3.15 LOAD RATING OF NEW BRIDGE DESIGN

The Load and Resistance Factor Rating (LRFR) methodology has been developed to provide uniform reliability in bridge load ratings.

Load rating analysis shall be performed for all new or replacement bridges, including Value Engineering or Value Engineering Change Proposals by the Contractor, using the LRFR Method as described in the current edition of the AASHTO Manual for Bridge Evaluation (MBE). This document provides guidance to load rating engineers for performing and submitting load rating calculations and serves as a supplement to the MBE to describe WVDOT specific load rating requirements.

Each bridge shall be load rated at design inventory and design operating levels for AASHTO’s HL93 loading as presented in the Governing Specifications on all routes. In addition, a legal rating analysis shall be completed for each of the following AASHTO legal loads: Type 3, Type 3S2, SU4, SU5, SU6, and SU7 on all routes. Also, bridges on non-interstate routes shall be load rated for the WV legal load, WV-2S2. All bridges shall be load rated for two emergency vehicles, EV2 and EV3. Bridges on a Coal Resource Transportation System (CRTS) Route shall be load rated for four additional trucks: WV-SU40, WV-SU45, WV-SU55, and WV-SU60. The AASHTO MBE lane-type legal models shall be applied as necessary to all spans except single spans less than and equal to 200 ft. The axle configurations and loads for the Legal Trucks are shown in Figure 3.15 and 3.16, and the CRTS and EV Trucks are shown in Figure 3.16.
### LEGAL VEHICLE LIVE LOADS

<table>
<thead>
<tr>
<th>Description</th>
<th>Load Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3 (GVW = 50 kips)</td>
<td>16.0</td>
</tr>
<tr>
<td>SU4 (GVW = 54 kips)</td>
<td>12.0, 8.0, 17.0, 17.0</td>
</tr>
<tr>
<td>SU5 (GVW = 52 kips)</td>
<td>12.0, 8.0, 8.0, 17.0, 17.0</td>
</tr>
<tr>
<td>SU6 (GVW = 60.5 kips)</td>
<td>11.5, 8.0, 8.0, 17.0, 17.0, 8.0</td>
</tr>
<tr>
<td>SU7 (GVW = 77.5 kips)</td>
<td>11.5, 8.0, 8.0, 17.0, 17.0, 8.0, 8.0</td>
</tr>
<tr>
<td>WV-2S2 (GVW = 72 kips)</td>
<td>12.0, 20.0, 20.0</td>
</tr>
<tr>
<td>3S2 (GVW = 72 kips)</td>
<td>10.0, 15.5, 15.5, 15.5</td>
</tr>
</tbody>
</table>

**Note:** All axle weights are in kips

*Figure 3.15*
LEGAL VEHICLE LIVE LOADS

Concentrated loads are axle loads in kips (75% of Type 3-3)
Legal Lane Weight/ft. = 0.2 klf

Lane-Type Legal Load Model (all load effects for spans >200ft)

Lane-Type Legal Load Model (for negative moment and interior reaction for all span lengths)

Figure 3.16
CRTS VEHICLE LIVE LOADS

WV-SU40

\begin{align*}
20.0 & \quad 32.0 & \quad 32.0 \\
\hline
\text{16"} & \quad \text{4'-5"} \\
\end{align*}

WV-SU45

\begin{align*}
20.0 & \quad 24.6 & \quad 24.9 & \quad 24.6 \\
\hline
\text{16"} & \quad \text{4'-4"} & \quad \text{4'-4"} \\
\end{align*}

WV-3S55

\begin{align*}
12.0 & \quad 25.9 & \quad 25.9 & \quad 25.9 & \quad 25.9 \\
\hline
\text{16"} & \quad \text{4'-6"} & \quad \text{24"} & \quad \text{4'-6"} \\
\end{align*}

WV-3S60

\begin{align*}
12.0 & \quad 24.0 & \quad 24.0 & \quad 22.0 & \quad 22.0 & \quad 22.0 \\
\hline
\text{16"} & \quad \text{4'-8"} & \quad \text{21"} & \quad \text{4'-3"} & \quad \text{4'-3"} \\
\end{align*}

EMERGENCY VEHICLE LIVE LOADS

EV2

\begin{align*}
24.0 & \quad 33.5 \\
\hline
\text{15°} \\
\end{align*}

EV3

\begin{align*}
24.0 & \quad 31.0 & \quad 31.0 \\
\hline
\text{15°} & \quad \text{4°} \\
\end{align*}

Note: All axle weights are in kips

Figure 3.17
The bridge load rating analysis using the LRFR Method shall be performed concurrent with the beam/girder final design to assure proper design and adequate rating. The target inventory ratings for new or replacement bridge designs are shown in Table 3.15.

<table>
<thead>
<tr>
<th>Route</th>
<th>Design-Inventory (Factor)</th>
<th>Legal [Tons]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WV-252</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SU4</td>
</tr>
<tr>
<td></td>
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<td>SU5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SU6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SU7</td>
</tr>
<tr>
<td>Interstate</td>
<td>1.00</td>
<td>25</td>
</tr>
<tr>
<td>65,000 lb</td>
<td>1.00</td>
<td>33</td>
</tr>
<tr>
<td>80,000 lb</td>
<td>1.00</td>
<td>33</td>
</tr>
<tr>
<td>CRTS</td>
<td>1.00</td>
<td>33</td>
</tr>
</tbody>
</table>

*Required for CRTS Routes Only
**Not required for single spans less than and equal to 200 feet

Table 3.15 – Target Inventory Ratings

If the rating of bridges designed using the LRFD Specifications is less than the target value, and the design is found to be adequate, the Bridge Project Manager in coordination with the evaluation section shall be contacted immediately to determine what actions are to be taken before proceeding further with the final design and detailing. If the HL93 Inventory rating requirement is satisfied, then it is expected that all legal loads will be satisfied with the possible exception of CRTS trucks. A bridge may satisfy the HL93 Design Inventory rating requirement but not satisfy the rating requirements for CRTS. All new designs for bridges on the CRTS must satisfy target ratings shown in Table 3.15.

The Designer shall state in the plans when redistribution of negative moments is utilized, for use in the permit rating of the bridge (see AASHTO LRFD 4.6.4).

A request for load rating shall be submitted to Maintenance Division (OM) by the Bridge Project Manager during the load rating submission. The request shall contain the following information:

- Load rating sheets containing tabulated section properties, live load distribution factors, dead load moments and shears, and live load moments and shears at critical locations in each span and at all supports
- Superstructure framing plan, typical cross section, girder elevation, and bridge general notes sheets
- The PS&E date of the project
The Designer shall be required to submit to OM original rating computations included with the design calculations and shall clearly identify or include the following information:

- Design specifications
- Design live load
- Member capacities
- Method of analysis – line girder, grid, or finite element
- Method used for calculation of live load distribution factors
- Live load distribution factors
- Table of applicable load factors
- Controlling limit states
- Inventory and Operating Ratings for the design load and legal ratings for applicable legal trucks for consultant designed bridges if required by project scope
- Relevant computer input and output information for consultant designed bridges if required by project scope

3.15.1 Rating Computations

The load rating shall be computed using the following general rating equation (see MBE 6A.4.2.1):

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

$RF$ = Rating Factor  
$C$ = Capacity  
$DC$ = Dead load effect due to structural components and attachments  
$DW$ = Dead load effects due to wearing surface and utilities  
$P$ = Permanent loads other than dead loads (secondary prestressing effects, etc.)  
$LL$ = Live load effect of the Rating Vehicle  
$IM$ = Dynamic load allowance  
$\gamma_{DC}$ = 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 = 1.0  
$\gamma_{LL}$ = Evaluation live load factor for the Rating Vehicle

Load factors shall be determined from MBE Table 6A.4.2.2-1 and MBE Table 6A.4.4.2.3a-1

3.15.1.1 For Strength Limit States:
\[ C = \phi_c \phi_s R_n \]

Where the following lower limit shall apply:
\[ \phi_c \phi_s \geq 0.85 \]

### 3.15.1.2 For All Non-Strength Limit States:

\[ C = f_R \]

- \( \phi_c \) = Condition Factor
- \( \phi_s \) = System Factor
- \( \phi \) = AASHTO LRFD Resistance Factor
- \( R_n \) = Nominal member resistance (as-built or as inspected)
- \( f_R \) = Allowable stress specified in the LRFD code

### 3.15.2 LRFR Limit States for Evaluation

The strength limit state is used for checking the ultimate capacity of structural members and is the primary limit state utilized for determining posting needs. Service and fatigue limit states are utilized to limit stresses, deformations, and cracking under regular service conditions. LRFR limit states for evaluation are shown in MBE, particularly MBE Table 6A.4.2.2-1. The required limit states shall be checked, but the optional checks shall only be performed if explicitly defined in the scope of work.

### 3.15.3 LOAD RATING OF NEW OR REPLACEMENT FRAMES, ARCHES, THREE SIDED STRUCTURES, AND CULVERTS

The load rating analysis shall be performed by the designer in accordance with the Governing Specifications and the MBE using the live load models presented in this document.

If it is determined that the depth of fill is such that live load effects can be neglected then the structure would have an infinite safe load capacity for HL93, all legal trucks, and CRTS Trucks as long as the structure has residual capacity remaining after dead load effects have been considered.

A 3D Finite Element Analysis shall be performed for any structure that is constructed on a longitudinal slope to determine the out of plane load effects on the structure in the final condition.
Calculations shall be submitted to the Bridge Project Manager for approval prior to fabrication of any primary structural elements.

### 3.15.4 LOAD RATING OF GUSSET PLATES

Load rating of gusset plates will be performed in accordance with the current edition of the MBE (including all interim revisions). The 2009 FHWA Guidance shall not be used as it has been superseded by the MBE revisions.

When load rating gusset plates with unknown material properties, member strength should be obtained from the current version of the MBE.

### 3.15.5 LOAD RATING OF REHABILITATED OR WIDENED STRUCTURES

Load rating of structures using combination specifications within the superstructure (e.g. a superstructure designed by LRFD for the new widened superstructure elements and the original superstructure elements designed by Load Factor Design) shall not be permitted.

Load rating of structures partially reconstructed resulting in the use of combination specifications between substructure and superstructure elements (e.g. a reconstructed superstructure designed by LRFD supported by the original substructure designed by Allowable Stress Design, Load Factor Design, or unknown specifications) is permitted. The method of analysis for a reconstructed superstructure shall be Load and Resistance Factor Rating.

### 3.15.6 CONVERSION FACTORS FOR REFINED ANALYSIS

When structures are designed using refined analyses, conversion factors shall be developed. The refined analyses methods include line girder analyses based on refined live load distribution factors, grid analyses and finite element analyses. The conversion factors indicate the relationship of live load design moments and shears, obtained from the refined analysis, to the live load moments and shears obtained from a standard line girder analysis with a live load distribution factor of 1.0 for a single lane (a single lane equals two wheels). Do not use AASHTO distribution factors for the line girder analysis.

The conversion factors for refined analyses shall be computed using the following equation:

$$ CF = \frac{\text{Moment (refined analysis)}}{\text{Moment (line girder analysis)}} $$

- Use of conversion factors

Subsequent analyses of the structure may be completed using a standard line girder analysis with a live load distribution factor 1.0 for a single lane (a single lane equals two wheels). Do not use AASHTO distribution factors for the line girder analysis. For additional loadings, or re-evaluation of the design vehicle, the live load moments and shears obtained from the standard line girder analysis shall be multiplied by the conversion factors obtained from refined analysis.
at appropriate girder location under investigation. For example, for Girder 3 at mid-span of span 2, the equivalent refined moment can be calculated as follows:

Girder 3, Location: Span 2.5

\[
\begin{align*}
CF & = 1.026 \text{ (listed in the table on the original plans)} \\
M_{(LG)} & = 3175.8 \text{ K-FT (live load moment from line girder analysis)}
\end{align*}
\]

\[
M_{(\text{refined})} = \frac{3175.8 \text{ K-FT} \times 1.026}{1.026} = 3258.4 \text{ K-FT (equivalent refined live load moment)}
\]

3.15.7 LOAD RATING PLAN SHEETS

The required information for the plan sheet submittal is located in section 4.4.1.18. Example plan sheets are also available for reference on the WVDOH website.
End of Section 4.4.1.18

<table>
<thead>
<tr>
<th>Rating Level</th>
<th>Design Load Ratings (Rating Factor)</th>
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</thead>
<tbody>
<tr>
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<td>Inventory</td>
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<tr>
<td></td>
<td>Operating</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rating Level</th>
<th>Legal Load Ratings (Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard</td>
</tr>
<tr>
<td></td>
<td>Type 3</td>
</tr>
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<td>SU4</td>
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<tr>
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<tr>
<td></td>
<td>3S-60</td>
</tr>
</tbody>
</table>

Commented [DDW8]: Need to change out the 1 table at the end of 4.4.1.18 to these two new tables.