COMPARISON OF LFR AND LRFR FOR CONCRETE BRIDGES

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ABSTRACT

NCHRP Project 12-46 has provided a specification for the rating of bridges that is based upon load and resistance factor methods (LRFR). This work was recently adopted by AASHTO as a guide specification. With the use of data obtained from AASHTO's Virtis Load Rating System, several concrete bridges have been analyzed and rated with the current and new methods using the traditional notional loads (HS20 and HL-93), standard AASHTO rating vehicles, and typical permit vehicles. The engineering process, comparison of findings, and observed trends are outlined. This work is relevant to national policy development associated with the long-term adoption of this new specification.

Keywords: LRFD Specifications (Transitions; Comparisons; Bridge Rating)

INTRODUCTION

For years, engineers have been designing and rating bridges according to AASHTO's *Standard Specifications for Highway Bridges*[1] and the *Manual for Condition Evaluation of Bridges*[2], respectively. These manuals are based on allowable stress and load factor methods. Then, in 1994, AASHTO published the *LRFD Bridge Design Specifications*[3], which is based upon load and resistance factor methods (LRFD). Since that time, engineers have anticipated a corresponding load and resistance factor rating specification (LRFR). In 2001, NCHRP Project 12-46[4] provided a specification for the rating of bridges that is based upon this state-of-the-art method. Most importantly, this work was recently adopted by AASHTO as a *guide* specification.

One of the most challenging tasks facing departments of transportation (DOT) and engineering firms will be to transition from rating by LFR methods to LRFR methods. Before agencies move entire rating operations to the LRFR method, they must be confident that the new LRFR ratings are reasonable, even if they are different from previous LFR ratings. Therefore, comparisons must be made between rating results obtained using the LFR and LRFR methods for a number of bridges.

Reinforced concrete bridge data was obtained from AASHTO's Virtis® Load Rating System[5]. These bridges have been analyzed and rated using the current LFR and new LRFR methods for a number of transient loads that include traditional notional loads (HS20 and HL-93), standard AASHTO rating vehicles, and typical permit vehicles. The engineering process, comparison of findings, and observed trends are outlined. The purpose of this study is to examine the similarities and differences between the rating results from the two rating methods, not to imply that one method is more correct than the other. This study is relevant to national policy development associated with the long-term adoption of this new LRFR specification.

ENGINEERING PROCESS

This study began by obtaining a sample of actual bridges and vehicles. BRASS™ (Bridge Rating and Analysis of Structural Systems) analysis engines, licensed by the Wyoming Department of Transportation, were utilized to analyze and rate these bridges with the LFR and LRFR methods. The results from each method were then compared and any trends were noted.

SAMPLE OF BRIDGES

A sample of *real* reinforced concrete T-beam bridges was obtained from AASHTO's Virtis Load Rating System. These simple- and continuous-span bridges were submitted by various agencies around the United States and are used in the validation of this system. Virtis is basically a database (fronted by a user interface) that contains the general description of a bridge, which includes materials, cross sections, span lengths, loads, etc. This general description is independent of any analysis process (engine) or specification. Virtis relies on *external* third-party engines to perform the structural analysis and associated ratings. Currently, there are two engines available for performing the analyses required for this study: BRASS-GIRDER™ [6] and BRASS-GIRDER(LRFD)™ [7]. The BRASS-GIRDER engine performs load factor ratings, while the BRASS-GIRDER(LRFD) engine performs load and resistance factor ratings.

Virtis was utilized to generate (export) data files necessary for analyzing each bridge with the two BRASS engines. The BRASS engines analyze each girder line within a bridge cross section separately with the aid of live load distribution factors either supplied by the user or automatically generated. Therefore, Virtis generally exports a minimum of one exterior girder line and one interior girder line. In many cases, the right exterior girder is identical to the left exterior girder, so only one of them is exported. Interior girders may be identical as well. BRASS considers each girder line as a separate bridge, so the term *girder line* may be used synonymously with *bridge* throughout the rest of this paper. Table 1 lists the number of spans and girder location associated with each girder line, which is given a unique bridge identifier.

Table 1 Bridge Descriptions

Bridge ID	**Number of Spans**	**Girder Location**
2001	1	Exterior
2002	1	Interior
2008	3	Exterior
2009	3	Interior
2010	3	Exterior
2011	3	Interior
2012	3	Exterior
2013	3	Interior
2014	4	Exterior
2015	4	Interior
2018	1	Interior
2020	1	Interior
2021	1	Interior
2022	1	Interior
2024	3	Interior
2025	3	Interior
2029	1	Interior
2030	1	Interior
2031	3	Interior
2032	3	Interior
2035	3	Interior
2036	3	Interior
2039	3	Exterior
2040	3	Interior

LOADS

Several transient loads were analyzed in this study. The traditional HS20 loads and the notional HL-93 loads were analyzed for LFR and LRFR, respectively. Additionally, standard AASHTO rating vehicles and typical permit vehicles were analyzed for both rating methods. Table 2 shows the array of vehicles analyzed in this study. Note that the legal and permit lane loads are only applicable to LRFR.

Table 2 Analysis Vehicles

Live Load Groups	Load Types	Live Loads
Design	HS20	Truck
		Lane
	HL-93	Design Truck
		Design Tandem
		Design Truck Train
		Design Lane
		Fatigue Truck
Legal	AASHTO Type	Type 3
		Type 3-3
		Type 3S2
	Lane	Legal Lane
Permit	CalTrans P-Loads[8]	P7
		P11
	Lane	Permit Lane

RATING FACTORS

The focus of this study is to examine the rating results from the two rating methods and establish the reason or reasons why the rating factors are different. For reinforced concrete bridges, various strength and service limit states are applicable to rating. Both BRASS engines calculate rating factors for flexure and shear, but only the BRASS-GIRDER(LRFD) engine calculates rating factors for shear friction, crack control, and deflection. Therefore, only *flexure* and *shear* results are investigated in this study.

The general LRFR and LFR rating factor equations, shown below respectively, consist of three basic components: factored resistance, factored dead load, and factored live load.

$$RF_{LRFR} = \frac{\phi_c \phi_s \phi R_n - \gamma_{DC} DC - \gamma_{DW} DW}{\gamma_L LL(1 + IM)} \tag{1}$$

$$RF_{LFR} = \frac{\phi R_n - \gamma \beta_D D}{\gamma \beta_L LL(1 + I)} \tag{2}$$

Although the format of the equations is similar, the composition of each component differs between the LRFR and LFR methods. Each component is now discussed.

Factored Resistance

The factored resistance component of the LRFR rating factor equation contains condition (ϕ_c) and system (ϕ_s) resistance factors, which are not present in the LFR equation. Because condition information for the bridges was not available, ϕ_c was assumed as 1.0. All of the bridges were sufficiently redundant to warrant a ϕ_s of 1.0 also. The primary resistance factors utilized in this study are shown in Table 3. Because the shear resistance factor is slightly higher for LRFR than LFR, higher shear rating factors are expected for LRFR.

Table 3 Resistance Factors

	LRFR	LFR
Flexure	0.90	0.90
Shear	0.90	0.85

Factored Dead Load

The factored dead load component differs between the two methods. The LRFR method, unlike the LFR method, assigns separate dead load factors to component (DC) and wearing surface (DW) loads. Wearing surface dead loads have a higher degree of variability than component dead loads, so dead load factors are assigned accordingly. Additionally, LRFR specifies that maximum and minimum values of the dead load factors be utilized to determine the critical load effect. The dead load factors utilized in this study are shown in Table 4.

Table 4 Dead Load Factors

Limit State	γ_{DC}		γ_{DW}		$\gamma\beta_D$
	Max	**Min**	**Max**	**Min**	
STRENGTH-I	1.25	0.90	1.50	0.65	1.30
STRENGTH-II	1.25	0.90	1.50	0.65	1.30

Factored Live Load

The factored live load component also differs between the two methods. The live load factors for the LRFR method vary depending on the type of vehicle. Additionally, the impact factors differ between the two methods. The LRFR dynamic load allowance (IM) is generally a fixed value, but may be reduced depending on the surface roughness of the roadway and the speed of the vehicle. The LFR impact factor (I) is determined from an equation in which the impact factor decreases as span length increases. The live load and impact factors utilized in this study are shown in Table 5. The Strength-I live load factors for LRFR are about 20% lower than the factor for the LFR method, while the Strength-II live load factors are comparable.

Table 5 Live Load and Impact Factors

Limit State	γ_L			**IM (DLA)**	$\gamma\beta_L$	I
	Design	**Legal**	**Permit**			
STRENGTH-I	1.75	1.75	N/A	0.33	2.17	Varies ($\leq$ 0.30)
STRENGTH-II	1.35	N/A	1.30		1.30	

The factored live load is also influenced by the distribution factors. The LRFD specifications introduced new formulas for determining live load distribution factors. Although these equations are undoubtedly more complex than the “S over” formulas of the Standard specifications, they result in more accurate live load distribution factors. The distribution factors for the bridges in this study were calculated according to the LRFD specifications for LRFR and by the Standard specifications for LFR.

Another important aspect of the factored live load is the difference between the HL-93 and HS20 load models. The HL-93 axle vehicles are combined with the design lane, which may result in a heavier live load when compared to the HS20 truck or lane.

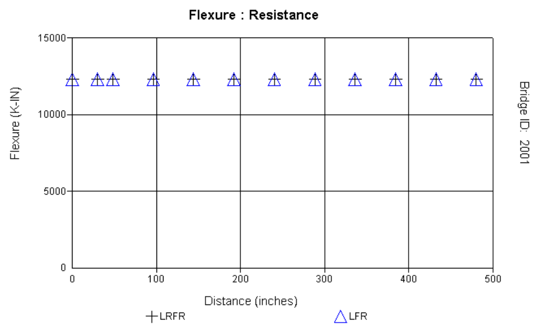
ANALYSIS

The sample of bridges from Table 1 were analyzed and rated using the current LFR and new LRFR methods for the vehicles from Table 2. Each BRASS engine generates a host of results that include dead load actions, live load actions, section resistances, and rating factors, which are written to output files using a method developed in NCHRP Project 12-50[9]. In this method, a unique number, dubbed a *report ID*, is assigned to each type of value from an engine or process (hand computation, spreadsheet, etc.). For every analysis location along the girder line, the report ID, its associated value, and the location along the girder are written to an output file along with IDs indicating the vehicle and limit state. Each engine generates this file for each bridge. Once the result files were generated for the bridges, the results were imported into a database for comparison.

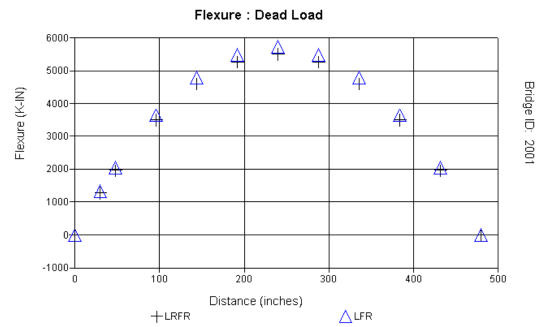
COMPARISON OF FINDINGS

The rating results were stored in a relational database, which could be filtered by the bridge ID, report ID, live load group, and limit state to obtain subsets of results. In most instances, the rating factors obtained from the LRFR and LFR methods were different, but to varying degrees. Therefore, it was necessary to evaluate each component from the general rating factor equation *separately* to determine the source of the difference. A graphical comparison method was found to be a useful tool for identifying the component or components that contributed to the difference.

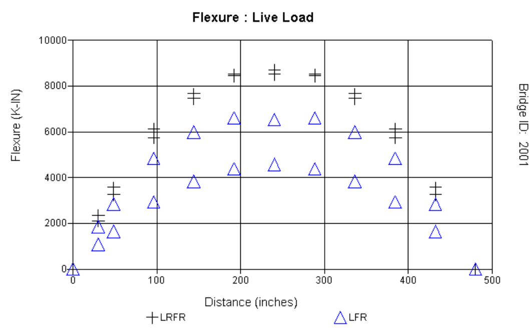
Graphical comparisons are shown in Fig. 1 through Fig. 4 for flexure and Fig. 5 through Fig. 8 for shear. These figures illustrate the factored resistances, factored dead loads, factored live loads, and rating factors for LRFR versus LFR along the length of the girder for a select group of bridges. These bridges were chosen to demonstrate an exterior and interior girder for simple and continuous span bridges. Refer to Table 1 for the number of spans and girder locations associated with a bridge. Within each figure, eight comparison plots are presented: (a) Factored Resistance, (b) Factored Dead Load, (c) Factored Live Load – Design, (d) Rating Factor – Design, (e) Factored Live Load – Legal, (f) Rating Factor – Legal, (g) Factored Live Load – Permit, and (h) Rating Factor – Permit. Because multiple live loads are assigned to the same live load group, some plots contain multiple data points at the same location along the girder.



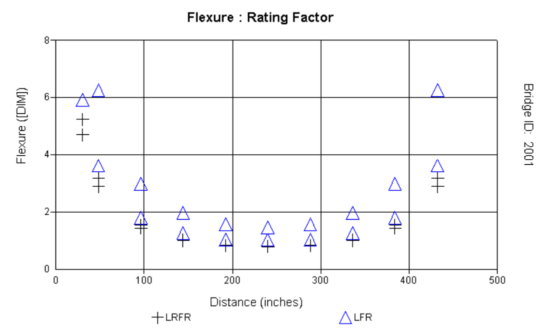
(a) Factored Resistance



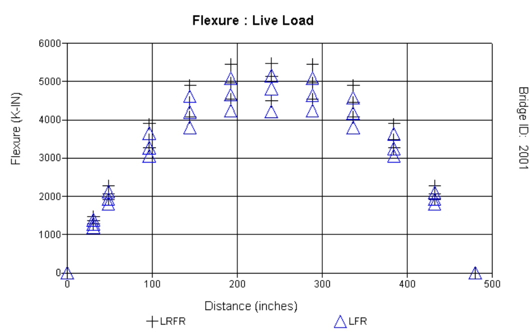
(b) Factored Dead Load



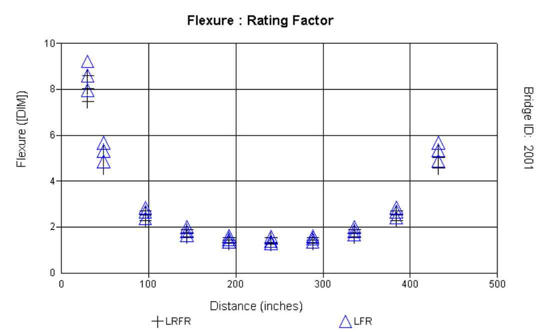
(c) Factored Live Load - Design



(d) Rating Factor - Design



(e) Factored Live Load - Legal



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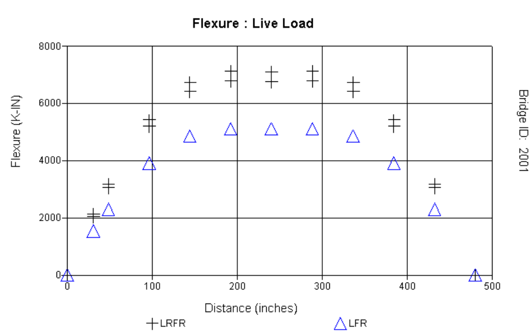
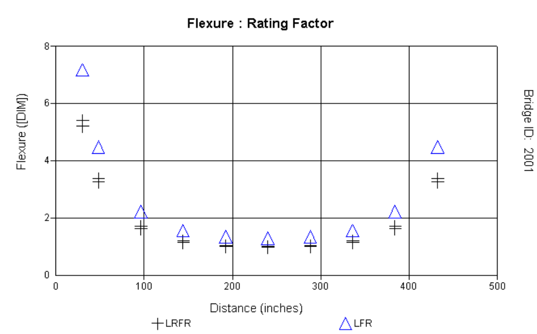
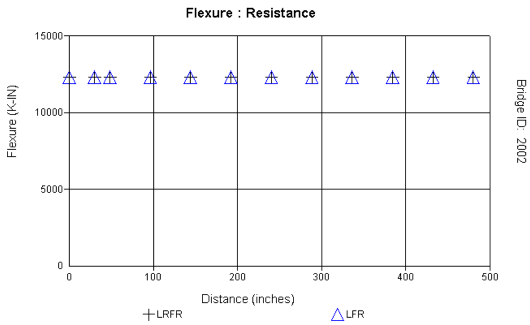


(g) Factored Live Load - Permit

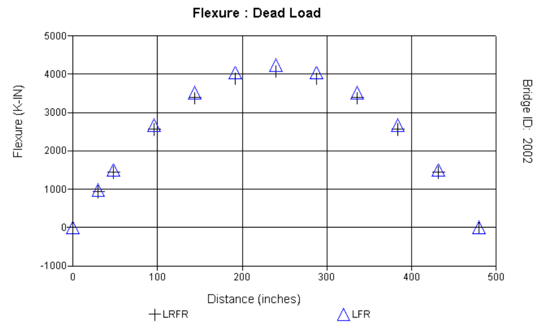


(h) Rating Factor - Permit

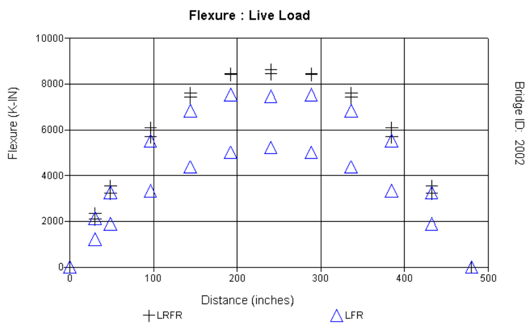
Fig. 1 LRFR vs. LFR for Flexure (Bridge ID 2001)



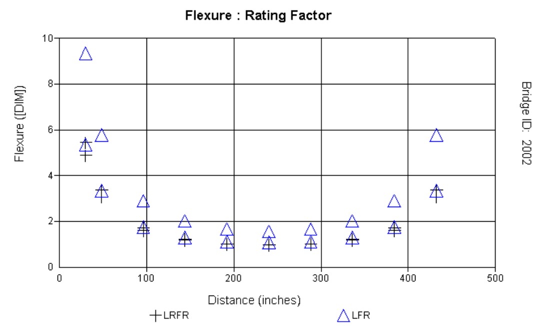
(a) Factored Resistance



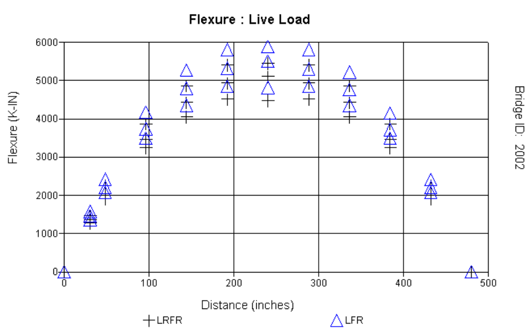
(b) Factored Dead Load



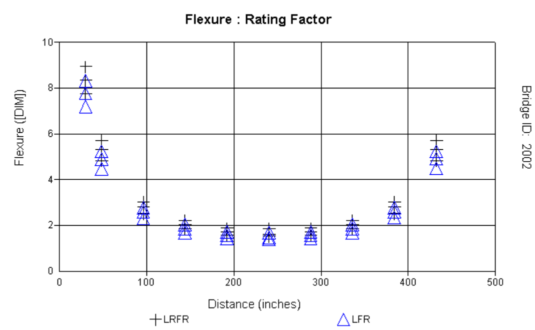
(c) Factored Live Load - Design



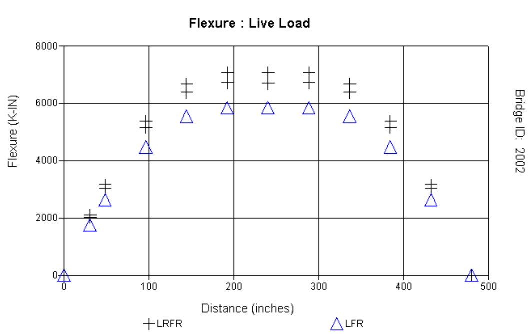
(d) Rating Factor - Design



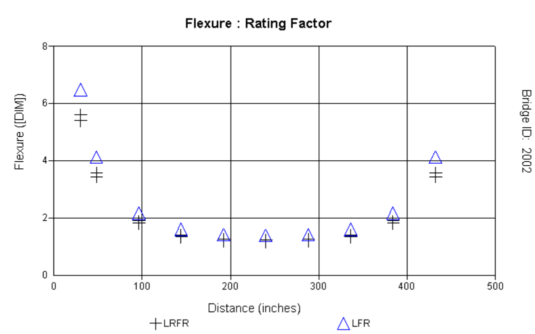
(e) Factored Live Load - Legal



(f) Rating Factor – Legal

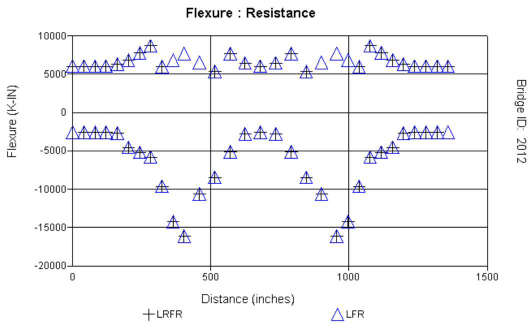


(g) Factored Live Load - Permit

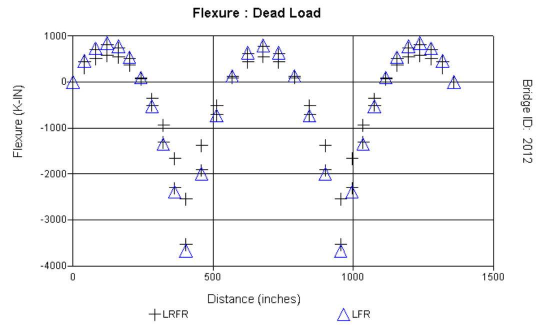


(h) Rating Factor - Permit

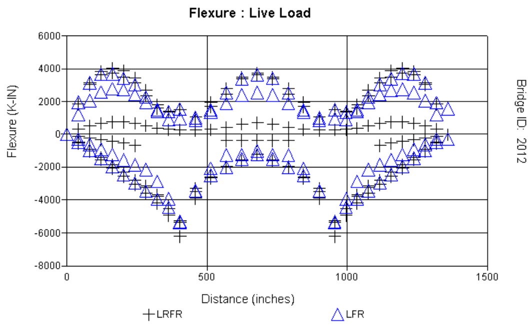
Fig. 2 LRFR vs. LFR for Flexure (Bridge ID 2002)



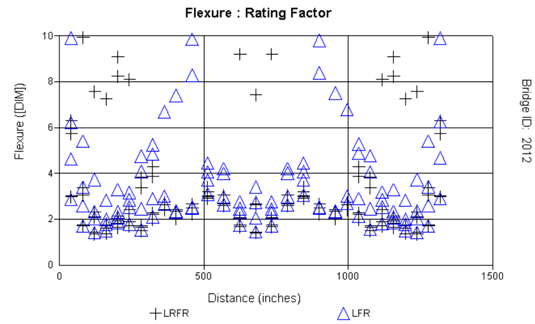
(a) Factored Resistance



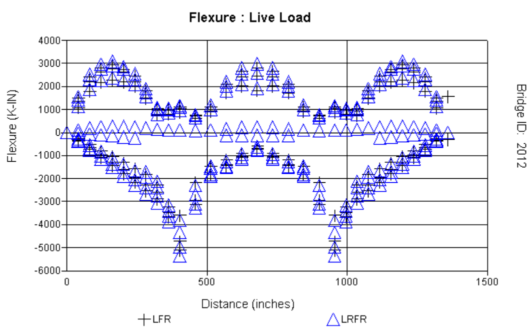
(b) Factored Dead Load



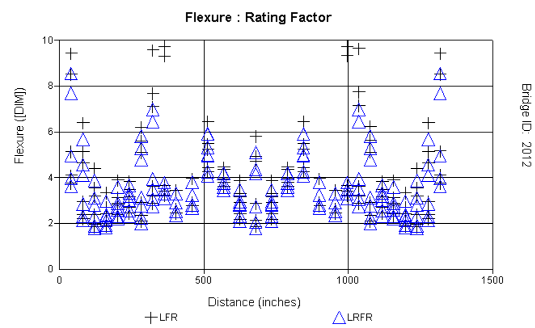
(c) Factored Live Load - Design



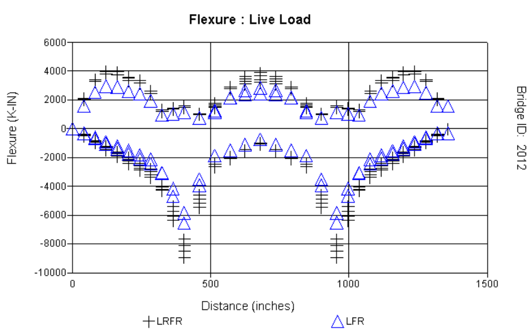
(d) Rating Factor - Design



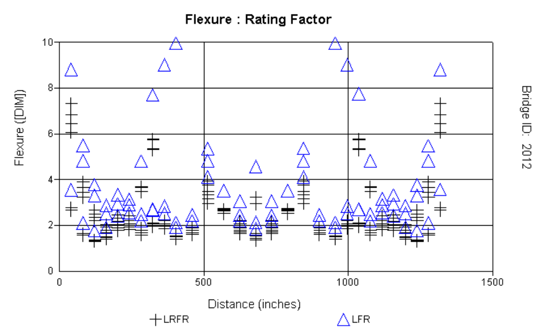
(e) Factored Live Load - Legal



(f) Rating Factor - Legal

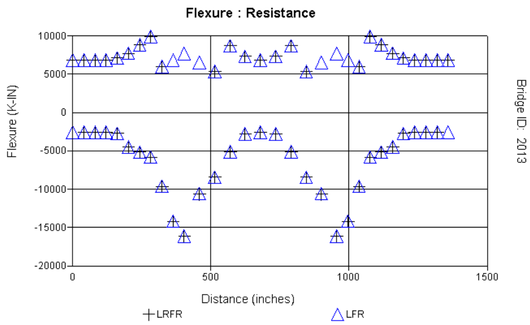


(g) Factored Live Load - Permit

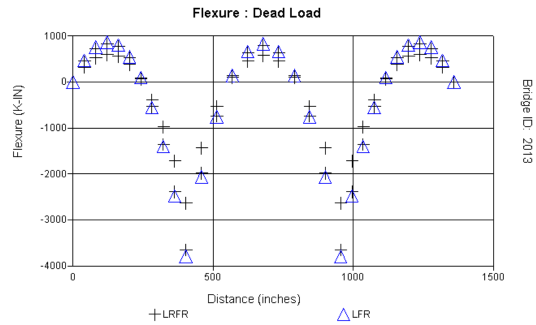


(h) Rating Factor - Permit

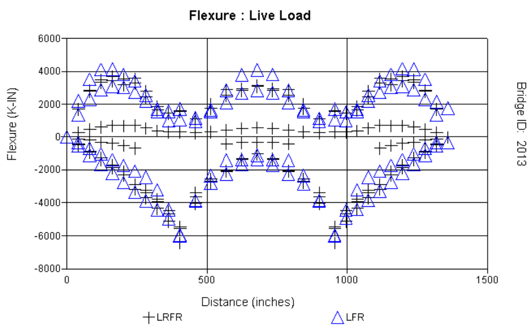
Fig. 3 LRFR vs. LFR for Flexure (Bridge ID 2012)



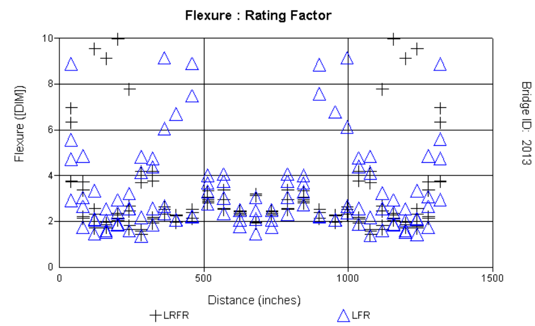
(a) Factored Resistance



(b) Factored Dead Load



(c) Factored Live Load - Design



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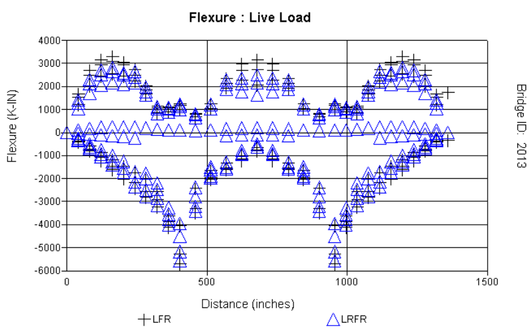
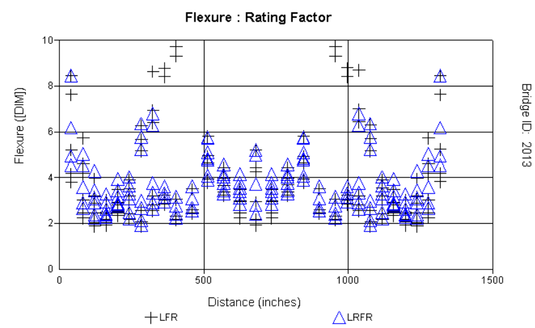


(e) Factored Live Load - Legal



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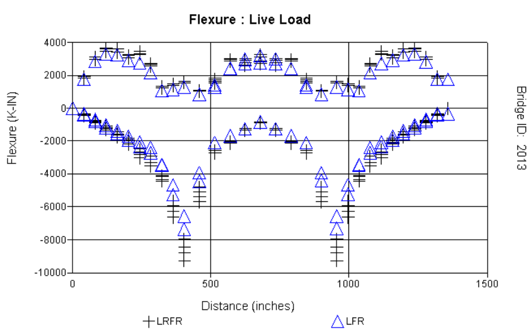
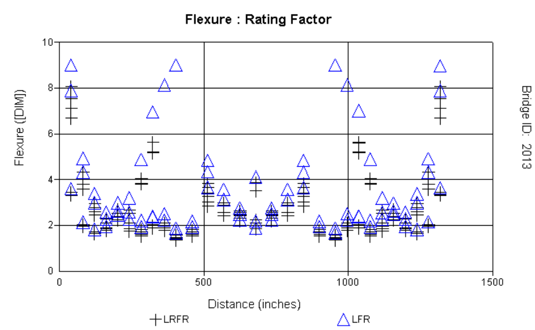
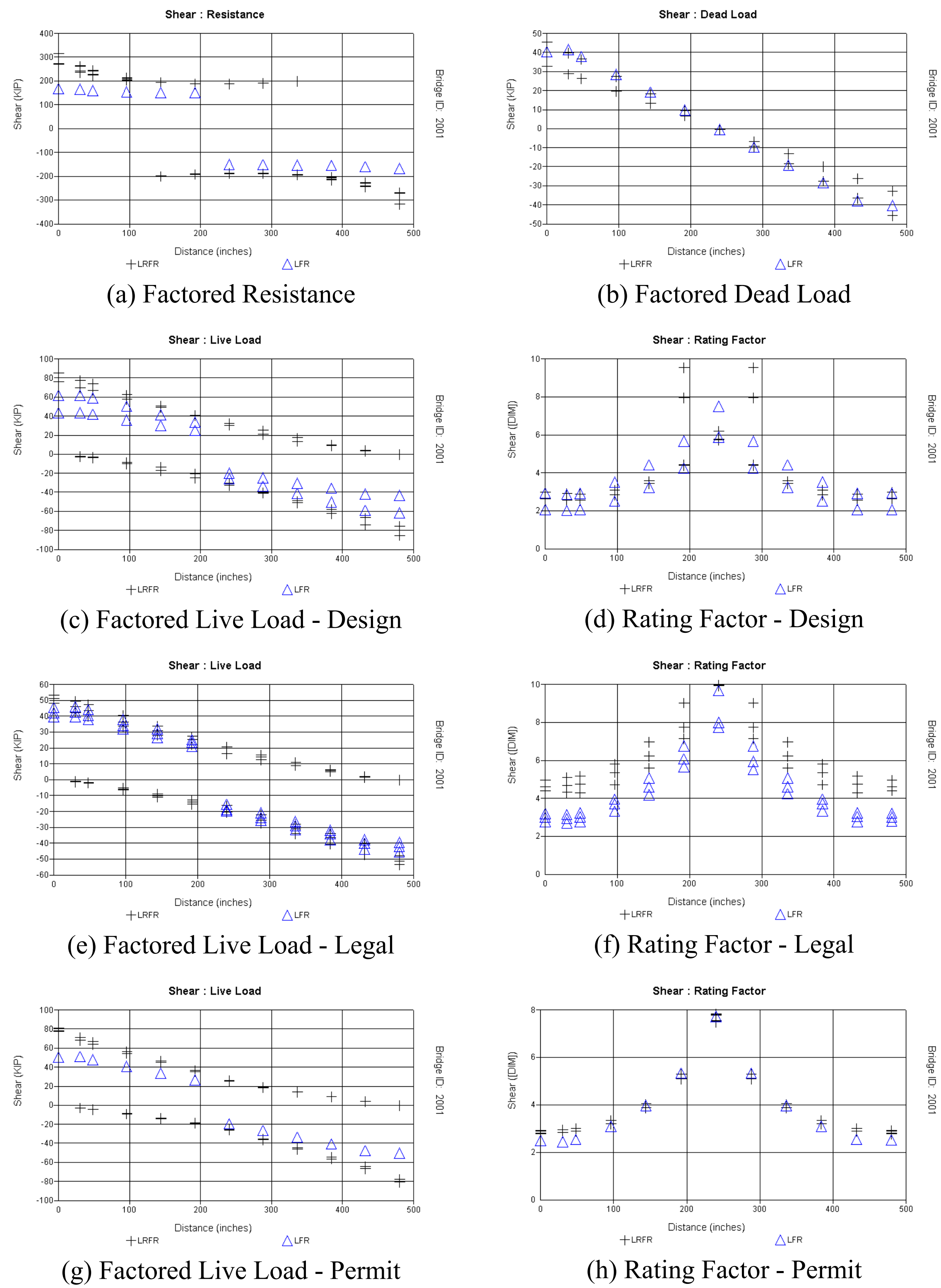


(g) Factored Live Load - Permit



(h) Rating Factor - Permit

Fig. 4 LRFR vs. LFR for Flexure (Bridge ID 2013)



(a) Factored Resistance

(b) Factored Dead Load

(c) Factored Live Load - Design

(d) Rating Factor - Design

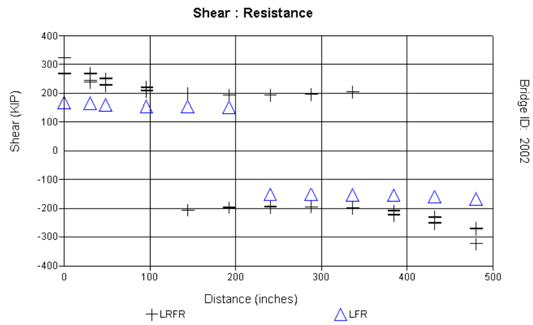
(e) Factored Live Load - Legal

(f) Rating Factor - Legal

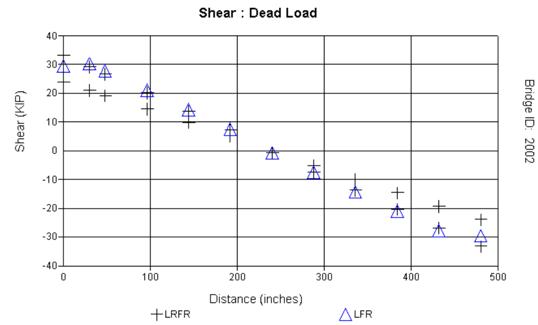
(g) Factored Live Load - Permit

(h) Rating Factor - Permit

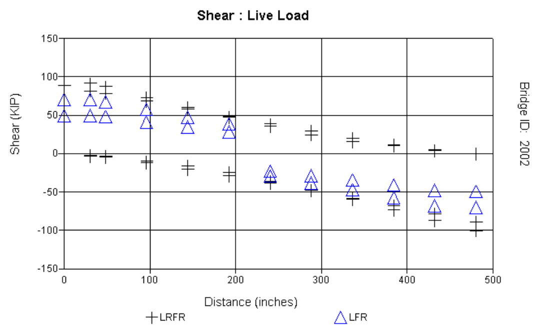
Fig. 5 LRFR vs. LFR for Shear (Bridge ID 2001)



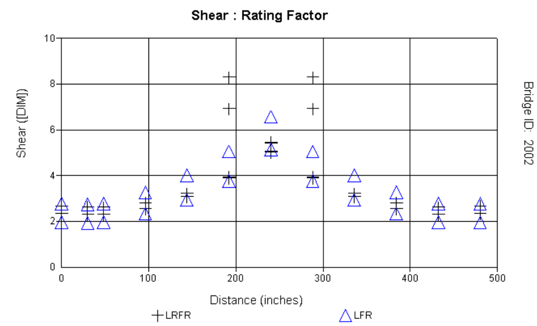
(a) Factored Resistance



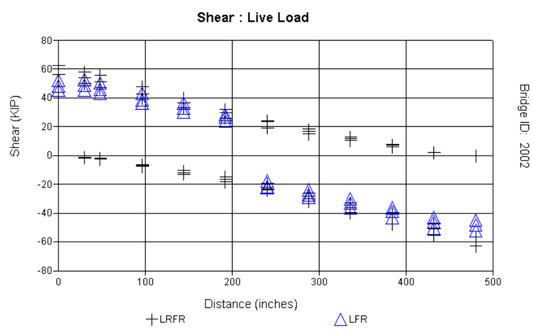
(b) Factored Dead Load



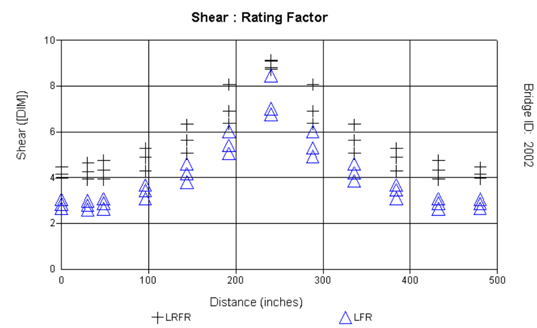
(c) Factored Live Load - Design



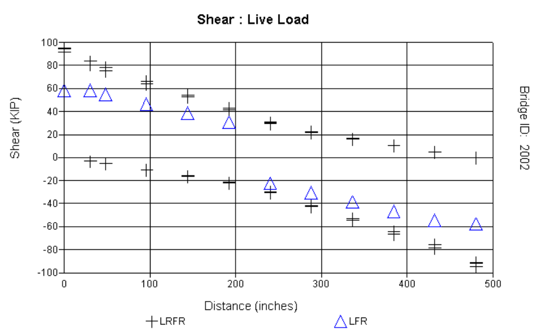
(d) Rating Factor - Design



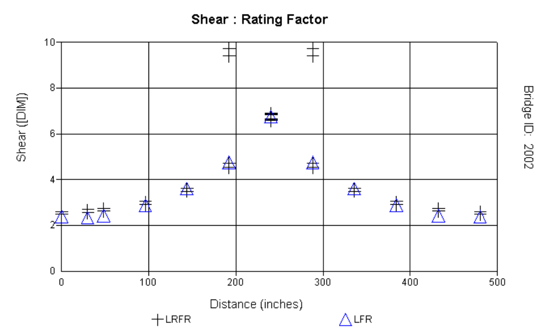
(e) Factored Live Load - Legal



(f) Rating Factor - Legal

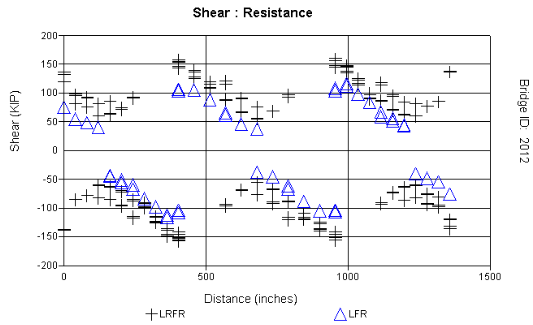


(g) Factored Live Load - Permit

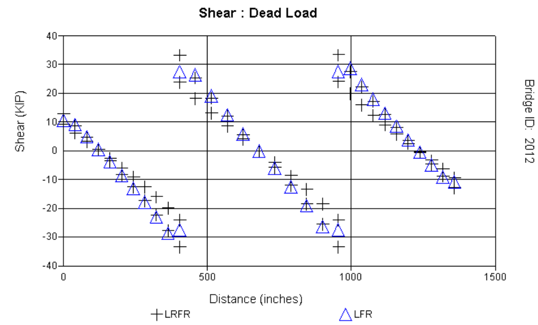


(h) Rating Factor - Permit

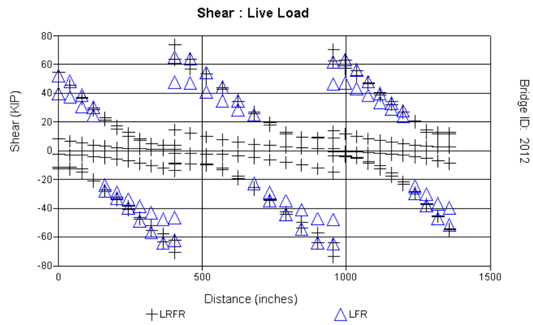
Fig. 6 LRFR vs. LFR for Shear (Bridge ID 2002)



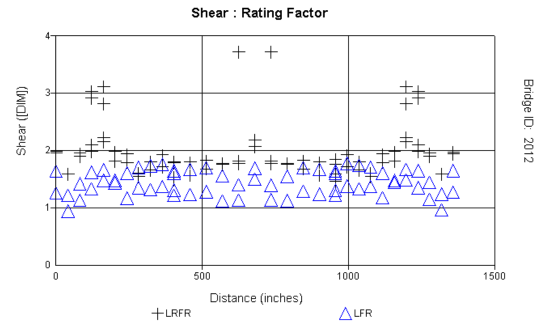
(a) Factored Resistance



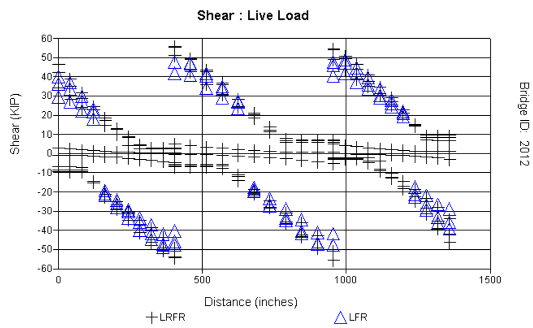
(b) Factored Dead Load



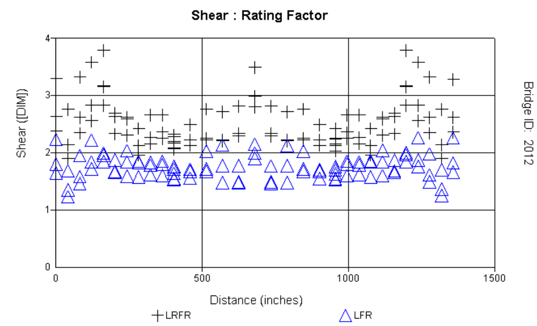
(c) Factored Live Load - Design



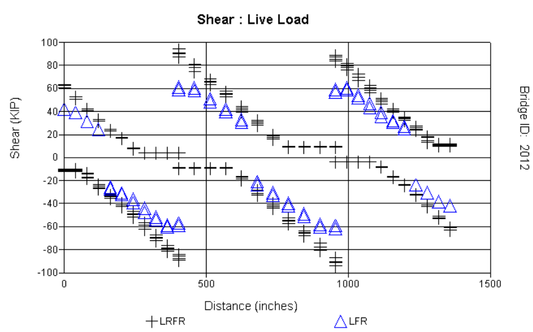
(d) Rating Factor - Design



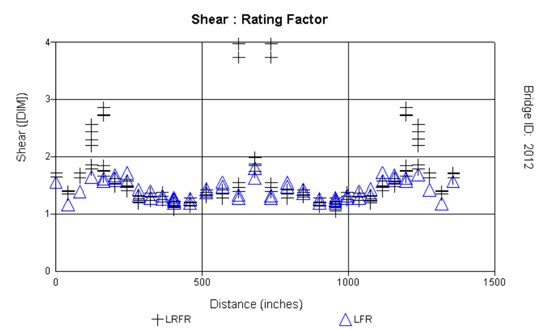
(e) Factored Live Load - Legal



(f) Rating Factor - Legal

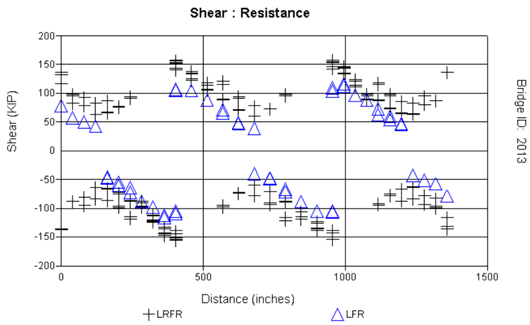


(g) Factored Live Load - Permit

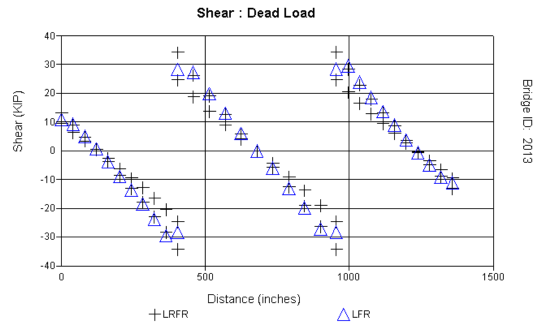


(h) Rating Factor - Permit

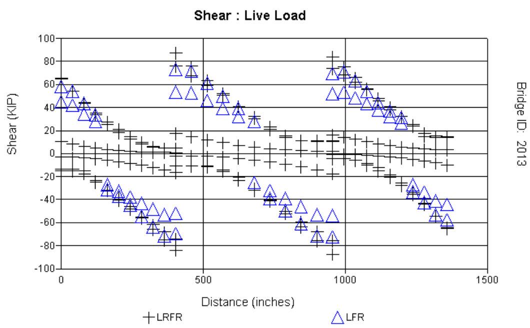
Fig. 7 LRFR vs. LFR for Shear (Bridge ID 2012)



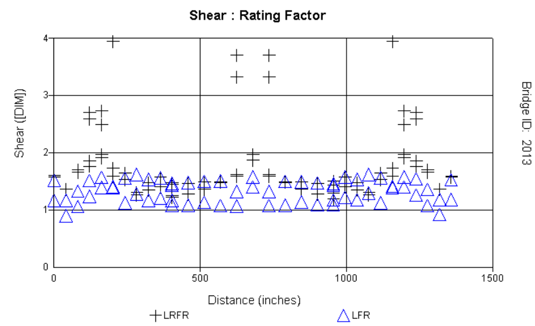
(a) Factored Resistance



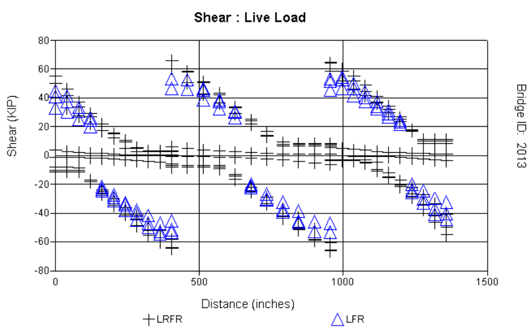
(b) Factored Dead Load



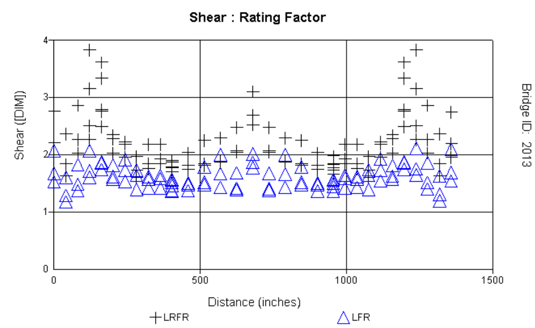
(c) Factored Live Load - Design



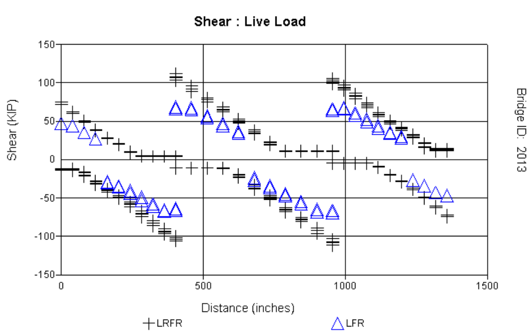
(d) Rating Factor - Design



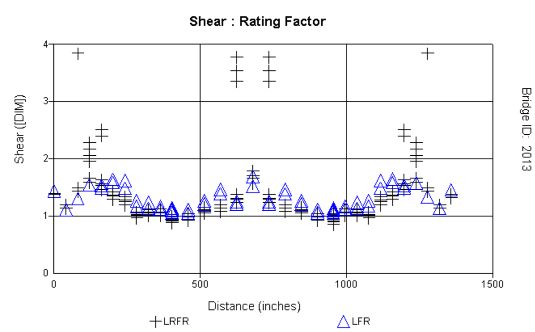
(e) Factored Live Load - Legal



(f) Rating Factor - Legal



(g) Factored Live Load - Permit



(h) Rating Factor - Permit

Fig. 8 LRFR vs. LFR for Shear (Bridge ID 2013)

FLEXURE

The LRFR rating factors for flexure were higher or lower than LFR depending on the live load group. The LRFR factored resistances for flexure were identical to those from LFR, and the LRFR factored dead load moments were nearly the same as those from LFR. Thus, the slight difference between the dead load factors did not influence the change in the rating factors. Therefore, the source of the difference lies within the factored live load component of the rating factor equation. The different live load factors, impact factors, and distribution factors as well as the heavier HL-93 load combinations each contributed to the difference in the rating factors.

Table 6 summarizes the LRFR and LFR rating factors for flexure for each live load group. The critical LFR rating factor was determined first, and then the corresponding LRFR rating factor was established. Additionally, the ratio of the LRFR rating factor to the LFR rating factor is recorded.

Table 6 Rating Factors for Flexure (LRFR vs. LFR)

Bridge ID	Design (Strength I)			Legal (Strength I)			Permit (Strength II)		
	LRFR	LFR	Ratio	LRFR	LFR	Ratio	LRFR	LFR	Ratio
2001	0.78	1.01	0.77	1.24	1.28	0.97	0.96	1.29	0.74
2002	0.95	1.08	0.88	1.51	1.37	1.10	1.17	1.38	0.84
2008	1.30	1.55	0.84	1.79	2.12	0.84	1.18	1.82	0.65
2009	1.66	1.25	1.32	2.07	1.62	1.27	1.44	1.45	1.00
2010	1.88	2.78	0.67	2.97	3.51	0.85	2.40	3.65	0.66
2011	1.86	1.96	0.95	2.94	2.47	1.19	2.20	2.57	0.85
2012	1.36	1.40	0.97	1.76	1.84	0.96	1.30	1.76	0.74
2013	1.43	1.36	1.05	1.91	1.87	1.03	1.34	1.67	0.80
2014	1.01	1.00	1.00	1.25	1.29	0.96	0.62	0.85	0.74
2015	1.25	1.16	1.08	1.52	1.46	1.04	0.76	0.95	0.80
2018	1.38	1.51	0.91	2.16	1.91	1.13	1.70	1.96	0.87
2020	1.23	1.39	0.89	2.05	1.73	1.18	1.63	1.77	0.92
2021	1.03	0.94	1.10	1.66	1.17	1.41	1.34	1.23	1.09
2022	1.25	1.42	0.88	2.03	1.88	1.08	1.30	1.55	0.84
2024	0.82	1.02	0.81	1.13	1.05	1.07	0.72	0.88	0.82
2025	0.73	1.03	0.71	1.23	1.33	0.92	0.76	1.08	0.70
2029	1.25	1.67	0.75	2.07	2.22	0.93	1.32	1.83	0.72
2030	0.90	1.01	0.89	1.49	1.34	1.11	0.95	1.11	0.85
2031	1.17	1.37	0.86	2.11	1.79	1.18	0.98	1.22	0.81
2032	1.41	1.77	0.80	2.56	2.36	1.09	1.26	1.69	0.74
2035	1.17	1.37	0.86	2.11	1.79	1.18	0.98	1.22	0.81
2036	1.41	1.77	0.80	2.56	2.36	1.09	1.26	1.69	0.74
2039	1.06	5.00	0.21	1.79	6.74	0.27	0.98	3.77	0.26
2040	1.45	1.43	1.01	2.03	1.71	1.19	1.12	1.24	0.90
Avg.			0.88			1.04			0.79

Fig. 9 compares the rating factors graphically. The diagonal baseline represents the ideal case where the LRFR and LFR rating factors are the same. Data points above the line (Ratio > 1) indicate that LRFR allows heavier live loads on a particular bridge, while data points below the line (Ratio < 1) indicate that LFR allows heavier live loads. Although some of the data points are located far from the baseline, these results are explainable. These outlying data points are associated with exterior girders where distribution factors are controlled by the lever-rule method for LFR or the rigid method for LRFR. Additionally, the curb extends from the left edge of the deck to or even past the left exterior girder. This configuration causes low LFR distribution factors to be calculated for the exterior girder. Also, the LRFR distribution factors controlled by the rigid method are generally larger than those calculated from the lever-rule method.

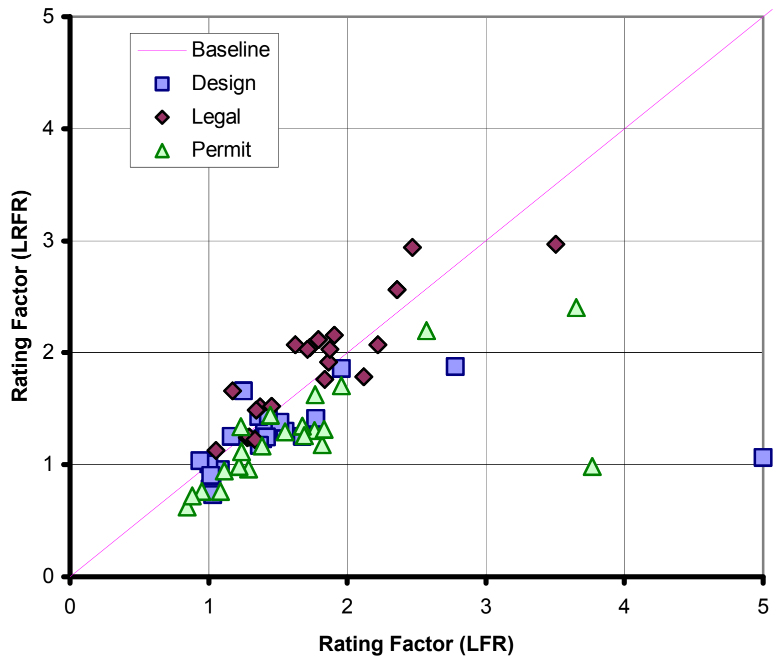


Fig. 9 LRFR vs. LFR (Flexure)

Fig. 10 illustrates how often a particular range of flexure rating factor ratios from Table 6 occurs. This *frequency* is indicated separately for each live load group.

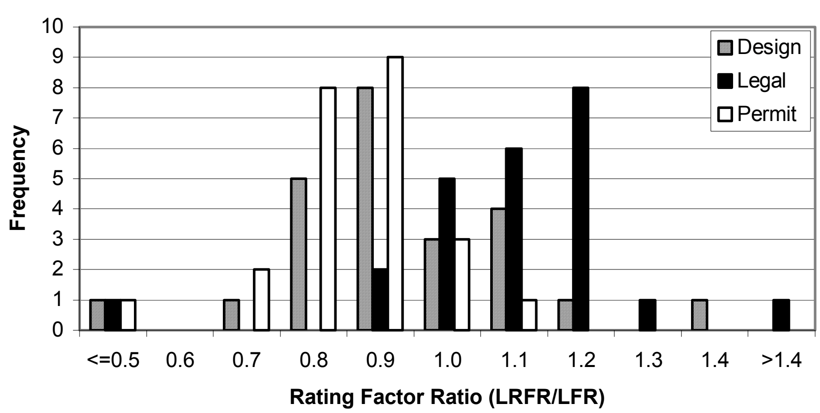


Fig. 10 Frequencies of Rating Factor Ratios (Flexure)

SHEAR

The LRFR rating factors for shear were generally higher than LFR regardless of the live load group. The LRFR factored resistances for shear were always higher than LFR for two reasons. First, LRFR used a slightly higher resistance factor than LFR. Second, the LRFR shear resistance is based on the Modified Compression Field Theory (MCFT), which results in larger resistances than those from the Standard specifications. The LRFR factored dead load shears were nearly the same as those from LFR. Again, the slight difference between the dead load factors did not influence the change in the rating factors. Another source of the difference lies within the factored live load component of the rating factor equation. The different live load factors, impact factors, and distribution factors as well as the heavier HL-93 load combinations each contributed to the difference in the rating factors.

Table 7 summarizes the LRFR and LFR rating factors for shear for each live load group. The shear rating factors for some bridges were not applicable (n/a) because the engineer who defined the bridge in Virtis chose to ignore shear. The critical LFR rating factor was determined first, and then the corresponding LRFR rating factor was established. Additionally, the ratio of the LRFR rating factor to the LFR rating factor is recorded.

Table 7 Rating Factors for Shear (LRFR vs. LFR)

Bridge ID	Design (Strength I)			Legal (Strength I)			Permit (Strength II)		
	LRFR	LFR	Ratio	LRFR	LFR	Ratio	LRFR	LFR	Ratio
2001	2.54	2.02	1.26	4.31	2.71	1.59	2.83	2.44	1.16
2002	2.30	1.92	1.20	3.92	2.59	1.52	2.57	2.33	1.10
2008	2.08	0.26	7.90	2.76	0.43	6.43	1.14	0.81	1.40
2009	1.63	0.16	10.05	2.18	0.25	8.74	0.87	0.58	1.51
2010	1.80	1.42	1.26	2.94	1.86	1.59	1.82	1.79	1.02
2011	1.32	0.91	1.46	2.06	1.24	1.66	1.25	1.22	1.03
2012	1.59	0.94	1.69	1.90	1.23	1.55	1.34	1.16	1.15
2013	1.36	0.90	1.52	1.63	1.17	1.39	0.93	1.05	0.89
2014	1.59	1.00	1.60	2.25	1.31	1.71	0.88	1.03	0.86
2015	1.65	1.15	1.43	2.32	1.52	1.52	0.93	1.19	0.77
2018	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2020	0.71	0.58	1.23	1.21	0.77	1.58	0.81	0.72	1.11
2021	1.40	1.05	1.34	2.30	1.37	1.68	1.59	1.30	1.22
2022	1.45	1.10	1.32	2.85	1.47	1.94	1.66	1.20	1.39
2024	0.56	0.57	0.97	0.96	0.74	1.30	0.55	0.61	0.90
2025	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2029	1.50	1.61	0.93	2.54	2.14	1.18	1.51	1.75	0.86
2030	1.11	0.94	1.18	1.91	1.26	1.52	1.12	1.03	1.09
2031	1.09	0.47	2.31	1.98	0.64	3.11	0.91	0.74	1.24
2032	1.42	0.82	1.72	2.53	1.11	2.28	1.20	1.23	0.98
2035	1.09	0.47	2.31	1.98	0.64	3.11	0.91	0.74	1.24
2036	1.42	0.82	1.72	2.53	1.11	2.28	1.20	1.23	0.98
2039	1.56	4.38	0.36	2.26	5.15	0.44	1.02	3.79	0.27
2040	1.02	0.91	1.13	1.95	1.24	1.57	0.99	0.97	1.02
Avg.			2.08			2.26			1.05

Fig. 11 compares the rating factors graphically using the same method as discussed for flexure. The outlying data points for shear are produced by the differences in the distribution factors as discussed for flexure.

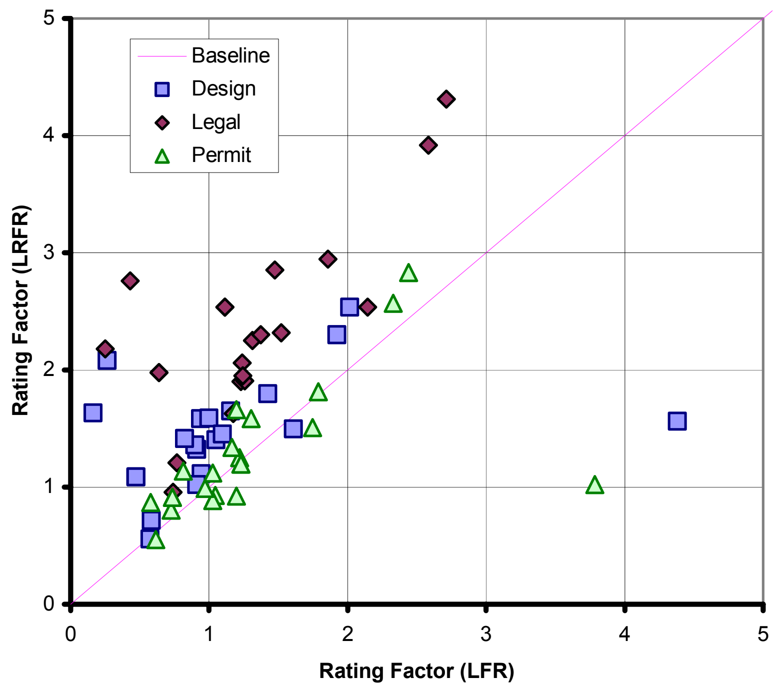


Fig. 11 LRFR vs. LFR (Shear)

Fig. 12 illustrates how often a particular range of shear rating factor ratios from Table 7 occurs. This *frequency* is indicated separately for each live load group.

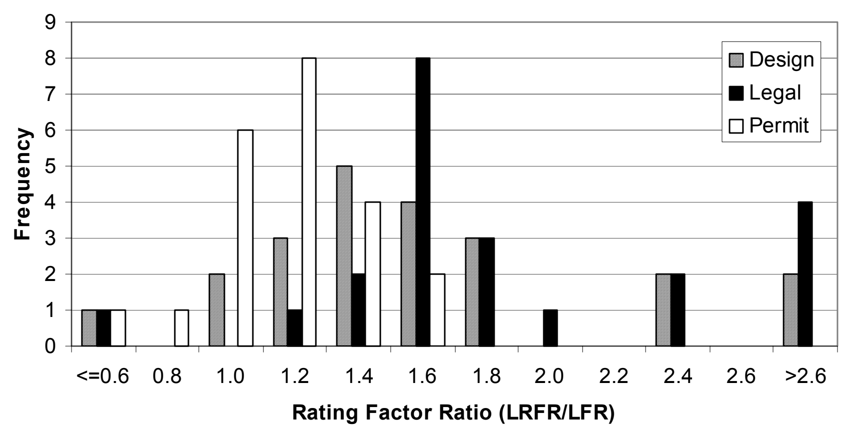


Fig. 12 Frequencies of Rating Factor Ratios (Shear)

CONCLUSIONS

This study compares live load ratings, obtained using the LFR and LRFR methods for a number of reinforced concrete bridges, for the purpose of establishing why the rating factors are similar or different between the two methods. This information is relevant to national policy development associated with the long-term adoption of the new LRFR specification and for engineers who will be transitioning to LRFR from LFR.

Design load ratings for flexure are generally lower for LRFR than LFR. Legal load ratings for flexure are somewhat higher for LRFR than LFR. Flexure ratings for the permit loads are also lower for LRFR than LFR. For flexure, factored resistances and dead load actions are nearly identical between the two methods, so they had little or no effect on the difference in the rating factors. The principal causes for differences in flexure ratings are the different live load factors, impact factors, distribution factors, and the heavier HL-93 load combinations.

Both design and legal load ratings for shear are higher for LRFR than LFR. Permit load ratings for shear are slightly higher for LRFR than LFR. For shear, factored dead load actions are nearly identical between the two methods, so they had little or no effect on the difference in the rating factors. The primary causes for differences in shear ratings are an increase in the factored shear resistance due to the MCFT, different live load factors, impact factors, distribution factors, and the heavier HL-93 load combinations.

Another observation is that permit load ratings will vary greatly between LRFR and LFR depending on the live load factors chosen for LRFR. The permit live load factor considered in this study was relatively low. Therefore, a larger live load factor would decrease the LRFR ratings.

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