APPENDIX M – LANE SPACING STUDY

When performing a rigorous method of analysis on a bridge superstructure, there are a number of ways that live loads can be positioned. The AASHTO Standard Specifications (AASHTO 1996) and the AASHTO LRFD Specifications (AASHTO 1998) specify a traffic lane width of 3.66 m (12 ft). This means that, when the minimum distance from the curb is considered, the first two trucks will be spaced 4 feet apart, and each subsequent truck will be at a spacing of 6 feet. When using an automated load positioning procedure, it is simpler to assume that the trucks have a constant spacing. For this project, a four foot spacing is used.

The issue of whether or not the variation in truck spacing beyond the first two trucks has a significant effect on live load distribution factors must be considered. For any given bridge, many options exist for live load placement. For example, a bridge with a clear roadway width of 50 ft, there are 8 possible loading cases. For four lanes loaded, the loading cases are as follows: 2-6-4-6-6-6-6-6 ft, 3-6-4-6-6-6-6-6 ft, etc. When the outermost line of wheels of the first vehicle is 4 ft from the barrier, the fourth vehicle can be spaced either 4 ft or 6 ft from the third vehicle. This many loading cases lengthen the analysis process. One possible simplified procedure for load placement is to place all vehicles 4 ft apart. The load placement is then 2-6-4-6-4-6-4-6 ft, 3-6-4-6-4-6-4-6 ft, etc. The objective of this study is to demonstrate that use of a constant four foot vehicle spacing will have a negligible effect on live load distribution factors.

Method of Analysis

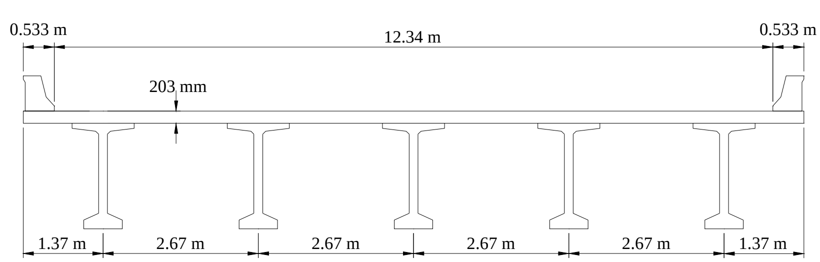
SAP2000 was used to model the bridge superstructures. The models were analyzed using the grillage analogy method. Frame elements were used to define the supporting members as well as the transverse deck slab members. The section properties for the supporting members were based on a composite section. The presence of end and intermediate diaphragms was not considered in this study.

Geometric and Structural Properties

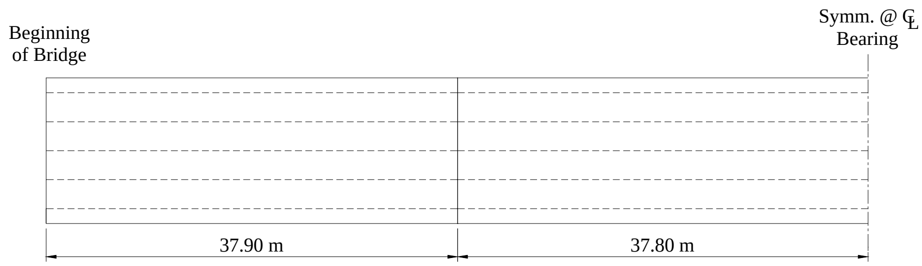
Two straight (no skew) bridges were investigated in this study. The first bridge, shown in Figure M-1, is a four span precast concrete bulb-tee beam bridge that is symmetric about the centerline of the second pier. The second bridge, shown in Figure M-2, is a two span steel I-beam bridge. The cross section of the steel I-beam varies along the span length. The same varied section is used for both the exterior and interior beams as well as both spans.

Vehicle Loading

All vehicles used in this study were an HL93 truck as specified in the AASHTO LRFD Specifications (1998). The automated load positioning capability of SAP2000 was utilized for maximum bending moment. However, point loads were applied near the support to obtain the maximum shear. The distance between the interior face of the barrier to the outer most line of wheels of the first vehicle was varied from 2 ft to 6 ft with 1 ft intervals transversely across the bridge. In the standard load configuration, all vehicles were spaced 4 ft apart, while in the varied load configuration, vehicles were spaced either 4 ft or 6 ft apart. The live load placement configurations are illustrated in Figure M-3 through Figure M-6.

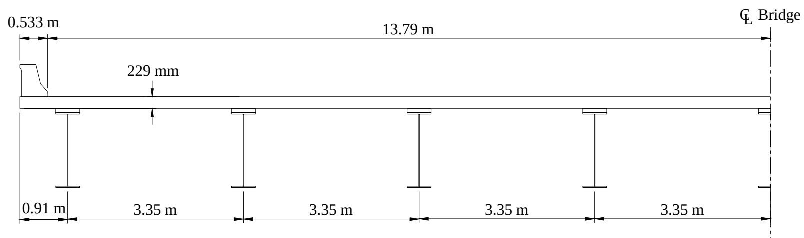


(a)

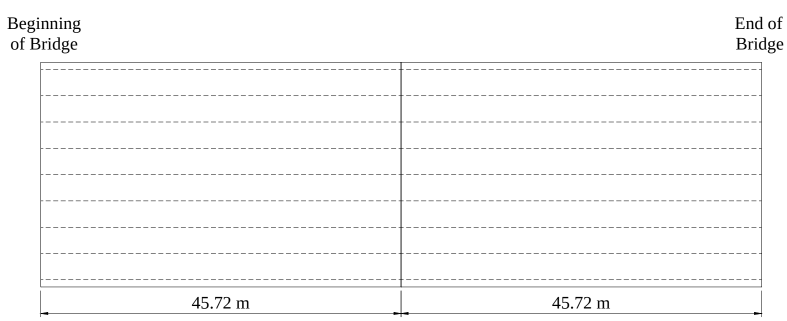


(b)

Figure M-1: Precast Bulb-Tee Beam Bridge: (a) Typical Cross Section; and (b) Plan View



(a)



(b)

Figure M-2: Steel I-Beam Bridge: (a) Typical Cross Section; and (b) Plan View

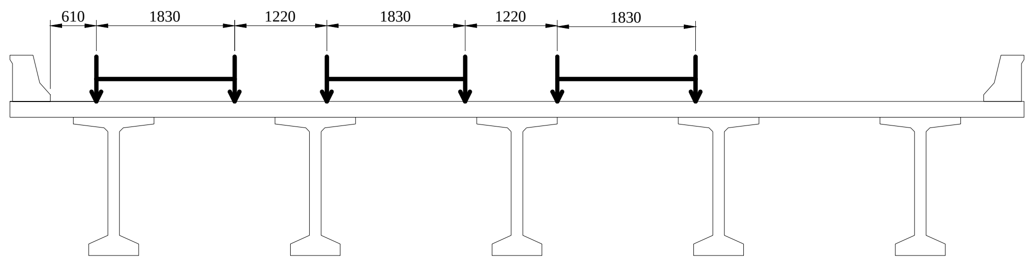


Figure M-3: Standard Vehicle Spacing (Precast Bulb-Tee Beam)

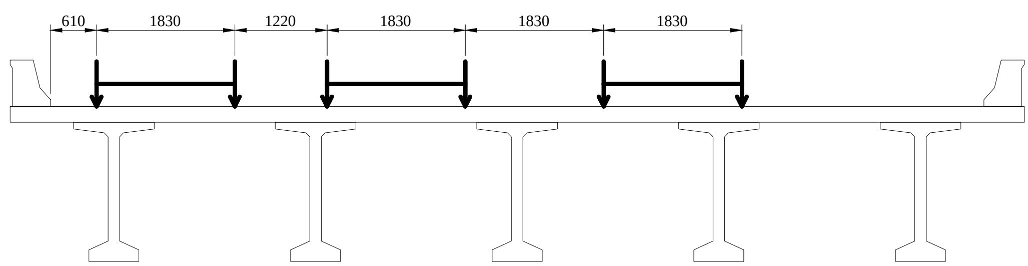


Figure M-4: Varied Vehicle Spacing (Precast Bulb-Tee Beam)

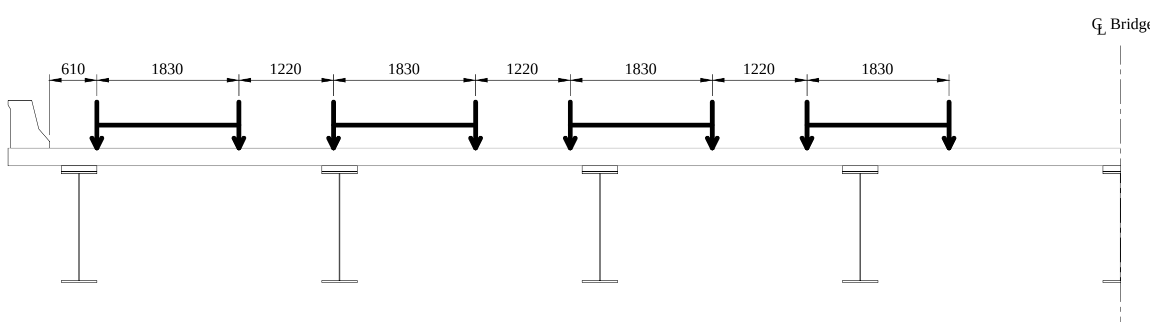


Figure M-5: Standard Vehicle Spacing (Steel I-Beam)

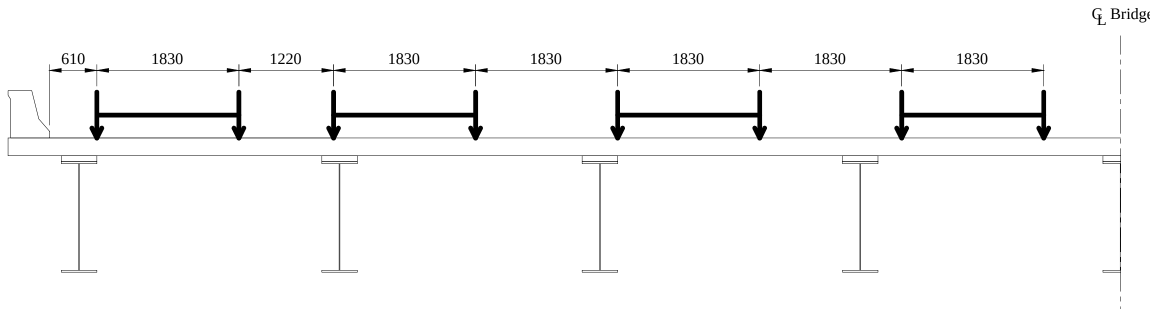


Figure M-6: Varied Vehicle Spacing (Steel I-Beam)

Results

Distribution factors are calculated by dividing the maximum response value (shear or moment) at a critical location by the maximum response value from a single beam line loaded with one vehicle. The critical location is determined from the beam line analysis. For the precast bulb-tee beam bridge, the maximum shear and moment from a beam line analysis is 290 kN and 2128 kN-m, respectively. For the steel I-beam bridge, the values are 294 kN and 2531 kN-m, respectively. The maximum shear and moment values from the grillage analysis are shown in Table M-1 and Table M-2 for the precast bulb-tee beam bridge and the steel I-beam bridge, respectively.

Table M-3 and Table M-4 show the differences in distribution factor when comparing the standard and varied load configuration. It is observed from these tables that the differences in shear distribution factors are well below 1% for the exterior girder loaded for maximum shear near the support. For the interior beam, when loaded for maximum shear, the differences are generally less than 2%. For both structures considered, the differences between moment distribution factors are generally less than 3.5% for both exterior and interior beams when three lanes are loaded. With four lanes loaded the differences are vary from 2 to 5 percent.

Table M-1: Shear and Moment Results for Precast Bulb-Tee Beam Bridge

No. Trucks	Load Case*	Load Placement**	Exterior V (kN)	Exterior DF	Exterior M (kN-m)	Exterior DF	Interior V (kN)	Interior DF	Interior M (kN-m)	Interior DF
3	1S	610-1830-1220-1830-1220-1830	208	0.719	1687	0.793	254	0.875	1812	0.852
	2S	915-1830-1220-1830-1220-1830	188	0.649	1504	0.707	242	0.835	1774	0.834
	3S	1220-1830-1220-1830-1220-1830	158	0.544	1330	0.625	241	0.830	1732	0.814
	4S	1525-1830-1220-1830-1220-1830	128	0.442	1167	0.548	247	0.853	1684	0.791
	5S	1830-1830-1220-1830-1220-1830	105	0.362	1017	0.478	245	0.844	1632	0.767
	1V	610-1830-1220-1830-1830-1830	208	0.717	1660	0.780	250	0.861	1748	0.821
	2V	915-1830-1220-1830-1830-1830	188	0.648	1484	0.697	239	0.824	1714	0.805
	3V	1220-1830-1220-1830-1830-1830	157	0.543	1320	0.620	238	0.820	1675	0.787
	4V	1525-1830-1220-1830-1830-1830	128	0.441	1164	0.547	244	0.843	1632	0.767
	5V	1830-1830-1220-1830-1830-1830	105	0.361	1019	0.479	242	0.834	1582	0.743

* S - Standard spacing; V - Varied spacing

** The first number is the distance from the barrier/curb

Table M-2: Shear and Moment Results for Steel I-Beam Bridge

No. Trucks	Load Case*	Load Placement**	Exterior V (kN)	Exterior DF	Exterior M (kN-m)	Exterior DF	Interior V (kN)	Interior DF	Interior M (kN-m)	Interior DF
3	1S	610-1830-1220-1830-1220-1830	210	0.714	2088	0.825	313	1.064	2317	0.915
	2S	915-1830-1220-1830-1220-1830	182	0.619	1926	0.761	307	1.045	2272	0.898
	3S	1220-1830-1220-1830-1220-1830	157	0.535	1770	0.699	303	1.031	2227	0.880
	4S	1525-1830-1220-1830-1220-1830	133	0.451	1621	0.640	301	1.024	2176	0.860
	5S	1830-1830-1220-1830-1220-1830	108	0.367	1480	0.585	299	1.018	2120	0.838
	1V	610-1830-1220-1830-1830-1830	208	0.709	2044	0.807	298	1.014	2248	0.888
	2V	915-1830-1220-1830-1830-1830	181	0.617	1885	0.745	301	1.024	2212	0.874
	3V	1220-1830-1220-1830-1830-1830	157	0.533	1732	0.684	299	1.017	2170	0.857
	4V	1525-1830-1220-1830-1830-1830	132	0.449	1586	0.626	297	1.011	2123	0.839
	5V	1830-1830-1220-1830-1830-1830	108	0.366	1447	0.572	295	1.004	2070	0.818
4	1S	610-1830-1220-1830-1220-1830-1220-1830	209	0.712	2133	0.843	319	1.084	2549	1.007
	2S	915-1830-1220-1830-1220-1830-1220-1830	181	0.616	1962	0.775	312	1.060	2491	0.984
	3S	1220-1830-1220-1830-1220-1830-1220-1830	156	0.531	1797	0.710	307	1.042	2429	0.959
	4S	1525-1830-1220-1830-1220-1830-1220-1830	132	0.447	1641	0.648	304	1.034	2362	0.933
	5S	1830-1830-1220-1830-1220-1830-1220-1830	107	0.363	1494	0.590	302	1.026	2291	0.905
	1V	610-1830-1220-1830-1830-1830-1830-1830	207	0.705	2058	0.813	301	1.022	2419	0.955
	2V	915-1830-1220-1830-1830-1830-1830-1830	180	0.613	1894	0.748	303	1.031	2368	0.935
	3V-a	1220-1830-1220-1830-1830-1830-1220-1830	156	0.529	1746	0.690	302	1.026	2340	0.925
	3V-b	1220-1830-1220-1830-1830-1830-1830-1830	156	0.529	1737	0.686	301	1.024	2312	0.913
	4V-a	1525-1830-1220-1830-1830-1830-1220-1830	131	0.445	1595	0.630	299	1.018	2279	0.900
	4V-b	1525-1830-1220-1830-1830-1830-1830-1830	131	0.445	1588	0.627	299	1.016	2252	0.890
	5V-a	1830-1830-1220-1830-1830-1830-1220-1830	106	0.362	1452	0.574	297	1.011	2212	0.874
	5V-b	1830-1830-1220-1830-1830-1830-1830-1830	106	0.362	1448	0.572	297	1.009	2187	0.864

* S - Standard spacing; V - Varied spacing

** The first number is the distance from the barrier/curb

Table M-3: Percent Differences Between Standard and Varied Load Configurations (Bulb-Tee Beam)

No. Trucks	Load Case		Exterior V	Exterior M	Interior V	Interior M
3	1S	1V	0.23%	1.63%	1.60%	3.56%
	2S	2V	0.19%	1.34%	1.25%	3.38%
	3S	3V	0.23%	0.78%	1.26%	3.24%
	4S	4V	0.28%	0.20%	1.22%	3.12%
	5S	5V	0.34%	0.15%	1.24%	3.04%

Table M-4: Percent Differences Between Standard and Varied Load Configurations (Steel I-Beam)

No. Trucks	Load Case		Exterior V	Exterior M	Interior V	Interior M
3	1S	1V	0.78%	2.13%	4.77%	2.97%
	2S	2V	0.39%	2.14%	2.03%	2.67%
	3S	3V	0.30%	2.16%	1.35%	2.56%
	4S	4V	0.35%	2.19%	1.35%	2.45%
	5S	5V	0.43%	2.21%	1.36%	2.37%
4	1S	1V	0.94%	3.55%	5.66%	5.14%
	2S	2V	0.51%	3.48%	2.71%	4.96%
	3S	3V-a	0.34%	2.88%	1.59%	3.64%
		3V-b	0.37%	3.37%	1.77%	4.80%
	4S	4V-a	0.39%	2.84%	1.53%	3.52%
		4V-b	0.42%	3.24%	1.72%	4.64%
	5S	5V-a	0.48%	2.79%	1.54%	3.43%
		5V-b	0.50%	3.08%	1.70%	4.51%

Summary and Conclusions

In this study, the sensitivity of live load shear and moment distribution factors due to standard and varied vehicle spacing is studied for two bridge superstructures using the grillage analogy method of analysis. The conclusions are as follows:

- The difference between the standard and varied vehicle spacing is less than 6% for all cases considered.
- These differences become even smaller when considering more localized load effects, such as shear.
- More conservative results are obtained when the standard load configuration is used.
- The interior girder is more affected by the vehicle spacing than the exterior girder.
- In general, live load distribution factors are relatively insensitive to different vehicle spacings for both the exterior and interior girders.