Live Load Testing and Long Term Monitoring of the Varina-Enon Bridge

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Outline

• Varina-Enon Bridge and observed distress
• Live load test results and comparison to simple models
• Long term monitoring system and one year of data
Designed by Figg and Mueller
Designed in 1985
Opened to traffic in 1990
Varina-Enon Approach Structure

- Northbound, Southern-most Approach Structure Unit
  - Six – 150 ft Spans
  - Externally Post-Tensioned
  - Distress noted by inspectors Summer 2012
Varina-Enon Approach Structure

- Northbound, South-most Approach Structure
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Varina-Enon Approach Structure

Visually Opening Joint between S2 and S3 (reportedly 1/16”)

0.3L
Span 6
Varina-Enon Approach Structure

- Northbound, South
- Approach Structure
  - Six – 150 ft Spans
  - Externally Post-Tensioned
- Flexural Cracking
- Looking up at Bottom Flange
  Cracks Exaggerated
- Span 5
- 0.5L

Backwalls (Total Bridge Length)
Face of Backwalls
- 900'-0"
Live Load Test Performed August 2012

- Two Low Boy Tractor-Trailers
  - R12106 – 101.2 kips
  - R08150 – 113.5 kips
Three Truck Crossing Paths

LC1

Snooper Moog

LC2

Snooper Moog

LC3

Snooper Moog
## Simplified Beam Line Analysis

<table>
<thead>
<tr>
<th></th>
<th>Concrete Box Only</th>
<th>Concrete Box plus Overlay, Barrier, Rebar and Tendons</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Area</strong></td>
<td>12630 in²</td>
<td>14730 in²</td>
</tr>
<tr>
<td><strong>Momment of Inertia</strong></td>
<td>33,853,000 in⁴</td>
<td>39,771,000 in⁴</td>
</tr>
<tr>
<td><strong>Centroid (from bottom)</strong></td>
<td>1019 in</td>
<td>106.4 in</td>
</tr>
</tbody>
</table>
## Comparisons to Tests

<table>
<thead>
<tr>
<th></th>
<th>LC1</th>
<th>LC2</th>
<th>LC3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured Deflection, in</td>
<td>0.030</td>
<td>0.035</td>
<td>0.062</td>
</tr>
<tr>
<td>Calculated Deflection, in</td>
<td>0.031</td>
<td>0.031</td>
<td>0.062</td>
</tr>
</tbody>
</table>

### Graph

**Section A - Mid-Span 5**

- **Calc Pos One Truck**
- **Meas Pos LC1&2**
- **Calc Pos Two Trucks**
- **Meas Pos LC3**
- **Calc Neg One Truck**
- **Meas Neg LC1&2**
- **Calc Neg Two Trucks**
- **Meas Neg LC3**

Legend:
- Green dashed line: Calc Pos One Truck
- Blue dashed line: Meas Pos LC1&2
- Purple dashed line: Calc Pos Two Trucks
- Purple line: Meas Pos LC3
- Brown solid line: Calc Neg One Truck
- Brown dashed line: Meas Neg LC1&2
- Blue dotted line: Calc Neg Two Trucks
- Blue solid line: Meas Neg LC3
Section C - Near Support Span 5

Section E - Opening Joint Span 6
Recap

• Visual estimate of joint opening prior to load test was 1/16 in. under traffic
  ▫ Opening was observed on June 29, 2012
  ▫ High temperature according to NOAA at the airport was 103 degrees F
• Joint opening measured during load tests was 1/64 in. under load
  ▫ Test was performed on August 21, 2012
  ▫ Heaviest test vehicle 113.5 kips (rear three axles 60k)
  ▫ Temperature at test time was mid 80s F
Long Term

- **S2/S3 Joint**
  - 2 LVDTs monitoring crack opening
  - 1 Strain transducer next to crack
  - 24 Thermocouples measuring thermal gradient
Long Term

- 0.4L
  - Single strain transducer at 0.4L from bridge end
  - Used to trigger events, trigger set at 12 με
September 2012 – September 2013 → 4673 Strain Events
September 2012 – September 2013 → 4673 Strain Events
→ 290 Crack Openings > 0.003”

Maximum Observed Crack Displacement
~1/32”
Influence of Temperature

- Positive thermal gradients induce bottom slab tension at critical joint location
- Compare warm month and cold month data to investigate
- AASHTO Design Thermal Gradient is 41°F (23°C) non-linear
- Actual design gradient, with live load, was 9°F (5°C) linear
July 2013 – 534 Strain Events

51 Crack Openings > 0.003

Typ. Max Concrete Temp 30-35°C
December 2012 – 277 Strain Events

ZERO Crack Openings > 0.003

Typ. Max Concrete Temp 5-10°C
July 23, 7am, 2.6°C diff.

At 0.4L

Max = 18 με

At Crack

Max = 4 με

2013-07-23 7:12:55.53

Maximum Measured Concrete Temp. = 29.4 °C

Maximum Delta Temp. = 2.6°C

Average Max = 0 inches
July 23, 3pm, 14.6°C diff.

At 0.4L
Max = 18 με

At Crack
Max = 6 με

2013-07-23 15:16:36.00
Maximum Measured Concrete Temp. = 39.1°C
Maximum Delta Temp. = 14.6°C

Average Max = 0.01 inches
All triggered events
July Triggered Events
December Triggered Events
Simplified Long Term Analysis

Equation

\[ M_f = M_{initial}e^{-\phi} + M_{final}(1 - e^{-\phi}) \]

For \( \phi = 0 \) – no change in moment distribution

For \( \phi = \infty \) - Creeps completely to final moment distribution

For \( \phi = 2.5 \) – Creeps over 90% toward final moment distribution

Analysis done for final system configuration (close enough)
\[ M_{\text{thermal}} = \int_Y E\alpha T(Y)b(Y)Y\,dY \]

Moment = 8727 k-ft
All Moments

- Thermal Restraint Moment
- Self Weight Moment
- Positive Truck Moment Env.
- Negative Truck Moment Env.
- Post Tensioning

Distance from abutment, ft

Moment, k-ft

0 150 300 450 600 750 900
-40000 -30000 -20000 -10000 0 10000 20000 30000 40000
Summations
Summary

• Maximum joint movement during load test:
  ▫ 1/64 in.
  ▫ Less than previously observed: 1/16 in.

• Maximum joint movement from ambient traffic over the past year:
  ▫ 1/32 in.

• Thermal gradient is affecting severity and frequency of crack opening

• Monitoring is continuing and other locations will be investigated
Questions?