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Reliability-Based Bridge Load Posting
- The LRFR Approach

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**Bridge Failure –**

*It could happen anytime and anywhere, if we don’t do things right....*

*It could happen, even if we do things right.*
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- **NBIS – 23 CFR 650 Subpart C**
  - 650.313 Inspection Procedures
    - (c) *Rate each bridge as to its safe load carrying capacity in accordance with the AASHTO Manual.* Post or restrict the bridge in accordance with the AASHTO Manual....

- To ensure safety, bridges must be inspected, load rated, and posted if necessary.

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- **AASHTO Manual for Bridge Evaluation**

- **Section 6: Load Rating**
  - Part A – Load and Resistance Factor Rating
    - Article 6A.8 – Posting of Bridges
  - Part B – Allowable Stress and Load Factor Rating
    - Article 6B.7 - Posting of Bridges (2nd Edition MBE)
    - Article 6B.9 - Posting of Bridges (1st Edition MBE)

- Section 7: Fatigue Evaluation of Steel Bridges
- Section 8: Nondestructive Load Testing
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- Findings of OIG’s Audit:
  - March, 2006
  - State Inspections Were Adequate, but Load Ratings and Maximum Weight Postings Were Not Accurate
  - Errors found in the calculation of load ratings or in the posting of maximum weight limits or other related errors for 33 of the 43 bridges reviewed in a sample from the three states.
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In-depth Load Rating and Posting Review: 2007-2010

Findings and Risks No. 4

- Not all bridges which require posting are posted in accordance with the NBIS.

- Not all bridges are load posted in accordance with the NBIS. Inaccurate or incomplete load ratings and postings could result in damaging loads on bridges. Other impacts could include commerce and improper allocation of available resources.
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Finding No. 4

Are all bridges which require posting in accordance with the NBIS, posted?

LEGEND: Good = Yes or All; Fair = Some, or all/most with minor issues; Poor = No or some with deficiencies.
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Concrete Bridges

Steel Bridges
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LRFR Implementation Status Survey - 2011

Has it been determined whether the MBE LRFR rating vehicles envelop the force effects of your State-specific legal vehicles?

Data by 10/05/2011
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Posting Signage

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MBE Articles 6A.8.2: When the maximum legal load under State law exceeds the safe load capacity of a bridge, restrictive load posting shall be required. Though there is variation among the States with respect to the type of signs preferred for posting bridges, most states use either a single weight-limit sign or a three-vehicle combination sign. In any case, the posting signs shall conform to the Manual on Uniform Traffic Control Devices (MUTCD).
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<table>
<thead>
<tr>
<th>North Carolina</th>
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<tbody>
<tr>
<td>WEIGHT LIMIT XX TONS</td>
</tr>
<tr>
<td>R12-1 24” x 30”</td>
</tr>
<tr>
<td>WEIGHT LIMIT SINGLE VEHICLE XX TONS</td>
</tr>
<tr>
<td>TRUCK TRACTOR SEMITRAILER XX TONS</td>
</tr>
<tr>
<td>R12-19 24” x 36”</td>
</tr>
<tr>
<td>42” x 48”</td>
</tr>
<tr>
<td>WEIGHT LIMIT TRUCK TRACTOR SEMITRAILER LEGAL SEMITRAILER GROSS WEIGHT</td>
</tr>
<tr>
<td>R12-18 24” x 36”</td>
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<table>
<thead>
<tr>
<th>Illinois</th>
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<tbody>
<tr>
<td>$100 FINE</td>
</tr>
<tr>
<td>R7-I101</td>
</tr>
<tr>
<td>17 MILES AHEAD</td>
</tr>
<tr>
<td>R12-I103</td>
</tr>
<tr>
<td>WEIGHT LIMIT 5 TONS JANUARY 5 TO APRIL 5</td>
</tr>
<tr>
<td>R12-I104</td>
</tr>
<tr>
<td>BRIDGE WEIGHT LIMIT - TONS</td>
</tr>
<tr>
<td>R12-I100</td>
</tr>
<tr>
<td>SINGLE VEHICLE 17 COMBINATIONS 3 OR 4 AXLES 21 5 OR MORE 23</td>
</tr>
<tr>
<td>R12-I101</td>
</tr>
<tr>
<td>BRIDGE WEIGHT LIMIT - TONS</td>
</tr>
<tr>
<td>R12-I102</td>
</tr>
<tr>
<td>SINGLE VEHICLE COMBINATION VEHICLE 16</td>
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<tr>
<td>R12-I101</td>
</tr>
<tr>
<td>BRIDGE AHEAD RESTRICTED TO ONE TRUCK AT A TIME</td>
</tr>
<tr>
<td>R12-I105</td>
</tr>
<tr>
<td>BRIDGE RESTRICTED TO ONE TRUCK AT A TIME</td>
</tr>
<tr>
<td>R12-I106</td>
</tr>
</tbody>
</table>
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- **Alabama**

- **Georgia**

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Posting Methodology

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- **Allowable Stress Rating:**
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- Load Factor Rating:

![Graph](image_url)

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- **Load Factor Rating:**

  **Posting Load:**
  
  \[ W \times RF \]

  \[
  RF_{op} = \frac{C - 1.3DL}{1.3(LL + I)}
  \]

  \[
  RF_{inv} = \frac{C - 1.3DL}{2.17(LL + I)}
  \]

  \( RF = \text{Legal load rating factor} \)

  \( W = \text{Weight of rating vehicle} \)

  **LFR LOAD POSTING CURVE**

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- LRFR

Posting Load:

\[ \frac{W}{0.7} \times (RF - 0.3) \]

RF = Legal load rating factor

W = Weight of rating vehicle

LRFR LOAD POSTING CURVE

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Structural Reliability

The limit state function is defined as

\[ g = R - D \]

where \( D \) and \( R \) are the load effect and resistance, respectively. Both \( D \) and \( R \) are statistically distributed with the uncertainty of their values at the time that the component is designed or evaluated. The probability of failure can be written as

\[ P_f = P[g < 0] = P[R < D] \]
Structural Reliability

The reliability index, $\beta$, to measure the safety margin,

$$\beta = \frac{\bar{g}}{\sigma_g}$$

where $\bar{g}$ and $\sigma_g$ represent the mean and standard deviation of the random number, $g$.

$$\beta = \frac{R - D}{\sqrt{\sigma_R^2 + \sigma_D^2}}$$

$$\beta = \frac{\ln\left(\frac{R}{D}\right)}{\sqrt{V_R^2 + V_D^2}}$$

(1) Normal Distribution  (2) Log-Normal Distribution  (3) Monte-Carlo Simulation
Structural Reliability

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Structural Reliability

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  The reliability level inherent in the posting curve is raised at the lower posting loads to achieve reliability targets closer to design Inventory levels rather than the evaluation or operating reliability characteristic of other practices in this Manual.
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- **LRFR**

![Equation Image]

\[
RF = \frac{R_n - \gamma_{DC} DC_n}{\gamma_{LL} LL_n} < 1.0
\]

\[
\beta_0 = \frac{(B_R \gamma_{DC} - B_{DC}) \xi + (RF B_R \gamma_{LL} - \zeta B_{LL})}{\sqrt{[C_{v,R} B_R (RF \gamma_{LL} + \xi \gamma_{DC})]^2 + (C_{v,DC} B_{DC} \xi)^2 + (\zeta C_{v,LL} B_{LL})^2}}
\]

\[
\xi = \frac{DC_n}{LL_n}
\]

\[
\zeta = \frac{LL'_n}{LL_n}
\]

where \(LL'_n\) is the allowed live load effect at the post limit corresponding to the target reliability index of \(\beta_0\).
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- LRFR

Probabilistic Load and Resistance Models: Normal Distribution

Allowed Live Load (Reliability Index: $\beta = 2.5$)

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FHWA’s Expectations

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- **FHWA’s Expectations**
  - **NBIS Compliance:**
    - Each bridge must have a valid load rating.
    - Re-evaluate and rate as loadings or conditions change.
    - Re-rate bridges anytime as deemed needed.
    - Post or restrict a bridge in accordance with MBE or State law.
Thank you for your attention!

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