SHRP R19B
BRIDGE FOR SERVICE LIFE BEYOND 100 YEARS: SERVICE LIMIT STATE DESIGN

Report to SCOBS 2011
Research Team

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SHRP R 19B and NCHRP 12-83

• Both projects have same core team – able to take advantage of synergy
• 12-83 deals with concrete SLS only and R19B inherits results – modifies as needed
• R19B
  – Framework – deterioration
  – Most of Live Load development
  – General SLS
  – Steel, foundations, bearings, joints
• Fatigue - joint
Phase I Report Submitted Last May

Bridges for Service Life Beyond 100 Years: Service Limit State Design
SHRP 2 / Project R19B
Phase I Report

Submitted by:
Modjeski and Masters, Inc.
with
University of Nebraska - Lincoln
University of Delaware
NCS Consultants

May 2010
Service and Fatigue LL has been a challenge

- Truck WIM was obtained from the FHWA and NCHRP Project 12-76
- Total number of records exceeds 50 million
- HL-93 adaptable as national notional SLS live load model
- Site/region specific live load should be accommodated
WIM Data Extensively Vetted

- The total length of the truck is 100.6ft
- GVW is 391.4 kips
- Vehicle should be categorized as a permit vehicle.
Initial Filtering Criteria For Non-Fatigue SLS (FHWA Unless Noted)

• Excluded Vehicles
  – Individual axle weight > 70kips -
  – GVW < 10
  – 7 >Total length >200 ft
  – First axle spacing <5 ft
  – Individual axle spacing < 3.4ft
  – 10 > Speed > 100 mph
  – GVW +/- the sum of the axle weights by more than 7%.
  – FHWA Classes 3 – 14
Additional Filtering

Filter #1
1 - Truck length > 120 ft
2 – sum of axle spacing > length of truck.
3 - any axle < 2 Kips
4 - GVW +/- sum of the axle weights by more than 10%
5 - GVW < 12 Kips

Filter #2
6 - Total # of axles < 3 AND GVW >50 kips
7 - Steering axle > 35 k
8 – individual axle weight > 45 kips

Filter #3
9 - Vehicles with GVW <20 Kips
Filtering By Limit State

• Vehicles Passing Filters #1 & #2 were used for calibration of all limit states except for Fatigue and the limit state for permit vehicles.

• Vehicles filtered by Filter #2 will be considered Permit vehicles and will be reviewed and may be filtered further.

• Vehicles passing all three filters will be used for the fatigue limit state
Data is plotted on the normal probability paper. A normal distribution function is represented by a straight line.
WIM Data - FHWA

- 14 sites – Representing 1 year of traffic
- Indiana site: 6 months of traffic
- New Mexico sites represent 8 months of traffic
- The maximum recorded GVW is 220 kips
- Mean values range from 20 to 65 kips
Analysis of the WIM Data

• Live load effect – maximum moment and shear
• Simple spans with span lengths of 30, 60, 90, 120 and 200 ft
• Trucks causing moments or shears < 0.15 (HL93) were removed
Moment and Return Periods

New York - 8382

Truck Moment / HL93 Moment

Standard Normal Variable

200ft Span
120ft Span
90ft Span
60ft Span
30ft Span
1 day
1 week
1 month
2 months
26 months
Removal of the Heavy Vehicles

- Filter – trucks causing moments or shears more than 1.35(HL93 live load effect) were removed
- Number of trucks before filtering – 1,551,454
- Number of trucks after filtering – 1,550,914
- Number of removed trucks – 540
- Percent of removed trucks – 0.03%
Multiple Presence Cases

• Simultaneous occurrence of trucks on the bridge:

• Filter based on time of a record and a speed of the truck

• Distance from the first axis of first truck to the first axis of the second truck maximum 200 ft

Two cases of the simultaneous occurrence

Headway Distance max 200 ft
Correlation Criteria

• Both trucks have the same number of axles

• GVW of the trucks is within +/- 5%

• All corresponding spacings between axles are within +/- 10%
Adjacent Lanes - Florida

- Florida I10 – Time record accuracy 1 second
- Number of Trucks: 1,654,004
- Number of Fully Correlated Trucks: 2,518
- Max GVW = 102 kips
Adjacent Lanes – Florida
2,518 of 1,654,000

Gross Vehicle Weight

Standard Normal Variable

Florida I10 - 1259 Correlated Trucks - Side by Side
Florida I10 - All Trucks
One Lane – Florida
8,380 of 1,654,000

Gross Vehicle Weight

Standard Normal Variable

Florida I10 - 4190 Correlated Trucks In One Lane
Florida I10 - All Trucks

MODJESKI and MASTERS
Experience great bridges.
Conclusions for Multiple Presence

• Vehicles representing the extreme tails of the CDF’s need not be considered to occur simultaneously in multiple lanes.

• For the SLS, only a single-lane live-load model need be considered.
Conclusion For Non-fatigue SLS

- Not necessary to envelop all trucks – SLS expected to be exceeded occasionally
- Scaled HL-93 looks reasonable
- Some states with less weight enforcement may have to have additional consideration
Statistics of Non-fatigue SLS Live Load

- Based on 95% limit:
  - ADTT = 1,000, Bias on HL 93 = 1.4
  - ADTT = 5,000, Bias on HL 93 = 1.45
- COV = 12%
- Based on 100 years – Bias varies with time interval which will be reflected in calibrated load factor
- Bias not strongly influenced by span length
Miner’s law yields one effective moment per span

Variety of spans and locations yields Mean, bias and COV
Examples Using FHWA WIM Data

\[ M_{eq} = \sqrt[3]{\sum_{i=1}^{n} (p_i \times m_i^3)} \]

\[ \text{M}_{\text{eff}} \text{ [kip-ft] for 3 sites} \]

<table>
<thead>
<tr>
<th></th>
<th>30 ft</th>
<th>60 ft</th>
<th>90 ft</th>
<th>120 ft</th>
<th>200 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>-81.8</td>
<td>-212.8</td>
<td>-290.4</td>
<td>-429.9</td>
<td>-876.8</td>
<td></td>
</tr>
<tr>
<td>-86.9</td>
<td>-218.6</td>
<td>-325.1</td>
<td>-490.4</td>
<td>-806.4</td>
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<tr>
<td>-85.1</td>
<td>-230.9</td>
<td>-314.0</td>
<td>-457.5</td>
<td>-969.1</td>
<td></td>
</tr>
</tbody>
</table>

13 sites processed so far, current viable
Example Using FHWA WIM Data – 3 sites

\[ \frac{M_{eq}}{M_{Fat - Trk}} \]

<table>
<thead>
<tr>
<th></th>
<th>30 ft (-184)</th>
<th>60 ft (-360)</th>
<th>90 ft (-530)</th>
<th>120 ft (-762)</th>
<th>200 ft (-1342)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue II Load Factors for 3 sites</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.445</td>
<td>0.591</td>
<td>0.548</td>
<td>0.564</td>
<td>0.653</td>
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<tr>
<td></td>
<td>0.472</td>
<td>0.607</td>
<td>0.613</td>
<td>0.644</td>
<td>0.601</td>
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<tr>
<td></td>
<td>0.463</td>
<td>0.640</td>
<td>0.593</td>
<td>0.600</td>
<td>0.0</td>
</tr>
</tbody>
</table>

So far looks good, now add cycles per Passage and compare to current
Cycles Per Passage

Continuous Bridges
Middle Support

Number of load cycles per truck

Span length
## Rainflow Cycles - $n_{rc}$

<table>
<thead>
<tr>
<th>Continuous Spans</th>
<th>30 ft</th>
<th>60 ft</th>
<th>90 ft</th>
<th>120 ft</th>
<th>200 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 ft</td>
<td>3.0</td>
<td>2.4</td>
<td>2.5</td>
<td>2.5</td>
<td>2.3</td>
</tr>
<tr>
<td>60 ft</td>
<td>2.9</td>
<td>2.3</td>
<td>2.4</td>
<td>2.4</td>
<td>2.6</td>
</tr>
<tr>
<td>90 ft</td>
<td>3.2</td>
<td>2.6</td>
<td>2.7</td>
<td>2.6</td>
<td>2.3</td>
</tr>
<tr>
<td>120 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200 ft</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Damage Factor Compared to Current

\[
\left( \frac{M_{eq}}{M_{Fat - Trk}} \right) (1/0.75)^3 \sqrt{\frac{n_{rc}}{n_{AASHTO}}}
\]

Normalized so current = 1.00

<table>
<thead>
<tr>
<th></th>
<th>30 ft</th>
<th>60 ft</th>
<th>90 ft</th>
<th>120 ft</th>
<th>200 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.67</td>
<td>0.67</td>
<td>0.92</td>
<td>0.87</td>
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<td>0.71</td>
<td>0.71</td>
<td>0.94</td>
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<tr>
<td>0.65</td>
<td>0.65</td>
<td>1.03</td>
<td>0.96</td>
<td>0.96</td>
<td>1.11</td>
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</tbody>
</table>
Current Status of LL Studies

• Fatigue II Being calibrated now – expect to be done this summer – Concrete and steel

• Other SLS
  – Design model will be HL93 factored per calibration
  – LL will be handed off to NCHRP 12-83 team for concrete SLS calibration shortly
  – SHRP team will follow with deflections and foundations – need reactions
  – Fatigue I needs LL model finalized
Questions?
Thoughts?
Advice?