Improved Load Rating of Existing Bridges for Permit Trucks

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Introduction

- Permit trucks often need bridge owners approval to cross their inventory.
- Bridge owner needs to make sure if a permit truck can safely cross a particular bridge of their inventory.
- There are two approaches for bridge owner:
  - Perform Bridge Load Rating Analysis
  - Use Bridge Formula Weights, FHWA Table
- An Improved Load Rating Method is proposed using a series of trucks to estimate the rating factor for permit trucks.
Objectives

- To develop a method to assist bridge owner to decide if a permit truck will be able to safely pass through a bridge.
- The method will be
  - Simple (table or graph)
  - Quick
  - Reliable
Presentation Outline

- Introduction
- Objectives
- Bridge Load Rating Analysis
- Bridge Formula Weights Approach
- Methodology for an Improved Load Method
- Example – California St. Overcrossing
  - Improved method vs FWHA
  - Improved method vs exact solution
- Concluding Remarks
- Questions & Answers
Bridge Load Rating

- Load rating is often performed on superstructure.
- Bridge Load Rating is performed:
  - Using a computer program (i.e., BRIDG, BRASS, etc).
  - Modal Testing of Structure.
- Bridge Load Rating can directly provide exact solution and reliable rating factors.
- Bridge Load Rating process requires a considerable time, resources and cost.
Bridge Load Rating

- Bridge Load Rating consists of following steps:
  - Model the structure
  - Model the permit truck
  - Compute nominal structure’s capacity $R_n$
  - Compute Dead Load (D), Pre-stressed Load (S) and Live Load (L) effects

$$RF = \frac{\phi \cdot R_n - \gamma_{DL} \cdot D \pm \gamma_{P} \cdot S}{\gamma_{L} \cdot L \cdot (1+I)}$$

- Determine rating factor (RF):
Bridge Formula Weights

- Bridge Formula Weights is provided by Federal Highway Administration (FHWA, 1994).
- Bridge Formula Weights limit the weight on groups of axles.
- The formula weights provide a conservative limit of axle weights.
- The Formula is used regardless of the bridge condition.
The weight formula can be expressed as follows:

\[ W = 500 \times \left[ \frac{L \times N}{N - 1} + 12 \times N + 36 \right] \]

where:

- \( W \): the maximum weight on a group of two or more axles
- \( L \): the distance in feet between the outer axles
- \( N \): is the number of axle
Improved LR Method

- New Inventory:
  - Perform load rating analysis as required for HS20, AASHTO 1-3, and OL1-2.
  - Perform additional load rating analysis for a series of trucks, which represent anticipated permit trucks to pass the Bridge.
Improved LR Method

- Inventory Load Rating:
  - Most of existing bridges in WA have been load rated.
  - The load rating analysis is readily available.
  - From the available analysis, a series of trucks can be easily added.
  - Load rating for a series of trucks will be performed to develop a reliable tool to use in load rating any permit truck.
Improved LR Method

• Similar to FHWA Table, some assumptions on truck configurations are as per following:
  – Number of axles from 2 to 9
  – Axle spacing from 4 feet to 86 feet
  – Axle weight of each axle is assumed at 100 kips
  – All axle weights are the same except for the first axle weight which is $\frac{1}{4}$ of others
• Relationship between the number of axle, the axle spacing and the axle weight can be estimated.
Example: California Street Overcrossing, Everett, WA

- 2 Span Concrete Box Girder Bridge (100’:100’).

- Bridge is often used for heavy trucks with different configurations due to the Port of Everett.

- It is desirable to have a handy tool to assess more realistic rating factors for those heavy trucks.
California St. Overcrossing

Deck View Looking East

Elevation View Looking North
California St. Overcrossing

Plan

Elevation
California St. Overcrossing

Bridge Cross Section
California St. Overcrossing

2 Axle Truck

3 Axle Truck
California St. Overcrossing

4 Axle Truck

5 Axle Truck
California St. Overcrossing

6 Axle Truck

7 Axle Truck
California St. Overcrossing

8 Axle Truck

9 Axle Truck
California St. Overcrossing

- FHWA Weight Formula underestimates the capacity of the Bridge
- FHWA Weight Formula does not consider the current condition of the Bridge
  - Old Bridge = New Bridge
  - Deteriorated Bridge = Good/Fair Bridge
- Overload trucks have less chance of passing a Bridge if FHWA formula is followed.
California St. Overcrossing

(a) OL-1 Class Truck

(b) Condensed OL-1 Class Truck

<table>
<thead>
<tr>
<th>S23 (ft)</th>
<th>Axle Weight (K)</th>
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<tbody>
<tr>
<td>14</td>
<td>50</td>
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<tr>
<td>16</td>
<td>52</td>
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<td>59</td>
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<td>30</td>
<td>61</td>
</tr>
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</table>
California St. Overcrossing

(a) OL-2 Class Truck

(b) Condensed OL-2 Class Truck

<table>
<thead>
<tr>
<th>S23 (ft)</th>
<th>S34 (ft)</th>
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</thead>
<tbody>
<tr>
<td>14</td>
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<tr>
<td>16</td>
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</table>
**Load Rating Summary**

<table>
<thead>
<tr>
<th>Truck Type</th>
<th>RF</th>
<th>Front Tons (US)</th>
<th>Controlling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS-20</td>
<td>1.5</td>
<td>Service</td>
<td>M at 52 ft from Pier 2 of Span 2, Girder H</td>
</tr>
<tr>
<td>AASHTO 1</td>
<td>2.07</td>
<td>Service</td>
<td>M at 53 ft from Pier 2 of Span 2, Girder H</td>
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<tr>
<td>AASHTO 2</td>
<td>1.72</td>
<td>Service</td>
<td>M at 35 ft from Pier 1 of Span 1, Girder H</td>
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<tr>
<td>AASHTO 3</td>
<td>1.64</td>
<td>Service</td>
<td>M at 53 ft from Pier 2 of Span 2, Girder H</td>
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<tr>
<td>OL-1</td>
<td>1.23</td>
<td>Service</td>
<td>M at 53 ft from Pier 2 of Span 2, Girder H</td>
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<tr>
<td>OL-2</td>
<td>0.78</td>
<td>Service</td>
<td>M at 52 ft from Pier 2 of Span 2, Girder H</td>
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<tr>
<td>IH-20 Lane</td>
<td>1.82</td>
<td>Service</td>
<td>M at 52 ft from Pier 2 of Span 2, Girder H</td>
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</table>

**NHI Rating**

<table>
<thead>
<tr>
<th>Type</th>
<th>RF</th>
<th>Front Tons (US)</th>
<th>Controlling Point</th>
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</thead>
<tbody>
<tr>
<td>Inventory</td>
<td>1.21</td>
<td>43.56</td>
<td>V at Pier 2, Girder H</td>
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<tr>
<td>Operating</td>
<td>2.02</td>
<td>72.72</td>
<td>V at Pier 2, Girder H</td>
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</tbody>
</table>

**Remarks:**

- Truck load posting is NOT required
Check for OL-1

- Using Eqn. (1), the second, third and fourth axle group loads (R) are:

\[
R = \sum_{i=1}^{n} W_i = 21.5 + 21.5 = 43 K
\]

- Using Eqn. (2) the location of the weight of the axle group from the first axle in the group is:

\[
d = \frac{\sum_{i=1}^{n} W_i d_i}{R} = \frac{21.5 \times 0 + 21.5 \times 4}{43} = 2.0'
\]

- \(S_{23}=16\) feet, the maximum allowable weight on an axle group is 52,000 pounds. The OL-1 truck has axle group weight of 43,000 pounds hence the truck shall be permitted to pass the Bridge.

- The minimum Rating Factor (RF) for this OL-1 class truck can be estimated from the following relationship:

\[
RF = \frac{52}{43} = 1.21 \sim 1.23
\]
Check for OL-2

- Using Eqn. (1), the second, third and fourth axle group loads (R) are:
  \[ R = \sum_{i=1}^{n} W_i = 21.5 + 22 + 21.5 = 65 K \]

- Using Eqn. (2) the location of the weight of the axle group from the first axle in the group is:
  \[ d = \frac{\sum_{i=1}^{n} W_i d_i}{R} = \frac{21.5 \times 0 + 21.5 \times 4 + 22 \times 10}{65} = 4.7' \]

- \( S_{23} = 26 \) feet and \( S_{34} = 24 \) feet, the maximum allowable weight on an axle group is 48,000 pounds. The OL-2 truck has axle group weight of 65,000 pounds hence the truck shall be permitted to pass the Bridge.

- The minimum Rating Factor (RF) for this OL-2 class truck can be estimated from the following relationship:
  \[ RF = \frac{48}{65} = 0.74 \sim 0.78 \]
### LR Factor Comparison

<table>
<thead>
<tr>
<th></th>
<th>HS20</th>
<th>AA-1</th>
<th>AA-2</th>
<th>AA-3</th>
<th>OL-1</th>
<th>OL-2</th>
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</thead>
<tbody>
<tr>
<td>Improved Method</td>
<td>1.45</td>
<td>2.0</td>
<td>1.79</td>
<td>1.73</td>
<td>1.18</td>
<td>0.74</td>
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<tr>
<td>Exact Method</td>
<td>1.5</td>
<td>2.07</td>
<td>1.72</td>
<td>1.64</td>
<td>1.24</td>
<td>0.78</td>
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<tr>
<td>Error (%)</td>
<td>-3.3</td>
<td>-3.3</td>
<td>+4.1</td>
<td>+5.5</td>
<td>-4.8</td>
<td>-5.1</td>
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</table>
Concluding Remarks

- A method is developed to assist bridge owners to quickly assess if a permit truck can safely cross a particular bridge.
- The method uses the Rating Factor (RF) as the threshold to determine the limit axle weight.
- Permit trucks of up to nine axles of different spacing from 4’-86’ are considered in the present study.
- The method can be used as a reliable and cost effective tool to load rate permit trucks with less than 5% of discrepancy compared to the exact method.
- The method provides more accurate results compared to the FHWA Table.