Unforeseen Effects of Secondary Members

MoDOT Team Conference

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History

• 5 ¼” open grid deck replaced in 1991 with 7” continuous concrete deck
• Added 1,000 kips of dead load
• Bolts have been intentionally loosened
  • First bay of upper lateral bracing
  • Exterior stringers
• Cracks in floorbeam web were evident in 2013
Crack Location
Crack Location

Westbound Upper Lateral Bracing Plan

Eastbound Upper Lateral Bracing Plan
<table>
<thead>
<tr>
<th>Floorbeam</th>
<th>Girder</th>
<th>2014 Inspection</th>
<th>2015 Inspection</th>
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<td>2</td>
<td>+/- 1/2&quot;</td>
<td>+/- 1/2&quot;</td>
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<td>+/- 1/2&quot;</td>
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<td>20</td>
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<td>+/- 2 1/2&quot; to 3&quot;</td>
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<tr>
<td>22</td>
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<td>+/- 2&quot;</td>
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Connection As-Designed

DETAIL "C"
Connection As-Designed

12" x 3/4" x 16'4" E

5/8" Shim Package Req'd

5/8" Gusset Plate

7/16" Web Plate

15/16" x 1/4" Slotted Holes in Bottom Flange of Floorbeam

12" x 3/4" x 16'4" Ø

(1/8" Ø Holes in Plate)

Grind To Bear.
Connection As-Built

No connection from gusset to stiffener
Connection As-Built

Location of omitted weld

FLOORBEAM

TAB BELOW

GUSSET

TOP LATERAL BRACING

FACE OF WEB FOR WELDED BOX GIRDER
Force Transfer

- Brace in compression
- Floorbeam web bending due to brace forces
- Brace in tension
- Top lateral bracing
- Face of web & top welded box gusset

- Floorbeam web
- Crack in floorbeam web
- Lateral bracing tab plate
- Floorbeam transverse stiffener
## Fatigue Category

### Section 7—Longitudinally Loaded Welded Attachments

7.1 Base metal in a longitudinally loaded component at a detail with a length $L$ in the direction of the primary stress and a thickness $t$ attached by groove or fillet welds parallel or transverse to the direction of primary stress where the detail incorporates no transition radius:

- $L < 2$ in.
- $2$ in. $\leq L \leq 12t$ or 4 in
- $L > 12t$ or 4 in
- $t < 1.0$ in.
- $t \geq 1.0$ in.

(Note: see Condition 7.2 for welded angle or tee section member connections to gusset or connection plates.)

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>$44 \times 10^8$</th>
<th>10</th>
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<tr>
<td>D</td>
<td></td>
<td>$22 \times 10^8$</td>
<td>7</td>
</tr>
<tr>
<td>E</td>
<td></td>
<td>$11 \times 10^8$</td>
<td>4.5</td>
</tr>
<tr>
<td>E'</td>
<td></td>
<td>$3.9 \times 10^8$</td>
<td>2.6</td>
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</table>

- In the primary member at the end of the weld at the weld toe.
Study Approach

- Increased dead load from deck replacement
- Modified deck stiffness
- Cyclic loading from live load
- Cyclic loading from wind load
- Cyclic loading from temperature
Global CSi Bridge Model
Increased Dead Load

- 5 ¼” grid deck to 7” solid deck = 1,000 k
- Increases the negative moment at LB connection
- Considered a half-cycle with 0.7 ksi change in stress
Modified Deck Stiffness

• With braces
  • No noticeable difference in brace forces

• Without braces
  • Slight increase in movement occurs before engaging deck due to stringer slots
  • Rely on stringer to floorbeam connections to transfer force
Global Behavior of Bracing

Westbound Lateral Bracing Plan

Eastbound Lateral Bracing Plan
Global Behavior of Bracing

Lower lateral bracing

Brace under consideration

Location of load for maximum tension in brace

Location of load for maximum compression in brace

Influence Surface of X-Braces
Global Behavior of Bracing

Influence Surface of Parallel Braces

- Brace under consideration
- Lower lateral bracing behind
- Location of load for maximum tension in brace
- Location of load for maximum compression in brace
Global Behavior of Bracing

Frame 361
Tension = 10.8 k
Compression = -14.0 k
Range = 24.8 k

All Braces Active
Global Behavior of Bracing

Frame 361
Tension = 12.4 k
Compression = -15.5 k
Range = 27.9 k

End Braces Removed
Local Lusas Model
Cyclic Live Load As-Built

Total Range = 17.3 ksi
Infinite Fatigue Life = 4.5 ksi
Cyclic Live Load As-Designed

Tension Stress

Total Range = 0.6 ksi
Infinite Fatigue Life = 4.5 ksi

Compression Stress
Cyclic Wind Load

- AASHTO 17th Edition 2002
- 100,000 wind cycles
- 22 ksi for category E detail
Cyclic Wind Load As-Built

- Max Tension = 30.62 ksi
- Max range = 61.24 ksi
- Allowable range = 22 ksi
Cyclic Wind Load As-Designed

- Max Tension = 0.34 ksi
- Max range = 0.68 ksi
- Allowable range = 22 ksi
Temperature

- Uniform Temperature
- Temperature Gradient
  - South Box exposed to sun
- Negligible effect
Results

- Fatigue cracks from shortened tab plate and missing weld
- Category E detail
- Additional weight of deck decreased allowable fatigue range
- Primary cause is LL fatigue cracking
Crack Repair – All Options

- Remove lateral bracing connection plate and weld.
- Sand smooth, option 1 and 2.
- Replace plate and weld, option 3 only.

**Weld Crack Repair Detail**
(Typical both options unless noted otherwise)

**Web Crack Repair Detail**
(Typical both options)
Proposed Solutions – Option 1

• Remove Upper Lateral Bracing
  • Prevents crack growth
  • Reduces negative moment in floorbeam
  • Rely on concrete deck for lateral load transfer at the top of the box
  • Temporary LB during deck replacement
  • Changes forces in bridge framing
Proposed Solutions – Option 2

• Bolted Connection Retrofit
  • Reinstate the original design intent
  • Global behavior is not modified
  • Field work includes field measurements
  • The load in the brace will still be present
Proposed Solution – Option 2

[Diagram showing a construction detail with labels indicating the locations of bolts, existing welds, and connection plates.]
Recommendations

- Remove Lateral Bracing
- Drill holes to arrest web cracks
- Remove tab plate and weld to arrest weld cracks
- Remove gusset plates at all locations (unbolting)
Crack Arrest Hole Repair

**Option 1**
- Place appropriately sized hole to envelope entire crack.
- 3" dia. max.
- 8" min.
- Floor beam web
- Existing weld to remain (TP)
- Crack in floor beam web
- Removed tab plate

**Option 2**
- Place appropriately sized hole at each end of the crack.
- 1" dia. max. (TP)
- Floor beam web
- Existing weld to remain (TP)
- Removed tab plate

**Weld Crack Repair Details**

09/29/2015
Actual Crack Mapping and Arrest Holes

Eastbound Bridge – Floorbeam 3
Questions