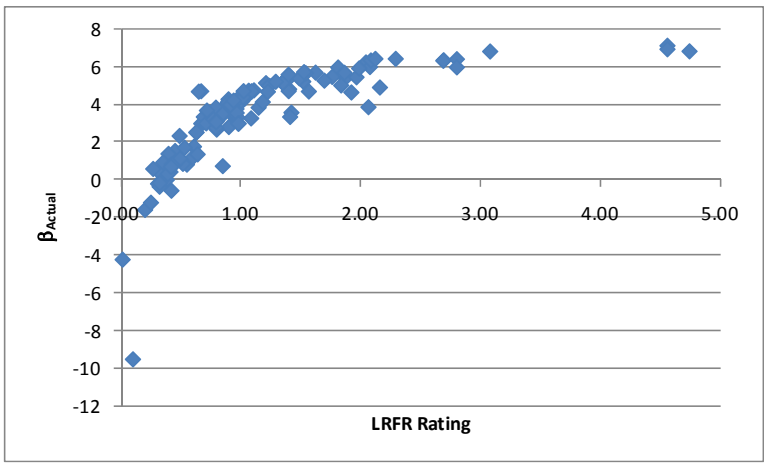
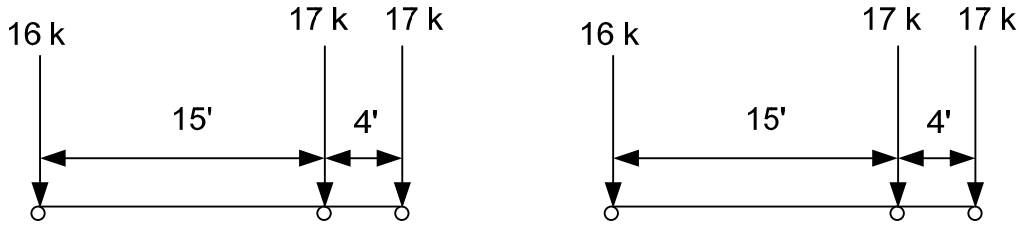


Figure E-107: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

E.1.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-108. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.



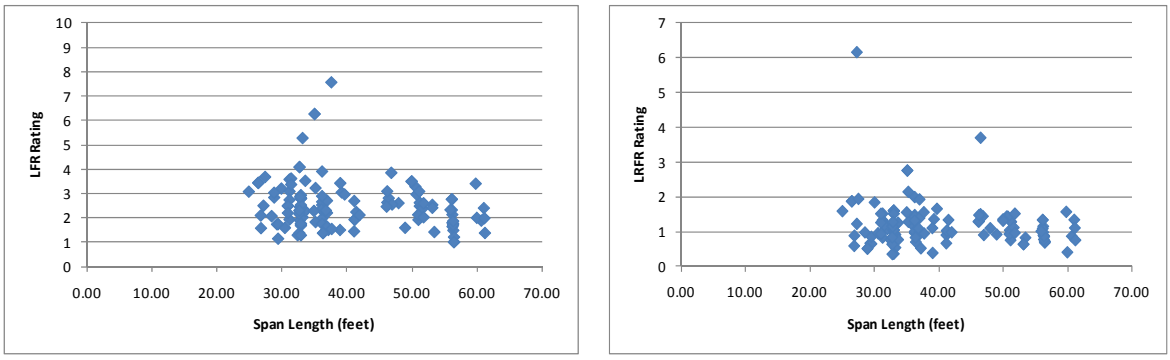
LFR Loading LRFR Loading

Figure E-108: Vehicle Loadings and Load Factors

E.1.11.1 Moment

E.1.11.1.1 Rating Factors

Figure E-109 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 52 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. All girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR rating is between one and four for most girders with three outliers eliminated with values of 12, 36, and 46. The LRFR rating is between 0.5 and 2.0.



(a) (b)

Figure E-109: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure E-110 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3 vehicle, a legal vehicle. 77% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 52.3% of girders when the ADTT is greater than 5,000. 100% of girders have LFR ratings greater than 1.0. Approximately 25% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 48% when the highest ADTT is considered.

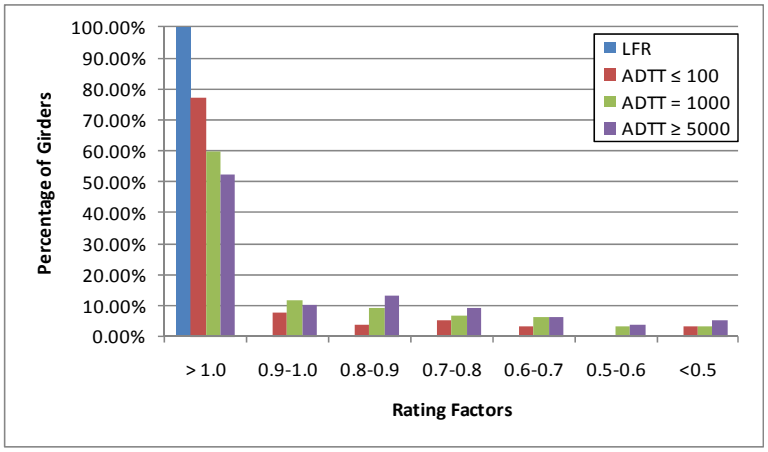


Figure E-110: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

E.1.11.1.2 Rating Factor Comparisons

Figure E-111 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.6.

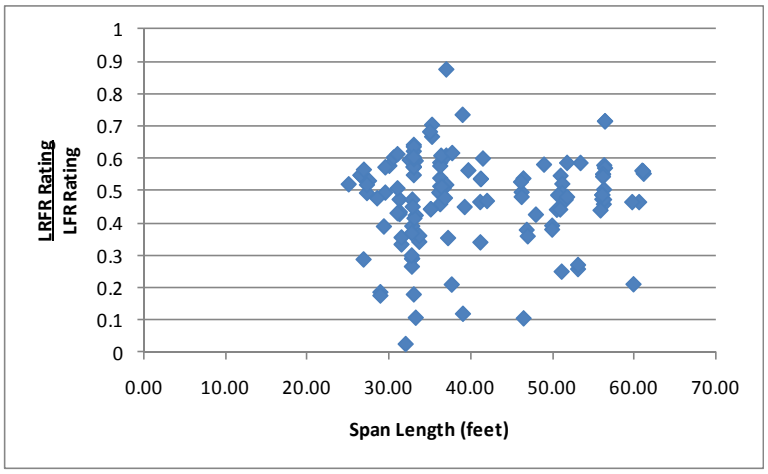


Figure E-111: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

E.1.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-112 shows that no girders have a reliability index less than the target reliability index of 2.5. The reliability index is between four and eight for most girders.

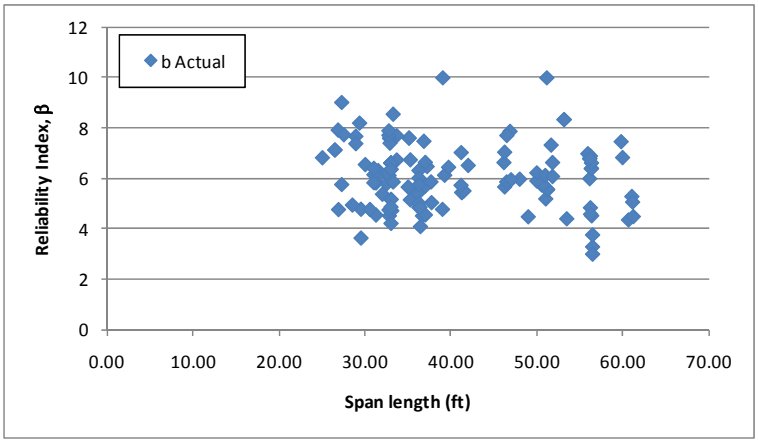


Figure E-112: Flexure Reliability Indices for Type 3 Vehicle

Figure E-113 shows the flexure reliability index plotted against the LRFR moment rating for the AASHTO Type 3 Vehicle. The average reliability index for a girder with a rating of 1.0 is approximately 5.0, greater than the target reliability of 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

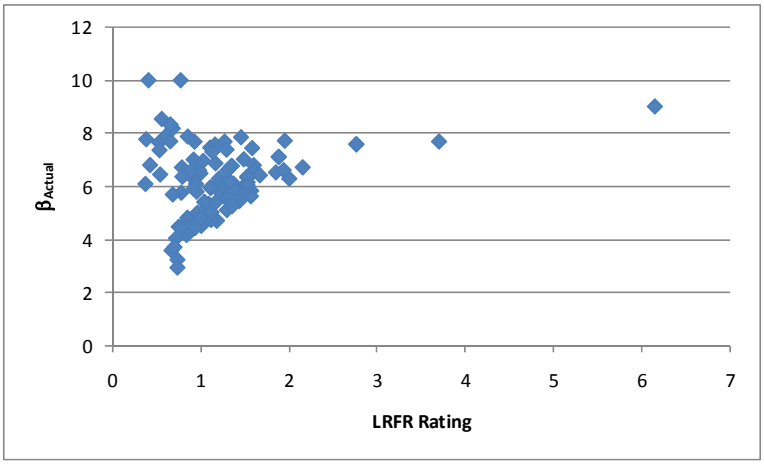
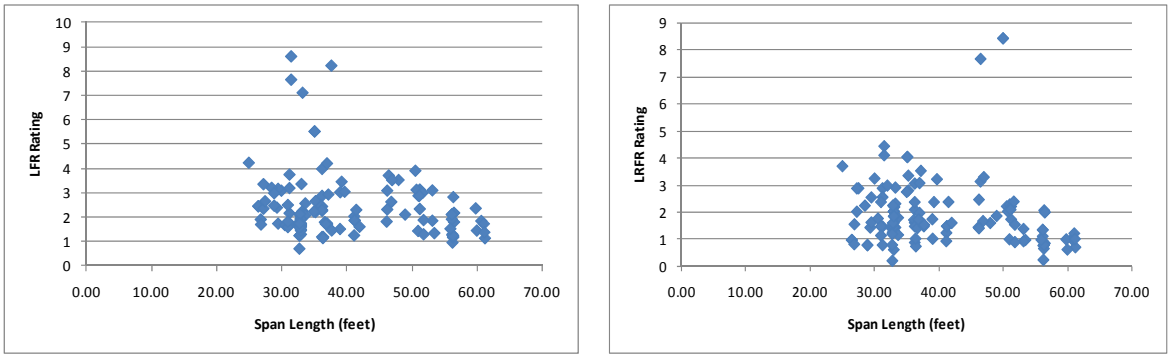


Figure E-113: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Vehicle

E.1.11.2 Shear

E.1.11.2.1 Rating Factors

For shear, there are two girders with LFR rating factors less than 1.0, 29 girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 80% of the girders in this subset. Figure E-114 shows the LFR and LRFR ratings. The LFR rating is between one and four for most girders; three outliers were removed with values of 13, 31, and 114 from the LFR rating graph. The LRFR rating is between 0.5 and 3.0 for a majority of the girders in this group.



(a) (b)

Figure E-114: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure E-115 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 88% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 75.4% of girders when the ADTT is greater than 5,000. 98% of girders have LFR ratings greater than 1.0. Approximately 10% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 25% when the highest ADTT is considered.

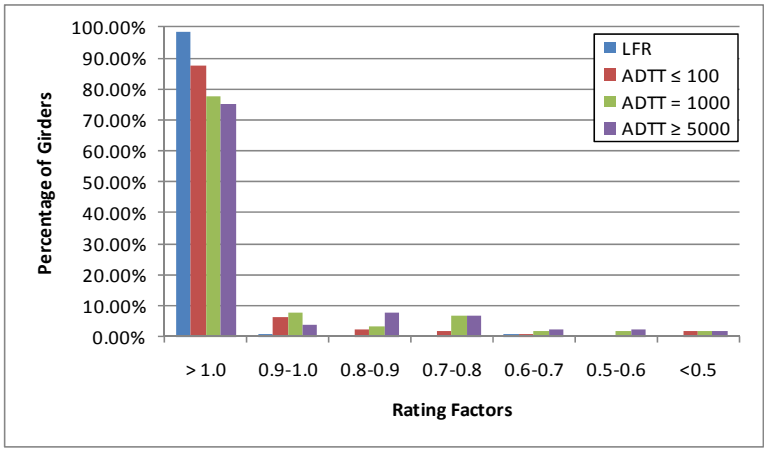


Figure E-115: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

E.1.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-116 show the comparison of rating factors. The ratio is generally between 0.6 and 1.2, with shorter spans generally having higher ratios. 20% of girders have LRFR ratings that exceed the LFR ratings.

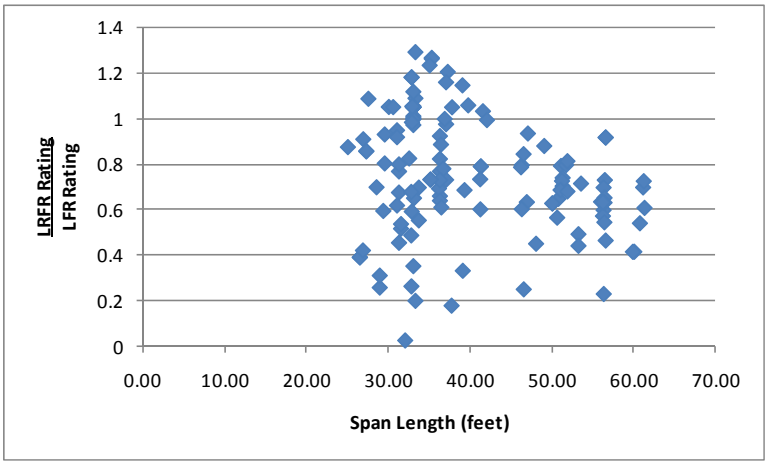


Figure E-116: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

E.1.11.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for 2 girders as shown in Figure E-117. The reliability index is between three and eight for most girders in this group.

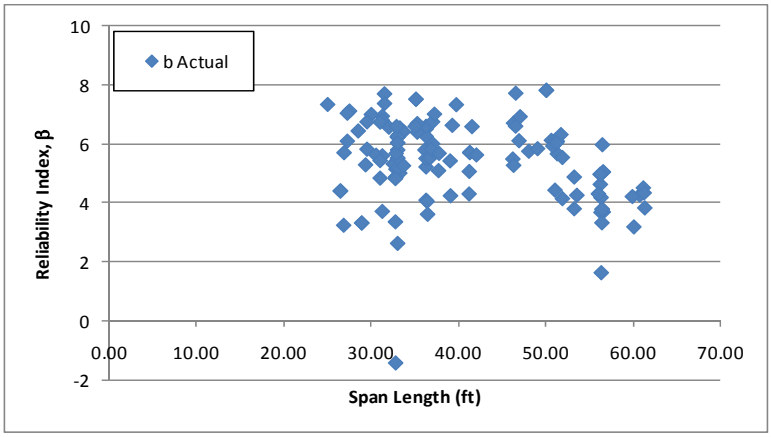


Figure E-117: Shear Reliability Indices for Type 3 Vehicle

Figure E-118 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 truck. The average reliability index for girders with ratings near one is estimated to be 4.25 exceeding the target reliability of 2.5. The average reliability index exceeding the target reliability indicates the LRFR live load factors are over-conservative and can be reduced.

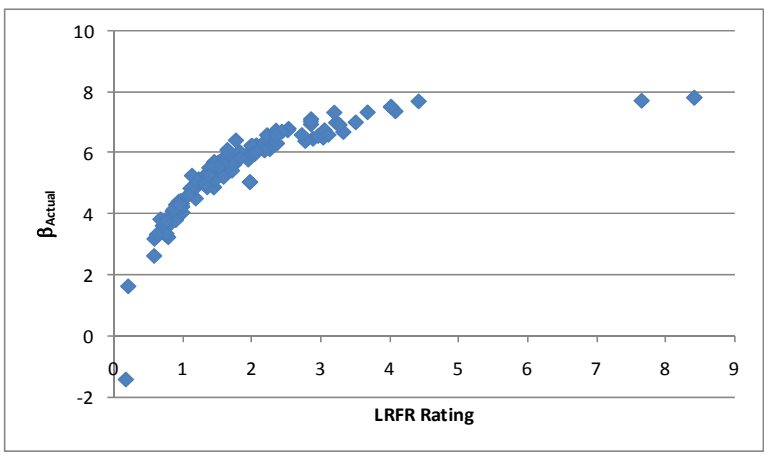


Figure E-118: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

E.1.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-119. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

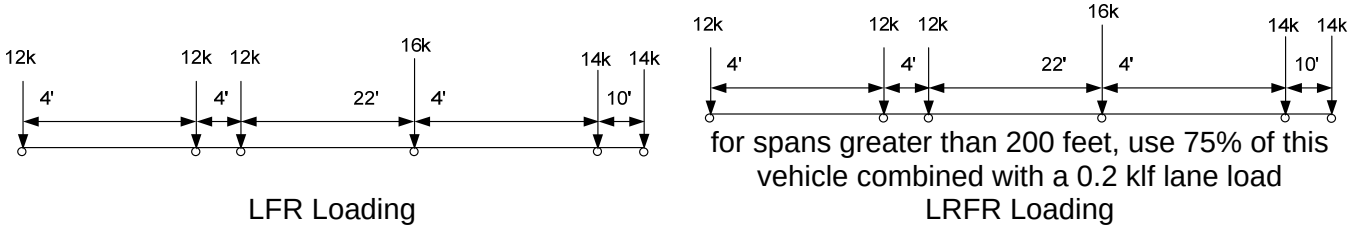
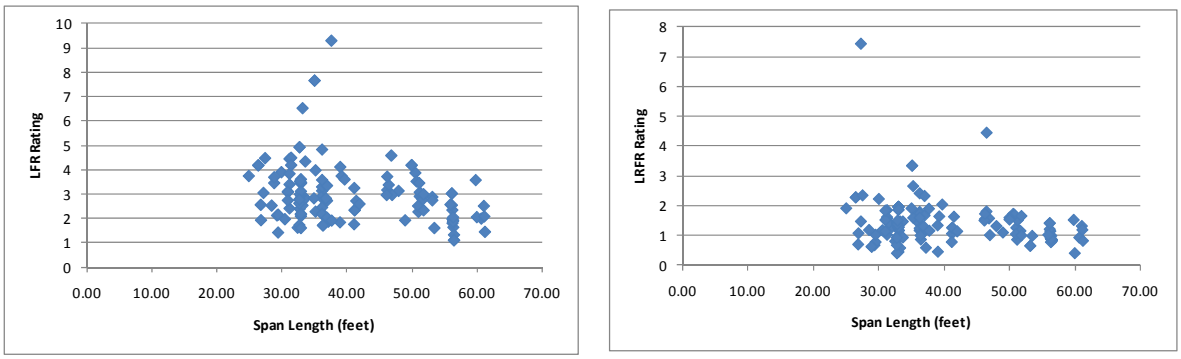


Figure E-119: Vehicle Loadings and Load Factors

E.1.12.1 Moment

E.1.12.1.1 Rating Factors

Figure E-120 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 36 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. All girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR ratings are between one and five for most girders; three outliers with values of 14, 43, and 58 were eliminated from the rating graph. The LRFR rating is between 0.5 and 2.0 for most girders.



(a) (b)

Figure E-120: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure E-121 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3-3 Truck, a legal vehicle. 85% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 65% of girders when the ADTT is greater than 5,000. 100% of girders have LFR ratings greater than 1.0. Approximately 15% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 35% when the highest ADTT is considered.

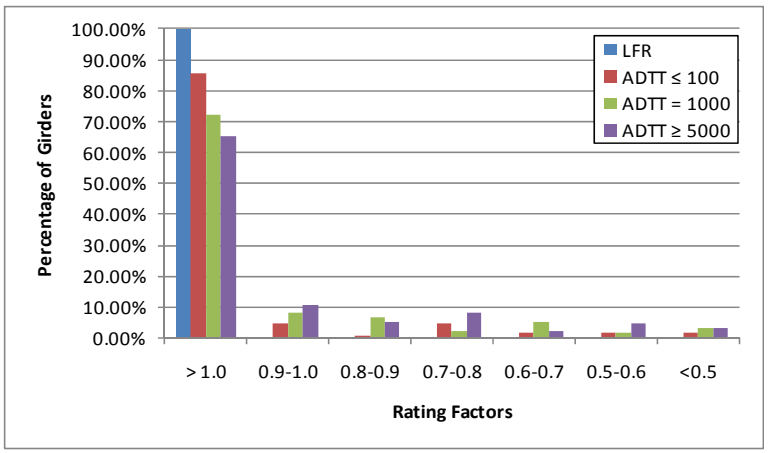


Figure E-121: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

E.1.12.1.2 Rating Factor Comparisons

Figure E-122 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.6. No girders exist for this vehicle that have LRFR ratings greater than the LFR ratings.

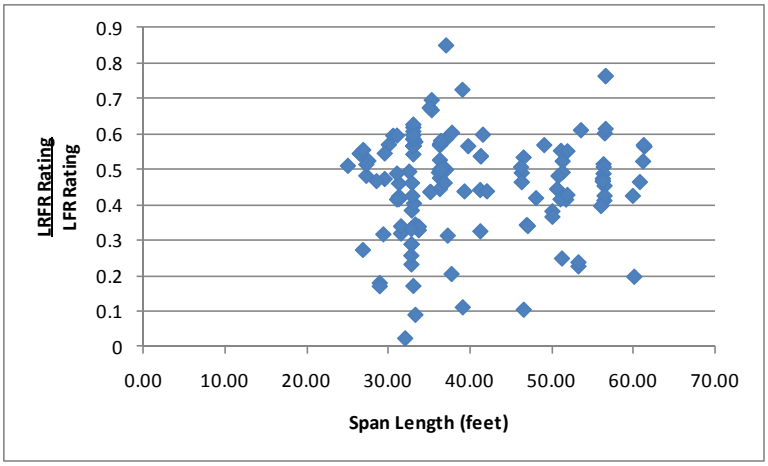


Figure E-122: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

E.1.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-123 shows that zero girders have a reliability index less than the target reliability index of 2.5. The reliability index is between four and eight for most girders with shorter girders having more variation in the reliability index.

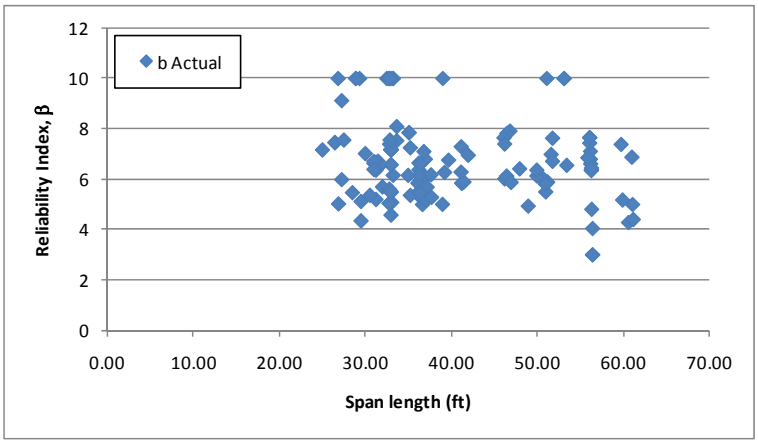


Figure E-123: Flexure Reliability Indices for Type 3-3 Vehicle

Figure E-124 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The average reliability index for girders with a rating of 1.0 is approximately five. This exceeds the target reliability of 2.5, indicating the live load factors in the MBE are over-conservative and can be reduced.

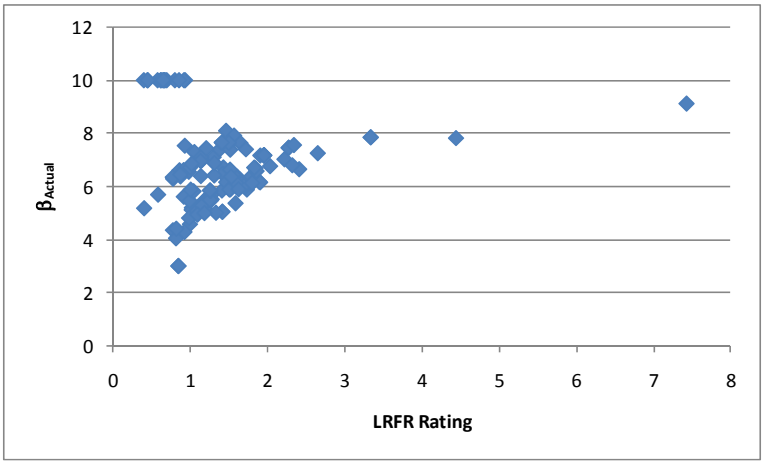
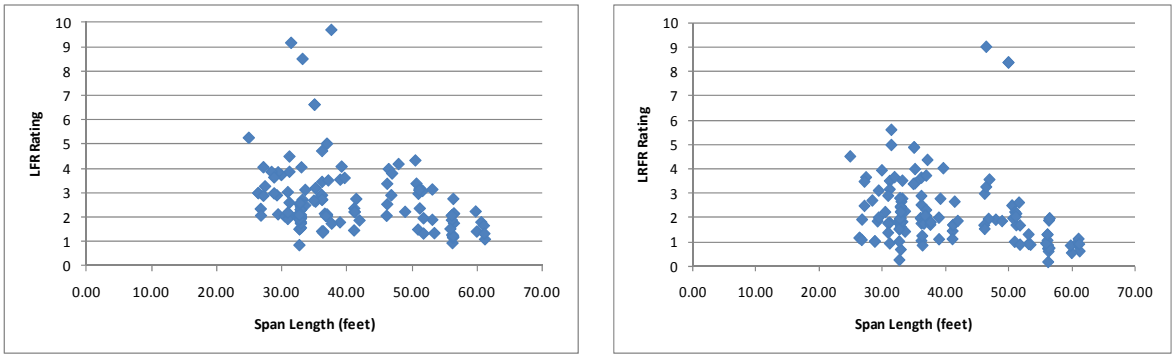


Figure E-124: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Vehicle

E.1.12.2 Shear

E.1.12.2.1 Rating Factors

For shear, there are two girders with LFR rating factors less than 1.0, 20 girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure E-125 shows the LFR and LRFR ratings. The LFR rating is between one and four for most girders; four outliers with values of 10, 14, 35, and 138 were removed from this figure. The LRFR rating is between one and four for most girders.



(a) (b)

Figure E-125: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure E-126 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 92.3% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 80% of girders when the ADTT is greater than 5,000. 98% of girders have LFR ratings greater than 1.0. Approximately 6% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 20% when the highest ADTT is considered.

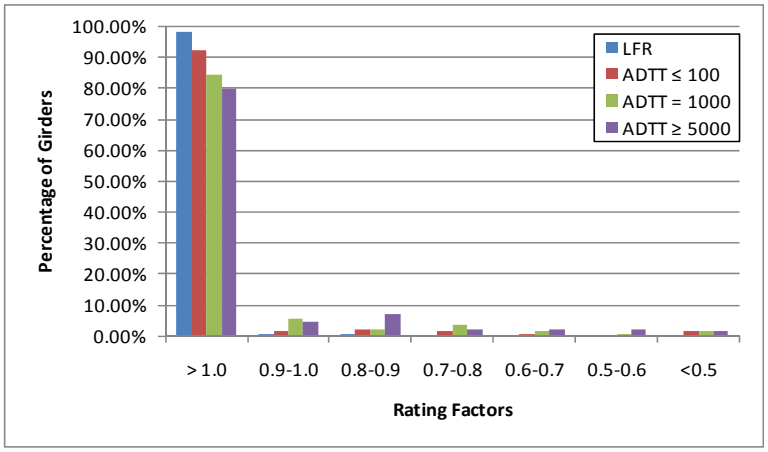


Figure E-126: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

E.1.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-127 show the comparison of rating factors. The ratio is generally between 0.6 and 1.2, with shorter spans generally having higher ratios. 24% of girders have an LRFR rating greater than the LFR rating.

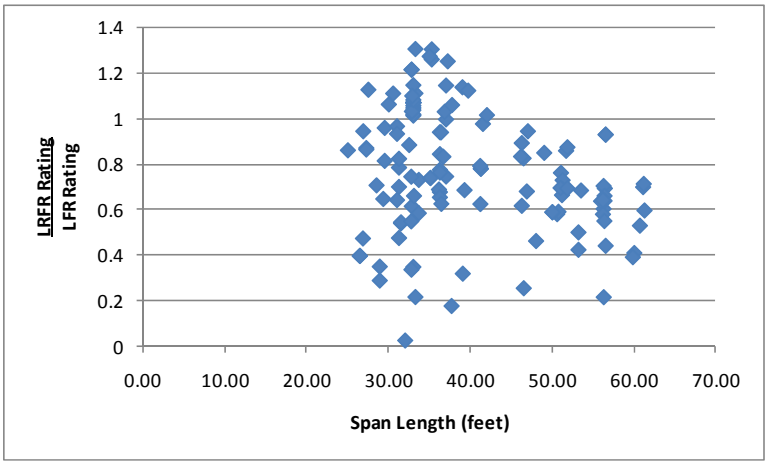


Figure E-127: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

E.1.12.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index for two girders as shown in Figure E-128. The reliability index is greater than three for all but two girders. The target reliability for the AASHTO Type 3-3 truck is 2.5.

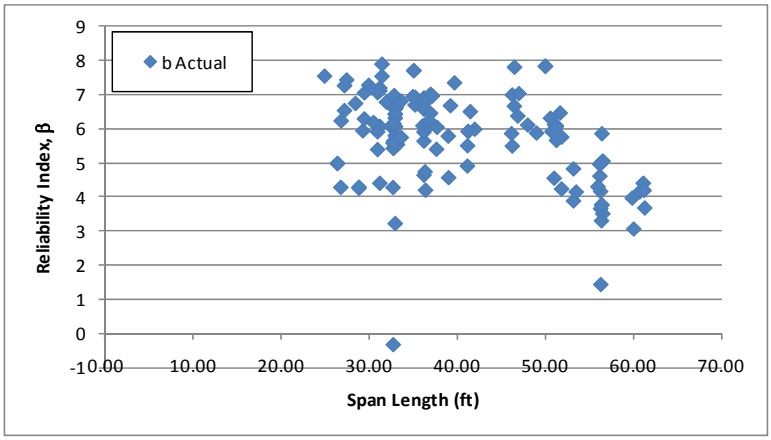


Figure E-128: Shear Reliability Indices for Type 3-3 Vehicle

Figure E-129 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 truck. The average reliability index for a girder with a rating near one is approximately 4.0, exceeding the target reliability of 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

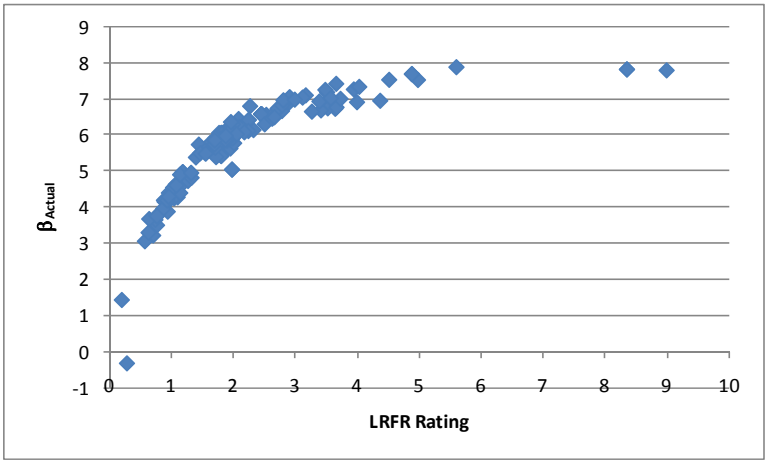


Figure E-129: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

E.1.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-130. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

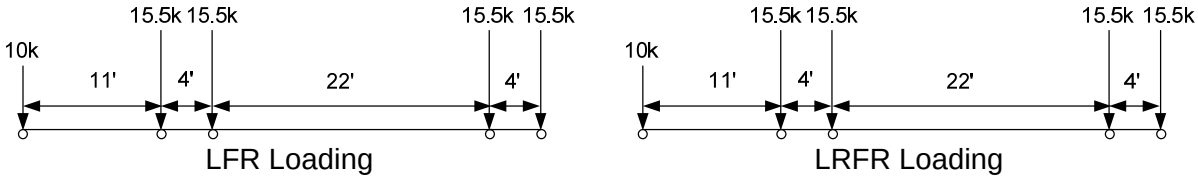
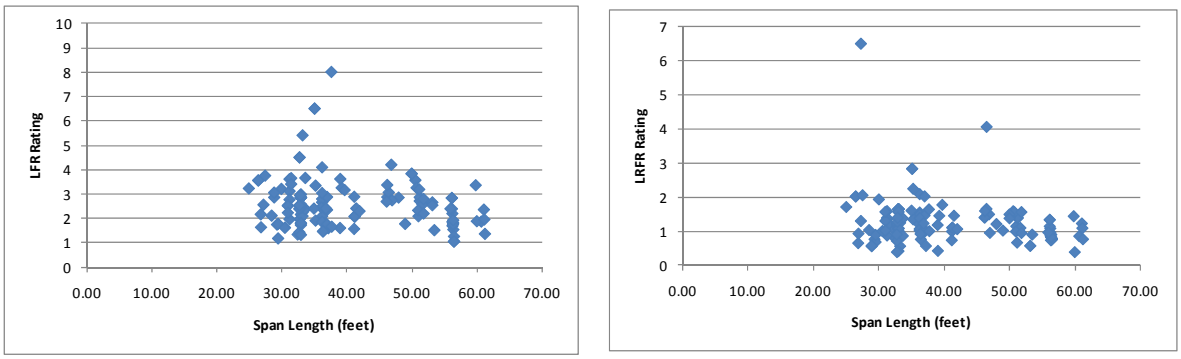


Figure E-130: Vehicle Loadings and Load Factors

E.1.13.1 Moment

E.1.13.1.1 Rating Factors

Figure E-131 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 46 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. All girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR rating is between one and four for most girders; three outliers with values of 12, 39, and 48 were removed from this graph to provide some clarity. The LRFR ratings range from 0.5 to 2.0 for most girders.



(a) (b)

Figure E-131: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure E-132 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 80% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 54% of girders when the ADTT is greater than 5,000. 100% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 45% when the highest ADTT is considered.

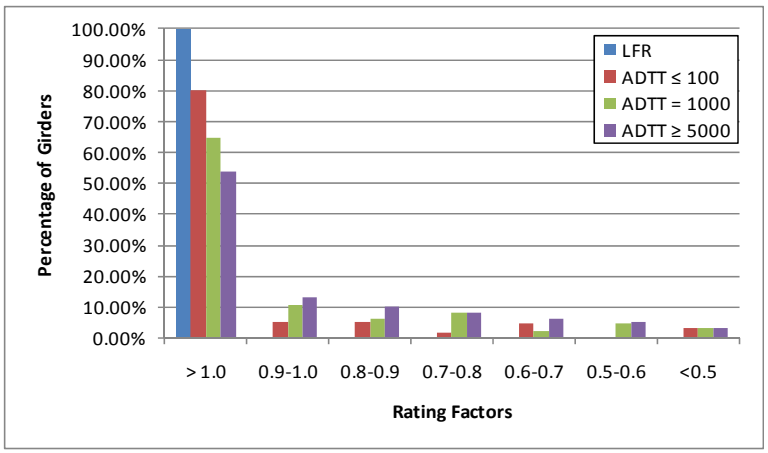


Figure E-132: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

E.1.13.1.2 Rating Factor Comparisons

Figure E-133 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.6; no girders have an LRFR rating greater than the LFR rating.

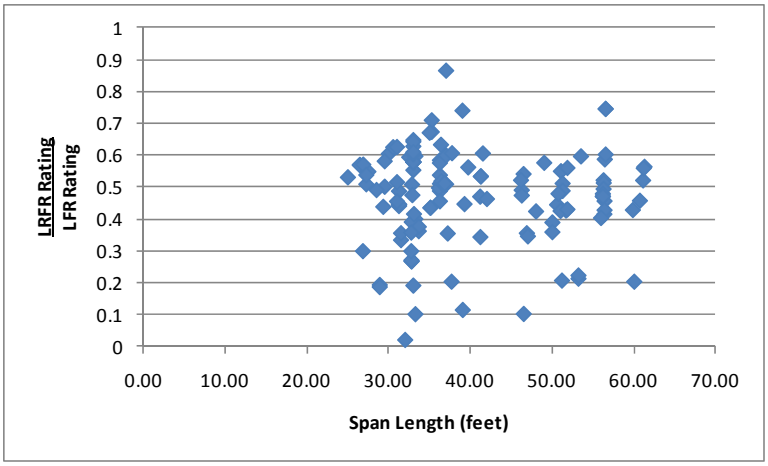


Figure E-133: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

E.1.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-134 shows that two girders have a reliability index less than the target reliability of 2.5. The reliability index is between three and eight for most girders.

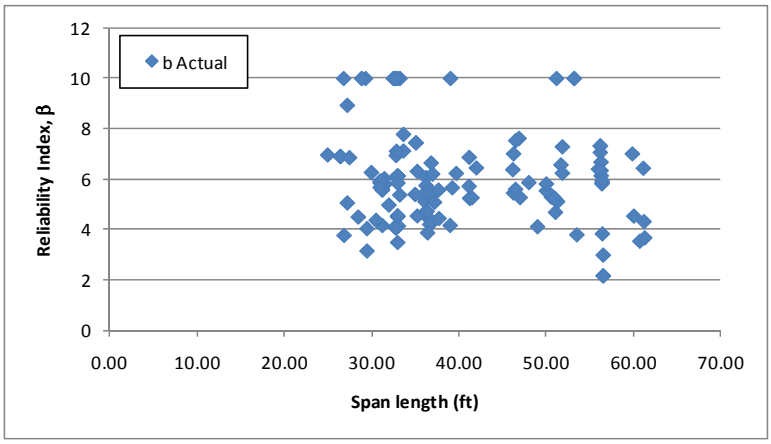


Figure E-134: Flexure Reliability Indices for Type 3S2 Vehicle

Figure E-135 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 Truck. The average reliability index for a girder with a rating of 1.0 is approximately 4.5, exceeding the target reliability of 2.5. This indicates the live load factors in the MBE are over-conservative and can be reduced.

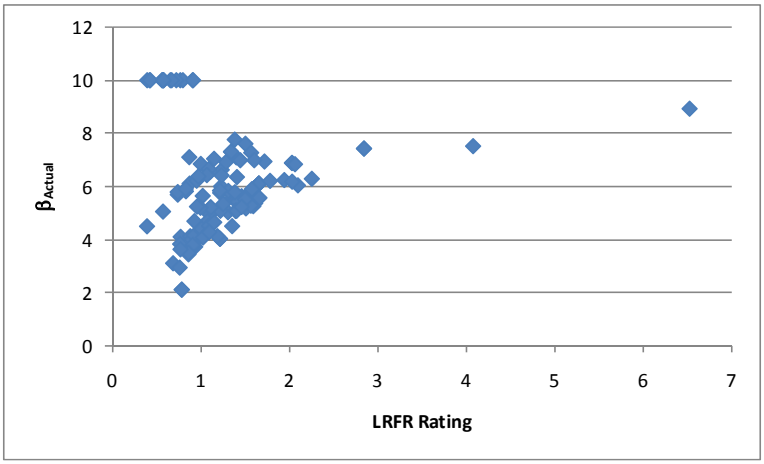
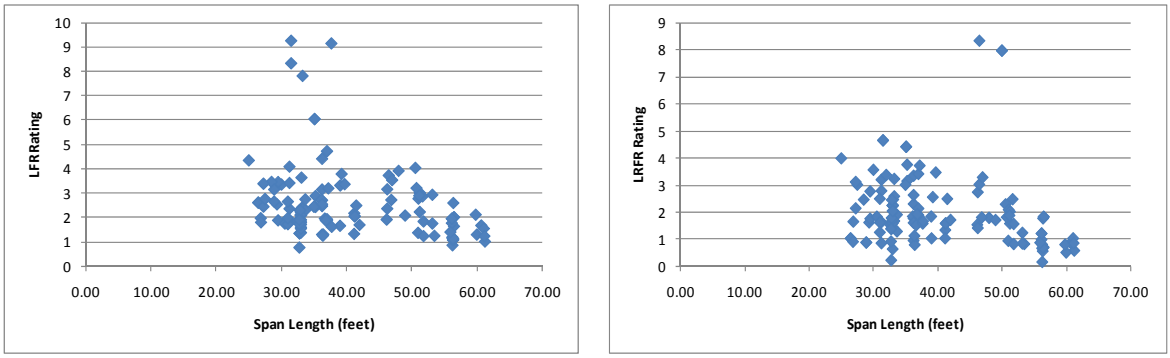


Figure E-135: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

E.1.13.2 Shear

E.1.13.2.1 Rating Factors

For shear, there are two girders with LFR rating factors less than 1.0, 26 girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure E-136 shows the LFR and LRFR ratings. The LFR rating is between one and four for most girder; three outliers with values of 13, 33, and 127 were removed from the rating graph. The LRFR rating is between 0.5 and 4.0 for most girders.



(a) (b)

Figure E-136: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure E-137 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 88.5% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 75.4% of girders when the ADTT is greater than 5,000. 98% of girders have LFR ratings greater than 1.0. Approximately 10% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 25% when the highest ADTT is considered.

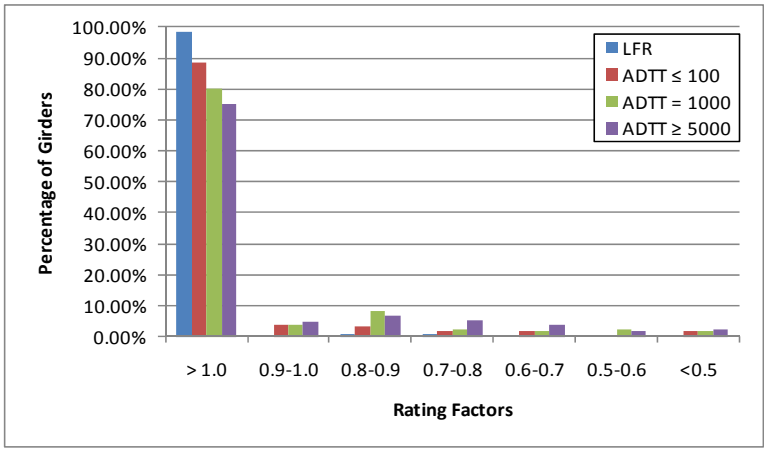


Figure E-137: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

E.1.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-138 show the comparison of rating factors. The ratio is generally between 0.6 and 1.2, with shorter spans generally having higher ratios. The LRFR rating is greater than the LFR rating for 24% of the girders.

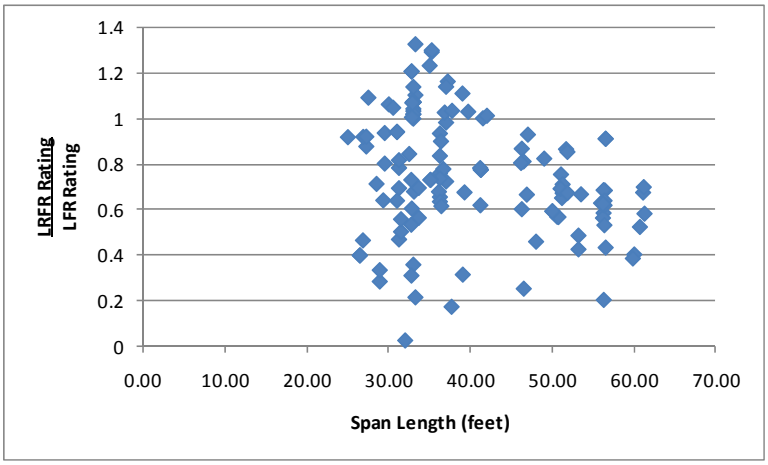


Figure E-138: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

E.1.13.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability of 2.5 for five girders as shown in Figure E-139. Girders with the target reliability typically had a reliability index between three and eight.

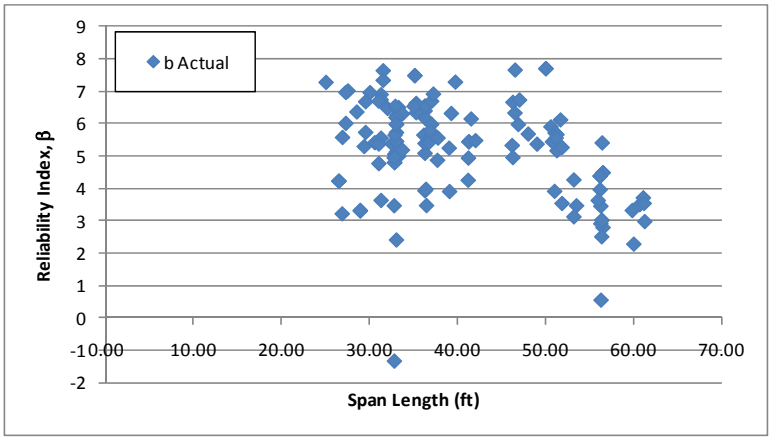


Figure E-139: Shear Reliability Indices for Type 3S2 Vehicle

Figure E-140 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 truck. The average reliability index for girders with ratings near one is approximately 3.75, exceeding the target value of 2.5. This indicates the live load factors in the MBE are over-conservative and can be reduced.

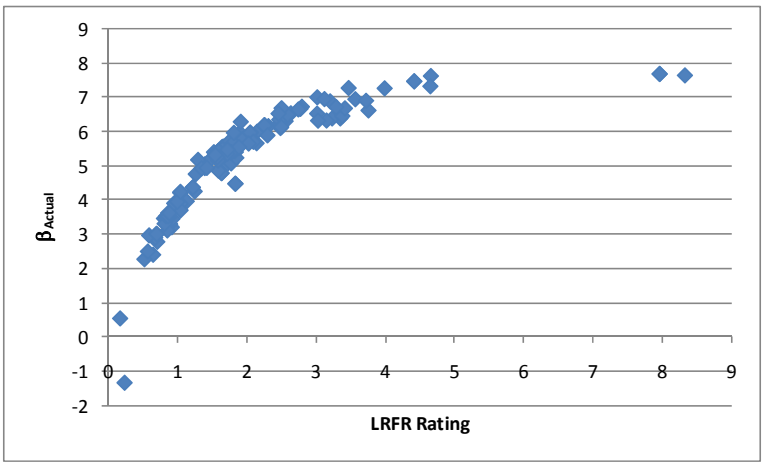


Figure E-140: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

E.1.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table E-1 shows the results for the moment ratings. The design vehicle and special permit vehicles cause the most girders with LFR ratings less than 1.0. The routine permit vehicles and legal vehicles did not cause many girders to have LFR ratings less than 1.0. Significant numbers of girders have ratings less than 1.0 for LRFR for all vehicles. All vehicles have a similar percentage of girders where the LFR rating is greater than the LRFR rating. An additional row was added to the table indicating how many of the girders with LRFR ratings less than 1.0 were controlled by the longitudinal steel rating. With the exception of three girders for the design vehicle and one girder for WA-02, all girders with LRFR ratings less than 1.0 were controlled by the longitudinal steel rating.

Table E-1: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	130	48	3	3	16	6	2	18	10	29	0	0	0
LRFR Rating less than 1.0		119	66	63	81	76	54	82	90	98	52	36	46
LFR and LRFR Rating less than 1.0		48	3	3	16	6	2	18	10	29	0	0	0
% with LFR RF greater than LRFR RF		100	100	100	99	100	100	99	100	99	100	100	100
Girders with LRFR rating less than 1.0 and controlled by longitudinal steel rating		116	66	63	81	76	54	82	90	97	52	36	46

E.1.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table E-2 shows the results for the shear ratings. All vehicles have a number of girders that do not have LFR ratings greater than 1.0, with the design vehicle, IL-01, OR-06, TX-04, and WA-02 having the most. For the LRFR ratings, all vehicles have at least 20 girders with LRFR ratings less than 1.0. The percentage of girders with LFR ratings greater than LRFR ratings seems to depend on the vehicle, which is expected because the LRFR shear strength equation uses the ratio of V_u/M_u.

Table E-2: Shear Rating Factor Results for All 12 Vehicles

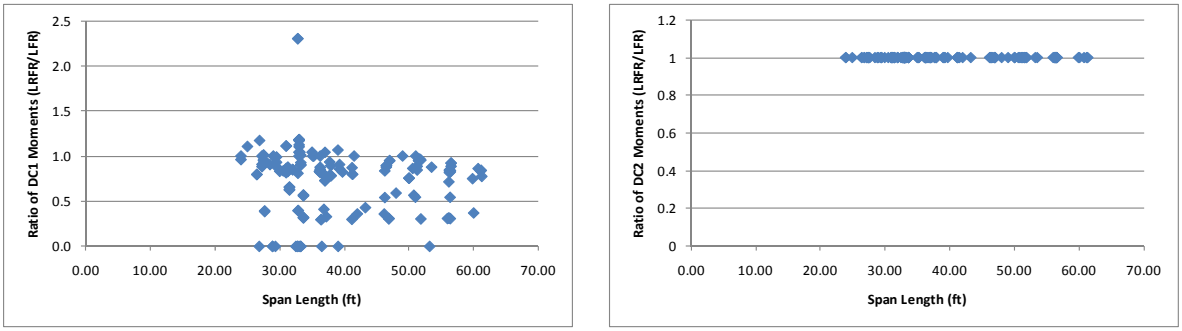
	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	130	72	6	5	22	6	2	25	18	36	2	2	2
LRFR Rating less than 1.0		82	33	33	48	36	30	51	56	71	29	20	26
LFR and LRFR Rating less than 1.0		61	6	5	22	6	2	21	18	34	2	2	2
% with LFR RF greater than LRFR RF		69	78	78	72	82	75	73	83	75	80	76	76

E.2 Interior Girders

E.2.1 Dead Loads

E.2.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure E-141a, the ratio of unfactored DC1 moments (self-weight, dead loads on non-composite section) varies significantly. This variation is due to the critical moment location varying between LFR and LRFR ratings. Figure E-141b shows that there is little variation within the DC2 loads; this is because there are no DC2 or DW loads.

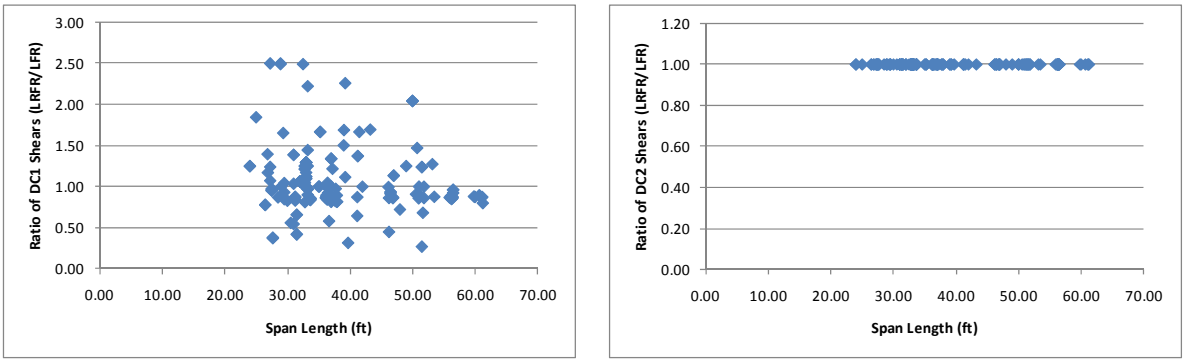


(a) (b)

Figure E-141: Ratios of DC1 and DC2 Moments (unfactored loads LRFR/LFR)

E.2.1.2 Shear

Figure E-142a shows that numerous girders have a ratio of DC1 shear close to 1.0, but there are also many where the ratio is either above or below 1.0. This is a mostly due to the variation of the critical section for shear. Figure E-142b shows that the shear due to DC2 and DW loads is either the same or both are zero thus setting the ratio equal to 1.



(a) (b)

Figure E-142: Ratio of DC1 and DC2 Shear (unfactored loads LRFR/LFR)

E.2.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure E-143. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

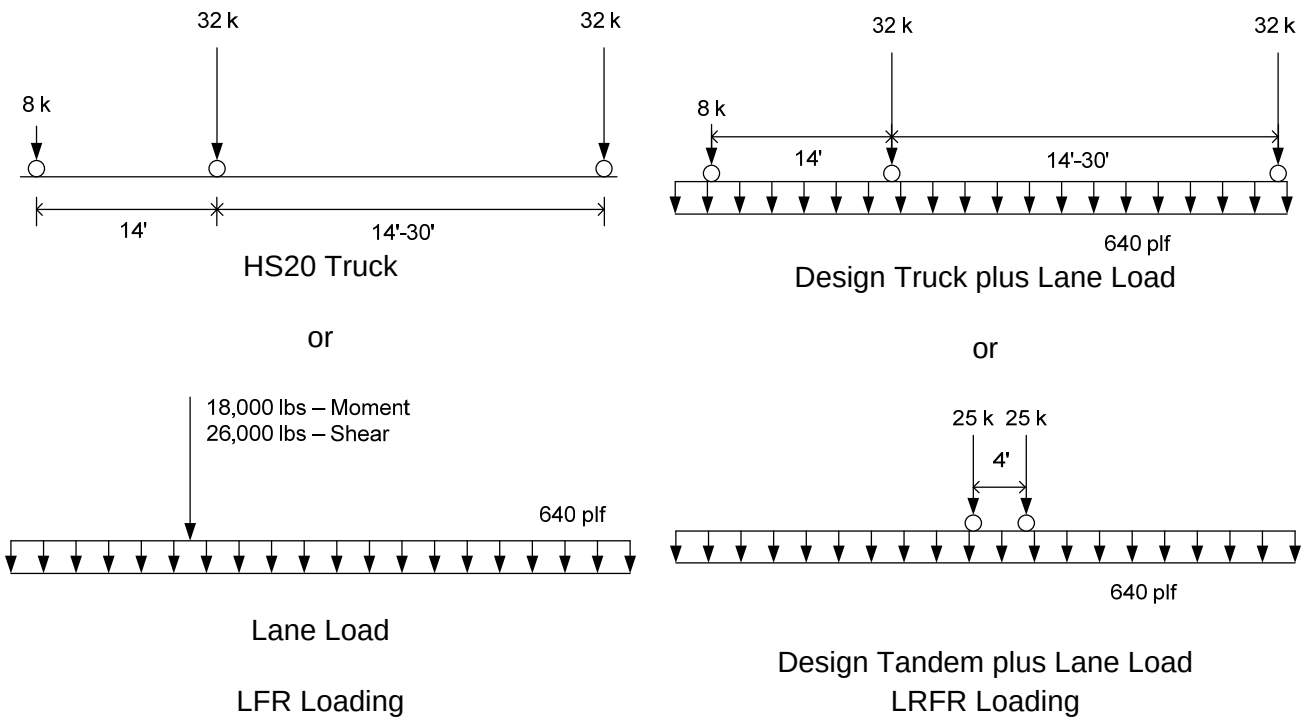
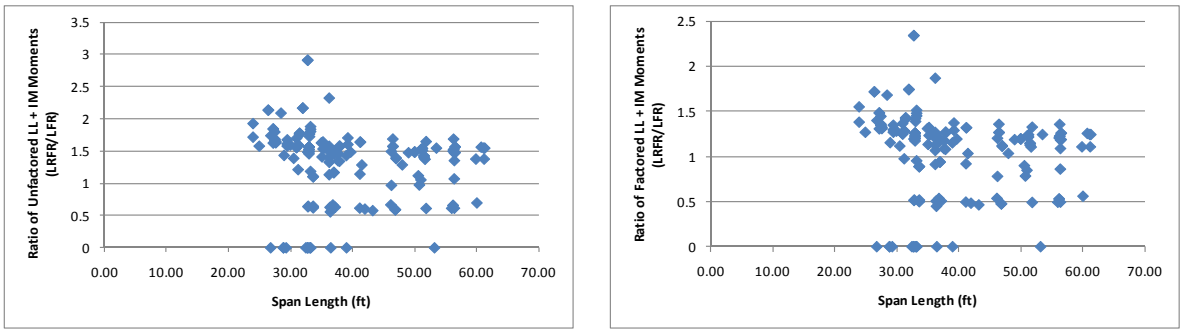


Figure E-143: Vehicle Loadings and Load Factors

E.2.2.1 Moment

E.2.2.1.1 Live Loads

Figure E-144a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.25 and 1.75 for most of the girders within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure E-144b shows that the results have shifted down and are between 1.0 and 1.5 for most cases. There a significant number of girders where the live loads are very different, these are girders where the critical locations vary between methods.



(a) (b)

Figure E-144: Ratio of Unfactored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

E.2.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure E-145 shows that the ratio of resistance is close to 1 for most girders. There are also a significant number of girders with a ratio of resistance near 0.55 and another group near 0.13. These are girders where the critical location varies between methods with the LRFR rating being away from midspan.

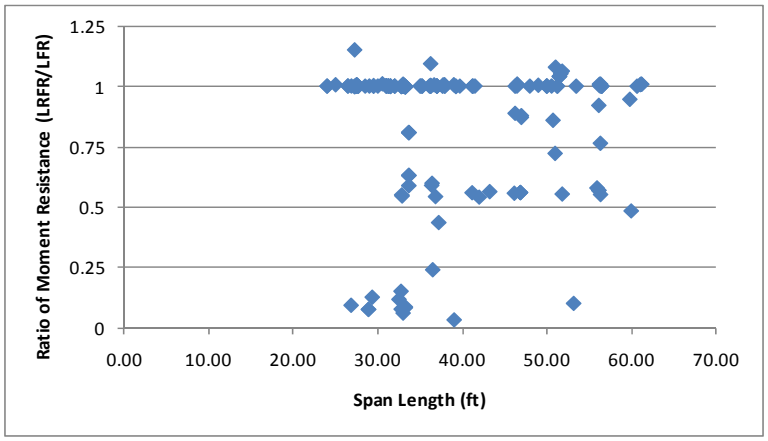
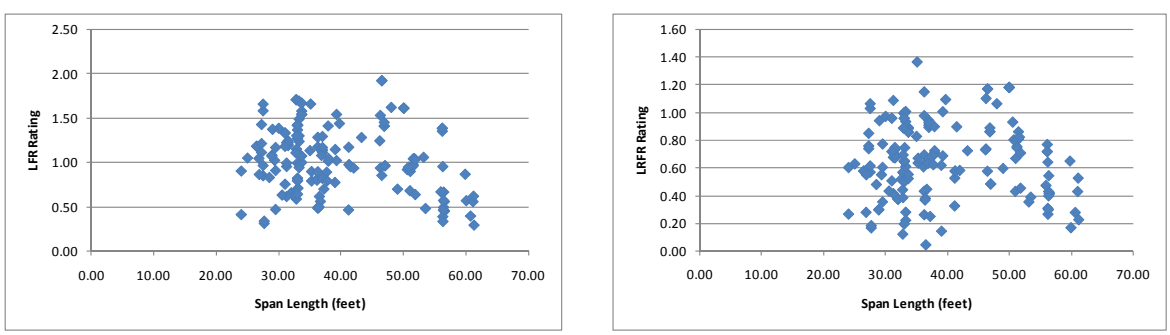


Figure E-145: Ratio of factored Moment Resistance (LFR/LRFR)

E.2.2.1.3 Rating Factors

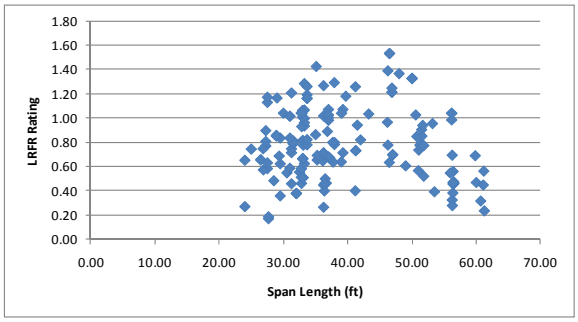
After comparing the loads and resistances to verify that those results seemed appropriate, the actual rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (165 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 83 girders with LFR ratings less than 1.0, 150 girders with LRFR ratings less than 1.0, and 83 girders where both the LFR and LRFR ratings are less than 1.0. 140 of the 150 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. Figure E-146 shows the LFR rating factors and LRFR rating factors. There are no obvious trends in the data for this vehicle. The LFR rating ranges from 0.5 to 1.5 for most girders while the LRFR rating is less than 1.4 for all girders.



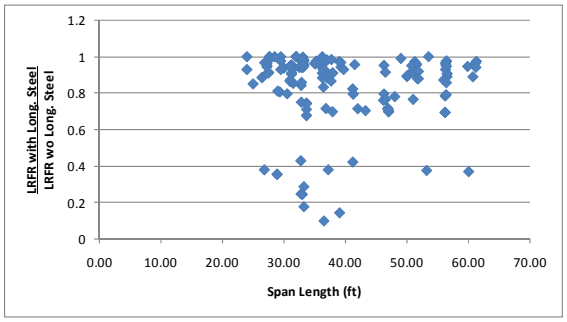
(a) (b)

Figure E-146: LFR and LRFR Flexure Rating Factors for Design Loadings

Figure E-147a shows the LRFR ratings when the longitudinal steel rating is ignored. 33 fewer girders have LRFR ratings less than 1.0 when the longitudinal steel rating is ignored. Most of the girders had ratings less than 0.4 when the longitudinal steel rating was included (Figure E-146b) and were also less than 40 feet in length. Figure E-147b shows the ratio of LRFR rating including the longitudinal steel rating divided by the LRFR rating excluding the longitudinal steel rating. The figure shows that most girders have longitudinal steel ratings that are 70-100% of the LRFR rating ignoring the longitudinal steel rating. There is also a group that is less than below 0.4.



(a)



(b)

Figure E-147: LFR and LRFR Flexure Rating Factors for Design Loadings

E.2.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure E-148. The results indicate that 99% of the girders in this set have LFR ratings greater than LRFR ratings. The ratio is between 0.5 and 0.8 for most girders with girders of longer spans having higher ratios.

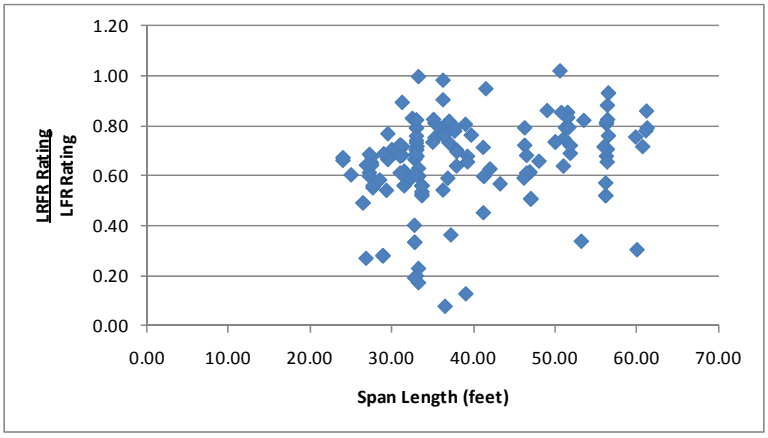


Figure E-148: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure E-149 shows the percentage of the total girders in each category with LRFR ratings less than one. The figure shows that most girders with LRFR ratings less than one have an LRFR rating that is 50-90% of the LFR rating. The figure shows how many girders are affected by switching to LRFR and the magnitude of the switch.

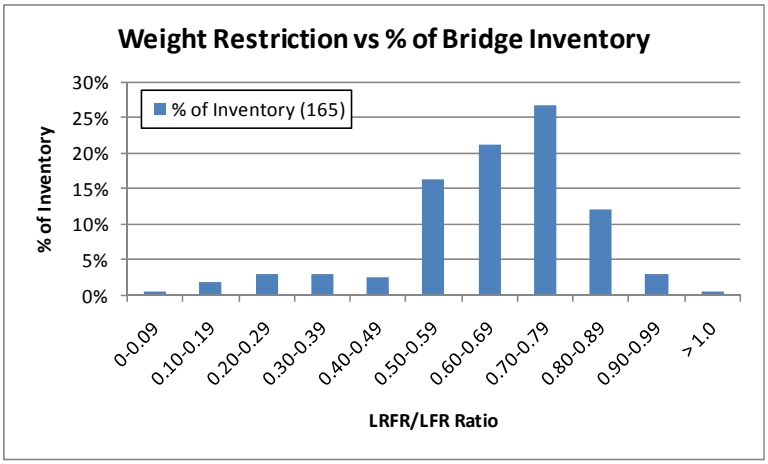


Figure E-149: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

E.2.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure E-150 shows that 72 girders have a reliability index lower than the target reliability of 3.5 inherent in the LRFD Design Specifications. The plot of the reliability index is similar to that of the rating factors (the shape is similar). The reliability index for most girders is less than six.

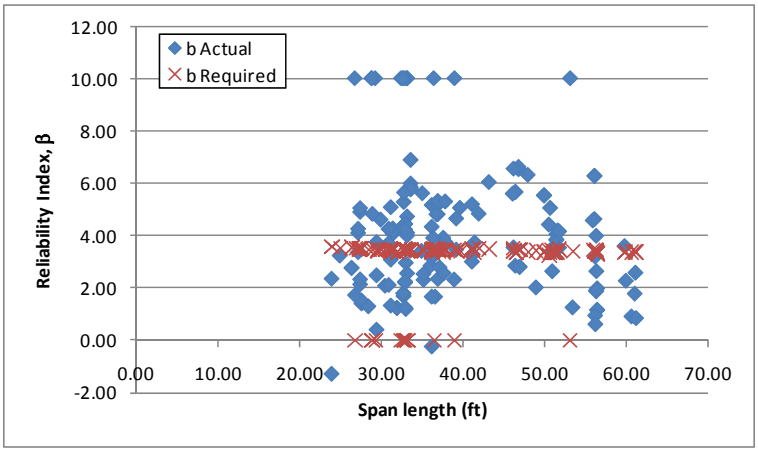


Figure E-150: Flexure Reliability Indices for HL-93 Loading

Figure E-151 shows the reliability index for moment plotted against the LRFR moment rating for the HL-93 Design Load. The figure shows that the reliability index increases with an increasing LRFR rating. The reliability index for a girder with a rating of one is approximately 4.5. It is expected that the reliability index for a girder with a rating of one would be above the target reliability of 3.5 as the live load factors in the Design Specifications were increased to provide a level of conservatism.

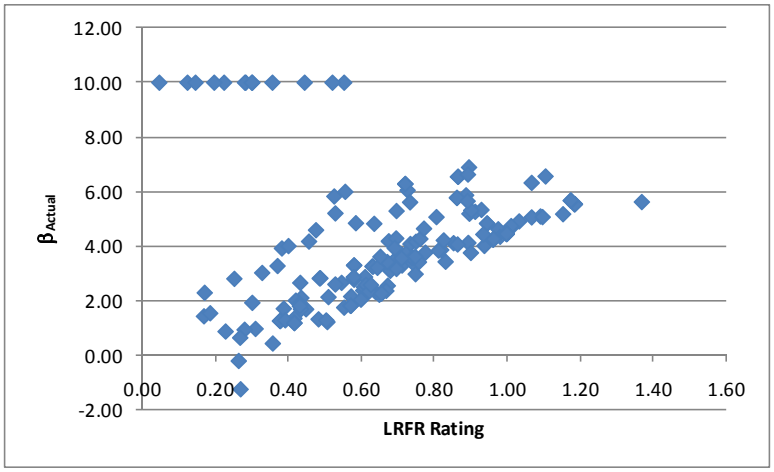


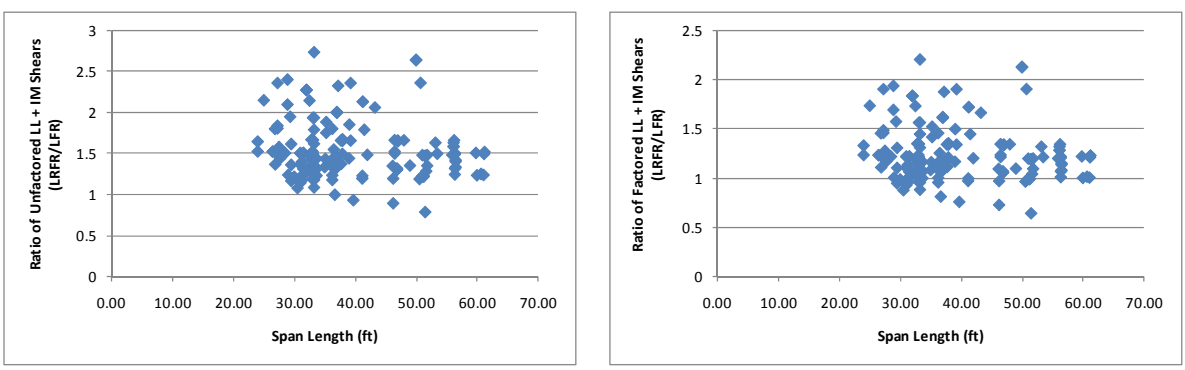
Figure E-151: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Loading

E.2.2.2 Shear

The following set of graphs looking at the effects of shear is for the same subset as used above for moment, that is simple span, interior reinforced concrete tee beams.

E.2.2.2.1 Live Loads

Figure E-152a shows that the ratio of unfactored shear varies significantly, with most girders between 1.0 and 1.5 with those not in this range generally higher than 1.5. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure E-152b shows that the ratio of factored live load shears has decreased and is generally between 0.8 and 1.25 for most cases.



(a) (b)

Figure E-152: Ratio of Unfactored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

Figure E-153 shows the location of the critical section for varies significantly for most girders in this subset. The variation in the factored shears shown in Figure E-152 was exacerbated by the difference in the critical section for shear rating.

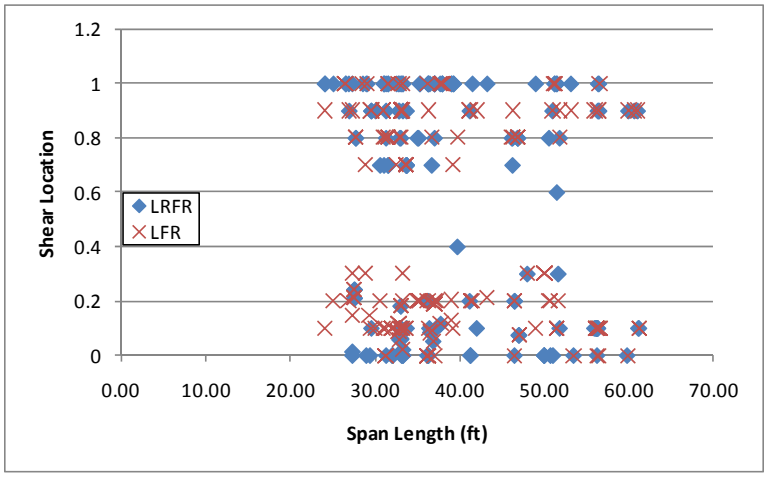


Figure E-153: Graph of critical shear location for Design Loadings

E.2.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure E-154 shows that the ratio of resistance is generally greater than 1.0 (LRFR resistance is greater than LFR resistance). The variation in resistance is expected due to the variation in critical location between LRFR and LFR methods.

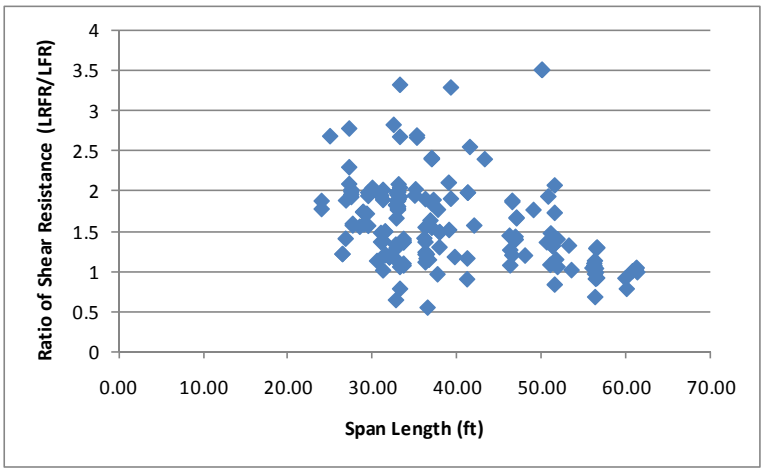
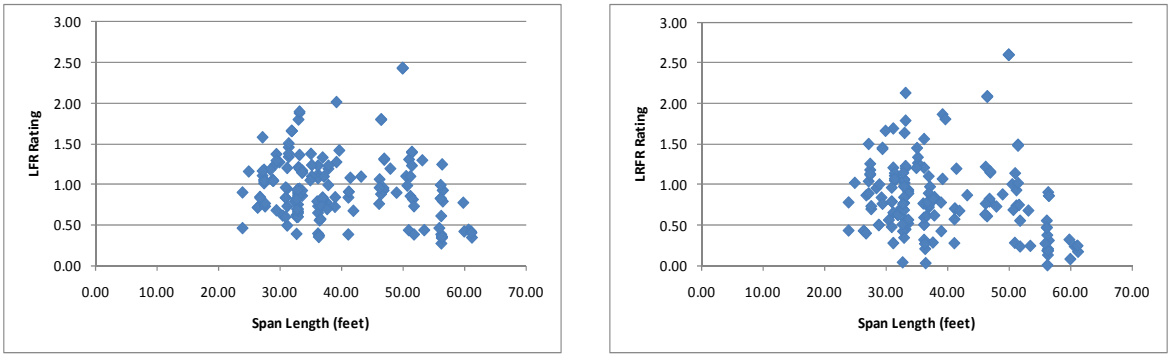


Figure E-154: Ratio of factored Shear Resistance (LRFR/LFR)

E.2.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results seemed appropriate, the actual rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 97 girders with LFR ratings less than 1.0, 112 girders with LRFR ratings less than 1.0, and 88 girders where both LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. For this subset, there is a significant number girders that have shear ratings less

than 1.0 for LRFR. The LFR rating was greater than the LRFR rating for 68% of the girders in this subset. Figure E-155 show the LFR rating factors and LRFR rating factors. The LFR and LRFR ratings are between 0.5 and 1.5 for most girders.



(a) (b)

Figure E-155: LFR and LRFR Shear Rating Factors for Design Loadings

E.2.2.2.4 Rating Factor Comparisons

Figure E-156 shows the ratio of the LRFR rating to the LFR rating. About 30% of the girders in this set have LRFR ratings greater than the LFR rating. The ratio is between 0.6 and 1.2 for most girders with longer spans having somewhat lower ratings than shorter spans.

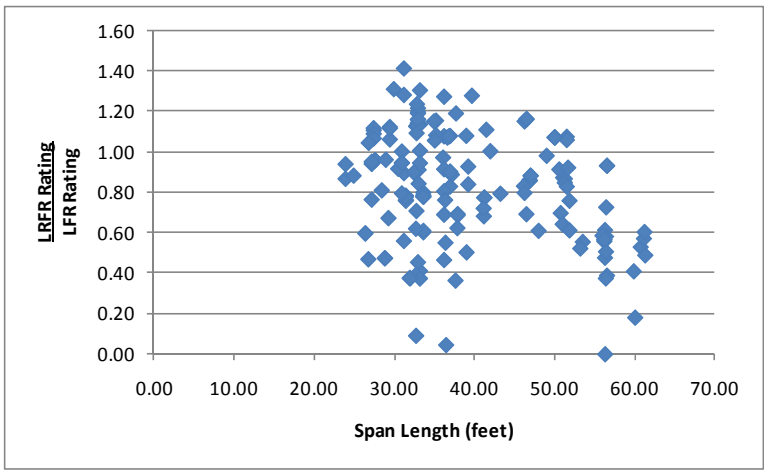


Figure E-156: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Vehicles

Figure E-157 shows the percentage of girders in each category for those with LRFR ratings less than 1.0. The figure shows that for girders with LRFR ratings less than 1.0, a similar number are in each category for those ratios greater than 50%. The figure shows that many girders will be affected by switching from LFR to LRFR but for some girders switching methods will actually increase the rating (>1 column).

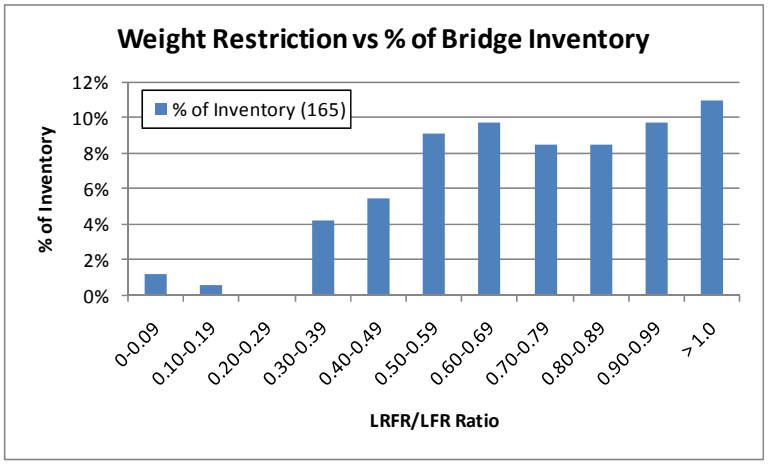


Figure E-157: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

E.2.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure E-158 shows that 85 girders have a reliability index less than the target reliability level of 3.5. Girders of all span lengths have reliability indices less than the target level. The girders with negative reliability indices likely do not have properly defined shear reinforcement in the Virtis file as many of these bridges had the shear rating turned off.

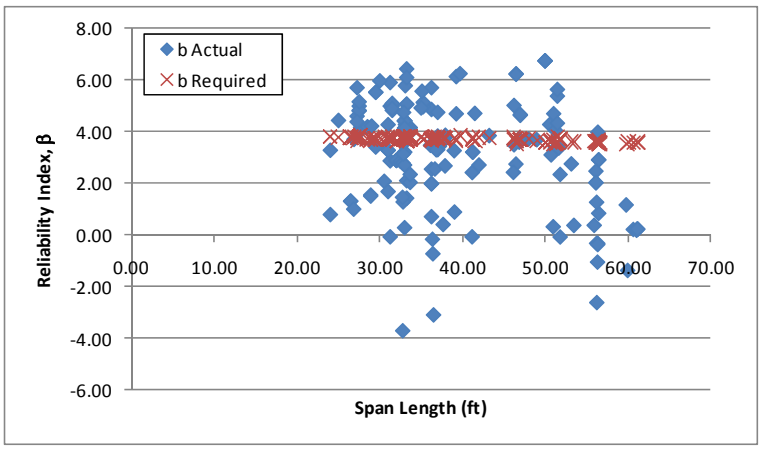


Figure E-158: Shear Reliability Indices for HL-93 Loading

Figure E-159 shows the reliability index for shear plotted against the LRFR shear rating for the design vehicle. The average reliability for girders with a rating of 1.0 is approximately 4.0. The fact that the reliability is above the target reliability of 3.5 is not surprising as the load factors in the LRFD Design Specification were increased to provide a conservative estimate of the live load.

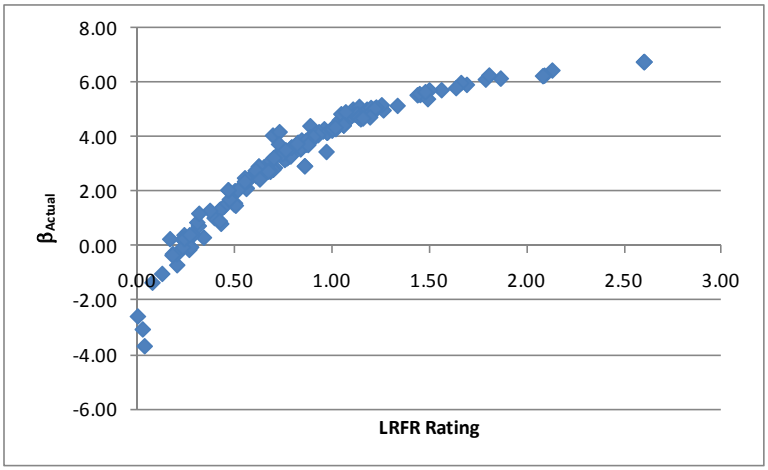


Figure E-159: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

E.2.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-160. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.

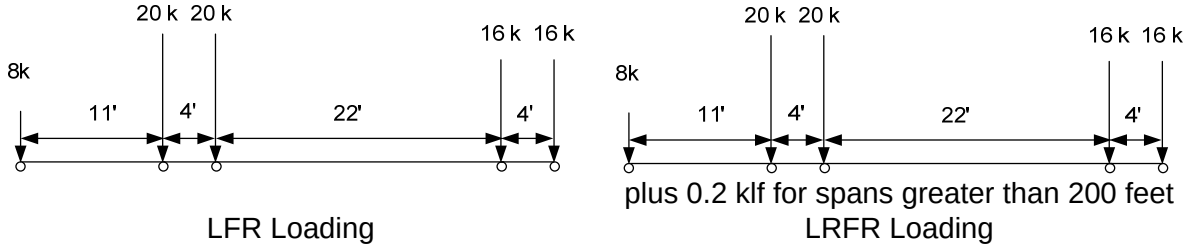


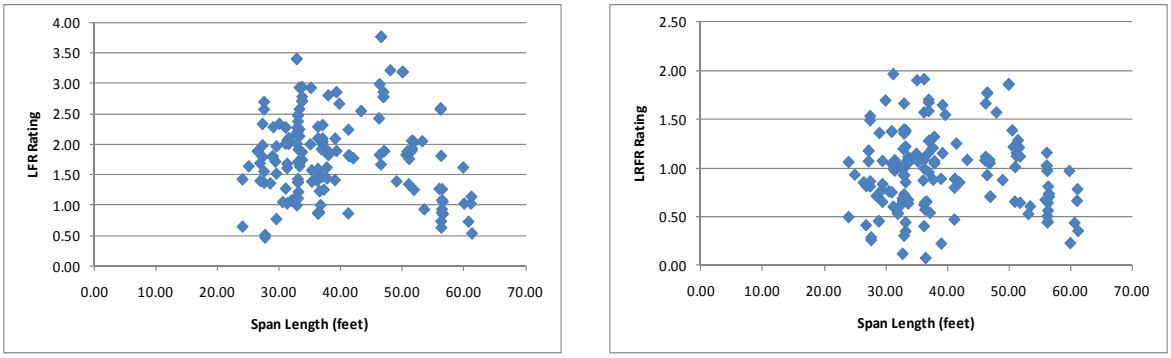
Figure E-160: Vehicle Loadings and Load Factors

E.2.3.1 Moment

The following section contains the results for interior, reinforced concrete tee beams within simple span bridges for the DE-07 Vehicle.

E.2.3.1.1 Rating Factors

Figure E-161 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 19 girders with an LFR rating less than 1.0, 84 girders with an LRFR rating less than 1.0, and 19 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The ratings are between 1.0 and 3.0 for most LFR ratings and between 0.5 and 1.5 for the LRFR ratings.



(a) (b)

Figure E-161: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure E-162 shows the percentage of girders with moment ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 59.4% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 30.9% of girders when the ADTT is greater than 5,000. 88% of girders have LFR ratings greater than 1.0. Approximately 30% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 60% when the highest ADTT is considered.

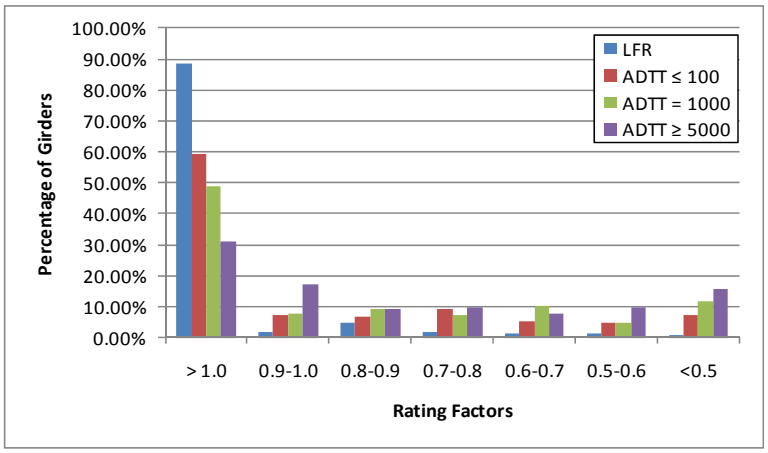


Figure E-162: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

E.2.3.1.2 Rating Factor Comparisons

Figure E-163 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.4 to 0.7. There are no girders with LRFR ratings greater than the LFR ratings.

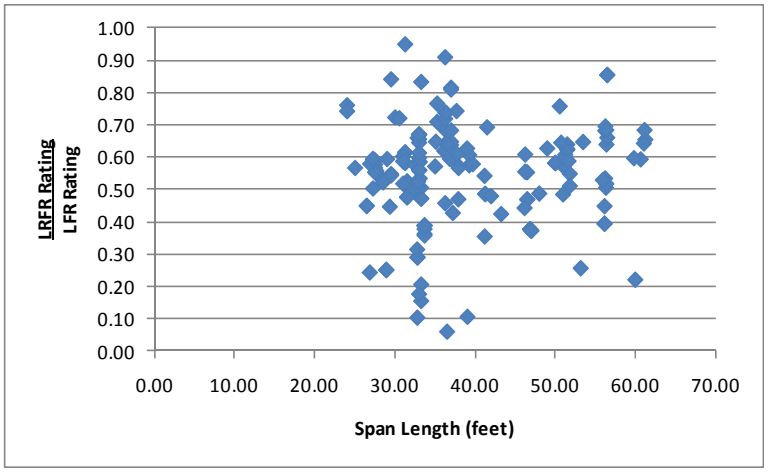


Figure E-163: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

E.2.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-164 shows four girders have a reliability index less than the target reliability index of 2.5. The reliability index is between four and seven for most girders.

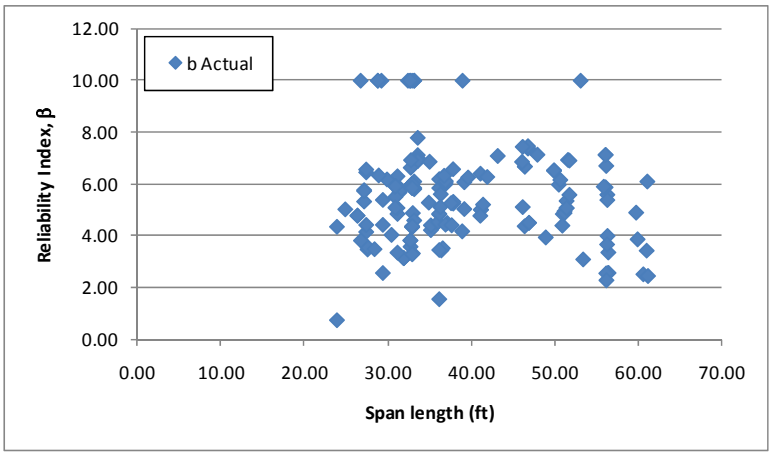


Figure E-164: Flexure Reliability Indices for DE-07 Vehicle

Figure E-165 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 vehicle. The figure shows that the reliability index increases with increasing rating factors. The average reliability index for a girder with a rating of 1.0 is approximately 5.0. This exceeds the target reliability index of 2.5, indicating the live load factors in the MBE are over-conservative and can be reduced.

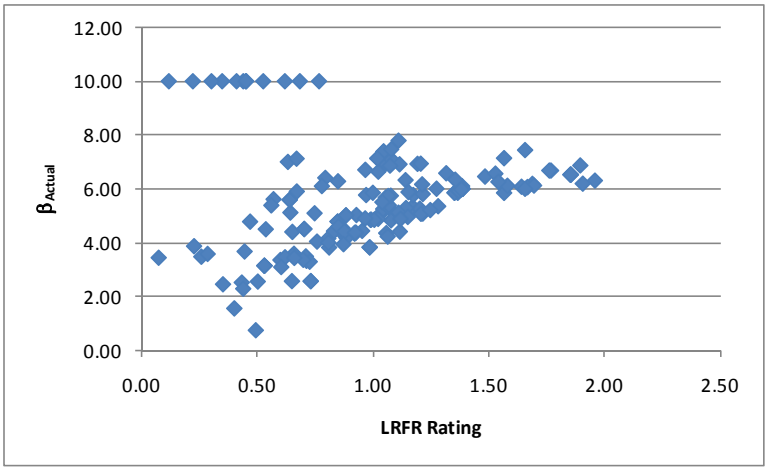
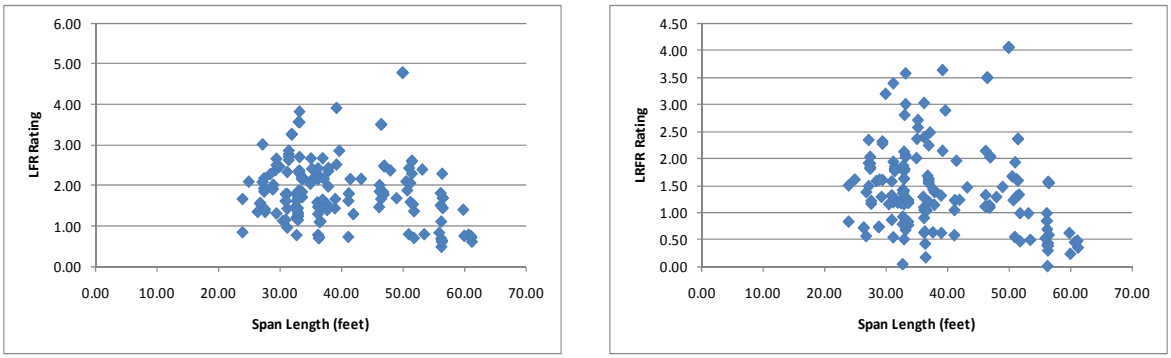


Figure E-165: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

E.2.3.2 Shear

E.2.3.2.1 Rating Factors

For shear, there are 21 girders that have rating factors less than 1.0 for LFR, 46 girders for LRFR, and 21 girders where both LFR and LRFR are less than 1.0. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure E-166 shows the LFR and LRFR ratings. The LRFR ratings are between one and three for most girders while the LRFR rating is between 0.5 and 2.5.



(a) (b)

Figure E-166: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure E-167 shows the percentage of girders with shear ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 75.2% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 67.3% of girders when the ADTT is greater than 5,000. 87% of girders have LFR ratings greater than 1.0. Approximately 12% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 20% when the highest ADTT is considered.

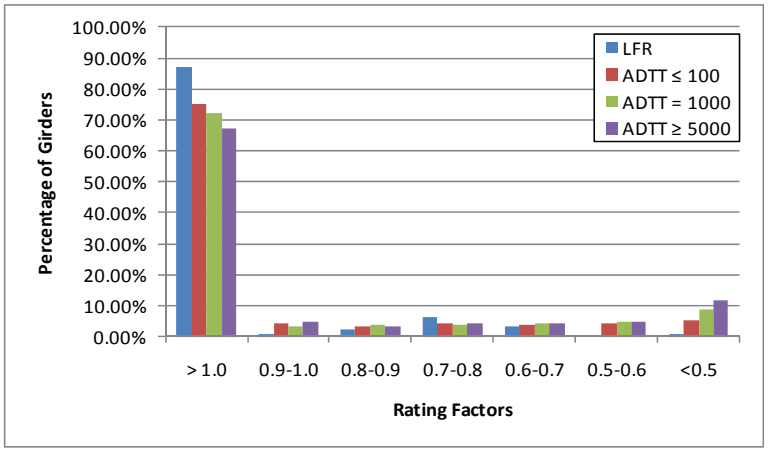


Figure E-167: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

E.2.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure E-168 show the comparison of rating factors. The ratio is less than 1.0 for 85% of the girders, with longer spans being the most likely to have a ratio less than 1.0. This shows that for about 15% of girders, switching to LRFR increases the rating from the LFR rating.

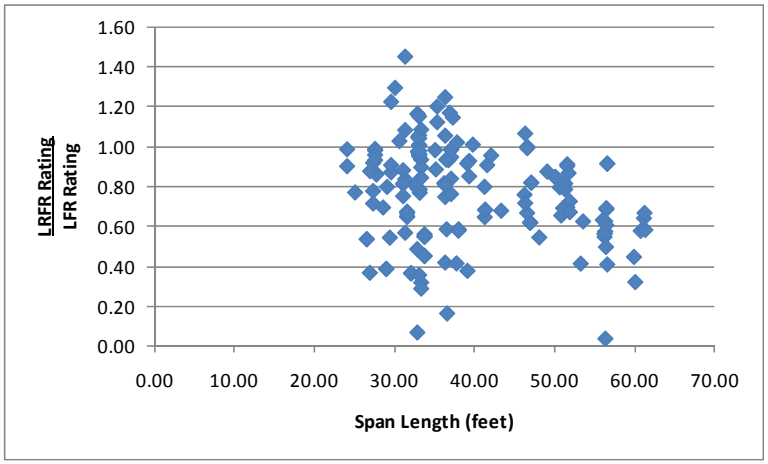


Figure E-168: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

E.2.3.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but 17 girders as shown in Figure E-169. Improper input of the shear reinforcement is the cause of most of the girders with reliability indices less than zero. The reliability index is between four and seven for most girders that have at least the target level of reliability.

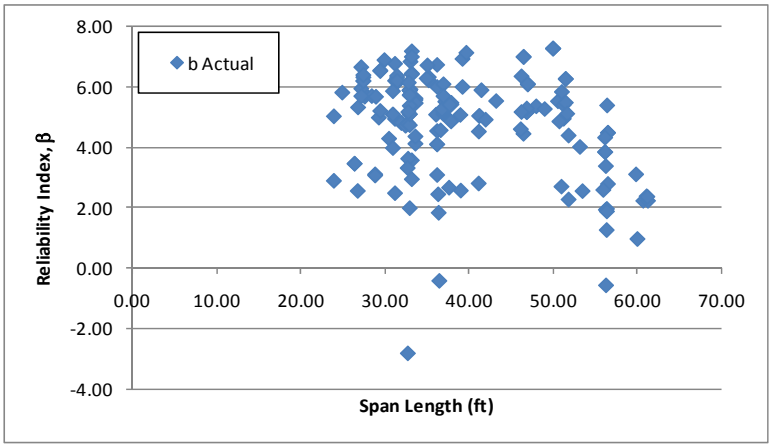


Figure E-169: Shear Reliability Indices for DE-07 Vehicle

Figure E-170 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 vehicle. The average reliability index for a girder with a rating of 1.0 is approximately 4.25. This exceeds the target reliability index of 2.5 and suggests that the live load factors in the MBE may be over-conservative and can be reduced.

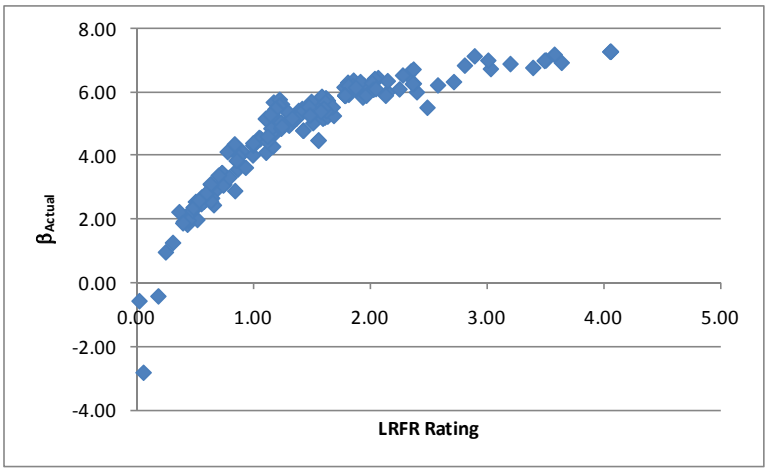
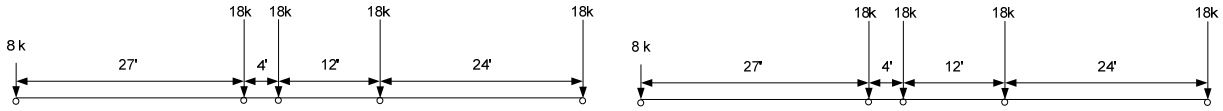


Figure E-170: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

E.2.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-171. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

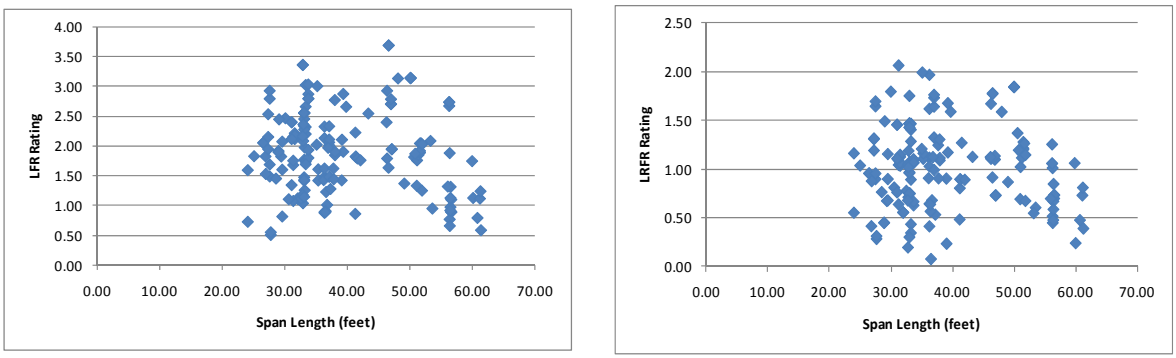
Figure E-171: Vehicle Loadings and Load Factors

E.2.4.1 Moment

The following section contains the results for interior reinforced concrete tee-beams within simple span bridges for the FL-04 Vehicle.

E.2.4.1.1 Rating Factors

Figure E-172 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 18 girders with an LFR rating less than 1.0, 76 girders with an LRFR rating less than 1.0, and 18 girders where both ratings are less than 1.0. 73 of the 76 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR ratings are between 1.0 and 3.0 for most girders. The LRFR ratings are between 0.5 and 2.0 for most girders.



(a) (b)

Figure E-172: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure E-173 shows the percentage of girders with moment ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 64.2% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 34.6% of girders when the ADTT is greater than 5,000. 89% of girders have LFR ratings greater than 1.0. Approximately 25% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 55% when the highest ADTT is considered.

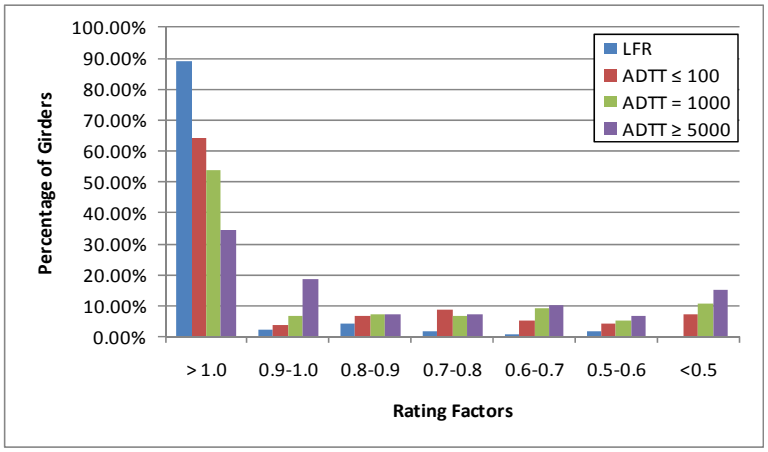


Figure E-173: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

E.2.4.1.2 Rating Factor Comparisons

Figure E-174 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. Zero girders have an LRFR rating greater than the LFR rating. The LRFR rating is typically 50 to 70% of the LFR rating for all span lengths.

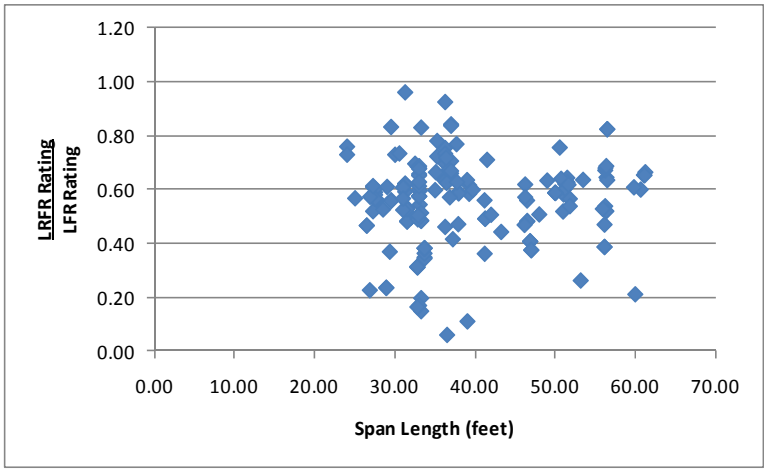


Figure E-174: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

E.2.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-175 shows that all but two girders have a reliability index greater than the target reliability index of 2.5. The reliability index is between four and eight for most girders.

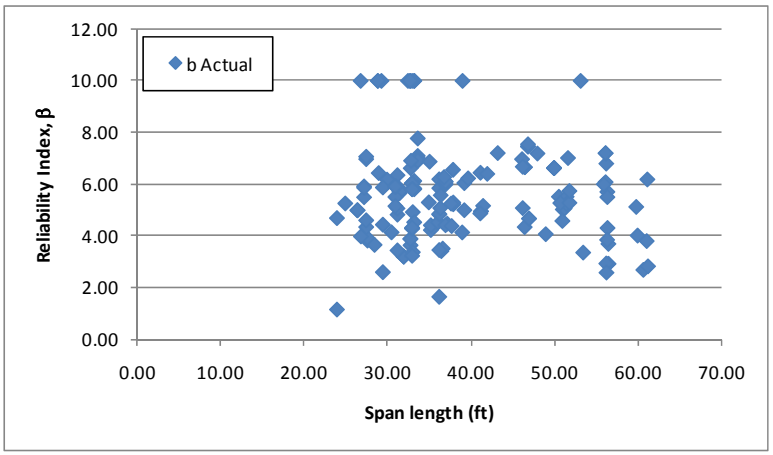


Figure E-175: Flexure Reliability Indices for FL-04 Vehicle

Figure E-176 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 vehicle. The figure shows that the reliability index increases with increasing LRFR rating. The average reliability index for a girder with a rating of 1.0 is approximately 4.5, higher than the target reliability of 2.5. This indicates that lower live load factors can be used to reduce the conservatism present in the current live load factors.

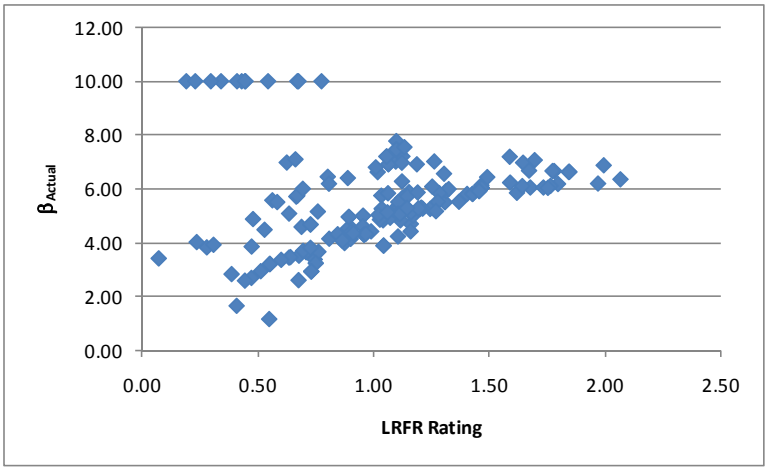
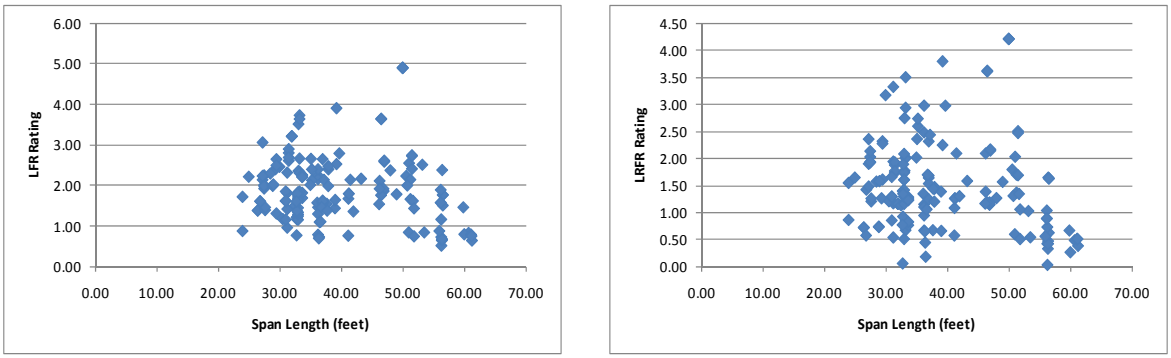


Figure E-176: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

E.2.4.2 Shear

E.2.4.2.1 Rating Factors

For shear, there are 21 girders that have LFR rating factors less than 1.0, 43 girders with LRFR ratings less than 1.0, and 21 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 83% of the girders in this subset. Figure E-177 show the LFR and LRFR ratings, respectively. The LFR ratings are between one and three while the LRFR rating is between 0.5 and 2.5 for most girders.



(a) (b)

Figure E-177: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure E-178 shows the percentage of girders with shear ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 76.4% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 70.3% of girders when the ADTT is greater than 5,000. 87.3% of girders have LFR ratings greater than 1.0. Approximately 10% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to 17% when the highest ADTT is considered.

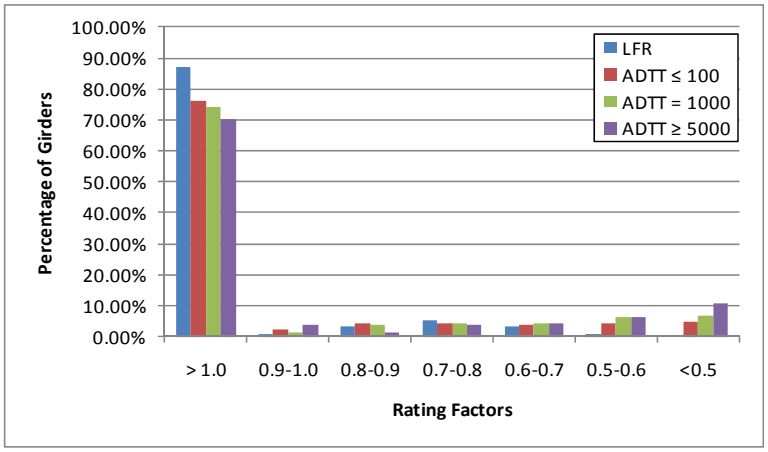


Figure E-178: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

E.2.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-179 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2; 17% of girders have LRFR ratings greater than the LFR ratings.

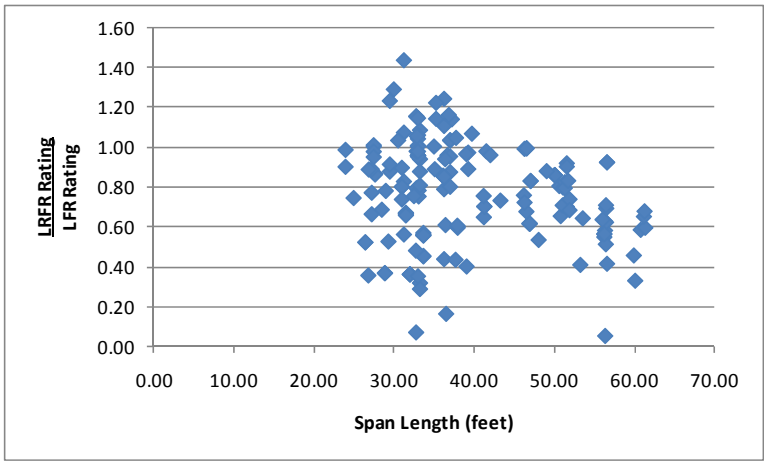


Figure E-179: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

E.2.4.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for 15 girders as shown in Figure E-180. There are several girders with reliability indices less than zero, indicating that the resistance is less than the applied loads. This is likely a result of the shear reinforcement not being properly defined. The reliability index for most girders is between four and seven.

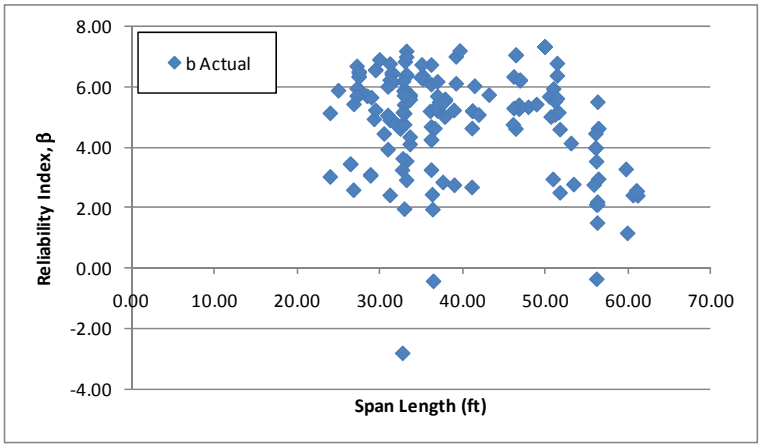


Figure E-180: Shear Reliability Indices for FL-04 Vehicle

Figure E-181 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 vehicle. The average reliability index for girders with a rating of 1.0 is approximately 4.25. This exceeds the target reliability index of 2.5 and indicates the LRFR live load factors may be over-conservative and can be reduced.

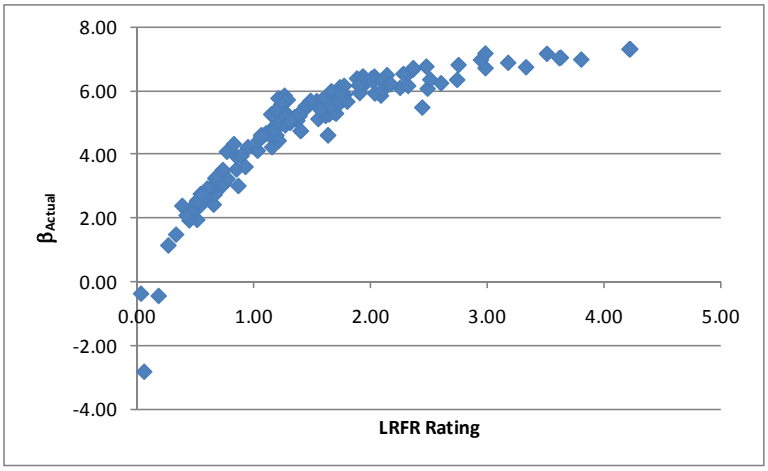
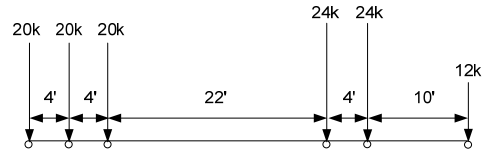


Figure E-181: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

E.2.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-182. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases multiple lanes may control.

LFR Loading



plus 0.2 klf for spans greater than 200 feet

LRFR Loading

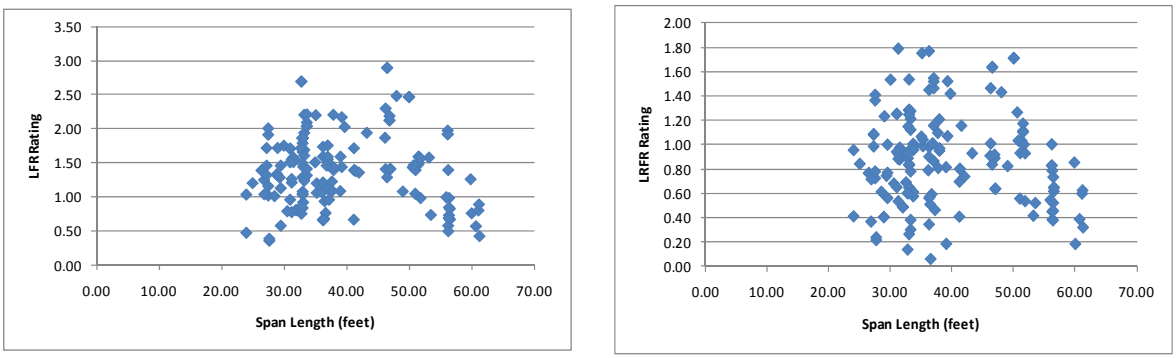
Figure E-182: Vehicle Loadings and Load Factors

E.2.5.1 Moment

The following section contains the results for interior reinforced concrete tee-beams within simple span bridges for the IL-01 Vehicle.

E.2.5.1.1 Rating Factors

Figure E-183 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 40 girders with an LFR rating less than 1.0, 109 girders with an LRFR rating less than 1.0, and 40 girders where both ratings are less than 1.0. 100 of 109 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 99% of the girders in this subset. The LFR ratings are generally less than 2.5 while the LRFR ratings are always less than 1.8.



(a) (b)

Figure E-183: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure E-184 shows the percentage of girders with moment ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 57.0% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 12.1% of girders for a multi-trip permit with an ADTT greater than 5,000. 75.8% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when a single trip, escorted permit is considered; this increases to over 60% when a multi-trip permit with an ADTT greater than 5,000 is considered.

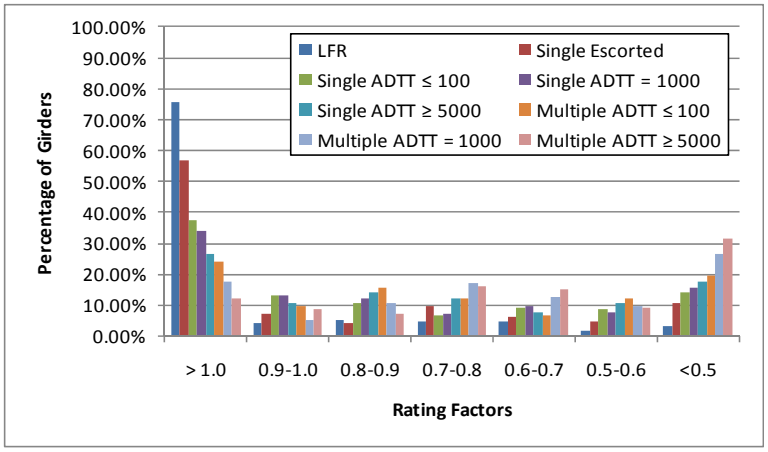


Figure E-184: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

E.2.5.1.2 Rating Factor Comparisons

Figure E-185 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is between 0.6 and 0.9 for most girders. Two girders have LRFR ratings greater than the LFR rating.

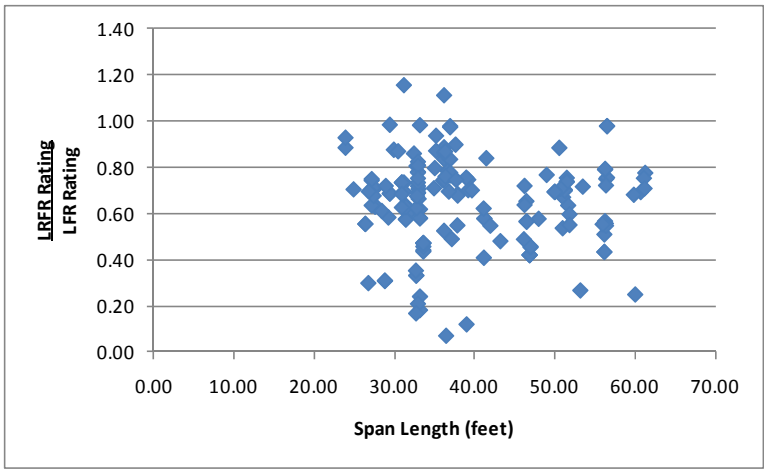


Figure E-185: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

E.2.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-186 shows that 12 girders have a reliability index less than the target reliability index of 3.5. The reliability index is between four and eight for most girders.

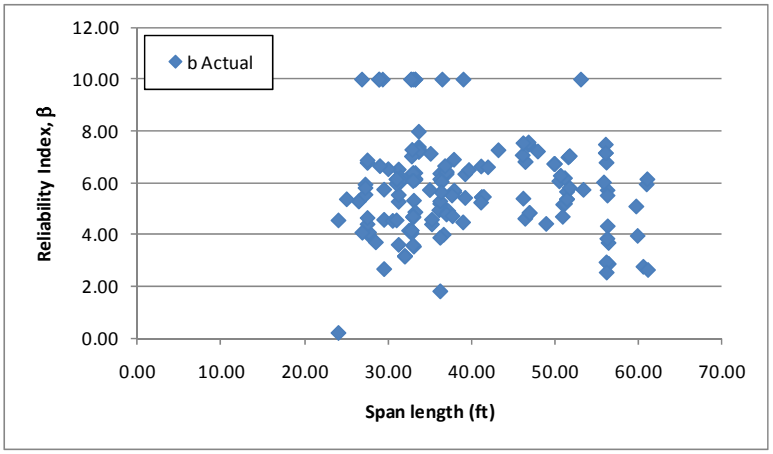


Figure E-186: Flexure Reliability Indices for IL-01 Vehicle

Figure E-187 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 Vehicle. The figure shows that the reliability increases with an increasing LRFR rating. The average reliability index for a girder with a rating of 1.0 is approximately 5.0, above the target reliability of 3.5. This indicates that the live load factors currently in the MBE are over-conservative and can be reduced.

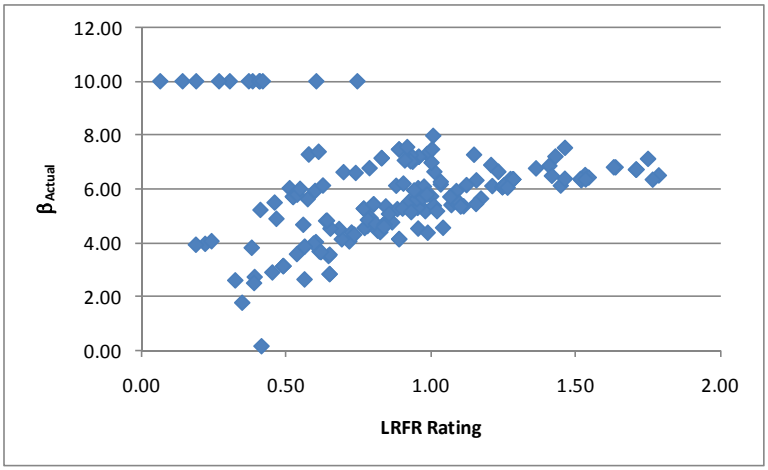
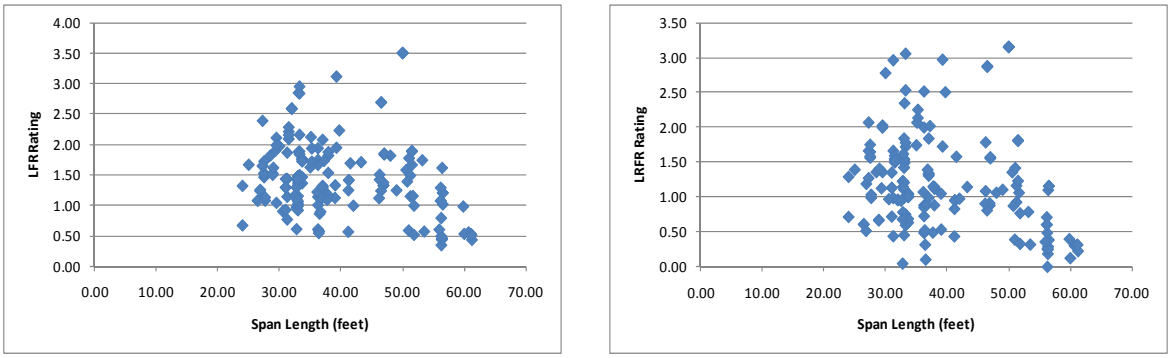


Figure E-187: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

E.2.5.2 Shear

E.2.5.2.1 Rating Factors

For shear, there are 34 girders that have LFR rating factors less than 1.0, 70 girders with LRFR ratings less than 1.0, and 31 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 73% of the girders in this subset. Figure E-188 shows the LFR and LRFR ratings. The LFR and LRFR ratings are between 0.5 and 2.0 for most girders. Almost all of the girders had ratings less than 2.0, with several girders having LRFR ratings being almost zero.



(a) (b)

Figure E-188: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure E-189 shows the percentage of girders with shear ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 71.5% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 37.6% of girders when a multi-trip permit with an ADTT greater than 5,000 is considered. 79.4% of girders have LFR ratings greater than 1.0. Less than 10% more girders have LRFR ratings less than 1.0 when a single trip, escorted permit is considered; this increases to more than 40% when the multi-trip permit with an ADTT greater than 5,000 is considered.

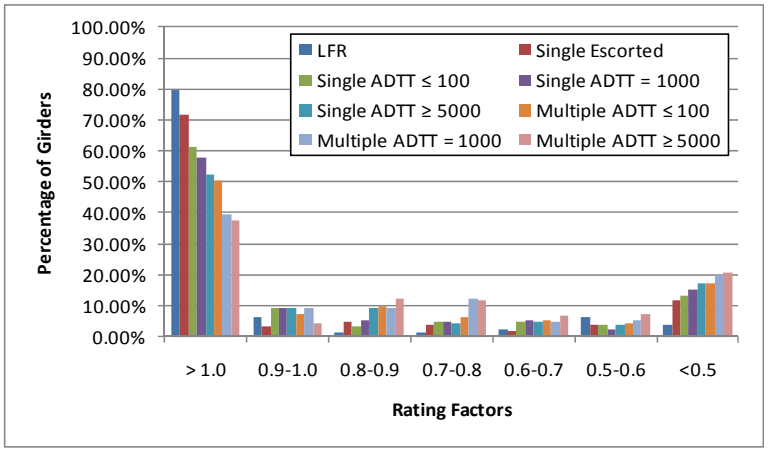


Figure E-189: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

E.2.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-190 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2, with longer spans having lower ratios. 27% of girders have an LRFR rating that is greater than the LFR rating.

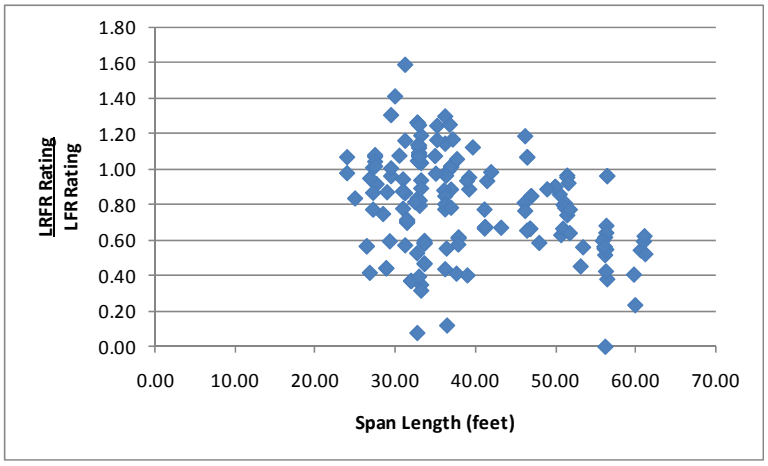


Figure E-190: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

E.2.5.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for 35 girders as shown in Figure E-191. The reliability index is between four and seven for most girders with the target level of reliability.

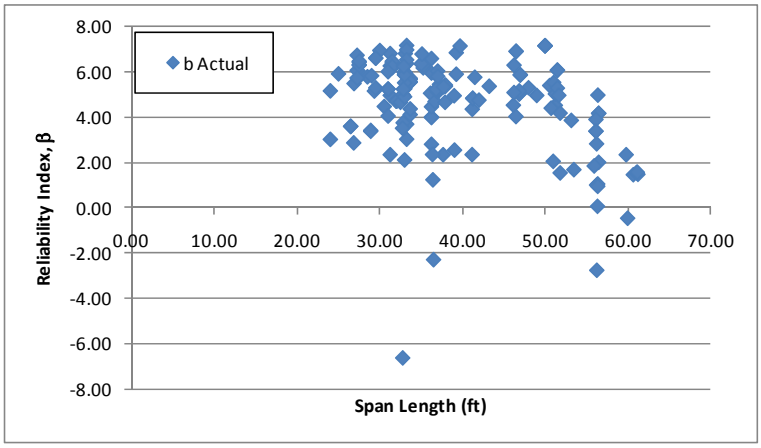


Figure E-191: Shear Reliability Indices for IL-01 Vehicle

Figure E-192 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 vehicle. The average reliability index for girders with LRFR ratings near one is 5.0, greater than the target reliability of 3.5. This indicates the live load factors in the MBE may be over-conservative and can be reduced.

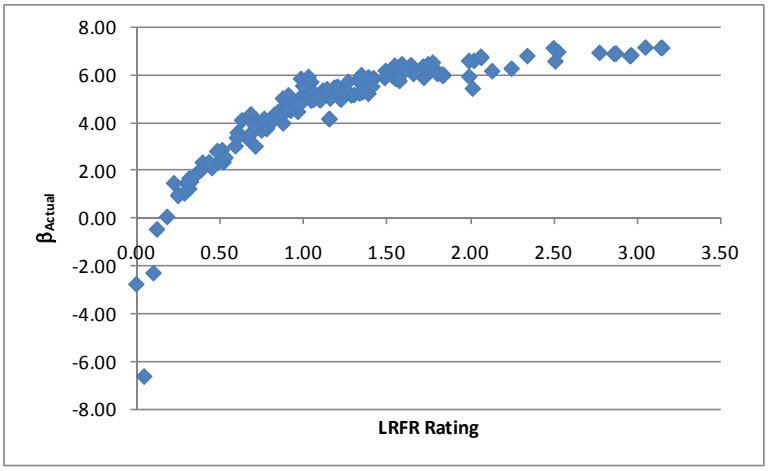


Figure E-192: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

E.2.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-193. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.

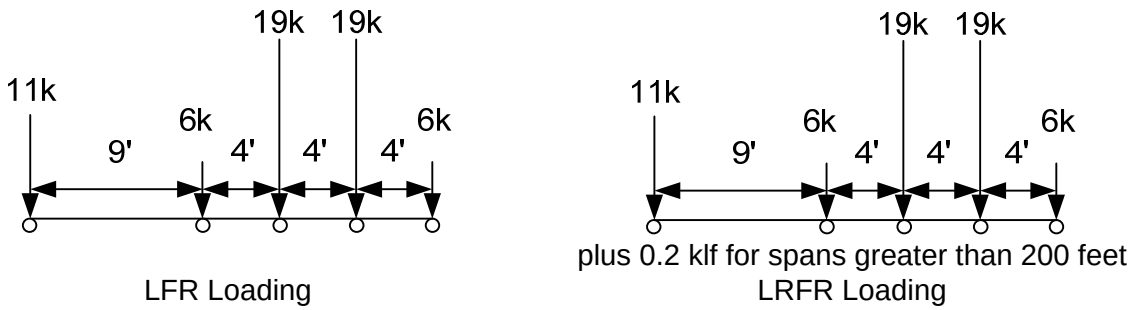


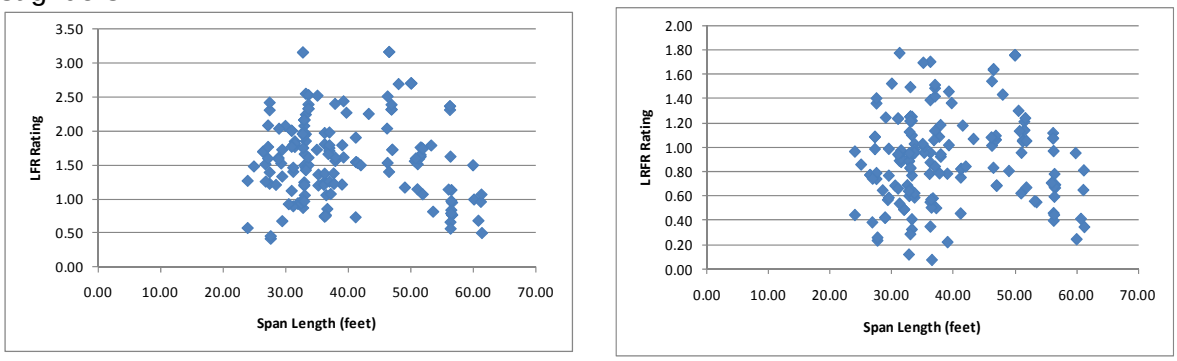
Figure E-193: Vehicle Loadings and Load Factors

E.2.6.1 Moment

The following section contains the results for interior, reinforced concrete tee beams within simple span bridges for the NC-21 Vehicle.

E.2.6.1.1 Rating Factors

Figure E-194 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 32 girders with an LFR rating less than 1.0, 102 girders with an LRFR rating less than 1.0, and 32 girders where both ratings are less than 1.0. 97 of the 102 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is between 1.0 and 2.5 for most girders while the LRFR rating is between 0.6 and 1.6 for most girders.



(a) (b)

Figure E-194: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure E-195 shows the percentage of girders with moment ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 53.3% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 25.5% of girders when the ADTT is greater than 5,000. 81% of girders have LFR ratings greater than 1.0. Approximately 30% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to 55% when the highest ADTT is considered.

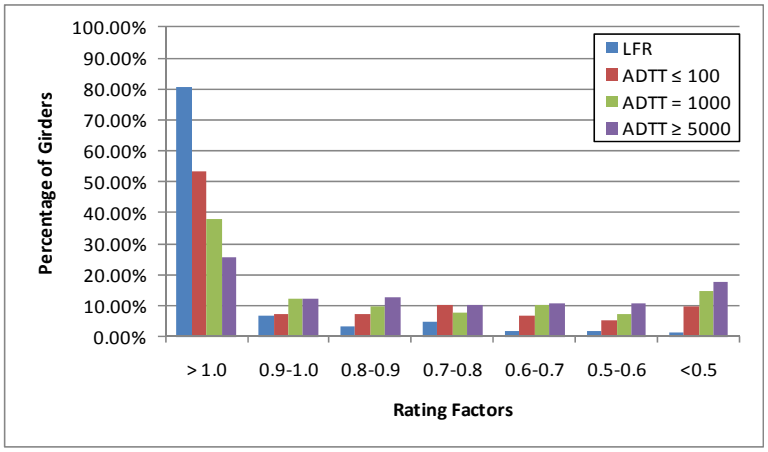


Figure E-195: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

E.2.6.1.2 Rating Factor Comparisons

Figure E-196 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.8 for this vehicle and there are no girders with LRFR ratings that are greater than the LFR rating.

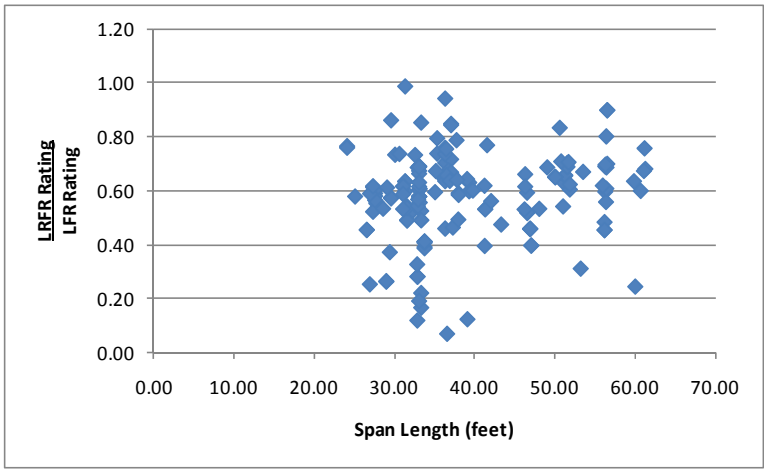


Figure E-196: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

E.2.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-197 shows 10 girders have a reliability index less than the target reliability index of 2.5. The reliability index is between three and seven for most girders.

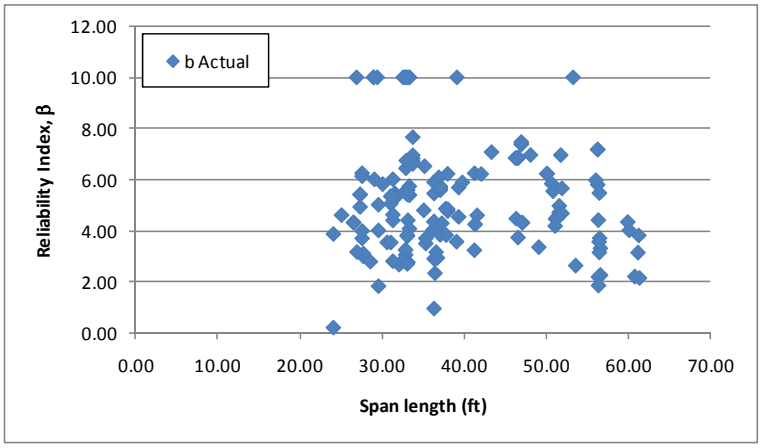


Figure E-197: Flexure Reliability Indices for NC-21 Vehicle

Figure E-198 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 vehicle. The figure shows that the reliability index increases with increasing LRFR ratings. The average reliability index for a girder with a rating of 1.0 is approximately 5.0, which is greater than the target reliability index of 2.5. This indicates that the current live load factors are over-conservative and can be reduced.

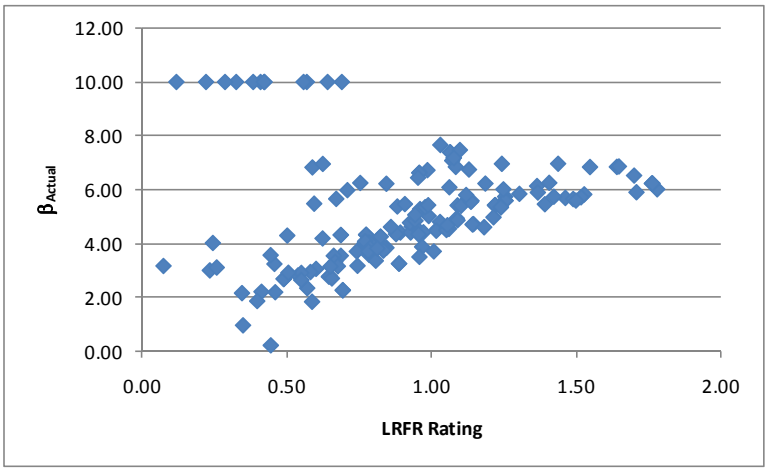
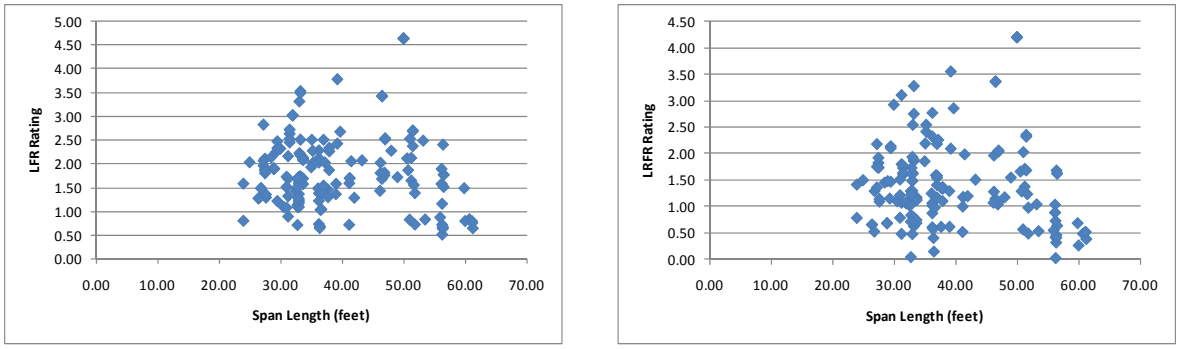


Figure E-198: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

E.2.6.2 Shear

E.2.6.2.1 Rating Factors

For shear, there are 21 girders that have LFR rating factors less than 1.0, 45 girders with LRFR ratings less than 1.0, and 21 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 87% of the girders in this subset. Figure E-199 shows the LFR and LRFR ratings, respectively. Both LFR and LRFR ratings are between 0.5 and 2.5 for most girders.



(a) (b)

Figure E-199: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure E-200 shows the percentage of girders with shear ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 75.8% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 61.8% of girders when the ADTT is greater than 5,000. 87% of girders have LFR ratings greater than 1.0. Approximately 11% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to approximately 25% when the highest ADTT is considered.

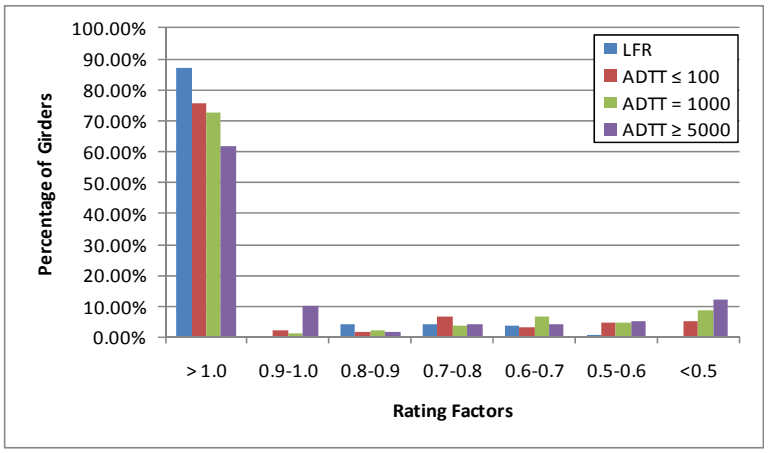


Figure E-200: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

E.2.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-201 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2. Longer span girders are more likely to have an LFR rating greater than the LRFR rating. 13% of the girders in this group have LRFR ratings that exceed the LFR rating.

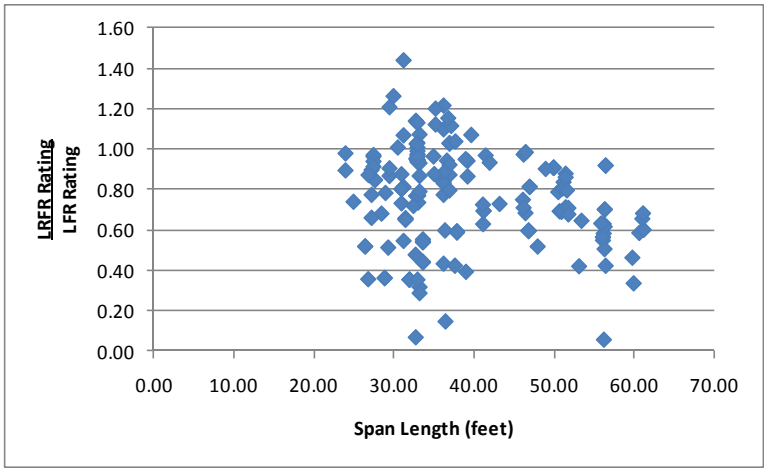


Figure E-201: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

E.2.6.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for 17 girders as shown in Figure E-202. The reliability index for girders with the target level of reliability is typically between four and seven. The girders with negative reliability indexes are girders where the shear reinforcement is either not input into the file or is input incorrectly.

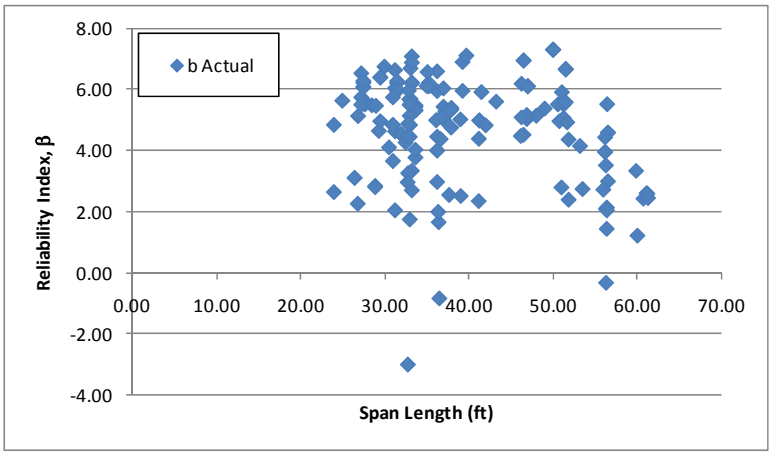


Figure E-202: Shear Reliability Indices for NC-21 Vehicle

Figure E-203 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 Vehicle. The average reliability index for a girder with a rating of 1.0 is approximately 4.5. This exceeds the target reliability of 2.5 and indicates that the live load factors in the MBE are over-conservative and can be reduced.

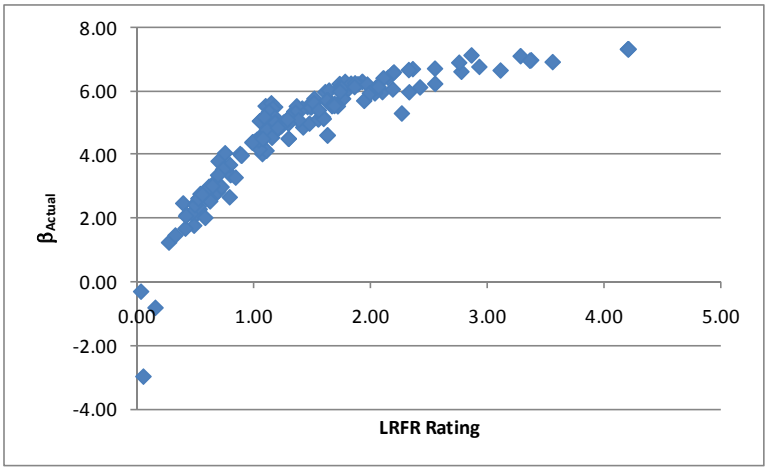


Figure E-203: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

E.2.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-204. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.

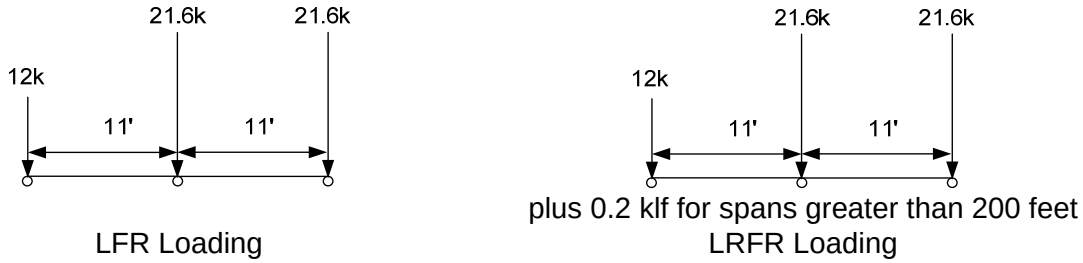


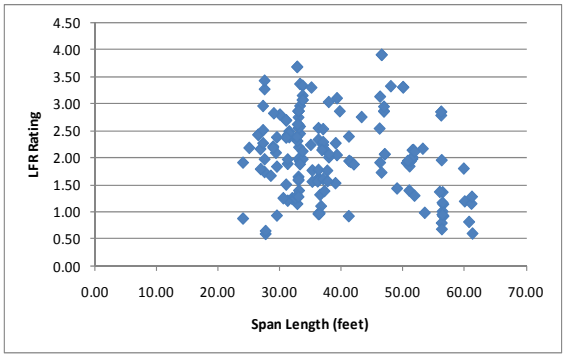
Figure E-204: Vehicle Loadings and Load Factors

E.2.7.1 Moment

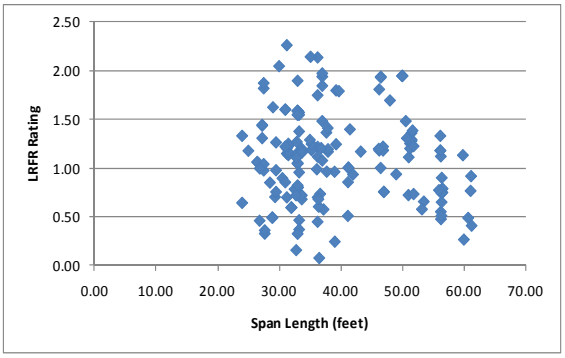
The following section contains the results for exterior, reinforced concrete tee-beams within simple span bridges for the NM-04 Vehicle.

E.2.7.1.1 Rating Factors

Figure E-205 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 17 girders with an LFR rating less than 1.0, 66 girders with an LRFR rating less than 1.0, and 17 girders where both ratings are less than 1.0. 63 of the 66 girders with an LRFR rating less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR ratings are between 0.5 and 3.5 while the LRFR ratings are between 0.5 and 2.0 for most girders.



(a)



(b)

Figure E-205: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure E-206 shows the percentage of girders with moment ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 67.3% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 51.5% of girders when the ADTT is greater than 5,000. 89.7% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to almost 40% when the highest ADTT is considered.

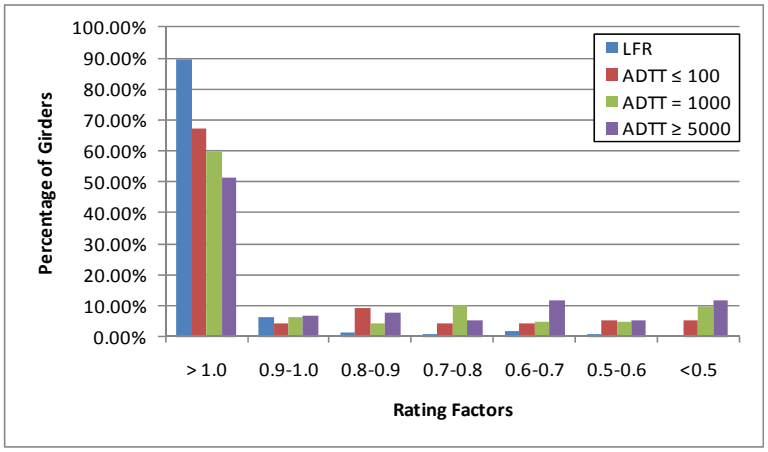


Figure E-206: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

E.2.7.1.2 Rating Factor Comparisons

Figure E-207 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0, of which there are none for this vehicle, indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.7.

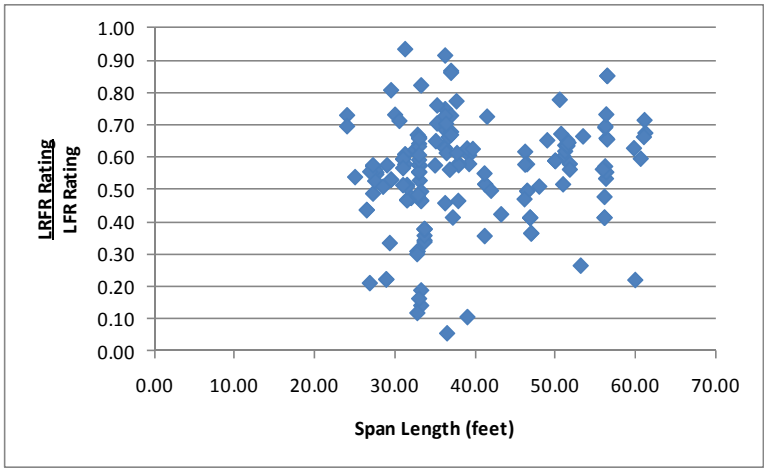


Figure E-207: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

E.2.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-208 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index for most girders in this group are between four and seven.

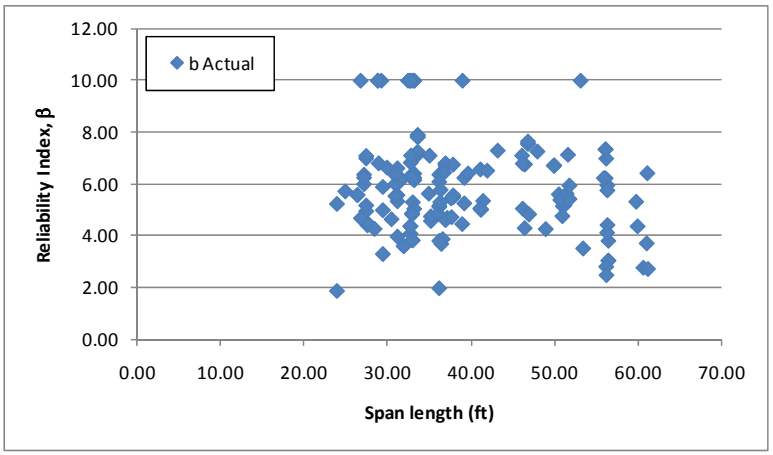


Figure E-208: Flexure Reliability Indices for NM-04 Vehicle

Figure E-209 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The reliability index increases with increasing LRFR ratings. The average reliability index for a girder with a rating of 1.0 is approximately 4.5, above the target reliability of 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

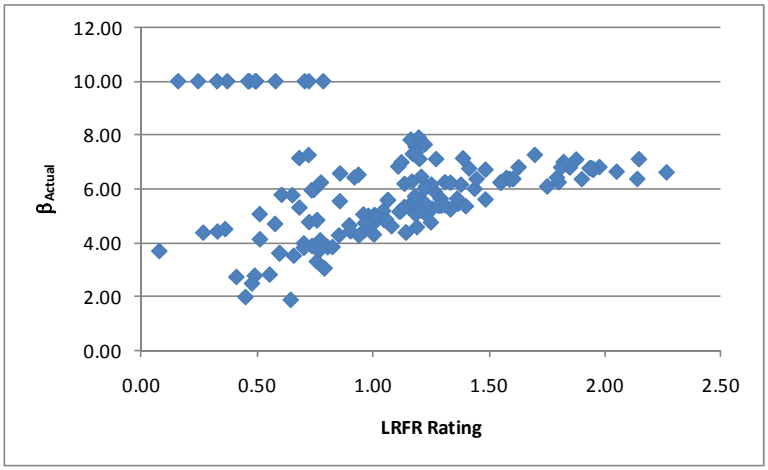
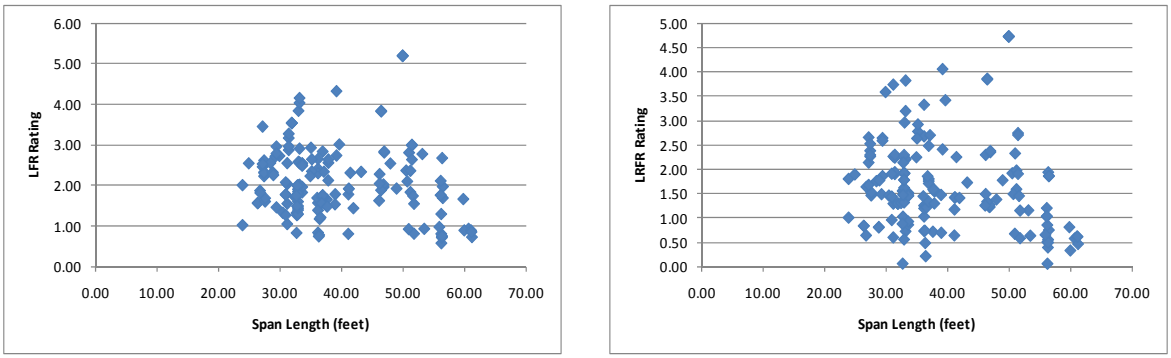


Figure E-209: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

E.2.7.2 Shear

E.2.7.2.1 Rating Factors

For shear, there are 19 girders that have an LFR rating factor less than 1.0, 38 girders with LRFR ratings less than 1.0, and 19 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 81% of the girders in this subset. Figure E-210 shows the LFR and LRFR ratings. The LFR ratings are between one and three while the LRFR ratings are between 0.5 and 2.5 for most girders.



(a) (b)

Figure E-210: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure E-211 shows the percentage of girders with shear ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 79.4% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 73.9% of girders when the ADTT is greater than 5,000. 88.5% of girders have LFR ratings greater than 1.0. Approximately 9% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used; this increases to 15% when the highest ADTT is considered.

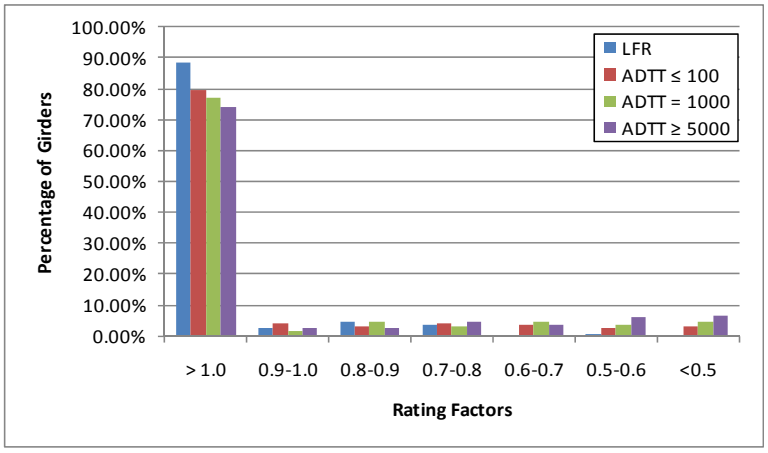


Figure E-211: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

E.2.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure E-212 show the comparison of rating factors. The ratio is generally between 0.6 and 1.2. 19% of girders have LRFR ratings greater than the LFR rating for this vehicle.

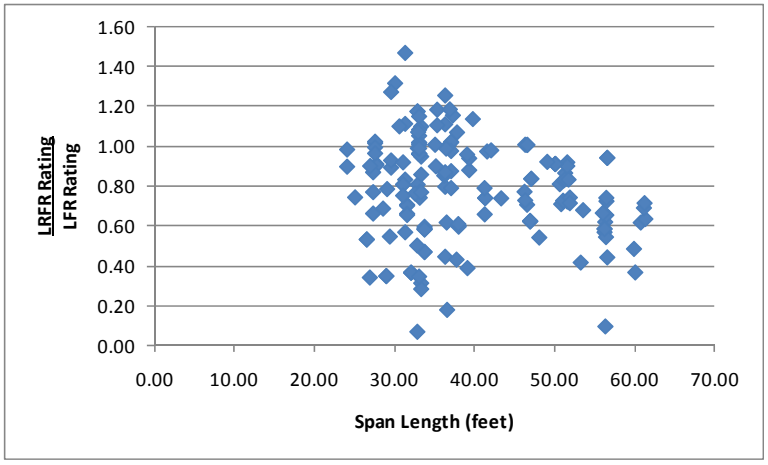


Figure E-212: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

E.2.7.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index for seven girders as shown in Figure E-213. The reliability index is between four and seven for most of the girders that have the target level of reliability.

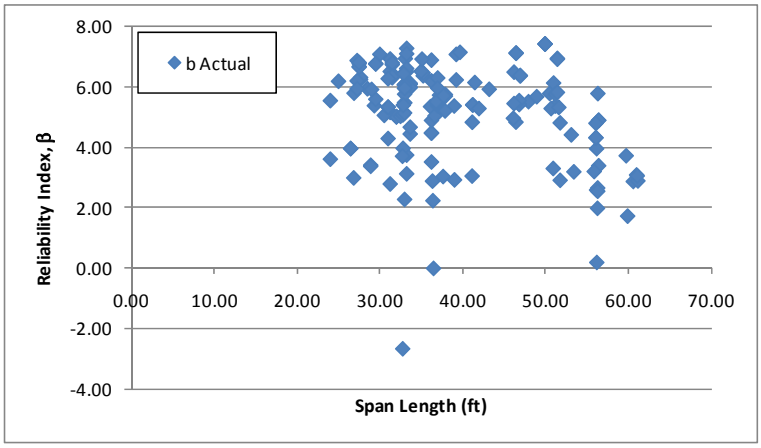


Figure E-213: Shear Reliability Indices for NM-04 Vehicle

Figure E-214 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. The average reliability index for a girder with a rating of 1.0 is approximately 4.0. This exceeds the target reliability index of 2.5 and indicates that the live load factors in the MBE are over-conservative and can be reduced.

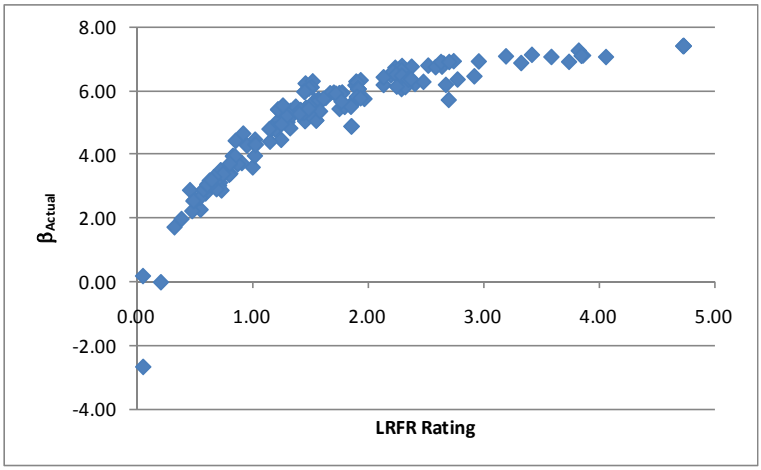
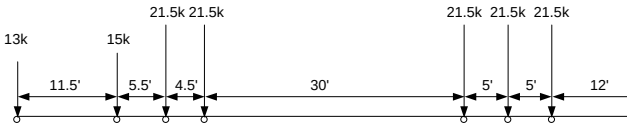


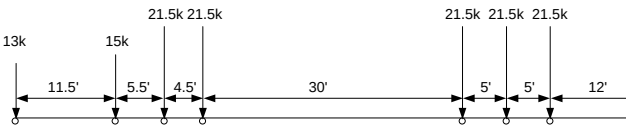
Figure E-214: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

E.2.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-215. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases multiple lanes may control.



LFR Loading



plus 0.2 klf for spans greater than 200 feet
LRFR Loading

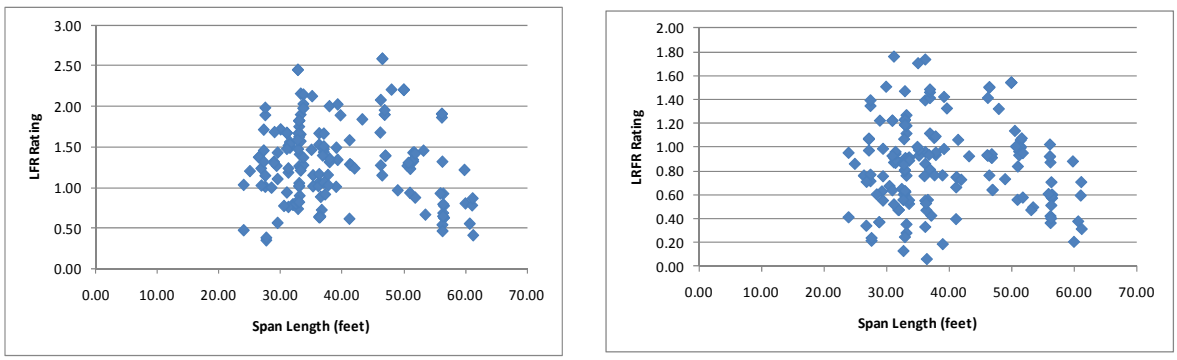
Figure E-215: Vehicle Loadings and Load Factors

E.2.8.1 Moment

The following section contains the results for interior reinforced concrete tee beams within simple span bridges for the OR-06 Vehicle.

E.2.8.1.1 Rating Factors

Figure E-216 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 43 girders with an LFR rating less than 1.0, 118 girders with an LRFR rating less than 1.0, and 43 girders where both ratings are less than 1.0. Of the 118 girders with LRFR ratings less than 1.0, 111 were controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 99% of the girders in this subset. The LFR ratings are between 0.5 and 2.5 while the LRFR ratings are much lower with the maximum rating being approximately 1.8 and most girders being less than 1.0.



(a) (b)

Figure E-216: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure E-217 shows the percentage of girders with moment ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 53.9% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 12.1% of girders for a multi-trip permit with ADTT at least 5,000. 73.9% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when the single trip, escorted permit is considered; this increases to over 60% when the multi-trip permit with ADTT at least 5,000 is considered.

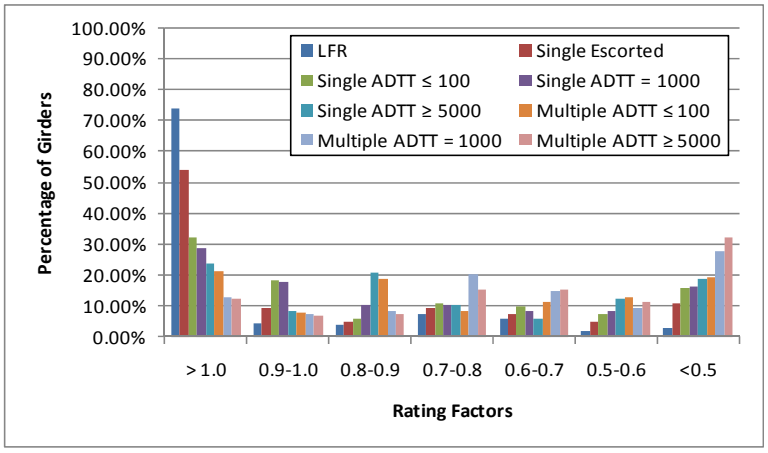


Figure E-217: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

E.2.8.1.2 Rating Factor Comparisons

Figure E-218 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.9; two girders have LRFR ratings that are higher than the LFR ratings.

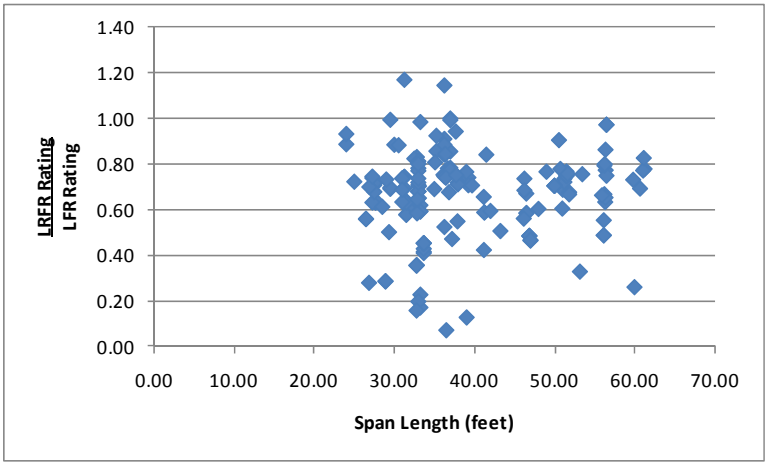


Figure E-218: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

E.2.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-219 shows that 13 girders have a reliability index less than the target reliability index of 3.5. The reliability index is between four and eight for girders with the target level of reliability. There is one girder with a reliability index very close to zero; it is likely that the applied loads are much larger than the resistance for this girder.

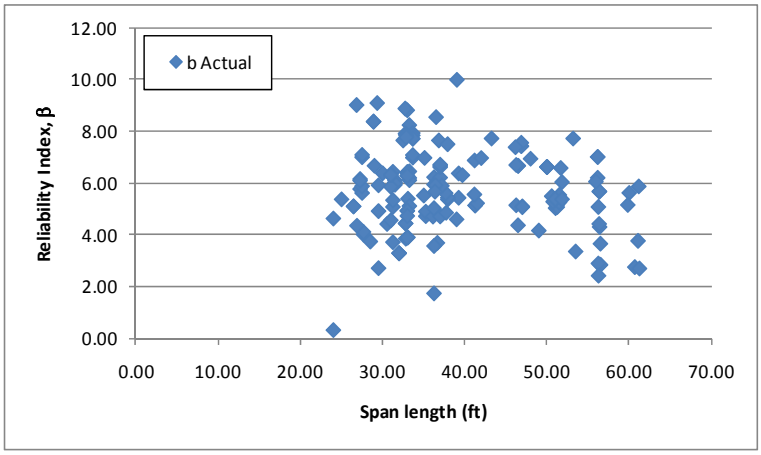


Figure E-219: Flexure Reliability Indices for OR-06 Vehicle

Figure E-220 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The figure shows the reliability index increases with increasing LRFR ratings. The average reliability index for a girder with a rating of 1.0 is approximately 5.5. This exceeds the target reliability of 3.5 and indicates that the live load factors in the MBE are over-conservative and can be reduced.

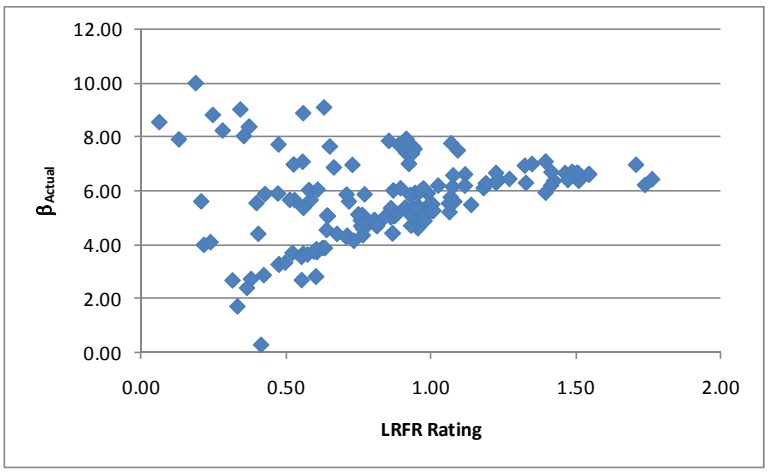
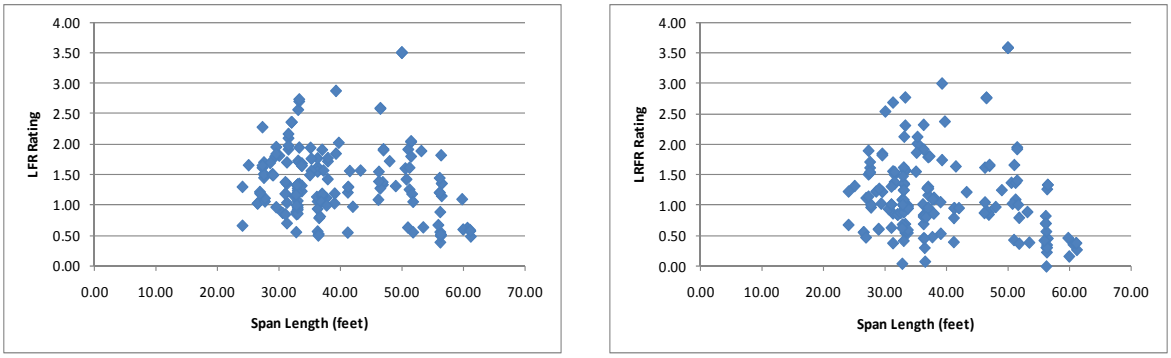


Figure E-220: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

E.2.8.2 Shear

E.2.8.2.1 Rating Factors

For shear, there are 38 girders with an LFR rating factor less than 1.0, 75 girders have LRFR ratings less than 1.0, and 32 girder has both ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 71% of the girders in this subset. Figure E-221 shows the LFR and LRFR ratings. The LFR rating is between 0.5 and 2.0 for a majority of girders while the LRFR rating is also between 0.5 and 2.0 with more girders less than 0.5 than for LFR.



(a) (b)

Figure E-221: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure E-222 shows the percentage of girders with shear ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 71.5% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 33.9% of girders when a multi-trip permit with ADTT greater than 5,000 is considered. 77% of girders have LFR ratings greater than 1.0. Approximately 5% more girders have LRFR ratings less than 1.0 when the single trip, escorted permit is considered; this increases to more than 40% when the multi-trip permit with an ADTT greater than 5,000.

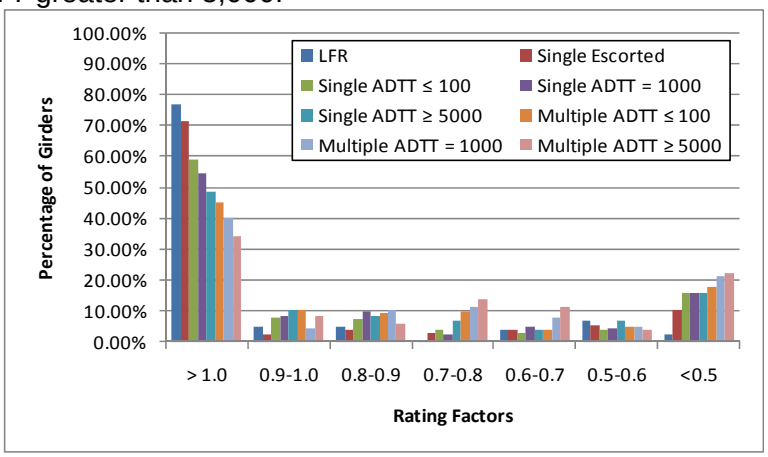


Figure E-222: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

E.2.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure E-223 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2 for this set of girders with this vehicle. 29% of girders have LRFR ratings that are higher than the LFR rating for the same girder.

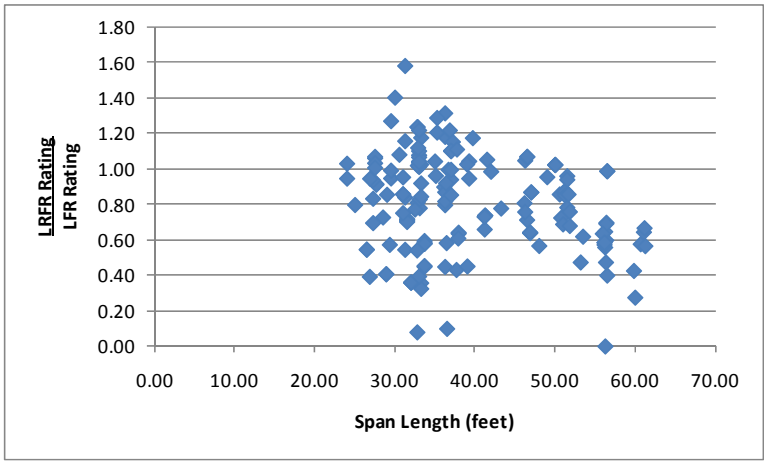


Figure E-223: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

E.2.8.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for 37 girders as shown in Figure E-224. The reliability index for girders having at least the target reliability index is typically between four and seven.

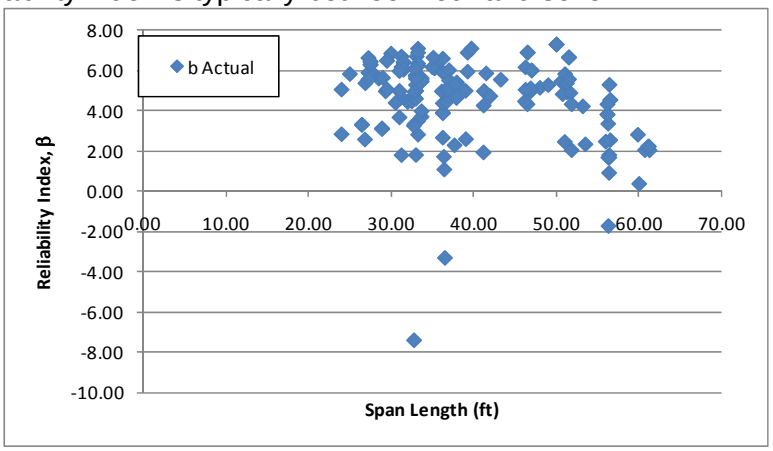


Figure E-224: Shear Reliability Indices for OR-06 Vehicle

Figure E-225 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The average reliability index for a girder with a rating of 1.0 is approximately 5.0, above the target reliability of 3.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

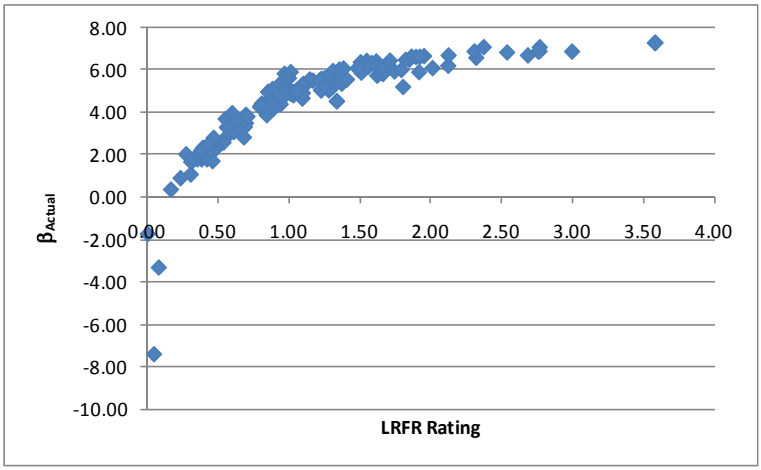


Figure E-225: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

E.2.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-226. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases a single lane may control.

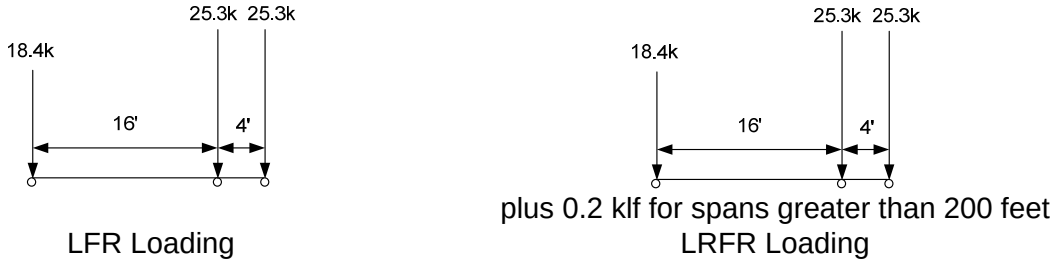


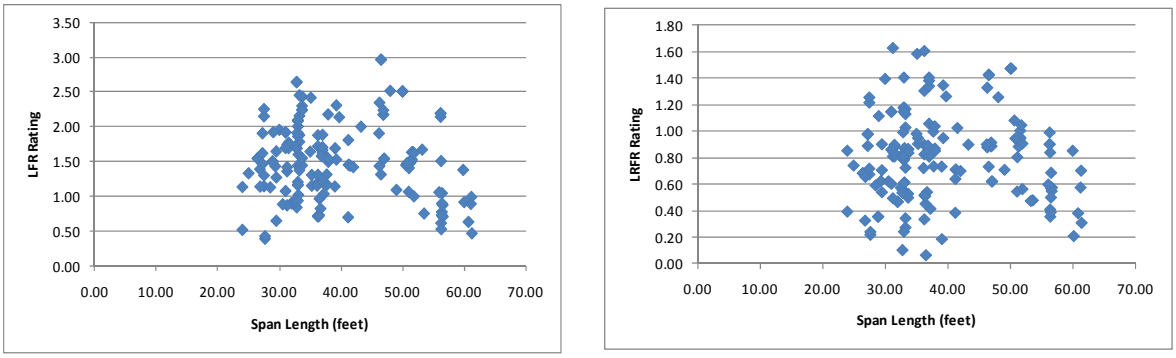
Figure E-226: Vehicle Loadings and Load Factors

E.2.9.1 Moment

The following section contains the results for interior, reinforced concrete tee-beams within simple span bridges for the TX-04 Vehicle.

E.2.9.1.1 Rating Factors

Figure E-227 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 35 girders with an LFR rating less than 1.0, 126 girders with an LRFR rating less than 1.0, and 35 girders where both ratings are less than 1.0. 123 of the 126 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is between one and two for most girders while the LRFR rating is between 0.4 and 1.0 for most girders. There is a significant reduction in the ratings when switching from LFR to LRFR.



(a) (b)

Figure E-227: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure E-228 shows the percentage of girders with moment ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 41.2% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 18.8% of girders when the ADTT is greater than 5,000. 78.8% of girders have LFR ratings greater than 1.0. Approximately 38% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to 60% when the highest ADTT is considered.

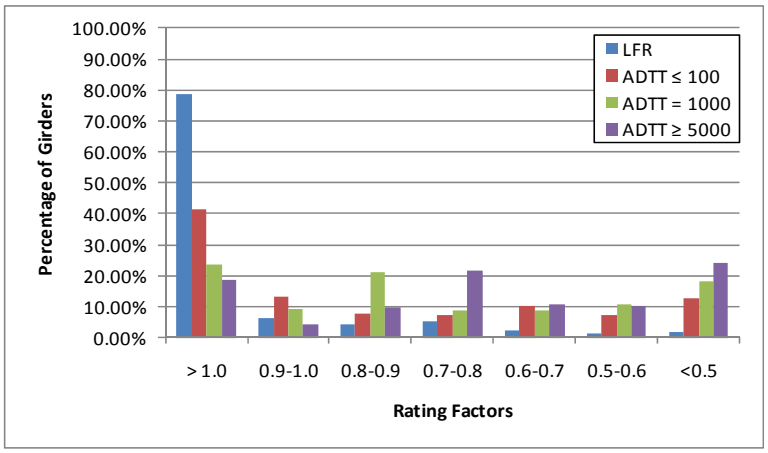


Figure E-228: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

E.2.9.1.2 Rating Factor Comparisons

Figure E-229 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The LRFR rating is generally 50 to 70% of the LFR rating with no girders having an LRFR rating greater than the LFR rating for moment.

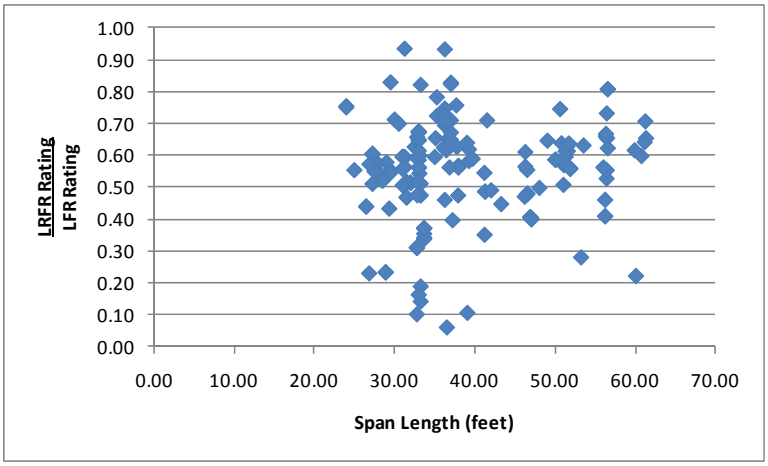


Figure E-229: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

E.2.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-230 shows 15 girders that have a reliability index less than the target reliability index of 2.5. The reliability index is between three and six for most girders.

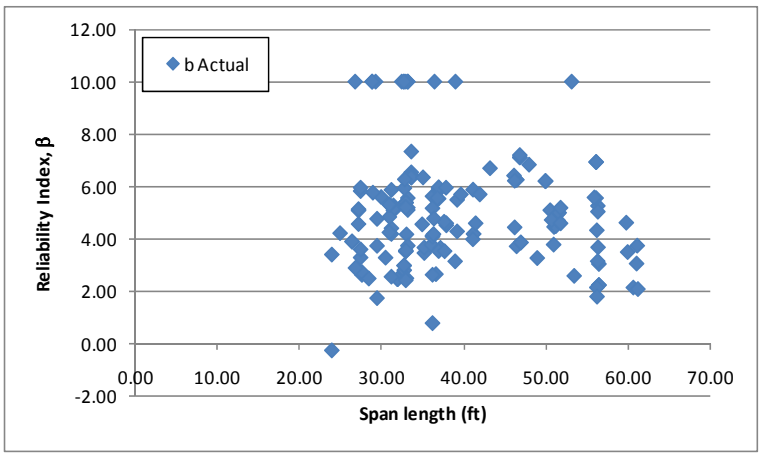


Figure E-230: Flexure Reliability Indices for TX-04 Vehicle

Figure E-231 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 Vehicle. The reliability index increases with increasing LRFR ratings. The average reliability index for a girder with a rating of 1.0 is approximately 5.0. This is greater than the target reliability index of 2.5 for this routine permit vehicle. The reliability index being greater than the target reliability index indicates that the live load factors currently in the MBE are over-conservative.

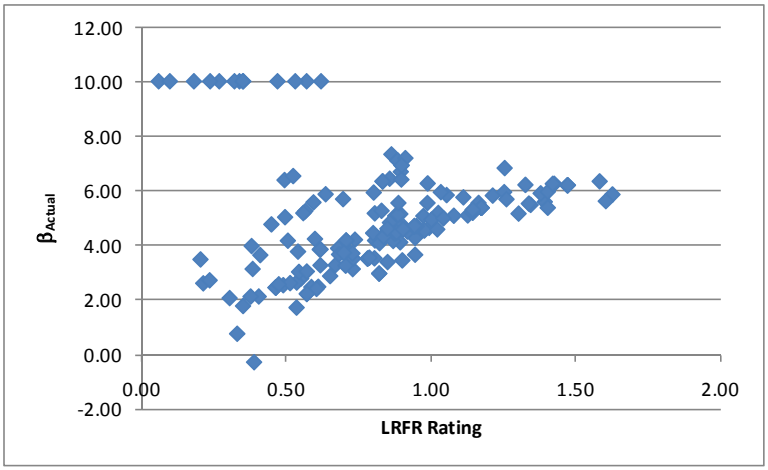
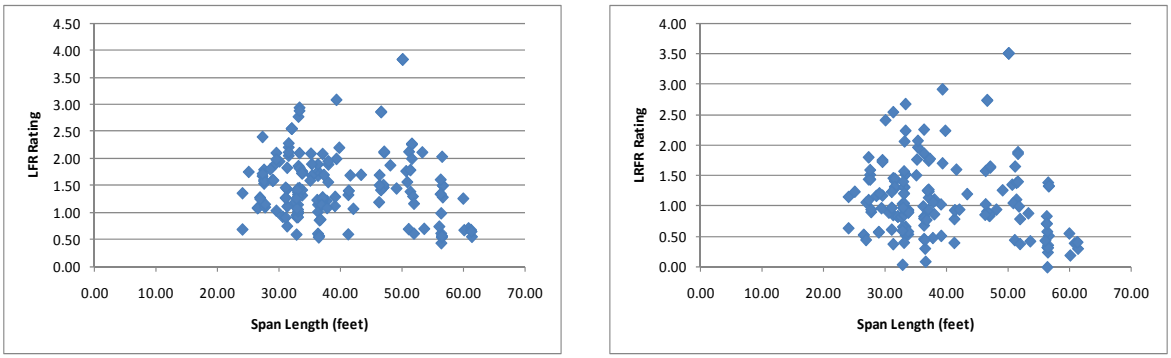


Figure E-231: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

E.2.9.2 Shear

E.2.9.2.1 Rating Factors

For shear, there are 31 girders that have LFR rating factors less than 1.0, 82 girders with LRFR ratings less than 1.0 and 29 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 91% of the girders in this subset. Figure E-232 shows the LFR and LRFR ratings, respectively. The LFR ratings are between 0.5 and 2.0 for most girders. The LRFR ratings are within a similar range but more girders have ratings less than 0.5.



(a) (b)

Figure E-232: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure E-233 shows the percentage of girders with shear ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 63.6% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 43.0% of girders when the ADTT is greater than 5,000. 81.2% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 40% when the highest ADTT is considered.

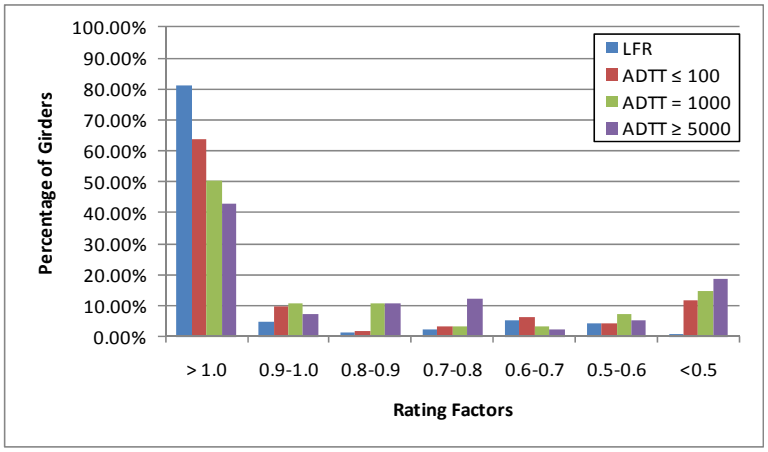


Figure E-233: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

E.2.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure E-234 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.2 for shear. The ratio tends to decrease with increasing span lengths but there is significant variation for spans in the range of 20-40 feet. 9% of girders have an LRFR rating that exceeds the LFR rating; all of these girders have spans that are less than forty feet in length.

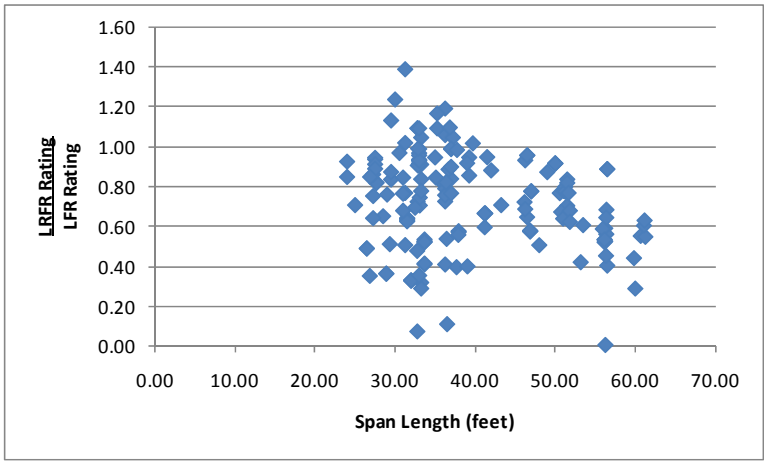


Figure E-234: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

E.2.9.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for 34 girders as shown in Figure E-235. The girders with at least the target reliability index are typically between four and seven. The girders with negative reliability indices are likely the result of shear reinforcement that was not defined resulting in extremely low shear strengths.

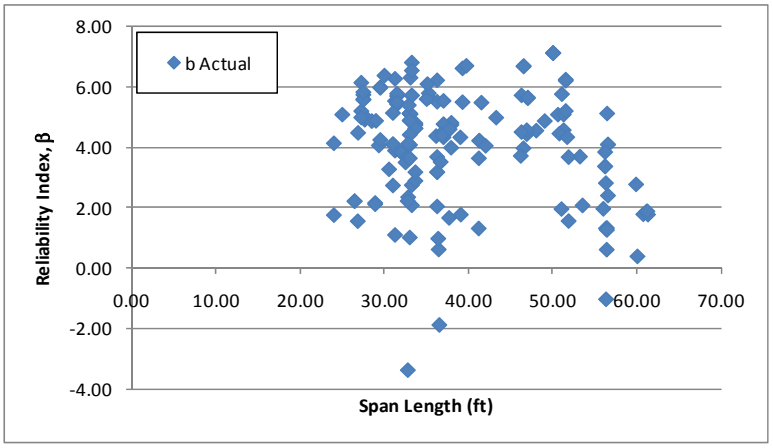


Figure E-235: Shear Reliability Indices for TX-04 Vehicle

Figure E-236 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 Vehicle. The approximate average reliability index for a girder with a rating of 1.0 is 4.5. This exceeds the target reliability of 2.5 and indicates that the live load factors in the MBE are over-conservative and can be reduced.

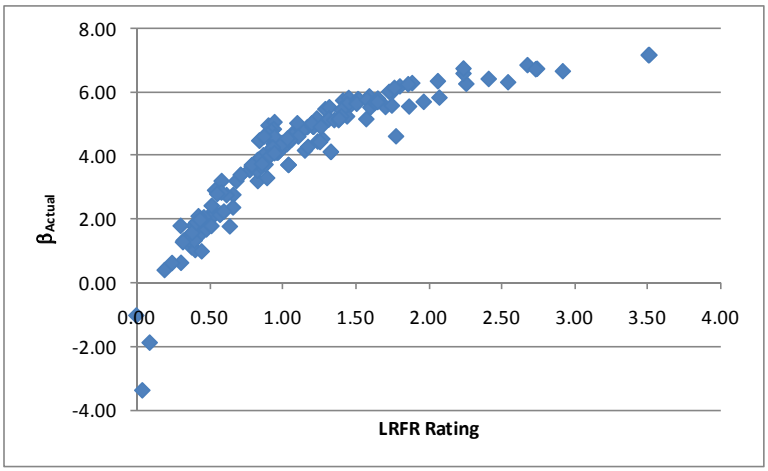


Figure E-236: Shear Reliability Index vs LRFR Shear Rating for TX-04

E.2.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-237. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. The number of lanes loaded is based upon the critical live load distribution factor, in some cases multiple lanes may control.

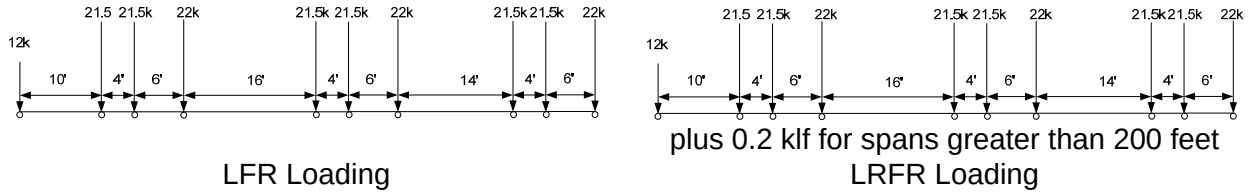


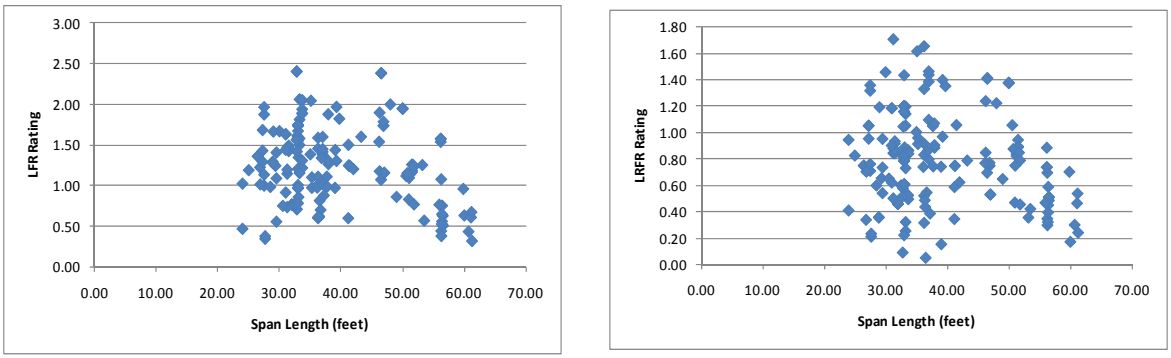
Figure E-237: Vehicle Loadings and Load Factors

E.2.10.1 Moment

The following section contains the results for interior, reinforced concrete tee-beams within simple span bridges for the WA-02 Vehicle.

E.2.10.1.1 Rating Factors

Figure E-238 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 51 girders with an LFR rating less than 1.0, 123 girders with an LRFR rating less than 1.0, and 51 girders where both ratings are less than 1.0. 111 of the 123 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 96% of the girders in this subset. The LFR rating is between 0.5 and 2.0 for most girders while the LRFR ratings are all less than 1.8 with most girders between 0.4 and 1.2.



(a) (b)

Figure E-238: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure E-239 shows the percentage of girders with moment ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 46.7% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 10.3% of girders when a multi-trip permit with ADTT greater than 5,000 is considered. 69.1% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 60% when the highest ADTT is considered.

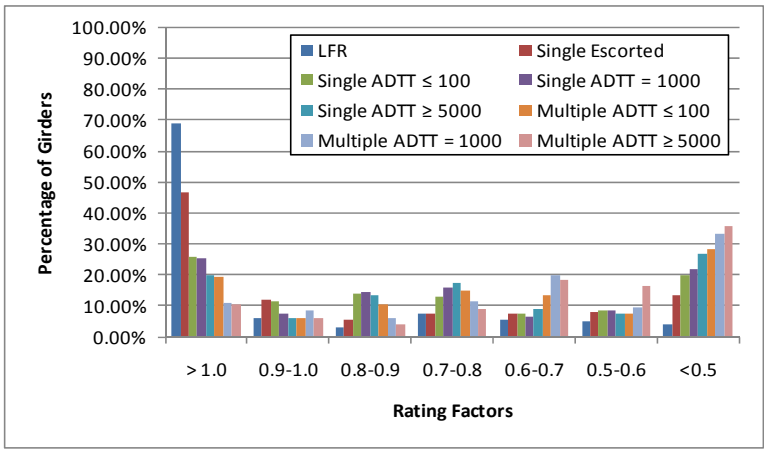


Figure E-239: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

E.2.10.1.2 Rating Factor Comparisons

Figure E-240 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8. There are four girders with LRFR ratings that exceed the LFR rating for this vehicle.

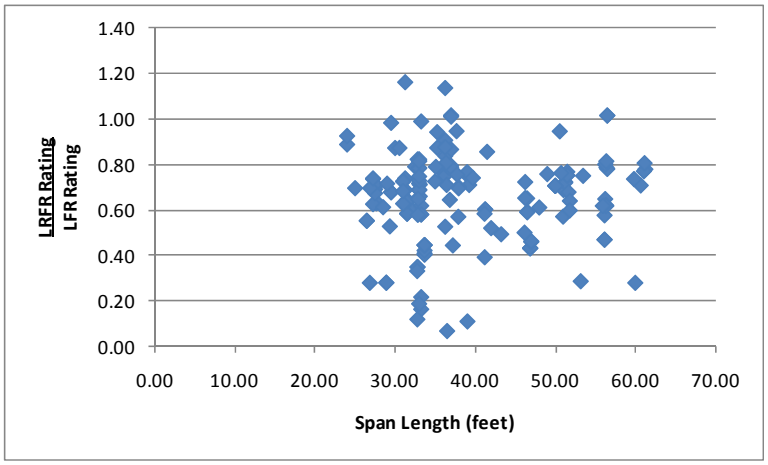


Figure E-240: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

E.2.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-241 shows 33 girders have a reliability index less than the target reliability index of 3.5. The reliability indexes for these girders are lower than for the other vehicles; this is a result of this vehicle being extremely heavy. The girders have reliability indexes between four and six for those with at least the target level of reliability.

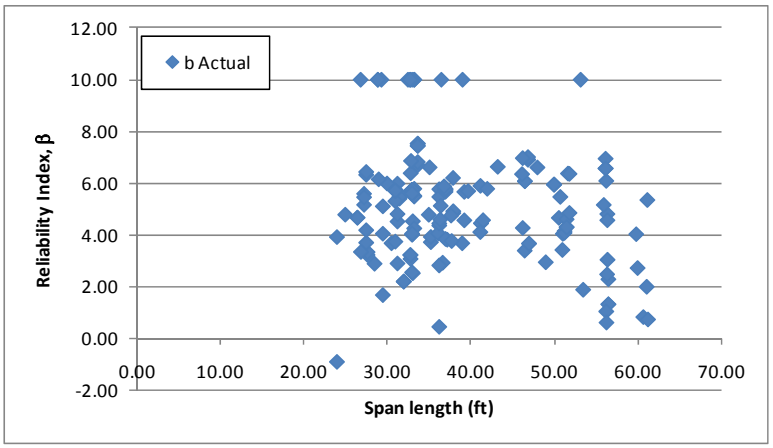


Figure E-241: Flexure Reliability Indices for WA-02 Vehicle

Figure E-242 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 Vehicle. The reliability index increases with increasing LRFR ratings. The average reliability index for a girder with a rating of 1.0 is approximately 5.0, above the target reliability of 3.5. This indicates the live load factors in the MBE are over-conservative and can be reduced.

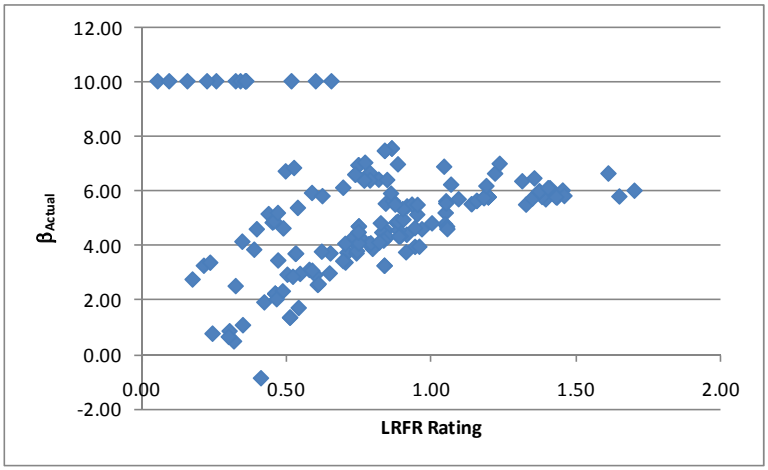
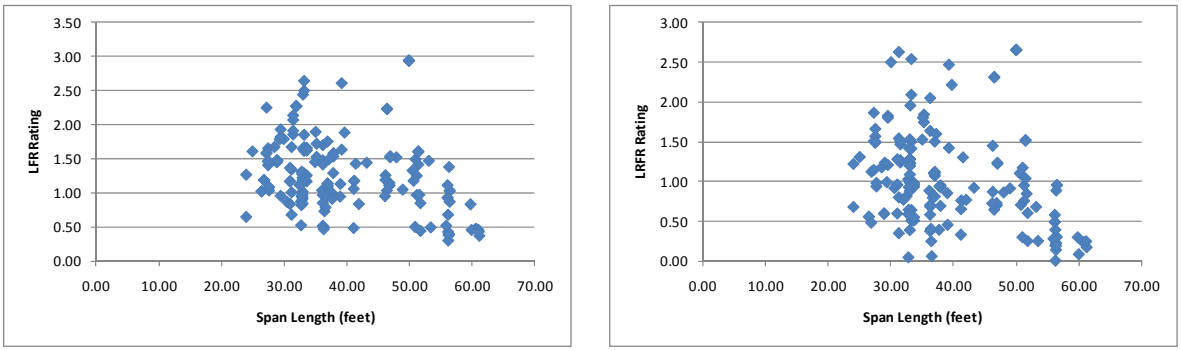


Figure E-242: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

E.2.10.2 Shear

E.2.10.2.1 Rating Factors

For shear, there are 50 girders with LFR rating factors less than 1.0, 95 girders with LRFR ratings less than 1.0, and 45 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure E-243 shows the LFR and LRFR ratings. The LFR and LRFR ratings are between 0.5 and 2.0 for most girders with the LRFR ratings having more girders less than 0.5.



(a) (b)

Figure E-243: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure E-244 shows the percentage of girders with shear ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 59.4% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 23.6% of girders when the multi-trip permit with ADTT greater than 5,000 is used. 69.7% of girders have LFR ratings greater than 1.0. Approximately 10% more girders have LRFR ratings less than 1.0 when the single trip, escorted permit category is considered; this increases to over 55% when the multi-trip permit with an ADTT of 5,000 is used.

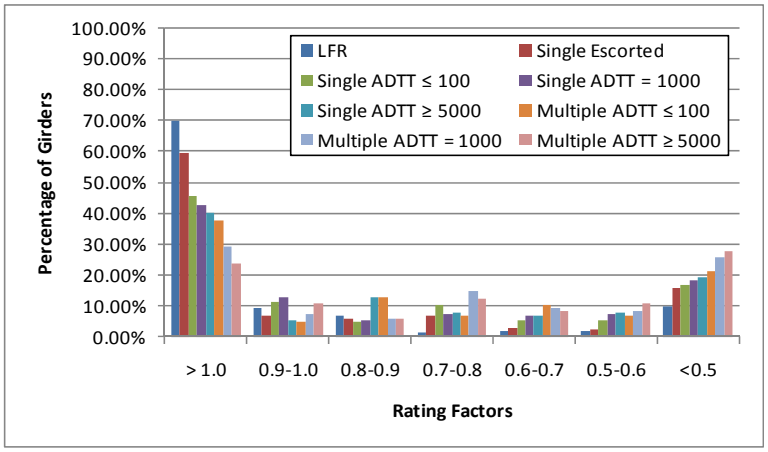


Figure E-244: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

E.2.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-245 show the comparison of rating factors. The ratio is generally between 0.6 and 1.2. The LRFR rating is greater than the LFR rating for 24% of the girders in this group. For most girders there is a significant reduction that occurs when switching from LFR to LRFR.

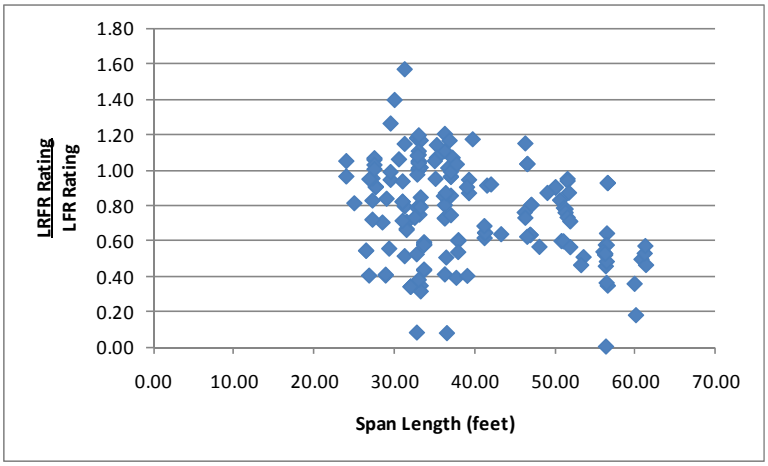


Figure E-245: LRFR Shear Rating divided by LFR Shear Rating

E.2.10.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for 56 girders as shown in Figure E-246. Most girders with spans of 55 feet or more do not have the target level of reliability. For those girders with at least the target level of reliability, the reliability index is between four and seven.

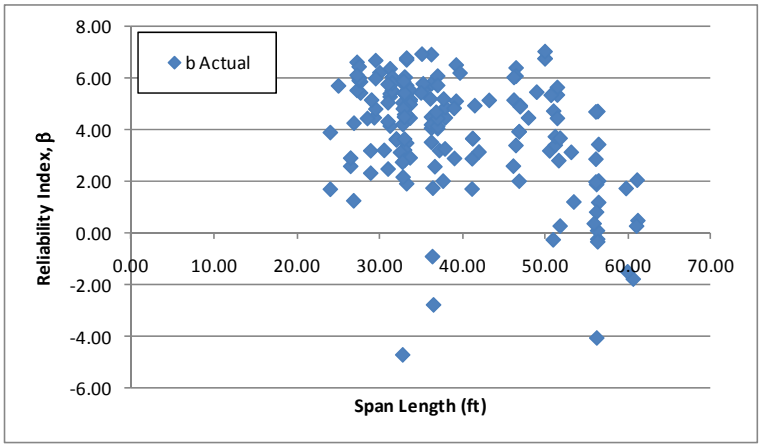


Figure E-246: Shear Reliability Indices for WA-02 Vehicle

Figure E-247 shows the reliability index for shear plotted against the LRFR rating for shear for the WA-02 vehicle. Compared to the other graphs for shear of the reliability index plotted against the rating factor, this graph is more scattered. The reliability index for a girder with a rating of 1.0 varies 3.5 to 6.0. This indicates that on average a girder with a rating of one will have a reliability index above the target reliability of 3.5 and suggests that the live load factors in the MBE can be reduced.

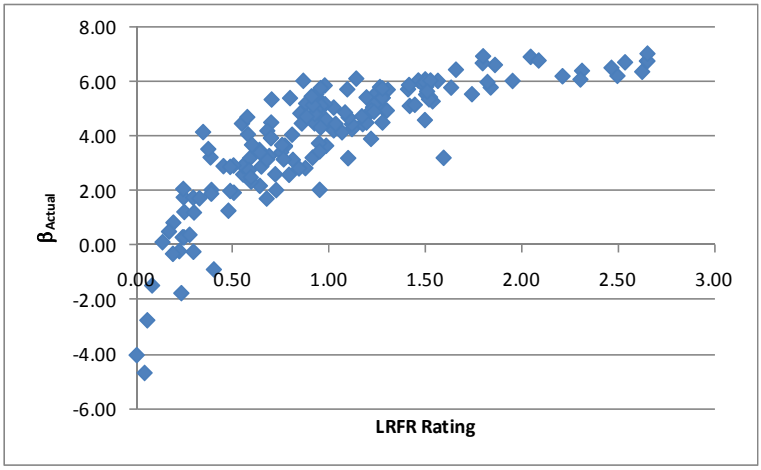


Figure E-247: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

E.2.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-248. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

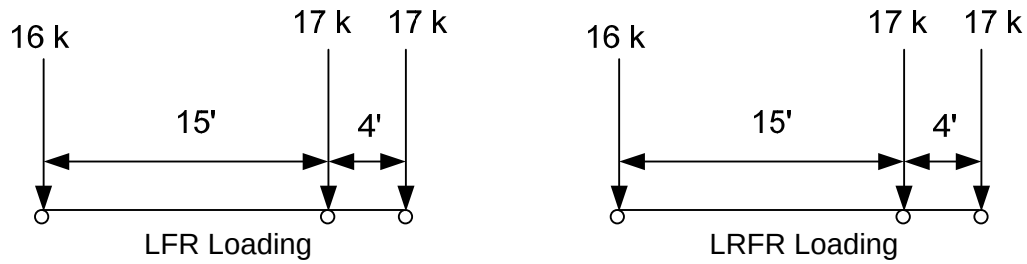
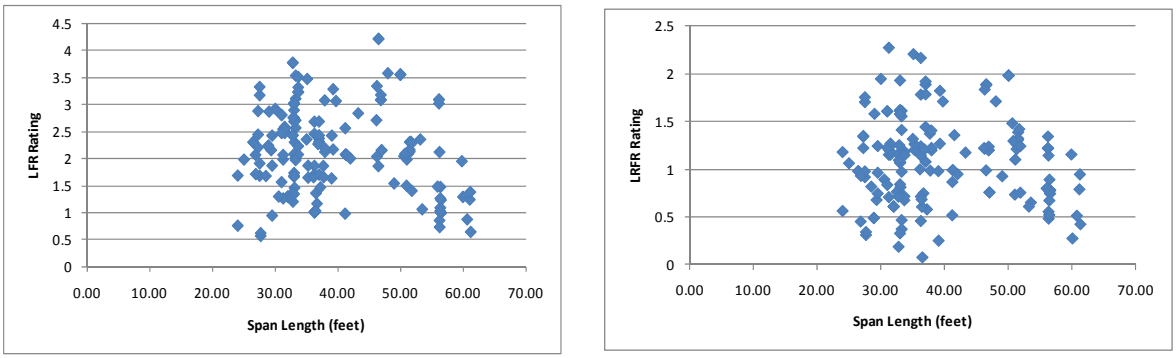


Figure E-248: Vehicle Loadings and Load Factors

E.2.11.1 Moment

E.2.11.1.1 Rating Factors

Figure E-249 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are nine girders with an LFR rating less than 1.0, 72 girders with an LRFR rating less than 1.0, and nine girders where both ratings are less than 1.0. 70 of the 72 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR rating is between one and three for most girders while the LRFR rating is between 0.5 and 1.5 for most girders.



(a) (b)

Figure E-249: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure E-250 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 67.8% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 53.3% of girders when the ADTT is greater than 5,000. 94.6% of girders have LFR ratings greater than 1.0. Approximately 27% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 40% when the highest ADTT is considered.

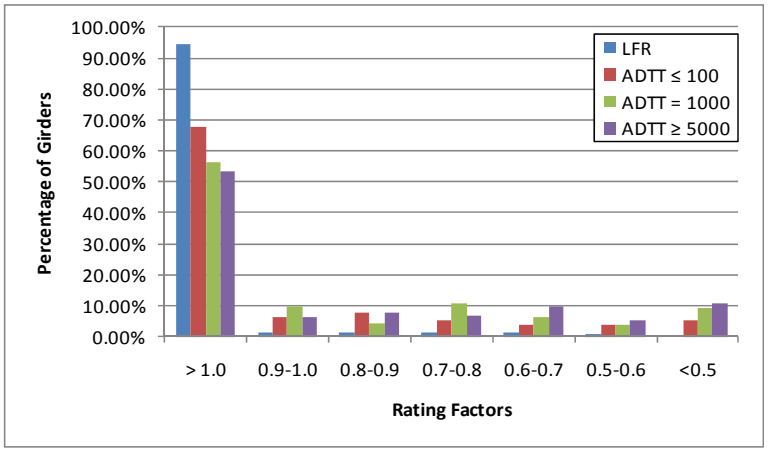


Figure E-250: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3Truck

E.2.11.1.2 Rating Factor Comparisons

Figure E-251 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.7. There are no girders with an LRFR rating that is greater than the LFR rating for the AASHTO Type 3 Truck.

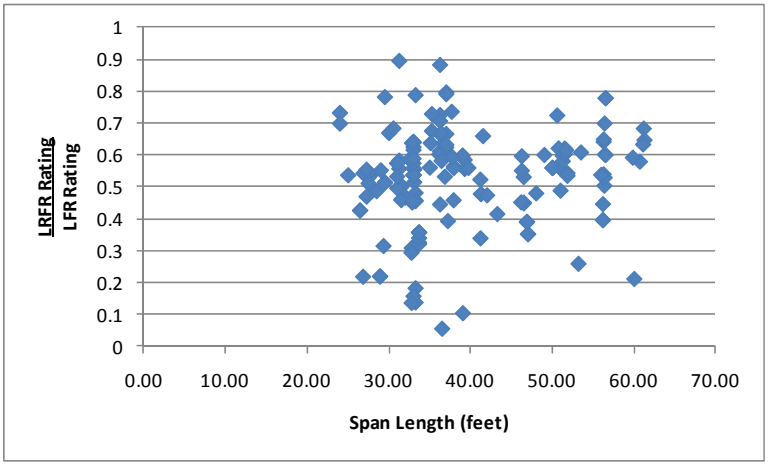


Figure E-251: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

E.2.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-252 shows that two girders have a reliability index less than the target reliability index of 2.5. The reliability index is between four and eight for most girders.

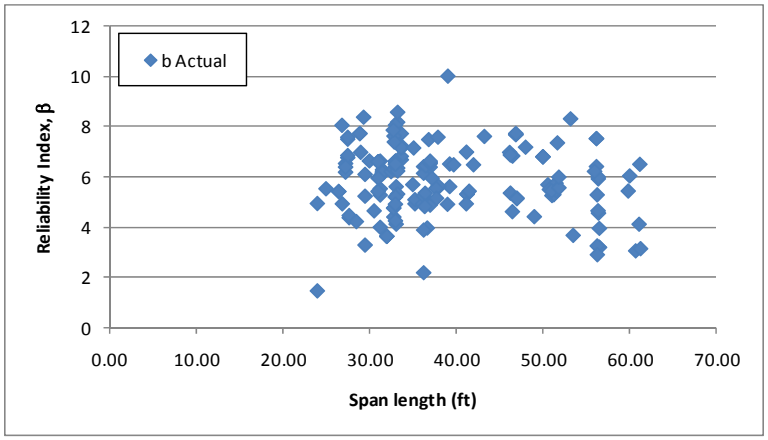


Figure E-252: Flexure Reliability Indices for Type 3 Vehicle

Figure E-253 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 Truck. The figure shows the reliability index increases with increasing rating factors. The reliability index for girders with a rating of 1.0 is approximately five. This is greater than the target reliability index of 2.5, indicating that the live load factors in the MBE may be over-conservative and can possibly be reduced.

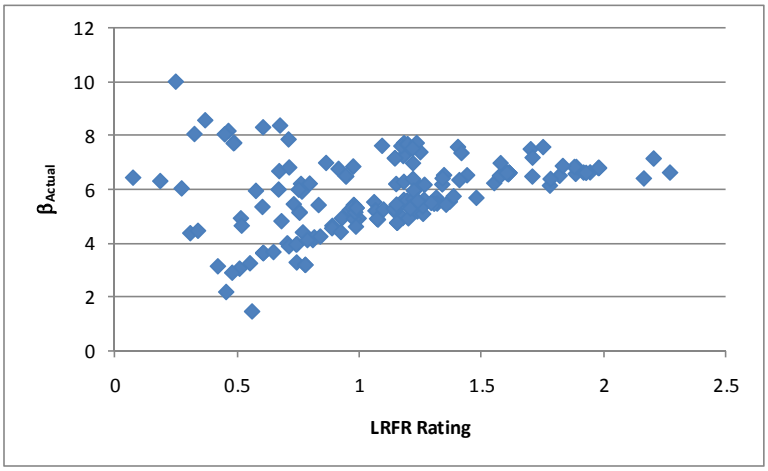
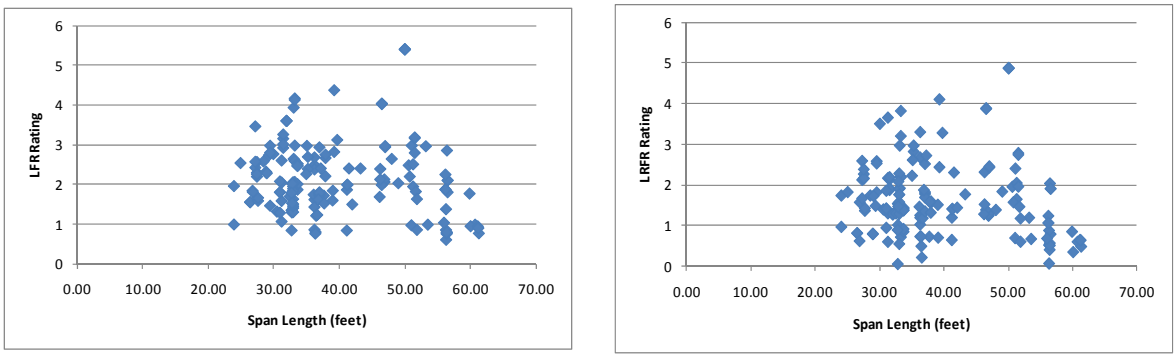


Figure E-253: Flexure Reliablity Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

E.2.11.2 Shear

E.2.11.2.1 Rating Factors

For shear, there are 19 girders with LFR rating factors less than 1.0, 39 girders with LRFR ratings less than 1.0, and 19 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 87% of the girders in this subset. Figure E-254 shows the LFR and LRFR ratings. The LFR and LRFR ratings are between one and three for most girders, with the LRFR ratings having more that are less than one.



(a) (b)

Figure E-254: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure E-255 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 81.2% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 73.9% of girders when the ADTT is greater than 5,000. 88.5% of girders have LFR ratings greater than 1.0. Approximately 7% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 15% when the highest ADTT is considered.

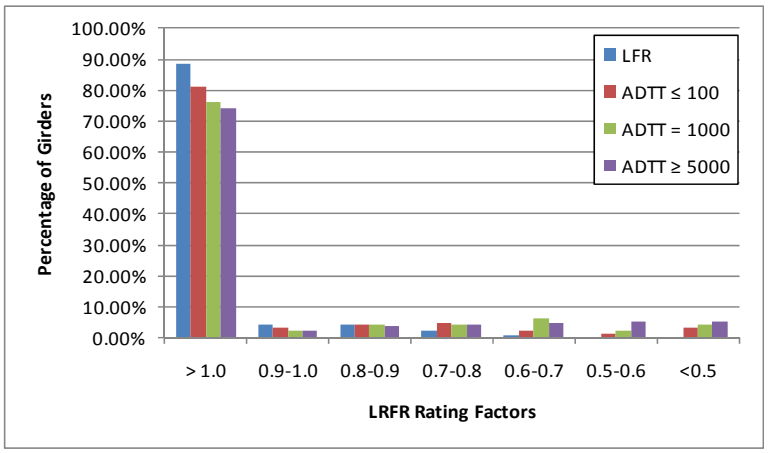


Figure E-255: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

E.2.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-256 show the comparison of rating factors. The ratio is generally between 0.6 and 1.2, with shorter spans generally having higher ratios. 13% of girders have an LRFR rating that is greater than the LFR rating for shear.

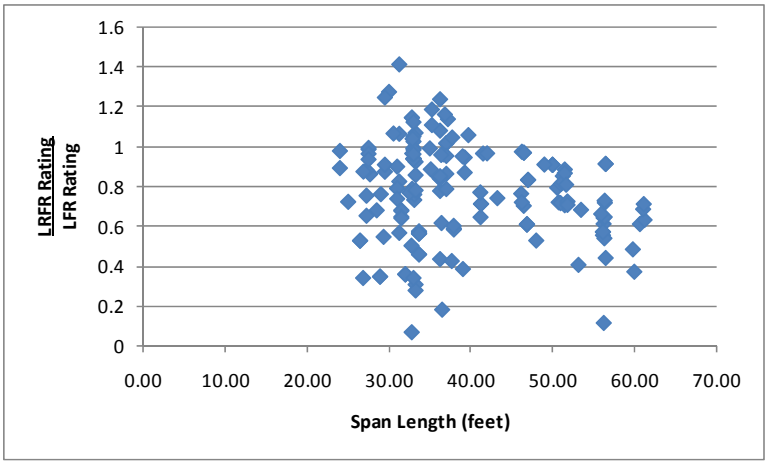


Figure E-256: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

E.2.11.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for seven girders as shown in Figure E-257. For girders with at least the target reliability index, the reliability index is between four and eight.

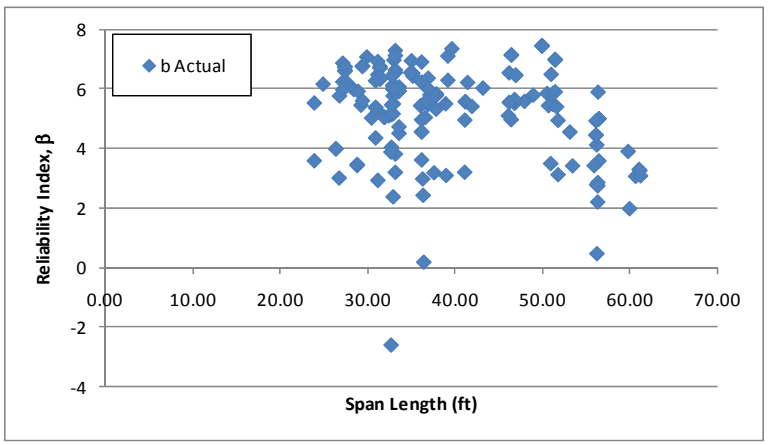


Figure E-257: Shear Reliability Indices for Type 3 Vehicle

Figure E-258 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 Truck. The average reliability index for a girder with a shear rating of 1.0 is approximately 4.5, above the target reliability of 2.5. This indicates that the live load factors in the MBE are over-conservative and can be reduced.

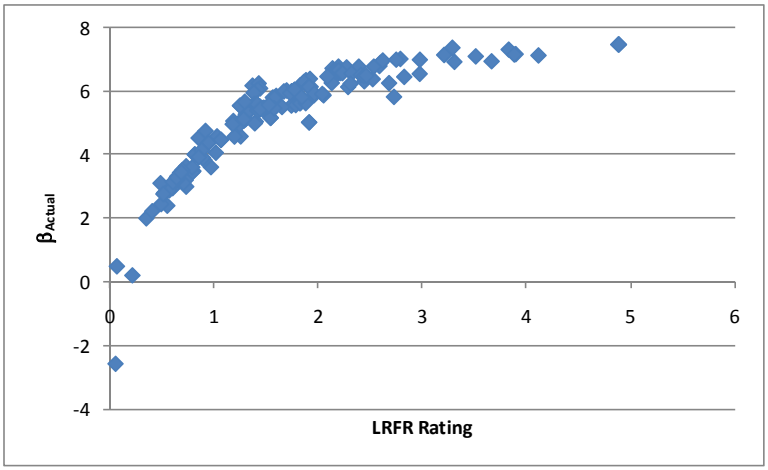


Figure E-258: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

E.2.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-259. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

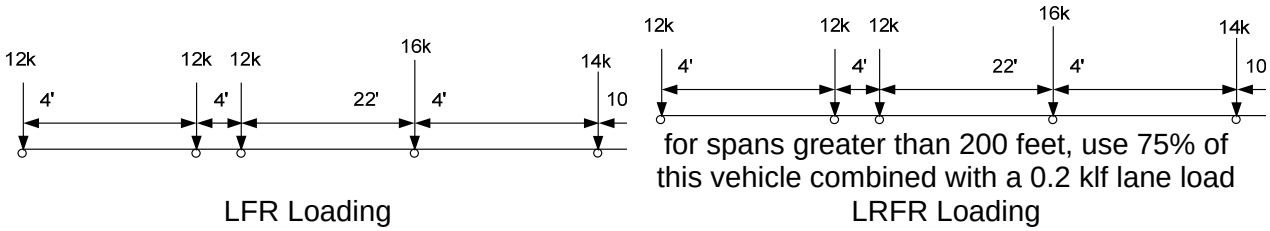
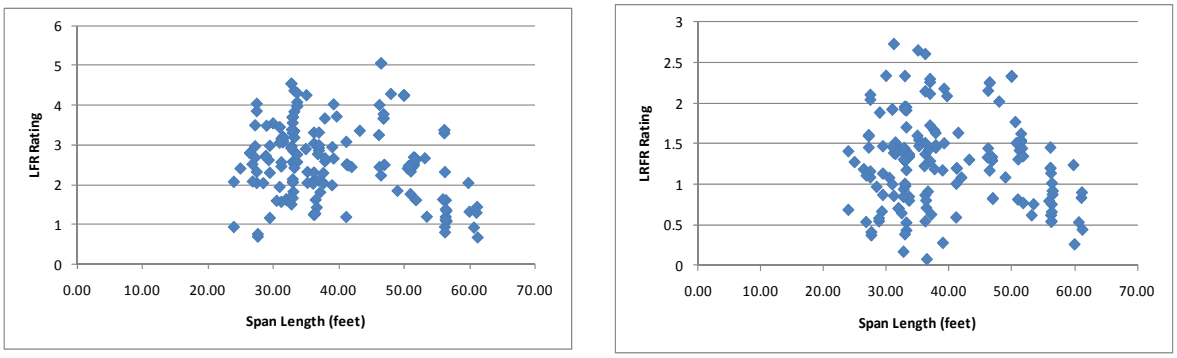


Figure E-259: Vehicle Loadings and Load Factors

E.2.12.1 Moment

E.2.12.1.1 Rating Factors

Figure E-260 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are seven girders with an LFR rating less than 1.0, 52 girders with an LRFR rating less than 1.0, and seven girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR ratings for moment are between one and four for most girders while the LRFR ratings are mostly between 0.5 and 2.0.



(a) (b)

Figure E-260: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure E-261 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 75.8% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 63.6% of girders when the ADTT is greater than 5,000. 95.8% of girders have LFR ratings greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 30% when the highest ADTT is considered.

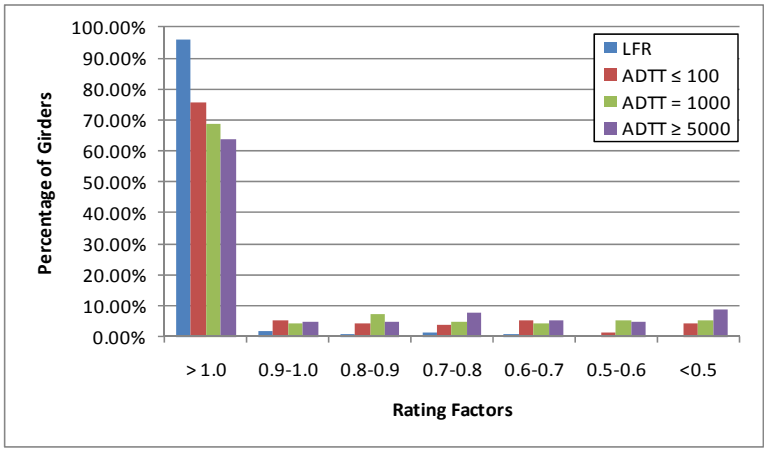


Figure E-261: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

E.2.12.1.2 Rating Factor Comparisons

Figure E-262 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.3 and 0.6. There are no girders with an LRFR rating greater than the LFR rating and most girders will be significantly affected by the switch from LFR to LRFR.

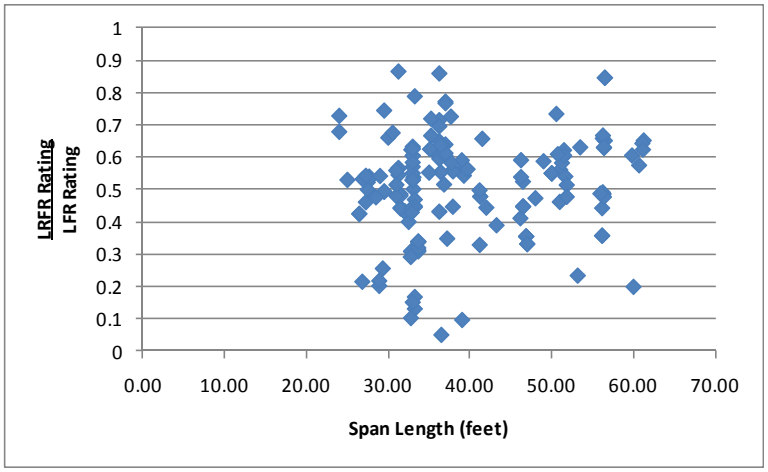


Figure E-262: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

E.2.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-263 shows that one girder has a reliability index less than the target reliability index of 2.5. The reliability index is between four and seven for most girders.

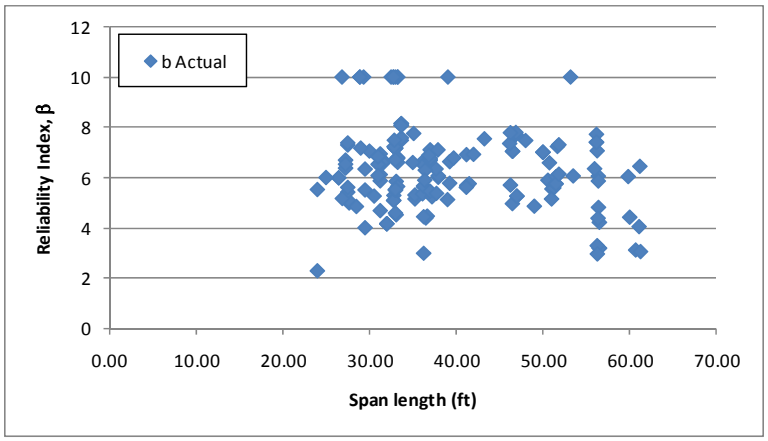


Figure E-263: Flexure Reliability Indices for Type 3-3 Vehicle

Figure E-264 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The reliability increases with increasing LRFR ratings. The reliability index for a girder with a rating of 1.0 is approximately 4.5, above the target reliability of 2.5. This indicates that lower live load factors than those currently in the MBE can be used.

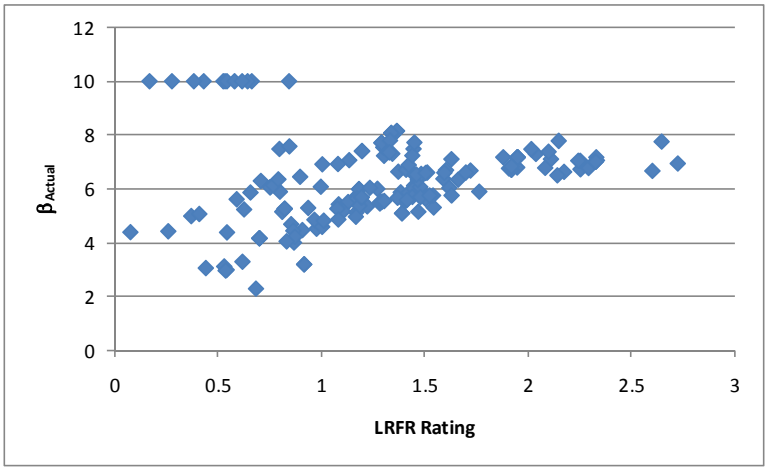
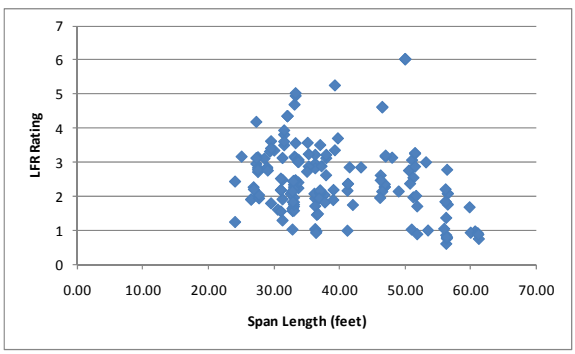


Figure E-264: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Vehicle

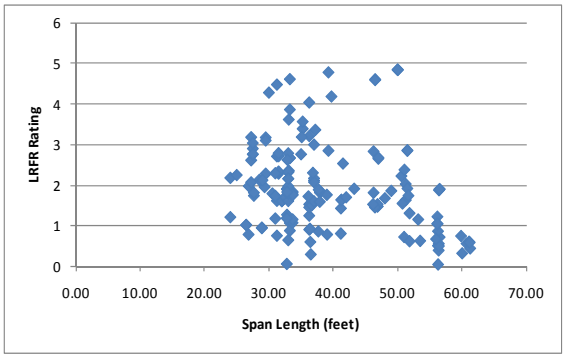
E.2.12.2 Shear

E.2.12.2.1 Rating Factors

For shear, there are 15 girders with LFR rating factors less than 1.0, 31 girders with LRFR ratings less than 1.0, and 15 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 80% of the girders in this subset. Figure E-265 shows the LFR and LRFR ratings. The LFR ratings are between one and 3.5 for most girders while the LRFR ratings are generally between one and three. As the figure shows, the LRFR ratings are generally lower than the LFR ratings and there are more girders less than one for LRFR.



(a)



(b)

Figure E-265: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure E-266 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3-3 Truck, a legal vehicle. 85.5% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 77.6% of girders when the ADTT is greater than 5,000. 90.9% of girders have LFR ratings greater than 1.0. Approximately 5% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 15% when the highest ADTT is considered.

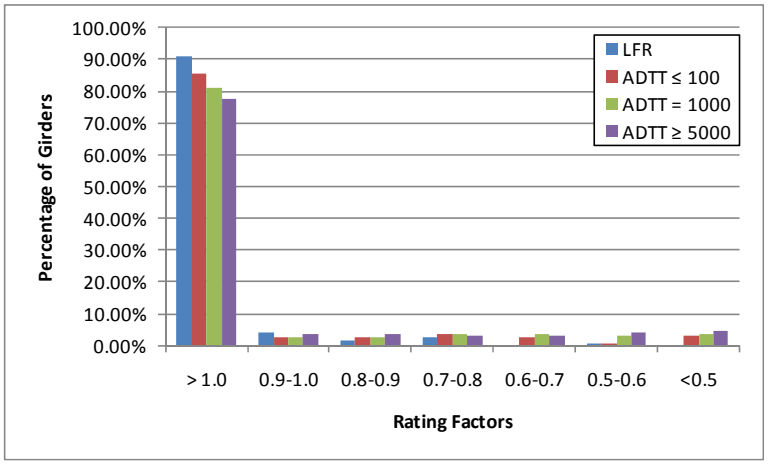


Figure E-266: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

E.2.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-267 show the comparison of rating factors. The ratio is generally between 0.6 and 1.2, with shorter spans generally having higher ratios. 20% of girders have an LRFR rating that is greater than the LFR rating for this group.

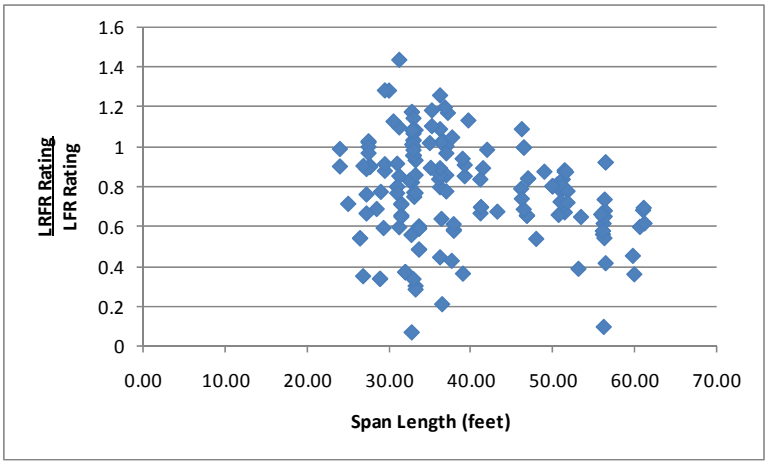


Figure E-267: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

E.2.12.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for five girders as shown in Figure E-268. The reliability index for most girders is between five and eight; other girders have reliability indices less than this range.

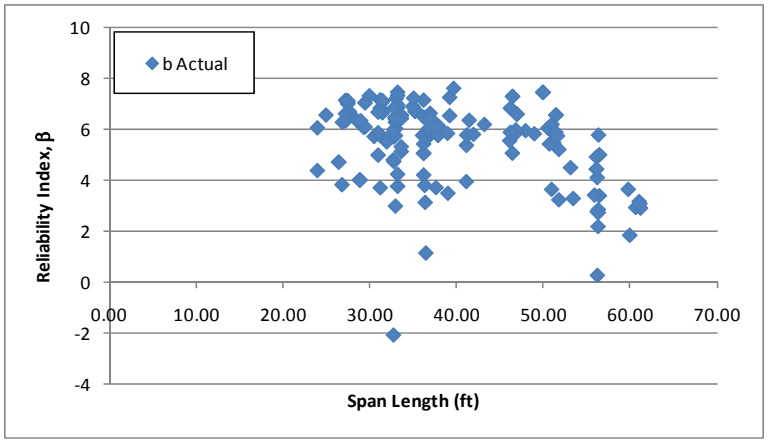


Figure E-268: Shear Reliability Indices for Type 3-3 Vehicle

Figure E-269 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 Truck. The figure shows the reliability index increases with increasing LRFR ratings. The reliability index for a girder with a rating of 1.0 is approximately 4.5, above the target reliability of 2.5. This indicates the live load factors in the MBE are over-conservative and can be reduced.

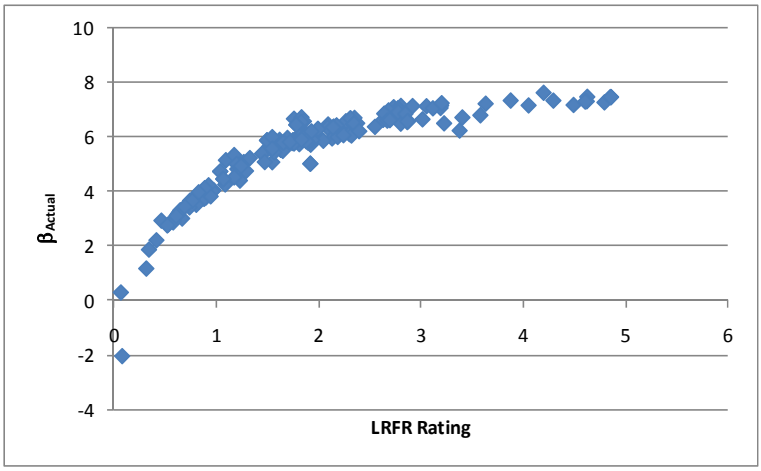


Figure E-269: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

E.2.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure E-270. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized.

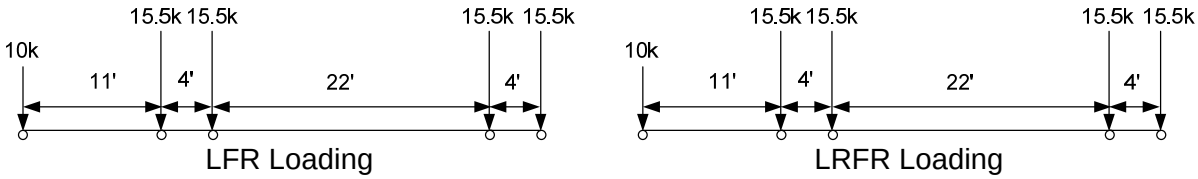
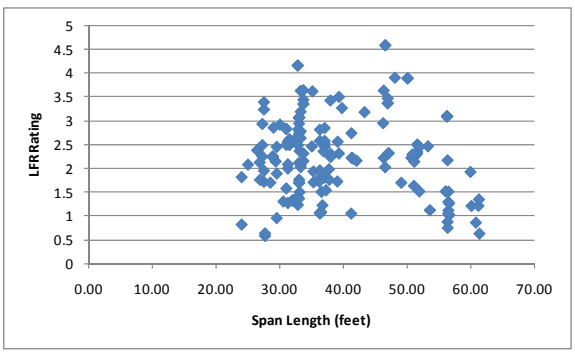


Figure E-270: Vehicle Loadings and Load Factors

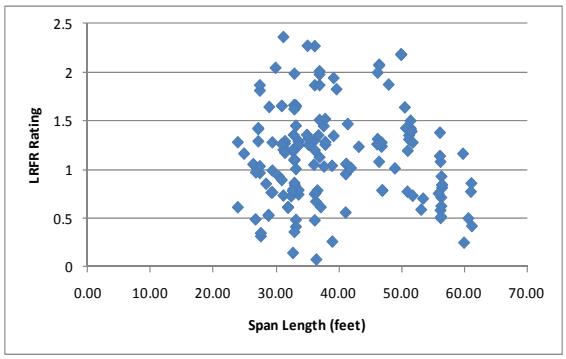
E.2.13.1 Moment

E.2.13.1.1 Rating Factors

Figure E-271 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are eight girders with an LFR rating less than 1.0, 60 girders with an LRFR rating less than 1.0, and eight girders where both ratings are less than 1.0. 58 of the 60 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR ratings are between one and three for most girders while the LRFR ratings are between 0.5 and 1.5 for most girders. The LRFR ratings are significantly less than the LFR ratings.



(a)



(b)

Figure E-271: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure E-272 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 69.7% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 55.8% of girders when the ADTT is greater than 5,000. 95.2% of girders have LFR ratings greater than 1.0. Approximately 25% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 40% when the highest ADTT is considered.

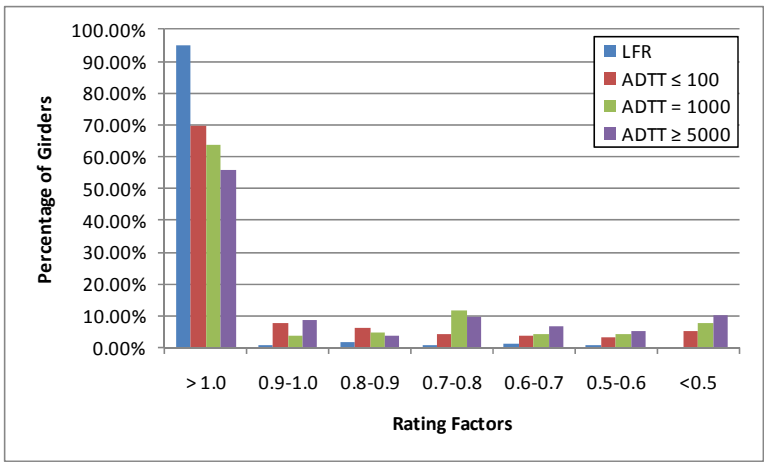


Figure E-272: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

E.2.13.1.2 Rating Factor Comparisons

Figure E-273 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.7. The LRFR ratings are less than the LFR ratings for all girders in this group for this vehicle.

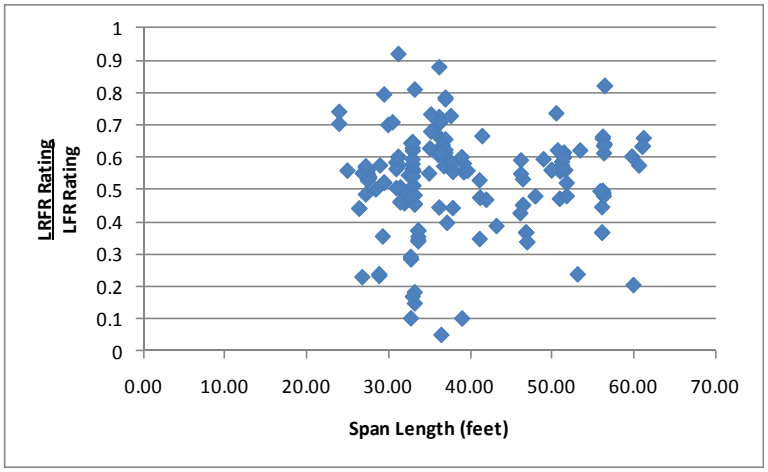


Figure E-273: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

E.2.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure E-274 shows that eight girders have a reliability index less than the target reliability index of 2.5. The reliability index is between four and seven for most girders.

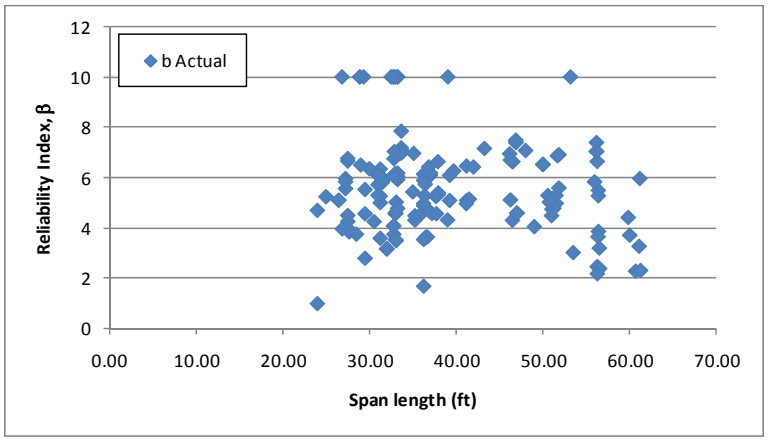


Figure E-274: Flexure Reliability Indices for Type 3S2 Vehicle

Figure E-275 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 truck. The reliability increases with increasing rating factors. The reliability index for a girder with a rating of 1.0 is approximately 4.5, above the target reliability of 2.5. This indicates the live load factors are over-conservative and can be reduced.

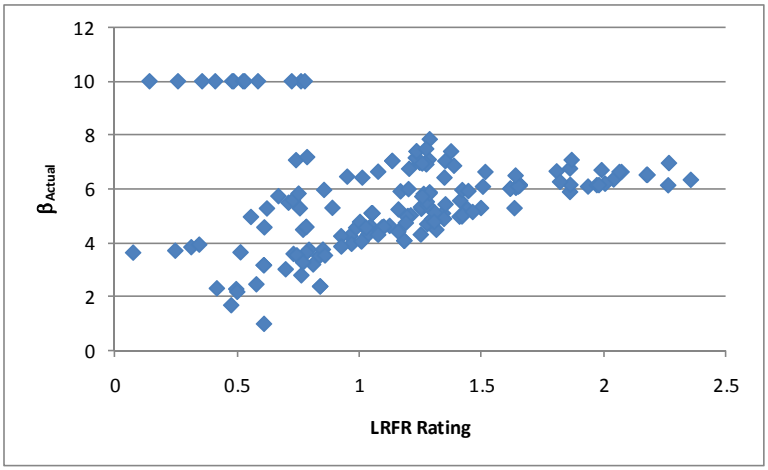
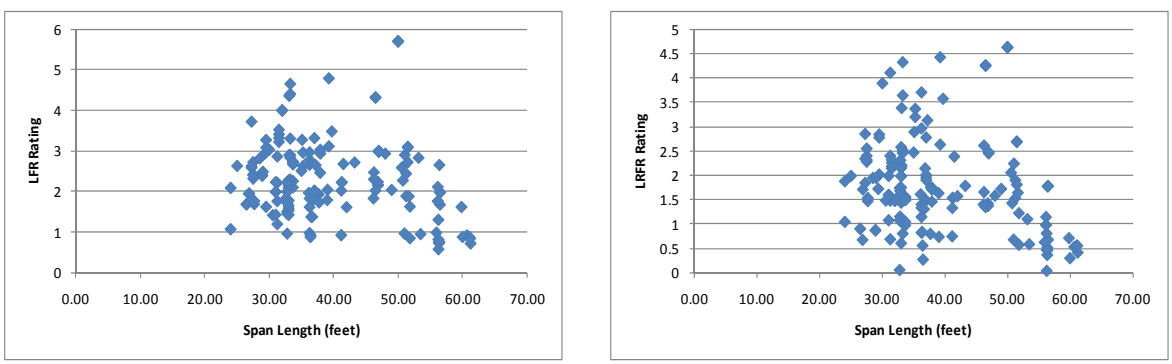


Figure E-275: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

E.2.13.2 Shear

E.2.13.2.1 Rating Factors

For shear, there are 19 girders with LFR rating factors less than 1.0, 36 girders with LRFR ratings less than 1.0, and 19 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure E-276 shows the LFR and LRFR ratings. LFR ratings are between one and three for most girders while the LRFR ratings are generally lower and in the range of 0.5 to 2.5.



(a) (b)

Figure E-276: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure E-277 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 82.4% of girders have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 75.2% of girders when the ADTT is greater than 5,000. 88.5% of girders have LFR ratings greater than 1.0. Approximately 5% more girders have LRFR ratings less than 1.0 when the lowest ADTT is used, this increases to almost 13% when the highest ADTT is considered.

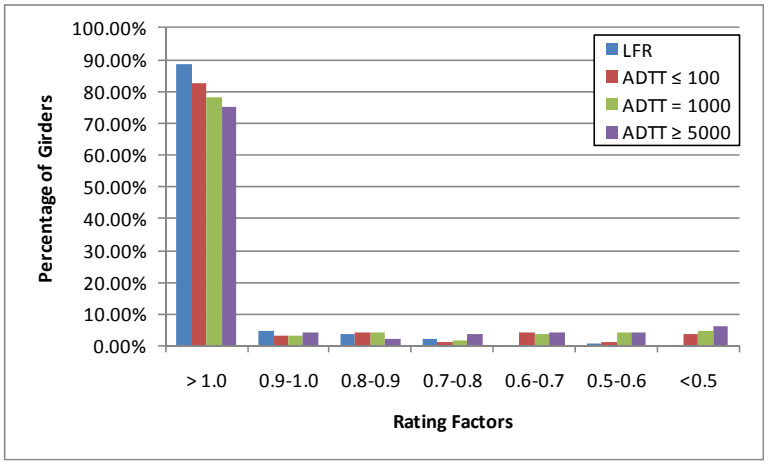


Figure E-277: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

E.2.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure E-278 show the comparison of rating factors. The ratio is generally between 0.6 and 1.2, with shorter spans generally having higher ratios. 15% of the girders have LRFR ratings that exceed the LFR rating.

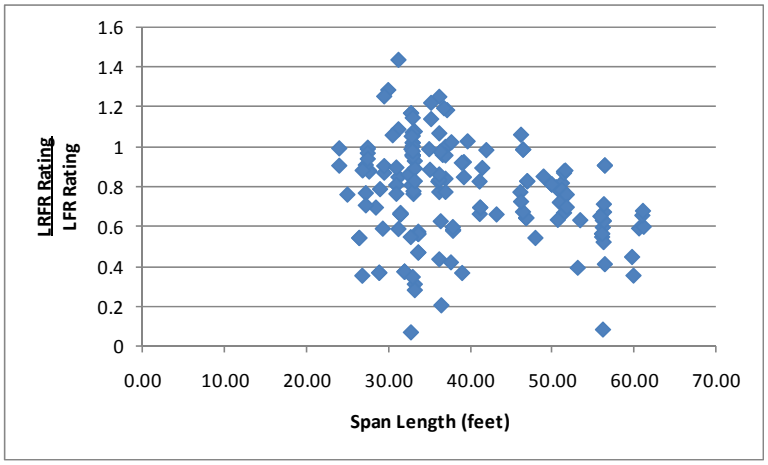


Figure E-278: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

E.2.13.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for 16 girders as shown in Figure E-279. The reliability index for most girders is above four, with numerous girders between two and four.

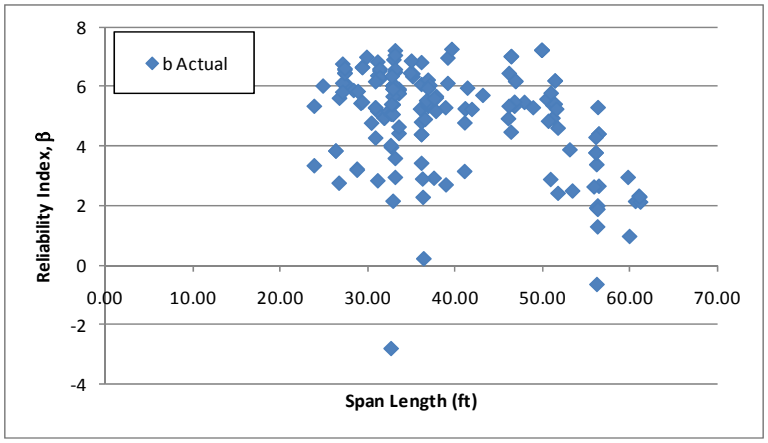


Figure E-279: Shear Reliability Indices for Type 3S2 Vehicle

Figure E-280 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 Truck. The average reliability index for a girder with a rating of 1.0 is approximately four. This is above the target reliability of 2.5 and indicates the live load factors in the MBE may be over-conservative and can be reduced.

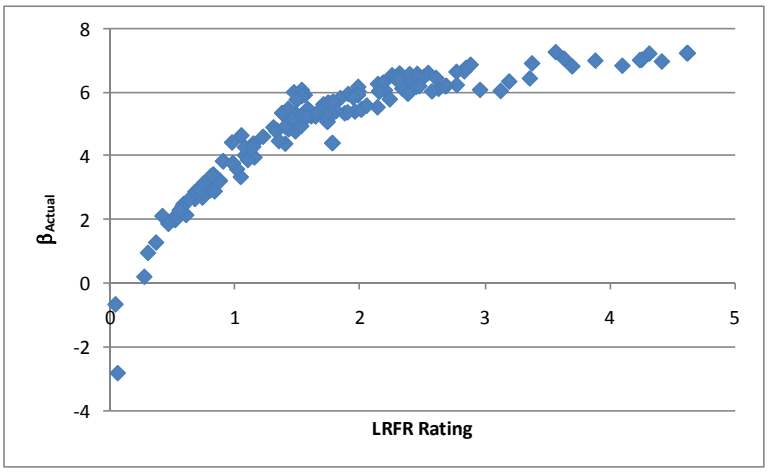


Figure E-280: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

E.2.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table E-3 shows the results for the moment ratings. For the design vehicle and special permit vehicles, at least one quarter of the girders had LFR ratings less than one. The routine permit and legal vehicles produce varying numbers of girders with LFR ratings less than 1.0. All vehicles result in an LRFR rating less than 1.0 for approximately one-third of the girders. The number of girders with ratings less than 1.0 increases significantly when switching from LFR to LRFR, some of this increase is due to the rating of the longitudinal steel reinforcement. A similar percentage of girders have LFR ratings that are greater than the LRFR rating for all vehicles. An additional row was added to the table to indicate how many girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating.

Table E-3: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	165	83	19	18	40	32	17	43	35	51	9	7	8
LRFR Rating less than 1.0		150	84	76	109	102	66	118	126	123	72	52	60
LFR and LRFR Rating less than 1.0		83	19	18	40	32	17	43	35	51	9	7	8
% with LFR RF greater than LRFR RF		99	100	100	99	100	100	99	100	96	100	100	100
Girders with LRFR rating less than 1.0 and controlled by longitudinal steel rating		140	81	73	100	97	63	111	123	111	70	50	58

E.2.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table E-4 shows the results for the shear ratings. All vehicles used in this study produce girders with both LFR and LRFR ratings less than 1.0. For the permit vehicles, routine and special, and legal vehicles, the number of girders with LRFR ratings less than one is approximately double the number of girders with LFR ratings less than 1.0. The percentage of girders with LFR ratings greater than LRFR ratings seems to depend on the vehicle, which is expected because the LRFR shear strength equation uses the ratio of V_u/M_u.

Table E-4: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	165	97	21	21	34	21	19	38	31	50	19	15	19
LRFR Rating less than 1.0		112	46	43	70	45	38	75	82	95	39	31	36
LFR and LRFR Rating less than 1.0		88	21	21	31	21	19	32	29	45	19	15	19
% with LFR RF greater than LRFR RF		68	85	83	73	87	81	71	91	76	87	80	85

F Simple Span Reinforced Concrete Slab Bridges

F.1 1 ft. Slab widths

There were very few slab bridges defined as a system, almost all were line slabs. Most had tributary widths of 1 foot, but there were several where the entire bridge width was utilized.

F.1.1 Dead Loads

F.1.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure F-1, the ratio of unfactored DC1 moments varies significantly between LRFR and LFR. Those less than one are slabs where the critical location for moment occurs away from midspan for LRFR while the LFR critical location is at midspan. The slabs at zero have a critical LRFR location at the support.

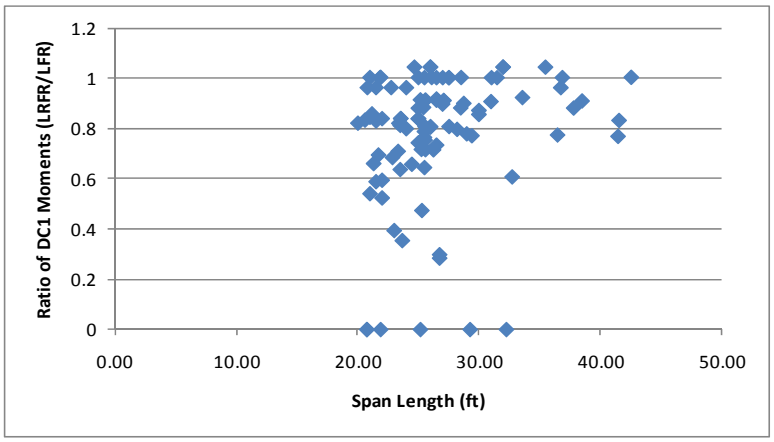


Figure F-1: Ratio of DC1 LRFR Moment to DC1 LFR Moment (unfactored loads)

F.1.1.2 Shear

Figure F-2 shows that numerous slabs have a ratio of DC1 shear close to 1.0, but there are also many where the ratio is either above or below 1.0. This is a mostly due to the variation of the critical section for shear. There is one girder where the critical location for shear is extremely different indicated by the point near five.

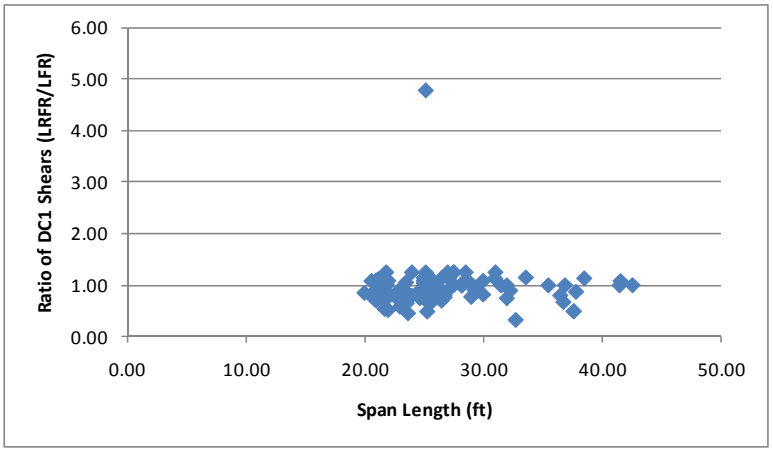


Figure F-2: Ratio of DC1 LRFR Shear to DC1 LFR Shear (unfactored loads)

F.1.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure F-3. The applicable load factors for the vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

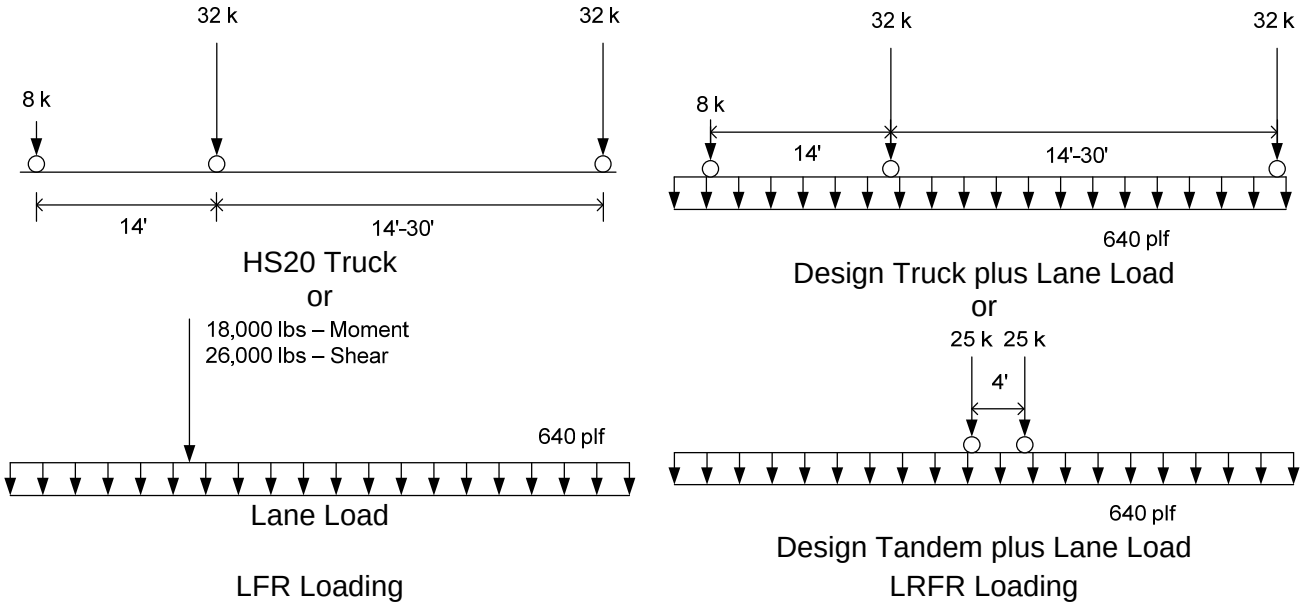


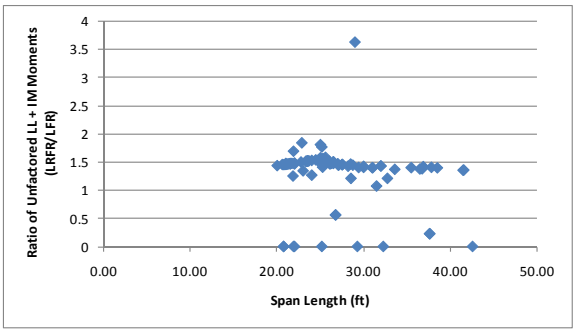
Figure F-3: Vehicle Loadings and Load Factors

F.1.2.1 Moment

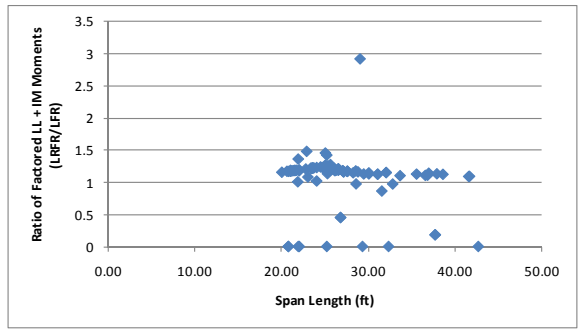
F.1.2.1.1 Live Loads

Figure F-4a shows the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused

by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is near 1.5 for most of the slabs within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure F-4b shows that the results have shifted down and are near 1.2 for most cases.



(a)



(b)

Figure F-4: Ratio of Unfactored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

F.1.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure F-5 shows that the ratio of resistance is generally 1.0. There are also several slabs where the resistance varies greatly from the expected value, those at near zero and seven are likely a result of different locations, the one with a value of -1.7 is a result of this model assuming fixed supports for the slab.

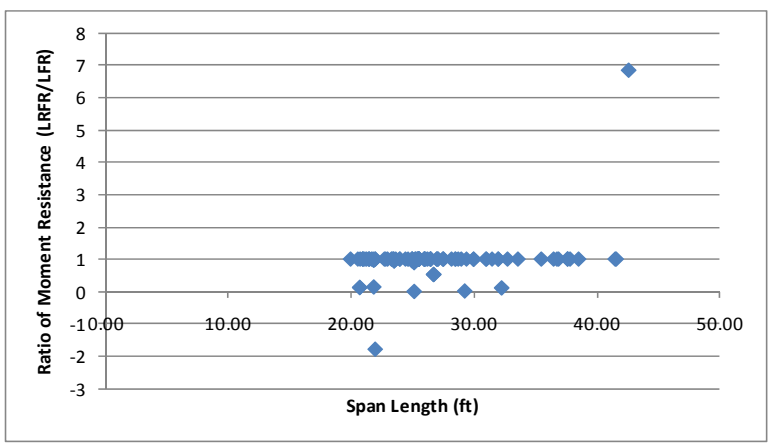
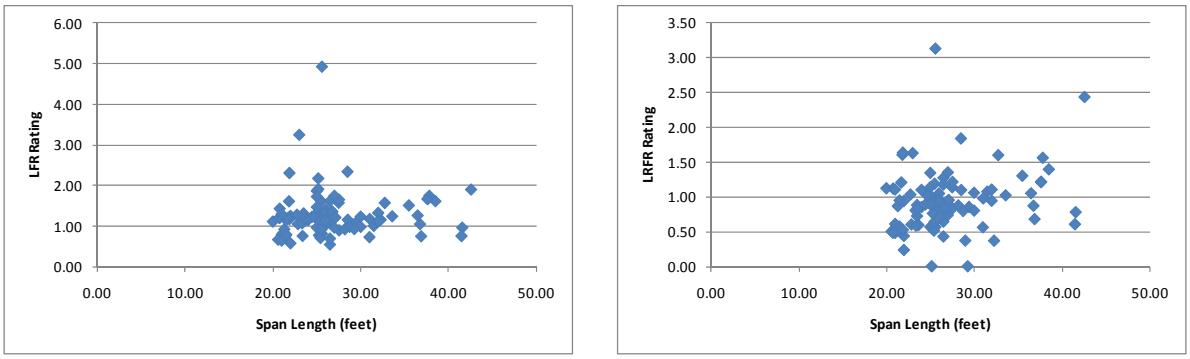


Figure F-5: Ratio of factored Moment Resistance (LRFR/LFR)

F.1.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many slabs within the subset (99 slabs) did not have rating factors greater than 1.0

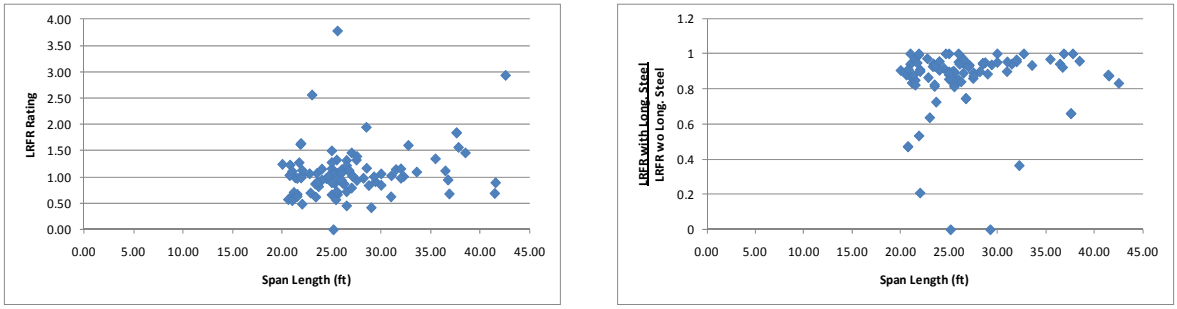
for LFR, LRFR, or both LFR and LRFR. The results show that there are 27 slabs with LFR ratings less than 1.0, 64 slabs with LRFR ratings less than 1.0, and 27 slabs where both the LFR and LRFR ratings are less than 1.0. 60 of the 64 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. Figure F-6 shows the LFR rating factors and LRFR rating factors, respectively. Both LFR and LRFR ratings are generally between 0.5 and 1.5.



(a) (b)

Figure F-6: LFR and LRFR Flexure Rating Factors for Design Loadings

Figure F-7a shows the LRFR ratings when the longitudinal steel rating is ignored. The LRFR ratings have increased for slabs in the range of about 25 feet when compared to Figure F-6b. 18 fewer slabs have ratings less than 1.0 when the longitudinal steel rating is ignored. Figure F-7b shows the ratio of the LRFR rating including the longitudinal steel rating divided by the LRFR rating excluding the longitudinal steel rating. 91% of slabs have LRFR ratings including the longitudinal steel rating that are less than the LRFR rating excluding the longitudinal steel rating.



(a) (b)

Figure F-7: Effect of Longitudinal Steel Rating on LRFR Ratings

F.1.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure F-8. The results indicated that 94% of the slabs in this set have LFR ratings greater than LRFR ratings. The ratio is between 0.6 and 0.8 for most slabs.

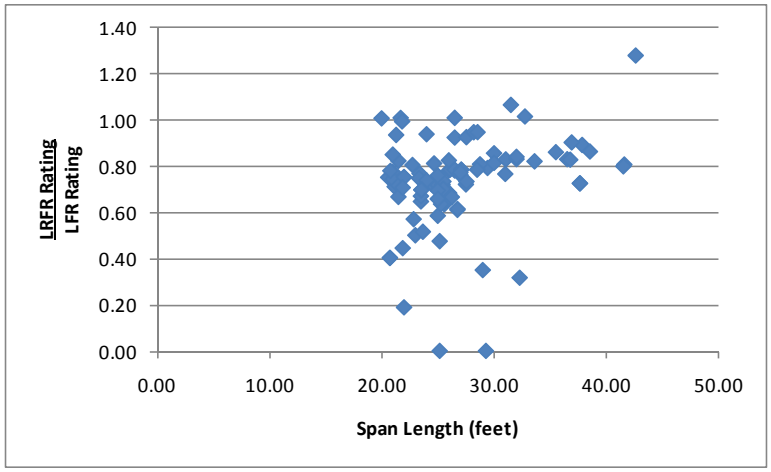


Figure F-8: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure F-9 shows the percentage of slabs with LRFR ratings less than 1.0 in each category of LRFR/LFR ratio. The figure shows that most slabs with LRFR ratings less than 1.0 have an LRFR rating that is 70-80% of the LFR rating. The figure also shows how many bridges will be affected by switching from LFR to LRFR and an estimate of the magnitude of the reduction in rating.

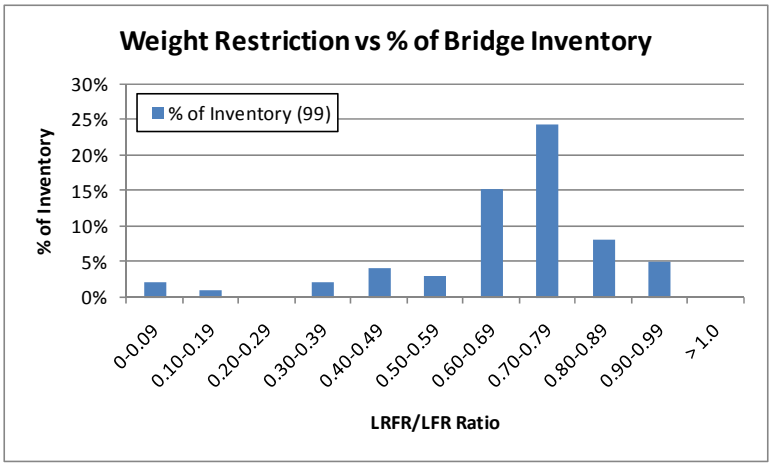


Figure F-9: Distribution of LRFR/LFR Ratio for Slabs with LRFR Rating less than 1.0

F.1.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure F-10 shows sixteen slabs that have a reliability index lower than the reliability index of 3.5 inherent in the AASHTO LRFD Design Specifications. The actual reliability index is between four and five for most slabs.

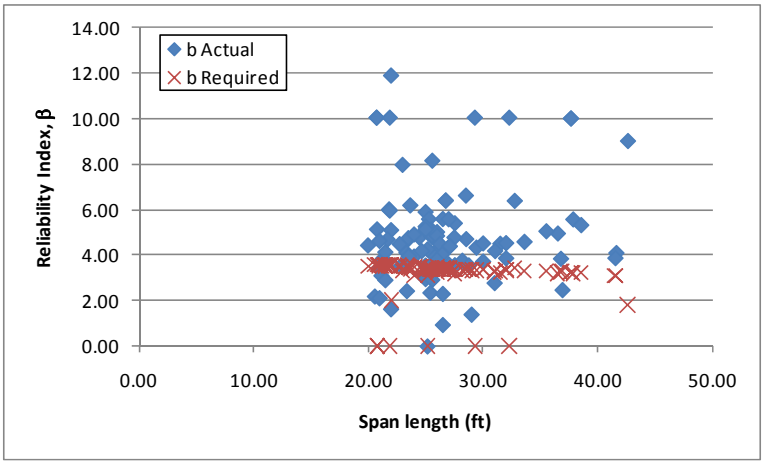


Figure F-10: Flexure Reliability Indices for HL-93 Loading

Figure F-11 shows the reliability index for moment plotted against the LRFR moment rating for the design vehicle. The figure shows that the reliability index increases with increasing rating factors. Slabs with a rating factor of 1.0 have a reliability index near the target value of 3.5.

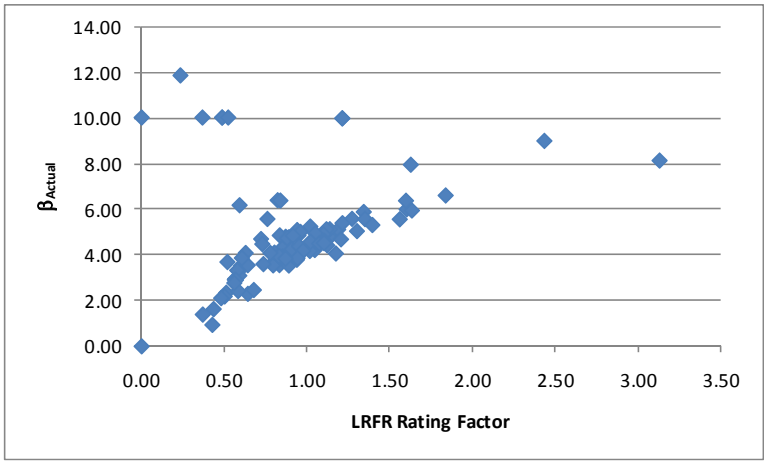
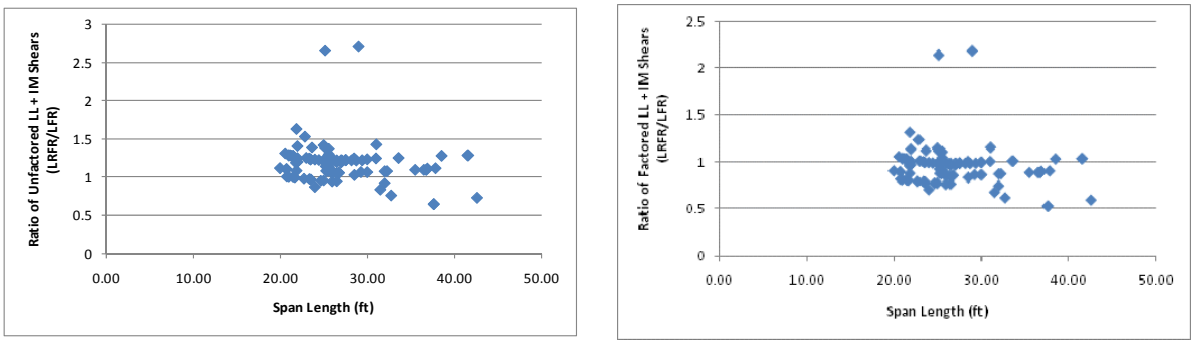


Figure F-11: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Vehicle

F.1.2.2 Shear

F.1.2.2.1 Live Loads

Figure F-12a shows that the ratio of unfactored shear varies significantly, with most slabs between 1.0 and 1.5. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure F-12b shows that the ratio of factored live load shears has decreased and is generally between 0.75 and 1.0 for most cases.



(a) (b)

Figure F-12: Ratio of Unfactored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

As shown in Figure F-13, the location of the critical section varies significantly for most slabs. The variation in factored shears shown in Figure F-12 is a result of the difference in the critical section for shear rating. The LRFR rating is typically either at the support or the eight-tenths point. The LFR rating is typically at the one- or nine-tenths point.

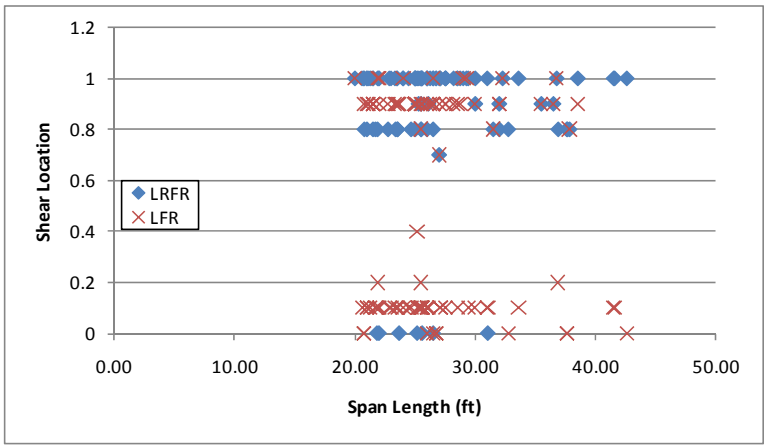


Figure F-13: Graph of critical shear location for Design Loadings

F.1.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure F-14 shows that the ratio of resistance is generally between 1.5 and 2.5 (LRFR resistance is greater than LFR resistance). The variation in critical location also affects the ratio of shear resistance.

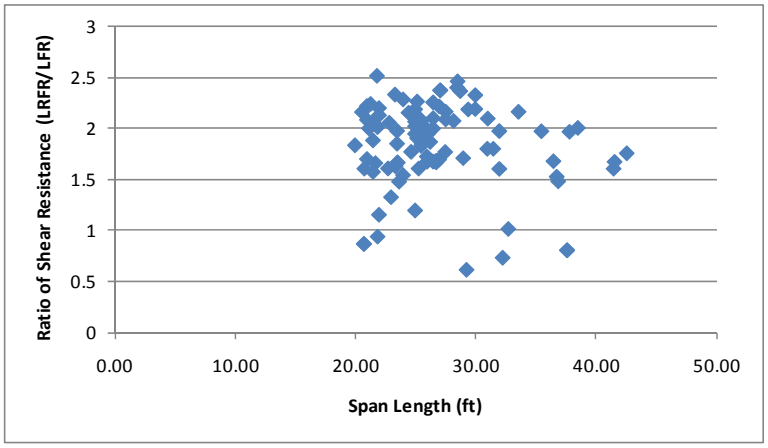
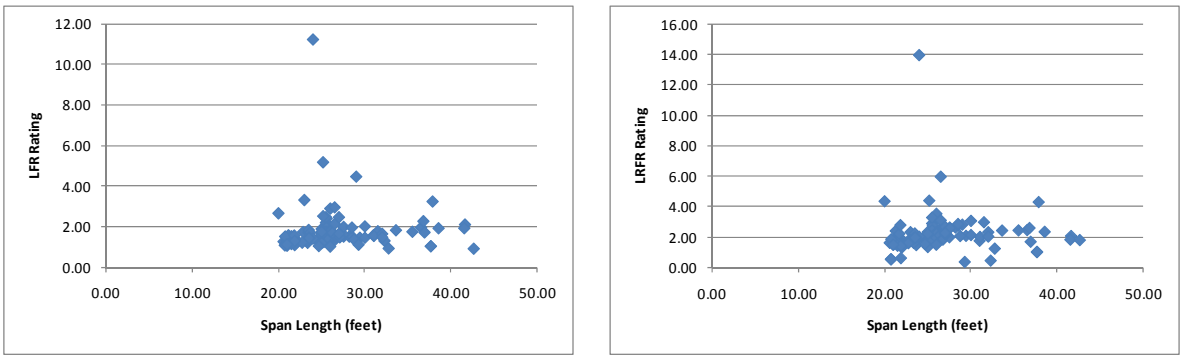


Figure F-14: Ratio of factored Shear Resistance (LRFR/LFR)

F.1.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many slabs within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are two slabs with LFR ratings less than 1.0, five slabs with LRFR ratings less than 1.0, and zero slabs where both LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. For this subset, there are few slabs that have shear ratings less than 1.0 for LRFR. In addition, the LRFR rating was greater than the LFR rating for 85% of the slabs in this subset. Figure F-15 shows the LFR rating factors and LRFR rating factors, respectively. The LFR rating is typically between one and two while the LRFR rating has increased slightly and is between 1.5 and 2.5 for most slabs.



(a) (b)

Figure F-15: LFR and LRFR Shear Rating Factors for Design Loadings

F.1.2.2.4 Rating Factor Comparisons

Figure F-16 shows the ratio of the LRFR rating to the LFR rating. 85% of the slabs have LRFR ratings higher than LFR ratings; this is the first case where a significant portion of the superstructure element had higher LRFR ratings than LFR ratings. Most of the slabs had LRFR ratings that were between 1 and 1.5 times larger than the LFR rating.

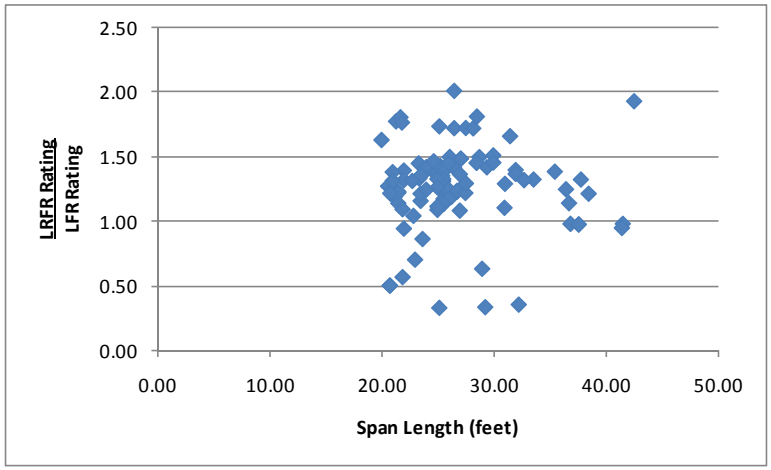


Figure F-16: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure F-17 shows the percentage of slabs in each category for those slabs with LRFR ratings less than one. There are five slabs with LRFR ratings less than 1.0; three have LRFR ratings that are between 50 and 60% of the LFR rating and two are between 30 and 40% of the LFR rating. The figure shows that few slabs are affected by switching from LFR to LRFR for shear.

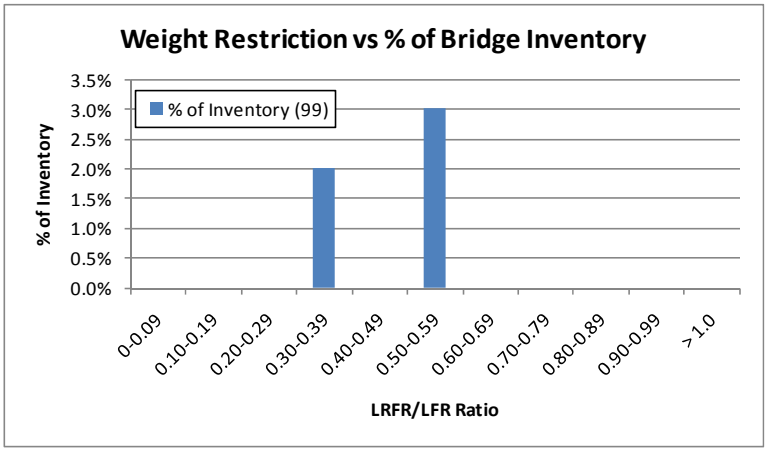


Figure F-17: Distribution of LRFR/LFR Ratio for Slabs with LRFR Ratings Less than 1.0

F.1.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure F-18 shows five slabs have a reliability index for shear less than the target reliability. The reliability index for most slabs is above 5.5 for shear.

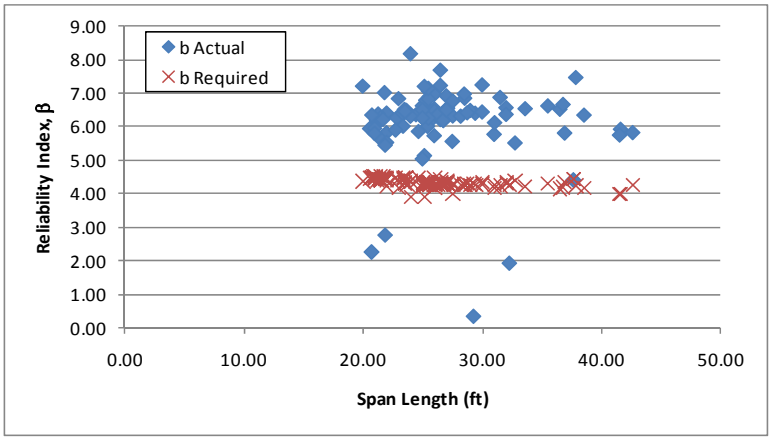


Figure F-18: Shear Reliability Indices for HL-93 Loading

Figure F-19 shows the reliability index for shear plotted against the LRFR shear rating for the design vehicle. The reliability index increases with increasing LRFR ratings. The average reliability index for a girder with a rating of 1.0 is approximately 4.25, above the target reliability of 3.5 assumed in the AASHTO LRFD Design Specifications. This is not unexpected as the live load factors in the LRFD Design Specifications were increased to provide a level of conservatism.

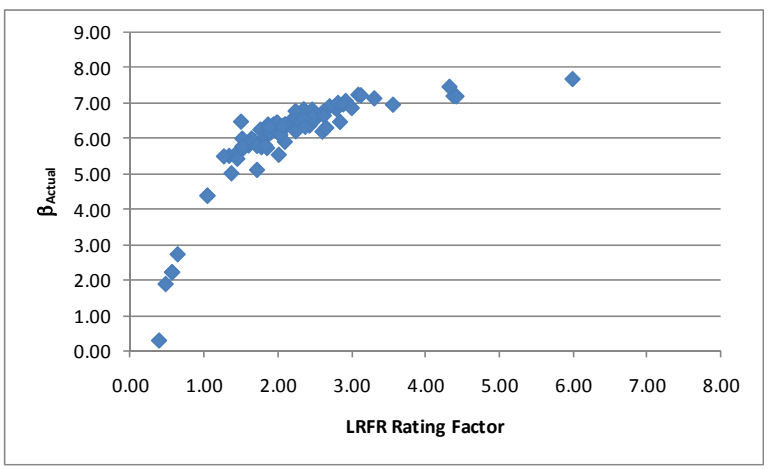
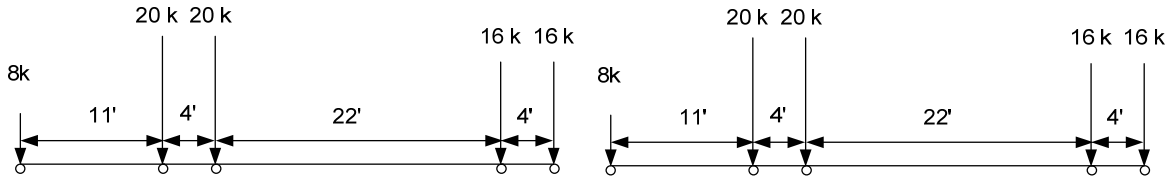


Figure F-19: Shear Reliability Index vs LRFR Shear Rating for HL-93 Design Load

F.1.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-20. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

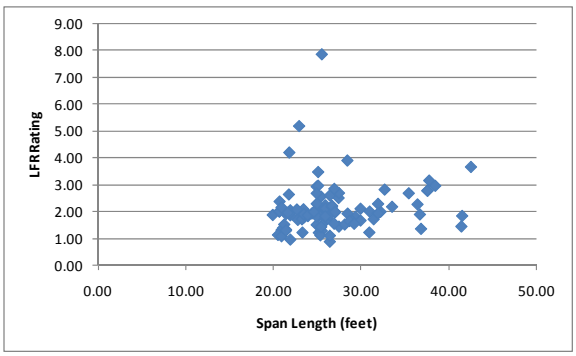
Figure F-20: Vehicle Loadings and Load Factors

F.1.3.1 Moment

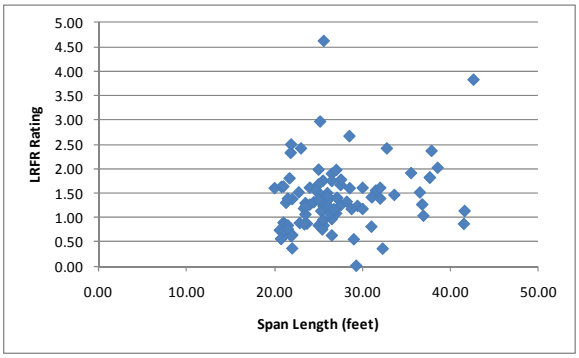
The following section contains the results for reinforced concrete slabs within simple span bridges for the DE-07 Vehicle.

F.1.3.1.1 Rating Factors

Figure F-21 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are two slabs with an LFR rating less than 1.0, 27 slabs with an LRFR rating less than 1.0, and two slabs where both ratings are less than 1.0. All 27 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 99% of the slabs in this subset. The LFR ratings are between one and three for most slabs while the LRFR ratings are generally between 0.5 and two.



(a)



(b)

Figure F-21: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure F-22 shows the percentage of slabs with moment ratings in each range for the DE-07 vehicle, a routine permit vehicle. 77.8% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 66.7% of slabs for the highest LRFR ADTT category. 98% of slabs have LFR ratings greater than 1.0. Approximately 12% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the lowest ADTT category; this increases to approximately 21% for the highest ADTT category.

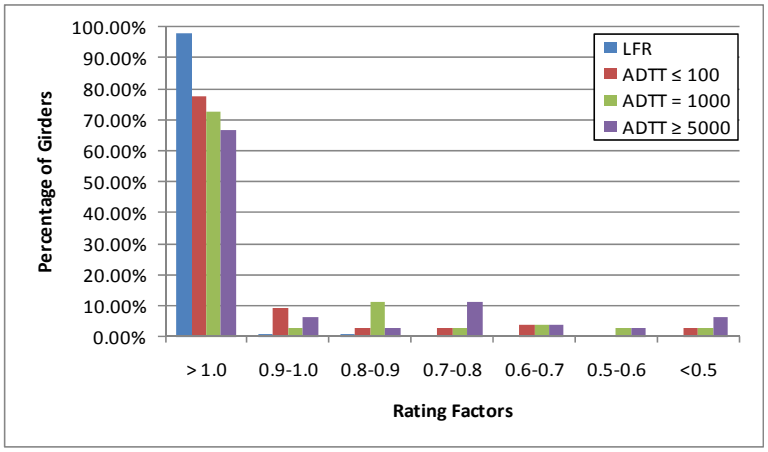


Figure F-22: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

F.1.3.1.2 Rating Factor Comparisons

Figure F-23 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8, with lower ratios generally corresponding to longer span lengths. One girder has an LRFR rating that is greater than the LFR rating.

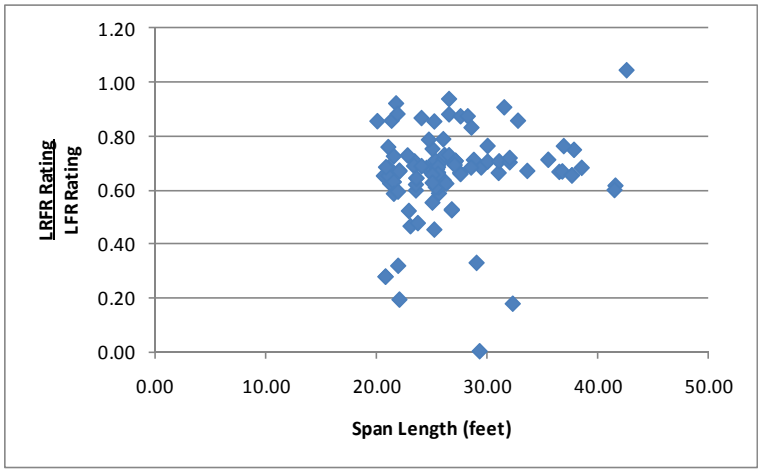


Figure F-23: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

F.1.3.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-24 shows that all slabs have a reliability index greater than the target reliability index of 2.5. The reliability index for a majority of slabs is between four and seven.

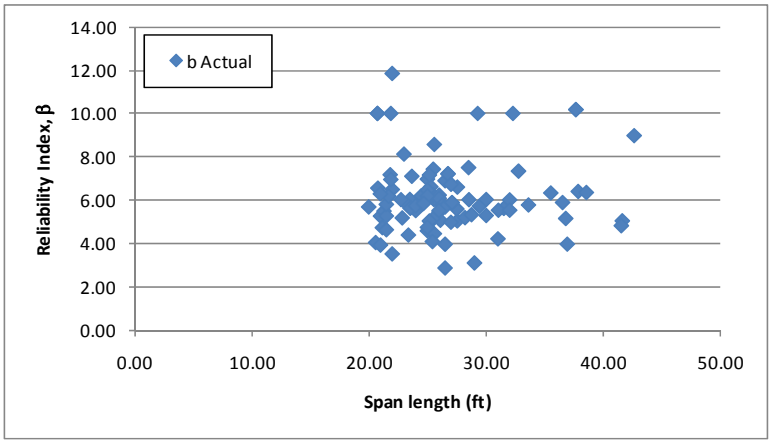


Figure F-24: Flexure Reliability Indices for DE-07 Vehicle

Figure F-25 shows the reliability index for moment plotted against the LRFR moment rating for DE-07 vehicle. The reliability increases with increasing LRFR ratings. The average reliability index for slabs with ratings near 1.0 is approximately five, greater than the target reliability of 2.5. This indicates that the current live load factors in the MBE may be over-conservative.

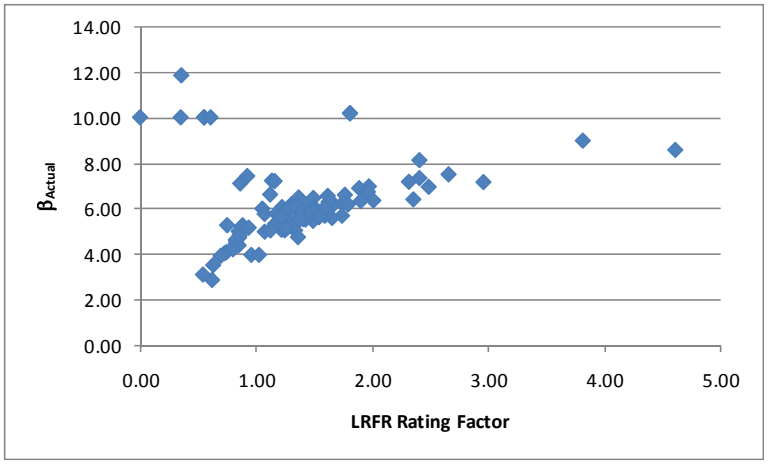
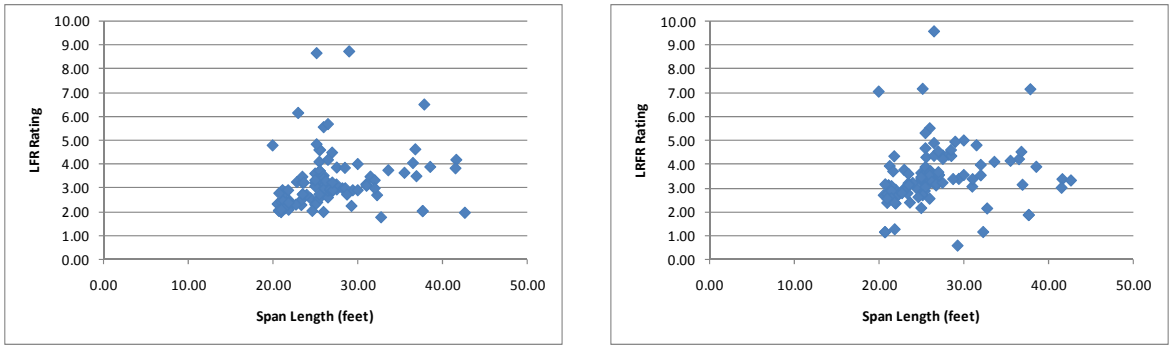


Figure F-25: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

F.1.3.2 Shear

F.1.3.2.1 Rating Factors

For shear, there are zero slabs that have rating factors less than 1.0 for LFR, one slab for LRFR, and zero slabs where both LFR and LRFR are less than 1.0. There are very few slabs where the rating factors are not satisfactory for shear. The LFR Rating is greater than the LRFR rating for 26% of the slabs in this subset. Figure F-26 shows the LFR and LRFR ratings. Both ratings are between two and four for most slabs. One outlier was removed from each graph with the LFR value being 21 and the LRFR value being 20.



(a) (b)

Figure F-26: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure F-27 shows the percentage of slabs with shear ratings in each range for the DE-07 vehicle, a routine permit vehicle. 99% of slabs have LRFR ratings greater than 1.0 for all ADTT categories used in the MBE. 99% of slabs also have LFR ratings greater than 1.0; there is no change in the number of slabs affected by switching from LFR to LRFR.

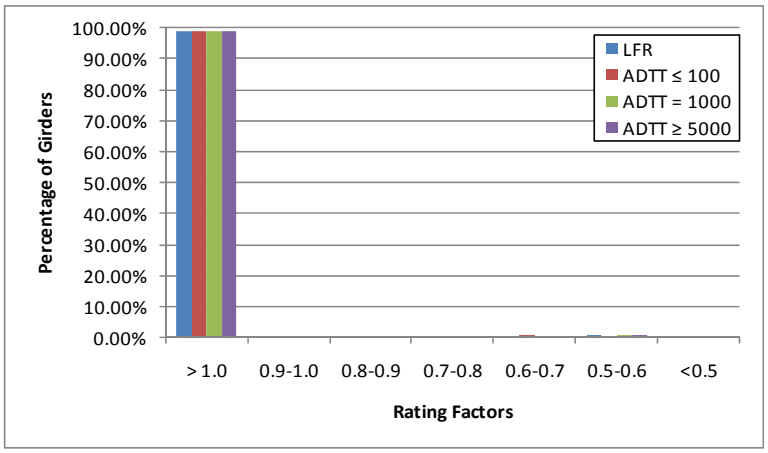


Figure F-27: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

F.1.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure F-28 shows the comparison of rating factors. The ratio is generally between 1.0 and 1.3.

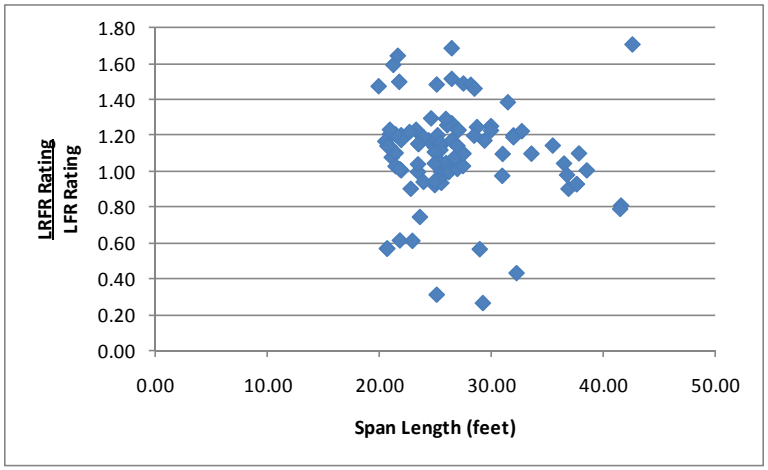


Figure F-28: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

F.1.3.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all slabs except for one as shown in Figure F-29. The reliability index is generally between six and eight.

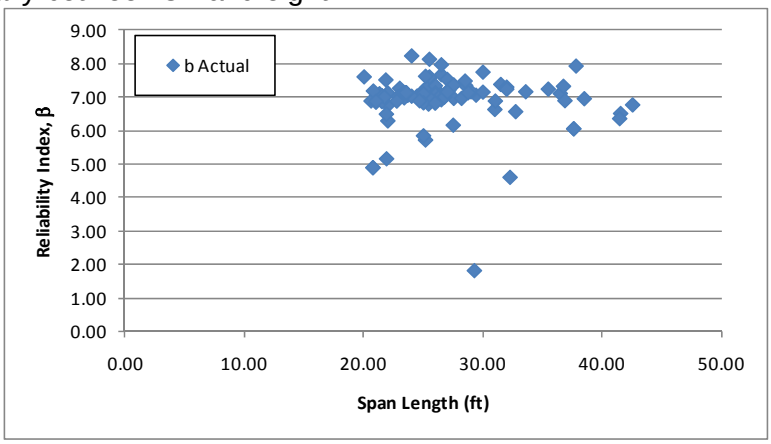


Figure F-29: Shear Reliability Indices for DE-07 Vehicle

Figure F-30 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 vehicle. The figure shows that the average reliability index for slabs with a rating of 1.0 is approximately 3.5. This exceeds the target reliability of 2.5 and indicates the LRFR live load factors may be over conservative.

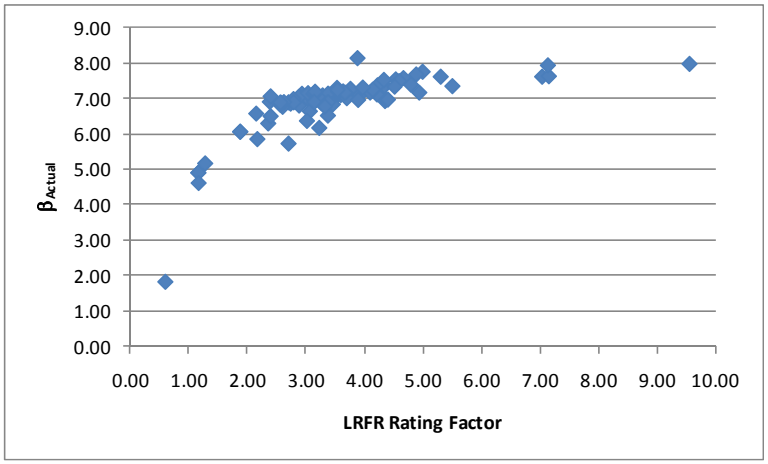
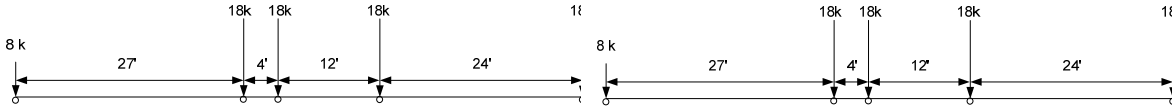


Figure F-30: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

F.1.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-31. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

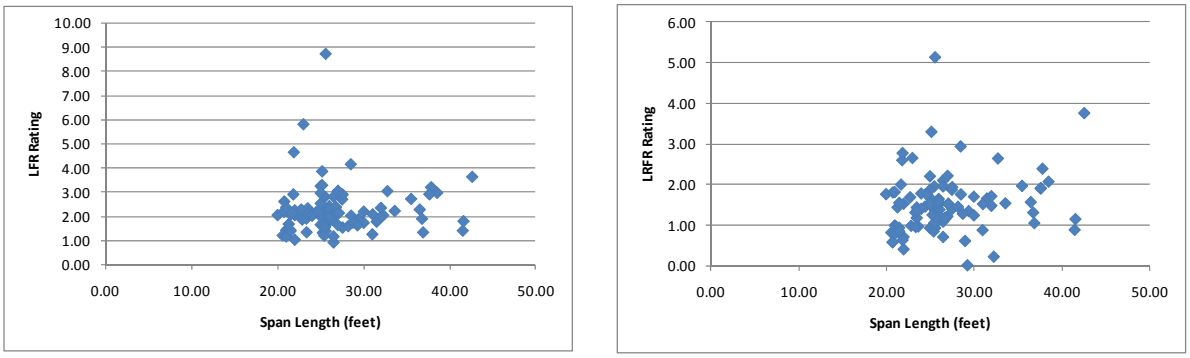
Figure F-31: Vehicle Loadings and Load Factors

F.1.4.1 Moment

The following section contains the results for reinforced concrete slabs within simple span bridges for the FL-04 Vehicle.

F.1.4.1.1 Rating Factors

Figure F-32 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one slab with an LFR rating less than 1.0, 24 slabs with an LRFR rating less than 1.0, and one slab where both ratings are less than 1.0. All slabs with an LRFR rating less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 99% of the slabs in this subset. The LFR ratings are generally between 1.0 and 3.0 while the LRFR ratings are between one and two for most slabs.



(a) (b)

Figure F-32: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure F-33 shows the percentage of slabs with moment ratings in each range for the FL-04 vehicle, a routine permit vehicle. 84.9% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 71.7% of slabs for the highest LRFR ADTT category. 99% of slabs have LFR ratings less than 1.0. Approximately 15% more slabs have LRFR ratings greater than 1.0 than have LFR ratings less than 1.0 for the lowest ADTT category; this increases to approximately 27% for the highest ADTT category.

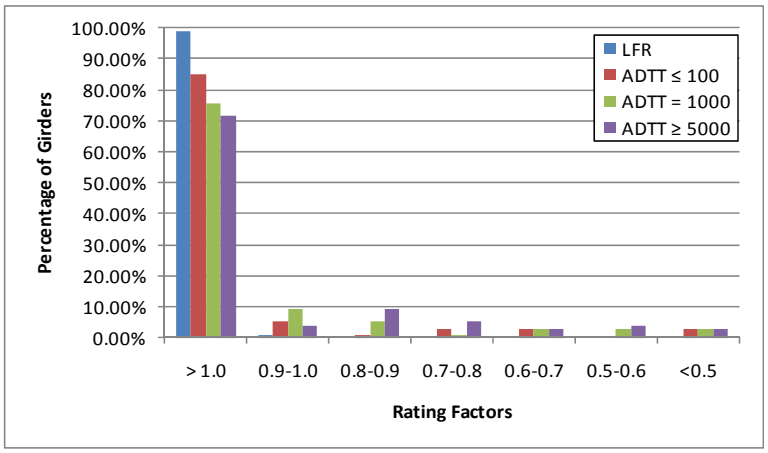


Figure F-33: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

F.1.4.1.2 Rating Factor Comparisons

Figure F-34 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. There is one slab with an LRFR rating greater than the LFR rating in this group. The LRFR rating is typically 60 to 80% of the LFR rating.

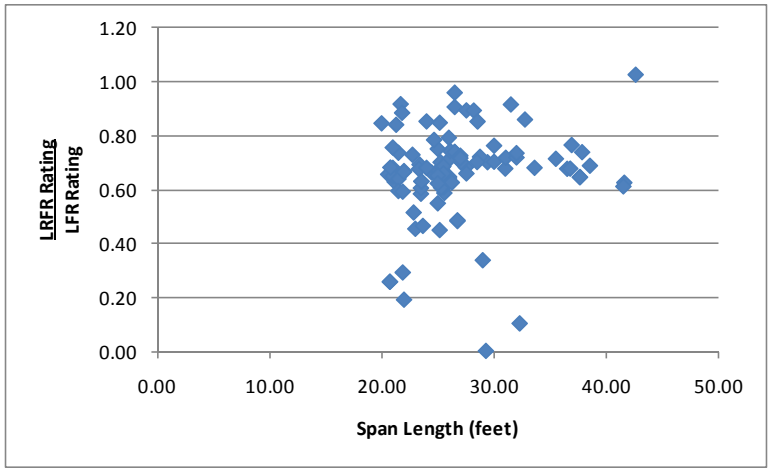


Figure F-34: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

F.1.4.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-35 shows that all slabs have a reliability index greater than the target reliability index of 2.5. The reliability index is between four and eight for most slabs.

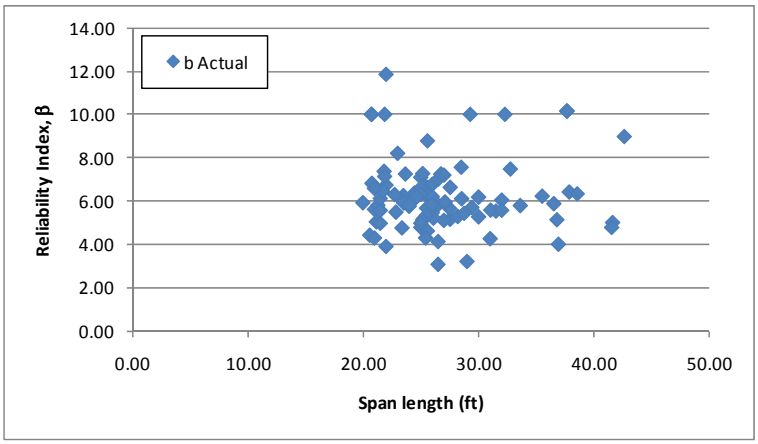


Figure F-35: Flexure Reliability Indices for FL-04 Vehicle

Figure F-36 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 vehicle. The figure shows the reliability index increases with increasing LRFR ratings. The average reliability index for a girder with a rating of 1.0 is approximately 5.0, above the target reliability of 2.5. This indicates the live load factors may be overly conservative and can be reduced.

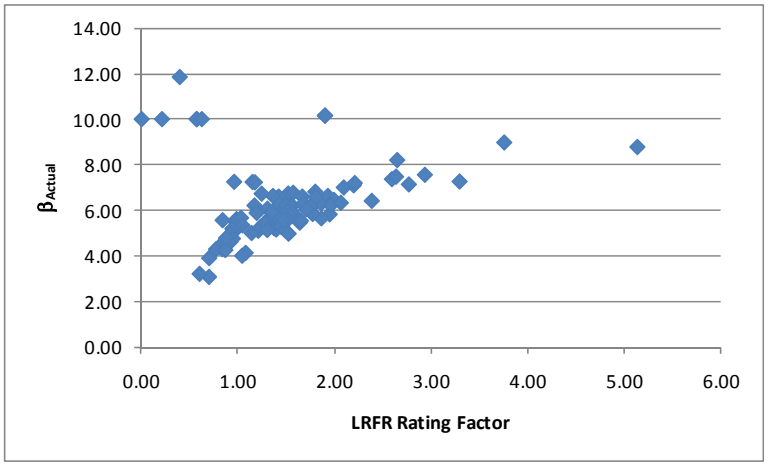
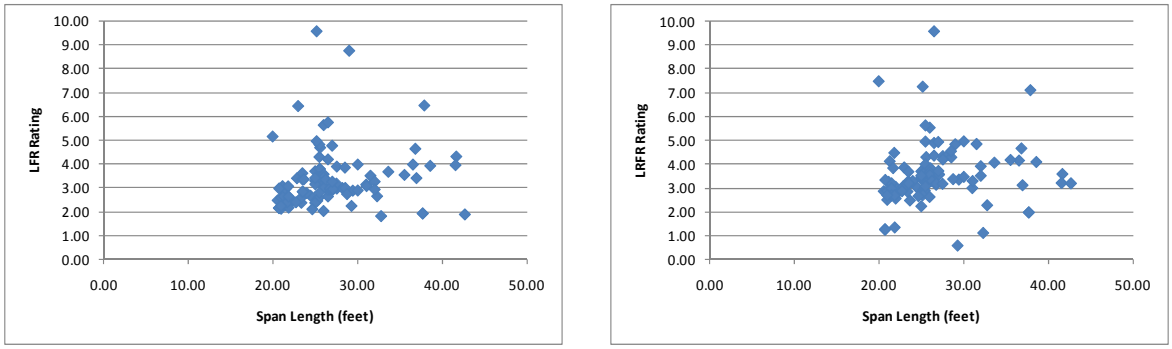


Figure F-36: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

F.1.4.2 Shear

F.1.4.2.1 Rating Factors

For shear, there are zero slabs that have LFR rating factors less than 1.0, one slab with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 23% of the slabs in this subset. Figure F-37 shows the LFR and LRFR ratings. Both ratings are between two and four for most span lengths with longer spans having slightly higher ratings. One outlier was removed from each graph with the LFR value being 22 and the LRFR value being 20.



(a) (b)

Figure F-37: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure F-38 shows the percentage of slabs with shear ratings in each range for the FL-04 vehicle, a routine permit vehicle. 99% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 98% of slabs for the highest LRFR ADTT category. 100% of slabs have LFR ratings greater than 1.0. Approximately 2% of slabs are affected by the switch from LFR to LRFR for shear.

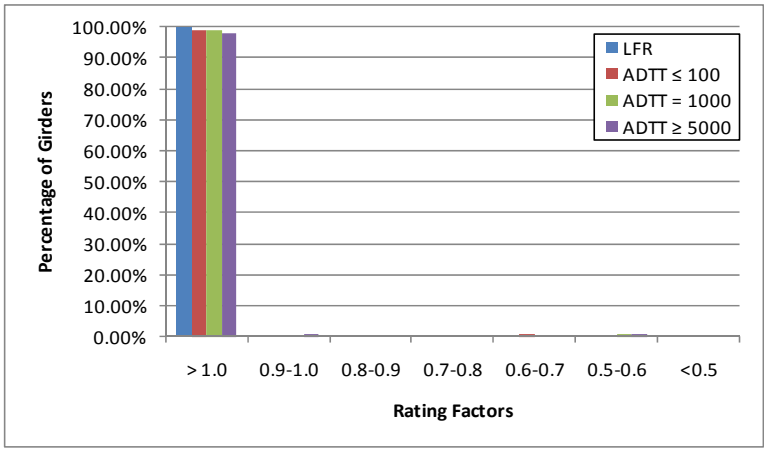


Figure F-38: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

F.1.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure F-39 shows the comparison of rating factors. The ratio is generally between 1.0 and 1.2. 77% of slabs have LRFR ratings that exceed the LFR rating.

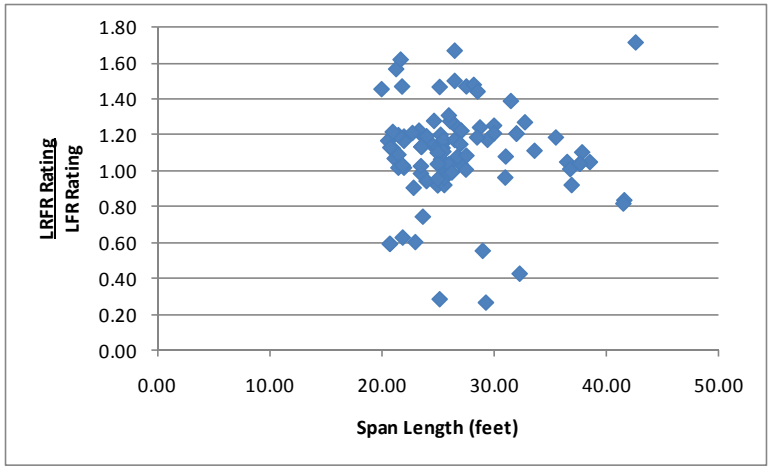


Figure F-39: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

F.1.4.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is greater than the target reliability index of 2.5 for all but one slab as shown in Figure F-40. The reliability index is near seven for most slabs.

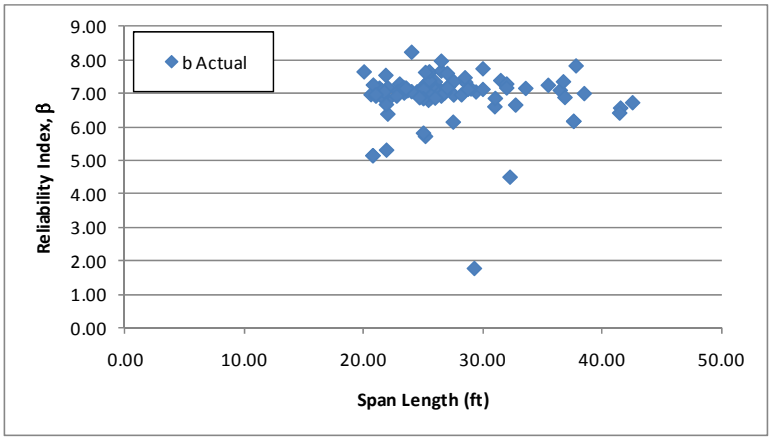


Figure F-40: Shear Reliability Indices for FL-04 Vehicle

Figure F-41 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 vehicle. The figure shows the reliability increases with increasing LRFR rating. The reliability index for a girder with a rating of approximately one can also be determined and is estimated to be four. This is greater than the target reliability of 2.5 and indicates the LRFR live load factors may be over-conservative.

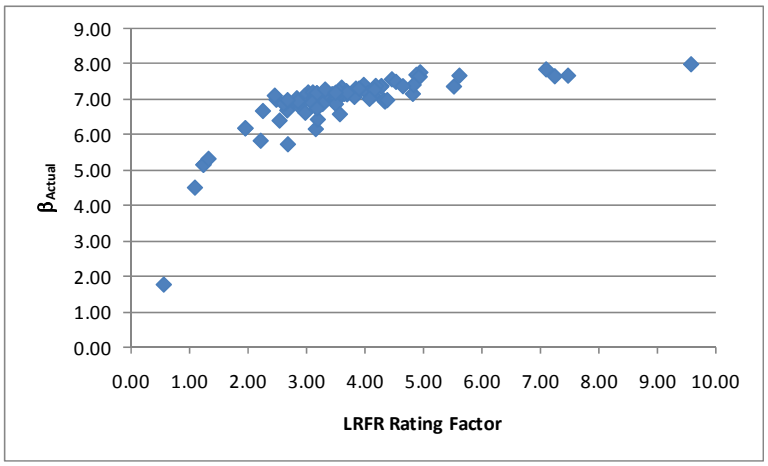


Figure F-41: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

F.1.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-42. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

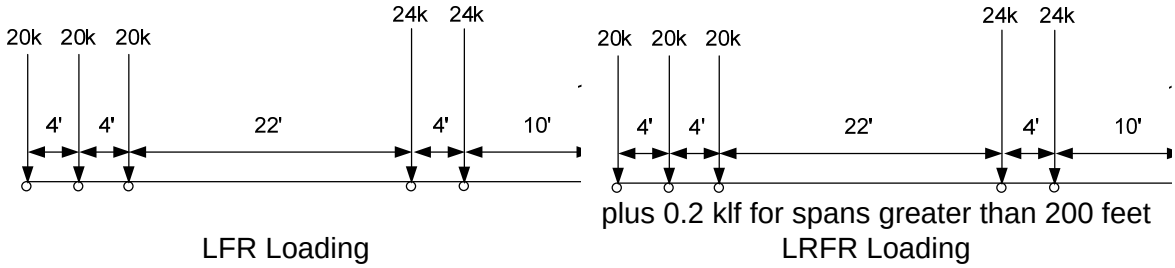


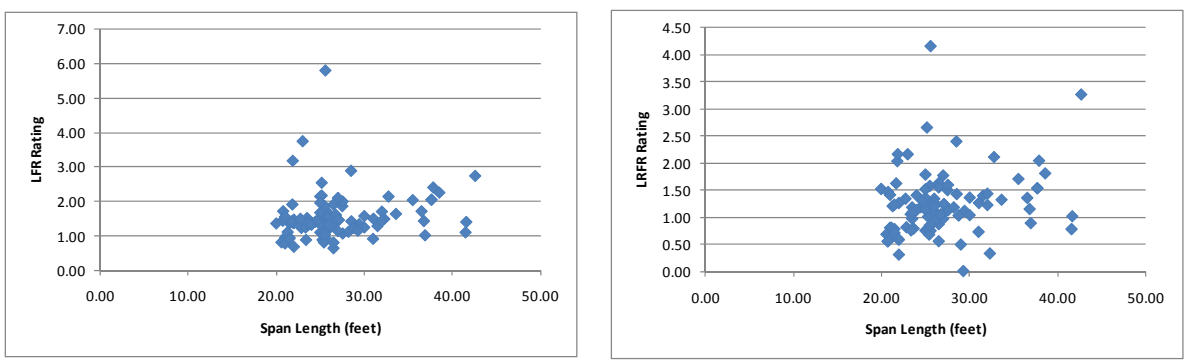
Figure F-42: Vehicle Loadings and Load Factors

F.1.5.1 Moment

The following section contains the results for reinforced concrete slabs within simple span bridges for the IL-01 Vehicle.

F.1.5.1.1 Rating Factors

Figure F-43 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 14 slabs with an LFR rating less than 1.0, 31 slabs with an LRFR rating less than 1.0, and 14 slabs where both ratings are less than 1.0. 30 of the 31 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 87% of the slabs in this subset. LFR ratings are typically between 1.0 and 2.0 while the LRFR ratings are typically between 0.5 and 1.5.



(a) (b)

Figure F-43: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure F-44 shows the percentage of slabs with moment ratings in each range for the IL-01 vehicle, a special permit vehicle. 75.8% of slabs have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 35.4% of slabs for the multi-trip, ADTT greater than 5,000 permit category. 85.9% of slabs have LFR ratings greater than 1.0. Approximately 10% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the single trip, escorted permit category; this increases to approximately 50% for the multi-trip, ADTT = 5,000 category.

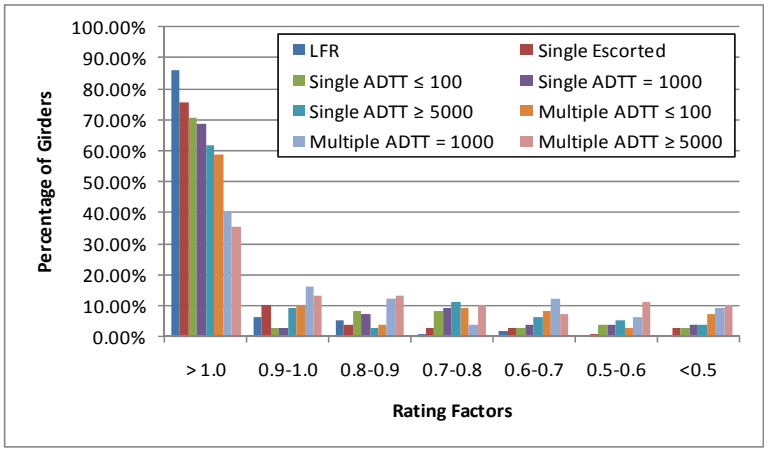


Figure F-44: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

F.1.5.1.2 Rating Factor Comparisons

Figure F-45 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.7 and 0.9. 13% of slabs have LRFR ratings exceeding the LFR rating for the same girder.

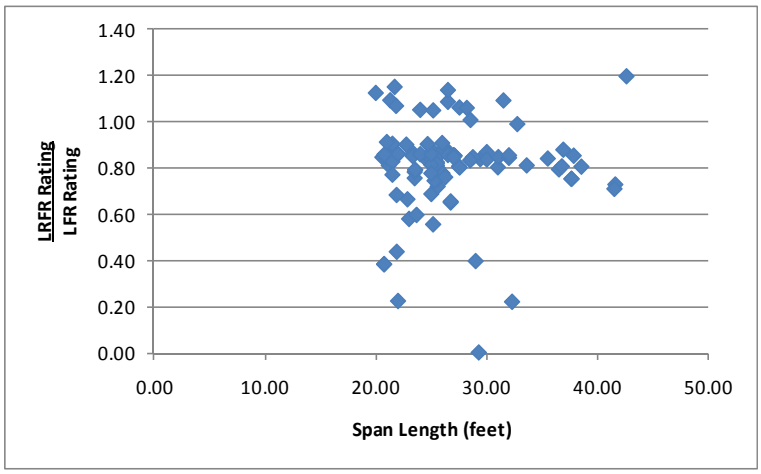


Figure F-45: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

F.1.5.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-46 shows that three of the slabs have a reliability index less than the target reliability index of 3.5. The reliability index is between four and six for most slabs.

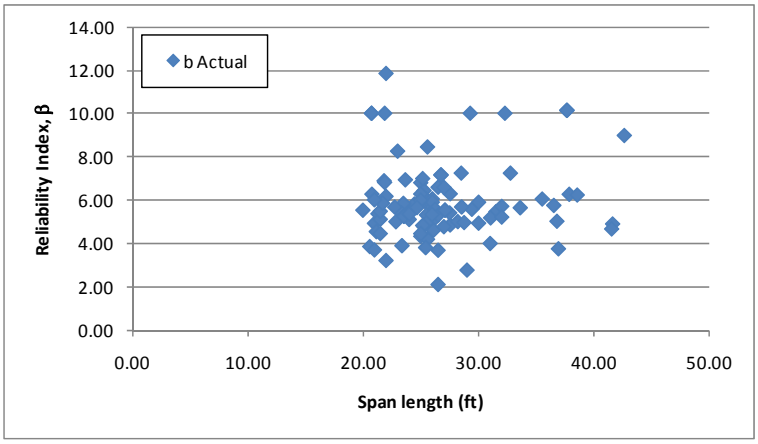


Figure F-46: Flexure Reliability Indices for IL-01 Vehicle

Figure F-47 shows the reliability index for moment plotted against the LRFR moment rating. The figure shows the reliability index increases with increasing rating factors. The estimate average reliability index for slabs with a rating of 1.0 is 5.0, above the target reliability of 3.5. This indicates that the LRFR live load factors may be overly conservative.

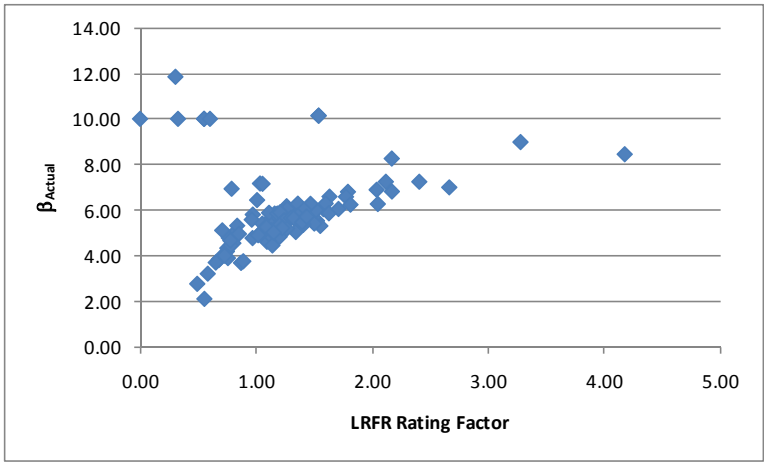
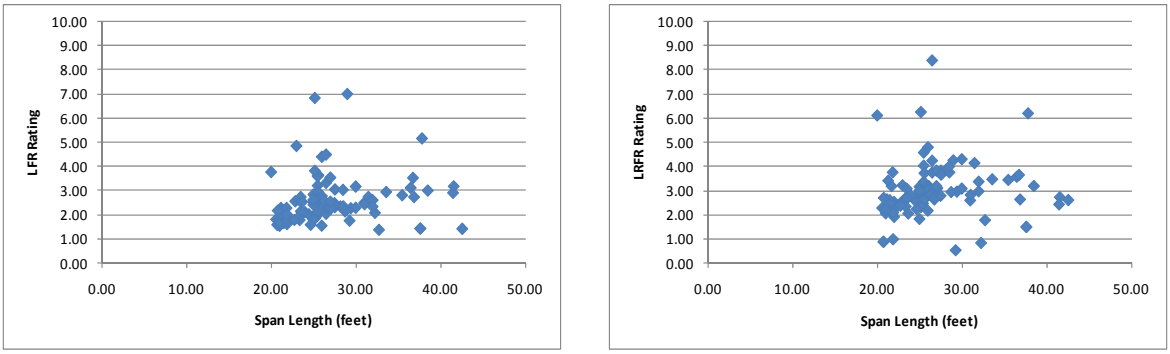


Figure F-47: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

F.1.5.2 Shear

F.1.5.2.1 Rating Factors

For shear, there are zero slabs that have LFR rating factors less than 1.0, five slabs with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 13% of the slabs in this subset. Figure F-48 show the LFR and LRFR ratings, respectively. The LFR rating is generally between 1.5 and 3.0 for all span lengths, while for LRFR rating is generally between 2.0 and 4.0. Both ratings increase with increasing span lengths. One outlier was removed from each graph with the LFR value being 17 and the LRFR value being 18.



(a) (b)

Figure F-48: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure F-49 shows the percentage of slabs with shear ratings in each range for the IL-01 vehicle, a special permit vehicle. 99% of slabs have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 95% of slabs for the multi-trip, ADTT = 5,000 permit category. 100% of slabs have LFR ratings greater than 1.0. Approximately 12% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the lowest ADTT category; this increases to approximately 21% for the highest ADTT category.

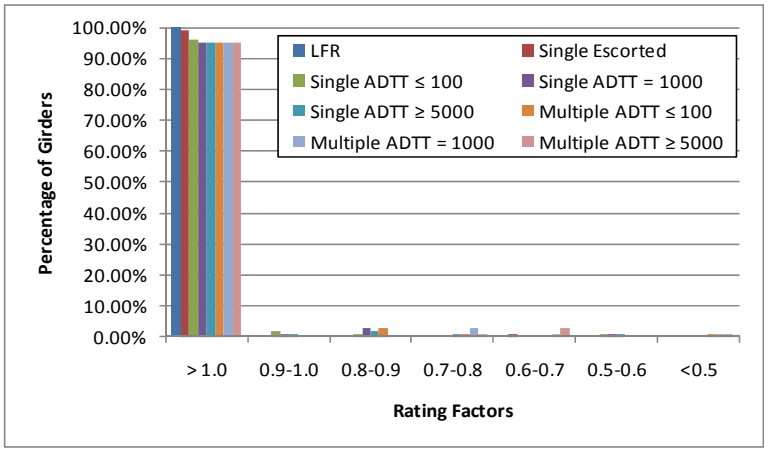


Figure F-49: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

F.1.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure F-50 shows the comparison of rating factors. The ratio is greater than 1.0 for 87% of slabs.

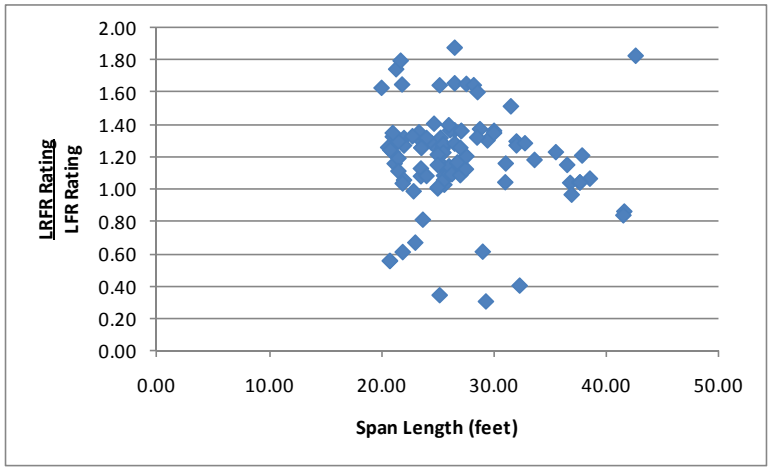


Figure F-50: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

F.1.5.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for most slabs as shown in Figure F-51. There is one slab with a reliability index less than the required. Most slabs have a reliability index between 6.5 and 7.0.

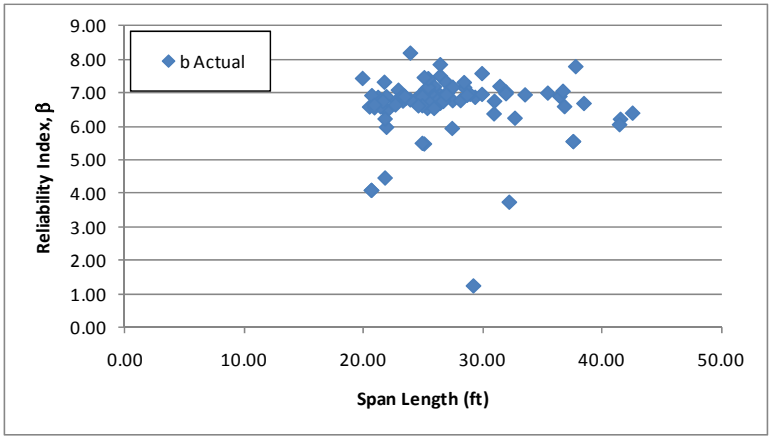


Figure F-51: Shear Reliability Indices for IL-01 Vehicle

Figure F-52 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 vehicle. The figure shows the reliability index increases with increasing ratings. The reliability index for a girder with a rating of one is approximately four, similar to the target reliability index.

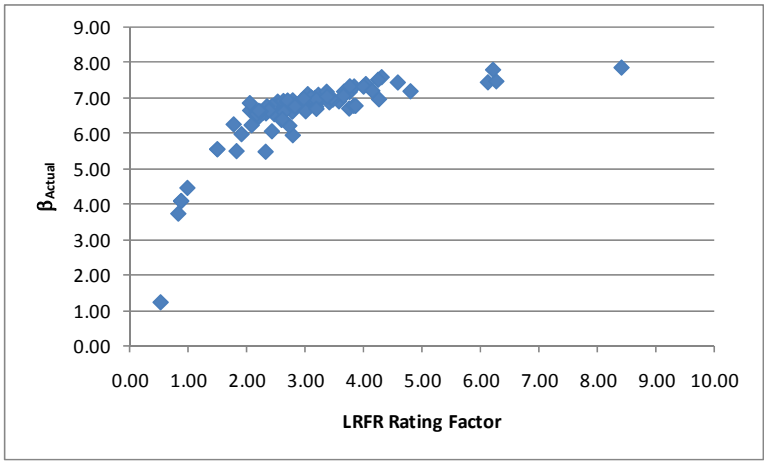


Figure F-52: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

F.1.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-53. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

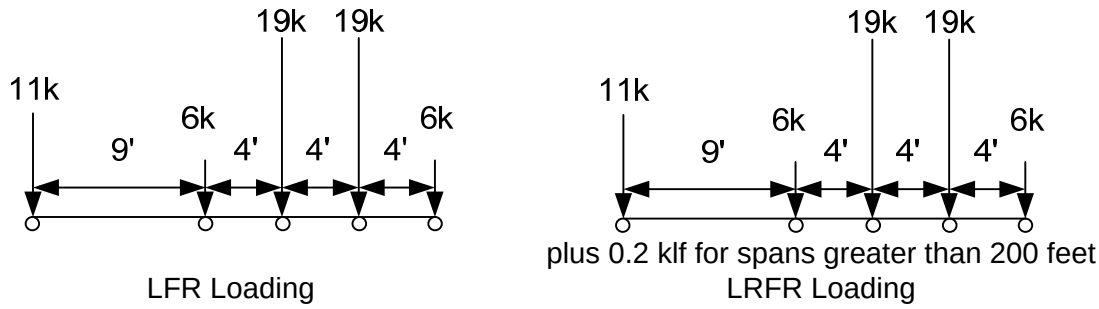


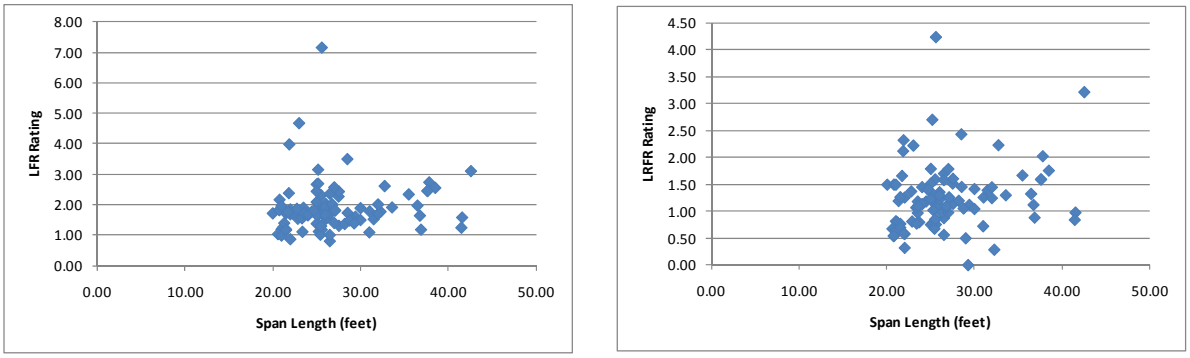
Figure F-53: Vehicle Loadings and Load Factors

F.1.6.1 Moment

The following section contains the results for reinforced concrete slabs within simple span bridges for the NC-21 Vehicle.

F.1.6.1.1 Rating Factors

Figure F-54 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are five slabs with an LFR rating less than 1.0, 32 slabs with an LRFR rating less than 1.0, and five slabs where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 99% of the slabs in this subset. The LFR rating is between one and two for most slabs while the LRFR ratings are shifted down and between 0.5 and 1.5 for most slabs.



(a) (b)

Figure F-54: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure F-55 shows the percentage of slabs with moment ratings in each range for the NC-21 vehicle, a routine permit vehicle. 72.7% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 55.6% of slabs for the highest LRFR ADTT category. 95% of slabs have LFR ratings greater than 1.0. Approximately 22% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the lowest ADTT category; this increases to approximately 40% for the highest ADTT category.

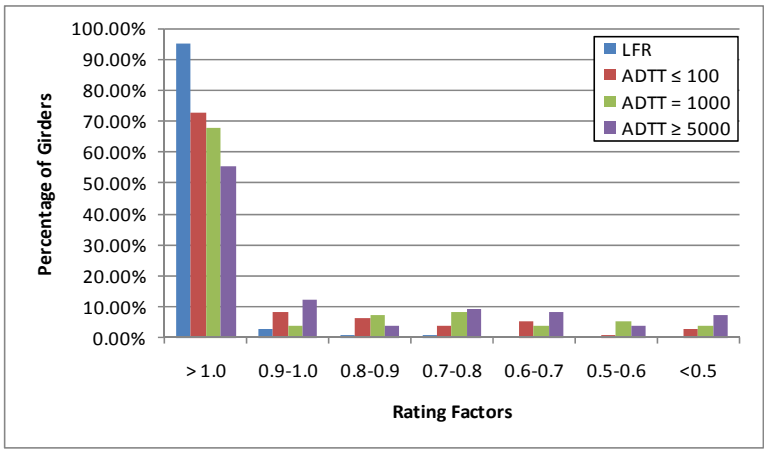


Figure F-55: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

F.1.6.1.2 Rating Factor Comparisons

Figure F-56 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8 for this vehicle with one girder having an LRFR rating that is greater than the LFR rating.

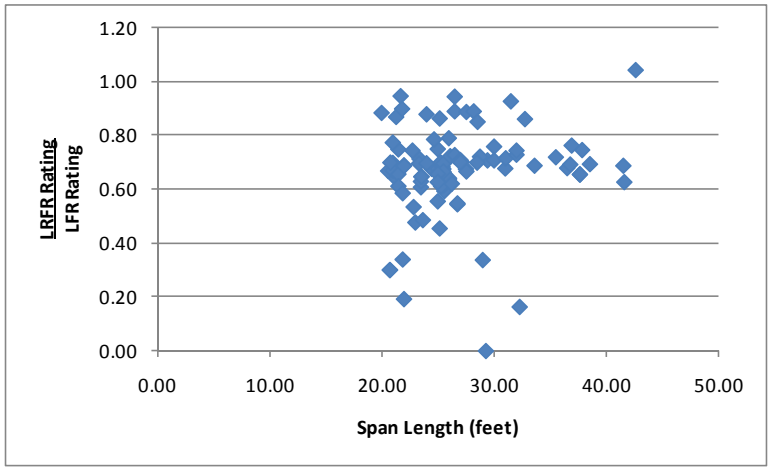


Figure F-56: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

F.1.6.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-57 shows that one slab has a reliability index less than the target reliability index of 2.5. The reliability index is between four and six for most slabs.

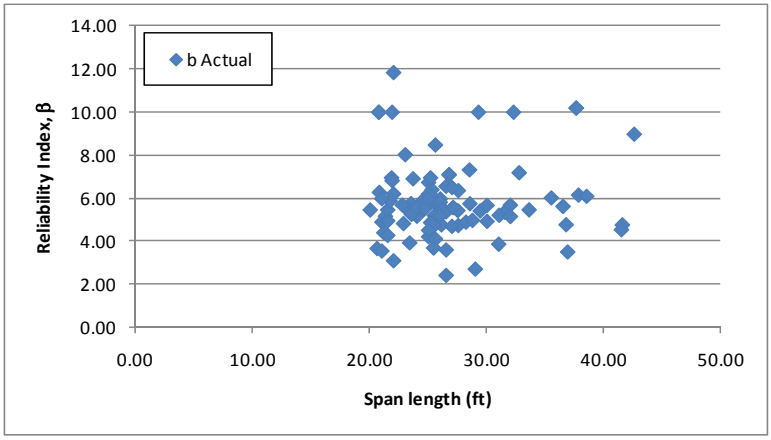


Figure F-57: Flexure Reliability Indices for NC-21 Vehicle

Figure F-58 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 vehicle. The reliability index increases as the LRFR rating increases. The average reliability index for a girder with an LRFR rating of one is approximately five, exceeding the target reliability of 2.5. This indicates that the LRFR live load factors may be over-conservative.

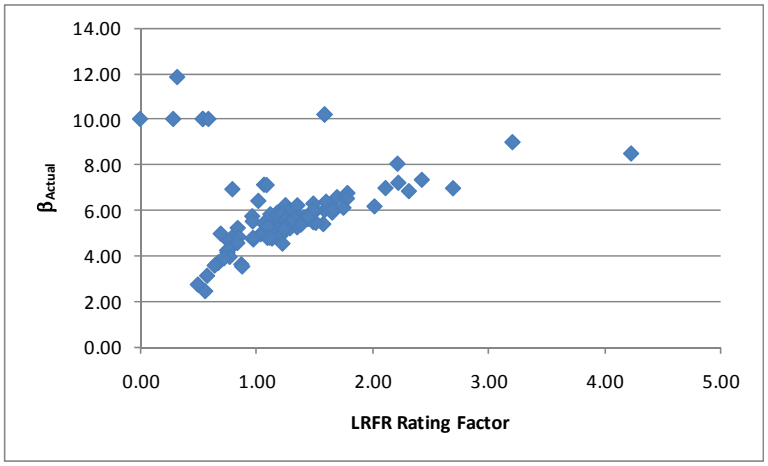
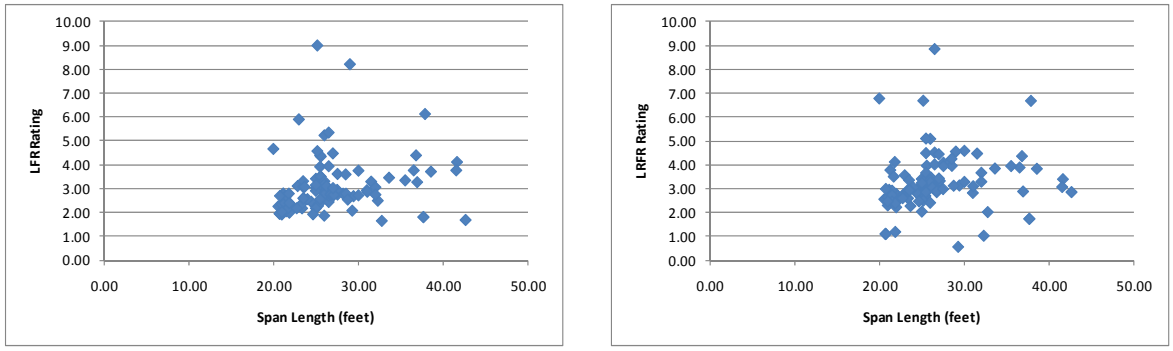


Figure F-58: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

F.1.6.2 Shear

F.1.6.2.1 Rating Factors

For shear, there are zero slabs that have LFR rating factors less than 1.0, one slab with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 29% of the slabs in this subset. Figure F-59 shows the LFR and LRFR ratings. Both ratings are between two and four for most slabs. One outlier was removed from each graph with the LFR value being 20 and the LRFR value being 19.



(a) (b)

Figure F-59: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure F-60 shows the percentage of slabs with shear ratings in each range for the NC-21 vehicle, a routine permit vehicle. 99% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 96% of slabs for the highest LRFR ADTT category. 100% of slabs have LFR ratings greater than 1.0. Very few slabs are affected by the switch from LFR to LRFR for shear in concrete slab bridges.

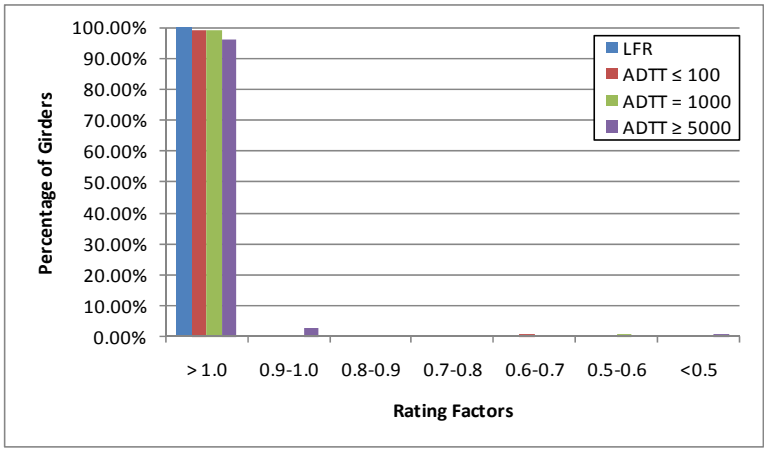


Figure F-60: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

F.1.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure F-61 shows the comparison of rating factors. The ratio is generally between 0.9 and 1.2. 71% of the concrete slabs have higher LRFR ratings than LFR ratings.

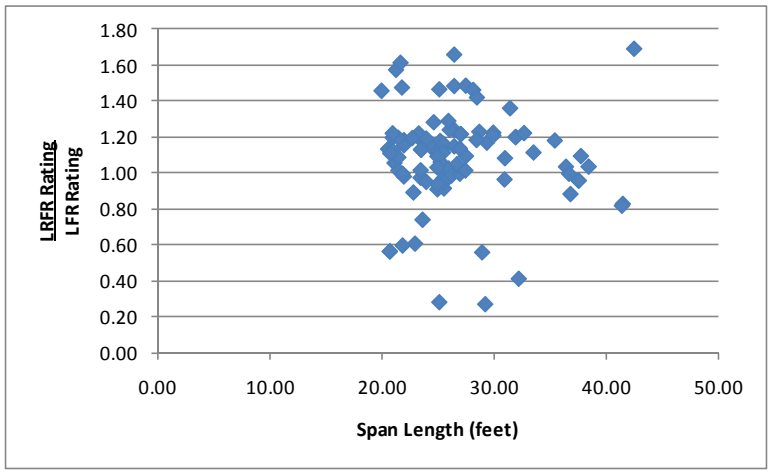


Figure F-61: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

F.1.6.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is greater than the target reliability index for all but one slab as shown in Figure F-62. The reliability index is between 6.5 and 7.5 for most slabs.

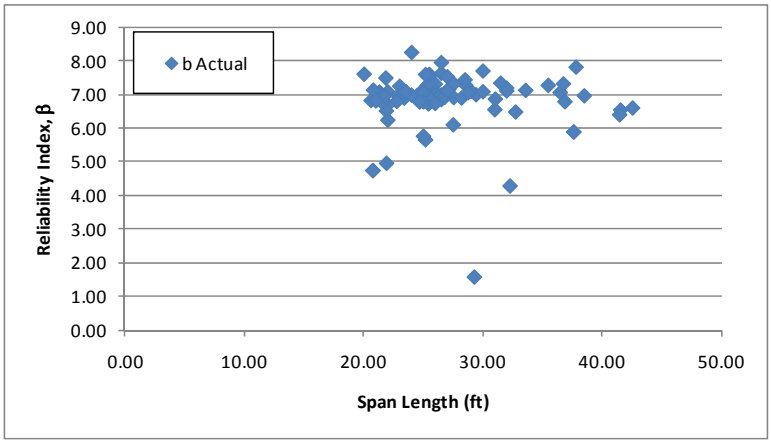


Figure F-62: Shear Reliability Indices for NC-21 Vehicle

Figure F-63 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 vehicle. The reliability index increases with increasing ratings. The reliability index corresponding to a rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This indicates that the LRFR live load factors may be over-conservative.

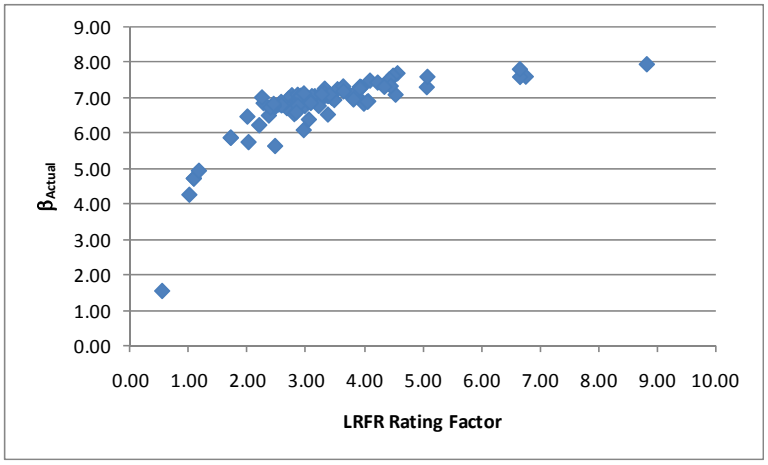


Figure F-63: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

F.1.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-64. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

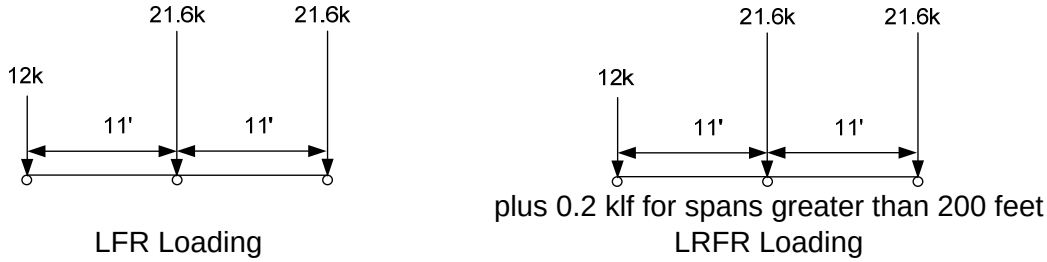


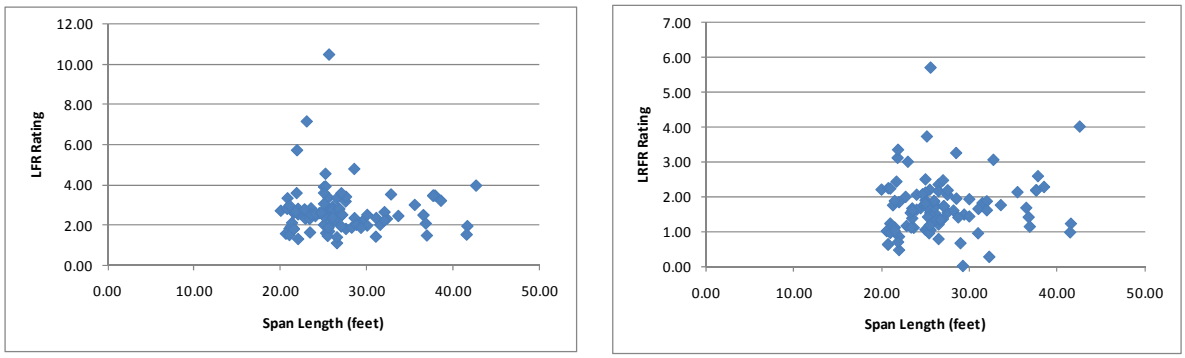
Figure F-64: Vehicle Loadings and Load Factors

F.1.7.1 Moment

The following section contains the results for reinforced concrete slabs within simple span bridges for the NM-04 Vehicle.

F.1.7.1.1 Rating Factors

Figure F-65 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero slabs with an LFR rating less than 1.0, 13 slabs with an LRFR rating less than 1.0, and zero slabs where both ratings are less than 1.0. All slabs with LRFR ratings less than one are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 99% of the slabs in this subset. The LFR ratings are generally between one and three while the LRFR ratings are typically between one and two.



(a) (b)

Figure F-65: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure F-66 shows the percentage of slabs with moment ratings in each range for the NM-04 vehicle, a routine permit vehicle. 90.9% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 78.8% of slabs for the highest LRFR ADTT category. 100% of slabs have LFR ratings greater than 1.0. Approximately 10% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the lowest ADTT category; this increases to approximately 22% for the highest ADTT category.

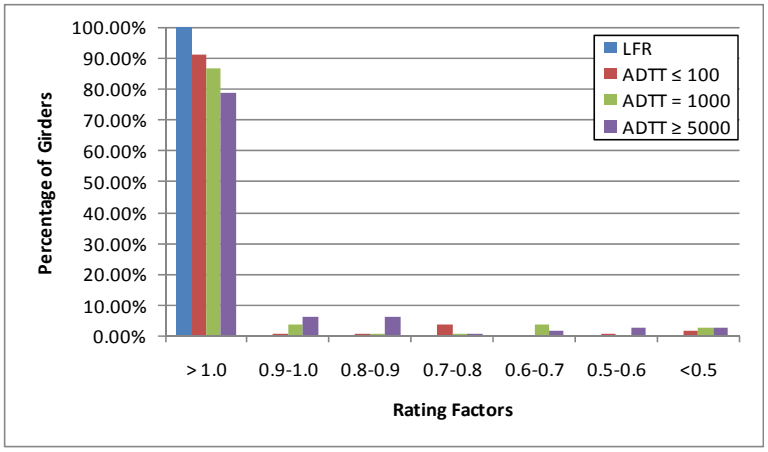


Figure F-66: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

F.1.7.1.2 Rating Factor Comparisons

Figure F-67 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8, with one slab having an LRFR rating greater than the associated LFR rating.

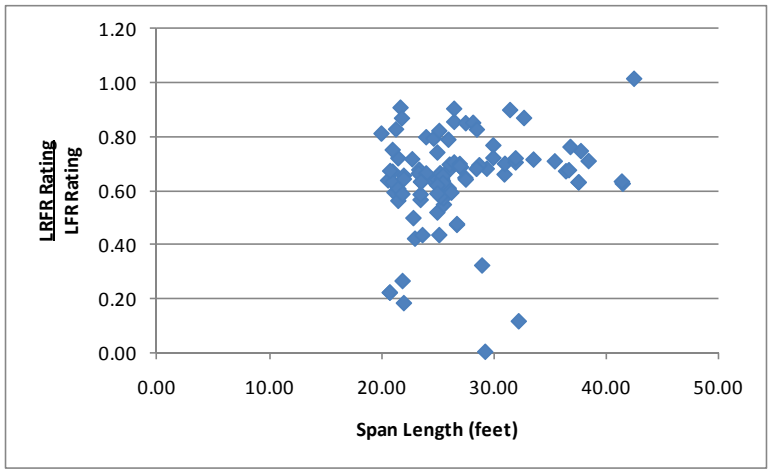


Figure F-67: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

F.1.7.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-68 shows that no slabs have a reliability index less than the target reliability index of 2.5. The figure shows that most slabs have a reliability index between five and eight.

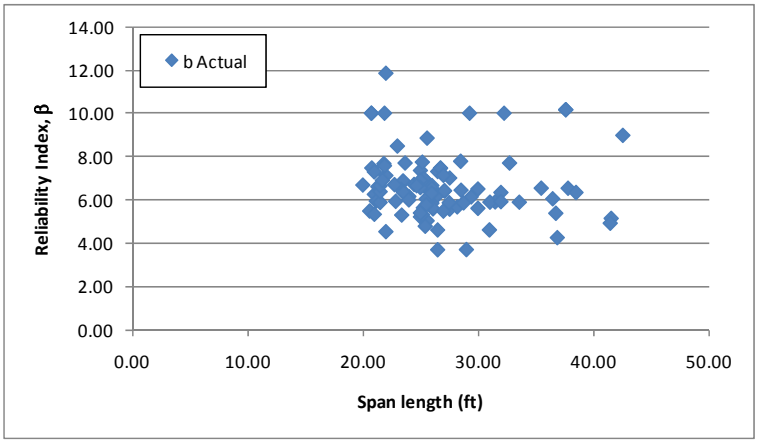


Figure F-68: Flexure Reliability Indices for NM-04 Vehicle

Figure F-69 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The figure shows that the reliability increases with increasing rating factors. The reliability index associated with a girder rating 1.0 is approximately five, higher than the target reliability of 2.5. This indicates that the live load factors in the MBE may be over-conservative.

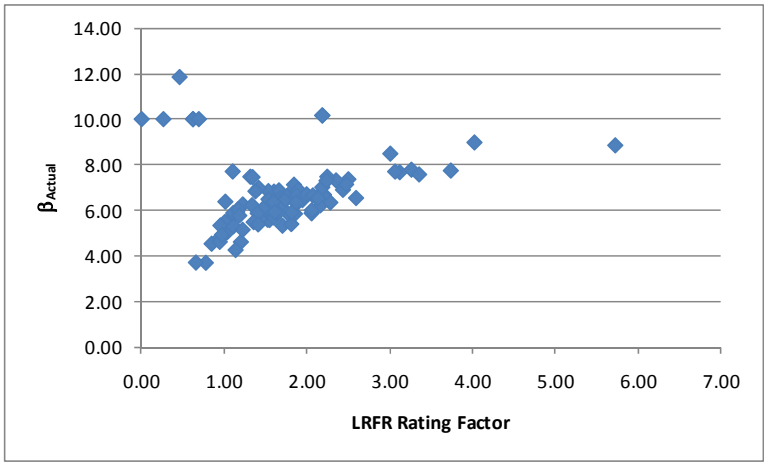
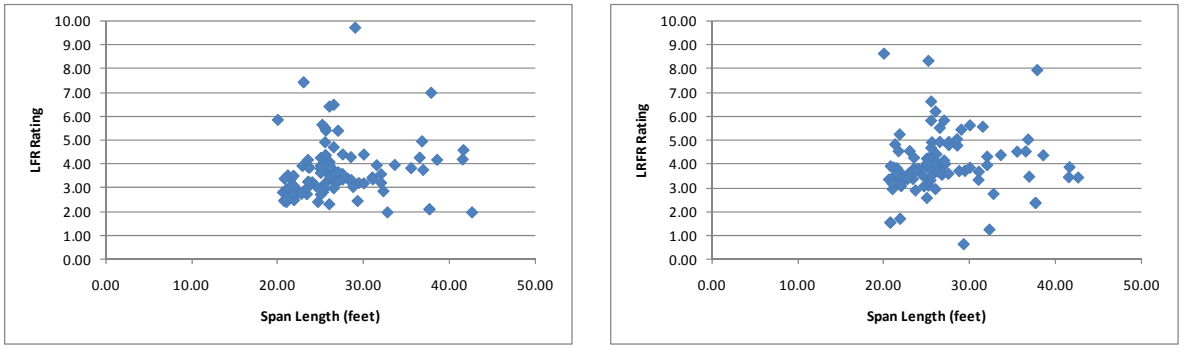


Figure F-69: Flexure Reliability Index vs LRFR Flexure Rating Factor for NM-04 Vehicle

F.1.7.2 Shear

F.1.7.2.1 Rating Factors

For shear, there are zero slabs that have an LFR rating factor less than 1.0, one slab with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 23% of the slabs in this subset. Figure F-70 shows the LFR and LRFR ratings. The LFR rating is typically between two and four while the LRFR rating is typically between three and five. Two outliers were removed from each graph with the LFR values being 11 and 25 and the LRFR values being 11 and 23.



(a) (b)

Figure F-70: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure F-71 shows the percentage of slabs with shear ratings in each range for the NM-04 vehicle, a routine permit vehicle. 99% of slabs have LRFR ratings greater than 1.0 for all ADTT categories. All slabs have LFR ratings that are greater than 1.0. Shear ratings are not significantly affected by the switch to LRFR nor by the varying load factors depending on ADTT.

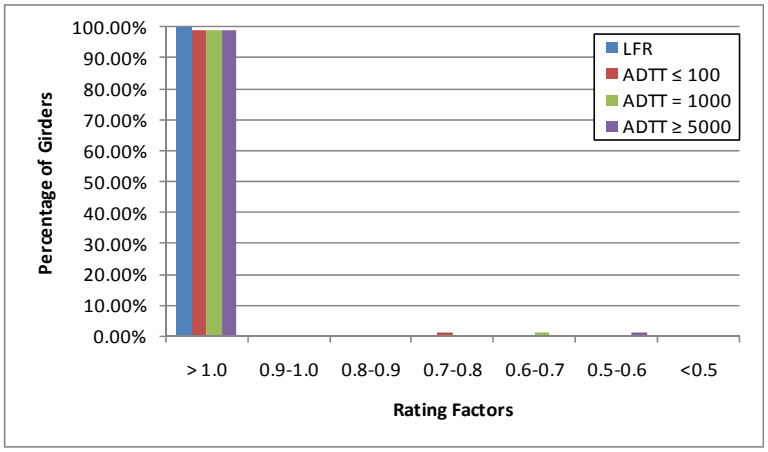


Figure F-71: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

F.1.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure F-72 shows the comparison of rating factors. The ratio is generally between 0.9 and 1.3. The LRFR ratings are greater than the LFR rating for 77% of the slabs.

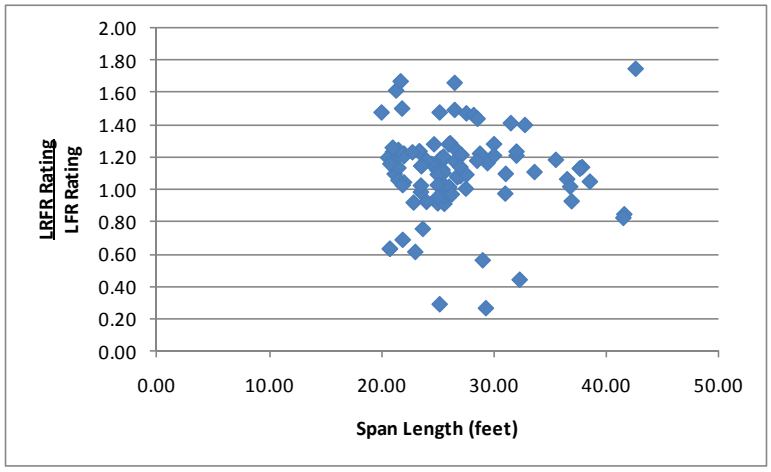


Figure F-72: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

F.1.7.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but one slab as shown in Figure F-73. The reliability index for most slabs was above seven.

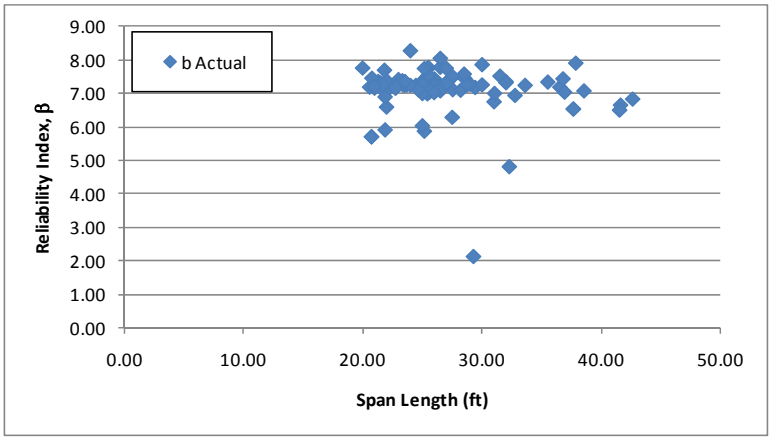


Figure F-73: Shear Reliability Indices for NM-04 Vehicle

Figure F-74 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. The reliability index increases as the rating increases. The reliability index corresponding to a rating of 1.0 is approximately 4.0, above the target of 2.5. This indicates the LRFR live load factors may be over-conservative.

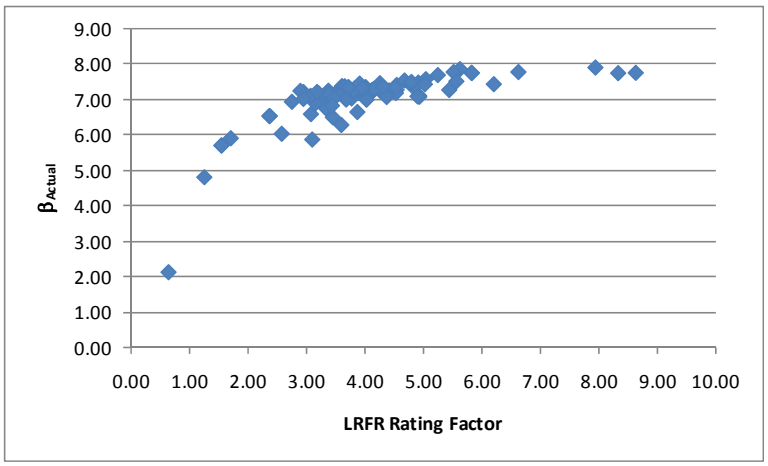
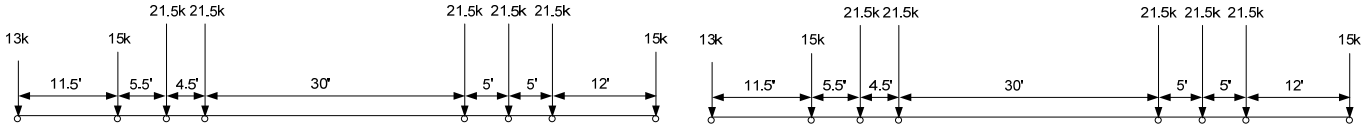


Figure F-74: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

F.1.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-75. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

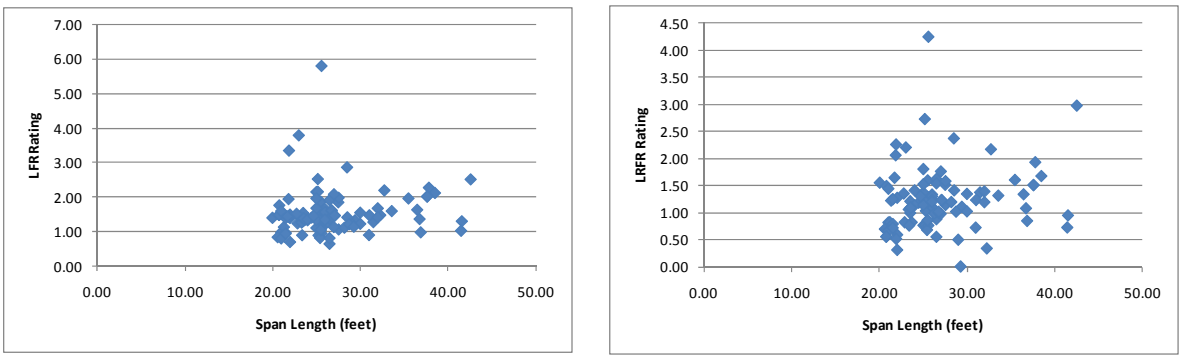
Figure F-75: Vehicle Loadings and Load Factors

F.1.8.1 Moment

The following section contains the results for reinforced concrete slabs within simple span bridges for the OR-06 Vehicle.

F.1.8.1.1 Rating Factors

Figure F-76 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 14 slabs with an LFR rating less than 1.0, 33 slabs with an LRFR rating less than 1.0, and 14 slabs where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 87% of the slabs in this subset. The LFR ratings are between one and two while the LRFR ratings between 0.5 and 1.5 for most slabs.



(a) (b)

Figure F-76: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure F-77 shows the percentage of slabs with moment ratings in each range for the OR-06 vehicle, a special permit vehicle. 75.8% of slabs have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 34.3% of slabs for the multi-trip, ADTT = 5,000 permit category. 85.9% of slabs have LFR ratings greater than 1.0. Approximately 10% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the single trip, escorted permit category; this increases to approximately 50% for the multi-trip, ADTT greater than 5,000 permit category.

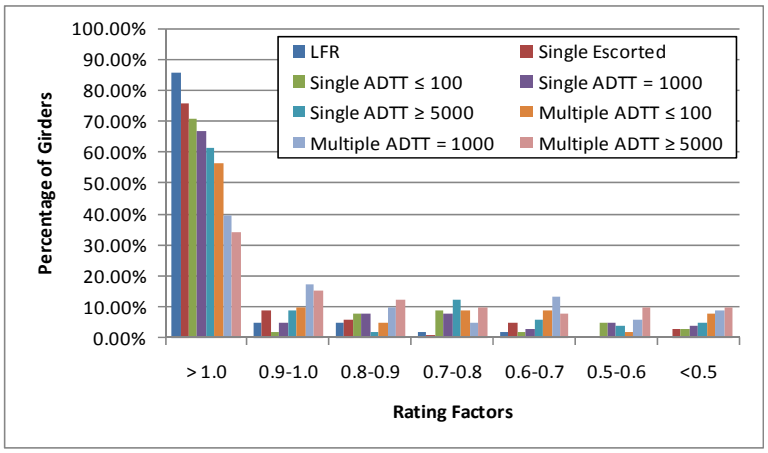


Figure F-77: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

F.1.8.1.2 Rating Factor Comparisons

Figure F-78 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.8 and 0.9, with shorter spans tending to have larger ratios. 13% of slabs have LRFR ratings that exceed the LFR rating.

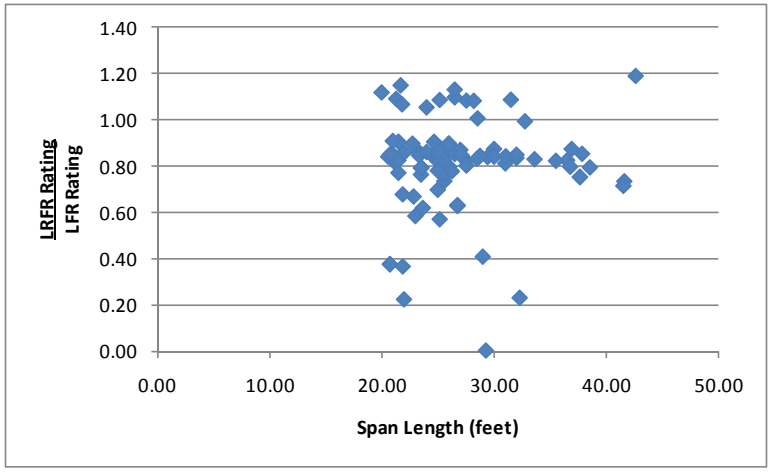


Figure F-78: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

F.1.8.1.3 Reliability Indices

The reliability index was calculated for these slabs. Figure F-79 shows that one slab has a reliability index based less than the target reliability index of 3.5. The reliability index for most slabs is between four and seven.

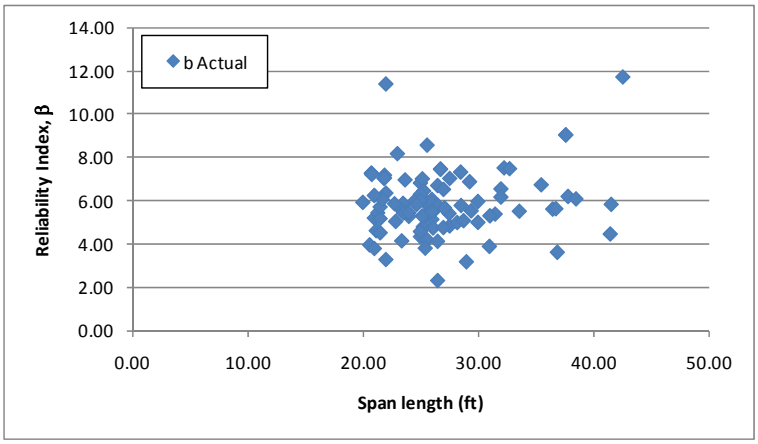


Figure F-79: Flexure Reliability Indices for OR-06 Vehicle

Figure F-80 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 vehicle. The reliability index increases with increasing rating factors. The reliability index corresponding to a rating of 1.0 is approximately five, above the target reliability of 3.5. This indicates that the live load factors in the MBE may be over-conservative.

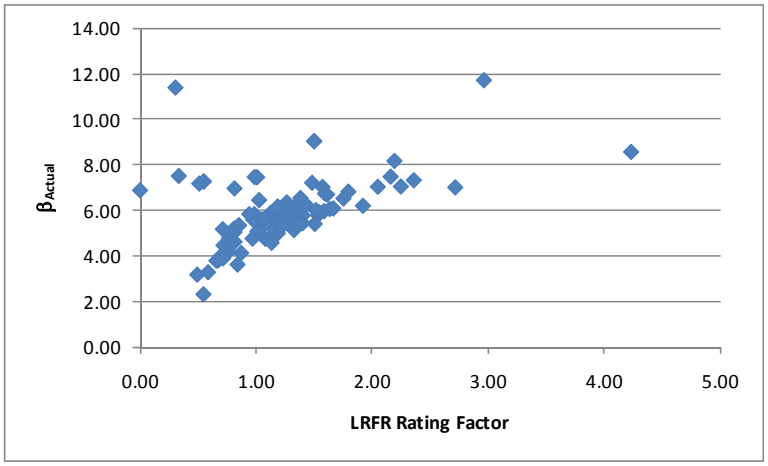
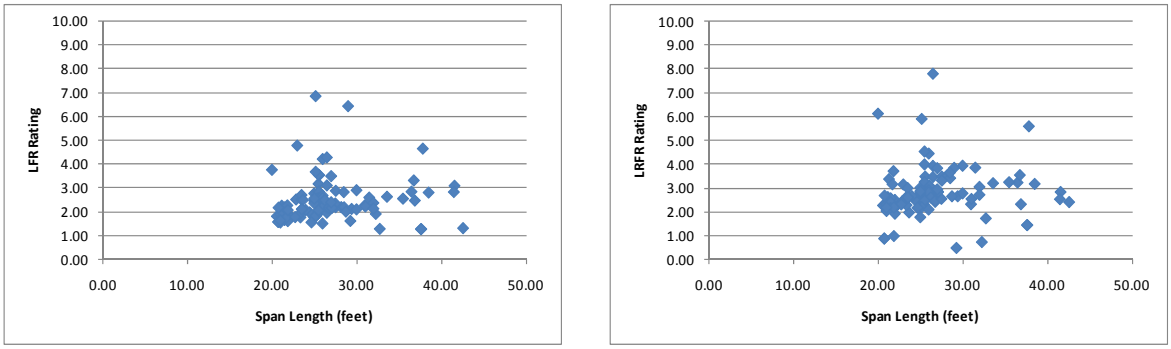


Figure F-80: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

F.1.8.2 Shear

F.1.8.2.1 Rating Factors

For shear, there are zero slabs that have LFR rating factors less than 1.0, five slabs have LRFR ratings less than 1.0, and zero slabs have both ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 16% of the slabs in this subset. Figure F-81 shows the LFR and LRFR ratings. Both ratings are generally between 2.0 and 4.0. One outlier was removed from each graph with the LFR value being 16 and the LRFR value being 17.



(a) (b)

Figure F-81: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure F-82 shows the percentage of slabs with shear ratings in each range for the OR-06 vehicle, a special permit vehicle. 98% of slabs have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 95% of slabs for the multi-trip, ADTT greater than 5,000 permit category. 100% of slabs have LFR ratings greater than 1.0. Most slabs are not affected by the switch from LFR to LRFR as only 5% of slabs have ratings less than 1.0 for the multi-trip, ADTT greater than 5,000 permit category.

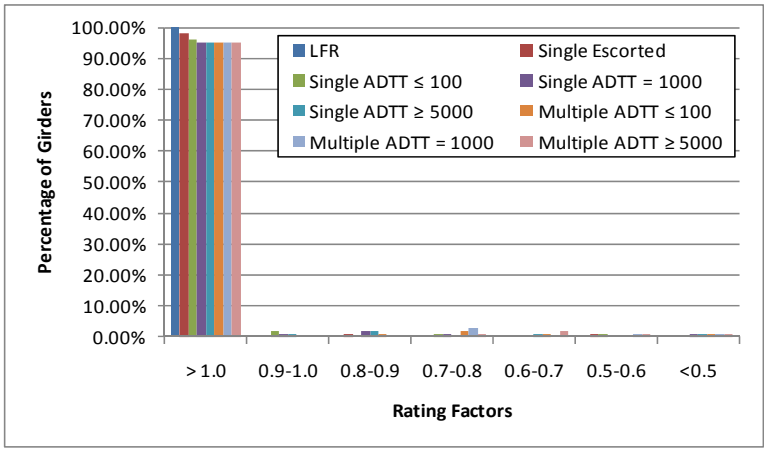


Figure F-82: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

F.1.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure F-83 shows the comparison of rating factors. The ratio is generally between 1.0 and 1.4 for this set of slabs with this vehicle. Shorter spans are more likely to have LRFR ratings greater than LFR rating. 84% of the slabs have an LRFR rating that is greater than the LFR rating.

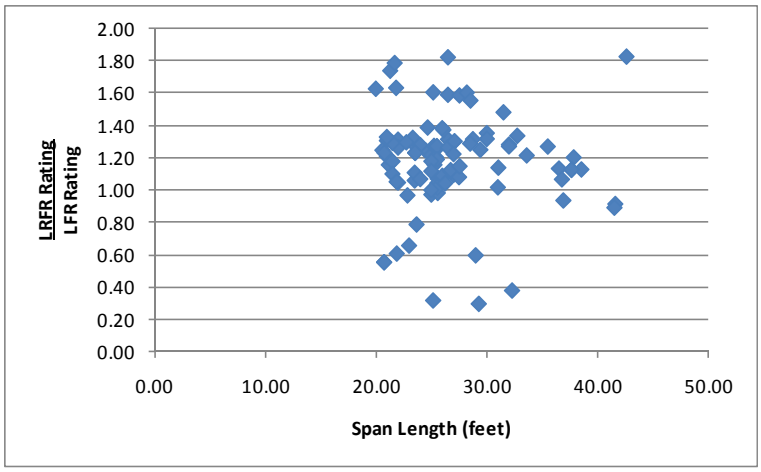


Figure F-83: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

F.1.8.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is greater than the target reliability index of 3.5 for all but two slabs as shown in Figure F-84. The reliability index for most slabs is between 6.5 and 7.0.

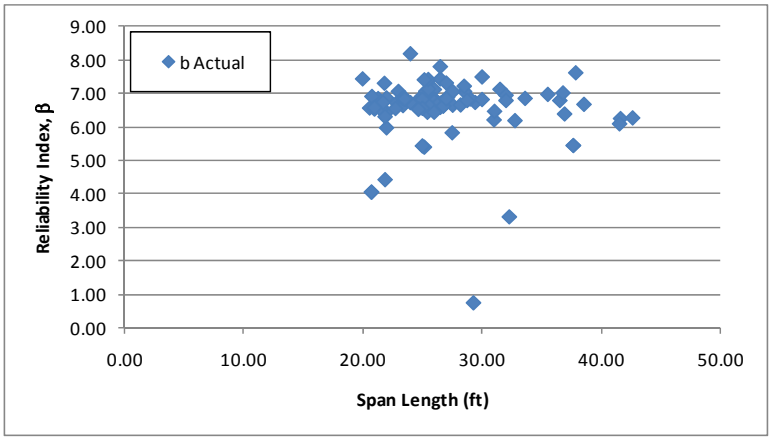


Figure F-84: Shear Reliability Indices for OR-06 Vehicle

Figure F-85 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 Vehicle. The reliability index increases with increasing ratings. The reliability index corresponding to an LRFR rating of 1.0 is approximately 4.5, exceeding the target reliability of 3.5.

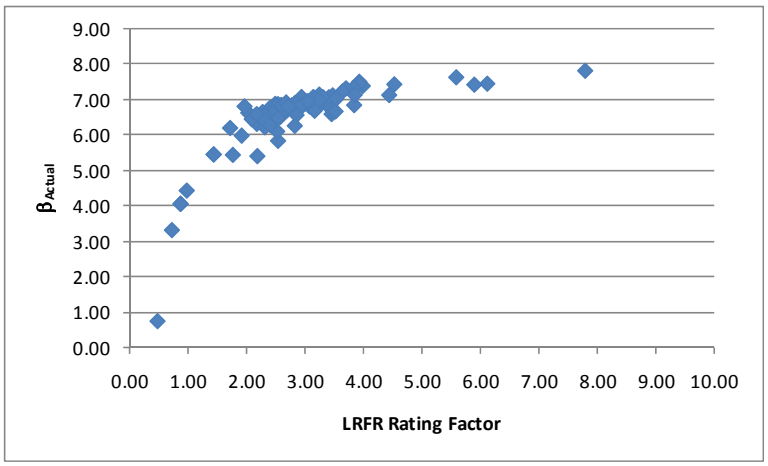
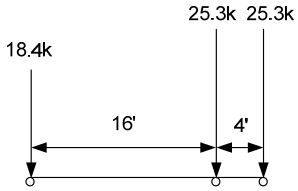


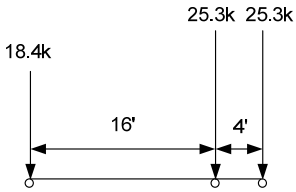
Figure F-85: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

F.1.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-86. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet

LRFR Loading

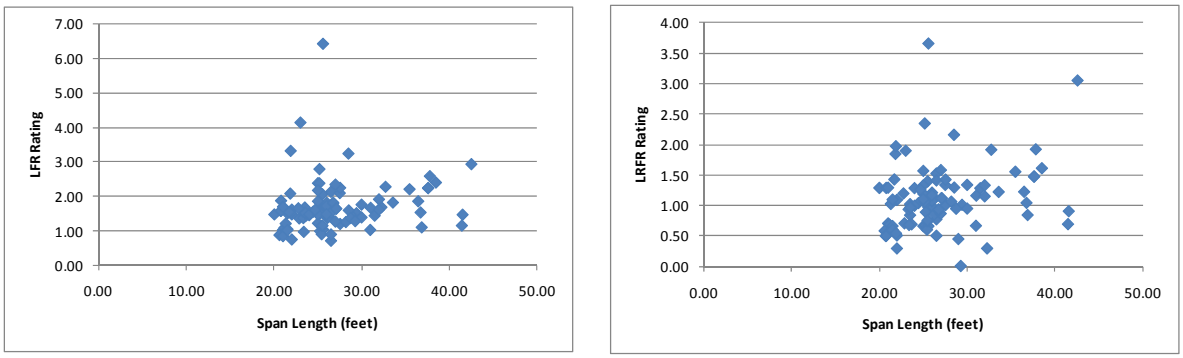
Figure F-86: Vehicle Loadings and Load Factors

F.1.9.1 Moment

The following section contains the results for reinforced concrete slabs within simple span bridges for the TX-04 Vehicle.

F.1.9.1.1 Rating Factors

Figure F-87 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are eight slabs with an LFR rating less than 1.0, 43 slabs with an LRFR rating less than 1.0, and eight slabs where both ratings are less than 1.0. 42 of the 43 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 99% of the slabs. The LFR ratings are generally between 1.0 and 2.0 for all spans while the LRFR ratings shift down and are between 0.5 and 1.5 for most slabs.



(a) (b)

Figure F-87: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure F-88 shows the percentage of slabs with moment ratings in each range for the TX-04 vehicle, a routine permit vehicle. 68.7% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 39.4% of slabs for the highest LRFR ADTT category. 91.9% of slabs have LFR ratings greater than 1.0. Approximately 22% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the lowest ADTT category; this increases to approximately 50% for the highest ADTT category.

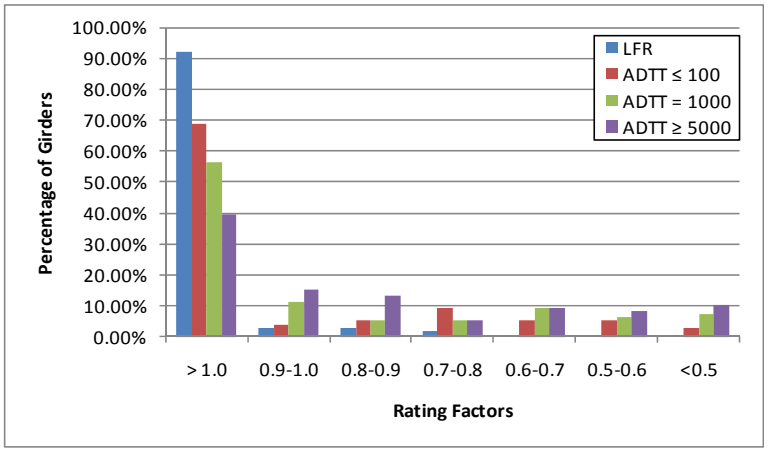


Figure F-88: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

F.1.9.1.2 Rating Factor Comparisons

Figure F-89 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is typically 60 to 70% of the LFR rating. One girder has an LRFR rating that is greater than the LFR rating.

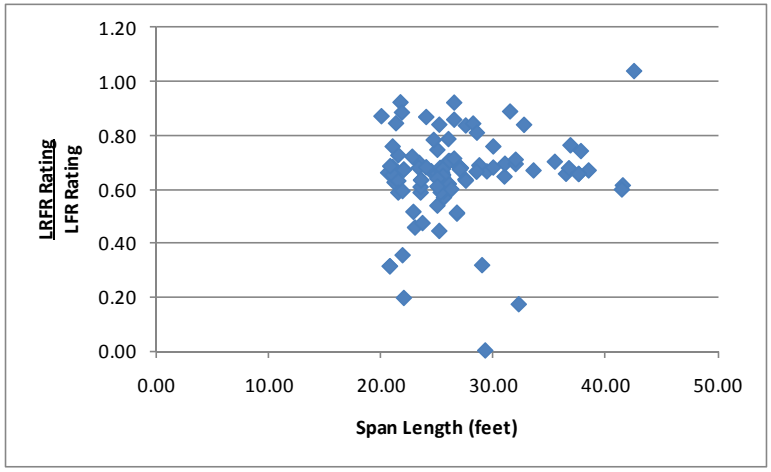


Figure F-89: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

F.1.9.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-90 shows two slabs that have a reliability index based less than the target reliability index of 2.5. The reliability index for most slabs is between four and six.

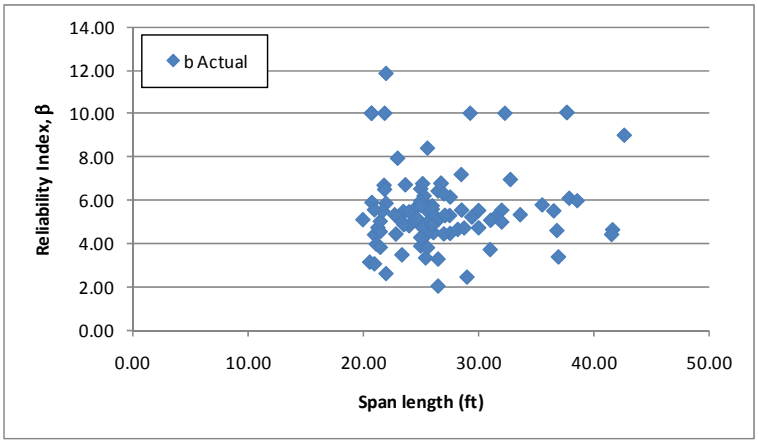


Figure F-90: Flexure Reliability Indices for TX-04 Vehicle

Figure F-91 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The reliability increases with an increase in rating. The reliability index corresponding to an LRFR rating of 1.0 is approximately 5.0, above the target reliability of 2.5. This indicates that the live load factors in the MBE may be over-conservative.

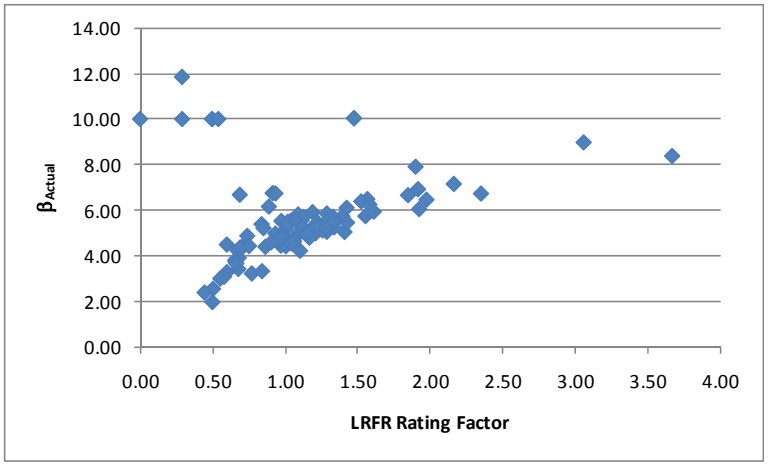
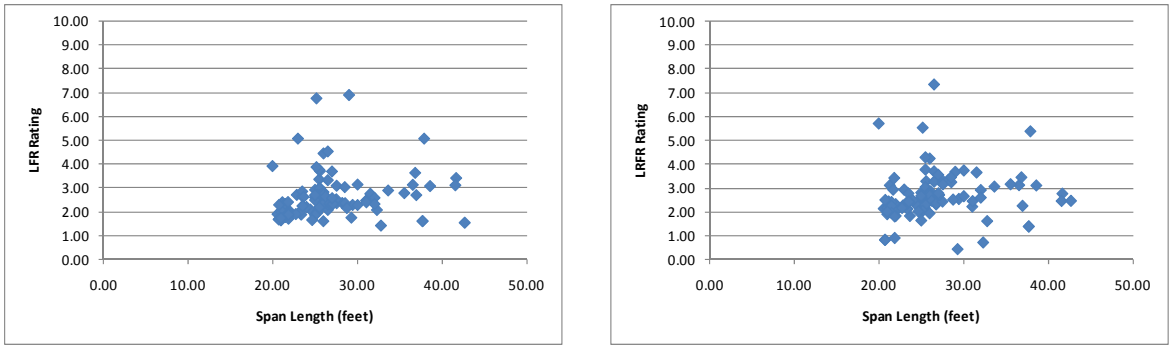


Figure F-91: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

F.1.9.2 Shear

F.1.9.2.1 Rating Factors

For shear, there are zero slabs that have LFR rating factors less than 1.0, five slabs with LRFR ratings less than 1.0 and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 36% of the slabs in this subset. Figure F-92 shows the LFR and LRFR ratings. The LFR ratings are generally between 1.5 and 3.0 while the LRFR ratings are between 2.0 and 4.0. One outlier was removed from each graph with the LFR value being 17 and the LRFR value being 16.



(a) (b)

Figure F-92: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure F-93 shows the percentage of slabs with shear ratings in each range for the TX-04 vehicle, a routine permit vehicle. 96% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 95% of slabs for the highest LRFR ADTT category. 100% of slabs have LFR ratings greater than 1.0. Few slabs are affected by the switch from LFR to LRFR as for the highest ADTT category has only 5% of slabs with ratings less than 1.0.

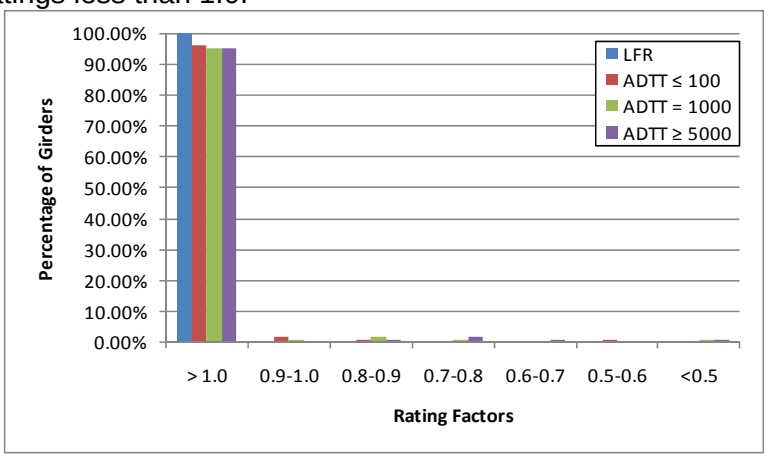


Figure F-93: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

F.1.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure F-94 shows the comparison of rating factors. The ratio is generally between 0.9 and 1.2 for shear. 64% of slabs have an LRFR rating greater than the corresponding LFR rating.

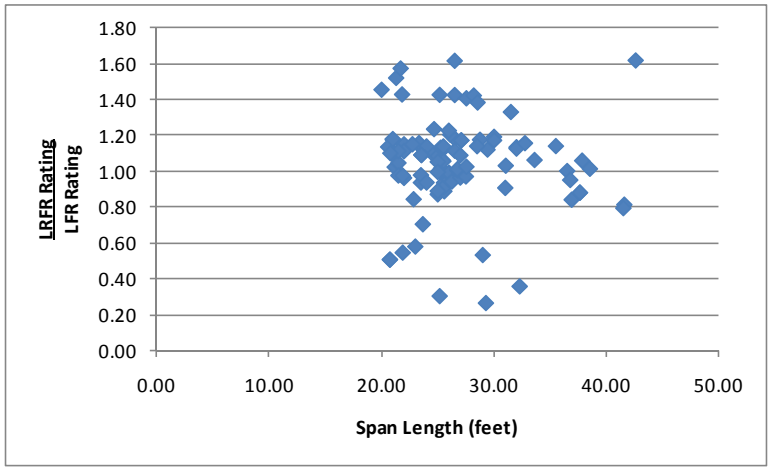


Figure F-94: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

F.1.9.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but one slab as shown in Figure F-95. The reliability index is generally between six and seven.

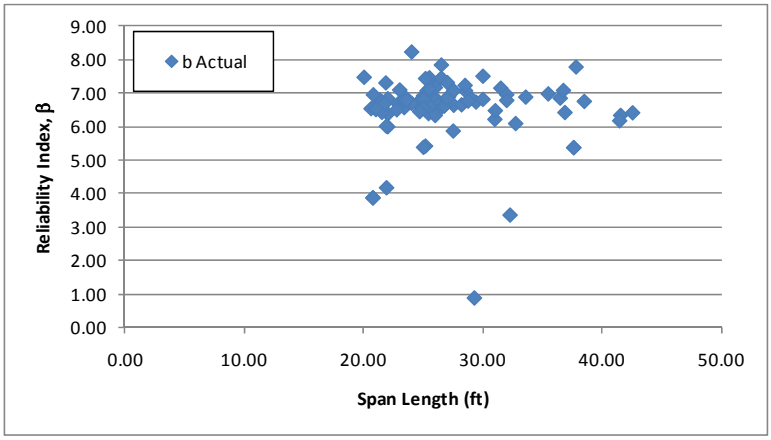


Figure F-95: Shear Reliability Indices for TX-04 Vehicle

Figure F-96 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The reliability index increases with increasing LRFR ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 4.5, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

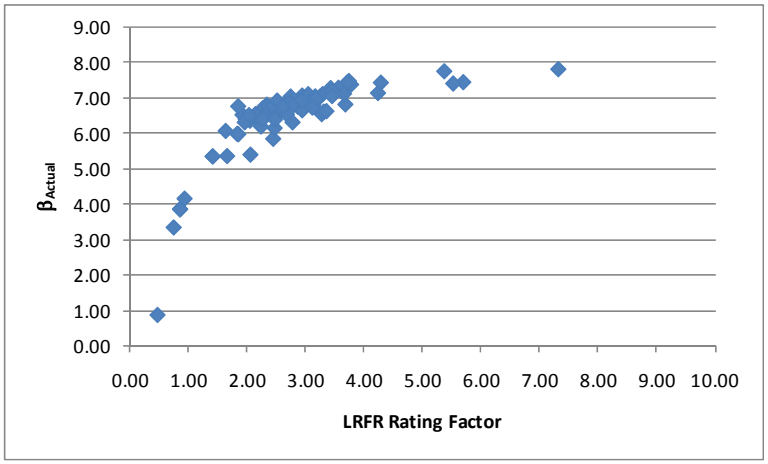
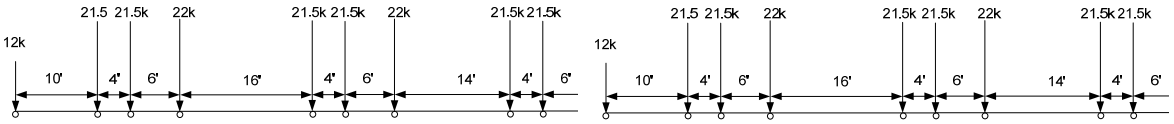


Figure F-96: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

F.1.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-97. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

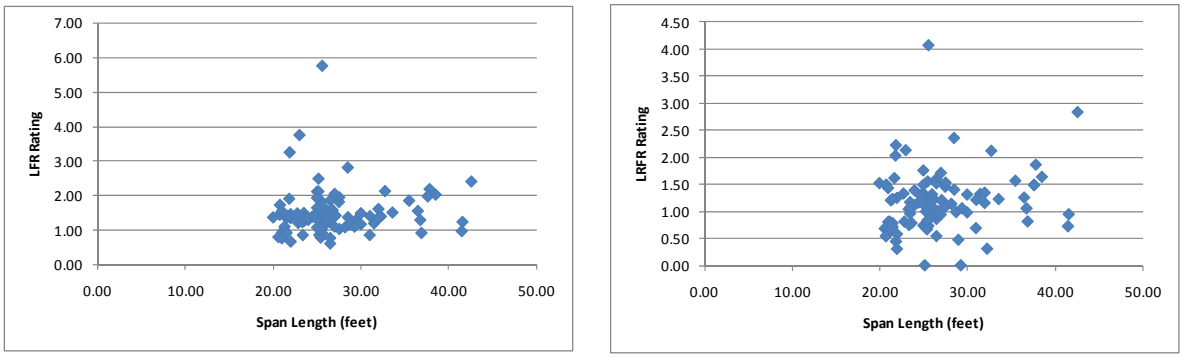
Figure F-97: Vehicle Loadings and Load Factors

F.1.10.1 Moment

The following section contains the results for reinforced concrete slabs within simple span bridges for the WA-02 Vehicle.

F.1.10.1.1 Rating Factors

Figure F-98 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 16 slabs with an LFR rating less than 1.0, 37 slabs with an LRFR rating less than 1.0, and 16 slabs where both ratings are less than 1.0. 35 of the 37 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 88% of the slabs in this subset. The rating is generally between 0.5 and 2.0 for both methods.



(a) (b)

Figure F-98: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure F-99 shows the percentage of slabs with moment ratings in each range for the WA-02 vehicle, a special permit vehicle. 73.7% of slabs have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 29.3% of slabs for the multi-trip, ADTT greater than 5,000 category. 83.8% of slabs have LFR ratings greater than 1.0. Approximately 10% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the single trip, escorted permit category; this increases to approximately 55% for the multi-trip, ADTT greater than 5,000 category.

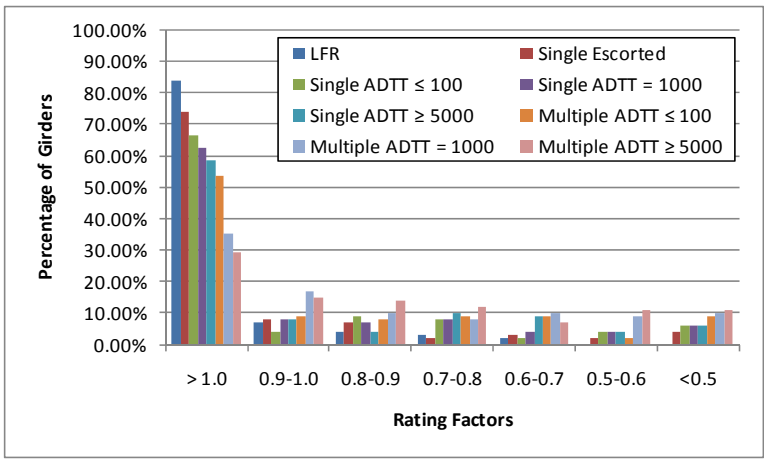


Figure F-99: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

F.1.10.1.2 Rating Factor Comparisons

Figure F-100 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.7 and 0.8, with 12% of slabs having an LRFR rating greater than the LFR rating.

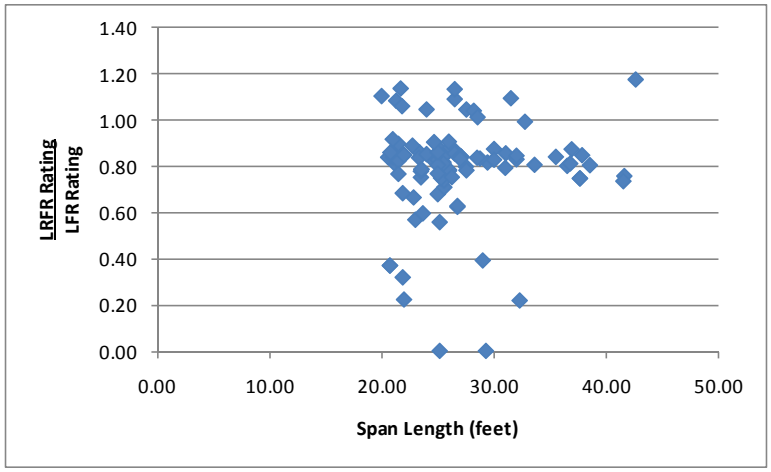


Figure F-100: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

F.1.10.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-101 shows that four slabs have a reliability index less than the target reliability index of 3.5. The reliability index is between four and six for most slabs.

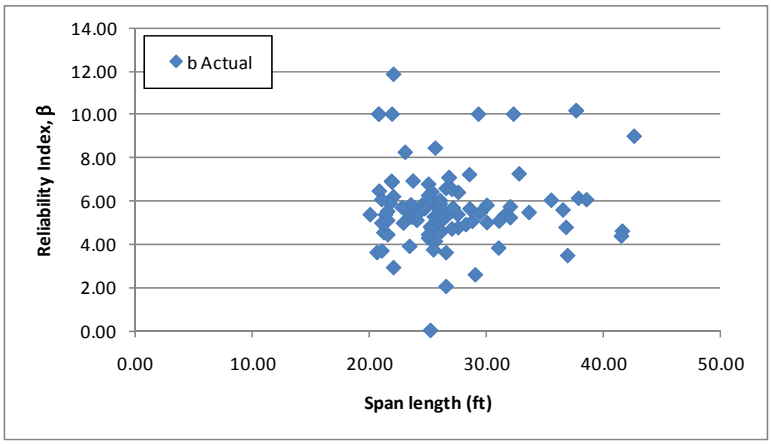


Figure F-101: Flexure Reliability Indices for WA-02 Vehicle

Figure F-102 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 Vehicle. The reliability index increases with increasing LRFR ratings. The reliability index corresponding to an LRFR rating of 1.0 is approximately 5.0, higher than the target reliability of 3.5.

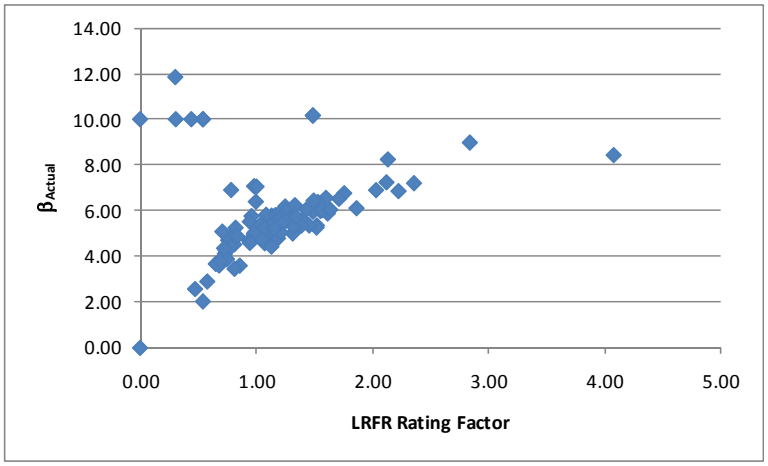
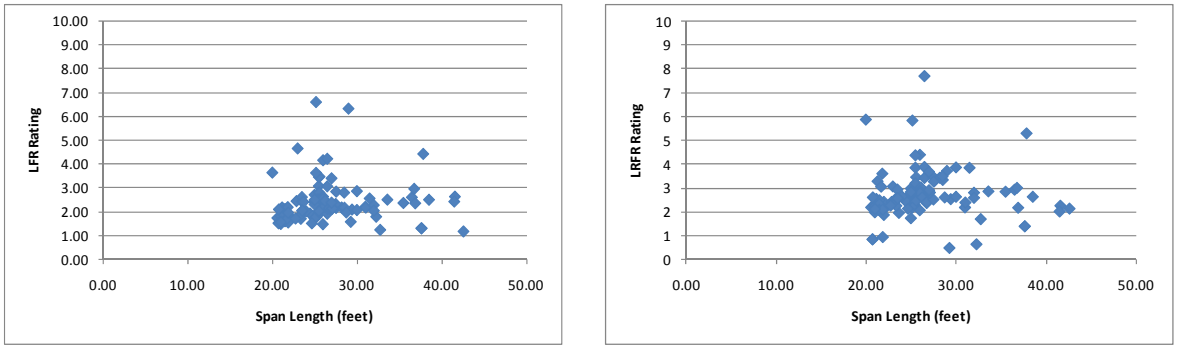


Figure F-102: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

F.1.10.2 Shear

F.1.10.2.1 Rating Factors

For shear, there are zero slabs with LFR rating factors less than 1.0, five slabs with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 17% of the slabs in this subset. Figure F-103 shows the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 3.0 with the LRFR rating between 2.0 and 4.0. One outlier was removed from each graph with the LFR value being 16 and the LRFR value being 17.



(a) (b)

Figure F-103: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure F-104 shows the percentage of slabs with shear ratings in each range for the WA-02 vehicle, a special permit vehicle. 98% of slabs have LRFR ratings greater than 1.0 for the single trip, escorted permit category. This decreases to 95% of slabs for the multi-trip, ADTT greater than 5,000 category. 100% of slabs have LFR ratings greater than 1.0. Shear ratings are not significantly affected by the switch from LFR to LRFR as shown in the graph. At most 5% of slabs will have LRFR ratings less than 1.0 that had an LFR rating greater than 1.0.

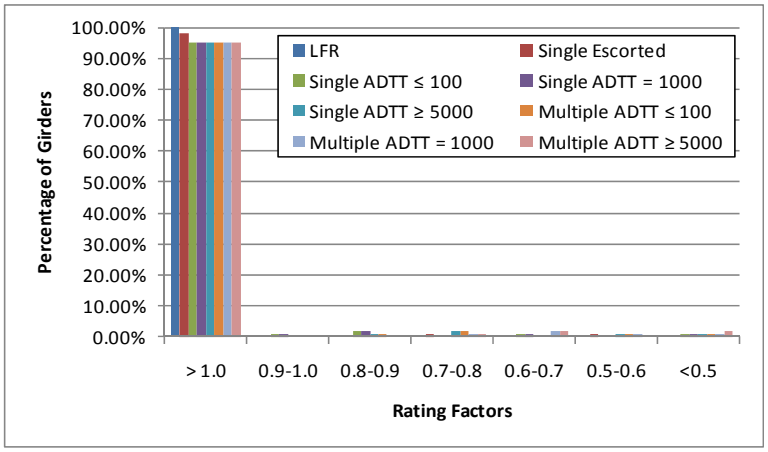


Figure F-104: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

F.1.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure F-105 show the comparison of rating factors. The ratio is generally between 1.0 and 1.4. 83% of slabs have an LRFR rating that exceeds the LFR rating.

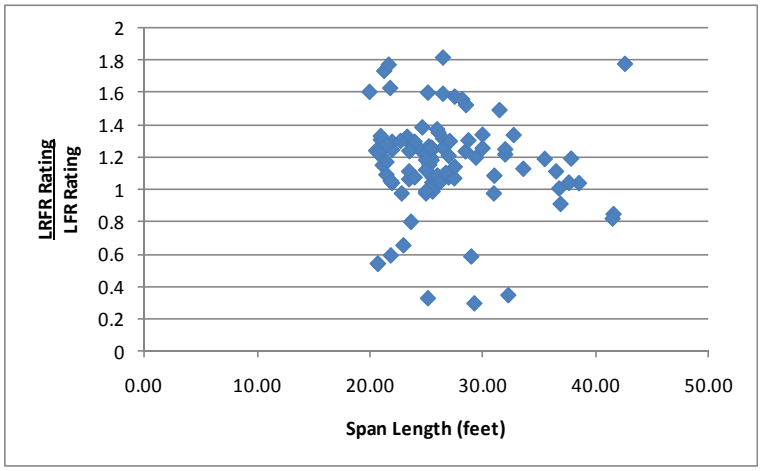


Figure F-105: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

F.1.10.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is less than the target reliability index of 3.5 for two slabs as shown in Figure F-106. The reliability index for most slabs is between six and seven.

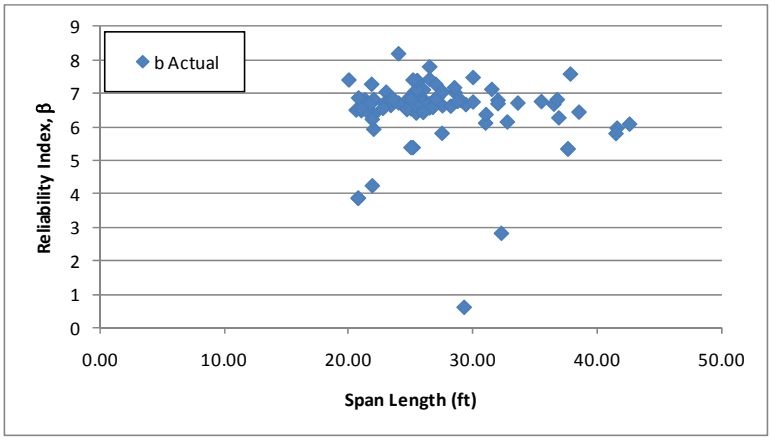


Figure F-106: Shear Reliability Indices for WA-02 Vehicle

Figure F-107 shows the reliability index for shear plotted against the LRFR shear rating for the WA-02 Vehicle. The reliability index increases with increasing rating factors. A reliability index of approximately 4.5 corresponds to a girder with a rating factor of 1.0. This is above the target reliability of 3.5 and suggests that the LRFR live load factors may be over-conservative.

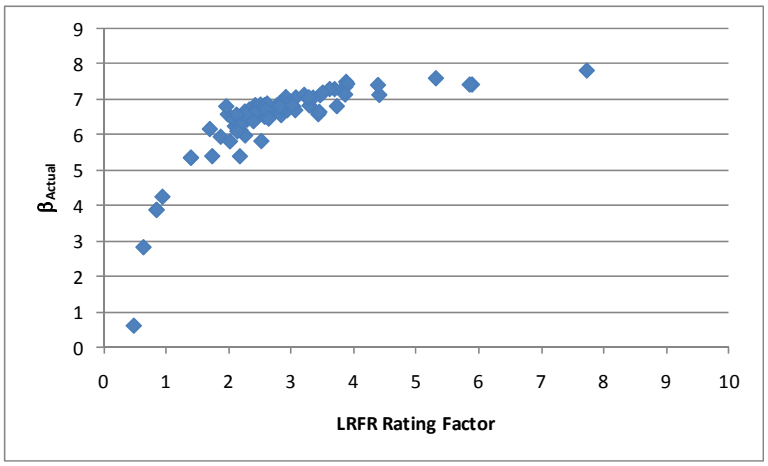


Figure F-107: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

F.1.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-108. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders

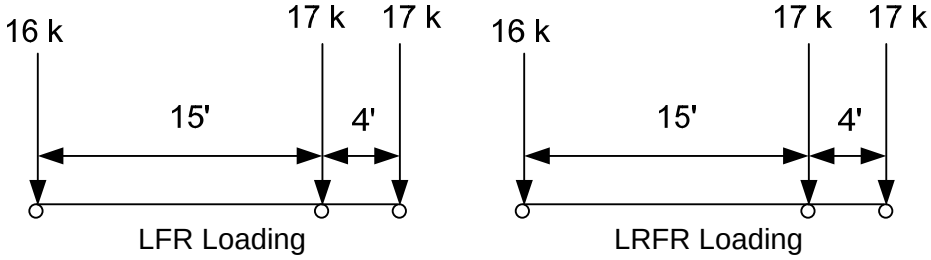
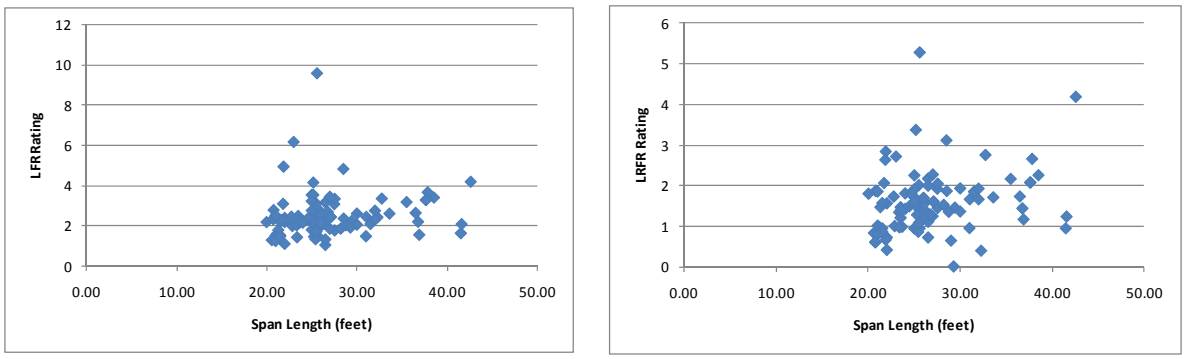


Figure F-108: Vehicle Loadings and Load Factors

F.1.11.1 Moment

F.1.11.1.1 Rating Factors

Figure F-109 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero slabs with an LFR rating less than 1.0, 23 slabs with an LRFR rating less than 1.0, and zero slabs where both ratings are less than 1.0. All 23 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 99% of the slabs. The LFR rating is between one and three while the LRFR rating is between one and two for most slabs.



(a) (b)

Figure F-109: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure F-110 shows the percentage of slabs with moment ratings in each range for the AASHTO Type 3 truck, a legal vehicle. 88.9% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 73.7% of slabs for the highest LRFR ADTT category. 100% of slabs have LFR ratings greater than 1.0. Approximately 11% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the lowest ADTT category; this increases to approximately 26% for the highest ADTT category.

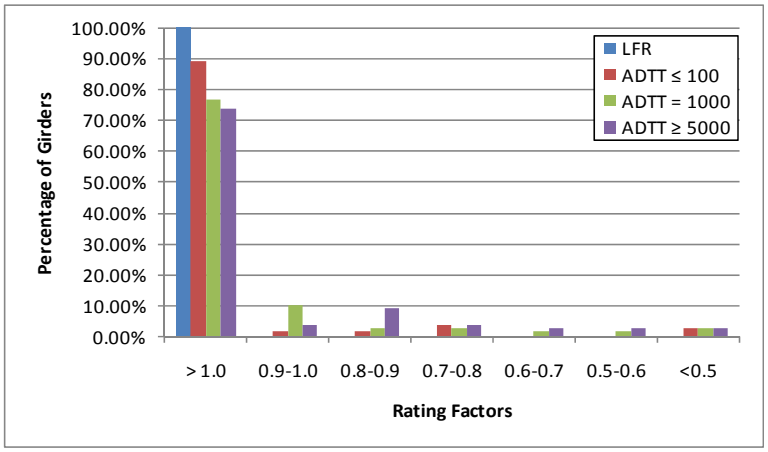


Figure F-110: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

F.1.11.1.2 Rating Factor Comparisons

Figure F-111 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.7, with one girder having an LRFR rating that is greater than the LFR rating.

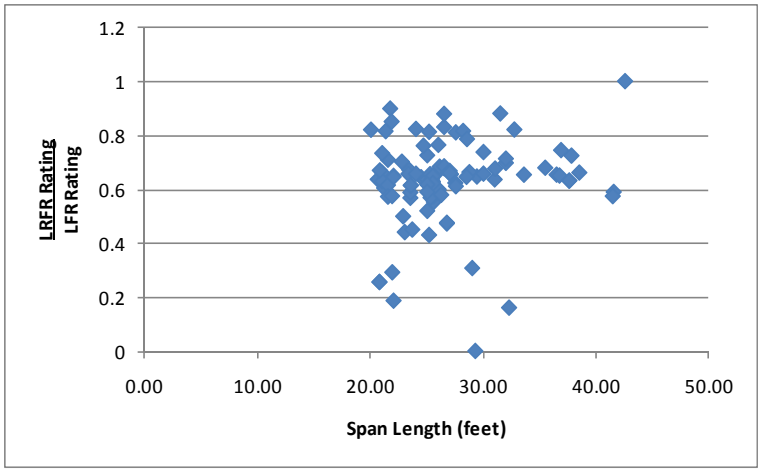


Figure F-111: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

F.1.11.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-112 shows zero slabs have a reliability index less than the target reliability index of 2.5. The reliability index is between four and eight for most slabs.

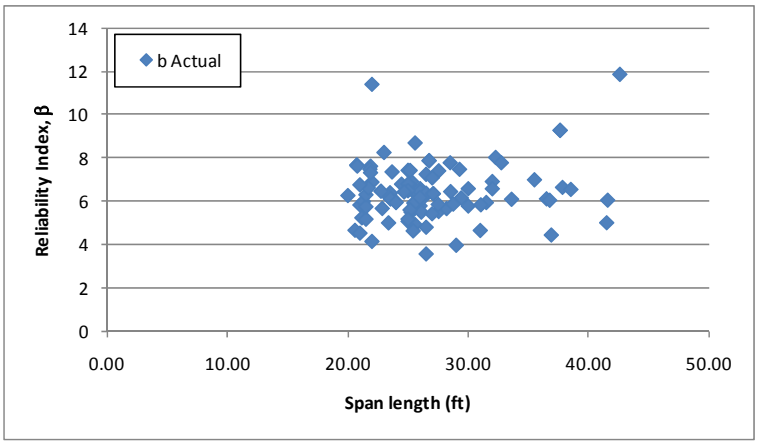


Figure F-112: Flexure Reliability Indices for Type 3 Vehicle

Figure F-113 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 Truck. The reliability index increases with LRFR ratings. A girder with a rating of one would have a reliability index of approximately 5.0, which is greater than the target reliability of 2.5.

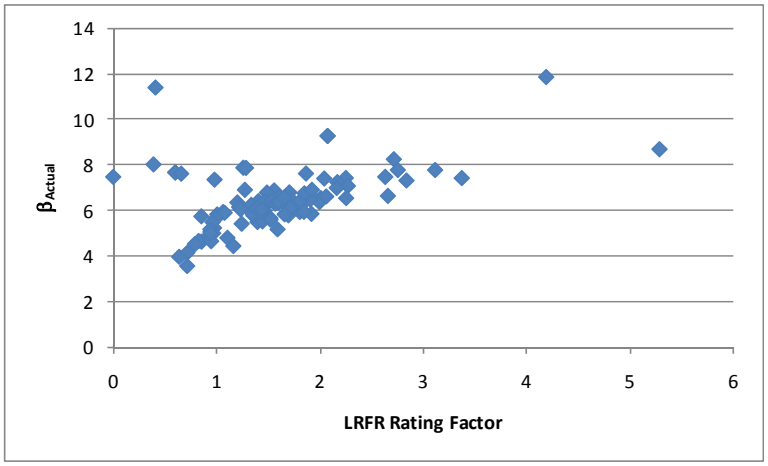
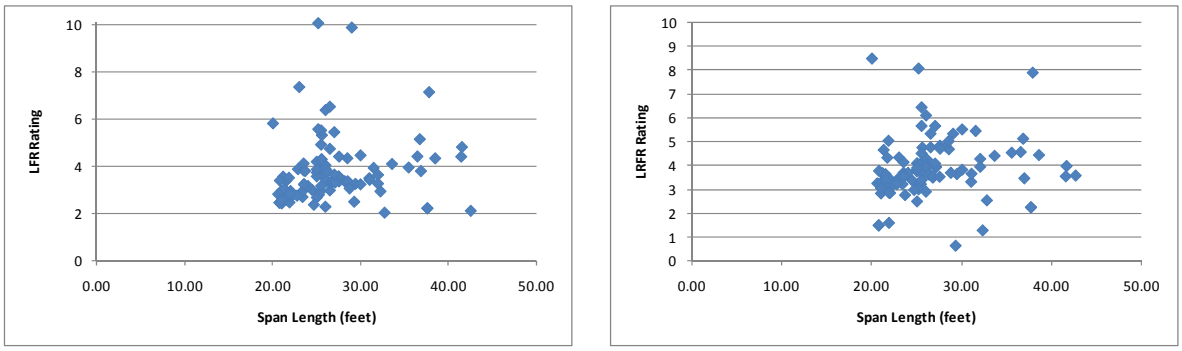


Figure F-113: Flexure Reliability Index vs LRFR Flexure Reliability Index for AASHTO Type 3 Vehicle

F.1.11.2 Shear

F.1.11.2.1 Rating Factors

For shear, there are zero slabs with LFR rating factors less than 1.0, one slab with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 25% of the slabs in this subset. Figure F-114 shows the LFR and LRFR ratings. The LFR ratings are between two and four while most of the LRFR ratings are between three and five. One outlier was removed from the LFR graph with the LFR value being 25 and two removed from the LRFR graph with values of 11 and 22.



(a) (b)

Figure F-114: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure F-115 shows the percentage of slabs with shear ratings in each range for the AASHTO Type 3 truck, a legal vehicle. 99% of slabs have LRFR ratings that are greater than 1.0 while all slabs have LFR ratings greater than 1.0. The shear ratings are not significantly for almost all slabs by the switch from LFR to LRFR.

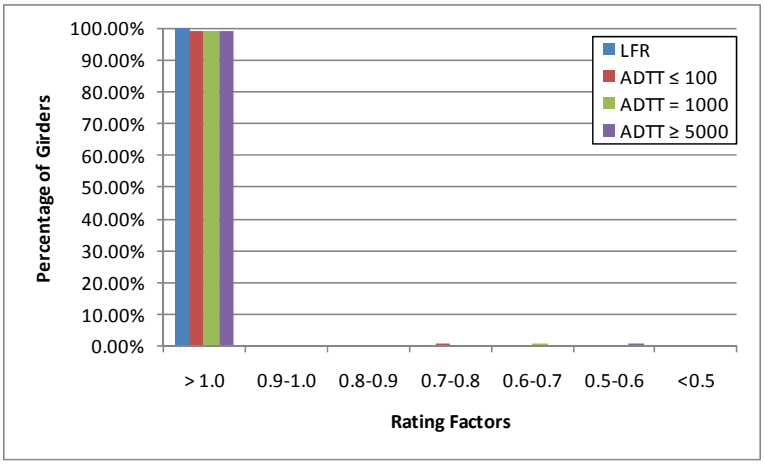


Figure F-115: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

F.1.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure F-116 show the comparison of rating factors. The ratio is generally between 0.8 and 1.2. 75% of the slabs have LRFR ratings that exceed the LFR rating.

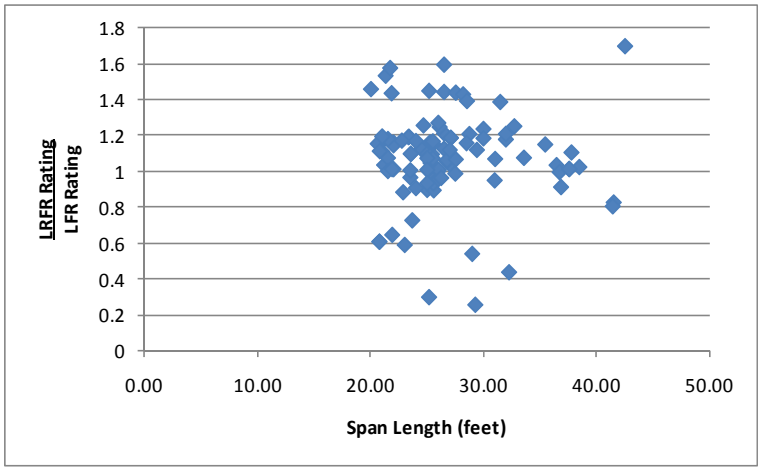


Figure F-116: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

F.1.11.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index for one slab as shown in Figure F-117. The reliability index is between seven and eight for most slabs.

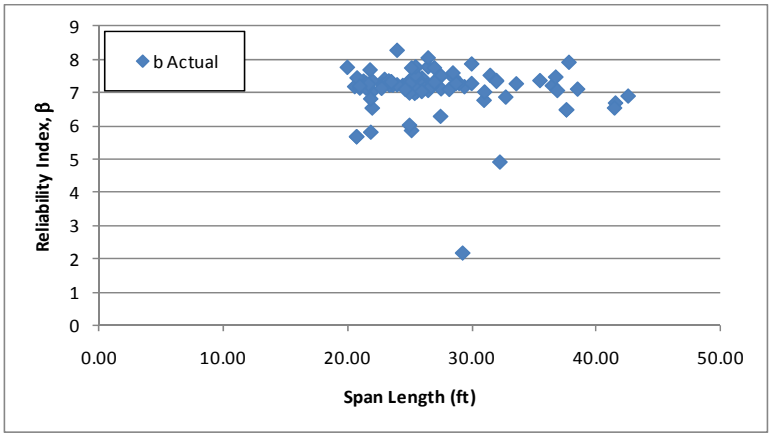


Figure F-117: Shear Reliability Indices for Type 3 Vehicle

Figure F-118 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 vehicle. The reliability index associate with a rating of 1.0 is approximately four, above the target reliability of 2.5. This indicates the live load factors in the MBE may be over-conservative.

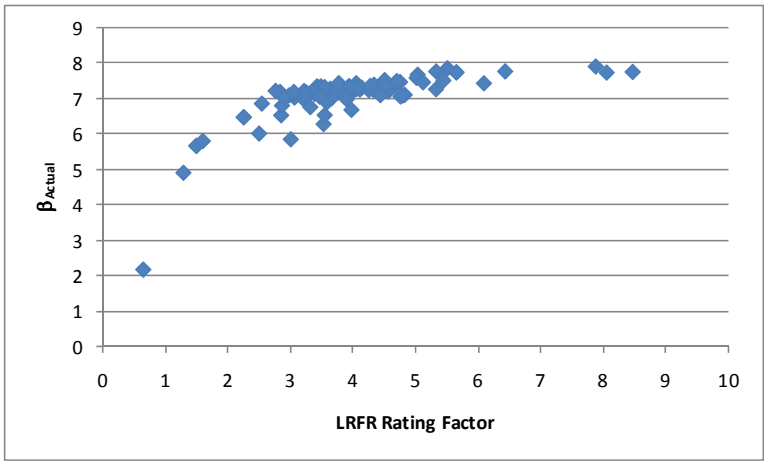
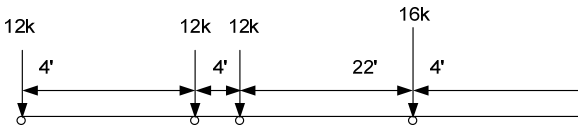


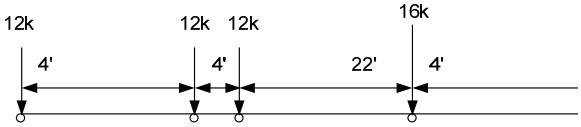
Figure F-118: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Vehicle

F.1.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-119. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders



LFR Loading



for spans greater than 200 feet, use 75% of this vehicle combined with a 0.2 klf lane load

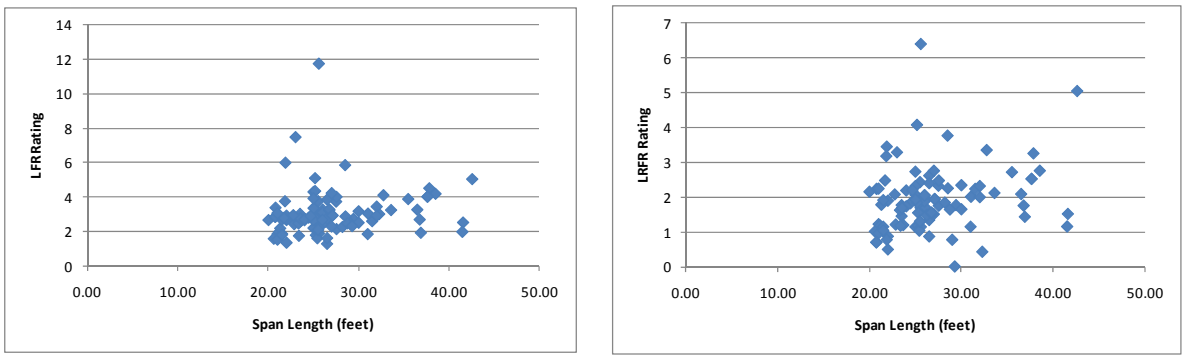
LRFR Loading

Figure F-119: Vehicle Loadings and Load Factors

F.1.12.1 Moment

F.1.12.1.1 Rating Factors

Figure F-120 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero slabs with an LFR rating less than 1.0, ten slabs with an LRFR rating less than 1.0, and zero slabs where both ratings are less than 1.0. All ten slabs with LRFR ratings less than one are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 99% of the slabs in this subset. The LFR rating is between two and four for most slabs while the LRFR rating is between one and 2.5 for most slabs.



(a) (b)

Figure F-120: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure F-121 shows the percentage of slabs with moment ratings in each range for the AASHTO Type 3-3 truck, a legal vehicle. 92.9% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 86.9% of slabs for the highest LRFR ADTT category. 100% of slabs have LFR ratings less than 1.0. Approximately 7% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the lowest ADTT category; this increases to approximately 13% for the highest ADTT category.

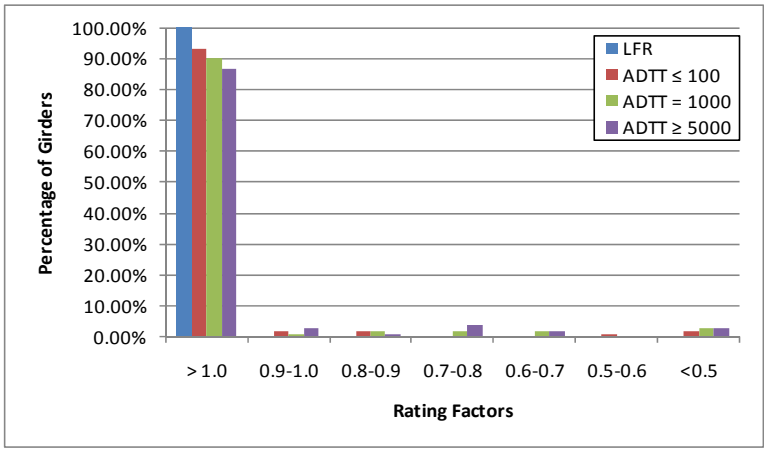


Figure F-121: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

F.1.12.1.2 Rating Factor Comparisons

Figure F-122 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.7, with one slab having an LRFR rating that is greater than the LFR rating.

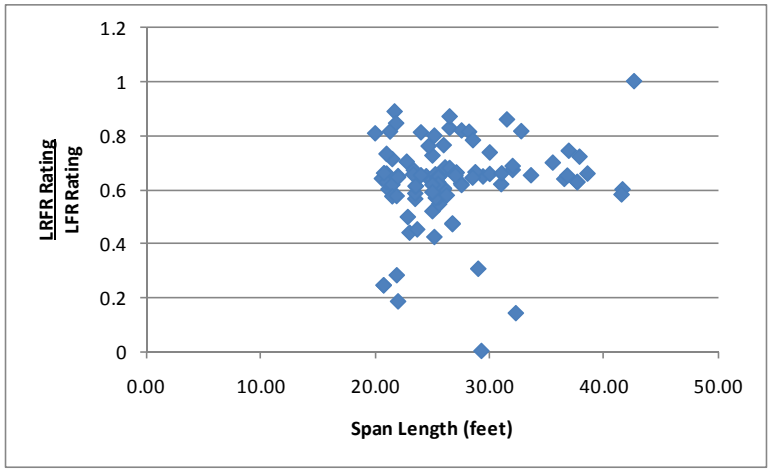


Figure F-122: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

F.1.12.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-123 shows that zero slabs have a reliability index less than the target reliability index of 2.5. The reliability index is between five and eight for most slabs.

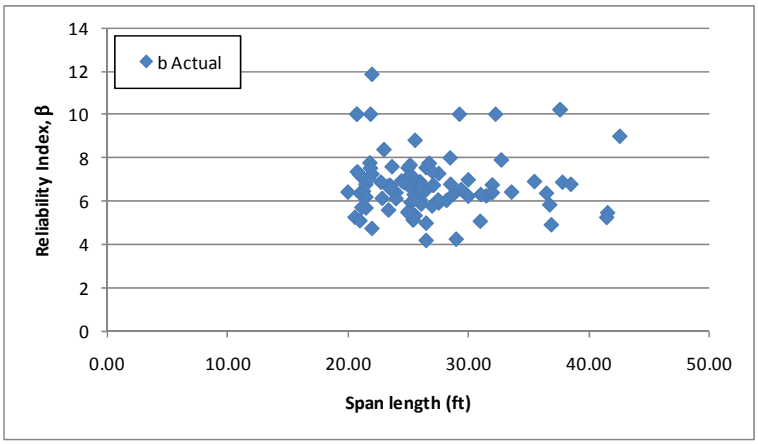


Figure F-123: Flexure Reliability Indices for Type 3-3 Vehicle

Figure F-124 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The reliability index increases with the LRFR rating. A girder with a rating of 1.0 is expected to have a reliability index of five, greater than the target reliability index of 2.5.

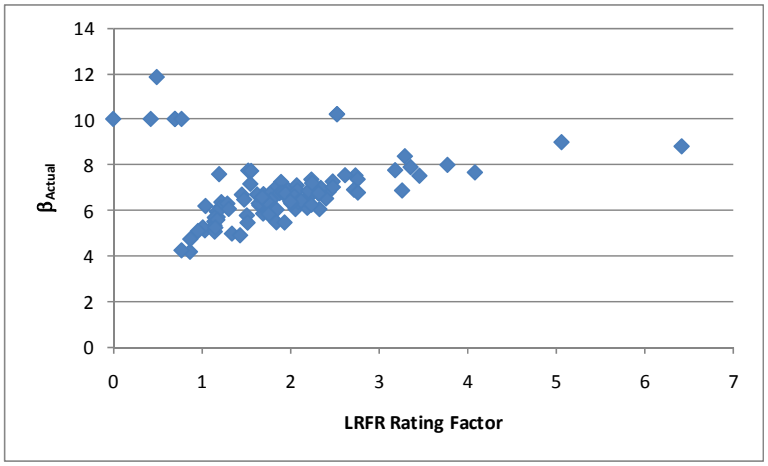
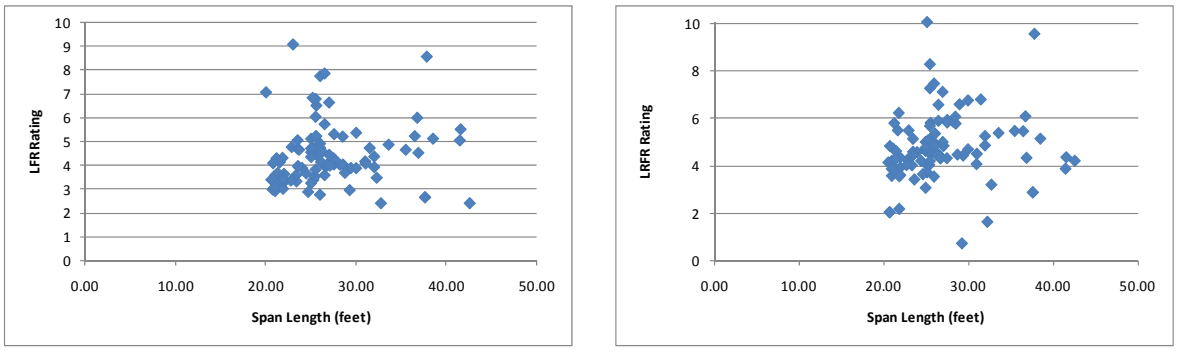


Figure F-124: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Vehicle

F.1.12.2 Shear

F.1.12.2.1 Rating Factors

For shear, there are zero slabs with LFR rating factors less than 1.0, one slab with LRFR rating less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 23% of the slabs in this subset. Figure F-125 shows the LFR and LRFR ratings. The LFR ratings are typically between there and five while the LRFR ratings are between four and six for most slabs. Three outliers were removed from each graph with the LFR values being 12, 12, and 30 and the LRFR values being 11, 13, and 27.



(a) (b)

Figure F-125: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure F-126 shows the percentage of slabs with shear ratings in each range for the AASHTO Type 3-3 truck, a legal vehicle. All three ADTT categories for LRFR have 99% of slabs with ratings greater than 1.0. All LFR ratings are greater than 1.0 for the AASHTO Type 3-3 truck. Shear ratings are not affected by the switch from LFR to LRFR for almost all slabs.

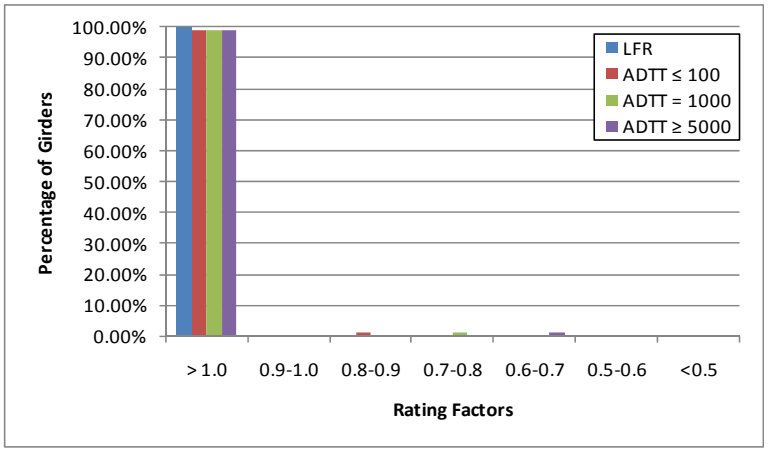


Figure F-126: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

F.1.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure F-127 shows the comparison of rating factors. The ratio is generally between 1.0 and 1.3, with 77% of slabs having an LRFR rating that is greater than the LFR rating.

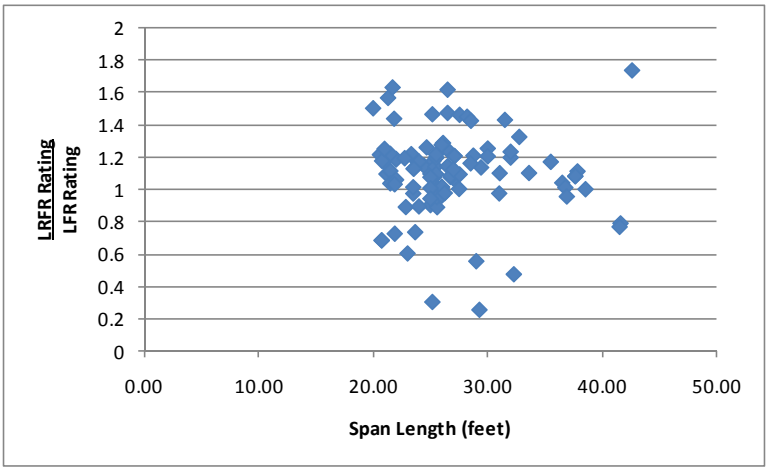


Figure F-127: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

F.1.12.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is less than the target reliability index for zero slabs as shown in Figure F-128. The reliability index is between seven and eight for most slabs.

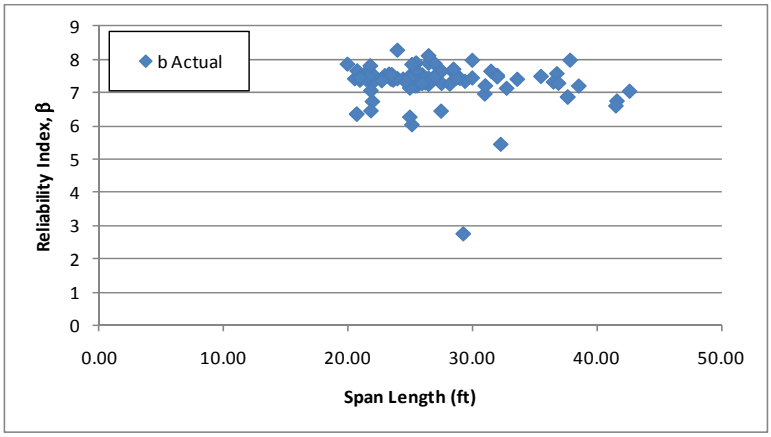


Figure F-128: Shear Reliability Indices for Type 3-3 Vehicle

Figure F-129 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 vehicle. The reliability index corresponding to a rating of one is approximately 3.75, which is greater than the target reliability index of 2.5. This indicates that the live load factors in the MBE may be over-conservative.

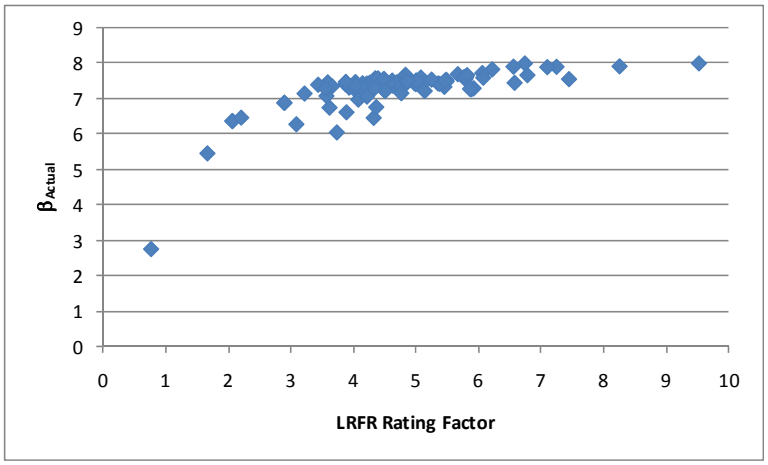


Figure F-129: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Vehicle

F.1.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure F-130. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders

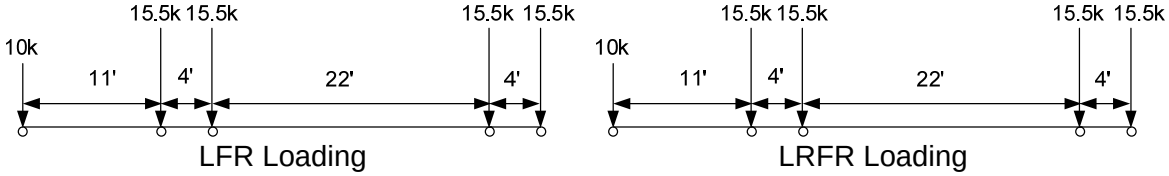
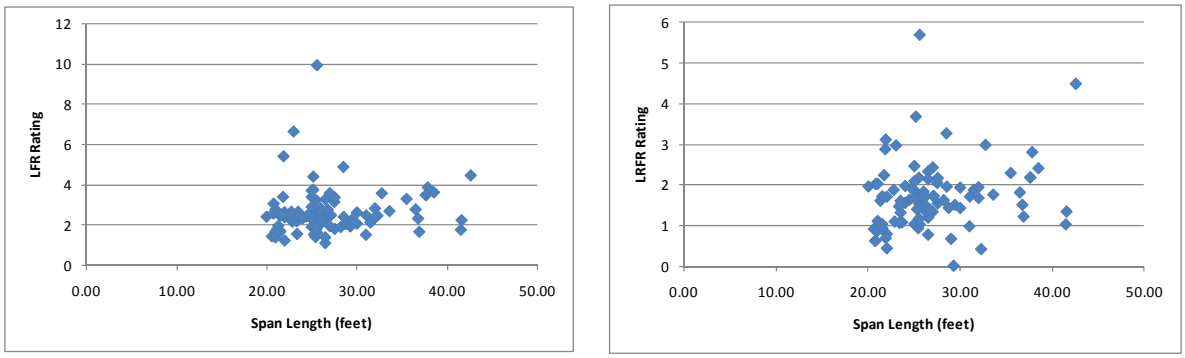


Figure F-130: Vehicle Loadings and Load Factors

F.1.13.1 Moment

F.1.13.1.1 Rating Factors

Figure F-131 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero slabs with an LFR rating less than 1.0, 14 slabs with an LRFR rating less than 1.0, and zero slabs where both ratings are less than 1.0. All slabs with LRFR ratings less than one are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR permit rating for 99% of the slabs in this subset. The LFR ratings are between one and three for most slabs while the LRFR ratings are mostly within the range of 1 to 2.



(a) (b)

Figure F-131: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure F-132 shows the percentage of slabs with moment ratings in each range for the AASHTO Type 3S2 truck, a legal vehicle. 90.9% of slabs have LRFR ratings greater than 1.0 for the lowest ADTT category. This decreases to 77.8% of slabs for the highest LRFR ADTT category. 100% of slabs have LFR ratings less than 1.0. Approximately 9% more slabs have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for the lowest ADTT category; this increases to approximately 22% for the highest ADTT category.

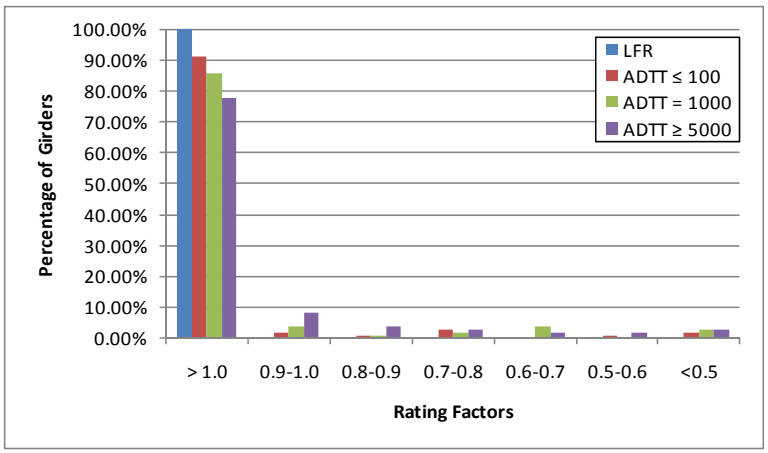


Figure F-132: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

F.1.13.1.2 Rating Factor Comparisons

Figure F-133 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8. There is one girder with an LRFR rating greater than the LFR rating.

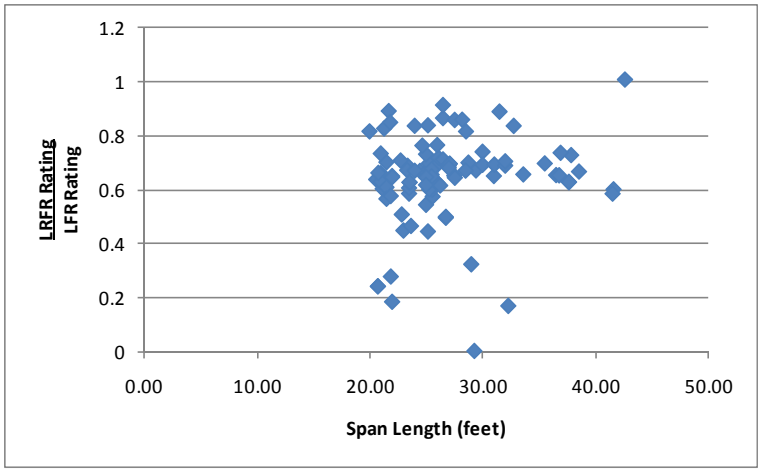


Figure F-133: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

F.1.13.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure F-134 shows that zero slabs have a reliability index less than the target reliability index of 2.5. The reliability index is between five and eight for most slabs.

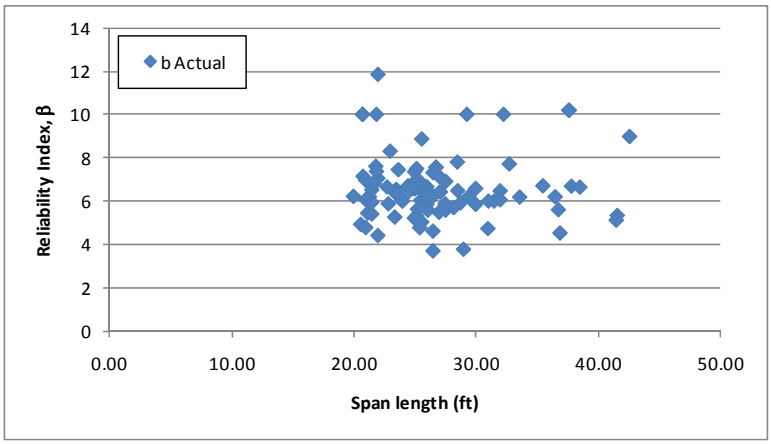


Figure F-134: Flexure Reliability Indices for Type 3S2 Vehicle

Figure F-135 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 Truck. The reliability index increases with increasing LRFR ratings. A girder with a rating of one has a reliability index of approximately five, higher than the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

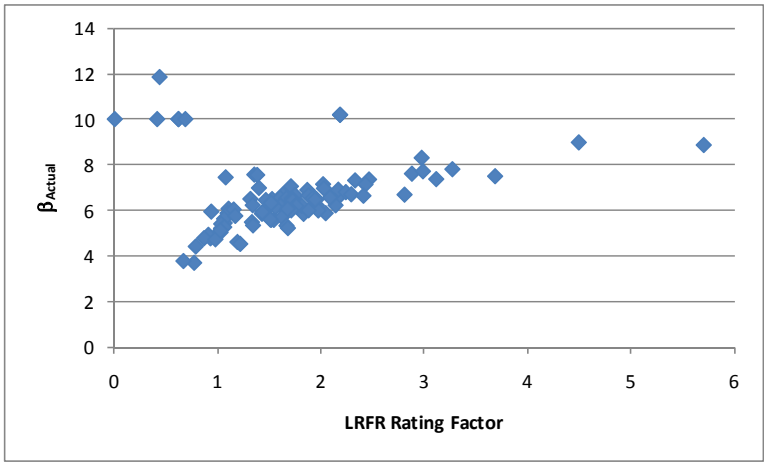
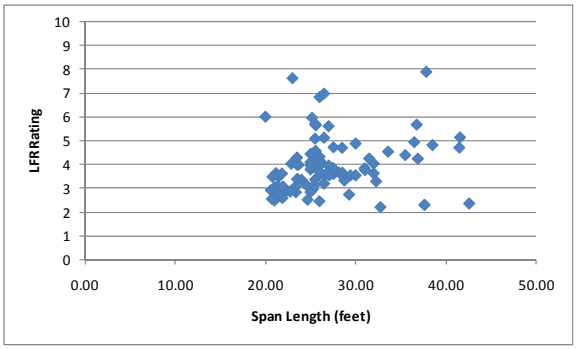


Figure F-135: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

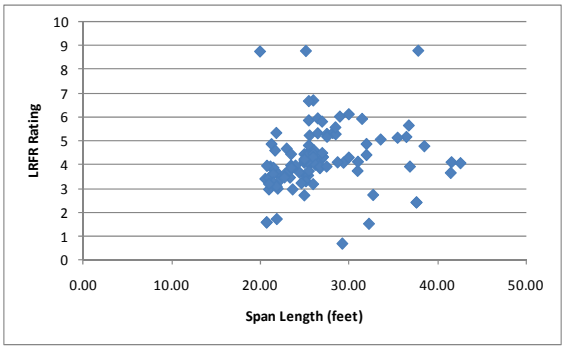
F.1.13.2 Shear

F.1.13.2.1 Rating Factors

For shear, there are zero slabs with LFR rating factors less than 1.0, one slab with LRFR rating less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 75% of the slabs in this subset. Figure F-136 shows the LFR and LRFR ratings. The LFR ratings are between two and five for most slabs while the LRFR ratings have increased and are between three and six for most slabs. Three outliers were removed from the LFR graph with the values being 11, 11, and 24 and two outlier removed from the LRFR graph with values of 12 and 24.



(a)



(b)

Figure F-136: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure F-137 shows the percentage of slabs with shear ratings in each range for the AASHTO Type 3S2 truck, a legal vehicle. 99% of slabs have ratings greater than 1.0 for all ADTT categories for LRFR. All slabs have ratings greater than 1.0 for LFR. Shear ratings are not affected by the switch from LFR to LRFR except for one slab.

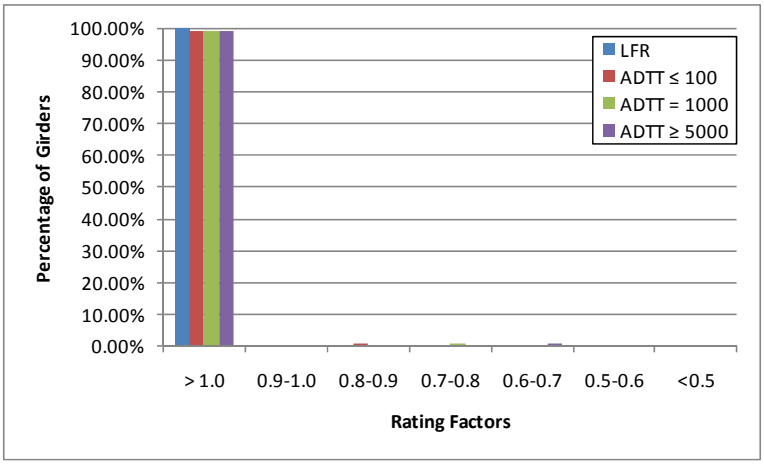


Figure F-137: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

F.1.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure F-138 show the comparison of rating factors. The ratio is generally between 0.9 and 1.3. 75% of slabs have LRFR ratings that exceed the corresponding LFR rating.

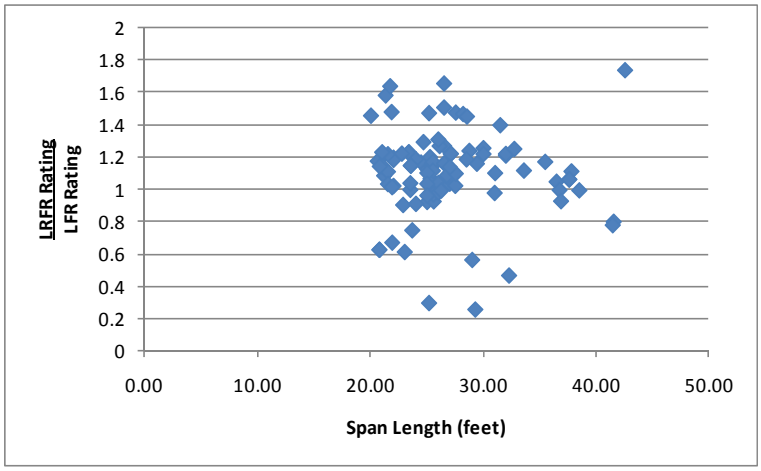


Figure F-138: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

F.1.13.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for one slab as shown in Figure F-139.

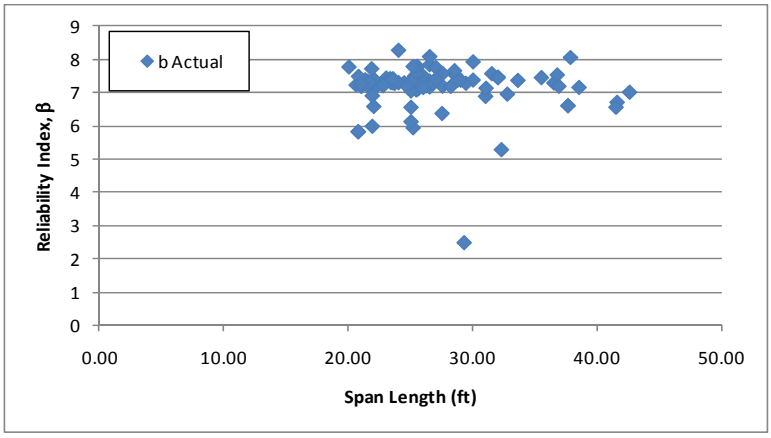


Figure F-139: Shear Reliability Indices for Type 3S2 Vehicle

Figure F-140 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 vehicle. The reliability index corresponding to a rating of one is approximately four, above the target reliability of 2.5. This indicates the live load factors in the MBE may be over-conservative.

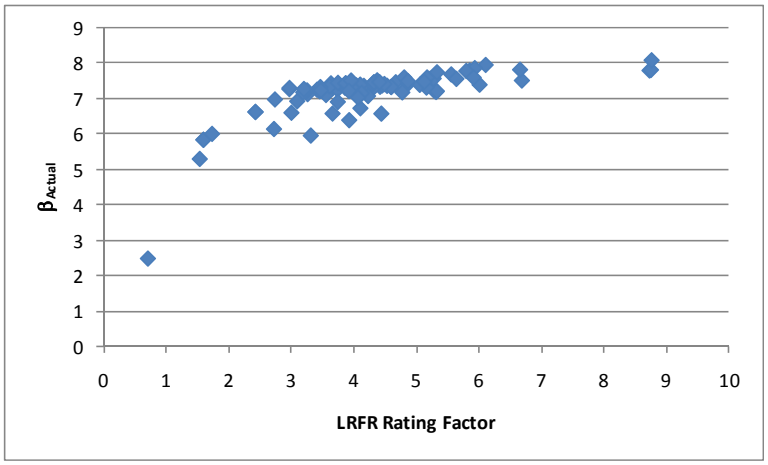


Figure F-140: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

F.1.14 Moment

The results shown in this section compare the number of slabs for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table F-1 shows the results for the moment ratings. For all vehicles, the number of slabs with insufficient LRFR ratings is significantly higher than the number of slabs with low LFR ratings. Most slabs with LRFR ratings less than one are controlled by the longitudinal steel rating. The percentage of slabs with LFR ratings greater than the LRFR ratings is similar for the routine permit and legal vehicles. The special permit vehicles had more slabs with higher LRFR ratings than LFR ratings. The design vehicle was between the routine permit/legal vehicles and special permit vehicles.

Table F-1: Flexure Rating Factor Results for All 12 Vehicles

	Total Slabs	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	99	27	2	1	14	5	0	14	8	16	0	0	0
LRFR Rating less than 1.0		64	27	24	31	32	13	33	43	37	23	10	14
LFR and LRFR Rating less than 1.0		27	2	1	14	5	0	14	8	16	0	0	0
% with LFR RF greater than LRFR RF		94	99	99	87	99	99	87	99	88	99	99	99
LRFR rating less than 1.0 and controlled by longitudinal steel rating		60	27	24	30	31	13	32	42	35	23	10	14

F.1.15 Shear

The results shown in this section compare the number of slabs for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table F-2 shows the results for the moment ratings. There are very few slabs where shear ratings were less than 1.0 for either method. This suggests that assuming shear strength to be satisfactory if the slab conforms to AASHTO LRFD 4.6.2.3 is reasonable. The percentage of slabs with LFR ratings greater than LRFR ratings seems to depend on the vehicle, which is expected because the LRFR shear strength equation uses the ratio of V_u/M_u. The special permit vehicles have the fewest slabs with LFR ratings that are greater than the LRFR ratings.

Table F-2: Shear Rating Factor Results for All 12 Vehicles

	Total Slabs	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	99	2	0	0	0	0	0	0	0	0	0	0	0
LRFR Rating less than 1.0		5	1	1	5	1	1	5	5	5	1	1	1
LFR and LRFR Rating less than 1.0		0	0	0	0	0	0	0	0	0	0	0	0
% with LFR RF greater than LRFR RF		15	26	23	13	29	23	16	36	17	25	23	25

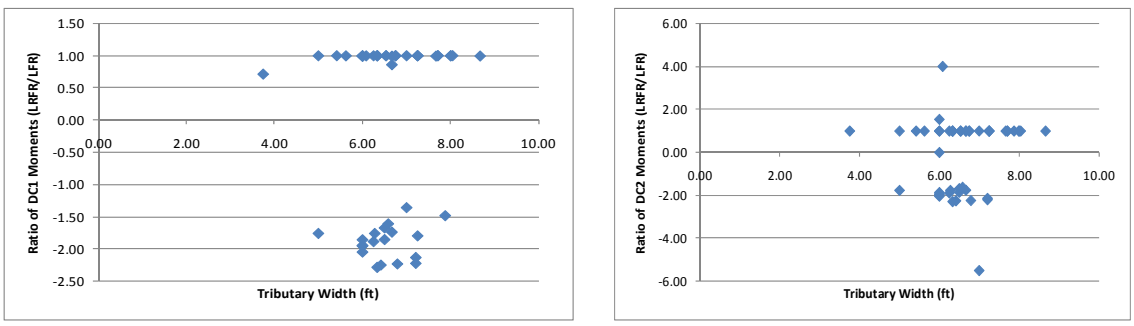
G Steel I-Girder Continuous Span Bridges

G.1 Interior Non-Composite Girders

G.1.1 Dead Loads

G.1.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure G-1a, the ratios of unfactored DC1 moments (self-weight, dead loads on composite section) are very close to 1.0. The negative ratios are from girders where the locations varied, with one being positive and the other being negative. Figure G-1b shows that there is more variation in the loads applied to the composite section (DC2 and DW loads). Similarities to the DC1 moment graph are noticed in the DC2 moment graph, with most of the girders being at 1.0 or -2.0.

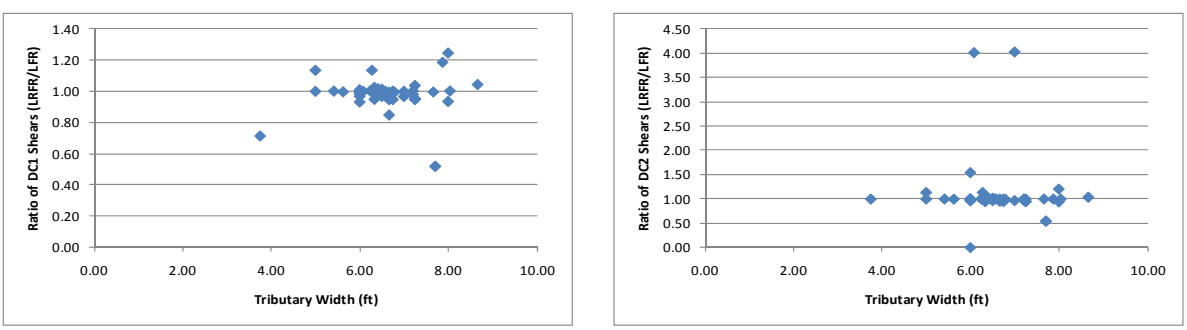


(a) (b)

Figure G-1: Ratios of DC1 and DC2 and DW Moments (unfactored loads LRFR/LFR)

G.1.1.2 Shear

Figure G-2a shows that numerous girders have a ratio of DC1 shear close to 1.0, but there are several where the ratio is either above or below 1.0. This is a mostly due to the variation of the critical section for shear. Figure G-2b shows the same trend as Figure G-2a in that the LFR shear is similar to the LRFR shear. There is also more variation within the DC2 and DW loads than in the DC1 loads.



(a) (b)

Figure G-2: Ratio of DC1 LFR Shear to DC1 LRFR Shear (unfactored loads LRFR/LFR)

G.1.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of

an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure G-3. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

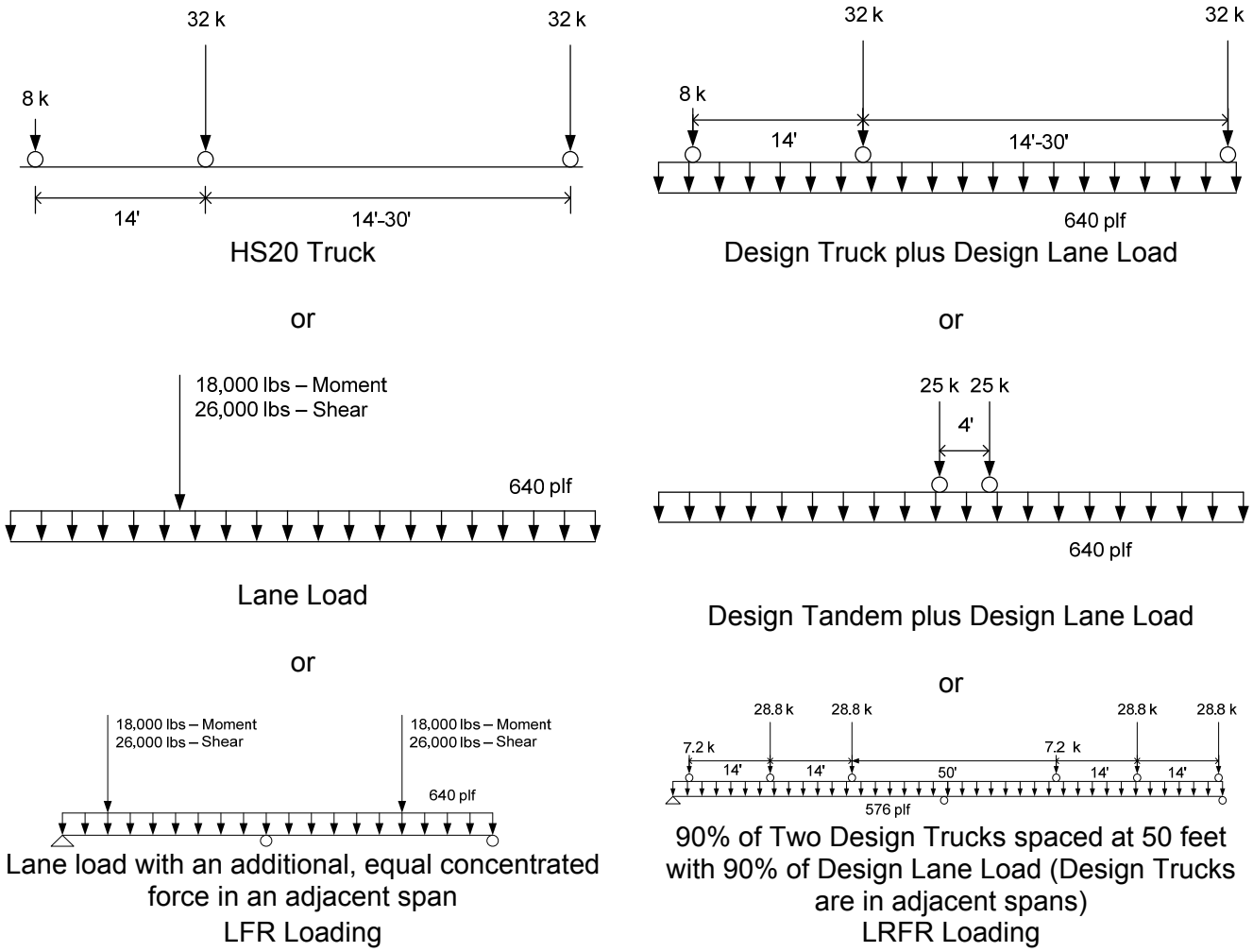
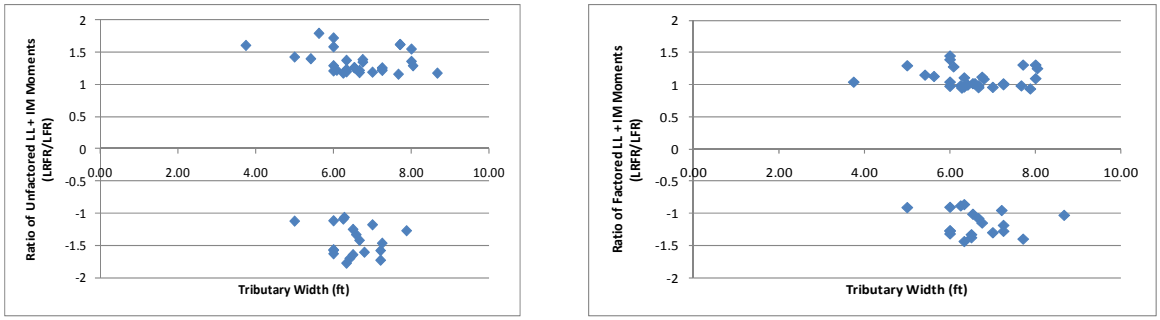


Figure G-3: Vehicle Loadings and Load Factors

G.1.2.1 Moment

G.1.2.1.1 Live Loads

Figure G-4a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.1 and 1.4 for positive ratios and between 1 and 1.75 for negative ratios. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure G-4b shows that the results have shifted and are between 1.0 and 1.2 for the positive ratios and between 1.0 and 1.5 for the negative ratios.



(a) (b)

Figure G-4: Ratio of Unfactored and Factored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

G.1.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure G-5 shows that the ratio of resistance is generally between 1.0 and 1.25, for the negative ratios and below 1.0 for the positive ratios.

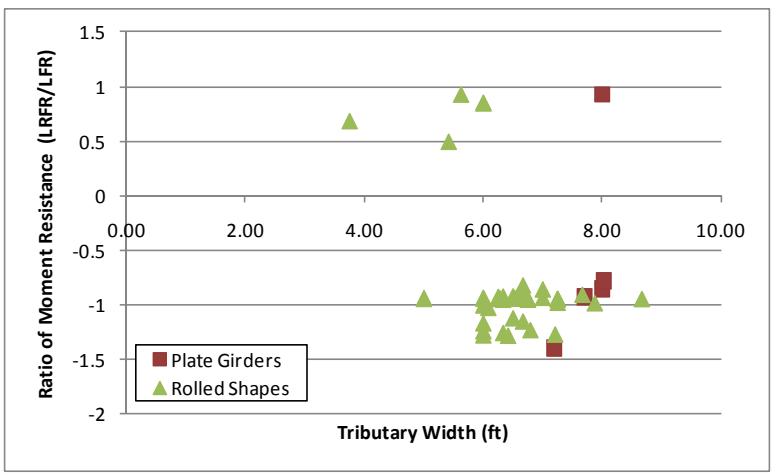
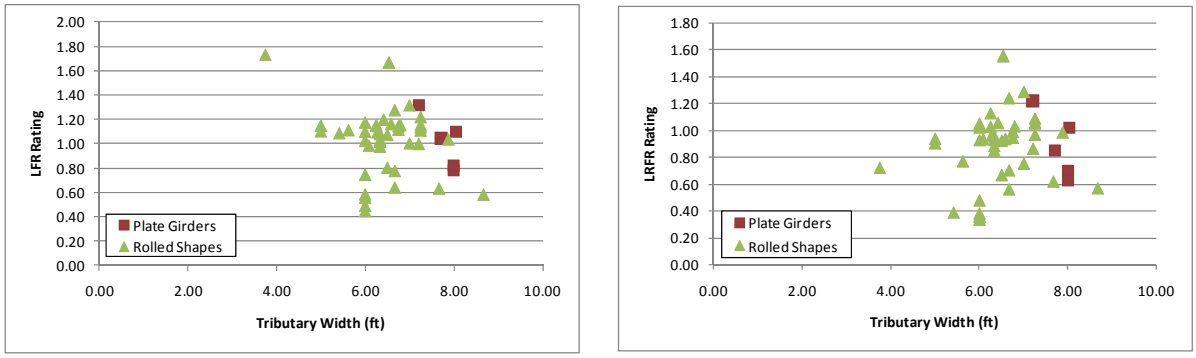


Figure G-5: Ratio of factored Moment Resistance (LRFR/LFR)

G.1.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (49 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 15 girders with LFR ratings less than 1.0, 34 girders with LRFR ratings less than 1.0, and 15 girders where both the LFR and LRFR ratings are less than 1.0. Figure G-6 shows the LFR rating factors and LRFR rating factors. The LFR ratings are between one and two for most girders while the LRFR ratings are between 0.9 and 1.0 for most girders.



(a) (b)

Figure G-6: LFR and LRFR Flexure Rating Factors for Design Loadings

G.1.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure G-7. The results indicated that 100% of the girders in this set have LFR ratings greater than LRFR ratings. Most of the girders have ratios between 0.8 and 1.0.

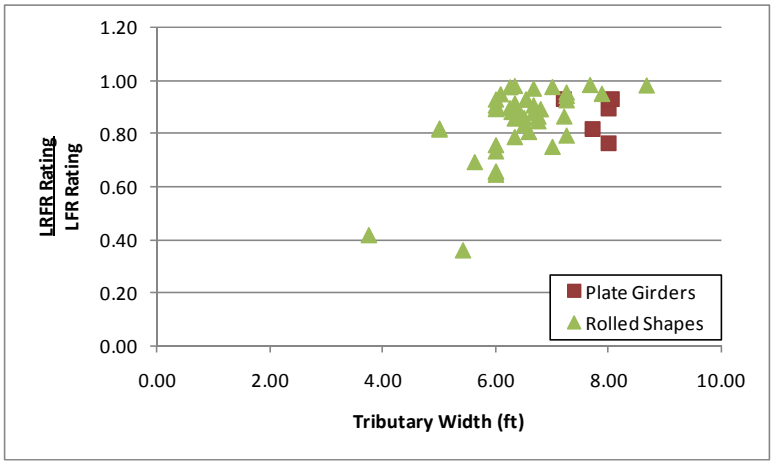


Figure G-7: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure G-8 shows the percentage of girders with LRFR ratings less than 1.0, that are in each category based on what the ratio of LRFR rating to LFR rating is. The figure shows that most girders have LRFR ratings that are between 80 and 100% of the LFR rating. This indicates that the reduction in rating is not significant for most girders. The figure provides an estimate of the number of girders that will be affected by switching from LFR to LRFR and how significant that effect will be.

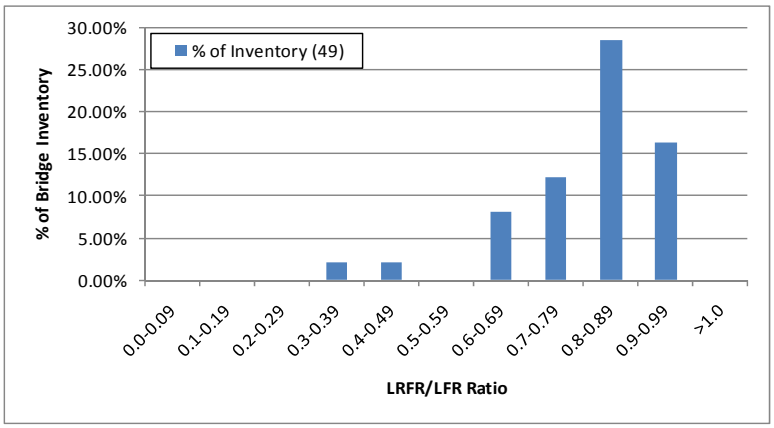


Figure G-8: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

G.1.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure G-9 shows that 30 girders have a reliability index lower than 3.5, the value inherent in the AASHTO LRFD Design Specification at this loading level.

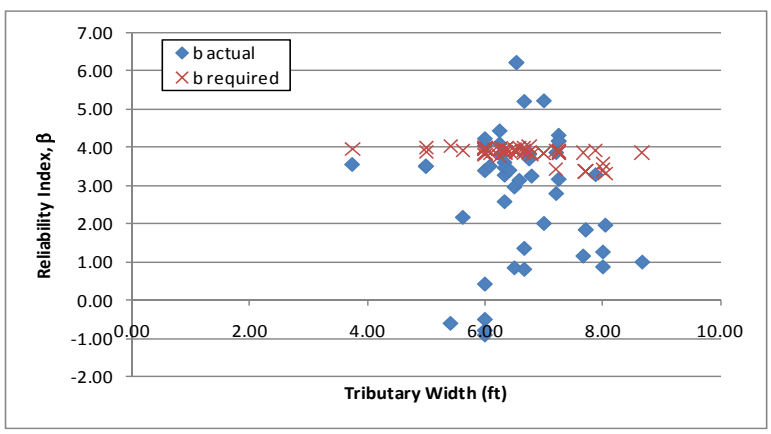


Figure G-9: Flexure Reliability Indices for HL-93 Loading

Figure G-10 shows the reliability index for moment plotted against the LRFR moment rating for the design loading. The figure shows that the reliability index for a girder with a rating of 1.0 is approximately 3.5. This verifies that the live load factor for the design load provides the target level of reliability.

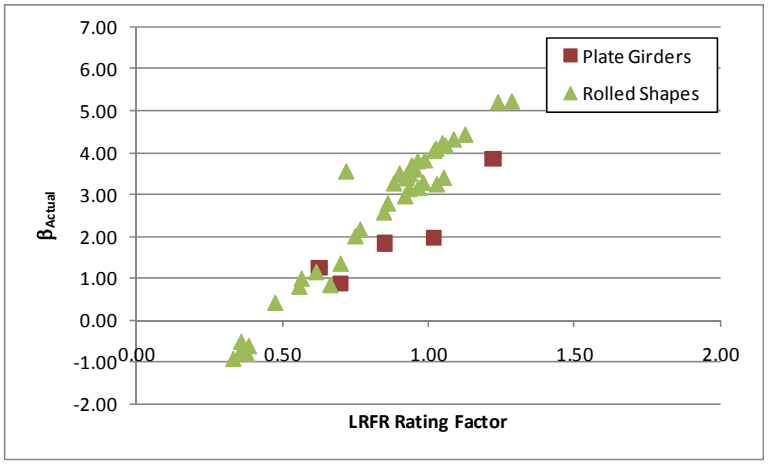
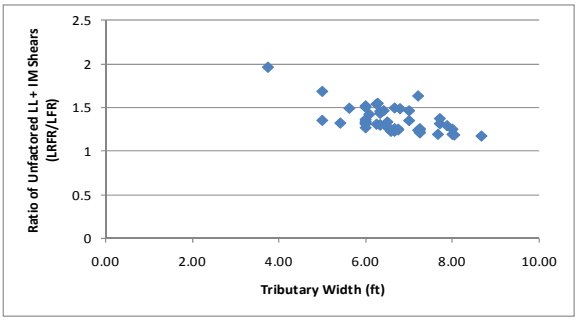


Figure G-10: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Loading

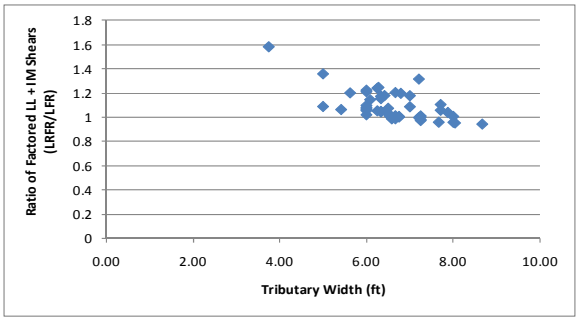
G.1.2.2 Shear

G.1.2.2.1 Live Loads

Figure G-11a shows that the ratio of unfactored shear varies significantly, with most girders between 1.25 and 1.5, with several above 1.5. The ratio appears to decrease with increasing tributary width. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure G-11b shows that the ratio of factored live load shears has decreased and is generally between 1.0 and 1.25 for most cases.



(a)



(b)

Figure G-11: Ratio of Unfactored and Factored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

G.1.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure G-12 shows that the ratio of resistance is very close to 1.0 for rolled shapes and varies for plate girders.

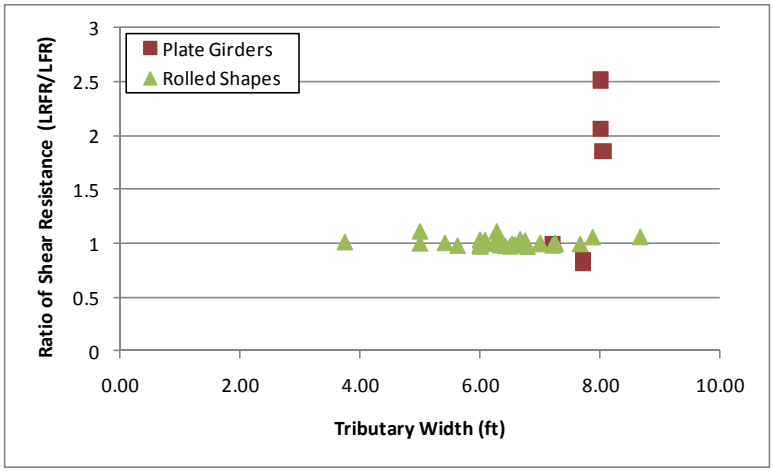
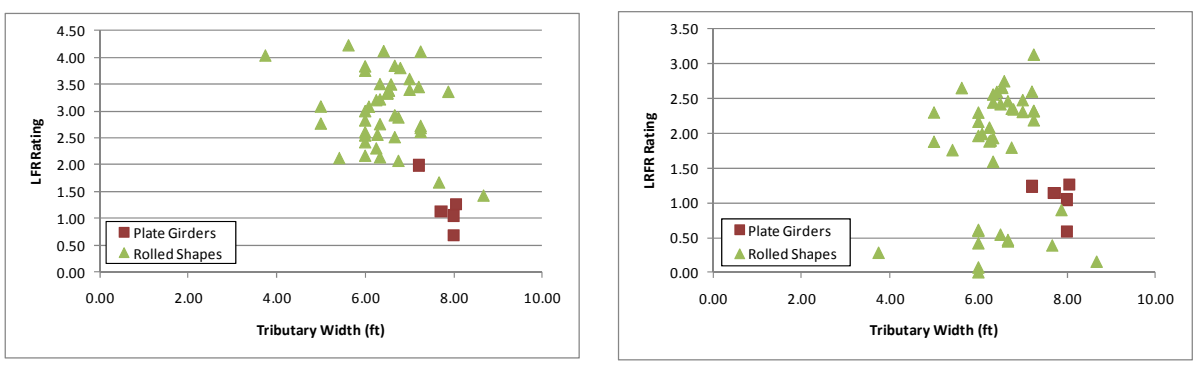


Figure G-12: Ratio of factored Shear Resistance (LFR/LRFR)

G.1.2.2.3 Rating Factors

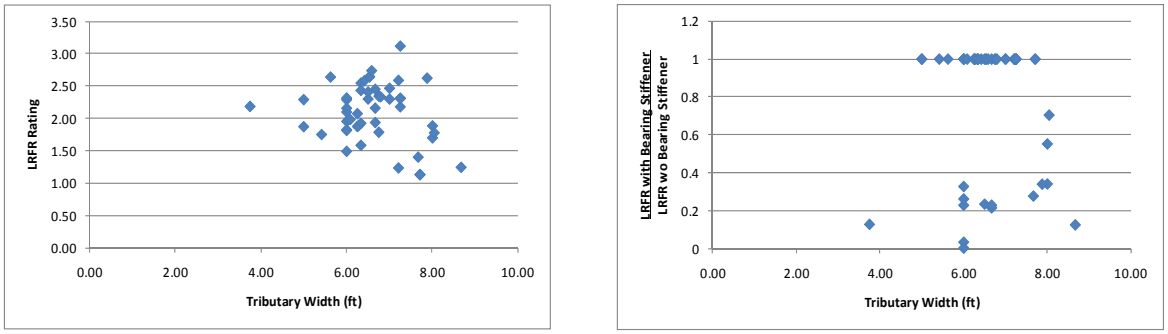
After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there is one girder with LFR ratings less than 1.0, 13 girders with LRFR ratings less than 1.0, and one girder where both LFR and LRFR ratings are less than 1.0. All thirteen girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. The LFR rating was greater than the LRFR rating for 96% of the girders in this subset. Figure G-13 shows the LFR rating factors and LRFR rating factors. Both ratings vary significantly with no clear trends.



(a) (b)

Figure G-13: LFR and LRFR Shear Rating Factors for Design Loadings

Figure G-14a shows the LRFR shear ratings when the bearing stiffener rating is ignored. Comparing Figure G-14a to Figure G-13b shows that there are no girders with shear ratings less than 1.0 when the bearing stiffener rating is ignored. Figure G-14b shows the ratio of the LRFR rating when the bearing stiffener is included divided by the LRFR rating when the bearing stiffener is ignored. The ratio shows that the rating of the bearing stiffener is significantly smaller than the web shear rating for those girders where the bearing stiffener controlled. 31% of girders were controlled by the bearing stiffener rating for this set of girders.



(a) (b)

Figure G-14: Effect of Bearing Stiffener Rating on LRFR Shear Ratings

G.1.2.2.4 Rating Factor Comparisons

Figure G-14 shows the ratio of the LRFR rating to the LFR rating. The ratio is generally between 0.6 and 0.8. Two girders have LRFR ratings that exceed the LFR rating.

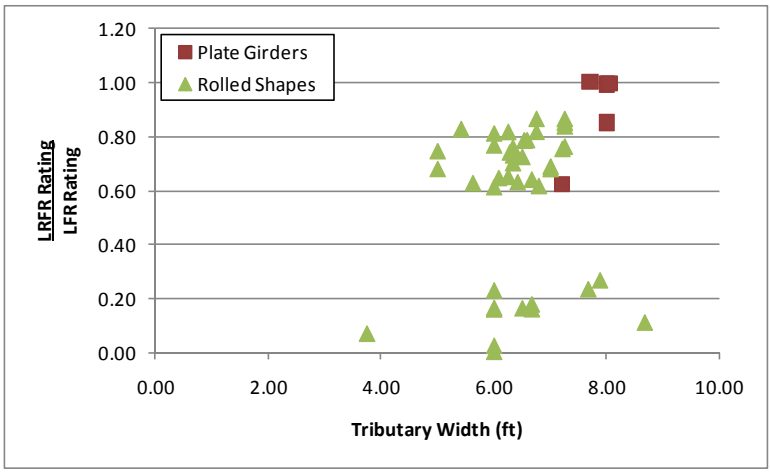


Figure G-15: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure G-16 shows even though most girders have LFR ratings that are significantly larger than the LRFR rating, no girders have LRFR ratings that are less than 1.0.

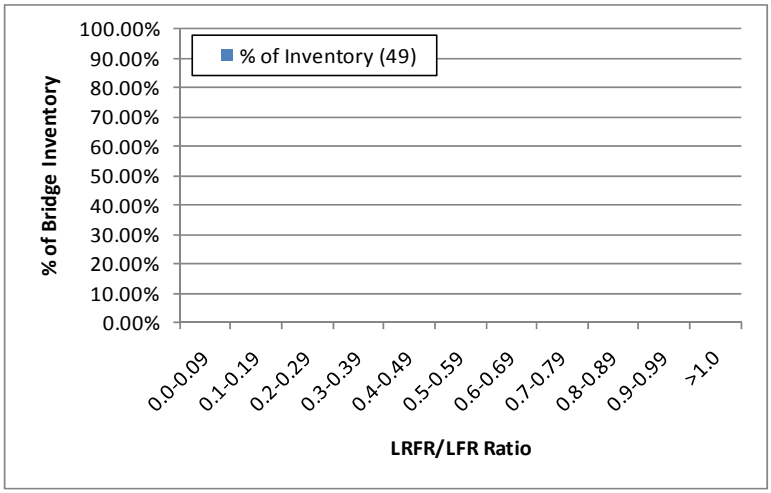


Figure G-16: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

G.1.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure G-17 shows that all but two girders have a reliability index for shear greater than the required level. The reliability index for most girders is between seven and nine.

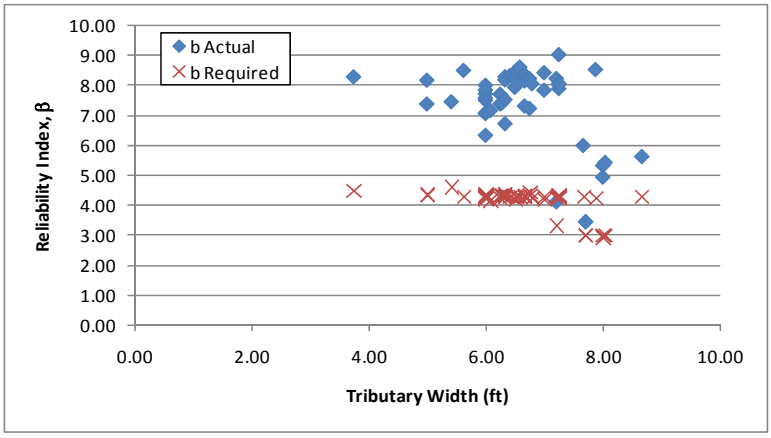


Figure G-17: Shear Reliability Indices for HL-93 Loading

Figure G-17 shows the reliability index for shear plotted against the LRFR shear rating for the design vehicle. The reliability index is approximately 3.5 for girders with an LRFR rating of 1.0. This is the target reliability in the LRFD Design Specification. The girders with low ratings and high reliability are those controlled by the bearing stiffener rating. The reliability is high because the reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

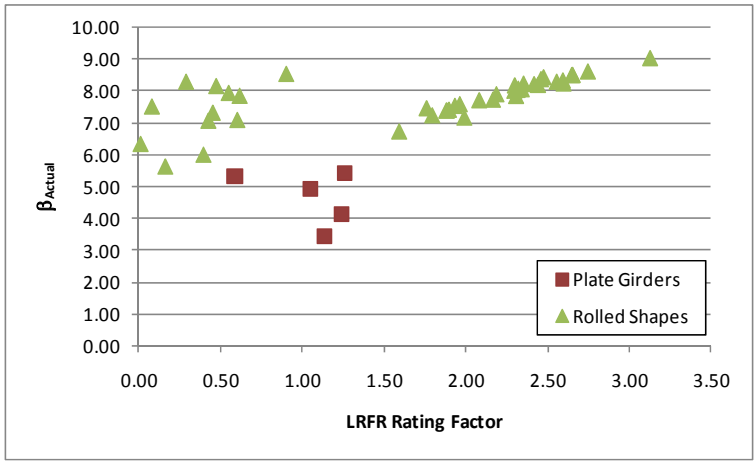


Figure G-18: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

G.1.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-19. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

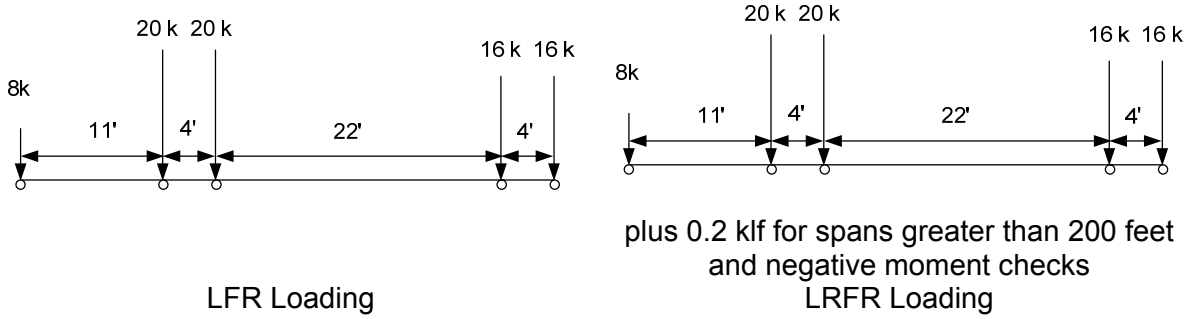


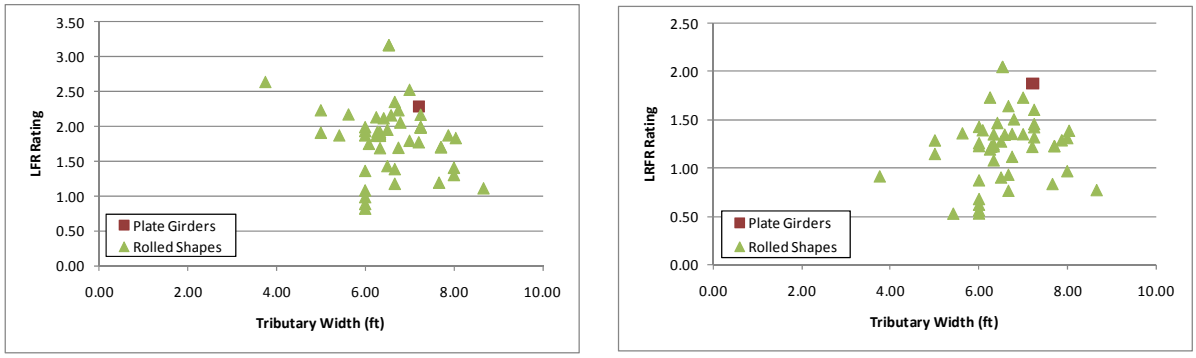
Figure G-19: Vehicle Loadings and Load Factors

G.1.3.1 Moment

The following section contains the results for interior, non-composite steel girders in continuous structures.

G.1.3.1.1 Rating Factors

Figure G-20 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are three girders with an LFR rating less than 1.0, 13 girders with an LRFR rating less than 1.0, and three girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for all girders in this subset. The LFR ratings are typically between 1.5 and 2.5 while the LRFR ratings are typically between 1.0 and 2.0.



(a) (b)

Figure G-20: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure G-21 shows the percentage of girders with moment ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 83.7% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders with ratings greater than 1.0 drops to 69.4% when the ADTT ≥ 5,000. 93.9% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is 10% for ADTT ≤ 100 and 24% for ADTT ≥ 5,000.

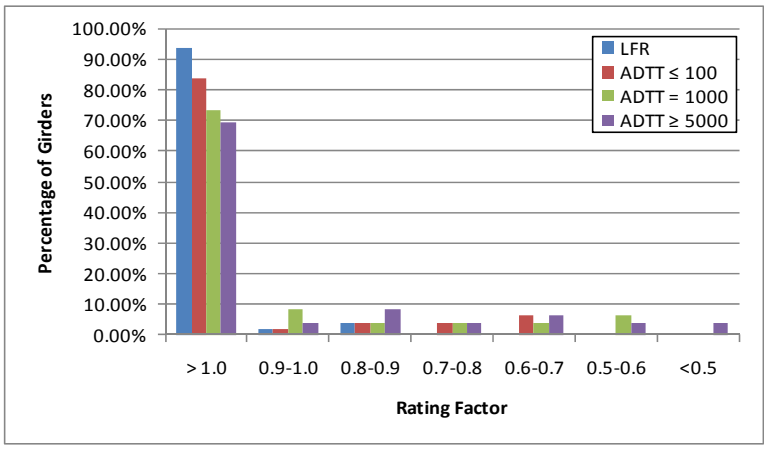


Figure G-21: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

G.1.3.1.2 Rating Factor Comparisons

Figure G-22 shows the ratio of the LRFR rating divided by the LFR rating. The ratio is generally in the range of 0.6 to 0.8, with lower ratios generally corresponding to narrower girder spacings.

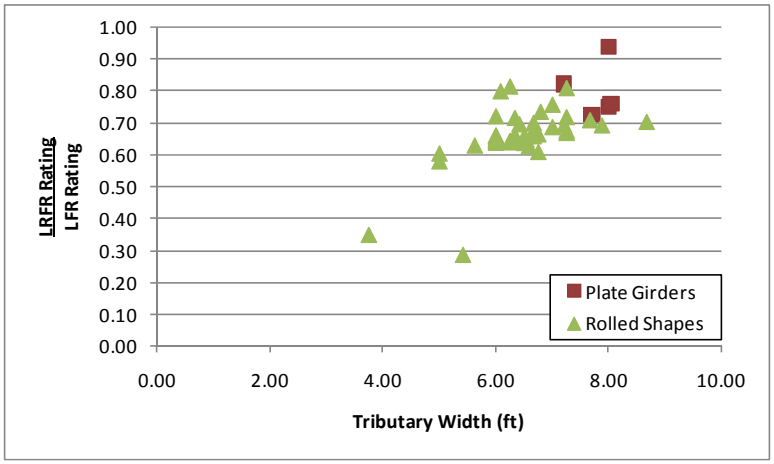


Figure G-22: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

G.1.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-23 shows that five girders have a reliability index less than the target reliability of 2.5. The reliability index for most girders is between five and seven for most girders.

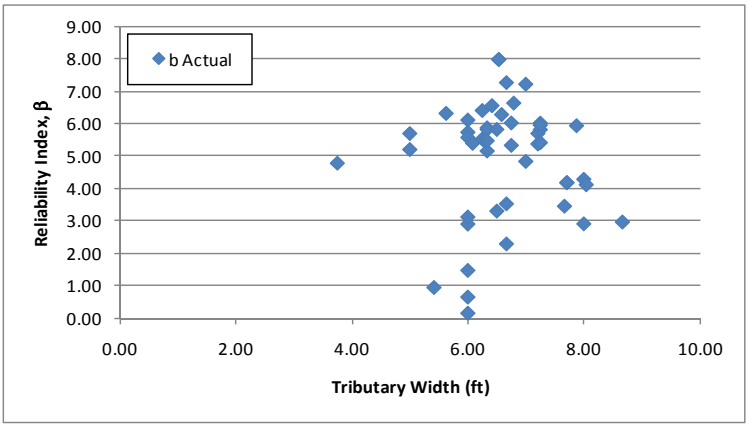


Figure G-23: Flexure Reliability Indices for DE-07 Vehicle

Figure G-22 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 vehicle. The average reliability index for girders with a rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This indicates that the live load factors currently in the MBE may be over-conservative.

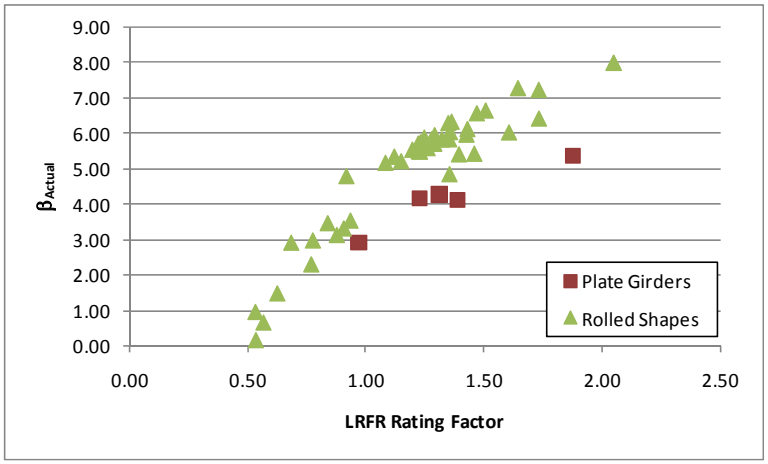
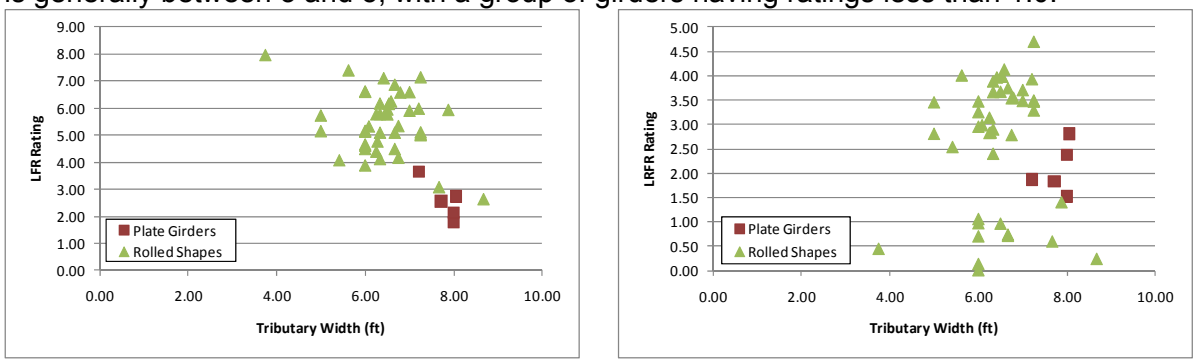


Figure G-24: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

G.1.3.2 Shear

G.1.3.2.1 Rating Factors

For shear, there are ten girders with an LRFR rating less than 1.0 and zero girders with an LFR rating less than 1.0. All ten girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 96% of the girders in this subset. Figure G-25 shows the LFR and LRFR ratings. The LFR rating is typically between 4 and 7 while the LRFR rating is generally between 3 and 5, with a group of girders having ratings less than 1.0.



(a) (b)

Figure G-25: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure G-26 shows the percentage of girders with shear ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 83.7% of girders have an LRFR rating greater than 1.0 for ADTT ≤ 100. This drops to 77.6% when the ADTT ≥ 5,000. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 16% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for ADTT ≤ 100; this increases to 22.4% when ADTT ≥ 5,000.

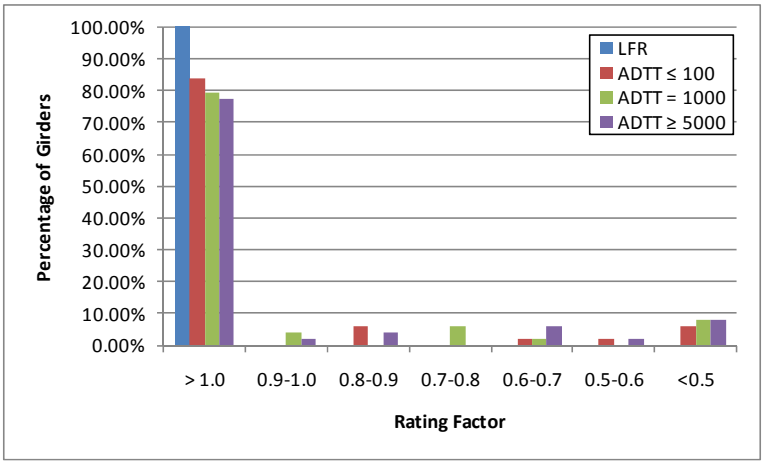


Figure G-26: Shear Ratings for Various ADTT in MBE for DE-07 Vehicle

G.1.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure G-24 shows the comparison of rating factors. The ratio is between 0.4 and 0.7, with widely spaced girders being the most likely to have a ratio greater than 1.0. There are two girders with an LRFR rating that exceeds the LFR rating.

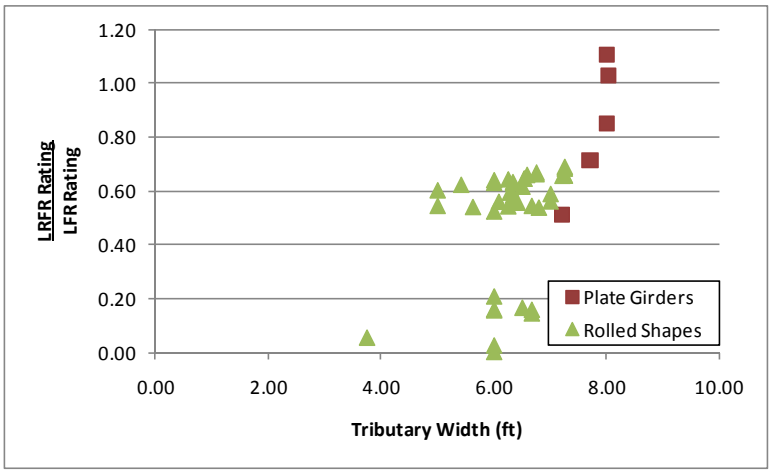


Figure G-27: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

G.1.3.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-28. The reliability index is between eight and ten for most girders.

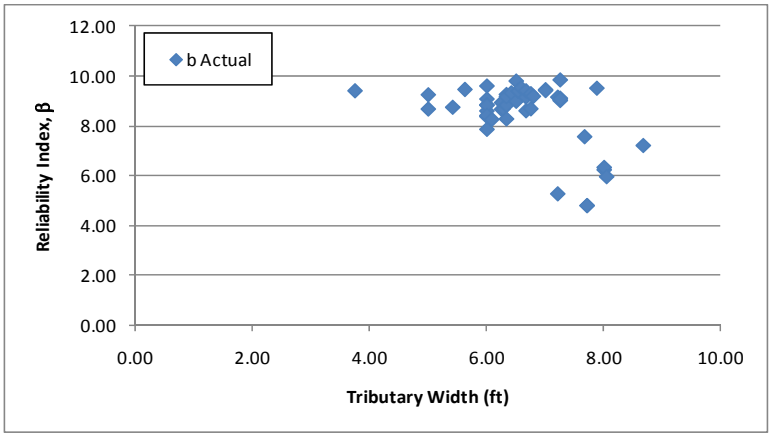


Figure G-28: Shear Reliability Indices for DE-07 Vehicle

Figure G-26 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 vehicle. The reliability index associated with a rating of 1.0 is approximately 4.0, above the target reliability of 2.5. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

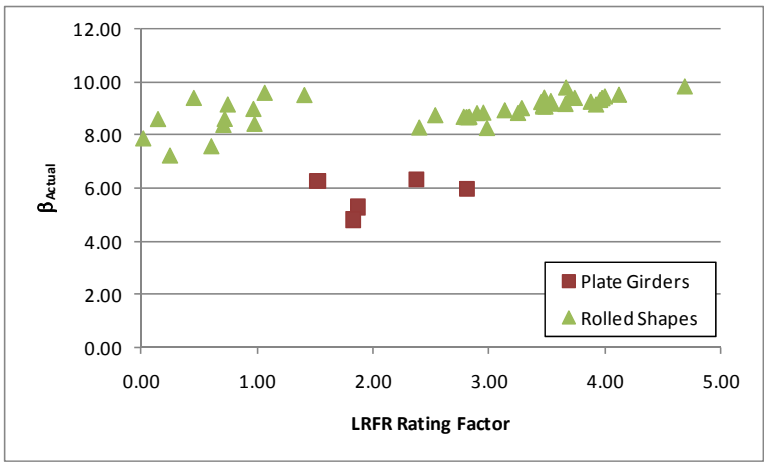
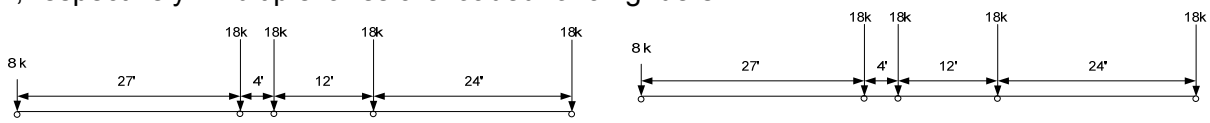


Figure G-29: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

G.1.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-30. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LFR Loading LRFR Loading

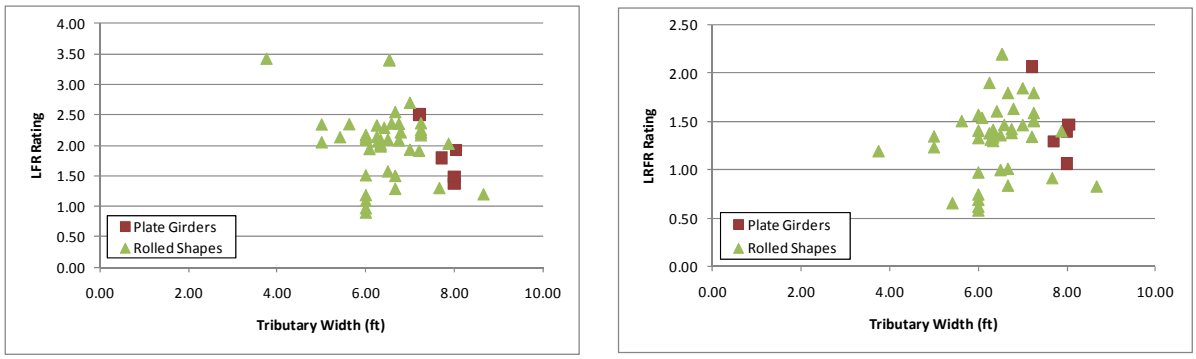
Figure G-30: Vehicle Loadings and Load Factors

G.1.4.1 Moment

The following section contains the results for interior, non-composite steel girders within continuous span bridges for the FL-04 Vehicle.

G.1.4.1.1 Rating Factors

Figure G-31 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are two girders with an LFR rating less than 1.0, ten girders with an LRFR rating less than 1.0, and two girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is typically between 2 and 2.5 while the LRFR rating is between 1.25 and 2.



(a) (b)

Figure G-31: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure G-32 shows the percentage of girders with moment ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 85.7% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders with ratings greater than 1.0 drops to 75.5% when the ADTT ≥ 5,000. 95.9% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is 10% for ADTT ≤ 100 and 20% for ADTT ≥ 5,000.

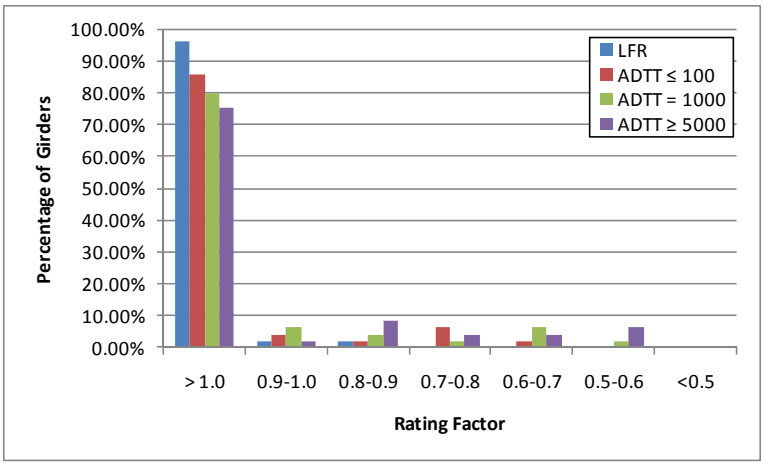


Figure G-32: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

G.1.4.1.2 Rating Factor Comparisons

Figure G-29 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is typically 60 to 80% of the LFR rating. Girders

with larger tributary widths generally had ratios closer to 1.0. No girders have LRFR ratings that exceed the LFR ratings.

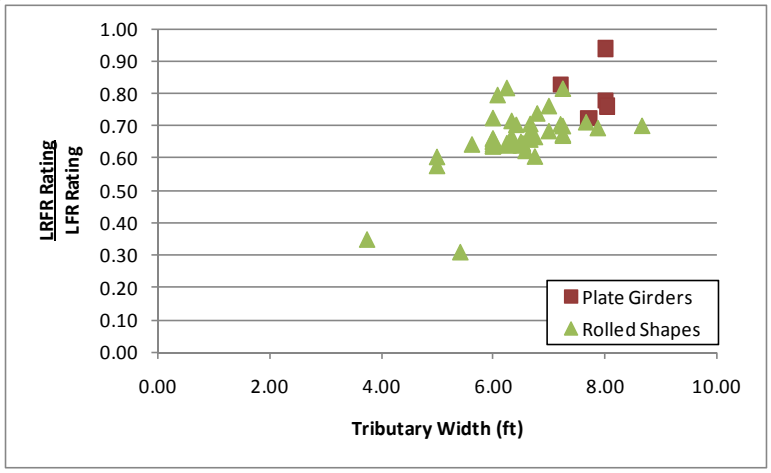


Figure G-33: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

G.1.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-34 shows that five girders have a reliability index less than the target reliability index of 2.5. The reliability index is between 5.5 and 7.0 for most girders.

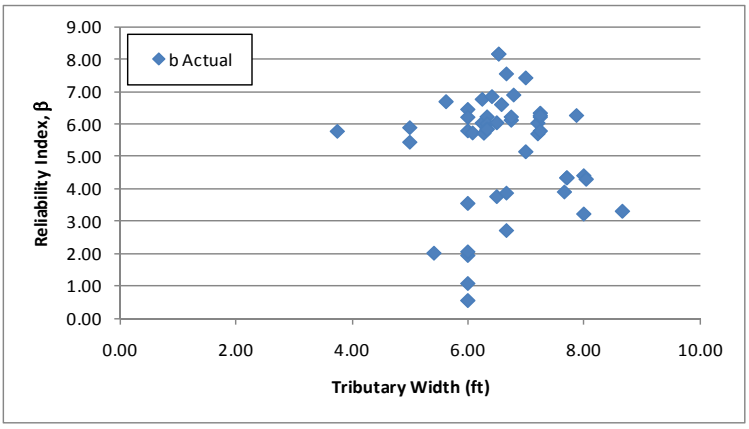


Figure G-34: Flexure Reliability Indices for FL-04 Vehicle

Figure G-31 shows the reliability index plotted against the LRFR moment rating for the FL-04 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, above the target reliability of 2.5. This indicates the LRFR live load factors in the MBE might be over-conservative.

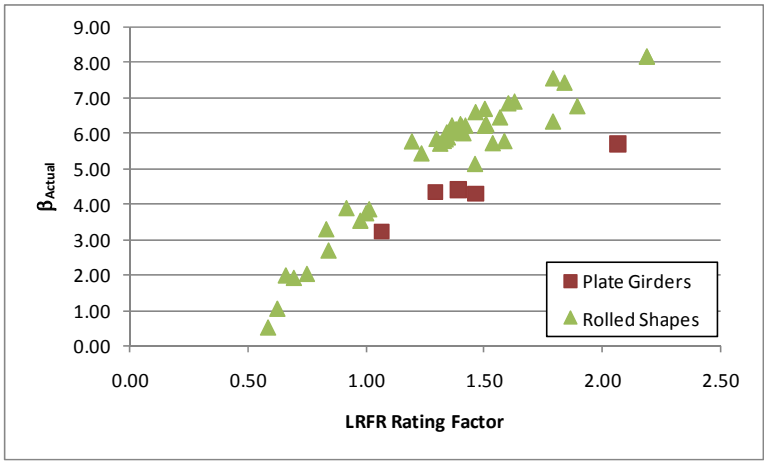
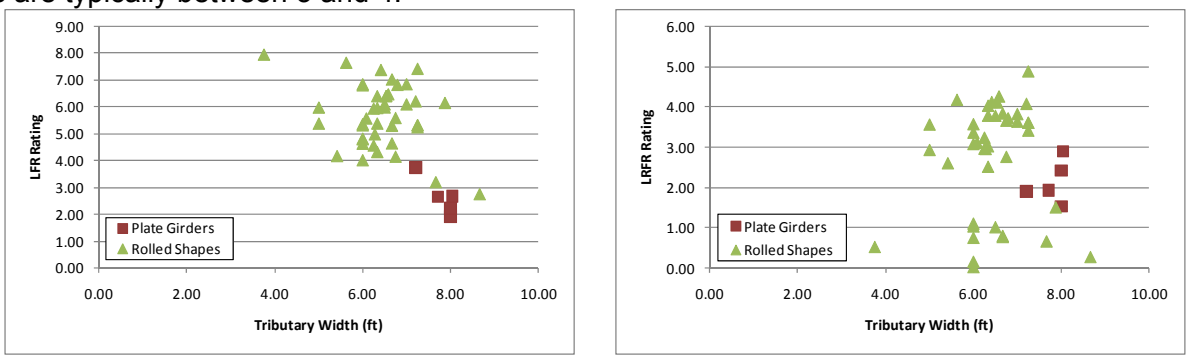


Figure G-35: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

G.1.4.2 Shear

G.1.4.2.1 Rating Factors

For shear, there are eight girders with an LRFR rating less than 1.0 and zero girders with LFR ratings less than 1.0. All eight girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 96% of the girders in this subset. Figure G-36 shows the LFR and LRFR ratings. The LFR ratings are typically between 4 and 7 while the LRFR ratings are typically between 3 and 4.



(a) (b)

Figure G-36: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure G-37 shows the percentage of girders with shear ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 83.7% of girders have an LRFR rating greater than 1.0 for ADTT ≤ 100. This drops to 77.6% when the ADTT ≥ 5,000. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 16% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for ADTT ≤ 100; this increases to 22.4% when ADTT ≥ 5,000.

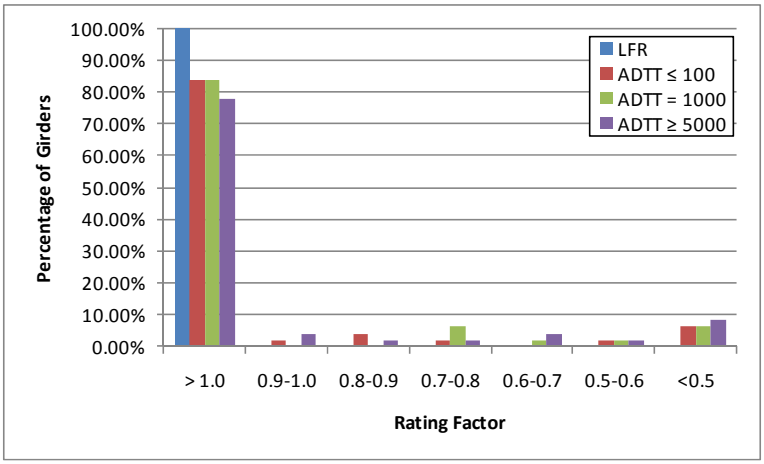


Figure G-37: Shear Ratings for Various ADTT in MBE for FL-04 Vehicle

G.1.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-38 shows the comparison of rating factors. The ratio is generally between 0.5 and 0.7, with the ratio increasing for longer span lengths. Two girders have an LRFR rating greater than the LFR rating, with both girders above 1.0 being plate girders.

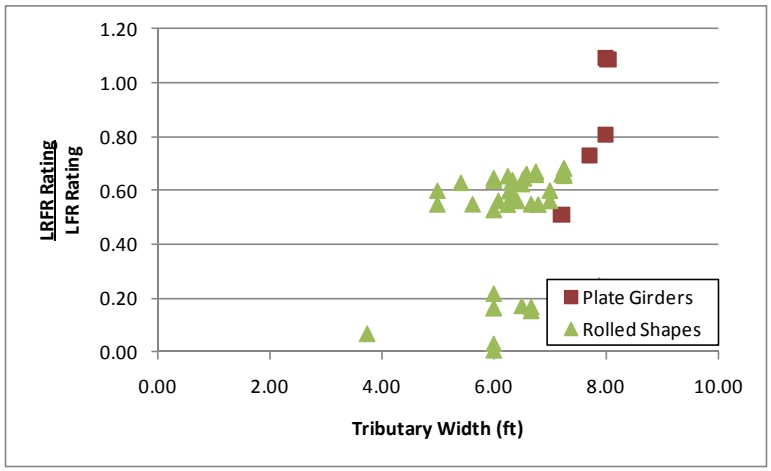


Figure G-38: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

G.1.4.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-39. The reliability index is between eight and ten for most girders.

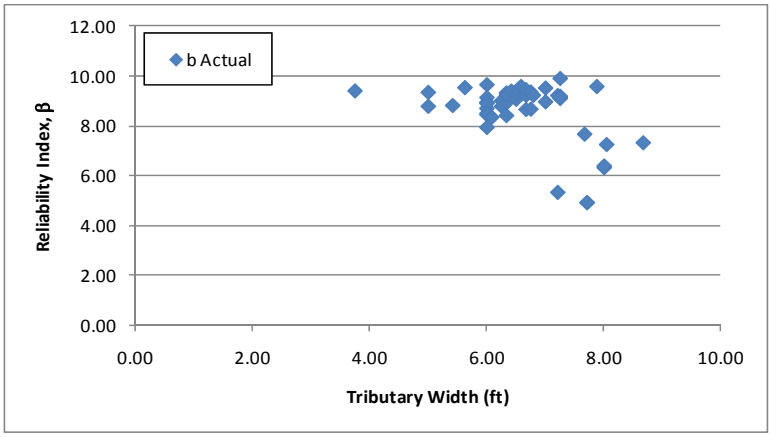


Figure G-39: Shear Reliability Indices for FL-04 Vehicle

Figure G-35 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This indicates that the live load factors in the MBE may be over-conservative. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance and not the bearing stiffener resistance.

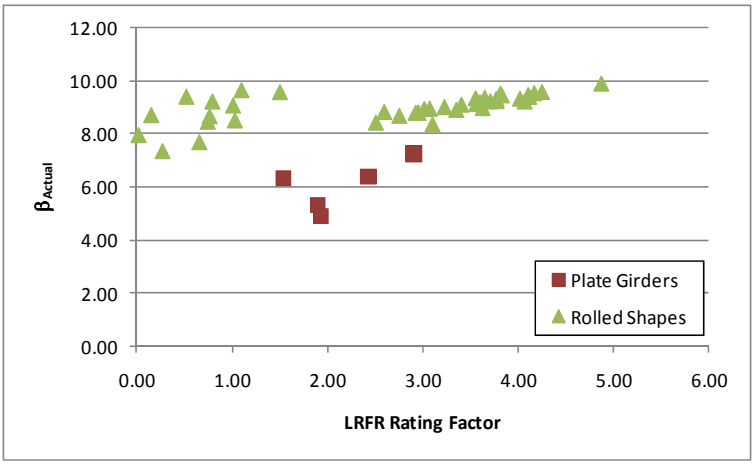


Figure G-40: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

G.1.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-41. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

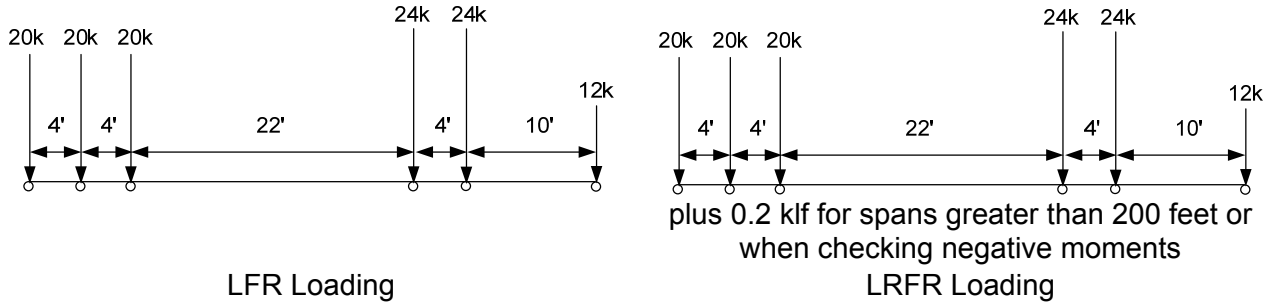


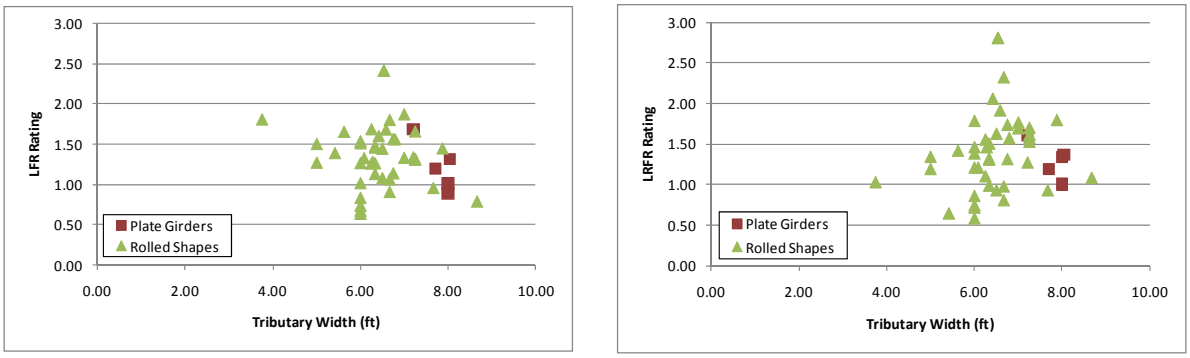
Figure G-41: Vehicle Loadings and Load Factors

G.1.5.1 Moment

The following section contains the results for interior, non-composite steel girders within continuous span bridges for the IL-01 Vehicle.

G.1.5.1.1 Rating Factors

Figure G-42 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are eight girders with an LFR rating less than 1.0, 10 girders with an LRFR rating less than 1.0, and six girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 41% of the girders in this subset. The LFR rating is between 1.0 and 1.75 for most girders while the LRFR ratings are within the same range.



(a) (b)

Figure G-42: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure G-43 shows the percentage of girders with moment ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 89.8% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders with ratings greater than 1.0 drops to 57.1% when the permit is for multiple trips and ADTT ≥ 5,000. 83.7% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is -6% for single trip, escorted permits and 26% for multiple trip permit and ADTT ≥ 5,000. The -6% indicates that more girders have ratings above one for this type of permit than for LFR.

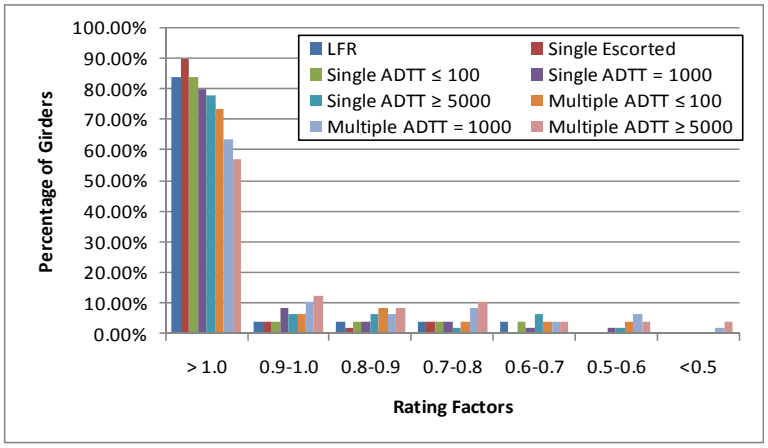


Figure G-43: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

G.1.5.1.2 Rating Factor Comparisons

Figure G-38 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.8 and 1.0 or between 1.1 and 1.2, with the higher ratios generally coming from longer spans.

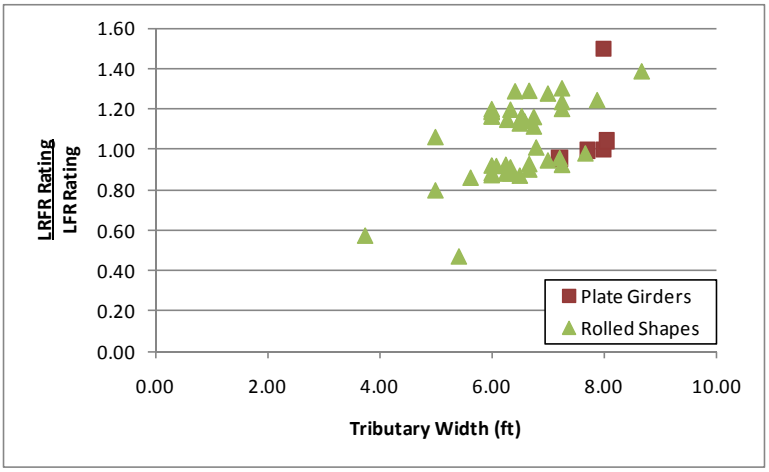


Figure G-44: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

G.1.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-45 shows three girders have a reliability index less than the target reliability index of 3.5. The reliability index is between six and eight for most girders.

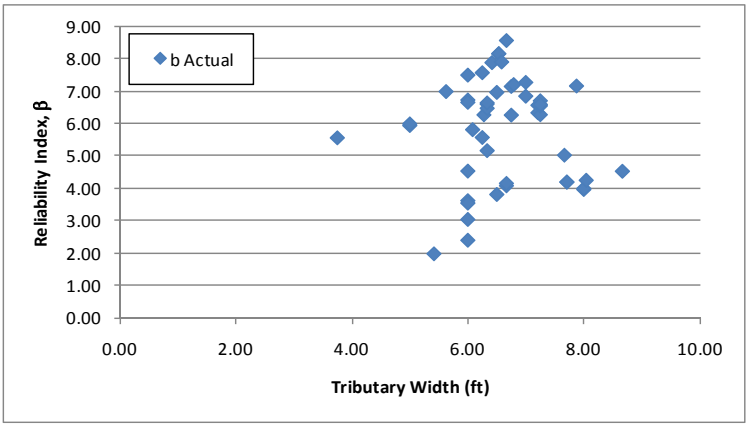


Figure G-45: Flexure Reliability Indices for IL-01 Vehicle

Figure G-40 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately 4.5, above the target reliability of 3.5. This indicates the live load factors in the MBE may be over-conservative.

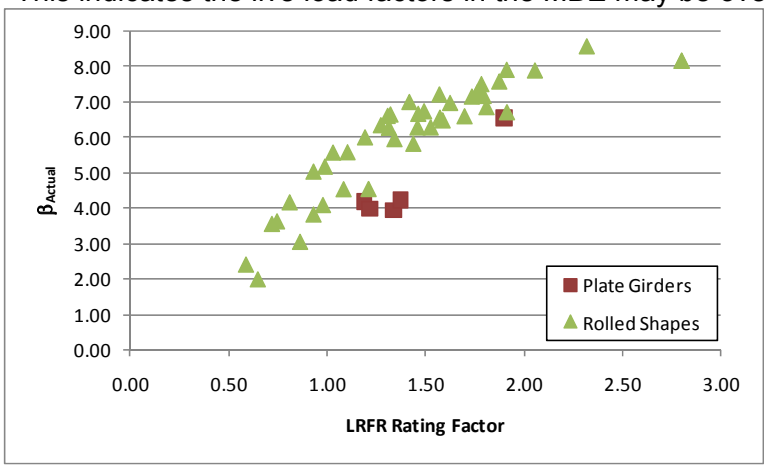
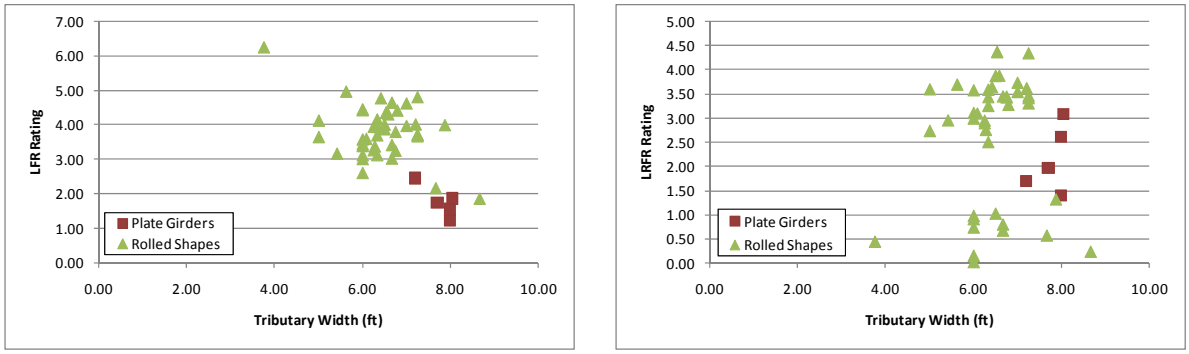


Figure G-46: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

G.1.5.2 Shear

G.1.5.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, ten girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 84% of the girders in this subset. All ten girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. Figure G-47 shows the LFR and LRFR ratings. The LFR rating is generally between 3.0 and 5.0 for all span lengths, while for LRFR the rating tends to be between 2.5 and 4.



(a) (b)

Figure G-47: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure G-48 shows the percentage of girders with shear ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 83.7% of girders have an LRFR rating greater than 1.0 for single trip, escorted permit category. This drops to 75.5% when the permit is for ADTT ≥ 5,000 and multiple trips. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 16% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for single trip, escorted permits; this increases to 25% when a multiple trip permit with ADTT ≥ 5,000 is used.

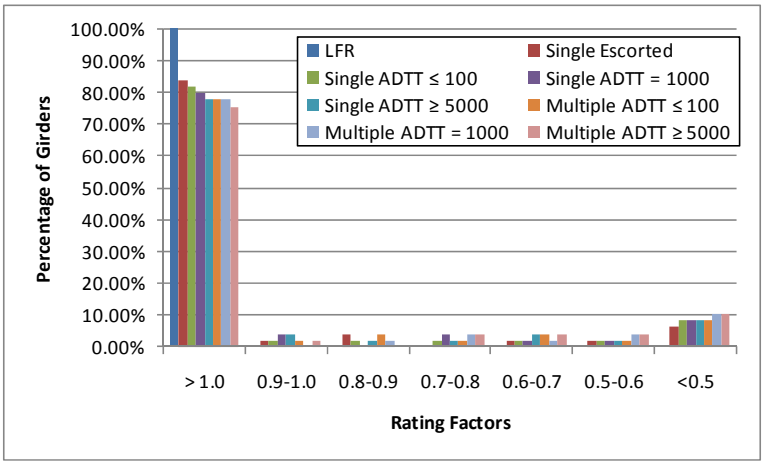


Figure G-48: Shear Ratings for Various ADTT in MBE for IL-01 Vehicle

G.1.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-42 shows the comparison of rating factors. The ratio is generally between 0.7 and 1.0 but girders more widely spaced tend to have an LRFR rating greater than the associated LFR rating. Eight girders have LRFR ratings greater than the LFR rating.

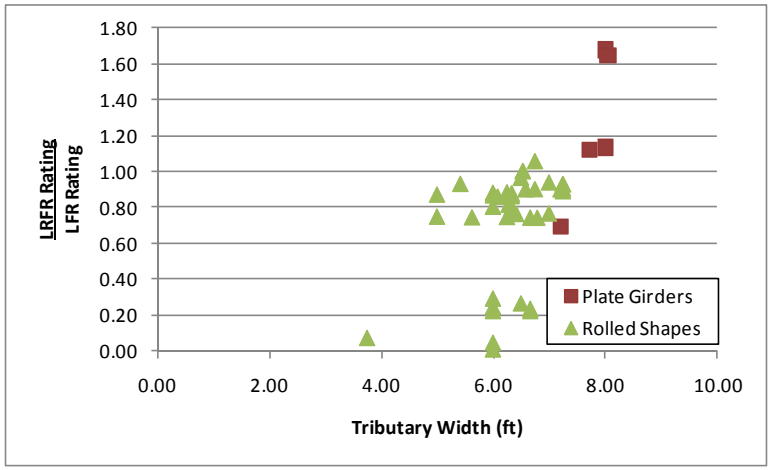


Figure G-49: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

G.1.5.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all girders as shown in Figure G-50. The reliability index is between eight and ten for most girders.

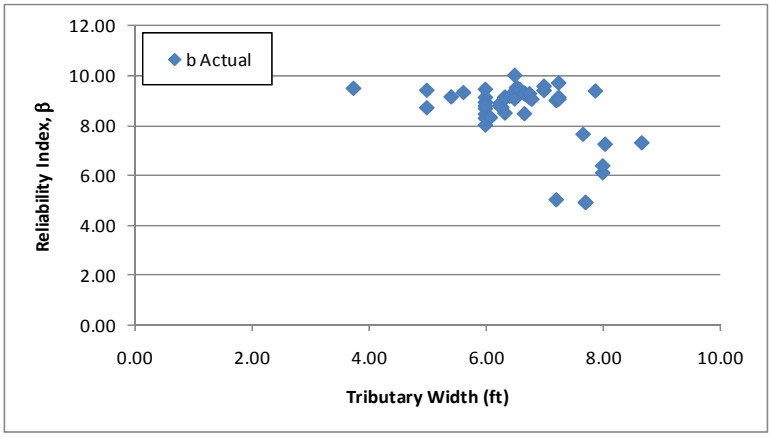


Figure G-50: Shear Reliability Indices for IL-01 Vehicle

Figure G-44 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 Vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately four, above the target reliability of 3.5. This indicates the LRFR live load factors may be slightly over-conservative.

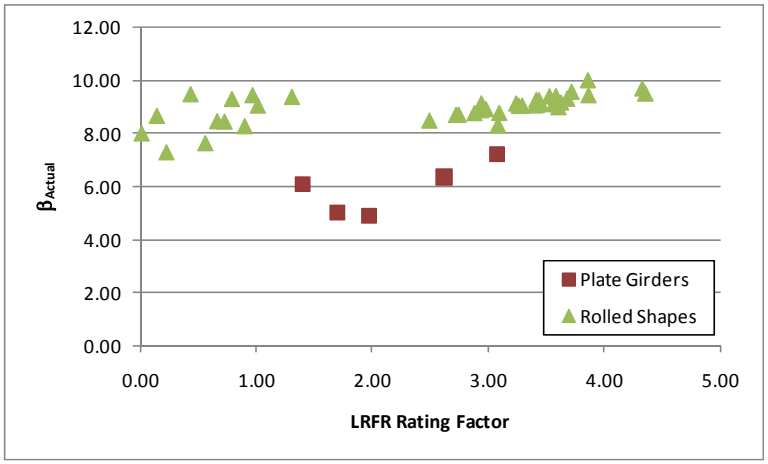


Figure G-51: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

G.1.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-52. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

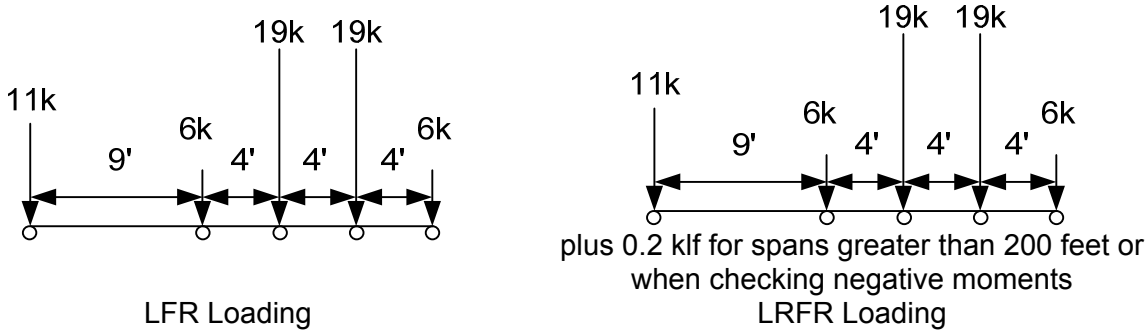


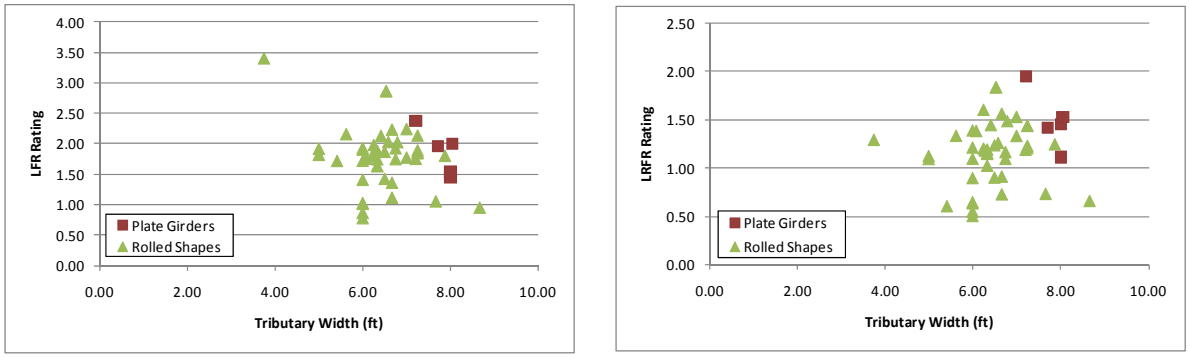
Figure G-52: Vehicle Loadings and Load Factors

G.1.6.1 Moment

The following section contains the results for interior, non-composite steel girders within continuous span bridges for the NC-21 Vehicle.

G.1.6.1.1 Rating Factors

Figure G-53 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are three girders with an LFR rating less than 1.0, 11 girders with an LRFR rating less than 1.0, and three girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR ratings are generally between 1.5 and 2.5, with the LRFR ratings generally between 1.0 and 1.75.



(a) (b)

Figure G-53: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure G-54 shows the percentage of girders with moment ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 83.7% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders with ratings greater than 1.0 drops to 65.3% when the ADTT ≥ 5,000. 93.9% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is 10% for ADTT ≤ 100 and 28% for ADTT ≥ 5,000.

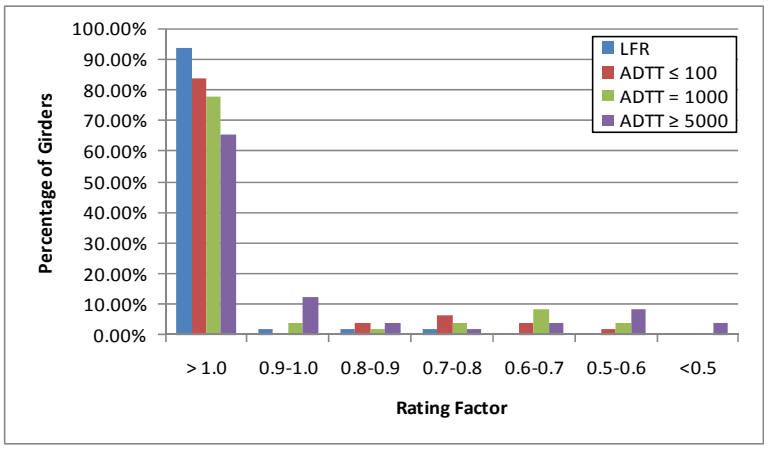


Figure G-54: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

G.1.6.1.2 Rating Factor Comparisons

Figure G-47 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8 for this vehicle, with the higher ratios corresponding to girders with larger tributary widths. No girders have an LRFR rating that is greater than the LFR rating.

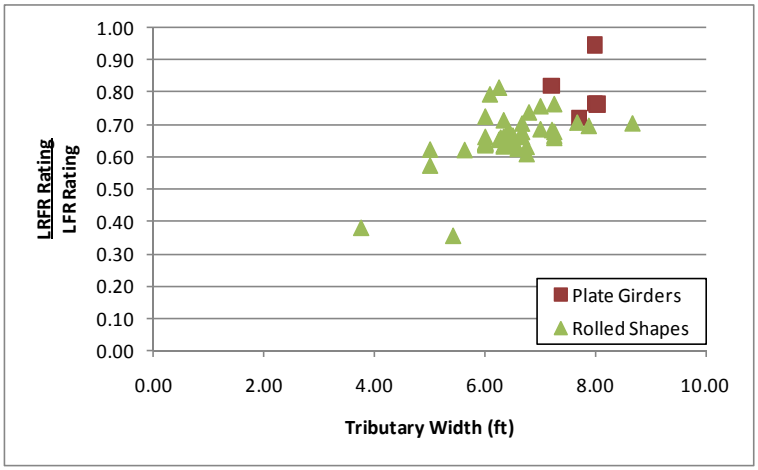


Figure G-55: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

G.1.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-56 shows that seven girders have a reliability index less than the target reliability index of 2.5. The reliability index varies about is between five and seven for most girders with at least the target level of reliability.

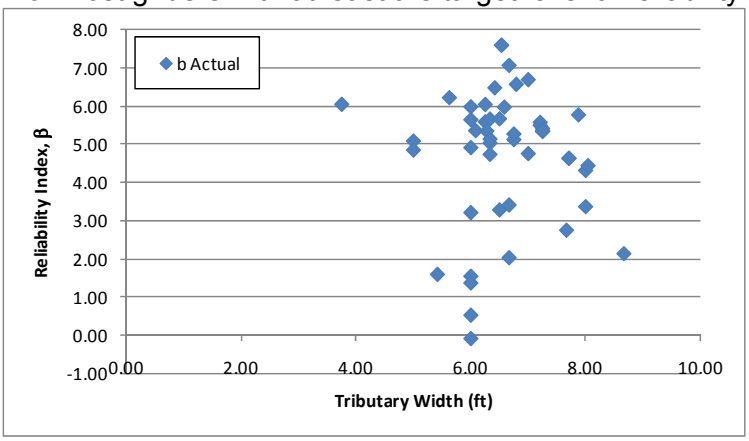


Figure G-56: Flexure Reliability Indices for NC-21 Vehicle

Figure G-49 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 Vehicle. The reliability index increases with increasing rating factors. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This indicates that the LRFR live load factors may be over-conservative.

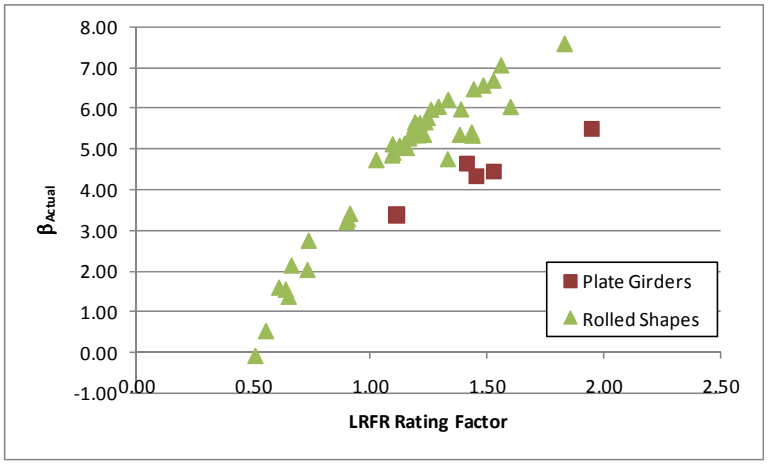
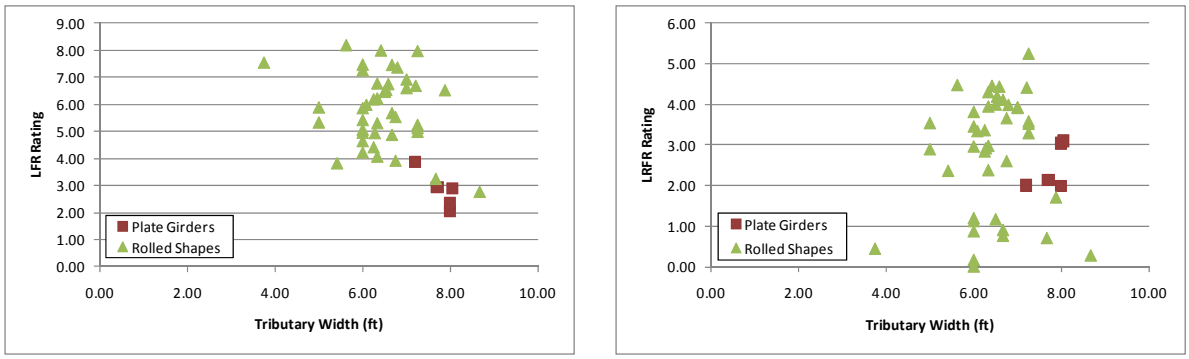


Figure G-57: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

G.1.6.2 Shear

G.1.6.2.1 Rating Factors

For shear, there are eight girders with an LRFR rating less than 1.0 for shear. The LFR Rating is greater than the LRFR rating for 96% of the girders in this subset. Figure G-58 shows the LFR and LRFR ratings. The LFR rating is generally between 4 and 7 while the LRFR rating is generally between 3 and 4.5.



(a) (b)

Figure G-58: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure G-59 shows the percentage of girders with shear ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 87.8% of girders have an LRFR rating greater than 1.0 for ADTT ≤ 100. This drops to 83.7% when the ADTT ≥ 5,000. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 12% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for ADTT ≤ 100; this increases to 16.3% when ADTT ≥ 5,000.

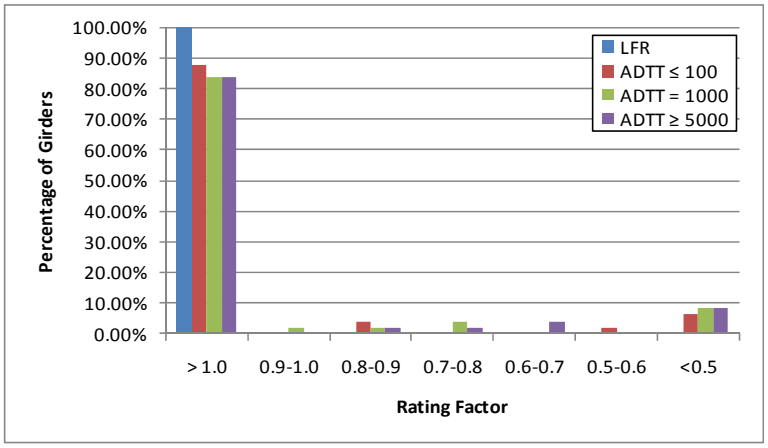


Figure G-59: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

G.1.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-51 shows the comparison of rating factors. The ratio is generally between 0.5 and 0.7. Girders with larger tributary widths are more likely to have an LRFR rating greater than the LFR rating. Two girders have an LRFR rating greater than the LFR rating.

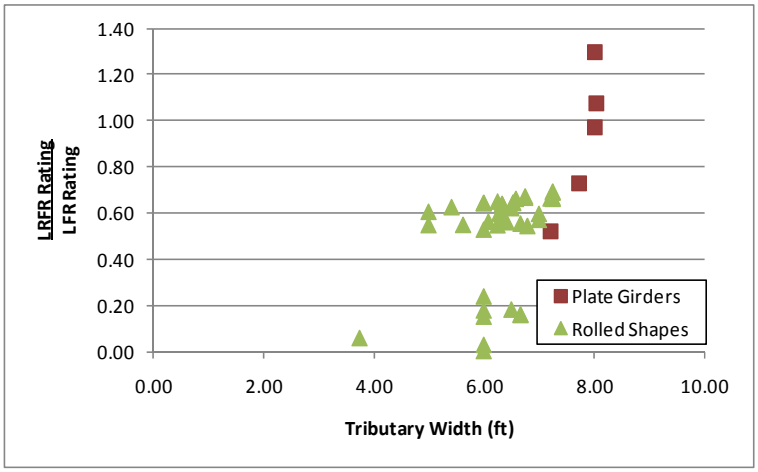


Figure G-60: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

G.1.6.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-61. The reliability index is between eight and ten for most girders.

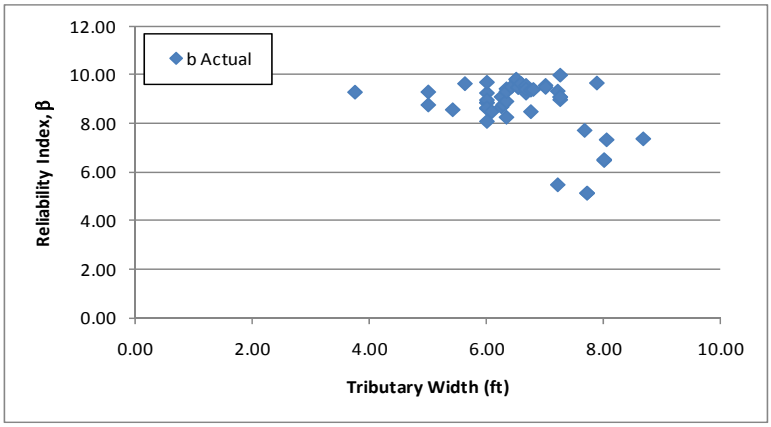


Figure G-61: Shear Reliability Indices for NC-21 Vehicle

Figure G-53 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 vehicle. The reliability index associated with an LRFR rating of 1.0 is above four, well above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear strength not the bearing stiffener resistance.

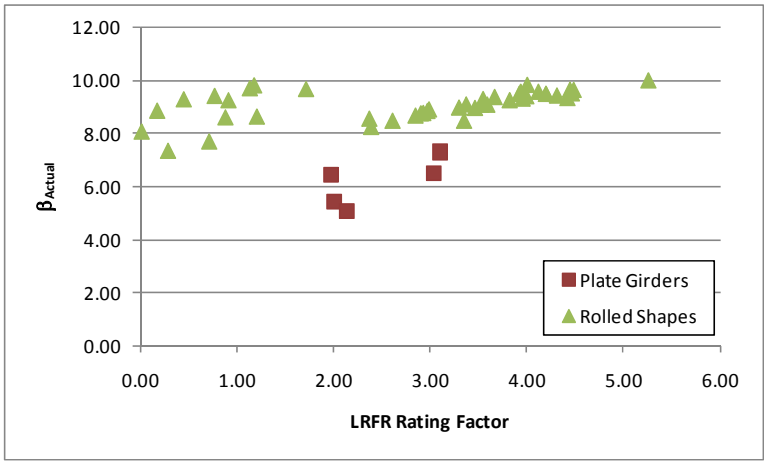


Figure G-62: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

G.1.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-63. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

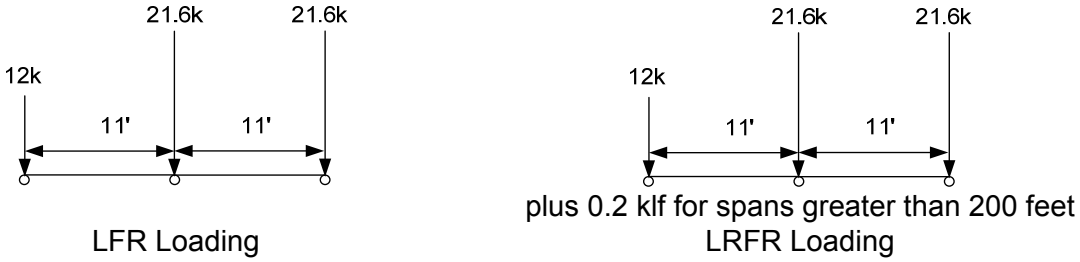


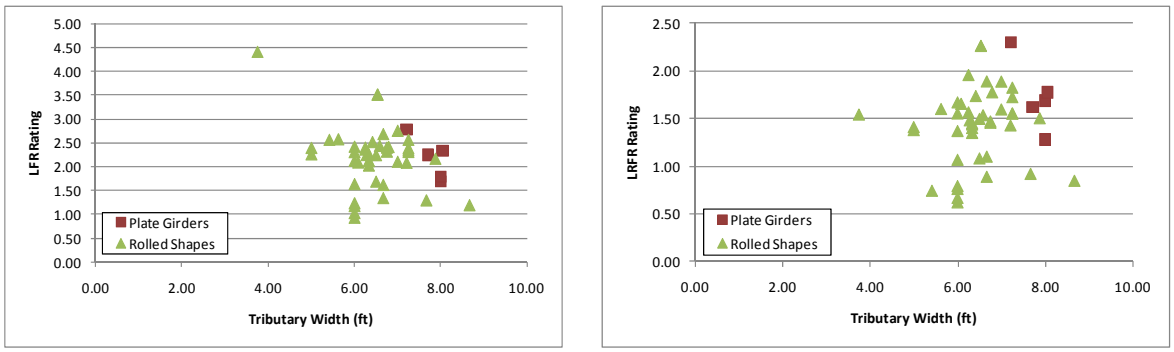
Figure G-63: Vehicle Loadings and Load Factors

G.1.7.1 Moment

The following section contains the results for interior, non-composite steel girders within continuous span bridges for the NM-04 Vehicle.

G.1.7.1.1 Rating Factors

Figure G-64 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, eight girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is generally between 2 and 2.5 while the LRFR rating is generally between 1.5 and 2.0.



(a) (b)

Figure G-64: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure G-65 shows the percentage of girders with moment ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 87.8% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders with ratings greater than 1.0 drops to 77.6% when the ADTT ≥ 5,000. 98.0% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is 10% for ADTT ≤ 100 and 20% for ADTT ≥ 5,000.

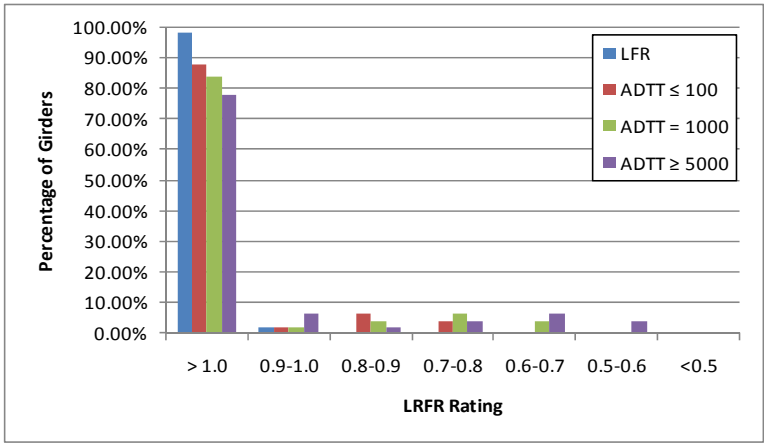


Figure G-65: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

G.1.7.1.2 Rating Factor Comparisons

Figure G-56 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8, with no

girders having LRFR ratings greater than the LFR rating. The ratio increases with increasing tributary widths.

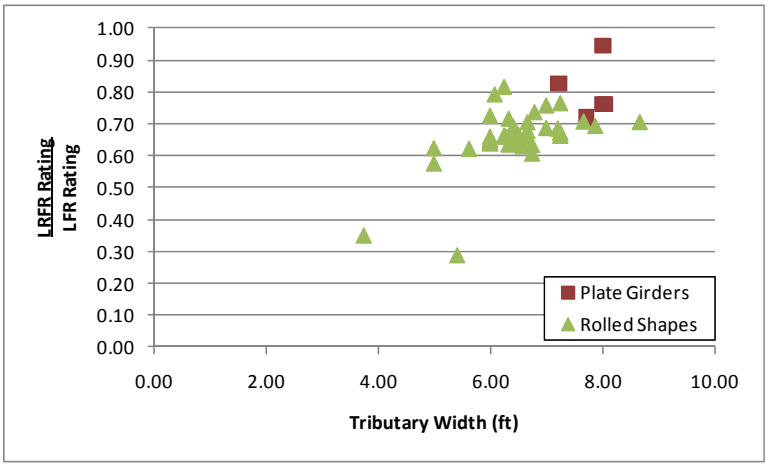


Figure G-66: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

G.1.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-67 shows that four girders have a reliability index less than the target reliability index of 2.5. The reliability index varies widely with most girders with at least the target level of reliability between 0.6 and 0.7.

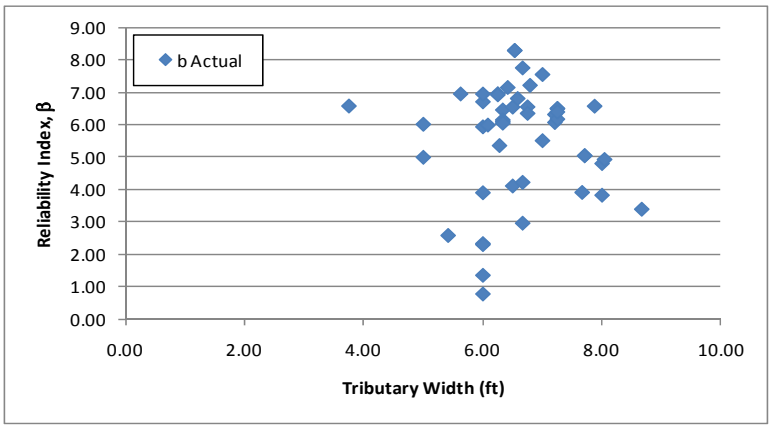


Figure G-67: Flexure Reliability Indices for NM-04 Vehicle

Figure G-58 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately four, above the target reliability of 2.5. This indicates that the LRFR live load factors may be over-conservative.

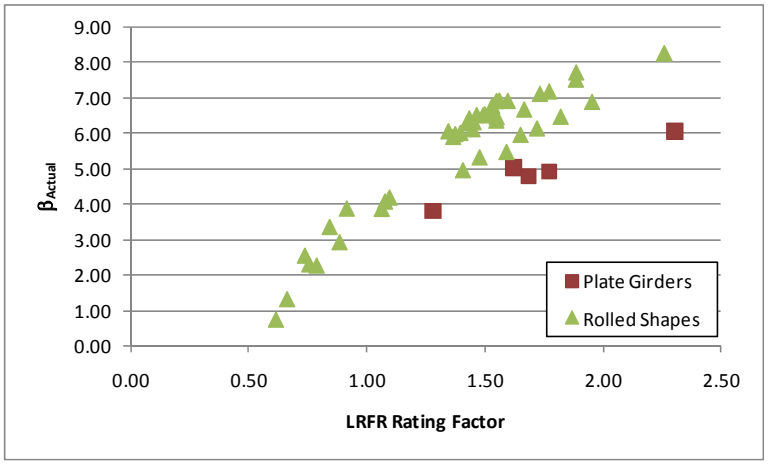
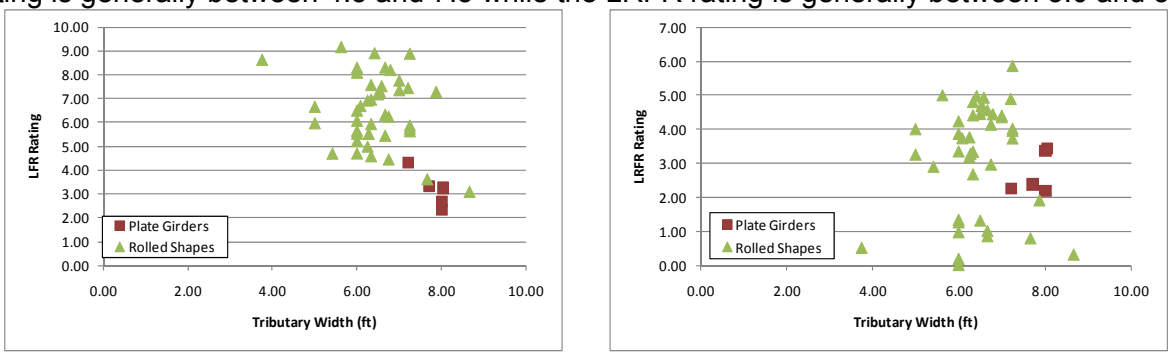


Figure G-68: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

G.1.7.2 Shear

G.1.7.2.1 Rating Factors

For shear, there are seven girders with an LRFR rating less than 1.0. All seven girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 96% of the girders in this subset. Figure G-69 shows the LFR and LRFR ratings. The LFR rating is generally between 4.5 and 7.5 while the LRFR rating is generally between 3.0 and 5.0.



(a) (b)

Figure G-69: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure G-70 shows the percentage of girders with shear ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 87.8% of girders have an LRFR rating greater than 1.0 for ADTT ≤ 100. This drops to 83.7% when the ADTT ≥ 5,000. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 12% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for ADTT ≤ 100; this increases to 16% when the ADTT ≥ 5,000.

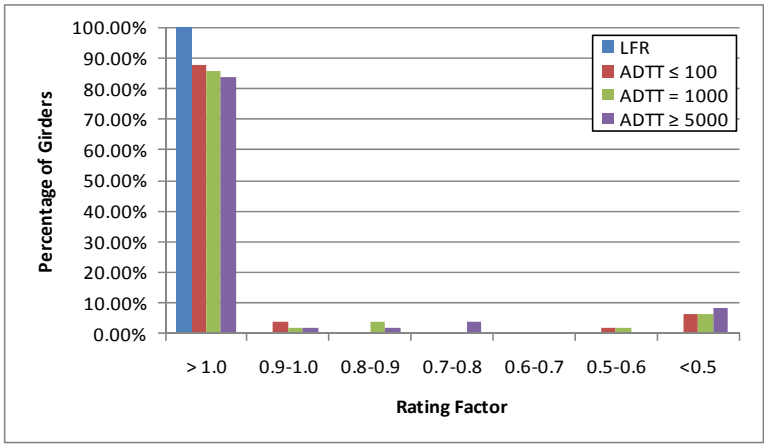


Figure G-70: Shear Ratings for Various ADTT in MBE for NM-04 Vehicle

G.1.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-60 shows the comparison of rating factors. The ratio is generally between 0.5 and 0.7. Girders with larger tributary widths have a higher ratio than those more narrowly spaced. Two girders have LRFR ratings that exceed the LFR rating for this vehicle.

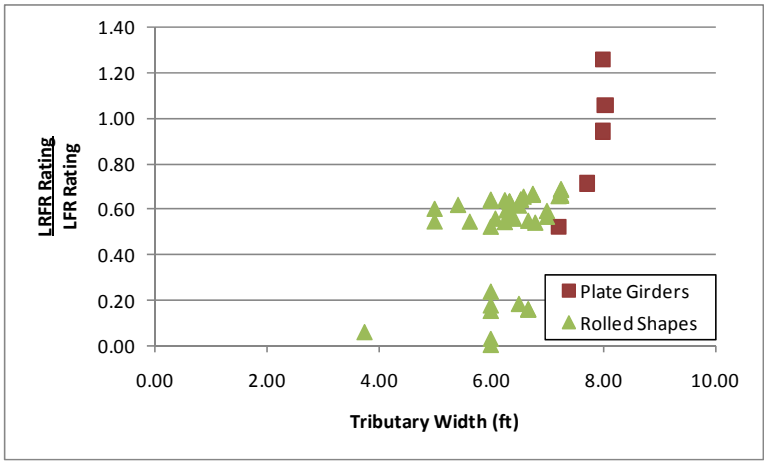


Figure G-71: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

G.1.7.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-72. The reliability index is between eight and ten for most girders.

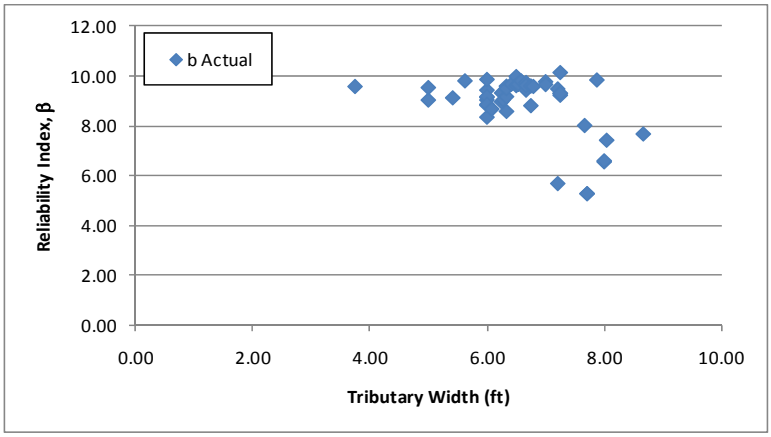


Figure G-72: Shear Reliability Indices for NM-04 Vehicle

Figure G-62 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0, well above the target reliability index of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

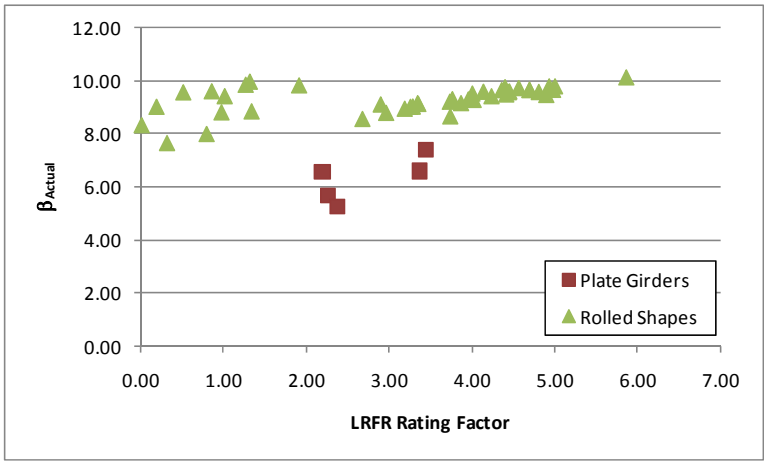
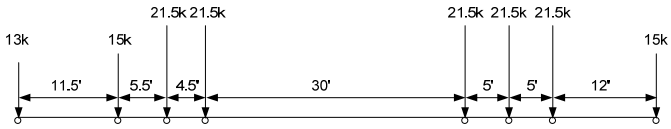


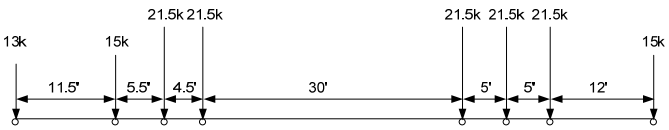
Figure G-73: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

G.1.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-74. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading



plus 0.2 klf for spans greater than 200 feet

LRFR Loading

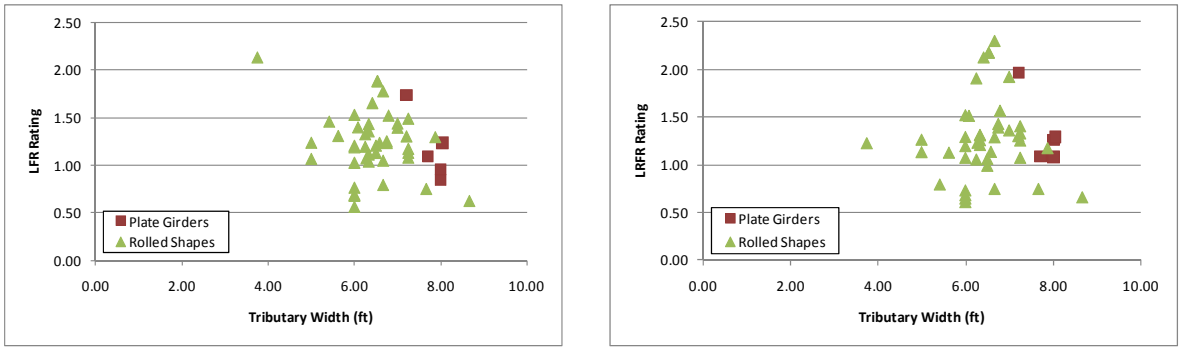
Figure G-74: Vehicle Loadings and Load Factors

G.1.8.1 Moment

The following section contains the results for interior, non-composite steel girders within continuous span bridges for the OR-06 Vehicle.

G.1.8.1.1 Rating Factors

Figure G-75 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are nine girders with an LFR rating less than 1.0, nine girders with an LRFR rating less than 1.0, and seven girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 49% of the girders in this subset. The LFR rating is generally within between 1.0 and 1.5 while the LRFR rating is also between 1.0 and 1.5.



(a) (b)

Figure G-75: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure G-76 shows the percentage of girders with moment ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 83.7% of girders have LRFR ratings greater than 1.0 for a single trip, escorted permit vehicle. The percentage of girders with ratings greater than 1.0 drops to 30.6% when the vehicle is a multiple trip permit with ADTT ≥ 5,000. 81.6% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is -2% for single trip, escorted permits and 51% for ADTT ≥ 5,000. More girders have ratings greater than 1.0 for the single trip, escorted permits and single trip permit with ADTT ≤ 100 than for LFR, this is indicated by the negative percentage.

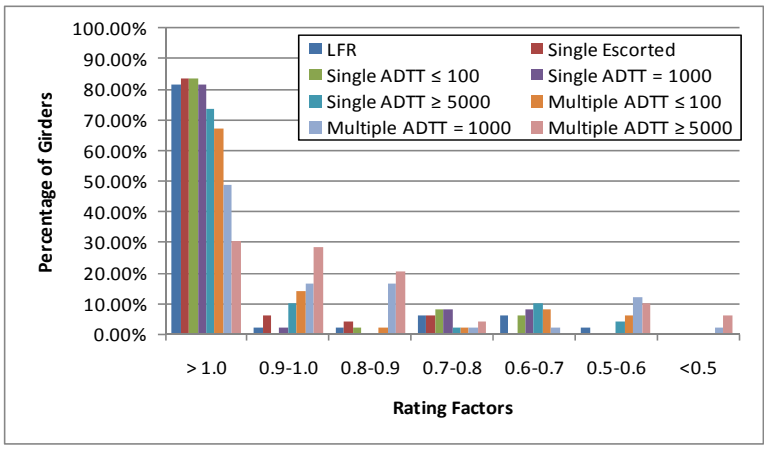


Figure G-76: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

G.1.8.1.2 Rating Factor Comparisons

Figure G-65 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.8 and 1.4, with larger tributary widths tending to have larger ratios. 51% of girders have an LRFR rating that is greater than the LFR rating.

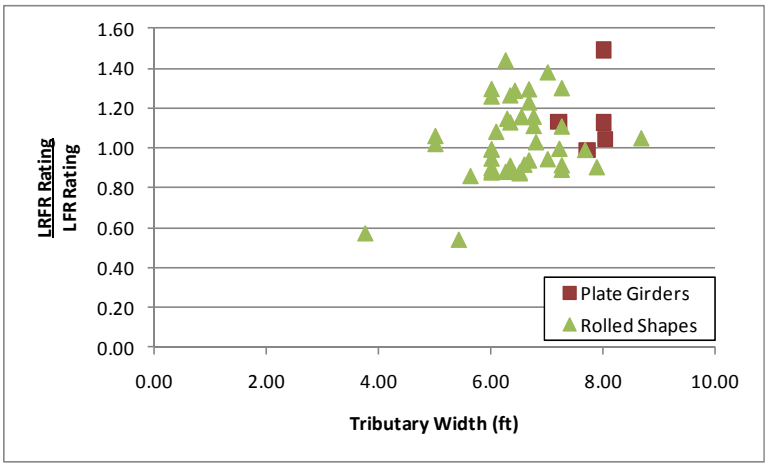


Figure G-77: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

G.1.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-78 shows there are eight girders with a reliability index that is less than the target reliability index of 3.5. Most girders are between five and eight for most girders.

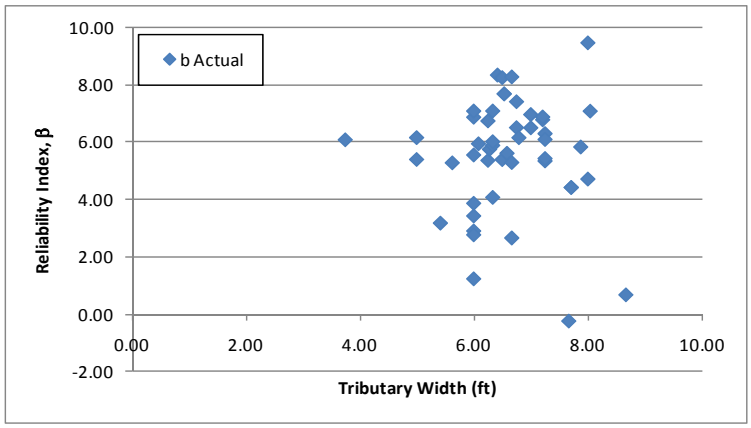


Figure G-78: Flexure Reliability Indices for OR-06 Vehicle

Figure G-67 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 vehicle. The reliability index for a girder with a rating of 1.0 is approximately 4.5, there is more variation in this graph than for other vehicles. The reliability index of 4.5 is above the target reliability of 3.5. This indicates the LRFR live load factors may be over-conservative.

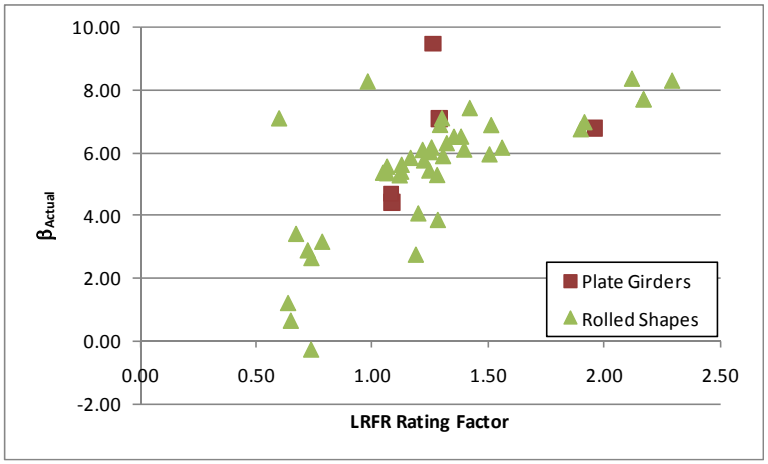
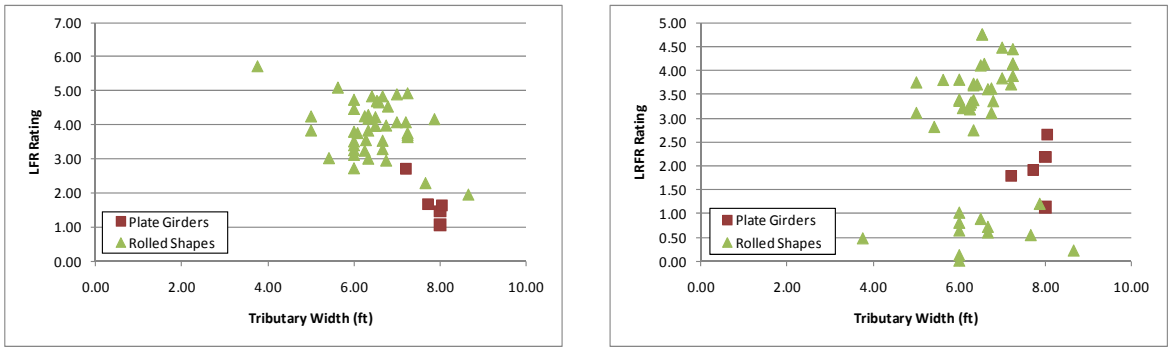


Figure G-79: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

G.1.8.2 Shear

G.1.8.2.1 Rating Factors

For shear, there are ten girders with an LRFR rating less than 1.0, and no girders with LFR ratings less than 1.0. All ten girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure G-80 shows the LFR and LRFR ratings. The LFR rating is generally between 3 and 5; the LRFR rating is generally between 3 and 4. The ratings for plate girders are typically less than the ratings for rolled shapes.



(a) (b)

Figure G-80: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure G-81 shows the percentage of girders with shear ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 81.6% of girders have an LRFR rating greater than 1.0 for a single trip, escorted permit. This drops to 73.5% when the permit is for multiple trips and ADTT ≥ 5,000. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 18% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for single trip, escorted permits; this increases to 26.5% when the permit is for multiple trips and ADTT ≥ 5,000.

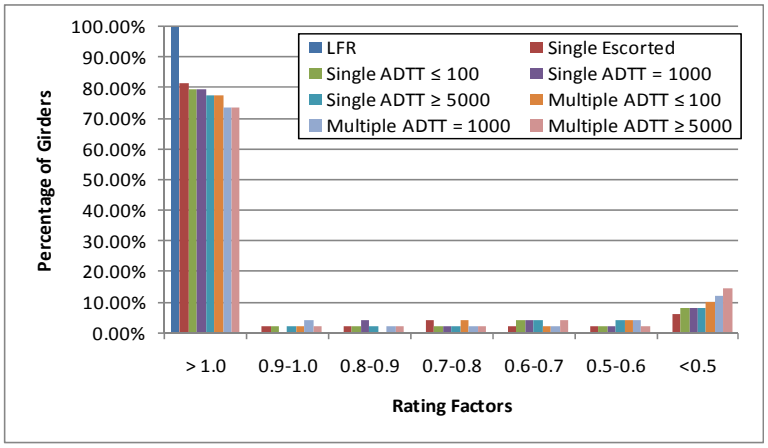


Figure G-81: Shear Ratings for Various ADTT in MBE for OR-06 Vehicle

G.1.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-69 shows the comparison of rating factors. The ratio is generally between 0.8 and 1.0 for this set of girders with this vehicle. There are twelve girders with LRFR ratings that are greater than the LFR rating.

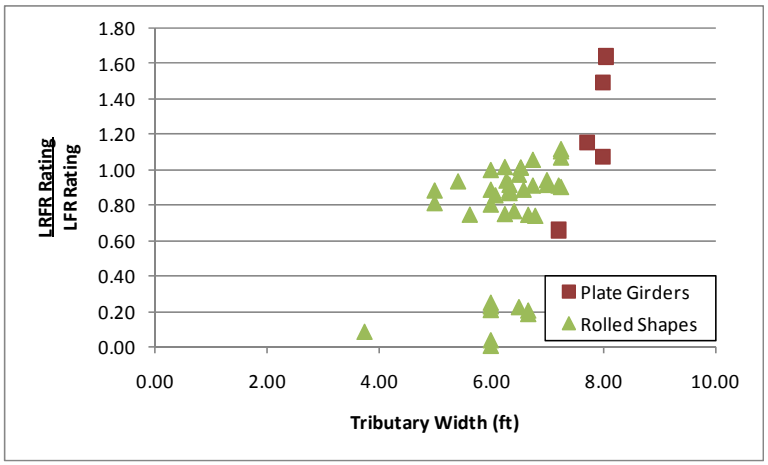


Figure G-82: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

G.1.8.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all girders as shown in Figure G-83. The reliability index is between eight and ten for most girders, with several that are lower.

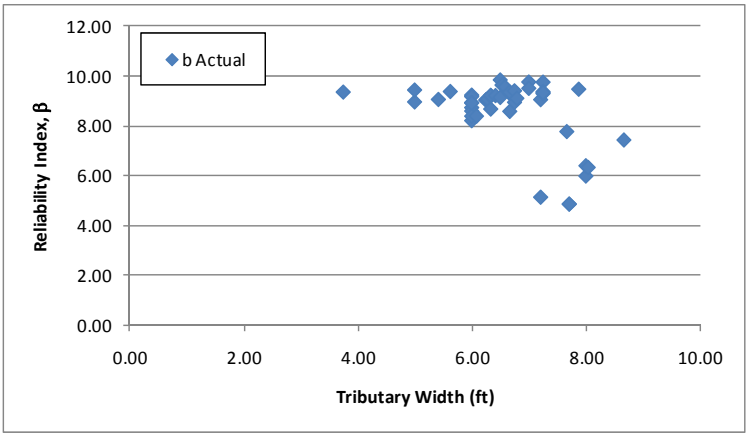


Figure G-83: Shear Reliability Indices for OR-06 Vehicle

Figure G-71 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, the target reliability index for this vehicle. This indicates the LRFR live load factors provide the target level of reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

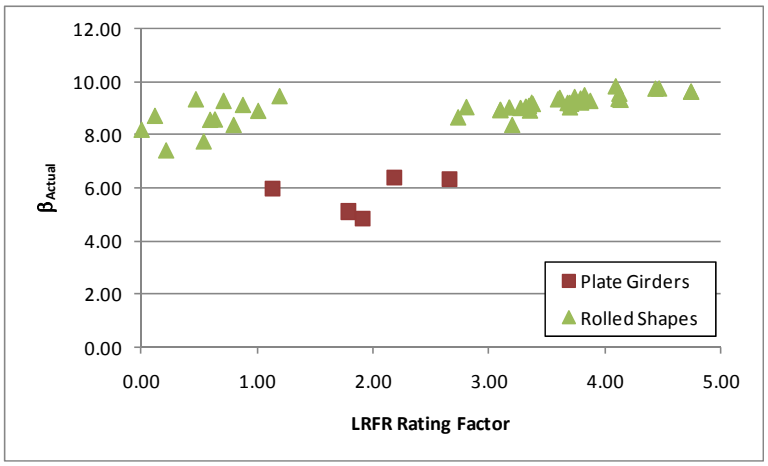
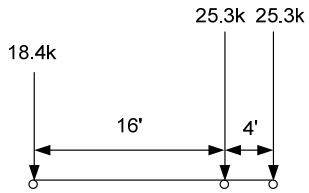


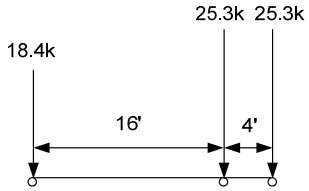
Figure G-84: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

G.1.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-85. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LRFR Loading

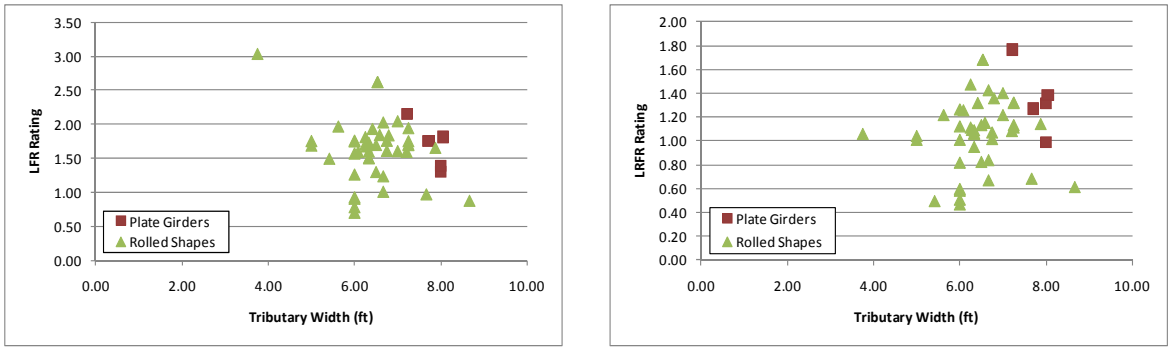
Figure G-85: Vehicle Loadings and Load Factors

G.1.9.1 Moment

The following section contains the results for interior, non-composite steel girders within continuous span bridges for the TX-04 Vehicle.

G.1.9.1.1 Rating Factors

Figure G-86 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are six girders with an LFR rating less than 1.0, 13 girders with an LRFR rating less than 1.0, and six girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is generally between 1.5 and 2.0 while for LRFR the rating is generally between 1.0 and 1.5.



(a) (b)

Figure G-86: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure G-87 shows the percentage of girders with moment ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 77.6% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders with ratings greater than 1.0 drops to 44.9% when the ADTT ≥ 5,000. 87.8% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is 10% for ADTT ≤ 100 and 43% for ADTT ≥ 5,000.

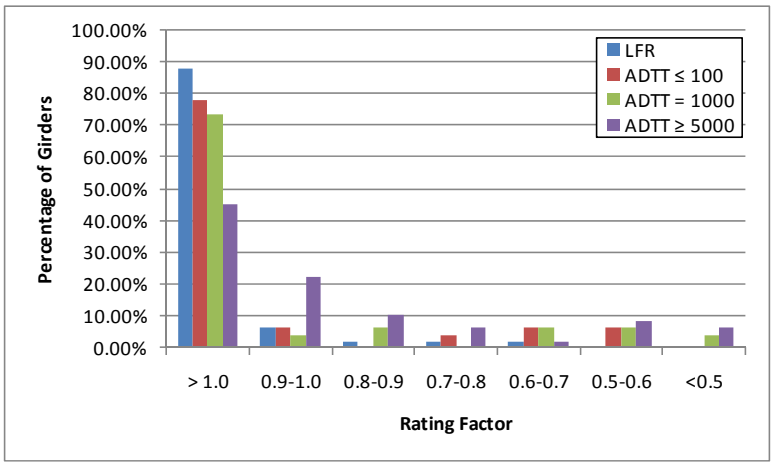


Figure G-87: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

G.1.9.1.2 Rating Factor Comparisons

Figure G-74 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is typically 60 to 80% of the LFR rating with the ratio increasing with increasing tributary widths. No girders have an LRFR rating that is greater than the LFR rating.

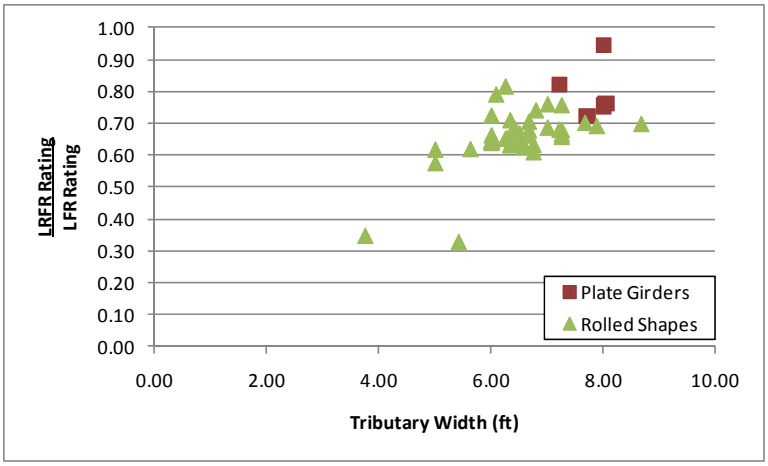


Figure G-88: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

G.1.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-89 shows eight girders have a reliability index less than the target reliability index of 2.5. Most girders have a reliability index between four and six for most girders that have at least the target level of reliability.

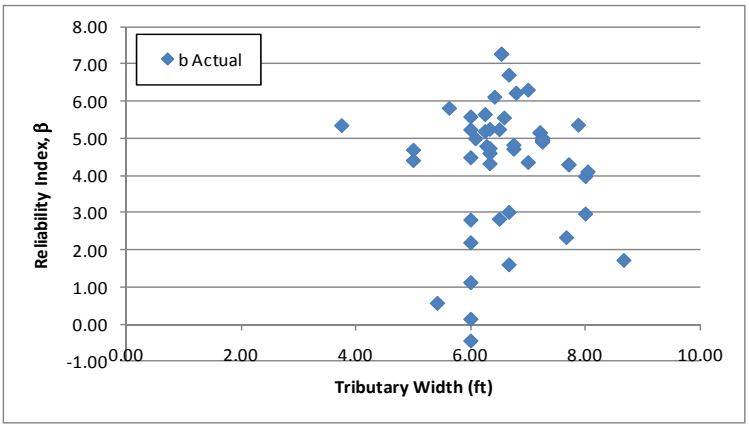


Figure G-89: Flexure Reliability Indices for TX-04 Vehicle

Figure G-76 shows the reliability index for moment plotted against the LRFR moment rating for TX-04 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

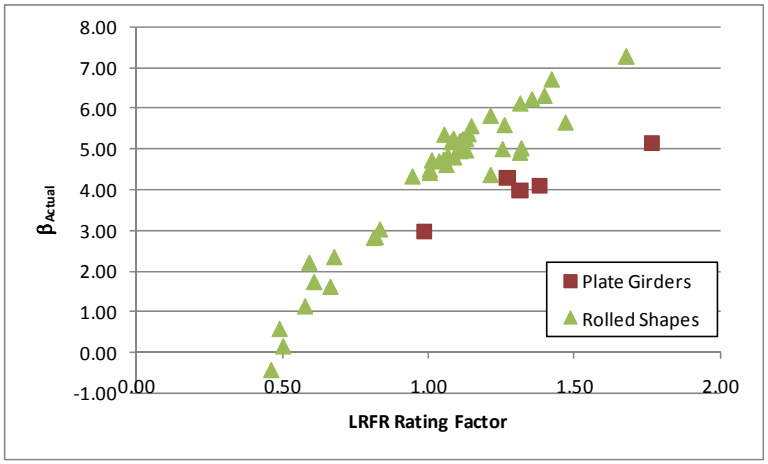
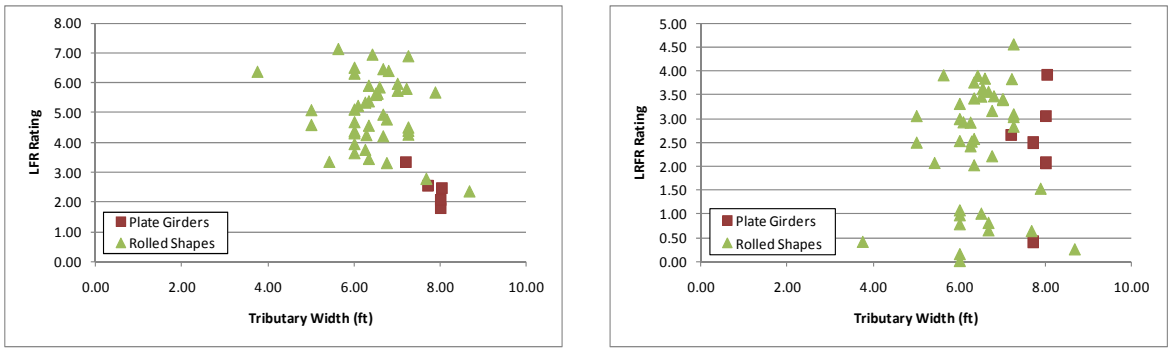


Figure G-90: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

G.1.9.2 Shear

G.1.9.2.1 Rating Factors

For shear, there are nine girders with an LRFR rating less than 1.0. The LFR Rating is greater than the LRFR rating for 96% of the girders in this subset. Figure G-91 shows the LFR and LRFR ratings. The LFR rating is between three and six for most girders while the LRFR rating is between two and four.



(a) (b)

Figure G-91: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure G-92 shows the percentage of girders with shear ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 83.7% of girders have an LRFR rating greater than 1.0 for ADTT ≤ 100. This drops to 77.6% when the ADTT ≥ 5,000. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 16% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for ADTT ≤ 100; this increases to 22.4% when ADTT ≥ 5,000.

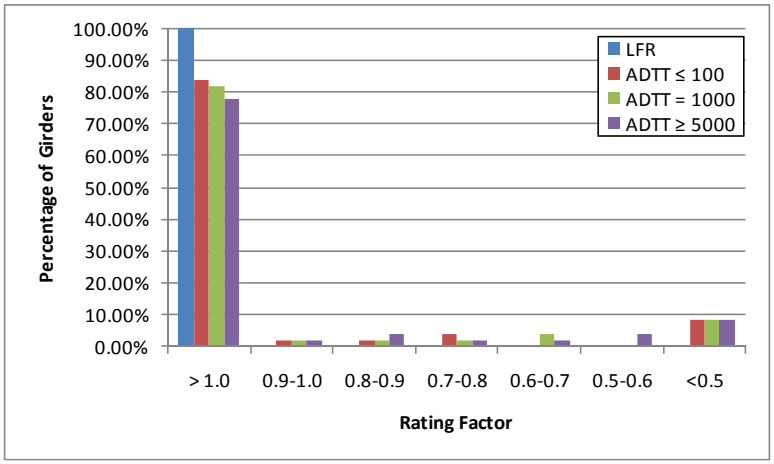


Figure G-92: Shear Ratings for Various ADTT in MBE for TX-04 Vehicle

G.1.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-78 shows the comparison of rating factors. The ratio is generally between 0.5 and 0.7 for shear, with larger tributary widths having higher ratios. Two girders have an LRFR rating that is greater than the LFR rating. Plate girders tend to have higher ratios than rolled shapes.

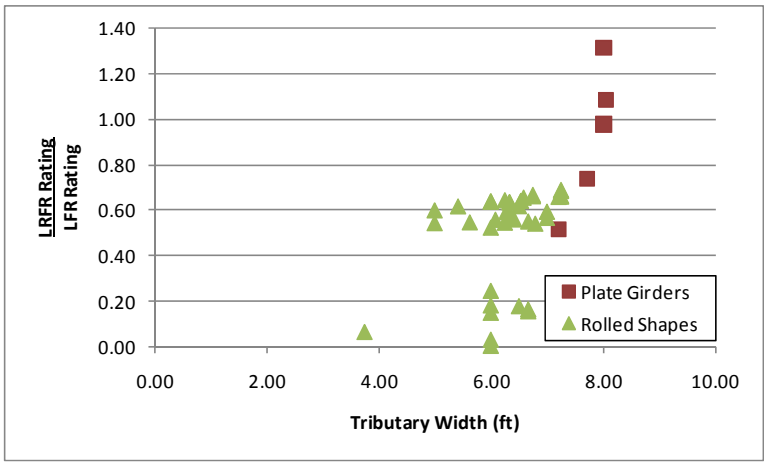


Figure G-93: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

G.1.9.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-94. Most girders have a reliability index between eight and ten.

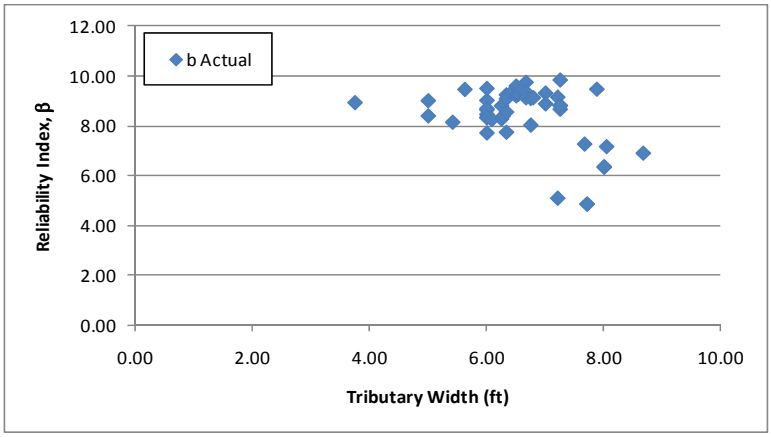


Figure G-94: Shear Reliability Indices for TX-04 Vehicle

Figure G-80 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately four, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

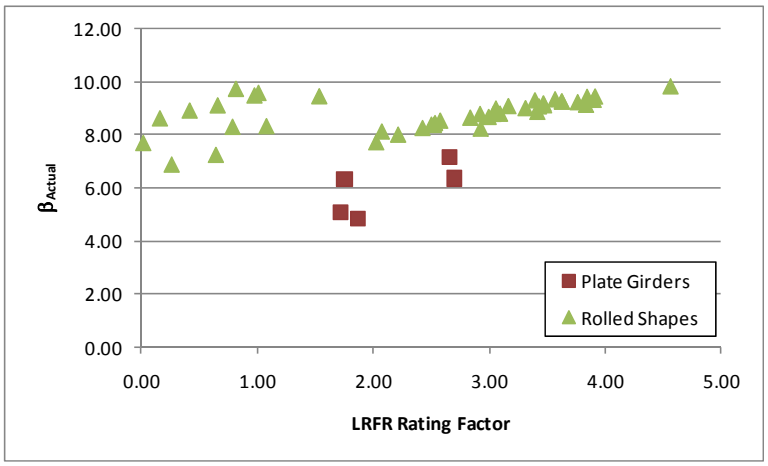
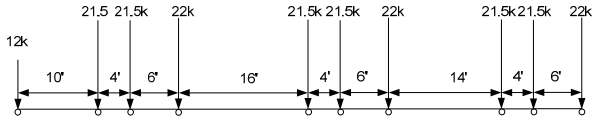


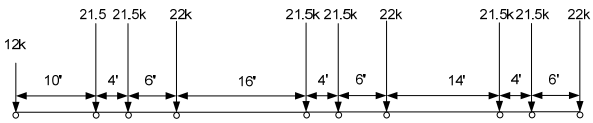
Figure G-95: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

G.1.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-96. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LRFR Loading

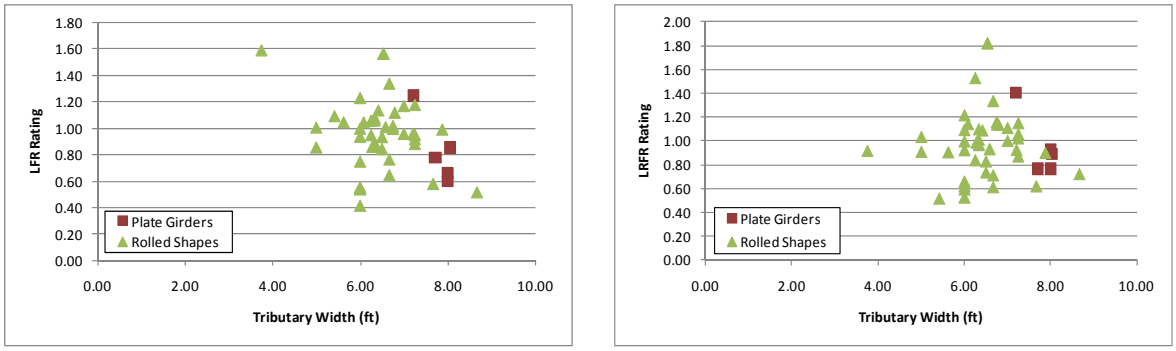
Figure G-96: Vehicle Loadings and Load Factors

G.1.10.1Moment

The following section contains the results for interior, non-composite steel girders within continuous span bridges for the WA-02 Vehicle.

G.1.10.1.1 Rating Factors

Figure G-97 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 30 girders with an LFR rating less than 1.0, 30 girders with an LRFR rating less than 1.0, and 24 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 47% of the girders in this subset. The LFR and LRFR ratings are both between 0.8 and 1.2 for most girders.



(a) (b)

Figure G-97: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure G-98 shows the percentage of girders with moment ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 73.5% of girders have LRFR ratings greater than 1.0 for a single trip, escorted permit. The percentage of girders with ratings greater than 1.0 drops to 10.2% when the permit is for multiple trips and ADTT ≥ 5,000. 38.8% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is -35% for single trip, escorted permits and 28% for permits for multiple trips and ADTT ≥ 5,000. Significantly more girders have LRFR ratings greater than 1.0 when the WA-02 vehicle is considered as a single trip, escorted permit than for LFR; this is indicated by the negative percentage increase.

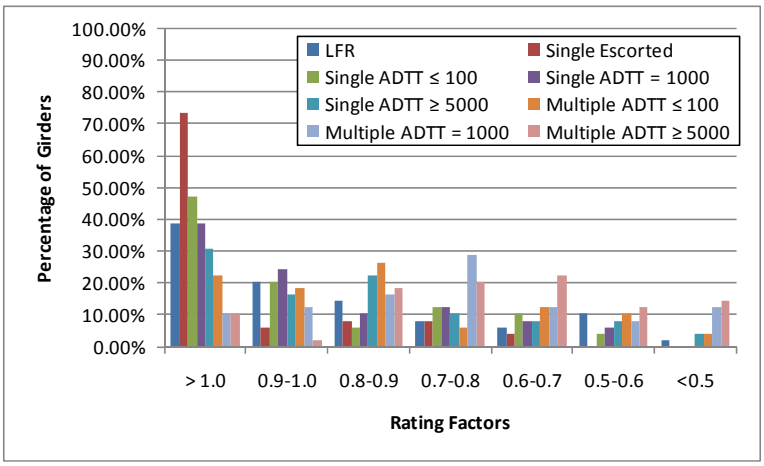


Figure G-98: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

G.1.10.1.2 Rating Factor Comparisons

Figure G-83 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.8 and 1.2 with larger ratios corresponding to larger tributary widths. 53% of the girders have LRFR ratings that are greater than the corresponding LFR rating.

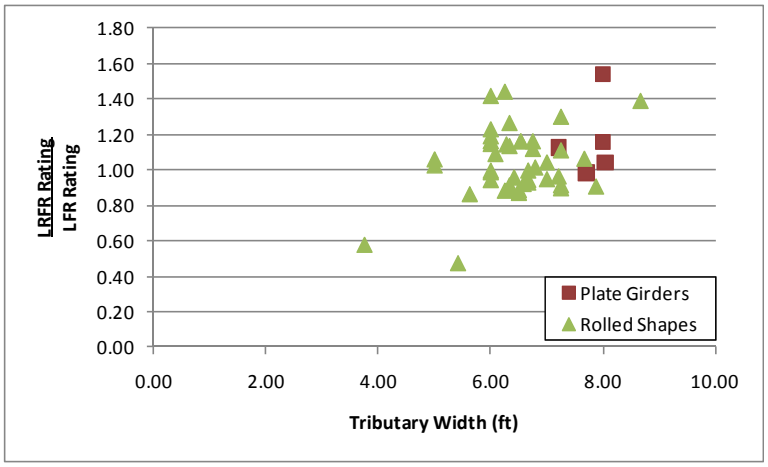


Figure G-99: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

G.1.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-100 shows that 14 girders have a reliability index less than the target reliability index of 3.5. The reliability index is between four and six for most girders that have at least the target reliability index.

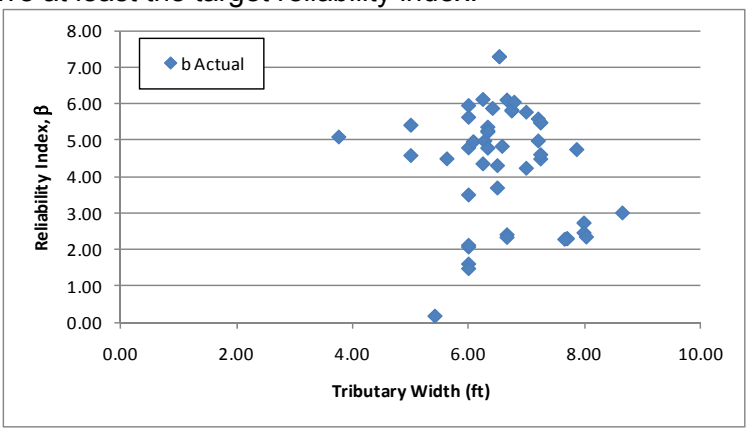


Figure G-100: Flexure Reliability Indices for WA-02 Vehicle

Figure G-85 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5 for plate girders and 4.5 for rolled shapes. The reliability index is near the target reliability for plate girders and above the target reliability for rolled shapes.

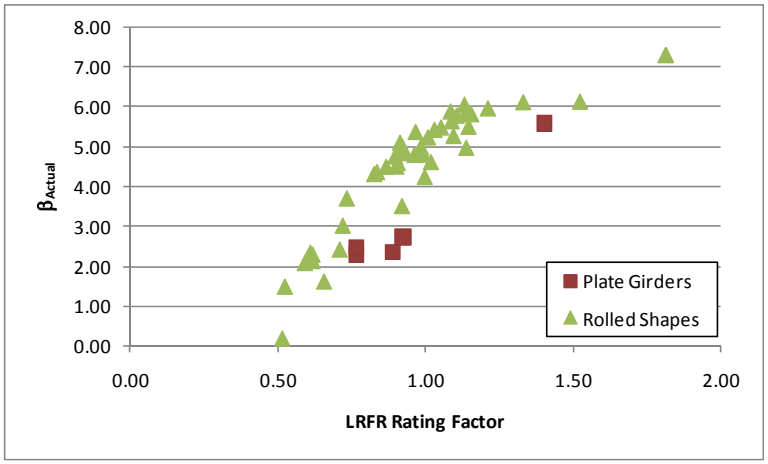
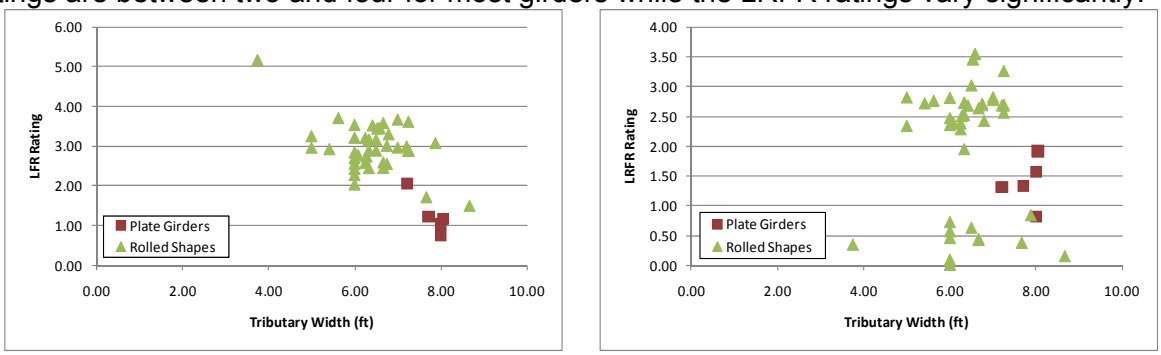


Figure G-101: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

G.1.10.2Shear

G.1.10.2.1 Rating Factors

For shear, there is one girder with LFR rating factors less than 1.0, thirteen girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. All thirteen girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 82% of the girders in this subset. Figure G-102 shows the LFR and LRFR ratings. LFR ratings are between two and four for most girders while the LRFR ratings vary significantly.



(a) (b)

Figure G-102: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure G-103 shows the percentage of girders with shear ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 77.6% of girders have an LRFR rating greater than 1.0 for single trip, escorted permits. This drops to 71.4% when the permit is for multiple trips and ADTT ≥ 5,000. 98% of the girders have LFR ratings that are greater than 1.0. Approximately 20% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for single trip, escorted permits; this increases to 26% when the permit is for multiple trips and ADTT ≥ 5,000.

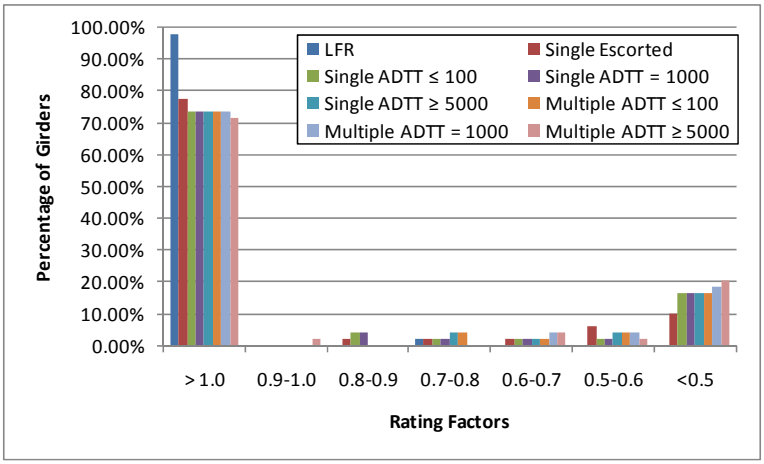


Figure G-103: Shear Ratings for Various ADTT in MBE for WA-02 Vehicle

G.1.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-87 show the comparison of rating factors. The ratio is generally between 0.6 and 1.0 and increasing with increasing tributary width. 18% of girders have an LRFR rating that is greater than the LFR rating for this vehicle.

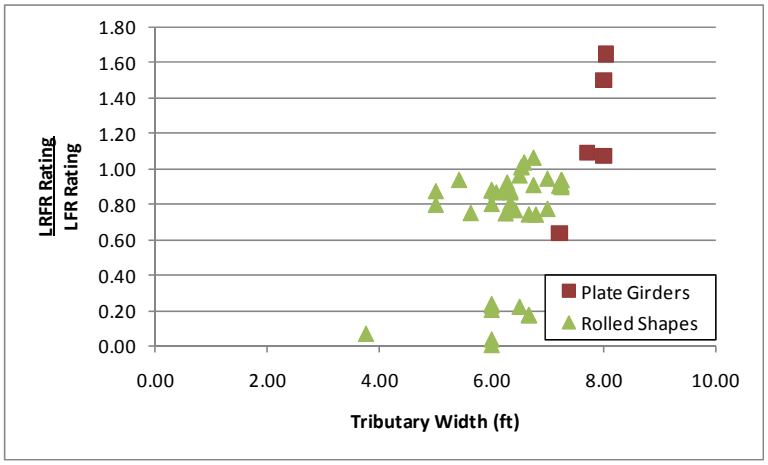


Figure G-104: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

G.1.10.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for zero girders as shown in Figure G-105.

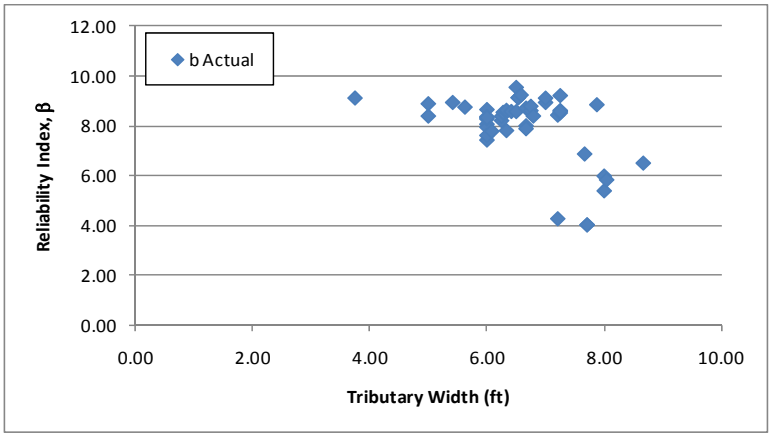


Figure G-105: Shear Reliability Indices for WA-02 Vehicle

Figure G-106 shows the reliability index for shear plotted against the LRFR shear rating for the WA-02 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, the target reliability index for this vehicle. The reliability index indicates that the LRFR live load factors result in the target reliability for this vehicle. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear strength not the bearing stiffener resistance.

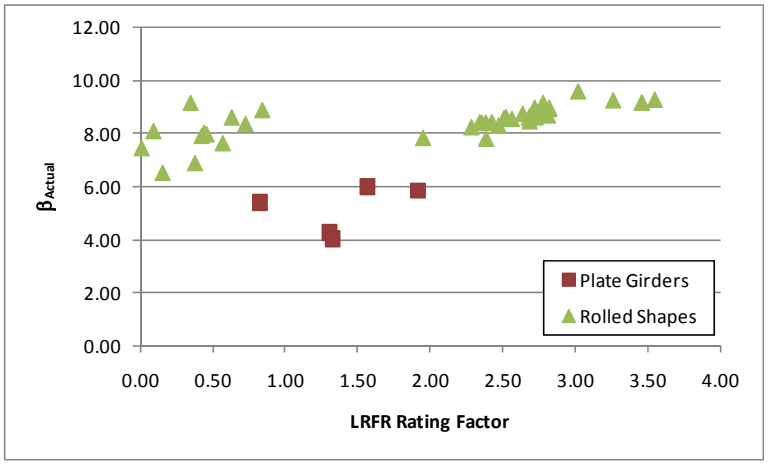
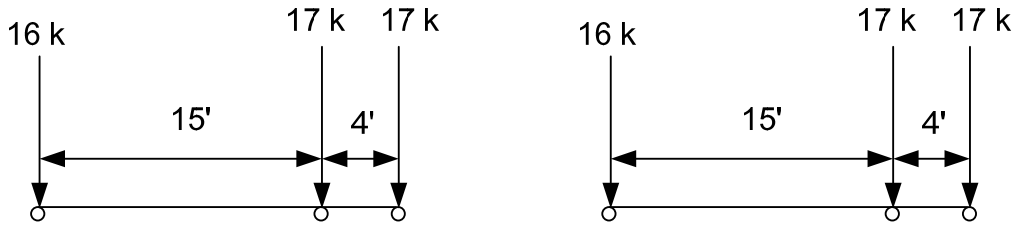


Figure G-106: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

G.1.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-107. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized



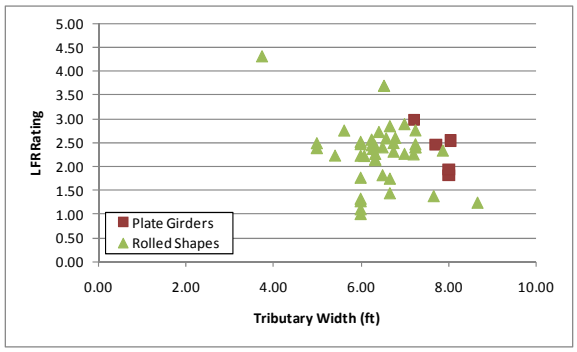
LFR Loading LRFR Loading

Figure G-107: Vehicle Loadings and Load Factors

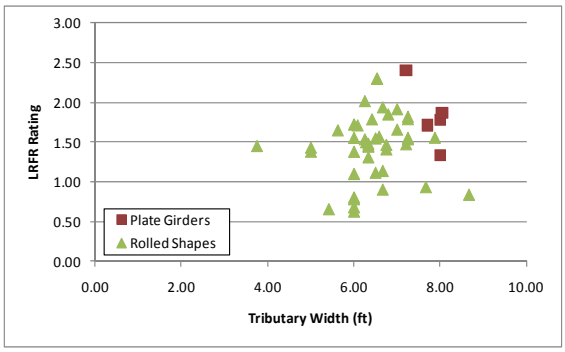
G.1.11.1Moment

G.1.11.1.1 Rating Factors

Figure G-108 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 8 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR ratings are between two and three for most girders while most LRFR ratings are between one and two.



(a)



(b)

Figure G-108: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure G-109 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 87.8% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders with ratings greater than 1.0 drops to 83.4% when the ADTT ≥ 5,000. 98% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is 10% for ADTT ≤ 100 and 15% for ADTT ≥ 5,000.

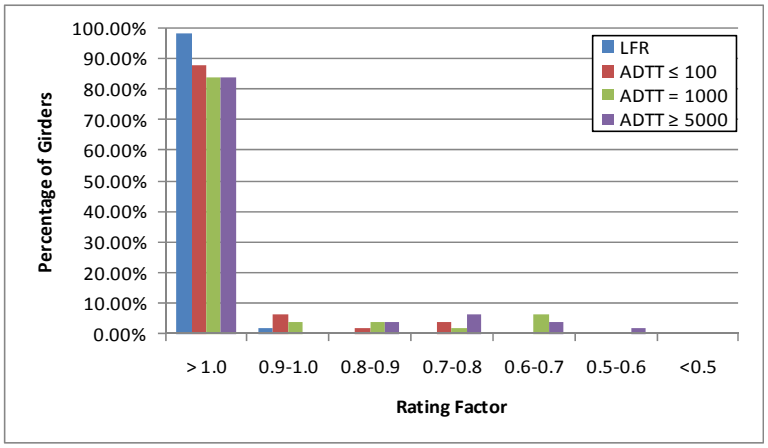


Figure G-109: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

G.1.11.1.2 Rating Factor Comparisons

Figure G-110 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8, with more widely spaced girders having higher ratios.

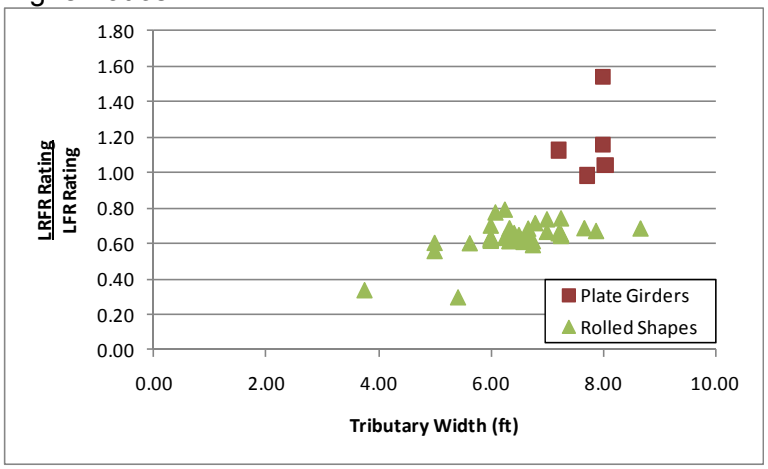


Figure G-110: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

G.1.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-111 shows that two girders have a reliability index less than the target reliability index of 2.5. The reliability index is between six and eight for most girders.

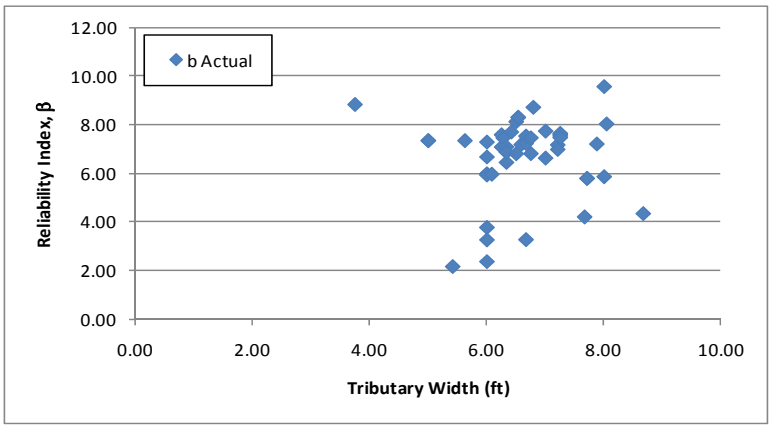


Figure G-111: Flexure Reliability Indices for Type 3 Vehicle

Figure G-112 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 Truck. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

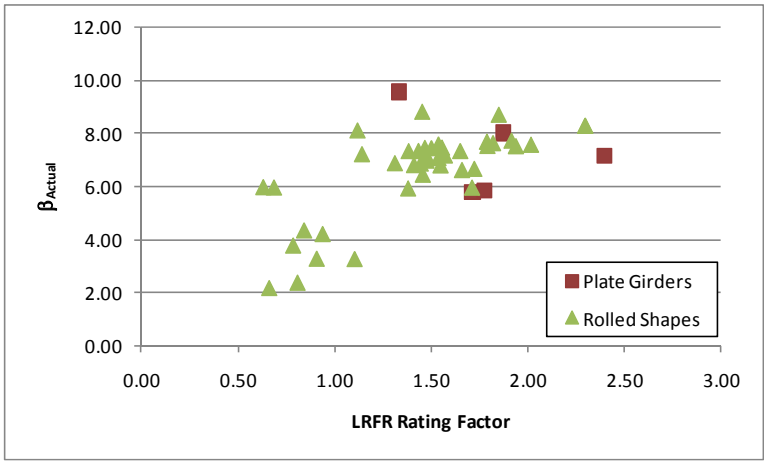
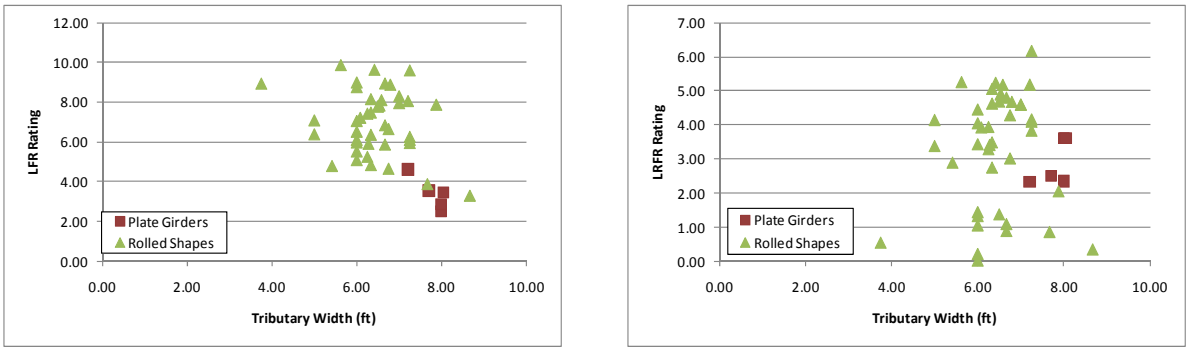


Figure G-112: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

G.1.11.2Shear

G.1.11.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, six girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. All six girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 96% of the girders in this subset. Figure G-113 shows the LFR and LRFR ratings. The LFR ratings are between four and ten while the LRFR ratings are between three and six for most girders.



(a) (b)

Figure G-113: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure G-114 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 91.8% of girders have an LRFR rating greater than 1.0 for ADTT ≤ 100. This drops to 85.7% when the ADTT ≥ 5,000. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 8% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for ADTT ≤ 100; this increases to 14.3% when ADTT ≥ 5,000.

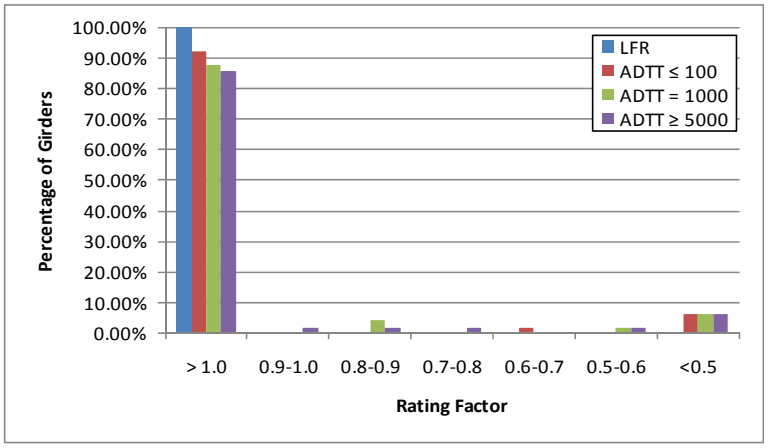


Figure G-114: Shear Ratings for Various ADTT in MBE for AASHTO Type 3 Truck

G.1.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-115 shows the comparison of rating factors. The ratio is generally between 0.5 and 0.7, with two girders having an LRFR rating that is greater than the LFR rating.

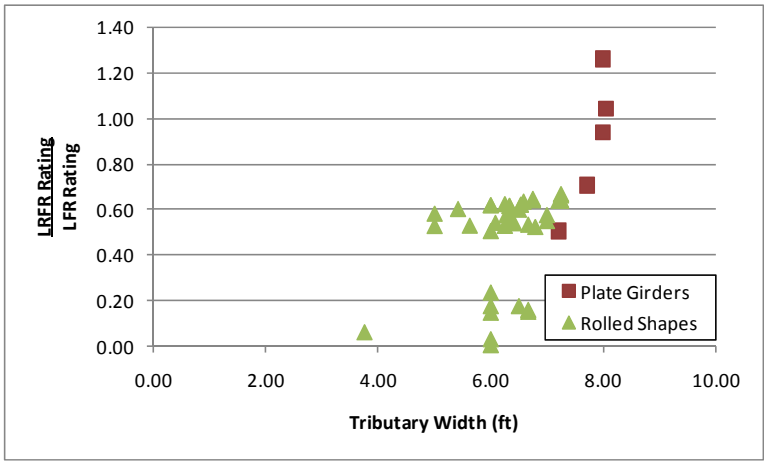


Figure G-115: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

G.1.11.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for no girders as shown in Figure G-116. The reliability index is between nine and ten for most girders.

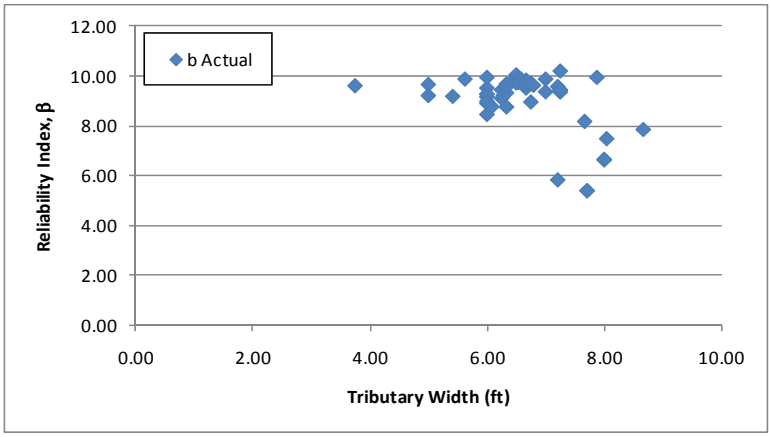


Figure G-116: Shear Reliability Indices for Type 3 Vehicle

Figure G-117 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 truck. The reliability index associated with an LRFR rating of 1.0 is approximately four, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating; the reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

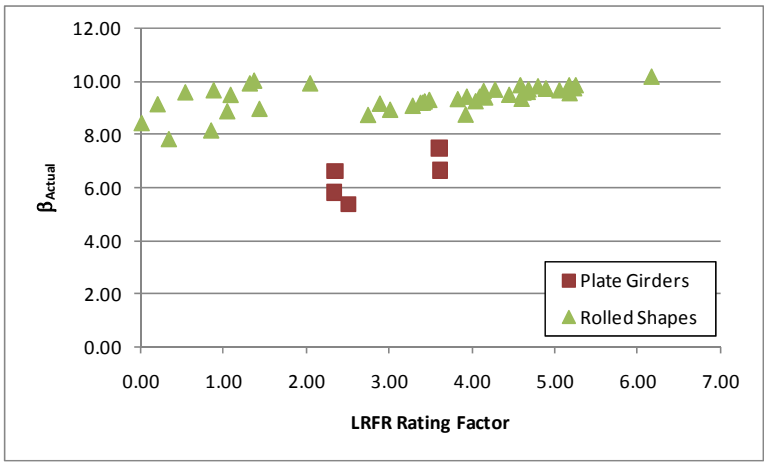


Figure G-117: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

G.1.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-118. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

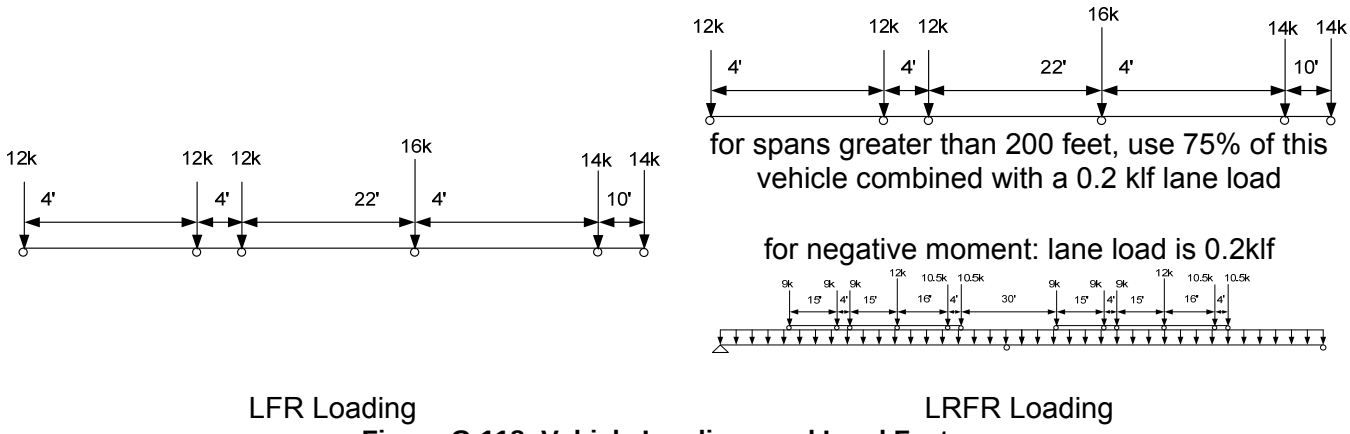
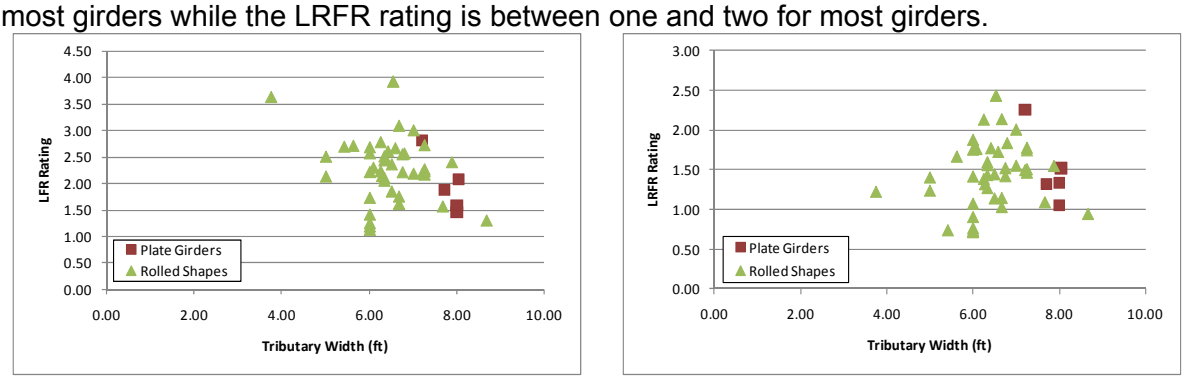


Figure G-118: Vehicle Loadings and Load Factors

G.1.12.1Moment

G.1.12.1.1 Rating Factors

Figure G-119 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, six girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 100% of the girders in this subset. The LFR rating is between two and three for most girders while the LRFR rating is between one and two for most girders.



(a) (b)

Figure G-119: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure G-120 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 91.8% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders with ratings greater than 1.0 drops to 81.6% when the ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is 8% for ADTT ≤ 100 and 18.4% for ADTT ≥ 5,000.

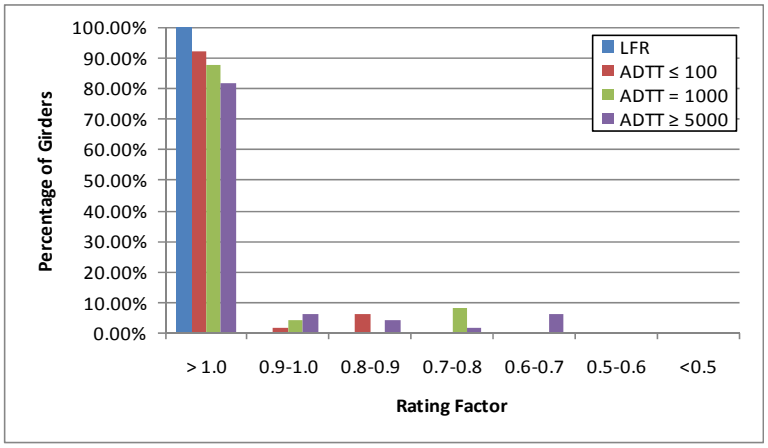


Figure G-120: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

G.1.12.1.2 Rating Factor Comparisons

Figure G-121 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8, with closely spaced girders having lower ratios. No girders have an LRFR rating that is greater than the associated LFR rating.

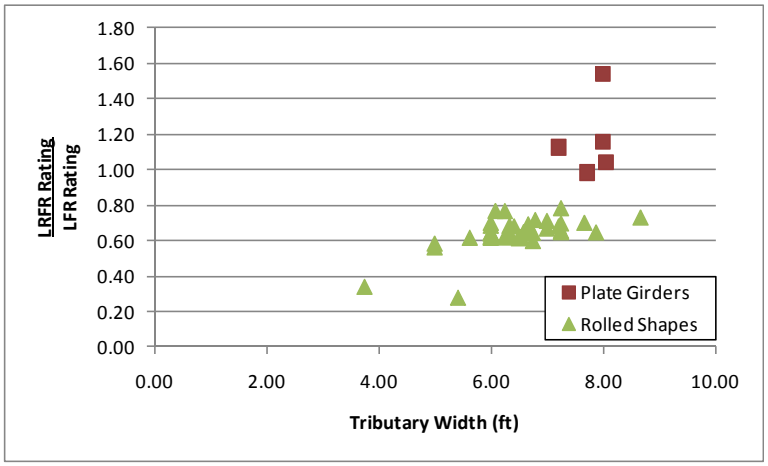


Figure G-121: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

G.1.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-122 shows that two girders have a reliability index less than the target reliability index of 2.5. The reliability index is between six and eight for most girders.

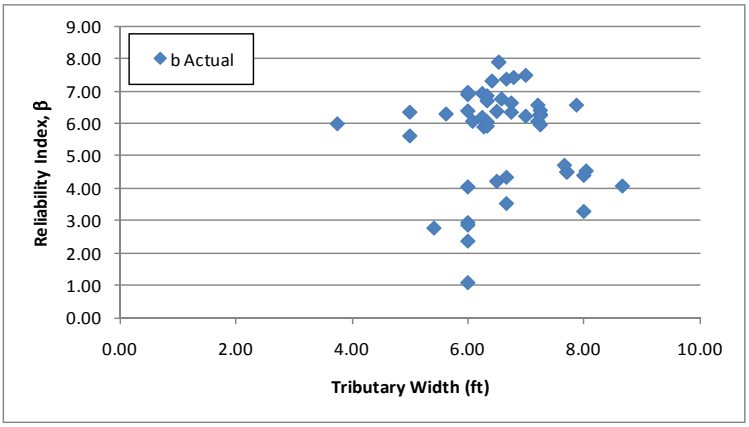


Figure G-122: Flexure Reliability Indices for Type 3-3 Vehicle

Figure G-123 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

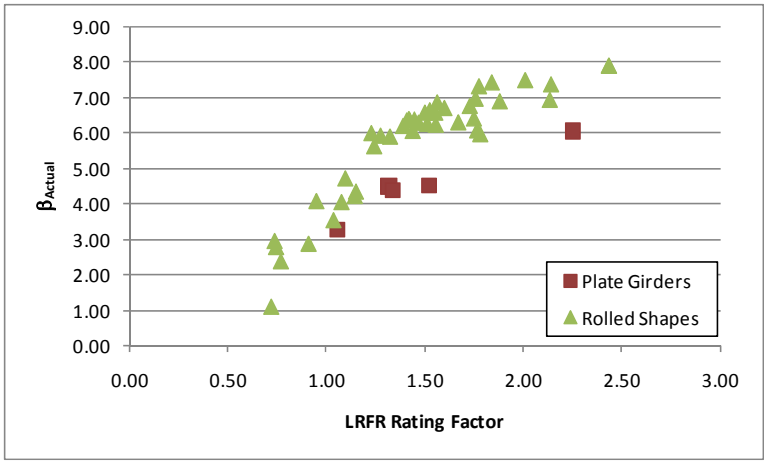
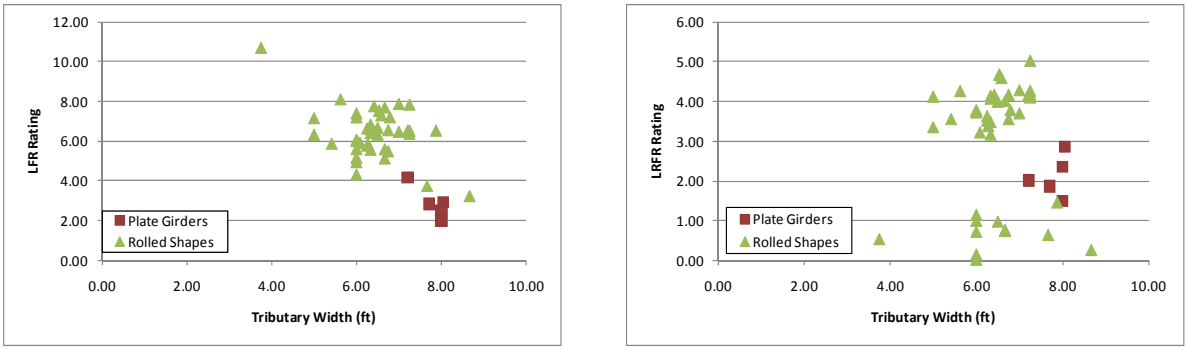


Figure G-123: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Vehicle

G.1.12.2Shear

G.1.12.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, ten girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. All ten girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 100% of the girders in this subset. Figure G-124 shows the LFR and LRFR ratings. The LFR ratings are typically between four and eight while the LRFR ratings are between three and five.



(a) (b)

Figure G-124: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure G-125 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 83.7% of girders have an LRFR rating greater than 1.0 for ADTT ≤ 100. This drops to 79.6% when the ADTT ≥ 5,000. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 16% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for ADTT ≤ 100; this increases to 20.4% when ADTT ≥ 5,000.

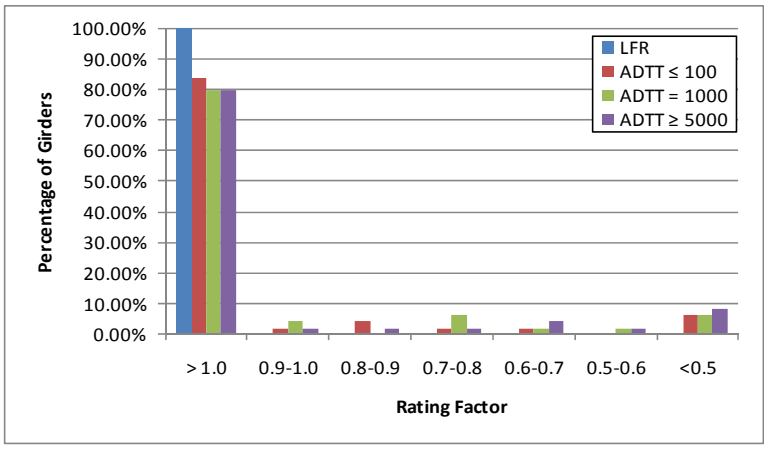


Figure G-125: Shear Ratings for Various ADTT in MBE for AASHTO Type 3-3 Truck

G.1.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-126 show the comparison of rating factors. The ratio is generally between 0.5 and 0.7, with more widely spaced girders having higher ratios. Plate girders have higher ratios than most rolled shapes.

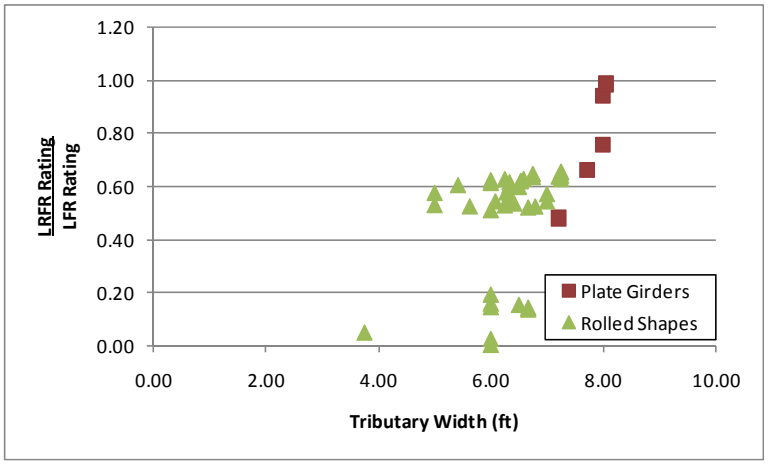


Figure G-126: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

G.1.12.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for approximately zero girders as shown in Figure G-127. The reliability index is between nine and ten for most girders.

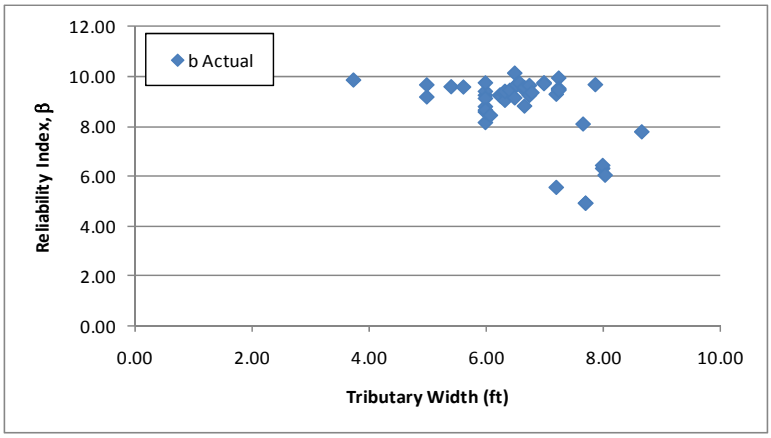


Figure G-127: Shear Reliability Indices for Type 3-3 Vehicle

Figure G-128 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 truck. The reliability index increases with increasing LRFR rating. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, above the target reliability index of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating; the reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

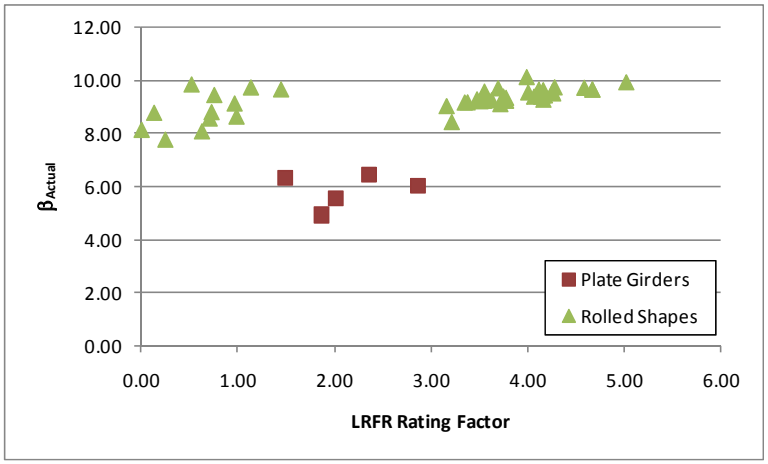


Figure G-128: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

G.1.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-129. The applicable load factors for these vehicles are 1.3 and 1.65X for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

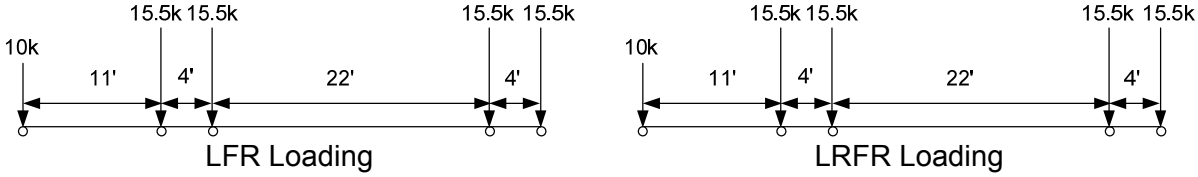
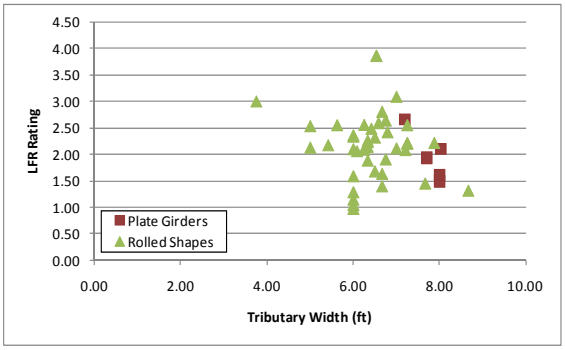


Figure G-129: Vehicle Loadings and Load Factors

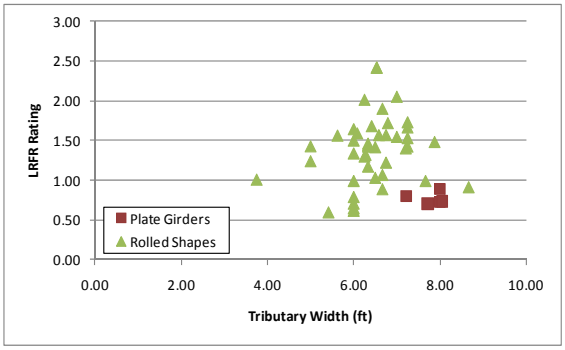
G.1.13.1Moment

G.1.13.1.1 Rating Factors

Figure G-130 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, nine girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR ratings are between 1.5 and 2.5 for most girders while LRFR ratings are between one and two for most girders.



(a)



(b)

Figure G-130: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure G-131 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 89.8% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders with ratings greater than 1.0 drops to 73.5% when the ADTT ≥ 5,000. 98.0% of girders have LFR ratings that are greater than 1.0. The increase in girders with LRFR ratings less than 1.0 from the percent of girders with LFR ratings less than 1.0 is 8% for ADTT ≤ 100 and 24.5% for ADTT ≥ 5,000.

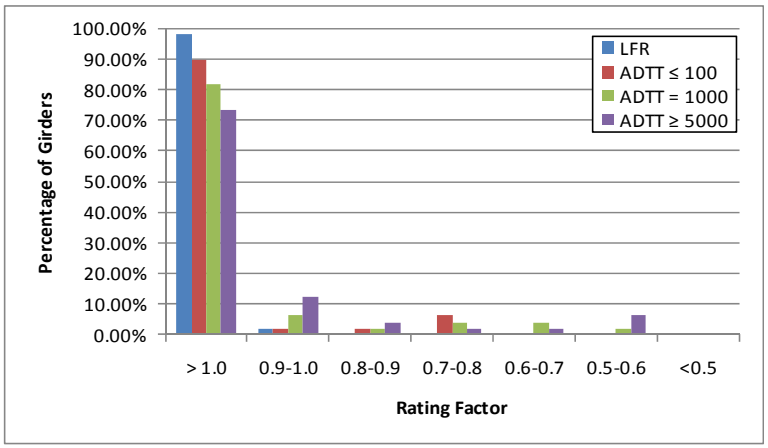


Figure G-131: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

G.1.13.1.2 Rating Factor Comparisons

Figure G-132 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.9, with narrowly spaced girders having lower ratios.

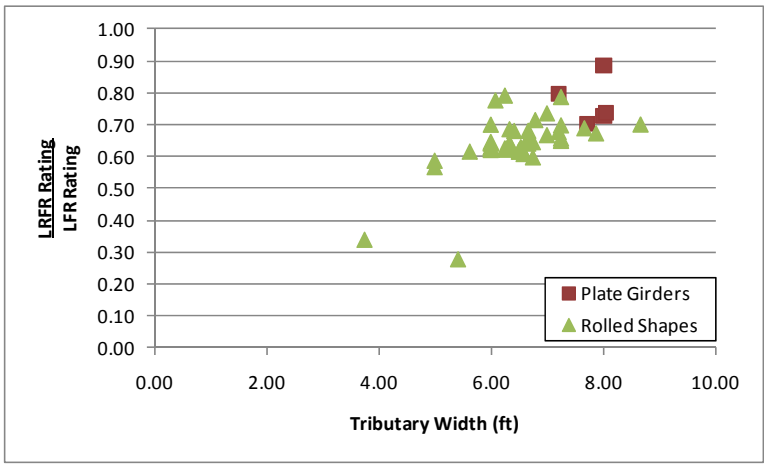


Figure G-132: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

G.1.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-133 shows that five girders have a reliability index less than the target reliability index of 2.5. The reliability index is between five and seven for most girders.

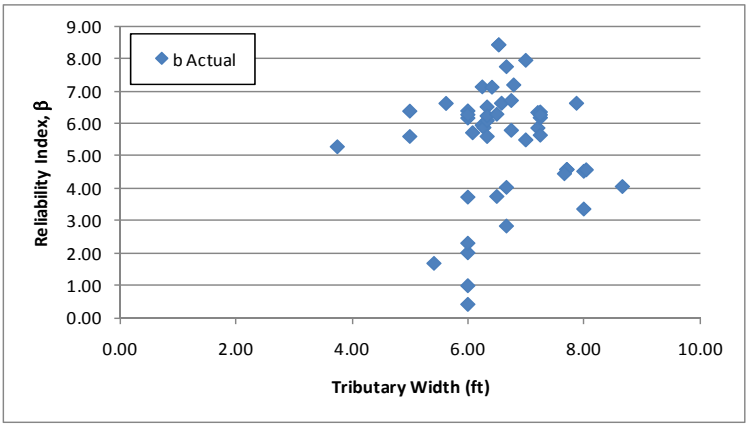


Figure G-133: Flexure Reliability Indices for Type 3S2 Vehicle

Figure G-134 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 truck. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, above the target reliability index of 2.5. This indicates the LRFR live load factors may be over-conservative.

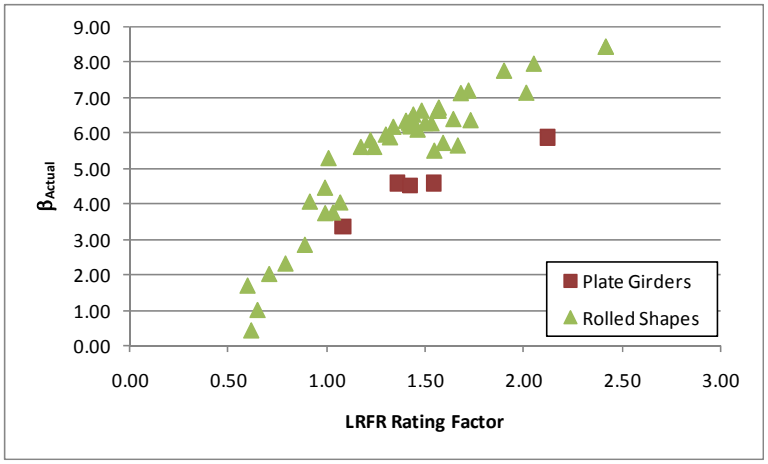
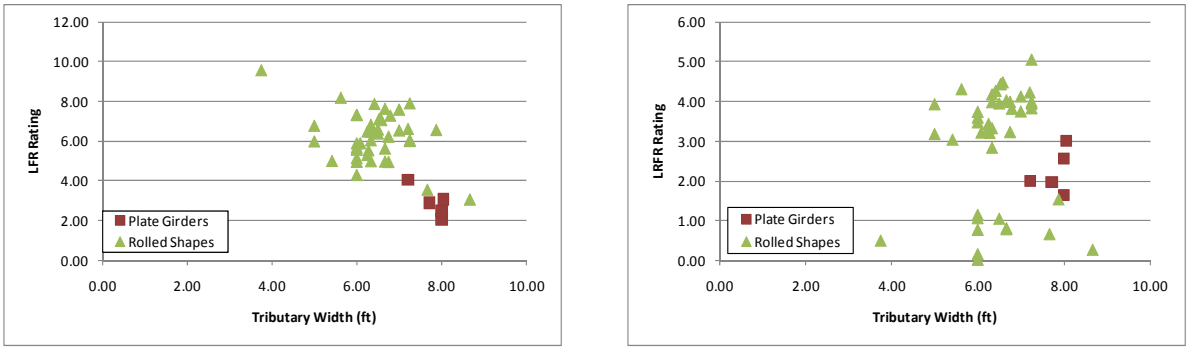


Figure G-134: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 vehicle

G.1.13.2Shear

G.1.13.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, eight girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The eight girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 98% of the girders in this subset. Figure G-135 shows the LFR and LRFR ratings. The LFR ratings are between four and eight for most girders while the LRFR ratings are between three and five.



(a) (b)

Figure G-135: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure G-136 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 83.7% of girders have an LRFR rating greater than 1.0 for ADTT ≤ 100. This drops to 79.6% when the ADTT ≥ 5,000. 100% of the girders have LFR ratings that are greater than 1.0. Approximately 16% more girders have LRFR ratings less than 1.0 than have LFR ratings less than 1.0 for ADTT ≤ 100; this increases to 20.4% when ADTT ≥ 5,000.

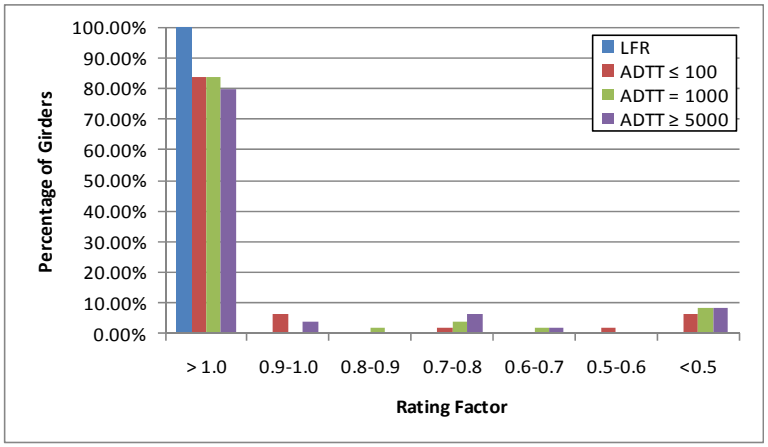


Figure G-136: Shear Ratings for Various ADTT in MBE for AASHTO Type 3S2 Truck

G.1.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-137 show the comparison of rating factors. The ratio is generally between 0.5 and 0.6, with shorter spans generally having higher ratios. One girder has an LRFR rating that is greater than the LFR rating.

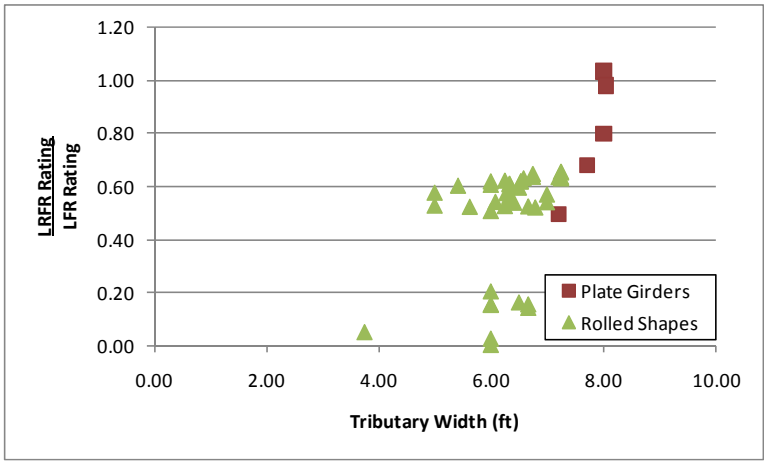


Figure G-137: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

G.1.13.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-138. The reliability index for most girders is between nine and ten.

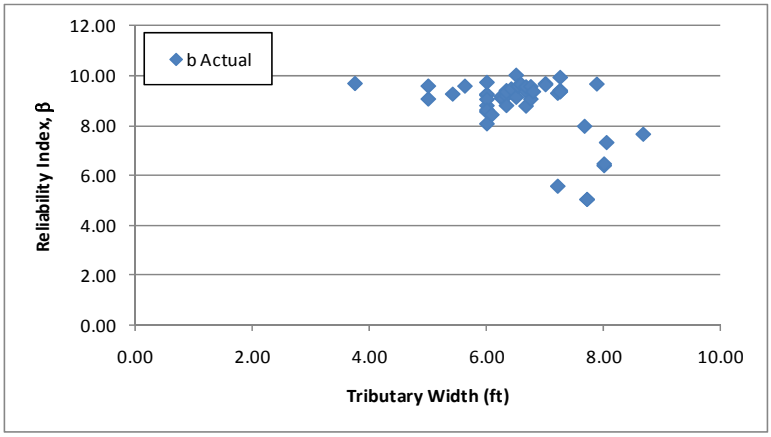


Figure G-138: Shear Reliability Indices for Type 3S2 Vehicle

Figure G-139 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 truck. The reliability index associated with an LRFR rating of 1.0 is approximately four, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance not the bearing stiffener resistance.

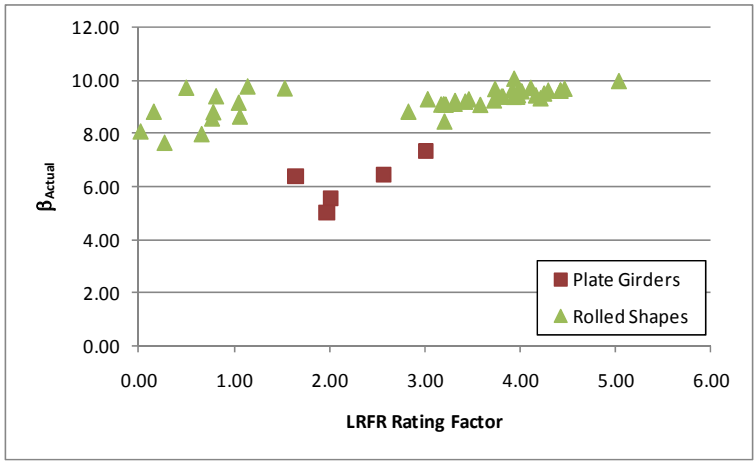


Figure G-139: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

G.1.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table G-1 shows the results for the moment ratings. The special permit vehicles have a similar number of girders for both methods with ratings less than 1.0. The routine permit and legal vehicles typically have more girders with LRFR ratings less than 1.0 than with LFR ratings less than 1.0. The special permit vehicles also have more girders with LRFR ratings that are greater than the LFR rating. The remainder of the vehicles all have a similar percentage of girders with LFR ratings greater than the LRFR rating.

Table G-1: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	49	15	3	2	8	3	1	9	6	30	1	0	1
LRFR Rating less than 1.0		34	13	10	10	11	8	9	13	30	8	6	9
LFR and LRFR Rating less than 1.0		15	3	2	6	3	1	7	6	24	1	0	1
% with LFR RF greater than LRFR RF		100	100	100	49	100	100	49	100	47	100	100	100

G.1.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table G-2 shows that most vehicles did not cause any girders to have LFR ratings less than 1.0. Those vehicles that did are again the heaviest vehicles used in this study. The number of girders with LRFR ratings less than one are all controlled by the bearing stiffener rating.

Table G-2: Shear Rating Factor Results for All 12 Vehicles

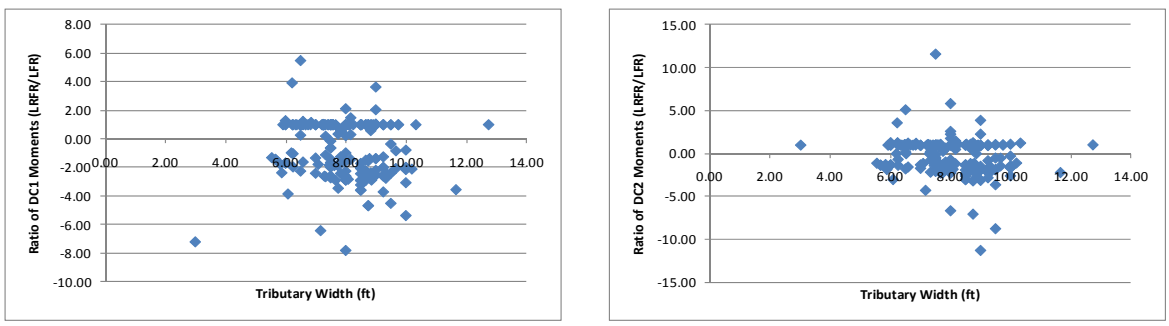
	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	49	1	0	0	0	0	0	0	0	1	0	0	0
LRFR Rating less than 1.0		13	10	8	10	8	7	10	9	13	6	10	8
LFR and LRFR Rating less than 1.0		1	0	0	0	0	0	0	0	1	0	0	0
% with LFR RF greater than LRFR RF		96	96	96	84	96	96	76	96	82	96	100	98

G.2 Interior Composite Girders

G.2.1 Dead Loads

G.2.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure G-140a, the ratio of DC1 moment, most of the values are 1.0 or near -2.0 with numerous outliers. Those that are negative are likely caused by the critical section being at different locations, with one being a section with critical positive moment while the other had critical negative moment. Figure G-140b shows that there is more variation in the loads applied to the composite section (DC2 and DW loads), but again most of the results are near 1.0 or -2.0 as explained for the DC1 moment.

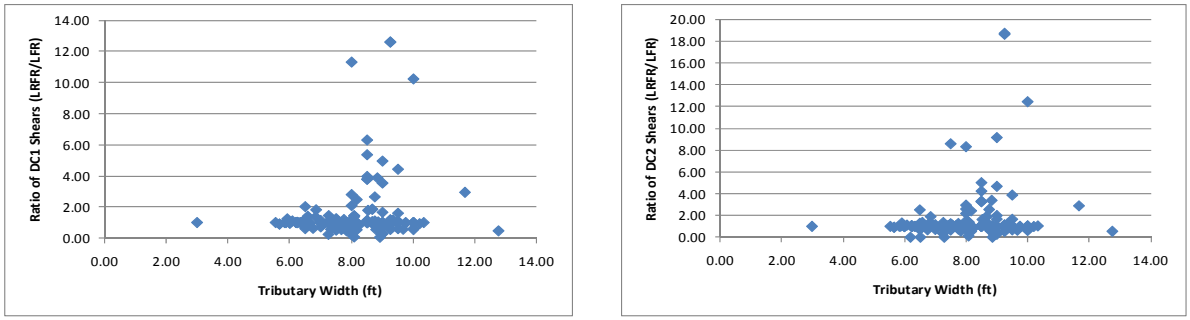


(a) (b)

Figure G-140: Ratios of DC1 and DC2 Moments (unfactored loads LRFR/LFR)

G.2.1.2 Shear

Figure G-141a shows that numerous girders have a ratio of DC1 shear close to 1.0, with some scatter and some that are very different. Some of the scatter may be due to the critical location varying. Figure G-141b shows the same trend as Figure G-141a in that the LFR shear is similar to the LRFR shear. There is also more variation within the DC2 and DW loads than in the DC1 loads.



(a) (b)

Figure G-141: Ratios of DC1 and DC2 Shears (unfactored loads LRFR/LFR)

G.2.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure G-3. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

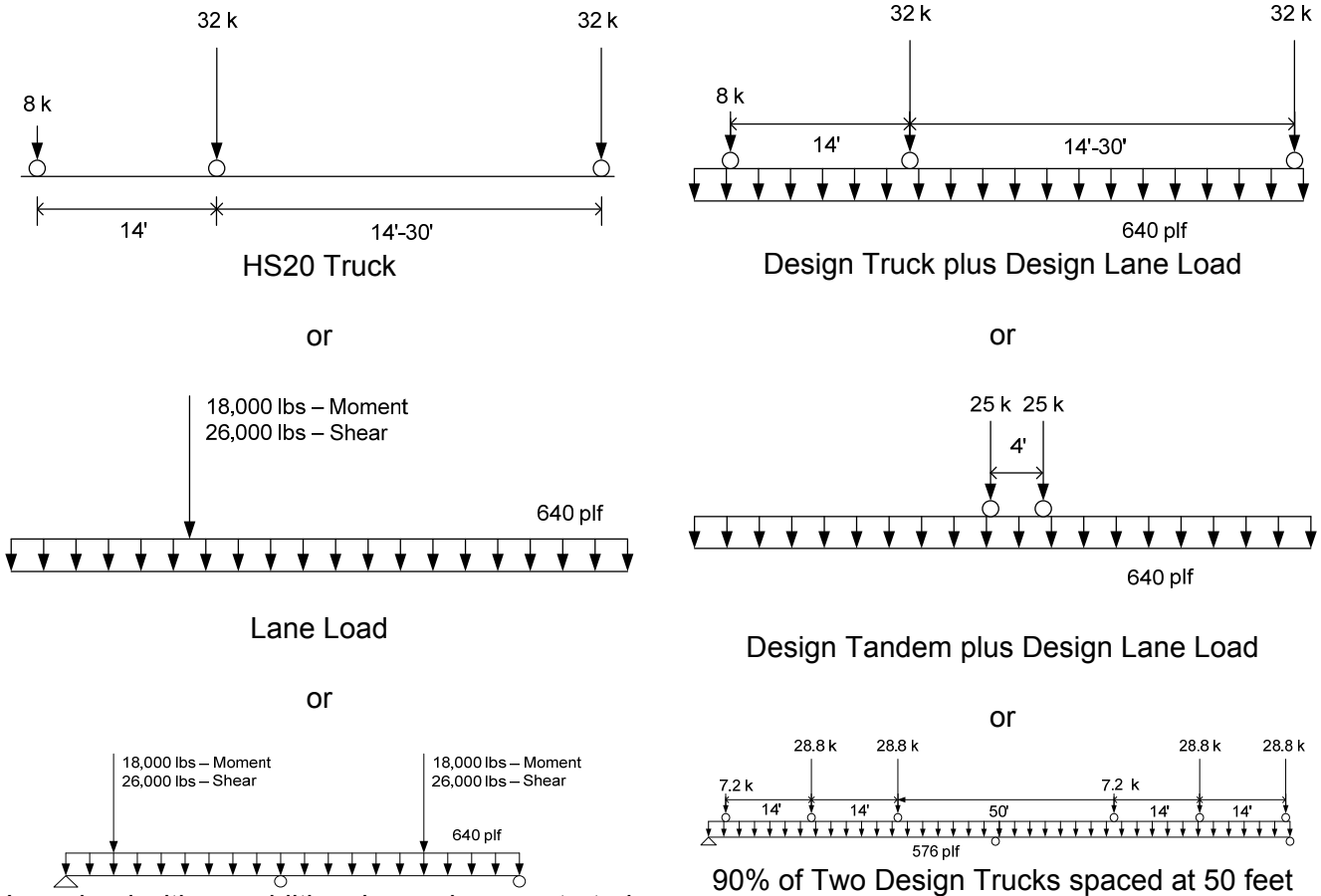
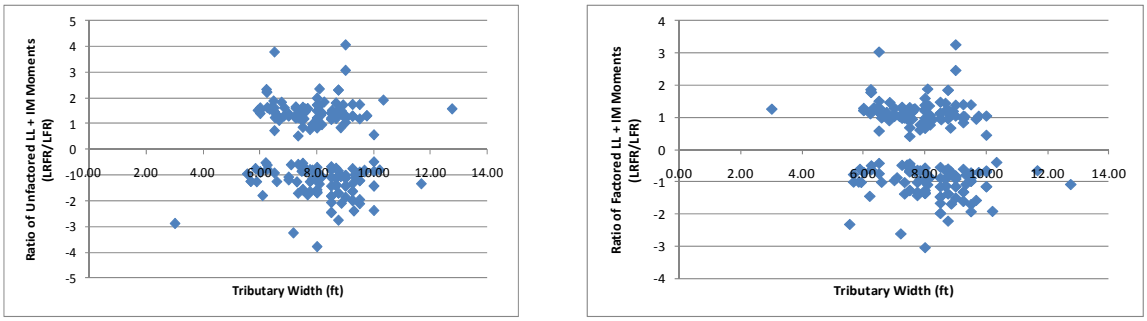


Figure G-142: Vehicle Loadings and Load Factors

G.2.2.1 Moment

G.2.2.1.1 Live Loads

Figure G-143a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored moments is typically between 1.0 and 2.0 for moments where the signs are the same and significant variation for those girders where the directions of the moments are opposite (likely a result of varying locations). The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure G-143b shows that the results have shifted closer to one, with significant scatter still present.



(a) (b)

Figure G-143: Ratios of Unfactored and Factored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

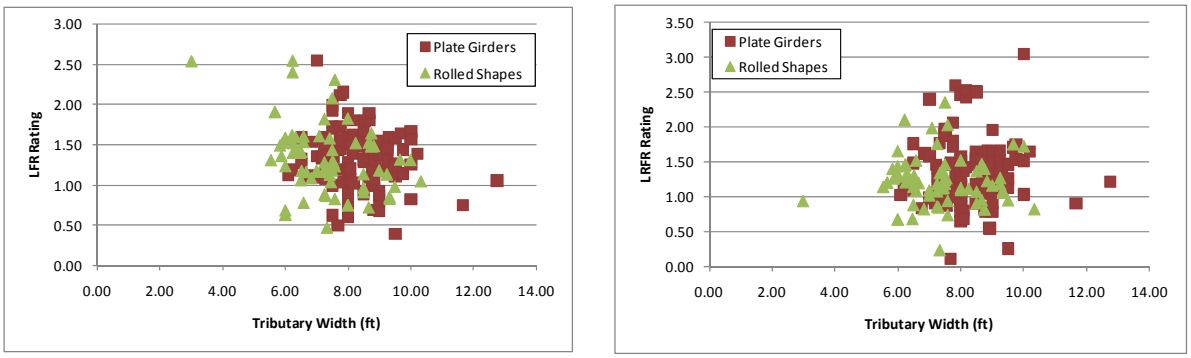
G.2.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure G-144 shows that the ratio of resistance varies greatly, for those with the same sign the ratio is generally very close to 1.0 while those with opposite signs vary largely.

Figure G-144: Ratio of factored Moment Resistance (LRFR/LFR)

G.2.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (195 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 37 girders with LFR ratings less than 1.0, 42 girders with LRFR ratings less than 1.0, and 25 girders where both the LFR and LRFR ratings are less than 1.0. Figure G-145 show the LFR rating factors and LRFR rating factors. The LFR ratings are generally between 1.0 and 1.75 while the LRFR ratings are generally between 0.75 and 1.5.



(a) (b)

Figure G-145: LFR and LRFR Flexure Rating Factors for Design Loadings

G.2.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure G-146. The results indicated that 57% of the girders in this set have LFR ratings greater than LRFR ratings. The ratio is generally between 0.5 and 1.5, with the ratio appearing to increase with increasing tributary widths.

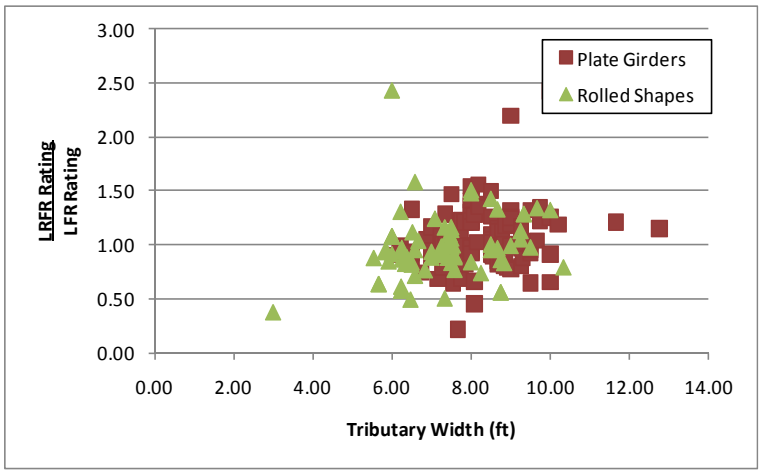


Figure G-146: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure G-147 shows the percentage of girders with LRFR ratings less than one within each category of the ratio between ratings. Most of the girders with LRFR ratings less than one have an LRFR rating that is at least 80% of the LFR rating. This indicates that while there is some reduction in rating by switching from LFR to LRFR, the reduction is not extremely large.

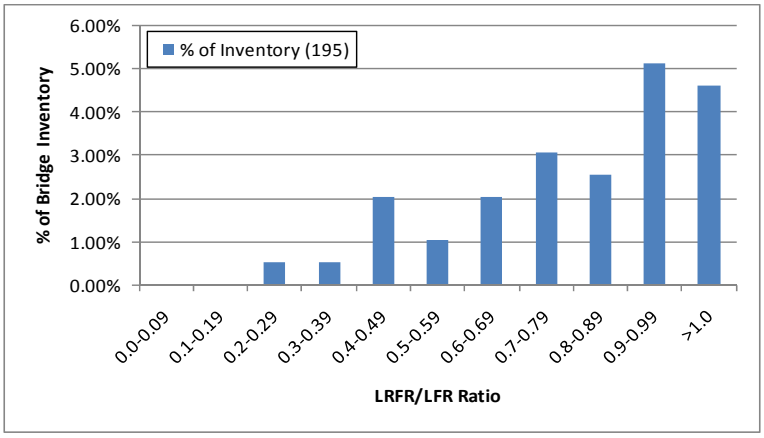


Figure G-147: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

G.2.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure G-148 shows that 57 girders have a reliability index lower than the target reliability index of 3.5. Most reliability indexes are between three and six.

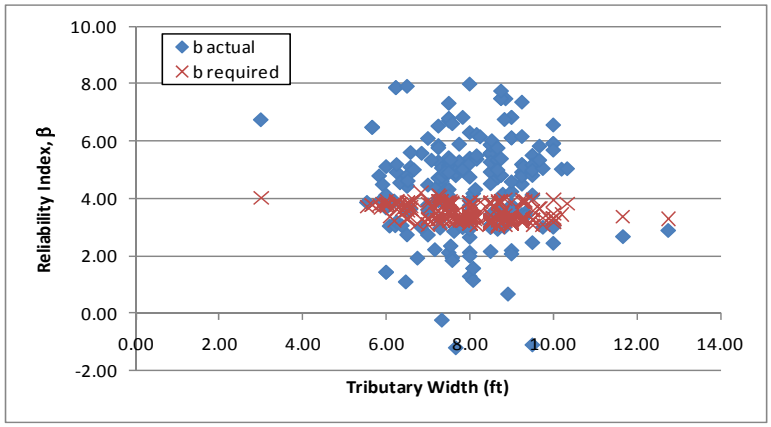


Figure G-148: Flexure Reliability Indices for HL-93 Loading

Figure G-149 shows the reliability index for moment plotted against the LRFR moment rating for the HL-93 design vehicle. The figure shows that the reliability index corresponding to an LRFR rating of 1.0 is approximately 3.5, the target reliability index.

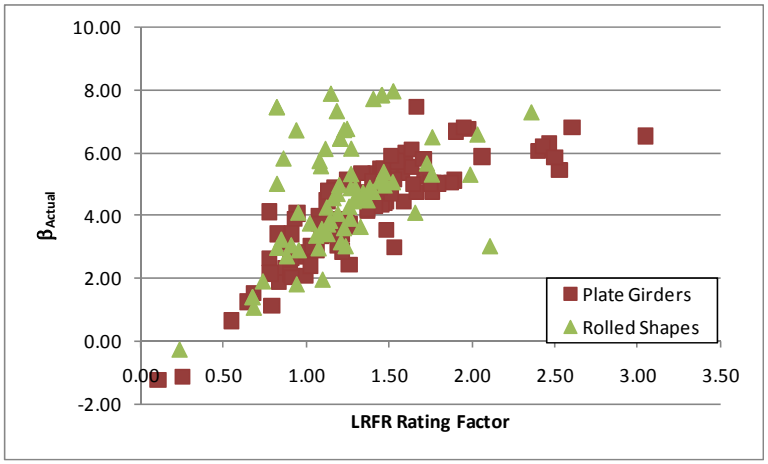
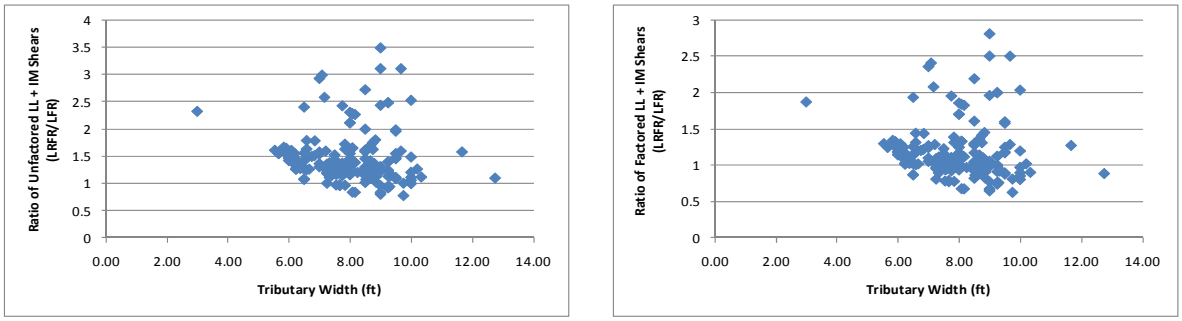


Figure G-149: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Loading

G.2.2.2 Shear

G.2.2.2.1 Live Loads

Figure G-150a shows that the ratio of unfactored shear varies significantly, with most ratios between 1.0 and 1.5, with some outside of this range. Some scatter is expected due to the different critical locations. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure G-150b shows that the ratio of factored live load shears has decreased and is generally between 0.9 and 1.4 for most cases.



(a) (b)

Figure G-150: Ratio of Unfactored and Factored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

G.2.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure G-151 shows that the ratio of resistance is close to 1.0 for rolled shapes while plate girders have varying resistances. The variation is likely a result of the critical location varying.

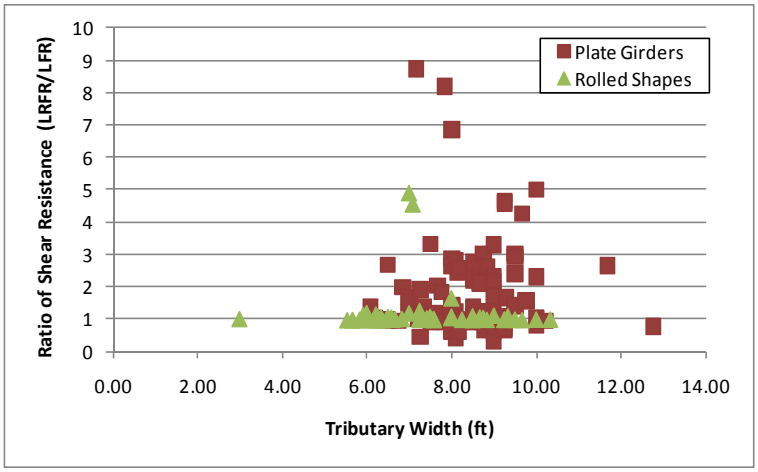
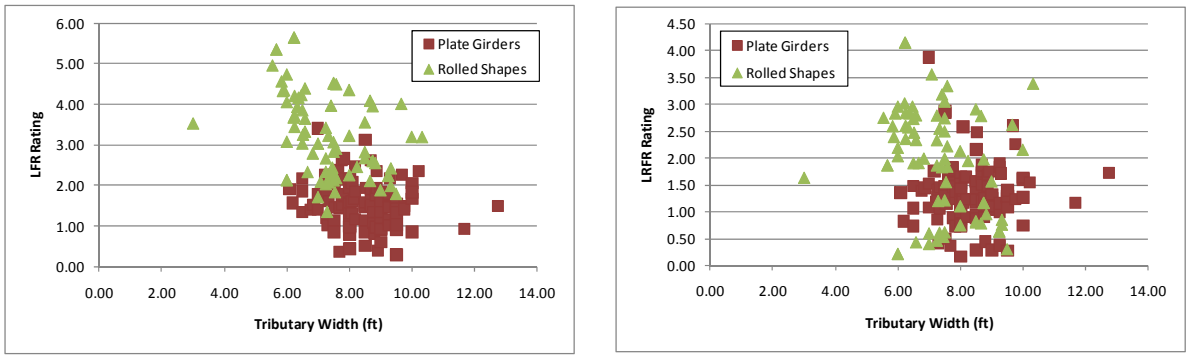


Figure G-151: Ratio of factored Shear Resistance (LFR/LRFR)

G.2.2.2.3 Rating Factors

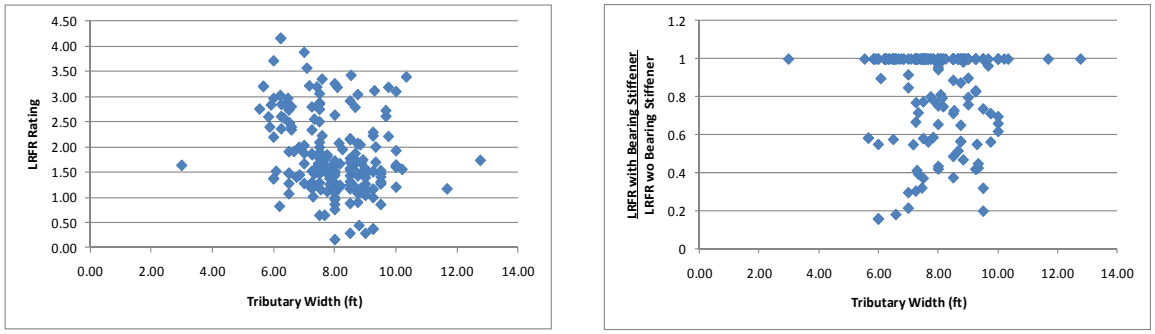
After comparing the loads and resistances to verify that those results seemed appropriate, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 18 girders with LFR ratings less than 1.0, 44 girders with LRFR ratings less than 1.0, and 12 girders where both LFR and LRFR ratings are less than 1.0. 31 of the 44 girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. The LFR rating was greater than the LRFR rating for 83% of the girders in this subset. Figure G-152 show the LFR rating factors and LRFR rating factors. The LFR rating varies significantly and decreases with increasing tributary width. The LRFR rating also varies significantly but does not decrease with increasing tributary width.



(a) (b)

Figure G-152: LFR and LRFR Shear Rating Factors for Design Loadings

Figure G-153a shows the LRFR rating when the bearing stiffener rating is ignored. When Figure G-153a is compared to Figure G-152b, shows that there are fewer ratings less than 1.0. 27 fewer girders have LRFR ratings less than 1.0 when the bearing stiffener is ignored than when it is included. Figure G-153b shows the ratio of the LRFR rating including the bearing stiffener divided by the LRFR rating excluding the bearing stiffener rating. The ratio of ratings indicates that the bearing stiffener rating varied significantly for the different girders compared to the other shear ratings. 35% of girders were controlled by the bearing stiffener rating for the interior composite girders.



(a) (b)

Figure G-153: Effect of Bearing Stiffener Rating on LRFR Shear Ratings

G.2.2.2.4 Rating Factor Comparisons

Figure G-154 shows the ratio of the LRFR rating to the LFR rating. There are a number of girders with LRFR ratings greater than LFR ratings, but this is only 17% of the girders in the set. The ratio for rolled shapes is generally less than 1.0 with those for plate girders appearing to be slightly above 1.0.

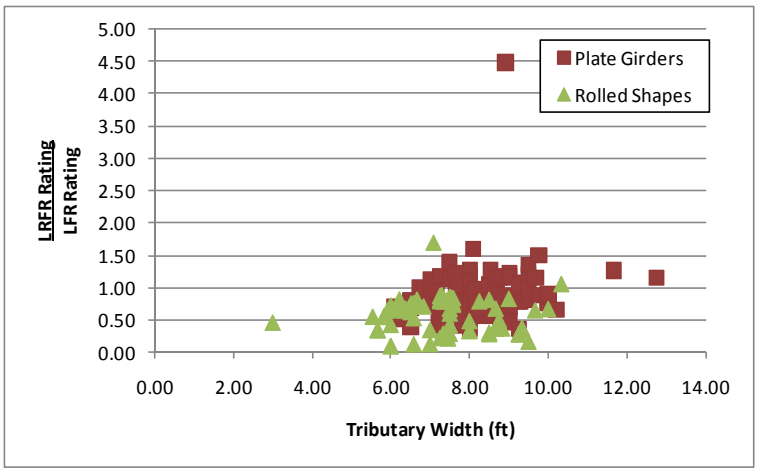


Figure G-154: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure G-155 shows the percentage of girders with LRFR ratings less than 1.0 within each category of LRFR/LFR ratio. The figure shows that most of the girders with LRFR ratings less than 1.0 are less than 0.4. This indicates that these girders will be significantly affected by switching from LFR to LRFR.

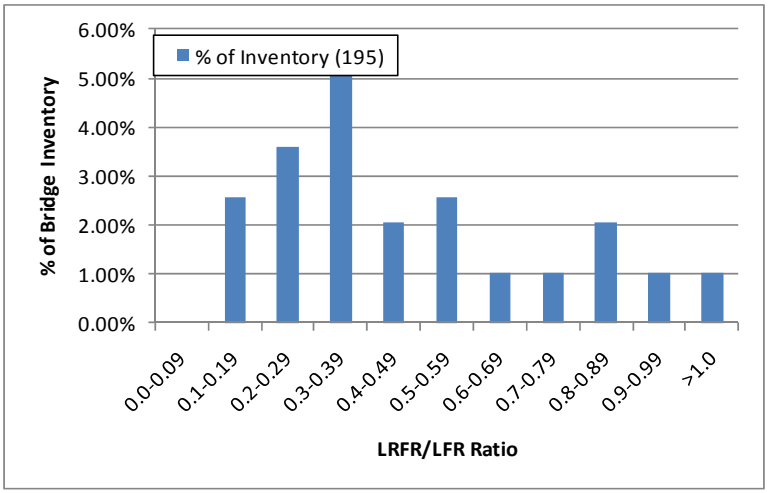


Figure G-155: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

G.2.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure G-156 shows that 33 girders have a reliability index for shear less than the target reliability of 3.5. There appears to be two levels of required reliability, these are for the rolled shapes and plate girders as different statistical parameters are used. The reliability index varies significantly for these girders.

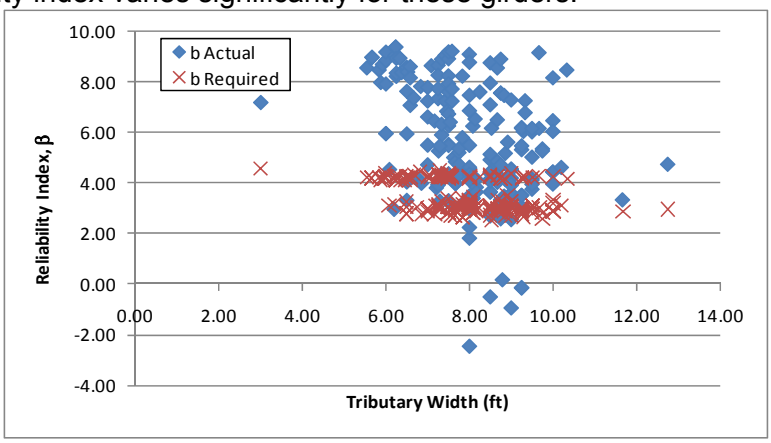


Figure G-156: Shear Reliability Indices for HL-93 Loading

Figure G-157 shows the reliability index for shear plotted against the LRFR shear rating for the design vehicle. The reliability index increases with increasing ratings. The average reliability index for girders with an LRFR rating of 1.0 is approximately 3.5, the target reliability level. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

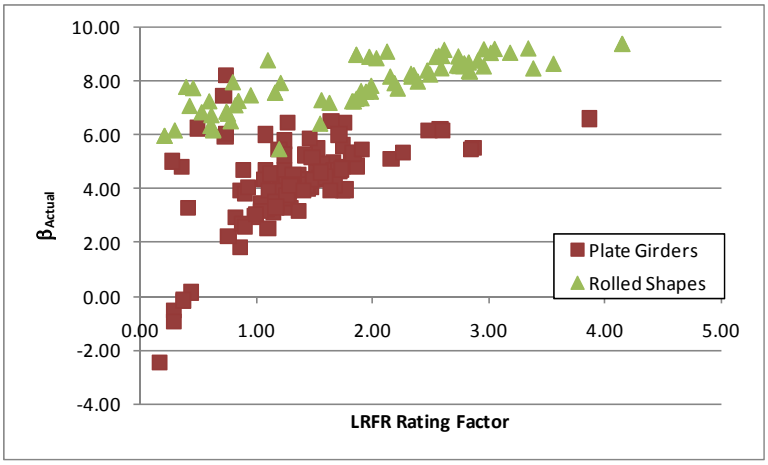


Figure G-157: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

G.2.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-158. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

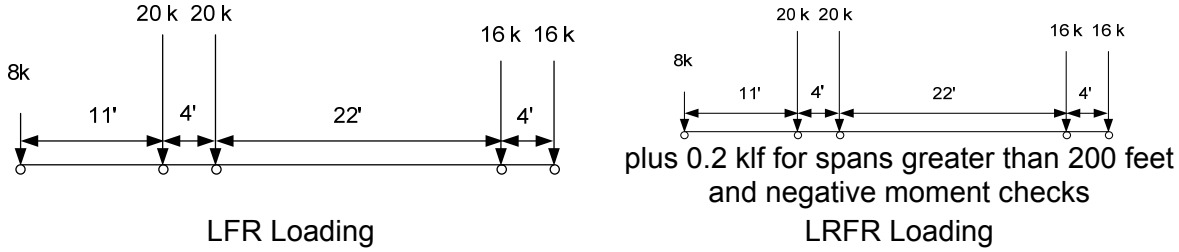


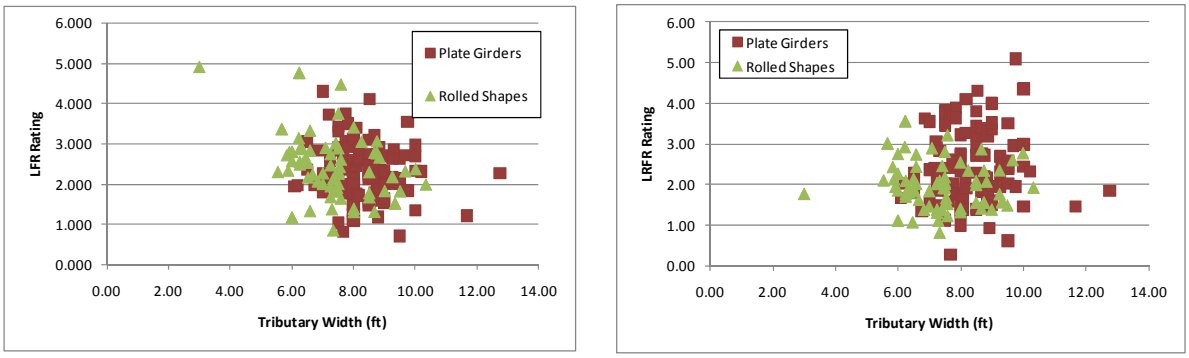
Figure G-158: Vehicle Loadings and Load Factors

G.2.3.1 Moment

The following section contains the results for interior, composite steel girders within continuous span bridges for the DE-07 Vehicle.

G.2.3.1.1 Rating Factors

Figure G-159 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are three girders with an LFR rating less than 1.0, five girders with an LRFR rating less than 1.0, and three girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 54% of the girders in this subset. The LFR rating is typically between 1.5 and 3 while the LRFR rating is typically between 1 and 3.



(a) (b)

Figure G-159: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure G-160 shows the percentage of girders with moment ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 98.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100 while 94.9% of girders have ratings greater than 1.0 for ADTT ≥ 5,000. 98.5% of girders have LFR ratings greater than 1.0. No additional girders have LRFR ratings less than 1.0 for ADTT ≤ 100 than for LFR; this increases to 3.6% more girders for ADTT ≥ 5,000.

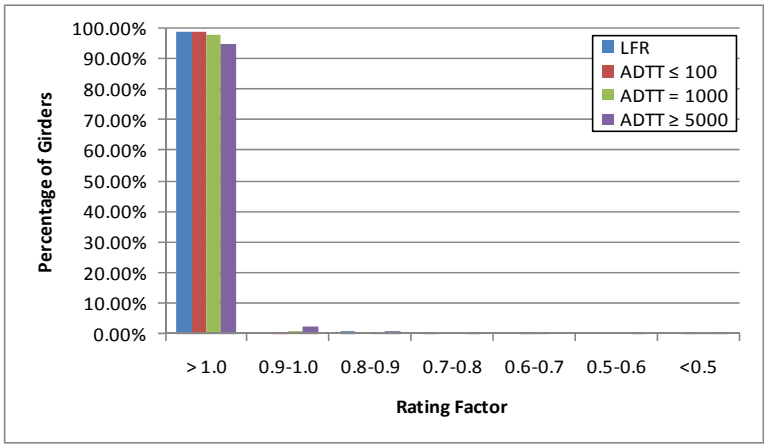


Figure G-160: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

G.2.3.1.2 Rating Factor Comparisons

Figure G-161 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.75 to 1.4, with lower ratios generally corresponding to more narrowly spaced girders. 46% of girders have LRFR ratings that are greater than the LFR rating.

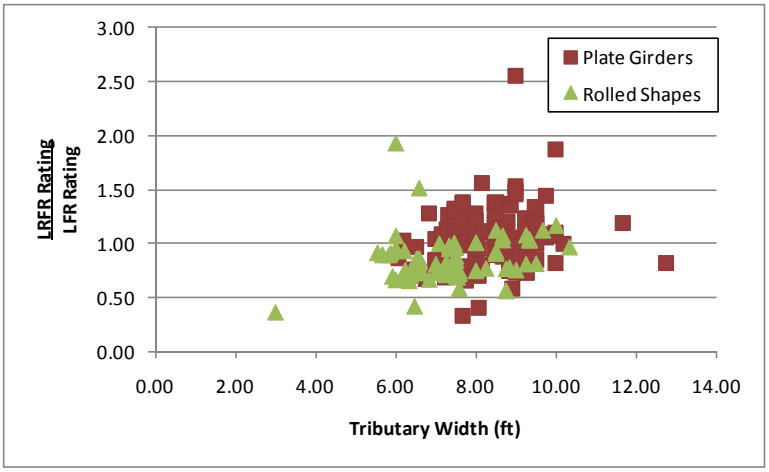


Figure G-161: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

G.2.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-162 shows that four girders have a reliability index less than the target reliability index based of 2.5. The reliability index is between four and eight for most girders.

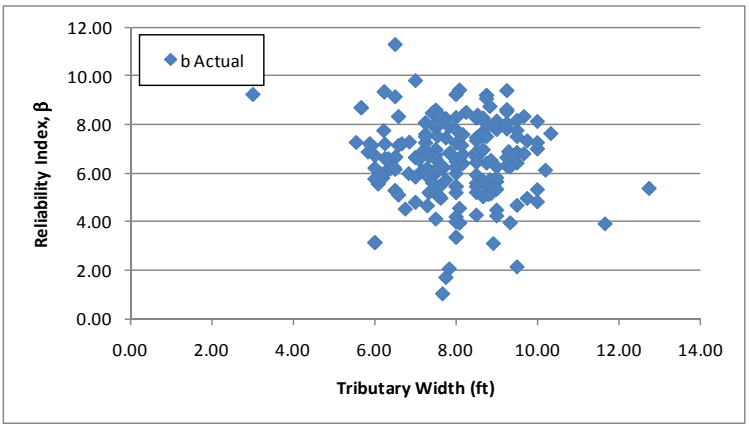


Figure G-162: Flexure Reliability Indices for DE-07 Vehicle

Figure G-163 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 vehicle. The figure shows that the reliability index increases with increasing rating factors. The reliability index associated with an LRFR rating is approximately 3.5, above the target reliability index of 2.5. This indicates that LRFR live load factors may be over-conservative.

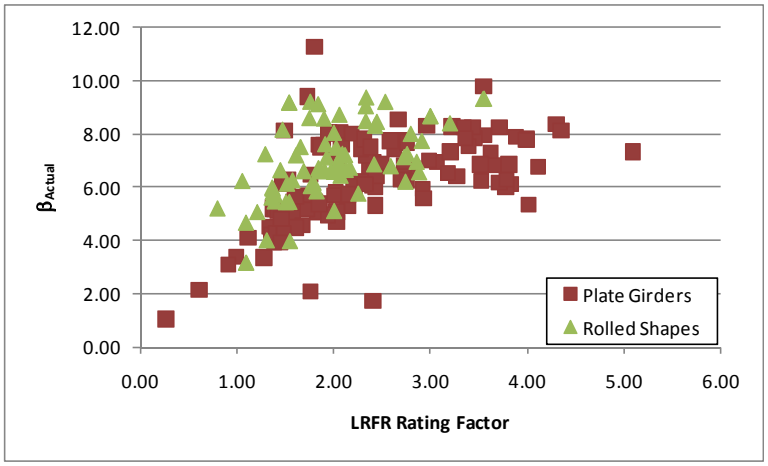
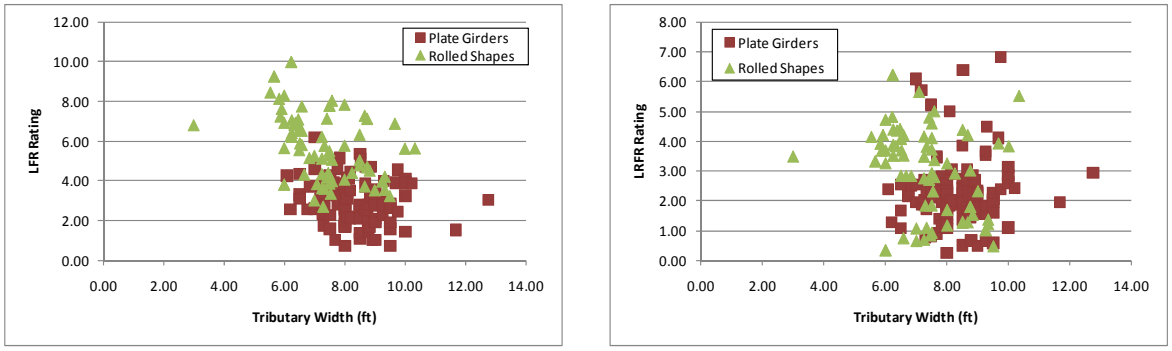


Figure G-163: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

G.2.3.2 Shear

G.2.3.2.1 Rating Factors

For shear, there are two girders with rating factors less than 1.0 for LFR, 18 girders for LRFR, and two girders where both LFR and LRFR are less than 1.0. Two-thirds of the girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 87% of the girders in this subset. Figure G-164 show the LFR and LRFR ratings. The LFR rating is between two and eight for most girders and decreases with increasing girder spacing. The LRFR rating varies from one to five for most girders.



(a) (b)

Figure G-164: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure G-165 shows the percentage of girders with shear ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 91.8% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 87.2% for ADTT ≥ 5,000. 99% of girders have LFR ratings less than 1.0. This is an increase of 7% of girders with ratings less than 1.0 by switching from LFR to LRFR with an ADTT ≤ 100; this increases to 11.8% for ADTT ≥ 5,000.

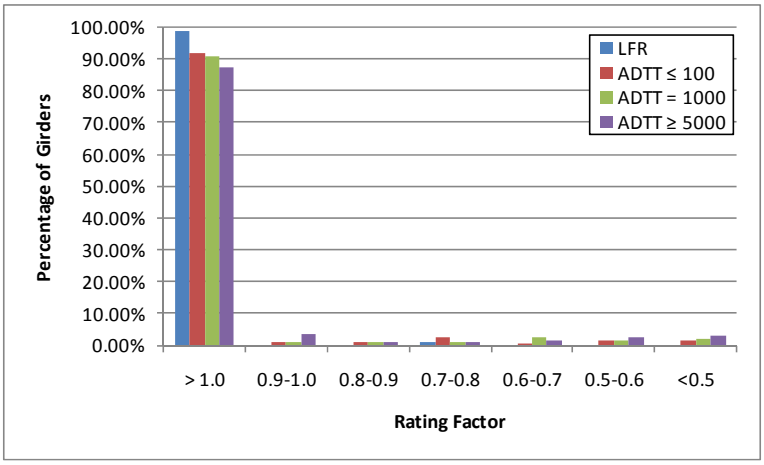


Figure G-165: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

G.2.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure G-166 show the comparison of rating factors. The ratio is generally less than 1.0, with larger tributary widths having larger ratios. 13% of girders have LRFR ratings that are greater than the LFR rating.

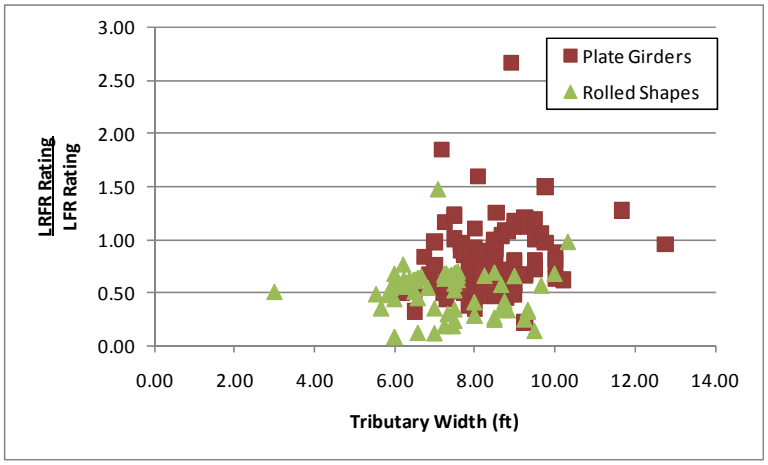


Figure G-166: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

G.2.3.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but six girders as shown in Figure G-167. There appears to be two groups of reliability indices; this is due to the different in statistical parameters for each cross-section type. The reliability index is between four and seven for most plate girders and between eight and ten for the rolled shapes.

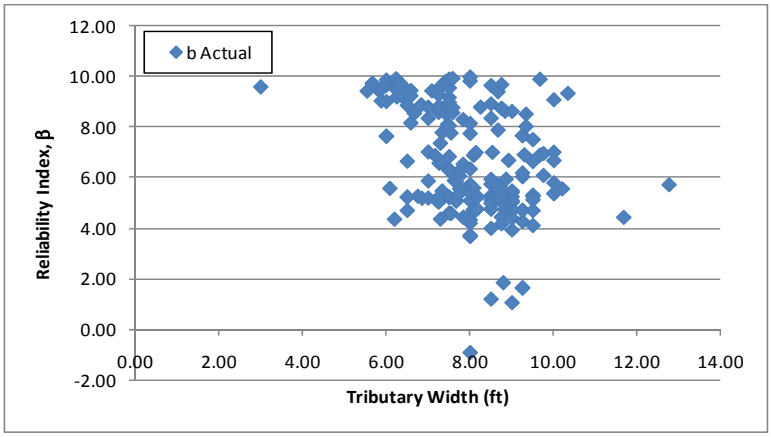


Figure G-167: Shear Reliability Indices for DE-07 Vehicle

Figure G-168 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 vehicle. The reliability index increases with increasing ratings. The reliability index for an LRFR rating of 1.0 is approximately three, above the target reliability of 2.5. This indicates the live load factors for LRFR may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

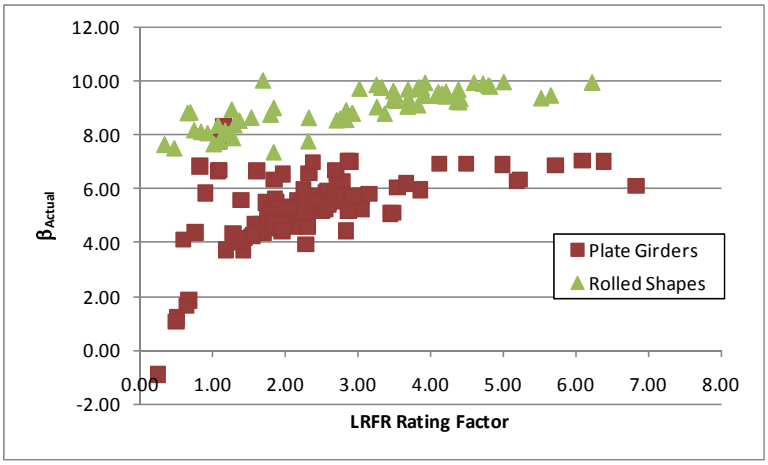
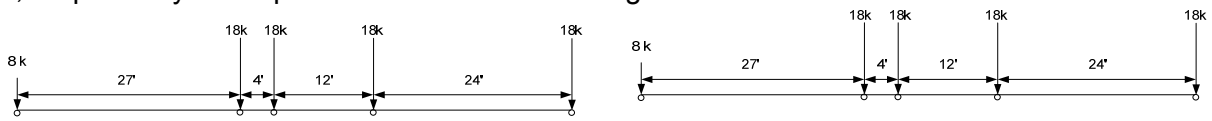


Figure G-168: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

G.2.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-30. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LFR Loading LRFR Loading

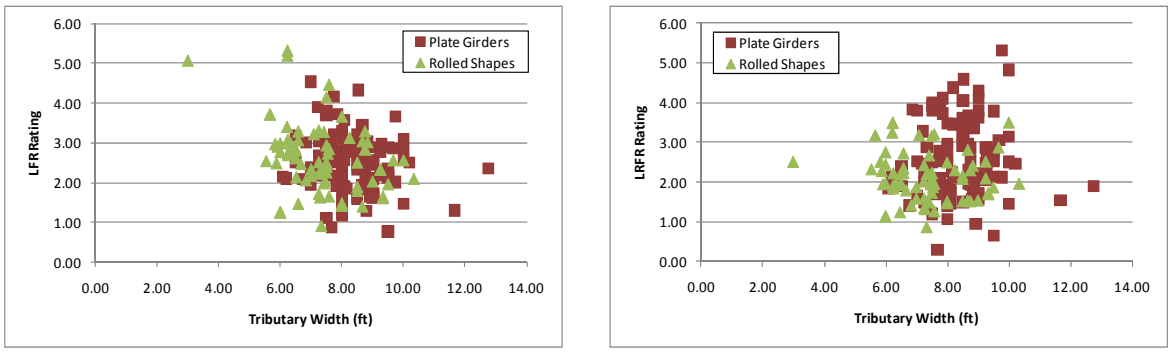
Figure G-169: Vehicle Loadings and Load Factors

G.2.4.1 Moment

The following section contains the results for interior, composite steel girders within continuous span bridges for the FL-04 Vehicle.

G.2.4.1.1 Rating Factors

Figure G-170 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there three girders that have an LFR rating less than 1.0, four girders with LRFR ratings less than 1.0 and three girders with both ratings less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 57% of the girders in this subset. The LFR rating is generally between 1 and 3, with the LRFR rating between 1 and 4.



(a) (b)

Figure G-170: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure G-171 shows the percentage of girders with moment ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 98.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100 while 97.4% of girders have ratings greater than 1.0 for ADTT ≥ 5,000. 98.5% of girders have LFR ratings greater than 1.0. No additional girders have LRFR ratings less than 1.0 for ADTT ≤ 100 than for LFR; this increases to 1.1% more girders for ADTT ≥ 5,000.

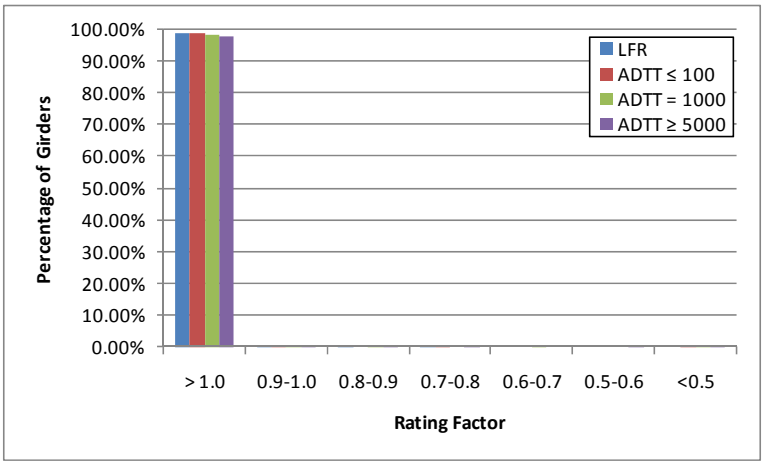


Figure G-171: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

G.2.4.1.2 Rating Factor Comparisons

Figure G-172 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is typically between 0.6 and 1.4, with larger tributary

widths having higher ratios. 43% of girders have LRFR ratings that exceed the LFR rating for this vehicle.

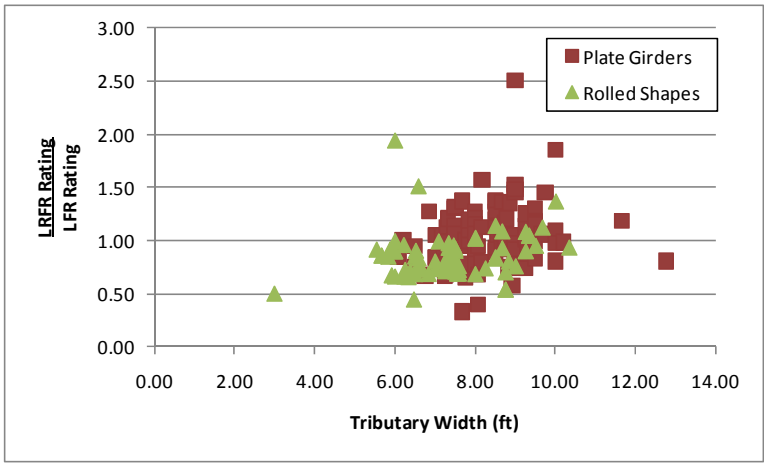


Figure G-172: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

G.2.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-173 shows that all but four girders have a reliability index greater than the target reliability index of 2.5. The reliability index is between four and nine for most girders.

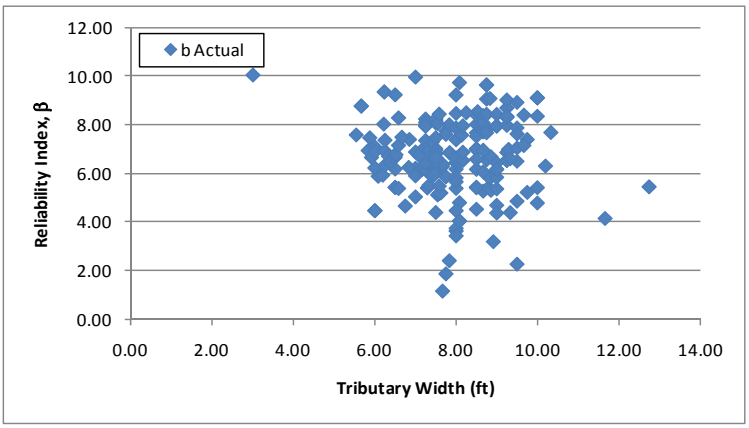


Figure G-173: Flexure Reliability Indices for FL-04 Vehicle

Figure G-174 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 vehicle. The reliability index increases with increasing LRFR ratings. A girder with an LRFR rating of 1.0 is expected to have a reliability index of approximately 3.5, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

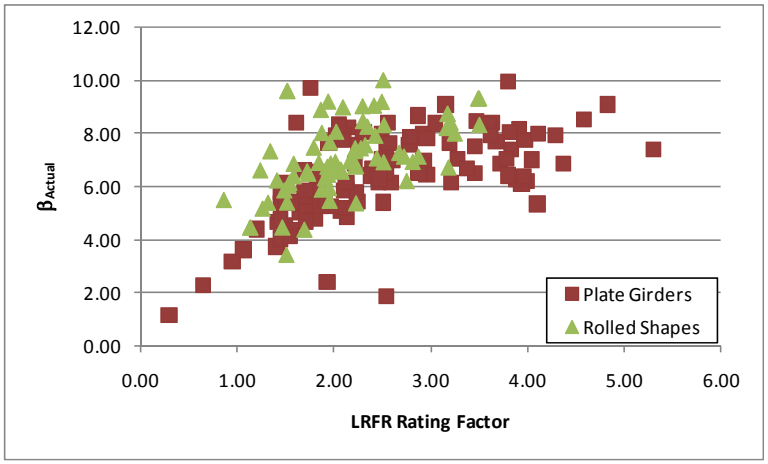
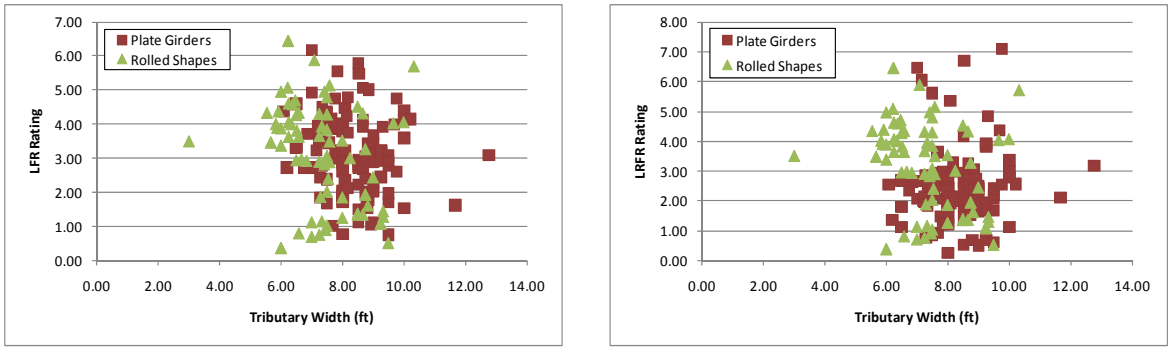


Figure G-174: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

G.2.4.2 Shear

G.2.4.2.1 Rating Factors

For shear, there are two girders that have LFR rating factors less than 1.0, 17 girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. Eleven of the seventeen girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 87% of the girders in this subset. Figure G-175 show the LFR and LRFR ratings. The LFR ratings remain fairly constant with increasing span lengths while the LRFR ratings tend to increase with increasing span length. The LFR ratings are between one and five for most girders while the LRFR ratings are slightly lower.



(a) (b)

Figure G-175: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure G-176 shows the percentage of girders with shear ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 92.3% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 89.2% for ADTT ≥ 5,000. 99% of girders have LFR ratings less than 1.0. This is an increase of 7% of girders with ratings less than 1.0 by switching from LFR to LRFR with an ADTT ≤ 100; this increases to 10.8% for ADTT ≥ 5,000.

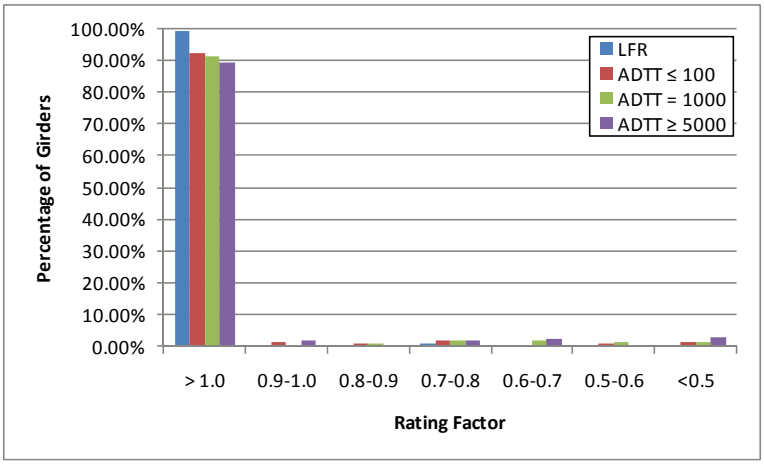


Figure G-176: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

G.2.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-177 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.25, with the ratio increasing for longer span lengths. The ratio for rolled shapes is generally less than 1.0, with the ratio for plate girders is generally between 0.5 and 1.25. 13% of girders have an LRFR rating that is greater than the LFR rating.

Figure G-177: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

G.2.4.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but six girders as shown in Figure G-178. The higher group of reliability indices is for the rolled shapes with the lower group being for the plate girders. The rolled shapes typically have reliability indexes between eight and ten while the plate girders are typically between four and seven.

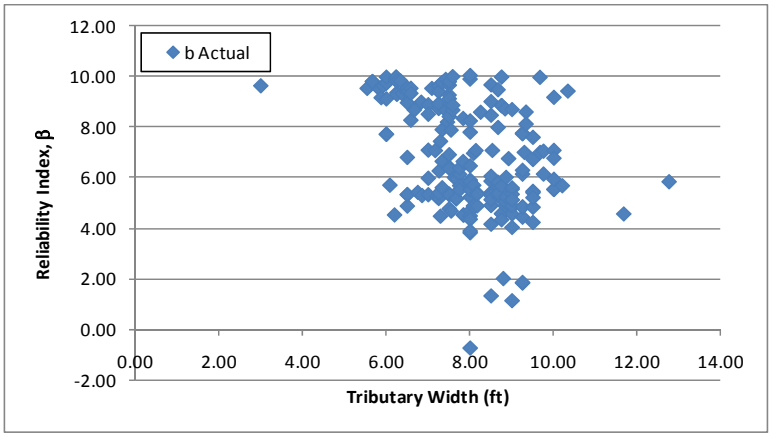


Figure G-178: Shear Reliability Indices for FL-04 Vehicle

Figure G-179 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 vehicle. The reliability index increases with ratings and has a value of approximately 3.5 for a girder with a rating of 1.0. This is above the target reliability of 2.5 and indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

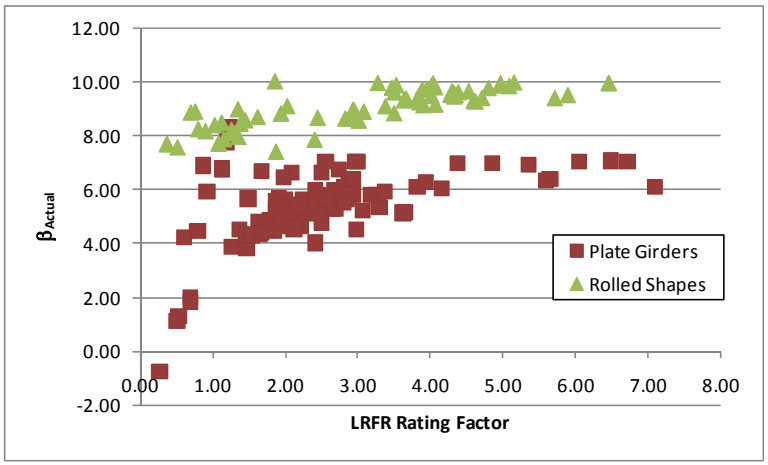


Figure G-179: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

G.2.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-41. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

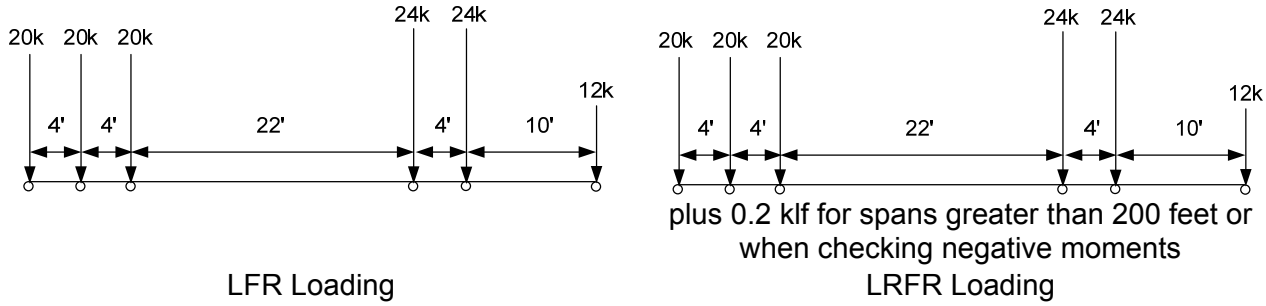


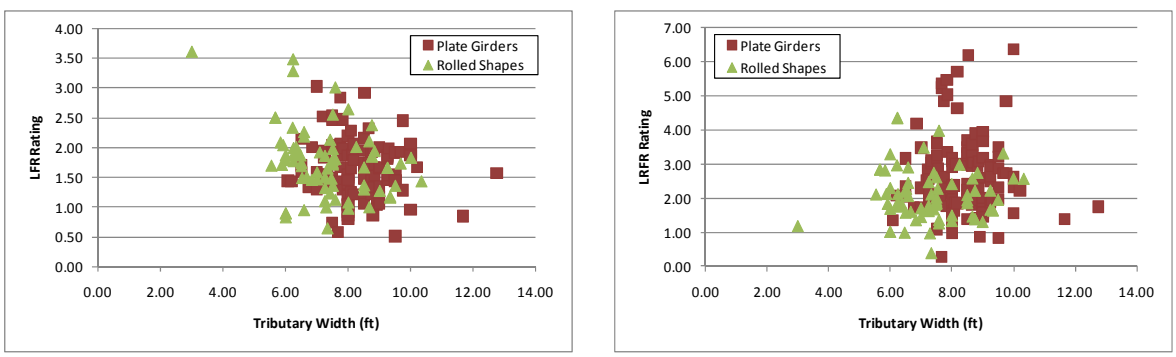
Figure G-180: Vehicle Loadings and Load Factors

G.2.5.1 Moment

The following section contains the results for interior, composite steel girders within continuous span bridges for the IL-01 Vehicle.

G.2.5.1.1 Rating Factors

Figure G-181 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 17 girders with an LFR rating less than 1.0, six girders with an LRFR rating less than 1.0, and four girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 12% of the girders in this subset. The LFR rating is generally between 1 and 2; the LRFR rating is generally between is also generally between 1 and 2 with more of the plate girders having higher ratings than in LFR. Also notice for this case that there are more girders with LFR ratings less than 1.0 than there are for LRFR. The reason most girders have higher LRFR ratings is the loading configuration required by the MBE of a single lane loaded without the multiple presence factor.



(a) (b)

Figure G-181: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure G-182 shows the percentage of girders with moment ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 99% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits while 92.3% of girders have ratings greater than 1.0 for multiple trip permits with ADTT ≥ 5,000. 91.3% of girders have LFR ratings greater than 1.0. For all LRFR special permit types, more girders have ratings above 1.0 for LRFR than for LFR.

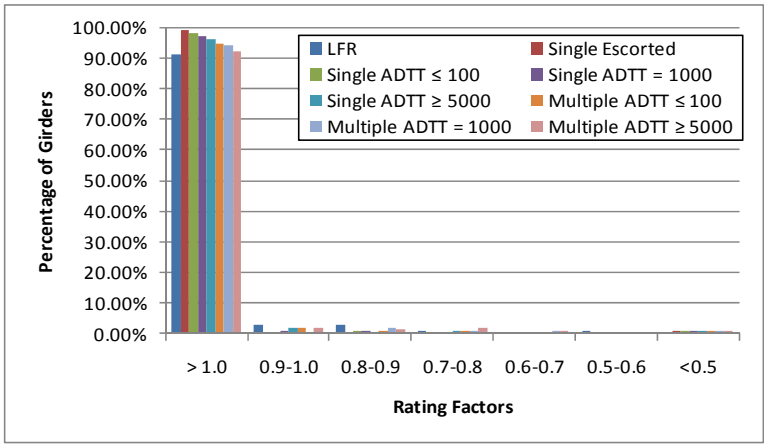


Figure G-182: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

G.2.5.1.2 Rating Factor Comparisons

Figure G-183 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 1.0 and 2.0, with the lower ratios generally coming from girders with smaller tributary widths. 88% of girders have LRFR ratings that are greater than the LFR ratings.

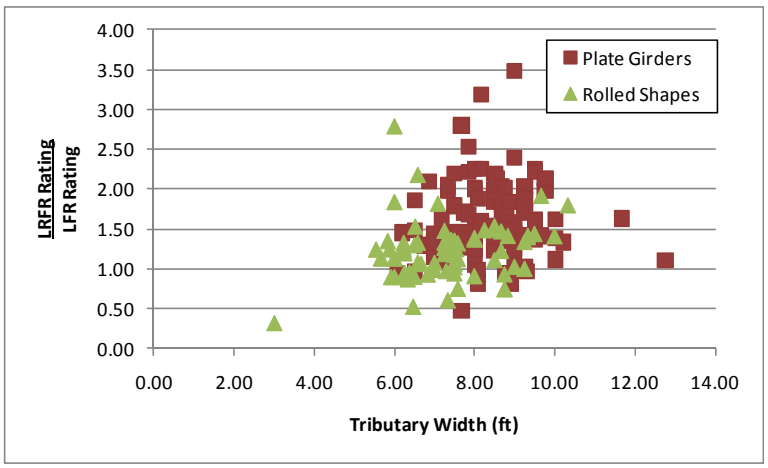


Figure G-183: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

G.2.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-184 shows that seven girders have a reliability index less than the target reliability index of 3.5. The reliability index is between five and nine for most girders.

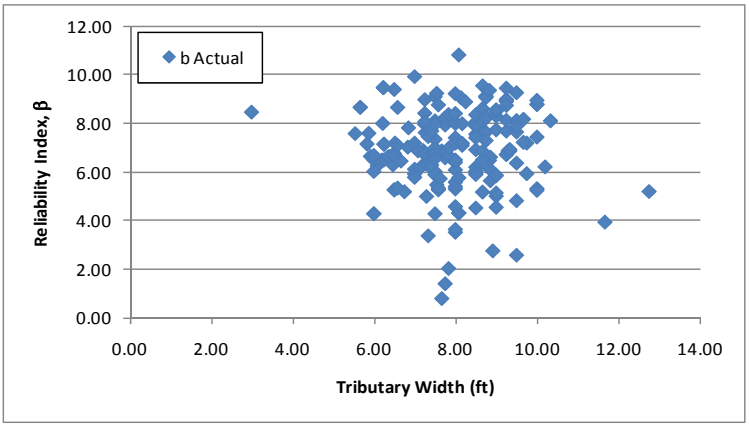


Figure G-184: Flexure Reliability Indices for IL-01 Vehicle

Figure G-185 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The reliability index increases with increasing ratings and is approximately 3.5 for an LRFR rating of 1.0. This indicates the live load factors currently in the MBE provide the target level of reliability for this vehicle.

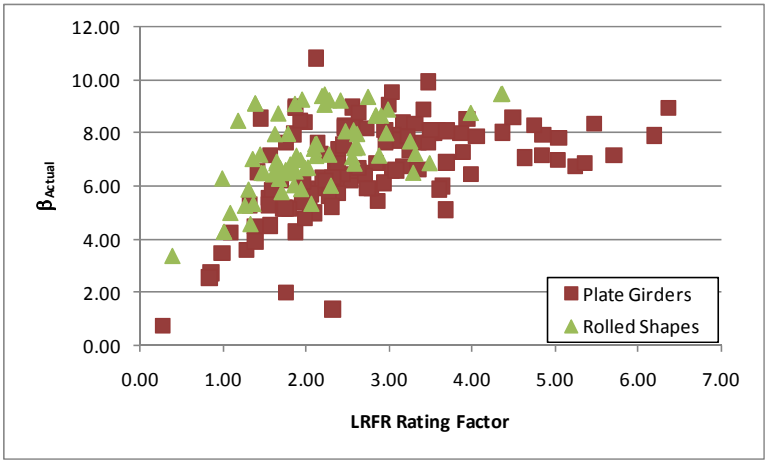
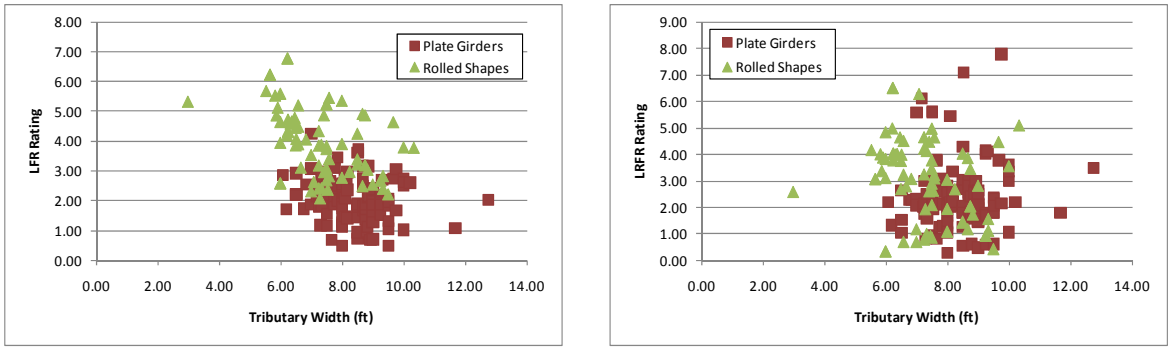


Figure G-185: Flexure Reliability Index vs LRFR Flexure Rating for IL-01

G.2.5.2 Shear

G.2.5.2.1 Rating Factors

For shear, there are eight girders that have an LFR rating factor less than 1.0, 20 girders with LRFR ratings less than 1.0, and six girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 58% of the girders in this subset. Figure G-186 shows the LFR and LRFR ratings. The LFR ratings are typically between one and three for plate girders and above two for rolled shapes. The LRFR ratings are typically between one and four for both rolled shapes and plate girders.



(a) (b)

Figure G-186: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure G-187 shows the percentage of girders with shear ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 93.3% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 83.1% for multiple trip permit with ADTT ≥ 5,000. 95.9% of girders have LFR ratings less than 1.0. This is an increase of 2.6% of girders with ratings less than 1.0 by switching from LFR to LRFR with a single trip, escorted permit; this increases to 16.9% for a multiple trip permit and ADTT ≥ 5,000.

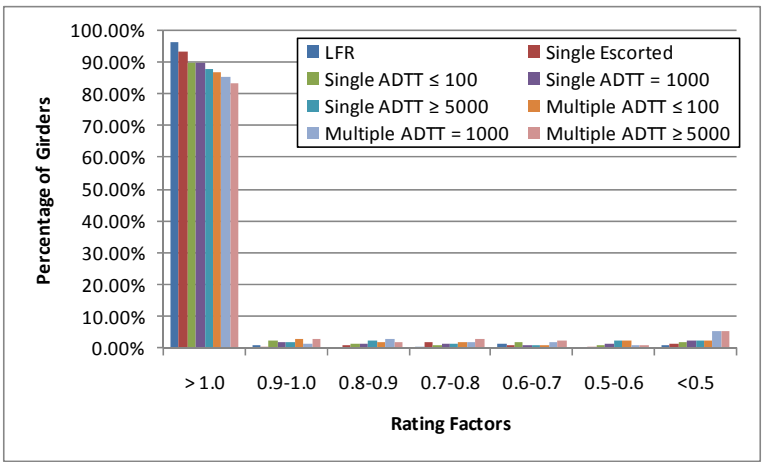


Figure G-187: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

G.2.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-188 shows the comparison of rating factors. The ratio for rolled shapes is typically between 0.5 and 1.0 while for plate girders it is typically between one and two. The LRFR rating is greater than the LFR rating for 42% of the girders.

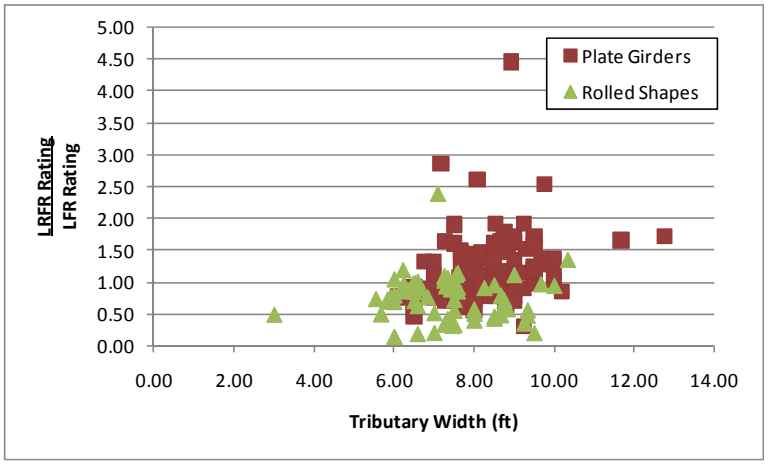


Figure G-188: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

G.2.5.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all but eight girders as shown in Figure G-189. The reliability index appears to be split into two separate groups; the upper group is the rolled shapes and they have reliability indices between six and eight while the lower group is the plate girders and is typically between four and seven.

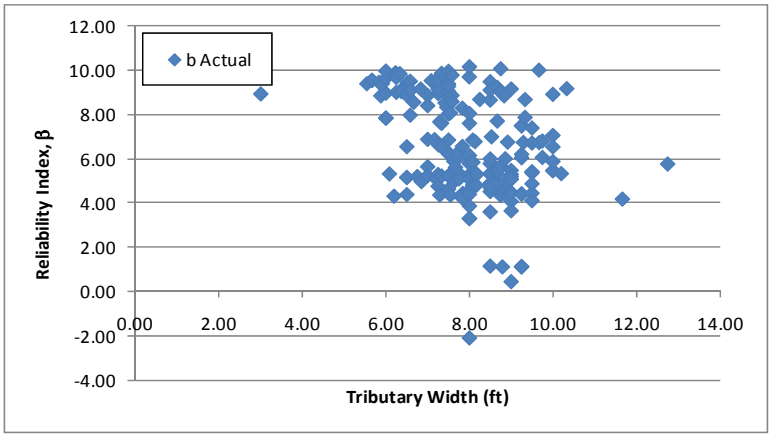


Figure G-189: Shear Reliability Indices for IL-01 Vehicle

Figure G-190 shows the reliability index plotted against the LRFR shear rating for the IL-01 vehicle. The reliability index increases with increasing ratings and is approximately 3.5 for a rating of 1.0. This indicates the live load factors currently in the MBE provide the target level of reliability. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

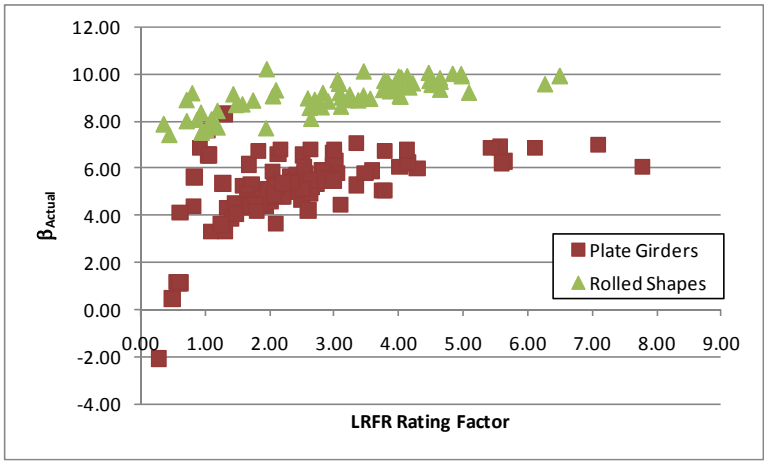


Figure G-190: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

G.2.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-191. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

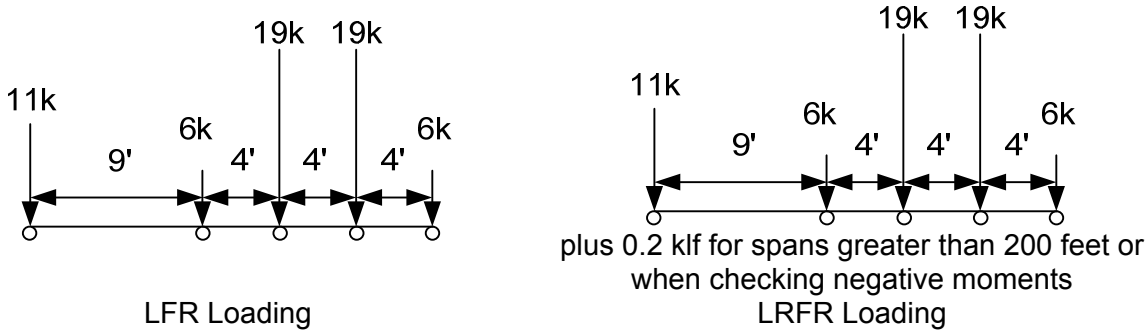


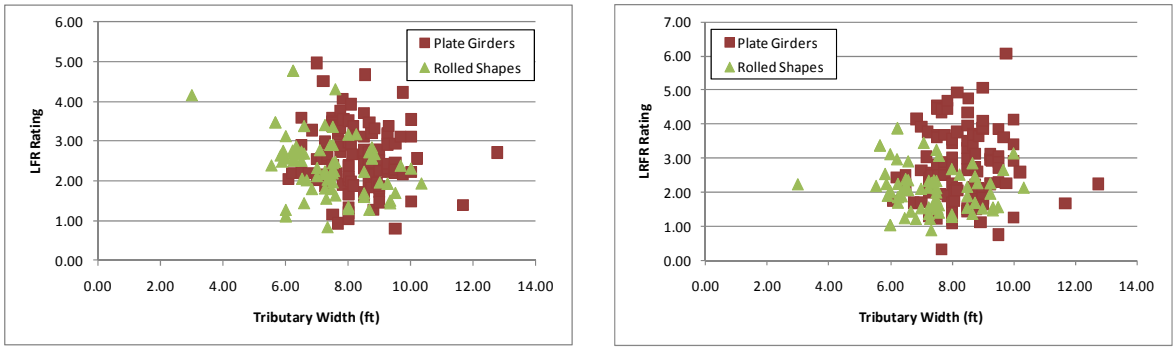
Figure G-191: Vehicle Loadings and Load Factors

G.2.6.1 Moment

The following section contains the results for interior, composite steel girders within continuous span bridges for the NC-21 Vehicle.

G.2.6.1.1 Rating Factors

Figure G-192 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are three girders with an LFR rating less than 1.0, three girders with an LRFR rating less than 1.0, and three girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 51% of the girders in this subset. The LFR rating is generally between 1 and 4 with the same being true for LRFR. For this vehicle, the number of girders with LFR ratings less than 1.0 is the same as the number of girders with LRFR ratings less than 1.0.



(a) (b)

Figure G-192: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure G-193 shows the percentage of girders with moment ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 99.0% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100 while 96.9% of girders have ratings greater than 1.0 for ADTT ≥ 5,000. 98.5% of girders have LFR ratings greater than 1.0. 0.5% more girders have LRFR ratings greater than 1.0 for ADTT ≤ 100 than for LFR; this increases to 1.6% more girders with LRFR ratings less than 1.0 than LFR ratings less than 1.0 for ADTT ≥ 5,000.

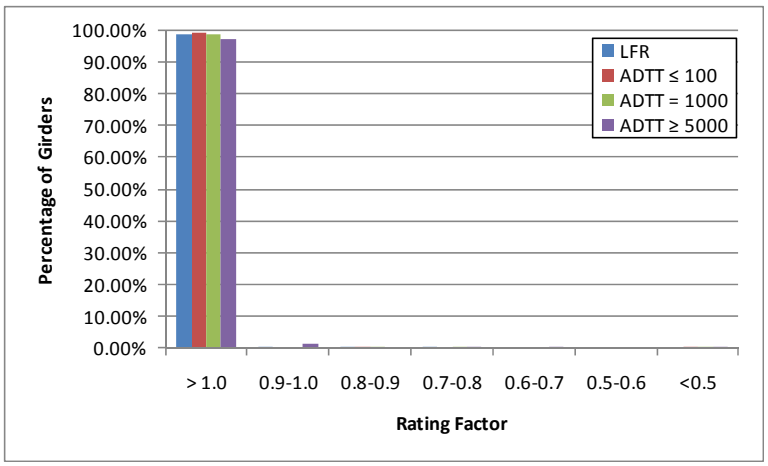


Figure G-193: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

G.2.6.1.2 Rating Factor Comparisons

Figure G-194 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.7 and 1.3 for this vehicle, with the lower ratios corresponding to girders with narrower spacing. 49% of girders have LRFR ratings that exceed the LFR rating.

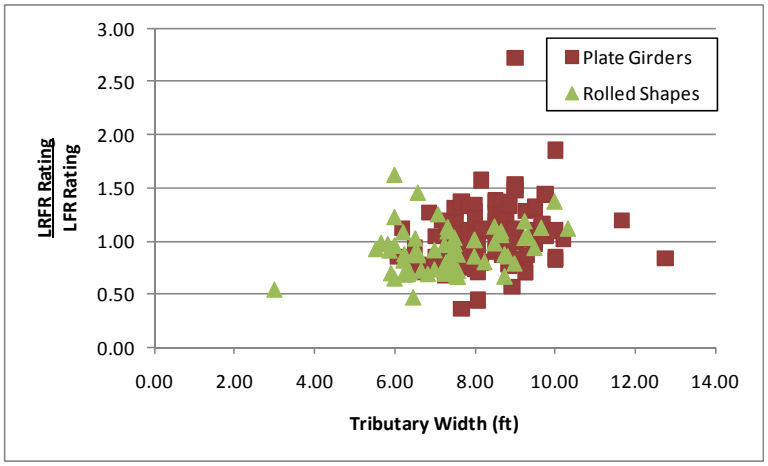


Figure G-194: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

G.2.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-195 shows that four girders have a reliability index less than the target reliability index of 2.5. The reliability index for most girders is between five and eight.

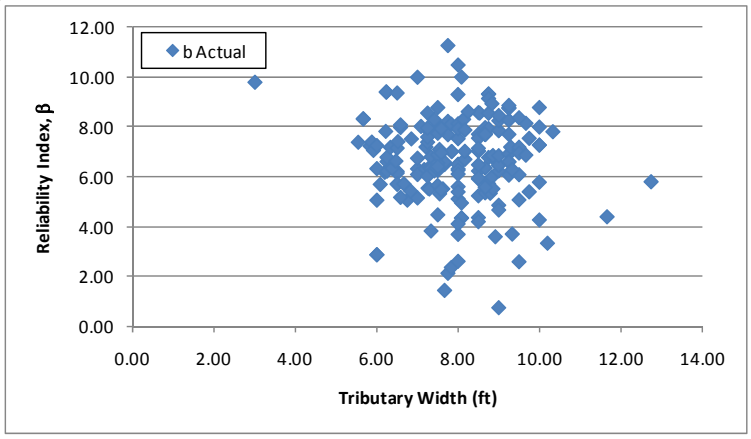


Figure G-195: Flexure Reliability Indices for NC-21 Vehicle

Figure G-196 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 vehicle. The reliability index increases with increasing rating factors and is approximately 3.5 for girders with an LRFR rating of 1.0. This indicates the live load factors may be over-conservative as the target reliability index is 2.5.

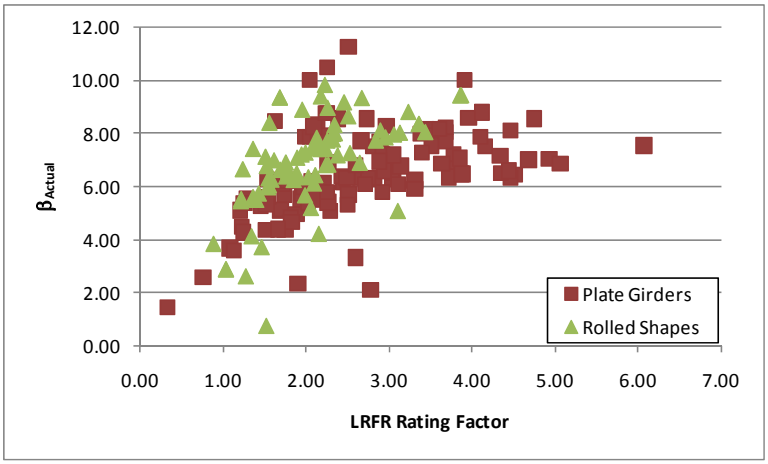
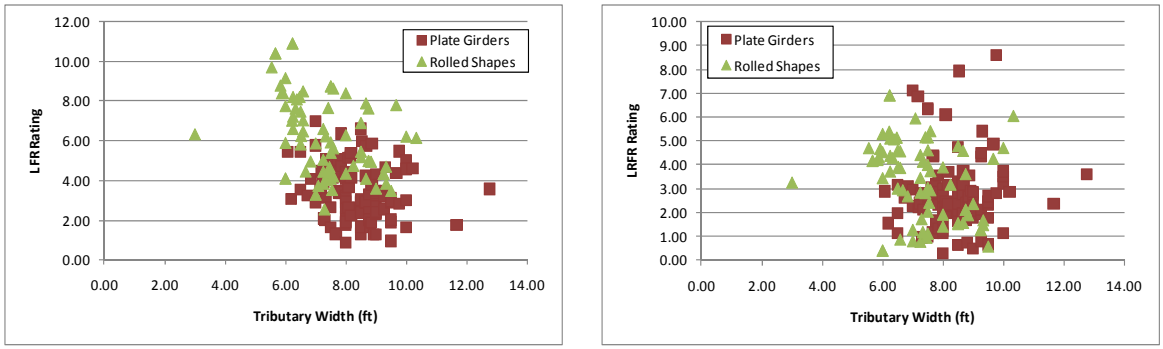


Figure G-196: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

G.2.6.2 Shear

G.2.6.2.1 Rating Factors

For shear, there are two girders that have an LFR rating factors less than 1.0, sixteen girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. Ten of the sixteen girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 84% of the girders in this subset. Figure G-197 shows the LFR and LRFR ratings. The LFR rating is between two and six for plate girders and between four and eight for rolled shapes. The LRFR rating is between one and five for both types of girders.



(a) (b)

Figure G-197: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure G-198 shows the percentage of girders with shear ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 93.8% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 90.8% for ADTT ≥ 5,000. 99% of girders have LFR ratings less than 1.0. This is an increase of 5% of girders with ratings less than 1.0 by switching from LFR to LRFR with an ADTT ≤ 100; this increases to 8.2% for ADTT ≥ 5,000.

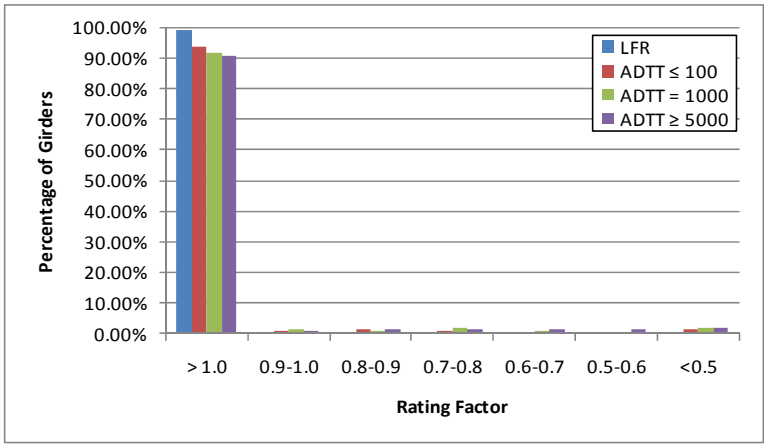


Figure G-198: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

G.2.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-199 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5 with plate girders more likely to be above 1.0. 16% of girders have LRFR ratings that are greater than the LFR rating.

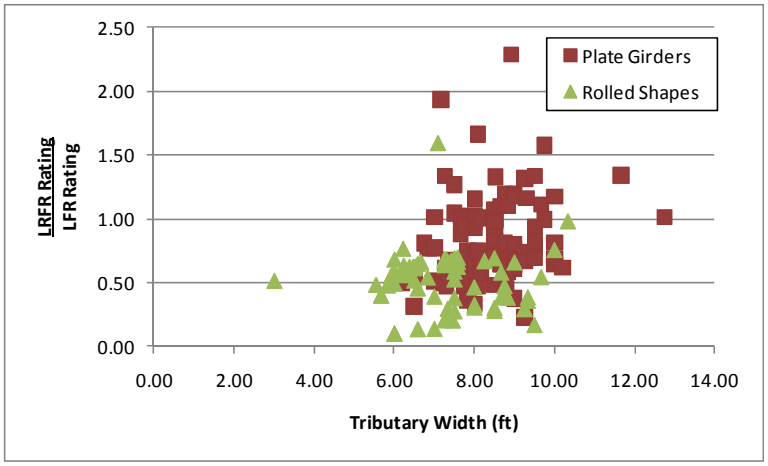


Figure G-199: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

G.2.6.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but six girders as shown in Figure G-200. The reliability index appears to be split into two groups; rolled shapes are typically between eight and ten while plate girders are typically between four and seven.

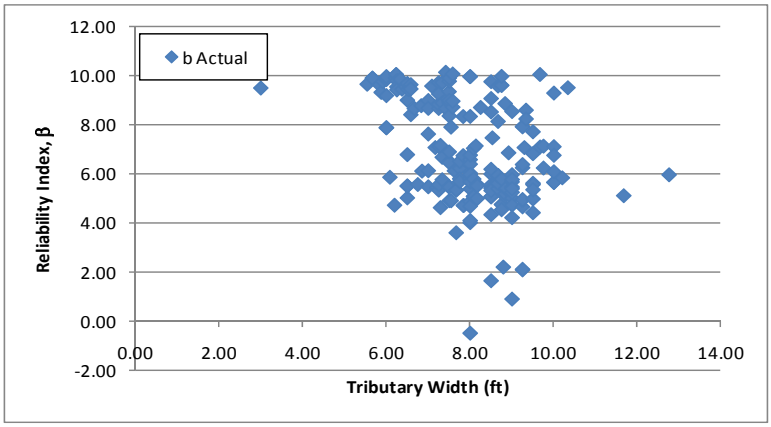


Figure G-200: Shear Reliability Indices for NC-21 Vehicle

Figure G-201 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 vehicle. The reliability index increases with increasing ratings and a reliability index of approximately three is expected for a girder with an LRFR rating of 1.0. This indicates the LRFR live load factors may be slightly over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

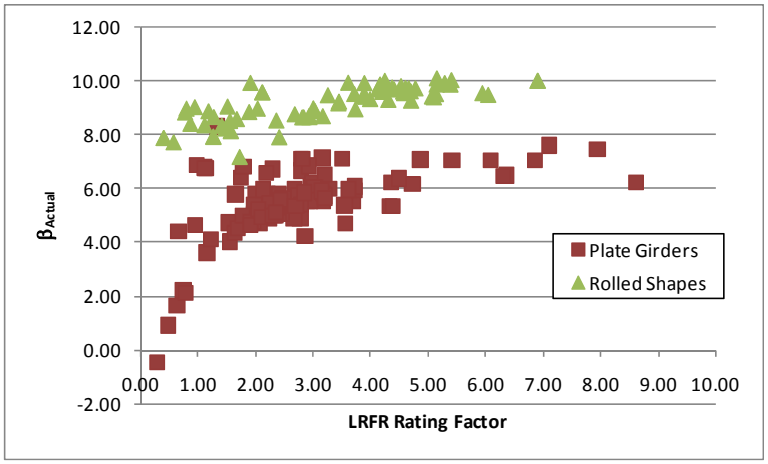


Figure G-201: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

G.2.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-202. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

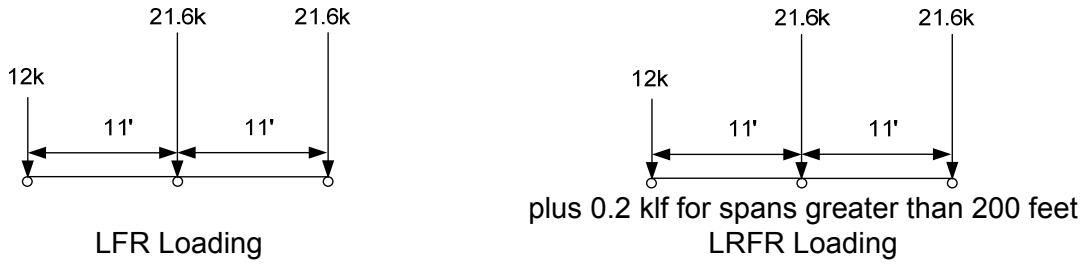


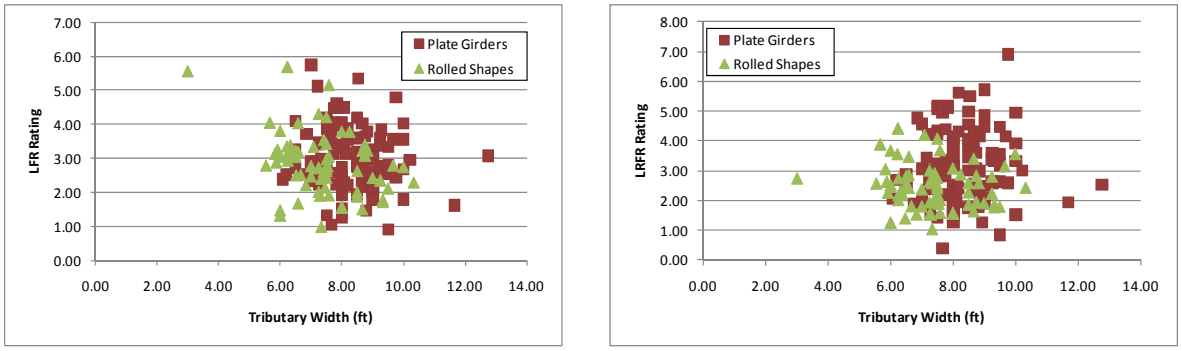
Figure G-202: Vehicle Loadings and Load Factors

G.2.7.1 Moment

The following section contains the results for interior, composite steel girders within continuous span bridges for the NM-04 Vehicle.

G.2.7.1.1 Rating Factors

Figure G-203 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are two girders with an LFR rating less than 1.0, two girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 52% of the girders in this subset. The ratings tend to remain between 2 and 4 for LFR and 1.0 and 5.0 for LRFR.



(a) (b)

Figure G-203: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure G-204 shows the percentage of girders with moment ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 99% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100 while 98.5% of girders have ratings greater than 1.0 for ADTT ≥ 5,000. 99% of girders have LFR ratings greater than 1.0. No additional girders have LRFR ratings less than 1.0 for ADTT ≤ 100 than for LFR; this increases to 0.5% more girders for ADTT ≥ 5,000.

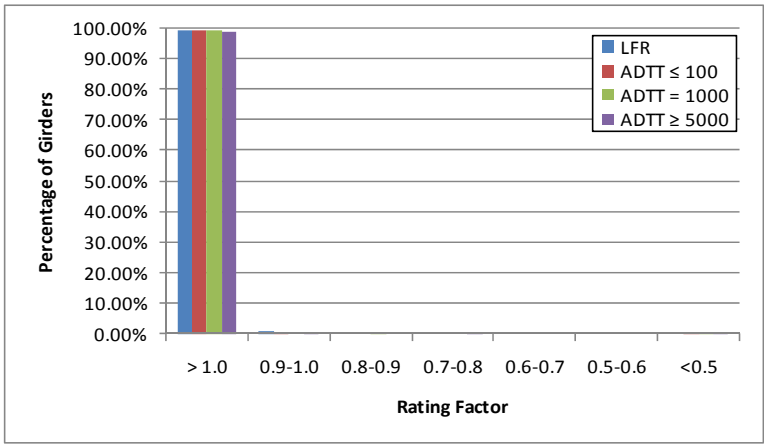


Figure G-204: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

G.2.7.1.2 Rating Factor Comparisons

Figure G-205 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.7 and 1.4, with higher ratios generally for girders with larger tributary widths. The LRFR ratings are greater than the LFR ratings for 48% of the girders.

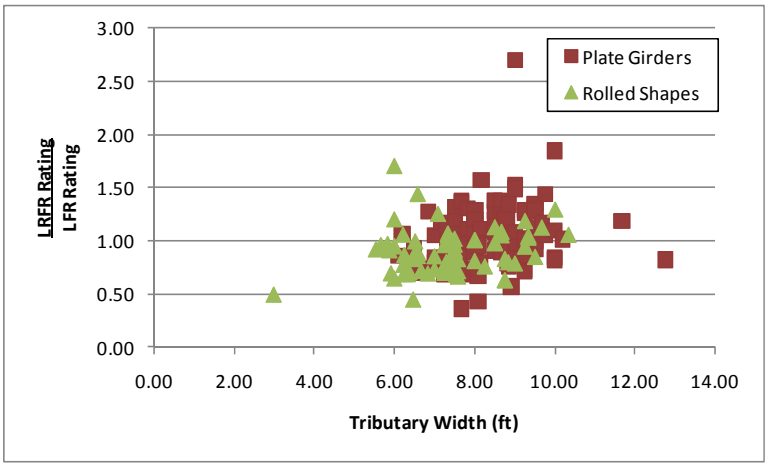


Figure G-205: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

G.2.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-206 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index is between five and nine for most girders.

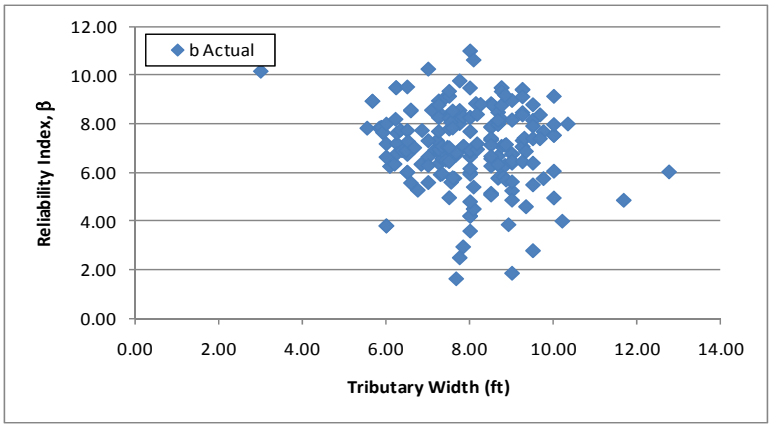


Figure G-206: Flexure Reliability Indices for NM-04 Vehicle

Figure G-207 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The reliability index increases with increasing ratings and is approximately 3.5 for girders with an LRFR rating of 1.0. This indicates that the live load factors in the MBE may be slightly over-conservative.

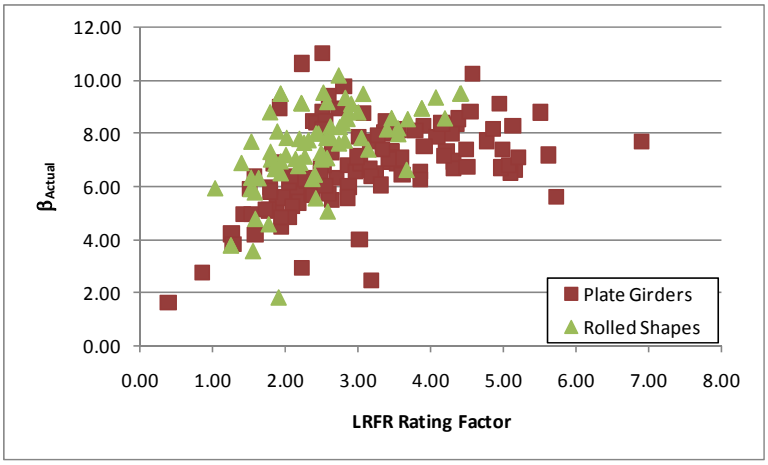
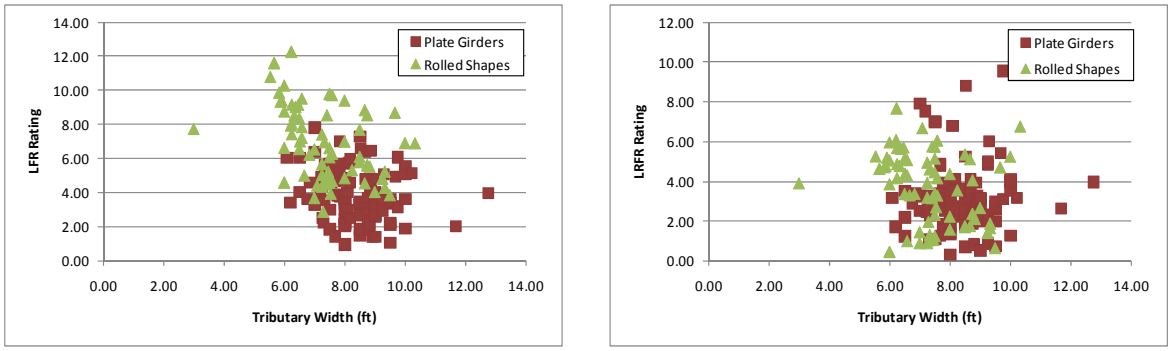


Figure G-207: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

G.2.7.2 Shear

G.2.7.2.1 Rating Factors

For shear, there is one girder that has an LFR rating factor less than 1.0, twelve girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. Six of the twelve girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 86% of the girders in this subset. Figure G-208 shows the LFR and LRFR ratings. The LFR ratings are between two and six for the plate girders and between four and ten for the rolled shapes. The LRFR ratings are typically between one and six for both girder types.



(a) (b)

Figure G-208: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure G-209 shows the percentage of girders with shear ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 95.4% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 91.8% for ADTT ≥ 5,000. 99.5% of girders have LFR ratings less than 1.0. This is an increase of 4% more girders with ratings less than 1.0 by switching from LFR to LRFR with an ADTT ≤ 100; this increases to 7.7% for ADTT ≥ 5,000.

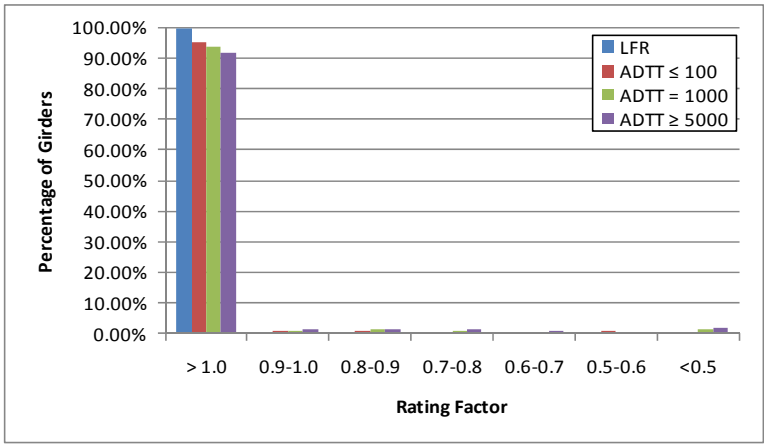


Figure G-209: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

G.2.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-210 show the comparison of rating factors. The ratio is generally between 0.5 and 1.0. Larger tributary widths are more likely to have higher LRFR ratings than LFR ratings. 14% of girders have LRFR ratings that are greater than the LFR rating.

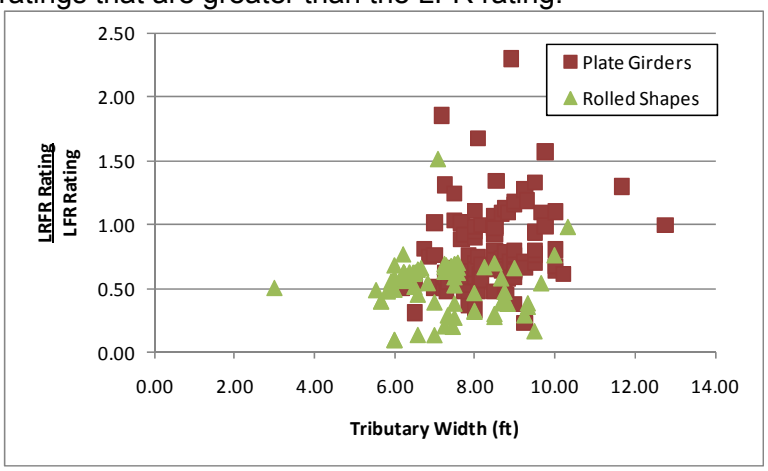


Figure G-210: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

G.2.7.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but five girders as shown in Figure G-211. The reliability index is split into two groups; the upper group is the rolled shapes with values between eight and ten and the lower group is the plate girders with values between four and seven.

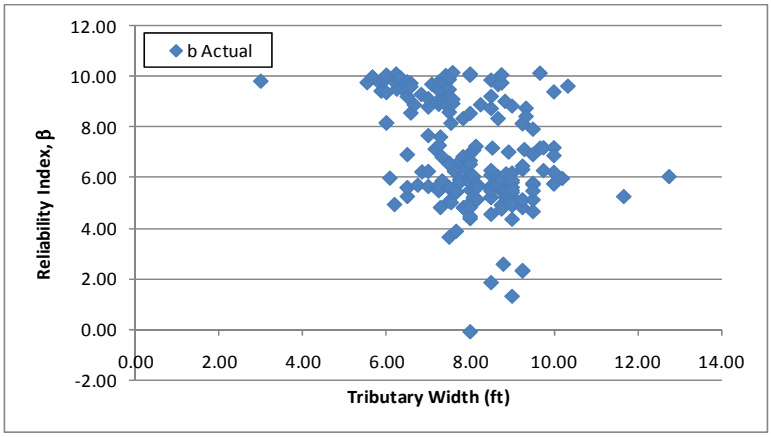


Figure G-211: Shear Reliability Indices for NM-04 Vehicle

Figure G-212 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. The reliability index increases with increasing rating factors. The reliability index associated with an LRFR rating of 1.0 is approximately three, above the target reliability of 2.5. This indicates the LRFR live load factors may be slightly over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

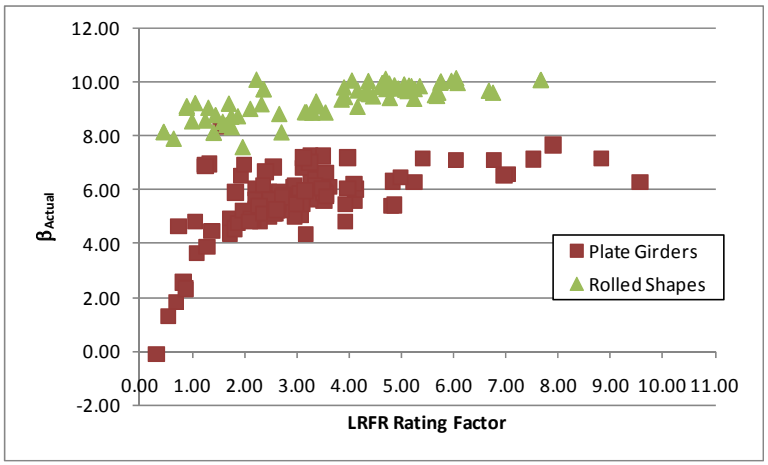
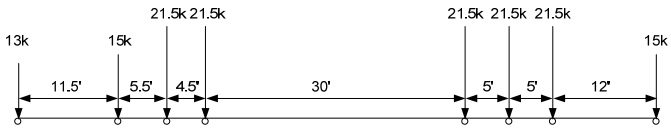


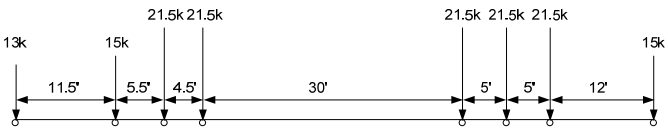
Figure G-212: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

G.2.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-213. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading



plus 0.2 klf for spans greater than 200 feet

LRFR Loading

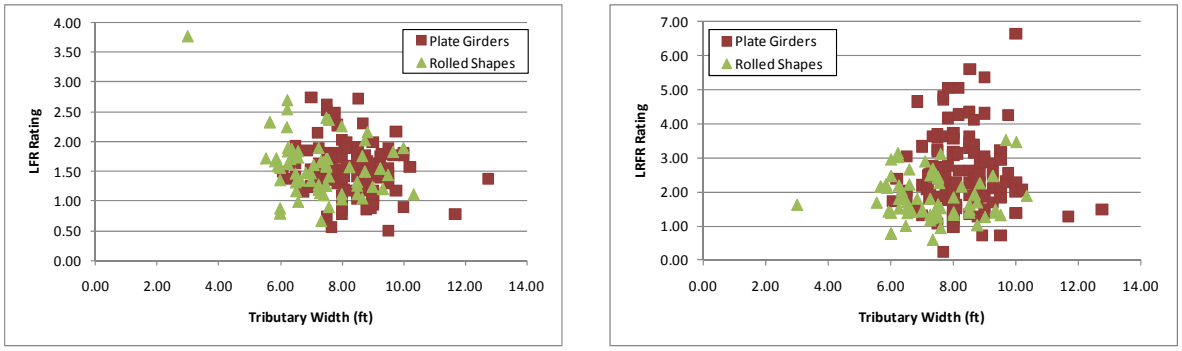
Figure G-213: Vehicle Loadings and Load Factors

G.2.8.1 Moment

The following section contains the results for interior, composite steel girders within continuous span bridges for the OR-06 Vehicle.

G.2.8.1.1 Rating Factors

Figure G-214 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 18 girders with an LFR rating less than 1.0, 8 girders with an LRFR rating less than 1.0, and eight girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 15% of the girders in this subset. The LFR rating is generally within the range of 1 to 2 and the LRFR rating is also between 1 and 2.



(a) (b)

Figure G-214: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure G-215 shows the percentage of girders with moment ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 96.9% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits while 89.2% of girders have ratings greater than 1.0 for multiple trip permits with ADTT ≥ 5,000. 90.8% of girders have LFR ratings greater than 1.0. 6% more girders have LRFR ratings greater than 1.0 for single trip, escorted permits than for LFR; 1.6% more girders have LRFR ratings for multiple trips and ADTT ≥ 5,000 less than 1.0 than with LFR ratings less than 1.0.

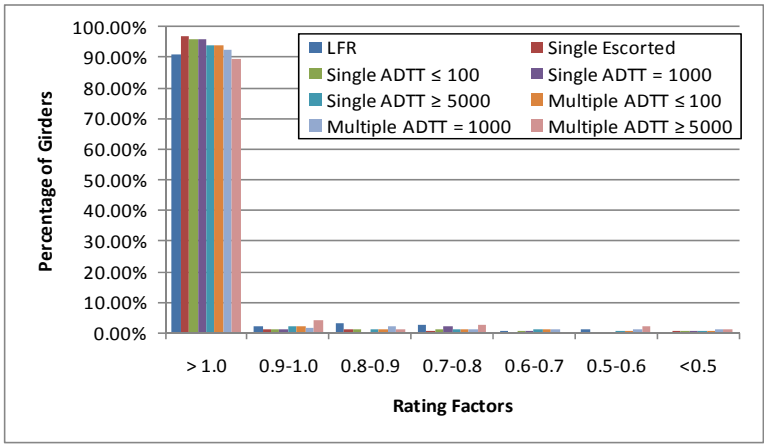


Figure G-215: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

G.2.8.1.2 Rating Factor Comparisons

Figure G-216 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 1.0 and 2.5. 85% of the girders have LRFR ratings that are greater than the LFR rating.

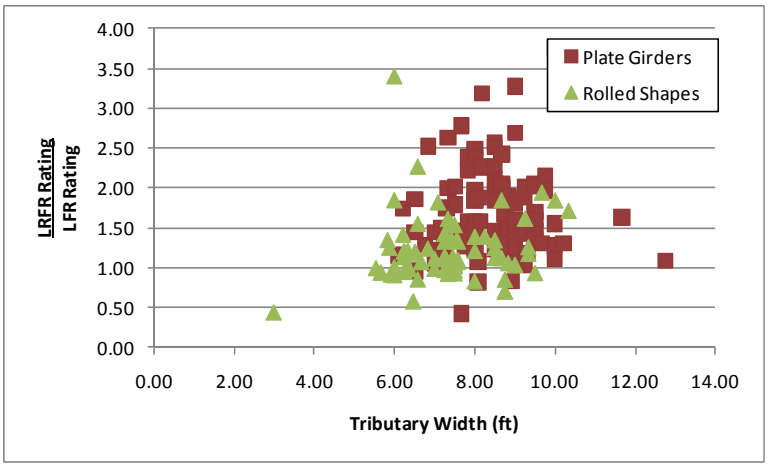


Figure G-216: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

G.2.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-217 shows that eight girders have a reliability index less than the target reliability index of 3.5. The reliability index is between five and ten for most girders.

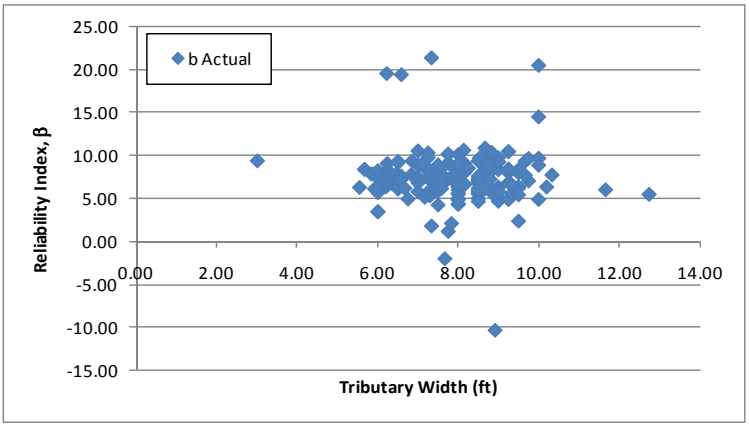


Figure G-217: Flexure Reliability Indices for OR-06 Vehicle

Figure G-218 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 Vehicle. The reliability index increases with increasing rating but not as significantly as for other vehicles. The reliability index associated with an LRFR rating of 1.0 is approximately four, just above the target reliability of 3.5. This indicates the LRFR live load factors provide the target reliability without exceeding it significantly.

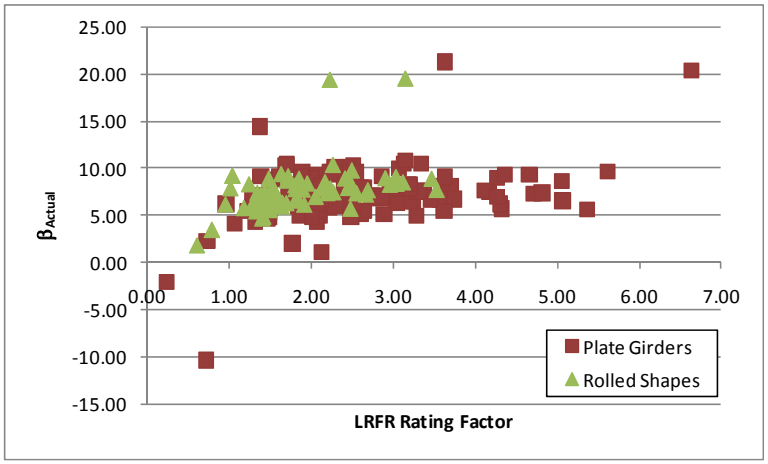
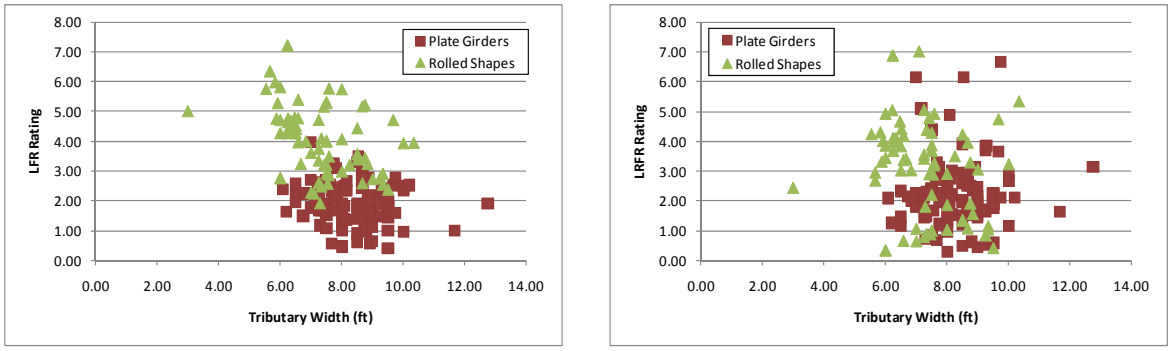


Figure G-218: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

G.2.8.2 Shear

G.2.8.2.1 Rating Factors

For shear, there are 11 girders that have an LFR rating factors less than 1.0, 22 girders have LRFR ratings less than 1.0, and six girders have both ratings less than 1.0. 16 of the 22 girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 55% of the girders in this subset. Figure G-219 shows the LFR and LRFR ratings. The LFR rating decreases with increasing tributary width; plate girders have ratings between one and three while rolled shapes are typically between three and six. The LRFR ratings are similar except that the rolled shapes are more variable.



(a) (b)

Figure G-219: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure G-220 shows the percentage of girders with shear ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 92.3% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 82.6% for multiple trip permits with ADTT ≥ 5,000. 94.4% of girders have LFR ratings less than 1.0. This is an increase of 2.1% of girders with ratings less than 1.0 by switching from LFR to LRFR with a single trip, escorted permit; this increases to 11.8% for a multiple trip permit with ADTT ≥ 5,000.

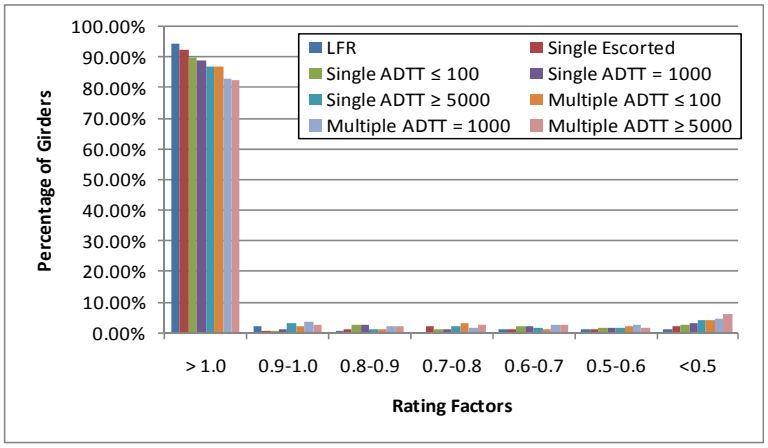


Figure G-220: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

G.2.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-221 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0 for this set of girders with this vehicle. Larger tributary widths are more likely to have LRFR ratings greater than LFR ratings. 45% of girders have an LRFR rating that is greater than the LFR rating.

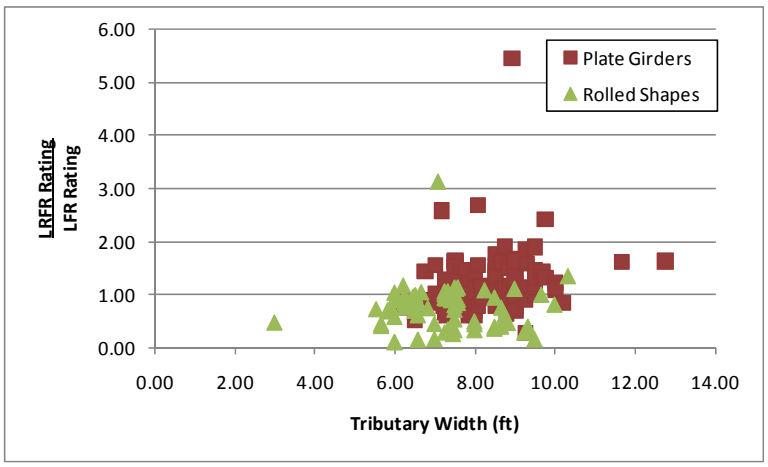


Figure G-221: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

G.2.8.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all but eight girders as shown in Figure G-222. The reliability index is split into two groups; those above are eight are typically rolled shapes and those between four and seven are typically plate girders. The difference in reliability index is due to the difference in statistical parameters.

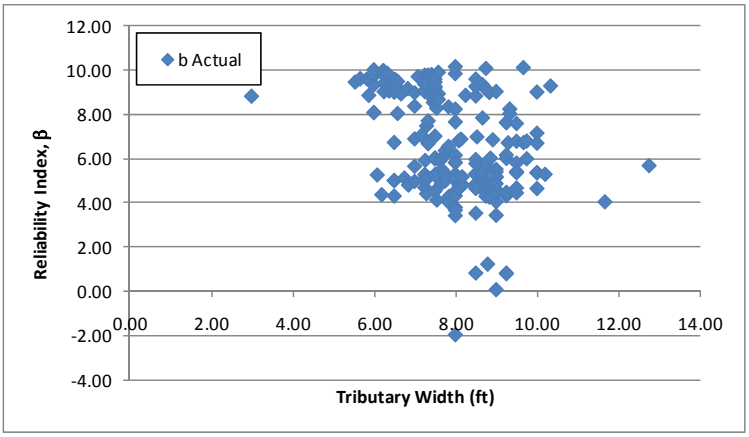


Figure G-222: Shear Reliability Indices for OR-06 Vehicle

Figure G-223 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The reliability index corresponding to a rating of 1.0 is approximately 3.5, the target reliability level. This indicates the current live load factors provided the target level of reliability. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

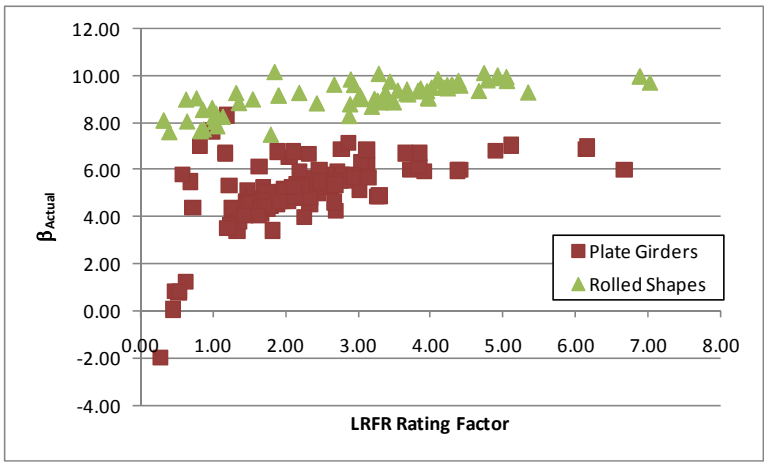
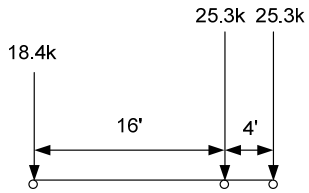


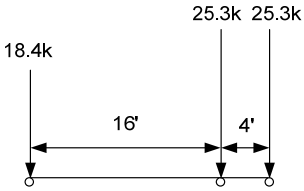
Figure G-223: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

G.2.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-224. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LRFR Loading

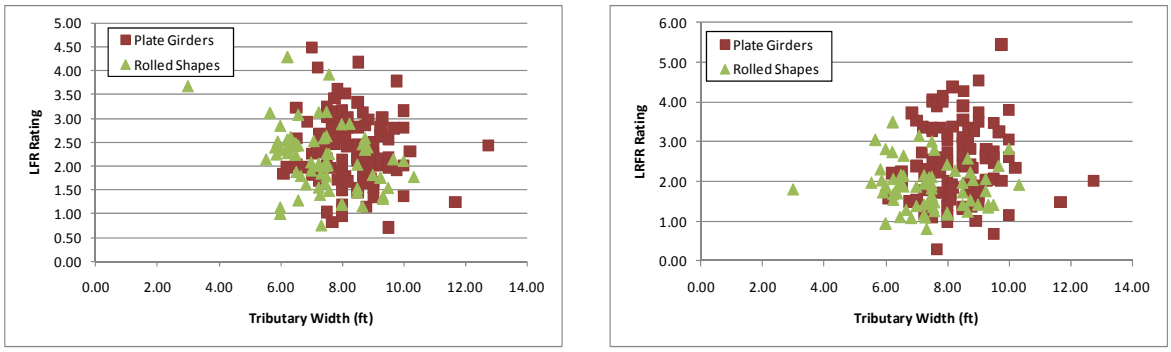
Figure G-224: Vehicle Loadings and Load Factors

G.2.9.1 Moment

The following section contains the results for interior, composite steel girders within continuous span bridges for the TX-04 Vehicle.

G.2.9.1.1 Rating Factors

Figure G-225 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are six girders with an LFR rating less than 1.0, six girders with an LRFR rating less than 1.0, and five girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 52% of the girders in this subset. The LFR rating is generally between 1 and 3.5; the LRFR rating is generally between 1 and 4. For this vehicle, the same number of girders has an LFR rating less than 1.0 as have an LRFR rating less than 1.0.



(a) (b)

Figure G-225: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure G-226 shows the percentage of girders with moment ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 98.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100 while 94.4% of girders have ratings greater than 1.0 for ADTT ≥ 5,000. 96.9% of girders have LFR ratings greater than 1.0. 1.6% fewer girders have LRFR ratings less than 1.0 for ADTT ≤ 100 than for LFR; this increases to 2.5% more girders for ADTT ≥ 5,000.

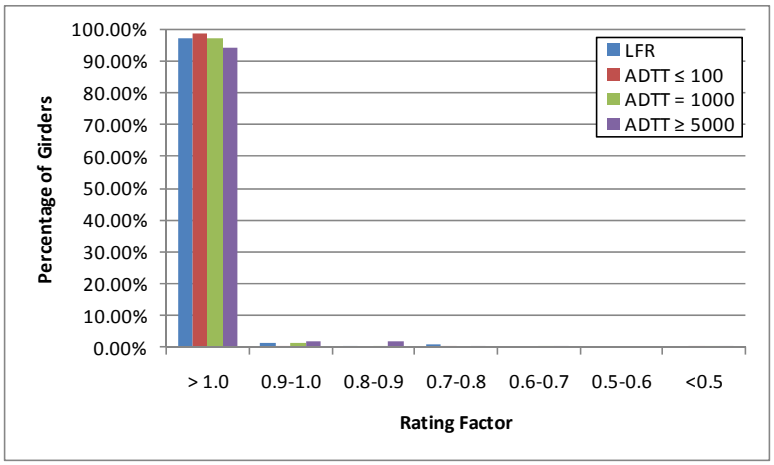


Figure G-226: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

G.2.9.1.2 Rating Factor Comparisons

Figure G-227 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.75 and 1.5 with larger ratios generally from girders with larger tributary widths. 48% of girders have LRFR ratings that exceed the LFR rating for this vehicle.

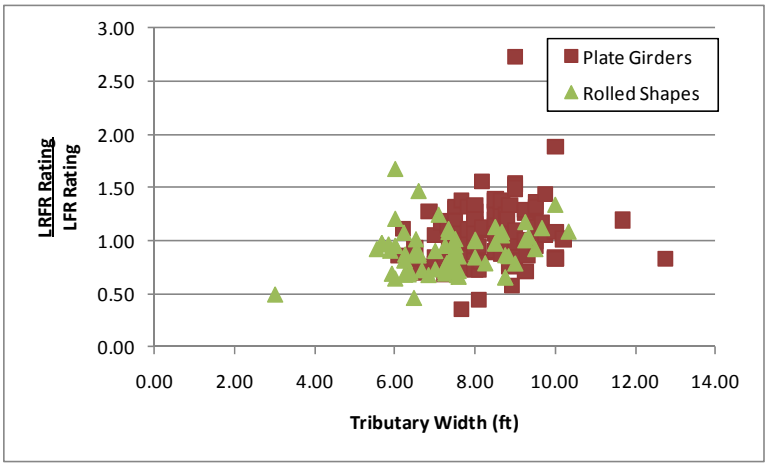


Figure G-227: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

G.2.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-228 shows seven girders that have a reliability index less than the target reliability index of 2.5. The reliability index is between five and eight for most girders.

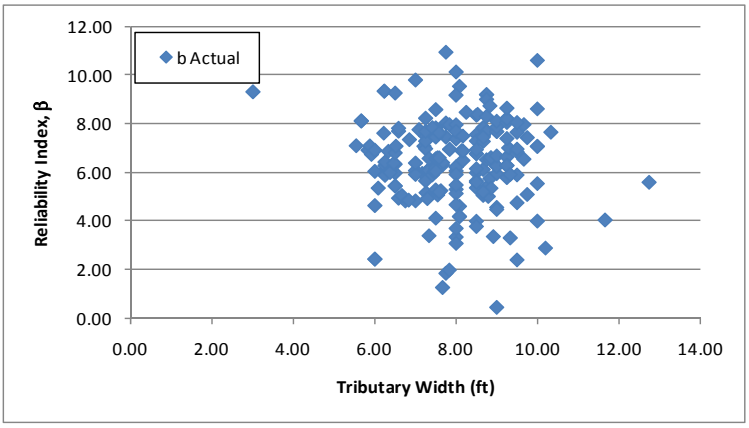


Figure G-228: Flexure Reliability Indices for TX-04 Vehicle

Figure G-229 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The reliability index increases with increasing rating factors and is approximately 3.5 for a rating of 1.0. This is above the target reliability index of 2.5 and indicates the LRFR live load factors may be over-conservative.

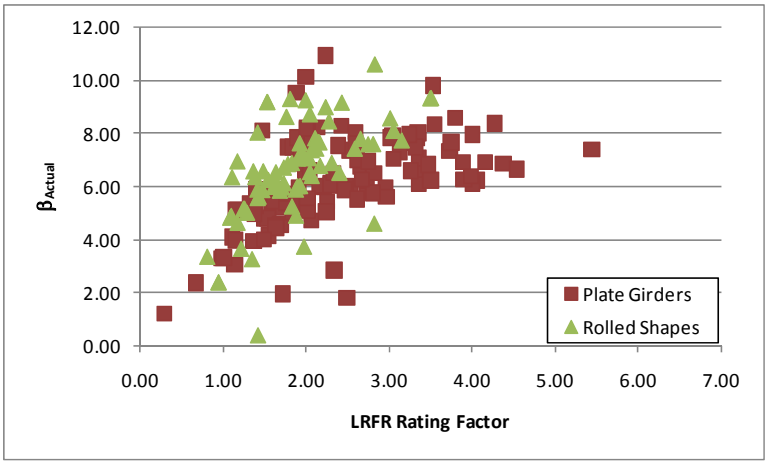
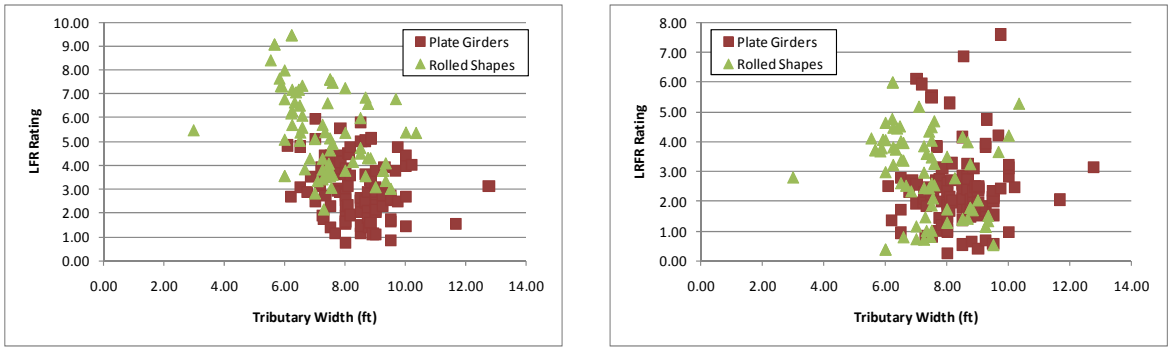


Figure G-229: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

G.2.9.2 Shear

G.2.9.2.1 Rating Factors

For shear, there are two girders that have an LFR rating factor less than 1.0, twenty one girders with LRFR ratings less than 1.0 and two girders where both ratings are less than 1.0. 13 of the 21 girders with an LRFR rating less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 83% of the girders in this subset. Figure G-230 shows the LFR and LRFR ratings. The LFR ratings are between one and five for most plate girders and between three and seven for most rolled shapes. The LRFR ratings are between one and four for both types of girders.



(a) (b)

Figure G-230: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure G-231 shows the percentage of girders with shear ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 91.8% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 88.2% for ADTT ≥ 5,000. 99% of girders have LFR ratings less than 1.0. This is an increase of 7% of girders with ratings less than 1.0 by switching from LFR to LRFR with an ADTT ≤ 100; this increases to 10.8% for ADTT ≥ 5,000.

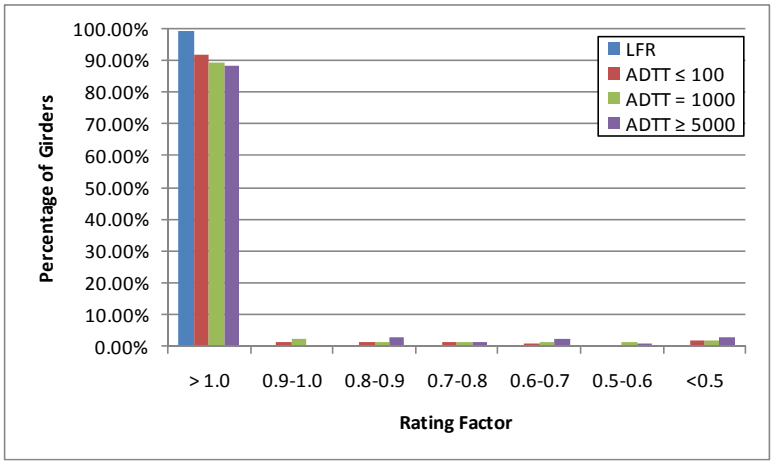


Figure G-231: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

G.2.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-232 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.25 for both girder types. 17% of girders have LRFR ratings that are greater than the LFR ratings; most of these are plate girders.

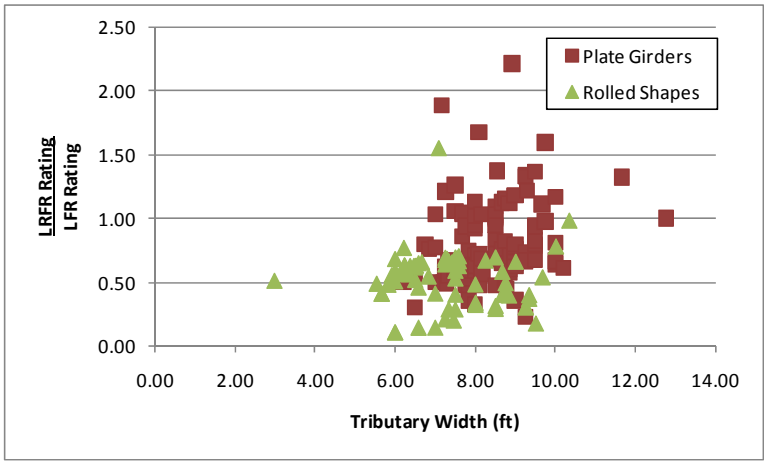


Figure G-232: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

G.2.9.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index for all but six girders as shown in Figure G-233. The reliability index is split into two groups; the upper group are the rolled shapes with reliability indices between eight and ten while the lower group are the plate girders with reliability indices between four and seven.

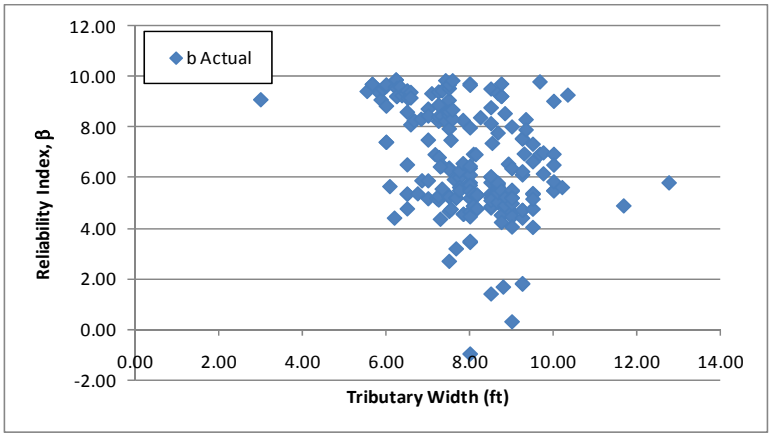


Figure G-233: Shear Reliability Indices for TX-04 Vehicle

Figure G-234 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The reliability index increases with increasing ratings and for a rating of 1.0 is approximately 3.5, above the target reliability of 3.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

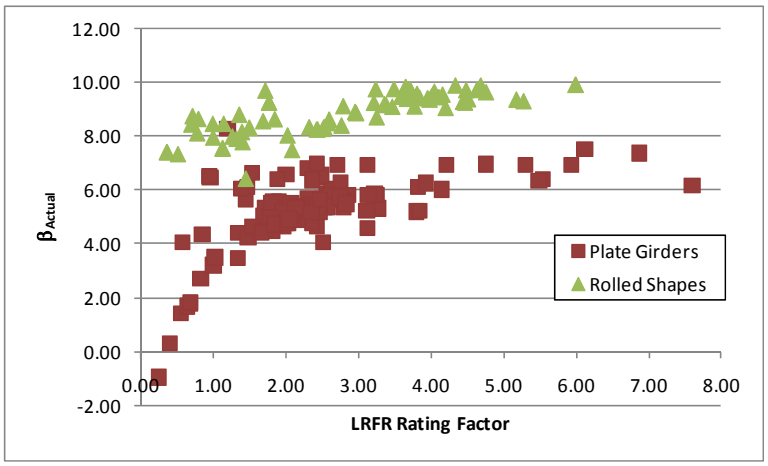
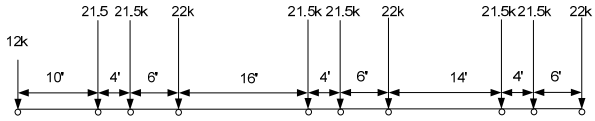


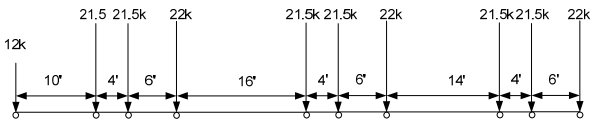
Figure G-234: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

G.2.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-235. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LRFR Loading

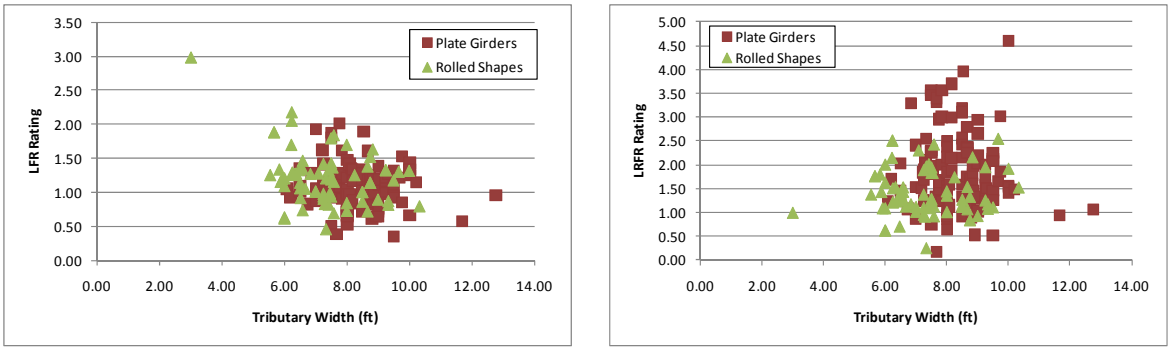
Figure G-235: Vehicle Loadings and Load Factors

G.2.10.1Moment

The following section contains the results for interior, composite steel girders within continuous span bridges for the WA-02 Vehicle.

G.2.10.1.1 Rating Factors

Figure G-236 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 64 girders with an LFR rating less than 1.0, 22 girders with an LRFR rating less than 1.0, and 18 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 15% of the girders in this subset. Both ratings are generally between 0.5 and 1.5. The LRFR ratings are between 0.5 and 2.5 for most girders with the plate girders having higher ratios.



(a) (b)

Figure G-236: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure G-237 shows the percentage of girders with moment ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 95.4% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits while 64.1% of girders have ratings greater than 1.0 for multiple trips permits with ADTT ≥ 5,000. 67.2% of girders have LFR ratings greater than 1.0. 28.2% fewer girders have LRFR ratings less than 1.0 for single trip, escorted permits than for LFR; this increases to 3.1% more girders for multiple trip permits with ADTT ≥ 5,000.

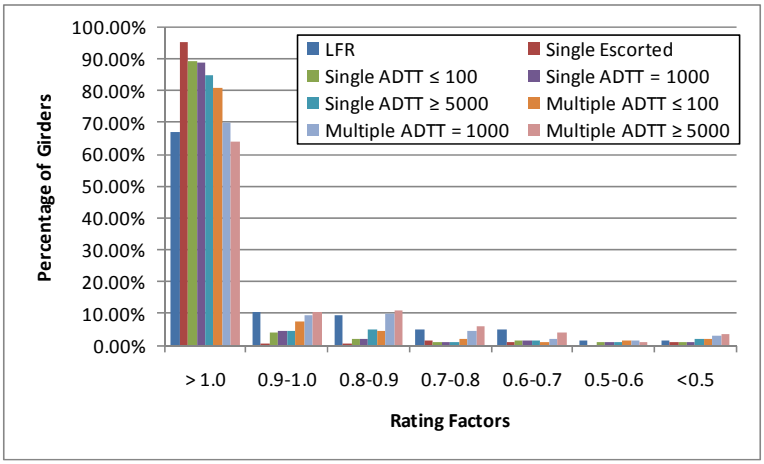


Figure G-237: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

G.2.10.1.2 Rating Factor Comparisons

Figure G-238 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 1.0 and 2.0.

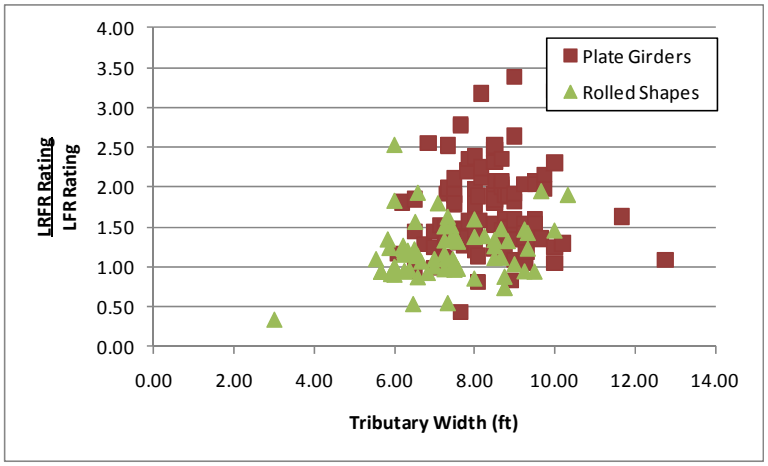


Figure G-238: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

G.2.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-239 shows that nineteen girders have a reliability index less than the target reliability index of 3.5. The reliability index for most of the girders is between four and eight.

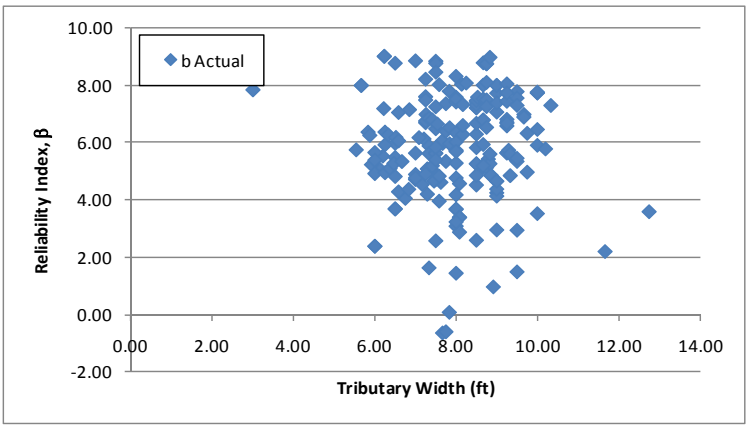


Figure G-239: Flexure Reliability Indices for WA-02 Vehicle

Figure G-240 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 vehicle. The reliability index increases with increasing rating factors and has a value of approximately 3.5 for a rating of 1.0, indicating the LRFR live load factors are providing the target level of reliability.

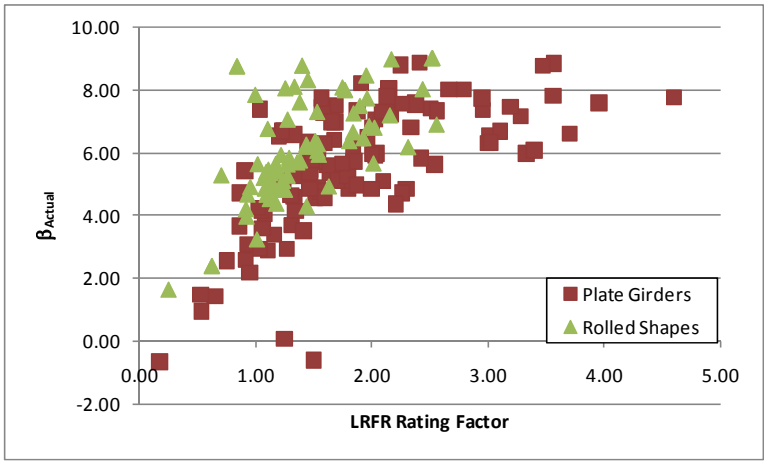
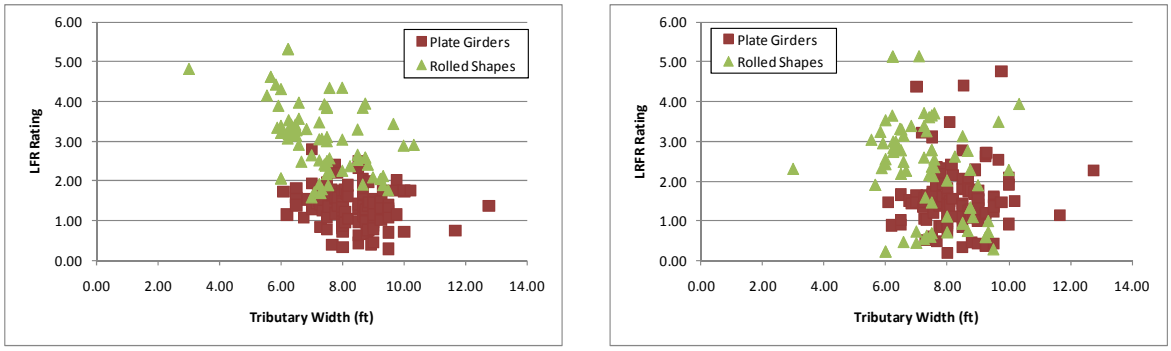


Figure G-240: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

G.2.10.2Shear

G.2.10.2.1 Rating Factors

For shear, there are 25 girders with LFR rating factors less than 1.0, 38 girders with LRFR ratings less than 1.0, and 14 girders where both ratings are less than 1.0. 27 of the 38 girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 56% of the girders in this subset. Figure G-241 shows the LFR and LRFR ratings. The LFR ratings decrease with increasing tributary widths with the plate girders ratings between 0.5 and 2.0 and the rolled shapes between two and four. The LRFR ratings are more scattered for the rolled shapes and the LRFR ratings between one and two.



(a) (b)

Figure G-241: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure G-242 shows the percentage of girders with shear ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 86.7% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 67.2% for multiple trip permits with ADTT ≥ 5,000. 87.2% of girders have LFR ratings less than 1.0. This is an increase of 0.5% of girders with ratings less than 1.0 by switching from LFR to LRFR for single trip, escorted permits; this increases to 20% for multiple trip permits with ADTT ≥ 5,000.

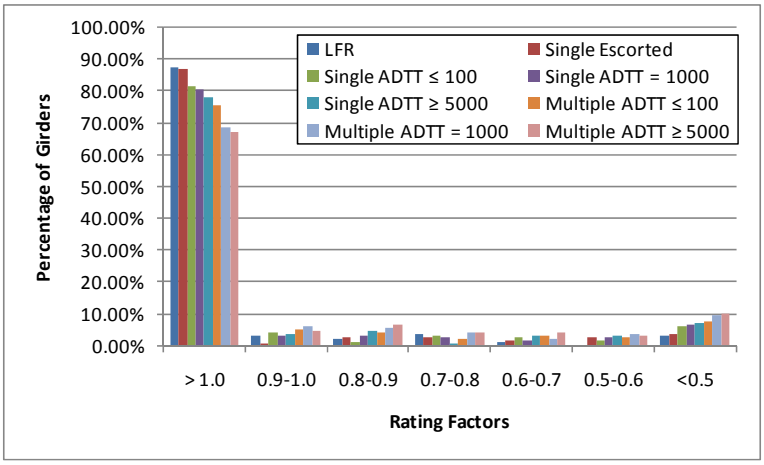


Figure G-242: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

G.2.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-243 show the comparison of rating factors. The ratio is generally between 0.5 and 2.0. 44% of the girders have an LRFR rating that is greater than the LFR rating for this vehicle.

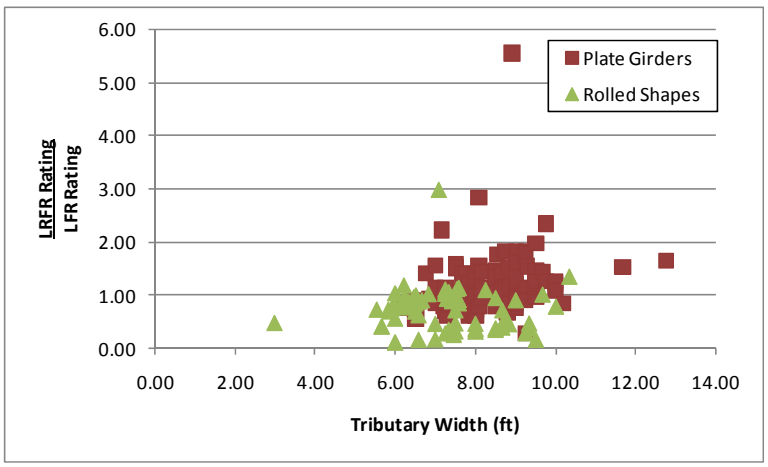


Figure G-243: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

G.2.10.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for 20 girders as shown in Figure G-244. The reliability index is between six and ten for the rolled shapes and between three and six for the plate girders.

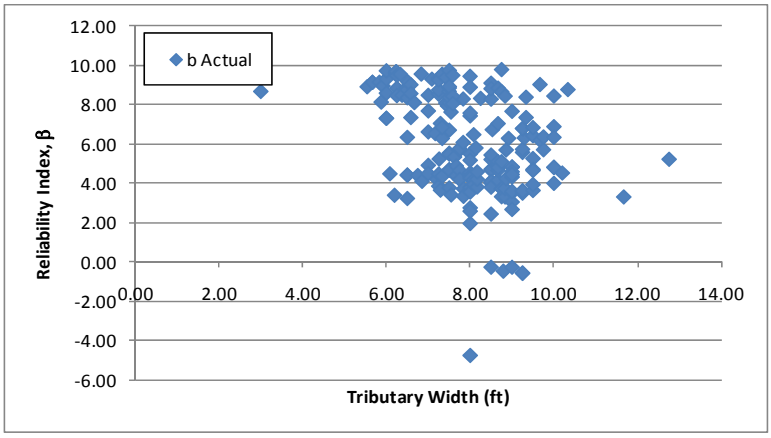


Figure G-244: Shear Reliability Indices for WA-02 Vehicle

Figure G-245 shows the reliability index plotted against the LRFR shear rating for the WA-02 vehicle. The reliability index increases with increasing LRFR ratings. A reliability index of 3.5 is what would be expected for a girder with a rating of 1.0. This is the target reliability index for this vehicle and indicates that the LRFR live load factors provide the target level of reliability. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

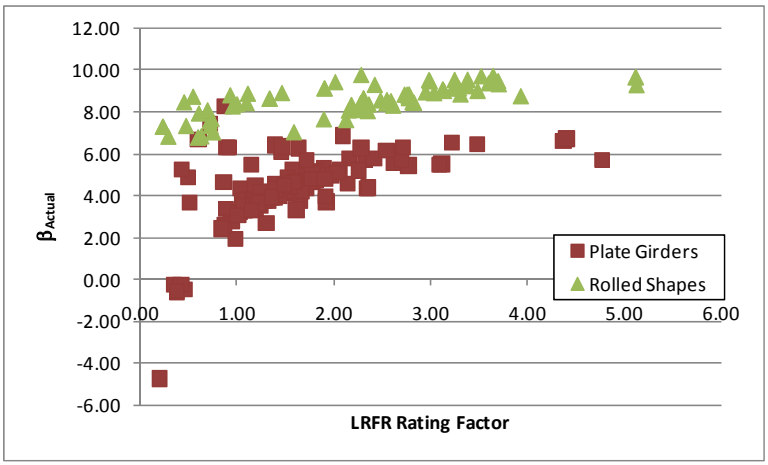


Figure G-245: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

G.2.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-246. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

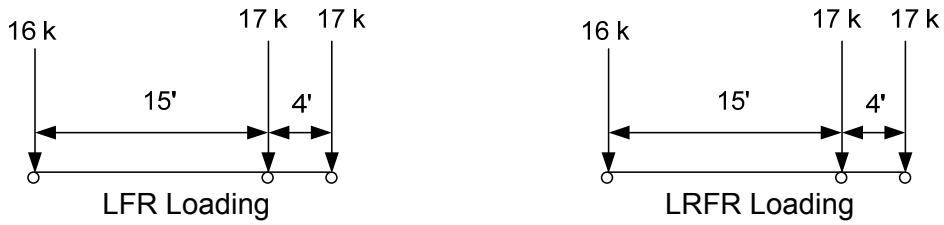


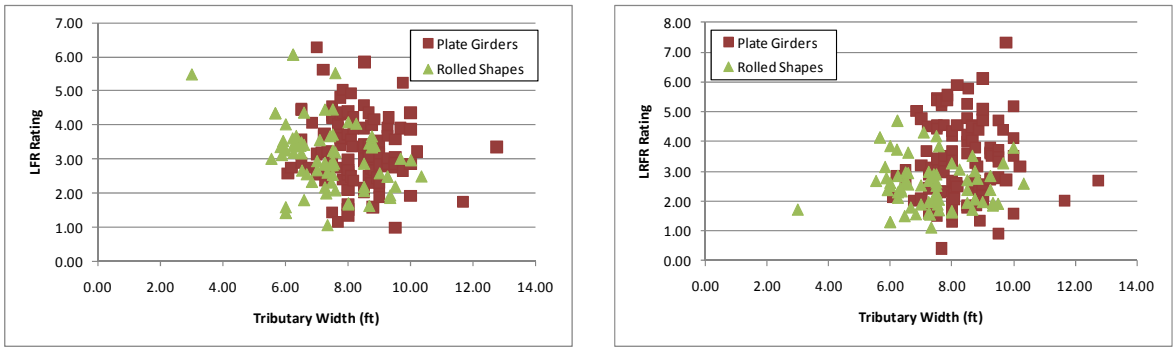
Figure G-246: Vehicle Loadings and Load Factors

G.2.11.1Moment

G.2.11.1.1 Rating Factors

Figure G-247 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than one, two girders with an LRFR rating less than 1.0 and one girder with both ratings less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 61% of the girders in this subset. The LFR ratings are between two and five for most girders while the LRFR ratings are between one and five for most girders

.



(a) (b)

Figure G-247: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure G-248 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 99.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100 while 99% of girders have ratings greater than 1.0 for ADTT ≥ 5,000. 99.5% of girders have LFR ratings greater than 1.0. No additional girders have LRFR ratings less than 1.0 for ADTT ≤ 100 than for LFR; this increases to 0.5% more girders for ADTT ≥ 5,000. Flexure ratings are not significantly affected by the switch from LFR to LRFR for the AASHTO Type 3 truck.

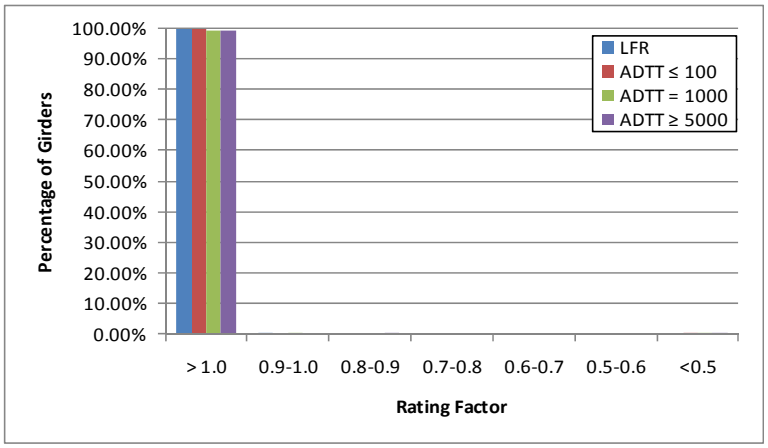


Figure G-248: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

G.2.11.1.2 Rating Factor Comparisons

Figure G-249 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.5. 39% of girders have LRFR ratings that are greater than the LFR rating.

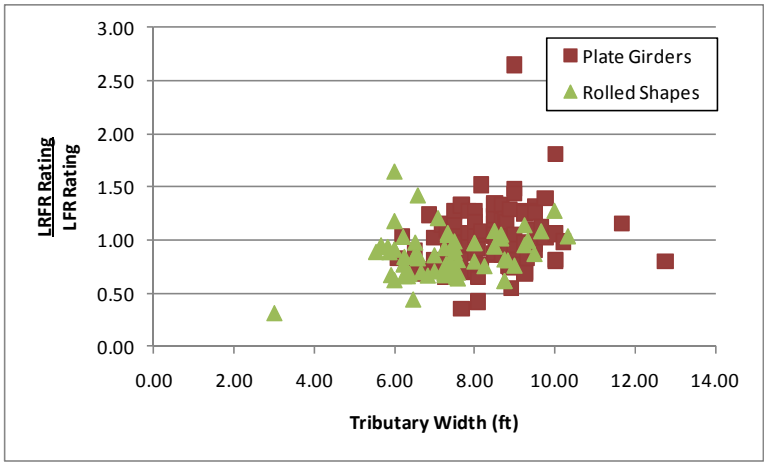


Figure G-249: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

G.2.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-250 shows that two girders have a reliability index less than the target reliability index of 2.5. The reliability index is between five and ten for most girders.

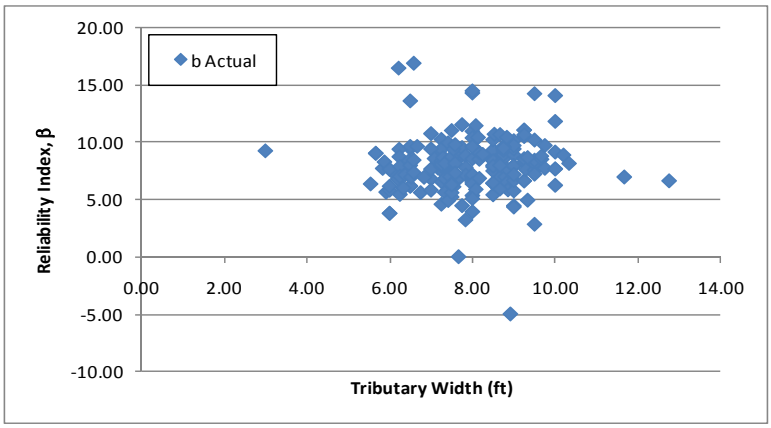


Figure G-250: Flexure Reliability Indices for Type 3 Vehicle

Figure G-251 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 Truck. The reliability index increases with increasing ratings and is approximately 3.5 for an LRFR rating of 1.0. This is greater than the target reliability index of 2.5 and indicates the LRFR live load factors may be over-conservative.

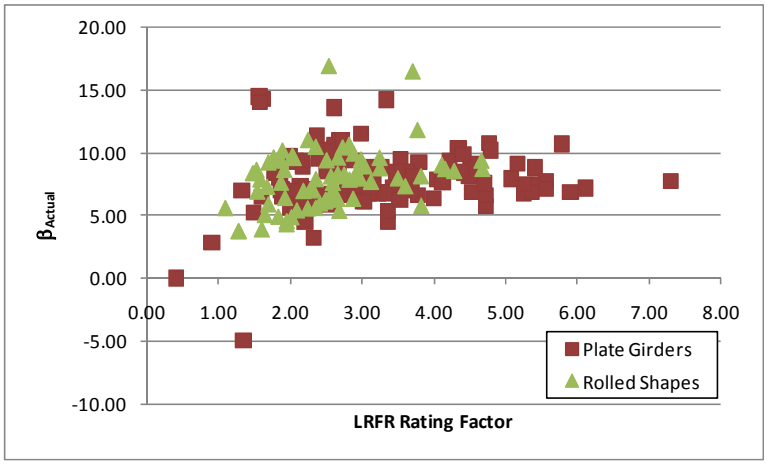
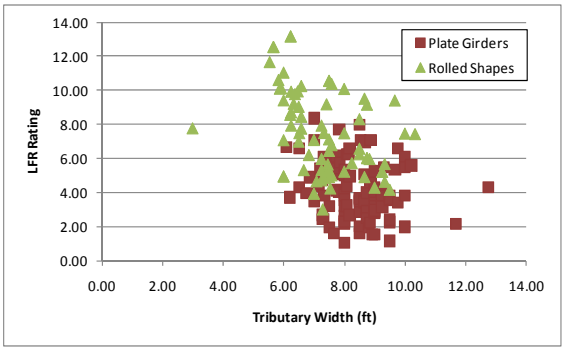


Figure G-251: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Vehicle

G.2.11.2Shear

G.2.11.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, 12 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. Six of the twelve girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 87% of the girders in this subset. Figure G-252 shows the LFR and LRFR ratings. The LFR ratings decrease with increasing tributary widths; plate girders are between two and six while rolled shapes are between four and ten. The LRFR ratings are between one and five for most girders.



(a)

(b)

Figure G-252: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure G-253 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 96.4% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 92.8% for ADTT ≥ 5,000. 100% of girders have LFR ratings less than 1.0. This is an increase of 3.6% of girders with ratings less than 1.0 by switching from LFR to LRFR with an ADTT ≤ 100; this increases to 7.2% for ADTT ≥ 5,000.

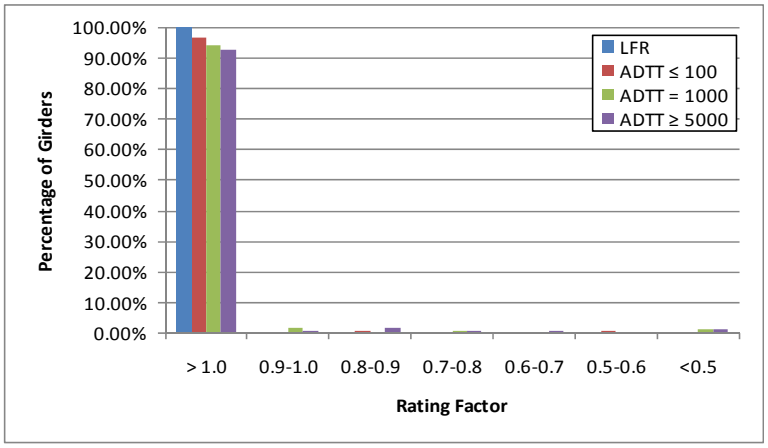


Figure G-253: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

G.2.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-254 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.25, with wider girder spacing having higher ratios.

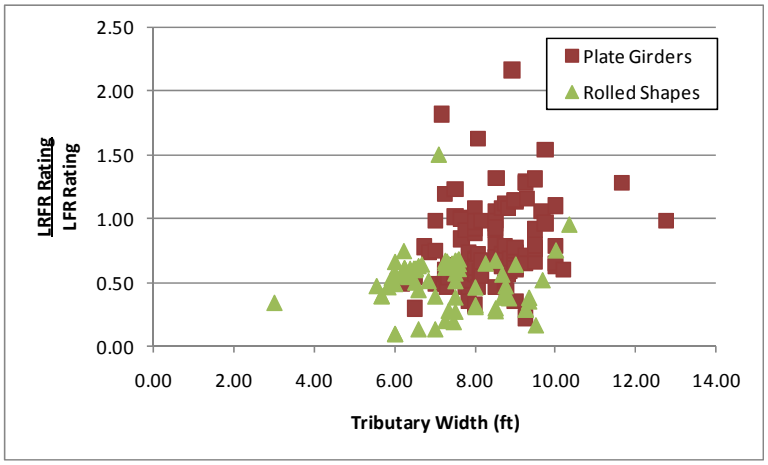


Figure G-254: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

G.2.11.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for five girders as shown in Figure G-255. The reliability index is split into two groups; the upper group being the rolled shapes with reliability indices between eight and ten and the lower group with being the plate girders with reliability indices between five and seven.

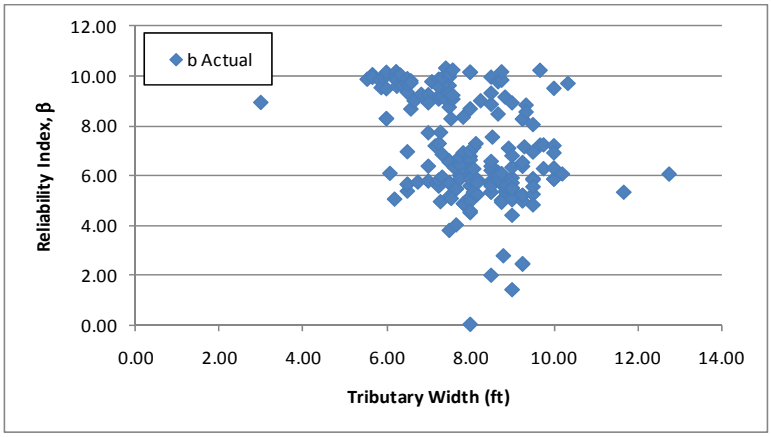


Figure G-255: Shear Reliability Indices for Type 3 Vehicle

Figure G-256 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 truck. The reliability index increases with increasing LRFR ratings and is approximately 3.5 for an LRFR rating of 1.0. This is above the target reliability index and indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

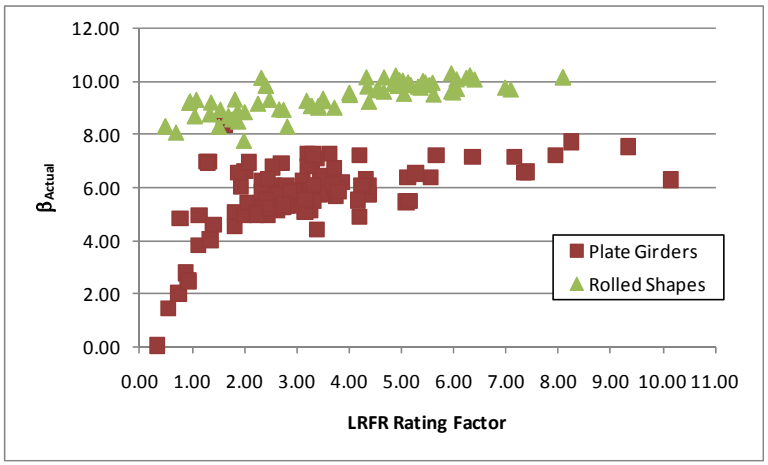
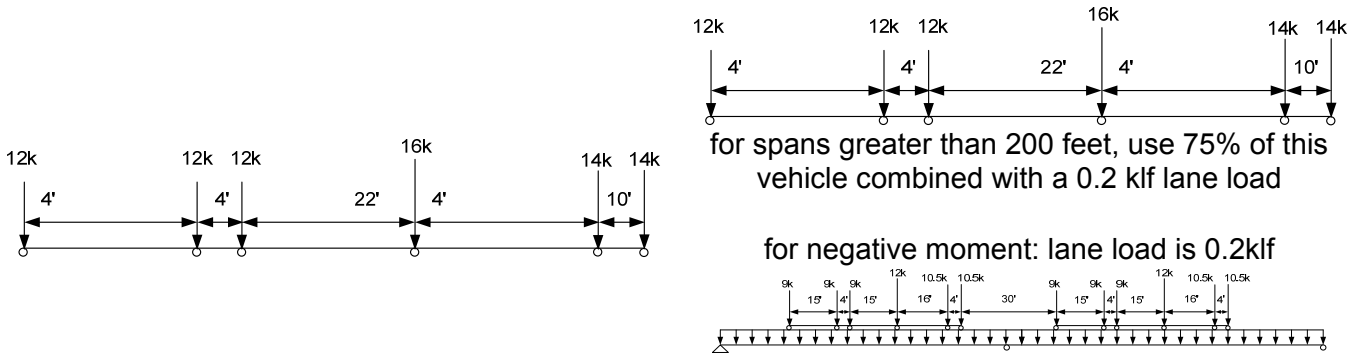


Figure G-256: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

G.2.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-257. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized



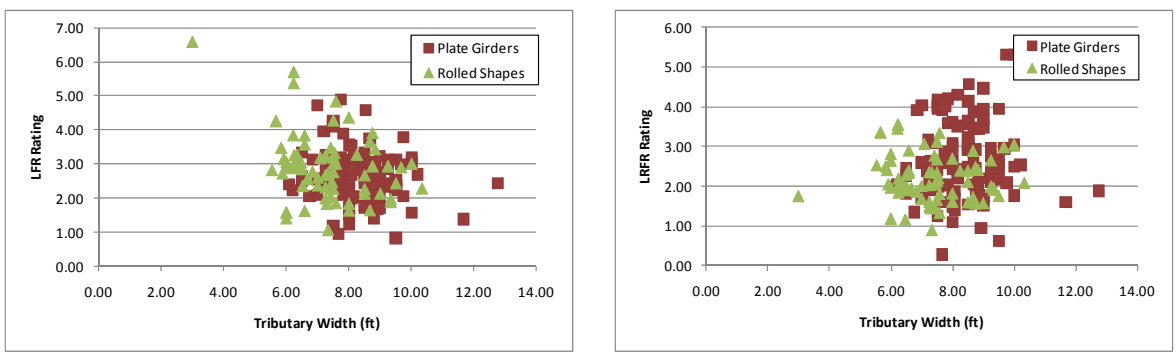
LFR Loading LRFR Loading

Figure G-257: Vehicle Loadings and Load Factors

G.2.12.1Moment

G.2.12.1.1 Rating Factors

Figure G-258 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are two girders with an LFR rating less than 1.0, four girders with an LRFR rating less than 1.0, and two girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 67% of the girders in this subset. The LFR ratings are between two and four for most girders while the LRFR ratings are between one and four.



(a) (b)

Figure G-258: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure G-259 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 99% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100 while 98% of girders have ratings greater than 1.0 for ADTT ≥ 5,000. 99% of girders have LFR ratings greater than 1.0. No additional girders have LRFR ratings less than 1.0 for ADTT ≤ 100 than for LFR; this increases to 1% more girders for ADTT ≥ 5,000. Flexure ratings are not significantly affected by the switch from LFR to LRFR.

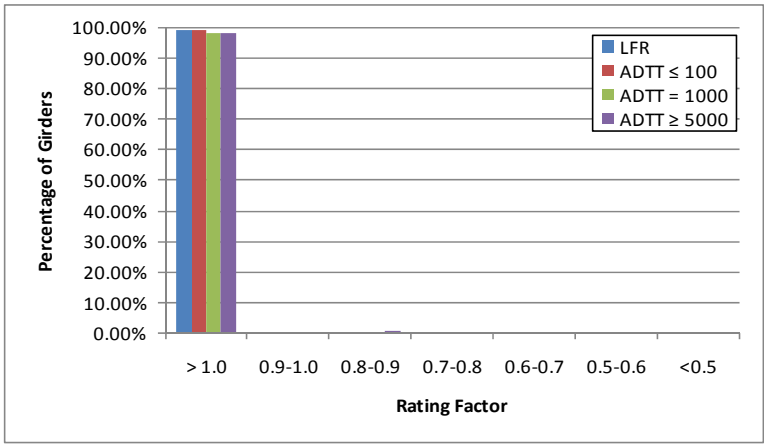


Figure G-259: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

G.2.12.1.2 Rating Factor Comparisons

Figure G-260 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.5, with wider spaced girders having higher ratios. One-third of the girders have an LRFR rating that is greater than the LFR rating.

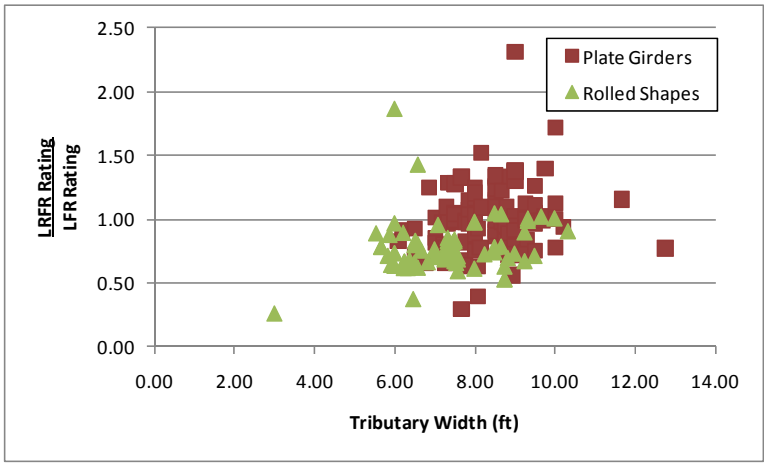


Figure G-260: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

G.2.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-261 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index is between five and nine for most girders.

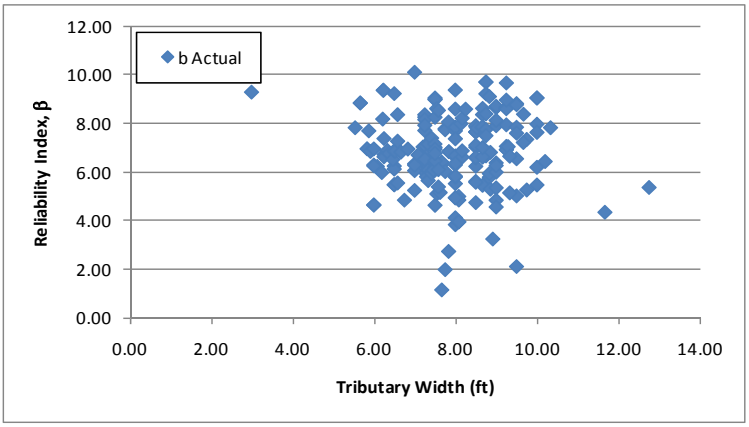


Figure G-261: Flexure Reliability Indices for Type 3-3 Vehicle

Figure G-262 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 truck. The reliability index increases with the rating and the reliability index associated with an LRFR rating of 1.0 is approximately 3.5. This is above the target reliability index of 2.5 and indicates the LRFR live load factors may be over-conservative.

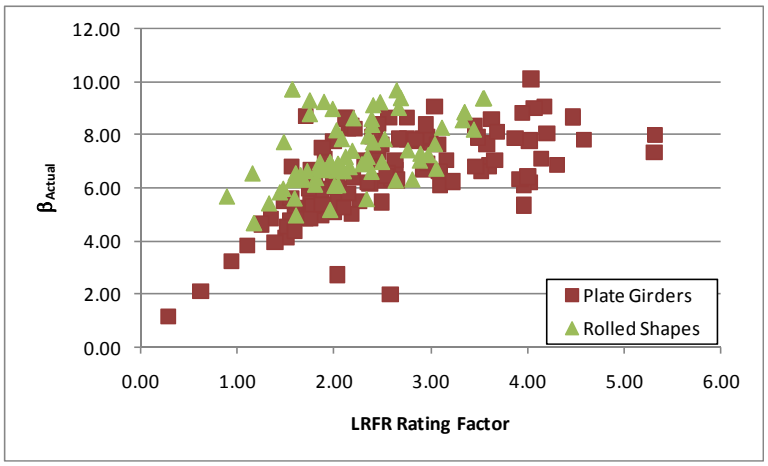
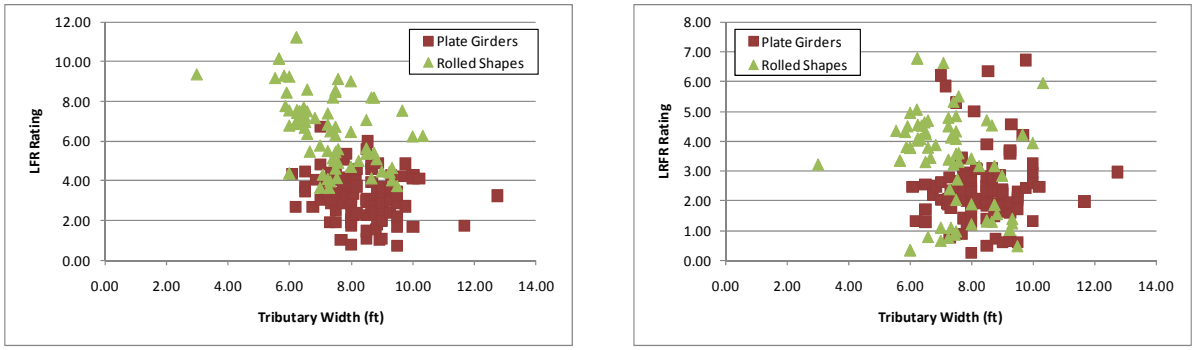


Figure G-262: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

G.2.12.2Shear

G.2.12.2.1 Rating Factors

For shear, there are two girders with LFR rating factors less than 1.0, 18 girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. Twelve of the 18 girders with LRFR ratings less than one are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 91% of the girders in this subset. Figure G-263 shows the LFR and LRFR ratings. LFR ratings decrease with increasing tributary width; plate girder ratings are typically between one and five while the rolled shape ratings are between four and eight. The LRFR ratings are between one and three for plate girders while the rolled shapes ratings are between three and five.



(a) (b)

Figure G-263: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure G-264 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 92.8% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 89.7% for ADTT ≥ 5,000. 99% of girders have LFR ratings less than 1.0. This is an increase of 6% more girders with ratings less than 1.0 by switching from LFR to LRFR with an ADTT ≤ 100; this increases to 9.3% for ADTT ≥ 5,000.

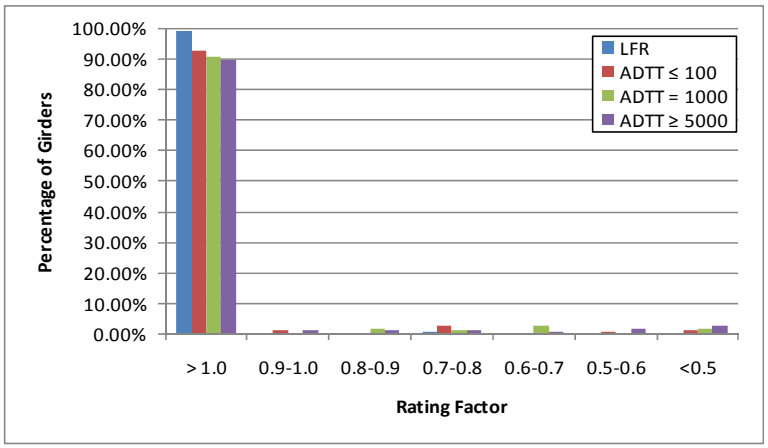


Figure G-264: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

G.2.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-265 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.0, with close girder spacings generally having lower ratios. 9% of girders have LRFR ratings that are greater than the LFR rating.

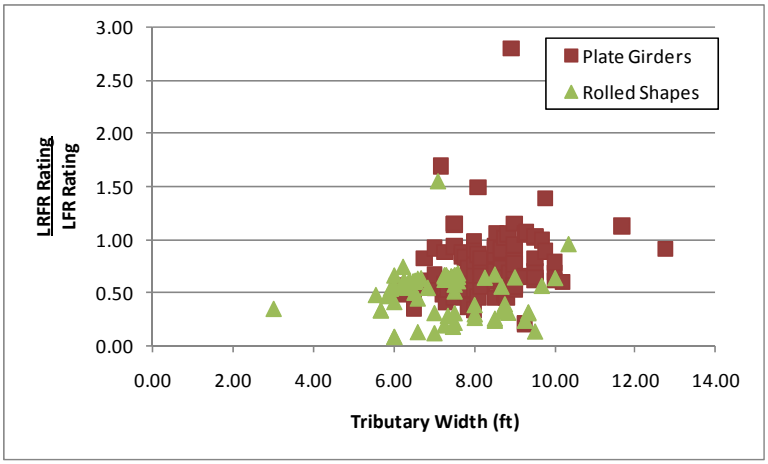


Figure G-265: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

G.2.12.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for six girders as shown in Figure G-266. The reliability index is split into two groups; the upper group is the rolled shapes with reliability indices between eight and ten while the lower group is the plate girders with reliability indices between four and seven.

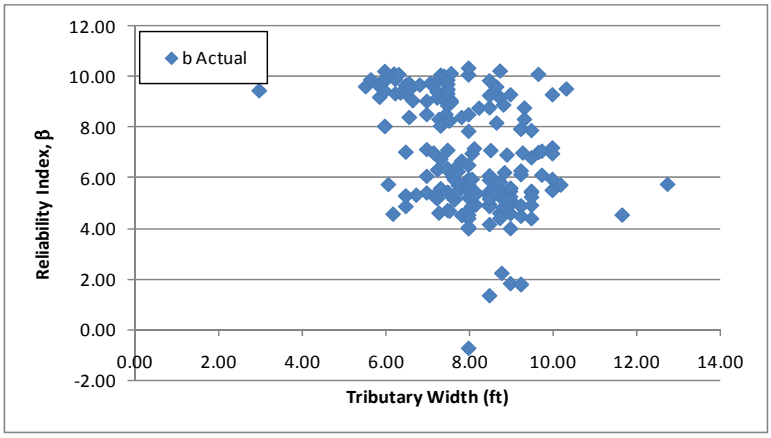


Figure G-266: Shear Reliability Indices for Type 3-3 Vehicle

Figure G-267 shows the reliability index plotted against the LRFR shear rating for the AASHTO Type 3-3 Truck. The reliability index increases with increasing rating factors and is approximately 3.5 for a rating of 1.0. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

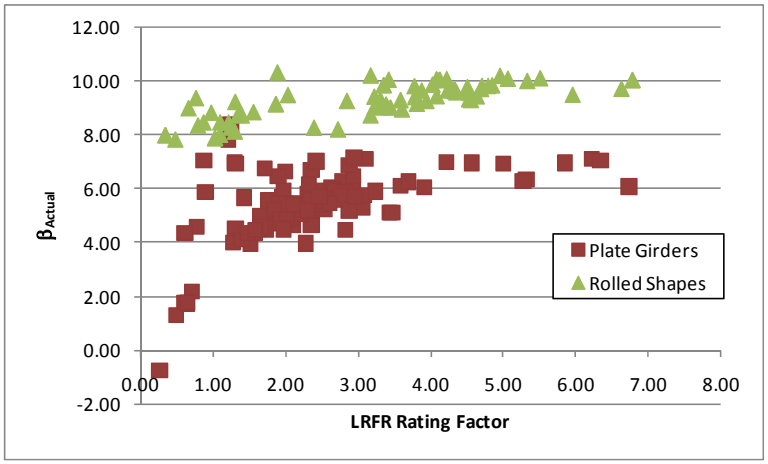


Figure G-267: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Vehicle

G.2.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-268. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

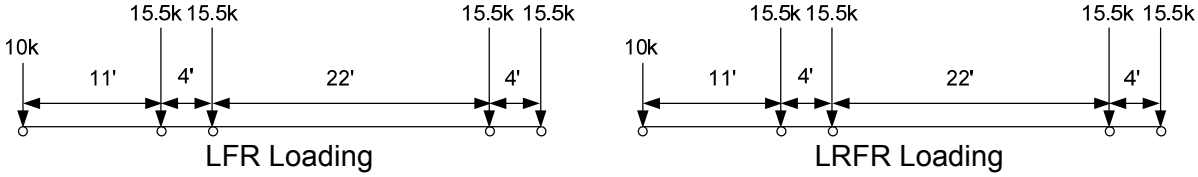
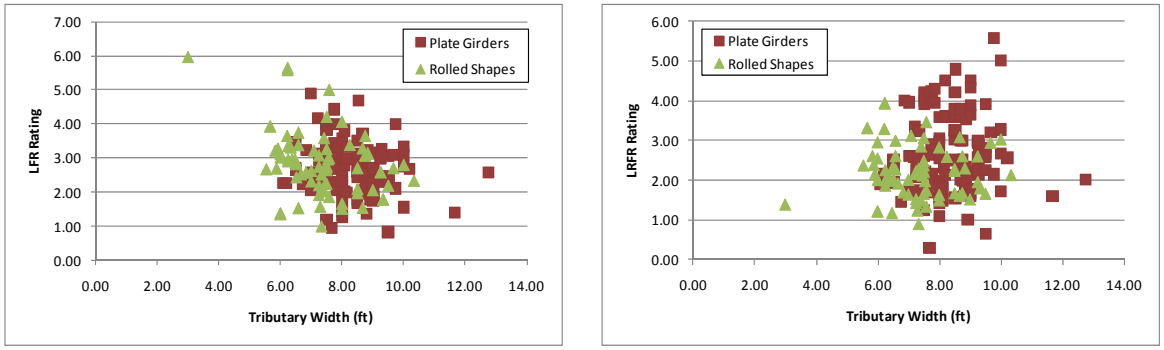


Figure G-268: Vehicle Loadings and Load Factors

G.2.13.1Moment

G.2.13.1.1 Rating Factors

Figure G-269 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are two girders with an LFR rating less than 1.0, four girders with an LRFR rating less than 1.0, and two girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 63% of the girders in this subset. Both LFR and LRFR ratings are between one and four for most girders.



(a) (b)

Figure G-269: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure G-270 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 99% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100 while 98% of girders have ratings greater than 1.0 for ADTT ≥ 5,000. 99% of girders have LFR ratings greater than 1.0. No additional girders have LRFR ratings less than 1.0 for ADTT ≤ 100 than for LFR; this increases to 1.0% more girders for ADTT ≥ 5,000. Flexure ratings are not significantly affected by the switch from LFR to LRFR, independent of ADTT used in LRFR.

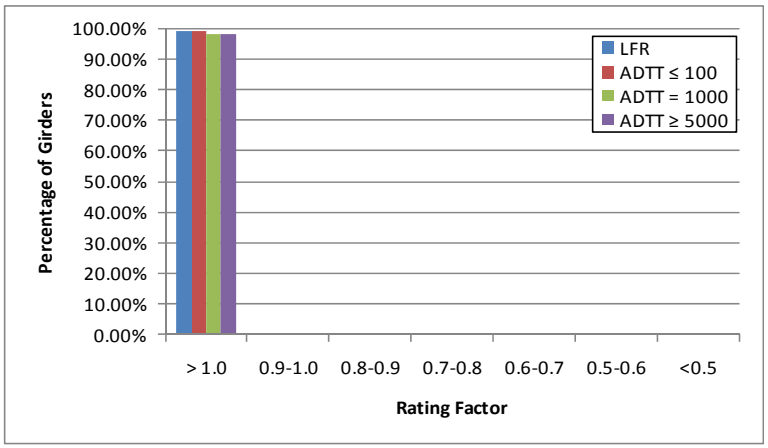


Figure G-270: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

G.2.13.1.2 Rating Factor Comparisons

Figure G-271 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.5, with closely spaced girders having lower ratios.

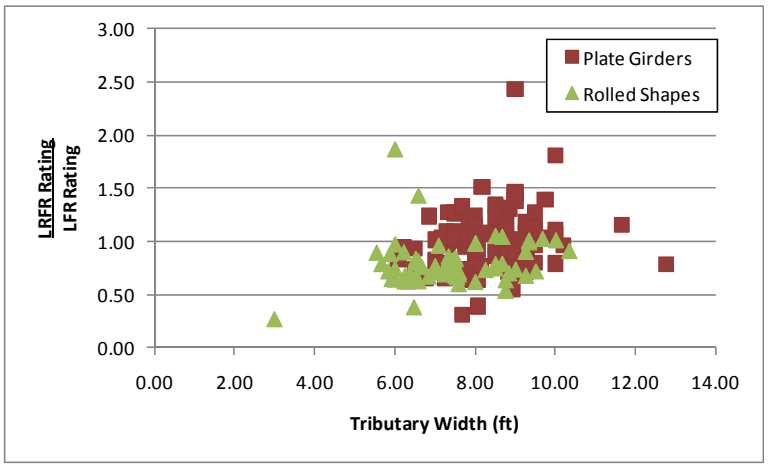


Figure G-271: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

G.2.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-272 shows that three girders have a reliability index less than the target reliability of 2.5. The reliability index is between four and nine for most girders.

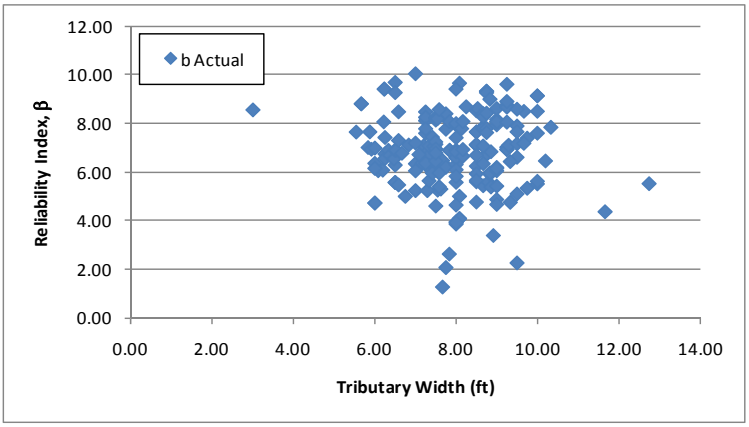


Figure G-272: Flexure Reliability Indices for Type 3S2 Vehicle

Figure G-273 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 truck. The reliability index increases with increasing ratings and is approximately 3.5 for a rating of 1.0. This is above the target reliability index of 2.5 and indicates the LRFR live load factors may be over-conservative.

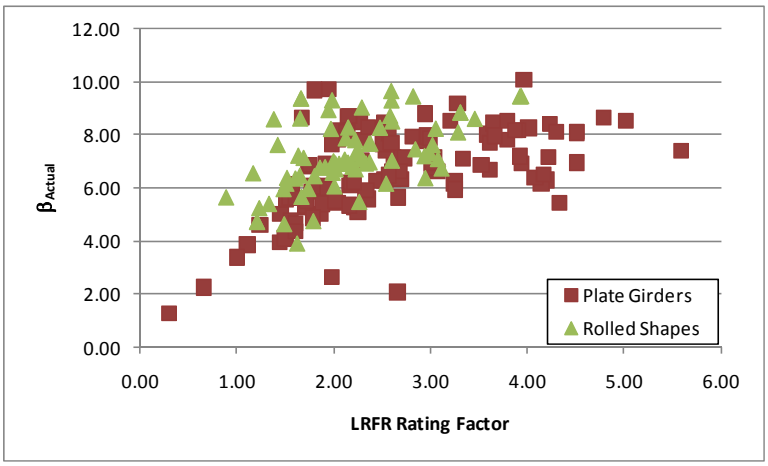
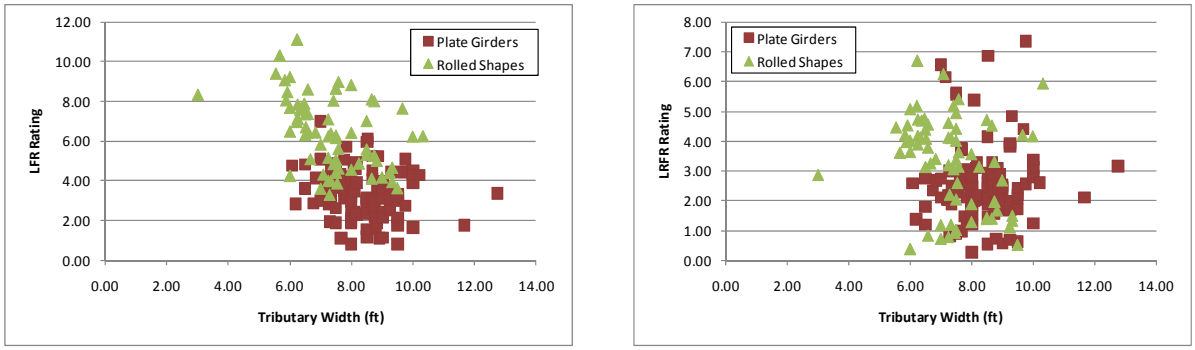


Figure G-273: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

G.2.13.2Shear

G.2.13.2.1 Rating Factors

For shear, there are two girders with LFR rating factors less than 1.0, 17 girders with LRFR ratings less than 1.0, and two girders where both ratings are less than 1.0. Eleven of the seventeen girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 90% of the girders in this subset. Figure G-274 shows the LFR and LRFR ratings. LFR ratings decrease with increasing tributary width; the plate girder ratings are generally between one and five while the rolled shape ratings are between four and eight. The LRFR ratings are between one and three for plate girders and are generally above three for rolled shapes.



(a) (b)

Figure G-274: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure G-275 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 92.8% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 90.8% for ADTT ≥ 5,000. 99% of girders have LFR ratings less than 1.0. This is an increase of 6% more girders with ratings less than 1.0 by switching from LFR to LRFR with an ADTT ≤ 100; this increases to 8.2% for ADTT ≥ 5,000.

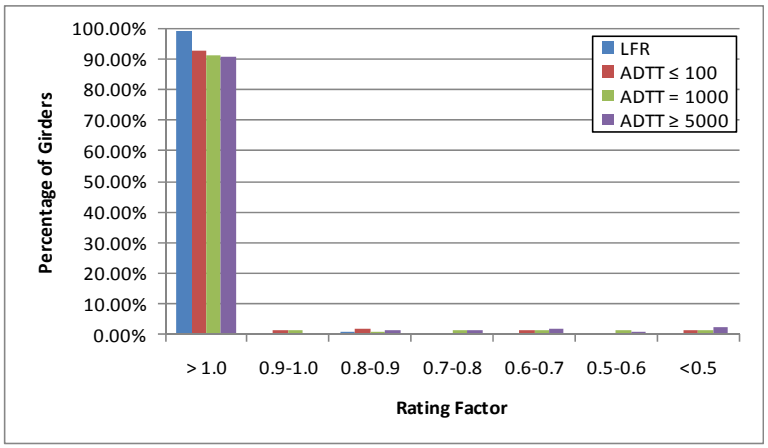


Figure G-275: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

G.2.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-276 show the comparison of rating factors. The ratio is generally between 0.5 and 1.25, with widely spaced girders generally having higher ratios. 10% of girders have LRFR ratings that are greater than the LFR rating.

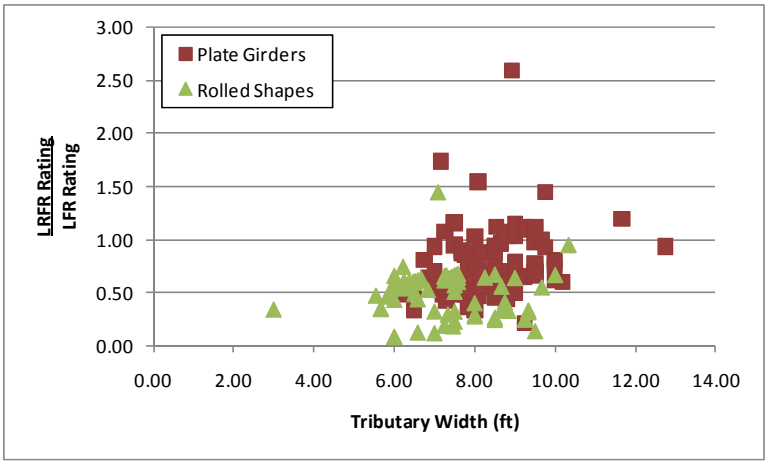


Figure G-276: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

G.2.13.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for six girders as shown in Figure G-277. The reliability index is between eight and ten for the rolled shapes and between four and seven for the plate girders.

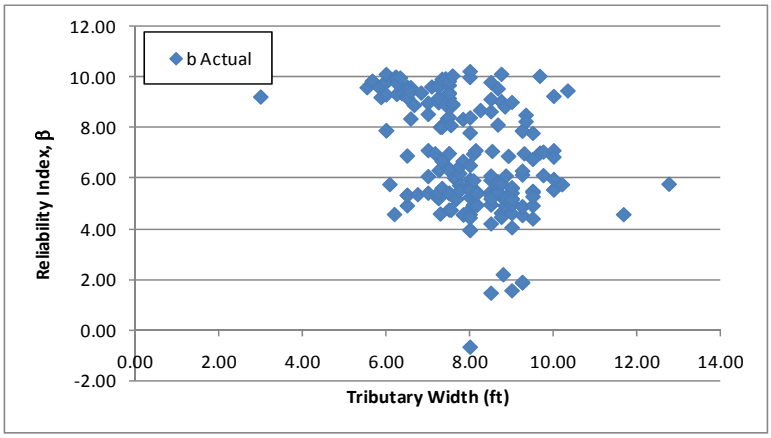


Figure G-277: Shear Reliability Indices for Type 3S2 Vehicle

Figure G-278 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 vehicle. The reliability index increases with increasing ratings and is approximately 3.5 for a rating of 1.0. The target reliability of 2.5 is exceeded for girders with a rating of 1.0; this indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

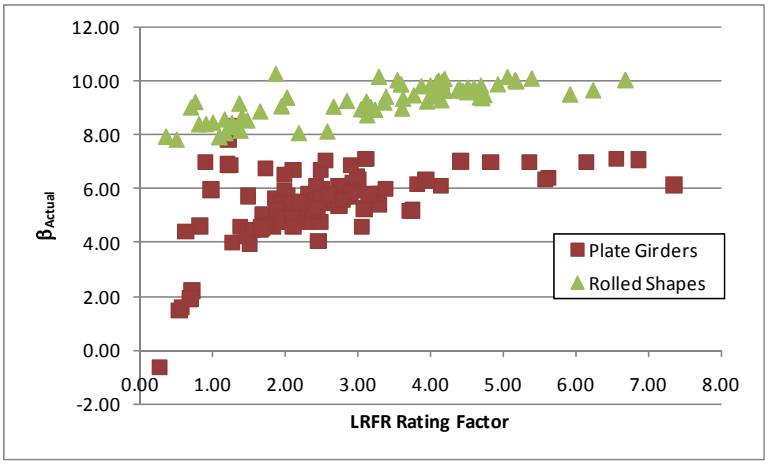


Figure G-278: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Vehicle

G.2.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table G-3 shows the results for the moment ratings. For most vehicles, the number of girders with LFR ratings less than 1.0 is very similar to the number of girders with LRFR ratings less than 1.0. The exception is the special permit vehicles where more girders have LFR ratings less than one than LRFR ratings less than 1.0 In several cases there are more girders with LFR ratings less than 1.0 than there are girders with LRFR ratings less than 1.0. The percentage of girders with LFR ratings greater than the LRFR ratings varied significantly between vehicles. At least one-third of girders had LRFR ratings that were greater than the LFR ratings for all vehicles, in some cases over 80% of the girders had LRFR ratings that were greater than the LFR rating.

Table G-3: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	195	37	3	3	17	3	2	18	6	64	1	2	2
LRFR Rating less than 1.0		42	5	4	7	3	2	8	6	22	2	4	4
LFR and LRFR Rating less than 1.0		25	3	3	5	3	1	8	5	18	1	2	2
% with LFR RF greater than LRFR RF		57	54	57	15	51	52	15	52	15	61	67	63

G.2.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table G-4 shows the results for the shear ratings. With the exception of the heaviest vehicles, there are very few girders with LFR ratings less than 1.0. Similar percentages of girders having LFR ratings greater than LRFR ratings exist for the design, routine permit, and legal vehicles. The special permit vehicles have significantly more girders with LRFR ratings greater than the LFR rating. An additional row was added to the table to indicate how many of the girders with LRFR ratings less than 1.0 were controlled by the bearing stiffener rating. As the table shows, typically two-thirds of the girders with LRFR ratings less than 1.0 were controlled by the bearing stiffener rating.

Table G-4: Shear Rating Factor Results for All 12 Vehicles

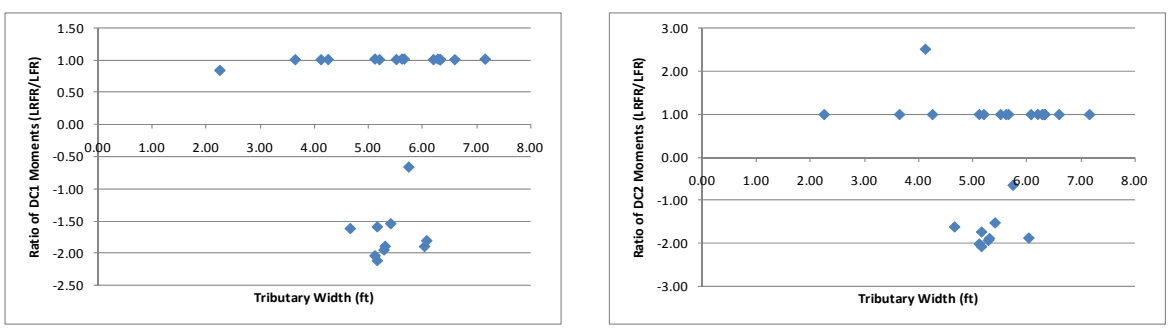
	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	195	18	2	2	8	2	1	11	2	25	0	2	2
LRFR Rating less than 1.0		44	18	17	20	16	12	22	21	38	12	18	17
LFR and LRFR Rating less than 1.0		12	2	2	6	2	1	6	2	14	0	2	2
% with LFR RF greater than LRFR RF		83	87	87	58	84	86	55	83	56	87	91	90
LRFR less than 1.0 and controlled by bearing stiffener rating		31	12	11	14	10	6	16	13	27	6	12	11

G.3 Exterior Non-Composite Girders

G.3.1 Dead Loads

G.3.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure G-279a, the ratio of unfactored DC1 moments (self-weight, dead loads on composite section) is very close to 1.0 for the girders where the critical location remained the same. For those girders in which the critical section changed, the ratio is between -1.5 and -2.0. Figure G-279b shows that there is some variation in the loads applied to the composite section (DC2 and DW loads). In most cases the ratio is near 1.0 or -2.0 as for the DC1 moments.

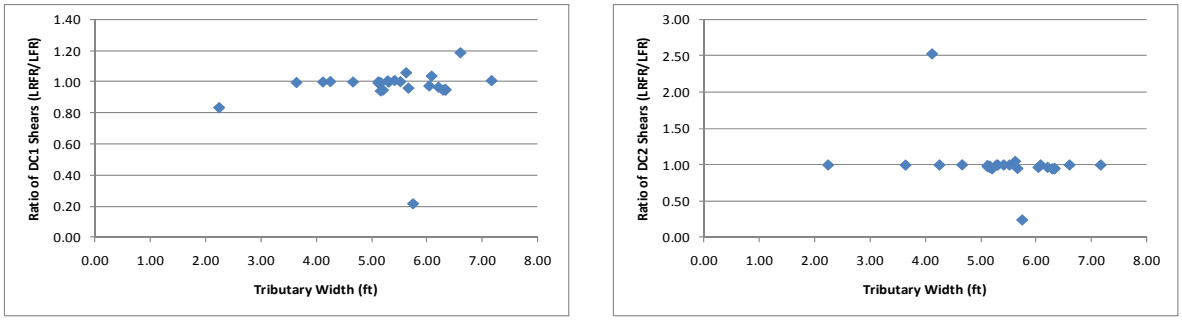


(a) (b)

Figure G-279: Ratios of DC1 and DC2 or DW Moments (unfactored loads LRFR/LFR)

G.3.1.2 Shear

Figure G-280a shows that numerous girders have a ratio of DC1 shear is close to 1.0, with one at 0.2 and another at 0.8. Figure G-280b shows the same trend as Figure G-280a in that the LFR shear is similar to the LRFR shear. There is also more variation within the DC2 and DW loads than in the DC1 loads. Again there are several points that are not close to 1.0 but two of them are from the same girders as mentioned for the DC1 shear.



(a) (b)

Figure G-280: Ratios of DC1 and DC2 or DW Shear (unfactored loads LRFR/LFR)

G.3.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure G-281. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

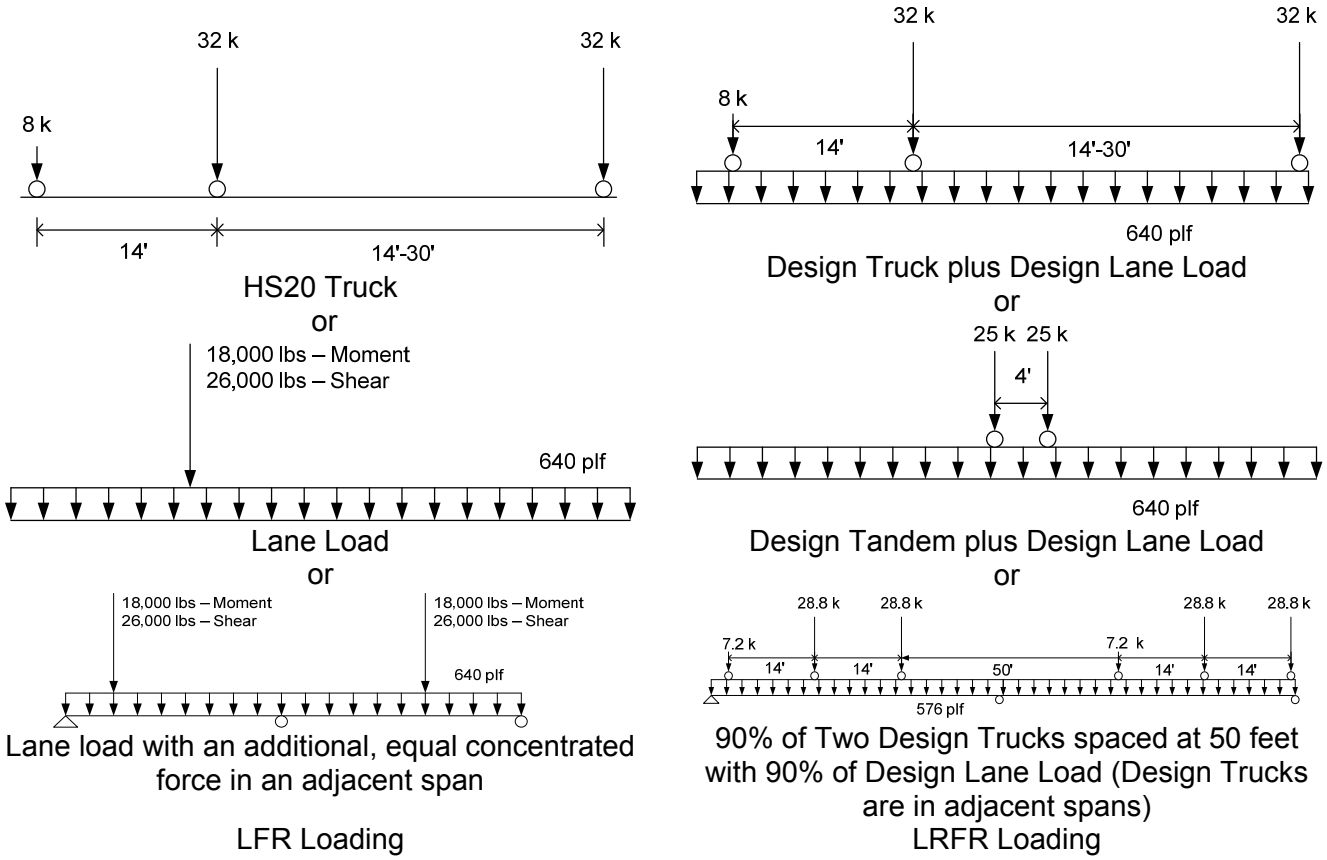
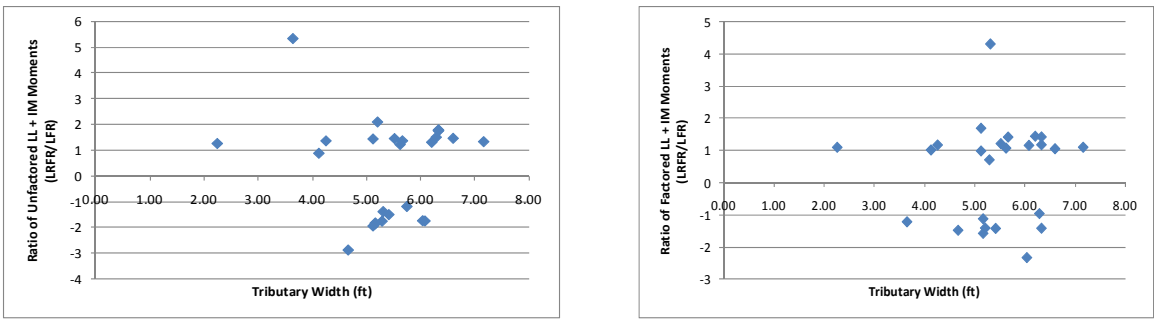


Figure G-281: Vehicle Loadings and Load Factors

G.3.2.1 Moment

G.3.2.1.1 Live Loads

Figure G-282a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.0 and 2.0 for the girders in this subset where the signs are the same and between -1.0 and -2.0 for the girders where the signs are different. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure G-282b shows that the results have shifted closer to 1.0 for the positive values as well as for the negative values.



(a) (b)

Figure G-282: Ratio of Unfactored and Factored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

G.3.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure G-283 shows that the ratio of resistance is generally close to 1.0.

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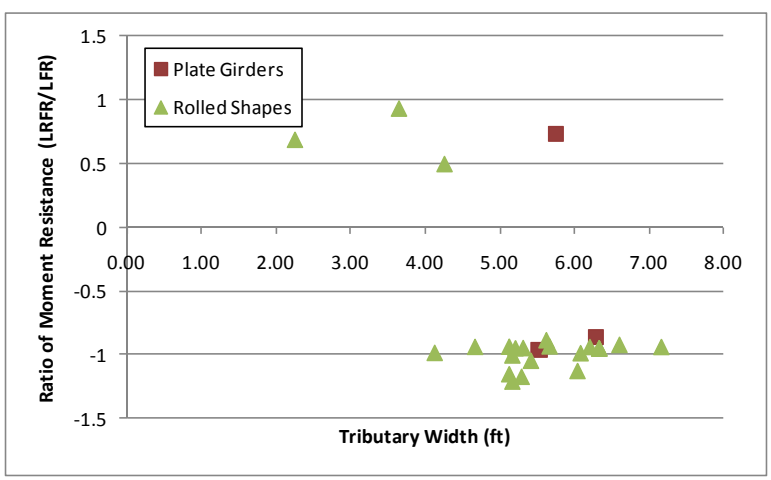
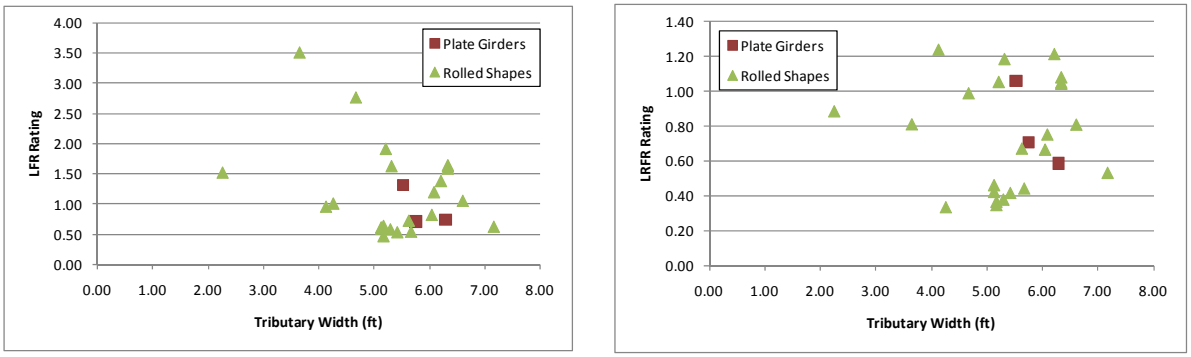


Figure G-283: Ratio of factored Moment Resistance (LRFR/LFR)

G.3.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (26 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 13 girders with LFR ratings less than 1.0, 18 girders with LRFR ratings less than 1.0, and 12 girders where both the LFR and LRFR ratings are less than 1.0. Figure G-284 shows the LFR rating factors and LRFR rating factors. There are very few girders in this subset making it difficult to determine if there are any trends present.



(a) (b)

Figure G-284: LFR and LRFR Flexure Rating Factors for Design Loadings

G.3.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure G-285. The results indicated that 96% of the girders in this set have LFR ratings greater than LRFR ratings. The ratio of rating factors makes it obvious that there is a trend of decreasing LRFR ratings with increasing tributary width.

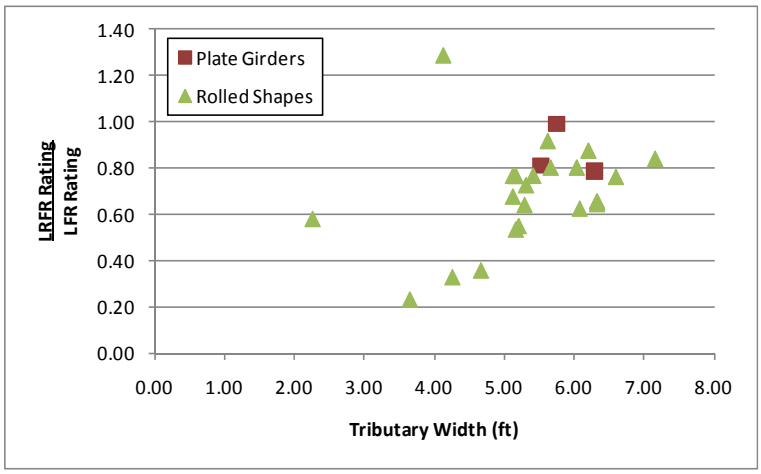


Figure G-285: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure G-286 shows the distribution of LRFR/LFR ratio for girders with LRFR ratings less than 1.0. The figure indicates that most girders are affected by switching from LFR to LRFR but a significant number of these girders have LFR ratings that are less than one. Only five girders were affected negatively by switching from LFR to LRFR to the point that they would no longer rate for the design vehicle.

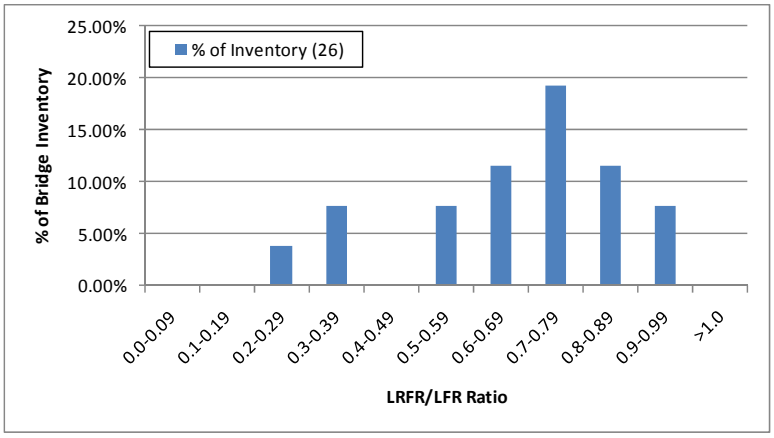


Figure G-286: Distribution of LRFR/LFR Ratio for LRFR Ratings less than 1.0

G.3.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure G-287 shows the reliability indices that were calculated for these girders. The reliability index is less than the target reliability index of 3.5 for 17 girders in this group.

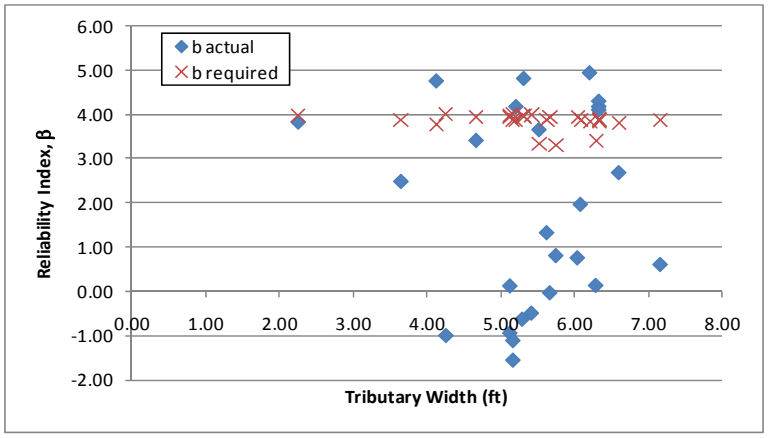


Figure G-287: Flexure Reliability Indices for HL-93 Loading

Figure G-288 shows the reliability index for moment plotted against the LRFR moment rating for the HL-93 design load. The reliability index increases with increasing ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5 which is the target reliability.

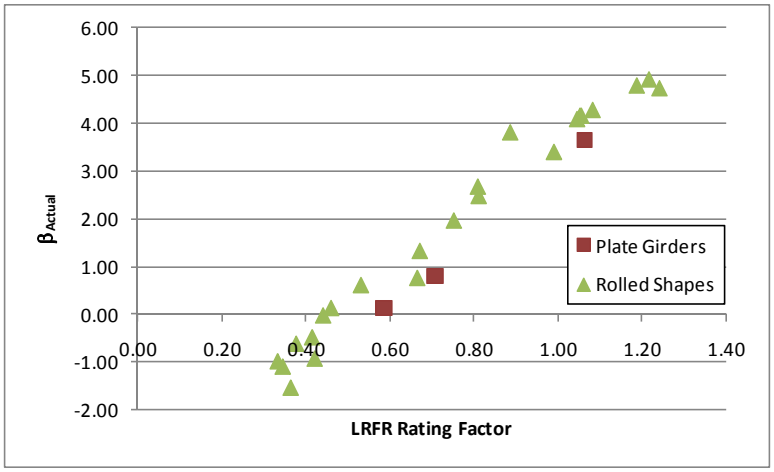
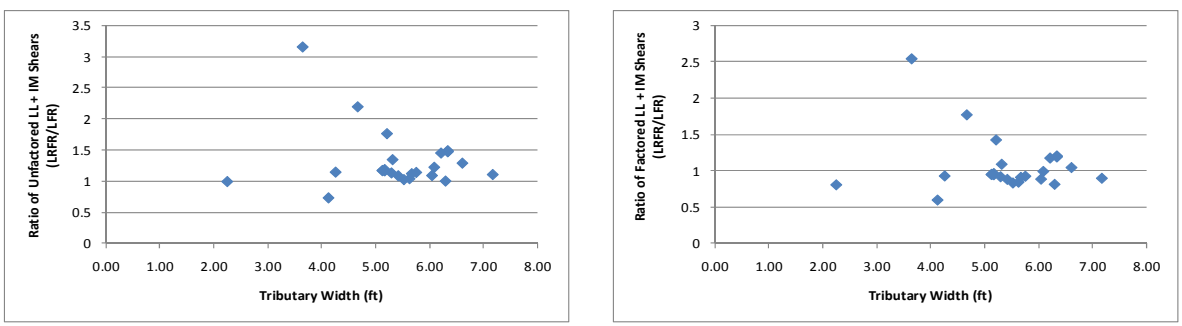


Figure G-288: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Design Load

G.3.2.2 Shear

G.3.2.2.1 Live Loads

Figure G-289a shows that the ratio of unfactored shear varies significantly, with most girders between 1.0 and 1.5. The ratio decreases with increasing tributary widths. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure G-289b shows that the ratio of factored live load shears has decreased and is generally between 0.8 and 1.2 for most cases.



(a) (b)

Figure G-289: Ratio of Unfactored and Factored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

G.3.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure G-290 shows that the ratio of resistance is generally very close to 1.0. The only girders that do not have a ratio of 1.0 are plate girders.

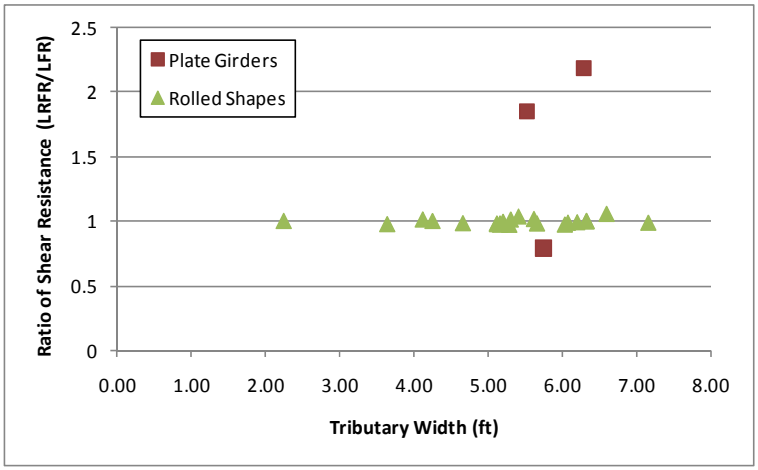
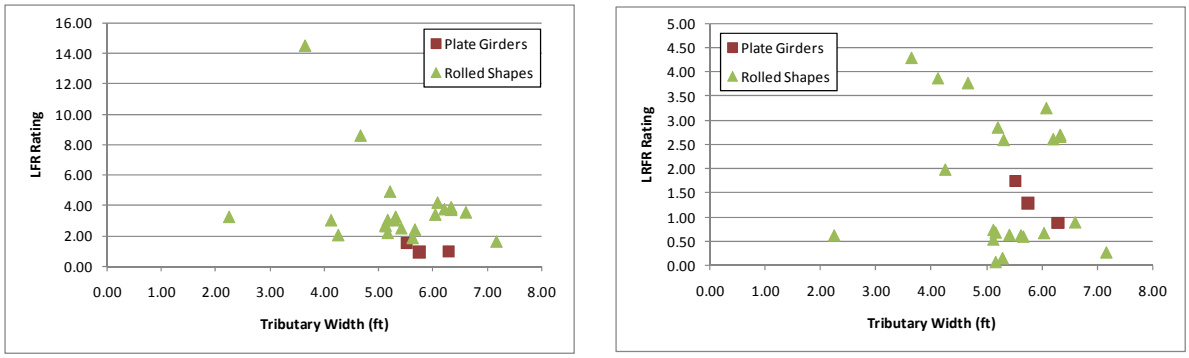


Figure G-290: Ratio of factored Shear Resistance (LFR/LRFR)

G.3.2.2.3 Rating Factors

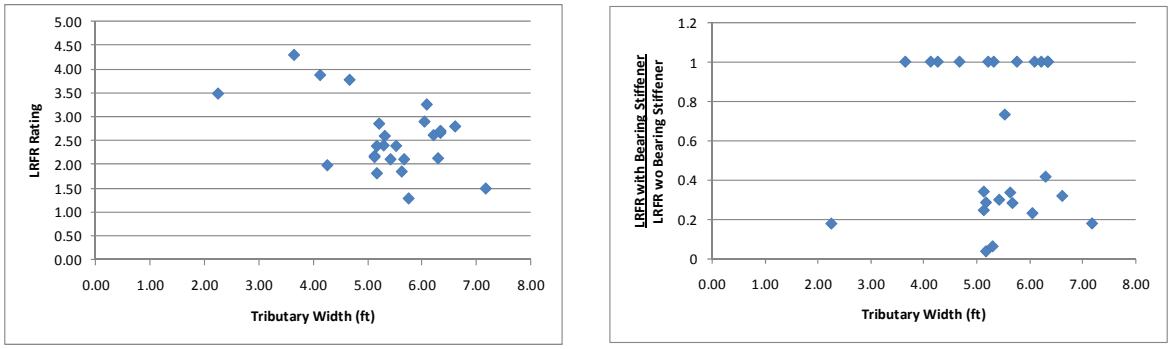
After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are two girders with LFR ratings less than 1.0, 13 girders with LRFR ratings less than 1.0, and one girder where both LFR and LRFR ratings are less than 1.0. All thirteen of the girders with LRFR ratings less than one are controlled by the bearing stiffener rating. One of the concerns with rating older bridges using the LRFR methodology when they may not have been designed using the LRFD specification, is that they would produce significantly lower ratings. The LFR rating was greater than the LRFR rating for 88% of the girders in this subset. Figure G-291 shows the LFR rating factors and LRFR rating factors. Both ratings appear to decrease with increasing tributary width.



(a) (b)

Figure G-291: LFR and LRFR Shear Rating Factors for Design Loadings

Figure G-292a shows the LRFR shear ratings excluding the bearing stiffener rating. Comparing Figure G-291b to Figure G-292a, there are no girders with ratings less than 1.0 and most ratings have increased significantly. Figure G-292b shows the ratio of LRFR rating including the bearing stiffener rating divided by the LRFR rating excluding the bearing stiffener rating. The bearing stiffener rating is typically about 30% of the web shear rating. 54% of the exterior, non-composite girders were controlled by the bearing stiffener rating.



(a) (b)

Figure G-292: Effect of Bearing Stiffener Rating on LRFR Shear Rating

G.3.2.2.4 Rating Factor Comparisons

Figure G-293 shows the ratio of the LRFR rating to the LFR rating. There are three girders with LRFR ratings greater than LFR ratings, but this is only 10% of the girders in the set. The ratio remains just below 1.0 for most of these girders as shown against tributary width.

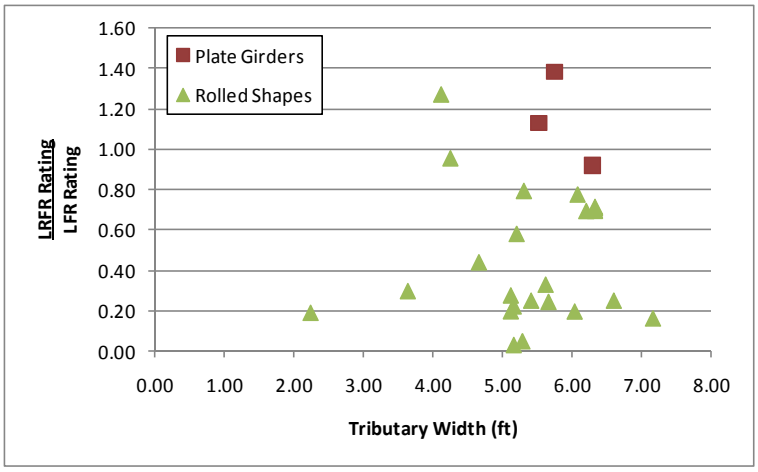


Figure G-293: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure G-294 shows the distribution of LRFR/LFR ratios for girders with LRFR ratings less than 1.0. The figure indicates that the LRFR ratings less than 1.0 are significantly less than the LFR ratings. Most of these are girders controlled by the bearing stiffener. The figure shows that many of the girders are affected by the switch from LFR to LRFR and that the effect is quite large.

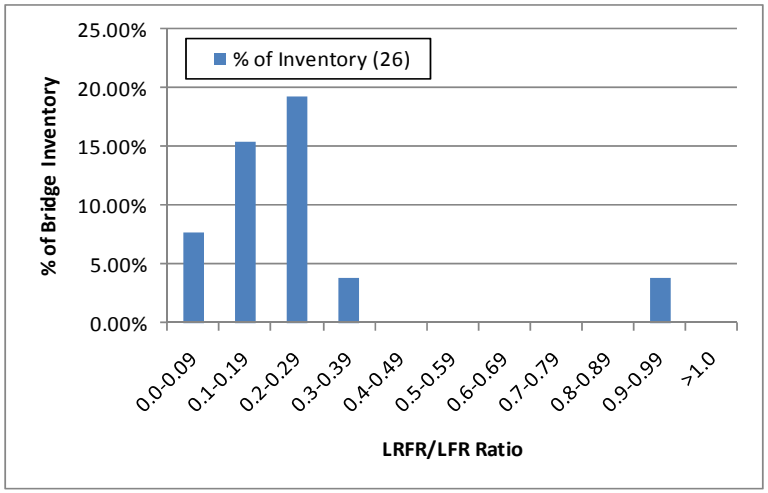


Figure G-294: Distribution of LRFR/LFR Ratio for LRFR Ratings less than 1.0

G.3.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure G-295 shows that most of the girders have a reliability index for shear greater than the target reliability of 3.5, with only one girder having a reliability index less than this level. The reliability index is between seven and nine for most girders.

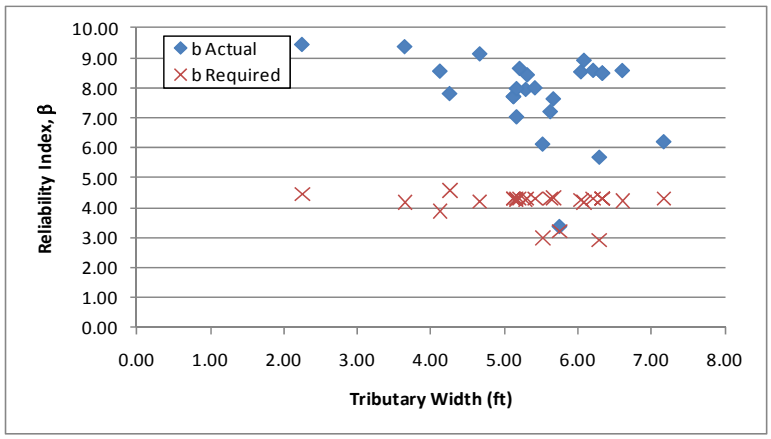


Figure G-295: Shear Reliability Indices for HL-93 Loading

Figure G-296 shows the reliability index for shear plotted against the shear rating factor for the LRFD design vehicle. The reliability index increases with increasing ratings and has a value of approximately 3.5 for a rating of 1.0. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

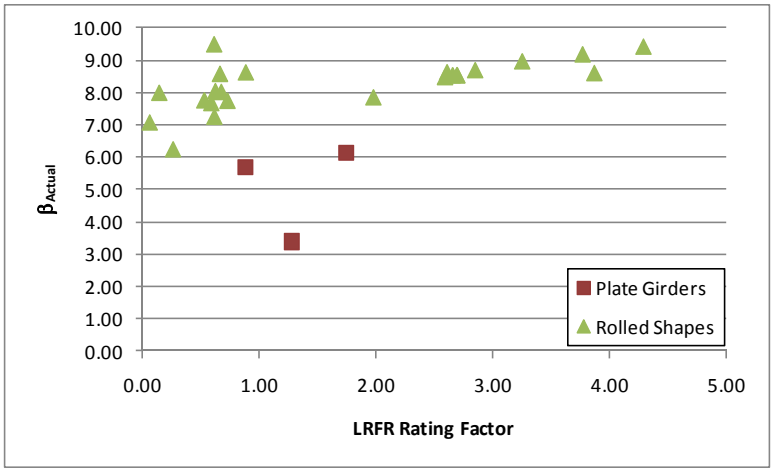


Figure G-296: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

G.3.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-297. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

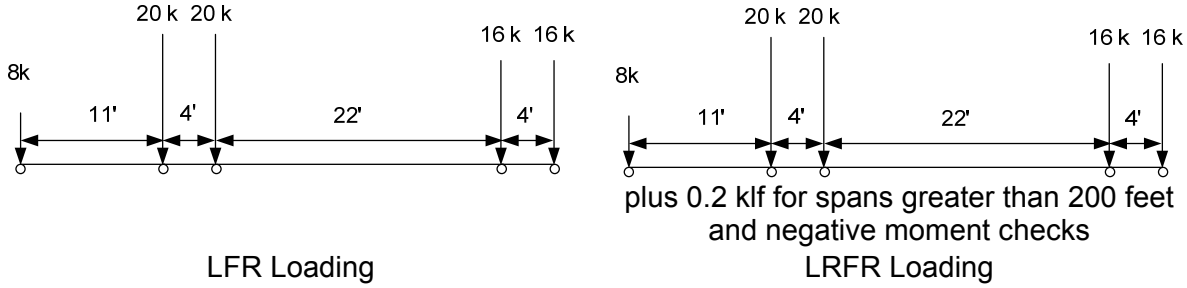


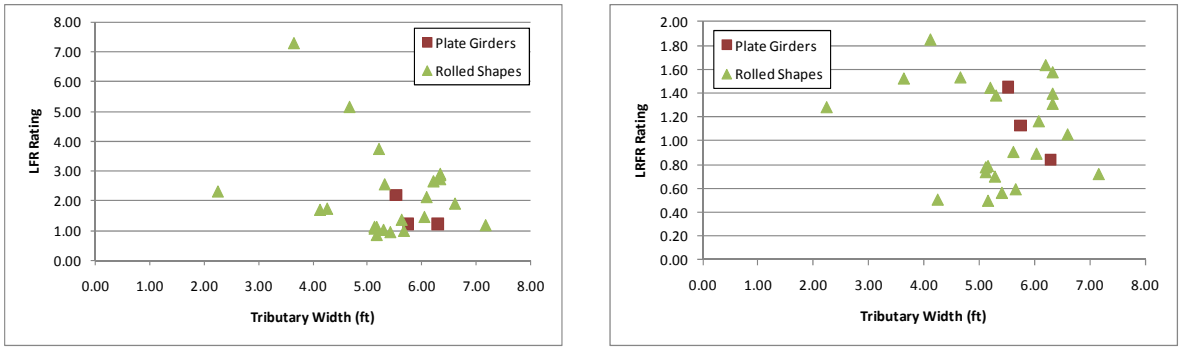
Figure G-297: Vehicle Loadings and Load Factors

G.3.3.1 Moment

The following section contains the results for exterior, non-composite steel girders within continuous span bridges for the DE-07 Vehicle.

G.3.3.1.1 Rating Factors

Figure G-298 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are two girders with an LFR rating less than 1.0, 12 girders with an LRFR rating less than 1.0, and two girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 96% of the girders in this subset. The LFR rating decreases with increasing tributary width while the LRFR rating appears to remain relatively constant or increasing with larger tributary widths.



(a) (b)

Figure G-298: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure G-299 shows the percentage of girders with moment ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 61.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 46.2% of girders for ADTT ≥ 5,000. 92.3% of girders have LFR ratings that are greater than 1.0. 30.8% more girders have ratings less than 1.0 for LRFR than LFR for ADTT ≤ 100; this increases to 46.1% for ADTT ≥ 5,000.

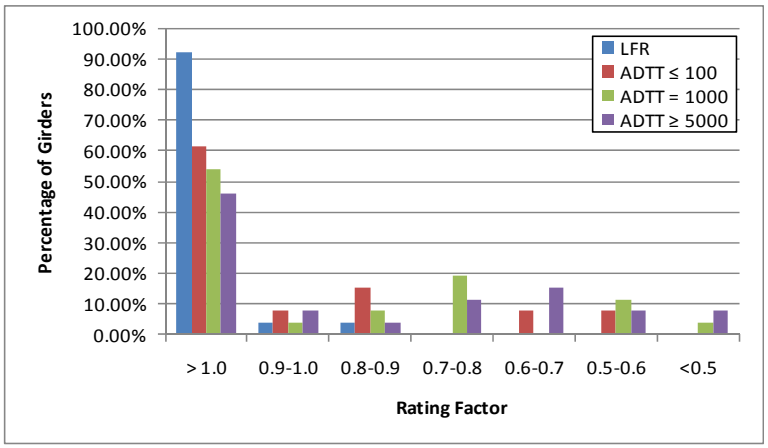


Figure G-299: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

G.3.3.1.2 Rating Factor Comparisons

Figure G-300 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.5 to 0.7, with higher ratios generally corresponding to larger tributary widths. One girder has an LRFR rating that is greater than the LFR rating for this group.

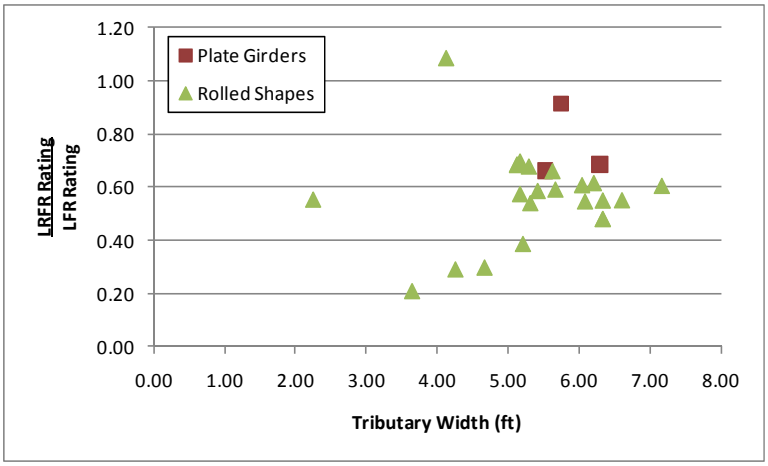


Figure G-300: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

G.3.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-301 shows six girders have a reliability index less than the target reliability index of 2.5. The reliability index varies greatly for the girders in this group.

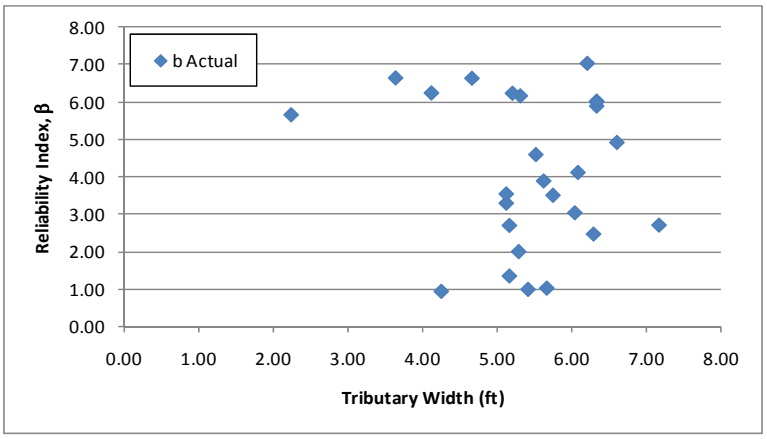


Figure G-301: Flexure Reliability Indices for DE-07 Vehicle

Figure G-302 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 vehicle. The reliability index increases approximately linearly with the LRFR rating factor. The reliability index corresponding to a rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

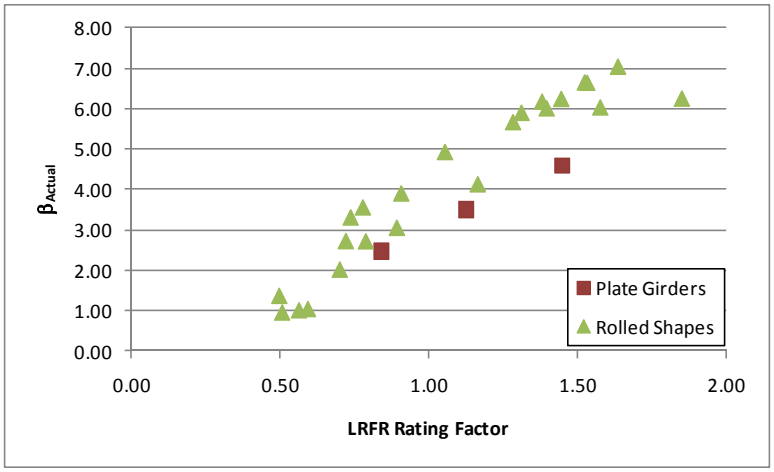
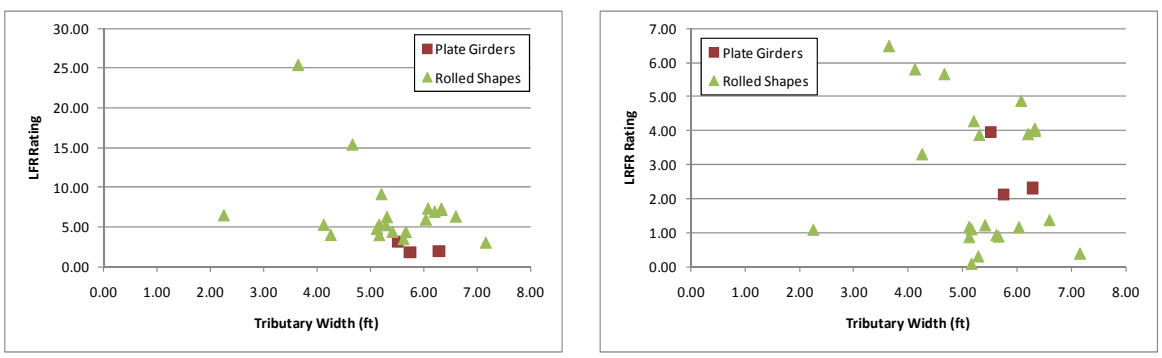


Figure G-302: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

G.3.3.2 Shear

G.3.3.2.1 Rating Factors

For shear, there are six girders with LRFR ratings less than 1.0; all six girders are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-303 shows the LFR and LRFR ratings. The LFR rating tends to decrease with increasing tributary widths while the LRFR rating also decreases with increasing tributary width.



(a) (b)

Figure G-303: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure G-304 shows the percentage of girders with shear ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 88.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 69.2% of girders for ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 11.5% for ADTT ≤ 100, increasing to 30.8% for ADTT ≥ 5,000.

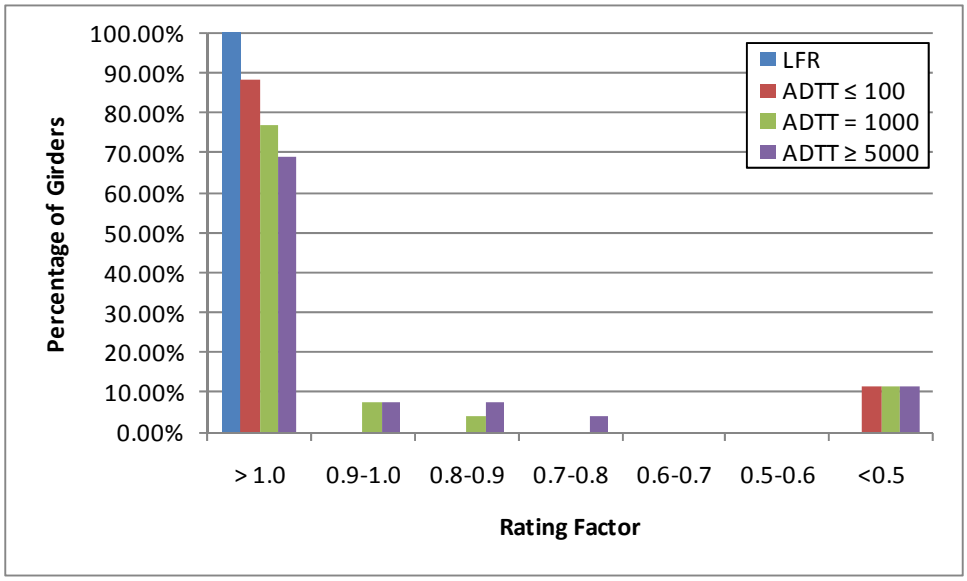


Figure G-304: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

G.3.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure G-305 shows the comparison of rating factors. The ratio is generally less than 1.0, with larger tributary widths having higher ratios. Four girders have LRFR ratings that are greater than the LFR rating.

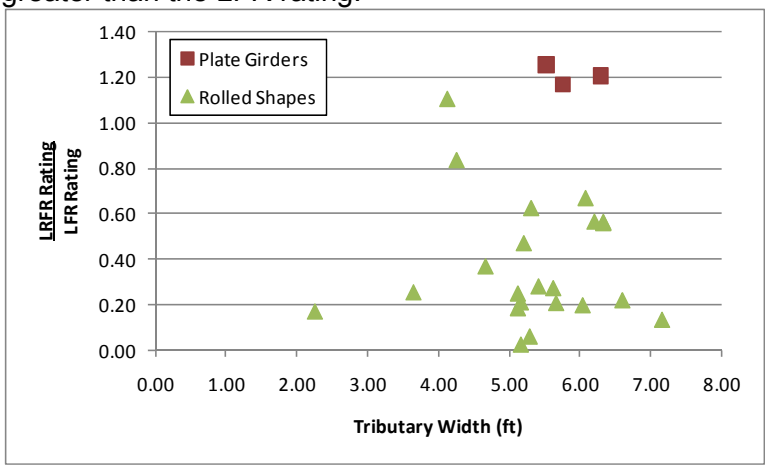


Figure G-305: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

G.3.3.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-306. The reliability index for shear is typically between eight and ten.

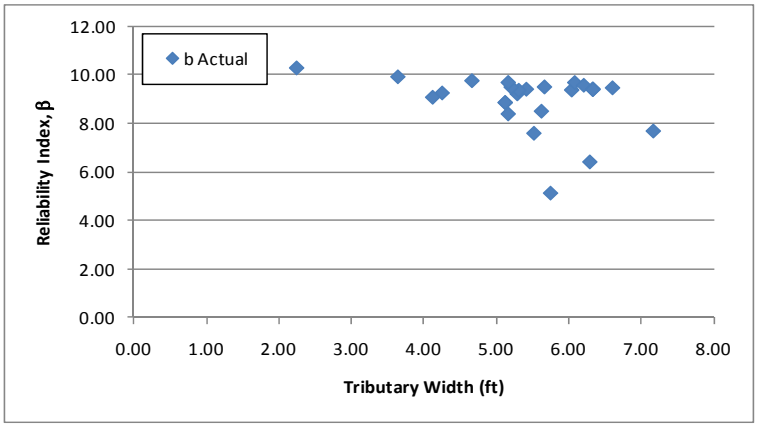


Figure G-306: Shear Reliability Indices for DE-07 Vehicle

Figure G-307 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 vehicle. The reliability index increases with increasing rating factors and a girder with a rating of 1.0 has a reliability index near 4.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

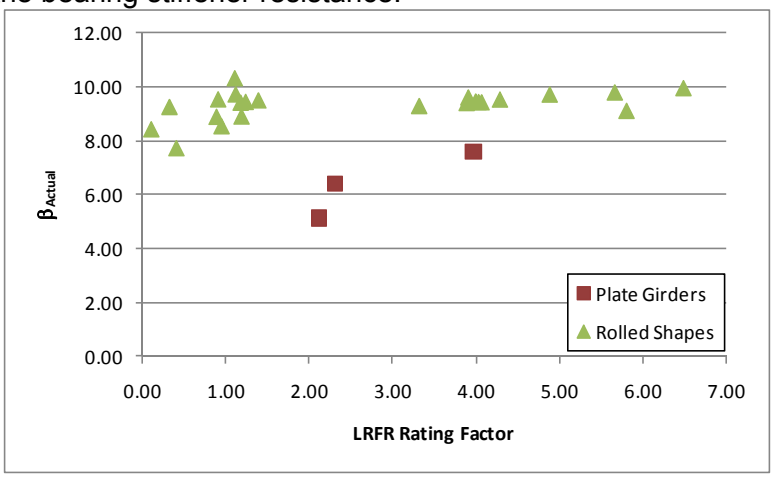


Figure G-307: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

G.3.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-308. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

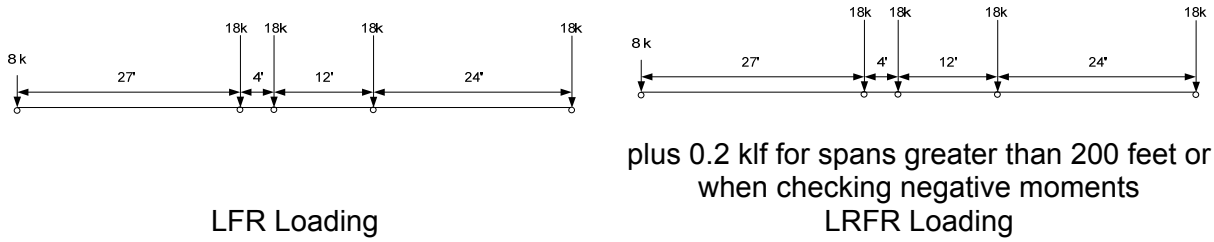


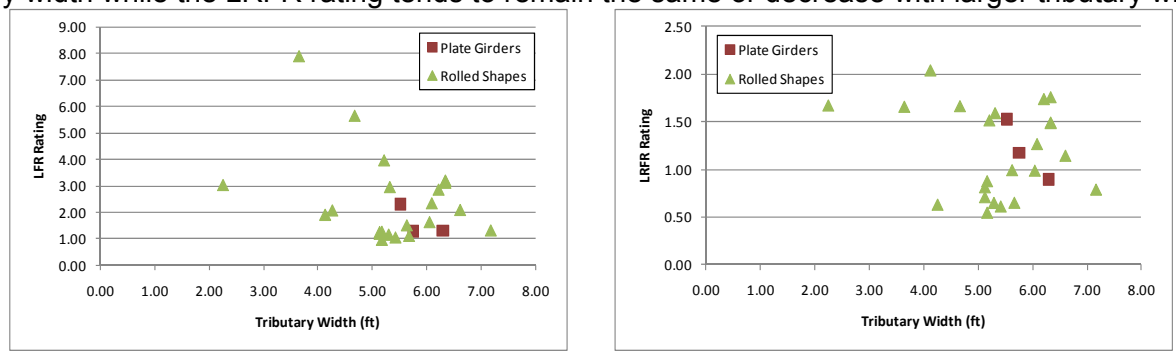
Figure G-308: Vehicle Loadings and Load Factors

G.3.4.1 Moment

The following section contains the results for exterior, non-composite steel girders within continuous span bridges for the FL-04 Vehicle.

G.3.4.1.1 Rating Factors

Figure G-309 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 12 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 96% of the girders in this subset. The LFR rating decreases with increasing tributary width while the LRFR rating tends to remain the same or decrease with larger tributary widths.



(a) (b)

Figure G-309: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure G-310 shows the percentage of girders with moment ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 69.2% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 53.8% of girders for ADTT ≥ 5,000. 96.2% of girders have LFR ratings that are greater than 1.0. 27% more girders have ratings less than 1.0 for LRFR than LFR for ADTT ≤ 100; this increases to 42.4% for ADTT ≥ 5,000.

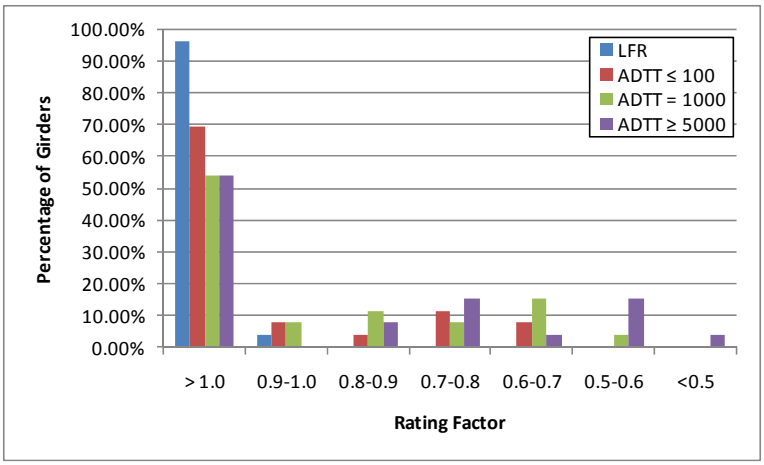


Figure G-310: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

G.3.4.1.2 Rating Factor Comparisons

Figure G-311 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is typically 50 to 70% of the LFR rating. The

ratio increases with tributary width as would be expected with the LFR rating decreasing with tributary width increasing. One girder has an LRFR rating that is greater than the LFR rating.

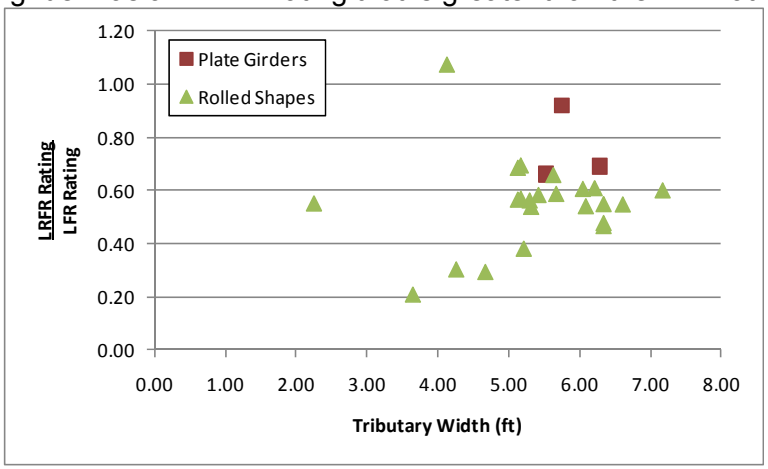


Figure G-311: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

G.3.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-312 shows seven girders have a reliability index less than the target reliability index of 2.5. The reliability index is widely scattered for this vehicle and girder combination.

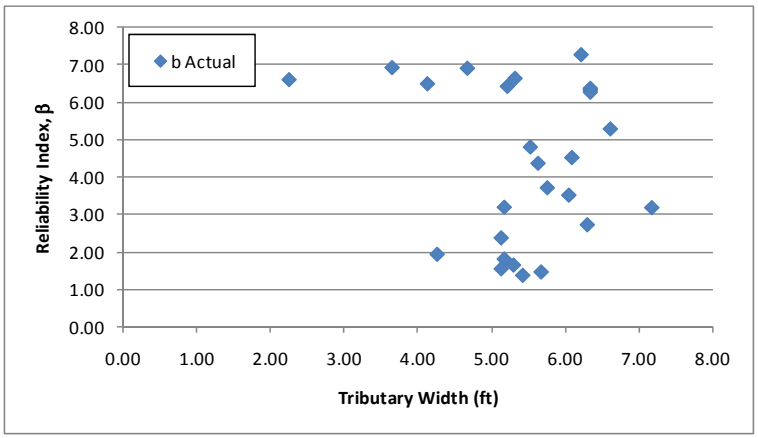


Figure G-312: Flexure Reliability Indices for FL-04 Vehicle

Figure G-313 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 vehicle. The figure shows the reliability index increases approximately linearly with the LRFR rating. The reliability index corresponding to a rating of 1.0 is approximately 3.5, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

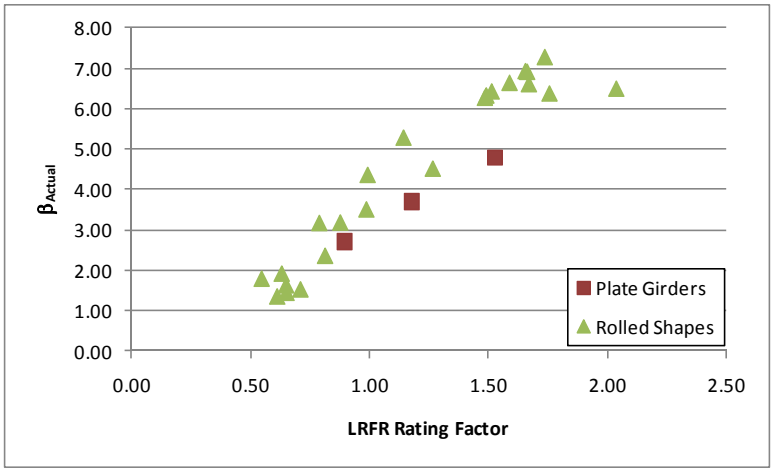
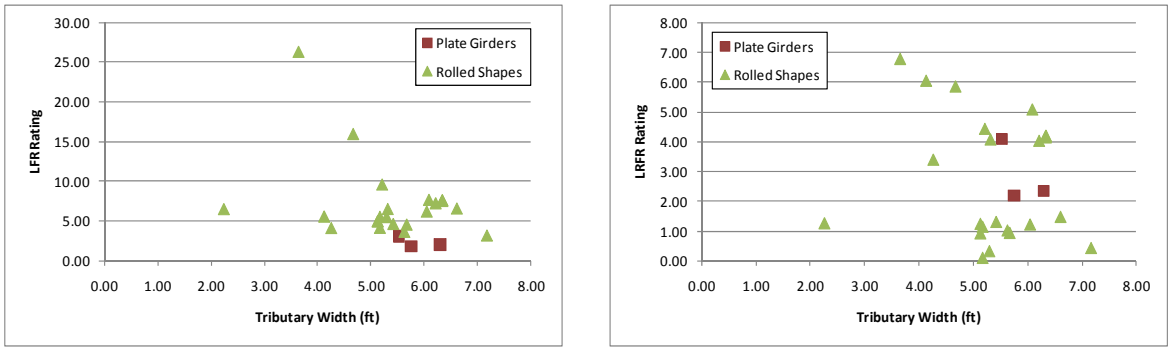


Figure G-313: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

G.3.4.2 Shear

G.3.4.2.1 Rating Factors

For shear, there are five girders with an LRFR rating less than 1.0. All five girders are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-314 shows the LFR and LRFR ratings. The LFR ratings decrease with increasing tributary widths while the LRFR ratings tend to decrease slightly with increasing tributary widths.



(a) (b)

Figure G-314: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure G-315 shows the percentage of girders with shear ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 88.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 76.9% of girders for ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 11.5% for ADTT ≤ 100, increasing to 23.1% for ADTT ≥ 5,000.

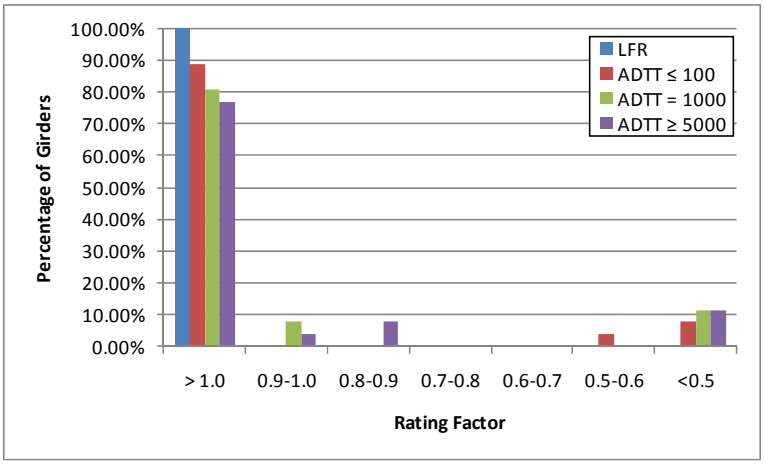


Figure G-315: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

G.3.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-316 shows the comparison of rating factors. The ratio is generally less than 1.0. Four girders have LRFR ratings greater than the LFR rating; three of these are plate girders.

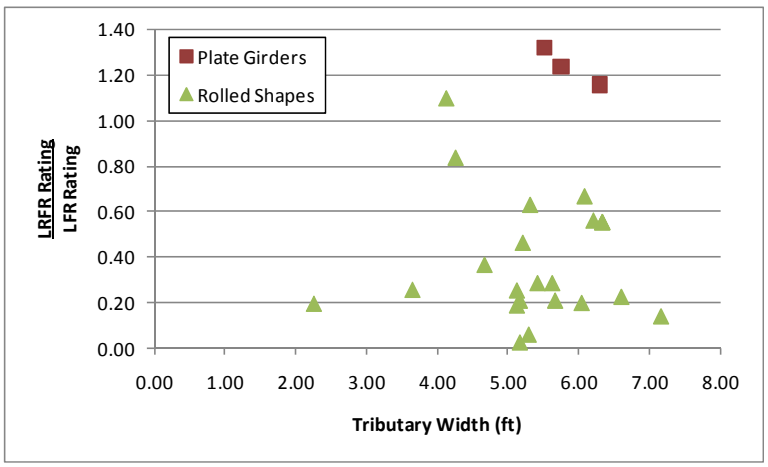


Figure G-316: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

G.3.4.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-317.

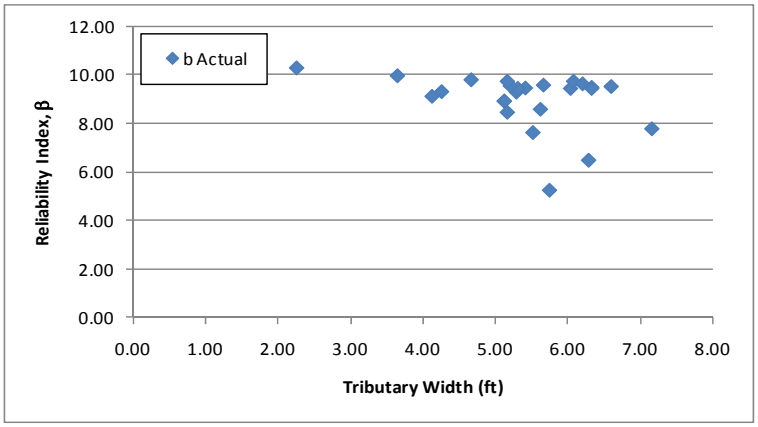


Figure G-317: Shear Reliability Indices for FL-04 Vehicle

Figure G-318 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 vehicle. The reliability index increases with LRFR rating and the reliability index associated with an LRFR rating of 1.0 is approximately four, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

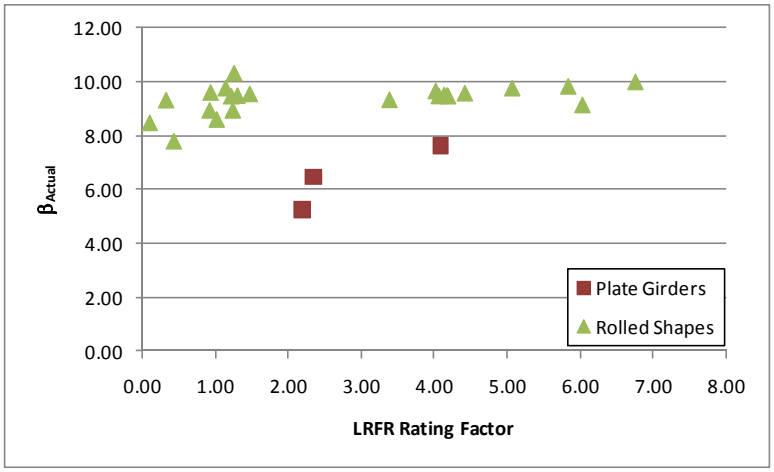


Figure G-318: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

G.3.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-319. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

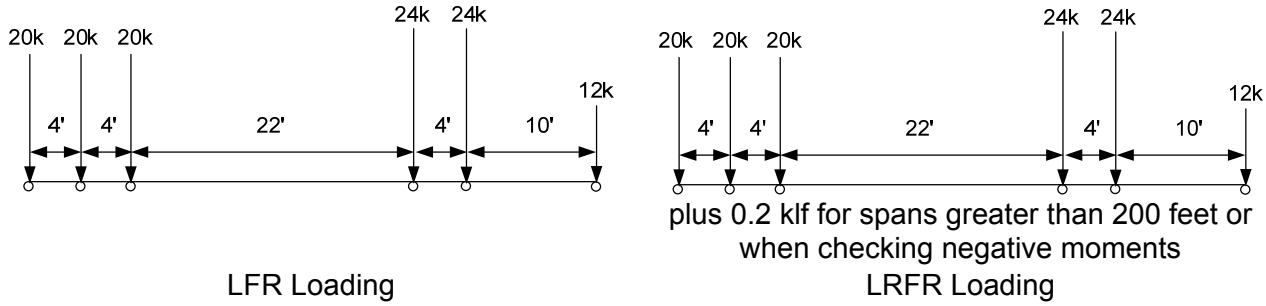


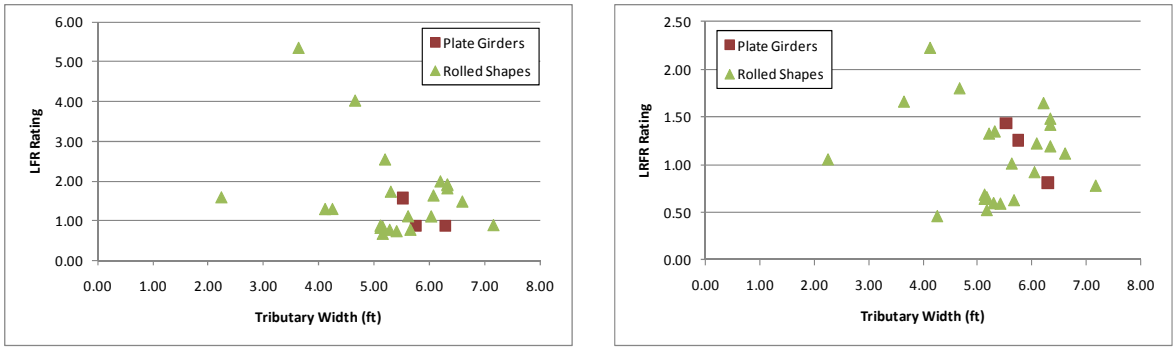
Figure G-319: Vehicle Loadings and Load Factors

G.3.5.1 Moment

The following section contains the results for exterior, non-composite steel girders within continuous span bridges for the IL-01 Vehicle.

G.3.5.1.1 Rating Factors

Figure G-320 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are ten girders with an LFR rating less than 1.0, 11 girders with an LRFR rating less than 1.0, and nine girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 92% of the girders in this subset. The LFR rating tends to decrease with increasing tributary widths while the LRFR ratings also decrease slightly.



(a) (b)

Figure G-320: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure G-321 shows the percentage of girders with moment ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 61.5% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 34.6% of girders for multiple trip permits and ADTT ≥ 5,000. 61.5% of girders have LFR ratings that are greater than 1.0. The same number of girders have ratings less than 1.0 for LRFR than LFR for single trip, escorted permits; this increases to 26.9% for multiple trip permits and ADTT ≥ 5,000.

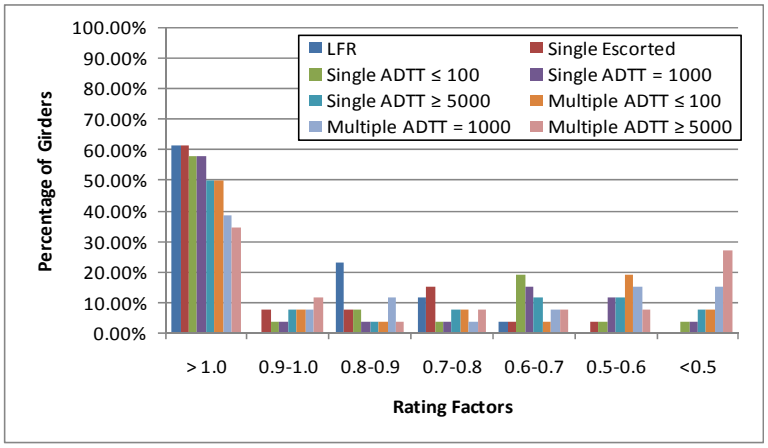


Figure G-321: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

G.3.5.1.2 Rating Factor Comparisons

Figure G-322 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 1.0, with the lower ratios generally coming from girders with narrow girder spacing and short overhangs. Two girders have LRFR ratings that are greater than the LFR ratings.

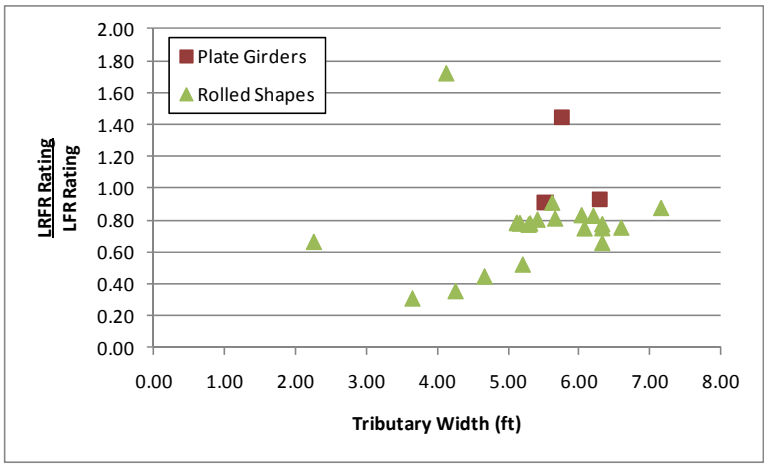


Figure G-322: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

G.3.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-323 shows that ten girders have a reliability index less than the target reliability index of 3.5. The reliability index is widely scattered for this group of girders.

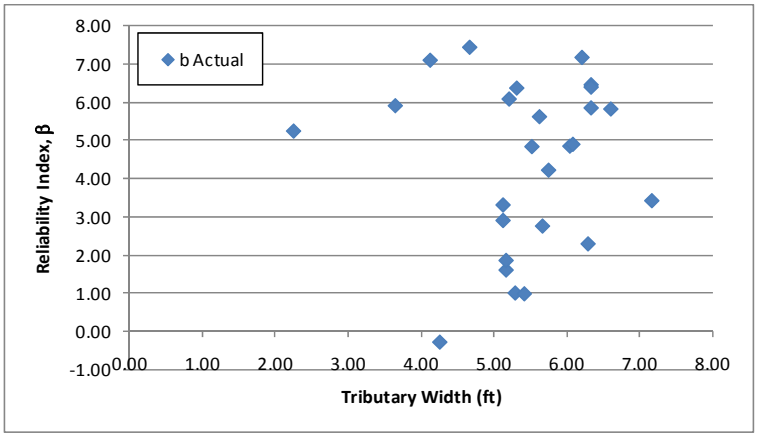


Figure G-323: Flexure Reliability Indices for IL-01 Vehicle

Figure G-324 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The reliability index increases with increasing LRFR rating; the reliability index associated with an LRFR rating is approximately 4.0, above the target value of 3.5. This indicates the LRFR live load factors may be slightly over-conservative.

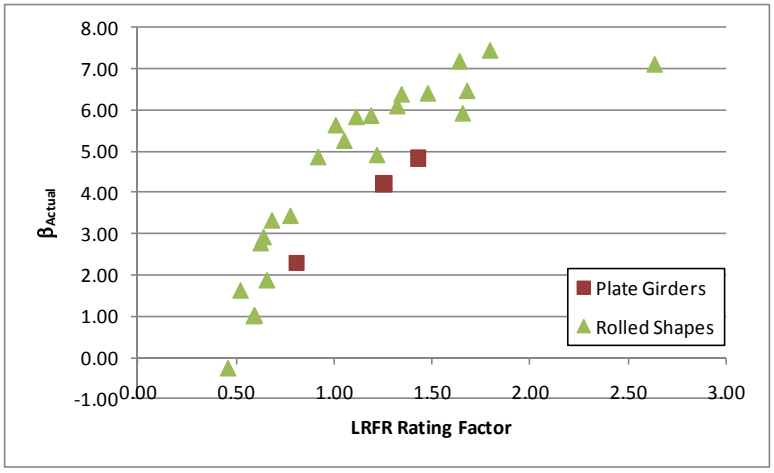
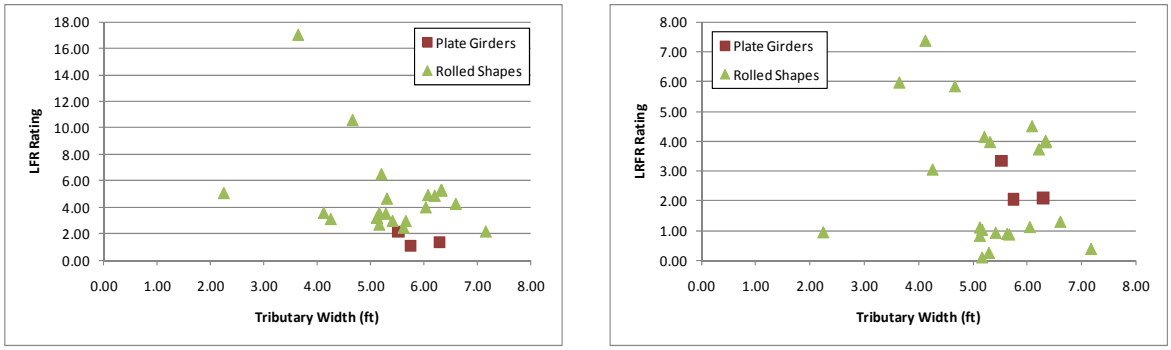


Figure G-324: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

G.3.5.2 Shear

G.3.5.2.1 Rating Factors

For shear, there are zero girders that have an LFR rating factor less than 1.0, eight girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. All eight girders are controlled by the bearing stiffener rating for LRFR. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-325 shows the LFR and LRFR ratings. The LFR rating decreases for increasing tributary widths, while for LRFR the rating also decreases.



(a) (b)

Figure G-325: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure G-326 shows the percentage of girders with shear ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 88.5% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 53.9% of girders for multiple trip permits with ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 11.5% for single trip, escorted permits, increasing to 46.1% for multiple trip permits with ADTT ≥ 5,000.

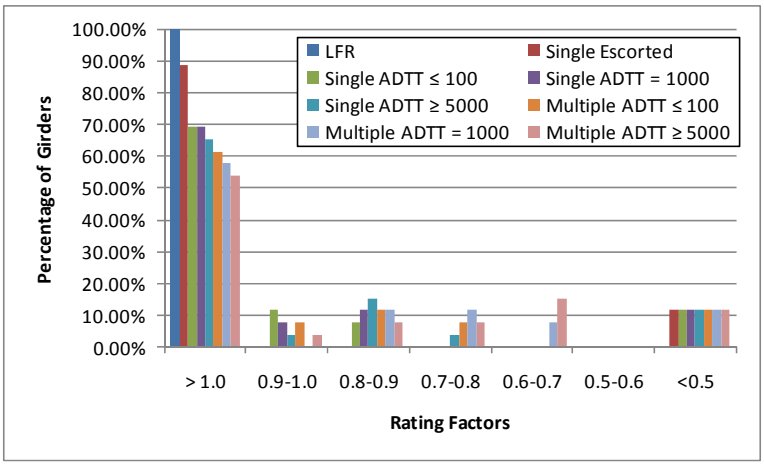


Figure G-326: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

G.3.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-327 shows the comparison of rating factors. The ratio is generally less than 1.0 for the rolled shapes while the ratio for plate girders is generally above 1.5. Four girders have an LRFR rating that is greater than the LFR rating.

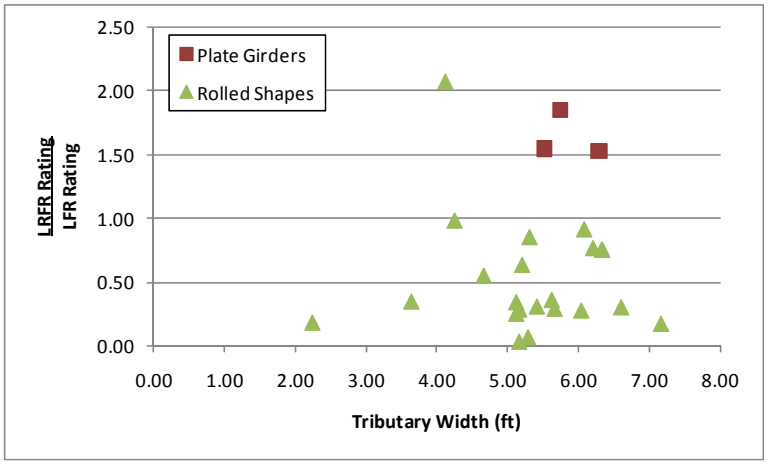


Figure G-327: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

G.3.5.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5for all girders as shown in Figure G-328. The reliability index is between eight and ten for most girders.

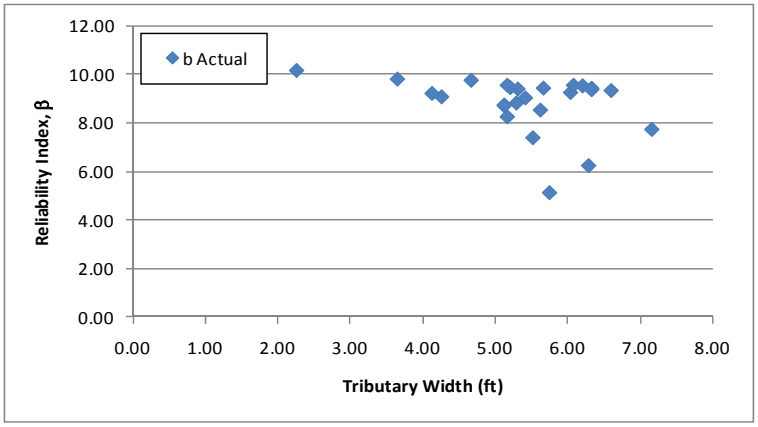


Figure G-328: Shear Reliability Indices for IL-01 Vehicle

Figure G-329 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 vehicle. The reliability index increases with increasing rating factors. The reliability index is approximately four for girders with a rating of 1.0, above the target reliability of 3.5. This indicates the LRFR live load factors may be slightly over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

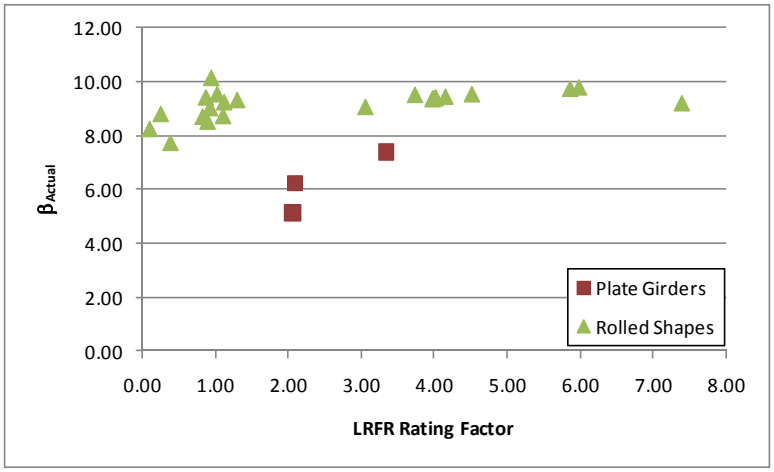


Figure G-329: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

G.3.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-330. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

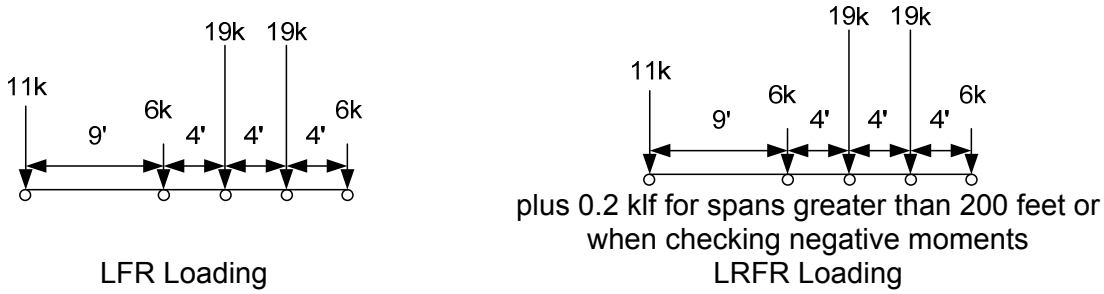


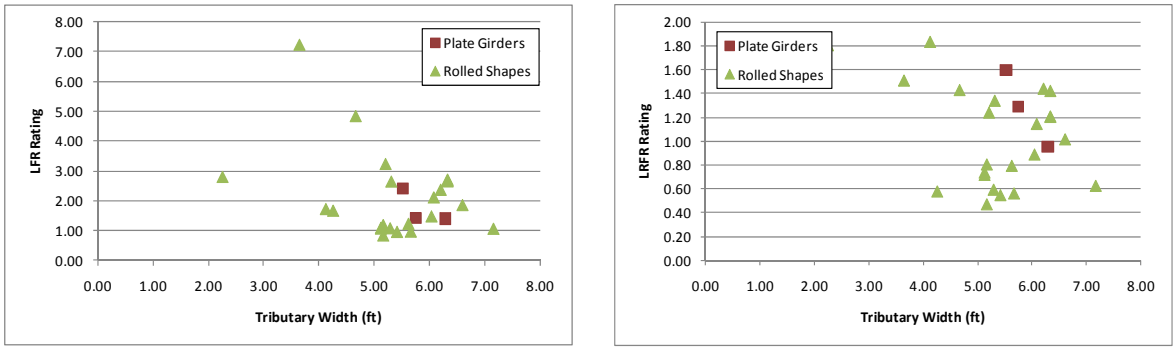
Figure G-330: Vehicle Loadings and Load Factors

G.3.6.1 Moment

The following section contains the results for exterior, non-composite steel girders within continuous span bridges for the NC-21 Vehicle.

G.3.6.1.1 Rating Factors

Figure G-331 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are three girders with an LFR rating less than 1.0, 12 girders with an LRFR rating less than 1.0, and three girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 96% of the girders in this subset. The LFR rating decreases with increasing tributary widths while the LRFR rating remains fairly constant but decreases slightly with increasing tributary widths.



(a) (b)

Figure G-331: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure G-332 shows the percentage of girders with moment ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 61.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 50.0% of girders for ADTT ≥ 5,000. 88.5% of girders have LFR ratings that are greater than 1.0. 27% more girders have ratings less than 1.0 for LRFR than LFR for ADTT ≤ 100; this increases to 38.5% for ADTT ≥ 5,000.

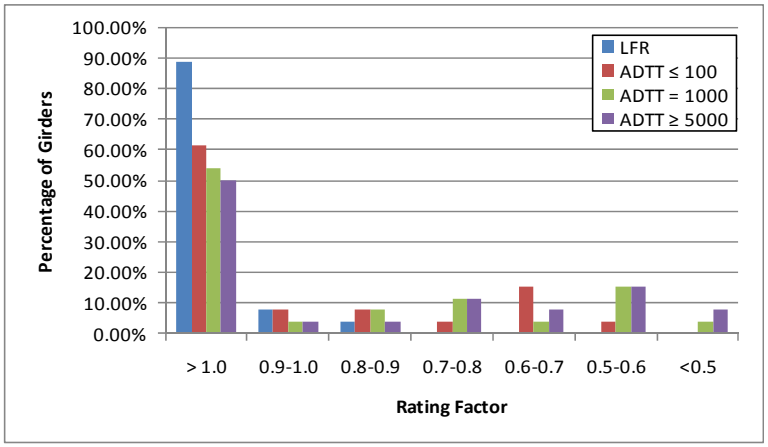


Figure G-332: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

G.3.6.1.2 Rating Factor Comparisons

Figure G-333 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.7 for this vehicle, with the lower ratios corresponding to girders with narrow spacing or short overhangs. One girder has an LRFR rating that is greater than the LFR Rating.

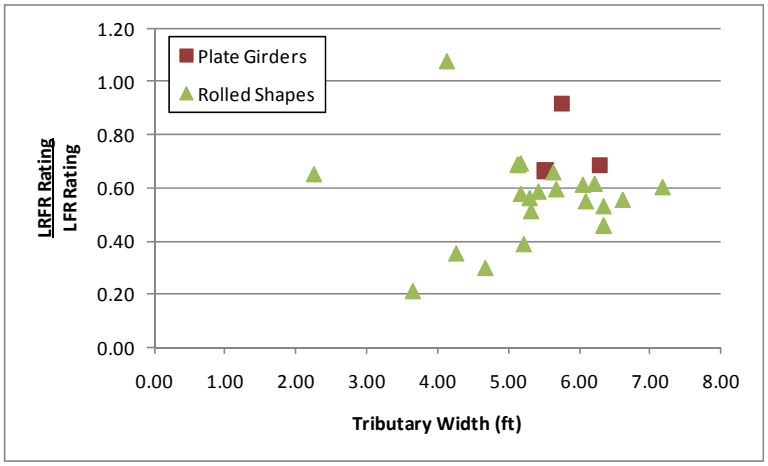


Figure G-333: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

G.3.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-334 shows that seven girders have a reliability index less than the target reliability index of 2.5. The reliability index is widely scattered for this vehicle.

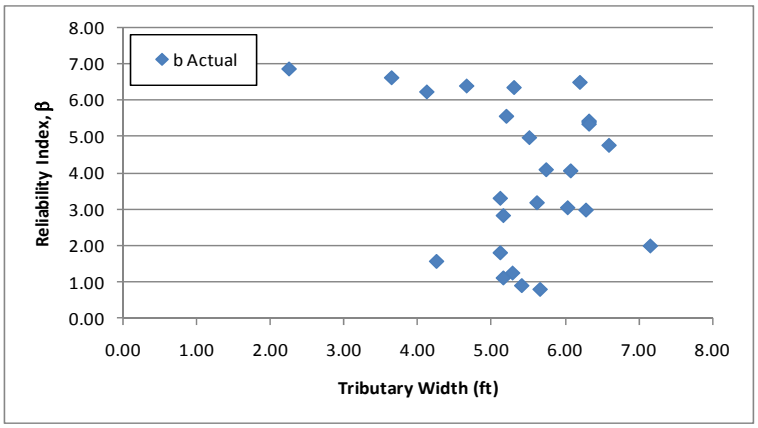


Figure G-334: Flexure Reliability Indices for NC-21 Vehicle

Figure G-335 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 vehicle. The reliability index increases approximately linearly with the rating factor. A girder with a rating factor of 1.0 has a reliability index of approximately 4.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

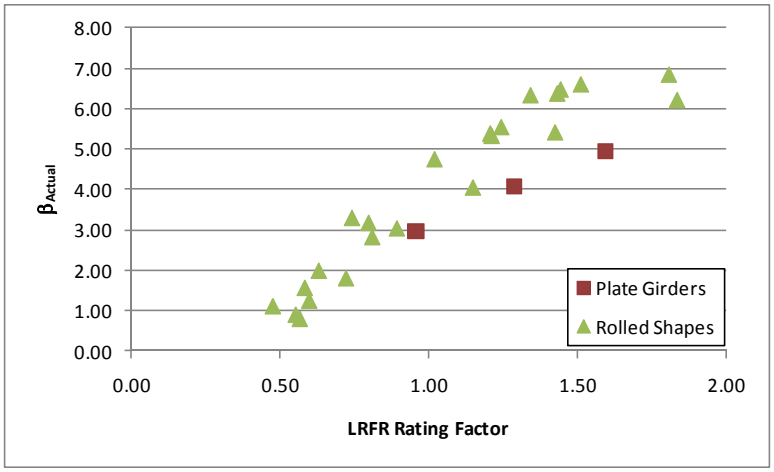
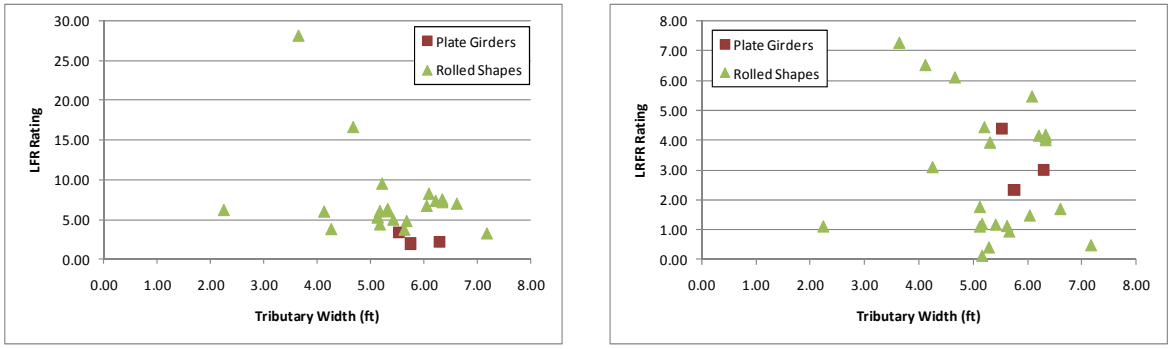


Figure G-335: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

G.3.6.2 Shear

G.3.6.2.1 Rating Factors

For shear, there are four girders with LRFR ratings less than 1.0. All four girders are controlled by the bearing stiffener rating for LRFR. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-336 shows the LFR and LRFR ratings. Both ratings decrease significantly with increasing tributary width.



(a) (b)

Figure G-336: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure G-337 shows the percentage of girders with shear ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 88.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 76.9% of girders for ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 11.5% for ADTT ≤ 100, increasing to 23.1% for ADTT ≥ 5,000.

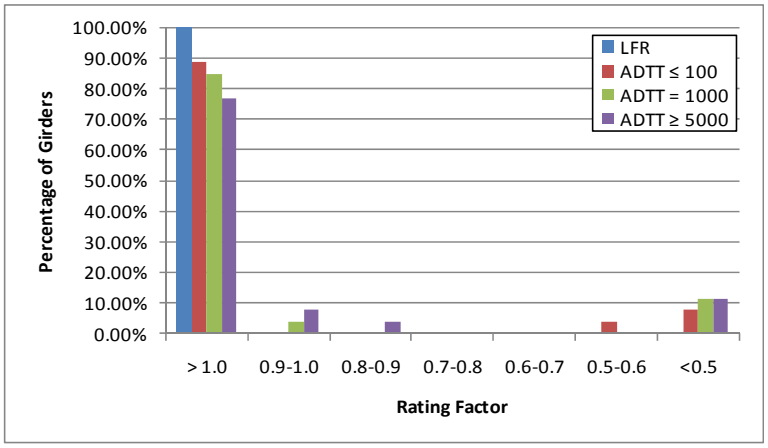


Figure G-337: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

G.3.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-338 shows the comparison of rating factors. The ratio is widely scattered with many of the ratios less than 0.5. There are four girders with LRFR ratings that are greater than the LFR rating.

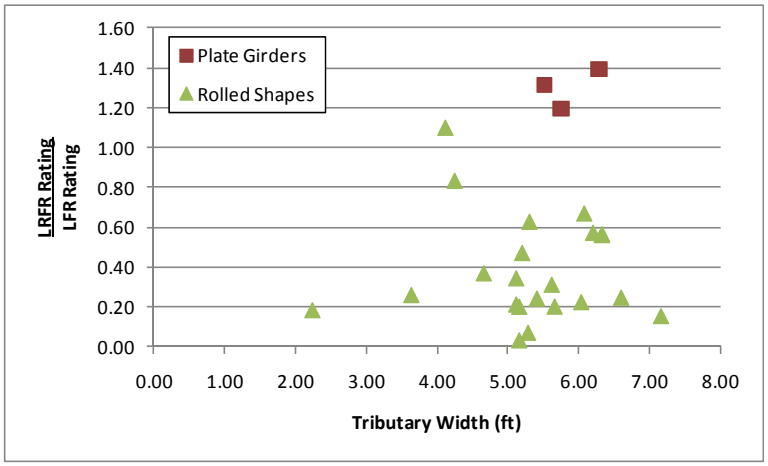


Figure G-338: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

G.3.6.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-339. The reliability index is between 0.8 and 1.0 for most girders.

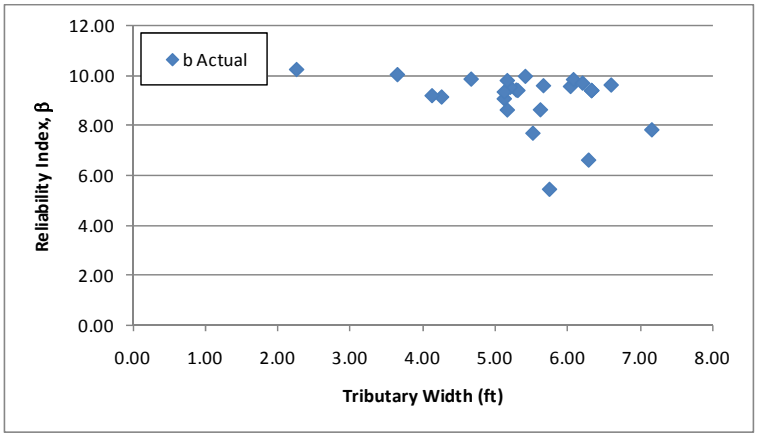


Figure G-339: Shear Reliability Indices for NC-21 Vehicle

Figure G-340 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 vehicle. The reliability index for a girder with a rating of 1.0 is estimated to be 4.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

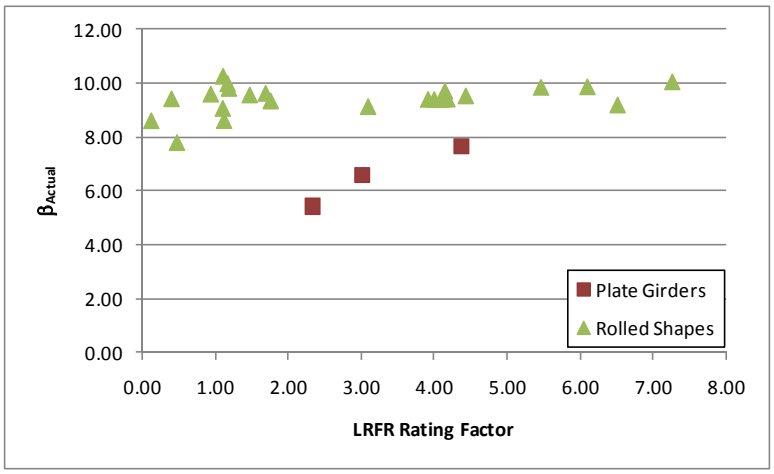


Figure G-340: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

G.3.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-341. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

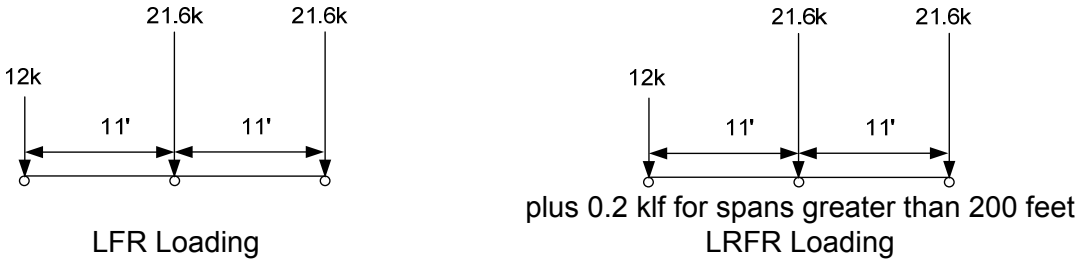


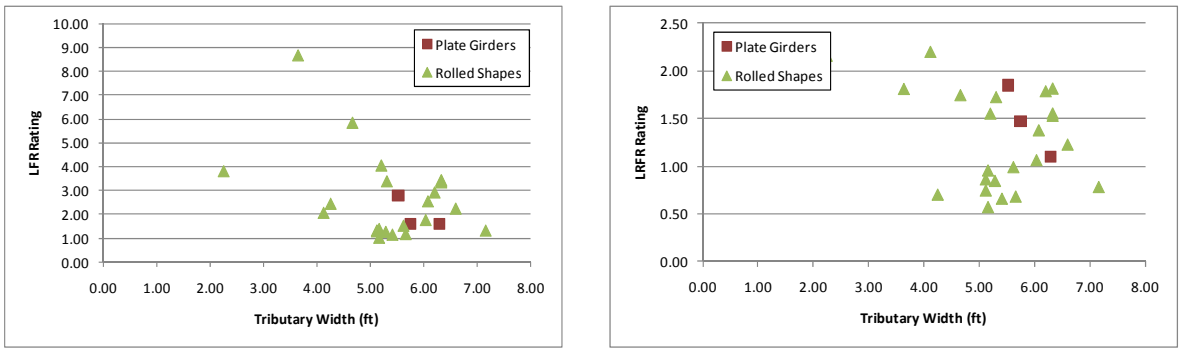
Figure G-341: Vehicle Loadings and Load Factors

G.3.7.1 Moment

The following section contains the results for exterior, non-composite steel girders within continuous span bridges for the NM-04 Vehicle.

G.3.7.1.1 Rating Factors

Figure G-342 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, ten girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 96% of the girders in this subset. The LFR rating decreases significantly with increasing tributary width while the LRFR rating decreases slightly with tributary width.



(a) (b)

Figure G-342: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure G-343 shows the percentage of girders with moment ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 69.2% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 53.9% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. 30.8% more girders have ratings less than 1.0 for LRFR than LFR for ADTT ≤ 100; this increases to 46.1% for ADTT ≥ 5,000.

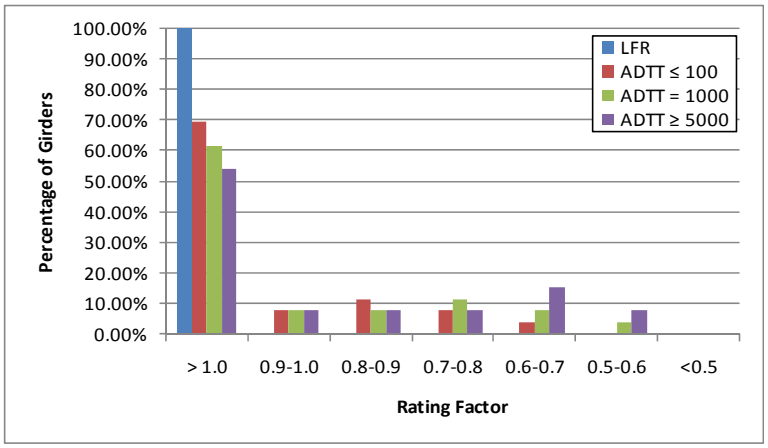


Figure G-343: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

G.3.7.1.2 Rating Factor Comparisons

Figure G-344 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.7, with one girder having an LRFR rating greater than the LFR rating.

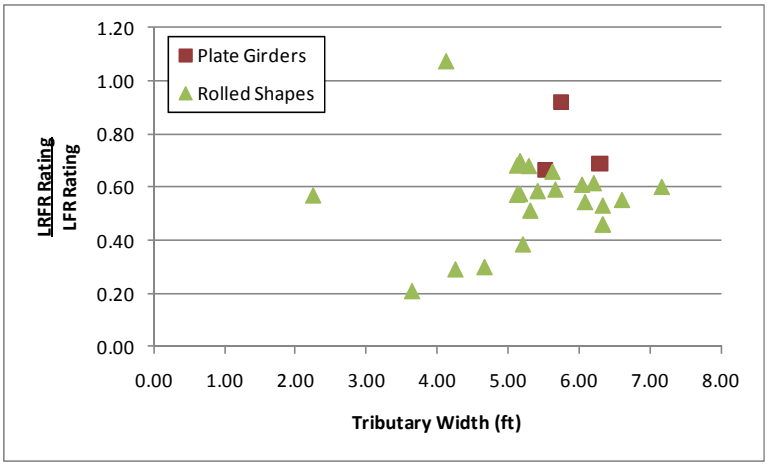


Figure G-344: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

G.3.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-345 shows that four girders have a reliability index less than the target reliability index of 2.5. The reliability index is widely scattered for this vehicle.

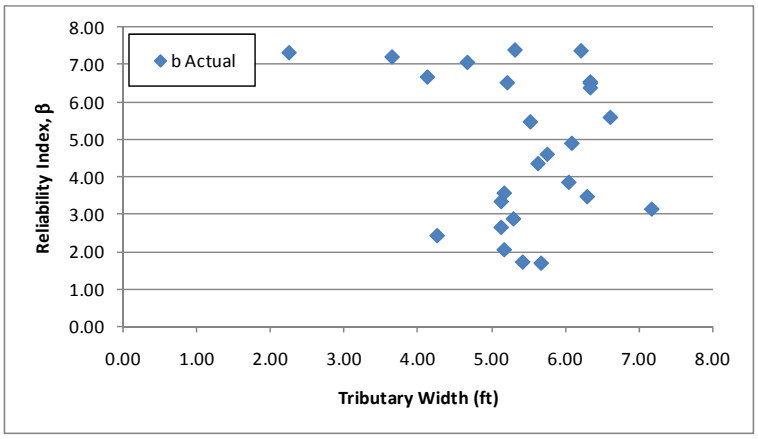


Figure G-345: Flexure Reliability Indices for NM-04 Vehicle

Figure G-346 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The reliability index increases approximately linearly with rating factor. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

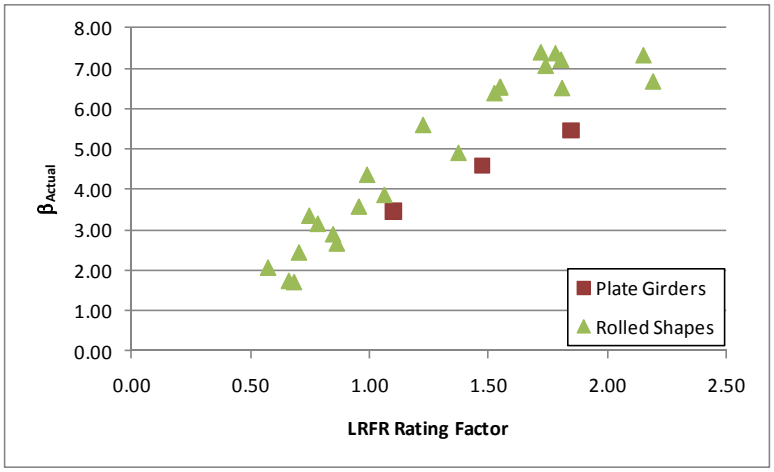
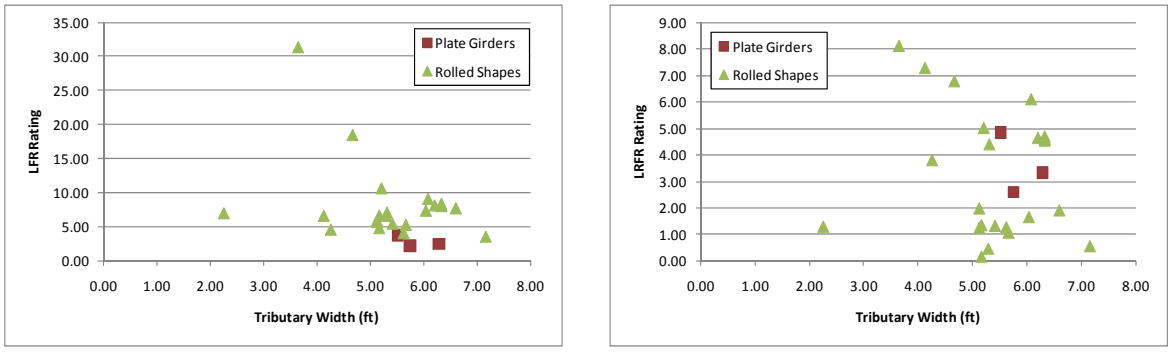


Figure G-346: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

G.3.7.2 Shear

G.3.7.2.1 Rating Factors

For shear, there are three girders with an LRFR rating less than 1.0 and all are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-347 shows the LFR and LRFR ratings. The LFR rating decreases with increasing tributary widths while the LRFR rating also decreases.



(a) (b)

Figure G-347: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure G-348 shows the percentage of girders with shear ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 88.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 84.6% of girders for ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 11.5% for ADTT ≤ 100, increasing to 15.4% for ADTT ≥ 5,000.

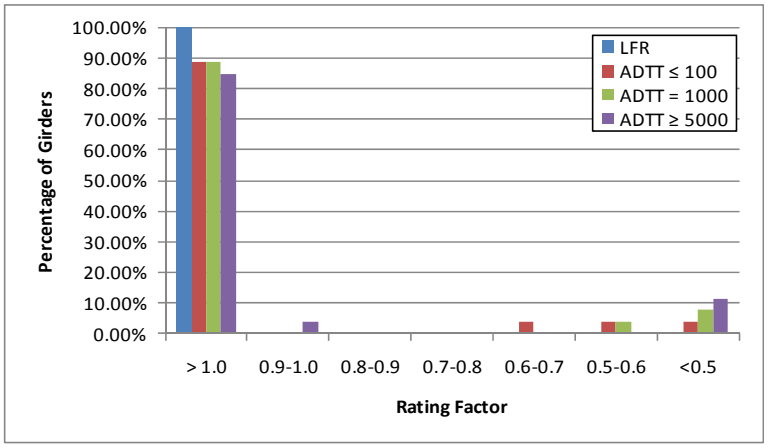


Figure G-348: Shear Ratings for Various ADTTs in MBE for NM-04

G.3.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-349 shows the comparison of rating factors. The ratio is generally less than 0.7 for rolled shapes; plate girders typically had ratios greater than 1.0.

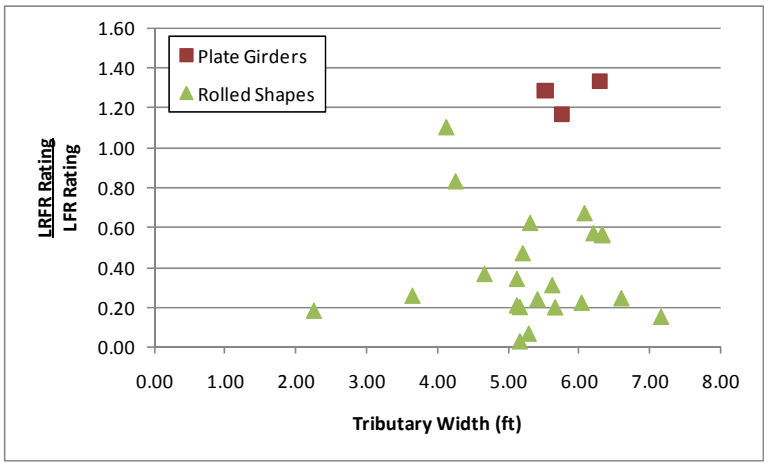


Figure G-349: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

G.3.7.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-350. The reliability index is between eight and ten for most girders.

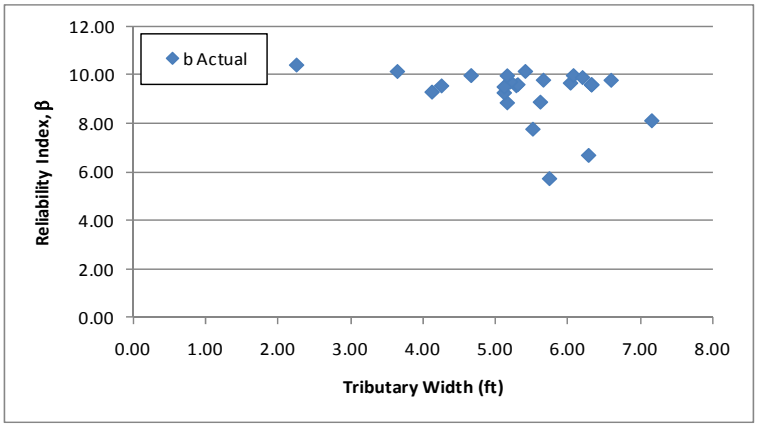


Figure G-350: Shear Reliability Indices for NM-04 Vehicle

Figure G-351 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. The reliability index increases with increasing rating factors. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0. This is greater than the target reliability index of 2.5, indicating the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

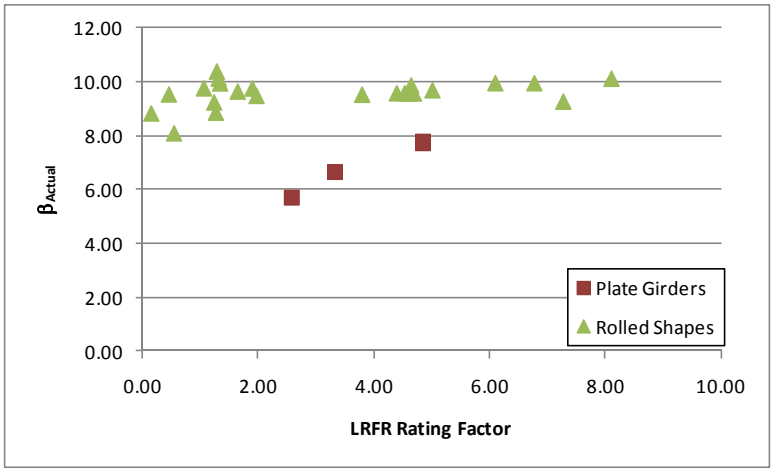
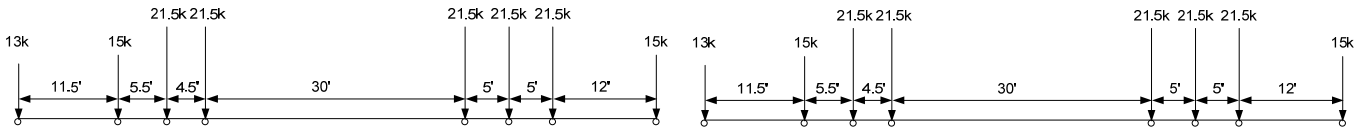


Figure G-351: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

G.3.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-352. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading

plus 0.2 klf for spans greater than 200 feet

LRFR Loading

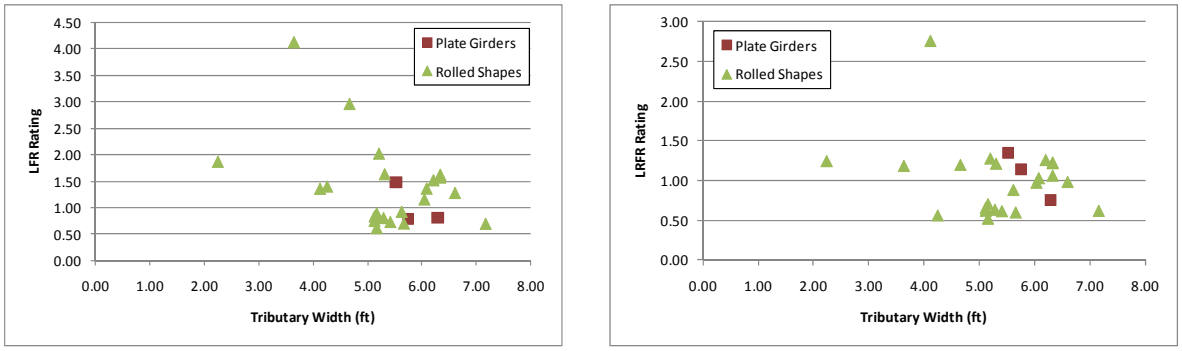
Figure G-352: Vehicle Loadings and Load Factors

G.3.8.1 Moment

The following section contains the results for exterior, non-composite steel girders within continuous span bridges for the OR-06 Vehicle.

G.3.8.1.1 Rating Factors

Figure G-353 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 11 girders with an LFR rating less than 1.0, 13 girders with an LRFR rating less than 1.0, and 10 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 92% of the girders in this subset. The LFR rating decreases with increasing tributary width; the LRFR rating does not decrease with increasing tributary widths.



(a) (b)

Figure G-353: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure G-354 shows the percentage of girders with moment ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 61.5% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 7.7% of girders for multiple trip permits with ADTT ≥ 5,000. 57.7% of girders have LFR ratings that are greater than 1.0. 3.8% fewer girders have ratings less than 1.0 for LRFR than LFR for single trip, escorted permits. 50% more girders have ratings less than 1.0 for LRFR than for LFR for a multiple trip permit with ADTT ≥ 5,000.

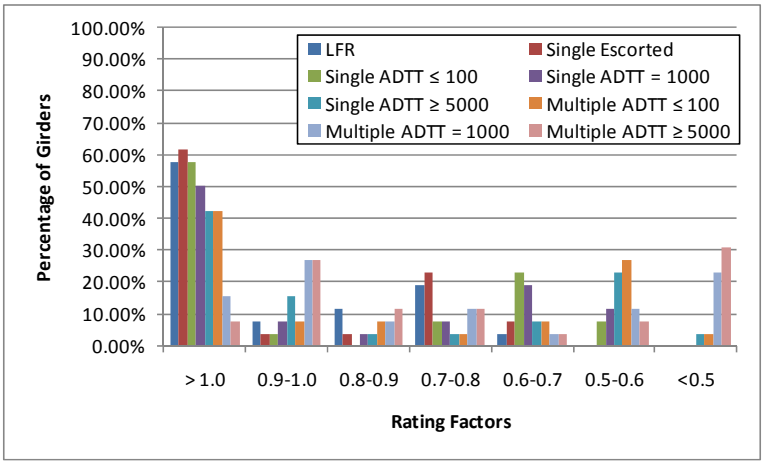


Figure G-354: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

G.3.8.1.2 Rating Factor Comparisons

Figure G-355 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8. There are two girders with LRFR ratings that are greater than the LFR rating.

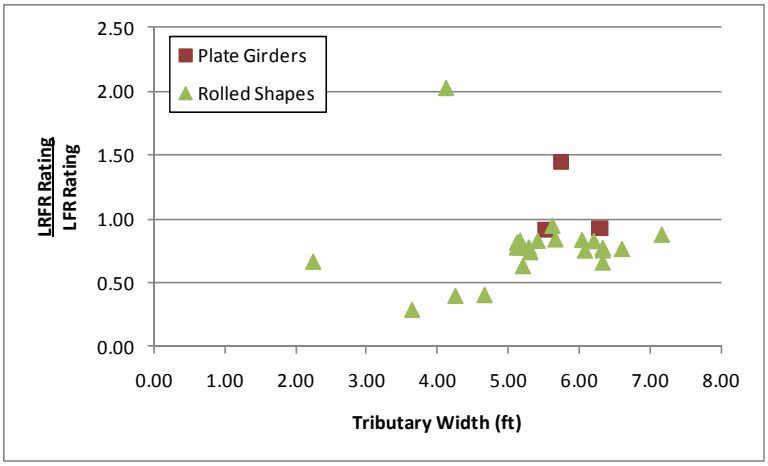


Figure G-355: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

G.3.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-356 shows that eight girders have a reliability index less than the target reliability index of 3.5. The reliability index is widely scattered for this vehicle.

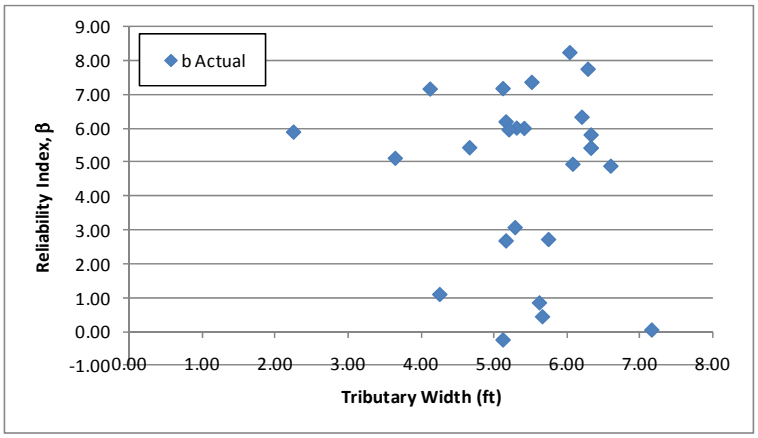


Figure G-356: Flexure Reliability Indices for OR-06 Vehicle

Figure G-357 shows the reliability index for moment plotted against the LRFR moment ratings for the OR-06 vehicle. The reliability index increases with increasing LRFR ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0, above the target reliability of 3.5. This indicates the LRFR live load factors may be slightly over-conservative.

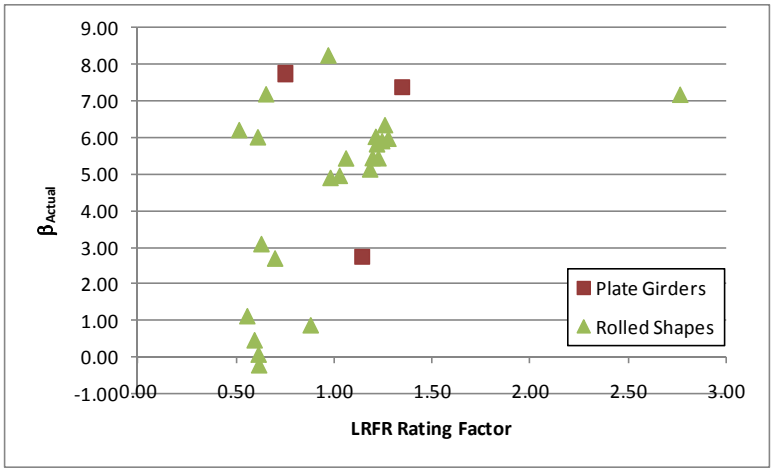
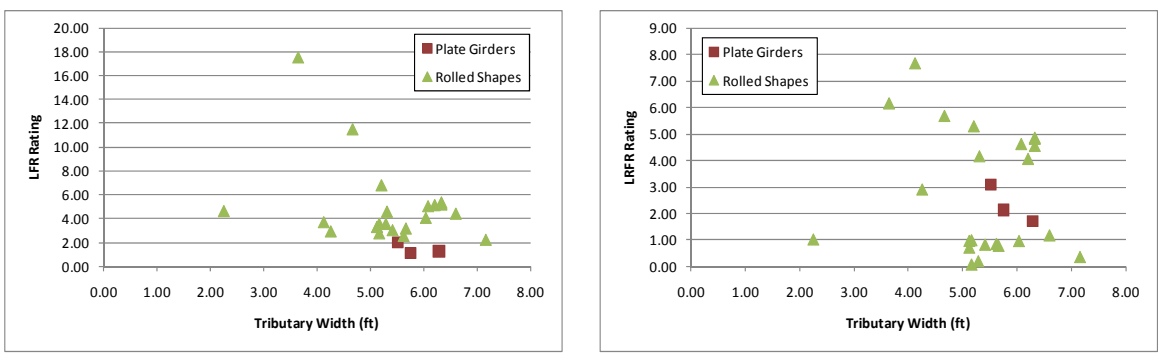


Figure G-357: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

G.3.8.2 Shear

G.3.8.2.1 Rating Factors

For shear, there are zero girders that have an LFR rating factors less than 1.0, nine girders have an LRFR rating less than 1.0, and zero girders have both ratings less than 1.0. All nine girders with an LRFR rating less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-358 shows the LFR and LRFR ratings. Both ratings decrease with increasing tributary width, with the magnitude of the decrease much larger for the LFR ratings.



(a) (b)

Figure G-358: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure G-359 shows the percentage of girders with shear ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 80.8% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 53.9% of girders for multiple trip permits with ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 19.2% for single trip, escorted permits, increasing to 46.1% for multiple trip permits with ADTT ≥ 5,000.

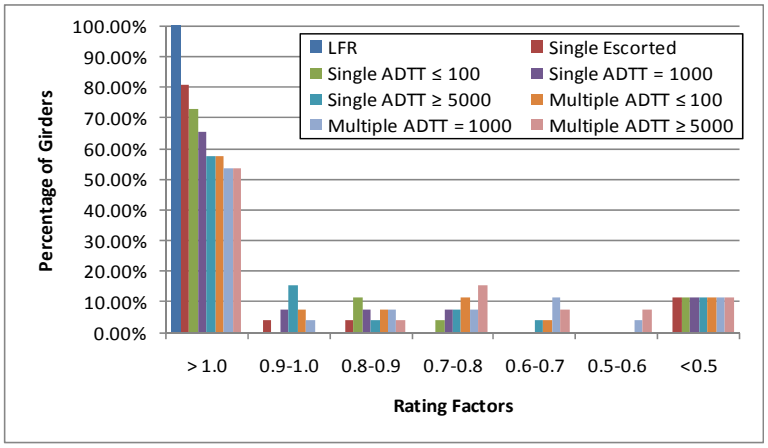


Figure G-359: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

G.3.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-360 shows the comparison of rating factors. The ratio varies greatly for this vehicle, with a group below 0.5, another group near 0.9, and then those above 1.0. Rolled shapes are more likely to have ratios less than 1.0. The three plate girders in this set all have ratios above 1.0.

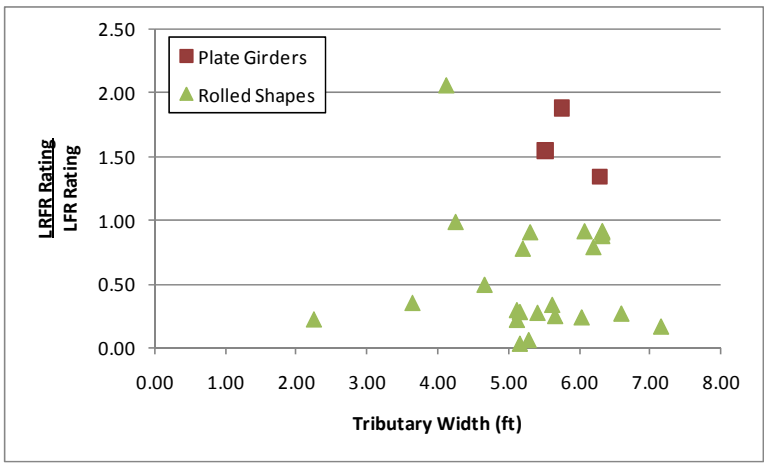


Figure G-360: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

G.3.8.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all girders as shown in Figure G-361. The reliability index for most girders is between eight and ten.

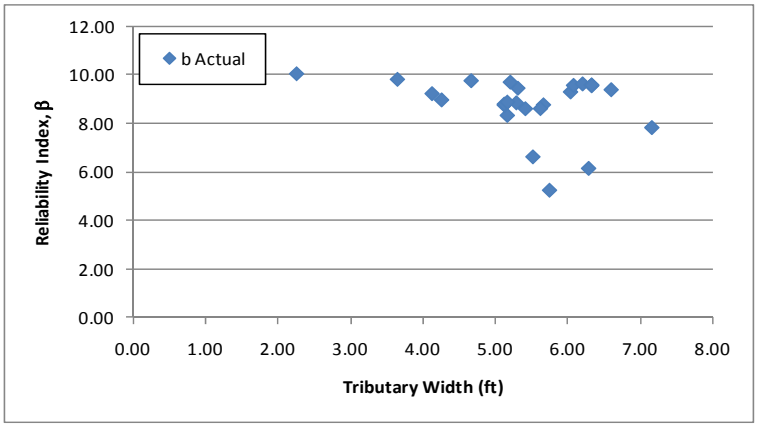


Figure G-361: Shear Reliability Indices for OR-06 Vehicle

Figure G-362 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The reliability index for a girder with an LRFR rating of 1.0 is estimate to be near 4.0, higher than the target reliability index of 3.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

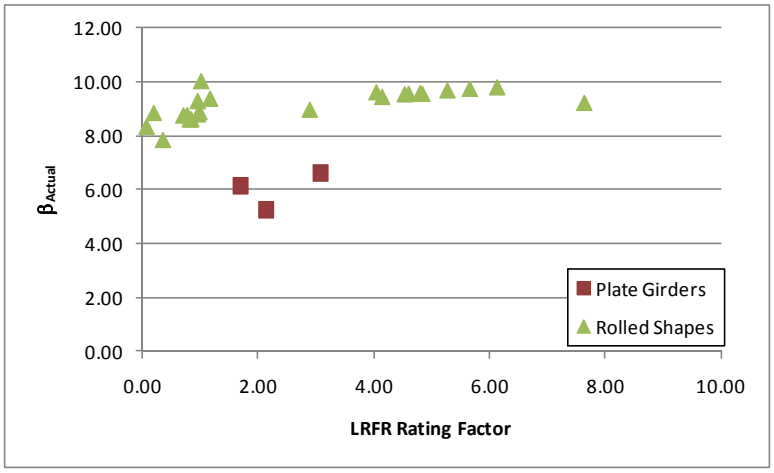
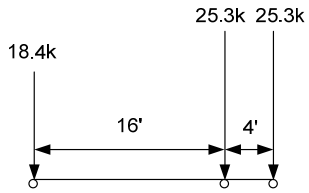


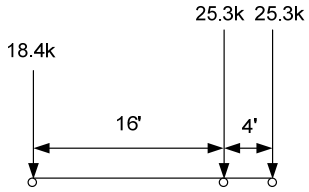
Figure G-362: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

G.3.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-363. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LRFR Loading

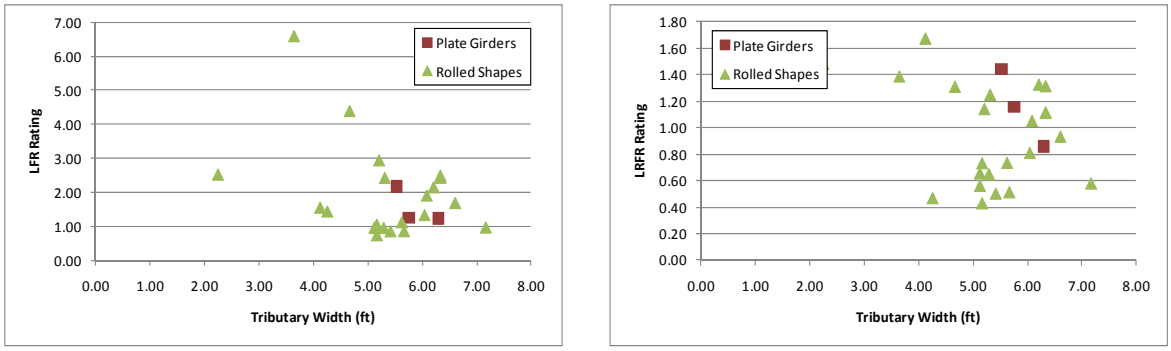
Figure G-363: Vehicle Loadings and Load Factors

G.3.9.1 Moment

The following section contains the results for exterior, non-composite steel girders within continuous span bridges for the TX-04 Vehicle.

G.3.9.1.1 Rating Factors

Figure G-364 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are seven girders with an LFR rating less than 1.0, 13 girders with an LRFR rating less than 1.0, and seven girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 96% of the girders in this subset. Both ratings decrease with increasing span lengths, but the LRFR rating does not decrease as significantly.



(a) (b)

Figure G-364: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure G-365 shows the percentage of girders with moment ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 53.9% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 38.5% of girders for ADTT ≥ 5,000. 73.1% of girders have LFR ratings that are greater than 1.0. 19.2% more girders have ratings less than 1.0 for LRFR than LFR for ADTT ≤ 100; this increases to 34.6% for ADTT ≥ 5,000.

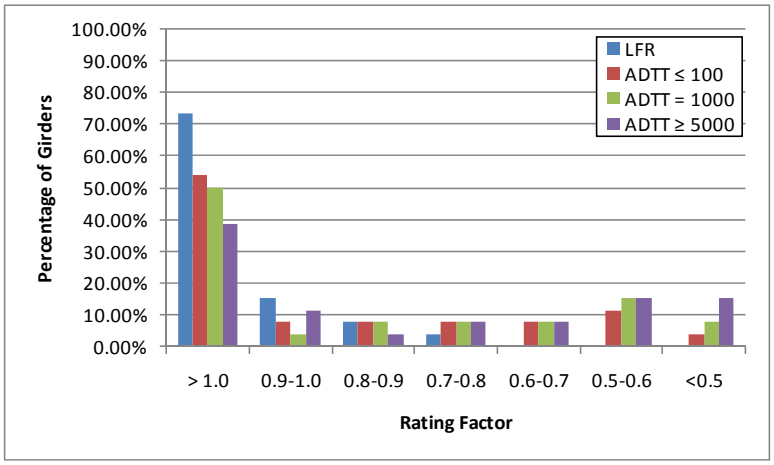


Figure G-365: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

G.3.9.1.2 Rating Factor Comparisons

Figure G-366 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is between 0.5 and 0.7, with larger tributary widths generally having higher ratios. There is one girder with an LRFR rating that is greater than the LFR rating.

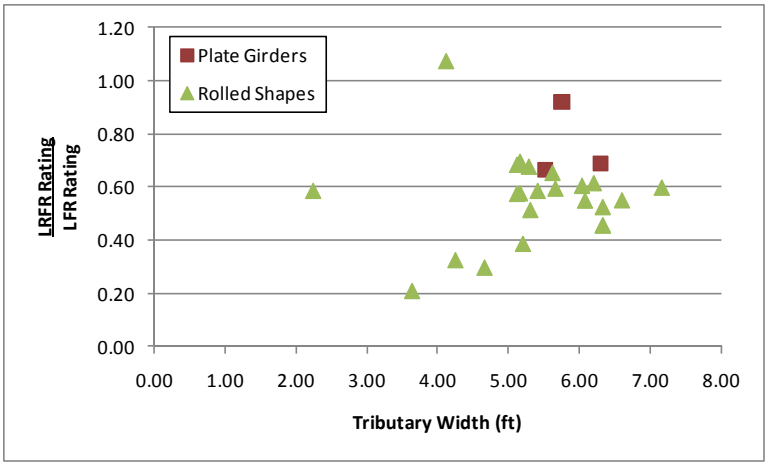


Figure G-366: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

G.3.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-367 shows eight girders have a reliability index less than the target reliability index of 2.5. The reliability index varies significantly for this vehicle.

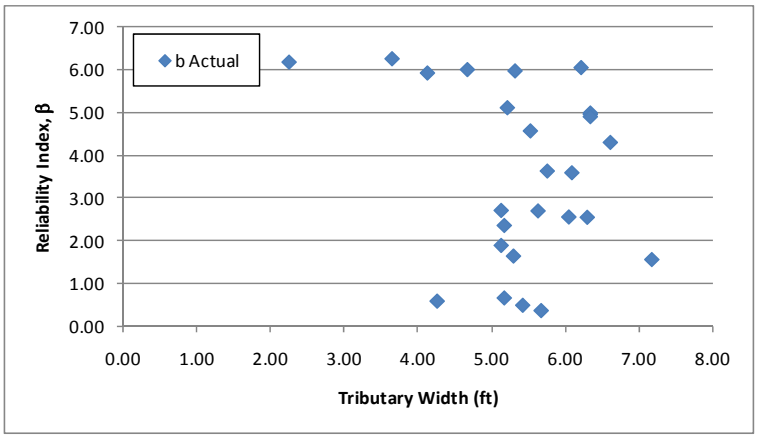


Figure G-367: Flexure Reliability Indices for TX-04 Vehicle

Figure G-368 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The reliability index increases with increasing LRFR rating. The reliability index is approximately 3.5 for a girder with an LRFR rating of 1.0. This is above the target reliability of 2.5, indicating the LRFR live load factors may be over-conservative.

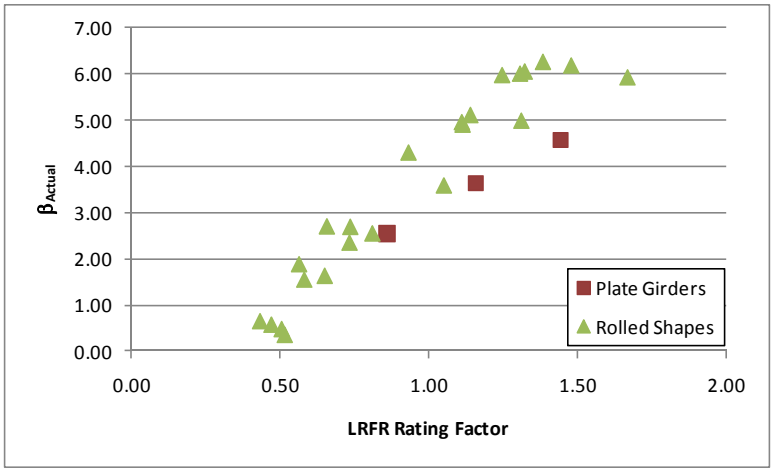
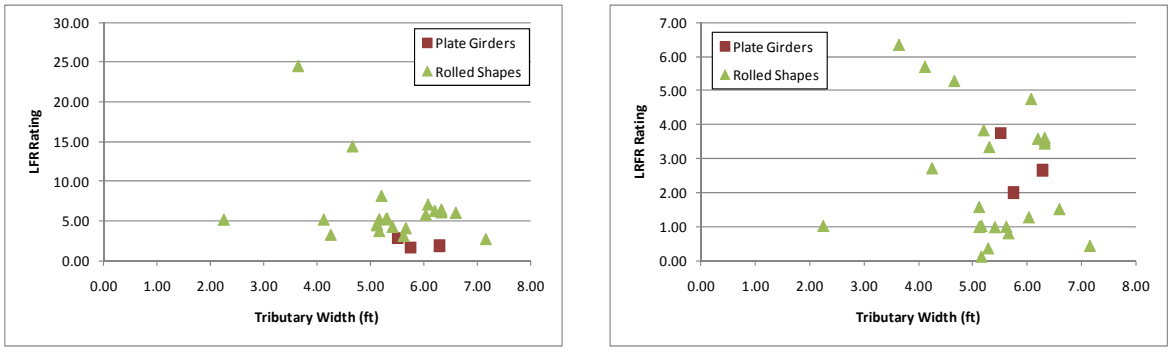


Figure G-368: Flexure Reliability Index vs LRFR Rating for TX-04 Vehicle

G.3.9.2 Shear

G.3.9.2.1 Rating Factors

For shear, there are seven girders with an LRFR rating less than 1.0 and all seven girders are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-369 shows the LFR and LRFR ratings. Most of the ratings are in the same range (0 to 10) with several outliers in the LFR rating.



(a) (b)

Figure G-369: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure G-370 shows the percentage of girders with shear ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 84.6% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 65.4% of girders for ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 15.4% for ADTT ≤ 100, increasing to 34.6% for ADTT ≥ 5,000.

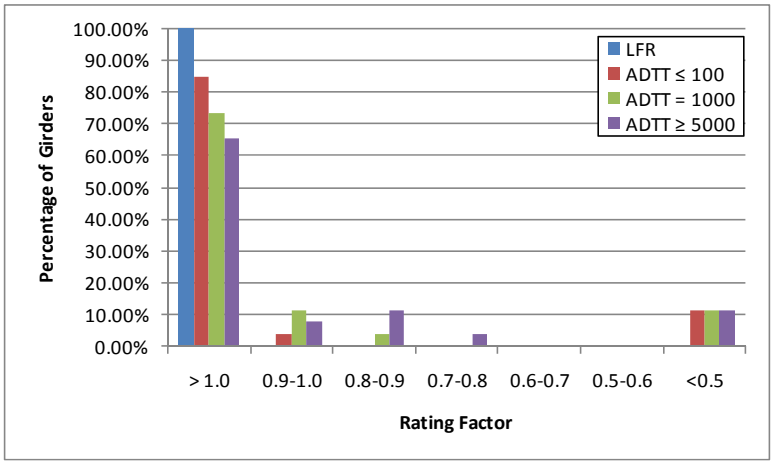


Figure G-370: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

G.3.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-371 shows the comparison of rating factors. The ratio is generally between 0.2 and 0.6 for rolled shapes with plate girders having ratios greater than 1.0. Four girders have an LRFR rating that is greater than the LFR rating.

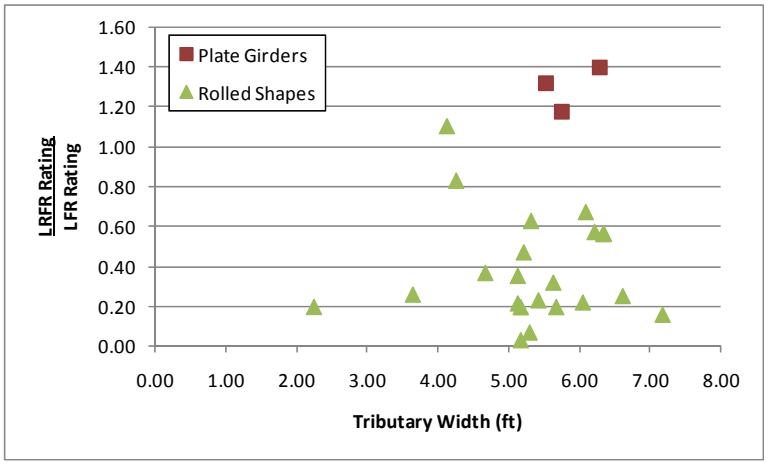


Figure G-371: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

G.3.9.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure G-372. The reliability index is between eight and ten for most girders.

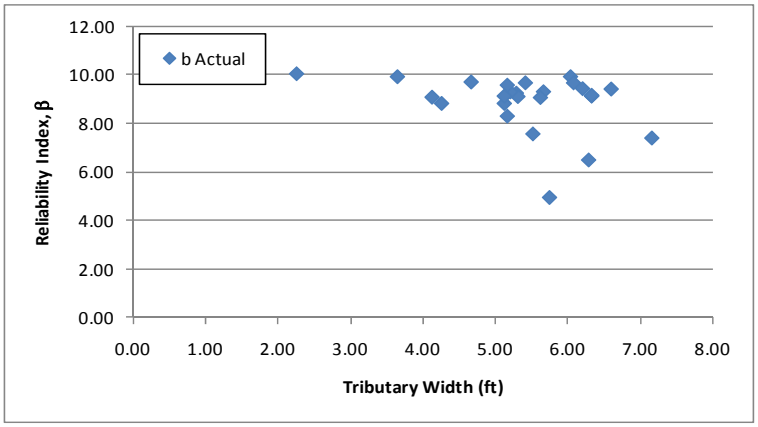


Figure G-372: Shear Reliability Indices for TX-04 Vehicle

Figure G-373 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The reliability index is approximately four for an LRFR rating of 1.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

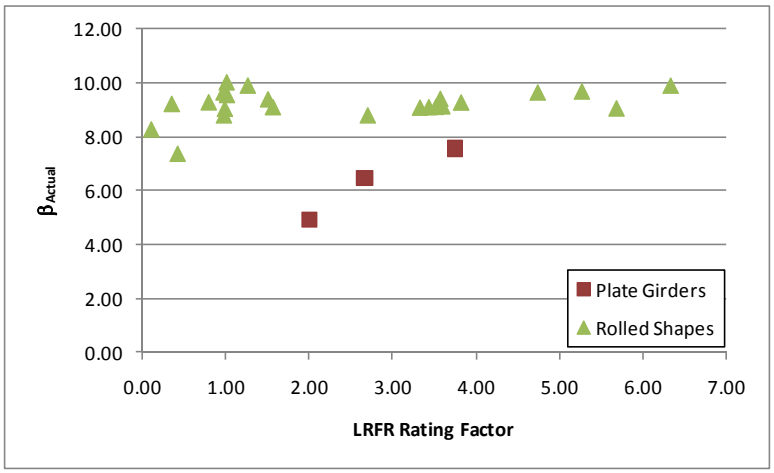
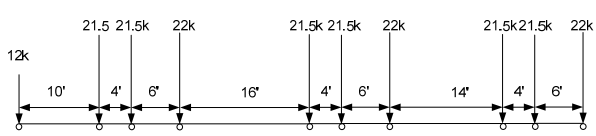
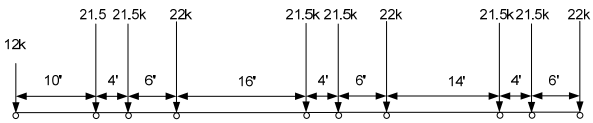


Figure G-373: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

G.3.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-374. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.





plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LFR Loading LRFR Loading

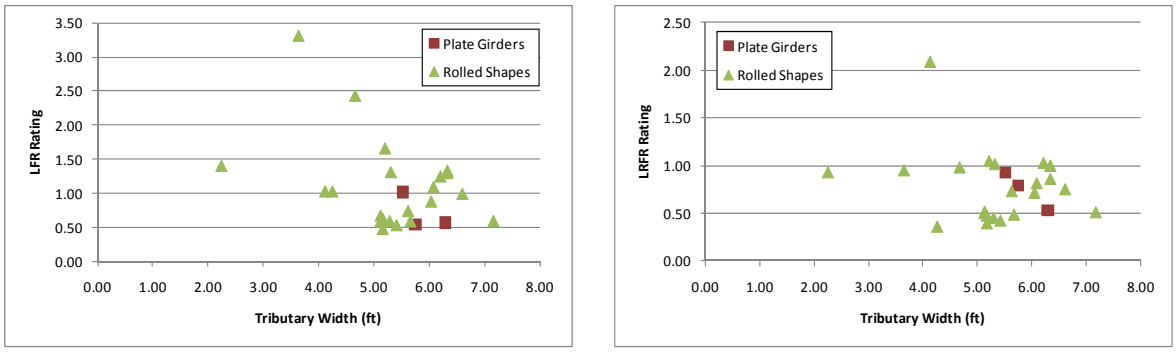
Figure G-374: Vehicle Loadings and Load Factors

G.3.10.1Moment

The following section contains the results for exterior, non-composite steel girders within continuous span bridges for the WA-02 Vehicle.

G.3.10.1.1 Rating Factors

Figure G-375 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are 13 girders with an LFR rating less than 1.0, 21 girders with an LRFR rating less than 1.0, and 13 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 88% of the girders in this subset. Both ratings for this vehicle decrease with increasing tributary widths and are within the same range for the largest tributary widths.



(a) (b)

Figure G-375: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure G-376 shows the percentage of girders with moment ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 42.3% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 3.9% of girders for multiple trip permits with ADTT ≥ 5,000. 50% of girders have LFR ratings that are greater than 1.0. 7.7% more girders have ratings less than 1.0 for LRFR than LFR for single trip, escorted permits; this increases to 46.1% for multiple trip permits with ADTT ≥ 5,000.

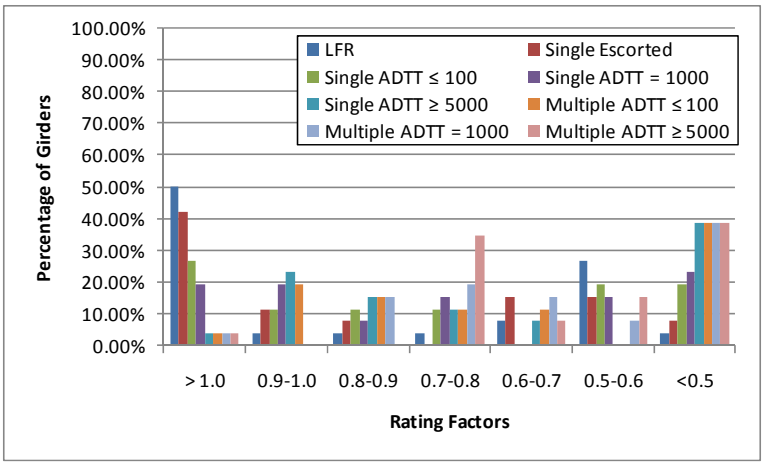


Figure G-376: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

G.3.10.1.2 Rating Factor Comparisons

Figure G-377 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.6 and 0.8. There are three girders with LRFR ratings that are greater than the LFR ratings.

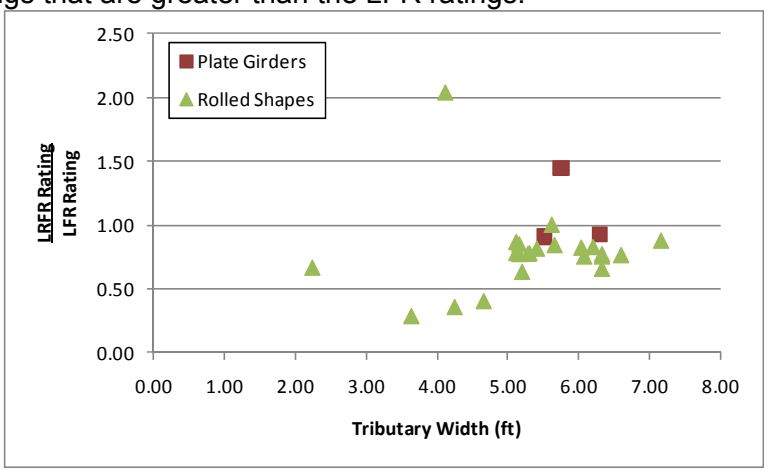


Figure G-377: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

G.3.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-378 shows 13 girders have a reliability index less than the target reliability index of 3.5. The reliability index for most girders is less than 6.0.

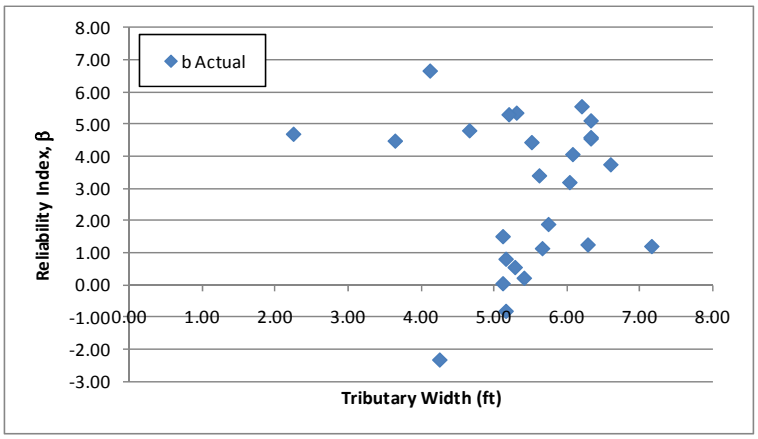


Figure G-378: Flexure Reliability Indices for WA-02 Vehicle

Figure G-379 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 vehicle. The reliability index increases with an increasing rating. The reliability index corresponding to an LRFR rating of 1.0 is approximately 4.5, above the target reliability of 3.5. This indicates the LRFR live load factors may be over-conservative.

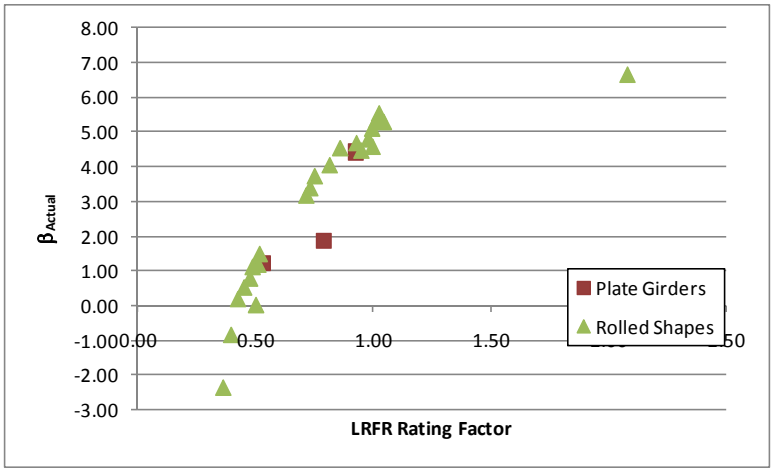
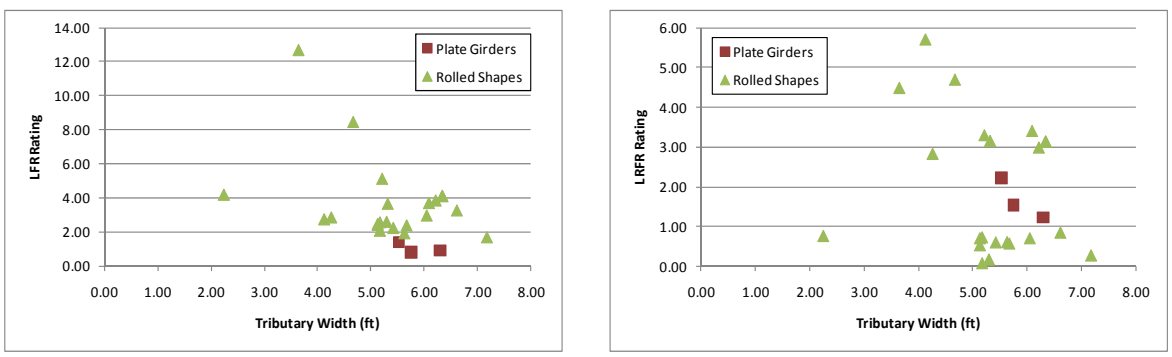


Figure G-379: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

G.3.10.2Shear

G.3.10.2.1 Rating Factors

For shear, there are two girders with LFR rating factors less than 1.0, twelve girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. All twelve girders with an LRFR rating less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-380 shows the LFR and LRFR ratings. Both ratings tend to decrease with increasing tributary width; all of the LRFR ratings are within the range of 0 to 6, while the LFR ratings go up above 12. There is significantly more scatter in the LFR ratings than in the LRFR ratings.



(a) (b)

Figure G-380: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure G-381 shows the percentage of girders with shear ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 57.7% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 50% of girders for multiple trip permits with ADTT ≥ 5,000. 92.3% of girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 34.6% for single trip, escorted permits, increasing to 42.3% for ADTT ≥ 5,000.

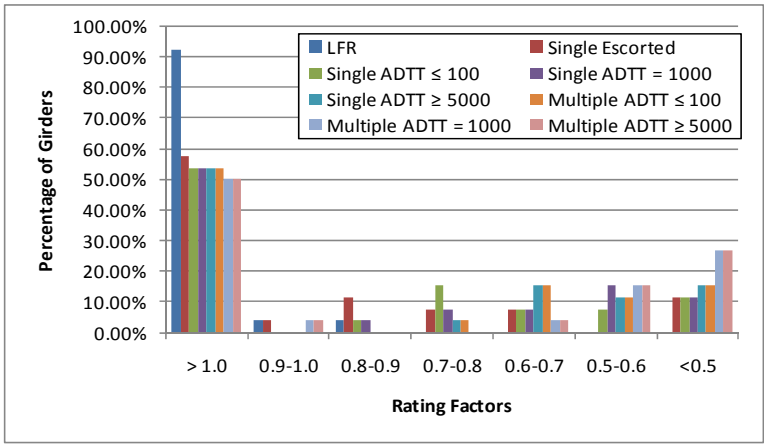


Figure G-381: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

G.3.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-382 shows the comparison of rating factors. The ratio is generally less than 1.0 for rolled shapes; plate girders typically have ratios greater than 1.0. Four girders have LRFR ratings that are greater than the LFR rating.

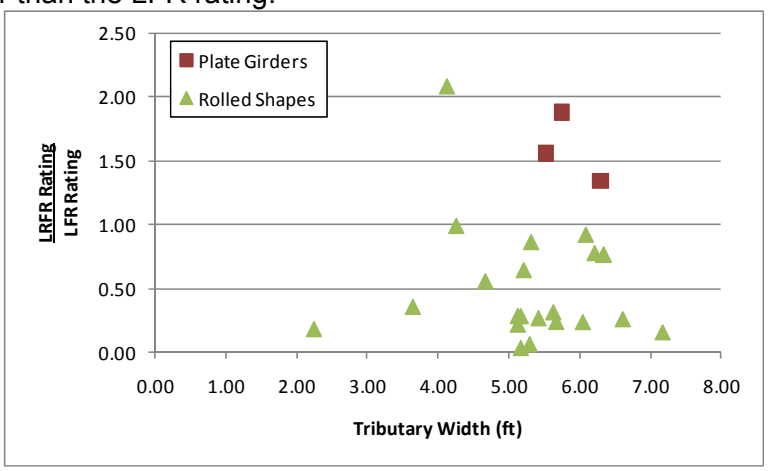


Figure G-382: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

G.3.10.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for no girders as shown in Figure G-383.

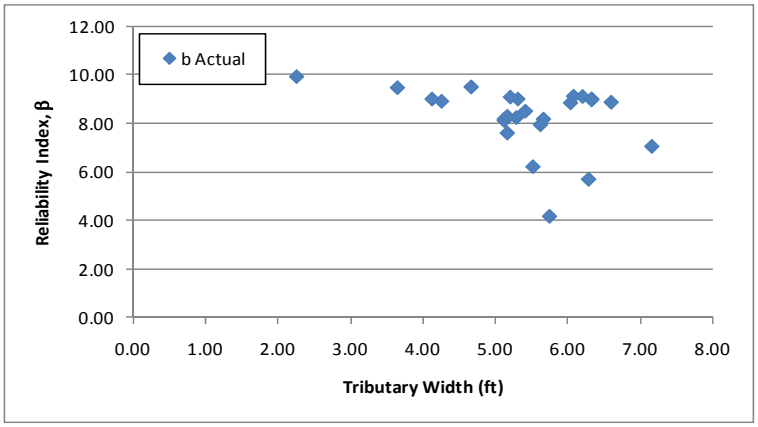


Figure G-383: Shear Reliability Indices for WA-02 Vehicle

Figure G-384 shows the reliability index for shear plotted against the LRFR shear rating for the WA-02 vehicle. The reliability index tends to increase with increasing ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, the target reliability index. This indicates that at least for this vehicle the LRFR live load factors produce the target reliability.

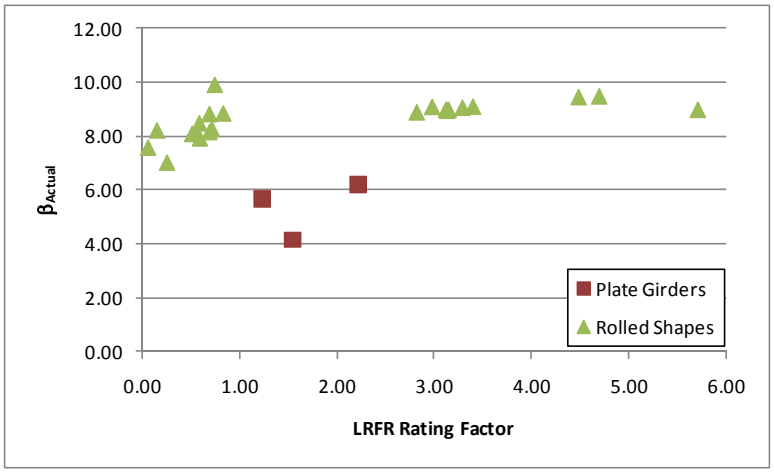


Figure G-384: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

G.3.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-385. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

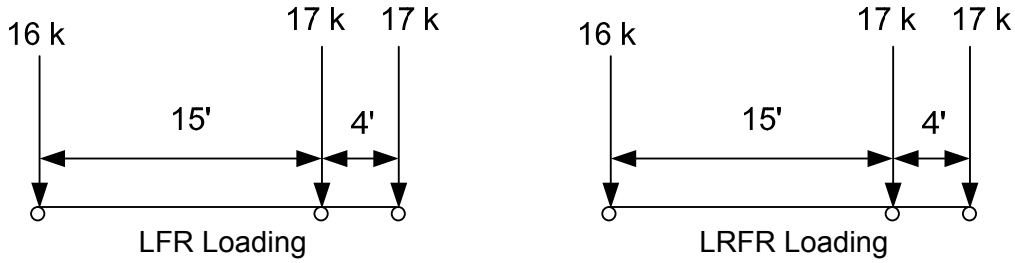
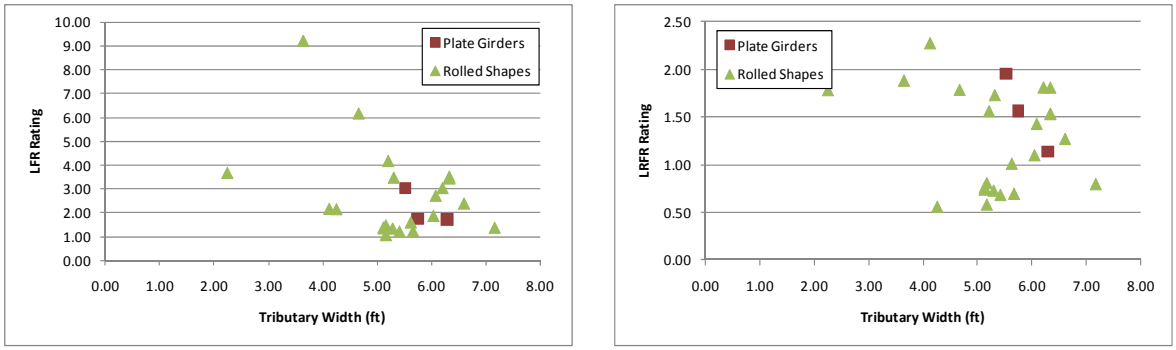


Figure G-385: Vehicle Loadings and Load Factors

G.3.11.1Moment

G.3.11.1.1 Rating Factors

Figure G-386 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, nine girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 96% of the girders in this subset. The LFR ratings decrease significantly with increasing tributary widths while the LRFR ratings decrease slightly with increasing tributary width.



(a) (b)

Figure G-386: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure G-387 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 65.4% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 61.5% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. 34.6% more girders have ratings less than 1.0 for LRFR than LFR for ADTT ≤ 100; this increases to 38.5% for ADTT ≥ 5,000.

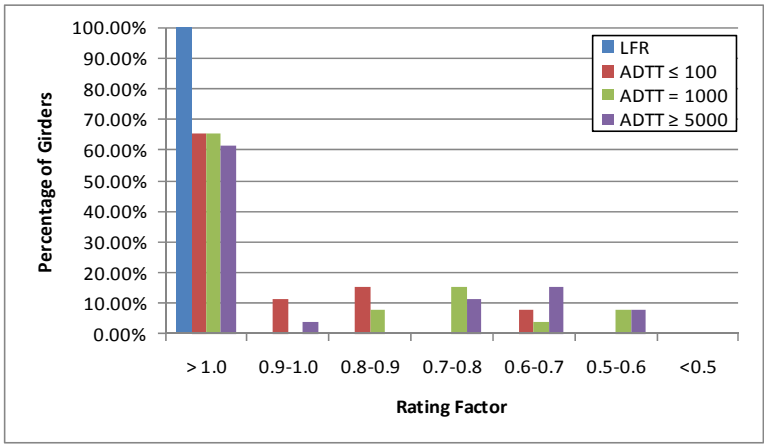


Figure G-387: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

G.3.11.1.2 Rating Factor Comparisons

Figure G-388 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.7, with widely spaced girders having higher ratios. There is one girder with an LRFR rating higher than the LFR rating.

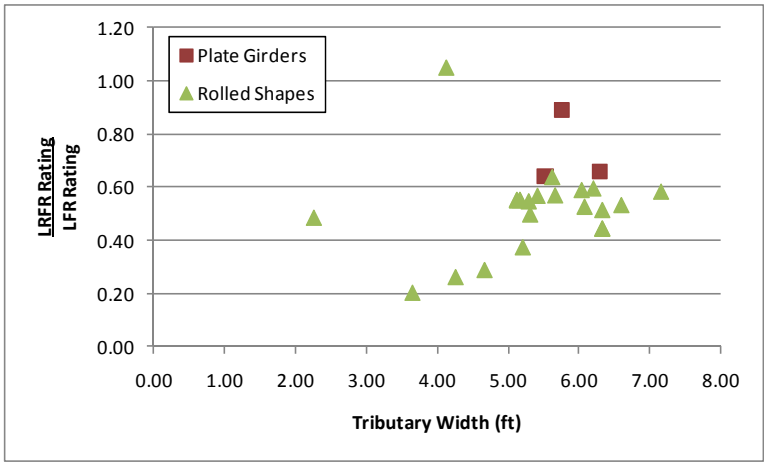


Figure G-388: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

G.3.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-389 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index is widely scattered for this vehicle.

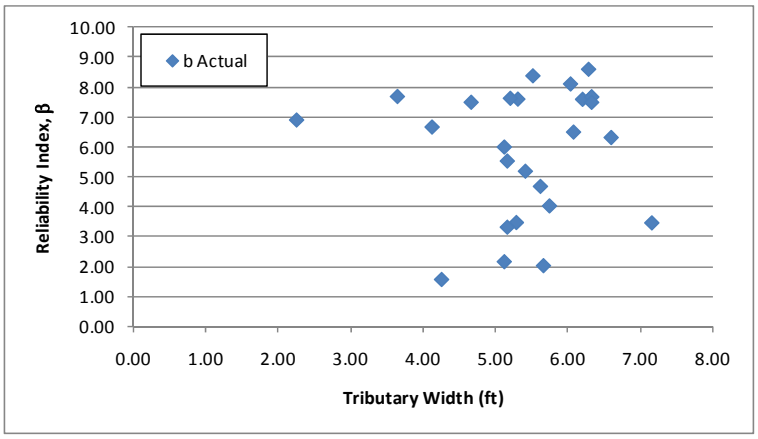


Figure G-389: Flexure Reliability Indices for Type 3 Vehicle

Figure G-390 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 Truck. The reliability index increases with increasing ratings. A reliability index of approximately four is expected for a girder with an LRFR rating of 1.0. This is above the target reliability of 2.5 and indicates the LRFR live load factors may be over-conservative.

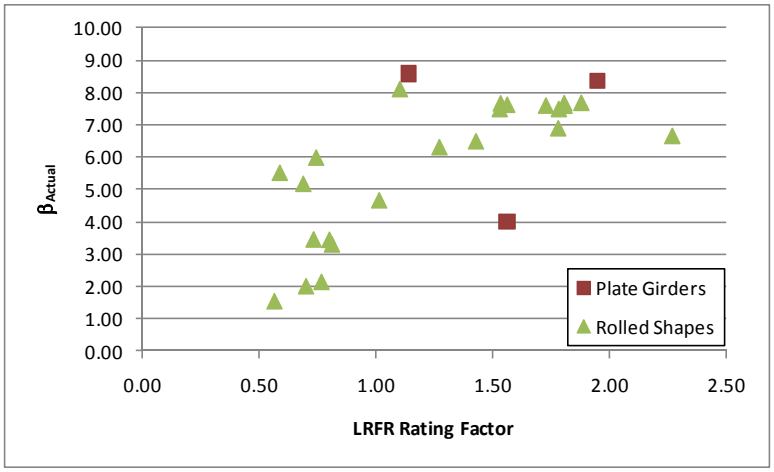
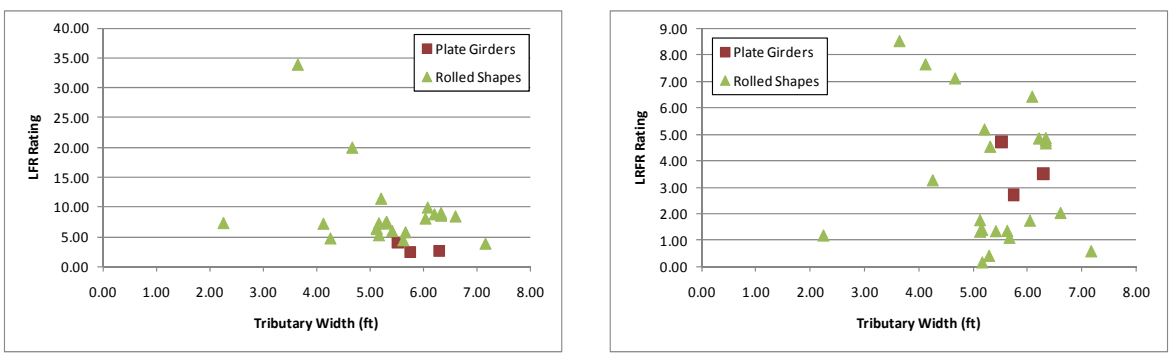


Figure G-390: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

G.3.11.2Shear

G.3.11.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, 16 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 77% of the girders in this subset. Figure G-391 shows the LFR and LRFR ratings. LFR ratings remain relatively constant, ignoring the two outliers, with increasing span while LRFR ratings tend to decrease with increasing span length.



(a) (b)

Figure G-391: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure G-392 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 88.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 84.6% of girders for ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 11.5% for ADTT ≤ 100, increasing to 15.4% for ADTT ≥ 5,000.

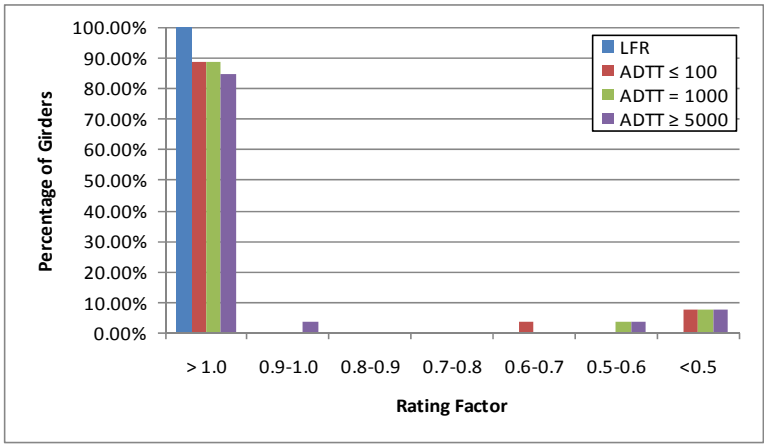


Figure G-392: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

G.3.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-393 show the comparison of rating factors. The ratio is generally less than 0.6 for rolled shapes while all plate girders are above 1.0.

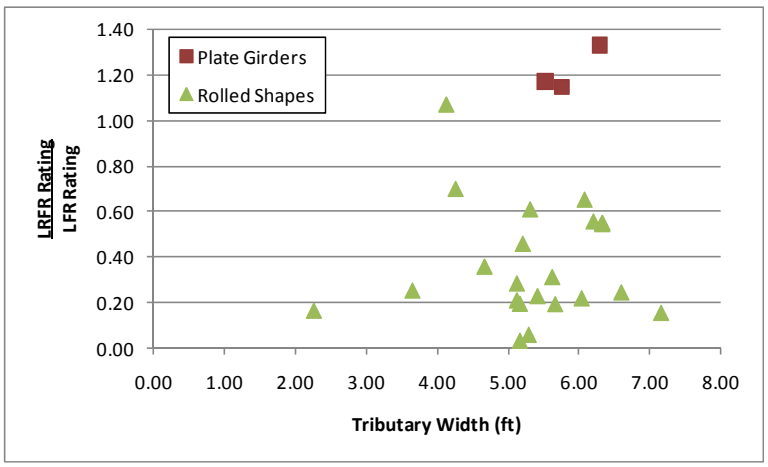


Figure G-393: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

G.3.11.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for zero as shown in Figure G-394. The reliability index is between eight and ten for most of the girders in this group.

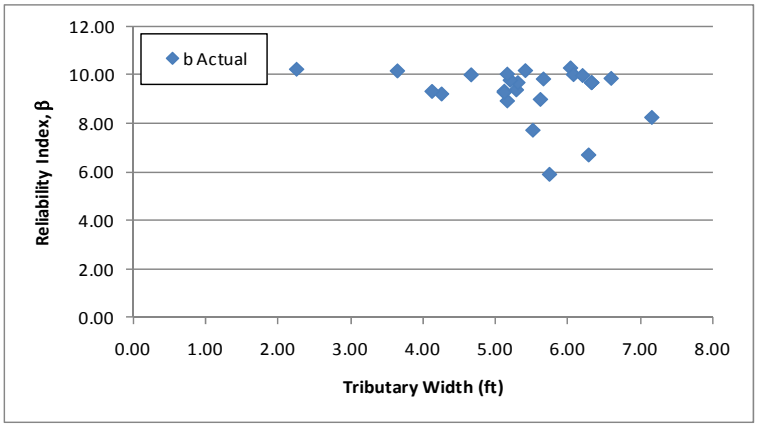


Figure G-394: Shear Reliability Indices for Type 3 Vehicle

Figure G-395 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 Truck. The reliability index increases with the rating factor; the reliability index associated with an LRFR rating of 1.0 is approximately four, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

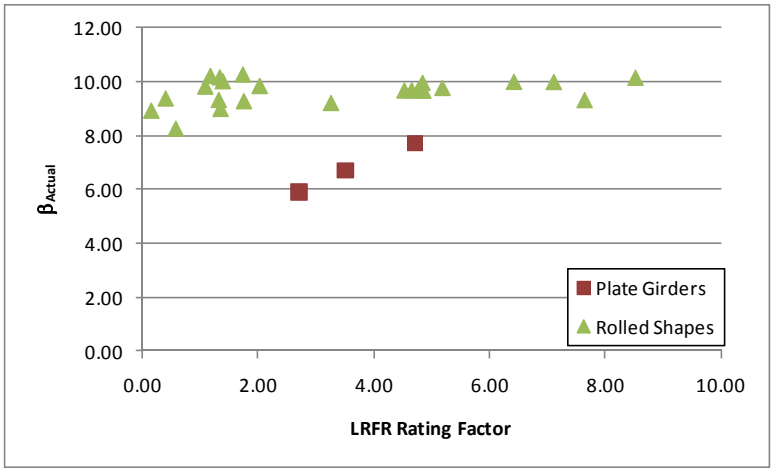


Figure G-395: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

G.3.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-396. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

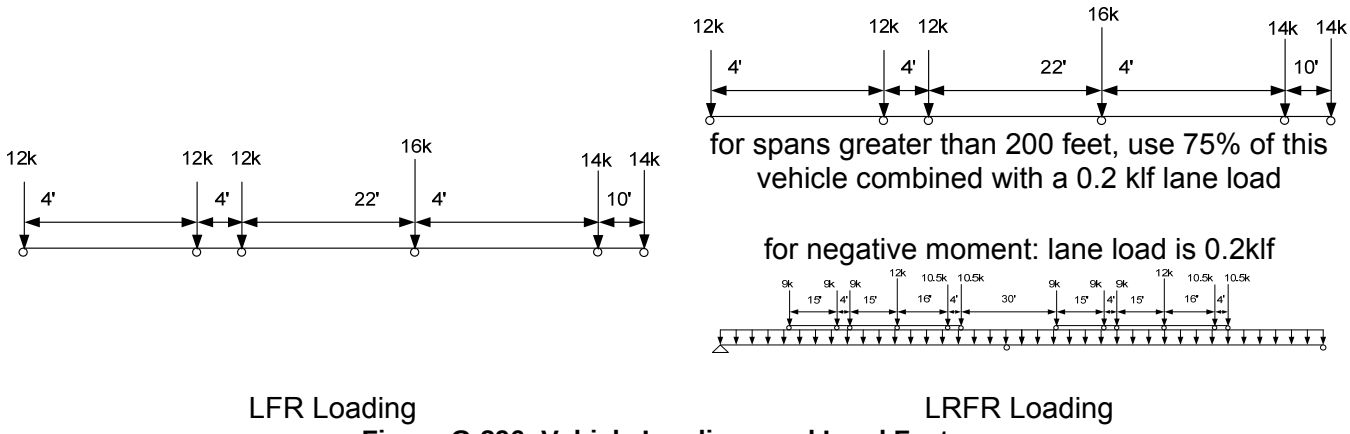
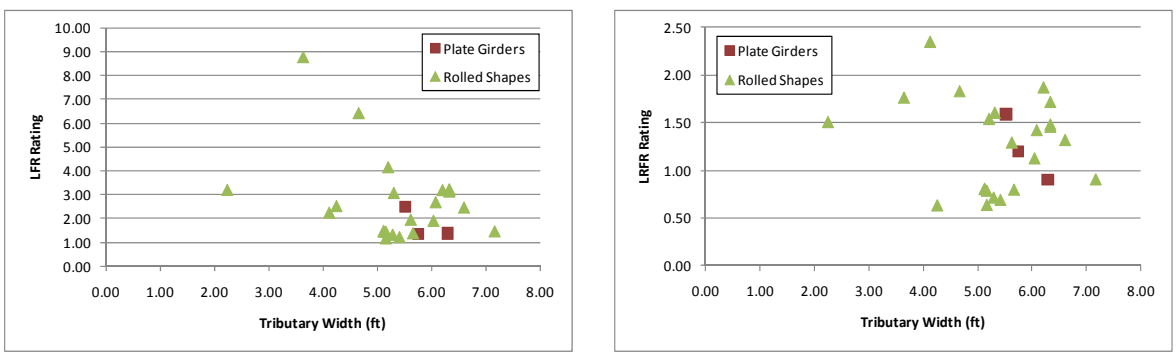


Figure G-396: Vehicle Loadings and Load Factors

G.3.12.1Moment

G.3.12.1.1 Rating Factors

Figure G-397 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, ten girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 96% of the girders in this subset. The LFR ratings decrease significantly with increasing tributary width while the LRFR ratings decrease slightly with increasing tributary width.



(a) (b)

Figure G-397: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure G-398 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 69.2% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 61.5% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. 30.8% more girders have ratings less than 1.0 for LRFR than LFR for ADTT ≤ 100; this increases to 38.5% for ADTT ≥ 5,000.

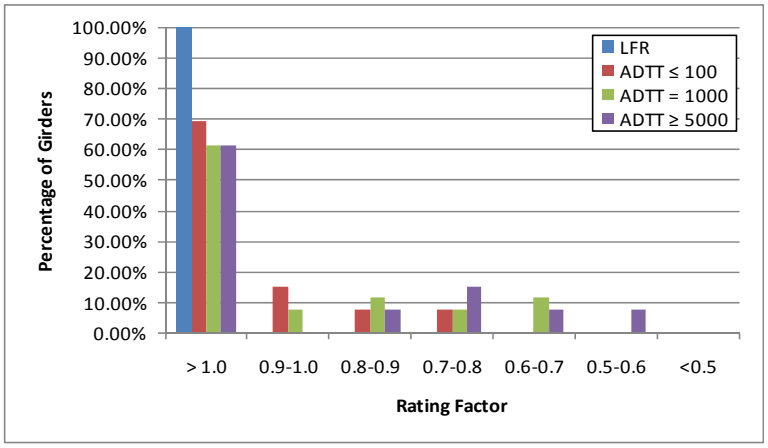


Figure G-398: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

G.3.12.1.2 Rating Factor Comparisons

Figure G-399 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.7, with closely spaced girders having lower ratios. One girder has an LRFR rating that is greater than the LFR rating.

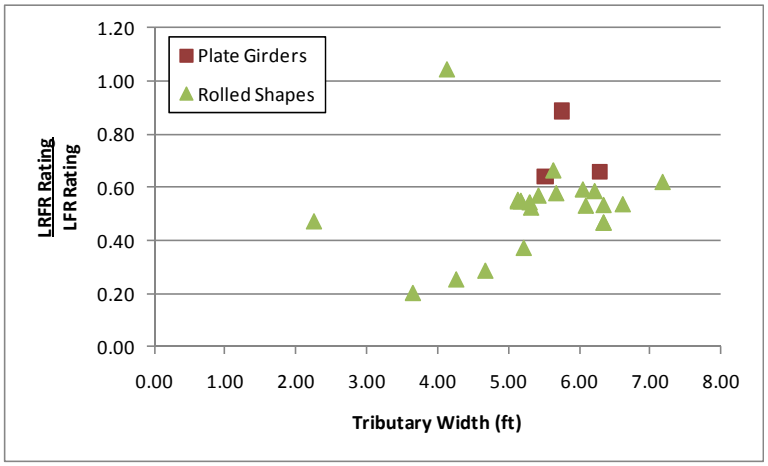


Figure G-399: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

G.3.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-400 shows that seven girders have a reliability index less than the target reliability index of 2.5. The reliability index is less than eight for all girders.

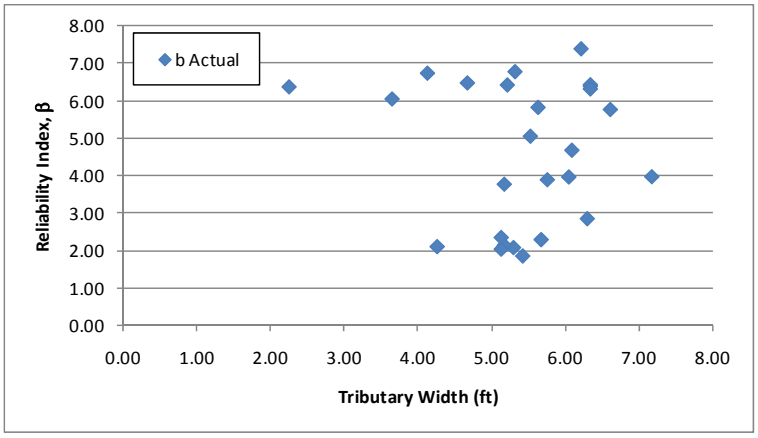


Figure G-400: Flexure Reliability Indices for Type 3-3 Vehicle

Figure G-401 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The reliability index increases with increasing rating and is approximately 3.5 for a rating of 1.0. The target reliability is 2.5; this indicates the LRFR live load factors may be over-conservative.

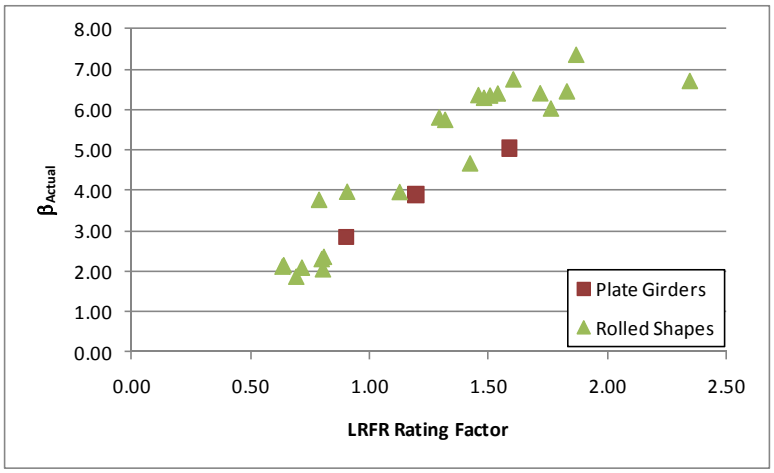
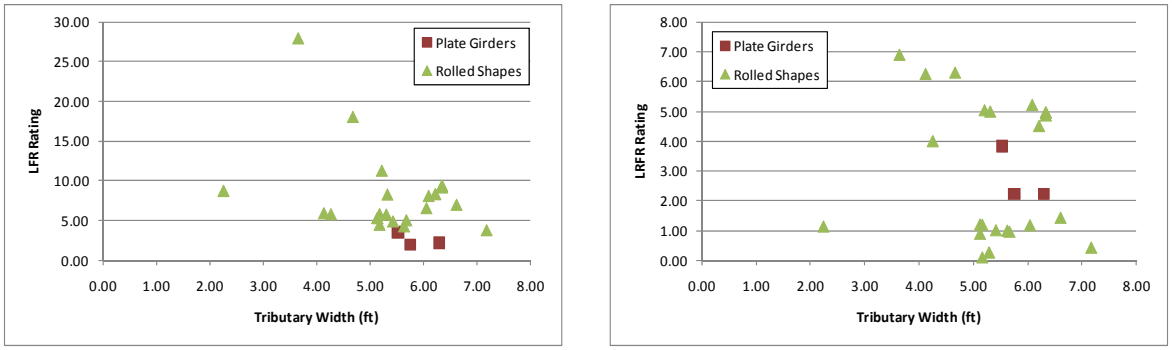


Figure G-401: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

G.3.12.2Shear

G.3.12.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, five girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. All five girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-402 shows the LFR and LRFR ratings. Both ratings decrease with increasing tributary width but the range is much larger for the LFR ratings.



(a) (b)

Figure G-402: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure G-403 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 88.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 73.1% of girders for ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 11.5% for ADTT ≤ 100, increasing to 26.9% for ADTT ≥ 5,000.

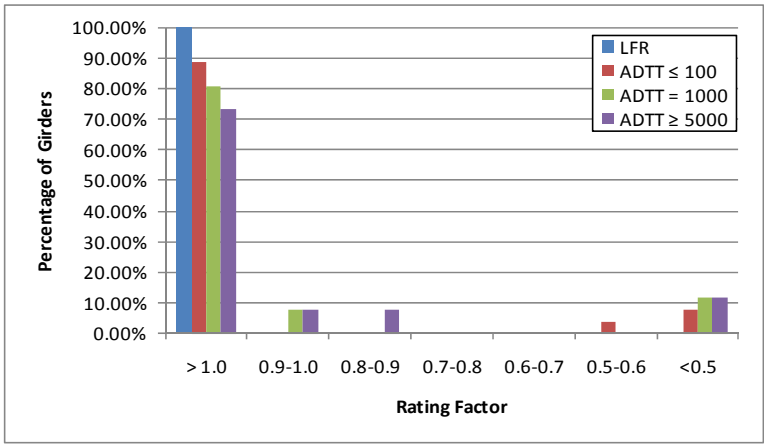


Figure G-403: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

G.3.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-404 show the comparison of rating factors. The ratio is generally less than 0.8 for most rolled shapes; the plate girders all have ratios greater than 1.0. There are four girders with LRFR ratings that are greater than the LFR rating.

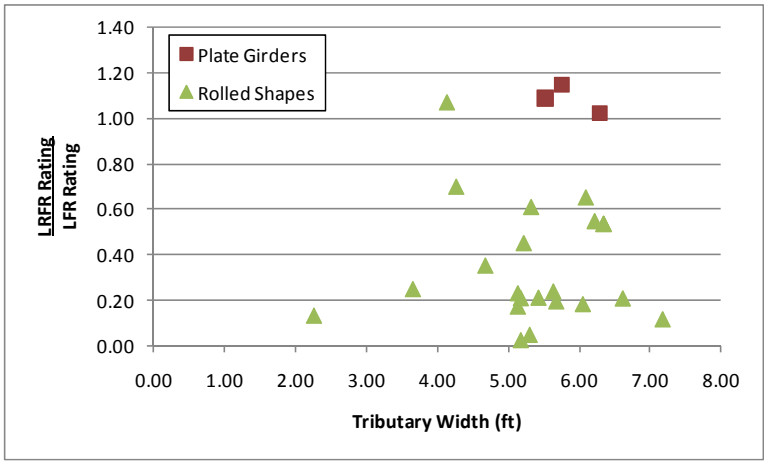


Figure G-404: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

G.3.12.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure G-405. The reliability index is between eight and ten for most girders.

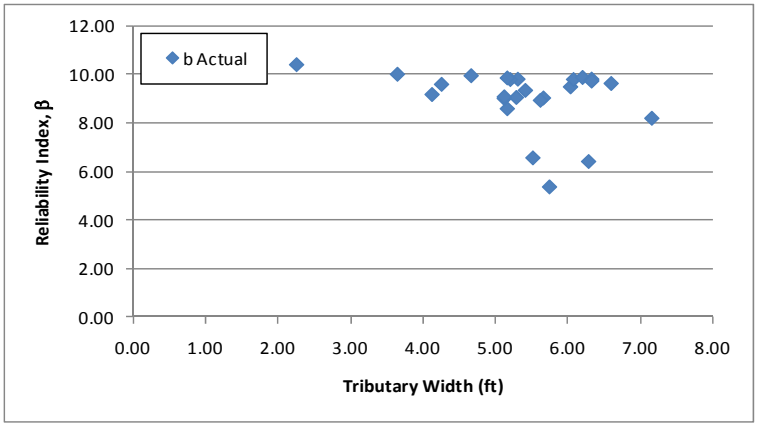


Figure G-405: Shear Reliability Indices for Type 3-3 Vehicle

Figure G-406 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 vehicle. The reliability index increases with increasing LRFR ratings. The reliability index for a girder with an LRFR rating of 1.0 is estimate to be approximately 4.0. This is above the target reliability of 2.5 and indicates that the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

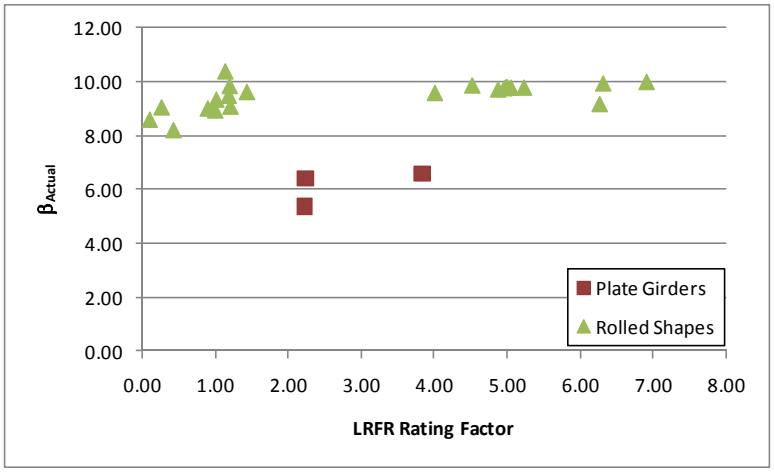


Figure G-406: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Vehicle

G.3.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-407. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

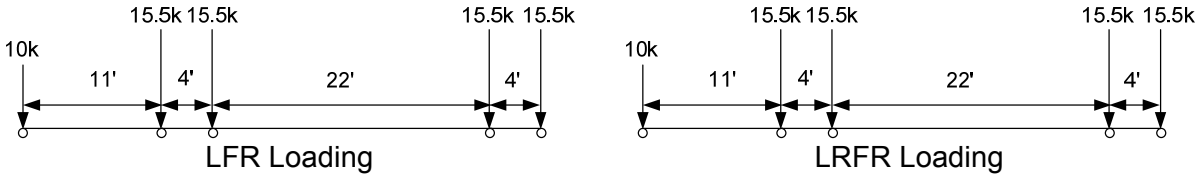
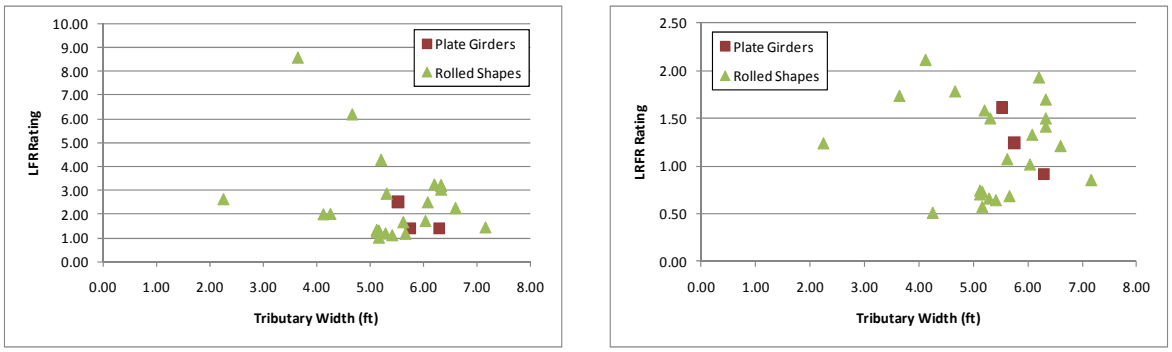


Figure G-407: Vehicle Loadings and Load Factors

G.3.13.1Moment

G.3.13.1.1 Rating Factors

Figure G-408 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, ten girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 96% of the girders in this subset. Both LFR and LRFR ratings decrease with increasing width; the reduction in LFR rating is much larger than that for the LRFR rating.



(a) (b)

Figure G-408: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure G-409 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 69.2% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 53.9% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. 30.8% more girders have ratings less than 1.0 for LRFR than LFR for ADTT ≤ 100; this increases to 46.1% for ADTT ≥ 5,000.

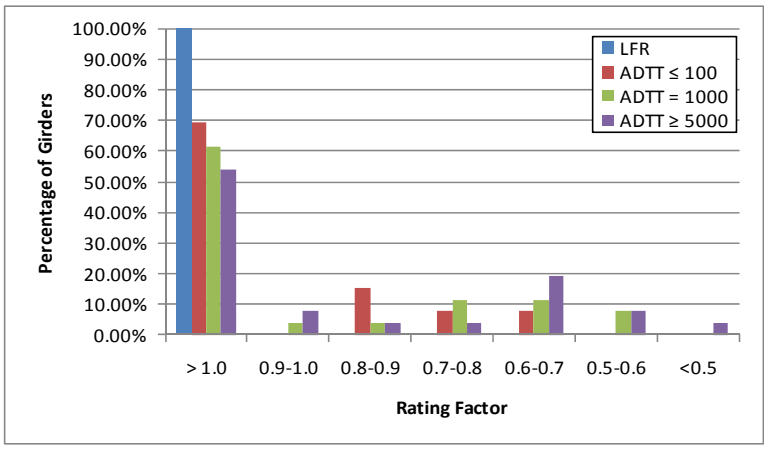


Figure G-409: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

G.3.13.1.2 Rating Factor Comparisons

Figure G-410 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.7, with closely spaced girders having lower ratios. One girder has an LRFR rating that is greater than the LFR rating.

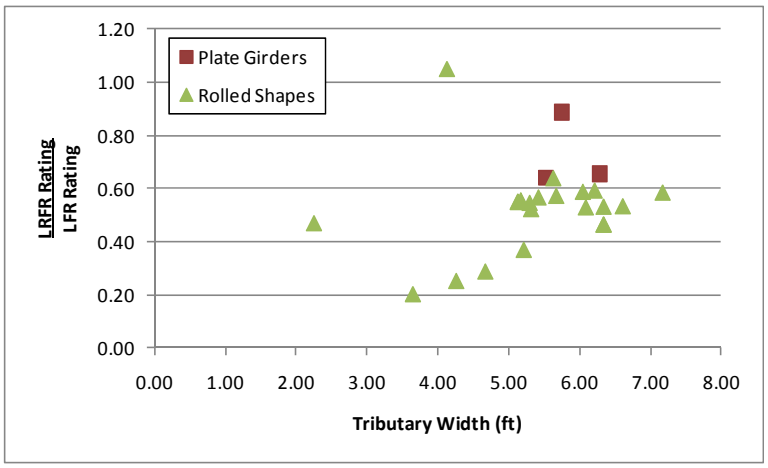


Figure G-410: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

G.3.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-411 shows that eight girders have a reliability index less than the target reliability index of 2.5. The reliability index is less than seven for most girders.

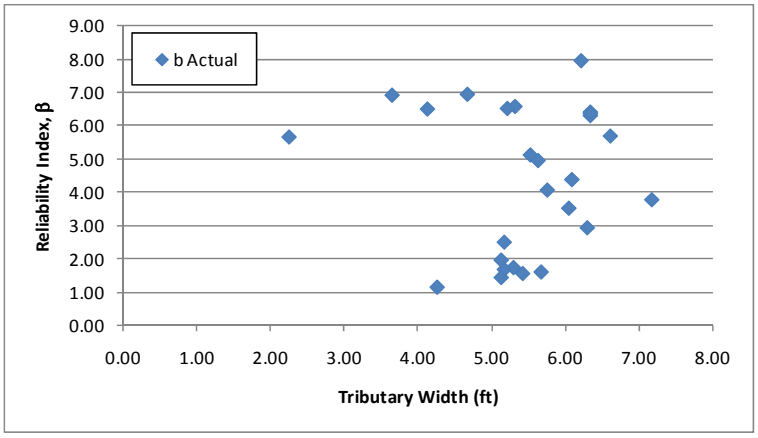


Figure G-411: Flexure Reliability Indices for Type 3S2 Vehicle

Figure G-412 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 Truck. The reliability index increases with increasing LRFR rating. A reliability index of approximately four is expected for a girder with an LRFR rating of 1.0. This indicates the LRFR live load factors may be over-conservative.

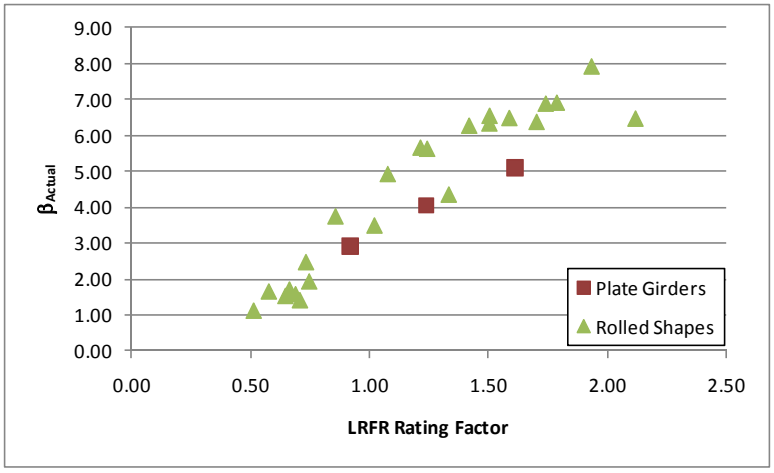
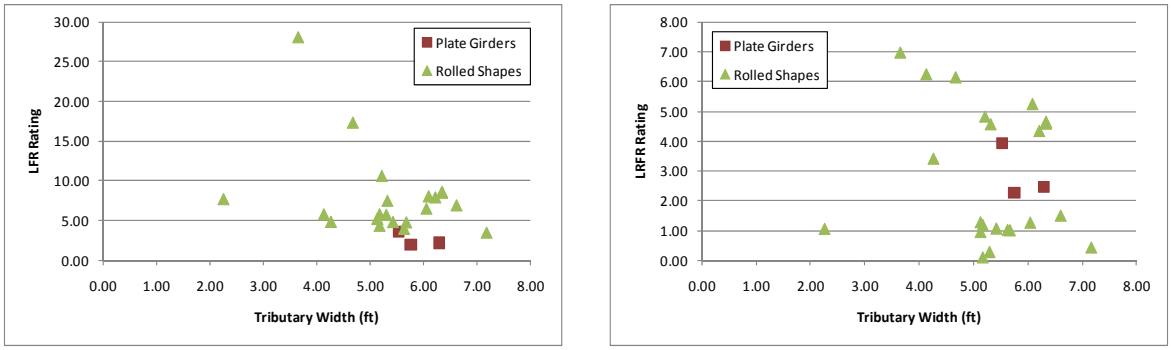


Figure G-412: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

G.3.13.2Shear

G.3.13.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, four girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. All four girders with an LRFR rating less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 85% of the girders in this subset. Figure G-413 shows the LFR and LRFR ratings. Both ratings decrease with increasing tributary widths; the LFR ratings are generally around five for the largest tributary widths while the LRFR ratings are generally around 3.0.



(a) (b)

Figure G-413: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure G-414 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 88.5% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 69.2% of girders for ADTT ≥ 5,000. All girders have LFR ratings greater than 1.0. This is an increase of girders with ratings less than 1.0 of 11.5% for ADTT ≤ 100, increasing to 30.8% for ADTT ≥ 5,000.

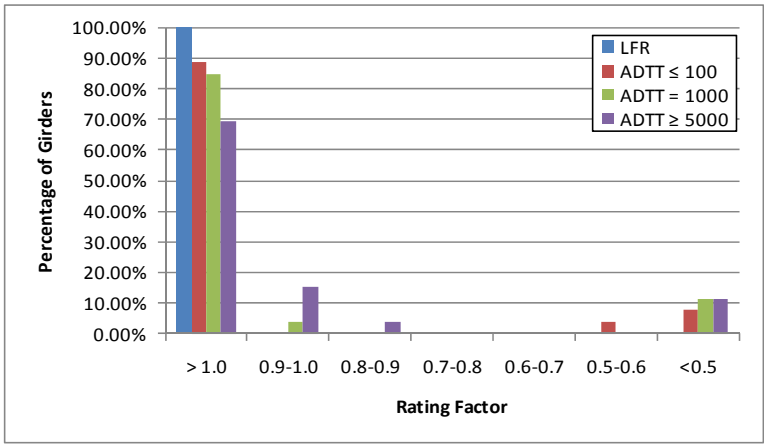


Figure G-414: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

G.3.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-415 show the comparison of rating factors. The ratio is generally less than 1.0 for rolled shapes and greater than 1.0 for plate girders.

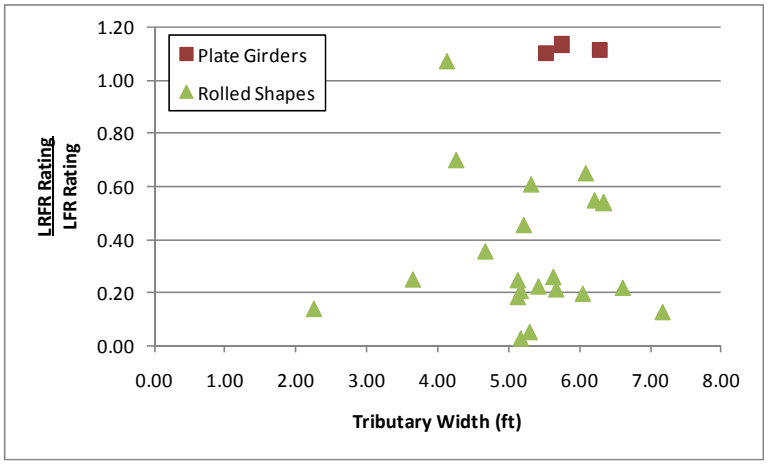


Figure G-415: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

G.3.13.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index for zero girders as shown in Figure G-416. The reliability index is between eight and ten for most girders.

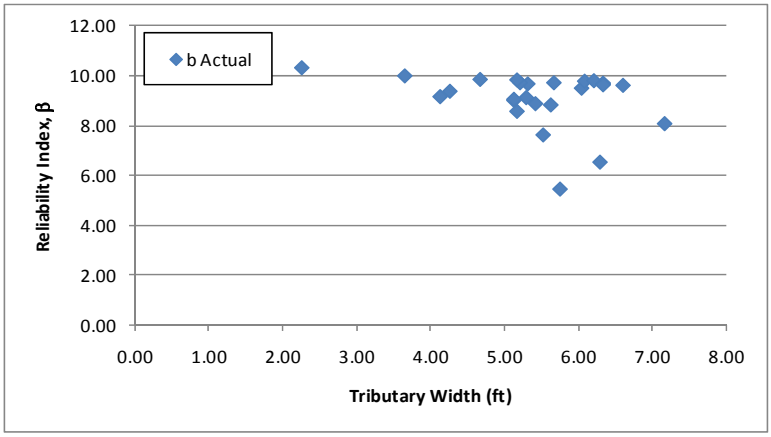


Figure G-416: Shear Reliability Indices for Type 3S2 Vehicle

Figure G-417 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 Truck. The reliability index increases with increasing ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. The girders with high reliability and low ratings are typically controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance instead of the bearing stiffener resistance.

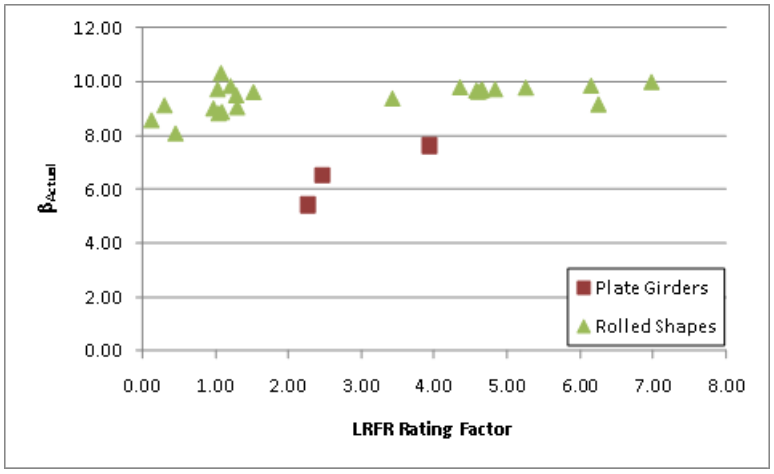


Figure G-417: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

G.3.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table G-5 shows the results for the moment ratings. The heaviest vehicles again have the largest number of girders with ratings less than 1.0, while the other vehicles have relatively few. All vehicles had approximately 90-95% of the girders having LFR ratings greater than the LRFR ratings. Switching from LFR to LRFR has a significant impact on these girders, especially those with tributary widths that are between five and eight feet.

Table G-5: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	26	13	2	1	10	3	0	11	7	13	0	0	0
LRFR Rating less than 1.0		18	12	12	11	12	10	13	13	21	9	10	10
LFR and LRFR Rating less than 1.0		12	2	1	9	3	0	10	7	13	0	0	0
% with LFR RF greater than LRFR RF		96	96	96	92	96	96	92	96	88	96	96	96

G.3.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table G-6 shows the results for the shear ratings. The design vehicle and WA-02 had girders that had LFR ratings less than 1.0, while the all twelve vehicles had at least three girders where the LRFR rating was less than 1.0. All vehicles had 85% of the girders have LFR ratings greater than the LRFR rating. All of the girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating and as shown for the design vehicle, the reduction in rating is very significant.

Table G-6: Shear Rating Factor Results for All 9 Vehicles

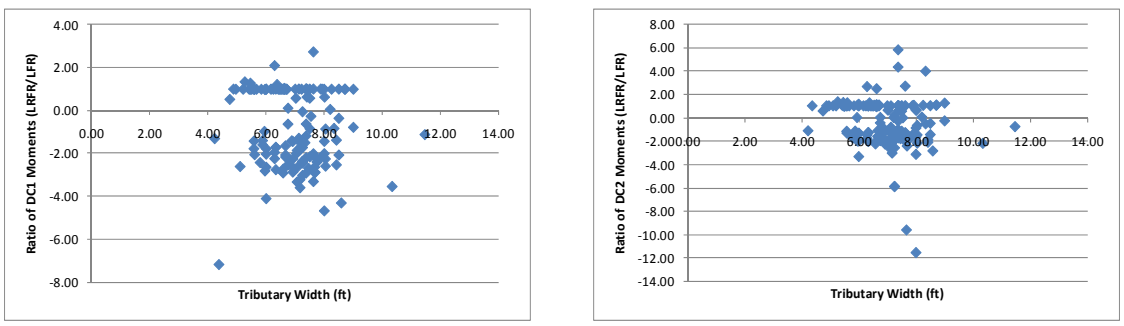
	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	26	2	0	0	0	0	0	0	0	2	0	0	0
LRFR Rating less than 1.0		13	6	5	8	4	3	9	7	12	3	5	4
LFR and LRFR Rating less than 1.0		1	0	0	0	0	0	0	0	0	0	0	0
% with LFR RF greater than LRFR RF		88	85	85	85	85	85	85	85	85	85	85	85

G.4 Exterior Composite Girders

G.4.1 Dead Loads

G.4.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure G-418a, the ratio of unfactored DC1 moments (self-weight, dead loads on non-composite section) is very close to either -2.5 or 1.0 for most girders. The range of this graph has been reduced due to a number of outliers with ratios of dead load moments exceeding +/- 20. Figure G-418b shows that there is similar amount of variation in the loads applied to the composite section (DC2 and DW loads). Again the range of this graph has been reduced to eliminate the outliers.

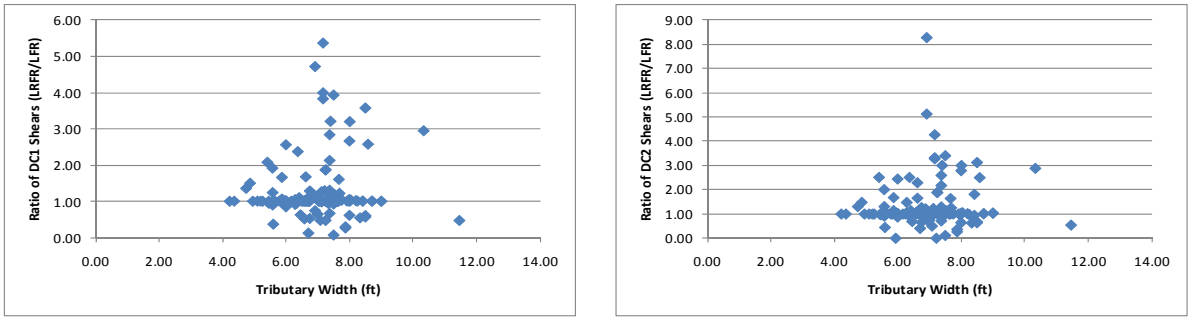


(a) (b)

Figure G-418: Ratio of DC1 LFR Moment to DC1 LRFR Moment (unfactored loads LRFR/LFR)

G.4.1.2 Shear

Figure G-419a shows that numerous girders have a ratio of DC1 shear close to 1.0, but there are also many where the ratio is either above or below 1.0. This is a due to the variation of the critical section for shear. The range of this graph has been reduced from 18 to 6; eliminating four points that were even more different. Figure G-419b shows the same trend as Figure G-419a in that the LFR shear is similar to the LRFR shear. There is a similar amount of variation within the DC2 and DW loads as for the DC1 loads. The range of this plot has been reduced to 9 and eliminates three data points.



(a) (b)

Figure G-419: Ratio of DC1 LFR Shear to DC1 LRFR Shear (unfactored loads LRFR/LFR)

G.4.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure G-420. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

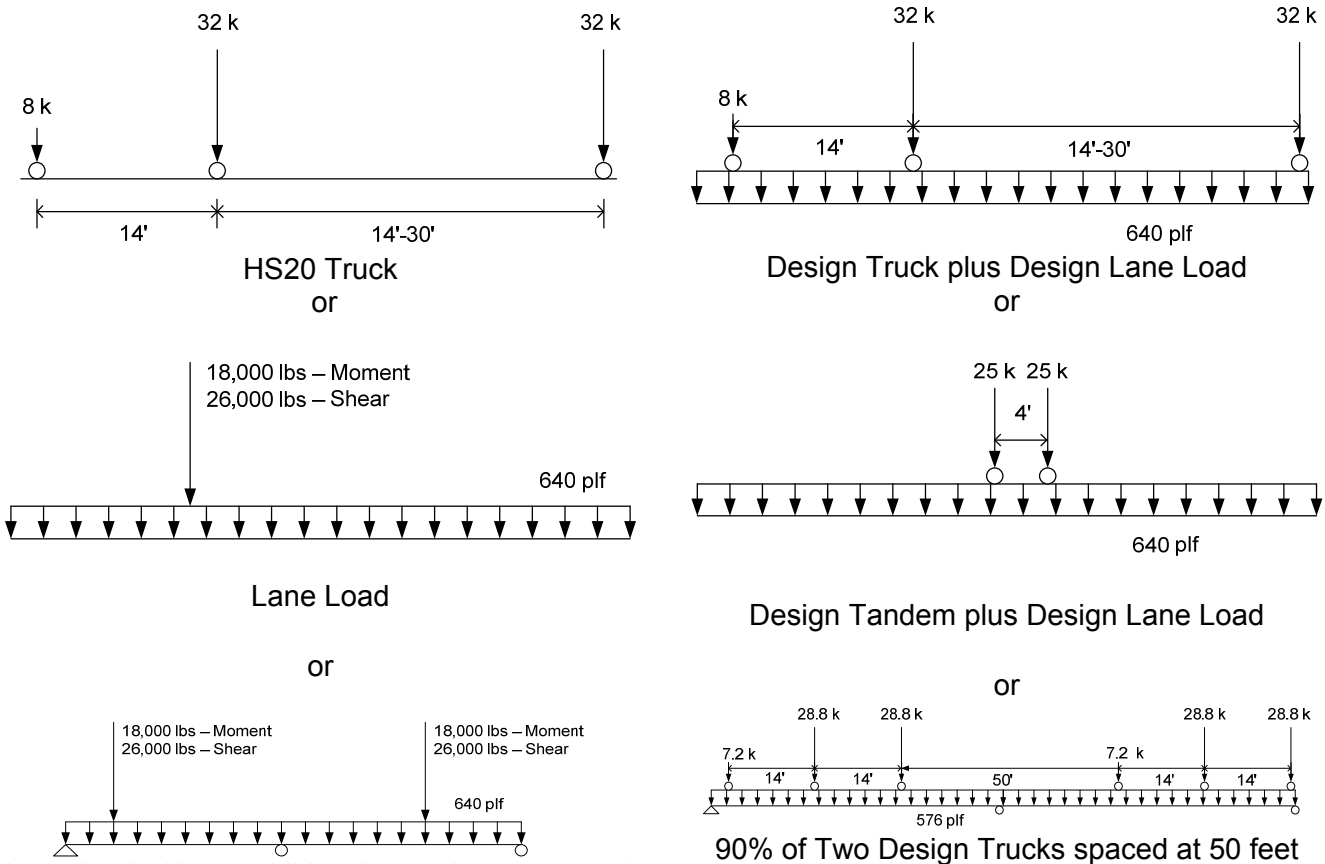
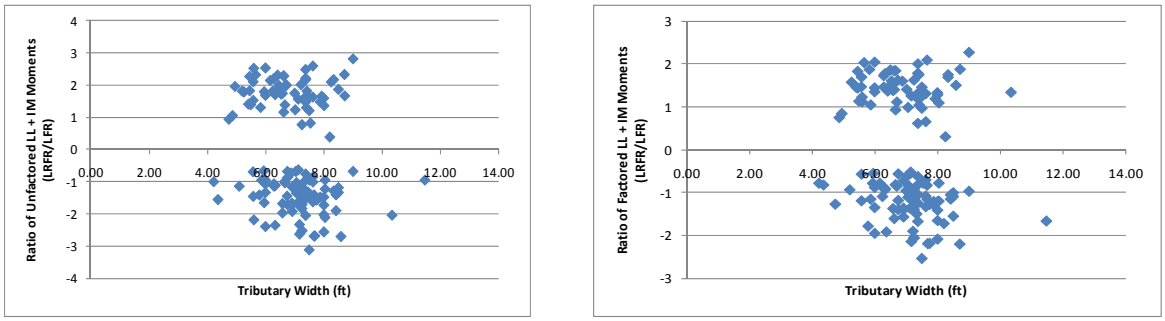


Figure G-420: Vehicle Loadings and Load Factors

G.4.2.1 Moment

G.4.2.1.1 Live Loads

Figure G-421a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.0 and 2.5 or -1.0 and -2.5 for most of the girders within this subset. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure G-421b shows that the results have shifted closer to 1.0 and are between 1.0 and 2.0 or -0.5 and -2.0 for most cases. The positive values indicate the moments are both positive or both negative; the negative values indicate that one value is positive and the other value is negative.



(a) (b)

Figure G-421: Ratio of Unfactored and Factored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

G.4.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure G-422 shows that the ratio of resistance is widely scattered. There is more scatter in the negative values for the moment resistance ratio. The negative ratios are also indicative of the critical location being in a positive moment region for one method and in the negative moment region for the other method.

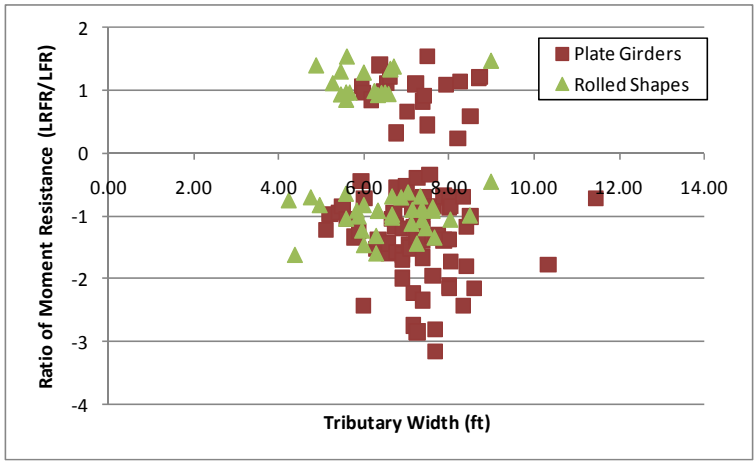
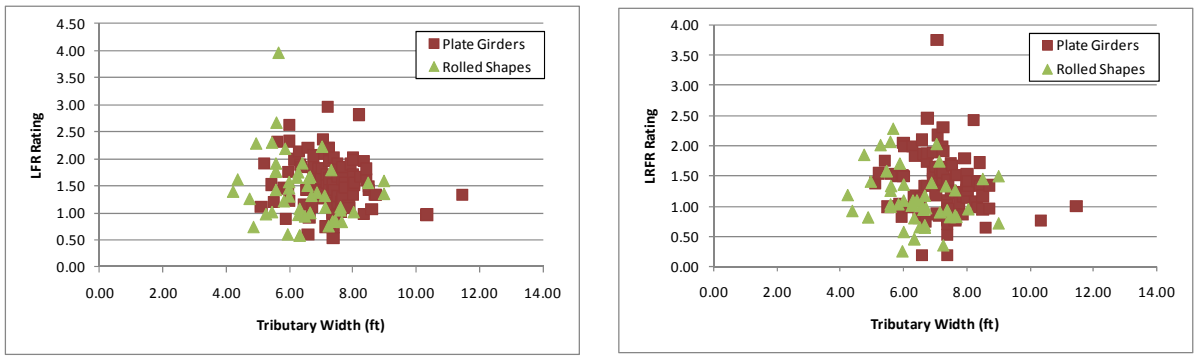


Figure G-422: Ratio of factored Moment Resistance (LRFR/LFR)

G.4.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (148 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 24 girders with LFR ratings less than 1.0, 51 girders with LRFR ratings less than 1.0, and 20 girders where both the LFR and LRFR ratings are less than 1.0. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. Figure G-423 shows the LFR rating factors and LRFR rating factors. The LFR rating is generally between 1.0 and 2.5; the LRFR rating is generally between 1.0 and 2.0.



(a) (b)

Figure G-423: LFR and LRFR Flexure Rating Factors for Design Loadings

G.4.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure G-424. The results indicated that 76% of the girders in this set have LFR ratings greater than LRFR ratings. The ratio of ratings is generally between 0.5 and 1.25 for the range of tributary widths.

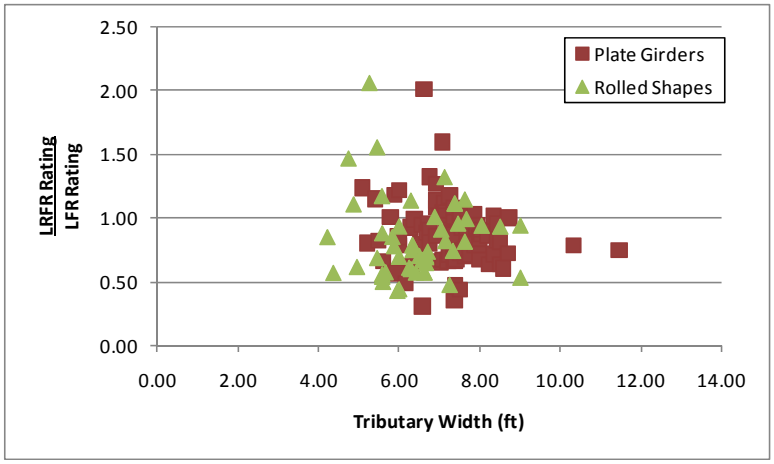


Figure G-424: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure G-425 shows the percentage of girders with LRFR ratings less than 1.0 in each category of LRFR/LFR ratio. The figure indicates that some girders will be affected significantly by the switch from LFR to LRFR, while some girders will rate better with LRFR than with LFR. Most girders will have an LRFR rating that is at least 70% of the LFR rating.

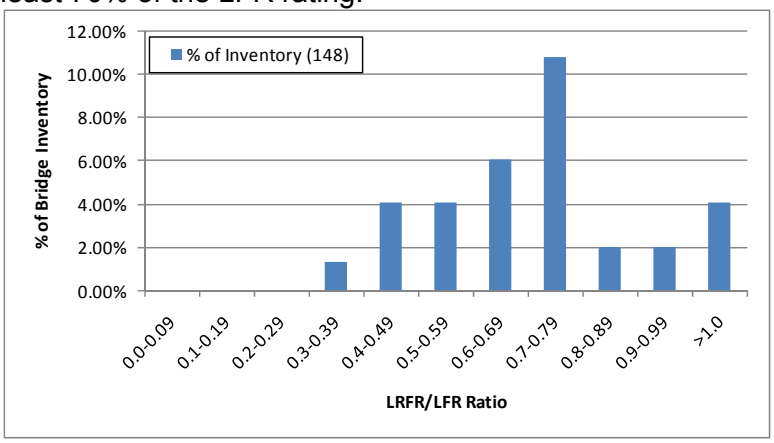


Figure G-425: Distribution of LRFR/LFR ratio for Girders with LRFR Ratings less than 1.0

G.4.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure G-426 shows 47 girders have a reliability index lower than the target value of 3.5 for the inventory level. The reliability index is between four and seven for girders with at least the target level of reliability.

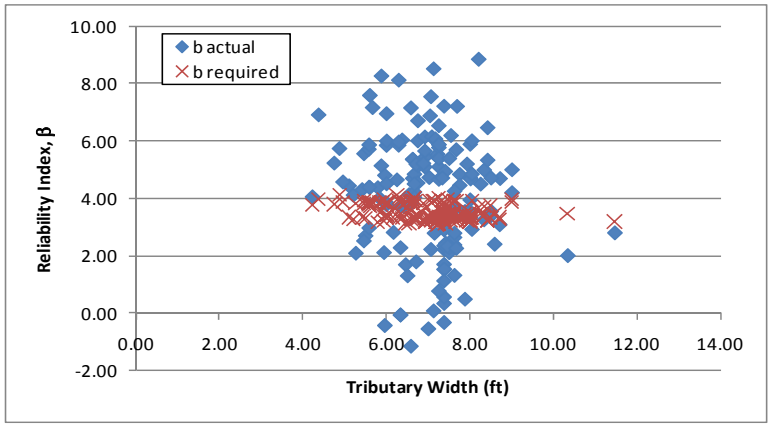


Figure G-426: Flexure Reliability Indices for HL-93 Loading

Figure G-427 shows the reliability index for moment plotted against the LRFR moment rating for the HL-93 vehicle. The reliability index for a rating factor of 1.0 is approximately 3.5, the target reliability level.

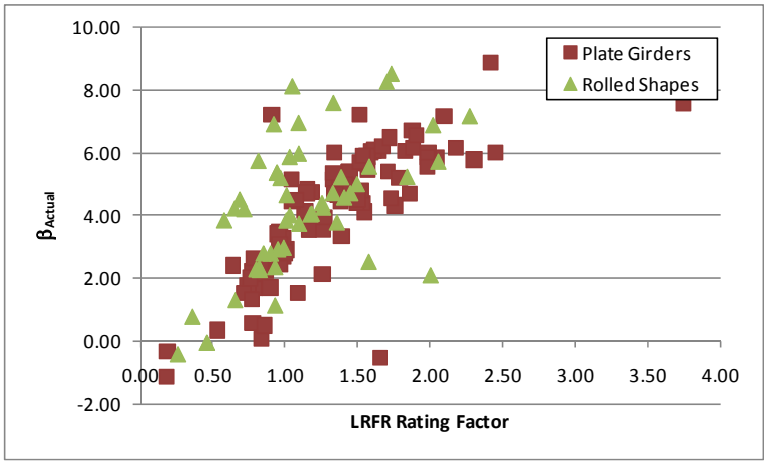
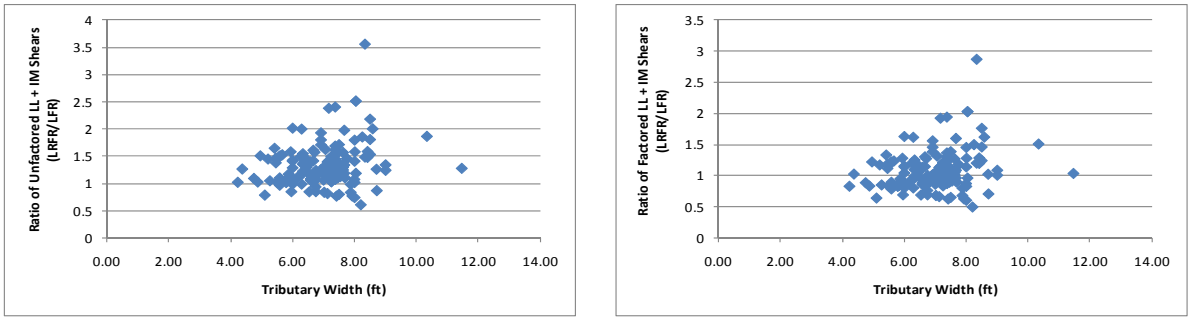


Figure G-427: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Rating

G.4.2.2 Shear

G.4.2.2.1 Live Loads

Figure G-428a shows that the ratio of unfactored shear varies significantly, with most girders having ratios between 1.0 and 1.5 with some outside this range of values. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure G-428b shows that the ratio of factored live load shears has decreased and is generally between 0.75 and 1.25 for most cases.



(a) (b)

Figure G-428: Ratio of Unfactored and Factored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

G.4.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure G-429 shows that the ratio of resistance is generally near 1.0 for rolled shapes. Plate girders are more variable as would be expected due to the variable spacing of the transverse stiffeners.

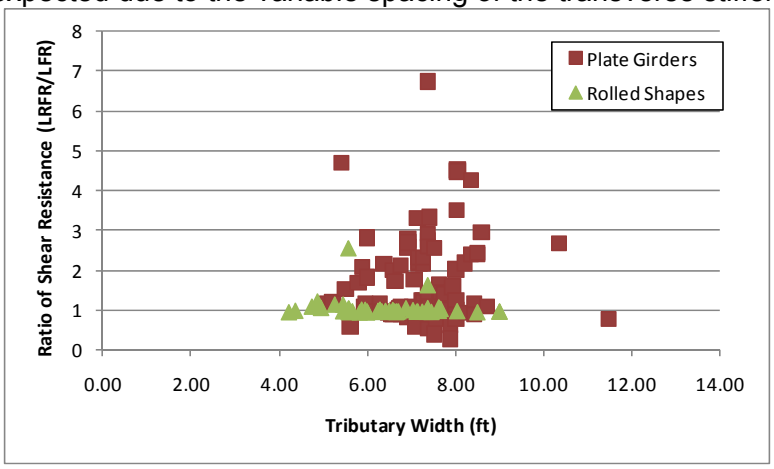
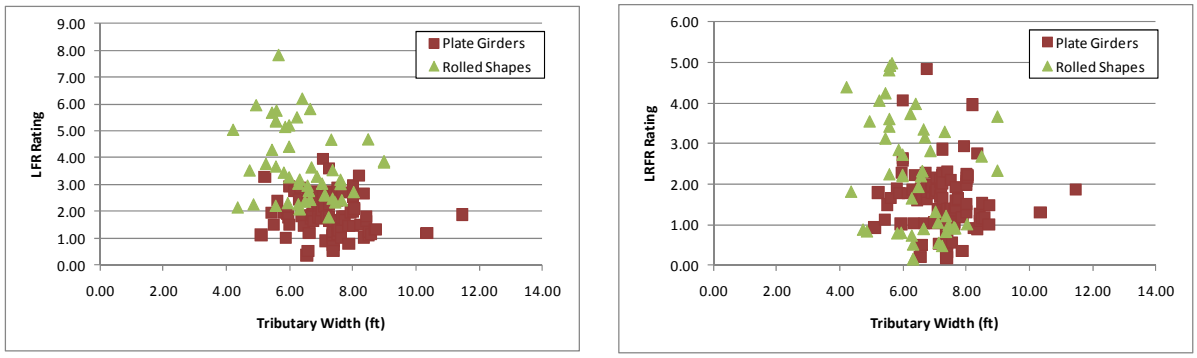


Figure G-429: Ratio of factored Shear Resistance (LRFR/LFR)

G.4.2.2.3 Rating Factors

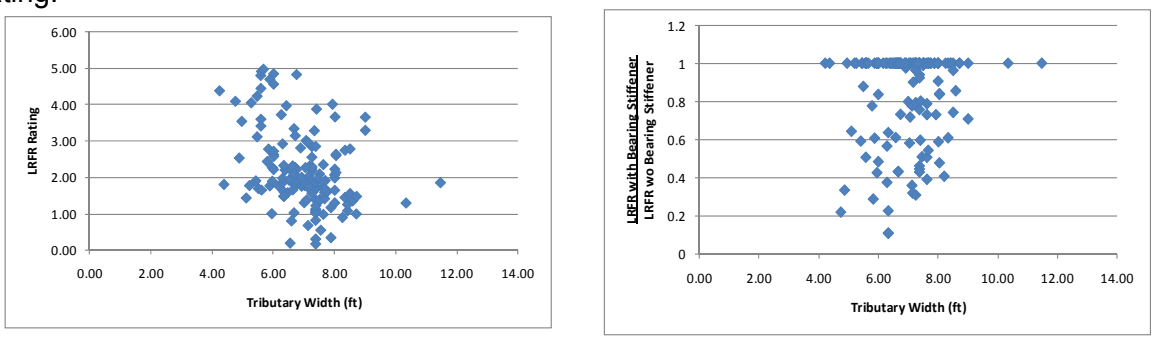
After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are eight girders with LFR ratings less than 1.0, 30 girders with LRFR ratings less than 1.0, and seven girders where both LFR and LRFR ratings are less than 1.0. 23 of the 30 girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR rating was greater than the LRFR rating for 78% of the girders in this subset. Figure G-430 shows the LFR rating factors and LRFR rating factors. The LFR ratings for plate girders are typically above 2.0, while the ratings for plate girders are between one and three. The LRFR ratings are generally lower and more scattered for rolled shapes; plate girders are generally between 1.0 and 2.5.



(a) (b)

Figure G-430: LFR and LRFR Shear Rating Factors for Design Loadings

Figure G-431a shows the LRFR shear ratings when the bearing stiffener rating is ignored, one outlier is removed with a value of 10. There are twenty-one fewer girders with LRFR ratings less than 1.0 when the bearing stiffener rating is ignored. Most of these girders are likely rolled shapes. Figure G-431b shows that a large number of girders have lower ratings when including the bearing stiffener rating. This is 42% of the girders in this group. The bearing stiffener is typically less than 80% of the web shear rating.



(a) (b)

Figure G-431: Effect of Bearing Stiffener Rating on LRFR Shear Ratings

G.4.2.2.4 Rating Factor Comparisons

Figure G-432 shows the ratio of the LRFR rating to the LFR rating. The ratio tends to remain within the range of 0.5 to 1.0, with some plate girders having ratios above 1.0. 22% of girders (mostly plate girders) have an LRFR rating that is greater than the LFR rating.

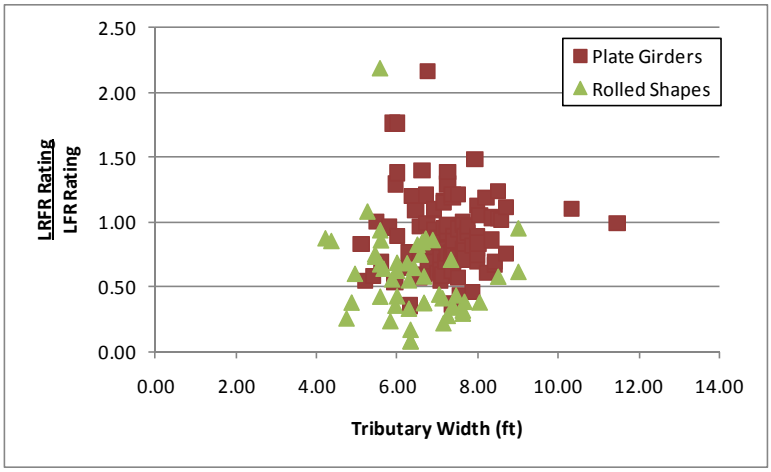


Figure G-432: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure G-433 shows the percentage of girders that have LRFR ratings less than 1.0, and what percentage of the LFR rating the LRFR rating is. The figure shows that most girders with LRFR ratings less than 1.0 are significantly affected by the switch to LRFR. Most girders have an LRFR rating that is less than 40% of the LFR rating; these are also likely to be controlled by the bearing stiffener rating.

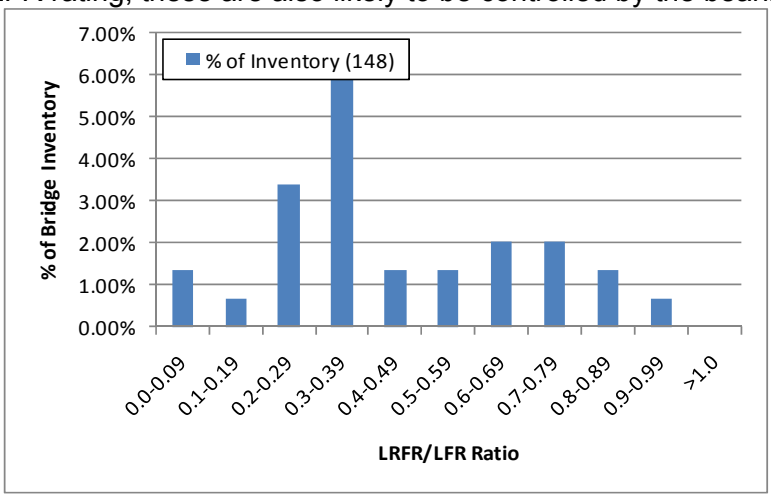


Figure G-433: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

G.4.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure G-434 shows twelve girders have a reliability index less than the target reliability of 3.5. Reliability indices less than zero indicate sections where the applied loads are greater than the resistance. The reliability index is between four and seven for plate girders and between eight and ten for rolled shapes.

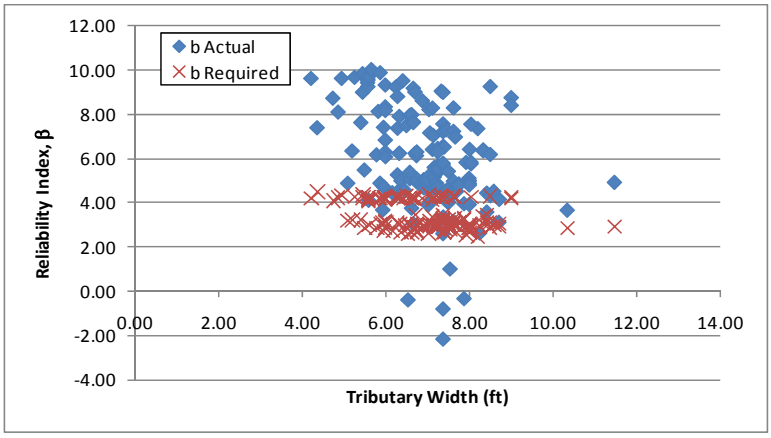


Figure G-434: Shear Reliability Indices for HL-93 Loading

Figure G-435 shows the reliability index for shear plotted against the LRFR shear rating for the design vehicle. The reliability index increases with increasing rating factor. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, the target reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

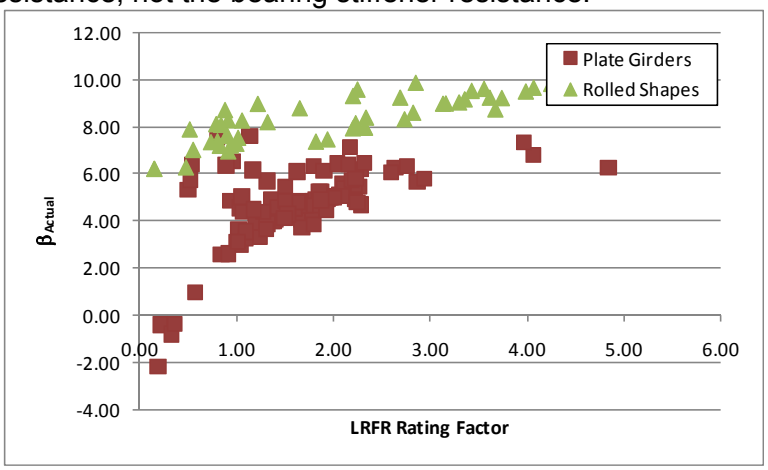


Figure G-435: Shear Reliability Index vs LRFR Shear Rating for HL-93 Loading

G.4.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-436. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

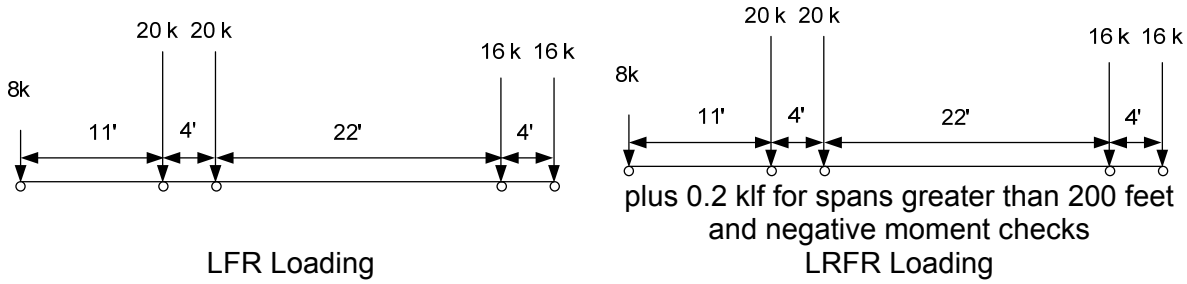


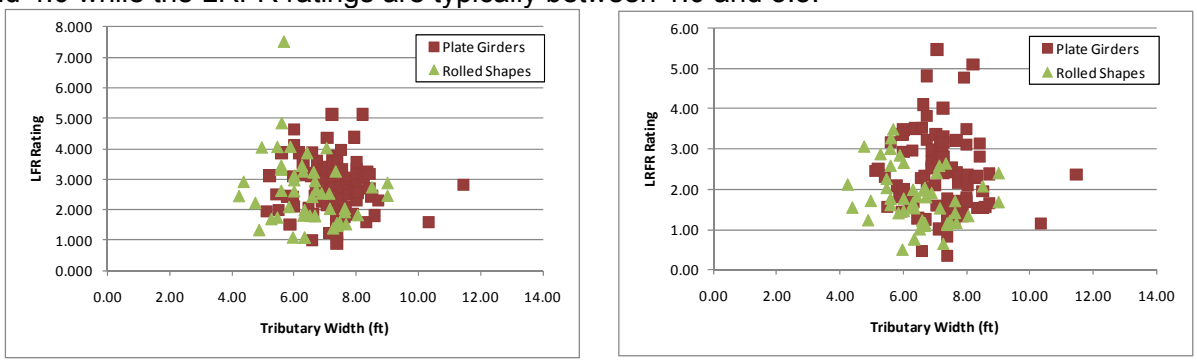
Figure G-436: Vehicle Loadings and Load Factors

G.4.3.1 Moment

The following section contains the results for exterior, composite steel girders within continuous span bridges for the DE-07 Vehicle.

G.4.3.1.1 Rating Factors

Figure G-437 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are two girders with an LFR rating less than 1.0, seven girders with an LRFR rating less than 1.0, and two girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 80% of the girders in this subset. The LFR ratings are typically between 2.0 and 4.0 while the LRFR ratings are typically between 1.0 and 3.5.



(a) (b)

Figure G-437: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure G-438 shows the percentage of girders with moment ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 95.3% of girders have LRFR ratings less than 1.0 for ADTT ≤ 100. This drops to 92.6% of girders for ADTT ≥ 5,000. 98.7% of girders have LFR ratings greater than 1.0. 3.4% more girders have ratings less than 1.0 when LFR is switched to LRFR with an ADTT ≤ 100; when LRFR with ADTT ≥ 5,000 is used, 6.1% more girders are affected.

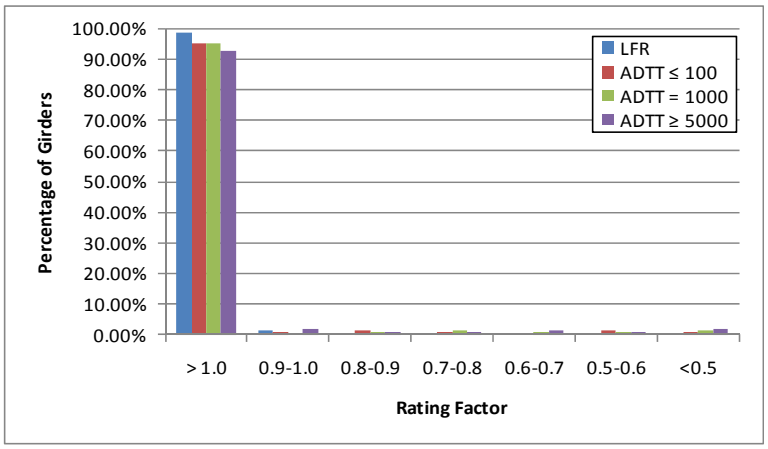


Figure G-438: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

G.4.3.1.2 Rating Factor Comparisons

Figure G-439 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.5 to 1.25. 20% of girders have an LRFR rating that is greater than the LFR rating for this vehicle.

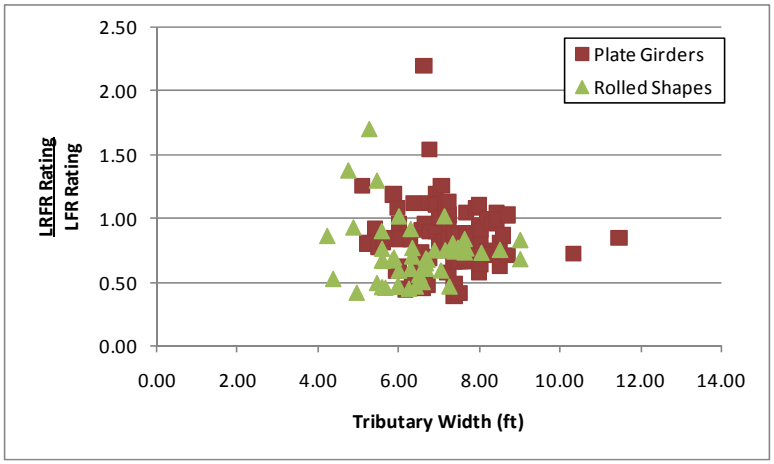


Figure G-439: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

G.4.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-440 shows three girders have a reliability index less than the target reliability index of 2.5. The reliability index is greater than four for most girders.

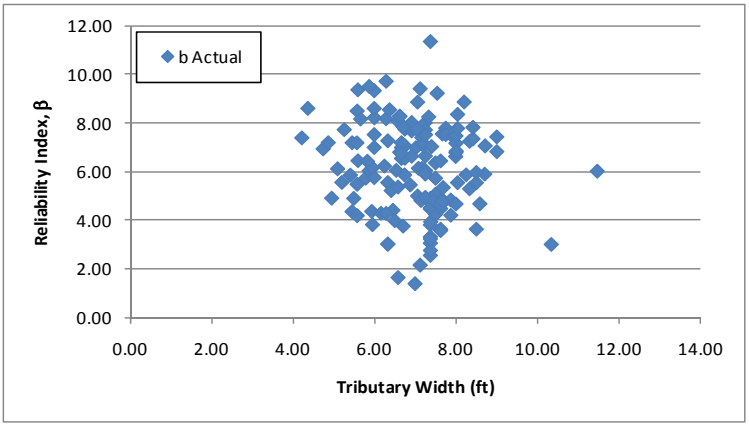


Figure G-440: Flexure Reliability Indices for DE-07 Vehicle

Figure G-441 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 vehicle. The reliability index increases with increasing rating factors. A rating factor of 1.0 corresponds to a reliability index of 2.5, the target reliability index. This indicates that for moment, the live load factors provide the target level of reliability.

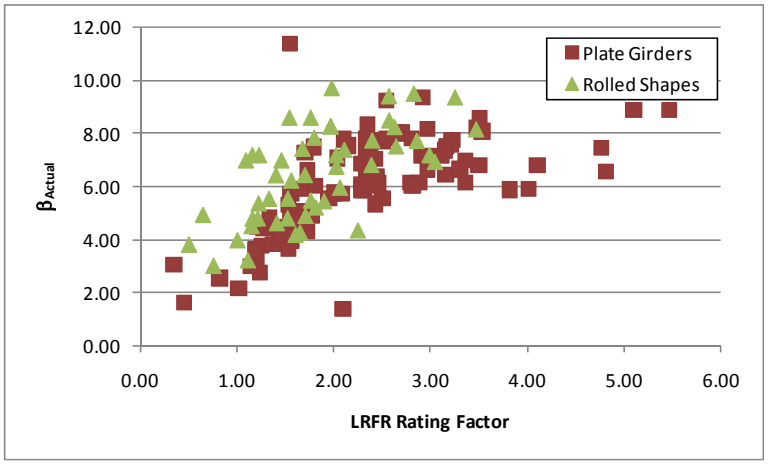
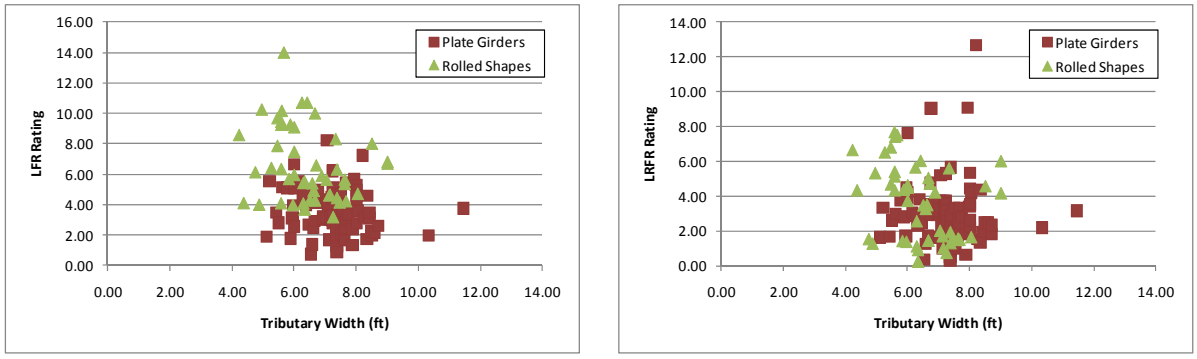


Figure G-441: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

G.4.3.2 Shear

G.4.3.2.1 Rating Factors

For shear, there are three girders that have rating factors less than 1.0 for LFR, eleven girders for LRFR, and three girders where both LFR and LRFR are less than 1.0. Six of the eleven girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 80% of the girders in this subset. Figure G-442 shows the LFR and LRFR ratings. The LFR ratings for rolled shapes are greater than four for most girders; while the plate girder ratings are between one and six. The LRFR ratings are generally less than four for the plate girders; the rolled shape rating varies from zero to eight.



(a) (b)

Figure G-442: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure G-443 shows the percentage of girders with shear ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 94.6% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 91.2% of girders for ADTT ≥ 5,000. 98% of girders have LFR ratings greater than 1.0. This is an increase of 3.4% of girders with LRFR ratings less than 1.0 for ADTT ≤ 100 when switching from LFR to LRFR; this increases to 6.8% for an ADTT ≥ 5,000.

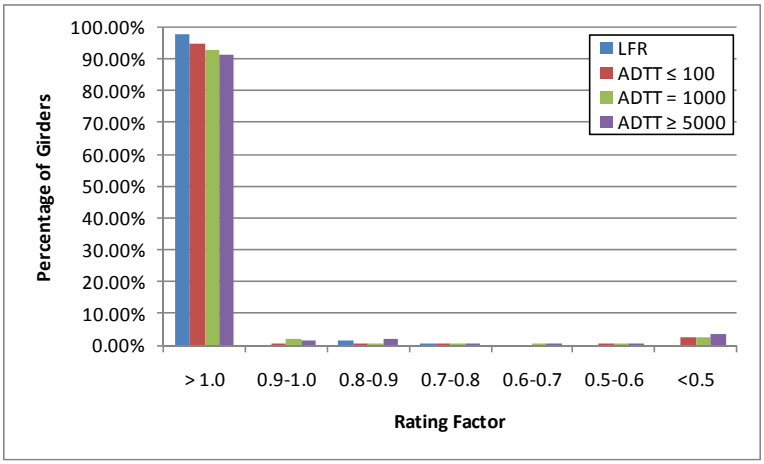


Figure G-443: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

G.4.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure G-444 show the comparison of rating factors. The ratio is generally less than 1.0, with most of those having ratios greater than 1.0 being plate girders. 20% of girders have an LRFR rating that is greater than the LFR rating.

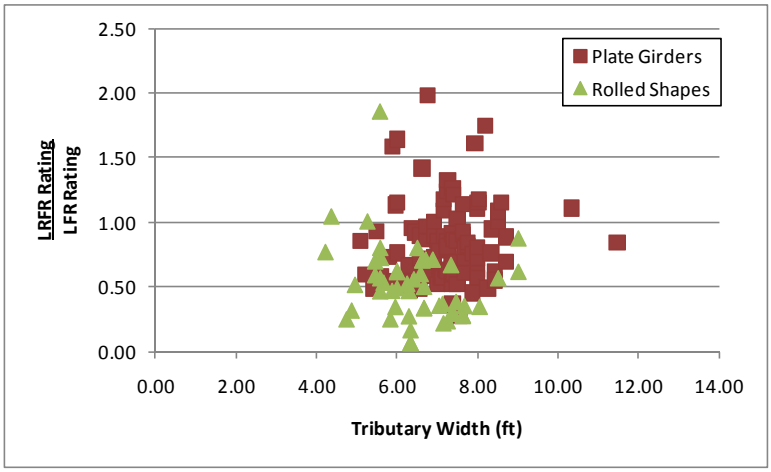


Figure G-444: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

G.4.3.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for four girders as shown in Figure G-445. The reliability index appears to be split into two groups; an upper group that is the rolled shapes and a lower group that is the plate girders. The rolled shapes typically have reliability indices greater than eight while the plate girders are between four and seven for most girders.

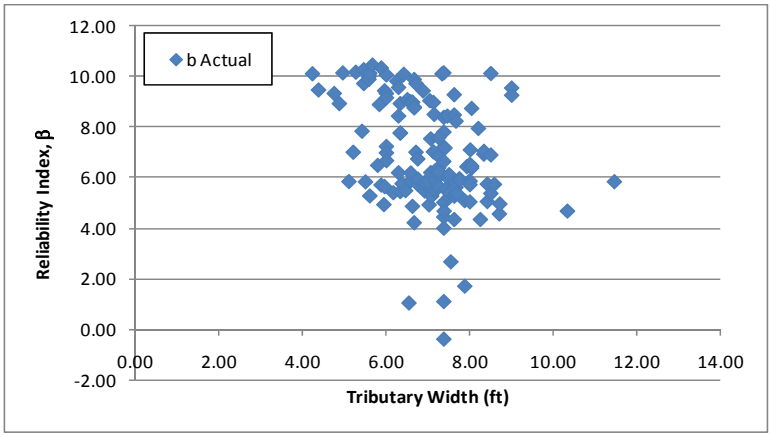


Figure G-445: Shear Reliability Indices for DE-07 Vehicle

Figure G-446 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 vehicle. The reliability index increases with increasing LRFR ratings. A reliability index of 2.5 is associated with an LRFR rating of 1.0; this indicates the live load factors provide the target level of reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

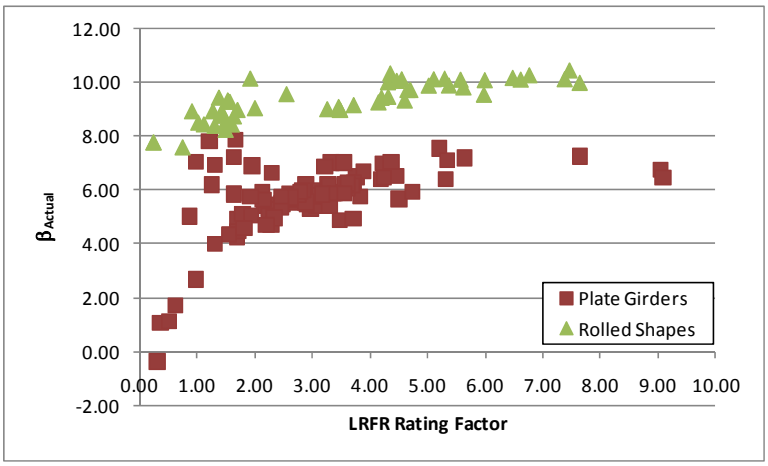


Figure G-446: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

G.4.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-447. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

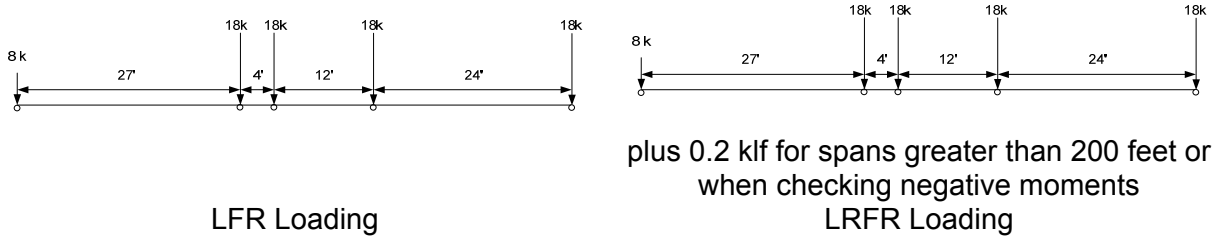


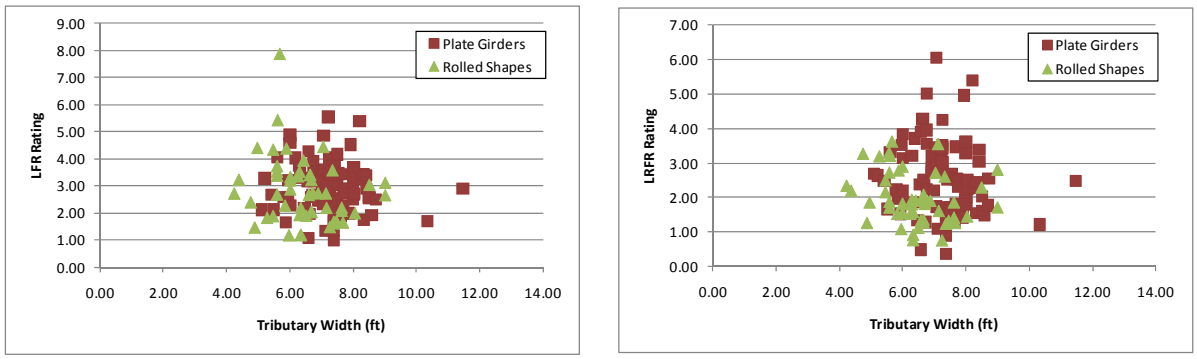
Figure G-447: Vehicle Loadings and Load Factors

G.4.4.1 Moment

The following section contains the results for exterior, composite steel girders within continuous span bridges for the FL-04 Vehicle.

G.4.4.1.1 Rating Factors

Figure G-448 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, six girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR permit rating for 80% of the girders in this subset. The LFR ratings are generally between 2 and 4. The LRFR ratings are generally between 1 and 4.



(a) (b)

Figure G-448: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure G-449 shows the percentage of girders with moment ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 97.3% of girders have LRFR ratings less than 1.0 for ADTT ≤ 100. This drops to 94.6% of girders for ADTT ≥ 5,000. 99.3% of girders have LFR ratings greater than 1.0. 2.0% more girders have ratings less than 1.0 when LFR is switched to LRFR with an ADTT ≤ 100; when LRFR with ADTT ≥ 5,000 is used, 4.7% more girders are affected.

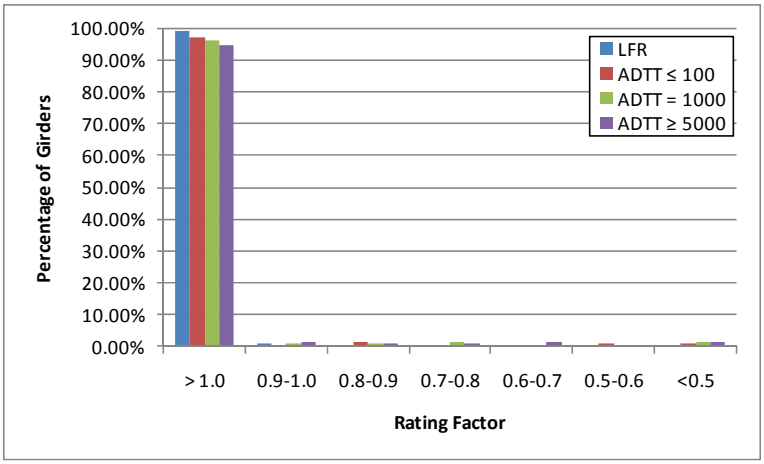


Figure G-449: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

G.4.4.1.2 Rating Factor Comparisons

Figure G-450 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. 20% of girders have an LRFR rating greater than the LFR rating.

The LRFR rating is typically 50 to 125% of the LFR rating. Most of the girders with LRFR ratings that are greater than the LFR rating are plate girders.

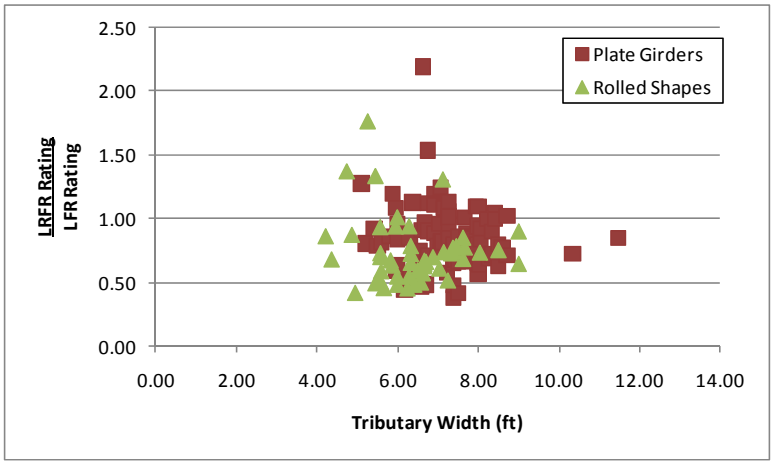


Figure G-450: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

G.4.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-451 shows four girders have a reliability index less than the target reliability index of 2.5. The reliability index is greater than four for most girders for the FL-04 vehicle.

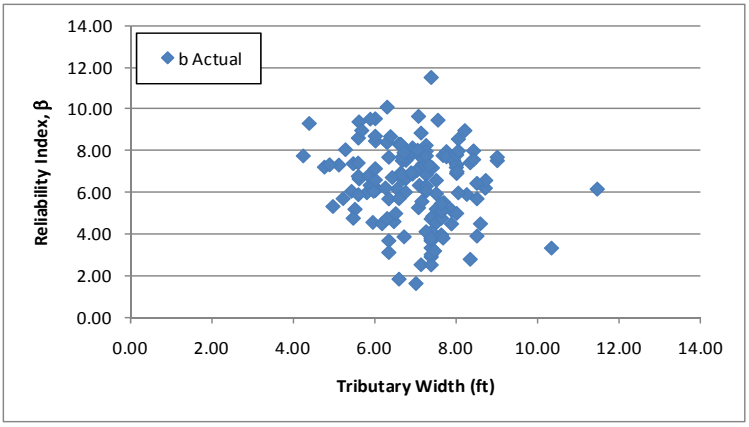


Figure G-451: Flexure Reliability Indices for FL-04 Vehicle

Figure G-452 shows the reliability index for moment plotted against the LRFR moment rating for FL-04 Vehicle. The reliability index increases with increasing ratings. A reliability index of 2.5 is associated with an LRFR rating of 1.0; this indicates the LRFR live load factors provide the target level of reliability.

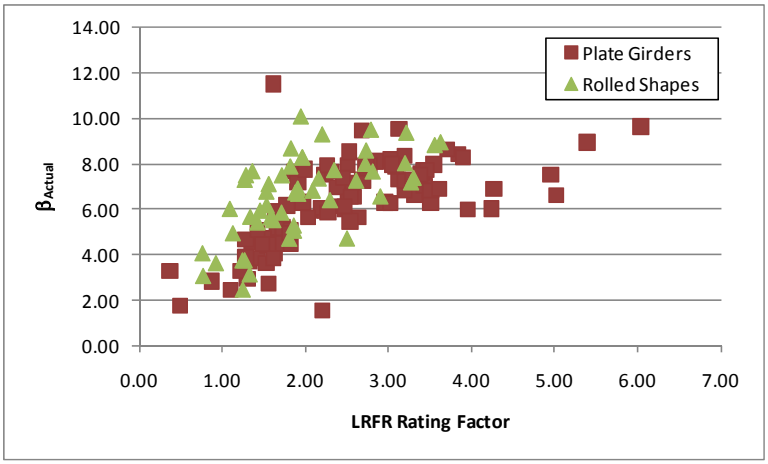
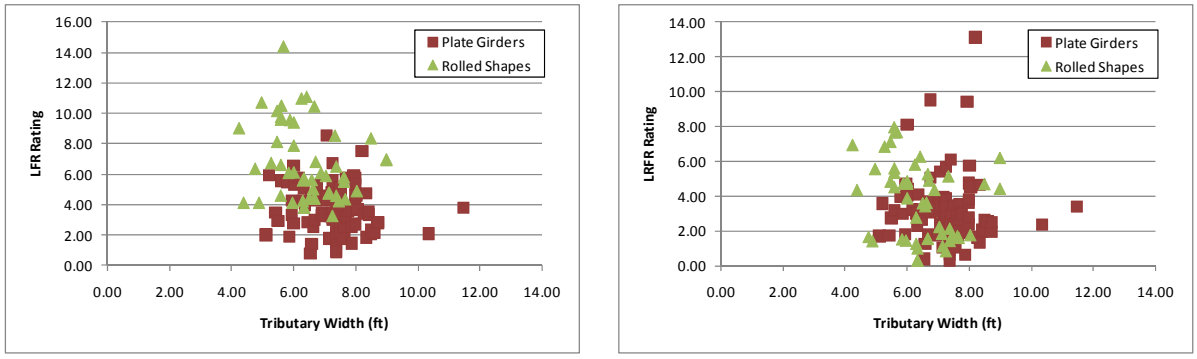


Figure G-452: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

G.4.4.2 Shear

G.4.4.2.1 Rating Factors

For shear, there are three girders that have LFR rating factors less than 1.0, nine girders with LRFR ratings less than 1.0, and three girders where both ratings are less than 1.0. Five of the nine girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 81% of the girders in this subset. Figure G-453 shows the LFR and LRFR ratings. The LFR rating is between one and six for the plate girders and above four for the rolled shapes. The LRFR rating is between one and four for most plate girders while the rating for the rolled shapes varies significantly.



(a) (b)

Figure G-453: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure G-454 shows the percentage of girders with shear ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 95.3% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 91.9% of girders for ADTT ≥ 5,000. 98% of girders have LFR ratings greater than 1.0. This is an increase of 2.7% of girders with LRFR ratings less than 1.0 for ADTT ≤ 100 when switching from LFR to LRFR; this increases to 6.1% for an ADTT ≥ 5,000.

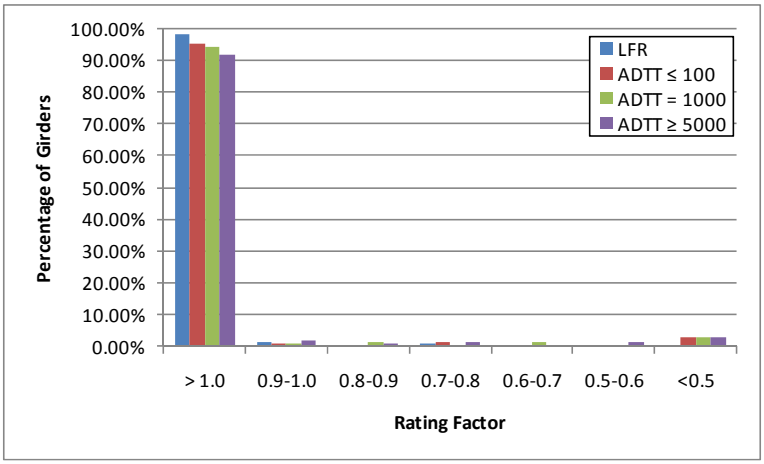


Figure G-454: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

G.4.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-455 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.25, with the ratio remaining in the same range for most tributary widths. 19% of girders have an LRFR rating that is greater than the LFR rating.

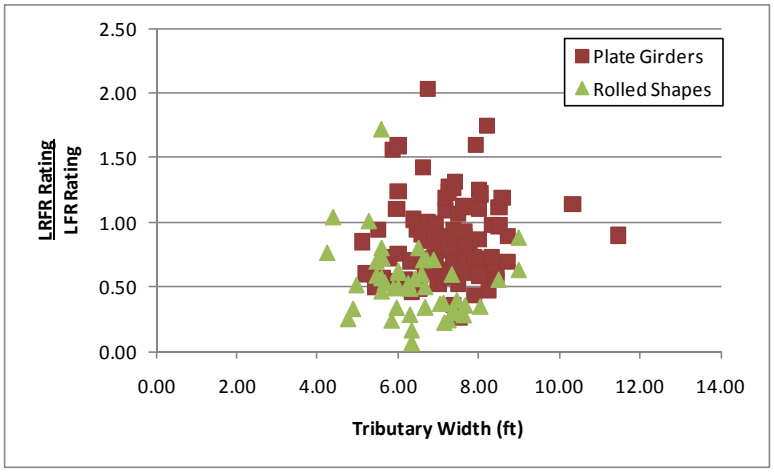


Figure G-455: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

G.4.4.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for four girders as shown in Figure G-456. The reliability index is split into two groups; the upper group is the rolled shapes while the lower group is the plate girders. The rolled shapes have reliability indexes above eight while the plate girders have a reliability index between five and seven for most shapes.

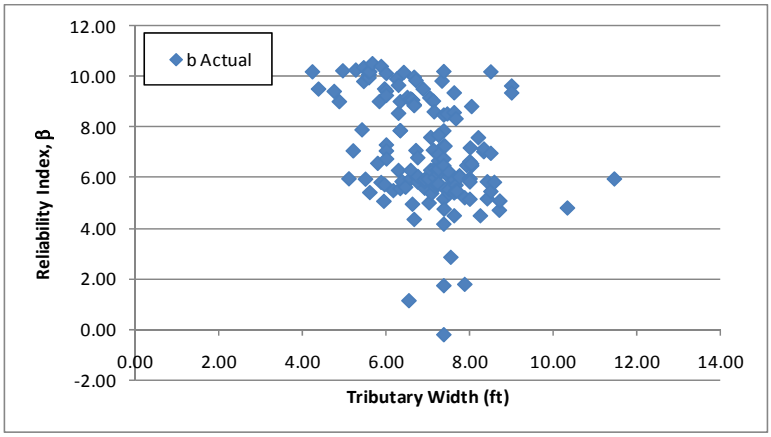


Figure G-456: Shear Reliability Indices for FL-04 Vehicle

Figure G-457 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 vehicle. The reliability index increases with increasing rating; a reliability index of 2.5 is associated with an LRFR rating of 1.0. This indicates the LRFR live load factors provide the target level of reliability for exterior composite steel girders. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

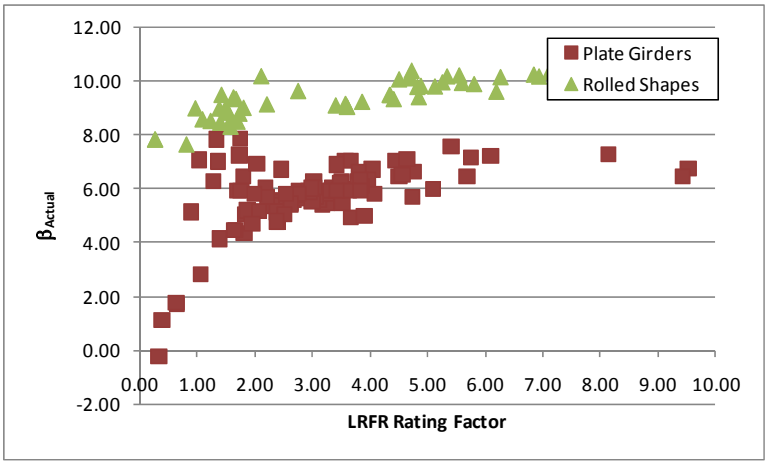


Figure G-457: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

G.4.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-458. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

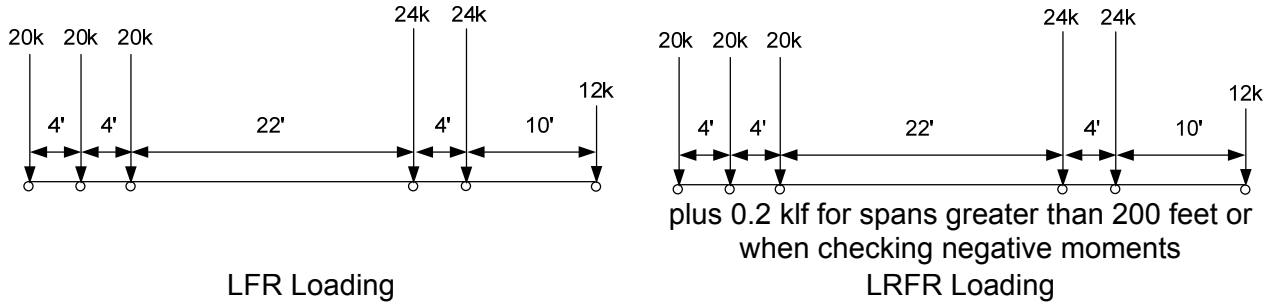


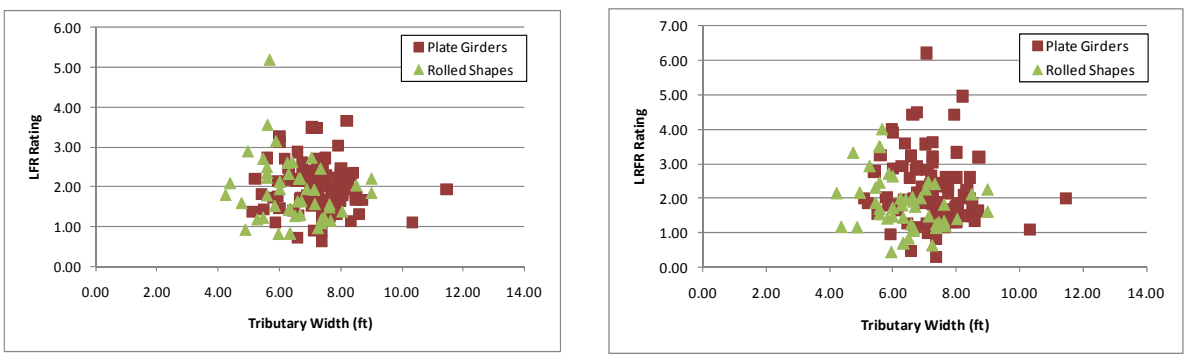
Figure G-458: Vehicle Loadings and Load Factors

G.4.5.1 Moment

The following section contains the results for exterior, composite steel girders within continuous span bridges for the IL-01 Vehicle.

G.4.5.1.1 Rating Factors

Figure G-459 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are nine girders with an LFR rating less than 1.0, eight girders with an LRFR rating less than 1.0, and seven girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 41% of the girders in this subset. The LFR ratings are typically between 1 and 3; the LRFR ratings are between 1 and 4.



(a) (b)

Figure G-459: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure G-460 shows the percentage of girders with moment ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 95.3% of girders have LRFR ratings less than 1.0 for single trip, escorted permits. This drops to 79.7% of girders for multiple trip permits with ADTT ≥ 5,000. 93.9% of girders have LFR ratings greater than 1.0. 1.4% fewer girders have ratings less than 1.0 when LFR is switched to LRFR with a single trip, escorted permit; when LRFR multiple trip permits with ADTT ≥ 5,000 is used, 14.2% more girders are affected.

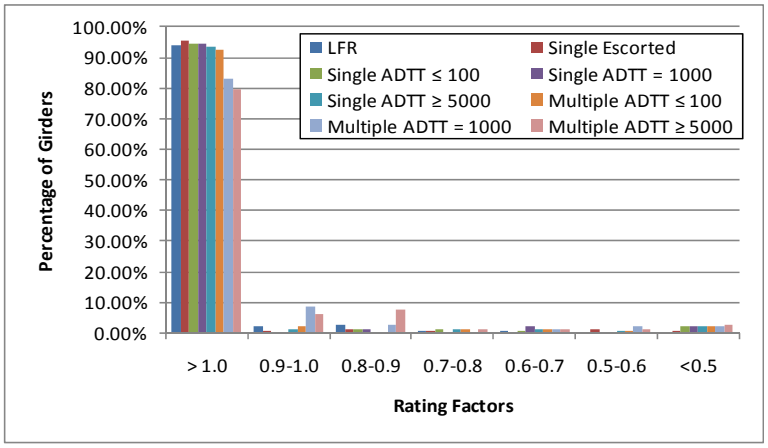


Figure G-460: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

G.4.5.1.2 Rating Factor Comparisons

Figure G-461 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.5. 59% of girders have an LRFR rating that is greater than the LFR rating for moment.

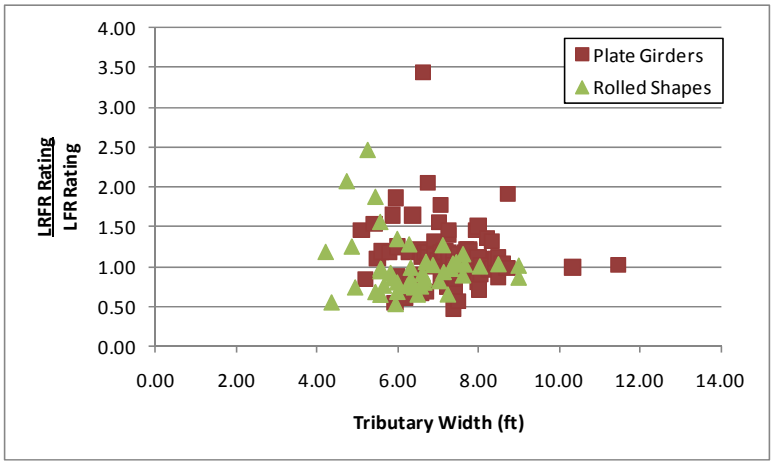


Figure G-461: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

G.4.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-462 shows thirteen girders have a reliability index less than the target reliability index of 3.5. The reliability index for most girders is above four.

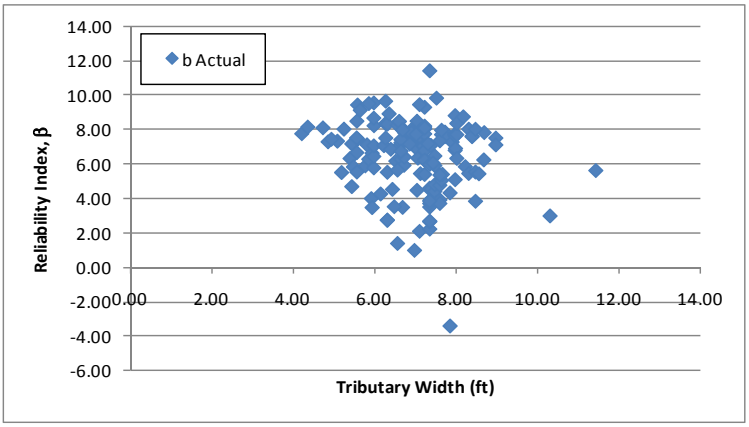


Figure G-462: Flexure Reliability Indices for IL-01 Vehicle

Figure G-463 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The reliability index increases with an increasing rating factor. A reliability index of 3.5 is associated with an LRFR rating of 1.0, this is the target reliability for this vehicle. This indicates that the live load factors in the MBE provide the target reliability.

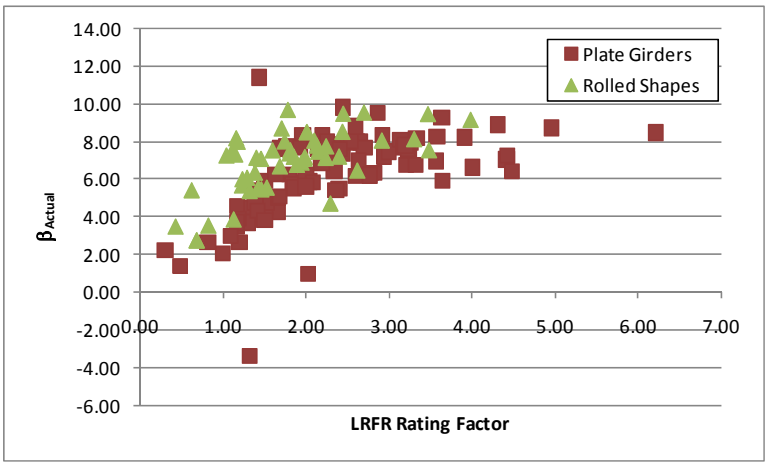
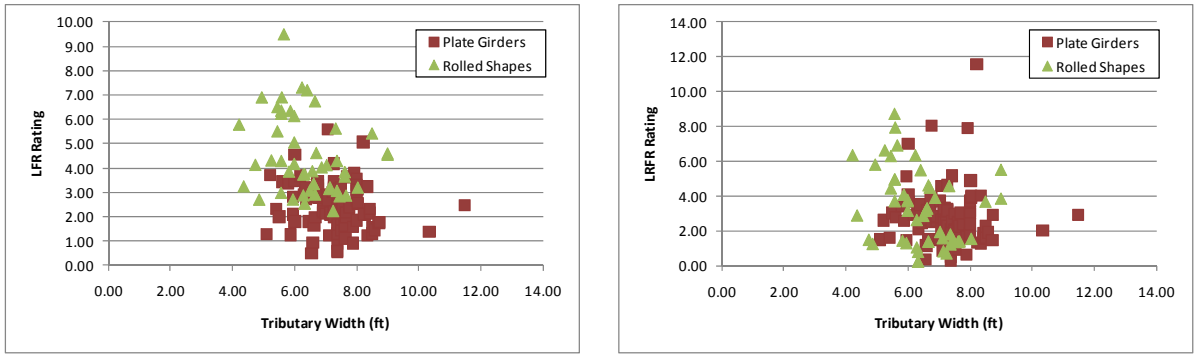


Figure G-463: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

G.4.5.2 Shear

G.4.5.2.1 Rating Factors

For shear, there are six girders that have an LFR rating factor less than 1.0, twelve girders with LRFR ratings less than 1.0, and five girders where both ratings are less than 1.0. Seven of the twelve girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 59% of the girders in this subset. Figure G-464 shows the LFR and LRFR ratings. The LFR ratings are between one and four for plate girders and above 2.5 for the rolled shapes. The LRFR rating is between one and four for plate girders and the rolled shape rating varies from approximately zero to greater than eight.



(a) (b)

Figure G-464: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure G-465 shows the percentage of girders with shear ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 93.9% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 86.5% of girders for multiple trip permits with ADTT ≥ 5,000. 96% of girders have LFR ratings greater than 1.0. This is an increase of 2.1% of girders with LRFR ratings less than 1.0 for single trip, escorted permits when switching from LFR to LRFR; this increases to 9.5% for multiple trip permits with ADTT ≥ 5,000.

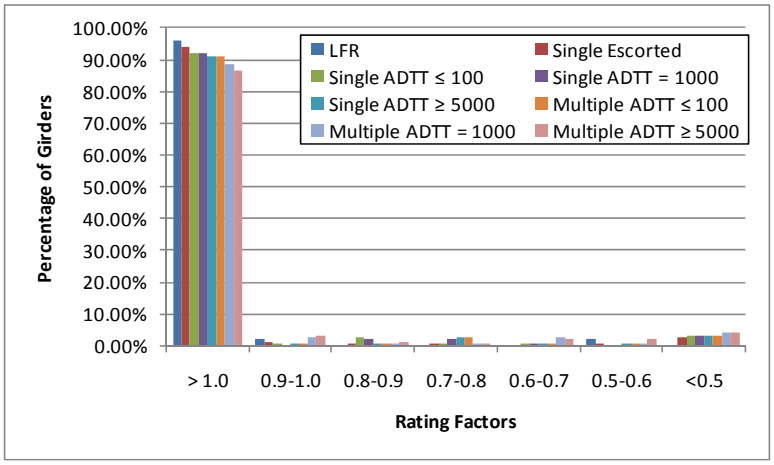


Figure G-465: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

G.4.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-466 shows the comparison of rating factors. The ratio for plate girders is typically between 0.6 and 1.5; with the ratio for rolled shapes varying from zero to three. 41% of girders have an LRFR rating that is greater than the LFR rating.

Figure G-466: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

G.4.5.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all but five girders as shown in Figure G-467. The reliability index is split into two groups; the upper group is the rolled shapes and the lower group is the plate girders. The rolled shapes have reliability indexes between eight and ten while the plate girders are between five and seven.

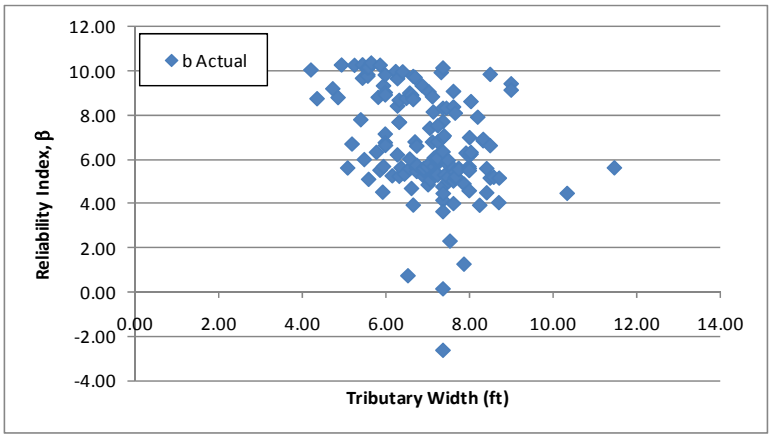


Figure G-467: Shear Reliability Indices for IL-01 Vehicle

Figure G-468 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 Vehicle. The reliability index increases with increasing ratings. An LRFR rating of 1.0 corresponds to a reliability index of approximately 3.5, the target level reliability for the special permit vehicles. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

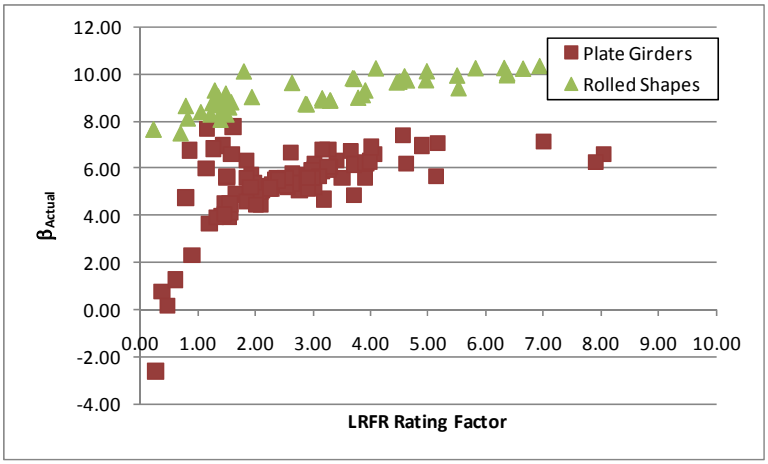


Figure G-468: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

G.4.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-469. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

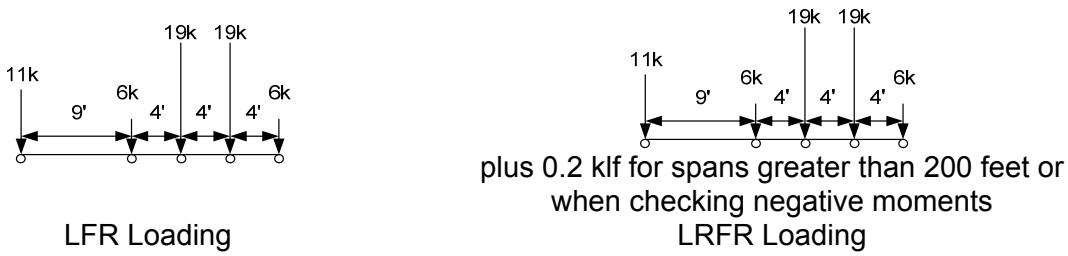


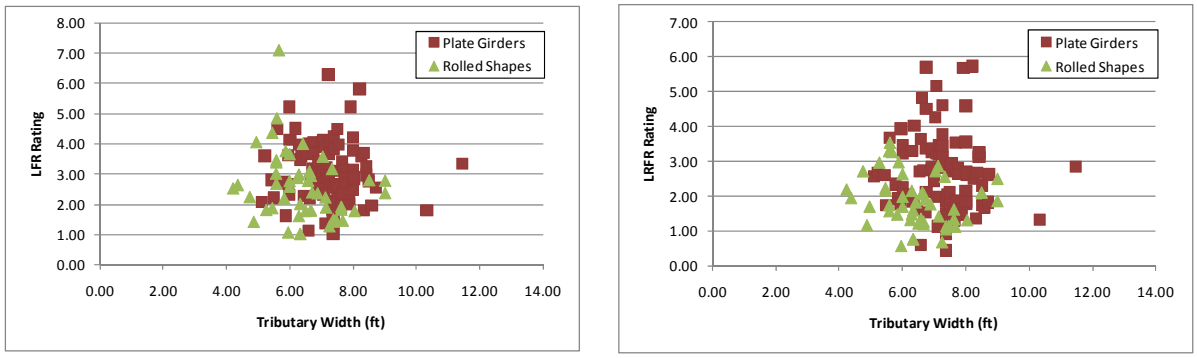
Figure G-469: Vehicle Loadings and Load Factors

G.4.6.1 Moment

The following section contains the results for exterior, composite steel girders within continuous span bridges for the NC-21 Vehicle.

G.4.6.1.1 Rating Factors

Figure G-470 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, seven girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 78% of the girders in this subset. The LFR ratings are typically between 1 and 4 while the LRFR ratings are also typically between 1 and 4.



(a) (b)

Figure G-470: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure G-471 shows the percentage of girders with moment ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 96% of girders have LRFR ratings less than 1.0 for ADTT ≤ 100. This drops to 93.9% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings greater than 1.0. 4% more girders have ratings less than 1.0 when LFR is switched to LRFR with an ADTT ≤ 100; when LRFR with ADTT ≥ 5,000 is used, 6.1% more girders are affected.

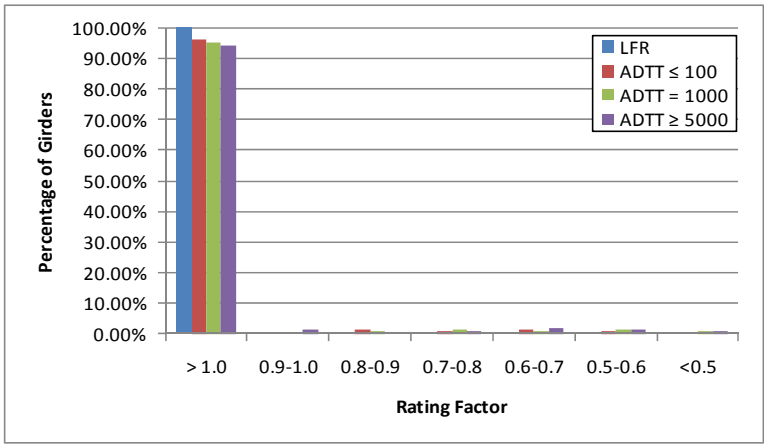


Figure G-471: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

G.4.6.1.2 Rating Factor Comparisons

Figure G-472 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.2 for this vehicle. The ratios for the rolled shapes are typically about 0.8 with more scatter present for the plate girders. 22% of girders have LRFR ratings that are greater than the LFR rating.

Figure G-472: LRFR flexure rating divided by LFR flexure rating for NC-21 Vehicle

G.4.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-473 shows that five girders have a reliability index less than the target reliability index of 2.5. The reliability index is greater than four for most girders.

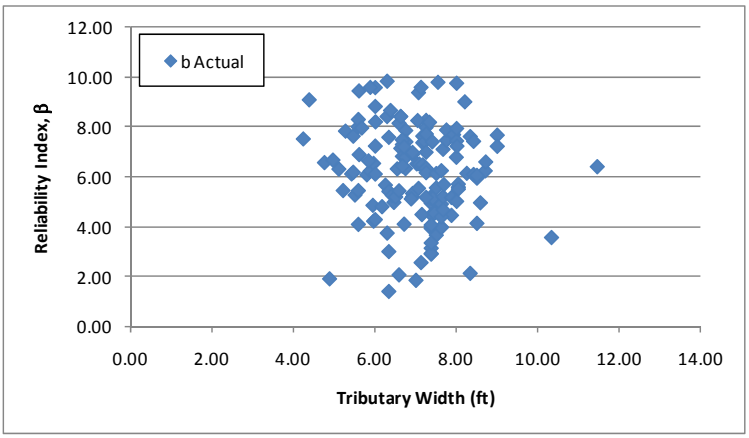


Figure G-473: Flexure Reliability Indices for NC-21 Vehicle

Figure G-474 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 vehicle. The reliability index increases with increasing ratings. An LRFR rating of 1.0 corresponds to an approximately reliability index of 2.5, the target value. This indicates the LRFR live load factors provide the target level of reliability for girders with a rating of 1.0.

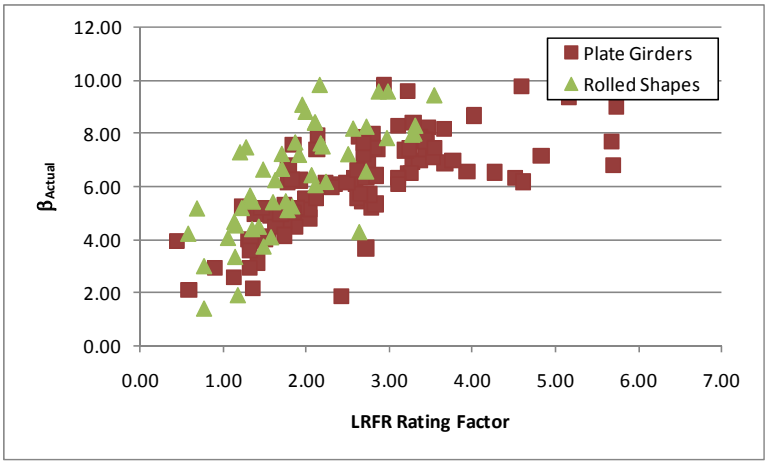
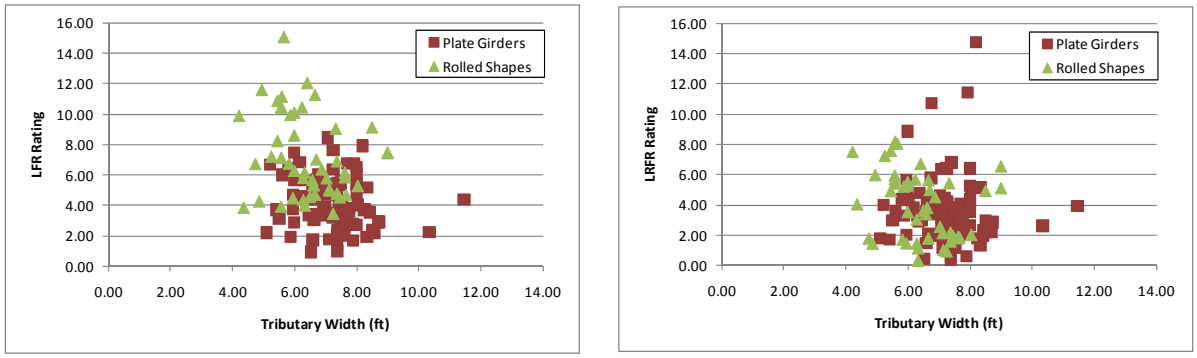


Figure G-474: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

G.4.6.2 Shear

G.4.6.2.1 Rating Factors

For shear, there is one girder that has an LFR rating factors less than 1.0, eight girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. Four of the eight girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 79% of the girders in this subset. Figure G-475 shows the LFR and LRFR ratings, respectively. The LFR ratings are between two and six for plate girders and above three for the rolled shapes. The LRFR rating is between two and six for most girders.



(a) (b)

Figure G-475: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure G-476 shows the percentage of girders with shear ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 96% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 93.9% of girders for ADTT ≥ 5,000. 99.3% of girders have LFR ratings greater than 1.0. This is an increase of 3.3% of girders with LRFR ratings less than 1.0 for ADTT ≤ 100 when switching from LFR to LRFR; this increases to 5.4% for an ADTT ≥ 5,000.

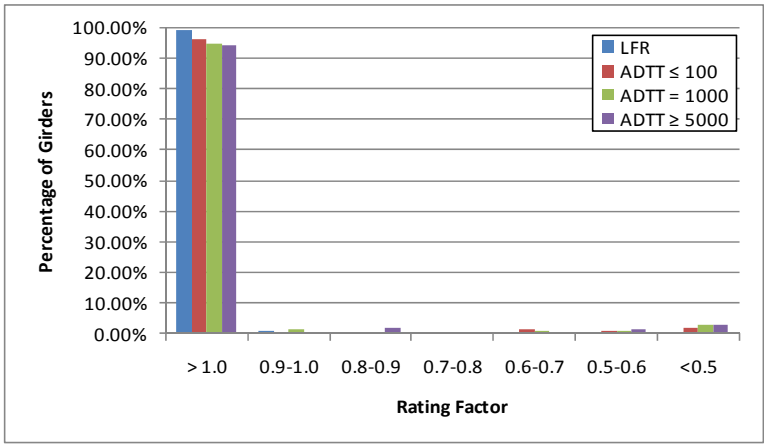


Figure G-476: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

G.4.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-477 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.3. 21% of girders have an LRFR rating that is greater than the LFR rating.

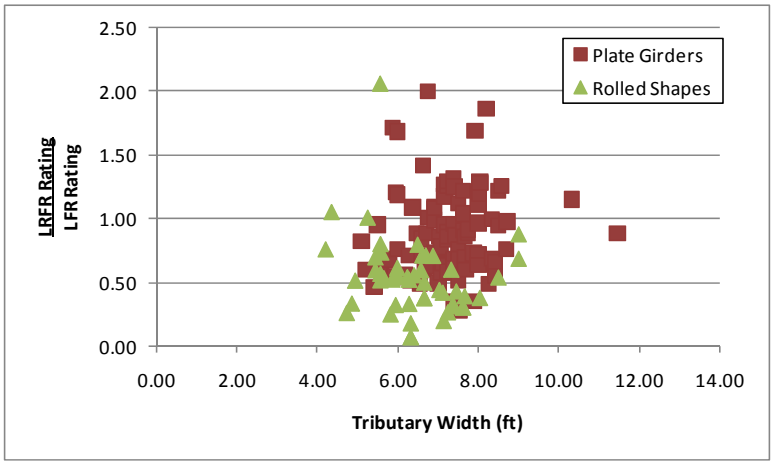


Figure G-477: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

G.4.6.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but four girders as shown in Figure G-478. The reliability index for shear is split into two groups by girder type; the upper group is the rolled shapes with reliability indices greater than eight and the lower group is the plate girders with reliability indices between five and seven.

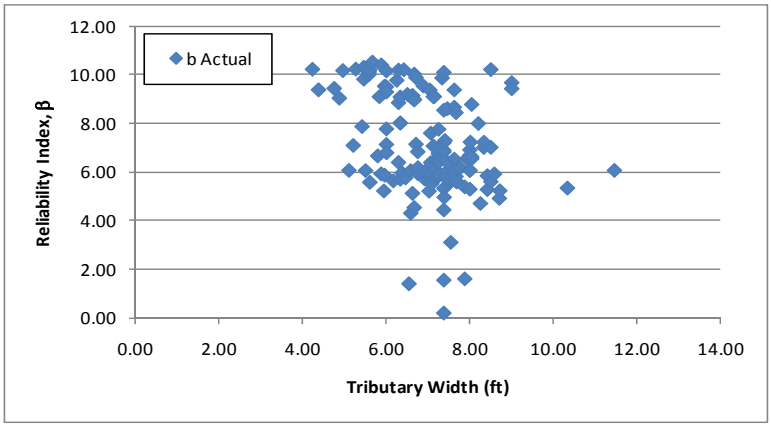


Figure G-478: Shear Reliability Indices for NC-21 Vehicle

Figure G-479 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 Vehicle. The reliability index increases with increasing LRFR rating factors. A reliability index of 2.5 is associated with an LRFR rating of 1.0. This indicates the LRFR live load factors provide the target reliability level for a girder with a rating of 1.0. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

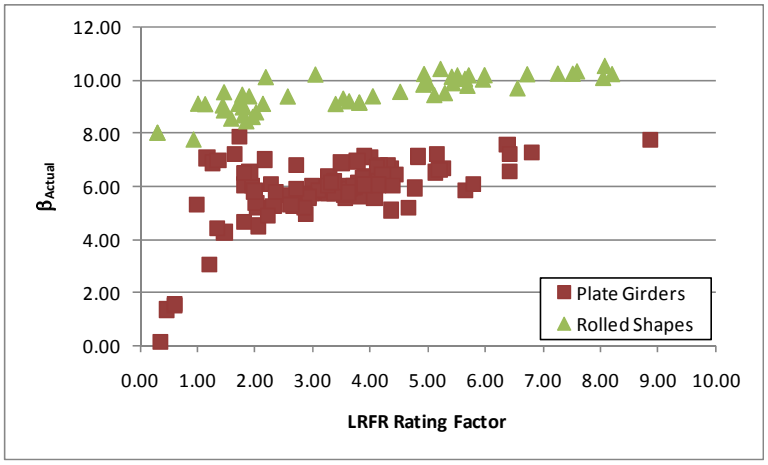


Figure G-479: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

G.4.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-480. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

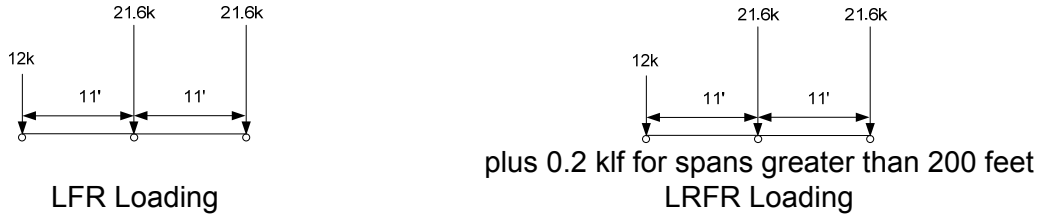


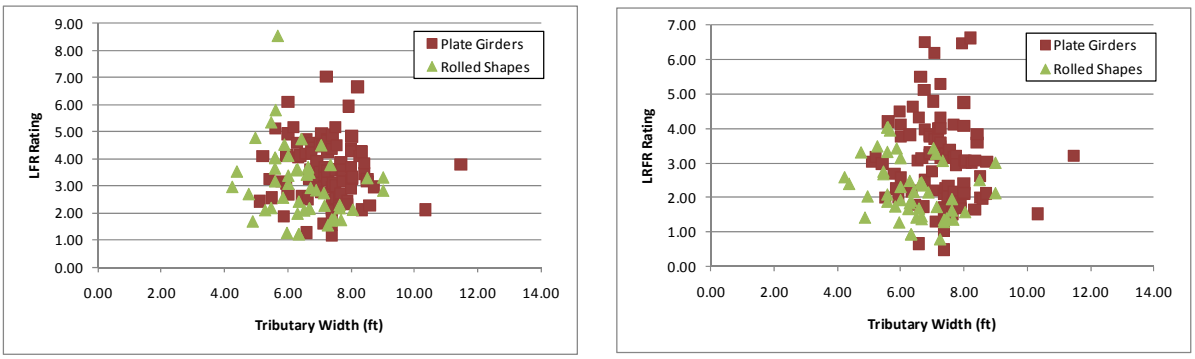
Figure G-480: Vehicle Loadings and Load Factors

G.4.7.1 Moment

The following section contains the results for exterior, composite steel girders within continuous span bridges for the NM-04 Vehicle.

G.4.7.1.1 Rating Factors

Figure G-481 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, five girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 78% of the girders in this subset. LFR ratings are typically between 2 and 5; LRFR ratings are generally in the range of 1.5 to 4.



(a) (b)

Figure G-481: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure G-482 shows the percentage of girders with moment ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 98% of girders have LRFR ratings less than 1.0 for ADTT ≤ 100. This drops to 96% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings greater than 1.0. 2.0% more girders have ratings less than 1.0 when LFR is switched to LRFR with an ADTT ≤ 100; when LRFR with ADTT ≥ 5,000 is used, 4.0% more girders are affected.

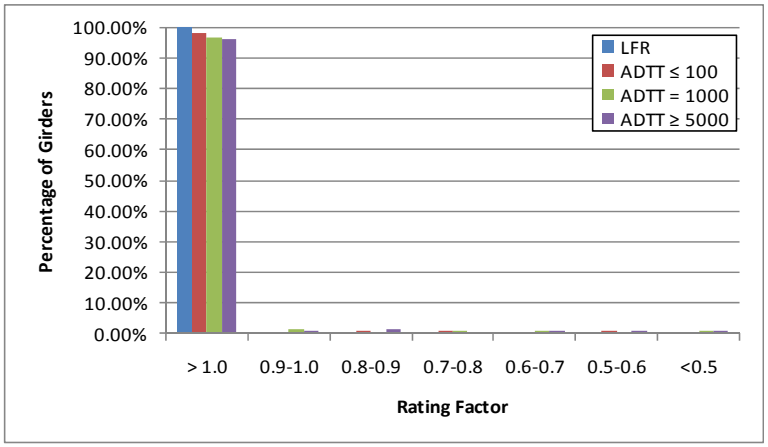


Figure G-482: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

G.4.7.1.2 Rating Factor Comparisons

Figure G-483 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.25. Most of

the ratios for rolled shapes are near 0.75 with more scatter in the plate girder ratios. 22% of the girders have LRFR ratings that are greater than the LFR rating.

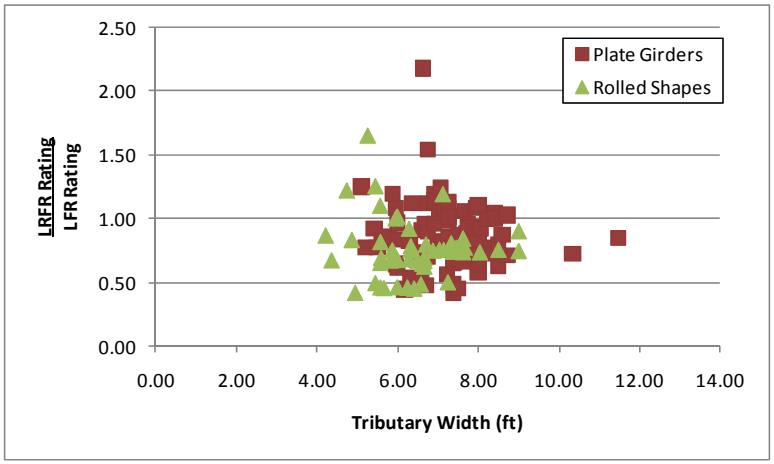


Figure G-483: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

G.4.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-484 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index for most girders is above four.

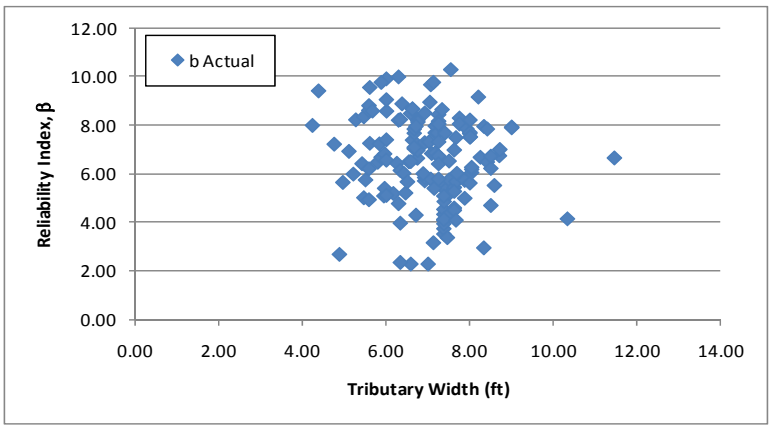


Figure G-484: Flexure Reliability Indices for NM-04 Vehicle

Figure G-485 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The reliability index increases with increasing ratings and is approximately 2.75 for a rating of 2.0. This indicates the LRFR live load factors provided the target reliability.

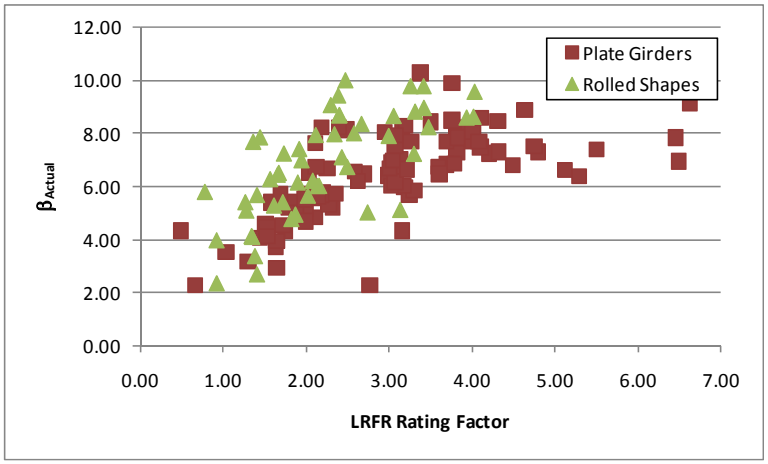
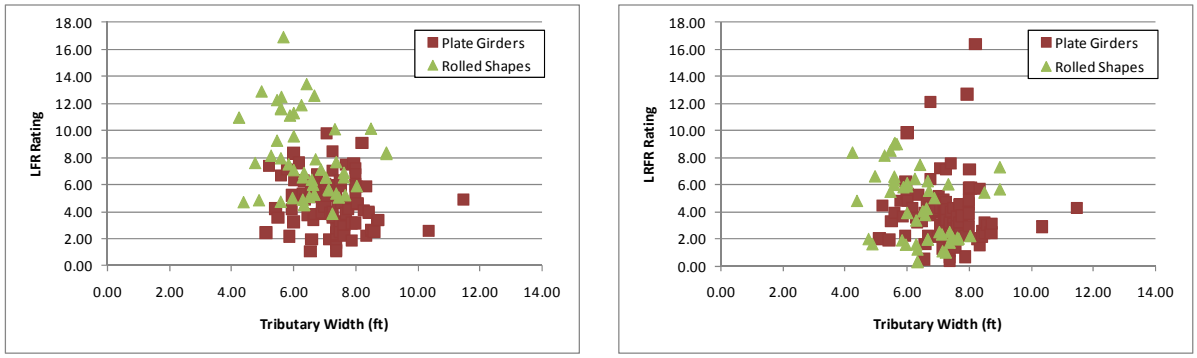


Figure G-485: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

G.4.7.2 Shear

G.4.7.2.1 Rating Factors

For shear, there are zero girders that have an LFR rating factor less than 1.0, six girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. Two of the six girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 80% of the girders in this subset. Figure G-486 shows the LFR and LRFR ratings, respectively. The LFR ratings are between two and eight for most girders while the LRFR ratings are between two and six.



(a) (b)

Figure G-486: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure G-487 shows the percentage of girders with shear ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 96% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 94.6% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings greater than 1.0. This is an increase of 4% of girders with LRFR ratings less than 1.0 for ADTT ≤ 100 when switching from LFR to LRFR; this increases to 5.4% for an ADTT ≥ 5,000.

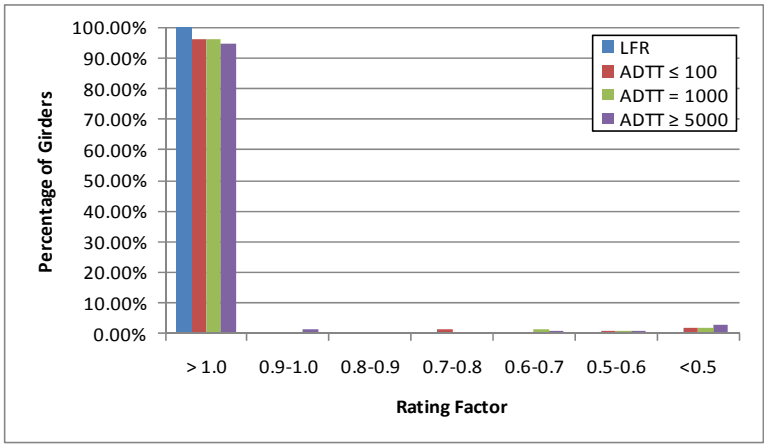


Figure G-487: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

G.4.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-488 show the comparison of rating factors. The ratio is generally between 0.5 and 1.25. 20% of girders have an LRFR rating that is greater than the LFR rating.

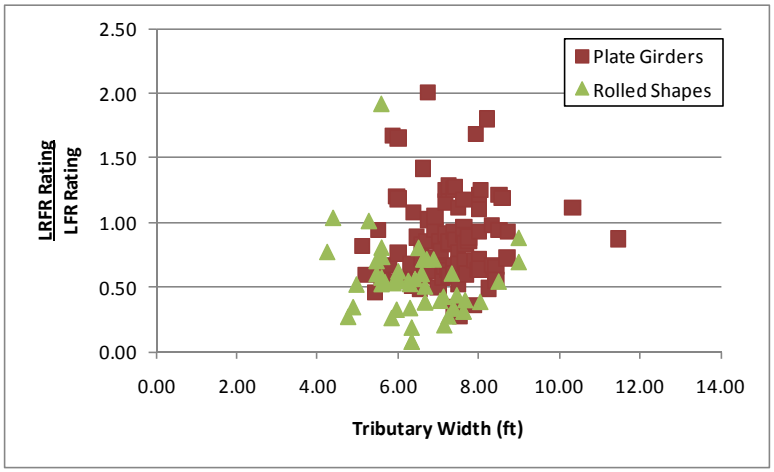


Figure G-488: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

G.4.7.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but four girders as shown in Figure G-489. The reliability index appears to be split into two groups. The upper group is the rolled shapes with reliability indices greater than eight; the lower group is the plate girders with reliability indices between five and seven.

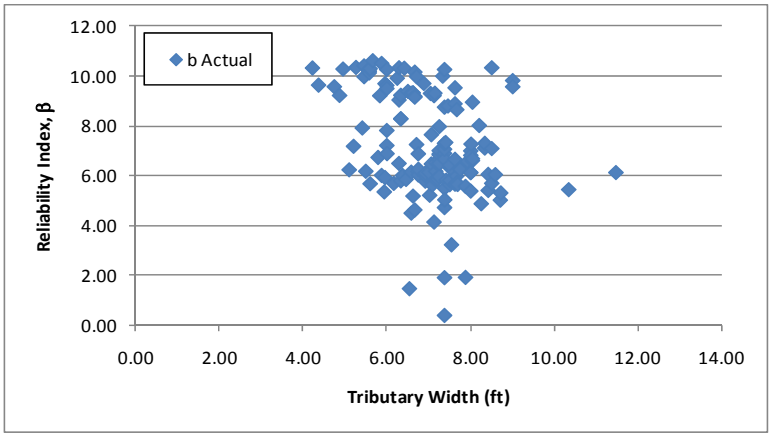


Figure G-489: Shear Reliability Indices for NM-04 Vehicle

Figure G-490 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. The reliability index increases with increasing LRFR rating factors. The reliability index associated with an LRFR rating of 1.0 is approximately 2.5, the target reliability index. This indicates the LRFR live load factors produce the target level of reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

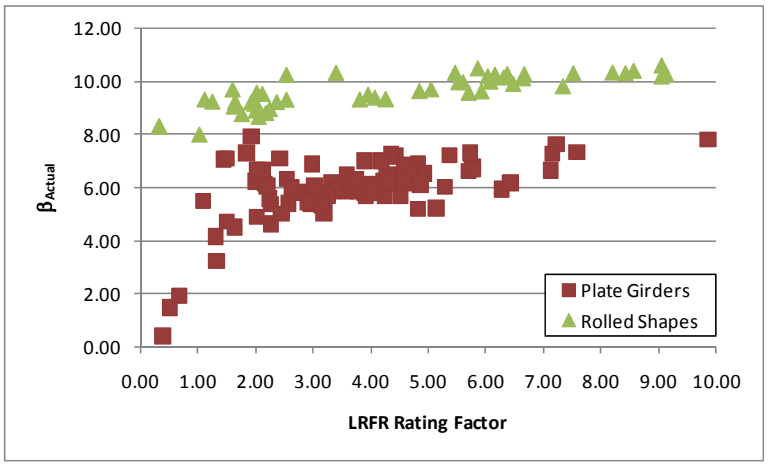
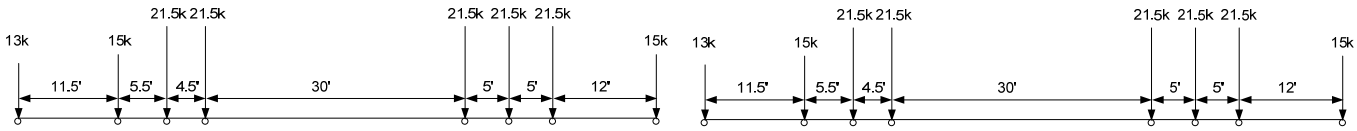


Figure G-490: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

G.4.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-491. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading

plus 0.2 klf for spans greater than 200 feet

LRFR Loading

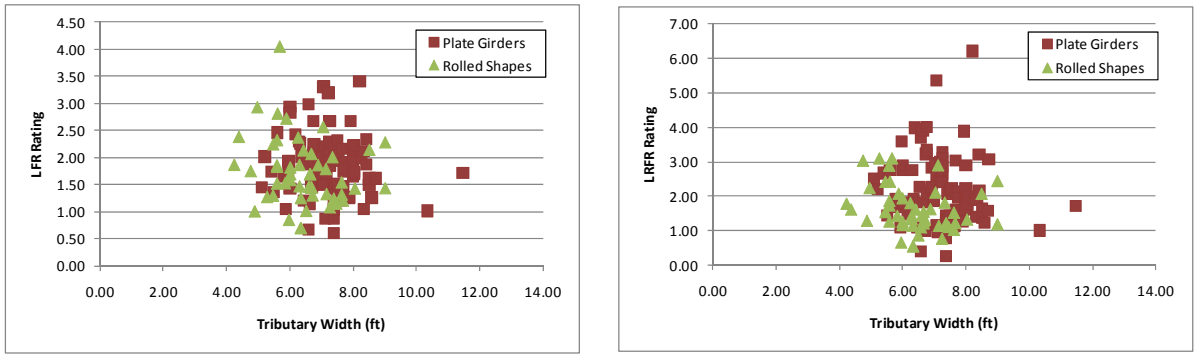
Figure G-491: Vehicle Loadings and Load Factors

G.4.8.1 Moment

The following section contains the results for exterior, composite steel girders within continuous span bridges for the OR-06 Vehicle.

G.4.8.1.1 Rating Factors

Figure G-492 show the LFR and LRFR rating factors calculated by BRASS. The results show that there are seven girders with an LFR rating less than 1.0, ten girders with an LRFR rating less than 1.0, and seven girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 48% of the girders in this subset. The LFR rating is generally between 1 and 2.5 while the LRFR rating is generally between 1 and 2.25.



(a) (b)

Figure G-492: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure G-493 shows the percentage of girders with moment ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 95.3% of girders have LRFR ratings less than 1.0 for single trip, escorted permits. This drops to 70.3% of girders for multiple trip permits with ADTT ≥ 5,000. 95.3% of girders have LFR ratings greater than 1.0. No additional girders have ratings less than 1.0 when LFR is switched to LRFR for a single trip, escorted permit; when LRFR an LRFR multiple trip permit with ADTT ≥ 5,000 is used, 25% more girders are affected.

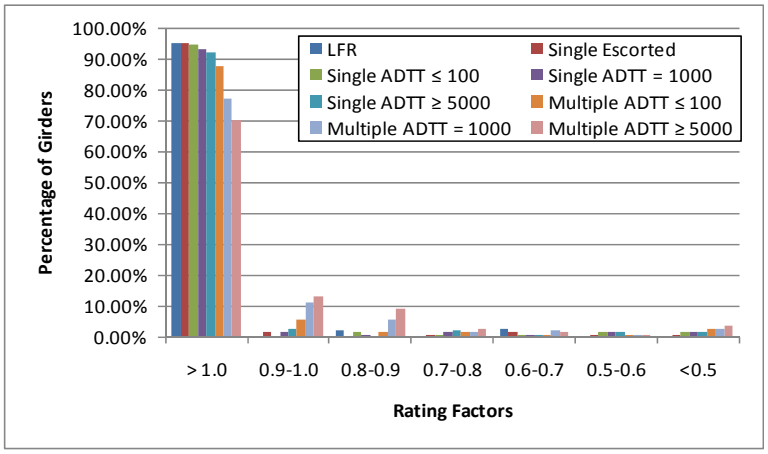


Figure G-493: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

G.4.8.1.2 Rating Factor Comparisons

Figure G-494 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.5. 52% of the girders have LRFR ratings that are greater than the LFR rating. Rolled shapes are more likely to have LRFR ratings that are less than the LFR rating.

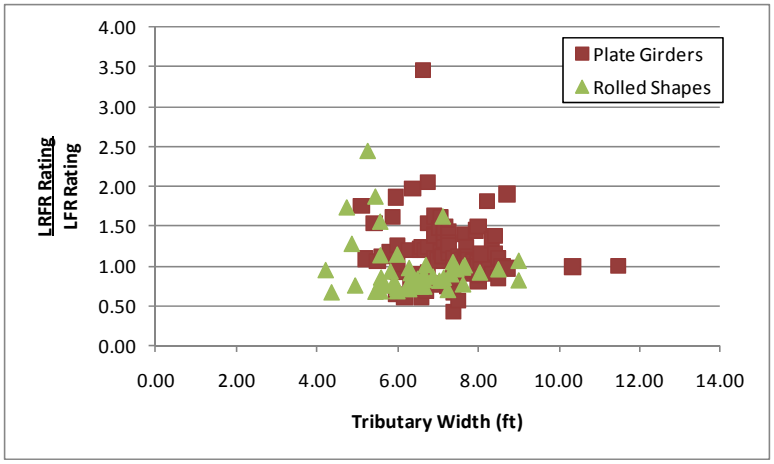


Figure G-494: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

G.4.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-495 shows ten girders have a reliability index less than the target reliability index of 3.5. The reliability index for most girders is between five and ten. Reliability indices less than zero indicate the applied loads are much greater than the resistance.

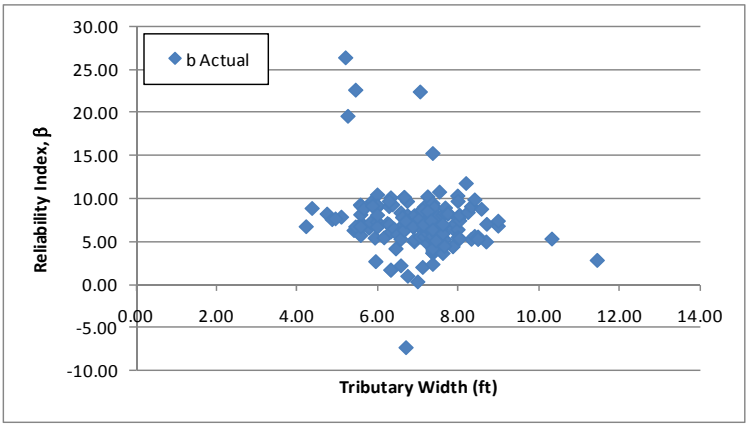


Figure G-495: Flexure Reliability Indices for OR-06 Vehicle

Figure G-496 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 vehicle. The reliability index increases with increasing rating; more scatter is present in this graph than for the other vehicles. The reliability index associated with an LRFR rating of 1.0 is approximately 3.5, the target reliability index. This indicates the LRFR live load factors provide the target level of reliability.

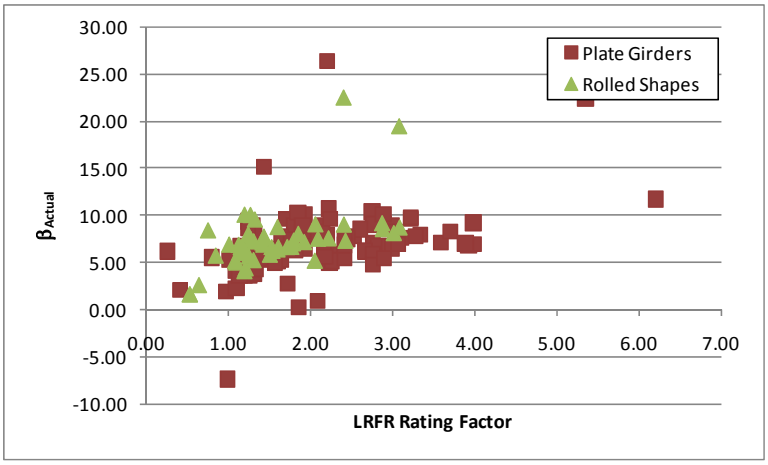
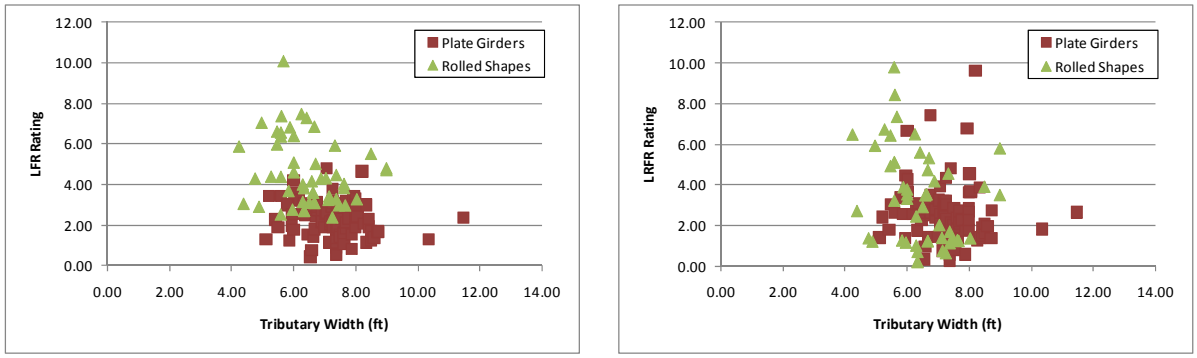


Figure G-496: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 vehicle

G.4.8.2 Shear

G.4.8.2.1 Rating Factors

For shear, there are six girders that have an LFR rating factors less than 1.0, thirteen girders have LRFR ratings less than 1.0, and six girders have both ratings less than 1.0. Eight of the thirteen girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 41% of the girders in this subset. Figure G-497 shows the LFR and LRFR ratings. The LFR ratings are between one and four for plate girders and above two for rolled shapes. The LRFR ratings are between one and four for plate girders with rolled shapes varying from zero to ten.



(a) (b)

Figure G-497: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure G-498 shows the percentage of girders with shear ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 91.9% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 83.1% of girders for multiple trip permits with ADTT ≥ 5,000. 96% of girders have LFR ratings greater than 1.0. This is an increase of 4.1% of girders with LRFR ratings less than 1.0 for single trip, escorted permits when switching from LFR to LRFR; this increases to 12.9% for multiple trip permits with ADTT ≥ 5,000.

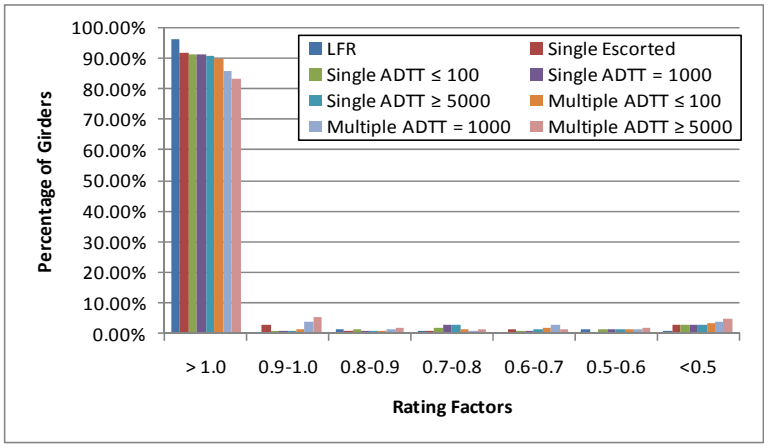


Figure G-498: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

G.4.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-499 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5 for this set of girders with this vehicle. 41% of girders have an LRFR rating that is greater than the LFR rating. Most girders with LRFR ratings greater than the LFR rating are plate girders.

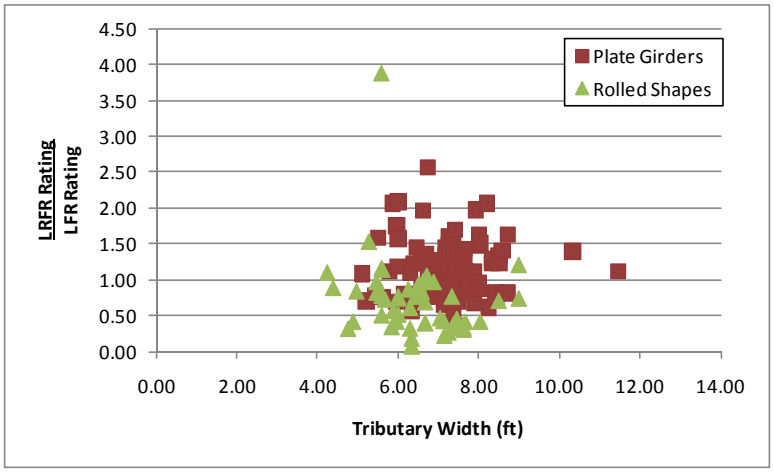


Figure G-499: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

G.4.8.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all but five girders as shown in Figure G-500. The reliability index is greater than eight for the rolled shapes and between four and seven for plate girders.

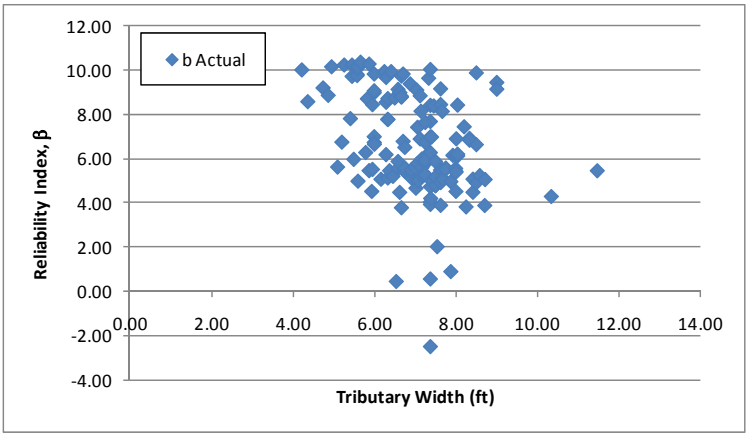


Figure G-500: Shear Reliability Indices for OR-06 Vehicle

Figure G-501 shows the shear reliability index plotted against the LRFR shear rating for the OR-06 vehicle. The reliability index increases with increasing LRFR ratings. A rating factor of 1.0 corresponds to a reliability index of 3.5, the target reliability index. This indicates the LRFR live load factors for special permits provide the target reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

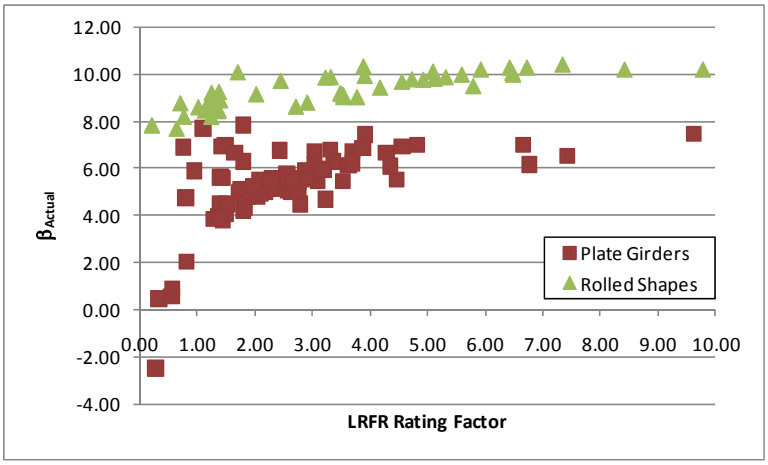


Figure G-501: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

G.4.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-502. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

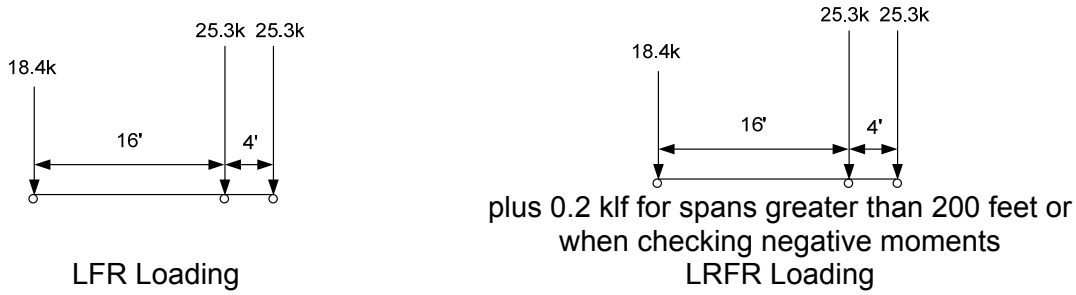


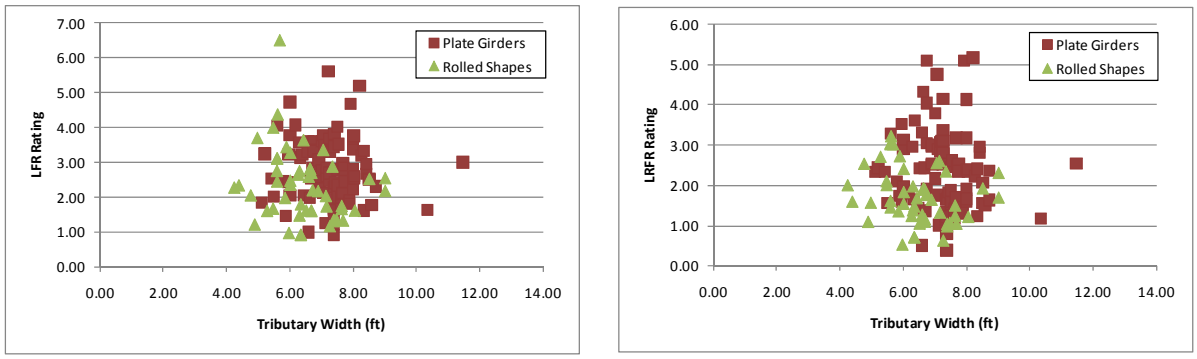
Figure G-502: Vehicle Loadings and Load Factors

G.4.9.1 Moment

The following section contains the results for exterior, composite steel girders within continuous span bridges for the TX-04 Vehicle.

G.4.9.1.1 Rating Factors

Figure G-503 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are five girders with an LFR rating less than 1.0, eight girders with an LRFR rating less than 1.0, and five girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 78% of the girders in this subset. Both ratings are generally between the values of 1 and 4.



(a) (b)

Figure G-503: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure G-504 shows the percentage of girders with moment ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 95.3% of girders have LRFR ratings less than 1.0 for ADTT ≤ 100. This drops to 89.9% of girders for ADTT ≥ 5,000. 96.6% of girders have LFR ratings greater than 1.0. 1.3% more girders have ratings less than 1.0 when LFR is switched to LRFR with an ADTT ≤ 100; when LRFR with ADTT ≥ 5,000 is used, 6.7% more girders are affected.

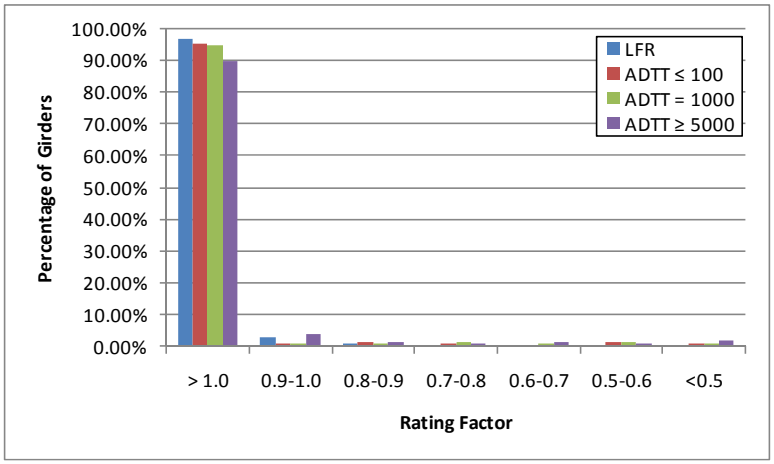


Figure G-504: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

G.4.9.1.2 Rating Factor Comparisons

Figure G-505 show the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.25, with the rolled shapes being clustered around 0.8 and the plate girders are more scattered. 22% of girders have an LRFR rating that is greater than the LFR rating TX-04 vehicle.

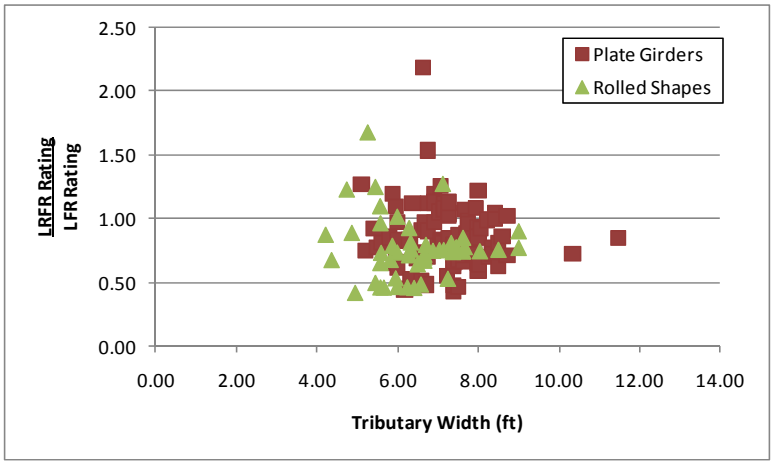


Figure G-505: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

G.4.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-506 shows seven girders that have a reliability index less than the target reliability index of 2.5. The reliability index for most girders is greater than four.

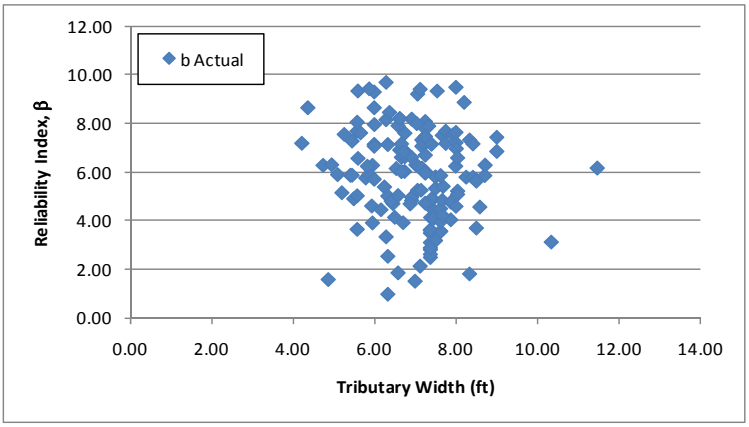


Figure G-506: Flexure Reliability Indices for TX-04 Vehicle

Figure G-507 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 Vehicle. The reliability index increases with increasing rating factors. An LRFR rating of 1.0 corresponds to a reliability index of 2.5, the target reliability index. This indicates the LRFR live load factors provide the target reliability level.

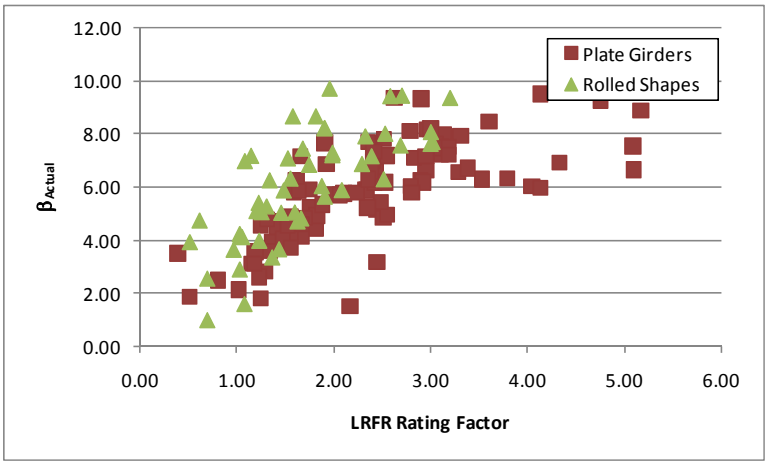
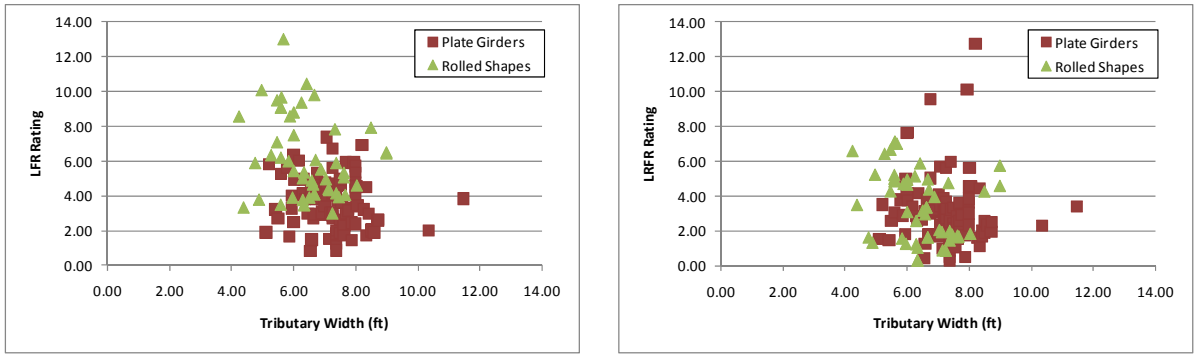


Figure G-507: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

G.4.9.2 Shear

G.4.9.2.1 Rating Factors

For shear, there are three girders that have LFR rating factors less than 1.0, ten girders with LRFR ratings less than 1.0, and three girders where both ratings are less than 1.0. Five of the ten girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 79% of the girders in this subset. Figure G-508 shows the LFR and LRFR ratings, respectively. The LFR ratings are typically between 2 and 6 while the LRFR ratings are typically between one and four.



(a) (b)

Figure G-508: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure G-509 shows the percentage of girders with shear ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 93.9% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 90.5% of girders for ADTT ≥ 5,000. 98% of girders have LFR ratings greater than 1.0. This is an increase of 4.1% of girders with LRFR ratings less than 1.0 for ADTT ≤ 100 when switching from LFR to LRFR; this increases to 7.5% for an ADTT ≥ 5,000.

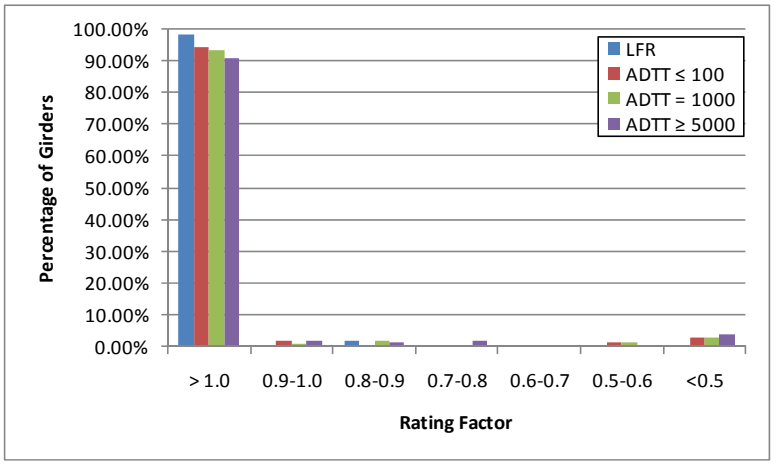


Figure G-509: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

G.4.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure G-510 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.3 for shear. 21% of girders have an LRFR rating that is greater than the LFR rating.

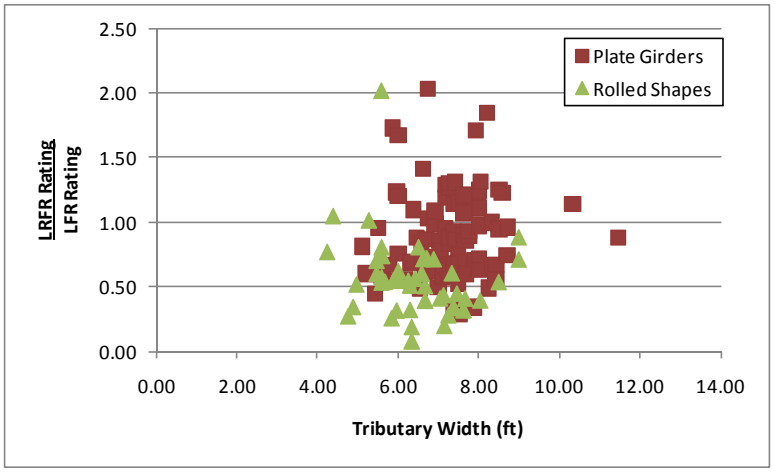


Figure G-510: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

G.4.9.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all but four girders as shown in Figure G-511. The reliability index appears to be split into two groups, the upper group corresponds to the rolled shapes and the lower group corresponds to the plate girders. The plate girders typically have reliability indices that are between five and seven while the rolled shapes are generally greater than eight.

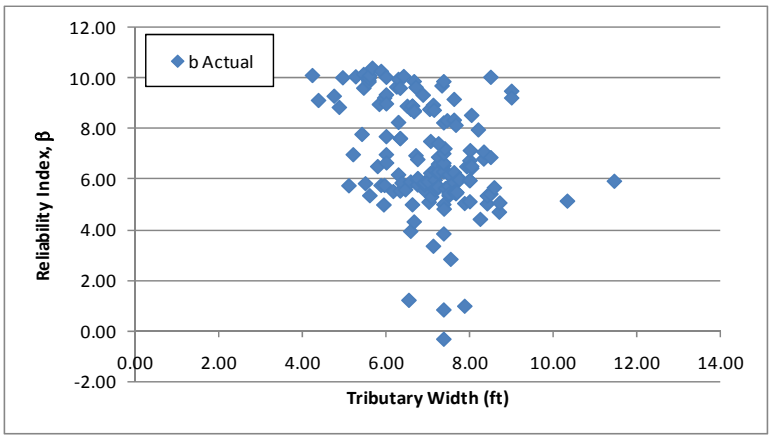


Figure G-511: Shear Reliability Indices for TX-04 Vehicle

Figure G-512 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The reliability index increases with increasing LRFR ratings. A girder with a rating of 1.0 is expected to have a reliability index near 2.5, the target reliability index. This indicates the LRFR live load factors provide the target reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

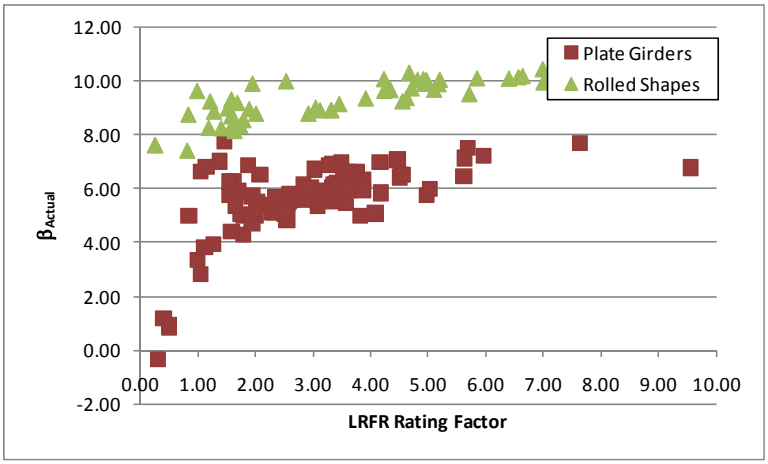
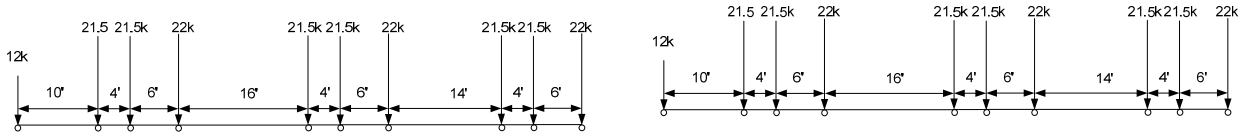


Figure G-512: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

G.4.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-513. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LFR Loading LRFR Loading

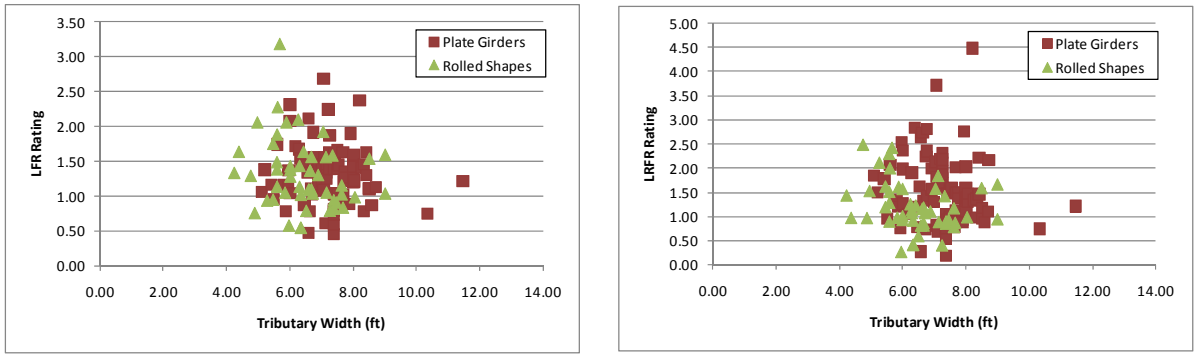
Figure G-513: Vehicle Loadings and Load Factors

G.4.10.1Moment

The following section contains the results for exterior, composite steel girders within continuous span bridges for the WA-02 Vehicle.

G.4.10.1.1 Rating Factors

Figure G-514 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 34 girders with an LFR rating less than 1.0, 49 girders with an LRFR rating less than 1.0, and 29 girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 43% of the girders in this subset. The LFR ratings are generally between 1.0 and 2.0 while the LRFR ratings are generally between 0.5 and 2.0.



(a) (b)

Figure G-514: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure G-515 shows the percentage of girders with moment ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 87.2% of girders have LRFR ratings less than 1.0 for single trip, escorted permits. This drops to 48.7% of girders when a multiple trip permit with ADTT ≥ 5,000 is considered. 77% of girders have LFR ratings greater than 1.0. 10.2% fewer girders have ratings less than 1.0 when LFR is switched to LRFR for single trip, escorted permit; when LRFR multiple trip permits with ADTT ≥ 5,000 are used, 28.3% more girders are affected.

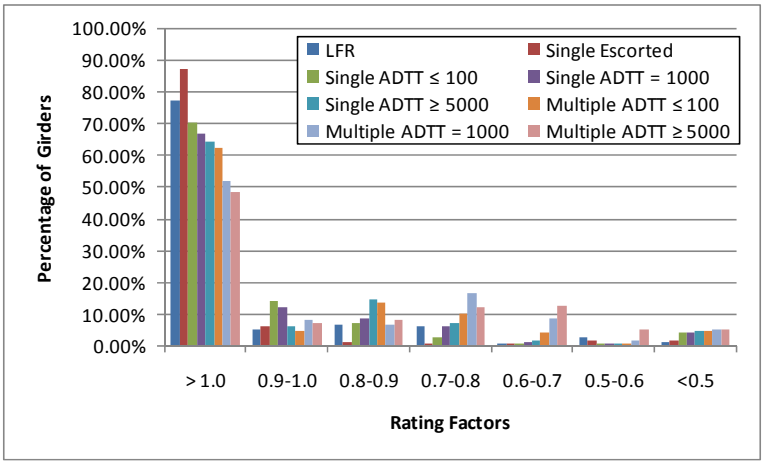


Figure G-515: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

G.4.10.1.2 Rating Factor Comparisons

Figure G-516 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.5, with 57% of girders having an LRFR rating that are greater than the LFR rating.

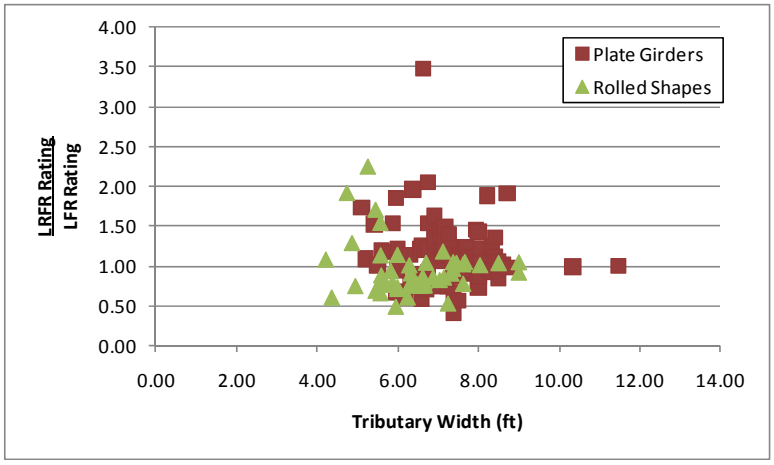


Figure G-516: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

G.4.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-517 shows thirty one girders that have reliability index less than the target reliability index of 3.5. The reliability index for most girders is greater than four.

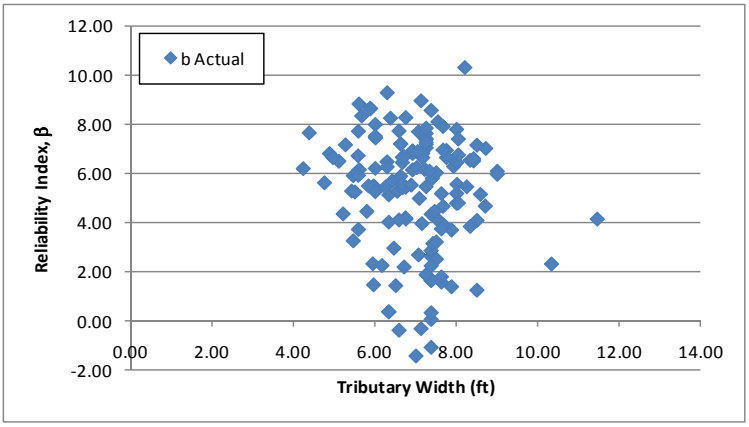


Figure G-517: Flexure Reliability Indices for WA-02 Vehicle

Figure G-518 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 vehicle. The reliability index increases with increasing rating factors. A girder with a rating factor of 1.0 is expected to have a reliability index near 3.5, the target reliability index. This indicates the LRFR live load factors provide the target level of reliability.

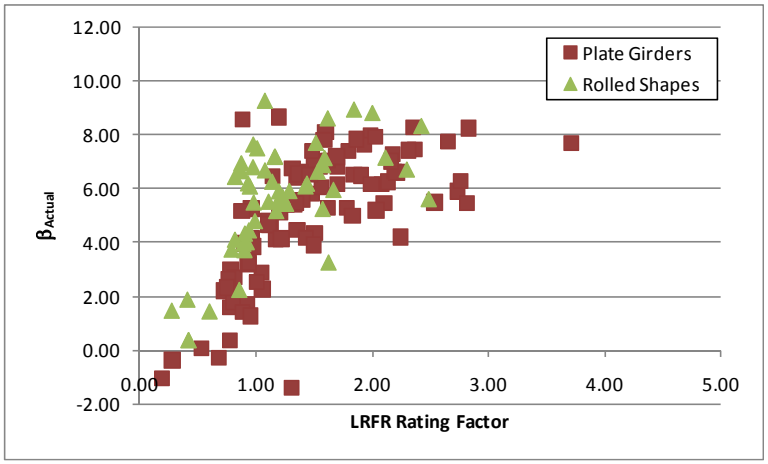
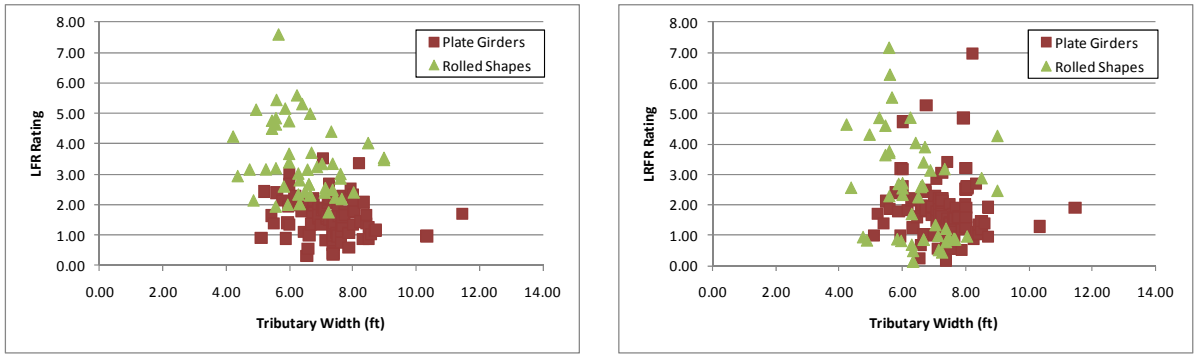


Figure G-518: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

G.4.10.2Shear

G.4.10.2.1 Rating Factors

For shear, there are 17 girders with LFR rating factors less than 1.0, 34 girders with LRFR ratings less than 1.0, and 10 girders where both ratings are less than 1.0. Twenty four of the thirty four girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 57% of the girders in this subset. Figure G-519 shows the LFR and LRFR ratings, respectively. The LFR ratings are between one and 2.5 for most plate girders while the rolled shapes generally have ratings greater than 2.0. The LRFR ratings are also between one and 2.5 for plate girders. LRFR ratings for rolled shapes vary significantly.



(a) (b)

Figure G-519: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure G-520 shows the percentage of girders with shear ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 89.2% of girders have LRFR ratings greater than 1.0 for single trip, escorted permits. This decreases to 66.9% of girders for multiple trip permits with ADTT ≥ 5,000. 88.5% of girders have LFR ratings greater than 1.0. This is a decrease of 0.7% of girders with LRFR ratings less than 1.0 for single trip, escorted permits when switching from LFR to LRFR; the number of girders with LRFR ratings less than 1.0 increases 21.6% for a multiple trip permit with ADTT ≥ 5,000.

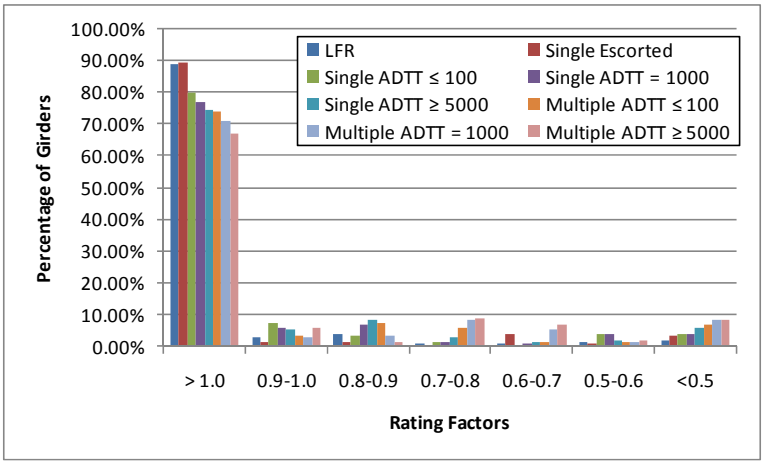


Figure G-520: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

G.4.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-521 shows the comparison of rating factors. The ratio is generally between 0.5 and 1.5. 43% of girders have LRFR ratings that are greater than the LFR rating; most girders with LRFR ratings greater than the LFR rating are plate girders.

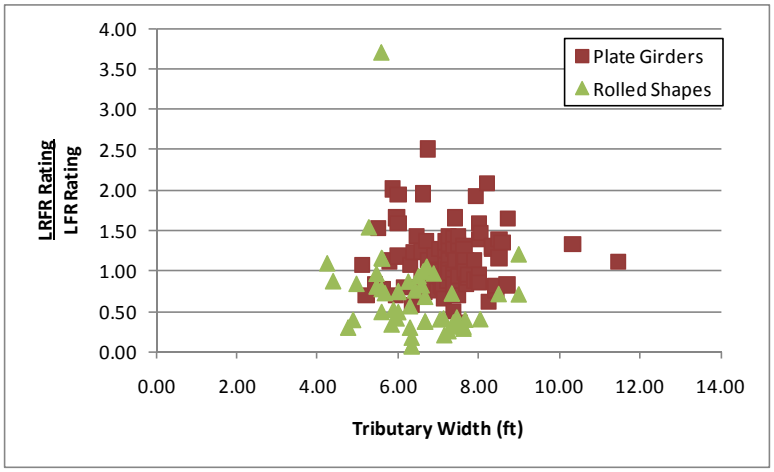


Figure G-521: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

G.4.10.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for 11 girders as shown in Figure G-522. The reliability index is between seven and ten for rolled shapes and four and seven for plate girders. Girders with low reliability are typically plate girders.

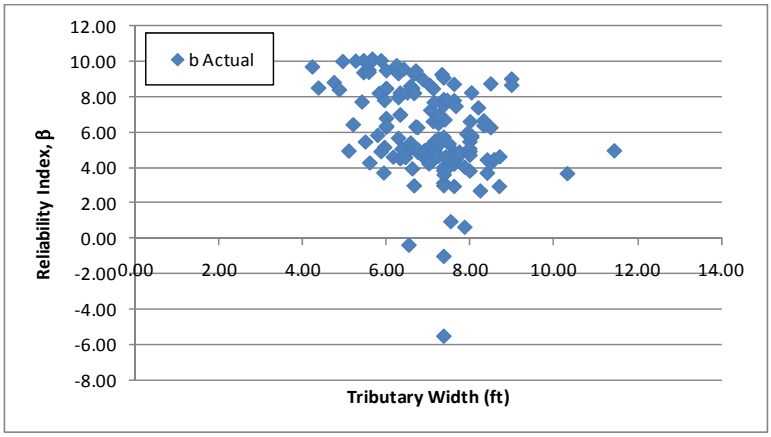


Figure G-522: Shear Reliability Indices for WA-02 Vehicle

Figure G-523 shows the shear reliability index plotted against the LRFR shear rating for the WA-02 Vehicle. The reliability index increases with increasing LRFR ratings. A reliability index of at least 3.5 is expected for a girder with a rating of 1.0. This indicates the LRFR live load factors provide the target level of reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

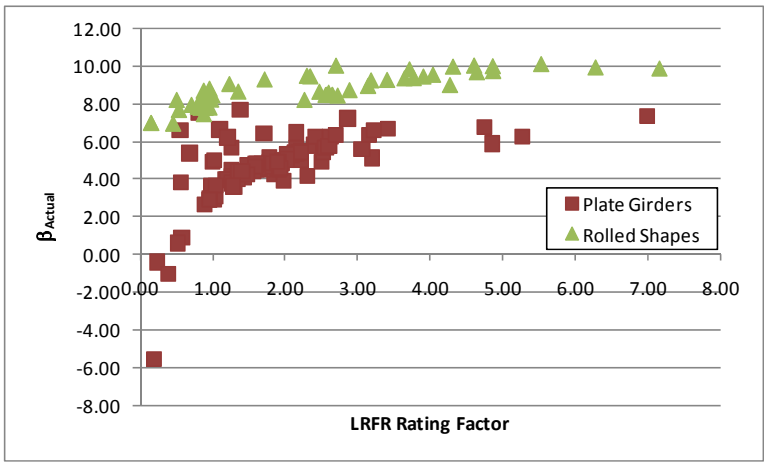


Figure G-523: Shear Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

G.4.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-524. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

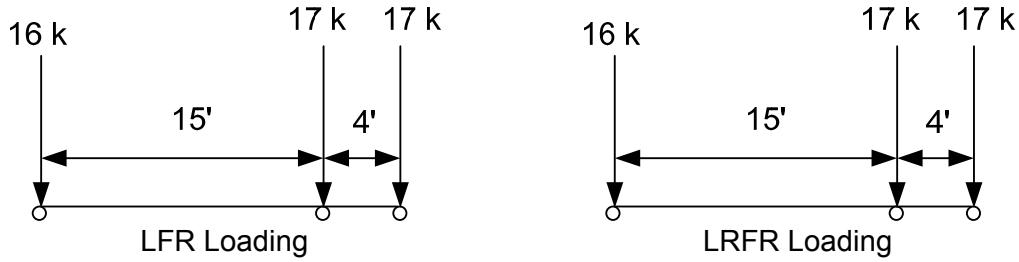
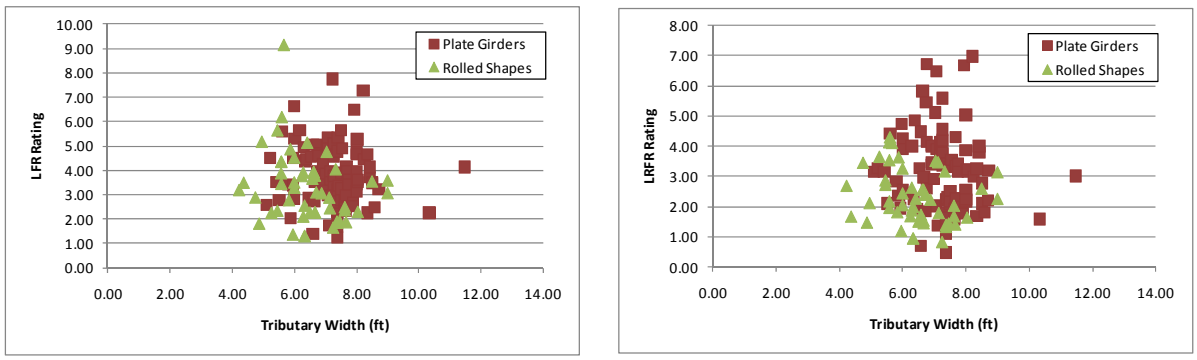


Figure G-524: Vehicle Loadings and Load Factors

G.4.11.1Moment

G.4.11.1.1 Rating Factors

Figure G-525 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, five girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 81% of the girders in this subset. The LFR rating is between two and five for most girders while the LRFR rating is also between two and five.



(a) (b)

Figure G-525: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure G-526 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 98% of girders have LRFR ratings less than 1.0 for ADTT ≤ 100. This drops to 96.6% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings greater than 1.0. 2% more girders have ratings less than 1.0 when LFR is switched to LRFR with an ADTT ≤ 100; when LRFR with ADTT ≥ 5,000 is used, 3.4% more girders are affected.

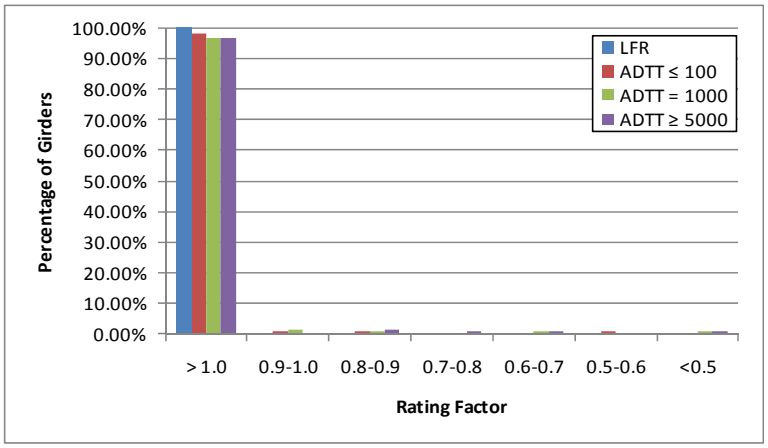


Figure G-526: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

G.4.11.1.2 Rating Factor Comparisons

Figure G-527 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.1. 19% of girders have LRFR ratings that are greater than the LFR rating.

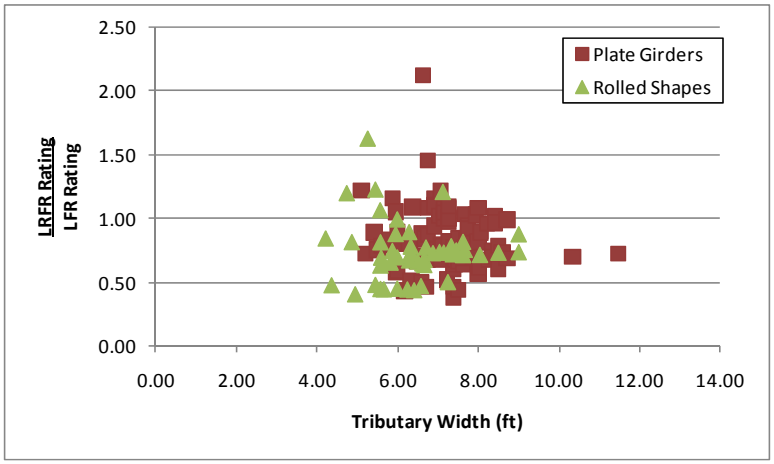


Figure G-527: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

G.4.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-528 shows that four girders have a reliability index less than the target reliability index 2.5. The reliability index is between five and ten for most girders.

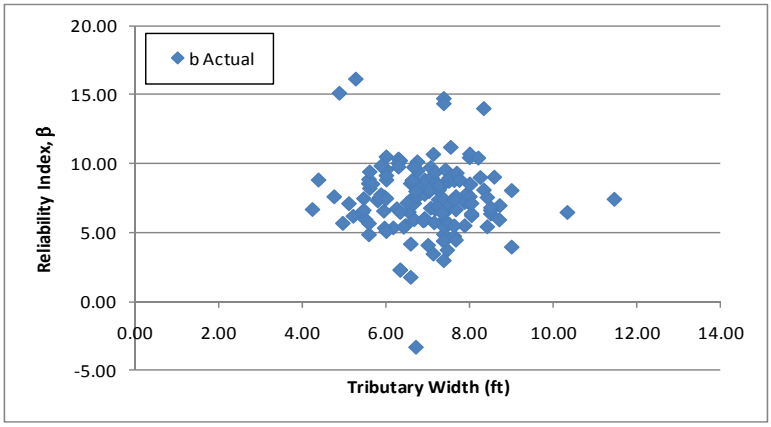


Figure G-528: Flexure Reliability Indices for Type 3 Vehicle

Figure G-529 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 Truck. The reliability index increases with increasing LRFR ratings and is approximately 2.5 for girders with a rating of 1.0. This indicates the LRFR live load factors provide the target level of reliability.

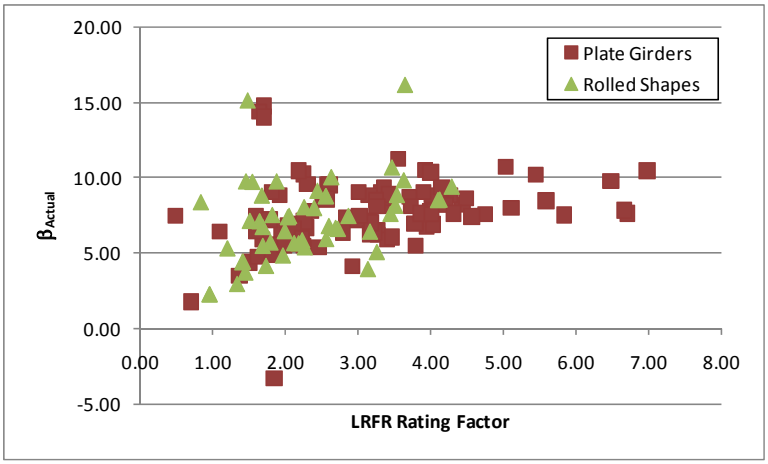
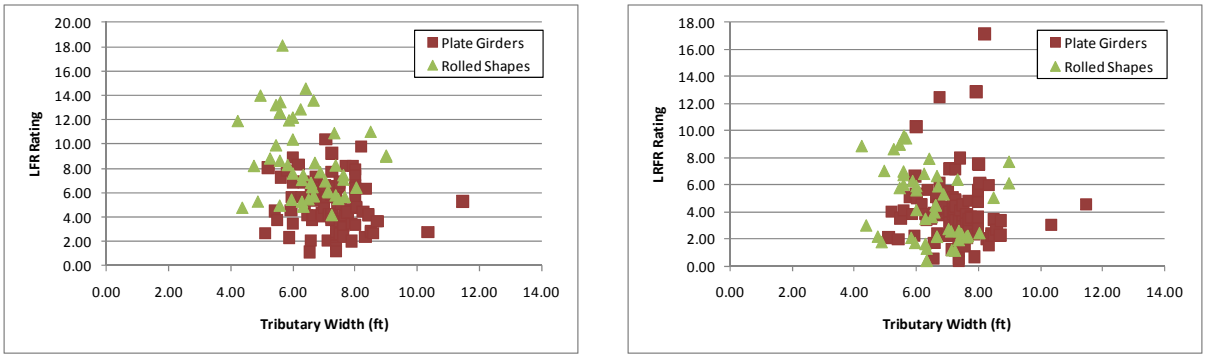


Figure G-529: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

G.4.11.2Shear

G.4.11.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, six girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. Two of the six girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 82% of the girders in this subset. Figure G-530 shows the LFR and LRFR ratings. LFR ratings are between two and eight for most girders while the LRFR ratings are between two and six for most girders.



(a) (b)

Figure G-530: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure G-531 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 96% of girders have LRFR ratings greater than 1.0 for all LRFR categories. 100% of girders have LFR ratings greater than 1.0. This is an increase of 4% of girders with LRFR ratings less than 1.0 for all ADTTs.

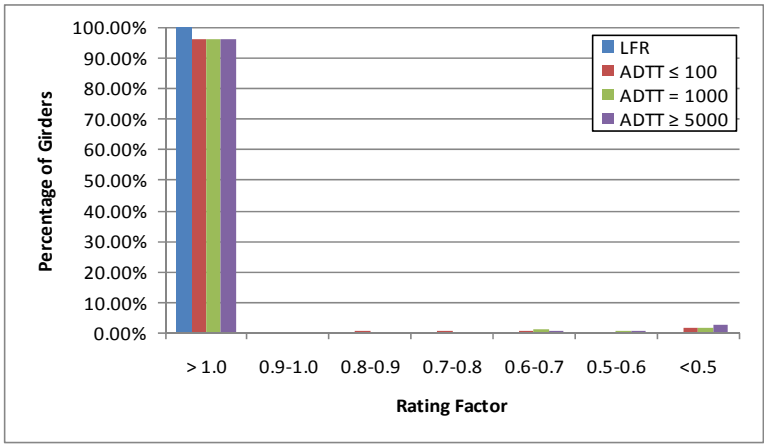


Figure G-531: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

G.4.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-532 show the comparison of rating factors. The ratio is generally between 0.5 and 1.25. The LRFR rating is greater than the LFR rating for 18% of girders, of which most of these are plate girders.

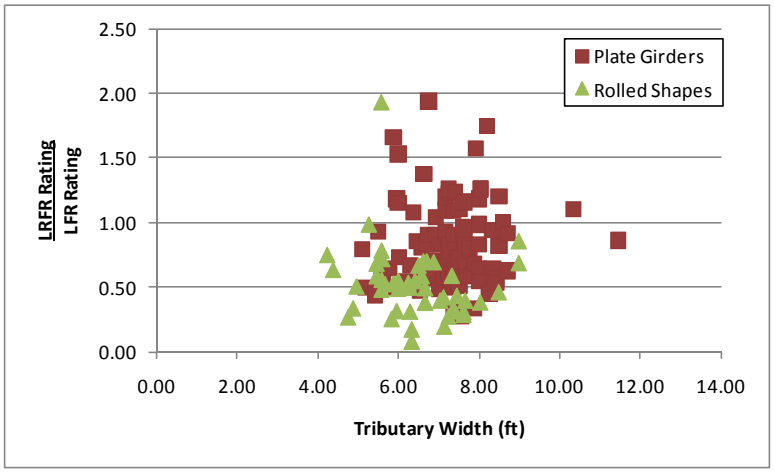


Figure G-532: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

G.4.11.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for four girders as shown in Figure G-533. The reliability index is above eight for rolled shapes and between five and seven for most plate girders.

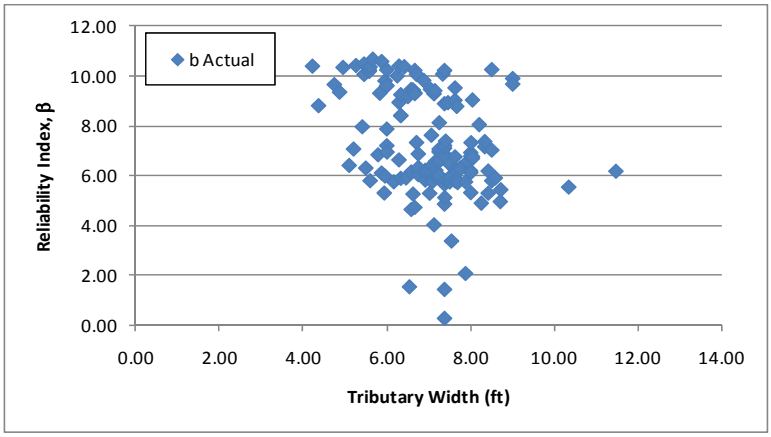


Figure G-533: Shear Reliability Indices for Type 3 Vehicle

Figure G-534 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 Truck. The reliability index increases with increasing ratings; a reliability index of 2.5 is expected for girders with ratings near 1.0. This indicates the live load factors in the MBE provide the target level of reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

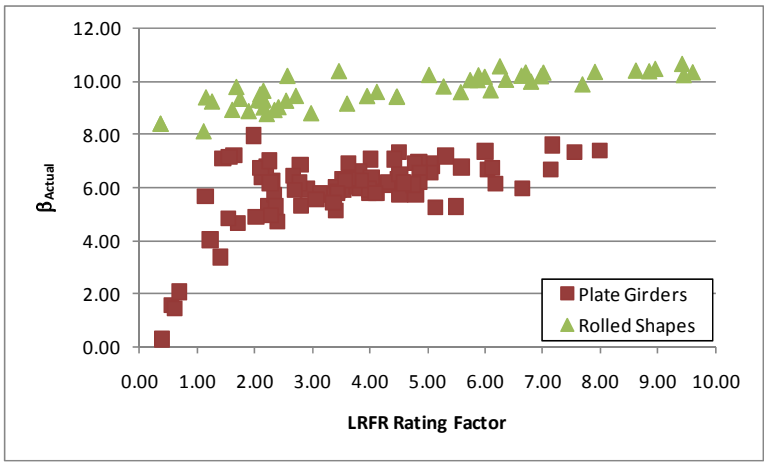


Figure G-534: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

G.4.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-535. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

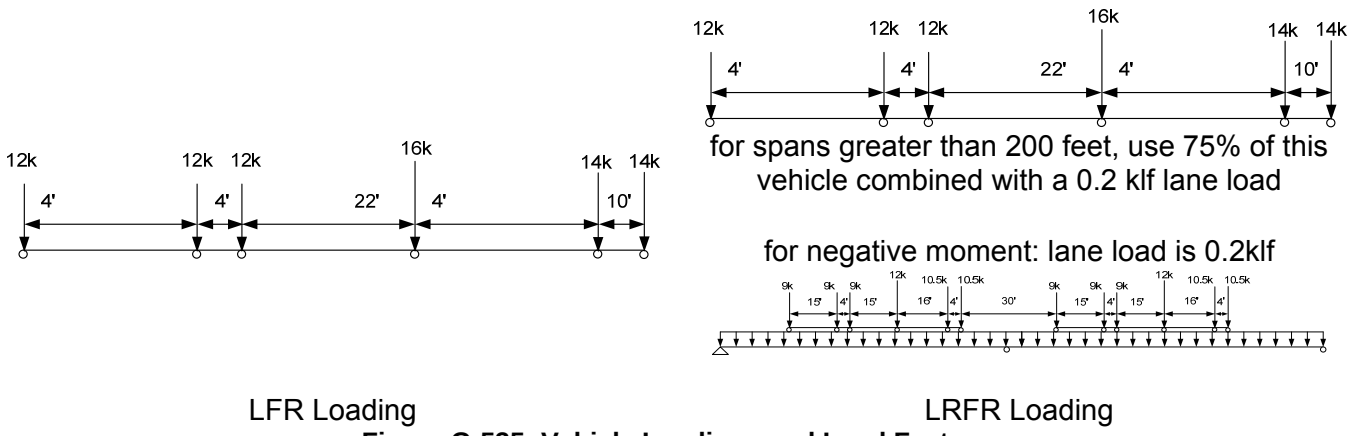
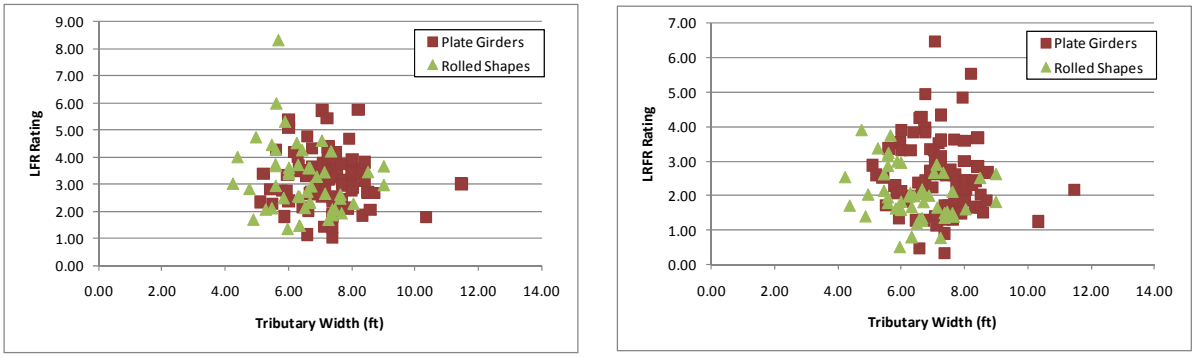


Figure G-535: Vehicle Loadings and Load Factors

G.4.12.1Moment

G.4.12.1.1 Rating Factors

Figure G-536 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, seven girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 86% of the girders in this subset. The LFR ratings are between two and four for most girders while the LRFR rating is between one and four for most girders.



(a) (b)

Figure G-536: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure G-537 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 96% of girders have LRFR ratings less than 1.0 for ADTT ≤ 100. This drops to 95.3% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings greater than 1.0. 4.0% more girders have ratings less than 1.0 when LFR is switched to LRFR with an ADTT ≤ 100; when LRFR with ADTT ≥ 5,000 is used, 4.7% more girders are affected.

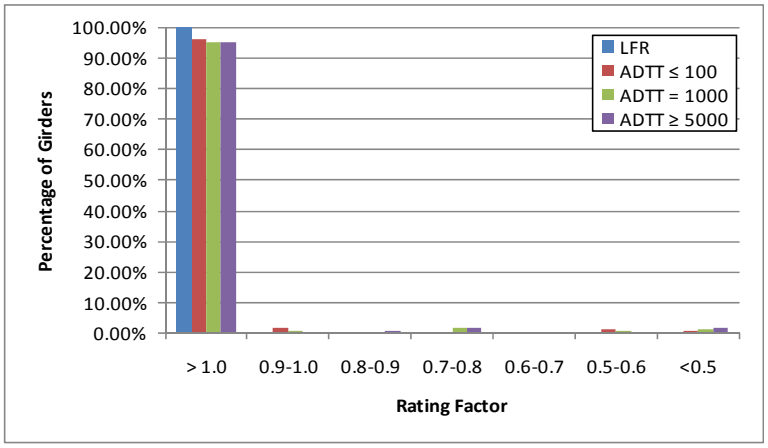


Figure G-537: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

G.4.12.1.2 Rating Factor Comparisons

Figure G-538 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 1.1. 14% of girders have LRFR ratings that are higher than the LFR rating.

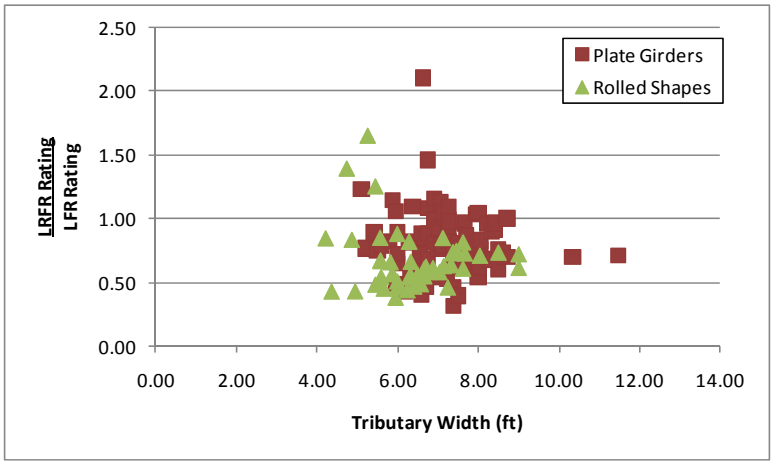


Figure G-538: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

G.4.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-539 shows that two girders have a reliability index less than the target reliability index of 2.5. The reliability index is greater than four for most girders.

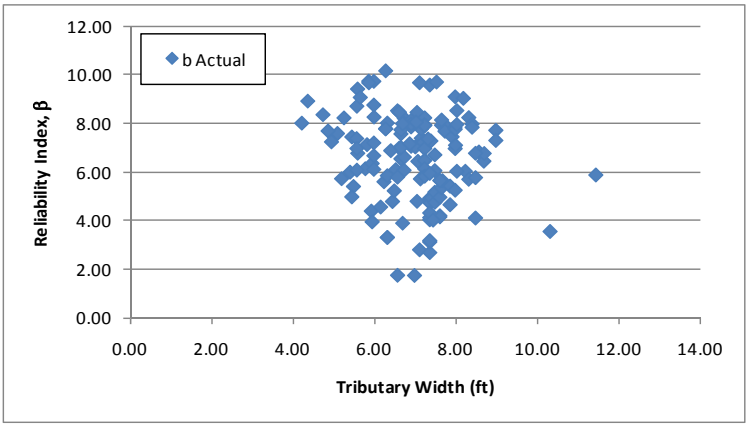


Figure G-539: Flexure Reliability Indices for Type 3-3 Vehicle

Figure G-540 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Vehicle. The reliability index increases for increasing LRFR ratings. A girder with an LRFR rating of 1.0 is expected to have a reliability index of 2.5. This is the target reliability index and indicates the live load factors provide the target reliability.

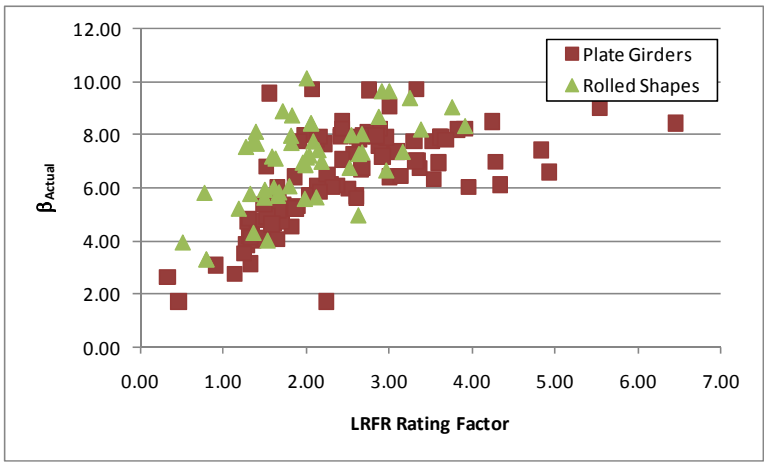
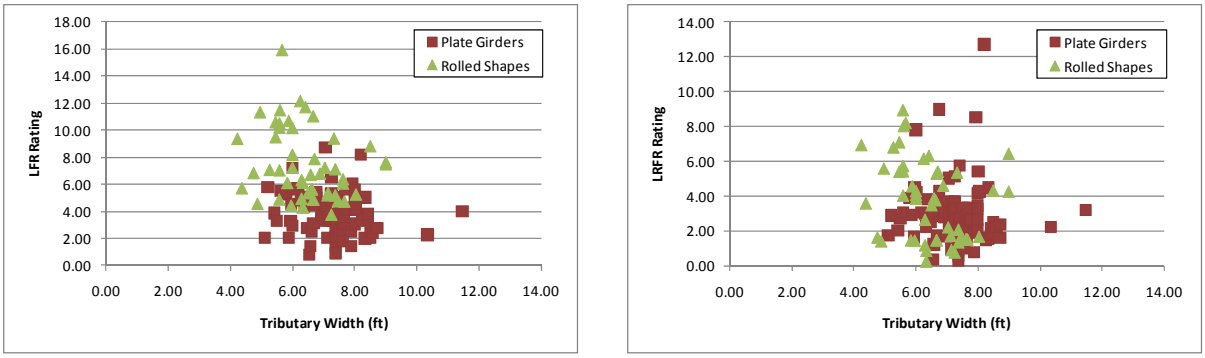


Figure G-540: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

G.4.12.2Shear

G.4.12.2.1 Rating Factors

For shear, there are three girders with LFR rating factors less than 1.0, 12 girders with LRFR ratings less than 1.0, and three girders where both ratings are less than 1.0. Seven of the twelve girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 90% of the girders in this subset. Figure G-541 shows the LFR and LRFR ratings. The LFR ratings are between two and six for most plate girders and greater than four for most rolled shapes. The LRFR ratings are between one and four for most plate girders and are widely scattered for the rolled shapes.



(a) (b)

Figure G-541: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure G-542 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 95.3% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 91.9% of girders for ADTT ≥ 5,000. 98% of girders have LFR ratings greater than 1.0. This is an increase of 2.7% of girders with LRFR ratings less than 1.0 for ADTT ≤ 100 when switching from LFR to LRFR; this increases to 6.1% for an ADTT ≥ 5,000.

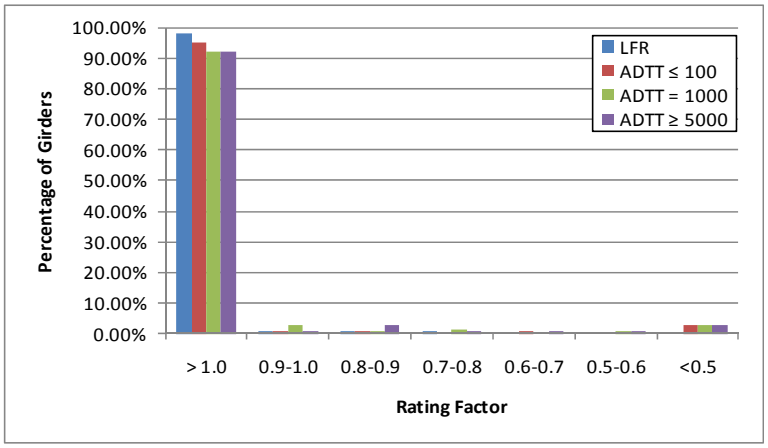


Figure G-542: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

G.4.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-543 shows the comparison of rating factors. The ratio is generally between 0.4 and 1.2. 10% of girders have LRFR ratings that are greater than the LFR Rating; most of these girders are plate girders.

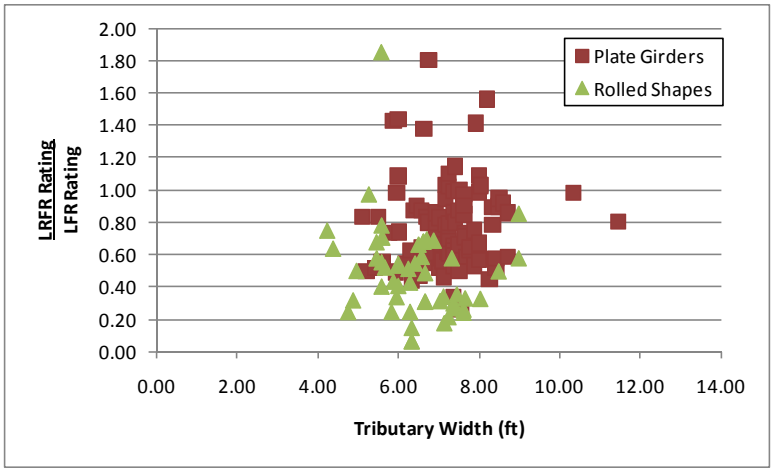


Figure G-543: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

G.4.12.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for four girders as shown in Figure G-544. The reliability index varies greatly for the girders in this group; rolled shapes typically have reliability indices that are greater than the reliability indices of the plate girders.

Figure G-544: Shear Reliability Indices for Type 3-3 Vehicle

Figure G-545 shows the reliability index plotted against the LRFR rating factor for shear due to the AASHTO Type 3-3 Vehicle. The reliability index increases with increasing LRFR ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 2.5, the target reliability index. This indicates the LRFR live load factors provide the target level of reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

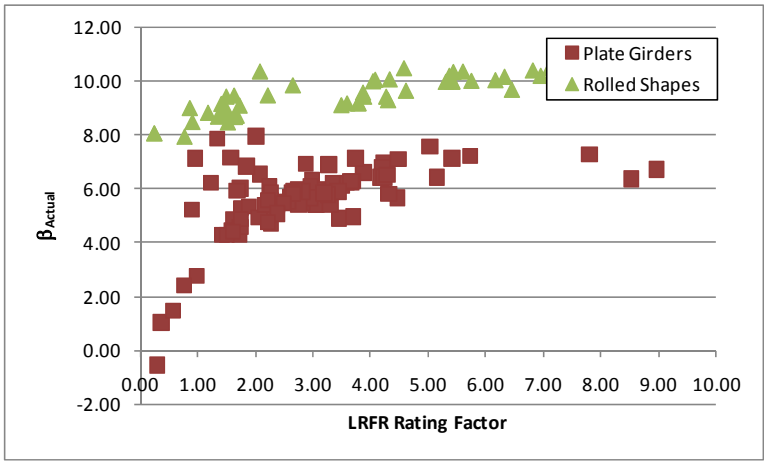


Figure G-545: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

G.4.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure G-546. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

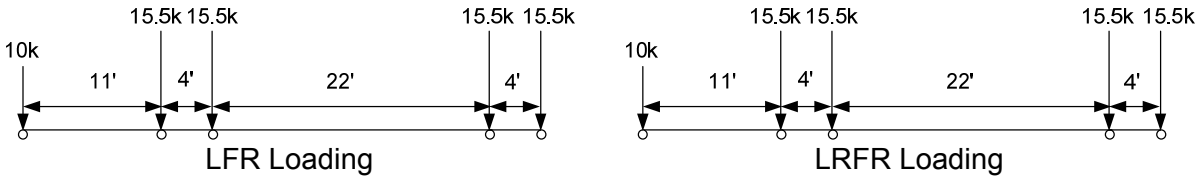
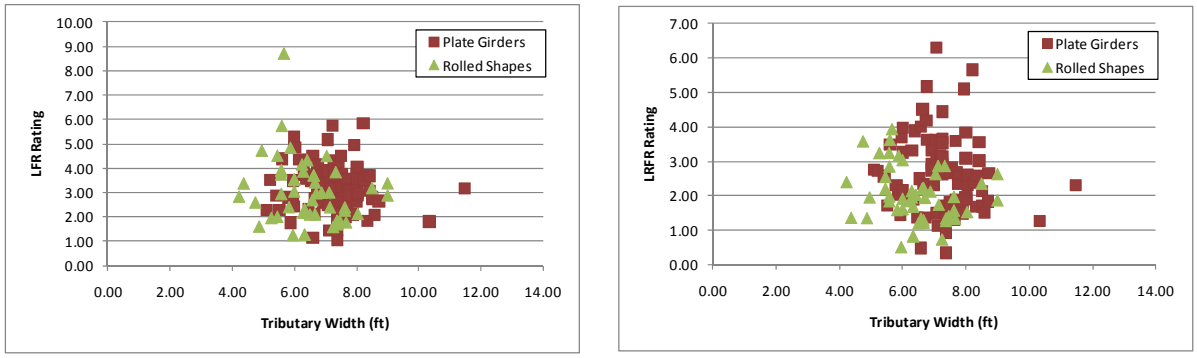


Figure G-546: Vehicle Loadings and Load Factors

G.4.13.1Moment

G.4.13.1.1 Rating Factors

Figure G-547 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, seven girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR legal rating for 86% of the girders in this subset. The LFR ratings are between two and four for most girders while the LRFR ratings are between one and three for most girders.



(a) (b)

Figure G-547: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure G-548 shows the percentage of girders with moment ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 96% of girders have LRFR ratings less than 1.0 for ADTT ≤ 100. This drops to 95.3% of girders for ADTT ≥ 5,000. 100% of girders have LFR ratings greater than 1.0. 4% more girders have ratings less than 1.0 when LFR is switched to LRFR with an ADTT ≤ 100; when LRFR with ADTT ≥ 5,000 is used, 4.7% more girders are affected.

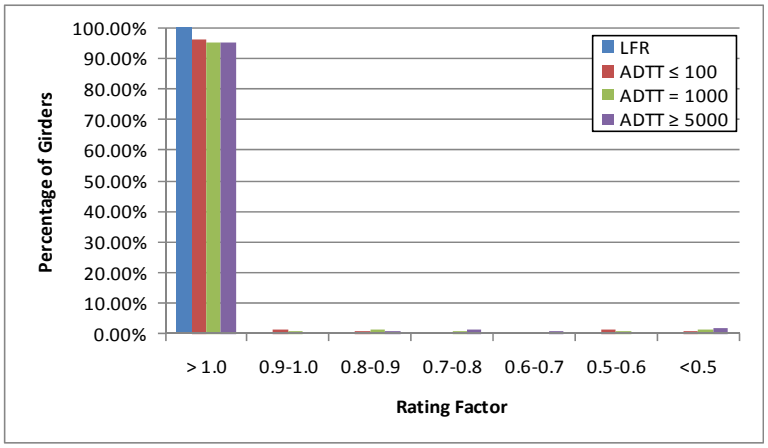


Figure G-548: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

G.4.13.1.2 Rating Factor Comparisons

Figure G-549 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 1.2. 14% of girders have an LRFR rating that is greater than the LFR rating.

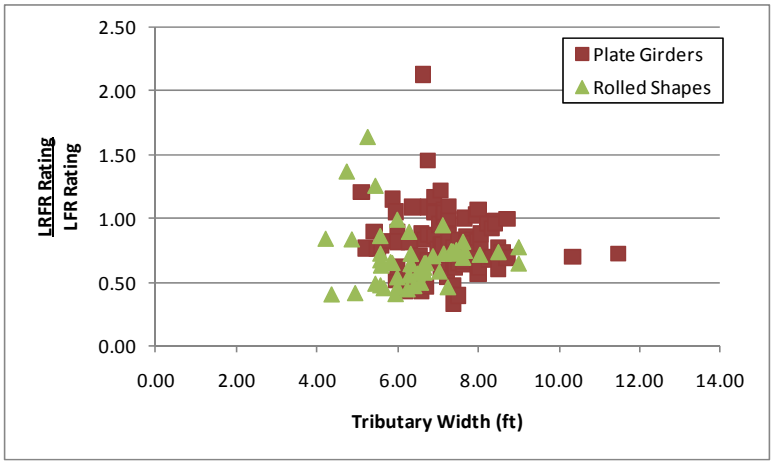


Figure G-549: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

G.4.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure G-550 shows that two girders have a reliability index less than the target reliability index of 2.5. The reliability index is between four and eight for most girders.

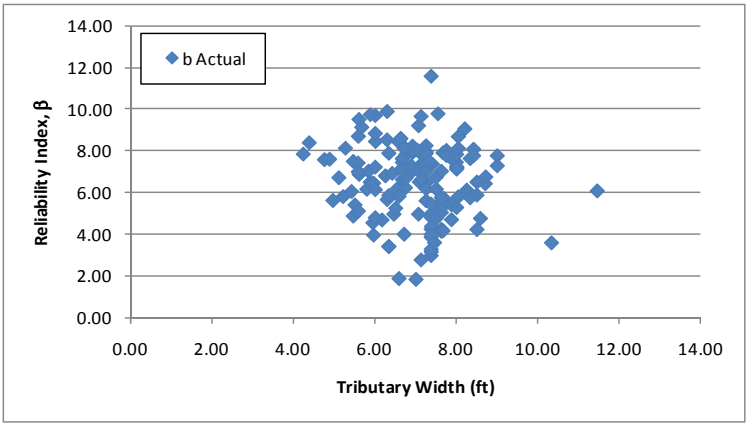


Figure G-550: Flexure Reliability Indices for Type 3S2 Vehicle

Figure G-551 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 vehicle. The reliability index increases with increasing rating factors. The reliability index corresponding to an LRFR rating of 1.0 is approximately 2.5, the target reliability index. This indicates the LRFR live load factors are producing the target reliability.

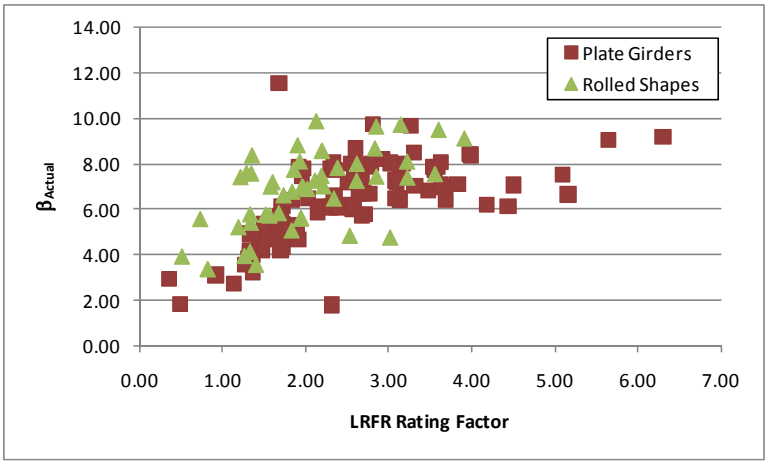
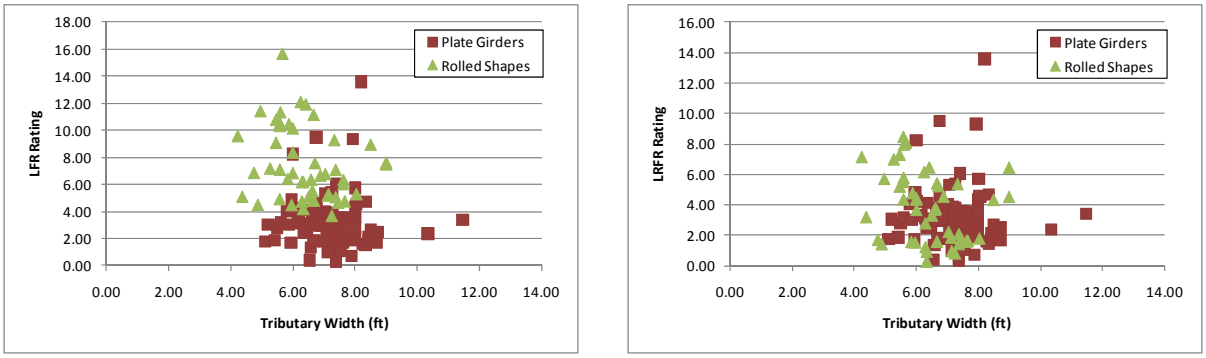


Figure G-551: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

G.4.13.2Shear

G.4.13.2.1 Rating Factors

For shear, there are three girders with LFR rating factors less than 1.0, eleven girders with LRFR ratings less than 1.0, and three girders where both ratings are less than 1.0. Seven of the eleven girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener rating. The LFR Rating is greater than the LRFR rating for 86% of the girders in this subset. Figure G-552 shows the LFR and LRFR ratings. The LFR rating is between one and four for most plate girders and greater than four for rolled shapes. The LRFR ratings are between one and four for most plate girders with the ratings for rolled shapes more varied.



(a) (b)

Figure G-552: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure G-553 shows the percentage of girders with shear ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 95.3% of girders have LRFR ratings greater than 1.0 for ADTT ≤ 100. This decreases to 91.9% of girders for ADTT ≥ 5,000. 98% of girders have LFR ratings greater than 1.0. This is an increase of 2.7% of girders with LRFR ratings less than 1.0 for ADTT ≤ 100 when switching from LFR to LRFR; this increases to 6.1% for an ADTT ≥ 5,000.

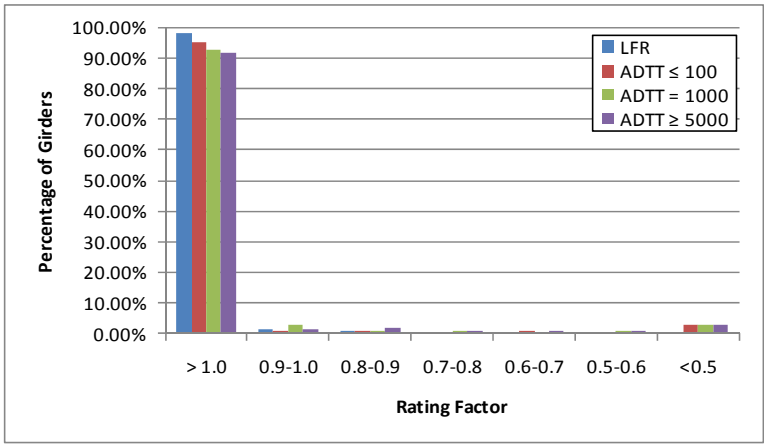


Figure G-553: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

G.4.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure G-554 show the comparison of rating factors. The ratio is generally between 0.5 and 1.3. 14% of girders have LRFR ratings greater than the LFR rating.

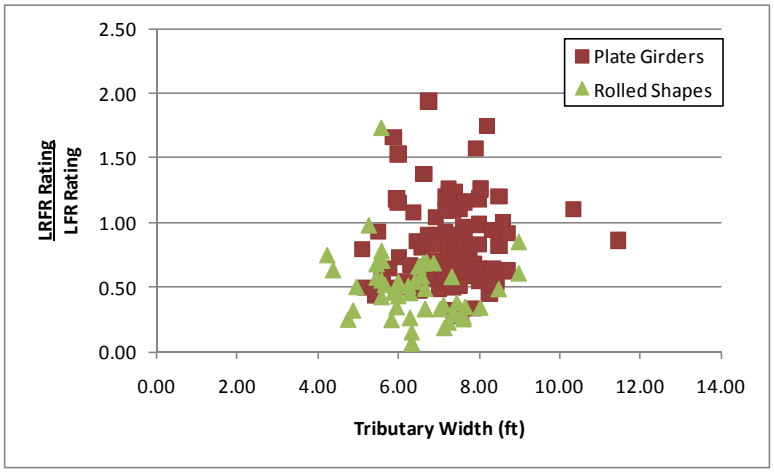


Figure G-554: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

G.4.13.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for four girders as shown in Figure G-555. The reliability index appears to be split into two groups; an upper group consisting of the rolled shapes and a lower group consisting of the plate girders. The reliability index is greater than four for most girders.

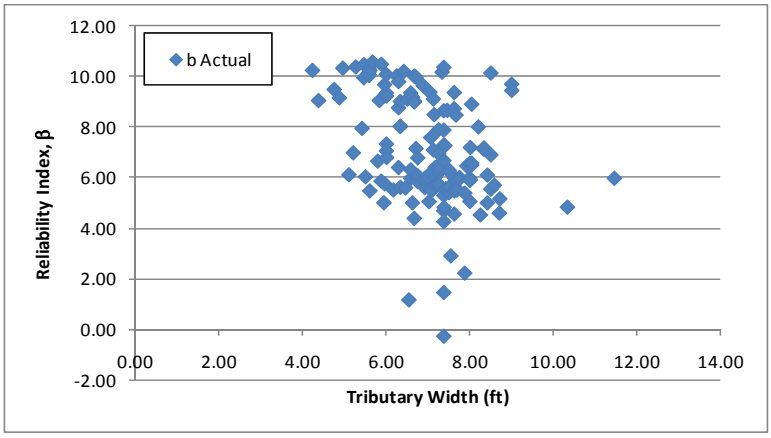


Figure G-555: Shear Reliability Indices for Type 3S2 Vehicle

Figure G-556 shows the reliability index for shear plotted against the LRFR shear rating for AASHTO Type 3S2 Truck. The reliability index increases with increasing ratings; the reliability index corresponding to a girder with an LRFR rating of 1.0 is approximately 2.5, the target reliability. This indicates the LRFR live load factors provide the target level of reliability. The girders with high reliability and low ratings are those controlled by the bearing stiffener rating. The reliability index is calculated using the web shear resistance, not the bearing stiffener resistance.

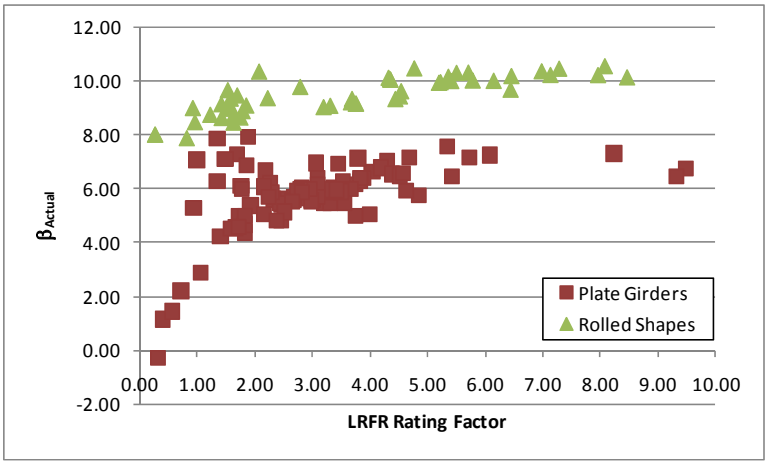


Figure G-556: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

G.4.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table G-7 shows the results for the moment ratings. The Design Vehicle and WA-02 cause the most girders to have ratings less than 1.0; these are the two vehicles that cause the largest force effects. The other ten vehicles typically resulted in many fewer girders having ratings less than 1.0. The design, routine permit, and legal vehicles resulted in 75-85% of the girders having LFR ratings greater than the LRFR rating. The special permit vehicles resulted in less than 50% of the girders having LFR ratings greater than the LRFR rating. This is a result of the MBE using a single lane loaded without the multiple presence factor for the special permit vehicles.

Table G-7: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	148	24	2	1	9	0	0	7	5	34	0	0	0
LRFR Rating less than 1.0		51	7	6	9	7	5	10	8	49	5	7	7
LFR and LRFR Rating less than 1.0		20	2	1	7	0	0	7	5	29	0	0	0
% with LFR RF greater than LRFR RF		76	80	80	44	78	78	48	78	43	81	86	86

G.4.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table G-8 shows the results for the shear ratings. WA-02 created the most problems with girders having insufficient ratings; the other eleven vehicles generally created very few problems with ratings being less than 1.0. An additional row has been added to indicate the number of girders with LRFR ratings less than 1.0 and controlled by bearing stiffener rating. The table indicates that usually about half of the girders with LRFR ratings less than 1.0 are controlled by the bearing stiffener.

Table G-8: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	148	8	3	3	6	1	0	6	3	17	0	3	3
LRFR Rating less than 1.0		30	11	9	12	8	6	13	10	34	6	12	11
LFR and LRFR Rating less than 1.0		7	3	3	5	1	0	6	3	10	0	3	3
% with LFR RF greater than LRFR RF		78	80	81	59	79	80	59	79	57	82	90	86
Girders with LRFR Rating less than 1.0 and controlled by bearing stiffener rating		23	6	5	7	4	2	8	5	24	2	7	7

H Continuous Reinforced Concrete Slab Bridges

H.1 One ft. Tributary Width

H.1.1 Dead Loads

H.1.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure H-1, the ratios of unfactored DC1 moments (self-weight, dead loads on non-composite section) are very close to 1.0 for most slabs. The ratio for DC2 and DW loads are not shown because they were all zero.

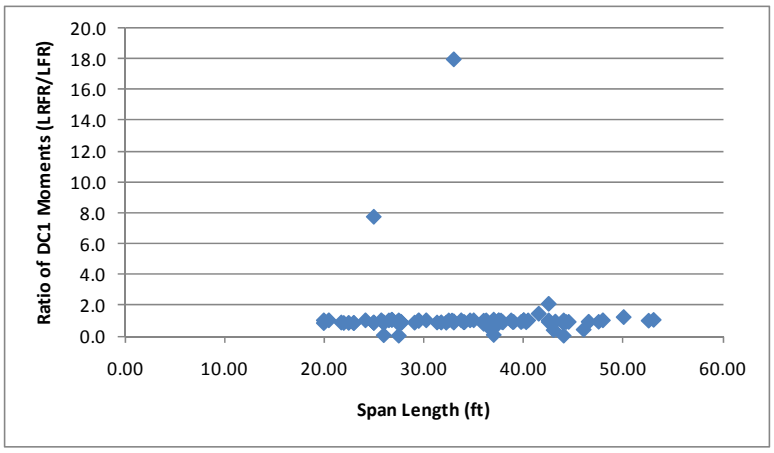


Figure H-1: Ratio of DC1 LRFR Moment to DC1 LFR Moment (unfactored loads)

H.1.1.2 Shear

Figure H-2 shows that numerous slabs have a ratio of DC1 shear close to 1.0, but there are some slabs where the ratio is either above or below 1.0. This is a mostly due to the variation of the critical section for shear.

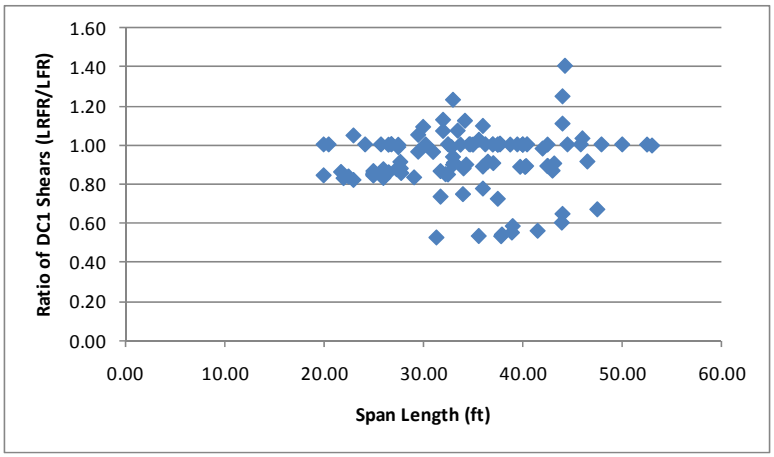


Figure H-2: Ratio of DC1 LRFR Shear to DC1 LFR Shear (unfactored loads)

H.1.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure H-3. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

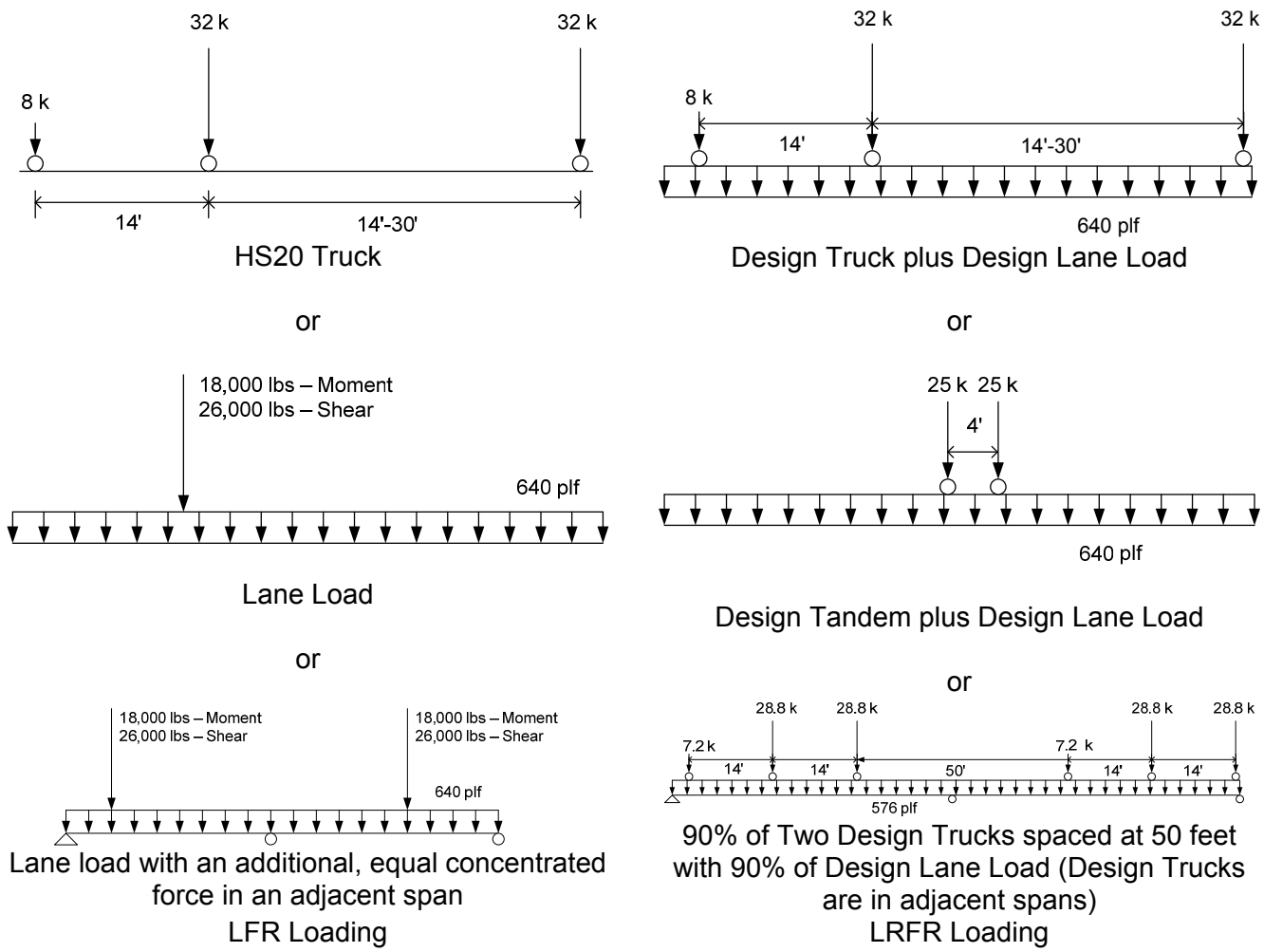


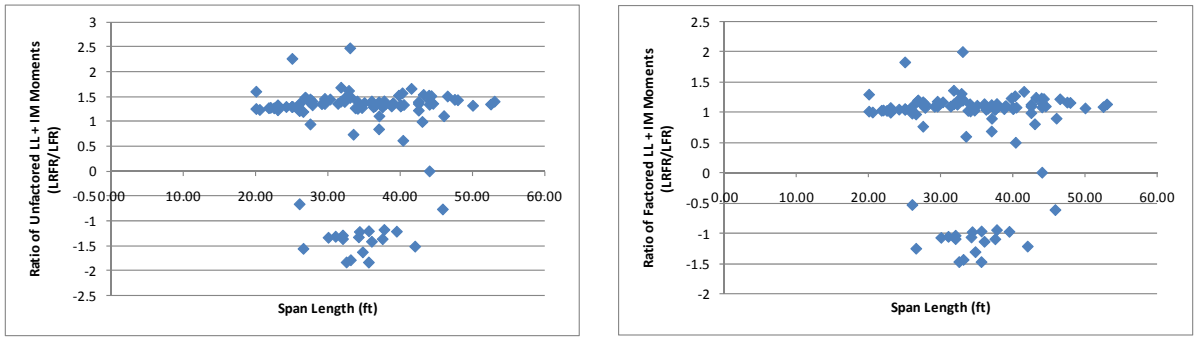
Figure H-3: Vehicle Loadings and Load Factors

H.1.2.1 Moment

H.1.2.1.1 Live Loads

Figure H-4a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is between 1.0 and 1.5 for most of the slabs within this subset. There is also a group near -1.3; these are slabs where the locations are different and the critical moment at one location is negative and at the other location is positive. The next step was to compare the factored live loads. This was

completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure H-4b shows that the results have shifted closer to 1.0.



(a) (b)

Figure H-4: Ratios of Unfactored and Factored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

H.1.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure H-5 shows that the ratio of resistance for most slabs is close to 1, but there are significant numbers of slabs with widely varying ratios of resistance. This is likely a result of the critical moment location varying between methods. The slabs with a ratio of resistance that is negative are those where one critical location is in a positive moment region and the other is in a negative moment region.

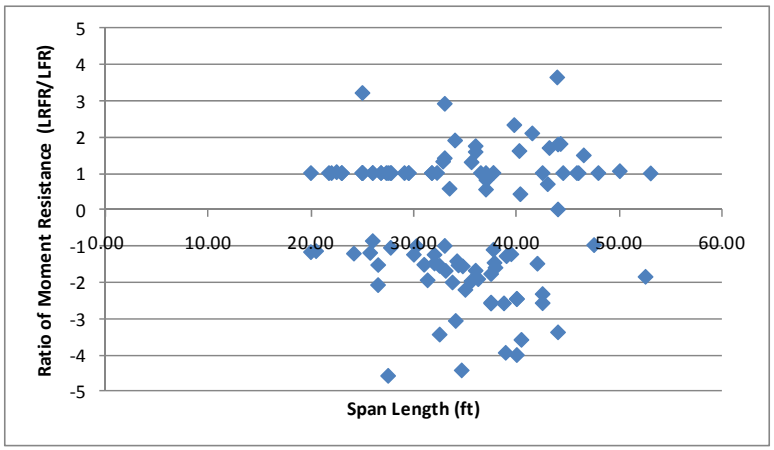
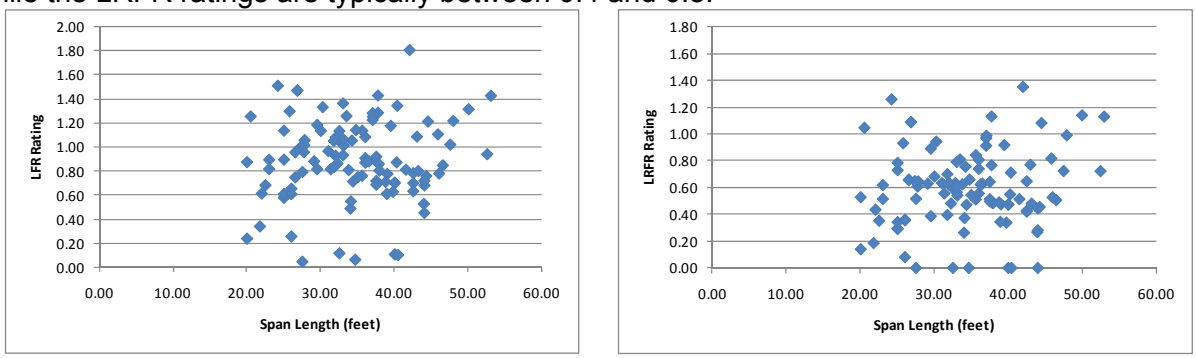


Figure H-5: Ratio of factored Moment Resistance (LRFR/LFR)

H.1.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results seemed appropriate, the rating factors were investigated. The purpose of this investigation was to determine how many slabs within the subset (105 slabs) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 66 slabs with LFR ratings less than 1.0, 96 slabs with LRFR ratings less than 1.0, and 66 slabs where both the LFR and LRFR ratings are less than 1.0. 95 of the 96 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. Figure H-6

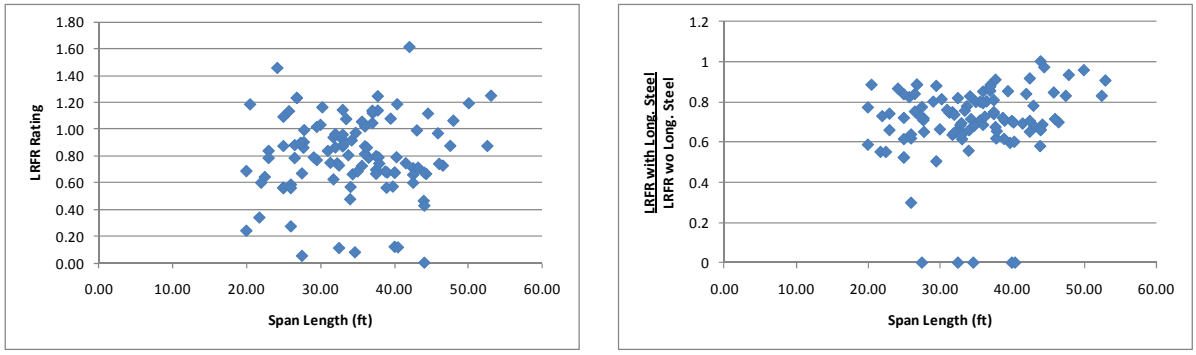
shows the LFR rating factors and LRFR rating factors. The LFR ratings are typically between 0.6 and 1.4 while the LRFR ratings are typically between 0.4 and 0.8.



(a) (b)

Figure H-6: LFR and LRFR Flexure Rating Factors for Design Loadings

Figure H-7a shows the LRFR ratings when the longitudinal steel rating is not included in the rating. The figure shows that the ratings are generally higher than those shown in Figure H-6b. The most ratings are between 0.6 and 1.0 where previously they were typically between 0.4 and 0.8. Figure H-7b shows the ratio of the LRFR rating including the longitudinal steel rating divided by the LRFR rating excluding the longitudinal steel rating. The ratio is typically between 0.6 and 0.9, indicating that most ratings increased when the longitudinal steel rating is ignored. Figure H-6b shows numerous slabs with LRFR ratings of zero, these slabs are no longer at zero in Figure H-7a but they still do not have satisfactory ratings. Ignoring the longitudinal steel rating causes 16 fewer slabs to have LRFR ratings less than 1.0. The 99% of slabs have higher ratings when the longitudinal steel rating is ignored.



(a) (b)

Figure H-7: Effect of Longitudinal Steel Rating on LRFR Moment Ratings

H.1.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure H-8. The results indicate 100% of the slabs in this set have LFR ratings greater than LRFR ratings. Most slabs have ratios of ratings between 0.5 and 0.8, with no slabs having LRFR ratings greater than the associated LFR rating.

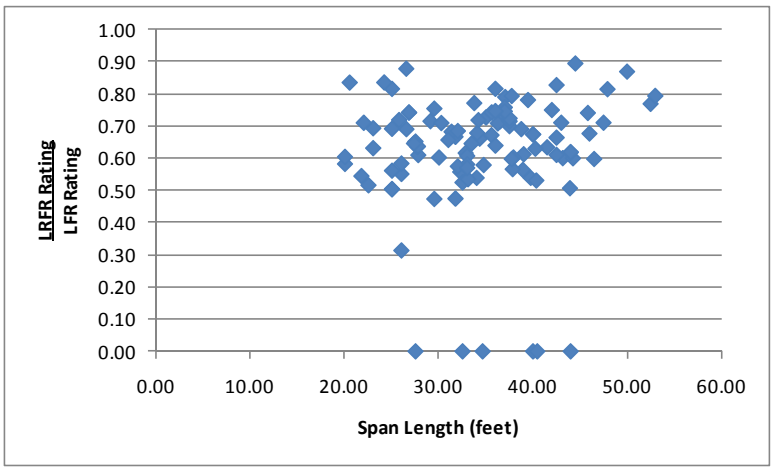


Figure H-8: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure H-9 shows the percentage of slabs with LRFR ratings less than 1.0 and the reduction in rating by switching from LFR to LRFR. All of the slabs are negatively affected by switching from LFR to LRFR. The slabs with LRFR ratings less than 1.0 have ratings that are generally between 50 and 80% of the LFR rating. This may appear to be a large reduction, but approximately two thirds of the continuous slab bridges already have ratings less than 1.0 so some of these slabs may already be rating less than 1.0.

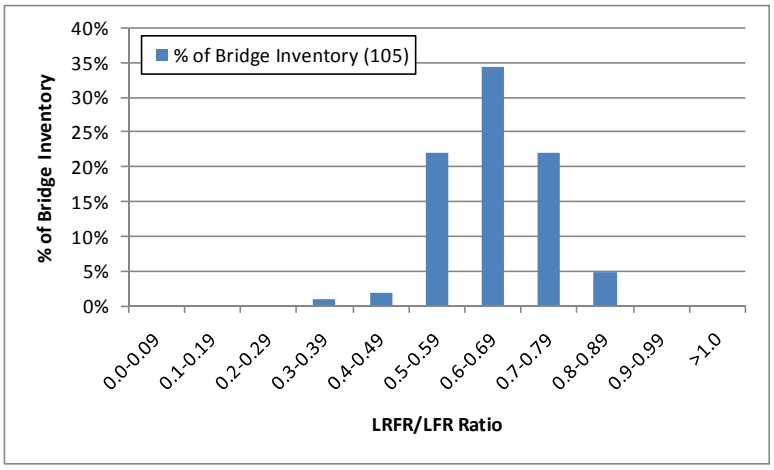


Figure H-9: Distribution of LRFR/LFR Ratio for Slabs with LRFR Ratings less than 1.0

H.1.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure H-10 shows six slabs have a reliability index lower than the target reliability of 3.5 assumed for the design-inventory rating. Most slabs have a reliability index greater than four.

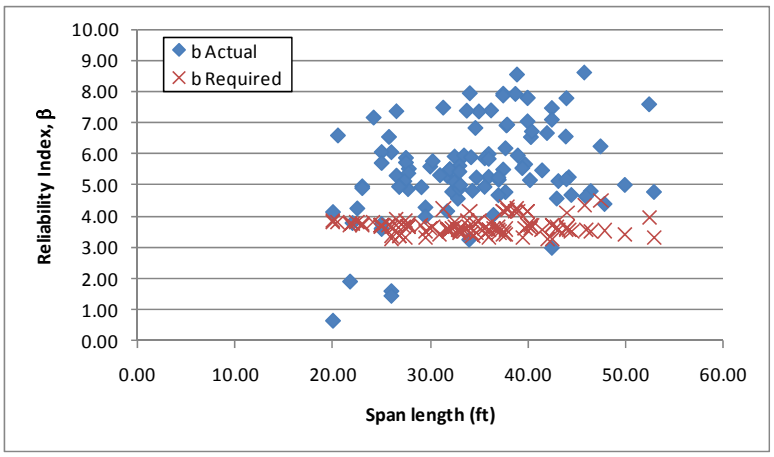


Figure H-10: Flexure Reliability Indices for HL-93 Loading

Figure H-11 shows the reliability index for moment plotted against the LRFR moment rating for the HL-93 Design load. The reliability index increases with increasing rating factors. The reliability index corresponding to an LRFR rating of 1.0 is approximately 6.5, well above the target reliability of 3.5. Slabs with high reliability and low ratings are those controlled by the longitudinal steel rating near the support. The reliability index is calculated using the moment resistance not the resistance of the longitudinal steel.

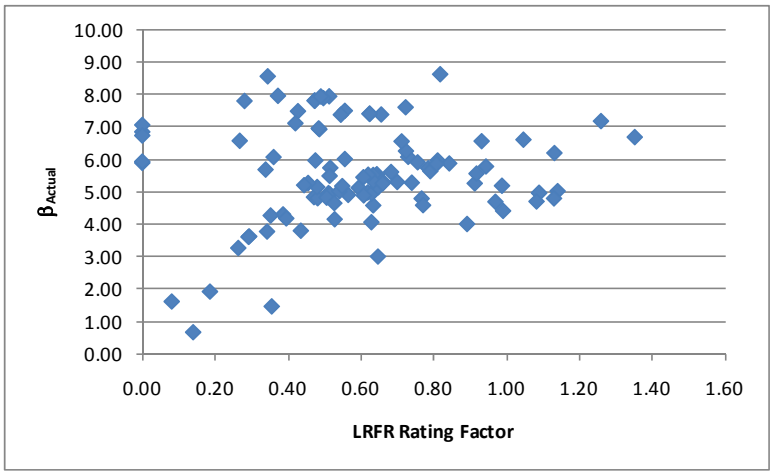
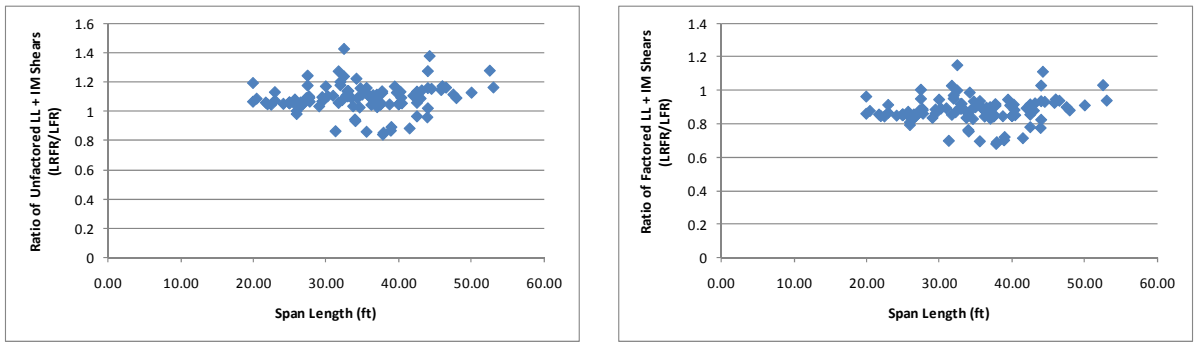


Figure H-11: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Design Load

H.1.2.2 Shear

H.1.2.2.1 Live Loads

Figure H-12a shows that the ratio of unfactored shear is very similar, with most slabs between 1.0 and 1.2, with several ratios below 1.0 as well as several above 1.2. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure H-12b shows that the ratio of factored live load shears has decreased and is generally between 0.8 and 1.0 for most cases.



(a) (b)

Figure H-12: Ratios of Unfactored and Factored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

H.1.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure H-13 shows that the ratio of resistance is between 0.75 and 1.5 for most slabs.

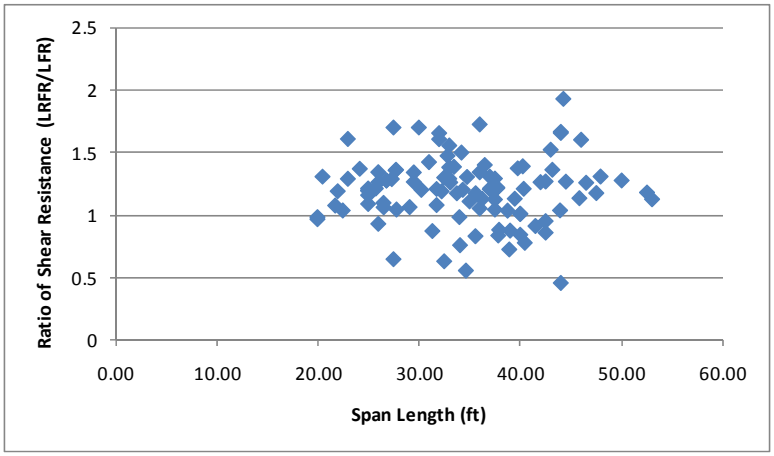
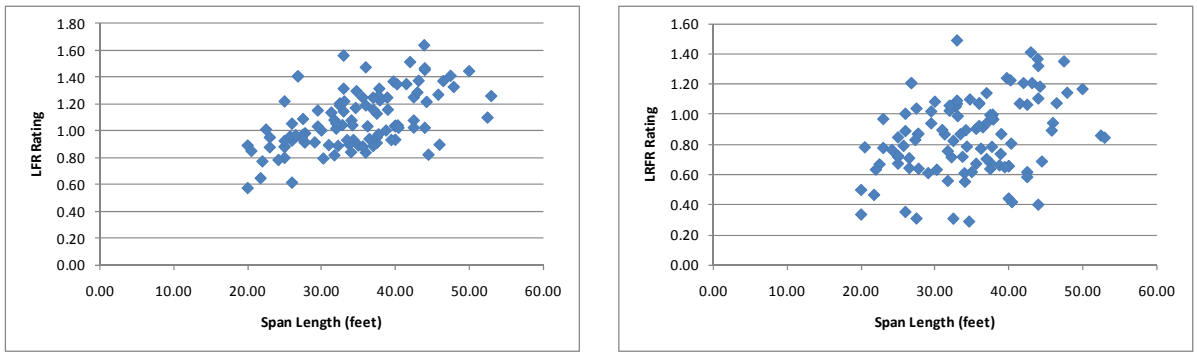


Figure H-13: Ratio of factored Shear Resistance (LRFR/LFR)

H.1.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many slabs within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 43 slabs with LFR ratings less than 1.0, 74 slabs with LRFR ratings less than 1.0, and 41 slabs where both LFR and LRFR ratings are less than 1.0. The LFR rating was greater than the LRFR rating for 90% of the slabs in this subset. Figure H-14 shows the LFR rating factors and LRFR rating factors. The LFR rating tends to increase with increasing span length, with LRFR showing the same trend with more scatter. Most LFR ratings are between 0.8 and 1.4 while the LRFR ratings are between 0.6 and 1.2.



(a) (b)

Figure H-14: LFR and LRFR Shear Rating Factors for Design Loadings

H.1.2.2.4 Rating Factor Comparisons

Figure H-15 shows the ratio of the LRFR rating to the LFR rating. The ratio is generally between 0.6 and 1.0 for all slabs in this set. 10% of slabs have LRFR ratings that are greater than the LFR rating.

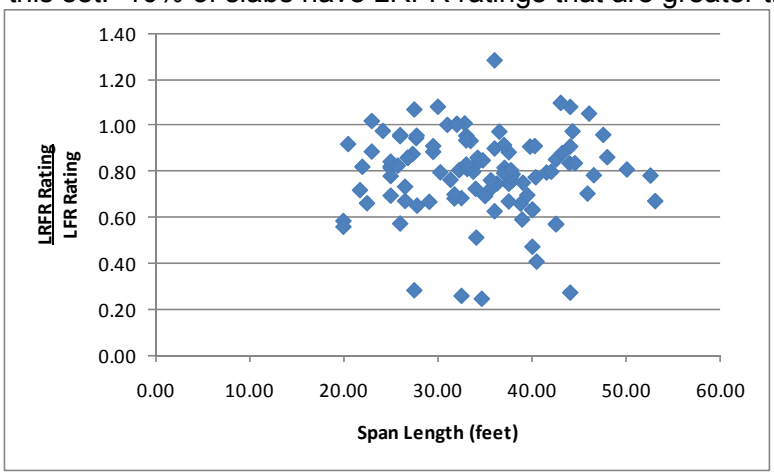


Figure H-15: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure H-16 shows the distribution of slabs with LRFR ratings less than 1.0 as a function of the ratio of LRFR to LFR ratings. The figure shows that most slabs with LRFR ratings less than 1.0 have LRFR ratings that are 60 to 90% of the LFR rating. The slabs are affected significantly be the reduction in ratings when switching from LFR to LRFR.

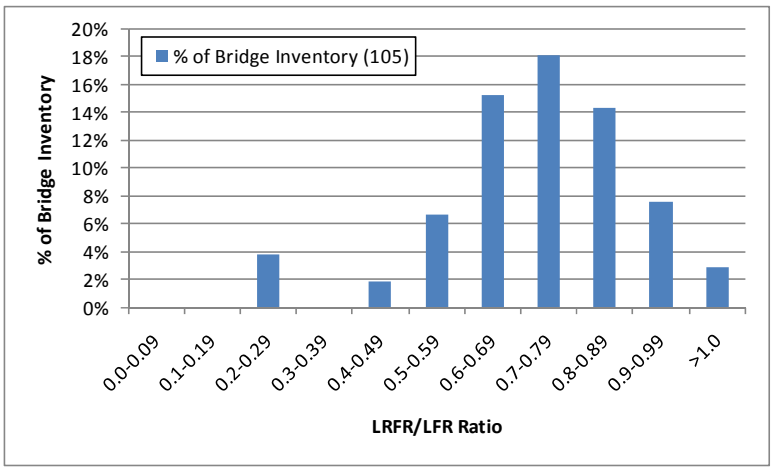


Figure H-16: Distribution of LRFR/LFR Ratio for Slabs with LRFR Ratings less than 1.0

H.1.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure H-17 shows that 44 slabs have a reliability index for shear less than the target reliability of 3.5. In several cases, the reliability index is less than zero, indicating the applied loads are significantly larger than the section resistance. The reliability index varies widely for the slabs.

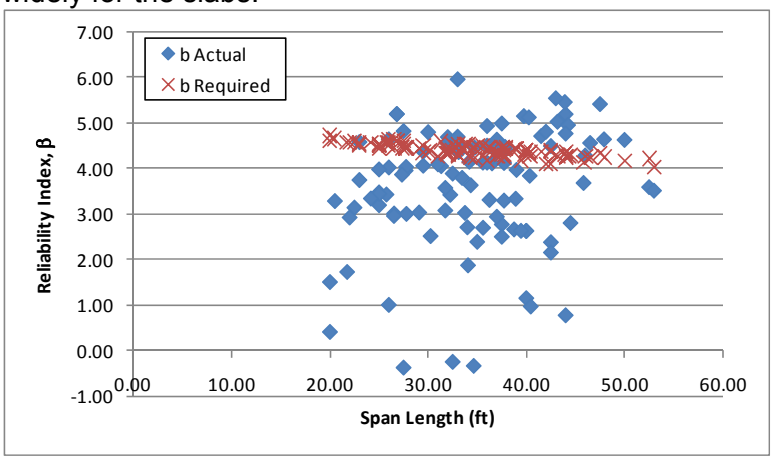


Figure H-17: Shear Reliability Indices for Design Loadings

Figure H-18 shows the reliability index for shear plotted against the LRFR shear rating for the design load. The reliability index increases with increasing rating and is approximately 4.5 for a rating of 1.0. The target reliability is 3.5 for the design load.

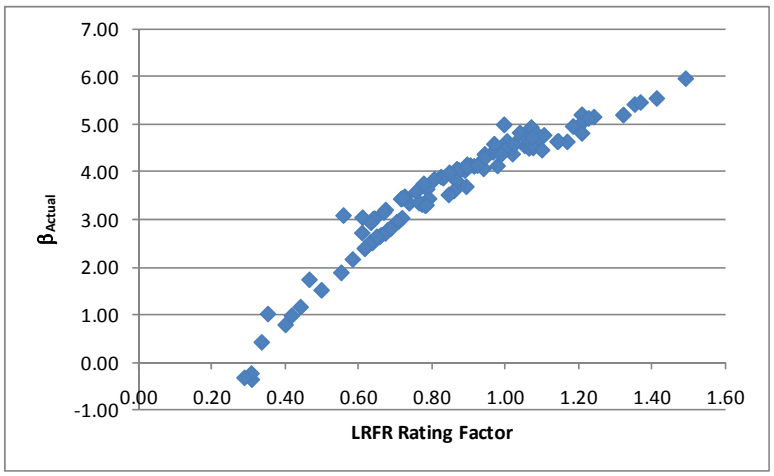


Figure H-18: Shear Reliability Index vs LRFR Shear Rating for HL-93 Design Load

H.1.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-19. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

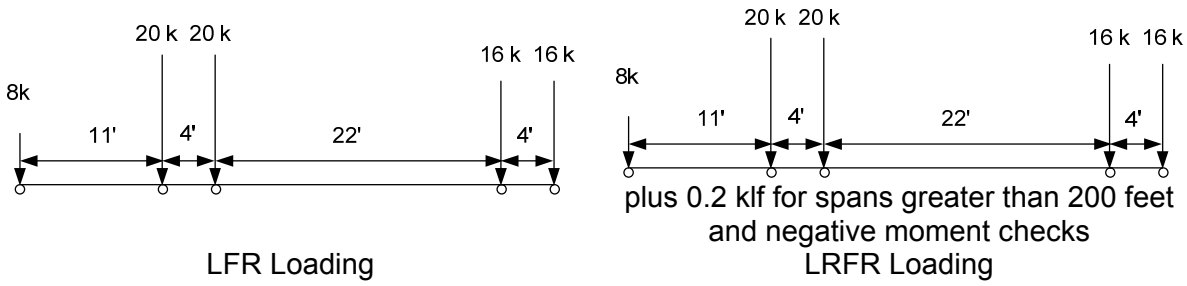


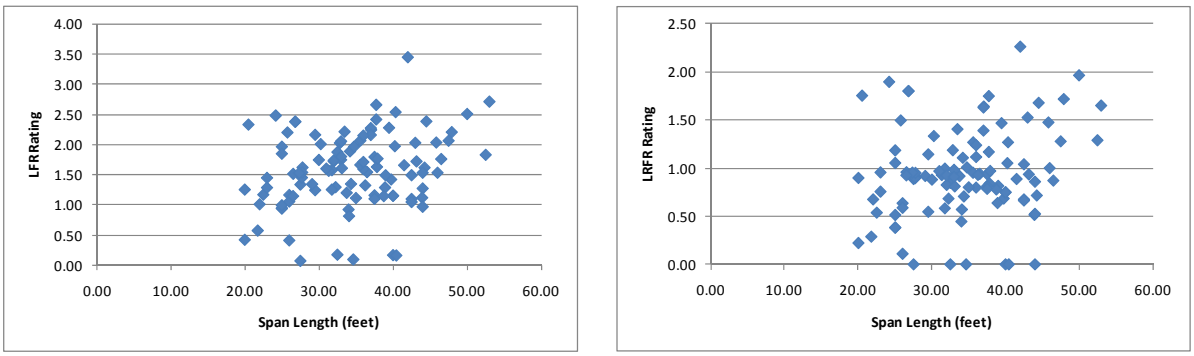
Figure H-19: Vehicle Loadings and Load Factors

H.1.3.1 Moment

The following section contains the continuous slab span bridge results for the DE-07 Vehicle.

H.1.3.1.1 Rating Factors

Figure H-20 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 14 slabs with an LFR rating less than 1.0, 70 slabs with an LRFR rating less than 1.0, and 14 slabs where both ratings are less than 1.0. Two of the 70 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR permit rating for 100% of the slabs in this subset. The LFR ratings are between 1.0 and 2.5 while the LRFR ratings are between 0.5 and 1.5.



(a) (b)

Figure H-20: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure H-21 shows the percentage of slabs with moment ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 35.2% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 32.4% when the ADTT ≥ 5,000. 86.7% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 51.5% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 54.3% for an ADTT ≥ 5,000.

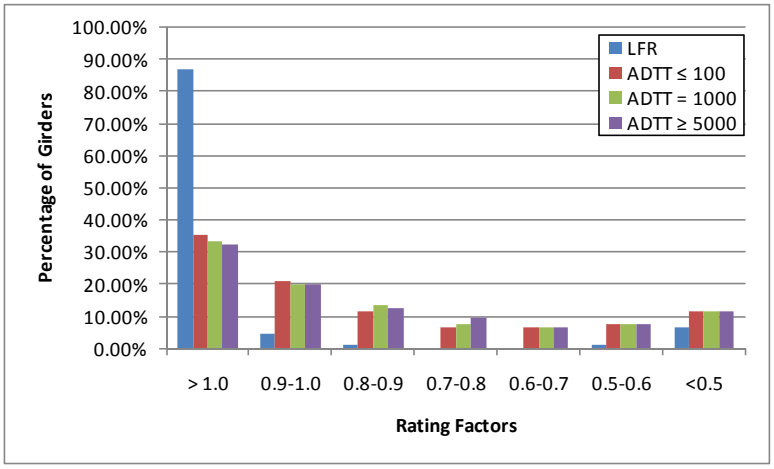


Figure H-21: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

H.1.3.1.2 Rating Factor Comparisons

Figure H-22 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.5 to 0.7, with the ratio remaining relatively constant for all span lengths.

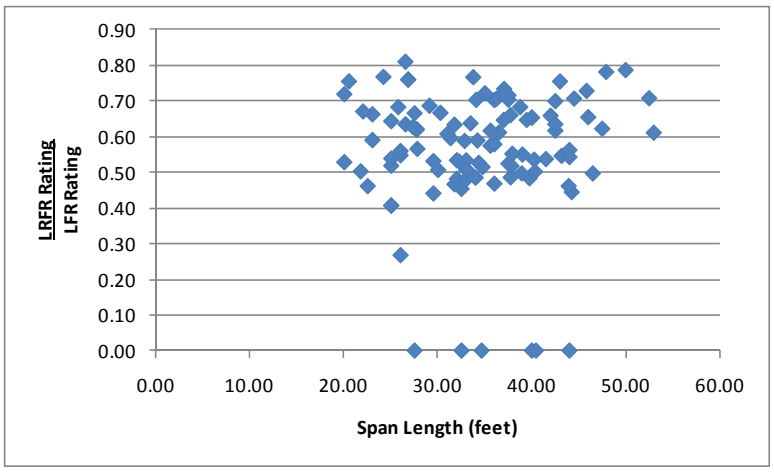


Figure H-22: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

H.1.3.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-23 shows that three slabs have a reliability index that is less than the target reliability index of 2.5. The reliability index is between four and seven for most slabs and increases with increasing span lengths.

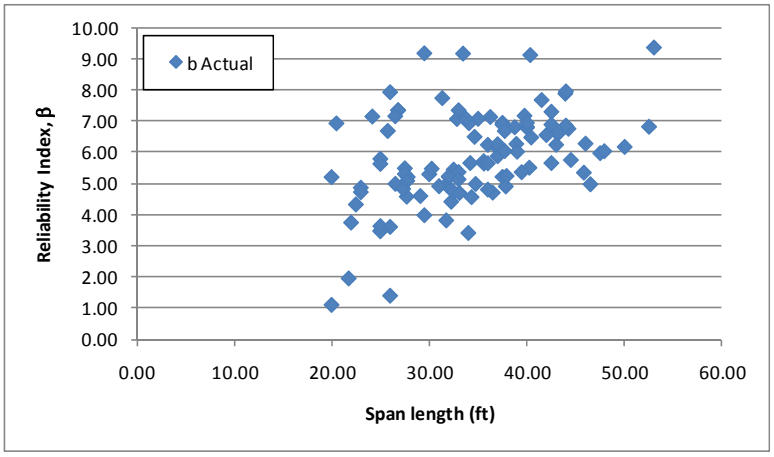


Figure H-23: Flexure Reliability Indices for DE-07 Vehicle

Figure H-24 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 Vehicle. The reliability index corresponding to an LRFR rating of 1.0 is approximately 5.0, above the target reliability of 2.5. This indicates the live load factors in the MBE are possibly over-conservative. Slabs with high reliability and low ratings are those controlled by the longitudinal steel rating near the support. The reliability index is calculated using the moment resistance not the resistance of the longitudinal steel.

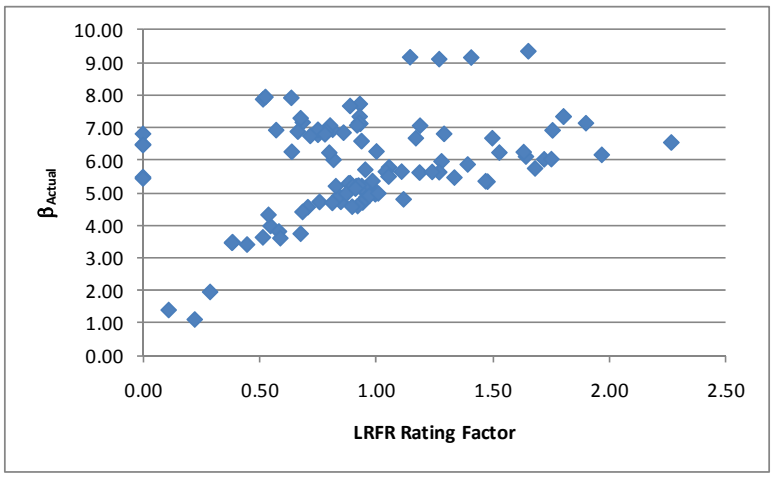
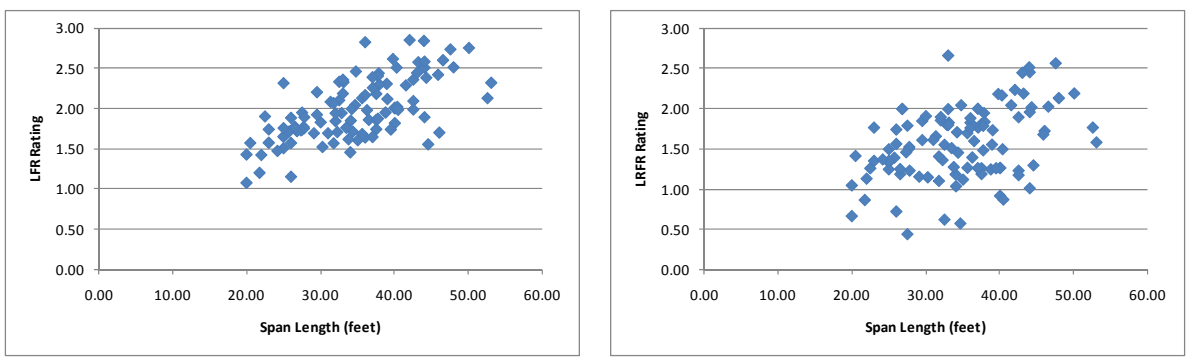


Figure H-24: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

H.1.3.2 Shear

H.1.3.2.1 Rating Factors

For shear, there are zero slabs that have rating factors less than 1.0 for LFR, eight slabs for LRFR, and zero slabs where both LFR and LRFR are less than 1.0. The LFR Rating is greater than the LRFR rating for 90% of the slabs in this subset. Figure H-25 shows the LFR and LRFR ratings. Both ratings increase with increasing span lengths, with the LFR rating having less scatter. The LFR rating is between 1.5 and 2.5 for most slabs while the LRFR ratings are between one and two.



(a) (b)

Figure H-25: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure H-26 shows the percentage of slabs with shear ratings in each rating range for the DE-07 vehicle, a routine permit vehicle. 93.3% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 87.6% when the ADTT ≥ 5,000. 100% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 6.7% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 12.4% for an ADTT ≥ 5,000.

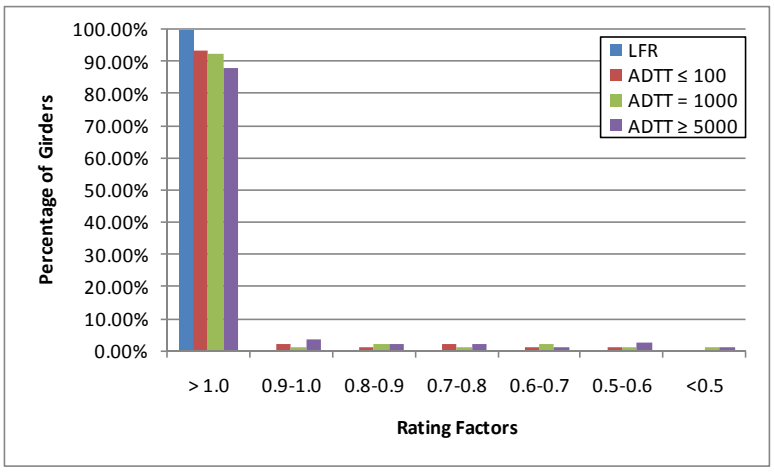


Figure H-26: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

H.1.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure H-27 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.0. 10% of slabs have LRFR shear ratings that are greater than the LFR rating.

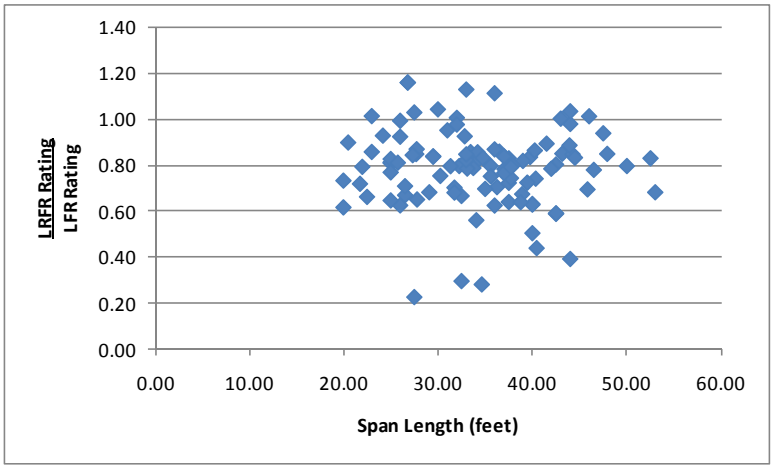


Figure H-27: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

H.1.3.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is greater than the target reliability index of 2.5 for all slabs except for two as shown in Figure H-28. The reliability index is between five and seven for most slabs.

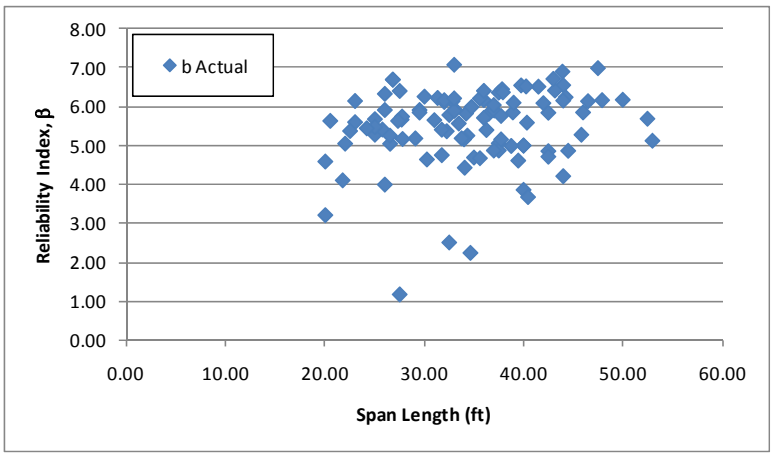


Figure H-28: Shear Reliability Indices for DE-07 Vehicle

Figure H-29 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 Vehicle. The reliability index is approximately four for an LRFR rating of 1.0, this is greater than the target reliability of 2.5. This would indicate the LRFR live load factors may be over-conservative but is not necessarily true as shear is not required to be checked in design as long as the slabs are designed according to AASHTO LRFD 4.6.2.3.

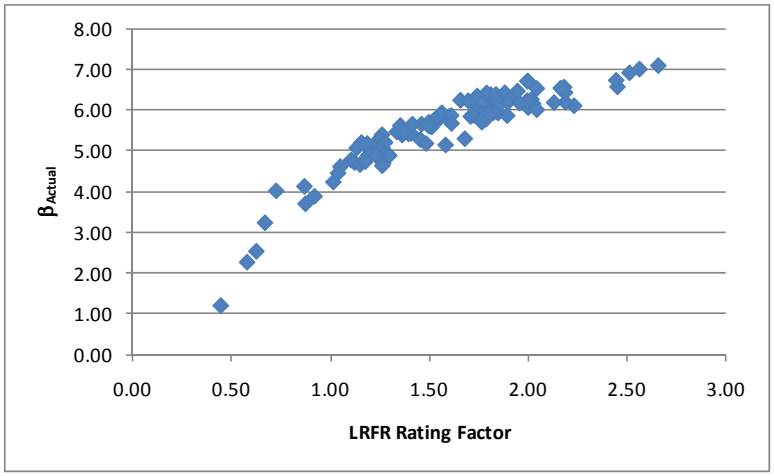


Figure H-29: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

H.1.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-30. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

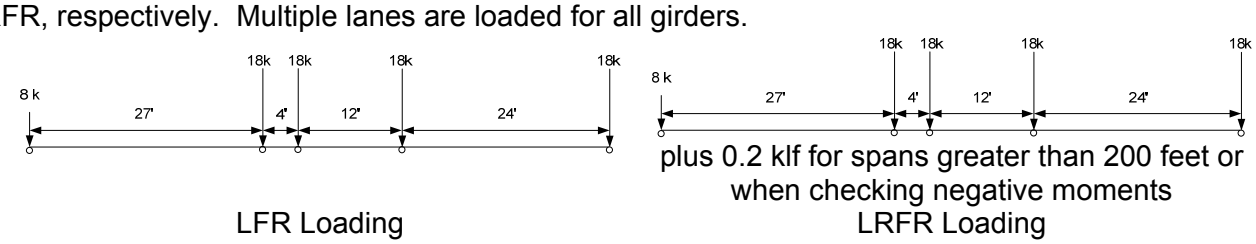


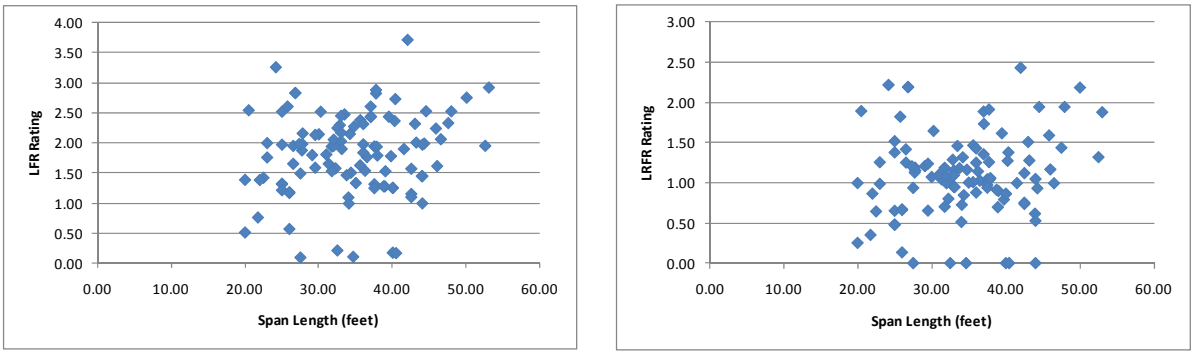
Figure H-30: Vehicle Loadings and Load Factors

H.1.4.1 Moment

The following section contains the results for continuous slab span bridges for the FL-04 Vehicle.

H.1.4.1.1 Rating Factors

Figure H-31 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are nine slabs with an LFR rating less than 1.0, 45 slabs with an LRFR rating less than 1.0, and nine slabs where both ratings are less than 1.0. Two of the 45 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the slabs in this subset. The LFR rating is generally between 1.0 and 2.5 with the LRFR rating between 0.5 and 1.5.



(a) (b)

Figure H-31: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure H-32 shows the percentage of slabs with moment ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 60.0% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 56.2% when the ADTT ≥ 5,000. 91.4% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 31.4% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 35.2% for an ADTT ≥ 5,000.

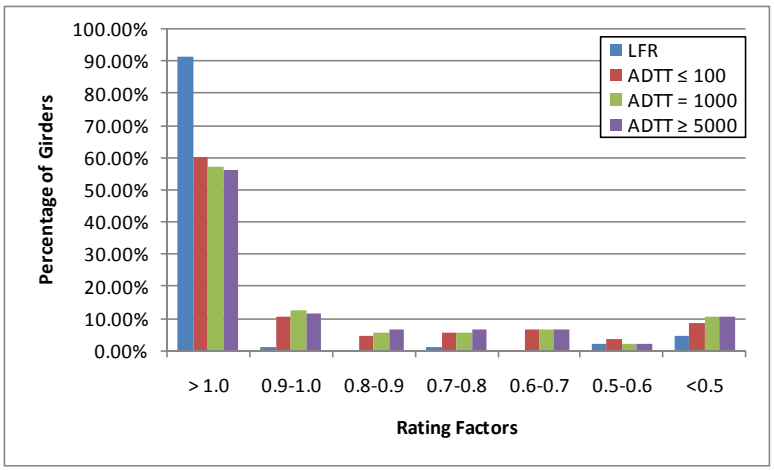


Figure H-32: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

H.1.4.1.2 Rating Factor Comparisons

Figure H-33 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio of LRFR rating to LFR rating is generally between 0.4 and 0.8. There are no slabs with LRFR ratings that exceed the LFR rating.

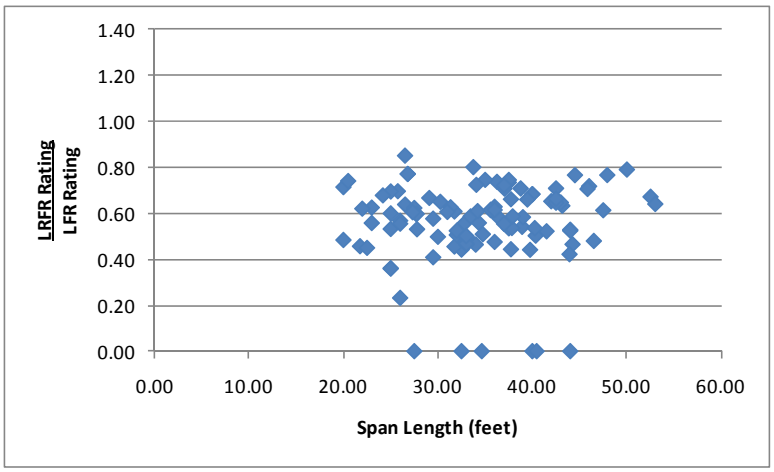


Figure H-33: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

H.1.4.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-34 shows that most slabs have a reliability index that is greater than the target reliability index. Only one slab does not have the target reliability of 2.5. The reliability index is greater than five for most slabs.

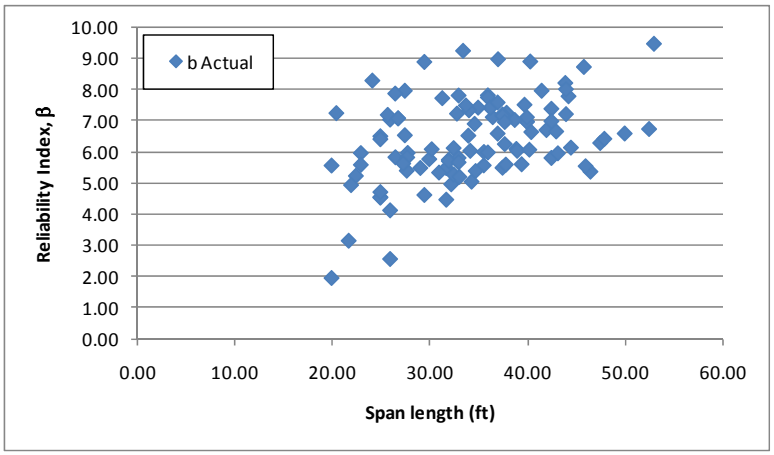


Figure H-34: Flexure Reliability Indices for FL-04 Vehicle

Figure H-35 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 Vehicle. The reliability index corresponding to a slab with a rating of 1.0 is approximately 5.5, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative.

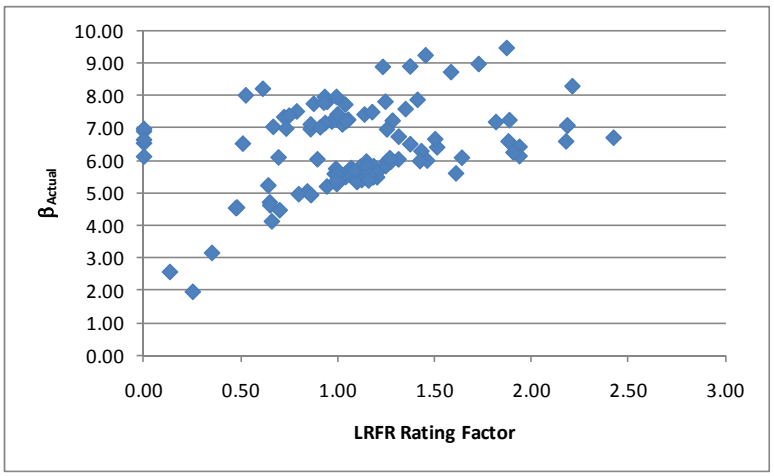
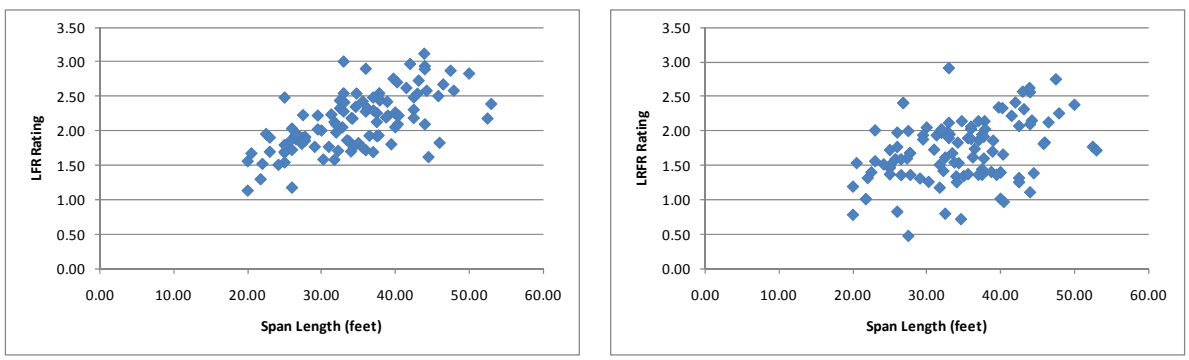


Figure H-35: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

H.1.4.2 Shear

H.1.4.2.1 Rating Factors

For shear, there are zero slabs that have LFR rating factors less than 1.0, six slabs with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 90% of the slabs in this subset. Figure H-36 shows the LFR and LRFR ratings. The LFR ratings are generally between 1.5 and 2.5 with larger ratings for longer maximum span lengths. LRFR ratings are between 1.25 and 2.25 and increase for longer span lengths.



(a) (b)

Figure H-36: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure H-37 shows the percentage of slabs with shear ratings in each rating range for the FL-04 vehicle, a routine permit vehicle. 95.2% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 91.4% when the ADTT ≥ 5,000. 100% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 4.8% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 8.6% for an ADTT ≥ 5,000.

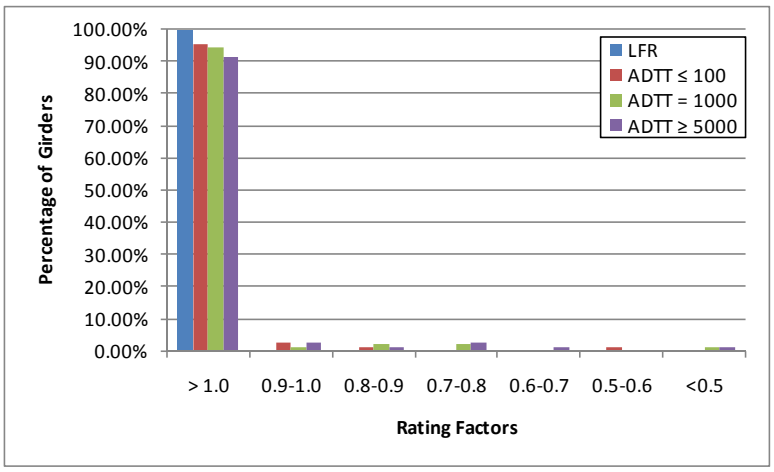


Figure H-37: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

H.1.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure H-38 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.0 and remains relatively constant with increasing maximum span lengths. 10% of slabs have LRFR ratings that exceed the LFR rating.

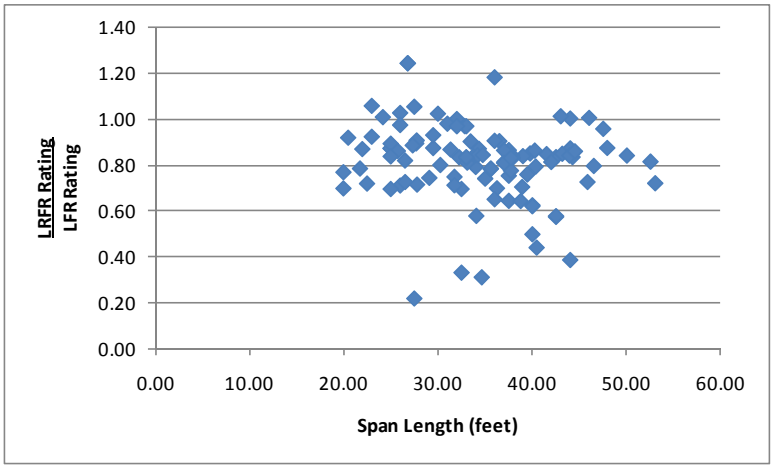


Figure H-38: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

H.1.4.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is greater than the target reliability index of 2.5 for all but one slab as shown in Figure H-39. The reliability index is between five and seven for most slabs.

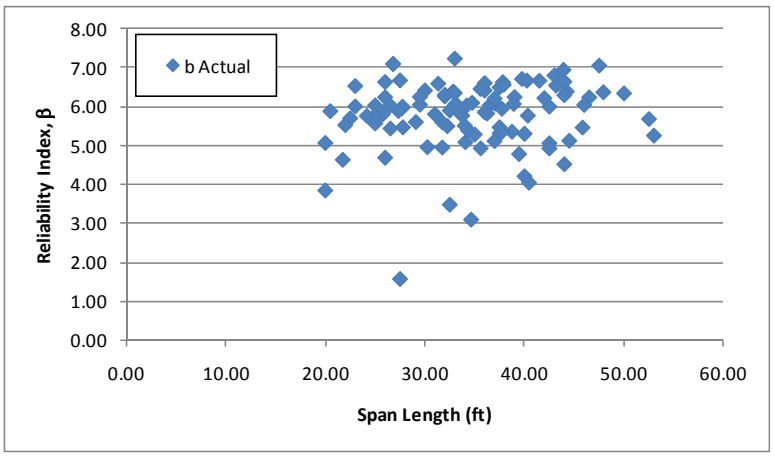


Figure H-39: Shear Reliability Indices for FL-04 Vehicle

Figure H-40 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 vehicle. The reliability index increases with increasing LRFR ratings. A slab with an LRFR rating of 1.0 is expected to have a reliability index of approximately 4.0, above the target reliability of 2.5. The LRFR live load factors may be over-conservative, except that shear is not a design criteria for concrete slab spans as long as AASHTO LRFD 4.6.2.3 is satisfied.

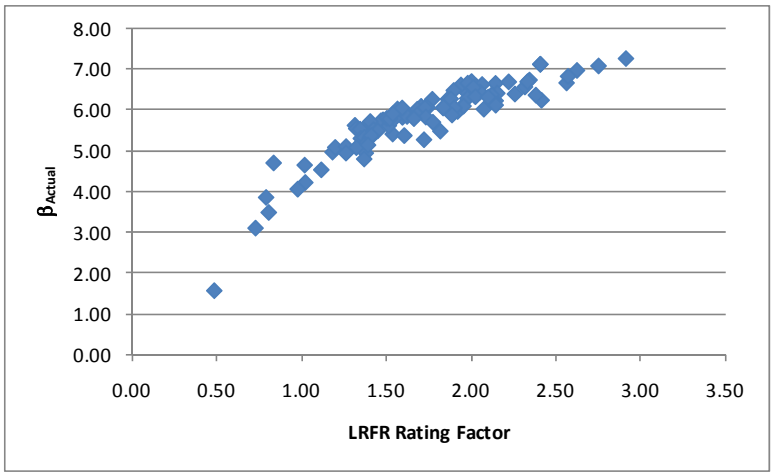


Figure H-40: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

H.1.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-41. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

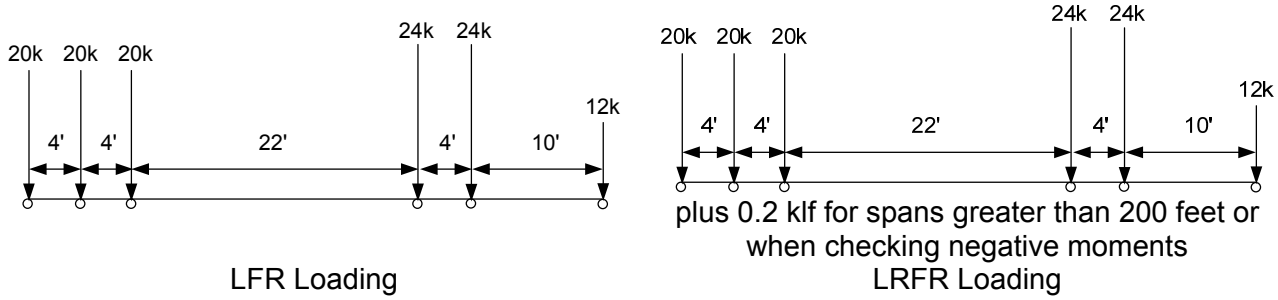


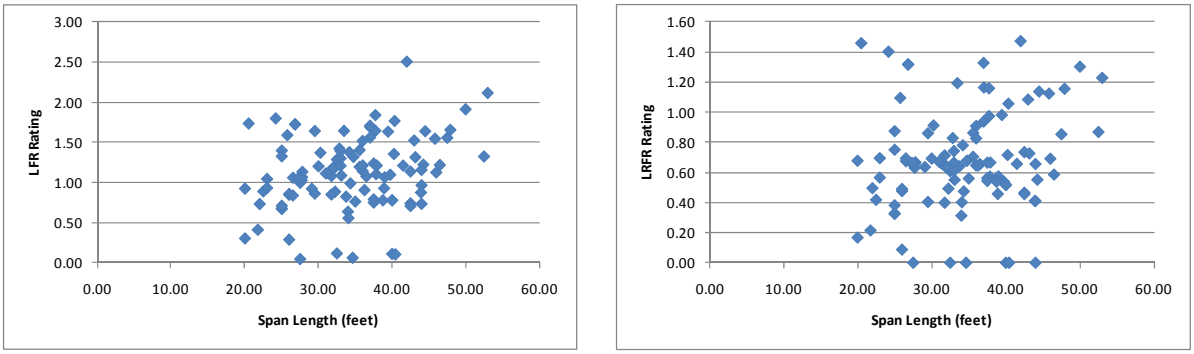
Figure H-41: Vehicle Loadings and Load Factors

H.1.5.1 Moment

The following section contains the results for continuous slab span bridges for the IL-01 Vehicle.

H.1.5.1.1 Rating Factors

Figure H-42 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 40 slabs with an LFR rating less than 1.0, 88 slabs with an LRFR rating less than 1.0, and 40 slabs where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR special permit rating for 100% of the slabs in this subset. Both ratings tend to increase with increasing maximum span lengths; the LFR rating is generally between 0.75 and 1.75 with the LRFR rating between 0.4 and 0.8.



(a) (b)

Figure H-42: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure H-43 shows the percentage of slabs with moment ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 17.1% of slabs have LRFR ratings greater than 1.0 for a single trip, escorted permit. The percentage decreases to 16.2% for all other permit types for special permit vehicles. 61.9% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 44.8% more slabs to have LRFR ratings less than 1.0 for a single trip, escorted permit than had LFR ratings less than 1.0. The percentage increases to 45.7% for all other special permit types.

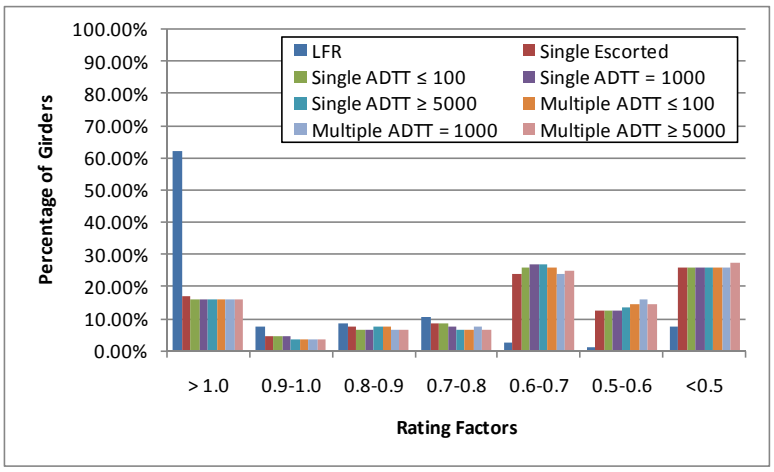


Figure H-43: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

H.1.5.1.2 Rating Factor Comparisons

Figure H-44 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.45 and 0.7. There are no slabs with an LRFR rating that is greater than the LFR rating.

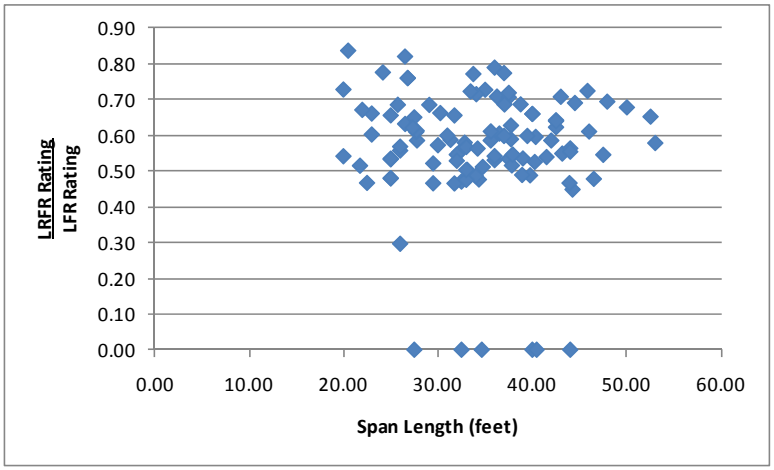


Figure H-44: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

H.1.5.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-45 shows 10 slabs have a reliability index that is less than the target reliability index of 3.5. The reliability index is between four and seven for most slabs. The reliability index also increases with increasing span lengths.

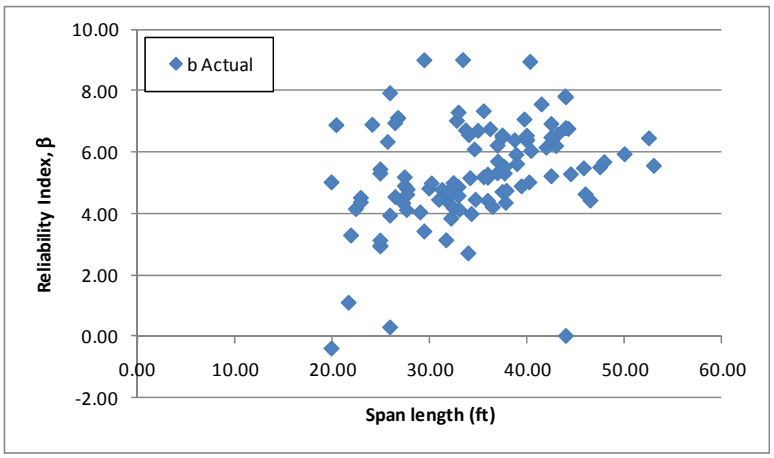


Figure H-45: Flexure Reliability Indices for IL-01 Vehicle

Figure H-46 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The reliability index increases with increasing rating factors. The reliability index corresponding to an LRFR rating of 1.0 is approximately 5.0, above the target reliability of 3.5. This indicates the LRFR live load factors may be over-conservative. Slabs with high reliability and low ratings are those controlled by the longitudinal steel rating near the support. The reliability index is calculated using the moment resistance not the resistance of the longitudinal steel.

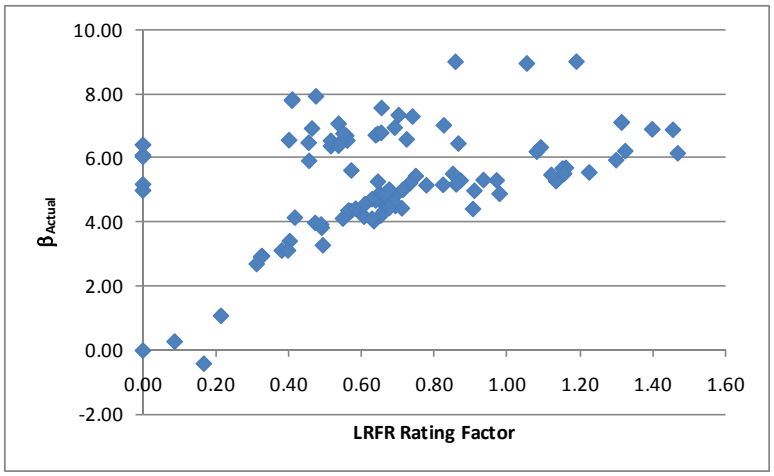
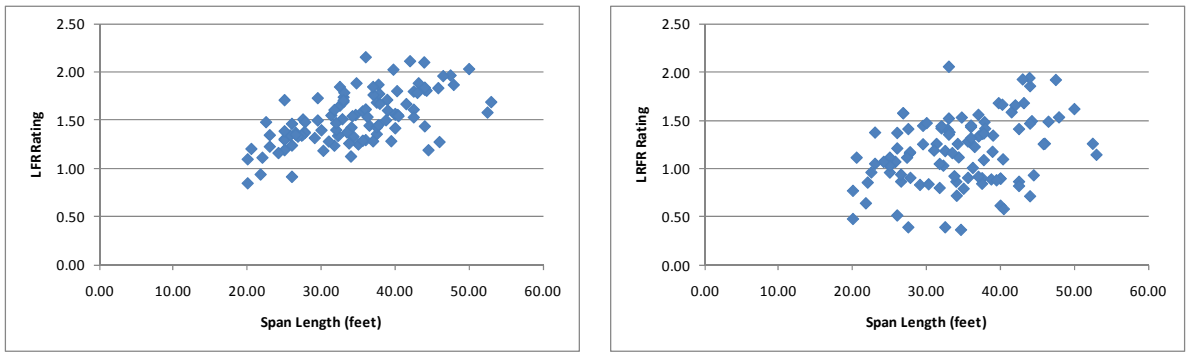


Figure H-46: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

H.1.5.2 Shear

H.1.5.2.1 Rating Factors

For shear, there are three slabs that have LFR rating factors less than 1.0, 34 slabs with LRFR ratings less than 1.0, and three slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 90% of the slabs in this subset. Figure H-47 shows the LFR and LRFR ratings. The LFR rating is generally between 1.0 and 2.0 for all span lengths, while the LRFR rating is generally between 0.75 and 1.5. Both ratings also tend to increase with increasing maximum span lengths.



(a) (b)

Figure H-47: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure H-48 shows the percentage of slabs with shear ratings in each rating range for the IL-01 vehicle, a special permit vehicle. 87.6% of slabs have LRFR ratings greater than 1.0 for a single trip, escorted permit. The percentage decreases to 37.1% when the permit is for multiple trips with ADTT ≥ 5,000. 97.1% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 9.5% more slabs to have LRFR ratings less than 1.0 for a single trip, escorted permit than had LFR ratings less than 1.0. The percentage increases to 60.0% with a permit for multiple trips and ADTT ≥ 5,000.

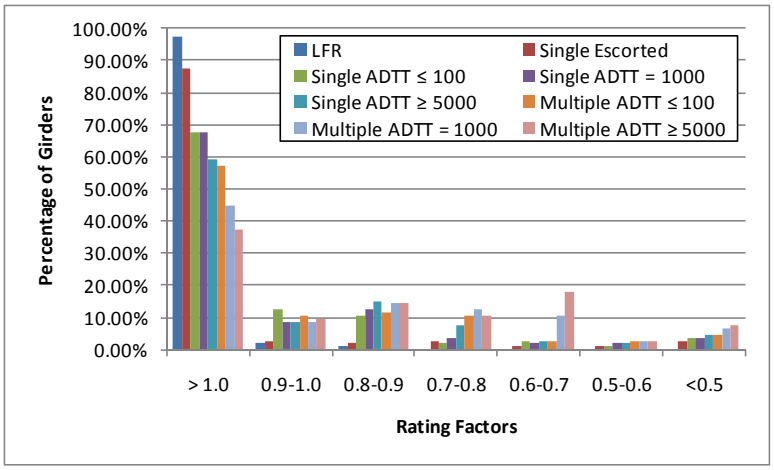


Figure H-48: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

H.1.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure H-49 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.0 for the entire range of maximum span lengths. 10% of slabs have an LRFR rating that is greater than the LFR rating.

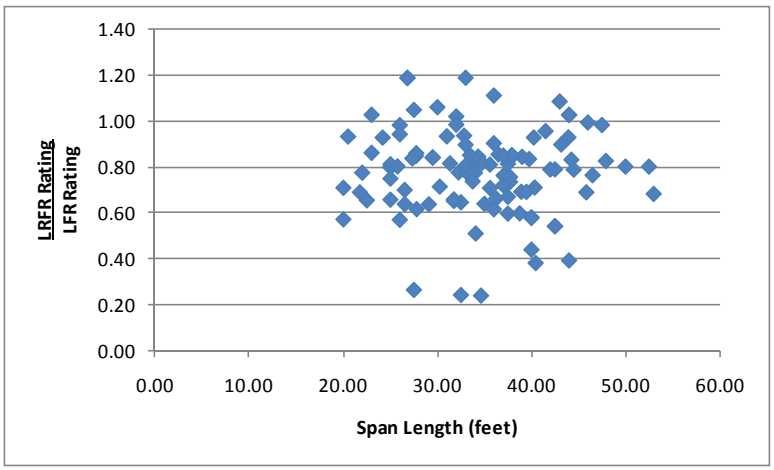


Figure H-49: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

H.1.5.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is less than the target reliability index of 3.5 for 12 slabs as shown in Figure H-50. There are several slabs where the reliability index is negative or near zero indicating that the applied loads are larger than the resistances. The reliability index is between four and six for most slabs.

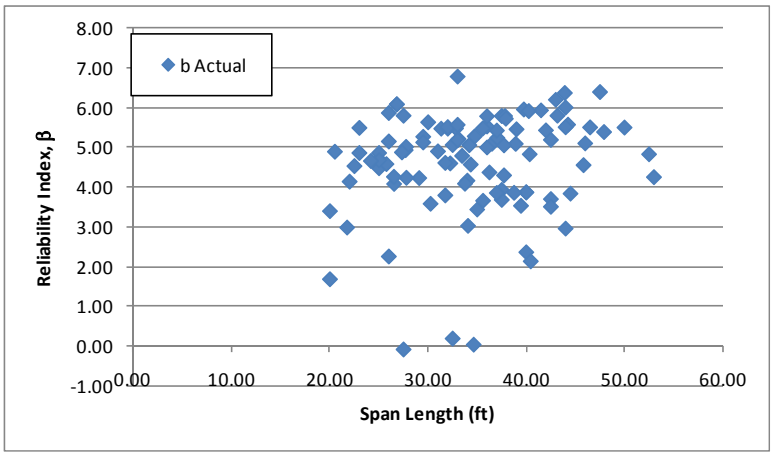


Figure H-50: Shear Reliability Indices for IL-01 Vehicle

Figure H-51 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 vehicle. The reliability index increases with increasing ratings; a reliability index of 4.5 is expected for a slab with an LRFR rating of 1.0. The reliability index is above the target reliability index of 3.5 for this vehicle. Shear does not have to be checked as long as the slab was designed for moment according to AASHTO LRFD 4.6.3.2, so this does not necessarily indicate the live load factors are over-conservative.

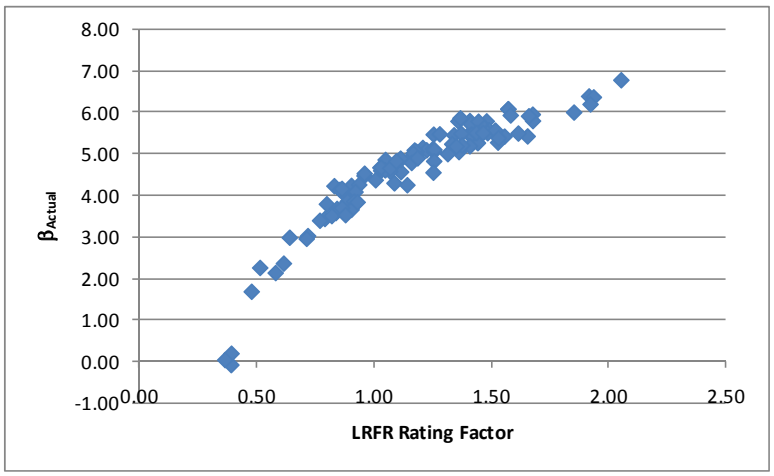


Figure H-51: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

H.1.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-52. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

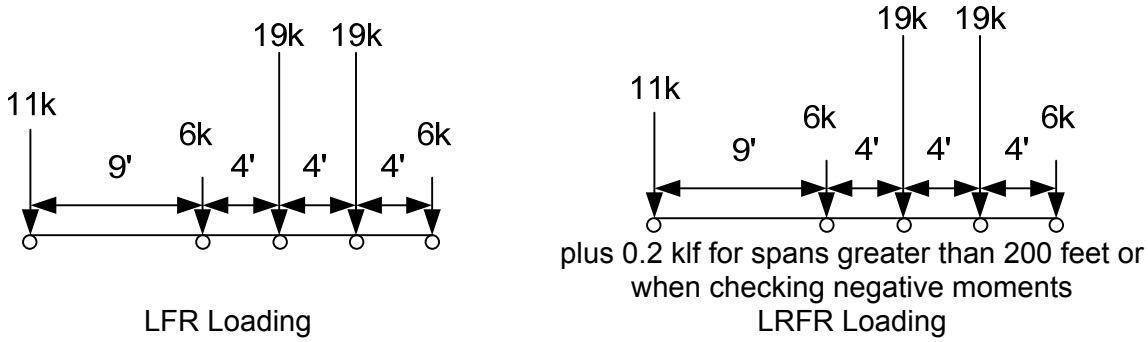


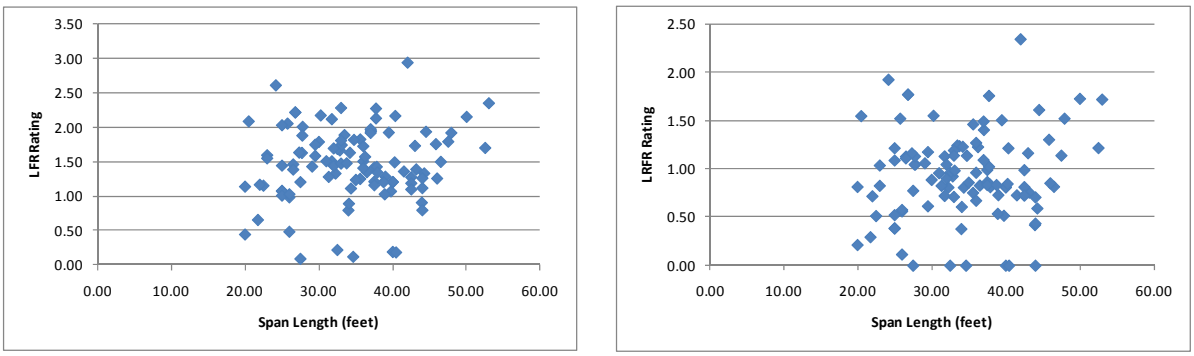
Figure H-52: Vehicle Loadings and Load Factors

H.1.6.1 Moment

The following section contains the results for continuous slab span bridges for the NC-21 Vehicle.

H.1.6.1.1 Rating Factors

Figure H-53 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 13 slabs with an LFR rating less than 1.0, 61 slabs with an LRFR rating less than 1.0, and 13 slabs where both ratings are less than 1.0. Two of the 61 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the slabs in this subset. The LFR rating is between 1.0 and 2.0 while the LRFR rating is between 0.5 and 1.5.



(a) (b)

Figure H-53: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure H-54 shows the percentage of slabs with moment ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 44.8% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 41.9% when the ADTT ≥ 5,000. 87.6% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 42.8% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 45.7% for an ADTT ≥ 5,000.

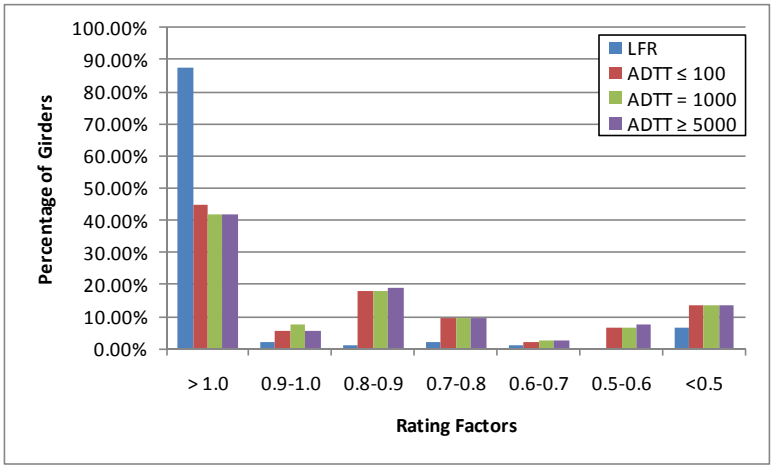


Figure H-54: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

H.1.6.1.2 Rating Factor Comparisons

Figure H-44 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.8 for this vehicle. There are no slabs with LRFR ratings greater than the LFR rating.

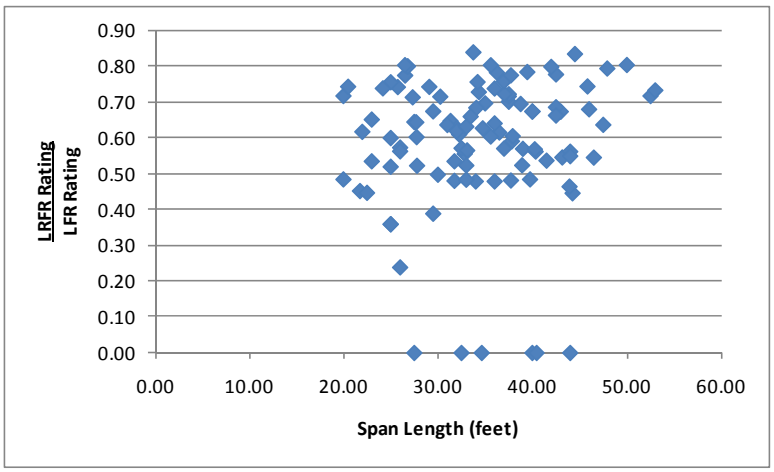


Figure H-55: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

H.1.6.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-56 shows two slabs have a reliability index that is less than the target reliability index of 2.5. The reliability index is generally between four and eight.

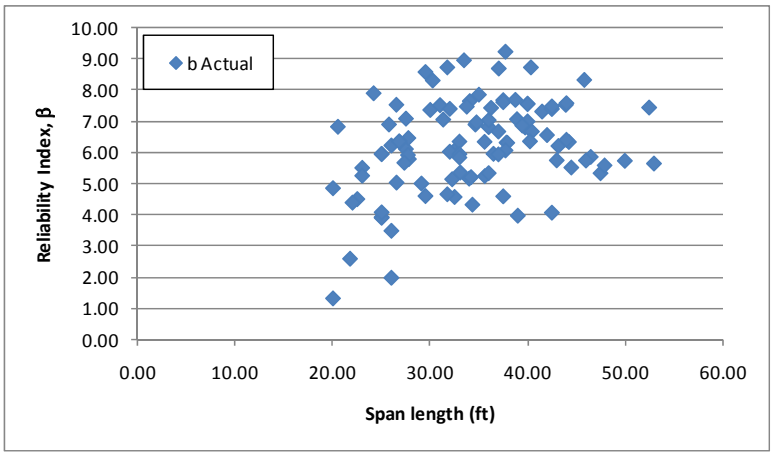


Figure H-56: Flexure Reliability Indices for NC-21 Vehicle

Figure H-57 shows the flexure reliability index vs LRFR flexure rating for the NC-21 vehicle. The reliability index increases with increasing LRFR ratings. The average reliability index for an LRFR rating of 1.0 is approximately 5.0, above the target reliability of 2.5. This may indicate that the LRFR live load factors are over-conservative. Slabs with high reliability and low ratings are those controlled by the longitudinal steel rating near the support. The reliability index is calculated using the moment resistance not the resistance of the longitudinal steel.

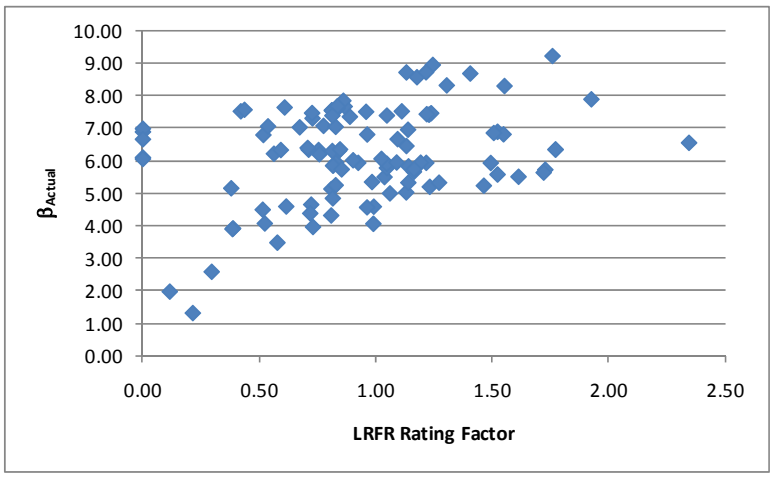
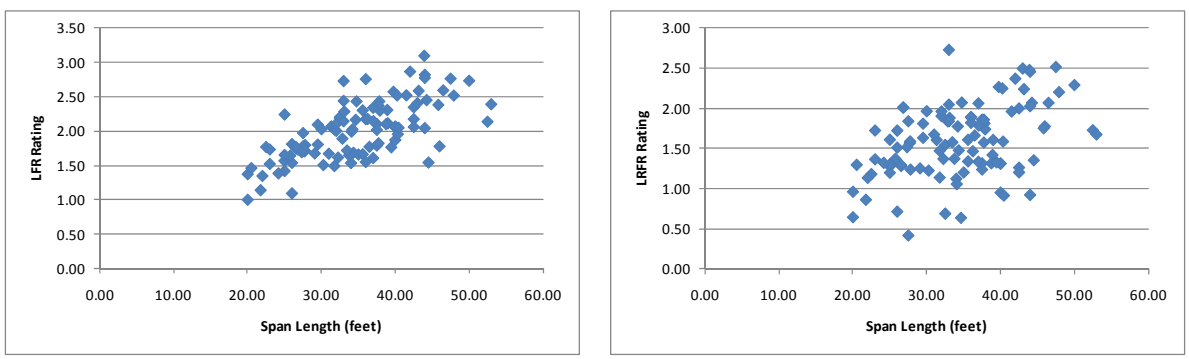


Figure H-57: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

H.1.6.2 Shear

H.1.6.2.1 Rating Factors

For shear, there are zero slabs that have LFR rating factors less than 1.0, ten slabs with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 95% of the slabs in this subset. Figure H-58 shows the LFR and LRFR ratings. The LFR ratings are generally between 1.5 and 2.5 and the LRFR ratings are between 1.0 and 2.0; they also increase with increasing maximum span lengths.



(a) (b)

Figure H-58: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure H-59 shows the percentage of slabs with shear ratings in each rating range for the NC-21 vehicle, a routine permit vehicle. 94.3% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 88.6% when the ADTT ≥ 5,000. 100% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 5.7% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 11.4% for an ADTT ≥ 5,000.

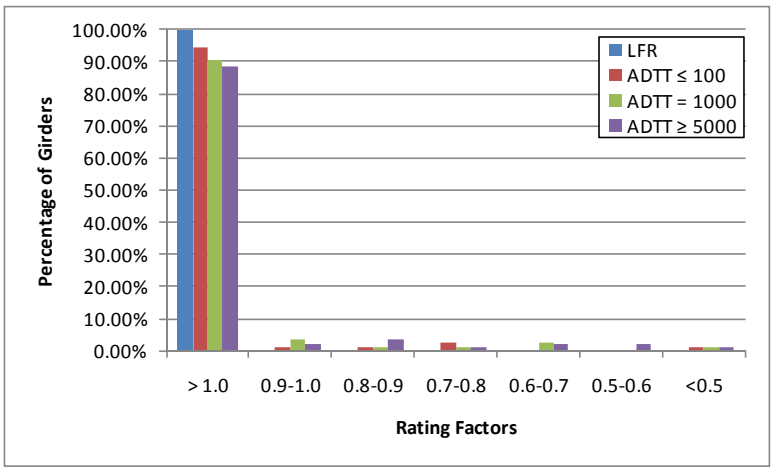


Figure H-59: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

H.1.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure H-60 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.0. The ratio is within this range for the entire range of maximum span lengths. 5% of slabs have LRFR ratings that exceed the LFR rating.

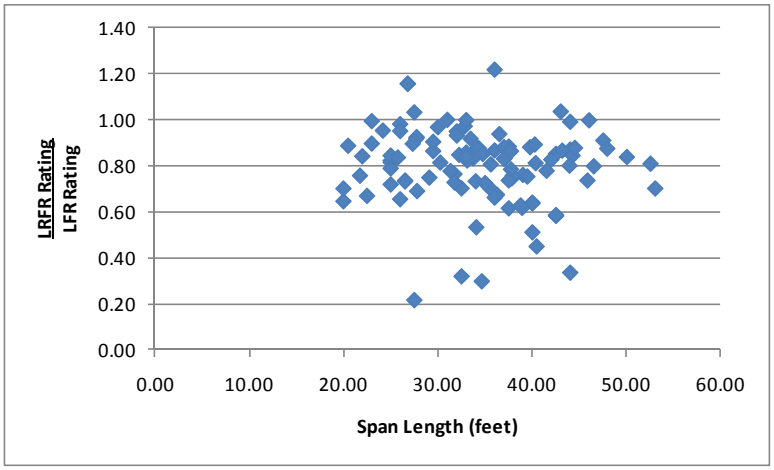


Figure H-60: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

H.1.6.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is greater than the target reliability index of 2.5 for all but one slab as shown in Figure H-61. The reliability index is between five and seven for most slabs.

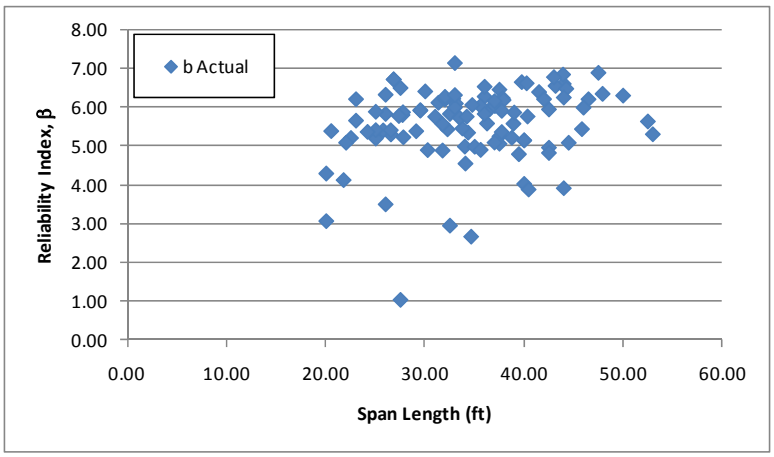


Figure H-61: Shear Reliability Indices for NC-21 Vehicle

Figure H-62 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 Vehicle. The reliability index increases with the rating factor. A reliability index of 4.5 is expected for an LRFR rating of 1.0, this is above the target reliability of 2.5.

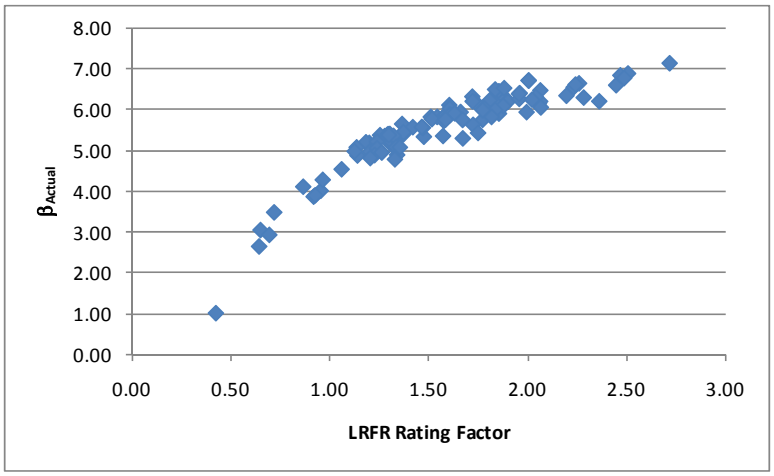


Figure H-62: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

H.1.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-63. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

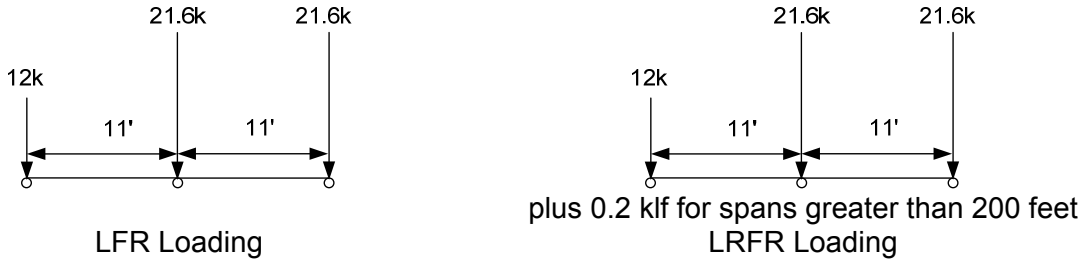


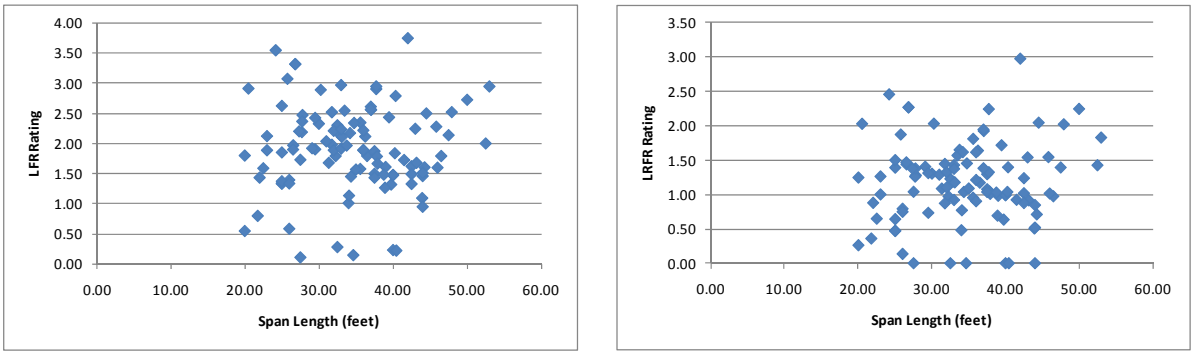
Figure H-63: Vehicle Loadings and Load Factors

H.1.7.1 Moment

The following section contains the results for continuous slab span bridges for the NM-04 Vehicle.

H.1.7.1.1 Rating Factors

Figure H-64 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are nine slabs with an LFR rating less than 1.0, 38 slabs with an LRFR rating less than 1.0, and nine slabs where both ratings are less than 1.0. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the slabs in this subset. The LFR rating is generally in the range of 1.5 and 2.5 while the LRFR rating is generally between 1.0 and 2.0.



(a) (b)

Figure H-64: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure H-65 shows the percentage of slabs with moment ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 65.7% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 62.9% when the ADTT ≥ 5,000. 91.4% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 25.7% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 28.5% for an ADTT ≥ 5,000.

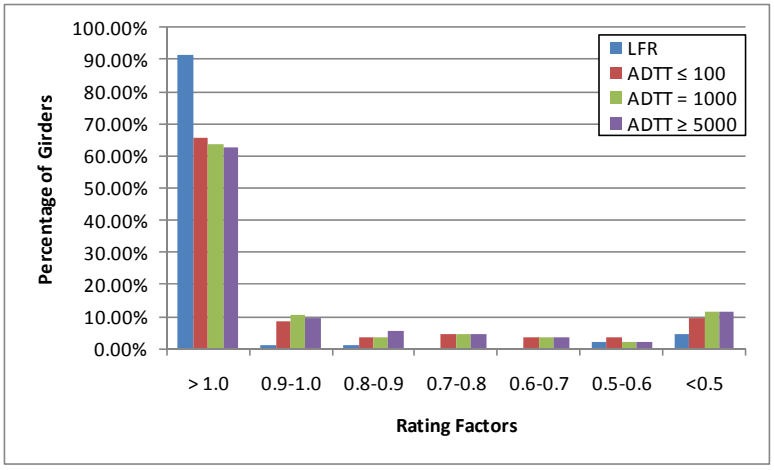


Figure H-65: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

H.1.7.1.2 Rating Factor Comparisons

Figure H-66 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.8, with zero slabs having LRFR ratings greater than the LFR rating.

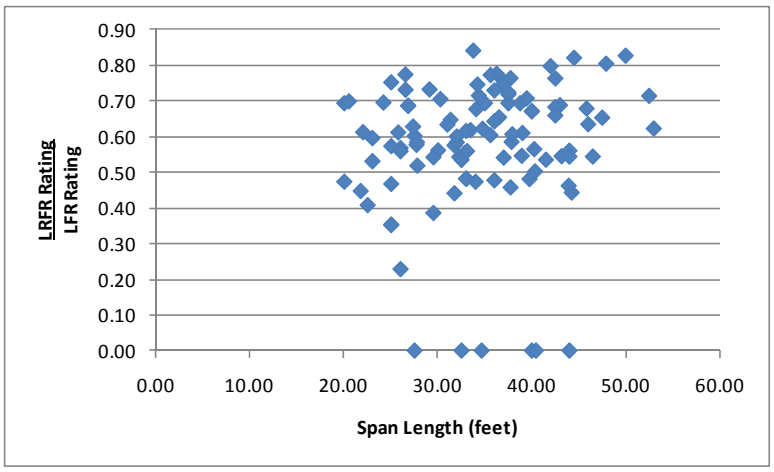


Figure H-66: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

H.1.7.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-67 shows that one slab has a reliability index that is less than the target reliability index of 2.5. The reliability index is between five and eight for most slabs.

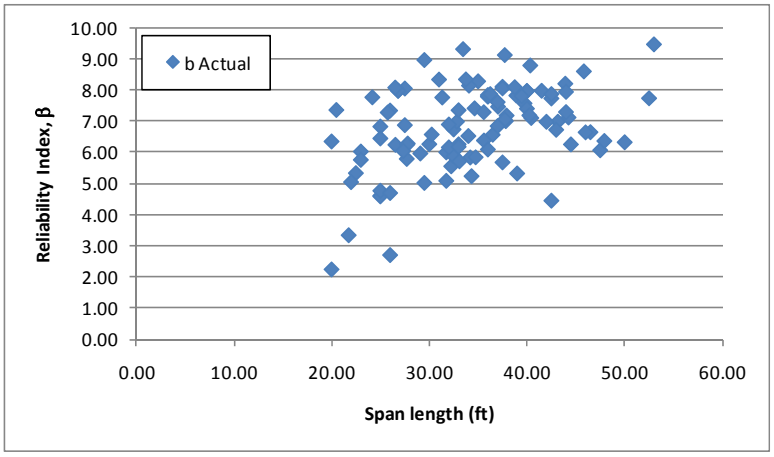


Figure H-67: Flexure Reliability Indices for NM-04 Vehicle

Figure H-68 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The reliability index increases with increasing ratings factors. The reliability index associated with an LRFR rating of 1.0 is approximately 5.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. Slabs with high reliability and low ratings are those controlled by the longitudinal steel rating near the support. The reliability index is calculated using the moment resistance not the resistance of the longitudinal steel.

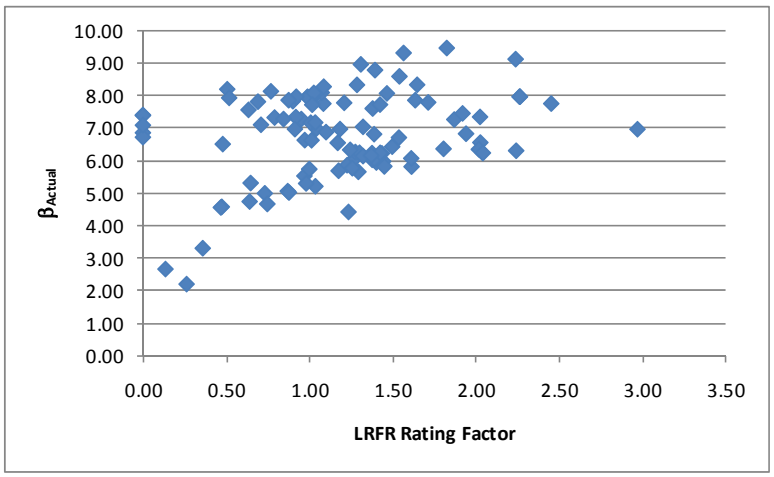
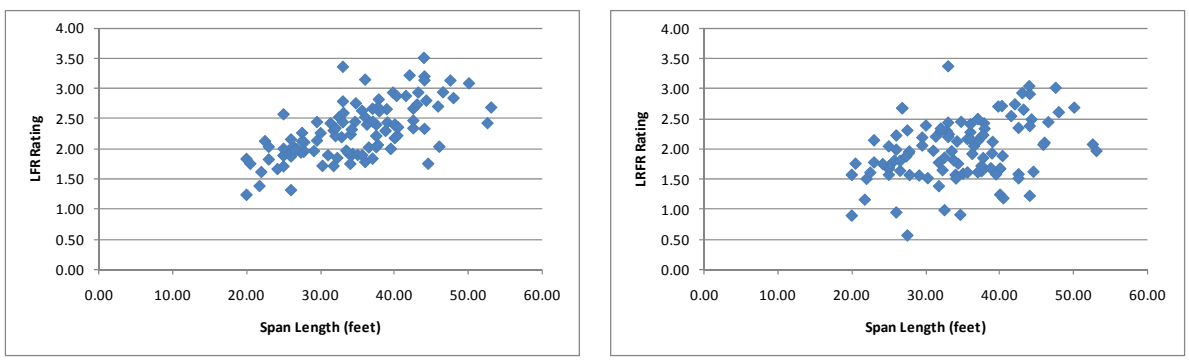


Figure H-68: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

H.1.7.2 Shear

H.1.7.2.1 Rating Factors

For shear, there are zero slabs that have an LFR rating factor less than 1.0, five slabs with an LRFR rating less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 81% of the slabs in this subset. Figure H-69 shows the LFR and LRFR ratings. The LFR ratings are generally between 1.5 and 3 and the LRFR ratings are between 1.5 and 2.5. The ratings increase for increasing maximum span lengths.



(a) (b)

Figure H-69: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure H-70 shows the percentage of slabs with shear ratings in each rating range for the NM-04 vehicle, a routine permit vehicle. 99.1% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 95.2% when the ADTT ≥ 5,000. 100% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 0.9% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 4.8% for an ADTT ≥ 5,000.

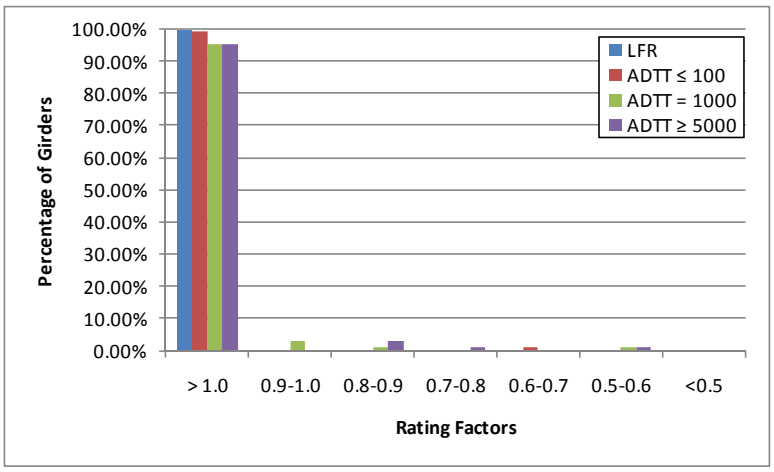


Figure H-70: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

H.1.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure H-71 shows the comparison of rating factors. The ratio is generally between 0.7 and 1.1 for the entire range of maximum span lengths.

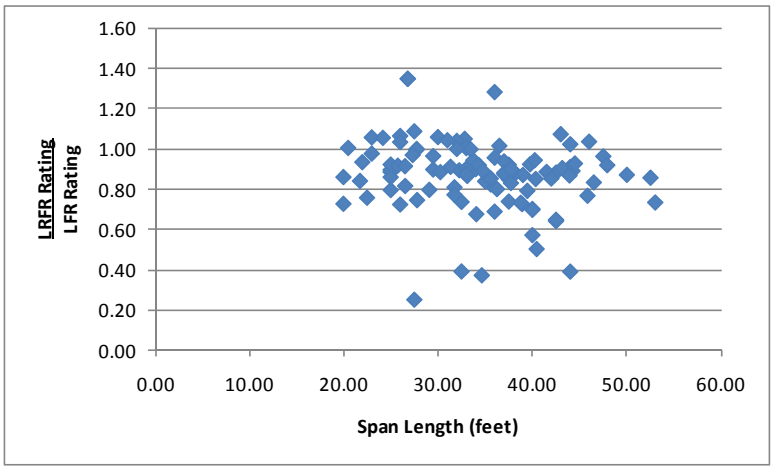


Figure H-71: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

H.1.7.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is greater than the target reliability index of 2.5 for all but one slab as shown in Figure H-72. The reliability index is between five and seven for most slabs.

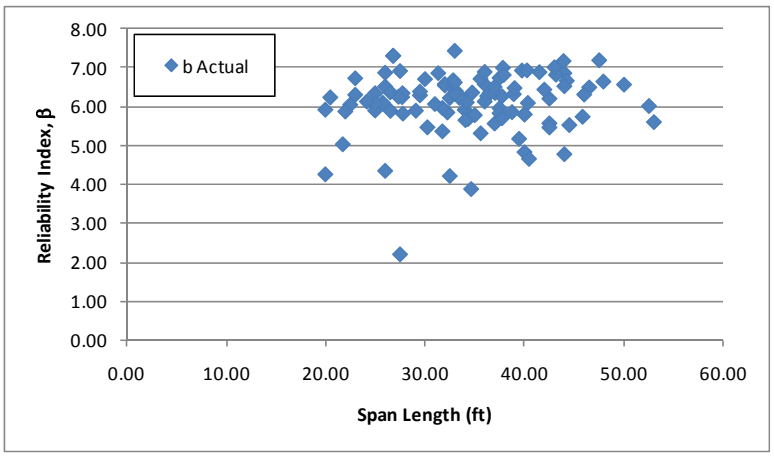


Figure H-72: Shear Reliability Indices for NM-04 Vehicle

Figure H-73 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 vehicle. The reliability index increases with increasing LRFR ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This may indicate the live load factors in the MBE are over-conservative.

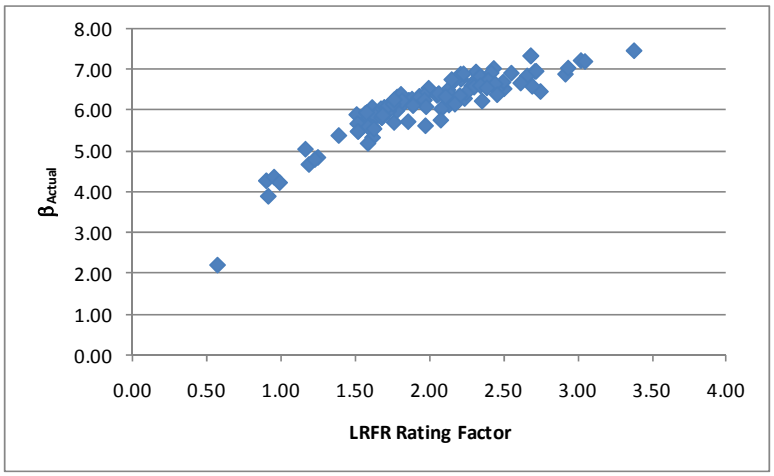
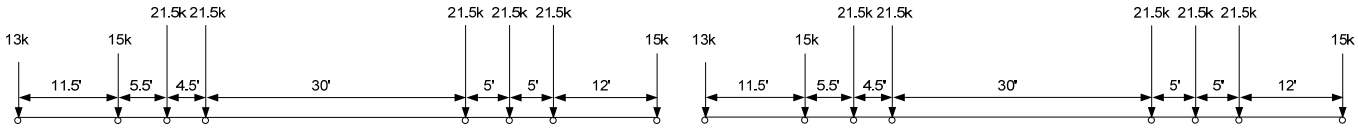


Figure H-73: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

H.1.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-74. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet

LFR Loading LRFR Loading

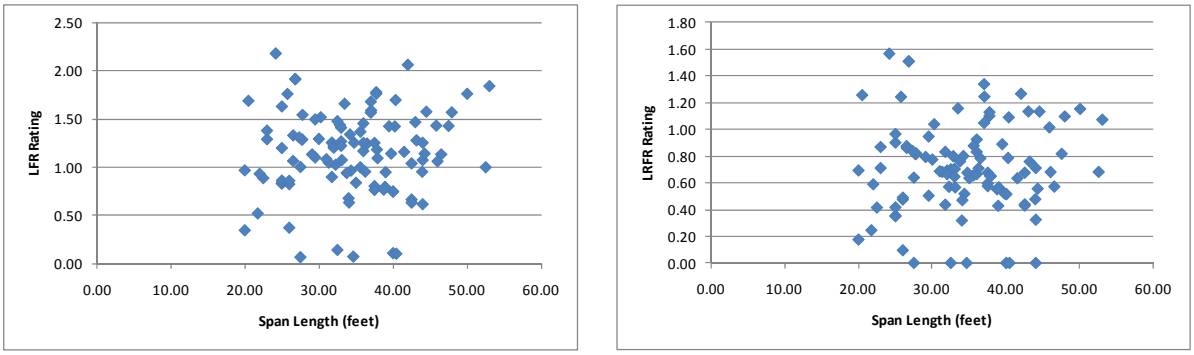
Figure H-74: Vehicle Loadings and Load Factors

H.1.8.1 Moment

The following section contains the results for continuous slab span bridges for the OR-06 Vehicle.

H.1.8.1.1 Rating Factors

Figure H-75 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 34 slabs with an LFR rating less than 1.0, 85 slabs with an LRFR rating less than 1.0, and 34 slabs where both ratings are less than 1.0. Two of the 85 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 100% of the slabs in this subset. The LFR rating is generally between 0.75 and 1.75 while the LRFR rating is generally between 0.5 and 1.1.



(a) (b)

Figure H-75: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure H-76 shows the percentage of slabs with moment ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 20.0% of slabs have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage decreases to 19.1% for all other special permit types. 67.6% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 47.6% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 48.5% for an ADTT ≥ 5,000.

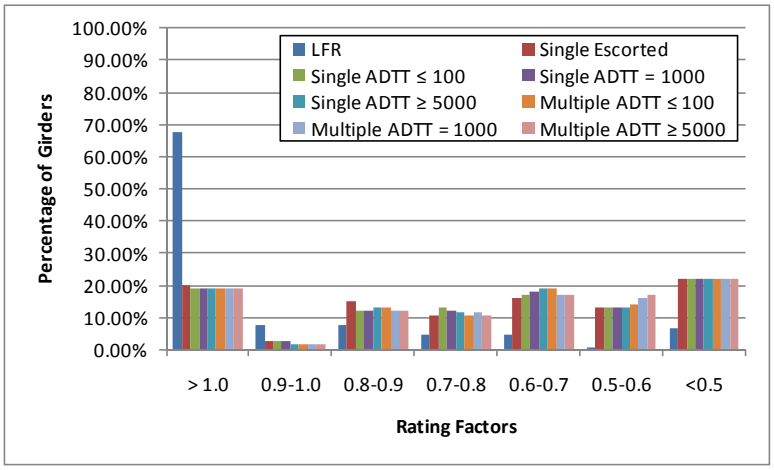


Figure H-76: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

H.1.8.1.2 Rating Factor Comparisons

Figure H-77 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.8. There are no slabs with LRFR ratings that are greater than the LFR rating.

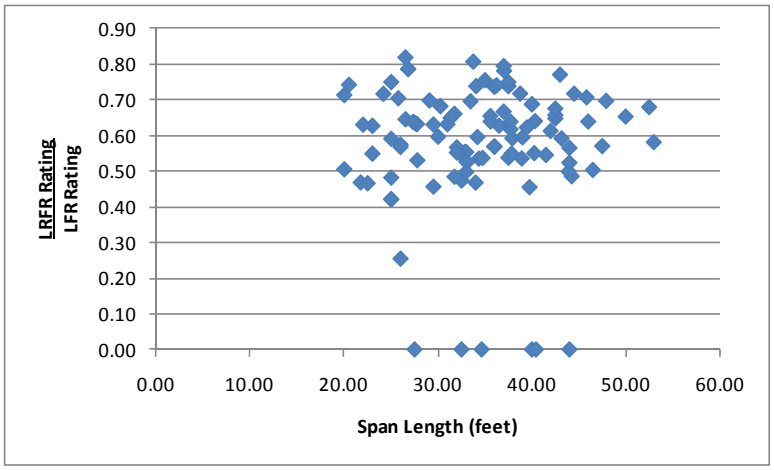


Figure H-77: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

H.1.8.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-78 shows four slabs have a reliability index that is less than the target reliability index of 3.5. The reliability index is between four and seven for most slabs and increases with increasing maximum span length.

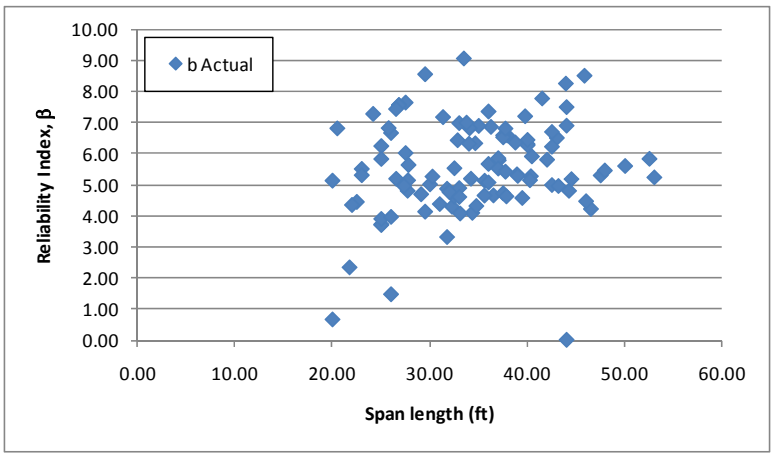


Figure H-78: Flexure Reliability Indices for OR-06 Vehicle

Figure H-79 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 vehicle. The reliability index increases with increasing LRFR ratings. The reliability index corresponding to an LRFR rating of 1.0 is approximately five. This is above the target reliability of 3.5, and may indicate the LRFR live load factors may be over-conservative.

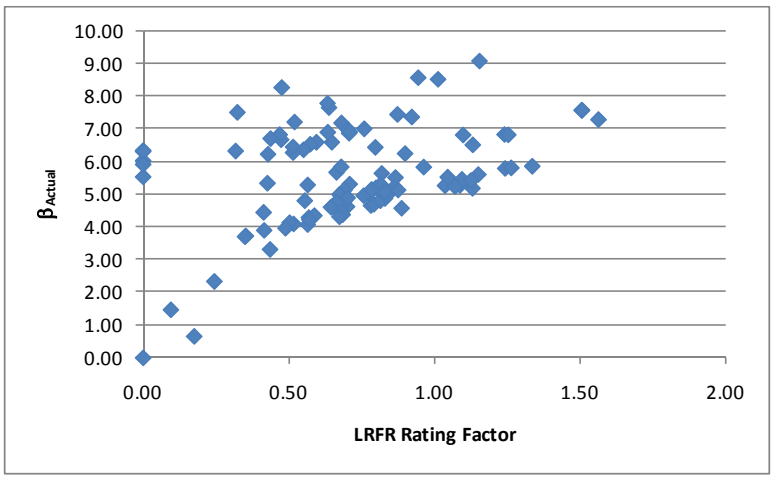
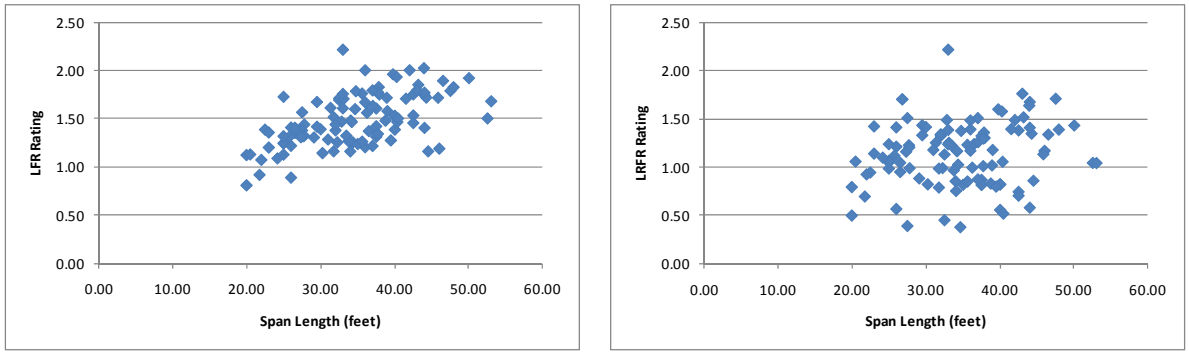


Figure H-79: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

H.1.8.2 Shear

H.1.8.2.1 Rating Factors

For shear, there are three slabs that have LFR rating factors less than 1.0, 36 slabs have LRFR ratings less than 1.0, and three slabs have both ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 90% of the slabs in this subset. Figure H-80 shows the LFR and LRFR ratings. The LFR rating is generally between 1.0 and 2.0 with the LRFR rating generally between 0.5 and 1.5.



(a) (b)

Figure H-80: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure H-81 shows the percentage of slabs with shear ratings in each rating range for the OR-06 vehicle, a special permit vehicle. 81.9% of slabs have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage decreases to 32.4% for the multi-trip permit category and an ADTT ≥ 5,000. 97.1% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 15.2% more slabs to have LRFR ratings less than 1.0 for the single trip, escorted permit category than had LFR ratings less than 1.0. The percentage increases to 64.7% for a multi-trip permit with an ADTT ≥ 5,000.

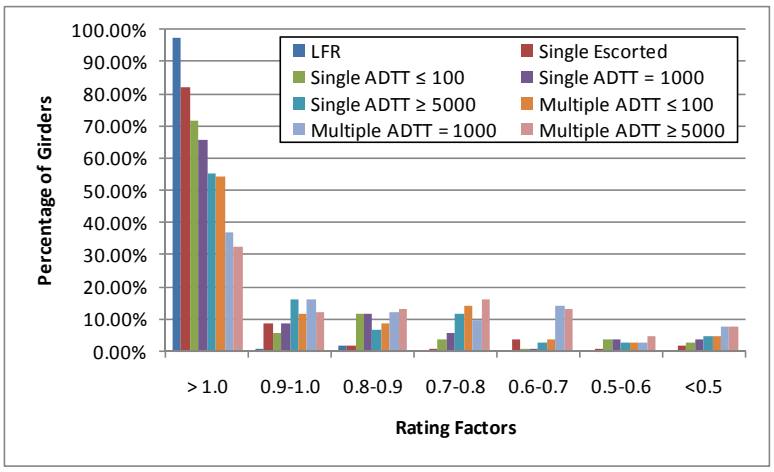


Figure H-81: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

H.1.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure H-82 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.0 for this set of slabs with this vehicle. The ratio appears to decrease with increasing maximum span lengths. 10% of slabs have LRFR ratings that are greater than the LFR rating.

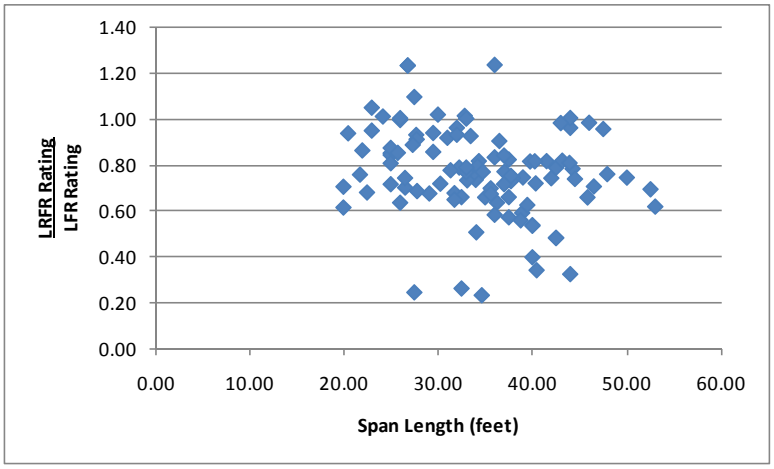


Figure H-82: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

H.1.8.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is less than the target reliability index for 13 slabs as shown in Figure H-83. The reliability index is between four and six for most slabs.

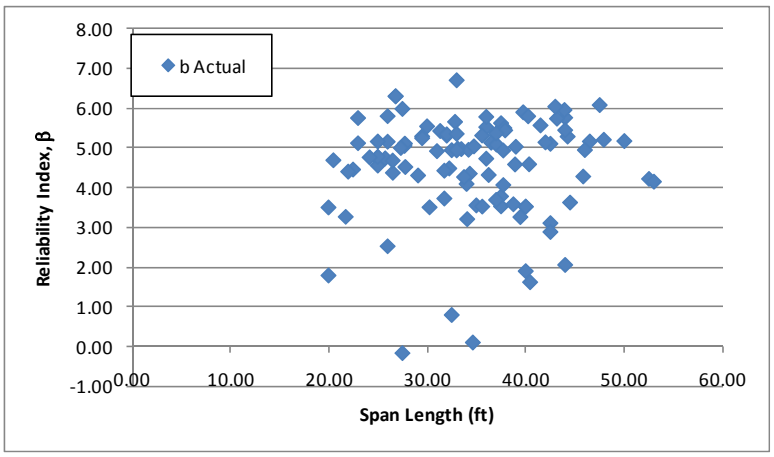


Figure H-83: Shear Reliability Indices for OR-06 Vehicle

Figure H-84 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The reliability index increases with increasing LRFR ratings. The reliability index increases to approximately 4.5 for an LRFR rating of 1.0. This is above the target reliability index of 3.5; shear is not a design criterion when the flexure design is performed as per AASHTO LRFD 4.6.2.3. This may partially indicate why the reliability index is above the target reliability.

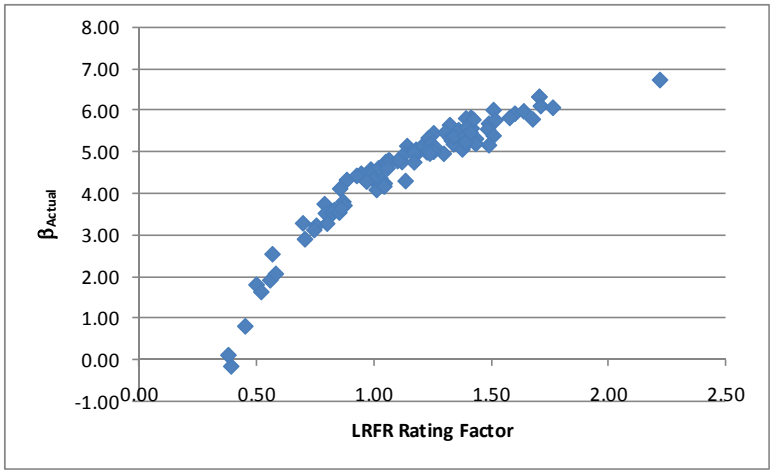
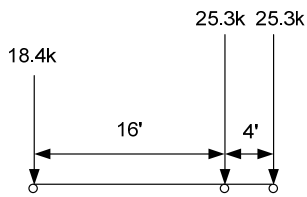


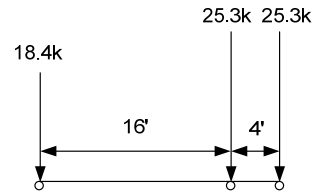
Figure H-84: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

H.1.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-85. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LRFR Loading

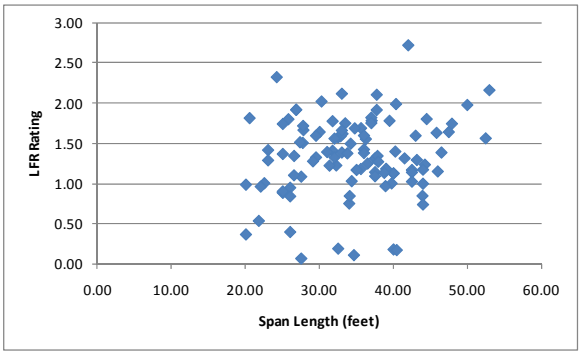
Figure H-85: Vehicle Loadings and Load Factors

H.1.9.1 Moment

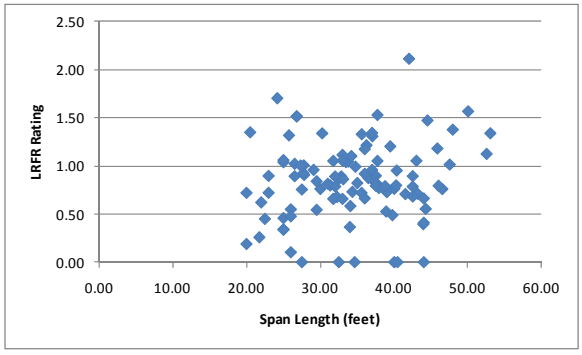
The following section contains the results for continuous slab span bridges for the TX-04 Vehicle.

H.1.9.1.1 Rating Factors

Figure H-86 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 20 slabs with an LFR rating less than 1.0, 71 slabs with an LRFR rating less than 1.0, and 20 slabs where both ratings are less than 1.0. Two of the 71 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the slabs in this subset. The LFR rating is generally between 1.0 and 2.0 with the LRFR rating generally between 0.5 and 1.0.



(a)



(b)

Figure H-86: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure H-87 shows the percentage of slabs with moment ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 33.3% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 32.4% when the ADTT ≥ 5,000. 81.0% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 47.7% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 48.6% for an ADTT ≥ 5,000.

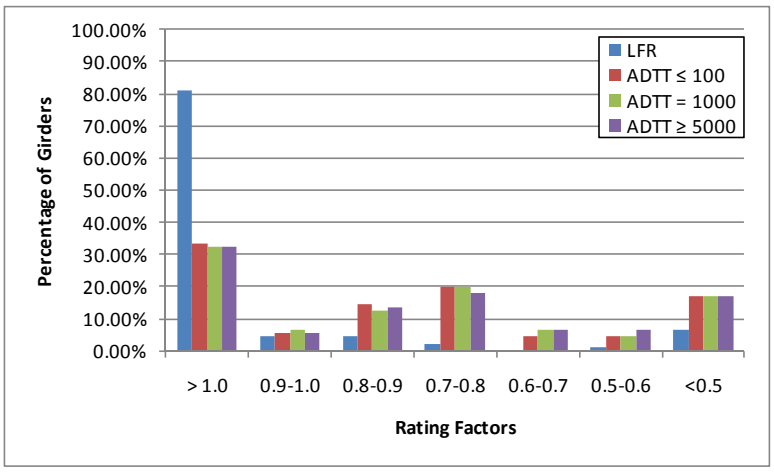


Figure H-87: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicles

H.1.9.1.2 Rating Factor Comparisons

Figure H-88 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is typically between 0.5 and 0.8, with several outside this range. No slabs have LRFR ratings that are greater than the LFR rating.

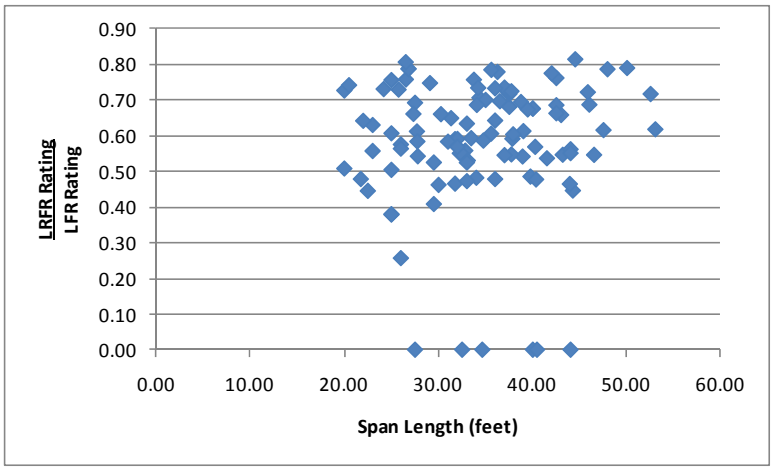


Figure H-88: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

H.1.9.1.3 Reliability Indices

The reliability index was calculated for this group of slabs. Figure H-89 shows three slabs that have a reliability index that is less than the target reliability index of 2.5. The reliability index increases with increasing maximum span length. The reliability index is between four and eight for most slabs.

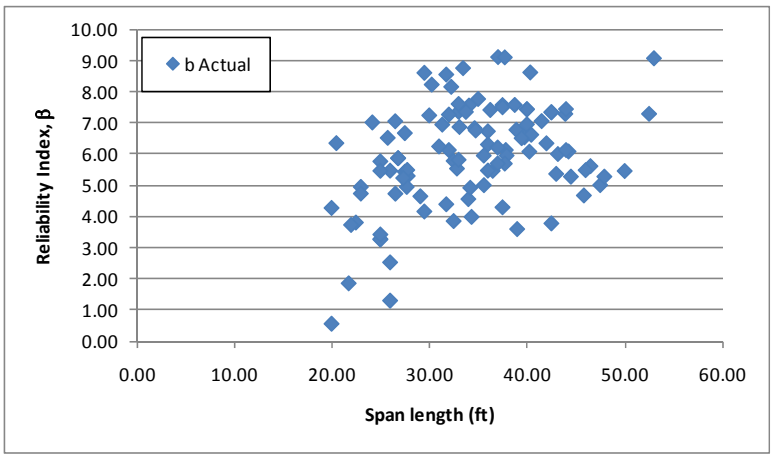


Figure H-89: Flexure Reliability Indices for TX-04 Vehicle

Figure H-90 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The reliability index increases with increasing LRFR ratings. An LRFR rating factor 1.0 corresponds to a reliability index of approximately five, above the target reliability index of 2.5. This indicates that the LRFR live load factors may be over-conservative. Slabs with high reliability and low ratings are those controlled by the longitudinal steel rating near the support. The reliability index is calculated using the moment resistance not the resistance of the longitudinal steel.

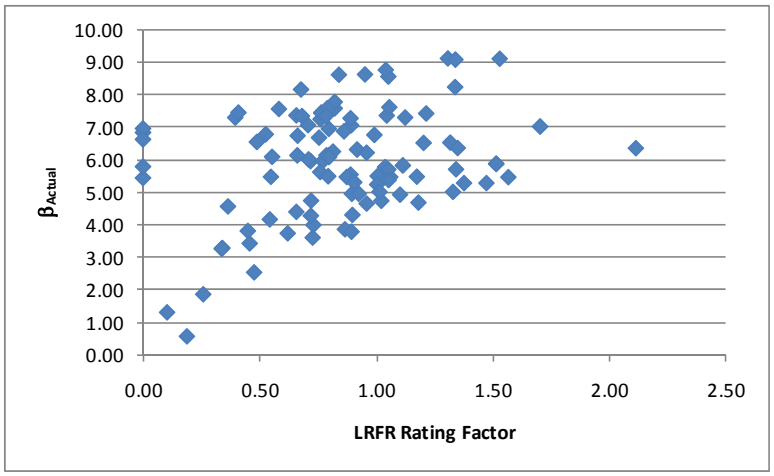
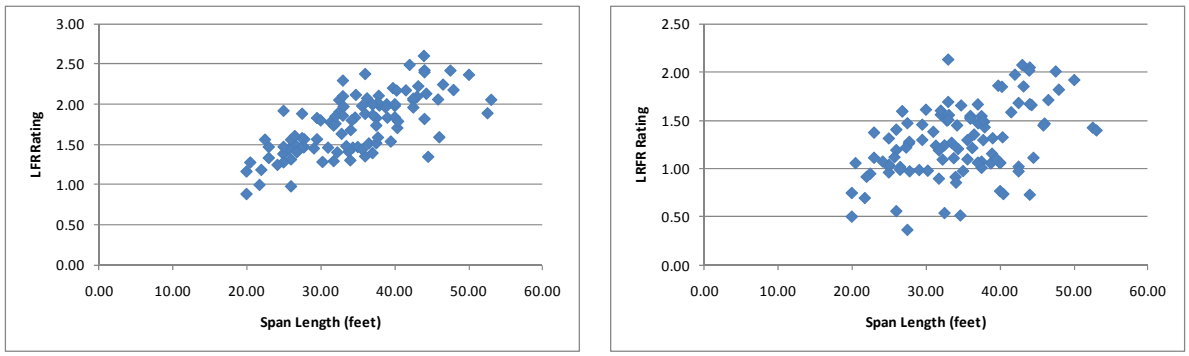


Figure H-90: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

H.1.9.2 Shear

H.1.9.2.1 Rating Factors

For shear, there are three slabs that have LFR rating factors less than 1.0, 22 slabs with LRFR ratings less than 1.0 and three slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 97% of the slabs in this subset. Figure H-91 shows the LFR and LRFR ratings. Both ratings appear to increase with increasing maximum span lengths. The LFR rating is generally between 1.25 and 2. 5 while the LRFR rating is generally between 1.0 and 2.0.



(a) (b)

Figure H-91: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure H-92 shows the percentage of slabs with shear ratings in each rating range for the TX-04 vehicle, a routine permit vehicle. 89.5% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 60.0% when the ADTT ≥ 5,000. 97.1% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 7.6% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 37.1% for an ADTT ≥ 5,000.

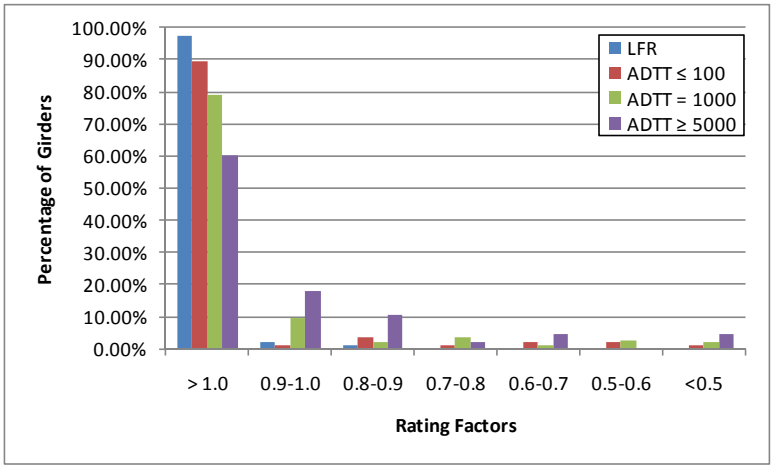


Figure H-92: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

H.1.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure H-93 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.0. 3% of slabs have an LRFR rating that is greater than the LFR rating.

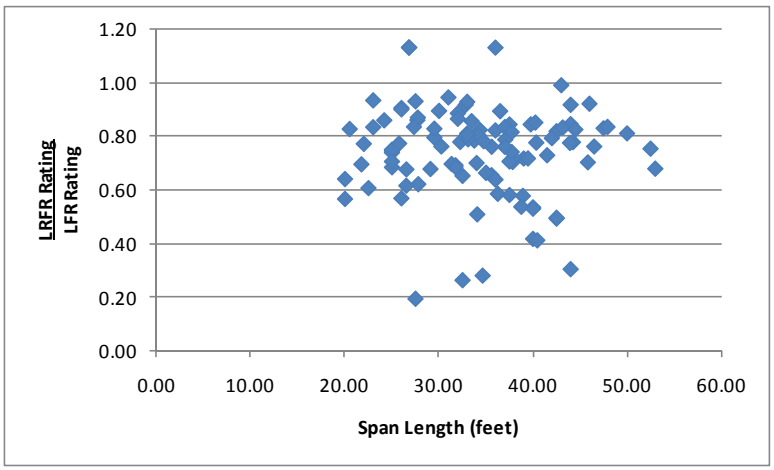


Figure H-93: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

H.1.9.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is less than the target reliability index of 2.5 for six slabs as shown in Figure H-94. The reliability index is between four and six for most slabs.

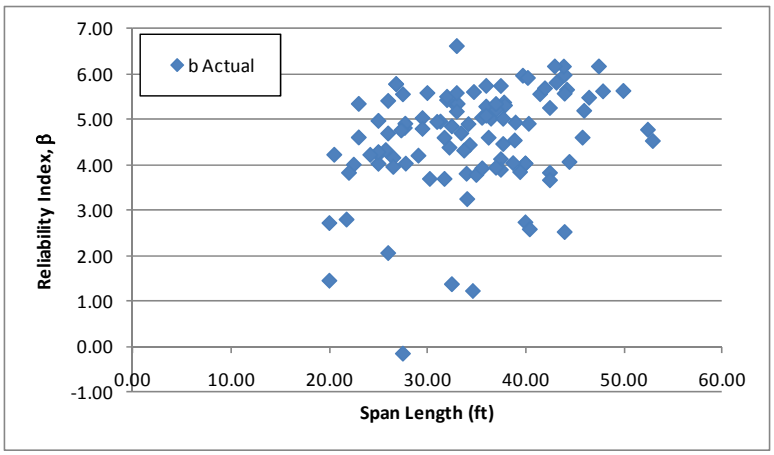


Figure H-94: Shear Reliability Indices for TX-04 Vehicle

Figure H-95 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The reliability index increases with increasing rating factors. The reliability index for an LRFR rating of 1.0 is 4.0, above the target reliability of 2.5. This indicates that the LRFR live load factors may be over-conservative but this may also be a side effect of slabs not being designed for shear as long as they have been designed for moment according to AASHTO LRFD 4.6.2.3.

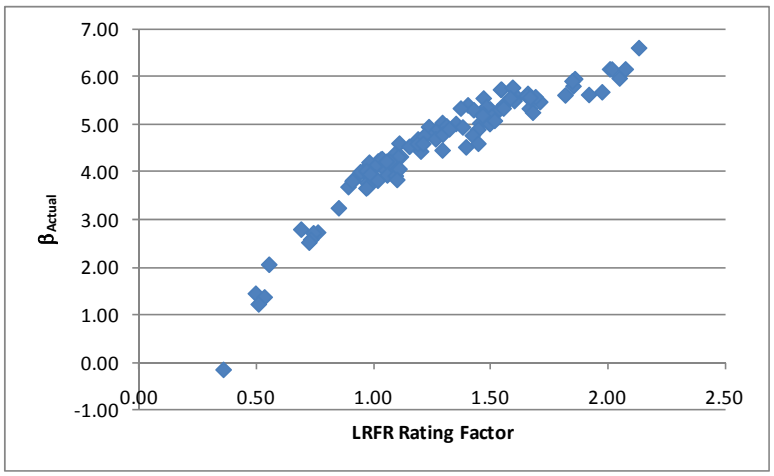


Figure H-95: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

H.1.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-96. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

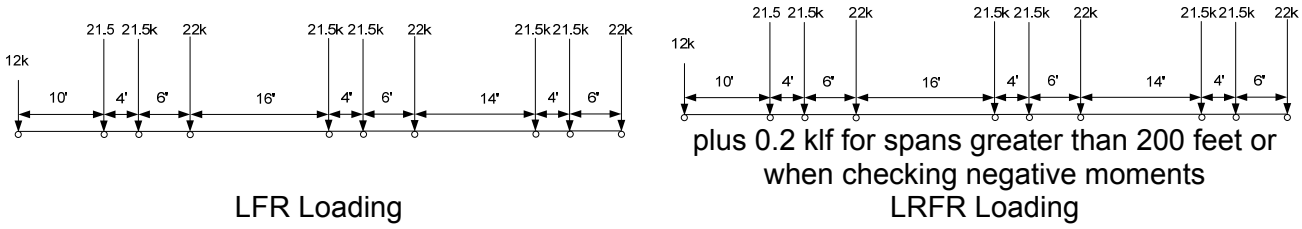


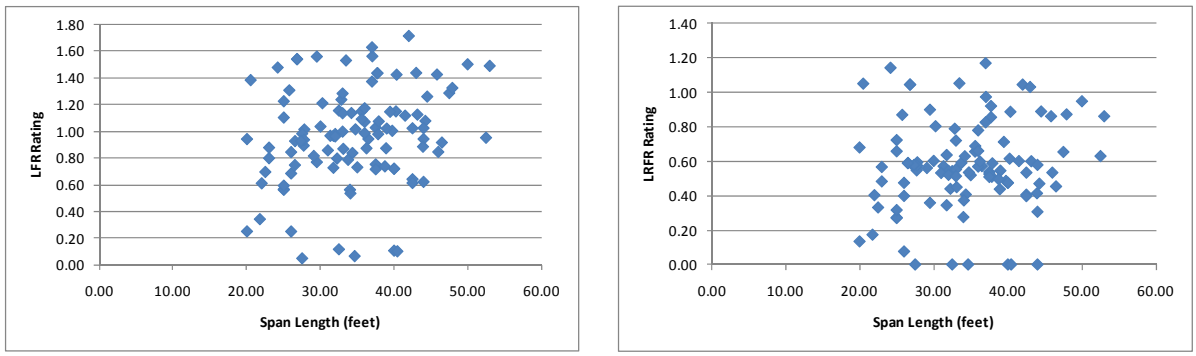
Figure H-96: Vehicle Loadings and Load Factors

H.1.10.1 Moment

The following section contains the results for continuous slab span bridges for the WA-02 Vehicle.

H.1.10.1.1 Rating Factors

Figure H-97 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 58 slabs with an LFR rating less than 1.0, 97 slabs with an LRFR rating less than 1.0, and 58 slabs where both ratings are less than 1.0. Two of the 97 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 100% of the slabs in this subset. The LFR ratings are generally between 0.7 and 1.2 while the LRFR ratings are generally between 0.4 and 0.8.



(a) (b)

Figure H-97: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure H-98 shows the percentage of slabs with moment ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 7.62% of slabs have LRFR ratings greater than 1.0 for all special permit types, from single trip, escorted permits to multiple trip permits with an ADTT ≥ 5,000. 44.8% of slabs have LFR ratings less than 1.0. Switching from LFR to LRFR causes 37.2% more slabs to have LRFR ratings less than 1.0 for all special permit categories than had LFR ratings less than 1.0.

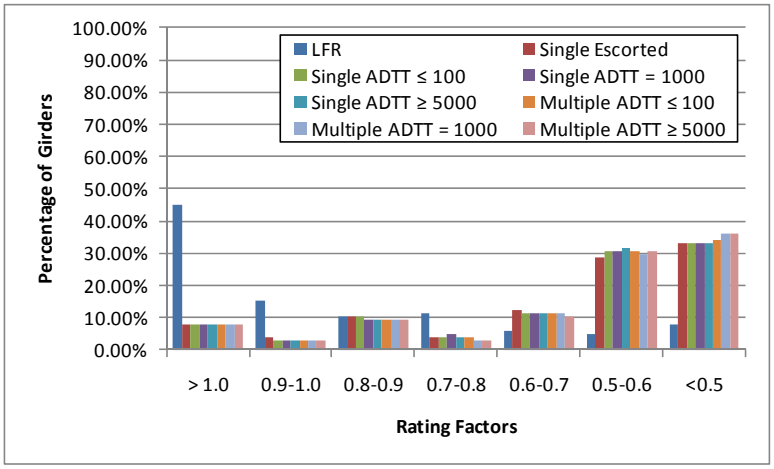


Figure H-98: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

H.1.10.1.2 Rating Factor Comparisons

Figure H-99 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.5 and 0.8. There are no slabs with an LRFR rating that is greater than the LFR rating.

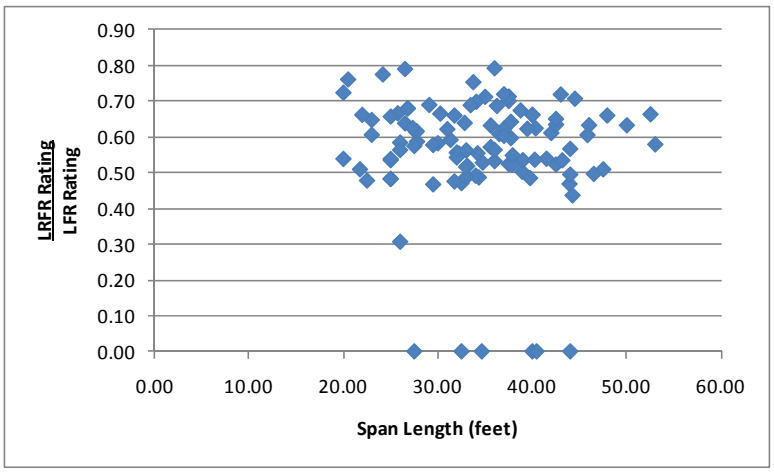


Figure H-99: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

H.1.10.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-100 shows 15 slabs have a reliability index less than the target reliability index of 3.5. The reliability index for most slabs is between four and seven.

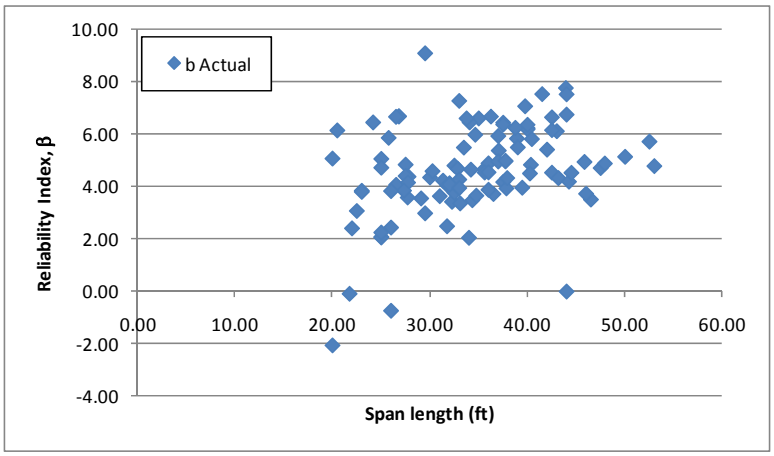


Figure H-100: Flexure Reliability Indices for WA-02 Vehicle

Figure H-101 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 Vehicle. The reliability index increases with increasing LRFR moment ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 5.0, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. Slabs with high reliability and low ratings are those controlled by the longitudinal steel rating near the support. The reliability index is calculated using the moment resistance not the resistance of the longitudinal steel.

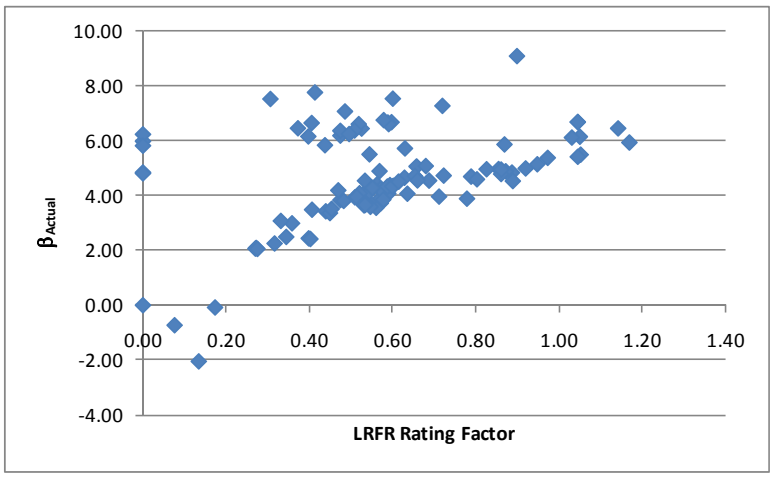
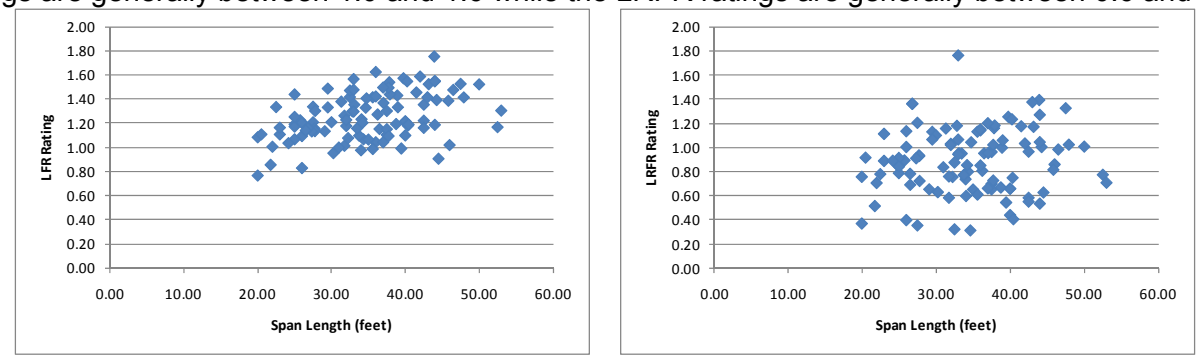


Figure H-101: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

H.1.10.2 Shear

H.1.10.2.1 Rating Factors

For shear, there are nine slabs with LFR rating factors less than 1.0, 68 slabs with LRFR ratings less than 1.0, and nine slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 96% of the slabs in this subset. Figure H-102 shows the LFR and LRFR ratings. LFR Ratings are generally between 1.0 and 1.6 while the LRFR ratings are generally between 0.6 and 1.2.



(a) (b)

Figure H-102: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure H-103 shows the percentage of slabs with shear ratings in each rating range for the WA-02 vehicle, a special permit vehicle. 59.1% of slabs have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage decreases to 5.7% for the multi-trip permit with ADTT ≥ 5,000 category. 91.4% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 32.3% more slabs to have LRFR ratings less than 1.0 for the single trip, escorted permit category than had LFR ratings less than 1.0. The percentage increases to 59.1% for the multi-trip permit with ADTT ≥ 5,000 category.

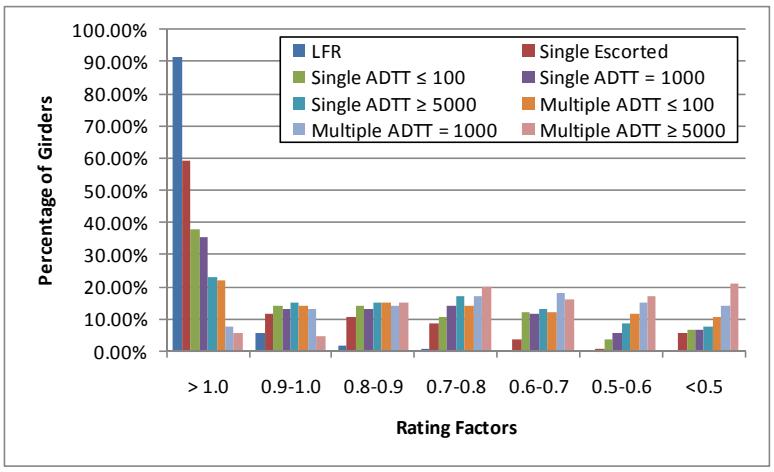


Figure H-103: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

H.1.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure H-104 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.0. 4% of slabs have LRFR ratings that are greater than the LFR rating.

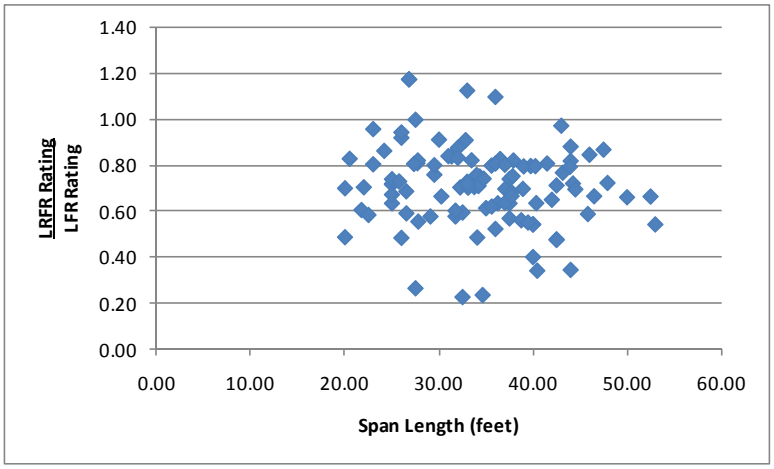


Figure H-104: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

H.1.10.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is less than the target reliability index of 3.5 for 35 slabs as shown in Figure H-105. The reliability index is between three and five for most slabs; indicating that for this vehicle the reliability index is low.

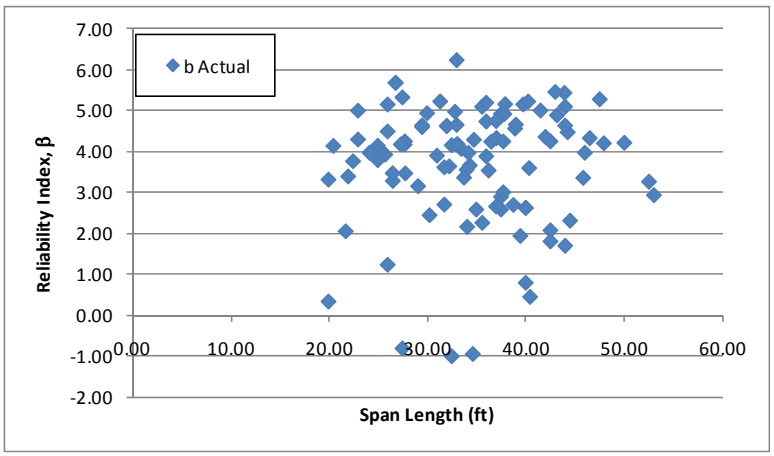


Figure H-105: Shear Reliability Indices for WA-02 Vehicle

Figure H-106 shows the reliability index for shear plotted against the LRFR shear rating for WA-02 vehicle. The reliability index increases with increasing LRFR rating factors. The reliability index associated with an LRFR rating of 1.0 is approximately four, above the target reliability of 3.5.

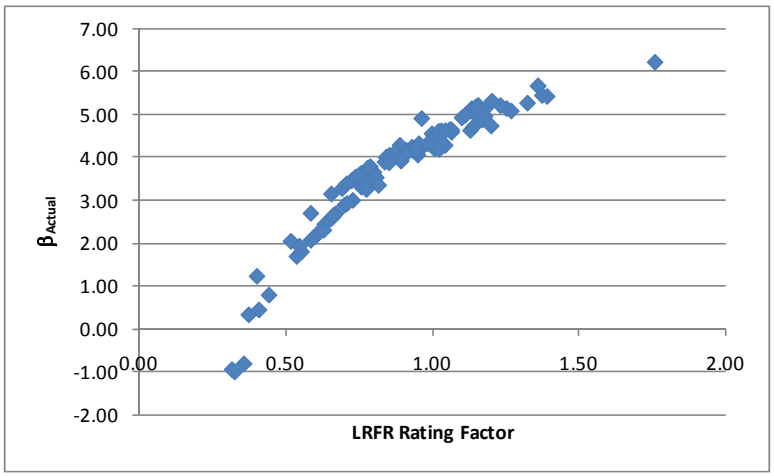


Figure H-106: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

H.1.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-107. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

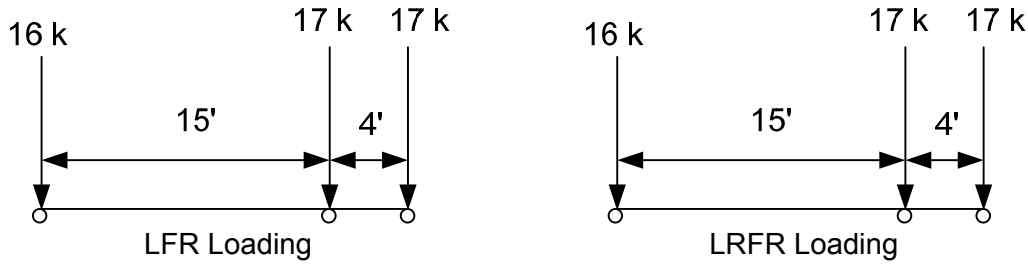
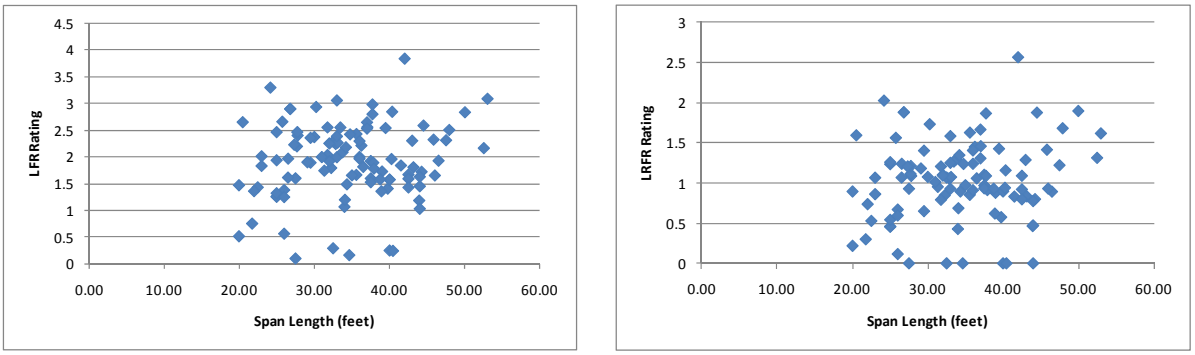


Figure H-107: Vehicle Loadings and Load Factors

H.1.11.1 Moment

H.1.11.1.1 Rating Factors

Figure H-108 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are eight slabs with an LFR rating less than 1.0, 51 slabs with an LRFR rating less than 1.0, and eight slabs where both ratings are less than 1.0. Fifty of the fifty one slabs with an LRFR rating less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the slabs in this subset. The LFR ratings are between 1.5 and 2.5 for most slabs while the LRFR ratings are between 0.75 and 1.5.



(a) (b)

Figure H-108: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure H-109 shows the percentage of slabs with moment ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 71.4% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 40.0% when the ADTT ≥ 5,000. 92.4% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 21.0% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 52.4% for an ADTT ≥ 5,000.

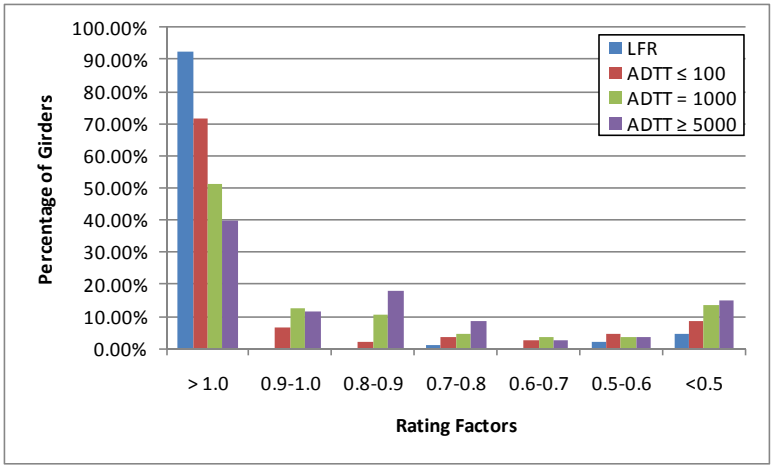


Figure H-109: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

H.1.11.1.2 Rating Factor Comparisons

Figure H-110 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating, which does not occur for this vehicle. The ratio is generally between 0.4 and 0.7.

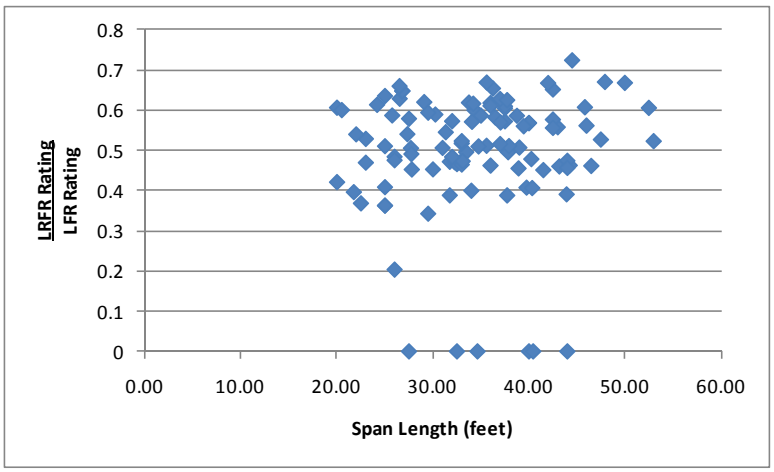


Figure H-110: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

H.1.11.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-111 shows one slab has a reliability index that is less than the target reliability index of 2.5. The reliability index is between five and eight for most slabs.

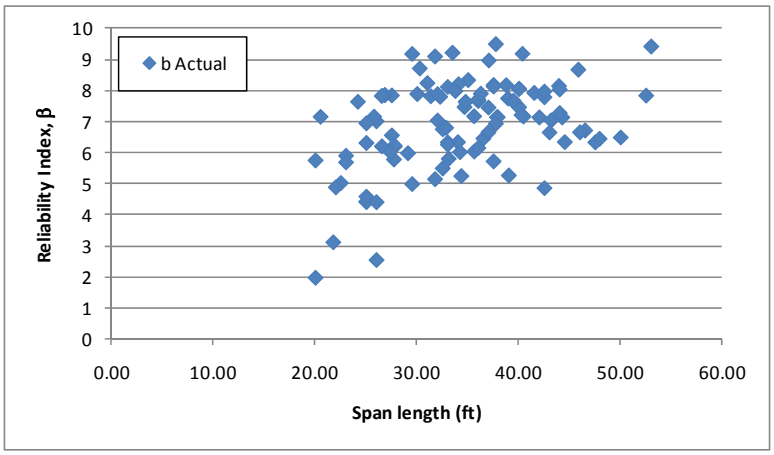


Figure H-111: Flexure Reliability Indices for Type 3 Vehicle

Figure H-112 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 Truck. The reliability index increases with increasing rating factors. The reliability index associate with an LRFR rating of 1.0 is approximately 5.5, above the target reliability of 2.5. This may indicate the live load factors in the MBE are over-conservative.

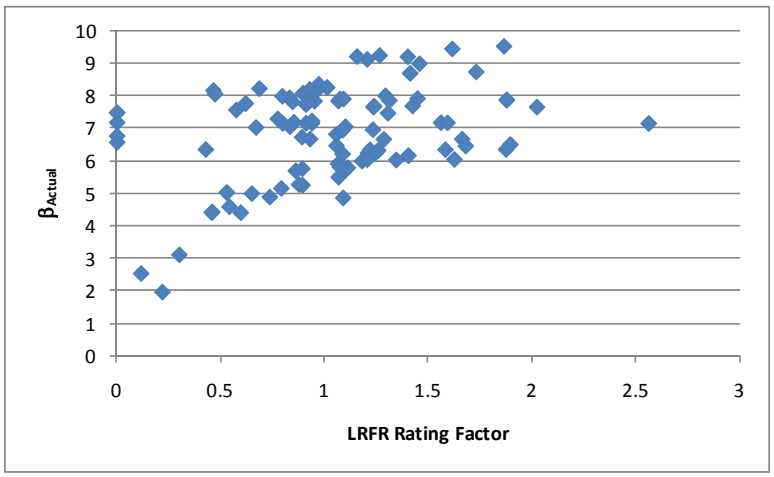
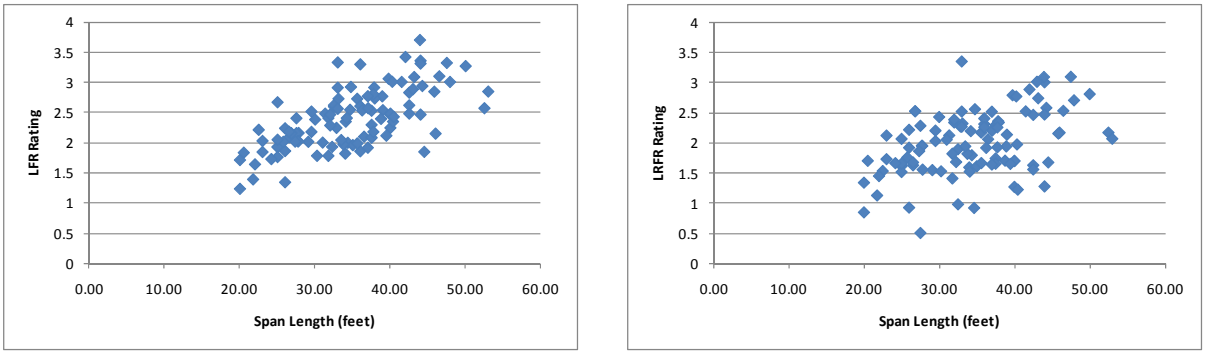


Figure H-112: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

H.1.11.2 Shear

H.1.11.2.1 Rating Factors

For shear, there are zero slabs with LFR rating factors less than 1.0, five slabs with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 87% of the slabs in this subset. Figure H-113 shows the LFR and LRFR ratings. The LFR ratings are between 1.5 and 3.0 for most slabs while the LRFR ratings are generally between 1.5 and 2.5.



(a) (b)

Figure H-113: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure H-114 shows the percentage of slabs with shear ratings in each rating range for the AASHTO Type 3 truck, a legal vehicle. 99.1% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 95.2% when the ADTT ≥ 5,000. 100% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 0.9% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 4.8% for an ADTT ≥ 5,000.

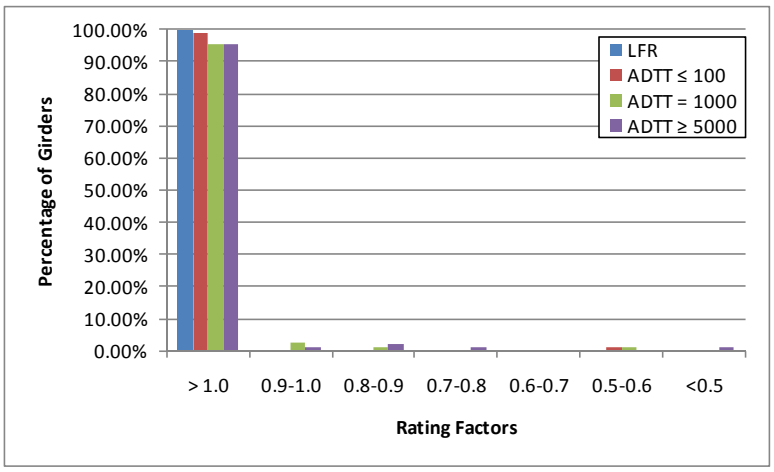


Figure H-114: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

H.1.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure H-115 show the comparison of rating factors. The ratio is generally between 0.6 and 1.0, with shorter spans generally having higher ratios. 13% of slabs have an LRFR rating that is greater than the LFR rating.

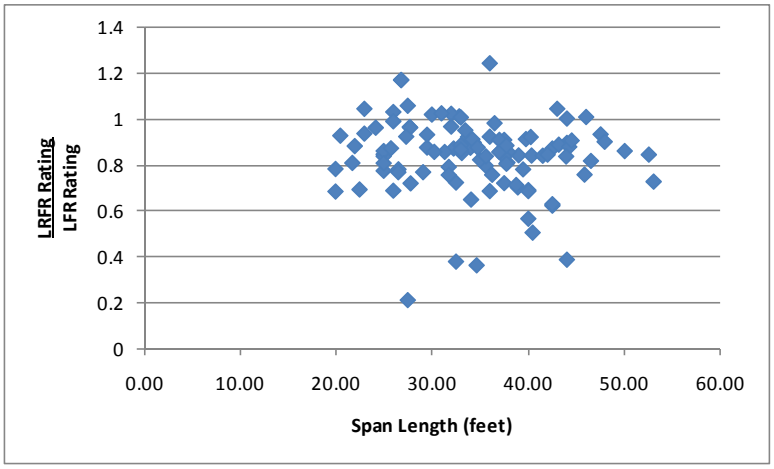


Figure H-115: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

H.1.11.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is less than the target reliability index of 2.5 for one slabs as shown in Figure H-116. The reliability index is between 5.5 and 7 for most slabs.

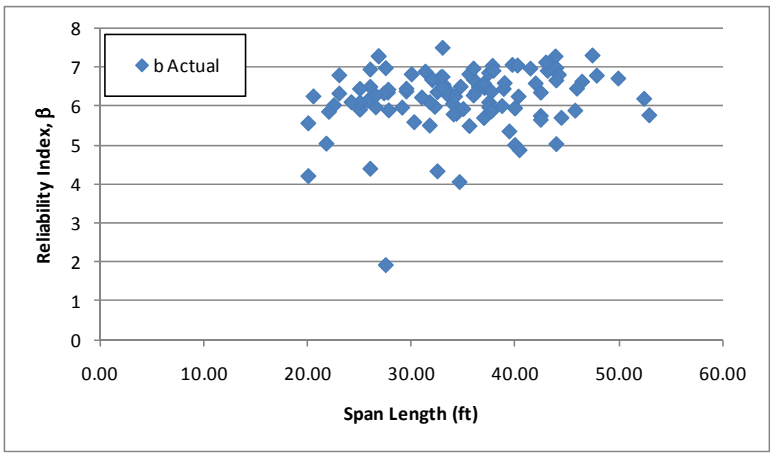


Figure H-116: Shear Reliability Indices for Type 3 Vehicle

Figure H-117 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 Truck. The reliability index increases with increasing rating factors. An LRFR rating factor of 1.0 corresponds to a reliability index of approximately four, above the target reliability of 2.5. This indicates that the LRFR live load factors may be over-conservative. This may also partially be a result of shear not being a design criterion if the slab bridge is designed meeting the requirements of AASHTO LRFD 4.6.3.2.

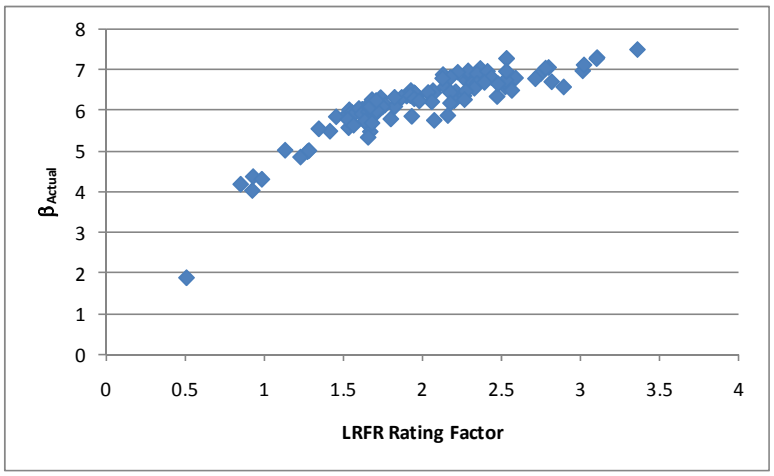


Figure H-117: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

H.1.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-118. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

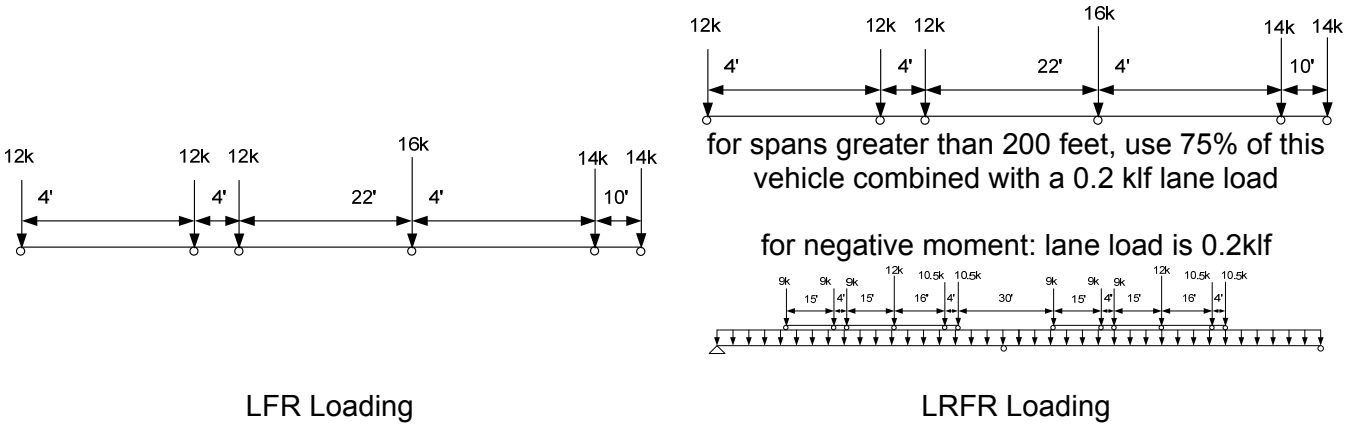
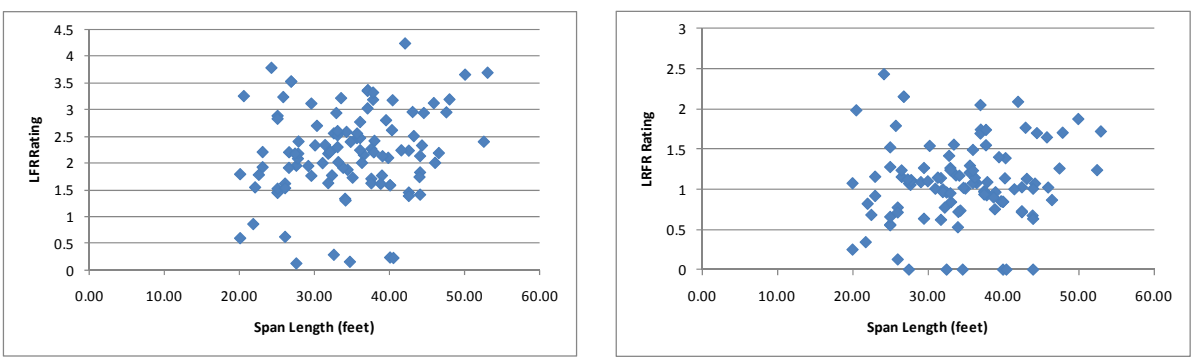


Figure H-118: Vehicle Loadings and Load Factors

H.1.12.1 Moment

H.1.12.1.1 Rating Factors

Figure H-119 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are eight slabs with an LFR rating less than 1.0, 42 slabs with an LRFR rating less than 1.0, and eight slabs where both ratings are less than 1.0. 41 of the 42 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the slabs in this subset. The LFR ratings are between 1.5 and 3.0 for most slabs while the LRFR ratings are between 0.5 and 1.5 for most slabs.



(a) (b)

Figure H-119: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure H-120 shows the percentage of slabs with moment ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 71.4% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 46.7% when the ADTT ≥ 5,000. 92.4% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 21.0% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 45.7% for an ADTT ≥ 5,000.

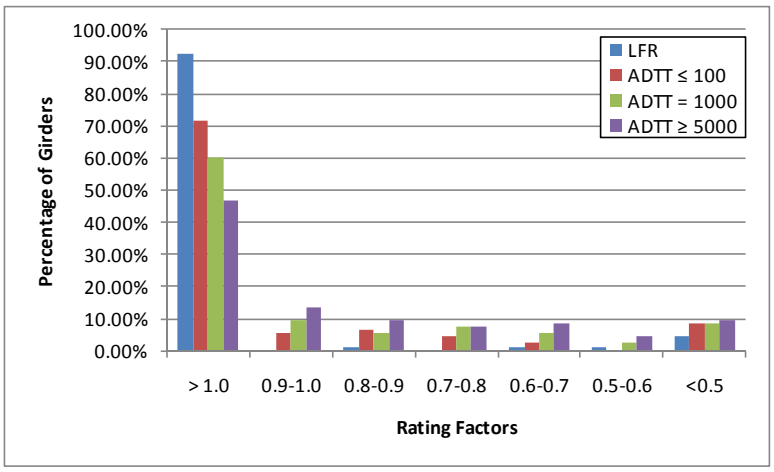


Figure H-120: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

H.1.12.1.2 Rating Factor Comparisons

Figure H-121 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.6. There are no slabs with LRFR ratings greater than the LFR rating.

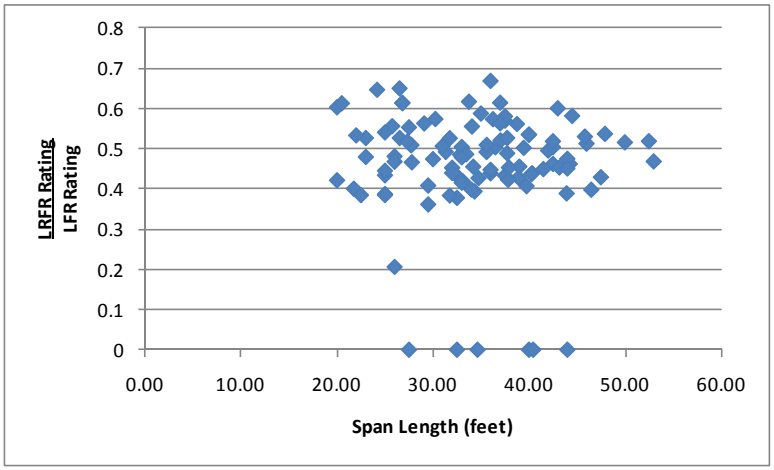


Figure H-121: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

H.1.12.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-122 shows one slab has a reliability index that is less than the target reliability index of 2.5. The reliability index is between five and eight for most slabs. The reliability index increases with increasing maximum span length.

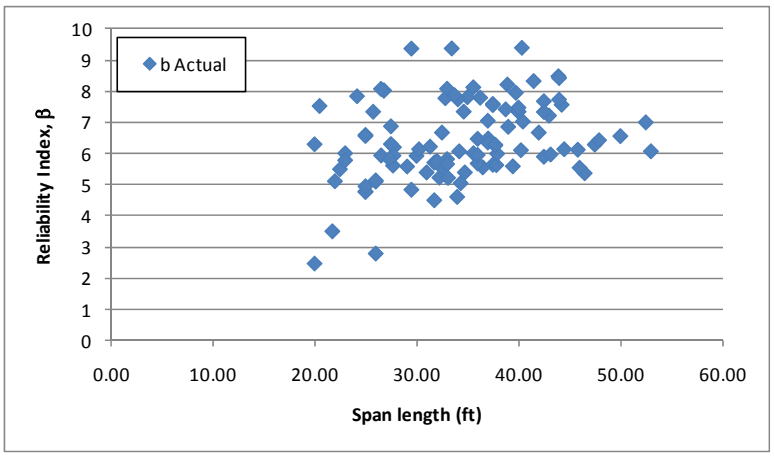


Figure H-122: Flexure Reliability Indices for Type 3-3 Vehicle

Figure H-123 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The reliability index increases with increasing rating factors. The reliability index for a slab with an LRFR rating of 1.0 is approximately 5.0, above the target reliability of 2.5. This may indicate that the live load factors in the MBE are over-conservative.

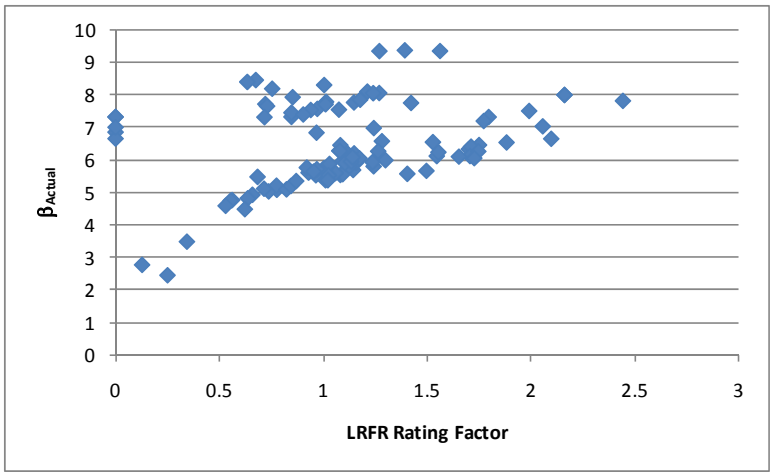
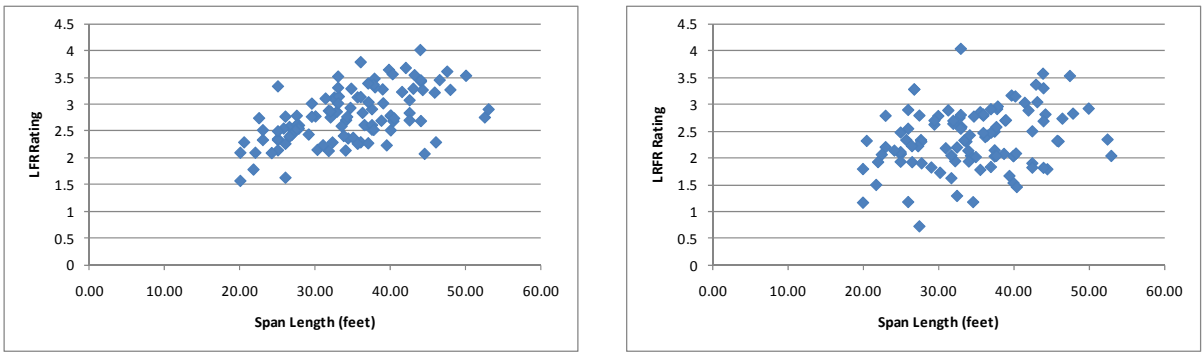


Figure H-123: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

H.1.12.2 Shear

H.1.12.2.1 Rating Factors

For shear, there are zero slabs with LFR rating factors less than 1.0, one slab with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 86% of the slabs in this subset. Figure H-124 shows the LFR and LRFR ratings. The LFR ratings are between two and 3.5 while the LRFR ratings were between 1.5 and 3.0.



(a) (b)

Figure H-124: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure H-125 shows the percentage of slabs with shear ratings in each rating range for the AASHTO Type 3-3 truck, a legal vehicle. 99.1% of slabs have LRFR ratings greater than 1.0 for all ADTT values. 100% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 0.9% more slabs to have LRFR ratings less than 1.0 for all ADTT values than had LFR ratings less than 1.0.

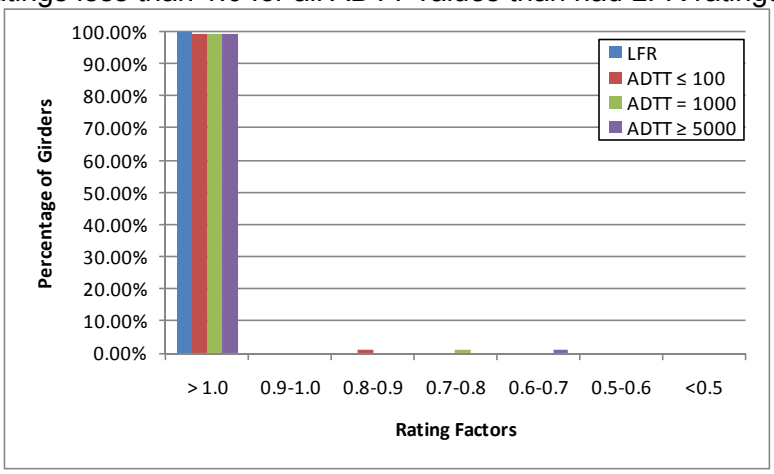


Figure H-125: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

H.1.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure H-126 show the comparison of rating factors. The ratio is generally between 0.7 and 1.0, with shorter spans generally having higher ratios. 14% of slabs have an LRFR rating that is greater than the LFR rating.

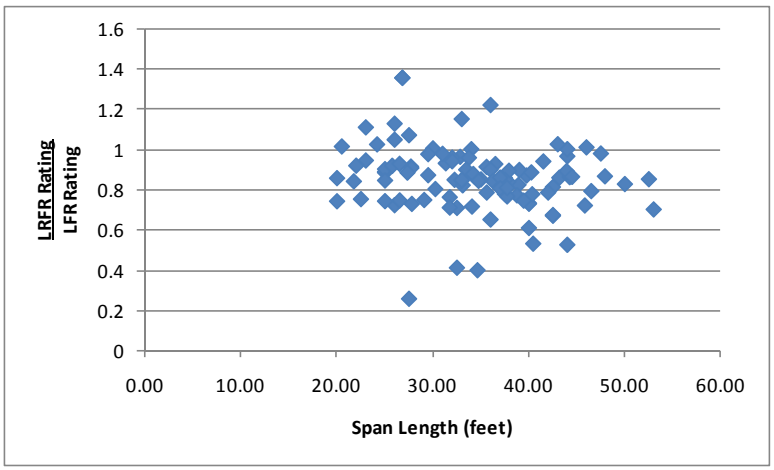


Figure H-126: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

H.1.12.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is less than the target reliability index of 2.5 for zero slabs as shown in Figure H-127. The reliability index is between five and seven for most slabs.

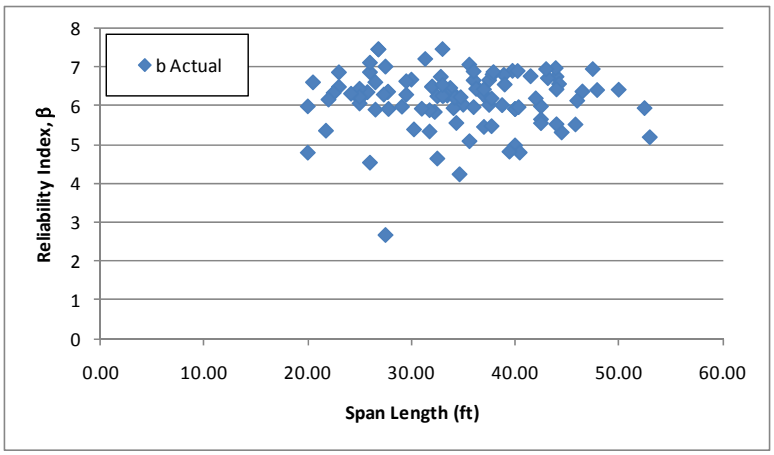


Figure H-127: Shear Reliability Indices for Type 3-3 Vehicle

Figure H-128 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 Truck. The reliability index increases with increasing LRFR rating factors. The reliability index corresponding to an LRFR rating of 1.0 is approximately 3.5, above the target reliability of 2.5. This may indicate the live load factors in the MBE are over-conservative.

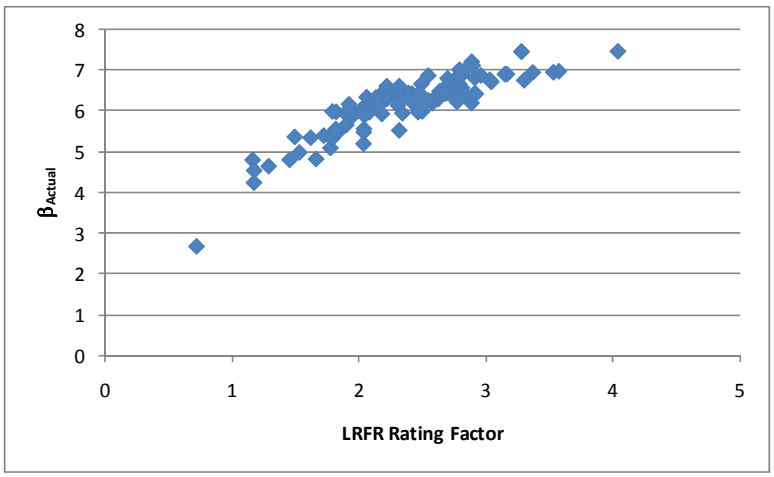


Figure H-128: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

H.1.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure H-129. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

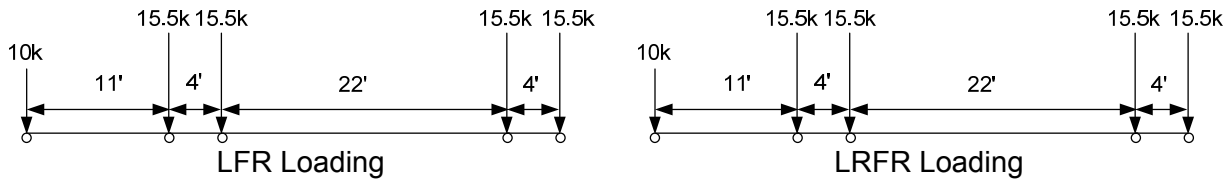
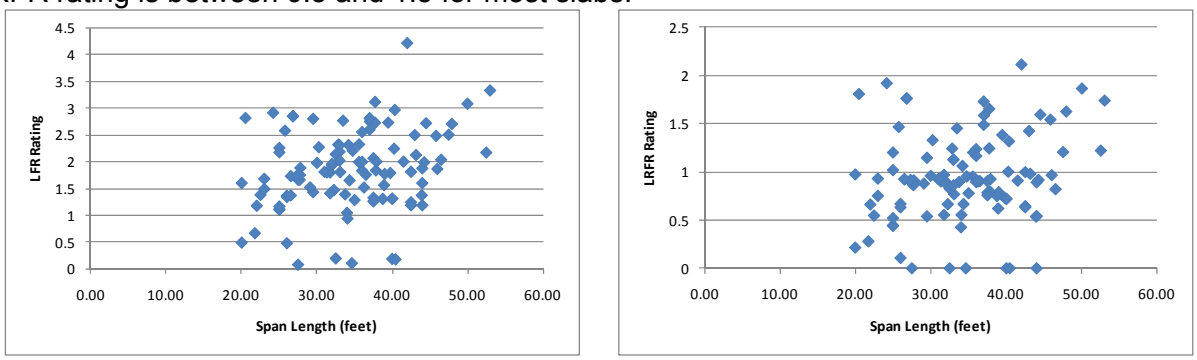


Figure H-129: Vehicle Loadings and Load Factors

H.1.13.1 Moment

H.1.13.1.1 Rating Factors

Figure H-130 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are nine slabs with an LFR rating less than 1.0, 71 slabs with an LRFR rating less than 1.0, and nine slabs where both ratings are less than 1.0. 70 of the 71 slabs with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the slabs in this subset. The LFR rating is between 1.0 and 3.0 for most slabs while the LRFR rating is between 0.5 and 1.5 for most slabs.



(a) (b)

Figure H-130: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure H-131 shows the percentage of slabs with moment ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 61.9% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 29.5% for an ADTT ≥ 5,000. 91.4% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 29.5% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 61.9% for an ADTT ≥ 5,000.

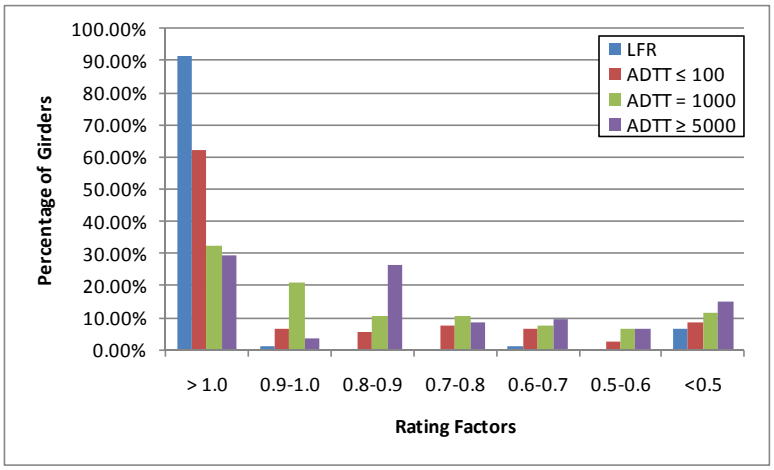


Figure H-131: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

H.1.13.1.2 Rating Factor Comparisons

Figure H-132 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.4 and 0.6; no slabs have LRFR ratings that are greater than the LFR rating.

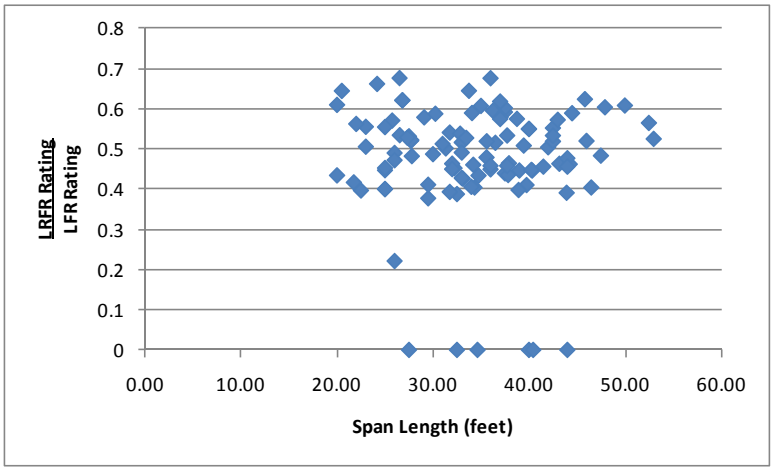


Figure H-132: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

H.1.13.1.3 Reliability Indices

The reliability index was calculated for this subset of slabs. Figure H-133 shows two slabs have a reliability index that is less than the target reliability index of 2.5. The reliability index increases with increasing maximum span lengths. A majority of slabs have reliability indices between five and eight.

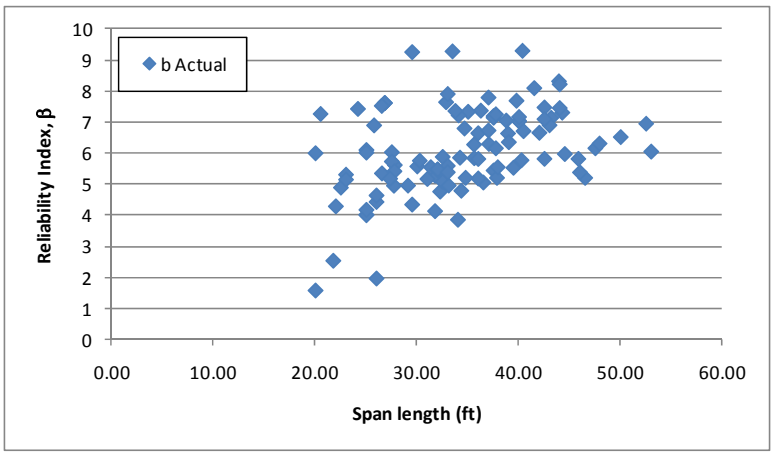


Figure H-133: Flexure Reliability Indices for Type 3S2 Vehicle

Figure H-134 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 truck. The reliability index increases to approximately 5.0 for an LRFR rating of 1.0. This is above the target reliability of 2.5; this may indicate the live load factors in the MBE are over-conservative.

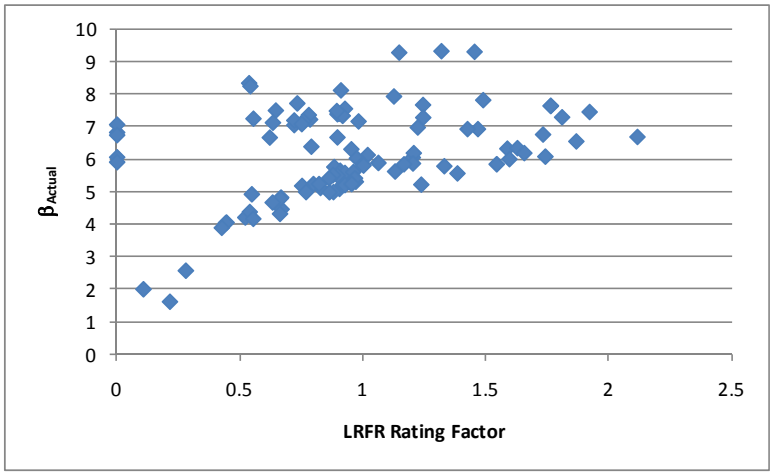
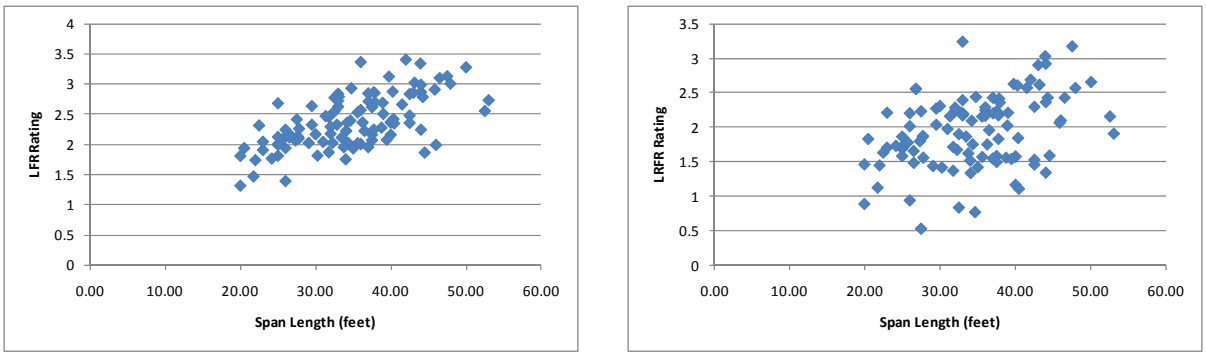


Figure H-134: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

H.1.13.2 Shear

H.1.13.2.1 Rating Factors

For shear, there are zero slabs with LFR rating factors less than 1.0, five slabs with LRFR ratings less than 1.0, and zero slabs where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 87% of the slabs in this subset. Figure H-135 shows the LFR and LRFR ratings. The LFR ratings are between two and three for most slabs while the LRFR ratings are slightly lower and are between 1.5 and 2.5.



(a) (b)

Figure H-135: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure H-136 shows the percentage of slabs with shear ratings in each rating range for the AASHTO Type 3S2 truck, a legal vehicle. 97.1% of slabs have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage decreases to 95.2% when the ADTT ≥ 5,000. 100% of slabs have LFR ratings greater than 1.0. Switching from LFR to LRFR causes 2.9% more slabs to have LRFR ratings less than 1.0 for an ADTT ≤ 100 than had LFR ratings less than 1.0. The percentage increases to 4.8% for an ADTT ≥ 5,000.

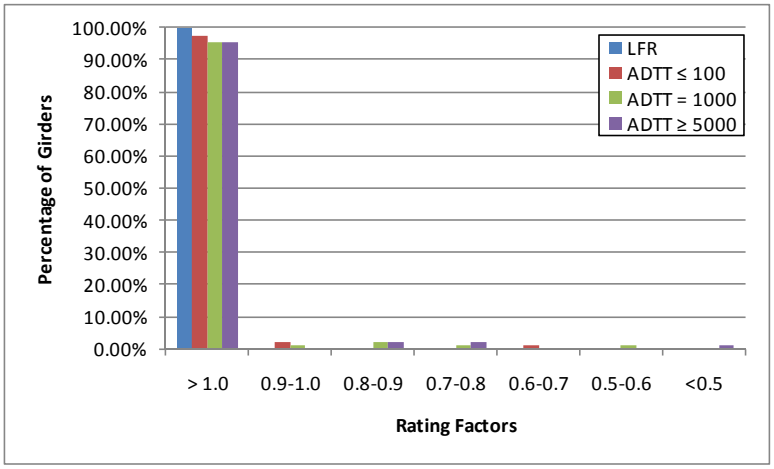


Figure H-136: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

H.1.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure H-137 shows the comparison of rating factors. The ratio is generally between 0.6 and 1.0, with shorter spans generally having higher ratios. The LRFR rating is greater than the LFR rating for 13% of the slabs.

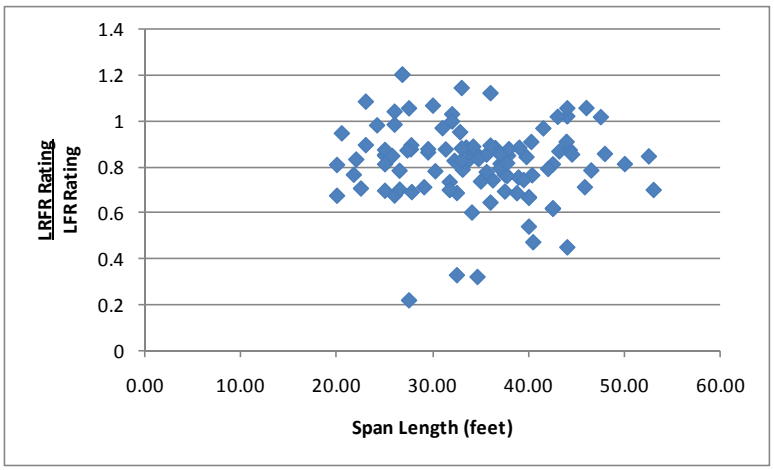


Figure H-137: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

H.1.13.2.3 Reliability Indices

The reliability indices were also calculated. The reliability index is less than the target reliability index of 2.5 for one slab as shown in Figure H-138. The reliability index for most slabs is between five and seven.

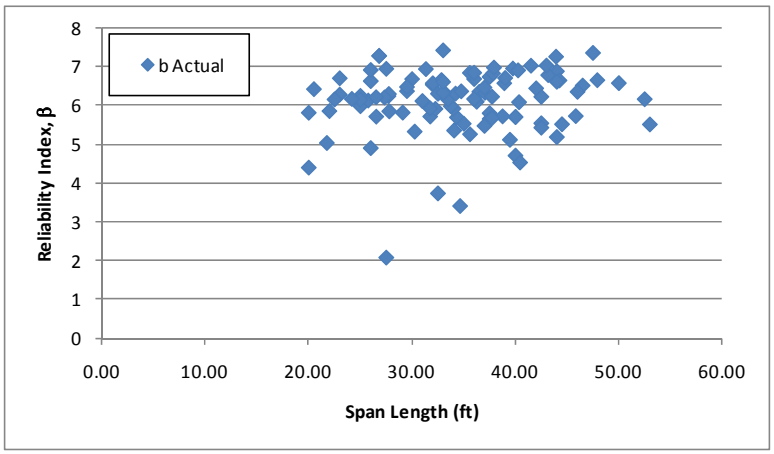


Figure H-138: Shear Reliability Indices for Type 3S2 Vehicle

Figure H-139 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 Truck. The reliability index increases with increasing LRFR rating factors. A reliability index of approximately 4.5 corresponds to an LRFR rating of 1.0; this is above the target reliability of 2.5. This may indicate that the LRFR live load factors in the MBE are over-conservative.

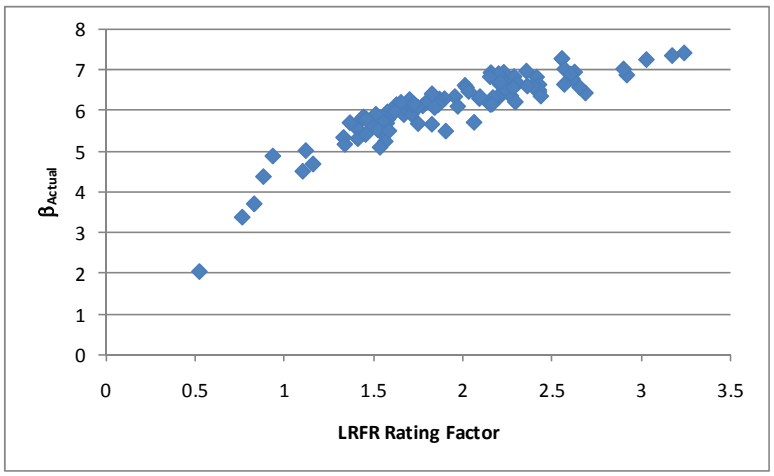


Figure H-139: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

H.1.14 Moment

The results shown in this section compare the number of slabs for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table H-1 shows the results for the moment ratings. The Design Vehicle, IL-01, OR-06, and WA-02 had the most slabs with ratings less than 1.0 for both methods. The other vehicles, while not having as many slabs with insufficient ratings, still had a number of slabs with poor ratings. The routine permit and legal vehicles had the fewest slabs with LFR ratings and LRFR ratings less than 1.0. An additional row is added to the table to indicate how many slabs with LRFR ratings less than 1.0 were controlled by the longitudinal steel rating. The design and legal vehicles had the most slabs with that were controlled by the longitudinal steel rating.

Table H-1: Flexure Rating Factor Results for All 12 Vehicles

	Total Slabs	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	105	66	14	9	40	13	9	34	20	58	8	8	9
LRFR Rating less than 1.0		96	70	45	88	61	38	85	71	97	51	42	71
LFR and LRFR Rating less than 1.0		66	14	9	40	13	9	34	20	58	8	8	9
% with LFR RF greater than LRFR RF		100	100	100	100	100	100	100	100	100	100	100	100
LRFR Rating less than 1.0 and controlled by longitudinal steel rating		95	2	2	2	2	2	2	2	2	50	41	70

H.1.15 Shear

The results shown in this section compare the number of slabs for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table H-2 shows the results for the shear ratings. For the eleven permit and legal vehicles that were used in this study, very few resulted in slabs having LFR ratings less than 1.0. The design vehicle resulted in about 40% of the slabs having rating less than 1.0. The four heavy vehicles (design, IL-01, OR-06, and WA-02) caused between 30 and 70% of the slabs to have LRFR ratings less than 1.0. The other vehicles resulted in 10% or less of the slabs having LRFR ratings less than 1.0. The percentage of slabs with LFR ratings greater than LRFR ratings

seems to depend on the vehicle, which is expected because the LRFR shear strength equation uses the ratio of V_u/M_u.

Table H-2: Shear Rating Factor Results for All 12 Vehicles

	Total Slabs	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	105	43	0	0	3	0	0	3	3	9	0	0	0
LRFR Rating less than 1.0		74	8	6	34	10	5	36	22	68	5	1	5
LFR and LRFR Rating less than 1.0		41	0	0	3	0	0	3	3	9	0	0	0
% with LFR RF greater than LRFR RF		90	90	90	90	95	81	90	97	96	87	86	87

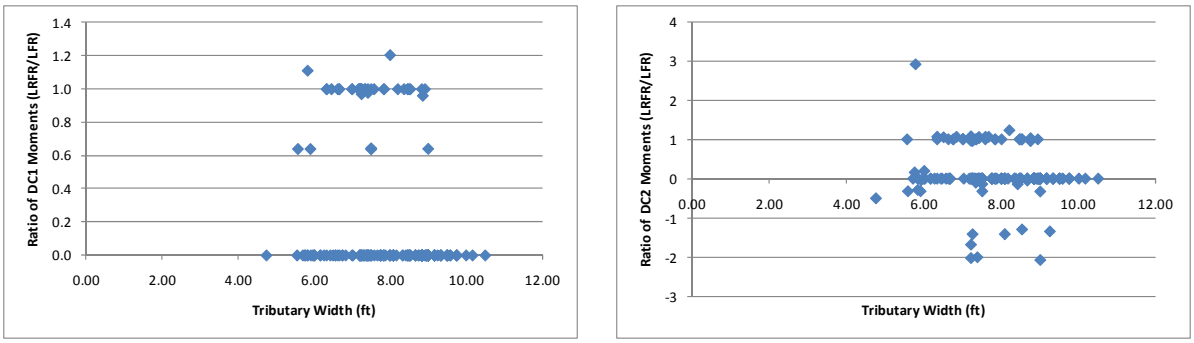
I Continuous Prestressed I Girder Bridges

I.1 Interior Composite Girders

I.1.1 Dead Loads

I.1.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure I-1a, the ratios of unfactored DC1 moments (self-weight, dead loads on composite section) are either very close to 1.0 or zero. Those at zero are likely because the critical location is at the support and continuity is provided by the deck, so the moment at the support will be zero for these loads. Figure I-1b shows that there is more variation in the loads applied to the composite section (DC2 and DW loads). Most of the ratios are either at 1.0 or -1.5; those at 1.0 are likely at the same location while those at -1.5 are at different locations.

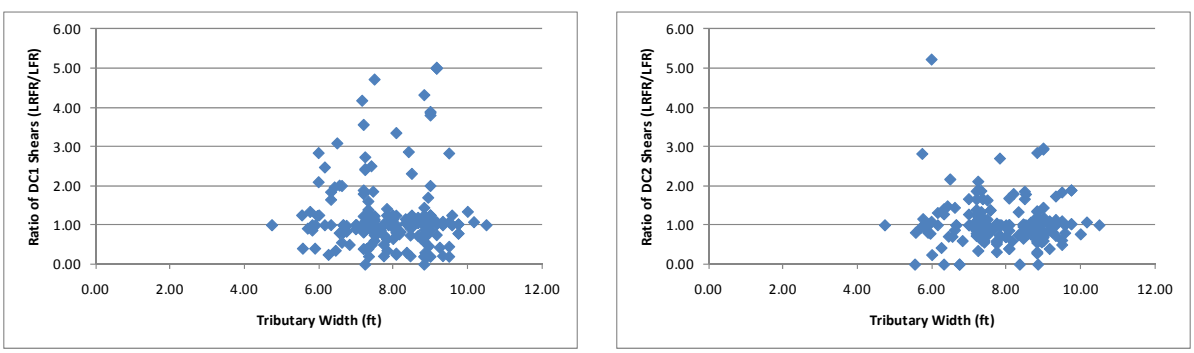


(a) (b)

Figure I-1: Ratio of DC1 and DC2 Moments (unfactored loads, LRFR/LFR)

I.1.1.2 Shear

Figure I-2 shows the ratios of DC1 and DC2 shears. The results are generally around 1 with significant variation shown in both DC1 and DC2 loads.



(a) (b)

Figure I-2: Ratios of DC1 and DC2 Shear (unfactored loads, LRFR/LFR)

I.1.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure I-3. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

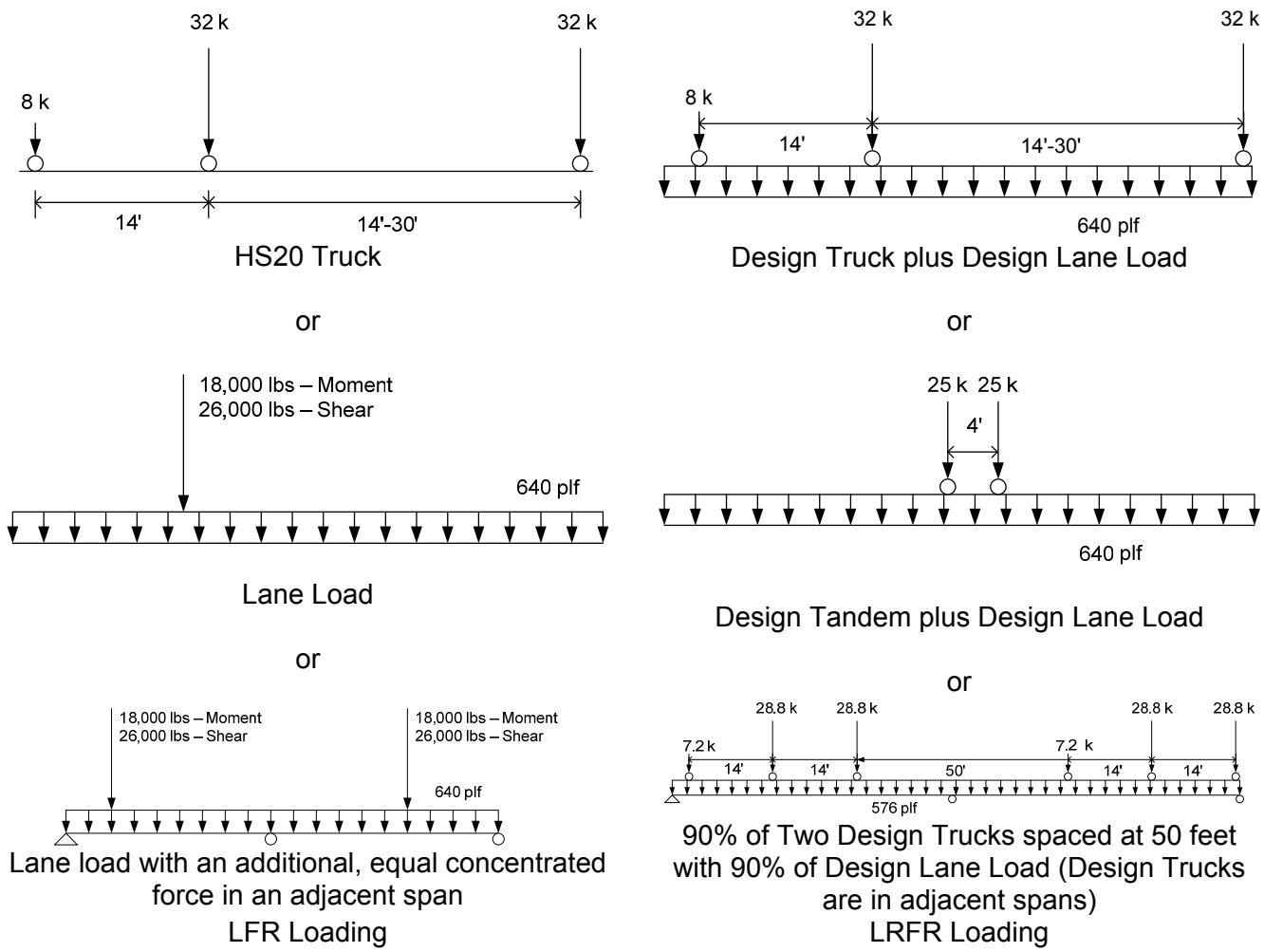


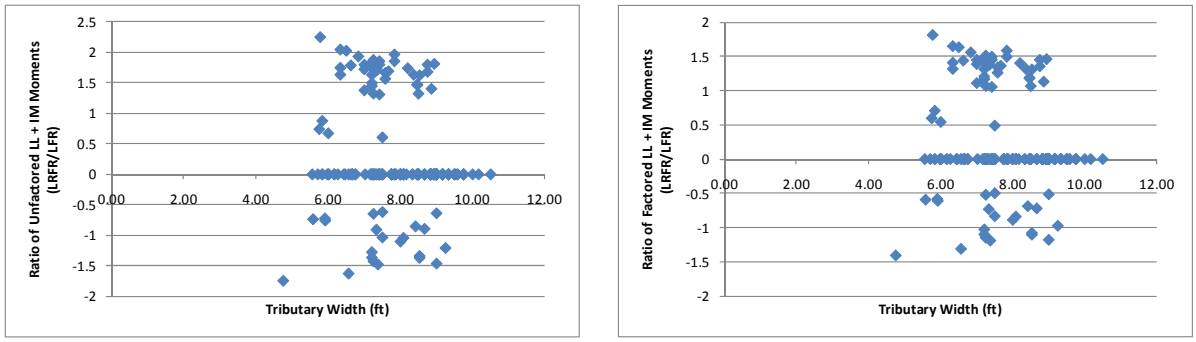
Figure I-3: Vehicle Loadings and Load Factors

I.1.2.1 Moment

I.1.2.1.1 Live Loads

Figure I-4 shows a plot of the unfactored and factored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). For most girders, the ratio is either between 1.25 and 2.0 or -0.75 and -1.5. There are many girders with unfactored and factored live load ratios, these girders are controlled by the longitudinal steel rating at the support. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the

LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure I-4b shows that the results have shifted closer to 1.0 and are between 1.0 and 1.5 for the positive ratios and between -0.5 and -1.25 for the negative values.



(a) (b)

Figure I-4: Ratio of Unfactored and Factored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

I.1.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure I-5 shows that the ratio of resistance is close to 1.0 or 0.25, with several less than zero. Where the ratio is greater than 1.0, the increased resistance for LRFR is due to the reduction in prestress losses. Those near 0.25 are controlled by the longitudinal steel rating.

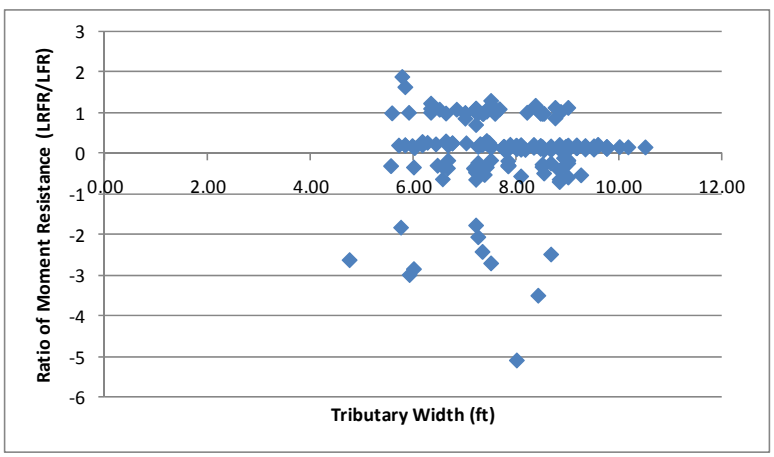
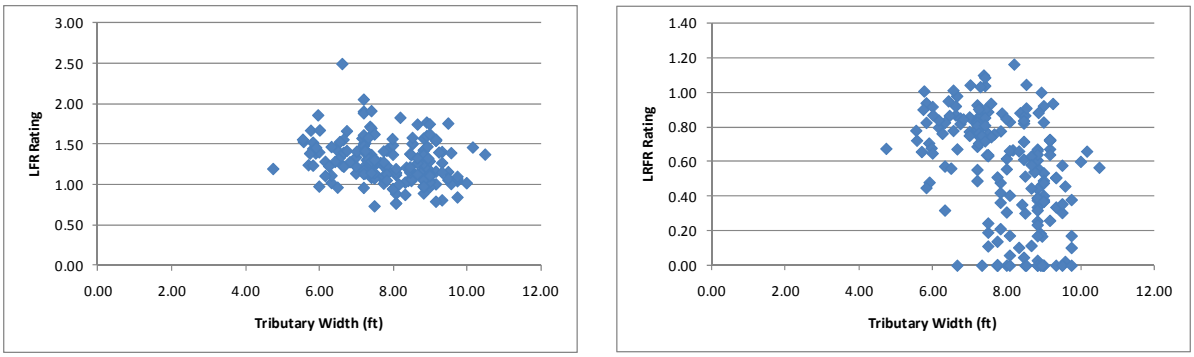


Figure I-5: Ratio of factored Moment Resistance (LRFR/LFR)

I.1.2.1.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (188 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 18 girders with LFR ratings less than 1.0, 180 girders with LRFR ratings less than 1.0, and 18 girders where both the LFR and LRFR ratings are less than 1.0. 179 of the 180 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. Figure I-6 shows the LFR rating factors and LRFR rating factors. The LFR ratings are generally

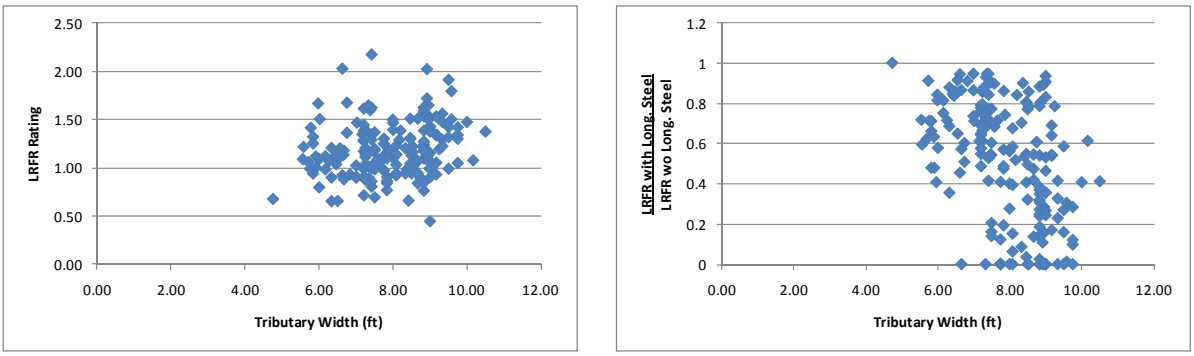
between 1.0 and 1.5 while the LRFR ratings range from zero to 1.2. Most of the girders have LRFR ratings that are less than 1.0.



(a) (b)

Figure I-6: LFR and LRFR Flexure Rating Factors for Design Loadings

Figure I-7a shows the LRFR ratings when the longitudinal steel rating is ignored. Most ratings are between 0.75 and 1.5, when the longitudinal steel rating was included (Figure I-6b) most ratings were less than 1.0. Ignoring the longitudinal steel rating, only 51 girders have LRFR ratings less than 1.0; including the longitudinal steel rating resulted in 180 girders having LRFR ratings less than 1.0. Figure I-7b shows the ratio of the LRFR rating including the longitudinal steel rating divided by the LRFR rating excluding the longitudinal steel rating. The figure shows that 99% of girders have lower rating when the longitudinal steel rating is included..



(a) (b)

Figure I-7: Effect of Longitudinal Steel Rating on LRFR Moment Ratings

I.1.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure I-8. The results indicated that 100% of the girders in this set have LFR ratings greater than LRFR ratings.

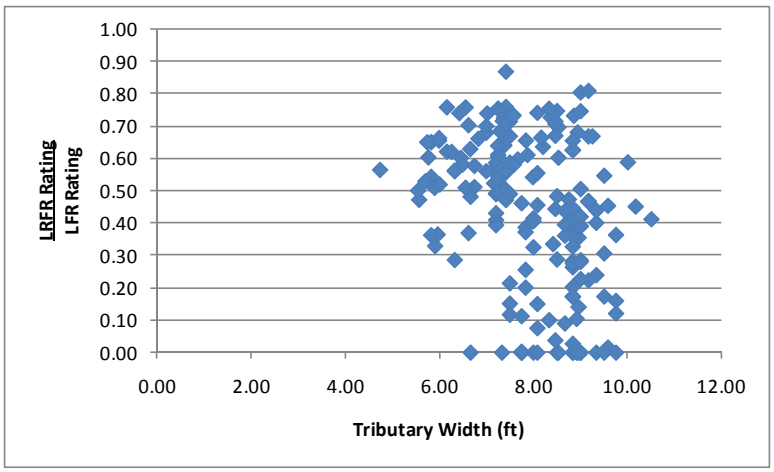


Figure I-8: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure I-9 shows the percentage of girders with LRFR ratings less than 1.0 in each category of LRFR/LFR ratio. The figure shows that many girders are significantly affected by switching from LFR to LRFR. Most girders have a rating that is reduced by at least 20% when switching from LFR to LRFR. A significant number of girders have LRFR ratings that have been reduced to less than 10% of the LFR rating. As mentioned above, most of these girders are controlled by the longitudinal steel rating.

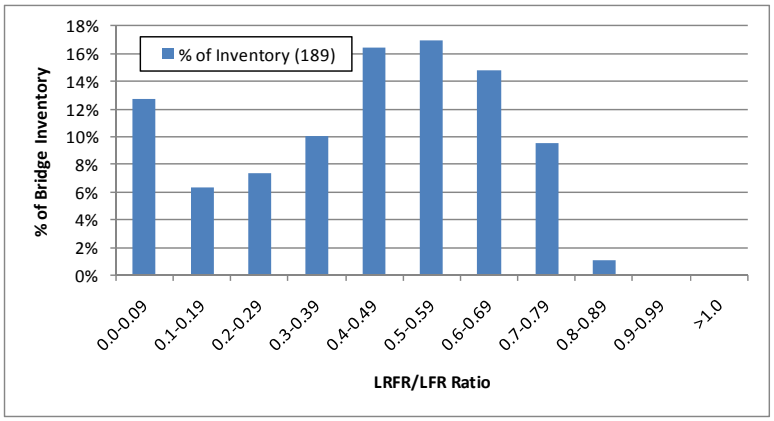


Figure I-9: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

I.1.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure I-10 shows that 20 girders have a reliability index less than the target reliability of 3.5. The reliability index is widely varied for the design vehicle. The girders controlled by the longitudinal steel rating have actual and required reliability indices of zero.

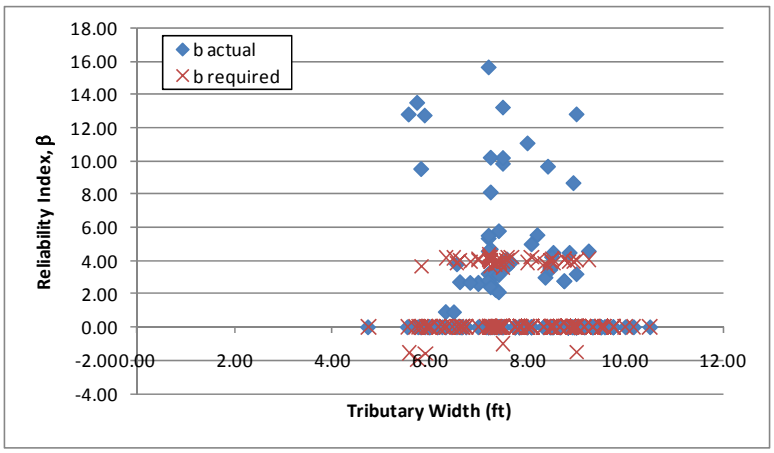


Figure I-10: Flexure Reliability Indices for HL-93 Loadings

Figure I-11 shows the reliability index for moment plotted against the LRFR moment rating for the HL-93 Design Load. Ignoring all the girders at zero, the reliability index for an LRFR rating of one is approximately four, near the target reliability of 3.5.

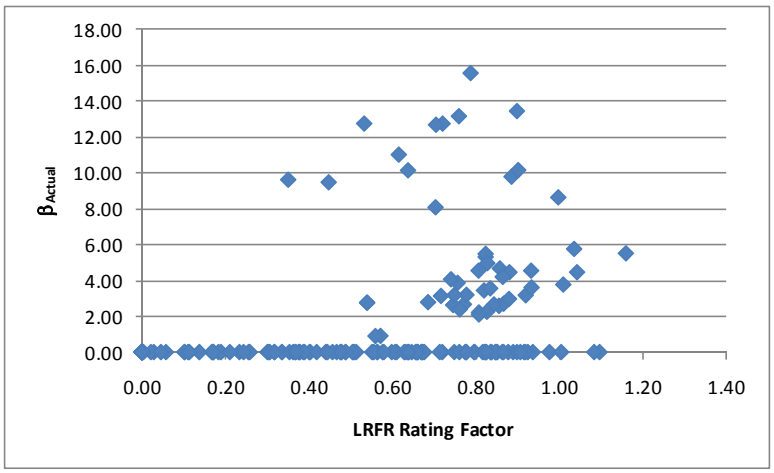
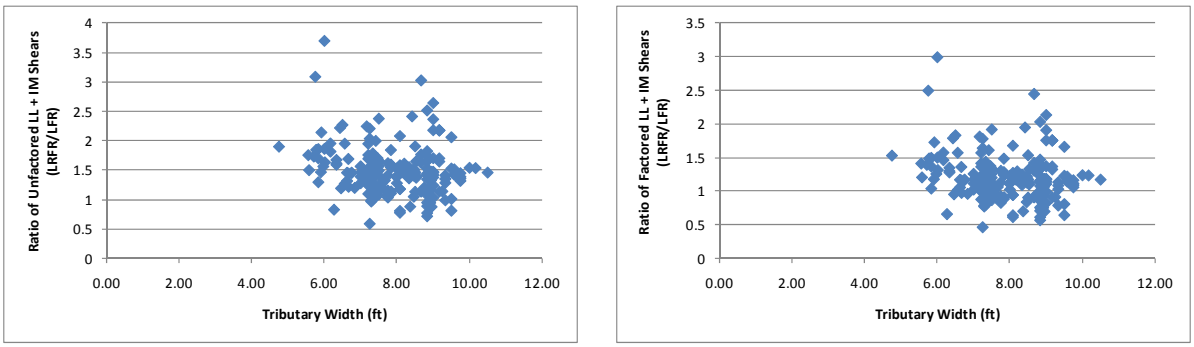


Figure I-11: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Design Loading

I.1.2.2 Shear

I.1.2.2.1 Live Loads

Figure I-12 shows the ratio of unfactored and factored shear. The figure shows that most girders have unfactored ratios between 1.0 and 2.0. Figure I-12 shows that the ratio of factored live load shears has decreased and is generally between 0.75 and 1.5 for most cases.



(a) (b)

Figure I-12: Ratios of Unfactored and Factored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

I.1.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure I-13 shows that the ratio of resistance is generally between 1.0 and 2.5.

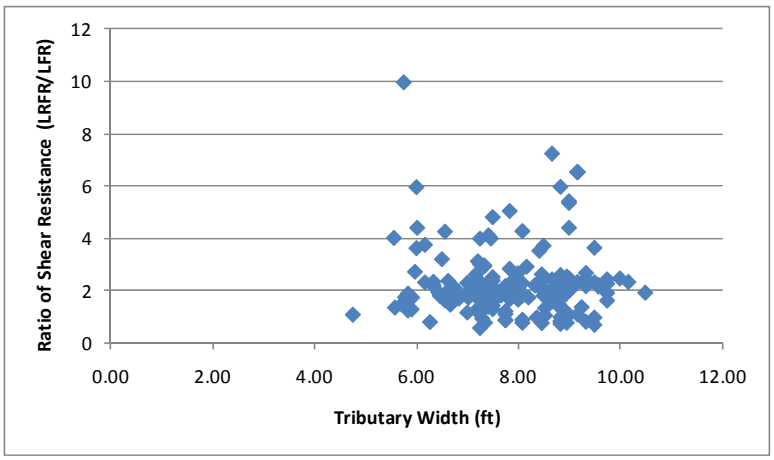
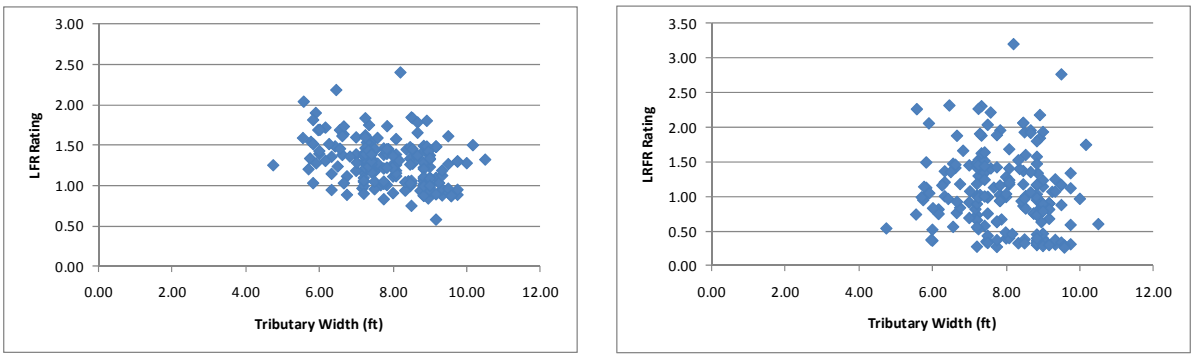


Figure I-13: Ratio of factored Shear Resistance (LRFR/LFR)

I.1.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results were reasonable, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there are 35 girders with LFR ratings less than 1.0, 93 girders with LRFR ratings less than 1.0, and 31 girders where both LFR and LRFR ratings are less than 1.0. The LFR rating was greater than the LRFR rating for 65% of the girders in this subset. Figure I-14 shows the LFR rating factors and LRFR rating factors. The LFR rating tends to decrease with increasing tributary width, with LRFR remaining relatively constant. The LFR rating is generally between 0.8 and 1.5 with the LRFR rating is generally between 0.4 and 1.5.



(a) (b)

Figure I-14: LFR and LRFR Shear Rating Factors for Design Loadings

I.1.2.2.4 Rating Factor Comparisons

Figure I-15 shows the ratio of the LRFR rating to the LFR rating. Girders with larger tributary widths are observed to be more likely to have LRFR ratings greater than LFR ratings. The ratio of ratings is typically between 0.4 and 1.5. 35% of girders have an LRFR rating that is greater than the LFR rating.

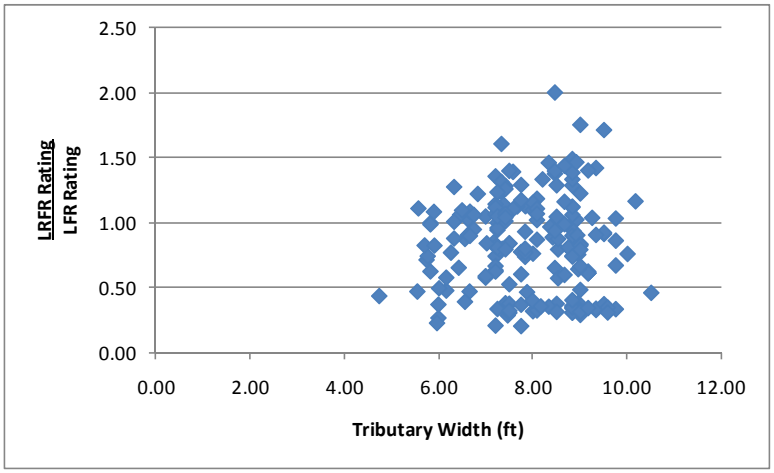


Figure I-15: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure I-16 shows the distribution of girders with LRFR ratings less than 1.0. A significant number of girders with LRFR ratings less than 1.0 have LRFR ratings that are 30 to 40% of the LFR rating. There are several girders where the LRFR rating is greater than the LFR rating. Overall, these girders will be negative affected by switching from LFR to LRFR, and a large number of these girders will be affected very significantly.

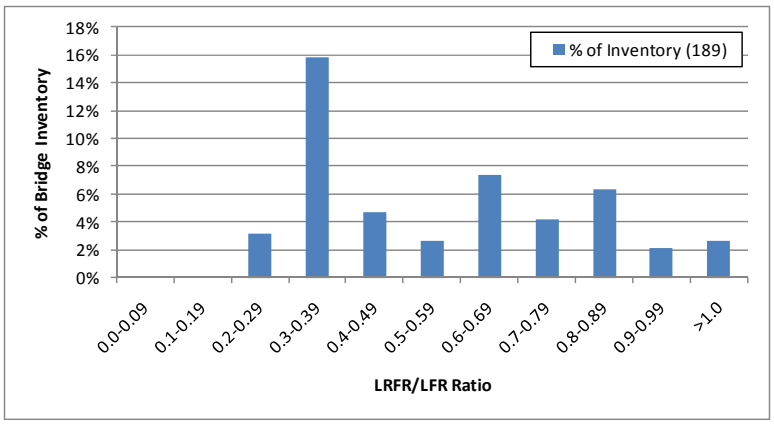


Figure I-16: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

I.1.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure I-17 shows that nine girders have a reliability index for shear less than the target reliability of 3.5. The reliability index is between five and seven for most girders.

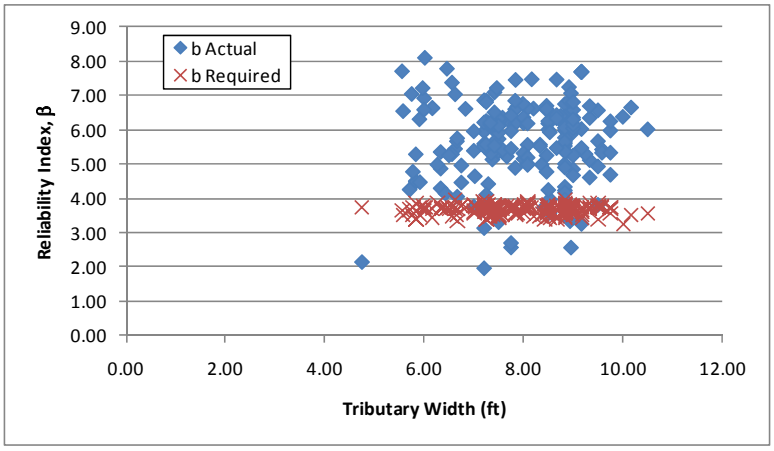


Figure I-17: Shear Reliability Indices for HL-93 Loading

Figure I-18 shows the reliability index for shear plotted against the LRFR shear rating for the HL-93 Design load. The reliability index increases with increasing rating factors. A reliability index of 4.25 is expected for a girder with an LRFR rating of 1.0, above the target reliability of 3.5.

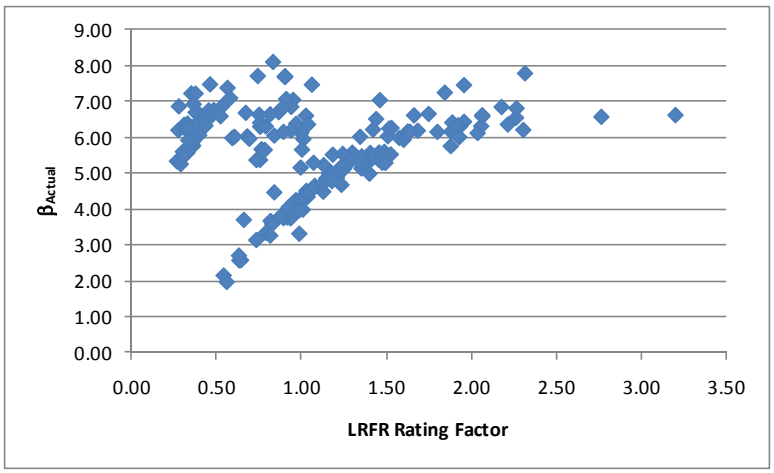


Figure I-18: Shear Reliability Index vs LRFR Shear Rating for HL-93 Design Load

I.1.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-19. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

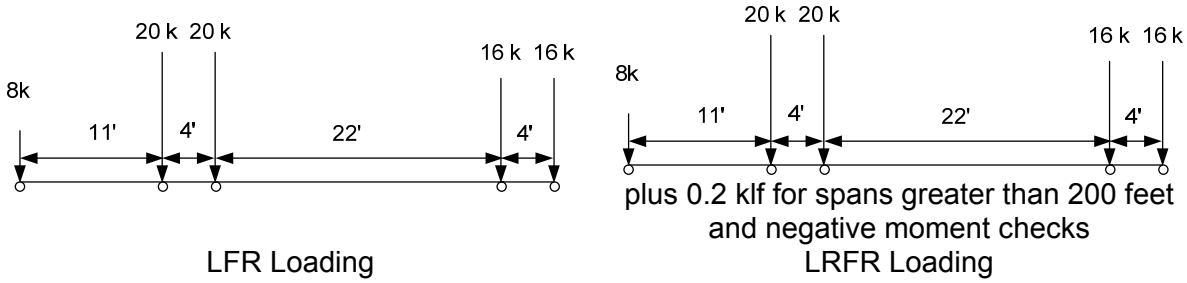


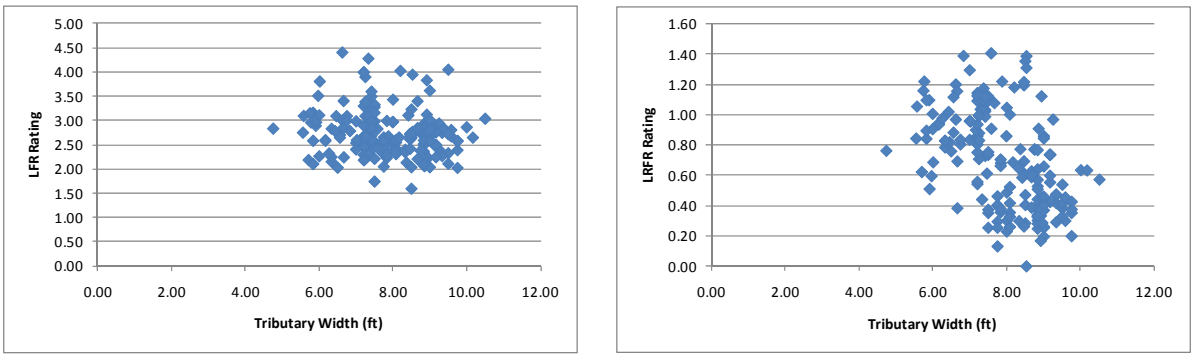
Figure I-19: Vehicle Loadings and Load Factors

I.1.3.1 Moment

The following section contains the results for interior, composite prestressed I girders within continuous span bridges for the DE-07 Vehicle.

I.1.3.1.1 Rating Factors

Figure I-20 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 148 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 147 of the 148 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR ratings are generally above 2.0 while the LRFR ratings are generally less than 1.0.



(a) (b)

Figure I-20: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure I-21 shows the percentage of girders with moment ratings in each range for the DE-07 vehicle, a routine permit vehicle. 32.3% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 9.5% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 67.7% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 90.5% when an ADTT ≥ 5,000 is used.

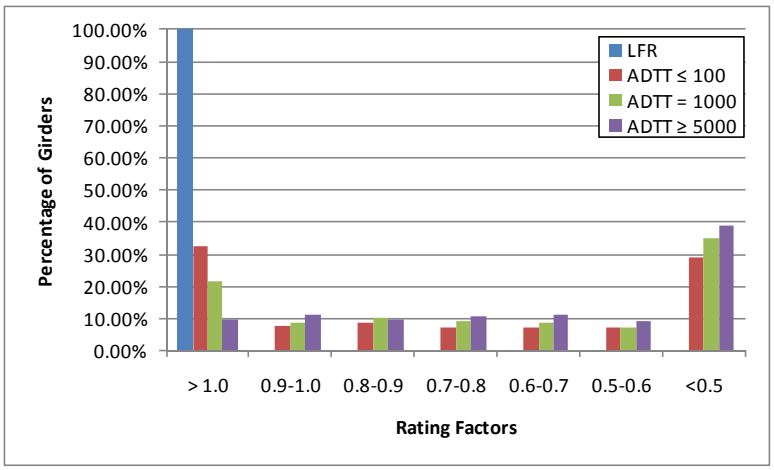


Figure I-21: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

I.1.3.1.2 Rating Factor Comparisons

Figure I-22 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.1 to 0.4. The effect of including the longitudinal steel rating is significant in the switch from LFR to LRFR, as when ignoring this rating criterion the lower bound of the ratio of ratings was 0.4, now it is the upper bound.

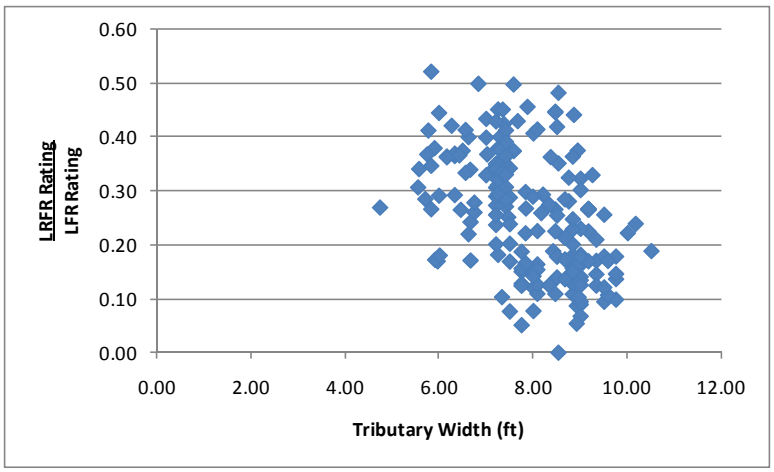


Figure I-22: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

I.1.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-23 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index for those girders with at least the target reliability and not controlled by the longitudinal steel rating is between six and ten.

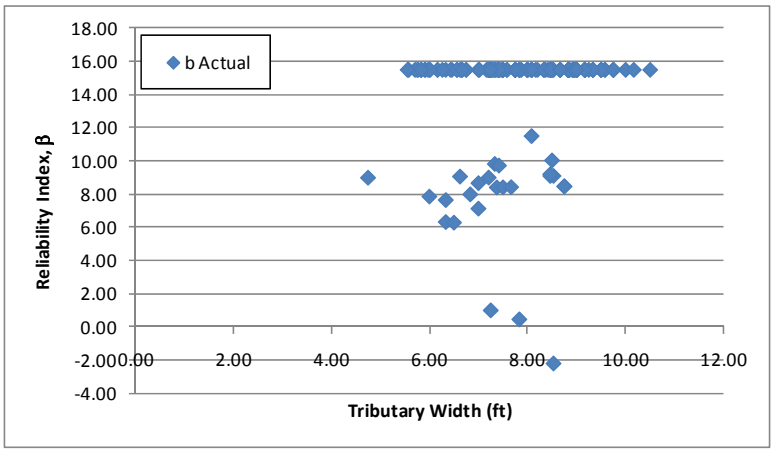


Figure I-23: Flexure Reliability Indices for DE-07 Vehicle

Figure I-24 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 vehicle. The reliability index increases with increasing LRFR ratings. The reliability index for a girder with an LRFR rating of 1.0 varies from one to eight. Since there are more data points near the larger reliability index it is possible that the LRFR live load factors are over-conservative.

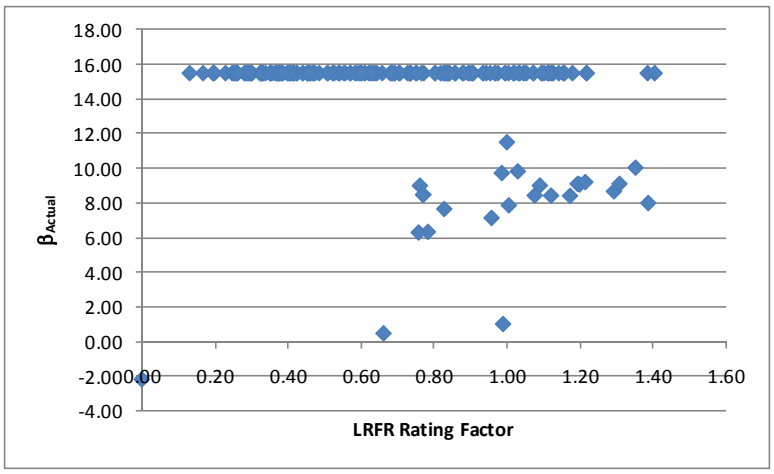
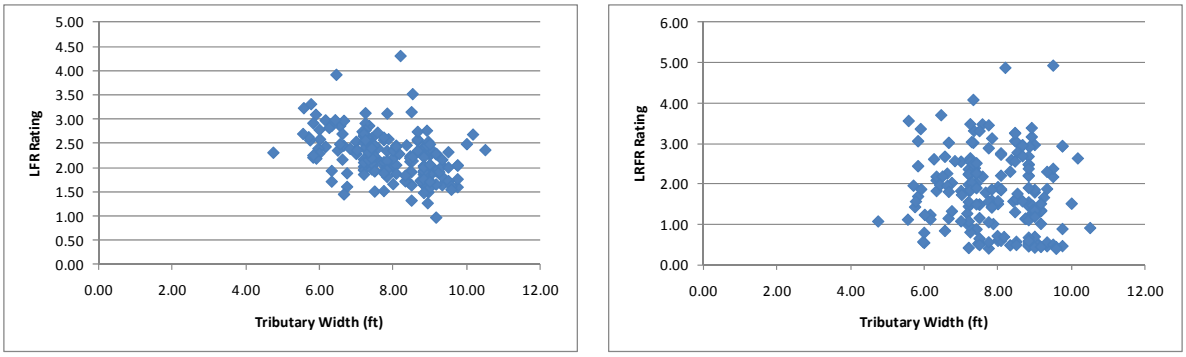


Figure I-24: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

I.1.3.2 Shear

I.1.3.2.1 Rating Factors

For shear, there is one girder that has a rating factor less than 1.0 for LFR, 41 girders for LRFR, and zero girders where both LFR and LRFR are less than 1.0. The LFR Rating is greater than the LRFR rating for 67% of the girders in this subset. Figure I-25 shows the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 3.0 and decreases with increasing tributary width; the LRFR rating is generally between 0.5 and 3 and remains within this range for all span lengths.



(a) (b)

Figure I-25: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure I-26 shows the percentage of girders with shear ratings in each range for the DE-07 vehicle, a routine permit vehicle. 80.4% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 74.1% for an ADTT ≥ 5,000. 99.5% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 19.1% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 25.4% when an ADTT ≥ 5,000 is used.

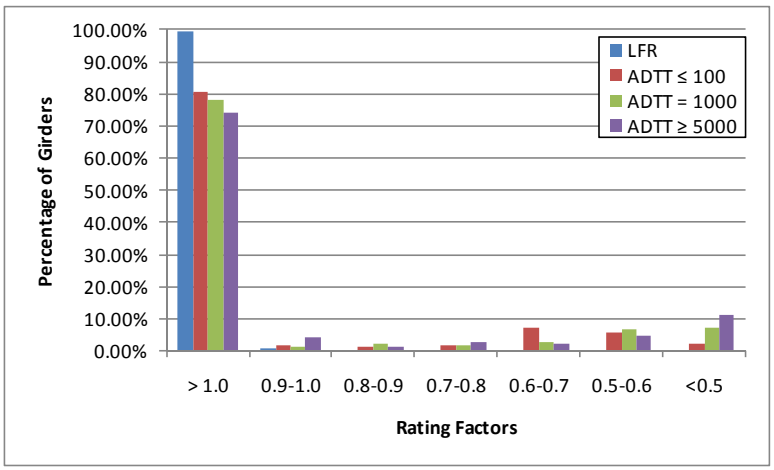


Figure I-26: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

I.1.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure I-27 show the comparison of rating factors. The ratio is generally between 0.25 and 1.5; larger tributary widths are more likely to have girders with higher LRFR ratings than LFR ratings. 33% of girders have LRFR ratings that are greater than the LFR rating.

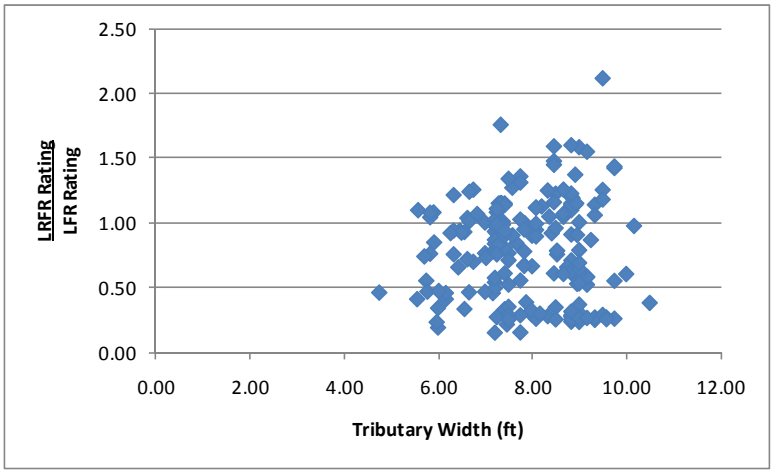


Figure I-27: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

I.1.3.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-28. The reliability index is between six and eight for most girders.

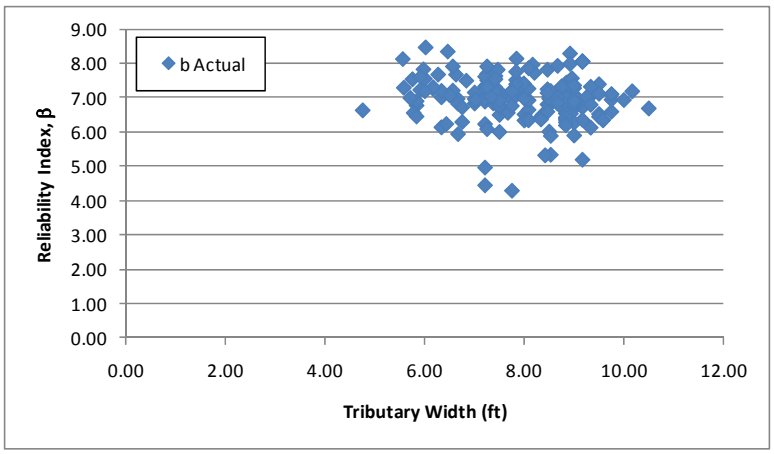


Figure I-28: Shear Reliability Indices for DE-07 Vehicle

Figure I-29 shows the reliability index for shear plotted against the LRFR shear rating for the DE-07 Vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately four, above the target reliability of 2.5. This may indicate the LRFR live load factors are over-conservative.

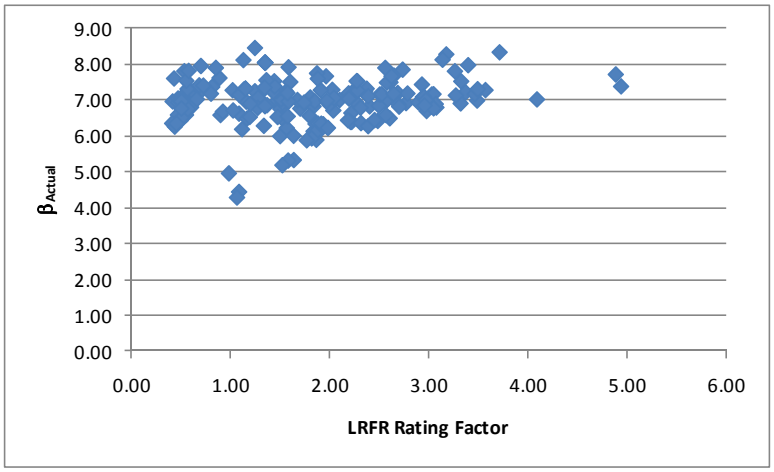
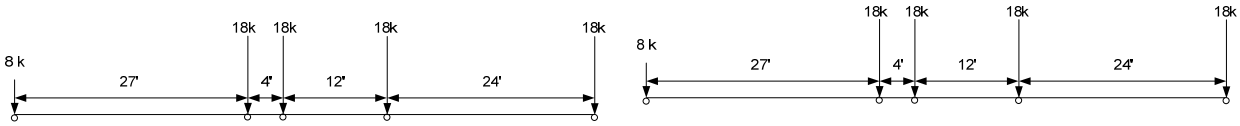


Figure I-29: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

I.1.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-30. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LFR Loading LRFR Loading

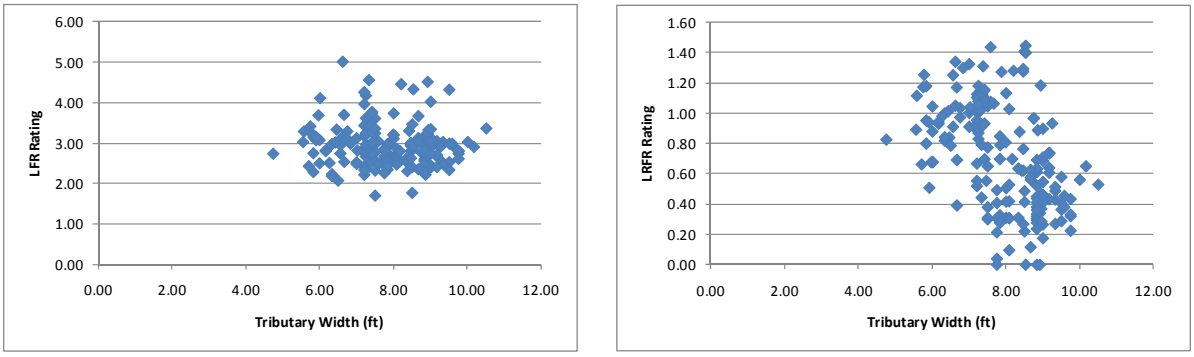
Figure I-30: Vehicle Loadings and Load Factors

I.1.4.1 Moment

The following section contains the results for interior, composite prestressed I girders within continuous span bridges for the FL-04 Vehicle.

I.1.4.1.1 Rating Factors

Figure I-31 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 140 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 138 of the 140 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is generally between 2 and 4 while the LRFR rating is generally less than 1.0.



(a) (b)

Figure I-31: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure I-32 shows the percentage of girders with moment ratings in each range for the FL-04 vehicle, a routine permit vehicle. 38.1% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 12.2% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 61.9% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 87.8% when an ADTT ≥ 5,000 is used.

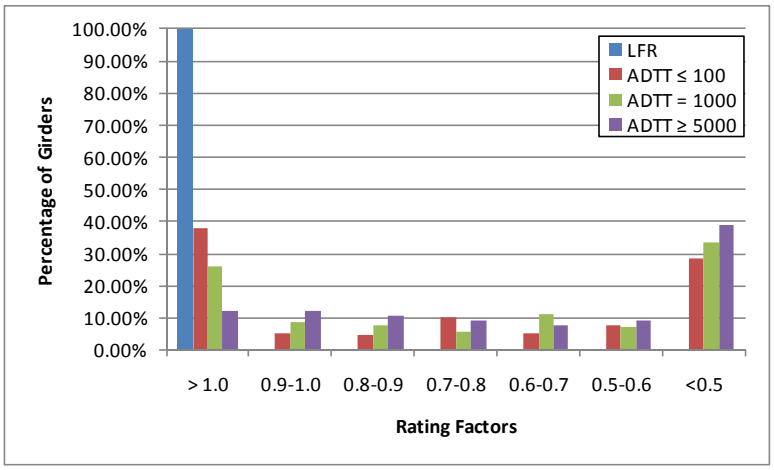


Figure I-32: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

I.1.4.1.2 Rating Factor Comparisons

Figure I-33 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The LRFR rating is typically 10 to 40% of the LFR rating.

There are no girders with LRFR ratings greater than the LFR rating; the reduction in rating is extremely significant when considering the longitudinal steel rating.

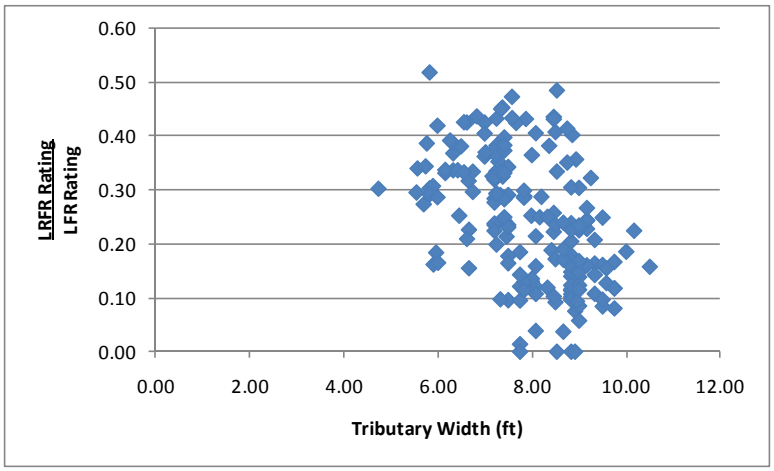


Figure I-33: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

I.1.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-34 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index is between six and twelve for those girders with at least the target reliability but not controlled by the longitudinal steel rating.

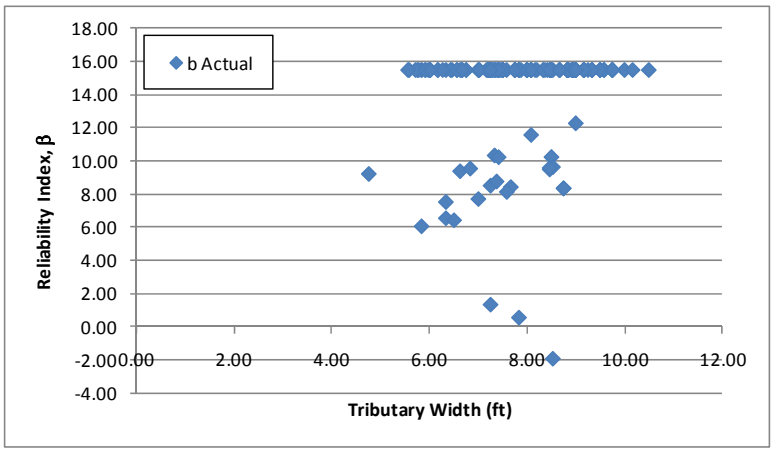


Figure I-34: Flexure Reliability Indices for FL-04 Vehicle

Figure I-35 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 vehicle. The reliability index increases with increasing ratings. The reliability index corresponding to an LRFR rating of 1.0 varies from one to approximately eight; since there are more data points near eight it is estimated that the reliability index would be closer to eight than to the lower value of 1.0. This may indicate that the live load factors in the MBE are over-conservative.

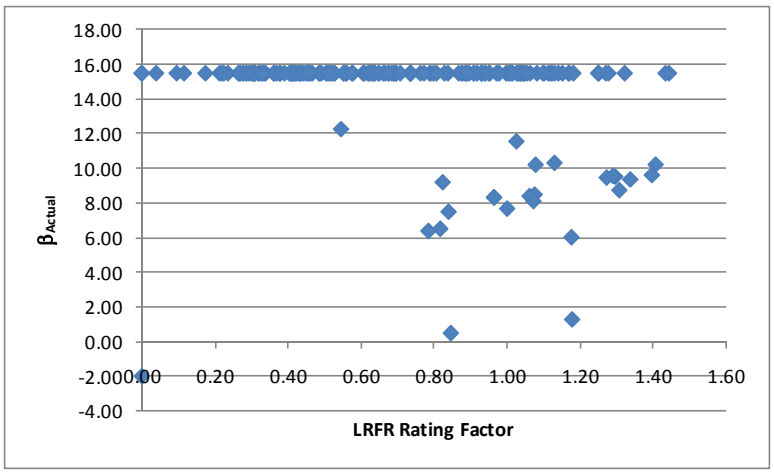
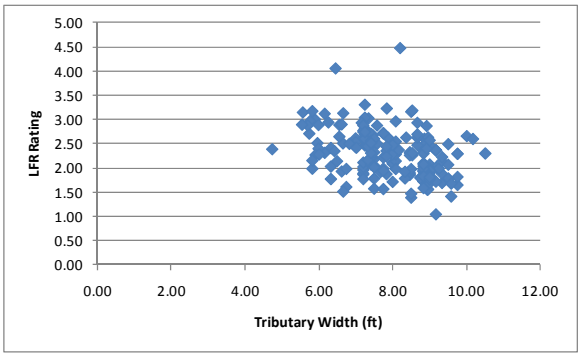


Figure I-35: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

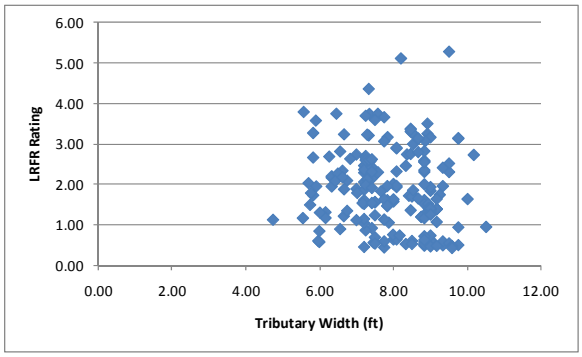
I.1.4.2 Shear

I.1.4.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, 40 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 67% of the girders in this subset. Figure I-36 shows the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 3.0; LRFR ratings are generally between 0.5 and 3.0.



(a)



(b)

Figure I-36: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure I-37 shows the percentage of girders with shear ratings in each range for the FL-04 vehicle, a routine permit vehicle. 81.0% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 75.7% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 19.0% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 24.3% when an ADTT ≥ 5,000 is used.

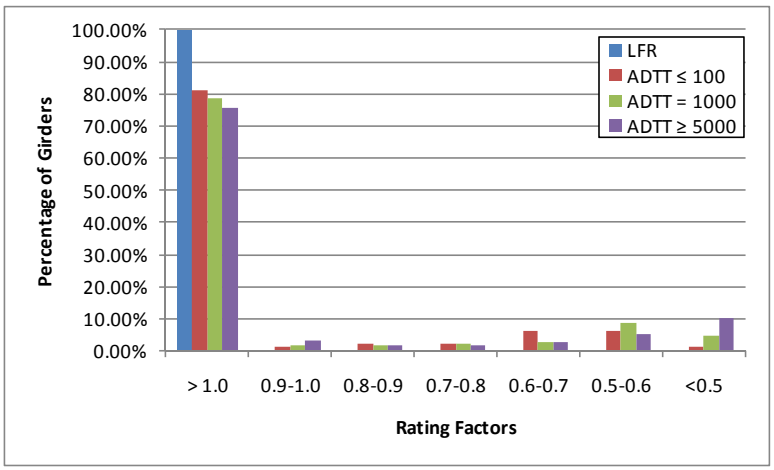


Figure I-37: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

I.1.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-38 shows the comparison of rating factors. The ratio is generally between 0.25 and 1.5, with the ratio increasing for longer span lengths. One-third of the girders have an LRFR rating that is greater than the LFR rating.

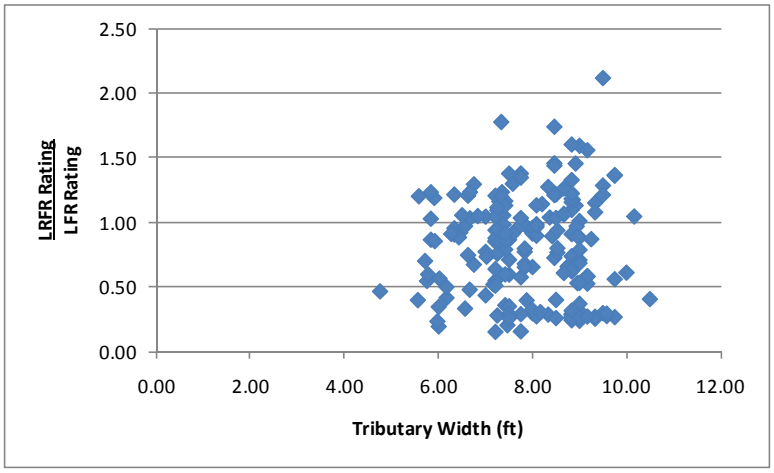


Figure I-38: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

I.1.4.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-39. The reliability index for most girders is between six and eight, well above the target reliability of 2.5.

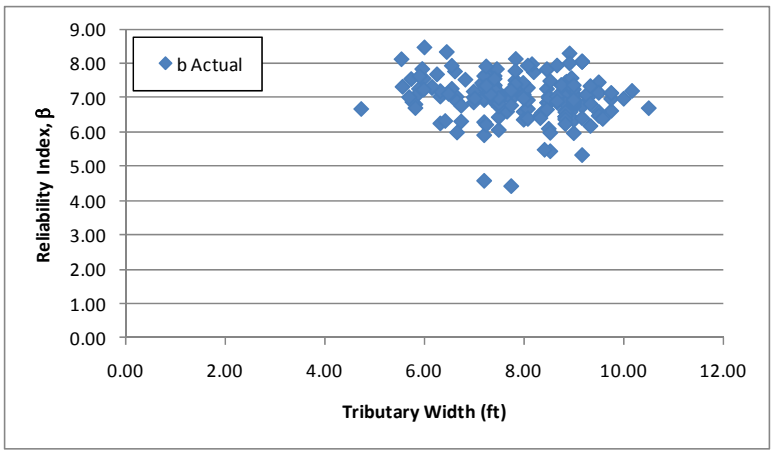


Figure I-39: Shear Reliability Indices for FL-04 Vehicle

Figure I-40 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 vehicle. The reliability index generally increases with increasing LRFR ratings. A reliability index of 4.0 is estimate for an LRFR rating of 1.0. This is above the target reliability index of 2.5 and indicates the LRFR live load factors may be over-conservative.

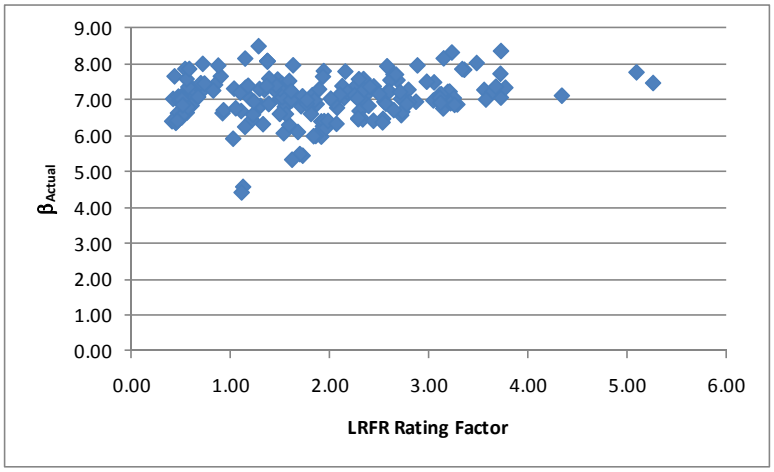


Figure I-40: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

I.1.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-41. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

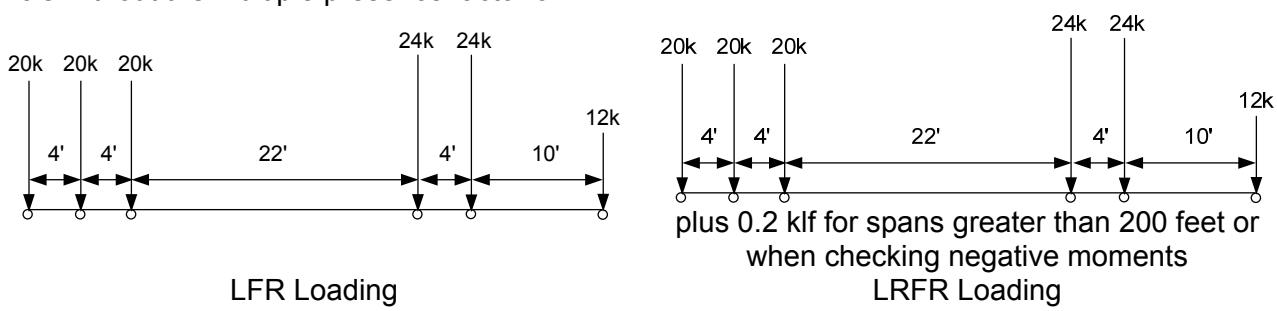


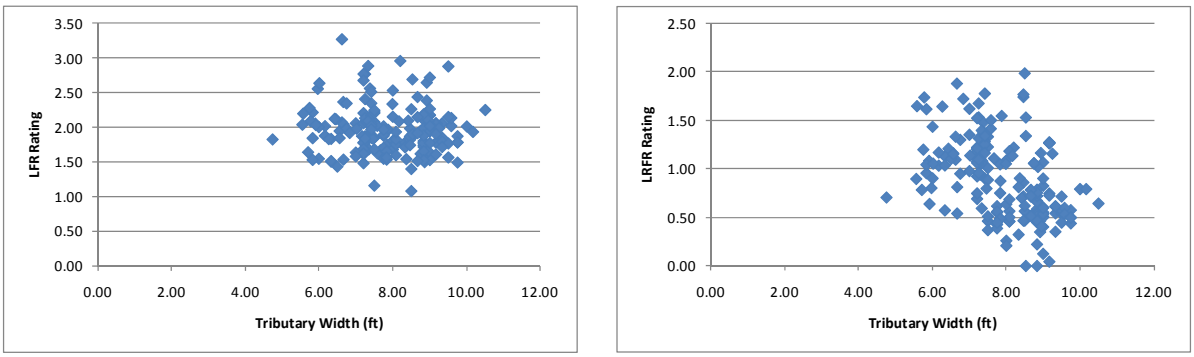
Figure I-41: Vehicle Loadings and Load Factors

I.1.5.1 Moment

The following section contains the results for interior, composite prestressed I girders within continuous span bridges for the IL-01 Vehicle.

I.1.5.1.1 Rating Factors

Figure I-42 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 110 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 108 of the 110 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 99% of the girders in this subset. The LFR rating is generally between 1.5 and 2. 5 while the LRFR rating is generally between 0. 5 and 1. 5.



(a) (b)

Figure I-42: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure I-43 shows the percentage of girders with moment ratings in each range for the IL-01 vehicle, a special permit vehicle. 49.7% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 18.0% for a multi-trip permit with an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 50.3% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 82.0% when an ADTT ≥ 5,000 is used.

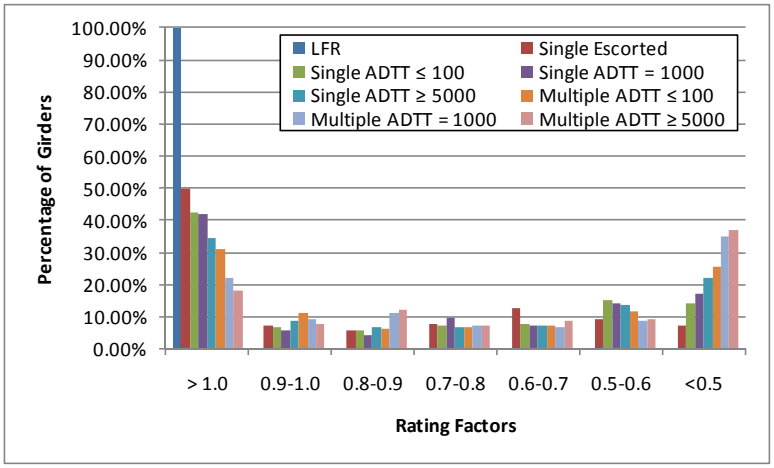


Figure I-43: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

I.1.5.1.2 Rating Factor Comparisons

Figure I-44 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.7. There is one girder with an LRFR rating greater than the LFR rating.

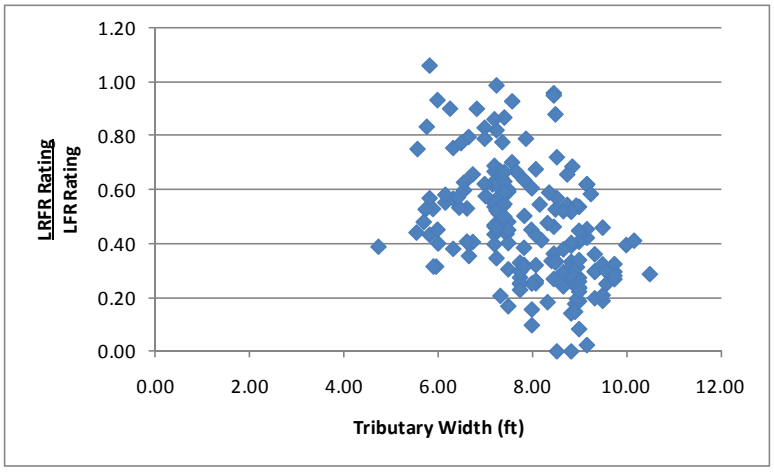


Figure I-44: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

I.1.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-45 shows that three girders have a reliability index less than the target reliability index of 3.5. The reliability index is between six and twelve for most girders.

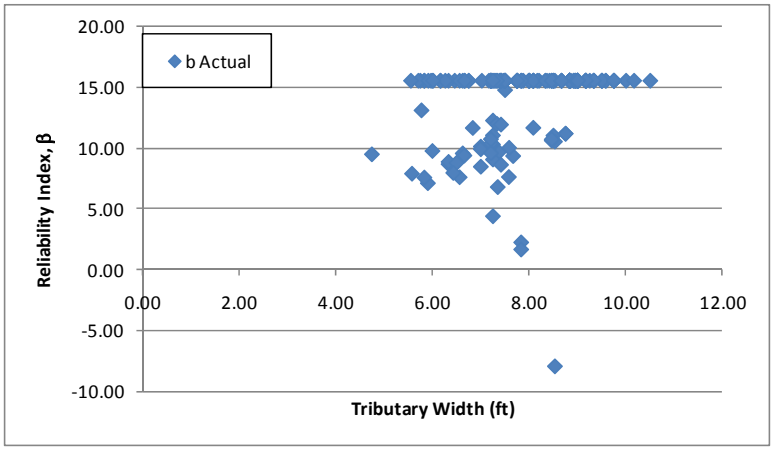


Figure I-45: Flexure Reliability Indices for IL-01 Vehicle

Figure I-46 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The reliability index increases with increasing ratings. A reliability indexes between one and six are observed for an LRFR rating of 1.0; with more data points near six, the average reliability index will be closer to six and above the target reliability of 3.5. This may indicate the LRFR live load factors are over-conservative.

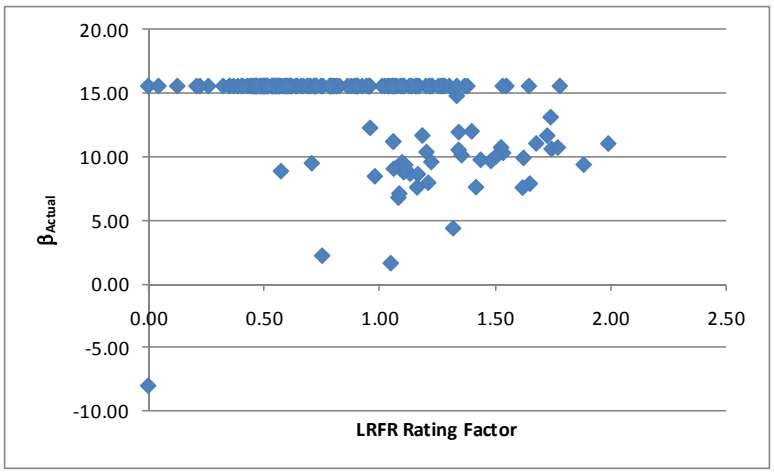
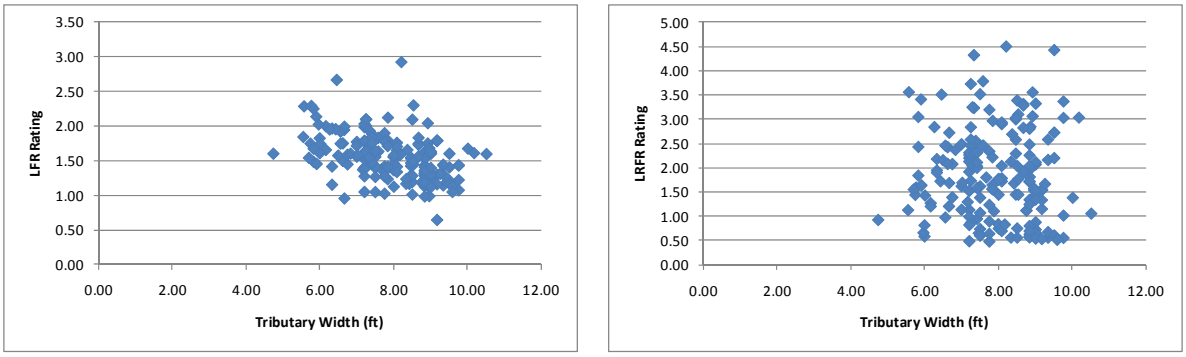


Figure I-46: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

I.1.5.2 Shear

I.1.5.2.1 Rating Factors

For shear, there are four girders that have LFR rating factors less than 1.0, 42 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 39% of the girders in this subset. Figure I-47 shows the LFR and LRFR ratings. The LFR rating is generally between 1.0 and 2.0 for all tributary widths, while the LRFR rating is within the range of 0.5 to 4.0.



(a) (b)

Figure I-47: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure I-48 shows the percentage of girders with shear ratings in each range for the IL-01 vehicle, a special permit vehicle. 82.5% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 69.3% for a multi-trip permit with an ADTT ≥ 5,000. 97.9% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 15.4% more girders with ratings less than 1.0 when a single trip, escorted permit is used; this increases to 30.7% when a multi-trip permit with ADTT ≥ 5,000 is used.

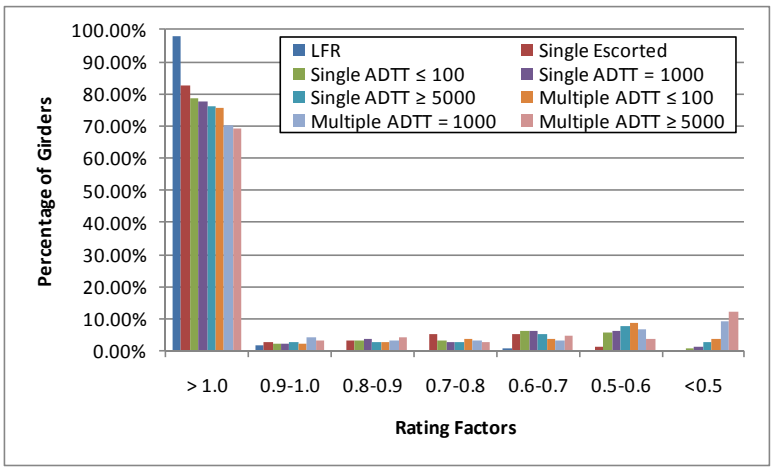


Figure I-48: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

I.1.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-49 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0. The LRFR rating is greater than the LFR rating for 61% of girders for this vehicle. This is a result of the live load configuration in the MBE for special permit vehicles.

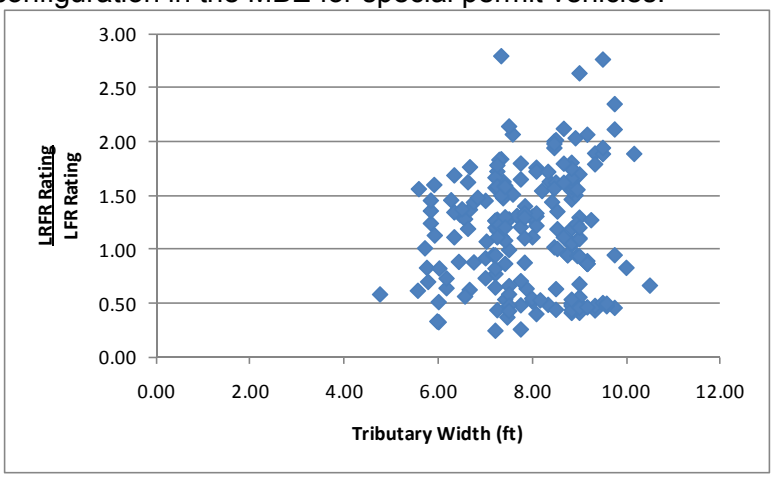


Figure I-49: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

I.1.5.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the required reliability index all but one girder as shown in Figure I-50. The reliability index is between six and eight for most girders.

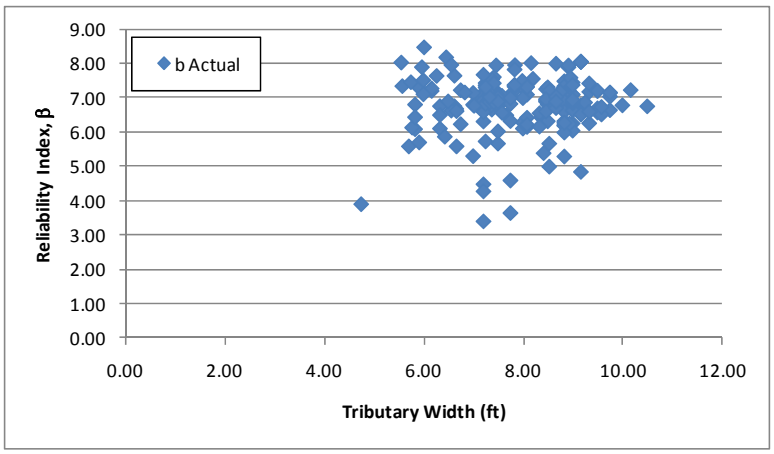


Figure I-50: Shear Reliability Indices for IL-01 Vehicle

Figure I-51 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 vehicle. The reliability index increases with increasing LRFR ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 4.5, above the target reliability of 3.5. This may indicate the LRFR live load factors are over-conservative. The girders with high reliability and low ratings (circled in Figure I-51) are controlled by the shear friction rating; the reliability index is calculated using the shear resistance.

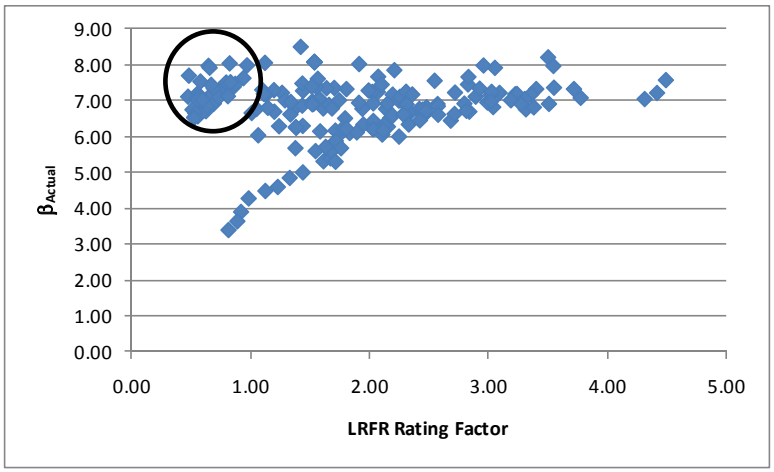


Figure I-51: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

I.1.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-52. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

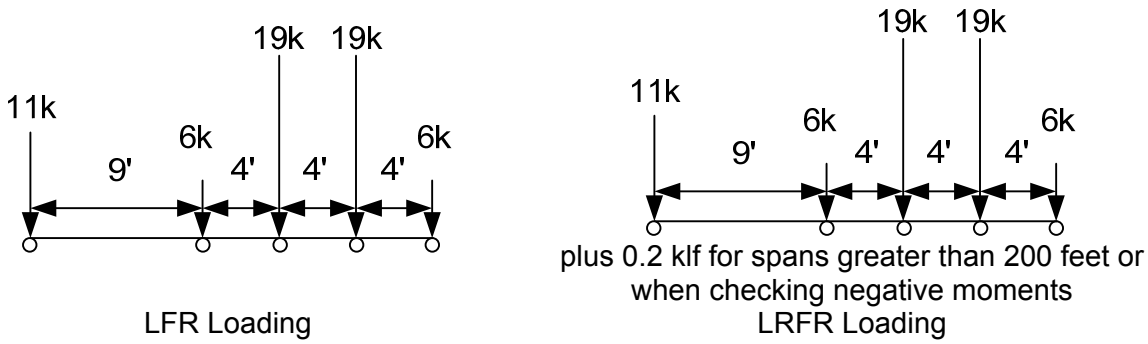


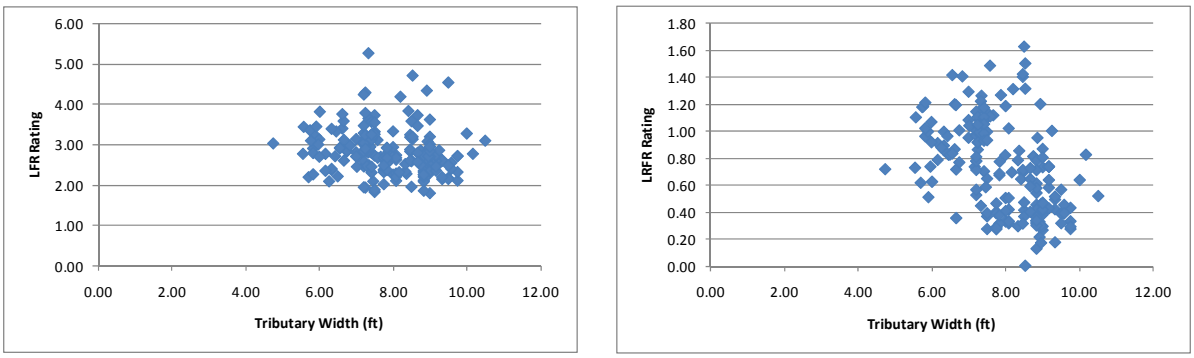
Figure I-52: Vehicle Loadings and Load Factors

I.1.6.1 Moment

The following section contains the results for interior, composite prestressed I girders within continuous span bridges for the NC-21 Vehicle.

I.1.6.1.1 Rating Factors

Figure I-53 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 145 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 144 of the 145 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating decreases with increasing tributary width and is generally between 2 and 4, while the LRFR rating is generally less than 1.0.



(a) (b)

Figure I-53: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure I-54 shows the percentage of girders with moment ratings in each range for the NC-21 vehicle, a routine permit vehicle. 33.9% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 12.7% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 66.1% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 87.3% when an ADTT ≥ 5,000 is used.

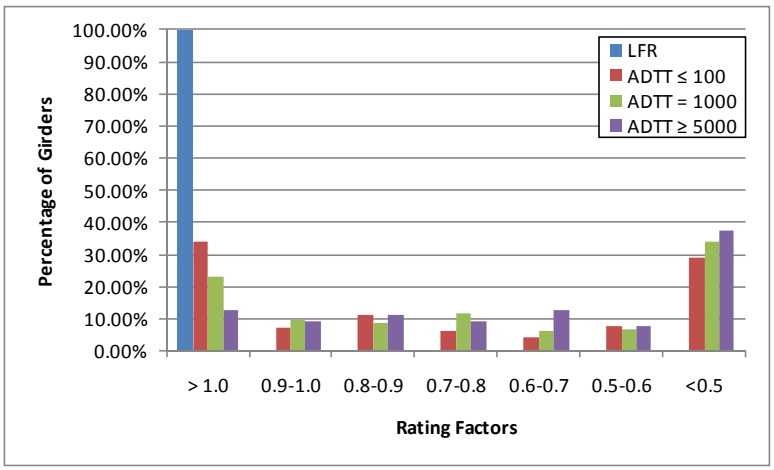


Figure I-54: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

I.1.6.1.2 Rating Factor Comparisons

Figure I-55 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating, which does not occur for any girders with this vehicle. The ratio is generally between 0.1 and 0.4 for this vehicle. The reduction in rating factor is significant when switching from LFR to LRFR.

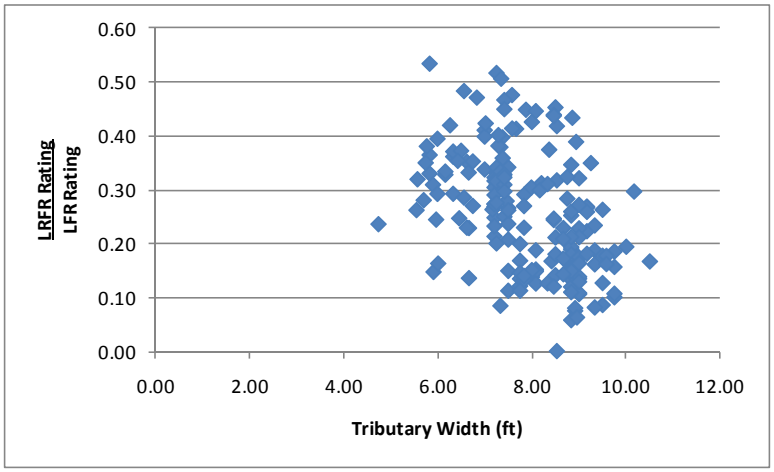


Figure I-55: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

I.1.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-56 shows four girders have a reliability index less than the target reliability index of 2.5. The reliability index is between six and twelve for most girders and increases with increasing tributary widths.

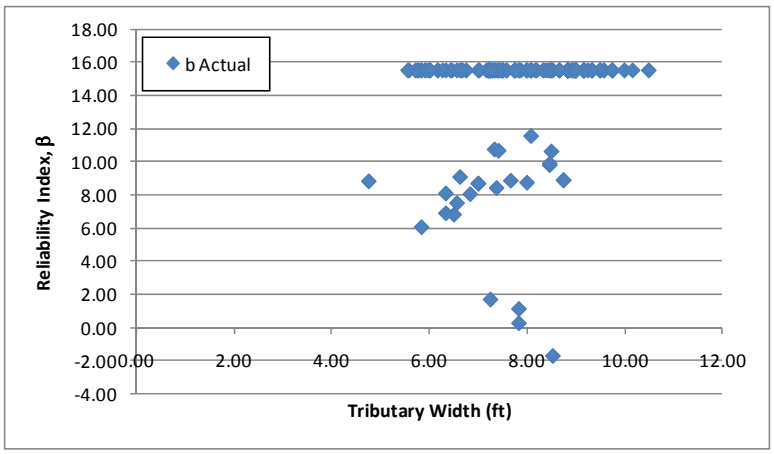


Figure I-56: Flexure Reliability Indices for NC-21 Vehicle

Figure I-57 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 vehicle. The reliability index appears to increase with increasing rating factors. The reliability index associated with an LRFR rating of 1.0 varies significantly. The average reliability index is approximately 4.0, above the target reliability of 2.5. This may indicate the LRFR live load factors in the MBE are over-conservative.

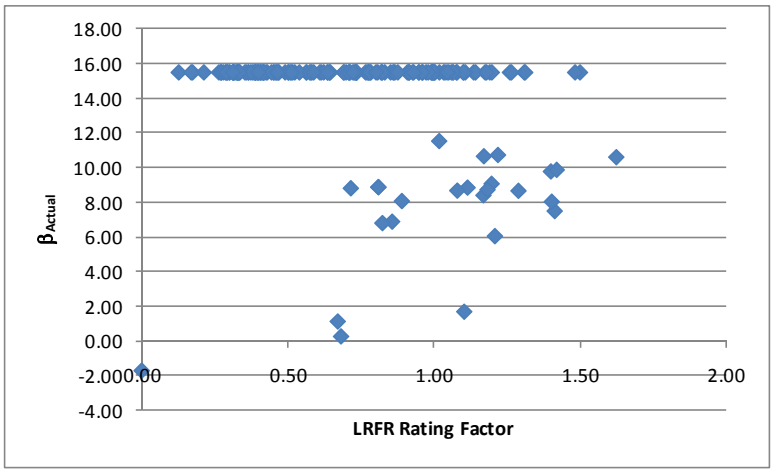
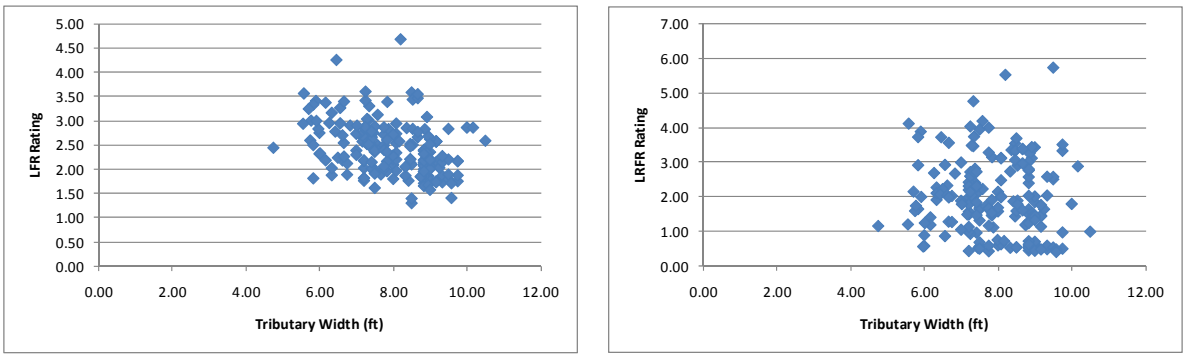


Figure I-57: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

I.1.6.2 Shear

I.1.6.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, 41 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 69% of the girders in this subset. Figure I-58 shows the LFR and LRFR ratings. The LFR rating is generally between 2 and 3 and decreases with increasing tributary width; LRFR ratings are generally between 0.5 and 4, remaining within this range for all tributary widths.



(a) (b)

Figure I-58: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure I-59 shows the percentage of girders with shear ratings in each range for the NC-21 vehicle, a routine permit vehicle. 81.5% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 76.7% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 18.5% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 23.3% when an ADTT ≥ 5,000 is used.

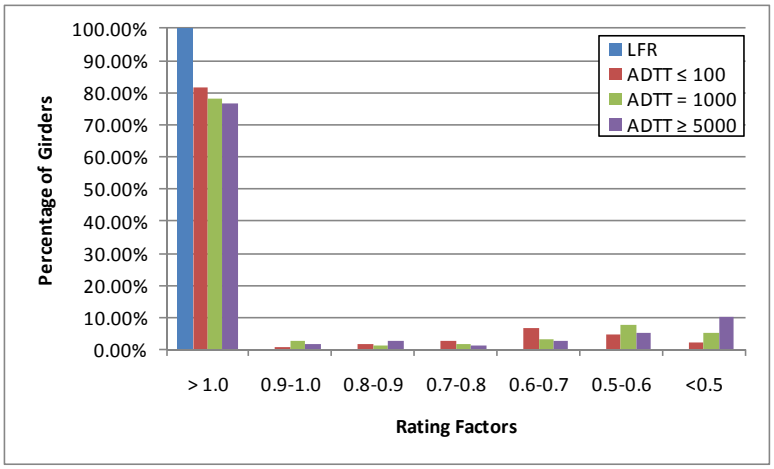


Figure I-59: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

I.1.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-60 shows the comparison of rating factors. The ratio is generally between 0.25 and 1.5. Larger tributary widths are the most likely to have an LRFR rating greater than the LFR rating. 31% of girders have an LRFR rating that is greater than the LFR rating.

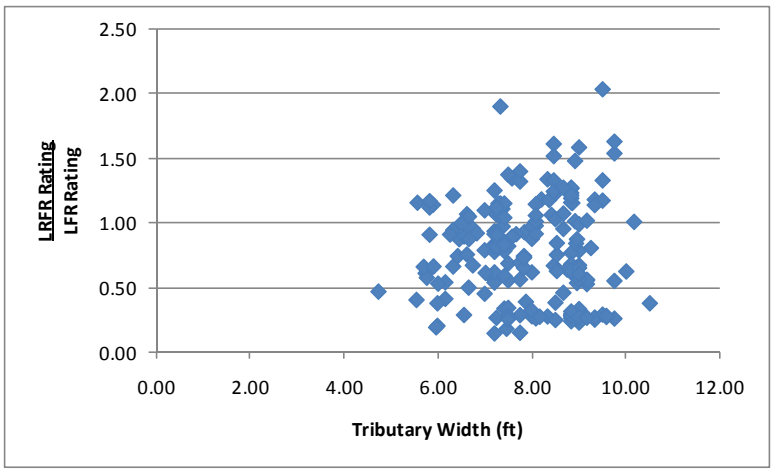


Figure I-60: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

I.1.6.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-61. The reliability index is between six and eight for most girders.

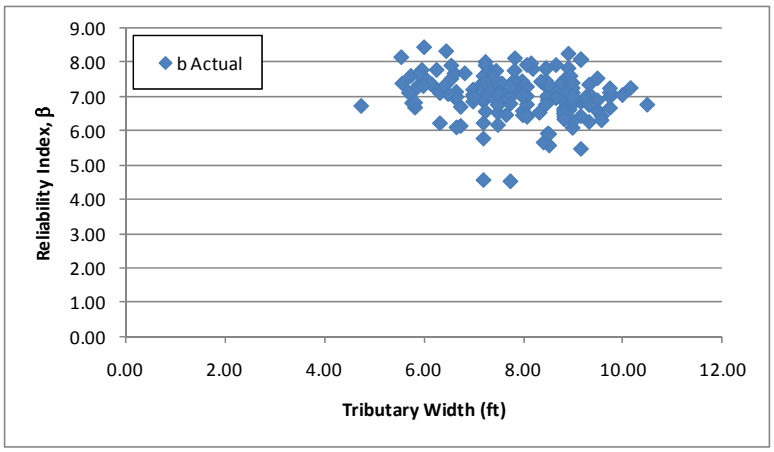


Figure I-61: Shear Reliability Indices for NC-21 Vehicle

Figure I-62 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 vehicle. The reliability index is approximately 4.25 for an LRFR rating of 1.0, above the target reliability of 2.5. This may indicate the LRFR live load factors are over-conservative. The data points with high reliability and low ratings are controlled by the shear friction rating. The reliability index is calculated using the shear resistance, not the shear friction resistance.

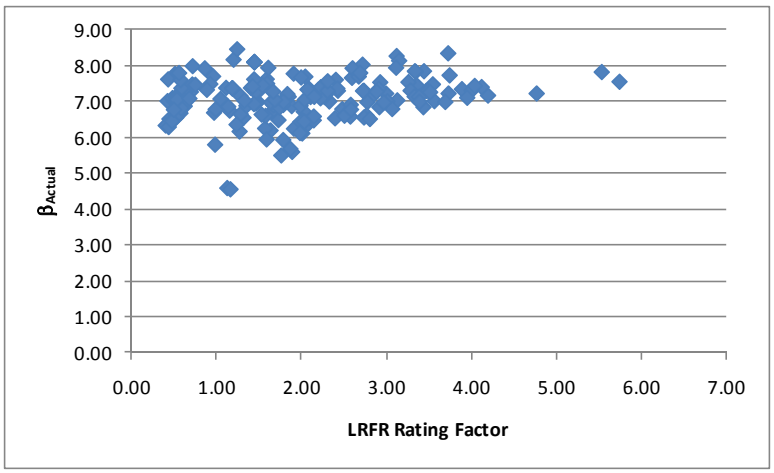


Figure I-62: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

I.1.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-63. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

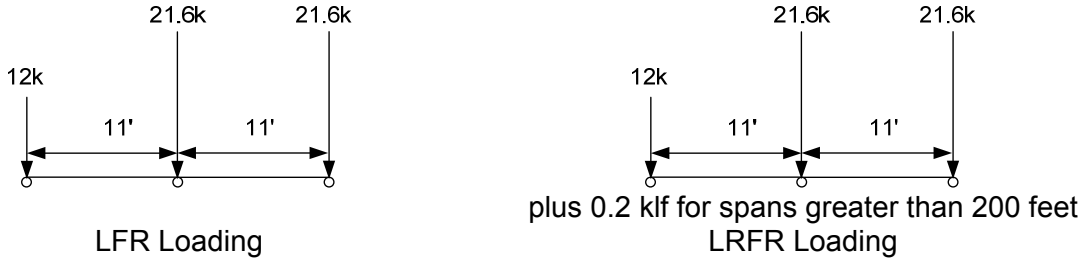


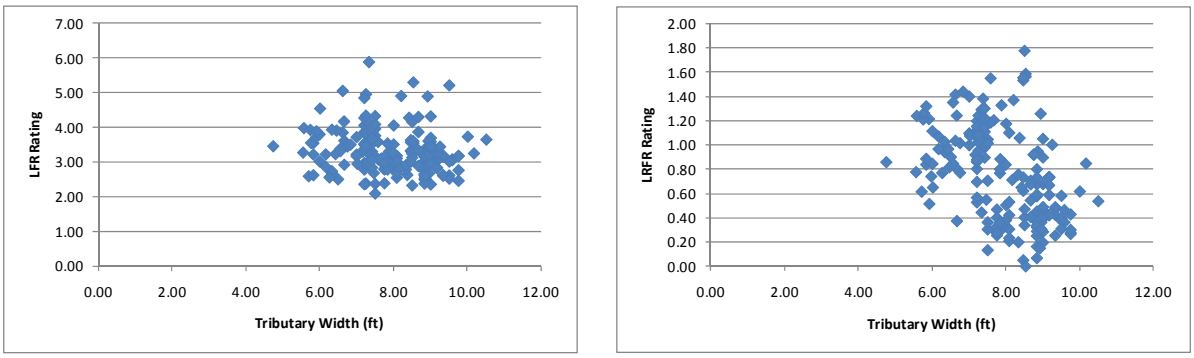
Figure I-63: Vehicle Loadings and Load Factors

I.1.7.1 Moment

The following section contains the results for interior, composite prestressed I girders within continuous span bridges for the NM-04 Vehicle.

I.1.7.1.1 Rating Factors

Figure I-64 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 132 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 131 of the 132 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is generally in the range of 2.5 to 4.0; the LRFR rating is less than 1.6 for most girders.



(a) (b)

Figure I-64: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure I-65 shows the percentage of girders with moment ratings in each range for the NM-04 vehicle, a routine permit vehicle. 39.7% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 17.5% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 60.3% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 82.5% when an ADTT ≥ 5,000 is used.

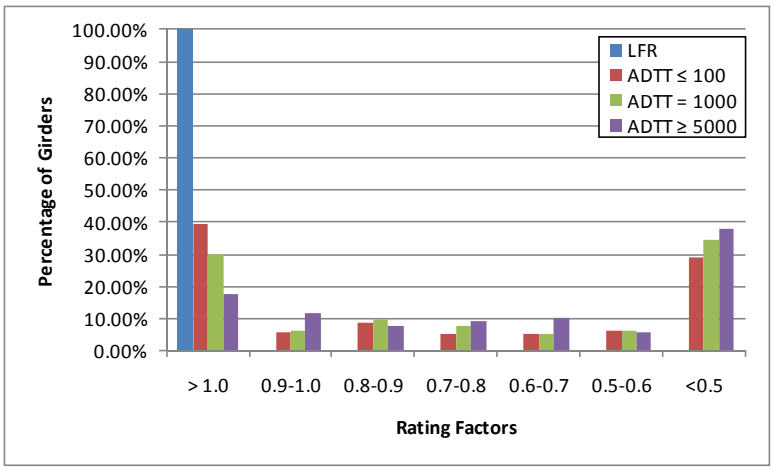


Figure I-65: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

I.1.7.1.2 Rating Factor Comparisons

Figure I-64 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.1 and 0.4, with zero girders having an LRFR rating greater than the LFR rating. The reduction in rating is significant when considering the longitudinal steel rating.

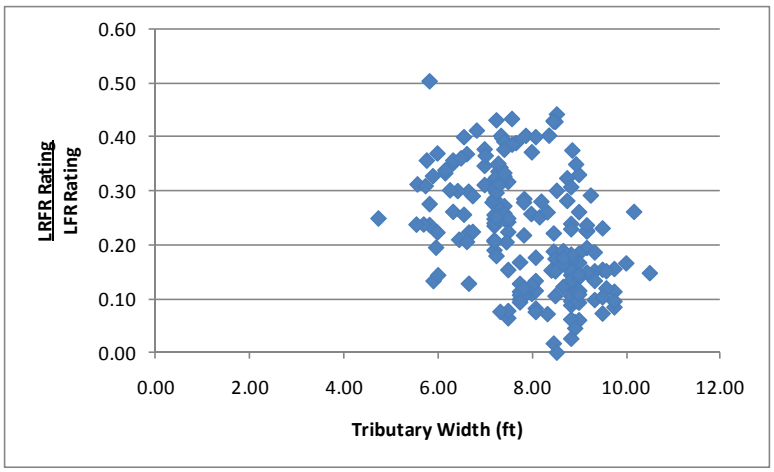


Figure I-66: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

I.1.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-67 shows that no girders have a reliability index less than the target reliability index of 2.5. The reliability index is between six and twelve for most girders.

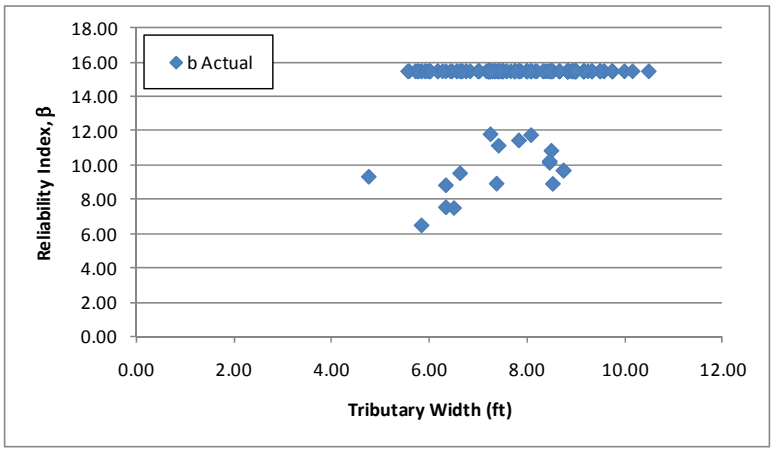


Figure I-67: Flexure Reliability Indices for NM-04 Vehicle

Figure I-68 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 vehicle. The reliability index increases slightly with increasing LRFR ratings. The estimate reliability index for a girder with an LRFR rating of 1.0 is approximately nine, well above the target reliability of 2.5. This may indicate the live load factors in the MBE are over-conservative but may also indicate that the longitudinal steel rating should not be used to calibrate the live load factors, as 186 of the 189 girders are controlled by the longitudinal steel rating.

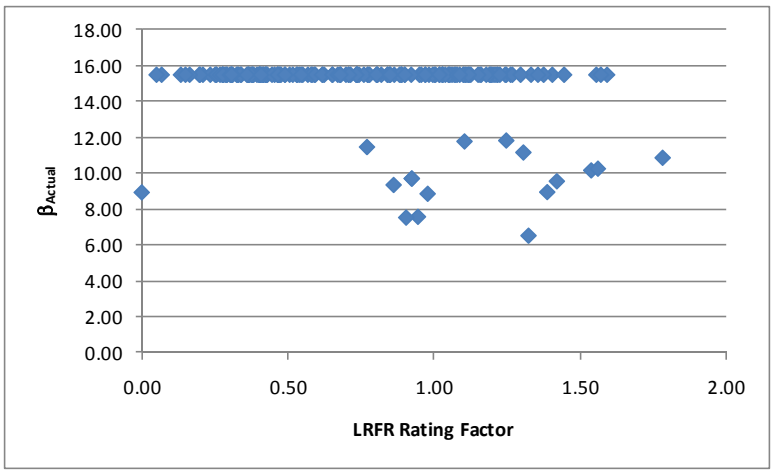
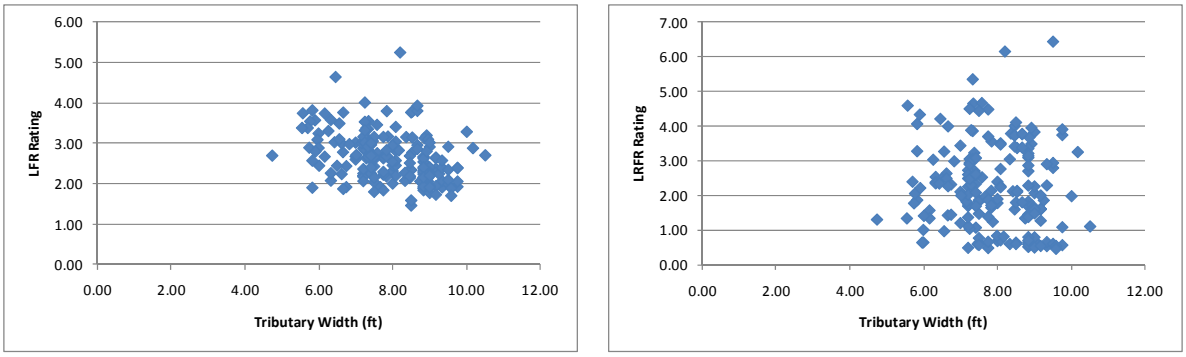


Figure I-68: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

I.1.7.2 Shear

I.1.7.2.1 Rating Factors

For shear, there are zero girders that have an LFR rating factor less than 1.0, 36 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 67% of the girders in this subset. Figure I-69 shows the LFR and LRFR ratings. The LFR rating is generally between 2 and 4 while the LRFR rating is generally between 0.5 and 4.0.



(a) (b)

Figure I-69: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure I-70 shows the percentage of girders with shear ratings in each range for the NM-04 vehicle, a routine permit vehicle. 82.0% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 78.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 18.0% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 21.7% when an ADTT ≥ 5,000 is used.

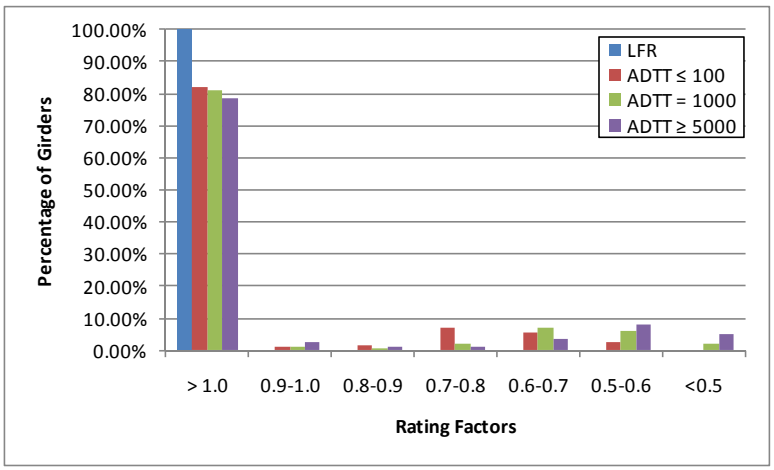


Figure I-70: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

I.1.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure I-71 show the comparison of rating factors. The ratio is generally between 0.25 and 1.5. Larger tributary widths are more likely to have LRFR ratings greater than narrowly spaced girders. 33% of girders have LRFR ratings that are greater than the LFR rating.

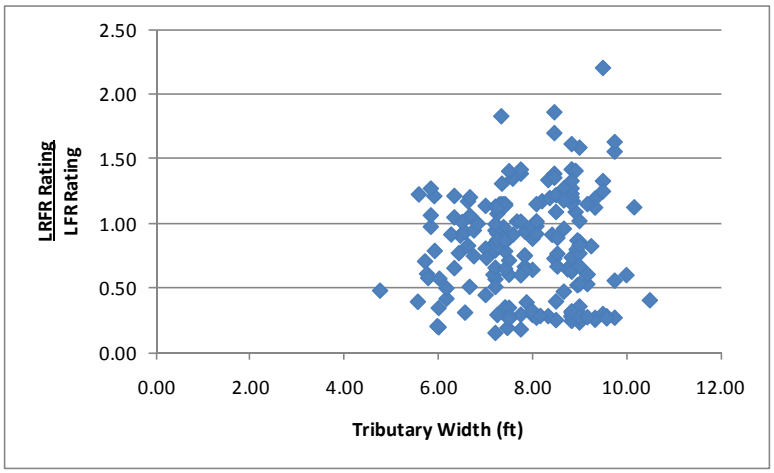


Figure I-71: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

I.1.7.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-72. The reliability index is between six and eight for most girders.

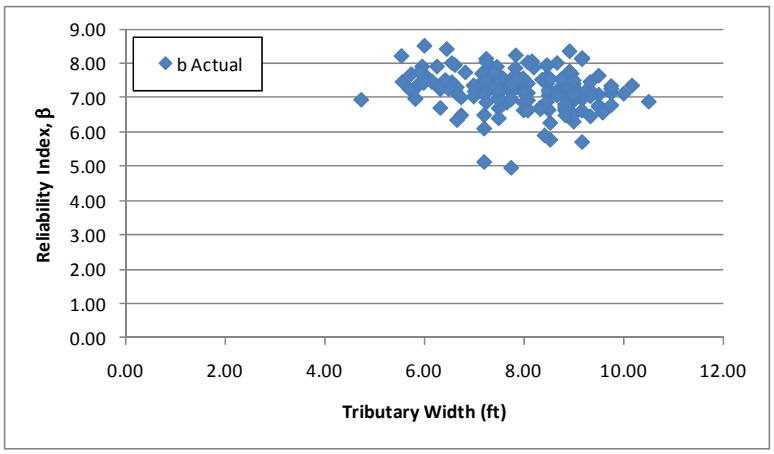


Figure I-72: Shear Reliability Indices for NM-04 Vehicle

Figure I-73 shows the reliability index for shear plotted against the LRFR shear rating for the NM-04 Vehicle. The reliability index increases slight with increasing LRFR ratings. A reliability index of four is approximated for an LRFR rating of 1.0, above the target reliability of 2.5. This may indicate the LRFR live load factors are over-conservative. The girders with high reliability and low ratings are typically controlled by the shear friction rating; the reliability index is calculated using the shear resistance not the shear friction resistance.

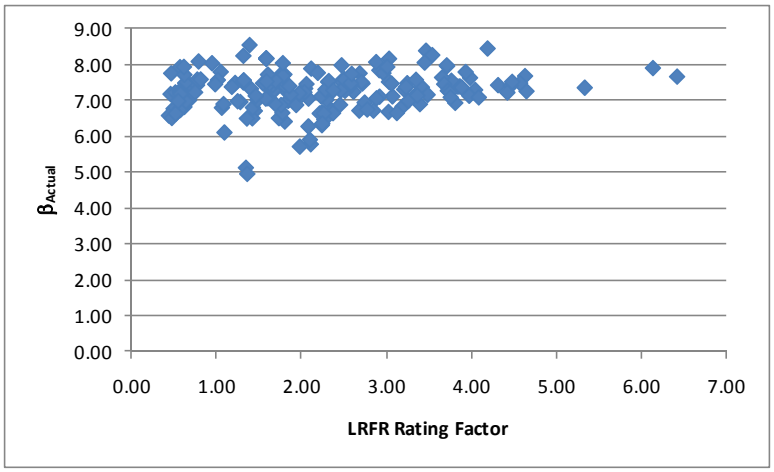
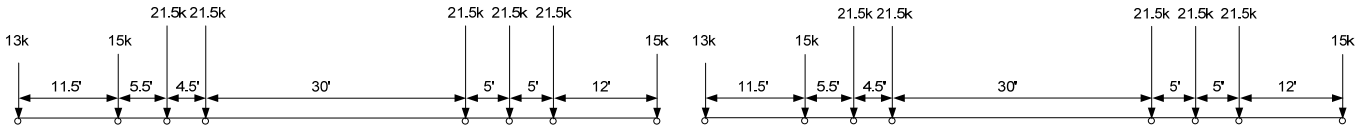


Figure I-73: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

I.1.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-74. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading

plus 0.2 klf for spans greater than 200 feet

LRFR Loading

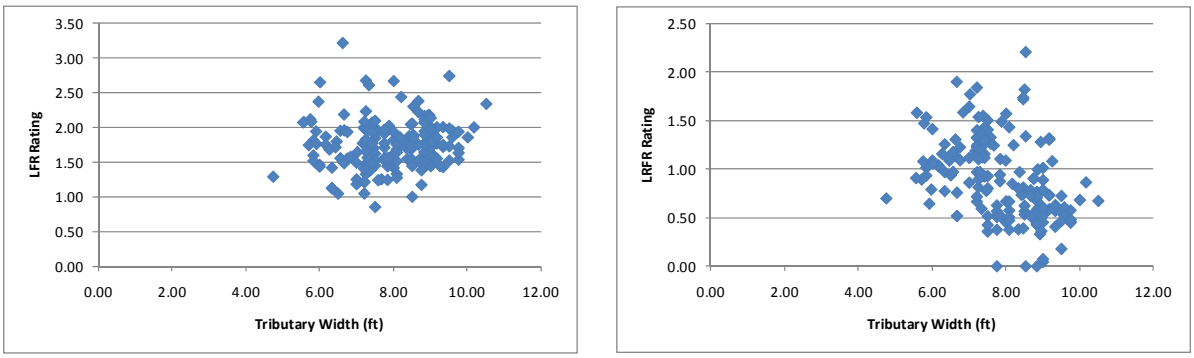
Figure I-74: Vehicle Loadings and Load Factors

I.1.8.1 Moment

The following section contains the results for interior, composite prestressed I girders within continuous span bridges for the OR-06 Vehicle.

I.1.8.1.1 Rating Factors

Figure I-75 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are two girders with an LFR rating less than 1.0, 117 girders with an LRFR rating less than 1.0, and two girders where both ratings are less than 1.0. 112 of the 117 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 94% of the girders in this subset. The LFR rating is generally between 1.25 and 2.0 and the LRFR rating is generally between 0.5 and 1.5.



(a) (b)

Figure I-75: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure I-76 shows the percentage of girders with moment ratings in each range for the OR-06 vehicle, a special permit vehicle. 48.2% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 16.4% when a multi-trip permit with an ADTT ≥ 5,000 is considered. 98.9% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 51.8% more girders with ratings less than 1.0 when a single trip, escorted permit is used; this increases to 83.6% when a multi-trip permit with ADTT ≥ 5,000 is used.

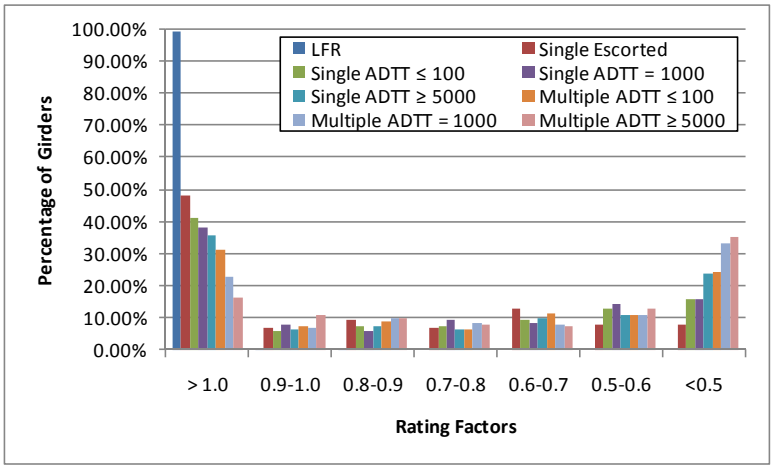


Figure I-76: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

I.1.8.1.2 Rating Factor Comparisons

Figure I-77 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.8. The LRFR rating is greater than the LFR rating for 6% of the girders in this group.

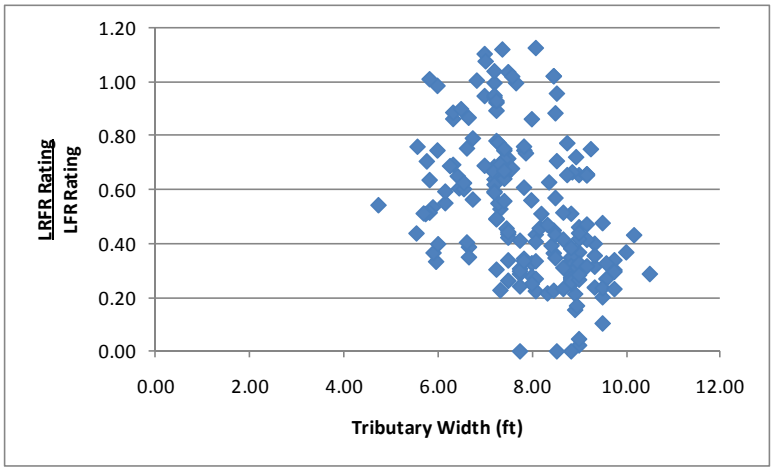


Figure I-77: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

I.1.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-78 shows that two girders have a reliability index less than the target reliability index of 3.5. The reliability index is between six and fourteen for most girders.

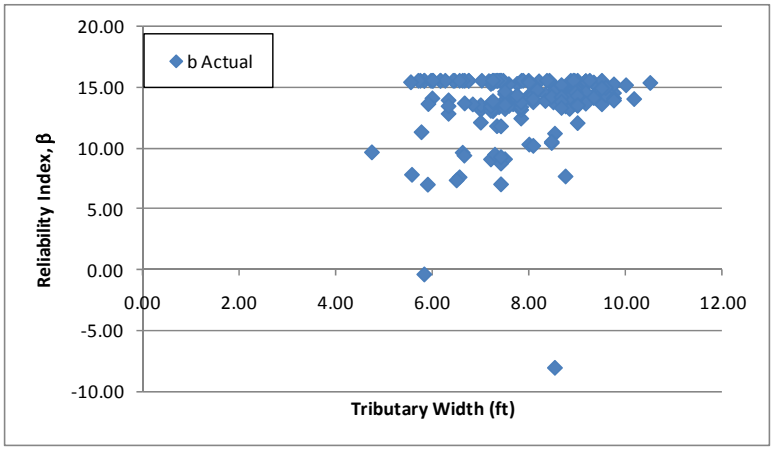


Figure I-78: Flexure Reliability Indices for OR-06 Vehicle

Figure I-79 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 vehicle. The reliability index does not display the same trends as shown for other vehicles but this may be due to the girders with ratings less than 1.0 not having a reliability index of 15.5. If these girders were moved up then the remaining girders would likely show that the reliability index increases with increasing ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 7.0, above the target reliability of 3.5. This may be due to the LRFR live load factors being over-conservative or the longitudinal steel rating should not be used to determine if the live load factors are correct.

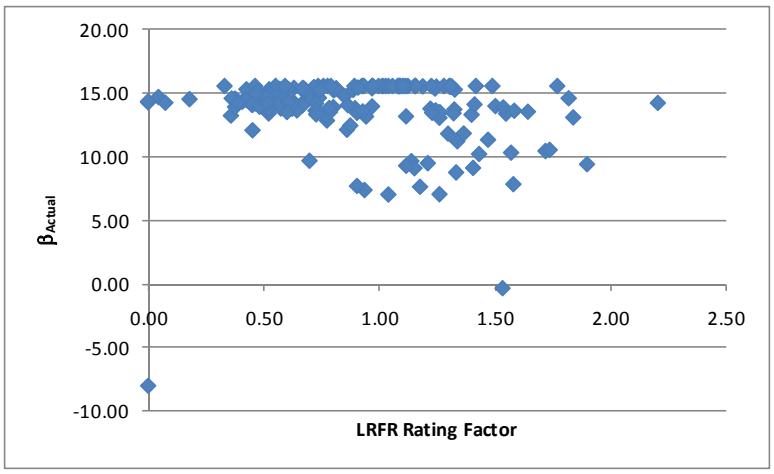
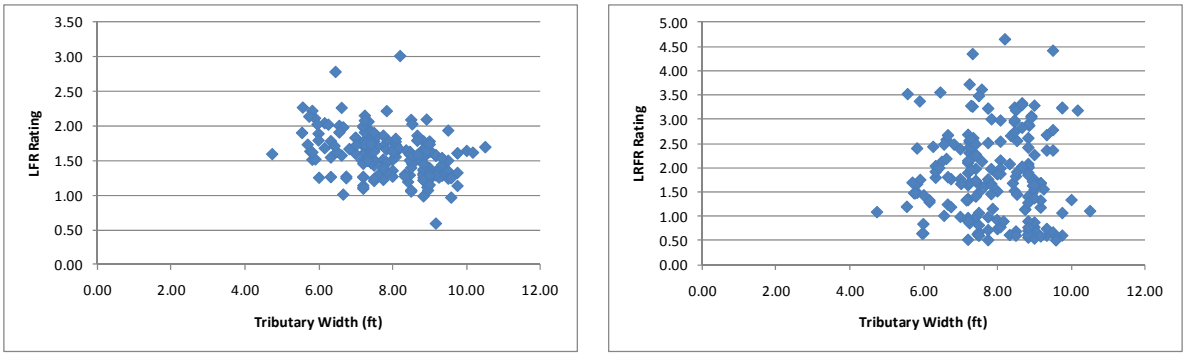


Figure I-79: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

I.1.8.2 Shear

I.1.8.2.1 Rating Factors

For shear, there are three girders that have LFR rating factors less than 1.0, 41 girders have LRFR ratings less than 1.0, and one girder has both ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 38% of the girders in this subset. Figure I-80 shows the LFR and LRFR ratings. The LFR rating is between one and two and decreases with increasing tributary widths while the LRFR rating remains within the range of 0.5 to 3.0.



(a) (b)

Figure I-80: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure I-81 shows the percentage of girders with shear ratings in each range for the OR-06 vehicle, a special permit vehicle. 84.1% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 70.9% for a multi-trip permit with an ADTT ≥ 5,000. 98.4% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 15.9% more girders with ratings less than 1.0 when a single trip, escorted permit is used; this increases to 29.1% when a multi-trip permit with ADTT ≥ 5,000 is used.

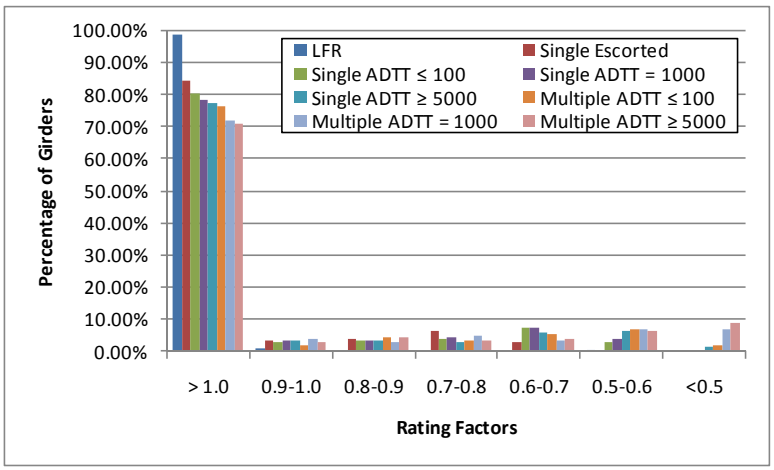


Figure I-81: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

I.1.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure I-82 shows the comparison of rating factors. The ratio is generally between 0.5 and 2.0 for this set of girders with this vehicle. Larger tributary widths are more likely to have LRFR ratings greater than LFR rating. 62% of girders have LRFR ratings that are greater than the LFR ratings.

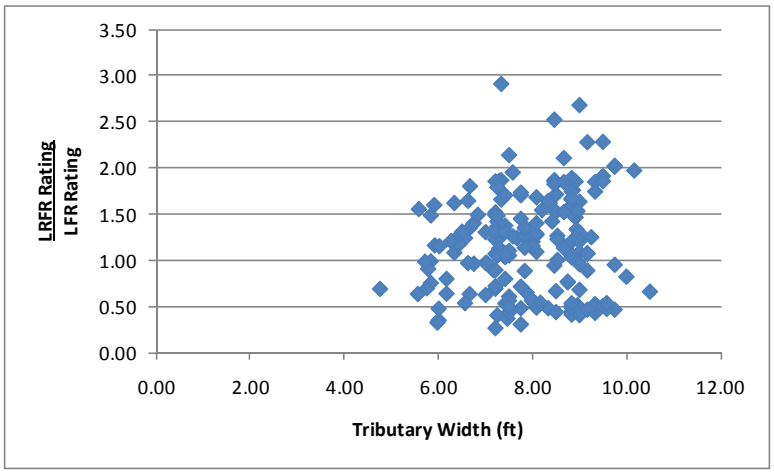


Figure I-82: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

I.1.8.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all girders as shown in Figure I-83. The reliability index is between six and eight for most girders.

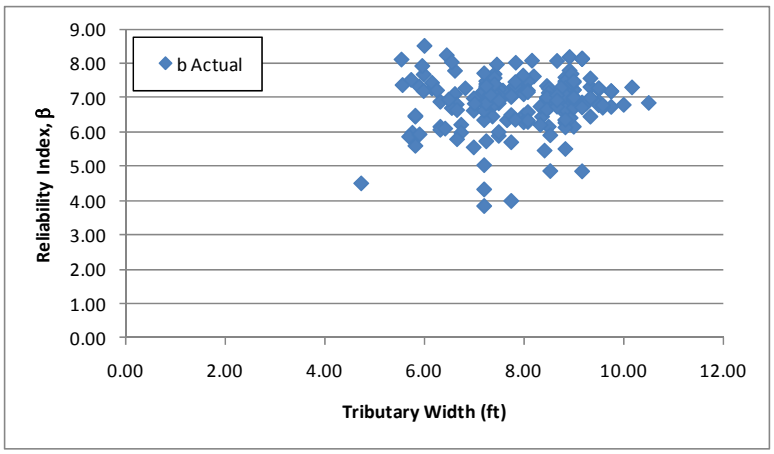


Figure I-83: Shear Reliability Indices for OR-06 Vehicle

Figure I-84 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 Vehicle. The reliability index increases with increasing LRFR ratings. A reliability index of four is estimated for an LRFR rating of 1.0, above the target reliability of 3.5. This indicates that the LRFR live load factors may be slightly over-conservative. Girders with high reliability and low ratings are likely controlled by the shear friction rating; the reliability index is calculated using the shear resistance not the shear friction resistance.

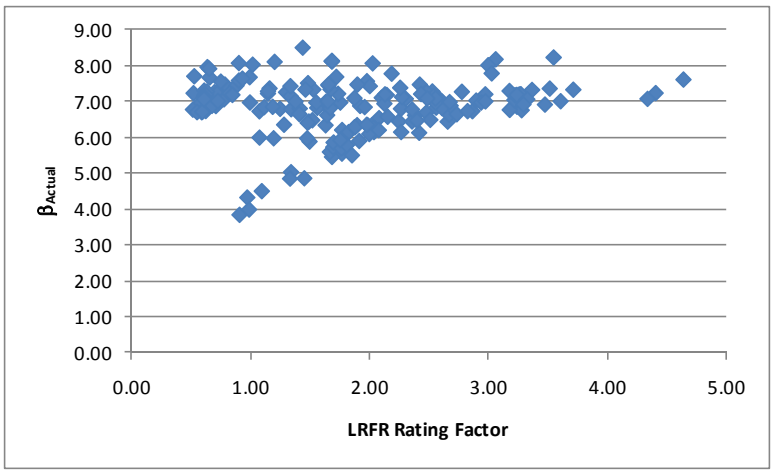
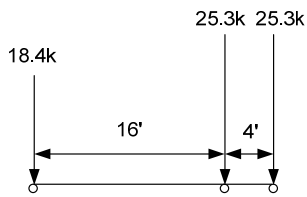


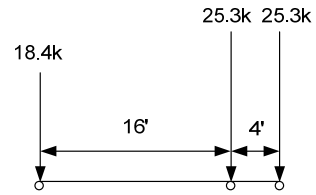
Figure I-84: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

I.1.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-85. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



LFR Loading



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LRFR Loading

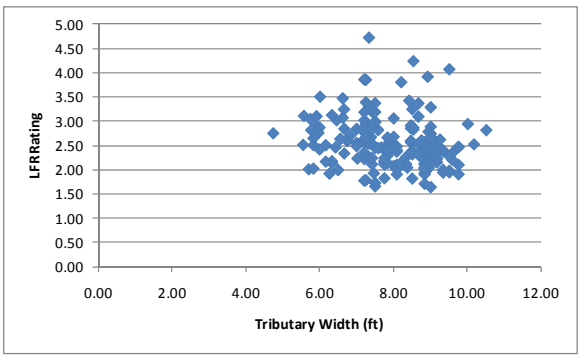
Figure I-85: Vehicle Loadings and Load Factors

I.1.9.1 Moment

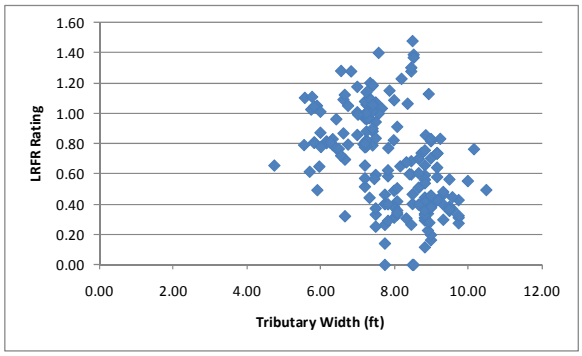
The following section contains the results for interior, composite prestressed I girders within continuous span bridges for the TX-04 Vehicle.

I.1.9.1.1 Rating Factors

Figure I-86 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 151 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 150 of the 151 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is generally between 1.5 and 3.5 while the LRFR rating is generally less than 1.2.



(a)



(b)

Figure I-86: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure I-87 shows the percentage of girders with moment ratings in each range for the TX-04 vehicle, a routine permit vehicle. 28.0% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 10.1% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 72.0% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 89.9% when an ADTT ≥ 5,000 is used.

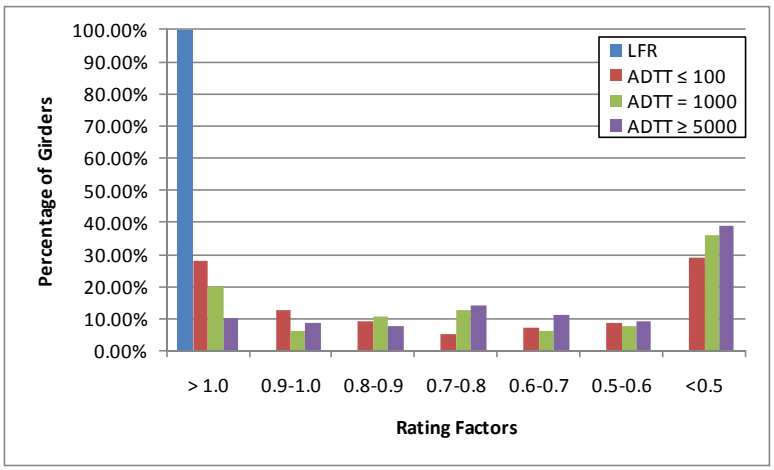


Figure I-87: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

I.1.9.1.2 Rating Factor Comparisons

Figure I-88 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. There are no clear trends in the data, but the LRFR rating is generally 10 to 50% of the LFR rating. The LRFR ratings are greater than the LFR rating for zero girders.

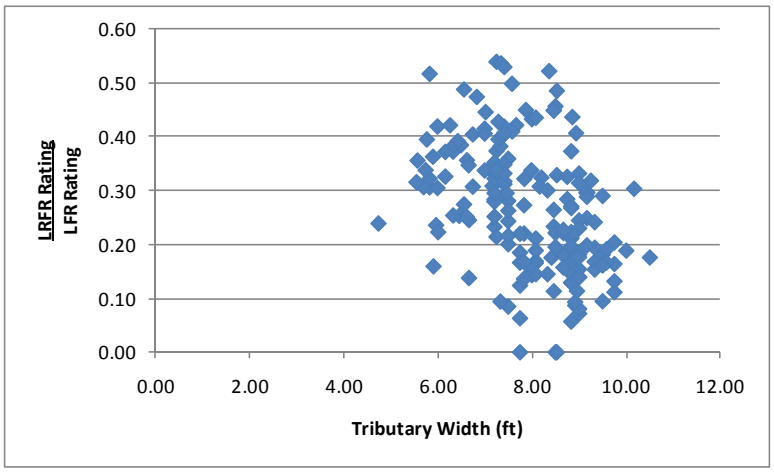


Figure I-88: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

I.1.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-89 shows no girders that have a reliability index less than the target reliability index of 2.5. The reliability index for most girders is between six and twelve.

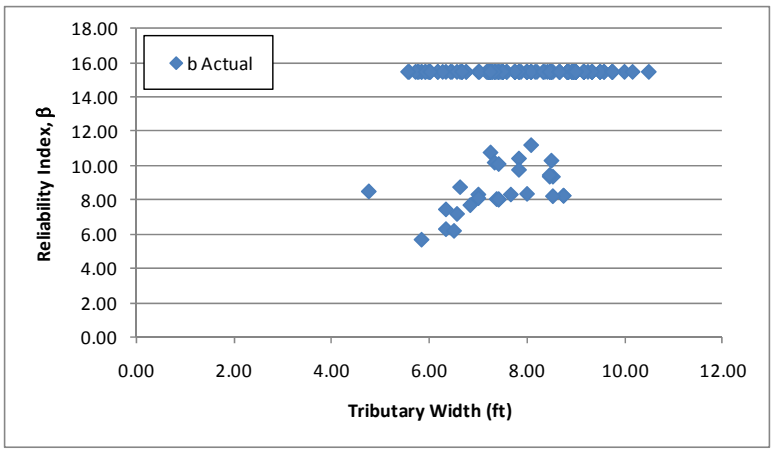


Figure I-89: Flexure Reliability Indices for TX-04 Vehicle

Figure I-90 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The reliability index increases slightly with increasing ratings. The reliability index associated with an LRFR rating of 1.0 is approximately eight, above the target reliability of 2.5. This may indicate the LRFR live load factors are over-conservative or it may indicate that the longitudinal steel rating should not be used to calibrate the load factors. The longitudinal steel rating controls 180 of the 189 girders for this vehicle.

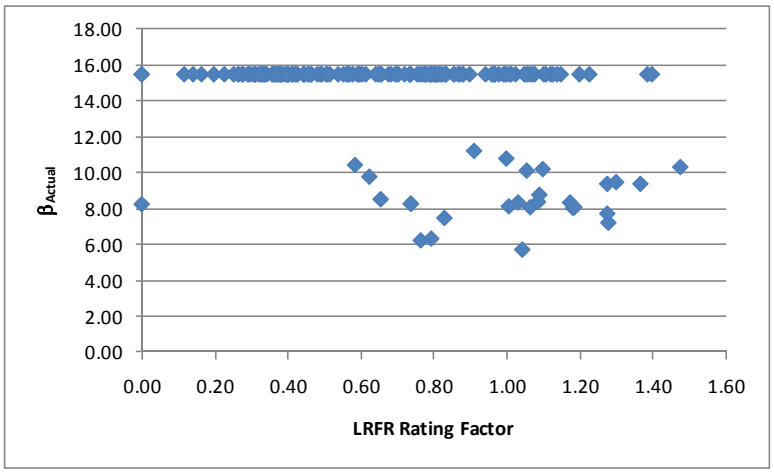
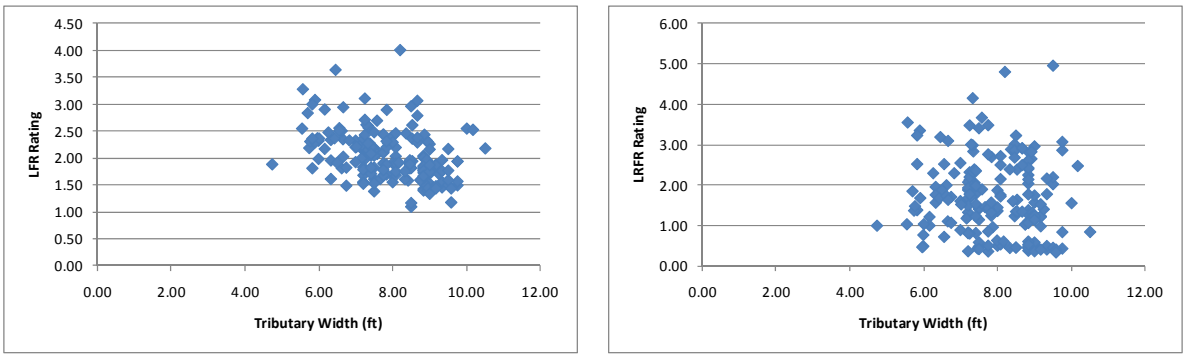


Figure I-90: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

I.1.9.2 Shear

I.1.9.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, 48 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 68% of the girders in this subset. Figure I-91 shows the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 2.5, while the LRFR rating is generally between 0.5 and 3.0.



(a) (b)

Figure I-91: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure I-92 shows the percentage of girders with shear ratings in each range for the TX-04 vehicle, a routine permit vehicle. 77.3% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 70.4% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 22.7% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 29.6% when an ADTT ≥ 5,000 is used.

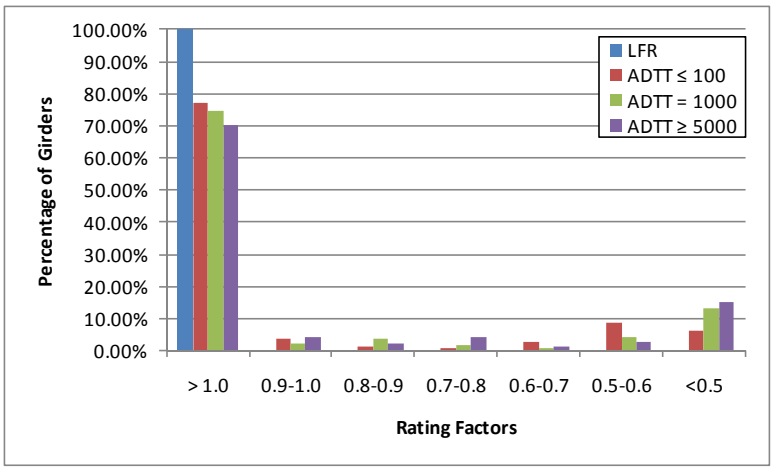


Figure I-92: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

I.1.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure I-93 shows the comparison of rating factors. The ratio is generally between 0.25 and 1.5 with more variation for girders with larger tributary widths. 32% of girders have an LRFR rating that is greater than the LFR rating.

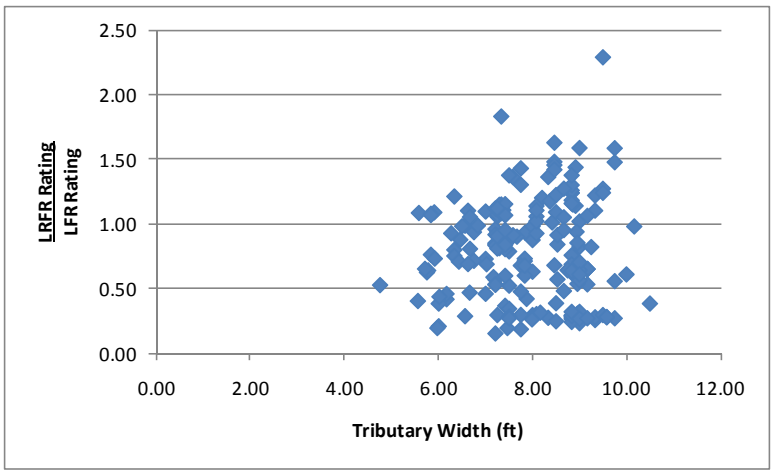


Figure I-93: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

I.1.9.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-94. The reliability index is between six and eight for most girders.

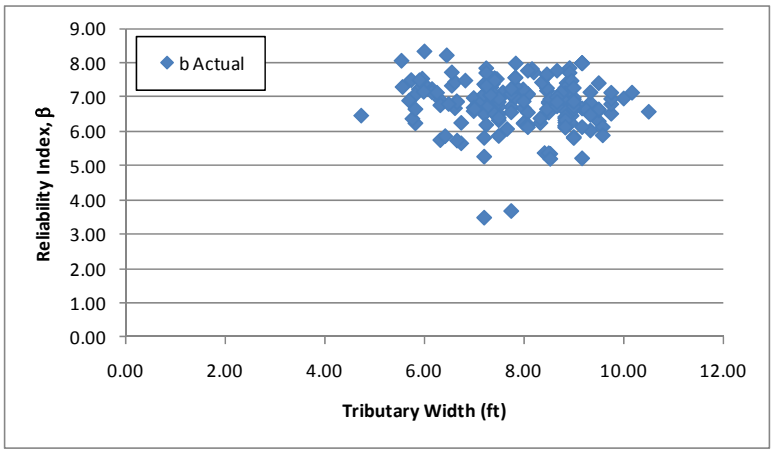


Figure I-94: Shear Reliability Indices for TX-04 Vehicle

Figure I-95 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The reliability index increases with increasing ratings. A reliability index of approximately 4.0 corresponds to an LRFR rating of 1.0, greater than the target reliability of 2.5. This may indicate the LRFR live load factors are over-conservative.

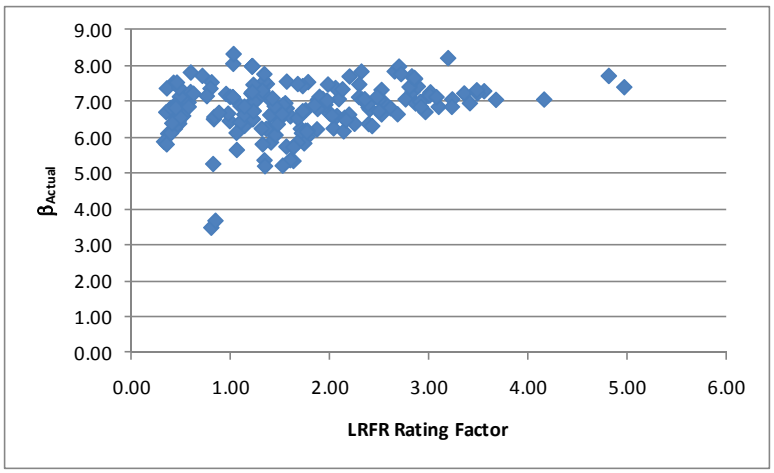
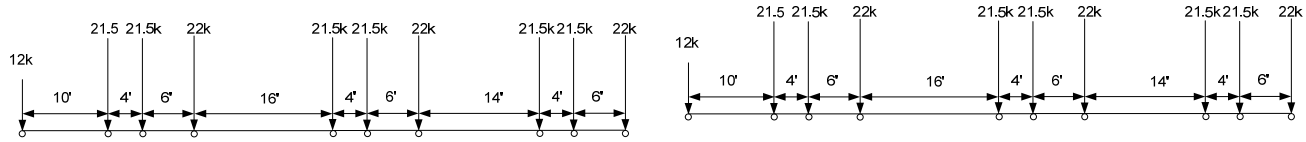


Figure I-95: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

I.1.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-96. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LFR Loading LRFR Loading

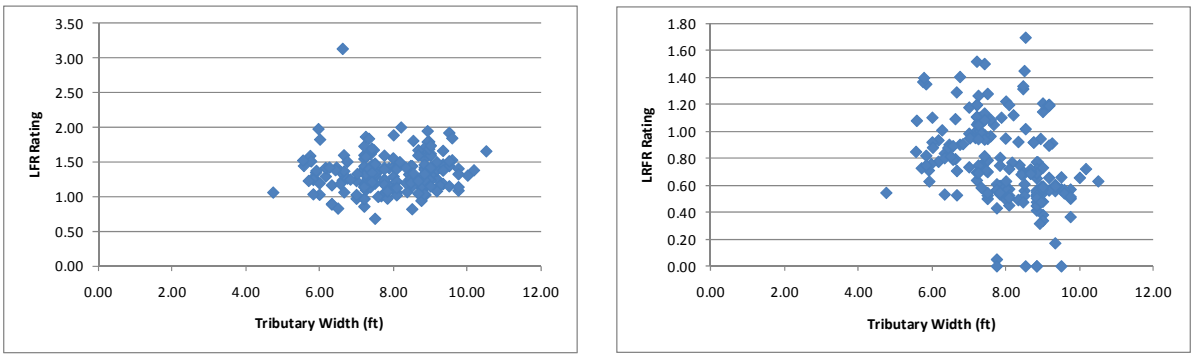
Figure I-96: Vehicle Loadings and Load Factors

I.1.10.1 Moment

The following section contains the results for interior, composite prestressed I girders within continuous span bridges for the WA-02 Vehicle.

I.1.10.1.1 Rating Factors

Figure I-97 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are 11 girders with an LFR rating less than 1.0, 142 girders with an LRFR rating less than 1.0, and 11 girders where both ratings are less than 1.0. 118 of the 142 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 92% of the girders in this subset. The LFR rating is generally between 1.0 and 1.5 while the LRFR rating is generally between 0.4 and 1.0.



(a) (b)

Figure I-97: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure I-98 shows the percentage of girders with moment ratings in each range for the WA-02 vehicle, a special permit vehicle. 34.9% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 10.1% for the multi-trip permit with ADTT ≥ 5,000 category. 94.2% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 59.3% more girders with ratings less than 1.0 when the single trip, escorted permit is used; this increases to 84.1% when a multi-trip permit with ADTT ≥ 5,000 is used.

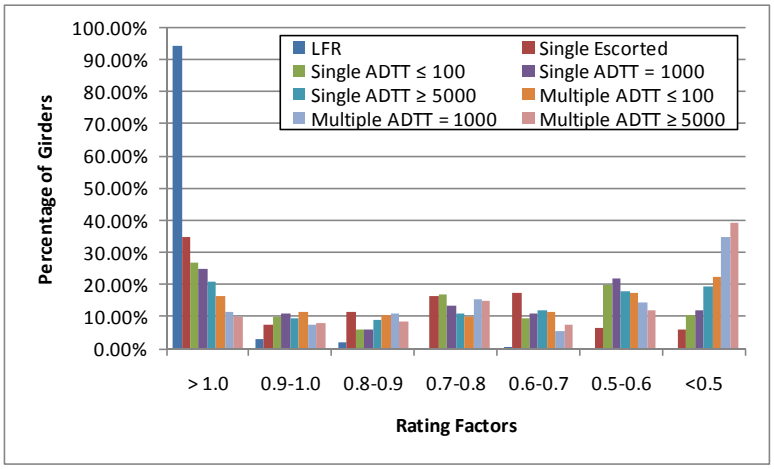


Figure I-98: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

I.1.10.1.2 Rating Factor Comparisons

Figure I-99 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.3 and 0.8. 8% of girders have an LRFR rating that is greater than the LFR rating.

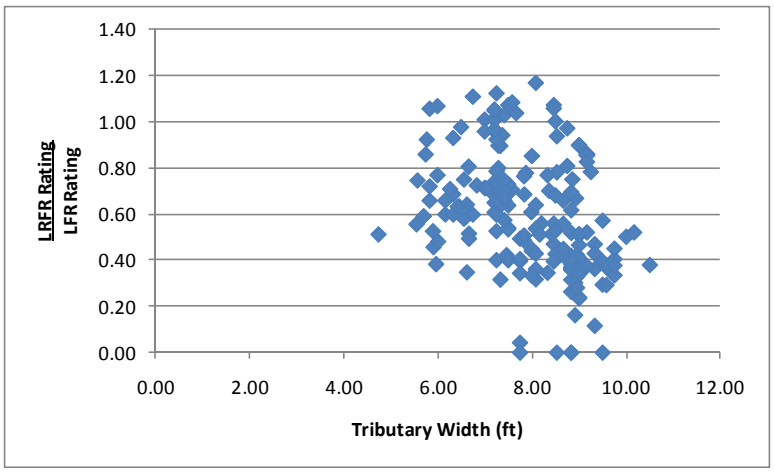


Figure I-99: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

I.1.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-100 shows zero girders have a reliability index less than the target reliability index of 3.5. The reliability index is between six and twelve for most girders and increases slightly with increasing tributary widths.

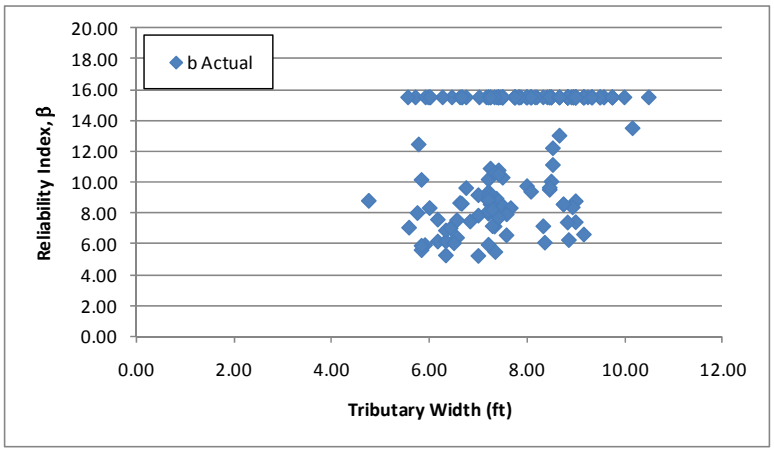


Figure I-100: Flexure Reliability Indices for WA-02 Vehicle

Figure I-101 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 Vehicle. The reliability index increases with increasing moment ratings. A reliability index of approximately 8.0 is observed for an LRFR rating of 1.0. This indicates that either the LRFR live load factors are over-conservative or that the longitudinal steel rating should not be used in calibrating live load factors.

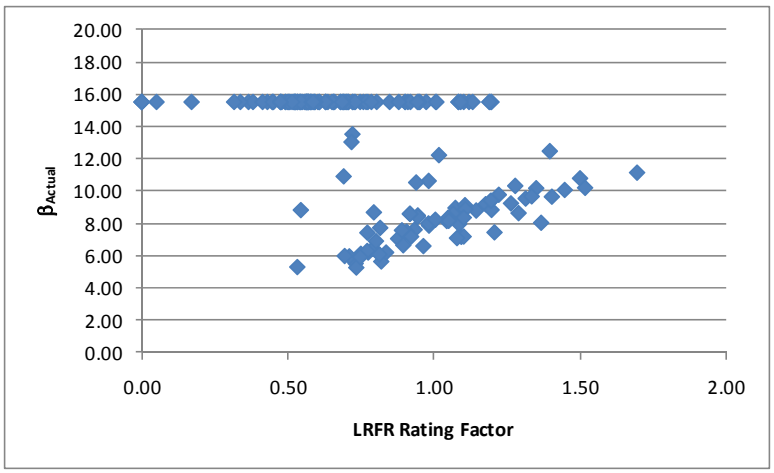
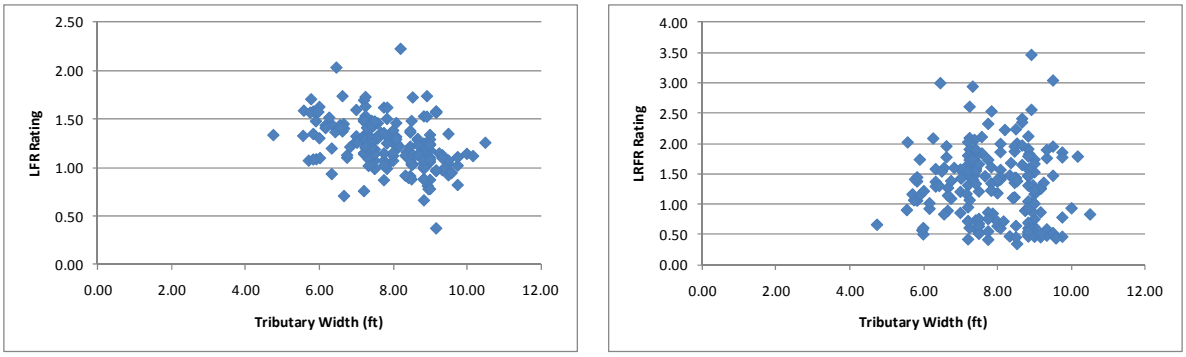


Figure I-101: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

I.1.10.2 Shear

I.1.10.2.1 Rating Factors

For shear, there are 26 girders with LFR rating factors less than 1.0, 62 girders with LRFR ratings less than 1.0, and 12 girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 42% of the girders in this subset. Figure I-102 shows the LFR and LRFR ratings. LFR ratings are between 1.0 and 1.5 and decrease with increasing tributary width while LRFR ratings remain within the range of 0.5 to 2.0.



(a) (b)

Figure I-102: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure I-103 shows the percentage of girders with shear ratings in each range for the WA-02 vehicle, a special permit vehicle. 75.1% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 49.7% for the multiple trip permit with ADTT ≥ 5,000 category. 86.2% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 11.1% more girders with ratings less than 1.0 when the single trip, escorted permit is used; this increases to 36.5% when the multi-trip with ADTT ≥ 5,000 permit is used.

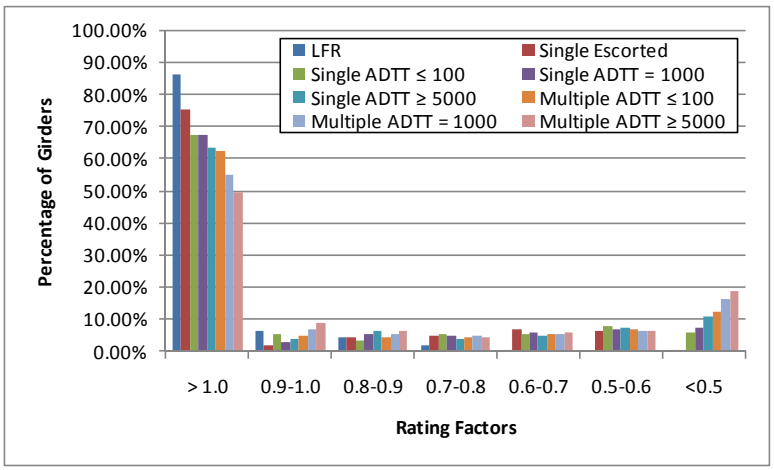


Figure I-103: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

I.1.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-104 show the comparison of rating factors. The ratio is generally between 0.5 and 1.75. 58% of girders have an LRFR rating that is greater than the LFR rating.

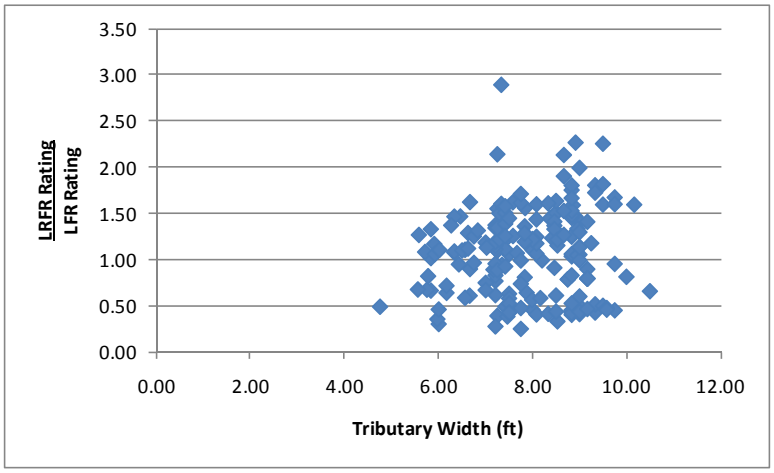


Figure I-104: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

I.1.10.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for nine girders as shown in Figure I-105. The reliability index for most girders is between five and eight.

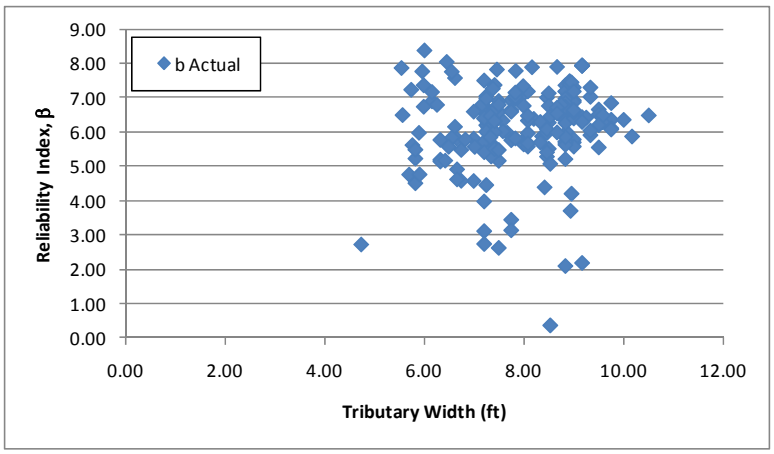


Figure I-105: Shear Reliability Indices for WA-02 Vehicle

Figure I-106 shows the reliability index for shear plotted against the LRFR shear rating for the WA-02 vehicle. The reliability index increases with increasing LRFR ratings. An LRFR rating of 1.0 corresponds to a reliability index of approximately 4.0, slightly above the target reliability of 3.5. This indicates the LRFR live load factors may be slightly over-conservative. Girders with high reliability and low ratings are controlled by the shear friction rating; the reliability index is calculated using the shear resistance not the shear friction resistance.

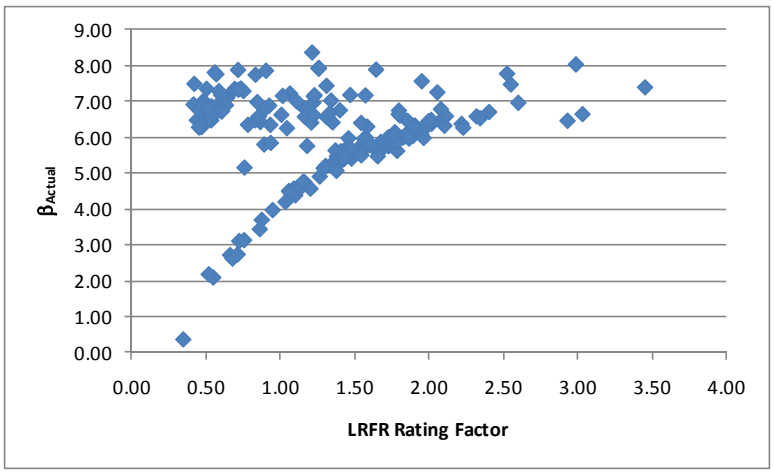


Figure I-106: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

I.1.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-107. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

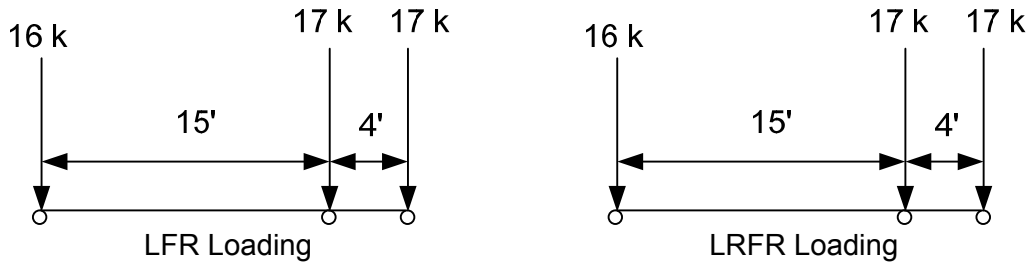
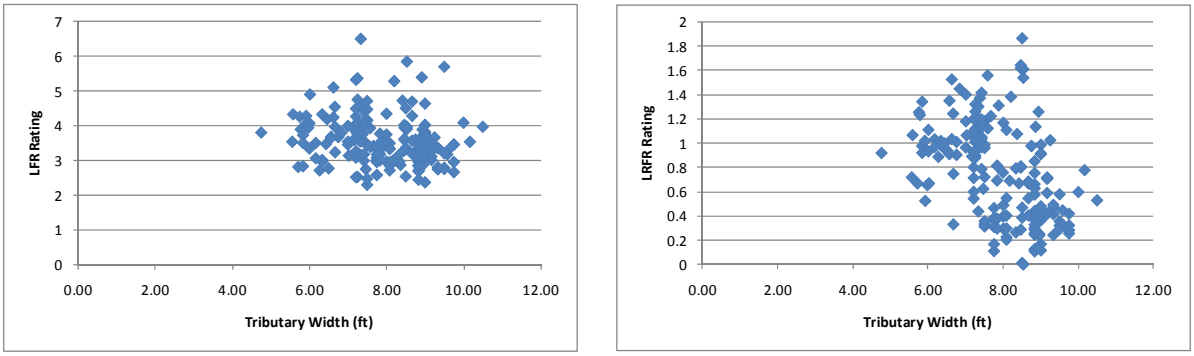


Figure I-107: Vehicle Loadings and Load Factors

I.1.11.1 Moment

I.1.11.1.1 Rating Factors

Figure I-108 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 134 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 133 of 134 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR ratings are between 2.5 and 5.0 for most girders while the LRFR rating is less than 1.4 for most girders.



(a) (b)

Figure I-108: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure I-109 shows the percentage of girders with moment ratings in each range for the AASHTO Type 3 truck, a legal vehicle. 43.4% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 20.6% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 56.6% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 79.4% when an ADTT ≥ 5,000 is used.

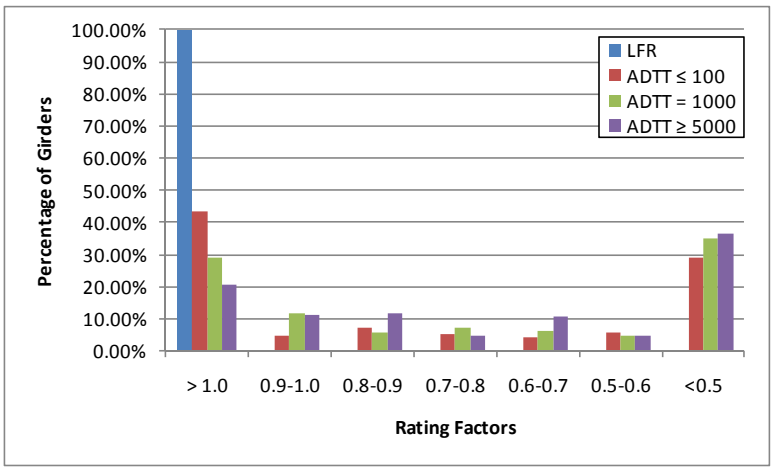


Figure I-109: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

I.1.11.1.2 Rating Factor Comparisons

Figure I-110 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.05 and 0.4. The ratio is generally lower for more widely spaced girders. There are no girders with an LRFR rating that is greater than the LFR rating.

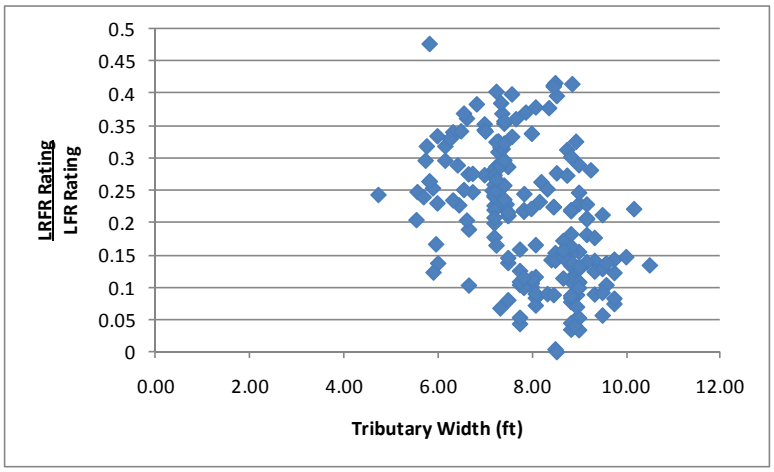


Figure I-110: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

I.1.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-111 shows that one girder has a reliability index less than the target reliability index of 2.5. The reliability index varies significantly with most girders above 14; 187 of 189 girders are controlled by the longitudinal steel rating.

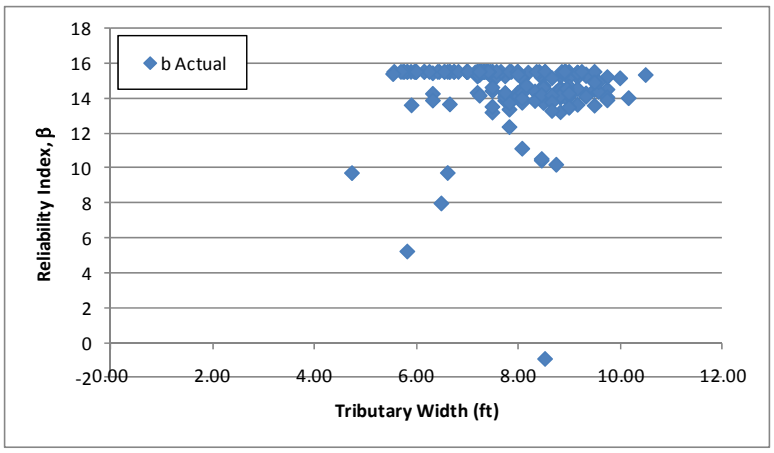


Figure I-111: Flexure Reliability Indices for Type 3 Vehicle

Figure I-112 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 Truck. There are no obvious trends in the data, except that the reliability index is generally greater than the target reliability index of 2.5. The graph may also indicate that using the longitudinal steel rating for calibration is not the best method as there are very few clear trends.

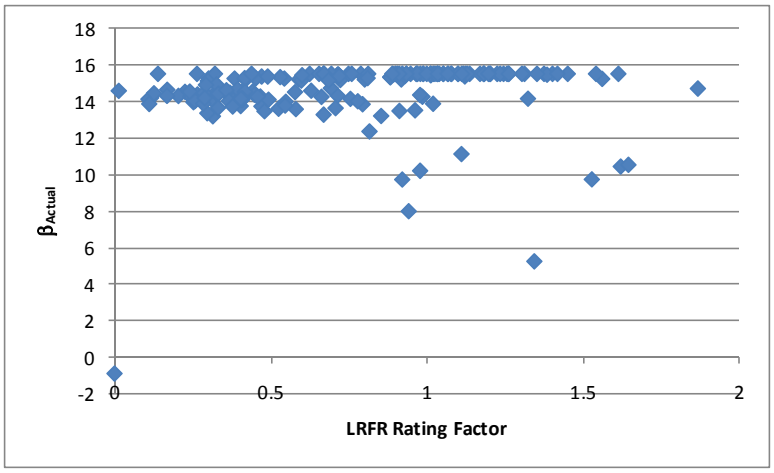
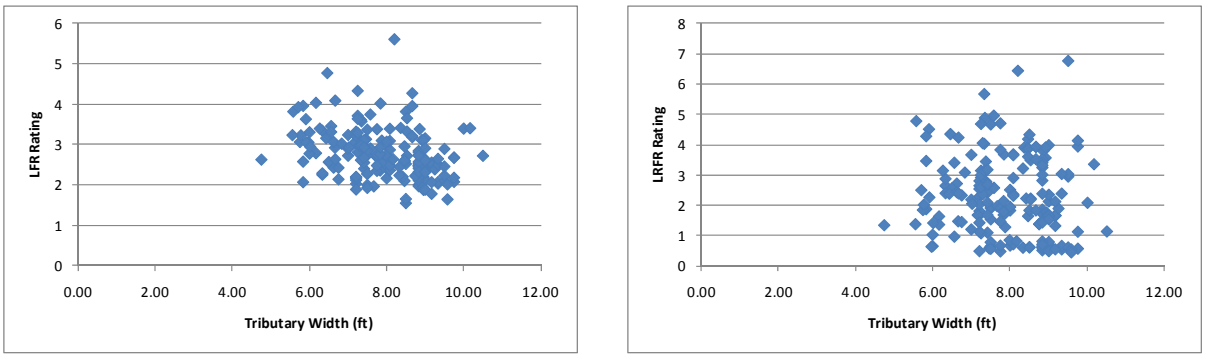


Figure I-112: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

I.1.11.2 Shear

I.1.11.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, 35 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 67% of the girders in this subset. Figure I-113 shows the LFR and LRFR ratings. The LFR ratings are between 2 and 3.5 and decrease with increasing tributary widths. The LRFR ratings are generally between 0.5 and 4.0 for most girders.



(a) (b)

Figure I-113: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure I-114 shows the percentage of girders with shear ratings in each range for the AASHTO Type 3 truck, a legal vehicle. 82.5% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 80.4% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 17.5% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 19.6% when an ADTT ≥ 5,000 is used.

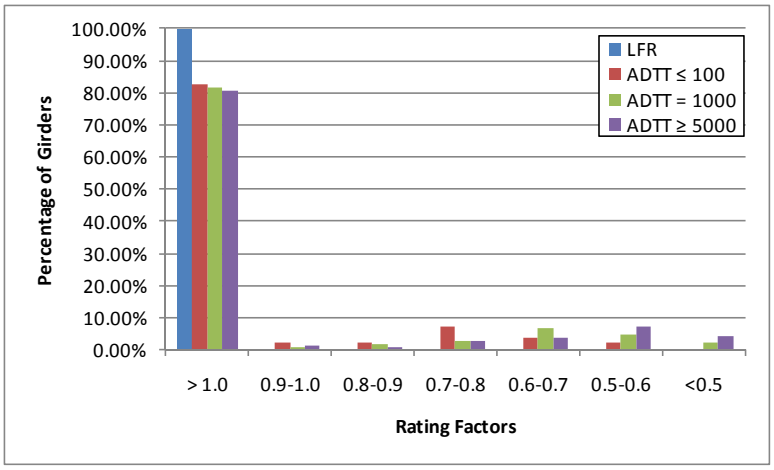


Figure I-114: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

I.1.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-115 show the comparison of rating factors. The ratio is generally between 0.25 and 1.5. The LRFR rating is greater than the LFR rating for 33% of the girders.

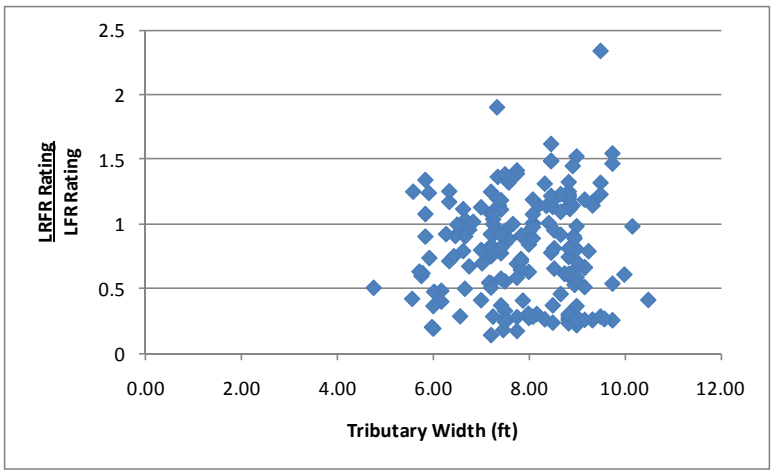


Figure I-115: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

I.1.11.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure I-116. The reliability index is between six and eight for most girders.

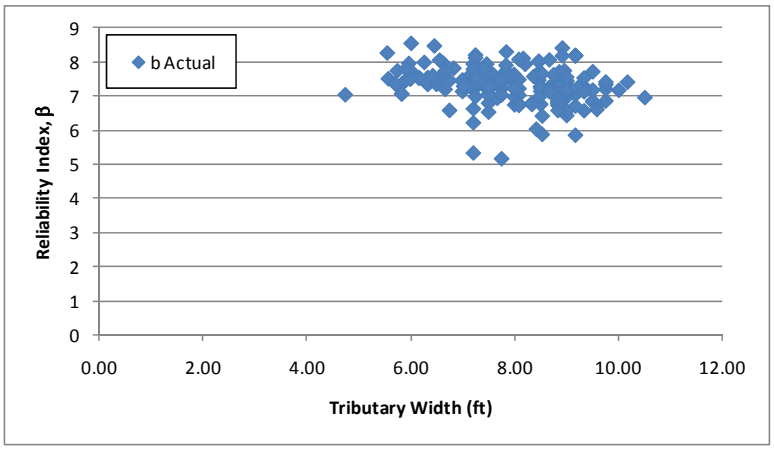


Figure I-116: Shear Reliability Indices for Type 3 Vehicle

Figure I-117 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 Truck. The reliability index increases with increasing ratings. An LRFR rating of 1.0 corresponds to a reliability index of approximately 4, above the target reliability of 2.5. This may indicate that the LRFR live load factors are over-conservative. The girders with high reliability and low ratings are those controlled by the shear friction rating; the reliability index is calculated using the shear resistance not the shear friction resistance.

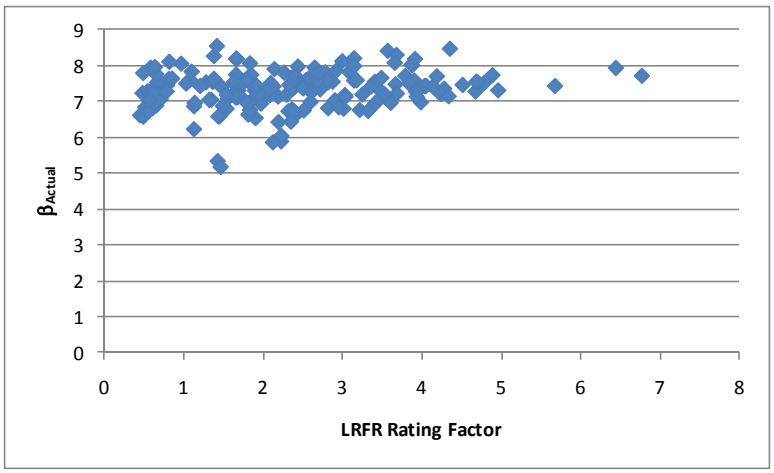


Figure I-117: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

I.1.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-118. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

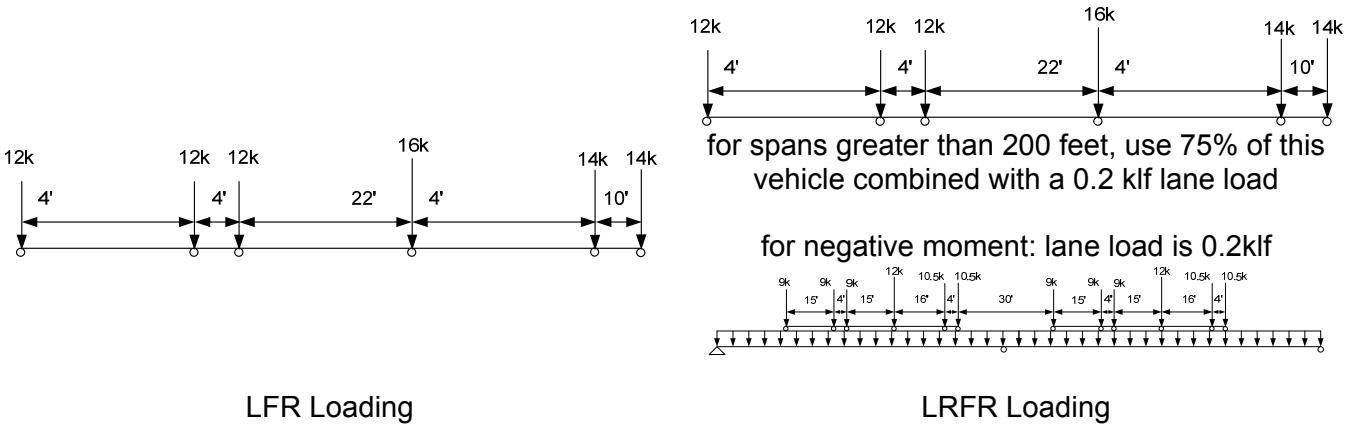
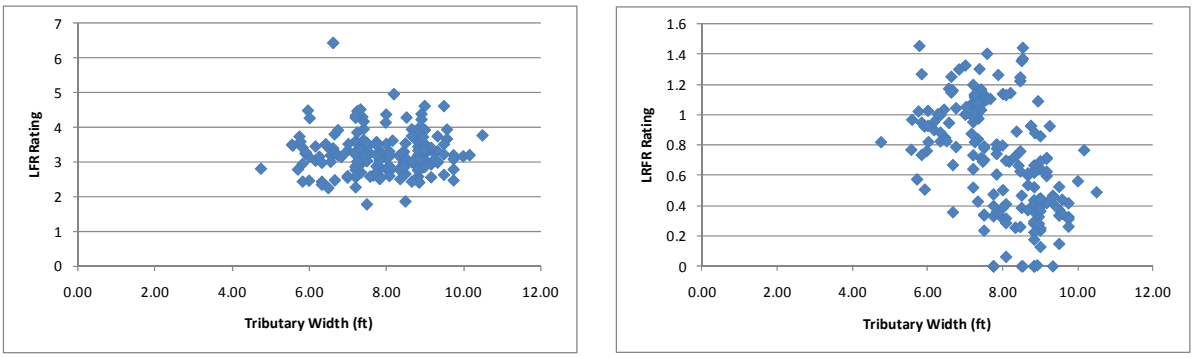


Figure I-118: Vehicle Loadings and Load Factors

I.1.12.1 Moment

I.1.12.1.1 Rating Factors

Figure I-119 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 139 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. All 139 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR ratings are between 2.5 and 4.0 for most girders while the LRFR ratings are all less than 1.6 with most less than 1.0



(a) (b)

Figure I-119: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure I-120 shows the percentage of girders with moment ratings in each range for the AASHTO Type 3-3 truck, a legal vehicle. 38.1% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 16.4% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 61.9% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 83.6% when an ADTT ≥ 5,000 is used.

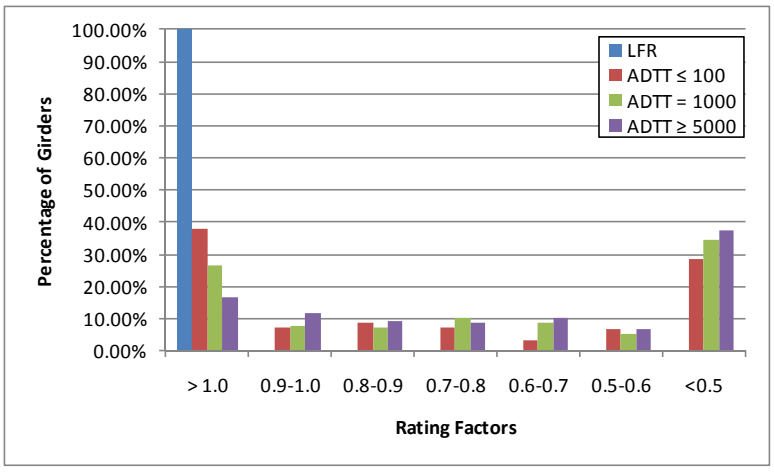


Figure I-120: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

I.1.12.1.2 Rating Factor Comparisons

Figure I-121 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0 and 0.4, with widely spaced girders having lower ratios. The LRFR rating is greater than the LFR rating for zero girders.

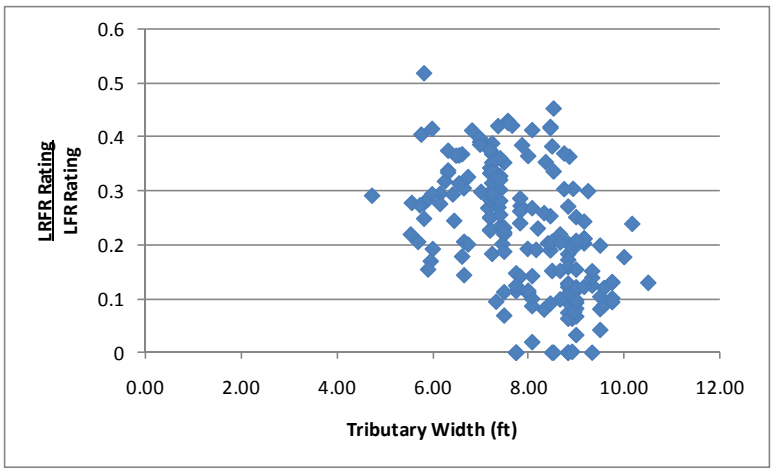


Figure I-121: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

I.1.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-122 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index increases with increasing girder spacing for most girders.

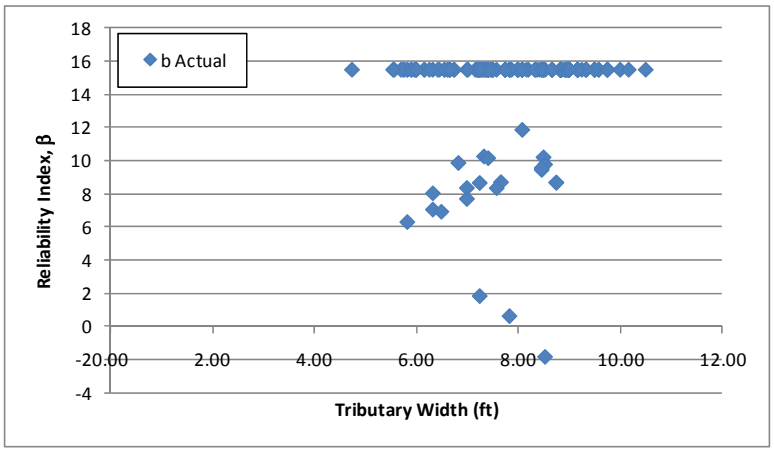


Figure I-122: Flexure Reliability Indices for Type 3-3 Vehicle

Figure I-123 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The reliability index increases with increasing ratings but is significantly higher than the target reliability index of 2.5. This indicates that utilizing the rating for the longitudinal steel to calibrate the LRFR live load factors is not a suitable method.

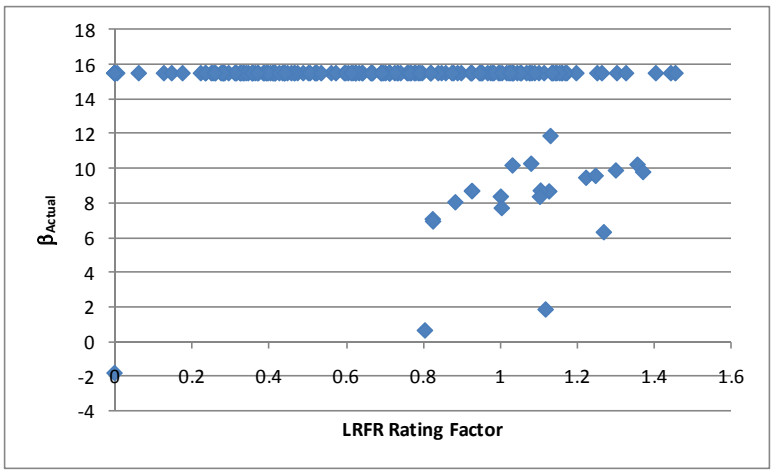
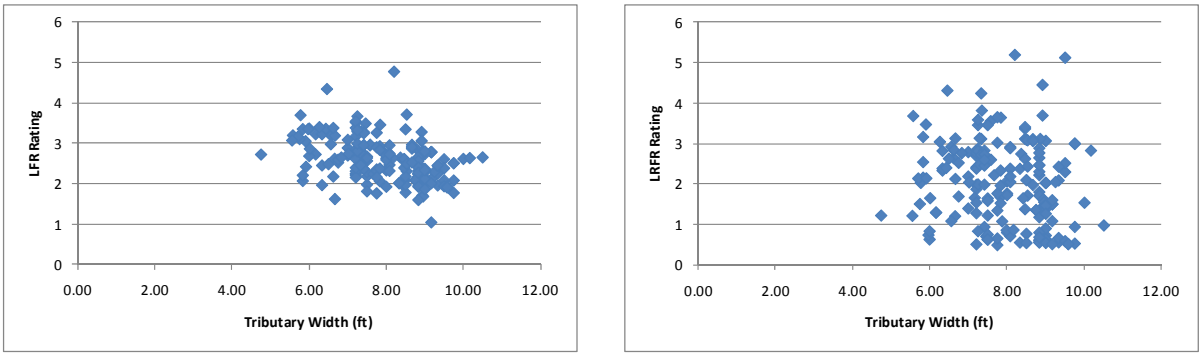


Figure I-123: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

I.1.12.2 Shear

I.1.12.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, 39 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 69% of the girders in this subset. Figure I-124 shows the LFR and LRFR ratings. The LFR ratings are between two and 3.5 for most girders while the LRFR ratings vary from 0.5 to 3.0 for most girders.



(a) (b)

Figure I-124: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure I-125 shows the percentage of girders with shear ratings in each range for the AASHTO Type 3-3 truck, a legal vehicle. 82.5% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 78.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 17.5% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 21.7% when an ADTT ≥ 5,000 is used.

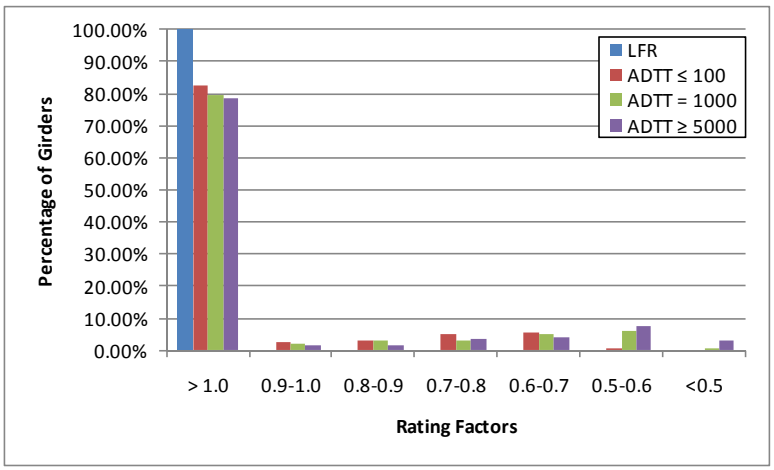


Figure I-125: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

I.1.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-126 show the comparison of rating factors. The ratio is generally between 0.25 and 1.5, with widely spaced girders generally having higher ratios. The LRFR rating is greater than the LFR rating for 31% of girders.

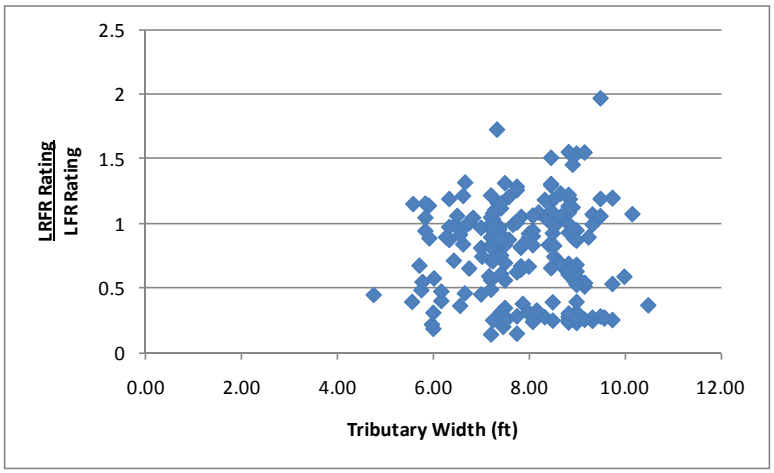


Figure I-126: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

I.1.12.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure I-127. The reliability index is between six and eight for most girders.

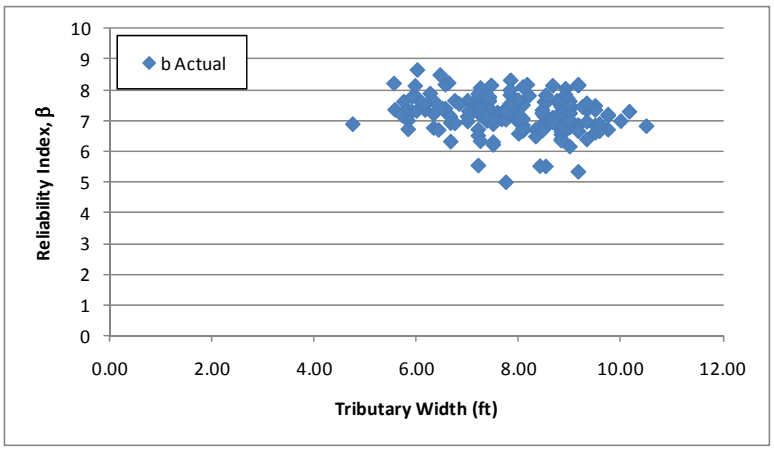


Figure I-127: Shear Reliability Indices for Type 3-3 Vehicle

Figure I-128 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 truck. The reliability index increases with increasing LRFR ratings. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0, above the target reliability of 2.5. This may indicate the LRFR live load factors are over-conservative.

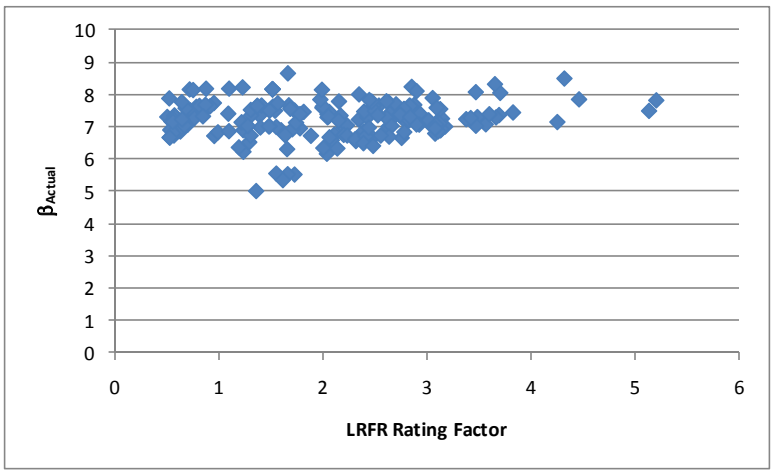


Figure I-128: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Truck

I.1.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-129. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

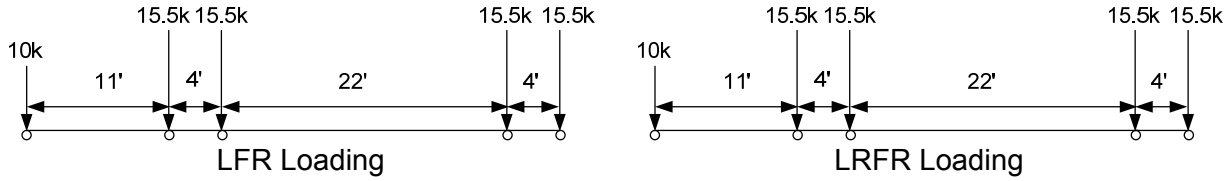
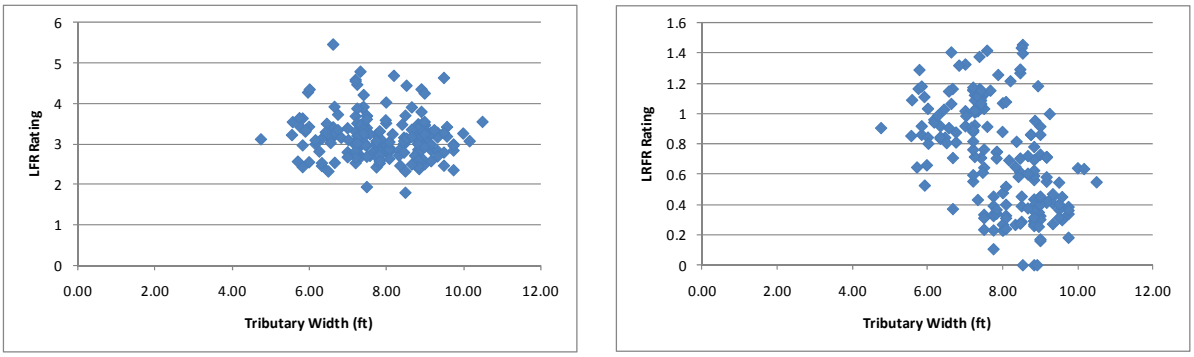


Figure I-129: Vehicle Loadings and Load Factors

I.1.13.1 Moment

I.1.13.1.1 Rating Factors

Figure I-130 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 140 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 139 of the 140 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR rating is between two and four for most girders. The LRFR rating is between 0.2 and 1.0 for most girders.



(a) (b)

Figure I-130: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure I-131 shows the percentage of girders with moment ratings in each range for the AASHTO Type 3S2 truck, a legal vehicle. 38.6% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 15.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 61.4% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 84.7% when an ADTT ≥ 5,000 is used.

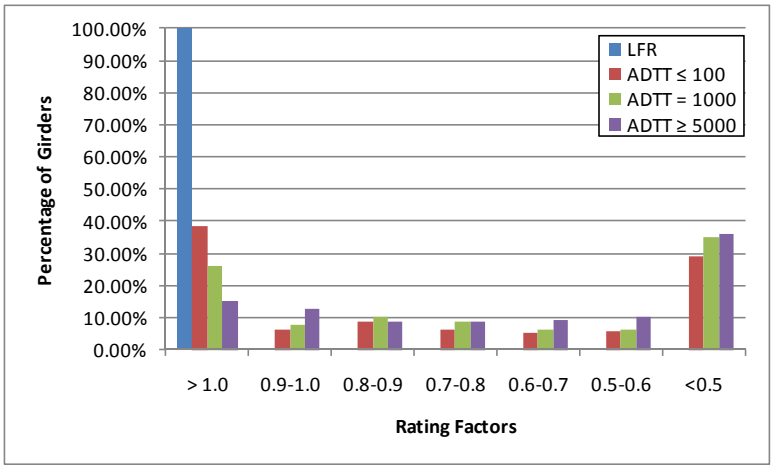


Figure I-131: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

I.1.13.1.2 Rating Factor Comparisons

Figure I-132 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.1 and 0.4. No girders have an LRFR rating that is greater than the LFR rating.

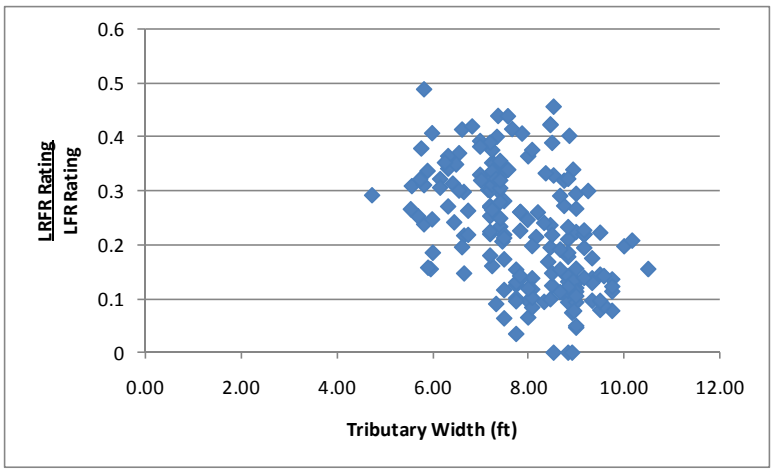


Figure I-132: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

I.1.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-133 shows that three girders have a reliability index less than the target reliability index of 2.5. The reliability index increases with increasing girder spacing. The reliability index is between seven and twelve for most girders.

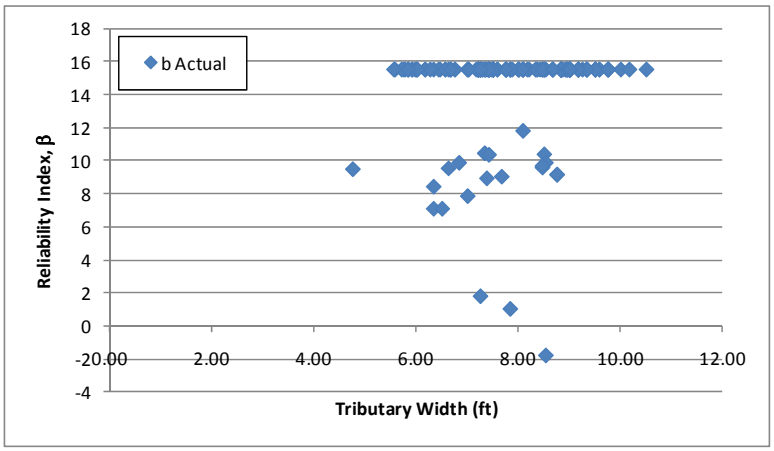


Figure I-133: Flexure Reliability Indices for Type 3S2 Vehicle

Figure I-134 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 truck. The reliability index increases with increasing ratings but is significantly higher than the target reliability of 2.5. This indicates that using the longitudinal steel rating to calibrate the LRFR live load factors is not recommended.

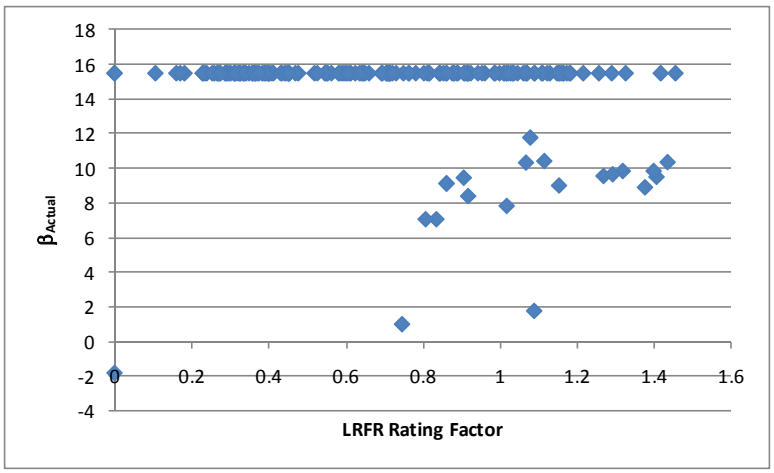
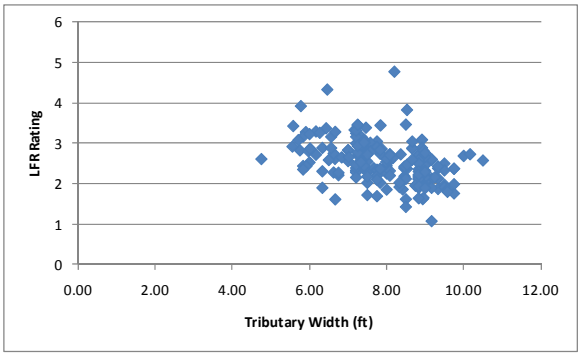


Figure I-134: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

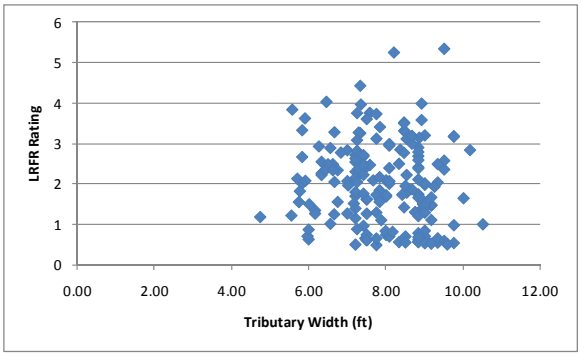
I.1.13.2 Shear

I.1.13.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, 40 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 69% of the girders in this subset. Figure I-135 shows the LFR and LRFR ratings. LFR ratings are between 1.5 and 3.5 for most girders while the LRFR ratings are between 0.5 and 4.0 for most girders.



(a)



(b)

Figure I-135: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure I-136 shows the percentage of girders with shear ratings in each range for the AASHTO Type 3S2 truck, a legal vehicle. 82.0% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 78.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 18.0% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 21.7% when an ADTT ≥ 5,000 is used.

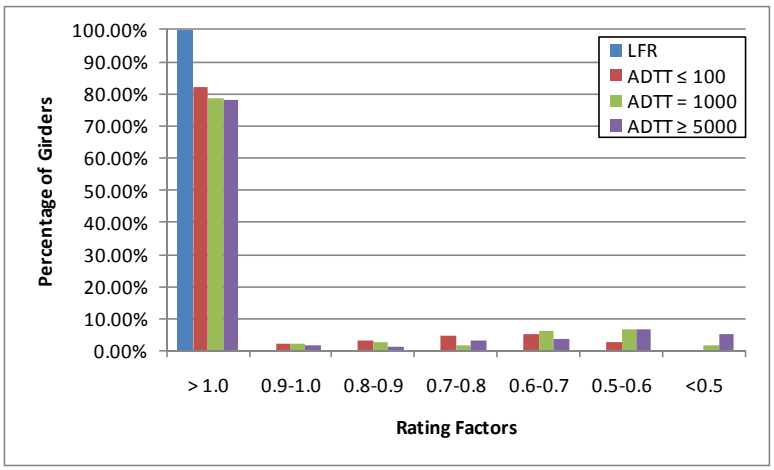


Figure I-136: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

I.1.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-137 show the comparison of rating factors. The ratio is generally between 0.25 and 1.5, with widely spaced girders generally having higher ratios. 31% of girders have LRFR ratings that are greater than the LFR rating.

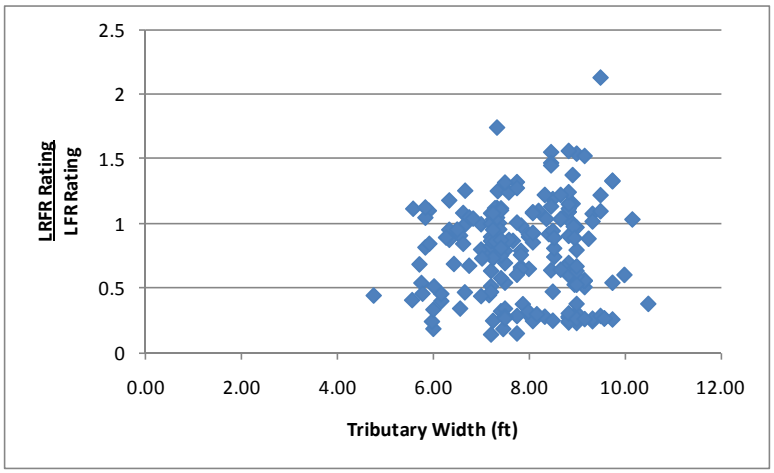


Figure I-137: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

I.1.13.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure I-138. The reliability index is between six and eight for most girders.

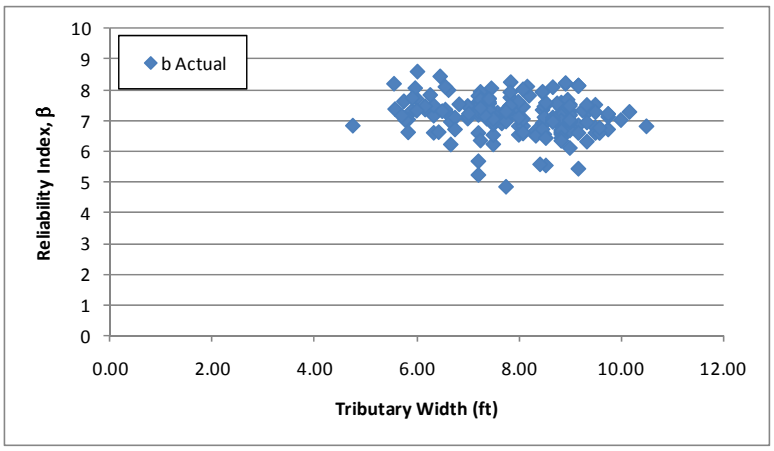


Figure I-138: Shear Reliability Indices for Type 3S2 Vehicle

Figure I-139 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 truck. The reliability index associated with an LRFR rating of 1.0 is approximately 4.0 above the target reliability of 2.5. This may indicate the live load factors in the MBE are over-conservative. The girders with high reliability and low ratings are controlled by the shear friction rating; the reliability index is calculated using the shear resistance not the shear friction resistance.

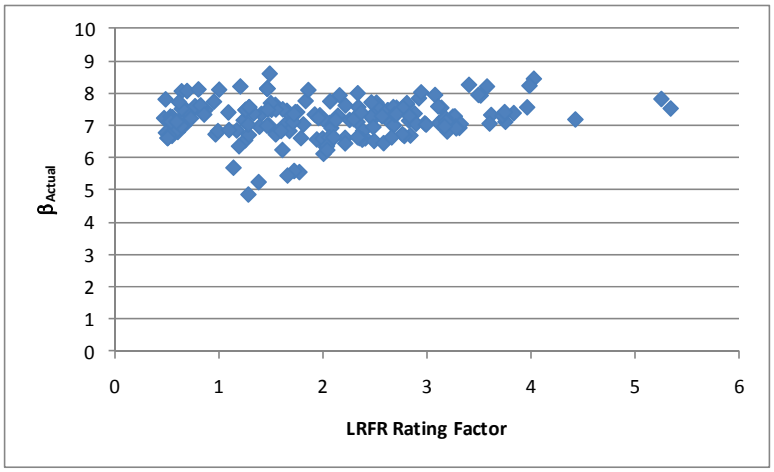


Figure I-139: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

I.1.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table I-1 shows the results for the moment ratings. The LRFR methodology results in many girders having ratings less than 1.0 even for the lightest vehicles. Most of the girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating as shown in the last row of the table; those not controlled by the longitudinal steel rating are controlled by a Service limit state limiting the concrete stress. For all vehicles except the special permit vehicles, the percentage of girders with LFR ratings greater than LRFR ratings was similar. The special permit vehicles have more girders with LRFR ratings that are greater than the LFR rating; this is due to the load configuration for the special permit vehicles.

Table I-1: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	189	18	0	0	0	0	0	2	0	11	0	0	0
LRFR Rating less than 1.0		180	148	140	110	145	132	117	151	142	134	139	140
LFR and LRFR Rating less than 1.0		18	0	0	0	0	0	2	0	11	0	0	0
% with LFR RF greater than LRFR RF		100	100	100	99	100	100	94	100	92	100	100	100
LRFR Rating less than 1.0 and controlled by longitudinal steel		179	147	138	108	144	131	112	150	118	133	139	139
LRFR Rating less than 1.0 and controlled by service limit state		1	1	2	2	1	1	4	1	24	1	0	1

I.1.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table I-2 shows the results for the shear ratings. Shear ratings for LRFR resulted in many girders for every vehicle with ratings less than 1.0 while for LFR only the HS-20 truck or lane and WA-02 caused a large number to have ratings less than 1.0. The other special permit vehicles caused several girders to have LFR ratings less than 1.0.

Table I-2: Shear Rating Factor Results for All 12 Vehicles

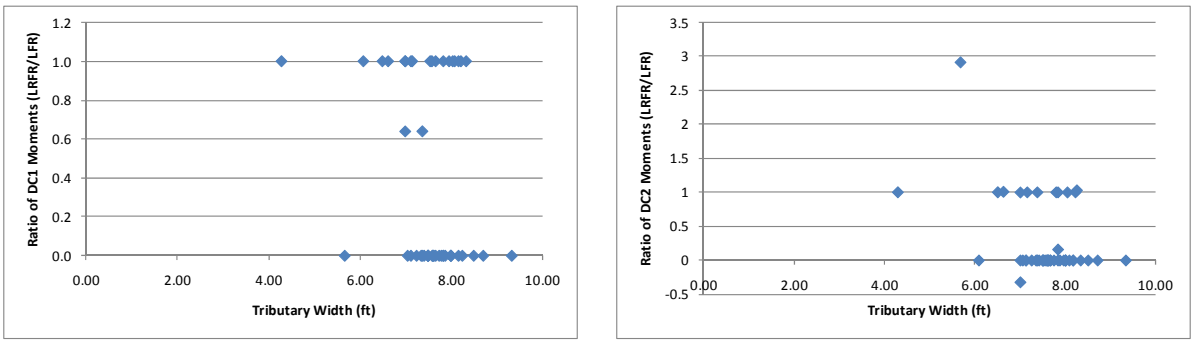
	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	189	35	1	0	4	0	0	3	0	26	0	0	0
LRFR Rating less than 1.0		93	41	40	42	41	36	41	48	62	35	39	40
LFR and LRFR Rating less than 1.0		31	0	0	0	0	0	1	0	12	0	0	0
% with LFR RF greater than LRFR RF		65	67	67	39	69	67	38	68	42	67	69	69

I.2 Exterior Composite Girders

I.2.1 Dead Loads

I.2.1.1 Moment

The first set of graphs show the results that were obtained for flexure. As shown in Figure I-140a, many of the ratios are zero because before placement of the deck, the girders act as simple spans. For the critical locations at the supports, the DC1 moment at this location would be zero. For critical locations that are not at the supports, the ratio is close to 1.0. Figure I-140b shows that the DC2 and DW dead loads acting on the composite section are close to 1.0 for those girders where the critical location is at the same location for both methods or zero when one method is at an exterior support.

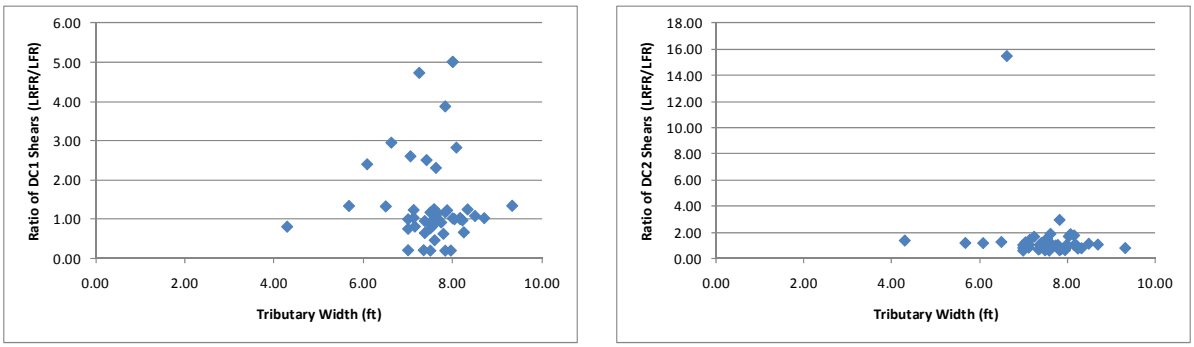


(a) (b)

Figure I-140: Ratio of DC1 and DC2 and DW LRFR/LFR Moments (unfactored loads)

I.2.1.2 Shear

Figure I-141a show that numerous girders have a ratio of DC1 shear close to 1.0, but there are also many where the ratio is either above or below 1.0. This is a mostly due to the variation of the critical section for shear. Figure I-141b shows that the LFR shear is similar to the LRFR shear for DC2 and DW loads.



(a) (b)

Figure I-141: Ratios of DC1 and DC2 Shear (unfactored loads LRFR/LFR)

I.2.2 Design Vehicle

The vehicles used in this section are the design vehicles from the AASHTO Standard Specification and the AASHTO LRFD Design Specification. The AASHTO Standard Specification uses the maximum of an HS20 Design Truck or the corresponding Lane Load. The AASHTO LRFD Design Specification uses the maximum of the Design Truck or Design Tandem combined with a 640 pound per linear foot lane load. The loadings are shown schematically in Figure I-142. The applicable load factors for these vehicles are 2.17 and 1.75 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized for the design vehicles.

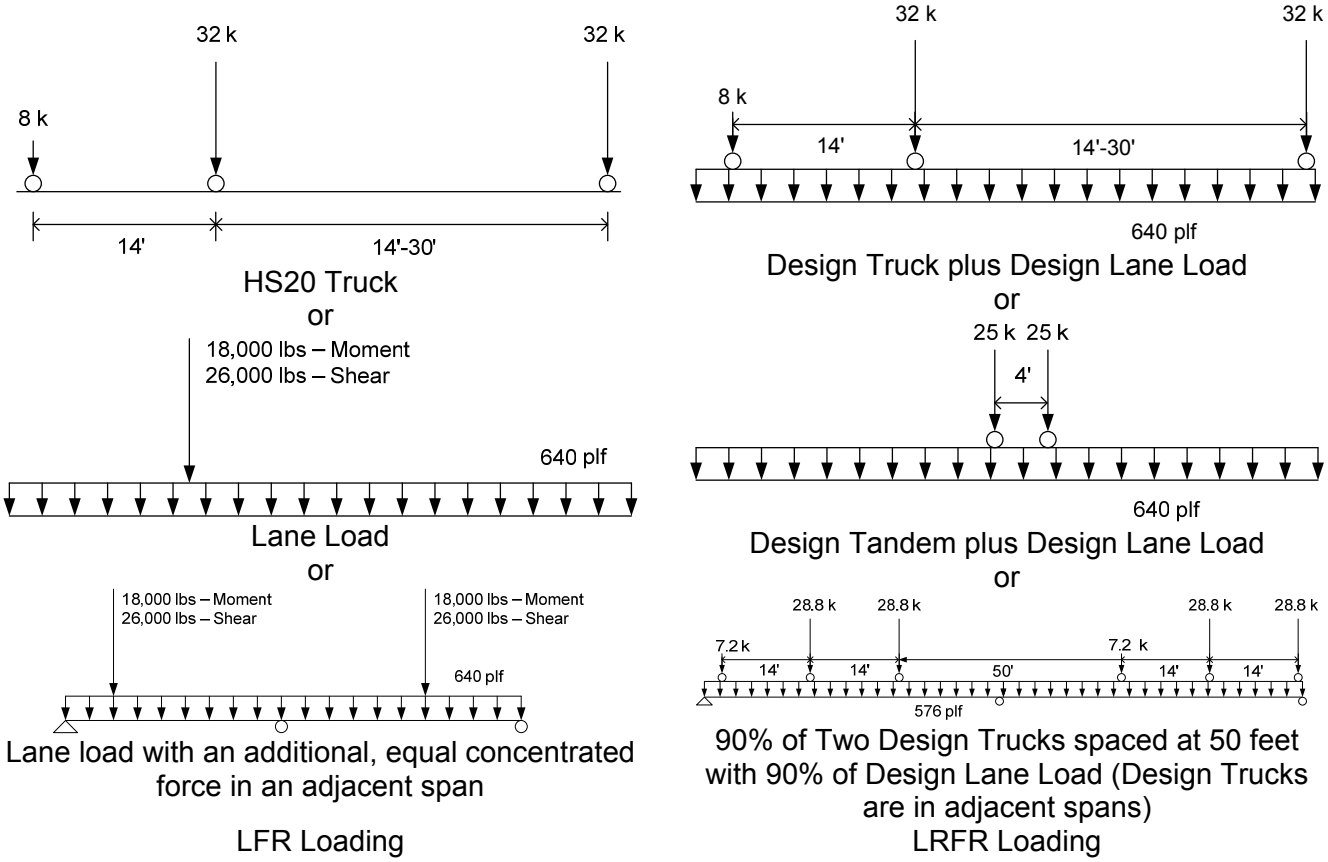
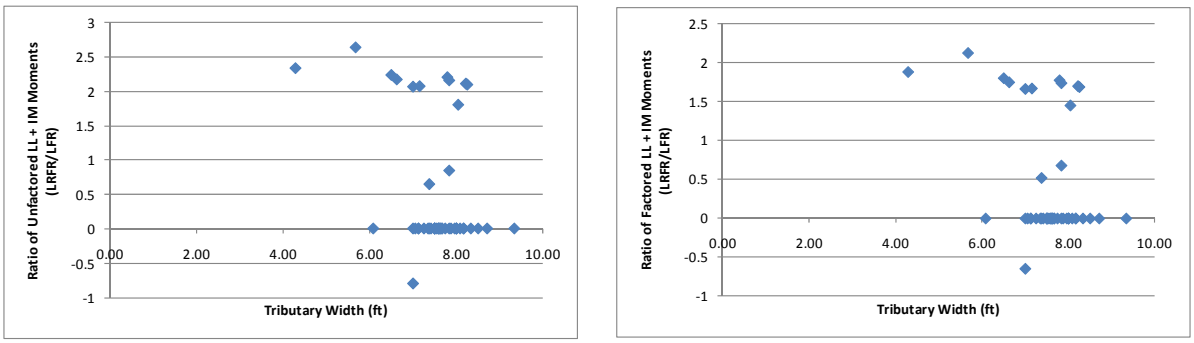


Figure I-142: Vehicle Loadings and Load Factors

I.2.2.1 Moment

I.2.2.1.1 Live Loads

Figure I-143a shows a plot of the unfactored live load moments caused by the HL-93 Design load (the controlling of the truck or tandem plus lane loading) divided by the moment caused by the HS-20 Design load (the controlling of the truck or lane load). The graph shows that the ratio of unfactored live loads is zero for most girders, or near two. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure I-143b shows that the results have shifted down between 1.5 and 2.0 for those girders that are not zero.



(a) (b)

Figure I-143: Ratios of Unfactored and Factored Live Load plus Impact Moments for Design Loadings (LRFR/LFR)

I.2.2.1.2 Resistance

The next step was to verify that the resistances were similar between the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data while the LFR resistance was calculated by solving the rating factor equation for the resistance since all other values are obtained from the data. Figure I-144 shows that the ratio of resistance is around 0.25 or -0.25 for most girders. Most other girders are near one, for those above 1.0 he increased resistance for LRFR may be due to the reduction in prestress losses..

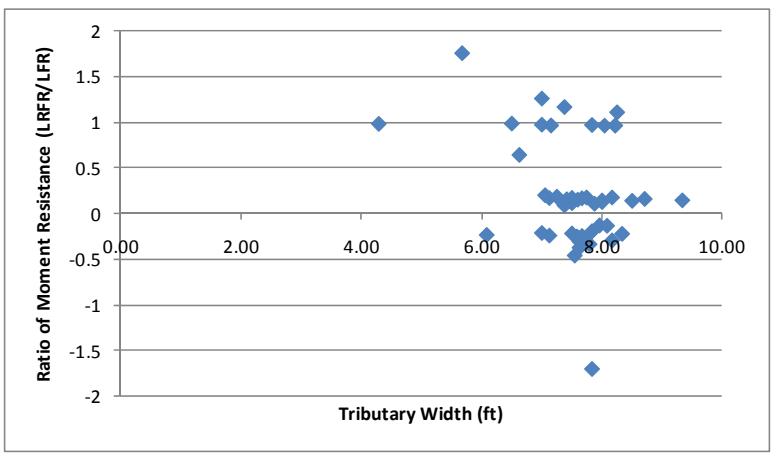
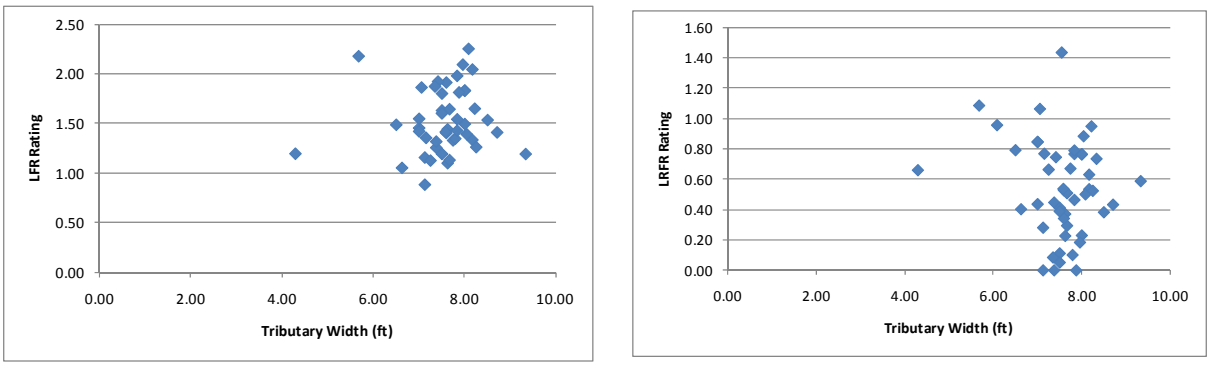


Figure I-144: Ratio of factored Moment Resistance (LRFR/LFR)

I.2.2.1.3 Rating Factors

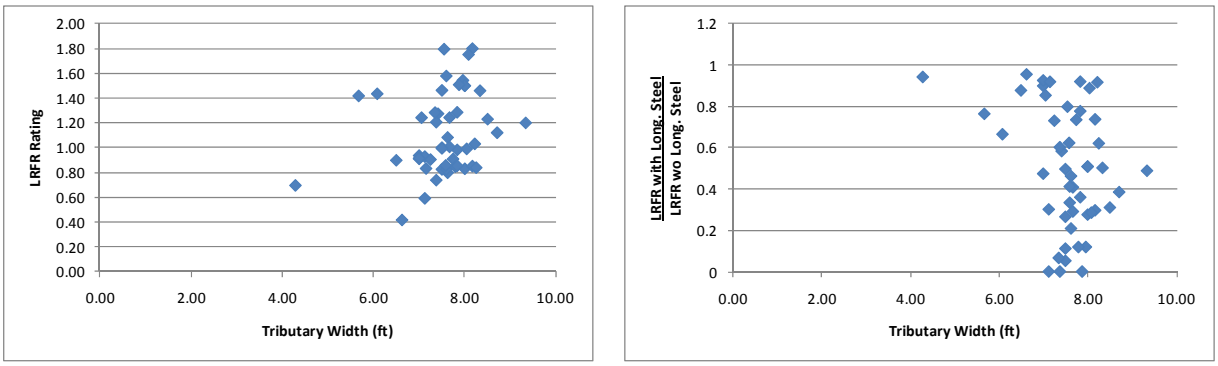
After comparing the loads and resistances to verify that those results seemed appropriate, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset (49 girders) did not have rating factors greater than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there is one girder with LFR ratings less than 1.0, 46 girders with LRFR ratings less than 1.0, and one girder where both the LFR and LRFR ratings are less than 1.0. All 46 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. One of the concerns with rating older bridges using LRFR when they were not designed using the LRFD specification, is that they would produce significantly lower ratings. Figure I-145 shows the LFR rating factors and LRFR rating factors. The LFR ratings are generally between one and two while the LRFR ratings are generally less than 1.0. Three girders were removed from the LFR graph as outliers; they had values of 8, 16, and 22.



(a) (b)

Figure I-145: LFR and LRFR Flexure Rating Factors for Design Loadings

Figure I-146a shows the LRFR ratings when the longitudinal steel rating is ignored. The figure shows that most girders have LRFR ratings greater than 0.8 when the longitudinal steel rating is ignored where as in Figure I-145b, most girders have ratings less than 0.8 when the longitudinal steel rating is considered. 22 fewer girders have LRFR ratings less than 1.0 when the longitudinal steel rating is ignored. Figure I-146b shows the ratio of LRFR ratings including the longitudinal steel rating divided by the LRFR rating when the longitudinal steel rating is ignored.



(a) (b)

Figure I-146: Effect of Longitudinal Steel Rating on LRFR Moment Ratings

I.2.2.1.4 Rating Factor Comparisons

The ratio of the rating factors, LRFR to LFR, is shown in Figure I-147. The results indicated that 100% of the girders in this set have LFR ratings greater than LRFR ratings. The ratio of ratings is generally less than 0.6.

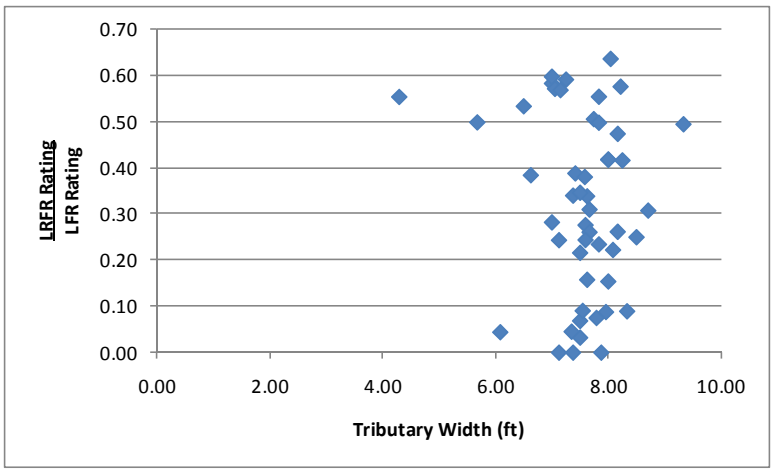


Figure I-147: Ratio of LRFR Flexure Rating to LFR Flexure Rating for Design Loadings

Figure I-148 shows the percentage of girders with LRFR ratings less than 1.0 in each category. The figure shows that almost all girders are significantly affected by the switch from LFR to LRFR. Most girders will have at least a 40% reduction in rating when switching to LRFR. Most of these girders are affected by the longitudinal steel rating.

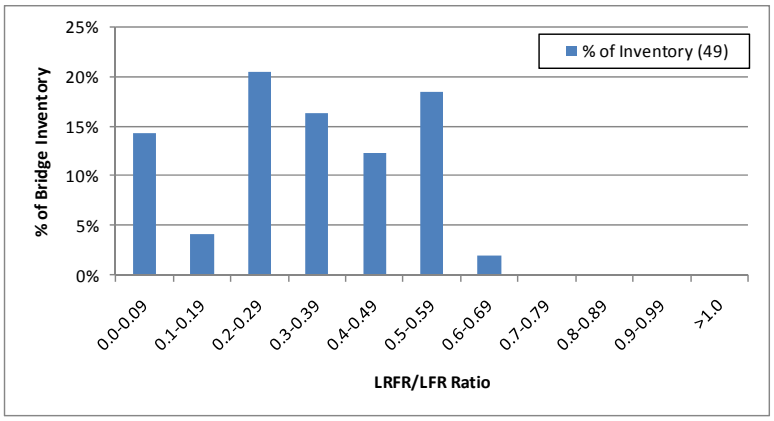


Figure I-148: Distribution of LRFR/LFR Ratio for Girders with LRFR Ratings less than 1.0

I.2.2.1.5 Reliability Indices

The next scatter plot is that of the reliability indices. Figure I-149 shows nine girders have a reliability index less than the target reliability of 3.5. Most girders have a reliability index of zero; these are the girders controlled by the longitudinal steel rating.

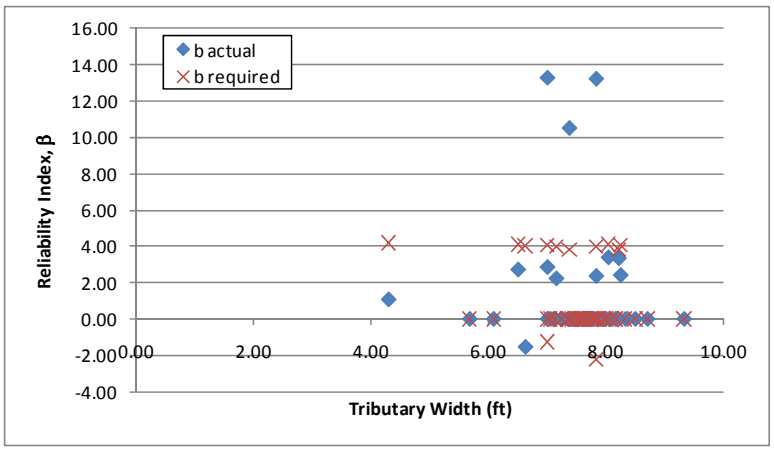


Figure I-149: Flexure Reliability Indices for HL-93 Loading

Figure I-150 shows the reliability index for moment plotted against the LRFR moment rating for the HL-93 Design Load. Ignoring all the girders at zero, the reliability index increases with increasing ratings. The reliability index corresponding to an LRFR rating of 1.0 is approximately 3.5, the target reliability.

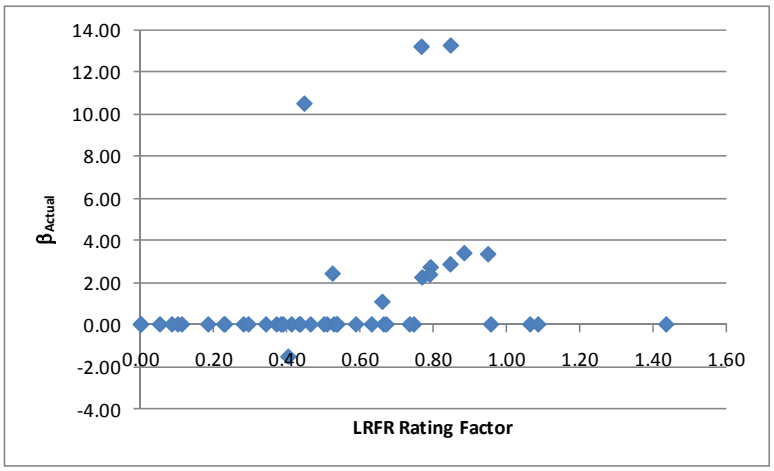
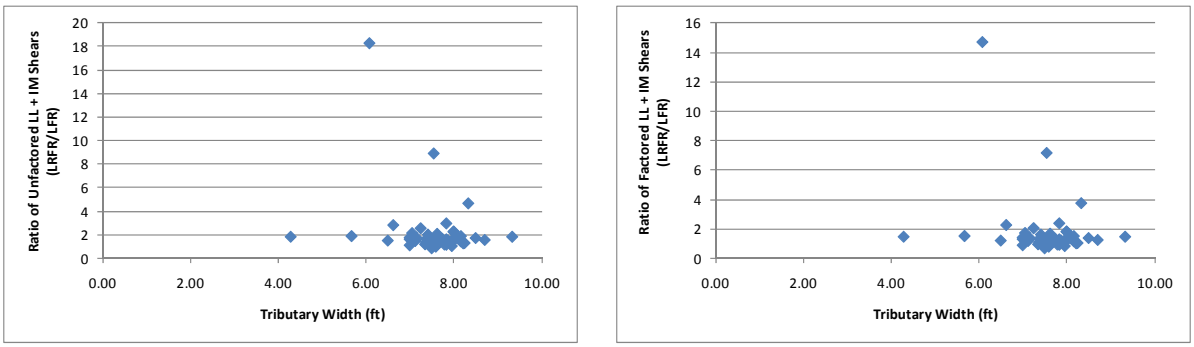


Figure I-150: Flexure Reliability Index vs LRFR Flexure Rating for HL-93 Vehicle

I.2.2.2 Shear

I.2.2.2.1 Live Loads

Figure I-151a shows that the ratio of unfactored shear varies significantly, with most girders between 1.0 and 2.0, with some outside this range. The next step was to compare the factored live loads. This was completed by multiplying the LFR live load by 2.17 and the LRFR live load by 1.75. These are the live load factors used in the rating factor equation for an inventory rating. Figure I-151b shows that the ratio of factored live load shears has decreased and is generally between 0.9 and 1.5 for most cases.



(a) (b)

Figure I-151: Ratios of Unfactored and Factored Live Load plus Impact Shears for Design Loadings (LRFR/LFR)

I.2.2.2.2 Resistance

The next step was to verify that the resistances were similar for the two methods. The LRFR resistance was obtained from the NCHRP 12-50 formatted data. The LFR resistance is not readily available in the NCHRP 12-50 data. Rather the LFR resistance was calculated by substituting the available values for DL shear components and LL shear in the rating factor equation and solving for the resistance. Figure I-152 shows that the ratio of resistance is generally greater than 1.0 (LRFR resistance is greater than LFR resistance). This is also an indication of the number of girders with varying critical locations. The same critical location should have a similar shear resistance whereas many of these are at or above two.

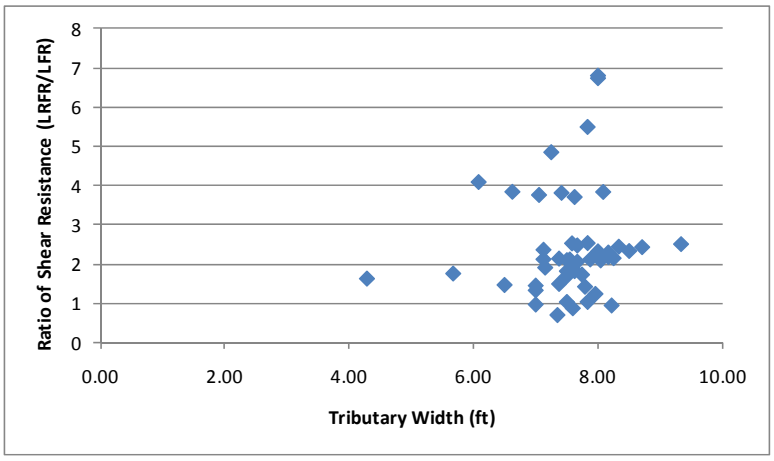
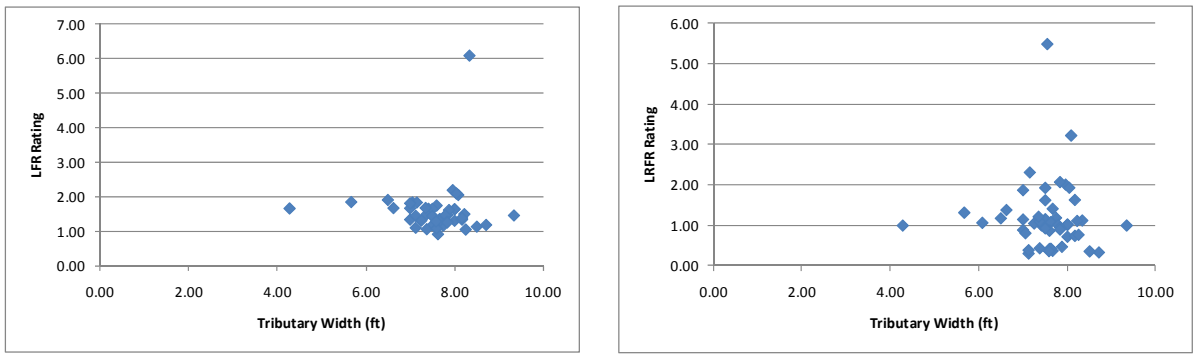


Figure I-152: Ratio of factored Shear Resistance (LRFR/LFR)

I.2.2.2.3 Rating Factors

After comparing the loads and resistances to verify that those results seemed appropriate, the rating factors were investigated. The purpose of this investigation was to determine how many girders within the subset had rating factors less than 1.0 for LFR, LRFR, or both LFR and LRFR. The results show that there is one girder with LFR ratings less than 1.0, 20 girders with LRFR ratings less than 1.0, and zero girders where both LFR and LRFR ratings are less than 1.0. The LFR rating was greater than the LRFR rating for 78% of the girders in this subset. Figure I-153 shows the LFR rating factors and LRFR rating factors. The LFR rating is generally between one and two while the LRFR rating is generally between 0.25 and 2.0. Two outliers were removed from the LFR rating graph; they had values of 23 and 25.



(a) (b)

Figure I-153: LFR and LRFR Shear Rating Factors for Design Loadings

I.2.2.2.4 Rating Factor Comparisons

Figure I-154 shows the ratio of the LRFR rating to the LFR rating. The ratio is generally between 0.2 and 1.0, with several above 1.0. 22% of girders have LRFR ratings greater than the LFR Rating.

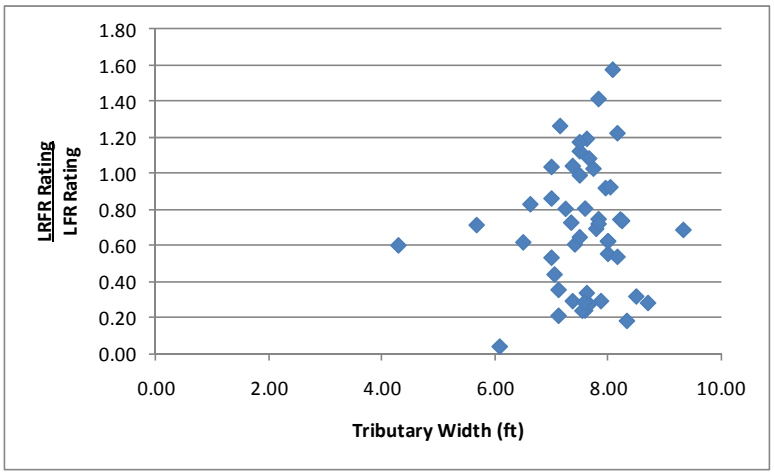


Figure I-154: Ratio of LRFR Shear Rating to LFR Shear Rating for Design Loadings

Figure I-155 shows the percentage of girders with LRFR ratings less than 1.0 plotted against the ratio of LRFR/LFR ratings. Numerous girders are affected by switching from LFR to LRFR and the affect is significant for most girders. Most of the girders with LRFR ratings less than 1.0 will have ratings that are at least 20% less than the LFR rating.

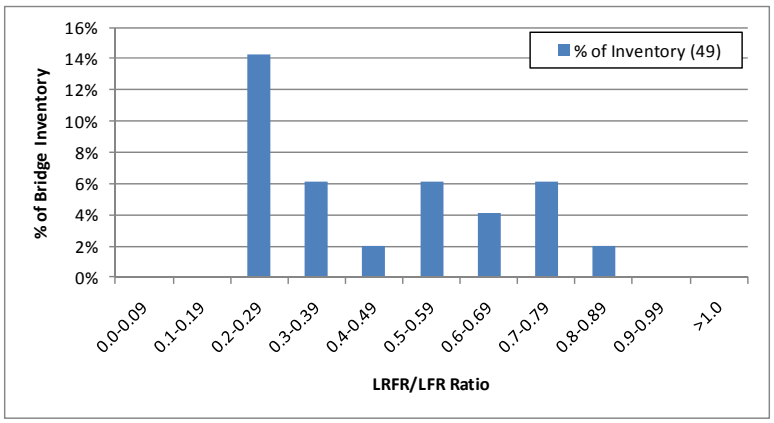


Figure I-155: Distribution of LRFR/LFR Ratio for Girders with LRFR Rating less than 1.0

I.2.2.2.5 Reliability Indices

The next scatter plot was that of the reliability indices. Figure I-156 shows one girder has a reliability index for shear less than the target reliability of 3.5. The reliability index is between six and eight for most girders.

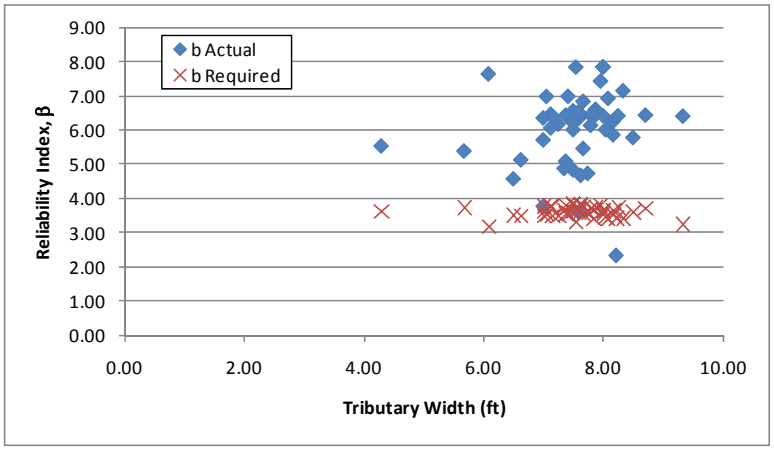


Figure I-156: Shear Reliability Indices for HL-93 Loading

Figure I-157 shows the reliability index for shear plotted against the LRFR shear rating for the HL-93 Design Load. The reliability index increases with increasing rating factors. A reliability index of 3.5 is associated with an LRFR rating of 1.0; this is the target reliability index. Girders with high reliability and low ratings are controlled by the shear friction rating; the reliability is calculated using the shear resistance not the shear friction resistance.

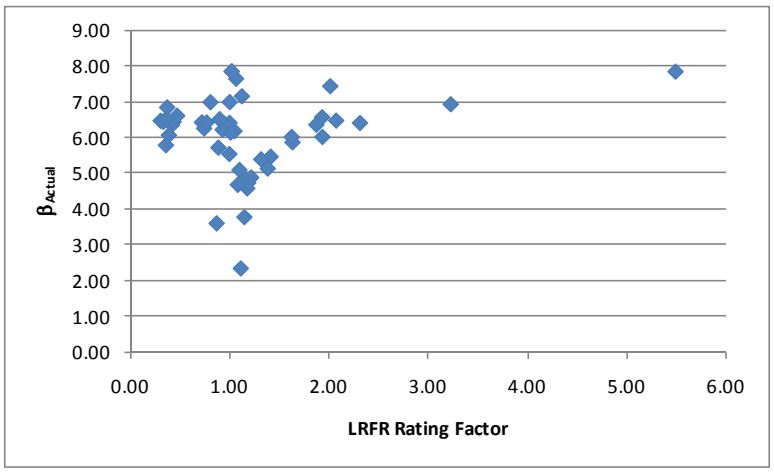


Figure I-157: Shear Reliability Index vs LRFR Shear Rating for HL-93 Design Loading

I.2.3 DE-07 Vehicle

The vehicle used in this section is the DE-07 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-158. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

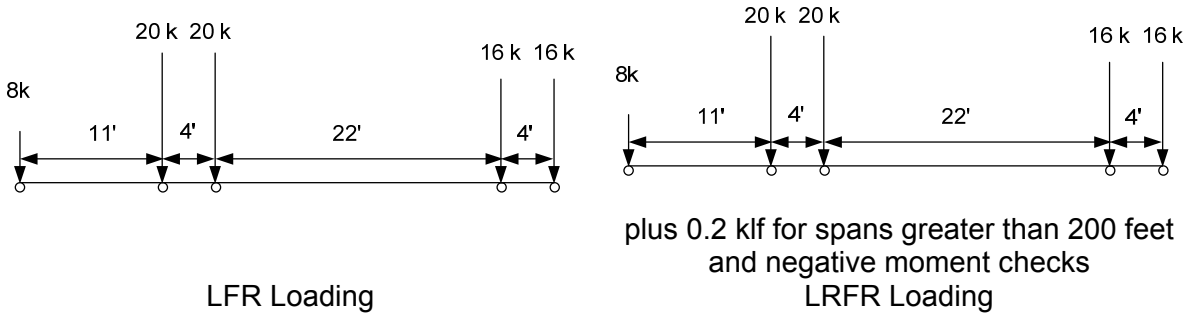


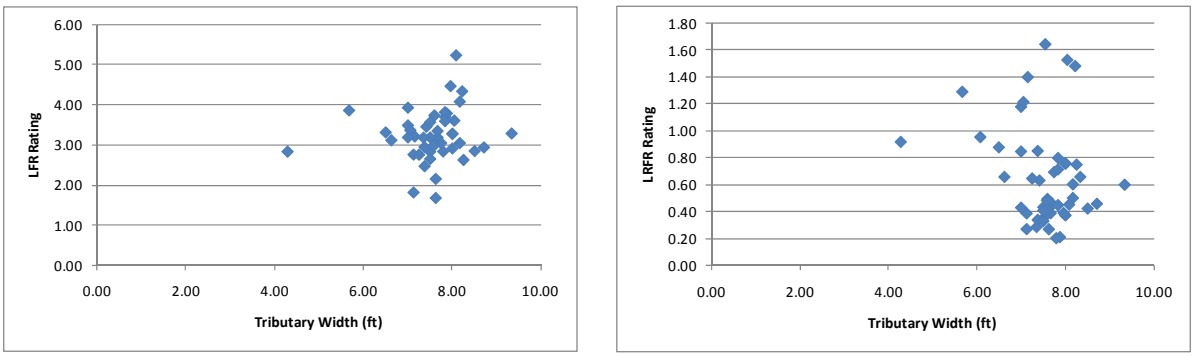
Figure I-158: Vehicle Loadings and Load Factors

I.2.3.1 Moment

The following section contains the results for exterior, composite prestressed I girders within continuous span bridges for the DE-07 Vehicle.

I.2.3.1.1 Rating Factors

Figure I-159 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 42 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 40 of the 42 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for all girders in this subset. The LFR rating is between 2.5 and 4 for most girders with the LRFR rating generally between 0.2 and 0.8. Three outliers were removed from the LFR graph with values of: 19, 40, and 60.



(a) (b)

Figure I-159: LFR and LRFR Flexure Rating Factors for DE-07 Vehicle

Figure I-160 shows the percentage of girders with moment ratings in each range for the DE-07 vehicle, a routine permit vehicle. 18.4% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 14.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 81.6% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 85.7% when an ADTT ≥ 5,000 is used.

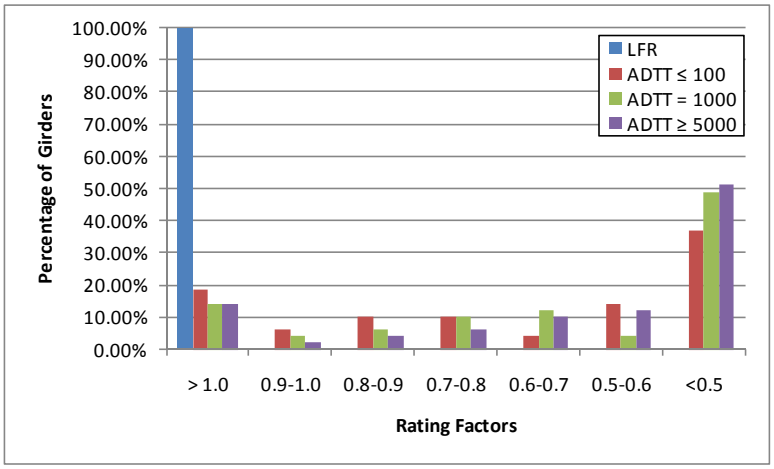


Figure I-160: Moment Ratings for Various ADTTs in MBE for DE-07 Vehicle

I.2.3.1.2 Rating Factor Comparisons

Figure I-161 shows the ratio of the LRFR rating divided by the LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally in the range of 0.05 to 0.35. There are no girders with LRFR ratings greater than the LFR rating for moment.

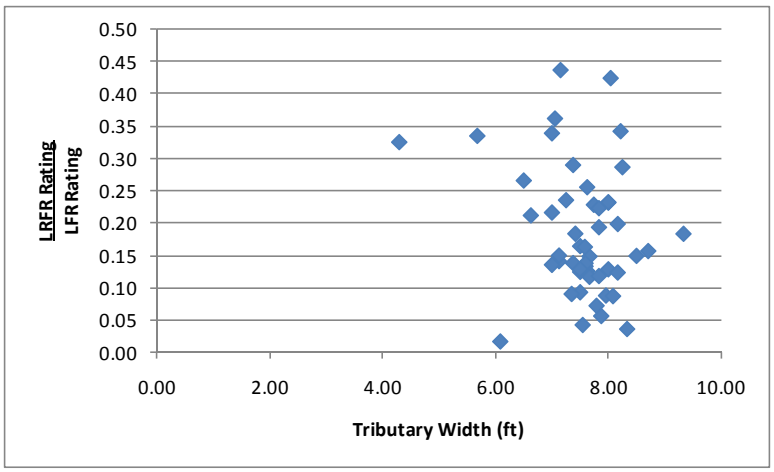


Figure I-161: LRFR Flexure rating divided by LFR Flexure rating for DE-07 Vehicle

I.2.3.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-162 shows that one girder has a reliability index less than the target reliability index of 2.5. The reliability index for most girders is between five and ten.

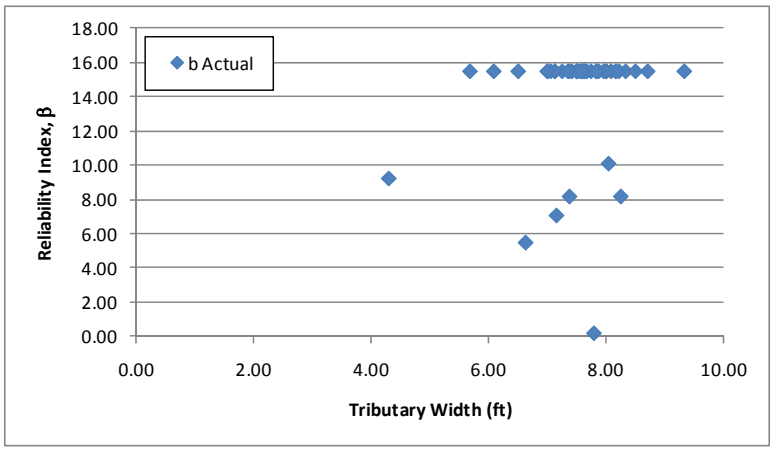


Figure I-162: Flexure Reliability Indices for DE-07 Vehicle

Figure I-163 shows the reliability index for moment plotted against the LRFR moment rating for the DE-07 Vehicle. The reliability index increases with LRFR rating. A reliability index of 8 corresponds to an LRFR rating of 1.0. This is significantly above the target reliability index and suggests that the rating and reliability index for the longitudinal steel rating should not be used to gage the accurateness of the current LRFR live load factors. 46 of the 49 girders are controlled by the longitudinal steel rating.

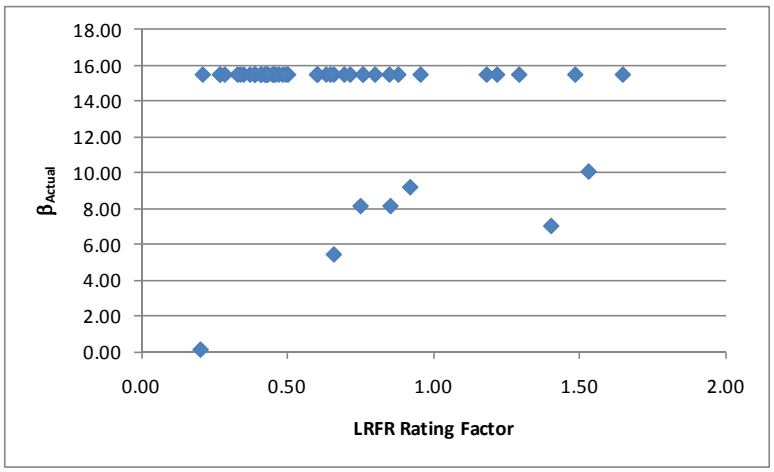
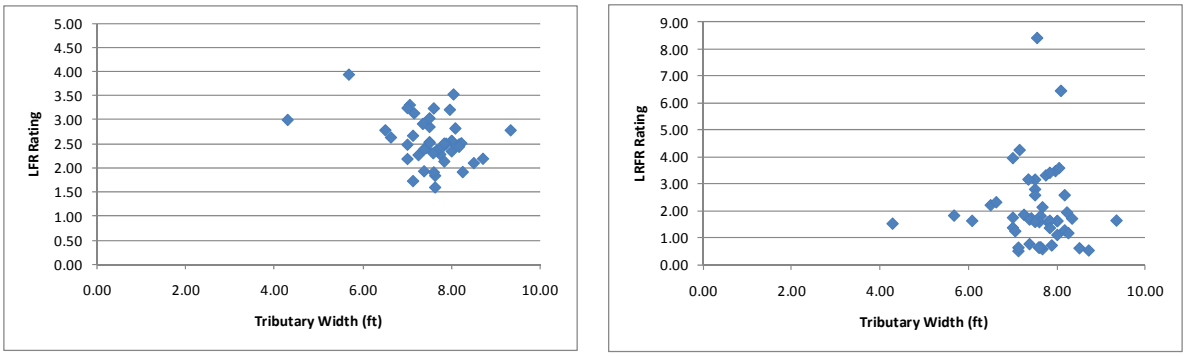


Figure I-163: Flexure Reliability Index vs LRFR Flexure Rating for DE-07 Vehicle

I.2.3.2 Shear

I.2.3.2.1 Rating Factors

For shear, there are zero girders that have rating factors less than 1.0 for LFR, 10 girders for LRFR, and zero girders where both LFR and LRFR are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure I-164 shows the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 3.5, with the LRFR rating generally between 0.5 and 4.0. Three girders were removed from the LFR graph as outliers with values of 10, 41, and 44.



(a) (b)

Figure I-164: LFR and LRFR Shear Ratings for DE-07 Vehicle

Figure I-165 shows the percentage of girders with shear ratings in each range for the DE-07 vehicle, a routine permit vehicle. 79.6% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 77.6% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 20.4% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 22.4% when an ADTT ≥ 5,000 is used.

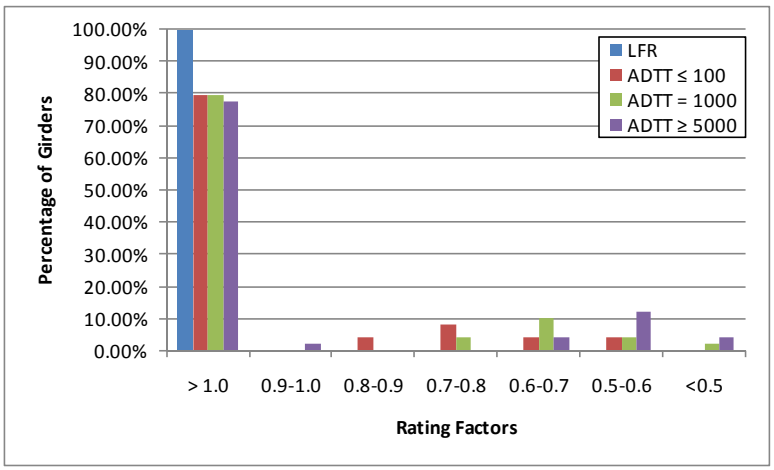


Figure I-165: Shear Ratings for Various ADTTs in MBE for DE-07 Vehicle

I.2.3.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating and examining the ratio. Figure I-166 show the comparison of rating factors. The ratio is generally between 0.5 and 1.5. The LRFR rating is greater than the LFR rating for 24% of the girders for this vehicle.

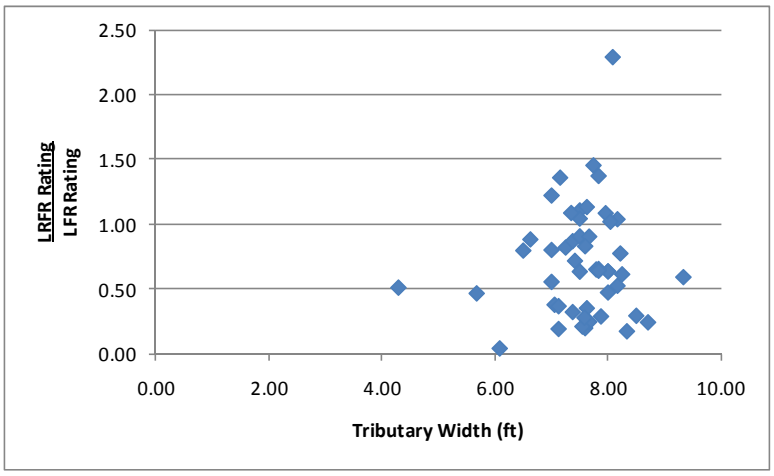


Figure I-166: LRFR Shear Rating divided by LFR Shear Rating for DE-07 Vehicle

I.2.3.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-167. The reliability index is between six and eight for most girders.

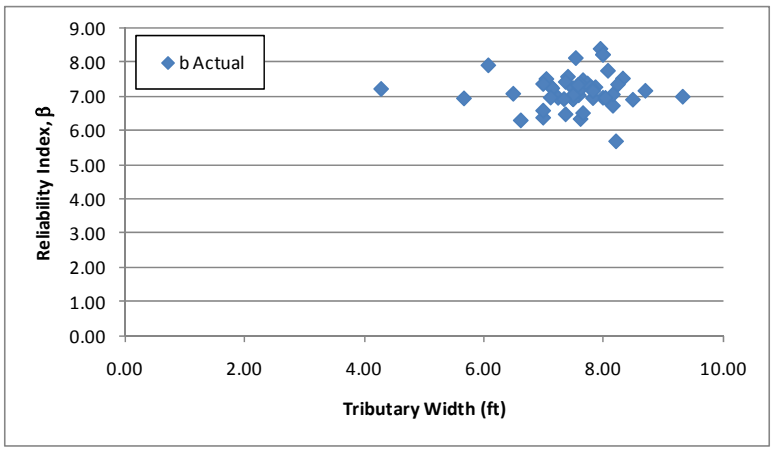


Figure I-167: Shear Reliability Indices for DE-07 Vehicle

Figure I-168 shows the shear reliability index plotted against the LRFR shear rating for the DE-07 vehicle. The reliability index increases with increasing LRFR ratings. A reliability index of approximately 4.0 corresponds to an LRFR rating of 1.0. This is above the target reliability index and may indicate that the LRFR live load factors are too conservative. Girders with high reliability and low ratings are typically controlled by the shear friction rating; the reliability index is calculated using the shear resistance not the shear friction resistance.

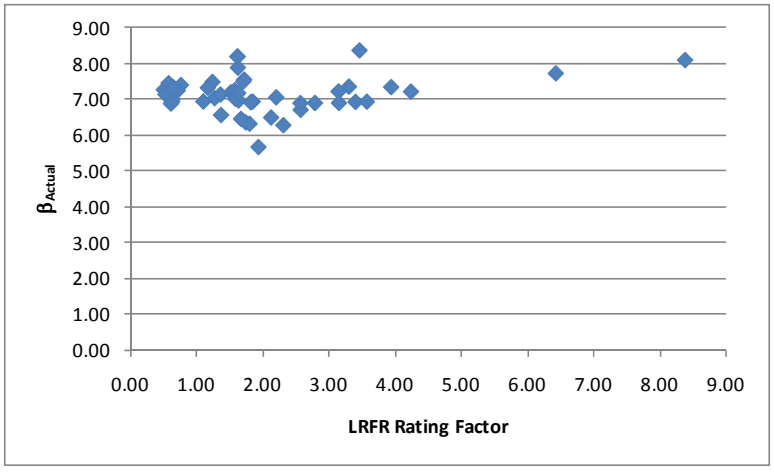
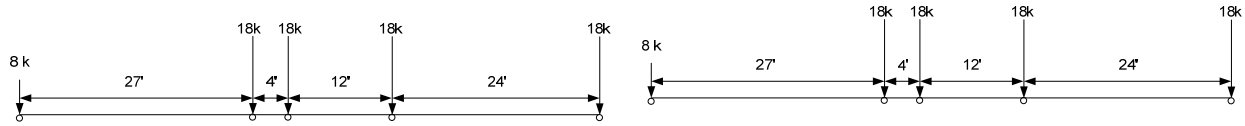


Figure I-168: Shear Reliability Index vs LRFR Shear Rating for DE-07 Vehicle

I.2.4 FL-04 Vehicle

The vehicle used in this section is the FL-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-169. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LFR Loading LRFR Loading

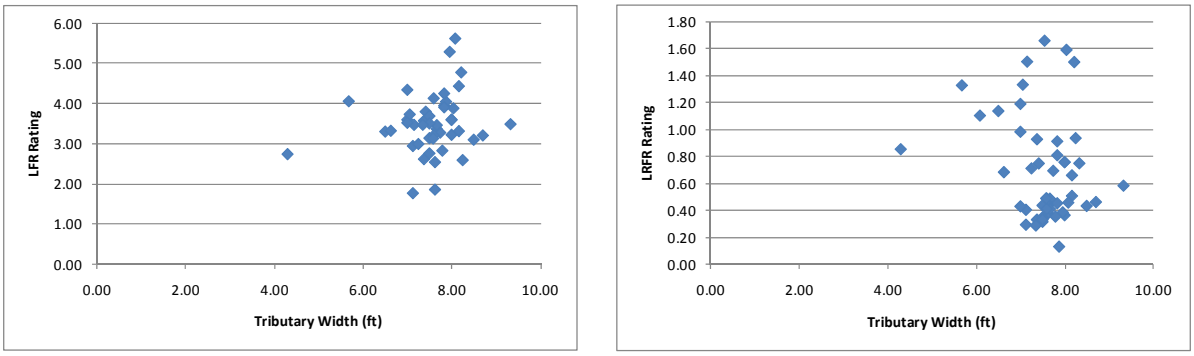
Figure I-169: Vehicle Loadings and Load Factors

I.2.4.1 Moment

The following section contains the results for exterior, composite prestressed I girders within continuous span bridges for the FL-04 Vehicle.

I.2.4.1.1 Rating Factors

Figure I-170 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 40 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 39 of the 40 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is generally between 2.5 and 4.0, while the LRFR rating is generally between 0.2 and 1.0. Three outliers were removed from the LFR graph with values of 20, 42, and 65.



(a) (b)

Figure I-170: LFR and LRFR Flexure Rating Factors for FL-04 Vehicle

Figure I-171 shows the percentage of girders with moment ratings in each range for the FL-04 vehicle, a routine permit vehicle. 24.5% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 16.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 75.5% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 83.7% when an ADTT ≥ 5,000 is used.

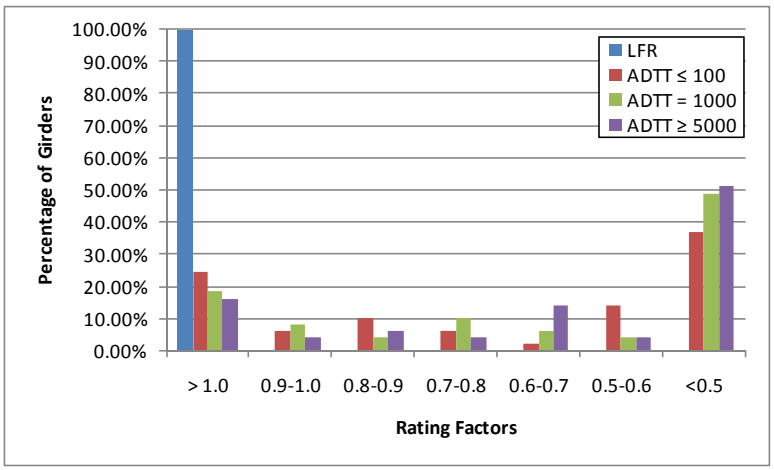


Figure I-171: Moment Ratings for Various ADTTs in MBE for FL-04 Vehicle

I.2.4.1.2 Rating Factor Comparisons

Figure I-172 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The LRFR rating is less than 45% of the LFR rating for all girders. No girders have an LRFR rating that is greater than the LFR rating.

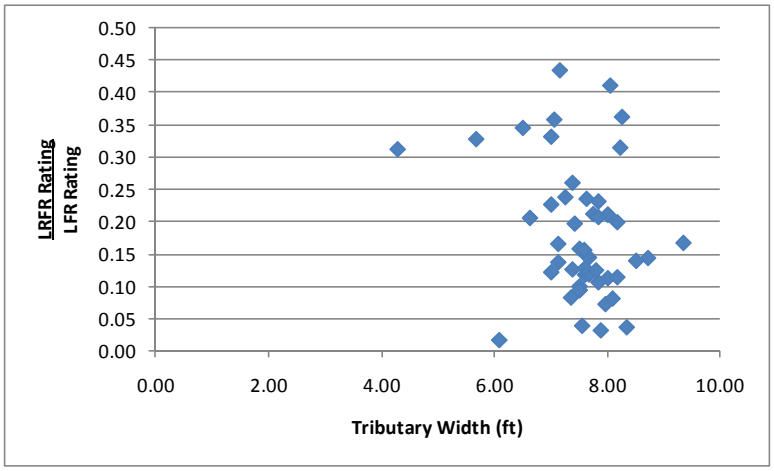


Figure I-172: LRFR Flexure rating divided by LFR Flexure rating for FL-04 Vehicle

I.2.4.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-173 shows that one girder has a reliability index less than the target reliability index of 2.5. The reliability index is between six and ten for most girders.

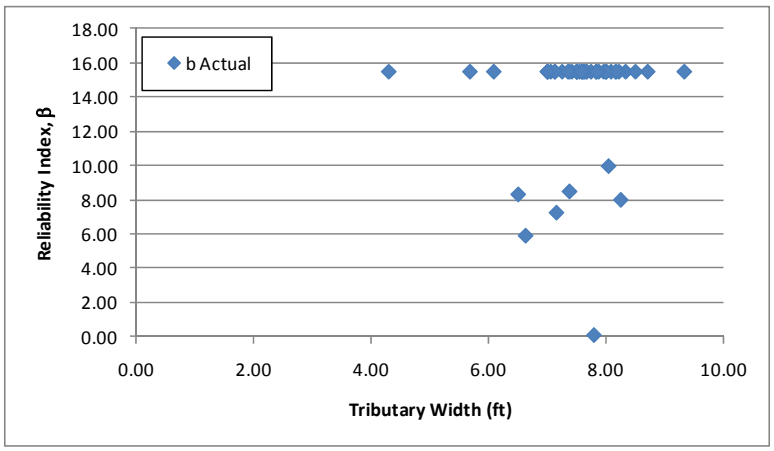


Figure I-173: Flexure Reliability Indices for FL-04 Vehicle

Figure I-174 shows the reliability index for moment plotted against the LRFR moment rating for the FL-04 vehicle. The reliability index increases with increasing rating factors; the reliability index associated with an LRFR rating of 1.0 is approximately six. This is above the target reliability index of 2.5 and suggests that the longitudinal steel rating should not be used to verify the correctness of the LRFR live load factors currently in the MBE.

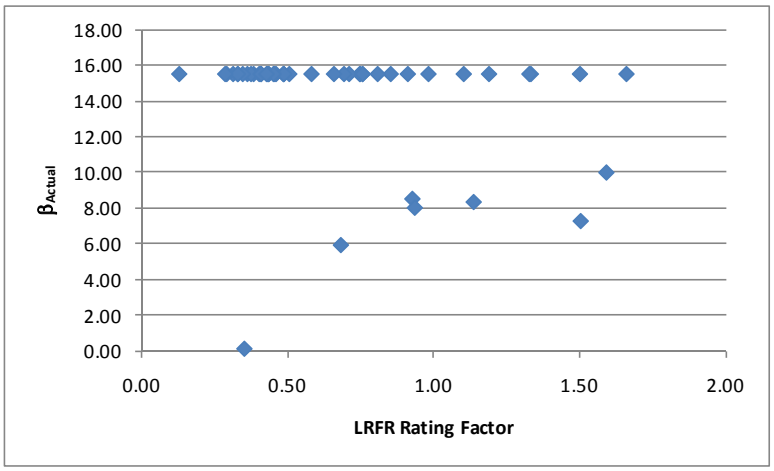
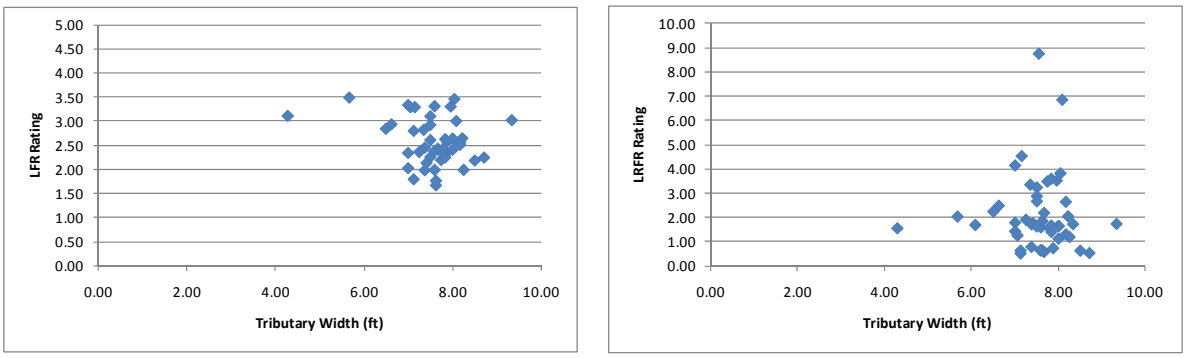


Figure I-174: Flexure Reliability Index vs LRFR Flexure Rating for FL-04 Vehicle

I.2.4.2 Shear

I.2.4.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, 10 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure I-175 shows the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 3.5; the LRFR rating is typically between 0.5 and 2.0. Three outliers were removed from the LFR graph with values of 10, 42, and 45.



(a) (b)

Figure I-175: LFR and LRFR Shear Ratings for FL-04 Vehicle

Figure I-176 shows the percentage of girders with shear ratings in each range for the FL-04 vehicle, a routine permit vehicle. 79.6% of girders have LRFR ratings greater than 1.0 for all ADTTs. 100% of girders have LFR ratings that are greater than 1.0. The switch from LFR to LRFR results in 20.4% more girders with ratings less than 1.0 for all ADTT values.

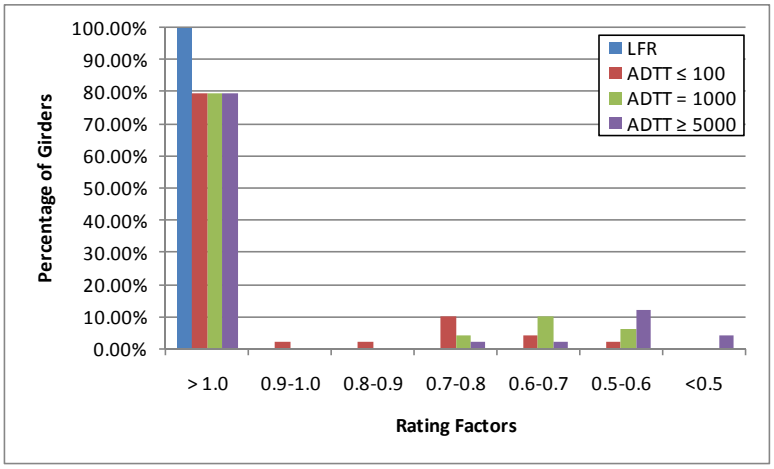


Figure I-176: Shear Ratings for Various ADTTs in MBE for FL-04 Vehicle

I.2.4.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-177 shows the comparison of rating factors. The ratio is very scattered with no clear trends. 24% of girders have LRFR ratings that are greater than the LFR rating for this vehicle.

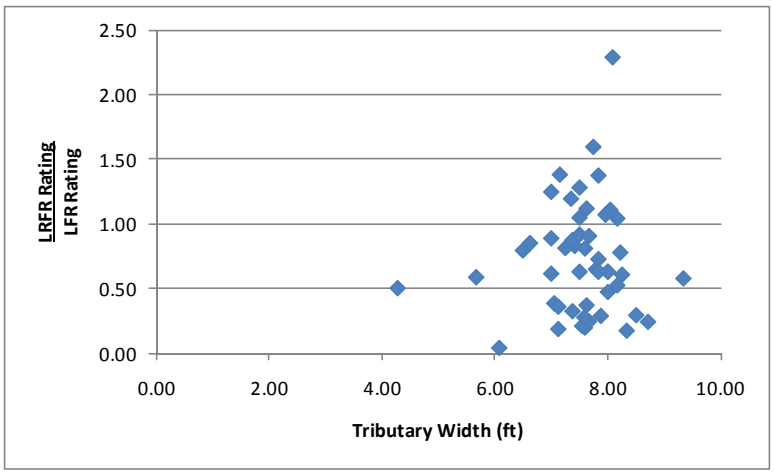


Figure I-177: LRFR Shear Rating divided by LFR Shear Rating for FL-04 Vehicle

I.2.4.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-178. The reliability index is between six and eight for most girders.

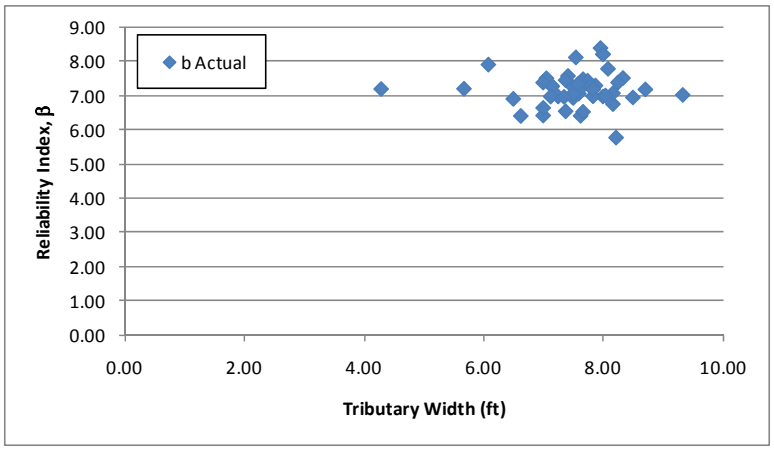


Figure I-178: Shear Reliability Indices for FL-04 Vehicle

Figure I-179 shows the reliability index for shear plotted against the LRFR shear rating for the FL-04 Vehicle. A reliability index of approximately 4.0 corresponds to an LRFR rating of 1.0; this is above the target reliability index of 2.5. This may indicate that the LRFR live load factors may be over-conservative. Girders with high reliability and low rating are controlled by the shear friction rating; the reliability index is calculated using the shear resistance not the shear friction resistance.

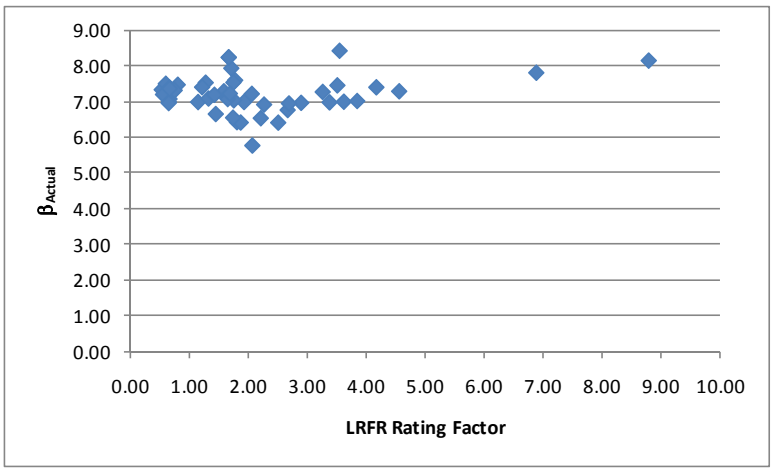


Figure I-179: Shear Reliability Index vs LRFR Shear Rating for FL-04 Vehicle

I.2.5 IL-01 Vehicle

The vehicle used in this section is the IL-01 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-180. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.

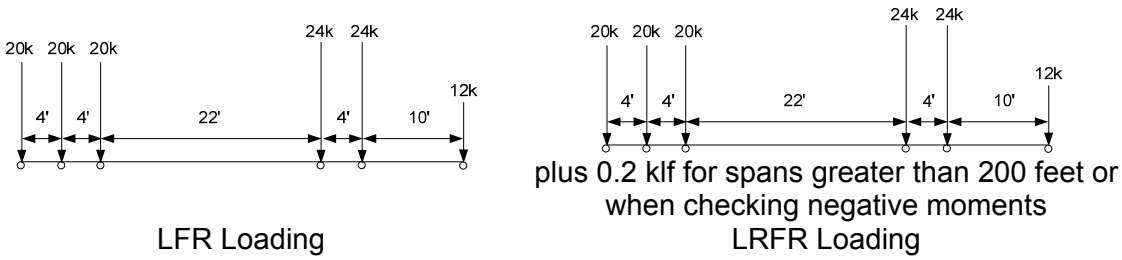


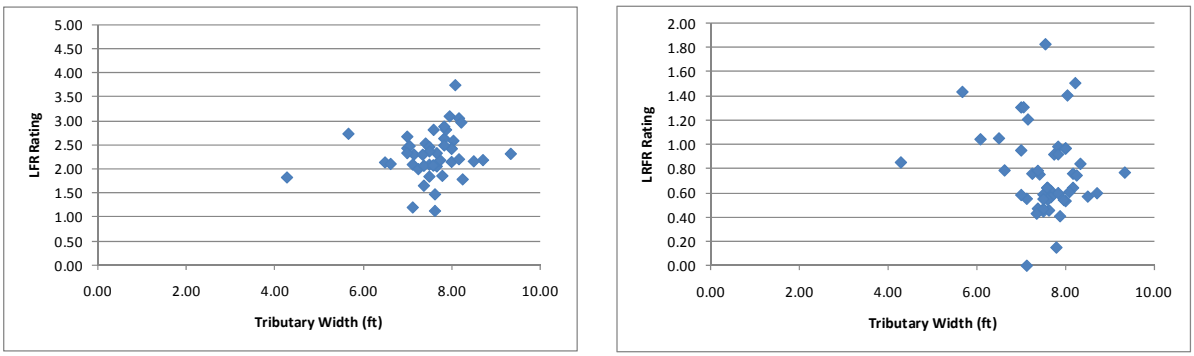
Figure I-180: Vehicle Loadings and Load Factors

I.2.5.1 Moment

The following section contains the results for exterior, composite prestressed I girders within continuous span bridges for the IL-01 Vehicle.

I.2.5.1.1 Rating Factors

Figure I-181 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 40 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 37 of the 40 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 100% of the girders in this subset. The LFR rating is generally between 2.0 and 3.0, while the LRFR rating is generally between 0.4 and 1.0. Three outliers were removed from the LFR rating graph with values of 13, 27, and 41.



(a) (b)

Figure I-181: LFR and LRFR Flexure Rating Factors for IL-01 Vehicle

Figure I-182 shows the percentage of girders with moment ratings in each range for the IL-01 vehicle, a special permit vehicle. 30.6% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 10.2% for the multi-trip permit with an ADTT ≥ 5,000 category. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 69.4% more girders with ratings less than 1.0 when a single trip, escorted permit is used; this increases to 89.8% when the multi-trip permit with an ADTT ≥ 5,000 is used.

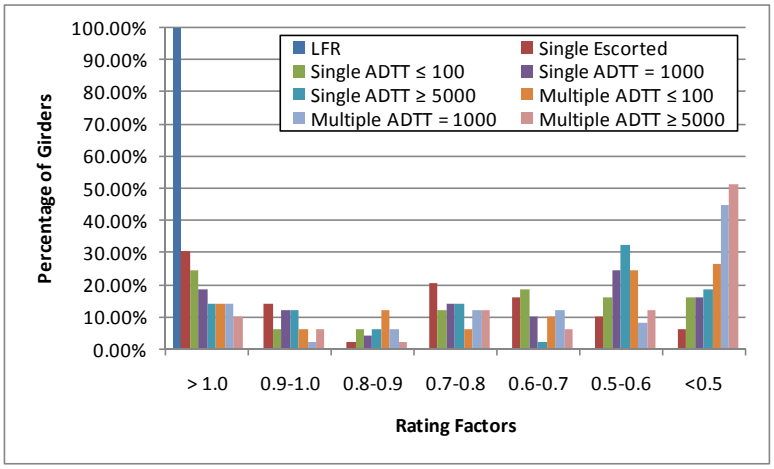


Figure I-182: Moment Ratings for Various ADTTs in MBE for IL-01 Vehicle

I.2.5.1.2 Rating Factor Comparisons

Figure I-183 shows the ratio of LRFR rating to LFR ratings. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.4, with significant scatter in the data. There are no girders with an LRFR rating that is greater than the LFR rating.

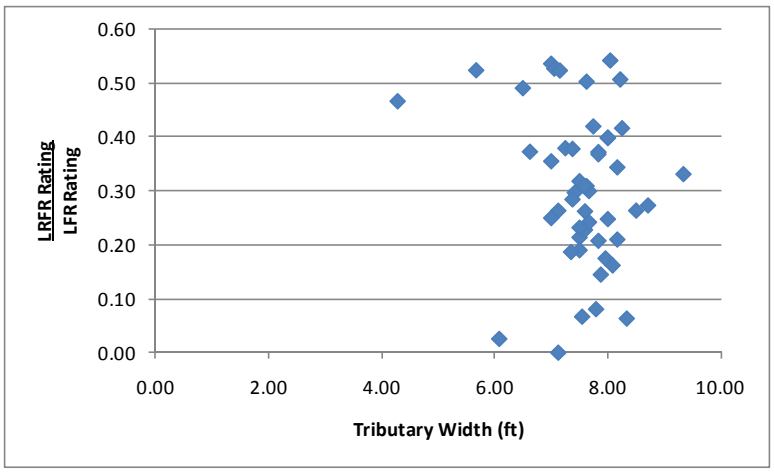


Figure I-183: LRFR Flexure rating divided by LFR Flexure rating for IL-01 Vehicle

I.2.5.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-184 shows that one girder has a reliability index less than the target reliability index of 3.5. The reliability index is between 7 and 10 for most girders not controlled by the longitudinal steel rating.

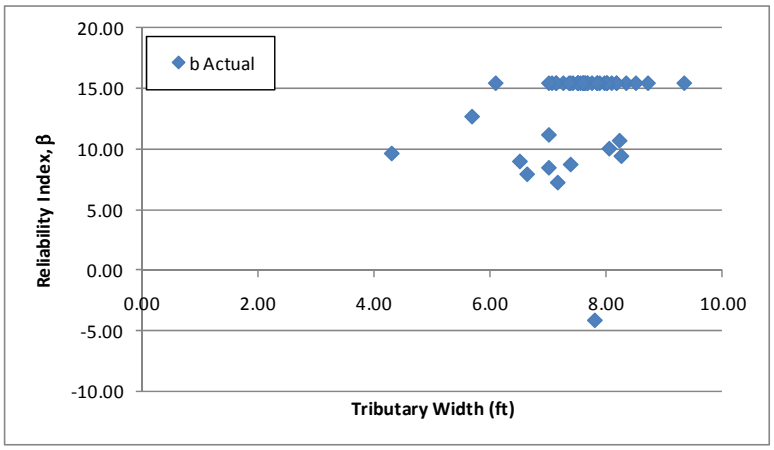


Figure I-184: Flexure Reliability Indices for IL-01 Vehicle

Figure I-185 shows the reliability index for moment plotted against the LRFR moment rating for the IL-01 vehicle. The reliability index increases slightly with increasing ratings. An LRFR rating of 1.0 corresponds to a reliability index of approximately nine, above the target reliability of 3.5. This indicates that utilizing the results for the longitudinal steel rating to check the correctness of the LRFR live load factors in the MBE.

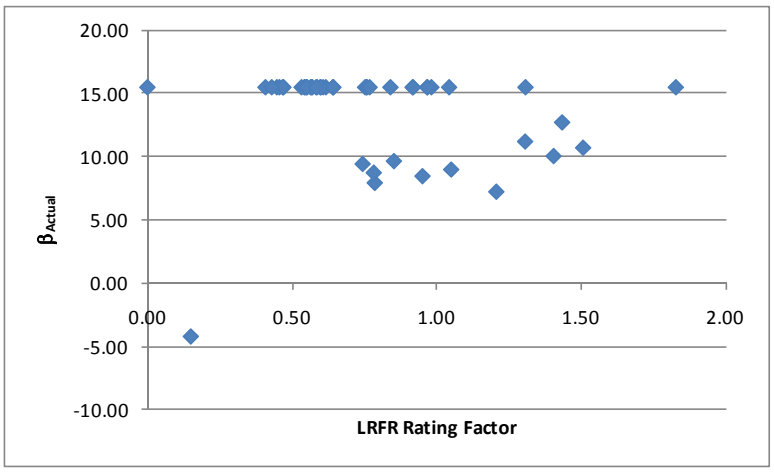
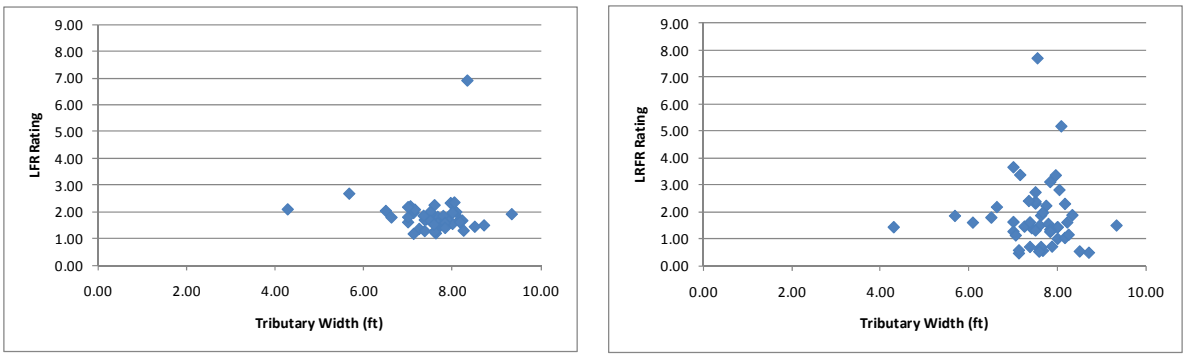


Figure I-185: Flexure Reliability Index vs LRFR Flexure Rating for IL-01 Vehicle

I.2.5.2 Shear

I.2.5.2.1 Rating Factors

For shear, there are zero girders that have an LFR rating factor less than 1.0, 11 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 63% of the girders in this subset. Figure I-186 shows the LFR and LRFR ratings. The LFR rating is generally between 1.0 and 2.25 for all tributary widths, while for LRFR the rating is generally between 0.5 and 3.0. Two outliers were removed from the LFR graph with values of 28 and 29.



(a) (b)

Figure I-186: LFR and LRFR Shear Ratings for IL-01 Vehicle

Figure I-187 shows the percentage of girders with shear ratings in each range for the IL-01 vehicle, a special permit vehicle. 79.6% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 65.3% for a multiple trip permit with ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 20.4% more girders with ratings less than 1.0 when a single trip, escorted permit is used; this increases to 34.7% when a multiple trip permit with ADTT ≥ 5,000 is used.

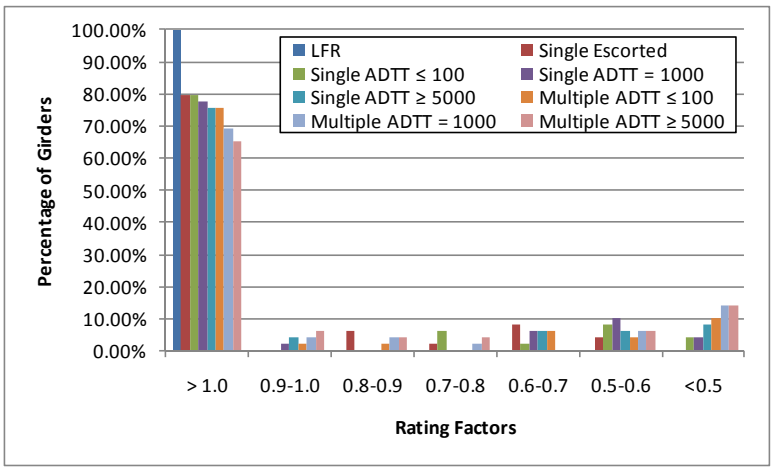


Figure I-187: Shear Ratings for Various ADTTs in MBE for IL-01 Vehicle

I.2.5.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-188 shows the comparison of rating factors. Most girders have a ratio that is between 0.25 and 1.5. The LRFR rating factor is greater than LFR rating factor for 37% of the girders in this group.

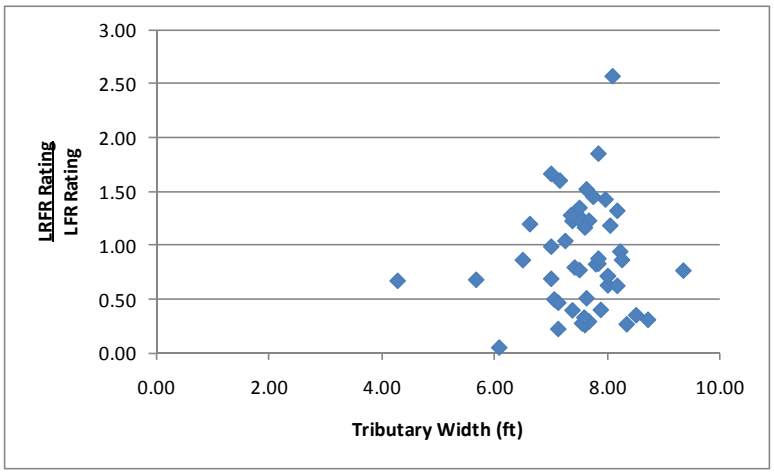


Figure I-188: LRFR Shear Rating divided by LFR Shear Rating for IL-01 Vehicle

I.2.5.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all girders as shown in Figure I-189. The reliability index is between six and eight for most girders.

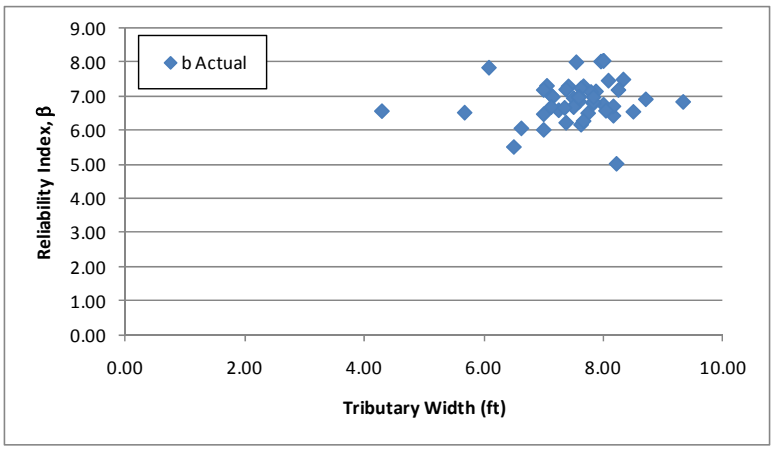


Figure I-189: Shear Reliability Indices for IL-01 Vehicle

Figure I-190 shows the reliability index for shear plotted against the LRFR shear rating for the IL-01 vehicle. The reliability index increases with increasing LRFR ratings. An LRFR rating of 1.0 corresponds to a reliability index of approximately 4.0, above the target reliability of 3.5. This indicates the LRFR live load factors may be over-conservative.

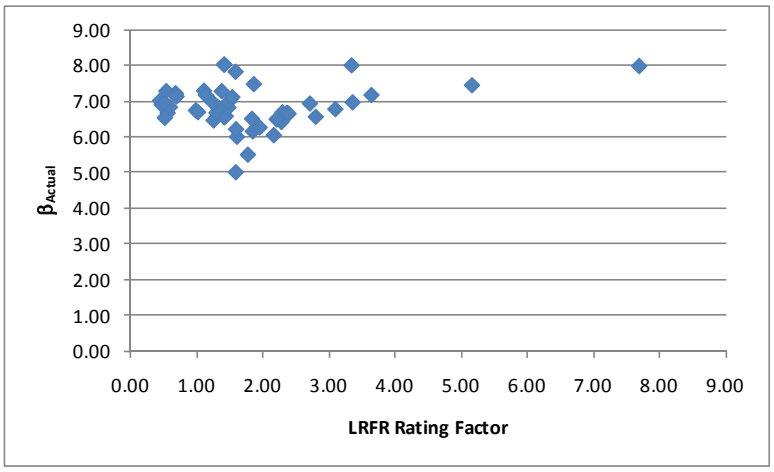


Figure I-190: Shear Reliability Index vs LRFR Shear Rating for IL-01 Vehicle

I.2.6 NC-21 Vehicle

The vehicle used in this section is the NC-21 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-191. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

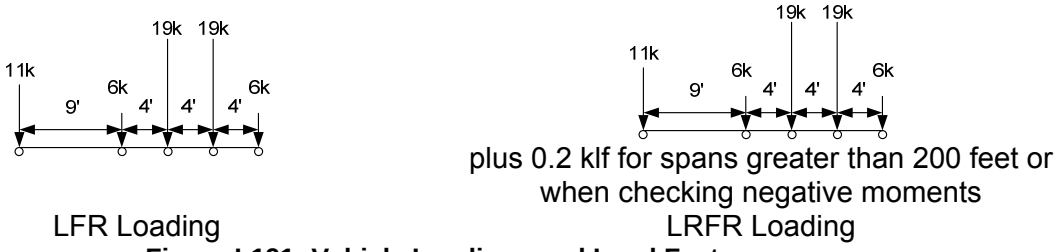


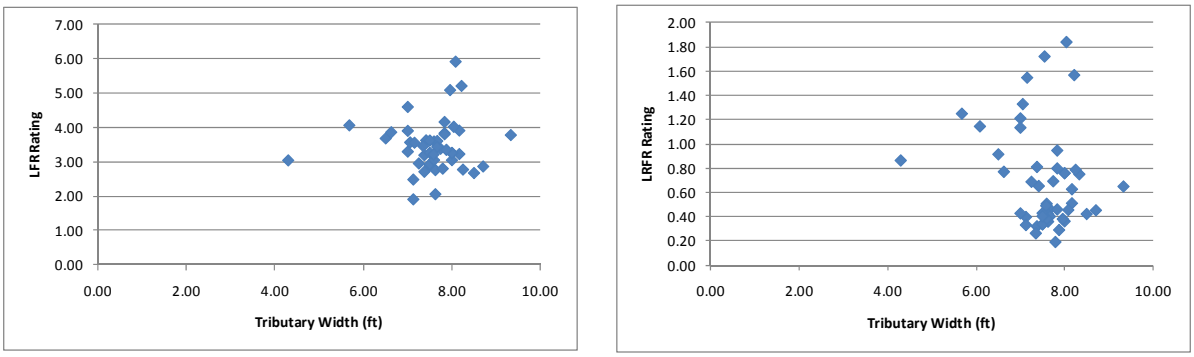
Figure I-191: Vehicle Loadings and Load Factors

I.2.6.1 Moment

The following section contains the results for exterior, composite prestressed I girders within continuous span bridges for the NC-21 Vehicle.

I.2.6.1.1 Rating Factors

Figure I-192 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 40 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 38 of the 40 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is generally between 2.5 and 4.0, while the LRFR rating is generally between 0.2 and 0.8. Three girders were removed as outliers from the LFR rating graph; the values were 19, 42, and 67.



(a) (b)

Figure I-192: LFR and LRFR Flexure Rating Factors for NC-21 Vehicle

Figure I-193 shows the percentage of girders with moment ratings in each range for the NC-21 vehicle, a routine permit vehicle. 22.5% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 18.4% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 77.5% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 81.6% when an ADTT ≥ 5,000 is used.

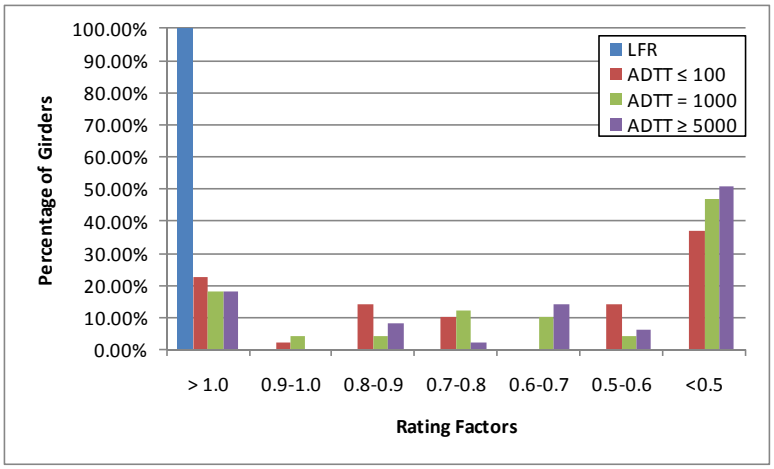


Figure I-193: Moment Ratings for Various ADTTs in MBE for NC-21 Vehicle

I.2.6.1.2 Rating Factor Comparisons

Figure I-194 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally less than 0.4 for this vehicle. There are no girders with LRFR ratings greater than the LFR rating.

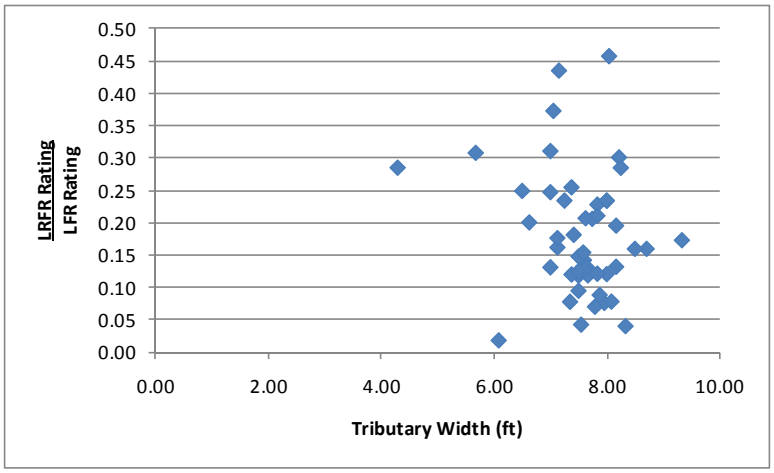


Figure I-194: LRFR Flexure rating divided by LFR Flexure rating for NC-21 Vehicle

I.2.6.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-195 shows that one girder has a reliability index less than the target reliability index of 2.5. The reliability index is between six and ten for most girders.

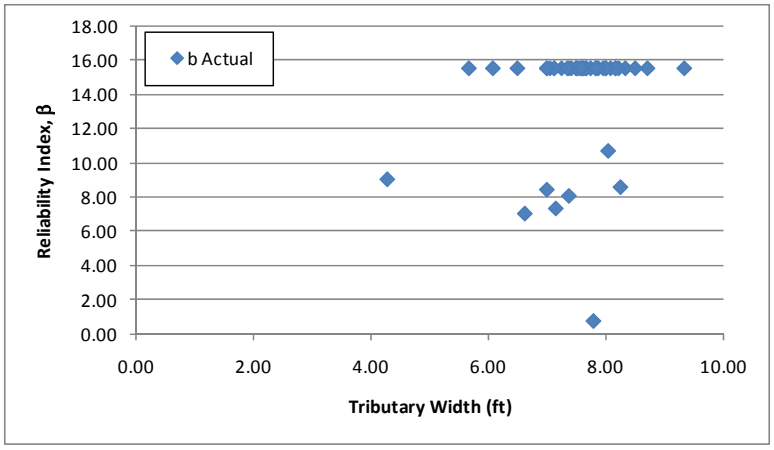


Figure I-195: Flexure Reliability Indices for NC-21 Vehicle

Figure I-196 shows the reliability index for moment plotted against the LRFR moment rating for the NC-21 vehicle. The reliability index increases with increasing LRFR ratings and has a value of approximately seven for an LRFR rating of 1.0. This indicates that using the longitudinal steel rating is not an accurate rating to calibrate the LRFR live load factors.

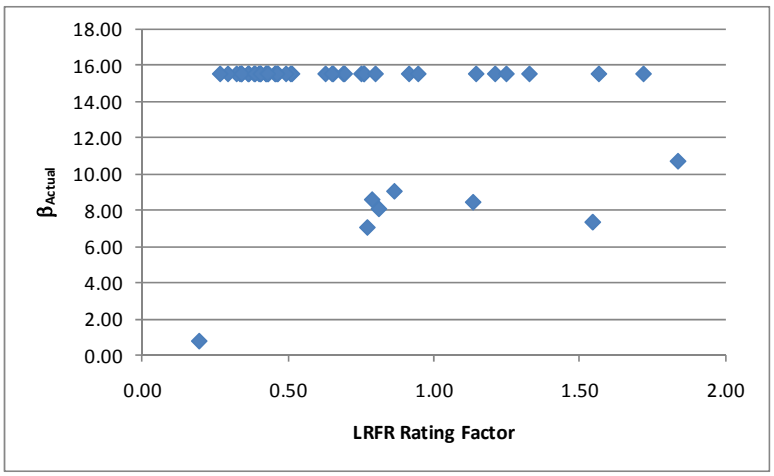
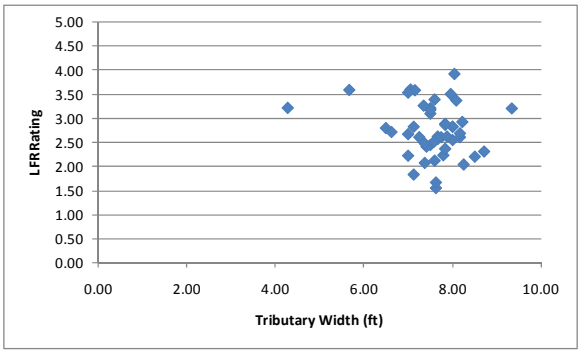


Figure I-196: Flexure Reliability Index vs LRFR Flexure Rating for NC-21 Vehicle

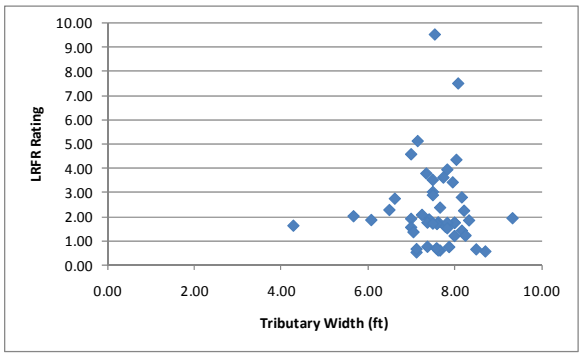
I.2.6.2 Shear

I.2.6.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, 10 girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure I-197 shows the LFR and LRFR ratings. The LFR rating is generally between 2 and 3.5 while the LRFR rating is generally between 0.5 and 3.0. Three outliers were removed from the LFR rating graph with values of 11, 44, and 49.



(a)



(b)

Figure I-197: LFR and LRFR Shear Ratings for NC-21 Vehicle

Figure I-198 shows the percentage of girders with shear ratings in each range for the NC-21 vehicle, a routine permit vehicle. 79.6% of girders have LRFR ratings greater than 1.0 for all ADTTs. 100% of girders have LFR ratings that are greater than 1.0. The switch from LFR to LRFR results in 20.4% more girders with ratings less than 1.0 for all ADTTs.

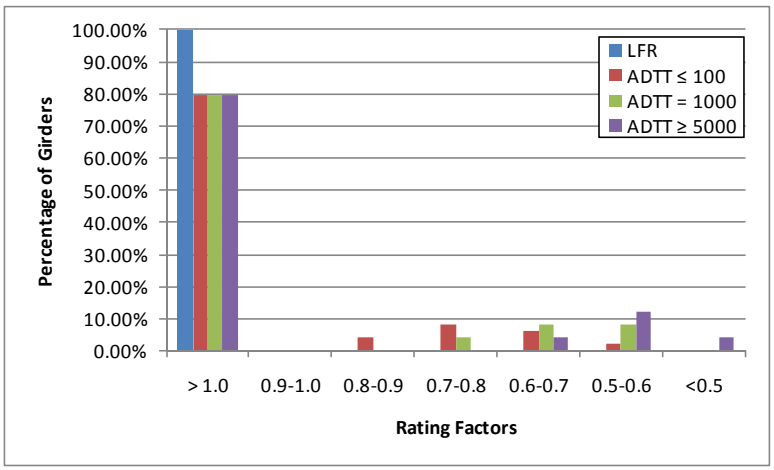


Figure I-198: Shear Ratings for Various ADTTs in MBE for NC-21 Vehicle

I.2.6.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-199 shows the comparison of rating factors. The ratio is generally between 0.25 and 1.5. 24% of the girders have LRFR ratings that are greater than the LFR rating for the NC-21 Vehicle.

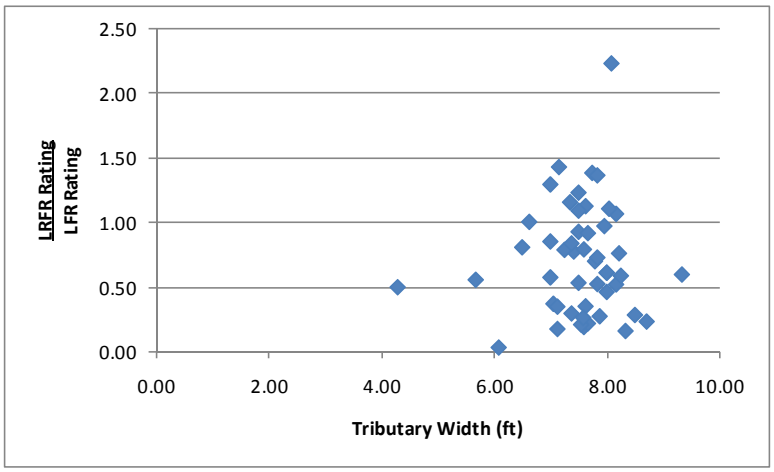


Figure I-199: LRFR Shear Rating divided by LFR Shear Rating for NC-21 Vehicle

I.2.6.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-200. The reliability index is between six and eight for most girders.

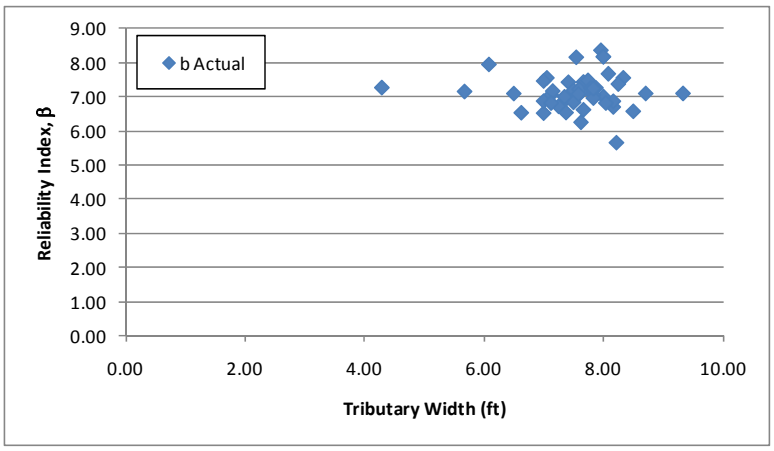


Figure I-200: Shear Reliability Indices for NC-21 Vehicle

Figure I-201 shows the reliability index for shear plotted against the LRFR shear rating for the NC-21 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately 4.5, above the target reliability of 2.5. This indicates the LRFR live load factors may be over-conservative. There are several girders with high reliability and low ratings; these girders are controlled by the shear friction rating. The reliability index is calculated using the shear resistance instead of the shear friction resistance.

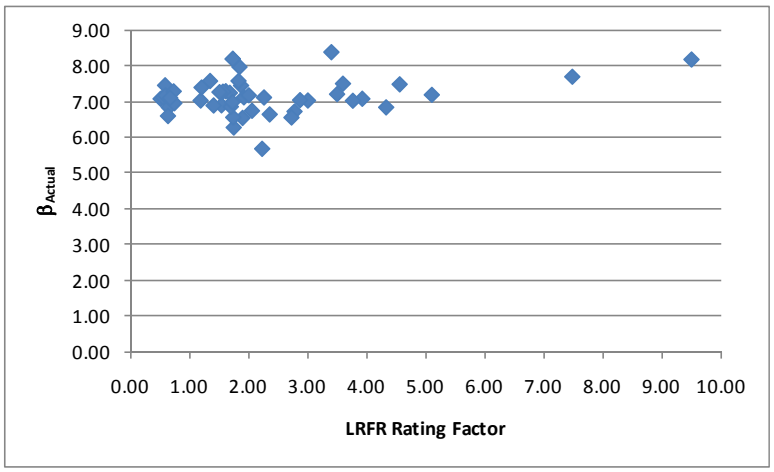


Figure I-201: Shear Reliability Index vs LRFR Shear Rating for NC-21 Vehicle

I.2.7 NM-04 Vehicle

The vehicle used in this section is the NM-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-202. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

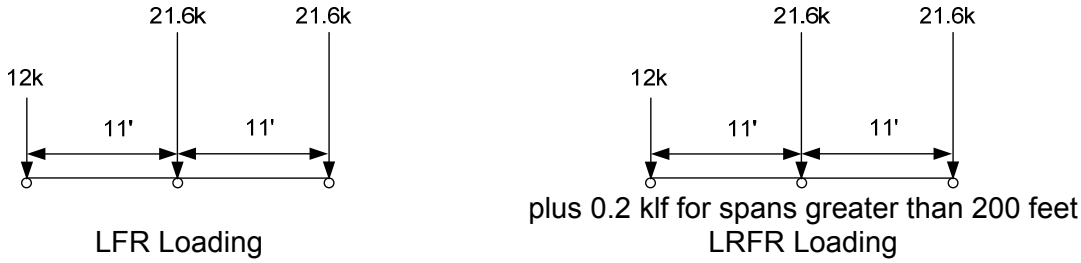


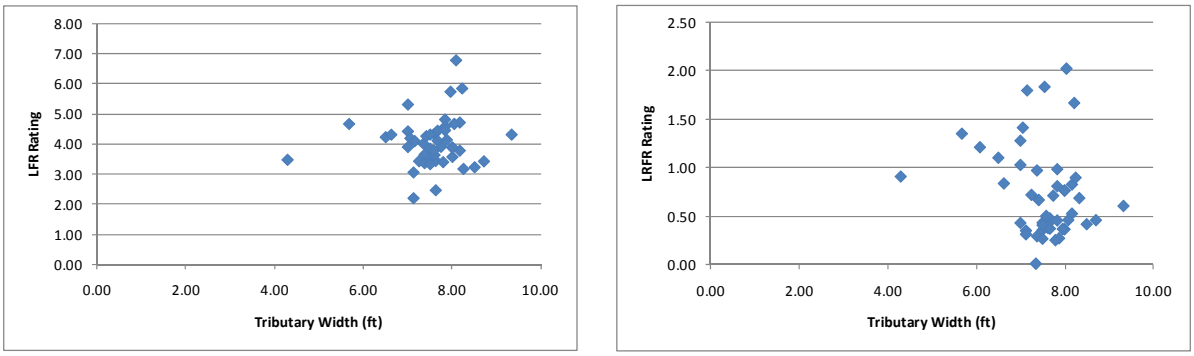
Figure I-202: Vehicle Loadings and Load Factors

I.2.7.1 Moment

The following section contains the results for exterior, composite prestressed I girders within continuous span bridges for the NM-04 Vehicle.

I.2.7.1.1 Rating Factors

Figure I-203 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 39 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 38 of the 39 girders with an LRFR rating less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is generally between 3 and 4.5 while the LRFR rating is generally between 0.25 and 1.0. Three outliers were removed from the LFR rating graph; they had values of 23, 49, and 78.



(a) (b)

Figure I-203: LFR and LRFR Flexure Rating Factors for NM-04 Vehicle

Figure I-204 shows the percentage of girders with moment ratings in each range for the NM-04 vehicle, a routine permit vehicle. 26.5% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 16.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 73.5% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 83.7% when an ADTT ≥ 5,000 is used.

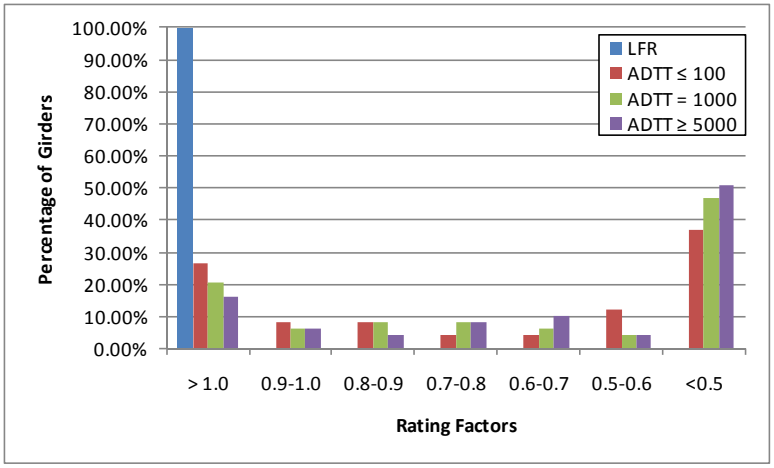


Figure I-204: Moment Ratings for Various ADTTs in MBE for NM-04 Vehicle

I.2.7.1.2 Rating Factor Comparisons

Figure I-205 shows the ratio of rating factors, LRFR divided by LFR. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating; there are no girders with an LRFR rating greater than the LFR rating. The ratio is generally less than 0.3 with all girders less than 0.45.

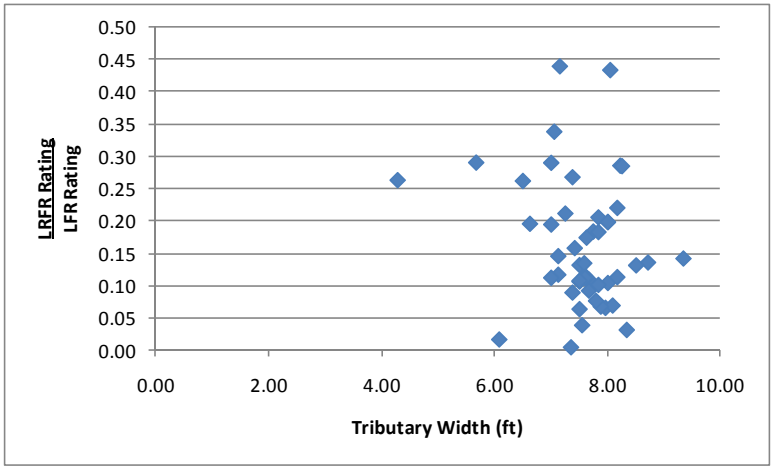


Figure I-205: LRFR Flexure rating divided by LFR Flexure rating for NM-04 Vehicle

I.2.7.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-206 shows that no girders have a reliability index less than the target reliability index of 2.5. The reliability index is between eight and twelve for girders not controlled by the longitudinal steel rating.

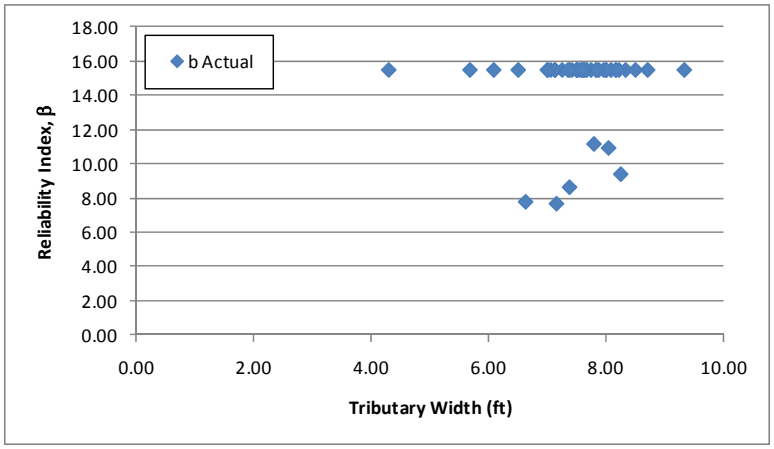


Figure I-206: Flexure Reliability Indices for NM-04 Vehicle

Figure I-207 shows the reliability index for moment plotted against the LRFR moment rating for the NM-04 Vehicle. The reliability index for a girder with an LRFR rating of 1.0 is approximately 8.0. This is above the target reliability of 2.5; this also suggests that using the results from the longitudinal steel rating will not provide an accurate comparison to determine if the current live load factors in the MBE are reasonable.

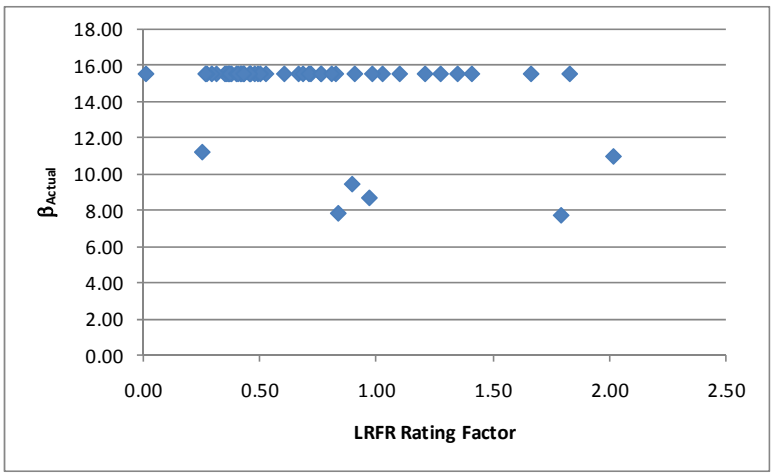
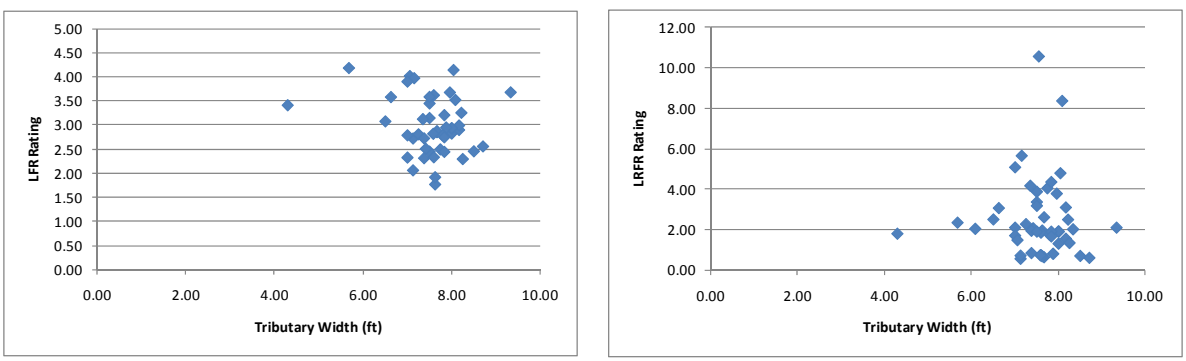


Figure I-207: Flexure Reliability Index vs LRFR Flexure Rating for NM-04 Vehicle

I.2.7.2 Shear

I.2.7.2.1 Rating Factors

For shear, there are zero girders that have an LFR rating factor less than 1.0, ten girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure I-208 shows the LFR and LRFR ratings. The LFR rating is generally in the range of 2.25 to 3.5 and the LRFR rating is between 0.5 and 4.0. Three outliers were removed from the LFR rating graph with values of 12, 50, and 54.



(a) (b)

Figure I-208: LFR and LRFR Shear Ratings for NM-04 Vehicle

Figure I-209 shows the percentage of girders with shear ratings in each range for the NM-04 vehicle, a routine permit vehicle. 79.6% of girders have LRFR ratings greater than 1.0 for all ADTT values. 100% of girders have LFR ratings that are greater than 1.0. The switch from LFR to LRFR results in 20.4% more girders with ratings less than 1.0 for all ADTT values.

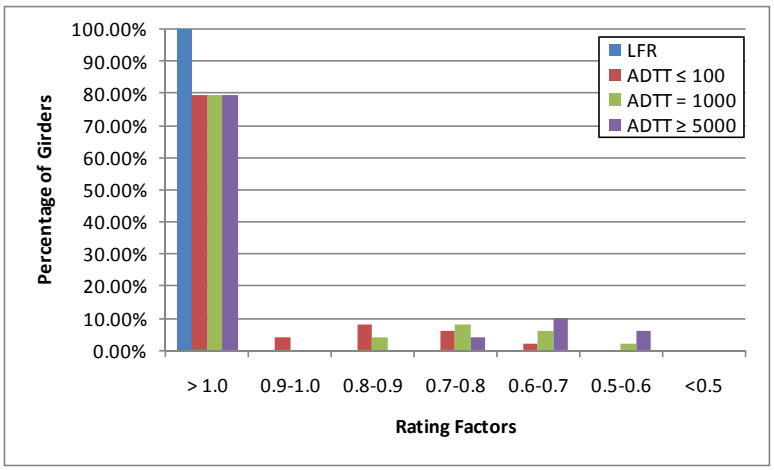


Figure I-209: Shear Ratings for Various ADTTs in MBE for NM-04 Vehicle

I.2.7.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure I-210 shows the comparison of rating factors. The ratio is generally between 0.25 and 1.5. 24% of girders have an LRFR rating that is greater than the LFR rating for the NM-04 vehicle.

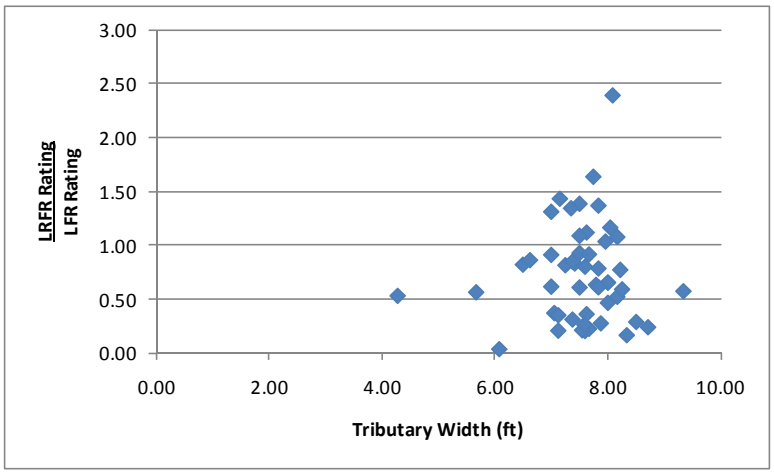


Figure I-210: LRFR Shear Rating divided by LFR Shear Rating for NM-04 Vehicle

I.2.7.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-211. The reliability index is between 6.5 and 8.0 for most girders.

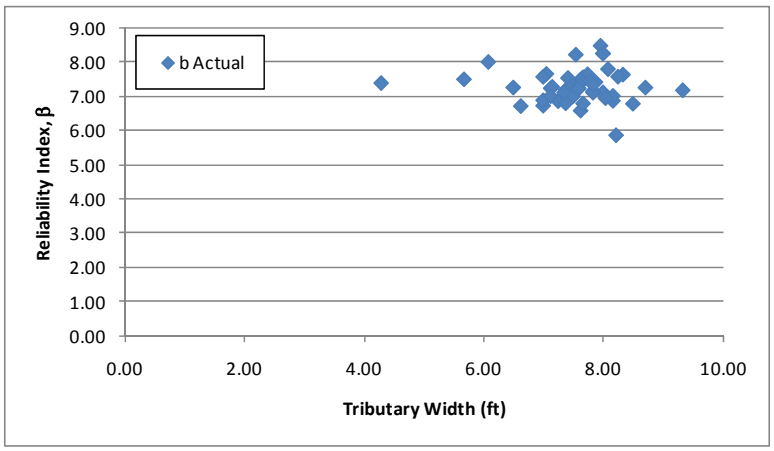


Figure I-211: Shear Reliability Indices for NM-04 Vehicle

Figure I-212 shows the shear reliability index plotted against the LRFR shear rating for the NM-04 vehicle. The reliability index increases with increasing LRFR ratings. A reliability index of approximately 5.0 corresponds to an LRFR rating of 1.0. This is greater than the target reliability index of 5.0 and may indicate that the LRFR live load factors are over-conservative. Girders with high reliability and low ratings are typically controlled by the shear friction rating. The reliability index is calculated using the shear resistance not the shear friction resistance.

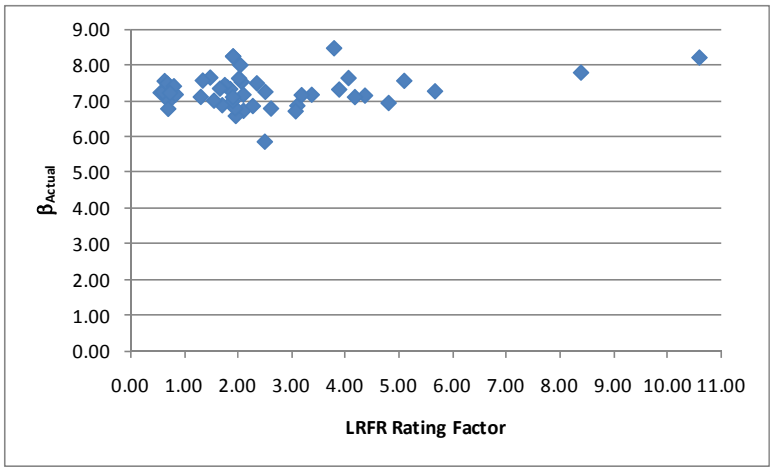
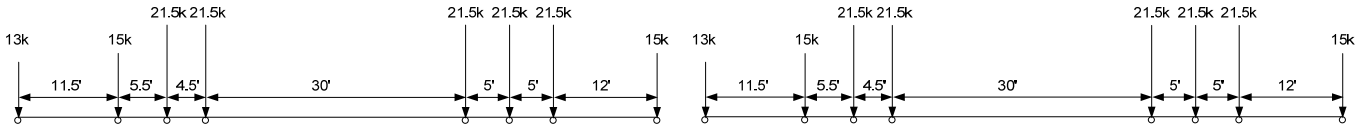


Figure I-212: Shear Reliability Index vs LRFR Shear Rating for NM-04 Vehicle

I.2.8 OR-06 Vehicle

The vehicle used in this section is the OR-06 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-213. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading

plus 0.2 klf for spans greater than 200 feet

LRFR Loading

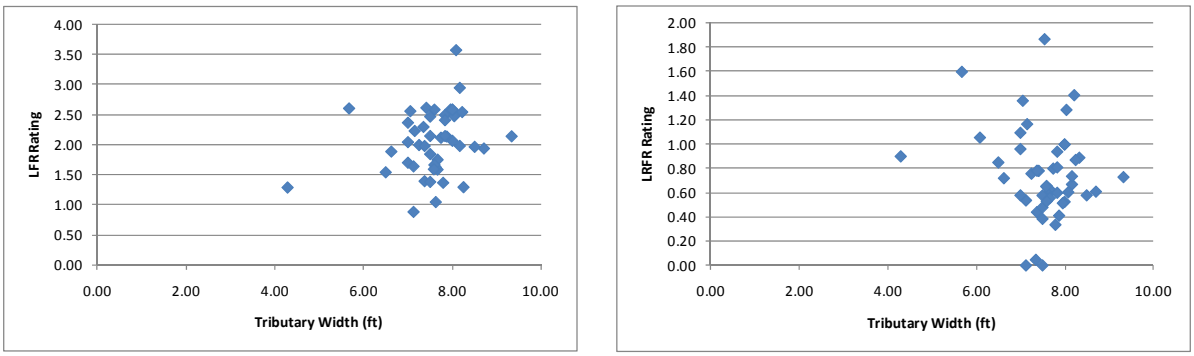
Figure I-213: Vehicle Loadings and Load Factors

I.2.8.1 Moment

The following section contains the results for exterior, composite prestressed I girders within continuous span bridges for the OR-06 Vehicle.

I.2.8.1.1 Rating Factors

Figure I-214 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there is one girder with an LFR rating less than 1.0, 41 girders with an LRFR rating less than 1.0, and one girder where both ratings are less than 1.0. 39 of the 41 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 100% of the girders in this subset. The LFR rating is generally between 1.5 and 2.5 with the LRFR rating generally between 0.4 and 1.0. Three outliers were removed from the LFR graph with values of 10, 21, and 37.



(a) (b)

Figure I-214: LFR and LRFR Flexure Rating Factors for OR-06 Vehicle

Figure I-215 shows the percentage of girders with moment ratings in each range for the OR-06 vehicle, a special permit vehicle. 30.6% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 10.2% for a multiple trip permit with ADTT ≥ 5,000 category. 98% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 67.4% more girders with ratings less than 1.0 when a single trip, escorted permit is used; this increases to 89.8% when a multiple trip permit with ADTT ≥ 5,000 is used.

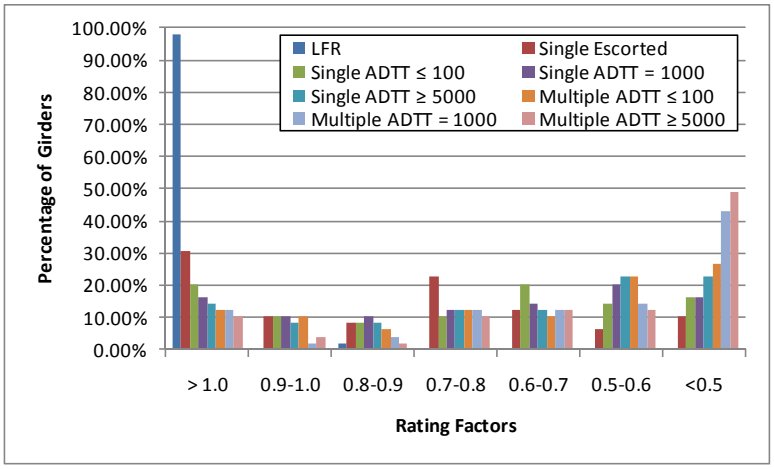


Figure I-215: Moment Ratings for Various ADTTs in MBE for OR-06 Vehicle

I.2.8.1.2 Rating Factor Comparisons

Figure I-216 shows the ratio of LRFR rating divided by LFR rating. Values greater than 1.0 would indicate the LRFR rating is greater than the LFR rating; there are no girders with an LRFR rating that is greater than the LFR rating. The ratio is less than 0.7 for all girders.

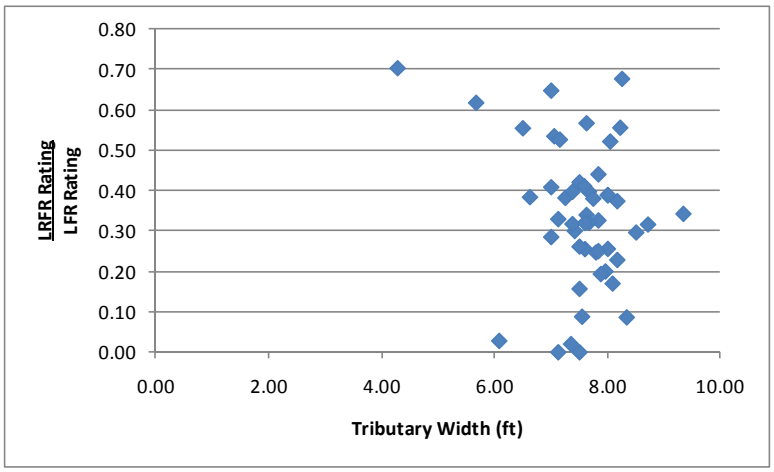


Figure I-216: LRFR Flexure rating divided by LFR Flexure rating for OR-06 Vehicle

I.2.8.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-217 shows that no girders have a reliability index less than the target reliability index of 3.5. The reliability index is between twelve and sixteen for most girders. There are also several grouped between six and ten.

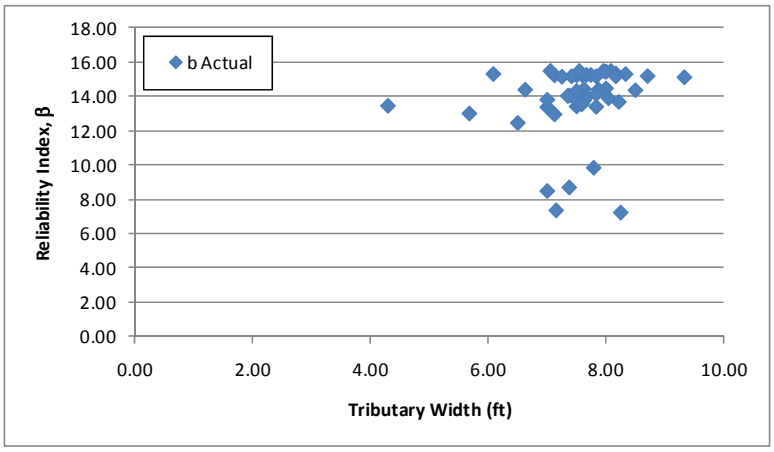


Figure I-217: Flexure Reliability Indices for OR-06 Vehicle

Figure I-218 shows the reliability index for moment plotted against the LRFR moment rating for the OR-06 vehicle. The reliability index associated with an LRFR rating of 1.0 is approximately eight, above the target reliability of 3.5. This indicates that using the longitudinal steel rating is not appropriate to determine the correctness of the current LRFR live load factors in the MBE.

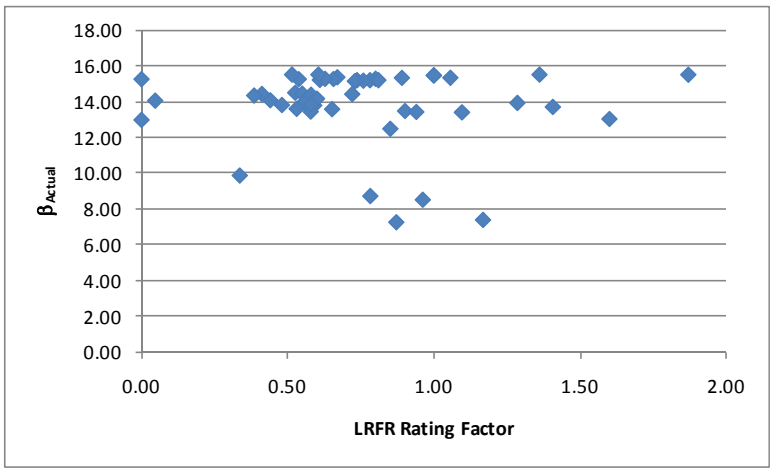
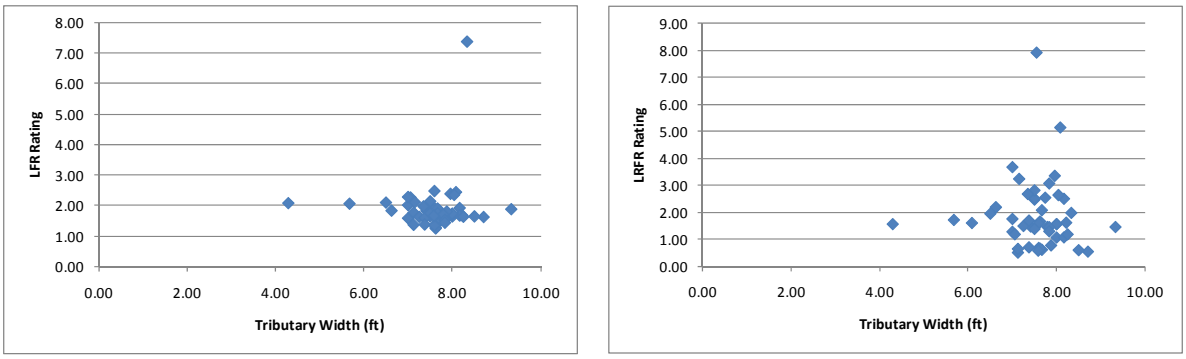


Figure I-218: Flexure Reliability Index vs LRFR Flexure Rating for OR-06 Vehicle

I.2.8.2 Shear

I.2.8.2.1 Rating Factors

For shear, there are zero girders that have an LFR rating factors less than 1.0, ten girders have LRFR ratings less than 1.0, and zero girders have both ratings less than 1.0. The LFR Rating is greater than the LRFR rating for 63% of the girders in this subset. Figure I-219 show the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 2.5 while the LRFR rating is generally between 0.5 and 2.5. Two outliers were removed from the LFR graph with values of 28 and 31.



(a) (b)

Figure I-219: LFR and LRFR Shear Ratings for OR-06 Vehicle

Figure I-220 shows the percentage of girders with shear ratings in each range for the OR-06 vehicle, a special permit vehicle. 79.6% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 67.4% for a multiple trip permit with ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 20.4% more girders with ratings less than 1.0 for the single trip, escorted permit is used; this increases to 32.6% when the multiple trip permit with ADTT ≥ 5,000 is used.

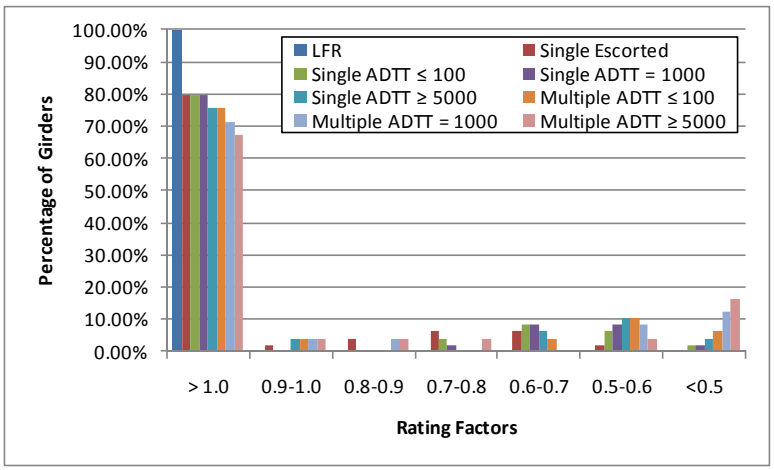


Figure I-220: Shear Ratings for Various ADTTs in MBE for OR-06 Vehicle

I.2.8.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure I-221 shows the comparison of rating factors. The ratio is varies from 0.25 to 1.5 for most girders. 37% of girders have LRFR ratings that are greater than the LFR rating.

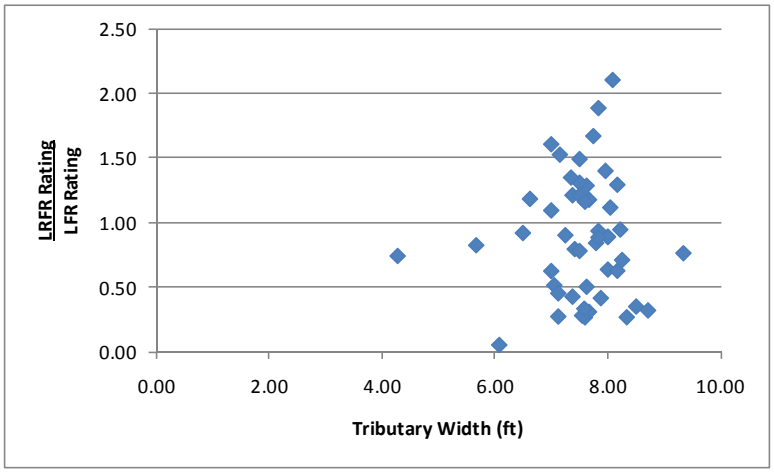


Figure I-221: LRFR Shear Rating divided by LFR Shear Rating for OR-06 Vehicle

I.2.8.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 3.5 for all girders as shown in Figure I-222. The reliability index is between six and eight for most girders.

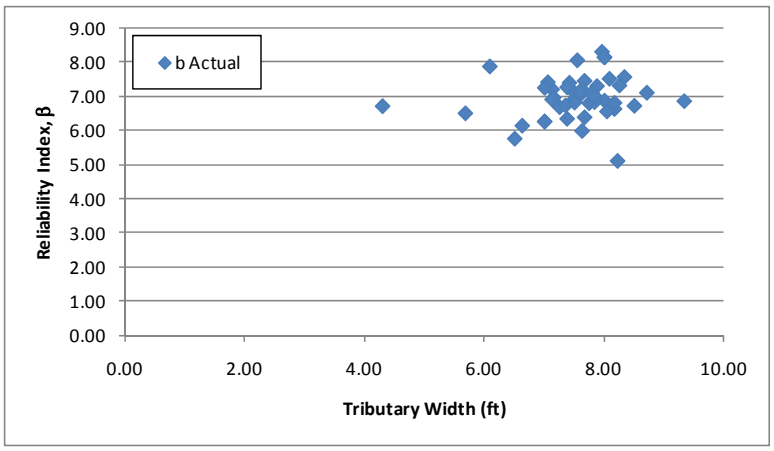


Figure I-222: Shear Reliability Indices for OR-06 Vehicle

Figure I-223 shows the reliability index for shear plotted against the LRFR shear rating for the OR-06 vehicle. The reliability index corresponding to an LRFR rating of 1.0 is approximately 4.25, above the target reliability of 3.5. This indicates that the LRFR live load factors may be over-conservative.

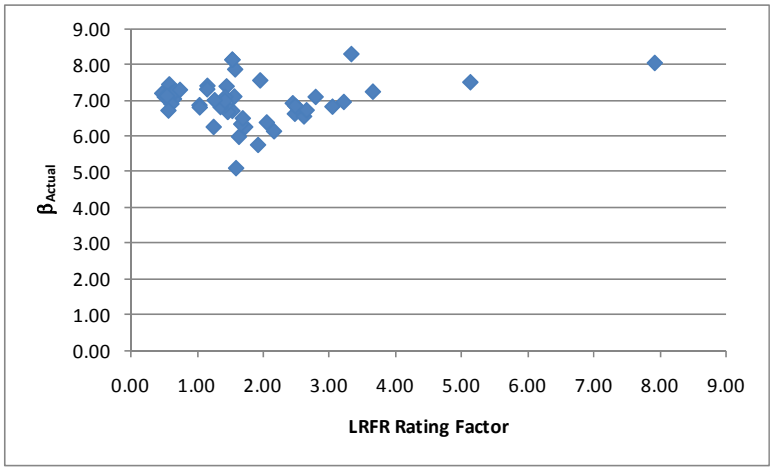


Figure I-223: Shear Reliability Index vs LRFR Shear Rating for OR-06 Vehicle

I.2.9 TX-04 Vehicle

The vehicle used in this section is the TX-04 vehicle. This vehicle is assumed to be a routine permit vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-224. The applicable load factors for these vehicles are 1.3 and 1.6 for LFR and LRFR, respectively. Multiple lanes are loaded for all girders.

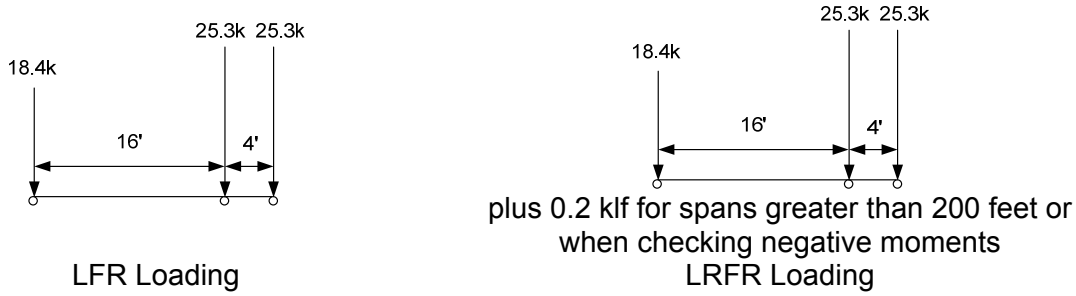


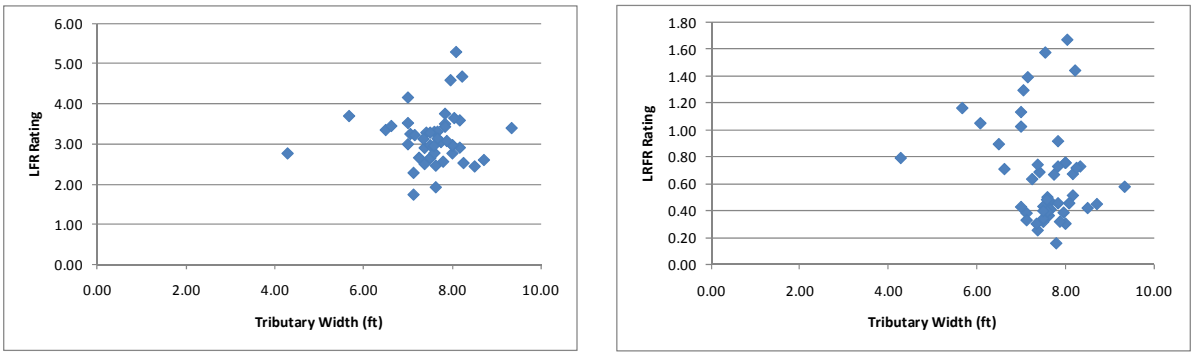
Figure I-224: Vehicle Loadings and Load Factors

I.2.9.1 Moment

The following section contains the results for exterior, composite prestressed I girders within continuous span bridges for the TX-04 Vehicle.

I.2.9.1.1 Rating Factors

Figure I-225 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 40 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. 38 of the 40 girders with LRFR ratings less than 1.0 are controlled by the longitudinal reinforcement rating. The LFR operating rating is greater than the LRFR routine permit rating for 100% of the girders in this subset. The LFR rating is generally between 2.5 and 3.5 while the LRFR rating is typically between 0.2 and 0.8. Three outliers were removed from the LFR graph with values of 17, 38, and 60.



(a) (b)

Figure I-225: LFR and LRFR Flexure Rating Factors for TX-04 Vehicle

Figure I-226 shows the percentage of girders with moment ratings in each range for the TX-04 vehicle, a routine permit vehicle. 22.5% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 16.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 77.5% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 83.7% when an ADTT ≥ 5,000 is used.

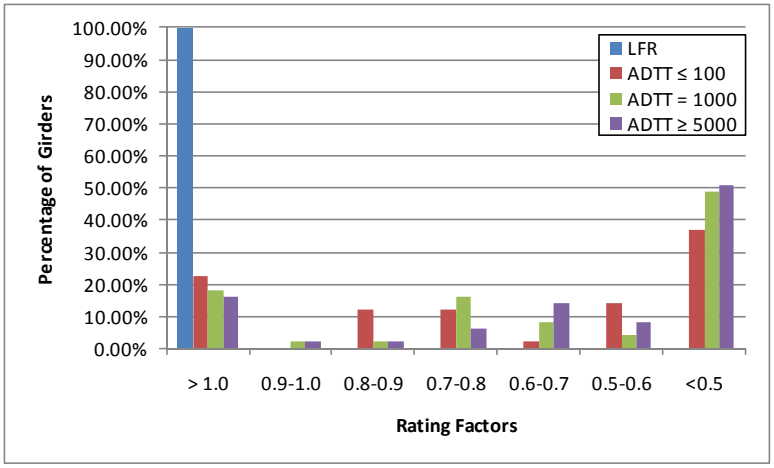


Figure I-226: Moment Ratings for Various ADTTs in MBE for TX-04 Vehicle

I.2.9.1.2 Rating Factor Comparisons

Figure I-227 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. There are no clear trends in the data, but the LRFR rating is generally less than 40% of the LFR rating. There are no girders with an LRFR rating that is greater than the LFR rating.

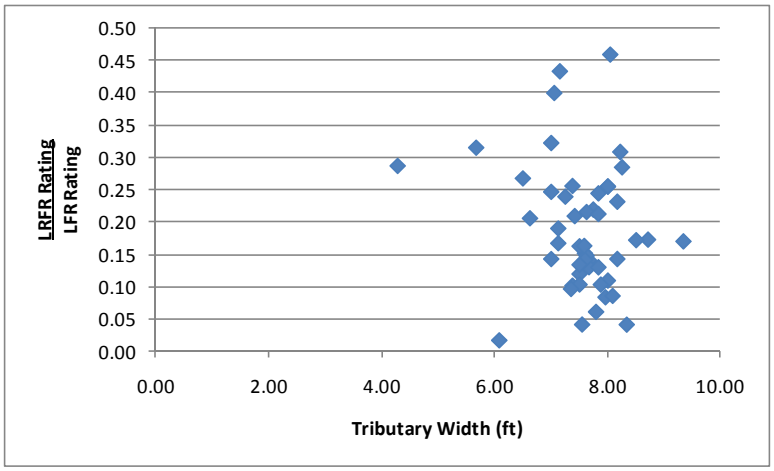


Figure I-227: LRFR Flexure rating divided by LFR Flexure rating for TX-04 Vehicle

I.2.9.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-228 shows no girders that have a reliability index less than the target reliability index of 2.5. The reliability index is between six and ten for most girders.

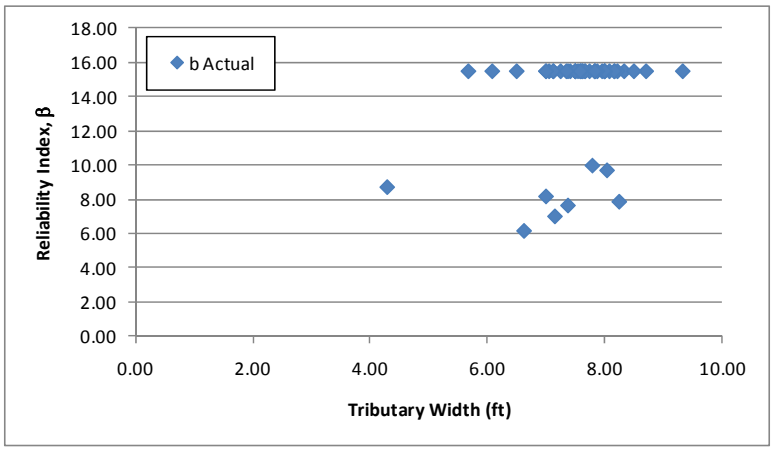


Figure I-228: Flexure Reliability Indices for TX-04 Vehicle

Figure I-229 shows the reliability index for moment plotted against the LRFR moment rating for the TX-04 vehicle. The reliability index corresponding to an LRFR rating of 1.0 is approximately 7.0, above the target reliability of 2.5. This indicates that the longitudinal steel rating should not be used to determine the appropriate LRFR live load factors.

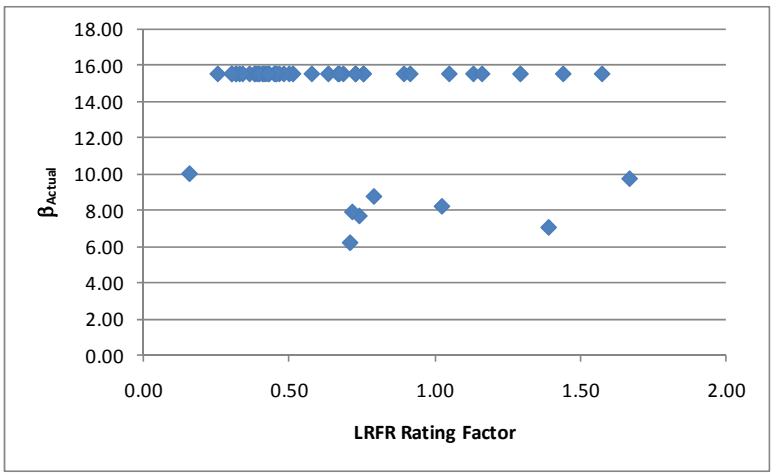
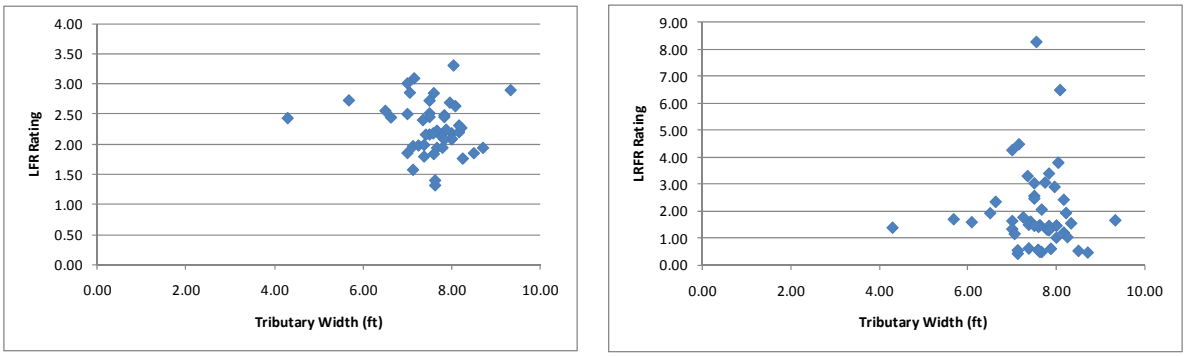


Figure I-229: Flexure Reliability Index vs LRFR Flexure Rating for TX-04 Vehicle

I.2.9.2 Shear

I.2.9.2.1 Rating Factors

For shear, there are zero girders that have LFR rating factors less than 1.0, 10 girders with LRFR ratings less than 1.0 and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure I-230 shows the LFR and LRFR ratings. The LFR rating is generally between 1.5 and 3.0 while the LRFR rating is varies greatly from 0.5 to 4.0. Three outliers were removed from the LFR graph with values of 10, 38, and 42.



(a) (b)

Figure I-230: LFR and LRFR Shear Ratings for TX-04 Vehicle

Figure I-231 shows the percentage of girders with shear ratings in each range for the TX-04 vehicle, a routine permit vehicle. 79.6% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 75.5% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 20.4% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 24.5% when an ADTT ≥ 5,000 is used.

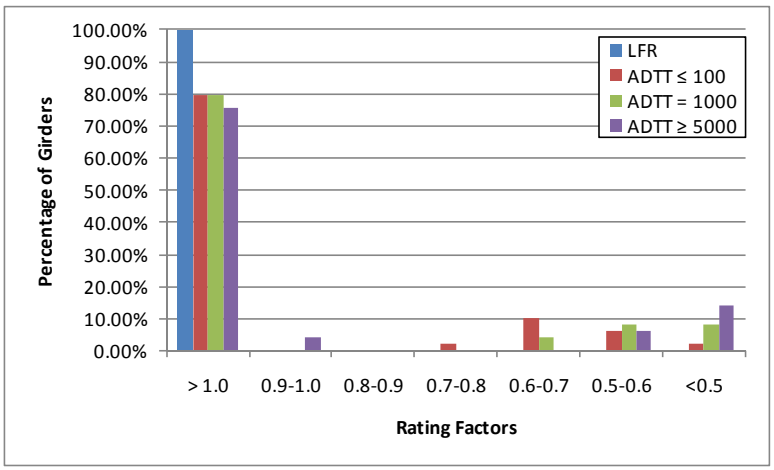


Figure I-231: Shear Ratings for Various ADTTs in MBE for TX-04 Vehicle

I.2.9.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating with the LFR Rating. Figure I-232 shows the comparison of rating factors. The ratio is generally between 0.25 and 1.5 for shear. 24% of girders have an LRFR rating that is greater than the LFR rating.

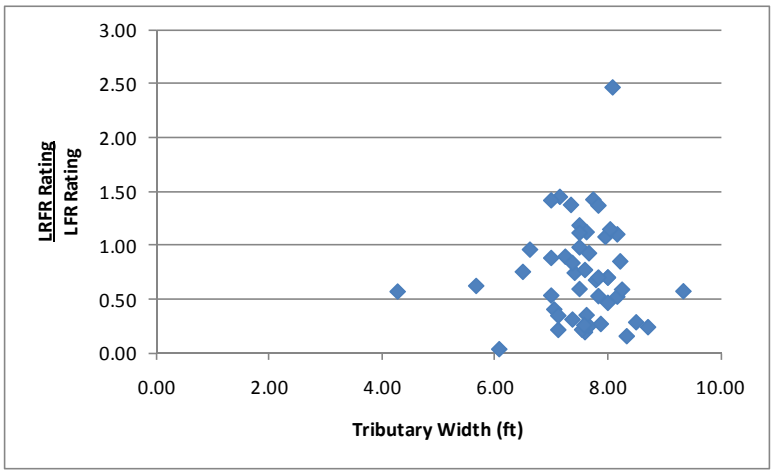


Figure I-232: LRFR Shear Rating divided by LFR Shear Rating for TX-04 Vehicle

I.2.9.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is greater than the target reliability index of 2.5 for all girders as shown in Figure I-233. The reliability index for most girders is between six and eight.

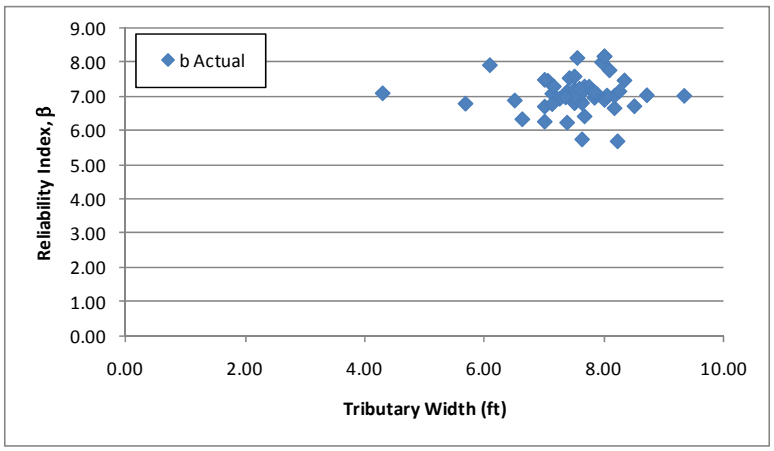


Figure I-233: Shear Reliability Indices for TX-04 Vehicle

Figure I-234 shows the reliability index for shear plotted against the LRFR shear rating for the TX-04 vehicle. The reliability index corresponding to an LRFR rating of 1.0 is approximately 4.5, above the target reliability of 2.5. This indicates that the LRFR live load factors may be over-conservative. There are a group of girders with high reliability and low ratings that are controlled by the shear friction rating. The reliability index is calculated using the shear resistance not the shear friction resistance.

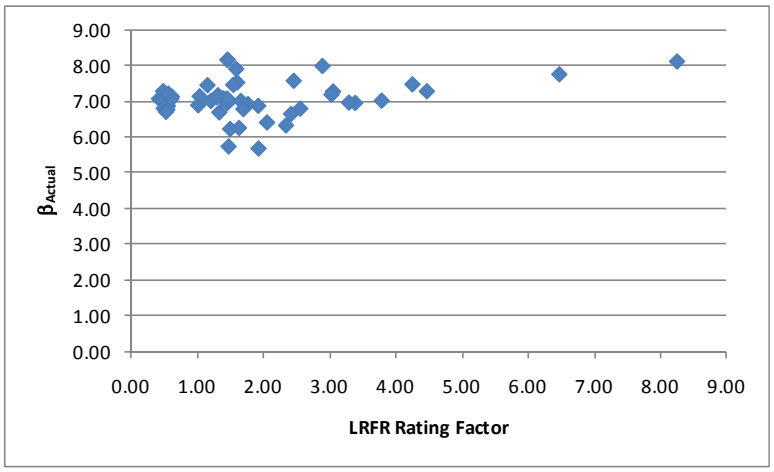
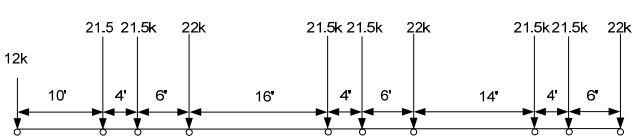


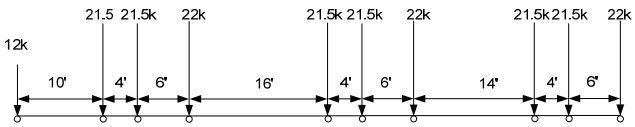
Figure I-234: Shear Reliability Index vs LRFR Shear Rating for TX-04 Vehicle

I.2.10 WA-02 Vehicle

The vehicle used in this section is the WA-02 vehicle. This vehicle is assumed to be a special, single trip permit vehicle that is allowed to mix with other traffic and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-235. The applicable load factors for these vehicles are 1.3 and 1.4 for LFR and LRFR, respectively. A single lane loaded is used for this vehicle without the multiple presence factor of 1.2.



LFR Loading



plus 0.2 klf for spans greater than 200 feet or when checking negative moments

LRFR Loading

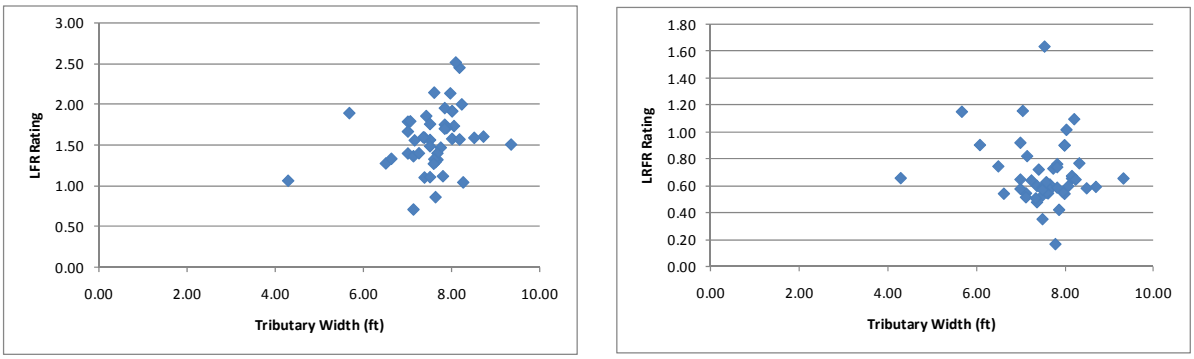
Figure I-235: Vehicle Loadings and Load Factors

I.2.10.1 Moment

The following section contains the results for exterior, composite prestressed I girders within continuous span bridges for the WA-02 Vehicle.

I.2.10.1.1 Rating Factors

Figure I-236 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are two girders with an LFR rating less than 1.0, 44 girders with an LRFR rating less than 1.0, and two girders where both ratings are less than 1.0. 39 of the 44 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR special permit rating for 100% of the girders in this subset. The LFR rating is generally between 1.0 and 2.0 with the LRFR rating generally between 0.5 and 1.5. The LFR graphs had three outliers removed with values of 8, 17, and 26.



(a) (b)

Figure I-236: LFR and LRFR Flexure Rating Factors for WA-02 Vehicle

Figure I-237 shows the percentage of girders with moment ratings in each range for the WA-02 vehicle, a special permit vehicle. 18.4% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 4.1% for the multiple trip permit with ADTT ≥ 5,000 category. 95.9% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 77.5% more girders with ratings less than 1.0 when the single trip, escorted permit category is used; this increases to 91.8% when the multiple trip permit with an ADTT ≥ 5,000 is used.

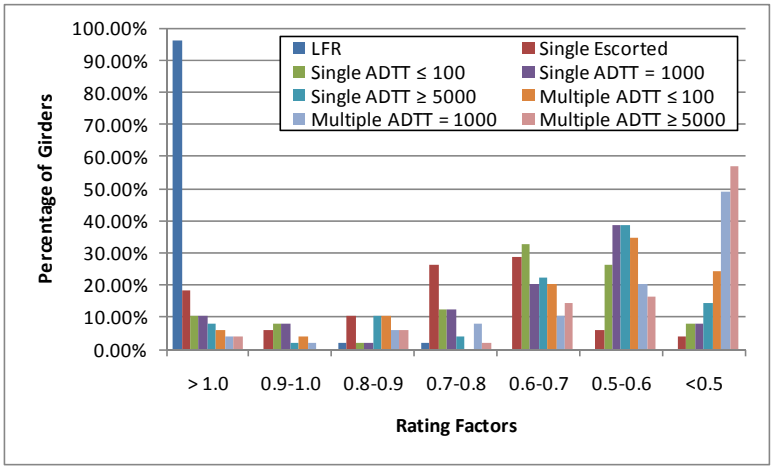


Figure I-237: Moment Ratings for Various ADTTs in MBE for WA-02 Vehicle

I.2.10.1.2 Rating Factor Comparisons

Figure I-238 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is generally between 0.2 and 0.6 but there are no clear trends. There are no girders with an LRFR rating that is greater than the LFR rating for the WA-02 Vehicle.

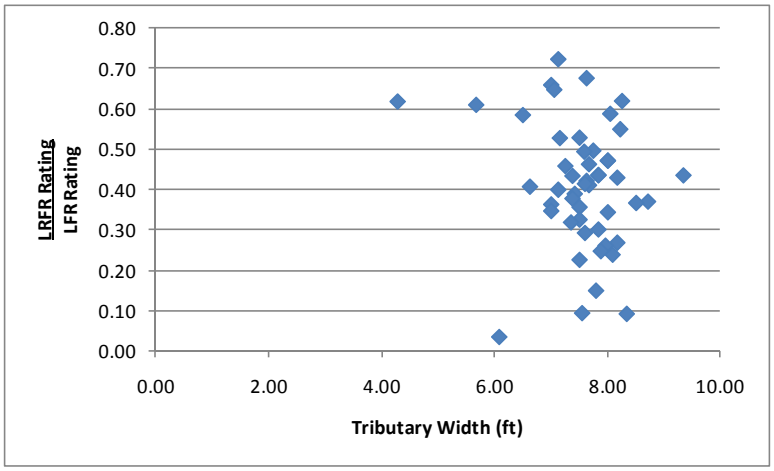


Figure I-238: LRFR Flexure rating divided by LFR Flexure rating for WA-02 Vehicle

I.2.10.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-239 shows that no girders have a reliability index less than the target reliability index of 3.5. The reliability index is between five and nine for most girders.

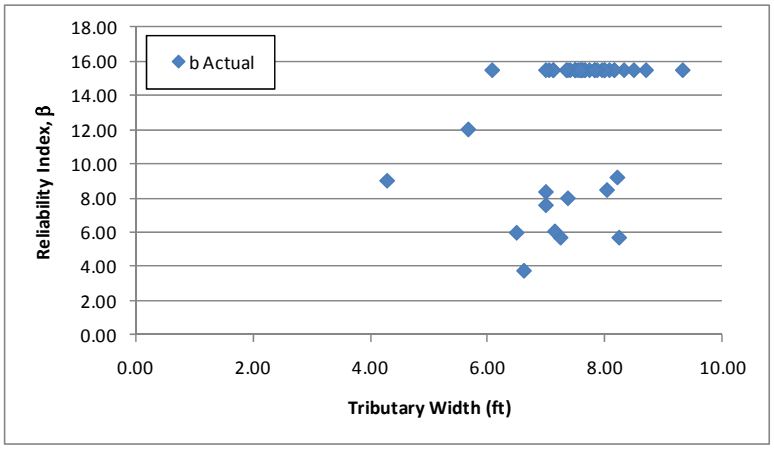


Figure I-239: Flexure Reliability Indices for WA-02 Vehicle

Figure I-240 shows the reliability index for moment plotted against the LRFR moment rating for the WA-02 vehicle. The reliability index increases with increasing LRFR rating. A rating of 1.0 produces a reliability index of approximately 8, above the target reliability of 3.5. This suggests that the ratings for the longitudinal steel should not be used to calibrate the LRFR live load factors.

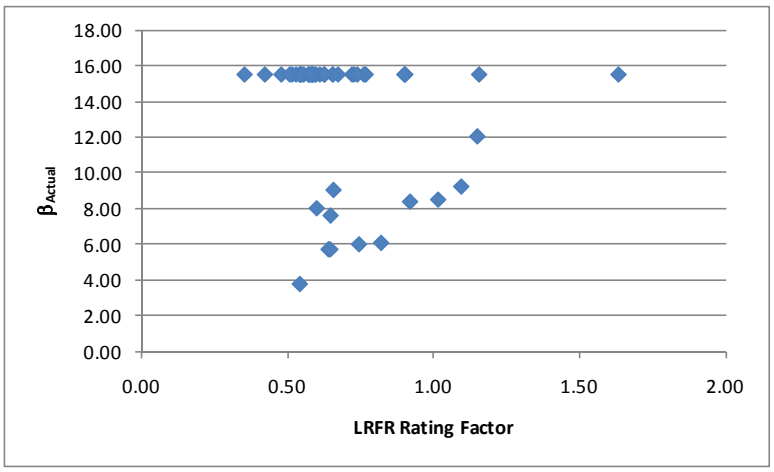
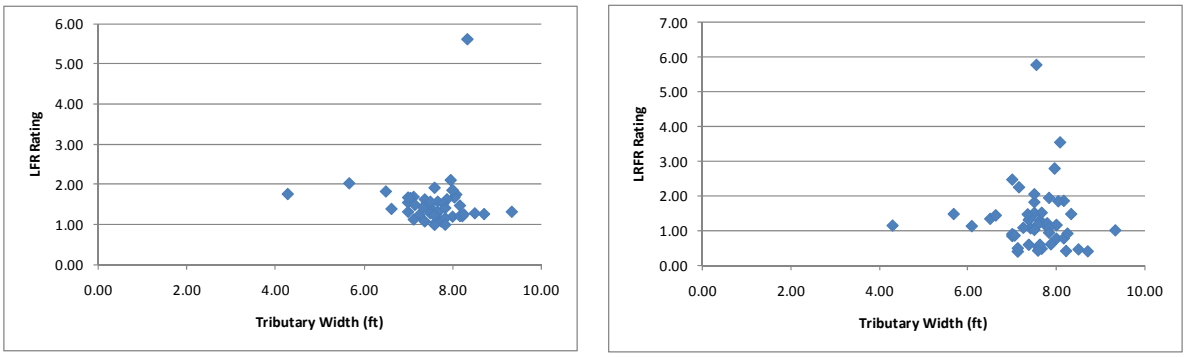


Figure I-240: Flexure Reliability Index vs LRFR Flexure Rating for WA-02 Vehicle

I.2.10.2 Shear

I.2.10.2.1 Rating Factors

For shear, there are two girders with an LFR rating factor less than 1.0, 18 girders with LRFR ratings less than 1.0, and one girder where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 65% of the girders in this subset. Figure I-241 shows the LFR and LRFR ratings. LFR rating is generally between 1.0 and 2.0 while the LRFR rating is generally between 0.25 and 1.75. Two outliers were removed from the LFR graph with values of 21 and 22.



(a) (b)

Figure I-241: LFR and LRFR Shear Ratings for WA-02 Vehicle

Figure I-242 shows the percentage of girders with shear ratings in each range for the WA-02 vehicle, a special permit vehicle. 73.5% of girders have LRFR ratings greater than 1.0 for the single trip, escorted permit category. The percentage of girders drops to 34.7% for the multiple trip permit with ADTT ≥ 5,000 category. 95.9% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 22.4% more girders with ratings less than 1.0 when the single trip, escorted permit is used; this increases to 61.2% when a multiple trip permit with ADTT ≥ 5,000 is used.

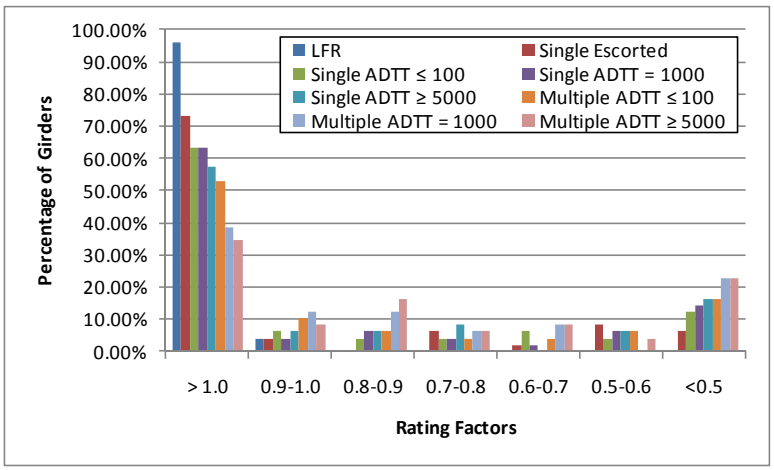


Figure I-242: Shear Ratings for Various ADTTs in MBE for WA-02 Vehicle

I.2.10.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-243 show the comparison of rating factors. The ratio is generally between 0.25 and 1.5. 35% of girders have an LRFR rating that exceeds the LFR rating for shear for the WA-02 Vehicle.

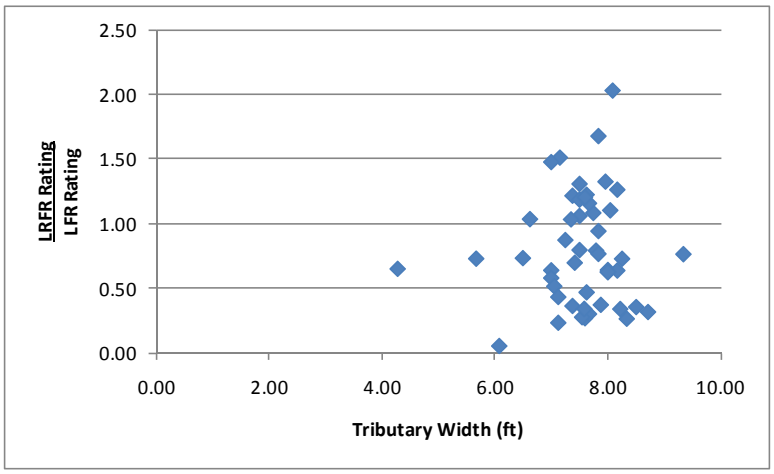


Figure I-243: LRFR Shear Rating divided by LFR Shear Rating for WA-02 Vehicle

I.2.10.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 3.5 for two girders as shown in Figure I-244. The reliability index is between five and seven for most girders.

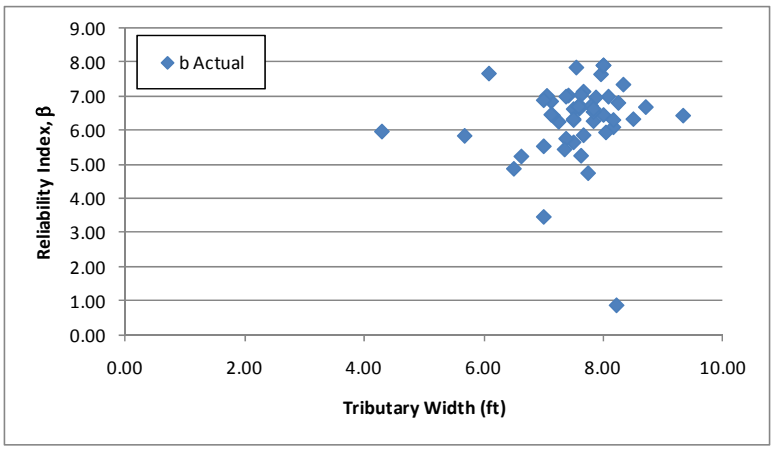


Figure I-244: Shear Reliability Indices for WA-02 Vehicle

Figure I-245 shows the reliability index for shear plotted against the LRFR shear rating for the WA-02 vehicle. The reliability index increases with increasing rating factors. A reliability index of approximately 4.0 is obtained for an LRFR rating of 1.0. The reliability index is slightly above the target reliability of 3.5. This indicates that the LRFR live load factor may be over-conservative.

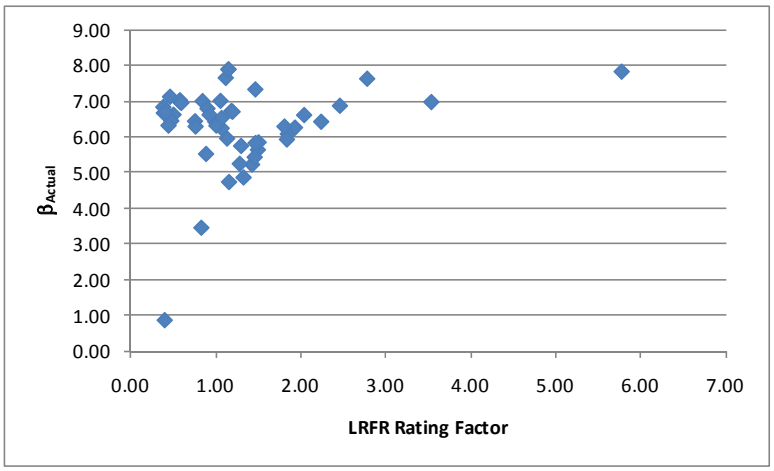


Figure I-245: Shear Reliability Index vs LRFR Shear Rating for WA-02 Vehicle

I.2.11 AASHTO Type 3

The vehicle used in this section is the AASHTO Type 3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-246. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

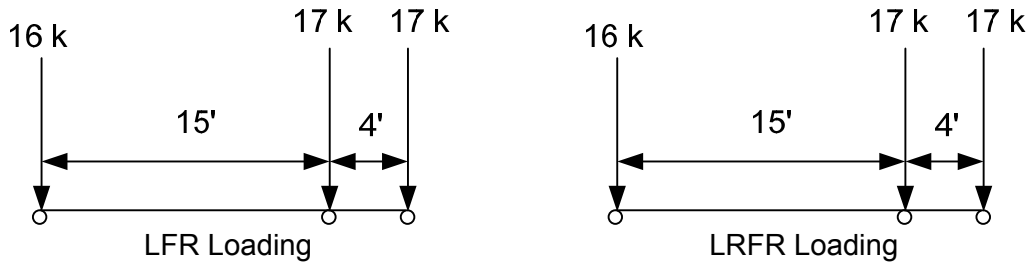
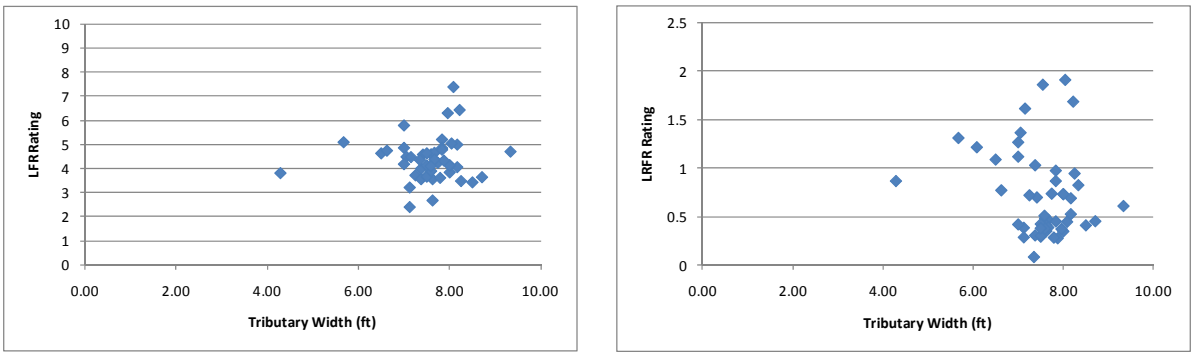


Figure I-246: Vehicle Loadings and Load Factors

I.2.11.1 Moment

I.2.11.1.1 Rating Factors

Figure I-247 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 38 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. All 38 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR rating is between three and five for most girders. Three outliers were removed from the LFR graph with values of 25, 52, and 84. The LRFR rating is between 0.25 and 1.0 for most girders.



(a) (b)

Figure I-247: LFR and LRFR Flexure Rating Factors for Type 3 Vehicle

Figure I-248 shows the percentage of girders with moment ratings in each range for the AASHTO Type 3 truck, a legal vehicle. 30.6% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 22.5% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 69.4% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 77.5% when an ADTT ≥ 5,000 is used.

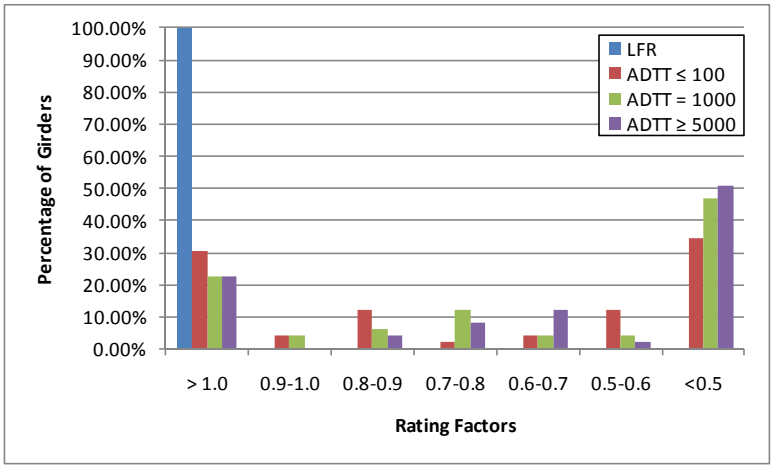


Figure I-248: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

I.2.11.1.2 Rating Factor Comparisons

Figure I-249 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is less than 0.4 for all girders. All girders have LFR ratings that are greater than the LFR rating.

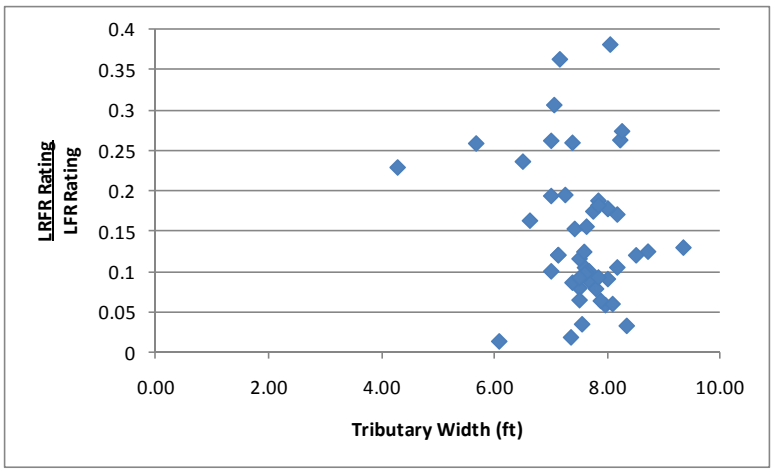


Figure I-249: LRFR Flexure rating divided by LFR Flexure rating for Type 3 Vehicle

I.2.11.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-250 shows that zero girders have a reliability index less than the reliability index. The reliability index is greater than twelve for most girders.

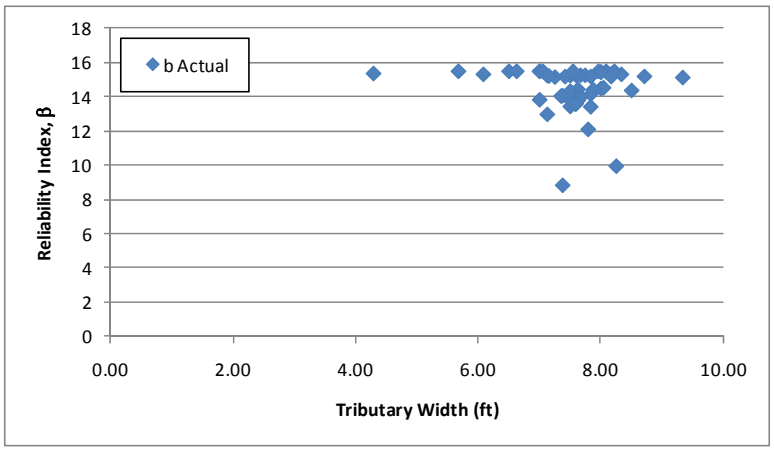


Figure I-250: Flexure Reliability Indices for Type 3 Vehicle

Figure I-251 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3 Truck. The graph shows no trends between rating and reliability index. The reliability index for an LRFR rating of 1.0 can be estimate to be at least eight because of the two data points present. This is in excess of the target reliability of 2.5. This indicates that ratings for moment strength should be used not the longitudinal steel rating.

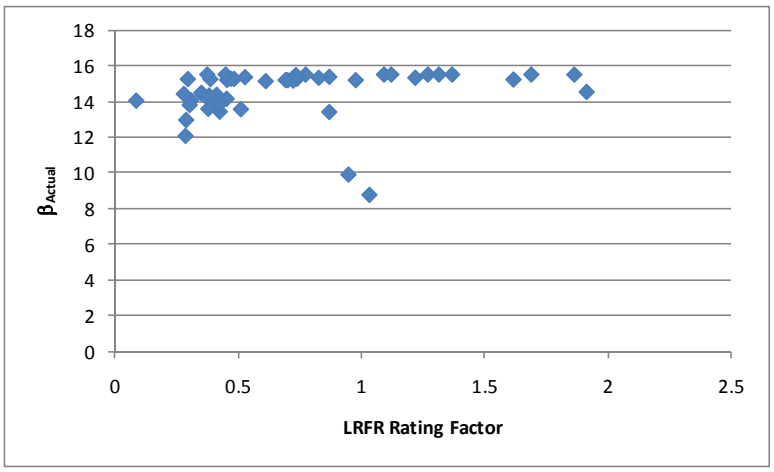
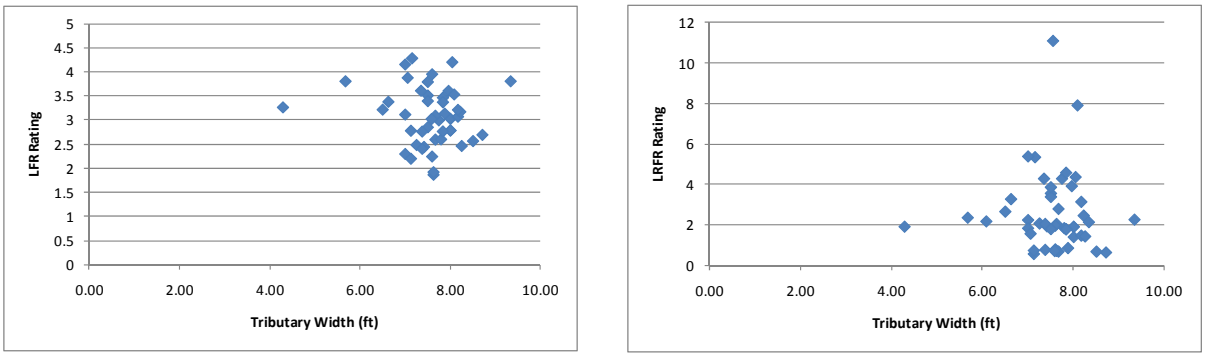


Figure I-251: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3 Truck

I.2.11.2 Shear

I.2.11.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, ten girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 76% of the girders in this subset. Figure I-252 shows the LFR and LRFR ratings. The LFR rating is between 2.5 and 4.0 for most girders while the LRFR rating is between 0.5 and 4.0. Three girders were removed as outliers from the LFR graph; they had values of 13, 53, and 57.



(a) (b)

Figure I-252: LFR and LRFR Shear Ratings for Type 3 Vehicle

Figure I-253 shows the percentage of girders with shear ratings in each range for the AASHTO Type 3 truck, a legal vehicle. 79.6% of girders have LRFR ratings greater than 1.0 for all ADTTs. 100% of girders have LFR ratings that are greater than 1.0. The switch from LFR to LRFR results in 20.4% more girders with ratings less than 1.0 for all ADTTs.

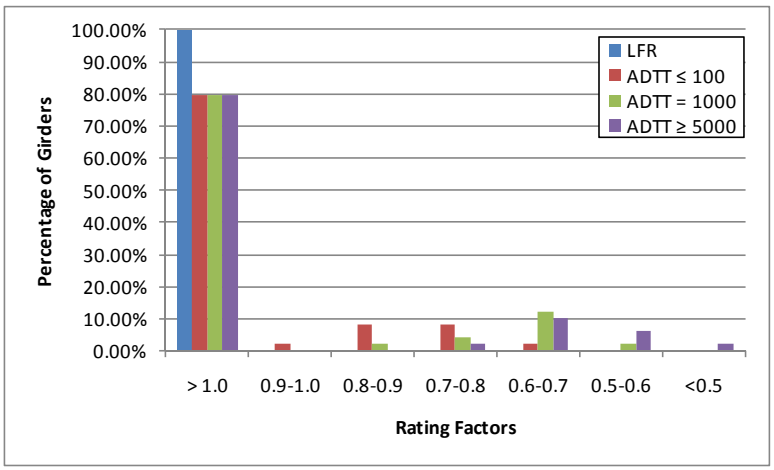


Figure I-253: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3 Truck

I.2.11.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-254 show the comparison of rating factors. The ratio is generally between 0.2 and 1.5. 24% of girders have an LRFR rating that is greater than the LFR rating.

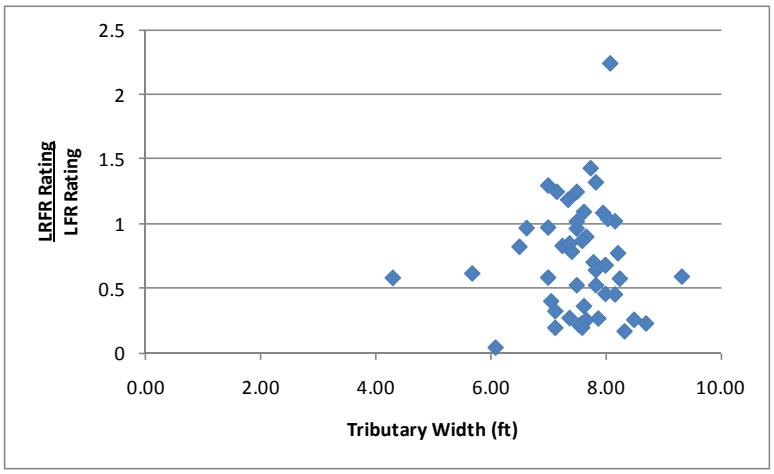


Figure I-254: LRFR Shear Rating divided by LFR Shear Rating for Type 3 Vehicle

I.2.11.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure I-255. The reliability index is between seven and eight for most girders.

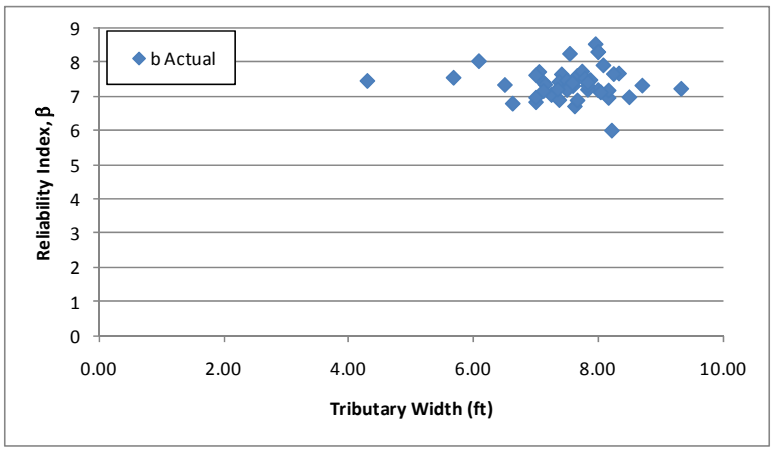


Figure I-255: Shear Reliability Indices for Type 3 Vehicle

Figure I-256 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3 Truck. The reliability index is approximately four for an LRFR rating of one. This is above the target reliability of 2.5. This may indicate that the LRFR live load factors are over-conservative.

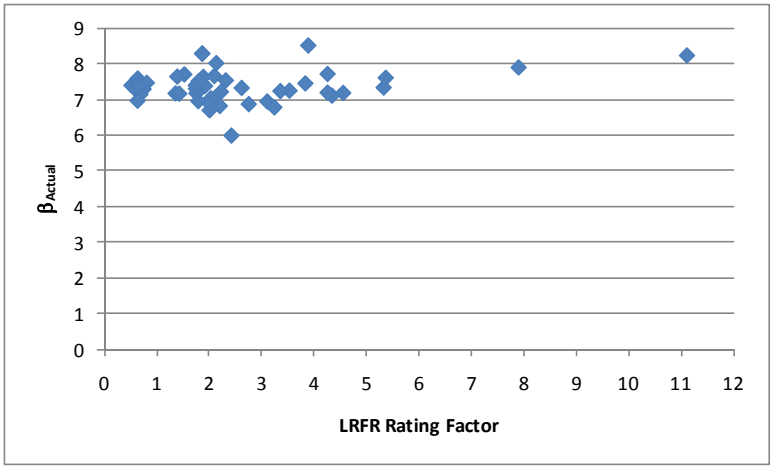


Figure I-256: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3 Truck

I.2.12 AASHTO Type 3-3

The vehicle used in this section is the AASHTO Type 3-3 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-257. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

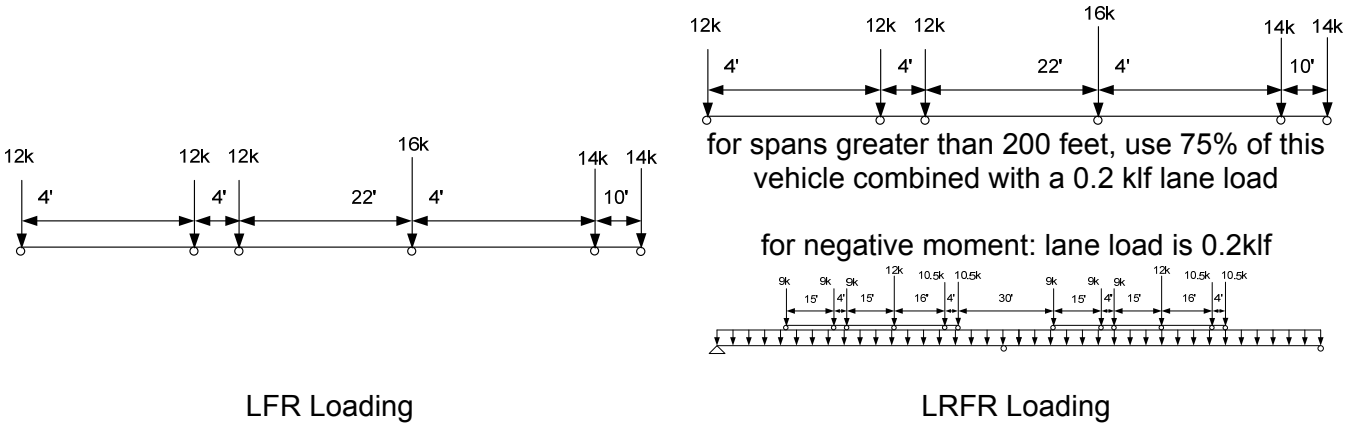
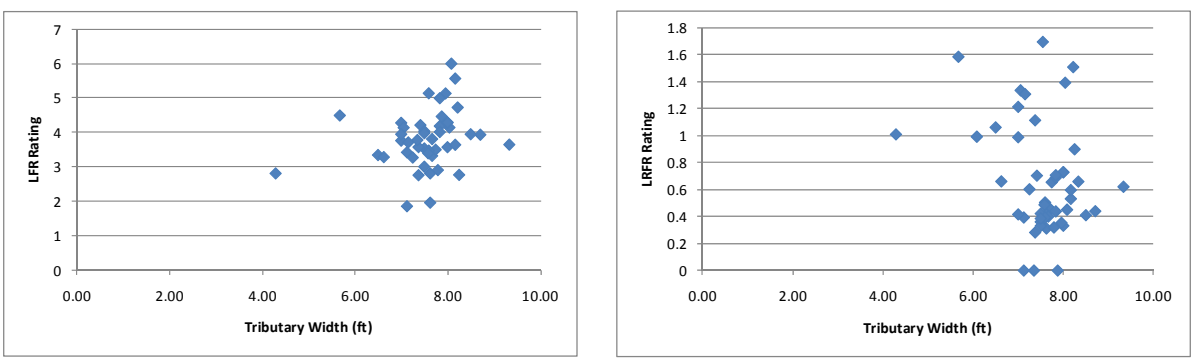


Figure I-257: Vehicle Loadings and Load Factors

I.2.12.1 Moment

I.2.12.1.1 Rating Factors

Figure I-258 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 39 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. All 39 girders with LRFR ratings less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR rating is between three and five for most girders while the LRFR rating is between 0.2 and 0.8. Three outliers were removed from the LFR graph with values of 22, 45, and 64.



(a) (b)

Figure I-258: LFR and LRFR Flexure Rating Factors for Type 3-3 Vehicle

Figure I-259 shows the percentage of girders with moment ratings in each range for the AASHTO Type 3-3 truck, a legal vehicle. 26.5% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 16.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 73.5% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 83.7% when an ADTT ≥ 5,000 is used.

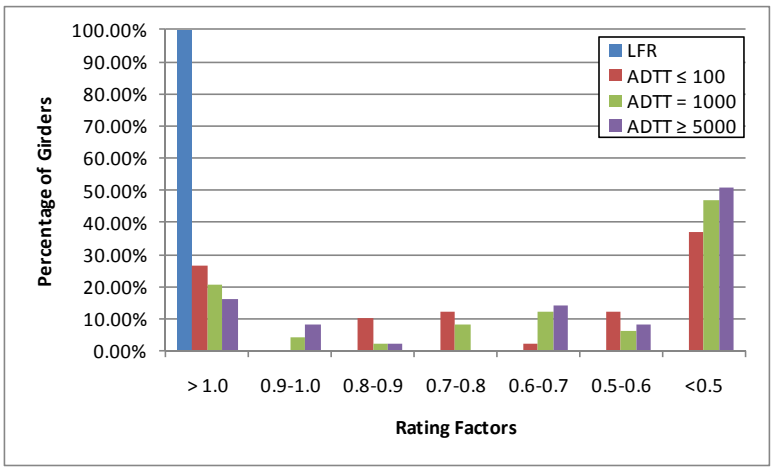


Figure I-259: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

I.2.12.1.2 Rating Factor Comparisons

Figure I-260 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is less than 0.4 for all girders. No girders have LRFR ratings greater than the LFR rating.

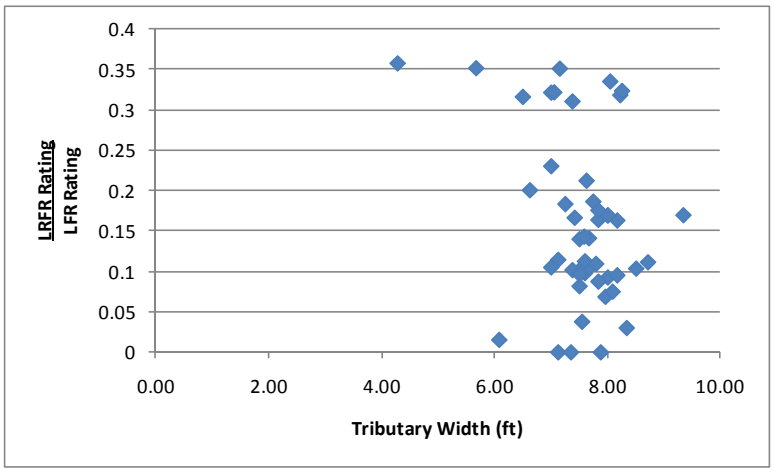


Figure I-260: LRFR Flexure rating divided by LFR Flexure rating for Type 3-3 Vehicle

I.2.12.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-261 shows that one girder has a reliability index less than the target reliability index of 2.5. The reliability index is between six and ten for most girders and increases with increasing tributary width.

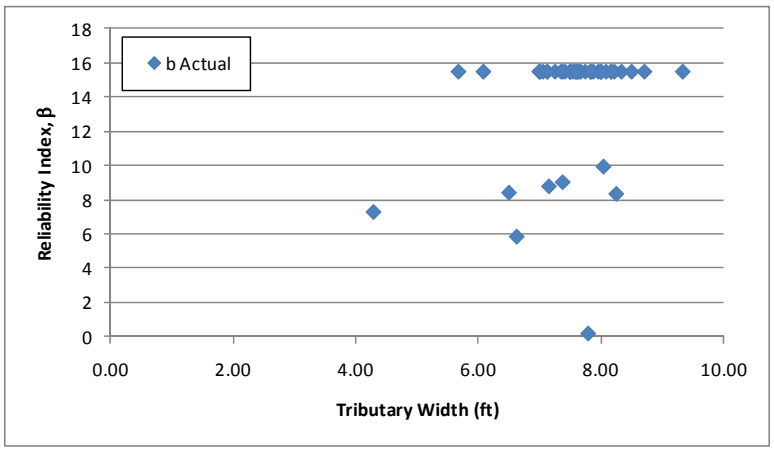


Figure I-261: Flexure Reliability Indices for Type 3-3 Vehicle

Figure I-262 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3-3 Truck. The reliability index increases with increasing ratings. A reliability index of approximately eight corresponds to an LRFR rating of 1.0. This indicates that using the longitudinal steel rating to investigate the correctness of the live load factors for LRFR is not useful.

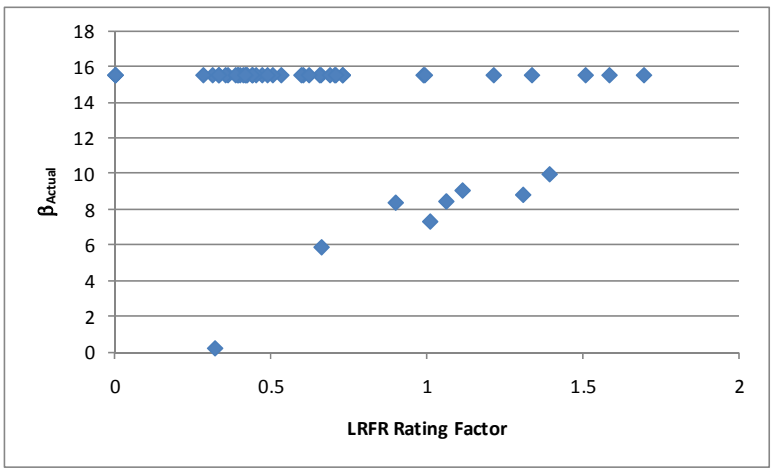
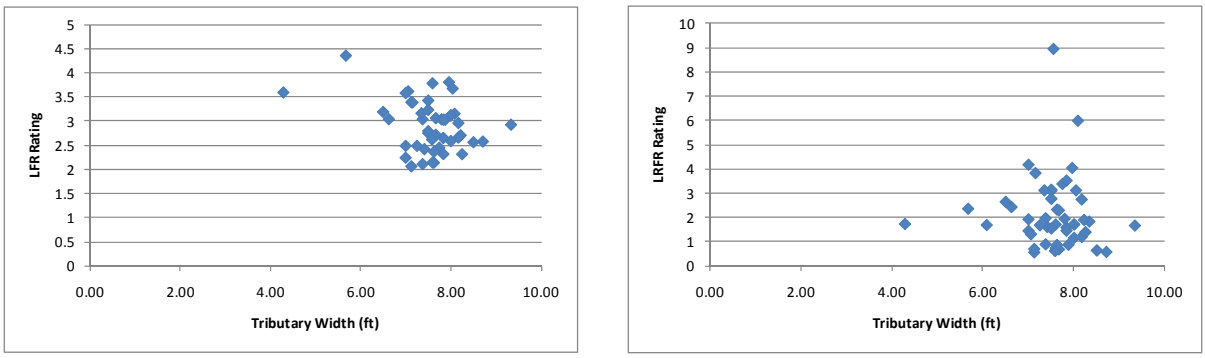


Figure I-262: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3-3 Truck

I.2.12.2 Shear

I.2.12.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, ten girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 84% of the girders in this subset. Figure I-263 shows the LFR and LRFR ratings. LFR ratings are between two and four for most girders while the LRFR ratings are between 0.5 and 3.0 for most girders. Three outliers were removed from the LFR graph with values of 11, 45, and 47.



(a) (b)

Figure I-263: LFR and LRFR Shear Ratings for Type 3-3 Vehicle

Figure I-264 shows the percentage of girders with shear ratings in each range for the AASHTO Type 3-3 truck, a special permit vehicle. 85.7% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 79.6% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 14.3% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 20.4% when an ADTT ≥ 5,000 is used.

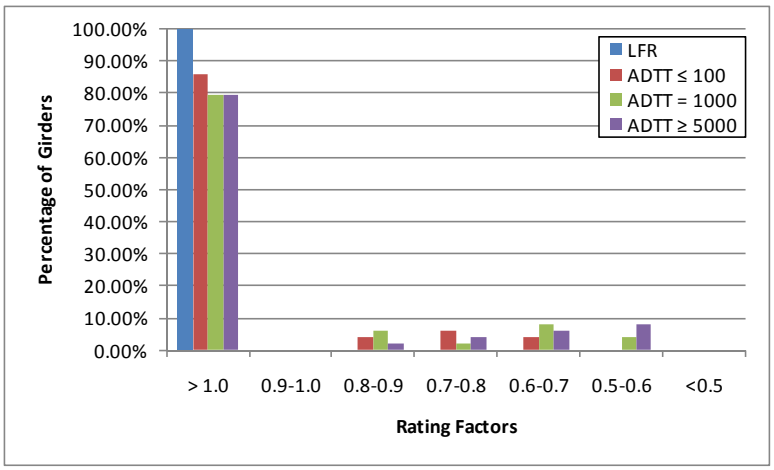


Figure I-264: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3-3 Truck

I.2.12.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-265 show the comparison of rating factors. The ratio is generally between 0.2 and 1.5. 16% of girders have an LRFR rating that is greater than the LFR rating.

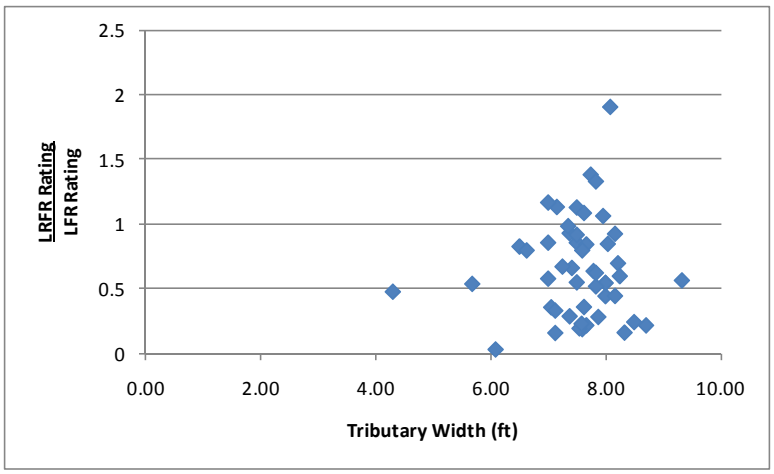


Figure I-265: LRFR Shear Rating divided by LFR Shear Rating for Type 3-3 Vehicle

I.2.12.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure I-266. The reliability index is between six and eight for most girders.

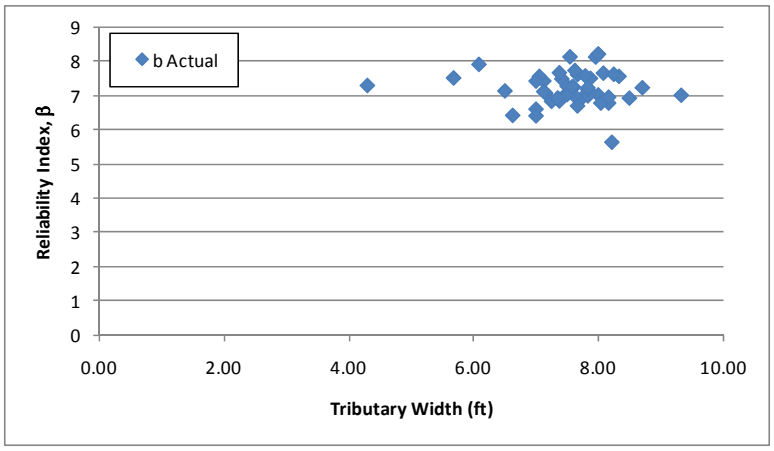


Figure I-266: Shear Reliability Indices for Type 3-3 Vehicle

Figure I-267 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3-3 Vehicle. The reliability index is approximately 4.0 for an LRFR rating of 1.0. This is above the target reliability of 2.5. The reliability index exceeding the target reliability of 2.5 indicates that the LRFR live load factors may be over-conservative.

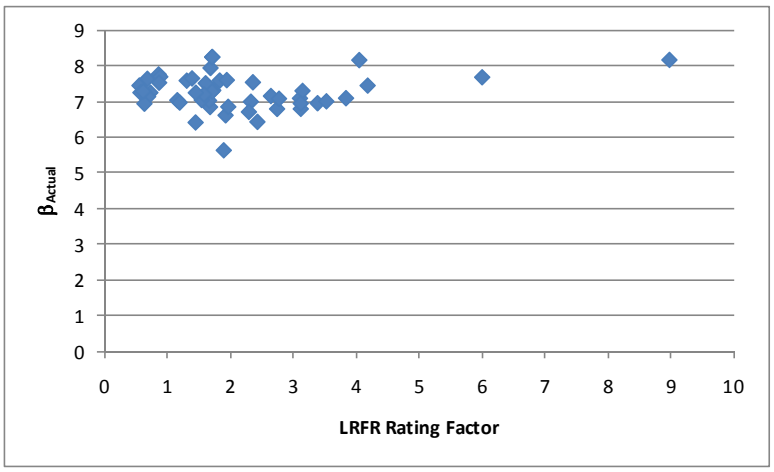


Figure I-267: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3-3 Vehicle

I.2.13 AASHTO Type 3S2

The vehicle used in this section is the AASHTO Type 3S2 vehicle. This vehicle is assumed to be a legal vehicle and uses the load factors prescribed in the MBE for an ADTT = 1,000. The loadings are shown schematically in Figure I-268. The applicable load factors for these vehicles are 1.3 and 1.65 for LFR and LRFR, respectively. The critical number of lanes loaded was utilized

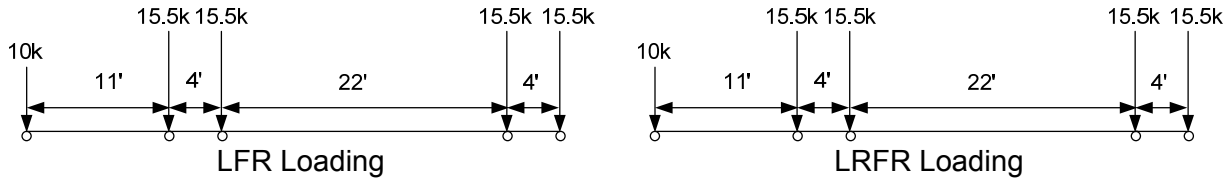
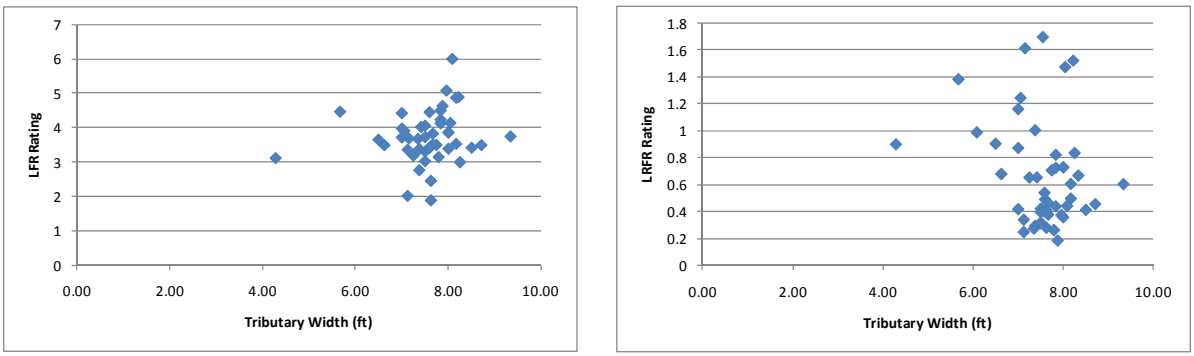


Figure I-268: Vehicle Loadings and Load Factors

I.2.13.1 Moment

I.2.13.1.1 Rating Factors

Figure I-269 shows the LFR and LRFR rating factors calculated by BRASS. The results show that there are zero girders with an LFR rating less than 1.0, 41 girders with an LRFR rating less than 1.0, and zero girders where both ratings are less than 1.0. All 41 girders with an LRFR rating less than 1.0 are controlled by the longitudinal steel rating. The LFR operating rating is greater than the LRFR legal rating for 100% of the girders in this subset. The LFR rating is between three and 4.5 for most girders while the LRFR rating is between 0.2 and 1.0 for most girders. The LFR graph had three outliers removed with values of 22, 45, and 68.



(a) (b)

Figure I-269: LFR and LRFR Flexure Rating Factors for Type 3S2 Vehicle

Figure I-270 shows the percentage of girders with moment ratings in each range for the AASHTO Type 3S2 truck, a legal vehicle. 24.5% of girders have LRFR ratings greater than 1.0 for an ADTT ≤ 100. The percentage of girders drops to 16.3% for an ADTT ≥ 5,000. 100% of girders have LFR ratings that are greater than 1.0. Switching from LFR to LRFR results in 75.5% more girders with ratings less than 1.0 when an ADTT ≤ 100 is used; this increases to 83.7% when an ADTT ≥ 5,000 is used.

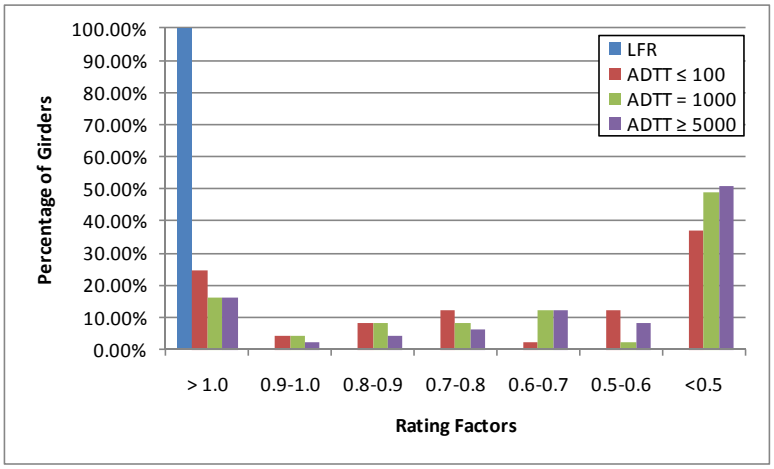


Figure I-270: Moment Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

I.2.13.1.2 Rating Factor Comparisons

Figure I-271 shows the ratio of LRFR rating to LFR rating. Values greater than 1.0 indicate the LRFR rating is greater than the LFR rating. The ratio is less than 0.45 for all girders; all girders have LFR ratings that are greater than the LRFR rating.

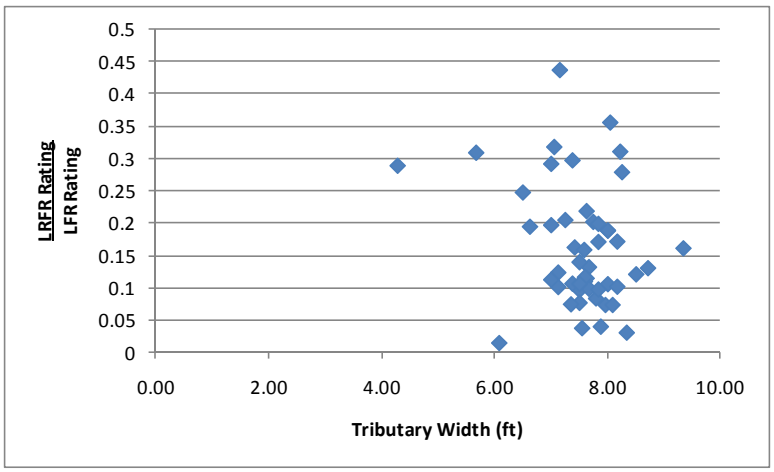


Figure I-271: LRFR Flexure rating divided by LFR Flexure rating for Type 3S2 Vehicle

I.2.13.1.3 Reliability Indices

The reliability index was calculated for this subset of girders. Figure I-272 shows that one girder has a reliability index less than the target reliability index of 2.5. The reliability index is between seven and ten for most girders not controlled by the longitudinal steel rating.

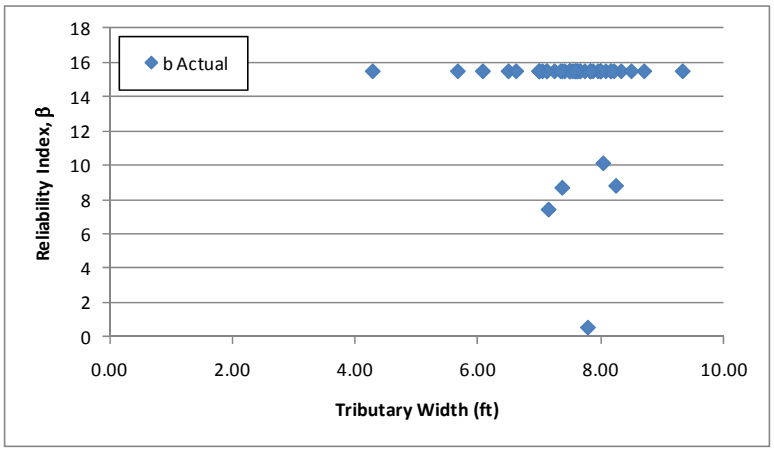


Figure I-272: Flexure Reliability Indices for Type 3S2 Vehicle

Figure I-273 shows the reliability index for moment plotted against the LRFR moment rating for the AASHTO Type 3S2 Truck. The reliability index associated with an LRFR rating of 1.0 is approximately 8.0, above the target reliability of 2.5. This indicates that using the ratings for the longitudinal steel to determine the effectiveness of the LRFR live load factors is not reasonable.

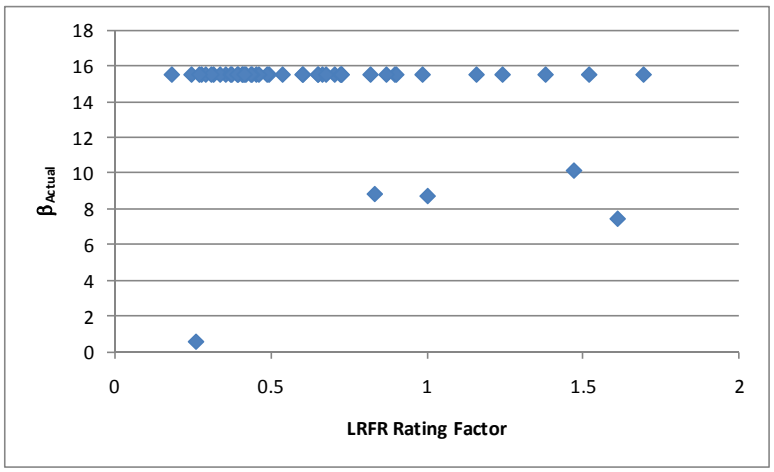
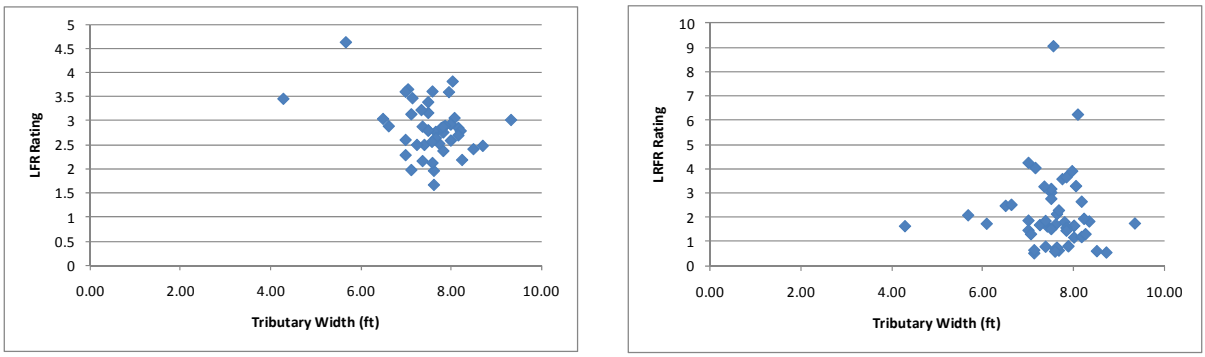


Figure I-273: Flexure Reliability Index vs LRFR Flexure Rating for AASHTO Type 3S2 Truck

I.2.13.2 Shear

I.2.13.2.1 Rating Factors

For shear, there are zero girders with LFR rating factors less than 1.0, ten girders with LRFR ratings less than 1.0, and zero girders where both ratings are less than 1.0. The LFR Rating is greater than the LRFR rating for 82% of the girders in this subset. Figure I-274 shows the LFR and LRFR ratings. LFR ratings are between two and 3.5 for most girders while the LRFR ratings are between 0.5 and three for most girders. Three outliers were removed from the LFR graph with values of 11, 45, and 48.



(a) (b)

Figure I-274: LFR and LRFR Shear Ratings for Type 3S2 Vehicle

Figure I-275 shows the percentage of girders with shear ratings in each range for the AASHTO Type 3S2 truck, a legal vehicle. 79.6% of girders have LRFR ratings greater than 1.0 for all ADTTs. 100% of girders have LFR ratings that are greater than 1.0. The switch from LFR to LRFR results in 20.4% more girders with ratings less than 1.0 for all ADTT values.

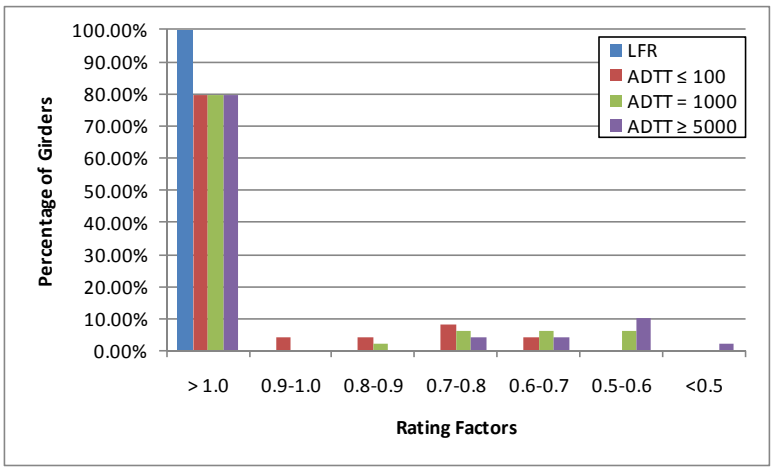


Figure I-275: Shear Ratings for Various ADTTs in MBE for AASHTO Type 3S2 Truck

I.2.13.2.2 Rating Factor Comparisons

The next step was to compare the rating factors. This was completed by dividing the LRFR Rating by the LFR Rating. Figure I-276 show the comparison of rating factors. The ratio is generally between 0.2 and 1.5. 18% of girders have an LRFR rating that is greater than the LFR rating.

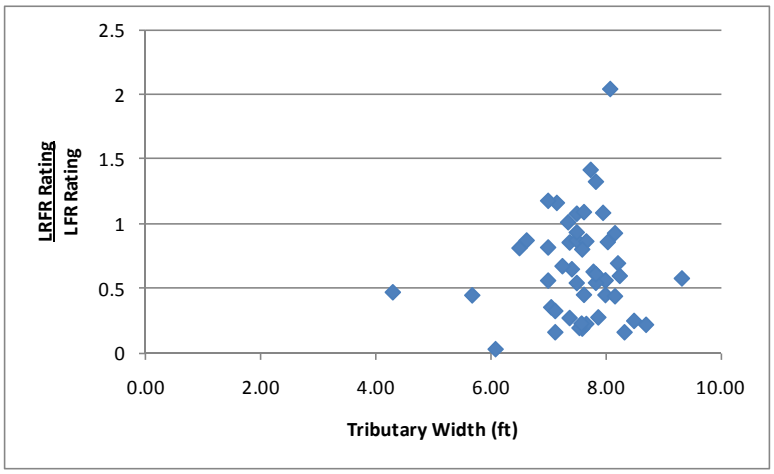


Figure I-276: LRFR Shear Rating divided by LFR Shear Rating for Type 3S2 Vehicle

I.2.13.2.3 Reliability Indices

The reliability index was also calculated. The reliability index is less than the target reliability index of 2.5 for zero girders as shown in Figure I-277. The reliability index is between six and eight for most girders.

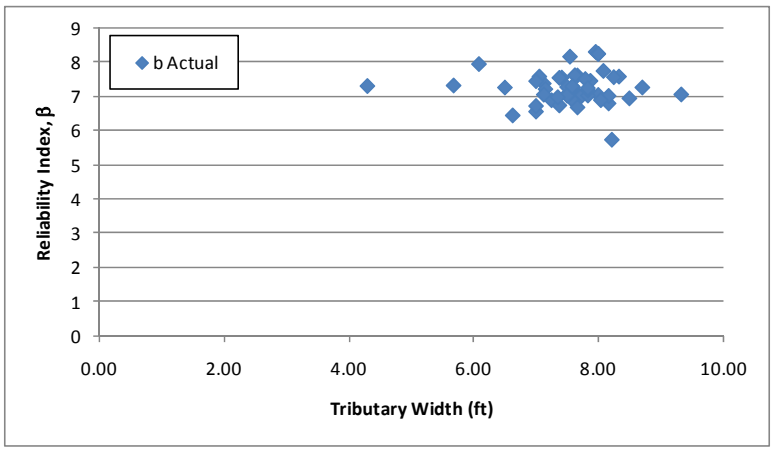


Figure I-277: Shear Reliability Indices for Type 3S2 Vehicle

Figure I-278 shows the reliability index for shear plotted against the LRFR shear rating for the AASHTO Type 3S2 Truck. The reliability index corresponding to an LRFR rating 1.0 is estimate to be about 4.0, above the target reliability of 2.5. This may indicate that the LRFR live load factors may be over-conservative.

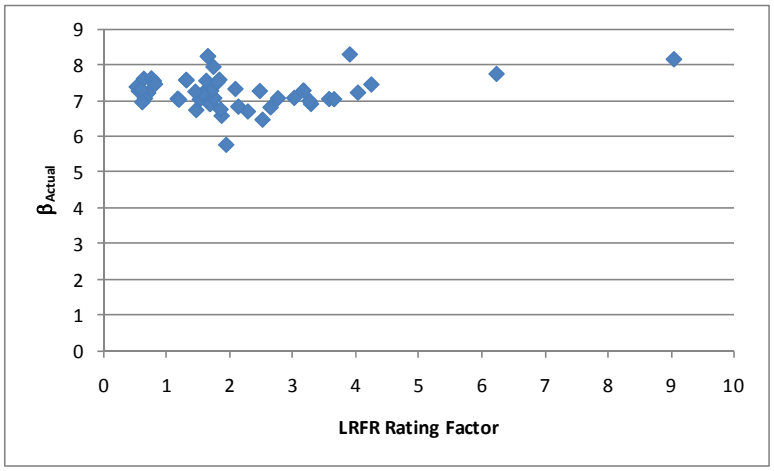


Figure I-278: Shear Reliability Index vs LRFR Shear Rating for AASHTO Type 3S2 Truck

I.2.14 Moment

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table I-3 shows the results for the moment ratings. Three of the twelve vehicles investigates, the Design Vehicle, OR-06, and WA-02, cause at least one girder to have an LRFR rating less than 1.0. All twelve vehicles cause at least 75% of the girders to have LRFR ratings less than 1.0. The second to last row in the table shows that most of the girders with LRFR ratings less than 1.0 were controlled by the longitudinal steel rating; those not controlled by the longitudinal steel rating were controlled by the Service III limit state. All girders had LFR ratings that were greater than the LRFR rating for all vehicles used in this study.

Table I-3: Flexure Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	49	1	0	0	0	0	0	1	0	2	0	0	0
LRFR Rating less than 1.0		46	42	40	40	40	39	41	40	44	38	39	41
LFR and LRFR Rating less than 1.0		1	0	0	0	0	0	1	0	2	0	0	0
% with LFR RF greater than LRFR RF		100	100	100	100	100	100	100	100	100	100	100	100
LRFR Rating less than 1.0 and controlled by longitudinal steel		46	40	39	37	38	38	39	38	39	38	39	41
LRFR Rating less than 1.0 and controlled by service limit state		0	2	1	3	2	1	2	2	5	0	0	0

I.2.15 Shear

The results shown in this section compare the number of girders for each vehicle that do not have ratings greater than 1.0 for LFR, LRFR, or both. Table I-4 shows the results for the shear ratings. Very few girders had LFR ratings less than 1.0 for any of the vehicles used in this study. The design, routine permit, and legal vehicles had 75 to 85% of the girders had LRFR ratings less than 1.0. The special permit vehicles had around 65% of girders with LFR ratings greater than the LRFR rating. The percentage of girders with LFR ratings greater than LRFR ratings seems to depend on the vehicle, which is expected because the LRFR shear strength equation uses the ratio of V_u/M_u.

Table I-4: Shear Rating Factor Results for All 12 Vehicles

	Total Girders	HL-93	DE-07	FL-04	IL-01	NC-21	NM-04	OR-06	TX-04	WA-02	Type 3	Type 3-3	Type 3S2
LFR Rating less than 1.0	49	1	0	0	0	0	0	0	0	2	0	0	0
LRFR Rating less than 1.0		20	10	10	11	10	10	10	10	18	10	10	10
LFR and LRFR Rating less than 1.0		0	0	0	0	0	0	0	0	1	0	0	0
% with LFR RF greater than LRFR RF		78	76	76	63	76	76	63	76	65	76	84	82

J Calculated Reliability Indices

The reliability indices are calculated for girder bridges as well as slab bridges for the moment and shear limit states. The results for twenty girders/slabs for each bridge type are presented in

Table J-1 through

Table J-22.

Table J-1 through Table J-7 present the results for simple span moment in composite steel girders, non-composite steel girders, prestressed concrete I-girders, composite prestressed box girders, non-composite prestressed box girders, reinforced concrete T-beams, and reinforced concrete slabs. Table J-8 through Table J-11 present the results for continuous span moments in composite steel girders, non-composite steel girders, reinforced concrete slabs, and prestressed concrete I-girders. Table J-12 through Table J-18 present the results for simple span shear in composite steel girders, non-composite steel girders, prestressed concrete I-girders, composite prestressed box girders, non-composite prestressed box girders, reinforced concrete T-beams, and reinforced concrete slabs. Table J-19 through Table J-22 present the results for continuous span shears in composite steel girders, non-composite steel girders, reinforced concrete slabs, and prestressed concrete I-girders.

For each girder, the following are provided: the mean total load, mQ, the standard deviation of total load, σ, the nominal resistance, R_n, bias factor for resistance, λ, coefficient of variation of resistance, V, and the reliability index, β. The reliability index, β, is calculated using the actual nominal resistance not the minimum value required based upon applied loads.

Shown below is an example of calculating the reliability index. Also shown are the equations required to calculate the standard deviation of each load as well as the standard deviation of the total load.

Example of Reliability analysis

Steel girder bridge, span 140 ft, girder spacing 7.75ft, non-composite plate girders, interior girder
Assume that multiple lanes loaded controls

Live load per lane (Positive Flexure at 0.4 pt)						
Design Truck	1405.2	k-ft				
Lane Load	903.5	k-ft				
Total LL	2308.7	k-ft				
Dynamic	463.7	k-ft				
LL + IM	2772.4	k-ft				
GDF	0.56		(includes 1.0 multiple presence factor)			
Nominal live load per girder	1292.9	k-ft				
Nominal live and impact per girder	1552.6	k-ft				
Bias for 1 lane loaded	0.98					
Bias factor for 2 lanes	0.98					
COV for live load	0.12					
mean live load	1267.01	k-ft				
mean live and impact	1393.72	k-ft				
COV for live and impact	0.19					
Standard deviation of live and impact	264.8	k-ft				
Dead load	Nominal		bias	COV	mean	st.dev
DC1 (steel girder)	334.8	k-ft	1.03	0.08	344.8	27.6
DC2 (slab)	785.0	k-ft	1.05	0.10	824.3	82.4
DW *(based on 3.5" wearing surface)*	209.1	k-ft	1.00	0.25	209.1	52.3
Mean total Load	2771.9	k-ft				
Standard deviation of total load	283.6	k-ft				
Resistance (lognormal)	Nominal		bias	COV	mean	st.dev
actual, S*Fn	4284.3	k-ft	1.12	0.10	4798.4	479.8
Code required R per girder	4430.3	k-ft	1.12	0.10	4961.96	496.2

Reliability Index	**beta**
Actual	**4.0**
Code required	**4.3**

Formula for reliability index, beta:

$$\beta = \frac{(1-2\cdot V_R)\left(1+LN\left(\frac{1}{1-2\cdot V_R}\right)\right)-\frac{\mu_Q}{\lambda_R R_n}}{\sqrt{\left(V_R-2V_R^{\ 2}\right)^2+\frac{\sigma_q^{\ 2}}{(\lambda_R R_N)^2}}}$$

Where:

V_R = coefficient of variation for resistance

μ_Q = mean total load

$\lambda_R R_n = \mu_R$ = actual mean resistance

σ_Q = standard deviation of total load

$= \sqrt{\sigma_{DC1}^2+\sigma_{DC2}^2+\sigma_{DW}^2}$

$\sigma = V\mu$

For code required beta, R_n is replaced with applied factored total load

Table J-1: Reliability Indices for HL-93, Simple Span Moment in Composite Steel Girders

Span (ft)	Spacing (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
82.33	8.00	2477.12	268.67	7203.89	1.08	0.11	7.09
80.00	10.50	2861.81	326.60	7765.78	1.08	0.11	6.71
109.00	7.67	3674.85	389.62	8275.75	1.08	0.11	5.85
153.61	7.25	5714.67	522.90	10511.81	1.08	0.11	4.83
27.00	1.83	330.77	49.08	465.49	1.12	0.10	2.78
35.00	6.17	467.42	68.97	931.50	1.12	0.10	5.11
25.86	8.00	423.92	51.70	613.00	1.12	0.10	3.29
32.00	3.91	320.71	39.81	761.06	1.12	0.10	6.50
45.33	7.81	985.68	110.89	2708.41	1.12	0.10	7.43
50.08	6.00	844.64	105.98	1419.78	1.12	0.10	4.30
39.77	5.79	582.38	79.78	1447.60	1.12	0.10	6.59
48.42	5.50	725.64	97.07	1740.81	1.12	0.10	6.43
53.00	8.00	1185.06	146.22	2854.93	1.12	0.10	6.60
51.42	8.25	1382.47	157.76	4429.99	1.12	0.10	8.13
34.17	7.33	559.37	74.48	1151.53	1.12	0.10	5.52
24.00	5.52	242.68	33.39	586.05	1.12	0.10	6.42
50.50	8.25	1074.88	134.99	3061.69	1.12	0.10	7.46
59.98	6.00	1096.12	132.40	2779.81	1.12	0.10	6.91
69.42	6.50	1697.35	180.48	3160.89	1.12	0.10	5.26
80.00	7.00	1467.55	185.23	3380.34	1.12	0.10	6.30

Table J-2: Reliability Indices for HL-93, Simple Span Moment in Non-Composite Steel Girders

Span (ft)	Spacing (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
30.00	5.67	381.11	53.31	797.38	1.11	0.12	4.85
36.67	6.42	461.23	55.47	659.45	1.12	0.10	3.23
48.42	6.00	759.33	94.32	593.50	1.12	0.10	-1.01
40.09	6.00	572.34	75.15	459.41	1.12	0.10	-0.80
51.76	8.00	1173.55	141.06	1365.80	1.12	0.10	1.73
43.00	3.00	580.08	89.27	380.26	1.12	0.10	-1.71
46.31	6.00	712.00	93.70	534.62	1.12	0.10	-1.20
31.50	3.21	384.35	58.57	318.28	1.12	0.10	-0.55
49.98	6.00	820.81	106.36	659.17	1.12	0.10	-0.81
47.35	6.50	807.41	112.56	1365.80	1.12	0.10	4.15
49.85	6.00	822.00	106.11	659.17	1.12	0.10	-0.82
52.70	1.98	708.34	118.44	500.14	1.12	0.10	-1.27
40.60	2.19	487.29	77.17	738.46	1.12	0.10	3.17
43.50	2.00	531.94	90.72	449.30	1.12	0.10	-0.40
26.17	5.00	235.30	37.82	543.50	1.12	0.10	5.84
51.60	4.67	609.46	97.94	1105.18	1.12	0.10	4.32
41.75	6.50	676.75	96.72	1350.12	1.12	0.10	5.18
46.85	3.05	692.33	101.53	659.70	1.12	0.10	0.26
69.17	6.00	1212.18	131.40	1098.27	1.12	0.10	-0.05
62.00	6.75	1504.65	172.54	1805.11	1.12	0.10	2.00

Table J-3: Reliability Indices for HL-93, Simple Span Moment in Prestrssed Concrete I-Girders

Span (ft)	Spacing (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
49.00	8.00	0.00	0.00	860.50	1.05	0.08	15.50
48.50	5.96	945.91	114.07	2190.81	1.05	0.08	7.14
38.50	9.17	0.00	0.00	134.35	1.05	0.08	15.50
47.67	8.00	405.60	53.98	1003.48	1.05	0.08	7.38
73.50	7.18	2264.02	228.59	3245.54	1.05	0.08	3.50
53.69	5.47	1040.92	116.53	2024.50	1.05	0.08	5.93
58.13	6.92	0.00	0.00	418.74	1.05	0.08	15.50
58.50	7.50	0.00	0.00	211.54	1.05	0.08	15.50
73.33	7.00	0.00	0.00	558.93	1.05	0.08	15.50
66.00	8.00	0.00	0.00	1022.65	1.05	0.08	15.50
67.50	6.67	1822.62	189.30	3045.21	1.05	0.08	4.81
100.00	6.00	3831.65	316.94	6865.36	1.05	0.08	5.90
98.13	7.75	0.00	0.00	1033.70	1.05	0.08	15.50
115.92	8.67	5950.98	508.15	10192.76	1.05	0.08	5.44
116.52	7.31	0.00	0.00	2789.73	1.05	0.08	15.50
137.13	5.88	6267.93	513.89	11065.14	1.05	0.08	5.78
28.33	9.25	0.00	0.00	159.17	1.05	0.08	15.50
64.83	6.75	1625.92	181.53	3172.90	1.05	0.08	5.96
89.71	6.17	2752.60	273.14	5176.84	1.05	0.08	5.93
90.00	10.58	0.00	0.00	1139.17	1.05	0.08	15.50

Table J-4: Reliability Indices for HL-93, Simple Span Moment in Composite Prestressed Box Girders

Span (ft)	Spacing (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
44.00	3.29	494.86	39.98	722.29	1.05	0.08	4.06
41.25	3.04	483.72	39.84	781.82	1.05	0.08	4.98
36.30	7.83	0.00	0.00	208.72	1.05	0.08	15.50
52.00	4.04	0.00	0.00	416.16	1.05	0.08	15.50
48.06	4.00	0.00	0.00	167.51	1.05	0.08	15.50
50.03	3.50	764.93	57.61	1164.06	1.05	0.08	4.57
72.15	3.04	0.00	0.00	433.50	1.05	0.08	15.50
75.00	3.79	0.00	0.00	499.36	1.05	0.08	15.50
82.67	4.67	3829.41	267.92	5537.29	1.05	0.08	4.19
72.50	3.14	1490.56	102.35	1749.24	1.05	0.08	2.09
57.27	6.92	0.00	0.00	445.03	1.05	0.08	15.50
79.96	3.54	0.00	0.00	1324.06	1.05	0.08	15.50
75.56	4.13	0.00	0.00	433.60	1.05	0.08	15.50
98.00	4.04	4032.86	257.74	4273.13	1.05	0.08	1.04
90.00	3.06	2466.19	161.84	2673.74	1.05	0.08	1.28
97.92	3.13	4048.26	346.01	3378.77	1.05	0.08	-1.31
51.97	5.97	0.00	0.00	311.93	1.05	0.08	15.50
70.83	3.13	0.00	0.00	239.86	1.05	0.08	15.50
73.82	3.79	0.00	0.00	520.66	1.05	0.08	15.50
28.32	4.00	331.02	29.46	483.61	1.05	0.08	3.90

Table J-5: Reliability Indices for HL-93, Simple Span Moment in Non-Composite Prestressed Box Girders

Span (ft)	Spacing (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
41.00	4.00	410.13	49.50	882.84	1.05	0.08	6.56
43.26	3.79	0.00	0.00	242.24	1.05	0.08	15.50
42.83	3.75	398.55	42.15	712.64	1.05	0.08	5.35
48.82	3.00	463.39	44.03	753.24	1.05	0.08	4.75
43.15	4.00	407.44	43.40	904.35	1.05	0.08	7.13
37.50	3.00	247.41	31.08	542.01	1.05	0.08	6.59
52.29	4.04	630.35	68.34	1127.48	1.05	0.08	5.30
51.39	4.04	553.85	54.85	1309.74	1.05	0.08	7.78
50.93	3.00	394.96	38.92	788.68	1.05	0.08	6.45
66.00	4.52	1341.58	147.26	2421.19	1.05	0.08	5.35
75.00	3.08	0.00	0.00	375.54	1.05	0.08	15.50
78.33	3.00	1004.16	96.95	1638.16	1.05	0.08	4.75
77.64	4.05	0.00	0.00	325.94	1.05	0.08	15.50
70.00	3.04	899.55	65.34	1479.15	1.05	0.08	5.35
74.88	3.00	891.13	77.99	1576.16	1.05	0.08	5.67
43.67	3.00	384.69	37.73	716.71	1.05	0.08	5.88
35.26	3.00	229.95	28.76	459.18	1.05	0.08	5.86
38.46	3.25	279.56	32.49	468.97	1.05	0.08	4.58
51.17	3.00	0.00	0.00	163.41	1.05	0.08	15.50
40.15	3.00	0.00	0.00	118.04	1.05	0.08	15.50

Table J-6: Reliability Indices for HL-93, Simple Span Moment in Reinforced Concrete T-Beams

Span (ft)	Spacing (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
39.25	5.15	658.07	78.93	1284.62	1.14	0.13	4.66
32.00	4.75	543.48	63.94	598.49	1.14	0.13	1.24
35.25	6.21	594.72	73.98	779.86	1.14	0.13	2.31
29.33	6.00	0.00	0.00	71.51	1.14	0.13	10.01
27.50	6.67	425.49	58.94	570.04	1.14	0.13	2.33
36.50	6.50	0.00	0.00	57.77	1.14	0.13	10.01
30.54	9.50	568.69	77.94	730.67	1.14	0.13	2.09
37.00	7.44	537.45	70.23	1225.29	1.14	0.13	5.33
33.00	8.50	582.84	83.17	657.33	1.14	0.13	1.26
37.90	6.75	473.92	61.63	1074.47	1.14	0.13	5.30
33.67	7.33	415.54	56.54	1079.63	1.14	0.13	5.86
39.04	8.25	0.00	0.00	40.76	1.14	0.13	10.01
31.00	7.50	509.58	71.52	660.60	1.14	0.13	2.12
51.50	6.90	1259.46	136.17	2080.37	1.14	0.13	3.85
50.00	6.03	1045.11	117.71	2412.17	1.14	0.13	5.53
56.50	5.67	1277.44	139.67	1382.20	1.14	0.13	1.16
60.00	9.00	749.08	89.85	971.46	1.14	0.13	2.28
46.88	7.33	413.19	50.18	1241.58	1.14	0.13	6.54
42.00	8.00	334.87	46.17	699.56	1.14	0.13	4.84
46.17	8.25	437.72	61.08	1078.26	1.14	0.13	5.60

Table J-7: Reliability Indices for HL-93, Simple Span Moment in Reinforced Concrete Slab Bridges

Span (ft)	Width (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
22.85	1.00	46.55	6.17	76.26	1.13	0.13	3.53
25.58	33.25	2080.35	240.12	2993.86	1.13	0.13	2.91
25.55	1.00	61.45	7.28	123.92	1.13	0.13	4.79
25.55	1.00	62.32	7.29	126.81	1.13	0.13	4.85
26.00	1.00	79.54	7.72	138.73	1.13	0.13	4.21
26.50	1.00	62.37	7.47	81.85	1.13	0.13	2.30
26.00	1.00	61.14	7.38	129.18	1.13	0.13	5.00
21.30	1.00	40.68	5.63	71.29	1.13	0.13	3.85
25.50	1.00	55.61	7.08	90.69	1.13	0.13	3.55
26.50	1.00	171.29	22.43	416.22	1.13	0.13	5.58
28.75	1.00	63.30	8.30	103.79	1.13	0.13	3.54
26.75	1.00	22.10	2.86	65.21	1.13	0.13	6.39
26.75	1.00	22.21	2.86	65.21	1.13	0.13	6.38
27.09	1.00	57.45	7.55	109.58	1.13	0.13	4.38
21.88	1.00	0.00	0.00	10.81	1.13	0.13	10.01
27.55	1.00	61.45	7.80	142.22	1.13	0.13	5.39
24.00	1.00	98.93	8.15	191.57	1.13	0.13	4.90
21.88	1.00	166.23	20.16	431.82	1.13	0.13	5.94
27.01	1.00	60.44	7.58	145.05	1.13	0.13	5.57
41.58	1.00	148.91	14.49	254.04	1.13	0.13	4.09

Table J-8: Reliability Indices for HL-93, Continuous Span Moment in Composite Steel Girders

Span (ft)	Spacing (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
84.17	6.08	-2544.63	246.07	-3625.70	1.05	0.10	3.02
116.00	7.00	-3946.70	343.27	-6688.09	1.05	0.10	4.44
56.00	7.33	980.38	118.46	1975.98	1.08	0.11	5.03
141.00	7.67	-7544.01	672.94	-13443.63	1.05	0.10	4.77
193.57	7.84	-7341.28	613.42	-13358.12	1.05	0.10	4.99
120.00	8.00	2359.26	288.92	2701.10	1.08	0.11	1.26
82.47	8.14	-3464.66	319.22	-5803.29	1.05	0.10	4.29
134.00	8.50	-9783.37	814.94	-18454.79	1.05	0.10	5.24
75.00	8.67	779.84	170.52	1808.41	1.08	0.11	4.69
267.83	8.92	14624.91	1425.48	15132.59	1.08	0.11	0.65
201.71	9.00	-5362.69	443.95	-8007.03	1.05	0.10	3.55
107.00	9.50	-5955.47	615.68	-4980.86	1.05	0.10	-1.13
58.09	10.00	-1698.00	163.34	-4056.25	1.05	0.10	6.54
62.83	5.83	-791.77	78.92	-1350.12	1.12	0.10	4.76
65.62	6.23	-1393.79	139.33	-4057.86	1.12	0.10	7.84
58.83	6.58	-1041.47	124.14	-2095.62	1.12	0.10	5.58
53.00	7.25	-838.67	100.09	-1732.81	1.12	0.10	5.74
61.00	7.50	-1115.70	117.10	-1796.59	1.12	0.10	4.29
76.00	8.00	1549.75	196.49	1877.39	1.12	0.10	1.96
66.13	8.83	-949.82	120.33	-2360.40	1.12	0.10	6.73

Table J-9: Reliability Indices for HL-93, Continuous Span Moment in Non-Composite Steel Girders

Span (ft)	Spacing (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
81.00	7.21	-2458.93	269.29	-4011.91	1.05	0.10	3.86
140.58	7.71	4148.33	491.97	5138.72	1.08	0.11	1.83
132.50	8.00	-2875.27	298.40	-3296.05	1.05	0.10	1.26
30.00	3.75	-168.73	20.38	-252.50	1.12	0.10	3.55
45.17	5.00	457.72	68.73	719.10	1.12	0.10	3.51
65.00	5.63	-1190.48	143.23	-1470.00	1.12	0.10	2.16
75.00	6.00	-1637.68	186.15	-1390.04	1.12	0.10	-0.51
60.00	6.00	-1134.52	136.29	-902.38	1.12	0.10	-0.92
48.50	6.00	588.35	82.19	890.67	1.12	0.10	3.38
90.00	6.00	-1394.63	149.12	-1345.26	1.12	0.10	0.42
35.75	6.25	-408.07	49.28	-659.17	1.12	0.10	4.09
41.92	6.28	-531.59	61.12	-814.30	1.12	0.10	3.79
46.58	6.33	511.81	75.77	811.57	1.12	0.10	3.60
67.50	6.33	692.10	96.72	1059.10	1.12	0.10	3.46
70.00	6.50	-1614.12	192.03	-1659.00	1.12	0.10	0.84
51.42	6.53	685.27	95.31	1601.89	1.12	0.10	6.21
57.25	6.58	-961.43	119.24	-1365.04	1.12	0.10	3.13
60.33	6.67	808.18	112.82	1603.63	1.12	0.10	5.20
33.33	6.75	360.32	54.64	583.22	1.12	0.10	3.69
81.00	6.79	-1515.93	175.26	-2154.44	1.12	0.10	3.24

Table J-10: Reliability Index for HL-93 Vehicle, Continuous Span Moment in Reinforced Concrete Slab Bridges

Span (ft)	Width (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
34.33	32.25	-1959.20	170.26	-3766.03	1.13	0.13	4.82
29.50	24.00	-1029.11	96.16	-1808.24	1.13	0.13	4.29
36.50	1.00	38.65	5.68	71.26	1.13	0.13	4.05
27.50	26.58	570.21	102.58	1574.78	1.13	0.13	5.73
31.33	1.00	-13.42	1.98	-57.43	1.13	0.13	7.49
27.75	1.00	-39.33	4.02	-86.98	1.13	0.13	5.38
34.00	30.75	650.16	114.86	1090.74	1.13	0.13	3.25
36.00	1.00	29.44	4.58	82.71	1.13	0.13	6.00
26.81	1.00	29.60	4.55	65.76	1.13	0.13	4.95
35.00	1.00	-23.70	2.61	-91.26	1.13	0.13	7.37
26.52	1.00	-15.46	1.97	-61.37	1.13	0.13	7.38
40.00	1.00	-22.11	2.85	-103.53	1.13	0.13	7.80
33.46	3.28	52.28	9.69	153.77	1.13	0.13	5.95
42.50	31.58	2924.54	321.19	4227.30	1.13	0.13	2.99
43.17	1.00	46.50	6.69	105.28	1.13	0.13	5.13
46.50	1.00	51.11	7.24	107.88	1.13	0.13	4.81
34.75	1.00	-77.20	6.60	-161.32	1.13	0.13	5.25
50.00	1.00	64.57	8.24	138.23	1.13	0.13	5.01
42.50	1.00	-31.92	3.24	-126.28	1.13	0.13	7.48
37.73	3.28	-208.33	18.63	-543.95	1.13	0.13	6.19

Table J-11: Reliability Indices for HL-93, Continuous Span Moment in Prestressed Concrete I-Girder

Span (ft)	Spacing (ft)	Load Effect (kip-ft)		Resistance (kip-ft)			β
		mQ	σ	R_n	λ	V	
60.88	7.00	-823.14	122.80	-1167.64	1.05	0.08	2.67
70.88	7.50	1386.65	114.14	4209.42	1.05	0.08	9.81
63.75	7.25	-997.76	151.07	-1414.13	1.05	0.08	2.63
73.50	9.00	-1325.96	218.49	-2071.09	1.05	0.08	3.18
74.42	7.00	-1068.67	179.36	-1546.50	1.05	0.08	2.59
82.41	8.20	-1682.02	243.15	-3391.68	1.05	0.08	5.52
119.09	5.91	802.12	155.07	6189.30	1.05	0.08	12.70
68.50	6.33	-1021.58	154.70	-1135.74	1.05	0.08	0.91
29.00	7.21	-207.54	44.52	1051.66	1.05	0.08	15.59
61.67	8.08	-733.98	108.91	-1395.07	1.05	0.08	4.97
116.54	8.42	3925.03	277.56	11214.70	1.05	0.08	9.63
49.25	7.25	926.18	104.96	1559.85	1.05	0.08	4.68
61.50	9.25	-868.88	145.03	-1634.54	1.05	0.08	4.55
60.25	8.75	-841.90	143.40	-1253.52	1.05	0.08	2.76
74.14	7.25	-1146.27	186.10	-1600.14	1.05	0.08	2.39
71.71	7.25	-901.24	162.22	414.54	1.05	0.08	8.09
60.25	8.75	-841.90	143.40	-1253.52	1.05	0.08	2.76
78.33	6.83	-1091.86	183.40	-1597.47	1.05	0.08	2.66
95.04	7.42	-1542.30	255.22	-2398.34	1.05	0.08	3.14
125.00	5.83	2379.71	159.14	6575.32	1.05	0.08	9.49

Table J-12: Reliability Indices for HL-93, Simple Span Shear in Composite Steel Girders

Span (ft)	Spacing (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
82.33	8.00	141.49	16.91	392.97	1.13	0.16	5.41
80.00	10.50	163.51	20.11	290.36	1.13	0.16	3.55
109.00	7.67	165.32	19.98	305.64	1.13	0.16	3.76
153.61	7.25	178.67	19.40	469.80	1.13	0.16	5.28
27.00	1.83	50.98	7.64	147.03	1.14	0.11	7.10
35.00	6.17	61.44	9.39	189.87	1.14	0.11	7.40
25.86	8.00	85.34	11.65	152.84	1.14	0.11	4.57
32.00	3.91	56.51	8.06	205.14	1.14	0.11	8.18
45.33	7.81	115.54	14.94	406.37	1.14	0.11	8.17
50.08	6.00	80.05	10.80	238.37	1.14	0.11	7.41
39.77	5.79	70.08	10.18	295.31	1.14	0.11	8.70
48.42	5.50	72.83	10.46	238.50	1.14	0.11	7.75
53.00	8.00	112.15	15.30	273.45	1.14	0.11	6.40
51.42	8.25	118.32	14.27	482.32	1.14	0.11	8.76
34.17	7.33	75.15	10.52	195.49	1.14	0.11	6.69
24.00	5.52	60.60	9.35	102.34	1.14	0.11	3.96
50.50	8.25	100.19	13.50	480.66	1.14	0.11	9.17
59.98	6.00	99.76	13.79	424.45	1.14	0.11	8.78
69.42	6.50	115.55	13.63	409.81	1.14	0.11	8.29
80.00	7.00	111.80	14.86	542.61	1.14	0.11	9.21

Table J-13: Reliability Indices for HL-93, Simple Span Shear in Non-Composite Steel Girders

Span (ft)	Spacing (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
30.00	5.67	57.40	8.34	131.55	1.13	0.16	4.54
36.67	6.42	71.66	10.02	242.59	1.14	0.11	7.92
48.42	6.00	88.48	12.59	203.34	1.14	0.11	6.00
40.09	6.00	75.71	10.98	177.71	1.14	0.11	6.08
51.76	8.00	106.92	13.89	406.37	1.14	0.11	8.45
43.00	3.00	59.60	9.37	162.63	1.14	0.11	6.74
46.31	6.00	79.00	11.37	202.82	1.14	0.11	6.58
31.50	3.21	51.68	7.98	176.29	1.14	0.11	7.82
49.98	6.00	79.99	11.18	238.37	1.14	0.11	7.36
47.35	6.50	76.34	11.05	406.37	1.14	0.11	9.40
49.85	6.00	82.67	11.63	238.37	1.14	0.11	7.20
52.70	1.98	58.04	9.80	248.63	1.14	0.11	8.58
40.60	2.19	53.02	8.55	241.54	1.14	0.11	8.85
43.50	2.00	54.52	9.41	232.89	1.14	0.11	8.55
26.17	5.00	40.81	6.70	317.41	1.14	0.11	10.16
51.60	4.67	60.00	10.02	306.18	1.14	0.11	9.16
41.75	6.50	75.15	11.22	463.86	1.14	0.11	9.74
46.85	3.05	63.91	9.57	254.67	1.14	0.11	8.47
69.17	6.00	92.77	11.73	348.36	1.14	0.11	8.43
62.00	6.75	107.97	13.09	497.39	1.14	0.11	9.13

Table J-14: Reliability Indices for HL-93, Simple Span Shear in Prestressed I-Girders

Span (ft)	Spacing (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
49.00	8.00	72.91	9.42	265.47	1.15	0.14	6.81
48.50	5.96	72.54	9.28	257.13	1.15	0.14	6.74
38.50	9.17	82.11	11.15	131.47	1.15	0.14	3.31
47.67	8.00	81.11	11.09	169.28	1.15	0.14	4.66
73.50	7.18	69.68	8.83	75.48	1.15	0.14	1.07
53.69	5.47	46.15	6.26	142.56	1.15	0.14	6.26
58.13	6.92	104.88	12.15	186.35	1.15	0.14	4.04
58.50	7.50	63.64	8.94	142.42	1.15	0.14	4.95
73.33	7.00	95.50	11.96	293.74	1.15	0.14	6.31
66.00	8.00	74.70	9.22	226.64	1.15	0.14	6.27
67.50	6.67	63.69	8.10	112.39	1.15	0.14	3.91
100.00	6.00	147.91	14.34	299.25	1.15	0.14	4.83
98.13	7.75	119.32	13.03	358.88	1.15	0.14	6.32
115.92	8.67	147.99	14.90	277.50	1.15	0.14	4.44
116.52	7.31	124.89	13.61	310.04	1.15	0.14	5.62
137.13	5.88	135.04	12.56	348.19	1.15	0.14	5.87
28.33	9.25	46.66	7.04	208.18	1.15	0.14	7.25
64.83	6.75	93.53	11.41	213.57	1.15	0.14	5.19
89.71	6.17	114.37	12.68	286.37	1.15	0.14	5.65
90.00	10.58	154.67	16.41	406.34	1.15	0.14	5.86

Table J-15: Reliability Indices for HL-93, Simple Span Shear in Composite Prestressed Box Girders

Span (ft)	Spacing (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
44.00	3.29	34.28	3.63	202.80	1.15	0.14	7.94
41.25	3.04	36.59	3.86	394.83	1.15	0.14	8.66
36.30	7.83	31.77	2.70	160.13	1.15	0.14	7.70
52.00	4.04	61.75	7.13	192.06	1.15	0.14	6.40
48.06	4.00	50.22	5.05	196.16	1.15	0.14	7.11
50.03	3.50	49.58	5.50	317.89	1.15	0.14	8.05
72.15	3.04	91.47	10.39	151.44	1.15	0.14	3.68
75.00	3.79	63.43	7.09	213.70	1.15	0.14	6.66
82.67	4.67	110.15	10.95	260.20	1.15	0.14	5.49
72.50	3.14	50.62	4.88	169.23	1.15	0.14	6.70
57.27	6.92	79.72	9.35	201.78	1.15	0.14	5.65
79.96	3.54	111.58	11.39	605.95	1.15	0.14	7.80
75.56	4.13	105.31	12.12	292.18	1.15	0.14	6.01
98.00	4.04	102.53	9.72	334.55	1.15	0.14	6.64
90.00	3.06	83.67	9.61	204.70	1.15	0.14	5.53
97.92	3.13	80.70	9.66	143.38	1.15	0.14	4.01
51.97	5.97	86.05	9.93	312.37	1.15	0.14	6.86
70.83	3.13	53.89	4.72	329.43	1.15	0.14	8.02
73.82	3.79	81.30	8.40	193.79	1.15	0.14	5.50
28.32	4.00	35.35	4.15	972.41	1.15	0.14	9.17

Table J-16: Reliability Indices for HL-93, Simple Span Shear in Non-Composite Prestressed Box Girders

Span (ft)	Spacing (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
41.00	4.00	41.74	5.29	112.65	1.15	0.14	5.83
43.26	3.79	49.27	6.35	113.23	1.15	0.14	5.16
42.83	3.75	22.98	3.09	65.31	1.15	0.14	5.97
48.82	3.00	35.50	3.95	134.68	1.15	0.14	7.00
43.15	4.00	38.17	4.85	147.08	1.15	0.14	6.97
37.50	3.00	23.09	3.07	131.62	1.15	0.14	7.82
52.29	4.04	24.80	3.96	71.89	1.15	0.14	5.88
51.39	4.04	45.93	5.68	155.05	1.15	0.14	6.61
50.93	3.00	34.22	4.35	132.33	1.15	0.14	6.98
66.00	4.52	49.25	6.63	97.34	1.15	0.14	4.42
75.00	3.08	71.43	8.93	124.29	1.15	0.14	3.85
78.33	3.00	26.24	3.12	56.58	1.15	0.14	4.96
77.64	4.05	107.28	12.59	173.91	1.15	0.14	3.53
70.00	3.04	76.14	9.55	132.69	1.15	0.14	3.86
74.88	3.00	47.31	5.32	142.46	1.15	0.14	6.30
43.67	3.00	31.17	3.29	137.04	1.15	0.14	7.37
35.26	3.00	23.64	3.19	113.29	1.15	0.14	7.47
38.46	3.25	17.39	2.45	69.56	1.15	0.14	7.01
51.17	3.00	37.29	4.04	51.28	1.15	0.14	2.66
40.15	3.00	35.41	4.15	44.94	1.15	0.14	2.11

Table J-17: Reliability Indices for HL-93, Simple Span Shear in Reinforced Concrete T-Beams

Span (ft)	Spacing (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
39.25	5.15	72.44	9.03	231.71	1.20	0.16	6.13
32.00	4.75	73.37	8.98	106.24	1.20	0.16	2.89
35.25	6.21	74.19	9.64	169.29	1.20	0.16	4.96
29.33	6.00	61.30	8.59	103.02	1.20	0.16	3.53
27.50	6.67	44.02	6.50	108.69	1.20	0.16	5.16
36.50	6.50	63.19	8.78	29.65	1.20	0.16	-3.09
30.54	9.50	48.38	7.52	62.82	1.20	0.16	2.08
37.00	7.44	89.61	12.85	150.33	1.20	0.16	3.50
33.00	8.50	55.19	8.25	80.08	1.20	0.16	2.71
37.90	6.75	84.43	11.82	120.22	1.20	0.16	2.68
33.67	7.33	41.69	6.22	80.00	1.20	0.16	4.09
39.04	8.25	94.00	13.18	97.02	1.20	0.16	0.89
31.00	7.50	67.13	9.49	79.87	1.20	0.16	1.69
51.50	6.90	109.47	12.48	272.13	1.20	0.16	5.38
50.00	6.03	96.18	11.27	387.54	1.20	0.16	6.74
56.50	5.67	84.87	9.92	122.43	1.20	0.16	2.91
60.00	9.00	113.46	13.71	79.33	1.20	0.16	-1.37
46.88	7.33	68.52	8.89	115.03	1.20	0.16	3.60
42.00	8.00	74.88	10.52	107.38	1.20	0.16	2.71
46.17	8.25	69.89	10.07	95.47	1.20	0.16	2.43

Table J-18: Reliability Indices for HL-93, Simple Span Shear in Reinforced Concrete Slab Bridges

Span (ft)	Width (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
22.85	1.00	8.41	1.11	28.36	1.20	0.16	6.25
25.58	33.25	334.90	38.39	1054.59	1.20	0.16	6.13
25.55	1.00	9.90	1.17	36.24	1.20	0.16	6.52
25.55	1.00	10.04	1.17	36.31	1.20	0.16	6.49
26.00	1.00	12.25	1.19	53.43	1.20	0.16	6.95
26.50	1.00	9.71	1.16	31.54	1.20	0.16	6.20
26.00	1.00	9.68	1.16	35.69	1.20	0.16	6.52
21.30	1.00	7.92	1.09	28.16	1.20	0.16	6.37
25.50	1.00	8.96	1.13	29.87	1.20	0.16	6.24
26.50	1.00	25.94	3.40	135.66	1.20	0.16	7.22
28.75	1.00	8.89	1.17	31.70	1.20	0.16	6.40
26.75	1.00	9.01	1.15	29.34	1.20	0.16	6.17
26.75	1.00	9.06	1.15	29.48	1.20	0.16	6.17
27.09	1.00	8.76	1.15	32.95	1.20	0.16	6.54
21.88	1.00	7.62	1.09	11.04	1.20	0.16	2.75
27.55	1.00	9.22	1.17	37.83	1.20	0.16	6.75
24.00	1.00	16.52	1.36	193.60	1.20	0.16	8.17
21.88	1.00	46.37	5.97	119.75	1.20	0.16	5.43
27.01	1.00	9.24	1.15	33.70	1.20	0.16	6.48
41.58	1.00	15.25	1.50	43.59	1.20	0.16	5.91

Table J-19: Reliability Indices for HL-93, Continuous Span Shear in Composite Steel Girders

Span (ft)	Spacing (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
84.17	6.08	170.61	19.80	371.04	1.13	0.16	4.51
116.00	7.00	212.15	22.92	591.51	1.13	0.16	5.48
56.00	7.33	128.37	16.42	419.64	1.13	0.16	5.88
141.00	7.67	265.23	25.98	494.29	1.13	0.16	3.95
193.57	7.84	295.09	28.01	465.66	1.13	0.16	3.15
120.00	8.00	182.45	20.19	282.90	1.13	0.16	2.95
82.47	8.14	186.65	21.90	768.39	1.13	0.16	6.51
134.00	8.50	288.15	28.67	250.07	1.13	0.16	-0.52
75.00	8.67	231.17	23.72	534.09	1.13	0.16	4.83
267.83	8.92	96.68	16.36	306.72	1.13	0.16	5.59
201.71	9.00	317.28	30.62	447.72	1.13	0.16	2.53
107.00	9.50	237.32	25.44	577.05	1.13	0.16	5.00
58.09	10.00	174.76	21.57	704.47	1.13	0.16	6.45
62.83	5.83	120.20	16.54	463.86	1.14	0.11	8.45
65.62	6.23	127.36	14.34	628.57	1.14	0.11	9.36
58.83	6.58	107.54	13.78	422.62	1.14	0.11	8.58
53.00	7.25	105.85	14.12	426.91	1.14	0.11	8.63
61.00	7.50	134.92	18.26	591.08	1.14	0.11	8.89
76.00	8.00	153.55	17.40	615.71	1.14	0.11	8.75
66.13	8.83	142.46	18.13	420.13	1.14	0.11	7.44

Table J-20: Reliability Indices for HL-93, Continuous Span Shear in Non-Composite Steel Girders

Span (ft)	Spacing (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
81.00	7.21	113.01	15.07	230.35	1.13	0.16	4.12
140.58	7.71	166.70	19.52	287.77	1.13	0.16	3.46
132.50	8.00	209.85	21.99	500.31	1.13	0.16	4.94
30.00	3.75	47.58	7.02	179.20	1.14	0.11	8.28
45.17	5.00	71.87	10.25	260.04	1.14	0.11	8.17
65.00	5.63	109.80	14.57	424.45	1.14	0.11	8.49
75.00	6.00	118.25	14.31	348.36	1.14	0.11	7.50
60.00	6.00	106.00	13.82	251.99	1.14	0.11	6.33
48.50	6.00	96.85	12.56	305.50	1.14	0.11	7.72
90.00	6.00	109.72	13.12	348.36	1.14	0.11	7.84
35.75	6.25	79.66	11.18	238.37	1.14	0.11	7.38
41.92	6.28	91.92	13.01	277.28	1.14	0.11	7.40
46.58	6.33	94.73	13.89	296.83	1.14	0.11	7.52
67.50	6.33	102.73	13.38	363.04	1.14	0.11	8.18
70.00	6.50	123.54	15.56	406.37	1.14	0.11	7.93
51.42	6.53	100.72	13.14	387.18	1.14	0.11	8.49
57.25	6.58	101.92	13.50	406.25	1.14	0.11	8.60
60.33	6.67	123.05	16.89	463.03	1.14	0.11	8.36
33.33	6.75	76.11	10.80	221.26	1.14	0.11	7.23
81.00	6.79	135.16	17.75	463.03	1.14	0.11	8.05

Table J-21: Reliability Index for HL-93, Continuous Span Shear in Reinforced Concrete Slab Bridges

Span (ft)	Width (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
34.33	32.25	416.27	43.27	672.44	1.15	0.14	3.63
29.50	24.00	274.73	29.98	514.58	1.15	0.14	4.36
36.50	1.00	10.03	1.22	18.21	1.15	0.14	4.11
27.50	26.58	243.81	31.25	517.42	1.15	0.14	4.81
31.33	1.00	6.50	0.88	11.95	1.15	0.14	4.05
27.75	1.00	9.83	1.19	17.59	1.15	0.14	4.03
34.00	30.75	223.81	28.68	318.57	1.15	0.14	2.71
36.00	1.00	10.26	1.24	22.06	1.15	0.14	4.92
26.81	1.00	6.81	0.95	16.02	1.15	0.14	5.19
35.00	1.00	7.98	1.02	10.76	1.15	0.14	2.39
26.52	1.00	6.70	0.94	10.13	1.15	0.14	2.96
40.00	1.00	8.74	1.08	12.20	1.15	0.14	2.63
33.46	3.28	32.04	3.87	54.72	1.15	0.14	3.79
42.50	31.58	461.74	47.11	876.27	1.15	0.14	4.48
43.17	1.00	11.81	1.34	25.56	1.15	0.14	5.02
46.50	1.00	12.79	1.40	24.90	1.15	0.14	4.55
34.75	1.00	13.21	1.38	24.97	1.15	0.14	4.45
50.00	1.00	13.43	1.46	26.49	1.15	0.14	4.62
42.50	1.00	9.14	1.11	12.20	1.15	0.14	2.38
37.73	3.28	41.90	4.53	64.13	1.15	0.14	3.29

Table J-22: Reliability Indices for HL-93, Continuous Span Shear in Prestressed Concrete I-Girders

Span (ft)	Spacing (ft)	Load Effect (kips)		Resistance (kips)			β
		mQ	σ	R_n	λ	V	
60.88	7.00	123.22	13.41	205.35	1.15	0.14	3.76
70.88	7.50	126.51	14.77	196.48	1.15	0.14	3.30
63.75	7.25	95.75	11.23	286.36	1.15	0.14	6.26
73.50	9.00	95.76	12.09	204.21	1.15	0.14	4.85
74.42	7.00	135.00	15.80	320.35	1.15	0.14	5.39
82.41	8.20	174.43	16.34	564.40	1.15	0.14	6.62
119.09	5.91	103.41	11.04	308.87	1.15	0.14	6.31
68.50	6.33	112.63	12.32	234.33	1.15	0.14	4.87
29.00	7.21	80.61	10.04	136.00	1.15	0.14	3.69
61.67	8.08	157.44	18.56	357.16	1.15	0.14	5.19
116.54	8.42	163.38	17.61	270.56	1.15	0.14	3.73
49.25	7.25	31.17	5.46	85.78	1.15	0.14	5.57
61.50	9.25	84.89	11.19	201.84	1.15	0.14	5.29
60.25	8.75	98.56	12.50	313.21	1.15	0.14	6.41
74.14	7.25	144.79	16.00	258.19	1.15	0.14	4.10
71.71	7.25	119.45	14.36	298.33	1.15	0.14	5.57
60.25	8.75	101.68	13.06	313.21	1.15	0.14	6.29
78.33	6.83	79.68	9.79	268.78	1.15	0.14	6.61
95.04	7.42	96.83	11.52	281.75	1.15	0.14	6.15
125.00	5.83	130.57	13.12	294.21	1.15	0.14	5.28

K Effect of Permit Type and ADTT on LRFR Ratings

The following sections provide tables for each bridge type containing the percentage of girders within each rating range for LFR and LRFR using the load factors currently specified for the AASHTO LFR and the current MBE. For the LRFR, all rating criteria were included in determining the controlling resistance. The tables cover all vehicles included in the study and are grouped based upon the vehicle type. The LRFR results for legal and routine permit vehicles are provided for each ADTT: less than 100, 1,000, and greater than 5,000. The LRFR results for special permit vehicles are provided for each type of special permit: single trip escorted, single trip allowed to mix with traffic, and multiple trip allowed to mix with traffic. The single trip and multiple trip permits allowed to mix with traffic are further divided into the same ADTT categories used for legal and routine permit vehicles. The results are shown for moment and shear and are split based on whether the girder is an interior or exterior girder and whether composite action is considered. For some bridge types, not all criteria (composite, non-composite, etc.) are applicable.

K.1 Simple Span Steel Girder Bridges

The tables in the following sections contain the percentage of girders in each rating category for the 1,037 simple span steel girders analyzed. Non-composite girders generally have significantly fewer girders with ratings above 1.0 than composite girders for flexure. The same trend is noted for shear except the difference is not as significant. The percentage of girders with passing ratings decreases with increasing ADTT as expected due to the increase in the load factor for live load.

K.1.1 AASHTO Legal Vehicles

Table 1 through Table 3 provide the distribution of rating factors for simple span steel girders for the three AASHTO Legal trucks: Type 3, Type 3-3, and Type 3S2.

Table 1: AASHTO Type 3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3	Moment	Exterior Composite	LFR	99.64%	0.00%	0.36%	0.00%	0.00%	0.00%
			ADTT ≤ 100	94.98%	2.51%	1.43%	0.72%	0.00%	0.36%
			ADTT = 1000	93.19%	0.72%	2.15%	2.51%	1.08%	0.36%
			ADTT ≥ 5000	92.11%	1.08%	1.08%	3.23%	1.79%	0.72%
		Exterior Non-Composite	LFR	75.19%	7.52%	10.53%	6.77%	0.00%	0.00%
			ADTT ≤ 100	52.63%	6.77%	6.02%	6.77%	9.02%	18.80%
			ADTT = 1000	48.87%	0.75%	6.77%	9.02%	5.26%	29.32%
			ADTT ≥ 5000	44.36%	4.51%	2.26%	8.27%	8.27%	32.33%
		Interior Composite	LFR	99.54%	0.46%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	97.22%	2.55%	0.23%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	93.52%	3.70%	2.55%	0.23%	0.00%	0.00%
		Interior Non-Composite	LFR	81.35%	7.25%	6.22%	2.07%	3.11%	0.00%
			ADTT ≤ 100	50.78%	4.15%	10.88%	16.06%	5.70%	12.44%
			ADTT = 1000	41.97%	6.22%	5.70%	10.36%	16.06%	19.69%
			ADTT ≥ 5000	38.34%	4.66%	7.25%	4.66%	14.51%	30.57%
AASHTO TYPE 3	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.92%	0.00%	0.00%	0.36%	0.72%	0.00%
			ADTT = 1000	98.21%	0.72%	0.00%	0.00%	0.36%	0.72%
			ADTT ≥ 5000	97.85%	0.36%	0.72%	0.00%	0.00%	1.08%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.98%	0.00%	3.01%	0.75%	0.75%	1.50%
			ADTT = 1000	91.73%	1.50%	0.75%	3.01%	0.75%	2.26%
			ADTT ≥ 5000	90.23%	1.50%	1.50%	0.75%	3.01%	3.01%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	99.07%	0.00%	0.23%	0.00%	0.46%	0.23%
			ADTT = 1000	98.38%	0.46%	0.23%	0.23%	0.00%	0.69%
			ADTT ≥ 5000	97.92%	0.46%	0.69%	0.00%	0.23%	0.69%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	92.23%	3.63%	0.00%	2.07%	0.52%	1.55%
			ADTT = 1000	90.67%	1.55%	3.11%	0.52%	1.55%	2.59%
			ADTT ≥ 5000	88.60%	2.59%	1.04%	3.63%	0.00%	4.15%

Table 2: AASHTO Type 3-3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3-3	Moment	Exterior Composite	LFR	99.64%	0.36%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	97.85%	1.08%	0.72%	0.00%	0.00%	0.36%
			ADTT = 1000	94.62%	2.51%	1.43%	1.08%	0.00%	0.36%
			ADTT ≥ 5000	93.19%	1.79%	2.51%	1.43%	0.72%	0.36%
		Exterior Non-Composite	LFR	88.72%	7.52%	3.76%	0.00%	0.00%	0.00%
			ADTT ≤ 100	62.41%	3.76%	4.51%	15.04%	9.77%	4.51%
			ADTT = 1000	53.38%	5.26%	5.26%	6.02%	12.78%	17.29%
			ADTT ≥ 5000	49.62%	4.51%	7.52%	4.51%	9.02%	24.81%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	99.77%	0.23%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	99.31%	0.46%	0.23%	0.00%	0.00%	0.00%
		Interior Non-Composite	LFR	89.12%	4.66%	4.15%	1.55%	0.52%	0.00%
			ADTT ≤ 100	60.62%	12.44%	6.74%	7.25%	9.33%	3.63%
			ADTT = 1000	49.74%	5.18%	12.44%	11.92%	6.74%	13.99%
			ADTT ≥ 5000	47.67%	2.59%	5.70%	17.10%	9.84%	17.10%
AASHTO TYPE 3-3	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.57%	0.36%	0.36%	0.00%	0.72%	0.00%
			ADTT = 1000	97.85%	0.72%	0.00%	0.72%	0.00%	0.72%
			ADTT ≥ 5000	97.49%	0.36%	0.72%	0.36%	0.36%	0.72%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.98%	0.00%	3.01%	0.75%	0.00%	2.26%
			ADTT = 1000	92.48%	0.00%	1.50%	3.01%	0.00%	3.01%
			ADTT ≥ 5000	90.23%	2.26%	0.75%	0.75%	3.01%	3.01%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	99.07%	0.00%	0.00%	0.23%	0.46%	0.23%
			ADTT = 1000	98.38%	0.46%	0.23%	0.00%	0.23%	0.69%
			ADTT ≥ 5000	98.15%	0.23%	0.69%	0.00%	0.00%	0.93%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	92.75%	1.55%	1.55%	2.07%	0.00%	2.07%
			ADTT = 1000	90.67%	2.07%	1.04%	2.07%	1.55%	2.59%
			ADTT ≥ 5000	89.12%	1.55%	2.07%	1.55%	1.55%	4.15%

Table 3: AASHTO Type 3S2 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3S2	Moment	Exterior Composite	LFR	99.64%	0.00%	0.36%	0.00%	0.00%	0.00%
			ADTT ≤ 100	96.77%	1.43%	1.08%	0.36%	0.00%	0.36%
			ADTT = 1000	93.19%	1.79%	2.51%	1.79%	0.36%	0.36%
			ADTT ≥ 5000	92.83%	0.72%	1.79%	2.87%	1.43%	0.36%
		Exterior Non-Composite	LFR	75.94%	12.78%	9.02%	2.26%	0.00%	0.00%
			ADTT ≤ 100	55.64%	6.02%	4.51%	7.52%	15.79%	10.53%
			ADTT = 1000	49.62%	3.01%	7.52%	5.26%	7.52%	27.07%
			ADTT ≥ 5000	45.86%	3.76%	5.26%	6.77%	6.02%	32.33%
		Interior Composite	LFR	99.54%	0.46%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	99.07%	0.69%	0.23%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	95.37%	3.94%	0.46%	0.23%	0.00%	0.00%
		Interior Non-Composite	LFR	84.46%	5.70%	4.66%	3.11%	2.07%	0.00%
			ADTT ≤ 100	53.89%	9.33%	7.25%	11.92%	9.84%	7.77%
			ADTT = 1000	45.60%	4.66%	5.70%	10.36%	16.06%	17.62%
			ADTT ≥ 5000	40.41%	6.22%	5.70%	10.88%	11.40%	25.39%
AASHTO TYPE 3S2	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.57%	0.36%	0.00%	0.36%	0.00%	0.72%
			ADTT = 1000	97.49%	0.72%	0.36%	0.36%	0.36%	0.72%
			ADTT ≥ 5000	97.49%	0.36%	0.72%	0.36%	0.36%	0.72%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.23%	0.75%	3.01%	0.00%	0.75%	2.26%
			ADTT = 1000	90.23%	2.26%	1.50%	2.26%	0.75%	3.01%
			ADTT ≥ 5000	88.72%	3.01%	0.75%	1.50%	3.01%	3.01%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	99.07%	0.00%	0.00%	0.23%	0.46%	0.23%
			ADTT = 1000	98.38%	0.23%	0.46%	0.00%	0.23%	0.69%
			ADTT ≥ 5000	98.15%	0.46%	0.23%	0.23%	0.00%	0.93%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	92.75%	1.55%	1.55%	0.00%	2.07%	2.07%
			ADTT = 1000	90.67%	1.04%	1.04%	3.11%	0.00%	4.15%
			ADTT ≥ 5000	88.08%	2.59%	1.55%	2.07%	1.55%	4.15%

K.1.2 Routine Permit Vehicles

Table 4 through Table 8 provide the distribution of rating factors for the different ADTTs for the five vehicles designated as routine permits: DE-07, FL-04, NC-21, NM-04 and TX-04.

Table 4: DE-07 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
DE-07	Moment	Exterior Composite	LFR	99.64%	0.00%	0.00%	0.36%	0.00%	0.00%
			ADTT ≤ 100	95.34%	2.51%	1.43%	0.00%	0.36%	0.36%
			ADTT = 1000	93.19%	1.43%	2.51%	2.15%	0.00%	0.72%
			ADTT ≥ 5000	90.68%	2.51%	1.43%	3.23%	1.43%	0.72%
		Exterior Non-Composite	LFR	65.41%	6.02%	12.03%	10.53%	6.02%	0.00%
			ADTT ≤ 100	51.88%	5.26%	8.27%	7.52%	15.79%	11.28%
			ADTT = 1000	45.86%	5.26%	5.26%	9.02%	10.53%	24.06%
			ADTT ≥ 5000	42.11%	3.76%	5.26%	6.02%	9.02%	33.83%
		Interior Composite	LFR	98.61%	0.46%	0.46%	0.46%	0.00%	0.00%
			ADTT ≤ 100	97.69%	2.08%	0.23%	0.00%	0.00%	0.00%
			ADTT = 1000	93.52%	2.55%	3.47%	0.46%	0.00%	0.00%
			ADTT ≥ 5000	90.74%	2.55%	2.78%	3.70%	0.23%	0.00%
		Interior Non-Composite	LFR	75.65%	3.11%	8.29%	7.77%	3.63%	1.55%
			ADTT ≤ 100	47.15%	8.29%	9.33%	6.22%	12.95%	16.06%
			ADTT = 1000	37.31%	5.18%	9.33%	12.95%	7.77%	27.46%
			ADTT ≥ 5000	33.16%	3.63%	5.70%	12.95%	10.88%	33.68%
DE-07	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.57%	0.00%	0.36%	0.00%	1.08%	0.00%
			ADTT = 1000	98.21%	0.00%	0.36%	0.36%	0.00%	1.08%
			ADTT ≥ 5000	97.49%	0.36%	0.36%	0.36%	0.36%	1.08%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.98%	0.00%	3.01%	0.00%	0.75%	2.26%
			ADTT = 1000	89.47%	3.76%	0.75%	3.01%	0.75%	2.26%
			ADTT ≥ 5000	87.97%	1.50%	3.76%	0.75%	3.01%	3.01%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.38%	0.46%	0.23%	0.00%	0.23%	0.69%
			ADTT = 1000	97.45%	0.93%	0.23%	0.46%	0.00%	0.93%
			ADTT ≥ 5000	96.30%	1.16%	0.93%	0.46%	0.23%	0.93%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	90.67%	1.04%	1.55%	2.59%	0.00%	4.15%
			ADTT = 1000	88.60%	0.52%	2.59%	1.55%	2.59%	4.15%
			ADTT ≥ 5000	87.56%	0.00%	1.55%	2.59%	3.11%	5.18%

Table 5: FL-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
FL-04	Moment	Exterior Composite	LFR	99.64%	0.00%	0.00%	0.36%	0.00%	0.00%
			ADTT ≤ 100	94.98%	2.51%	1.79%	0.00%	0.36%	0.36%
			ADTT = 1000	92.83%	1.79%	2.87%	1.79%	0.00%	0.72%
			ADTT ≥ 5000	91.76%	1.08%	1.79%	2.87%	1.79%	0.72%
		Exterior Non-Composite	LFR	66.92%	7.52%	7.52%	12.03%	6.02%	0.00%
			ADTT ≤ 100	51.13%	8.27%	6.77%	9.77%	14.29%	9.77%
			ADTT = 1000	46.62%	4.51%	6.02%	9.02%	12.03%	21.80%
			ADTT ≥ 5000	41.35%	5.26%	4.51%	8.27%	8.27%	32.33%
		Interior Composite	LFR	98.61%	0.93%	0.46%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.61%	1.39%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	93.75%	3.94%	2.08%	0.23%	0.00%	0.00%
			ADTT ≥ 5000	91.67%	2.08%	3.94%	2.31%	0.00%	0.00%
		Interior Non-Composite	LFR	76.17%	4.15%	7.25%	7.25%	3.63%	1.55%
			ADTT ≤ 100	46.63%	6.74%	10.36%	7.77%	15.03%	13.47%
			ADTT = 1000	39.38%	4.66%	8.29%	11.40%	8.81%	27.46%
			ADTT ≥ 5000	35.23%	3.63%	5.18%	9.33%	12.44%	34.20%
FL-04	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.57%	0.36%	0.00%	0.36%	0.72%	0.00%
			ADTT = 1000	98.21%	0.36%	0.00%	0.36%	0.36%	0.72%
			ADTT ≥ 5000	97.85%	0.36%	0.36%	0.36%	0.00%	1.08%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.98%	0.00%	3.01%	0.75%	0.75%	1.50%
			ADTT = 1000	90.98%	2.26%	0.75%	3.01%	0.75%	2.26%
			ADTT ≥ 5000	88.72%	2.26%	2.26%	0.75%	3.01%	3.01%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.61%	0.46%	0.00%	0.00%	0.23%	0.69%
			ADTT = 1000	97.92%	0.46%	0.46%	0.23%	0.00%	0.93%
			ADTT ≥ 5000	96.99%	0.69%	0.69%	0.69%	0.00%	0.93%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	90.67%	1.04%	3.11%	1.04%	1.55%	2.59%
			ADTT = 1000	88.60%	2.07%	1.04%	3.11%	1.04%	4.15%
			ADTT ≥ 5000	87.56%	1.04%	2.07%	1.04%	3.11%	5.18%

Table 6: NC-21 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NC-21	Moment	Exterior Composite	LFR	97.85%	1.79%	0.00%	0.00%	0.36%	0.00%
			ADTT ≤ 100	92.11%	2.15%	2.87%	2.15%	0.00%	0.72%
			ADTT = 1000	91.40%	0.72%	2.15%	2.87%	2.15%	0.72%
			ADTT ≥ 5000	88.53%	2.51%	1.08%	2.15%	3.23%	2.51%
		Exterior Non-Composite	LFR	57.14%	7.52%	9.77%	4.51%	15.79%	5.26%
			ADTT ≤ 100	45.86%	4.51%	4.51%	9.77%	10.53%	24.81%
			ADTT = 1000	41.35%	4.51%	3.76%	5.26%	12.78%	32.33%
			ADTT ≥ 5000	36.84%	3.76%	5.26%	4.51%	9.02%	40.60%
		Interior Composite	LFR	97.22%	1.39%	0.69%	0.69%	0.00%	0.00%
			ADTT ≤ 100	93.52%	3.47%	2.55%	0.46%	0.00%	0.00%
			ADTT = 1000	90.51%	3.01%	2.31%	3.70%	0.46%	0.00%
			ADTT ≥ 5000	86.81%	3.47%	3.24%	3.47%	3.01%	0.00%
		Interior Non-Composite	LFR	71.50%	3.63%	3.11%	8.81%	8.29%	4.66%
			ADTT ≤ 100	36.79%	6.74%	7.77%	12.44%	8.29%	27.98%
			ADTT = 1000	32.64%	3.11%	7.77%	7.77%	12.44%	36.27%
			ADTT ≥ 5000	25.91%	6.74%	3.11%	7.77%	9.84%	46.63%
NC-21	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.57%	0.36%	0.00%	0.00%	1.08%	0.00%
			ADTT = 1000	98.21%	0.36%	0.36%	0.00%	0.00%	1.08%
			ADTT ≥ 5000	97.85%	0.36%	0.36%	0.36%	0.00%	1.08%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.23%	0.75%	3.01%	0.75%	1.50%	0.75%
			ADTT = 1000	90.98%	2.26%	0.75%	3.01%	0.75%	2.26%
			ADTT ≥ 5000	88.72%	2.26%	2.26%	0.75%	3.01%	3.01%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.38%	0.46%	0.23%	0.23%	0.00%	0.69%
			ADTT = 1000	97.69%	0.23%	0.93%	0.23%	0.23%	0.69%
			ADTT ≥ 5000	96.76%	0.93%	0.23%	0.93%	0.23%	0.93%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	90.67%	1.55%	2.59%	1.04%	1.55%	2.59%
			ADTT = 1000	88.60%	1.55%	2.07%	2.59%	1.04%	4.15%
			ADTT ≥ 5000	88.08%	0.52%	1.55%	2.07%	3.63%	4.15%

Table 7: NM-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NM-04	Moment	Exterior Composite	LFR	99.64%	0.00%	0.00%	0.36%	0.00%	0.00%
			ADTT ≤ 100	96.42%	2.15%	0.72%	0.00%	0.36%	0.36%
			ADTT = 1000	94.27%	1.79%	2.51%	0.72%	0.00%	0.72%
			ADTT ≥ 5000	92.47%	1.43%	2.15%	2.51%	0.72%	0.72%
		Exterior Non-Composite	LFR	72.93%	5.26%	10.53%	9.77%	1.50%	0.00%
			ADTT ≤ 100	55.64%	7.52%	8.27%	9.02%	14.29%	5.26%
			ADTT = 1000	47.37%	6.02%	9.77%	8.27%	9.77%	18.80%
			ADTT ≥ 5000	46.62%	0.75%	6.02%	9.77%	10.53%	26.32%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	99.54%	0.46%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	96.76%	2.55%	0.69%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	94.91%	1.62%	2.78%	0.69%	0.00%	0.00%
		Interior Non-Composite	LFR	77.72%	4.66%	9.33%	4.15%	2.59%	1.55%
			ADTT ≤ 100	51.30%	9.84%	7.25%	9.33%	9.84%	12.44%
			ADTT = 1000	43.52%	5.70%	10.36%	8.81%	10.88%	20.73%
			ADTT ≥ 5000	39.90%	3.63%	5.70%	11.92%	9.33%	29.53%
NM-04	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.92%	0.00%	0.00%	1.08%	0.00%	0.00%
			ADTT = 1000	98.57%	0.36%	0.00%	0.00%	1.08%	0.00%
			ADTT ≥ 5000	98.21%	0.36%	0.36%	0.00%	0.00%	1.08%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.98%	3.01%	0.75%	0.75%	0.75%	0.75%
			ADTT = 1000	93.23%	0.75%	3.01%	0.75%	0.75%	1.50%
			ADTT ≥ 5000	90.98%	2.26%	0.75%	3.01%	0.75%	2.26%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.84%	0.23%	0.00%	0.23%	0.46%	0.23%
			ADTT = 1000	98.38%	0.46%	0.23%	0.00%	0.23%	0.69%
			ADTT ≥ 5000	97.69%	0.69%	0.46%	0.23%	0.23%	0.69%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	92.23%	2.59%	1.04%	0.00%	2.07%	2.07%
			ADTT = 1000	90.16%	2.07%	2.59%	1.04%	1.55%	2.59%
			ADTT ≥ 5000	88.60%	1.55%	2.07%	2.59%	1.04%	4.15%

Table 8: TX-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
TX-04	Moment	Exterior Composite	LFR	95.34%	3.58%	0.72%	0.00%	0.00%	0.36%
			ADTT ≤ 100	92.11%	1.79%	1.08%	3.58%	0.72%	0.72%
			ADTT = 1000	89.61%	2.51%	1.08%	1.79%	3.58%	1.43%
			ADTT ≥ 5000	84.59%	4.66%	2.87%	1.79%	2.15%	3.94%
		Exterior Non-Composite	LFR	55.64%	4.51%	6.02%	9.77%	14.29%	9.77%
			ADTT ≤ 100	45.86%	0.75%	5.26%	9.02%	9.77%	29.32%
			ADTT = 1000	40.60%	1.50%	4.51%	5.26%	9.77%	38.35%
			ADTT ≥ 5000	32.33%	6.77%	3.01%	4.51%	7.52%	45.86%
		Interior Composite	LFR	95.83%	1.39%	1.39%	0.69%	0.69%	0.00%
			ADTT ≤ 100	92.59%	1.16%	4.40%	1.85%	0.00%	0.00%
			ADTT = 1000	87.96%	3.24%	2.55%	4.40%	1.85%	0.00%
			ADTT ≥ 5000	82.87%	4.86%	3.47%	2.55%	4.86%	1.39%
		Interior Non-Composite	LFR	67.36%	5.70%	3.63%	5.18%	9.84%	8.29%
			ADTT ≤ 100	35.23%	4.15%	6.22%	12.44%	9.84%	32.12%
			ADTT = 1000	29.53%	5.18%	3.63%	7.25%	14.51%	39.90%
			ADTT ≥ 5000	23.32%	5.70%	5.70%	4.66%	8.81%	51.81%
TX-04	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.21%	0.00%	0.72%	0.00%	0.00%	1.08%
			ADTT = 1000	97.85%	0.36%	0.00%	0.72%	0.00%	1.08%
			ADTT ≥ 5000	97.13%	0.72%	0.36%	0.00%	0.72%	1.08%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	90.98%	2.26%	0.75%	3.01%	0.75%	2.26%
			ADTT = 1000	87.22%	2.26%	3.76%	0.75%	3.01%	3.01%
			ADTT ≥ 5000	84.21%	2.26%	3.01%	3.76%	0.75%	6.02%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	97.69%	0.23%	0.69%	0.46%	0.23%	0.69%
			ADTT = 1000	95.60%	1.62%	0.69%	0.69%	0.46%	0.93%
			ADTT ≥ 5000	91.67%	3.47%	2.08%	0.69%	0.93%	1.16%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	88.08%	0.52%	3.63%	2.07%	1.55%	4.15%
			ADTT = 1000	87.56%	0.52%	0.52%	3.63%	2.07%	5.70%
			ADTT ≥ 5000	87.05%	0.52%	0.52%	0.52%	3.63%	7.77%

K.1.3 Special Permit Vehicles

Table 9 through Table 11 provide the distribution of rating factors for the different permit types and ADTTs that are applicable to special permit vehicles. The special permit vehicles include: IL-01, OR-06, and WA-02.

Table 9: IL-01 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
IL-01	Moment	Exterior Composite	LFR	94.98%	1.79%	2.87%	0.00%	0.00%	0.36%
			Single Escorted	93.55%	1.79%	2.51%	1.43%	0.36%	0.36%
			Single ADTT ≤ 100	91.76%	1.43%	1.43%	2.87%	1.79%	0.72%
			Single ADTT = 1000	91.04%	1.08%	2.15%	2.87%	1.79%	1.08%
			Single ADTT ≥ 5000	89.96%	1.79%	1.43%	1.79%	3.23%	1.79%
			Multiple ADTT ≤ 100	89.25%	1.79%	1.08%	2.51%	2.87%	2.51%
			Multiple ADTT = 1000	84.23%	5.02%	1.79%	1.79%	2.15%	5.02%
			Multiple ADTT ≥ 5000	82.80%	3.58%	3.94%	1.79%	2.15%	5.73%
		Exterior Non-Composite	LFR	51.13%	5.26%	7.52%	6.02%	15.79%	14.29%
			Single Escorted	50.38%	3.76%	6.77%	4.51%	9.02%	25.56%
			Single ADTT ≤ 100	42.86%	6.02%	3.76%	6.77%	6.02%	34.59%
			Single ADTT = 1000	41.35%	7.52%	2.26%	6.02%	6.02%	36.84%
			Single ADTT ≥ 5000	36.09%	6.77%	6.77%	3.76%	8.27%	38.35%
			Multiple ADTT ≤ 100	36.09%	5.26%	7.52%	3.76%	7.52%	39.85%
			Multiple ADTT = 1000	32.33%	3.01%	6.02%	7.52%	4.51%	46.62%
			Multiple ADTT ≥ 5000	30.08%	3.01%	4.51%	9.02%	4.51%	48.87%
		Interior Composite	LFR	93.29%	3.01%	1.16%	1.62%	0.46%	0.46%
			Single Escorted	99.07%	0.93%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≤ 100	98.38%	0.46%	0.69%	0.46%	0.00%	0.00%
			Single ADTT = 1000	97.92%	0.69%	0.69%	0.69%	0.00%	0.00%
			Single ADTT ≥ 5000	96.99%	1.39%	0.69%	0.93%	0.00%	0.00%
			Multiple ADTT ≤ 100	96.30%	1.85%	0.69%	0.69%	0.46%	0.00%
			Multiple ADTT = 1000	93.52%	2.55%	1.85%	0.93%	1.16%	0.00%
			Multiple ADTT ≥ 5000	92.13%	2.55%	2.55%	1.16%	0.93%	0.69%
		Interior Non-Composite	LFR	62.69%	7.25%	5.18%	2.07%	10.88%	11.92%
			Single Escorted	57.51%	4.15%	6.74%	15.54%	9.33%	6.74%
			Single ADTT ≤ 100	48.70%	5.18%	4.66%	9.84%	15.03%	16.58%
			Single ADTT = 1000	45.60%	6.74%	5.18%	8.81%	14.51%	19.17%
			Single ADTT ≥ 5000	39.90%	8.81%	5.70%	5.18%	16.06%	24.35%
			Multiple ADTT ≤ 100	38.34%	7.77%	7.77%	4.66%	9.84%	31.61%
			Multiple ADTT = 1000	32.12%	4.66%	8.81%	8.29%	5.70%	40.41%
			Multiple ADTT ≥ 5000	30.57%	3.63%	7.25%	8.29%	7.77%	42.49%
IL-01	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	98.21%	0.36%	0.36%	0.36%	0.00%	0.72%
			Single ADTT ≤ 100	97.49%	0.00%	0.72%	0.36%	0.72%	0.72%
			Single ADTT = 1000	97.49%	0.00%	0.72%	0.36%	0.36%	1.08%
			Single ADTT ≥ 5000	97.13%	0.36%	0.00%	1.08%	0.36%	1.08%
			Multiple ADTT ≤ 100	97.13%	0.36%	0.00%	0.72%	0.72%	1.08%
			Multiple ADTT = 1000	96.42%	0.72%	0.36%	0.00%	1.08%	1.43%
			Multiple ADTT ≥ 5000	96.42%	0.36%	0.36%	0.36%	0.72%	1.79%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	92.48%	0.00%	1.50%	3.01%	0.00%	3.01%
			Single ADTT ≤ 100	87.22%	3.01%	2.26%	1.50%	3.01%	3.01%
			Single ADTT = 1000	86.47%	3.76%	2.26%	1.50%	3.01%	3.01%
			Single ADTT ≥ 5000	84.21%	3.01%	3.01%	2.26%	1.50%	6.02%
			Multiple ADTT ≤ 100	83.46%	3.01%	3.76%	2.26%	1.50%	6.02%
			Multiple ADTT = 1000	82.71%	0.00%	3.76%	3.76%	2.26%	7.52%
			Multiple ADTT ≥ 5000	81.95%	0.75%	3.01%	3.76%	3.01%	7.52%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	98.84%	0.23%	0.00%	0.23%	0.46%	0.23%
			Single ADTT ≤ 100	98.61%	0.23%	0.23%	0.00%	0.23%	0.69%
			Single ADTT = 1000	97.92%	0.69%	0.46%	0.00%	0.00%	0.93%
			Single ADTT ≥ 5000	97.22%	1.39%	0.23%	0.23%	0.00%	0.93%
			Multiple ADTT ≤ 100	97.22%	0.93%	0.69%	0.23%	0.00%	0.93%
			Multiple ADTT = 1000	92.36%	4.17%	1.39%	0.93%	0.23%	0.93%
			Multiple ADTT ≥ 5000	92.36%	0.93%	4.40%	0.93%	0.46%	0.93%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	92.75%	1.55%	1.55%	0.00%	2.07%	2.07%
			Single ADTT ≤ 100	90.67%	1.04%	2.07%	2.07%	0.00%	4.15%
			Single ADTT = 1000	89.64%	1.55%	2.59%	1.04%	1.04%	4.15%
			Single ADTT ≥ 5000	88.08%	2.59%	1.04%	2.07%	2.07%	4.15%
			Multiple ADTT ≤ 100	88.08%	1.55%	2.07%	2.07%	2.07%	4.15%
			Multiple ADTT = 1000	87.56%	0.52%	1.55%	2.07%	2.07%	6.22%
			Multiple ADTT ≥ 5000	87.56%	0.00%	1.04%	2.59%	2.59%	6.22%

Table 10: OR-06 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
OR-06	Moment	Exterior Composite	LFR	93.91%	1.43%	2.87%	1.43%	0.00%	0.36%
			Single Escorted	93.19%	1.79%	2.51%	1.79%	0.36%	0.36%
			Single ADTT ≤ 100	92.11%	1.08%	1.08%	3.23%	1.43%	1.08%
			Single ADTT = 1000	91.40%	1.79%	0.36%	2.51%	2.87%	1.08%
			Single ADTT ≥ 5000	90.32%	1.79%	1.08%	1.79%	3.23%	1.79%
			Multiple ADTT ≤ 100	89.61%	1.79%	1.79%	1.08%	3.23%	2.51%
			Multiple ADTT = 1000	84.95%	3.58%	2.87%	1.79%	1.79%	5.02%
			Multiple ADTT ≥ 5000	83.87%	2.15%	4.66%	2.15%	1.08%	6.09%
		Exterior Non-Composite	LFR	48.87%	4.51%	5.26%	8.27%	9.02%	24.06%
			Single Escorted	50.38%	3.76%	5.26%	6.02%	6.77%	27.82%
			Single ADTT ≤ 100	44.36%	5.26%	1.50%	7.52%	6.77%	34.59%
			Single ADTT = 1000	43.61%	3.76%	3.01%	6.77%	8.27%	34.59%
			Single ADTT ≥ 5000	38.35%	6.02%	5.26%	3.76%	7.52%	39.10%
			Multiple ADTT ≤ 100	36.84%	6.77%	3.76%	3.76%	8.27%	40.60%
			Multiple ADTT = 1000	32.33%	3.76%	7.52%	6.02%	3.76%	46.62%
			Multiple ADTT ≥ 5000	29.32%	4.51%	4.51%	7.52%	4.51%	49.62%
		Interior Composite	LFR	90.51%	3.70%	3.01%	1.39%	0.93%	0.46%
			Single Escorted	99.77%	0.23%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≤ 100	98.38%	0.69%	0.93%	0.00%	0.00%	0.00%
			Single ADTT = 1000	98.15%	0.69%	0.93%	0.23%	0.00%	0.00%
			Single ADTT ≥ 5000	97.22%	1.16%	0.93%	0.69%	0.00%	0.00%
			Multiple ADTT ≤ 100	96.76%	1.39%	0.93%	0.93%	0.00%	0.00%
			Multiple ADTT = 1000	93.29%	2.31%	2.55%	0.93%	0.93%	0.00%
			Multiple ADTT ≥ 5000	93.06%	1.39%	3.47%	0.93%	1.16%	0.00%
		Interior Non-Composite	LFR	61.14%	5.18%	6.74%	3.63%	5.70%	17.62%
			Single Escorted	55.96%	5.18%	9.33%	9.33%	13.47%	6.74%
			Single ADTT ≤ 100	49.74%	3.11%	5.70%	10.88%	10.36%	20.21%
			Single ADTT = 1000	46.63%	5.18%	5.70%	8.81%	11.92%	21.76%
			Single ADTT ≥ 5000	41.97%	7.77%	3.63%	5.70%	13.47%	27.46%
			Multiple ADTT ≤ 100	41.45%	5.18%	5.18%	6.74%	11.40%	30.05%
			Multiple ADTT = 1000	32.12%	6.22%	8.29%	5.18%	7.25%	40.93%
			Multiple ADTT ≥ 5000	31.09%	4.66%	6.74%	8.29%	7.25%	41.97%
OR-06	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	98.21%	0.36%	0.36%	0.36%	0.00%	0.72%
			Single ADTT ≤ 100	97.49%	0.36%	0.72%	0.36%	0.36%	0.72%
			Single ADTT = 1000	97.49%	0.36%	0.36%	0.72%	0.00%	1.08%
			Single ADTT ≥ 5000	97.13%	0.36%	0.36%	0.72%	0.36%	1.08%
			Multiple ADTT ≤ 100	97.13%	0.36%	0.36%	0.36%	0.72%	1.08%
			Multiple ADTT = 1000	97.13%	0.00%	0.36%	0.36%	0.72%	1.43%
			Multiple ADTT ≥ 5000	96.42%	0.72%	0.00%	0.72%	0.36%	1.79%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	91.73%	2.26%	3.01%	0.00%	0.75%	2.26%
			Single ADTT ≤ 100	90.23%	1.50%	2.26%	0.75%	2.26%	3.01%
			Single ADTT = 1000	89.47%	2.26%	0.75%	1.50%	3.01%	3.01%
			Single ADTT ≥ 5000	85.71%	4.51%	1.50%	2.26%	3.01%	3.01%
			Multiple ADTT ≤ 100	84.96%	5.26%	1.50%	2.26%	3.01%	3.01%
			Multiple ADTT = 1000	82.71%	2.26%	4.51%	2.26%	2.26%	6.02%
			Multiple ADTT ≥ 5000	81.95%	2.26%	2.26%	5.26%	0.75%	7.52%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	99.07%	0.00%	0.00%	0.69%	0.00%	0.23%
			Single ADTT ≤ 100	98.84%	0.23%	0.00%	0.00%	0.69%	0.23%
			Single ADTT = 1000	97.92%	1.16%	0.00%	0.00%	0.23%	0.69%
			Single ADTT ≥ 5000	97.69%	1.16%	0.23%	0.00%	0.00%	0.93%
			Multiple ADTT ≤ 100	97.69%	0.46%	0.93%	0.00%	0.00%	0.93%
			Multiple ADTT = 1000	93.52%	4.17%	0.23%	1.16%	0.00%	0.93%
			Multiple ADTT ≥ 5000	92.82%	2.78%	2.08%	1.16%	0.23%	0.93%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	93.78%	2.07%	0.00%	2.07%	0.52%	1.55%
			Single ADTT ≤ 100	91.19%	2.59%	1.04%	1.04%	2.07%	2.07%
			Single ADTT = 1000	90.67%	2.07%	1.04%	2.07%	2.07%	2.07%
			Single ADTT ≥ 5000	89.12%	2.07%	2.59%	2.07%	0.00%	4.15%
			Multiple ADTT ≤ 100	88.08%	3.11%	2.59%	1.04%	1.04%	4.15%
			Multiple ADTT = 1000	87.56%	0.52%	2.59%	3.11%	2.07%	4.15%
			Multiple ADTT ≥ 5000	87.56%	0.00%	2.07%	2.07%	2.07%	6.22%

Table 11: WA-02 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
WA-02	Moment	Exterior Composite	LFR	89.96%	3.94%	2.51%	1.79%	1.43%	0.36%
			Single Escorted	91.40%	0.72%	2.15%	2.87%	1.79%	1.08%
			Single ADTT ≤ 100	87.10%	2.87%	1.79%	1.79%	3.58%	2.87%
			Single ADTT = 1000	85.30%	3.23%	2.87%	1.43%	2.87%	4.30%
			Single ADTT ≥ 5000	81.36%	5.73%	2.87%	2.15%	2.51%	5.38%
			Multiple ADTT ≤ 100	80.65%	4.66%	3.23%	3.23%	2.51%	5.73%
			Multiple ADTT = 1000	77.06%	3.58%	4.66%	3.23%	3.58%	7.89%
			Multiple ADTT ≥ 5000	74.55%	4.66%	2.15%	6.81%	3.23%	8.60%
		Exterior Non-Composite	LFR	42.11%	9.02%	3.76%	6.02%	8.27%	30.83%
			Single Escorted	44.36%	1.50%	6.77%	3.76%	8.27%	35.34%
			Single ADTT ≤ 100	31.58%	10.53%	3.01%	6.77%	4.51%	43.61%
			Single ADTT = 1000	31.58%	9.02%	4.51%	5.26%	5.26%	44.36%
			Single ADTT ≥ 5000	27.82%	3.76%	11.28%	2.26%	8.27%	46.62%
			Multiple ADTT ≤ 100	27.07%	4.51%	9.77%	3.76%	7.52%	47.37%
			Multiple ADTT = 1000	24.06%	2.26%	5.26%	10.53%	3.01%	54.89%
			Multiple ADTT ≥ 5000	24.06%	0.75%	3.01%	7.52%	9.77%	54.89%
		Interior Composite	LFR	89.12%	3.24%	3.70%	2.31%	1.16%	0.46%
			Single Escorted	98.61%	1.16%	0.23%	0.00%	0.00%	0.00%
			Single ADTT ≤ 100	96.06%	1.85%	1.62%	0.46%	0.00%	0.00%
			Single ADTT = 1000	94.44%	2.78%	1.85%	0.93%	0.00%	0.00%
			Single ADTT ≥ 5000	93.29%	2.78%	1.85%	1.62%	0.46%	0.00%
			Multiple ADTT ≤ 100	93.06%	1.39%	3.24%	1.62%	0.69%	0.00%
			Multiple ADTT = 1000	89.81%	2.55%	2.08%	3.24%	1.85%	0.46%
			Multiple ADTT ≥ 5000	88.19%	3.70%	1.39%	3.94%	1.85%	0.93%
		Interior Non-Composite	LFR	59.07%	1.04%	7.77%	5.18%	4.15%	22.80%
			Single Escorted	48.19%	4.15%	6.74%	8.81%	10.36%	21.76%
			Single ADTT ≤ 100	39.90%	7.77%	3.63%	4.66%	11.40%	32.64%
			Single ADTT = 1000	37.82%	7.25%	4.66%	4.15%	10.88%	35.23%
			Single ADTT ≥ 5000	34.72%	5.18%	7.77%	3.63%	8.81%	39.90%
			Multiple ADTT ≤ 100	32.12%	5.70%	9.33%	4.15%	6.22%	42.49%
			Multiple ADTT = 1000	26.94%	4.15%	6.74%	9.84%	3.63%	48.70%
			Multiple ADTT ≥ 5000	19.17%	8.81%	6.74%	7.25%	7.77%	50.26%
WA-02	Shear	Exterior Composite	LFR	99.64%	0.00%	0.00%	0.36%	0.00%	0.00%
			Single Escorted	97.49%	0.00%	0.36%	0.36%	1.08%	0.72%
			Single ADTT ≤ 100	97.13%	0.36%	0.00%	0.36%	0.36%	1.79%
			Single ADTT = 1000	96.77%	0.36%	0.36%	0.36%	0.36%	1.79%
			Single ADTT ≥ 5000	96.06%	1.08%	0.36%	0.00%	0.72%	1.79%
			Multiple ADTT ≤ 100	95.34%	1.43%	0.36%	0.36%	0.36%	2.15%
			Multiple ADTT = 1000	92.83%	2.15%	1.79%	0.72%	0.00%	2.51%
			Multiple ADTT ≥ 5000	91.40%	2.51%	2.15%	1.08%	0.36%	2.51%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	86.47%	3.01%	3.01%	1.50%	3.01%	3.01%
			Single ADTT ≤ 100	83.46%	2.26%	3.76%	3.01%	1.50%	6.02%
			Single ADTT = 1000	82.71%	2.26%	3.01%	4.51%	0.75%	6.77%
			Single ADTT ≥ 5000	81.95%	1.50%	2.26%	3.76%	3.01%	7.52%
			Multiple ADTT ≤ 100	81.95%	0.75%	2.26%	4.51%	3.01%	7.52%
			Multiple ADTT = 1000	81.95%	0.00%	0.75%	3.01%	3.76%	10.53%
			Multiple ADTT ≥ 5000	81.95%	0.00%	0.75%	0.75%	5.26%	11.28%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	97.45%	1.16%	0.46%	0.00%	0.00%	0.93%
			Single ADTT ≤ 100	93.06%	3.47%	2.08%	0.46%	0.00%	0.93%
			Single ADTT = 1000	92.82%	3.47%	2.08%	0.46%	0.23%	0.93%
			Single ADTT ≥ 5000	91.67%	1.39%	3.47%	2.08%	0.46%	0.93%
			Multiple ADTT ≤ 100	91.67%	1.16%	3.47%	2.08%	0.69%	0.93%
			Multiple ADTT = 1000	90.28%	1.39%	1.16%	3.47%	2.31%	1.39%
			Multiple ADTT ≥ 5000	88.66%	2.78%	0.69%	3.70%	2.55%	1.62%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	89.64%	2.07%	2.07%	0.52%	1.55%	4.15%
			Single ADTT ≤ 100	87.56%	1.04%	2.59%	2.59%	0.52%	5.70%
			Single ADTT = 1000	87.56%	1.04%	1.55%	2.59%	1.55%	5.70%
			Single ADTT ≥ 5000	87.56%	0.00%	1.04%	3.11%	2.07%	6.22%
			Multiple ADTT ≤ 100	87.56%	0.00%	1.04%	2.59%	2.59%	6.22%
			Multiple ADTT = 1000	87.05%	0.52%	0.00%	1.04%	3.11%	8.29%
			Multiple ADTT ≥ 5000	85.49%	1.55%	0.52%	0.52%	2.59%	9.33%

K.2 Simple Span Prestressed I-Girder Bridges

The tables in the following sections contain the percentage of girders in each rating category for the 467 simple span prestressed I-girders analyzed. Similar numbers of interior and exterior girders had ratings greater than 1.0 for flexure. For shear, more exterior girders had ratings greater than 1.0 than interior girders. The percentage of girders with LRFR flexure ratings less than 1.0 is significantly larger than LFR due to the consideration of the effect of shear on the longitudinal reinforcement. The percentage of girders with passing ratings decreases with increasing ADTT as expected due to the increase in the load factor for live load.

K.2.1 AASHTO Legal Vehicles

Table 12 through Table 14 provide the results for the three AASHTO Legal vehicles: Type 3, Type 3-3, and Type 3S2.

Table 12: AASHTO Type 3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	69.43%	9.84%	6.74%	4.15%	4.66%	5.18%
			ADTT = 1000	59.59%	7.25%	9.84%	8.81%	5.70%	8.81%
			ADTT ≥ 5000	53.37%	7.25%	9.84%	11.40%	6.74%	11.40%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	69.71%	8.03%	5.84%	6.93%	5.11%	4.38%
			ADTT = 1000	59.85%	6.93%	9.12%	7.30%	7.66%	9.12%
			ADTT ≥ 5000	50.73%	10.22%	9.12%	9.85%	8.03%	12.04%
AASHTO TYPE 3	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	96.37%	1.55%	0.00%	0.52%	0.52%	1.04%
			ADTT = 1000	95.85%	0.00%	1.04%	1.04%	0.52%	1.55%
			ADTT ≥ 5000	95.34%	0.52%	0.52%	1.55%	0.00%	2.07%
		Interior	LFR	99.64%	0.00%	0.00%	0.00%	0.00%	0.36%
			ADTT ≤ 100	91.97%	3.28%	2.19%	0.73%	0.36%	1.46%
			ADTT = 1000	90.15%	1.82%	2.55%	2.92%	0.73%	1.82%
			ADTT ≥ 5000	88.32%	2.19%	1.46%	3.28%	2.92%	1.82%

Table 13: AASHTO Type 3-3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3-3	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	64.77%	10.36%	7.25%	7.25%	5.18%	5.18%
			ADTT = 1000	51.30%	8.81%	13.47%	9.33%	7.77%	9.33%
			ADTT ≥ 5000	41.97%	12.44%	11.40%	11.92%	8.81%	13.47%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	67.88%	5.11%	6.57%	8.76%	5.47%	6.20%
			ADTT = 1000	53.28%	9.12%	8.03%	9.12%	9.85%	10.58%
			ADTT ≥ 5000	46.72%	9.49%	9.49%	8.76%	8.76%	16.79%
AASHTO TYPE 3-3	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	97.41%	0.52%	0.00%	0.52%	0.00%	1.55%
			ADTT = 1000	94.82%	2.07%	1.04%	0.00%	0.52%	1.55%
			ADTT ≥ 5000	93.26%	2.07%	1.55%	1.04%	0.00%	2.07%
		Interior	LFR	99.64%	0.00%	0.00%	0.00%	0.00%	0.36%
			ADTT ≤ 100	92.70%	1.46%	2.19%	1.82%	0.36%	1.46%
			ADTT = 1000	87.96%	2.55%	3.65%	2.19%	1.82%	1.82%
			ADTT ≥ 5000	86.13%	3.28%	1.82%	2.92%	3.28%	2.55%

Table 14: AASHTO Type 3S2 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3S2	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	65.28%	10.36%	7.25%	4.66%	5.70%	6.74%
			ADTT = 1000	52.33%	9.33%	13.47%	9.33%	3.63%	11.92%
			ADTT ≥ 5000	44.04%	12.44%	10.88%	11.40%	7.77%	13.47%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	66.79%	9.12%	5.11%	8.39%	5.47%	5.11%
			ADTT = 1000	52.19%	9.85%	10.22%	8.03%	9.85%	9.85%
			ADTT ≥ 5000	44.89%	10.58%	8.76%	13.50%	9.12%	13.14%
AASHTO TYPE 3S2	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	97.41%	0.52%	0.00%	0.00%	0.52%	1.55%
			ADTT = 1000	94.82%	1.04%	2.07%	0.00%	0.00%	2.07%
			ADTT ≥ 5000	93.26%	1.55%	2.59%	0.52%	0.00%	2.07%
		Interior	LFR	99.64%	0.00%	0.00%	0.00%	0.00%	0.36%
			ADTT ≤ 100	91.97%	2.55%	1.82%	1.82%	0.00%	1.82%
			ADTT = 1000	87.96%	2.19%	4.01%	2.19%	1.09%	2.55%
			ADTT ≥ 5000	86.13%	2.19%	2.55%	3.65%	2.92%	2.55%

K.2.2 Routine Permit Vehicles

Table 15 through Table 19 provide the results for the five vehicles utilized as routine permit vehicles: DE-07, FL-04, NC-21, NM-04, and TX-04.

Table 15: DE-07 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
DE-07	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	60.10%	11.40%	6.74%	8.81%	3.63%	9.33%
			ADTT = 1000	53.37%	8.29%	10.88%	7.77%	8.29%	11.40%
			ADTT ≥ 5000	41.45%	12.44%	9.84%	11.92%	8.81%	15.54%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	60.95%	10.58%	6.20%	8.39%	6.20%	7.66%
			ADTT = 1000	48.54%	13.14%	9.85%	6.20%	11.68%	10.58%
			ADTT ≥ 5000	37.23%	13.50%	11.68%	9.85%	10.58%	17.15%
DE-07	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.34%	1.55%	1.04%	0.00%	0.52%	1.55%
			ADTT = 1000	94.30%	1.04%	1.04%	1.55%	0.00%	2.07%
			ADTT ≥ 5000	91.71%	2.59%	1.04%	1.55%	1.04%	2.07%
		Interior	LFR	99.27%	0.36%	0.00%	0.00%	0.00%	0.36%
			ADTT ≤ 100	88.69%	2.55%	1.82%	4.38%	0.73%	1.82%
			ADTT = 1000	85.40%	1.82%	3.28%	2.55%	4.38%	2.55%
			ADTT ≥ 5000	77.74%	6.93%	2.55%	4.01%	3.28%	5.47%

Table 16: FL-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
FL-04	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	63.73%	12.44%	5.70%	6.74%	3.11%	8.29%
			ADTT = 1000	54.92%	7.77%	12.95%	7.25%	6.74%	10.36%
			ADTT ≥ 5000	44.04%	11.92%	8.81%	14.51%	5.70%	15.03%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	65.33%	7.66%	6.20%	8.03%	6.57%	6.20%
			ADTT = 1000	54.38%	8.76%	9.49%	7.30%	8.76%	11.31%
			ADTT ≥ 5000	39.42%	12.77%	10.95%	10.58%	9.12%	17.15%
FL-04	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.34%	2.07%	0.52%	0.00%	0.52%	1.55%
			ADTT = 1000	94.82%	0.52%	2.07%	0.52%	0.00%	2.07%
			ADTT ≥ 5000	92.23%	2.07%	1.04%	2.07%	0.52%	2.07%
		Interior	LFR	99.27%	0.36%	0.00%	0.00%	0.00%	0.36%
			ADTT ≤ 100	88.69%	2.55%	2.55%	3.65%	0.73%	1.82%
			ADTT = 1000	85.77%	2.92%	2.55%	2.55%	3.65%	2.55%
			ADTT ≥ 5000	80.66%	5.11%	2.92%	2.55%	4.01%	4.74%

Table 17: NC-21 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NC-21	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	63.21%	8.81%	9.84%	4.15%	5.70%	8.29%
			ADTT = 1000	54.40%	7.77%	11.92%	9.33%	5.18%	11.40%
			ADTT ≥ 5000	46.11%	8.29%	10.88%	11.40%	9.84%	13.47%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	65.33%	6.57%	8.76%	4.74%	6.57%	8.03%
			ADTT = 1000	54.01%	10.58%	6.57%	9.85%	7.66%	11.31%
			ADTT ≥ 5000	44.89%	9.85%	10.22%	7.66%	10.95%	16.42%
NC-21	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.85%	0.52%	1.55%	0.00%	0.52%	1.55%
			ADTT = 1000	93.78%	1.55%	1.04%	1.55%	0.00%	2.07%
			ADTT ≥ 5000	92.23%	1.55%	1.55%	1.04%	1.55%	2.07%
		Interior	LFR	99.27%	0.00%	0.36%	0.00%	0.00%	0.36%
			ADTT ≤ 100	90.15%	1.82%	2.19%	3.28%	0.73%	1.82%
			ADTT = 1000	86.50%	2.55%	2.55%	2.55%	3.28%	2.55%
			ADTT ≥ 5000	80.66%	5.47%	2.92%	2.92%	2.92%	5.11%

Table 18: NM-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NM-04	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	68.91%	6.22%	9.33%	4.15%	4.15%	7.25%
			ADTT = 1000	60.62%	6.74%	7.25%	11.40%	3.63%	10.36%
			ADTT ≥ 5000	52.85%	8.29%	6.74%	9.33%	10.36%	12.44%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	70.44%	5.47%	5.47%	8.39%	4.01%	6.20%
			ADTT = 1000	60.22%	8.03%	6.93%	7.30%	7.66%	9.85%
			ADTT ≥ 5000	49.27%	9.85%	9.85%	8.76%	6.57%	15.69%
NM-04	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	97.41%	0.52%	0.00%	0.52%	0.52%	1.04%
			ADTT = 1000	95.34%	1.04%	1.55%	0.00%	0.52%	1.55%
			ADTT ≥ 5000	95.34%	0.00%	1.04%	1.55%	0.00%	2.07%
		Interior	LFR	99.64%	0.00%	0.00%	0.00%	0.00%	0.36%
			ADTT ≤ 100	91.97%	2.19%	3.28%	0.73%	0.00%	1.82%
			ADTT = 1000	89.78%	1.46%	1.46%	4.74%	0.73%	1.82%
			ADTT ≥ 5000	86.13%	2.55%	2.55%	2.92%	3.28%	2.55%

Table 19: TX-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
TX-04	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	55.44%	13.47%	11.40%	5.18%	5.18%	9.33%
			ADTT = 1000	47.15%	11.92%	12.95%	8.81%	6.74%	12.44%
			ADTT ≥ 5000	38.34%	11.92%	12.95%	10.36%	11.40%	15.03%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	59.85%	9.85%	6.93%	6.93%	8.76%	7.66%
			ADTT = 1000	47.45%	12.77%	9.85%	7.30%	8.03%	14.60%
			ADTT ≥ 5000	36.50%	13.50%	10.58%	10.22%	9.12%	20.07%
TX-04	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.78%	1.55%	0.52%	1.55%	0.52%	2.07%
			ADTT = 1000	89.64%	3.63%	2.07%	0.52%	2.07%	2.07%
			ADTT ≥ 5000	84.97%	4.66%	3.63%	2.07%	0.52%	4.15%
		Interior	LFR	98.91%	0.36%	0.00%	0.36%	0.00%	0.36%
			ADTT ≤ 100	84.31%	4.01%	2.19%	1.82%	5.11%	2.55%
			ADTT = 1000	78.10%	5.84%	4.38%	2.19%	3.28%	6.20%
			ADTT ≥ 5000	69.34%	8.39%	6.20%	4.38%	3.28%	8.39%

K.2.3 Special Permit Vehicles

Table 20 through Table 22 provide the results for the three vehicles assumed to be special permits: IL-01, OR-06, and WA-02.

Table 20: IL-01 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
IL-01	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	66.32%	11.40%	10.88%	3.11%	3.11%	5.18%
			Single ADTT ≤ 100	58.03%	15.54%	9.84%	7.25%	3.11%	6.22%
			Single ADTT = 1000	55.96%	16.06%	10.36%	6.74%	4.66%	6.22%
			Single ADTT ≥ 5000	50.78%	16.06%	13.99%	5.70%	6.74%	6.74%
			Multiple ADTT ≤ 100	49.22%	15.54%	15.03%	5.70%	7.77%	6.74%
			Multiple ADTT = 1000	41.97%	16.06%	13.47%	11.40%	5.70%	11.40%
			Multiple ADTT ≥ 5000	35.75%	17.10%	13.99%	12.95%	7.77%	12.44%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	93.43%	0.73%	0.73%	1.09%	0.36%	3.65%
			Single ADTT ≤ 100	88.32%	5.11%	1.09%	1.46%	0.36%	3.65%
			Single ADTT = 1000	87.23%	4.74%	2.55%	1.46%	0.36%	3.65%
			Single ADTT ≥ 5000	83.21%	5.11%	5.84%	1.82%	0.36%	3.65%
			Multiple ADTT ≤ 100	81.39%	5.84%	6.20%	2.19%	0.73%	3.65%
			Multiple ADTT = 1000	74.45%	5.84%	7.66%	7.30%	1.09%	3.65%
			Multiple ADTT ≥ 5000	71.17%	5.84%	9.49%	6.57%	2.92%	4.01%
IL-01	Shear	Exterior	LFR	99.48%	0.52%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	95.34%	1.55%	0.52%	0.00%	1.04%	1.55%
			Single ADTT ≤ 100	92.23%	2.59%	1.55%	1.04%	0.00%	2.59%
			Single ADTT = 1000	91.71%	3.11%	1.04%	1.55%	0.00%	2.59%
			Single ADTT ≥ 5000	90.67%	1.55%	2.59%	2.07%	0.52%	2.59%
			Multiple ADTT ≤ 100	89.12%	2.59%	3.11%	1.55%	1.04%	2.59%
			Multiple ADTT = 1000	79.27%	6.22%	6.22%	3.11%	2.07%	3.11%
			Multiple ADTT ≥ 5000	75.13%	6.74%	8.81%	2.59%	2.59%	4.15%
		Interior	LFR	96.35%	1.09%	1.82%	0.36%	0.00%	0.36%
			Single Escorted	91.24%	0.73%	4.38%	1.82%	0.36%	1.46%
			Single ADTT ≤ 100	86.13%	3.28%	2.19%	3.28%	3.28%	1.82%
			Single ADTT = 1000	85.77%	3.28%	2.55%	1.82%	4.01%	2.55%
			Single ADTT ≥ 5000	84.31%	1.82%	4.38%	1.09%	4.74%	3.65%
			Multiple ADTT ≤ 100	82.85%	2.92%	3.65%	2.19%	4.38%	4.01%
			Multiple ADTT = 1000	78.83%	3.65%	3.28%	3.65%	2.19%	8.39%
			Multiple ADTT ≥ 5000	72.63%	8.03%	4.38%	2.55%	4.01%	8.39%

Table 21: OR-06 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
OR-06	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	63.21%	13.47%	10.36%	5.18%	3.11%	4.66%
			Single ADTT ≤ 100	52.85%	17.62%	11.40%	6.74%	5.70%	5.70%
			Single ADTT = 1000	51.81%	15.54%	12.44%	8.29%	6.22%	5.70%
			Single ADTT ≥ 5000	49.74%	11.92%	15.03%	10.36%	6.74%	6.22%
			Multiple ADTT ≤ 100	45.60%	15.03%	13.47%	12.44%	6.74%	6.74%
			Multiple ADTT = 1000	38.86%	15.03%	12.95%	12.95%	9.33%	10.88%
			Multiple ADTT ≥ 5000	36.27%	13.99%	15.03%	10.88%	11.40%	12.44%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	92.34%	2.19%	1.82%	0.36%	0.36%	2.92%
			Single ADTT ≤ 100	89.42%	3.28%	2.19%	1.82%	0.36%	2.92%
			Single ADTT = 1000	88.32%	4.01%	2.55%	1.82%	0.36%	2.92%
			Single ADTT ≥ 5000	82.85%	7.30%	4.38%	1.82%	0.73%	2.92%
			Multiple ADTT ≤ 100	81.39%	7.66%	4.74%	1.46%	1.82%	2.92%
			Multiple ADTT = 1000	75.91%	5.84%	8.76%	4.01%	2.19%	3.28%
			Multiple ADTT ≥ 5000	70.80%	6.93%	8.76%	6.20%	2.92%	4.38%
OR-06	Shear	Exterior	LFR	99.48%	0.52%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	94.82%	0.52%	2.07%	0.00%	1.04%	1.55%
			Single ADTT ≤ 100	91.71%	3.11%	0.52%	2.07%	0.00%	2.59%
			Single ADTT = 1000	91.71%	3.11%	0.52%	2.07%	0.00%	2.59%
			Single ADTT ≥ 5000	89.64%	2.07%	3.11%	0.52%	2.07%	2.59%
			Multiple ADTT ≤ 100	89.12%	2.59%	3.11%	0.52%	2.07%	2.59%
			Multiple ADTT = 1000	80.83%	6.74%	4.15%	3.11%	0.52%	4.66%
			Multiple ADTT ≥ 5000	77.20%	8.81%	3.63%	4.66%	1.04%	4.66%
		Interior	LFR	97.08%	0.36%	1.82%	0.00%	0.36%	0.36%
			Single Escorted	91.24%	2.55%	4.38%	0.00%	0.36%	1.46%
			Single ADTT ≤ 100	87.59%	2.92%	2.55%	4.38%	0.73%	1.82%
			Single ADTT = 1000	86.13%	4.01%	2.19%	3.65%	2.19%	1.82%
			Single ADTT ≥ 5000	84.67%	2.92%	2.92%	2.92%	4.74%	1.82%
			Multiple ADTT ≤ 100	83.94%	2.19%	4.01%	2.92%	4.38%	2.55%
			Multiple ADTT = 1000	80.66%	2.92%	2.55%	4.38%	2.92%	6.57%
			Multiple ADTT ≥ 5000	76.64%	5.84%	2.55%	3.28%	4.38%	7.30%

Table 22: WA-02 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
WA-02	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	38.34%	11.40%	12.95%	9.84%	8.29%	19.17%
			Single ADTT ≤ 100	32.64%	9.84%	13.47%	12.44%	12.44%	19.17%
			Single ADTT = 1000	31.61%	10.36%	12.44%	12.44%	12.95%	20.21%
			Single ADTT ≥ 5000	26.42%	13.47%	10.36%	15.03%	13.99%	20.73%
			Multiple ADTT ≤ 100	23.83%	15.03%	11.40%	13.99%	15.03%	20.73%
			Multiple ADTT = 1000	19.69%	9.84%	17.10%	11.92%	15.03%	26.42%
			Multiple ADTT ≥ 5000	16.58%	10.88%	15.54%	13.99%	14.51%	28.50%
		Interior	LFR	97.81%	1.82%	0.36%	0.00%	0.00%	0.00%
			Single Escorted	76.64%	9.49%	3.28%	4.74%	0.73%	5.11%
			Single ADTT ≤ 100	71.53%	12.41%	5.11%	5.11%	0.73%	5.11%
			Single ADTT = 1000	69.34%	13.87%	4.74%	6.20%	0.73%	5.11%
			Single ADTT ≥ 5000	65.69%	14.23%	7.30%	6.57%	1.09%	5.11%
			Multiple ADTT ≤ 100	62.77%	15.33%	8.39%	7.30%	1.09%	5.11%
			Multiple ADTT = 1000	54.01%	16.06%	10.58%	10.95%	2.92%	5.47%
			Multiple ADTT ≥ 5000	51.46%	14.60%	12.04%	10.58%	5.47%	5.84%
WA-02	Shear	Exterior	LFR	95.85%	1.55%	2.07%	0.52%	0.00%	0.00%
			Single Escorted	89.64%	1.55%	2.59%	2.07%	1.04%	3.11%
			Single ADTT ≤ 100	79.27%	7.77%	3.11%	3.11%	2.59%	4.15%
			Single ADTT = 1000	76.68%	8.81%	4.15%	3.11%	3.11%	4.15%
			Single ADTT ≥ 5000	72.54%	6.74%	8.29%	3.63%	2.59%	6.22%
			Multiple ADTT ≤ 100	71.50%	5.70%	8.29%	4.66%	3.11%	6.74%
			Multiple ADTT = 1000	60.10%	9.33%	7.25%	10.36%	4.15%	8.81%
			Multiple ADTT ≥ 5000	54.92%	8.81%	9.84%	8.29%	7.77%	10.36%
		Interior	LFR	86.86%	4.74%	3.65%	1.09%	2.92%	0.73%
			Single Escorted	82.85%	4.74%	2.55%	2.92%	3.28%	3.65%
			Single ADTT ≤ 100	75.91%	6.20%	2.92%	5.11%	2.92%	6.93%
			Single ADTT = 1000	72.99%	6.93%	4.38%	4.38%	2.92%	8.39%
			Single ADTT ≥ 5000	68.61%	7.30%	6.57%	4.01%	4.01%	9.49%
			Multiple ADTT ≤ 100	65.69%	7.30%	7.30%	4.74%	5.11%	9.85%
			Multiple ADTT = 1000	55.47%	9.49%	8.03%	8.39%	5.11%	13.50%
			Multiple ADTT ≥ 5000	51.82%	9.12%	9.12%	9.12%	5.47%	15.33%

K.3 Simple Span Prestressed Box Girder Bridges

The tables in the following sections contain the percentage of girders in each rating category for the 377 simple span prestressed box-girders analyzed. Similar numbers of interior and exterior girders had ratings greater than 1.0 for flexure and shear. The percentage of girders with passing ratings decreases with increasing ADTT as expected due to the increase in the load factor for live load.

K.3.1 AASHTO Legal Vehicles

Table 23 through Table 25 provide the distribution of rating factors for the three AASHTO Legal vehicles: Type 3, Type 3-3, and Type 3S2.

Table 23: AASHTO Type 3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	90.91%	2.27%	2.27%	0.00%	0.00%	4.55%
			ADTT = 1000	88.64%	3.41%	3.41%	0.00%	0.00%	4.55%
			ADTT ≥ 5000	87.50%	4.55%	2.27%	1.14%	0.00%	4.55%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	90.57%	3.77%	0.00%	1.89%	0.00%	3.77%
			ADTT = 1000	86.79%	5.66%	1.89%	1.89%	0.00%	3.77%
			ADTT ≥ 5000	84.91%	5.66%	1.89%	3.77%	0.00%	3.77%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	87.88%	2.27%	1.52%	2.27%	0.76%	5.30%
			ADTT = 1000	86.36%	2.27%	1.52%	3.03%	1.52%	5.30%
			ADTT ≥ 5000	86.36%	1.52%	1.52%	3.03%	2.27%	5.30%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	82.69%	3.85%	1.92%	2.88%	2.88%	5.77%
			ADTT = 1000	81.73%	3.85%	1.92%	3.85%	1.92%	6.73%
			ADTT ≥ 5000	79.81%	4.81%	2.88%	3.85%	1.92%	6.73%
AASHTO TYPE 3	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	98.86%	0.00%	1.14%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	98.86%	0.00%	1.14%	0.00%	0.00%	0.00%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	98.11%	0.00%	1.89%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	98.11%	0.00%	0.00%	1.89%	0.00%	0.00%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	99.24%	0.76%	0.00%	0.00%	0.00%	0.00%
		Interior Non-Composite	LFR	99.04%	0.00%	0.00%	0.96%	0.00%	0.00%
			ADTT ≤ 100	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT = 1000	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT ≥ 5000	98.08%	0.96%	0.00%	0.00%	0.00%	0.96%

Table 24: AASHTO Type 3-3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3-3	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	86.36%	2.27%	5.68%	1.14%	1.14%	3.41%
			ADTT = 1000	85.23%	3.41%	4.55%	1.14%	2.27%	3.41%
			ADTT ≥ 5000	84.09%	3.41%	5.68%	1.14%	2.27%	3.41%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	94.34%	0.00%	0.00%	1.89%	0.00%	3.77%
			ADTT = 1000	92.45%	0.00%	1.89%	1.89%	0.00%	3.77%
			ADTT ≥ 5000	86.79%	5.66%	1.89%	1.89%	0.00%	3.77%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	87.12%	3.03%	1.52%	1.52%	1.52%	5.30%
			ADTT = 1000	84.85%	3.79%	3.03%	0.76%	2.27%	5.30%
			ADTT ≥ 5000	84.09%	3.03%	3.79%	1.52%	1.52%	6.06%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	84.62%	2.88%	0.00%	1.92%	1.92%	8.65%
			ADTT = 1000	82.69%	4.81%	0.00%	1.92%	1.92%	8.65%
			ADTT ≥ 5000	80.77%	4.81%	1.92%	1.92%	1.92%	8.65%
AASHTO TYPE 3-3	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	98.86%	1.14%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	97.73%	1.14%	1.14%	0.00%	0.00%	0.00%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	98.11%	1.89%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	98.11%	0.00%	1.89%	0.00%	0.00%	0.00%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	99.24%	0.76%	0.00%	0.00%	0.00%	0.00%
		Interior Non-Composite	LFR	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT ≤ 100	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT = 1000	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT ≥ 5000	98.08%	0.96%	0.00%	0.00%	0.00%	0.96%

Table 25: AASHTO Type 3S2 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3S2	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	84.09%	2.27%	6.82%	2.27%	0.00%	4.55%
			ADTT = 1000	82.95%	3.41%	6.82%	1.14%	1.14%	4.55%
			ADTT ≥ 5000	80.68%	4.55%	7.95%	1.14%	1.14%	4.55%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	92.45%	1.89%	0.00%	1.89%	0.00%	3.77%
			ADTT = 1000	86.79%	5.66%	1.89%	1.89%	0.00%	3.77%
			ADTT ≥ 5000	84.91%	3.77%	5.66%	1.89%	0.00%	3.77%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	84.85%	5.30%	2.27%	0.76%	0.76%	6.06%
			ADTT = 1000	81.82%	6.82%	3.03%	1.52%	0.76%	6.06%
			ADTT ≥ 5000	81.06%	5.30%	3.79%	2.27%	1.52%	6.06%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	83.65%	2.88%	0.96%	1.92%	1.92%	8.65%
			ADTT = 1000	81.73%	3.85%	1.92%	1.92%	1.92%	8.65%
			ADTT ≥ 5000	79.81%	4.81%	2.88%	1.92%	1.92%	8.65%
AASHTO TYPE 3S2	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	98.86%	0.00%	1.14%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	97.73%	1.14%	1.14%	0.00%	0.00%	0.00%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	98.11%	0.00%	1.89%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	98.11%	0.00%	0.00%	1.89%	0.00%	0.00%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	98.48%	1.52%	0.00%	0.00%	0.00%	0.00%
		Interior Non-Composite	LFR	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT ≤ 100	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT = 1000	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT ≥ 5000	97.12%	1.92%	0.00%	0.00%	0.00%	0.96%

K.3.2 Routine Permit Vehicles

Table 26 through Table 30 provide the distribution of rating factors for the five vehicles considered to be routine permits: DE-07, FL-04, NC-21, NM-04, and TX-04.

Table 26: DE-07 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
DE-07	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	71.59%	5.68%	6.82%	6.82%	0.00%	9.09%
			ADTT = 1000	67.05%	9.09%	7.95%	5.68%	1.14%	9.09%
			ADTT ≥ 5000	65.91%	6.82%	10.23%	6.82%	0.00%	10.23%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	71.70%	5.66%	11.32%	5.66%	1.89%	3.77%
			ADTT = 1000	71.70%	3.77%	9.43%	9.43%	1.89%	3.77%
			ADTT ≥ 5000	71.70%	3.77%	7.55%	7.55%	5.66%	3.77%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	84.85%	3.03%	1.52%	1.52%	0.76%	8.33%
			ADTT = 1000	84.09%	3.03%	2.27%	0.76%	1.52%	8.33%
			ADTT ≥ 5000	83.33%	3.03%	2.27%	1.52%	0.76%	9.09%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	81.73%	5.77%	6.73%	0.96%	0.96%	3.85%
			ADTT = 1000	79.81%	5.77%	7.69%	1.92%	0.96%	3.85%
			ADTT ≥ 5000	75.00%	9.62%	6.73%	2.88%	1.92%	3.85%
DE-07	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	97.73%	2.27%	0.00%	0.00%	0.00%	0.00%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	96.23%	3.77%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	92.45%	3.77%	3.77%	0.00%	0.00%	0.00%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	99.24%	0.76%	0.00%	0.00%	0.00%	0.00%
		Interior Non-Composite	LFR	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT ≤ 100	97.12%	0.00%	1.92%	0.00%	0.00%	0.96%
			ADTT = 1000	96.15%	0.96%	0.00%	1.92%	0.00%	0.96%
			ADTT ≥ 5000	93.27%	2.88%	0.96%	0.00%	1.92%	0.96%

Table 27: FL-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
FL-04	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	75.00%	6.82%	7.95%	1.14%	1.14%	7.95%
			ADTT = 1000	70.45%	9.09%	10.23%	1.14%	1.14%	7.95%
			ADTT ≥ 5000	69.32%	7.95%	10.23%	3.41%	1.14%	7.95%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	77.36%	7.55%	7.55%	1.89%	1.89%	3.77%
			ADTT = 1000	77.36%	5.66%	7.55%	3.77%	1.89%	3.77%
			ADTT ≥ 5000	77.36%	5.66%	5.66%	3.77%	3.77%	3.77%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	86.36%	3.03%	1.52%	0.76%	0.76%	7.58%
			ADTT = 1000	85.61%	3.03%	1.52%	1.52%	0.76%	7.58%
			ADTT ≥ 5000	84.85%	3.03%	1.52%	1.52%	1.52%	7.58%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	87.50%	3.85%	3.85%	0.96%	0.96%	2.88%
			ADTT = 1000	84.62%	5.77%	3.85%	1.92%	0.96%	2.88%
			ADTT ≥ 5000	79.81%	8.65%	4.81%	1.92%	1.92%	2.88%
FL-04	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	96.23%	3.77%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	94.34%	1.89%	3.77%	0.00%	0.00%	0.00%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Interior Non-Composite	LFR	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT ≤ 100	97.12%	0.96%	0.96%	0.00%	0.00%	0.96%
			ADTT = 1000	96.15%	0.96%	0.00%	1.92%	0.00%	0.96%
			ADTT ≥ 5000	93.27%	2.88%	0.96%	0.96%	0.96%	0.96%

Table 28: NC-21 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NC-21	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	75.00%	9.09%	6.82%	2.27%	2.27%	4.55%
			ADTT = 1000	73.86%	10.23%	6.82%	2.27%	2.27%	4.55%
			ADTT ≥ 5000	72.73%	10.23%	7.95%	2.27%	2.27%	4.55%
		Exterior Non-Composite	LFR	98.11%	1.89%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	79.25%	5.66%	7.55%	0.00%	3.77%	3.77%
			ADTT = 1000	79.25%	3.77%	7.55%	1.89%	3.77%	3.77%
			ADTT ≥ 5000	79.25%	3.77%	5.66%	1.89%	5.66%	3.77%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	71.21%	11.36%	6.06%	4.55%	0.76%	6.06%
			ADTT = 1000	69.70%	12.12%	6.82%	3.03%	2.27%	6.06%
			ADTT ≥ 5000	69.70%	10.61%	7.58%	3.79%	1.52%	6.82%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	74.04%	3.85%	7.69%	3.85%	0.96%	9.62%
			ADTT = 1000	73.08%	3.85%	6.73%	5.77%	0.96%	9.62%
			ADTT ≥ 5000	70.19%	6.73%	5.77%	4.81%	2.88%	9.62%
NC-21	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.86%	0.00%	1.14%	0.00%	0.00%	0.00%
			ADTT = 1000	98.86%	0.00%	0.00%	1.14%	0.00%	0.00%
			ADTT ≥ 5000	96.59%	2.27%	0.00%	0.00%	1.14%	0.00%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.11%	0.00%	1.89%	0.00%	0.00%	0.00%
			ADTT = 1000	98.11%	0.00%	0.00%	1.89%	0.00%	0.00%
			ADTT ≥ 5000	94.34%	3.77%	0.00%	0.00%	1.89%	0.00%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Interior Non-Composite	LFR	99.04%	0.00%	0.00%	0.00%	0.96%	0.00%
			ADTT ≤ 100	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT = 1000	98.08%	0.96%	0.00%	0.00%	0.00%	0.96%
			ADTT ≥ 5000	94.23%	3.85%	0.96%	0.00%	0.00%	0.96%

Table 29: NM-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NM-04	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	86.36%	4.55%	4.55%	0.00%	0.00%	4.55%
			ADTT = 1000	85.23%	5.68%	4.55%	0.00%	0.00%	4.55%
			ADTT ≥ 5000	82.95%	5.68%	6.82%	0.00%	0.00%	4.55%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	90.57%	0.00%	3.77%	1.89%	1.89%	1.89%
			ADTT = 1000	88.68%	1.89%	1.89%	3.77%	1.89%	1.89%
			ADTT ≥ 5000	86.79%	1.89%	3.77%	1.89%	3.77%	1.89%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	87.88%	2.27%	3.03%	0.76%	2.27%	3.79%
			ADTT = 1000	86.36%	3.03%	3.03%	0.76%	3.03%	3.79%
			ADTT ≥ 5000	86.36%	1.52%	3.79%	0.76%	3.79%	3.79%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	82.69%	3.85%	1.92%	1.92%	4.81%	4.81%
			ADTT = 1000	81.73%	2.88%	3.85%	1.92%	3.85%	5.77%
			ADTT ≥ 5000	80.77%	2.88%	2.88%	3.85%	3.85%	5.77%
NM-04	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	98.86%	0.00%	1.14%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	98.86%	0.00%	0.00%	1.14%	0.00%	0.00%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.11%	1.89%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	98.11%	0.00%	1.89%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	98.11%	0.00%	0.00%	1.89%	0.00%	0.00%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Interior Non-Composite	LFR	99.04%	0.00%	0.00%	0.00%	0.96%	0.00%
			ADTT ≤ 100	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT = 1000	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			ADTT ≥ 5000	98.08%	0.96%	0.00%	0.00%	0.00%	0.96%

Table 30: TX-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
TX-04	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	68.18%	9.09%	9.09%	6.82%	2.27%	4.55%
			ADTT = 1000	67.05%	10.23%	7.95%	7.95%	2.27%	4.55%
			ADTT ≥ 5000	62.50%	13.64%	9.09%	6.82%	3.41%	4.55%
		Exterior Non-Composite	LFR	98.11%	0.00%	1.89%	0.00%	0.00%	0.00%
			ADTT ≤ 100	71.70%	9.43%	11.32%	0.00%	1.89%	5.66%
			ADTT = 1000	71.70%	7.55%	11.32%	1.89%	1.89%	5.66%
			ADTT ≥ 5000	67.92%	11.32%	9.43%	1.89%	3.77%	5.66%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	63.64%	10.61%	9.85%	6.82%	2.27%	6.82%
			ADTT = 1000	63.64%	9.85%	9.85%	6.06%	3.79%	6.82%
			ADTT ≥ 5000	62.88%	10.61%	9.09%	6.06%	3.79%	7.58%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	66.35%	11.54%	3.85%	4.81%	2.88%	10.58%
			ADTT = 1000	61.54%	13.46%	5.77%	4.81%	3.85%	10.58%
			ADTT ≥ 5000	61.54%	9.62%	7.69%	6.73%	2.88%	11.54%
TX-04	Shear	Exterior Composite	LFR	98.86%	1.14%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	96.59%	1.14%	1.14%	1.14%	0.00%	0.00%
			ADTT = 1000	96.59%	0.00%	1.14%	1.14%	1.14%	0.00%
			ADTT ≥ 5000	96.59%	0.00%	0.00%	1.14%	1.14%	1.14%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	96.23%	1.89%	0.00%	1.89%	0.00%	0.00%
			ADTT = 1000	92.45%	3.77%	1.89%	0.00%	1.89%	0.00%
			ADTT ≥ 5000	90.57%	1.89%	3.77%	1.89%	0.00%	1.89%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	99.24%	0.76%	0.00%	0.00%	0.00%	0.00%
			ADTT = 1000	98.48%	0.76%	0.76%	0.00%	0.00%	0.00%
			ADTT ≥ 5000	95.45%	2.27%	1.52%	0.76%	0.00%	0.00%
		Interior Non-Composite	LFR	98.08%	0.96%	0.00%	0.00%	0.00%	0.96%
			ADTT ≤ 100	96.15%	1.92%	0.00%	0.96%	0.00%	0.96%
			ADTT = 1000	93.27%	1.92%	1.92%	0.96%	0.96%	0.96%
			ADTT ≥ 5000	91.35%	1.92%	1.92%	2.88%	0.00%	1.92%

K.3.3 Special Permit Vehicles

Table 31 through Table 33 provide the results for the three vehicles assumed to be special permits: IL-01, OR-06, and WA-02.

Table 31: IL-01 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
IL-01	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	77.27%	3.41%	6.82%	2.27%	4.55%	5.68%
			Single ADTT ≤ 100	77.27%	3.41%	6.82%	2.27%	4.55%	5.68%
			Single ADTT = 1000	77.27%	3.41%	6.82%	2.27%	4.55%	5.68%
			Single ADTT ≥ 5000	76.14%	4.55%	6.82%	2.27%	4.55%	5.68%
			Multiple ADTT ≤ 100	76.14%	4.55%	6.82%	2.27%	4.55%	5.68%
			Multiple ADTT = 1000	75.00%	4.55%	7.95%	2.27%	4.55%	5.68%
			Multiple ADTT ≥ 5000	75.00%	3.41%	9.09%	2.27%	4.55%	5.68%
		Exterior Non-Composite	LFR	98.11%	0.00%	1.89%	0.00%	0.00%	0.00%
			Single Escorted	83.02%	3.77%	5.66%	1.89%	0.00%	5.66%
			Single ADTT ≤ 100	81.13%	3.77%	7.55%	1.89%	0.00%	5.66%
			Single ADTT = 1000	79.25%	5.66%	7.55%	1.89%	0.00%	5.66%
			Single ADTT ≥ 5000	79.25%	5.66%	7.55%	1.89%	0.00%	5.66%
			Multiple ADTT ≤ 100	79.25%	3.77%	7.55%	3.77%	0.00%	5.66%
			Multiple ADTT = 1000	77.36%	5.66%	5.66%	3.77%	1.89%	5.66%
			Multiple ADTT ≥ 5000	75.47%	7.55%	5.66%	3.77%	1.89%	5.66%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	75.00%	7.58%	6.82%	1.52%	1.52%	7.58%
			Single ADTT ≤ 100	74.24%	7.58%	7.58%	1.52%	1.52%	7.58%
			Single ADTT = 1000	73.48%	8.33%	6.82%	2.27%	1.52%	7.58%
			Single ADTT ≥ 5000	73.48%	7.58%	7.58%	2.27%	1.52%	7.58%
			Multiple ADTT ≤ 100	72.73%	8.33%	7.58%	1.52%	2.27%	7.58%
			Multiple ADTT = 1000	71.97%	6.82%	8.33%	3.03%	2.27%	7.58%
			Multiple ADTT ≥ 5000	70.45%	8.33%	8.33%	2.27%	2.27%	8.33%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	78.85%	3.85%	0.96%	2.88%	2.88%	10.58%
			Single ADTT ≤ 100	78.85%	3.85%	0.96%	2.88%	1.92%	11.54%
			Single ADTT = 1000	77.88%	4.81%	0.96%	2.88%	1.92%	11.54%
			Single ADTT ≥ 5000	76.92%	5.77%	0.96%	2.88%	1.92%	11.54%
			Multiple ADTT ≤ 100	76.92%	4.81%	1.92%	2.88%	1.92%	11.54%
			Multiple ADTT = 1000	73.08%	7.69%	1.92%	3.85%	1.92%	11.54%
			Multiple ADTT ≥ 5000	72.12%	6.73%	2.88%	4.81%	1.92%	11.54%
IL-01	Shear	Exterior Composite	LFR	97.73%	0.00%	2.27%	0.00%	0.00%	0.00%
			Single Escorted	98.86%	1.14%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≤ 100	95.45%	1.14%	3.41%	0.00%	0.00%	0.00%
			Single ADTT = 1000	95.45%	1.14%	2.27%	1.14%	0.00%	0.00%
			Single ADTT ≥ 5000	94.32%	1.14%	2.27%	2.27%	0.00%	0.00%
			Multiple ADTT ≤ 100	94.32%	1.14%	1.14%	3.41%	0.00%	0.00%
			Multiple ADTT = 1000	92.05%	2.27%	1.14%	1.14%	3.41%	0.00%
			Multiple ADTT ≥ 5000	88.64%	3.41%	2.27%	1.14%	3.41%	1.14%
		Exterior Non-Composite	LFR	96.23%	3.77%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≤ 100	98.11%	0.00%	1.89%	0.00%	0.00%	0.00%
			Single ADTT = 1000	98.11%	0.00%	1.89%	0.00%	0.00%	0.00%
			Single ADTT ≥ 5000	92.45%	5.66%	0.00%	1.89%	0.00%	0.00%
			Multiple ADTT ≤ 100	92.45%	5.66%	0.00%	1.89%	0.00%	0.00%
			Multiple ADTT = 1000	90.57%	1.89%	5.66%	0.00%	1.89%	0.00%
			Multiple ADTT ≥ 5000	90.57%	0.00%	7.55%	0.00%	1.89%	0.00%
		Interior Composite	LFR	99.24%	0.00%	0.76%	0.00%	0.00%	0.00%
			Single Escorted	98.48%	0.00%	0.00%	1.52%	0.00%	0.00%
			Single ADTT ≤ 100	95.45%	1.52%	1.52%	0.00%	1.52%	0.00%
			Single ADTT = 1000	95.45%	1.52%	1.52%	0.00%	0.76%	0.76%
			Single ADTT ≥ 5000	93.94%	1.52%	1.52%	1.52%	0.00%	1.52%
			Multiple ADTT ≤ 100	93.94%	1.52%	1.52%	1.52%	0.00%	1.52%
			Multiple ADTT = 1000	90.15%	3.79%	1.52%	1.52%	1.52%	1.52%
			Multiple ADTT ≥ 5000	88.64%	3.79%	1.52%	2.27%	2.27%	1.52%
		Interior Non-Composite	LFR	97.12%	0.00%	1.92%	0.00%	0.00%	0.96%
			Single Escorted	97.12%	1.92%	0.00%	0.00%	0.00%	0.96%
			Single ADTT ≤ 100	96.15%	0.96%	1.92%	0.00%	0.00%	0.96%
			Single ADTT = 1000	95.19%	1.92%	1.92%	0.00%	0.00%	0.96%
			Single ADTT ≥ 5000	94.23%	1.92%	0.96%	1.92%	0.00%	0.96%
			Multiple ADTT ≤ 100	94.23%	0.96%	1.92%	1.92%	0.00%	0.96%
			Multiple ADTT = 1000	90.38%	1.92%	2.88%	1.92%	1.92%	0.96%
			Multiple ADTT ≥ 5000	90.38%	0.96%	2.88%	2.88%	1.92%	0.96%

Table 32: OR-06 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
OR-06	Moment	Exterior Composite	LFR	98.86%	1.14%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	77.27%	2.27%	7.95%	2.27%	4.55%	5.68%
			Single ADTT ≤ 100	77.27%	2.27%	7.95%	2.27%	4.55%	5.68%
			Single ADTT = 1000	77.27%	2.27%	7.95%	2.27%	4.55%	5.68%
			Single ADTT ≥ 5000	77.27%	2.27%	7.95%	2.27%	4.55%	5.68%
			Multiple ADTT ≤ 100	77.27%	2.27%	7.95%	2.27%	4.55%	5.68%
			Multiple ADTT = 1000	75.00%	4.55%	7.95%	2.27%	4.55%	5.68%
			Multiple ADTT ≥ 5000	75.00%	4.55%	7.95%	2.27%	4.55%	5.68%
		Exterior Non-Composite	LFR	98.11%	0.00%	0.00%	1.89%	0.00%	0.00%
			Single Escorted	81.13%	1.89%	9.43%	1.89%	1.89%	3.77%
			Single ADTT ≤ 100	81.13%	1.89%	9.43%	1.89%	1.89%	3.77%
			Single ADTT = 1000	81.13%	1.89%	9.43%	1.89%	1.89%	3.77%
			Single ADTT ≥ 5000	81.13%	1.89%	9.43%	1.89%	1.89%	3.77%
			Multiple ADTT ≤ 100	81.13%	1.89%	9.43%	1.89%	1.89%	3.77%
			Multiple ADTT = 1000	79.25%	3.77%	9.43%	1.89%	1.89%	3.77%
			Multiple ADTT ≥ 5000	77.36%	3.77%	11.32%	1.89%	1.89%	3.77%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	73.48%	8.33%	6.82%	2.27%	1.52%	7.58%
			Single ADTT ≤ 100	72.73%	9.09%	6.06%	3.03%	1.52%	7.58%
			Single ADTT = 1000	72.73%	8.33%	6.82%	2.27%	2.27%	7.58%
			Single ADTT ≥ 5000	71.21%	9.85%	6.82%	2.27%	2.27%	7.58%
			Multiple ADTT ≤ 100	70.45%	10.61%	6.82%	2.27%	2.27%	7.58%
			Multiple ADTT = 1000	70.45%	8.33%	8.33%	3.03%	1.52%	8.33%
			Multiple ADTT ≥ 5000	70.45%	8.33%	6.82%	3.79%	2.27%	8.33%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	75.96%	5.77%	0.96%	3.85%	3.85%	9.62%
			Single ADTT ≤ 100	75.00%	6.73%	0.96%	3.85%	2.88%	10.58%
			Single ADTT = 1000	75.00%	6.73%	0.96%	3.85%	2.88%	10.58%
			Single ADTT ≥ 5000	74.04%	6.73%	1.92%	3.85%	2.88%	10.58%
			Multiple ADTT ≤ 100	74.04%	6.73%	1.92%	3.85%	2.88%	10.58%
			Multiple ADTT = 1000	72.12%	7.69%	1.92%	4.81%	2.88%	10.58%
			Multiple ADTT ≥ 5000	71.15%	7.69%	2.88%	4.81%	2.88%	10.58%
OR-06	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Multiple ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Multiple ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Multiple ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Multiple ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Multiple ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Multiple ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Multiple ADTT ≤ 100	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Multiple ADTT = 1000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Multiple ADTT ≥ 5000	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Interior Non-Composite	LFR	99.04%	0.00%	0.00%	0.00%	0.96%	0.00%
			Single Escorted	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			Single ADTT ≤ 100	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			Single ADTT = 1000	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			Single ADTT ≥ 5000	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			Multiple ADTT ≤ 100	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			Multiple ADTT = 1000	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%
			Multiple ADTT ≥ 5000	99.04%	0.00%	0.00%	0.00%	0.00%	0.96%

Table 33: WA-02 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
WA-02	Moment	Exterior Composite	LFR	94.32%	4.55%	1.14%	0.00%	0.00%	0.00%
			Single Escorted	52.27%	10.23%	6.82%	6.82%	7.95%	15.91%
			Single ADTT ≤ 100	52.27%	10.23%	6.82%	6.82%	7.95%	15.91%
			Single ADTT = 1000	52.27%	10.23%	6.82%	6.82%	7.95%	15.91%
			Single ADTT ≥ 5000	51.14%	11.36%	6.82%	6.82%	7.95%	15.91%
			Multiple ADTT ≤ 100	51.14%	11.36%	6.82%	6.82%	7.95%	15.91%
			Multiple ADTT = 1000	50.00%	10.23%	9.09%	6.82%	7.95%	15.91%
			Multiple ADTT ≥ 5000	48.86%	11.36%	7.95%	7.95%	7.95%	15.91%
		Exterior Non-Composite	LFR	92.45%	1.89%	1.89%	3.77%	0.00%	0.00%
			Single Escorted	62.26%	9.43%	5.66%	11.32%	1.89%	9.43%
			Single ADTT ≤ 100	62.26%	7.55%	5.66%	13.21%	1.89%	9.43%
			Single ADTT = 1000	60.38%	9.43%	5.66%	13.21%	1.89%	9.43%
			Single ADTT ≥ 5000	60.38%	9.43%	5.66%	13.21%	1.89%	9.43%
			Multiple ADTT ≤ 100	60.38%	7.55%	7.55%	11.32%	3.77%	9.43%
			Multiple ADTT = 1000	58.49%	9.43%	5.66%	13.21%	3.77%	9.43%
			Multiple ADTT ≥ 5000	56.60%	9.43%	7.55%	13.21%	1.89%	11.32%
		Interior Composite	LFR	96.21%	1.52%	1.52%	0.76%	0.00%	0.00%
			Single Escorted	53.03%	8.33%	7.58%	9.85%	6.06%	15.15%
			Single ADTT ≤ 100	50.76%	10.61%	7.58%	9.09%	6.82%	15.15%
			Single ADTT = 1000	50.76%	9.85%	8.33%	9.09%	6.82%	15.15%
			Single ADTT ≥ 5000	50.00%	9.09%	9.85%	9.09%	6.82%	15.15%
			Multiple ADTT ≤ 100	50.00%	9.09%	9.85%	9.09%	6.06%	15.91%
			Multiple ADTT = 1000	50.00%	8.33%	8.33%	11.36%	6.06%	15.91%
			Multiple ADTT ≥ 5000	49.24%	9.09%	8.33%	9.85%	7.58%	15.91%
		Interior Non-Composite	LFR	95.19%	0.96%	3.85%	0.00%	0.00%	0.00%
			Single Escorted	65.38%	2.88%	5.77%	4.81%	6.73%	14.42%
			Single ADTT ≤ 100	63.46%	4.81%	5.77%	4.81%	6.73%	14.42%
			Single ADTT = 1000	63.46%	3.85%	6.73%	4.81%	6.73%	14.42%
			Single ADTT ≥ 5000	60.58%	5.77%	7.69%	4.81%	6.73%	14.42%
			Multiple ADTT ≤ 100	59.62%	6.73%	7.69%	4.81%	6.73%	14.42%
			Multiple ADTT = 1000	57.69%	3.85%	10.58%	6.73%	6.73%	14.42%
			Multiple ADTT ≥ 5000	56.73%	4.81%	7.69%	7.69%	8.65%	14.42%
WA-02	Shear	Exterior Composite	LFR	96.59%	1.14%	0.00%	2.27%	0.00%	0.00%
			Single Escorted	90.91%	1.14%	2.27%	3.41%	1.14%	1.14%
			Single ADTT ≤ 100	88.64%	2.27%	1.14%	1.14%	3.41%	3.41%
			Single ADTT = 1000	87.50%	2.27%	2.27%	0.00%	4.55%	3.41%
			Single ADTT ≥ 5000	86.36%	2.27%	2.27%	1.14%	3.41%	4.55%
			Multiple ADTT ≤ 100	86.36%	1.14%	3.41%	1.14%	1.14%	6.82%
			Multiple ADTT = 1000	82.95%	3.41%	1.14%	3.41%	1.14%	7.95%
			Multiple ADTT ≥ 5000	78.41%	4.55%	3.41%	2.27%	3.41%	7.95%
		Exterior Non-Composite	LFR	92.45%	0.00%	3.77%	3.77%	0.00%	0.00%
			Single Escorted	92.45%	3.77%	1.89%	0.00%	1.89%	0.00%
			Single ADTT ≤ 100	88.68%	1.89%	3.77%	1.89%	1.89%	1.89%
			Single ADTT = 1000	86.79%	3.77%	3.77%	1.89%	1.89%	1.89%
			Single ADTT ≥ 5000	83.02%	5.66%	1.89%	3.77%	3.77%	1.89%
			Multiple ADTT ≤ 100	81.13%	7.55%	1.89%	3.77%	1.89%	3.77%
			Multiple ADTT = 1000	73.58%	7.55%	5.66%	3.77%	3.77%	5.66%
			Multiple ADTT ≥ 5000	73.58%	5.66%	5.66%	5.66%	3.77%	5.66%
		Interior Composite	LFR	98.48%	0.76%	0.00%	0.76%	0.00%	0.00%
			Single Escorted	90.91%	3.79%	0.76%	1.52%	0.00%	3.03%
			Single ADTT ≤ 100	87.88%	2.27%	2.27%	3.03%	1.52%	3.03%
			Single ADTT = 1000	87.12%	2.27%	2.27%	3.79%	1.52%	3.03%
			Single ADTT ≥ 5000	83.33%	4.55%	3.03%	2.27%	3.03%	3.79%
			Multiple ADTT ≤ 100	83.33%	3.79%	2.27%	3.03%	3.03%	4.55%
			Multiple ADTT = 1000	77.27%	6.06%	3.79%	3.03%	3.03%	6.82%
			Multiple ADTT ≥ 5000	74.24%	7.58%	1.52%	4.55%	4.55%	7.58%
		Interior Non-Composite	LFR	93.27%	2.88%	0.96%	0.96%	0.96%	0.96%
			Single Escorted	92.31%	1.92%	0.00%	2.88%	1.92%	0.96%
			Single ADTT ≤ 100	89.42%	2.88%	1.92%	0.00%	1.92%	3.85%
			Single ADTT = 1000	89.42%	0.96%	2.88%	0.96%	1.92%	3.85%
			Single ADTT ≥ 5000	85.58%	3.85%	2.88%	1.92%	1.92%	3.85%
			Multiple ADTT ≤ 100	83.65%	5.77%	1.92%	2.88%	0.00%	5.77%
			Multiple ADTT = 1000	78.85%	3.85%	6.73%	2.88%	1.92%	5.77%
			Multiple ADTT ≥ 5000	74.04%	5.77%	5.77%	4.81%	2.88%	6.73%

K.4 Simple Span Reinforced Concrete Tee-Beam Bridges

The tables in the following sections contain the percentage of girders in each rating category for the 295 simple span reinforced concrete tee-beams analyzed. For flexure

and shear, exterior girders typically had more girders with ratings above 1.0 than interior girders for all types of vehicles. The percentage of girders passing an LRFR rating as significantly lower than the percentage of girders passing the LFR rating, even when considering the lowest ADTT category. The percentage of girders with passing ratings decreases with increasing ADTT as expected due to the increase in the load factor for live load.

K.4.1 AASHTO Legal Vehicles

Table 34 through Table 36 provide the distribution of rating factors for the three AASHTO Legal vehicles: Type 3, Type 3-3, and Type 3S2.

Table 34: AASHTO Type 3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	76.92%	7.69%	3.85%	5.38%	3.08%	3.08%
			ADTT = 1000	60.00%	11.54%	9.23%	6.92%	6.15%	6.15%
			ADTT ≥ 5000	52.31%	10.00%	13.08%	9.23%	6.15%	9.23%
		Interior	LFR	94.55%	1.21%	1.21%	1.21%	1.21%	0.61%
			ADTT ≤ 100	67.88%	6.06%	7.88%	5.45%	3.64%	9.09%
			ADTT = 1000	56.36%	9.70%	4.24%	10.91%	6.06%	12.73%
			ADTT ≥ 5000	53.33%	6.06%	7.88%	6.67%	9.70%	16.36%
AASHTO TYPE 3	Shear	Exterior	LFR	98.46%	0.77%	0.00%	0.00%	0.77%	0.00%
			ADTT ≤ 100	87.69%	6.15%	2.31%	1.54%	0.77%	1.54%
			ADTT = 1000	77.69%	7.69%	3.08%	6.92%	1.54%	3.08%
			ADTT ≥ 5000	75.38%	3.85%	7.69%	6.92%	2.31%	3.85%
		Interior	LFR	88.48%	4.24%	4.24%	2.42%	0.61%	0.00%
			ADTT ≤ 100	81.21%	3.03%	4.24%	4.85%	2.42%	4.24%
			ADTT = 1000	76.36%	2.42%	4.24%	4.24%	6.06%	6.67%
			ADTT ≥ 5000	73.94%	2.42%	3.64%	4.24%	4.85%	10.91%

Table 35: AASHTO Type 3-3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3-3	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	85.38%	4.62%	0.77%	4.62%	1.54%	3.08%
			ADTT = 1000	72.31%	8.46%	6.92%	2.31%	5.38%	4.62%
			ADTT ≥ 5000	65.38%	10.77%	5.38%	8.46%	2.31%	7.69%
		Interior	LFR	95.76%	1.82%	0.61%	1.21%	0.61%	0.00%
			ADTT ≤ 100	75.76%	5.45%	4.24%	3.64%	5.45%	5.45%
			ADTT = 1000	68.48%	4.24%	7.27%	4.85%	4.24%	10.91%
			ADTT ≥ 5000	63.64%	4.85%	4.85%	7.88%	5.45%	13.33%
AASHTO TYPE 3-3	Shear	Exterior	LFR	98.46%	0.77%	0.77%	0.00%	0.00%	0.00%
			ADTT ≤ 100	92.31%	1.54%	2.31%	1.54%	0.77%	1.54%
			ADTT = 1000	84.62%	5.38%	2.31%	3.85%	1.54%	2.31%
			ADTT ≥ 5000	80.00%	4.62%	6.92%	2.31%	2.31%	3.85%
		Interior	LFR	90.91%	4.24%	1.82%	2.42%	0.00%	0.61%
			ADTT ≤ 100	85.45%	2.42%	2.42%	3.64%	2.42%	3.64%
			ADTT = 1000	81.21%	2.42%	2.42%	3.64%	3.64%	6.67%
			ADTT ≥ 5000	77.58%	3.64%	3.64%	3.03%	3.03%	9.09%

Table 36: AASHTO Type 3S2 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3S2	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	80.00%	5.38%	5.38%	1.54%	4.62%	3.08%
			ADTT = 1000	64.62%	10.77%	6.15%	8.46%	2.31%	7.69%
			ADTT ≥ 5000	53.85%	13.08%	10.00%	8.46%	6.15%	8.46%
		Interior	LFR	95.15%	0.61%	1.82%	0.61%	1.21%	0.61%
			ADTT ≤ 100	69.70%	7.88%	6.06%	4.24%	3.64%	8.48%
			ADTT = 1000	63.64%	3.64%	4.85%	11.52%	4.24%	12.12%
			ADTT ≥ 5000	55.76%	8.48%	3.64%	9.70%	6.67%	15.76%
AASHTO TYPE 3S2	Shear	Exterior	LFR	98.46%	0.00%	0.77%	0.77%	0.00%	0.00%
			ADTT ≤ 100	88.46%	3.85%	3.08%	1.54%	1.54%	1.54%
			ADTT = 1000	80.00%	3.85%	8.46%	2.31%	1.54%	3.85%
			ADTT ≥ 5000	75.38%	4.62%	6.92%	5.38%	3.85%	3.85%
		Interior	LFR	88.48%	4.85%	3.64%	2.42%	0.00%	0.61%
			ADTT ≤ 100	82.42%	3.03%	4.24%	1.21%	4.24%	4.85%
			ADTT = 1000	78.18%	3.03%	4.24%	1.82%	3.64%	9.09%
			ADTT ≥ 5000	75.15%	4.24%	2.42%	3.64%	4.24%	10.30%

K.4.2 Routine Permit Vehicles

Table 37 through **Table 41** provide the distribution of rating factors for the five vehicles considered to be routine permits: DE-07, FL-04, NC-21, NM-04, and TX-04.

Table 37: DE-07 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
DE-07	Moment	Exterior	LFR	97.69%	0.77%	1.54%	0.00%	0.00%	0.00%
			ADTT ≤ 100	60.77%	10.00%	11.54%	8.46%	3.85%	5.38%
			ADTT = 1000	49.23%	8.46%	13.08%	11.54%	8.46%	9.23%
			ADTT ≥ 5000	38.46%	7.69%	11.54%	13.08%	13.85%	15.38%
		Interior	LFR	88.48%	1.82%	4.85%	1.82%	1.21%	1.82%
			ADTT ≤ 100	59.39%	7.27%	6.67%	9.09%	5.45%	12.12%
			ADTT = 1000	49.09%	7.88%	9.09%	7.27%	10.30%	16.36%
			ADTT ≥ 5000	30.91%	16.97%	9.09%	9.70%	7.88%	25.45%
DE-07	Shear	Exterior	LFR	95.38%	3.08%	0.00%	0.77%	0.77%	0.00%
			ADTT ≤ 100	76.92%	3.85%	7.69%	4.62%	3.08%	3.85%
			ADTT = 1000	74.62%	1.54%	3.85%	8.46%	5.38%	6.15%
			ADTT ≥ 5000	70.00%	4.62%	1.54%	4.62%	10.00%	9.23%
		Interior	LFR	87.27%	0.61%	2.42%	6.06%	3.03%	0.61%
			ADTT ≤ 100	75.15%	4.24%	3.03%	4.24%	3.64%	9.70%
			ADTT = 1000	72.12%	3.03%	3.64%	3.64%	4.24%	13.33%
			ADTT ≥ 5000	67.27%	4.85%	3.03%	4.24%	4.24%	16.36%

Table 38: FL-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
FL-04	Moment	Exterior	LFR	97.69%	2.31%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	66.92%	8.46%	7.69%	6.92%	4.62%	5.38%
			ADTT = 1000	51.54%	10.00%	12.31%	9.23%	10.00%	6.92%
			ADTT ≥ 5000	41.54%	10.00%	10.00%	13.85%	10.77%	13.85%
		Interior	LFR	89.09%	2.42%	4.24%	1.82%	0.61%	1.82%
			ADTT ≤ 100	64.24%	3.64%	6.67%	8.48%	5.45%	11.52%
			ADTT = 1000	53.94%	6.67%	7.27%	6.67%	9.09%	16.36%
			ADTT ≥ 5000	34.55%	18.79%	7.27%	7.27%	10.30%	21.82%
FL-04	Shear	Exterior	LFR	96.15%	2.31%	0.00%	0.77%	0.77%	0.00%
			ADTT ≤ 100	77.69%	5.38%	5.38%	6.15%	2.31%	3.08%
			ADTT = 1000	74.62%	2.31%	4.62%	6.92%	6.92%	4.62%
			ADTT ≥ 5000	69.23%	4.62%	3.08%	6.15%	7.69%	9.23%
		Interior	LFR	87.27%	0.61%	3.03%	5.45%	3.03%	0.61%
			ADTT ≤ 100	76.36%	2.42%	4.24%	4.24%	3.64%	9.09%
			ADTT = 1000	73.94%	1.21%	3.64%	4.24%	4.24%	12.73%
			ADTT ≥ 5000	70.30%	3.64%	1.21%	3.64%	4.24%	16.97%

Table 39: NC-21 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NC-21	Moment	Exterior	LFR	95.38%	2.31%	0.77%	1.54%	0.00%	0.00%
			ADTT ≤ 100	54.62%	10.77%	12.31%	10.00%	6.15%	6.15%
			ADTT = 1000	41.54%	10.00%	13.08%	13.08%	10.00%	12.31%
			ADTT ≥ 5000	30.00%	10.00%	11.54%	13.85%	15.38%	19.23%
		Interior	LFR	80.61%	6.67%	3.03%	4.85%	1.82%	3.03%
			ADTT ≤ 100	53.33%	7.27%	7.27%	10.30%	6.67%	15.15%
			ADTT = 1000	38.18%	12.12%	9.70%	7.88%	10.30%	21.82%
			ADTT ≥ 5000	25.45%	12.12%	12.73%	10.30%	10.91%	28.48%
NC-21	Shear	Exterior	LFR	95.38%	3.08%	0.77%	0.00%	0.00%	0.77%
			ADTT ≤ 100	76.92%	4.62%	6.15%	6.15%	2.31%	3.85%
			ADTT = 1000	72.31%	3.85%	3.85%	7.69%	7.69%	4.62%
			ADTT ≥ 5000	67.69%	4.62%	3.85%	5.38%	6.92%	11.54%
		Interior	LFR	87.27%	0.00%	4.24%	4.24%	3.64%	0.61%
			ADTT ≤ 100	75.76%	2.42%	1.82%	6.67%	3.03%	10.30%
			ADTT = 1000	72.73%	1.21%	2.42%	3.64%	6.67%	13.33%
			ADTT ≥ 5000	61.82%	10.30%	1.82%	4.24%	4.24%	17.58%

Table 40: NM-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NM-04	Moment	Exterior	LFR	98.46%	1.54%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	73.85%	9.23%	5.38%	3.85%	4.62%	3.08%
			ADTT = 1000	58.46%	13.85%	9.23%	6.92%	3.85%	7.69%
			ADTT ≥ 5000	47.69%	10.77%	13.85%	10.77%	6.15%	10.77%
		Interior	LFR	89.70%	6.06%	1.21%	0.61%	1.82%	0.61%
			ADTT ≤ 100	67.27%	4.24%	9.09%	4.24%	4.24%	10.91%
			ADTT = 1000	60.00%	6.06%	4.24%	10.30%	4.85%	14.55%
			ADTT ≥ 5000	51.52%	6.67%	7.88%	5.45%	11.52%	16.97%
NM-04	Shear	Exterior	LFR	98.46%	0.00%	0.77%	0.00%	0.77%	0.00%
			ADTT ≤ 100	84.62%	3.85%	6.92%	0.77%	2.31%	1.54%
			ADTT = 1000	76.92%	6.15%	5.38%	6.92%	1.54%	3.08%
			ADTT ≥ 5000	75.38%	0.77%	6.92%	5.38%	6.92%	4.62%
		Interior	LFR	88.48%	2.42%	4.85%	3.64%	0.00%	0.61%
			ADTT ≤ 100	79.39%	4.24%	3.03%	4.24%	3.64%	5.45%
			ADTT = 1000	76.97%	1.82%	4.85%	3.03%	4.85%	8.48%
			ADTT ≥ 5000	73.94%	2.42%	2.42%	4.85%	3.64%	12.73%

Table 41: TX-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
TX-04	Moment	Exterior	LFR	92.31%	4.62%	0.77%	2.31%	0.00%	0.00%
			ADTT ≤ 100	43.08%	10.00%	14.62%	12.31%	9.23%	10.77%
			ADTT = 1000	30.77%	10.00%	11.54%	15.38%	13.08%	19.23%
			ADTT ≥ 5000	17.69%	11.54%	11.54%	12.31%	16.15%	30.77%
		Interior	LFR	78.79%	6.06%	4.24%	5.45%	2.42%	3.03%
			ADTT ≤ 100	41.21%	13.33%	7.88%	7.27%	10.30%	20.00%
			ADTT = 1000	23.64%	9.09%	21.21%	8.48%	8.48%	29.09%
			ADTT ≥ 5000	18.79%	4.24%	9.70%	21.82%	10.91%	34.55%
TX-04	Shear	Exterior	LFR	86.15%	4.62%	7.69%	0.00%	0.77%	0.77%
			ADTT ≤ 100	69.23%	3.85%	3.85%	6.92%	6.92%	9.23%
			ADTT = 1000	56.92%	12.31%	2.31%	5.38%	7.69%	15.38%
			ADTT ≥ 5000	46.92%	8.46%	13.85%	3.85%	3.85%	23.08%
		Interior	LFR	81.21%	4.85%	1.21%	2.42%	5.45%	4.85%
			ADTT ≤ 100	63.64%	9.70%	1.82%	3.03%	6.06%	15.76%
			ADTT = 1000	50.30%	10.91%	10.91%	3.03%	3.03%	21.82%
			ADTT ≥ 5000	43.03%	7.27%	10.91%	12.12%	2.42%	24.24%

K.4.3 Special Permit Vehicles

Table 42 through Table 44 provide the results for the three vehicles assumed to be special permits: IL-01, OR-06, and WA-02.

Table 42: IL-01 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
IL-01	Moment	Exterior	LFR	87.69%	5.38%	4.62%	0.00%	2.31%	0.00%
			Single Escorted	56.15%	10.77%	11.54%	9.23%	6.15%	6.15%
			Single ADTT ≤ 100	42.31%	9.23%	12.31%	13.08%	10.00%	13.08%
			Single ADTT = 1000	37.69%	10.00%	10.77%	13.85%	13.08%	14.62%
			Single ADTT ≥ 5000	33.08%	9.23%	9.23%	13.85%	13.85%	20.77%
			Multiple ADTT ≤ 100	29.23%	9.23%	12.31%	13.08%	14.62%	21.54%
			Multiple ADTT = 1000	16.92%	10.77%	10.00%	13.85%	13.85%	34.62%
			Multiple ADTT ≥ 5000	10.00%	10.77%	13.08%	11.54%	13.08%	41.54%
		Interior	LFR	75.76%	4.24%	5.45%	4.85%	4.85%	4.85%
			Single Escorted	56.97%	7.27%	4.24%	9.70%	6.06%	15.76%
			Single ADTT ≤ 100	37.58%	13.33%	10.91%	6.67%	9.09%	22.42%
			Single ADTT = 1000	33.94%	13.33%	12.12%	7.27%	9.70%	23.64%
			Single ADTT ≥ 5000	26.67%	10.91%	13.94%	12.12%	7.88%	28.48%
			Multiple ADTT ≤ 100	24.24%	9.70%	15.76%	12.12%	6.67%	31.52%
			Multiple ADTT = 1000	17.58%	5.45%	10.91%	16.97%	12.73%	36.36%
			Multiple ADTT ≥ 5000	12.12%	8.48%	7.27%	16.36%	15.15%	40.61%
IL-01	Shear	Exterior	LFR	83.08%	1.54%	6.92%	4.62%	2.31%	1.54%
			Single Escorted	72.31%	3.85%	1.54%	6.15%	6.15%	10.00%
			Single ADTT ≤ 100	68.46%	1.54%	3.08%	4.62%	6.15%	16.15%
			Single ADTT = 1000	63.08%	6.15%	3.85%	4.62%	4.62%	17.69%
			Single ADTT ≥ 5000	59.23%	9.23%	2.31%	4.62%	3.85%	20.77%
			Multiple ADTT ≤ 100	54.62%	9.23%	6.15%	3.08%	4.62%	22.31%
			Multiple ADTT = 1000	39.23%	13.85%	10.00%	6.92%	5.38%	24.62%
			Multiple ADTT ≥ 5000	36.15%	10.00%	13.85%	8.46%	4.62%	26.92%
		Interior	LFR	79.39%	6.06%	1.21%	1.21%	2.42%	9.70%
			Single Escorted	71.52%	3.03%	4.85%	3.64%	1.82%	15.15%
			Single ADTT ≤ 100	61.21%	9.09%	3.03%	4.85%	4.85%	16.97%
			Single ADTT = 1000	57.58%	9.09%	5.45%	4.85%	5.45%	17.58%
			Single ADTT ≥ 5000	52.12%	9.09%	9.09%	4.24%	4.85%	20.61%
			Multiple ADTT ≤ 100	50.30%	7.27%	9.70%	6.06%	5.45%	21.21%
			Multiple ADTT = 1000	39.39%	9.09%	9.09%	12.12%	4.85%	25.45%
			Multiple ADTT ≥ 5000	37.58%	4.24%	12.12%	11.52%	6.67%	27.88%

Table 43: OR-06 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
OR-06	Moment	Exterior	LFR	86.15%	5.38%	3.85%	2.31%	2.31%	0.00%
			Single Escorted	54.62%	12.31%	11.54%	7.69%	6.92%	6.92%
			Single ADTT ≤ 100	41.54%	7.69%	12.31%	13.85%	10.77%	13.85%
			Single ADTT = 1000	36.92%	7.69%	10.77%	16.15%	13.08%	15.38%
			Single ADTT ≥ 5000	28.46%	13.08%	9.23%	12.31%	17.69%	19.23%
			Multiple ADTT ≤ 100	25.38%	13.08%	6.92%	16.15%	15.38%	23.08%
			Multiple ADTT = 1000	10.00%	13.08%	13.85%	10.00%	16.15%	36.92%
			Multiple ADTT ≥ 5000	9.23%	6.92%	13.85%	14.62%	12.31%	43.08%
		Interior	LFR	73.94%	4.24%	3.64%	7.27%	6.06%	4.85%
			Single Escorted	53.94%	9.09%	4.85%	9.09%	7.27%	15.76%
			Single ADTT ≤ 100	32.12%	18.18%	6.06%	10.91%	9.70%	23.03%
			Single ADTT = 1000	28.48%	17.58%	10.30%	10.30%	8.48%	24.85%
			Single ADTT ≥ 5000	23.64%	8.48%	20.61%	10.30%	6.06%	30.91%
			Multiple ADTT ≤ 100	21.21%	7.88%	18.79%	8.48%	11.52%	32.12%
			Multiple ADTT = 1000	12.73%	7.27%	8.48%	20.00%	14.55%	36.97%
			Multiple ADTT ≥ 5000	12.12%	6.67%	7.27%	15.15%	15.15%	43.64%
OR-06	Shear	Exterior	LFR	80.77%	5.38%	6.92%	4.62%	0.77%	1.54%
			Single Escorted	71.54%	4.62%	2.31%	7.69%	5.38%	8.46%
			Single ADTT ≤ 100	66.15%	4.62%	1.54%	6.15%	7.69%	13.85%
			Single ADTT = 1000	60.77%	6.92%	3.85%	5.38%	6.15%	16.92%
			Single ADTT ≥ 5000	53.08%	13.08%	4.62%	3.85%	4.62%	20.77%
			Multiple ADTT ≤ 100	48.46%	13.85%	8.46%	1.54%	6.15%	21.54%
			Multiple ADTT = 1000	42.31%	6.15%	12.31%	10.00%	3.85%	25.38%
			Multiple ADTT ≥ 5000	39.23%	4.62%	9.23%	14.62%	4.62%	27.69%
		Interior	LFR	76.97%	4.85%	4.85%	0.61%	3.64%	9.09%
			Single Escorted	71.52%	2.42%	3.64%	3.03%	3.64%	15.76%
			Single ADTT ≤ 100	58.79%	7.88%	7.27%	3.64%	3.03%	19.39%
			Single ADTT = 1000	54.55%	8.48%	9.70%	2.42%	4.85%	20.00%
			Single ADTT ≥ 5000	48.48%	10.30%	8.48%	6.67%	3.64%	22.42%
			Multiple ADTT ≤ 100	44.85%	10.30%	9.09%	9.70%	3.64%	22.42%
			Multiple ADTT = 1000	40.00%	4.24%	10.30%	11.52%	7.88%	26.06%
			Multiple ADTT ≥ 5000	33.94%	8.48%	6.06%	13.94%	11.52%	26.06%

Table 44: WA-02 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
WA-02	Moment	Exterior	LFR	77.69%	9.23%	6.15%	3.08%	2.31%	1.54%
			Single Escorted	48.46%	6.92%	12.31%	11.54%	6.15%	14.62%
			Single ADTT ≤ 100	31.54%	9.23%	11.54%	11.54%	14.62%	21.54%
			Single ADTT = 1000	24.62%	14.62%	9.23%	13.85%	14.62%	23.08%
			Single ADTT ≥ 5000	22.31%	9.23%	12.31%	10.77%	15.38%	30.00%
			Multiple ADTT ≤ 100	19.23%	6.15%	14.62%	12.31%	13.08%	34.62%
			Multiple ADTT = 1000	10.00%	6.92%	7.69%	16.15%	13.85%	45.38%
			Multiple ADTT ≥ 5000	8.46%	2.31%	11.54%	13.08%	13.08%	51.54%
		Interior	LFR	69.09%	6.06%	3.03%	7.27%	5.45%	9.09%
			Single Escorted	46.67%	12.12%	5.45%	7.27%	7.27%	21.21%
			Single ADTT ≤ 100	26.06%	11.52%	13.94%	12.73%	7.27%	28.48%
			Single ADTT = 1000	25.45%	7.27%	14.55%	15.76%	6.67%	30.30%
			Single ADTT ≥ 5000	20.00%	6.06%	13.33%	17.58%	9.09%	33.94%
			Multiple ADTT ≤ 100	19.39%	6.06%	10.30%	15.15%	13.33%	35.76%
			Multiple ADTT = 1000	10.91%	8.48%	6.06%	11.52%	20.00%	43.03%
			Multiple ADTT ≥ 5000	10.30%	6.06%	4.24%	9.09%	18.18%	52.12%
WA-02	Shear	Exterior	LFR	72.31%	6.92%	5.38%	4.62%	6.15%	4.62%
			Single Escorted	63.85%	5.38%	4.62%	4.62%	3.08%	18.46%
			Single ADTT ≤ 100	50.77%	10.00%	7.69%	3.85%	6.15%	21.54%
			Single ADTT = 1000	45.38%	11.54%	6.92%	6.92%	6.92%	22.31%
			Single ADTT ≥ 5000	40.77%	10.00%	10.00%	8.46%	5.38%	25.38%
			Multiple ADTT ≤ 100	38.46%	6.92%	14.62%	8.46%	5.38%	26.15%
			Multiple ADTT = 1000	33.08%	4.62%	7.69%	15.38%	8.46%	30.77%
			Multiple ADTT ≥ 5000	32.31%	3.85%	5.38%	14.62%	10.00%	33.85%
		Interior	LFR	69.70%	9.09%	6.67%	1.21%	1.82%	11.52%
			Single Escorted	59.39%	6.67%	6.06%	6.67%	3.03%	18.18%
			Single ADTT ≤ 100	45.45%	11.52%	4.85%	10.30%	5.45%	22.42%
			Single ADTT = 1000	42.42%	12.73%	5.45%	7.27%	6.67%	25.45%
			Single ADTT ≥ 5000	40.00%	5.45%	12.73%	7.88%	6.67%	27.27%
			Multiple ADTT ≤ 100	37.58%	4.85%	12.73%	6.67%	10.30%	27.88%
			Multiple ADTT = 1000	29.09%	7.27%	6.06%	14.55%	9.09%	33.94%
			Multiple ADTT ≥ 5000	23.64%	10.91%	6.06%	12.12%	8.48%	38.79%

K.5 Simple Span Reinforced Concrete Slab Bridges

The tables in the following sections contain the percentage of girders in each rating category for the 99 simple span reinforced concrete slabs analyzed. For flexure, the number of girders with LRFR ratings greater than 1.0 is typically at least 7% lower than the number of girders with LFR ratings greater than 1.0 with the percentage varying for each vehicle. For shear, the percentage of girders with LRFR ratings greater than 1.0 is typically between 95 and 99 percent with little affect due to ADTT. The percentage of girders with passing ratings decreases with increasing ADTT as expected due to the increase in the load factor for live load.

K.5.1 AASHTO Legal Vehicles

Table 45 through Table 47 provide the distribution of rating factors for the three AASHTO Legal vehicles: Type 3, Type 3-3, and Type 3S2.

Table 45: AASHTO Type 3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3	Moment	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	88.89%	2.02%	2.02%	4.04%	0.00%	3.03%
		ADTT = 1000	76.77%	10.10%	3.03%	3.03%	2.02%	5.05%
		ADTT ≥ 5000	73.74%	4.04%	9.09%	4.04%	3.03%	6.06%
AASHTO TYPE 3	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	98.99%	0.00%	0.00%	1.01%	0.00%	0.00%
		ADTT = 1000	98.99%	0.00%	0.00%	0.00%	1.01%	0.00%
		ADTT ≥ 5000	98.99%	0.00%	0.00%	0.00%	0.00%	1.01%

Table 46: AASHTO Type 3-3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3-3	Moment	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	92.93%	2.02%	2.02%	0.00%	0.00%	3.03%
		ADTT = 1000	89.90%	1.01%	2.02%	2.02%	2.02%	3.03%
		ADTT ≥ 5000	86.87%	3.03%	1.01%	4.04%	2.02%	3.03%
AASHTO TYPE 3-3	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	98.99%	0.00%	1.01%	0.00%	0.00%	0.00%
		ADTT = 1000	98.99%	0.00%	0.00%	1.01%	0.00%	0.00%
		ADTT ≥ 5000	98.99%	0.00%	0.00%	0.00%	1.01%	0.00%

Table 47: AASHTO Type 3S2 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3S2	Moment	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	90.91%	2.02%	1.01%	3.03%	0.00%	3.03%
		ADTT = 1000	85.86%	4.04%	1.01%	2.02%	4.04%	3.03%
		ADTT ≥ 5000	77.78%	8.08%	4.04%	3.03%	2.02%	5.05%
AASHTO TYPE 3S2	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	98.99%	0.00%	1.01%	0.00%	0.00%	0.00%
		ADTT = 1000	98.99%	0.00%	0.00%	1.01%	0.00%	0.00%
		ADTT ≥ 5000	98.99%	0.00%	0.00%	0.00%	1.01%	0.00%

K.5.2 Routine Permit Vehicles

Table 48 through **Table 52** provide the distribution of rating factors for the five vehicles considered to be routine permits: DE-07, FL-04, NC-21, NM-04, and TX-04.

Table 48: DE-07 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
DE-07	Moment	LFR	97.98%	1.01%	1.01%	0.00%	0.00%	0.00%
		ADTT ≤ 100	77.78%	9.09%	3.03%	3.03%	4.04%	3.03%
		ADTT = 1000	72.73%	3.03%	11.11%	3.03%	4.04%	6.06%
		ADTT ≥ 5000	66.67%	6.06%	3.03%	11.11%	4.04%	9.09%
DE-07	Shear	LFR	98.99%	0.00%	0.00%	0.00%	0.00%	1.01%
		ADTT ≤ 100	98.99%	0.00%	0.00%	0.00%	1.01%	0.00%
		ADTT = 1000	98.99%	0.00%	0.00%	0.00%	0.00%	1.01%
		ADTT ≥ 5000	98.99%	0.00%	0.00%	0.00%	0.00%	1.01%

Table 49: FL-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
FL-04	Moment	LFR	98.99%	1.01%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	84.85%	5.05%	1.01%	3.03%	3.03%	3.03%
		ADTT = 1000	75.76%	9.09%	5.05%	1.01%	3.03%	6.06%
		ADTT ≥ 5000	71.72%	4.04%	9.09%	5.05%	3.03%	7.07%
FL-04	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	98.99%	0.00%	0.00%	0.00%	1.01%	0.00%
		ADTT = 1000	98.99%	0.00%	0.00%	0.00%	0.00%	1.01%
		ADTT ≥ 5000	97.98%	1.01%	0.00%	0.00%	0.00%	1.01%

Table 50: NC-21 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NC-21	Moment	LFR	94.95%	3.03%	1.01%	1.01%	0.00%	0.00%
		ADTT ≤ 100	72.73%	8.08%	6.06%	4.04%	5.05%	4.04%
		ADTT = 1000	67.68%	4.04%	7.07%	8.08%	4.04%	9.09%
		ADTT ≥ 5000	55.56%	12.12%	4.04%	9.09%	8.08%	11.11%
NC-21	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	98.99%	0.00%	0.00%	0.00%	1.01%	0.00%
		ADTT = 1000	98.99%	0.00%	0.00%	0.00%	0.00%	1.01%
		ADTT ≥ 5000	95.96%	3.03%	0.00%	0.00%	0.00%	1.01%

Table 51: NM-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NM-04	Moment	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	90.91%	1.01%	1.01%	4.04%	0.00%	3.03%
		ADTT = 1000	86.87%	4.04%	1.01%	1.01%	4.04%	3.03%
		ADTT ≥ 5000	78.79%	6.06%	6.06%	1.01%	2.02%	6.06%
NM-04	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	98.99%	0.00%	0.00%	1.01%	0.00%	0.00%
		ADTT = 1000	98.99%	0.00%	0.00%	0.00%	1.01%	0.00%
		ADTT ≥ 5000	98.99%	0.00%	0.00%	0.00%	0.00%	1.01%

Table 52: TX-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
TX-04	Moment	LFR	91.92%	3.03%	3.03%	2.02%	0.00%	0.00%
		ADTT ≤ 100	68.69%	4.04%	5.05%	9.09%	5.05%	8.08%
		ADTT = 1000	56.57%	11.11%	5.05%	5.05%	9.09%	13.13%
		ADTT ≥ 5000	39.39%	15.15%	13.13%	5.05%	9.09%	18.18%
TX-04	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	95.96%	2.02%	1.01%	0.00%	0.00%	1.01%
		ADTT = 1000	94.95%	1.01%	2.02%	1.01%	0.00%	1.01%
		ADTT ≥ 5000	94.95%	0.00%	1.01%	2.02%	1.01%	1.01%

K.5.3 Special Permit Vehicles

Table 53 through Table 55 provide the results for the three vehicles assumed to be special permits: IL-01, OR-06, and WA-02.

Table 53: IL-01 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
IL-01	Moment	LFR	85.86%	6.06%	5.05%	1.01%	2.02%	0.00%
		Single Escorted	75.76%	10.10%	4.04%	3.03%	3.03%	4.04%
		Single ADTT ≤ 100	70.71%	3.03%	8.08%	8.08%	3.03%	7.07%
		Single ADTT = 1000	68.69%	3.03%	7.07%	9.09%	4.04%	8.08%
		Single ADTT ≥ 5000	61.62%	9.09%	3.03%	11.11%	6.06%	9.09%
		Multiple ADTT ≤ 100	58.59%	10.10%	4.04%	9.09%	8.08%	10.10%
		Multiple ADTT = 1000	40.40%	16.16%	12.12%	4.04%	12.12%	15.15%
		Multiple ADTT ≥ 5000	35.35%	13.13%	13.13%	10.10%	7.07%	21.21%
IL-01	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Single Escorted	98.99%	0.00%	0.00%	0.00%	1.01%	0.00%
		Single ADTT ≤ 100	95.96%	2.02%	1.01%	0.00%	0.00%	1.01%
		Single ADTT = 1000	94.95%	1.01%	3.03%	0.00%	0.00%	1.01%
		Single ADTT ≥ 5000	94.95%	1.01%	2.02%	1.01%	0.00%	1.01%
		Multiple ADTT ≤ 100	94.95%	0.00%	3.03%	1.01%	0.00%	1.01%
		Multiple ADTT = 1000	94.95%	0.00%	0.00%	3.03%	1.01%	1.01%
		Multiple ADTT ≥ 5000	94.95%	0.00%	0.00%	1.01%	3.03%	1.01%

Table 54: OR-06 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
OR-06	Moment	LFR	85.86%	5.05%	5.05%	2.02%	2.02%	0.00%
		Single Escorted	75.76%	9.09%	6.06%	1.01%	5.05%	3.03%
		Single ADTT ≤ 100	70.71%	2.02%	8.08%	9.09%	2.02%	8.08%
		Single ADTT = 1000	66.67%	5.05%	8.08%	8.08%	3.03%	9.09%
		Single ADTT ≥ 5000	61.62%	9.09%	2.02%	12.12%	6.06%	9.09%
		Multiple ADTT ≤ 100	56.57%	10.10%	5.05%	9.09%	9.09%	10.10%
		Multiple ADTT = 1000	39.39%	17.17%	10.10%	5.05%	13.13%	15.15%
		Multiple ADTT ≥ 5000	34.34%	15.15%	12.12%	10.10%	8.08%	20.20%
OR-06	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Single Escorted	97.98%	0.00%	1.01%	0.00%	0.00%	1.01%
		Single ADTT ≤ 100	95.96%	2.02%	0.00%	1.01%	0.00%	1.01%
		Single ADTT = 1000	94.95%	1.01%	2.02%	1.01%	0.00%	1.01%
		Single ADTT ≥ 5000	94.95%	1.01%	2.02%	0.00%	1.01%	1.01%
		Multiple ADTT ≤ 100	94.95%	0.00%	1.01%	2.02%	1.01%	1.01%
		Multiple ADTT = 1000	94.95%	0.00%	0.00%	3.03%	0.00%	2.02%
		Multiple ADTT ≥ 5000	94.95%	0.00%	0.00%	1.01%	2.02%	2.02%

Table 55: WA-02 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
WA-02	Moment	LFR	83.84%	7.07%	4.04%	3.03%	2.02%	0.00%
		Single Escorted	73.74%	8.08%	7.07%	2.02%	3.03%	6.06%
		Single ADTT ≤ 100	66.67%	4.04%	9.09%	8.08%	2.02%	10.10%
		Single ADTT = 1000	62.63%	8.08%	7.07%	8.08%	4.04%	10.10%
		Single ADTT ≥ 5000	58.59%	8.08%	4.04%	10.10%	9.09%	10.10%
		Multiple ADTT ≤ 100	53.54%	9.09%	8.08%	9.09%	9.09%	11.11%
		Multiple ADTT = 1000	35.35%	17.17%	10.10%	8.08%	10.10%	19.19%
		Multiple ADTT ≥ 5000	29.29%	15.15%	14.14%	12.12%	7.07%	22.22%
WA-02	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		Single Escorted	97.98%	0.00%	0.00%	1.01%	0.00%	1.01%
		Single ADTT ≤ 100	94.95%	1.01%	2.02%	0.00%	1.01%	1.01%
		Single ADTT = 1000	94.95%	1.01%	2.02%	0.00%	1.01%	1.01%
		Single ADTT ≥ 5000	94.95%	0.00%	1.01%	2.02%	0.00%	2.02%
		Multiple ADTT ≤ 100	94.95%	0.00%	1.01%	2.02%	0.00%	2.02%
		Multiple ADTT = 1000	94.95%	0.00%	0.00%	1.01%	2.02%	2.02%
		Multiple ADTT ≥ 5000	94.95%	0.00%	0.00%	1.01%	2.02%	2.02%

K.6 Continuous Span Steel Girder Bridges

The tables in the following sections contain the percentage of girders in each rating category for the 418 continuous span steel girders analyzed. For flexure and shear, composite girders typically had more girders with ratings above 1.0 than non-composite girders for all types of vehicles. The percentage of girders passing an LRFR rating is lower than the percentage of girders passing the LFR rating for all ADTT categories. For some vehicles, the difference between LFR and LRFR is small while for others the difference is large. The percentage of girders with passing ratings decreases with increasing ADTT as expected due to the increase in the load factor for live load.

It is also noted that for shear, more girders have LFR ratings greater than 1.0 for non-composite girders than for composite girders while for LRFR more girders have ratings greater than 1.0 for composite girders than non-composite girders. The difference is typically between 5 an 10% for the LFR ratings.

K.6.1 AASHTO Legal Vehicles

Table 56 through Table 58 provide the distribution of rating factors for the three AASHTO Legal vehicles: Type 3, Type 3-3, and Type 3S2.

Table 56: AASHTO Type 3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	97.97%	0.68%	0.68%	0.00%	0.00%	0.68%
			ADTT = 1000	96.62%	1.35%	0.68%	0.00%	0.68%	0.68%
			ADTT ≥ 5000	96.62%	0.00%	1.35%	0.68%	0.68%	0.68%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	65.38%	11.54%	15.38%	0.00%	7.69%	0.00%
			ADTT = 1000	65.38%	0.00%	7.69%	15.38%	3.85%	7.69%
			ADTT ≥ 5000	61.54%	3.85%	0.00%	11.54%	15.38%	7.69%
		Interior Composite	LFR	99.49%	0.51%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	99.49%	0.00%	0.00%	0.00%	0.00%	0.51%
			ADTT = 1000	98.97%	0.51%	0.00%	0.00%	0.00%	0.51%
			ADTT ≥ 5000	98.97%	0.00%	0.51%	0.00%	0.00%	0.51%
		Interior Non-Composite	LFR	97.96%	2.04%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	87.76%	6.12%	2.04%	4.08%	0.00%	0.00%
			ADTT = 1000	83.67%	4.08%	4.08%	2.04%	6.12%	0.00%
			ADTT ≥ 5000	83.67%	0.00%	4.08%	6.12%	4.08%	2.04%
AASHTO TYPE 3	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.95%	0.00%	0.68%	0.68%	0.68%	2.03%
			ADTT = 1000	95.95%	0.00%	0.00%	0.00%	1.35%	2.70%
			ADTT ≥ 5000	95.95%	0.00%	0.00%	0.00%	0.68%	3.38%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	88.46%	0.00%	0.00%	0.00%	3.85%	7.69%
			ADTT = 1000	88.46%	0.00%	0.00%	0.00%	0.00%	11.54%
			ADTT ≥ 5000	84.62%	3.85%	0.00%	0.00%	0.00%	11.54%
		Interior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	96.41%	0.51%	1.03%	0.00%	0.51%	1.54%
			ADTT = 1000	93.85%	2.05%	0.51%	1.03%	0.51%	2.05%
			ADTT ≥ 5000	92.82%	1.03%	2.05%	1.03%	1.03%	2.05%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	91.84%	0.00%	0.00%	0.00%	2.04%	6.12%
			ADTT = 1000	87.76%	0.00%	4.08%	0.00%	0.00%	8.16%
			ADTT ≥ 5000	85.71%	2.04%	2.04%	2.04%	0.00%	8.16%

Table 57: AASHTO Type 3-3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3-3	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.95%	2.03%	0.00%	0.00%	0.00%	2.03%
			ADTT = 1000	95.27%	0.68%	0.00%	2.03%	0.00%	2.03%
			ADTT ≥ 5000	95.27%	0.00%	0.68%	2.03%	0.00%	2.03%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	69.23%	15.38%	7.69%	7.69%	0.00%	0.00%
			ADTT = 1000	61.54%	7.69%	11.54%	7.69%	11.54%	0.00%
			ADTT ≥ 5000	61.54%	0.00%	7.69%	15.38%	7.69%	7.69%
		Interior Composite	LFR	98.97%	0.51%	0.51%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.97%	0.00%	0.00%	0.51%	0.00%	0.51%
			ADTT = 1000	97.95%	0.51%	0.51%	0.00%	0.51%	0.51%
			ADTT ≥ 5000	97.95%	0.00%	1.03%	0.00%	0.00%	1.03%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	91.84%	2.04%	6.12%	0.00%	0.00%	0.00%
			ADTT = 1000	87.76%	4.08%	0.00%	8.16%	0.00%	0.00%
			ADTT ≥ 5000	81.63%	6.12%	4.08%	2.04%	6.12%	0.00%
AASHTO TYPE 3-3	Shear	Exterior Composite	LFR	97.97%	0.68%	0.68%	0.68%	0.00%	0.00%
			ADTT ≤ 100	95.27%	0.68%	0.68%	0.00%	0.68%	2.70%
			ADTT = 1000	91.89%	2.70%	0.68%	1.35%	0.00%	3.38%
			ADTT ≥ 5000	91.89%	0.68%	2.70%	0.68%	0.68%	3.38%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	88.46%	0.00%	0.00%	0.00%	0.00%	11.54%
			ADTT = 1000	80.77%	7.69%	0.00%	0.00%	0.00%	11.54%
			ADTT ≥ 5000	73.08%	7.69%	7.69%	0.00%	0.00%	11.54%
		Interior Composite	LFR	98.97%	0.00%	0.00%	1.03%	0.00%	0.00%
			ADTT ≤ 100	92.82%	1.54%	0.51%	2.56%	0.00%	2.56%
			ADTT = 1000	90.77%	0.51%	2.05%	1.54%	2.56%	2.56%
			ADTT ≥ 5000	89.74%	1.54%	1.54%	1.54%	1.03%	4.62%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	83.67%	2.04%	4.08%	2.04%	2.04%	6.12%
			ADTT = 1000	79.59%	4.08%	0.00%	6.12%	2.04%	8.16%
			ADTT ≥ 5000	79.59%	2.04%	2.04%	2.04%	4.08%	10.20%

Table 58: AASHTO Type 3S2 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3S2	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.95%	1.35%	0.68%	0.00%	0.00%	2.03%
			ADTT = 1000	95.27%	0.68%	1.35%	0.68%	0.00%	2.03%
			ADTT ≥ 5000	95.27%	0.00%	0.68%	1.35%	0.68%	2.03%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	69.23%	0.00%	15.38%	7.69%	7.69%	0.00%
			ADTT = 1000	61.54%	3.85%	3.85%	11.54%	11.54%	7.69%
			ADTT ≥ 5000	53.85%	7.69%	3.85%	3.85%	19.23%	11.54%
		Interior Composite	LFR	97.97%	1.35%	0.68%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.27%	0.68%	0.68%	0.00%	0.68%	2.70%
			ADTT = 1000	92.57%	2.70%	0.68%	0.68%	0.00%	3.38%
			ADTT ≥ 5000	91.89%	1.35%	2.03%	0.68%	0.68%	3.38%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	88.46%	0.00%	0.00%	0.00%	0.00%	11.54%
			ADTT = 1000	84.62%	3.85%	0.00%	0.00%	0.00%	11.54%
			ADTT ≥ 5000	69.23%	15.38%	3.85%	0.00%	0.00%	11.54%
AASHTO TYPE 3S2	Shear	Exterior Composite	LFR	97.97%	1.35%	0.68%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.27%	0.68%	0.68%	0.00%	0.68%	2.70%
			ADTT = 1000	92.57%	2.70%	0.68%	0.68%	0.00%	3.38%
			ADTT ≥ 5000	91.89%	1.35%	2.03%	0.68%	0.68%	3.38%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	88.46%	0.00%	0.00%	0.00%	0.00%	11.54%
			ADTT = 1000	84.62%	3.85%	0.00%	0.00%	0.00%	11.54%
			ADTT ≥ 5000	69.23%	15.38%	3.85%	0.00%	0.00%	11.54%
		Interior Composite	LFR	98.97%	0.00%	1.03%	0.00%	0.00%	0.00%
			ADTT ≤ 100	92.82%	1.54%	2.05%	0.51%	1.54%	1.54%
			ADTT = 1000	91.28%	1.54%	1.03%	1.54%	1.54%	3.08%
			ADTT ≥ 5000	90.77%	0.51%	1.54%	1.54%	2.05%	3.59%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	83.67%	6.12%	0.00%	2.04%	0.00%	8.16%
			ADTT = 1000	83.67%	0.00%	2.04%	4.08%	2.04%	8.16%
			ADTT ≥ 5000	79.59%	4.08%	0.00%	6.12%	2.04%	8.16%

K.6.2 Routine Permit Vehicles

Table 59 through Table 63 provide the distribution of rating factors for the five vehicles considered to be routine permits: DE-07, FL-04, NC-21, NM-04, and TX-04.

Table 59: DE-07 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
DE-07	Moment	Exterior Composite	LFR	98.65%	1.35%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.27%	0.68%	1.35%	0.68%	0.00%	2.03%
			ADTT = 1000	95.27%	0.00%	0.68%	1.35%	0.68%	2.03%
			ADTT ≥ 5000	92.57%	2.03%	0.68%	0.68%	1.35%	2.70%
		Exterior Non-Composite	LFR	92.31%	3.85%	3.85%	0.00%	0.00%	0.00%
			ADTT ≤ 100	61.54%	7.69%	15.38%	0.00%	7.69%	7.69%
			ADTT = 1000	53.85%	3.85%	7.69%	19.23%	0.00%	15.38%
			ADTT ≥ 5000	46.15%	7.69%	3.85%	11.54%	15.38%	15.38%
		Interior Composite	LFR	98.46%	0.00%	1.03%	0.51%	0.00%	0.00%
			ADTT ≤ 100	98.46%	0.51%	0.00%	0.00%	0.51%	0.51%
			ADTT = 1000	97.44%	1.03%	0.51%	0.00%	0.51%	0.51%
			ADTT ≥ 5000	94.87%	2.56%	1.03%	0.51%	0.00%	1.03%
		Interior Non-Composite	LFR	93.88%	2.04%	4.08%	0.00%	0.00%	0.00%
			ADTT ≤ 100	83.67%	2.04%	4.08%	4.08%	6.12%	0.00%
			ADTT = 1000	73.47%	8.16%	4.08%	4.08%	4.08%	6.12%
			ADTT ≥ 5000	69.39%	4.08%	8.16%	4.08%	6.12%	8.16%
DE-07	Shear	Exterior Composite	LFR	97.97%	0.00%	1.35%	0.68%	0.00%	0.00%
			ADTT ≤ 100	94.59%	0.68%	0.68%	0.68%	0.00%	3.38%
			ADTT = 1000	92.57%	2.03%	0.68%	0.68%	0.68%	3.38%
			ADTT ≥ 5000	91.22%	1.35%	2.03%	0.68%	0.68%	4.05%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	88.46%	0.00%	0.00%	0.00%	0.00%	11.54%
			ADTT = 1000	76.92%	7.69%	3.85%	0.00%	0.00%	11.54%
			ADTT ≥ 5000	69.23%	7.69%	7.69%	3.85%	0.00%	11.54%
		Interior Composite	LFR	98.97%	0.00%	0.00%	1.03%	0.00%	0.00%
			ADTT ≤ 100	91.79%	1.03%	1.03%	2.56%	0.51%	3.08%
			ADTT = 1000	90.77%	1.03%	1.03%	1.03%	2.56%	3.59%
			ADTT ≥ 5000	87.18%	3.59%	1.03%	1.03%	1.54%	5.64%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	83.67%	0.00%	6.12%	0.00%	2.04%	8.16%
			ADTT = 1000	79.59%	4.08%	0.00%	6.12%	2.04%	8.16%
			ADTT ≥ 5000	77.55%	2.04%	4.08%	0.00%	6.12%	10.20%

Table 60: FL-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
FL-04	Moment	Exterior Composite	LFR	99.32%	0.68%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	97.30%	0.00%	1.35%	0.00%	0.00%	1.35%
			ADTT = 1000	95.95%	0.68%	0.68%	1.35%	0.00%	1.35%
			ADTT ≥ 5000	94.59%	1.35%	0.68%	0.68%	1.35%	1.35%
		Exterior Non-Composite	LFR	96.15%	3.85%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	69.23%	7.69%	3.85%	11.54%	7.69%	0.00%
			ADTT = 1000	53.85%	7.69%	11.54%	7.69%	15.38%	3.85%
			ADTT ≥ 5000	53.85%	0.00%	7.69%	15.38%	3.85%	19.23%
		Interior Composite	LFR	98.46%	0.51%	0.51%	0.51%	0.00%	0.00%
			ADTT ≤ 100	98.46%	0.51%	0.00%	0.51%	0.00%	0.51%
			ADTT = 1000	97.95%	0.51%	0.51%	0.00%	0.51%	0.51%
			ADTT ≥ 5000	97.44%	0.51%	0.51%	0.51%	0.00%	1.03%
		Interior Non-Composite	LFR	95.92%	2.04%	2.04%	0.00%	0.00%	0.00%
			ADTT ≤ 100	85.71%	4.08%	2.04%	6.12%	2.04%	0.00%
			ADTT = 1000	79.59%	6.12%	4.08%	2.04%	6.12%	2.04%
			ADTT ≥ 5000	75.51%	2.04%	8.16%	4.08%	4.08%	6.12%
FL-04	Shear	Exterior Composite	LFR	97.97%	1.35%	0.00%	0.68%	0.00%	0.00%
			ADTT ≤ 100	95.27%	0.68%	0.00%	1.35%	0.00%	2.70%
			ADTT = 1000	93.92%	0.68%	1.35%	0.00%	1.35%	2.70%
			ADTT ≥ 5000	91.89%	2.03%	0.68%	1.35%	0.00%	4.05%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	88.46%	0.00%	0.00%	0.00%	0.00%	11.54%
			ADTT = 1000	80.77%	7.69%	0.00%	0.00%	0.00%	11.54%
			ADTT ≥ 5000	76.92%	3.85%	7.69%	0.00%	0.00%	11.54%
		Interior Composite	LFR	98.97%	0.00%	0.00%	1.03%	0.00%	0.00%
			ADTT ≤ 100	92.31%	1.54%	1.03%	2.05%	0.51%	2.56%
			ADTT = 1000	91.28%	0.51%	1.03%	2.05%	2.05%	3.08%
			ADTT ≥ 5000	89.23%	2.05%	0.51%	2.05%	2.56%	3.59%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	83.67%	2.04%	4.08%	2.04%	0.00%	8.16%
			ADTT = 1000	83.67%	0.00%	0.00%	6.12%	2.04%	8.16%
			ADTT ≥ 5000	77.55%	4.08%	2.04%	2.04%	4.08%	10.20%

Table 61: NC-21 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NC-21	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.95%	0.00%	1.35%	0.68%	1.35%	0.68%
			ADTT = 1000	95.27%	0.00%	0.68%	1.35%	0.68%	2.03%
			ADTT ≥ 5000	93.92%	1.35%	0.00%	0.68%	2.03%	2.03%
		Exterior Non-Composite	LFR	88.46%	7.69%	3.85%	0.00%	0.00%	0.00%
			ADTT ≤ 100	61.54%	7.69%	7.69%	3.85%	15.38%	3.85%
			ADTT = 1000	53.85%	3.85%	7.69%	11.54%	3.85%	19.23%
			ADTT ≥ 5000	50.00%	3.85%	3.85%	11.54%	7.69%	23.08%
		Interior Composite	LFR	98.46%	0.51%	0.51%	0.51%	0.00%	0.00%
			ADTT ≤ 100	98.97%	0.00%	0.51%	0.00%	0.00%	0.51%
			ADTT = 1000	98.46%	0.00%	0.51%	0.51%	0.00%	0.51%
			ADTT ≥ 5000	96.92%	1.54%	0.00%	0.51%	0.51%	0.51%
		Interior Non-Composite	LFR	93.88%	2.04%	2.04%	2.04%	0.00%	0.00%
			ADTT ≤ 100	83.67%	0.00%	4.08%	6.12%	4.08%	2.04%
			ADTT = 1000	77.55%	4.08%	2.04%	4.08%	8.16%	4.08%
			ADTT ≥ 5000	65.31%	12.24%	4.08%	2.04%	4.08%	12.24%
NC-21	Shear	Exterior Composite	LFR	99.32%	0.68%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.95%	0.00%	0.00%	0.00%	1.35%	2.70%
			ADTT = 1000	94.59%	1.35%	0.00%	0.00%	0.68%	3.38%
			ADTT ≥ 5000	93.92%	0.00%	2.03%	0.00%	0.00%	4.05%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	88.46%	0.00%	0.00%	0.00%	0.00%	11.54%
			ADTT = 1000	84.62%	3.85%	0.00%	0.00%	0.00%	11.54%
			ADTT ≥ 5000	76.92%	7.69%	3.85%	0.00%	0.00%	11.54%
		Interior Composite	LFR	98.97%	0.51%	0.51%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.85%	1.03%	1.54%	1.03%	0.51%	2.05%
			ADTT = 1000	91.79%	1.54%	1.03%	2.05%	1.03%	2.56%
			ADTT ≥ 5000	90.77%	1.03%	1.54%	1.54%	1.54%	3.59%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	87.76%	0.00%	4.08%	0.00%	0.00%	8.16%
			ADTT = 1000	83.67%	2.04%	2.04%	4.08%	0.00%	8.16%
			ADTT ≥ 5000	83.67%	0.00%	2.04%	2.04%	4.08%	8.16%

Table 62: NM-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NM-04	Moment	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	97.97%	0.00%	0.68%	0.68%	0.00%	0.68%
			ADTT = 1000	96.62%	1.35%	0.00%	0.68%	0.68%	0.68%
			ADTT ≥ 5000	95.95%	0.68%	1.35%	0.00%	0.68%	1.35%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	69.23%	7.69%	11.54%	7.69%	3.85%	0.00%
			ADTT = 1000	61.54%	7.69%	7.69%	11.54%	7.69%	3.85%
			ADTT ≥ 5000	53.85%	7.69%	7.69%	7.69%	15.38%	7.69%
		Interior Composite	LFR	98.97%	1.03%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	98.97%	0.51%	0.00%	0.00%	0.00%	0.51%
			ADTT = 1000	98.97%	0.00%	0.51%	0.00%	0.00%	0.51%
			ADTT ≥ 5000	98.46%	0.51%	0.00%	0.51%	0.00%	0.51%
		Interior Non-Composite	LFR	97.96%	2.04%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	87.76%	2.04%	6.12%	4.08%	0.00%	0.00%
			ADTT = 1000	83.67%	2.04%	4.08%	6.12%	4.08%	0.00%
			ADTT ≥ 5000	77.55%	6.12%	2.04%	4.08%	6.12%	4.08%
NM-04	Shear	Exterior Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.95%	0.00%	0.00%	1.35%	0.00%	2.70%
			ADTT = 1000	95.95%	0.00%	0.00%	0.00%	1.35%	2.70%
			ADTT ≥ 5000	94.59%	1.35%	0.00%	0.00%	0.68%	3.38%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	88.46%	0.00%	0.00%	0.00%	3.85%	7.69%
			ADTT = 1000	88.46%	0.00%	0.00%	0.00%	0.00%	11.54%
			ADTT ≥ 5000	84.62%	3.85%	0.00%	0.00%	0.00%	11.54%
		Interior Composite	LFR	99.49%	0.51%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.38%	1.03%	1.03%	0.51%	0.51%	1.54%
			ADTT = 1000	93.85%	1.03%	1.54%	1.03%	0.51%	2.05%
			ADTT ≥ 5000	91.79%	1.54%	1.54%	1.54%	1.03%	2.56%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	87.76%	4.08%	0.00%	0.00%	0.00%	8.16%
			ADTT = 1000	85.71%	2.04%	4.08%	0.00%	0.00%	8.16%
			ADTT ≥ 5000	83.67%	2.04%	2.04%	4.08%	0.00%	8.16%

Table 63: TX-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
TX-04	Moment	Exterior Composite	LFR	96.62%	2.70%	0.68%	0.00%	0.00%	0.00%
			ADTT ≤ 100	95.27%	0.68%	1.35%	0.68%	0.00%	2.03%
			ADTT = 1000	94.59%	0.68%	0.68%	1.35%	0.68%	2.03%
			ADTT ≥ 5000	89.86%	4.05%	1.35%	0.68%	1.35%	2.70%
		Exterior Non-Composite	LFR	73.08%	15.38%	7.69%	3.85%	0.00%	0.00%
			ADTT ≤ 100	53.85%	7.69%	7.69%	7.69%	7.69%	15.38%
			ADTT = 1000	50.00%	3.85%	7.69%	7.69%	7.69%	23.08%
			ADTT ≥ 5000	38.46%	11.54%	3.85%	7.69%	7.69%	30.77%
		Interior Composite	LFR	96.92%	1.54%	0.51%	1.03%	0.00%	0.00%
			ADTT ≤ 100	98.46%	0.51%	0.00%	0.51%	0.00%	0.51%
			ADTT = 1000	96.92%	1.54%	0.51%	0.00%	0.51%	0.51%
			ADTT ≥ 5000	94.36%	2.05%	2.05%	0.51%	0.51%	0.51%
		Interior Non-Composite	LFR	87.76%	6.12%	2.04%	2.04%	2.04%	0.00%
			ADTT ≤ 100	77.55%	6.12%	0.00%	4.08%	6.12%	6.12%
			ADTT = 1000	73.47%	4.08%	6.12%	0.00%	6.12%	10.20%
			ADTT ≥ 5000	44.90%	22.45%	10.20%	6.12%	2.04%	14.29%
TX-04	Shear	Exterior Composite	LFR	97.97%	0.00%	2.03%	0.00%	0.00%	0.00%
			ADTT ≤ 100	93.92%	2.03%	0.00%	0.00%	0.00%	4.05%
			ADTT = 1000	93.24%	0.68%	2.03%	0.00%	0.00%	4.05%
			ADTT ≥ 5000	90.54%	2.03%	1.35%	2.03%	0.00%	4.05%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	84.62%	3.85%	0.00%	0.00%	0.00%	11.54%
			ADTT = 1000	73.08%	11.54%	3.85%	0.00%	0.00%	11.54%
			ADTT ≥ 5000	65.38%	7.69%	11.54%	3.85%	0.00%	11.54%
		Interior Composite	LFR	98.97%	0.00%	0.51%	0.51%	0.00%	0.00%
			ADTT ≤ 100	91.79%	1.54%	1.54%	1.54%	1.03%	2.56%
			ADTT = 1000	89.23%	2.56%	1.54%	1.54%	1.54%	3.59%
			ADTT ≥ 5000	88.21%	0.51%	3.08%	1.54%	2.56%	4.10%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	83.67%	2.04%	2.04%	4.08%	0.00%	8.16%
			ADTT = 1000	81.63%	2.04%	2.04%	2.04%	4.08%	8.16%
			ADTT ≥ 5000	77.55%	2.04%	4.08%	2.04%	2.04%	12.24%

K.6.3 Special Permit Vehicles

Table 64 through Table 66 provide the results for the three vehicles assumed to be special permits: IL-01, OR-06, and WA-02.

Table 64: IL-01 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
IL-01	Moment	Exterior Composite	LFR	93.92%	2.03%	2.70%	0.68%	0.68%	0.00%
			Single Escorted	95.27%	0.68%	1.35%	0.68%	0.00%	2.03%
			Single ADTT ≤ 100	94.59%	0.00%	1.35%	1.35%	0.68%	2.03%
			Single ADTT = 1000	94.59%	0.00%	1.35%	0.00%	2.03%	2.03%
			Single ADTT ≥ 5000	93.24%	1.35%	0.00%	1.35%	1.35%	2.70%
			Multiple ADTT ≤ 100	92.57%	2.03%	0.00%	1.35%	1.35%	2.70%
			Multiple ADTT = 1000	83.11%	8.78%	2.70%	0.00%	1.35%	4.05%
			Multiple ADTT ≥ 5000	79.73%	6.08%	7.43%	1.35%	1.35%	4.05%
		Exterior Non-Composite	LFR	61.54%	0.00%	23.08%	11.54%	3.85%	0.00%
			Single Escorted	61.54%	7.69%	7.69%	15.38%	3.85%	3.85%
			Single ADTT ≤ 100	57.69%	3.85%	7.69%	3.85%	19.23%	7.69%
			Single ADTT = 1000	57.69%	3.85%	3.85%	3.85%	15.38%	15.38%
			Single ADTT ≥ 5000	50.00%	7.69%	3.85%	7.69%	11.54%	19.23%
			Multiple ADTT ≤ 100	50.00%	7.69%	3.85%	7.69%	3.85%	26.92%
			Multiple ADTT = 1000	38.46%	7.69%	11.54%	3.85%	7.69%	30.77%
			Multiple ADTT ≥ 5000	34.62%	11.54%	3.85%	7.69%	7.69%	34.62%
		Interior Composite	LFR	91.28%	3.08%	3.08%	1.03%	0.51%	1.03%
			Single Escorted	98.97%	0.00%	0.00%	0.00%	0.00%	1.03%
			Single ADTT ≤ 100	97.95%	0.00%	1.03%	0.00%	0.00%	1.03%
			Single ADTT = 1000	96.92%	1.03%	1.03%	0.00%	0.00%	1.03%
			Single ADTT ≥ 5000	95.90%	2.05%	0.00%	1.03%	0.00%	1.03%
			Multiple ADTT ≤ 100	94.87%	2.05%	1.03%	1.03%	0.00%	1.03%
			Multiple ADTT = 1000	94.36%	0.51%	2.05%	1.03%	1.03%	1.03%
			Multiple ADTT ≥ 5000	92.31%	2.05%	1.54%	2.05%	1.03%	1.03%
		Interior Non-Composite	LFR	83.67%	4.08%	4.08%	4.08%	4.08%	0.00%
			Single Escorted	89.80%	4.08%	2.04%	4.08%	0.00%	0.00%
			Single ADTT ≤ 100	83.67%	4.08%	4.08%	4.08%	4.08%	0.00%
			Single ADTT = 1000	79.59%	8.16%	4.08%	4.08%	2.04%	2.04%
			Single ADTT ≥ 5000	77.55%	6.12%	6.12%	2.04%	6.12%	2.04%
			Multiple ADTT ≤ 100	73.47%	6.12%	8.16%	4.08%	4.08%	4.08%
			Multiple ADTT = 1000	63.27%	10.20%	6.12%	8.16%	4.08%	8.16%
			Multiple ADTT ≥ 5000	57.14%	12.24%	8.16%	10.20%	4.08%	8.16%
IL-01	Shear	Exterior Composite	LFR	95.95%	2.03%	0.00%	0.00%	0.00%	2.03%
			Single Escorted	93.92%	1.35%	0.68%	0.68%	0.00%	3.38%
			Single ADTT ≤ 100	91.89%	0.68%	2.70%	0.68%	0.68%	3.38%
			Single ADTT = 1000	91.89%	0.00%	2.03%	2.03%	0.68%	3.38%
			Single ADTT ≥ 5000	91.22%	0.68%	0.68%	2.70%	0.68%	4.05%
			Multiple ADTT ≤ 100	91.22%	0.68%	0.68%	2.70%	0.68%	4.05%
			Multiple ADTT = 1000	88.51%	2.70%	0.68%	0.68%	2.70%	4.73%
			Multiple ADTT ≥ 5000	86.49%	3.38%	1.35%	0.68%	2.03%	6.08%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	88.46%	0.00%	0.00%	0.00%	0.00%	11.54%
			Single ADTT ≤ 100	69.23%	11.54%	7.69%	0.00%	0.00%	11.54%
			Single ADTT = 1000	69.23%	7.69%	11.54%	0.00%	0.00%	11.54%
			Single ADTT ≥ 5000	65.38%	3.85%	15.38%	3.85%	0.00%	11.54%
			Multiple ADTT ≤ 100	61.54%	7.69%	11.54%	7.69%	0.00%	11.54%
			Multiple ADTT = 1000	57.69%	0.00%	11.54%	11.54%	7.69%	11.54%
			Multiple ADTT ≥ 5000	53.85%	3.85%	7.69%	7.69%	15.38%	11.54%
		Interior Composite	LFR	95.90%	1.03%	0.00%	0.51%	1.54%	1.03%
			Single Escorted	93.33%	0.51%	1.03%	2.05%	1.03%	2.05%
			Single ADTT ≤ 100	89.74%	2.56%	1.54%	1.03%	2.05%	3.08%
			Single ADTT = 1000	89.74%	2.05%	1.54%	1.54%	1.03%	4.10%
			Single ADTT ≥ 5000	87.69%	2.05%	2.56%	1.54%	1.03%	5.13%
			Multiple ADTT ≤ 100	86.67%	3.08%	2.05%	2.05%	1.03%	5.13%
			Multiple ADTT = 1000	85.13%	1.54%	3.08%	2.05%	2.05%	6.15%
			Multiple ADTT ≥ 5000	83.08%	3.08%	2.05%	3.08%	2.56%	6.15%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	83.67%	2.04%	4.08%	0.00%	2.04%	8.16%
			Single ADTT ≤ 100	81.63%	2.04%	2.04%	2.04%	2.04%	10.20%
			Single ADTT = 1000	79.59%	4.08%	0.00%	4.08%	2.04%	10.20%
			Single ADTT ≥ 5000	77.55%	4.08%	2.04%	2.04%	4.08%	10.20%
			Multiple ADTT ≤ 100	77.55%	2.04%	4.08%	2.04%	4.08%	10.20%
			Multiple ADTT = 1000	77.55%	0.00%	2.04%	4.08%	2.04%	14.29%
			Multiple ADTT ≥ 5000	75.51%	2.04%	0.00%	4.08%	4.08%	14.29%

Table 65: OR-06 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
OR-06	Moment	Exterior Composite	LFR	95.27%	0.00%	2.03%	0.00%	2.70%	0.00%
			Single Escorted	95.27%	1.35%	0.00%	0.68%	1.35%	1.35%
			Single ADTT ≤ 100	94.59%	0.00%	1.35%	0.68%	0.68%	2.70%
			Single ADTT = 1000	93.24%	1.35%	0.68%	1.35%	0.68%	2.70%
			Single ADTT ≥ 5000	91.89%	2.70%	0.00%	2.03%	0.68%	2.70%
			Multiple ADTT ≤ 100	87.84%	5.41%	1.35%	1.35%	0.68%	3.38%
			Multiple ADTT = 1000	77.03%	10.81%	5.41%	1.35%	2.03%	3.38%
			Multiple ADTT ≥ 5000	70.27%	12.84%	8.78%	2.70%	1.35%	4.05%
		Exterior Non-Composite	LFR	57.69%	7.69%	11.54%	19.23%	3.85%	0.00%
			Single Escorted	61.54%	3.85%	3.85%	23.08%	7.69%	0.00%
			Single ADTT ≤ 100	57.69%	3.85%	0.00%	7.69%	23.08%	7.69%
			Single ADTT = 1000	50.00%	7.69%	3.85%	7.69%	19.23%	11.54%
			Single ADTT ≥ 5000	42.31%	15.38%	3.85%	3.85%	7.69%	26.92%
			Multiple ADTT ≤ 100	42.31%	7.69%	7.69%	3.85%	7.69%	30.77%
			Multiple ADTT = 1000	15.38%	26.92%	7.69%	11.54%	3.85%	34.62%
			Multiple ADTT ≥ 5000	7.69%	26.92%	11.54%	11.54%	3.85%	38.46%
		Interior Composite	LFR	90.77%	2.05%	3.08%	2.56%	0.51%	1.03%
			Single Escorted	96.92%	1.03%	1.03%	0.51%	0.00%	0.51%
			Single ADTT ≤ 100	95.90%	1.03%	1.03%	1.03%	0.51%	0.51%
			Single ADTT = 1000	95.90%	1.03%	0.00%	2.05%	0.51%	0.51%
			Single ADTT ≥ 5000	93.85%	2.05%	1.03%	1.03%	1.03%	1.03%
			Multiple ADTT ≤ 100	93.85%	2.05%	1.03%	1.03%	1.03%	1.03%
			Multiple ADTT = 1000	92.31%	1.54%	2.05%	1.03%	1.03%	2.05%
			Multiple ADTT ≥ 5000	89.23%	4.10%	1.03%	2.56%	0.00%	3.08%
		Interior Non-Composite	LFR	81.63%	2.04%	2.04%	6.12%	6.12%	2.04%
			Single Escorted	83.67%	6.12%	4.08%	6.12%	0.00%	0.00%
			Single ADTT ≤ 100	83.67%	0.00%	2.04%	8.16%	6.12%	0.00%
			Single ADTT = 1000	81.63%	2.04%	0.00%	8.16%	8.16%	0.00%
			Single ADTT ≥ 5000	73.47%	10.20%	0.00%	2.04%	10.20%	4.08%
			Multiple ADTT ≤ 100	67.35%	14.29%	2.04%	2.04%	8.16%	6.12%
			Multiple ADTT = 1000	48.98%	16.33%	16.33%	2.04%	2.04%	14.29%
			Multiple ADTT ≥ 5000	30.61%	28.57%	20.41%	4.08%	0.00%	16.33%
OR-06	Shear	Exterior Composite	LFR	95.95%	0.00%	1.35%	0.68%	0.00%	2.03%
			Single Escorted	91.89%	2.70%	0.68%	0.68%	1.35%	2.70%
			Single ADTT ≤ 100	91.22%	0.68%	1.35%	2.03%	0.68%	4.05%
			Single ADTT = 1000	91.22%	0.68%	0.68%	2.70%	0.68%	4.05%
			Single ADTT ≥ 5000	90.54%	0.68%	0.68%	2.70%	1.35%	4.05%
			Multiple ADTT ≤ 100	89.86%	1.35%	0.68%	1.35%	2.03%	4.73%
			Multiple ADTT = 1000	85.81%	4.05%	1.35%	0.68%	2.70%	5.41%
			Multiple ADTT ≥ 5000	83.11%	5.41%	2.03%	1.35%	1.35%	6.76%
		Exterior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	80.77%	3.85%	3.85%	0.00%	0.00%	11.54%
			Single ADTT ≤ 100	73.08%	0.00%	11.54%	3.85%	0.00%	11.54%
			Single ADTT = 1000	65.38%	7.69%	7.69%	7.69%	0.00%	11.54%
			Single ADTT ≥ 5000	57.69%	15.38%	3.85%	7.69%	3.85%	11.54%
			Multiple ADTT ≤ 100	57.69%	7.69%	7.69%	11.54%	3.85%	11.54%
			Multiple ADTT = 1000	53.85%	3.85%	7.69%	7.69%	11.54%	15.38%
			Multiple ADTT ≥ 5000	53.85%	0.00%	3.85%	15.38%	7.69%	19.23%
		Interior Composite	LFR	94.36%	2.05%	0.51%	0.00%	1.03%	2.05%
			Single Escorted	92.31%	0.51%	1.03%	2.05%	1.03%	3.08%
			Single ADTT ≤ 100	89.74%	0.51%	2.56%	1.03%	2.05%	4.10%
			Single ADTT = 1000	88.72%	1.03%	2.56%	1.03%	2.05%	4.62%
			Single ADTT ≥ 5000	86.67%	3.08%	1.03%	2.05%	1.54%	5.64%
			Multiple ADTT ≤ 100	86.67%	2.05%	1.03%	3.08%	1.03%	6.15%
			Multiple ADTT = 1000	83.08%	3.59%	2.05%	1.54%	2.56%	7.18%
			Multiple ADTT ≥ 5000	82.56%	2.56%	2.05%	2.56%	2.56%	7.69%
		Interior Non-Composite	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	81.63%	2.04%	2.04%	4.08%	2.04%	8.16%
			Single ADTT ≤ 100	79.59%	2.04%	2.04%	2.04%	4.08%	10.20%
			Single ADTT = 1000	79.59%	0.00%	4.08%	2.04%	4.08%	10.20%
			Single ADTT ≥ 5000	77.55%	2.04%	2.04%	2.04%	4.08%	12.24%
			Multiple ADTT ≤ 100	77.55%	2.04%	0.00%	4.08%	2.04%	14.29%
			Multiple ADTT = 1000	73.47%	4.08%	2.04%	2.04%	2.04%	16.33%
			Multiple ADTT ≥ 5000	73.47%	2.04%	2.04%	2.04%	4.08%	16.33%

Table 66: WA-02 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
WA-02	Moment	Exterior Composite	LFR	77.03%	5.41%	6.76%	6.08%	0.68%	4.05%
			Single Escorted	87.16%	6.08%	1.35%	0.68%	0.68%	4.05%
			Single ADTT ≤ 100	70.27%	14.19%	7.43%	2.70%	0.68%	4.73%
			Single ADTT = 1000	66.89%	12.16%	8.78%	6.08%	1.35%	4.73%
			Single ADTT ≥ 5000	64.19%	6.08%	14.86%	7.43%	2.03%	5.41%
			Multiple ADTT ≤ 100	62.16%	4.73%	13.51%	10.14%	4.05%	5.41%
			Multiple ADTT = 1000	52.03%	8.11%	6.76%	16.89%	8.78%	7.43%
			Multiple ADTT ≥ 5000	48.65%	7.43%	8.11%	12.16%	12.84%	10.81%
		Exterior Non-Composite	LFR	50.00%	3.85%	3.85%	3.85%	7.69%	30.77%
			Single Escorted	42.31%	11.54%	7.69%	0.00%	15.38%	23.08%
			Single ADTT ≤ 100	26.92%	11.54%	11.54%	11.54%	0.00%	38.46%
			Single ADTT = 1000	19.23%	19.23%	7.69%	15.38%	0.00%	38.46%
			Single ADTT ≥ 5000	3.85%	23.08%	15.38%	11.54%	7.69%	38.46%
			Multiple ADTT ≤ 100	3.85%	19.23%	15.38%	11.54%	11.54%	38.46%
			Multiple ADTT = 1000	3.85%	0.00%	15.38%	19.23%	15.38%	46.15%
			Multiple ADTT ≥ 5000	3.85%	0.00%	0.00%	34.62%	7.69%	53.85%
		Interior Composite	LFR	67.18%	10.26%	9.23%	5.13%	5.13%	3.08%
			Single Escorted	95.38%	0.51%	0.51%	1.54%	1.03%	1.03%
			Single ADTT ≤ 100	89.23%	4.10%	2.05%	1.03%	1.54%	2.05%
			Single ADTT = 1000	88.72%	4.62%	2.05%	1.03%	1.54%	2.05%
			Single ADTT ≥ 5000	84.62%	4.62%	5.13%	1.03%	1.54%	3.08%
			Multiple ADTT ≤ 100	81.03%	7.69%	4.62%	2.05%	1.03%	3.59%
			Multiple ADTT = 1000	69.74%	9.23%	9.74%	4.62%	2.05%	4.62%
			Multiple ADTT ≥ 5000	64.10%	10.26%	10.77%	6.15%	4.10%	4.62%
		Interior Non-Composite	LFR	38.78%	20.41%	14.29%	8.16%	6.12%	12.24%
			Single Escorted	73.47%	6.12%	8.16%	8.16%	4.08%	0.00%
			Single ADTT ≤ 100	46.94%	20.41%	6.12%	12.24%	10.20%	4.08%
			Single ADTT = 1000	38.78%	24.49%	10.20%	12.24%	8.16%	6.12%
			Single ADTT ≥ 5000	30.61%	16.33%	22.45%	10.20%	8.16%	12.24%
			Multiple ADTT ≤ 100	22.45%	18.37%	26.53%	6.12%	12.24%	14.29%
			Multiple ADTT = 1000	10.20%	12.24%	16.33%	28.57%	12.24%	20.41%
			Multiple ADTT ≥ 5000	10.20%	2.04%	18.37%	20.41%	22.45%	26.53%
WA-02	Shear	Exterior Composite	LFR	88.51%	2.70%	4.05%	0.68%	0.68%	3.38%
			Single Escorted	89.19%	1.35%	1.35%	0.00%	4.05%	4.05%
			Single ADTT ≤ 100	79.73%	7.43%	3.38%	1.35%	0.00%	8.11%
			Single ADTT = 1000	77.03%	6.08%	6.76%	1.35%	0.68%	8.11%
			Single ADTT ≥ 5000	74.32%	5.41%	8.11%	2.70%	1.35%	8.11%
			Multiple ADTT ≤ 100	73.65%	3.38%	7.43%	6.08%	1.35%	8.11%
			Multiple ADTT = 1000	70.95%	2.70%	3.38%	8.11%	5.41%	9.46%
			Multiple ADTT ≥ 5000	66.89%	6.08%	1.35%	8.78%	6.76%	10.14%
		Exterior Non-Composite	LFR	92.31%	3.85%	3.85%	0.00%	0.00%	0.00%
			Single Escorted	57.69%	3.85%	11.54%	7.69%	7.69%	11.54%
			Single ADTT ≤ 100	53.85%	0.00%	3.85%	15.38%	7.69%	19.23%
			Single ADTT = 1000	53.85%	0.00%	3.85%	7.69%	7.69%	26.92%
			Single ADTT ≥ 5000	53.85%	0.00%	0.00%	3.85%	15.38%	26.92%
			Multiple ADTT ≤ 100	53.85%	0.00%	0.00%	3.85%	15.38%	26.92%
			Multiple ADTT = 1000	50.00%	3.85%	0.00%	0.00%	3.85%	42.31%
			Multiple ADTT ≥ 5000	50.00%	3.85%	0.00%	0.00%	3.85%	42.31%
		Interior Composite	LFR	87.18%	3.08%	2.05%	3.59%	1.03%	3.08%
			Single Escorted	86.67%	0.51%	2.56%	2.56%	1.54%	6.15%
			Single ADTT ≤ 100	81.54%	4.10%	1.03%	3.08%	2.56%	7.69%
			Single ADTT = 1000	80.51%	3.08%	3.08%	2.56%	1.54%	9.23%
			Single ADTT ≥ 5000	77.95%	3.59%	4.62%	0.51%	3.08%	10.26%
			Multiple ADTT ≤ 100	75.38%	5.13%	4.10%	2.05%	3.08%	10.26%
			Multiple ADTT = 1000	68.72%	6.15%	5.64%	4.10%	2.05%	13.33%
			Multiple ADTT ≥ 5000	67.18%	4.62%	6.67%	4.10%	4.10%	13.33%
		Interior Non-Composite	LFR	97.96%	0.00%	0.00%	2.04%	0.00%	0.00%
			Single Escorted	77.55%	0.00%	2.04%	2.04%	2.04%	16.33%
			Single ADTT ≤ 100	73.47%	0.00%	4.08%	2.04%	2.04%	18.37%
			Single ADTT = 1000	73.47%	0.00%	4.08%	2.04%	2.04%	18.37%
			Single ADTT ≥ 5000	73.47%	0.00%	0.00%	4.08%	2.04%	20.41%
			Multiple ADTT ≤ 100	73.47%	0.00%	0.00%	4.08%	2.04%	20.41%
			Multiple ADTT = 1000	73.47%	0.00%	0.00%	0.00%	4.08%	22.45%
			Multiple ADTT ≥ 5000	71.43%	2.04%	0.00%	0.00%	4.08%	22.45%

K.7 Continuous Span Reinforced Concrete Slab Bridges

The tables in the following sections contain the percentage of slabs in each rating category for the 105 continuous reinforced concrete slabs analyzed. For flexure,

significantly fewer concrete slabs have LRFR ratings greater than 1.0 than LFR ratings greater than 1.0, even when an ADTT of less than 100 is considered. For shear, the percentage of girders with ratings greater than 1.0 is similar for both LFR and LRFR with an ADTT less than 100, with LRFR typically having more girders with ratings less than 1.0. As the ADTT and permit type changes, significantly more girders have an LRFR rating less than 1.0 than an LFR rating less than 1.0. The percentage of girders with passing ratings decreases with increasing ADTT as expected due to the increase in the load factor for live load.

K.7.1 AASHTO Legal Vehicles

Table 67 through Table 69 provide the distribution of rating factors for the three AASHTO Legal vehicles: Type 3, Type 3-3, and Type 3S2.

Table 67: AASHTO Type 3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3	Moment	LFR	92.38%	0.00%	0.00%	0.95%	0.00%	6.67%
		ADTT ≤ 100	71.43%	6.67%	1.90%	3.81%	2.86%	13.33%
		ADTT = 1000	51.43%	12.38%	10.48%	4.76%	3.81%	17.14%
		ADTT ≥ 5000	40.00%	11.43%	18.10%	8.57%	2.86%	19.05%
AASHTO TYPE 3	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	99.05%	0.00%	0.00%	0.00%	0.00%	0.95%
		ADTT = 1000	95.24%	2.86%	0.95%	0.00%	0.00%	0.95%
		ADTT ≥ 5000	95.24%	0.95%	1.90%	0.95%	0.00%	0.95%

Table 68: AASHTO Type 3-3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3-3	Moment	LFR	92.38%	0.00%	0.95%	0.00%	0.95%	5.71%
		ADTT ≤ 100	71.43%	5.71%	6.67%	4.76%	2.86%	8.57%
		ADTT = 1000	60.00%	9.52%	5.71%	7.62%	5.71%	11.43%
		ADTT ≥ 5000	46.67%	13.33%	9.52%	7.62%	8.57%	14.29%
AASHTO TYPE 3-3	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	99.05%	0.00%	0.95%	0.00%	0.00%	0.00%
		ADTT = 1000	99.05%	0.00%	0.00%	0.95%	0.00%	0.00%
		ADTT ≥ 5000	99.05%	0.00%	0.00%	0.00%	0.95%	0.00%

Table 69: AASHTO Type 3S2 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3S2	Moment	LFR	91.43%	0.95%	0.00%	0.00%	0.95%	6.67%
		ADTT ≤ 100	61.90%	6.67%	5.71%	7.62%	6.67%	11.43%
		ADTT = 1000	32.38%	20.95%	10.48%	10.48%	7.62%	18.10%
		ADTT ≥ 5000	29.52%	3.81%	26.67%	8.57%	9.52%	21.90%
AASHTO TYPE 3S2	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	97.14%	1.90%	0.00%	0.00%	0.95%	0.00%
		ADTT = 1000	95.24%	0.95%	1.90%	0.95%	0.00%	0.95%
		ADTT ≥ 5000	95.24%	0.00%	1.90%	1.90%	0.00%	0.95%

K.7.2 Routine Permit Vehicles

Table 70 through Table 74 provide the distribution of rating factors for the five vehicles considered to be routine permits: DE-07, FL-04, NC-21, NM-04, and TX-04.

Table 70: DE-07 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
DE-07	Moment	LFR	86.67%	4.76%	0.95%	0.00%	0.00%	7.62%
		ADTT ≤ 100	35.24%	20.95%	11.43%	6.67%	6.67%	19.05%
		ADTT = 1000	33.33%	20.00%	13.33%	7.62%	6.67%	19.05%
		ADTT ≥ 5000	32.38%	20.00%	12.38%	9.52%	6.67%	19.05%
DE-07	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	93.33%	1.90%	0.95%	1.90%	0.95%	0.95%
		ADTT = 1000	92.38%	0.95%	1.90%	0.95%	1.90%	1.90%
		ADTT ≥ 5000	87.62%	3.81%	1.90%	1.90%	0.95%	3.81%

Table 71: FL-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
FL-04	Moment	LFR	91.43%	0.95%	0.00%	0.95%	0.00%	6.67%
		ADTT ≤ 100	60.00%	10.48%	4.76%	5.71%	6.67%	12.38%
		ADTT = 1000	57.14%	12.38%	5.71%	5.71%	6.67%	12.38%
		ADTT ≥ 5000	56.19%	11.43%	6.67%	6.67%	6.67%	12.38%
FL-04	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	95.24%	2.86%	0.95%	0.00%	0.00%	0.95%
		ADTT = 1000	94.29%	0.95%	1.90%	1.90%	0.00%	0.95%
		ADTT ≥ 5000	91.43%	2.86%	0.95%	2.86%	0.95%	0.95%

Table 72: NC-21 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NC-21	Moment	LFR	87.62%	1.90%	0.95%	1.90%	0.95%	6.67%
		ADTT ≤ 100	44.76%	5.71%	18.10%	9.52%	1.90%	20.00%
		ADTT = 1000	41.90%	7.62%	18.10%	9.52%	2.86%	20.00%
		ADTT ≥ 5000	41.90%	5.71%	19.05%	9.52%	2.86%	20.95%
NC-21	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	94.29%	0.95%	0.95%	2.86%	0.00%	0.95%
		ADTT = 1000	90.48%	3.81%	0.95%	0.95%	2.86%	0.95%
		ADTT ≥ 5000	88.57%	1.90%	3.81%	0.95%	1.90%	2.86%

Table 73: NM-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NM-04	Moment	LFR	91.43%	0.95%	0.95%	0.00%	0.00%	6.67%
		ADTT ≤ 100	65.71%	8.57%	3.81%	4.76%	3.81%	13.33%
		ADTT = 1000	63.81%	10.48%	3.81%	4.76%	3.81%	13.33%
		ADTT ≥ 5000	62.86%	9.52%	5.71%	4.76%	3.81%	13.33%
NM-04	Shear	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
		ADTT ≤ 100	99.05%	0.00%	0.00%	0.00%	0.95%	0.00%
		ADTT = 1000	95.24%	2.86%	0.95%	0.00%	0.00%	0.95%
		ADTT ≥ 5000	95.24%	0.00%	2.86%	0.95%	0.00%	0.95%

Table 74: TX-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
TX-04	Moment	LFR	80.95%	4.76%	4.76%	1.90%	0.00%	7.62%
		ADTT ≤ 100	33.33%	5.71%	14.29%	20.00%	4.76%	21.90%
		ADTT = 1000	32.38%	6.67%	12.38%	20.00%	6.67%	21.90%
		ADTT ≥ 5000	32.38%	5.71%	13.33%	18.10%	6.67%	23.81%
TX-04	Shear	LFR	97.14%	1.90%	0.95%	0.00%	0.00%	0.00%
		ADTT ≤ 100	89.52%	0.95%	3.81%	0.95%	1.90%	2.86%
		ADTT = 1000	79.05%	9.52%	1.90%	3.81%	0.95%	4.76%
		ADTT ≥ 5000	60.00%	18.10%	10.48%	1.90%	4.76%	4.76%

K.7.3 Special Permit Vehicles

Table 75 through Table 77 provide the results for the three vehicles assumed to be special permits: IL-01, OR-06, and WA-02.

Table 75: IL-01 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
IL-01	Moment	LFR	61.90%	7.62%	8.57%	10.48%	2.86%	8.57%
		Single Escorted	17.14%	4.76%	7.62%	8.57%	23.81%	38.10%
		Single ADTT ≤ 100	16.19%	4.76%	6.67%	8.57%	25.71%	38.10%
		Single ADTT = 1000	16.19%	4.76%	6.67%	7.62%	26.67%	38.10%
		Single ADTT ≥ 5000	16.19%	3.81%	7.62%	6.67%	26.67%	39.05%
		Multiple ADTT ≤ 100	16.19%	3.81%	7.62%	6.67%	25.71%	40.00%
		Multiple ADTT = 1000	16.19%	3.81%	6.67%	7.62%	23.81%	41.90%
		Multiple ADTT ≥ 5000	16.19%	3.81%	6.67%	6.67%	24.76%	41.90%
IL-01	Shear	LFR	97.14%	1.90%	0.95%	0.00%	0.00%	0.00%
		Single Escorted	87.62%	2.86%	1.90%	2.86%	0.95%	3.81%
		Single ADTT ≤ 100	67.62%	12.38%	10.48%	1.90%	2.86%	4.76%
		Single ADTT = 1000	67.62%	8.57%	12.38%	3.81%	1.90%	5.71%
		Single ADTT ≥ 5000	59.05%	8.57%	15.24%	7.62%	2.86%	6.67%
		Multiple ADTT ≤ 100	57.14%	10.48%	11.43%	10.48%	2.86%	7.62%
		Multiple ADTT = 1000	44.76%	8.57%	14.29%	12.38%	10.48%	9.52%
		Multiple ADTT ≥ 5000	37.14%	9.52%	14.29%	10.48%	18.10%	10.48%

Table 76: OR-06 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
OR-06	Moment	LFR	67.62%	7.62%	7.62%	4.76%	4.76%	7.62%
		Single Escorted	20.00%	2.86%	15.24%	10.48%	16.19%	35.24%
		Single ADTT ≤ 100	19.05%	2.86%	12.38%	13.33%	17.14%	35.24%
		Single ADTT = 1000	19.05%	2.86%	12.38%	12.38%	18.10%	35.24%
		Single ADTT ≥ 5000	19.05%	1.90%	13.33%	11.43%	19.05%	35.24%
		Multiple ADTT ≤ 100	19.05%	1.90%	13.33%	10.48%	19.05%	36.19%
		Multiple ADTT = 1000	19.05%	1.90%	12.38%	11.43%	17.14%	38.10%
		Multiple ADTT ≥ 5000	19.05%	1.90%	12.38%	10.48%	17.14%	39.05%
OR-06	Shear	LFR	97.14%	0.95%	1.90%	0.00%	0.00%	0.00%
		Single Escorted	81.90%	8.57%	1.90%	0.95%	3.81%	2.86%
		Single ADTT ≤ 100	71.43%	5.71%	11.43%	3.81%	0.95%	6.67%
		Single ADTT = 1000	65.71%	8.57%	11.43%	5.71%	0.95%	7.62%
		Single ADTT ≥ 5000	55.24%	16.19%	6.67%	11.43%	2.86%	7.62%
		Multiple ADTT ≤ 100	54.29%	11.43%	8.57%	14.29%	3.81%	7.62%
		Multiple ADTT = 1000	37.14%	16.19%	12.38%	9.52%	14.29%	10.48%
		Multiple ADTT ≥ 5000	32.38%	12.38%	13.33%	16.19%	13.33%	12.38%

Table 77: WA-02 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
WA-02	Moment	LFR	44.76%	15.24%	10.48%	11.43%	5.71%	12.38%
		Single Escorted	7.62%	3.81%	10.48%	3.81%	12.38%	61.90%
		Single ADTT ≤ 100	7.62%	2.86%	10.48%	3.81%	11.43%	63.81%
		Single ADTT = 1000	7.62%	2.86%	9.52%	4.76%	11.43%	63.81%
		Single ADTT ≥ 5000	7.62%	2.86%	9.52%	3.81%	11.43%	64.76%
		Multiple ADTT ≤ 100	7.62%	2.86%	9.52%	3.81%	11.43%	64.76%
		Multiple ADTT = 1000	7.62%	2.86%	9.52%	2.86%	11.43%	65.71%
		Multiple ADTT ≥ 5000	7.62%	2.86%	9.52%	2.86%	10.48%	66.67%
WA-02	Shear	LFR	91.43%	5.71%	1.90%	0.95%	0.00%	0.00%
		Single Escorted	59.05%	11.43%	10.48%	8.57%	3.81%	6.67%
		Single ADTT ≤ 100	38.10%	14.29%	14.29%	10.48%	12.38%	10.48%
		Single ADTT = 1000	35.24%	13.33%	13.33%	14.29%	11.43%	12.38%
		Single ADTT ≥ 5000	22.86%	15.24%	15.24%	17.14%	13.33%	16.19%
		Multiple ADTT ≤ 100	21.90%	14.29%	15.24%	14.29%	12.38%	21.90%
		Multiple ADTT = 1000	7.62%	13.33%	14.29%	17.14%	18.10%	29.52%
		Multiple ADTT ≥ 5000	5.71%	4.76%	15.24%	20.00%	16.19%	38.10%

K.8 Continuous Span Prestressed Concrete I-Girder Bridges

The tables in the following sections contain the percentage of girders in each rating category for the 238 continuous prestressed concrete I-girders analyzed. For flexure, interior girders typically had more girders with ratings above 1.0 than exterior girders for all types of vehicles. The same typically is true for shear with the exception of several cases. The percentage of girders passing an LRFR rating as significantly lower than the percentage of girders passing the LFR rating, even when considering the lowest ADTT category. The low percentage of girders with LRFR ratings greater than 1.0 is due to considering the effect of shear on the longitudinal steel reinforcement. The percentage of girders with passing ratings decreases with increasing ADTT as expected due to the increase in the load factor for live load.

K.8.1 AASHTO Legal Vehicles

Table 78 through Table 80 provide the distribution of rating factors for the three AASHTO Legal vehicles: Type 3, Type 3-3, and Type 3S2.

Table 78: AASHTO Type 3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	30.61%	4.08%	12.24%	2.04%	4.08%	46.94%
			ADTT = 1000	22.45%	4.08%	6.12%	12.24%	4.08%	51.02%
			ADTT ≥ 5000	22.45%	0.00%	4.08%	8.16%	12.24%	53.06%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	43.39%	4.76%	7.41%	5.29%	4.23%	34.92%
			ADTT = 1000	29.10%	11.64%	5.82%	7.41%	6.35%	39.68%
			ADTT ≥ 5000	20.63%	11.11%	11.64%	4.76%	10.58%	41.27%
AASHTO TYPE 3	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	79.59%	2.04%	8.16%	8.16%	2.04%	0.00%
			ADTT = 1000	79.59%	0.00%	2.04%	4.08%	12.24%	2.04%
			ADTT ≥ 5000	79.59%	0.00%	0.00%	2.04%	10.20%	8.16%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	82.54%	2.12%	2.12%	7.41%	3.70%	2.12%
			ADTT = 1000	81.48%	0.53%	1.59%	2.65%	6.88%	6.88%
			ADTT ≥ 5000	80.42%	1.06%	0.53%	2.65%	3.70%	11.64%

Table 79: AASHTO Type 3-3 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3-3	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	26.53%	0.00%	10.20%	12.24%	2.04%	48.98%
			ADTT = 1000	20.41%	4.08%	2.04%	8.16%	12.24%	53.06%
			ADTT ≥ 5000	16.33%	8.16%	2.04%	0.00%	14.29%	59.18%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	38.10%	7.41%	8.47%	7.41%	3.17%	35.45%
			ADTT = 1000	26.46%	7.94%	7.41%	10.05%	8.47%	39.68%
			ADTT ≥ 5000	16.40%	11.64%	8.99%	8.47%	10.05%	44.44%
AASHTO TYPE 3-3	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	85.71%	0.00%	4.08%	6.12%	4.08%	0.00%
			ADTT = 1000	79.59%	0.00%	6.12%	2.04%	8.16%	4.08%
			ADTT ≥ 5000	79.59%	0.00%	2.04%	4.08%	6.12%	8.16%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	82.54%	2.65%	3.17%	5.29%	5.82%	0.53%
			ADTT = 1000	79.37%	2.12%	3.17%	3.17%	5.29%	6.88%
			ADTT ≥ 5000	78.31%	1.59%	1.59%	3.70%	4.23%	10.58%

Table 80: AASHTO Type 3S2 Truck – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
AASHTO TYPE 3S2	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	24.49%	4.08%	8.16%	12.24%	2.04%	48.98%
			ADTT = 1000	16.33%	4.08%	8.16%	8.16%	12.24%	51.02%
			ADTT ≥ 5000	16.33%	2.04%	4.08%	6.12%	12.24%	59.18%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	38.62%	6.35%	8.47%	6.35%	5.29%	34.92%
			ADTT = 1000	25.93%	7.94%	10.05%	8.47%	6.35%	41.27%
			ADTT ≥ 5000	15.34%	12.70%	8.47%	8.47%	8.99%	46.03%
AASHTO TYPE 3S2	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	79.59%	4.08%	4.08%	8.16%	4.08%	0.00%
			ADTT = 1000	79.59%	0.00%	2.04%	6.12%	6.12%	6.12%
			ADTT ≥ 5000	79.59%	0.00%	0.00%	4.08%	4.08%	12.24%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	82.01%	2.12%	3.17%	4.76%	5.29%	2.65%
			ADTT = 1000	78.84%	2.12%	2.65%	1.59%	6.35%	8.47%
			ADTT ≥ 5000	78.31%	1.59%	1.06%	3.17%	3.70%	12.17%

K.8.2 Routine Permit Vehicles

Table 81 through Table 85 provide the distribution of rating factors for the five vehicles considered to be routine permits: DE-07, FL-04, NC-21, NM-04, and TX-04.

Table 81: DE-07 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
DE-07	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	18.37%	6.12%	10.20%	10.20%	4.08%	51.02%
			ADTT = 1000	14.29%	4.08%	6.12%	10.20%	12.24%	53.06%
			ADTT ≥ 5000	14.29%	2.04%	4.08%	6.12%	10.20%	63.27%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	32.28%	7.94%	8.47%	7.41%	7.41%	36.51%
			ADTT = 1000	21.69%	8.47%	10.05%	8.99%	8.47%	42.33%
			ADTT ≥ 5000	9.52%	11.11%	9.52%	10.58%	11.11%	48.15%
DE-07	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	79.59%	0.00%	4.08%	8.16%	4.08%	4.08%
			ADTT = 1000	79.59%	0.00%	0.00%	4.08%	10.20%	6.12%
			ADTT ≥ 5000	77.55%	2.04%	0.00%	0.00%	4.08%	16.33%
		Interior	LFR	99.47%	0.53%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	80.42%	1.59%	1.06%	1.59%	7.41%	7.94%
			ADTT = 1000	78.31%	1.06%	2.12%	1.59%	2.65%	14.29%
			ADTT ≥ 5000	74.07%	4.23%	1.06%	2.65%	2.12%	15.87%

Table 82: FL-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
FL-04	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	24.49%	6.12%	10.20%	6.12%	2.04%	51.02%
			ADTT = 1000	18.37%	8.16%	4.08%	10.20%	6.12%	53.06%
			ADTT ≥ 5000	16.33%	4.08%	6.12%	4.08%	14.29%	55.10%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	38.10%	5.29%	4.76%	10.05%	5.29%	36.51%
			ADTT = 1000	25.93%	8.47%	7.94%	5.82%	11.11%	40.74%
			ADTT ≥ 5000	12.17%	12.17%	10.58%	8.99%	7.94%	48.15%
FL-04	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	79.59%	2.04%	2.04%	10.20%	4.08%	2.04%
			ADTT = 1000	79.59%	0.00%	0.00%	4.08%	10.20%	6.12%
			ADTT ≥ 5000	79.59%	0.00%	0.00%	2.04%	2.04%	16.33%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	80.95%	1.06%	2.12%	2.12%	6.35%	7.41%
			ADTT = 1000	78.84%	1.59%	1.59%	2.12%	2.65%	13.23%
			ADTT ≥ 5000	75.66%	3.17%	1.59%	1.59%	2.65%	15.34%

Table 83: NC-21 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NC-21	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	22.45%	2.04%	14.29%	10.20%	0.00%	51.02%
			ADTT = 1000	18.37%	4.08%	4.08%	12.24%	10.20%	51.02%
			ADTT ≥ 5000	18.37%	0.00%	8.16%	2.04%	14.29%	57.14%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	33.86%	7.41%	11.11%	6.35%	4.23%	37.04%
			ADTT = 1000	23.28%	9.52%	8.47%	11.64%	6.35%	40.74%
			ADTT ≥ 5000	12.70%	8.99%	11.11%	8.99%	12.70%	45.50%
NC-21	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	79.59%	0.00%	4.08%	8.16%	6.12%	2.04%
			ADTT = 1000	79.59%	0.00%	0.00%	4.08%	8.16%	8.16%
			ADTT ≥ 5000	79.59%	0.00%	0.00%	0.00%	4.08%	16.33%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	81.48%	0.53%	1.59%	2.65%	6.88%	6.88%
			ADTT = 1000	78.31%	2.65%	1.06%	1.59%	3.17%	13.23%
			ADTT ≥ 5000	76.72%	1.59%	2.65%	1.06%	2.65%	15.34%

Table 84: NM-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
NM-04	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	26.53%	8.16%	8.16%	4.08%	4.08%	48.98%
			ADTT = 1000	20.41%	6.12%	8.16%	8.16%	6.12%	51.02%
			ADTT ≥ 5000	16.33%	6.12%	4.08%	8.16%	10.20%	55.10%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	39.68%	5.82%	8.47%	5.29%	5.29%	35.45%
			ADTT = 1000	30.16%	6.35%	9.52%	7.94%	5.29%	40.74%
			ADTT ≥ 5000	17.46%	11.64%	7.94%	8.99%	10.05%	43.92%
NM-04	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	79.59%	4.08%	8.16%	6.12%	2.04%	0.00%
			ADTT = 1000	79.59%	0.00%	4.08%	8.16%	6.12%	2.04%
			ADTT ≥ 5000	79.59%	0.00%	0.00%	4.08%	10.20%	6.12%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	82.01%	1.06%	1.59%	6.88%	5.82%	2.65%
			ADTT = 1000	80.95%	1.06%	0.53%	2.12%	6.88%	8.47%
			ADTT ≥ 5000	78.31%	2.65%	1.06%	1.06%	3.70%	13.23%

Table 85: TX-04 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
TX-04	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	22.45%	0.00%	12.24%	12.24%	2.04%	51.02%
			ADTT = 1000	18.37%	2.04%	2.04%	16.33%	8.16%	53.06%
			ADTT ≥ 5000	16.33%	2.04%	2.04%	6.12%	14.29%	59.18%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	28.04%	12.70%	8.99%	5.29%	7.41%	37.57%
			ADTT = 1000	20.11%	6.35%	10.58%	12.70%	6.35%	43.92%
			ADTT ≥ 5000	10.05%	8.47%	7.94%	14.29%	11.11%	48.15%
TX-04	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	79.59%	0.00%	0.00%	2.04%	10.20%	8.16%
			ADTT = 1000	79.59%	0.00%	0.00%	0.00%	4.08%	16.33%
			ADTT ≥ 5000	75.51%	4.08%	0.00%	0.00%	0.00%	20.41%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			ADTT ≤ 100	77.25%	3.70%	1.06%	0.53%	2.65%	14.81%
			ADTT = 1000	74.60%	2.12%	3.70%	1.59%	0.53%	17.46%
			ADTT ≥ 5000	70.37%	4.23%	2.12%	4.23%	1.06%	17.99%

K.8.3 Special Permit Vehicles

Table 86 through Table 88 provide the results for the three vehicles assumed to be special permits: IL-01, OR-06, and WA-02.

Table 86: IL-01 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
IL-01	Moment	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	30.61%	14.29%	2.04%	20.41%	16.33%	16.33%
			Single ADTT ≤ 100	24.49%	6.12%	6.12%	12.24%	18.37%	32.65%
			Single ADTT = 1000	18.37%	12.24%	4.08%	14.29%	10.20%	40.82%
			Single ADTT ≥ 5000	14.29%	12.24%	6.12%	14.29%	2.04%	51.02%
			Multiple ADTT ≤ 100	14.29%	6.12%	12.24%	6.12%	10.20%	51.02%
			Multiple ADTT = 1000	14.29%	2.04%	6.12%	12.24%	12.24%	53.06%
			Multiple ADTT ≥ 5000	10.20%	6.12%	2.04%	12.24%	6.12%	63.27%
		Interior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	49.74%	7.41%	5.82%	7.94%	12.70%	16.40%
			Single ADTT ≤ 100	42.33%	6.88%	5.82%	7.41%	7.94%	29.63%
			Single ADTT = 1000	41.80%	5.82%	4.23%	9.52%	7.41%	31.22%
			Single ADTT ≥ 5000	34.39%	8.47%	6.88%	6.88%	7.41%	35.98%
			Multiple ADTT ≤ 100	31.22%	11.11%	6.35%	6.88%	7.41%	37.04%
			Multiple ADTT = 1000	22.22%	8.99%	11.11%	7.41%	6.88%	43.39%
			Multiple ADTT ≥ 5000	17.99%	7.94%	12.17%	7.41%	8.47%	46.03%
IL-01	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	79.59%	0.00%	6.12%	2.04%	8.16%	4.08%
			Single ADTT ≤ 100	79.59%	0.00%	0.00%	6.12%	2.04%	12.24%
			Single ADTT = 1000	77.55%	2.04%	0.00%	0.00%	6.12%	14.29%
			Single ADTT ≥ 5000	75.51%	4.08%	0.00%	0.00%	6.12%	14.29%
			Multiple ADTT ≤ 100	75.51%	2.04%	2.04%	0.00%	6.12%	14.29%
			Multiple ADTT = 1000	69.39%	4.08%	4.08%	2.04%	0.00%	20.41%
			Multiple ADTT ≥ 5000	65.31%	6.12%	4.08%	4.08%	0.00%	20.41%
		Interior	LFR	97.88%	1.59%	0.00%	0.00%	0.53%	0.00%
			Single Escorted	82.54%	2.65%	3.17%	5.29%	5.29%	1.06%
			Single ADTT ≤ 100	78.84%	2.12%	3.17%	3.17%	6.35%	6.35%
			Single ADTT = 1000	77.78%	2.12%	3.70%	2.65%	6.35%	7.41%
			Single ADTT ≥ 5000	76.19%	2.65%	2.65%	2.65%	5.29%	10.58%
			Multiple ADTT ≤ 100	75.66%	2.12%	2.65%	3.70%	3.70%	12.17%
			Multiple ADTT = 1000	70.37%	4.23%	3.17%	3.17%	3.17%	15.87%
			Multiple ADTT ≥ 5000	69.31%	3.17%	4.23%	2.65%	4.76%	15.87%

Table 87: OR-06 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
OR-06	Moment	Exterior	LFR	97.96%	0.00%	2.04%	0.00%	0.00%	0.00%
			Single Escorted	30.61%	10.20%	8.16%	22.45%	12.24%	16.33%
			Single ADTT ≤ 100	20.41%	10.20%	8.16%	10.20%	20.41%	30.61%
			Single ADTT = 1000	16.33%	10.20%	10.20%	12.24%	14.29%	36.73%
			Single ADTT ≥ 5000	14.29%	8.16%	8.16%	12.24%	12.24%	44.90%
			Multiple ADTT ≤ 100	12.24%	10.20%	6.12%	12.24%	10.20%	48.98%
			Multiple ADTT = 1000	12.24%	2.04%	4.08%	12.24%	12.24%	57.14%
			Multiple ADTT ≥ 5000	10.20%	4.08%	2.04%	10.20%	12.24%	61.22%
		Interior	LFR	98.94%	0.53%	0.53%	0.00%	0.00%	0.00%
			Single Escorted	48.15%	6.88%	9.52%	6.88%	12.70%	15.87%
			Single ADTT ≤ 100	41.27%	5.82%	7.41%	7.41%	9.52%	28.57%
			Single ADTT = 1000	38.10%	7.94%	5.82%	9.52%	8.47%	30.16%
			Single ADTT ≥ 5000	35.45%	6.35%	7.41%	6.35%	10.05%	34.39%
			Multiple ADTT ≤ 100	31.22%	7.41%	8.99%	6.35%	11.11%	34.92%
			Multiple ADTT = 1000	22.75%	6.88%	10.05%	8.47%	7.94%	43.92%
			Multiple ADTT ≥ 5000	16.40%	10.58%	10.05%	7.94%	7.41%	47.62%
OR-06	Shear	Exterior	LFR	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	79.59%	2.04%	4.08%	6.12%	6.12%	2.04%
			Single ADTT ≤ 100	79.59%	0.00%	0.00%	4.08%	8.16%	8.16%
			Single ADTT = 1000	79.59%	0.00%	0.00%	2.04%	8.16%	10.20%
			Single ADTT ≥ 5000	75.51%	4.08%	0.00%	0.00%	6.12%	14.29%
			Multiple ADTT ≤ 100	75.51%	4.08%	0.00%	0.00%	4.08%	16.33%
			Multiple ADTT = 1000	71.43%	4.08%	4.08%	0.00%	0.00%	20.41%
			Multiple ADTT ≥ 5000	67.35%	4.08%	4.08%	4.08%	0.00%	20.41%
		Interior	LFR	98.41%	1.06%	0.00%	0.00%	0.00%	0.53%
			Single Escorted	84.13%	3.17%	3.70%	6.35%	2.65%	0.00%
			Single ADTT ≤ 100	80.42%	2.65%	3.17%	3.70%	7.41%	2.65%
			Single ADTT = 1000	78.31%	3.17%	3.17%	4.23%	7.41%	3.70%
			Single ADTT ≥ 5000	77.25%	3.17%	3.17%	2.65%	5.82%	7.94%
			Multiple ADTT ≤ 100	76.19%	2.12%	4.23%	3.17%	5.29%	8.99%
			Multiple ADTT = 1000	71.96%	3.70%	2.65%	4.76%	3.17%	13.76%
			Multiple ADTT ≥ 5000	70.90%	2.65%	4.23%	3.17%	3.70%	15.34%

Table 88: WA-02 – Distribution of LFR and LRFR Ratings for Different ADTTs

Vehicle	Demand	Girder Type	Rating	>1.0	0.9-1.0	0.8-0.9	0.7-0.8	0.6-0.7	<0.6
WA-02	Moment	Exterior	LFR	95.92%	0.00%	2.04%	2.04%	0.00%	0.00%
			Single Escorted	18.37%	6.12%	10.20%	26.53%	28.57%	10.20%
			Single ADTT ≤ 100	10.20%	8.16%	2.04%	12.24%	32.65%	34.69%
			Single ADTT = 1000	10.20%	8.16%	2.04%	12.24%	20.41%	46.94%
			Single ADTT ≥ 5000	8.16%	2.04%	10.20%	4.08%	22.45%	53.06%
			Multiple ADTT ≤ 100	6.12%	4.08%	10.20%	0.00%	20.41%	59.18%
			Multiple ADTT = 1000	4.08%	2.04%	6.12%	8.16%	10.20%	69.39%
			Multiple ADTT ≥ 5000	4.08%	0.00%	6.12%	2.04%	14.29%	73.47%
		Interior	LFR	94.18%	3.17%	2.12%	0.00%	0.53%	0.00%
			Single Escorted	34.92%	7.41%	11.64%	16.40%	17.46%	12.17%
			Single ADTT ≤ 100	26.98%	10.05%	5.82%	16.93%	9.52%	30.69%
			Single ADTT = 1000	24.87%	11.11%	5.82%	13.23%	11.11%	33.86%
			Single ADTT ≥ 5000	20.63%	9.52%	8.99%	11.11%	12.17%	37.57%
			Multiple ADTT ≤ 100	16.40%	11.64%	10.58%	10.05%	11.64%	39.68%
			Multiple ADTT = 1000	11.64%	7.41%	11.11%	15.34%	5.29%	49.21%
			Multiple ADTT ≥ 5000	10.05%	7.94%	8.47%	14.81%	7.41%	51.32%
WA-02	Shear	Exterior	LFR	95.92%	4.08%	0.00%	0.00%	0.00%	0.00%
			Single Escorted	73.47%	4.08%	0.00%	6.12%	2.04%	14.29%
			Single ADTT ≤ 100	63.27%	6.12%	4.08%	4.08%	6.12%	16.33%
			Single ADTT = 1000	63.27%	4.08%	6.12%	4.08%	2.04%	20.41%
			Single ADTT ≥ 5000	57.14%	6.12%	6.12%	8.16%	0.00%	22.45%
			Multiple ADTT ≤ 100	53.06%	10.20%	6.12%	4.08%	4.08%	22.45%
			Multiple ADTT = 1000	38.78%	12.24%	12.24%	6.12%	8.16%	22.45%
			Multiple ADTT ≥ 5000	34.69%	8.16%	16.33%	6.12%	8.16%	26.53%
		Interior	LFR	86.24%	6.35%	4.23%	2.12%	0.53%	0.53%
			Single Escorted	75.13%	2.12%	4.23%	4.76%	6.88%	6.88%
			Single ADTT ≤ 100	67.20%	5.29%	3.17%	5.29%	5.29%	13.76%
			Single ADTT = 1000	67.20%	2.65%	5.29%	4.76%	5.82%	14.29%
			Single ADTT ≥ 5000	63.49%	3.70%	6.35%	3.70%	4.76%	17.99%
			Multiple ADTT ≤ 100	62.43%	4.76%	4.23%	4.23%	5.29%	19.05%
			Multiple ADTT = 1000	55.03%	6.88%	5.29%	4.76%	5.29%	22.75%
			Multiple ADTT ≥ 5000	49.74%	8.99%	6.35%	4.23%	5.82%	24.87%

L Effect of LRFR Rating on Operating Rating

The following sections provide an indication into the affect of switching to LRFR from LFR for the eleven legal and permit vehicles considered in this study for each structure type. The first column in each table is a range of LRFR divided by LFR ratios. The second column indicates the number of girders with LRFR ratings less than 1.0 and a ratio within the specified range. The third column indicates the percent of the total number of girders that have an LRFR rating less than 1.0 and a ratio within the given range. The fourth and fifth columns specify how many girders with an LRFR rating less than 1.0 have LFR ratings less than or greater than 1.0, respectively. The last row in each table indicates what the average ratio of ratings is; this provides an indication into the reduction in rating factor that may be expected if the existing load factors are used.

The rating factors used to construct these tables are based on using the load factors currently specified for the AASHTO LFR and the current MBE.

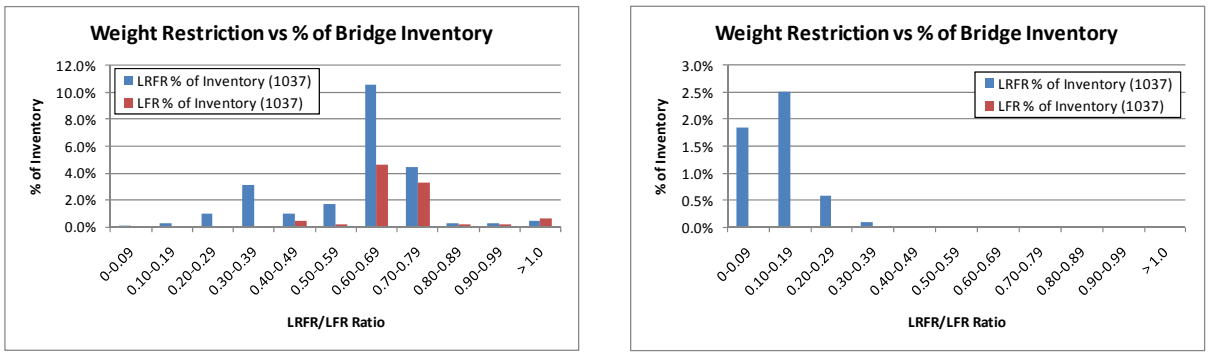
All values are calculated considering all rating criteria and utilize the load factors for live load presently in the MBE.

L.1 Simple Span Steel

Table 1 and Figure 1 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 1 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the DE-07 vehicle is 0.76 for moment and 0.55 for shear.

Table 1: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.10%	0	1	19	1.83%	0	19
0.1-0.19	3	0.29%	0	3	26	2.51%	0	26
0.2-0.29	10	0.96%	0	10	6	0.58%	0	6
0.3-0.39	32	3.09%	0	32	1	0.10%	0	1
0.4-0.49	10	0.96%	5	5	0	0.00%	0	0
0.5-0.59	18	1.74%	2	16	0	0.00%	0	0
0.6-0.69	109	10.51%	48	61	0	0.00%	0	0
0.7-0.79	46	4.44%	34	12	0	0.00%	0	0
0.8-0.89	3	0.29%	2	1	0	0.00%	0	0
0.9-0.99	3	0.29%	2	1	0	0.00%	0	0
> 1.00	5	0.48%	5	0	0	0.00%	0	0
Total	240		98	142	52		0	52
Average LRFR/LFR	0.76				0.55			



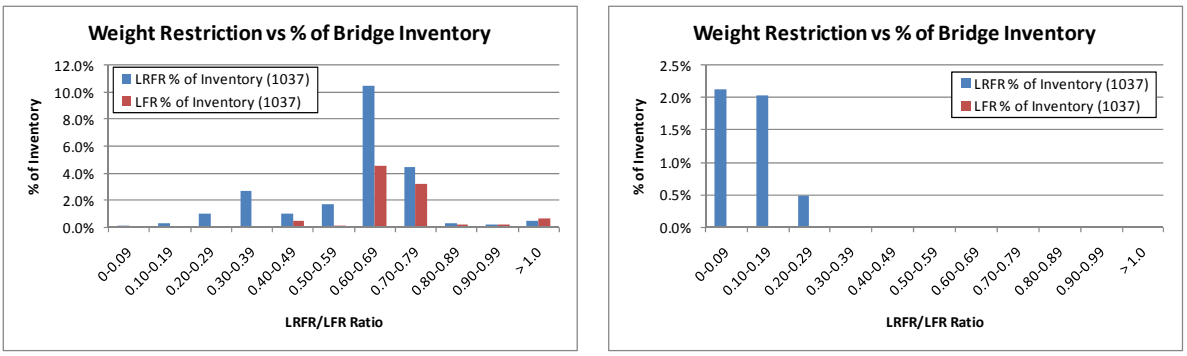
(a) (b)

Figure 1: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

Table 2 and Figure 2 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 2 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the FL-04 vehicle is 0.76 for moment and 0.55 for shear.

Table 2: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.10%	0	1	22	2.12%	0	22
0.1-0.19	3	0.29%	0	3	21	2.03%	0	21
0.2-0.29	10	0.96%	0	10	5	0.48%	0	5
0.3-0.39	28	1.74%	0	28	0	0.00%	0	0
0.4-0.49	10	0.96%	5	5	0	0.00%	0	0
0.5-0.59	18	1.74%	1	17	0	0.00%	0	0
0.6-0.69	109	10.51%	47	62	0	0.00%	0	0
0.7-0.79	46	4.44%	33	13	0	0.00%	0	0
0.8-0.89	3	0.29%	2	1	0	0.00%	0	0
0.9-0.99	2	0.19%	2	0	0	0.00%	0	0
> 1.00	5	0.48%	5	0	0	0.00%	0	0
Total	235		95	140	48		0	48
Average LRFR/LFR	0.76				0.55			



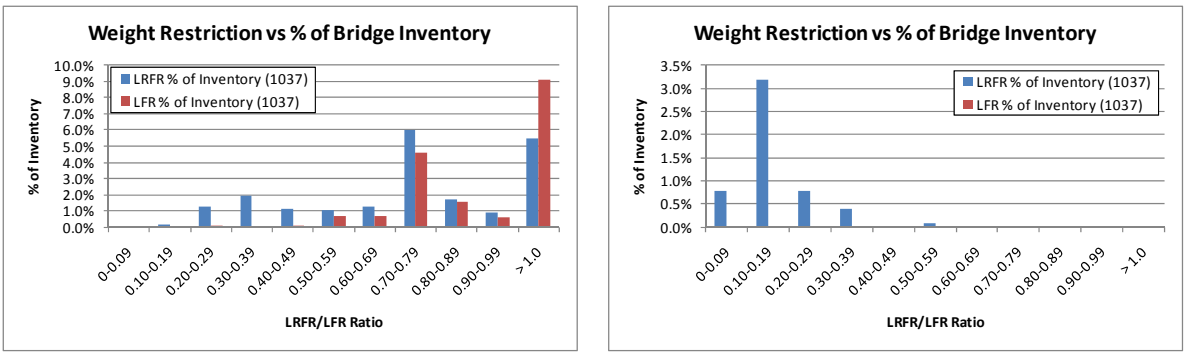
(a) (b)

Figure 2: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 3 and Figure 3 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 3 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the IL-01 vehicle is 1.12 for moment and 0.79 for shear.

Table 3: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	8	0.8%	0	8
0.1-0.19	2	0.2%	0	2	33	3.2%	0	33
0.2-0.29	13	1.3%	1	12	8	0.8%	0	8
0.3-0.39	20	1.9%	0	20	4	0.4%	0	4
0.4-0.49	12	1.2%	1	11	0	0.0%	0	0
0.5-0.59	11	1.1%	7	4	1	0.1%	0	1
0.6-0.69	13	1.3%	7	6	0	0.0%	0	0
0.7-0.79	62	6.0%	48	14	0	0.0%	0	0
0.8-0.89	18	1.7%	16	2	0	0.0%	0	0
0.9-0.99	9	0.9%	6	3	0	0.0%	0	0
> 1.00	57	5.5%	57	0	0	0.0%	0	0
Total	217		143	74	54		0	54
Average LRFR/LFR	1.12				0.79			



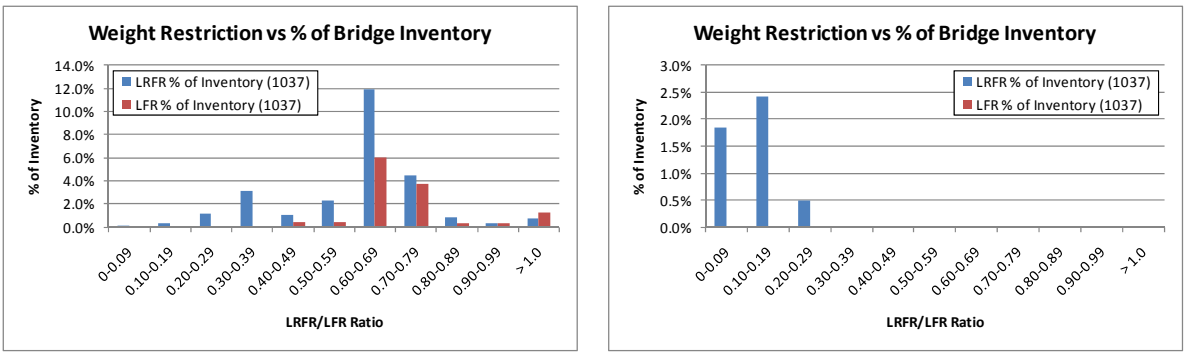
(a) (b)

Figure 3: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

Table 4 and Figure 4 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 4 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NC-21 vehicle is 0.75 for moment and 0.56 for shear.

Table 4: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.1%	0	1	19	1.8%	0	19
0.1-0.19	3	0.3%	0	3	25	2.4%	0	25
0.2-0.29	12	1.2%	0	12	5	0.5%	0	5
0.3-0.39	32	3.1%	0	32	0	0%	0	0
0.4-0.49	11	1.1%	5	6	0	0%	0	0
0.5-0.59	24	2.3%	5	19	0	0%	0	0
0.6-0.69	123	11.9%	62	61	0	0%	0	0
0.7-0.79	46	4.4%	39	7	0	0%	0	0
0.8-0.89	9	0.9%	3	6	0	0%	0	0
0.9-0.99	4	0.4%	3	1	0	0%	0	0
> 1.00	8	0.8%	8	0	0	0%	0	0
Total	273		125	148	49		0	49
Average LRFR/LFR	0.75				0.56			



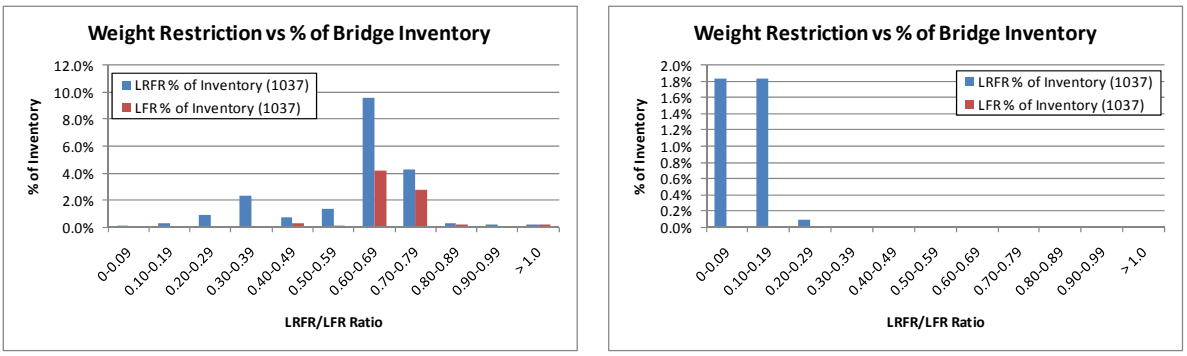
(a) (b)

Figure 4: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 5 and Figure 5 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 5 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NM-04 vehicle is 0.76 for moment and 0.56 for shear.

Table 5: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.1%	0	1	19	1.8%	0	19
0.1-0.19	3	0.3%	0	3	19	1.8%	0	19
0.2-0.29	9	0.9%	0	9	1	0.1%	0	1
0.3-0.39	24	2.3%	0	24	0	0%	0	0
0.4-0.49	8	0.8%	3	5	0	0%	0	0
0.5-0.59	14	1.4%	1	13	0	0%	0	0
0.6-0.69	99	9.6%	43	56	0	0%	0	0
0.7-0.79	44	4.2%	29	15	0	0%	0	0
0.8-0.89	3	0.3%	2	1	0	0%	0	0
0.9-0.99	2	0.2%	0	2	0	0%	0	0
> 1.00	2	0.2%	2	0	0	0%	0	0
Total	209		80	129	39		0	39
Average LRFR/LFR	0.76				0.56			



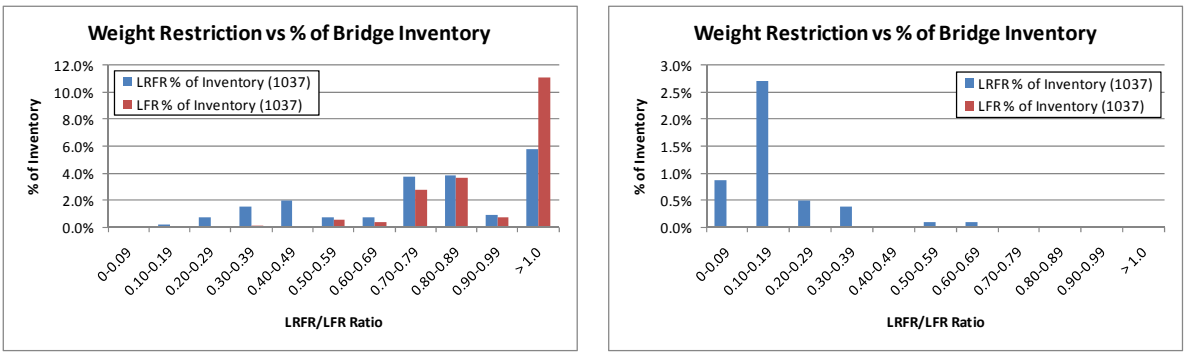
(a) (b)

Figure 5: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 6 and Figure 6 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 6 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the OR-06 vehicle is 1.20 for moment and 0.81 for shear.

Table 6: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	0.9%	0	9
0.1-0.19	2	0.2%	0	2	28	2.7%	0	28
0.2-0.29	8	0.8%	0	8	5	0.5%	0	5
0.3-0.39	16	1.5%	1	15	4	0.4%	0	4
0.4-0.49	20	1.9%	0	20	0	0.0%	0	0
0.5-0.59	8	0.8%	6	2	1	0.1%	0	1
0.6-0.69	8	0.8%	4	4	1	0.1%	0	1
0.7-0.79	39	3.8%	29	10	0	0.0%	0	0
0.8-0.89	40	3.9%	38	2	0	0.0%	0	0
0.9-0.99	9	0.9%	8	1	0	0.0%	0	0
> 1.00	60	5.8%	60	0	0	0.0%	0	0
Total	210		146	64	48		0	48
Average LRFR/LFR	1.20				0.81			



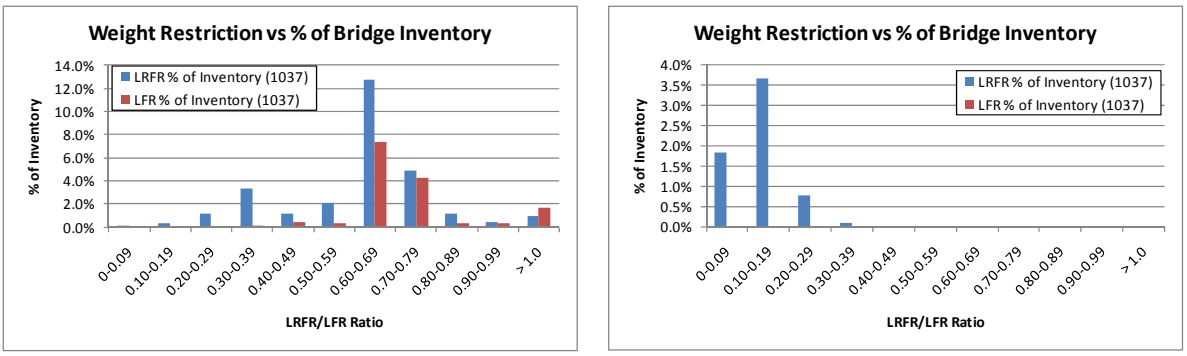
(a) (b)

Figure 6: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 7 and Figure 7 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 7 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the TX-04 vehicle is 0.75 for moment and 0.56 for shear.

Table 7: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.1%	0	1	19	1.8%	0	19
0.1-0.19	4	0.4%	0	4	38	3.7%	0	38
0.2-0.29	12	1.2%	0	12	8	0.8%	0	8
0.3-0.39	35	3.4%	1	34	1	0.1%	0	1
0.4-0.49	12	1.2%	5	7	0	0%	0	0
0.5-0.59	22	2.1%	4	18	0	0%	0	0
0.6-0.69	132	12.7%	76	56	0	0%	0	0
0.7-0.79	51	4.9%	44	7	0	0%	0	0
0.8-0.89	12	1.2%	3	9	0	0%	0	0
0.9-0.99	5	0.5%	3	2	0	0%	0	0
> 1.00	10	1.0%	10	0	0	0%	0	0
Total	296		146	150	66		0	66
Average LRFR/LFR	0.75				0.56			



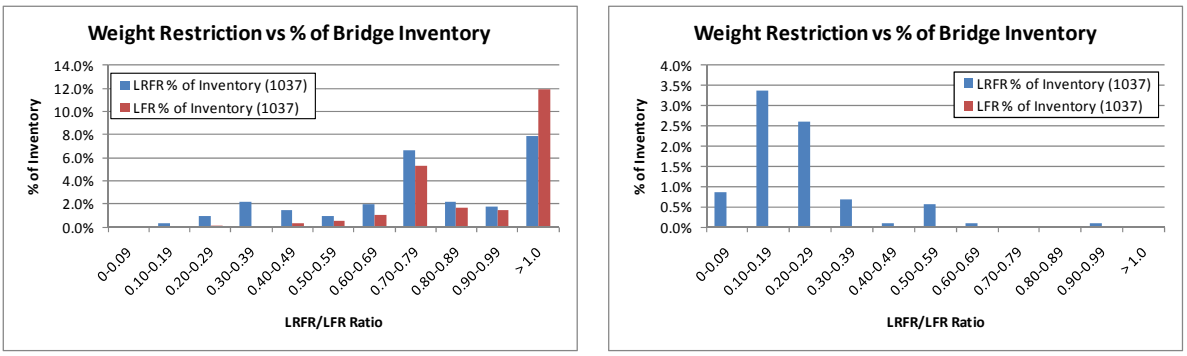
(a) (b)

Figure 7: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 8 and Figure 8 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 8 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the WA-02 vehicle is 1.12 for moment and 0.78 for shear.

Table 8: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	0.9%	0	9
0.1-0.19	4	0.4%	0	4	35	3.4%	0	35
0.2-0.29	10	1.0%	1	9	27	2.6%	0	27
0.3-0.39	23	2.2%	0	23	7	0.7%	0	7
0.4-0.49	15	1.5%	3	12	1	0.1%	0	1
0.5-0.59	10	1.0%	6	4	6	0.6%	0	6
0.6-0.69	21	2.0%	11	10	1	0.1%	0	1
0.7-0.79	69	6.7%	55	14	0	0.0%	0	0
0.8-0.89	23	2.2%	17	6	0	0.0%	0	0
0.9-0.99	19	1.8%	15	4	1	0.1%	0	1
> 1.00	82	7.9%	82	0	0	0.0%	0	0
Total	276		190	86	87		0	87
Average LRFR/LFR	1.12				0.78			



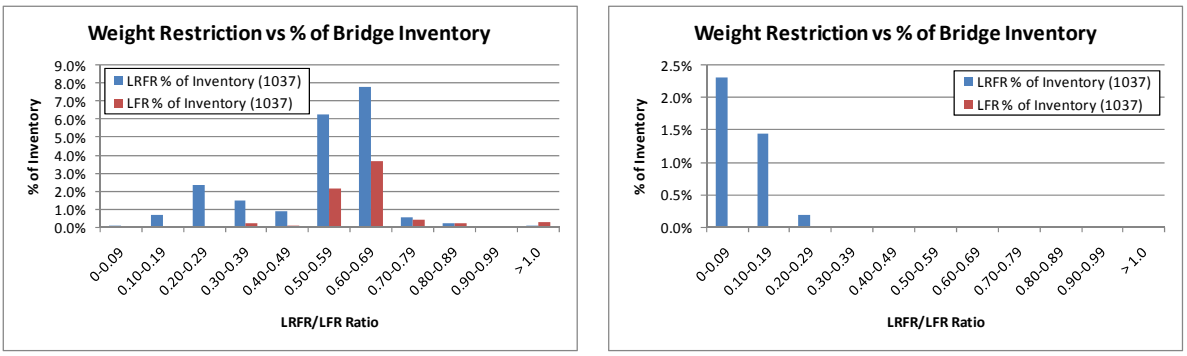
(a) (b)

Figure 8: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 9 and Figure 9 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 9 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASTHO Type 3 vehicle is 0.71 for moment and 0.52 for shear.

Table 9: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.1%	0	1	24	2.3%	0	24
0.1-0.19	7	0.7%	0	7	15	1.5%	0	15
0.2-0.29	24	2.3%	0	24	2	0.2%	0	2
0.3-0.39	15	1.5%	2	13	0	0.0%	0	0
0.4-0.49	9	0.9%	1	8	0	0.0%	0	0
0.5-0.59	65	6.3%	22	43	0	0.0%	0	0
0.6-0.69	81	7.8%	38	43	0	0.0%	0	0
0.7-0.79	6	0.6%	4	2	0	0.0%	0	0
0.8-0.89	2	0.2%	2	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	1	0.1%	1	0	0	0.0%	0	0
Total	211		70	141	41		0	41
Average LRFR/LFR	0.71				0.52			



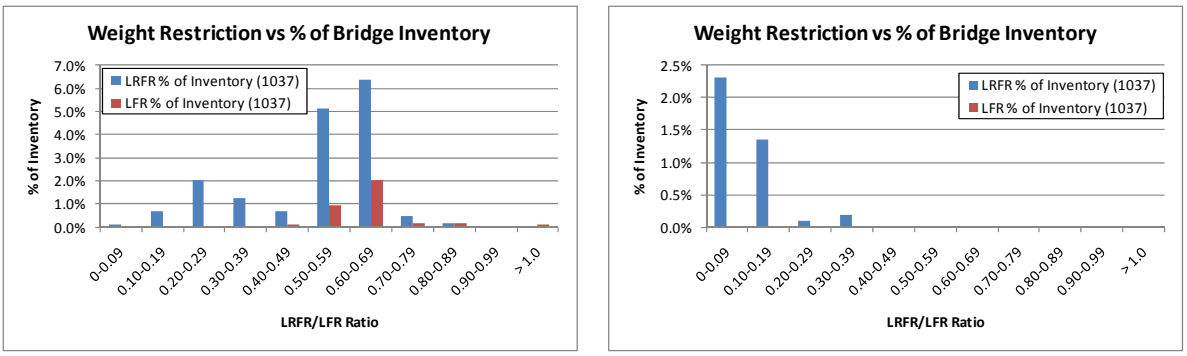
(a) (b)

Figure 9: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 10 and Figure 10 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 10 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASTHO Type 3-3 vehicle is 0.71 for moment and 0.50 for shear.

Table 10: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.1%	0	1	24	2.3%	0	24
0.1-0.19	7	0.7%	0	7	14	1.4%	0	14
0.2-0.29	21	2.0%	0	21	1	0.1%	0	1
0.3-0.39	13	1.3%	0	13	2	0.2%	0	2
0.4-0.49	7	0.7%	1	6	0	0.0%	0	0
0.5-0.59	53	5.1%	10	43	0	0.0%	0	0
0.6-0.69	66	6.4%	21	45	0	0.0%	0	0
0.7-0.79	5	0.5%	2	3	0	0.0%	0	0
0.8-0.89	2	0.2%	2	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	175		36	139	41		0	41
Average LRFR/LFR	0.71				0.50			



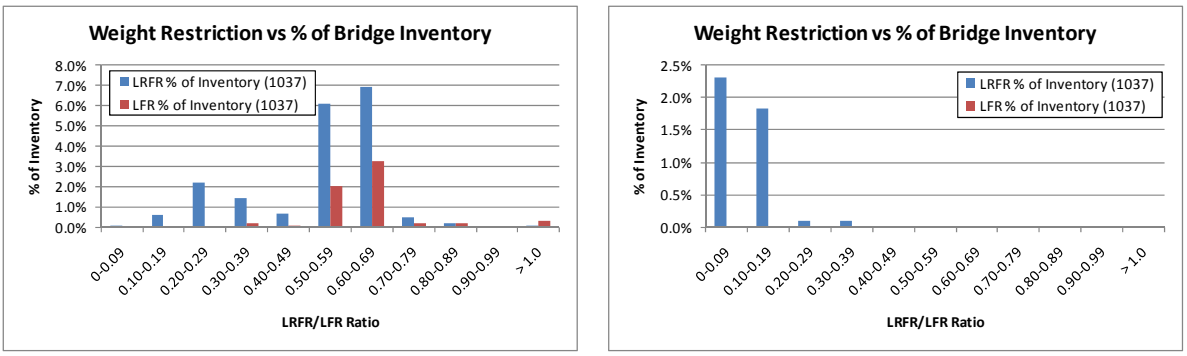
(a) (b)

Figure 10: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

Table 11 and Figure 11 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 11 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASTHO Type 3S2 vehicle is 0.71 for moment and 0.51 for shear.

Table 11: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.1%	0	1	24	2.3%	0	24
0.1-0.19	6	0.6%	0	6	19	1.8%	0	19
0.2-0.29	23	2.2%	0	23	1	0.1%	0	1
0.3-0.39	15	1.5%	2	13	1	0.1%	0	1
0.4-0.49	7	0.7%	1	6	0	0.0%	0	0
0.5-0.59	63	6.1%	21	42	0	0.0%	0	0
0.6-0.69	72	6.9%	34	38	0	0.0%	0	0
0.7-0.79	5	0.5%	2	3	0	0.0%	0	0
0.8-0.89	2	0.2%	2	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	1	0.1%	1	0	0	0.0%	0	0
Total	195		63	132	45		0	45
Average LRFR/LFR	0.71				0.51			



(a) (b)

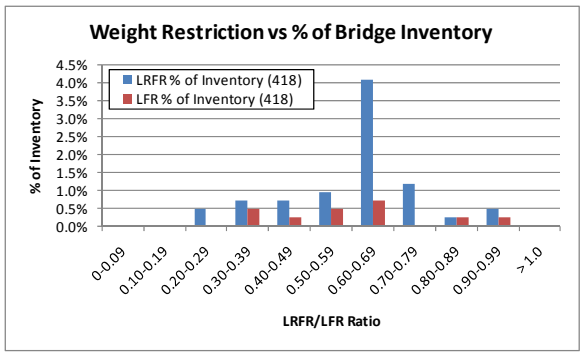
Figure 11: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

L.2 Continuous Span Steel

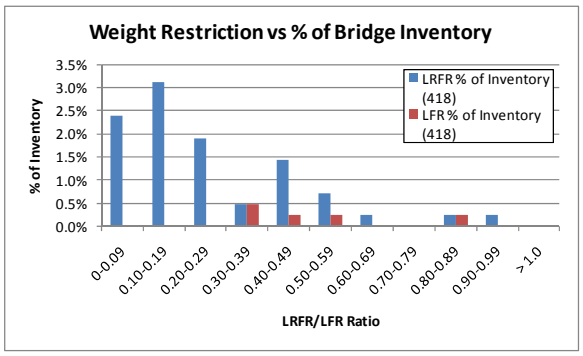
Table 12 and Figure 12 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 12 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the DE-07 vehicle is 0.86 for moment and 0.67 for shear.

Table 12: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	10	2.4%	0	10
0.1-0.19	0	0.0%	0	0	13	3.1%	0	13
0.2-0.29	2	0.5%	0	2	8	1.9%	0	8
0.3-0.39	3	0.7%	2	1	2	0.5%	2	0
0.4-0.49	3	0.7%	1	2	6	1.4%	1	5
0.5-0.59	4	1.0%	2	2	3	0.7%	1	2
0.6-0.69	17	4.1%	3	14	1	0.2%	0	1
0.7-0.79	5	1.2%	0	5	0	0.0%	0	0
0.8-0.89	1	0.2%	1	0	1	0.2%	1	0
0.9-0.99	2	0.5%	1	1	1	0.2%	0	1
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	37		10	27	45		5	40
Average LRFR/LFR	0.86				0.67			



(a)



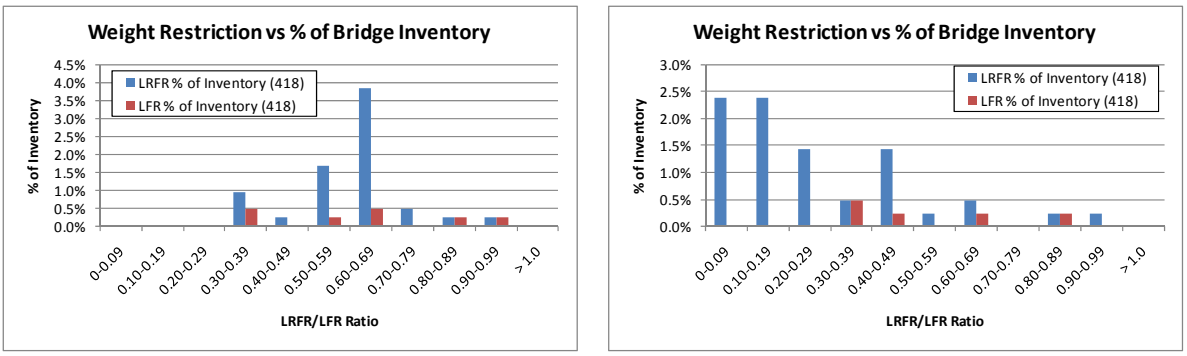
(b)

Figure 12: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

Table 13 and Figure 13 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 13 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the FL-04 vehicle is 0.86 for moment and 0.67 for shear.

Table 13: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	10	2.4%	0	10
0.1-0.19	0	0.0%	0	0	10	2.4%	0	10
0.2-0.29	0	0.0%	0	0	6	1.4%	0	6
0.3-0.39	4	1.0%	2	2	2	0.5%	2	0
0.4-0.49	1	0.2%	0	1	6	1.4%	1	5
0.5-0.59	7	1.7%	1	6	1	0.2%	0	1
0.6-0.69	16	3.8%	2	14	2	0.5%	1	1
0.7-0.79	2	0.5%	0	2	0	0.0%	0	0
0.8-0.89	1	0.2%	1	0	1	0.2%	1	0
0.9-0.99	1	0.2%	1	0	1	0.2%	0	1
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	32		7	25	39		5	34
Average LRFR/LFR	0.86				0.67			



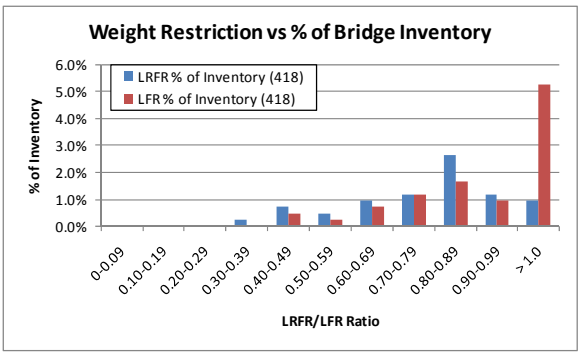
(a) (b)

Figure 13: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

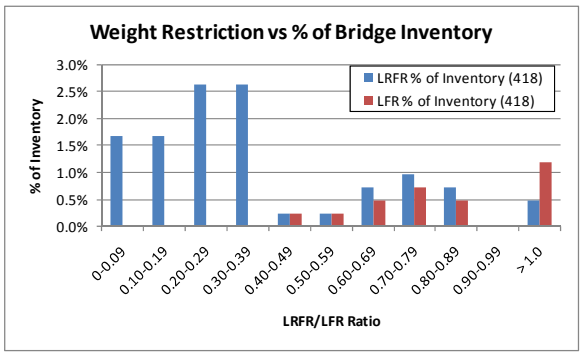
Table 14 and Figure 14 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 14 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the IL-01 vehicle is 1.28 for moment and 0.96 for shear.

Table 14: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	7	1.7%	0	7
0.2-0.29	0	0.0%	0	0	11	2.6%	0	11
0.3-0.39	1	0.2%	0	1	11	2.6%	0	11
0.4-0.49	3	0.7%	2	1	1	0.2%	1	0
0.5-0.59	2	0.5%	1	1	1	0.2%	1	0
0.6-0.69	4	1.0%	3	1	3	0.7%	2	1
0.7-0.79	5	1.2%	5	0	4	1.0%	3	1
0.8-0.89	11	2.6%	7	4	3	0.7%	2	1
0.9-0.99	5	1.2%	4	1	0	0.0%	0	0
> 1.00	4	1.0%	4	0	2	0.5%	2	0
Total	35		26	9	50		11	39
Average LRFR/LFR	1.28				0.96			



(a)



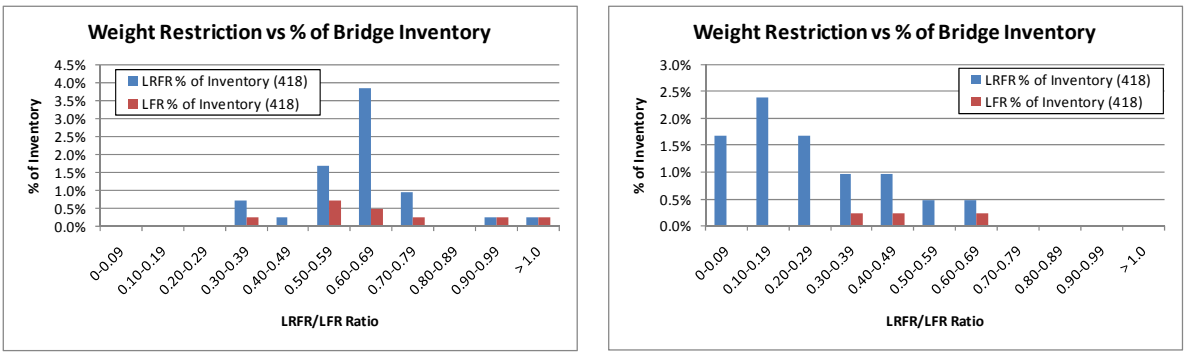
(b)

Figure 14: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

Table 15 and Figure 15 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 15 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NC-21 vehicle is 0.88 for moment and 0.69 for shear.

Table 15: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	10	2.4%	0	10
0.2-0.29	0	0.0%	0	0	7	1.7%	0	7
0.3-0.39	3	0.7%	1	2	4	1.0%	1	3
0.4-0.49	1	0.2%	0	1	4	1.0%	1	3
0.5-0.59	7	1.7%	3	4	2	0.5%	0	2
0.6-0.69	16	3.8%	2	14	2	0.5%	1	1
0.7-0.79	4	1.0%	1	3	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	1	0.2%	1	0	0	0.0%	0	0
> 1.00	1	0.2%	1	0	0	0.0%	0	0
Total	33		9	24	36		3	33
Average LRFR/LFR	0.88				0.69			



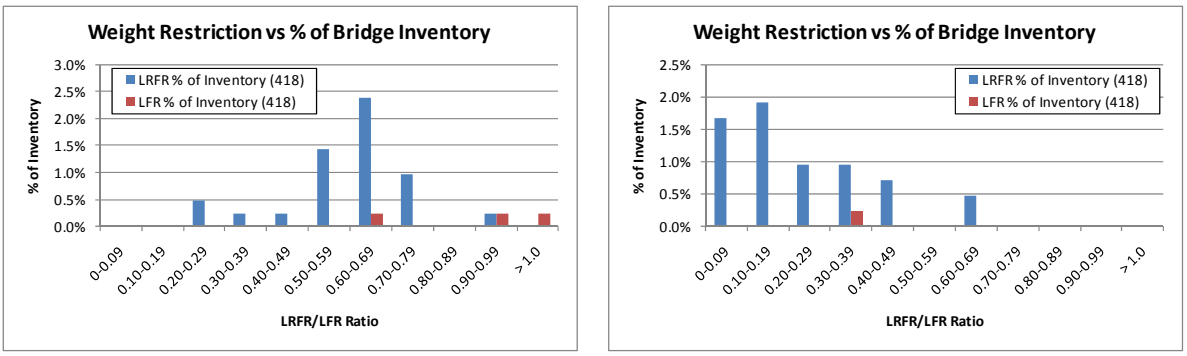
(a) (b)

Figure 15: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 16 and Figure 16 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 16 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NM-04 vehicle is 0.87 for moment and 0.68 for shear.

Table 16: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	8	1.9%	0	8
0.2-0.29	2	0.5%	0	2	4	1.0%	0	4
0.3-0.39	1	0.2%	0	1	4	1.0%	1	3
0.4-0.49	1	0.2%	0	1	3	0.7%	0	3
0.5-0.59	6	1.4%	1	6	0	0.0%	0	0
0.6-0.69	10	2.4%	1	9	2	0.5%	0	2
0.7-0.79	4	1.0%	0	4	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	1	0.2%	1	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	25		3	23	28		1	27
Average LRFR/LFR	0.87				0.68			



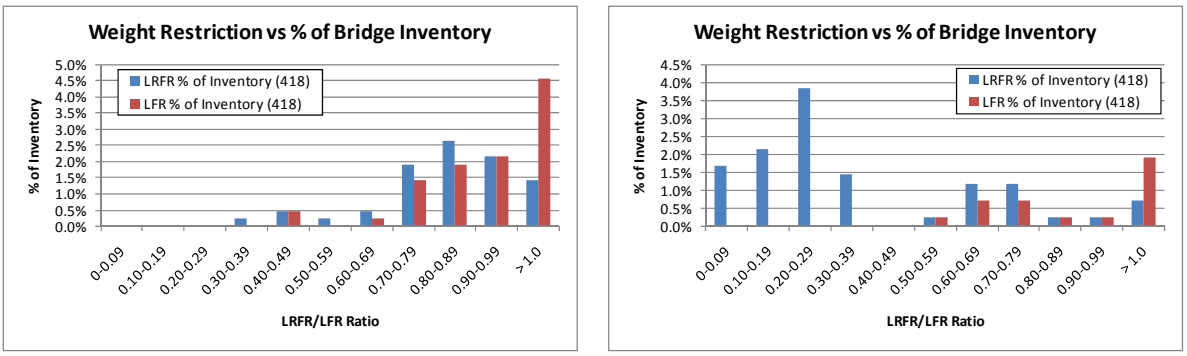
(a) (b)

Figure 16: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 17 and Figure 17 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 17 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the OR-06 vehicle is 1.27 for moment and 0.96 for shear.

Table 17: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	9	2.2%	0	9
0.2-0.29	0	0.0%	0	0	16	3.8%	0	16
0.3-0.39	1	0.2%	0	1	6	1.4%	0	6
0.4-0.49	2	0.5%	2	0	0	0.0%	0	0
0.5-0.59	1	0.2%	0	1	1	0.2%	1	0
0.6-0.69	2	0.5%	1	1	5	1.2%	3	2
0.7-0.79	8	1.9%	6	2	5	1.2%	3	2
0.8-0.89	11	2.6%	8	3	1	0.2%	1	0
0.9-0.99	9	2.2%	9	0	1	0.2%	1	0
> 1.00	6	1.4%	6	0	3	0.7%	3	0
Total	40		32	8	54		12	42
Average LRFR/LFR	1.27				0.96			



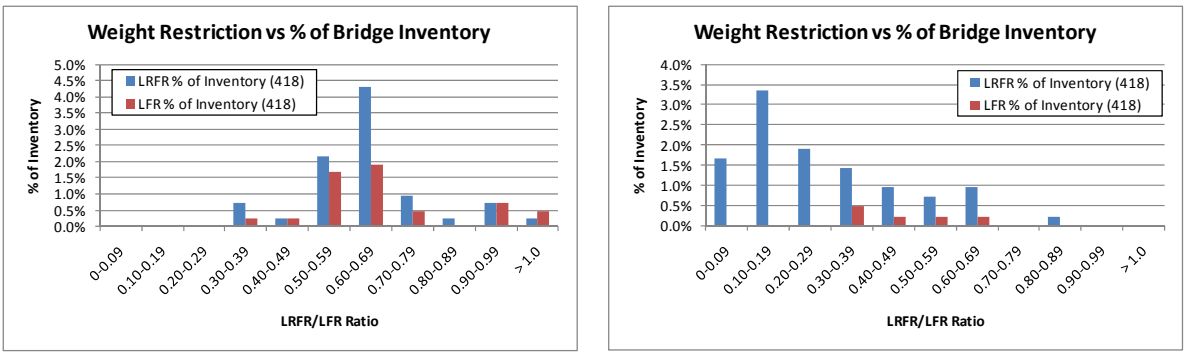
(a) (b)

Figure 17: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 18 and Figure 18 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 18 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the TX-04 vehicle is 0.88 for moment and 0.69 for shear.

Table 18: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	14	3.4%	0	14
0.2-0.29	0	0.0%	0	0	8	1.9%	0	8
0.3-0.39	3	0.7%	1	2	6	1.4%	2	4
0.4-0.49	1	0.2%	1	0	4	1.0%	1	3
0.5-0.59	9	2.2%	7	2	3	0.7%	1	2
0.6-0.69	18	4.3%	8	10	4	1.0%	1	3
0.7-0.79	4	1.0%	2	2	0	0.0%	0	0
0.8-0.89	1	0.2%	0	1	1	0.2%	0	1
0.9-0.99	3	0.7%	3	0	0	0.0%	0	0
> 1.00	1	0.2%	1	0	0	0.0%	0	0
Total	40		23	17	47		5	42
Average LRFR/LFR	0.88				0.69			



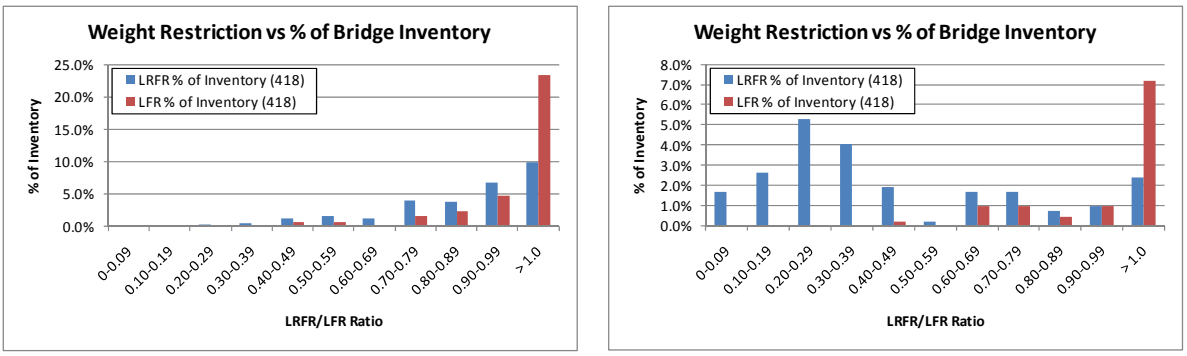
(a) (b)

Figure 18: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 19 and Figure 19 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 19 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the WA-02 vehicle is 1.25 for moment and 0.94 for shear.

Table 19: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	11	2.6%	0	11
0.2-0.29	1	0.2%	0	1	22	5.3%	0	22
0.3-0.39	2	0.5%	0	2	17	4.1%	0	17
0.4-0.49	5	1.2%	3	2	8	1.9%	1	7
0.5-0.59	7	1.7%	3	4	1	0.2%	0	1
0.6-0.69	5	1.2%	0	5	7	1.7%	4	3
0.7-0.79	17	4.1%	7	10	7	1.7%	4	3
0.8-0.89	16	3.8%	10	6	3	0.7%	2	1
0.9-0.99	28	6.7%	20	8	4	1.0%	4	0
> 1.00	41	9.8%	41	0	10	2.4%	10	0
Total	122		84	38	97		25	72
Average LRFR/LFR	1.25				0.94			



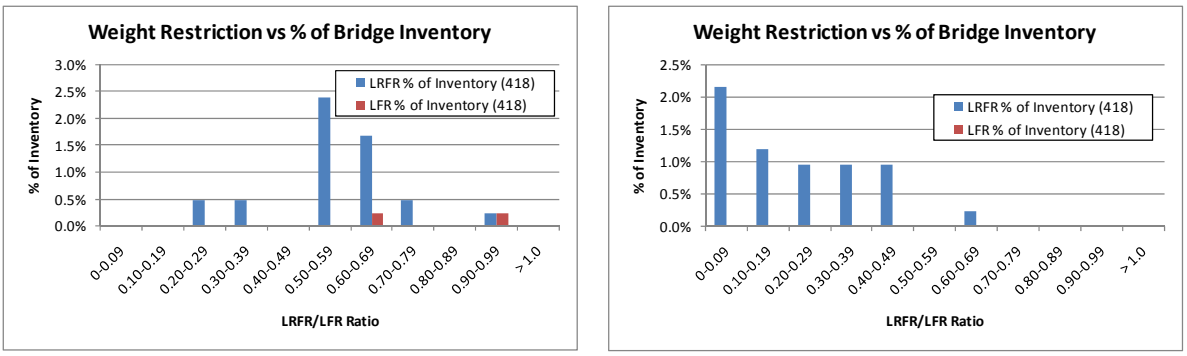
(a) (b)

Figure 19: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 20 and Figure 20 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 20 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASTHO Type 3 vehicle is 0.85 for moment and 0.66 for shear.

Table 20: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	2.2%	0	9
0.1-0.19	0	0.0%	0	0	5	1.2%	0	5
0.2-0.29	2	0.5%	0	2	4	1.0%	0	4
0.3-0.39	2	0.5%	0	2	4	1.0%	0	4
0.4-0.49	0	0.0%	0	0	4	1.0%	0	4
0.5-0.59	10	2.4%	0	10	0	0.0%	0	0
0.6-0.69	7	1.7%	1	6	1	0.2%	0	1
0.7-0.79	2	0.5%	0	2	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	1	0.2%	1	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	24		2	22	27		0	27
Average LRFR/LFR	0.85				0.66			



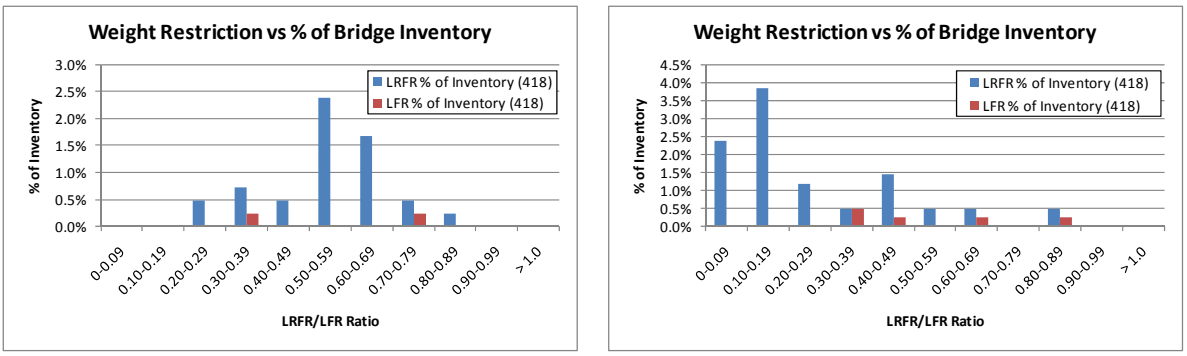
(a) (b)

Figure 20: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 21 and Figure 21 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 21 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASTHO Type 3-3 vehicle is 0.81 for moment and 0.63 for shear.

Table 21: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	10	2.4%	0	10
0.1-0.19	0	0.0%	0	0	16	3.8%	0	16
0.2-0.29	2	0.5%	0	2	5	1.2%	0	5
0.3-0.39	3	0.7%	1	2	2	0.5%	2	0
0.4-0.49	2	0.5%	0	2	6	1.4%	1	5
0.5-0.59	10	2.4%	0	10	2	0.5%	0	2
0.6-0.69	7	1.7%	0	7	2	0.5%	1	1
0.7-0.79	2	0.5%	1	1	0	0.0%	0	0
0.8-0.89	1	0.2%	0	1	2	0.5%	1	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	27		2	25	45		5	40
Average LRFR/LFR	0.81				0.63			



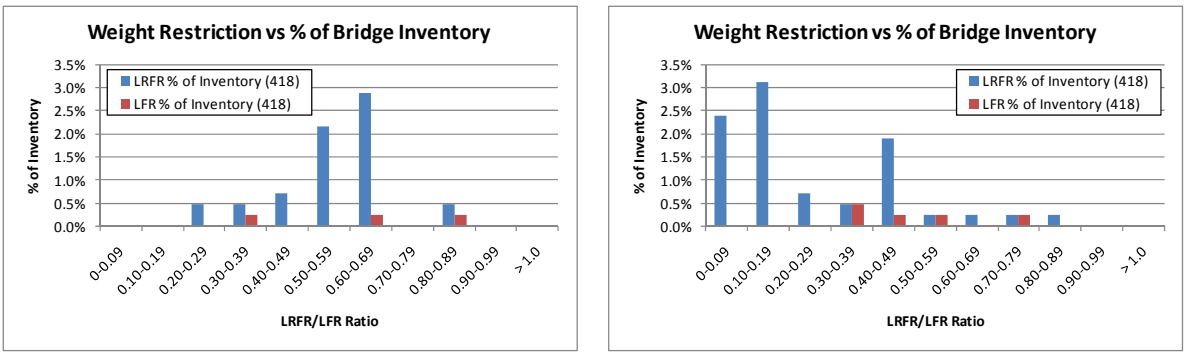
(a) (b)

Figure 21: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

Table 22 and Figure 22 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 22 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASTHO Type 3S2 vehicle is 0.82 for moment and 0.64 for shear.

Table 22: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	10	2.4%	0	10
0.1-0.19	0	0.0%	0	0	13	3.1%	0	13
0.2-0.29	2	0.5%	0	2	3	0.7%	0	3
0.3-0.39	2	0.5%	1	1	2	0.5%	2	0
0.4-0.49	3	0.7%	0	3	8	1.9%	1	7
0.5-0.59	9	2.2%	0	9	1	0.2%	1	0
0.6-0.69	12	2.9%	1	11	1	0.2%	0	1
0.7-0.79	0	0.0%	0	0	1	0.2%	1	0
0.8-0.89	2	0.5%	1	1	1	0.2%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	30		3	27	40		5	35
Average LRFR/LFR	0.82				0.64			



(a) (b)

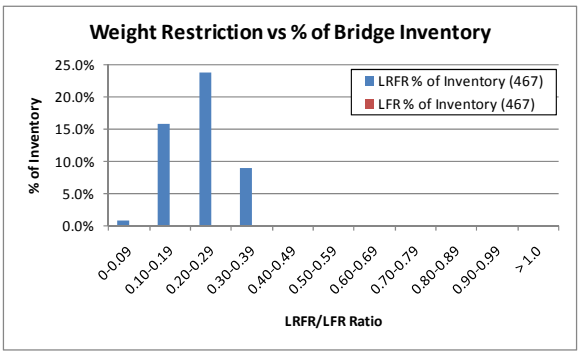
Figure 22: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

L.3 Simple Span Prestressed I-Girder Bridges

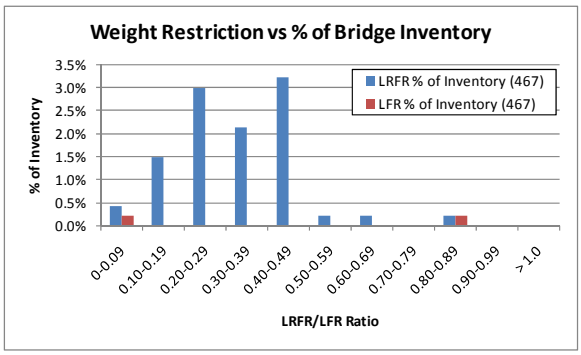
Table 23 and Figure 23 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 23 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the DE-07 vehicle is 0.30 for moment and 0.79 for shear.

Table 23: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	4	0.9%	0	4	2	0.4%	1	1
0.1-0.19	74	15.9%	0	74	7	1.5%	0	7
0.2-0.29	111	23.8%	0	111	14	3.0%	0	14
0.3-0.39	42	9.0%	0	42	10	2.1%	0	10
0.4-0.49	0	0.0%	0	0	15	3.2%	0	15
0.5-0.59	0	0.0%	0	0	1	0.2%	0	1
0.6-0.69	0	0.0%	0	0	1	0.2%	0	1
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	1	0.2%	1	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	231		0	231	51		2	49
Average LRFR/LFR	0.30				0.79			



(a)



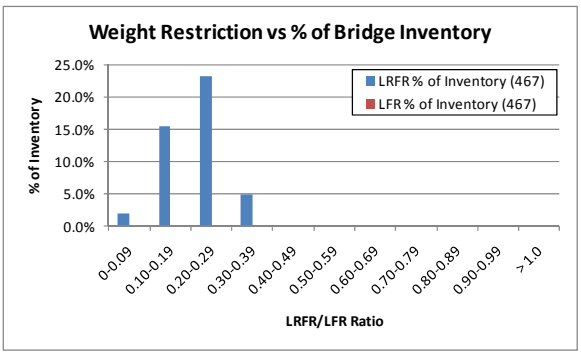
(b)

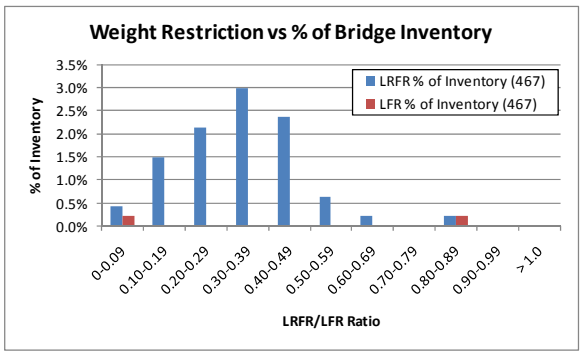
Figure 23: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

Table 24 and Figure 24 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 24 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the FL-04 vehicle is 0.29 for moment and 0.81 for shear.

Table 24: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	9	1.9%	0	9	2	0.4	1	1
0.1-0.19	72	15.4%	0	72	7	1.5	0	7
0.2-0.29	108	23.1%	0	108	10	2.1	0	10
0.3-0.39	23	4.9%	0	23	14	3.0	0	14
0.4-0.49	0	0.0%	0	0	11	2.4	0	11
0.5-0.59	0	0.0%	0	0	3	0.6	0	3
0.6-0.69	0	0.0%	0	0	1	0.2	0	1
0.7-0.79	0	0.0%	0	0	0	0.0	0	0
0.8-0.89	0	0.0%	0	0	1	0.2	1	0
0.9-0.99	0	0.0%	0	0	0	0.0	0	0
> 1.00	0	0.0%	0	0	0	0.0	0	0
Total	212		0	212	49		2	47
Average LRFR/LFR	0.29				0.81			





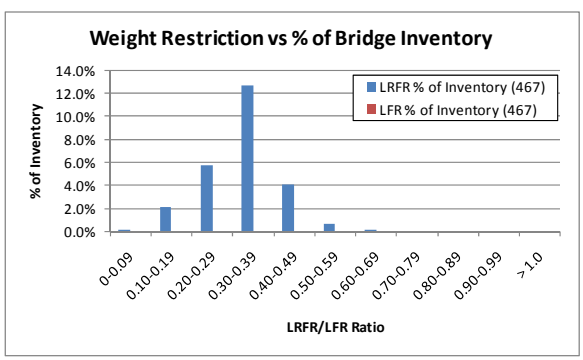
(a) (b)

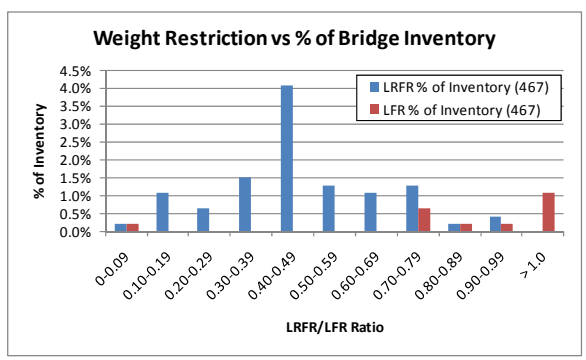
Figure 24: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 25 and Figure 25 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 25 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the IL-01 vehicle is 0.52 for moment and 1.08 for shear.

Table 25: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.2%	0	1	1	0.2%	1	0
0.1-0.19	10	2.1%	0	10	5	1.1%	0	5
0.2-0.29	27	5.8%	0	27	3	0.6%	0	3
0.3-0.39	59	12.6%	0	59	7	1.5%	0	7
0.4-0.49	19	4.1%	0	19	19	4.1%	0	19
0.5-0.59	3	0.6%	0	3	6	1.3%	0	6
0.6-0.69	1	0.2%	0	1	5	1.1%	0	5
0.7-0.79	0	0.0%	0	0	6	1.3%	3	3
0.8-0.89	0	0.0%	0	0	1	0.2%	1	0
0.9-0.99	0	0.0%	0	0	2	0.4%	1	1
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	120		0	120	55		6	49
Average LRFR/LFR	0.52				1.08			





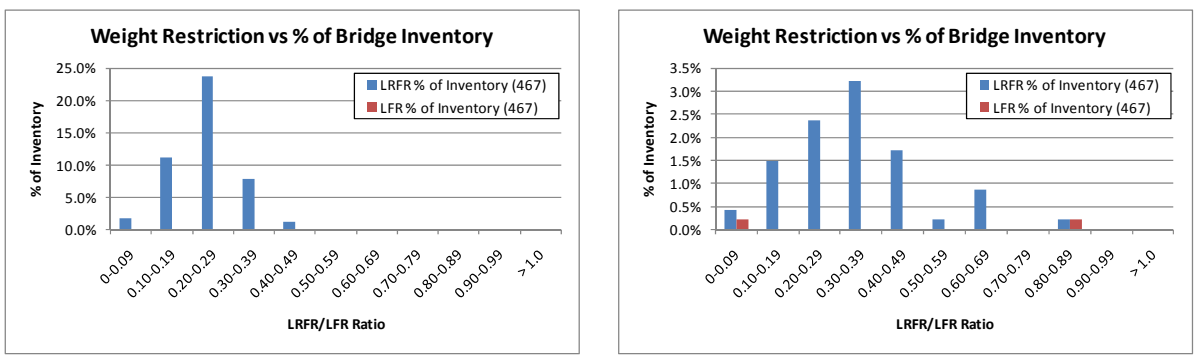
(a) (b)

Figure 25: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

Table 26 and Figure 26 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 26 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NC-21 vehicle is 0.31 for moment and 0.82 for shear.

Table 26: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	8	1.7%	0	8	2	0.4%	1	1
0.1-0.19	52	11.1%	0	52	7	1.5%	0	7
0.2-0.29	111	23.8%	0	111	11	2.4%	0	11
0.3-0.39	37	7.9%	0	37	15	3.2%	0	15
0.4-0.49	6	1.3%	0	6	8	1.7%	0	8
0.5-0.59	0	0.0%	0	0	1	0.2%	0	1
0.6-0.69	0	0.0%	0	0	4	0.9%	0	4
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	1	0.2%	1	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	214		0	214	49		2	47
Average LRFR/LFR	0.31				0.82			



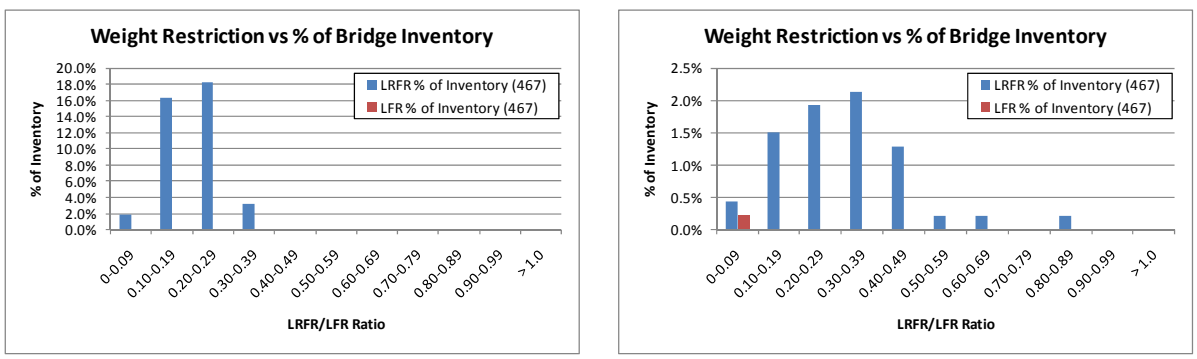
(a) (b)

Figure 26: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 27 and Figure 27 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 27 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NM-04 vehicle is 0.28 for moment and 0.83 for shear.

Table 27: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	9	1.9%	0	9	2	0.4%	1	1
0.1-0.19	76	16.3%	0	76	7	1.5%	0	7
0.2-0.29	85	18.2%	0	85	9	1.9%	0	9
0.3-0.39	15	3.2%	0	15	10	2.1%	0	10
0.4-0.49	0	0.0%	0	0	6	1.3%	0	6
0.5-0.59	0	0.0%	0	0	1	0.2%	0	1
0.6-0.69	0	0.0%	0	0	1	0.2%	0	1
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	1	0.2%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	185		0	185	37		1	36
Average LRFR/LFR	0.28				0.83			



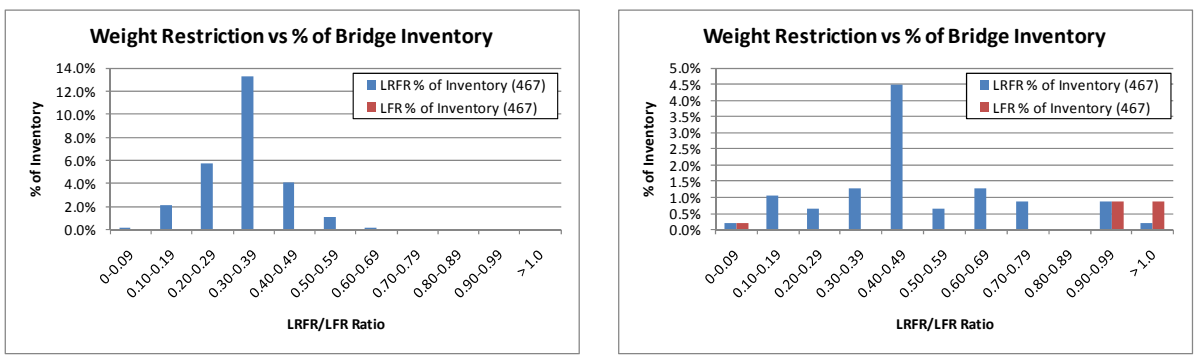
(a) (b)

Figure 27: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 28 and Figure 28 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 28 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the OR-06 vehicle is 0.52 for moment and 1.07 for shear.

Table 28: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.21%	0	1	1	0.21%	1	0
0.1-0.19	10	2.1%	0	10	5	1.1%	0	5
0.2-0.29	27	5.8%	0	27	3	0.6%	0	3
0.3-0.39	62	13.3%	0	62	6	1.3%	0	6
0.4-0.49	19	4.1%	0	19	21	4.5%	0	21
0.5-0.59	5	1.1%	0	5	3	0.6%	0	3
0.6-0.69	1	0.2%	0	1	6	1.3%	0	6
0.7-0.79	0	0.0%	0	0	4	0.9%	0	4
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	4	0.9%	4	0
> 1.00	0	0.0%	0	0	1	0.2%	1	0
Total	125		0	125	54		6	48
Average LRFR/LFR	0.52				1.07			



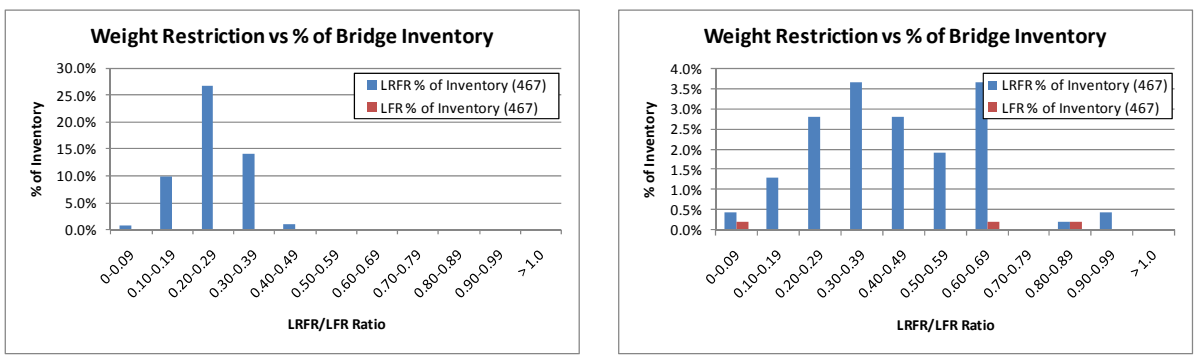
(a) (b)

Figure 28: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 29 and Figure 29 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 29 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the TX-04 vehicle is 0.31 for moment and 0.80 for shear.

Table 29: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	4	0.9%	0	4	2	0.4	1	1
0.1-0.19	46	9.9%	0	46	6	1.3	0	6
0.2-0.29	125	26.8%	0	125	13	2.8	0	13
0.3-0.39	66	14.1%	0	66	17	3.6	0	17
0.4-0.49	5	1.1%	0	5	13	2.8	0	13
0.5-0.59	0	0.0%	0	0	9	1.9	0	9
0.6-0.69	0	0.0%	0	0	17	3.6	1	16
0.7-0.79	0	0.0%	0	0	0	0.0	0	0
0.8-0.89	0	0.0%	0	0	1	0.2	1	0
0.9-0.99	0	0.0%	0	0	2	0.4	0	2
> 1.00	0	0.0%	0	0	0	0.0	0	0
Total	246		0	246	80		3	77
Average LRFR/LFR	0.31				0.80			



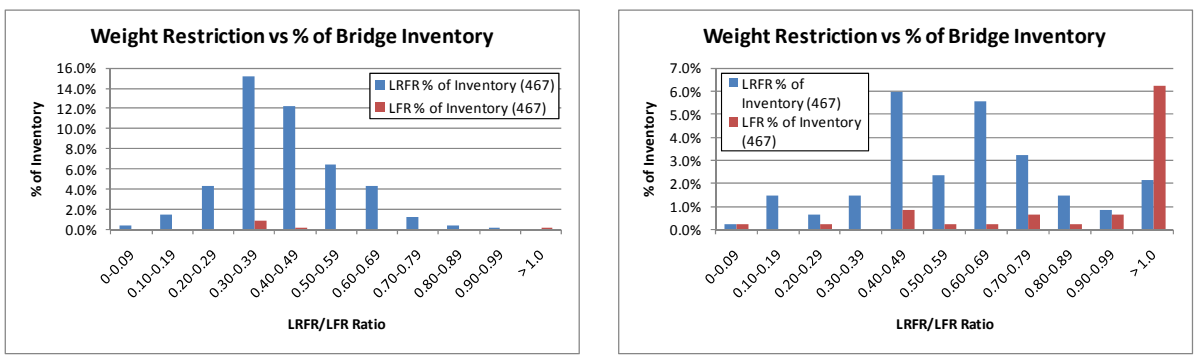
(a) (b)

Figure 29: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 30 and Figure 30 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 30 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the WA-02 vehicle is 0.56 for moment and 1.00 for shear.

Table 30: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.4%	0	2	1	0.2%	1	0
0.1-0.19	7	1.5%	0	7	7	1.5%	0	7
0.2-0.29	20	4.3%	0	20	3	0.6%	1	2
0.3-0.39	71	15.2%	4	67	7	1.5%	0	7
0.4-0.49	57	12.2%	1	56	28	6.0%	4	24
0.5-0.59	30	6.4%	0	30	11	2.4%	1	10
0.6-0.69	20	4.3%	0	20	26	5.6%	1	25
0.7-0.79	6	1.3%	0	6	15	3.2%	3	12
0.8-0.89	2	0.4%	0	2	7	1.5%	1	6
0.9-0.99	1	0.2%	0	1	4	0.9%	3	1
> 1.00	0	0.0%	0	0	10	2.1%	10	0
Total	216		5	211	119		25	94
Average LRFR/LFR	0.56				1.00			



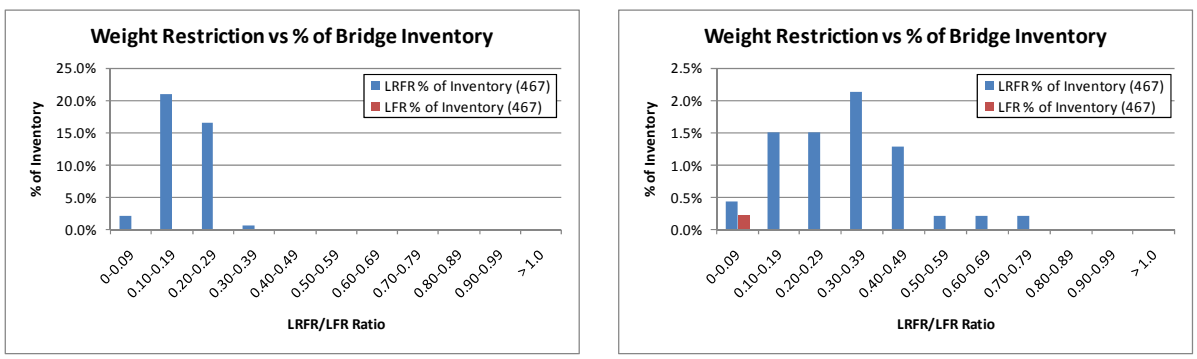
(a) (b)

Figure 30: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 31 and Figure 31 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 31 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3 vehicle is 0.26 for moment and 0.81 for shear.

Table 31: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	10	2.1%	0	10	2	0.4%	1	1
0.1-0.19	98	21.0%	0	98	7	1.5%	0	7
0.2-0.29	77	16.5%	0	77	7	1.5%	0	7
0.3-0.39	3	0.6%	0	3	10	2.1%	0	10
0.4-0.49	0	0.0%	0	0	6	1.3%	0	6
0.5-0.59	0	0.0%	0	0	1	0.2%	0	1
0.6-0.69	0	0.0%	0	0	1	0.2%	0	1
0.7-0.79	0	0.0%	0	0	1	0.2%	0	1
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	188		0	188	35		1	34
Average LRFR/LFR	0.26				0.81			



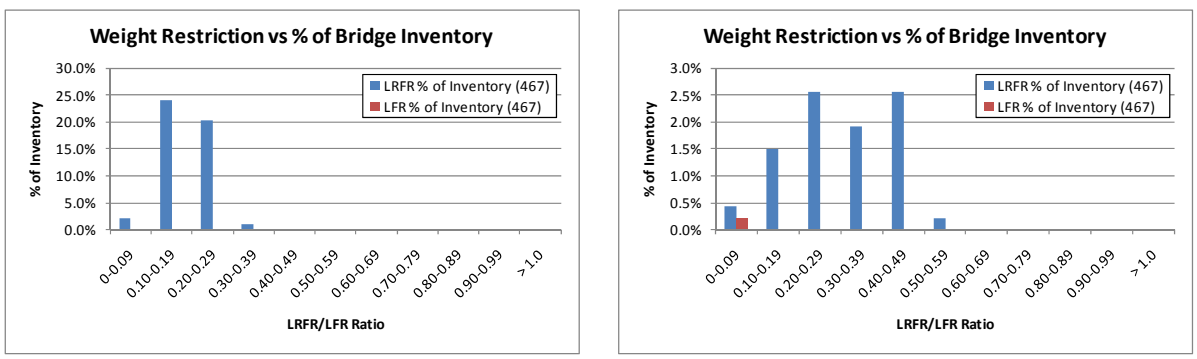
(a) (b)

Figure 31: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 32 and Figure 32 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 32 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3-3 vehicle is 0.25 for moment and 0.78 for shear.

Table 32: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	10	2.1%	0	10	2	0.4%	1	1
0.1-0.19	112	24.0%	0	112	7	1.5%	0	7
0.2-0.29	95	20.3%	0	95	12	2.6%	0	12
0.3-0.39	5	1.1%	0	5	9	1.9%	0	9
0.4-0.49	0	0.0%	0	0	12	2.6%	0	12
0.5-0.59	0	0.0%	0	0	1	0.2%	0	1
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	222		0	222	43		1	42
Average LRFR/LFR	0.25				0.78			



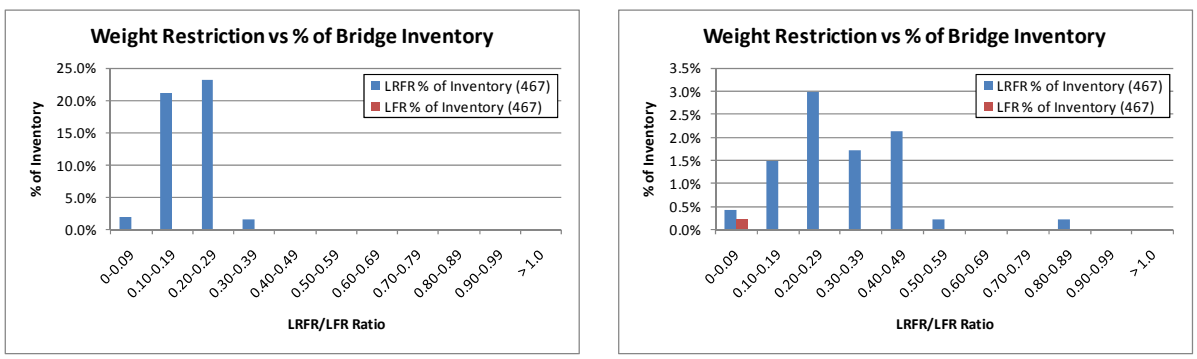
(a) (b)

Figure 32: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

Table 33 and Figure 33 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 33 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3S2 vehicle is 0.26 for moment and 0.77 for shear.

Table 33: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	9	1.9%	0	9	2	0.4%	1	1
0.1-0.19	99	21.2%	0	99	7	1.5%	0	7
0.2-0.29	108	23.1%	0	108	14	3.0%	0	14
0.3-0.39	7	1.5%	0	7	8	1.7%	0	8
0.4-0.49	0	0.0%	0	0	10	2.1%	0	10
0.5-0.59	0	0.0%	0	0	1	0.2%	0	1
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	1	0.2%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	223		0	223	43		1	42
Average LRFR/LFR	0.26				0.77			



(a) (b)

Figure 33: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

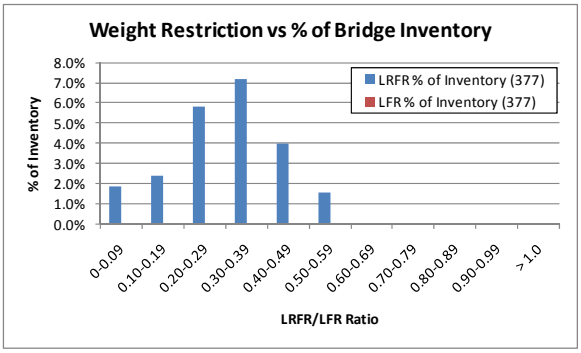
L.4 Simple Span Prestressed Box Girder Bridges

Table 34 and Figure 34 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 34 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the DE-07 vehicle is 0.48 for moment and 1.04 for shear.

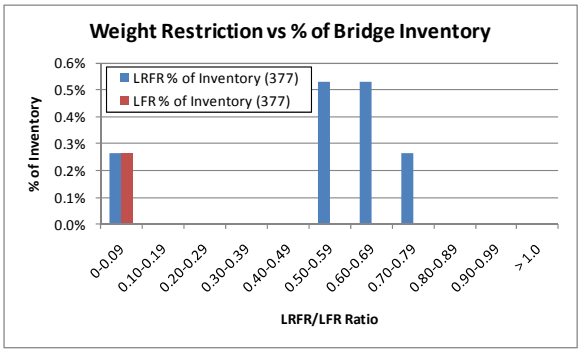
Table 34: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0

0.1-0.19	9	2.4%	0	9	0	0.0%	0	0
0.2-0.29	22	5.8%	0	22	0	0.0%	0	0
0.3-0.39	27	7.2%	0	27	0	0.0%	0	0
0.4-0.49	15	4.0%	0	15	0	0.0%	0	0
0.5-0.59	6	1.6%	0	6	2	0.5%	0	2
0.6-0.69	0	0.0%	0	0	2	0.5%	0	2
0.7-0.79	0	0.0%	0	0	1	0.3%	0	1
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	86		0	86	6		1	5
Average LRFR/LFR	0.48				1.04			



(a)



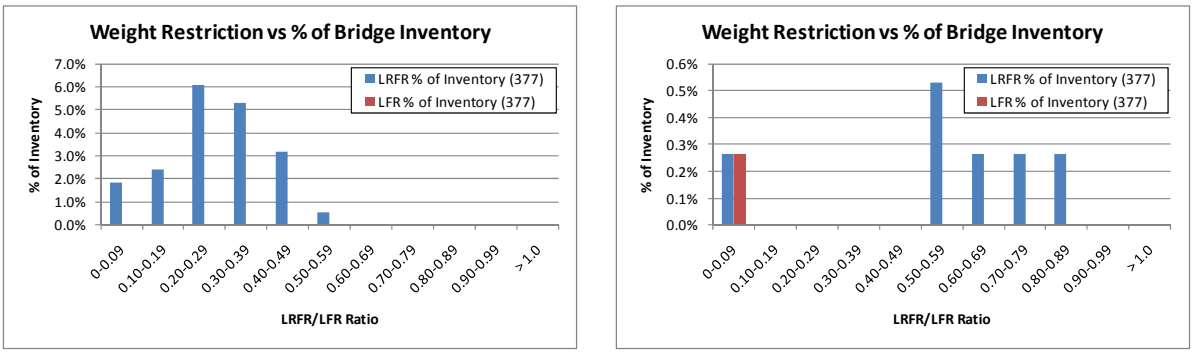
(b)

Figure 34: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

Table 35 and Figure 35 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 35 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the FL-04 vehicle is 0.48 for moment and 1.06 for shear.

Table 35: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	9	2.4%	0	9	0	0.0%	0	0
0.2-0.29	23	6.1%	0	23	0	0.0%	0	0
0.3-0.39	20	5.3%	0	20	0	0.0%	0	0
0.4-0.49	12	3.2%	0	12	0	0.0%	0	0
0.5-0.59	2	0.5%	0	2	2	0.5%	0	2
0.6-0.69	0	0.0%	0	0	1	0.3%	0	1
0.7-0.79	0	0.0%	0	0	1	0.3%	0	1
0.8-0.89	0	0.0%	0	0	1	0.3%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	73		0	86	6		1	5
Average LRFR/LFR	0.48				1.06			



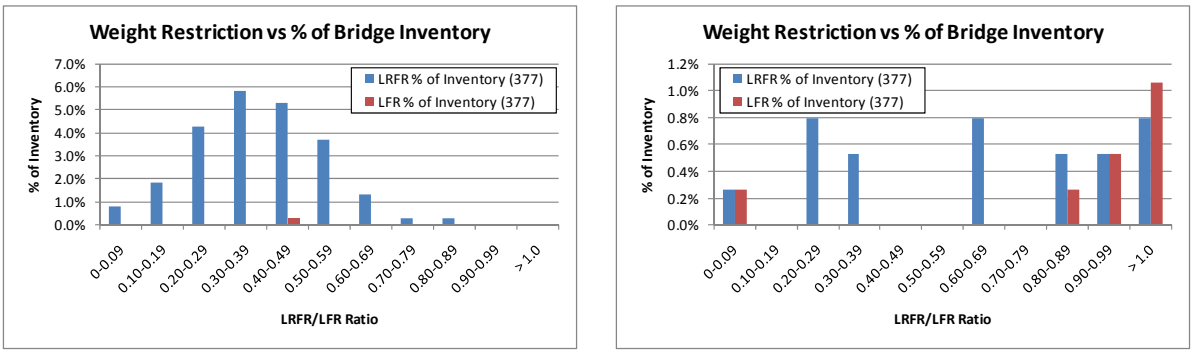
(a) (b)

Figure 35: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 36 and Figure 36 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 36 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the IL-01 vehicle is 0.64 for moment and 1.30 for shear.

Table 36: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	3	0.8%	0	3	1	0.3%	1	0
0.1-0.19	7	1.9%	0	7	0	0.0%	0	0
0.2-0.29	16	4.2%	0	16	3	0.8%	0	3
0.3-0.39	22	5.8%	0	22	2	0.5%	0	2
0.4-0.49	20	5.3%	1	19	0	0.0%	0	0
0.5-0.59	14	3.7%	0	14	0	0.0%	0	0
0.6-0.69	5	1.3%	0	5	3	0.8%	0	3
0.7-0.79	1	0.3%	0	1	0	0.0%	0	0
0.8-0.89	1	0.3%	0	1	2	0.5%	1	1
0.9-0.99	0	0.0%	0	0	2	0.5%	2	0
> 1.00	0	0.0%	0	0	3	0.8%	3	0
Total	89		1	88	16		7	9
Average LRFR/LFR	0.64				1.30			



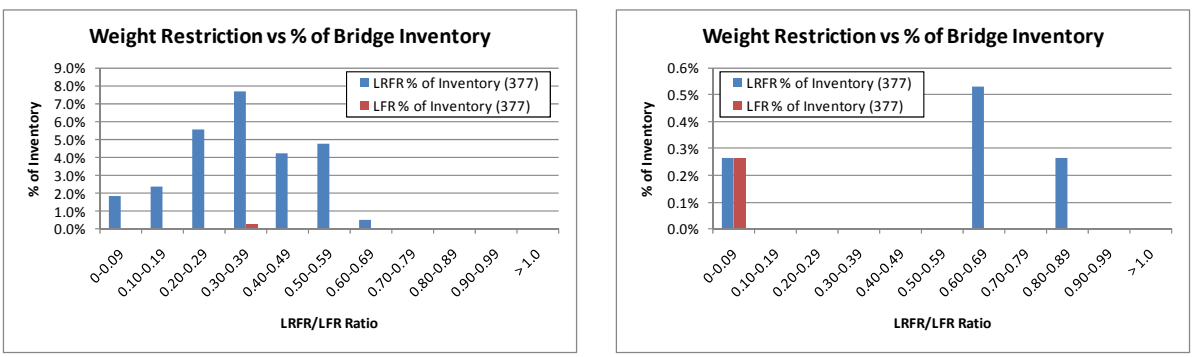
(a) (b)

Figure 36: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

Table 37 and Figure 37 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 37 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NC-21 vehicle is 0.49 for moment and 1.07 for shear.

Table 37: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	1
0.1-0.19	9	2.4%	0	9	0	0.0%	0	0
0.2-0.29	21	5.6%	0	21	0	0.0%	0	0
0.3-0.39	29	7.7%	1	28	0	0.0%	0	0
0.4-0.49	16	4.2%	0	16	0	0.0%	0	0
0.5-0.59	18	4.8%	0	18	0	0.0%	0	0
0.6-0.69	2	0.5%	0	2	2	0.5%	0	2
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	1	0.3%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	102		1	101	4		1	4
Average LRFR/LFR	0.49				1.07			



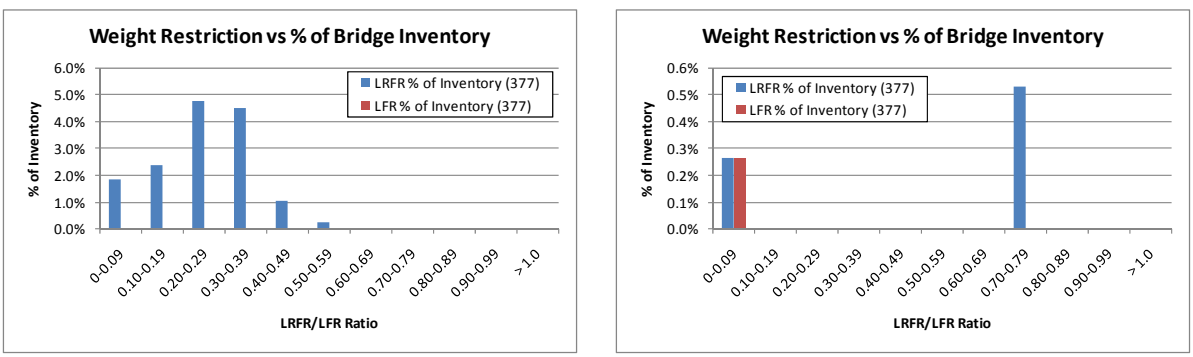
(a) (b)

Figure 37: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 38 and Figure 38 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 38 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NM-04 vehicle is 0.48 for moment and 1.11 for shear.

Table 38: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	9	2.4%	0	9	0	0.0%	0	0
0.2-0.29	18	4.8%	0	18	0	0.0%	0	0
0.3-0.39	17	4.5%	0	17	0	0.0%	0	0
0.4-0.49	4	1.1%	0	4	0	0.0%	0	0
0.5-0.59	1	0.3%	0	1	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	2	0.5%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	56		0	56	3		1	0
Average LRFR/LFR	0.48				1.11			



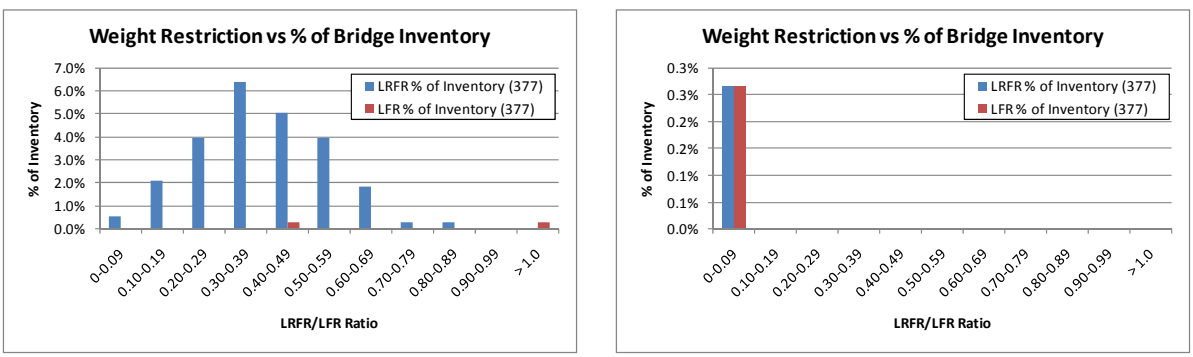
(a) (b)

Figure 38: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 39 and Figure 39 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 39 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the OR-06 vehicle is 0.65 for moment and 1.58 for shear.

Table 39: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.5%	0	2	1	0.3%	1	0
0.1-0.19	8	2.1%	0	8	0	0.0%	0	0
0.2-0.29	15	4.0%	0	15	0	0.0%	0	0
0.3-0.39	24	6.4%	0	24	0	0.0%	0	0
0.4-0.49	19	5.0%	1	18	0	0.0%	0	0
0.5-0.59	15	4.0%	0	15	0	0.0%	0	0
0.6-0.69	7	1.9%	0	7	0	0.0%	0	0
0.7-0.79	1	0.3%	0	1	0	0.0%	0	0
0.8-0.89	1	0.3%	0	1	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	92		1	91	1		1	0
Average LRFR/LFR	0.65				1.58			



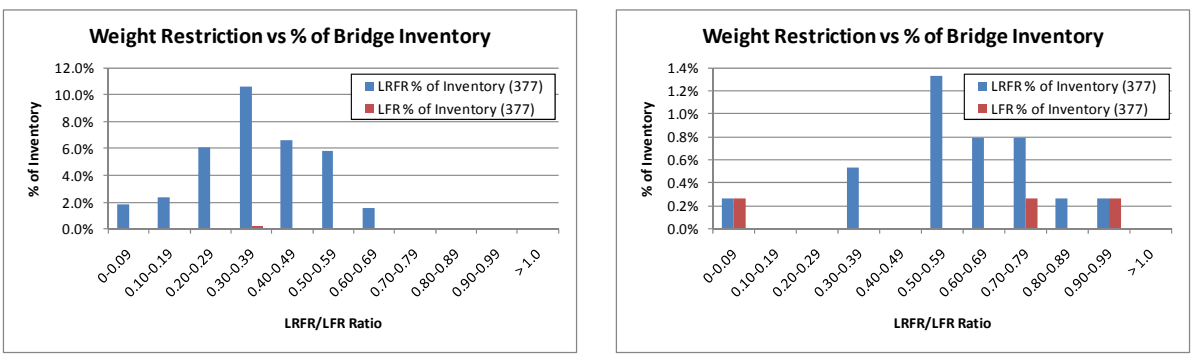
(a) (b)

Figure 39: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 40 and Figure 40 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 40 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the TX-04 vehicle is 0.49 for moment and 0.99 for shear.

Table 40: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	9	2.4%	0	9	0	0.0%	0	0
0.2-0.29	23	6.1%	0	23	0	0.0%	0	0
0.3-0.39	40	10.6%	1	39	2	0.5%	0	2
0.4-0.49	25	6.6%	0	25	0	0.0%	0	0
0.5-0.59	22	5.8%	0	22	5	1.3%	0	5
0.6-0.69	6	1.6%	0	6	3	0.8%	0	3
0.7-0.79	0	0.0%	0	0	3	0.8%	2	2
0.8-0.89	0	0.0%	0	0	1	0.3%	1	1
0.9-0.99	0	0.0%	0	0	1	0.3%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	132		1	131	16		4	13
Average LRFR/LFR	0.49				0.99			



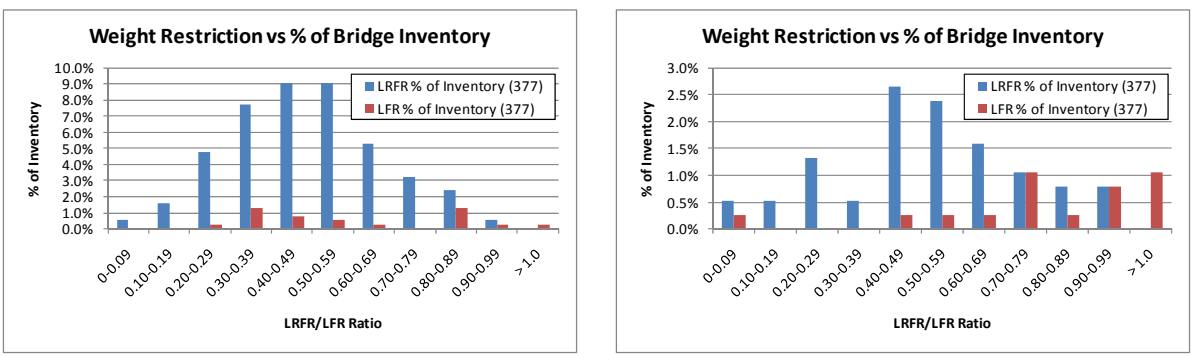
(a) (b)

Figure 40: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 41 and Figure 41 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 41 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the WA-02 vehicle is 0.65 for moment and 1.18 for shear.

Table 41: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.5%	0	2	2	0.5%	1	1
0.1-0.19	6	1.6%	0	6	2	0.5%	0	2
0.2-0.29	18	4.8%	1	17	5	1.3%	0	5
0.3-0.39	29	7.7%	5	24	2	0.5%	0	2
0.4-0.49	34	9.0%	3	31	10	2.7%	1	9
0.5-0.59	34	9.0%	2	32	9	2.4%	1	8
0.6-0.69	20	5.3%	1	19	6	1.6%	1	5
0.7-0.79	12	3.2%	0	12	4	1.1%	4	0
0.8-0.89	9	2.4%	5	4	3	0.8%	1	2
0.9-0.99	2	0.5%	1	1	3	0.8%	3	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	166		18	148	46		12	34
Average LRFR/LFR	0.65				1.18			



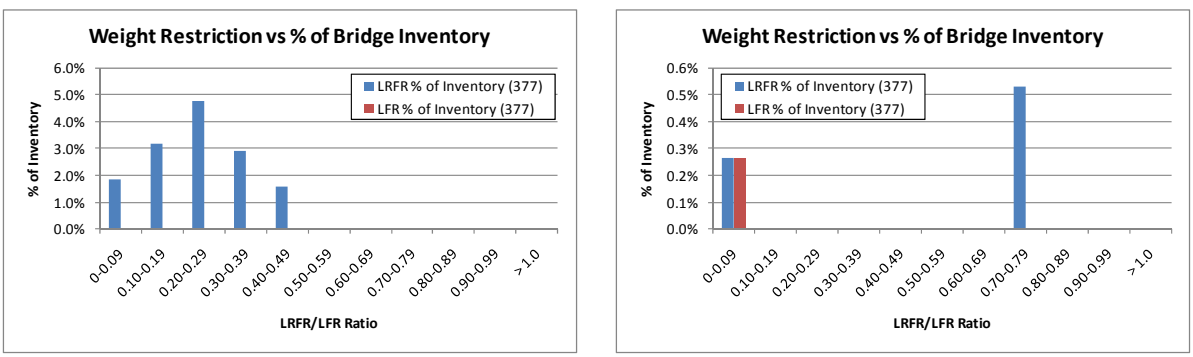
(a) (b)

Figure 41: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 42 and Figure 42 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 42 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3 vehicle is 0.46 for moment and 1.06 for shear.

Table 42: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	12	3.2%	0	12	0	0.0%	0	0
0.2-0.29	18	4.8%	0	18	0	0.0%	0	0
0.3-0.39	11	2.9%	0	11	0	0.0%	0	0
0.4-0.49	6	1.6%	0	6	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	2	0.5%	0	2
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	54		0	54	3		1	2
Average LRFR/LFR	0.46				1.06			



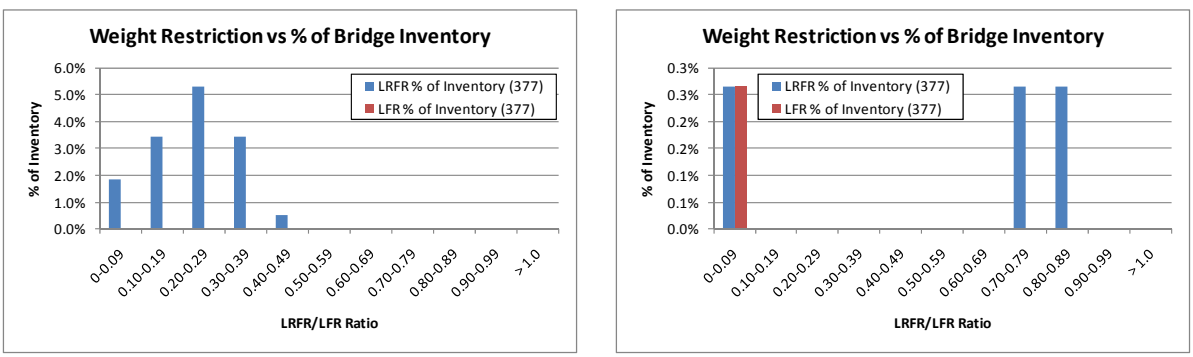
(a) (b)

Figure 42: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 43 and Figure 43 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 43 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3-3 vehicle is 0.44 for moment and 1.05 for shear.

Table 43: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	13	3.5%	0	13	0	0.0%	0	0
0.2-0.29	20	5.3%	0	20	0	0.0%	0	0
0.3-0.39	13	3.5%	0	13	0	0.0%	0	0
0.4-0.49	2	0.5%	0	2	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	1	0.3%	0	1
0.8-0.89	0	0.0%	0	0	1	0.3%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	55		0	55	3		1	2
Average LRFR/LFR	0.44				1.05			



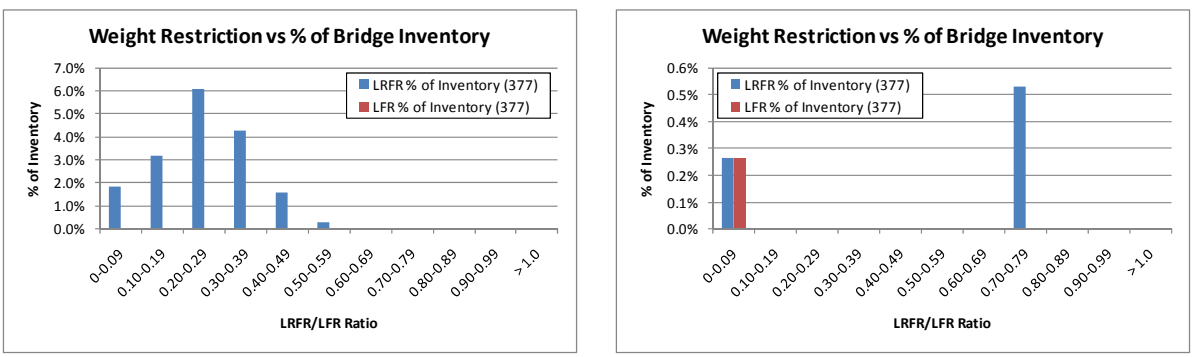
(a) (b)

Figure 43: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

Table 44 and Figure 44 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 44 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3S2 vehicle is 0.45 for moment and 1.03 for shear.

Table 44: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	12	3.2%	0	12	0	0.0%	0	0
0.2-0.29	23	6.1%	0	23	0	0.0%	0	0
0.3-0.39	16	4.2%	0	16	0	0.0%	0	0
0.4-0.49	6	1.6%	0	6	0	0.0%	0	0
0.5-0.59	1	0.3%	0	1	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	2	0.5%	0	2
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	65		0	65	3		1	2
Average LRFR/LFR	0.45				1.03			



(a) (b)

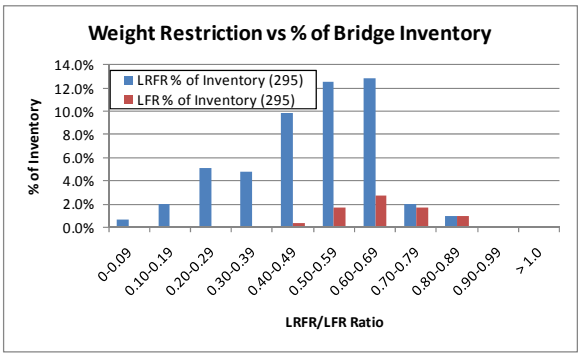
Figure 44: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

L.5 Simple Span Reinforced Concrete Tee-Beam Bridges

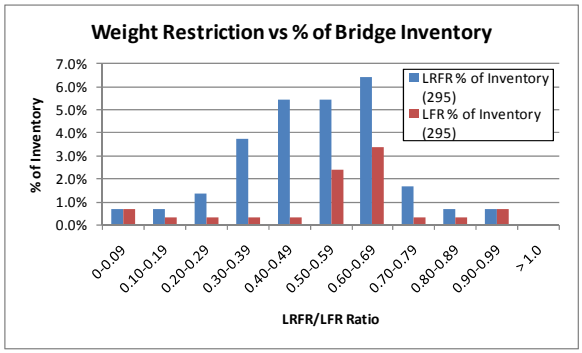
Table 45 and Figure 45 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 45 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the DE-07 vehicle is 0.53 for moment and 0.76 for shear.

Table 45: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	0	2	2	0.7%	2	0
0.1-0.19	6	2.0%	0	6	2	0.7%	1	1
0.2-0.29	15	5.1%	0	15	4	1.4%	1	3
0.3-0.39	14	4.8%	0	14	11	3.7%	1	10
0.4-0.49	29	9.8%	1	28	16	5.4%	1	15
0.5-0.59	37	12.5%	5	32	16	5.4%	7	9
0.6-0.69	38	12.9%	8	30	19	6.4%	10	9
0.7-0.79	6	2.0%	5	1	5	1.7%	1	4
0.8-0.89	3	1.0%	3	0	2	0.7%	1	1
0.9-0.99	0	0.0%	0	0	2	0.7%	2	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	150		22	128	79		27	52
Average LRFR/LFR	0.53				0.76			



(a)



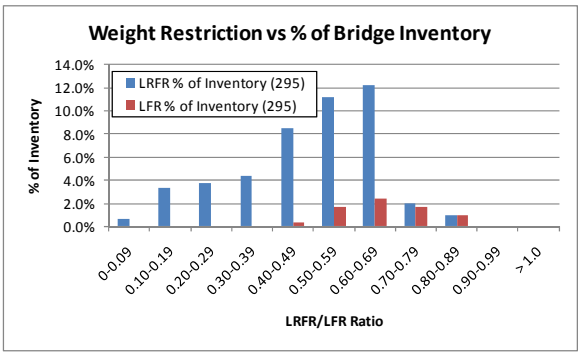
(b)

Figure 45: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

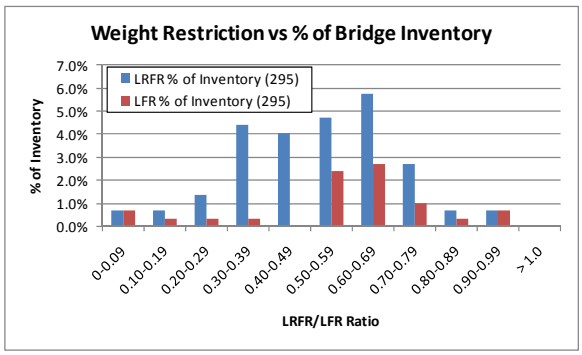
Table 46 and Figure 46 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 46 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the FL-04 vehicle is 0.53 for moment and 0.76 for shear.

Table 46: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	0	2	2	0.7%	2	0
0.1-0.19	10	3.4%	0	10	2	0.7%	1	1
0.2-0.29	11	3.7%	0	11	4	1.4%	1	3
0.3-0.39	13	4.4%	0	13	13	4.4%	1	12
0.4-0.49	25	8.5%	1	24	12	4.1%	0	12
0.5-0.59	33	11.2%	5	28	14	4.8%	7	7
0.6-0.69	36	12.2%	7	29	17	5.8%	8	9
0.7-0.79	6	2.0%	5	1	8	2.7%	3	5
0.8-0.89	3	1.0%	3	0	2	0.7%	1	1
0.9-0.99	0	0.0%	0	0	2	0.7%	2	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	139		21	118	76		26	50
Average LRFR/LFR	0.53				0.76			



(a)



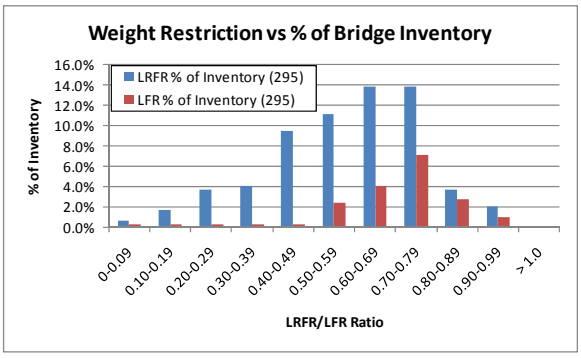
(b)

Figure 46: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

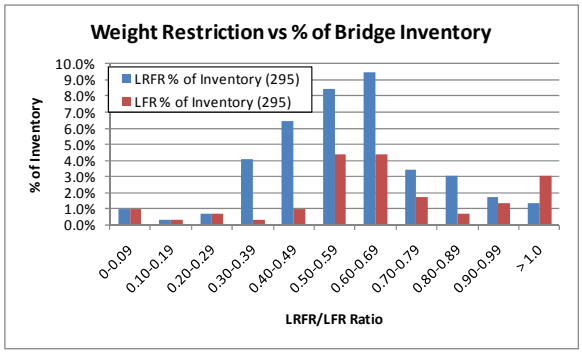
Table 47 and Figure 47 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 47 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the IL-01 vehicle is 0.62 for moment and 0.80 for shear.

Table 47: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	1	1	3	1.0%	3	0
0.1-0.19	5	1.7%	1	4	1	0.3%	1	0
0.2-0.29	11	3.7%	1	10	2	0.7%	2	0
0.3-0.39	12	4.1%	1	11	12	4.1%	1	11
0.4-0.49	28	9.5%	1	27	19	6.4%	3	16
0.5-0.59	33	11.2%	7	26	25	8.5%	13	12
0.6-0.69	41	13.9%	12	29	28	9.5%	13	15
0.7-0.79	41	13.9%	21	20	10	3.4%	5	5
0.8-0.89	11	3.7%	8	3	9	3.1%	2	7
0.9-0.99	6	2.0%	3	3	5	1.7%	4	1
> 1.00	0	0.0%	0	0	4	1.4%	4	0
Total	190		56	134	118		51	67
Average LRFR/LFR	0.62				0.80			



(a)



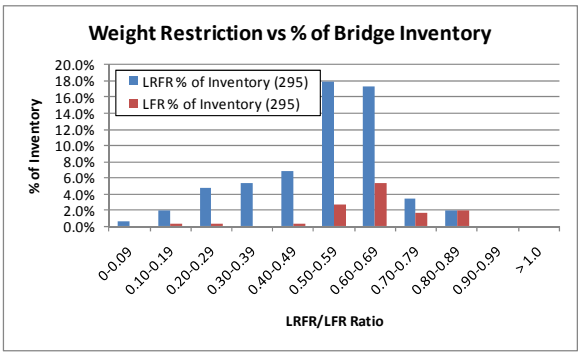
(b)

Figure 47: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

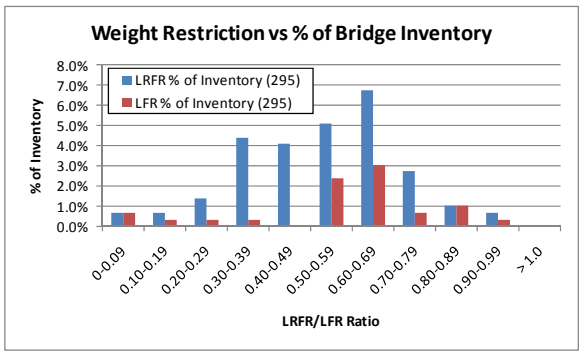
Table 48 and Figure 48 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 48 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NC-21 vehicle is 0.56 for moment and 0.76 for shear.

Table 48: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	0	2	2	0.7%	2	0
0.1-0.19	6	2.0%	1	5	2	0.7%	1	1
0.2-0.29	14	4.8%	1	13	4	1.4%	1	3
0.3-0.39	16	5.4%	0	16	13	4.4%	1	12
0.4-0.49	20	6.8%	1	19	12	4.1%	0	12
0.5-0.59	53	18.0%	8	45	5	5.1%	7	8
0.6-0.69	51	17.3%	16	35	20	6.8%	9	11
0.7-0.79	10	3.4%	5	5	8	2.7%	2	6
0.8-0.89	6	2.0%	6	0	3	1.0%	3	0
0.9-0.99	0	0.0%	0	0	2	0.7%	1	1
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	178		38	140	71		27	54
Average LRFR/LFR	0.56				0.76			



(a)



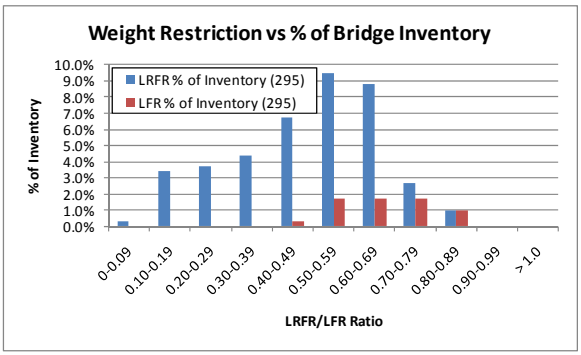
(b)

Figure 48: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

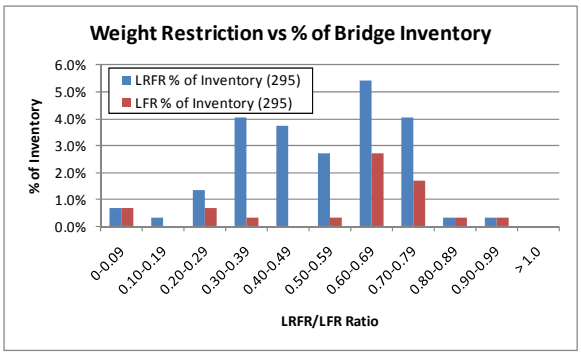
Table 49 and Figure 49 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 49 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NM-04 vehicle is 0.53 for moment and 0.78 for shear.

Table 49: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	2	0.7%	2	0
0.1-0.19	10	3.4%	0	10	1	0.3%	0	1
0.2-0.29	11	3.7%	0	11	4	1.4%	2	2
0.3-0.39	13	4.4%	0	13	12	4.1%	1	11
0.4-0.49	20	6.8%	1	19	11	3.7%	0	11
0.5-0.59	28	9.5%	5	23	8	2.7%	1	7
0.6-0.69	26	8.8%	5	21	16	5.4%	8	8
0.7-0.79	8	2.7%	5	3	12	4.1%	5	7
0.8-0.89	3	1.0%	3	0	1	0.3%	1	0
0.9-0.99	0	0.0%	0	0	1	0.3%	1	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	120		19	101	68		21	47
Average LRFR/LFR	0.53				0.78			



(a)



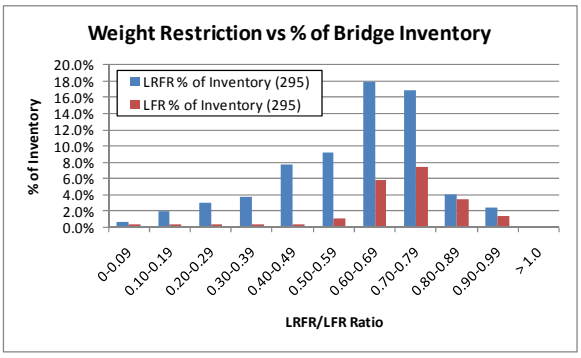
(b)

Figure 49: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

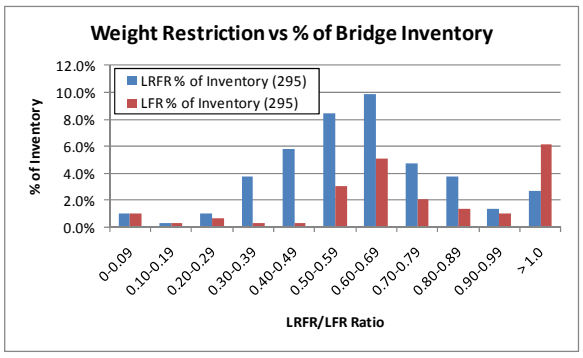
Table 50 and Figure 50 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 50 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the OR-06 vehicle is 0.64 for moment and 0.81 for shear.

Table 50: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	1	1	3	1.0%	3	0
0.1-0.19	6	2.0%	1	5	1	0.3%	1	0
0.2-0.29	9	3.0%	1	8	3	1.0%	2	1
0.3-0.39	11	3.7%	1	10	11	3.7%	1	10
0.4-0.49	23	7.8%	1	22	17	5.8%	1	16
0.5-0.59	27	9.2%	3	24	25	8.5%	9	16
0.6-0.69	53	18.0%	17	36	29	9.8%	15	14
0.7-0.79	50	17.0%	22	28	14	4.8%	6	8
0.8-0.89	12	4.1%	10	2	11	3.7%	4	7
0.9-0.99	7	2.4%	4	3	4	1.4%	3	1
> 1.00	0	0.0%	0	0	8	2.7%	8	0
Total	200		61	139	126		53	73
Average LRFR/LFR	0.64				0.81			



(a)



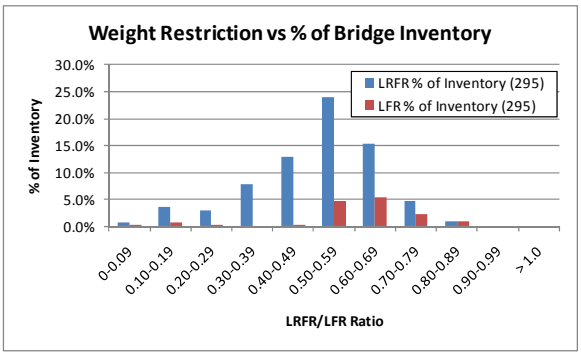
(b)

Figure 50: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

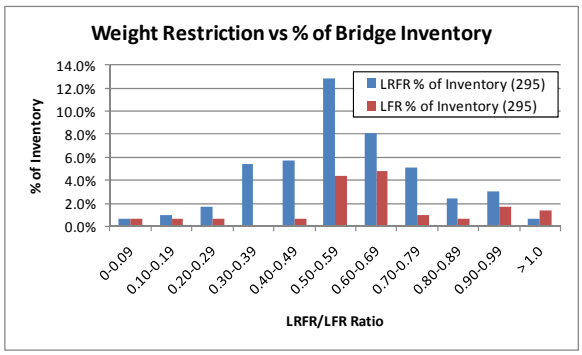
Table 51 and Figure 51 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 51 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the TX-04 vehicle is 0.53 for moment and 0.72 for shear.

Table 51: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	1	1	2	0.7%	2	0
0.1-0.19	11	3.7%	2	9	3	1.0%	2	1
0.2-0.29	9	3.1%	1	8	5	1.7%	2	3
0.3-0.39	23	7.8%	0	23	16	5.4%	0	16
0.4-0.49	38	12.9%	1	37	17	5.8%	2	15
0.5-0.59	71	24.1%	14	57	38	12.9%	13	25
0.6-0.69	45	15.3%	16	29	24	8.1%	14	10
0.7-0.79	14	4.8%	7	7	15	5.1%	3	12
0.8-0.89	3	1.0%	3	0	7	2.4%	2	5
0.9-0.99	0	0.0%	0	0	9	3.1%	5	4
> 1.00	0	0.0%	0	0	2	0.7%	2	0
Total	216		45	171	138		47	91
Average LRFR/LFR	0.53				0.72			



(a)



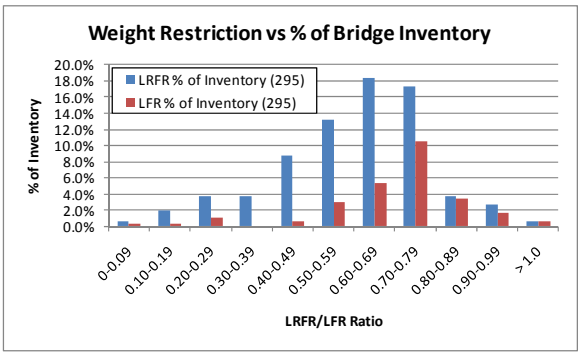
(b)

Figure 51: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

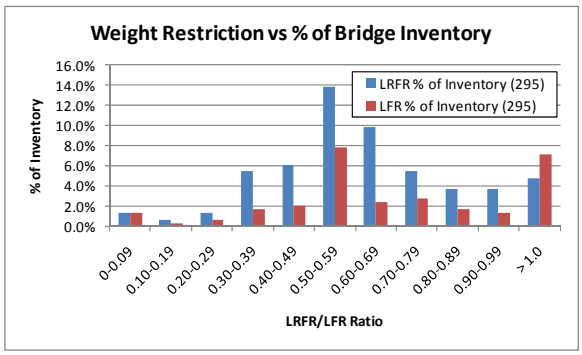
Table 52 and Figure 52 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 52 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the WA-02 vehicle is 0.63 for moment and 0.76 for shear.

Table 52: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	1	1	4	1.4	4	0
0.1-0.19	6	2.0%	1	5	2	0.7	1	1
0.2-0.29	11	3.7%	3	8	4	1.4	2	2
0.3-0.39	11	3.7%	0	11	16	5.4	5	11
0.4-0.49	26	8.8%	2	24	18	6.1	6	12
0.5-0.59	39	13.2%	9	30	41	13.9	23	18
0.6-0.69	54	18.3%	16	38	29	9.8	7	22
0.7-0.79	51	17.3%	31	20	16	5.4	8	8
0.8-0.89	11	3.7%	10	1	11	3.7	5	6
0.9-0.99	8	2.7%	5	3	11	3.7	4	7
> 1.00	2	0.7%	2	0	14	4.8	14	0
Total	221		80	141	166		79	87
Average LRFR/LFR	0.63				0.76			



(a)



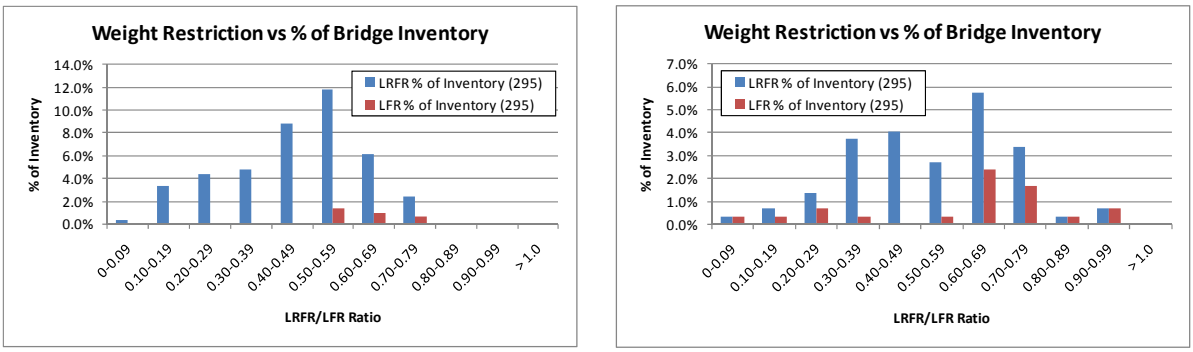
(b)

Figure 52: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 53 and Figure 53 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 53 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3 vehicle is 0.50 for moment and 0.76 for shear.

Table 53: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	1	0.3%	1	0
0.1-0.19	10	3.4%	0	10	2	0.7%	1	1
0.2-0.29	13	4.4%	0	13	4	1.4%	2	2
0.3-0.39	14	4.8%	0	14	11	3.7%	1	10
0.4-0.49	26	8.8%	0	26	12	4.1%	0	12
0.5-0.59	35	11.9%	4	31	8	2.7%	1	7
0.6-0.69	18	6.1%	3	15	17	5.8%	7	10
0.7-0.79	7	2.4%	2	5	10	3.4%	5	5
0.8-0.89	0	0.0%	0	0	1	0.3%	1	0
0.9-0.99	0	0.0%	0	0	2	0.7%	2	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	124		9	115	68		21	47
Average LRFR/LFR	0.50				0.76			



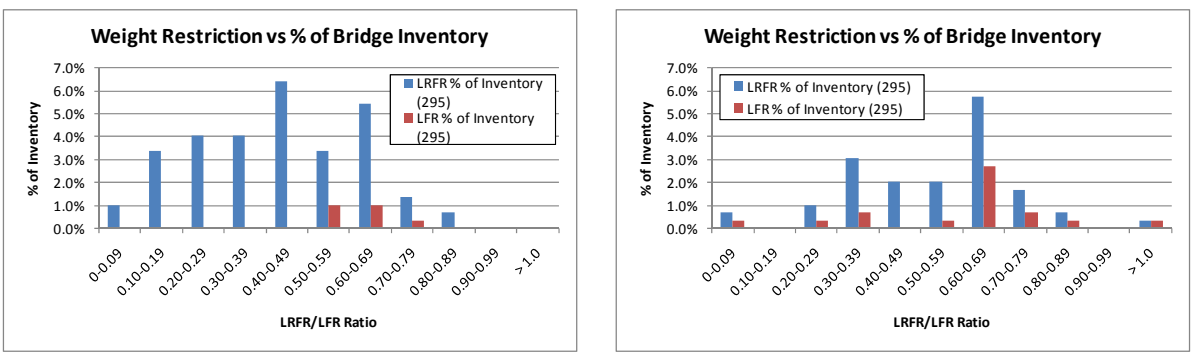
(a) (b)

Figure 53: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 54 and Figure 54 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 54 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3-3 vehicle is 0.49 for moment and 0.78 for shear.

Table 54: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	3	1.0%	0	3	2	0.7%	1	1
0.1-0.19	10	3.4%	0	10	0	0.0%	0	0
0.2-0.29	12	4.1%	0	12	3	1.0%	1	2
0.3-0.39	12	4.1%	0	12	9	3.0%	2	7
0.4-0.49	19	6.4%	0	19	6	2.0%	0	6
0.5-0.59	10	3.4%	3	7	6	2.0%	1	5
0.6-0.69	16	5.4%	3	13	17	5.8%	8	9
0.7-0.79	4	1.4%	1	3	5	1.7%	2	3
0.8-0.89	2	0.7%	0	2	2	0.7%	1	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	1	0.3%	1	0
Total	88		7	81	51		17	34
Average LRFR/LFR	0.49				0.78			



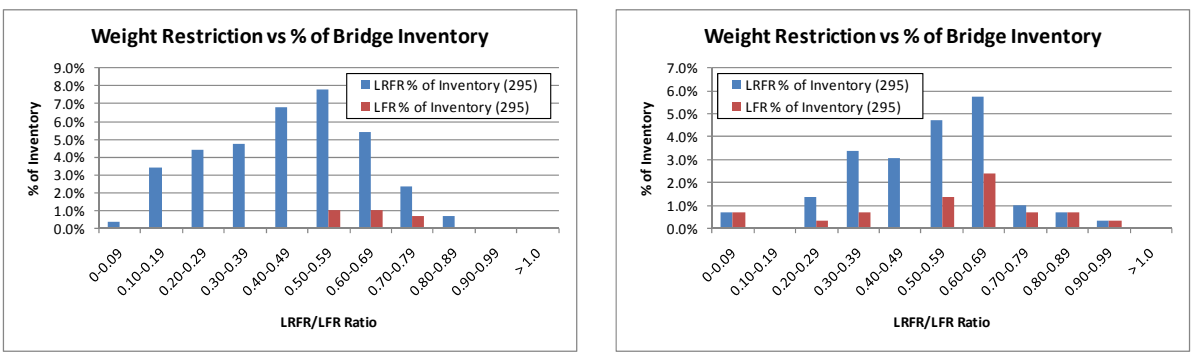
(a) (b)

Figure 54: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

Table 55 and Figure 55 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 55 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3S2 vehicle is 0.50 for moment and 0.77 for shear.

Table 55: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	2	0.7%	2	0
0.1-0.19	10	3.4%	0	10	0	0.0%	0	0
0.2-0.29	13	4.4%	0	13	4	1.4%	1	3
0.3-0.39	14	4.8%	0	14	10	3.4%	2	8
0.4-0.49	20	6.8%	0	20	9	3.1%	0	9
0.5-0.59	23	7.8%	3	20	14	4.8%	4	10
0.6-0.69	16	5.4%	3	13	17	5.8%	7	10
0.7-0.79	7	2.4%	2	5	3	1.0%	2	1
0.8-0.89	2	0.7%	0	2	2	0.7%	2	0
0.9-0.99	0	0.0%	0	0	1	0.3%	1	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	106		8	98	62		21	41
Average LRFR/LFR	0.50				0.77			



(a) (b)

Figure 55: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

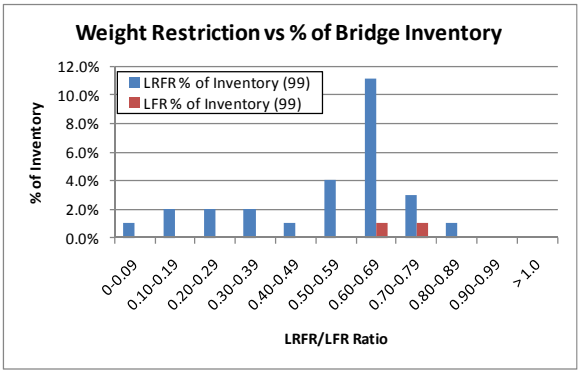
L.6 Simple Span Reinforced Concrete Slab Bridges

Table 56 and Figure 56 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 56 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the DE-07 vehicle is 0.66 for moment and 1.10 for shear.

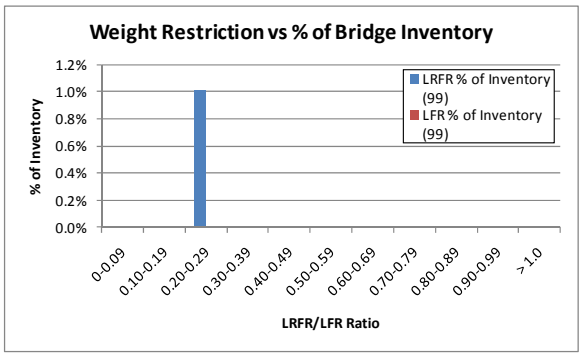
Table 56: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0

0.1-0.19	2	2.0%	0	2	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	1	1.0%	0	1
0.3-0.39	2	2.0%	0	2	0	0.0%	0	0
0.4-0.49	1	1.0%	0	1	0	0.0%	0	0
0.5-0.59	4	4.0%	0	4	0	0.0%	0	0
0.6-0.69	11	11.1%	1	10	0	0.0%	0	0
0.7-0.79	3	3.0%	1	2	0	0.0%	0	0
0.8-0.89	1	1.0%	0	1	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	27		2	25	1		0	1
Average LRFR/LFR	0.66				1.10			



(a)



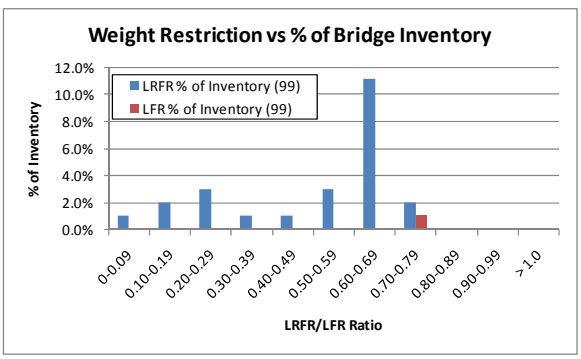
(b)

Figure 56: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

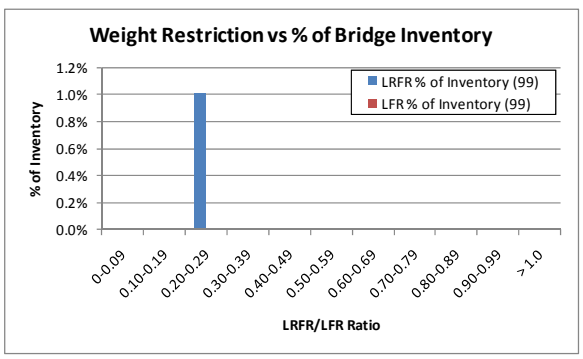
Table 57 and Figure 57 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 57 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the FL-04 vehicle is 0.66 for moment and 1.10 for shear.

Table 57: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.1%	0	1	0	0.0%	0	0
0.1-0.19	2	2.0%	0	2	0	0.0%	0	0
0.2-0.29	3	3.0%	0	3	1	1.0%	0	1
0.3-0.39	1	1.0%	0	1	0	0.0%	0	0
0.4-0.49	1	1.0%	0	1	0	0.0%	0	0
0.5-0.59	3	3.0%	0	3	0	0.0%	0	0
0.6-0.69	11	11.1%	0	11	0	0.0%	0	0
0.7-0.79	2	2.0%	1	1	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	24		1	23	1		0	1
Average LRFR/LFR	0.66				1.10			



(a)



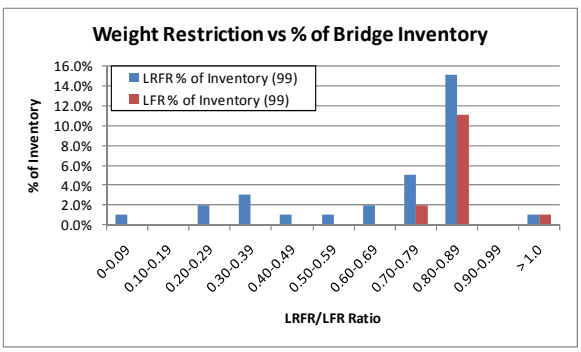
(b)

Figure 57: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

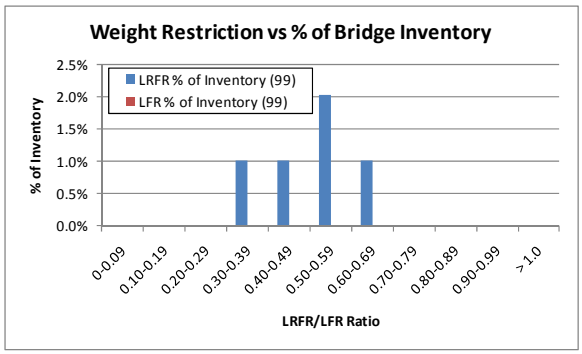
Table 58 and Figure 58 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 58 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the IL-01 vehicle is 0.81 for moment and 1.19 for shear.

Table 58: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	0	0.0%	0	0
0.3-0.39	3	3.0%	0	3	1	1.0%	0	1
0.4-0.49	1	1.0%	0	1	1	1.0%	0	1
0.5-0.59	1	1.0%	0	1	2	2.0%	0	2
0.6-0.69	2	2.0%	0	2	1	1.0%	0	1
0.7-0.79	5	5.1%	2	3	0	0.0%	0	0
0.8-0.89	15	15.2%	11	4	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	1	1.0%	1	0	0	0.0%	0	0
Total	31		14	17	5		51	5
Average LRFR/LFR	0.81				1.19			



(a)



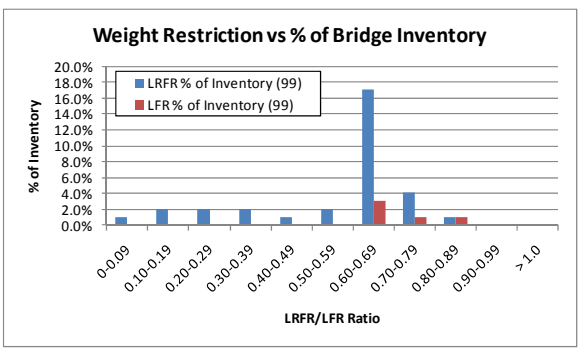
(b)

Figure 58: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

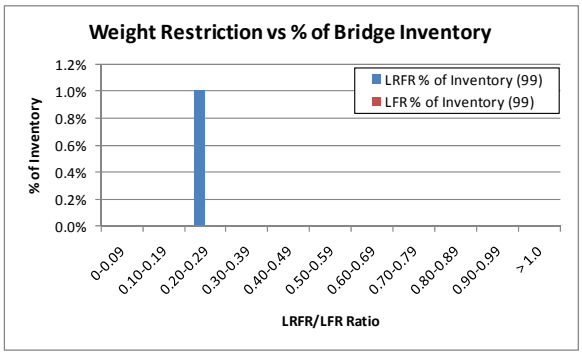
Table 59 and Figure 59 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 59 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NC-21 vehicle is 0.67 for moment and 1.08 for shear.

Table 59: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	2	2.0%	0	2	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	1	1.0%	0	1
0.3-0.39	2	2.0%	0	2	0	0.0%	0	0
0.4-0.49	1	1.0%	0	1	0	0.0%	0	0
0.5-0.59	2	2.0%	0	2	0	0.0%	0	0
0.6-0.69	17	17.2%	3	14	0	0.0%	0	0
0.7-0.79	4	4.0%	1	3	0	0.0%	0	0
0.8-0.89	1	1.0%	1	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	32		5	27	1		0	1
Average LRFR/LFR	0.67				1.08			



(a)



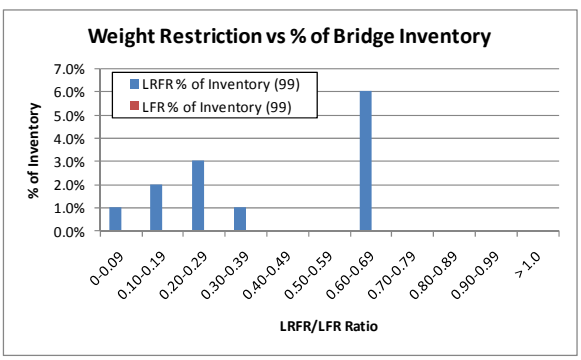
(b)

Figure 59: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

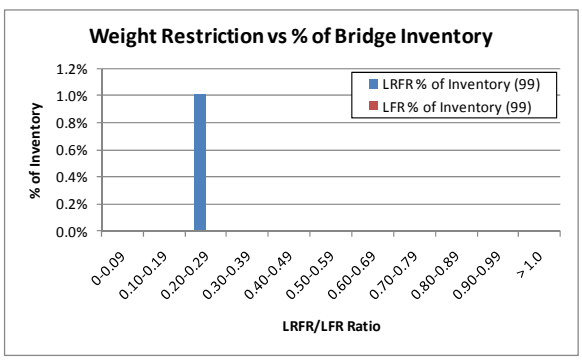
Table 60 and Figure 60 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 60 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NM-04 vehicle is 0.64 for moment and 1.11 for shear.

Table 60: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	2	2.0%	0	2	0	0.0%	0	0
0.2-0.29	3	3.0%	0	3	1	1.0%	0	1
0.3-0.39	1	1.0%	0	1	0	0.0%	0	0
0.4-0.49	0	0.0%	0	0	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	6	6.1%	0	6	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	13		0	13	1		0	1
Average LRFR/LFR	0.64				1.11			



(a)



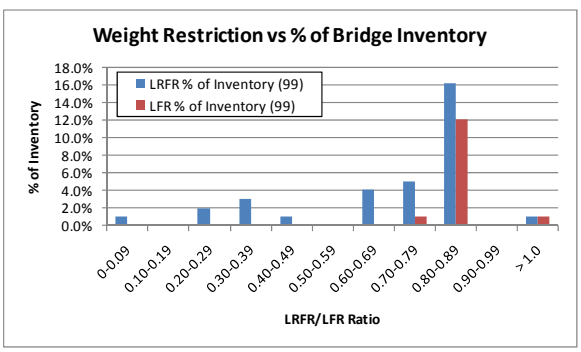
(b)

Figure 60: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

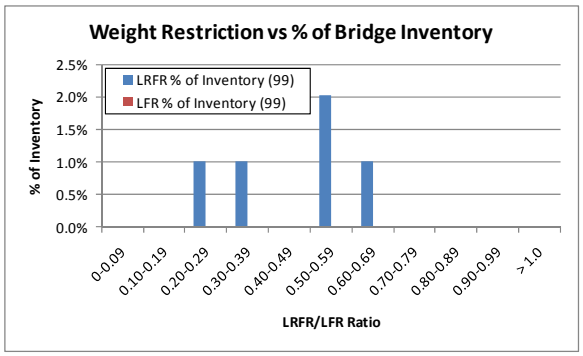
Table 61 and Figure 61 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 61 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the OR-06 vehicle is 0.81 for moment and 1.18 for shear.

Table 61: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	1	1.0%	0	1
0.3-0.39	3	3.0%	0	3	1	1.0%	0	1
0.4-0.49	1	1.0%	0	1	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	2	2.0%	0	2
0.6-0.69	4	4.0%	0	4	1	1.0%	0	1
0.7-0.79	5	5.0%	1	4	0	0.0%	0	0
0.8-0.89	16	16.2%	12	4	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	1	1.0%	1	0	0	0.0%	0	0
Total	33		14	19	5		0	5
Average LRFR/LFR	0.81				1.18			



(a)



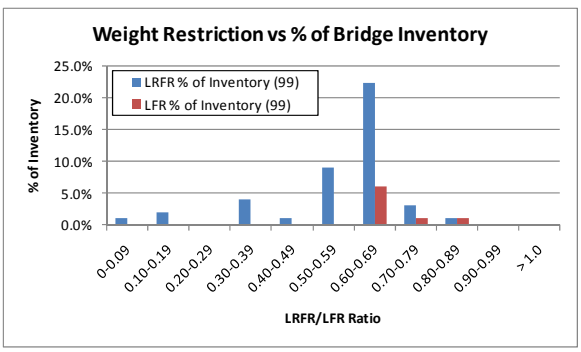
(b)

Figure 61: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

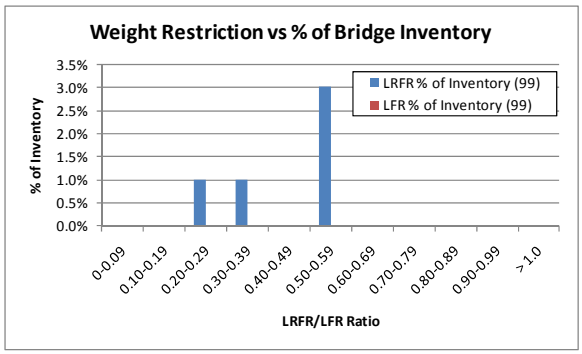
Table 62 and Figure 62 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 62 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the TX-04 vehicle is 0.65 for moment and 1.05 for shear.

Table 62: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	2	2.0%	0	2	0	0.0%	0	0
0.2-0.29	0	0.0%	0	0	1	1.0%	0	1
0.3-0.39	4	4.0%	0	4	1	1.0%	0	1
0.4-0.49	1	1.0%	0	1	0	0.0%	0	0
0.5-0.59	9	9.1%	0	9	3	3.0%	0	3
0.6-0.69	22	22.2%	6	16	0	0.0%	0	0
0.7-0.79	3	3.0%	1	2	0	0.0%	0	0
0.8-0.89	1	1.0%	1	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	43		8	35	5		0	5
Average LRFR/LFR	0.65				1.05			



(a)



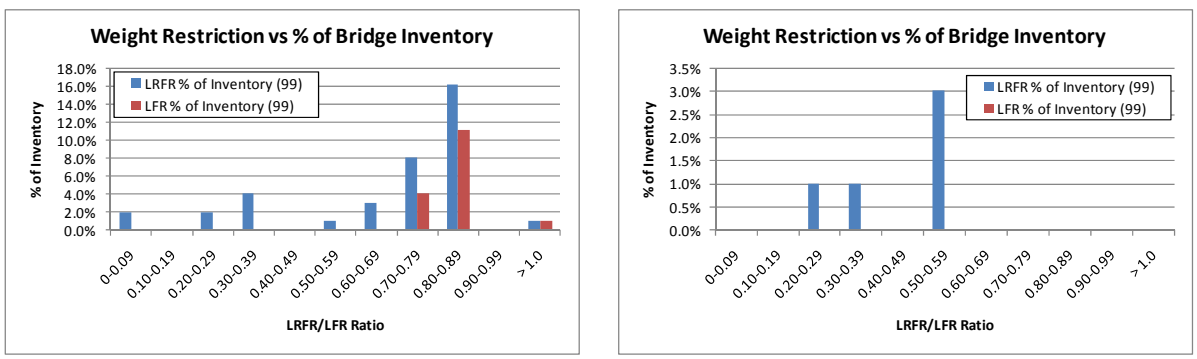
(b)

Figure 62: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 63 and Figure 63 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 63 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the WA-02 vehicle is 0.79 for moment and 1.17 for shear.

Table 63: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	2.0%	0	2	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	1	1.0%	0	1
0.3-0.39	4	4.0%	0	4	1	1.0%	0	1
0.4-0.49	0	0.0%	0	0	0	0.0%	0	0
0.5-0.59	1	1.0%	0	1	3	3.0%	0	3
0.6-0.69	3	3.0%	0	3	0	0.0%	0	0
0.7-0.79	8	8.1%	4	4	0	0.0%	0	0
0.8-0.89	16	16.2%	11	5	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	1	1.0%	1	0	0	0.0%	0	0
Total	37		16	21	5		0	5
Average LRFR/LFR	0.79				1.17			



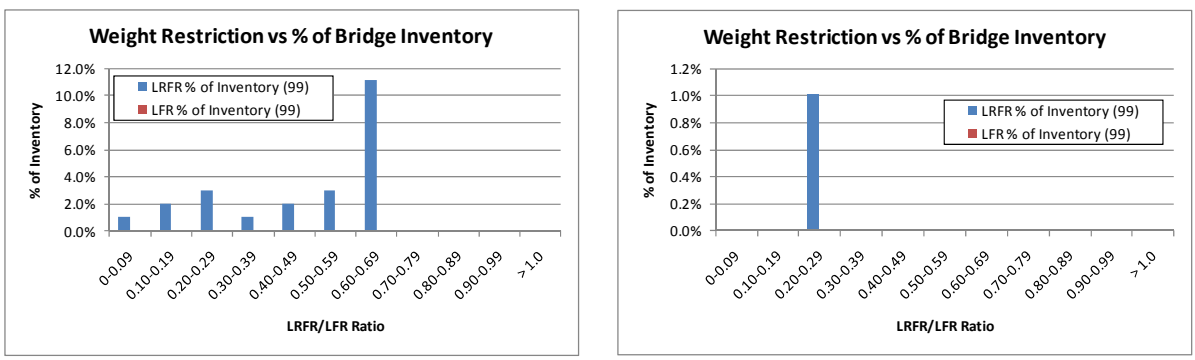
(a) (b)

Figure 63: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 64 and Figure 64 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 64 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3 vehicle is 0.63 for moment and 1.08 for shear.

Table 64: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	2	2.0%	0	2	0	0.0%	0	0
0.2-0.29	3	3.0%	0	3	1	1.0%	0	1
0.3-0.39	1	1.0%	0	1	0	0.0%	0	0
0.4-0.49	2	2.0%	0	2	0	0.0%	0	0
0.5-0.59	3	3.0%	0	3	0	0.0%	0	0
0.6-0.69	11	11.1%	0	11	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	23		0	23	1		0	1
Average LRFR/LFR	0.63				1.08			



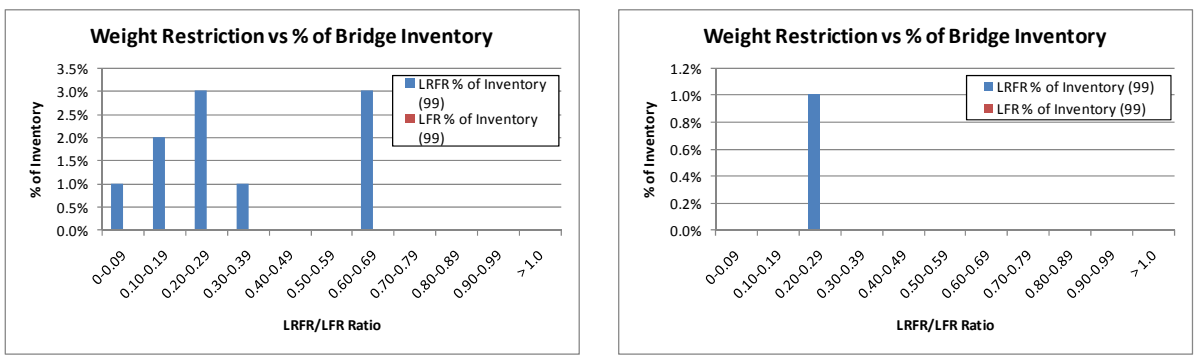
(a) (b)

Figure 64: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 65 and Figure 65 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 65 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3-3 vehicle is 0.63 for moment and 1.10 for shear.

Table 65: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	2	2.0%	0	2	0	0.0%	0	0
0.2-0.29	3	3.0%	0	3	1	0.0%	0	1
0.3-0.39	1	1.0%	0	1	0	0.0%	0	0
0.4-0.49	0	0.0%	0	0	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	3	3.0%	0	3	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	10		0	10	1		0	1
Average LRFR/LFR	0.63				1.10			



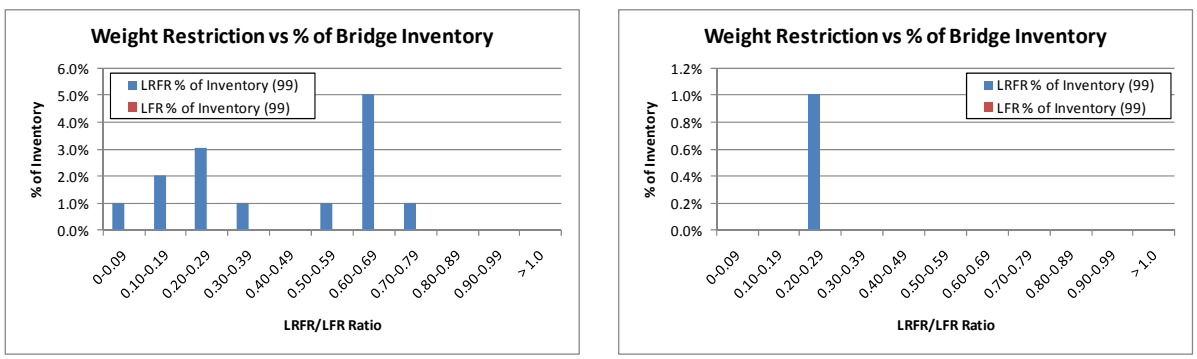
(a) (b)

Figure 65: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

Table 66 and Figure 66 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 66 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3S2 vehicle is 0.64 for moment and 1.10 for shear.

Table 66: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	2	2.0%	0	2	0	0.0%	0	0
0.2-0.29	3	3.0%	0	3	1	1.0%	0	1
0.3-0.39	1	1.0%	0	1	0	0.0%	0	0
0.4-0.49	0	0.0%	0	0	0	0.0%	0	0
0.5-0.59	1	1.0%	0	1	0	0.0%	0	0
0.6-0.69	5	5.1%	0	5	0	0.0%	0	0
0.7-0.79	1	1.0%	0	1	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	14		0	14	1		0	1
Average LRFR/LFR	0.64				1.10			



(a) (b)

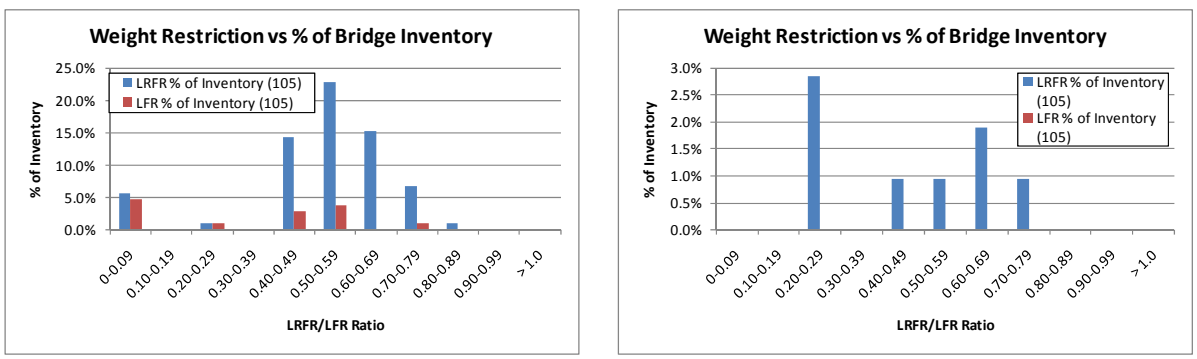
Figure 66: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

L.7 Continuous Span Reinforced Concrete Slab Bridges

Table 67 and Figure 67 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 67 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the DE-07 vehicle is 0.56 for moment and 0.79 for shear.

Table 67: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	3	2.9%	0	3
0.3-0.39	0	0.0%	0	0	0	0.0%	0	0
0.4-0.49	15	14.3%	3	12	1	1.0%	0	1
0.5-0.59	24	22.9%	4	20	1	1.0%	0	1
0.6-0.69	16	15.2%	0	16	2	1.9%	0	2
0.7-0.79	7	6.7%	1	6	1	1.0%	0	1
0.8-0.89	1	1.0%	0	1	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	70		14	56	8		0	8
Average LRFR/LFR	0.56				0.79			



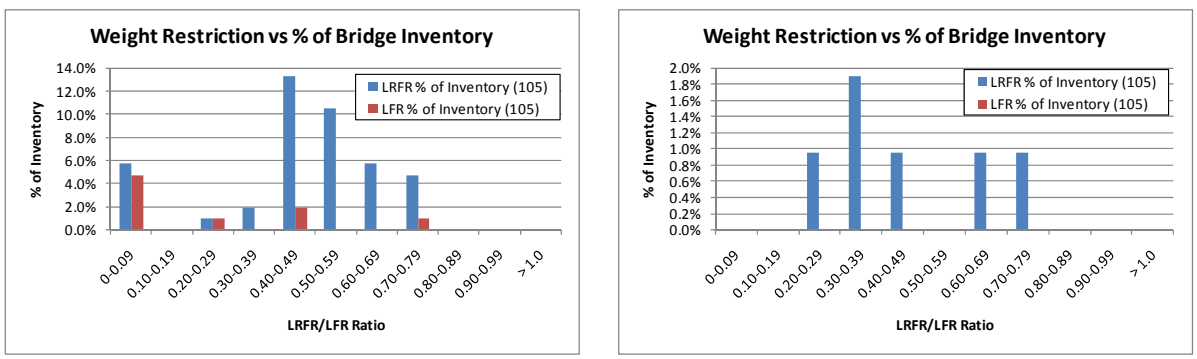
(a) (b)

Figure 67: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

Table 68 and Figure 68 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 68 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the FL-04 vehicle is 0.56 for moment and 0.81 for shear.

Table 68: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	1	1.0%	0	1
0.3-0.39	2	1.9%	0	2	2	1.9%	0	2
0.4-0.49	14	13.3%	2	12	1	1.0%	0	1
0.5-0.59	11	10.5%	0	11	0	0.0%	0	0
0.6-0.69	6	5.7%	0	6	1	1.0%	0	1
0.7-0.79	5	4.8%	1	4	1	1.0%	0	1
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	45		9	36	6		0	6
Average LRFR/LFR	0.56				0.81			



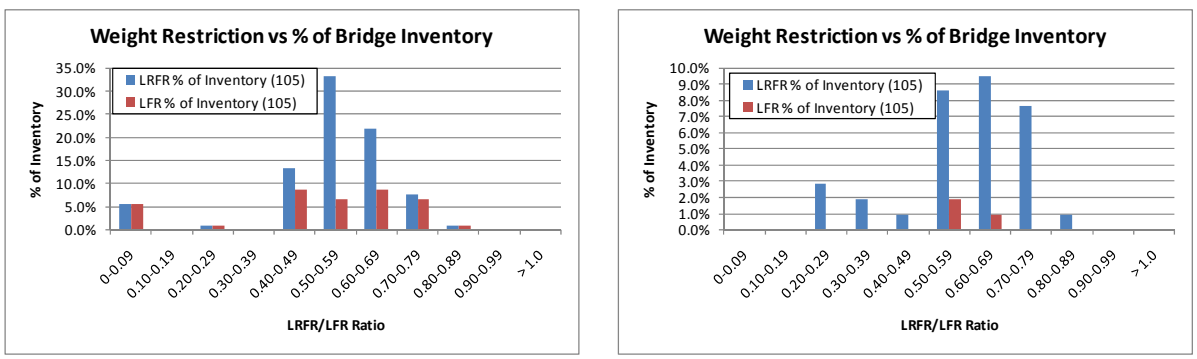
(a) (b)

Figure 68: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 69 and Figure 69 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 69 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the IL-01 vehicle is 0.57 for moment and 0.78 for shear.

Table 69: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	6	0	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	3	2.9%	0	3
0.3-0.39	0	0.0%	0	0	2	1.9%	0	2
0.4-0.49	14	13.3%	9	5	1	1.0%	0	1
0.5-0.59	35	33.3%	7	28	9	8.6%	2	7
0.6-0.69	23	21.9%	9	14	10	9.5%	1	9
0.7-0.79	8	7.6%	7	1	8	7.6%	0	8
0.8-0.89	1	1.0%	1	0	1	1.0%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	88		40	48	34		3	31
Average LRFR/LFR	0.57				0.78			



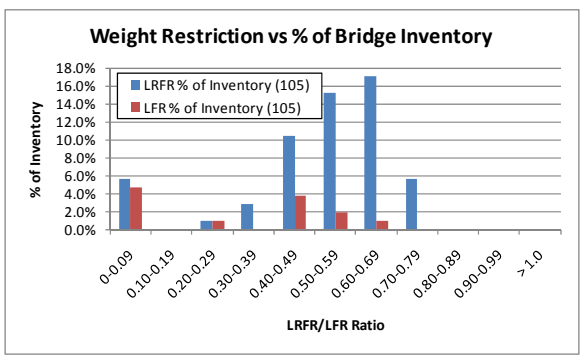
(a) (b)

Figure 69: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

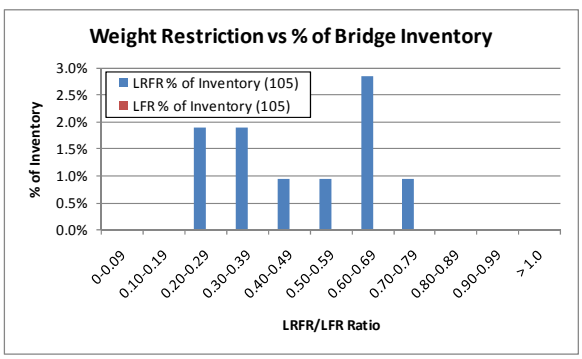
Table 70 and Figure 70 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 70 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NC-21 vehicle is 0.59 for moment and 0.80 for shear.

Table 70: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	2	1.9%	0	2
0.3-0.39	3	2.9%	0	3	2	1.9%	0	2
0.4-0.49	11	10.5%	4	7	1	1.0%	0	1
0.5-0.59	16	15.2%	2	14	1	1.0%	0	1
0.6-0.69	18	17.1%	1	17	3	2.9%	0	3
0.7-0.79	6	5.7%	0	6	1	1.0%	0	1
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	61		13	48	10		0	10
Average LRFR/LFR	0.59				0.80			



(a)



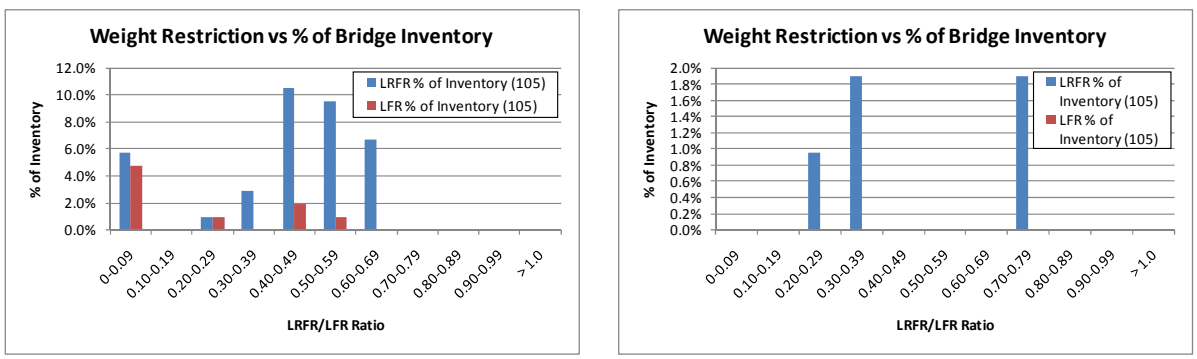
(b)

Figure 70: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 71 and Figure 71 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 71 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NM-04 vehicle is 0.58 for moment and 0.87 for shear.

Table 71: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	1	1.0%	0	1
0.3-0.39	3	2.9%	0	3	2	1.9%	0	2
0.4-0.49	11	10.5%	2	9	0	0.0%	0	0
0.5-0.59	10	9.5%	1	9	0	0.0%	0	0
0.6-0.69	7	6.7%	0	7	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	2	1.9%	0	2
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	38		9	29	5		0	5
Average LRFR/LFR	0.58				0.87			



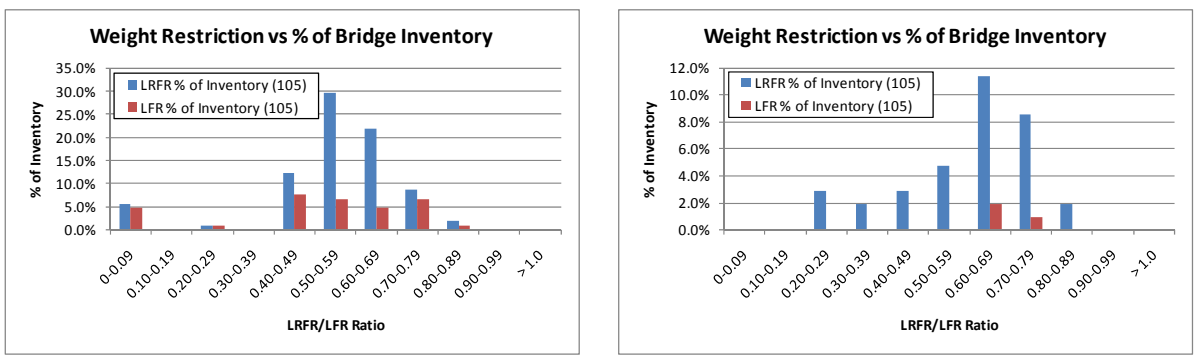
(a) (b)

Figure 71: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 72 and Figure 72 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 72 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the OR-06 vehicle is 0.58 for moment and 0.77 for shear.

Table 72: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	3	2.9%	0	3
0.3-0.39	0	0.0%	0	0	2	1.9%	0	2
0.4-0.49	13	12.4%	8	5	3	2.9%	0	3
0.5-0.59	31	29.5%	7	24	5	4.8%	0	5
0.6-0.69	23	21.9%	5	18	12	11.4%	2	10
0.7-0.79	9	8.6%	7	2	9	8.6%	1	8
0.8-0.89	2	1.9%	1	1	2	1.9%	0	2
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	85		34	51	36		3	33
Average LRFR/LFR	0.58				0.77			



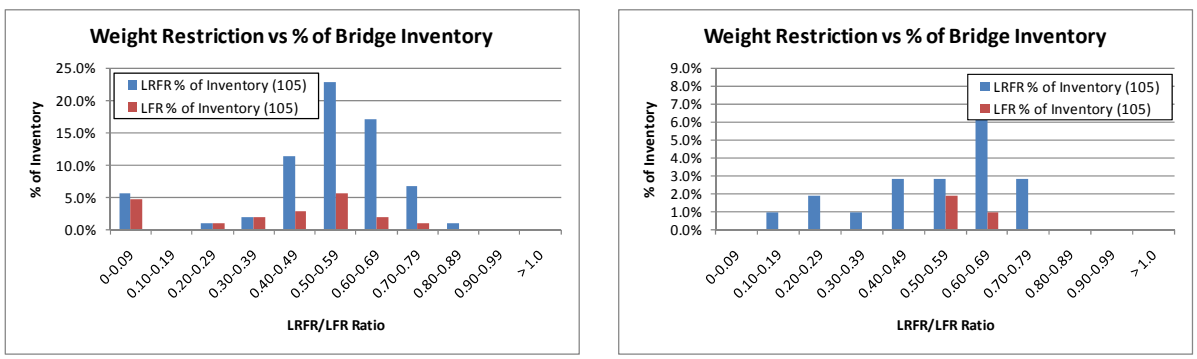
(a) (b)

Figure 72: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 73 and Figure 73 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 73 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the TX-04 vehicle is 0.59 for moment and 0.74 for shear.

Table 73: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	1	1.0%	0	1
0.2-0.29	1	1.0%	1	0	2	1.9%	0	2
0.3-0.39	2	1.9%	2	0	1	1.0%	0	1
0.4-0.49	12	11.4%	3	9	3	2.9%	0	3
0.5-0.59	24	22.9%	6	18	3	2.9%	2	1
0.6-0.69	18	17.1%	2	16	9	8.6%	1	8
0.7-0.79	7	6.7%	1	6	3	2.9%	0	3
0.8-0.89	1	1.0%	0	1	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	71		20	51	22		3	19
Average LRFR/LFR	0.59				0.74			



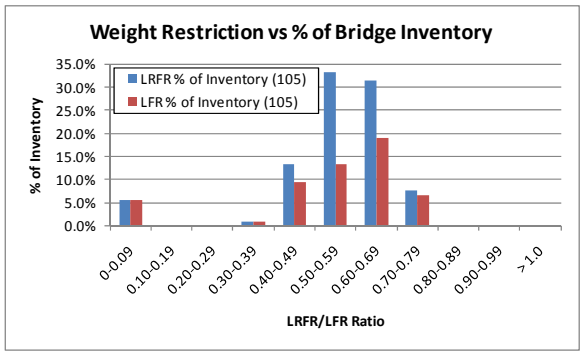
(a) (b)

Figure 73: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

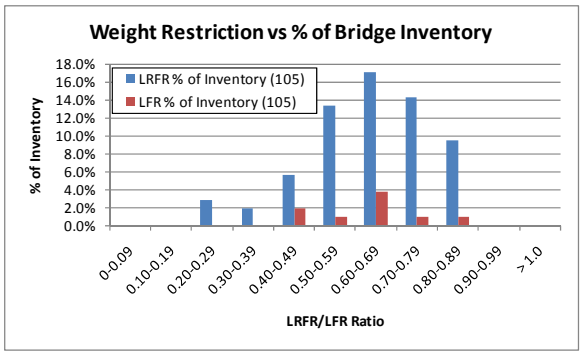
Table 74 and Figure 74 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 74 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the WA-02 vehicle is 0.56 for moment and 0.71 for shear.

Table 74: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	6	0	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	0	0.0%	0	0	3	2.9%	0	3
0.3-0.39	1	1.0%	1	0	2	1.9%	0	2
0.4-0.49	14	13.3%	10	4	6	5.7%	2	4
0.5-0.59	35	33.3%	14	21	14	13.3%	1	13
0.6-0.69	33	31.4%	20	13	18	17.1%	4	14
0.7-0.79	8	7.6%	7	1	15	14.3%	1	14
0.8-0.89	0	0.0%	0	0	10	9.5%	1	9
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	97		58	39	68		9	59
Average LRFR/LFR	0.56				0.71			



(a)



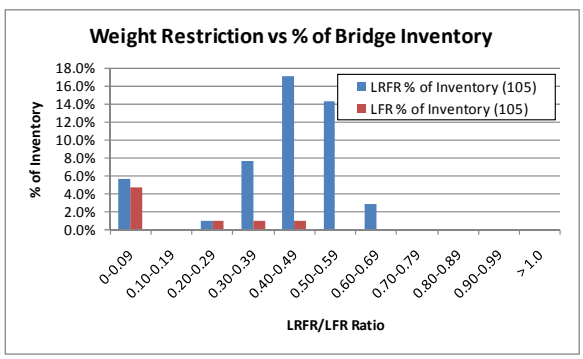
(b)

Figure 74: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

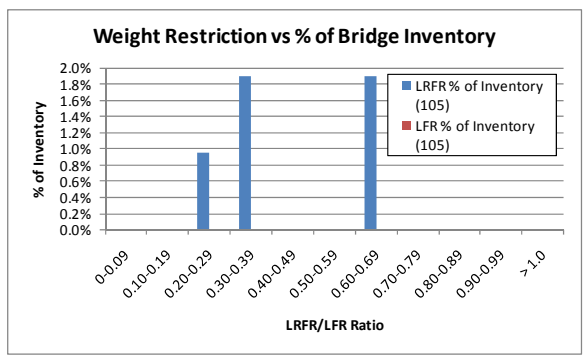
Table 75 and Figure 75 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 75 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3 vehicle is 0.50 for moment and 0.84 for shear.

Table 75: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0	0	0
0.1-0.19	0	0.0%	0	0	0	0.0	0	0
0.2-0.29	1	1.0%	1	0	1	1.0	0	1
0.3-0.39	8	7.6%	1	7	2	1.9	0	2
0.4-0.49	18	17.1%	1	17	0	0.0	0	0
0.5-0.59	15	14.3%	0	15	0	0.0	0	0
0.6-0.69	3	2.9%	0	3	2	1.9	0	2
0.7-0.79	0	0.0%	0	0	0	0.0	0	0
0.8-0.89	0	0.0%	0	0	0	0.0	0	0
0.9-0.99	0	0.0%	0	0	0	0.0	0	0
> 1.00	0	0.0%	0	0	0	0.0	0	0
Total	51		8	43	5		0	5
Average LRFR/LFR	0.50				0.84			



(a)



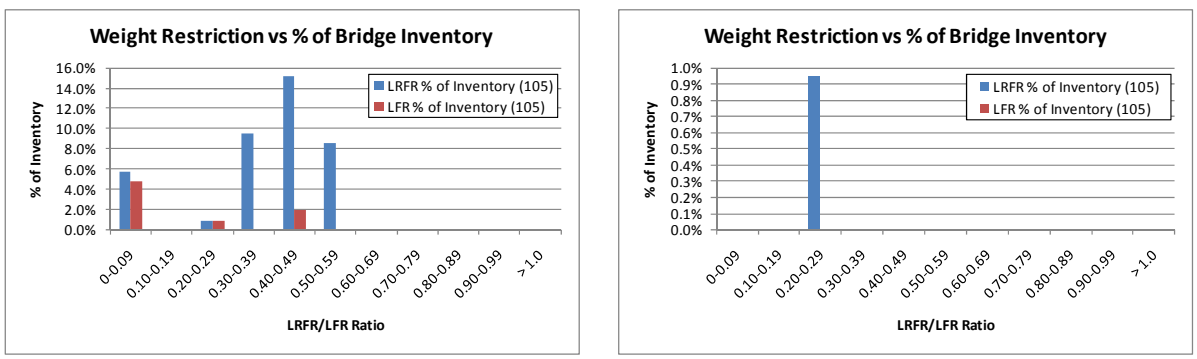
(b)

Figure 75: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 76 and Figure 76 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 76 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3-3 vehicle is 0.46 for moment and 0.85 for shear.

Table 76: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	1
0.2-0.29	1	1.0%	1	0	1	1.0%	0	0
0.3-0.39	10	9.5%	0	10	0	0.0%	0	0
0.4-0.49	16	15.2%	2	14	0	0.0%	0	0
0.5-0.59	9	8.6%	0	9	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	42		8	34	1		0	1
Average LRFR/LFR	0.46				0.85			



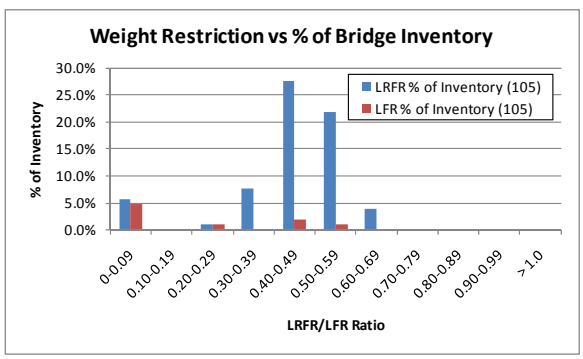
(a) (b)

Figure 76: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

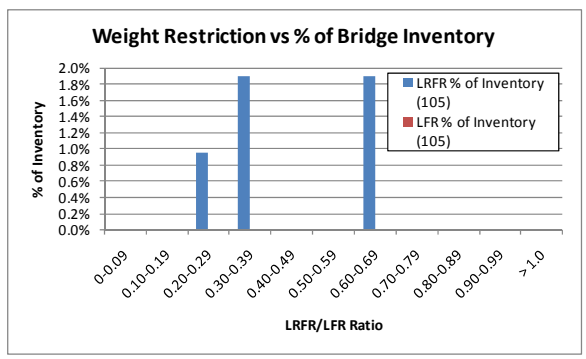
Table 77 and Figure 77 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 77 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3S2 vehicle is 0.48 for moment and 0.82 for shear.

Table 77: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	1	1.0%	0	1
0.3-0.39	8	7.6%	0	8	2	1.9%	0	2
0.4-0.49	29	27.6%	2	27	0	0.0%	0	0
0.5-0.59	23	21.9%	1	22	0	0.0%	0	0
0.6-0.69	4	3.8%	0	4	2	1.9%	0	2
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	71		9	62	5		0	5
Average LRFR/LFR	0.48				0.82			



(a)



(b)

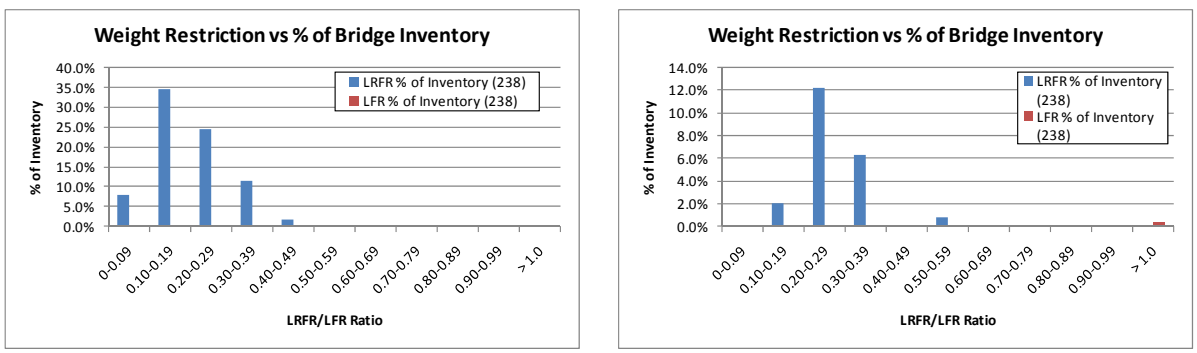
Figure 77: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

L.8 Continuous Span Prestressed Concrete I-Girder Bridges

Table 78 and Figure 78 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 78 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the DE-07 vehicle is 0.24 for moment and 0.78 for shear.

Table 78: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	19	8.0%	0	19	0	0.0%	0	0
0.1-0.19	82	34.5%	0	82	5	5.1%	0	5
0.2-0.29	58	24.4%	0	58	29	12.2%	0	29
0.3-0.39	27	11.3%	0	27	15	6.3%	0	15
0.4-0.49	4	1.7%	0	4	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	2	0.8%	0	2
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	190		0	190	51		0	51
Average LRFR/LFR	0.24				0.78			



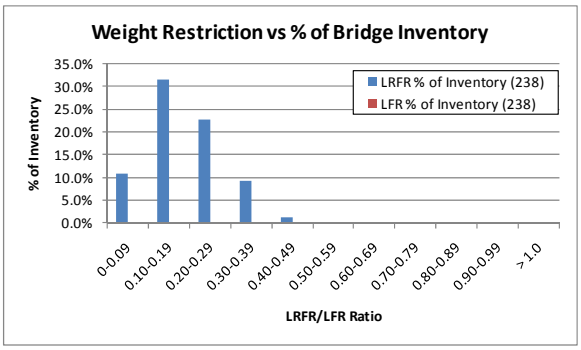
(a) (b)

Figure 78: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

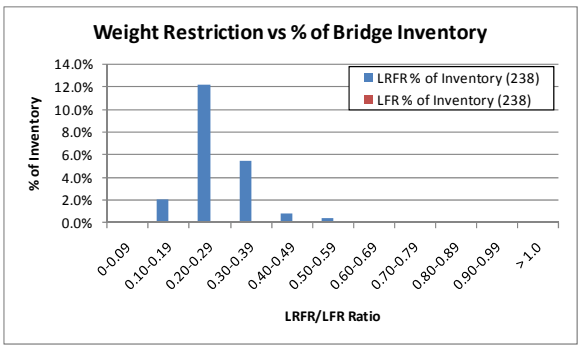
Table 79 and Figure 79 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 79 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the FL-04 vehicle is 0.23 for moment and 0.80 for shear.

Table 79: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	26	10.9%	0	26	0	0.0%	0	0
0.1-0.19	75	31.5%	0	75	5	2.1%	0	5
0.2-0.29	54	22.7%	0	54	29	12.2%	0	29
0.3-0.39	22	9.2%	0	22	13	5.5%	0	13
0.4-0.49	3	1.3%	0	3	2	0.8%	0	2
0.5-0.59	0	0.0%	0	0	1	0.4%	0	1
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	180		0	180	50		0	50
Average LRFR/LFR	0.23				0.80			



(a)



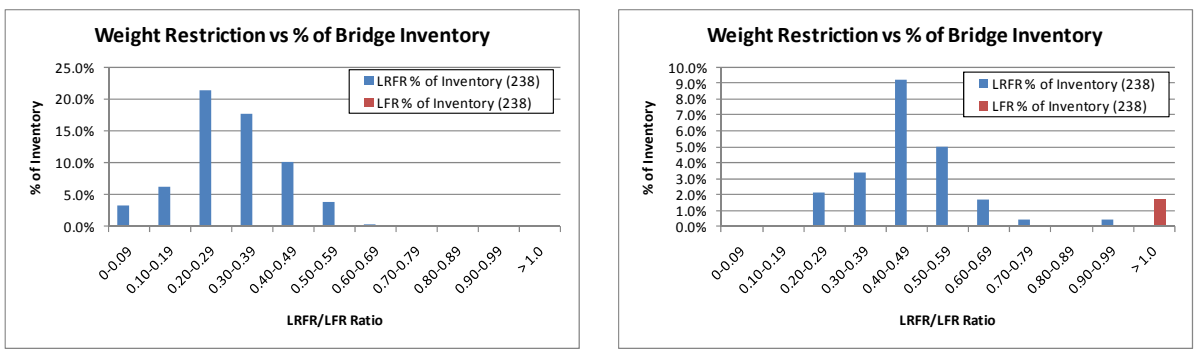
(b)

Figure 79: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 80 and Figure 80 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 80 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the IL-01 vehicle is 0.43 for moment and 1.12 for shear.

Table 80: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	8	3.4%	0	8	0	0.0%	0	0
0.1-0.19	15	6.3%	0	15	0	0.0%	0	0
0.2-0.29	51	21.4%	0	51	5	2.1%	0	5
0.3-0.39	42	17.7%	0	42	8	3.4%	0	8
0.4-0.49	24	10.1%	0	24	22	9.2%	0	22
0.5-0.59	9	3.8%	0	9	12	5.0%	0	12
0.6-0.69	1	0.4%	0	1	4	1.7%	0	4
0.7-0.79	0	0.0%	0	0	1	0.4%	0	1
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	1	0.4%	0	1
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	150		0	150	53		0	53
Average LRFR/LFR	0.43				1.12			



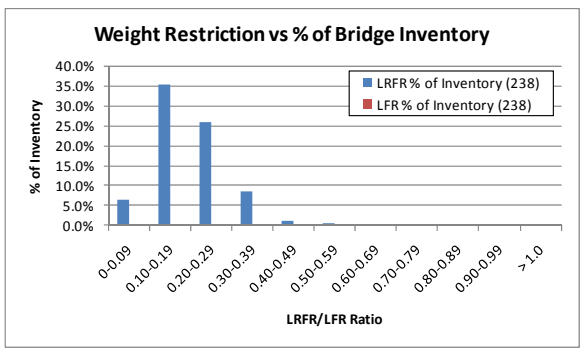
(a) (b)

Figure 80: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

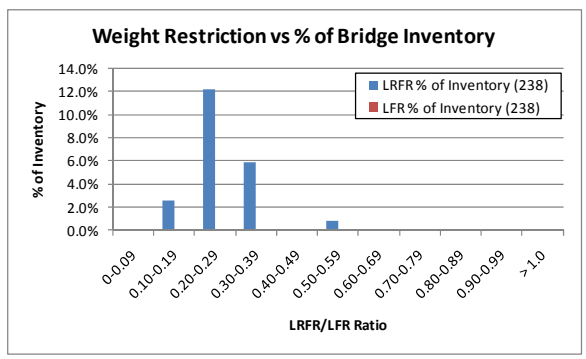
Table 81 and Figure 81 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 81 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NC-21 vehicle is 0.24 for moment and 0.78 for shear.

Table 81: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	15	6.3%	0	15	0	0.0%	0	0
0.1-0.19	84	35.3%	0	84	6	2.5%	0	6
0.2-0.29	62	26.1%	0	62	29	12.2%	0	29
0.3-0.39	20	8.4%	0	20	14	5.9%	0	14
0.4-0.49	3	1.3%	0	3	0	0.0%	0	0
0.5-0.59	1	0.4%	0	1	2	0.8%	0	2
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	185		0	185	51		0	51
Average LRFR/LFR	0.24				0.78			



(a)



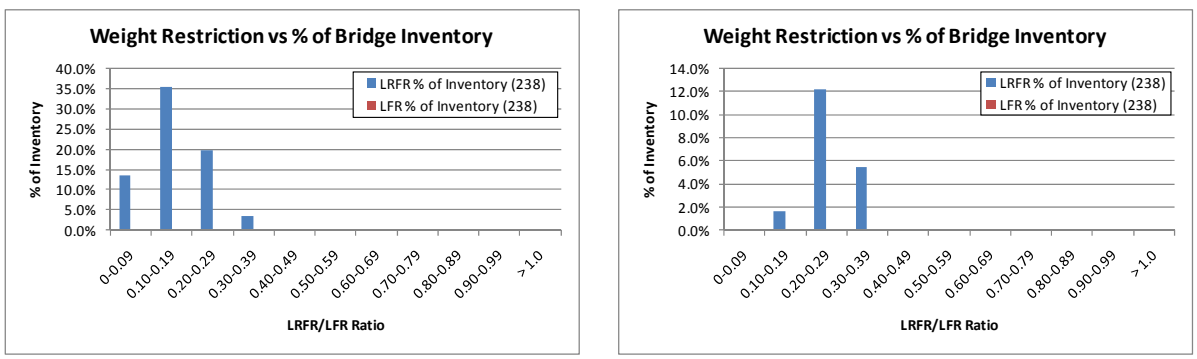
(b)

Figure 81: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 82 and Figure 82 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 82 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the NM-04 vehicle is 0.21 for moment and 0.80 for shear.

Table 82: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	32	13.5%	0	32	0	0.0%	0	0
0.1-0.19	84	35.3%	0	84	4	1.7%	0	4
0.2-0.29	47	19.8%	0	47	29	12.2%	0	29
0.3-0.39	8	3.4%	0	8	13	5.5%	0	13
0.4-0.49	0	0.0%	0	0	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	171		0	171	46		0	46
Average LRFR/LFR	0.21				0.80			



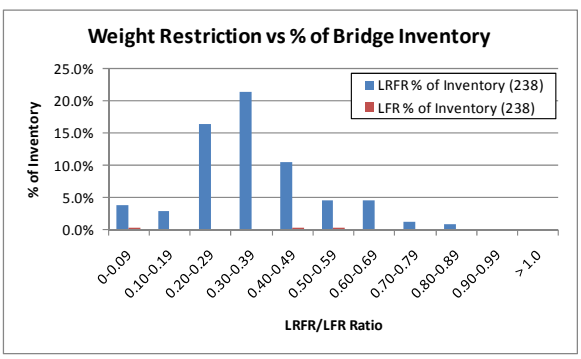
(a) (b)

Figure 82: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

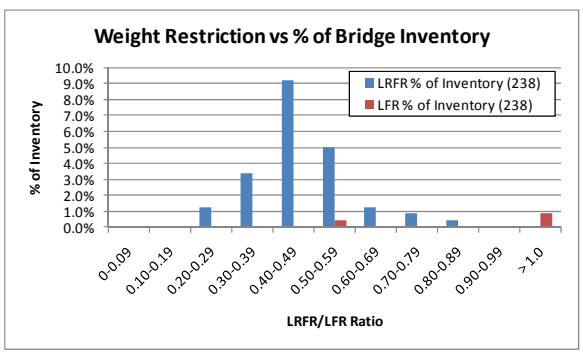
Table 83 and Figure 83 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 83 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the OR-06 vehicle is 0.49 for moment and 1.11 for shear.

Table 83: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	9	3.8%	1	8	0	0.0%	0	0
0.1-0.19	7	2.9%	0	7	0	0.0%	0	0
0.2-0.29	39	16.4%	0	39	3	1.3%	0	3
0.3-0.39	51	21.4%	0	51	8	3.4%	0	8
0.4-0.49	25	10.5%	1	24	22	9.2%	0	22
0.5-0.59	11	4.6%	1	10	12	5.0%	1	11
0.6-0.69	11	4.6%	0	11	3	1.3%	0	3
0.7-0.79	3	1.3%	0	3	2	0.8%	0	2
0.8-0.89	2	0.8%	0	2	1	0.4%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	158		3	155	51		1	50
Average LRFR/LFR	0.49				1.11			



(a)



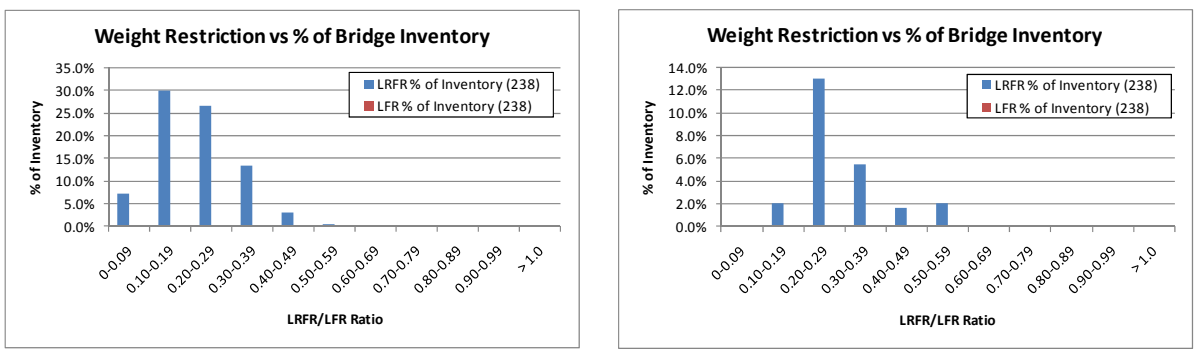
(b)

Figure 83: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 84 and Figure 84 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 84 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the TX-04 vehicle is 0.25 for moment and 0.79 for shear.

Table 84: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	17	7.1%	0	17	0	0.0%	0	0
0.1-0.19	71	29.8%	0	71	5	2.1%	0	5
0.2-0.29	63	26.5%	0	63	31	13.0%	0	31
0.3-0.39	32	13.5%	0	32	13	5.5%	0	13
0.4-0.49	7	2.9%	0	7	4	1.7%	0	4
0.5-0.59	1	0.4%	0	1	5	2.1%	0	5
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	191		0	191	58		0	58
Average LRFR/LFR	0.25				0.79			



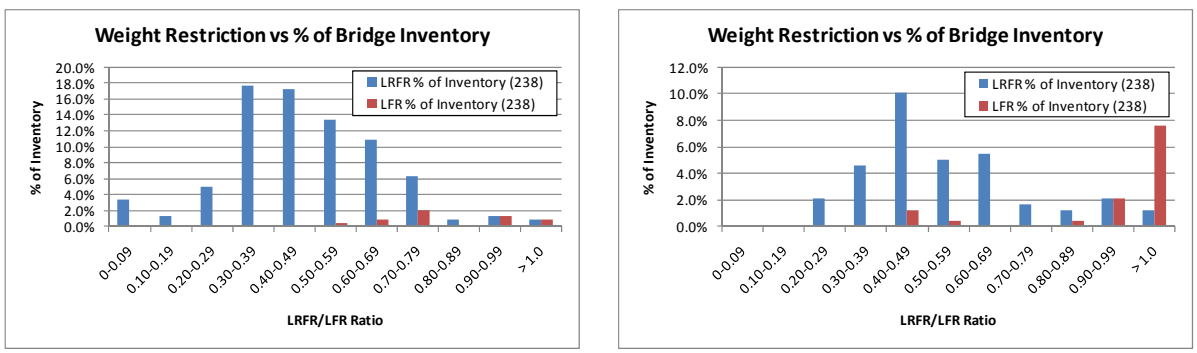
(a) (b)

Figure 84: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 85 and Figure 85 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 85 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the WA-02 vehicle is 0.56 for moment and 1.02 for shear.

Table 85: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	8	3.4%	0	8	0	0.0%	0	0
0.1-0.19	3	1.3%	0	3	0	0.0%	0	0
0.2-0.29	12	5.0%	0	12	5	2.1%	0	5
0.3-0.39	42	17.7%	0	42	11	4.6%	0	11
0.4-0.49	41	17.2%	0	41	24	10.1%	3	21
0.5-0.59	32	13.5%	1	31	12	5.0%	1	11
0.6-0.69	26	10.9%	2	24	13	5.5%	0	13
0.7-0.79	15	6.3%	5	10	4	1.7%	0	4
0.8-0.89	2	0.8%	0	2	3	1.3%	1	2
0.9-0.99	3	1.3%	3	0	5	2.1%	5	0
> 1.00	2	0.8%	2	0	3	1.3%	3	0
Total	186		13	173	119		13	67
Average LRFR/LFR	0.56				1.02			



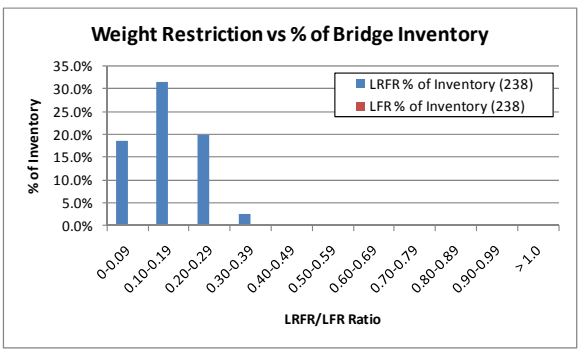
(a) (b)

Figure 85: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

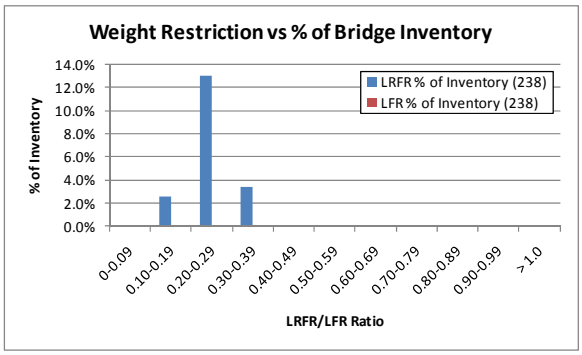
Table 86 and Figure 86 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 86 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3 vehicle is 0.20 for moment and 0.79 for shear.

Table 86: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	44	18.5%	0	44	0	0.0%	0	0
0.1-0.19	75	31.5%	0	75	6	2.5%	0	6
0.2-0.29	47	19.8%	0	47	31	13.0%	0	31
0.3-0.39	6	2.5%	0	6	8	3.4%	0	8
0.4-0.49	0	0.0%	0	0	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	172		0	188	45		0	45
Average LRFR/LFR	0.20				0.79			



(a)



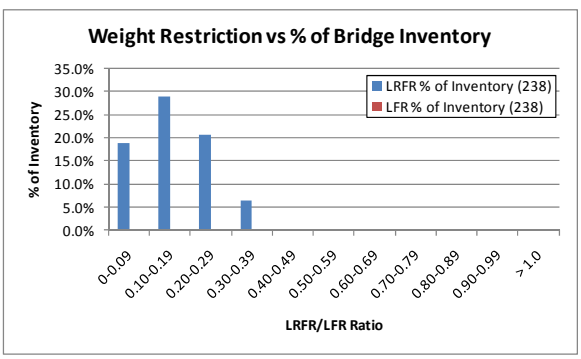
(b)

Figure 86: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

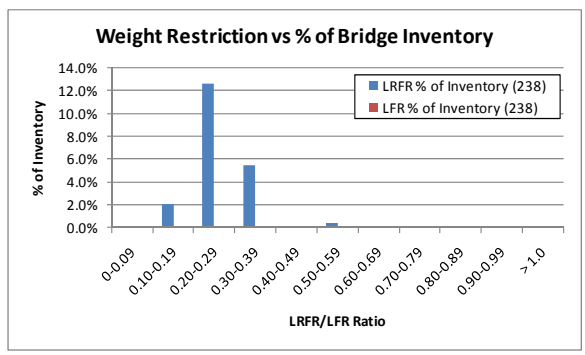
Table 87 and Figure 87 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 87 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3-3 vehicle is 0.21 for moment and 0.76 for shear.

Table 87: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	45	18.9%	0	45	0	0.0%	0	0
0.1-0.19	69	29.0%	0	69	5	2.1	0	5
0.2-0.29	49	20.6%	0	49	30	12.6	0	30
0.3-0.39	15	6.3%	0	15	13	5.5	0	13
0.4-0.49	0	0.0%	0	0	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	1	0.4	0	1
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	178		0	178	49		0	49
Average LRFR/LFR	0.21				0.76			



(a)



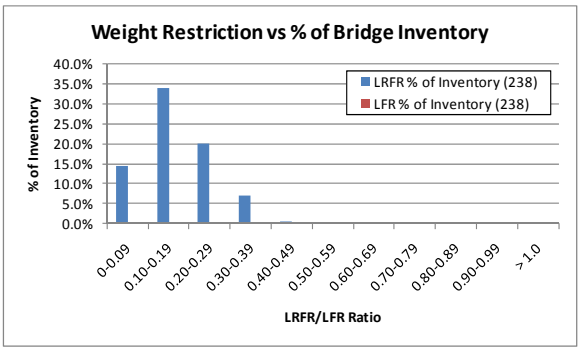
(b)

Figure 87: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

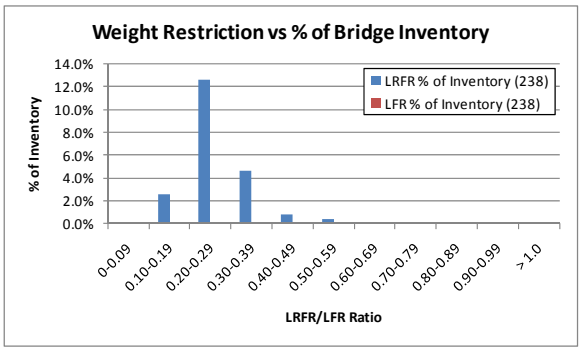
Table 88 and Figure 88 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 88 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the existing load factors for the AASHTO Type 3S2 vehicle is 0.21 for moment and 0.76 for shear.

Table 88: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	34	14.3%	0	34	0	0.0%	0	0
0.1-0.19	81	34.0%	0	81	6	2.5%	0	6
0.2-0.29	48	20.2%	0	48	30	12.6%	0	30
0.3-0.39	17	7.1%	0	17	11	4.6%	0	11
0.4-0.49	1	0.4%	0	1	2	0.8%	0	2
0.5-0.59	0	0.0%	0	0	1	0.4%	0	1
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	181		0	181	51		0	50
Average LRFR/LFR	0.21				0.76			



(a)



(b)

Figure 88: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

M Effect of LRFR on Rating Using Proposed Load Factors

The following sections provide an indication into the affect of switching to LRFR from LFR for the eleven legal and permit vehicles for each structure type. The first column in each table is a range of LRFR divided by LFR ratios. The second column indicates the number of girders with LRFR ratings less than 1.0 and a ratio within the specified range. The third column indicates the percent of the total number of girders that have an LRFR rating less than 1.0 and a ratio within the given range. The fourth and fifth columns specify how many girders with an LRFR rating less than 1.0 have LFR ratings less than or greater than 1.0, respectively. The last row in each table indicates what the average ratio of ratings is; this provides an indication into the reduction in rating factor that may be expected when the proposed live load factors are used.

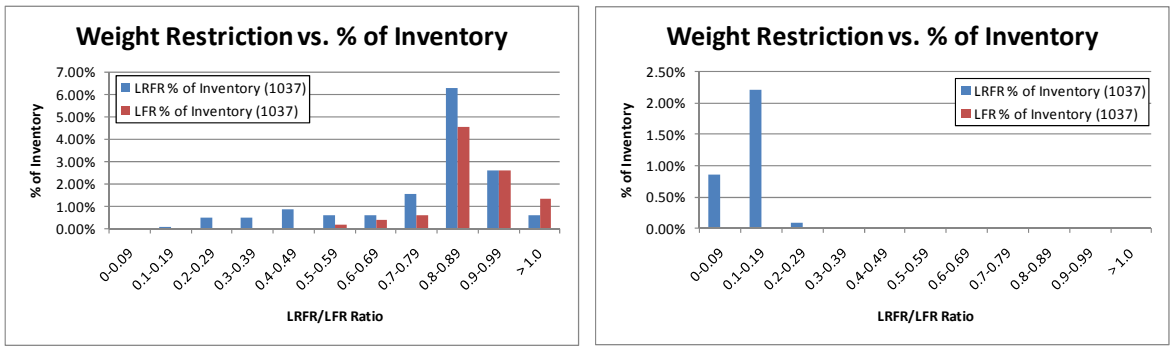
All values are calculated considering all rating criteria and utilize the new load factors proposed for live load. For the special permit vehicles (IL-01, OR-06, WA-02), the values shown correspond to a target reliability index of 2.5. This target reliability index is lower than that assumed in the development of the corresponding load factors in the current MBE.

M.1 Simple Span Steel Girder Bridges

Table 1 and Figure 1 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 1 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the DE-07 vehicle is 0.97 for moment and 0.71 for shear.

Table 1: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	0.9%	0	9
0.1-0.19	1	0.1%	0	1	23	2.2%	0	23
0.2-0.29	5	0.5%	0	5	1	0.1%	0	1
0.3-0.39	5	0.5%	0	5	0	0.0%	0	0
0.4-0.49	9	0.9%	0	9	0	0.0%	0	0
0.5-0.59	6	0.6%	2	4	0	0.0%	0	0
0.6-0.69	6	0.6%	4	2	0	0.0%	0	0
0.7-0.79	16	1.5%	6	10	0	0.0%	0	0
0.8-0.89	65	6.3%	47	18	0	0.0%	0	0
0.9-0.99	27	2.6%	27	0	0	0.0%	0	0
> 1.00	6	0.6%	6	0	0	0.0%	0	0
Total	146		92	54	33		0	33
Average LRFR/LFR	0.97				0.71			



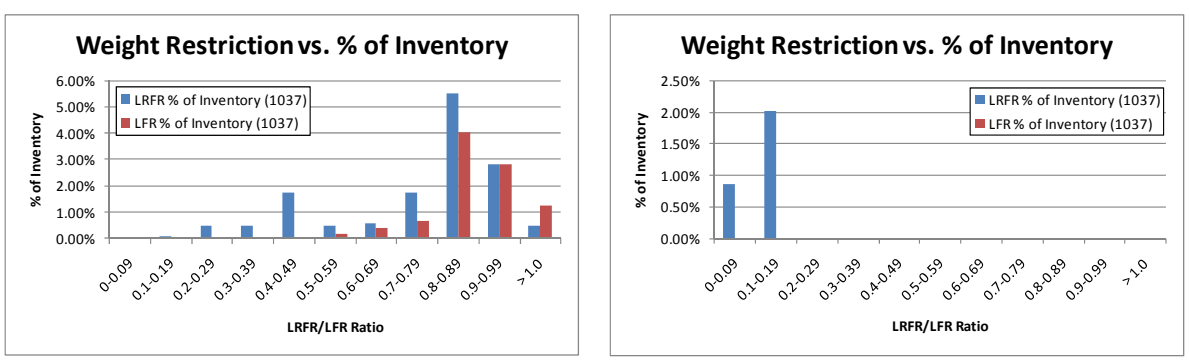
(a) (b)

Figure 1: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

Table 2 and Figure 2 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 2 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the FL-04 vehicle is 0.76 for moment and 0.55 for shear.

Table 2: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	0.9%	0	9
0.1-0.19	1	0.1%	0	1	21	2.0%	0	21
0.2-0.29	5	0.5%	0	5	0	0.0%	0	0
0.3-0.39	5	0.5%	0	5	0	0.0%	0	0
0.4-0.49	18	1.7%	0	18	0	0.0%	0	0
0.5-0.59	5	0.5%	2	3	0	0.0%	0	0
0.6-0.69	6	0.6%	4	2	0	0.0%	0	0
0.7-0.79	18	1.7%	7	11	0	0.0%	0	0
0.8-0.89	57	5.5%	42	15	0	0.0%	0	0
0.9-0.99	29	2.8%	29	0	0	0.0%	0	0
> 1.00	5	0.5%	5	0	0	0.0%	0	0
Total	149		89	60	30		0	30
Average LRFR/LFR	0.97				0.71			



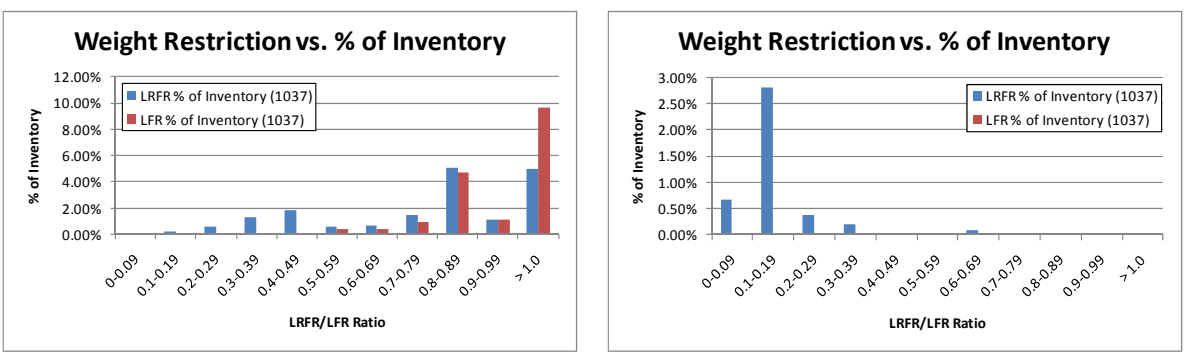
(a) (b)

Figure 2: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 3 and Figure 3 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 3 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the IL-01 vehicle is 1.26 for moment and 0.88 for shear.

Table 3: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	0.7%	0	7
0.1-0.19	2	0.2%	0	2	29	2.8%	0	29
0.2-0.29	6	0.6%	0	6	4	0.4%	0	4
0.3-0.39	14	1.4%	1	13	2	0.2%	0	2
0.4-0.49	19	1.8%	0	19	0	0.0%	0	0
0.5-0.59	6	0.6%	4	2	0	0.0%	0	0
0.6-0.69	7	0.7%	4	3	1	0.1%	0	1
0.7-0.79	15	1.5%	10	5	0	0.0%	0	0
0.8-0.89	53	5.1%	49	4	0	0.0%	0	0
0.9-0.99	12	1.2%	12	0	0	0.0%	0	0
> 1.00	52	5.0%	52	0	0	0.0%	0	0
Total	186		132	54	43		0	43
Average LRFR/LFR	1.26				0.88			



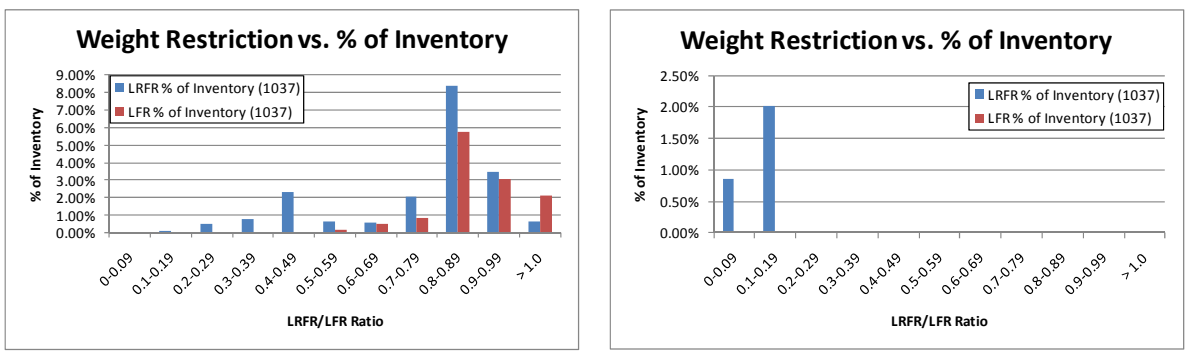
(a) (b)

Figure 3: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

Table 4 and Figure 4 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 4 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NC-21 vehicle is 0.97 for moment and 0.72 for shear.

Table 4: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	0.9%	0	9
0.1-0.19	1	0.1%	0	1	21	2.0%	0	21
0.2-0.29	5	0.5%	0	5	0	0.0%	0	0
0.3-0.39	8	0.8%	0	8	0	0.0%	0	0
0.4-0.49	24	2.3%	0	24	0	0.0%	0	0
0.5-0.59	7	0.7%	2	5	0	0.0%	0	0
0.6-0.69	6	0.6%	5	1	0	0.0%	0	0
0.7-0.79	21	2.0%	9	12	0	0.0%	0	0
0.8-0.89	87	8.4%	60	27	0	0.0%	0	0
0.9-0.99	36	3.5%	32	4	0	0.0%	0	0
> 1.00	7	0.7%	7	0	0	0.0%	0	0
Total	202		115	87	30		0	30
Average LRFR/LFR	0.97				0.72			



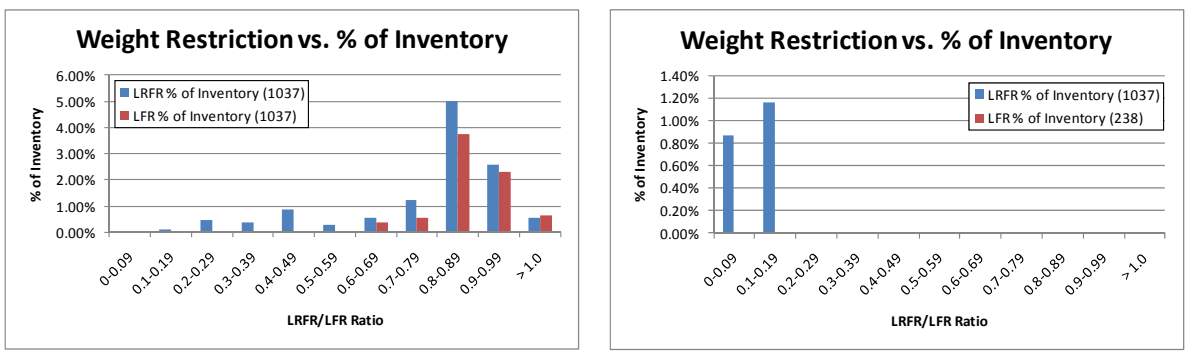
(a) (b)

Figure 4: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 5 and Figure 5 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 5 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NM-04 vehicle is 0.97 for moment and 0.72 for shear.

Table 5: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	0.9%	0	9
0.1-0.19	1	0.1%	0	1	12	1.2%	0	12
0.2-0.29	5	0.5%	0	5	0	0.0%	0	0
0.3-0.39	4	0.4%	0	4	0	0.0%	0	0
0.4-0.49	9	0.9%	0	9	0	0.0%	0	0
0.5-0.59	3	0.3%	0	3	0	0.0%	0	0
0.6-0.69	6	0.6%	4	2	0	0.0%	0	0
0.7-0.79	13	1.3%	6	7	0	0.0%	0	0
0.8-0.89	52	5.0%	39	13	0	0.0%	0	0
0.9-0.99	27	2.6%	24	3	0	0.0%	0	0
> 1.00	6	0.6%	6	0	0	0.0%	0	0
Total	126		79	47	21		0	21
Average LRFR/LFR	0.97				0.72			



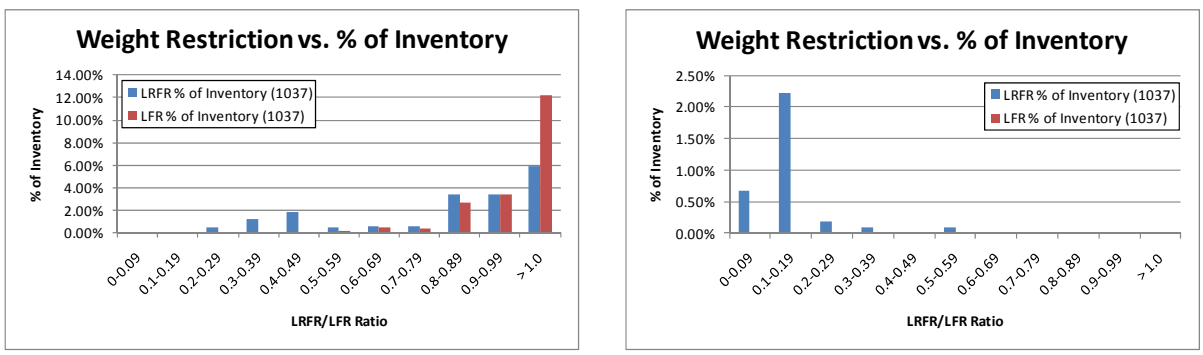
(a) (b)

Figure 5: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 6 and Figure 6 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 6 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the OR-06 vehicle is 1.35 for moment and 0.90 for shear.

Table 6: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	0.7%	0	7
0.1-0.19	1	0.1%	0	1	23	2.2%	0	23
0.2-0.29	5	0.5%	0	5	2	0.2%	0	2
0.3-0.39	13	1.3%	1	12	1	0.1%	0	1
0.4-0.49	19	1.8%	0	19	0	0.0%	0	0
0.5-0.59	5	0.5%	2	3	1	0.1%	0	1
0.6-0.69	6	0.6%	5	1	0	0.0%	0	0
0.7-0.79	6	0.6%	4	2	0	0.0%	0	0
0.8-0.89	35	3.4%	28	7	0	0.0%	0	0
0.9-0.99	35	3.4%	35	0	0	0.0%	0	0
> 1.00	61	5.9%	61	0	0	0.0%	0	0
Total	186		136	50	34		0	34
Average LRFR/LFR	1.35				0.90			



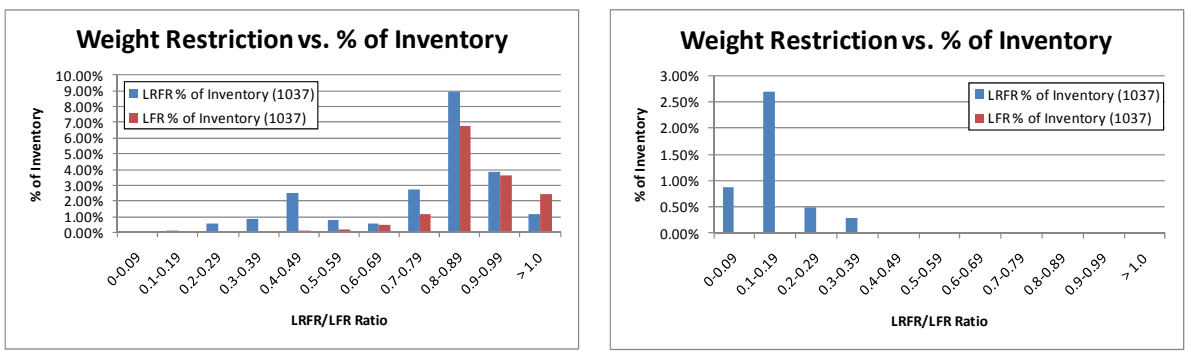
(a) (b)

Figure 6: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 7 and Figure 7 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 7 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the TX-04 vehicle is 0.97 for moment and 0.72 for shear.

Table 7: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	0.9%	0	9
0.1-0.19	1	0.1%	0	1	28	2.7%	0	28
0.2-0.29	6	0.6%	0	6	5	0.5%	0	5
0.3-0.39	9	0.9%	0	9	3	0.3%	0	3
0.4-0.49	26	2.5%	1	25	0	0.0%	0	0
0.5-0.59	8	0.8%	2	6	0	0.0%	0	0
0.6-0.69	6	0.6%	5	1	0	0.0%	0	0
0.7-0.79	28	2.7%	12	16	0	0.0%	0	0
0.8-0.89	93	9.0%	70	23	0	0.0%	0	0
0.9-0.99	40	3.9%	38	2	0	0.0%	0	0
> 1.00	12	1.2%	12	0	0	0.0%	0	0
Total	229		140	89	45		0	45
Average LRFR/LFR	0.97				0.72			



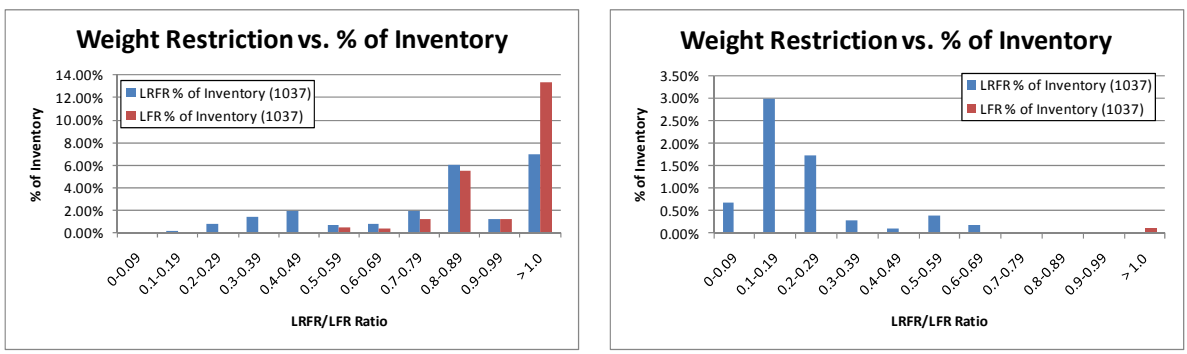
(a) (b)

Figure 7: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 8 and Figure 8 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 8 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the WA-02 vehicle is 1.26 for moment and 0.88 for shear.

Table 8: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	0.7%	0	7
0.1-0.19	2	0.2%	0	2	31	3.0%	0	31
0.2-0.29	8	0.8%	0	8	18	1.7%	0	18
0.3-0.39	15	1.5%	1	14	3	0.3%	0	3
0.4-0.49	20	1.9%	0	20	1	0.1%	0	1
0.5-0.59	7	0.7%	5	2	4	0.4%	0	4
0.6-0.69	8	0.8%	4	4	2	0.2%	0	2
0.7-0.79	20	1.9%	13	7	0	0.01%	0	0
0.8-0.89	63	6.1%	57	6	0	0.0%	0	0
0.9-0.99	13	1.3%	13	0	0	0.0%	0	0
> 1.00	72	6.9%	72	0	0	0.0%	0	0
Total	228		165	63	66		0	66
Average LRFR/LFR	1.26				0.88			



(a) (b)

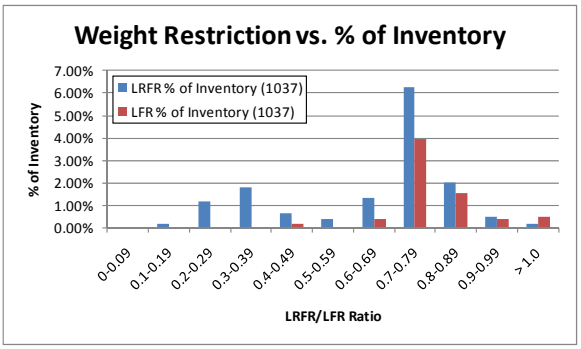
Figure 8: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 9 and Figure 9 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 9 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASTHO Type 3 vehicle is 0.90 for moment and 0.67 for shear.

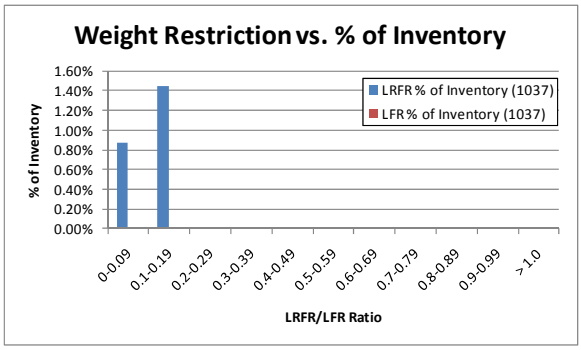
Table 9: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	0.9%	0	9
0.1-0.19	2	0.2%	0	2	15	1.5%	0	15
0.2-0.29	12	1.2%	0	12	0	0.0%	0	0
0.3-0.39	19	1.8%	0	19	0	0.0%	0	0

0.4-0.49	7	0.7%	2	5	0	0.0%	0	0
0.5-0.59	4	0.4%	0	4	0	0.0%	0	0
0.6-0.69	14	1.4%	4	10	0	0.0%	0	0
0.7-0.79	65	6.3%	41	24	0	0.0%	0	0
0.8-0.89	21	2.0%	16	5	0	0.0%	0	0
0.9-0.99	5	0.5%	4	1	0	0.0%	0	0
> 1.00	2	0.2%	2	0	0	0.0%	0	0
Total	151		69	82	24		0	24
Average LRFR/LFR	0.90				0.67			



(a)



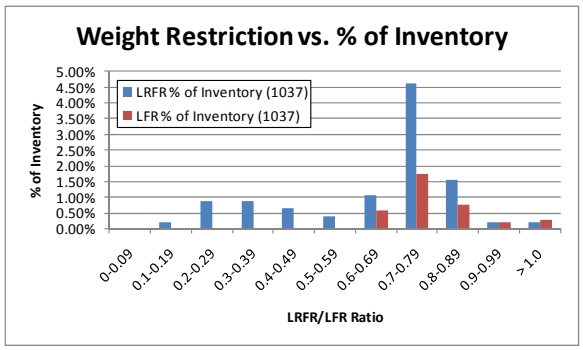
(b)

Figure 9: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

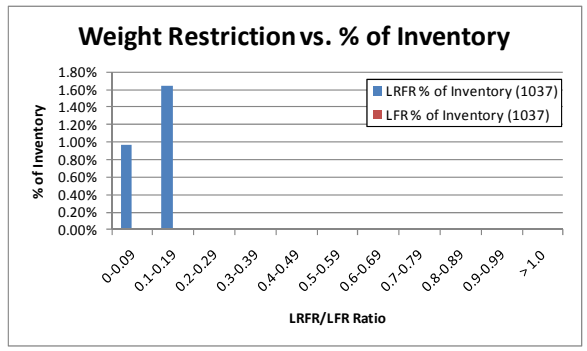
Table 10 and Figure 10 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 10 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASTHO Type 3-3 vehicle is 0.90 for moment and 0.64 for shear.

Table 10: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	10	1.0%	0	10
0.1-0.19	2	0.2%	0	2	17	1.6%	0	17
0.2-0.29	9	0.9%	0	9	0	0.0%	0	0
0.3-0.39	9	0.9%	0	9	0	0.0%	0	0
0.4-0.49	7	0.7%	0	7	0	0.0%	0	0
0.5-0.59	4	0.4%	0	4	0	0.0%	0	0
0.6-0.69	11	1.1%	6	5	0	0.0%	0	0
0.7-0.79	48	4.6%	18	30	0	0.0%	0	0
0.8-0.89	16	1.5%	8	8	0	0.0%	0	0
0.9-0.99	2	0.2%	2	0	0	0.0%	0	0
> 1.00	2	0.2%	2	0	0	0.0%	0	0
Total	110		36	74	27		0	27
Average LRFR/LFR	0.90				0.64			



(a)



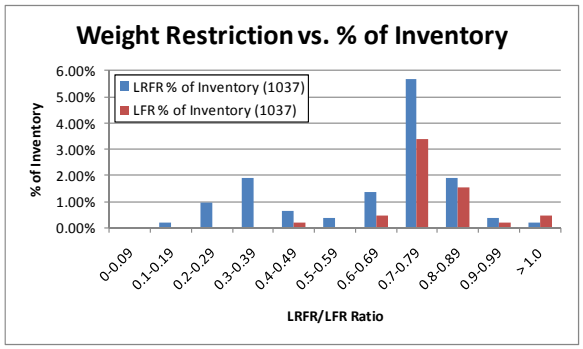
(b)

Figure 10: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

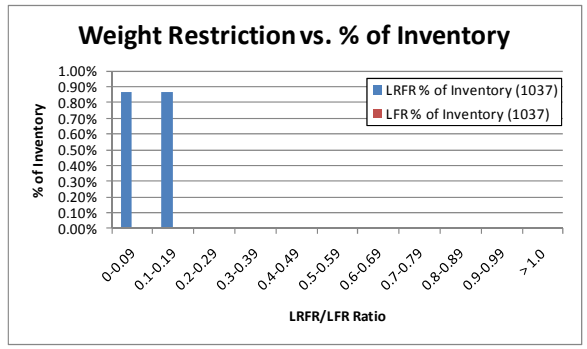
Table 11 and Figure 11 show the distribution of rating factor ratios for simple span steel girders with LRFR ratings less than 1.0. Figure 11 also shows the distribution of rating factor ratios for simple span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASTHO Type 3S2 vehicle is 0.92 for moment and 0.76 for shear.

Table 11: Distribution of Rating Factor Ratios for Simple Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (1037)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	9	0.9%	0	9
0.1-0.19	2	0.2%	0	2	9	0.9%	0	9
0.2-0.29	10	1.0%	0	10	0	0.0%	0	0
0.3-0.39	20	1.9%	0	20	0	0.0%	0	0
0.4-0.49	7	0.7%	2	5	0	0.0%	0	0
0.5-0.59	4	0.4%	0	4	0	0.0%	0	0
0.6-0.69	14	1.4%	5	9	0	0.0%	0	0
0.7-0.79	59	5.7%	35	24	0	0.0%	0	0
0.8-0.89	20	1.9%	16	4	0	0.0%	0	0
0.9-0.99	4	0.4%	2	2	0	0.0%	0	0
> 1.00	2	0.2%	2	0	0	0.0%	0	0
Total	142		62	80	18		0	18
Average LRFR/LFR	0.92				0.76			



(a)



(b)

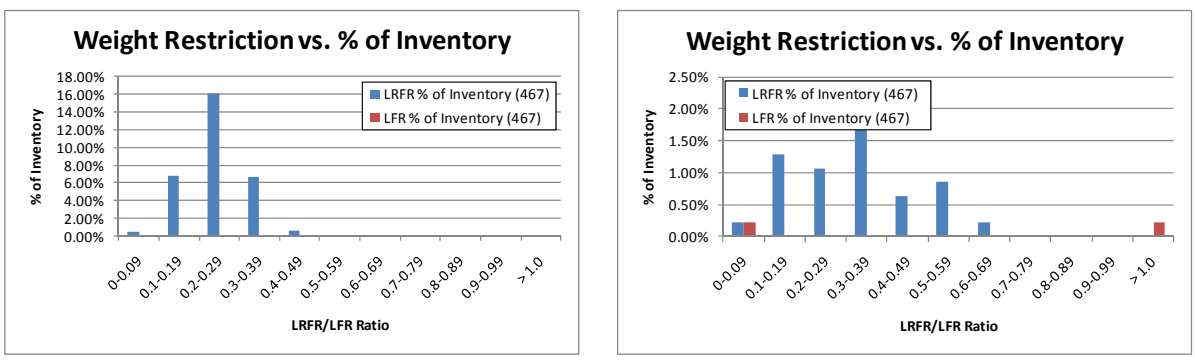
Figure 11: Distribution of Rating Factor Ratio for Simple Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

M.2 Simple Span Prestressed I-Girder Bridges

Table 12 and Figure 12 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 12 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the DE-07 vehicle is 0.35 for moment and 1.01 for shear.

Table 12: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.4%	0	2	1	0.2%	1	0
0.1-0.19	32	6.9%	0	32	6	1.3%	0	6
0.2-0.29	75	16.1%	0	75	5	1.1%	0	4
0.3-0.39	31	6.6%	0	31	9	1.9%	0	7
0.4-0.49	3	0.6%	0	3	3	0.6%	0	5
0.5-0.59	0	0.0%	0	0	4	0.9%	0	4
0.6-0.69	0	0.0%	0	0	1	0.2%	0	1
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	143		0	143	29		1	27
Average LRFR/LFR	0.35				1.01			



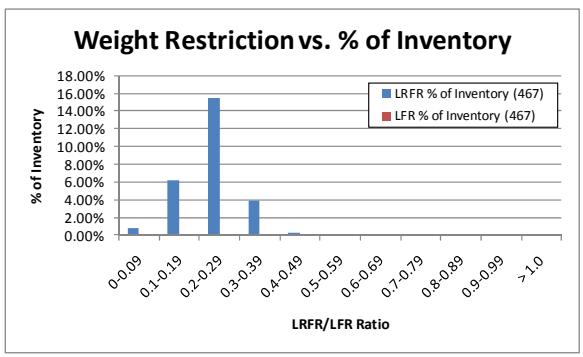
(a) (b)

Figure 12: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

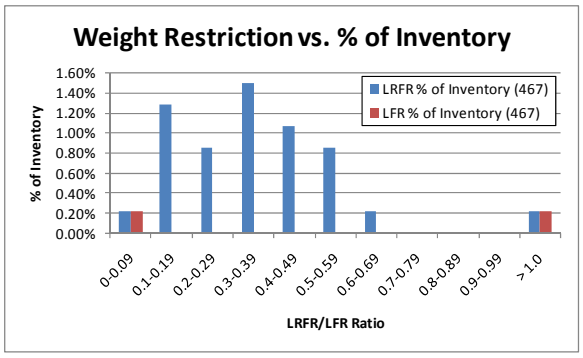
Table 13 and Figure 13 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 13 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the FL-04 vehicle is 0.34 for moment and 1.04 for shear.

Table 13: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	4	0.9%	0	4	1	0.2%	1	0
0.1-0.19	29	6.2%	0	29	6	1.3%	0	6
0.2-0.29	72	15.4%	0	72	4	0.9%	0	4
0.3-0.39	18	3.9%	0	18	7	1.5%	0	7
0.4-0.49	1	0.2%	0	1	5	1.1%	0	5
0.5-0.59	0	0.0%	0	0	4	0.9%	0	4
0.6-0.69	0	0.0%	0	0	1	0.2%	0	1
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	1	0.2%	1	0
Total	124		0	212	29		2	27
Average LRFR/LFR	0.34				1.04			



(a)



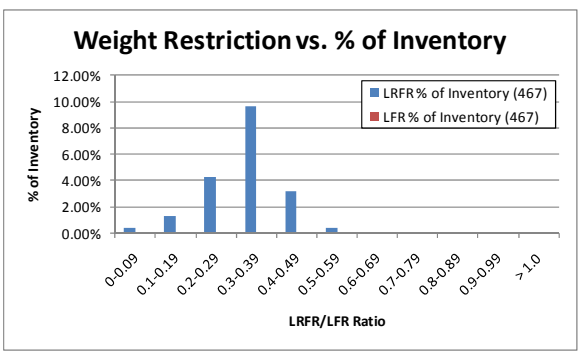
(b)

Figure 13: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

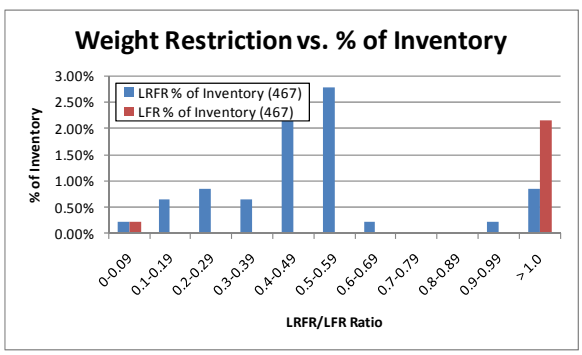
Table 14 and Figure 14 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 14 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the IL-01 vehicle is 0.55 for moment and 1.24 for shear.

Table 14: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.4%	0	2	1	0.2%	1	0
0.1-0.19	6	1.3%	0	6	3	0.6%	0	3
0.2-0.29	20	4.3%	0	20	4	0.9%	0	4
0.3-0.39	45	9.6%	0	45	3	0.6%	0	3
0.4-0.49	15	3.2%	0	15	10	2.1%	0	10
0.5-0.59	2	0.4%	0	2	13	2.8%	0	13
0.6-0.69	0	0.0%	0	0	1	0.2%	0	1
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	1	0.2%	0	1
> 1.00	0	0.0%	0	0	4	0.9%	4	0
Total	90		0	90	40		5	35
Average LRFR/LFR	0.55				1.24			



(a)



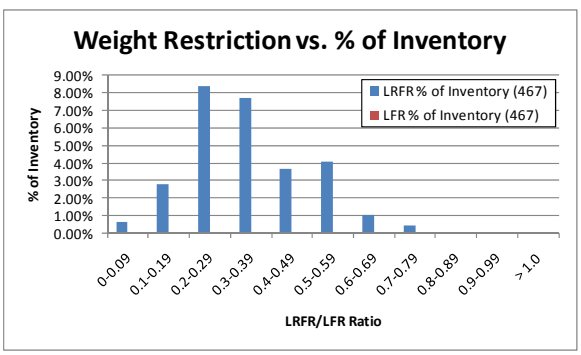
(b)

Figure 14: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

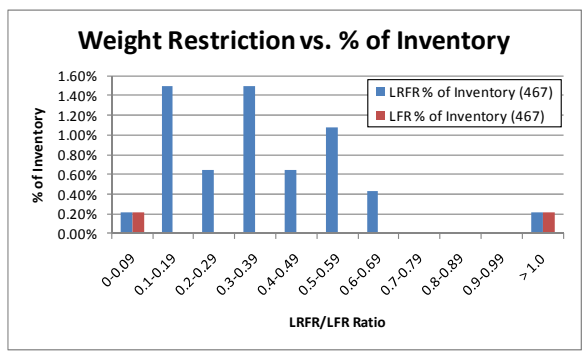
Table 15 and Figure 15 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 15 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NC-21 vehicle is 0.43 for moment and 0.92 for shear.

Table 15: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	3	0.6%	0	3	1	0.2%	1	0
0.1-0.19	13	2.8%	0	13	7	1.5%	0	7
0.2-0.29	39	8.4%	0	39	3	0.6%	0	3
0.3-0.39	36	7.7%	0	36	7	1.5%	0	7
0.4-0.49	17	3.6%	0	17	3	0.6%	0	3
0.5-0.59	19	4.1%	0	19	5	1.1%	0	5
0.6-0.69	5	1.1%	0	5	2	0.4%	0	2
0.7-0.79	2	0.4%	0	2	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	1	0.2%	1	0
Total	134		0	134	29		2	27
Average LRFR/LFR	0.43				0.92			



(a)



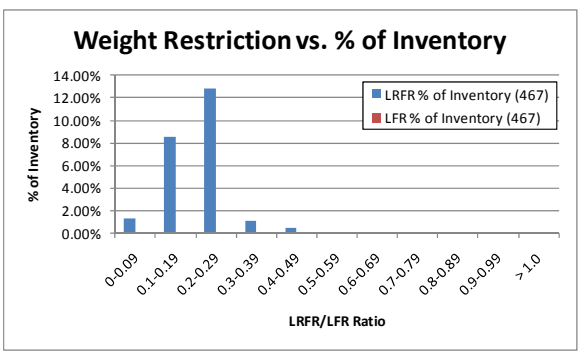
(b)

Figure 15: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

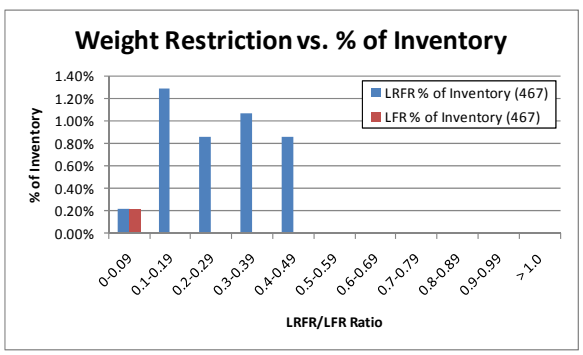
Table 16 and Figure 16 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 16 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NM-04 vehicle is 0.30 for moment and 0.96 for shear.

Table 16: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	1.3%	0	6	1	0.2%	1	0
0.1-0.19	40	8.6%	0	40	6	1.3%	0	6
0.2-0.29	60	12.9%	0	60	4	0.9%	0	4
0.3-0.39	5	1.1%	0	5	5	1.1%	0	5
0.4-0.49	2	0.4%	0	2	4	0.9%	0	4
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	113		0	113	20		1	19
Average LRFR/LFR	0.30				0.96			



(a)



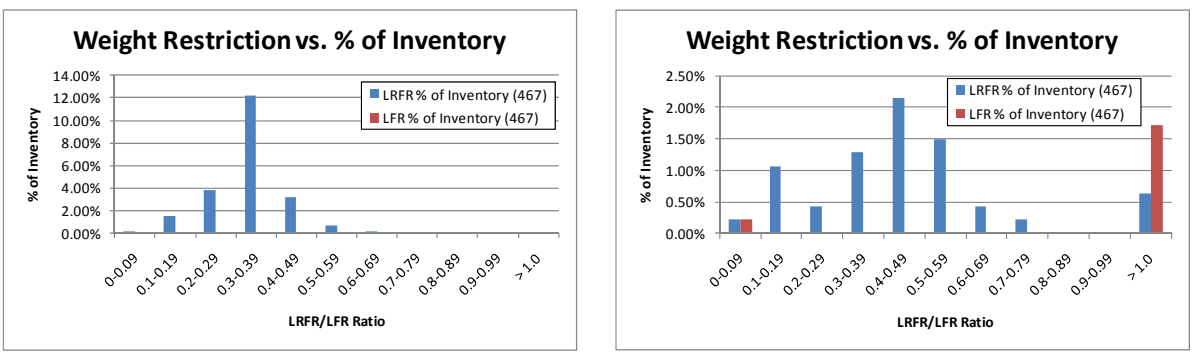
(b)

Figure 16: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 17 and Figure 17 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 17 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the OR-06 vehicle is 0.56 for moment and 1.20 for shear.

Table 17: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.2%	0	1	1	0.2%	1	0
0.1-0.19	7	1.5%	0	7	5	1.1%	0	5
0.2-0.29	18	3.8%	0	18	2	0.4%	0	2
0.3-0.39	57	12.2%	0	57	6	1.3%	0	6
0.4-0.49	15	3.2%	0	15	10	2.1%	0	10
0.5-0.59	3	0.6%	0	3	7	1.5%	0	7
0.6-0.69	1	0.2%	0	1	2	0.4%	0	2
0.7-0.79	0	0.0%	0	0	1	0.2%	0	1
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	3	0.6%	0	3
Total	102		0	102	37		1	36
Average LRFR/LFR	0.56				1.20			



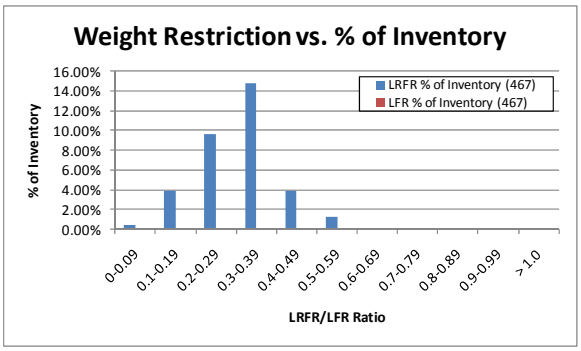
(a) (b)

Figure 17: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

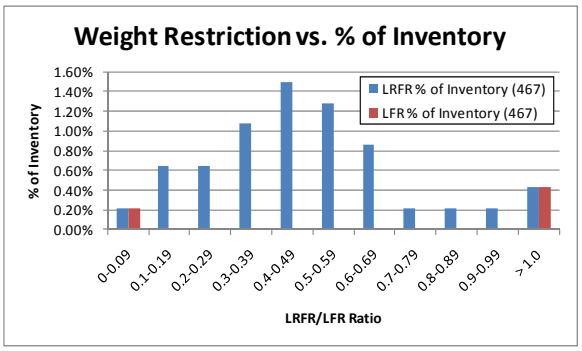
Table 18 and Figure 18 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 18 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the TX-04 vehicle is 0.43 for moment and 1.32 for shear.

Table 18: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.4%	0	2	1	0.2%	1	0
0.1-0.19	18	3.9%	0	18	3	0.6%	0	3
0.2-0.29	45	9.6%	0	45	3	0.6%	0	3
0.3-0.39	69	14.8%	0	69	5	1.1%	0	5
0.4-0.49	18	3.9%	0	18	7	1.5%	0	7
0.5-0.59	6	1.3%	0	6	6	1.3%	0	6
0.6-0.69	0	0.0%	0	0	4	0.9%	0	4
0.7-0.79	0	0.0%	0	0	1	0.2%	0	1
0.8-0.89	0	0.0%	0	0	1	0.2%	0	1
0.9-0.99	0	0.0%	0	0	1	0.2%	0	1
> 1.00	0	0.0%	0	0	2	0.4%	0	2
Total	158		0	158	34		1	33
Average LRFR/LFR	0.43				1.32			



(a)



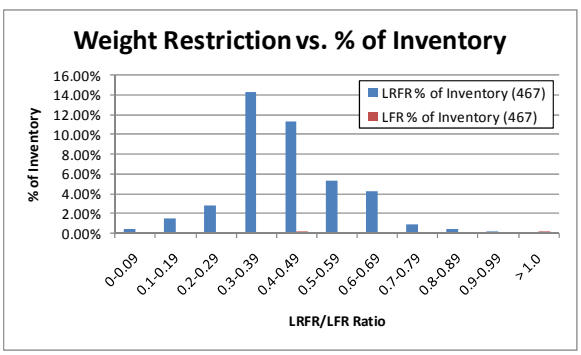
(b)

Figure 18: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

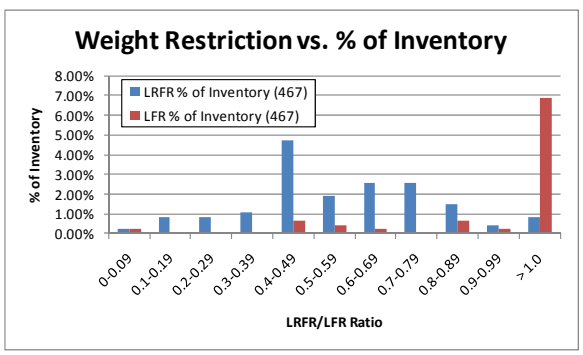
Table 19 and Figure 19 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 19 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the WA-02 vehicle is 0.58 for moment and 1.12 for shear.

Table 19: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.4%	0	2	1	0.2%	1	0
0.1-0.19	7	1.5%	0	7	4	0.9%	0	4
0.2-0.29	13	2.8%	0	13	4	0.9%	0	4
0.3-0.39	67	14.4%	4	63	5	1.1%	1	4
0.4-0.49	53	11.4%	1	52	22	4.7%	3	19
0.5-0.59	25	5.4%	0	25	9	1.9%	2	7
0.6-0.69	20	4.3%	0	20	12	2.6%	1	11
0.7-0.79	4	0.9%	0	4	12	2.6%	0	12
0.8-0.89	2	0.4%	0	2	7	1.5%	3	4
0.9-0.99	1	0.2%	0	1	2	0.4%	1	1
> 1.00	0	0.0%	0	0	4	0.9%	4	0
Total	194		5	189	82		16	66
Average LRFR/LFR	0.58				1.12			



(a)



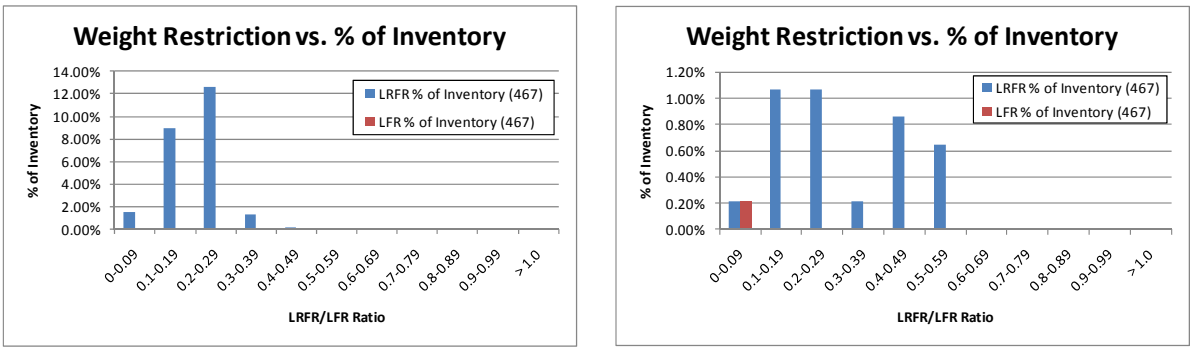
(b)

Figure 19: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 20 and Figure 20 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 20 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3 vehicle is 0.31 for moment and 1.02 for shear.

Table 20: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.5%	0	7	1	0.2%	1	0
0.1-0.19	42	9.0%	0	42	5	1.1%	0	5
0.2-0.29	59	12.6%	0	59	5	1.1%	0	5
0.3-0.39	6	1.3%	0	6	1	0.2%	0	1
0.4-0.49	1	0.2%	0	1	4	0.9%	0	4
0.5-0.59	0	0.0%	0	0	3	0.6%	0	3
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	115		0	115	19		1	18
Average LRFR/LFR	0.31				1.02			



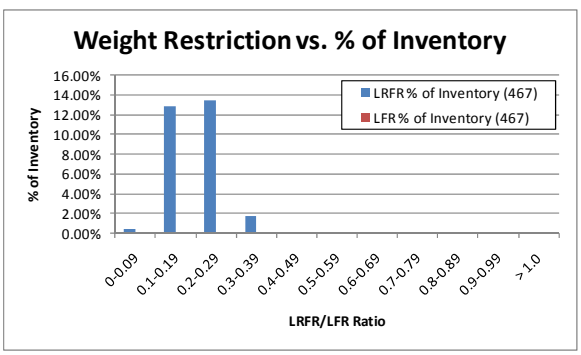
(a) (b)

Figure 20: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

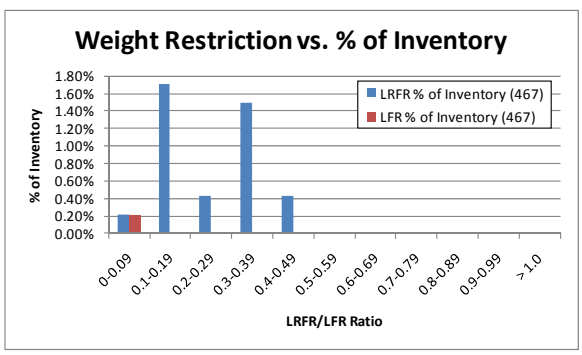
Table 21 and Figure 21 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 21 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3-3 vehicle is 0.30 for moment and 1.00 for shear.

Table 21: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.4%	0	2	1	0.2%	1	0
0.1-0.19	60	12.9%	0	60	8	1.7%	0	8
0.2-0.29	63	13.5%	0	63	2	0.4%	0	2
0.3-0.39	8	1.7%	0	8	7	1.5%	0	7
0.4-0.49	0	0.0%	0	0	2	0.4%	0	2
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	133		0	133	20		1	19
Average LRFR/LFR	0.30				1.00			



(a)



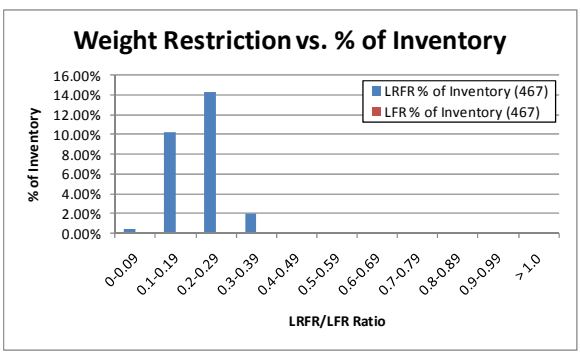
(b)

Figure 21: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

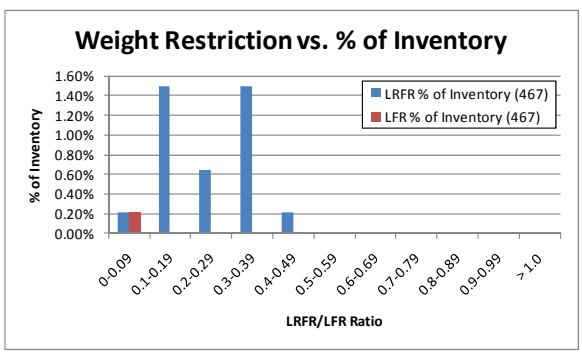
Table 22 and Figure 22 show the distribution of rating factor ratios for simple span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 22 also shows the distribution of rating factor ratios for simple span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3S2 vehicle is 0.31 for moment and 0.97 for shear.

Table 22: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete I-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (467)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.4	0	2	1	0.2%	1	0
0.1-0.19	48	10.3	0	48	7	1.5%	0	7
0.2-0.29	67	14.4	0	67	3	0.6%	0	3
0.3-0.39	9	1.9	0	9	7	1.5%	0	7
0.4-0.49	0	0.0%	0	0	1	0.2%	0	1
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	126		0	126	19		1	18
Average LRFR/LFR	0.31				0.97			



(a)



(b)

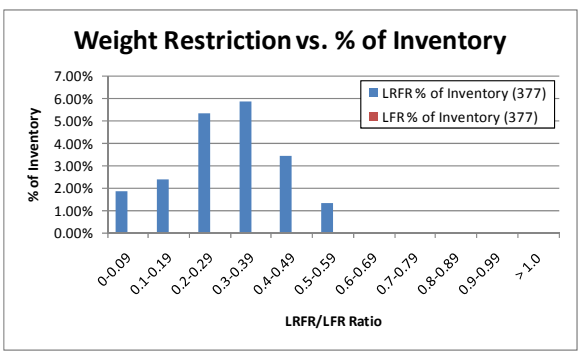
Figure 22: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

M.3 Simple Span Prestressed Concrete Box Girder Bridges

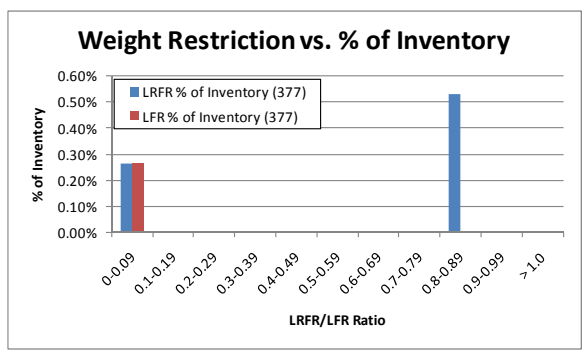
Table 23 and Figure 23 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 23 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the DE-07 vehicle is 0.50 for moment and 1.33 for shear.

Table 23: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	9	2.4%	0	9	0	0.0%	0	0
0.2-0.29	20	5.3%	0	20	0	0.0%	0	0
0.3-0.39	22	5.8%	0	22	0	0.0%	0	0
0.4-0.49	13	3.5%	0	13	0	0.0%	0	0
0.5-0.59	5	1.3%	0	5	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	2	0.5%	0	2
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	76		0	76	3		1	2
Average LRFR/LFR	0.50				1.33			



(a)



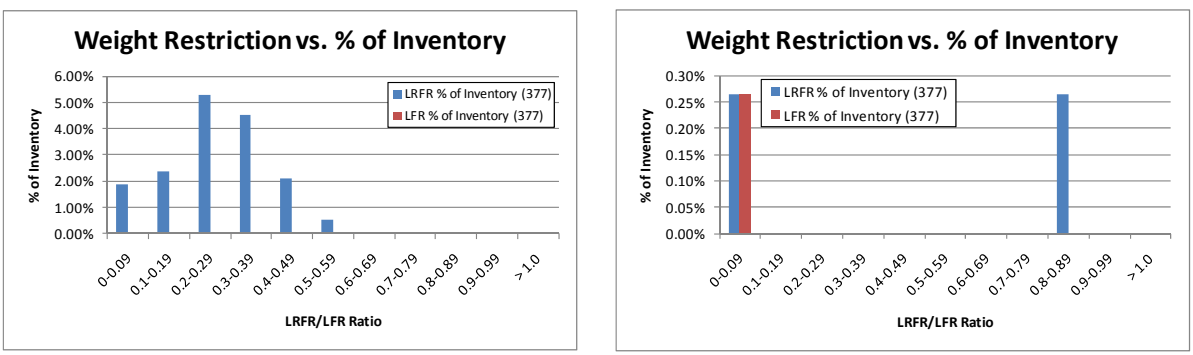
(b)

Figure 23: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

Table 24 and Figure 24 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 24 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the FL-04 vehicle is 0.51 for moment and 1.36 for shear.

Table 24: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	9	2.4%	0	9	0	0.0%	0	0
0.2-0.29	20	5.3%	0	20	0	0.0%	0	0
0.3-0.39	17	4.5%	0	17	0	0.0%	0	0
0.4-0.49	8	2.1%	0	8	0	0.0%	0	0
0.5-0.59	2	0.5%	0	2	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	1	0.3%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	63		0	63	2		1	1
Average LRFR/LFR	0.51				1.36			



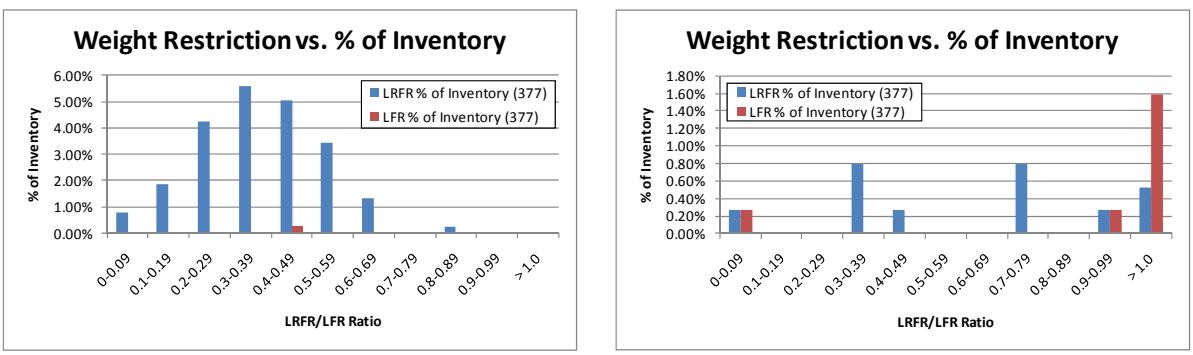
(a) (b)

Figure 24: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 25 and Figure 25 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 25 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the IL-01 vehicle is 0.66 for moment and 1.46 for shear.

Table 25: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	3	0.8%	0	3	1	0.3%	1	0
0.1-0.19	7	1.9%	0	7	0	0.0%	0	0
0.2-0.29	16	4.2%	0	16	0	0.0%	0	0
0.3-0.39	21	5.6%	0	21	3	0.8%	0	3
0.4-0.49	19	5.0%	1	18	1	0.3%	0	1
0.5-0.59	13	3.5%	0	13	0	0.0%	0	0
0.6-0.69	5	1.3%	0	5	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	3	0.8%	0	3
0.8-0.89	1	0.3%	0	1	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	1	0.3%	1	0
> 1.00	0	0.0%	0	0	2	0.5%	2	0
Total	85		1	84	11		4	7
Average LRFR/LFR	0.66				1.46			



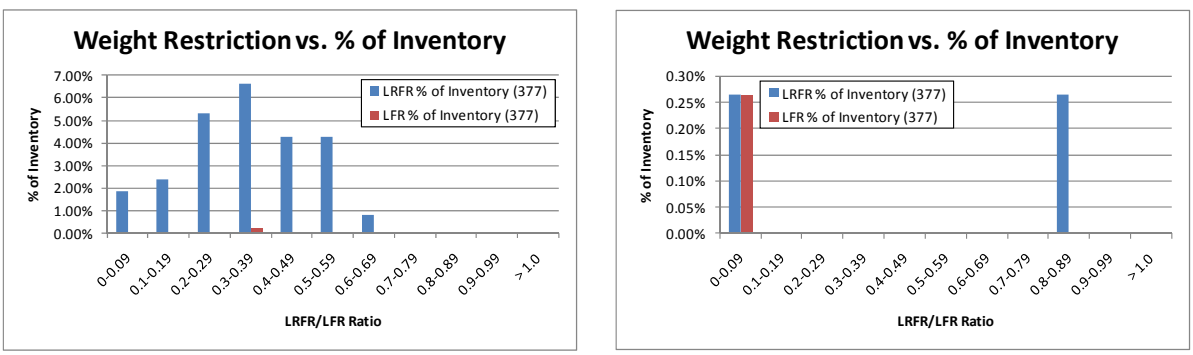
(a) (b)

Figure 25: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

Table 26 and Figure 26 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 26 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NC-21 vehicle is 0.51 for moment and 1.37 for shear.

Table 26: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	9	2.4%	0	9	0	0.0%	0	0
0.2-0.29	20	5.3%	0	20	0	0.0%	0	0
0.3-0.39	25	6.6%	1	24	0	0.0%	0	0
0.4-0.49	16	4.2%	0	16	0	0.0%	0	0
0.5-0.59	16	4.2%	0	16	0	0.0%	0	0
0.6-0.69	3	0.8%	0	3	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	1	0.3%	1	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	96		1	95	2		2	0
Average LRFR/LFR	0.51				1.37			



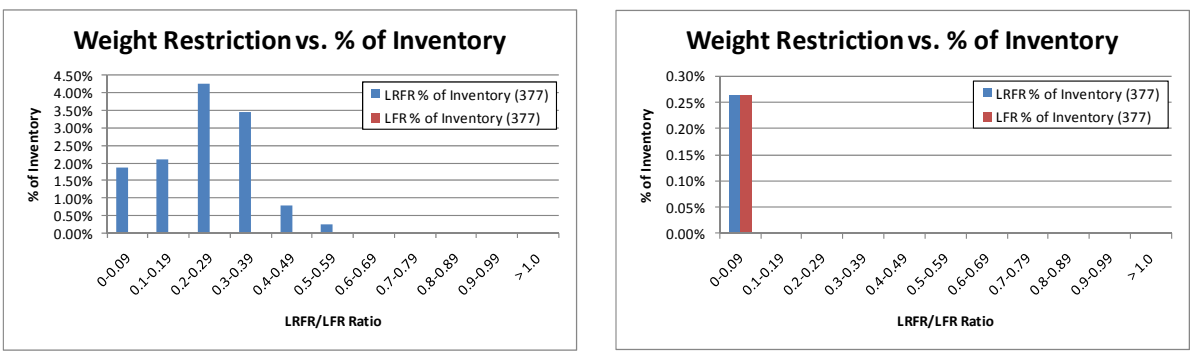
(a) (b)

Figure 26: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 27 and Figure 27 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 27 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NM-04 vehicle is 0.50 for moment and 1.41 for shear.

Table 27: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	1
0.1-0.19	8	2.1%	0	8	0	0.0%	0	0
0.2-0.29	16	4.2%	0	16	0	0.0%	0	0
0.3-0.39	13	3.5%	1	12	0	0.0%	0	0
0.4-0.49	3	0.8%	0	3	0	0.0%	0	0
0.5-0.59	1	0.3%	0	1	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	48		1	47	1		1	0
Average LRFR/LFR	0.50				1.41			



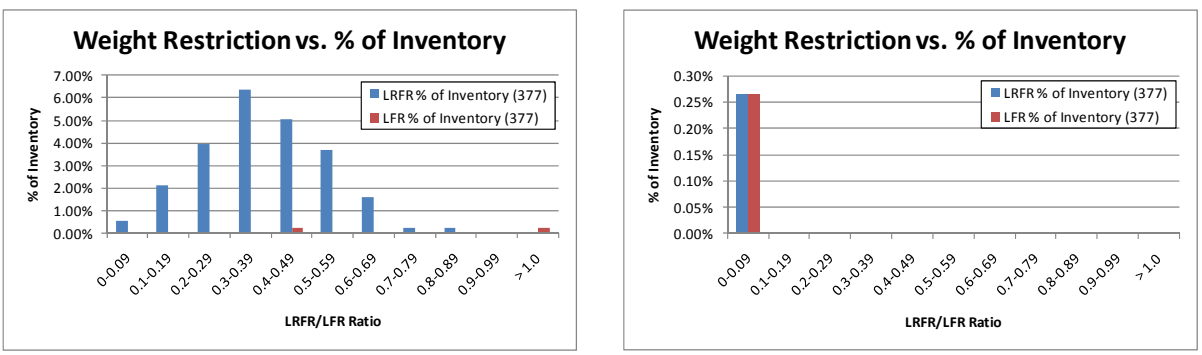
(a) (b)

Figure 27: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 28 and Figure 28 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 28 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the OR-06 vehicle is 0.66 for moment and 1.77 for shear.

Table 28: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.5%	0	2	1	0.3%	1	0
0.1-0.19	8	2.1%	0	8	0	0.0%	0	0
0.2-0.29	15	4.0%	0	15	0	0.0%	0	0
0.3-0.39	24	6.4%	0	24	0	0.0%	0	0
0.4-0.49	19	5.0%	1	18	0	0.0%	0	0
0.5-0.59	14	3.7%	0	14	0	0.0%	0	0
0.6-0.69	6	1.6%	0	6	0	0.0%	0	0
0.7-0.79	1	0.3%	0	1	0	0.0%	0	0
0.8-0.89	1	0.3%	0	1	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	90		1	89	1		1	0
Average LRFR/LFR	0.66				1.77			



(a) (b)

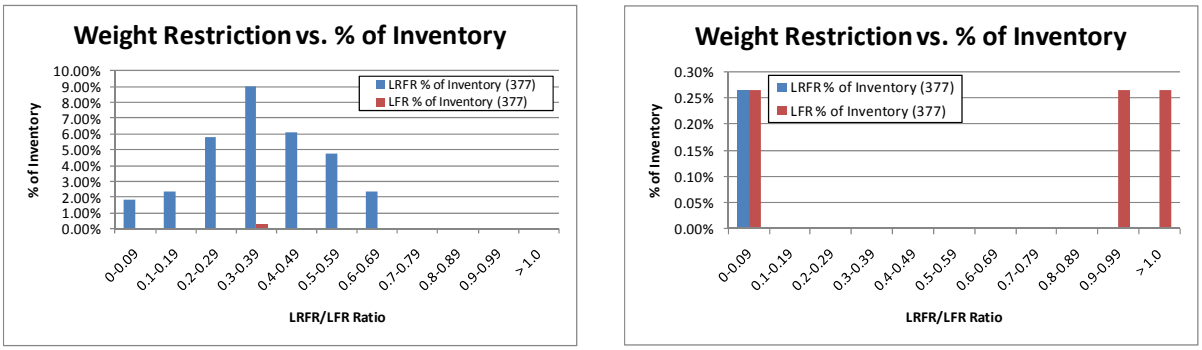
Figure 28: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 29 and Figure 29 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 29 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the TX-04 vehicle is 0.51 for moment and 1.27 for shear.

Table 29: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	9	2.4%	0	9	0	0.0%	0	0
0.2-0.29	22	5.8%	0	22	0	0.0%	0	0
0.3-0.39	34	9.0%	0	34	0	0.0%	0	0

0.4-0.49	23	6.1%	0	23	0	0.0%	0	0
0.5-0.59	18	4.8%	0	18	0	0.0%	0	0
0.6-0.69	9	2.4%	0	9	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	122		0	122	1		1	0
Average LRFR/LFR	0.51				1.27			



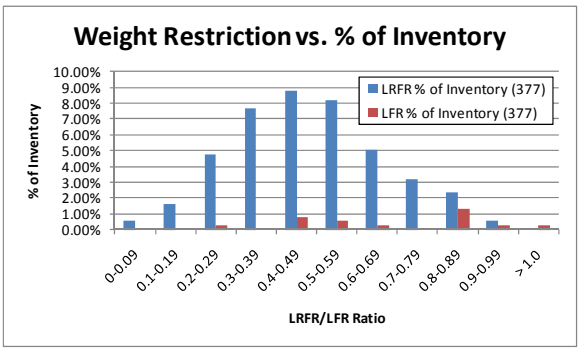
(a) (b)

Figure 29: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

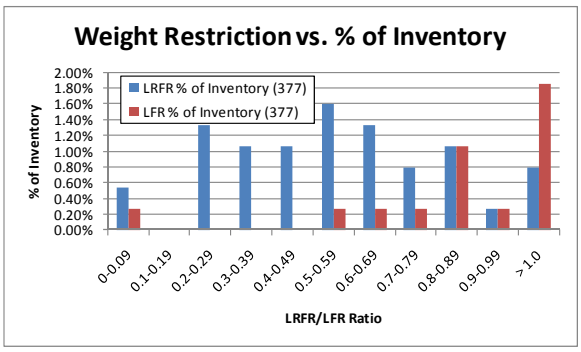
Table 30 and Figure 30 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 30 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the WA-02 vehicle is 0.66 for moment and and 1.32 for shear.

Table 30: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.5%	0	2	2	0.5%	1	1
0.1-0.19	6	1.6%	0	6	0	0.0%	0	0
0.2-0.29	18	4.8%	1	17	5	1.3%	0	5
0.3-0.39	29	7.7%	5	24	4	1.1%	0	4
0.4-0.49	33	8.8%	3	30	4	1.1%	0	4
0.5-0.59	31	8.2%	2	29	6	1.6%	1	5
0.6-0.69	19	5.0%	1	18	5	1.3%	1	4
0.7-0.79	12	3.2%	0	12	3	0.8%	1	2
0.8-0.89	9	2.4%	5	4	4	1.1%	4	0
0.9-0.99	2	0.5%	1	1	1	0.3%	1	0
> 1.00	0	0.0%	0	0	3	0.8%	3	0
Total	161		18	143	37		12	25
Average LRFR/LFR	0.66				1.32			



(a)



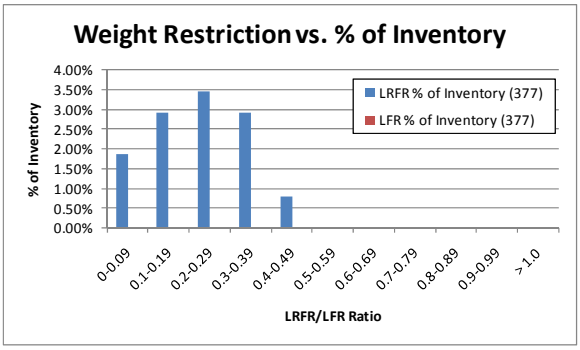
(b)

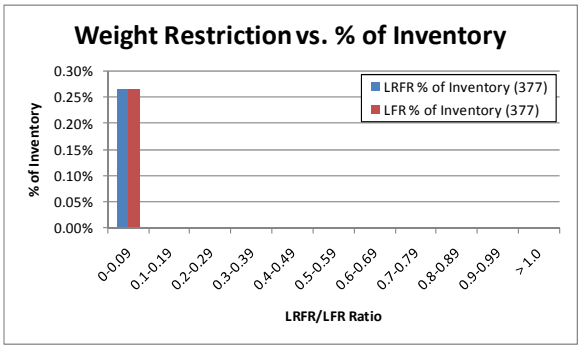
Figure 30: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 31 and Figure 31 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 31 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3 vehicle is 0.48 for moment and 1.34 for shear.

Table 31: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	11	2.9%	0	11	0	0.0%	0	0
0.2-0.29	13	3.5%	0	13	0	0.0%	0	0
0.3-0.39	11	2.9%	0	11	0	0.0%	0	0
0.4-0.49	3	0.8%	0	3	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	45		0	45	1		1	0
Average LRFR/LFR	0.48				1.34			





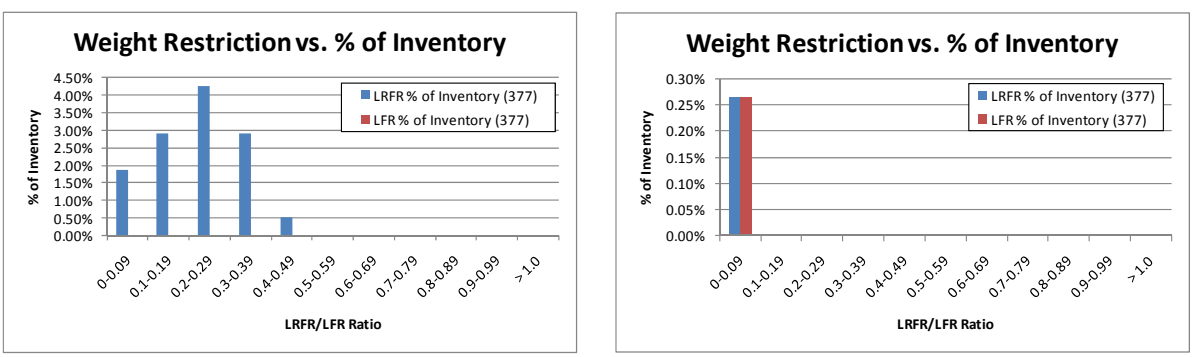
(a) (b)

Figure 31: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 32 and Figure 32 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 32 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3-3 vehicle is 0.47 for moment and 1.33 for shear.

Table 32: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	11	2.9%	0	11	0	0.0%	0	0
0.2-0.29	16	4.2%	0	16	0	0.0%	0	0
0.3-0.39	11	2.9%	0	11	0	0.0%	0	0
0.4-0.49	2	0.5%	0	2	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	47		0	47	1		1	0
Average LRFR/LFR	0.47				1.33			



(a) (b)

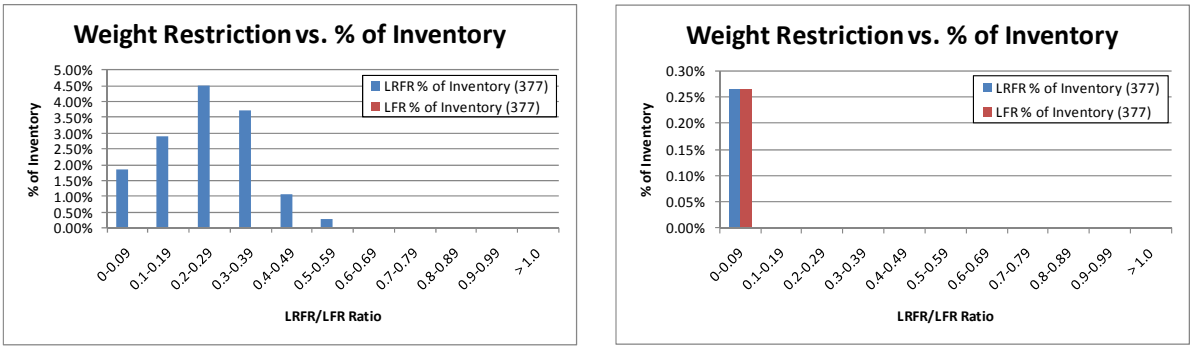
Figure 32: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

Table 33 and Figure 33 show the distribution of rating factor ratios for simple span prestressed concrete box girders with LRFR ratings less than 1.0. Figure 33 also shows the distribution of rating factor ratios for simple span prestressed concrete box girders

with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3S2 vehicle is 0.48 for moment and 1.31 for shear.

Table 33: Distribution of Rating Factor Ratios for Simple Span Prestressed Concrete Box-Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (377)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	1.9%	0	7	1	0.3%	1	0
0.1-0.19	11	2.9%	0	11	0	0.0%	0	0
0.2-0.29	17	4.5%	0	17	0	0.0%	0	0
0.3-0.39	14	3.7%	0	14	0	0.0%	0	0
0.4-0.49	4	1.1%	0	4	0	0.0%	0	0
0.5-0.59	1	0.3%	0	1	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	54		0	65	1		1	0
Average LRFR/LFR	0.45				1.03			



(a) (b)

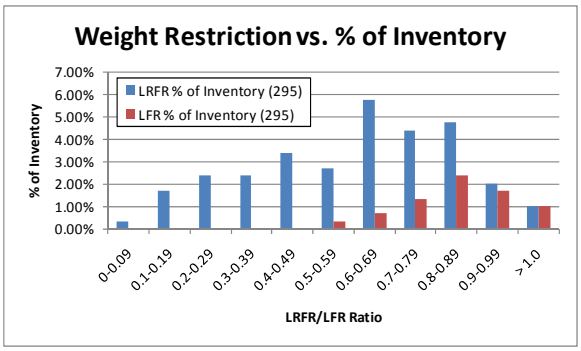
Figure 33: Distribution of Rating Factor Ratio for Simple Span Prestressed Concrete Box-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

M.4 Simple Span Reinforced Concrete Tee-Beam Bridges

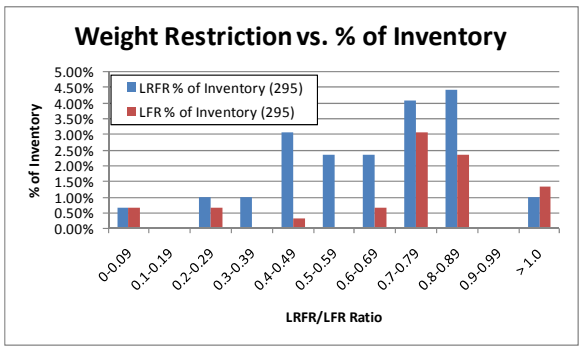
Table 34 and Figure 34 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 34 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the DE-07 vehicle is 0.67 for moment and 0.97 for shear.

Table 34: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	2	0.7%	2	0
0.1-0.19	5	1.7%	0	5	0	0.0%	0	0
0.2-0.29	7	2.4%	0	7	3	1.0%	2	1
0.3-0.39	7	2.4%	0	7	3	1.0%	0	3
0.4-0.49	10	3.4%	0	10	9	3.1%	1	8
0.5-0.59	8	2.7%	1	7	7	2.4%	0	7
0.6-0.69	17	5.8%	2	15	7	2.4%	2	5
0.7-0.79	13	4.4%	4	9	12	4.1%	9	3
0.8-0.89	14	4.8%	7	7	13	4.4%	7	6
0.9-0.99	6	2.0%	5	1	0	0.0%	0	0
> 1.00	3	1.0%	3	0	3	1.0%	3	0
Total	91		22	69	59		26	33
Average LRFR/LFR	0.67				0.97			



(a)



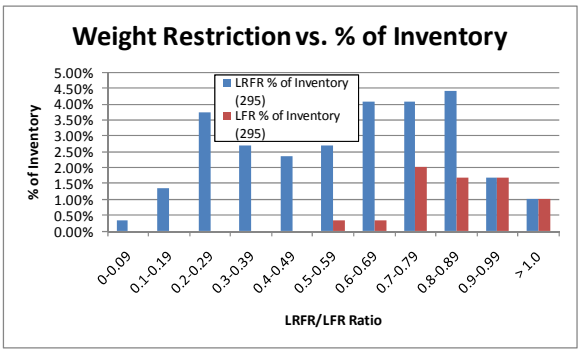
(b)

Figure 34: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

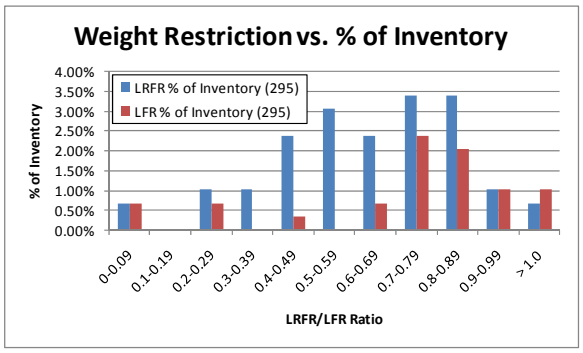
Table 35 and Figure 35 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 35 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the FL-04 vehicle is 0.67 for moment and 0.98 for shear.

Table 35: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	2	0.7%	2	0
0.1-0.19	4	1.4%	0	4	0	0.0%	0	0
0.2-0.29	11	3.7%	0	11	3	0.7%	2	1
0.3-0.39	8	2.7%	0	8	3	0.0%	0	3
0.4-0.49	7	2.4%	0	7	7	0.3%	1	6
0.5-0.59	8	2.7%	1	7	9	0.0%	0	9
0.6-0.69	12	4.1%	1	11	7	0.7%	2	5
0.7-0.79	12	4.1%	6	6	10	2.4%	7	3
0.8-0.89	13	4.4%	5	8	10	2.0%	6	4
0.9-0.99	5	1.7%	5	0	3	1.0%	3	0
> 1.00	3	1.0%	3	0	2	1.0%	2	0
Total	84		21	63	56		25	31
Average LRFR/LFR	0.67				0.98			



(a)



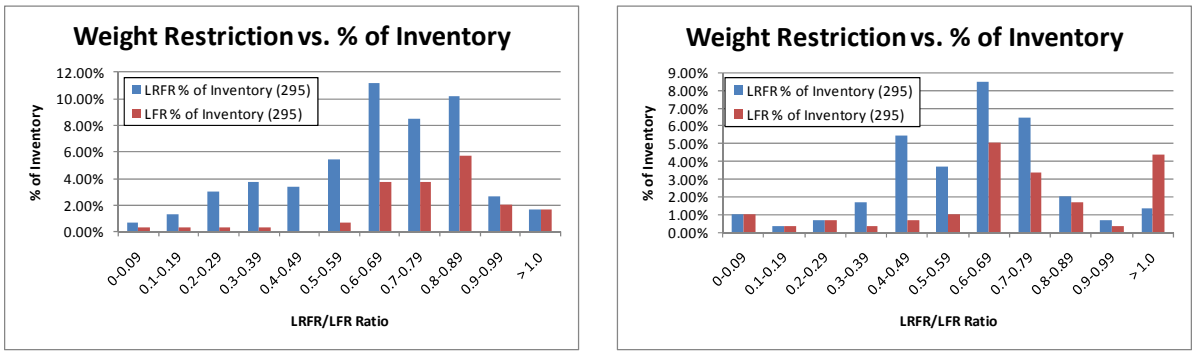
(b)

Figure 35: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 36 and Figure 36 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 36 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the IL-01 vehicle is 0.70 for moment and 0.89 for shear.

Table 36: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	1	1	3	1.0%	3	0
0.1-0.19	4	1.4%	1	3	1	0.3%	1	0
0.2-0.29	9	3.1%	1	8	2	0.7%	2	0
0.3-0.39	11	3.7%	1	10	5	1.7%	1	4
0.4-0.49	10	3.4%	0	10	16	5.4%	2	14
0.5-0.59	16	5.4%	2	14	11	3.7%	3	8
0.6-0.69	33	11.2%	11	22	25	8.5%	15	10
0.7-0.79	25	8.5%	11	14	19	6.4%	10	9
0.8-0.89	30	10.2%	17	13	6	2.0%	5	1
0.9-0.99	8	2.7%	6	2	2	0.7%	1	1
> 1.00	5	1.7%	5	0	4	1.4%	4	0
Total	153		56	97	94		47	47
Average LRFR/LFR	0.70				0.89			



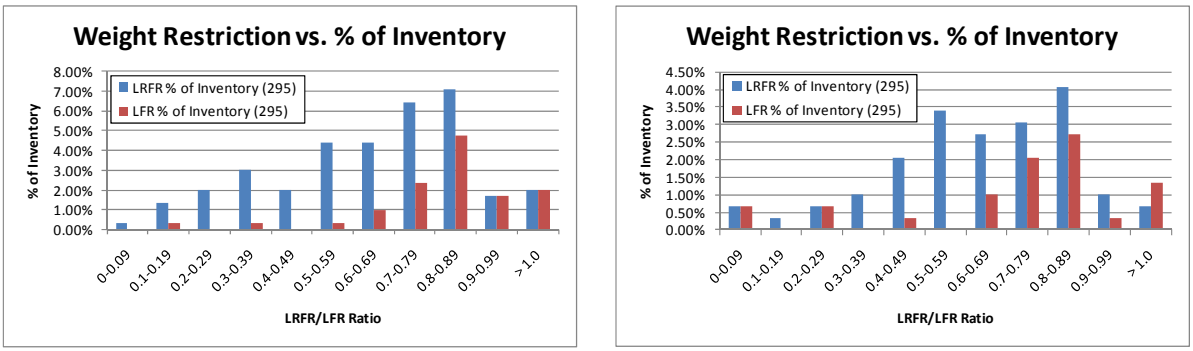
(a) (b)

Figure 36: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

Table 37 and Figure 37 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 37 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NC-21 vehicle is 0.71 for moment and 0.97 for shear.

Table 37: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	2	0.7%	2	0
0.1-0.19	4	1.4%	1	3	1	0.3%	0	1
0.2-0.29	6	2.0%	0	6	2	0.7%	2	0
0.3-0.39	9	3.1%	1	8	3	1.0%	0	3
0.4-0.49	6	2.0%	0	6	6	2.0%	1	5
0.5-0.59	13	4.4%	1	12	10	3.4%	0	10
0.6-0.69	13	4.4%	3	10	8	2.7%	3	5
0.7-0.79	19	6.4%	7	12	9	3.1%	6	3
0.8-0.89	21	7.1%	14	7	12	4.1%	8	4
0.9-0.99	5	1.7%	5	0	3	1.0%	1	2
> 1.00	6	2.0%	6	0	2	0.7%	2	0
Total	103		38	65	58		25	33
Average LRFR/LFR	0.71				0.97			



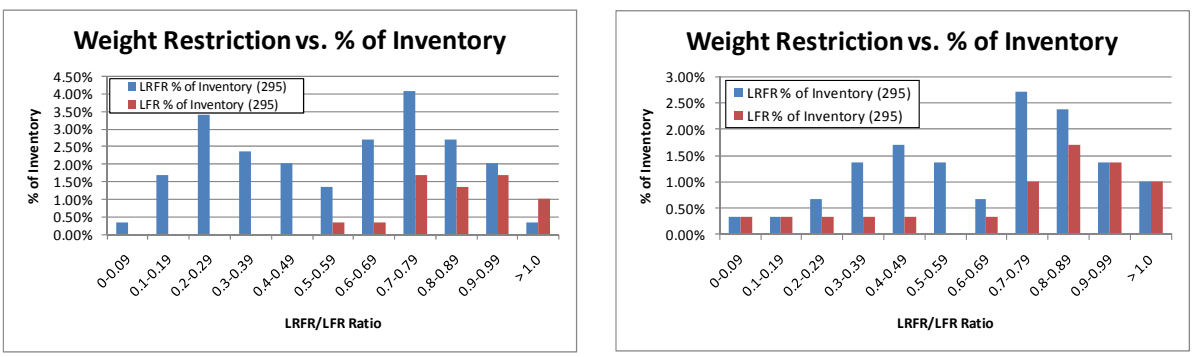
(a) (b)

Figure 37: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 38 and Figure 38 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 38 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NM-04 vehicle is 0.68 for moment and 1.00 for shear.

Table 38: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	1	0.3%	1	0
0.1-0.19	5	1.7%	0	5	1	0.3%	1	0
0.2-0.29	10	3.4%	0	10	2	0.7%	1	1
0.3-0.39	7	2.4%	0	7	4	1.4%	1	3
0.4-0.49	6	2.0%	0	6	5	1.7%	1	4
0.5-0.59	4	1.4%	1	3	4	1.4%	0	4
0.6-0.69	8	2.7%	1	7	2	0.7%	1	1
0.7-0.79	12	4.1%	5	7	8	2.7%	3	5
0.8-0.89	8	2.7%	4	4	7	2.4%	5	2
0.9-0.99	6	2.0%	5	1	4	1.4%	4	0
> 1.00	1	0.3%	1	0	3	1.0%	3	0
Total	68		17	51	41		21	20
Average LRFR/LFR	0.68				1.00			



(a) (b)

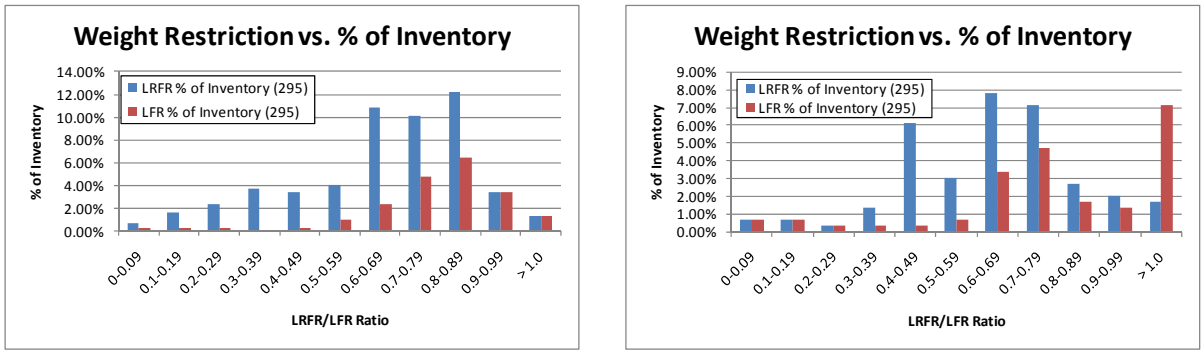
Figure 38: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 39 and Figure 39 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 39 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the OR-06 vehicle 0.71 for moment and 0.90 for shear.

Table 39: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	1	1	2	0.7%	2	0
0.1-0.19	5	1.7%	1	4	2	0.7%	2	0
0.2-0.29	7	2.4%	1	6	1	0.3%	1	0
0.3-0.39	11	3.7%	0	11	4	1.4%	1	3

0.4-0.49	10	3.4%	1	9	18	6.1%	1	17
0.5-0.59	12	4.1%	3	9	9	3.1%	2	7
0.6-0.69	32	10.9%	7	25	23	7.8%	10	13
0.7-0.79	30	10.2%	14	16	21	7.1%	14	7
0.8-0.89	36	12.2%	19	17	8	2.7%	5	3
0.9-0.99	10	3.4%	10	0	6	2.0%	4	2
> 1.00	4	1.4%	4	0	5	1.7%	5	0
Total	159		61	98	99		47	52
Average LRFR/LFR	0.71				0.90			



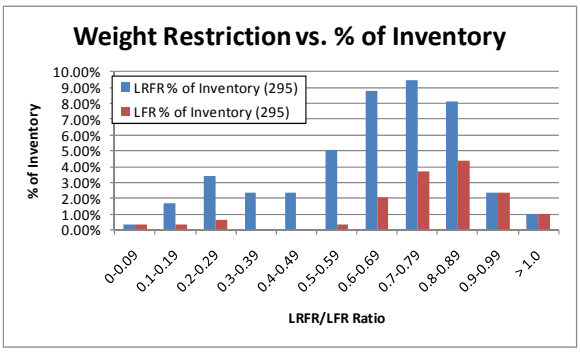
(a) (b)

Figure 39: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

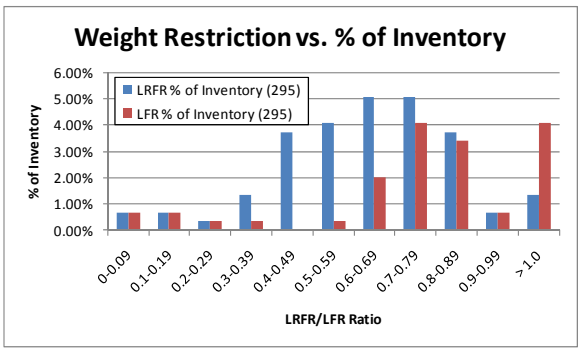
Table 40 and Figure 40 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 40 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the TX-04 vehicle is 0.68 for moment and 0.93 for shear.

Table 40: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	1	0	2	0.7%	2	0
0.1-0.19	5	1.7%	1	4	2	0.7%	2	0
0.2-0.29	10	3.4%	2	8	1	0.3%	1	0
0.3-0.39	7	2.4%	0	7	4	1.4%	1	3
0.4-0.49	7	2.4%	0	7	11	3.7%	0	11
0.5-0.59	15	5.1%	1	14	12	4.1%	1	11
0.6-0.69	26	8.8%	6	20	15	5.1%	6	9
0.7-0.79	28	9.5%	11	17	15	5.1%	12	3
0.8-0.89	24	8.1%	13	11	11	3.7%	10	1
0.9-0.99	7	2.4%	7	0	2	0.7%	2	0
> 1.00	3	1.0%	3	0	4	1.4%	4	0
Total	133		45	88	79		41	38
Average LRFR/LFR	0.68				0.93			



(a)



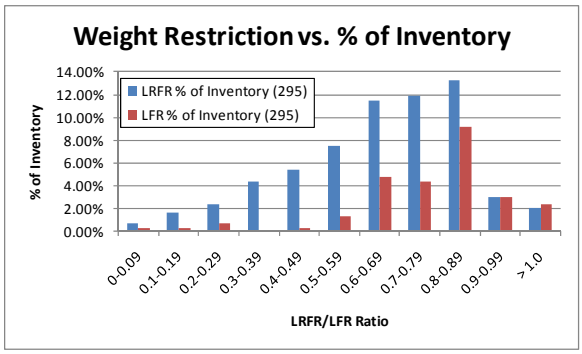
(b)

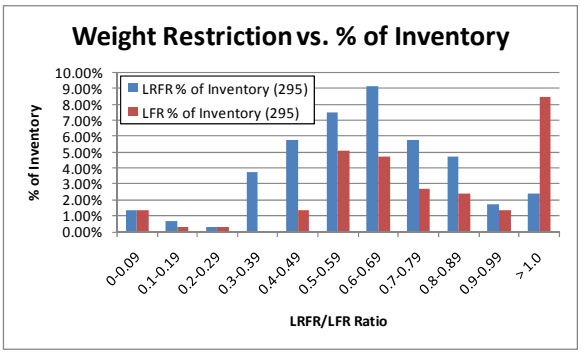
Figure 40: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 41 and Figure 41 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 41 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the WA-02 vehicle is 0.71 for moment and and 0.86 for shear.

Table 41: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	0.7%	1	1	4	1.4%	4	0
0.1-0.19	5	1.7%	1	4	2	0.7%	1	1
0.2-0.29	7	2.4%	2	5	1	0.3%	1	0
0.3-0.39	13	4.4%	1	12	11	3.7%	3	8
0.4-0.49	16	5.4%	1	15	17	5.8%	4	13
0.5-0.59	22	7.5%	4	18	22	7.5%	15	7
0.6-0.69	34	11.5%	14	20	27	9.2%	14	13
0.7-0.79	35	11.9%	13	22	17	5.8%	8	9
0.8-0.89	39	13.2%	27	12	14	4.8%	7	7
0.9-0.99	9	3.1%	9	0	5	1.7%	4	1
> 1.00	6	2.0%	6	0	7	2.4%	7	0
Total	188		79	109	127		68	59
Average LRFR/LFR	0.71				0.86			





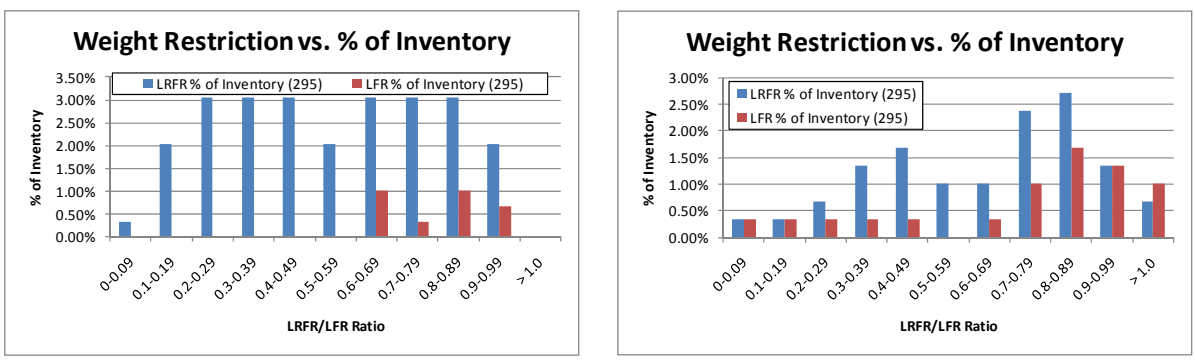
(a) (b)

Figure 41: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 42 and Figure 42 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 42 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3 vehicle is 0.64 for moment and 0.97 for shear.

Table 42: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	1	0.3%	1	0
0.1-0.19	6	2.0%	0	6	1	0.3%	1	0
0.2-0.29	9	3.1%	0	9	2	0.7%	1	1
0.3-0.39	9	3.1%	0	9	4	1.4%	1	3
0.4-0.49	9	3.1%	0	9	5	1.7%	1	4
0.5-0.59	6	2.0%	0	6	3	1.0%	0	3
0.6-0.69	9	3.1%	3	6	3	1.0%	1	2
0.7-0.79	9	3.1%	1	8	7	2.4%	3	4
0.8-0.89	9	3.1%	3	6	8	2.7%	5	3
0.9-0.99	6	2.0%	2	4	4	1.4%	4	0
> 1.00	0	0.0%	0	0	2	0.7%	2	0
Total	73		9	64	40		20	20
Average LRFR/LFR	0.64				0.97			



(a) (b)

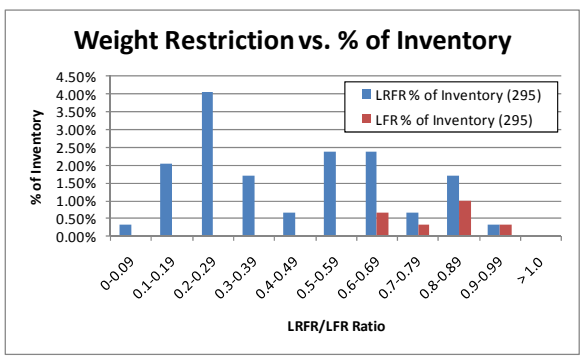
Figure 42: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 43 and Figure 43 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 43 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the

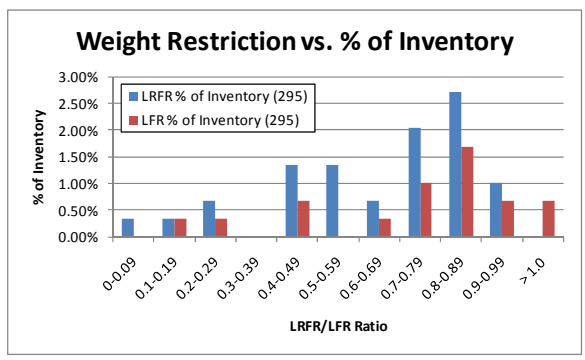
proposed load factors for the AASHTO Type 3-3 vehicle is 0.62 for moment and 0.99 for shear.

Table 43: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	1	0.3%	0	1
0.1-0.19	6	2.0%	0	6	1	0.3%	1	0
0.2-0.29	12	4.1%	0	12	2	0.7%	1	1
0.3-0.39	5	1.7%	0	5	0	0.0%	0	0
0.4-0.49	2	0.7%	0	2	4	1.4%	2	2
0.5-0.59	7	2.4%	0	7	4	1.4%	0	4
0.6-0.69	7	2.4%	2	5	2	0.7%	1	1
0.7-0.79	2	0.7%	1	1	6	2.0%	3	3
0.8-0.89	5	1.7%	3	2	8	2.7%	5	3
0.9-0.99	1	0.3%	1	0	3	1.0%	2	1
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	48		7	41	31		15	16
Average LRFR/LFR	0.62				0.99			



(a)



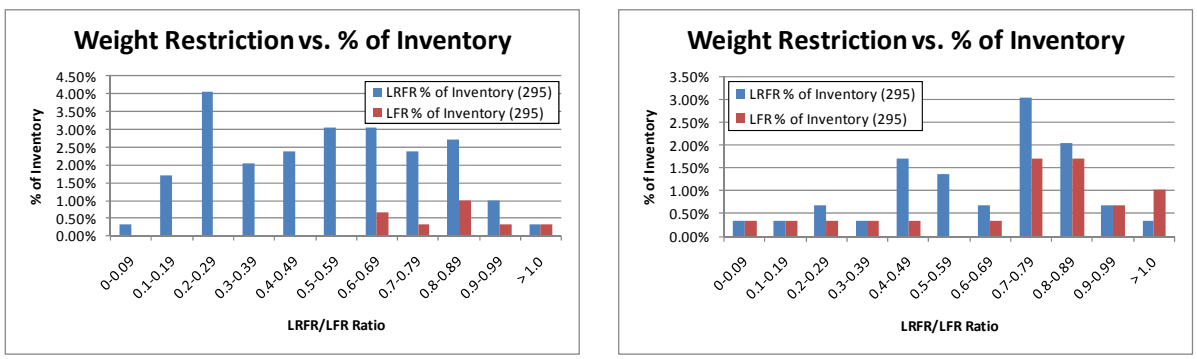
(b)

Figure 43: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

Table 44 and Figure 44 show the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LRFR ratings less than 1.0. Figure 44 also shows the distribution of rating factor ratios for simple span reinforced concrete tee-beams with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3S2 vehicle is 0.64 for moment and 0.97 for shear.

Table 44: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Tee-Beams with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (295)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	0.3%	0	1	1	0.3%	1	0
0.1-0.19	5	1.7%	0	5	1	0.3%	1	0
0.2-0.29	12	4.1%	0	12	2	0.7%	1	1
0.3-0.39	6	2.0%	0	6	1	0.3%	1	0
0.4-0.49	7	2.4%	0	7	5	1.7%	1	4
0.5-0.59	9	3.1%	0	9	4	1.4%	0	4
0.6-0.69	9	3.1%	2	7	2	0.7%	1	1
0.7-0.79	7	2.4%	1	6	9	3.1%	5	4
0.8-0.89	8	2.7%	3	5	6	2.0%	5	1
0.9-0.99	3	1.0%	1	2	2	0.7%	2	0
> 1.00	1	0.3%	1	0	1	0.3%	1	0
Total	68		8	60	34		19	15
Average LRFR/LFR	0.64				0.97			



(a) (b)

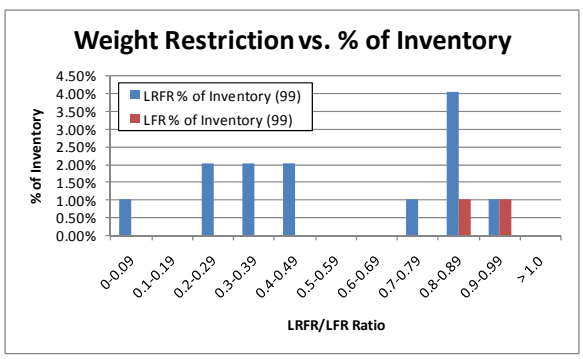
Figure 44: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Tee-Beams with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

M.5 Simple Span Reinforced Concrete Slab Bridges

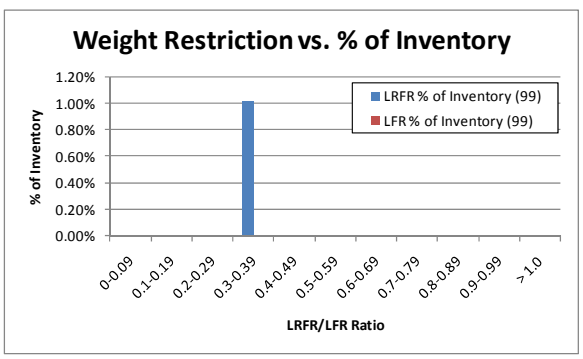
Table 45 and Figure 45 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 45 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the DE-07 vehicle is 0.85 for moment and 1.41 for shear.

Table 45: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	0	0.0%	0	0
0.3-0.39	2	2.0%	0	2	1	1.0%	0	1
0.4-0.49	2	2.0%	0	2	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	1	1.0%	0	1	0	0.0%	0	0
0.8-0.89	4	4.0%	1	3	0	0.0%	0	0
0.9-0.99	1	1.0%	1	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	13		2	11	1		0	1
Average LRFR/LFR	0.85				1.41			



(a)



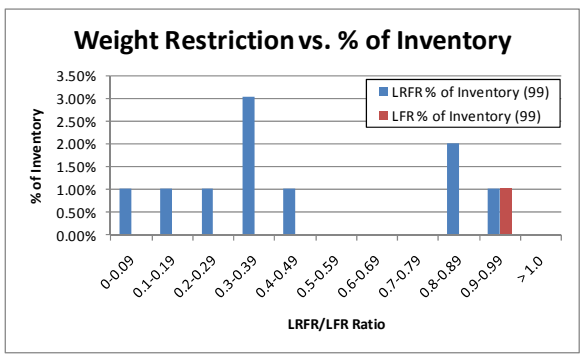
(b)

Figure 45: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

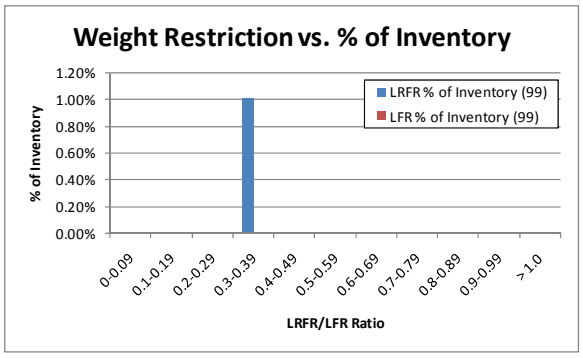
Table 46 and Figure 46 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 46 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the FL-04 vehicle is 0.85 for moment and 1.40 for shear.

Table 46: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	1	1.0%	0	1	0	0.0%	0	0
0.2-0.29	1	1.0%	0	1	0	0.0%	0	0
0.3-0.39	3	3.0%	0	3	1	1.0%	0	1
0.4-0.49	1	1.0%	0	1	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	2	2.0%	0	2	0	0.0%	0	0
0.9-0.99	1	1.0%	1	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	10		1	9	1		0	1
Average LRFR/LFR	0.85				1.40			



(a)



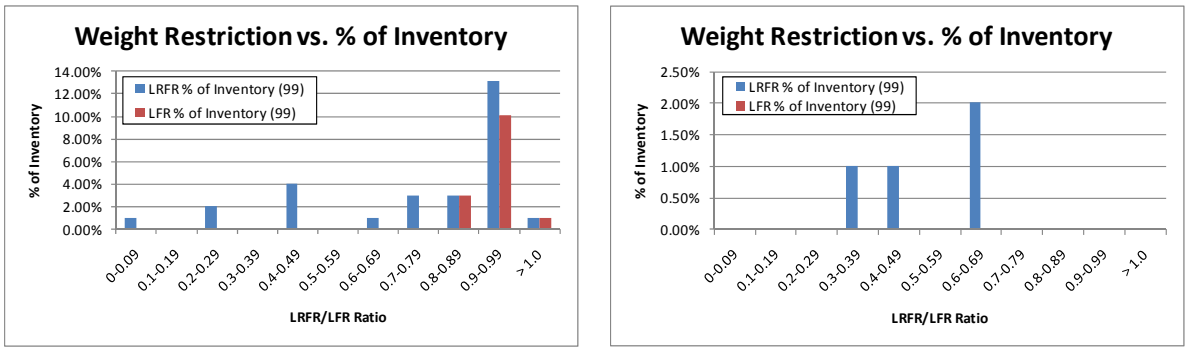
(b)

Figure 46: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 47 and Figure 47 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 47 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the IL-01 vehicle is 0.90 for moment and 1.34 for shear.

Table 47: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	0	0.0%	0	0
0.3-0.39	0	0.0%	0	0	1	1.0%	0	1
0.4-0.49	4	4.0%	0	4	1	0.0%	0	1
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	1	1.0%	0	1	2	0.0%	0	2
0.7-0.79	3	3.0%	0	3	0	0.0%	0	0
0.8-0.89	3	3.0%	3	0	0	0.0%	0	0
0.9-0.99	13	13.1%	10	3	0	0.0%	0	0
> 1.00	1	1.0%	1	0	0	0.0%	0	0
Total	28		14	14	4		0	4
Average LRFR/LFR	0.90				1.34			



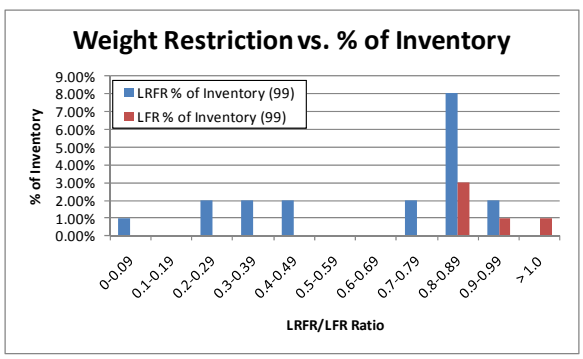
(a) (b)

Figure 47: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

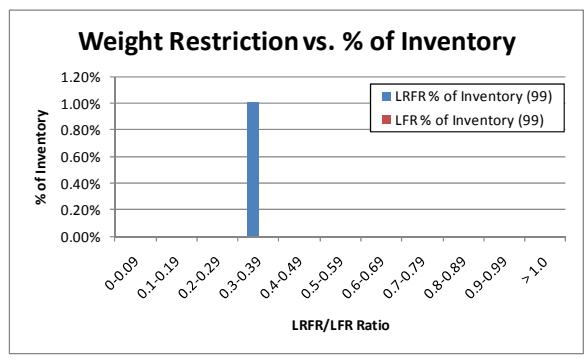
Table 48 and Figure 48 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 48 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NC-21 vehicle is 0.86 for moment and 1.39 for shear.

Table 48: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	0	0.0%	0	0
0.3-0.39	2	2.0%	0	2	1	1.0%	0	1
0.4-0.49	2	2.0%	0	2	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	2	2.0%	0	2	0	0.0%	0	0
0.8-0.89	8	8.1%	3	5	0	0.0%	0	0
0.9-0.99	2	2.0%	1	1	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	19		4	15	1		0	1
Average LRFR/LFR	0.86				1.39			



(a)



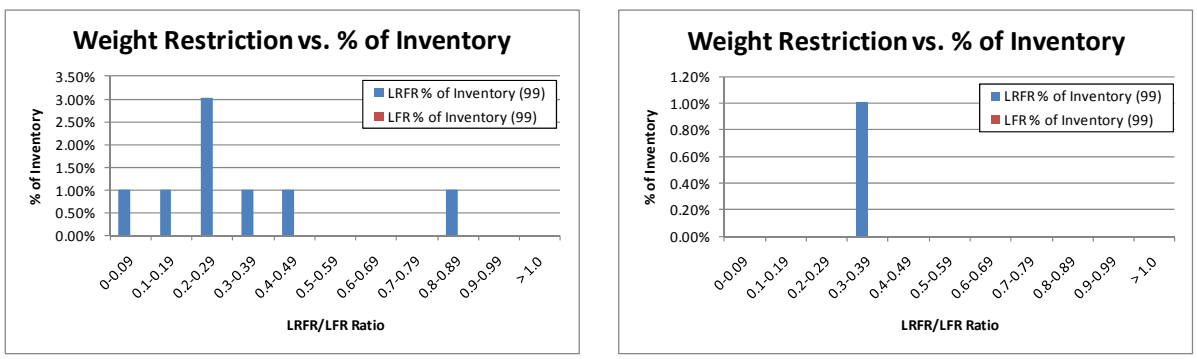
(b)

Figure 48: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 49 and Figure 49 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 49 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NM-04 vehicle is 0.64 for moment and 1.11 for shear.

Table 49: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	1	1.0%	0	1	0	0.0%	0	0
0.2-0.29	3	3.0%	0	3	0	0.0%	0	0
0.3-0.39	1	1.0%	0	1	1	1.0%	0	1
0.4-0.49	1	1.0%	0	1	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	1	1.0%	0	1	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	8		0	8	1		0	1
Average LRFR/LFR	0.82				1.42			



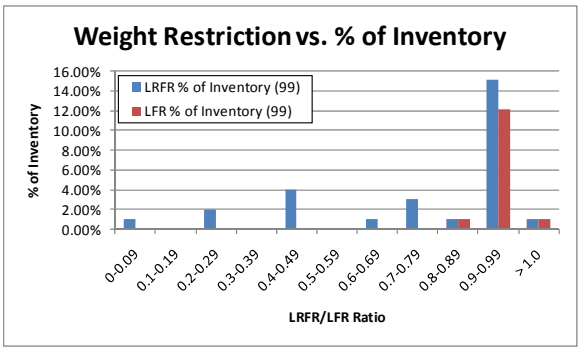
(a) (b)

Figure 49: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

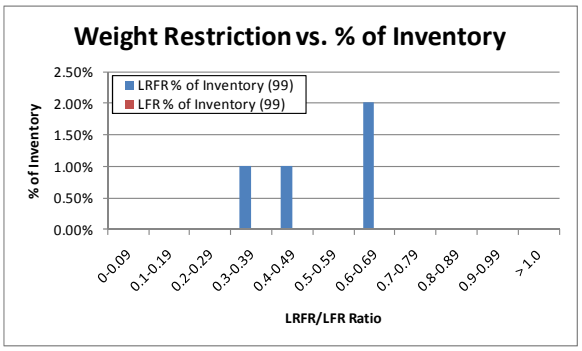
Table 50 and Figure 50 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 50 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the OR-06 vehicle is 0.91 for moment and and 1.32 for shear.

Table 50: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	0	0.0%	0	0
0.3-0.39	0	0.0%	0	0	1	1.0%	0	1
0.4-0.49	4	4.0%	0	4	1	1.0%	0	1
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	1	1.0%	0	1	2	2.0%	0	2
0.7-0.79	3	3.0%	0	3	0	0.0%	0	0
0.8-0.89	1	1.0%	1	0	0	0.0%	0	0
0.9-0.99	15	15.2%	12	3	0	0.0%	0	0
> 1.00	1	1.0%	1	0	0	0.0%	0	0
Total	28		14	14	4		0	4
Average LRFR/LFR	0.91				1.32			



(a)



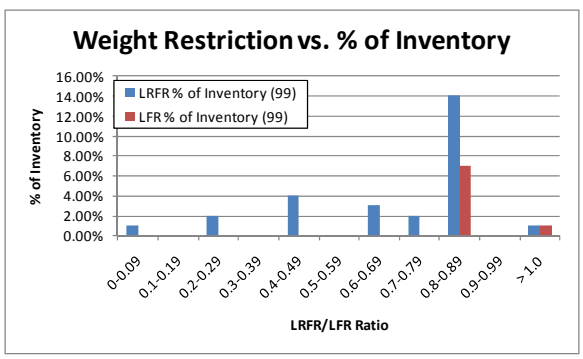
(b)

Figure 50: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

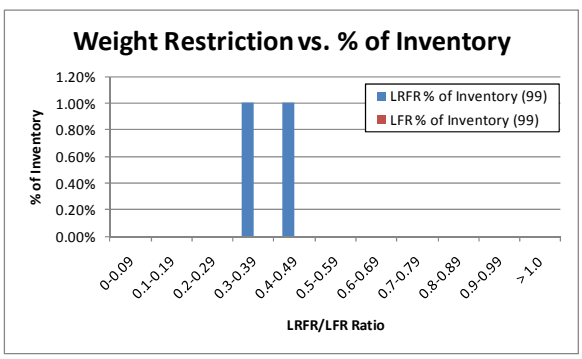
Table 51 and Figure 51 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 51 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the TX-04 vehicle is 0.84 for moment and 1.34 for shear.

Table 51: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	0	0.0%	0	0
0.3-0.39	0	0.0%	0	0	1	1.0%	0	1
0.4-0.49	4	4.0%	0	4	1	1.0%	0	1
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	3	3.0%	0	3	0	0.0%	0	0
0.7-0.79	2	2.0%	0	2	0	0.0%	0	0
0.8-0.89	14	14.1%	7	7	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	1	1.0%	1	0	0	0.0%	0	0
Total	27		8	19	2		0	2
Average LRFR/LFR	0.84				1.34			



(a)



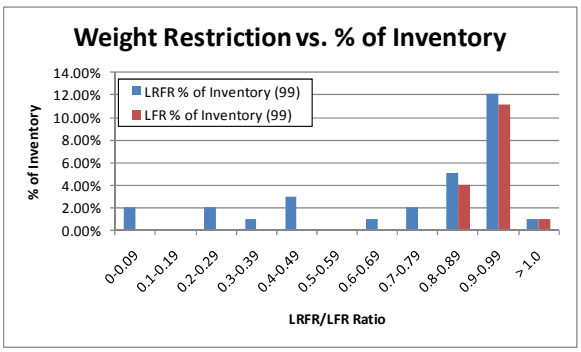
(b)

Figure 51: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

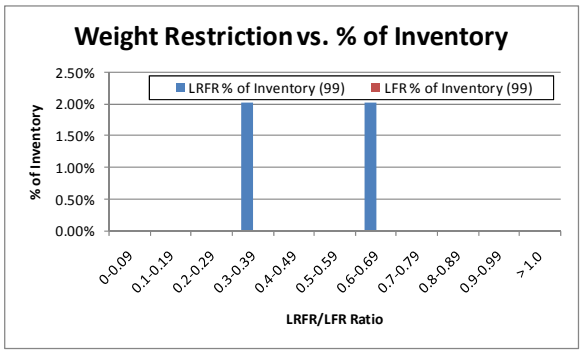
Table 52 and Figure 52 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 52 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the WA-02 vehicle is 0.89 for moment and 1.31 for shear.

Table 52: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	2	2.0%	0	2	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	0	0.0%	0	0
0.3-0.39	1	1.0%	0	1	2	2.0%	0	2
0.4-0.49	3	3.0%	0	3	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	1	1.0%	0	1	2	2.0%	0	2
0.7-0.79	2	2.0%	0	2	0	0.0%	0	0
0.8-0.89	5	5.0%	4	1	0	0.0%	0	0
0.9-0.99	12	12.1%	11	1	0	0.0%	0	0
> 1.00	1	1.0%	1	0	0	0.0%	0	0
Total	29		16	13	4		0	4
Average LRFR/LFR	0.89				1.31			



(a)



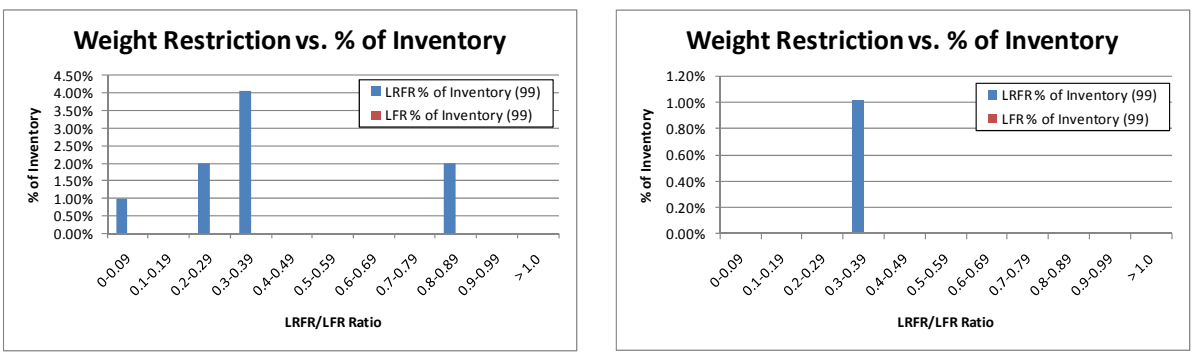
(b)

Figure 52: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 53 and Figure 53 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 53 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3 vehicle is 0.80 for moment and 1.37 for shear.

Table 53: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	0	0.0%	0	0
0.3-0.39	4	4.0%	0	4	1	1.0%	0	1
0.4-0.49	0	0.0%	0	0	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	2	2.0%	0	2	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	9		0	9	1		0	1
Average LRFR/LFR	0.63				1.08			



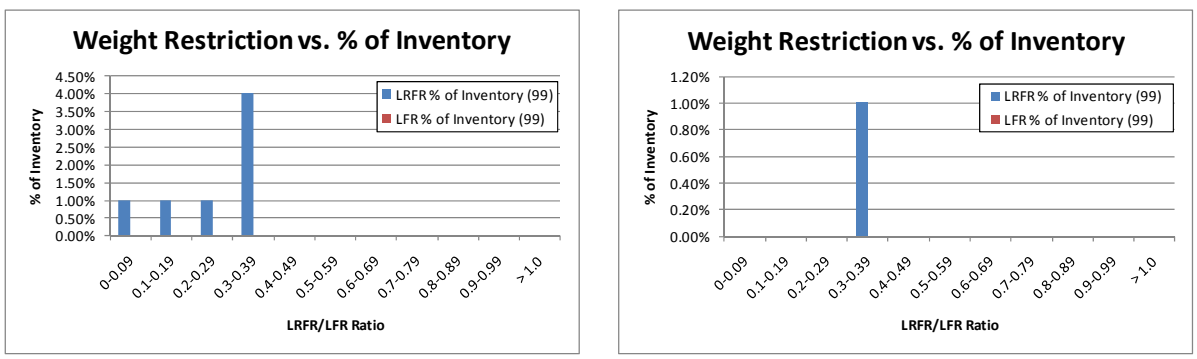
(a) (b)

Figure 53: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 54 and Figure 54 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 54 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3-3 vehicle is 0.80 for moment and 1.40 for shear.

Table 54: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	1	1.0%	0	1	0	0.0%	0	0
0.2-0.29	1	1.0%	0	1	0	0.0%	0	0
0.3-0.39	4	4.0%	0	4	1	1.0%	0	1
0.4-0.49	0	0.0%	0	0	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	7		0	7	1		0	1
Average LRFR/LFR	0.80				1.40			



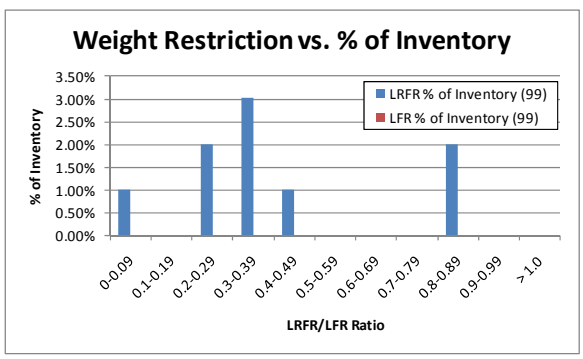
(a) (b)

Figure 54: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

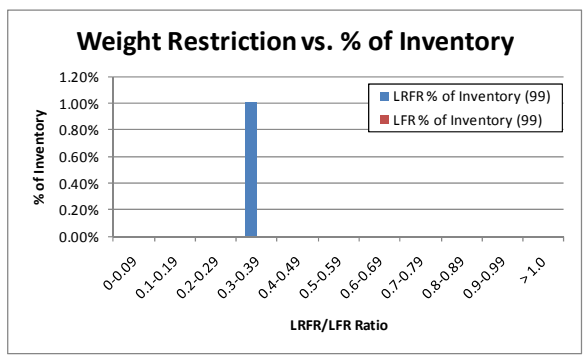
Table 55 and Figure 55 show the distribution of rating factor ratios for simple span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 55 also shows the distribution of rating factor ratios for simple span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3S2 vehicle is 0.82 for moment and 1.40 for shear.

Table 55: Distribution of Rating Factor Ratios for Simple Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (99)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	1	1.0%	0	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	2	2.0%	0	2	0	0.0%	0	0
0.3-0.39	3	3.0%	0	3	1	1.0%	0	1
0.4-0.49	1	1.0%	0	1	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	2	2.0%	0	2	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	9		0	9	1		0	1
Average LRFR/LFR	0.82				1.40			



(a)



(b)

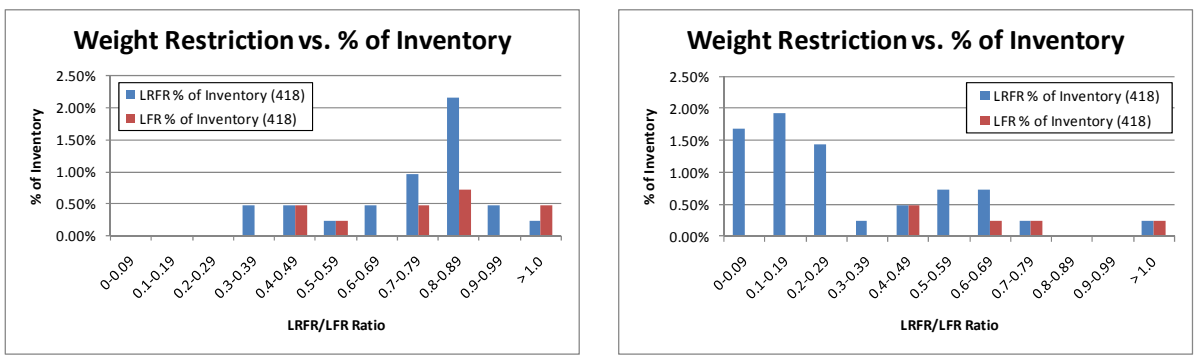
Figure 55: Distribution of Rating Factor Ratio for Simple Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

M.6 Continuous Span Steel Girder Bridges

Table 56 and Figure 56 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 56 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the DE-07 vehicle is 1.10 for moment and 0.86 for shear.

Table 56: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	8	1.9%	0	8
0.2-0.29	0	0.0%	0	0	6	1.4%	0	6
0.3-0.39	2	0.5%	0	2	1	0.2%	0	1
0.4-0.49	2	0.5%	2	0	2	0.5%	2	0
0.5-0.59	1	0.2%	1	0	3	0.7%	0	3
0.6-0.69	2	0.5%	0	2	3	0.7%	1	2
0.7-0.79	4	1.0%	2	2	1	0.2%	1	0
0.8-0.89	9	2.2%	3	6	0	0.0%	0	0
0.9-0.99	2	0.5%	0	2	0	0.0%	0	0
> 1.00	1	0.2%	1	0	1	0.2%	1	0
Total	23		9	14	32		5	27
Average LRFR/LFR	1.10				0.86			



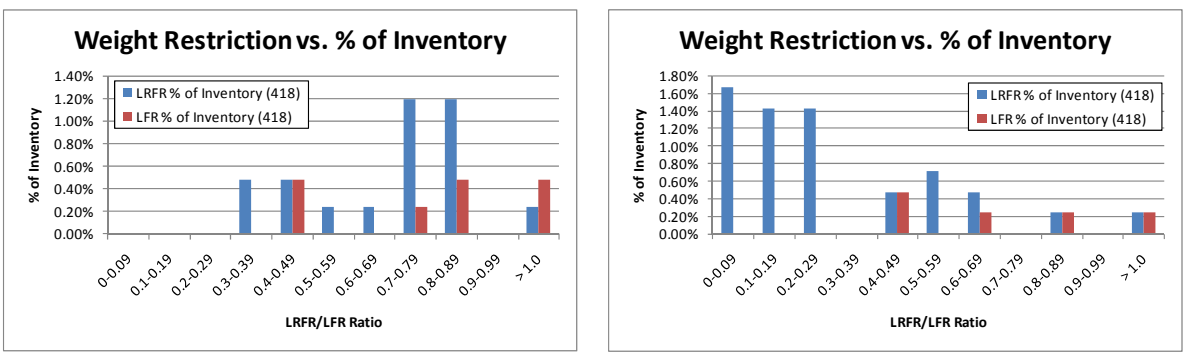
(a) (b)

Figure 56: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

Table 57 and Figure 57 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 57 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the FL-04 vehicle is 1.10 for moment and 0.86 for shear.

Table 57: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	6	1.4%	0	6
0.2-0.29	0	0.0%	0	0	6	1.4%	0	6
0.3-0.39	2	0.5%	0	2	0	0.0%	0	0
0.4-0.49	2	0.5%	2	0	2	0.5%	2	0
0.5-0.59	1	0.2%	0	1	3	0.7%	0	3
0.6-0.69	1	0.2%	0	1	2	0.5%	1	1
0.7-0.79	5	1.2%	1	4	0	0.0%	0	0
0.8-0.89	5	1.2%	2	3	1	0.2%	1	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	1	0.2%	1	0	1	0.2%	1	0
Total	17		6	11	28		5	23
Average LRFR/LFR	1.10				0.86			



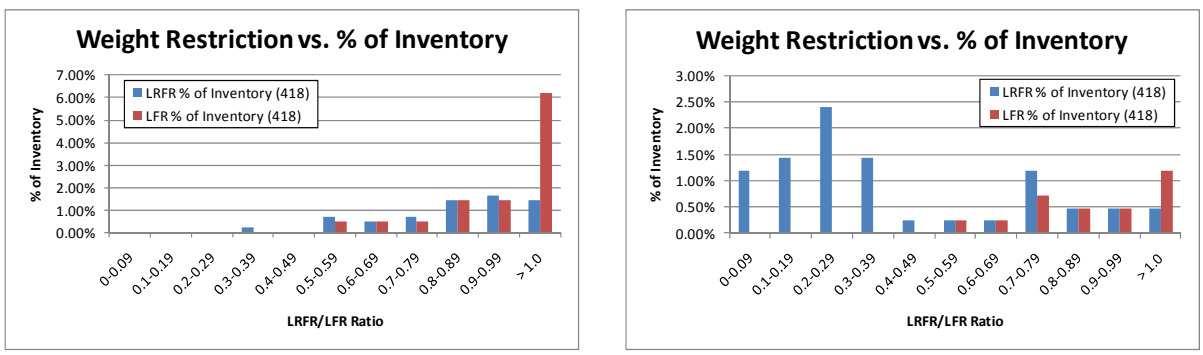
(a) (b)

Figure 57: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

Table 58 and Figure 58 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 58 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the IL-01 vehicle is and 1.44 for moment and and 1.07 for shear.

Table 58: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	5	1.2%	0	5
0.1-0.19	0	0.0%	0	0	6	1.4%	0	6
0.2-0.29	0	0.0%	0	0	10	2.4%	0	10
0.3-0.39	1	0.2%	0	1	6	1.4%	0	6
0.4-0.49	0	0.0%	0	0	1	0.2%	0	1
0.5-0.59	3	0.7%	2	1	1	0.2%	1	0
0.6-0.69	2	0.5%	2	0	1	0.2%	1	0
0.7-0.79	3	0.7%	2	1	5	1.2%	3	2
0.8-0.89	6	1.4%	6	0	2	0.5%	2	0
0.9-0.99	7	1.7%	6	1	2	0.5%	2	0
> 1.00	6	1.4%	6	0	2	0.5%	2	0
Total	28		24	4	41		11	30
Average LRFR/LFR	1.44				1.07			



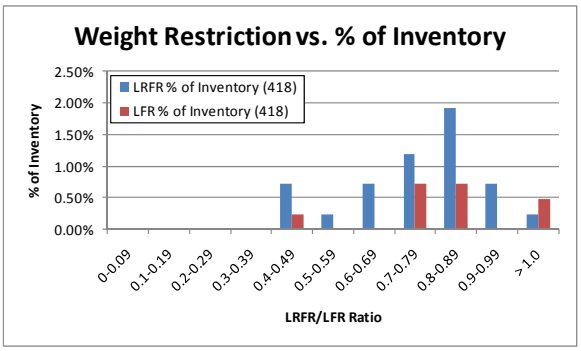
(a) (b)

Figure 58: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

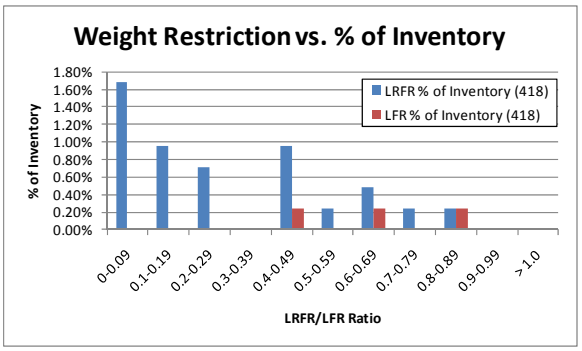
Table 59 and Figure 59 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 59 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NC-21 vehicle is 1.12 for moment and 0.89 for shear.

Table 59: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	4	1.0%	0	4
0.2-0.29	0	0.0%	0	0	3	0.7%	0	3
0.3-0.39	0	0.0%	0	0	0	0.0%	0	0
0.4-0.49	3	0.7%	1	2	4	1.0%	1	3
0.5-0.59	1	0.2%	0	1	1	0.2%	0	1
0.6-0.69	3	0.7%	0	3	2	0.5%	1	1
0.7-0.79	5	1.2%	3	2	1	0.2%	0	1
0.8-0.89	8	1.9%	3	5	1	0.2%	1	0
0.9-0.99	3	0.7%	0	3	0	0.0%	0	0
> 1.00	1	0.2%	1	0	0	0.0%	0	0
Total	24		8	16	23		3	20
Average LRFR/LFR	1.12				0.89			



(a)



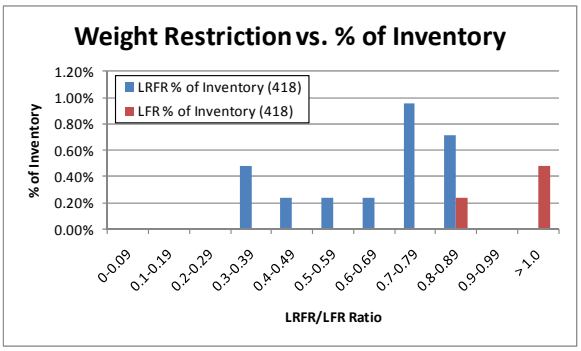
(b)

Figure 59: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 60 and Figure 60 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 60 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NM-04 vehicle is 1.12 for moment and 0.88 for shear.

Table 60: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	4	1.0%	0	4
0.2-0.29	0	0.0%	0	0	1	0.2%	0	1
0.3-0.39	2	0.5%	0	2	0	0.0%	0	0
0.4-0.49	1	0.2%	0	1	4	1.0%	1	3
0.5-0.59	1	0.2%	0	1	0	0.0%	0	0
0.6-0.69	1	0.2%	0	1	2	0.5%	0	2
0.7-0.79	4	1.0%	0	4	1	0.2%	0	1
0.8-0.89	3	0.7%	1	2	1	0.2%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	12		1	11	20		1	19
Average LRFR/LFR	1.12				0.88			



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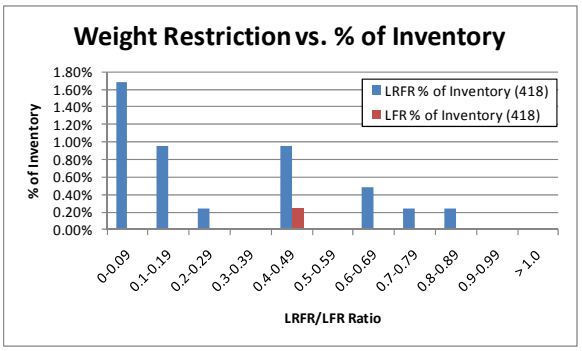


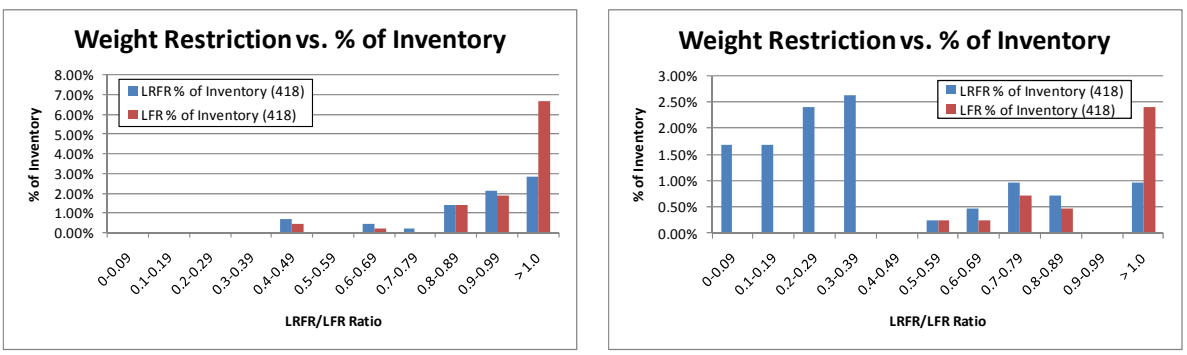
(b)

Figure 60: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 61 and Figure 61 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 61 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the OR-06 vehicle is 1.42 for moment and 1.08 for shear.

Table 61: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	7	1.7%	0	7
0.2-0.29	0	0.0%	0	0	10	2.4%	0	10
0.3-0.39	0	0.0%	0	0	11	2.6%	0	11
0.4-0.49	3	0.7%	2	1	0	0.0%	0	0
0.5-0.59	0	0.0%	0	0	1	0.2%	1	0
0.6-0.69	2	0.5%	1	1	2	0.5%	1	1
0.7-0.79	1	0.2%	0	1	4	1.0%	3	1
0.8-0.89	6	1.4%	6	0	3	0.7%	2	1
0.9-0.99	9	2.2%	8	1	0	0.0%	0	0
> 1.00	12	2.9%	12	0	4	1.0%	4	0
Total	33		29	4	49		11	38
Average LRFR/LFR	1.42				1.08			



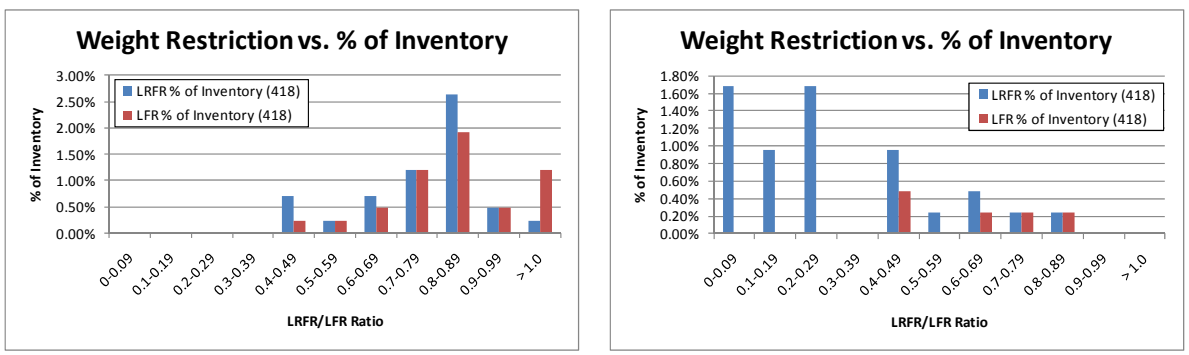
(a) (b)

Figure 61: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 62 and Figure 62 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 62 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the TX-04 vehicle is 1.12 for moment and 0.89 for shear.

Table 62: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	4	1.0%	0	4
0.2-0.29	0	0.0%	0	0	7	1.7%	0	7
0.3-0.39	0	0.0%	0	0	0	0.0%	0	0
0.4-0.49	3	0.7%	1	2	4	1.0%	2	2
0.5-0.59	1	0.2%	1	0	1	0.2%	0	1
0.6-0.69	3	0.7%	2	1	2	0.5%	1	1
0.7-0.79	5	1.2%	5	0	1	0.2%	1	0
0.8-0.89	11	2.6%	8	3	1	0.2%	1	0
0.9-0.99	2	0.5%	2	0	0	0.0%	0	0
> 1.00	1	0.2%	1	0	0	0.0%	0	0
Total	26		20	6	27		5	22
Average LRFR/LFR	1.12				0.89			



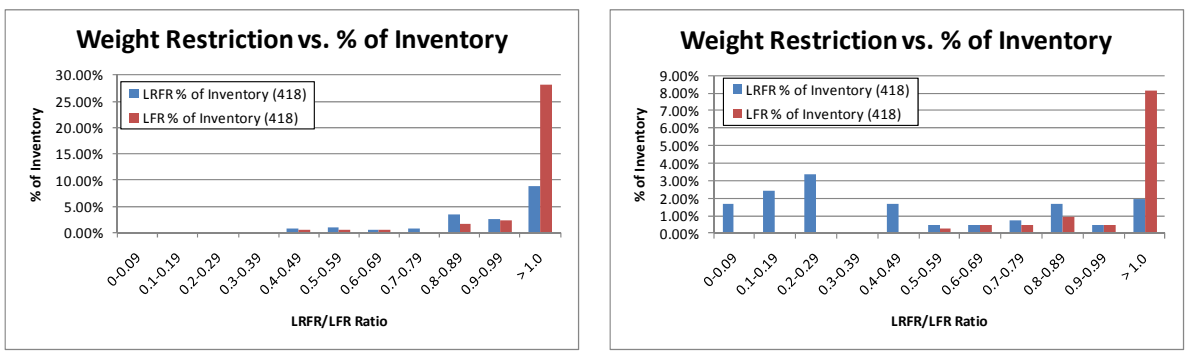
(a) (b)

Figure 62: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 63 and Figure 63 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 63 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the WA-02 vehicle is 1.40 for moment and 1.06 for shear.

Table 63: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	10	2.4%	0	10
0.2-0.29	0	0.0%	0	0	14	3.4%	0	14
0.3-0.39	0	0.0%	0	0	17	0.0%	0	17
0.4-0.49	3	0.7%	2	1	7	1.7%	0	7
0.5-0.59	4	1.0%	2	2	2	0.5%	1	1
0.6-0.69	2	0.5%	2	0	2	0.5%	2	0
0.7-0.79	3	0.7%	0	3	3	0.7%	2	1
0.8-0.89	15	3.6%	7	8	7	1.7%	4	3
0.9-0.99	11	2.6%	10	1	2	0.5%	2	0
> 1.00	37	8.9%	37	0	8	1.9%	8	0
Total	75		60	15	79		19	60
Average LRFR/LFR	1.40				1.06			



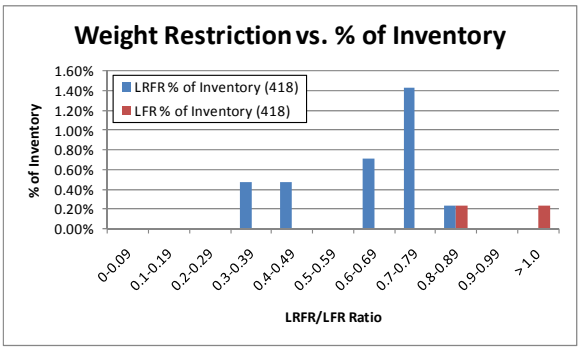
(a) (b)

Figure 63: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

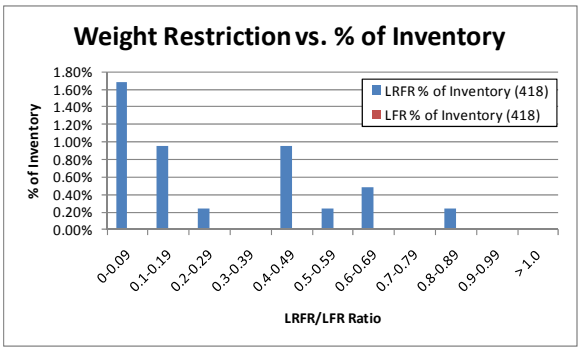
Table 64 and Figure 64 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 64 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASTHO Type 3 vehicle is 1.07 for moment and 0.84 for shear.

Table 64: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	4	1.0%	0	4
0.2-0.29	0	0.0%	0	0	1	0.2%	0	1
0.3-0.39	2	0.5%	0	2	0	0.0%	0	0
0.4-0.49	2	0.5%	0	2	4	1.0%	0	4
0.5-0.59	0	0.0%	0	0	1	0.2%	0	1
0.6-0.69	3	0.7%	0	3	2	0.5%	0	2
0.7-0.79	6	1.4%	0	6	0	0.0%	0	0
0.8-0.89	1	0.2%	1	0	1	0.2%	0	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	14		1	13	20		0	20
Average LRFR/LFR	1.07				0.84			



(a)



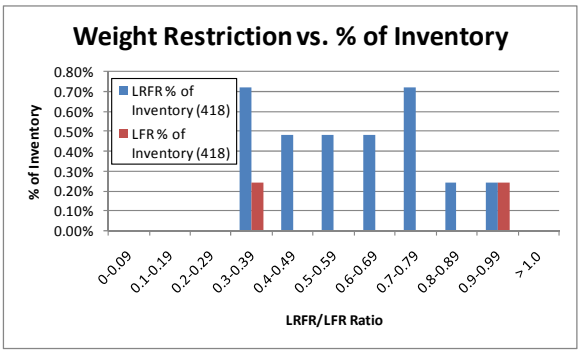
(b)

Figure 64: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

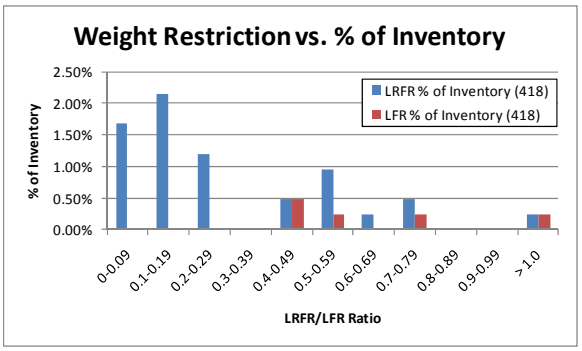
Table 65 and Figure 65 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 65 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASTHO Type 3-3 vehicle is 1.02 for moment and 0.79 for shear.

Table 65: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	9	2.2%	0	9
0.2-0.29	0	0.0%	0	0	5	1.2%	0	5
0.3-0.39	3	0.7%	1	2	0	0.0%	0	0
0.4-0.49	2	0.5%	0	2	2	0.5%	2	0
0.5-0.59	2	0.5%	0	2	4	1.0%	1	3
0.6-0.69	2	0.5%	0	2	1	0.2%	0	1
0.7-0.79	3	0.7%	0	3	2	0.5%	1	1
0.8-0.89	1	0.2%	0	1	0	0.0%	0	0
0.9-0.99	1	0.2%	1	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	1	0.2%	1	0
Total	14		2	12	31		5	26
Average LRFR/LFR	1.02				0.79			



(a)



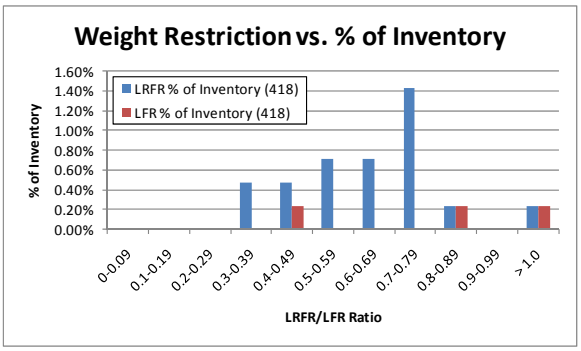
(b)

Figure 65: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

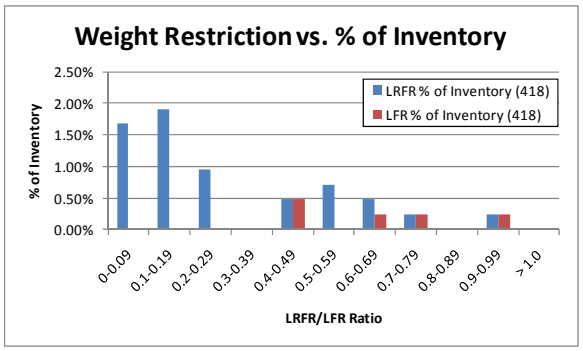
Table 66 and Figure 66 show the distribution of rating factor ratios for continuous span steel girders with LRFR ratings less than 1.0. Figure 66 also shows the distribution of rating factor ratios for continuous span steel girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASTHO Type 3S2 vehicle is 1.04 for moment and 0.81 for shear.

Table 66: Distribution of Rating Factor Ratios for Continuous Span Steel Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (418)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	0	0.0%	0	0	7	1.7%	0	7
0.1-0.19	0	0.0%	0	0	8	1.9%	0	8
0.2-0.29	0	0.0%	0	0	4	1.0%	0	4
0.3-0.39	2	0.5%	0	2	0	0.0%	0	0
0.4-0.49	2	0.5%	1	1	2	0.5%	2	0
0.5-0.59	3	0.7%	0	3	3	0.7%	0	3
0.6-0.69	3	0.7%	0	3	2	0.5%	1	1
0.7-0.79	6	1.4%	0	6	1	0.2%	1	0
0.8-0.89	1	0.2%	1	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	1	0.2%	1	0
> 1.00	1	0.2%	1	0	0	0.0%	0	0
Total	18		3	15	28		5	23
Average LRFR/LFR	1.04				0.81			



(a)



(b)

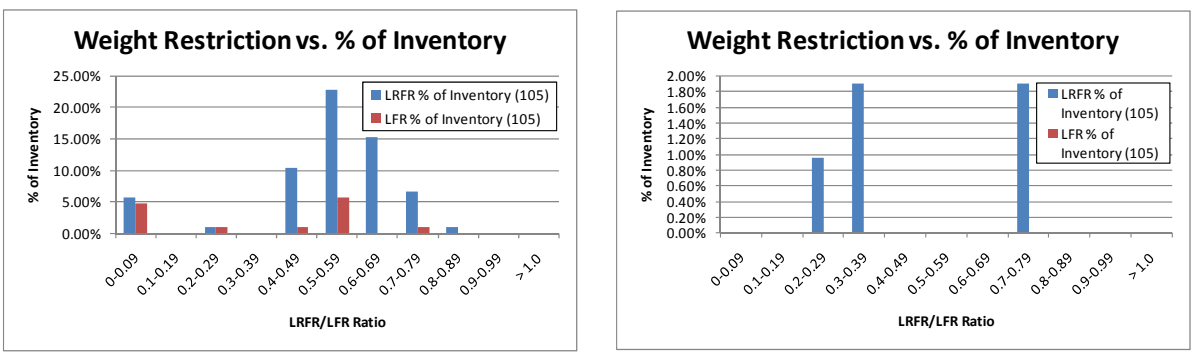
Figure 66: Distribution of Rating Factor Ratio for Continuous Span Steel Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

M.7 Continuous Span Reinforced Concrete Slab Bridges

Table 67 and Figure 67 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 67 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the DE-07 vehicle is 0.57 for moment and 1.01 for shear.

Table 67: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	1	1.0%	0	1
0.3-0.39	0	0.0%	0	0	2	1.9%	0	2
0.4-0.49	11	10.5%	1	10	0	0.0%	0	0
0.5-0.59	24	22.9%	6	18	0	0.0%	0	0
0.6-0.69	16	15.2%	0	16	0	0.0%	0	0
0.7-0.79	7	6.7%	1	6	2	1.9%	0	2
0.8-0.89	1	1.0%	0	1	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	66		14	52	5		0	8
Average LRFR/LFR	0.57				1.01			



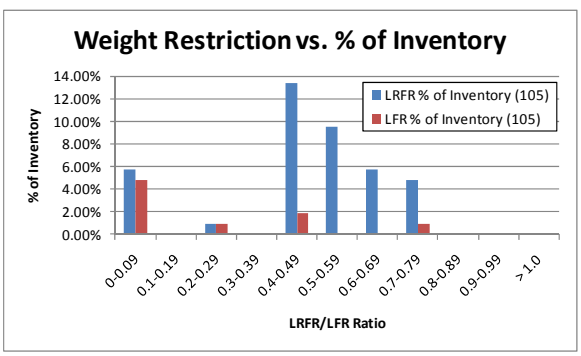
(a) (b)

Figure 67: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

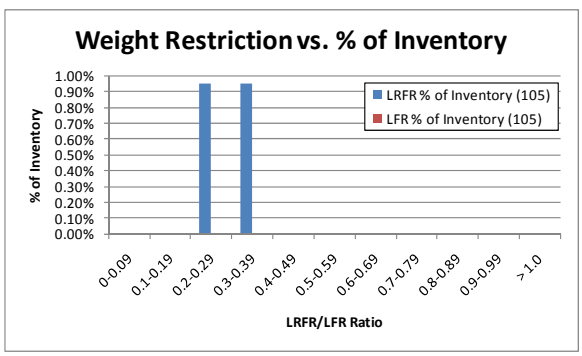
Table 68 and Figure 68 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 68 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the FL-04 vehicle is 0.57 for moment and 1.04 for shear.

Table 68: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	1	1.0%	0	1
0.3-0.39	0	0.0%	0	0	1	1.0%	0	1
0.4-0.49	14	13.3%	2	12	0	0.0%	0	0
0.5-0.59	10	9.5%	0	10	0	0.0%	0	0
0.6-0.69	6	5.7%	0	6	0	0.0%	0	0
0.7-0.79	5	4.8%	1	4	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	42		9	33	2		0	2
Average LRFR/LFR	0.57				1.04			



(a)



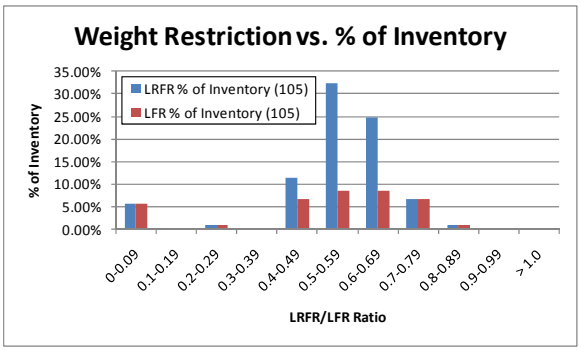
(b)

Figure 68: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

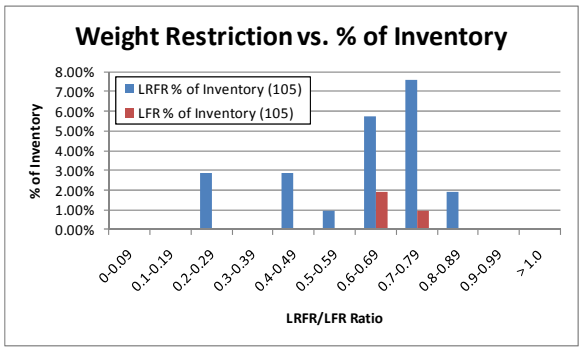
Table 69 and Figure 69 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 69 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the IL-01 vehicle is 0.57 for moment and 0.87 for shear.

Table 69: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	6	0	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	3	2.9%	0	3
0.3-0.39	0	0.0%	0	0	0	0.0%	0	0
0.4-0.49	12	11.4%	7	5	3	2.9%	0	3
0.5-0.59	34	32.4%	9	25	1	1.0%	0	1
0.6-0.69	26	24.8%	9	17	6	5.7%	2	4
0.7-0.79	7	6.7%	7	0	8	7.6%	1	7
0.8-0.89	1	1.0%	1	0	2	1.9%	0	2
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	87		40	47	23		3	20
Average LRFR/LFR	0.57				0.87			



(a)



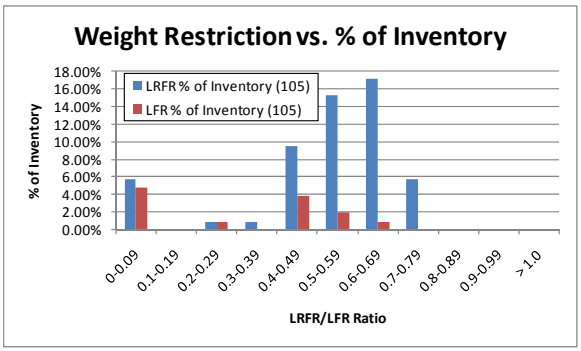
(b)

Figure 69: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

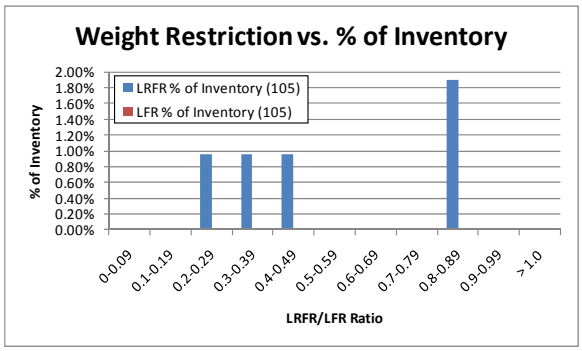
Table 70 and Figure 70 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 70 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NC-21 vehicle is 0.60 for moment and 1.02 for shear.

Table 70: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	1	1.0%	0	1
0.3-0.39	1	1.0%	0	1	1	1.0%	0	1
0.4-0.49	10	9.5%	4	6	1	1.0%	0	1
0.5-0.59	16	15.2%	2	14	0	0.0%	0	0
0.6-0.69	18	17.1%	1	17	0	0.0%	0	0
0.7-0.79	6	5.7%	0	6	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	2	1.9%	0	2
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	58		13	45	5		0	5
Average LRFR/LFR	0.60				1.02			



(a)



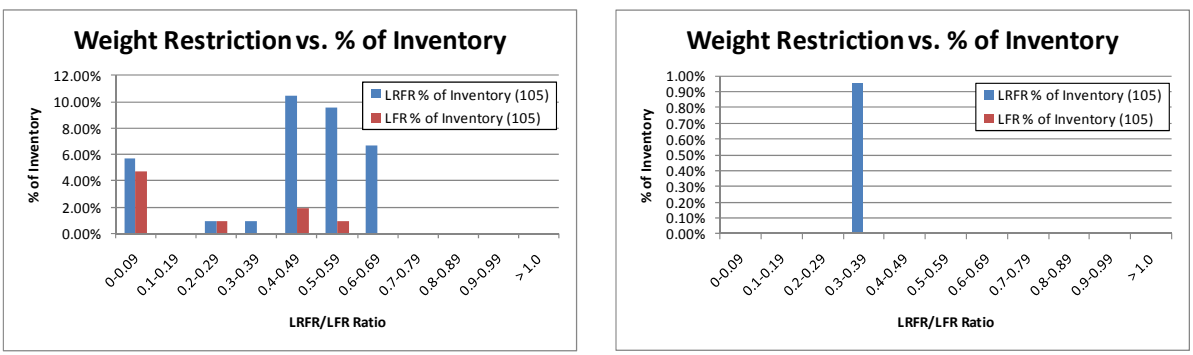
(b)

Figure 70: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

Table 71 and Figure 71 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 71 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NM-04 vehicle is 0.59 for moment and 1.12 for shear.

Table 71: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	0	0.0%	0	0
0.3-0.39	1	1.0%	0	1	1	1.0%	0	1
0.4-0.49	11	10.5%	2	9	0	0.0%	0	0
0.5-0.59	10	9.5%	1	9	0	0.0%	0	0
0.6-0.69	7	6.7%	0	7	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	36		9	27	1		0	1
Average LRFR/LFR	0.59				1.12			



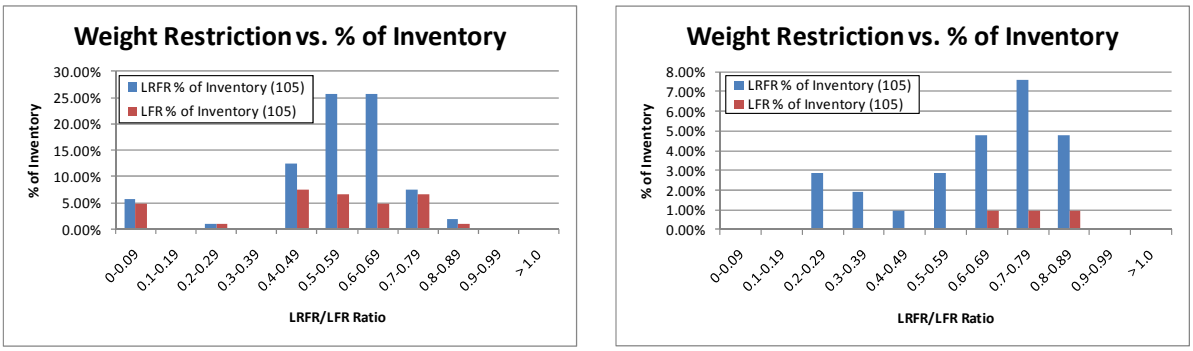
(a) (b)

Figure 71: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 72 and Figure 72 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 72 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the OR-06 vehicle is 0.58 for moment and 0.86 for shear.

Table 72: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	3	2.9%	0	3
0.3-0.39	0	0.0%	0	0	2	1.9%	0	2
0.4-0.49	13	12.4%	8	5	1	1.0%	0	1
0.5-0.59	27	25.7%	7	20	3	2.9%	0	3
0.6-0.69	27	25.7%	5	22	5	4.8%	1	4
0.7-0.79	8	7.6%	7	1	8	7.6%	1	7
0.8-0.89	2	1.9%	1	1	5	4.8%	1	4
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	84		34	50	27		3	24
Average LRFR/LFR	0.58				0.86			



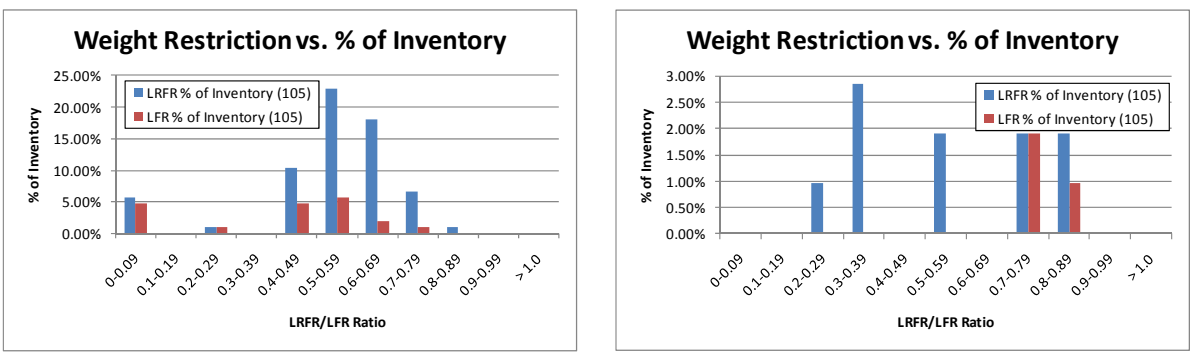
(a) (b)

Figure 72: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 73 and Figure 73 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 73 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the TX-04 vehicle is 0.59 for moment and 0.95 for shear.

Table 73: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	1	1.0%	0	1
0.3-0.39	0	0.0%	0	0	3	2.9%	0	3
0.4-0.49	11	10.5%	5	6	0	0.0%	0	0
0.5-0.59	24	22.9%	6	18	2	1.9%	0	2
0.6-0.69	19	18.1%	2	17	0	0.0%	0	0
0.7-0.79	7	6.7%	1	6	2	1.9%	2	0
0.8-0.89	1	1.0%	0	1	2	1.9%	1	1
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	69		20	49	10		3	7
Average LRFR/LFR	0.59				0.95			



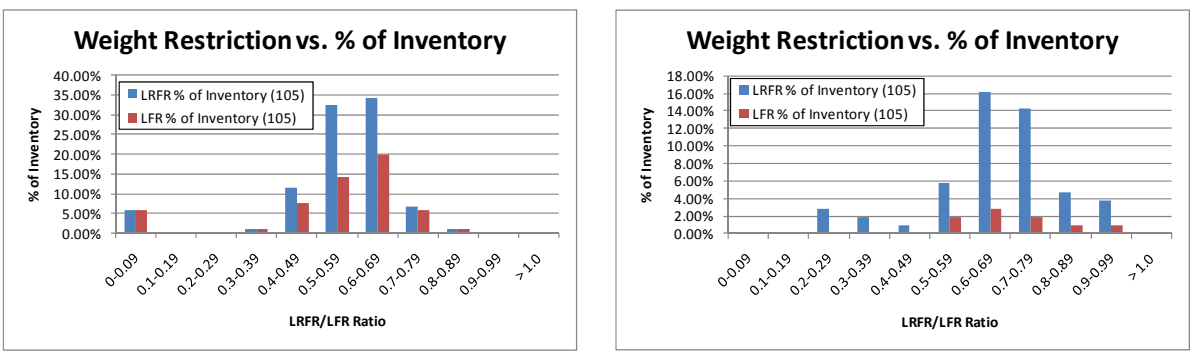
(a) (b)

Figure 73: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

Table 74 and Figure 74 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 74 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the WA-02 vehicle is 0.57 for moment and 0.80 for shear.

Table 74: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	6	0	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	0	0.0%	0	0	3	2.9%	0	3
0.3-0.39	1	1.0%	1	0	2	1.9%	0	2
0.4-0.49	12	11.4%	8	4	1	1.0%	0	1
0.5-0.59	34	32.4%	15	19	6	5.7%	2	4
0.6-0.69	36	34.3%	21	15	17	16.2%	3	14
0.7-0.79	7	6.7%	6	1	15	14.3%	2	13
0.8-0.89	1	1.0%	1	0	5	4.8%	1	4
0.9-0.99	0	0.0%	0	0	4	3.8%	1	3
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	97		58	39	53		9	44
Average LRFR/LFR	0.57				0.80			



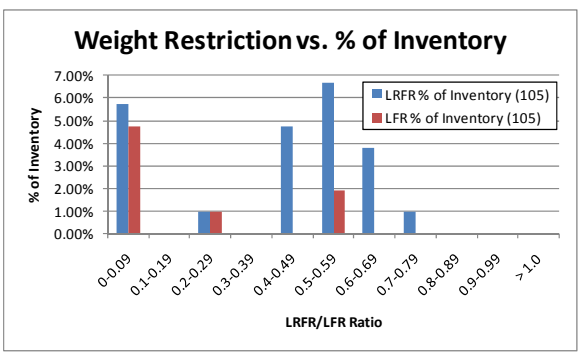
(a) (b)

Figure 74: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

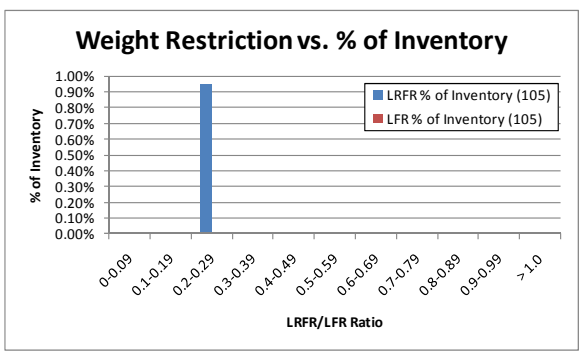
Table 75 and Figure 75 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 75 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3 vehicle is 0.63 for moment and 1.07 for shear.

Table 75: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	1	1.0%	0	1
0.3-0.39	0	0.0%	0	0	0	0.0%	0	0
0.4-0.49	5	4.8%	0	5	0	0.0%	0	0
0.5-0.59	7	6.7%	2	5	0	0.0%	0	0
0.6-0.69	4	3.8%	0	4	0	0.0%	0	0
0.7-0.79	1	1.0%	0	1	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	24		8	16	1		0	1
Average LRFR/LFR	0.63				1.07			



(a)



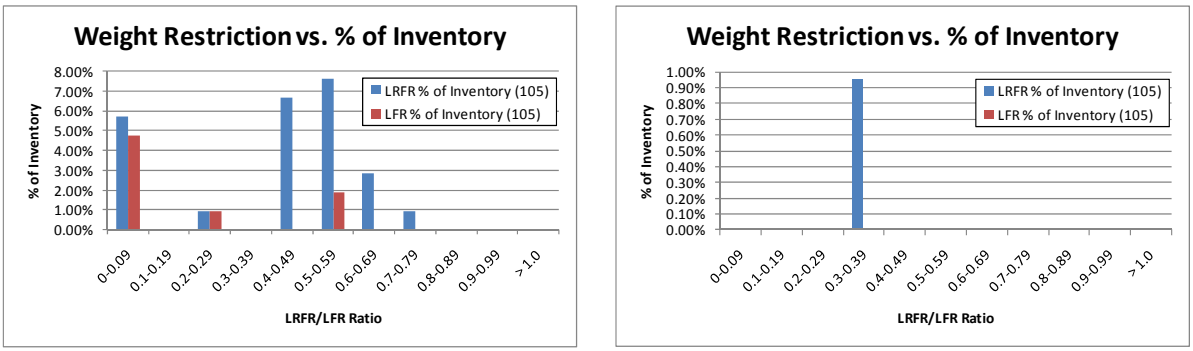
(b)

Figure 75: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 76 and Figure 76 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 76 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3-3 vehicle is 0.59 for moment and 1.09 for shear.

Table 76: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	0	0.0%	0	0
0.3-0.39	0	0.0%	0	0	1	1.0%	0	1
0.4-0.49	7	6.7%	0	7	0	0.0%	0	0
0.5-0.59	8	7.6%	2	6	0	0.0%	0	0
0.6-0.69	3	2.9%	0	3	0	0.0%	0	0
0.7-0.79	1	1.0%	0	1	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	26		8	18	1		0	1
Average LRFR/LFR	0.59				1.09			



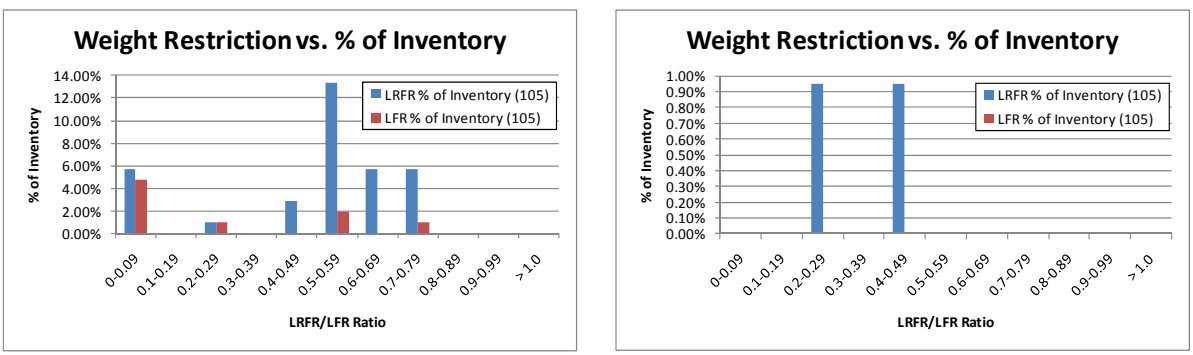
(a) (b)

Figure 76: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

Table 77 and Figure 77 show the distribution of rating factor ratios for continuous span reinforced concrete slabs with LRFR ratings less than 1.0. Figure 77 also shows the distribution of rating factor ratios for continuous span reinforced concrete slabs with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3S2 vehicle is 0.60 for moment and 1.04 for shear.

Table 77: Distribution of Rating Factor Ratios for Continuous Span Reinforced Concrete Slabs with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (105)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	5.7%	5	1	0	0.0%	0	0
0.1-0.19	0	0.0%	0	0	0	0.0%	0	0
0.2-0.29	1	1.0%	1	0	1	1.0%	0	1
0.3-0.39	0	0.0%	0	0	0	0.0%	0	0
0.4-0.49	3	2.9%	0	3	1	1.0%	0	1
0.5-0.59	14	13.3%	2	12	0	0.0%	0	0
0.6-0.69	6	5.7%	0	6	0	0.0%	0	0
0.7-0.79	6	5.7%	1	5	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	36		9	27	2		0	2
Average LRFR/LFR	0.60				1.04			



(a) (b)

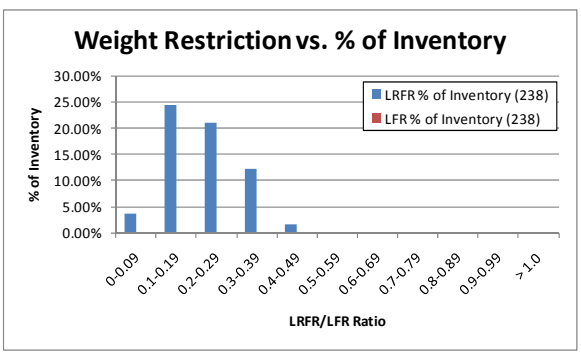
Figure 77: Distribution of Rating Factor Ratio for Continuous Span Reinforced Concrete Slabs with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

M.8 Continuous Span Prestressed Concrete I-Girder Bridges

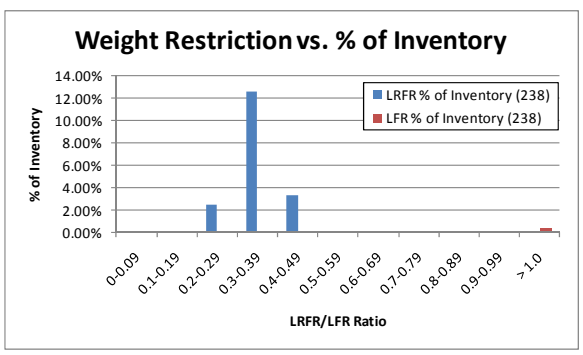
Table 78 and Figure 78 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 78 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the DE-07 vehicle is 0.31 for moment and 1.00 for shear.

Table 78: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for DE-07 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	9	3.8%	0	9	0	0.0%	0	0
0.1-0.19	58	24.4%	0	58	0	0.0%	0	0
0.2-0.29	50	21.0%	0	50	6	2.5%	0	6
0.3-0.39	29	12.2%	0	29	30	12.6%	0	30
0.4-0.49	4	1.7%	0	4	8	3.4%	0	8
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	150		0	150	44		0	44
Average LRFR/LFR	0.31				1.00			



(a)



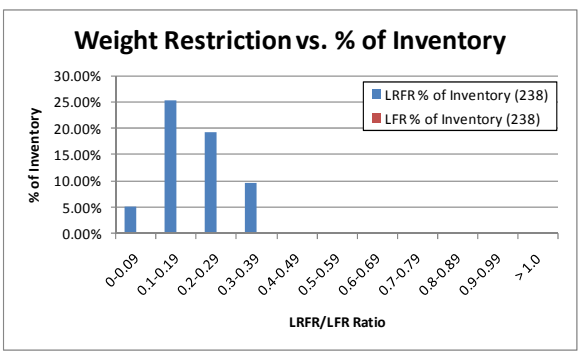
(b)

Figure 78: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for DE-07 Vehicle

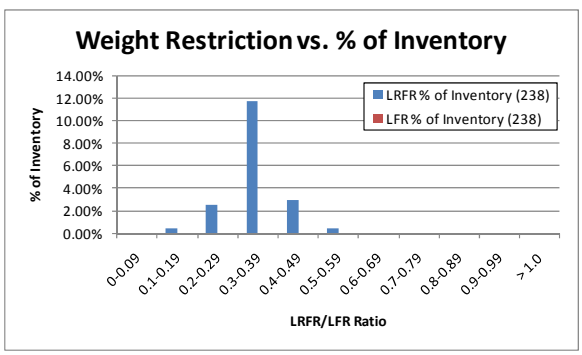
Table 79 and Figure 79 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 79 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the FL-04 vehicle is 0.29 for moment and 1.02 for shear.

Table 79: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for FL-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	12	5.0%	0	12	0	0.0%	0	0
0.1-0.19	60	25.2%	0	60	1	0.4%	0	1
0.2-0.29	46	19.3%	0	46	6	2.5%	0	6
0.3-0.39	23	9.7%	0	23	28	11.8%	0	28
0.4-0.49	0	0.0%	0	0	7	2.9%	0	7
0.5-0.59	0	0.0%	0	0	1	0.4%	0	1
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	141		0	141	43		0	43
Average LRFR/LFR	0.29				1.02			



(a)



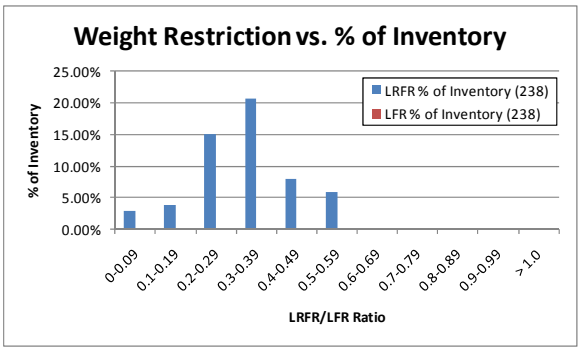
(b)

Figure 79: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for FL-04 Vehicle

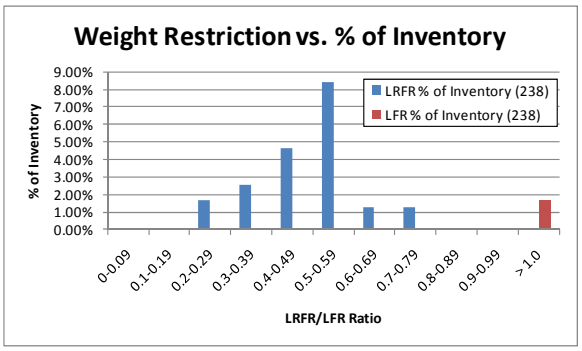
Table 80 and Figure 80 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 80 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the IL-01 vehicle is 0.47 for moment and 1.25 for shear.

Table 80: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for IL-01 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	7	2.9%	0	7	0	0.0%	0	0
0.1-0.19	9	3.8%	0	9	0	0.0%	0	0
0.2-0.29	36	15.1%	0	36	4	1.7%	0	4
0.3-0.39	49	20.6%	0	49	6	2.5%	0	6
0.4-0.49	19	8.0%	0	19	11	4.6%	0	11
0.5-0.59	14	5.9%	0	14	20	8.4%	0	20
0.6-0.69	0	0.0%	0	0	3	1.3%	0	3
0.7-0.79	0	0.0%	0	0	3	1.3%	0	3
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	134		0	134	47		0	47
Average LRFR/LFR	0.47				1.25			



(a)



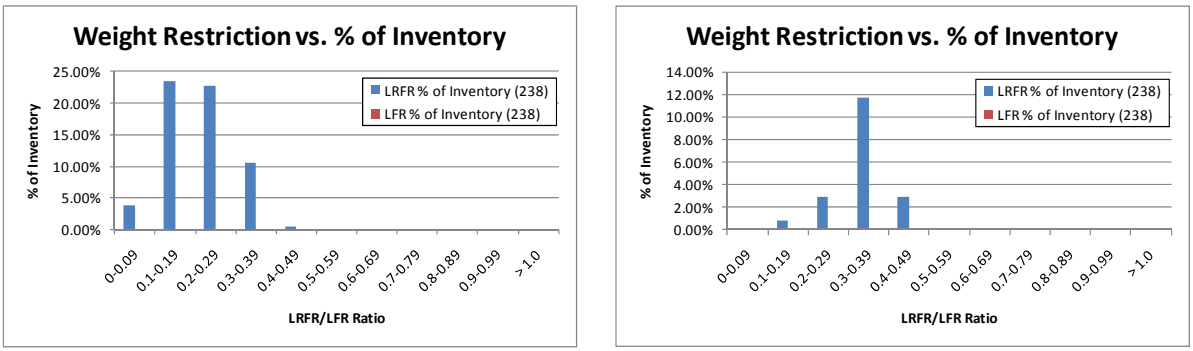
(b)

Figure 80: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for IL-01 Vehicle

Table 81 and Figure 81 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 81 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NC-21 vehicle is 0.30 for moment and 0.99 for shear.

Table 81: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for NC-21 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	9	3.8%	0	9	0	0.0%	0	0
0.1-0.19	56	23.5%	0	56	2	0.8%	0	2
0.2-0.29	54	22.7%	0	54	7	2.9%	0	7
0.3-0.39	25	10.5%	0	25	28	11.8%	0	28
0.4-0.49	1	0.4%	0	1	7	2.9%	0	7
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	145		0	145	44		0	44
Average LRFR/LFR	0.30				0.99			



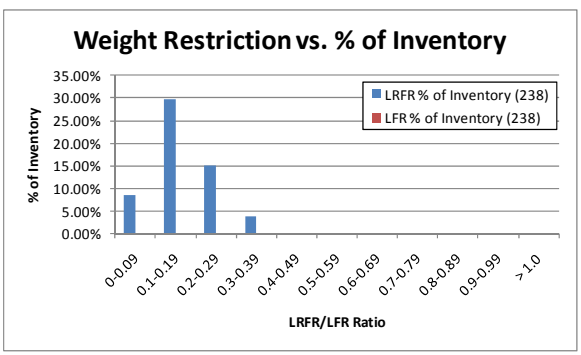
(a) (b)

Figure 81: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NC-21 Vehicle

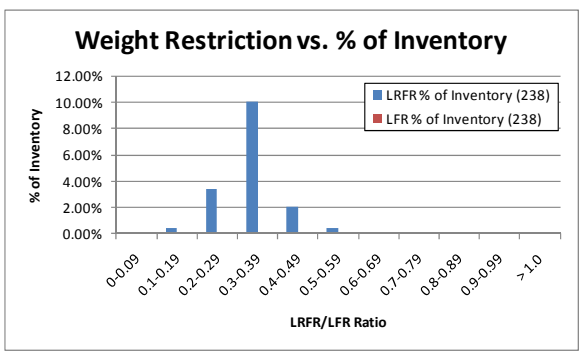
Table 82 and Figure 82 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 82 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the NM-04 vehicle is 0.27 for moment and 1.02 for shear.

Table 82: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for NM-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	20	8.4%	0	20	0	0.0%	0	0
0.1-0.19	71	29.8%	0	71	1	0.4%	0	1
0.2-0.29	36	15.1%	0	36	8	3.4%	0	8
0.3-0.39	9	3.8%	0	9	24	10.1%	0	24
0.4-0.49	0	0.0%	0	0	5	2.1%	0	5
0.5-0.59	0	0.0%	0	0	1	0.4%	0	1
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	136		0	171	39		0	39
Average LRFR/LFR	0.27				1.02			



(a)



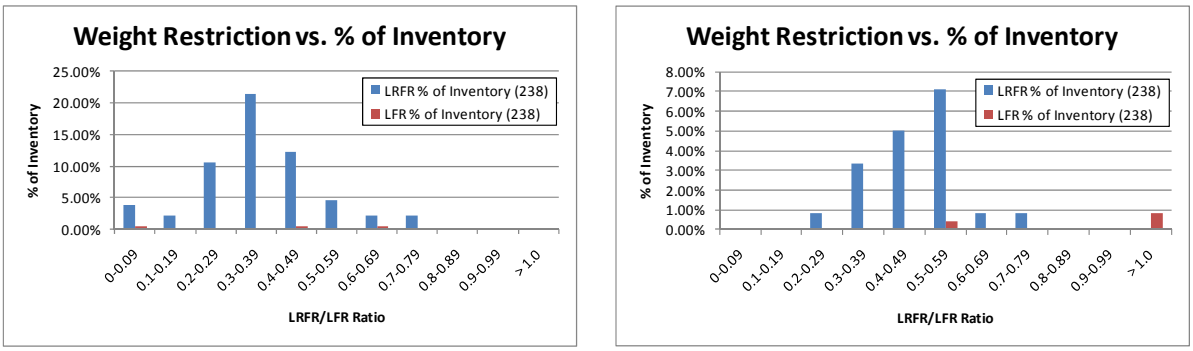
(b)

Figure 82: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for NM-04 Vehicle

Table 83 and Figure 83 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 83 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the OR-06 vehicle is 0.54 for moment and 1.24 for shear.

Table 83: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for OR-06 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	9	3.8%	1	8	0	0.0%	0	0
0.1-0.19	5	2.1%	0	5	0	0.0%	0	0
0.2-0.29	25	10.5%	0	25	2	0.8%	0	2
0.3-0.39	51	21.4%	0	51	8	3.4%	0	8
0.4-0.49	29	12.2%	1	28	12	5.0%	0	12
0.5-0.59	11	4.6%	0	11	17	7.1%	1	16
0.6-0.69	5	2.1%	1	4	2	0.8%	0	2
0.7-0.79	5	2.1%	0	5	2	0.8%	0	2
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	140		3	137	43		1	42
Average LRFR/LFR	0.54				1.24			



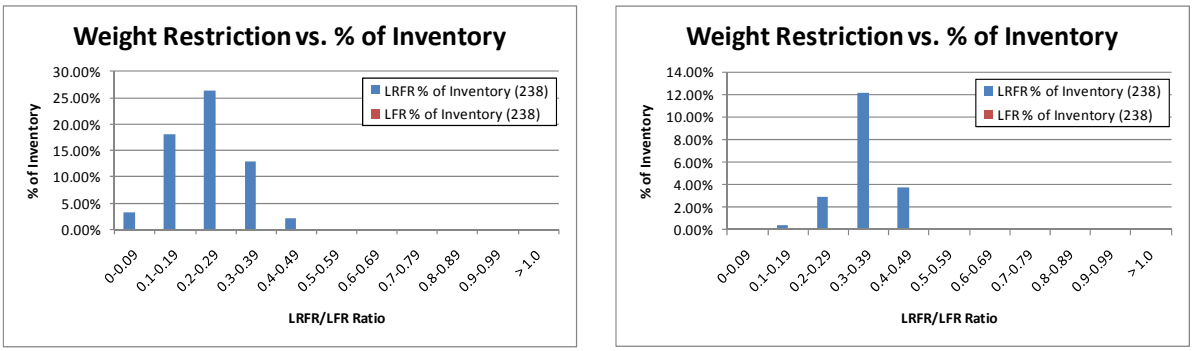
(a) (b)

Figure 83: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for OR-06 Vehicle

Table 84 and Figure 84 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 84 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the TX-04 vehicle is 0.32 for moment and 1.01 for shear.

Table 84: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for TX-04 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	8	3.4%	0	8	0	0.0%	0	0
0.1-0.19	43	18.1%	0	43	1	0.4%	0	1
0.2-0.29	63	26.5%	0	63	7	2.9%	0	7
0.3-0.39	31	13.0%	0	31	29	12.2%	0	29
0.4-0.49	5	2.1%	0	5	9	3.8%	0	9
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	150		0	150	46		0	46
Average LRFR/LFR	0.25				0.79			



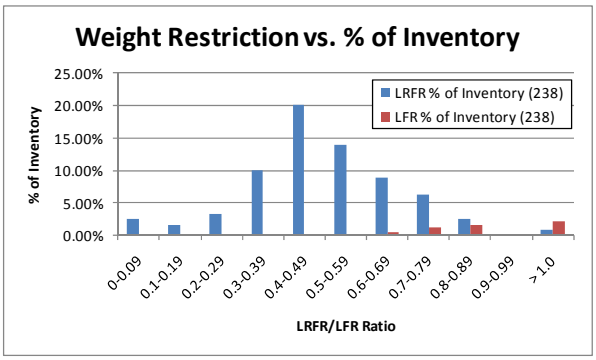
(a) (b)

Figure 84: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for TX-04 Vehicle

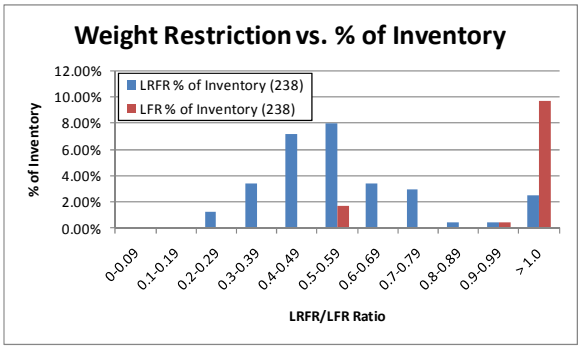
Table 85 and Figure 85 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 85 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the WA-02 vehicle is 0.61 for moment and 1.14 for shear.

Table 85: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for WA-02 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	6	2.5%	0	6	0	0.0%	0	0
0.1-0.19	4	1.7%	0	4	0	0.0%	0	0
0.2-0.29	8	3.4%	0	8	3	1.3%	0	3
0.3-0.39	24	10.1%	0	24	8	3.4%	0	8
0.4-0.49	48	20.2%	0	48	17	7.1%	0	17
0.5-0.59	33	13.9%	0	33	19	8.0%	4	15
0.6-0.69	21	8.8%	1	20	8	3.4%	0	8
0.7-0.79	15	6.3%	3	12	7	2.9%	0	7
0.8-0.89	6	2.5%	4	2	1	0.4%	0	1
0.9-0.99	0	0.0%	0	0	1	0.4%	1	0
> 1.00	2	0.8%	2	0	6	2.5%	6	0
Total	167		10	157	70		11	59
Average LRFR/LFR	0.61				1.14			



(a)



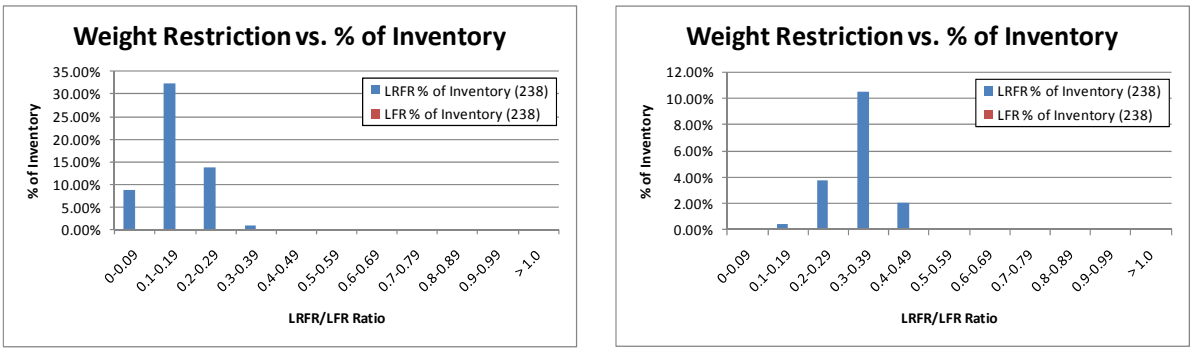
(b)

Figure 85: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for WA-02 Vehicle

Table 86 and Figure 86 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 86 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3 vehicle is 0.25 for moment and 1.00 for shear.

Table 86: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for AASHTO Type 3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	21	8.8%	0	21	0	0.0%	0	0
0.1-0.19	77	32.4%	0	77	1	0.4%	0	1
0.2-0.29	33	13.9%	0	33	9	3.8%	0	9
0.3-0.39	2	0.8%	0	2	25	10.5%	0	25
0.4-0.49	0	0.0%	0	0	5	2.1%	0	5
0.5-0.59	0	0.0%	0	0	0	0.0%	0	0
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	133		0	133	40		0	40
Average LRFR/LFR	0.25				1.00			



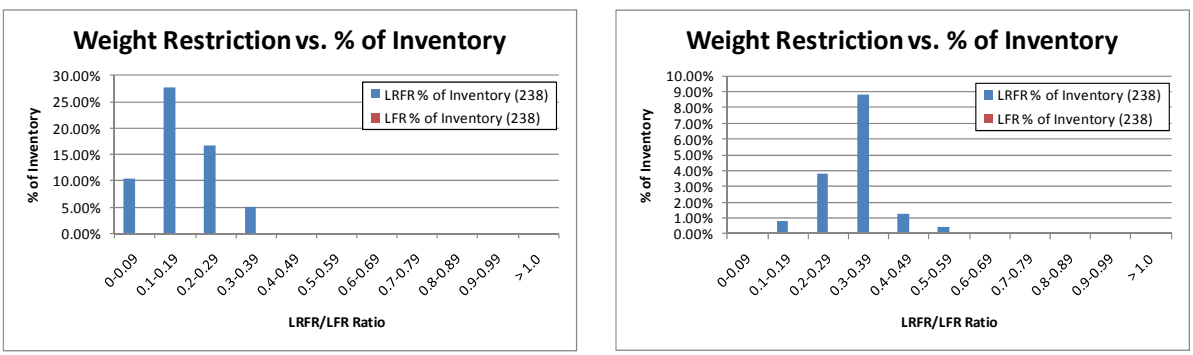
(a) (b)

Figure 86: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3 Vehicle

Table 87 and Figure 87 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 87 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3-3 vehicle is 0.26 for moment and 0.97 for shear.

Table 87: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for AASHTO Type 3-3 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	25	10.5%	0	25	0	0.0%	0	0
0.1-0.19	66	27.7%	0	66	2	0.8%	0	2
0.2-0.29	40	16.8%	0	40	9	3.8%	0	9
0.3-0.39	12	5.0%	0	12	21	8.8%	0	21
0.4-0.49	0	0.0%	0	0	3	1.3%	0	3
0.5-0.59	0	0.0%	0	0	1	0.4%	0	1
0.6-0.69	0	0.0%	0	0	0	0.0%	0	0
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	143		0	143	36		0	36
Average LRFR/LFR	0.26				0.97			



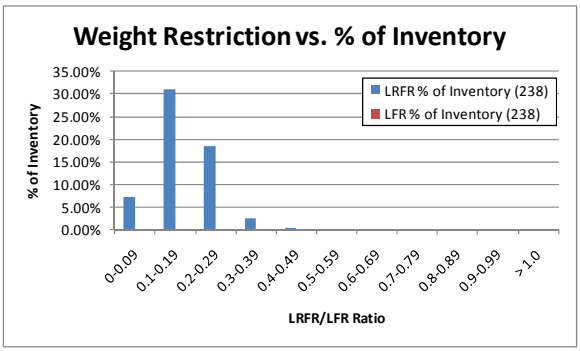
(a) (b)

Figure 87: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3-3 Vehicle

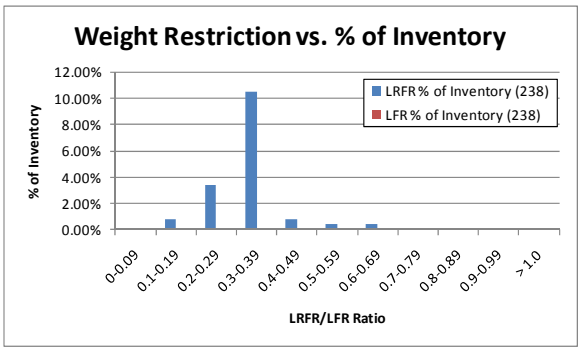
Table 88 and Figure 88 show the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LRFR ratings less than 1.0. Figure 88 also shows the distribution of rating factor ratios for continuous span prestressed concrete I-girders with LFR ratings less than 1.0. The average ratio of LRFR rating to LFR rating using the proposed load factors for the AASHTO Type 3S2 vehicle is 0.27 for moment and 0.96 for shear.

Table 88: Distribution of Rating Factor Ratios for Continuous Span Prestressed Concrete I- Girders with LRFR Ratings less than 1.0 for AASHTO Type 3S2 Vehicle

LRFR/LFR Range	Moment				Shear			
	LRFR		LFR		LRFR		LFR	
	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0	No. of Girders	% of Total Inventory (238)	No. of Girders < 1.0	No. of Girders > 1.0
0.0-0.09	17	7.1%	0	17	0	0.0%	0	0
0.1-0.19	74	31.1%	0	74	2	0.8%	0	2
0.2-0.29	44	18.5%	0	44	8	3.4%	0	8
0.3-0.39	6	2.5%	0	6	25	10.5%	0	25
0.4-0.49	1	0.4%	0	1	2	0.8%	0	2
0.5-0.59	0	0.0%	0	0	1	0.4%	0	1
0.6-0.69	0	0.0%	0	0	1	0.4%	0	1
0.7-0.79	0	0.0%	0	0	0	0.0%	0	0
0.8-0.89	0	0.0%	0	0	0	0.0%	0	0
0.9-0.99	0	0.0%	0	0	0	0.0%	0	0
> 1.00	0	0.0%	0	0	0	0.0%	0	0
Total	142		0	142	39		0	39
Average LRFR/LFR	0.27				0.96			



(a)



(b)

Figure 88: Distribution of Rating Factor Ratio for Continuous Span Prestressed Concrete I-Girders with LRFR Rating less than 1.0 (a) Moment and (b) Shear for AASHTO Type 3S2 Vehicle

The RT has modified the example problems in Appendix A of the MBE to reflect the proposed modifications to the MBE. These modifications are typically to the load factors in MBE Tables 6A4.4.2.3a, 6A.4.4.2.3b-1, and 6A.4.5.4.2a-1 for routine commercial traffic, specialized hauling vehicles, and permit loads, respectively. Additional modifications are proposed to Article 6A.5.9 regarding the requirement of shear evaluation for permit loads. These modifications were in response to the Panel Comments received on the Task 6 Report and require shear evaluation for permit vehicles when the factored shear due to the permit load exceeds the factored shear due to the design load.

Examples Problems A6 and A8 only determined rating factors for the design load. The proposed modifications to the MBE dealt with legal and permit loads; therefore, these examples will remain unchanged.

N-1

APPENDIX A:

ILLUSTRATIVE EXAMPLES

A1—SIMPLE SPAN COMPOSITE STEEL STRINGER BRIDGE

PART A—LOAD AND RESISTANCE FACTOR RATING METHOD

A1A.1—Evaluation of an Interior Stringer

A1A.1.1—Bridge Data

Span:	65 ft
Year Built:	1964
Material:	A36 Steel
	F_y = 36 ksi
	f'_c = 3 ksi
Condition:	No deterioration (NBI Item 59 = 7)
	Member is in good condition
Riding Surface:	Minor surface deviations (Field verified and documented)
ADTT (one direction):	1000
Skew:	0°
Additional Information:	Diaphragms spaced at 16 ft 3 in.

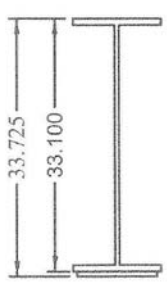
A1A.1.2—Section Properties

In unshored construction, the noncomposite steel stringer must support its own weight plus the weight of the concrete slab. For the composite section, the concrete is transformed into an equivalent area of steel by dividing the area of the slab by the modular ratio. Live load plus impact stresses are carried by the composite section using a modular ratio of *n*. To account for the effect of creep, superimposed dead-load stresses are carried by the composite section using a modular ratio of 3*n* (LRFD Design 6.10.1.1.b). The as-built section properties are used in this analysis as there is no deterioration.

A1A.1.2.1—Noncomposite Section Properties

Section properties of rolled shapes are subject to change with changes in rolling practices of the steel industry. Identify steel components from available records, construction date, and field measurements. The section properties for this beam were determined from *AISC Manual of Steel Construction*, Sixth Edition, printed during the period from July 1963 to March 1967, which is consistent with the "Year Built" date for this bridge.

W 33 × 130	PL $^5/_8$ in. × 10 $^1/_2$ in.
t_f = 0.855 in.	t = 0.625 in.
b_f = 11.51 in.	b = 10.5 in.
t_w = 0.58 in.	
A = 38.26 in.^{2}	$A = t \times b$ = 6.56 in.^{2}
I = 6699 in.^{4}	I ~0 in.^{4} (negligible)



$$\bar{y} = \frac{\left(\frac{D_{W33\times130}}{2} + t_{PL}\right)\left(A_{W33\times130}\right) + \left(\frac{t_{PL}}{2}\right)\left(t_{PL} \times b_{PL}\right)}{A_{W33\times130} + \left(t_{PL} \times b_{PL}\right)}$$

$$\bar{y} = \frac{(17.175)(38.26) + (0.313)(6.56)}{38.26 + 6.56} \text{ Distance to } C.G.$$

$\bar{y} = 14.71$ in. from bottom of section to centroid

$$I_x = 6699 + 38.26(2.47)^2 + 6.56(14.40)^2$$

$$I_x = 8293 \text{ in.}^4$$

$$S_t = \frac{8293}{19.02} = 436.0 \text{ in.}^3 \quad \text{Section Modulus at top of steel}$$

$$S_b = \frac{8293}{14.71} = 563.7 \text{ in.}^3 \quad \text{Section Modulus at bottom of steel}$$

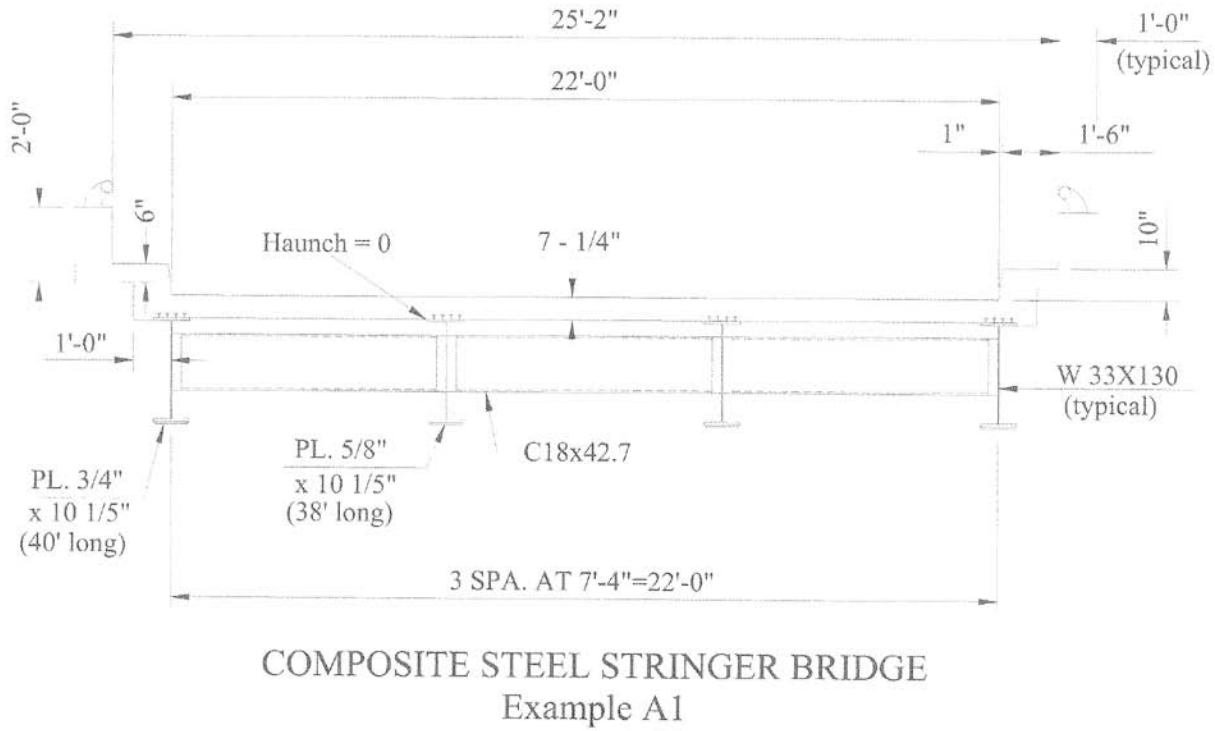


Figure A1A.1.2.1-1—Composite Steel Stringer Bridge

A1A.1.2.2—Composite Section Properties (LFRD Design 4.6.2.6.1)

Effective Flange Width, b_e

Minimum of:

i. $1/4(L)$
ii. $12.0t_s +$ greater of: t_w or $1/2b_{f\ top}$
iii. S

i.	1/4(65)(12)	=	195 in.
ii.	(7.25)(12) + 1/2(11.51)	=	92.8 in.
iii.	(7.33)(12)	=	88 in. controls

Modular Ratio, n LRFD Design 6.10.1.1.1b

f'_c = 3 ksi

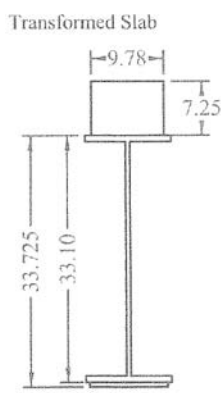
For $2.9 < f'_c < 3.6$, $n = 9$ LRFD Design C6.10.1.1.1b

Typical Interior Stringer:

Short-Term Composite, (n):

$W33 \times 130$, $PL\ ^5/_8$ in. × $10^1/_2$ in. and *Conc.* $7^1/_4$ in. × 88 in.

Effective Flange Width, $b_e = \dfrac{88}{n} = 9.78$ in.



$$\bar{y} = \frac{(17.175)(38.26) + (0.313)(6.56) + \left(\frac{88}{9} \times 7.25\right)(37.35)}{38.26 + 6.56 + \left(\frac{88}{9} \times 7.25\right)}$$

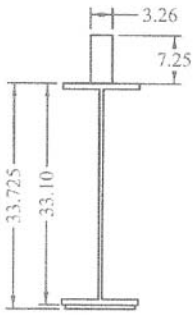
$\bar{y}$ = 28.58 in. from bottom of section to centroid

$$I_x = (6699) + (38.26)(11.40)^2 + (6.56)(28.27)^2 + \frac{\left(\frac{88}{9}\right)(7.25)^3}{12} + \left(\frac{88}{9} \times 7.25\right) \times (8.77)^2$$

I_x = 22677 in.^{4}

$S_t = \dfrac{22677}{5.14} = 4412$ in.^{3} Section Modulus at top of steel

$S_b = \dfrac{22677}{28.58} = 793$ in.^{3} Section Modulus at bottom of steel



Long-Term Composite, 3*n*:

*W*33 × 130, *PL* $^5/_8$ in. × 10 $^1/_2$ in. and *Conc.* 7 $^1/_4$ in. × 88 in.

Effective Flange Width, $b_e = \dfrac{88}{(3\times 9)} = 3.26$ in.

$$\bar{y} = \frac{(17.175)(38.26)+(0.313)(6.56)+\left(\frac{88}{27}\times 7.25\right)(37.35)}{38.26+6.56+\left(\frac{88}{27}\times 7.25\right)}$$

$\bar{y} = 22.52$ in. from bottom of section to centroid

$$I_x = (6699)+(38.26)(5.34)^2+(6.56)(22.21)^2+ \frac{\left(\frac{88}{27}\right)(7.25)^3}{12}+\left(\frac{88\times 7.25}{27}\right)\times(14.83)^2$$

$I_x = 16326$ in.^{4}

$S_t = \dfrac{16326}{11.20} = 1458$ in.^{3} Section Modulus at top of steel

$S_b = \dfrac{16326}{22.52} = 725$ in.^{3} Section Modulus at bottom of steel

A1A.1.2.3—Summary of Section Properties at Midspan

A1A.1.2.3a—Steel Section Only

S_{TOP} = 436 in.^{3}

S_{BOT} = 563.7 in.^{3}

A1A.1.2.3b—Composite Section—Short Term, n = 9

$S_{TOPsteel}$ = 4412 in.^{3}

S_{BOT} = 793 in.^{3}

A1A.1.2.3c—Composite Section—Long Term, 3n = 27

$S_{TOPsteel}$ = 1458 in.^{3}

S_{BOT} = 725 in.^{3}

A1A.1.3—Dead-Load Analysis—Interior Stringer

A1A.1.3.1—Components and Attachments, DC

In general, attachments may include connection plates, stiffeners, diaphragms, bracing, and other miscellaneous components. A refined rating calculation accounts for major weight components; alternatively, a percentage of stringer weight can be used as an estimate. For this example, three interior diaphragms were taken into account and end diaphragms that are directly over the supports were neglected when estimating uniform span loads.

A1A.1.3.1a—Noncomposite Dead Loads, DC_1

Deck: $(7.33\text{ ft})\dfrac{(7.25\text{ in.})}{12}(0.150\text{ kcf})$ = 0.664 kip/ft

Stringer: (0.130 kip/ft) (1.06) = 0.138 kip/ft
(six percent increase for connections)

Cover Plate:

$$\frac{(0.625\text{ in.})(10.5\text{ in.})\left(\dfrac{0.490\text{ kcf}}{144}\right)(1.06)(38\text{ ft})}{65\text{ ft}} = 0.014\text{ kip/ft}$$

Diaphragms: $\dfrac{(3)(0.0427\text{ kip/ft})(7.33\text{ ft})(1.06)}{65\text{ ft}}$ = 0.015 kip/ft

Total per stringer = 0.831 kip/ft

$$M_{DC1} = \frac{0.831(65)^2}{8} = 439\text{ kip-ft at midspan}$$

$$V_{DC1} = 0.831\left(\frac{65}{2}\right) = 27\text{ kips at bearing}$$

A1A.1.3.1b—Composite Dead Loads, DC_2

All permanent loads on the deck are uniformly distributed among the beams. LRFD Design 4.6.2.2.1

The unit weight of reinforced concrete is generally taken as .005 kcf greater than the unit weight of plain concrete, hence for estimating concrete loads 0.150 kcf was assumed. LRFD Design C3.5.1

Curb: $(1\text{ ft})\left(\dfrac{10\text{ in.}}{12}\right)(0.150\text{ kcf})\left(\dfrac{2\text{ curbs}}{4\text{ beams}}\right)$ = 0.062 kip/ft

Parapet:

$$\left[\left(\frac{6\text{ in.}\times 19\text{ in.}}{144}\right)+\left(\frac{18\text{ in.}\times 12\text{ in.}}{144}\right)\right](0.150\text{ kcf})\left(\frac{2\text{ parapets}}{4\text{ beams}}\right) = 0.172\text{ kip/ft}$$

Railing: Assume $0.020\text{ kip/ft}\left(\dfrac{2\text{ railings}}{4\text{ beams}}\right)$ = 0.010 kip/ft

Total per stringer = 0.244 kip/ft

$$M_{DC2} = \frac{0.244(65)^2}{8} = 129 \text{ kip-ft at midspan}$$

$$V_{DC2} = 0.244\left(\frac{65}{2}\right) = 8 \text{ kips at bearing}$$

A1A.1.3.2—Wearing Surface

$DW = 0$

A1A.1.4—Live Load Analysis—Interior Stringer (LRFD Design Table 4.6.2.2.1-1)

A1A.1.4.1—Compute Live Load Distribution Factors (Type (a) cross section)

Longitudinal Stiffness Parameter, K_g LRFD Design 4.6.2.2.1

$$K_g = n\left(I + Ae_g^2\right)$$ LRFD Design Eq. 4.6.2.2.1-1

in which $n = \frac{E_B}{E_D}$ LRFD Design Eq. 4.6.2.2.1-2

$$E_D = 33000\left(w_c\right)^{1.5}\sqrt{f'_c}$$ LRFD Design Eq. 5.4.2.4-1

$$= 33000\left(0.145\right)^{1.5}\sqrt{3}$$

$$= 3155.9 \text{ ksi}$$

$$E_B = 29000 \text{ ksi}$$

Beam + Cov. *PL*

I = 8293 in.^{4}

A = 44.82 in.^{2}

e_g = 1/2 (7.25) + 19.02 = 22.65 in.

$$K_g = \frac{29000}{3155.9}\left(8293 + 44.82 \times 22.65^2\right)$$

K_g = 287498 in.^{4}

A1A.1.4.1a—Distribution Factor for Moment, g_m (LRFD Design Table 4.6.2.2.2b-1)

$$\frac{K_g}{12.0Lt_s^3} = \frac{287498}{12 \times 65 \times 7.25^3} = 0.967$$

One Lane Loaded:

$$g_{m1} = 0.06 + \left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$$

$$= 0.06 + \left(\frac{7.33}{14}\right)^{0.4}\left(\frac{7.33}{65}\right)^{0.3}(0.967)^{0.1}$$

$$= 0.460$$

Two or More Lanes Loaded:

$$g_{m2} = 0.075 + \left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$$

$$= 0.075 + \left(\frac{7.33}{9.5}\right)^{0.6}\left(\frac{7.33}{65}\right)^{0.2}(0.967)^{0.1}$$

$$= 0.626 > 0.460$$

$\therefore$ use $g_m = 0.626$

A1A.1.4.1b—Distribution Factor for Shear, g_v (LRFD Design 4.6.2.2.3a)

One Lane Loaded:

$$g_{v_1} = 0.36 + \frac{S}{25.0}$$ LRFD Design Table 4.6.2.2.3a-1

$$= 0.36 + \frac{7.33}{25.0}$$

$$= 0.653$$

Two or More Lanes Loaded:

$$g_{v_2} = 0.2 + \frac{S}{12} - \left(\frac{S}{35}\right)^{2.0}$$ LRFD Design Table 4.6.2.2.3a-1

$$= 0.2 + \frac{7.33}{12} - \left(\frac{7.33}{35}\right)^{2.0}$$

$$= 0.767 > 0.653$$

$\therefore$ use $g_v = 0.767$

A1A.1.4.2—Compute Maximum Live Load Effects

A1A.1.4.2a—Maximum Design Live Load (HL-93) Moment at Midspan

The maximum moment effects are estimated to occur with the design live load centered on the span. Calculate moments by statics.

Design Lane Load Moment $= \dfrac{wl^2}{8} = \dfrac{0.640\,\text{klf}\,(65\,\text{ft})^2}{8} = 338\,\text{kip-ft}$

Design Truck Moment with the middle axle located at midspan:

Design Truck Moment $= \dfrac{P_{32}\ell}{4} + \dfrac{(P_8 + P_{32})xb}{\ell}$

$= \dfrac{32^k \times 65\,\text{ft}}{4} + \dfrac{(8^k + 32^k)32.5\,\text{ft} \times 18.5\,\text{ft}}{65\,\text{ft}}$

Design Truck Moment = 890 kip-ft Governs

Tandem Axles Moment with tandem axles located equidistant from midspan:

Tandem Axles Moment $= P_{25}a = 25^k \times 30.5\,\text{ft} =$ 762.5 kip-ft

IM = 33% LRFD Design Table 3.6.2.1-1

M_{LL+IM} = 338 + 890 × 1.33

= 1521.7 kip-ft

A1A.1.4.2b—Maximum Design Live Load Shear at Beam Ends

The maximum shear effects occur with the heaviest axle located to create the maximum end reaction. Calculate shears by statics.

Design Lane Load Shear $= \dfrac{w\ell}{2} = \dfrac{0.640\,\text{klf}\,(65\,\text{ft})}{2} = 20.8\,\text{kips}$

Design Truck Shear $= P_{32} + P_{32}\left(\dfrac{\ell - x_{32}}{\ell}\right) + P_8\left(\dfrac{\ell - x_8}{\ell}\right)$

$= 32^k + 32^k\left(\dfrac{65\,\text{ft} - 14\,\text{ft}}{65\,\text{ft}}\right) + 8^k\left(\dfrac{65\,\text{ft} - 28\,\text{ft}}{65\,\text{ft}}\right)$

Design Truck Shear = 61.7 kips Governs

Tandem Axles Shear $= P_{25} + P_{25}\left(\dfrac{\ell - x_{25}}{\ell}\right) = 25^k + 25^k\left(\dfrac{65\text{ ft} - 4\text{ ft}}{65\text{ ft}}\right) = 48.5$ kips

V_{LL+IM} = 20.8 kips + 61.7 kips × 1.33

= 102.9 kips

A1A.1.4.2c—Distributed Live Load Moments and Shears

Design Live-Load HL-93:

M_{LL+IM} = 1521.7 × g_m

= 1521.7 × 0.626

= 952.6 kip-ft

V_{LL+IM} = $102.9 \times g_v$

= 102.9×0.767

= 78.9 kips

A1A.1.5—Compute Nominal Resistance of Section at Midspan

Locate Plastic Neutral Axis PNA:

t_f = 0.855 in.

t_w = 0.58 in.

b_f = 11.51 in.

Cov. *PL* Area A_p

= 6.56 in.^{2}

(*PL* $^5/_8$ in. × $10^1/_2$ in.)

Web Depth:

D = 33.10 in. – 2 (0.855 in.)

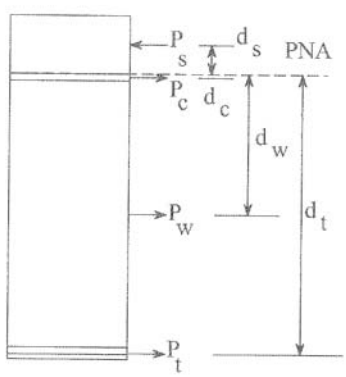
= 31.39 in.

Treat the bottom flange and the cover plate as one element.

$$A_t = (11.51)(0.855)+(10.5)(0.625)=16.40 \text{ in.}^2$$

$$y = \frac{(11.51)(0.855)\dfrac{(0.855)}{2}+(10.5)(0.625)\left(0.855+\dfrac{0.625}{2}\right)}{(11.51)(0.855)+(10.5)(0.625)}$$

= 0.724 in. (from top of tension flange to centroid of flange and cover plate)



Plastic Forces LRFD Design Appendix D6.1

Note the forces in longitudinal reinforcement may be conservatively neglected.

Set P_{rb} and P_{rt} = 0

P_s = $0.85 f'_c b_{eff} t_s$

= $0.85 \times 3.0 \times 88 \times 7.25$

= 1626.9 kips

$$\frac{c_{rb}}{t_s}=\frac{5.25}{7.25}$$

where c_{rb} is the distance from the top of the concrete slab to the center of the bottom layer of the longitudinal concrete deck reinforcement and t_s is the thickness of the concrete deck. Asssume cover + $^1/_2$ bar diameter = 2 in., then c_{rb} equals 5.25 in.

$$P_c = F_y A_c \text{ where } A_c = b_f t_f$$
$$= 36 \times 11.51 \times 0.855$$
$$= 354.3 \text{ kips}$$

$$P_w = F_y D t_w$$
$$D = 33.10 - 2 \times 8.55 = 31.39$$
$$= 36 \times 31.39 \times 0.58$$
$$= 655.4 \text{ kips}$$

$$P_t = F_y A_t \text{ where } A_t = b_f t_f + A_p$$
$$= 36(11.51 \times 0.855 + 6.56)$$
$$= 590.4 \text{ kips}$$

$$P_t + P_w + P_c = 590.4 + 655.4 + 354.3 = 1600.1 \text{ kips}$$

$$\frac{c_{rb}}{t_s} P_s + P_{rb} + P_{rt} = \frac{5.25}{7.25} 1626.9 + 0.0 + 0.0 \text{ kips} = 1178.1 \text{ kips}$$

$$P_c + P_w + P_t \geq \frac{c_{rb}}{t_s} P_s + P_{rb} + P_{rt}$$

$$1600.1 \geq 1178.1$$

The PNA lies in the slab; only a portion of the slab (depth = $\overline{y}$) is required to balance the plastic forces in the steel beam.

$$\overline{Y} = (t_s)\left[\frac{P_c + P_w + P_t - P_{rt} - P_{rb}}{P_s}\right]$$

LRFD Design

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$$\overline{Y} = (7.25)\frac{1600.1}{1626.9}$$

$\overline{Y}$ = 7.13 in. from the top of the concrete deck slab

A1A.1.5.1—Classify Section (LRFD Design 6.10.7 and Figure C6.4.5-1)

Following the I-Sections in Positive Flexure Flowchart
(Section is considered to be Constant Depth)

A1A.1.5.1a—Check Web Slenderness (LRFD Design 6.10.6.2.2)

Since PNA is in the slab, the web slenderness requirement is automatically satisfied.

For composite sections in positive bending, the remaining stability criteria are automatically satisfied. The section is compact.

A1A.1.5.1b—Check Ductility Requirement (LRFD Design 6.10.7.1.2)

$$D_p = \overline{Y} = 7.13 \text{ in.}$$

$$D_t = \text{Depth of Composite Section}$$
$$= d + t_s = 33.725 + 7.25$$
$$= 40.98 \text{ in.}$$

If $D_p \le 0.1D_t$, then $M_n = M_p$ LRFD Design Eq. 6.10.7.1.2-1

Otherwise, $M_n = M_p\left(1.07 - 0.7\frac{D_p}{D_t}\right)$ LRFD Design Eq. 6.10.7.1.2-2

$0.1D_t = 0.1 \times 40.98 = 4.098$ in.

7.13 in. $\not\le$ 4.098 in. therefore calculate $M_n < M_p$

A1A.1.5.2—Plastic Moment, M_p

Moment arms about the PNA:

Compression Flange:

$$d_c = \left(t_s - \overline{Y}\right) + \frac{t_c}{2}$$

$$= (7.25 - 7.13) + \frac{0.855}{2}$$

$$= 0.55 \text{ in.}$$

$$d_w = \left(t_s - \overline{Y}\right) + t_c + \frac{D}{2}$$

$$= (7.25 - 7.13) + 0.855 + \frac{31.39}{2}$$

$$= 16.67 \text{ in.}$$

Tension Flange:

$$d_t = \left(t_s - \overline{Y}\right) + t_c + D + \frac{t_t}{2}$$

$$= (7.25 - 7.13) + 0.855 + 31.39 + 0.724$$

(0.724 in. is the distance to the centroid of the bottom flange and cover plate from the top of the flange)

$$= 33.09 \text{ in.}$$

The plastic moment M_p is the sum of the moments of the plastic forces about the PNA.

$$M_p = \left(\frac{\overline{Y}^2 P_s}{2t_s}\right) + \left[Prtdrt + Prbdrb + P_c n_c + P_w d_w + P_t d_t\right]$$ LRFD Design Table D6.1-1

$$= \left(\frac{7.13^2 \times 1626.9}{2 \times 7.25}\right) + \left[0 + 0 + 354.3 \times 0.55 + 655.4 \times 16.67 + 590.4 \times 33.09\right]$$

$$= 36361 \text{ kip-in. or } 3030 \text{ kip-ft}$$

A1A.1.5.3—Nominal Flexural Resistance, M_n (LRFD Design 6.10.7.1.2)

$D_p \not\le 0.1D_t$ LRFD Design Eq. 6.10.7.1.2-1

Therefore, $M_n = M_p\left(1.07 - 0.7\frac{D_p}{D_t}\right)$ LRFD Design Eq. 6.10.7.1.2-2

Flange lateral bending stress: $f_l = 0$.

A1A.1.5.4—Nominal Shear Resistance, V_n (LRFD Design 6.10.9.2)

*W*33 × 130 Rolled section, no stiffeners.

Web Depth clear of fillet = 29.75 in.

Total Depth – 2 (Flange thicknesses) = 31.39 in.

If $\frac{D}{t_w} \le 1.12\sqrt{\frac{Ek}{F_{yw}}}$ with $k = 5$ for unstiffened web, then $C = 1.0$

$$\frac{D}{t_w} = \frac{29.75}{0.580} = 51.3$$

$$1.12\sqrt{\frac{Ek}{F_{yw}}} = 1.12\sqrt{\frac{29000 \times 5}{36}}$$ LRFD Design Eq. 6.10.9.3.2-4

$51.3 \le 71.1$, therefore $C = 1.0$

then:

$$V_n = V_{cr} = CV_p$$ LRFD Design Eq. 6.10.9.2-1

where $V_p = 0.58F_{yw}Dt_w$ LRFD Design Eq. 6.10.9.2-2

= 1.0 x 0.58 × 36 × 29.75 × 0.580

= 360.3 kips

A1A.1.5.5—Summary for Interior Stringer

	Dead Load DC_1	Dead Load DC_2	LiveLoad Distribution Factor	Dist. Live Load + Impact	Nominal Capacity
Moment, kip-ft	439.0	129.0	gm = 0.626	952.6	2873.0
Shear, kips	27.0	8.0	gv = 0.767	78.9	360.3

A1A.1.6—General Load-Rating Equation

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_L)(LL + IM)}$$ LRFD Design Eq. 6A.4.2.1.-1

A1A.1.7—Evaluation Factors (for Strength Limit States)

1. Resistance Factor, φ LRFD Design 6.5.4.2
   φ = 1.0 for flexure and shear
2. Condition Factor, φ_c 6A4.2.3
   φ_c = 1.0 Member is in good condition. NBI Item 59 = 7.
3. System Factor, φ_s 6A.4.2.4

$\varphi_s = 1.0$ 4-girder bridge, spacing > 4 ft (for flexure and shear).

A1A.1.8—Design Load Rating (6A.4.3)

A1A.1.8.1—Strength I Limit State (6A.6.4.1)

Capacity $C = (\varphi_c)(\varphi_s)(\varphi)R_n$

$$RF = \frac{(\varphi_c)(\varphi_s)(\varphi)R_n - (\gamma_{DC})(DC) - (\gamma_{DW})(DW)}{(\gamma_L)(LL + IM)}$$

A1A.1.8.1a—Inventory Level

Load	Load Factor γ	Table 6A.4.2.2-1
DC	1.25	
LL	1.75	

Flexure: $RF = \dfrac{(1.0)(1.0)(1.0)(2873) - (1.25)(439) - (1.25)(129)}{(1.75)(952.6)}$

$= 1.2975$

Note: The general rule for simple spans carrying moving concentrated loads states: the maximum bending moment produced by moving concentrated loads occurs under one of the loads when that load is as far from one support as the center of gravity of all the moving loads on the beam is from the other support. In a refined analysis with the HL-93 truck located in such a manner, the resulting rating factor for flexure is *RF* = 1.2922 for this stringer. It should be understood that locating the precise critical section and load position for rating depends on the combined influence of dead load, live load, member capacity and load factors that make up the general Rating Factor equation.

Shear: $RF = \dfrac{(1.0)(1.0)(1.0)(360.3) - (1.25)(27 + 8)}{(1.75)(78.9)}$

$= 2.29$

A1A.1.8.1b—Operating Level

Load	Load Factor γ	Table 6A.4.2.2-1
DC	1.25	
LL	1.35	

For Strength I Operating Level, only the live-load factor changes; therefore, the rating factor can be calculated by direct proportions.

Flexure: $RF = 1.29 \times \dfrac{1.75}{1.35}$

$= 1.67$

Shear: $RF = 2.29 \times \dfrac{1.75}{1.35}$

$= 2.97$

A1A.1.8.2—Service II Limit State (6A.6.4.1)

Capacity $C = f_R$

$$RF = \frac{f_R - (\gamma_{DC})(f_{DC}) - (\gamma_{DW})(f_{DW}) \pm (\gamma_P)(f_P)}{(\gamma_{LL})(f_{LL+IM})}$$ Eq. 6A.6.4.2.1-1

For this example, the terms:

$$(\gamma_{DW})(f_{DW}) \pm (\gamma_P)(f_P)$$

do not contribute and the general equation reduces to:

$$RF = \frac{f_R - (\gamma_{DC})(f_{DC})}{(\gamma_{LL})(f_{LL+IM})}$$

A1A.1.8.2a—Inventory Level

Allowable Flange Stress for tension flange $f_R = 0.95R_hF_{yf}$ $(f_\ell = 0)$ LRFD Design Eq. 6.10.4.2.2-2

Checking the tension flange as compression flanges typically do not govern for composite sections.

R_h = 1.0 for non-hybrid sections LRFD Design 6.10.1.10.1

f_R = 0.95 × 1.0 × 36

= 34.2 ksi

f_D = $f_{DC_1} + f_{DC_2}$

$$= \frac{439 \times 12}{563.7} + \frac{129 \times 12}{725}$$

= 9.35 + 2.14 = 11.49 ksi

$$f_{LL+IM} = \frac{952.6 \times 12}{793} = 14.42 \text{ ksi}$$

γ_{LL} = 1.30 γ_{DC} = 1.0 Table 6A.4.2.2-1

= 1.21

$$RF = \frac{34.2 - (1.0)(11.49)}{(1.3)(14.42)}$$

A1A.1.8.2b—Operating Level

γ_{LL} = 1.0 γ_{DC} = 1.0 Table 6A.4.2.2-1

$$RF = \frac{34.2 - (1.0)(11.49)}{(1.0)(14.42)}$$

= 1.57

A1A.1.8.3—Fatigue Limit State (6A.6.4.1)

Determine if the bridge has any fatigue-prone details (Category C or lower).

The transverse welds detail connecting the ends of cover plates to the flange are fatigue-prone details. Category E' details because the flange thicknesss = 0.855 in. is greater than 0.8 in. — LRFD Design Table 6.6.1.2.3-1

If $2R_s(\Delta f)_{tension} > f_{dead\text{-}load\ compression}$, the detail may be prone to fatigue.

$f_{dead\text{-}load\ compression}$ — 7.2.3

= 0 at cover plate at all locations because beam is a simple span and cover plate is located in the tension zone

∴ must consider fatigue; compute *RF* for fatigue load for infinite life.

$$RF = \frac{f_R - (\gamma_{DC})(f_{DC})}{(\gamma_{LL})(\Delta f_{LL+IM})_{max}}$$

$f_R = (\Delta F)_{TH}$

$\gamma_{LL} = 0.75 \quad \gamma_{DC} = 0.00$ — Table 6A.4.2.2-1

Composite section properties without cover plate.

$$\bar{y} = \frac{\sum A \times \bar{y}}{\sum A} = \frac{(38.26)(16.55) + \left(\frac{88}{9} \times 7.25\right)(36.725)}{(38.26) + \left(\frac{88}{9} \times 7.25\right)}$$

= 29.65 in. from bottom of flange

$$I_x = 6699 + (38.26)(13.10)^2 + \frac{\left(\frac{88}{9}\right)(7.25)^3}{12} + \frac{88}{9}(7.25)(7.07)^2$$

= 17119 in.^{4}

$$S_b = \frac{17119}{29.65} = 577 \text{ in.}^3$$

Live Load at Cover Plate Cut-Off (13.5 ft. from centerline of bearing)

Fatigue Load: Design truck with a spacing of 30 ft between 32 kip axles. — LRFD Design 3.6.1.4.1 and Figure 3.6.1.2.2-1

M_{LL} = (32 kips) (10.69 ft) + (32 kips) (4.46 ft) + (8 kips) (1.56 ft)

= 497 kip-ft = 5967 kip-in. — Using influence lines.

IM = 15% — LRFD Design Table 3.6.2.1-1

M_{LL+IM} = (1.15) (5967) = 6862 kip-in.

A1A.1.8.3a—Load Distribution for Fatigue LRFD Design 3.6.1.4.3b

The single-lane distribution factor will be used for fatigue. LRFD Design 3.6.1.1.2

Remove multiple presence factor from the single-lane distribution. LRFD Design C3.6.1.1.2

$$g_{Fatigue} = \frac{1}{1.2}(g_{m1})$$

$$= \frac{1}{1.2}(0.46)$$

$$= 0.383$$

Distributed Live-Load Moment:

$$gM_{LL+IM} = (0.383)\ (6862)$$

$$= 2628 \text{ kip-in.}$$

Fatigue Load Stress Range:

$$\Delta f_{LL+IM} = \frac{2628}{577}$$

$$= 4.56 \text{ ksi at the cover plate weld}$$

Nominal fatigue resistance for infinite life.

$(\Delta F)_{TH}$ = 2.6 ksi for Detail Category E′ LRFD Design Table 6.6.1.2.5-3

Infinite-Life Fatigue Check: 7.2.4

R_{sa} = 1.0 stress range by simplified analysis Table 7.2.2.1-1

R_{st} = 1.0 truck weight per LRFD Design Specifications

R_s = $R_{sa} \times R_{st} = 1.0$

$$\Delta f_{eff} = (R_s)(\gamma_{LL})(\Delta f_{LL+IM}) = 1.0(0.75)(4.56) = 3.42 \text{ ksi}$$

$(\Delta f_{LL+IM})_{max}$ 7.2.4

$= (2.0)\ (\Delta f_{eff}) = 2.0\ (3.42) = 6.84$ ksi

$$RF = \frac{(\Delta F)_{TH}}{(\Delta f_{LL+IM})_{max}}$$

$$= \frac{2.6}{6.84} = 0.38 < 1.0$$

The detail does not possess infinite fatigue life per LRFD new bridge standards.

Evaluate remaining fatigue life using procedures given in Section 7 of this Manual.

A1A.1.8.3b—Calculation of Remaining Fatigue Life

Finite life determination:

$$Y = \frac{R_R A}{365 n \left(ADTT \right)_{SL} \left[\left(\Delta f \right)_{eff} \right]^3}$$ 7.2.5.1

ADTT (one direction) = 1000

$ADTT_{SL}$ = 0.85 (1000) = 850 LRFD Design Table 3.6.1.4.2-1

Using a two percent growth rate and age of 43 y (2007–1964) Figure C7.2.5.1-1

ADTT multiplier = 1.02

Lifetime average $ADTT_{SL}$ = (1.02) (850) 867

For Category E′ evaluation life:

R_R = 1.6 Table 7.2.5.2-1

A = 3.9×10^8 ksi^3 LRFD Design Table 6.6.1.2.5-1

n = 1.0 simple span girders with L > 40 ft LRFD Design Table 6.6.1.2.5-2

$$Y = \frac{1.3\left(3.9 \times 10^8 \right)}{365(1.0)(867)(3.42)^3}$$

= 40 y

Remaining life = Y – current age = 40 y – 43 y
= –3 y, the acceptable remaining life has been exceded

When the remaning fatigue life is unacceptable, strategies to improve the remaining fatigue include acceptance of greater risk, refined evaluation through more accuater data, or retrofit. 7.2.7

A1A.1.9—Legal Load Rating 6A.6.4.2

Note: The Inventory Design Load Rating produced rating factors greater than 1.0 (with the exception of Fatigue). This indicates that the bridge has adequate load capacity to carry all legal loads within LRFD exclusion limits and need not be subject to Legal Load Ratings. The load rating computations that follow have been done for illustrative purposes. Shear ratings have not been illustrated. Appendix A6A

Live Load: AASHTO Legal Loads—Type 3, 3S2, 3-3 (Rate for all three)

g_m = 0.626

IM = 20% The standard dynamic load allowance of 33 percent is decreased based on a field evaluation verifying that the approach and bridge riding surfaces have only minor surface deviations or depressions. Table C6A.4.4.3-1

The following table compares interpolating to determine M_{LL} without impact for 65 ft span with exact values determined by statics. Note that for the Type 3-3, interpolating M_{LL} results in a value that is 1.5 percent greater than the true value. Judgement should be exercised whether to interpolate tabulated values. Table E6A-1

	Type 3	Type 3S2	Type 3-3	
M_{LL} interpolated	660.7	707.2	654.5	kip-ft
M_{LL} statics	660.77	707.03	644.68	kip-ft
gM_{LL+IM}	496.3	531.2	484.3	kip-ft

Live Load: AASHTO Legal Loads—Specialized Hauling Units and Notional Rating Load—SU4, SU5, SU6, SU7, and NRL

Interpolated values shall be used for the Specialized Hauling Units in this example for illustrative purposes and to familiarize the reader with the Appendix tables. Table E6A-2

Interpolating to determine M_{LL} without impact for 65 ft span

	SU4	SU5	SU6	SU7	NRL	
M_{LL} interpolated	744.7	821.2	913.5	994.1	1037.0	kip-ft
gM_{LL+IM}	559.4	616.9	686.2	746.8	779.0	kip-ft

A1A.1.9.1—Strength I Limit State 6A.6.4.2.1

For Types 3, 3S2, and 3-3

Dead Load *DC*: $\gamma_{DC} = 1.25$ Table 6A.4.2.2-1

ADTT = 1000

Generalized Live-Load Factor for Legal Loads, $\gamma_{LL} = 1.30$ Table 6A.4.4.2.3a-1

Flexure: $RF = \dfrac{(1.0)(1.0)(1.0)(2873)-(1.25)(439)-(1.25)(129)}{(1.30)(M_{LL+IM})}$

	Type 3	Type 3S2	Type 3-3
RF	3.35	3.13	3.44

For Specialized Hauling Units and NRL

Dead Load *DC*: $\gamma_{DC} = 1.25$ Table 6A.4.2.2-1

ADTT = 1000 Assumed

Generalized Live Load Factor for Legal Loads $\gamma_{LL} = 1.30$ Table 6A.4.4.2.3b-1

Flexure: $RF = \dfrac{(1.0)(1.0)(1.0)(2873)-(1.25)(439)-(1.25)(129)}{(1.30)(M_{LL+IM})}$

	SU4	SU5	SU6	SU7	NRL
RF	2.97	2.70	2.42	2.23	2.14

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A1A.1.9.2—Service II Limit State 6A.6.4.2.2

For Types 3, 3S2, and 3-3, and for Specialized Hauling Units and NRL

γ_{LL} = 1.3 γ_D = 1.0 Table 6A.4.2.2-1

f_R = 34.2 ksi

f_D = $f_{DC_1} + f_{DC_2}$

$$= \frac{439 \times 12}{563.7} + \frac{129 \times 12}{725} = 11.49 \text{ ksi}$$

$$f_{LL+IM} = \frac{M_{LL+IM} \times 12}{793}$$

$$RF = \frac{34.2 - 11.49}{1.3\left(f_{LL+IM}\right)}$$

	Type 3	Type 3S2	Type 3-3	
f_{LL+IM}	7.51	8.04	7.33	ksi
RF	2.33	2.17	2.38	

	SU4	SU5	SU6	SU7	NRL	
f_{LL+IM}	8.47	9.34	10.38	11.30	11.79	ksi
RF	2.06	1.87	1.68	1.55	1.48	

No posting required as *RF* > 1.0.

A1A.1.9.3—Summary

Truck	Type 3	Type 3S2	Type 3-3
Weight (tons)	25	36	40
RF (Service II Controlling)	2.33	2.17	2.38
Safe Load Capacity (tons)	58	78	95

Truck	SU4	SU5	SU6	SU7	NRL
Weight (tons)	27	31	34.8	38.8	40
RF (Service II Controlling)	2.06	1.87	1.68	1.55	1.48
Safe Load Capacity (tons)	55	58	58	60	59

The NRL rating demonstrates Article C6A.4.4.2.1b: "Bridges that rate for the NRL loading will have adequate load capacity for all legal Formula B truck configurations up to 80 kips."

Example A1 shows this holding true NRL *RF* > 1 and all SU *RF* > 1, while Example A2 shows when NRL *RF* < 1, *RF* for the SUs may or may not be >1 and need to be checked on an individual basis.

A1A.1.10—Permit Load Rating 6A.6.4.2

Permit Type: Special (Single-Trip, Escorted)
Permit Weight: 220 kips
Permit Vehicle: Shown in Figure 1
ADTT (one direction): 1000

From Live Load Analysis by Computer Program:

Undistributed Maximum M_{LL} = 2127.9 kip-ft

Undistributed Maximum V_{LL} = 143.5 kips

A1A.1.10.1—Strength II Limit State 6A.6.4.2.1

γ_{LL} = 1.15 (Single-Trip, Escorted) Table 6A.4.5.4.2a-1

Use One-Lane Distribution Factor and divide out the 1.2 multiple presence factor. 6A.4.5.4.2b

$$g_{m1} = \frac{0.46}{1.2} = 0.383$$

$$g_{v1} = \frac{0.653}{1.2} = 0.544$$

IM = 20% (no speed control, minor surface deviations) 6A.4.5.5

Distributed Live-Load Effects:

M_{LL+IM} = (2127.9) (0.383) (1.20)
= 978.0 kip-ft

V_{LL+IM} = (143.5) (0.544) (1.20)
= 93.7 kips

Flexure: $$RF = \frac{(1.0)(1.0)(1.0)(2873)-(1.25)(439)-(1.25)(129)}{(1.15)(978.0)}$$

= 1.92 > 1.0 OK

Shear: $$RF = \frac{(1.0)(1.0)(1.0)(360.3)-(1.25)(27+8)}{(1.15)(93.7)}$$

= 2.94 > 1.0 OK

A1A.1.10.2—Service II Limit State (Optional) 6A.6.4.2.2

$$RF = \frac{f_R - f_D}{\gamma_L\left(f_{LL+IM}\right)}$$

IM = 20% (no speed control, minor surface deviations)

γ_L = 1.0 γ_D = 1.0 Table 6A.4.2.2-1

f_R = 34.2 ksi

f_D = 11.49 ksi

Live-load effects for the Service II permit rating of vehicles that mix with traffic are calculated using the LRFD distribution analysis methods. This check is based on past practice and does not use the one-lane distribution with permit load factors that have been calibrated for the Strength II permit rating. For escorted permits, a one-lane distribution factor can be used as the permit crosses the bridge with no other vehicles allowed on the bridge at the same time. C6A.6.4.2.2

g_m = 0.383 (m = 1.2 has been divided out)

M_{LL+IM} = (2127.9) (0.383) (1.2) = 978.0 kip-ft. = 11736 kip-in.

$$f_{LL+IM} = \frac{M_{LL+IM}}{S_b} = \frac{11736}{793} = 14.8 \text{ ksi}$$

$$RF = \frac{34.2-(1.0)(11.49)}{(1.0)(14.8)} = 1.53$$

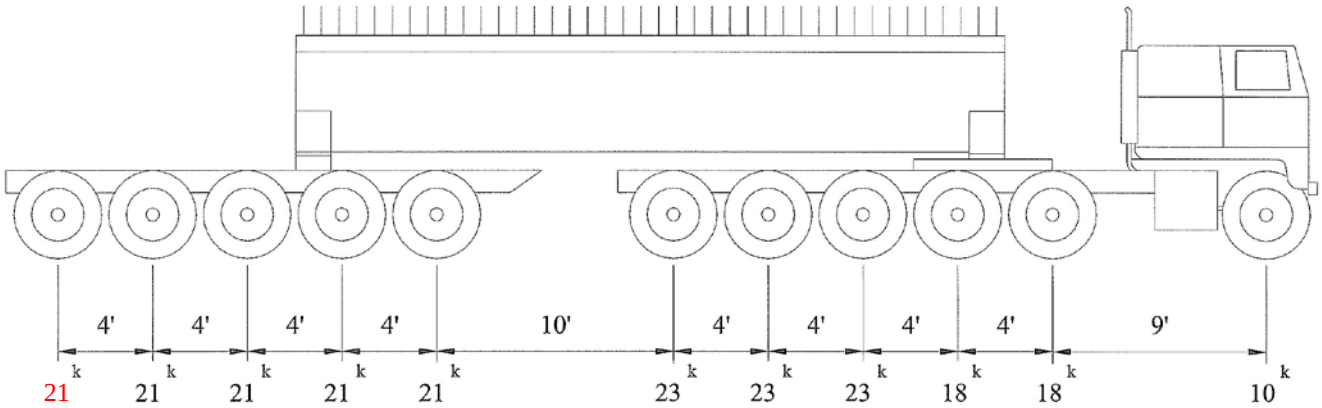


Figure A1A.1.10-1—Permit Truck Loading Configuration

A1A.2—Evaluation of an Exterior Stringer

The same given bridge data as for interior stringers applies.

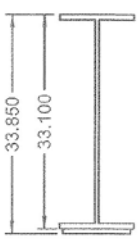
A1A.2.1—Section Properties

A1A.2.1.1—Noncomposite Section Properties

W 33 × 130 and *PL* $^3/_4$ in. × 10 $^1/_2$ in.

The section properties for this beam were determined from the *AISC Manual of Steel Construction*, Sixth Edition, printed during the period from July 1963 to March 1967, which is consistent with the "Year Built" date for this bridge.

W 33 × 130	*PL* $^3/_4$ in. × 10 $^1/_2$ in.
t_f = 0.855 in.	t = 0.750 in.
b_f = 11.51 in.	b = 10.5
t_w = 0.58 in.	
A = 38.26 in.^{2}	$A = t \times b$ = 7.875 in.^{2}
I = 6699 in.^{4}	I ~0 in.^{4} (negligible)



$$\bar{y} = \frac{(17.30)(38.26)+(0.375)(7.875)}{38.26+7.875} \quad \text{Distance to } C.G.$$

$\bar{y} = 14.41$ in. from bottom of section to centroid

$$I_x = 6699 + 38.26(2.89)^2 + 7.875(14.04)^2$$

$$I_x = 8570.9 \text{ in.}^4$$

$$S_t = \frac{8570.9}{19.44} = 440.8 \text{ in.}^3 \quad \text{Section Modulus at top of steel}$$

$$S_b = \frac{8570.9}{14.41} = 594.7 \text{ in.}^3 \quad \text{Section Modulus at bottom of steel}$$

A1A.2.1.2—Composite Section Properties

Barrier is not known to be structurally continuous.

Effective Flange Width, b_e LRFD Design 4.6.2.6.1

$\frac{1}{2}$ Interior b_e + minimum of:

i. $\frac{1}{8}L$

ii. $6.0t_s$ + greater of: $\frac{1}{2}t_w$ or $\frac{1}{4}b_{ftop}$

iii. Overhang

i. $\frac{1}{8}(65)(12)$ = 97.5 in.

ii. $(6.0)(7.25)+\frac{1}{4}(11.51)$ = 46.4 in.

iii. Overhang = 12 in. controls

Effective Flange Width $b_e = \frac{1}{2}(88 \text{ in.}) + 12 \text{ in.} = 56 \text{ in.}$

Modular Ratio, n LRFD Design 6.10.1.1.1b

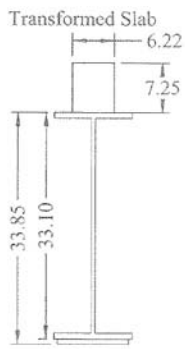
f'_c = 3 ksi

For 2.9 $< f'_c <$ 3.6, n = 9 LRFD Design C6.10.1.1.1b

Short-Term Composite, n:

W 33 × 130, PL $^3/_4$ in. × $10^1/_2$ in. and $Conc.$ $7^1/_4$ in. × 56 in.

$\frac{56}{9} = 6.22$ in.



$$\bar{y} = \frac{(17.30)(38.26)+(0.375)(7.875)+\left(\frac{56}{9}\right)(7.25)(37.475)}{38.26+7.875+\left(\frac{56}{9}\right)(7.25)}$$

$\bar{y}$ = 25.81 in. from bottom of section to centroid

$$I_x = 6699+38.26(8.51)^2+(7.875)(25.43)^2 + \frac{\left(\frac{56}{9}\right)(7.25)^3}{12}+\left(\frac{56}{9}\right)(7.25)(11.66)^2$$

I_x = 20893 in.^{4}

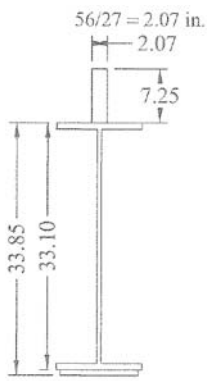
$S_t = \frac{20893}{8.04} = 2599$ in.^{3} Section Modulus at top of steel

$S_b = \frac{20893}{25.81} = 809$ in.^{3} Section Modulus at bottom of steel

Long-Term Composite, 3n:

3n = 3 × 9 = 27

W 33 × 130, PL $^3/_4$ in. × $10^1/_2$ in. and $Conc.$ $7^1/_4$ in. × 56 in.



$$\bar{y} = \frac{(17.30)(38.26)+(0.375)(7.875)+\left(\frac{56}{27}\times 7.25\right)(37.475)}{38.26+7.875+\left(\frac{56}{27}\times 7.25\right)}$$

$\bar{y}$ = 20.08 in. from bottom of section to centroid

$$I_x = 6699+38.26(2.78)^2+(7.875)(19.70)^2 + \frac{\left(\frac{56}{27}\right)(7.25)^3}{12}+\left(\frac{56}{27}\right)(7.25)(17.39)^2$$

I_x = 14664 in.^{4}

$S_t = \frac{14664}{13.77} = 1065$ in.^{3} Section Modulus at top of steel

$S_b = \frac{14664}{20.08} = 730$ in.^{3} Section Modulus at bottom of steel

A1A.2.1.3—Summary of Section Properties at Midspan

1. Steel Section Only

S_{TOP} = 440.8 in.^{3}

S_{BOT} = 594.7 in.^{3}

2. Composite Section—Short Term, n = 9

$S_{TOP\ steel}$ = 2599 in.^{3}

S_{BOT} = 809 in.^{3}

3. Composite Section—Long Term, 3n = 27

$S_{TOP\ steel}$ = 1065 in.^{3}

S_{BOT} = 730 in.^{3}

A1A.2.2—Dead Load Analysis—Exterior Stringer

A1A.2.2.1—Components and Attachments, DC

A1A.2.2.1a—Noncomposite Dead Loads, DC_1

Deck: $\left(1+\frac{7.33}{2}\right)\left(\frac{7.25}{12}\right)(0.150\text{ kip/ft})$ = 0.423 kip/ft

Stringer: (same as interior) = 0.138 kip/ft

Cover Plate: $\frac{0.75\times 10.5}{144\text{ in.}^2/\text{ft}^2}\times 0.490\text{ klf}\times 1.06\times\frac{40\text{ ft}}{65\text{ ft}}$ = 0.017 kip/ft

Diaphragms: $\frac{(3)(0.0427)\left(\frac{7.33}{2}\right)(1.06)}{65\text{ ft}}$ = 0.008 kip/ft

Total per stringer = 0.586 kip/ft

$M_{DC_1} = \frac{(0.586)(65)^2}{8} = 309.5$ kip-ft at midspan

$V_{DC_1} = (0.586)\left(\frac{65}{2}\right) = 19.0$ kips at bearing

A1A.2.2.1b—Composite Dead Loads, DC_2 (same as interior)

$M_{DC_2} = 129$ kip-ft

$V_{DC_2} = 8$ kips

A1A.2.2.2—Wearing Surface

$DW = 0$

A1A.2.3—Live Load Analysis—Exterior Stringer

A1A.2.3.1—Compute Live Load Distribution Factors

A1A.2.3.1a—Distribution Factor for Moment, g_m (LRFD Design Table 4.6.2.2.2d-1)

One Lane Loaded:

Lever Rule

For one lane loaded, the multiple presence factor, $m = 1.20$ LRFD Design Table 3.6.1.1.2-1

For:

$S + d_e = 7.33 \text{ ft} + 0 \text{ ft} < 8 \text{ ft}$ one wheel acting upon the girder

$$g_{m1} = m\left(\frac{S + d - 2 \text{ ft}}{2S}\right) = 1.2\left(\frac{7.33 + 0 - 2}{2(7.33)}\right) = 0.436$$

Two or More Lanes Loaded:

$g_{m2} = eg_{interior}$ $e = 0.77 + \frac{d_e}{9.1} = 0.77$

$g_{m2} = (0.77)(0.626) = 0.482 > 0.436$

A1A.2.3.1b—Distribution Factor for Shear, g_v (LRFD Design Table 4.6.2.2.3b-1)

One Lane Loaded:

Lever Rule

$g_{v1} = g_{m1} = 0.436$

Two or More Lanes Loaded:

$g = eg_{interior}$ $e = 0.6 + \frac{d_e}{10} = 0.6$

$g_{v2} = (0.6)(0.767) = 0.460 > 0.436$

A1A.2.3.1c—Special Analysis for Exterior Girders with Diaphragms or Cross-Frames (LRFD Design 4.6.2.2.2d)

Roadway Layout: two 11-ft wide lanes

LRFD Design Eq. C4.6.2.2.2d-1

$$R = \frac{N_L}{N_b} + \frac{X_{ext} \sum^{N_L} e}{\sum^{N_b} x^2}$$

$g_{special}$ = $(m)\ (R)$

One Lane Loaded:

$$R = \frac{1}{4} + \frac{(11)(6)}{\left[11^2 + 3.67^2 + (-3.67)^2 + (-11)^2\right]} = 0.495$$

$g_{special1}$ = 1.2 (0.495) = 0.595

Two Lanes Loaded:

$$R = \frac{2}{4} + \frac{(11)\left[6 + (-5)\right]}{\left[11^2 + 3.67^2 + (-3.67)^2 + (-11)^2\right]} = 0.541$$

$g_{special2}$ = 1.0 (0.541) = 0.541

A1A.2.3.1d—Summary of Distribution Factors for the Exterior Girders

Moment, g_m

1 Lane	=	0.436	
2 or More Lanes	=	0.482	
Special Analysis (1 Lane)	=	0.595	Governs
Special Analysis (2 Lanes)	=	0.541	
g_m	=	0.595	

Shear, g_v

1 Lane	=	0.436	
2 or More Lanes	=	0.460	
Special Analysis (1 Lane)	=	0.595	Governs
Special Analysis (2 Lanes)	=	0.541	
g_v	=	0.595	

A1A.2.3.2—Compute Maximum Live Load Effects for HL-93

Same as for interior girder

Midspan: M_{LL+IM} = 1521.7 kip-ft

Bearing: V_{LL+IM} = 102.9 kips

A1A.2.3.2a—Distributed Live Load Moments and Shears

Design Live Load HL-93

M_{LL+IM} = 1521.7 × g_m = (1521.7) (0.595)

= 905.4 kip-ft

V_{LL+IM} = 102.9 kips × g_v = (102.9) (0.595)

= 61.2 kips

A1A.2.4—Compute Nominal Resistance of Section at Midspan

Locate PNA:

D = 31.39 in.

t_f = 0.855 in.

t_w = 0.58 in.

b_f = 11.51 in.

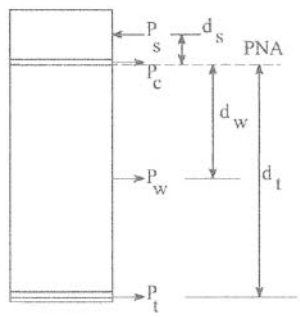
Cov. PL A_p = 7.875 in.^{2}
(PL $^3/_4$ in. × $10^1/_2$ in.)

Treat the bottom flange and the cover plate as one component.

A_t = (11.51) (0.855) + (10.5) (0.75) = 17.72 in.^{2}

$$y = \frac{(11.51)(0.855)\frac{(0.855)}{2}+(10.5)(0.75)\left(0.855+\frac{0.75}{2}\right)}{(11.51)(0.855)+(10.5)(0.75)}$$

= 0.784 in. (from top of tension flange to centroid of flange and cover plate)



Plastic Forces

LRFD Design Article D6.1

Note the forces in longitudinal reinforcement may be conservatively neglected.

Set P_{rb} and $P_{rt} = 0$

$P_s = 0.85f'_c b_{eff} t_s$

$= 0.85\ (3.0)\ (56)\ (7.25)$

$= 1035.3$ kips

$P_c = F_y b_f t_f$

$= (36)\ (11.51)\ (0.855)$

$= 354.3$ kips

$P_w = F_y D t_w$

$= (36)\ (31.39)\ (0.58)$

$= 655.4$ kips

$P_t = F_y\ (b_f t_f + A_p)$

$= 36\ (11.51 \times 0.855 + 7.875)$

$= 637.8$ kips

$P_t + P_w < P_c + P_s + P_{rb} + P_{rt}$ $\therefore$ Conditions for Case I are not met

$P_t + P_w + P_c \geq P_s + P_{rb} + P_{rt}$ $\therefore$ The PNA lies in the top flange

LRFD Design Table D6.1-1

$$\overline{Y} = \left(\frac{t_c}{2}\right)\left(\frac{P_w + P_t - P_s}{P_c} + 1\right) = \left(\frac{0.855}{2}\right)\left(\frac{655.4 + 637.8 - 1035.3}{354.3} + 1\right)$$

$= 0.739$ in. from top of flange

A1A.2.4.1—Classify Section

Following the I-Sections in Flexure Flowchart (section is considered to be constant depth).

LRFD Design Figure C6.4.5-1

A1A.2.4.1a—Check Web Slenderness

Since PNA is in the top flange, the web slenderness requirement is automatically satisfied.

For composite sections in positive bending, the remaining stability criteria are automatically satisfied. The section is compact.

A1A.2.4.1b—Check Ductility (LRFD Design 6.10.7.1.2)

$D_p = t_s + \overline{Y} = 7.25 + 0.739$

$= 7.99$ in.

$D_t = 33.85 + 7.25 = 41.1$ in.

If $D_p \leq 0.1 D_t$, then $M_n = M_p$

LRFD Design Eq. 6.10.7.1.2-1

Otherwise, $M_n = M_p \left(1.07 - 0.7\dfrac{D_p}{D_t}\right)$

$0.1D_t = 0.1 \times 41.1 = 4.11\text{in.}$ LRFD Design Eq. 6.10.7.1.2-2

$7.99\text{in.} \not\leq 4.11\text{in.}$ therefore calculate $M_n < M_p$

A1A.2.4.2—Plastic Moment, M_p

Moment arms about the PNA.

Slab:

$$d_s = \frac{t_s}{2} + \overline{Y}$$

$$= \frac{7.25}{2} + 0.739$$

$$= 4.36 \text{ in.}$$

Web:

$$d_w = \frac{D}{2} + t - \overline{Y}$$

$$= \frac{31.39}{2} + 0.855 - 0.739$$

$$= 15.81 \text{ in.}$$

Tension Flange:

$$d_t = t_c - \overline{Y} + D + 0.784$$

$$= 0.855 - 0.739 + 31.39 + 0.784$$

$$= 32.29 \text{ in.}$$

LRFD Design Table D6.1-1

$$M_p = \frac{P_c}{2t_c}\left[\left(\overline{Y}\right)^2 + \left(t_c - \overline{Y}\right)^2\right] + P_s d_s + P_{rt} d_{rt} + P_{rb} d_{rb} + P_w d_w + P_t d_t$$

$$= \left\{\begin{array}{l} \frac{354.3}{2(0.855)}\left[(0.739)^2 + (0.855 - 0.739)^2\right] \\ +(1035.3)(4.36) + 0 + 0 + (655.4)(15.81) + (637.8)(32.29) \end{array}\right\}$$

$$= 35586 \text{ kip-in.} = 2965\text{kip-ft}$$

A1A.2.4.3—Nominal Flexural Resistance, M_n (LRFD Design 6.10.7.1.2)

$D_p \not\leq 0.1D_t$ LRFD Design Eq. 6.10.7.1.2-1

Therefore, $M_n = M_p(1.07 - 0.7\frac{D_p}{D_t})$ LRFD Design Eq. 6.10.7.1.2-2

$= 2965(1.07 - 0.7 \times 0.194)$

$= 2770.0$ kip-ft

A1A.2.4.4—Nominal Shear Resistance, V_n

Classification and Resistance same as for interior.

V_n = 360.3 kips

A1A.2.4.5—Summary for Exterior Stringer

	Dead Load DC_1	Dead Load DC_2	LiveLoad Distribution Factor	Dist. Live Load + Impact	Nominal Capacity
Moment kip-ft	309.5	129.0	gm = 0.595	905.4	2770.0
Shear kips	19.0	8.0	gm = 0.595	61.2	360.3

A1A.2.5—General Load-Rating Equation

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_{LL})(LL + IM)}$$ Eq. 6A.4.2.1-1

A1A.2.6—Evaluation Factors (for Strength Limit State)

1. Resistance Factor, φ LRFD Design 6.5.4.2
   φ = 1.0 for flexure and shear

Condition Factor, φ_c 6A.4.2.3

Member is in good condition. NBI Item 59 = 7.

φ_c = 1.0

System Factor, φ_s 6A.4.2.4

φ_s = 1.0 Multi-girder bridge.

A1A.2.7—Design Load Rating (6A.4.3)

A1A.2.7.1—Strength I Limit State (6A.6.4.1)

$$RF = \frac{(\varphi_c)(\varphi_s)(\varphi)R_n - (\gamma_{DC})(DC) - (\gamma_{DW})(DW)}{(\gamma_{LL})(LL + IM)}$$

A1A.2.7.1a—Inventory Level

Table 6A.4.2.2-1

Load	Load Factor γ
DC	1.25
LL	1.75

Flexure:

$$RF = \frac{(1.0)(1.0)(1.0)(2770) - (1.25)(309.5 + 129)}{(1.75)(905.4)}$$

= 1.40

Shear:

$$RF = \frac{(1.0)(1.0)(1.0)(360.3) - (1.25)(19 + 8)}{(1.75)(61.2)}$$

= 3.05

A1A.2.7.1b—Operating Level

Table 6A.4.2.2-1

Load	Load Factor γ
DC	1.25
LL	1.35

For Strength I Operating Level, only the live load factor changes; therefore the rating factor can be calculated by direct proportions.

Flexure:

$$RF = 1.40 \times \frac{1.75}{1.35}$$

$$= 1.81$$

Shear:

$$RF = 3.05 \times \frac{1.75}{1.35}$$

$$= 3.95$$

A1A.2.7.2—Service II Limit State (6A.6.4.1)

For Service Limit States, Capacity C = f_R

$$RF = \frac{f_R - (\gamma_D)(f_D)}{(\gamma_L)(f_{LL+IM})}$$

A1A.2.7.2a—Inventory Level

Allowable Flange Stress for tension flange:

$f_R = 0.95 R_h F_{yf}$ ($f_\ell = 0$) LRFD Design Eq. 6.10.4.2.2-2

Checking the tension flange as a compression flange typically does not govern for composite sections.

R_h = 1.0 for non-hybrid sections LRFD Design 6.10.1.10.1

f_R = 0.95 × 1.0 × 36

= 34.2 ksi

$f_D = f_{DC_1} + f_{DC_2}$

$$f_D = \frac{(309.5)(12)}{594.7} + \frac{(129)(12)}{730}$$

= 6.24 + 2.12 = 8.36 ksi

$$f_{LL+IM} = \frac{(905.4)(12)}{809} = 13.43 \text{ ksi}$$

γ_{LL} = 1.30 γ_{DC} = 1.0 Table 6A.4.2.2-1

$$RF = \frac{34.2-(1.0)(8.36)}{1.3(13.43)}$$

$$= 1.48$$

A1A.2.7.2b—Operating Level

γ_{LL} = 1.0 γ_{DC} = 1.0 Table 6A.4.2.2-1

$$RF = \frac{34.2-(1.0)(8.36)}{1.0(13.43)}$$

$$= 1.92$$

A1A.2.7.3—Fatigue Limit State

The calculations are not shown. See the calculations for interior stringers.

A1A.2.8—Legal Load Rating (6A.6.4.2)

Note: The design load check produced a rating factor greater than 1.0 for the Inventory Design Load Rating. This indicates that the bridge has adequate load capacity to carry all legal loads and need not be subject to load ratings for legal loads. The load rating computations that follow have been done for illustrative purposes. Shear ratings have not been illustrated.

Live Load: AASHTO Legal Loads—Types 3, 3S2, and 3-3 (Rate for all three) Appendix D6A

g_m = 0.595
IM = 20% Table C6A.4.4.3-1

The standard dynamic load allowance of 33 percent is decreased based on a field evaluation certifying that the approach and bridge riding surfaces have only minor surface deviations or depressions.

	Type 3	Type 3S2	Type 3-3	
M_{LL}	660.7	707.2	644.7	kip-ft
gM_{LL+IM}	471.7	504.9	460.3	kip-ft

Live Load: AASHTO Leagal Loads—Specialized Hauling Units and Notional Rating Load —SU4, SU5, SU6, SU7, and NRL

Interpolating to determine M_{LL} without impact for 65 ft span Table E6A-2

	SU4	SU5	SU6	SU7	NRL	
M_{LL}	744.7	821.2	913.5	994.1	1037.0	kip-ft
gM_{LL+IM}	531.7	586.3	652.2	709.8	740.4	kip-ft

A1A.2.8.1—Strength I Limit State (6A.6.4.2.1)

Dead load and capacity remain the same

For Types 3, 3S2, and 3-3

Dead Load *DC*: γ_{DC} = 1.25 Table 6A.4.2.2-1

$ADTT$ = 1000

Generalized Live-Load Factor for Legal Loads:

γ_{LL} = 1.30 Table 6A.4.4.2.3a-1

Flexure:

$$RF = \frac{(1.0)(1.0)(1.0)(2770)-(1.25)(309.5+129)}{(1.30)(M_{LL+IM})}$$

	Type 3	Type 3S2	Type 3-3
RF	3.62	3.39	3.71

For Specialized Hauling Units and NRL

Dead Load *DC*: γ_{DC} = 1.25 Table 6A.4.2.2-1

ADTT = 1000 Assumed

Generalized Live-Load Factor for Legal Loads γ_{LL} = 1.30 Table 6A.4.4.2.3b-1

Flexure: $RF = \frac{(1.0)(1.0)(1.0)(2770)-(1.25)(309.5+129)}{(1.30)(M_{LL+IM})}$

	SU4	SU5	SU6	SU7	NRL
RF	3.21	2.92	2.62	2.41	2.31

A1A.2.8.2—Service II Limit State (6A.6.4.2.2)

For Types 3, 3S2, and 3-3, and for Specialized Hauling Units and NRL

γ_{LL} = 1.3 γ_{DC} = 1.0 Table 6A.4.2.2-1

f_R = 34.2 ksi

f_D = 8.36 ksi

$$f_{LL+IM} = \frac{M_{LL+IM} \times 12}{809}$$

Service II: $RF = \frac{34.2-(1.0)(8.36)}{(1.3)(f_{LL+IM})}$

	Type 3	Type 3S2	Type 3-3	
f_{LL+IM}	7.00	7.49	6.82	ksi
RF	2.84	2.65	2.91	

	SU4	SU5	SU6	SU7	NRL	
f_{LL+IM}	7.89	8.70	9.67	10.53	10.98	ksi
RF	2.52	2.29	2.05	1.89	1.81	

No posting is required as for all legal loads, *RF* > 1.0.

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A1A.2.8.3—Summary (6A.4.4.4)

Safe Load Capacity (tons), $RT = RF \times W$ Eq. 6A.4.4.4-1

Truck	Type 3	Type 3S2	Type 3-3
Weight (tons)	25	36	40
RF (Service II Controlling)	2.84	2.65	2.91
Safe Load Capacity (tons)	71	95	116

Truck	SU4	SU5	SU6	SU7	NRL
Weight (tons)	27	31	34.8	38.8	40
RF (Service II Controlling)	2.52	2.29	2.05	1.89	1.81
Safe Load Capacity (tons)	68	70	71	73	72

A1A.2.9—Permit Load Rating (6A.6.4.2)

Permit Type: Special (Single-Trip, Escorted)

Permit Weight: 220 kips

Permit Vehicle: Shown in Figure A1A.1.10-1.

ADDT: 1000

From Live-Load Analysis by Computer Program:

Undistributed Maximum:

M_{LL} = 2127.9 kip-ft

V_{LL} = 143.5 kips

A1A.2.9.1—Strength II Limit State (6A.6.4.2.1)

Dead load and capacity remain the same as that calculated for the design load rating

γ_{LL} = 1.15 Table 6A.4.5.4.2a-1

γ_{DC} = 1.25

Use the One-Lane Loaded Distribution Factor and divide out the 1.2 multiple presence factor. 6A.4.5.4.2b

$g_{special1}$ = 0.595 (Special method for rigid torsional behavior governs.) LRFD Design 4.6.2.2.2d

g_{m1} = $g_{v1} = \dfrac{g_{special1}}{1.2} = 0.496$

Distributed Live-Load Effects:

IM = 20% (no speed control, minor surface deviations)

M_{LL+IM} = (2127.9) (0.496) (1.2)

= 1266.5 kip-ft

V_{LL+IM} = (143.5) (0.496) (1.2)

= 85.4 kips

Flexure: $RF = \dfrac{(1.0)(1.0)(1.0)(2770)-(1.25)(309.5+129)}{(1.15)(1266.5)}$

$= 1.53 > 1.0$ OK

Shear: $RF = \dfrac{(1.0)(1.0)(1.0)(360.3)-(1.25)(19+8)}{(1.15)(85.4)}$

$= 3.33 > 1.0$ OK

A1A.2.9.2—Service II Limit State (Optional)

$$RF = \frac{f_R - \gamma_{DC} f_D}{\gamma_{LL}\left(f_{LL+IM}\right)}$$

IM = 20% (no speed control, minor deviations)

γ_{LL} = 1.0 γ_{DC} = 1.0 Table 6A.4.2.2-1

Dead load and capacity expressed in terms of stresses remain the same as that calculated for the design load rating

f_R = 34.2 ksi

f_D = 8.36 ksi

Live-load effects for the Service II permit rating of an escorted permit are calculated using the same one-lane-loaded procedures as for the Strength II rating. C6A.6.4.2.2

g_{m1} = 0.496

M_{LL+IM} = (2127.9) (0.496) (1.2) = 1266.5 kip-ft

= 15198 kip-in.

$$f_{LL+IM} = \frac{M_{LL+IM}}{S_b} = \frac{15192}{809} = 18.8 \text{ ksi}$$

$$RF = \frac{34.2-(1.0)8.36}{1.0(18.8)} = 1.37 > 1.0 \quad \text{OK}$$

A1A.3—Summary of Rating Factors for Load and Resistance Factor Rating Method

Table A1A.3-1—Summary of Rating Factors for Load and Resistance Factor Rating Method—Interior Stringer

Limit State		Design Load Rating		Legal Load Rating								Permit Load Rating
		Inventory	Operating	Type 3	Type 3S2	Type 3-3	SU4	SU5	SU6	SU7	NRL	
Strength I	Flexure	1.29	1.67	3.35	3.13	3.44	2.97	2.70	2.42	2.23	2.14	—
	Shear	2.29	2.97	—	—	—	—	—	—	—	—	—
Strength II	Flexure	—	—	—	—	—	—	—	—	—	—	1.92
	Shear	—	—	—	—	—	—	—	—	—	—	2.94
Service II		1.21	1.57	2.33	2.17	2.38	2.06	1.87	1.68	1.55	1.48	1.53
Fatigue		0.38	—	—	—	—	—	—	—	—	—	—

Table A1A.3-2—Summary of Rating Factors for Load and Resistance Factor Rating Method—Exterior Stringer

Limit State		Design Load Rating		Legal Load Rating								Permit Load Rating
		Inventory	Operating	Type 3	Type 3S2	Type 3-3	SU4	SU5	SU6	SU7	NRL	
Strength I	Flexure	1.40	1.81	3.62	3.39	3.71	3.21	2.92	2.62	2.41	2.31	—
	Shear	3.05	3.95	—	—	—	—	—	—	—	—	—
Strength II	Flexure	—	—	—	—	—	—	—	—	—	—	1.53
	Shear	—	—	—	—	—	—	—	—	—	—	3.33
Service II		1.48	1.92	2.84	2.65	2.91	2.52	2.29	2.05	1.89	1.81	1.37

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PART B—ALLOWABLE STRESS AND LOAD FACTOR RATING METHODS

A1B.1—EVALUATION OF AN INTERIOR STRINGER

A1B.1.1—Bridge Data

Refer to Article A1A.1.1 for Simple Span Composite Steel Stringer Bridge Data.

A1B.1.2—Section Properties

In unshored construction, the steel stringer must support its own weight plus the weight of the concrete slab. For the composite section, the concrete is transformed into an equivalent area of steel by dividing the area of the slab by the modular ratio. Live load plus impact stresses are carried by the composite section using a modular ratio of *n*. To account for the effect of creep, superimposed dead load stresses are carried by the composite section using a modular ratio of 3*n* (AASHTO 10.38.1). The as-built section properties are used in this analysis.

A1B.1.2.1—Noncomposite Section Properties

Section properties of rolled shapes are subject to change with changes in rolling practices of the steel industry. Identify steel components from available records, construction date, and field measurements. The section properties for this beam were determined from the *AISC Manual of Steel Construction*, Sixth Edition, printed during the period from July 1963 to March 1967, which is consistent with the "Year Built" date for this bridge.

W 33 × 130 and PL $^5/_8$ in. × $10^1/_2$ in.
t_f = 0.855 in.; b_f = 11.51 in.; t_w = 0.58 in.
A = 38.26 in.^{2}

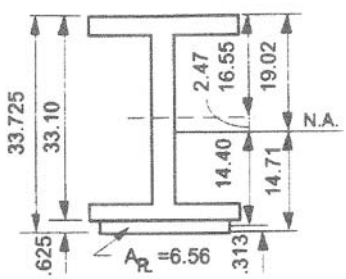

Figure A1B.1.2.1-1 Cross Section—Interior Stringer, Noncomposite

$$\bar{y} = \frac{\overset{W}{(17.175)(38.26)} + \overset{PL}{(0.313)(6.56)}}{38.26 + 6.56}$$

$$\bar{y} = 14.71 \text{ in.}$$

$$I_x = \overset{W}{6699} + \overset{W}{38.26(2.47)^2} + \overset{PL}{6.56(14.40)^2}$$
$$= 8293 \text{ in.}^4$$

$$S_t = \frac{8293}{19.02} = 436.0 \text{ in.}^3 = S_t^{DL}$$

$$S_b = \frac{8293}{14.71} = 563.7 \text{ in.}^3 = S_b^{DL}$$

A1B.1.2.2—Composite Section Properties

Effective Flange Width AASHTO 10.38.3.1

$^1/_4$ (65)(12)	=	195 in.	
(7.33)(12)	=	88 in.	
(7.25)(12)	=	87 in.	⇐ Controls

Modular Ratio *n* 6B.6.2.4

for $f_c' = 3,000$ psi – $n = 10$

Composite *n* = *n*: *W* 33 × 130, *PL* $^5/_8$ in. × 10$^1/_2$ in. and *Conc.* 7$^1/_4$ in. × 87 in.

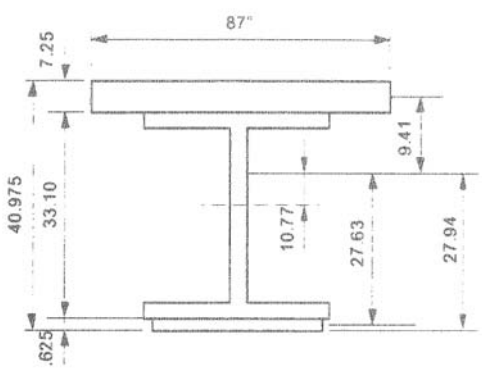

Figure A1B.1.2.2-1—Cross Section—Interior Stringer, Composite *n* = *n*

$$\bar{y} = \frac{\overset{W}{(17.175)(38.26)} + \overset{PL}{(0.313)(6.56)} + \overset{Conc.}{(87 \times 7.25 \div 10)(37.35)}}{38.26 + 6.56 + (87 \times 7.25) \div 10}$$

$\bar{y} = 27.94$ in.

$$I_x = \overset{W}{6699} + \overset{W}{(38.26)(10.77)^2} + \overset{PL}{(6.56)(27.63)^2} + \overset{Conc.}{\frac{(87 \div 10)(7.25)^3}{12}} + \overset{Conc.}{(87 \times 7.25) \div 10(9.41)^2}$$

$= 22007$ in.^{4}

Note: I_x for the bottom cover plate is negligible, however, its Ad^2 term makes a significant contribution.

$$S_t = \frac{22007}{5.79} = 3801 \text{ in.}^3 \text{ Section modulus at top of steel}$$

$$S_b = \frac{22007}{27.94} = 787.7 \text{ in.}^3 = S_b^L$$

Use with Live Load.

Composite $n = 3n$: W 33 × 130, PL $^5/_8$ in. × $10^1/_2$ in. and $Conc.$ $7^1/_4$ in. × 87 in.

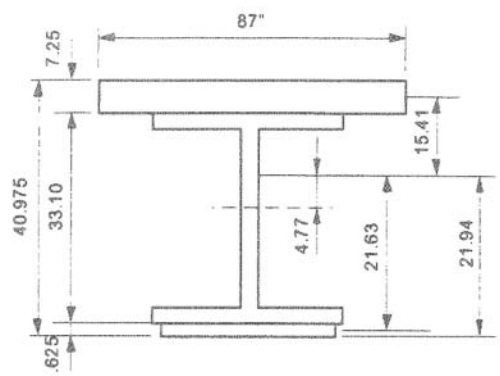

Figure A1B.1.2.2-2—Cross Section—Interior Stringer, Composite *n* = 3*n*

$$\bar{y} = \frac{\overset{W}{(17.175)(38.26)} + \overset{PL}{(0.313)(6.56)} + \overset{Conc.}{(87 \times 7.25 \div 30)(37.35)}}{38.26 + 6.56 + (87 \times 7.25) \div 30}$$

$\bar{y} = 21.94$ in.

$$I_x = \overset{W}{6699} + \overset{W}{(38.26)(4.77)^2} + \overset{PL}{(6.56)(21.63)^2} + \overset{Conc.}{\frac{(87 \div 30)(7.25)^3}{12} + \left(\frac{87 \times 7.25}{30}\right)(15.41)^2}$$

$I_x = 15725$ in.^{4}

$S_t = \frac{15725}{11.79} = 1333.8$ in.^{3} (Section modulus at top of steel)

$$S_b = \frac{15725}{21.94} = 716.7 \text{ in.}^3 = S_b^{SDL}$$

Use with Superimposed Dead Load (*SDL*).

A1B.1.3—Dead Load Analysis—Interior Stringer

A1B.1.3.1—Dead Loads (Includes an Allowance of Six Percent of Steel Weight for Connections)

Deck $(7.33)\left(\frac{7.25}{12}\right)(150 \text{ pcf})$	=	664.3 lb/ft
Stringer $(130)(1.06)$	=	137.8 lb/ft

Cover *PL* $(0.625)(10.5)(490 \div 144)(1.06)(38) \div 65$	=	13.8 lb/ft
Diaphragms $(3)(42.7)(7.33)(1.06) \div 65$	=	15.4 lb/ft
Total per stringer	=	831.3 lb/ft

A1B.1.3.2—Superimposed Dead Loads (AASHTO 3.23.2.3.1.1)

Curb $(1)\left(\frac{10}{12}\right)(150 \text{ pcf}) \times \left(\frac{2 \text{ curbs}}{4 \text{ beams}}\right)$	=	62.5 lb/ft
Parapet $\left[\left(\frac{6 \times 19}{144}\right) + \left(\frac{18 \times 12}{144}\right)\right](150 \text{ pcf}) \times \left(\frac{2 \text{ parapets}}{4 \text{ beams}}\right)$	=	171.9 lb/ft
Railing $(\text{assume } 20 \text{ plf}) \times \left(\frac{2 \text{ railings}}{4 \text{ beams}}\right)$	=	10.0 lb/ft
Wearing Surface	=	0.0 lb/ft
Total per stringer	=	244.4 lb/ft

A1B.1.4—Live Load Analysis—Interior Stringer

Live Load: Rate for HS-20

Moments:

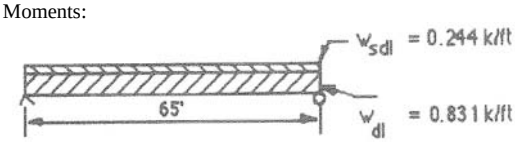

Figure A1B.1.4-1—Load Diagram—Interior Stringer, Dead Load and Superimposed Dead Load

$$M_{DL} = \frac{w_{DL}L^2}{8} = \frac{0.831(65)^2}{8} = 439 \text{ kip-ft}$$

$$M_{SDL} = \frac{w_{SDL}L^2}{8} = \frac{0.244(65)^2}{8} = 129 \text{ kip-ft}$$

M_{LL} Appendix C6B[a]

Span	M_{LL}	
60	403.3	$M_{LL} = \frac{403.3 + 492.8}{2}$
		$\Leftarrow$ 65 ft
70	492.8	$M_{LL} = 448$ kip-ft[b] (without Impact, without Distribution)

a Note the moments given in the MBE are for one line of wheels. The values given in AASHTO are for the entire axle and are therefore twice the MBE value.

b Maximum M_{LL} without impact for 65 ft span, with exact values determined by statics, is 448.02 kip-ft. Nevertheless, judgment should be exercised whether to interpolate tabulated values. The general rule for simple spans carrying moving concentrated loads states that the maximum bending moment produced by moving concentrated loads occurs under one of the loads when that load is as far from one support as the center of gravity of all the moving loads on the beam is from the other support. It should be understood that locating the precise critical section and load position for rating depends on the combined influence of dead load, live load, and member capacity that make up the general Rating Factor equation.

A1B.1.5—Allowable Stress Rating (6B.4.1, 6B.5.2, and 6B.6.2)

Consider Maximum Moment Section only for this example.

A1B.1.5.1—Impact (Use Standard AASHTO) (6B.7.4, AASHTO 3.8.2.1)

$$I = \frac{50}{L+125} \leq 0.3$$

$$I = \frac{50}{65+125} = 0.26$$

A1B.1.5.2—Distribution (Use Standard AASHTO) (6B.7.3, AASHTO 3.23.2.2, and Table 3.23.1)

Thus:

$$DF = \frac{S_s}{5.5} = \frac{7.33 \text{ ft}}{5.5} = 1.33$$

$$M_{LL+I} = M_{LL}\left(1+I\right) \times DF = 448\left(1+0.26\right)\left(1.33\right)$$

$$M_{LL+I} = 751 \text{ kip-ft}$$

A1B.1.5.3—Inventory Level (Bottom Tension Controls) (6B.6.2.1, Table 6B.6.2.1-1)

For steel with $F_y = 36 \text{ ksi} \rightarrow f_I = 0.55 f_y$

Thus:

$$f_I = 0.55\left(36\right) = 20 \text{ ksi}$$

The Resisting Capacity $\left(M_{RI}\right) = f_I S_x^L$

$$M_{RI} = 20 \text{ ksi } \left(787.7 \text{ in.}\right)^3 = 15754 \text{ kip-in.} = 1313 \text{ kip-ft}$$

Then:

$$RF_I = \frac{M_{RI} - M_{DL}\dfrac{S_b^L}{S_b^{DL}} - M_{SDL}\dfrac{S_b^L}{S_b^{SDL}}}{M_{LL+I}}$$

$$= \frac{1313 - 439\dfrac{787.7}{563.7} - 129\dfrac{787.7}{716.7}}{751} = \frac{557.8}{751}$$

$$= \underline{\underline{0.74}} \text{ or } 0.74 \times 36 \text{ tons} = \underline{\underline{26.7 \text{ tons}}}$$

Alternatively, in terms of stress:

$$RF_I = \frac{f_s - \dfrac{M_{DL}}{S_b^{DL}} - \dfrac{M_{SDL}}{S_b^{SDL}}}{\dfrac{M_{LL+I}}{S_b^{LL+I}}}$$

$$= \frac{20 \text{ ksi} - \dfrac{439 \text{ ft-kips} \times 12 \text{ in./ft}}{563.7 \text{ in.}^3} - \dfrac{129 \text{ ft-kips} \times 12 \text{ ft-kips}}{716.7 \text{ in.}^3}}{\dfrac{751 \text{ ft-kips} \times 12 \text{ in./ft}}{787.7 \text{ in.}^3}}$$

$$= \frac{20 - 9.345 - 2.160}{11.441}$$

$$= \frac{8.495}{11.441} = 0.74 \text{ as above}$$

A1B.1.5.4—Operating Level (6B.6.2.1, Table 6B.6.2.1-2)

For steel with $F_y = 36 \text{ ksi} \rightarrow f_O = 0.75 f_y$

Thus:

$$f_O = 0.75(36) = 27 \text{ ksi}$$

and

$$M_{RO} = 27(787.7) = 21268 \text{ kip-in.} = 1772 \text{ kip-ft}$$

and:

$$RF_O = \frac{1772 - 439\dfrac{787.7}{563.7} - 129\dfrac{787.7}{716.7}}{751} = \frac{1016.8}{751}$$

$RF_O = \underline{1.35}$ or 1.35 × 36 tons = <u>48.7 tons</u>

A1B.1.5.5—Summary of Ratings for Allowable Stress Rating Method

Table A1B.1.5.5-1—Summary of Ratings for Allowable Stess Rating Method—Interior Stringer

	RF	Tons
Inventory	0.74	26.7
Operating	1.35	48.7

A1B.1.6—Load Factor Rating (6B.4.2, 6B.5.3, and 6B.6.3)

Consider maximum moment section only for this example. See general notes.

A1B.1.6.1—Impact (Use Standard AASHTO) (6B.7.4)

From Allowable Stress Rating $I = 0.26$

A1B.1.6.2—Distribution (Use Standard AASHTO) (6B.7.3)

From Allowable Stress Rating $DF = 1.33$

$$M_{LL+I} = M_{LL}(1+I)DF = 448(1+0.26)(1.33)$$

$$= 751 \text{ kip-ft (as for AS Rating)}$$

A1B.1.6.3—Capacity of Section, M_R (6B.6.3.1)

For braced, compact, composite sections:

$$M_R = M_u$$ AASHTO 10.50.1.1

where M_u is found in accordance with applicable load factor provisions of AASHTO.

Check assumptions:

1. Section is fully braced along top flange by composite deck (for Live Load and *SDL*).
2. To check if section is compact, need to apply provisions of AASHTO 10.50.1.1.1. These checks follow.

The compressive force in the slab C is equal to the smallest value given by the following equations: AASHTO 10.50.1.1.1(a)

$$C = 0.85 f_c' b t_s + (AF_y)_c$$ AASHTO Eq. 10-123

Neglecting that part of the reinforcement that lies in the compressive zone the equation reduces to:

$$C_{CONC} = 0.85 f_c' b_{eff} t_s = 0.85(3 \text{ ksi})(87 \text{ in.})(7.25 \text{ in.}) = 1608 \text{ kips}^*$$

$$C = (AF_y)_{bf} + (AF_y)_{tf} + (AF_y)_w$$ AASHTO Eq. 10-124

where $(AF_y)_{bf}$ includes cover plate, this equation reduces to:

$$C_{STL} = A_s f_y = (38.26 \text{ in.}^2 + 6.56 \text{ in.}^2)(36 \text{ ksi}) = 1613.5 \text{ kips}$$

$$C_{CONC} < C_{STL} \therefore C_{CONC} = 1608 \text{ controls}$$

Capacity:

$$C' = \frac{\sum(AF_y) - C}{2} = \frac{1613.5 - 1608}{2} = 2.75 \text{ kips}$$ AASHTO Eq. 10-126

$$(AF_y)_{TF} = (11.51 \times 0.855)(36) = 354 \text{ kips} >>> 2.75 \text{ kips} \therefore \text{ NA in top flange}$$ AASHTO 10.50.1.1.1(d)

$$\bar{y} = \frac{C'}{(AF_y)_{TF}} t_{TF} = \frac{2.75}{354}(0.855) = 0.007 \text{ in. neglect. Say NA at top of steel.}$$ AASHTO Eq. 10-127

Since the PNA is at the top of the flange, the depth of the web in compression at the plastic moment, D_{cp}, is equal to zero. Hence, the web slenderness requirement given by Eq. 10-129 in AASHTO Article 10.50.1.1.2 is automatically satisfied.

Check the ductility requirement given by Eq. 10-129a in AASHTO Article 10.50.1.1.2:

$$\left(\frac{D_p}{D'}\right) \le 5$$ AASHTO Eq. 10.129a

$$D' = \beta \frac{(d + t_s + t_h)}{7.5} \qquad \beta = 0.9 \text{ for } F_y = 36{,}000 \text{ psi}$$

$$D' = 0.9\frac{(33.725 + 7.25 + 0.0)}{7.5} = 4.92$$

$D_p = 7.25$ in.

$$\left(\frac{D_p}{D'}\right) = \frac{7.25}{4.92} = 1.47 < 5 \text{ OK}$$

Since the top flange is braced by the hardened concrete deck, local and lateral buckling requirements need not be checked. The capacity of composite beams in simple spans satisfying the preceding web slenderness and ductility requirements is given by Eq. 10-129c in AASHTO 10.50.1.1.2 when D_p exceeds D':

$D' < D_p \leq 5D'$

4.92 in. < 7.25 in. ≤ 5 x 4.92 in . = 24.6 in.

Therefore:

$$C = M_R = M_U = \frac{5M_p - 0.85M_y}{4} + \frac{0.85M_y - M_p}{4}\left(\frac{D_p}{D'}\right) \qquad \text{AASHTO Eq. 10.129c}$$

$$M_y = F_y S = (36)\frac{787.7}{12} = 2363 \text{ kip-ft}$$

Compute the plastic moment capacity M_p

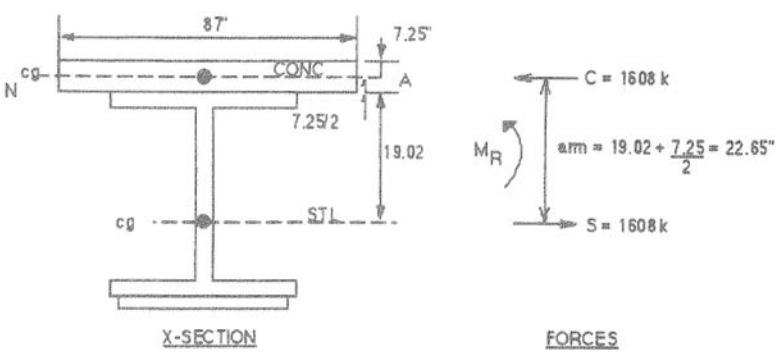

Figure A1B.1.6.3-1—Cross Section—Interior Stringer, for Determining Plastic Moment Capacity M_p

$$M_p = C \times arm = 1608(22.65) = 36421 \text{ kip-in.} = 3035 \text{ kip-ft}$$

$$M_R = \frac{5(3035) - 0.85(2363)}{4} + \frac{0.85(2363) - 3035}{4}(1.47) = 2914 \text{ kip-ft}$$

A1B.1.6.4—Inventory Level (6B.5.1 and 6B.6.3)

$$RF_I^{LF} = \frac{M_R - A_1 M_D}{A_2 M_{L+I}} \qquad \text{Eq. 6B.5.1-1}$$

where: 6B.5.3

$A_1 = 1.3$

$A_2 = 2.17$

Thus:

$$RF_I^{LF} = \frac{(2914) - 1.3(439 + 129)}{2.17(751)}$$

$RF_I^{LF} = \underline{1.33}$ or 1.33 × 36 tons = <u>47.9 tons</u>

A1B.1.6.5—Operating Level (6B.5.3)

Only change is A_2 = 1.3

Thus:

$$RF_O^{LF} = \frac{2.17}{1.3} RF_I^{LF} = \frac{2.17}{1.3}(1.33)$$

$RF_O^{LF} = \underline{2.22}$ or 2.22 × 36 tons = <u>79.9 tons</u>

A1B.1.6.6—Check Serviceability Criteria

For HS loadings overload is defined as $D + 5(L + I)/3$ AASHTO 10.57

A1B.1.6.6a—At Inventory Level (Bottom Steel in Tension Controls)

$f_{DL} + f_{SDL} + 1.67(f_{LL+I}) \leq$ Serv. Strength $= 0.95F_y$ AASHTO 10.57.2

Thus A_1 = 1.0 and A_2 = 1.67 for service rating:

$$RF_I^{LF} = \frac{0.95F_y - (1.0)\, f_{DL} - (1.0)\, f_{SDL}}{(1.67)\, f_{LL+I}}$$

$$= \frac{0.95(36 \text{ ksi}) - \frac{439(12)}{563.7} - \frac{129(12)}{716.7}}{1.67\frac{751(12)}{787.7}}$$

$= RF_I^{LF} =$ <u>1.19</u> or 1.19 × 36 tons = <u>42.8 tons</u>

Check the web compressive stress:

$$C = F_{cr} = \frac{26200000\alpha k}{\left(\frac{D}{t_w}\right)^2} \leq F_{yw}$$ AASHTO Eq. 10-173

where:

$k = 9(D \div D_c)^2$

$\alpha = 1.3$

Since D_c is a function of the dead-to-live load stress ratio according to the provisions of AASHTO 10.50(b), an iterative procedure may be necessary to determine the rating factor:

Compute the compressive stresses at the top of the web:

$$f_{DL} = \frac{439(12)(18.165)}{8293} = 11.5 \text{ ksi}$$

$$f_{SDL} = \frac{129(12)(10.935)}{15725} = 1.1 \text{ ksi}$$

$$f_{LL+I} = \frac{(751)(12)(4.935)}{22007} = 2.02 \text{ ksi}$$

$$\sum = 14.62 \text{ ksi}$$

Compute the tensile stresses at the bottom of the web:

$$f_{DL} = \frac{439(12)(13.23)}{8293} = 8.4 \text{ ksi}$$

$$f_{SDL} = \frac{129(12)(20.46)}{15725} = 2.0 \text{ ksi}$$

$$f_{L+I} = \frac{(751)(12)(26.46)}{22007} = 10.84 \text{ ksi}$$

$$\sum = 21.24 \text{ ksi}$$

$$D_c = 31.39\left(\frac{14.62}{14.62 + 21.24}\right) = 12.80 \text{ in.}$$

$$k = 9(D \div D_c)^2 = 9(31.39 \div 12.80)^2 = 54.1$$

$$C = F_{cr} = \frac{26200000(1.3)(54.1)}{\left(\frac{31.39}{0.58}\right)^2 (1000)} = 629 \text{ ksi} > F_{yw}$$

$$\therefore F_{cr} = F_{yw} = 36 \text{ ksi}$$

$$RF_I^{LF} = \frac{36 - 11.5 - 1.1}{1.67(2.02)} = \underline{6.9} \text{ or } 6.9 \times 36 \text{ tons} = \underline{248.4 \text{ tons}}$$

Since the computed rating factor would cause the total stresses in the tension flange to far exceed F_y (causing the neutral axis to be higher on the web), further iterations are not necessary in this case. The web compressive stress does not govern the serviceability rating.

A1B.1.6.6b—At Operating Level

$$f_D = RF_O^{LF}\left(f_{L+I}\right) \leq \text{ Serv. Strength}$$

Thus A_1 = 1.0 and A_2 = 1.0 for service rating:

$$RF_O^{LF} = RF_I^{LF} \times 1.67 = 1.19 \times 1.67$$

RF_O^{LF} = <u>1.98</u> or 1.98 × 36 tons = <u>71.3 tons</u>

A1B.1.6.7—Summary of Ratings for Load Factor Rating Method

Table A1B.1.6.7-1—Summary of Ratings for Load Factor Rating Method—Interior Stringer

	RF	Tons	Controlled
Inventory	1.19	42.8	AASHTO 10.57.2
Operating	1.98	71.3	AASHTO 10.57.2

A1B.1.7—Load Factor Rating—Rate for Single-Unit Formula B Loads

M_{LL+I} from Appendix C6B:

Span	HS-20	NRL	SU4	SU5	SU6	SU7	
60 ft	512.2	595.1	430.2	472.5	525.0	569.9	kip-ft
70 ft	619.2	714.2	510.2	564.4	628.3	685.4	kip-ft

By interpolation:

65 ft	565.7	654.7	470.2	518.5	576.7	627.7	kip-ft

Apply distribution factor DF = 1.33

65 ft	751.0	870.8	625.4	689.6	767.0	834.8	kip-ft

Capacity of Section M_R = 2914 kip-ft

Dead Load M_{DL} = 439 kip-ft

Superimposed Dead Loads M_{SDL} = 129 kip-ft

$$\text{Inv. } RF = \frac{2914 - 1.3(439 + 129)}{2.17(M_{L+I})}$$

$$\text{Opr. } RF = \frac{2914 - 1.3(439 + 129)}{1.3(M_{L+I})}$$

Strength Rating Factors:

	HS-20	NRL	SU4	SU5	SU6	SU7
Inventory	1.33	1.15	1.60	1.45	1.31	1.20
Operating	2.22	1.92	2.67	2.42	2.19	2.00

Check Serviceability Criteria:

$$RF = \frac{0.95F_y - f_{DL} - f_{SDL}}{1.67\, f_{LL+I}}$$

$$RF = \frac{34.2 - 9.35 - 2.16}{1.67\left(M_L + I \times 12 \times 1.0 / 787.7\right)}$$

Serviceability Rating Factors (Controls):

HS-20	NRL	SU4	SU5	SU6	SU7
1.19	1.03	1.43	1.29	1.16	1.07

As the Notional Rating Load NRL *RF* > 1.0 for strength and serviceability, the bridge has adequate capacity for all legal loads, including the single-unit Formula B trucks.

PART C—SUMMARY

A1C.1—Summary of All Ratings for Example A1

Table A1C.1-1—Summary of Rating Factors for All Rating Methods—Interior Stringer

			Design Load Rating (HL-93)		Legal Load Rating								Permit Load Rating	HS-20 Rating	
			Inventory	Operating	Type 3	Type 3S2	Type 3-3	SU4	SU5	SU6	SU7	NRL		Inventory	Operating
LRFR Method Limit State	Strength I	Flexure	1.29	1.67	3.35	3.13	3.44	2.97	2.70	2.42	2.23	2.14	—		
		Shear	2.29	2.97	—	—	—	—	—	—	—	—	—	—	—
	Strength II	Flexure	—	—	—	—	—	—	—	—	—	—	1.92	—	—
		Shear	—	—	—	—	—	—	—	—	—	—	2.94	—	—
	Service II		1.21	1.57	2.33	2.17	2.38	2.06	1.87	1.68	1.55	1.48	1.53	—	—
	Fatigue		0.38	—	—	—	—	—	—	—	—	—	—	—	—
Allowable Stress Method			—	—	—	—	—	—	—	—	—	—	—	0.74	1.35
Load Factor Method	Strength		—	—	—	—	—	1.60	1.45	1.31	1.20	1.15	—	1.33	2.22
	Serviceability		—	—	—	—	—	1.43	1.29	1.16	1.07	1.03	—	1.19	1.98

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Deleted: 2.07
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Table A1C.1-2—Summary of Rating Factors for Load and Resistance Factor Rating Method—Exterior Stringer

Limit State		Design Load Rating		Legal Load Rating								Permit Load Rating
		Inventory	Operating	Type 3	Type 3S2	Type 3-3	SU4	SU5	SU6	SU7	NRL	
Strength I	Flexure	1.40	1.81	3.62	3.39	3.71	3.21	2.92	2.62	2.41	2.31	—
	Shear	3.05	3.95	—	—	—	—	—	—	—	—	—
Strength II	Flexure	—	—	—	—	—	—	—	—	—	—	1.53
	Shear	—	—	—	—	—	—	—	—	—	—	3.33
Service II		1.48	1.92	2.84	2.65	2.91	2.52	2.29	2.05	1.89	1.81	1.37

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Deleted: 2.58
Deleted: 2.32
Deleted: 2.13
Deleted: 2.05

A1C.2—References

AASHTO. 2002. *Standard Specification for Highway Bridges*, 17th Edition, HB-17. American Association of State Highway and Transportation Officials, Washington, DC.

AASHTO. 2007. *AASHTO LRFD Bridge Design Specifications*, Fourth Edition, LRFDUS-4-M or LRFDSI-4. American Association of State Highway and Transportation Officials, Washington, DC.

NCHRP. 2007. *Legal Truck Loads and AASHTO Legal Loads for Posting*. Transportation Research Board, National Research Council, Washington, DC.

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A2—REINFORCED CONCRETE T-BEAM BRIDGE: EVALUATION OF AN INTERIOR BEAM

PART A—LOAD AND RESISTANCE FACTOR RATING METHOD

A2A.1—Bridge Data

Span:	26 ft
Year Built	1925
Materials:	
Concrete:	f'_c = 3 ksi
Reinforcing Steel:	Unknown f_y
Condition:	Minor deterioration has been observed, but no section loss.
	NBI Item 59 = 6
	Shear distress has not been observed.
Riding Surface:	Field verified and documented: Smooth approach and deck
ADTT (one direction):	1850
Skew:	0°

A2A.2—Dead-Load Analysis—Interior Beam

Permanent loads on the deck are distributed uniformly among the beams. LRFD Design 4.6.2.2.1

A2A.2.1—Components and Attachments, *DC*

Structural Concrete:

Consisting of deck + stem + haunches (conservatively, $2^1/_2$-in. chamfers were not deducted)

$$\left[\frac{6\text{ in.}}{12}\times 6.52\text{ ft}+1.25\text{ ft}\times 2\text{ ft}+2\left(\frac{1}{2}\times\frac{6\text{ in.}}{12}\times\frac{6\text{ in.}}{12}\right)\right]\times(0.150\text{ kcf})$$

$$= 0.902\text{ kip/ft}$$

Railing and curb $0.200\text{ kip/ft}\times\frac{1}{2}$ = 0.100 kip/ft

Total per beam, *DC* = 1.002 kip/ft

$$M_{DC} = \frac{1}{8}\times 1.002\times 26^2 = 84.7\text{ kip-ft}$$

$$V_{DCmax} = 1.002(0.5\times 26) = 13.0\text{ kips}$$

A2A.2.2—Wearing Surface, *DW*

Thickness was field measured: 6A.2.2.3

Asphalt Overlay:

$$\left(\frac{5\text{ in.}}{12}\right)(22\text{ ft})(0.144\text{ kcf})\left(\frac{1}{4}\right) = 0.330\text{ kip/ft}$$

$$M_{DW} = \frac{1}{8}\times 0.330\times 26^2 = 27.9\text{ kip-ft}$$

$$V_{DWmax} = 0.33(0.5\times 26) = 4.3\text{ kips}$$

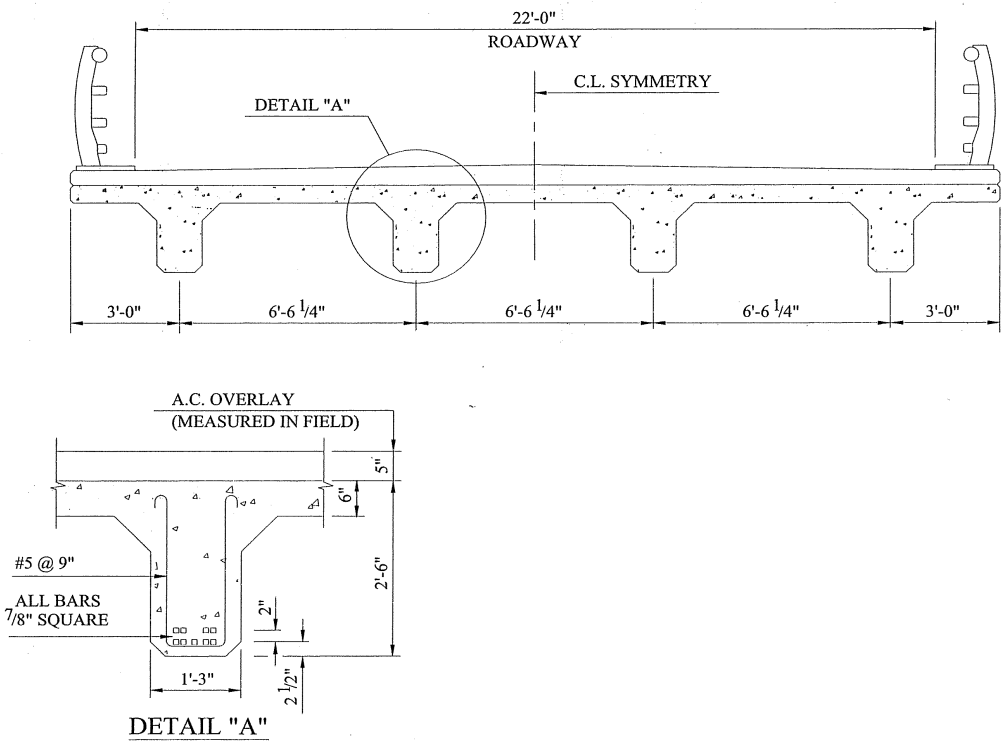

Figure A2A.2.2-1—Reinforced Concrete T-Beam Bridge

A2A.3—Live-Load Analysis—Interior Beam

A2A.3.1—Compute Live-Load Distribution Factor

AASHTO LRFD Type (e) cross section — LRFD Design Table 4.6.2.2.1-1

Longitudinal Stiffness Parameter, K_g

$K_g = n\left(I + Ae_g^2\right)$ — LRFD Design Eq. 4.6.2.2.1-1

$n = 1.0$

$I = \frac{1}{12} \times 15 \times 24^3 = 17280 \text{ in.}^4$

$A = 15 \times 24 = 360 \text{ in.}^2$

$e_g = \frac{1}{2}(24+6) = 15 \text{ in.}$

$K_g = 1.0\ (17280 + 360 \times 15^2)$

$= 98280 \text{ in.}^4$

$$\frac{K_g}{12Lt_s^3} = \frac{98280}{12 \times 26 \times 6^3} = 1.46$$

A2A.3.1.1—Distribution Factor for Moment, g_m (LRFD Design Table 4.6.2.2.2b-1)

One Lane Loaded:

$$g_{m1} = 0.06 + \left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12Lt_s^3}\right)^{0.1}$$

$$= 0.06 + \left(\frac{6.52}{14}\right)^{0.4}\left(\frac{6.52}{26}\right)^{0.3}(1.46)^{0.1}$$

$= 0.565$

Two or More Lanes Loaded:

$$g_{m2} = 0.075 + \left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12Lt_s^3}\right)^{0.1}$$

$$= 0.075 + \left(\frac{6.52}{9.5}\right)^{0.6}\left(\frac{6.52}{26}\right)^{0.2}(1.46)^{0.1}$$

$= 0.703 > 0.565$

$\therefore$ use $g_m = 0.703$

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A2A.3.2—Compute Maximum Live Load Effects

A2A.3.2.1—Maximum Design Live Load (HL-93) Moment at Midspan

Design Lane Load Moment = 54.1 kip-ft

Design Truck Moment = 208.0 kip-ft

Tandem Axles Moment = 275.0 kip-ft Governs

IM = 33% LRFD Design Table 3.6.2.1-1

M_{LL+IM} = 54.1 + 275.0 × 1.33

= 419.9 kip-ft

A2A.3.2.2—Maximum Design Live Load Shear (HL-93) at Critical Section

See Article A2A.7.

A2A.3.2.3—Distributed Live Load Moments

Design Live Load HL-93:

M_{LL+IM} = 419.9 × 0.703

= 295.2 kip-ft

A2A.4—Compute Nominal Flexural Resistance

A2A.4.1—Compute Effective Flange Width, b_e (LRFD Design 4.6.2.6.1)

Effective Flange Width Minimum of:

i. $\frac{1}{4}(L)$

ii. $12.0t_s$ + greater of: t_w or $\frac{1}{2}b_{f\ top}$

iii. S

i. $\frac{1}{4} \times 26$ = 6.5 ft = 78 in. Governs

ii. $12t_s$ + Web Thickness = (12 × 6 + 15) = 87 in.

iii. Average Spacing of Beams = 6 × 12 + 6.25 = 78.25 in.

∴ use b_e = 78 in.

A2A.4.2—Compute Distance to Neutral Axis, c LRFD Design 5.7.3.1.1

Assume rectangular section behavior.

β_1 = 0.85 for f'_c = 3000 psi LRFD Design 5.7.2.2

$$c = \frac{A_s f_y}{0.85 f'_c \beta_1 b}$$ LRFD Design Eq. 5.7.3.1.1-4

A_s = $9\left(\frac{7}{8}\right)^2$ = 6.89 in.^{2} (nine $^7/_8$-in.^{2} bars)

b = 78 in.

f_y = 33 ksi (unknown steel) Table 6A.5.2.2-1

$c = \dfrac{6.89 \times 33}{0.85 \times 3.0 \times 0.85 \times 78}$

$= 1.34 \text{ in.} < 6 \text{ in.}$

The neutral axis is within the slab. Therefore, there will be rectangular section behavior.

$a = c\beta$

$= 1.34 \times 0.85$

$= 1.14 \text{ in.}$

Distance from bottom of section to *CG* of reinforcement, $\bar{y}$

$\bar{y} = \dfrac{4 \times 4.5 + 5 \times 2.5}{9}$

$\bar{y} = 3.39 \text{ in.}$

$d_s = h - \bar{y}$

$h = 30 \text{ in.}$

$d_s = 30 \text{ in.} - 3.39 \text{ in.}$

$= 26.61 \text{ in.}$

$M_n = A_s f_y \left(d_s - \dfrac{a}{2} \right)$ LRFD Design 5.7.3.2.3, LRFD Design Eq. 5.7.3.2.2-1

$= 6.89 \times 33 \left(26.61 - \dfrac{1.14}{2} \right) \dfrac{1}{12}$

$= 493.4 \text{ kip-ft}$

A2A.5—Minimum Reinforcement (6A.5.7)

The amount of reinforcement must be sufficient to develop M_r equal to the lesser of: LRFD Design 5.7.3.3.2

$1.2M_{cr}$ or $1.33M_u$

$M_r = \varphi_f M_n = 0.90 \times 493.4 \text{ kip-ft}$

$= 444.1 \text{ kip-ft}$

1. $1.33M_u = 1.33\,(1.75 \times 295.2 + 1.25 \times 84.7 + 1.25 \times 27.9)$

$= 874.3 \text{ kip-ft} > 444.1 \text{ kip-ft}$ No Good

2. $1.2M_{cr} = 1.2\left(f_r + f_{pb} \right) S_{bc} - M_{d,nc} \left(\dfrac{S_{bc}}{S_b} - 1 \right)$ LRFD Design Eq. 5.7.3.3.2-1

$M_{dnc} = 0$ Total unfactored dead load moment acting on the monolithic or noncomposite section

$f_{cpe} = 0$ Compressive stress in concrete due to effective prestress forces only at extreme fiber of section where tensile stress is caused by externally applied loads

$S_{nc} = \dfrac{I}{y_t}$ Uncracked section modulus (neglect steel)

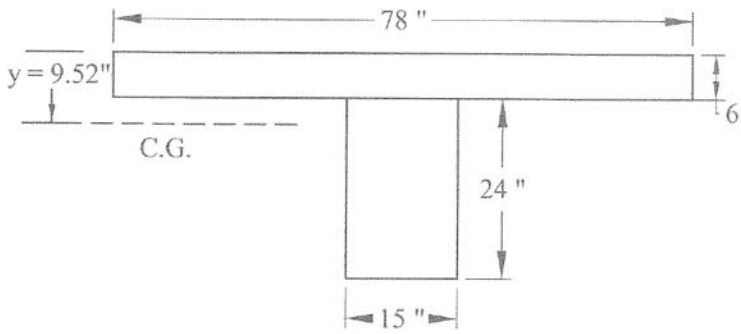

Figure A2A.5-1 Cross Section of Concete T-Beam—Depth to Centroid of Uncracked Section

$$y = \frac{\sum(A_i \times y_i)}{\sum A_i}$$

$$y = \frac{(78\times6\times3)+(24\times15\times18)}{(78\times6)+(24\times15)} = 9.52 \text{ in.}$$

from top of slab to centroid of uncracked section

$$I = \sum\left(I_o + A_c d^2\right) \qquad \text{where } I_0 = bh^3/12$$

	y	A_c	$A_c y$	d	Ad^2	I_0
slab	3	468	1404	6.52	19895	1404
stem	18	360	6480	8.48	25888	17280
		828	7884		45783	18684

$$I = (18684 + 45783) = 64467$$

$$y_b = 30 \text{ in.} - 9.52 \text{ in.} = 20.48 \text{ in.}$$

$$S_{bc} = \frac{64467}{20.48} = 3148 \text{ in.}^3$$

$$f_r = 0.37\sqrt{f'_c} = 0.37\sqrt{3.0} = 0.641\text{ksi}$$

$$M_{cr} = 0.641\times 3148 = 2017.9 \text{ kip-in.} = 168 \text{ kip-ft}$$ LRFD Design 5.4.2.6

$$1.2M_{cr} = 1.2 \times 168 = 201.6 \text{ kip-ft}$$

$$M_r = 444.1 \text{ kip-ft} > 1.2\, M_{cr} = 201.6 \text{ kip-ft} \quad \text{OK}$$

The section meets the requirements for minimum reinforcement.

A2A.6—Maximum Reinforcement (6A.5.6)

$$\frac{c}{d_e} \le 0.42$$

The factored resistance (φ factor) of compression controlled sections shall be reduced in accordance with LRFD Design Article 5.5.4.2.1. This approach limits the capacity of over-reinforced (compression controlled) sections. C6A.5.6

The net tensile strain, ε_t, is the tensile strain at nominal strength and determined by strain compatibility using similar triangles. LRFD Design C5.7.2.1

Given an allowable concrete strain of 0.003 and depth to neutral axis c = 1.34 in.

$$\frac{\varepsilon_c}{c} = \frac{\varepsilon_t}{d-c}$$

$$\frac{0.003}{1.34 \text{ in.}} = \frac{\varepsilon_t}{26.61 \text{ in.} - 1.34 \text{ in.}}$$

Solving for ε_t, ε_t = 0.0566.

For ε_t = 0.0566 > 0.005, the section is tension controlled. LRFD Design 5.7.2.1

For conventional construction and tension controlled reinforced concrete sections resistance factor φ shall be taken as 0.90. LRFD Design 5.5.4.2.1

A2A.7—Compute Nominal Shear Resistance

As shear distress has not been observed, evaluation of shear for design and legal loads is not required and evaluation of shear for permit loads is not required so long as the factored load effects due to the permit load are less than the factored load effects from the design load.

Shear calculations are included for illustrative purposes only, as shear distress has not been observed.

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Stirrups: #5 bars at 9 in.

$$A_v = 2 \times \frac{\pi}{4}\left(\frac{5}{8}\right)^2 = 0.6136 \text{ in.}^2$$

Unknown $f_y \rightarrow 33$ ksi

Critical section for shear: LRFD Design 5.8.3.2

Effective Shear Depth: d_v LRFD Design 5.8.2.9

1. Distance, meassured perpendicular to the neutral axis, between resultants of the tensile and compressive forces. It need not be taken to be less than the greater of:
2. $0.9d_e$
3. $0.72h$

1. $d_v = \dfrac{M_n}{A_s f_y + A_{ps} f_{ps}}$ LRFD Design Eq. C5.8.2.9-1

This quantity depends upon the transfer and development of the reinforcement. Conservatively, we will take d_v as the greater of the remaining criteria to reduce required calculations.

2. 0.9 (26.61) = 23.95 in.
3. 0.72 (30.0) = 21.60 in.

d_v = 23.95 in.

Assume θ = 45°

$0.5d_v \cot\theta$ = (0.5) (26.04) (cot 45) = $0.5d_v < d_v$ Use d_v

Critical section for shear at 23.95 in. from face of support.

Bearing pad width = 4 in.

Calculate shear at $23.95 + \frac{4}{2} = 25.95$ in. from centerline of bearing.

Maximum Shear at Critical Section Near Support (25.95 in.) calculated by statics:

V_{TANDEM} = 41.9 kips Governs

V_{TRUCK} = 41.4 kips

V_{LANE} = 7.0 kips

Total Live-Load Shear = (1.33) (41.9) + 7.0 = 62.7 kips LRFD Design Table 3.6.2.1-1

(including 33 percent increase for dynamic load allowance)

Distributed Shear, V_{LL+IM} = (62.7) (0.709) = 44.5 kips

Dead-Load Shears:

$$V_{DC} = 1.002\left(0.5 \times 26 - \frac{25.95}{12}\right) = 10.8 \text{ kips}$$

$$V_{DW} = 0.33\left(0.5 \times 26 - \frac{25.95}{12}\right) = 3.6 \text{ kips}$$

Resistance:

The lesser of :

$V_n = V_c + V_s + V_p$ LRFD Design Eq. 5.8.3.3-1

$V_n = 0.25 f'_c b_v d_v + V_p$ LRFD Design Eq. 5.8.3.3-2

In this case there is no V_p contribution, and:

Effective shear depth, d_v = 23.95 in. LRFD Design Eq. 5.8.2.9

Minimum web width within the depth d_v, b_v = 15 in. LRFD Design Eq. 5.8.2.9

$V_c = 0.0316\beta\sqrt{f'_c} b_v d_v$ LRFD Design Eq. 5.8.3.3-3

$V_s = \frac{A_v f_y d_v \cot\theta}{s}$ (for α = 90°) LRFD Design Eq. 5.8.3.3-4

Simplified Approach: LRFD Design 5.8.3.4.1

β = 2.0

θ = 45

$$V_c = (0.0316)(2)\sqrt{3.0}(15)(23.95) = 39.3 \text{ kips}$$

$$V_s = \frac{(0.6136)(33)(23.95)\cot 45}{9} = 53.9 \text{ kips}$$

V_n = 39.3 + 53.9 = 93.2 kips

V_n = 0.25 × 3.0 × 15 × 23.95 = 269.4 kips

93.2 kips < 269.4 kips, therefore V_n = 93.2 kips

A2A.8—Summary for Interior Concrete T-Beam

	Dead Load *DC*	Dead Load *DW*	LiveLoad Distribution Factor	Dist. Live Load + Impact	Nominal Capacity
Moment, kip-ft	84.7	27.9	g_m = 0.703	295.2	493.4
Shear, kips	10.8	3.6	g_v = 0.709	44.5	93.2

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A2A.9—General Load Rating Equation

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_L)(LL + IM)} \text{ s}$$ Eq. 6A.4.2.1-1

For Strength Limit States $C = (\varphi_c)(\varphi_s)(\varphi)R_n$

A2A.10—Evaluation Factors (for Strength Limit States)

1. Resistance Factor, φ LRFD Design 5.5.4.2.1

   φ = 0.90 for flexure and shear of normal weight concrete

2. Condition Factor, φ_c 6A.4.2.3

   No member condition information available. NBI Item 59 = 6.

   φ_c = 1.0

3. System Factor, φ_s 6A.4.2.4

   φ_s = 1.0 4-girder bridge with *S* > 4 ft (for flexure and shear)

A2A.11—Design Load Rating (6A.4.3)

A2A.11.1—Strength I Limit State

$$RF = \frac{(\varphi_c)(\varphi_s)(\varphi)R_n - (\gamma_{DC})(DC) - (\gamma_{DW})(DW)}{(\gamma_L)(LL + IM)}$$

A2A.11.2—Inventory Level (6A.5.4.1)

Table 6A.4.2.2-1

Load	Load Factor
DC	1.25
DW	1.25
LL	1.75

Thickness was field verified

Flexure:

$$RF = \frac{(1.0)(1.0)(0.90)(493.4)-\left[(1.25)(84.7)+(1.25)(27.9)\right]}{(1.75)(295.2)}$$

$$= 0.59$$

Shear:

$$RF = \frac{(1.0)(1.0)(0.90)(93.2)-\left[(1.25)(10.8)+(1.25)(3.6)\right]}{(1.75)(44.5)}$$

$$= 0.85$$

The shear ratings factors for Design Load Rating are calculated for illustration purposes only. In-service concrete bridges that show no visible signs of shear distress need not be checked for shear during design load or legal load ratings. 6A.5.9

A2A.11.3—Operating Level

Table 6A.4.2.2-1

Load	Load Factor γ
DC	1.25
DW	1.25
LL	1.35

For Strength I Operating Level only the live load factor changes; therefore the rating factor can be calculated by direct proportions.

Flexure:

$$RF = 0.59 \times \frac{1.75}{1.35}$$

$$= 0.76$$

Shear:

$$RF = 0.85 \times \frac{1.75}{1.35}$$

$$= 1.10$$

Note: The shear resistance using MCFT varies along the length. The simplified assumptions of $\beta = 2.0$ and $\theta = 45°$ in this example are conservative for high shear–low moment regions. Example A3 demonstrates a case where the shear rating must be performed at multiple locations along the length of the member. Tension in the longitudinal reinforcement caused by moment-shear interaction (LRFD Design Article 5.8.3.5) has not been checked in this example. Example A3 includes demonstrations of this check.

No service limit states apply to reinforced concrete bridge members at the design load check.

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A2A.12—Legal Load Rating (6A.5.4.2)

Note: Since the Operating Level Design Load Rating produced *RF* < 1.0 for flexure, load ratings for legal loads should be performed to determine the need for posting.

Live Load: AASHTO Legal Loads—Types 3, 3S2, and 3-3 (Rate for all three) 6A.4.4.2.1

g_m = 0.703

L = 26 ft (L < 40 ft)

IM = 33%

Even though the condition of the wearing surface has been field evaluated as smooth, the length of the flexure members prevents the use of a reduced *IM*. C6A.4.4.3

	Type 3	Type 3S2	Type 3-3	
M_{LL+IM} =	250.6	240.7	206.2	kip-ft
gM_{LL+IM} =	176.2	169.2	145.0	kip-ft

Table E6A-1

Live Load: AASHTO Legal Loads—Specialized hauling Units and Notional Rating Load—SU4, SU5, SU6, SU7, and NRL 6A.4.4.2.1b

As before:

g_m = 0.703

L = 26 ft (L <40 ft)

IM = 33% C6A.4.4.3

	SU4	SU5	SU6	SU7	NRL	
M_{LL+IM} =	296.9	323.2	350.1	358.6	360.4	kip-ft
gM_{LL+IM} =	208.7	227.2	246.1	252.1	253.4	kip-ft

Table E6A-2

A2A.12.1—Strength I Limit State (6A.5.4.2.1)

ADTT = 1850

For AASHTO Legal Loads—Types 3, 3S2, and 3-3

Generalized Live-Load Factor:

Linear interpolation is permitted for other ADTT. Therefore: Table 6A.4.4.2.3a-1

$$\gamma_L = 1.30 + \frac{1850-1000}{5000-1000}(1.45-1.30) = 1.33$$

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γ_L = 1.33

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Flexure:

$$RF = \quad RF = \frac{(1.0)(1.0)(0.9)(493.4)-[(1.25)(84.7)+(1.25)(27.9)]}{(1.33)(M_{LL+IM})}$$

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Truck	Type 3	Type 3S2	Type 3-3
RF =	1.29	1.35	1.57
Vehicle Weight (tons)	25	36	40
Safe Load Capacity (tons)	32	48	62

For Specialized Hauling Units and Notional Rating Load—SU4, SU5, SU6, SU7, and NRL

Generalized Live-Load Factor:

γ_L = 1.33 by interpolation Table 6A.4.4.2.3b-1

Flexure:

$$RF = \frac{(1.0)(1.0)(0.90)(493.4)-\left[(1.25)(84.7)+(1.25)(27.9)\right]}{(1.33)(M_{LL+IM})}$$

Truck	SU4	SU5	SU6	SU7	NRL
RF	1.09	1.00	0.93	0.90	0.90
Vehicle Weight, tons	27	31	34.8	38.8	40
Safe Load Capacity, tons	29	31	32	34	36

No posting is required for the Types 3, 3S2, and 3-3.

Comparison of the above safe capacities for the SU4, SU5, SU6, and SU7 to the NRL Safe Load Capacity demonstrates that for bridges that do not rate the NRL Load, a posting analysis should be performed to resolve posting requirements for single unit multiaxle trucks. The above results show that the Safe Load Capacity for the SU4 and SU5 vehicles is adequate; however, posting may be required for SU6, and SU7 vehicles. 6A.8.2 and C6A.8.2

The descision to post a bridge should be made by the Bridge Owner. When for any legal truck the Rating Factor *RF* is between 0.3 and 1.0 then the following formula should be used to establish the safe posting load for that vehicle type. 6A.8.3

$$\text{Safe Posting Load} = \frac{W}{0.7}\left[(RF)-0.3\right] \qquad \text{Eq. 6A.8.3-1}$$

Therefore, for SU6 and SU7, the recommended safe posting loads are:

		SU6	SU7
Safe Posting Load		31	33

No service limit states apply to reinforced concrete bridge members at the legal load check. This example focused on the interior stringer for illustrative purposes only. Before a final posting descision can be made the exterior beam should be analyzed.

A2A.12.2—Summary

Truck	Type 3	Type 3S2	Type 3-3	SU4	SU5	SU6	SU7	NRL
Weight, tons	25	36	40	27	31	34.8	38.8	40
RF	1.29	1.35	1.57	1.09	1.10	0.93	0.90	0.90
Safe Load Capacity, tons	32	48	62	29	31	32	34	36
Safe Posting Load (tons)	—	—	—	—	—	31	33	

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A2A.13—Permit Load Rating (6A.4.5)

Permit Type: Special, Multiple-Trips, no speed control

Permit Weight: 175 kips

Permit Vehicle: Shown in Figure A2A.13-1.

ADTT (one direction): 1850

IM = 33% (L < 40 ft) C6A.4.4.3

Undistributed Maximum:

M_{LL} = 347.3 kip-ft at midspan
V_{LL} = 52.6 kips at 26 in.

A2A.13.1—Strength II Limit State (6A.5.4.2.1)

ADTT (one direction): 1850

Load Factor, γ_L: $\left(1.50 + \frac{(1850-1000)}{(5000-1000)}(1.60-1.50)\right)$ Table 6A.4.5.4.2a-1

γ_L =1.52

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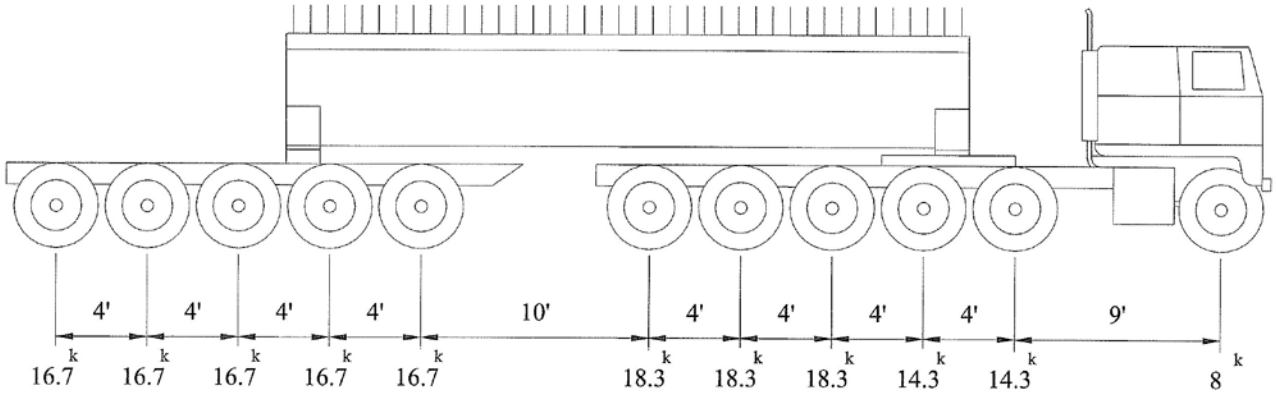

Figure A2A.13-1—Permit Truck Loading Configuration

Use One-Lane Distribution Factor and divide out the 1.2 multiple presence factor. 6A.4.5.4.2b

$$g_{m1} = 0.565 \times \frac{1}{1.2} = 0.471$$

$$g_{v1} = 0.621 \times \frac{1}{1.2} = 0.518$$

Distributed Live-Load Effect:

M_{LL+IM} = (347.3) (0.471) (1.33) = 217.6 kip-ft

V_{LL+IM} = (52.6) (0.518) (1.33) = 36.2 kips

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_L)(LL + IM)}$$ Eq. 6A.4.2.1-1

For Strength Limit States: $C = (\varphi_c)(\varphi_s)(\varphi) R_n$

Flexure:

$$RF_M = \left(\frac{(1.0)(1.0)(0.9)(493.4) - (1.25)(84.7) - (1.25)(27.9)}{(1.52)(217.6)} \right)$$

= 0.92 < 1.0 No Good

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Shear: Shear evaluation is not required for Permit Load Ratings so long as the factored permit load shear does not exceed the factored design load shear and no shear distress has been observed. $V_{LL+IM,Permit}$ = 1.52 × 36.2 = 55.0 kips $V_{LL+IM, HL-93}$ = 1.75 × 44.5 = 77.9 kips As shown, the factored shear due to the permit load does not exceed the factored shear due to the design load, therefore shear evaluation for the permit load is not required but is shown below for completeness. 6A.5.9

A2A.13.2—Service I Limit State (Optional) (6A.5.4.2.2b)

Deleted: Since V_n was determined by the simplified approach, it is not dependent upon the vehicle. ...

γ_L = γ_{DC} = γ_{DW} = 1.0 Table 6A.4.2.2-1

Use the distribution factors that were used for the design and for legal loads. C6A.5.4.2.2b

g_m = 0.703

Distributed Live-Load Effect

M_{LL+IM} = (347.3) (0.703) (1.33) = 324.7 kip-ft

M_{DC} = 84.7 kip-ft

M_{DW} = 27.9 kip-ft

A2A.13.2.1—Simplified Check Using 0.75M_n (C6A.5.4.2.2b)

Unfactored Moments:

$M_{DC} + M_{DW} + M_{LL+IM}$ = 437.3 kip-ft

Nominal flexural resistance:

M_n = 493.4 kip-ft

(Use nominal resistance, not factored.)

$0.75M_n$ = 0.75 × 493.4 = 370.1 kip-ft < 437.3 kip-ft No Good

Moment Ratio = $\dfrac{0.75M_n}{M_{DC}+M_{DW}+M_{LL+IM}} = \dfrac{370.1}{437.3} = 0.86 < 1.0$ No Good

A2A.13.2.2—Refined Check Using 0.9f_y

$M_{DC} + M_{DW}$ = 112.6 kip-ft

The Service I moments act upon the cracked section to produce stress in the reinforcement. An elastic model of the cracked concrete section with transformed steel is used to calculate the stress in the reinforcement due to the Service I loads.

$E_c = 1820\sqrt{f'_c}$ LRFD Design C5.4.2.4

$= 1820\sqrt{3.0}$

= 3152 ksi

E_s = 29000 ksi

$n = \dfrac{29000}{3152} = 9.2$ Use n = 9

For permanent loads at the Service limit states, use an effective modular ratio of 2n. LRFD Design 5.7.1

b_e = 78 in.

t_s = 6 in.

t_w = 15 in.

A_s = 6.89 in.^{2}

d_s = 26.61 in.

Assume neutral axis is within the slab.

$$\bar{y} = \frac{(b_e \times \bar{y})\dfrac{\bar{y}}{2} + (n \times A_s)(d_s)}{(b_e \times \bar{y}) + (n \times A_s)}$$

For n = 9:

$\bar{y}$ = 5.76 in. (within the slab)

$$I = \frac{1}{12} b_e \times \bar{y}^3 + (b_e \times \bar{y})\left(\frac{\bar{y}}{2}\right)^2 + (n \times A_s)(d_s - \bar{y})^2$$

$$= \frac{1}{12} \times 78 \times 5.76^3 + (78 \times 5.76)\left(\frac{5.76}{2}\right)^2 + (9 \times 6.89)(26.61 - 5.76)^2$$

$$= 31926 \text{ in.}^3$$

For $2n = 18$:

$\overline{y}$ = 7.75 in. (outside the slab)

T-section behavior for the stress due to permanent loads:

$$\overline{y} = \frac{\left[\left(b_e - t_w\right)\times t_s\right]\left(\frac{t_s}{2}\right) + \left(t_w \times \overline{y}\right)\left(\frac{\overline{y}}{2}\right) + \left(n \times A_s\right)\left(d_s\right)}{\left[\left(b_e - t_w\right)\times t_s\right] + \left(t_w \times \overline{y}\right) + \left(n \times A_s\right)}$$

For $2n = 18$:

$\overline{y}$ = 7.9 in. (within the beam)

$$I = \left\{\begin{array}{l} \frac{1}{12}\left(b_e - t_w\right)\times t_s^3 + \left[\left(b_e - t_w\right)\times t_s\right]\left(\overline{y} - \frac{t_s}{2}\right)^2 + \frac{1}{12}t_w \times \left(\overline{y}\right)^3 \\ + \left(\overline{y} \times t_w\right)\left(\frac{\overline{y}}{2}\right)^2 + \left(n \times A_s\right)\left(d_s - \overline{y}\right)^2 \end{array}\right\}$$

$$= \left\{\begin{array}{l} \frac{1}{12}(78-15)\times 6^3 + \left[(78-15)\times 6\right]\left(7.9 - \frac{6}{2}\right)^2 + \frac{1}{12}\times 15 \times 7.9^3 \\ + (7.9\times 15)\left(\frac{7.9}{2}\right)^2 + (18\times 6.89)(26.61 - 7.9)^2 \end{array}\right\}$$

= 56090 in.^{3}

Stress in the extreme tension reinforcement:

$$\text{bending stress, } f = n \times \frac{M \times 12 \times \left(h - cov. - \overline{y}\right)}{I}$$

f_{LL+IM} = $9 \times \frac{324.7 \times 12 \times (30 - 2.5 - 5.76)}{31926}$ = 23.88 ksi

f_D = $18 \times \frac{112.6 \times 12 \times (30 - 2.5 - 7.9)}{56090}$ = 8.50 ksi

f_s = $f_{LL+IM} + f_D$ = 23.88 + 8.50 = 32.4 ksi

f_R = $0.90 f_y$ = 0.90 × 33 ksi = 29.7 ksi 6A.5.4.2.2b

29.7 < 32.4 No Good

Stress Ratio:

$$\frac{f_R - f_{DC} - f_{DW}}{f_{LL+IM}} = \frac{29.7 - 8.50}{23.88} = 0.89 \text{ No Good}$$

Some improvement versus the simplified check, but not enough to allow the permit if this optional check is applied. The truck also has an $RF < 1.0$ under flexure.

A2A.14—Summary of Rating Factors for Load and Resistance Factor Rating Method

Table A2A.14-1—Summary of Rating Factors for Load and Resistance Factor Rating Method—Interior Beam

Limit State		Design Load Rating		Legal Load Rating								Permit Load Rating
		Inventory	Operating	Type 3	Type 3S2	Type 3-3	SU4	SU5	SU6	SU7	NRL	
Strength I	Flexure	0.59	0.76	1.29	1.35	1.57	1.09	1.00	0.93	0.90	0.90	—
Strength II	Flexure	—	—	—	—	—	—	—	—	—	—	0.92
Service I		—	—	—	—	—	—	—	—	—	—	Stress Ratio = 0.89

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PART B—ALLOWABLE STRESS AND LOAD FACTOR RATING METHODS

A2B.1—Bridge Data

Refer to Article A2A.1 for Bridge Data.

A2B.2—Section Properties

Find cg steel:

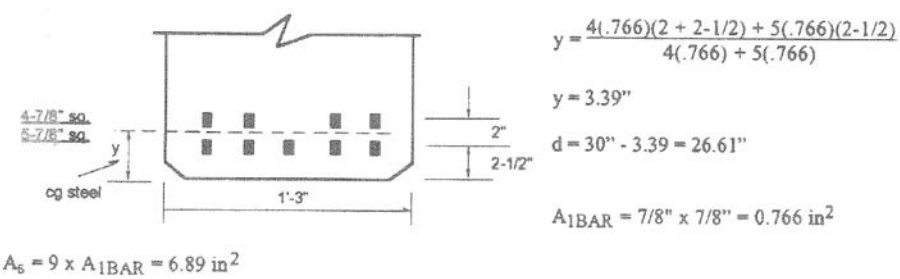

Figure A2B.2-1—Steel Reinforcement Arrangment

Effective Slab Width (for T-Girder): AASHTO 8.10.1.1

$$\frac{1}{4}L = \frac{26\text{ ft} \times 12\text{ in./ft}}{4} = 78\text{ in.}$$

or:

$$CC\ SPCG = 6\text{ ft} - 6\ 1/4\text{ in.} = 78.25\text{ in.}$$

or:

$$12t_s = 12 \times 6\text{ in.} = 72\text{ in.} \Leftarrow \text{Controls}$$

$$\rho_{act} = \frac{As}{b_{eff}d} = \frac{6.89\text{ in}^2}{78\text{ in.} \times 26.61\text{ in.}} = 0.0036$$

(if compression within flange)

A2B.3—Dead-Load Analysis—Interior Beam

Structural Concrete:

$$0.15\text{ kip/ft}^3\left[\left(\frac{6\text{ in.}}{12\text{ in./ft}} \times 6.52\text{ ft}\right) + \left(1.25\text{ ft} \times 2.0\text{ ft}\right) + 2\left(\frac{1}{2}\frac{6}{12}\frac{6}{12}\right)\right] = 0.92\text{ kip/ft}$$

AC Overlay:

$$0.144\text{ kip/ft}^3\left(\frac{5\text{ in.}}{12\text{ in./ft}} \times 6.52\text{ ft}\right) = 0.39\text{ kip/ft}$$

$W_{DL} = 0.902 + 0.39 = 1.292$ kip/ft <u>say 1.3 kip/ft</u>

Midspan Moments:

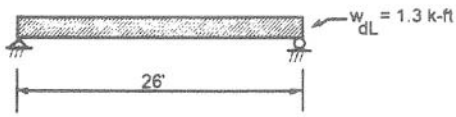

Figure A2B.3-1—Load Diagram for Uniform Dead Load

$$M_{DL} = \frac{W_{DL}L^2}{8} = \frac{1.3 \text{ kip/ft} \times 26^2 \text{ ft}^2}{8} = 109.9 \text{ kip-ft}$$

A2B.4—Live-Load Analysis—Interior Beam

Rate for HS-20 vehicle. Figure 6B.7.2-1

For HS-20—Using Table C6B-1, select from column "Without Impact." Appendix C6B

$M_L = 111.1$ kip-ft (without impact and without distribution)

A2B.5—Allowable Stress Rating (6B.4.1, 6B.5.2, and 6B.6.2)

For this example, we consider only the maximum moment section.

A2B.5.1—Impact (Use standard AASHTO) (6B.7.4, AASHTO 3.8.2.1)

$$I = \frac{50}{L+125} \leq 0.30$$

$$I = \frac{50}{26+125} = 0.33 \text{ use } \underline{\underline{0.30}}$$

A2B.5.2—Distribution (Use standard AASHTO) (6B.7.3, AASHTO 3.23.2.2 and Table 3.23.1)

$$DF = \frac{S_G}{6.0} \text{ Concrete T-Beam}$$

$$DF = \frac{6 \text{ ft} - 6 \text{ 1/4 in.}}{6.0} = \frac{6.52 \text{ ft}}{6} = 1.087$$

Thus:

$$M_{L+I} = M_L(1+I)(DF) = 111.1(1+0.30)(1.087) = 157 \text{ kip-ft}$$

A2B.5.3—Inventory Level (6B.5.2, 6B.6.2.4)

The inventory unit stresses are determined in accordance with AASHTO Article 8.15, "Service Load Design Method," or taken from 6B.6.2.4[a].

Inventory allowable stresses: AASHTO 8.15.2.1.1

$f_c^I = 1200 \text{ psi} = 1.2 \text{ ksi}$ 6B.6.2.4.1

[a] Note the moments given in the MBE are for one line of wheels. The values given in AASHTO are for the entire axle and are therefore twice the MBE values.

For Reinforcing Steel, 6B.6.2.3 controls:

$f_s^I = 18000 \text{ psi} = 18 \text{ ksi (unknown steel prior to 1954)}$ 6B.6.2.3

Capacity (Traditional Approach):

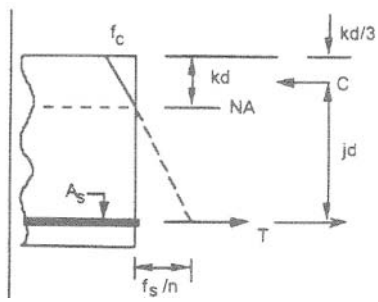

Figure A2B.5.3-1—Stress and Force Diagram, *nts*

The actual steel and concrete stresses are not known and must be found. Since this is a T-beam, assume neutral axis NA is within slab. Thus, rectangular beam formulas apply. Check this assumption later.

The following formulas for the Traditional Approach were referenced from *Reinforced Concrete Design Handbook* Working Stresss Method in accordance with ACI 318-63, ACI Publication SP-3.

Position of Neutral Axis:

$$k = \sqrt{2\rho n + (\rho n)^2} - \rho n$$ SP-3 Eq. (2)

where:

$$\rho = \frac{A_s}{bd} = \frac{6.89 \text{ in.}^2}{(72 \text{ in.})(26.61 \text{ in.})}$$ SP-3 Table 1

$$\rho = 0.0036$$

$$n = \frac{E_s}{E_c}$$

$$n = 10$$ 6B.6.2.4

$$k = \sqrt{2(0.0036)(10) + \left[(0.0036)(10)\right]^2} - (0.0036)(10)$$

$$k = 0.235$$

$$j = 1 - \frac{k}{3} = 1 - \frac{0.235}{3} = 0.922$$ SP-3 Table 1

then:

Capacity if concrete allowable stress controls:

$$M_c = \frac{1}{2} f_c jkbd^2$$

$$= \frac{1}{2}(1.2\text{ ksi})(0.922)(0.235)(72\text{ in.})(26.61\text{ in.})^2$$

$$= 6622.8\text{ kip-in.} = 552\text{ kip-ft}$$

Capacity if steel reinforcement allowable stress controls:

$$M_s = A_s f_s jd$$

$$M_s = (6.89\text{ in.}^2)(18\text{ ksi})(0.922)(26.61\text{ in.})$$

$$M_s = 3042.8\text{ kip-in.} = 253\text{ kip-ft} \Leftarrow \text{Controls since } M_s < M_c$$

Check neutral axis assumption:

k_d = (0.235)(26.61 in.) = 6.25 in. > 6 in. the slab thickness $\therefore NA$ is below bottom of slab and slightly into web. This could be ignored in this case. However, for the sake of completeness, capacity will be figured below based on the *NA* below the slab and ignoring the compression in the stem concrete.

$$kd = \frac{2ndA_s + bt^2}{2nA_s + 2bt}$$

$$kd = \frac{2(10)(26.61\text{ in.})(6.89\text{ in.}) + (72\text{ in.})(6\text{ in.})^2}{2(10)(6.89\text{ in.}) + 2(72\text{ in.})(6\text{ in.})} = \frac{6258.9}{1001.8}$$

$$kd = 6.25\text{ in.} \rightarrow k = \frac{kd}{d} = \frac{6.25\text{ in.}}{26.61\text{ in.}} = 0.235$$

$$Z = \left(\frac{3kd - 2t}{2kd - t}\right)\frac{t}{3}$$

$$Z = \left(\frac{3(6.25\text{ in.}) - 2(6\text{ in.})}{2(6.25\text{ in.}) - (6\text{ in.})}\right)\frac{6\text{ in.}}{3} = \frac{6.75\text{ in.}}{6.5\text{ in.}}(2\text{ in.})$$

$$Z = 2.077\text{ in.}$$

$$jd = d - Z$$

$$jd = 26.61\text{ in.} - 2.077\text{ in.} = 24.53\text{ in.}$$

$$M_s = A_s f_s jd$$

$$M_s = (6.89\text{ in.}^2)(18\text{ ksi})(24.53\text{ in.}) = 3042.2\text{ kip-in.}$$

$$M_s = 253\text{ kip-ft as before}$$

(Note concrete was not checked since capacity of section is limited by steel allowable stress.)

$$RF_I^A = \frac{M_{RI} - M_D}{M_{L+I}} \qquad \text{Eq. 6B.5.1-1}$$

$$RF_I^A = \frac{253 \text{ kip-ft} - 109.9 \text{ kip-ft}}{157 \text{ kip-ft}} = 0.91$$

A2B.5.4—Operating Level (6B.6.2)

The Operating allowable stresses for concrete with f'_c = 3,000 psi:

$$f_c^o = 1900 \text{ psi} = 1.9 \text{ ksi}$$ 6B.6.2.4.1

For reinforcing steel:

$$f_s^o = 25{,}000 \text{ psi} = 25 \text{ ksi (unknown steel, prior to 1954)}$$ 6B.6.2.3

The basic relationships defined previously apply:

Since ρ and *n* do not change, the neutral axis, *k*, *j*, and *Z* terms do not change.

Thus:

$$M_s = A_s f_s jd$$

$$= \left(6.89 \text{ in.}^2\right)\left(25 \text{ ksi}\right)\left(24.53 \text{ in.}\right)$$

$$= 4225.3 \text{ kip-in.} = 352 \text{ kip-ft}$$

and checking concrete stress to ensure that concrete does not control:

$$f_c = \frac{f_s}{n}\left(\frac{k}{1-k}\right)$$ SP-3 Table 1

$$f_c = \left(\frac{25 \text{ ksi}}{10}\right)\left(\frac{0.235}{1-0.235}\right) = 0.77 \text{ ksi} << 1.9 \text{ ksi allowable}$$

Therefore, capacity of section is controlled by allowable steel stress.

$$M_{R_O} = 352 \text{ kip-ft}$$

$$RF_O^A = \frac{M_{R_O} - M_{DL}}{M_{L+I}} = \frac{352 \text{ kip-ft} - 109.9 \text{ kip-ft}}{157 \text{ kip-ft}}$$

$$RF_O^A = 1.54$$

A2B.6—Load Capacity Based on Allowable Stress

Inventory: $0.91 \times 36^T = 32.8^T\ HS$

Operating: $1.54 \times 36^T = 55.4^T\ HS$

To transform HS rating to H rating, multiply HS rating factor by ratio of HS moment to H moment:

For 26-ft span:

$$M_L^{\text{HS-20}} = 111.1 \text{ kip-ft}$$

$\rightarrow M_L^{\text{H-15}} = 78$ kip-ft Table C6B-1

Then:

$$M_L^{\text{H-20}} = \frac{20T}{15T} \times 78 \text{ kip-ft} = 104 \text{ kip-ft}$$

and:

$$\text{Ratio} = \frac{M_L^{\text{HS-20}}}{M_L^{\text{H-20}}} = \frac{111.1}{104} = 1.068$$

Thus for H-20 Truck:

Inventory: $0.91 \times 1.068 \times 20^T = 19.4^T H$

Operating: $1.54 \times 1.068 \times 20^T = 32.9^T H$

A2B.7—Capacity (Alternate Approach)

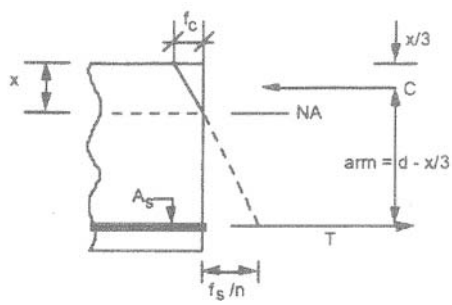

Figure A2B.7-1—Stress and Force Diagram, *nts*

Since the location of the neutral axis *NA* and the corresponding stresses in the steel and concrete are not known, these must be determined consistent with the principles of equilibrium of the cross section.

1. From the stresses on the cross section using similar triangles:

$$\frac{f_c}{x} = \frac{f_s \div n}{d - x} \rightarrow f_c = \frac{f_s}{n}\left(\frac{x}{d - x}\right) \qquad \text{(A2B.7-1)}$$

2. Assume the steel allowable stress controls the capacity of the section. This will be checked later. Then:

$$T = A_s f_s = \left(6.89 \text{ in.}^2\right)\left(18 \text{ ksi}\right) = 124 \text{ kips}$$

and:

$$C = \frac{1}{2} f_c b x$$

but:

$$C = T$$

thus:

$$\frac{1}{2} f_c bx = A_s f_s$$

$$x = \frac{A_s f_s}{\frac{1}{2} f_c b} \qquad \text{(A2B.7-2)}$$

Solve Eqs. 1 and 2 to find location of neutral axis. This may be done by trial and error as follows.

Assume f_s = 18 ksi, i.e., steel allowable stress controls.

Try x = 6.0 in. Then by Eq. 1:

$$f_c = \frac{f_s}{n}\left(\frac{x}{d-x}\right) = \frac{18 \text{ ksi}}{10}\left(\frac{6.0 \text{ in.}}{26.61 \text{ in.} - 6.0 \text{ in.}}\right) = 0.524 \text{ ksi} < 1.2 \text{ ksi} \qquad \text{allowable OK}$$

and by Eq. 2:

$$x = \frac{A_s f_s}{\frac{1}{2} f_c b} = \frac{\left(6.89 \text{ in.}^2\right)\left(18 \text{ ksi}\right)}{\frac{1}{2}\left(0.524 \text{ ksi}\right)\left(72 \text{ in.}\right)} = 6.57 \text{ in.} > 6.0 \qquad \text{assumed. Try again}$$

Try x = 6.25 in.

$$f_c = \frac{18}{10}\left(\frac{6.25}{26.61 - 6.25}\right) = 0.552 < 1.2 \text{ ksi} \qquad \text{allowable OK}$$

and:

$$x = \frac{(6.89)(18)}{\frac{1}{2}(0.552)(72)} = 6.24 \approx 6.25 \qquad \text{assumed OK}$$

3. Since x = 6.24 > t = 6.0, *NA* is below bottom of slab and slightly into web. If web concrete in compression is neglected:

$arm \approx d - \frac{x}{3}$ for this example.

$$arm \approx 26.61 - \frac{6.24}{3} = 24.53 \text{ in.}$$

and capacity is:

$$M = A_s f_s \left(arm\right) = \left(6.89\right)\left(18\right)\left(24.53\right) = 3042.2 \text{ kip-in.} = 253 \text{ kip-ft} \qquad \text{as before}$$

The exact *arm* may be determined from the concrete stress diagram as follows:

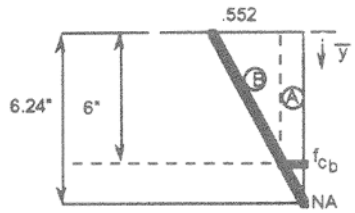

Figure A2B.7-2—Concrete Stress Diagram for Slab Portion of T-Beam, *nts*

at bottom of slab:

$$f_{c_b} = 0.552\left(\frac{0.24}{6.24}\right) = 0.021$$

Next find centroid of stress diagram from top of slab.

$$\bar{y} = \frac{\sum A_y}{\sum A} = \frac{(0.021)(6)\left(\frac{6}{2}\right) + (0.552 - 0.021)(6)\left(\frac{1}{2}\right)\left(\frac{6}{3}\right)}{(0.021)(6) + (0.552 - 0.021)(6)\left(\frac{1}{2}\right)}$$

$$\bar{y} = \frac{3.576}{1.722} = 2.08 \text{ in.}$$

$\therefore arm = 26.61 - 2.08 = 24.53$ in. as found previously

4. The operating capacity may be found as above and will be the same as for the "traditional method." The rating calculations are not shown here since they too will be the same as for the traditional method.

A2B.8—Allowable Stress Rating—Rate for AASHTO Legal Loads

M_{L+I} from Appendix C6B (all values have 30 percent impact):

Span	Type 3	Type 3S2	Type 3-3	
26 ft	122.4	117.7	100.8	kip-ft

Span	NRL	SU4	SU5	SU6	SU7	
26 ft	176.2	145.1	158.0	171.1	175.2	kip-ft

Apply distribution factor DF = 1.087

Span	Type 3	Type 3S2	Type 3-3	
26 ft	133.0	127.9	109.6	kip-ft

Span	NRL	SU4	SU5	SU6	SU7	
26 ft	191.5	157.7	171.7	186.0	190.4	kip-ft

Capacity of section as previously determined in A2B.5.3 and A2B.5.4 respectively:

Inventory Level M_{RI} = 253 kip-ft Operating Level M_{RO} = 352 kip-ft.

Dead Load M_{DL} = 109.9 kip-ft.

For Alowable Stress Method A_1 = 1.0 and A_2 = 1.0 6B.5.2

$$RF_I^A = \frac{M_{RI} - A_1 M_D}{A_2 M_{L+I}} = \frac{253 \text{ kip-ft} - (1.0)109.9 \text{ kip-ft}}{(1.0)M_{L+I}} \qquad \text{Eq. 6B.5.1-1}$$

$$RF_O^A = \frac{M_{R_O} - A_1 M_{DL}}{A_2 M_{L+I}} = \frac{352 \text{ kip-ft} - (1.0)109.9 \text{ kip-ft}}{(1.0)M_{L+I}}$$

Alowable Stress Method Rating Factors:

	Type 3	Type 3S2	Type 3-3
Inventory	1.08	1.12	1.31
Operating	1.82	1.89	2.21

	NRL	SU4	SU5	SU6	SU7
Inventory	0.75	0.91	0.83	0.77	0.75
Operating	1.26	1.53	1.41	1.30	1.27

Load Capacity in Tons:

Inventory: $RF_I^A \times \text{vehicle weight} = \text{Inv.Cap.}$

Operating: $RF_O^A \times \text{vehicle weight} = \text{Opr.Cap.}$

Load	Type 3	Type 3S2	Type 3-3
Vehicle Weight	25	36	40
Inv. Cap.	27.0	40.3	52.4
Opr. Cap.	45.5	68.0	88.4

Load	NRL	SU4	SU5	SU6	SU7
Vehicle Weight	40	27	31	34.8	38.8
Inv. Cap.	30.0	24.6	25.7	26.8	29.1
Opr. Cap.	50.4	41.3	43.7	45.2	49.3

A2B.9—Summary of Ratings for Allowable Stress Rating Method

Table A2B.9-1 Summary of Ratings for Allowable Stess Rating Method—Interior Beam

Load	HS-20	H-20	Type 3	Type 3S2	Type 3-3
Vehicle Weight (tons)	36	20	25	36	40
Inventory RF	0.91	0.91	1.08	1.12	1.31
Inv. Cap.	32.8	19.4	27.0	40.3	52.4
Operating RF	1.54	1.54	1.82	1.89	2.21
Opr. Cap.	55.4	32.9	45.5	68.0	88.4

Load	NRL	SU4	SU5	SU6	SU7
Vehicle Weight (tons)	40	27	31	34.8	38.8
Inventory RF	0.75	0.91	0.83	0.77	0.75
Inv. Cap.	30.0	24.6	25.7	26.8	29.1
Operating RF	1.26	1.53	1.41	1.30	1.27
Opr. Cap.	50.4	41.3	43.7	45.2	49.3

A2B.10—Load Factor Rating (6B.4.2, 6B.5.3, 6B.6.3)

For this example, we consider only the maximum moment section.

A2B.10.1—Impact (Use standard AASHTO) (6B.7.4, AASHTO 3.8.2.1)

$$I = \frac{50}{L+125} \leq 0.30$$

$$I = \frac{50}{26+125} = 0.33 \text{ use } \underline{0.30}$$

A2B.10.2—Distribution (Use standard AASHTO) (6B.7.3, AASHTO 3.23.2.2 and Table 3.23.1)

$$DF = \frac{S_G}{6.0} = \frac{6.52 \text{ ft}}{6} = 1.087$$

Thus:

$$M_{LL+I} = M_L(1+I) \times DF = 111.1(1+0.30)(1.087) = 157 \text{ kip-ft}$$

A2B.10.3—Capacity of Section (6B.6.3.2)

For unknown steel prior to 1954, f_y = 33,000 psi = 33 ksi

M_u is found in accordance with applicable strength requirements of AASHTO Article 8.16.

Consider a rectangular section with compression limited to top slab. Then check 6B.6.3.2 requirement for 75 percent of balanced condition.

$$\rho_{max} = 0.75\rho_{bal} = 0.75\frac{0.85\beta_1 f_c'}{f_y}\frac{87000}{87000+f_y}$$ AASHTO Eq. 8-18

$$\rho_{max} = 0.75\frac{0.85(0.85)(3000)}{33000}\left(\frac{87000}{87000+33000}\right)$$

$$\rho_{act} = 0.0036 << \rho_{max}$$ OK

Then:

$$a = \frac{A_s f_y}{0.85 f_c' b_{eff}}$$ AASHTO Eq. 8-17

$$a = \frac{6.89 \text{ in.}^2 (33 \text{ ksi})}{0.85(3 \text{ ksi})72 \text{ in.}} = 1.24 \text{ in.} < 6 \text{ in.}$$ OK within slab

$$M_R = A_s f_y \left(d - \frac{a}{2}\right)$$ AASHTO Eq. 8-16

$$M_R = (6.89 \text{ in.}^2)(33 \text{ ksi})\left(26.61 \text{ in.} - \frac{1.24}{2}\right)$$

$$M_R = 5909 \text{ kip-in.} = \underline{492 \text{ kip-ft}}$$

$M_u = \phi M_R$

where $\phi = 0.90$ AASHTO 8.16.1.2.2

$M_u = 0.90 \times 492 = 443$ kip-ft.

A2B.10.4—Inventory Level (6B.5.1, 6B.6.3)

M_{DL} is the same as what was estimated for the ASD rating calculation:

$$R_I^{LF} = \frac{M_u - A_1 M_{DL}}{A_2 M_{L+I}}$$ Eq. 6B.5.1-1

where in accordance with 6B.5.3:

$A_1 = 1.3$

$A_2 = 2.17$

Thus:

$$RF_I^{LF} = \frac{443 - 1.3(109.9)}{2.17(157)} = 0.88$$

A2B.10.5—Operating Level (6B.5.1, 6B.6.3)

$$R_O^{LF} = \frac{M_u - A_1 M_{DL}}{A_2 M_{L+I}}$$ Eq. 6B.5.1-1

where in accordance with 6B.5.3:

$A_1 = 1.3$

$A_2 = 1.3$

Thus:

$$RF_O^{LF} = \frac{443 - 1.3(109.9)}{1.3(157)} = 1.47$$

Load capacity based on Load Factor Method, HS-20 truck:

Inventory: $0.88 \times 36^T = 31^T\ HS$

Operating: $1.47 \times 36^T = 52^T\ HS$

Load capacity based on Load Factor Method, H-20 truck, where the ratio of HS moment to H moment has been determined in A2B.6 as 1.068:

Inventory: $0.88 \times 1.068 \times 20^T = 18.8^T\ H$

Operating: $1.47 \times 1.068 \times 20^T = 31.4^T\ H$

A2B.10.6—Summary of Ratings for Load Factor Rating Method

Table A2B.10.6-1—Summary of Ratings for Load Factor Rating Method—Interior Beam

	RF	HS-20 Rating, tons	H-20 Rating, tons
Inventory	0.88	31.7	18.8
Operating	1.47	52.9	31.4

A2B.10.7—Load Factor Rating—Rate for AASHTO Legal Loads

M_{L+I} from Appendix C6B (all values have 30 percent impact)

Span	Type 3	Type 3S2	Type 3-3	
26 ft	122.4	117.7	100.8	kip-ft

Apply distribution factor DF = 1.087

26 ft	133.0	127.9	109.6	kip-ft

Capacity of Section M_U = 443 kip-ft

Dead Load M_{DL} = 109.9 kip-ft

For Inventory level, A_1 = 1.3 and A_2 = 2.17 6B.5.3

$$\text{Inv. } RF = \frac{443 - 1.3(109.9)}{2.17(M_{L+I})}$$

For Operating level, A_1 = 1.3 and A_2 = 2.17 6B.5.3

$$\text{Opr. } RF = \frac{443 - 1.3(109.9)}{1.3(M_{L+I})}$$

Strength Rating Factors:

	Type 3	Type 3S2	Type 3-3
Inventory	1.01	1.05	1.22
Operating	1.74	1.81	2.11

Load Capacity in Tons:

Load	Type 3	Type 3S2	Type 3-3
Vehicle Weight	25	36	40
Inv. Cap.	25.3	37.8	48.8
Opr. Cap.	43.5	65.2	84.4

The bridge has adequate Inventory load capacity for Types 3, 3S2, and 3-3 Legal Loads.

A2B.10.8—Load Factor Rating—Rate for Single-Unit Formula B Loads

M_{L+I} from Appendix C6B (all values have 30 percent impact)

Span	NRL	SU4	SU5	SU6	SU7	
26 ft	176.2	145.1	158.0	171.1	175.2	kip-ft

Apply distribution factor DF = 1.087

Span	NRL	SU4	SU5	SU6	SU7	
26 ft	191.5	157.7	171.7	186.0	190.4	kip-ft

Capacity of Section M_U = 443 kip-ft

Dead Load M_{DL} = 109.9 kip-ft

For Inventory level, A_1 = 1.3 and A_2 = 2.17 6B.5.3

$$\text{Inv. } RF = \frac{443 - 1.3(109.9)}{2.17(M_{L+I})}$$

For Operating level, A_1 = 1.3 and A_2 = 2.17 6B.5.3

$$\text{Opr. } RF = \frac{443 - 1.3(109.9)}{1.3(M_{L+I})}$$

Strength Rating Factors:

	NRL	SU4	SU5	SU6	SU7
Inventory	0.72	0.88	0.81	0.74	0.73
Operating	1.20	1.47	1.35	1.24	1.22

Load Capacity in Tons:

Load	NRL	SU4	SU5	SU6	SU7
Vehicle Weight	40	27	31	34.8	38.8
Inv. Cap.	28.8	23.8	25.1	25.8	28.3
Opr. Cap.	48.0	39.7	41.9	43.2	47.3

The bridge has inadequate Inventory load capacity for the notional rating load NRL, and the posting loads SU4, SU5, SU6, and SU7.

PART C—SUMMARY

A2C.1—Summary of All Ratings for Example A2

Table A2C.1-1—Summary of Rating Factors for All Rating Methods—Interior Beam

Limit State		Design Load Rating				Legal Load Rating								Permit Load Rating
		Inventory	Operating	HS-20 Rating	H-20 Rating	Type 3	Type 3S2	Type 3-3	SU4	SU5	SU6	SU7	NRL	
Strength I	Flexure	0.59	0.76			1.29	1.35	1.57	1.09	1.00	0.93	0.90	0.90	—
	~~Shear~~	~~0.85~~	~~1.10~~			—	—	—	—	—	—	—	—	—
Strength II	Flexure	—	—			—	—	—	—	—	—	—	—	0.75 (0.92)
	~~Shear~~	—	—			—	—	—	—	—	—	—	—	~~0.97 (1.20)~~
Service II		—	—	—	—	—	—	—	—	—	—	—	—	—
Service I		—	—	—	—	—	—	—	—	—	—	—	—	Stress Ratio = 0.89
Allowable Stress Method	Inv.	—	—	0.91	0.97	1.08	1.12	1.31	0.91	0.83	0.77	0.75	0.75	—
	Opr.	—	—	1.54	1.64	1.82	1.89	2.21	1.53	1.41	1.30	1.27	1.26	
Load Factor Method	Inv.	—	—	0.88	0.94	1.01	1.05	1.22	0.88	0.81	0.74	0.73	0.72	—
	Opr.	—	—	1.47	1.57	1.74	1.81	2.11	1.47	1.35	1.24	1.22	1.20	—

--Where two values are located in a cell, the first value is for a target reliability index of 3.5 while the second value in parenthesis is for a target reliability index of 2.5. Only one value will be shown when a consensus has been reached as to the target reliability index for special, limited crossing permit vehicles.

--The Shear rows under the Strength I and Strength II Limit States will be removed when the final example is submitted.

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A2C.2—References

AASHTO. 2002. Standard Specifications for Highway Bridges, 17th Edition, HB-17. *American Association of State Highway and Transportation Officials*, Washington, DC.

AASHTO. 2007. AASHTO LRFD Bridge Design Specifications, Fourth Edition, LRFDUS-4-M or LRFDSI-4. *American Association of State Highway and Transportation Officials*, Washington, DC.

ACI. 1963. *Reinforced Concrete Design Handbook*, SP-3. American Concrete Institute, Farmington Hills, MI.

NCHRP. 2007. *Legal Truck Loads and AASHTO Legal Loads for Posting*, NCHRP Report 575. Transportation Research Board, National Research Council, Washington, DC.

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A3—SIMPLE SPAN PRESTRESSED CONCRETE: I-GIRDER BRIDGE EVALUATION OF AN INTERIOR GIRDER (LRFR ONLY)

Note: This example illustrates rating an interior prestressed concrete girder at midspan for moment, at the critical section for shear, and at a change in stirrup spacing for shear. The example member contains debonded tendons to illustrate how this affects the rating at the two shear locations.

A3.1—Bridge Data

Span:	80 ft (Total Length = 81 ft)
Year Built:	1985
Materials:	
Concrete:	$f'_c = 4$ ksi (Deck)
	$f'_c = 5$ ksi (P/S Beam)
	$f_{ci} = 4$ ksi (P/S Beam at transfer)
Prestressing Steel:	$^1/_2$ in. diameter, 270 ksi, Low-Relaxation Strands
	$A_{ps} = 0.153$ in.^{2} per strand
	32 prestressing strands; ten are debonded over the last 12 ft on each end
Stirrups:	#4 at 9 in. over end 20 ft
	#3 at 12 in. over center 40 ft
Compression Steel:	six #6 Grade 60
Condition:	No Deterioration, NBI Item 59 Code = 6
	No shear distress has been observed in structure
Riding Surface:	Minor surface deviations (Field verified and documented)
ADTT (one direction)	5000
Skew:	0°
Effective Flange Width	b_e — LFRD Design 4.6.2.6.1
Minimum of:	
i)	$^1/_4(L)$
ii)	$12t_s +$ greater of either t_w or $1/2\ b_{f\ top}$
iii)	S

i) $\frac{80 \text{ ft}}{4} \times 12 = 240$ in.

ii) $8.5 \text{ ft} \times 12 \text{ in./ft} + 1/2 \times 20 \text{ in.} = 112$ in.

iii) $8 \text{ ft} \times 12 \text{ in./ft} + 6 \text{ in.} = 102$ in. Governs

Effective Flange Width $b_e = 102$ in.

$E_c = 33000\ W_c^{1.5}\sqrt{f'_c}$ — LRFD Design Eq. 5.4.2.4-1

For deck, $E_c = 33000 \times (0.145)^{1.5}\sqrt{4.0} = 3.64 \times 10^3$ ksi

For P/S Beam, $E_c = 33000 \times (0.145)^{1.5}\sqrt{5.0} = 4.07 \times 10^3$ ksi

Modular Ratio, $n = \frac{E_{deck}}{E_{beam}} = \frac{3.64 \times 10^3}{4.07 \times 10^3} = 0.89$

Transformed Width, $b_{trans} = 102 \text{ in.} \times 0.89 = 90.8$ in.

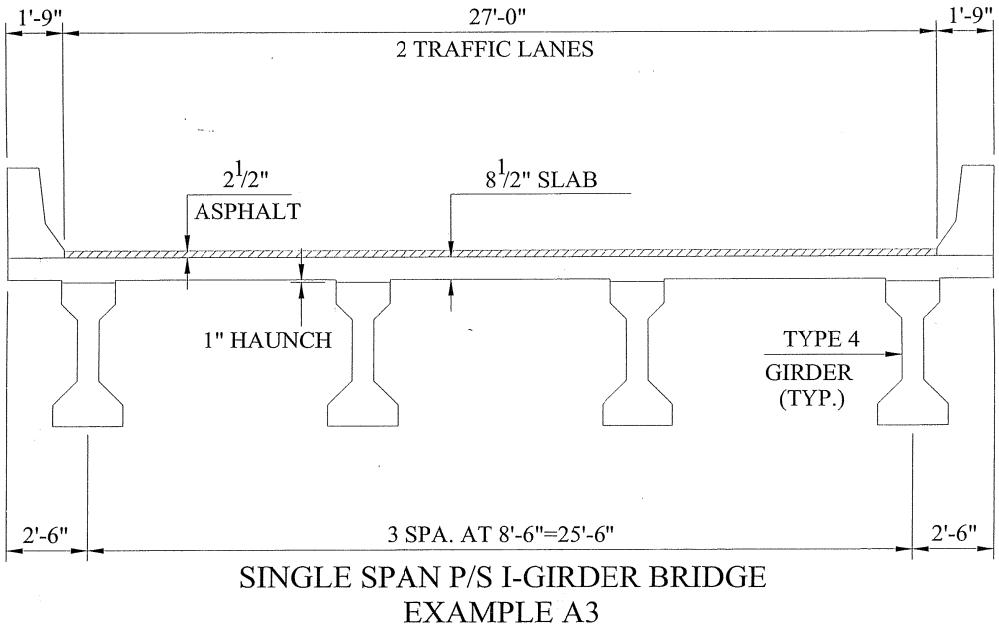

Figure A3.1-1—Cross Section—Single Span Prestressed I-Girder Bridge

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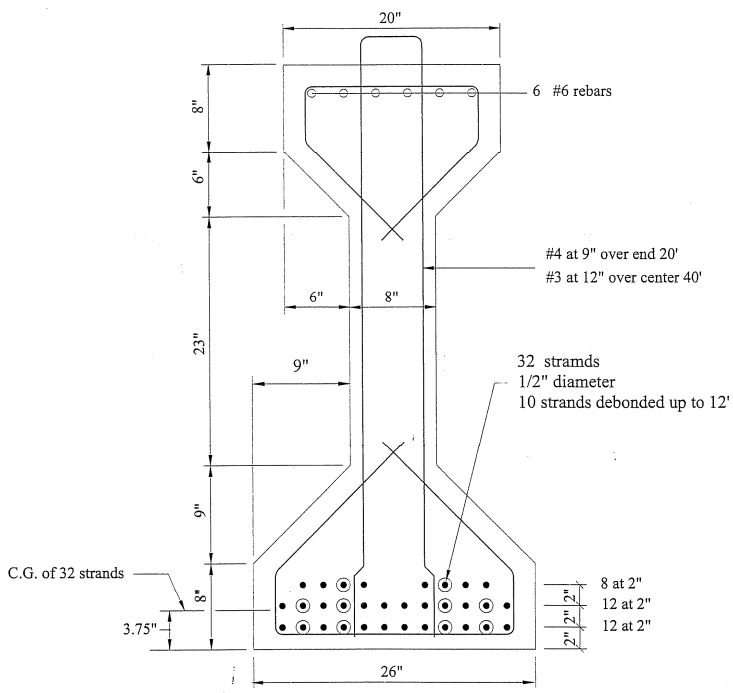

Figure A3.1-2 Cross Section—Interior Girder AASHTO Type 4 I-Girder

A3.2—Summary of Section Properties

Type 4 Girder:

h = 54 in.

A = 789 in.^{2}

I = 260,730 in.^{4}

Y_b = 24.73 in.

S_b = 10,543 in.^{3}

S_t = 8,908 in.^{3}

Composite Section

	Area, in.^{2}	y, in.	Ay	d	Ad^2 in.^{4}	I_0 in.^{4}
P/S beam	789	24.73	19512	17.07	229903	260730
Slab	772	59.25	45741	17.45	235076	4647
Totals	1561		65253		464979	265377

Area slab = 8.5 in. × 90.8 in. = 772 in.^{2} (uses full slab thickness of deck)

y slab = 54 in. + 1 in. + 1/2 × 8.5 in. = 59.25 in. (includes 1-in. haunch)

$\bar{y}$ = 65253 ÷ 1561 = 41.80 in.

d = $y - \bar{y}$

y_{bot} = $\bar{y}$ = 41.80 in. y_{top} = $h - \bar{y}$ = 54 in. – 41.80 in. = 12.20 in.

I_0 slab = $\frac{bh^3}{12} = \frac{90.8 \times (8.5)^3}{12}$ = 4,647 in.^{4}

I_{comp} = $\sum I_0 + \sum Ad^2$ = 464979 + 265377 = 730356 in.^{4}

S_b = $\frac{I}{y_{bot}}$ = 730356 ÷ 41.80 = 17473 in.^{3} (Bottom of Beam)

S_t = $\frac{I}{y_{top}}$ = 730356 ÷ 12.20 = 59865 in.^{3} (Top of Beam)

A3.3—Dead Load Analysis—Interior Girder

A3.3.1—Components and Attachments, *DC*

A3.3.1.1—Noncomposite Dead Loads, DC_1

Girder Self Weight: = 0.822 kip/ft *PCI Design Manual*

Diaphragms: = 0.150 kip/ft

Slab + haunch:

$$\left[\frac{8.5\text{ in.}}{12\text{ in./ft}} \times 8.5\text{ ft} + \frac{1\text{ in.} \times 20\text{ in.}}{144\text{ in.}^2/\text{ft}^2}\right] \times 0.15\text{ kcf} = 0.925\text{ kip/ft}$$

Total per Girder DC_1 = 1.90 kip/ft

$$V_{DC_1} = 1.90\text{ kip/ft} \times \frac{80\text{ ft}}{2} = 76\text{ kip}$$ At support

$$M_{DC_1} = \frac{1}{8} \times 1.90\text{ kip/ft} \times (80\text{ ft})^2 = 1520\text{ kip-ft}$$ At midspan

A3.3.1.2—Composite Dead Load, DC_2

Concrete Barriers: LRFD Design 4.6.2.2.1

Assuming equal distribution among 4 beams

$$(2 \times 0.500\text{ kip/ft}) \div 4 = 0.25\text{ kip/ft}$$

$$V_{DC_2} = 0.25\text{ kip/ft} \times \frac{80\text{ ft}}{2} = 10\text{ kips}$$ At support

$$M_{DC_2} = \frac{1}{8} \times 0.25\text{ kip/ft} \times (80\text{ ft})^2 = 200\text{ kip-ft}$$ At midspan

A3.3.2—Wearing Surface, *DW*

Asphalt Overlay: $\frac{2.5\,\text{in.}}{12\,\text{in./ft}} \times 27\,\text{ft} \times 0.144\,\text{kcf} \div 4\,\text{beams} = 0.203\ \text{kip/ft}$

Overlay thickness was not field measured. Use $\gamma_{DW} = 1.5$

$V_{DW} = 0.203\,\text{kip/ft} \times \frac{80\ \text{ft}}{2} = 8.12\ \text{kips}$ At support

$M_{DW} = \frac{1}{8} \times 0.203\ \text{kip/ft} \times 80^2 = 162\ \text{kip-ft}$ At midspan

A3.4—Live Load Analysis—Interior Girder

A3.4.1—Compute Live Load Distribution Factors, *g*

AASHTO LRFD Type (k) cross-section LRFD Design Table 4 4.6.2.2.1-1

Longitudinal Stiffness Parameter, K_g:

$K_g = n\,(I + Ae_g^{\,2})$

$n = \frac{E_B}{E_D} = \frac{4.07 \times 10^3\ \text{ksi}}{3.64 \times 10^3\ \text{ksi}} = 1.12$

$A = 789\ \text{in.}^4$

$I = 260730\ \text{in.}^4$

$L = 80\ \text{ft}$

$t_s = 8.5\ \text{in.}$

e_g = girder depth – Y_b + haunch + $t_s/2$

$= (54 - 24.73) + 1 + \frac{8.5}{2}$

$= 34.52\ \text{in.}$

$K_g = 1.12\,(260730 + 789 \times 34.52^2)$

$= 1345038\ \text{in.}$

$\frac{K_g}{12\,Lt_s^{\,3}} = \frac{1345038}{12 \times 80 \times 8.5^3} = 2.28$

A3.4.1.1—Distribution Factor for Moment, g_m (LRFD Design Table 4.6.2.2.2b-1)

One Lane Loaded:

$$g_{m1} = 0.06 + \left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$$

$$= 0.06 + \left(\frac{8.5}{14}\right)^{0.4}\left(\frac{8.5}{80}\right)^{0.3}(2.28)^{0.1}$$

$$= 0.514$$

Two or More Lanes Loaded:

$$g_{m2} = 0.075 + \left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12.0Lt_s^3}\right)^{0.1}$$

$$= 0.075 + \left(\frac{8.5}{9.5}\right)^{0.6}\left(\frac{8.5}{80}\right)^{0.2}(2.28)^{0.1}$$

$$= 0.724 > 0.514$$

Use $g_m = 0.724$

A3.4.1.2—Distribution Factor for Shear, gv (LRFD Design Table 4.6.2.2.3a-1)

One Lane Loaded:

$$g_{v1} = 0.36 + \frac{S}{25}$$

$$= 0.36 + \frac{8.50}{25}$$

$$= 0.70$$

Two or More Lanes Loaded:

$$g_{v2} = 0.2 + \left(\frac{S}{12}\right) - \left(\frac{S}{35}\right)^2$$

$$= 0.2 + \left(\frac{8.5}{12}\right) - \left(\frac{8.5}{35}\right)^2$$

$$= 0.849 > 0.70$$

use $g_v = 0.849$

A3.4.2—Compute Maximum Live Load Effects

A3.4.2.1—Maximum Design Live Load (HL-93)—Moment at Midspan

Note: The general rule for simple spans carrying moving concentrated loads states that the maximum bending moment produced by moving concentrated loads occurs under one of the loads when that load is as far from one support as the center of gravity of all the moving loads on the beam is from the other support. It should be understood that locating the precise critical section and load position for rating depends on the combined influence of dead load, live load, member capacity and load factors that make up the general Rating Factor equation. For simplicity and illustrative purposes only, the moment at midspan is used to closely approximate the maximum moment. See also Example A1, which illustrates that for a beam with a constant section capacity throughout the maximum moment region and a long span, the resulting rating factor obtained by a refined analysis yields only a small difference compared to the rating factor obtained from the maximum moment approximated at midspan.

Calculated by statics with the load centered at midspan:

Design Lane Load Moment = $0.64 \text{ klf} \times \dfrac{(80 \text{ ft})^2}{8} = 512 \text{ kip-ft}$

Design Truck Moment = $\dfrac{\left(8^k + 32^k\right) \times 40 \text{ ft} \times 26 \text{ ft}}{80 \text{ ft}} + \dfrac{32^k \times 80 \text{ ft}}{4} = 1160 \text{ kip-ft}$ Governs

Tandem Axles Moment = $25^k \times 38 \text{ ft} = 950 \text{ kip-ft}$

$IM = 33\%$ LRFD Design Table 3.6.2.1-1

$M_{LL+IM} = 512 + 1160 \times 1.33$

$= 2054.8 \text{ kip-ft}$

Distributed Live Load Moment at Midspan:

$$\begin{aligned} M_{LL+IM} &= 2054.8 \times g_m \\ &= 2054.8 \times 0.724 \\ &= 1487.7 \text{ kip-ft} \end{aligned}$$

A3.5—Compute Nominal Flexural Resistance at Midspan

$$f_{ps} = f_{pu}\left(1 - k\frac{c}{d_p}\right)$$ LRFD Design Eq. 5.7.3.1.1-1

k = 0.28 for low-relaxation strands

f_{pu} = 270 ksi

d_p = distance from extreme compression fiber to the centroid of the prestressing tendons

	Strands	y	Strands × y
Layer 1	12	2	24
Layer 2	12	4	48
Layer 3	8	6	48
Total	32		120

$\bar{y} = \dfrac{strands \times y}{strands} = \dfrac{120}{32}$

$\bar{y}$ = 3.75 in. distance from bottom of girder to centroid of prestressing strands

$d_p = (54+1+8.5)-3.75 = 59.75$ in.

c = distance from the neutral axis to the compressive face

To compute *c,* assume rectangular section behavior. (Neglect any nonprestressed reinforcement.)

Given A_{ps} = 0.153 in.^{2} for $^1/_2$-in. diameter Low-Relaxation strands:

$$c = \frac{A_{ps} f_{pu}}{0.85 f_c' \beta_1 b + k A_{ps} \dfrac{f_{pu}}{d_p}}$$ LRFD Design Eq. 5.7.3.1.1-4

A_{ps} = = 4.896 in.2

b = be = 102 in.2 (Effective Flange Width of Deck)

f'_c = 4.0 ksi (Deck Concrete Strength)

β_1 = 0.85

$$c = \frac{4.896\text{ in.}^2 \times 270\text{ksi}}{0.85 \times 4.0\text{ksi} \times 0.85 \times 102\text{in.} + 0.28 \times 4.896\text{in.}^2 \times \dfrac{270\text{ksi}}{59.75\text{in.}}}$$ LRFD Design 5.7.2.2

$a = \beta_1 c = 0.85 \times 4.39 = 3.73$ in. < ts = 8.5 in. LRFD Design 5.7.2.2

Therefore, the rectangular section behavior assumption is valid.

$$f_{ps} = 270\left(1 - 0.28 \times \frac{4.39}{59.75}\right)$$
$$= 264.4 \text{ ksi}$$

Nominal Flexural Resistance (Midspan): LRFD Design Eq. 5.7.3.2.2-1

$$M_n = A_{ps} f_{ps}\left(d_p - \frac{a}{2}\right)$$
$$= 4.896 \times 264.4\left(59.75 - \frac{3.73}{2}\right)\frac{1}{12}$$
$$= 6244.4 \text{ kip-ft}$$

A3.6—Maximum Reinforcement 6A.5.6

The factored resistance (φ factor) of compression controlled sections shall be reduced in accordance with LRFD Design Article 5.5.4.2.1. This approach limits the capacity of over-reinforced (compression controlled) sections. C6A.5.6

The net tensile strain, ε_t, is the tensile strain at nominal strength and determined by strain compatibility using similar triangles. LRFD Design C5.7.2.1

Given an allowable concrete strain of 0.003 and depth to neutral axis c = 4.39 in. and a depth from the extreme concrete compression fiber to the center of gravity of the prestressing strands d_p = 59.75 in. LRFD Design C5.7.2.1

$$\frac{\varepsilon_c}{c} = \frac{\varepsilon_t}{d-c}$$

$$\frac{0.003}{4.39 \text{ in.}} = \frac{\varepsilon_t}{59.75 \text{ in.} - 4.39 \text{ in.}}$$

$$\varepsilon_t = 0.0378$$

For ε_t = 0.0378 > 0.005, the section is tension controlled and Resistance Factor φ shall be taken as 1.0. LRFD Design 5.7.2.1, 5.5.4.2

$$P_{pe} = A_{ps} f_{pe}$$

Total Prestress Losses $\Delta f_{pT} = \Delta f_{pES} + \Delta f_{pLT}$ immediately before transfer LRFD Design Eq. 5.9.5.1-1

Effective Prestress f_{pe} = Initial Prestress – Total Prestress Losses

A3.7—Minimum Reinforcement 6A.5.7

Amount of reinforcement must be sufficient to develop M_r equal to the lesser of: LRFD Design 5.7.3.3.2

1.2 M_{cr} or 1.33 M_u

Load	Load Factor, γ
DC	1.25
DW	1.50
LL	1.75

LRFD Design Tables 3.4.1-1, 3.4.1-2

M_R = φM_n = (1.0) (6244.4) = 6244.4 kip-ft

1. $1.33M_u$ = 1.33 [1.75 (1487.7) + 1.25 (1520 + 200) + 1.5 (162)]

= 6645.3 kip-ft > 6244.4 kip-ft No Good

2. M_{cr} = $S_c\left(f_r + f_{cpe}\right) - M_{dnc}\left(\frac{S_c}{S_{nc}} - 1\right) \geq S_c f_r$ 6A.5.7, LRFD Design Eq. 5.7.3.3.2-1

M_{dnc} = M_{DC1} = 1520 kip-ft

S_c = 17473 in.^{3}

S_{nc} = 10543 in.^{3}

Modulus of Rupture $f_r = 0.37\sqrt{f'_c}$ LRFD Design 5.4.2.6

= $0.37\sqrt{5}$ = 0.827 ksi

f_{cpe} = compressive stress in concrete due to effective prestress force (after allowance for all prestress losses) at extreme fiber of section where tensile stress is caused by externally applied loads.

$$f_{cpe} = \frac{P_{pe}}{A} + \frac{P_{pe}e}{S_b}$$

where P_{pe} = Effective Prestress Force

A3.7.1—Determine Effective Prestress Force, P_{pe}

$$P_{pe} = A_{ps} f_{pe}$$

Total Prestress Losses $\Delta f_{pT} = \Delta f_{pES} + \Delta f_{pLT}$ immediately before transfer — LRFD Design Eq. 5.9.5.1-1

Effective Prestress f_{pe} = Initial Prestress – Total Prestress Losses

A3.7.1.1—Loss Due to Elastic Shortening and/or External Loads, Δf_{pES} — LRFD Design 5.9.5.2.3a

$$\Delta f_{pES} = \frac{E_p}{E_{ct}} f_{cgp}$$

$$f_{cgp} = \frac{P_i}{A} + \frac{P_i e^2}{I} - \frac{M_D e}{I}$$

Initial Prestress immediately prior to transfer = $0.75 f_{pu}$ for low-relaxation prestressing strands — LRFD Design Table 5.9.3-1

For estimating P_i immediately after transfer, use $0.90(0.75 f_{pu})$ — LRFD Design 5.9.5.2.3a

P_i = $0.90 \times (0.75 \times 270 \text{ ksi})\ 32 \times 0.153$

= 892.3 kips

M_D = Moment due to Self-Weight of Member at Section of Maximum Moment (Midspan)

= $\frac{1}{8} \times 0.822 \times 80^2$

= 657.6 kip-ft

Y_b = 24.73 basic beam section

$\bar{y}$ = 3.75 in. distance from bottom of girder to centroid of prestressing strands

e = 24.73 – 3.75 = 20.98 in.

P_i = 0.90 × (0.75 × 270 ksi) 32 × 0.153

eccentricity of P/S strands from *CG* of beam

LRFD Design 5.4.4.2

$$f_{cgp} = \frac{892.3}{789} + \frac{892.3 \times 20.98^2}{260741} - \frac{657.6 \times 12 \times 20.98}{260741}$$

$$= 1.131 + 1.506 - 0.635$$

$$= 2.002 \text{ ksi}$$

$$E_p = 28500 \text{ ksi}$$

LRFD Design Eq. 5.4.2.4-1

$$E_{ct} = 33000(w_c)^{1.5}\sqrt{f'_{ci}}$$

$$= 33000\ (0.145)^{1.5}\sqrt{4.0}$$

$$= 3644 \text{ ksi}$$

LRFD Design Eq. C5.9.5.2.3a-1

$$\Delta f_{pES} = \frac{28500}{3644} \times 2.002$$

$$= 15.658 \text{ ksi}$$

A3.7.1.2—Approximate Lump Sum Estimate of Time-Dependent Losses, Δf_{pLT}

Time-dependent losses include shrinkage of concrete, creep of concrete, and relaxation of steel. For refined estimates:

LRFD Design Eq. 5.9.5.4.1-1

$$\Delta f_{pLT} = \left(\Delta f_{pSR} + \Delta f_{pCR} + \Delta f_{pR1}\right)_{id} + \left(\Delta f_{pSD} + \Delta f_{pCD} + \Delta f_{pR} - \Delta f_{pSS}\right)_{df}$$

for I-Girders, time-dependent losses can be approximated by: LRFD Design 5.9.5.3

LRFD Design Eq. 5.9.5.3-1

$$\Delta f_{pLT} = 10.0\frac{f_{pi}A_{ps}}{A_g}\gamma_h\gamma_{st} + 12.0\gamma_h\gamma_{st} + \Delta f_{pR}$$

where $\gamma_h = 1.7 - 0.01H$ LRFD Design Eq. 5.9.5.3-2

Assuming a relative humidity H ranging between 40 to 100 percent.

For this example, assume H = 70% or refer to LRFD Design Figure 5.4.2.3.3-1

$$\gamma_h = 1.7 - 0.01(70) = 1.0$$

and: LRFD Design Eq. 5.9.5.3-3

$$\gamma_{st} = \frac{5}{1 + f'_{ci}}$$

$$\gamma_{st} = \frac{5}{1+4} = 1.0$$

and:

Δf_{pR} = an estimate of relaxation loss

$$\Delta f_{pR} = 2.5 \text{ ksi}$$

and:

$$\Delta f_{pi} = 0.75 \times 270 \text{ ksi} = 202.5 \text{ ksi}$$

then:

$$\Delta f_{pLT} = 10.0 \times \frac{202.5 \times (32 \times 0.153)}{789} \times 1.0 \times s1.0 + 12.0 \times 1.0 \times 1.0 + 2.5$$

$$\Delta f_{pLT} = 27.07 \text{ ksi}$$

A3.7.1.3—Total Prestress Losses, Δf_{pT}

$$\Delta f_{pT} = \Delta f_{pES} + \Delta f_{pLT}$$

LRFD Design Eq. 5.9.5.1-1

$$= 15.658 + 27.07$$

$$= 42.73 \text{ ksi}$$

$$f_{pe} = \text{Initial Prestress} - \text{Total Prestress Losses}$$

$$= 0.75 \times 270 - 42.73 = 159.77 \text{ ksi}$$

$$P_{pe} = 159.77 \times 32 \times 0.153$$

$$= 782.2 \text{ kips}$$

Substitute in:

$$f_{pb} = \frac{P_{pe}}{A} + \frac{P_{pe}e}{S_b}$$

$$= \frac{782.2}{789} + \frac{(782.2)(20.98)}{10543}$$

$$= 2.548 \text{ ksi}$$

$$M_{cr} = S_c\left(f_r + f_{cpe}\right) - M_{dnc}\left(\frac{S_c}{S_{nc}} - 1\right) \geq S_c f_r$$ LRFD Design Eq. 5.7.3.3.2-1

$$S_c\left(f_r + f_{cpe}\right) - M_{dnc}\left(\frac{S_c}{S_{nc}} - 1\right) =$$

$$\frac{17473}{12}(0.827 + 2.548) - 1520\left(\frac{17473}{10543} - 1\right) = 3915.2 \text{ kip-ft}$$

$$S_c f_r = \frac{17473}{12} \times 0.827 = 1204 \text{ kip-ft}$$

Therefore, $M_{cr} =$ 3915.2 kip-ft and:

$1.2 \times M_{cr} = 1.2 \times 3915.2 \text{ kip-ft} = 4698.2 \text{ kip-ft}$

$1.33 M_u = 6645.3$ kip-ft (previously calculated)

$1.2 \times M_{cr} < 1.33\ M_u$ therefore, $1.2 \times M_{cr}$ governs

$M_r = 6244.4$ kip-ft (previously calculated)

$M_r = 6244.4 \text{ kip-ft} > 4698.2 \text{ kip-ft}$ OK 6A.5.7

The minimum reinforcement check is satisfied.

A3.8—Compute Nominal Shear Resistance at First Critical Section

Article 6A.5.9 of this Manual does not require a shear evaluation for the design load and legal loads if the bridge shows no visible sign of shear distress and for permit loads resulting in factored force effects less than the factored design load force effects. The calculations shown below are for the special permit load shown in Example A1, Figure A1A.1.10-1.

Shear Location:

Critical section for shear near the supports is the greater of d_v or $0.5d_v \cot \theta$ from the face of support. LRFD Design 5.8.3.2

Effective Shear Depth, d_v: LRFD Design 5.8.2.9

Maximum of:

i) distance between resultants of the tensile and compressive forces

ii) $0.9d_e$

iii) $0.72h$

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The first critical section will, by inspection, be within the 12-ft debonded end region. Ten strands have been debonded at the ends.

$$c = \frac{A_{ps} f_{pu}}{0.85 f'_c \beta_1 b + k A_{ps} \dfrac{f_{pu}}{d_p}}$$ LRFD Design Eq. 5.7.3.1.1-4

A_{ps} = $(32-10)(0.153) = 3.366 \text{ in}^2$

b = b_e = 102 in. (Effective flange width of deck)

β_1 = 0.85

f'_c = 4.0 ksi (Deck concrete strength)

k = 0.28 for low-relaxation strands

f_{pu} = 270 ksi

	Strands	y	Strands × y
Layer 1	8	2	16
Layer 2	8	4	32
Layer 3	6	6	36
Total	22		84

$$\bar{y} = \frac{\text{strands} \times y}{\text{strands}} = \frac{84}{22}$$

distance from bottom of beam to 22 strand centroid = 3.82 in.

d_p = $(54 + 1 + 8.5) - 3.82 = 59.68$ in.

$$c = \frac{3.366 \text{ in.}^2 \times 270 \text{ ksi}}{0.85 \times 4.0 \text{ ksi} \times 0.85 \times 102 \text{ in.} + 0.28 \times 3.366 \text{ in.}^2 \times \dfrac{270 \text{ ksi}}{59.68 \text{ in.}}}$$

c = 3.04 in. $a = \beta_1 c = 2.58$ in.

d_v = $59.68 - \dfrac{2.58}{2} = 58.4$ in.

For establishing the critical shear section assume: θ = 30°, a high assumption is conservative.

$$0.5 d_v \cot\theta = (0.5)\ (d_v)\ (\cot 30°)$$
$$= 0.87 d_v < d_v$$

Distance from face of support to centerline of bearing = 6 in. (12-in. bearing pads)

Distance from centerline of bearing to critical shear section:

= 58.4 in. + 6 in. LRFD Design 5.11.4

= 64.4 in.

= 5.37 ft

A3.8.1—Maximum Shear at Critical Section Near Supports

Calculated by statics with the loads applied no closer than 5.37 ft from the supports

$$V_{PERMIT} = \frac{21^k(74.63\,ft + 70.63\,ft + 66.63\,ft + 62.63\,ft + 58.63\,ft) + 23^k(48.63\,ft + 44.63\,ft + 40.63\,ft) + 18^k(36.63\,ft + 32.63\,ft) + 10^k(2}{80\,ft}$$

$$= 144.5\,kips$$

Total Shear = $V_{PERMIT} \times 1.20$ = 173.4 kips

For Special Permits, use single lane distribution factor divided by 1.2:

Distributed V_{LL+IM} = 173.4 kips × 0.70/1.2 = 101.1 kips

From Analysis, Distributed V_{LL+IM} for HL-93 = 85.3 kips. Factored Permit Load Shear: $V_{u,LL+IM,Permit}$ = 1.6 × 101.1 = 161.8 kips. Factored Design Load Shear: $V_{u,LL+IM,HL-93}$ = 1.75 × 85.3 = 149.3 kips. Therefore, shear must be checked for permit load. 6A.5.9

Dead Load Shears:

From A3.3.1, DC_1 = 1.90 kip/ft and DC_2 = 0.25 kip/ft

From A3.3.2, DW = 0.203 kip/ft

V_{DC} = (1.90 klf + 0.25 klf)(0.5 ×80 ft – 5.37 ft) = 74.5 kips

V_{DW} = (0.203 klf) (0.5 ×80 ft – 5.37 ft) = 7.03 kips

A3.8.2—Compute Nominal Shear Resistance

The nominal shear resistance V_n shall be the lesser of:

$V_n = V_s + V_c + V_p$ LRFD Design Eqs. 5.8.3.3-1, 5.8.3.3-2

$V_n = 0.25 f_c' b_v d_v + V_p$

$V_p = 0.0$ as straight tendons are provided

Critical section for shear near the support is at 64.4 in. from centerline of bearing (within the debonded length). Transverse reinforcement provided at critical section: #4 vertical stirrups at 9-in. spacings.

Minimum Transverse Reinforcement LRFD Design 5.8.2.5

effective web width, b_v = 8 in.

stirrup spacing, s = 9 in.

Grade 60 rebar, f_y = 60 ksi

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$V_{TANDEM} = 25^k \times \frac{(74.63\text{ ft}+70.63\text{ ft})}{80\text{ ft}} = 45.4$

$V_{TRUCK} = \frac{32^k(74.63\text{ ft}+60.63\text{ ft})+8^k(46}{80\text{ ft}}$

$V_{LANE} = \frac{0.64\text{ klf}(74.63\text{ ft})^2}{2\times 80\text{ ft}} = 22.3$ kips

$IM = 33\%$

¶

= 45.4 kips

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$A_v = 0.0316\sqrt{f_c'}\dfrac{b_v s}{f_y}$

$= 0.0316\sqrt{5}\dfrac{(8)(9)}{60}$

$= 0.0815$ in.²

Area provided 2 legs × 0.20 in.^{2} = 0.40 in.^{2} > 0.0815 in.^{2} OK

$V_c = 0.0316\beta\sqrt{f_c'}b_v d_v$ LRFD Design Eq. 5.8.3.3-3

$V_s = \dfrac{A_v f_y d_v \cot\theta}{s}$ for α= 90° LRFD Design Eq. 5.8.3.3-4

$0.25 f_c' b_v d_v + V_p = 0.25 \times 5.0 \times 8\text{in.} \times 58.4\text{in.} + 0.0 = 584$ kips LRFD Design Eq. 5.8.3.3-2

These equations are based on the Modified Compression Field Theory (MCFT) and require the determination of β and θ by detailed analysis. A simplified analysis using θ = 45° and β = 2.0 may be utilized for an initial evaluation before resorting to the MCFT, if necessary, for likely improved shear capacity. C6A.5.9

A3.8.2.1—Simplified Approach

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θ = 45° β = 2.0

Concrete: $V_c = 0.0316\beta\sqrt{f_c'}b_v d_v$

Effective Web Width: $b_v = 8$ in.

Effective Shear Depth: $d_v = 58.4$ in.

$V_c = (0.0316)(2.0)\sqrt{5.0}(8)(58.4)$

$= 66.0$ kips

Steel:

$V_s = \dfrac{A_v f_y d_v \cot\theta}{s}$

#4 at 9 in.

$A_v = 2 \times 0.20 = 0.40$ in.^{2}

$V_s = \dfrac{(0.40)(60)(58.4)(\cot 45)}{9}$

$= 155.7$ kips

Total Nominal Shear Resistance, V_n:

$V_c + V_s + V_p = 66.0 + 155.7 + 0.0 = 221.7$ kips

221.7 kips < 584 kips, $\therefore$ V_n = 221.7 kips

φV_n = 0.9 × 221.7= 199.5 kips

Maximum distributed shears at critical section (Strength II Permit Loading):

V_{LL+IM} = 101.1 kips

V_{DC} = 74.5 kips

V_{DW} = 7.03 kips

Load	Load Factor γ
DC	1.25
DW	1.50
LL	1.60

LRFD Design Tables 3.4.1-1, 3.4.1-2

Factored Shear:

$$V_u = (1.60)(101.1) + (1.25)(74.5) + (1.5)(7.03)$$
$$= 265.4\,kips > 199.5 kips \qquad No\ Good$$

Try MCFT approach.

A3.8.2.2—MCFT Approach

LRFD Design Eq. 5.8.2.9-1

Shear stress on the concrete:

$$v = \frac{V_u - \varphi V_p}{\varphi b_v d_v}$$
$$= \frac{265.4}{(0.9)(8)(58.4)} = 0.631 ksi$$

$$\frac{v}{f_c'} = \frac{0.601}{5.0} = 0.126 < 0.25$$

OK

At First Critical Section for Shear (64.4 in. from centerline of bearing)

Live Load Moments at first critical section determined by statics:

From Analysis: M_{PERMIT} =772.5 kip-ft

M_{LL+IM} = 1.20 × 772.5 kip-ft = 927 kip-ft

Impact = 20% Field Verified riding surface with minor surface deviations or depressions

Distributed Moment:

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$= 252.8$ kips > 199.5 kips < 252

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$$v = \frac{V_u - \varphi V_p}{\varphi b_v d_v}$$
$$= \frac{252.8}{(0.9)(8)(58.4)} = 0.601 \text{ ksi}$$

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$$\frac{32^k \times 5.37 \text{ ft}(74.63 \text{ ft} + 60.63 \text{ ft}) + 8^k \times 5.37}{80 \text{ ft}}$$
= 315.6

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$$0.64 \text{klf} \times \frac{(74.63 \text{ ft})^2}{2 \times 80 \text{ ft}} \times 5.37 \text{ ft} = 119.6$$
kip-ft¶

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$$g_m \times M_{LL+IM} = \frac{0.514}{1.2} \times 927 = 397.1\,kip - ft$$

Dead Load Moments at First Critical Section for Shear:

M_{DC} = 0.5 (1.90 klf + 0.25 klf) (5.37 ft) (80 ft – 5.37 ft) = 430.8 kip-ft

M_{DW} = 0.5 (0.203 klf) (5.37 ft) (80 ft – 5.37 ft) = 40.7 kip-ft

Load	Load Factor, γ
DC	1.25
DW	1.50
LL	1.60

LRFD Design Table 3.4.1-2 and MBE Table 6A.4.5..4.2a-1

Factored Moment:

$$M_u = (1.6)(397.1) + (1.25)(430.8) + (1.50)(40.7)$$
$$= 1234.9\,kip - ft$$

Following the approach in the LRFD Shear Design Flowchart and LRFD Design Table 5.8.3.4.2-1:

LRFD Design Figure C5.8.3.4.2-5

Transfer Length 60 strand diameters = 30 in. < 64.4 in.

As the section is outside the transfer length, the full value of f_{po} is used in calculating the shear resistance.

The Modified Compression Field Theory (MCFT) follows an iterative process:

$\frac{v}{f_c'} = 0.126$ (≤ 0.150, row 4 of LRFD Table B5.2-1)

LRFD Design Figure C5.8.3.4.2-5, LRFD Design Table B5.2-1

Assume $\varepsilon_x \le -0.10 \times 10^{-3}$ $(\varepsilon_x \times 1000 \le -0.10)$

From LRFD Design Table B5.2-1 (row 4, column 2) :

$\theta = 23.3°$ $\beta = 2.79$

Calculate ε_x:

LRFD Design Eq. 5.8.3.4.2-1

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LRFD Design 5.8.3.4.2

$$\varepsilon_x = \frac{\frac{|M_u|}{d_v} + 0.5N_u + 0.5|V_u - V_p|\cot\theta - A_{ps}f_{po}}{2(E_sA_s + E_pA_{ps})} \le 0.001$$

A_{ps} = 22 × 0.153 = 3.366 in.^{2}

f_{po} = $0.7f_{pu}$ = 0.7 × 270 = 189 ksi

$$\varepsilon_x = \frac{\frac{|12\times1234.9|}{58.4} + 0.5|265.4|(\cot 23.3°) - (3.366)(189)}{2(0+28500\times3.366)}$$

$$= -0.387\times10^{-3}$$

If ε_x is negative, it must be recalculated including concrete stiffness.

LRFD Design Figure 5.8.3.4.2-1

A_c = Area below $h/2$
= (8)(26) + 1/2 (8 + 26)(9) + (10)(8)
= 441 in.^{2}

LRFD Design Eq. 5.8.3.4.2-3

$$\varepsilon_x = \frac{\frac{|M_u|}{d_v} + 0.5N_u + 0.5|V_u - V_p|\cot\theta - A_{ps}f_{po}}{2(E_cA_c + E_sA_s + E_pA_{ps})}$$

$$\varepsilon_x = \frac{\frac{|12\times1234.9|}{58.4} + 0.5|265.4|(\cot 23.3°) - (3.366)(189)}{2[(4030)(441) + 0 + 28500\times3.366]}$$

$$= -0.02\times10^{-3} > assumed\ \varepsilon_x \le -0.10\times10^{-3}$$

Assume $\varepsilon_x \le 0$

From LRFD Design Table 5.8.3.4.2-1 (row 3, column 4):

$\theta = 25.0°$ $\beta = 2.72$

Calculate ε_x:

$$\varepsilon_x = \frac{\frac{|12\times1234.9|}{58.4} + 0.5|265.4|(\cot 25.0°) - (3.366)(189)}{2[(4030)(441) + 0 + 28500\times3.366]}$$

= -0.026×10^{-3} < assumed $\varepsilon_x \le 0$ OK

Note $-0.026 \times 10^{-3} > -0.05 \times 10^{-3}$ (adjacent column), ∴ no further iterations needed.

Calculate V_n:

LRFD Design Eq. 5.8.3.3-3

$$V_c = 0.0316\beta\sqrt{f'_c}b_vd_v$$
$$= (0.0316)(2.72)\sqrt{5}(8)(58.4)$$
$$= 89.79 kips$$

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$$\frac{\frac{|M_u|}{d_v} + 0.5N_u + 0.5|V_u - V_p|\cot\theta - A_{ps}f_{po}}{2(E_sA_s + E_pA_{ps})} \le$$
¶
A_{ps} = . 22 × 0.153 = 3.366 in.^{2}¶
f_{po} = . $0.7f_{pu}$ = 0.7 × 270 = 189 ksi¶
ε_x = .
$$\frac{\frac{|12\times1282.9|}{58.4} + 0.5|252.8|(\cot 21.9°) - (3.366}{2(0+28500\times3.366)}$$
¶
. = . -0.303×10^{-3}

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$\varepsilon_x = \frac{\frac{12\times1282.9}{58.4} + (0.5)(252.8)(c}{2[(4030)(441) + 0 +}$
$= -0.016\times10^{-3}$ > assumed ε_x
¶

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Deleted: $\frac{\frac{12\times1282.9}{58.4} + (0.5)(252.8)(\cot 23.7}{2[(4030)(441) + 0 + (2850(}$

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$= (0.0316)(2.87)\sqrt{5}(8)(58.4)$
$= 94.75$ kips

$$V_s = \frac{A_v f_y d_v \cot\theta}{s} = \frac{(0.39)(60)(58.4)(\cot 25.0)}{9} = 325.6\ kips$$

LRFD Design Eq. 5.8.3.3-4

Deleted: $V_s = \frac{A_v f_y d_v \cot\theta}{s} = \frac{(0.39)(60)(58.4)(\cot 23.7°)}{9} = 345.9$ kips

Total Nominal Shear Resistance:

$$V_n = V_c + V_s = 89.79 + 325.6 = 415.4 kips$$

LRFD Design Eq. 5.8.3.3-1

Deleted: $V_n = V_c + V_s = 94.75 + 345.9 = 440.7$ kips

(versus 217.8 by simplified method)

$0.25 f_c' b_v d_v + V_p = 584$ kips (previously calculated)

LRFD Design Eq. 5.8.3.3-1

415.4 kips < 584 kips, ∴ V_n = 415.4 kips

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φV_n = 0.9 x 415.4 = 373.9 kips

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A3.8.2.3—Check Longitudinal Reinforcement (LRFD Design 5.8.3.5)

Tensile capacity of the longitudinal reinforcement on the flexural tension side of the member shall be proportioned to satisfy LRFD Design Eq. 5.8.3.5-1. "Any lack of full development shall be accounted for."

$$A_{ps} f_{ps} + A_s f_y \geq \frac{|M_u|}{d_v \varphi_f} + 0.5\frac{N_u}{\varphi_c} + \left[\left|\frac{V_u}{\varphi_v} - V_p\right| - 0.5 V_s\right]\cot\theta$$

LRFD Design Eq. 5.8.3.5-1

Calculate minimum required tensile capacity:

$$V_s = 354.8 kips > \frac{V_u}{\varphi} = \frac{265.4}{0.9} = 294.9 \quad use\ 294.9\ kips$$

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The right side of LRFD Design Eq. 5.8.3.5-1 yields:

Deleted: 354.8 kips > $\frac{V_u}{\varphi} = \frac{252.8}{0.9} = 280.9$ use 280.9 ¶

$$= \frac{|(1234.9)(12)|}{(58.4)(1.0)} + \left(\left|\frac{265.4}{0.9}\right| - 0.5(294.9)\right)\cot 23.7°$$

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$$= 569.9 \text{ kips}$$

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Deleted: 578.0 kips

Transfer Length:

LRFD Design 5.11.4.1

ℓ_t = 60 strand diameters

= 60 × 0.5 in.= 30 in.

Development Length:

LRFD Design Eq. 5.11.4.2-1

$$\ell_d \geq k(f_{ps} - 2/3 f_{pe}) d_b$$

where k = 1.6 for pretensioned members with a depth greater than 24.0 in.

$$\ell_d \geq 1.6 \times (264.4 - \frac{2}{3} \times 159.77) \times 0.5 = 126.3 \text{in}$$

The 22 effective strands at the critical shear section are bonded over the full length of the beam. The section at 64.4 in. from centerline of the bearing is between the transfer length (30 in. from end of beam, 24 in. from centerline of bearing) and the development length (126.3 in. from end of beam, 120.3 in. from centerline of bearing). Use a linear growth in strand capacity from f_{pe} at the transfer length to f_{ps} at the development length.

LRFD Design 5.11.4.3
LRFD Design 5.11.4.1

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ℓ_{px} = 64.4 in. to critical section

LRFD Design Eq. 5.11.4.2-3

$$f_{px} = f_{pe} + \frac{\ell_{px} - 60d_b}{\ell_d - 60d_b}(f_{ps} - f_{pe})$$

$$f_{px} = 159.77 + \frac{64.4 - 30}{126.3 - 30}(264.4 - 159.77) = 197.15$$

The left side of LRFD Design Eq. 5.8.3.5-1 yields:

$$= f_{px} \times A_{ps} = 197.15 \text{ ksi} \times 3.366 \text{ in.}^2 = 663.6 \text{ kips}$$

$$A_{ps}f_{ps} + A_s f_y \geq \frac{|M_u|}{d_v \varphi_f} + 0.5\frac{N_u}{\varphi_c} + \left[\left|\frac{V_u}{\varphi_v} - V_p\right| - 0.5V_s\right]\cot\theta \text{ reduces to}$$

663.6 kips ≥ 569.9 kips OK

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A3.9—Compute Nominal Shear Resistance at Stirrup Change/ Quarter Point (6A.5.9) C6A.5.9

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Multiple locations need to be checked for shear. Typically, locations near the quarter point could be critical because earlier design methods allowed a reduction in transverse reinforcement that is more than allowed by the AASHTO LRFD. Check for Permit Load only as no visible shear distress exists.

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(20 ft from centerline of bearing)

Effective Shear Depth, d_v, is based upon 32 strands.

→ check transfer length LRFD Design 5.11.4

60 strand diameters = 30 in.

debonded length = 12 ft

All 32 strands are bonded at: 12 ft + 30 in. = 14.5 ft < 20 ft OK

LRFD Design 5.8.2.9

$$d_v = d_e - \frac{a}{2}$$

$$d_e = h - \bar{y} = 63.5 - 3.75 = 59.75 \text{ in.}$$

$$d_v = d_e - \frac{a}{2}$$

a = 3.73 in. (from Article A3.5 of this example)

d_v need not be less than the greater of minimum effective shear depth limits $0.9d_e$ or $0.72h$.

$$d_v = 57.89 \text{ in.} > 0.9d_e = 53.78 \text{ in.}$$

$> \quad 0.72h = 45.72$ in.

If we base d_v on:

LRFD Design Eq. C5.8.2.9-1

$$d_v = \frac{M_n}{A_s f_y + A_{ps} f_{ps}}$$

including the effects of development, then:

$$d_v = \frac{6244.4 \text{ kip-ft} \times 12 \text{ in./ft}}{0 + \left(32 \times 0.153 \text{ in.}^2\right) 264.4 \text{ ksi}} = 57.89 \text{ in.}$$

A3.9.1—Maximum Shear at Stirrup Change

(20 ft from centerline of bearing)

for Permit loading

Calculated by statics with the loads applied no closer than 20 ft from the support

$$V_{PERMIT} = \frac{\left\{\begin{array}{l} 21^k(60ft + 56ft + 52ft + 48ft + 44ft) + \\ 23^k(34ft + 30ft + 26ft) + 18^k(22ft + 18ft) + 10^k(9ft) \end{array}\right\}}{80ft} = 104.25 \text{ kips}$$

IM = 20% (Field Verified minor deviations in riding surface)

V_{LL+IM} = 1.20 × 104.25 kips = 125.1 kips

Distributed g_v = 0.70/1.2 = 0.583

$g_v V_{LL+IM}$ = 0.583 × 125.1 = 72.9 kips

Dead Load Shears:

From A3.3.1, DC_1 = 1.90 kip/ft and DC_2 = 0.25 kip/ft

From A3.3.2, DW = 0.203 kip/ft

V_{DC} = (1.90 klf + 0.25 klf)(0.5 ×80 ft – 20 ft)

V_{DC} = 38 + 5 = 43 kips

V_{DW} = (0.203klf) (0.5 ×80 ft – 20 ft)

V_{DW} = 4.1 kips

A3.9.2—Compute Nominal Shear Resistance

Minimum Transverse Reinforcement:

Effective Web Width:

LRFD Design Eq. 5.8.2.5-1

b_v = 8 in.

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Spacing of Transverse Reinforcement:

s = 12 in.

$$A_v = 0.0316\sqrt{f'_c}\frac{b_v s}{f_y}$$

$$A_v = 0.0316\sqrt{5}\frac{(8)(12)}{60} = 0.113 \text{ in.}^2$$

Area provided 2 # 3 = 2 (0.11) = 0.22 in.² > 0.113 in.² OK

A3.9.2.1—Simplifed Approach

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θ = 45°

β = 2.0

Concrete:

$$V_c = 0.0316\beta\sqrt{f'_c}b_v d_v$$

LRFD Design Eq. 5.8.3.3-3

Effective Shear Depth:

d_v = 57.89 in.

$$V_c = (0.0316)(2.0)\sqrt{5.0}(8)(57.89)$$
$$= 66.0 \text{ kips}$$

Steel:

$$V_s = \frac{A_v f_y d_v \cot\theta}{s}$$

#3 at 12 in.

A_v = 2 (0.110) = 0.22 in.^{2}

$$V_s = \frac{(0.22)(60)(57.89)\cot 45°}{12}$$

V_s = 63.7 kips

Total Nominal Shear Resistance:

$$V_n = V_c + V_s$$
$$= 65.4 + 63.7 = 129.1 \text{ kips}$$

$$0.25 f'_c b_v d_v + V_p = 0.25 \times 5.0 \times 8 \text{ in.} \times 57.89 \text{ in.} + 0.0 = 578.9 \text{ kips}$$

LRFD Design Eq. 5.8.3.3-2

129.1 kips < 578.9 kips ∴ V_n = 129.1 kips

φV_n = 0.9x129.1 = 116.2 kips

Factored Shear V_u:

V_u = 1.60 (72.9) + 1.25 (43) + 1.5 (4.1) = 176.5 kips

116.2 kips < 176.5 kips No Good

Try MCFT Approach.

A3.9.2.2—MCFT Approach

Shear stress on the concrete:

$$v = \frac{V_u - \varphi V_p}{\varphi b_v d_v} = \frac{176.5}{(0.9)(8)(57.89)} = 0.423 \text{ ksi}$$ LRFD Design Eq. 5.8.2.9-1

$$\frac{v}{f'_c} = \frac{0.423}{5} = 0.0847 < 0.25$$ OK

At Stirrup Change:

M_{PERMIT} = 2258.3 kip-ft

M_{LL+IM} = 1.20×2258.3 = 2710 kip-ft

$g_m M_{LL+IM}$ = $\frac{0.514}{1.2}$ × (2710) = 1160.8 kip-ft

M_{DC} = 0.5 (1.90 klf + 0.25 klf) (20 ft) (80 ft – 20 ft) = 1290 kip-ft

M_{DW} = 0.5 (0.203 klf) (20 ft) (80 ft – 20 ft) =121.8 kip-ft

M_u = 1.60 (1160.8) + 1.25 (1290) + 1.5 (121.8)

= 3652.5 kip-ft

Following the approach in the LRFD Shear Design Flowchart and LRFD Design Table 5.8.3.4.2-1: LRFD Design 5.8.3.4.2

Check upper limit of shear V_n

$$0.25 f'_c b_v d_v + V_p = 0.25 \times 5.0 \times 8 \text{ in.} \times 57.89 \text{ in.} + 0.0 = 578.9 \text{ kips}$$ LRFD Design Eq. 5.8.3.3-2

$$\frac{v}{f'_c} = 0.0828 \le 0.100 \text{ (2nd row)}$$ LRFD Design Figure C5.8.3.4.2-5, Table 5.8.3.4.2-1, 5.8.3.4.2

$$A_{ps} = 32 \times 0.153 = 4.896 \text{ in.}^2$$

$$f_{po} = 0.7 f_{pu} = 0.7 \times 270 = 189 \text{ ksi}$$

$$\varepsilon_x = \frac{\frac{|M_u|}{d_v} + 0.5N_u + 0.5|V_u - V_p|\cot\theta - A_{ps} f_{po}}{2(E_s A_s + E_p A_{ps})} \le 0.001$$ LRFD Design Eq. 5.8.3.4.2-1

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$$\varepsilon_x = \frac{\frac{|12 \times 3652.5|}{57.89} + 0.5|176.5|(\cot\theta) - (4.896)(189)}{2(0 + 28500 \times 4.896)}$$

$= 0.316 \times 10^{-3} \cot\theta - 0.603 \times 10^{-3}$

Assume $\varepsilon_x \le 0.125 \times 10^{-3}$ ($\varepsilon_x \times 1000 \le 0.125$)

From LRFD Design Table 5.8.3.4.2-1 (row 2, column 5):

$\theta = 24.9°$ $\beta = 2.91$

$\varepsilon_x = 0.316 \times 10^{-3} \cot 24.9° - 0.603 \times 10^{-3} = 0.0778 \times 10^{-3}$

The calculated ε_x is less than the assumed but not less than the adjacent ε_x value 0.0, ∴ the assumption was not too conservative OK

Calculate V_n:

$$V_c = 0.0316\beta\sqrt{f_c'}b_v d_v$$ LRFD Design Eq. 5.8.3.3-3

$$V_c = (0.0316)(2.91)\sqrt{5}(8)(57.89) = 95.2 \text{ kips}$$

$$V_s = \frac{A_v f_y d_v \cot\theta}{s}$$ LRFD Design Eq. 5.8.3.3-4

$$V_s = \frac{(0.22)(60)(57.89)(\cot 24.9°)}{12} = 137 \text{ kips}$$

$V_n = V_c + V_s = 95.2 + 137.2$ LRFD Design Eq. 5.8.3.3-1

$V_n = 232.4$ kips

$0.25 f_c' b_v d_v + V_p = 578.9$ kips (previously calculated)

232.4 kips < 578.9 kips therefore $V_n = 232.4$ kips

$\varphi V_n = 0.9 \times 232.4 = 209.1$ kips

A3.9.2.3—Check Longitudinal Reinforcement (LRFD Design 5.8.3.5)

$$A_{ps} f_{ps} + A_s f_y \ge \frac{|M_u|}{d_v \varphi_f} + 0.5\frac{N_u}{\varphi_c} + \left[\left|\frac{V_u}{\varphi_v} - V_p\right| - 0.5V_s\right]\cot\theta$$ LRFD Design Eq. 5.8.3.5-1

$$V_s = 137\,kips < \frac{V_u}{\varphi} = \frac{176.5}{0.9} = 196.1$$ use 137 kips

The right side of LRFD Design Eq. 5.8.3.5-1 yields:

$$= \frac{|(3652.5)(12)|}{(57.89)(1.0)} + \left(\left|\frac{176.5}{0.9}\right| - 0.5(137)\right)\cot 24.9° = 1032.0 \text{ kips}$$

The 20 fully bonded strands are fully developed at this location (f_{ps} = 264.4 ksi). As a portion of the remaining ten strands are debonded, their LRFD Design 5.11.4.3

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$\varepsilon_x = 0.3092 \times 10^{-3} \cot\theta - 0.5694$

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$V_c = (0.0316)(2.75)\sqrt{5}(8)(57.89) =$

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$V_n = 227$ kips

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development length from the end of the debonded zone is calculated by LRFD Design Eq. 5.11.4.2-1 with $k = 2.0$.

$$\ell_d \geq k(f_{ps} - 2/3 f_{pe})d_b$$ LRFD Design Eq. 5.11.4.2-1

$$\ell_d \geq 2 \times (264.4 - \frac{2}{3} \times 159.77)0.5 = 157.9 \text{ in.}$$

Check to see that the debonded strands are fully developed at the stirrup change location.

157.9 in. + 12 ft = 25.2 ft > 20 ft

Therefore, the strands are not fully developed and f_{px} must be determined.

Using a linear increase from f_{pe} at the transfer length to f_{ps} at the development length

From end of debonded zones

$$\ell_{px} = (20 \text{ ft} - 12 \text{ ft}) \times 12 \text{ in./ft} = 96 \text{ in.}$$

$$f_{px} = 159.77 + \frac{96 - 30}{157.9 - 30}(264.4 - 159.77) = 213.8 \text{ ksi}$$

Then, the left side of LRFD Design Eq. 5.8.3.5-1 yields:

$$= \quad 264.4 \times 22 \times 0.153 + 213.8 \times 10 \times 0.153 = 1217 \text{ kips}$$ OK

$$A_{ps} f_{ps} + A_s f_y \geq \frac{|M_u|}{d_v \varphi_f} + 0.5 \frac{N_u}{\varphi_c} + \left[\left| \frac{V_u}{\varphi_v} - V_p \right| - 0.5 V_s \right] \cot\theta$$ LRFD Design Eq. 5.8.3.5-1

reduces to: 1217 kips ≥ 1032 kips OK

A3.10—SUMMARY

Table A3.10-1—Summary of Midspan Moments for HL-93 and Intermediate Shears for Permit Truck

Location	Support	Critical Shear	Stirrup Change	Midspan
Vehicle	Dead Loads	Permit Truck	Permit Truck	HL-93
x/L	0.0	0.067	0.25	0.5
X, ft	0.0	5.37	20	40
V_{DC1}, kips	76	65.8	38	—
V_{DC2}, kips	10	8.7	5	—
V_{DW}, kips	8.12	7.03	4.1	—
$g_m V_{LL+IM}$, kips	—	101.1	72.9	—
V_n, kips, simplified	—	221.7	129.1	—
V_n, kips, MCFT	—	440.7	232.4	—
M_{DC1}, kip-ft	—	380.7	1140	1520
M_{DC2}, kip-ft	—	50.1	150	200
M_{DW}, kip-ft	—	40.7	121.8	162
$g_m M_{LL+IM}$, kip-ft	—	397.1	1160.8	1487.7
M_n, kip-ft	—	—	—	6244.4

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A3.11—General Load Rating Equation (6A.4.2)

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$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_L)(LL + IM)}$$ Eq. 6A.4.2.1-1

A3.11.1 Evaluation Factors (for Strength Limit State)

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A3.11.1.1—Resistance Factor, φ (LRFD Design 5.5.4.2.1)

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φ = 1.0 for flexure (previously determined to be a tension-controlled section; see Article A3.6)

φ = 0.9 for shear

A3.11.1.2—Condition Factor, φ_c (6A.4.2.3)

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φ_c = 1.0 No member deterioration, NBI Item 59 Code = 6

A3.11.1.3—System Factor, φ_s (6A.4.2.4)

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φ_s = 1.0 4-girder bridge with spacing > 4 ft

A3.11.2—Design Load Rating (6A.4.3)

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A3.11.2.1—Strength I Limit State (6A.5.4.1)

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$$RF = \frac{(\varphi_c)(\varphi_s)(\varphi)R_n - (\gamma_{DC})(DC) - (\gamma_{DW})(DW)}{(\gamma_L)(LL + IM)}$$

A3.11.2.1a—Inventory Level

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Table 6A.4.2.2-1

Load	Load Factor
DC	1.25
DW	1.50 Overlay thickness was not field measured.
LL	1.75

Flexure at Midspan:

$$RF = \frac{(1.0)(1.0)(1.0)(6244.4) - [(1.25)(1520 + 200) + (1.5)(162)]}{(1.75)(1487.7)}$$

$$= 1.48$$

Shear: Visible shear distress has not been observed; shear evaluation not required for design load.

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A3.11.2.1b—Operating Level

For Strength I Operating Level only the live load factor changes; therefore the rating factor can be calculated by direct proportions.

Table 6A.4.2.2-1

Load	Load Factor, γ
DC	1.25
DW	1.50
LL	1.35

Flexure at Midspan:

$$RF = 1.48 \times \frac{1.75}{1.35}$$

$$= 1.92$$

Flexure rating should be checked at maximum moment sections and at sections where there are changes in flexural resistance.

The checks performed for minimum and maximum reinforcement will also vary along the length; these checks are required to be satisfied at each cross section in the LRFD Design specification.

A3.11.2.2—Service III Limit State (Inventory Level) (6A.5.4.1)

$$RF = \frac{f_R - (\gamma_D)(f_D)}{(\gamma_L)(f_{LL+IM})}$$

Flexural Resistance $f_R = f_{pb}$ + Allowable tensile stress

f_{pb} = Compressive stress due to effective prestress

= 2.548 ksi (from Article A3.7.1.3 of this example)

Allowable Tensile Stress $= 0.19\sqrt{f'_c}$ LRFD Design 5.9.4.2.2

$$= 0.19\sqrt{5}$$

$$= 0.425 \text{ ksi}$$

$$f_R = 2.548 + 0.425$$

$$= 2.973 \text{ ksi}$$

Determine Dead Load Stresses at Midspan:

From A3.3.1, M_{DC1} = 1520 kip-ft and M_{DC2} = 200 kip-ft

From A3.3.2, M_{DW} = 162 kip-ft

From A3.2, $S_{b\,(nc)}$ = 10543 in.^{3} $S_{b\,(comp)}$ = 17473 in.^{3}

$$f_{DC} = \frac{1520 \times 12}{10543} + \frac{200 \times 12}{17473} \qquad = 1.87 \text{ ksi}$$

$$f_{DW} = \frac{162 \times 12}{17473} \qquad = 0.11 \text{ ksi}$$

Total f_D $= 1.98$ ksi

Live Load Stress at Midspan:

From A3.4.2, M_{LL+IM} = 1487.7 kip-ft

From A3.2, $S_{b\,(comp)}$ =17473 in.^{3}

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$$f_{LL+IM} = \frac{1487.7 \times 12}{17473} = 1.02 \text{ ksi}$$

$$RF = \frac{2.973 - (1.0)(1.98)}{(0.8)(1.02)}$$

$$= 1.22$$

A3.11.3—Legal Load Rating (6A.4.4)

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Inventory Design Load Rating $RF > 1.0$, therefore the legal load ratings do not need to be performed and no posting is required. 6A.4.3.1

A3.11.4—Permit Load Rating (6A.4.5)

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Permit Type: Special, single-trip, mix with traffic, no escort
Permit Weight: 220 kips

Permit Vehicle: Shown in Example A1, Figure A1A.1.10-1

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ADTT (one direction): 5000

From Live-Load Analysis by Computer Program:

Undistributed Maximum M_{LL} = 2949.1 kip-ft

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Undistributed Maximum V_{LL} = 159.2 kips

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A3.11.4.1—Strength II Limit State (6A.5.4.2.1)

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Load	Load Factor, γ
DC	1.25
DW	1.5
LL	1.35

LRFD Design Tables 3.4.1-1, 3.4.1-2; Table 6A.4.5.4.2a-1

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Use One-Lane Distribution Factor and divide out the 1.2 multiple presence factor. 6A.4.5.4.2b

6A.4.5.5

$$g_{m1} = 0.514 \times \frac{1}{1.2} = 0.428$$

$$g_{v1} = 0.70 \times \frac{1}{1.2} = 0.583$$

IM = 20% (Riding surface condition verified by inspection: Minor Deviations)

Maximum Live Load Effect:

M_{LL+IM} = (2949.1) (0.428) (1.20)

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= 1515.8 kip-ft at midspan

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V_{LL+IM} = (157.9) (0.583) (1.20)

= 111.4 kips

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φ factors are the same as those for the design calculations. See Article A3.13.1.

A3.11.4.1a—Flexure

$$RF = \frac{(1.0)(1.0)(1.0)(6244.4) - [(1.25)(1520 + 200) + (1.5)(162)]}{(1.35)(1515.8)}$$

$$= 2.88 > 1.00$$

OK

Shear evaluation is required for Permit Load Rating when the factored force effects due to the permit load are greater than the factored force effects due to the design load or when shear distress is observed. 6A.5.9

A3.11.4.1b—Shear

Shear at First Critical Shear Section (64.4 in. from centerline of bearing):

1. Simplified Approach

$$RF = \frac{(1.0)(1.0)(0.9)(221.7) - [(1.25)(65.8 + 8.7) + (1.5)(7.03)]}{(1.35)(101.1)}$$

$$= 0.70$$

NO GOOD

2. MCFT

$$RF = \frac{(1.0)(1.0)(0.9)(440.7) - [(1.25)(65.8 + 8.7) + (1.5)(7.03)]}{(1.35)(101.1)}$$

$$= 2.15$$

OK

Shear at Stirrup Change (20 ft from centerline of bearing):

1. Simplified Approach

$$RF = \frac{(1.0)(1.0)(0.9)(129.1) - [(1.25)(38 + 5) + (1.5)(4.1)]}{(1.35)(72.9)}$$

$$= 0.56$$

OK

2. MCFT

$$RF = \frac{(1.0)(1.0)(0.9)(227) - [(1.25)(38 + 5) + (1.5)(4.1)]}{(1.35)(72.9)}$$

$$= 1.47$$

OK

Shear resistance taken for Permit Vehicle. It is acceptable and conservative to

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take the shear resistance for HL-93 as long as M_u and V_u for HL-93 are both greater than or equal to M_u and V_u for permit. In this case, the permit values are greater and were used to calculate the shear resistance.

This example has illustrated the calculation for the shear rating factor with the longitudinal yield check at the first critical section for shear and at a stirrup change. Due to the variation of resistances for shear along the length of this prestressed concrete I-beam, it is not certain that these two locations govern for the Strength I limit state. A systematic evaluation of the shear and longitudinal yield criteria based on shear-moment interaction should be performed along the length of the beam.

A3.11.4.2—Service I Limit State (Optional) (6A.5.4.2.2b)

$\gamma_L = \gamma_{DC} = \gamma_{DW} = 1.0$ Table 6A.4.2.2-1

LRFD distribution analysis methods as described in LRFD Design Article 4.6.2 should be used. 6A.4.5.4.2a

$g_m = 0.724$

Distributed Live-Load Effect:

Dead Load Moments at Midspan:

From A3.3.1, M_{DC1} = 1520 kip-ft and M_{DC2} = 200 kip-ft

From A3.3.2, M_{DW} = 162 kip-ft

$M_{LL+IM} = (2950.5)(0.724)(1.2) = 2563.4$ kip-ft

$M_{DC} + M_{DW} + M_{LL+IM} = (1520 + 200) + 162 + 2563.4 = 4445.4$ kip-ft

A3.11.4.2a—Simplified Check Using 0.75M_n (C6A.4.2.2)

Nominal flexural resistance: M_n = 6244.4 kip-ft
(use nominal, not factored resistance)

$0.75M_n = 0.75 \times 6244.4 = 4683.3$ kip-ft > 4445.4 kip-ft OK

$$\text{Moment Ratio} = \frac{0.75M_n}{M_{DC} + M_{DW} + M_{LL+IM}} = \frac{4683.3}{4445.4} = 1.05 > 1.0$$ OK

A3.11.4.2b—Refined Check Using 0.9f_y

Calculate stress in outer reinforcement at Midspan. Stress due to moments in excess of the cracking moment acts upon the cracked section. The moments up to the cracking moment cause stress in the reinforcement equal to the effective prestress.

$f_R = 0.9F_y = 0.9(0.9F_{pu}) = 0.9(0.9 \times 270) = 218.7$ ksi 6A.5.4.2.2b, Table 6A.5.4.2.2b-1

M_{cr} = 3915.2 kip-ft (previously calculated; see Article A3.7.1.3)

Effective prestress: (0.75 × 270 – 42.73) = 159.77 ksi (previously calculated; see Article A3.7.1.3)

$M_{DC} + M_{DW} + M_{LL+IM} - M_{cr} = 4445.4 - 3915.2 = 530.2$

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Section Properties for the Cracked Composite Section:

b_{trans} = 102 in. × 0.89 = 90.8 in. (see Article A3.2)

h = 54 in. + 1 in. + 8.5 in. = 63.5 in.

A_{ps} = 32 × 0.153 in.^{2} = 4.896 in.^{2}

Modular ratio, n:

$$n = \frac{E_{ps}}{E_{beam}} = \frac{28.5\times10^3}{4.07\times10^3}$$

A_{trans} = 4.896 in.^{2} × 7 = 34.3 in.^{2}

y = 3.75 in. (see Article A3.5)

Outer strand y = 2 in.

Assume neutral axis is in the slab.

$$c = \frac{\left(\frac{c}{2}\right)\left(b_{trans}\times c\right)+(h-y)(A_{trans})}{\left(b_{trans}\times c\right)+(A_{trans})}$$

$$c = \frac{\frac{c}{2}(90.8)c+(63.5-3.75)(34.3)}{(90.8)c+34.3}$$

$$45.4c^2+34.3c-2049.4=0$$

Solving for c:

$$c = \frac{-34.3\pm\sqrt{34.3^2-4\left(45.4\right)\left(-2049.4\right)}}{2\left(45.4\right)}$$

$$c = 6.35\,\text{in.}$$

$$I_{cr} = \frac{1}{12}(90.8)(6.35)^3+(90.8)(6.35)\left(\frac{6.35}{2}\right)^2+(34.3)(63.5-3.75-6.35)^2$$

= 105558 in.^{4}

Stress beyond the effective prestress (increase in stress after cracking):

$$f_s = n\frac{M_y}{I} = 7\frac{(530.2)(12)(63.5-2.0-6.35)}{105558} = 23.3\text{ ksi}$$

Stress in the reinforcement at Permit crossing Service I:

$f_s = 159.77+23.3 = 183.1$ ksi $< f_R = 0.9F_y = 218.7$ ksi OK

Stress Ratio $= \frac{0.9f_y}{f_s} = \frac{218.7}{183.1} = 1.19 > 1.0$ OK

All permit checks for an interior girder are satisfied.

A3.12—Summary of Rating Factors

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Table A3.14-1—Summary of Rating Factors—Interior Girder

Limit State	Design Load Rating (HL-93)		Permit Load Rating
	Inventory	Operating	
Strength I	—	—	—
Flexure (at midspan)	1.48	1.92	—
Strength II	—	—	—
Flexure (at midspan)	—	—	1.59 (2.03)
Shear (at 64.4 in)	—	—	1.81 (2.32)
Shear (at 20 feet)	—	—	1.24 (1.59)
Service III	—	—	—
Flexure (at midspan)	1.22	—	—
Service I	—	—	Stress Ratio = 1.19

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A3.15—References

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AASHTO. 2007. *AASHTO LRFD Bridge Design Specifications*, Fourth Edition, LRFDUS-4-M or LRFDSI-4. American Association of State Highway and Transportation Officials, Washington, DC.

NCHRP. 2007. *Legal Truck Loads and AASHTO Legal Loads for Posting*, NCHRP Report 575. Transportation Research Board, National Research Council, Washington, DC.

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Shear: Visible shear distress has not been observed; shear evaluation is not required for design load. Shear evaluation is shown in A3.11.4.1b below for the permit load. The shear rating factors for Design Load Rating are calculated for illustration purposes only. In-service concrete bridges that show no visible signs of shear distress need not be checked for shear during design load or legal load ratings. 6A.5.9

Shear at First Critical Shear Section (64.4 in. from centerline of bearing):

Simplified Approach

$$RF = \frac{(1.0)(1.0)(0.9)(221.7) - \left[(1.25)(65.8+8.7)+(1.50)(7.03)\right]}{(1.75)(85.3)}$$

$$= 0.64$$

MCFT

$$RF = \frac{(1.0)(1.0)(0.9)(440.7) - \left[(1.25)(65.8+8.7)+(1.50)(7.03)\right]}{(1.75)(85.3)}$$

$$= 1.96$$

Shear at Stirrup Change (20 ft from centerline of bearing):

Simplified Approach

$$RF = \frac{(1.0)(1.0)(0.9)(129.1) - [(1.25)(38+5)+(1.50)(4.1)]}{(1.75)(63.7)}$$

$$= 0.51$$

MCFT

$$RF = \frac{(1.0)(1.0)(0.9)(227) - [(1.25)(38+5)+(1.50)(4.1)]}{(1.75)(63.7)}$$

$$= 1.30$$

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Shear: Prestressed concrete shear capacity is load-dependent. Therefore, the change in the rating factor using MCFT will not be linear with the change in the live-load factor. The Operating Design Load Rating for shear is not illustrated here.

This example has illustrated the calculation for the shear rating factor with the longitudinal yield check at the first critical section for shear and at a stirrup change. Due to the variation of resistances for shear along the length of this prestressed concrete I-beam, it is not certain that these two locations govern for the Strength I limit state. A systematic evaluation of the shear and longitudinal yield criteria based on shear-moment interaction should be performed along the length of the beam.

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$$RF = \frac{(1.0)(1.0)(0.9)(440.7) - [(1.25)(72.0) + (1.50)(6.7)]}{(1.5)(110.5)}$$

$$= 1.79 > 1.0$$ OK

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Shear (at 64 in.)	1.96	—	—
Shear (at 20 ft)	1.30	—	—

A4—TIMBER STRINGER BRIDGE: EVALUATION OF AN INTERIOR STRINGER

PART A—LOAD AND RESISTANCE FACTOR RATING METHOD

A4A.1—Bridge Data

Span:	17 ft 10 in.
Year Built:	1930
Year Reconstructed:	1967
Material:	Southern Pine No. 2
Condition:	No deterioration. NBI Item 59 Code = 6
Riding Surface:	Unknown condition
Traffic:	Two Lanes
ADTT (one direction):	150
Skew:	0°

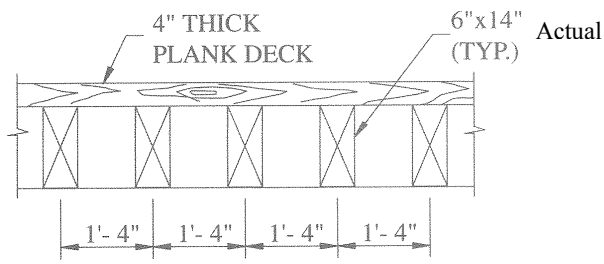

Figure A4A.1-1—Partial Cross Section of Deck

A4A.2—Dead Load Analysis—Interior Stringer in Flexure

A4A.2.1—Components and Attachments, *DC*

Deck: $\frac{16}{12} \times \frac{4}{12} \times 0.050$ = 0.022 kip/ft LRFD Design Table 3.5.1-1

Stringer: $\frac{6 \times 14}{144} \times 0.050$ = 0.029 kip/ft

Total per stringer = 0.051 kip/ft

$$M_{DC} = \frac{1}{8} \times 0.051 \times 17.83^2$$

= 2.03 kip-ft

A4A.2.2—Wearing Surface

$DW = 0$

A4A.3—Live Load Analysis—Interior Stringer in Flexure

A4A.3.1—Distribution Factor for Moment and Shear

AASHTO LRFD Type ℓ cross section — LRFD Design Table 4.6.2.2.1-1

One Lane Loaded: — LRFD Design Table 4.6.2.2.2a-1

$$g_1 = \frac{S}{6.7}$$

$$= \frac{\frac{16}{12}}{6.7} = 0.20$$

Two or More Lanes Loaded:

$$g_2 = \frac{S}{7.5}$$

$$= \frac{\frac{16}{12}}{7.5} = 0.18 < 0.20$$

One Lane Loaded Governs

$$g = 0.20$$

A4A.3.2—Compute Maximum Live Load Effects

A4A.3.2.1—Maximum Design Live Load (HL-93) Moment at Midspan

Design Lane Load Moment	=	25.4 kip-ft	
Design Truck Moment	=	142.6 kip-ft	
Design Tandem Moment	=	175.7 kip-ft	Governs
IM	=	0%	6A.7.5
M_{LL}	=	25.4 + 175.7	
	=	201.1 kip-ft	

A4A.3.2.2—Distributed Live-Load Moments

Design Live Load HL-93:

$$g \times M_{LL} = 0.20 \times 201.1$$

$$= 40.2 \text{ kip-ft}$$

A4A.4—Compute Nominal Flexural Resistance

Section Properties for Stringers (based on actual dimensions):

$I_x = \frac{bh^3}{12} = \frac{6 \times 14^3}{12} = 1372 \text{ in.}^4$

$S_x = \frac{I_x}{\frac{h}{2}} = \frac{1372}{\frac{14}{2}} = 196 \text{ in.}^3$

$A = bh = 6 \times 14 = 84 \text{ in.}^2$

A4A.4.1—LRFD Design, Fourth Edition

$F_b = F_{bo} C_{KF} C_M \left(C_F \text{ or } C_V\right) C_{fu} C_i C_d C_\lambda$ LRFD Design Eq. 8.4.4.1-1

F_{bo} = 0.85 ksi Reference Design Value LRFD Design Table 8.4.1.1.4-1

C_{KF} = 2.5/ϕ = 2.5 / 0.85 = 2.94 Format Conversion Factor LRFD Design 8.4.4.2

C_M = 1.0 Wet Service Factor LRFD Design 8.4.4.3

(reduction for wet use not required due to species and member size)

C_F = Size Effect Factor for sawn lumber $\left(\frac{12}{d}\right)^{\frac{1}{9}} = \left(\frac{12}{14}\right)^{\frac{1}{9}} = 0.98 \le 1.0$ LRFD Design Eq. 8.4.4.4-2

C_{fu} = 1.0 Flat Use Factor LRFD Design 8.4.4.6

C_i = 1.0 Incising Factor (only apply to dimension lumber) LRFD Design 8.4.4.7

C_d = 1.0 Deck Factor LRFD Design 8.4.4.8

C_λ = 0.8 Time Effect Factor for Strength I LRFD Design 8.4.4.9

F_b = 0.85 × 2.94 × 1.0 × 0.98 × 1.0 ×1.0 × 1.0 × 0.8 = 1.96

Adjusted Design Value = F_b = 1.96 ksi

Nominal Resistance $M_n = F_b S C_L$ LRFD Design Eq. 8.6.2-1

C_L = 1.0

M_n = 1.96 ksi × 196 in.^{3} × 1.0 × 1ft/12 in. = 32.01 kip-ft

A4A.5—General Load-Rating Equation (6A.4.2)

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_L)(LL + IM)}$$ Eq. 6A.4.2.1-1

A4A.6—Evaluation Factors (for Strength Limit State)

1. Resistance Factor, φ LRFD Design 8.5.2.2

   φ = 0.85 for Flexure
   φ = 0.75 for Shear

2. Condition Factor, φ_c 6A.4.2.3

   $\varphi_c = 1.0$ Good Condition

3. System Factor φ_s 6A.4.2.4

   $\varphi_s = 1.0$ for flexure and shear in timber bridges

A4A.7—Design Load Rating (6A.4.3)

A4A.7.1—Strength I Limit State (6A.7.4.1)

$$RF = \frac{(\varphi_c)(\varphi_s)(\varphi)R_n - (\gamma_{DC})(DC) - (\gamma_{DW})(DW)}{(\gamma_L)(LL + IM)}$$

A4A.7.1.1—Inventory Level

Table 6A.4.2.2-1

Load	Load Factor
DC	1.25
LL	1.75

Flexure:

$$RF = \frac{(1.0)(1.0)(0.85)(32.0) - (1.25)(2.03)}{(1.75)(40.2)}$$

$= 0.35$

A4A.7.1.2—Operating Level

Table 6A.4.2.2-1

Load	Load Factor
DC	1.25
LL	1.35

Flexure:

$$RF = 0.35 \times \frac{1.75}{1.35}$$

$= 0.45$

A4A.7.1.3—Shear (Horizontal Shear) (LRFD Design 8.7)

Critical Section for Live Load Shear is at a distance d = 14 in. = 1.17 ft from face of support

Place live load to cause maximum shear at lesser of:

1. Three times the depth = 3 × 14 = 42 in. = 3.5 ft Governs

2. $\frac{1}{4}$ of span length = $\frac{1}{4} \times 17.83$ = 4.46 ft

A4A.7.1.4—Compute Maximum Shear at Critical Section (14 in. = 1.17 ft)

A4A.7.1.4a—Dead Load Shear

$$V_{DC} = \frac{1}{2}(0.051)(17.83) - (0.051)(1.17)$$

$= 0.395$ kips

A4A.7.1.4b—Live Load Shear (HL-93)

Live load placed at 3.5 ft from face of support:

V_{TANDEM} = 34.6 kips Governs

V_{TRUCK} = 26.3 kips

V_{LANE} = 3.7 kips

Undistributed Shear:

V_{LU} = 3.7 + 34.6

= 38.3 kips

Distributed:

V_{LD} = 38.3 × 0.20

= 7.7 kips

For Horizontal Shear:

$V_{LL} = 0.50\left[\left(0.60V_{LU}\right)+V_{LD}\right]$ LRFD Design Eq. 4.6.2.2.2a-1

V_{LU} = Maximum vertical shear at 3*d* or *L*/4 due to undistributed wheel loads (kips)

= For undistributed wheel loads, one line of wheels is assumed to be carried by one bending member. LRFD Design 4.6.2.2.2a

$= \frac{V_{LU}}{2} = \frac{(38.3)}{2} = 19.1$ kips

V_{LD} = Maximum vertical shear at 3*d* or *L*/4 due to wheel loads distributed laterally as specified herein (kips)

= 7.7 kips

V_{LL} = 0.50[(0.60×19.1) + 7.7] = 9.58 kips

A4A.7.1.5—Compute Nominal Shear Resistance

A4A.7.1.5a—LRFD Design, Fourth Edition

$V_n = \frac{F_v bd}{1.5}$ LRFD Design Eq. 8.7-2

$F_v = F_{vo}C_{KF}C_M C_i C_\lambda$ LRFD Design Eq. 8.4.4.1-2

F_{vo} = 0.165 ksi Reference Design Value LRFD Design Table 8.4.1.1.4-1

C_{KF} = 2.5/φ = 2.5 / 0.75 = 3.33 Format Conversion Factor LRFD Design 8.4.4.2

C_M = 1.0 Wet Service Factor LRFD Design 8.4.4.3

(reduction for wet use not required due to species and member size)

C_i = 1.0 Incising Factor LRFD Design 8.4.4.7

C_λ = 0.8 Time Effect Factor for Strength I LRFD Design 8.4.4.9

F_v = 0.165 × 3.33 × 1.0 ×1.0 × 0.8

Adjusted Design Value:

F_v = 0.440 ksi

$$V_n = \frac{(0.440)(6)(14)}{1.5} = 24.6 \text{ kips}$$

A4A.7.1.5b—Inventory Level

Load	Load Factor
DC	1.25
LL	1.75

Shear:

$$RF = \frac{(1.0)(1.0)(0.75)(24.6)-(1.25)(0.395)}{(1.75)(9.58)}$$

$$=1.07$$

A4A.7.1.5c—Operating Level

Shear:

$$RF = 1.07 \times \frac{1.75}{1.35} = 1.39$$

No service limit states apply.

A4A.8—Legal Load Rating (6A.4.4)

Live Load: AASHTO Legal Loads—Types 3, 3S2, and 3-3 (Rate for all three) 6A.4.4.2.1

g = 0.20

IM = 0% 6A.7.5

	Type 3	Type 3S2	Type 3-3	
M_{LL}	119.5	108.9	98.4	kip-ft
gM_{LL}	23.9	21.8	19.7	kip-ft

A4A.8.1—Strength I Limit State (6A.7.4.2)

Dead Load *DC*:

Load Factor = 1.25 Table 6A.4.2.2-1

ADTT = 150

Live-Load Factor = 1.30 Table 6A.4.4.2.3a-1

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Flexure:

$$RF = \frac{(1.0)(1.0)(0.85)(32)-(1.25)(2.03)}{(1.30)(M_{LL})}$$

	Type 3	Type 3S2	Type 3-3
RF	0.79	0.87	0.96

A4A.8.1.1—Shear Capacity

Live load shear at critical section (14 in.) with live load placed to cause maximum shear effect at 3.5 ft (3*d*).

g = 0.20

IM = 0% 6A.7.5

The distributed live load is calculated in the same manner as demonstrated for the design load check.

$$V_{LL} = 0.50\left[(0.60V_{LU})+V_{LD}\right]$$ LRFD Design Eq. 4.6.2.2.2a-1

	Type 3	Type 3S2	Type 3-3	
V_{LU}	11.76	10.72	9.68	kips
V_{LD}	4.70	4.29	3.87	kips
V_{LL}	5.87	5.35	4.83	kips

Shear:

$$RF = \frac{(1.0)(1.0)(0.75)(24.6)-(1.25)(0.395)}{(1.30)(V_{LL})}$$

	Type 3	Type 3S2	Type 3-3
RF	2.36	2.58	2.86

A4A.8.2—Summary

Truck	Type 3	Type 3S2	Type 3-3
Weight, tons	25	36	40
RF	0.79	0.87	0.96
Safe Load Capacity, tons	19	31	38

A4A.9—Summary of Rating Factors for Load and Resistance Factor Rating Method

Table A4A.9-1—Summary of Rating Factors for Load and Resistance Factor Method—Interior Stringer

Limit State		Design Load Rating		Legal Load Rating		
		Inventory	Operating	Type 3	Type 3S2	Type 3-3
Strength I	Flexure	0.35	0.45	0.79	0.87	0.96
	Shear	1.07	1.39	2.36	2.58	2.86

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PART B—ALLOWABLE STRESS RATING METHOD

A4B.1—Bridge Data

Refer to Article A4A.1 for Bridge Data.

A4B.2—Section Properties

$$I_x = \frac{bh^3}{12} = \frac{6 \times 14^3}{12} = 1372 \text{ in.}^4$$

$$S_x = \frac{I_x}{h \div 2} = \frac{1372}{14 \div 2} = 196 \text{ in.}^3$$

$$A = bh = 6 \times 14 = 84 \text{ in.}^2$$

A4B.3—Dead Load Analysis—Interior Stringer

Deck:

$$\frac{(1 \text{ ft} - 4 \text{ in.})4 \text{ in.}}{144 \text{ in.}^2/\text{ft}^2} \times 50 \text{ lb./ft}^3 = 22.2 \text{ lb/ft}$$

Stringer:

$$\frac{6 \text{ in.} \times 14 \text{ in.}}{144} \times 50 = \frac{29.2 \text{ lb/ft}}{51.4 \text{ lb/ft}}$$ say 0.051 kip/ft

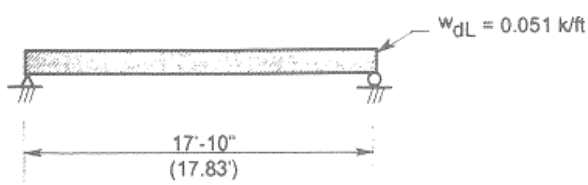

Figure A4B.3-1—Load Diagram for Interior Stringer—Uniform Dead Load

$$M_{DL} = \frac{w_{DL}L^2}{8} = \frac{0.051(17.83)^2}{8}$$

$$M_{DL} = 2.03 \text{ kip-ft}$$

A4B.4—Live Load Analysis—Interior Stringer

Live Load: Rate for H-15 truck

Determine the maximum live load moment by statics. For small spans, verify that the maximum moment will occur at midspan with the heaviest wheel positioned at midspan.

$$M_L = PL/4$$

$$M_L = (12 \text{ kips} \times 17.83 \text{ ft})/4 = 53.49 \text{ kip-ft}$$

Alternatively interpolation could be used for estimating. Note that for longer spans and for interpolation between span increments greater than 1 ft, interpolated values yield approximate results. Appendix C6B

Span	M_L	
17 ft	51 kip-ft	
		← For 17.83-ft span, interpolate
18 ft	54 kip-ft	
$M_L = 51 + \frac{17.83-17}{18-17}(54-51) = 53.5$ kip-ft		

A4B.5—Allowable Stress Rating (6B.4.1, 6B.5.2, 6B.6.2)

Consider stringer only; consider maximum moment and shear sections only for this example.

A4B.5.1—Impact (Use standard AASHTO) (6B.7.4)

No impact for timber members: AASHTO 3.8.1.2

$I = 0$

A4B.5.2—Distribution (Use standard AASHTO) (6B.7.3)

For two lanes and plank deck [a]: AASHTO 3.23.2.2, Table 3.23.1

$$DF = \frac{S}{3.75} = \frac{16 \text{ in.}/12 \text{ in.}/\text{ft}}{3.75} = 0.36$$

a Note that the moments given in MBE are for one line of wheels. The values given in AASHTO are for the entire rear axle and are therefore twice the MBE values.

Thus:

$$M_{LL} = M_L \times DF = 53.5 \text{kip-ft} \times 0.36$$

$$M_{LL} = 19.26 \text{kip-ft}$$

A4B.5.3—Stresses to be Used (Use NDS, *National Design Specification for Wood Construction*, 2005 Edition)

The general equations for adjusted Reference Design Values are:

$F_b' = F_b \times C_D C_M C_t C_L C_F C_{fu} C_i C_r$

$F_V' = F_V \times C_D C_M C_t C_i$

F_b = 850 psi Reference Design Value, NDS Table 4D

F_V = 165 psi Reference Design Value, NDS Table 4D

C_D = 1.15 Load Duration Factor for two months is assumed as cumulative effect of live load. Wood bridges are typically located on low-volume roads; therefore, the accumulated live load duration is lower than 30 days. It is assumed that the live load duration is two months in the reliability analysis.

C_M = 1.0 Wet Service Factor is in NDS Table 4D for Sothern Pine

C_t = 1.0 Temperature Factor

C_L = 1.0 Beam Stability Factor

C_F = 0.98 Size Factor = $(12/d)^{1/9}$ for beam depth exceeding 12 in.

C_{fu} = 1.0 Flat Use Factor; not applicable

C_i = 1.0 Incising Factor

C_r = 1.0 Repetitive Use Factor, not applicable

A4B.5.3.1—Inventory Level Stresses (6B.6.2.7)

$F_b^I = 850 \times 1.15 \times 0.98 \times 1.0 = 958 \text{ psi} = 0.96 \text{ ksi}$

$C_D = 1.15$

$C_F = 0.98$

$C_i = 1.0$

and:

$F_V^I = 165 \times 1.15 \times 1.0 = 190 \text{ psi} = 0.19 \text{ ksi}$

A4B.5.3.2—Operating Level Stresses (Use standard AASHTO) (6B.6.2.7)

$F_b^O = F_b^I \times 1.33 = 950 \times 1.33$

$F_b^O = 1274 \text{ psi} = 1.27 \text{ ksi}$

and:

$F_V^O = 1.33 F_V^I = 1.33 \times 190 \text{ psi} = 253 \text{ psi}$

A4B.5.4—Inventory Level Rating for Flexure

Capacity:

$M_{R_I} = F_b^I S_x = 0.96 \text{ ksi} \times 196 \text{ in.}^3 = 188 \text{ kip-in.}$

$M_{R_I} = 15.68 \text{ kip-ft}$

then:

$$RF_I^M = \frac{M_{R_I} - M_{DL}}{M_{LL}} = \frac{15.68 \text{ kip-ft} - 2.03 \text{ kip-ft}}{19.26 \text{ kip-ft}} \qquad \text{Eq. 6B.5.1-1}$$

$RF_I^M =$ <u>0.71</u> or 0.71 × 15 tons = <u>10.7 tons</u> H truck

A4B.5.5—Operating Level Rating for Flexure

Capacity:

$M_{R_O} = F_b^O S_x = 1.27 \text{ ksi} \times 196 \text{ in.}^3 = 248.9 \text{ kip-in.}$

$M_{R_O} = 20.74 \text{ kip-ft}$

then:

$$RF_O^M = \frac{M_{R_O} - M_{DL}}{M_{LL}} = \frac{20.74\,\text{kip-ft} - 2.03\,\text{kip-ft}}{19.26\text{kip-ft}}$$ Eq. 6B.5.1-1

RF_O^M = 0.97 or 0.97 × 15 tons = 14.6 tons H truck

A4B.5.6—Check Horizontal Shear

Computed shear at: AASHTO 13.6.5.2

1. A distance from the support equal to three times the depth of the stringer, or
2. At the quarter point, whichever is less.

Thus by:

1. $3(14\text{ in.}) = 42\text{ in.} \leftarrow \text{ Controls} = 3.5\text{ ft}$
2. $\dfrac{17.83\text{ ft} \times 12\text{ in./ft}}{4} = 53.5\text{ in.}$

For H-15 Truck:

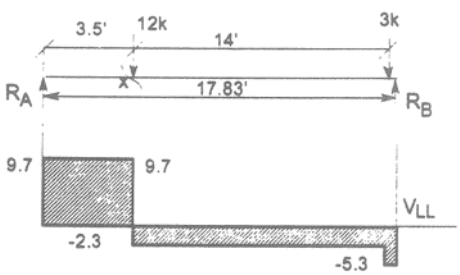

Figure A4B.5.6-1—Shear Diagram for Interior Stringer—H-15 Live Load

$$V_x = \frac{15(x - 2.8)}{L}$$ Appendix H6B

where L = 17.83 ft

$x = 17.83 - 3.5 = 14.33$ ft

$$V_x = \frac{15(14.33 - 2.8)}{17.83} = 9.7 \text{ kips per wheel line without distribution}$$

$$V_{L_x} = \frac{1}{2}\left(0.6V_x^{L\ no\ dist.} + DFV_x^{L\ no\ dist.}\right)$$ AASHTO 13.6.5.2, Eq. 13-10

$$V_{L_x} = \frac{1}{2}\left[0.6(9.7) + 0.36(9.7)\right]$$

$V_{L_x} = 4.7$ kips

For $w_{DL} = 0.051$ kip/ft

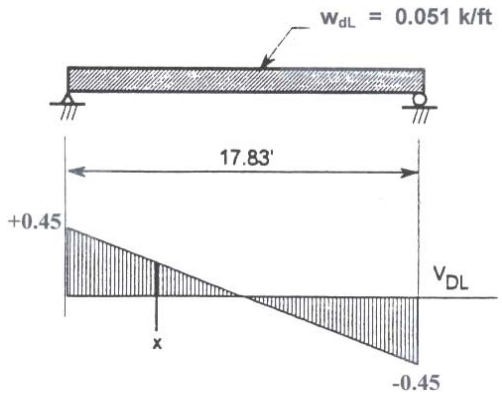

Figure A4B.5.6-2—Load and Shear Diagrams—Uniform Dead Load

$$R_A = R_B = \frac{1}{2} w_{DL} L$$

$$= \frac{1}{2}(0.051) \times 17.83$$

$$= 0.45 \text{ kips}$$

$$V_{D_x} = 0.45 - 0.051 \times 14/12$$

$$V_{D_x} = 0.4 \text{ kips}$$

A4B.5.7—Inventory Level Rating for Shear

Capacity:

$$V_R = \frac{2}{3} b d f_v$$ AASHTO Eq. 13-9

then:

$$V_{R_I} = \frac{2}{3}(6)(14)(190) \text{ psi} = 10640 \text{ lbs} = 10.64 \text{ kips}$$

$$RF_I^V = \frac{V_{R_I} - V_{D_x}}{V_{L_x}} = \frac{10.64 \text{ kips} - 0.4 \text{ kips}}{4.7 \text{ kips}}$$ Eq. 6B.5.1-1

RF_I^V = <u>2.18</u> or 2.18 × 15 tons = <u>32.7 tons</u> H truck

A4B.5.8—Operating Level Rating for Shear

Capacity:

$$V_{R_O} = \frac{2}{3}(6)(14)(253)\text{ psi} = 14168\text{ lbs} = 14.17\text{ kips}$$

$$RF_O^V = \frac{V_{R_O} - V_{D_x}}{V_{L_x}} = \frac{14.17\text{ kips} - 0.4\text{ kips}}{4.7\text{ kips}} \qquad \text{Eq. 6B.5.1-1}$$

RF_O^V = 2.93 or 2.93 × 15 tons = 43.95 tons H truck

A4B.5.9—Summary of Ratings for Allowable Stress Rating Method

Table A4B.5.9-1—Summary of Ratings for Allowable Stress Rating Method—Interior Stringer

Method/Force	*RF*	H Truck Max. Load, tons
Allowable Stress Moment:		
Inventory	0.71	10.7
Operating	0.97	14.6
Allowable Stress Shear:		
Inventory	2.18	32.7
Operating	2.93	43.9

∴ Rating governed by moment rather than shear.

A4B.6—Load Factor Rating

Not currently available for timber.

PART C—SUMMARY

A4C.1—Summary of All Ratings for Example A4

Table A4C-1—Summary of Rating Factors for All Rating Methods—Interior Stringer

Method		Design Load Rating		Legal Load Rating			H-15 Rating			
							Flexure		Shear	
		Inventory	Operating	Type 3	Type 3S2	Type 3-3	Inv.	Opr.	Inv.	Opr.
LRFR Strength I Limit State	Flexure	0.35	0.45	0.79	0.87	0.96	—	—	—	—
	Shear	1.07	1.39	2.36	2.58	2.86	—	—	—	—
Allowable Stress Method		—	—	—	—	—	0.71	0.97	2.18	2.93
Load Factor Method		—	—	—	—	—	—	—	—	—

A4C.2—References

AASHTO. 2002. *Standard Specifications for Highway Bridges*, 17th Edition, HB-17. American Association of State Highway and Transportation Officials, Washington, DC.

AASHTO. 2007. *AASHTO LRFD Bridge Design Specifications*, Fourth Edition, LRFDUS-4-M or LRFDSI-4. American Association of State Highway and Transportation Officials, Washington, DC.

NFPA. 2005. *National Design Specification for Wood Construction*. National Forest Products Association, Washington, DC.

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A5—FOUR-SPAN CONTINUOUS STRAIGHT WELDED PLATE GIRDER BRIDGE: EVALUATION OF AN INTERIOR GIRDER

Note: This example demonstrates the rating calculations for a straight, continuous plate girder for the design load, legal loads, and a permit load. Ratings have been performed only at critical moment and shear locations.

A5.1—Bridge Data

Span Lengths: 112 ft—140 ft—140 ft—112 ft
Year Built: 1965 (HS20 Design Load)
Noncomposite construction LRFD Design C6.10.1.6
Top flange is considered to be continuously braced by encasement in concrete
Haunches
Material: $F_y = 32$ ksi
$f_c' = 3$ ksi
Condition: No Deterioration
Riding Surface: Not field verified and documented
ADTT (one direction): 5500
Skew: 0°

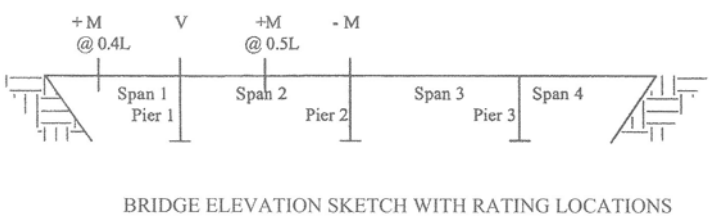

Figure A5.1-1—Bridge Elevation

A5.1.1—Girder Bracing

1. Cross Frames

   Spaced at 18 ft 2 in. at piers.

   Spaced at 24 ft 4 in. elsewhere.

2. Stiffeners

   Welded vertical intermediate stiffeners at 5 ft spacing.

A5.1.2—Girder Section Properties

See Figure A5.2.1-1.

	Region	Area (in.^{2})	I (in.^{4})	S (in.^{3})
	A	54.63	42540	1189.9
*	B	66.63	58038	1606.6
	C	54.63	42540	1189.9
	D	74.63	68550	1884.6
*	E	98.63	100965	2719.6
	F	74.63	68550	1884.6
	G	54.63	42540	1189.9
*	H	66.63	58038	1606.6

A5.1.3—Girder Sections

Region	Web Depth	Web Thickness	Top Flange Width	Top Flange Thickness	Bottom Flange Width	Bottom Flange Thickness
B	70 in.	0.4375 in.	16 in.	1.125 in.	16 in.	1.125 in.
C	70 in.	0.4375 in.	16 in.	0.75 in.	16 in.	0.75 in.
D	70 in.	0.4375 in.	16 in.	1.375 in.	16 in.	1.375 in.
E	70 in.	0.4375 in.	16 in.	2.125 in.	16 in.	2.125 in.
H	70 in.	0.4375 in.	16 in.	1.125 in.	16 in.	1.125 in.

A5.2—Dead Load Analysis—Interior Girder

Since the girders are noncomposite, all dead loads act upon the steel section.

A5.2.1—Components and Attachments, *DC*

Permanent loads on the deck are distributed uniformly among the beams.

Deck $\left(\frac{7.5}{12}\right)(7.833)(0.150) = 0.734\,\text{kip/ft}$

Haunch = 0.066 kip/ft

Stay-in-place forms = 0.098 kip/ft

Average Girder Self Weight: $\left(\frac{66}{144}\right)(0.490) = 0.224\,\text{kip/ft}$

Web Stiffeners = 0.011 kip/ft

Diaphragms = 0.015 kip/ft

Parapet Weight per girder = 0.310 kip/ft

Total per girder = 1.458 kip/ft

Say *DC* = 1.50 kip/ft

A5.2.2—Wearing Surface, *DW*

Overlay thickness was not field measured.

1.5 in. LMC Overlay: $\left(\frac{1.5}{12}\right)(32.7)(0.150)\times\frac{1}{5} = 0.122$ kip/ft

Say *DW* = 0.12 kip/ft

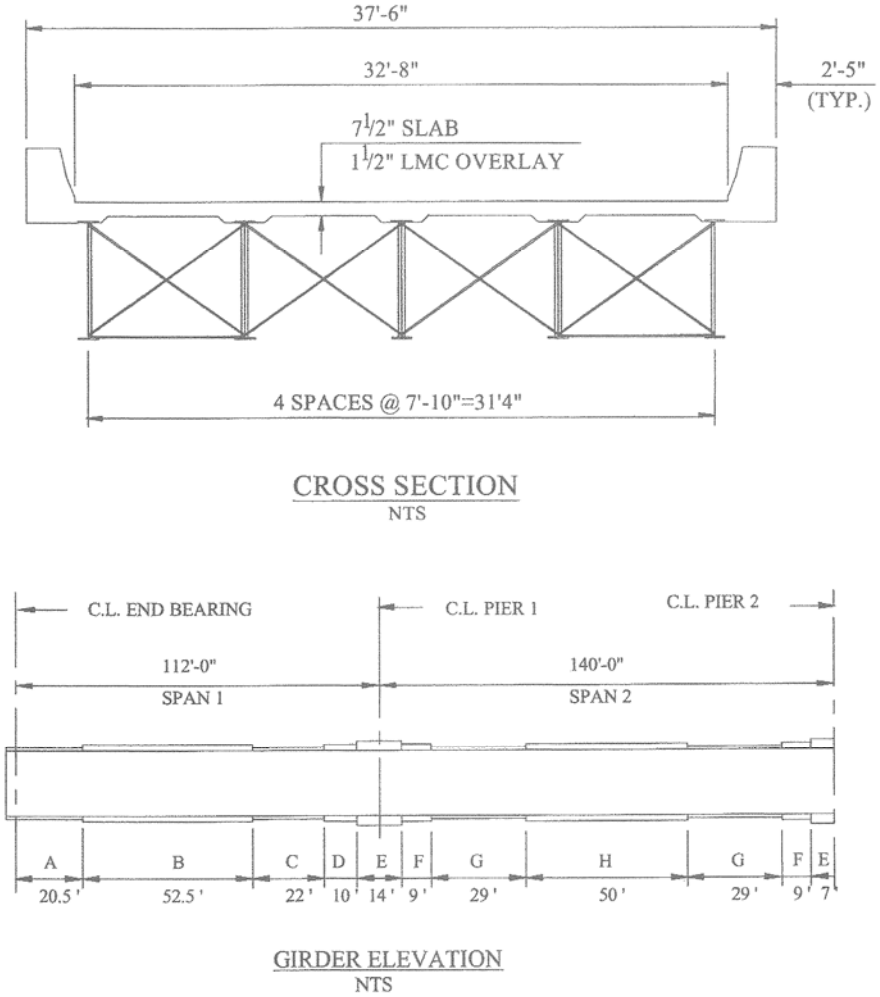

Figure A5.2.1-1—Bridge Cross-Section and Plate Girder Elevation

A5.3—Dead Load Effects

Continuous beam analysis results:

A5.3.1—Maximum Positive Moment at Span 1 (at 0.4*L* = 44.8 ft)

M_{DC} = 1236.6 kip-ft

M_{DW} = 98.9 kip-ft

A5.3.2—Maximum Positive Moment at Span 2 (at 0.5*L* = 182 ft)

M_{DC} = 1119.8 kip-ft

M_{DW} = 89.6 kip-ft

A5.3.3—Maximum Negative Moment at Pier 2 (252 ft)

M_{DC} = 2558.0 kip-ft

M_{DW} = 204.6 kip-ft

A5.3.4—Maximum Shear left of Pier 1 (112 ft)

V_{DC} = –106.8 kips

V_{DW} = –8.5 kips

A5.3.5—Negative Moments at Pier 1

M_{DC} = –2557.2 kip-ft

M_{DW} = –204.6 kip-ft

A5.4—Live Load Distribution Factors

AASHTO Type (a) cross section — LRFD Design Table 4.6.2.2.1-1

A5.4.1—Positive Flexure and Shear to the Left of Pier 1

Span 1 (same for Span 4)

$$K_g = n\left(I + Ae_g^{\,2}\right)$$

n = 9

For noncomposite construction, $e_g = 0$

I = 58037.9 in.^{4} (Region B and Region H)

K_g = 9 × 58037.9

= 522341 in.^{4}

$$\frac{K_g}{12Lt_s^3} = \frac{522341}{12\times112\left(7.5\right)^3}$$

= 0.92

Weighted Average of K_g may also be used, but distribution factor is not overly sensitive to K_g

A5.4.1.1—Interior Girder

$$g_{m1} = 0.06 + \left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12Lt_s^3}\right)^{0.1}$$

$$= 0.06 + \left(\frac{7.833}{14}\right)^{0.4}\left(\frac{7.833}{112}\right)^{0.3}(0.92)^{0.1}$$

$$g_{m1} = 0.414$$

$$g_{m2} = 0.075 + \left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12Lt_s^3}\right)^{0.1}$$

$$= 0.075 + \left(\frac{7.833}{9.5}\right)^{0.6}\left(\frac{7.833}{112}\right)^{0.2}(0.92)^{0.1}$$

$$= 0.594 > 0.414$$

$g_m = g_{m2} = 0.594$ For checking $+M$ at 44.8 ft

(0.4L of Span 1)

$$g_{V1} = 0.36 + \frac{S}{25}$$

$$= 0.36 + \frac{7.833}{25}$$

$$= 0.673$$

$$g_{V2} = 0.2 + \frac{S}{12} - \left(\frac{S}{35}\right)^{2.0}$$

$$= 0.2 + \frac{7.833}{12} - \left(\frac{7.833}{35}\right)^{2.0}$$

$$= 0.803 > 0.673$$

$g_V = g_{V2} = 0.803$ For checking V left of Pier 1 (112 ft)

Span 2 and Span 3:

Substitute $L = 126_{ave}$ ft into the distribution factor equations.

$g_m = 0.560$ For checking $+M$ at 182 ft

(0.5L of Span 2)

A5.4.2—Negative Flexure

Use K_g based on the section properties of the Pier section.

L = 140 ft for center pier (Pier 2) as adjacent spans are both 140 ft LRFD Design Table C4.6.2.2.1-1

L = (140 + 112)/2 = 126 ft for Pier 1

Pier 2:

$K_g = n\left(I + Ae_g^{\,2}\right)$

n = 9

e_g = 0 noncomposite section

I = 100965.1 in.^{4}(Region E)

K_g = 9 × 100965.1 = 908686

$$\frac{K_g}{12Lt_s^3} = \frac{908686}{12(140)(7.5)^3} = 1.282$$

A5.4.2.1—Interior Girder

$$g_{m1} = 0.06 + \left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12Lt_s^3}\right)^{0.1}$$

$$= 0.06 + \left(\frac{7.833}{14}\right)^{0.4}\left(\frac{7.833}{140}\right)^{0.3}(1.282)^{0.1}$$

$$g_{m1} = 0.402$$

$$g_{m2} = 0.075 + \left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12Lt_s^3}\right)^{0.1}$$

$$= 0.075 + \left(\frac{7.833}{9.5}\right)^{0.6}\left(\frac{7.833}{140}\right)^{0.2}(1.282)^{0.1}$$

$$= 0.588 > 0.402$$

$g_m = g_{m2} = 0.588$ For checking –M at Pier 2.

Pier 1:

Substitute L = 140 ft into the distribution factor equations.

g_m = 0.604 For checking –M at Pier 1.

A5.5—Live Load Effects

Continuous beam analysis results are described in Articles A5.5.1 through A5.5.4 below.

A5.5.1—Maximum Positive Moment at Span 1 (at 0.4*L*)

A5.5.1.1—Design Live Load (HL-93)

Design Lane Load = 841.0 kip-ft

Design Truck = 1404.0 kip-ft Governs

Design Tandem = 1108.0 kip-ft

IM = 33% 6A.4.3.3

M_{LL+IM} = $841.0 + 1404.0 \times 1.33 = 2708.3$ kip-ft

$g_m \times M_{LL+IM}$ = $(0.594)(2708.3) = 1608.7$ kip-ft

A5.5.1.2—Legal Loads

Use only truck loads as span length < 200 ft

1. Type 3 = 1011.1 kip-ft
2. Type 3S2 = 1230.1 kip-ft
3. Type 3-3 = 1232.6 kip-ft Governs

IM = 33% 6A.4.4.3

M_{LL+IM} = 1232.6 × 1.33 unknown riding surface condition = 1639.4 kip-ft

$g_m \times M_{LL+IM}$ = $(0.594)(1639.4) = 973.8$ kip-ft

A5.5.2—Maximum Positive Moment at Span 2 (at 0.5*L*)

A5.5.2.1—Design Live Load (HL-93)

Design Lane Load = 903.5 kip-ft

Design Truck = 1405.2 kip-ft Governs

Design Tandem = 1109.2 kip-ft

IM = 33%

M_{LL+IM} = $903.5 + 1405.2 \times 1.33 =$ 2772.4 kip-ft

$g_m \times M_{LL+IM}$ = $(0.560)(2772.4) =$ 1552.5 kip-ft

A5.5.2.2—Legal Loads (Use Only Truck Loads)

4. Type 3 = 1012.8 kip-ft
5. Type 3S2 = 1234.7 kip-ft
6. Type 3-3 = 1259.1 kip-ft Governs

IM = 33%

M_{LL+IM} = $1259.1 \times 1.33 = 1674.6$ kip-ft

$g_m \times M_{LL+IM}$ = $(0.560)(1674.6) =$ 937.8 kip-ft

A5.5.3—Maximum Negative Moment at Pier 2

Live-load analysis for negative moment and reactions at interior piers in a continuous bridge requires the consideration of an additional lane-type load model. LRFD and LRFR recognize the possibility of more than one truck in a lane causing the maximum force effect. The influence line for moment at Pier 2 is shown in Figure 1 along with the governing load placement for the design load case, the legal load case and the permit load case.

Live Load Models and Placement:

Design Load	6A.4.3.2.1
Legal Load	6A.4.4.2.1
Permit Load	6A.4.5.4.1

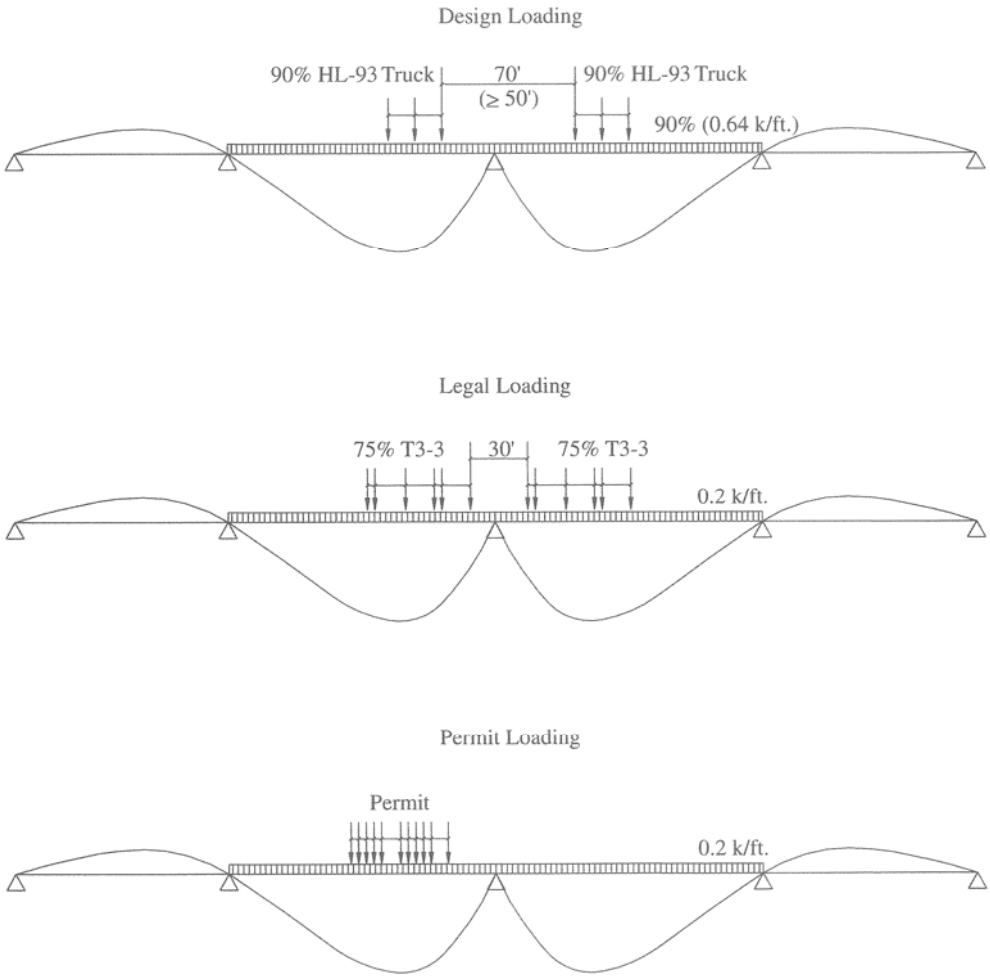

Figure A5.5.3-1—Influence Line for Moment Over Center Pier (Pier 2) with Design, Legal, and Permit Loading

(shows lane-type loading)

A5.5.3.1—Calculate Maximum Negative Moment at Pier 2

A5.5.3.1a—Design Live Load (HL-93)

Design Lane Load = –1388 kip-ft

Design Truck = –895.5 kip-ft

Design Tandem = –612.8 kip-ft

Double Trucks = –1790.1 kip-ft

IM = 33%

Lane Load + Design Truck = –1388 – 895.5 × 1.33 = –2579 kip-ft

Lane Load + Tandem Axles = –1388 – 612.8 × 1.33 = –2203 kip-ft

0.9 (Lane Load + Double Trucks) = 0.9(–1388 – 1790.1 × 1.33) = –3392 kip-ft Governs

M_{LL+IM} = –3392 kip-ft

$g_m \times M_{LL+IM}$ = (0.588)(–3392) = –1994.5 kip-ft

A5.5.3.1b—Legal Loads (Truck Loads and Lane-Type Load)

1. Type 3 = –582.0 kip-ft
2. Type 3S2 = –800.6 kip-ft
3. Type 3-3 = –858.9 kip-ft Governs
4. Lane Type Load

   Axle Loads = –1291.0 kip-ft

   Uniform Load = –433.9 kip-ft

IM = 33%

is applied to axle loads only.

Type 3 = (–582.0 × 1.33)

= –774.1 kip-ft

Type 3S2 = (–800.6 × 1.33)

= –1065 kip-ft

Type 3-3 = (–858.9 × 1.33)

= –1142 kip-ft

Lane-Type Load = (–1291.0 × 1.33) + (–433.9)

= –2150.9 kip-ft Governs

M_{LL+IM} = –2150.9 kip-ft

$g_m \times M_{LL+IM}$ = (0.588)(–2150.9)

= 1264.7 kip-ft

Table A5.5.3.1b-1—Girder Bending Stresses at Critical Sections

Location	S (in.^{3})	Live Load	$g_m M_{LL+IM}$ (kip-ft)	f_{LL+IM} (ksi)	M_{DC} (kip-ft)	M_{DW} (kip-ft)	f_{DC} (ksi)	f_{DW} (ksi)
Span 1 at 0.4L	1606.6	HL-93 Legal Load	1608.7 973.8	12.02 7.27	1236.6	98.9	9.24	0.74
Pier 2	2719.6	HL-93 Legal Load	–1994.5 –1264.7	–8.80 –5.58	–2558.0	–204.6	–11.29	–0.90
Span 2 at 0.5L	1606.6	HL-93 Legal Load	1552.5 937.8	11.60 7.00	1119.8	89.6	8.36	0.67

A5.5.4—Maximum Shear at Pier 1 (Left of Support)

A5.5.4.1—Design Live Load (HL-93)

Design Lane Load = –53.9 kips

Design Truck = –68.3 kips Governs

Design Tandem = –49.5 kips

IM = 33%

= –53.9 – 68.3 × 1.33

V_{LL+IM} = –144.7 kips

$g_v \times V_{LL+IM}$ = (0.803)(–144.7)

= –116.2 kips

A5.5.4.2—Legal Loads

1. Type 3 = –48.0 kips 6A.4.4.2.1
2. Type 3S2 = –63.9 kips
3. Type 3-3 = –67.7 kips Governs

Note: Lane-type load is not required when checking shear.

IM = 33%

V_{LL+IM} = (–67.7)(1.33)

= –90.0 kips

$g_v \times V_{LL+IM}$ = (0.803)(–90.0)

= –72.3 kips

A5.6—Compute Nominal Flexural Resistance of Section (Positive and Negative Moment)

A5.6.1—Noncomposite Symmetric Section

A5.6.1.1—Check Web for Noncompact Slenderness Limit

$$\frac{2D_c}{t_w} < 5.7\sqrt{\frac{E}{F_{yc}}}$$ LRFD Design Eq. 6.10.6.2.3-1

$$\frac{2D_c}{t_w} = \frac{70}{0.4375} = 160$$

$$5.7\sqrt{\frac{E}{F_{yc}}} = 5.7\sqrt{\frac{29000}{32}} = 171.6 > \frac{2D_c}{t_w}$$

And check that flanges satisfy the ratio:

$$\frac{I_{yc}}{I_{yt}} \geq 0.3$$ LRFD Design Eq. 6.10.6.2.3-2

in this case:

$$\frac{I_{yc}}{I_{yt}} = 1.0 \geq 0.3$$

Because the bridge is straight and F_y of the flanges does not exceed 70 ksi, the optional provisions of LRFD Design Appendix A may be applied to determine the nominal flexural resistance of noncomposite sections. LRFD Design C6.10.6.2.3

A5.6.2—Regions B and H—Positive Moment Sections with Continuously Braced Compression Flanges

$M_u \leq \varphi_f R_{pc} M_{yc}$ where R_{pc} = Web Plastification Factor LRFD Design Eq. A6.1.3-1

For rating $R_n = R_{pc}M_{yc}$

Noncomposite sections that satisfy the following shall qualify as compact web sections:

$$\frac{2D_{cp}}{t_w} \leq \lambda_{pw(D_{cp})}$$ LRFD Design Eq. A6.2.1-1

$$\frac{2D_{cp}}{t_w} = 160$$

$$\lambda_{pw(D_{cp})} = \frac{\sqrt{\frac{E}{F_{yc}}}}{\left[0.54\frac{M_p}{R_h M_y} - 0.09\right]^2} \leq \lambda_{rw}\left(\frac{D_{cp}}{D_c}\right)$$ LRFD Design Eq. A6.2.1-2

where:

$$\lambda_{rw}\left(\frac{D_{cp}}{D_c}\right)=5.7\sqrt{\frac{29000}{32}}\left(\frac{35}{35}\right)=171.59$$

A5.6.2.1—Calculate Plastic Moment, M_p (LRFD Design D6.1)

Top flange:

P_c = 16 in. × 1.125 in. × 32 ksi = 576 kips

Bottom flange:

P_t = 16 in. × 1.125 in. × 32 ksi = 576 kips

Web:

P_w = 70 in. × 0.4375 in. × 32 ksi = 980 kips

d_t = $d_c = \frac{70}{2}+\frac{1.125}{2}=35.56$ in.

D = 70 in.

Referring to LRFD Design Appendix D6.1, Table 6.1-1, Case I:

$$\bar{y} = \frac{D}{2}=35 \text{ in.}$$

$$M_p = \frac{P_w}{2D}\left[\bar{y}^2+(D-\bar{y})^2\right]+(P_c d_c+P_t d_t)$$

$$= \frac{980}{2\times 70}\left[35^2+(70-35)^2\right]+2\times 576\times 35.56$$

$$= (17150+40965.1)\times\frac{1}{12 \text{ in./ft}}$$

$$= 4842.9 \text{ kip-ft}$$

M_y = $F_y S$ LRFD Design D6.2.1

$$= 32\times 1606.6\times\frac{1}{12}$$

$$= 4284.3 \text{ kip-ft}$$

R_h = 1.0

$$\lambda_{pw(D_{cp})} = \frac{\sqrt{\frac{29000}{32}}}{\left[0.54\times\frac{4842.9}{1.0\times 4284.3}-0.09\right]^2}$$

$$= 111.16 < \frac{2D_{cp}}{t_w}=160$$

Therefore, the web section is not compact.

Check if section satisfies the requirements for noncompact web sections. LRFD Design A6.2.2

$\lambda_w < \lambda_{rw}$ LRFD Design Eq. A6.2.2-1

$\lambda_w = \frac{2D_c}{t_w} = 160$ LRFD Design Eq. A6.2.2-2

$\lambda_{rw} = 5.7\sqrt{\frac{E}{F_{yc}}} = 171.6$ LRFD Design Eq. A6.2.1-3

$\lambda_w = 160 < \lambda_{rw} = 171.6$

Therefore, the section qualifies as a noncompact web section.

R_{pc} shall be taken as:

$$R_{pc} = \left[1-\left(1-\frac{R_h M_{yc}}{M_p}\right)\left(\frac{\lambda_w-\lambda_{pw(D_c)}}{\lambda_{rw}-\lambda_{pw(D_c)}}\right)\right]\frac{M_p}{M_{yc}} \le \frac{M_p}{M_{yc}}$$ LRFD Design Eq. A6.2.2-4

$$\lambda_{pw(D_c)} = \lambda_{pw(D_{cp})}\left(\frac{D_c}{D_{cp}}\right) \le \lambda_{rw}$$ LRFD Design Eq. A6.2.2-6

$$111.16\left(\frac{35}{35}\right) = 111.16 \le 171.6$$

$$= \left[1-\left(1-\frac{1.0\times 4284.3}{4842.9}\right)\left(\frac{160-111.16}{171.6-111.16}\right)\right]\frac{4842.9}{4284.3}$$

$$= 0.9068\frac{M_p}{M_{yc}} \le \frac{M_p}{M_{yc}}$$

$$= 1.025 \le 1.13$$

$R_{pc} = 1.025$

$M_n = R_{pc} M_{yc} = 1.025 \times 4284.3$ kip-ft $= 4391.5$ kip-ft

Because f_ℓ is equal to zero in this case and M_{yc} is equal to M_{yt}, the flexural resistance based on the discretely braced tension flange at this section does not control and need not be checked (LRFD Design CA6.1.2).

$\therefore R_n = M_n = 4391.5$ kip-ft

A5.6.3—Region E—Negative Moment Sections with Discretely Braced Compression Flange (LRFD Design A6.1.1)

$$M_u + \frac{1}{3} f_\ell S_{xc} \le \phi M_{nc}$$ LRFD Design Eq. A6.1.1-1

For rating:

$R_n = M_{nc} - \frac{1}{3} f_\ell S_{xc}$

where:

M_{nc} = nominal flexural resistance specified in LRFD Design Appendix A6.3 and based on the compression flange. M_{nc} is to be determined as the smaller of the local buckling resistance and the lateral torsional buckling resistance.

A5.6.3.1—Calculate Local Buckling Resistance (LRFD Design A6.3.2)

$\lambda_f = \frac{b_{fc}}{2t_{fc}}$ LRFD Design Eq. A6.3.2-3

$= \frac{16}{2 \times 2.125} = 3.76$

$\lambda_{pf} = 0.38\sqrt{\frac{E}{F_{yc}}}$ LRFD Design Eq. A6.3.2-4

$= 0.38\sqrt{\frac{29000}{32}}$

$= 11.4 > \lambda_f$

As $\lambda_f \leq \lambda_{pf}$, then: LRFD Design Eq. A6.3.2-1

$M_{nc} = R_{pc} M_{yc}$

Recalculating $M_n = R_{pc} M_{yc}$ for Region E:

$M_{yc} = F_y S$

$= \frac{32 \text{ ksi} \times 2719.6 \text{ in.}^3}{12 \text{ in./ft}}$

$= 7252.3$ kip-ft

P_c = 16 in. × 2.125 in. × 32 ksi = 1088 kips

$P_t = P_c$ = 1088 kips

P_w = 980 kips

$d_t = d_c = \frac{70}{2} + \frac{2.125}{2} = 36.06$ in.

D = 70 in.

$\bar{y}$ = 35 in.

$M_p = \frac{980}{2 \times 70}\left[35^2 + (70-35)^2\right] + 2 \times 1088 \times 36.06$

$= 17150 + 78467$

= 95617 kip-in.

= 7968 kip-ft

Then:

$$R_{pc} = \left[1-\left(1-\frac{R_h M_{yc}}{M_p}\right)\left(\frac{\lambda_w-\lambda_{pw(D_c)}}{\lambda_{rw}-\lambda_{pw(D_c)}}\right)\right]\frac{M_p}{M_{yc}} \le \frac{M_p}{M_{yc}}$$

where:

$$\lambda_{pw(D_c)} = \lambda_{pw(D_{cp})}\left[\frac{D_c}{D_{cp}}\right] \le \lambda_{rw}$$

$$\frac{\sqrt{\frac{29000\,\text{ksi}}{32\,\text{ksi}}}}{\left(0.54\times\frac{7968\,\text{kip-ft}}{1.0\times 7252.3}-0.09\right)^2}\times\frac{35}{35} = 118.85 \le \lambda_{rw}$$

λ_{rw} = 171.6 λ_w = 160

$$R_{pc} = \left[1-\left(1-\frac{1.0\times 7252.3}{7968}\right)\left(\frac{160-118.85}{171.6-118.85}\right)\right]\frac{7968}{7252.3} \le \frac{7968}{7252.3}$$

= 0.9299 × 1.0987

= 1.0217 ≤ 1.0987

M_{nc} = 1.0217 × 7252.3 = 7409.7 kip-ft

A5.6.3.2—Calculate Lateral Torsional Buckling Resistance (LRFD Design A6.3.3)

L_b = Unbraced length = 18 ft 2 in. = 218 in.

In this example, the unbraced length encompasses three cross-section regions, C, D, and E (or E, F, and G). LRFD Design Article C6.10.8.2.3 states that for unbraced lengths containing one or more transitions, only transitions located within 20 percent of the unbraced length from the brace point with the smaller moment may be ignored and the lateral torsional buckling resistance of the remaining nonprismatic unbraced length may be computed as the smallest resistance based on the remaining sections. Because only the transition between Regions C and D is located within 20 percent of the unbraced length from the brace point with the smaller moment, that particular transition may be ignored. The lateral torsional buckling must be computed based on the section in Region D.

Determine L_p and L_r for Section D:

$b_{fc} = b_{ft}$ = 16 in., $t_{fc} = t_{ft}$ = 1.375 in., web depth D = 70 in. t_w = 0.4375 in.

Calculate effective radius of gyration r_t:

$$r_t = \frac{b_{fc}}{\sqrt{12\left(1+\frac{1}{3}\frac{D_c t_w}{b_{fc} t_{fc}}\right)}}$$

LRFD Design Eq. A6.3.3-10

$$= \frac{16}{\sqrt{12\left(1+\frac{1}{3}\times\frac{35\times 0.4375}{16\times 1.375}\right)}}$$

$$= 4.16 \text{ in.}$$

LRFD Design Eq. A6.3.3-4

$$L_p = 1.0 r_t \sqrt{\frac{E}{F_{yc}}}$$

$$L_p = 1.0\times 4.16\sqrt{\frac{29000}{32}} = 125.23 \text{ in.}$$

Calculate St. Venant torsional constant J

LRFD Design Eq. A6.3.3-9

$$J = \frac{Dt_w^3}{3}+\frac{b_{fc}t_{fc}^3}{3}\left(1-0.63\frac{t_{fc}}{b_{fc}}\right)+\frac{b_{ft}t_{ft}^3}{3}\left(1-0.63\frac{t_{ft}}{b_{ft}}\right)$$

$$= \frac{70\times 0.4375^3}{3}+\frac{16\times 1.375^3}{3}\left(1-0.63\times\frac{1.375}{16}\right)+\frac{16\times 1.375^3}{3}\left(1-0.63\times\frac{1.375}{16}\right)$$

$$= 28.18 \text{ in.}^4$$

Depth between centerline of flanges, h = 70 in. + 1.375 in. = 71.375 in.

Calculate F_{yr} in order to compute L_r, where F_{yr} is the smaller of: LRFD Design A6.3.3

$0.7F_{yc}$ = 0.7×32 ksi = 22.4 ksi

and:

$$R_h F_{yt}\frac{S_{xt}}{S_{xc}} = 1.0\times 32 \text{ ksi}\times\frac{1884.6 \text{ in.}^3}{1884.6 \text{ in.}^3} = 32 \text{ ksi}$$

but not less than $0.5F_{yc}$ = 0.5×32 ksi = 16 ksi

Therefore, 22.4 ksi governs.

LRFD Design Eq. A6.3.3-5

$$L_r = 1.95 r_t \frac{E}{F_{yr}}\sqrt{\frac{J}{S_{xc}h}}\sqrt{1+\sqrt{1+6.76\left(\frac{F_{yr}}{E}\times\frac{S_{xc}h}{J}\right)^2}}$$

$$= 1.95\times 4.16\times\frac{29000}{22.4}\sqrt{\frac{28.18}{1884.6\times 71.375}}\sqrt{1+\sqrt{1+6.76\left(\frac{22.4}{29000}\cdot\frac{1884.6\times 71.375}{28.18}\right)^2}}$$

$$= 495.8 \text{ in.}$$

The moment gradient modifier C_b can be taken equal to 1.0 in this case according to LRFD Design Article A6.3.3.

Note: If all transitions had been located within 20 percent of the unbraced length from the brace point with the smaller moment, C_b would not have to be taken equal to 1.0 and the Lateral Torsional Buckling resistance could be based on the larger flange. Under those circumstances, C_b should be calculated because the results would lead to a larger rating.

Determine R_{pc} in accordance with LRFD Design Articles A6.2.1 or A6.2.2 as applicable and determine M_{yc}:

Top flange P_c = 16 in. × 1.375 in. × 32 ksi = 704 kips

Bottom flange P_t = 16 in. × 1.375 in. × 32 ksi = 704 kips

Web P_w = 70 in. × 0.4375 in. × 32 ksi = 980 kips

$$d_t = d_c = \frac{70}{2} + \frac{1.375}{2} = 36.375 \text{ in.}$$

$$D = 70 \text{ in.}$$

Referring to LRFD Design Appendix D6.1, Table 6.1-1, Case I:

$$\bar{y} = \frac{D}{2} = 35 \text{ in.}$$

$$M_p = \frac{P_w}{2D}\left[\bar{y}^2 + (D-\bar{y})^2\right] + (P_c d_c + P_t d_t)$$

$$= \frac{980}{2\times 70}\left[35^2 + (70-35)^2\right] + 2\times 704\times 36.375$$

$$= (17150 + 51216)\times\frac{1}{12 \text{ in./ft}}$$

$$= 5697.2 \text{ kip-ft}$$

$$M_y = F_y S$$ LRFD Design D6.2.1

$$= 32\times 1884.6\times\frac{1}{12}$$

$$= 5025.6 \text{ kip-ft}$$

$$R_h = 1.0$$

$$\lambda_{pw(D_{cp})} = \frac{\sqrt{\frac{29000}{32}}}{\left[0.54\times\frac{5697.2}{1.0\times 5025.6} - 0.09\right]^2} = 110.4$$

$$\frac{2D_{cp}}{t_w} = \frac{2\times 35}{0.4375} = 160$$

$$= 110.4 < 160$$

Therefore, the web section is not compact.

Check if section satisfies the requirements for noncompact web sections: LRFD Design A6.2.2

$\lambda_w < \lambda_{rw}$ LRFD Design Eq. A6.2.2-1

$\lambda_w = \dfrac{2D_c}{t_w} = 160$ LRFD Design Eq. A6.2.2-2

$\lambda_{rw} = 5.7\sqrt{\dfrac{E}{F_{yc}}} = 171.6$ LRFD Design Eq. A6.2.1-3

$\lambda_w = 160 < \lambda_{rw} = 171.6$

R_{pc} shall be taken as:

$$R_{pc} = \left[1-\left(1-\frac{R_h M_{yc}}{M_p}\right)\left(\frac{\lambda_w-\lambda_{pw(D_c)}}{\lambda_{rw}-\lambda_{pw(D_c)}}\right)\right]\frac{M_p}{M_{yc}} \le \frac{M_p}{M_{yc}}$$ LRFD Design Eq. A6.2.2-4

$$\lambda_{pw(D_c)} = \lambda_{pw(D_{cp})}\left(\frac{D_c}{D_{cp}}\right) \le \lambda_{rw}$$ LRFD Design Eq. A6.2.2-6

$$110.4\left(\frac{35}{35}\right) = 110.4 \le 171.6$$

$$= \left[1-\left(1-\frac{1.0\times 5025.6}{5697.2}\right)\left(\frac{160-110.4}{171.6-110.4}\right)\right]\frac{5697.2}{5025.6}$$

$$= 0.9045\frac{M_p}{M_{yc}} \le \frac{M_p}{M_{yc}}$$

$$= 1.025 \le 1.13$$

R_{pc} = 1.025 and M_{yc} = 5025.6 kip-ft = 60307 kip-in.

Then:

$$M_{nc}\,(\text{for Region D}) = C_b\left[1-\left[1-\frac{F_{yr}S_{xc}}{R_{pc}M_{yc}}\right]\left[\frac{L_b-L_p}{L_r-L_p}\right]\right]R_{pc}M_{yc} \le R_{pc}M_{yc}$$

where F_{yr} was previously determined by $0.7F_{yc}$ = 0.7×32 ksi = 22.4 ksi LRFD Design A6.3.3

$$M_{nc} = 1.0\left[1-\left[1-\frac{22.4\,\text{ksi}\times 1884.6\text{ in.}^3}{1.025\times 60307\text{ kip-in.}}\right]\left[\frac{218\text{ in.}-125.23\text{ in.}}{495.8\text{ in.}-125.23\text{ in.}}\right]\right]R_{pc}M_{yc} \le R_{pc}M_{yc}$$

$$M_{nc} = 1.0\times\left[1-(1-0.6829)(0.2503)\right]\times 1.025\times 5025.6\text{ kip-ft} = 4742.4\text{ kip-ft}$$

$$M_{nc(pier)} = M_{nc}\times\frac{S_{xc(Region\,E)}}{S_{xc(Region\,D)}} = 4742.4\times\frac{2719.6}{1884.6} = 6843.6\text{ kip-ft}$$

6843.6 kip-ft $\le M_{nc}$ for local buckling = 7409.7 kip-ft

Because M_{yc} is equal to M_{yt}, the flexural resistance based on the continuously braced tension flange at this section does not control and need not be checked.

Therefore, $R_n = M_{nc(pier)} = 6943.6$ kip-ft

A5.7—General Load Rating Equation (6A.4.2)

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_L)(LL + IM)}$$ Eq. 6A.4.2.1-1

Evaluation Factors (for Strength Limit State)

- Resistance Factor, φ LRFD Design 6.5.4.2

φ = 1.0 for flexure and shear

- Condition Factor, φ_c 6A.4.2.3

φ_c = 1.0 No deterioration

- System Factor, φ_s 6A.4.2.4

φ_s = 1.0 Multi-girder bridge

A5.8—Design Load Rating 6A.4.3

A5.8.1—Strength I Limit State 6A.6.4.1

$$RF = \frac{(\varphi_c)(\varphi_s)(\varphi) R_n - (\gamma_{DC})(DC) - (\gamma_{DW})(DW)}{(\gamma_L)(LL + IM)}$$

A5.8.1.1—Flexure at Span 1, 0.4L

$$\text{Inventory } RF = \frac{(1.0)(1.0)(1.0)(4391.5) - (1.25)(1236.6) - (1.5)(98.9)}{(1.75)(1608.7)}$$

= 0.96 Governs

$$\text{Operating } RF = 0.96 \times \frac{1.75}{1.35}$$

= 1.24 Governs

A5.8.1.2—Flexure at Span 2, 0.5L

$$\text{Inventory } RF = \frac{(1.0)(1.0)(1.0)(4391.5) - (1.25)(1119.8) - (1.5)(89.6)}{(1.75)(1552.5)}$$

= 1.05

$$\text{Operating } RF = 1.05 \times \frac{1.75}{1.35}$$

= 1.36

A5.8.1.3—Flexure at Pier 2

$$\text{Inventory } RF = \frac{(1.0)(1.0)(1.0)(6943.7) - (1.25)(2558.0) - (1.5)(204.6)}{(1.75)(1994.5)}$$

= 0.99 Governs

Operating RF = $0.99 \times \frac{1.75}{1.35}$

= 1.28

A5.8.2—Service II Limit State (6A.6.4.1)

Calculated for illustration; does not govern for noncomposite, noncompact sections as discussed later.

For Service Limit States, $C = f_R$ 6A.4.2.1

$$RF = \frac{f_R - (\gamma_D)(f_D)}{(\gamma_L)(f_{LL+IM})}$$

f_R = $0.80R_hF_{yf}$ for noncomposite sections LRFD Design 6.10.4.2.2

R_h was previously determined to be 1.0

f_R = 0.80 × 1.0 × 32

= 25.6 ksi

γ_D = $\gamma_{DC} = \gamma_{DW} = 1.0$ Table 6A.4.2.2-1

γ_L = 1.3 for Inventory

= 1.0 for Operating

A5.8.2.1—At Span 1, 0.4L

Inventory RF = $\frac{25.6 - (1.0)(9.24 + 0.74)}{(1.3)(12.02)} = 1.00$

Operating RF = $1.00 \times \frac{1.30}{1.00} = 1.30$

A5.8.2.2—At Span 2, 0.5L

Inventory RF = $\frac{25.6 - (1.0)(8.36 + 0.67)}{(1.3)(11.60)} = 1.10$

Operating RF = $1.10 \times \frac{1.30}{1.00} = 1.43$

A5.8.2.3—At Pier 2

Inventory RF = $\frac{25.6 - (1.0)(11.29 + 0.90)}{(1.3)(8.80)} = 1.17$

Operating RF = $1.17 \times \frac{1.30}{1.00} = 1.52$

As seen here the Strength I rating factors govern over the corresponding Service II rating factors. This is a true statement for all noncomposite, noncompact steel beams. During normal ratings the Service II rating factors do not need to be calculated for the Design Load Rating when the steel beam is both noncomposite and noncompact. This is true in both LRFD and LRFR.

A5.8.3—Legal Load Rating (6A.4.4)

The Design Load Ratings at the inventory level were not all > 1.0. The Design Load Ratings at operating level were all > 1.0. If a state (or owner) allows legal vehicles that exceed the AASHTO legal loads then load ratings with the State legal vehicles will be necessary. Legal Load Ratings using the AASHTO legal loads are demonstrated for illustration.

Type 3-3 is governed for the positive moment locations and the Lane-Type Loading is governed for the negative moment location. The rating factors will be demonstrated using only the governing loadings. (See Table A5.5.3.1b-1 for girder bending stresses.)

A5.8.3.1—Strength I Limit State (6A.6.4.2.1)

$ADTT = 5500$ Table 6A.4.4.2.3a-1

$\gamma_L = 1.45$

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A5.8.3.1a—Flexure at Span 1, 0.4L

Type 3-3 + $g_m M_{LL+IM}$ = 973.8 kip-ft

$$RF = \frac{(1.0)(1.0)(1.0)(4391.5)-(1.25)(1236.6)-(1.5)(98.9)}{(1.45)(973.8)}$$

$$= 1.91$$

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A5.8.3.1b—Flexure at Span 2, 0.5L

Type 3-3 + $g_m M_{LL+IM}$ = 937.8 kip-ft

$$RF = \frac{(1.0)(1.0)(1.0)(4391.5)-(1.25)(1119.8)-(1.5)(89.6)}{(1.45)(937.8)}$$

$$= 2.10$$

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A5.8.3.1c—Flexure at Pier 2

Lane-Type Load – $g_m M_{LL+IM}$ = 1264.7 kip-ft

$$RF = \frac{(1.0)(1.0)(1.0)(6943.6)-(1.25)(2558.0)-(1.5)(204.6)}{(1.45)(1264.7)}$$

$$= 1.88 \quad \text{Governs}$$

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A5.8.3.2—Service II Limit State (6A.6.4.2.2)

$f_R = 0.80 R_h F_{yf}$ for noncomposite sections

R_h was previously determined to be 1.0 LRFD Design 6.10.4.2.2

$f_R = 0.80 \times 1.0 \times 32$ Table 6A.4.2.2-1

= 25.6 ksi

γ_D = $\gamma_{DC} = \gamma_{DW} = 1.0$

γ_{LL} = 1.3

A5.8.3.2a—At Span 1, 0.4L (Type 3-3 Truck Governs)

$$RF = \frac{25.6-(1.0)(9.24+0.74)}{(1.3)(7.27)}$$

= 1.65

A5.8.3.2b—At Span 2, 0.5L (Type 3-3 Truck Governs)

$$RF = \frac{25.6-(1.0)(8.36+0.67)}{(1.3)(7.00)}$$

= 1.82

A5.8.3.2c—At Pier 2 (Lane-Type Load Governs)

$$RF = \frac{25.6-(1.0)(11.29+0.90)}{(1.3)(5.58)}$$

= 1.85

A5.9—Shear Evaluation 6A.6.10

Maximum shear at Pier 1 (see previous calculations):

V_{DC} = 106.8 kips

V_{DW} = 8.5 kips

$g_v V_{LL+IM}$ = 116.2 kips (HL-93)

$g_v V_{LL+IM}$ = 72.3 kips (Type 3-3)

A5.9.1—Shear Resistance at Pier 1

Spacing of vertical stiffeners = 5 ft c/c

Web depth:

D = 70 in. = 5.83 ft

$3D$ = 3 × 70 in. = 210 in. = 17.5 ft

As transverse stiffener spacing is less than $3D$, the interior web panels are considered stiffened. LRFD Design 6.10.9

A5.9.2—Shear Resistance for Interior Panel

Check: LRFD Design Eq. 6.10.9.3.2-1

$$\frac{2Dt_w}{(b_{fc}t_{fc}+b_{ft}t_{ft})} \le 2.5$$

$$\frac{2Dt_w}{(b_{fc}t_{fc}+b_{ft}t_{ft})}=\frac{2\times 70\times 0.4375}{(16\times 2.125+16\times 2.125)}=0.9\le 2.5$$

Then:

LRFD Design Eq. 6.10.9.3.2-2

$$V_n = V_p\left[C+\frac{0.87(1-C)}{\sqrt{1+\left(\frac{d_o}{D}\right)^2}}\right]$$

LRFD Design Eq. 6.10.9.3.2-3

$$V_n = 0.58F_{yw}Dt_w$$

$$= 0.58 \times 32 \times 70 \times 0.4375$$

$$= 568.4 \text{ kips}$$

Determine C:

LRFD Design Eq. 6.10.9.3.2-7

$$k = 5+\frac{5}{\left(\frac{d_o}{D}\right)^2}$$

where d_o = stiffener spacing = 60 in.

$$k = 5+\frac{5}{\left(\frac{60}{70}\right)^2}=11.81$$

If:

LRFD Design Eq. 6.10.9.3.2-4

$$\frac{D}{t_w} < 1.12\sqrt{\frac{Ek}{F_{yw}}}$$

then:

$$C = 1.0$$

$$\frac{D}{t_w} = \frac{70}{0.4375}=160$$

$$1.12\sqrt{\frac{Ek}{F_{yw}}} = 1.12\sqrt{\frac{29000\times 11.81}{32}}=115.9$$

160 > 115.9 FAIL

If:

LRFD Design Eq. 6.10.9.3.2-5

$$1.12\sqrt{\frac{Ek}{F_{yw}}} \le \frac{D}{t_w}\le 1.40\sqrt{\frac{Ek}{F_{yw}}}$$

then:

$$C = \frac{1.12}{\left(\frac{D}{t_w}\right)^2}\left(\frac{Ek}{F_{yw}}\right)$$

$$1.40\sqrt{\frac{Ek}{F_{yw}}} = 144.9$$

160 > 144.9 FAIL

If: LRFD Design Eq. 6.10.9.3.2-6

$$\frac{D}{t_w} > 1.40\sqrt{\frac{Ek}{F_{yw}}} \quad \text{TRUE}$$

then:

$$C = \frac{1.57}{\left(\frac{D}{t_w}\right)^2}\left(\frac{Ek}{F_{yw}}\right)$$

$$C = \frac{1.57}{160^2}\left(\frac{29000\times 11.81}{32}\right) = 0.656$$

$$V_n = V_p\left[C + \frac{0.87(1-C)}{\sqrt{1+\left(\frac{d_o}{D}\right)^2}}\right]$$

$$= 568.4\left[0.656 + \frac{0.87(1-0.656)}{\sqrt{1+\left(\frac{60}{70}\right)^2}}\right]$$

$$= 502.0 \text{ kips}$$

$$V_r = \varphi_v V_n$$

$$= 1.0 \times 502.0 = 502.0 \text{ kips}$$

A5.10—Shear Rating at Pier 1

φ_v = 1.00 LRFD Design 6.5.4.2

φ_c = 1.00 6A.4.2.3

φ_s = 1.00 6A.4.2.4

A5.10.1—Design Load Rating 6A.4.3

Strength I Limit State: 6A.6.4.1

Inventory Shear:

$$RF = \frac{(1.0)(1.0)(1.0)(502.0)-(1.25)(106.8)-(1.50)(8.5)}{(1.75)(116.2)}$$

$$= 1.75$$

Operating Shear:

$$RF = 1.75 \times \frac{1.75}{1.35} = 2.27$$

using same R as inventory.

A5.10.2—Legal Load Rating (Type 3-3 Governs) 6A.4.4

Strength I Limit State: 6A.6.4.2.1

Shear:

$$RF = \frac{(1.0)(1.0)(1.0)(502.0)-(1.25)(106.8)-(1.50)(8.5)}{(1.45)(72.3)}$$

$$= 3.39$$

Using same shear resistance as for HL-93.

Note: R could be recalculated for Legal loads resulting in a higher resistance and rating.

A5.10.3—Permit Load Rating (6A.4.5)

Permit Type: Routine 6A.4.5.2
Legal Load $RF > 1.0$ ∴ bridge may be evaluated for permits
Permit Weight: 220 kips

The permit vehicle is shown in Example A1A, Figure A1A.1.10-1

ADTT (one direction): 5500

Strength II Limit State: 6A.6.4.2

Load Factor $\gamma_L = 1.45$ Table 6A.4.5.4.2a-1

IM = 33% (riding surface condition is unknown) 6A.4.5.5

Use the Multi-Lane Loaded Live Load Distribution Factors. 6A.4.5.4.2a

Span 1: $+M$ g_m = 0.594

Span 2: $+M$ g_m = 0.560

Pier 2: $-M$ g_m = 0.588

Pier 1: Max V g_v = 0.803

g_m = 0.604

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		Permit	Lane Load, 0.2 kip/ft
Max +*M*	Span 1	3775.3	NA
Max +*M*	Span 2	3884.8	NA
–M at	Pier 2	2621.8	433.9 No *IM* for lane load
Max *V* left of	Pier 1	190.6	NA

Distributed Load Effects with *IM*:

Span 1: $+M_{LL+IM}$ = (3775.3)(1.33)(0.594) = 2982.6 kip-ft

Span 2: $+M_{LL+IM}$ = (3884.8)(1.33)(0.560) = 2893.4 kip-ft

Pier 2: $-M_{LL+IM}$ = [(2621.8)(1.33) + 433.0](0.588) = 2305.0 kip-ft

Pier 1: V_{LL+IM} = (190.6)(1.33)(0.803) = 203.6 kips

Flexure	S, in.^{3}	$g_m M_{LL+IM}$, kip-ft	f_{LL+IM}, ksi	f_{DC}, ksi	f_{DW}, ksi
Span 1 at 0.4*L*	1606.6	2982.6	22.3	9.24	0.74
Pier 2	2719.6	2305.0	10.2	11.29	0.90
Span 2 at 0.5*L*	1606.6	2893.4	21.6	8.36	0.67

The nominal flexure resistance of each section was previously determined. See Article A5.6.

For positive moment Regions B and H, M_n = 4391.5 kip-ft

For negative moment Region E, M_{nc}= 6943.6 kip-ft

Flexural Rating Factors

A5.10.3.1—Flexure at Span 1, 0.4L

$$RF = \frac{(1.0)(1.0)(1.0)(4391.5)-(1.25)(1236.6)-(1.5)(98.9)}{(1.45)(2982.6)}$$

$$= 0.62 < 1.0 \qquad \text{Governs}$$

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A5.10.3.2—Flexure at Span 2, 0.5L

$$RF = \frac{(1.0)(1.0)(1.0)(4391.5)-(1.25)(1119.8)-(1.5)(89.6)}{(1.45)(2893.4)}$$

$$= 0.68 < 1.0$$

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A5.10.3.3—Flexure at Pier 2

$$RF = \frac{(1.0)(1.0)(1.0)(6943.6)-(1.25)(2558.0)-(1.5)(204.6)}{(1.45)(2305.0)}$$

$$= 1.03 > 1.0$$

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As the governing flexure:

$$RF = 0.62 < 1.0$$

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The permit check fails in flexure.

If the flexural Strength II rating factors were greater than 1.0, the shear Strength II and Service II rating factors should also be evaluated prior to permit approval.

A5.11—Summary of Rating Factors

Table A5.11-1—Summary of Rating Factors—Interior Girder

Limit State	Design Load Rating (HL-93)		Legal Load Rating		Permit Load Rating
	Inventory	Operating	Governing Load		
Strength I					
Flexure at 0.4*L* (+*M*)	0.96	1.24	Type 3-3	1.91	
Flexure at 0.5*L* (+*M*)	1.05	1.36	Type 3-3	2.10	
Flexure at pier 2 (–*M*)	0.99	1.28	Lane	1.88	
Shear at pier 1	1.75	2.27	Type 3-3	3.39	
Service II					
Flexure at 0.4*L* (+*M*)	1.00	1.30	Type 3-3	1.65	
Flexure at 0.5*L* (+*M*)	1.10	1.43	Type 3-3	1.82	
Flexure at pier 2 (–*M*)	1.17	1.52	Lane	1.85	
Strength II					
Flexure at 0.4*L* (+*M*)					0.62
Flexure at 0.5*L* (+*M*)					0.68
Flexure at pier 2 (–*M*)					1.03

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A5.12—References

AASHTO. 2007. *AASHTO LRFD Bridge Design Specifications*, Fourth Edition, LRFDUS-4-M or LRFDSI-4. American Association of State Highway and Transportation Officials, Washington, DC.

A5—FOUR-SPAN CONTINUOUS STRAIGHT WELDED PLATE GIRDER BRIDGE: EVALUATION OF AN INTERIOR GIRDER A-137
A5.1—Bridge Data A-137
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A7—REINFORCED CONCRETE SLAB BRIDGE DESIGN AND LEGAL LOAD CHECK

A7.1—Bridge Data

Span Length:	21.5 ft (simple span)	
Year Built:	1963	
Material:	Concrete	$f_c' = 3$ ksi
	Reinforced Steel	$f_y = 40$ ksi
Condition:	No deterioration. NBI Item 59 Code = 6	
Riding Surface:	Not field verified and documented	
ADTT (one direction):	Unknown	
Skew:	0°	

A7.2—Dead Load Analysis

A7.2.1—Interior Strip—Unit Width

A7.2.1.1—Components, DC

Concrete slab:

$$\left(\frac{14}{12}\right)(1.0)(0.150) = 0.175 \text{ kip/ft}$$

Parapet and curb:

$$\frac{2\left[(1.5)(1.5)+(2.33)(1.0)\right](1.0)(0.150)}{43} = \underline{0.032 \text{ kip/ft}}$$

$$DC = 0.207 \text{ kip/ft}$$

$$M_{DC} = \frac{1}{8}\times 0.207\times 21.5^2$$

$$= 12.0 \text{ kip-ft}$$

A7.2.1.2—Wearing Surface, DW

Asphalt Thickness = $3^1/_2$ in. (field measured)

Asphalt Overlay = $\left(\frac{3.5}{12}\right)(1.0)(0.144) = 0.042$ kip/ft

$$M_{DW} = \frac{1}{8}\times 0.042\times 21.5^2$$

$$= 2.4 \text{ kip-ft}$$

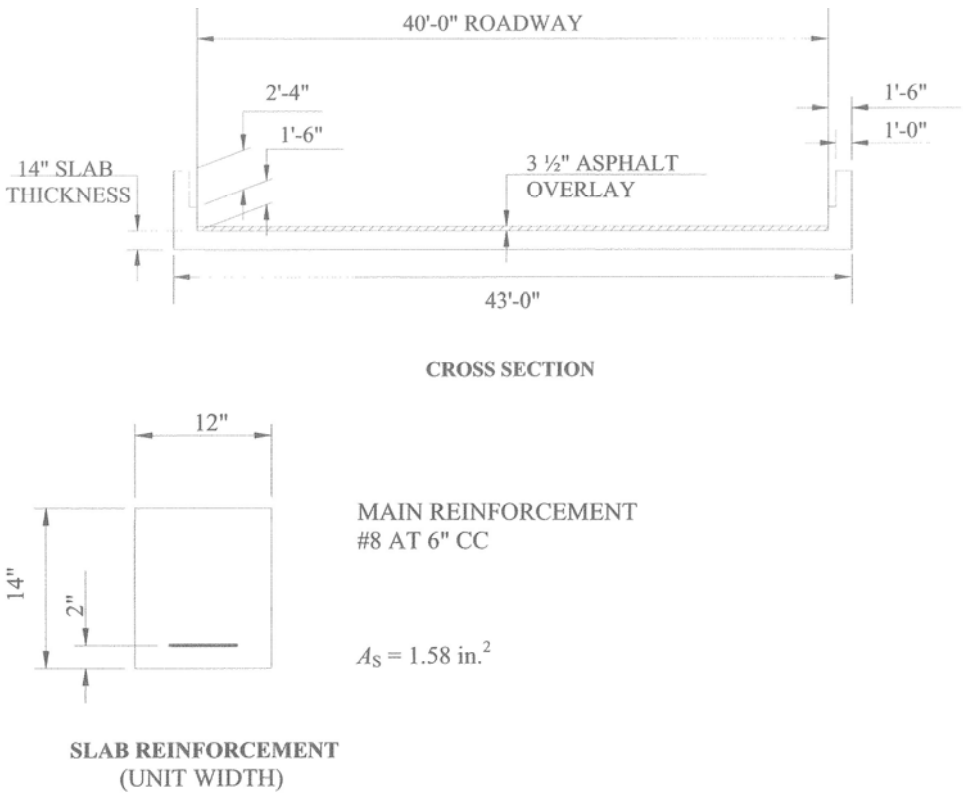

Figure A7.1-1—Reinforced Concrete Slab Bridge

A7.3—Live Load Analysis (Design Load Check)

Equivalent strip width for slab type bridges (Interior Strip) — LRFD Design 4.6.2.3

A7.3.1—One Lane Loaded

$E = 10.0 + 5.0\sqrt{L_1 W_1}$ — LRFD Design Eq. 4.6.2.3-1

L_1 = 21.5 ft < 60 ft

W_1 = Lesser of 43.0 ft or 30.0 ft

= 30.0 ft

$E = 10.0 + 5.0\sqrt{21.5 \times 30}$

= 137.0 in.

= 11.41 ft

A7.3.2—More than One Lane Loaded

$$E = 84.0 + 1.44\sqrt{L_1 W_1} \leq \frac{12.0\,W}{N_L}$$

L_1 = 21.5 ft < 60.0 ft

W_1 = Lesser of 43.0 ft or 60.0 ft

= 43.0 ft

$$E = 84 + 1.44\sqrt{21.5 \times 43}$$ LRFD Design Eq. 4.6.2.3-2

= 127.8 in. = 10.65 ft < 11.41 ft

$$N_L = \frac{40.0}{12} = 3 \text{ Design Lanes}$$

$$\frac{12.0\,W}{N_L} = \frac{12 \times 43}{3} = 172 \text{ in.} > 127.8 \text{ in.}$$ OK

Use E = 10.65 ft

For Longitudinal Edge Strips, the effective strip width is:

Sum of: LRFD Design 4.6.2.1.4b

the distance between the edge of the deck and the inside face of the barrier

+ one-quarter the strip width specified in either LRFD Design Article 4.6.2.1.3, 4.6.2.3, or 4.6.2.10 as appropriate

+ 12.0 in.

The effective edge strip width shall not exceed either one-half the full strip width or 72.0 in.

E_2 = 18.0 in. + 0.25 x 137.0 in. + 12.0 in. = 64.25 in.

E_2 = 0.5 x 137.0 in. = 68.5 in.

E_2 = 72 in.

64.25 in ≤ 68.5 in.

∴ use E_2 = 64.25 in.

LRFD Design Article 4.6.2.1.4b assumes the longitudinal edge strip supports one wheel line and a tributary portion of the design lane load where appropriate.

By comparison of the ratios of the tributary design lane load width to effective slab width, the edge strip is estimated not to govern for this bridge. Note that parapet dead load was assumed to be uniformly distributed across the full bridge width and that parapet width can play an influential role when determining the governing case.

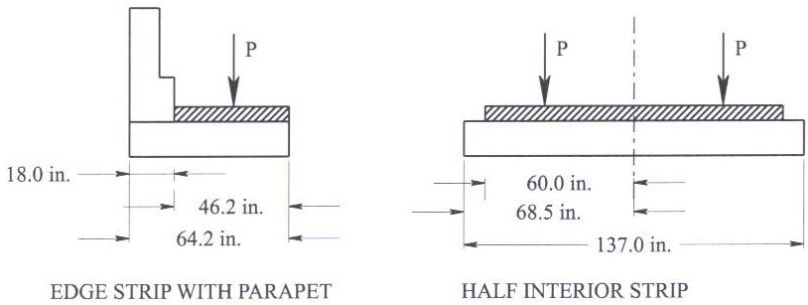

Figure A7.3.2-1—Longitudinal Edge Strip Comparison

Ratio edge strip:

46.25/64.25 = 0.72

Ratio half interior strip:

60.0/68.5 = 0.88 Governs

The rating will consider only the interior strip width.

A7.3.2.1—Midspan Live Load Force Effects (HL-93)

Dynamic Load Allowance = 33%

Equivalent Strip Width = 10.65 ft

Design-Lane Load Moment = 37.0 kip-ft

Design Truck Moment = 172.0 kip-ft

Design Tandem Moment = 219.4 kip-ft Governs

M_{LL+IM} = 37.0 + 319.4 × 1.33

= 328.8 kip-ft

Live Load Moment per unit width of slab:

$$M_{LL+IM} = \frac{328.8}{10.65} = 30.9 \text{ kip-ft/ft}$$

A7.4—Compute Nominal Resistance

Flexural Resistance:

Rectangular Section = $b_w = b = 12$ in. LRFD Design 5.7.3.2.3

$$c = \frac{A_s f_y}{0.85 f_c' \beta_1 b}$$ LRFD Design Eq. 5.7.3.1.1-4

A_s = 0.79×2 #8 bars at 6 in.

= 1.58 in.^{2}/ft

β = 0.85

b = 12 in.

$$c = \frac{1.58 \times 40}{0.85 \times 3 \times 0.85 \times 12}$$

= 2.43 in.

a = $c\beta_1$ LRFD Design 5.7.3.2.3

= 2.43×0.85

= 2.07 in.

d_s = 14 – 2 = 12 in. Distance to *C.G.* of steel

$$M_n = A_s f_y \left(d_s - \frac{a}{2} \right)$$

$$= 1.58 \times 40 \left(12 - \frac{2.07}{2} \right) \times \frac{1}{12}$$

= 57.75 kip-ft/ft

A7.5—Minimum Reinforcement (6A.5.7)

Amount of reinforcement must be sufficient to develop M_r equal to the lesser of: LRFD Design 5.7.3.3.2

$1.2M_{cr}$ or $1.33M_u$

M_{cr} = $\varphi M_n = 0.90 \times 57.75$ kip-ft=51.98 kip-ft

1. $1.33M_u$ = $1.33\ M_u = 1.33 \times (1.75 \times 30.9 + 1.25 \times 12 + 1.25 \times 2.4)$

= 95.9 kip-ft > 51.98 kip-ft No Good

2. M_{cr} = $S_c \left(f_r + f_{cpe} \right) - M_{dnc} \left(\frac{S_c}{S_{nc}} - 1 \right) \geq S_c f_r$ LRFD Design Eq. 5.7.3.3.2-1

Where a monolithic or non-composite section is designed to resist all the loads, S_{nc} is substituted for S_c. In this case, $f_{cpe} = 0$, therefore:

M_{cr} = $S_{nc} f_r$

$$S_{nc} = \frac{I}{y_t}$$

where:

I = moment of inertia of uncracked section (neglecting reinforcement steel)

y_t = distance from the neutral axis of the uncracked section to the extreme tension fiber

$= \frac{14}{2} = 7$ in.

$I = \frac{1}{12} \times 12 \times 14^3 = 2744$ in.^{4}

$S_{nc} = \frac{2744}{7} = 392$ in.^{3}

$f_r = 0.37\sqrt{f_c'} = 0.37\sqrt{3} = 0.641$ ksi — LRFD Design 5.4.2.6

$M_{cr} = 0.641 \times 392 = 251$ kip-in. = 20.9 kip-ft

$1.2M_{cr} = 1.2 \times 20.9 = 25.1$ kip-ft < 51.98 kip-ft OK

The section meets the requirements for minimum reinforcement.

A7.6—Maximum Reinforcement (6A.5.6)

Current provisions of the LRFD specification have eliminated the check for maximum reinforcement. Instead, the factored resistance (φ factor) of compression controlled sections shall be reduced in accordance with LRFD Design Article 5.5.4.2.1. This approach limits the capacity of over-reinforced (compression controlled) sections. — C6A.5.6

The net tensile strain, ε_t, is the tensile strain at nominal strength and determined by strain compatibility using similar triangles. — LRFD Design C5.7.2.1

Given an allowable concrete strain of 0.003 and depth to neutral axis c = 2.43 in.

$$\frac{\varepsilon_c}{c} = \frac{\varepsilon_t}{d-c}$$

$$\frac{0.003}{2.43 \text{ in.}} = \frac{\varepsilon_t}{12 \text{ in.} - 2.43 \text{ in.}}$$

$\varepsilon_t = 0.0118$

For $\varepsilon_t = 0.0118 > 0.005$, the section is tension controlled and Resistance Factor φ shall be taken as 0.90. — LRFD Design 5.7.2.1, 5.5.4.2

A7.7—Shear

Concrete slabs and slab bridges designed in conformance with AASHTO specifications may be considered satisfactory for shear. — LRFD Design 5.14.4.1

Also shear need not be checked for design load and legal load ratings of concrete members. — 6A.5.9

A7.8—General Load-Rating Equation (6A.4.2)

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_L)(LL + IM)}$$ — Eq. 6A.4.2.1-1

A7.9—Evaluation Factors (for Strength Limit States)

A7.9.1—Resistance Factor, φ (LRFD Design 5.5.4.2)

φ = 0.90 For flexure

A7.9.2—Condition Factor, φ_c (6A.4.2.3)

φ_c = 1.0 No deterioration

A7.9.3—System Factor, φ_s (6A.4.2.4)

φ_s = 1.0 Slab bridge

A7.10—Design Load Rating (6A.4.3)

A7.10.1—Strength I Limit State (6A.5.4.1)

$$RF = \frac{(\varphi_c)(\varphi_s)(\varphi)R_n - (\gamma_{DC})(DC) - (\gamma_{DW})(DW)}{(\gamma_L)(LL + IM)}$$

Table 6A.4.2.2-1

Load	Inventory	Operating	
DC, *DW*	1.25	1.25	Asphalt thickness was field measured
LL + *IM*	1.75	1.35	

Inventory:

$$RF = \frac{(1.0)(1.0)(0.9)(57.75) - (1.25)(12.0) - (1.25)(2.4)}{(1.75)(30.9)}$$

$$= 0.63$$

Operating:

$$RF = 0.63 \times \frac{1.75}{1.35}$$

$$= 0.82$$

A7.10.2—Service Limit State

No service limit states apply to reinforced concrete bridge members. As $RF < 1.0$ for HL-93, evaluate the bridge for Legal Loads.

A7.11—Legal Load Rating (6A.4.4)

Live Load: AASHTO Legal Loads—Type 3, 3S2, 3-3 (Rate for all 3) 6A.4.4.2.1

E = 10.65 ft 6A.4.4.3

IM = 33% Unknown riding surface conditions

	Type 3	Type 3S2	Type 3–3	
M_{LL}	150.4	137.1	123.8	kip-ft
$\frac{M_{LL+IM}}{E}$	18.8	17.1	15.5	kip-ft/ft

A7.11.1—Strength I Limit State 6A.5.4.2.1

Generalized Live-Load Factor: Table 6A.4.4.2.3a-1

γ_L = 1.45

ADTT = Unknown

Flexure:

$$RF = \frac{(1.0)(1.0)(0.90)(57.75)-[(1.25)(12.0)+(1.25)(2.4)]}{(1.45)(M_{LL+IM})}$$

	Type 3	Type 3S2	Type 3-3
RF	1.25	1.37	1.51

No posting required as *RF* > 1.0 for all AASHTO Legal Loads.

A7.11.2—Service Limit State

No service limit states apply to reinforced concrete bridge members at the Legal Load Rating.

A7.11.3—Shear LRFD Design 5.14.4.1

Concrete slabs and slab bridges designed in conformance with AASHTO Specifications may be considered satisfactory for shear.

Shear need not be checked for Legal Loads. 6A.5.9

A7.11.4—Summary

Truck	Type 3	Type 3S2	Type 3-3
Weight, tons	25	36	40
RF	1.25	1.37	1.51
Safe Load Capacity, tons	31	49	60

A7.12—Summary of Rating Factors

Table A7.12-1 Summary of Rating Factors—Concrete Slab Interior Strip

Limit State		Design Load Rating		Legal Load Rating		
		Inventory	Operating	Type 3	Type 3S2	Type 3-3
Strength I	Flexure	0.63	0.82	1.25	1.37	1.51

A7.13—References

AASHTO. 2007. *AASHTO LRFD Bridge Design Specifications*, Fourth Edition, LRFDUS-4-M or LRFDSI-4. American Association of State Highway and Transportation Officials, Washington, DC.

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A9—P/S CONCRETE ADJACENT BOX-BEAM BRIDGE: DESIGN LOAD AND PERMIT LOAD RATING OF AN INTERIOR BEAM

Note: This example demonstrates the rating calculations for moment at the centerline of a prestressed concrete adjacent box beam bridge.

A9.1—Bridge Data

Span Length:	70 ft (simple span)
Year Built:	1988
Concrete:	f'_c = 5 ksi (P/S beam)
	f'_{ci} = 4 ksi (P/S beam at transfer)
Prestressing Steel:	$^1/_2$ in. diameter, 270 ksi stress-relieved strand
Reinforcing Steel:	Grade 60
Condition:	No deterioration. NBI Item 59 Code = 7
Riding Surface:	Field verified and documented: Smooth approach and deck
ADTT (one direction):	4600
Skew:	0°

A9.1.1—Section Properties

48 in. × 33 in. Box Beams

A = 753 in.^{2}

I_x = 110499 in.^{4}

S_{bot} = 6767 in.^{3}

S_{top} = 6629 in.^{3}

A9.2—Dead Load Analysis—Interior Beam

The beams are sufficiently transversley post tensioned to act as a unit. Conditions given in LRFD Design Article 4.6.2.2.1 are also satisfied. Therefore, permanent loads due to barrier, wearing surface, and utilities may be uniformly distributed among the beams.

A9.2.1—Components and Attachments, *DC*

Beam Self Weight (including diaphragms) = 0.815 kip/ft

Sidewalks:

$$2\left(\frac{10.25}{12}\times 7\times 0.150\right)\frac{1}{12}=0.150 \text{ kip/ft}$$

Parapets:

$$2\left(1.0\times 2.25\times 0.150\right)\frac{1}{12}=0.056 \text{ kip/ft}$$

Railing:

$$2\times 0.02 \text{ kip/ft}\times\frac{1}{12}=0.003 \text{ kip/ft}$$

Total *DC* = 1.024 kip/ft

M_{DC} = $M_{DC}=\frac{1}{8}\times 1.024\times 70^2$

= 627.2 kip-ft

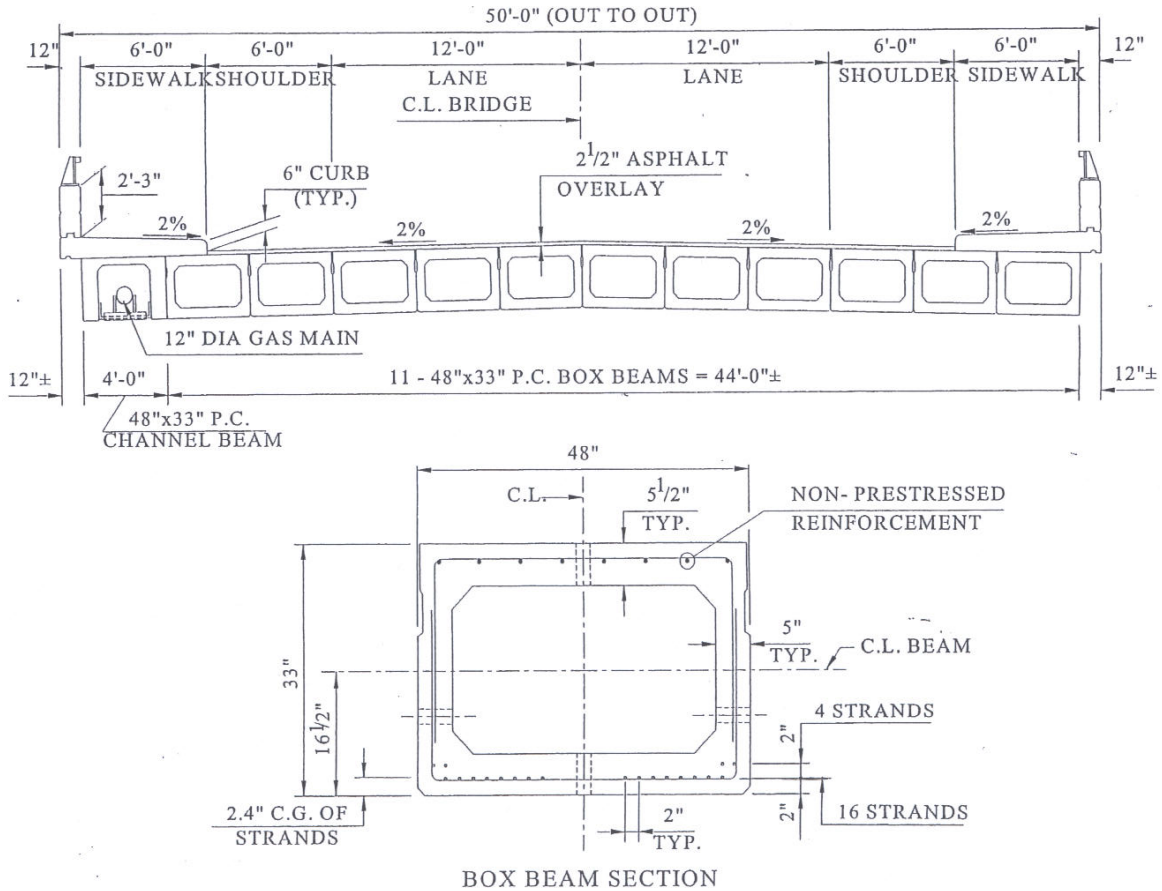

Figure A9.2.1-1—Bridge Cross Section and Interior Box Beam Cross Section

Asphalt thickness = $2^1/_2$ in. (not field measured)

A9.2.2—Wearing Surface and Utilities, *DW*

Asphalt Overlay:

$$\frac{2.5}{12} \times 36.0 \times 0.144 \times \frac{1}{12} = 0.09 \text{ kip/ft}$$

12-in. Gas Main:

$$0.05 \text{ kip/ft} \times \frac{1}{12} = 0.005 \text{ kip/ft}$$

Total DW = 0.095 kip/ft

$$M_{DW} = \frac{1}{8} \times 0.095 \times 70^2$$

$$= 58.2 \text{ kip-ft}$$

A9.3—Live Load Analysis—Interior Girder

Type (g) cross section. LRFD Design Table 4.6.2.2.1-1

The beams are transversely post-tensioned to act as a unit.

A9.3.1—Compute Live Load Distribution Factors for an Interior Beam (LRFD Design Table 4.6.2.2.2b-1)

N_b = 12

$$k = 2.5\left(N_b\right)^{-0.2} \geq 1.5$$

$$= (2.5)(12)^{-0.2} = 1.52 \qquad \text{Say } 1.5$$

I = 110499 in.^{4}

b = 48 in.

For closed thin-walled shapes: LRFD Design Eq. C.4.6.2.2.1-3

$$J = \frac{4A_o^2}{\Sigma \frac{s}{t}}$$

A_o = Area enclosed by the centerlines of elements

$$= (48 - 5)(33 - 5\ ^1/_2) = 1182.5 \text{ in.}^2$$

s = Length of a side element

$$J = \frac{4 \times 1182.5^2}{\frac{2(48-5)}{5.5} + \frac{2(33-5.5)}{5}}$$

$$= 209985 \text{ in.}^4$$

A9.3.1.1—Distribution Factor for Moment

One Lane Loaded:

$$g_{m1} = k\left(\frac{b}{33.3L}\right)^{0.5}\left(\frac{I}{J}\right)^{0.25}$$

$$= 1.50\left(\frac{48}{33.3\times 70}\right)^{0.50}\left(\frac{110499}{209985}\right)^{0.25}$$

$$= 0.183$$

Two or More Lanes Loaded:

$$g_{m2} = k\left(\frac{b}{305}\right)^{0.6}\left(\frac{b}{12L}\right)^{0.2}\left(\frac{I}{J}\right)^{0.06}$$

$$= 1.50\left(\frac{48}{305}\right)^{0.6}\left(\frac{48}{12\times 70}\right)^{0.2}\left(\frac{110499}{209985}\right)^{0.06}$$

$$= 0.268 > 0.183$$

$$g_m = g_{m2} = 0.268$$

A9.3.2—Maximum Live Load (HL-93) Moment at Midspan

Design Lane Load:

$$0.64\,\text{klf} \times \frac{(70\ \text{ft})^2}{8} = 392.0 \text{ kip-ft}$$

Design Truck (with the middle axle positioned at midspan):

$$\frac{32^K \times 70\,\text{ft}}{4} + \frac{\left(8^K + 32^K\right)\times 21\,\text{ft}\times 35\,\text{ft}}{70} = 980.0 \text{ kip-ft} \quad \text{Governs}$$

Design Tandem (with tandem centered on midspan):

$$25^K \times 33\,\text{ft} = 825.0 \text{ kip-ft}$$

$$IM = 33\%$$

$$M_{LL+IM} = 392.0 + 980.0 \times 1.33$$

$$= 1695.4 \text{ kip-ft}$$

$$g \times M_{LL+IM} = (0.268)(1695.4)$$

$$= 454.4 \text{ kip-ft}$$

A9.4—Compute Nominal Flexural Resistance

$$f_{ps} = f_{pu}\left(1 - k\frac{c}{d_p}\right)$$ LRFD Design Eq. 5.7.3.1.1-1

k = 0.38 for stress-relieved strands — LRFD Design Table C5.7.3.1.1-1

f_{pu} = 270 ksi

d_p = distance from extreme compression fiber to the *C.G.* of prestressing tendons

= 33 in. – 2.4 in.

= 30.6 in.

For rectangular section:

$$c = \frac{A_{ps} f_{pu}}{0.85 f_c' \beta_1 b + k\, A_{ps} \dfrac{f_{pu}}{d_p}}$$

LRFD Design Eq. 5.7.3.1.1-4

Neglects nonprestressed reinforcement.

A_{ps} = 20 × 0.153

= 3.06 in.^{2}

b = 48 in.

f'_c = 5 ksi

β_1 = 0.80

$$c = \frac{3.06 \times 270}{0.85 \times 5 \times 0.80 \times 48 + 0.38 \times 3.06 \times \dfrac{270}{30.6}}$$

LRFD Design 5.7.2.2

= 4.76 in.

a = $\beta_1 c$ — LRFD Design 5.7.2.2

= 0.80 × 4.76

= 3.81 in. < 5.5 in.

Therefore, the rectangular section behavior assumption is valid.

$$f_{ps} = 270\left(1 - 0.38 \times \frac{4.76}{30.6}\right)$$

= 254.0 ksi

$$M_n = A_{ps} f_{ps}\left(d_p - \frac{a}{2}\right)$$

LRFD Design Eq. 5.7.3.2.2-1

$$= 3.06 \times 254.0\left(30.6 - \frac{3.81}{2}\right)\frac{1}{12}$$

= 1858.6 kip-ft

A9.5—Maximum Reinforcement (C6A.5.6)

The factored resistance (φ factor) of compression controlled sections shall be reduced in accordance with LRFD Design Article 5.5.4.2.1. This approach limits the capacity of over-reinforced (compression controlled) sections. C6A.5.6

The net tensile strain, ε_t, is the tensile strain at nominal strength and determined by strain compatibility using similar triangles. LRFD Design C5.7.2.1

Given an allowable concrete strain of 0.003 and depth to neutral axis c = 4.76 in. and a depth from the extreme concrete compression fiber to the center of gravity of the prestressing strands, d_p = 30.6 in.

$$\frac{\varepsilon_c}{c} = \frac{\varepsilon_t}{d-c}$$

$$\frac{0.003}{4.76 \text{ in.}} = \frac{\varepsilon_t}{30.6 \text{ in.} - 4.76 \text{ in.}}$$

$$\varepsilon_t = 0.0163$$

For ε_t = 0.0163 > 0.005, the section is tension controlled and Resistance Factor φ shall be taken as 1.0. LRFD Design 5.7.2.1, 5.5.4.2

A9.6—Minimum Reinforcement 6A.5.7

Amount of reinforcement must be sufficient to develop M_r equal to the lesser of: LRFD Design 5.7.3.3.2

$1.33M_u$ or $1.2M_{cr}$

$$M_r = \varphi M_n = (1.0)(1858.6) = 1858.6$$

$$M_u = 1.75(454.4) + 1.25(627.2) + 1.5(58.2) = 1666.5$$

$1.33M_u$ = 2216.4 > M_r check $M_r \geq 1.2M_{cr}$

$$M_{cr} = S_c\left(f_r + f_{cpe}\right) - M_{dnc}\left(\frac{S_c}{S_{nc}} - 1\right) \geq S_c f_r$$ LRFD Design Eq. 5.7.3.3.2-1

Where a monolithic or noncomposite section is designed to resist all the loads, S_{nc} is substituted for S_c. Therefore:

$$M_{cr} = S_{nc}\,(f_r + f_{cpe}) \geq S_{nc} f_r$$

S_{nc} = S_b = 6767 in.^{3}

f_{cpe} = compressive stress in concrete due to effective prestress force (after allowance for all prestress losses) at extreme fiber of section where tensile stress is caused by externally applied loads

$$f_{cpe} = \frac{P_{pe}}{A} + \frac{P_{pe}e}{S_b}$$

where:

P_{pe} = effective prestress force

Modulus of Rupture: LRFD Design 5.4.2.6

$f_r = 0.37\sqrt{f'_c}$

$= 0.37\sqrt{5}$

$= 0.827$ ksi

A9.6.1—Determine Effective Prestress Force, P_{pe}

$P_{pe} = A_{ps}f_{pe}$

Total Prestress Losses: LRFD Design Eq. 5.9.5.1-1

$\Delta f_{pT} = \Delta f_{pES} + \Delta f_{pLT}$ immediately before transfer

Effective Prestress:

f_{pe} = Initial Prestress – Total Prestress Losses

A9.6.1.1—Loss Due to Elastic Shortening, Δf_{pES} (LRFD Design 5.9.5.2.3a)

$$\Delta f_{pES} = \frac{E_p}{E_{ct}} f_{cgp}$$ LRFD Design Eq. 5.9.5.2.3a-1

$$f_{cgp} = \frac{P_i}{A} + \frac{P_i e^2}{I} - \frac{M_D e}{I}$$

Initial Prestress immediately prior to transfer = $0.7f_{pu}$ if not available in plans. LRFD Design Table 5.9.3-1

For estimating P_i immediately after transfer, use $0.90(0.7f_{pu})$. LRFD Design C5.9.5.2.3a

$P_i = 0.90 \times (0.7 \times 270)\ 20 \times 0.153$

$= 520.5$ kips

$A = 753$ in.^{2}

$I = 110499$ in.^{4}

$e = 16.5$ in. – 2.4 in.

$= 14.1$ in.

M_D = Moment due to self-weight of the member

$$= \frac{1}{8} \times 0.815 \times 70^2 = 499.2 \text{ kip-ft}$$

$$f_{cgp} = \frac{520.5}{753} + \frac{520.5 \times 14.1^2}{110499} - \frac{499.2 \times 14.1 \times 12}{110499}$$

$= 0.691 + 0.936 - 0.764$

$= 0.863$ ksi

$$E_{ct} = 33000 K_1 (w_c)^{1.5} \sqrt{f'_{ct}}$$ LRFD Design Eq. 5.4.2.4-1

$= 33000(1.0)(0.145)^{1.5}\sqrt{4.0}$

$= 3644$ ksi — LRFD Design C5.4.2.4

$E_p = 28500$ ksi — LRFD Design 5.4.4.2

$\Delta f_{pES} = \frac{28500}{3644} \times 0.863$ — LRFD Design Eq. 5.9.5.2.3a-1

$= 6.750$ ksi

A9.6.1.2—Approximate Lump Sum Estimate of Time-Dependent Losses, Δf_{pLT} (LRFD Design 5.9.5.3)

Includes creep, shrinkage, and relaxation of steel.

$\Delta f_{pLT} = 19.0 + 4 \times PPR$ (average for box girder) — LRFD Design Table 5.9.5.3-1

$PPR = \frac{A_{ps} f_{py}}{A_{ps} f_{py} + A_s f_y}$ — LRFD Design Eq. 5.5.4.2.1-4

$A_{ps} = 3.06$ in.^{2}

$f_{py} = 0.85 \times \varphi_{\pi\upsilon}$ Stress-relieved strand — LRFD Design Table 5.4.4.1-1

$= 0.85 \times 270$

$= 229.5$ ksi

$A_s = 0$

$PPR = 1.0$

$\Delta f_{pLT} = 19.0 + 4 \times 1.0$

$= 23$ ksi

A9.6.1.3—Total Prestress Losses, Δf_{pT}

$\Delta f_{pT} = \Delta f_{pES} + \Delta f_{pLT}$ — LRFD Design Eq. 5.9.5.1-1

$= 6.75 + 23.0$

$= 29.75$ ksi

f_{pe} = Initial Prestress – Total Prestress Losses

$= (0.7 \times 270) - 29.75$

$= 159.3$ ksi

$P_{pe} = 159.3 \times 20 \times 0.153$

$= 487.5$ kips

$$f_{pb} = \frac{P_{pe}}{A} + \frac{P_{pe}e}{S_b}$$

$$= \frac{487.5}{753} + \frac{487.5(16.5-2.4)}{6767}$$

$$= 1.663 \text{ ksi}$$

$$M_{cr} = \left(f_r + f_{cpe}\right)S_b$$

$$= (0.827+1.663)6767 \times \frac{1}{12}$$

$$= 1404.2 \text{ kip-ft}$$

$$M_{cr} = \varphi M_n$$

$$= 1.0 \times 1858.6 = 1858.6 \text{ kip-ft}$$

M_r = 1858.6 > $1.2M_{cr}$ = 1.2 × 1404.2 = 1685.0 OK

Minimum reinforcement check is satisfied. 6A.5.7

A9.7—General Load-Rating Equation (6A.4.2)

$$RF = \frac{C-(\gamma_{DC})(DC)-(\gamma_{DW})(DW)\pm(\gamma_P)(P)}{(\gamma_L)(LL+IM)}$$ Eq. 6A.4.2.1-1

A9.7.1—Evaluation Factors for Strength Limit States

A9.7.1.1—Resistance Factor, φ LRFD Design 5.5.4.2.1

φ = 1.0 for flexure

A9.7.1.2—Condition Factor, φ_c 6A.4.2.3

φ_c = 1.0 no deterioriation

A9.7.1.3—System Factor, φ_s 6A.4.2.4

φ_s = 1.0

A9.7.2—Design Load Rating (6A.4.3)

A9.7.2.1—Strength I Limit State (6A.5.4.1)

$$RF = \frac{(\varphi_c)(\varphi_s)(\varphi)R_n-(\gamma_{DC})(DC)-(\gamma_{DW})(DW)}{(\gamma_L)(LL+IM)}$$

Table 6A.4.2.2-1

Load	Inventory	Operating	
DC	1.25	1.25	
DW	1.50	1.50	Asphalt thickness was not field measured
LL + IM	1.75	1.35	

A9.7.2.1a—Flexure at Midspan

Inventory:

$$RF = \frac{(1.0)(1.0)(1.0)(1858.6)-(1.25)(627.2)-(1.50)(58.2)}{(1.75)(454.4)}$$

$$= 1.24$$

Operating:

$$RF = 1.24 \times \frac{1.75}{1.35}$$

$$= 1.61$$

Shear need not be checked for the design load as the bridge does not exhibit signs of shear distress.

A9.7.2.2—Service III Limit State for Inventory Level (6A.5.4.1)

$$RF = \frac{f_R - (\gamma_D)(f_D)}{(\gamma_L)(f_{LL+IM})}$$

Flexural Resistance:

f_R = f_{pb} + Allowable tensile stress

f_{pb} = compressive stress due to effective prestress

= 1.663 (See previous calculation, A9.6.1.3)

Allowable Tensile Stress $= 0.19\sqrt{f'_c}$ LRFD Design Table 5.9.4.2.2-1

$$= 0.19\sqrt{5}$$

= 0.425 ksi

f_R = 1.663 + 0.425

= 2.088 ksi

Dead Load Stress:

$$f_{DC} = \frac{627.2 \times 12}{6767} = 1.112 \text{ ksi}$$

$$f_{DW} = \frac{58.2 \times 12}{6767} = 0.103 \text{ ksi}$$

Total f_D = 1.215 ksi

Live Load Stress:

$$f_{LL+IM} = \frac{454.4 \times 12}{6767} = 0.806 \text{ ksi}$$

γ_L = 0.80

γ_D = 1.0

$$RF = \frac{2.088-(1.0)(1.215)}{(0.80)(0.806)}$$ Table 6A.4.2.2-1

$$= 1.35 > 1.0 \quad \text{OK}$$

A9.7.3—Legal Load Rating (6A.4.4)

Inventory design load rating $RF > 1.0$, therefore the legal load ratings do not need to be performed and no posting is required. 6A.4.3.1

A9.7.4—Permit Load Rating (6A.4.5)

Permit Type: Routine

Permit Weight: 240 kips

Permit Vehicle: Shown in Example A1, Figure A1A.1.10-1

ADTT (one direction): 4600

From Live Load Analysis by Computer Program:

Undistributed maximum:

$M_{LL} =$ 2592 kip-ft

A9.7.4.1—Strength II Limit State 6A.4.5.4.2a

$$\gamma_L = \frac{1.45-1.25}{5000-1000} = \frac{\gamma_L-1.25}{4600-1000}$$ Table 6A.4.5.4.2a-1

$$= 1.43$$

For a routine permit, use a multi-lane loaded distribution factor. 6A.4.5.4.2a

g_m = 0.268 (two lanes loaded distribution factor)

IM = 10% Field inspection verified: Smooth Riding Surface Table C6A.4.4.3-1

Distributed Live Load Effects:

$$M_{LL+IM} = (2592)(0.268)(1.10) = 764.1 \text{ kip-ft}$$

Flexure:

$$RF = \frac{(1.0)(1.0)(1.0)(1858.6)-1.25(627.2)-1.5(58.2)}{1.43(764.1)}$$

$$RF = 0.90 < 1.0 \quad \text{NO GOOD}$$

Note: Permit trucks should be checked for shear incrementally along the length of the member when shear distress is observed or when the factored force effects due to the permit load exceed the factored force effects due to the HL-93 Design Load. Evaluation of shear is not illustrated here; Example A3 shows the process of evaluating for shear using both the simplified method and Modified Compression Field Theory for a permit vehicle. 6A.5.9

A9.7.4.2—Service I Limit State 6A.6.4.2.2

$$\gamma_L = \gamma_{DC} = \gamma_{DW} = 1.0$$ Table 6A.4.2.2-1

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LRFD distribution analysis methods as described in LRFD 4.6.2 should be used. C6A.6.4.2.2

g_m = 0.268

M_{LL+LL} = (2592)(0.268)(1.10) = 764.1 kip-ft

M_{DC} = 627.2 kip-ft

M_{DW} = 58.2 kip-ft

M_{cr} = 1404.2 kip-ft (previously calculated)

f_{pe} = 159.3 ksi (previously calculated)

$M_{DC} + M_{DW} + M_{LL+IM} - M_{cr}$ = 627.2 + 58.2 + 764.1 – 1404.2 = 45.3 kip-ft

A9.7.4.2a—Simplified check using 0.75M_n

$M_{DC} + M_{DW} + M_{LL+IM}$ = 1449.5 kip-ft

$0.75M_n$ = 0.75 × 1858.6 kip-ft

= 1394.0 kip-ft < 1449.5 kip-ft NO GOOD

Moment Ratio:

$$\frac{0.75\,M_n}{M_{DC}+M_{DW}+M_{LL+IM}} = \frac{1394.0}{1449.5} = 0.96 < 1.0 \qquad \text{NO GOOD}$$

A9.7.4.2b—Refined check using 0.90f_y

Calculate stress in outer reinforcement at midspan. Stress due to moments in excess of the cracking moment acts upon the cracked section. The moments up to the cracking moment cause stress in the reinforcement equal to the effective prestress.

f_R = $0.9f_y = 0.9(0.85f_{pu}) = 0.9(0.85\times 270) = 206.6$ ksi LRFD Design Table 5.4.4.1-1

Section Properties for the Cracked Section:

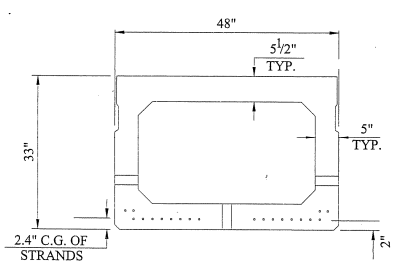

Figure A9.7.4.2b-1—Box Beam Cross Section

Assume neutral axis is in the top flange.

A_{ps} = 3.06 in.^{2} LRFD Design 5.7.1

f'_c = 5 ksi

Effective modular ratio of 2n is applicable

$n = \frac{E_p}{E_c} = \frac{28500}{4000}$

n = 7; therefore, $2n = 14$

$A_{trans} = A_{ps}\,2n = 3.06 \times 14 = 42.8\text{in.}^2$

$$c = \frac{\frac{c}{2}(b)(c) + (d_e)(A_{trans})}{(b)(c) + A_{trans}}$$

$$c = \frac{\frac{c}{2}(48)(c) + (33 - 2.4)(42.8)}{(48)(c) + 42.8}$$

$$24c^2 + 42.8c - 1309.7 = 0$$

Solving for c:

c = 6.55 in. > 5.50 in. assumed; therefore, find neutral axis depth by trial and adjustment

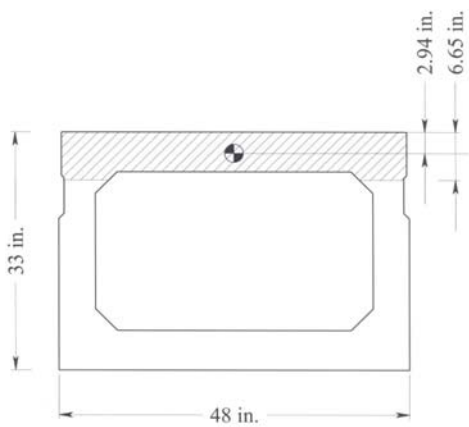

Figure A9.7.4.2b-1—Box Beam Cross Section for Determining *c*

Table A9.7.4.2b-1—Trial and Adjustment Values for *c*

Trial *c*	Centroid	Area Concrete	Calculated *c*	Difference Trial – Calculated
5.5	2.75	264.0000	6.6383	–1.138
5.8294	2.8041	264.7872	6.6749	–0.846
6.3	2.8827	271.3392	6.6621	–0.362
6.6	2.9318	275.1264	6.6596	–0.060
6.65	2.9400	275.7456	6.6594	–0.009
6.7	2.9482	276.3504	6.6595	+0.041

By trial and adjustment, c approximately equals 6.65:

$$c = \frac{2.94(275.7456) + \left[(16\times.153\text{ in.}^2\times31\text{ in.}) + (4\times.153\text{ in.}^2\times29\text{ in.})\right]\times14}{(275.7456) + (20\times.153\text{ in.}^2\times14)} = 6.65$$

$$I_{cr} = \left[\begin{array}{l} \frac{1}{12}(47.25)(5.5)^3 + (47.25)(5.5)\left(6.65 - \frac{5.5}{2}\right)^2 + \\ 2\times\left[\frac{1}{12}(6.9)(1.15)^3 + (6.9)(1.15)(0.58)^2\right] + \\ (42.8)(33 - 2.4 - 6.65)^2 \end{array}\right] = 29165\text{ in.}^4$$

Stress beyond the effective prestress (increase in stress after cracking):

$$f = n\frac{M_y}{I} = 7\frac{(42.9)(12)(33-2-6.65)}{29165} = 3.01\text{ ksi}$$

Stress in the reinforcement at Permit crossing Service I:

$$f_s = 159.3 + 3.01 = 162.31\text{ ksi} < f_R = 0.9F_y = 206.6\text{ ksi} \qquad \text{OK}$$

Stress Ratio:

$$\frac{0.9f_y}{f_s} = \frac{206.6}{162.31} = 1.27 > 1.0 \qquad \text{OK}$$

For this bridge, the simplified check indicates that the Service I condition is violated for the permit truck; the more detailed check indicates that the condition is acceptable.

A9.8—Summary of Rating Factors

Table A9.8-1—Summary of Rating Factors—Interior Box Beam

Limit State		Design Load Rating (HL-93)		Permit Load Rating
		Inventory	Operating	
Strength I	Flexure	1.25	1.61	—
Strength II	Flexure	—	—	0.90
Service III		1.35	—	—
Service I	Approximate	—	—	Stress Ratio = 0.96
	Refined	—	—	Stress Ratio = 1.27

Deleted: 1.00

A9.9—References

AASHTO. 2007. *AASHTO LRFD Bridge Design Specifications*, Fourth Edition, LRFDUS-4-M or LRFDSI-4. American Association of State Highway and Transportation Officials, Washington, DC.

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Review of the NBI database

The 2008 National Bridge Inventory provided by the FHWA contains 718,763 individual records. Because the bridges that will be used for this research project will be run in AASTHTOWare™ Virtis, certain parameters (NBI Items) will be restricted when querying the NBI database. A list of the restrictions are shown in Table O-1.

Table O-1 - NBI item query restrictions

NBI Item	Description	Restriction
5a	*Record type*	*Ignore values <> 1* *(i.e. only look at records where Route carried "on" the structure).* *This item was requested in the comments to Interim Report.*
31	Design Load	Ignore: 7: :Pedestrian 8: Railroad
41	Structure Open/Posted/Closed	For the queries provided in this report, the following items will be ignored. *D – Open, would be posted or closed except for temporary shoring, etc. to allow for unrestricted traffic flow.* E – Open, temporary structure in place K – Bridge closed to all traffic
43A	Kind of Material and/or Design	Ignore: 0 - Other 8 – Masonry 9 – Aluminum, Wrought Iron, or Cast Iron
43B	Type of Design and/or Construction	Ignore: 0 - Other 7 – Frame (except Frame Culverts) 11 – Arch -Deck 12 – Arch-Thru 13 – Suspension 14 – Stayed Girder 15 – Movable-Lift 16 – Movable-Bascule 17 – Movable-Swing 18 – Tunnel 19 – Culvert 20 – Mixed Types 21 – Segmental Box Girder
48	Length of maximum span	The minimum span length that will be used to query the database is 6.1 m (20 feet) and a maximum span length of 150 m (492 feet).
103	*Temporary Structure Designation*	*Ignore values where Item 103 = T*

Based on these restrictions, the NBI database was queried using the query software tool developed for this project. Using this tool a comparative analysis was made between the NBI

data and the Virtis database collection provided by the states. A summary of the comparison is shown in Table O-4 through Table O-10.

This comparison will be used to make sure that the final bridge sample domain matches to some degree the National Bridge Inventory.

General queries

Some general queries of the NBI data are presented on the following pages from Figure O-1 to Figure O-6. While these queries weren't used directly in providing comparisons between the NBI data and collected Virtis data, they be of use as the project proceeds into Phase II.

Using the 'Design Load' query (see Figure O-3), bridges with older design (H-10, H-15, H-20) loads can be located. With this information, combined with the NBI code, we can query the collected Virtis database to find bridges that may have used these design loads.

State Code (NBI Item_1)	Total	Percent %
Alabama	9,517	1.85%
Alaska	1,195	0.23%
Arizona	4,477	0.87%
Arkansas	9,430	1.83%
California	29,323	5.70%
Colorado	7,174	1.39%
Connecticut	4,403	0.86%
Delaware	1,694	0.33%
Florida	11,822	2.30%
Georgia	9,930	1.93%
Hawaii	857	0.17%
Idaho	3,798	0.74%
Illinois	24,271	4.72%
Indiana	17,277	3.36%
Iowa	20,629	4.01%
Kansas	16,430	3.19%
Kentucky	12,223	2.37%
Louisiana	6,266	1.22%
Maine	2,324	0.45%
Maryland	4,431	0.86%
Massachusetts	4,702	0.91%
Michigan	12,283	2.39%
Minnesota	10,164	1.97%
Mississippi	10,678	2.07%
Missouri	20,726	4.03%
Montana	4,818	0.94%
Nebraska	12,675	2.46%
Nevada	1,317	0.26%
New Hampshire	1,994	0.39%
New Jersey	8,106	1.57%
New Mexico	2,681	0.52%
New York	18,150	3.53%
North Carolina	14,748	2.87%
North Dakota	3,657	0.71%
Ohio	29,251	5.68%
Oklahoma	15,534	3.02%
Oregon	7,150	1.39%
Pennsylvania	25,387	4.93%
Puerto Rico	2,157	0.42%
Rhode Island	858	0.17%
South Carolina	6,178	1.20%
South Dakota	4,671	0.91%
Tennessee	12,933	2.51%
Texas	36,407	7.07%
Utah	2,887	0.56%
Vermont	2,748	0.53%
Virginia	13,143	2.55%
Washington	7,730	1.50%
West Virginia	6,681	1.30%
Wisconsin	14,041	2.73%
Wyoming	2,790	0.54%
Total	514,716	100.00%

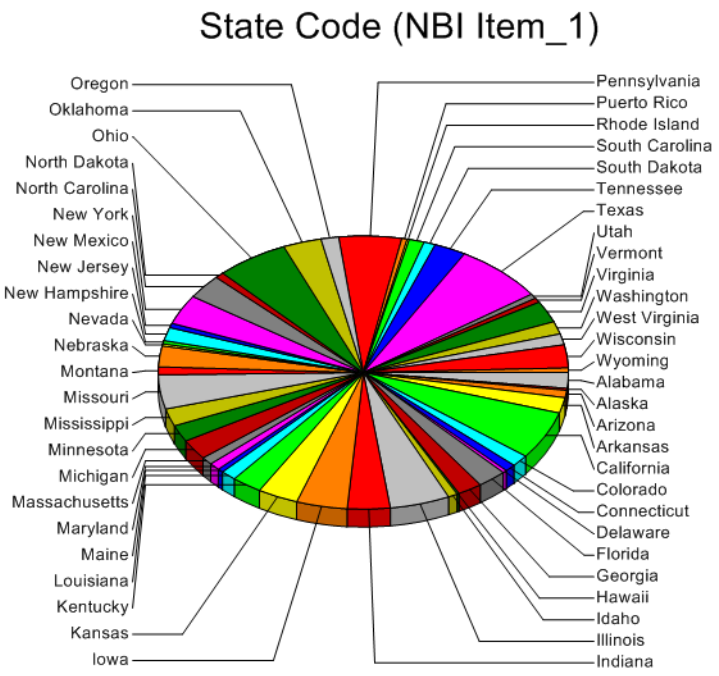
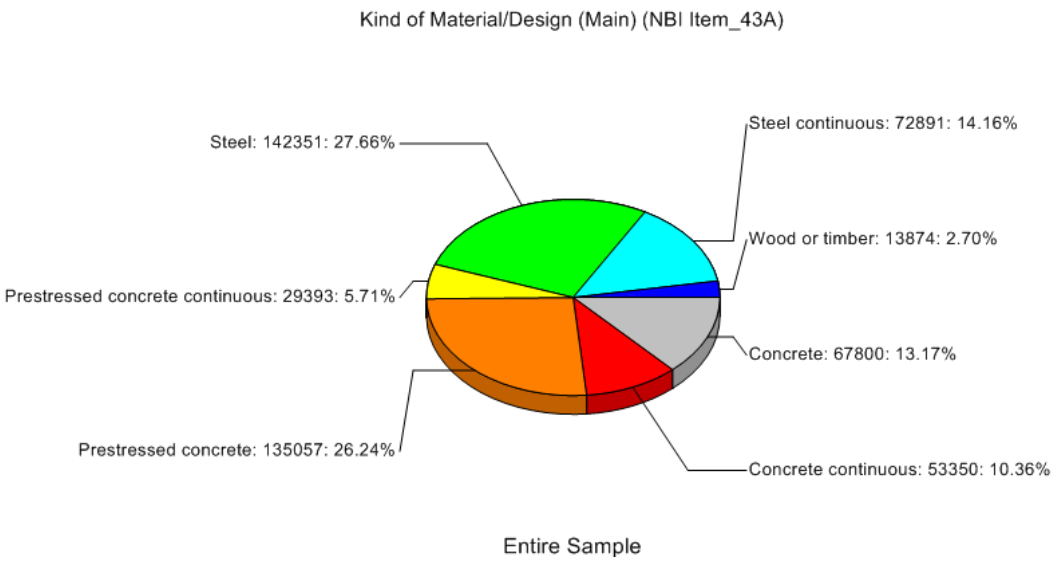
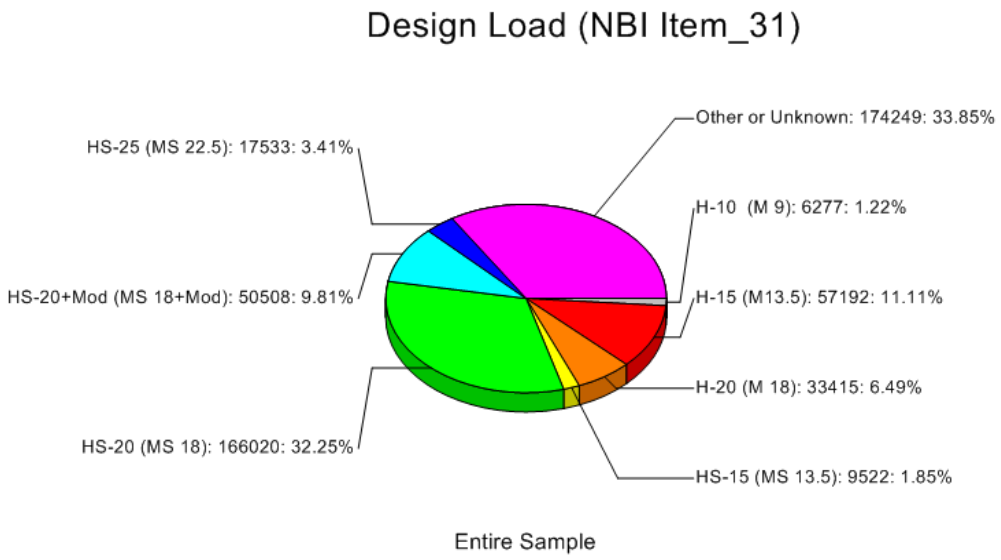


Figure O-1 – NBI Database breakdown by State



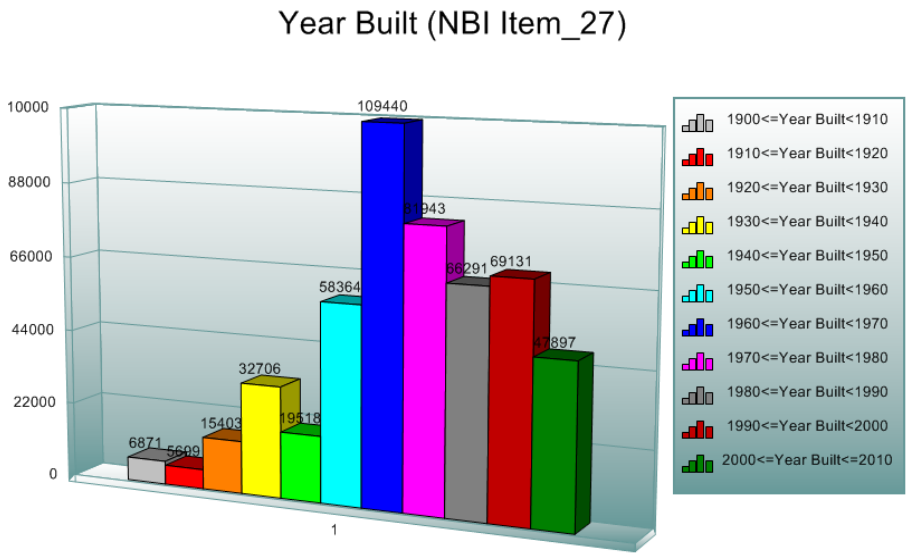
Kind of Material/Design (Main) (NBI Item_43A)	Total	Percent %
Concrete	67,800	13.17%
Concrete continuous	53,350	10.36%
Prestressed concrete	135,057	26.24%
Prestressed concrete continuous	29,393	5.71%
Steel	142,351	27.66%
Steel continuous	72,891	14.16%
Wood or timber	13,874	2.70%
Total	514,716	100.00%

Figure O-2 – Breakdown of the NBI database by type of material



Design Load (NBI Item_31)	Total	Percent %
H-10 (M 9)	6,277	1.22%
H-15 (M13.5)	57,192	11.11%
H-20 (M 18)	33,415	6.49%
HS-15 (MS 13.5)	9,522	1.85%
HS-20 (MS 18)	166,020	32.25%
HS-20+Mod (MS 18+Mod)	50,508	9.81%
HS-25 (MS 22.5)	17,533	3.41%
Other or Unknown	174,249	33.85%
Total	514,716	100.00%

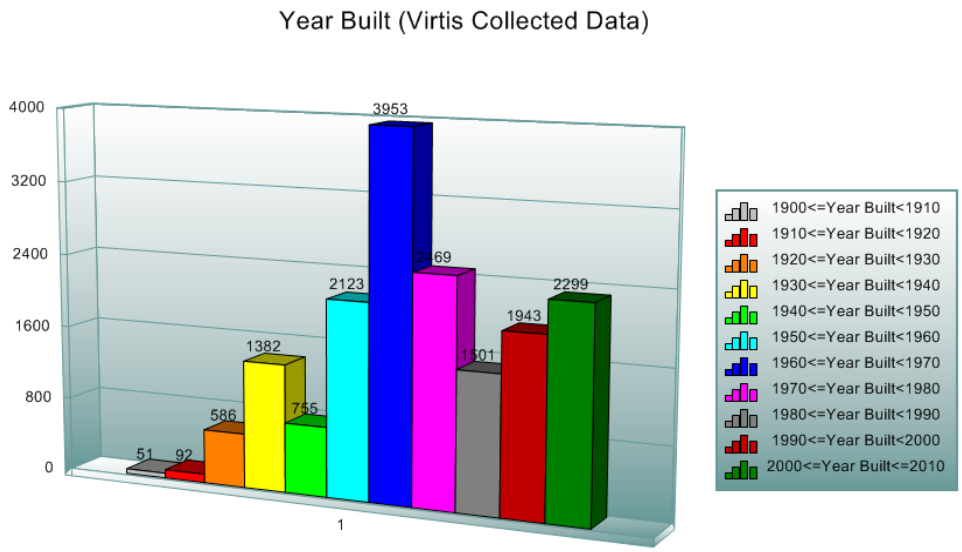
Figure O-3 – Breakdown of the NBI data by Design Load



	Total	Percent %
1900<=Year Built<1910	6,871	1.34%
1910<=Year Built<1920	5,699	1.11%
1920<=Year Built<1930	15,403	3.00%
1930<=Year Built<1940	32,706	6.37%
1940<=Year Built<1950	19,518	3.80%
1950<=Year Built<1960	58,364	11.37%
1960<=Year Built<1970	109,440	21.32%
1970<=Year Built<1980	81,943	15.97%
1980<=Year Built<1990	66,291	12.92%
1990<=Year Built<2000	69,131	13.47%
2000<=Year Built<=2010	47,897	9.33%
Total	513,263	100.00%

Figure O-4 – Breakdown of the NBI data by year built

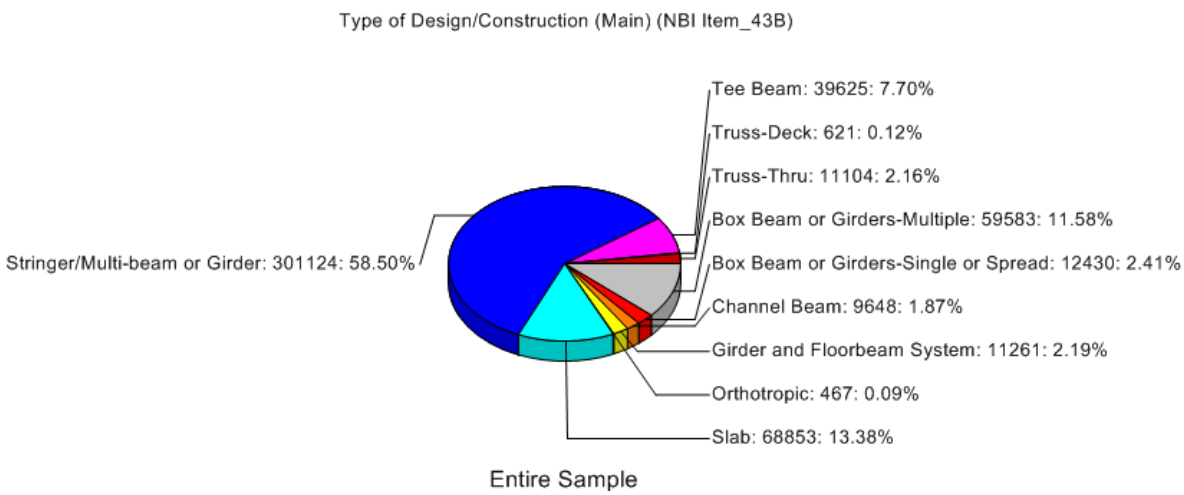
Note that the NBI breakdown has a fairly close correspondence to the breakdown of data of the Virtis collected database (see Figure O-5).



	Total	Percent %
1900<=Year Built<1910	51	0.30%
1910<=Year Built<1920	92	0.54%
1920<=Year Built<1930	586	3.42%
1930<=Year Built<1940	1,382	8.06%
1940<=Year Built<1950	755	4.40%
1950<=Year Built<1960	2,123	12.38%
1960<=Year Built<1970	3,953	23.04%
1970<=Year Built<1980	2,469	14.39%
1980<=Year Built<1990	1,501	8.75%
1990<=Year Built<2000	1,943	11.33%
2000<=Year Built<=2010	2,299	13.40%
Total	17,154*	100.00%

*Note: Date not provided for all Virtis bridge ID's

Figure O-5 – Breakdown of the collected Virtis Database by year built



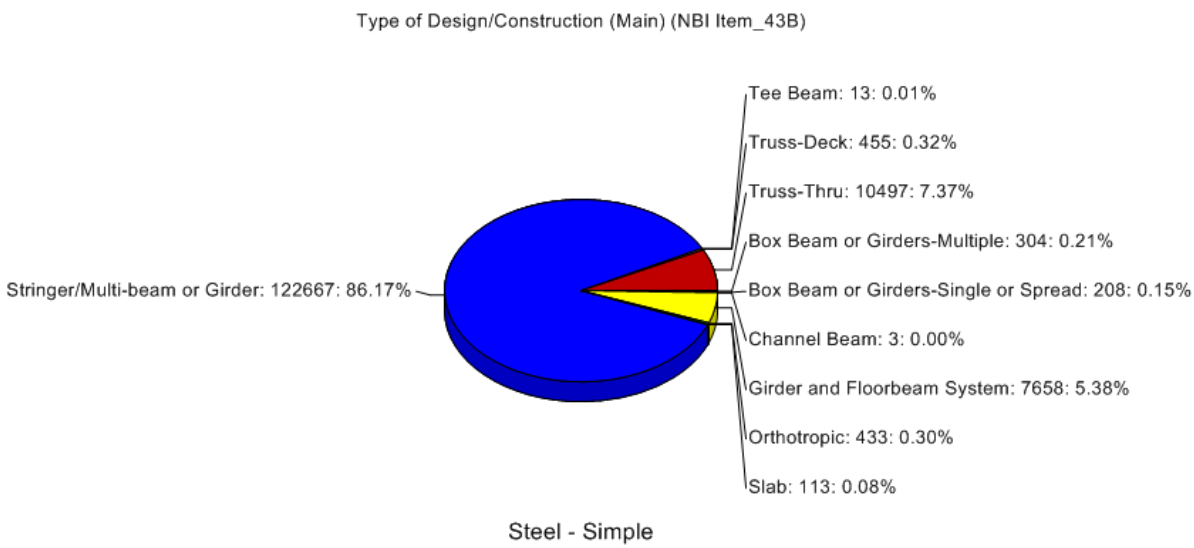
Type of Design/Construction (Main) (NBI Item_43B)	Total	Percent %
Box Beam or Girders-Multiple	59,583	11.58%
Box Beam or Girders-Single or Spread	12,430	2.41%
Channel Beam	9,648	1.87%
Girder and Floorbeam System	11,261	2.19%
Orthotropic	467	0.09%
Slab	68,853	13.38%
Stringer/Multi-beam or Girder	301,124	58.50%
Tee Beam	39,625	7.70%
Truss-Deck	621	0.12%
Truss-Thru	11,104	2.16%
Total	514,716	100.00%

Figure O-6 – Breakdown of the NBI data by type of design/construction

Breakdown by Material Type

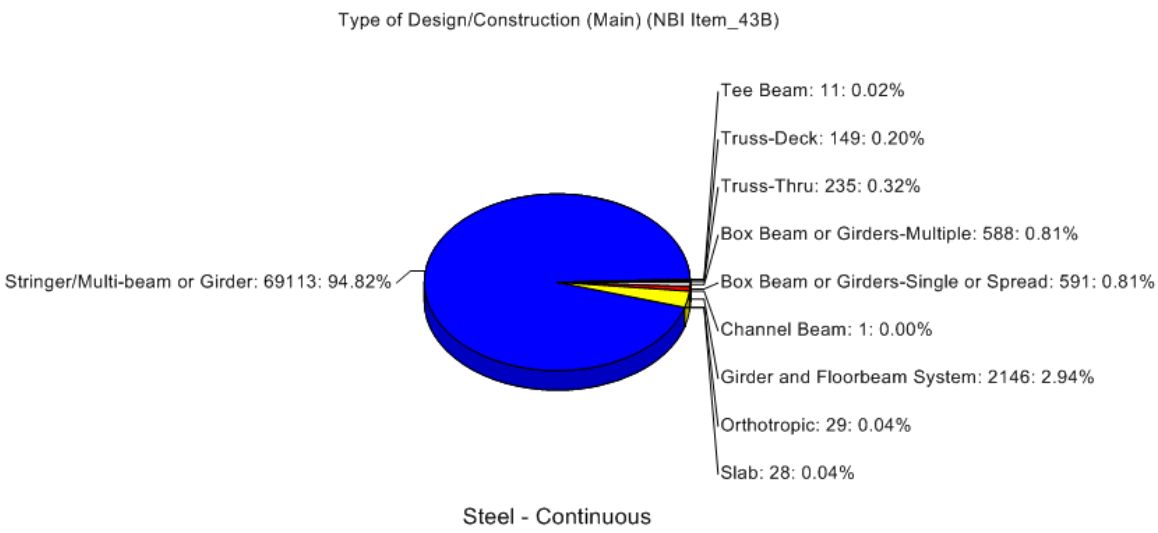
The following sections breakdown the NBI database by material type. Ultimately, these breakdowns will be used to extract a comparative sample (percentage-wise) from the collected Virtis database.

Steel



Type of Design/Construction (Main) (NBI Item_43B)	Total	Percent %
Box Beam or Girders-Multiple	304	0.21%
Box Beam or Girders-Single or Spread	208	0.15%
Channel Beam	3	0.00%
Girder and Floorbeam System	7,658	5.38%
Orthotropic	433	0.30%
Slab	113	0.08%
Stringer/Multi-beam or Girder	122,667	86.17%
Tee Beam	13	0.01%
Truss-Deck	455	0.32%
Truss-Thru	10,497	7.37%
Total	142,351	100.00%

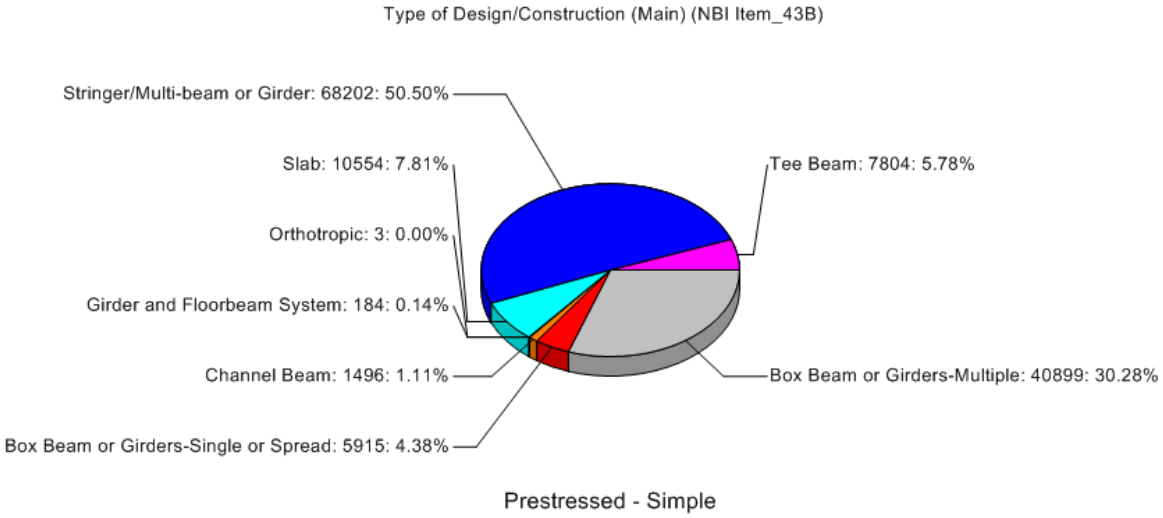
Figure O-7 – Breakdown of steel simple span in the NBI database



Type of Design/Construction (Main) (NBI Item_43B) Steel - Continuous	Total	Percent %
Box Beam or Girders-Multiple	588	0.81%
Box Beam or Girders-Single or Spread	591	0.81%
Channel Beam	1	0.00%
Girder and Floorbeam System	2,146	2.94%
Orthotropic	29	0.04%
Slab	28	0.04%
Stringer/Multi-beam or Girder	69,113	94.82%
Tee Beam	11	0.02%
Truss-Deck	149	0.20%
Truss-Thru	235	0.32%
Total	72,891	100.00%

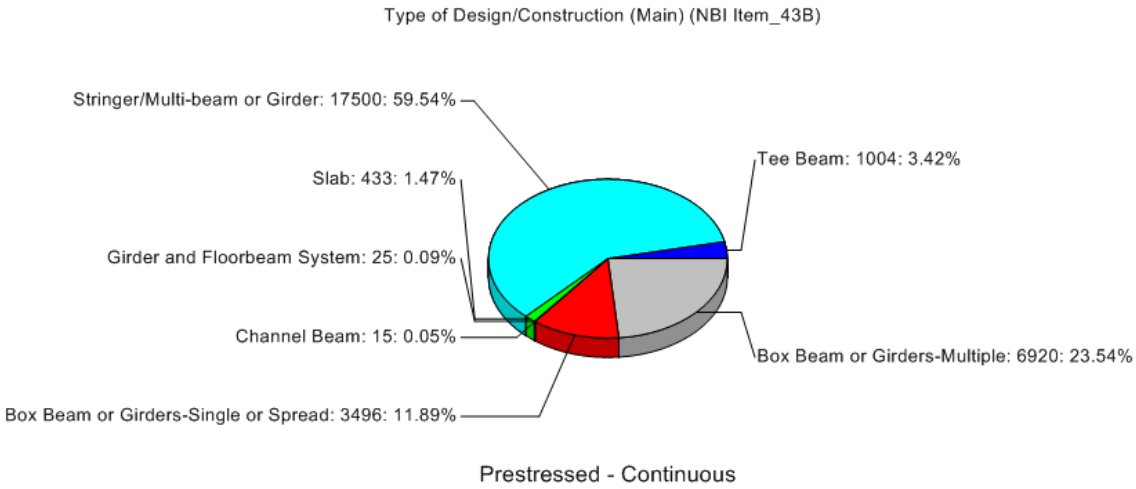
Figure O-8 – Breakdown of steel continuous span in the NBI database

Prestressed Concrete



Type of Design/Construction (Main) (NBI Item_43B) Prestressed - Simple	Total	Percent %
Box Beam or Girders-Multiple	40,899	30.28%
Box Beam or Girders-Single or Spread	5,915	4.38%
Channel Beam	1,496	1.11%
Girder and Floorbeam System	184	0.14%
Orthotropic	3	0.00%
Slab	10,554	7.81%
Stringer/Multi-beam or Girder	68,202	50.50%
Tee Beam	7,804	5.78%
Total	135,057	100.00%

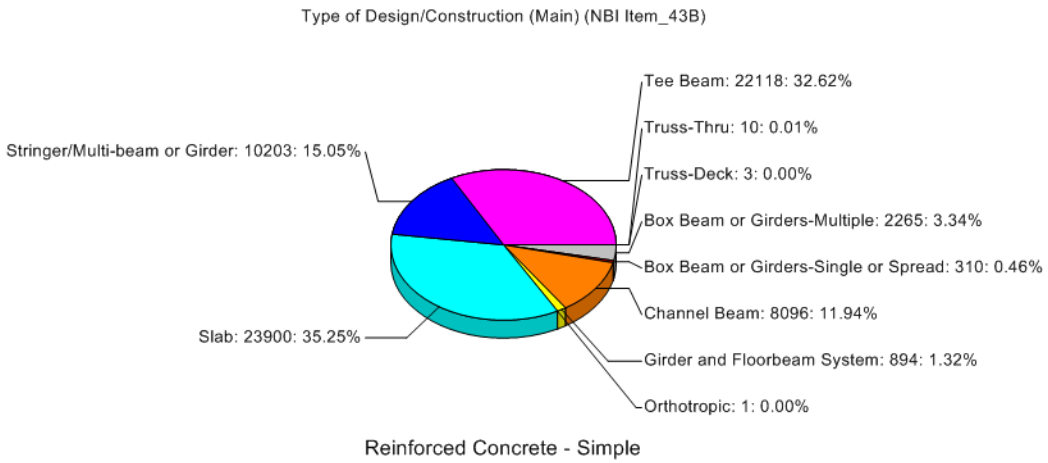
Figure O-9 – Breakdown of prestressed simple span in the NBI database



Type of Design/Construction (Main) (NBI Item_43B) Prestressed - Continuous	Total	Percent %
Box Beam or Girders-Multiple	6,920	23.54%
Box Beam or Girders-Single or Spread	3,496	11.89%
Channel Beam	15	0.05%
Girder and Floorbeam System	25	0.09%
Slab	433	1.47%
Stringer/Multi-beam or Girder	17,500	59.54%
Tee Beam	1,004	3.42%
Total	29,393	100.00%

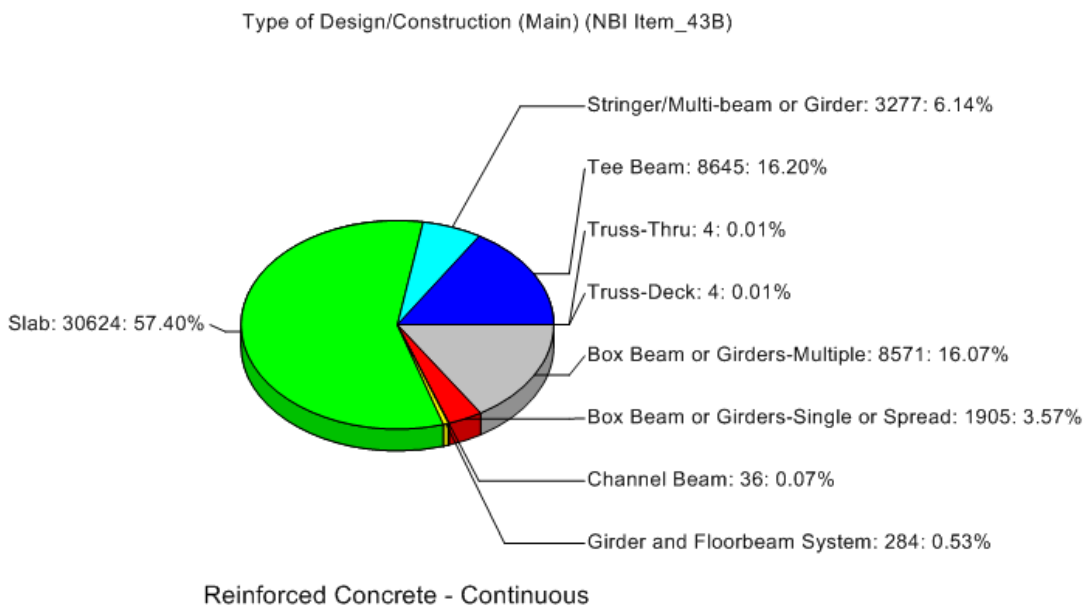
Figure O-10 – Breakdown of prestressed continuous span in the NBI database

Reinforced Concrete



Type of Design/Construction (Main) (NBI Item_43B) Reinforced Concrete - Simple	Total	Percent %
Box Beam or Girders-Multiple	2,265	3.34%
Box Beam or Girders-Single or Spread	310	0.46%
Channel Beam	8,096	11.94%
Girder and Floorbeam System	894	1.32%
Orthotropic	1	0.00%
Slab	23,900	35.25%
Stringer/Multi-beam or Girder	10,203	15.05%
Tee Beam	22,118	32.62%
Truss-Deck	3	0.00%
Truss-Thru	10	0.01%
Total	67,800	100.00%

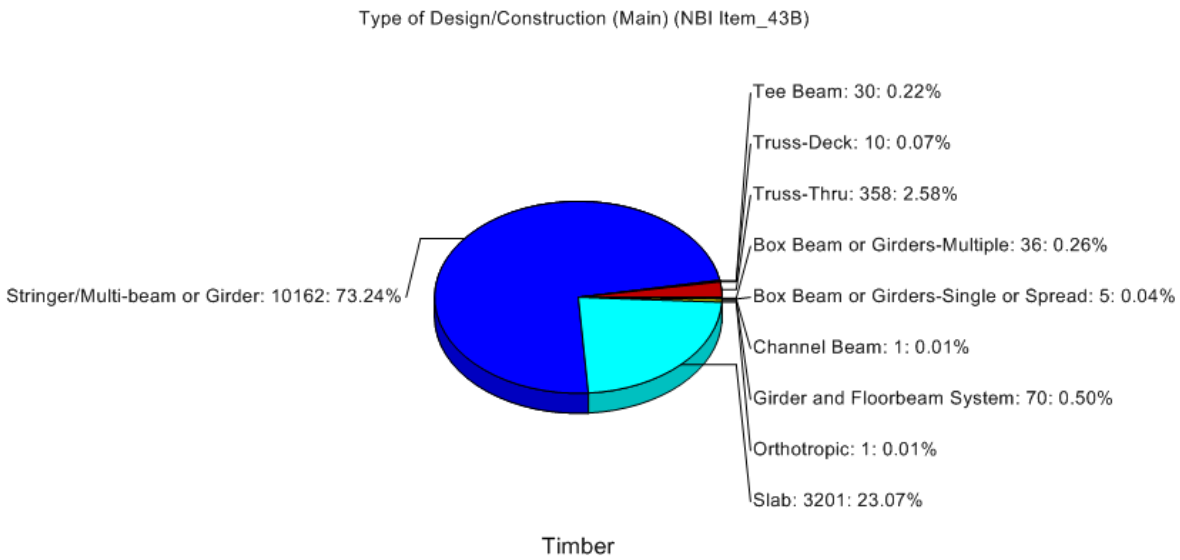
Figure O-11 – Breakdown of reinforced concrete simple span in the NBI database



Type of Design/Construction (Main) (NBI Item_43B)	Total	Percent %
Box Beam or Girders-Multiple	8,571	16.07%
Box Beam or Girders-Single or Spread	1,905	3.57%
Channel Beam	36	0.07%
Girder and Floorbeam System	284	0.53%
Slab	30,624	57.40%
Stringer/Multi-beam or Girder	3,277	6.14%
Tee Beam	8,645	16.20%
Truss-Deck	4	0.01%
Truss-Thru	4	0.01%
Total	53,350	100.00%

Figure O-12 – Breakdown of reinforced concrete continuous span in the NBI database

Timber



Type of Design/Construction (Main) (NBI Item_43B) Timber	Total	Percent %
Box Beam or Girders-Multiple	36	0.26%
Box Beam or Girders-Single or Spread	5	0.04%
Channel Beam	1	0.01%
Girder and Floorbeam System	70	0.50%
Orthotropic	1	0.01%
Slab	3,201	23.07%
Stringer/Multi-beam or Girder	10,162	73.24%
Tee Beam	30	0.22%
Truss-Deck	10	0.07%
Truss-Thru	358	2.58%
Total	13,874	100.00%

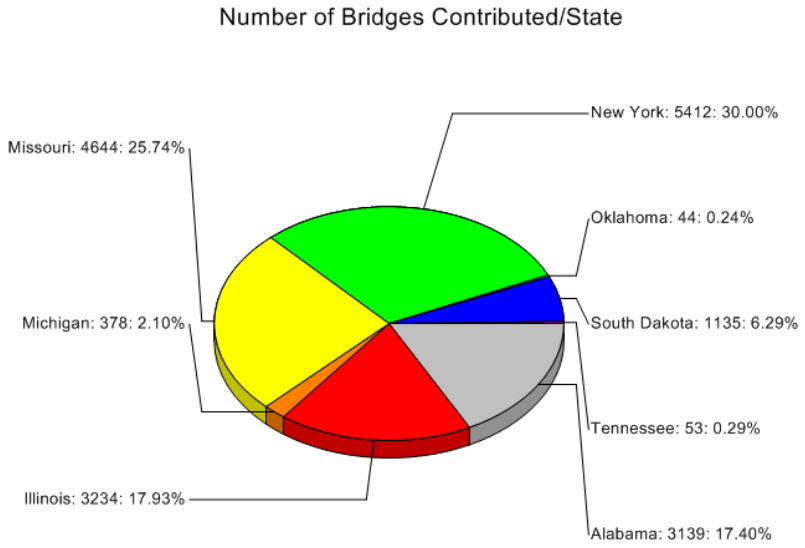
Figure O-13 – Breakdown of timber in the NBI database

Review of collected Virtis Database

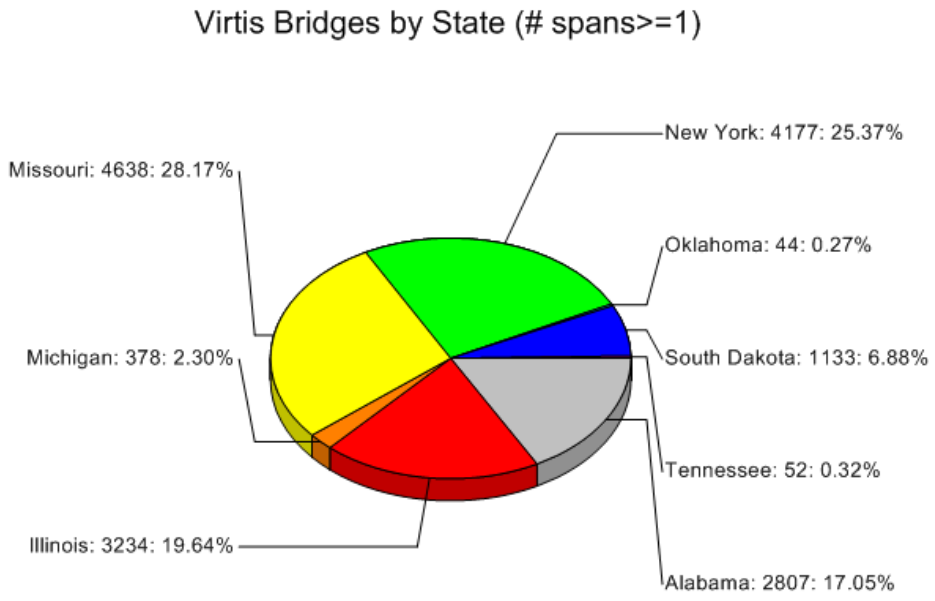
During the collection of the survey data, several states voluntarily submitted Virtis database information from their state bridge inventories. Below is a summary of the bridges by the states at the writing of this Interim report. Because the bridge sample domain provided in this report will not be finalized until the actual analysis of the bridges begins, any additional bridge data that the project team receives beyond the date of this report can still be utilized to fill gaps in the sample domain. The software used to sort through the 18,000+ bridges received thus far can continue to be used as new data is received.

Table O-2 – List of Virtis datasets contributed by State

State Name (NBI state_name)	Total	Percent %
Alabama	3,139	17.40%
Illinois	3,234	17.93%
Michigan	378	2.10%
Missouri	4,644	25.74%
New York	5,412	30.00%
Oklahoma	44	0.24%
South Dakota	1,135	6.29%
Tennessee	53	0.29%
Total	18,039	100.00%



The structure type breakdown of the 18,039 bridges in the current Virtis database is described in Table O-3. Querying the database for number of spans greater than or equal to 1 reveals that only 16,463 of the bridges have useable data. Spot review of the bridge IDs with spans less than 1 indicate that these bridge ID's do not contain bridge description data and are likely place holders in the Virtis database.



State Name (NBI state_name)	Total	Percent %
Alabama	2,807	17.05%
Illinois	3,234	19.64%
Michigan	378	2.30%
Missouri	4,638	28.17%
New York	4,177	25.37%
Oklahoma	44	0.27%
South Dakota	1,133	6.88%
Tennessee	52	0.32%
Total	16,463	100.00%

Figure O-14 – Bridge IDs with useable data from the collect Virtis database

There also are multiple structure types for some Bridge ID's (e.g. some bridge ID's may contain alternates(1 plate girder, 1 rolled beam) or multiple structures (main span, approach span)). When multiple structure options exist within a bridge ID, they will need to be reviewed on a case by case basis to determine whether both of them or just one is a feasible test bridge. The structure type breakdown of the collected Virtis database is shown in Table O-3.

Table O-3 – Structure Type breakdown in the collected Virtis Database

Structure Type	Number
Precast Box	1075
Precast I	2742
Precast T	35
Precast U	0
Timber - Rect	383
Rein. Concrete I	67
Rein. Concrete Slab	1599
Rein. Concrete T	1786
Steel Built-Up	230
Steel Plate	3030
Steel Rolled	6825
Steel Truss	79

Comparative tables (NBI vs. Collected Data)

To summarize the comparisons of the various bridge/material types and to determine the possible holes or anomalies in the data collection/comparison process, the tables on the following pages were produced using the querying software developed, the NBI database, and the flat database produced from the Virtis data collection.

For the purposes of reviewing the numbers in the tables, the following constants were used

TOTAL_NBI: NBI DB Sample Size (with query restrictions as provided in Table O-1 of this appendix): 514,716

Bridge_Sample_Size: Expected size of 12-78 Bridge Sample 1,500

Table O-1 shown below provides a description of the columns provided in the tables on the following pages.

Table O-1 – Column Description

Column Name	**Description**
Description	Superstructure description.
Number of Spans	Number of spans considered
Maximum Span Length (m)	The NBI database provides a 'length of maximum span' for each bridge record as Item 48. When querying the Virtis database, the query was simplified by choosing the maximum span length of all span lengths within that particular bridge ID.
Number in NBI DB Sample	Total number of records from the NBI DB Sample.
NBI Cumulative Total	NBI subtotal for the particular superstructure description.
% of NBI Sample	('Number of NBI DB Sample '/ 'NBI DB Sample') * 100
12-78 Bridge Domain Total	'% of NBI Sample' * Bridge_Sample_Size
Bridge Domain Total	subtotal of '12-78 Bridge Domain Total' for the particular superstructure description.
Number in Virtis Sample	Number available for the collected Virtis Data
Diff (+/-)	Difference between the 'Number in Virtis Sample' and '12-78 Bridge Domain Total' In general: (+) – more bridges collected than needed

Table O-4 – NBI/Virtis data comparison (Steel Simple Span)

Steel Bridge (Simple Span)

Description	Number of Spans	Maximum Span Length (m)	Number in NBI DB Sample	NBI Cumul. Total	% of NBI Sample	12-78 Bridge Domain Total	Bridge Domain Total	Number in Virtis Sample	Diff (+/-)
Multi Girder	All Spans			122,667					
		6.1 <= Span< 16.1	67,714		13.16%	197		2,451	2254
		16.1 <= Span< 26.1	32,231		6.26%	94		1,429	1335
		26.1 <= Span< 36.1	13,807		2.68%	40		883	843
		>= 36.1	8,915		1.73%	26		683	657
							357	5,446	5089
Girder-Floorbeam	All Spans			7,658					
		6.1 <= Span< 16.1	2,938		0.57%	9		0	(9)
		16.1 <= Span< 26.1	2,666		0.52%	8		0	(8)
		26.1 <= Span< 36.1	1,297		0.25%	4		0	(4)
		>= 36.1	757		0.15%	2		0	(2)
							22	0	(22)
Truss-Through and Deck	All Spans			10,952					
		6.1 <= Span< 16.1	2,116		0.41%	6		1	(5)
		16.1 <= Span< 26.1	3,766		0.73%	11		8	(3)
		26.1 <= Span< 36.1	2,173		0.42%	6		14	8
		>= 36.1	2,897		0.56%	8		42	34
							32	65	33
Box Beam	All Spans			512					
		6.1 <= Span< 16.1	103		0.02%	0			
		16.1 <= Span< 26.1	90		0.02%	0			
		26.1 <= Span< 36.1	62		0.01%	0			
		>= 36.1	257		0.05%	1			
							1	0	0
Others	All Spans			562					
		6.1 <= Span< 16.1	293		0.06%	1			
		16.1 <= Span< 26.1	192		0.04%	1			
		26.1 <= Span< 36.1	60		0.01%	0			
		>= 36.1	17		0.00%	0			
							2	0	0
			Totals	142,351	0	415	415	5,511	5099

Table O-5 – NBI/Virtis data comparison (Steel Continuous Span)

Description	Number of Spans	Maximum Span Length (m)	Number in NBI DB Sample	NBI Cumul. Total	% of NBI Sample	12-78 Bridge Domain Total	Bridge Domain Total	Number in Virtis Sample	Diff (+/-)
Multi Girder				69,113					
	<2*	6.1 <= Span< 16.1	3,506		0.68%	10		88	78
		16.1 <= Span< 26.1	9,795		1.90%	29		140	111
		26.1 <= Span< 36.1	10,725		2.08%	31		297	266
		>= 36.1	11,264		2.19%	33		231	198
	3	6.1 <= Span< 16.1	3,809		0.74%	11		371	360
		16.1 <= Span< 26.1	8,300		1.61%	24		1,256	1232
		26.1 <= Span< 36.1	3,955		0.77%	12		608	596
		>= 36.1	3,284		0.64%	10		371	361
	>=4	6.1 <= Span< 16.1	1,180		0.23%	3		85	82
		16.1 <= Span< 26.1	5,651		1.10%	16		710	694
		26.1 <= Span< 36.1	3,855		0.75%	11		452	441
		>= 36.1	3,789		0.74%	11		495	484
							201	5,104	4903
Girder-Floorbeam				2,146					
	>=2	6.1 <= Span< 16.1	306		0.06%	1		n/a	
		16.1 <= Span< 26.1	260		0.05%	1		n/a	
		26.1 <= Span< 36.1	393		0.08%	1		n/a	
		>= 36.1	1,187		0.23%	3		n/a	
							6	0	0
Truss-Through and Deck				384					
	All Spans	6.1 <= Span< 16.1	34		0.01%	0		0	(0)
		16.1 <= Span< 26.1	15		0.00%	0		0	(0)
		26.1 <= Span< 36.1	24		0.00%	0		2	2
		>= 36.1	311		0.06%	1		17	16
							1	19	18
Box Beam				1,179					
	All Spans	6.1 <= Span< 16.1	9		0.00%	0		0	(0)
		16.1 <= Span< 26.1	51		0.01%	0		0	(0)
		26.1 <= Span< 36.1	157		0.03%	0		0	(0)
		>= 36.1	962		0.19%	3		0	(3)
							3	0	(3)
Others				69					
	All Spans	6.1 <= Span< 16.1	24		0.00%	0		0	
		16.1 <= Span< 26.1	14		0.00%	0		0	
		26.1 <= Span< 36.1	14		0.00%	0		0	
		>= 36.1	17		0.00%	0		0	
							0	0	0
			Totals	72,891	0	212	212	5,123	4917

* The NBI Data at times will have a 0 or 1 even though+A200 the record is considered Steel(continuous).
These records are considered here.

Table O-6 – NBI/Virtis data comparison (Prestressed Simple Span)

Description	Number of Spans	Maximum Span Length (m)	Number in NBI DB Sample	NBI Cumul. Total	% of NBI Sample	12-78 Bridge Domain Total	Bridge Domain Total	Number in Virtis Sample	Diff (+/-)
P/S I-Beam	All Spans			68,202					
		6.1 <= Span< 16.1	12,051		2.34%	35		227	192
		16.1 <= Span< 26.1	30,563		5.94%	89		349	260
		26.1 <= Span< 36.1	19,177		3.73%	56		254	198
		>= 36.1	6,411		1.25%	19		105	86
							199	935	736
P/S Bpx Beam	All Spans			46,814					
		6.1 <= Span< 16.1	24,695		4.80%	72		510	438
		16.1 <= Span< 26.1	15,640		3.04%	46		376	330
		26.1 <= Span< 36.1	3,574		0.69%	10		99	89
		>= 36.1	2,905		0.56%	8		3	(5)
							136	988	852
P/S Slab	All Spans			10,554					
		6.1 <= Span< 16.1	9,133		1.77%	27		0	(27)
		16.1 <= Span< 26.1	1,354		0.26%	4		0	(4)
		26.1 <= Span< 36.1	52		0.01%	0		0	(0)
		>= 36.1	15		0.00%	0		0	(0)
							31	0	(31)
P/S Tee Beam	All Spans			7,804					
		6.1 <= Span< 16.1	5,216		1.01%	15		3	(12)
		16.1 <= Span< 26.1	1,734		0.34%	5		1	(4)
		26.1 <= Span< 36.1	550		0.11%	2		0	(2)
		>= 36.1	304		0.06%	1			(1)
							23	4	(19)
Others	All Spans			1,683					
		6.1 <= Span< 16.1	1,444		0.28%	4		0	(4)
		16.1 <= Span< 26.1	162		0.03%	0		0	(0)
		26.1 <= Span< 36.1	44		0.01%	0		0	(0)
		>= 36.1	33		0.01%	0		0	(0)
							5	0	(5)
			Totals	135,057	0	394	394	1,927	1,533

Table O-7 – NBI/Virtis data comparison (Prestressed Continuous Span)

Description	Number of Spans	Maximum Span Length (m)	Number in NBI DB Sample	NBI Cumul. Total	% of NBI Sample	12-78 Bridge Domain Total	Bridge Domain Total	Number in Virtis Sample	Diff (+/-)
P/S I-Beam				17,500					
	<2*	6.1 <= Span< 16.1	368		0.07%	1		21	20
		16.1 <= Span< 26.1	2,198		0.43%	6		59	53
		26.1 <= Span< 36.1	2,877		0.56%	8		62	54
		>= 36.1	1,342		0.26%	4		32	28
	>=3	6.1 <= Span< 16.1	2,428		0.47%	7		321	314
		16.1 <= Span< 26.1	5,039		0.98%	15		762	747
		26.1 <= Span< 36.1	2,370		0.46%	7		234	227
		>= 36.1	878		0.17%	3		72	
							51	1,563	1443
P/S Box Beam				10,416					
	<2*	6.1 <= Span< 16.1	353		0.07%	1		1	(0)
		16.1 <= Span< 26.1	807		0.16%	2		9	7
		26.1 <= Span< 36.1	1,480		0.29%	4		5	1
		>= 36.1	4,114		0.80%	12		4	(8)
	>=3	6.1 <= Span< 16.1	1,020		0.20%	3		12	9
		16.1 <= Span< 26.1	931		0.18%	3		16	13
		26.1 <= Span< 36.1	487		0.09%	1		7	6
		>= 36.1	1,224		0.24%	4		2	(2)
							30	37	26
P/S Slab				433					
	All Spans	6.1 <= Span< 16.1	199		0.04%	1		0	(1)
		16.1 <= Span< 26.1	155		0.03%	0		0	(0)
		26.1 <= Span< 36.1	53		0.01%	0		0	(0)
		>= 36.1	26		0.01%	0		0	(0)
							1	0	(1)
P/S Tee Beam				1,004					
	All Spans	6.1 <= Span< 16.1	475		0.09%	1		30	29
		16.1 <= Span< 26.1	130		0.03%	0			(0)
		26.1 <= Span< 36.1	244		0.05%	1			(1)
		>= 36.1	155		0.03%	0			(0)
							3	30	27
Others				40					
	All Spans	6.1 <= Span< 16.1	7		0.00%	0			(0)
		16.1 <= Span< 26.1	14		0.00%	0			(0)
		26.1 <= Span< 36.1	13		0.00%	0			(0)
		>= 36.1	6		0.00%	0			(0)
							0	0	(0)
			Totals	29,393	0	86	86	1,630	1495

* The NBI Data at times will have a 0 or 1 even though the record is considered continuous.
These records are considered here.

Table O-8 – NBI/Virtis data comparison (Reinforced Concrete Simple Span)

Description	Number of Spans	Maximum Span Length (m)	Number in NBI DB Sample	NBI Cumul. Total	% of NBI Sample	12-78 Bridge Domain Total	Bridge Domain Total	Number in Virtis Sample	Diff (+/-)
Multi-Girder I	All Spans			10,203					
		6.1 <= Span< 9.1	1,285		0.25%	4		0	(4)
		9.1 <= Span< 12.1	4,693		0.91%	14		3	(11)
		12.1 <= Span< 15.1	3,019		0.59%	9		9	0
		>= 15.1	1,206		0.23%	4		19	15
							30	31	1
Tee Beam	All Spans			22,118					
		6.1 <= Span< 9.1	5,800		1.13%	17		153	136
		9.1 <= Span< 12.1	8,440		1.64%	25		768	743
		12.1 <= Span< 15.1	5,235		1.02%	15		260	245
		>= 15.1	2,643		0.51%	8		153	145
							64	1,334	1270
Slab	All Spans			23,900					
		6.1 <= Span< 9.1	15,664		3.04%	46		195	149
		9.1 <= Span< 12.1	5,670		1.10%	17		44	27
		12.1 <= Span< 15.1	1,709		0.33%	5		24	19
		>= 15.1	857		0.17%	2		43	41
							70	306	236
Channel Beam	All Spans			8,096					
		6.1 <= Span< 9.1	2,739		0.53%	8		0	(8)
		9.1 <= Span< 12.1	5,051		0.98%	15		0	(15)
		12.1 <= Span< 15.1	255		0.05%	1		0	(1)
		>= 15.1	51		0.01%	0		0	(0)
							24	0	(24)
Others	All Spans			3,483					
		6.1 <= Span< 16.1	514		0.10%	1		0	(1)
		16.1 <= Span< 26.1	574		0.11%	2		0	(2)
		26.1 <= Span< 36.1	351		0.07%	1		0	(1)
		>= 36.1	2,044		0.40%	6		0	(6)
							10	0	(10)
			Totals	67,800	0	198	198	1,671	1,473

Table O-9 – NBI/Virtis data comparison (Reinforced Concrete Span)

Description	Number of Spans	Maximum Span Length (m)	Number in NBI DB Sample	NBI Cumul. Total	% of NBI Sample	12-78 Bridge Domain Total	Bridge Domain Total	Number in Virtis Sample	Diff (+/-)
Slab				30,624					
	<2*	6.1 <= Span< 9.1	1,290		0.25%	4		7	3
		9.1 <= Span< 12.1	1,394		0.27%	4		11	7
		12.1 <= Span< 15.1	1,637		0.32%	5		2	(3)
		>= 15.1	1,731		0.34%	5		54	49
	>=3	6.1 <= Span< 9.1	5,975		1.16%	17		211	194
		9.1 <= Span< 12.1	8,119		1.58%	24		274	250
		12.1 <= Span< 15.1	6,703		1.30%	20		313	293
		>= 15.1	3,775		0.73%	11		122	111
							89	994	905
Box Beam				10,476					
	<2*	6.1 <= Span< 9.1	5		0.00%	0		0	(0)
		9.1 <= Span< 12.1	14		0.00%	0		0	(0)
		12.1 <= Span< 15.1	42		0.01%	0		0	(0)
		>= 15.1	6,256		1.22%	18		0	(18)
	>=3	6.1 <= Span< 9.1	5		0.00%	0		0	(0)
		9.1 <= Span< 12.1	7		0.00%	0		0	(0)
		12.1 <= Span< 15.1	33		0.01%	0		0	(0)
		>= 15.1	4,114		0.80%	12		0	(12)
							31	0	-31
Tee Beam				8,645					
	>=2	6.1 <= Span< 9.1	329		0.06%	1		0	(1)
		9.1 <= Span< 12.1	571		0.11%	2		8	6
		12.1 <= Span< 15.1	1,331		0.26%	4		18	14
		>= 15.1	6,414		1.25%	19		193	174
							25	219	194
Multi Girder				3,277					
	>=2	6.1 <= Span< 9.1	536		0.10%	2		0	(2)
		9.1 <= Span< 12.1	501		0.10%	1		0	(1)
		12.1 <= Span< 15.1	497		0.10%	1		0	(1)
		>= 15.1	1,743		0.34%	5		43	38
							10	43	33
Others				328					
	>=2	6.1 <= Span< 9.1	42		0.01%	0		0	(0)
		9.1 <= Span< 12.1	60		0.01%	0		0	(0)
		12.1 <= Span< 15.1	36		0.01%	0		0	(0)
		>= 15.1	190		0.04%	1		0	(1)
							1	0	-1
			Totals	53,350	0	155	155	1,256	1,101

* The NBI Data at times will have a 0 or 1 even though the record is considered continuous.
These records are considered here.

Table O-10 – NBI/Virtis data comparison (Timber)

Description	Number of Spans	Maximum Span Length (m)	Number in NBI DB Sample	NBI Cumul. Total	% of NBI Sample	12-78 Bridge Domain Total	Bridge Domain Total	Number in Virtis Sample	Diff (+/-)
Multi-Girder	All Spans			10,162					
		6.1 <= Span< 9.1	7,043		1.37%	21		41	20
		9.1 <= Span< 12.1	2,213		0.43%	6		30	24
		12.1 <= Span< 15.1	433		0.08%	1		25	24
		>= 15.1	473		0.09%	1		25	24
							30	121	91
Slab	All Spans			3,201					
		6.1 <= Span< 9.1	2,430		0.47%	7		0	(7)
		9.1 <= Span< 12.1	717		0.14%	2		0	(2)
		12.1 <= Span< 15.1	34		0.01%	0		0	(0)
		>= 15.1	20		0.00%	0		0	(0)
							9	0	-9
Others	All Spans			511					
		6.1 <= Span< 16.1	42		0.01%	0		0	(0)
		16.1 <= Span< 26.1	55		0.01%	0		0	(0)
		26.1 <= Span< 36.1	61		0.01%	0		0	(0)
		>= 36.1	353		0.07%	1		0	(1)
							1	0	-1
			Totals	13,874	0	40	40	121	81

Miscellaneous

References

For a description of the NBI data, see ***"Recording and Coding Guide for the Structure Inventory and Appraisal of the Nations Bridges"***, Report No. FHWA-PD-96-001, U.S. Department of Transprotation, Federal Higway Administration, Office of Engineering, Bridge Division, December, 1995.

MemorandumUpdates:
http://www.fhwa.dot.gov/bridge/032204.htm
Memorandum, *INFORMATION: Revisions to Items 63-66 to Support Load Reporting by Rating Factor*, U.S. Department of Transprotation, Federal Higway Administration

http://www.fhwa.dot.gov/bridge/nbi/20070517.cfm
Memorandum, *INFORMATION: Public Disclosure of National Bridge Inventory (NBI) Data*, U.S. Department of Transprotation, Federal Higway Administration

Interpretations of NBI Data

To facilitate querying of the NBI data the following changes were made.

Item 5B – 276 records with Null set to '8' (other).
Item 5C – 273 records with Null set to '0' (None of the below)
Item 26 – 483 records with Null. Set to 0 (new definition of 'Unknown)
Item 41 – Structure Open, Posted or Closed to traffic
102,534 records with null. Replaced with new definition of ('x' unknown).
Item 31 – Interpreted blanks (or nulls) as 0 – Other – Approximately 105,000 records had nulls.
Item bbb- Status – Interpreted Blanks (or nulls) as N- Not applicable. 100,209 records.
Also for Item ddd- Sufficiency Rating; replaced all nulls with 0. Generally the nulls for this field corresponded with nulls for the status field which were converted to N (not applicable).

As Co-Principal Investigators for **NCHRP project 12-78 *"Evaluation of Load Rating by Load and Resistance Factor Rating (LRFR)"*** we seek your input regarding the implementation of the new LRFR specification in your state ***via the attached survey***. A synopsis of this project can be viewed directly at the following URL:

http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=1629

or go to

http://www.trb.org/CRP/NCHRP/NCHRPProjects.asp

and follow the links to NCHRP 12-78. Further description is provided in the 'Introduction' section provided on the following page.

This survey of information will ultimately help us with the development of a comprehensive data base of rating comparisons for the purpose of recommending refinements to the LRFR methods in the *AASHTO Manual for Bridge Evaluation.*

Because your state participates in the AASHTOWare™ VIRTIS/OPIS software development, we also ask that you consider providing data from your AASHTOWare database that we could use in the development of our test database.

To help facilitate the completion of this survey, *we would like to talk to you at your convenience to discuss this survey*. We hope that speaking to you directly could help reduce your time needed for the survey and provide us with appreciably better results.

If you could respond to this email and provide us with a date/time that we can reach you, we will make every effort to accommodate that time and complete the interview as quickly as possible. Once the interview is completed, we will email you back your responses for your record. If you do not wish to be contacted, please let us know and respond either electronically or via mail at the address below.

Thank you for your participation.

Mark Mlynarski, P.E.	Michael Baker Jr., Inc.	Co-principal Investigator
Wagdy G. Wassef, Ph.D., P.E.	Modjeski and Masters	Co-principal Investigator

Call 412.269.7933 to discuss this survey or if you wish, email or fax the survey to the following:

Michael Baker Jr., Inc.
Airside Business Park
100 Airside Drive
Moon Township, PA 15108
Attn: Mark Mlynarski

mmlynarski@mbakercorp.com
FAX: 412.269.3999

Introduction

Over the past decade, a great deal of State and Federal resources have been expended to develop a state-of-the-art set of reliability-based bridge design and load rating specifications, the LRFD and LRFR. In June of 2000, the FHWA released a memorandum requiring all new bridge designs to be LRFD-based after October 1, 2007. In line with this directive, the FHWA has been coordinating efforts to merge to LRFR-based ratings. As such, the FHWA has set a date of October 1, 2010 after which all new bridges are to be rated using the LRFR method. In the time period between October 1, 2007 and October 1, 2010, both LFR and LRFR ratings are deemed acceptable by the FHWA, although the preferred method is LRFR.

Ratings for existing bridges in the inventory are also being migrated toward the LRFR specification and ASD-based (ASR) ratings are only permissible as an exception for certain timber and masonry bridges. This being said, the FHWA provides considerably more leeway in the determination of the Bridge Posting rating (NBI Item 70). Presumably, this policy is to allow the states to extend the service life of their existing bridge inventories for bridges that may not rate using the preferred methods, yet seem to be performing well in service.

From these policies, as well as the decision to sunset the Standard Specifications for Highway Bridges as of the 17th Edition (2002), it is clear that the bridge community is moving toward a nationwide policy of reliability-based design and rating specifications. However, recent surveys by Ralph Anderson, IDOT Chief Bridge Engineer, (2006) indicate that the States are at varying stages of implementation of such a policy. Such surveys are indicative of both the level of effort required to migrate to an alternate rating methodology and the uncertainty associated with such a migration. Without sufficient data to show what impacts may be realized through the full-scale adoption of LRFR-methodologies, some states are proceeding with a great deal of caution. This hesitation is understandable given the thinly-stretched budgets of many State DOTs. As a result, the bridge community finds itself in a transitional period of non-uniformity in terms of bridge rating policy.

Although some work has been done to predict the effects of a migration to LRFR methods, such efforts have not been able to provide a full understanding of what difficulties might arise out of a full-scale adoption of the LRFR manual. The primary objective of the NCHRP 12-78 project is to identify these difficulties and determine whether there are ways to eliminate or minimize these issues via straightforward revisions to the LRFR specifications.

One of the initial tasks for the NCHRP 12-78 project is to conduct a survey of State DOTs to determine their current bridge inventory management practices as they relate to load rating, posting and permitting. One of the primary objectives of this survey is to allow the DOTs to have some input as to the makeup of the inventory of bridges that will be considered in the evaluation/comparison of rating results using the LFR and LRFR methodologies. Furthermore, this survey will allow the DOTs to aid in fine tuning the objectives of this research project, i.e., what issues do they expect to be answered as a part of this work? By addressing such concerns, some of the existing roadblocks that may be contributing to delays in implementing LRFR can be eliminated.

SURVEY

Usage: Rating/Posting Methodology for Existing Bridges:

1) Are you currently using LRFR to load rate **existing** bridges? (Yes/No)

If the answer to the question above is "Yes":

1.a.) What types of bridges are you rating using LRFR and what types using alternate methods?

Rating Methodology for New Bridges:

2) Are you currently using LRFR to load rate **newly designed** bridges? (Yes | No)

3) How many bridges in your inventory have been rated with LRFR? (if possible, quantify by bridge type)

4) What live load vehicles do you use for rating using LFR? (Attach axle load/spacing data for non-standard vehicles)

4.a) Inventory:

4.b) Operating:

4.c) Posting:

5) Does your agency rate bridges for (Strength | Service | Both) ?

6) Does your agency rate for Fatigue? (Yes| No)

7) What load demands are considered for rating beam and girder elements for Strength (Moment | Shear | Both)?

8) Which of the following levels does your agency use to **post** bridges?
(Inventory | Operating | Between Inventory and Operating)

9) Which of the following levels does your agency use to **rate** bridges?
(Inventory | Operating | Between Inventory and Operating)

10) What live load vehicles do you use for rating using LRFR? (Attach axle load/spacing data for non-standard vehicles)

10.a) Inventory:

10.b) Operating:

10.c) Posting:

11) Do you use special vehicles for design of new bridges that are not also used as rating vehicles? (if so, please specify vehicle name and attach axle load/spacing data)

12) Does your agency use "standard" permit trucks for your permit policy? (Attach axle load/spacing data for non-standard vehicles)

13) Does your agency rate substructures? (Yes | No)

Results

14) Have you experienced significant differences in ratings using LRFR vs. LFR? (Yes/No)

If the answer to the question above is "Yes":

14.a) For what types of bridges?

14.b) What components/loads/force effects controlled the ratings?

Implementation

15) What is your target date (or completion date) for full implementation of LRFR for existing bridges?

16) Please list software currently being used (or planned for use) for rating:

LFR:

LRFR:

Concerns

17) What concerns do you have about implementing LRFR for your agency? (i.e., costs of implementation, training, low ratings, specific technical issues, software availability, etc.)

18) List any difficulties you have encountered in implementing the Manual for Condition Evaluation?

Suggestions

19) List specific areas/questions that you think need to be addressed as part of the NCHRP 12-78 research:

Implementing *NCHRP 12-50* in Virtis

While Process 12-50 (see previous section) has been implemented in part in Virtis and BRASS, changes were required in the BRASS export of Virtis to take advantage of the data produced for this project. The upcoming release of Virtis 6.1 has features to request 12-50 data for LRFD/LRFR within the Virtis/Opis input menus. However, the 12-50 data produced for LRFD was not is not sufficiently separated to distinguish data for separate girders. The NCHRP 12-50 data request feature is not available in release 6.1 for LFD analysis/rating.

For Virtis LRFD, *the ProcessID (see previous section) is hardcoded as '199' and the descriptive information regarding the girder is only available through the Virtis folder naming system*. As an example, consider the sample Virtis bridge workspace shown in Figure Q-1.

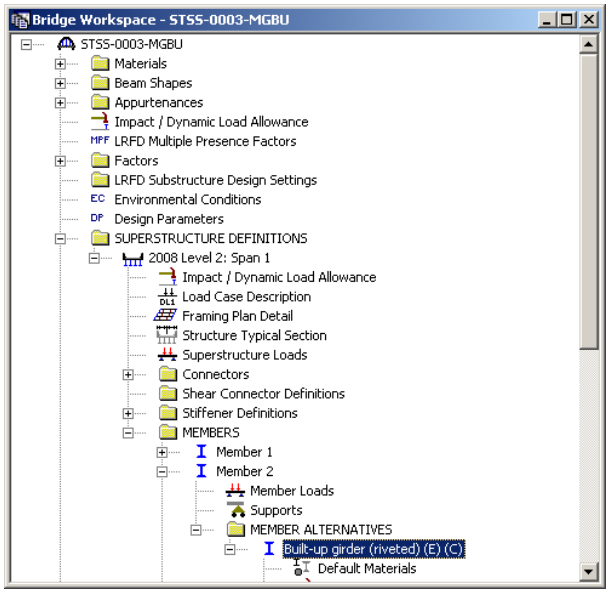


Figure Q-1 – Sample Virtis Bridge Workspace

Based on this sample Bridge Workspace, the Process 12-50 files for the '*Member Alternative'* titled '*Built-up_girder_(riveted)*' will be placed in the folder as shown in Figure Q-2.

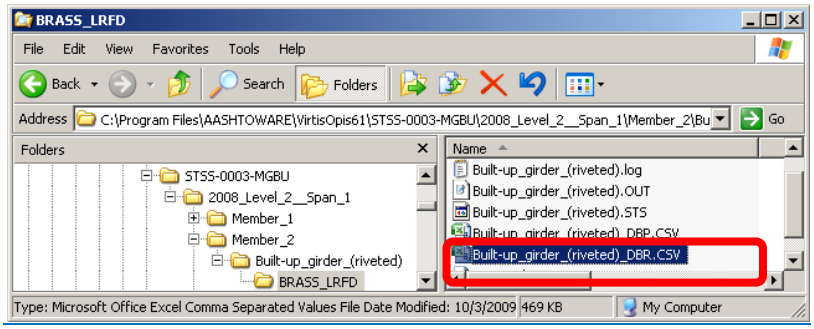
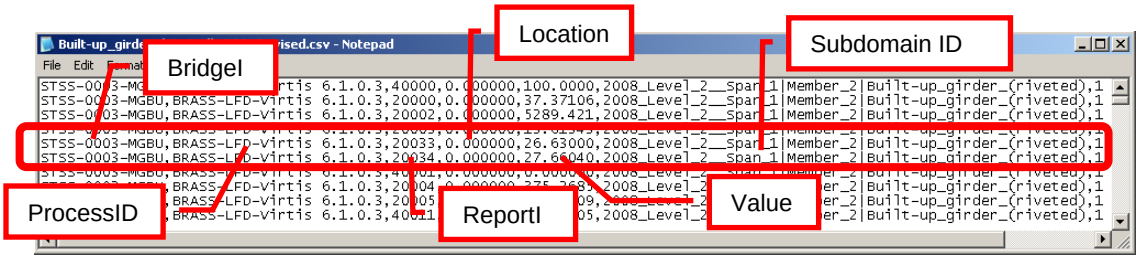


Figure Q-2 – Folder hierarchy for Process 12-50 location produced by Virtis

The girder description, however, is not provided within the Process 12-50 file itself. The girder information is vital in order to distinguish the data in the NCHRP 12-50 viewer (described later in this QPR). To remedy this, the following changes have been made to the BRASS export in version 6.1 of Virtis. (NOTE: these changes will not be available in the delivered version of Virtis 6.1 but will be available for this research project)

- Allow Process 12-50 to be produced for LFD runs. Currently there is no way for the user to specify NCHRP results output for LFD runs (this option is currently only available for LRFD/LRFR) so the version of Virtis used for this project has the option 'hard-coded' to always produce Process 12-50 results for LFD runs.
- Modify the Process 12-50 file through Virtis upon return from running BRASS. This is a post-processing procedure that modifies the file produced internally in BRASS. The steps were necessary since BRASS currently only permits numeric input for the 'ProcessID' and 'Subdomain ID'. For the purposes of uniquely identifying the data produced for each member, the following modifications were made to the BRASS export within Virtis:
    - Substituting the ProcessID of '199' with 'BRASS-LFD-Virtis 6.1.0.3' or 'BRASS-LRFD-Virtis 6.1.0.3' for LFD and LRFD runs respectively.
    - Include the bridge 'Superstructure Definition' hierarchal structure as the 'SubdomainID' in order to distinguish each member. For example, the subdomain ID for the sample shown in Figure Q-1 and Figure Q-2 would be *'2008_Level_2__Span_1|Member_2|Built-up_girder_(riveted)'*, where the folders are separated by the '|' (pipe) character. This distinguishing characteristic permits the import of all of the 12-50 files to be imported into the same relational database and examined as separate girders. A sample of the revised Process 12-50 formatted file is shown below



    - Automatically copy the revised Process 12-50 file to a single folder. Having the files in a single location allows for easy concatenation of the multiple files into one single file. Once concatenated, the single file is then imported into a Process 12-50 database for use with the Process 12-50 Report Viewer (described later in this QPR). Currently, the copy is performed only if a directory named 'C:\temp\VirtisBRASSCSV' exists on the users computer ('C:\temp\VirtisVIRTISCSV' if running the Virtis Specification Checker).

(NOTE: these changes will not be available in version 6.1 of Virtis as the software was too close to release to risk including these additions. They will however be available for this project and as a permanent addition to future releases of Virtis/Opis pending AASHTOWare task force approval).

These changes will facilitate the generation and gathering of the Process 12-50 files and will provide benefits beyond this project. Future research projects will be able to generate and gather information in an organized manner and compare the results regressively (comparing an older version of the software and/or the specification with future versions).

File naming convention

The file naming convention described in this section will be used to uniquely name the files and description field for the 1500 bridge database used for this research. The function of the naming convention is to allow for quick identification of both external files (Virtis formatted XML files) and to quickly identify the bridge in the Virtis Bridge Explorer. The format for XML files copied from the Main Virtis database is as defined in Figure Q-3.

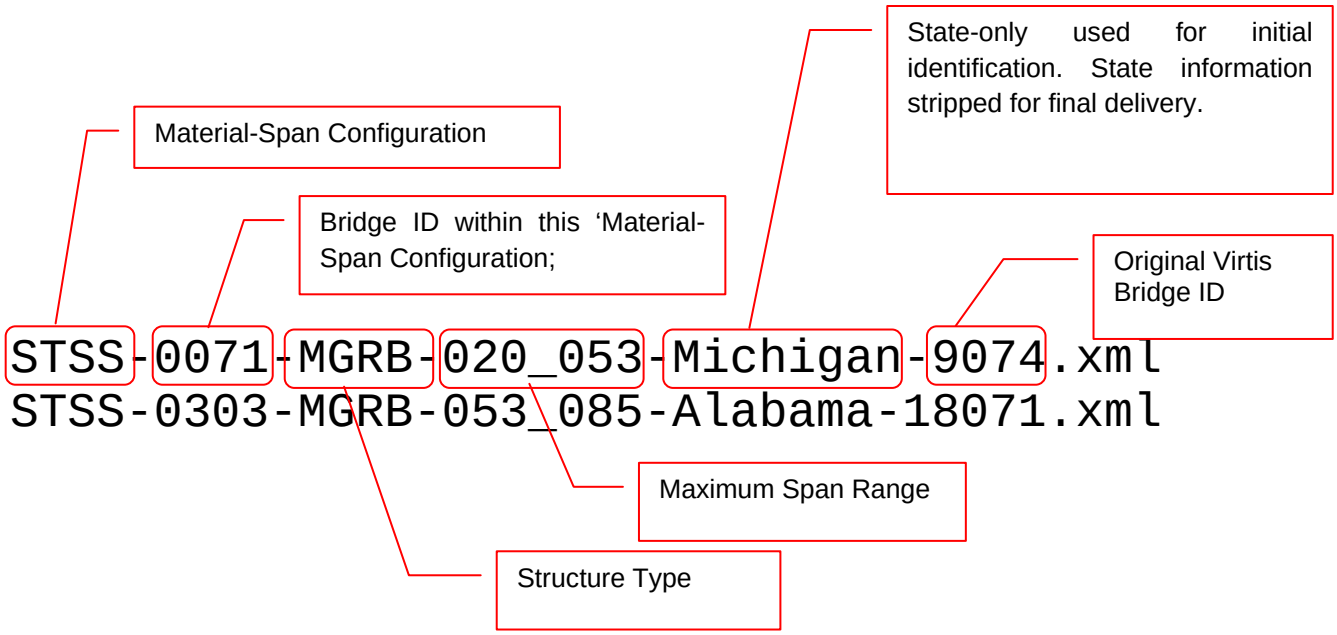


Figure Q-3 – XML file definition for files copied from the main database

The file name components shown in Figure Q-3 are described in detail in Table 1.

Table 1 – NCHRP 12-78 File naming conventions

Component	**Description**
Material-Span Configuration	This component defines the material type and type of span configuration. The first two letters specify the material type: ST – Steel PS – Prestress RC – Reinforced Concrete TI – Timber The second two letters indicate the span configuration and is simply defined as: SS – Simple span MS – multiple spans
Bridge ID	This component defines a unique 4 digit bridge id within this Material-Span Configuration category.
Structure type	This up to 4 character component defines the type of structure for this bridge. The definitions are as follows: MGBU – Multi-girder built-up member MGRB – Multi-girder rolled beam MGSP – Multi-girder steel plate girder GF – Girder floor beam TF – Truss Floor beam PSIB –P/S I-beam PSBX –girder box beam PSTB – P/S T-beam RCSL – Reinforced concrete slab RCTB – Reinforced concrete T-beam RCIB – reinforced concrete I-beam
Maximum Span Range	Provides the range in feet of the maximum span length for this structure. For multiple span structures, this represents the MAXIMUM span length of all spans in the structure.
State	The state that donated the data. This information will ultimately be hidden in the final set of 1500 bridges.
Original Bridge ID	This value corresponds to the original set of data donated by the states during the survey. This number will be retained as a cross reference to the original data.

In addition to using the naming convention for the Virtis XML export files, Virtis will use the moniker to provide a quick reference in the Bridge Explorer. A sample of the bridge explorer displaying the simple span steel girders is shown in Figure Q-4.

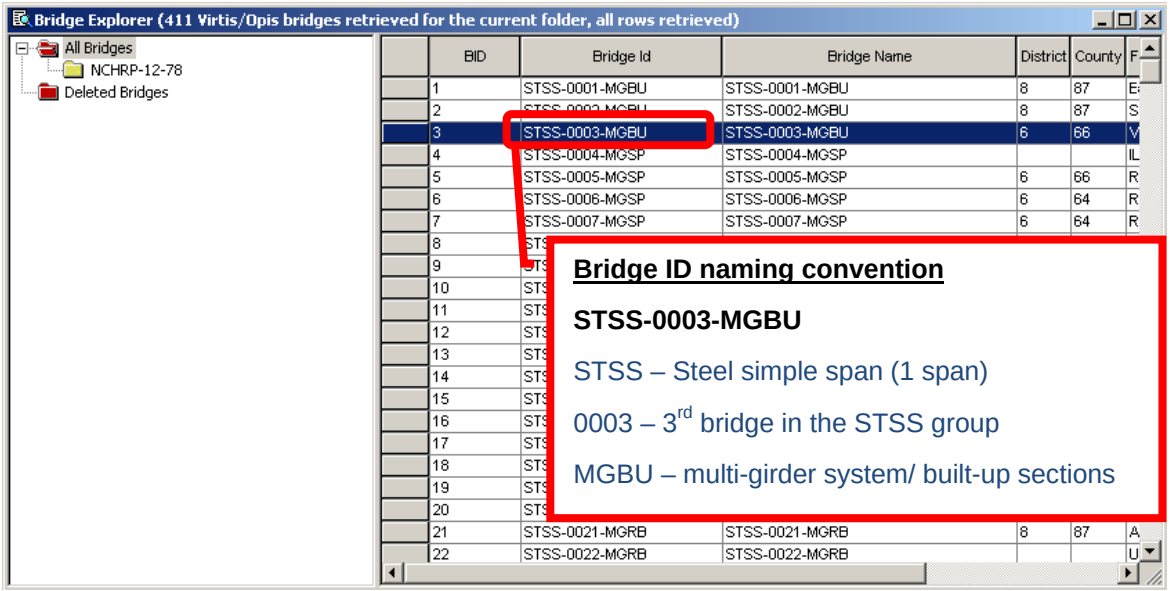


Figure Q-4 – Virtis Bridge explorer with the 12-78 file naming convention

NCHRP 12-50 changes

Since the scope of NCHRP 12-50 was to produce primarily analysis output from an analysis engine, information that corresponds to user input is generally not available. The extraction of this information was necessary however, in order to perform the reliability calculations in an automated manner. This information includes data such as girder spacing that is not produced as part of the BRASS Process 12-50 output. In addition, the girder spacing is not directly available from the Virtis database; it is calculated on the fly in Virtis based on stored girder coordinate geometry and thus cannot be queried directly from the Virtis DB. A programmatic solution is required.

To obtain this data and to keep it in a Process 12-50 format (for a description of Process 12-50, see the September, 2009 QPR) a separate software process has been developed that accesses a Virtis database directly and extracts the necessary information in Process 12-50 format. The new 12-50 report IDs are defined in Table Q-2. The software produces a Process 12-50 file that can then be imported into a 12-50 database along with the BRASS 12-50 output results. The combined results provide the necessary information required for the reliability index calculation.

Table Q-2 – NCHRP Process 12-50 New Report IDs

ReportID	Description 1	Description 2
5001	Left Girder Spacing	0 if left exterior girder
5002	Right Girder Spacing	0 if right exterior girder
5003	Recent count ADTT	
5004	Design ADTT	
5005	Average spacing	Average of (L/R) spacing
5006	Number of lanes	
5007	Future wearing surface thickness	FWS
5008	Slab thickness	
5009	Beam depth	
5010	Composite/non composite	>0.0 composite
5011	Span length (actual) at this location	
5013	Skew angle (left support)	
5014	Skew angle (righ support)	
5015	Left overhang	0- if interior girder or right exterior girder
5016	Right overhang	0 if interior girder or left exterior girder
5017	Previous span length	< 0.0 if no previous span
5018	Next span length	< 0.0 if no next span

Software automation changes – Simple modifications for LRFR input

Some of the LRFR data was not present in Virtis data provided by the states and had not yet been run in LRFR. Two prevalent examples are the calculation of the Effective Flange Width and the setting of the transfer length for LRFD for prestressed girders.

For the automated calculation of the effective flange width, the project team recommended and the panel concurred that the effective flange width will be based on the average of the two girder spacings as per the specfications. Since the girder spacings in Virtis are only available through calculation of the girder line coordinates, the same process that was used to generate the Process 12-50 Report IDs described in the previous section, is used to modify the effective flange widths based on the geometric calculation of the girder spacings.

Other modification options include:

- Changing the ADTT (for bulk changes of the ADTT if necessary).

- Change the Prestressed transfer length (default multiplier of 1.2 of the Std length). We will use this default for all P/S girders unless the example already has a defined LRFD value.

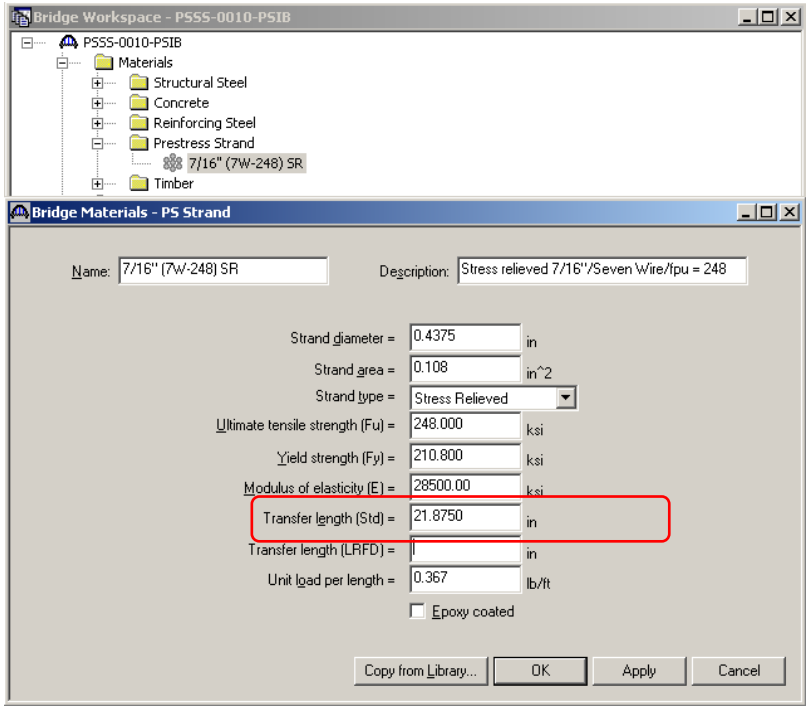


Figure Q-5 – Virtis screen showing LRFD transfer length

A screen capture of the simple interface used to produce the additional Process 12-50 output and to make minor bulk modifications to a Virtis database is shown in Figure Q-6.

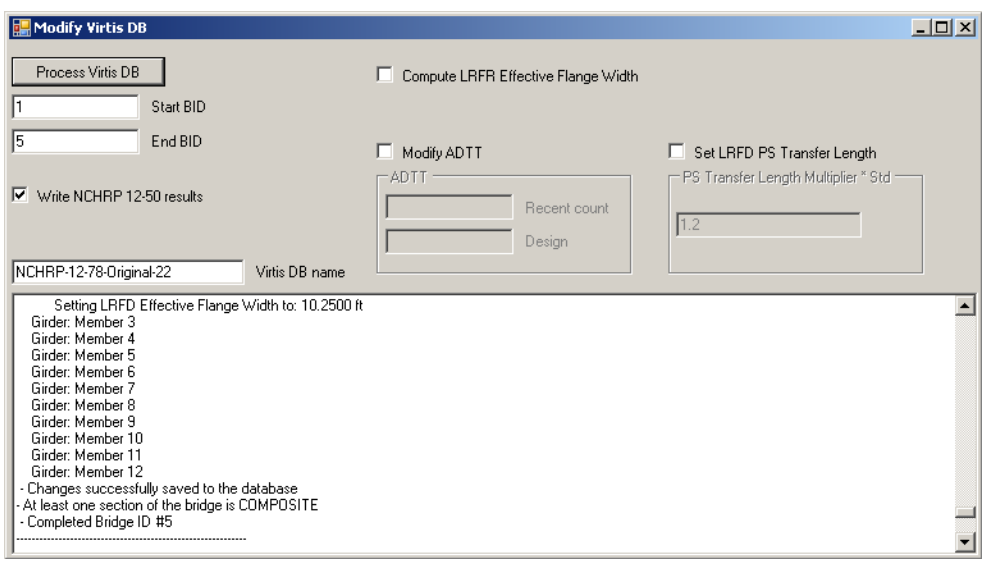


Figure Q-6 - Virtis DB interface

Querying Program tool (NBI and Virtis Data Sorter)

A software application was written for this project for the dual purpose of querying the NBI database as well as the flat database produced from querying the collected Virtis database. The software works with a simple, flat Access database. In one case the NBI data and in another, the Virtis data collected in a flat tabular form. The Virtis table is described in the previous section of this appendix.

Features of the software include:

- Querying the data to produce graphs of information (the graphs shown in Appendix E were produced with this software)
- Querying the data to produce tables (tables were created from queries to produce the Intial Bridge Domain tables shown in '***Error! Reference source not found.***')

This software tool will continue to be used in Phase II of this research project.

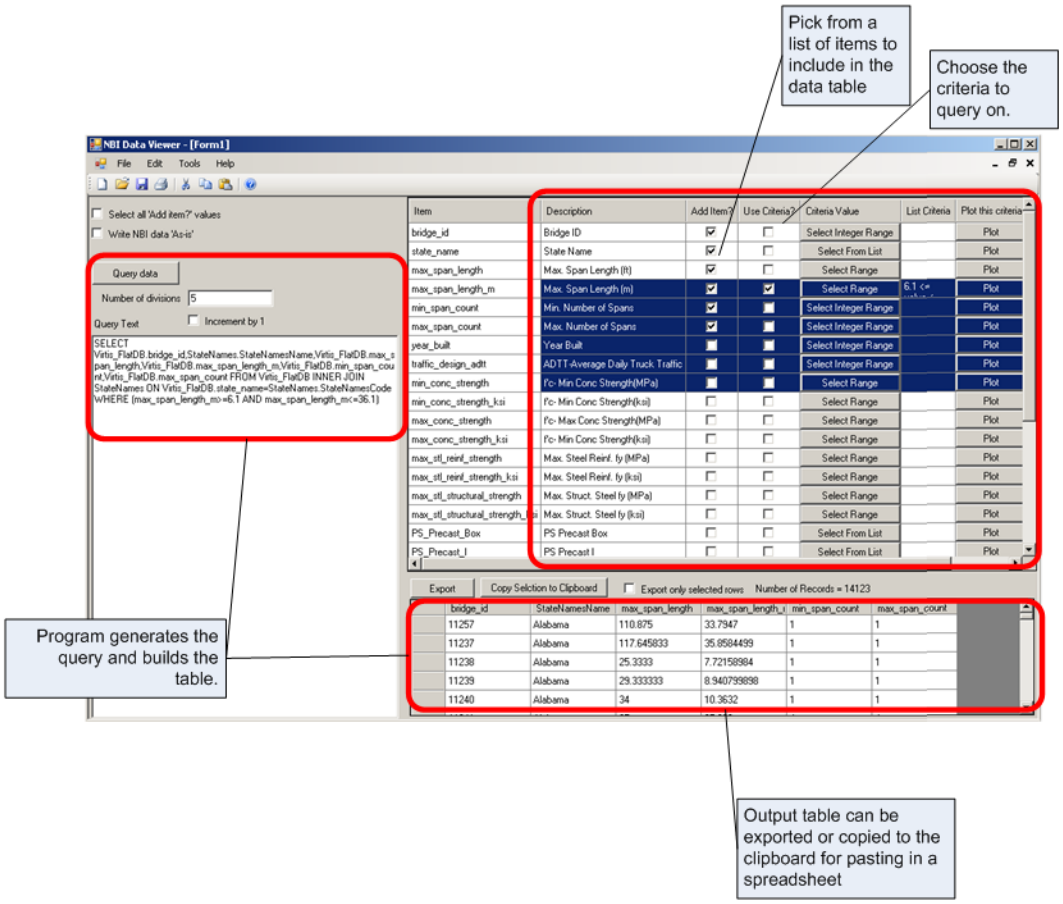


Figure Q-7 – Using the software with Virtis table

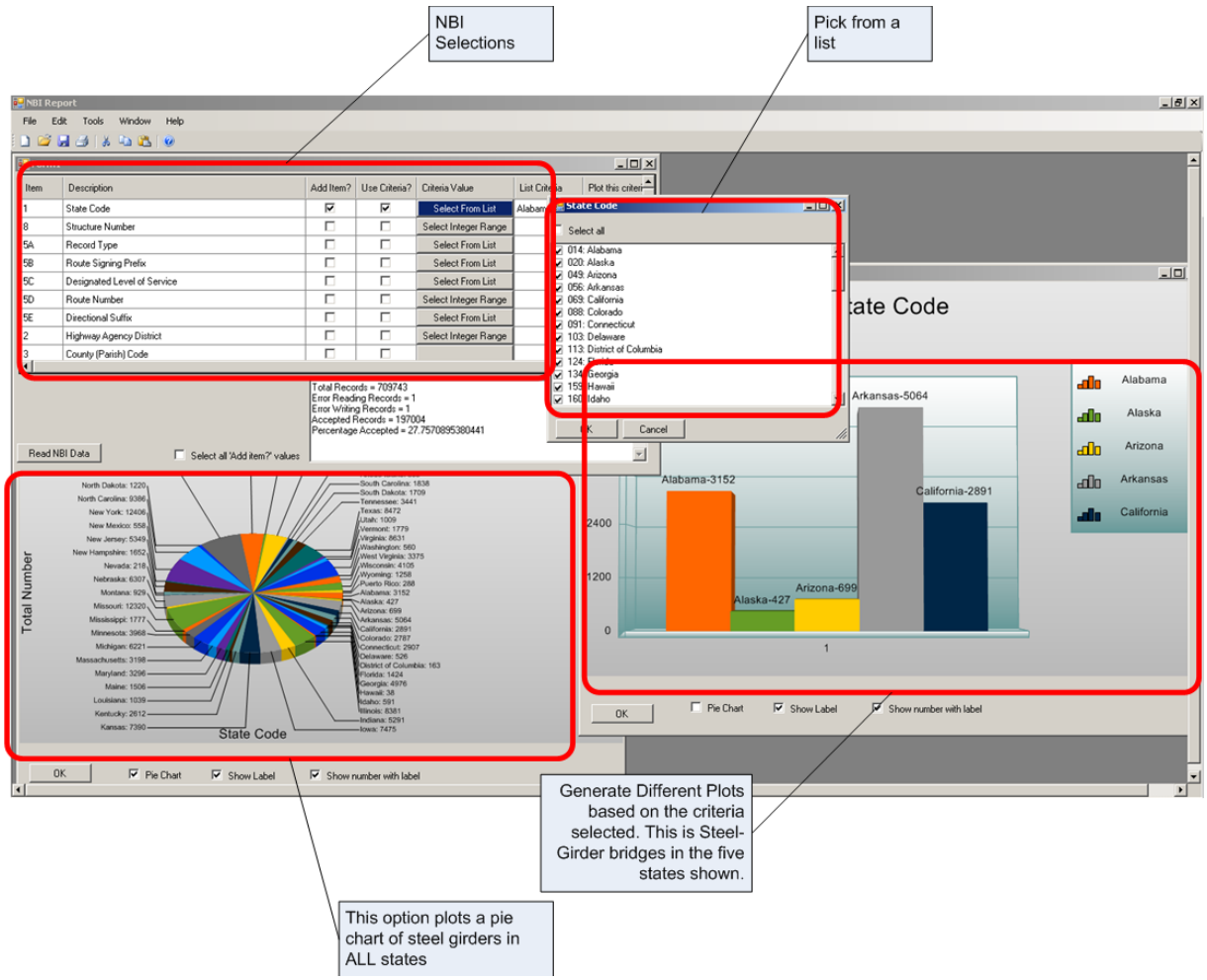


Figure Q-8 – Using the software with NBI data

The following table provides the format of the CSV output file produced by the Reliability Index Output Generator (RIO) software written for the NCHRP 12-78 project.

Column	Description	Report ID	Comments
1	Bridge ID		
2	Span # and Girder #	Subdomain ID	
3	Moment/Shear indicator.	Either: 1- Moment, 0- Shear	Based on this value, the subsequent data is defined in the "Moment" or "Shear" column
4	Inventory/Operating Indicator	Either: 1- Inventory, 0- Operating	
5	Vehicle Name		
6	Location (For LRFR)	Location along the girder	
7	Location (For LFR rating only)	Location along the girder	
8	Controlling Rating Factor - LRFR Inventory/Operating based on indicator		
9	Controlling Rating Factor - LFR - Inventory/Operating based on indicator		
10	Report ID for LRFR controlling rating		
11	Report ID for LFR controlling rating		
12	Rating Factor - LFR (Same location as LRFR) - Inventory/Operating based on indicator.		This value is the LFR rating provided at the same location as the LRFR location.
13	Maximum positive moment from the HL-93 Design Truck on a per girder basis LRFR	max(32000, 0.0)	
14	Minimum negative moment from the HL-93 Design Truck on a per girder basis LRFR	min(32001, 0.0)	
15	Maximum positive shear from the HL-93 Design Truck on a per girder basis LRFR	max(32002, 0.0)	
16	Minimum negative shear from the HL-93 Design Truck on a per girder basis LRFR	min(32003, 0.0)	
17	Maximum positive moment from the HL-93 Design Lane on a per girder basis LRFR	max(32012, 0.0)	

Column	Description	Report ID	Comments
18	Minimum negative moment from the HL-93 Design Lane. LRFR	min(32013, 0.0)	
19	Maximum positive shear from the HL-93 Design Lane on a per girder basis LRFR	max(32014, 0.0)	
20	Minimum negative shear from the HL-93 Design Lane. LRFR	min(32015, 0.0)	
21	Maximum positive moment from HL-93 Design Tandem. LRFR	max(32024,0.0)	
22	Minimum negative moment for the HL-93 Design Tandem. LRFR	min(32025, 0.0)	
23	Maximum positive shear from HL-93 Design Tandem. LRFR	max (32026,0.0)	
24	Minimum negative shear for the HL-93 Design Tandem. LRFR	min(32027,0.0)	
25	Minimum negative moment for the HL-93 truck train. LRFR	min(32055, 0.0)	
26	Minimum negative shear for the HL-93 truck train. LRFR	min(32057, 0.0)	
27	Minimum negative moment for the HL-93 dual tandem LRFR	min(32073, 0.0)	
28	Minimum negative shear for the HL-93 dual tandem LRFR	min(32075,0.0)	
29	Positive Moment due to Permit Load LRFR	max(32500,0)	
30	Negative Moment due to Permit Load LRFR	min(32501,0)	
31	Positive Shear due to Permit Load LRFR	max(32502,0)	
32	Negative Shear due to Permit Load LRFR	min(32503,0)	
33	Moment Distribution factor (controlling)	12384 + 3*(n-1), where n = girder number	This is the most important value to get.
34	Shear Distribution factor (controlling)	12385 + 3*(n-1), where n = girder number	
35	Moment Distribution factor (single lane)	12000-12359- Based on cross section, Girder #, Single Lane, Multi-Lane	
36	Moment Distribution Factor (multi-lane)	12000-12359- Based on cross section,Girder #, Single Lane, Multi-Lane	
37	Shear Distribution factor (single lane)	12000-12359 - Based on cross section,Girder #,	

Column	Description	Report ID	Comments
		Single Lane, Multi-Lane	
38	Shear Distribution factor (multi lane)	12000-12359 Based on cross section, Girder #, Single Lane, Multi-Lane	
39	Bias for # of Lanes Loaded, based upon critical number of lanes loaded and action being looked at (moment or shear), from NCHRP 20-07, Task 186	Using DF's for appropriate cross section for one and two + lanes loaded to determine live load bias	Comes from Andy. Leave blank.
40	COV for live load, based upon number of lanes loaded and action (moment or shear), from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
41	COV for Live + Impact, from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
42	Moment due to girder self-weight	30000	
43	Shear due to girder self-weight	30001	
44	Moment due to all DC1 loads	30036	
45	Shear due to all DC1 loads	30037	
46	Moment due to Superimposed DL #1	30024	
47	Shear due to Superimposed DL #1	30025	
48	Moment due to Superimposed DL #2 LRFR	30027	
49	Shear due to Superimposed DL #2 LRFR	30028	
50	Moment due to Superimposed DL #3 LRFR	30030	
51	Shear due to Superimposed DL #3 LRFR	30031	
52	Moment due to Prestressing LRFR	30033	
53	Shear due to Prestressing LRFR	30034	
54	Moment due to Superimposed DL #4 LRFR	30048	
55	Shear due to Superimposed DL #4 LRFR	30049	
56	Moment due to Superimposed DL #5 LRFR	30051	
57	Shear due to Superimposed DL #5 LRFR	30052	
58	Bias for DC1 loading, from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
59	COV for DC1 loading, from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
60	Moment DC2 loads no DW	30057	

Column	Description	Report ID	Comments
61	Shear DC2 loads no DW	30058	
62	Value due to the weight of slab		Not sure if we can currently get this.
63	Bias for DC2 loading, from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
64	COV for DC2 loading from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
65	Moment due to wearing surface (DW)	30060	
66	Shear due to wearing surface (DW)	30061	
67	Bias for DW loading, from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
68	COV for DW loading, from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
69	Factored flexural resistance (k-in) LRFR	40049-compact steel section 40052*min(20013, 20014 – non compact steel; 50029 – concrete	For Steel: Check 40037. If (40037 = 1.0) then Compact Else noncompact
70	Factored shear resistance (k) LRFR	40093 – steel; 50042 - concrete	
71	Bias of factored resistance, based upon material, composite action, section compactness, and action (value or shear), from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
72	COV of factored resistance, based upon same factors as the bias, from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
73	Load factors for DC loads		Leave blank
74	Load factors for DW loads		Leave blank
75	Load factors for LL loads		Leave blank
76	Bias for factored load, based upon material, composite action, section compactness, and action (value or shear), from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
77	COV for factored load, based upon material, composite action, section compactness, and action (value or shear), from NCHRP 20-07, Task 186		Comes from Andy. Leave blank.
78	**Composite**	5010	>0 Composite

Column	Description	Report ID	Comments
79	Compact Indicator	40037 – steel Blank – all others	
80	Single Lane/Multi Lane DF control	1-Single, 2-Multi, 0 – Unknown	
81	Controlling distribution factors for Reinforced Concrete Tees and Precast Double Tees w/ shear key		Vanessa to send example
82	Reinforced Concrete Tees and Precast Double Tees w/ shear keys. Single Lane/Multi Lane DF control	1-Single, 2-Multi, 0 – Unknown	Vanessa to send example
83	Skew angle (left Support)	5013	
84	Skew Angle (right Support)	5014	
85	Left Girder Spacing	5001	0 if left exterior girder
86	Right Girder Spacing	5002	0 if right exterior girder
87	Span Length	5011	
88	Previous Span Length	5017	<0 if no previous span
89	Next Span Length	5018	<0 if no next span
90	Effective Span Length	5012	
91	Cross Section (Bridge Type)	5021	Integer Code: 24106-Rolled Beam: 24107-Plate Girder: 24108-Built-Up: 24119-Rolled Beam: 24112-PS Box Beam: 24111-PS I-Beam: 24120-PS U-beam: 24121-PS T-Beam: 24115-RC I-beam: 24116-RC Slab: 24117-RC T-beam: 24118-Timber beam
92	Simple or Continuous	5023	1-Simpe, 2-Continous, 0-Unkown
93	Left overhang	5015	0 - if interior girder or right exterior girder

Column	Description	Report ID	Comments
94	Right overhang	5016	0 - if interior girder or left exterior girder
95	Design ADTT	5004	
96	Recent ADTT	5003	
97	Future Wearing Surface Thickness	5007	
98	Slab thickness	5008	
99	Beam depth	20033 - noncomp steel; 20034 - composite steel; 25033 - noncomp concrete; 25034 - composite concrete	
100	Number of Lanes	5006	
101	Year of Construction	5020	
102	# of Girders in Cross-Section	5022	
103	Maximum positive moment from Truck #1 on a per girder basis LFR	max(37001, 0.0)	
104	Minimum negative moment from Truck #1 on a per girder basis LFR	min(37002, 0.0)	
105	Maximum positive shear from Truck #1 on a per girder basis LFR	max(37003, 0.0)	
106	Minimum negative shear from Truck #1 on a per girder basis LFR	min(37004, 0.0)	
107	Maximum positive moment from Truck #2 on a per girder basis LFR	max(37011, 0.0)	
108	Minimum negative moment from Truck #2 on a per girder basis LFR	min(37012, 0.0)	
109	Maximum positive shear from Truck #2 on a per girder basis LFR	max(37013, 0.0)	
110	Minimum negative shear from Truck #2 on a per girder basis LFR	min(37014, 0.0)	
111	Moment due to girder self-weight LFR	35001	
112	Shear due to girder self-weight LFR	35002	
113	Moment due to all DC1 loads LFR	35043	
114	Shear due to all DC1 loads LFR	35044	
115	Moment due to Superimposed uniform dead load Stage 1 LFR	35008	Deck
116	Shear due to superimposed uniform dead load Stage 1 LFR	35009	Deck
117	Moment due to Superimposed DL #1 Stage 1 LFR	35015	

Column	Description	Report ID	Comments
118	Shear due to Superimposed DL#1 Stage 1 LFR	35016	
119	Moment due to Superimposed DL #2 Stage 1 LFR	35022	
120	Shear due to Superimposed DL #2 Stage 1 LFR	35023	
121	Moment due to Superimposed DL #3 Stage 1 LFR	35029	
122	Shear due to Superimposed DL #3 Stage 1 LFR	35030	
123	Moment due to Superimposed DL #4 Stage 1 LFR	35036	Prestress
124	Shear due to Superimposed DL #4 Stage 1 LFR	35037	Prestress
125	Moment due to Superimposed uniform dead load Stage 2 LFR	35055	DW + appurtenances
126	Shear due to superimposed uniform dead load Stage 2 LFR	35056	DW + appurtenances
127	Moment due to Superimposed DL #1 Stage 2 LFR	35062	
128	Shear due to Superimposed DL#1 Stage 2 LFR	35063	
129	Moment due to Superimposed DL #2 Stage 2 LFR	35069	
130	Shear due to Superimposed DL #2 Stage 2 LFR	35070	
131	Moment due to Superimposed DL #3 Stage 2 LFR	35076	
132	Shear due to Superimposed DL #3 Stage 2 LFR	35077	
133	Moment due to Superimposed DL #4 Stage 2 LFR	35083	Prestress
134	Shear due to Superimposed DL #4 Stage 2 LFR	35084	Prestress
135	Factored flexural resistance (k-ft) LFR	40049-compact steel section 40052*min(20013, 20014 – non compact steel; 50029 – concrete	For Steel: Check 40037. If (40037 = 1.0) then Compact Else noncompact
136	Factored shear resistance (k) LFR	40093 – steel; 50042 - concrete	
137	Moment due to all DC2 loads (k-ft) LFR	35090	
138	Shear due to all DC2 loads (k) LFR	35091	
139	LRFR-LFR Difference Indicator		

Column	Description	Report ID	Comments
140	Original LFR Location (negative if same as LRFR)		
141	Original LFR Rating (negative if same as LRFR)		
142	Original LFR Controlling Report ID (negative if same as LRFR)		
143	Distribution factor (Lever rule)	12360-12371	
144	Distribution factor (Rigid Method)	12372-12383	