Liberty Bridge Incident
QAW February 2018
Tom Macioce, P.E.
Chief Bridge Engineer
PennDOT
Liberty Bridge Rehab by the Numbers

- Contract Value: $80,081,294.35
- Prime Contractor: JB Fay
- Let Date: 6/25/15, NTP: 8/19/15
- Completion: 7/27/18
Liberty Bridge

- Completed 1928
- Key route into downtown Pittsburgh
- 8-Span steel truss
- 470’-6” main span
2016 Work Overview

**Liberty Bridge**
- Phased Full Deck Reconstruction Spans 4-11 & Ramps (180 Day Milestone)
- Blast/Prime/Paint Liberty Bridge Truss Spans 1-15
- Miscellaneous Liberty Bridge Steel Repairs Spans 1-15
- Cantilever deck truss
- Bottom chord near pier
- Continuous span
Condition on Sept 2, 2016

- Last phase of construction (phase 1D) for 2016:
Typical Deck & Stringer Demo Operations:
A fire ignited on the lower safe span platform causing damage to the bottom chord of west truss (downstream side) behind pier 7.

Fire started at approximately 1:00pm, September 2\textsuperscript{nd}
The fire was ignited by errant sparks from a welder’s torch from above deck remove operations (last phase of existing deck removal). These sparks ignited plastic piping, which then lit a containment tarp draping the bridge.
The fire was extinguished by the City of Pittsburgh Fire Department within a half hour of their arrival. There were no injuries reported.
The City of Pittsburgh Firefighters did a great job of getting the fire out in 30 minutes.
• 30’ primary member compression chord L31/L32 severally damaged.
• Local lateral buckling shortened the beam (by ~2” and bent in the lateral direction by 6 ¾”), load shedding to other members of the bridge.
Fire Damage to L31L32 West Truss

- Note:
  - Sagging of lacing channels
  - Crippled flanges
Post Fire – 1.88” Movement of L31W

Displacements due to fire

Legend
- Entity: Force/Moment - Thick 3D Beam
- Component: Fx (Units: kip)

-2.0E3
-1.5E3
-1.0E3
-500.0
0.0
500.0
1.0E3
1.5E3
2.0E3
East Truss Bearing Measurement
Night of September 2, 2016

- Bridge to remain closed
- Safety assessment of bridge
  - Initial 3D model by HDR
- Monitor bridge for movement
  - Survey
Coordination

Interagency Coordination
• District Executive held numerous press conferences each day
• City of Pittsburgh
• US Coast Guard
  – River Traffic initially restricted
• FHWA

PennDOT/Contractor Coordination
• 24 hours engineering submission, review approval
3D Structure Model – Load Shedding

- Change in axial load due to shortening of L31L32W
  - Blue – compression added
  - Red – Tension added
• Deformed shape of bottom chords and lower lateral system due to shortening of L31L32W
  • Blue – compression added
  • Red – Tension added
Deformed Shape of Damaged Bridge – From Analysis
• Starting September 2\textsuperscript{nd}, daily meetings took place to discuss design
• \textbf{Initial} team consisting of PennDOT, HDR, SAI, Fay, A&I, Amelie and Iron Workers
• Initial plan temporarily support the bridge with the goal of reopening the bridge to traffic on Monday, September 12\textsuperscript{th}. 
SAI & HDR developed similar concepts
Jacking frame to span the localized damage
  - Brackets attached to webs of L31L32 chord
  - HP section struts
  - Jacking

Rotation @ L31 joint major concern
  - Initially, restrain the frame & joint from movement
Anticipated severing distorted angles and possibly webs to reduce jacking load
Initial Repair Schedule

- Initial goal - Open by 9/12/16 with a temporary repair and a permanent repair at a later date.
- 9/03/16 Jacking Frame Concept approved
- Fay Material Procurement:
  - Long threaded A490 HS Bolts, St. Louis Screw & Bolt
  - Jacking Bracket plates: 3 separate fabricators
    - Hall Industries, Littel Steel, Shanefelter industries
    - FCM material for jacking brackets
  - HP strut sections
- 5 days to do the repair once material was on site.
- Problems with testing of bolts, material procurement, concerns with L31 Joint rotation/global behavior, and an “evolving design” delayed the job another week.
- Opening pushed to 9/19/16 on 9/10/16
- By Saturday, 9/10/16, initial repair was to cut out pieces or splice in new section. Heat straightening was ruled out as the main repair concept because it would take 3 weeks
- On Tuesday, 9/13/16, Fay proposed a new repair involving combined lateral & axial jacking, heat softening, lateral web jacking/straightening, and strengthening.
Expanding Team

- **Initial** team consisted of:
  - PennDOT, JB Fay, HDR, SAI, Baker, Abate & Irwin, Amelie and Local #3 Iron Workers

- **Expanded Team:**
  - FHWA Structure Engineers
  - Modjeski & Masters – 3D modeling during jacking
  - Lehigh University – Strain Gage monitoring during jacking
  - Wiss, Janney, Elstner Associates, Inc. – Structural Engineers to assist w/ repair design and on site fabrication inspection/monitoring.
  - Jim Ronning, P.E., recognized jacking expert
  - Purdue University
Final temporary repair of Damaged Truss Member
Final temporary repair of Damaged Truss Member

- 565 Ton Jacks
- Jacking Beams
- Damaged Lower Chord
- 100 Ton Jacks
Temporary Repair

Fire Damaged Chord
Temporary Repair

Cheese Plates
Temporary Repair

Brackets
Temporary Repair
Temporary Repair

565 Ton Jacks
Temporary Repair

100 Ton Jacks
Temporary Repair
Temporary Repair

100 Ton Jack
Temporary Repair
Temporary Repair

Vertical External Bracing @ L32
Temporary Repair

Lateral Bracing @ L31

Jacking strut for L31
Repairs began on Sunday night, September 4th by removing rivets and replacing them with temporary A325 bolts. 200 Bolts were replaced, 4 at a time, 1 in each corner of the damaged lower chord.
Rivet removal
A490s Bolt ROCAP Testing
Bolt issues – procurement, cracks, testing
Cheese plate

Jacking frame pieces
Jacking Brackets from fab. Shop w/ only ¼ stiffeners, permitted bolt tensioning.
Jacking assembly continue – torque verification of bolts at bottom plate, L31 and L32
• 3 Barges & tugs:
  – delivery barge, crane barge for material delivery.
  – 3rd barge & crane on shore to receive over the road deliveries
• Jacking box
• 4 – 565 T Jacks
• Concerns:
  1. Severing/cutting of L31L32: Safety of workers, Sudden movement of joints
  2. Stability of L31 & L32 joints
  3. Resolving the eccentricity of jacking loads
  4. Rotation of Joint L31 back to original position
  5. Permanent repair, salvaging webs for splicing
  6. Monitoring of bridge during jacking
  7. Shifting of loads
• Addition of X bracing to frame, later eliminated
• Internal dia. strut and all thread (ecc. Loads)
• External bracing added at both L31 & L32 joints
• “Poor boys hinge” concept to accommodate L31 joint rotation.
• Lateral jacking system added @ L31 joint
• Web plates to remain for splicing permanent repair
• Web straightening procedure via center hole jacks
External Bracing @ L32

VERTICAL BRACING

LATERAL BRACING
“Poor Boy’s Hinge”

- The HP strut was not flush with the bracket due to the rotation at Joint L31. A “poor boy’s hinge” allowed rotation at this joint.

HP BEARING DETAIL
(PLAN VIEW BEFORE ROTATION)
Heat Straightening
Apply 1000 kips without removing stiffeners
Average longitudinal displacement of 0.05”

- Out-of-Plane Deformations
Bottom Chord Model

- Apply 1000 kips after removing angles and diaphragms
  - Average longitudinal displacement of 0.31”
Jacking Procedure

- 84 steps to jack the damaged member
  - Combined Axial & lateral
  - Read / hold points to move member 1.88” to get a 30 ton posting
  - Comb. heat softening & web jacks to straighten webs

- 4 person operation
  - Wade Clark and Jim Ronning (Wiss Janey Eng.)
  - Tom Murphy (M&M – 3D model)
  - Jason Zang (PADOT Structure Control Engineer)
Data check to M&M

- M&M 3D model to evaluate load redistribution and determine a posting level.
  - Survey data (i.e. L31L32 length change)
  - Strain gage data
  - Jack pressures (used indirectly)
- String line measurements are used to confirm that the members that are displaced are returning to straight and no new members are being deformed
Final Temporary Repair Work Schedule

• Friday 9/23/16 – worked from 7:00am until 7:30pm
• Saturday 9/24/16 – worked from 7:00am until 7:00pm
• Sunday 9/25/16 – posting decision was made – 9 ton and Fay continued finishing final temporary repairs.
• Monday 9/26/16 – final repairs finished by afternoon and open bridge to afternoon rush hour (3:30 PM)
Lehigh University Strain Gages
Lehigh’s wires for monitoring strain gauges
M&M 3D Model for load re-distribution

- L31L32 length measurements
- Strain gage data dump
  - stiffness refinements
- Continually refining 3D models as jacking progresses
Steel Temperature check, Friday 9/23/16
- Command Center
- Incident Mgmt. Plan
Saturday, September 24th at

Damaged Diaphragms
Lacing removed
Saturday Lunch!

Accelerated delivery system
Cross bracing starting to straighten
Temporary Repair
Temporary Repair
Temporary Repair
Temporary Repair
Post Jacking – Restored Displacement of 1.63”
Bridge opened to traffic with 9 ton restriction

At 3:30pm, September 26th
By 8 AM, State Police Motor Carrier Enforcement Team had caught their first tractor trailer attempting to enter the tunnels from the suburban side.

Also redirected trucks attempting to cross the bridge from McArdle Roadway

Numerous trucks were crossing the bridge from I 579 Crosstown Expressway

City of Pittsburgh Weigh Team was called out to assist on the City side of the bridge

Press Office re-emphasized the 9 ton weight limit
Permanent Repair to Damaged Truss

• WJE designing this repair (first draft received on 9/26 PM)
• Installation by Fay expected in the coming weeks to bring the bridge back up to 30 tons and 1.5 operating rating
Post Jacking Work

- L29L30 strengthening from 9 ton to 30 ton
- 98 square inches of steel added to East Truss member L29L30
- 30 Ton Weight Limit Restored on 9/29/16
Post Jacking Work – Material Testing

- Cores samples from web
  - from location where no significant effects from the buckling and straightening of the plates
- Cores sent to Lehigh for yield stress testing
  - Average yield stress is 29.4 ksi
  - Maximum result is 31.0 ksi, min. 28.2 ksi
  - Further review on evidence of fire impact of material, correlation of hardness data and discussion on relationship between test results will be conducted.
Stage I: Final Repair L31L32

Green shows existing 6 angles and plate added
Post Jacking Work - Final Repair L31L32 - Stage II

- Angles on gusset, L31 Batten, Top Structural, Bottom Cover Short & Long, Top cover Short

Green – existing steel added
Red – stage 2 steel added
Post Jacking Work - Final Repair L31L32 - Stage III

- Bottom outside angles, 2 side plates, top cover plate long

Legend:
- Green – existing steel added
- Red – stage 2 steel added
- Blue – stage 3 steel added
THANK YOU

- HDR – Roger Eaton
- WJE – Wade Clark
- SAI
- M&M – Tom Murphy
- Baker – Inspection and CM Staff
- HRV
- FHWA
- Lehigh
- CMU
- Purdue
- J.B. Fay & Local 3 Iron Workers