Sherman Minton Bridge
Structure Retrofit
Background
Background

- The bridge carries approximately 70,000 vehicles per day on I-64 over the Ohio River.
- Consists of two 800 foot simple span tied arches.
- There are two decks. The lower deck carries traffic into Kentucky while the upper deck carries traffic to Indiana.
Background

- Designed in 1959
- First Deck opened in 1961
- Second deck opened in 1962
- 100 ksi
Figure 1. Bridge and major elements identified.
Background
Why was there concern?
Type of Construction

- Tied arches are FRACTURE CRITICAL bridges.
- Failure of the tie = likely collapse of the entire span
Type of Construction

- Think of a bow (like in a bow and arrow...)
  - Stand it on a table like shown
  - Push down on the bow
  - What would happen if we cut the string?
Type of Construction

- ...the serious consequences of weld cracking associated with the tie girder of a tied arch structure should not be overlooked.

- ...it is one of the most nonredundant structures, relying entirely on the capability of two tie girders to accommodate the total thrust imposed by the arch ribs.

Source: 1978 FHWA Technical Advisory
Material Properties

- Type of Material
  - “T1” Steel
    - VERY high strength steel
    - Susceptible to FRACTURE at cold temperatures and with small cracks
    - Fractures are cracks that propagate through the steel at rates faster than the speed of sound
    - Hydrogen induced cracks may form during welding
Material Properties

- **Toughness of steel**
  - The ability of material to carry load in presence of crack
  - Decreases with decreasing temperature
- **Cold temperature + low toughness + cracks** = increased probability of failure

Slide courtesy of Baker
Sensitive Details

- Tie girder welds
- Diaphragm plates
- Lateral bracing details
- Some longitudinal fillet welds
Sensitive Details

Tie Girder Welds

Slide courtesy of Baker
Sensitive Details

Tie Girder Welds

176 Individual welds per tie x 2 ties x 2 spans = 704 potential fracture sites
Sensitive Details

Diaphragm Lugs

Slide courtesy of Baker
Diaphragm Lugs

33 diaphragms per tie x 2 ties x 2 spans x 8 lugs per diaphragm x 2 legs = 2112 welds
Sensitive Details

Lateral Bracing Plates
Sensitive Details

Lateral Bracing Plates

11 panels x 2 plates per panel x 2 ties x 2 spans = 88 connection plates
Inspection
Inspection

- Comprehensive Inspection Plan Developed
  - Visual Inspections
  - Instrumentation
  - NDT
    - Magnetic Particle
    - Ultrasound
    - High Intensity X-ray
    - Radiography
Inspection

- Material samples
- Fracture Mechanics analysis
- Inspectors were proof tested
  - NDT
  - Vision
**Inspection**

**Panel Point: 4**

- **Upstream or Downstream Tie:** Upstream

Below is a diagram indicating the inspection points and their respective measurements. The diagram shows various defects and their locations, along with their sizes and severity levels in decibels (dB). The measurements include dimensions such as diameter (D), length (L), and angles (α, β). The defects are marked as either 'Rejectable' or 'Recordable,' with the latter accompanied by additional notes regarding the severity or type of defect.

The diagram also includes references to specific points and panels, such as 'Kentucky Side' and 'Indiana Side.' The measurements are precise, indicating the dimensions and locations of each defect in detail.

**Notes:**
- The inspection point at Panel Point 4 includes a detailed list of defects, their locations, and their respective measurements.
- The defects are categorized into those that are 'Rejectable' and those that are 'Recordable,' with the latter often requiring further investigation or documentation.
FHWA Technical Advisories

- 5140-32
  - Inspection of Fracture Critical Bridges Fabricated from AASHTO M270 Grade 100 (ASTM A514/A517) Steel
Retrofit #1

- Remove diaphragm lugs
- Retrofit lateral bracing connections
- Begin dog-bone installation
Retrofit #1

Lug Removal Details

DETAIL A (10 LUGS TO BE REMOVED)
DETAIL B (12 LUGS TO BE REMOVED)

No Scale
Retrofit #1

Lateral Bracing Details
Retrofit #1

Diaphragm Details
CUT HORIZONTAL SLOT IN EXIST. COVER PLATE JOINING DRILL HOLES (TYP.) USE OF PLASMA CUTTING OR GRINDING WHEEL ALLOWED.
Why was the bridge closed?
Why was the bridge closed?
Why was the bridge closed?
Retrofit # 2
Retrofit # 2

Crack Isolation
Retrofit #2

Timeline

- Bridge was closed September 9, 2011
- Repair plan announced September 30, 2011
- Contract let October 19, 2011
Retrofit #2

**Brain Storming Ideas**

- Internal cable restraint for the end supports running inside the bridge hollow members within a transparent plastic conduit for the lower and possibly the upper chord.
- External cable restraint for the end supports for the upper and lower chord. Inspection will be easier, to achieve as in #1.
- Series of horizontal or inclined cables to relieve or reverse the stresses in members.
- Inclined bottom chord cable around a hinge at the lower region of middle pier or in the middle of each span (with a new vertical member). This will result in lower tension in the cable, and make use of the bridge weight.
- Outside restraint system at the outer supports by straight and inclined piles or a series of piles.
Retrofit #2

**BRAIN STORMING IDEAS**

- Restraint system at the supports by retrofitting the supports, so that failure of the bottom chord will not result in opening of the top arch. #5 will do the same.
- Electric tape or blanket wrap or other electric means of keeping the critical bridge members above 30 degrees during the winter months. Some continuous heating devise inside hollow members can be investigated.
- Add continuous straight members for the lower chord and upper chord, as needed.
- Run pre-stressing strands on the milled roadway (or under the deck) to restrain the top chords and build 4” overlay to run traffic on. This should be designed to reverse stresses.
- Pre-stressing strand loop around each span to create uplift in the top and bottom chords. Can it be designed to reverse stresses?
- Build additional permanent supports between the middle pier and end supports.
Retrofit #2

Short Listed ideas

- Local Plating
- Global Plating
- Post-tensioning
- Replacing the Tie
Retrofit #2

Considerations

- Location of indications
- Future Inspection
- Availability of steel
- Length of Construction
Retrofit #2

Local Plating Option

NOTE: SPlice is symmetric about CL. Bracing connections vary at each joint.

OUTSIDE SPlice NOT SHOWN

INSIDE FACE
TOP FLANGE

ELEVATION VIEW
INSIDE FACE

OUTSIDE SPlice NOT SHOWN

INSIDE FACE
BOTTOM FLANGE

SECTION A-A

- Existing Bolt
- A-325 bolt replaced one at a time with A490 bolt
- A490 bolt added in field drilled hole prior to splice plates
- A490 bolt replaced after all plate thicknesses are added.

DRAFT NOT FOR CONSTRUCTION
Retrofit #2

Global Plating Option
Retrofit #2

Global Plating Option
Retrofit #2

Global Plating Option
Retrofit #2

EXISTING - VIEW B - B (ODD JOINTS)
Global Plating Option
Retrofit #2

- Replacing the Tie
  - This would consist of
    - Installing jacking assemblies to 2 panels at the beginning and end of a 5 panel run
    - Stressing the tie
    - Removing the existing tie
    - Replacing the tie
    - Repeating the process
Retrofit #2

- Post-tensioning
  - This would consist of either internal or external post-tensioning
Retrofit #2

Dog-Bone Details

CUT HORIZONTAL SLOT IN EXIST. COVER PLATE JOINING DRILL HOLES (TYP.) USE OF PLASMA CUTTING OR GRINDING WHEEL ALLOWED.

COVER PLATE BUTT WELD
Retrofit #2

- Chosen Solution
  - Global Plating
  - Installation of dog-bones to isolate the welds in the top and bottom plate of the tie-girder
Thank you to:

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Questions?

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