What is Load Rating?

The safe live load carrying capacity of a highway structure is called its load rating.

It is usually expressed as a Rating Factor (RF) or in terms of tonnage for a particular vehicle.
**TYPES OF RATINGS**

Inventory Rating

- Axial
- Moment
- Shear
- Serviceability
- Moment Shear Interaction

Operating Rating

IN LRFR INVENTORY & OPERATING RATINGS ARE DEFINED IN TERMS OF ASSOCIATED RELIABILITY INDICES ($\beta=3.5$ INV, $\beta=2.5$ OPR)

**RATING FACTOR**

$$RF = \frac{C - A_1 \times D}{A_2 \times L^*(1 + I)}$$

- $A_1 = $ Factor for dead loads
- $A_2 = $ Factor for live load
- $C = $ Capacity of the bridge
- $D = $ Dead load effect
- $I = $ Impact factor (Dynamic Load Allowance)
- $L = $ Live load effect
Why Do We Load Rate Bridges?

- Different design vehicles have been used in the past for the design of bridges (e.g., H-15, HS20-44, HS25, HL-93, ...).
- Some bridges have aged, deteriorated or become structurally deficient during the course of their life.
- To have a consistent summary of the load carrying capacities, all bridges are rated using a standard set of vehicles, called Legal Loads.
- For the safety of general public and traffic using highway structures, the loading rating is performed.
- Bridges that have insufficient load capacity are posted for restricted loads.

Data Collection for LRFR Load Rating

Loading and Traffic Data

- Actual wearing surface thickness, if present
- Non-structural attachments and utilities
- Depth of fill (buried structures)
- Number and positioning of traffic lanes
- ADTT or traffic volume and % trucks
- Posted load limit, if any
- Roadway surface conditions.
THE LRFR PHILOSOPHY

- Reliability-based, limit states approach consistent with LRFD.
  - Rating done at Strength limit state and checked for serviceability.
- Provides more flexible rating procedures with uniform reliability.
  - Calibrated live load factors for different live load models and loading uncertainties.

THE LRFR LOAD RATING PROCESS

1) DESIGN LOAD RATING (HL-93)

2) LEGAL LOAD RATING (POSTING)

3) PERMIT LOAD RATING (OVERWEIGHT TRUCKS)
Flow Chart for LRFR Load Rating

![Flow Chart Image]

DESIGN LOAD RATING (HL 93)

- HL93 is a notional representation of trucks permitted under “Grandfather” exclusion to weight laws.
- Bridges that rate for HL93 are safe for all legal loads (including grandfather trucks).
- RF < 1.0  Identifies vulnerable bridges for further evaluations (need for posting).
- Results suitable for NBI reporting of LRFR Ratings (Similar to HS20).
DESIGN LOAD RATING (HL 93)

- Do not convert HL-93 rating factors to tonnage. It’s a notional load that includes a lane load.
- Report ratings as rating factors to the NBI.
- Provides a metric for assessing existing bridges to current (LRFD) design standards.

FHWA REPORTING

- Recent revisions to the Coding Guide to allow reporting of HL-93 LRFR Rating Factors (Items 63 and 65)
- Allows reporting of Rating Factors instead of Tons.
**RELIABILITY LEVELS FOR HL-93**

1) For States that allow “Exclusion Loads”
   \[ \beta = 3.5 \text{ (Inventory Level)} \]
   Live Load Factor = 1.75

2) For States that comply with federal weight laws (incl. Formula B):
   \[ \beta = 2.5 \text{ (Operating Level)} \]
   Live Load Factor = 1.35

---

**LRFR FLOW CHART FOR HL-93**

- **NO ACTION REQ'D**
  - RF > 1.0

- **DESIGN LOAD CHECK HL93 DESIGN RELIABILITY**
  - SERVICEABILITY
    - RF < 1.0
  - STRENGTH
    - RF < 1.0

- **CHECK OPERATING LEVEL RATING**
  - RF > 1.0
  - RF < 1.0

- **IDENTIFIES VULNERABLE LIMIT STATES FOR FUTURE INSPECTIONS/Maintenance/LOAD RATING**

- **TO LOAD RATING**

- **NO ACTION REQ'D**
LEGAL LOAD RATING

- Bridges with RF < 1.0 for HL-93 should be load rated for AASHTO & State legal loads.
- Bridges with RF < 1.0 for legal loads should be posted.
- Single load rating at $\beta = 2.5$ for legal loads.
- LRFR Provides a single safe load capacity for indefinite use.

**Load Factor Operating Rating** --- Maximum permissible live load for the structure, suitable for one-time or Limited Crossings.

LEGAL LOAD RATING

- Single load rating ($\beta = 2.5$) for a given legal load. Departure from current practice of INV & OPR ratings.
- Provides Load Ratings using AASHTO Legal Loads (Type 3, Type 3-3, Type 3S2) & Specialized hauling Vehicles
- Legal load ratings are used to establish need for posting (RF < 1.0) or bridge strengthening
- Do not use HL-93 results for posting purposes
STRENGTH LIMIT STATE EVALUATION

General Load Rating Equation

\[ RF = \frac{\phi_C \phi_S \phi \gamma_{DC} R - \gamma_{DW} DW \pm \gamma_P P}{\gamma_L (1 + IM)} \]

Where:
- \( RF \) = Rating Factor
- \( \gamma_{DC} \) = LRFD Load factor for structural components and attachments
- \( \gamma_{DW} \) = LRFD Load factor for wearing surfaces and utilities
- \( \gamma_P \) = LRFD Load factor for permanent loads other than dead loads
- \( \gamma_L \) = Evaluation live load factor
- \( \phi_C \) = Condition factor
- \( \phi_S \) = System factor
- \( \phi \) = LRFD resistance factor
- \( R \) = Nominal member resistance
- \( DC \) = Dead load effect due to structural components and attachments
- \( DW \) = Dead load effect due to wearing surface and utilities
- \( P \) = Permanent loads other than dead loads
- \( L \) = Live load effect
- \( IM \) = Dynamic load allowance
**LRFR LOAD FACTORS FOR HL-93**

\[ \beta = 3.5 \text{ (Inventory Level)} \]
Live Load Factor = 1.75

\[ \beta = 2.5 \text{ (Operating Level)} \]
Live Load Factor = 1.35

**LOAD FACTORS FOR LEGAL LOADS**

\[ \beta = 2.5 \]

- **TRAFFIC VOLUME**
  - ADTT > 5000
  - ADTT = 1000
  - ADTT < 100

- **LOAD FACTOR**
  - 1.80
  - 1.65
  - 1.40

- For ADTT between 100 and 5000 interpolate the load factor.
LRFR RATING EQUATION

\[ RF = \frac{\phi_c \phi_s \phi R - \gamma_{dc} DC - \gamma_{dw} DW}{\gamma_1 (LL + IM)} \]

\[ \phi_c \phi_s \geq 0.85 \]

\( \phi_s \) OPTIONAL SYSTEM FACTOR FOR REDUNDANCY

\( \phi_c \) OPTIONAL MEMBER CONDITION FACTOR

\( \phi \) LRFD RESISTANCE FACTOR

BRIDGE SAFETY AND REDUNDANCY

- LRFD IS CALIBRATED TO PROVIDE UNIFORM MEMBER SAFETY FOR REDUNDANT PARALLEL GIRDER SUPERSTRUCTURE SYSTEMS (CONSIDERED REPRESENTATIVE OF CURRENT AND FUTURE TRENDS IN BRIDGE CONSTRUCTION)

- MANY EXISTING BRIDGES HAVE NON-REDUNDANT SUPERSTRUCTURE SYSTEMS

- REDUNDANT SYSTEMS:
  - SYSTEM SAFETY > MEMBER SAFETY

- NON-REDUNDANT SYSTEMS:
  - SYSTEM SAFETY = MEMBER SAFETY
System Factors are Multipliers to the Nominal Resistance to Reflect the Level of Redundancy of the Complete Superstructure System.

- Non-Redundant Bridges will Have Their Factored Member Capacities Reduced, and, Accordingly, will Have Lower Ratings.
- System Factors are Used to Maintain an Adequate Level of System Safety.
- The Aim of \( \phi_s \) is to Add Reserve Capacity (to non-redundant member) such That System Reliability is Increased from an Operating Level Reliability to an Inventory Level Reliability

For Redundant Bridges, \( \phi_s = 1.00 \)

Non-redundant Bridges \( \phi_s = 0.85 \)

**Non-redundant Members with Internal Redundancy**

- Riveted Two-Girder/Truss Bridges \( \phi_s = 0.90 \)
- Multiple Eyebar Members in Trusses \( \phi_s = 0.90 \)
- Floorbeams with Spacing > 12 ft \( \phi_s = 0.85 \)

System Factors are Not Appropriate for Shear as Shear Failures Tend to Be Brittle. Without Ductility System Reserve is Not Possible.
CONDITION FACTOR $\phi_c$

$$C = \phi_c \phi_s R$$

Resistance of Deteriorated Bridges:

- LRFD Resistance Factors for New Members Must be Reduced When Applied to Deteriorated Members
- There is Increased Uncertainty and Variability in Resistance of Deteriorated Members
- They are Prone to Accelerated Future Deterioration. (increased additional losses between inspection cycles)
- Improved Inspections will Reduce, but not Totally Eliminate, the Increased Resistance Variability in Deteriorated Bridges.

CONDITION FACTOR $\phi_c$

- Condition Factor $\phi_c$ is Tied to The Condition of The Member Being Evaluated (element level data preferred):
  - Good or Satisfactory $\phi_c = 1.00$
  - Fair $\phi_c = 0.95$
  - Poor $\phi_c = 0.85$

- If Element Level Condition Data is not Collected, NBI Ratings for the Superstructure May be Used to Set $\phi_c$
  - $\phi_c = 0.85$ for NBI Rating of 4
  - $\phi_c = 0.95$ for NBI Rating of 5
  - $\phi_c = 1.00$ for NBI Rating 6 or higher

Increases beta from 2.5 to a target of 3.5 to account for the increased variability of resistance of deteriorated members.
LRFD DYNAMIC LOAD ALLOWANCE (IM)

<table>
<thead>
<tr>
<th>Component</th>
<th>IM</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Components</td>
<td></td>
</tr>
<tr>
<td>• Fatigue &amp; Fracture Limit State</td>
<td>15%</td>
</tr>
<tr>
<td>• All Other Limit States</td>
<td>33%</td>
</tr>
</tbody>
</table>

- Standard IM specified for use with all load models
- IM is Applied to HL-93 Design Truck Only ... Not to Design Lane Load
- This simple approach is based upon a study which revealed that the most influential factor is roadway surface roughness (not span length).

LRFR DYNAMIC LOAD ALLOWANCE

IM = 33% Is Standard. Following Values are Optional:

- **Legal Load rating**
  - Riding surface conditions  IM
    - smooth                      10%
    - minor surface irregularities 20%
    - major surface irregularities 33%

- **Permits** - same, except for:
  - slow moving (<5mph) vehicles 0%
LRFR DEAD LOAD FACTORS

DC - Dead Load, except wearing surfaces and utilities

DW - wearing surfaces and utilities, acting on the long-term composite section.

$\gamma_{DC} = 1.25$

$\gamma_{DW} = 1.50$

$\gamma_{DW} = 1.25$ When overlay thickness is filed measured.

LRFR LOAD POSTING OF BRIDGES

Illinois

Alabama
SETTING A POSTING WEIGHT LIMIT
Current Practice (LFR)

Bridge Safe Load Capacity or posting load is commonly based on the following factors:

• Condition of the bridge
• Bridge redundancy
• Site traffic conditions
• Sometimes the inspection frequency

Very little consistency among various jurisdictions in this regard. These factors are not currently considered in the LFR load rating process.

POSTING BRIDGES FOR UNIFORM RELIABILITY

• Post Bridges when RF < 1.0 for legal loads.
• The LRFR philosophy of uniform reliability applies to load ratings & posting.
• Bridges should also be posted to maintain uniform reliability.
• The rating analysis is aimed at determining a rating factor or tonnage for a specific truck.
• The posting analysis provides the safe posting level for a bridge when RF < 1.0.
POSTING BRIDGES FOR UNIFORM RELIABILITY

- Relationship between posting load and rating factor is not linear in a reliability based evaluation.
- The lower the posting load, the greater the possibility of illegal overloads and multiple presence.
  - 5 Ton Capacity vs 20 Ton capacity; which bridge has a greater probability of illegal overloads?
- The overload probabilities are higher for low rated bridges, which should be considered in the posting analysis.
- A more conservative posting is required for low rated bridges to maintain the same level of reliability used in the rating analysis.
- Posting analysis translates rating factors into posting loads. Provides a more rational assessment of bridge safe load capacity.

LRFR POSTING ANALYSIS

1) When $0.3 < RF < 1.0$

$$\text{Posting Load} = \left( \frac{W}{0.7} \right) \left[ (RF) - 0.3 \right]$$

$W=$ Weight of rating vehicle
$RF=$ Legal load rating factor

2) When $RF < 0.3$ for all three AASHTO loads, bridge should be closed

If a bridge cannot support the empty weight of a legal truck, the bridge should be closed.
POSTING LOAD vs RATING FACTOR

LRFR POSTING CURVES

Criteria: A bridge with acceptable capacity less than 3 tons should be closed.

Increase beta from operating target of 2.5 to 3.5 to account for historical failure occurrences in posted bridges

Allow an overweight “cushion” of 10,000 lbs