Hale Boggs Cable Stayed Bridge –
Inspection, Fatigue Analysis & Repair

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- **Paul Norton – Part I**
  - Introduction
  - Inspection findings
  - Scope of work

- **Jian Huang – Part II**
  - Fatigue evaluation procedure and specifications
  - 3-D structural analysis
  - Fatigue stress ranges
  - Remaining mean/safe fatigue lives
  - Conclusions and recommendations
  - Repair plans
Location of Hale Boggs Bridge

Interstate I-310 over the Mississippi River between Destrehan and Luling. Also known as the Luling Bridge.
Hale Boggs Cable Stayed Bridge

- Bridge open to traffic in Oct. 1983
- The third major cable stayed bridge in the United States
- The first cable stayed bridge added to the interstate highway system
Hale Boggs Cable Stayed Bridge

- Weathering steel towers and superstructure
- Orthotropic deck (first in cable stayed bridges in US)
The main river crossing is a cable stayed bridge having a total length of 2,732 ft.
2-Steel tub girders connected with floor beams and diaphragms
82 ft bridge width
Problem Statement

- **Major Rehabilitation Project**
  - $28M – Replacement of All Cables

- **Our recent bridge inspection found:**
  - Cracks occurred in the deck plate and the fillet weld at the connection of the box girder web transverse stiffener to the orthotropic deck (112 cracks out of 800+ total locations).
  - Cracks exhibited only in the outboard web of the box girders (under the outside wheel line of traffic in each direction).
  - Cracks in other components (lifting lugs & cross girder)
Crack in orthotropic deck plate at end of transverse stiffener weld

- Crack Location
  - 75 Cracks in Orthotropic Deck Plate
  - 37 Cracks in Weld Only

Transverse Stiffener
Crack in orthotropic deck rib at Lifting Lug

13 Cracks in Orthotropic Deck Rib
Crack inside cross girder at internal diaphragm

- 3 Cracks in Cross Girders
Crack Locations

- West = 4, 27, 27, 15, 5
- East = 0, 3, 16, 10, 5
Crack Locations

WEST BOX GIRDER

SPAN M2
(FB14 - FB28)

EAST BOX GIRDER

2011 IBTTA Maintenance Conference, Nashville, October 24th – 26th
Crack Location
Scope of Work

- Determine the stress levels in the problematic area
- Perform a fatigue evaluation of the critical area
- Calculate the remaining mean fatigue and safe fatigue lives of the critical details
- Develop the repair plans
Fatigue Evaluation Procedure and Specifications

The fatigue analysis was performed in accordance with

- AASHTO Guide Specifications for Fatigue Evaluation of Existing Steel Bridges, 1990 with interims through 1995
- NCHRP 299, Fatigue Evaluation Procedures for Steel Bridges
3-D Structural Analysis Model

Modeling features:

- SAP2000 program
- Modeling: Longitudinal segment, Transverse half section
- Shell elements
- Refined shell element size, max. 1”x1” mesh in the area of interest
- Edge constraint between intersecting shell elements
- Boundary joints at the centerline of the bridge: free but fixed rotation about the bridge direction
- Boundary joints at ends of the analyzed segment: fixed translations and free rotations
General View of the 3-D Analysis Model

- Refined mesh
- Floor beam
- Deck
- Web of Box Girder
Fatigue Truck Loading

Applied Wheel Loads:

- One truck (outside lane or inside lane)
- 2 -12 kips x 1.1 (impact assumed) = 13.2 kips wheels spaced at 6 feet transversely
- Applied as area load
Analytical Results: Outside Lane Loaded

- Concentrated stress at the web transverse stiffener to the deck plate connection (outer web).

![Concentrated stress diagram](image)
### Table 1 – Fatigue Stress Ranges in Deck Plates
Along Outer Web of Box Girder

<table>
<thead>
<tr>
<th>Location</th>
<th>Outside Web</th>
<th>AASHTO Limiting Stress Range (Cat. C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Axial, ksi)</td>
<td>(ksi)</td>
</tr>
<tr>
<td>At Web Stiffener</td>
<td>6.635</td>
<td>4.4</td>
</tr>
<tr>
<td>At Non Web Stiffener</td>
<td>0.099</td>
<td>4.4</td>
</tr>
</tbody>
</table>

### Table 2 – Fatigue Stress Ranges in Deck Plates Along Inner Web of Box Girder

<table>
<thead>
<tr>
<th>Location</th>
<th>Inner Web</th>
<th>AASHTO Limiting Stress Range (Cat. C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Axial, ksi)</td>
<td>(ksi)</td>
</tr>
<tr>
<td>At Web Stiffener</td>
<td>1.188</td>
<td>4.4</td>
</tr>
<tr>
<td>At Non Web Stiffener</td>
<td>0.058</td>
<td>4.4</td>
</tr>
</tbody>
</table>
Fatigue Stress in Web Stiffeners

At outer Web

6.6 ksi

At inner web

1.2 ksi
**Fatigue Stress Ranges in Web Stiffeners**

**Table 3 – Fatigue Stress Ranges in Web Transverse Stiffener to Deck Connection at Outer Web**

<table>
<thead>
<tr>
<th>Location</th>
<th>Outside Web</th>
<th>AASHTO Limiting Stress Range (Cat. C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Vertical, ksi)</td>
<td>(ksi)</td>
</tr>
<tr>
<td>Corner at Crack</td>
<td>6.635</td>
<td>4.4</td>
</tr>
<tr>
<td>Corner Closer to Box Girder Web</td>
<td>0.337</td>
<td>4.4</td>
</tr>
</tbody>
</table>

**Table 4 – Fatigue Stress Ranges in Web Transverse Stiffener to Deck Connection at Inner Web**

<table>
<thead>
<tr>
<th>Location</th>
<th>Inside Web</th>
<th>AASHTO Limiting Stress Range (Cat. C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Vertical, ksi)</td>
<td>(ksi)</td>
</tr>
<tr>
<td>Corner at Crack</td>
<td>1.188</td>
<td>4.4</td>
</tr>
<tr>
<td>Corner Closer to Box Girder Web</td>
<td>0.203</td>
<td>4.4</td>
</tr>
</tbody>
</table>
Check for Infinite Safe Fatigue Life (if fatigue is an issue)

- Factored fatigue stress range
- AASHTO Limiting stress range (Cat. C)

<table>
<thead>
<tr>
<th>Location Type</th>
<th>Factored Stress</th>
<th>AASHTO Limiting Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer web locations</td>
<td>9.0 ksi</td>
<td>4.4 ksi</td>
</tr>
<tr>
<td>Inner web locations</td>
<td>1.6 ksi</td>
<td>4.4 ksi</td>
</tr>
</tbody>
</table>

Outboard web locations will crack, 75 locations have already cracked.
Remaining Safe Fatigue Life and Mean Fatigue Life

Safe Fatigue Life vs. Mean Fatigue Life: Safe/Mean = 1/2

Remaining Fatigue Life at outer web locations:
- Mean fatigue life: -8.8 years
- Safe fatigue life: -21.3 years
  (negative means exceeded its fatigue life)

Remaining Fatigue Life at inner web locations:
- Infinite
**Repair Scheme Development**

- **No repair action**
  - Consider restricting traffic from the right travel lanes
  - Fatigue cracking on the inside detail would not occur for 15 years
  - Monitor detail on a more frequent basis (say every 12 months)

- **2-in diameter arrest holes in the deck plate**

- **Separation of the web transverse stiffener from the deck plate**

- **Combined repair schemes**
Analytical Results if No Repair Action

- A 5-in long crack modeled (typical cracking found).

- The deck stresses redistributed and decreased, but not enough.

- The stress ranges implies further crack may occur.

4.5 ksi at stiffener (crack location)

3.2 ksi at tip of crack

3.6 ksi at tip of crack

2.1 ksi at stiffener edge near web

1.9 ksi (Edge of Stiffener at Crack Location)

1.45 ksi (Edge of Stiffener Adjacent to Web)
2-in Diameter Arresting Holes

- Two 2-in diameter holes.

- The stress range at crack decreased by 54%.

- All stress ranges less than 4.4 ksi.
The web transverse stiffener to deck connection removed.

The stresses in the deck significantly reduced.

- 0.9 ksi at the drilled hole
- 0.4 ksi at stiffener edge near web
- 0.4 ksi at stiffener (crack location)
Cutting Web Stiffener at Locations with No Cracking

- The web transverse stiffener to deck connection removed.

- The stresses in the deck significantly reduced.

0.4 ksi at stiffener edge (vs. 6.6 ksi)

0.6 ksi at stiffener edge near web
Fatigue Stress Ranges Vs. Repair Schemes

<table>
<thead>
<tr>
<th>3-D Models/Repair Schemes</th>
<th>At Crack Initiation</th>
<th>Stiffener Edge Near Web</th>
<th>Tip of Crack/Hole</th>
<th>Web at Stiffener Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ksi)</td>
<td>(ksi)</td>
<td>(ksi)</td>
<td>(ksi)</td>
</tr>
<tr>
<td>As Built Condition</td>
<td>6.6</td>
<td>0.3</td>
<td>N/A</td>
<td>0.3</td>
</tr>
<tr>
<td>5-in Crack Occurred</td>
<td>4.5</td>
<td>2.1</td>
<td>3.6</td>
<td>0.6</td>
</tr>
<tr>
<td>5-in Crack + 2-in Ø Arrest Holes</td>
<td>2.0</td>
<td>2.2</td>
<td>1.6</td>
<td>0.6</td>
</tr>
<tr>
<td>5-in Crack + 2-in Ø Arrest Holes + Cutting Stiffener</td>
<td>0.4</td>
<td>0.4</td>
<td>0.9</td>
<td>0.2</td>
</tr>
<tr>
<td>As Built Condition + Cutting Stiffener</td>
<td>0.4</td>
<td>0.6</td>
<td>N/A</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Repair Plans: Drilled Patterns

DRILL PATTERN - 5" LONG CRACK
N.T.S.

DRILL PATTERN - 2 1/2" LONG CRACK
N.T.S.

DRILL PATTERN - 1 1/2" LONG CRACK
N.T.S.

DRILL PATTERN - 3" LONG CRACK
N.T.S.

DRILL PATTERN - 2" LONG CRACK
N.T.S.

DRILL PATTERN - 1" LONG CRACK
N.T.S.
Repair Plans: Cutting Transverse Stiffeners

WORKING INSIDE THE BOX GIRDERS

1. CLEAN THE AREA USING SP-3/PWB FOR 12 INCHES EACH SIDE OF THE TRANSVERSE STIFFENER.

2. ESTABLISH WPT 1 AT THE END OF THE WELDS, THIS POINT IS IDENTIFIED AS THE INTERSECTION OF A TANGENT LINE AT THE ENDS OF WELD WITH THE CENTERLINE OF TRANSVERSE STIFFENER.

3. CUT THE TOP OF THE TRANSVERSE STIFFENER TO WITHIN 5/16-INCH OF THE ORTHOTROPIC STEEL PLATE AS SHOWN IN DETAIL A.

4. REMOVE THE TOP OF THE TRANSVERSE STIFFENER BY CUTTING ON A 7-INCH RADIUS FROM A POINT NEAR THE TOP OF STIFFENER WITHIN 5/15-INCH OF THE WEB TO THE EXISTING ANGLE BREAKPOINT IN THE STIFFENER.

5. REMOVE THE REMAINING PORTION OF THE TOP OF STIFFENER BY GRINDING AND BUFFING.

6. PERFORM MAGNETIC PARTICLE (MP) TESTING ON THE Underside OF THE ORTHOTROPIC
Acknowledgement

- Owner of the Bridge: Louisiana DOT & Development
- CTL – prime consultant for design & inspection
- IBT – prime consultant for construction management
- TranSystems – subconsultant to CTL & IBT
Thank you and any questions?

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