Session 47

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LRFR Methodology

Topic Description

The application and basis of the Load and Resistance Factor Rating procedures of the new AASHTO Manual for Condition Evaluation and the Florida Structure Manual are discussed.

Speaker Biography

Professor Mertz teaches bridge engineering at the University of Delaware, and is the Director of the University's Center for Innovative Bridge Engineering (CIBrE). Previous to his appointment to the University, he was an Associate of the bridge design firm of Modjeski & Masters, Inc.

Dennis was the Co-Principal Investigator of the NCHRP research project which wrote the original edition of the AASHTO LRFD Bridge Design Specifications. He continues to be active in its further development and implementation.

All of Professor Mertz's engineering degrees are from Lehigh University in Bethlehem, Pennsylvania. He is also a Professional Engineer in the Commonwealth of Pennsylvania.

LRFR: FDOT Rating Policies & Procedures

Dennis R. Mertz

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Part 1

BACKGROUND

Objective of LRFD

Develop a comprehensive and consistent <u>L</u>oad and <u>R</u>esistance <u>F</u>actor <u>D</u>esign (LRFD) specification that is calibrated to obtain uniform reliability (a measure of safety) at the <u>strength limit state</u> for all materials.

CALIBRATION

Selection of a set of γ's and ϕ's to approximate a target level of reliability in an LRFD-format specification.

What's not LRFD?

- New limit states,
- New, more complex live-load distribution factors,
- New unified-concrete shear design using modified compression-field theory,
- Strut-and-tie model for concrete, and
- Many other state-of-the-art additions.

Limit States

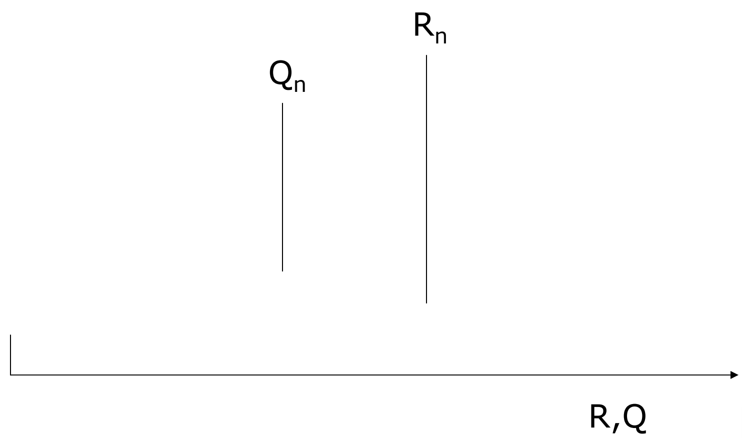
- Service limit states,
- Fatigue-and-fracture limit states,
- Strength limit states, and
- Extreme-event limit states.

Only the strength limit states of the *LRFD Specifications* are calibrated based upon the theory of structural reliability, wherein statistical load and resistance data are required.

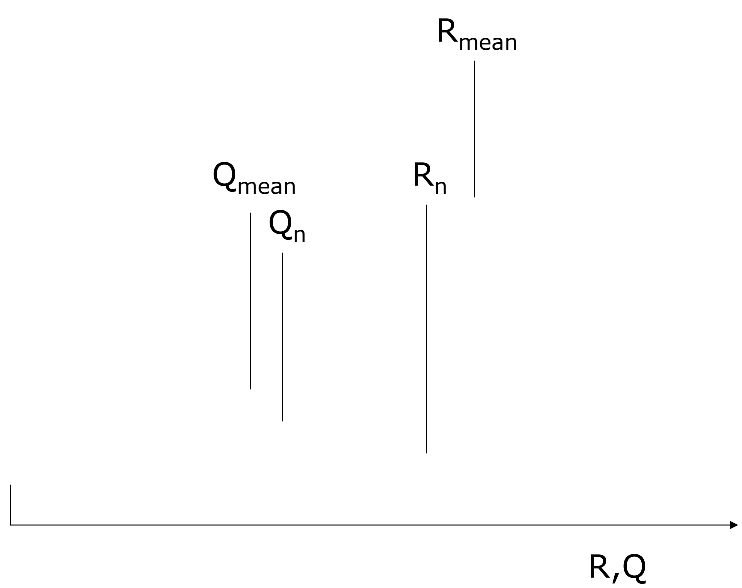
The other limit states are based upon the design criteria of the *Standard Specifications*.

Calibration consists of up to three steps:

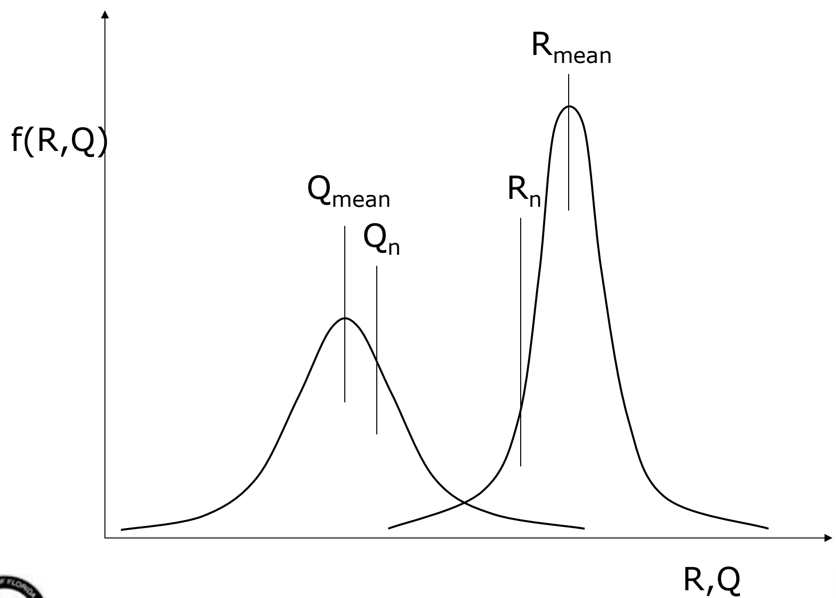
- **Reliability-based calibration,**
- **Calibration or comparison to past practice, and**
- **Liberal doses of engineering judgment.**



Summer 2006 Design Conference 9

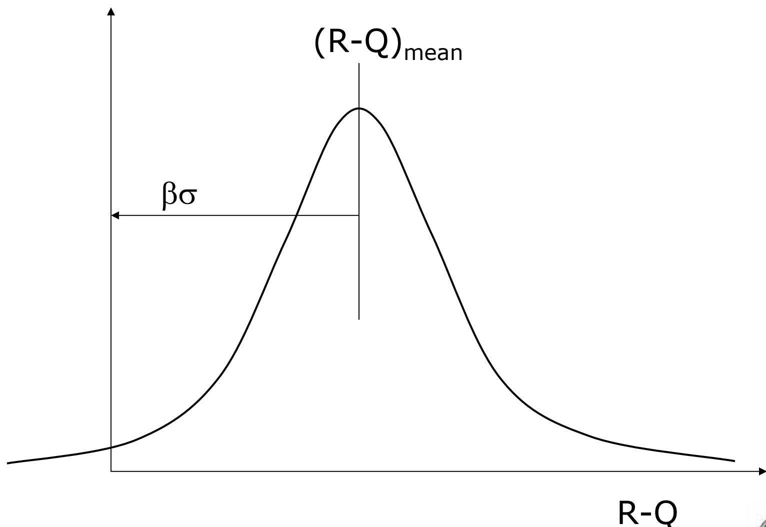


Summer 2006 Design Conference 10



INDEPENDENT OF DESIGN METHODOLOGY

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 TARGET RELIABILITY INDEX β IS A UNIQUE QUANTITY.

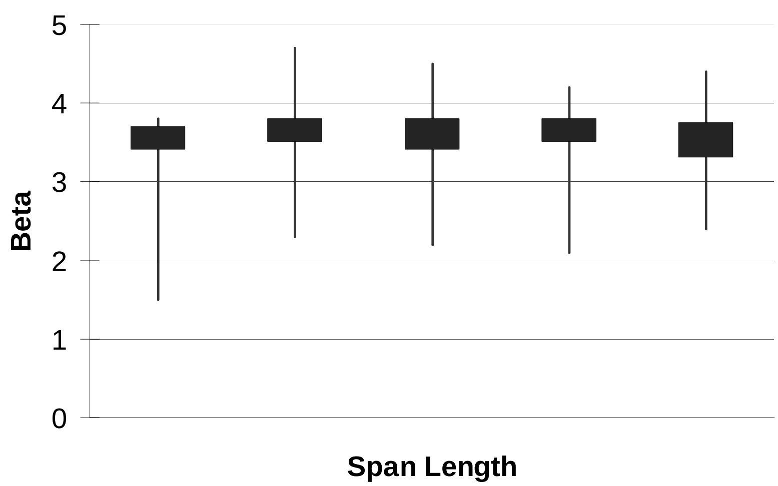
Many different sets of γ's and φ's can be selected to achieve the unique reliability index β.

What is an acceptable value for β?

Can we examine human behavior to choose a target β for bridge design?

Summer 2006 Design Conference 15

Reliability Indices



Summer 2006 Design Conference 16

If load and resistance are normal random variables,

$$\sigma_{(R-Q)} = \sqrt{{\sigma_R}^2 + {\sigma_Q}^2}$$

and

$$\beta = \frac{R_{mean} - Q_{mean}}{\sqrt{{\sigma_R}^2 + {\sigma_Q}^2}}$$

LRFD requires that:

$$\phi R \geq \sum_i \gamma_i Q_i$$

And the nominal design resistance is defined as:

$$R_n = \frac{R_{mean}}{\lambda}$$

From the definitions of β and λ

$$R_{mean} = Q_{mean} + \beta\sqrt{\sigma_R^{\ 2} + \sigma_Q^{\ 2}} = \lambda R_n$$

but

$$\phi R_n \geq \sum_i \gamma_i Q_i$$

Finally, solving for ϕ yields

$$\phi = \frac{\lambda_R \sum_i \gamma_i Q_i}{Q_{mean} + \beta\sqrt{\sigma_R^{\ 2} + \sigma_Q^{\ 2}}}$$

With three "unknowns," ϕ, the γ_i's and β

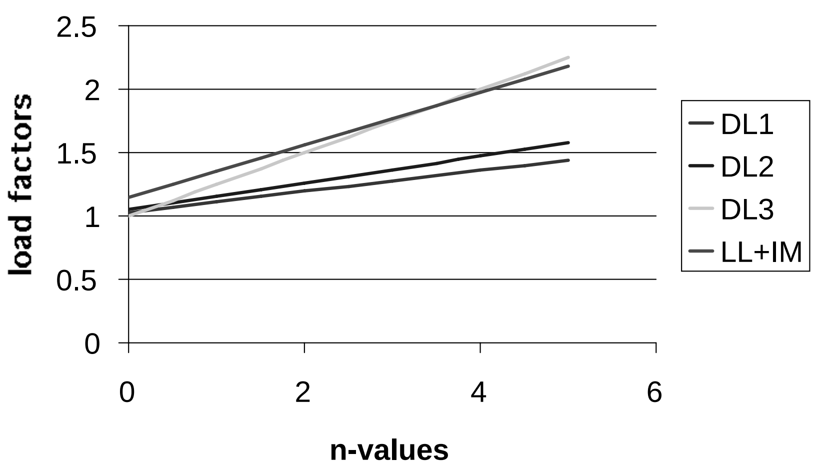
Load factors can be chosen such that all of the factored loads have an equal probability of being exceeded.

In equation form,

$$\gamma_i = \lambda_i (1 + nV_i)$$

where n is a constant for all load components.

Load Factors



With the target β and the γ's chosen, the ϕ's to achieve the approximate desired level of reliability can be determined.

The process is repeated until a set of γ's and ϕ's agreeable to the codewriters is obtained.

After much investigation, it was determined that:

- the total load, Q, can be accurately assumed to be a normal random variable, and
- the resistance, R, can be accurately assumed to be a lognormal random variable.

Nowak's equation D-25 (adapted)

$$\beta = \frac{R_n \lambda_n (1 - nV_R)[1 - \ln(1 - nV_R)] - Q_{mean}}{\sqrt{[R_n V_n \lambda_n (1 - nV_R)]^2 + \sigma_Q^2}}$$

but

$$R^* = \phi R_n = Q^* = \sum \gamma Q$$

and

$$R^* = R_{mean}(1 - nV_R) = \lambda_R R_n (1 - nV_R) = \phi R_n$$

Thus, the calibration of the *LRFD Specifications* became a huge spreadsheet/bookkeeping iterative problem (see Nowak's Appendix F).

The calibration represented in the current edition of the *LRFD Specifications* was made in the late 1980's and early 1990's.

Today, calibration is done differently. Due to modern computer resources, calibration is done by simulation, Monte Carlo Simulation.

MONTE CARLO SIMULATION

- "Bins" of data are developed holding values of distributed loads and resistances.
- Values are extracted randomly, and the LRFD comparison is made, in other words, is factored resistance greater than or equal to factored load?
- Many, many such comparisons are made until the sampling allows the probability of failure, and thus β, to be determined.

THE LRFD LIMIT STATES ARE CALIBRATED BASED UPON PAST PRACTICE.

The strength limit states are calibrated to achieve levels of reliability comparable to the *Standard Specifications*.

The service, and fatigue-and-fracture limit states are calibrated to achieve member proportions comparable to the *Standard Specifications*.

Summer 2006 Design Conference 29

THE SERVICE LIMIT STATES GENERALLY GOVERN THE PROPORTIONS OF SUPERSTRUCTURE MEMBERS.

Positive-moment regions of steel girders are governed by the service II load combination.

Prestressed concrete members are governed by the service I or III load combinations.

Summer 2006 Design Conference 30

MANY QUESTIONS REMAIN TO BE ANSWERED.

- What is the appropriate β for bridge design and evaluation?
- Should all bridge components have the same β?
- Should all limit states have the same β?
- Is an "analysis factor" needed?

CONCLUSIONS

The reliability-based LRFD design methodology is not perfect, but it represents an improvement over the ASD and LFD methodologies.

LRFD utilizes structural reliability to help us select improved load and resistance factors, and it provides a framework for future improvement.

CONCLUSIONS (continued)

Most of the features which designers dislike about the LRFD Specifications have little, if anything, to do with the LRFD design methodology.

NCHRP Project 20-07/Task 122

LOAD RATING BY LOAD AND RESISTANCE FACTOR EVALUATION METHOD

FINAL REPORT to
AASHTO Technical Committee T-18

OBJECTIVE

The objective of this project is to provide explicit comparisons between the ratings produced by the LRFR methods of the *Guide Manual for the Condition Evaluation and Load and Resistance Factor Rating of Highway Bridges* 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.

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

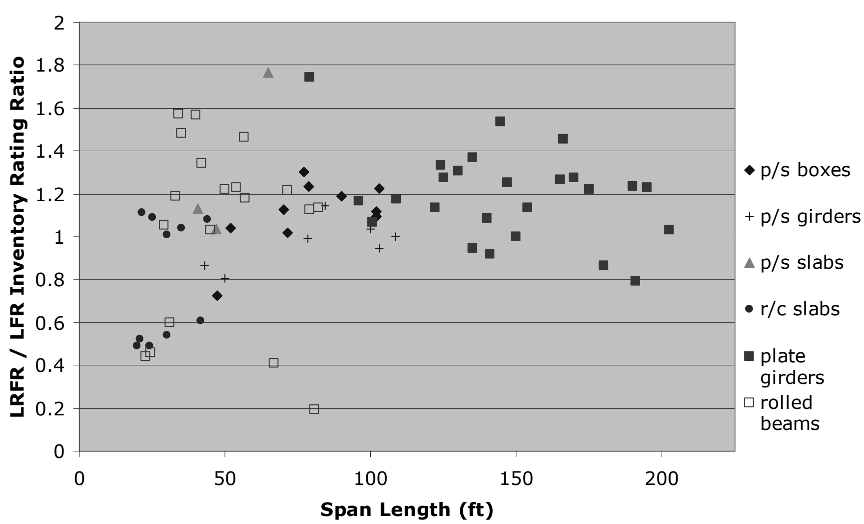
DESIGN-LOAD RATING FACTOR COMPARISON

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

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

SPAN-LENGTH EFFECT



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

MONTE CARLO SIMULATION

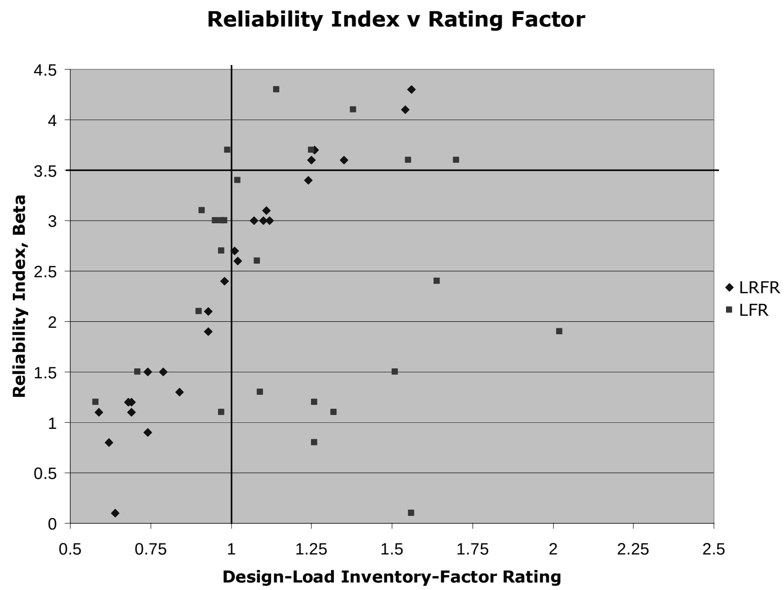
The reliability of the example bridges was established through Monte Carlo simulation. The application of Monte Carlo simulation employed for this study compares two distributions of values; in this case, load and resistance; and determines a random value of resistance minus load for a given design criteria, in this case the Strength I limit state for flexure.

STATISTICS

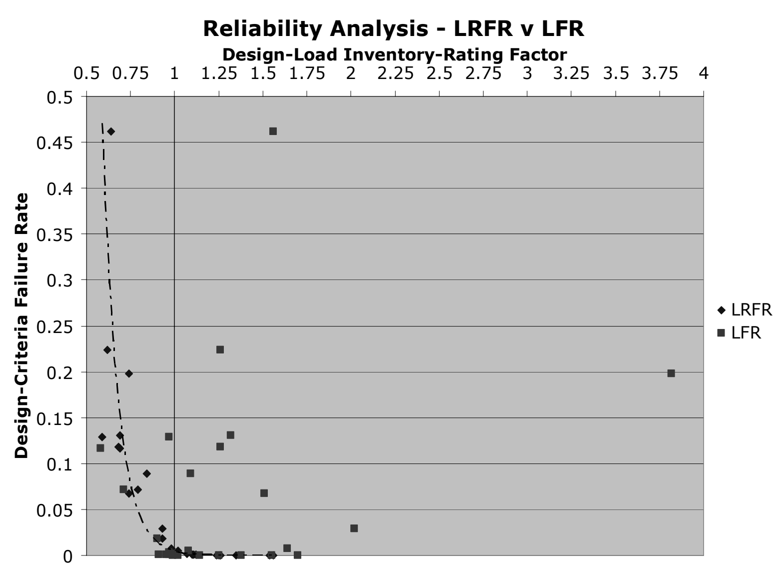
Parameter	Assumed Distribution	Bias Factor, λ, associated with LRFD	Coefficient of Variation, V
D, dead load	normal	1.05	0.10
L, live load plus impact		1.30	0.18
R, composite-steel flexural resistance	lognormal	1.12	0.10
R, reinforced-concrete flexural resistance		1.12	0.13
R, prestressed-concrete flexural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

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 (β > about 4.5).



Summer 2006 Design Conference 45



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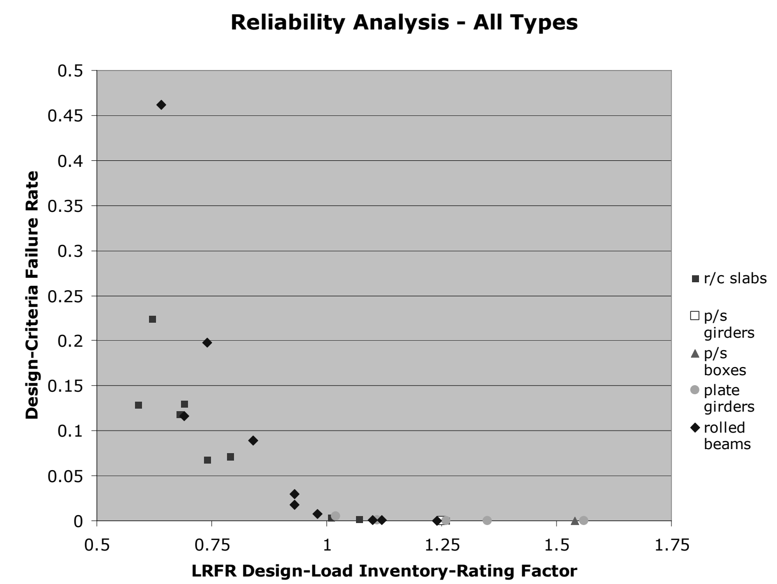


CONCLUSIONS

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 demonstrated, the lower slab-bridge ratings are technically appropriate

This study suggests that LRFR is technically sound with the LRFR rating factors in good correlation with the failure rates. 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.

RECOMMENDATIONS

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.

Part 2

back to

FDOT RATING POLICIES & PROCEDURES

TERMINOLOGY

LRFR = AASHTO *Manual for Bridge Evaluation* (2006)

FDOT = Florida's proposed additions, revisions & deletions

DESIGN METHODOLOGY	LOAD-RATING METHODOLOGY		
	ALLOWABLE STRESS RATING (ASR)	LOAD FACTOR RATING (LFR)	LOAD AND RESISTANCE FACTOR RATING (LRFR)
Allowable Stress Design (ASD)	✓	✓	✓
Load Factor Design (LFD)		✓	✓
Load and Resistance Factor Design (LRFD)			✓

AASHTO LRFR seems to assume that every permit load will be evaluated.

FDOT LRFR assumes that blanket permits will be issued based upon previously established operating-level ratings.

LRFR EVALUATION LEVELS

1. **Design-load rating**
2. **Legal-load rating**
3. **Permit-load rating**

FDOT EVALUATION LEVELS

1. **Design-load & permit-load rating**
2. **Legal-load rating**

LRFR RATING LEVELS

- **Inventory – β = 3.5 (*represents LRFD design*)**
- **Operating – β = 2.5 (*represents traditional operating*)**

TYPE	BRIDGE	CORVEN	LEAP	SDR	FDOT
Simple-span prestressed concrete beam simple-spans	__0074	✓✓	✓✓	✓✓	
	__0052	✓✓	✓✓	✓✓	
	__0057 - span 2 & 3	✓✓	✓✓	✓✓	✓✓
	__0057 - span 1 & 4	✓✓			
	__0196 - 3 wb	✓✓	✓✓	✓✓	
	__0196 - 7 wb	✓✓			
	__0196 - 14 wb	✓✓			
	__0081	✓✓	✓✓	✓✓	
Continuous flat slabs	__0091	✓✓		✓✓	✓✓ (edge)
	__4094	✓✓		✓✓	
Continuous prestressed concrete spliced girder	__0108 - 4-span unit	✓	✓✓		
	__0108 3-span channel unit	✓	✓✓		

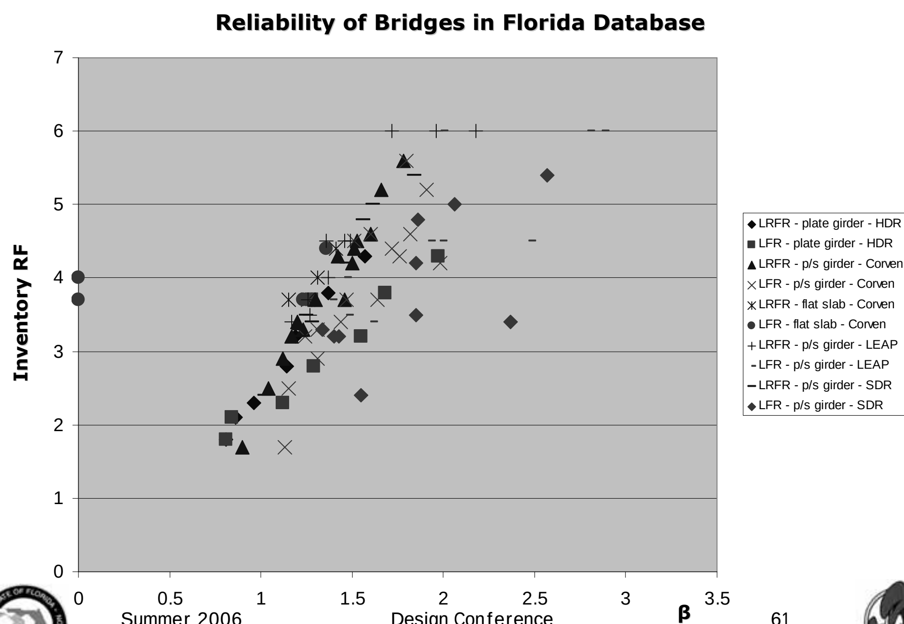
Florida Database of Concrete Bridges

✓✓ analysis complete & results in spreadsheet

✓ analysis complete

Florida's Database of Steel Bridges

Bridge Type	Span Type	Bridge Number	Analysis	
			Simple	Refined
Plate Girder	Simple	__0620	✓✓	✓✓
	Continuous	__0323	✓✓	✓✓
Tub Girder	Simple	______		✓
	Continuous	______		✓



AASHTO LRFR makes service limit states optional acknowledging that:

- **the rater should protect the bridge from damage, yet**
- **traditionally designed bridges may not rate at the service limit states for legal and permit loads.**

FDOT LRFR calibrates the service limit states so that:

- **the rater protects the bridge from damage, yet**
- **traditionally designed bridges will not rate so poorly at the service limit states for legal and permit loads.**

The LRFR Equation

(LRFR Eq 6-1)

$$RF = \frac{C - (\gamma_{DC})(DC) - (\gamma_{DW})(DW) \pm (\gamma_P)(P)}{(\gamma_L)(LL + IM)}$$

where

$$C = \phi_c \phi_s \phi R_n$$ **for strength**

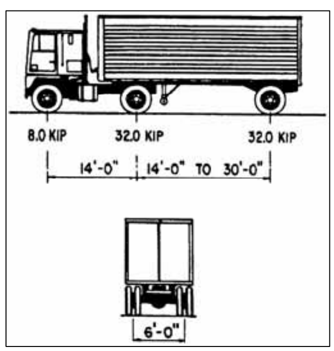
$$C = f_R$$ **for service**

CONCEPT OF A NOTIONAL LIVE LOAD MODEL

A load model which does not necessarily “look” like a truck, but which produces force effects (for example, moments & shears) representative of actual trucks.

Design Vehicular Live Loads

Design Truck



Design Tandem

Two 25.0 KIP axles spaced 4.0 FT apart

Design Lane Load

Uniformly distributed load of 0.64 KLF

Application of Design Vehicular LL

LRFD 3.6.1.2.1 and 3.6.1.3.1
Designation: HL-93
Service and Strength Limit States:

Design Truck OR Design Tandem
AND
Design Lane Load

The design lane load is not interrupted for the design truck or design tandem. Interruption is needed only where pattern loadings are used to produce maximum effects.

Comparison of LRFD Notional v. HS20

The notional model produces live load moments and shears significantly greater than those caused by the HS20 loading especially for longer spans.

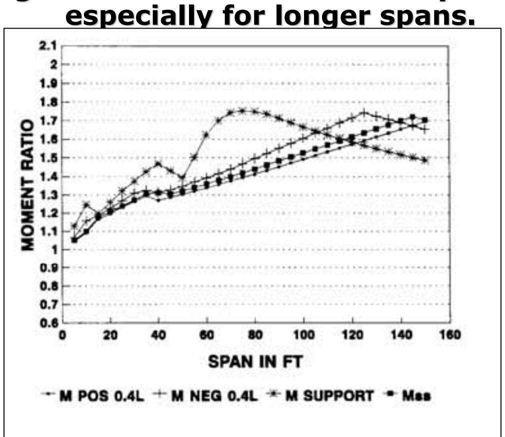


Figure C3.6.1.2.1-5 - Moment Ratios - Notional Model to HS20 (truck or lane) or two 24.0-KIP Axles at 4.0 FT

Justification for New LL

New "notional" live load model simulates the shear and moment effects of a group of "exclusion" vehicles currently allowed to routinely travel on highways in various states.

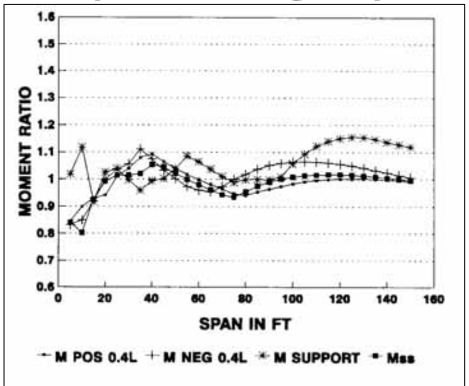


Figure C3.6.1.2.1-3 - Moment Ratios - Exclusion Vehicles to Notional Model

EFFECT OF SUPERPOSITION OF VEHICLES & LANE LOAD

- **Short spans governed by wheels – lane load has little effect,**
- **Long spans governed by the lane load – the vehicle has little effect, but**
- **Intermediate length spans – the lane load amplifies the vehicle effect (without specifying a "super-legal" load.**

Therefore, the HL-93 rating factor represents a ratio of the entire effect (in other words, the governing vehicle and the lane) not just the vehicle!

The intent of the superposition explains the application of the dynamic load allowance (IM) to the vehicle force effects only.

LONGITUDINAL V. TRANSVERSE ANALYSIS

- Longitudinal & transverse ratings for bridges with prestressed concrete decks (e.g., segmental boxes)
- Longitudinal ratings only for all others

Loads for Longitudinal Rating

LOADS		DESIGN LOADS		LEGAL LOADS	PERMIT LOADS (annual blanket permits with mixed traffic)
		INV	**OPR**	**OPR**	**OPR**
vehicles	**HL93 notional live-load model**	✓	✓		
	SU4, C5 and ST5 trucks only (same truck in each lane, do not mix trucks)			✓	
	HL93 design truck (*old HS-20*) and T160 truck with coincident 0.20 kips per foot lane load				✓

Loads for Transverse Rating

LOADS		DESIGN LOADS		LEGAL LOADS	PERMIT LOADS (annual blanket permits with mixed traffic)
		INV	OPR	OPR	OPR
vehicles	HL93 truck or tandem without coincident lane load	✓	✓	✓	
	SU4, C5, ST5 and HL93 truck or tandem (same truck in each lane, do not mix trucks)			✓	
	T160 in one lane and HL93 design truck or design tandem without coincident design lane load in the other lanes				✓

Limit-State Load Combinations (dead load + live load)

BRIDGE TYPE	LIMIT-STATE LOAD COMBINATIONS	DEAD LOADS		LIVE LOAD			
				DESIGN LOAD		LEGAL LOAD	PERMIT LOAD
		DC	DW	INV	OPR	OPR	
				LL			
All Bridges	Strength I	1.25	1.50	1.75	1.35	1.35[1]	na
	Strength II	1.25	1.50	na			1.35[2]
Steel	Service II	1.00	1.00	1.30	1.00	1.30	1.00
R/C	Service I	1.00	1.00	na			1.00
P/C	Service III	1.00	1.00	0.80[3]			0.75[3]
	Service I	1.00	1.00	1.00			

[1]For all traffic volumes
[2]For all types and frequencies of permit
[3]For longitudinal analysis of post-tensioned bridges use striped lanes

REDUNDANCY

LRFD – load modifier, η_R

LRFR – system factor, ϕ_s

Summer 2006 Design Conference 77

REDUNDANCY

- **Structural redundancy,**
- **Load-path redundancy, &**
- **Internal redundancy.**

Summer 2006 Design Conference 78

REVISED LRFR SYSTEM FACTORS BASED UPON:

- NCHRP Report 406 (Ghosen & Moses),
- Observed bridge behavior, &
- Liberal doses of engineering judgment.

General System Factors

Superstructure Type	System Factors (ϕ_s)
Welded Members in Two Truss/Arch Bridges	0.85
Riveted Members in Two Truss/Arch Bridges	0.90
Multiple Eyebar Members in Truss Bridges	0.90
Floorbeams with Spacing > 12 feet and Non-continuous Stringers & Deck	0.85
Floorbeams with Spacing > 12 feet and Non-continuous Stringers but with Continuous Deck	0.90
Redundant Stringer subsystems between Floorbeams	1.0
All beams in non-spliced concrete girder bridges	1.0

General Steel-Bridge System Factors (ϕs)

Superstructure Type	System Factors (ϕ_s)
Welded Members in Two Truss/Arch Bridges	0.85
Riveted Members in Two Truss/Arch Bridges	0.90
Multiple Eyebar Members in Truss Bridges	0.90
Floorbeams with Spacing > 12 feet and Non-continuous Stringers	0.85
Floorbeams with Spacing > 12 feet and Non-continuous Stringers but with Continuous Composite Concrete Deck	0.90
Floorbeams with Spacing > 12 feet and Non-continuous Stringers but with Continuous Metal Deck	0.95
Redundant Stringer subsystems between Floorbeams	1.0
All beams in non-spliced concrete girder bridges	1.0

System Factors (ϕs) for Post-Tensioned Concrete Beams

Number of Girders in Cross Section	Span Type	Number of Hinges Required for Mechanism	System Factors (ϕ_s)			
			Number of Tendons per Web			
			1	2	3	4
2	Interior	3	0.85	0.90	0.95	1.00
	End	2	0.85	0.85	0.90	0.95
	Simple	1	0.85	0.85	0.85	0.90
3 or 4	Interior	3	1.00	1.05	1.10	1.15
	End	2	0.95	1.00	1.05	1.10
	Simple	1	0.90	0.95	1.00	1.05
5 or more	Interior	3	1.05	1.10	1.15	1.20
	End	2	1.00	1.05	1.10	1.15
	Simple	1	0.95	1.00	1.05	1.10

The above tabularized values may be increased by 0.05 for spans containing more than 3 intermediate, evenly spaced diaphragms in addition to the diaphragms at the end of each span.

System Factors (ϕs) for Steel Girder Bridges

Number of Girders in Cross Section	Span Type	# of Hinges Required for Mechanism	System Factors
2	Interior	3	0.85
	End	2	0.85
	Simple	1	0.85
3 or 4	Interior	3	1.00
	End	2	0.95
	Simple	1	0.90
5 or more	Interior	3	1.05
	End	2	1.00
	Simple	1	0.95

- **The above tabularized values may be increased by 0.10 for spans containing evenly spaced intermediate diaphragms in addition to the diaphragms at the end of each span.**
- **The above tabularized values may be increased by 0.05 for riveted members**

System Factors (ϕs) for Post-Tensioned Segmental Concrete Bridges

Bridge Type	Span Type	# of Hinges to Failure	System Factors (ϕ_s) No. of Tendons per Web: 1	2	3	4
Precast Balanced Cantilever Type A Joints	Interior	3	0.90	1.05	1.15	1.20
	End or Hinge	2	0.85	1.00	1.10	1.15
	Statically Determinate	1	na	0.90	1.00	1.10
Precast Span-by-Span Type A Joints	Interior	3	na	1.00	1.10	1.20
	End or Hinge	2	na	0.95	1.05	1.15
	Statically Determinate	1	na	na	1.00	1.10
Precast Span-by-Span Type B Joints	Interior	3	na	1.00	1.10	1.20
	End or Hinge	2	na	0.95	1.05	1.15
	Statically Determinate	1	na	na	1.00	1.10
Cast-in-Place Balanced Cantilever	Interior	3	0.90	1.05	1.15	1.20
	End or Hinge	2	0.85	1.00	1.10	1.15
	Statically Determinate	1	na	0.90	1.00	1.10

(For box girder bridges with 3 or more webs, table values may be increased by 0.10)

APPLICATION OF SYSTEM FACTORS

These system factors shall apply for flexural and axial effects at the Strength limit states.

Higher values than those tabulated may be considered on a case-by-case basis with the approval of the Department.

System factors need not be less than 0.85. In no case shall the system factor exceed 1.25.

PRECISION OF RATINGS

Is a rating factor of 0.95 acceptable?

How accurate are our models? How precise are they?

Is conservatism precise?

Part 3

FUTURE CHALLENGES

EXTREME EVENTS & LOAD COMBINATIONS

Turkstra’s Rule

“Bad things do not happen all at once.”

SCOUR

- Not a load, but a change in foundation conditions
- Clear-ware v. live-bed scour

HURRICANES

- Buoyancy,
- Horizontal wave attack, or
- Combinations of both?

HURRICANES

- Extreme-event, or
- Strength limit state?

LOAD COMBINATIONS WITH SCOUR

- Vessel collision & scour
- Hurricanes & scour

SYSTEM PRESERVATION

Distribution of Trucks including blanket permits v. LRFD & LRFR assumed live-load models

SYSTEM PRESERVATION

Standard Specifications' 50 to 60-year design life v. LRFD Specifications' 75-year design life

CALIBRATION OF THE SERVICE LIMIT STATES

- **Service I,**
- **Service II, &**
- **Service III**

THE SERVICE LIMIT STATES GENERALLY GOVERN THE PROPORTIONS OF SUPERSTRUCTURE MEMBERS.

Positive-moment regions of steel girders are governed by the service II load combination.

Prestressed concrete members are governed by the service I or III load combinations.

The *LRFD Specifications* & the new *Condition Evaluation Manual* (including LRFR) are far from perfect and are works in progress, but they remain the best framework for future development.

QUESTIONS OR COMMENTS?

Thank you for your attention.

Questions or comments beyond:
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FOR STRICT APPLICATION OF FDOT's PROCEDURES SEE:
www.dot.state.fl.us