LOAD RATING BY LOAD AND RESISTANCE FACTOR EVALUATION METHOD

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Highway Subcommittee on Bridge and Structures

Prepared by:

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NCHRP Project 20-07/Task 122
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FINAL REPORT

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BACKGROUND

The Draft *Manual for the Condition Evaluation and Load and Resistance Factor Rating of Highway Bridges* was developed under NCHRP Project 12-46. The Manual, and in particular the section on load rating have been extensively reviewed by Technical Committee T-18, Bridge Management Evaluation and Rehabilitation. As a result of this review, several changes were made to Section 6, Load and Resistance Factor Rating. The revised version was adopted as a Guide Manual at the May 2002 Meeting of the AASHTO Subcommittee on Bridges and Structures (SCOBS).

The load and resistance factor rating (LRFR) methodology of the Manual is based upon calibrated load factors using the principals of structural reliability. Further, the LRFR procedures were subjected to trial analyses as part of the development. Nonetheless, there exists a need to further demonstrate that the method gives valid, consistent results for all major bridge types and span ranges, and to document and explain differences between LRFR and current load factor ratings (LFR) results. Improved validation and comparisons are necessary for LRFR to be accepted by state DOT's before they will be willing to accept LRFR for bridge sufficiency evaluation, load posting and overload permit approval analysis.

OBJECTIVE

The objective of this project is to provide explicit comparisons between the ratings produced by the LRFR methods of the Guide Manual and LFR ratings from the latest edition of the AASHTO *Manual for Condition Evaluation of Bridges*. The comparisons are based upon flexural-strength ratings. For girder-type bridges, the rating comparisons further concentrate on the interior girder.

COMPUTER SOFTWARE

The AASHTO Bridgeware Task Force kindly provided a limited license for Virtis/Opis version 5.1 and the Wyoming Department of Transportation provided limited licenses for BRASS-GIRDER™ (version 5, release 08, level 6) and BRASS-GIRDER(LRFD) ™ (version 1, release 5, level 4, beta version). These programs were used as the basis for the ratings identified in this report.

EXAMPLE-BRIDGE DATABASE

Assemblage of Example-Bridge Data

An example-bridge data matrix of 145 example bridges was developed by the project panel to provide an appropriate cross section of bridge types to be utilized in the rating comparison. The data matrix was to be extracted from a subset of those bridges already coded into the Virtis database. Any omissions were requested from other State DOT's that were compiling Virtis data for their bridge inventory. NYSDOT had an extensive number of bridge systems coded into the Virtis database, and 97 of the possible 145 example bridges were available. WYDOT identified 20 candidate bridges coded as girder lines in BRASS-GIRDER™.

Assemblage of Example-Bridge Rating Database

NYSDOT Data Files

The example-bridge data provided by the NYSDOT was delivered in Virtis/Opis format. The data was converted to BRASS-GIRDER™ input data by running the data file in Virtis. Subsequently, the generated input data files are run in BRASS-GIRDER™ to generate LFR ratings. The data was also converted to BRASS-GIRDER(LRFD)™ input data by running it in Opis. The researcher could only 51 out of 97 files to run in Opis. Additional input-data entries are made in some cases to convert the BRASS-GIRDER™ input data into BRASS-GIRDER(LRFD)™ input data. These modified input data files are subsequently run in BRASS-GIRDER(LRFD)™ to generate LRFR ratings.

After the panel meeting of September 2004, the NYSDOT delivered BRASS-GIRDER files for five simple-span reinforced-concrete slab bridges.

WYDOT Data Files

The example-bridge data provided by the WYDOT was delivered in the form of BRASS-GIRDER™ and BRASS-GIRDER(LRFD)™ input and output files. The LFR ratings are obtained directly from the BRASS-GIRDER™ output files. Unfortunately, the BRASS-GIRDER(LRFD)™ output files were generated for an incomplete set of live loads (with the special HL-93 negative–moment load condition of AASHTO LRFD Article 3.6.1.3.1 missing) and the program had to be rerun with the modified live-load input commands to generate the LRFR ratings. Two of the WYDOT bridges had questionable results (despite being generated with seemingly correct input data), and were not included in the example bridge database used for this study.

As a result of the panel meeting of September 2004, WYDOT reviewed several data sets that produced an LRFR design-load inventory load divided by the LFR design-load inventory rating of less than 0.7 (suggesting low LRFR ratings relative to LFR). WYDOT found that the process they were using to develop the LRFR data sets resulted in the calculation of a composite-girder moment capacity based upon a non-composite girder section. WYDOT modified the data sets to obtain corrected moment capacity of the composite girder and reran BRASS-GIRDER(LRFD)™ to generate the LRFR ratings.

Resultant Example-Bridge Database

The bridge type and source of the resultant example-bridge database are tabulated in Table 1 below.

TABLE 1 - EXAMPLE-BRIDGE DATABASE BY TYPE AND SOURCE

Bridge Type	**Data Source**	**Number**	
prestressed-concrete box	NY	10	10
	WY	0	
prestressed-concrete I-girder	NY	3	7
	WY	4	
prestressed-concrete slab superstructure	NY	3	3
	WY	0	
reinforced-concrete slab superstructure	NY	5	10
	WY	5	
steel plate girder	NY	21	25
	WY	4	
steel rolled beam	NY	14	19
	WY	5	
Total Number of Example Bridges			74

The example-bridge database is tabulated in more detail in Table 2 below. Unrepresented bridge types are longer-span (greater than 115-foot spans) prestressed-concrete I-girders.

TABLE 2 - EXAMPLE-BRIDGE DATABASE

Bridge Type	**Continuity**	**Span Length (Ft)**	**Number of Bridges**	
reinforced-concrete slab superstructure	simple	25±10	4	5
		50±10	1	
	continuous	25±10	4	5
		50±10	1	
steel multi-girder	simple	25±10	5	26
		50±10	6	
		75±10	4	
		100±10	3	
		125±10	2	
		150±10	3	
		175±10	2	
		200±10	1	
	continuous	25±10	2	18
		50±10	1	
		75±10	2	
		100±10	0	
		125±10	4	
		150±10	3	
		175±10	3	
		200±10	3	
prestressed-concrete I-girder	simple	50±10	2	7
		75±10	2	
		100±10	3	
		125±10	0	
		150±10	0	
prestressed-concrete slabs/boxes	simple	50±10	4	13
		75±10	5	
		100±10	4	
Total Number of Example Bridges				74

SUMMARY OF RESULTS

Design-Load Ratings

Rating Factors

The statistics of the ratios of the LRFR rating factor divided by the LFR rating factor for the respective design loads at inventory and operating levels are compared in Table 3. A mean value greater than one indicates that the LRFR rating factor is greater than the LFR rating factor. The statistics are first given for all of the example bridges and divided by bridge type. The basic rating factors are given in the appendix in Table A1.

Globally, the sampling of example bridges suggests that in general the design-load inventory rating factors by LRFR are greater than the corresponding inventory rating factors by LFR, while the design-load operating rating factors are less. Only in the case of reinforced concrete slabs are the LRFR factors less than the LFR factors for both the inventory and operating ratings.

One must remember that the design-load levels are different for LRFR and LFR. The design-load level for LFR is HS20 weighing 36 tons. The HL-93 design load for LRFR is a notional load (In other words, it does not "look" like a simple truck with a specified tonnage.). It may be recalled however that in the original development of the HL-93 load model, a truck-type live-load model, the HTL57 was proposed which produced similar moments and shears. The HTL57 was longer than a traditional HS20 but weighed 57 tons. There is no simple relationship to relate the LRFR design-load rating factor to the LRFR design-load rating in equivalent tons, but a simple approximation would be to multiply by the 57 tons of the HTL57 (This approximation is more appropriate for longer spans where the configuration of the truck is less significant than the weight.). Thus, an LRFR design-load rating factor of 36/57 or 0.63 could be simplistically considered equivalent to an LFR rating factor of 1.00 for a longer bridge. A better comparison of ratings would be to compare an equivalent HL-93 rating in tons to the HS20 rating in tons.

TABLE 3 - DESIGN-LOAD RATING FACTOR COMPARISON

Type	**LRFR Rating Factor / LFR Rating Factor**			
	Inventory		**Operating**	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
all	1.07	0.31	0.84	0.25
p/s-concrete box	1.11	0.16	0.86	0.13
p/s-concrete girder	0.97	0.11	0.75	0.09
p/s-concrete slab	1.31	0.40	1.01	0.31
r/c slab	0.80	0.29	0.62	0.22
steel plate girder	1.19	0.21	0.93	0.16
steel rolled beam	1.05	0.42	0.80	0.36

Rating-Factor Ratios

Some owners are concerned about maintaining a certain interval between inventory and operating rating levels in order to adequately operate their system in terms of issuing permits. (This has been pointed out to the researcher by the Florida Department of Transportation in particular.) To better understand the interval between inventory and operating, the ratios of the operating rating factor divided by inventory rating factor for the design-load is tabulated in Table A1 of the appendix. The statistics of the ratios are given in Table 4.

TABLE 4 - DESIGN-LOAD RATING-FACTOR RATIO COMPARISON

Type	Operating Rating Factor / Inventory Rating Factor			
	LFR		LRFR	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
all	1.68	0.038	1.31	0.059
p/s-concrete box	1.67	0.005	1.30	0.002
p/s-concrete girders	1.68	0.002	1.30	0.002
p/s-concrete slab	1.67	0.001	1.30	0.001
r/c slab	1.67	0.005	1.29	0.005
steel plate girder	1.68	0.018	1.31	0.086
steel rolled beam	1.69	0.073	1.31	0.063

The ratios are consistently lower for LRFR than the traditional ratios for LFR. The LRFR procedure produces a lower bound of about 1.30 for this ratio (the LRFR inventory live-load load factor of 1.75 divided by the LRFR operating live-load load factor of 1.35), while the traditional lower bound for LFR is about 1.67 (the traditional inventory live-load load factor of 2.17 divided by the traditional live-load load factor of 1.3).

Span-Length Effect

Other than the obviously dependency of the design-load rating factor ratios on bridge type shown in Table 3, the only other dependency discovered was that of span length. Figure 1 shows a plot of design-load inventory rating ratios versus span length (the largest span length for continuous bridges).

If we assume, for the moment, that the LRFR ratings are correct, then values of the ratio much different than 1.0, either greater or lesser, demonstrate where the LFR procedures produce inappropriate ratings (If the ratio is much greater than 1.0, the LFR rating is too low. If the ratio is much less than 1.0, the LFR rating is too high.). In figure 1, the design-load inventory ratios seem mildly a function of span length with the ratios below 100 feet showing more deviation from 1.0 with the most deviation below 50-foot span lengths. This is not surprising as such a dependency, but stronger, was demonstrated for the *LRFD Bridge Design Specifications*.

The ratios of LRFR ratings divided by LFR ratings demonstrated no other functionalities. This is not surprising again as the LFR rating procedures are not calibrated. As demonstrated in the LRFD development, comparisons of a calibrated code versus and uncalibratred code result in scatter, not trends.

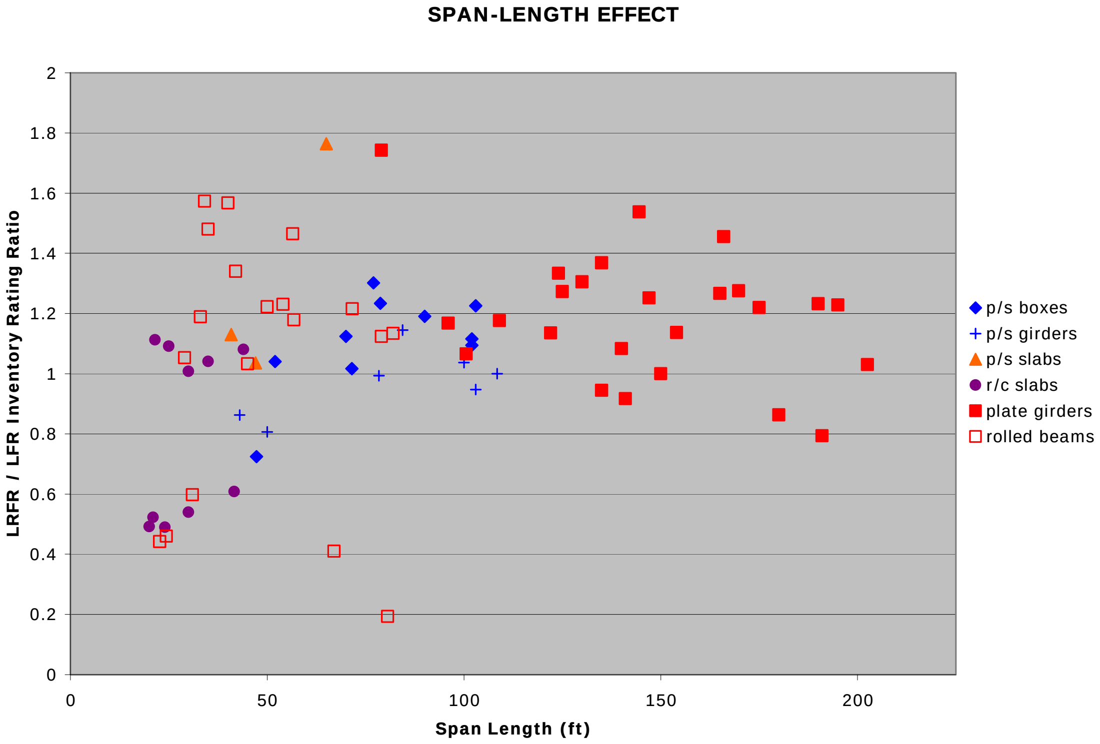

Figure 1 – The Effect of Span Length on Design-Load Inventory Rating Ratios

LEGAL-LOAD AND PERMIT-TRUCK RATINGS

The operating ratings for the legal loads and our project-specific permit truck are given in Table A2 and A3 of the appendix. The statistics of the ratios of the LRFR rating divided by the LFR rating are tabulated in Table 5 by bridge type. The permit-truck axle weights and configuration are shown in Figure 2.

The LRFR-specified live-load factors for legal loads are a function of the average daily truck traffic (ADTT) and the LRFR-specified live-load factors for permit loads are a function of permit type, frequency, ADTT and permit weight. This functionality was not investigated in this study as the default live-load factors of the BRASS™ programs (1.3 for LFR and 1.35 for LRFR) were used. In most cases, the load factors of the Guide Manual (see Tables 6-5 and 6-6 of the Guide Manual) are greater than 1.35, thus the ratings could be lower than those reported herein. In the case of routine or annual permits and single-trip escorted special or limited crossings with no other vehicles on the bridge, the load factors are less than 1.35 and the rating could be higher.

TABLE 5 - OPERATING RATING COMPARISON

Type	**LRFR Rating / LFR Rating**							
	Legal Loads						**Permit Truck**	
	Type 3		**Type 3S2**		**Type 3-3**			
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
all	1.17	0.37	1.18	0.37	1.18	0.37	1.14	0.35
p/s-concrete box	1.14	0.20	1.14	0.20	1.14	0.19	1.14	0.20
p/s-concrete girders	0.99	0.16	1.03	0.17	1.03	0.17	0.96	0.21
p/s-concrete slab	1.27	0.42	1.27	0.41	1.27	0.41	1.27	0.42
r/c slab	0.83	0.28	0.87	0.33	0.85	0.30	0.83	0.28
steel plate girder	1.42	0.24	1.42	0.26	1.43	0.27	1.36	0.24
steel rolled beam	1.10	0.46	1.10	0.46	1.09	0.46	1.07	0.43

In the case of the legal loads and the permit loads, since these are all real loads, not notional loads, the ratings in tons can in all cases be determined by directly multiplying the rating factor given in Tables A2 and A3 by the weight of the vehicle.

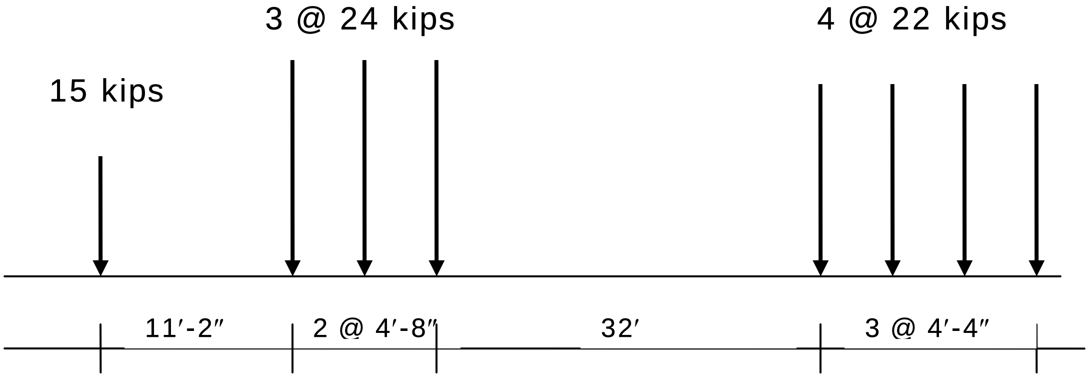

FIGURE 2 - 175-KIP 8-AXLE PERMIT VEHICLE
(an actual permit vehicle analyzed for a single trip in New York State)

A comparison of the tabulated ratios suggests that in general the LRFR ratings are equal to or a bit greater than the corresponding LFR ratings for the legal and permit loads. Only the reinforced-concrete slab bridges rated lower for legal and permit loads in LRFR compared with LFR at approximately 85% of LFR. This observation is consistent with the inventory and operating ratings of reinforced-concrete slabs shown earlier also.

RELIABILITY ANALYSES

The reliability of the example bridges was established through Monte Carlo simulation. The application of Monte Carlo simulation employed for this study compares two distributions of values; in this case, load and resistance; and determines a random value of resistance minus load for a given design criteria, in this case the Strength I limit state for flexure. The resultant value is independent of the design methodology employed in the design of the bridge as a probable resistance is compared to a probable load with no regard to the design methodology.

The design methodology enters the simulation through the bias factors and nominal values of load and resistance used to construct the distributions. The distributions are then constructed from the statistics of the load and resistance. The statistics used as input data for this study are the bias factors, the coefficients of variation and the nominal values of load and resistance. These statistics used in this study are summarized in Table 6.

TABLE 6 – STATISTICS

Parameter	**Assumed Distribution**	**Bias Factor, λ, associated with LRFD**	**Coefficient of Variation, V**
D, dead load	normal	1.05	0.10
L, live load plus impact		1.30	0.18
R, composite-steel flexural resistance	lognormal	1.12	0.10
R, reinforced-concrete flexural resistance		1.12	0.13
R, prestressed-concrete flexural resistance		1.05	0.075

Note: The mean value of a parameter, μ, is equal to the nominal value times the bias factor. The standard deviation, σ, is equal to the coefficient of variation, V, times the mean value.

The nominal values are not given in the table as they are unique and vary for each simulation. For each individual simulation, the mean values of load and resistance are determined by multiplying the unique nominal values by the common bias factors of Table 6. Thus, the design method-independent distributions are defined utilizing the unique nominal values and the common bias factors associated with a specific design method, in this case the LRFD methodology. Theoretically, identical distributions of load and resistance would result using the unique nominal values and the common bias factors associated with the SLD or LFD methodology.

The practicing engineer has little experiential “feel” for the concept of reliability indices. The first question asked of a researcher discussing various reliability indices is what the corresponding failure rates are. In a Monte Carlo simulation, the failure rates are determined initially with the reliability indices to follow.

The researcher believes that while reliability indices are valuable to code writers in specification calibration as comparative values, they become cumbersome in a presentation such as this. Thus, an attempt is made to concentrate on the failure rates from the reliability analyses.

The reliability of the sample bridges for the HL-93 design-load inventory rating was determined through Monte Carlo simulation using MS Excel® following a 10-step computational procedure (adapted from Nowak) as follows:

1. determine the nominal dead load, D_n, the nominal live load plus impact, L_n, and the nominal resistance, R_n, for the subject bridge according to the *LRFD Bridge Design Specifications*.
2. assume i=1.
3. generate a uniformly distributed random number $0 \leq u_{Di} \leq 1$ using the command RAND.
4. calculate the corresponding value of D_i (a normal random variable)
   $D_i = \mu_D + \sigma_D \Phi^{-1}(u_{Di})$
   where Φ^{-1} = the inverse standard normal distribution function calculated using the command NORMSINV
   $\mu_D = \lambda_D D_n$
   $\sigma_D = V_D \mu_D$.
5. generate a uniformly distributed random number $0 \leq u_{Li} \leq 1$ using the command RAND.
6. calculate the corresponding value of L_i (a normal random variable)
   $L_i = \mu_L + \sigma_L \Phi^{-1}(u_{Li})$
   where Φ^{-1} = the inverse standard normal distribution function calculated using the command NORMSINV
   $\mu_L = \lambda_L L_n$
   $\sigma_L = V_L \mu_L$.
7. generate a uniformly distributed random number $0 \leq u_{Ri} \leq 1$ using the command RAND.
8. calculate the corresponding value of R_i (a lognormal random variable)
   $R_i = \exp(\mu_{\ln R} + \sigma_{\ln R} \Phi^{-1}(u_{Ri}))$
   where Φ^{-1} = the inverse standard normal distribution function calculated using the command NORMSINV
   $\mu_{\ln R} = \ln(\mu_R) - \frac{1}{2} \sigma_{\ln R}^2$
   $\sigma_{\ln R} = (\ln(V_R^2+1))^{1/2}$.
9. calculate the limit state function, $Y_i = R_i - (D_i + L_i)$, and save the value.
10. assume i=i+1, go back to step 3 and iterate until the desired number of simulations, N, is obtained.

For each sample bridge, 1,000,000 Monte Carlo simulations are made. For a number much greater than 1,000,000, the computational effort becomes onerous. When the Y_i value of step 9 is negative, the simulation has resulted in a "failure" of the limit state. (not necessarily a structural failure, but a failure to satisfy the design or rating criteria). For relatively safe bridges ($\beta > 4$), a significant number of failures (greater than 10) will not occur in 1,000,000 simulations. In these cases, the traditional reliability approach is to extrapolate a reliability index. The researcher is weary of the accuracy of such extrapolations and has avoided them.

Twenty six of the bridges in the 74 bridge database demonstrated a failure rate of more than 10 failures out of 1,000,000 simulations. The design-criteria failure rate and corresponding LRFD and LFR design-load inventory rating factors are tabulated in Table 7 for these 26 bridges. For completeness, the reliability index, β, is also given for each of the bridges. The other 48 bridges yield no significant number of failures of the design criteria in 1,000,000 simulations. These bridges were not investigated further. With rating factors in excess of about 1.5, the assumptions inherent in the design and rating procedures become suspect, in the mind of the researcher. It is suffice to say such bridges are safe enough (with LFR or LRFR). Bridges with ratings near the design point are more telling.

TABLE 7 - RELIABILITY-ANALYSIS RESULTS

bridge	year built	design load	design method	maximum span length (ft)	continuous?	girder spacing (ft)	failure rate	β	design-load inventory rating factor	
									LRFR	LFR
prestressed-concrete boxes										
1040180	1986	HS20	LFD	102	no	4.04	1.96E-05	4.1	1.54	1.38
prestressed-concrete girders										
boc	1960	HS20	SLD	50	no	5.25	0.00015	3.6	1.25	1.55
reinforced-concrete slabs										
1094200	1924	H15	SLD	20	no	na	0.2242	0.8	0.62	1.26
1009360	1955	?	SLD	21	no	na	0.1302	1.1	0.69	1.32
acr	1954	H20	SLD	21.5	yes	na	0.0714	1.5	0.79	0.71
1051360	1932	H15	SLD	24	no	na	0.0677	1.5	0.74	1.51
aab	1963	H20	SLD	25	yes	na	0.0015	3.0	1.07	0.98
1030240	1953	?	SLD	30	no	na	0.1182	1.2	0.68	1.26
adk	1958	H20	SLD	30	yes	na	0.0001	3.7	1.26	1.25
aag	1964	H20	SLD	35	yes	na	0.0037	2.7	1.01	0.97
1016780	1945	H20	SLD	41.6	no	na	0.1288	1.1	0.59	0.97
steel plate girders										
1090880	1970	HS20	SLD	125	yes	8.75	0.0001	3.7	1.26	0.99
1075610	1967	HS20	SLD	135	yes	9.77	8.26E-06	4.3	1.56	1.14
4443852	1981	HS20	SLD	135	yes	9.38	0.0053	2.6	1.02	1.08
dda	1977	HS20	SLD	175	yes	8.25	0.0011	3.1	1.11	0.91
dew	1981	HS20	LFD	191	yes	9.33	1.57E-04	3.6	1.35	1.70
steel rolled beams										
2255970	1977	HS20	SLD	22.7	no	2.0	0.0889	1.3	0.84	1.90
2214710	1972	?	SLD	24.4	no	2.0	0.0293	1.9	0.93	2.02
1026980	1941	H20	SLD	31	no	7.21	0.0076	2.4	0.98	1.64
1045470	1931	H20	SLD	33	no	4.5	0.1164	1.2	0.69	0.58
bny	1948	H15	SLD	45	no	7.08	0.0180	2.1	0.93	0.90
1090900	1946	H20	SLD	56.8	no	7.75	0.0012	3.0	1.12	0.95
2213960	1979	H20	SLD	67	no	2.0	0.4618	0.1	0.64	1.56
1066580	1961	HS20	SLD	71.63	yes	7.5	0.0003	3.4	1.24	1.02
2216820	1996	HS25	LFD	80.6	no	2.0	0.1976	0.9	0.74	3.82
aus	1967	HS20	SLD	82	yes	8.53	0.0012	3.0	1.1	0.97

Note: The unknown design loads indicated as "?", are most likely HS20 based upon the year built.

Figure 3 shows a plot of the design-criteria failure rate versus the LRFR and LFR design-load inventory ratings for the 26 bridges investigated. As the rating factor gets greater, the failure rate should approach zero. This figure demonstrates that the LRFR inventory ratings, shown as blue diamonds, are appropriate with smaller rating factors yielding greater failure rates. A least-squares fit line of the LRFR data is shown as a dot-dashed line. The LFR design-load inventory ratings also shown in the figure as red squares demonstrate little or no correlation between the LFR rating factor and the failure rate suggesting that the LFR ratings are not appropriate. Any value plotted to the right of the vertical line representing a rating factor of one should fall very near the bottom of the plot area with a very low probability of failure. Such is the case for LRFR values (blue diamonds) with rating factors above one. It is not true for LFR values (red squares) with rating factors above one, where significant failure rates are observed. In other words, the LFR rating factors do not predict safety adequately. Significant failure rates are observed for bridges with LFR rating factors above one. The corresponding LRFR rating factors are below one. The rapid fall in reliability (rapid increase in failure rate) for values of LRFR design-load inventory-rating factors below about 0.75 should be noted.

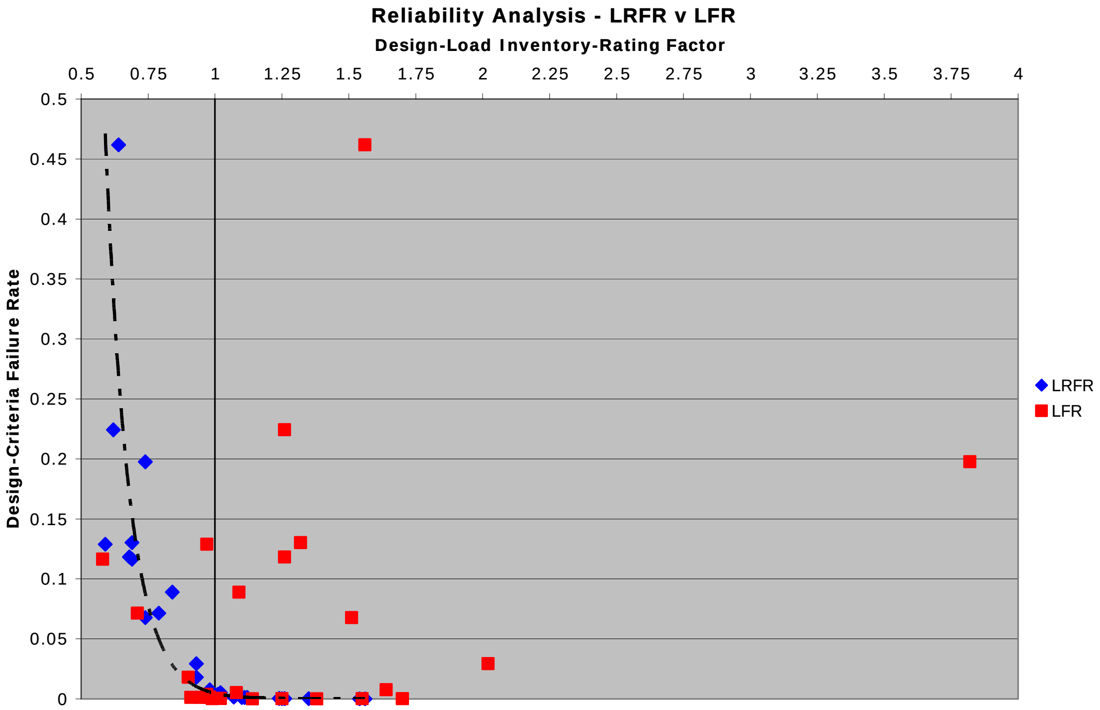

Figure 3 – Design-Criteria Failure Rate versus Design-Load Inventory Rating Factor

The LRFR design-load inventory ratings are examined further in Figure 4 where the values are plotted by bridge type. The example bridges with high failure rates and correspondingly low rating factors are all reinforced concrete slab bridges or rolled steel beam bridges, all relatively short-span bridges (The span lengths are tabulated in Table 7.).

Figure 5 illustrates a comparison between simple and continuous spans for reinforced-concrete slab bridges. As shown in Table 7, the only significant comparison between simple and continuous spans can be made within the reinforced-concrete slab bridge types. Too few examples of one or the other type of continuity exist within the other bridge types. In Figure 5, it is seen that the continuous slabs, indicated as red diamonds and green circles for LRFR and LFR ratings respectively, show relatively good correlation, while the simple slabs, indicated as blues squares and yellow triangles for LRFR and LFR, respectively, show poor correlation. In other words, the LRFR ratings for simple slabs are much lower than the LFR ratings, with 4 of the 5 bridges deemed unreliable by LRFR where LFR suggests otherwise. It should be noted that all the data for the simple slabs comes from the WYDOT, while the continuous-slab data come from NYSDOT.

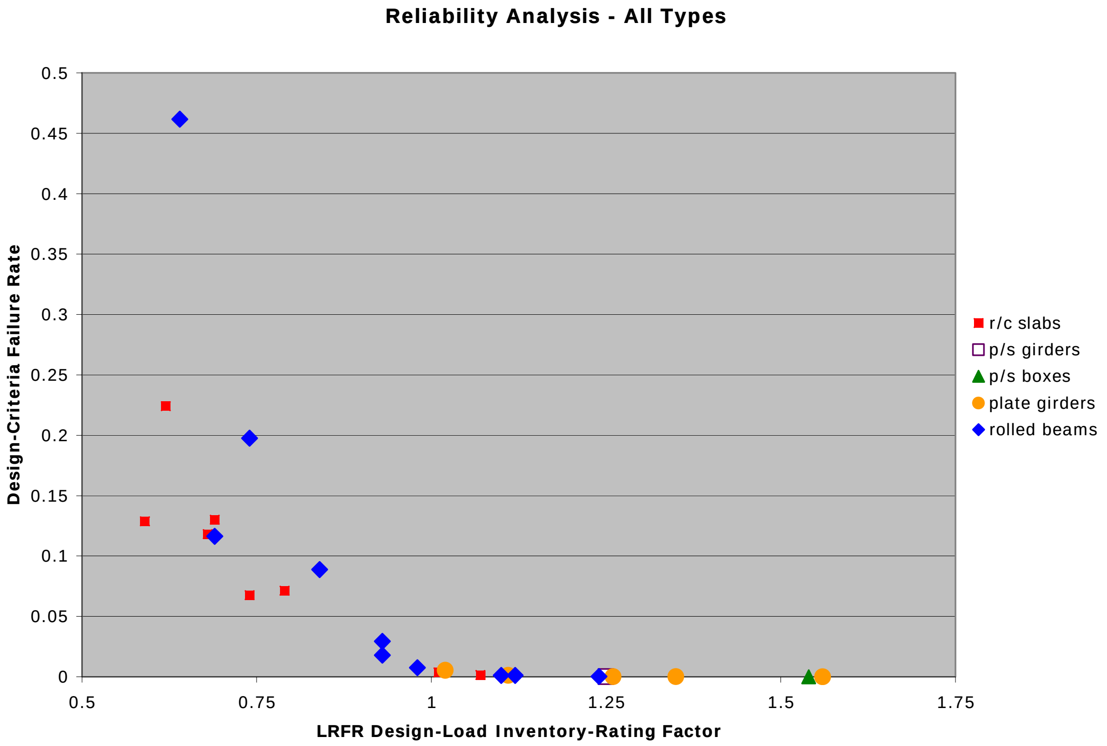

Figure 4 – LRFR Failure Rate versus LRFR Inventory Rating by Bridge Type

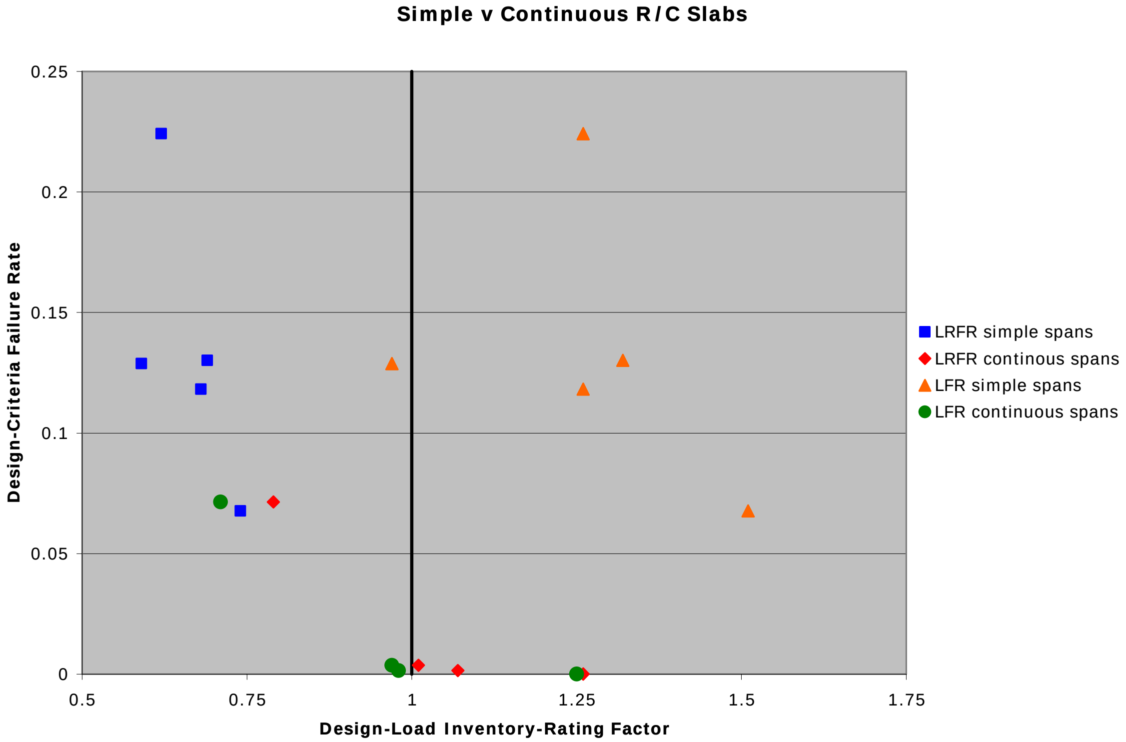

Figure 5 – Simple versus Continuous Reinforced Concrete Slab Bridges

The effects of stringer spacing is studied in Figure 6 by plotting the LRFR and LFR design-load inventory-rating factors versus stringer spacing for the stringer-bridge types. Little correlation is evident except that the steel rolled beam bridges with two-foot stringer spacing exhibit much lower LFR rating factors than LRFR rating factors. This is not unexpected. It has previously been shown that the traditional "s-over" distribution factors of the *Standard Specifications* are unconservative at lower spacings in comparison with the Imbsen factors in the *LFRD Specificaitons*, despite that fact that the Imbsen factors were not intended for such small spacings.

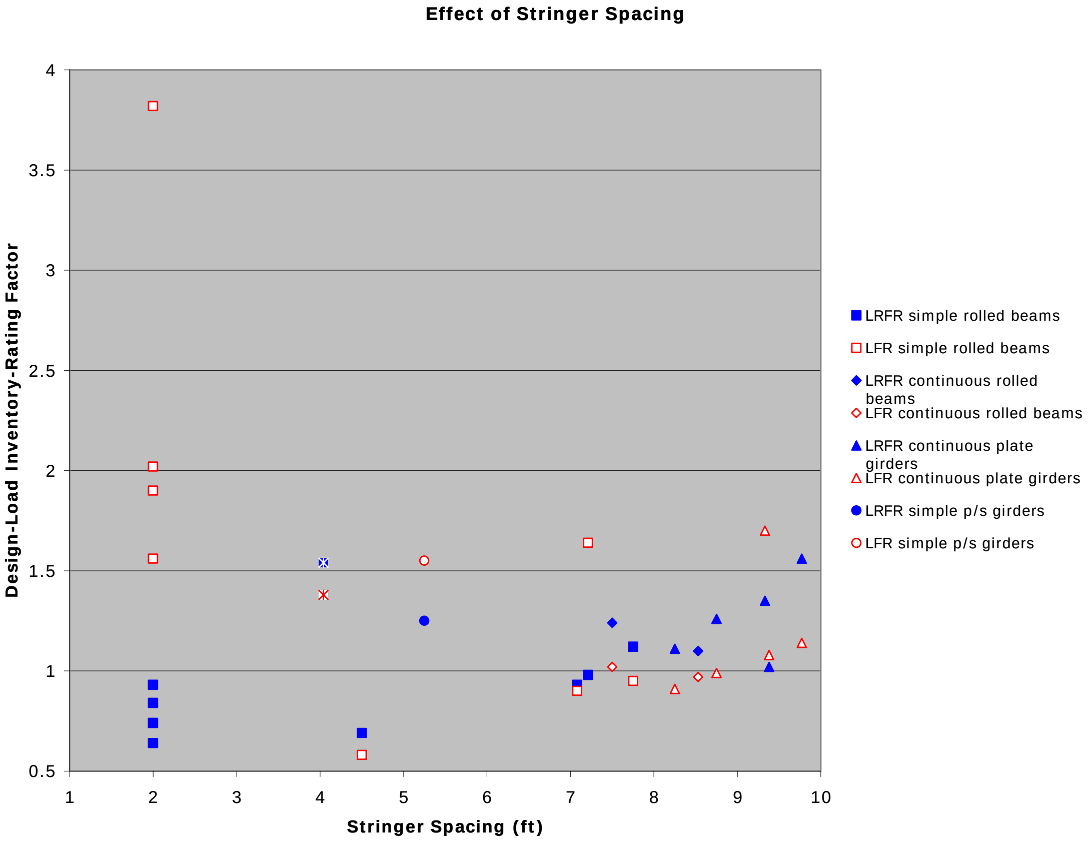

Figure 6 – Stringer-Spacing Effects

For completeness, a plot comparing the reliability index, β, versus the design-load inventory-rating factors for both LRFR and LFR is given in Figure 7. In the figure, LRFR is represented by blue diamonds, while LFR is represented by red squares. Again, little correlation is demonstrated by the LFR ratings while a strong, more linear correlation is demonstrated by the LRFR ratings. Figure 3 is more revealing as the rapid drop in reliability with rating factor is not evident in Figure 7, validating the primary use of failure rate over reliability index.

Figure 7 suggests that the target reliability index of 3.5 is not achieved. The intersection of the line representing a rating factor of one and the blue diamonds representing the LRFR ratings seems to fall closer to 2.5.

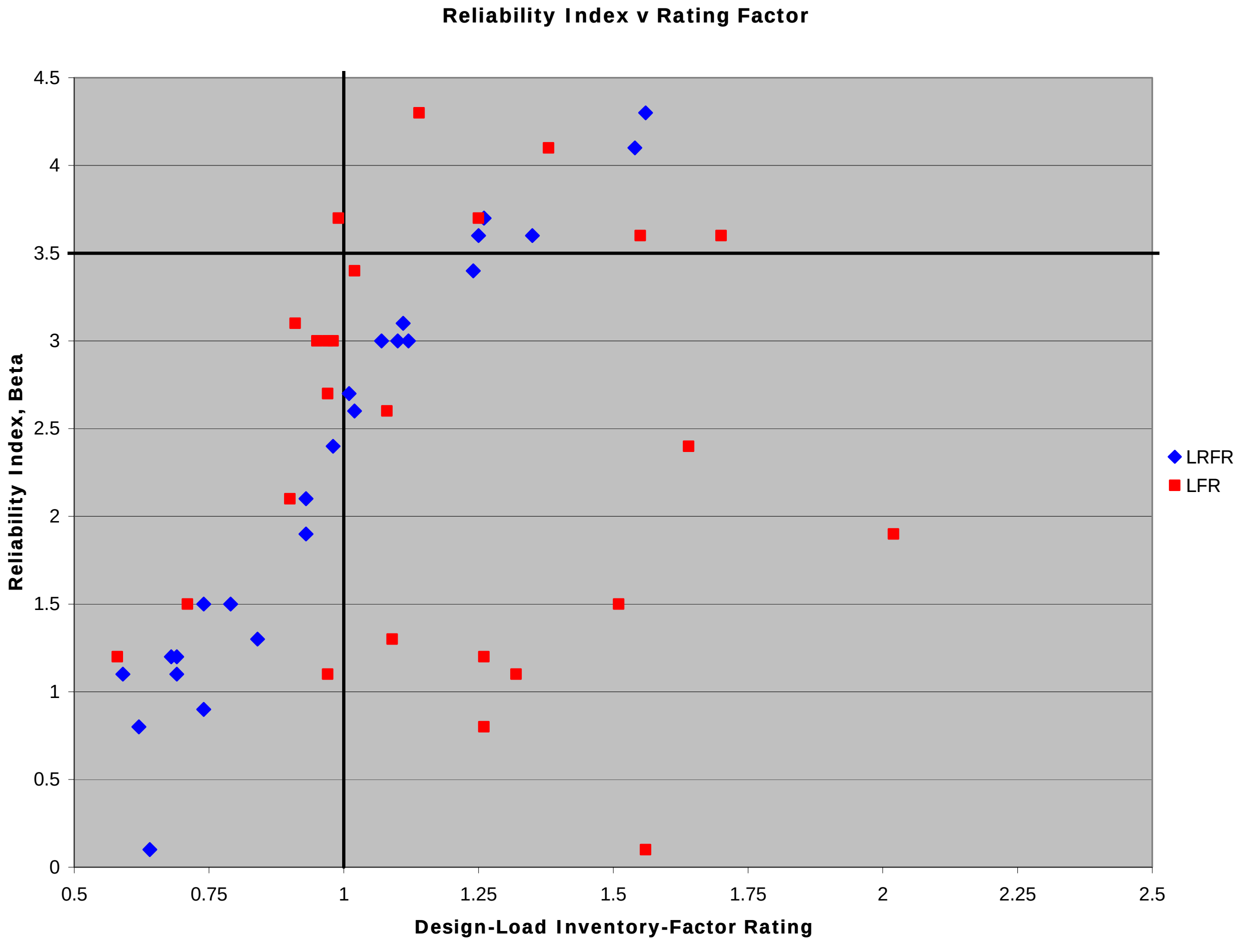

Figure 7 – Reliability Index versus Design-Load Inventory-Rating Factor

CONCLUSIONS AND RECCOMENDATIONS

Introduction

The conclusions and recommendations from this study are narrowly based upon the scope. Only flexural strength ratings were made and these ratings were made by the BRASS™ programs. (The researcher is weary of the great dependency he, and the profession, has on software to perform the ratings. The differences in design methodology between LRFR and LFR only relate to how load and resistance is compared. The same basic loads and resistances should be used, but different load and resistance factors are used. We have introduced much complication into the process.) The researcher assumes that the ratings as produced by BRASS™ are correct. The investigation of reliability made by the researcher using Monte Carlo simulation suggests this to be true.

Conclusions

Based upon the results of this investigation, in general, LRFR rating factors are equal to or greater than LFR ratings factors except for reinforced-concrete slab bridges. These types of slab bridges may represent a problem in terms of LRFR rating. As was demonstrated, the researcher believes that the lower slab bridge ratings are technically appropriate (These low ratings are included in Figure 4 where a correlation between rating factor and failure rate in demonstrated.). The effect of these low slab-bridge ratings on operating a bridge system must be assessed by the owners.

Recommendations

This limited study suggests that LRFR is technically sound with the LRFR rating factors in good correlation with the failure rates. In other words, LRFR rating factors lower than one demonstrated relatively high failure rates. LFR ratings did not correlate well. In fact, many bridges with LFR rating factors above one demonstrated unacceptably high failure rates. This is not to say that the continued use of LFR rating is necessarily unsafe, just irrational.

Questions about LRFR versus LFR for force effects other than moment and limit states other than strength are not answered. Nonetheless, the researcher recommends adoption of the LRFR methodology for rating bridges. Assuming the LRFR calibration process is sound, comparable results should result for other more extensive studies. The service limit states which are uncalibrated and optional in LRFR need additional thought.

If the diminished range between inventory and operating ratings shown in Table 4 is not acceptable from an operational standpoint, them the target reliability index, β_T, for the operating rating in LRFR should be re-evaluated. Decreasing β_T, will increase this range.

APPENDIX

TABLE A1 - DESIGN-LOAD RATING FACTORS

State	Bridge	Type	Span Lengths (ft)	Design-Load Rating Factors					
				LFR (HS20)			LRFR (HL-93)		
				Inventory	Operating	Ratio	Inventory	Operating	Ratio
NY	1017110	p/s concrete box	47.25	2.47	4.12	1.6680162	1.79	2.32	1.296089
NY	1038290	p/s concrete box	52	2.49	4.16	1.6706827	2.59	3.35	1.293436
NY	1060420	p/s concrete box	70	1.69	2.84	1.6804734	1.9	2.46	1.294737
NY	1000690	p/s concrete box	71.5	1.81	3.02	1.6685083	1.84	2.39	1.298913
NY	1029560	p/s concrete box	77	1.39	2.32	1.6690647	1.81	2.35	1.298343
NY	1018010	p/s concrete box	78.74	1.84	3.07	1.6684783	2.27	2.94	1.295154
NY	1030930	p/s concrete box	90	1.78	2.99	1.6797753	2.12	2.75	1.29717
NY	1031020	p/s concrete box	102	1.91	3.19	1.6701571	2.09	2.71	1.296651
NY	1040180	p/s concrete box	102	1.38	2.31	1.673913	1.54	2	1.298701
NY	1029390	p/s concrete box	103	1.64	2.74	1.6707317	2.01	2.61	1.298507
WY	bod	p/s concrete girder	43	1.75	2.93	1.6742857	1.51	1.96	1.298013
WY	boc	p/s concrete girder	50	1.55	2.6	1.6774194	1.25	1.62	1.296
WY	fln	p/s concrete girder	78.42	1.44	2.42	1.6805556	1.43	1.86	1.300699
WY	flk	p/s concrete girder	84.41	1.38	2.31	1.673913	1.58	2.05	1.297468
NY	3224000	p/s concrete girder	100	1.61	2.7	1.6770186	1.67	2.17	1.299401
NY	1090642	p/s concrete girder	103	2.1	3.52	1.6761905	1.99	2.58	1.296482
NY	2269170a	p/s concrete girder	108.42	1.86	3.12	1.6774194	1.86	2.41	1.295699
NY	1025280	p/s concrete slab	40.85	2.23	3.73	1.6726457	2.52	3.27	1.297619
NY	3304310	p/s concrete slab	47	1.96	3.28	1.6734694	2.03	2.63	1.295567
NY	1010040	p/s concrete slab	65	1.57	2.63	1.6751592	2.77	3.59	1.296029
NY	1094200	reinforced concrete slab	20	1.26	2.11	1.6746032	0.62	0.8	1.290323
NY	1009360	reinforced concrete slab	21	1.32	2.2	1.6666667	0.69	0.89	1.289855
WY	acr	reinforced concrete slab	18 - 21.5 - 21.5 - 18	0.71	1.19	1.6751592	0.79	1.02	1.291139
NY	1051360	reinforced concrete slab	24	1.51	2.52	1.6688742	0.74	0.96	1.297297
WY	aab	reinforced concrete slab	16.75 - 25 - 16.75	0.98	1.64	1.6734694	1.07	1.39	1.299065

State	Bridge	Type	Span Lengths (ft)	Design-Load Rating Factors					
				LFR (HS20)			LRFR (HL-93)		
				Inventory	Operating	Ratio	Inventory	Operating	Ratio
NY	1030240	reinforced concrete slab	30	1.26	2.11	1.6746032	0.68	0.88	1.294118
WY	adk	reinforced concrete slab	24 - 30 - 24	1.25	2.09	1.6734694	1.26	1.64	1.301587
WY	aag	reinforced concrete slab	23.25 - 35 - 23.25	0.97	1.63	1.672	1.01	1.31	1.29703
NY	1016780	reinforced concrete slab	41.6	0.97	1.61	1.6597938	0.59	0.76	1.288136
WY	ays	reinforced concrete slab	32 - 44 - 32	1.11	1.85	1.6666667	1.2	1.56	1.3
NY	1016320	steel plate girder	49.5 - 79 - 79 - 55.5	1.4	2.34	1.6714286	2.44	3.16	1.295082
NY	1054732	steel plate girder	96	1.43	2.39	1.6713287	1.67	2.16	1.293413
NY	1090702	steel plate girder	100.56	2.13	3.56	1.6713615	2.27	2.95	1.299559
NY	1001700	steel plate girder	109	2.15	3.59	1.6697674	2.53	3.28	1.296443
NY	1072450	steel plate girder	122 - 122	1.55	2.6	1.6774194	1.76	2.28	1.295455
NY	1090442	steel plate girder	124	1.65	2.75	1.6666667	2.2	2.86	1.3
NY	1090880	steel plate girder	96 - 125 - 96	0.99	1.67	1.6868687	1.26	1.64	1.301587
NY	1070032	steel plate girder	130	1.77	2.95	1.6666667	2.31	3	1.298701
NY	1075610	steel plate girder	104 - 135 - 104	1.14	1.91	1.6754386	1.56	2.02	1.294872
NY	4443852	steel plate girder	78 - 135 - 82	1.08	1.8	1.6666667	1.02	1.76	1.72549
NY	1094912	steel plate girder	140	1.55	2.59	1.6709677	1.68	2.18	1.297619
NY	1070152	steel plate girder	141 - 141	1.69	2.82	1.6686391	1.55	2.01	1.296774
NY	1069040	steel plate girder	144.5 - 144.5	1.19	1.99	1.6722689	1.83	2.37	1.295082
NY	1069070	steel plate girder	147 - 147	1.43	2.39	1.6713287	1.79	2.33	1.301676
NY	4443361	steel plate girder	150	2.18	3.65	1.6743119	2.18	2.82	1.293578
NY	1071002	steel plate girder	154	1.68	2.81	1.672619	1.91	2.47	1.293194
NY	1072720	steel plate girder	130 - 165	1.35	2.26	1.6740741	1.71	2.22	1.298246
NY	1008720	steel plate girder	162 - 166	1.47	2.46	1.6734694	2.14	2.77	1.294393
NY	1061902	steel plate girder	169.83	1.38	2.32	1.6811594	1.76	2.29	1.301136
WY	dda	steel plate girder	135 - 175 - 135	0.91	1.6	1.7582418	1.11	1.44	1.297297
NY	1026840	steel plate girder	180	2.56	4.27	1.6679688	2.21	2.86	1.294118
NY	1056220	steel plate girder	190	1.29	2.15	1.6666667	1.59	2.07	1.301887
WY	dew	steel plate girder	139 - 191 - 139	1.7	2.84	1.6705882	1.35	1.75	1.296296

State	Bridge	Type	Span Lengths (ft)	Design-Load Rating Factors					
				LFR (HS20)			**LRFR (HL-93)**		
				Inventory	**Operating**	**Ratio**	**Inventory**	**Operating**	**Ratio**
WY	fev	steel plate girder	150 - 195 - 150	1.53	2.55	1.6666667	1.88	2.44	1.297872
WY	fhy	steel plate girder	156 - 202.5 - 156	1.65	2.76	1.6727273	1.7	2.2	1.294118
NY	2255970	steel rolled beam	22.7	1.9	3.18	1.6736842	0.84	1.09	1.297619
NY	2214710	steel rolled beam	24.4	2.02	3.38	1.6732673	0.93	1.21	1.301075
WY	fbw	steel rolled beam	22.64 - 29 - 22.64	1.32	2.21	1.6742424	1.39	1.8	1.294964
NY	1026980	steel rolled beam	31	1.64	2.74	1.6707317	0.98	1.27	1.295918
NY	1045470	steel rolled beam	33	0.58	0.97	1.6724138	0.69	0.89	1.289855
NY	1015040	steel rolled beam	34.1	1.29	2.15	1.6666667	2.03	2.63	1.295567
WY	bhh	steel rolled beam	29.25 - 35 - 35 - 29.25	1.04	1.74	1.6730769	1.54	2	1.298701
NY	2247160	steel rolled beam	40 - 37.5 - 40	2.31	3.86	1.6709957	3.62	4.69	1.29558
NY	1030630	steel rolled beam	42	1.41	2.36	1.6737589	1.89	2.45	1.296296
WY	bny	steel rolled beam	45	0.9	1.51	1.6777778	0.93	1.21	1.301075
NY	3300750	steel rolled beam	50	1.62	2.7	1.6666667	1.98	2.57	1.29798
NY	1000630	steel rolled beam	54	1.56	2.61	1.6730769	1.92	2.49	1.296875
WY	diw	steel rolled beam	56.5	1.42	2.38	1.6760563	2.08	2.7	1.298077
NY	1090900	steel rolled beam	56.8	0.95	1.89	1.9894737	1.12	1.76	1.571429
NY	2213960	steel rolled beam	67	1.56	2.6	1.6666667	0.64	0.83	1.296875
NY	1066580	steel rolled beam	71.63 - 71.63	1.02	1.7	1.6666667	1.24	1.6	1.290323
NY	1045550	steel rolled beam	79	1.61	2.7	1.6770186	1.81	2.35	1.298343
NY	2216820	steel rolled beam	80.6	3.82	6.39	1.6727749	0.74	0.96	1.297297
WY	aus	steel rolled beam	63.5 - 82 - 63.5	0.97	1.63	1.6804124	1.1	1.43	1.3
					average	1.6778908		*average*	1.306175
					standard deviation	0.0383043		*standard deviation*	0.05891

TABLE A2 - LEGAL LOAD RATINGS

State	Bridge	Type	Span Lengths (ft)	Legal-Load Operating Ratings								
				Type 3			Type 3S2			Type 3-3		
				LFR	LRFR	Ratio	LFR	LRFR	Ratio	LFR	LRFR	Ratio
NY	1017110	p/s concrete box	47.25	5.41	3.75	0.693161	5.94	4.1	0.690236	6.49	4.5	0.693374
NY	1038290	p/s concrete box	52	5.52	5.54	1.003623	5.85	5.88	1.005128	6.34	6.43	1.014196
NY	1060420	p/s concrete box	70	3.85	4.36	1.132468	3.56	4.01	1.126404	3.75	4.24	1.130667
NY	1000690	p/s concrete box	71.5	4.15	4.25	1.024096	3.77	3.88	1.029178	3.99	4.08	1.022556
NY	1029560	p/s concrete box	77	3.19	4.26	1.335423	2.84	3.79	1.334507	2.93	3.91	1.334471
NY	1018010	p/s concrete box	78.74	4.19	5.36	1.279236	3.71	4.73	1.274933	3.81	4.86	1.275591
NY	1030930	p/s concrete box	90	4.14	5.19	1.253623	3.53	4.41	1.249292	3.53	4.41	1.249292
NY	1031020	p/s concrete box	102	4.48	5.28	1.178571	3.67	4.36	1.188011	3.61	4.28	1.185596
NY	1040180	p/s concrete box	102	3.24	3.91	1.20679	2.65	3.22	1.215094	2.61	3.16	1.210728
NY	1029390	p/s concrete box	103	3.82	5.11	1.337696	3.16	4.2	1.329114	3.11	4.13	1.327974
					average	1.144469		*average*	1.14419		*average*	1.144444
					stdev	0.196377		*stdev*	0.195636		*stdev*	0.194236
WY	bod	p/s concrete girder	43	3.79	3.1	0.817942	4.1	3.34	0.814634	4.61	3.75	0.813449
WY	boc	p/s concrete girder	50	3.42	2.66	0.777778	3.72	2.91	0.782258	4.09	3.17	0.775061
WY	fln	p/s concrete girder	78.42	3.3	3.03	0.918182	2.92	3.43	1.174658	3.01	3.48	1.156146
WY	flk	p/s concrete girder	84.41	3.2	3.81	1.190625	2.77	3.29	1.187726	2.78	3.33	1.197842
NY	3224000	p/s concrete girder	100	3.75	4.2	1.12	3.11	3.48	1.118971	3.06	3.43	1.120915
NY	1090642	p/s concrete girder	103	4.89	5.05	1.03272	4.04	4.15	1.027228	3.97	4.08	1.027708
NY	2269170a	p/s concrete girder	108.42	4.35	4.79	1.101149	3.54	3.9	1.101695	3.44	3.8	1.104651
					average	0.994057		*average*	1.029596		*average*	1.027967
					stdev	0.158648		*stdev*	0.166645		*stdev*	0.168219
NY	1025280	p/s concrete slab	40.85	4.79	5.11	1.066806	5.07	5.48	1.080868	5.76	6.22	1.079861
NY	3304310	p/s concrete slab	47	4.25	4.25	1	4.68	4.65	0.99359	5.15	5.1	0.990291
NY	1010040	p/s concrete slab	65	3.56	6.25	1.755618	3.4	5.94	1.747059	3.63	6.34	1.746556
					average	1.274141		*average*	1.273839		*average*	1.272236
					stdev	0.418307		*stdev*	0.412137		*stdev*	0.413207
NY	1094200	reinforced concrete slab	20	2.48	1.32	0.532258	2.72	1.45	0.533088	3.01	1.61	0.534884
NY	1009360	reinforced concrete slab	21	2.56	1.47	0.574219	2.81	1.61	0.572954	3.11	1.79	0.575563

State	Bridge	Type	Span Lengths (ft)	Legal-Load Operating Ratings								
				Type 3			Type 3S2			Type 3-3		
				LFR	LRFR	Ratio	LFR	LRFR	Ratio	LFR	LRFR	Ratio
WY	acr	reinforced concrete slab	18-21.5-21.5-18	1.45	1.68	1.158621	1.59	1.79	1.125786	1.76	1.92	1.090909
NY	1051360	reinforced concrete slab	24	2.82	1.6	0.567376	3.04	1.71	0.5625	3.47	1.94	0.559078
WY	aab	reinforced concrete slab	16.75-25-16.75	2.02	2.26	1.118812	2.27	2.43	1.070485	2.35	2.65	1.12766
NY	1030240	reinforced concrete slab	30	2.64	1.51	0.57197	2.65	1.51	0.569811	3.21	1.83	0.570093
WY	adk	reinforced concrete slab	24-30-24	2.61	2.74	1.049808	2.28	2.95	1.29386	2.98	3.22	1.080537
WY	aag	reinforced concrete slab	23.25-35-23.25	2	2.16	1.08	1.81	2.26	1.248619	2.21	2.65	1.199095
NY	1016780	reinforced concrete slab	41.6	2.09	1.2	0.574163	2.23	1.29	0.578475	2.52	1.45	0.575397
WY	ays	reinforced concrete slab	32-44-32	2.49	2.57	1.032129	2.38	2.73	1.147059	2.72	3.14	1.154412
					average	0.825935		*average*	0.870264		*average*	0.846763
					stdev	0.278486		*stdev*	0.329443		*stdev*	0.301056
NY	1016320	steel plate girder	49.5-79-79-55.5	3.16	5.66	1.791139	2.94	6.03	2.05102	3.12	6.68	2.141026
NY	1054732	steel plate girder	96	3.33	4.14	1.243243	2.78	3.46	1.244604	2.74	3.43	1.251825
NY	1090702	steel plate girder	100.56	4.94	5.73	1.159919	4.09	4.74	1.158924	4.04	4.67	1.155941
NY	1001700	steel plate girder	109	4.97	6.51	1.309859	4.07	5.3	1.302211	3.97	5.17	1.302267
NY	1072450	steel plate girder	122-122	3.65	4.5	1.232877	2.96	3.66	1.236486	2.89	3.66	1.266436
NY	1090442	steel plate girder	124	3.84	5.87	1.528646	3.07	4.62	1.504886	2.96	4.53	1.530405
NY	1090880	steel plate girder	96-125-96	2.31	3.16	1.367965	1.97	2.69	1.365482	1.96	2.75	1.403061
NY	1070032	steel plate girder	130	4.14	6.28	1.516908	3.26	4.96	1.521472	3.12	4.75	1.522436
NY	1075610	steel plate girder	104-135-104	2.9	5.27	1.817241	2.41	4.39	1.821577	2.44	4.39	1.79918
NY	4443852	steel plate girder	78-135-82	2.54	4.08	1.606299	2.12	2.98	1.40566	2.07	2.79	1.347826
NY	1094912	steel plate girder	140	3.65	4.68	1.282192	2.83	3.65	1.289753	2.71	3.48	1.284133
NY	1070152	steel plate girder	141-141	3.92	6.42	1.637755	3.11	5.08	1.633441	3.01	4.93	1.637874
NY	1069040	steel plate girder	144.5-144.5	2.81	5.01	1.782918	2.2	3.94	1.790909	2.13	3.81	1.788732
NY	1069070	steel plate girder	147-147	3.37	4.91	1.456973	2.63	3.87	1.471483	2.57	3.75	1.459144
NY	4443361	steel plate girder	150	5.26	6.21	1.180608	4.05	4.8	1.185185	3.85	4.56	1.184416
NY	1071002	steel plate girder	154	4.09	5.46	1.334963	3.16	4.18	1.322785	3	4.01	1.336667
NY	1072720	steel plate girder	130-165	3.29	4.89	1.486322	2.54	3.78	1.488189	2.43	3.62	1.489712
NY	1008720	steel plate girder	162-166	3.59	6.34	1.766017	2.77	4.9	1.768953	2.67	4.69	1.756554
NY	1061902	steel plate girder	169.83	3.61	5.32	1.473684	2.77	4.05	1.462094	2.6	3.82	1.469231

State	Bridge	Type	Span Lengths (ft)	Legal-Load Operating Ratings								
				Type 3			Type 3S2			Type 3-3		
				LFR	LRFR	Ratio	LFR	LRFR	Ratio	LFR	LRFR	Ratio
WY	dda	steel plate girder	135-175-135	2.53	3.03	1.197628	1.99	2.39	1.201005	1.95	2.34	1.2
NY	1026840	steel plate girder	180	6.96	6.71	0.96408	5.28	5.09	0.964015	4.95	4.78	0.965657
NY	1056220	steel plate girder	190	3.63	5.83	1.606061	2.74	4.37	1.594891	2.56	4.08	1.59375
WY	dew	steel plate girder	139-191-139	3.99	3.96	0.992481	3.14	3.1	0.987261	3.05	2.96	0.970492
WY	fev	steel plate girder	150-195-150	3.74	5.39	1.441176	2.9	4.22	1.455172	2.8	4.08	1.457143
WY	fhy	steel plate girder	156-202.5-156	4.1	5.5	1.341463	3.19	4.29	1.344828	3.09	4.13	1.33657
					average	1.420737		*average*	1.422891		*average*	1.426019
					stdev	0.239141		*stdev*	0.258404		*stdev*	0.266788
NY	2255970	steel rolled beam	22.7	3.53	1.81	0.512748	3.83	1.97	0.51436	4.28	2.2	0.514019
NY	2214710	steel rolled beam	24.4	3.85	2.03	0.527273	4.16	2.16	0.519231	4.67	2.47	0.528908
WY	fbw	steel rolled beam	22.64-29-22.64	2.79	3	1.075269	2.49	2.79	1.120482	3.24	3.41	1.052469
NY	1026980	steel rolled beam	31	3.42	2.16	0.631579	3.45	2.17	0.628986	4.24	2.65	0.625
NY	1045470	steel rolled beam	33	1.19	1.48	1.243697	1.21	1.52	1.256198	1.49	1.85	1.241611
NY	1015040	steel rolled beam	34.1	2.67	4.33	1.621723	2.75	4.47	1.625455	3.28	5.33	1.625
WY	bhh	steel rolled beam	29.25-35-35-29.25	2.21	2.68	1.21267	1.78	2.28	1.280899	2.08	2.66	1.278846
NY	2247160	steel rolled beam	40-37.5-40	4.91	7.46	1.519348	4.97	6.46	1.299799	5.35	6.96	1.300935
NY	1030630	steel rolled beam	42	3.03	3.86	1.273927	3.27	4.15	1.269113	3.69	4.68	1.268293
WY	bny	steel rolled beam	45	1.97	1.93	0.979695	2.14	2.27	1.060748	2.36	2.52	1.067797
NY	3300750	steel rolled beam	50	3.55	4.22	1.188732	3.85	4.62	1.2	4.25	5.04	1.185882
NY	1000630	steel rolled beam	54	3.46	4.15	1.199422	3.62	4.29	1.185083	3.92	4.68	1.193878
WY	diw	steel rolled beam	56.5	2.38	4.55	1.911765	2.44	4.66	1.909836	2.58	4.99	1.934109
NY	1090900	steel rolled beam	56.8	2.52	2.92	1.15873	2.62	3.02	1.152672	2.88	3.32	1.152778
NY	2213960	steel rolled beam	67	3.51	1.45	0.413105	3.31	1.36	0.410876	3.51	1.45	0.413105
NY	1066580	steel rolled beam	71.63-71.63	2.33	4.09	1.755365	2.14	3.76	1.757009	2.32	4.13	1.780172
NY	1045550	steel rolled beam	79	3.72	4.28	1.150538	3.29	3.77	1.145897	3.36	3.87	1.151786
NY	2216820	steel rolled beam	80.6	8.82	1.76	0.199546	7.7	1.55	0.201299	7.84	1.58	0.201531
WY	aus	steel rolled beam	63.5-82-63.5	2.2	2.81	1.277273	2.04	2.6	1.27451	2.16	2.76	1.277778
					average	1.097495		*average*	1.095392		*average*	1.094416
					stdev	0.462193		*stdev*	0.455097		*stdev*	0.458555

TABLE A3 - PERMIT TRUCK LOAD RATINGS

State	**Bridge**	**Type**	**Span Lengths (ft)**	**Permit Truck Operating Ratings**		
				LFR	**LRFR**	**Ratio**
NY	1017110	p/s concrete box	47.25	2.78	1.92	0.69064748
NY	1038290	p/s concrete box	52	2.86	2.87	1.0034965
NY	1060420	p/s concrete box	70	2.05	2.32	1.13170732
NY	1000690	p/s concrete box	71.5	2.21	2.26	1.02262443
NY	1029560	p/s concrete box	77	1.67	2.25	1.34730539
NY	1018010	p/s concrete box	78.74	2.18	2.78	1.27522936
NY	1030930	p/s concrete box	90	1.99	2.51	1.26130653
NY	1031020	p/s concrete box	102	2.01	2.37	1.17910448
NY	1040180	p/s concrete box	102	1.47	1.77	1.20408163
NY	1029390	p/s concrete box	103	1.73	2.29	1.32369942
average						1.14392025
standard deviation						0.19709047
WY	bod	p/s concrete girder	43	1.92	1.56	0.8125
WY	boc	p/s concrete girder	50	1.76	1.37	0.77840909
WY	fln	p/s concrete girder	78.42	3.01	2.04	0.67774086
WY	flk	p/s concrete girder	84.41	1.58	1.93	1.22151899
NY	3224000	p/s concrete girder	100	1.66	1.86	1.12048193
NY	1090642	p/s concrete girder	103	2.18	2.23	1.02293578
NY	2269170a	p/s concrete girder	108.42	1.88	2.07	1.10106383
average						0.96209293
standard deviation						0.2050925
NY	1025280	p/s concrete slab	40.85	2.39	2.56	1.07112971
NY	3304310	p/s concrete slab	47	2.18	2.17	0.99541284
NY	1010040	p/s concrete slab	65	1.89	3.31	1.75132275
average						1.27262177
standard deviation						0.41629225
NY	1094200	reinforced concrete slab	20	1.34	0.72	0.53731343
NY	1009360	reinforced concrete slab	21	1.36	0.78	0.57352941

State	Bridge	Type	Span Lengths (ft)	Permit Truck Operating Ratings		
				LFR	LRFR	Ratio
WY	acr	reinforced concrete slab	18-21.5-21.5-18	0.79	0.92	1.16455696
NY	1051360	reinforced concrete slab	24	1.43	0.81	0.56643357
WY	aab	reinforced concrete slab	16.75-25-16.75	1.16	1.3	1.12068966
NY	1030240	reinforced concrete slab	30	1.25	0.71	0.568
WY	adk	reinforced concrete slab	24-30-24	1.34	1.37	1.02238806
WY	aag	reinforced concrete slab	23.25-35-23.25	1.01	1.09	1.07920792
NY	1016780	reinforced concrete slab	41.6	1.05	0.6	0.57142857
WY	ays	reinforced concrete slab	32-44-32	1.18	1.31	1.11016949
					average	0.83137171
					standard deviation	0.28488511
NY	1016320	steel plate girder	49.5-79-79-55.5	1.71	2.94	1.71929825
NY	1054732	steel plate girder	96	1.53	1.94	1.26797386
NY	1090702	steel plate girder	100.56	2.25	2.61	1.16
NY	1001700	steel plate girder	109	2.17	2.83	1.30414747
NY	1072450	steel plate girder	122-122	1.51	1.79	1.18543046
NY	1090442	steel plate girder	124	1.57	2.27	1.44585987
NY	1090880	steel plate girder	96-125-96	1	1.45	1.45
NY	1070032	steel plate girder	130	1.64	2.5	1.52439024
NY	1075610	steel plate girder	104-135-104	1.28	2.32	1.8125
NY	4443852	steel plate girder	78-135-82	1.02	1.02	1
NY	1094912	steel plate girder	140	1.41	1.8	1.27659574
NY	1070152	steel plate girder	141-141	1.53	1.64	1.07189542
NY	1069040	steel plate girder	144.5-144.5	1.08	1.92	1.77777778
NY	1069070	steel plate girder	147-147	1.29	1.89	1.46511628
NY	4443361	steel plate girder	150	1.97	2.33	1.18274112
NY	1071002	steel plate girder	154	1.53	1.96	1.28104575
NY	1072720	steel plate girder	130-165	1.21	1.8	1.48760331
NY	1008720	steel plate girder	162-166	1.32	2.33	1.76515152
NY	1061902	steel plate girder	169.83	1.3	1.89	1.45384615

State	**Bridge**	**Type**	**Span Lengths (ft)**	**Permit Truck Operating Ratings**		
				LFR	**LRFR**	**Ratio**
WY	dda	steel plate girder	135-175-135	0.98	1.19	1.21428571
NY	1026840	steel plate girder	180	2.48	2.39	0.96370968
NY	1056220	steel plate girder	190	1.27	1.74	1.37007874
WY	dew	steel plate girder	139-191-139	1.55	1.5	0.96774194
WY	fev	steel plate girder	150-195-150	1.42	2.05	1.44366197
WY	fhy	steel plate girder	156-202.5-156	1.54	2	1.2987013
					average	1.3555821
					standard deviation	0.24435
NY	2255970	steel rolled beam	22.7	1.8	0.93	0.51666667
NY	2214710	steel rolled beam	24.4	1.92	1.02	0.53125
WY	fbw	steel rolled beam	22.64-29-22.64	1.39	1.52	1.09352518
NY	1026980	steel rolled beam	31	1.63	1.02	0.62576687
NY	1045470	steel rolled beam	33	0.57	0.71	1.24561404
NY	1015040	steel rolled beam	34.1	1.29	2.1	1.62790698
WY	bhh	steel rolled beam	29.25-35-35-29.25	1.03	1.3	1.26213592
NY	2247160	steel rolled beam	40-37.5-40	2.48	3.15	1.27016129
NY	1030630	steel rolled beam	42	1.53	1.94	1.26797386
WY	bny	steel rolled beam	45	1.01	0.98	0.97029703
NY	3300750	steel rolled beam	50	1.83	2.17	1.18579235
NY	1000630	steel rolled beam	54	1.81	2.16	1.19337017
WY	diw	steel rolled beam	56.5	1.24	2.38	1.91935484
NY	1090900	steel rolled beam	56.8	1.32	1.52	1.15151515
NY	2213960	steel rolled beam	67	1.88	0.77	0.40957447
NY	1066580	steel rolled beam	71.63-71.63	1.16	1.55	1.3362069
NY	1045550	steel rolled beam	79	1.92	2.2	1.14583333
NY	2216820	steel rolled beam	80.6	4.41	0.89	0.20181406
WY	aus	steel rolled beam	63.5-82-63.5	1.04	1.34	1.28846154
					average	1.06543266
					standard deviation	0.43031464