LOAD & RESISTANCE FACTOR RATING OF HIGHWAY BRIDGES

Thomas Saad, P.E.
FHWA

FHWA MEMORANDUM: OCT. 30, 2006
BRIDGE LOAD RATING FOR THE NATIONAL BRIDGE INVENTORY

For bridges and total replacement bridges designed by LRFD Specifications using HL-93 loading, prior to October 1, 2010, Items 63, 64, 65 and 66 are to be computed and reported to the NBI as either a Rating Factor (RF) or in metric tons. Rating factors shall be based on LRFR methods using HL-93 loading (see Appendix A - Example 1) or LFR methods using MS18 loading (see Appendix).

For bridges and total replacement bridges designed by LRFD Specifications using HL-93, after October 1, 2010 Items 63, 64, 65 and 66 are to be computed and reported to the NBI as a RF based on LRFR methods using HL-93 loading (see Appendix A - Example 1).
NHI Course 130092 – LRFR of Highway Bridges

- Comprehensive 5-day course
- Modular Delivery
  - Module I (2-day): Intro. to LRFR (Load Rating Process, Rating for Design, Legal and Permit Loads and Load Posting)
  - Module II (1-day): Load Rating of Concrete Superstructure Bridges
  - Module III (1-day): Load Rating of Steel Superstructure Bridges
  - Module IV (1-day): Load Rating of Bridge Substructures
- Under development - Available January 2009

LOAD & RESISTANCE FACTOR RATING OF HIGHWAY BRIDGES

OUTLINE OF PRESENTATION

SESSION 1: INTRODUCTION TO LRFR
SESSION 2: LOAD MODELS FOR LRFR
SESSION 3: LRFR LOAD RATING PROCESS & LOAD RATING EQUATION
SESSION 4: LRFR LIMIT STATES, RELIABILITY INDICES & LOAD FACTORS
SESSION 5: THE NEW AASHTO MANUAL FOR BRIDGE EVALUATION
SESSION 6: P/S GIRDER BRIDGE LRFR RATING
SESSION 7: STEEL GIRDER BRIDGE LRFR RATING
INTRODUCTION
TO LRFR

Effect of LRFD and LRFR Specs on Bridges

1- More Reliable and Safer Bridges

2- Increased Bridge Life

3- Meaningful Load Ratings!
LRFD / LRFR

- RELIABILITY-BASED LIMIT STATES SPECIFICATIONS
- USE PROBABILISTIC METHODS TO DERIVE LOAD & RESISTANCE FACTORS
- UNIFORM RELIABILITY IN DESIGN & LOAD RATINGS / POSTINGS
- PRESENTATION SUCH THAT PRIOR KNOWLEDGE OF RELIABILITY WILL NOT BE NECESSARY.

LOAD FACTOR RATING METHOD

- A Strength-based load rating method
- Uncalibrated code. Load factors were established based on engineering judgment (Unknown reliability)
- No guidance on adjusting load and resistance factors for changed uncertainty in loadings or member resistance.
LRFR GOAL: UNIFORM RELIABILITY

CALIBRATION OF LIMIT STATES

- Only the Strength Limit State was calibrated based upon structural reliability theory. Other limit states were calibrated to current practice.
- Reliability indices of bridges designed by the Standard Specs ranged from 1.5 to 4.5.
- Target reliability index of 3.5 was selected for new designs.
- Design Reliability $\beta = 3.5$; 1 in 10,000 notional failure probability.
- For evaluation $\beta = 2.5$ or a 1 in 100 notional failure probability.
LRFR RATING EQUATION

\[
RF = \frac{\phi_c \phi_s \phi R - \gamma_{DC} DC - \gamma_{DW} DW}{\gamma_L (LL + IM)}
\]

\[\phi_c \phi_s \geq 0.85\]

\(\phi_s\) SYSTEM FACTOR FOR REDUNDANCY

\(\phi_c\) MEMBER CONDITION FACTOR

PROBABILISTIC DESIGN & EVALUATION

Each variable represented by mean and standard deviation.
RELIABILITY INDEX $\beta$

New Measure of Safety

$R - Q = \text{SAFETY MARGIN}$

LRFR GOAL: UNIFORM RELIABILITY

LFD
LFR

LRFD
LRFR
**Time Dependant Reliability**

Loads ($Q^T$) Increase, Resistance ($R^T$) Decreases

Reliability Decreases with Time

---

**1944 Live Loads**

- 480 lb/ft
  - 13,500 lb for Moment
  - 19,500 lb for Shear
- 640 lb/ft
  - 18,000 lb for Moment
  - 26,000 lb for Shear
LRFD Live Load, HL-93

- **Design Truck:**

- **Design Tandem:**
  - superimposed on
  - Design Lane Load

![Diagram showing load configurations](image)

NCHRP REPORT 454
Calibration of Load Factors for LRFR Bridge Evaluation
LRFR CALIBRATION

• The calibration uses a data base consistent with the calibration of the AASHTO LRFD Bridge Design Specifications.
• Live load factors are given for legal load rating, posting, and permit load checking.
• Live load factors could utilize, where available, site specific traffic information.
• Target safety indices are calibrated to bridge performance history using AASHTO LFR rating methods.
• Uniform consistent target reliabilities are achieved with the new LRFR bridge evaluation format.

NCHRP PROJECT 20-07/Task 122

LOAD RATING BY LOAD AND RESISTANCE FACTOR EVALUATION METHOD

FINAL REPORT JUNE 2005

• The objective of this project is to provide explicit comparisons between the ratings produced by the LRFR method and Load Factor ratings (LFR).
• The comparisons of 74 bridges are based upon flexural-strength ratings.
• Design criteria failure rates & reliability indices determined using Monte Carlo simulations.
FAILURE RATE VERSUS LRFR HL-93 INVENTORY RATING FACTOR

FAILURE RATE VERSUS LRFR & LFR DESIGN LOAD INVENTORY RATING FACTORS
RELIABILITY INDEX VERSUS LRFR & LFR DESIGN LOAD INVENTORY RATING FACTORS

RELIABILITY INDICES FOR AASHTO STD. SPECS. SIMPLE SPAN MOMENTS IN STEEL GIRDERS

Ref: NCHRP 12-33 Calibration of LRFD Bridge Design Code
RELIALIBILITY INDICES FOR AASHTO STD. SPECS.
SIMPLE SPAN SHEAR IN STEEL GIRDERS

Influence
of DF

Ref: NCHRP 12-33 Calibration of LRFD Bridge Design Code

RELIALIBILITY-BASED EVALUATION OF EXISTING BRIDGES

CAN THE LRFD CODE BE USED FOR EVALUATION?

EVALUATION IS NOT THE INVERSE OF DESIGN
### DESIGN vs EVALUATION

<table>
<thead>
<tr>
<th></th>
<th>Design</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added cost of conservatism</td>
<td>Marginal</td>
<td>Can be prohibitive</td>
</tr>
<tr>
<td>Exposure period</td>
<td>75 years</td>
<td>2 years</td>
</tr>
<tr>
<td>Live load uncertainty</td>
<td>High</td>
<td>Lower</td>
</tr>
<tr>
<td>Resistance uncertainty</td>
<td>Low</td>
<td>Higher</td>
</tr>
</tbody>
</table>

### CAN THE LRFD CODE BE USED FOR EVALUATION?

- Is the design level reliability of 3.5 appropriate for evaluation?
- Existing bridges have a beta in the 2.5 to 4.5 range (many below 3.5).
- Should all serviceability limit states be imposed on existing bridges?
- How should overweight permit loads be evaluated?
- Design impact factors (33%) may be too conservative for evaluation.
CAN THE LRFD CODE BE USED FOR EVALUATION?

- The HL-93 loading does not bear any resemblance to actual trucks.
- HL-93 is a notional load not suitable for posting.
- LRFD only addresses redundant superstructure systems. Many existing bridges are non-redundant.
- LRFD is focused on new bridges, not degraded bridges.
- Older materials & connections (rivets) are not covered in the LRFD Specs.

GOALS FOR THE NEW LRFR MANUAL

- Maintain consistency with LRFD philosophy & codes.
- Presentation such that prior knowledge of reliability methods will not be necessary.
- Replace the 1994 AASHTO Manual for Condition Evaluation of Bridges (MCE).
MAJOR OVERHAUL OF 1994 AASHTO CONDITION EVALUATION MANUAL

2003 LRFR GUIDE MANUAL

- Only inspection & material testing sections were retained
- New sections:
  - Load and Resistance Factor Rating (LRFR)
  - Fatigue evaluation of bridges
  - Non-destructive load testing of Bridges
  - Introduction to Bridge Management Systems
- Parallel commentary & many Illustrative examples.
## LOAD & RESISTANCE FACTOR RATING

Can be used for the load rating of:

- **Existing Bridges Designed Using the Standard Specifications:**
- **New Bridges Designed Using the LRFD Specifications**
LRFR Rating of New Bridges Designed Using the LRFD Specifications

• Ratings can be checked for:
  • In-service LRFD bridges, or
  • For bridges still in the design phase.
• Rating consistent with the design approach.
• Maintains uniform reliability as the basis for design and evaluation
• Consistent treatment of serviceability criteria over the Life of the bridge.

LRFR Rating of Existing Bridges Designed Using the Standard Specifications

• Introduces uniform reliability as the basis for evaluation, load posting, and overload permitting.
• Promotes more confidence in rating and posting values.
• Introduces superior serviceability criteria that could guide inspections and enhance long-term maintainability.
• Provides guidance for evaluation of overloads
• Introduces state-of-the-art technologies that could benefit existing bridges.
2005 AASHTO BRIDGE MEETING

AASHTO Adopted the LRFR Manual to replace the 1994 *Manual for Condition Evaluation* with the following modifications:

- Change title to “The Manual for Bridge Evaluation”
- Include LRFR, Load Factor and Allowable Stress rating methods in Section 6 of the new Manual.
- Update to be consistent with LRFD Latest Edition.

THANK YOU

*Thomas Saad, P.E.*
**Structural Design Engineer**
FHWA Resource Center
Olympia fields, IL
(708) 283-3521
thomas.saad@fhwa.dot.gov