Western
Bridge
Conference
2007

Load Rating of Prestressed Concrete Girder Bridges:

Interior vs. Exterior Girders

Introduction

- Importance of Bridge Evaluation
  - Viaducts within the U.S. Highway infrastructure are on average 40 years old with a theoretical design life of 50 years.
- 2006 National Bridge Inventory: Deficient/Obsolete
  - Nationwide: 26%
  - New Mexico: 692 Bridges (291 – Obsolete, 401 – Deficient)
- Vehicle Miles of Travel (VMT) have increased 148% in the last 30 years.

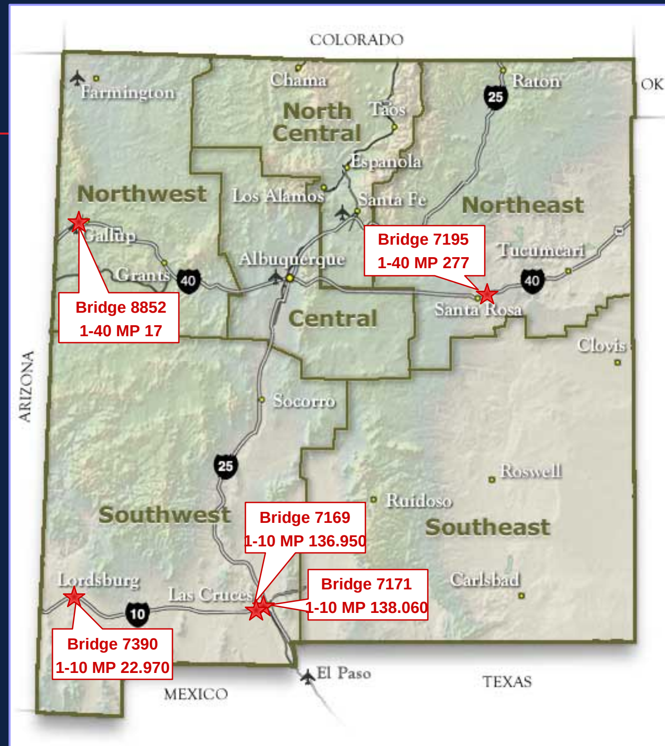
Objective

- Support the AASHTO Subcommittee on Bridges and Structures implementation of load and resistance factor design by continuing the transition from LFR to LRFR.
- Rate 5 prestressed concrete girder bridges, courtesy of the NM bridge inventory, for LFR and LRFR using the Bridge Rating and Analysis of Structural Systems (BRASS) Software.
- Specific Objectives
  - Identify differences and trends in LFR and LRFR rating factors.
  - Compare rating factors for interior and exterior girders.
  - Examine trends in rating factors as affected by bridge geometry.

Bridge Rating and Analysis of Structural Systems (BRASS) Software

- Used to load rate superstructure elements.
- BRASS-GIRDER is current with the 16th edition of the AASHTO Standard Specifications for Highway Bridges (1996), including the 1997 thru 2000 Interims.
- BRASS-GIRDER (LRFD) is current with the 2nd edition of the AASHTO LRFD Bridge Design Specifications (1998), including the 2000 Interim.

Bridge Sample

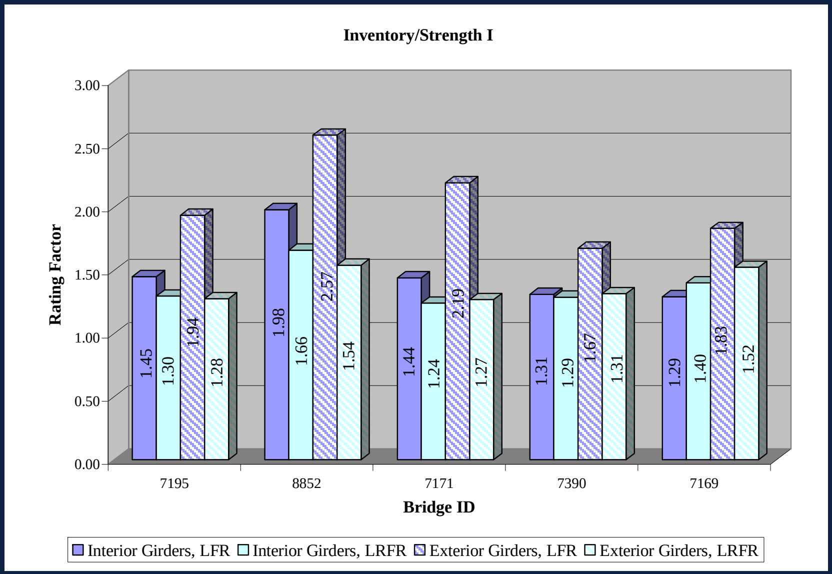


Bridge Description

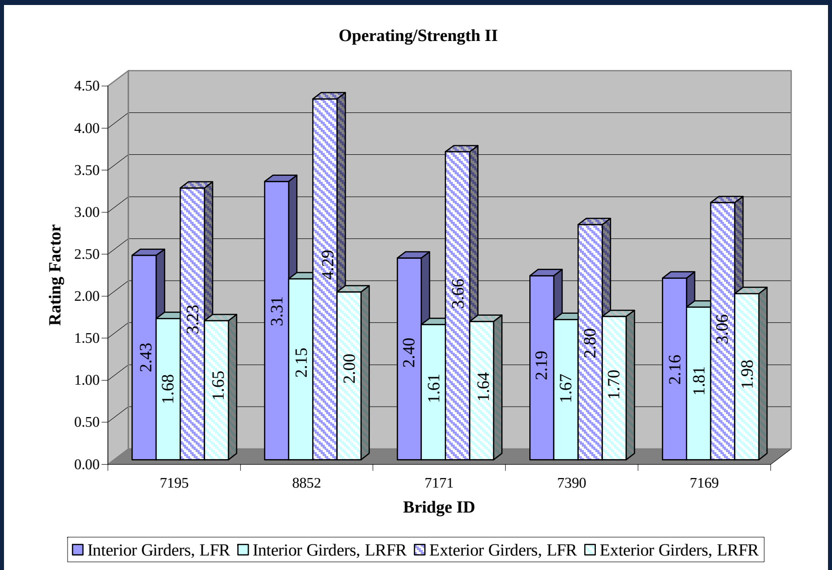
	Bridge ID				
	7195	8852	7171	7390	7169
Span Length	107’	97’	80’ 6 ¼ ”	58 ¾’	38 ¼’
Girder Type	AASHTO-V	AASHTO-IV	AASHTO-III	AASHTO-III	AASHTO-II
No. of Girders	5	6	7	6	5
Girder Spacing	9’ 7”	7’	6’ 8”	9’ 1”	9’ 9”
No. of Harped Strands	18	10	8	4	4
No. of Straight Strands	44	34	30	16	14
Strand Type	Stress-relieved	Low-relaxation	Stress-relieved	Stress-relieved	Stress-relieved
Strand Diameter, in.	7/16	½	7/16	½	7/16
Stirrup Spacing, in.	11	4	15 ¼	8	10
f'_c, ksi	5	5.5	5	5	5
f'_{ci}, ksi	4.5	4.75	4.5	4.5	4.5
Slab thickness, in.	7 ¼	8	6 7/16	8	7 9/16
Skew, degrees	~ 21	~ 19	20	~ 20	30
FWS, lbs/ft^2	15	30	15	15	15

Note. Similar for all bridges: 1.) f’cslab = 3 ksi and 2.) transverse reinforcement consists of #4 double leg stirrups.

Results
Critical Rating Factors - Flexure

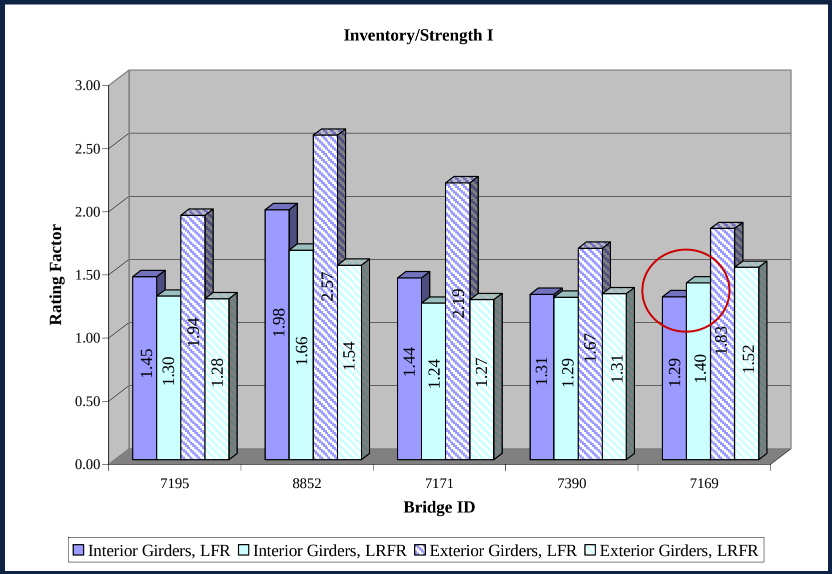


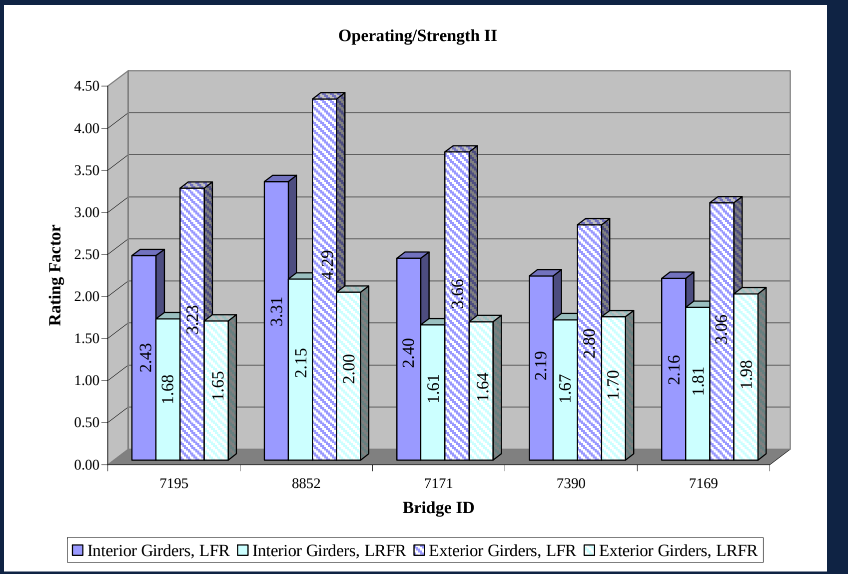
Inventory / Strength I



Operating / Strength II

Results
Critical Rating Factors - Flexure

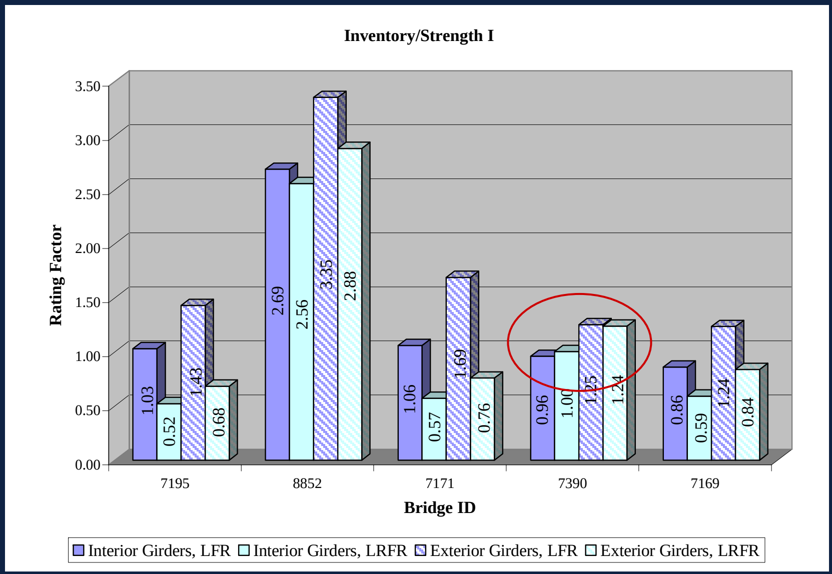


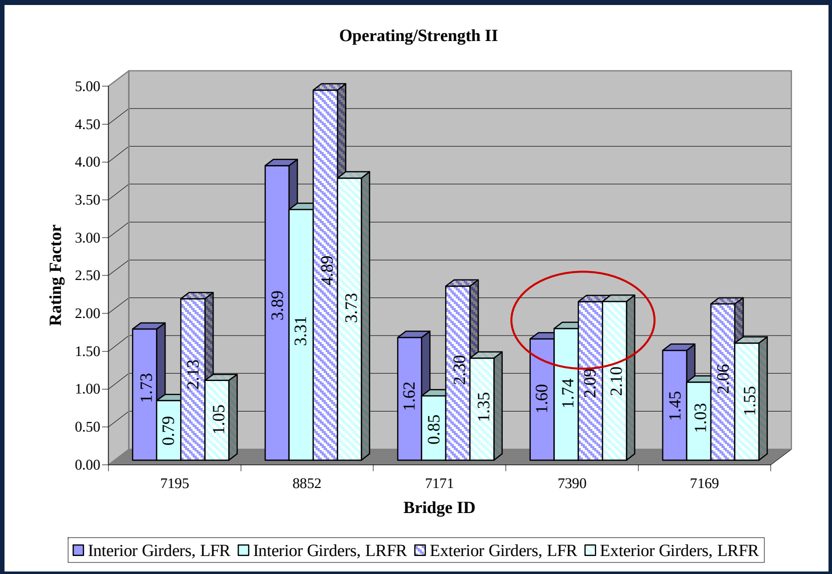


Inventory / Strength I

Operating / Strength II

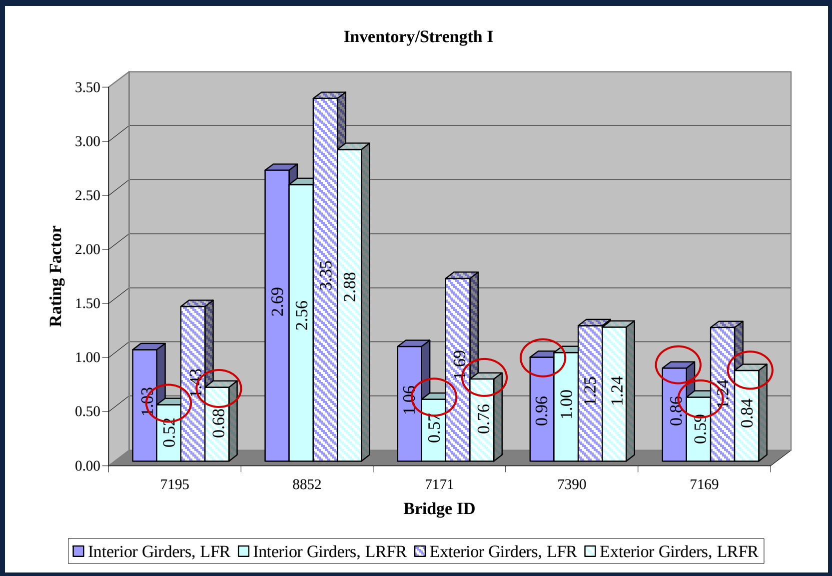
Results
Critical Rating Factors - Shear

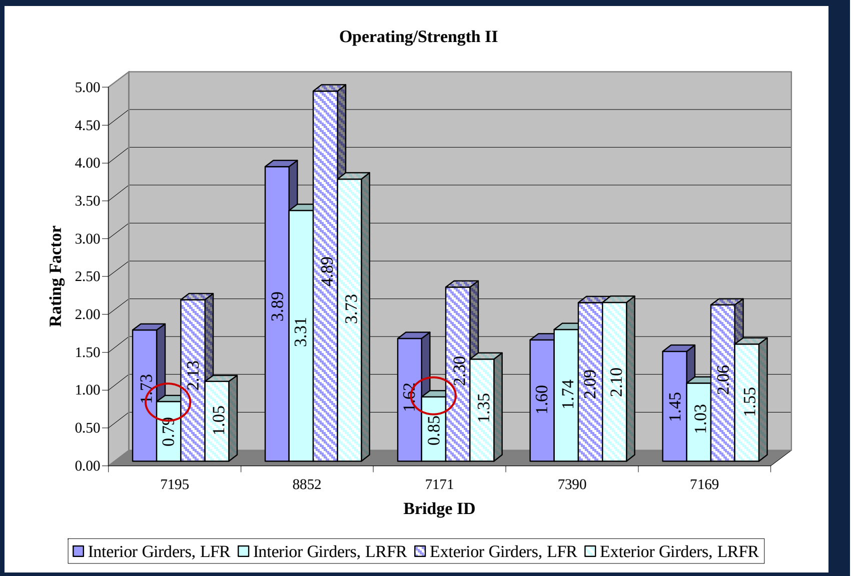




Inventory / Strength I **Operating / Strength II**

Results
Critical Rating Factors - Shear

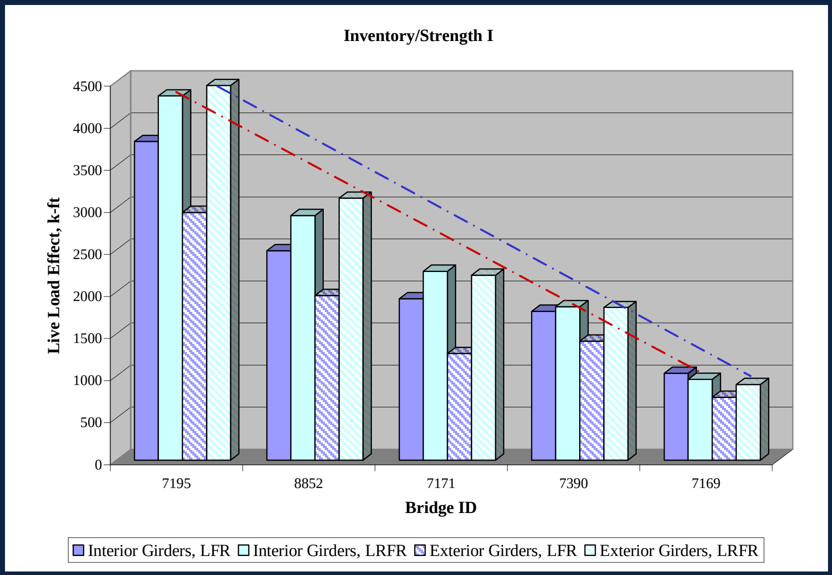




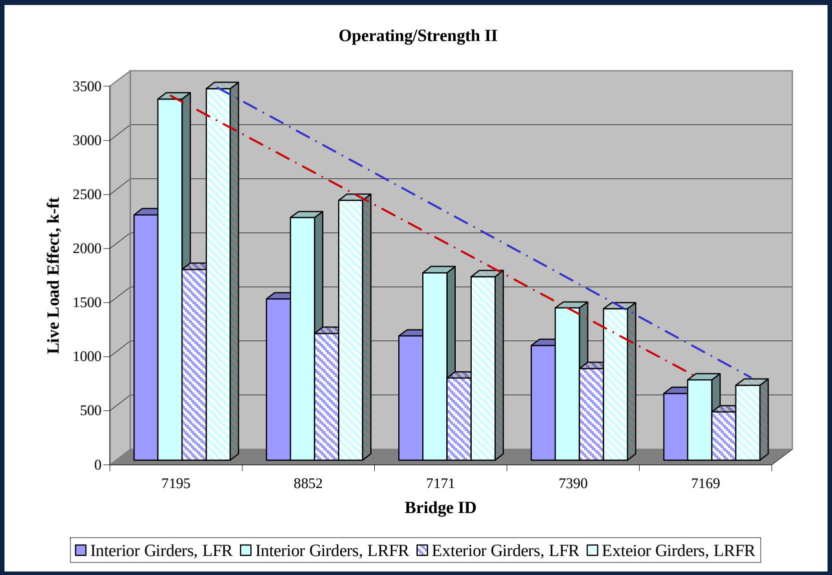
Inventory / Strength I **Operating / Strength II**

$$RF = \frac{\text{Capacity} - \text{DL Effects}}{\text{LL Effects}}$$

Results
Critical Live Load Effect - Flexure



Inventory / Strength I



Operating / Strength II

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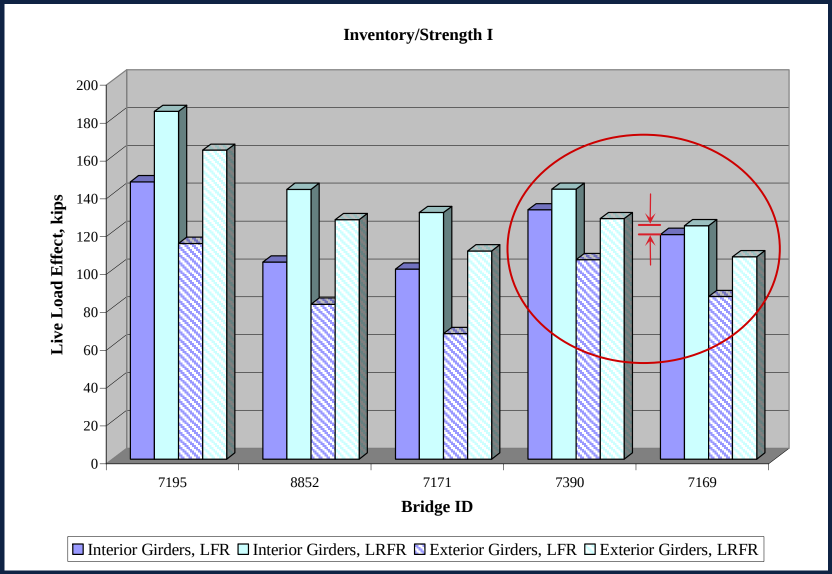

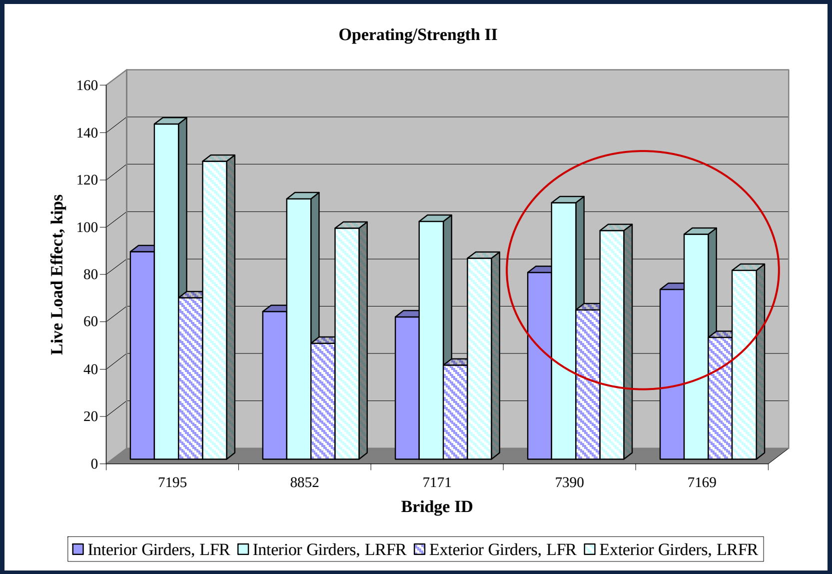

Inventory / Strength I

Operating / Strength II

Results
Live Load Effects

- Dynamic Load Allowance or Impact Factor
  - LFR:
    - Based on span length
    - Ranges from 21.6% to 30% for the bridges under consideration
    - Shorter span bridges produce larger impact factor, therefore producing effects similar to LRFR
  - LRFR: 33%
- Live Load Factors

LFR	LRFR
Inventory – 2.17	Strength I – 1.75
Operating – 1.30	Strength II – 1.35

Results
Live Load Effects

- Distribution Factors

Distribution Factor	Girder	7195	8852	7171	7390	7169
LFR	Interior	0.871	0.636	0.606	0.826	0.886
	Exterior	0.677	0.500	0.400	0.661	0.641
LRFR – Shear	Interior	0.924	0.719	0.719	0.890	0.935
	Exterior	0.820	0.660	0.607	0.793	0.810
LRFR - Moment	Interior	0.798	0.616	0.620	0.797	0.834
	Exterior	0.820	0.660	0.607	0.793	0.780

Results
Live Load Effects

- Distribution Factors

Girder Spacing: S=9'7" (7195), S=9'1" (7390), S=9'9" (7169)

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Live Load Effects

- Distribution Factors

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LRFR – Flexure: Similar for Interior and Exterior Girders

Results
Live Load Effects

- **Distribution Factors**

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LRFR – Flexure: Similar for Interior and Exterior Girders

LRFR – Shear: Smaller for Exterior Girder

Results
Live Load Effects

- **Distribution Factors**

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LRFR – Flexure: Similar for Interior and Exterior Girders

LRFR – Shear: Smaller for Exterior Girder

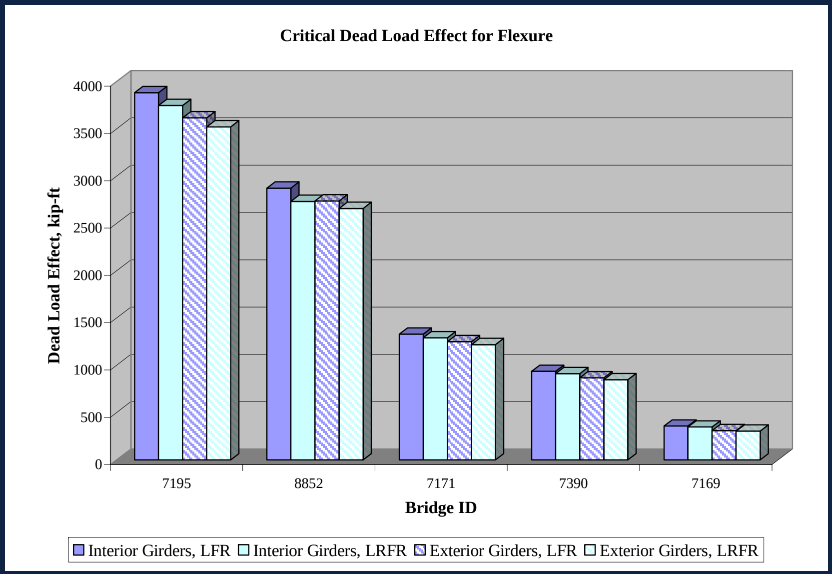
LFR: Smaller for Exterior Girder

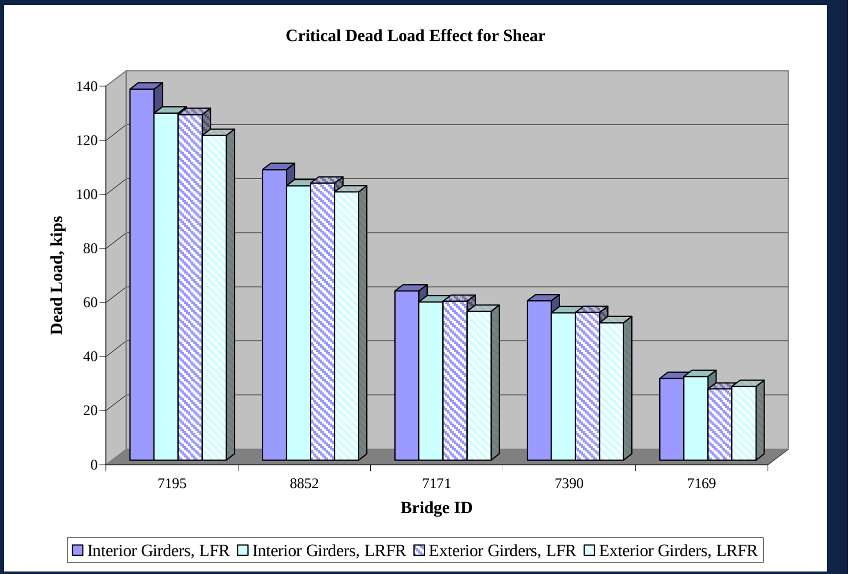
Results
Live Load Effects

- Design Loads
  - LRFR: HL-93
  - LFR: HS-20

- Effects of Skew
  - Only considered in LRFR for skews > or = 30º
  - With the exception of Bridge 7169, the effects of skew are negligible.
  - Bridge 7169 was designed with a skew of 30º, therefore slightly reducing the distribution factor.

Results
Critical Dead Load Effect





Flexure

Shear

Results
Critical Dead Load Effect

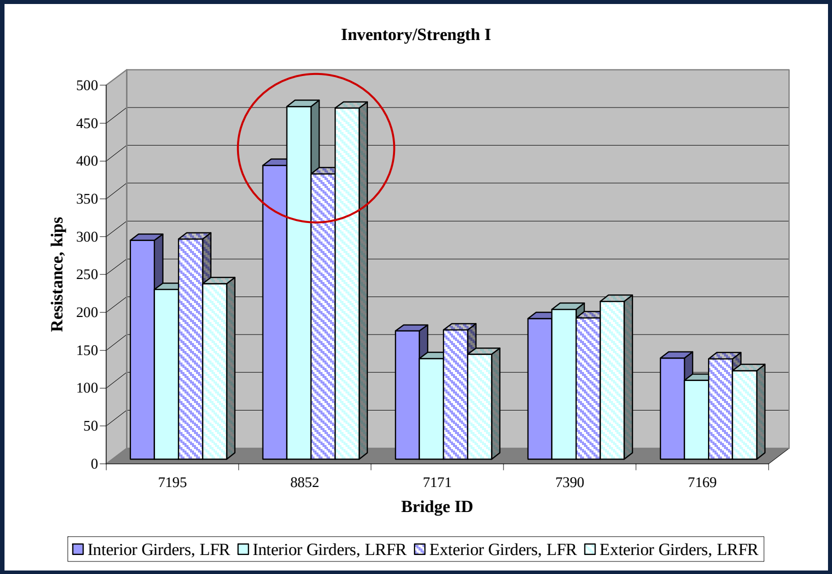
- **Dead Load Factors**
  - **LFR: 1.3**
  - **LRFR: 1.25DC + 1.50DW**

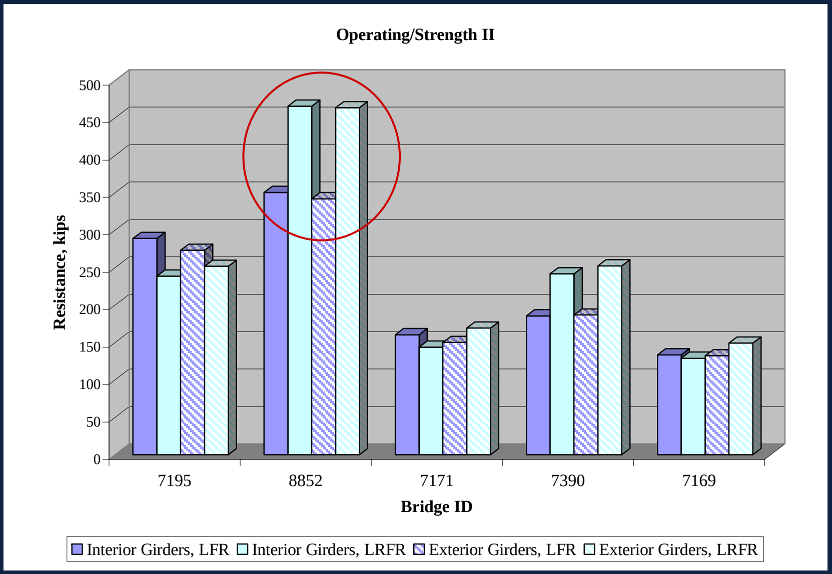
- **Dead load effects due to shear are affected by the location of the critical section.**

Method	Level/ Limit State	Bridge ID				
		7195	8852	7171	7390	7169
LFR	Inventory/Operating	100.27	100.46	100.26	100.38	100.95
LRFR	Strength I	100.42	100.49	100.44	100.60	100.73
	Strength II	100.46	100.46	100.48	100.70	100.73

Larger critical sections result in smaller dead loads since the point of interest is further from the support.

Results
Critical Resistance - Shear





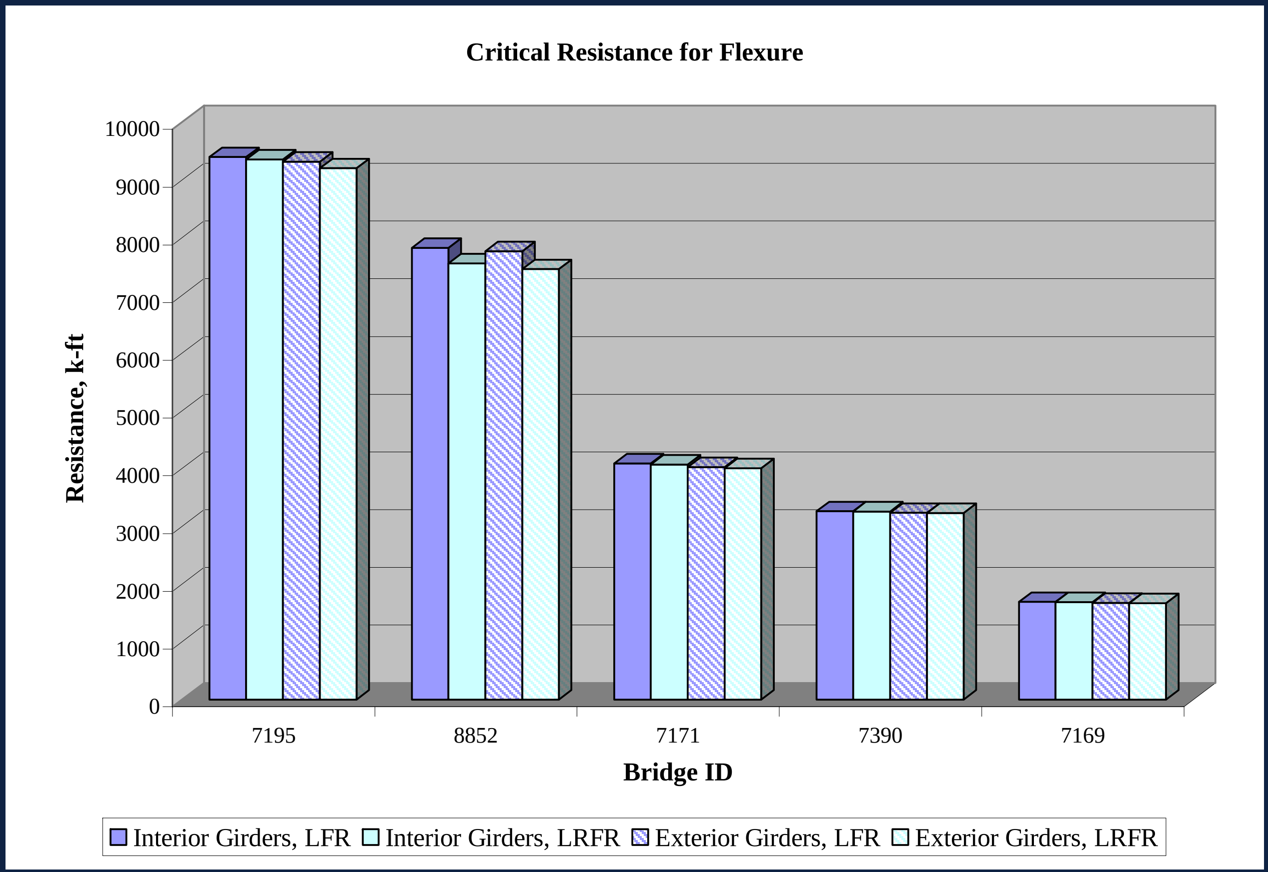
Inventory / Strength I

Operating / Strength II

Results
Critical Resistance - Shear

- **Notable differences between LFR and LRFR**
  - **Angle of compressive stresses, θ**
  - **Location of critical section**
- **Notable differences in Figure (Critical Shear Resistance)**
  - **Concrete Compressive Strength**
  - **Stirrup Spacing**
  - **Strand Type: low-relaxation vs. stress relieved**
- **General Comparisons**
  - **Shear resistance depends on an interaction of variables**

Results
Critical Resistance – Flexure



Conclusions
Contributing Parameters

- Flexure
  - Contributing Parameters: Live Load Effects
  - Negligible Parameters: Dead Load Effects and Flexural Resistance
- Shear
  - Contributing Parameters: Live Load Effects and Shear Resistance
  - Negligible Parameters: Dead Load Effects

Conclusions
Comparison of Rating Factors - Flexure

- LRFR method yielded lower rating factors, with the longer span bridges demonstrating a larger deviation between LFR and LRFR
- Operating/Strength II limit state showed greater variance between LFR and LRFR when compared to Inventory/Strength I limit state
- LRFR produced similar rating factors between the interior and exterior girders
- LFR yielded larger rating factors for the exterior girders
- Exterior girders showed a larger discrepancy between rating method (LFR vs. LRFR)
- All five bridges are structurally adequate (i.e. rating factor > 1)

Conclusions
Comparison of Rating Factors - Shear

- LRFR method yielded lower rating factors
- Operating/Strength II ratings displayed a more notable difference in rating method than Inventory/Strength I
- LFR and LRFR rating factors are greater for the exterior girders with LFR yielding a larger discrepancy in values between the exterior and interior girders
- A number of bridges are structurally inadequate
  (i.e. rating factor < 1.0)

Conclusions
General Comparisons

- LRFR method generally resulted in lower rating factors for flexure and shear
- The shorter span bridges were often controlled by the LFR method
- The shear ratings typically controlled over the flexure ratings

Recommendations

- **Further investigation of the contribution of the concrete to the shear resistance is recommended**
- **Further research relating to LRFR is suggested. Parameters not studied in this research should be considered, in particular continuous span bridges. Larger samples are recommended**
- **Further comparison of the applied live loads, in particular permit loads, is recommended**

Acknowledgements

- The authors would like to thank the New Mexico Department of Transportation (NMDOT) and the Wyoming Department of Transportation (WYDOT) for supplying the NM bridge plans/other supplementary information and the Bridge Rating and Analysis of Structural Systems (BRASS) software, respectively

- The authors also extend their sincerest gratitude to the Federal Highway Administration (FHWA) and NMDOT for funding the research presented herein

Thank You