# Liberty Bridge Incident

QAW February 2018

Tom Macioce, P.E.
Chief Bridge Engineer
PennDOT

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# 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

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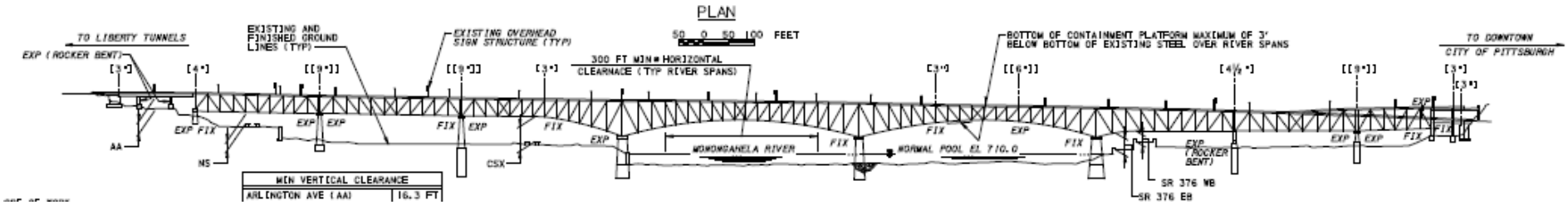
# Liberty Bridge





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

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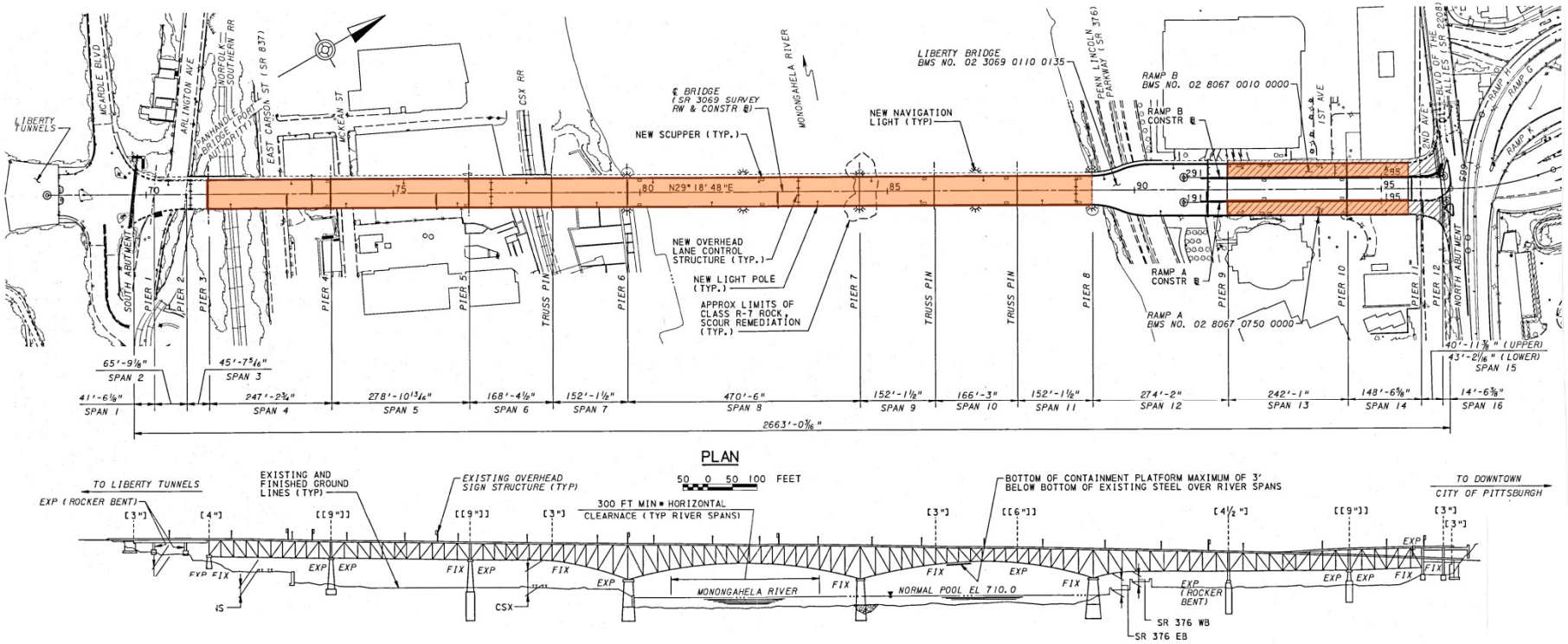
# 2016 Work Overview

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



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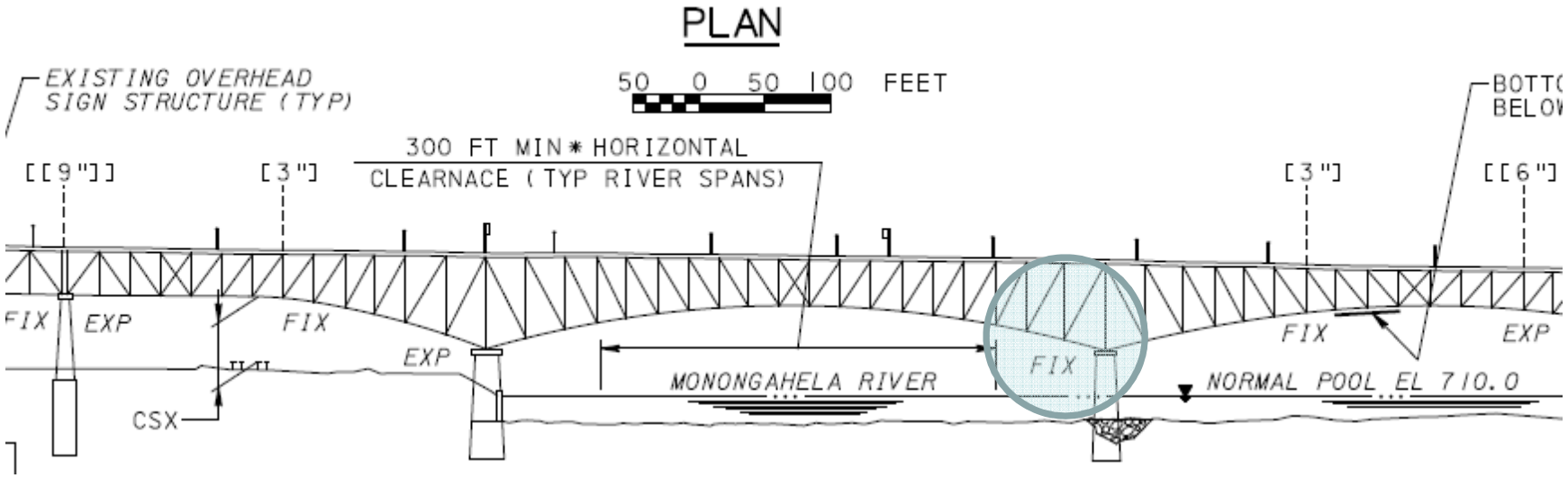


- Cantilever deck truss
- Bottom chord near pier
- Continuous span

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# Condition on Sept 2, 2016

- Last phase of construction (phase 1D) for 2016:

# Typical Deck & Stringer Demo Operations:

# Liberty Bridge Fire – 9-2-2016

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 2nd

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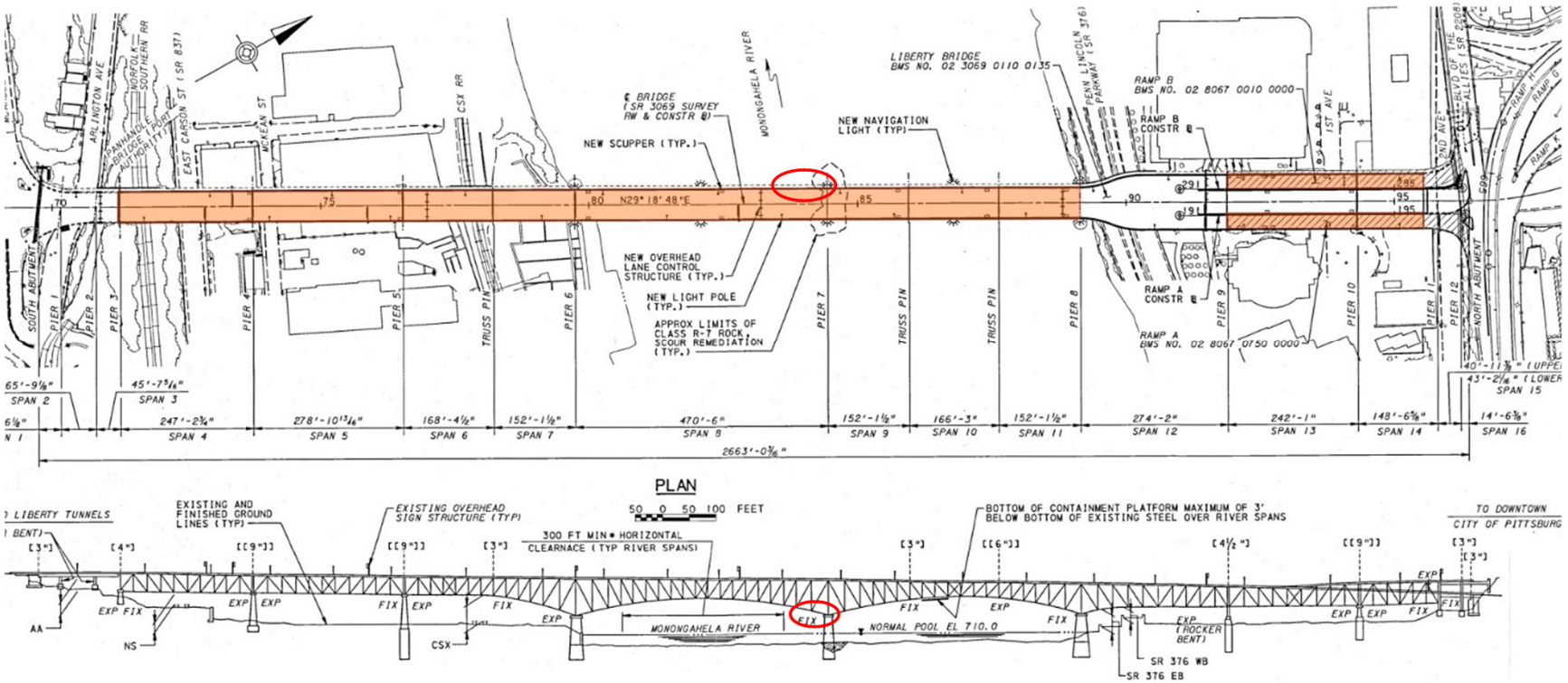
# Liberty Bridge Fire – 9-2-2016

1:14pm 9-2-16

# Liberty Bridge Fire – 9-2-2016




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.

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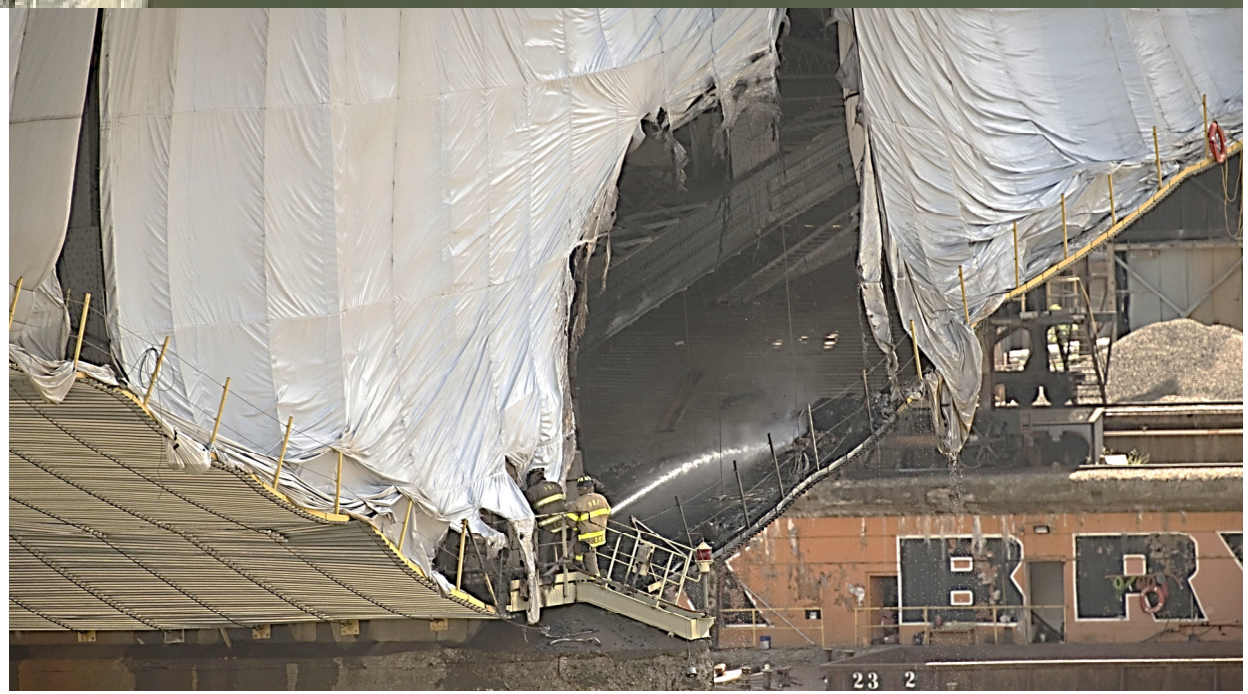
# Liberty Bridge Fire – 9-2-2016

# Liberty Bridge Fire – 9-2-2016

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.

# Liberty Bridge Fire – 9-2-2016

- 30’ primary member compression chord L31L32 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.

# Material Storage

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# Fire Damage to L31L32 West Truss

- Note:
  - Sagging of lacing channels
  - Crippled flanges

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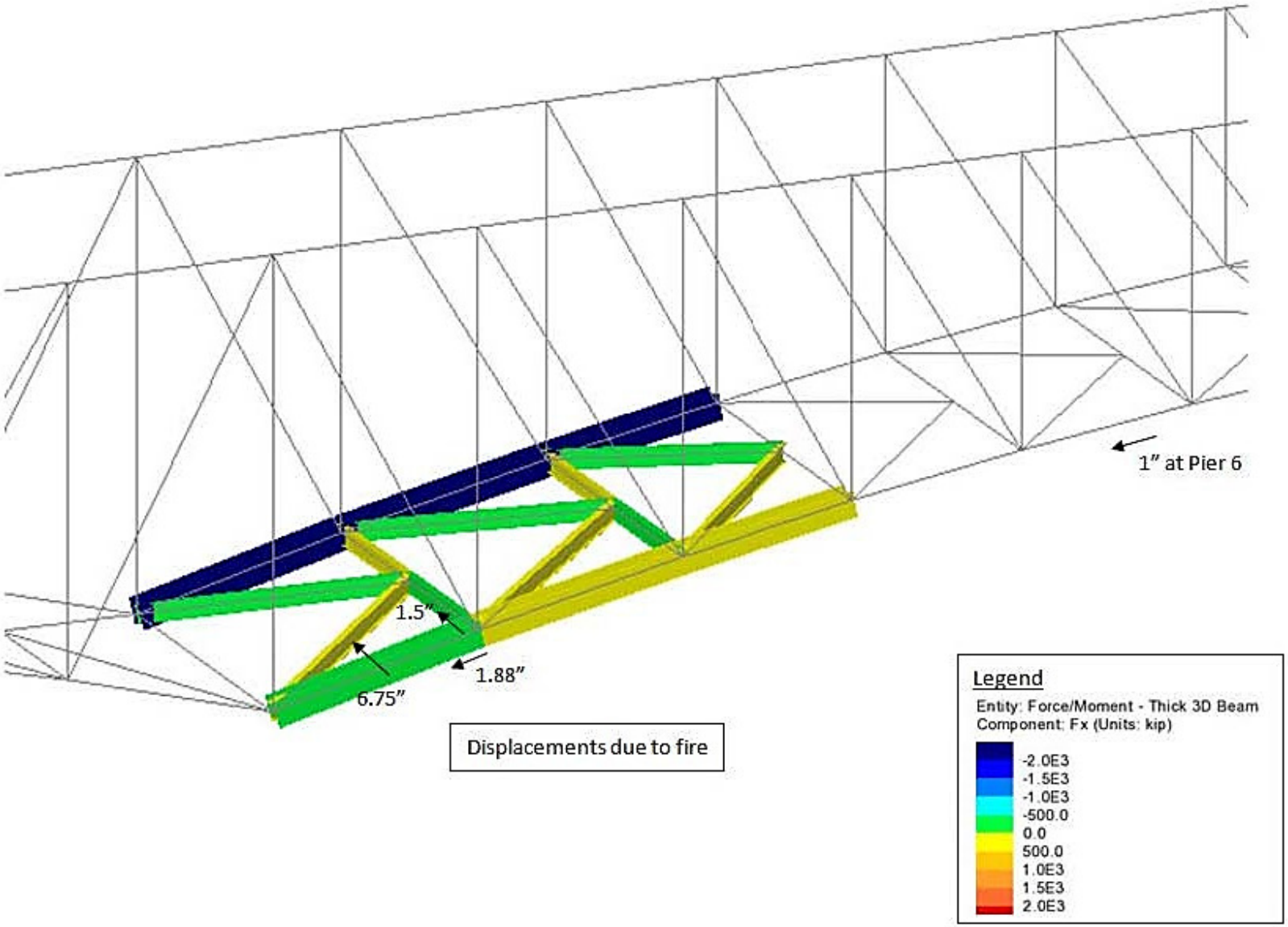
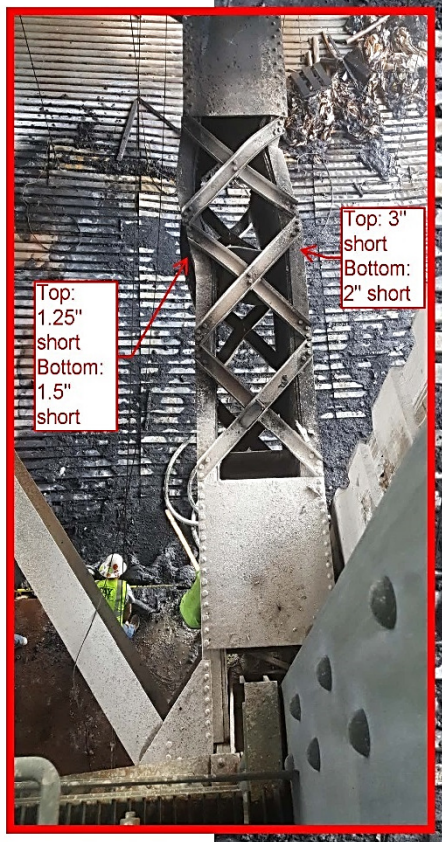
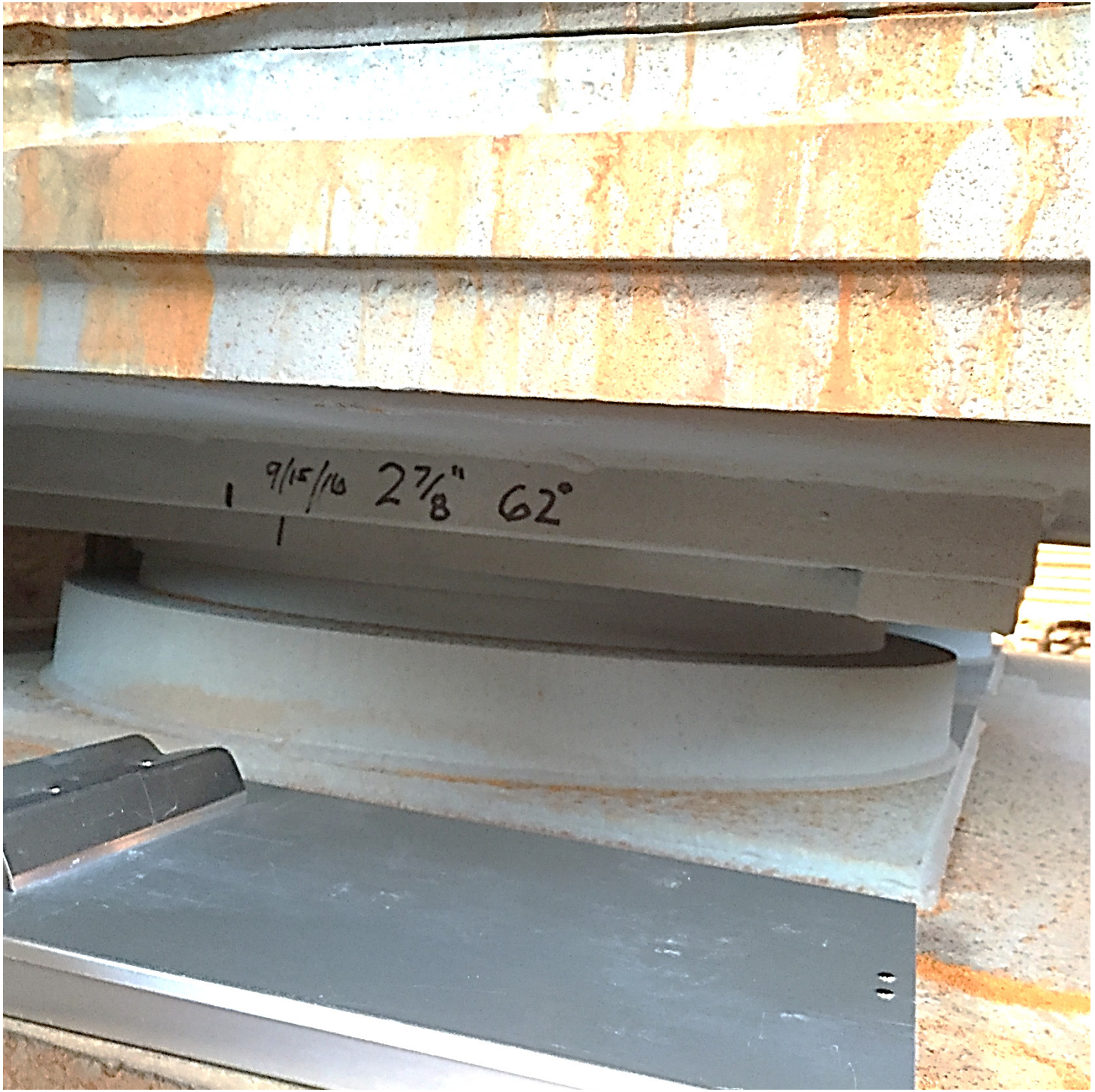
# Post Fire – 1.88” Movement of L31W



Location of Cheese Plates and Jacking Brackets, typ.






East Truss Bearing Measurement

# Liberty Bridge Fire – 9-2-2016

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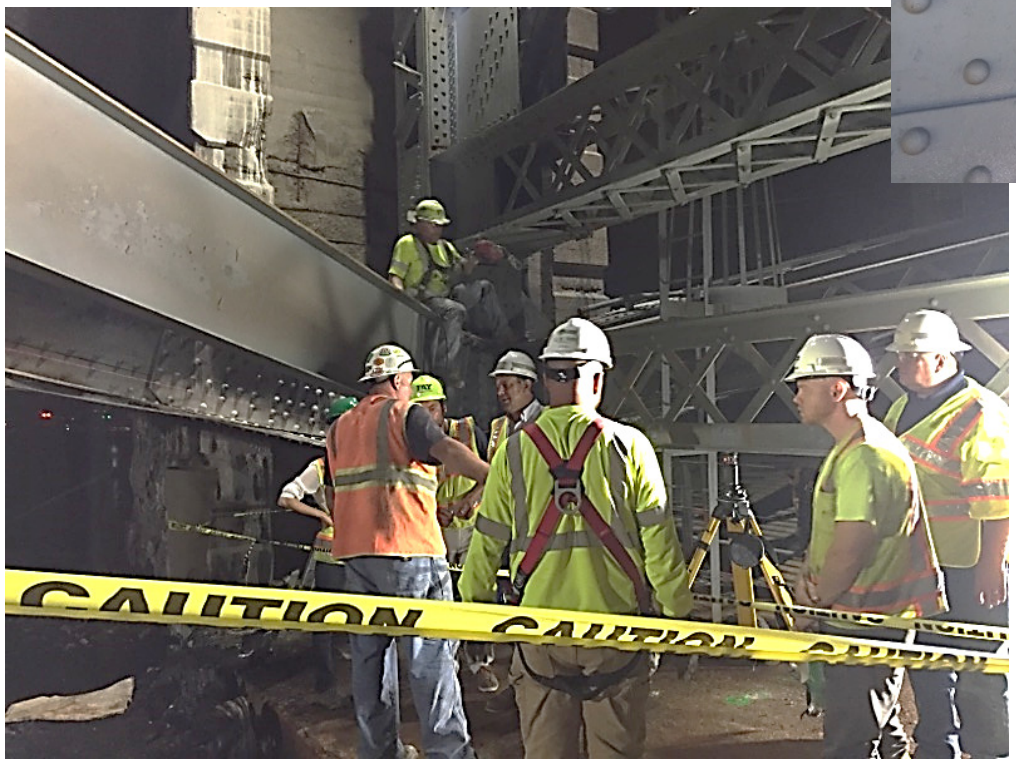
# Night of September 2, 2016

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

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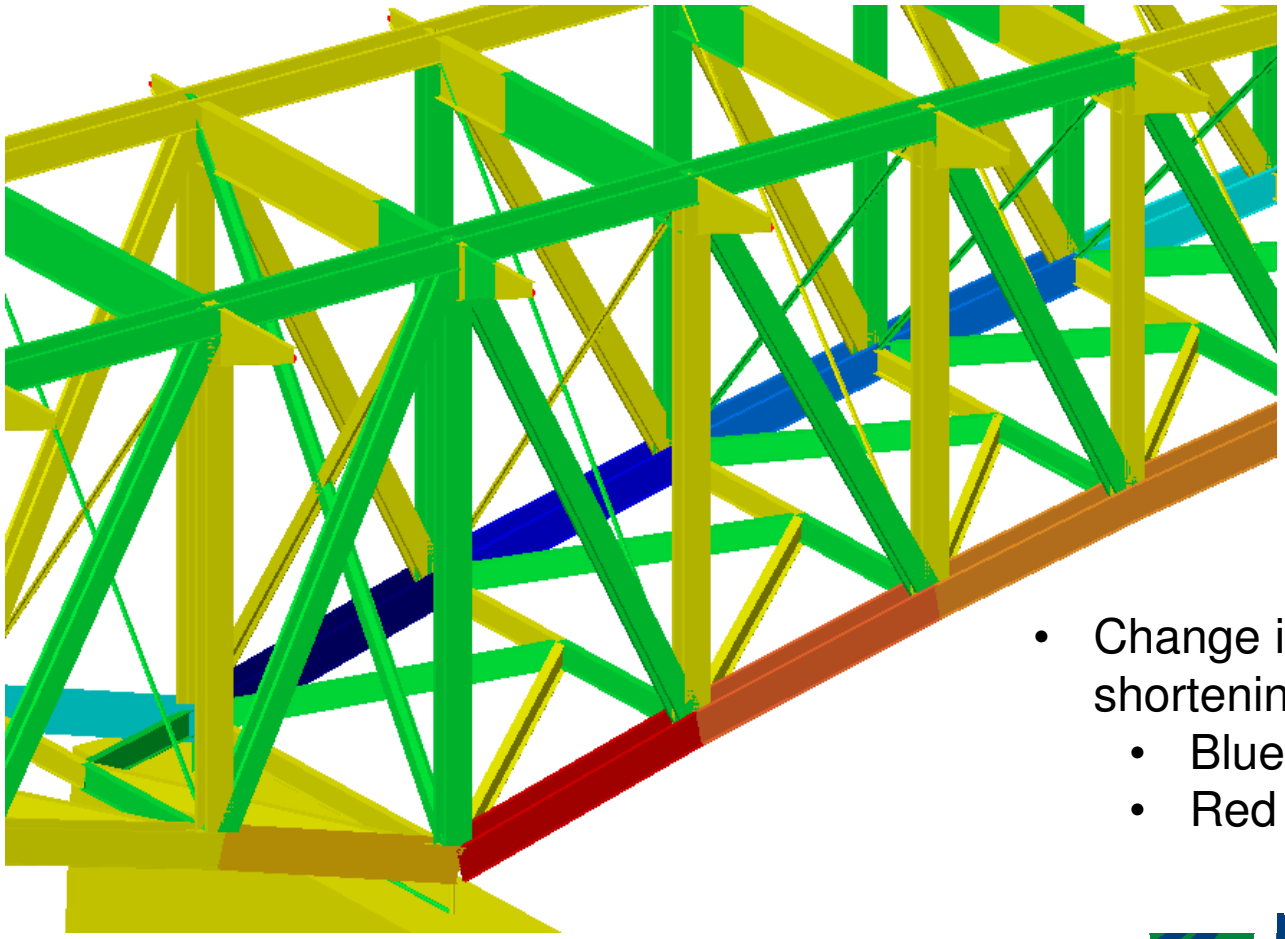
# 3D Structure Model – Load Shedding



- Change in axial load due to shortening of L31L32W
  - Blue – compression added
  - Red – Tension added

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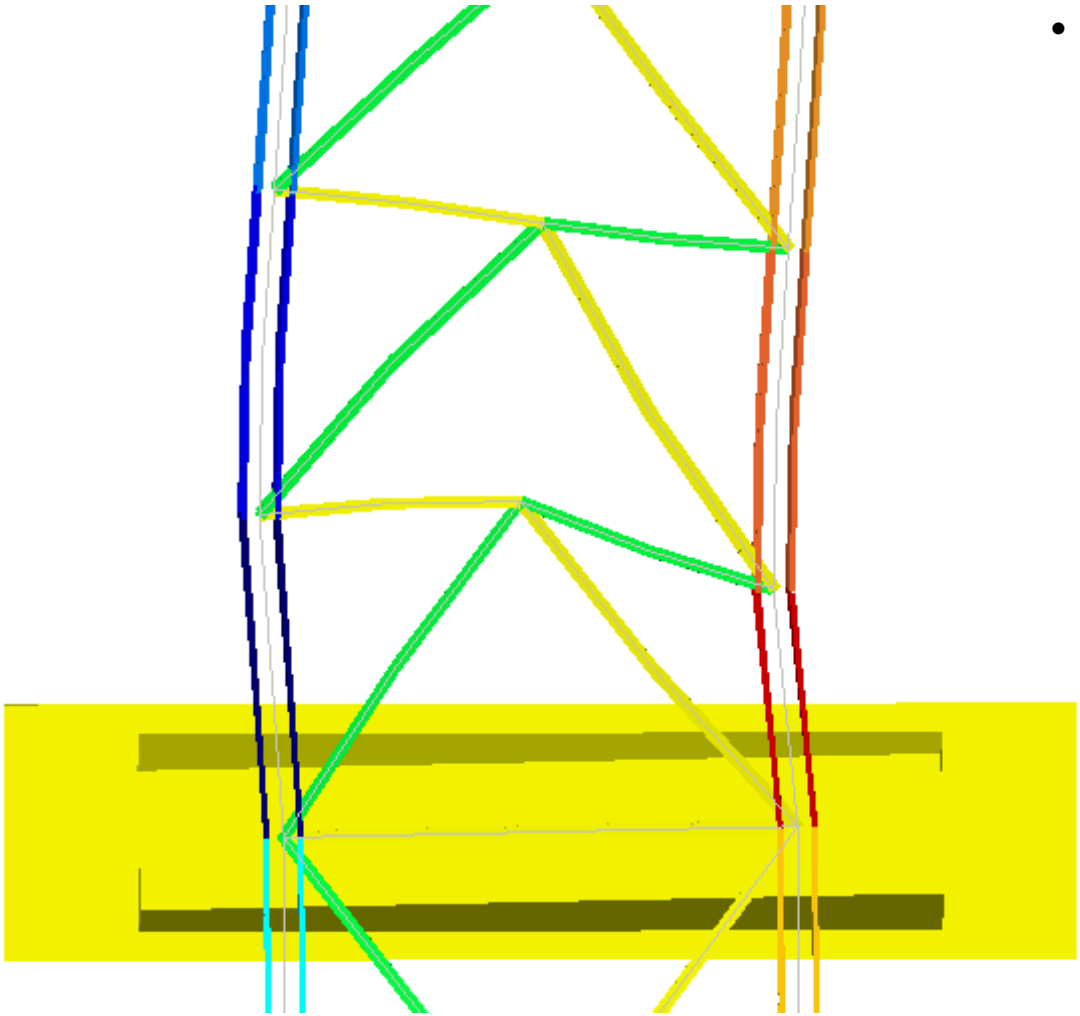
# 3D Structure Model - Deformations



- Deformed shape of bottom chords and lower lateral system due to shortening of L31L32W
  - Blue – compression added
  - Red – Tension added

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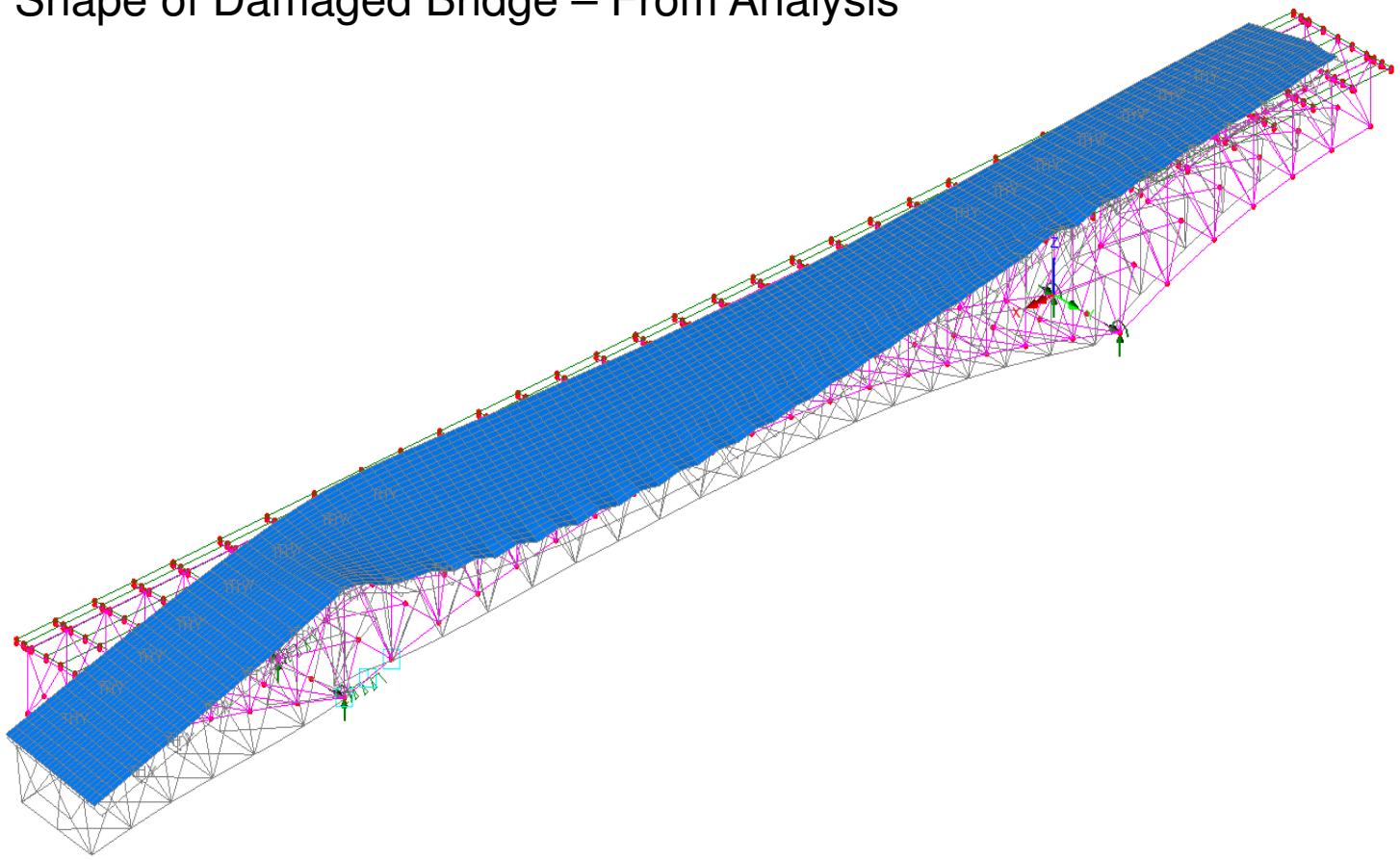
# 3D Structure Model - Deformations

Deformed Shape of Damaged Bridge – From Analysis



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- Starting September 2nd, daily meetings took place to discuss design
- 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 12th.

# INITIAL REPAIR CONCEPT

- 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

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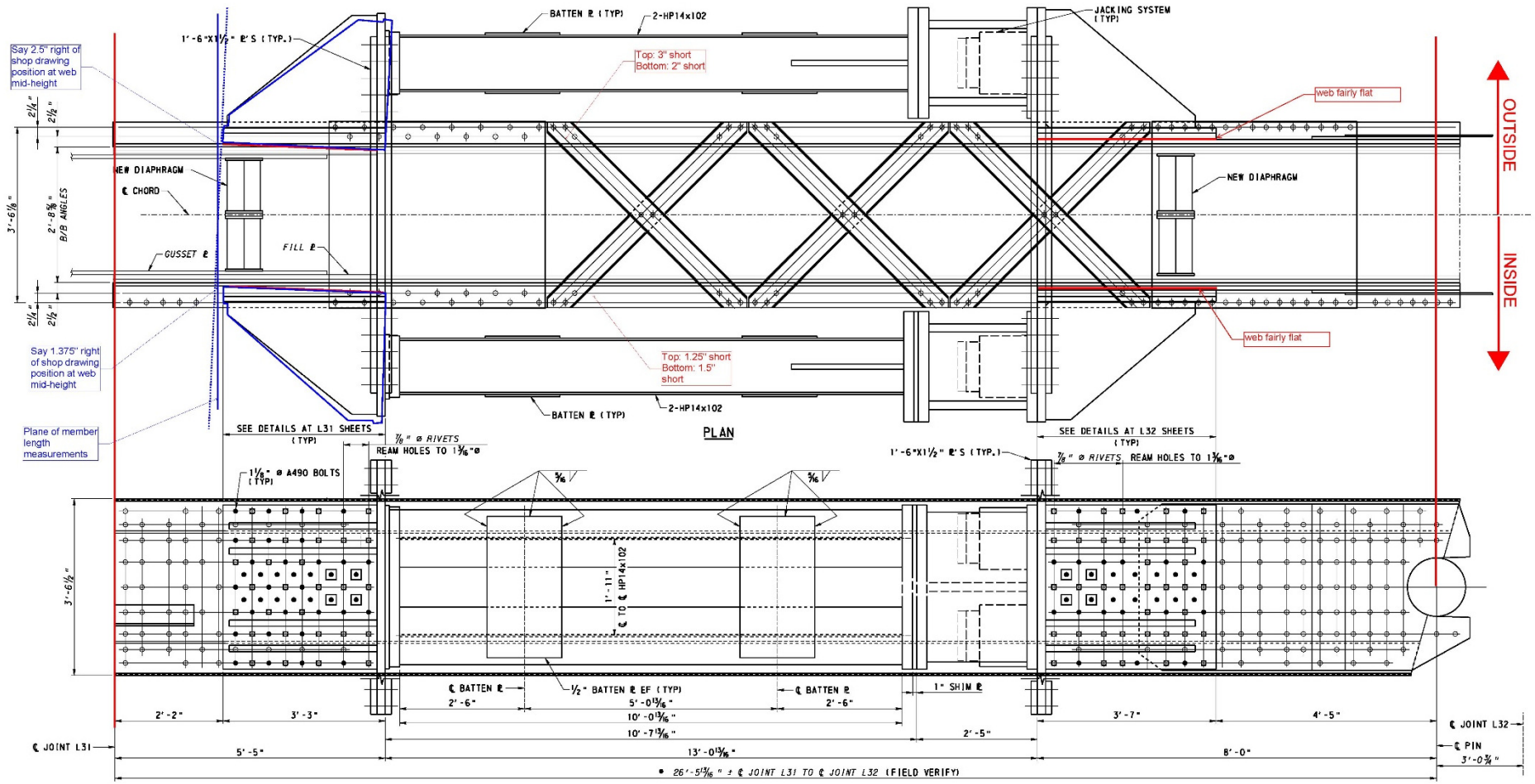


ELEVATION

NOTE:

1. FOR LOCATION OF BRACING AND DETAILS SEE BRACING DETAIL SHEET

LEGEND:

- ○ EXISTING RIVET
- ● NEW BOLT & NEW HOLE
- □ NEW BOLT & EXISTING HOLE
- □ LOCATION OF 1" ø ALL THREAD BAR

1' 0' 1'

•DIMENSION FROM ORIGINAL SHOP DRAWING, SHEET NO. 246

| MARK | DESCRIPTION | BY | CHK'D. | APP'D. | DATE |
|---|---|---|---|---|---|
| 1 | ADDRESS REVIEW COMMENTS 9/7/16 (11:00 AM) | RLC | KAM | | |
| 2 | ADDRESS REVIEW COMMENTS 9/7/16 (8:00 PM) | RLC | KAM | | |
| REVISIONS | | | | | |

| | |
|---|---|
| DESIGNED BY | JDA |
| DRAWN BY | RLC |

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

ALLEGHENY COUNTY
SR 3069 SECTION A20

SEG. 0110 OFF. 1485
S.R. 3069 STA. 83+05.08
OVER THE MONONGAHELA RIVER

EMERGENCY REPAIR

PLAN AND ELEVATION

RECOMMENDED _____

SHEET 2 OF 8

# 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 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.

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# 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

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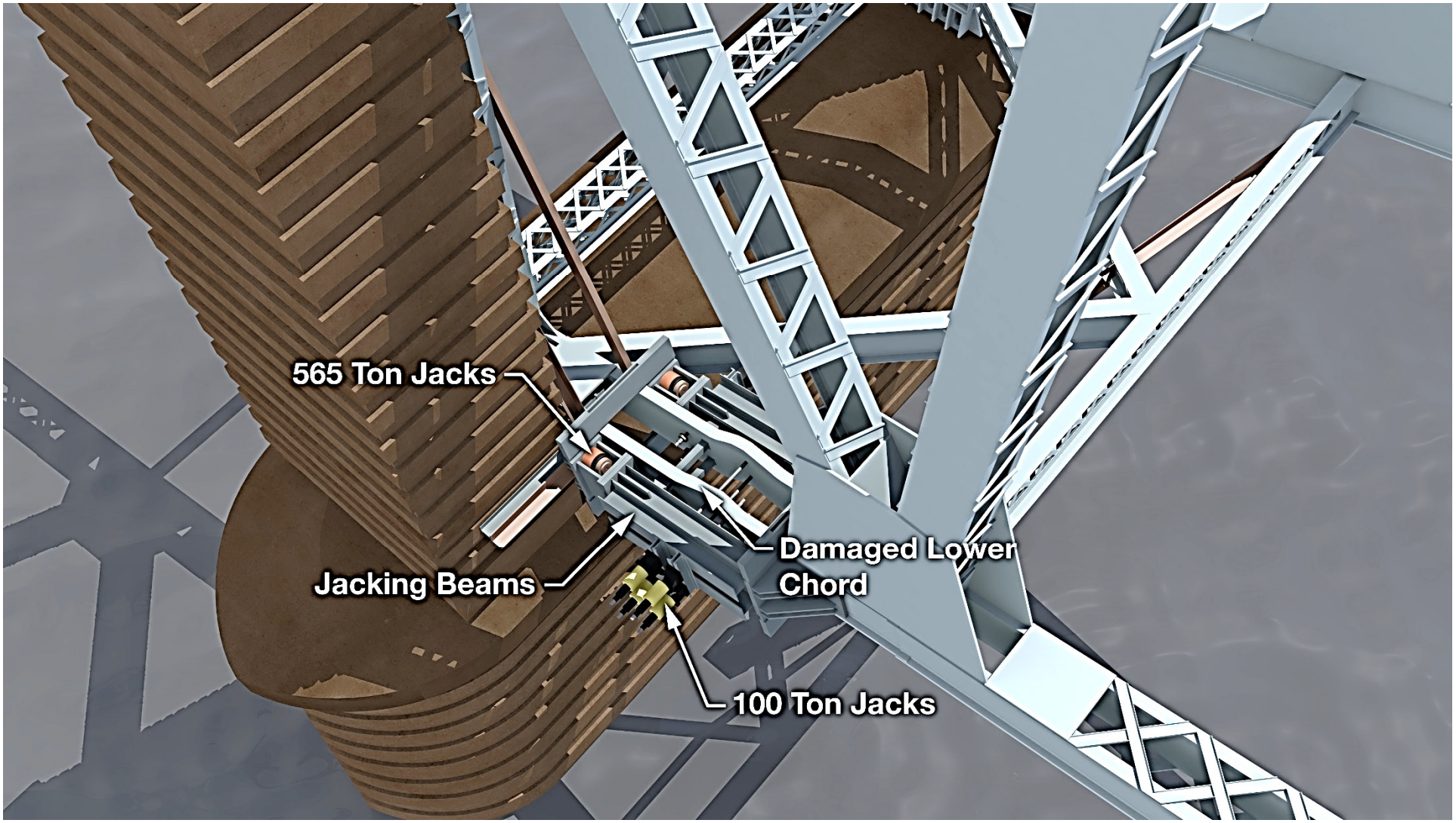
# Final temporary repair of Damaged Truss Member



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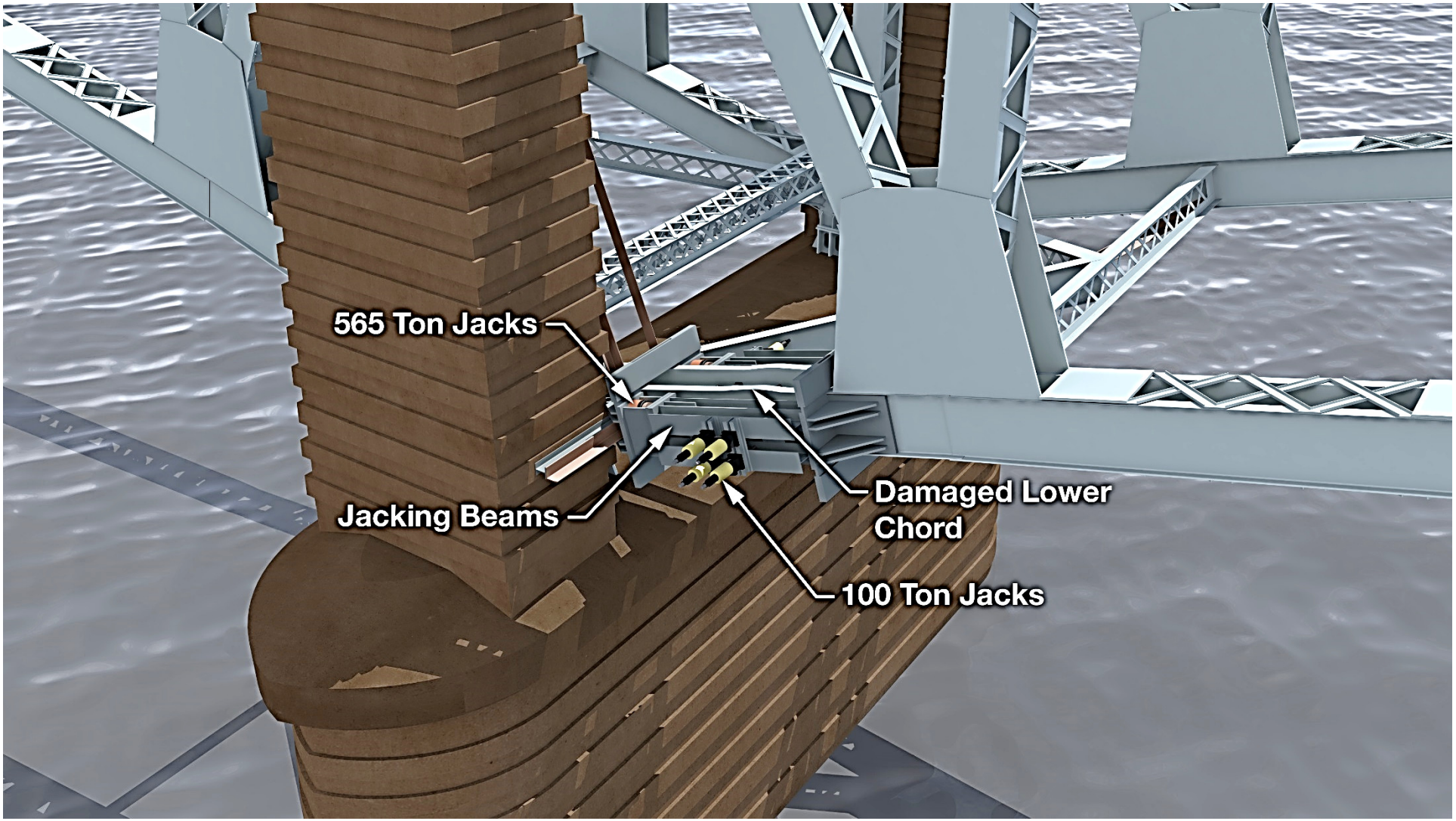
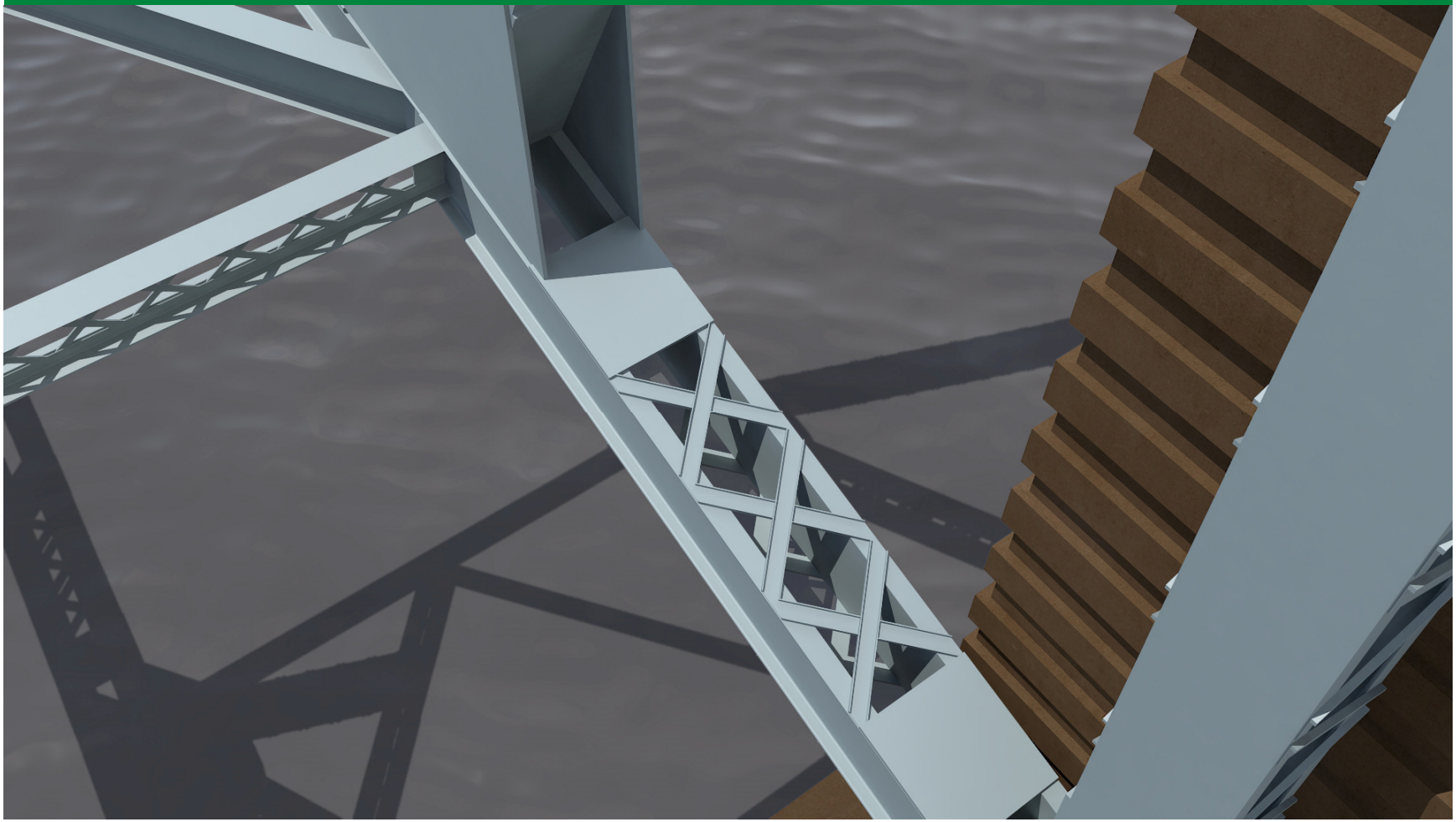


# Temporary Repair



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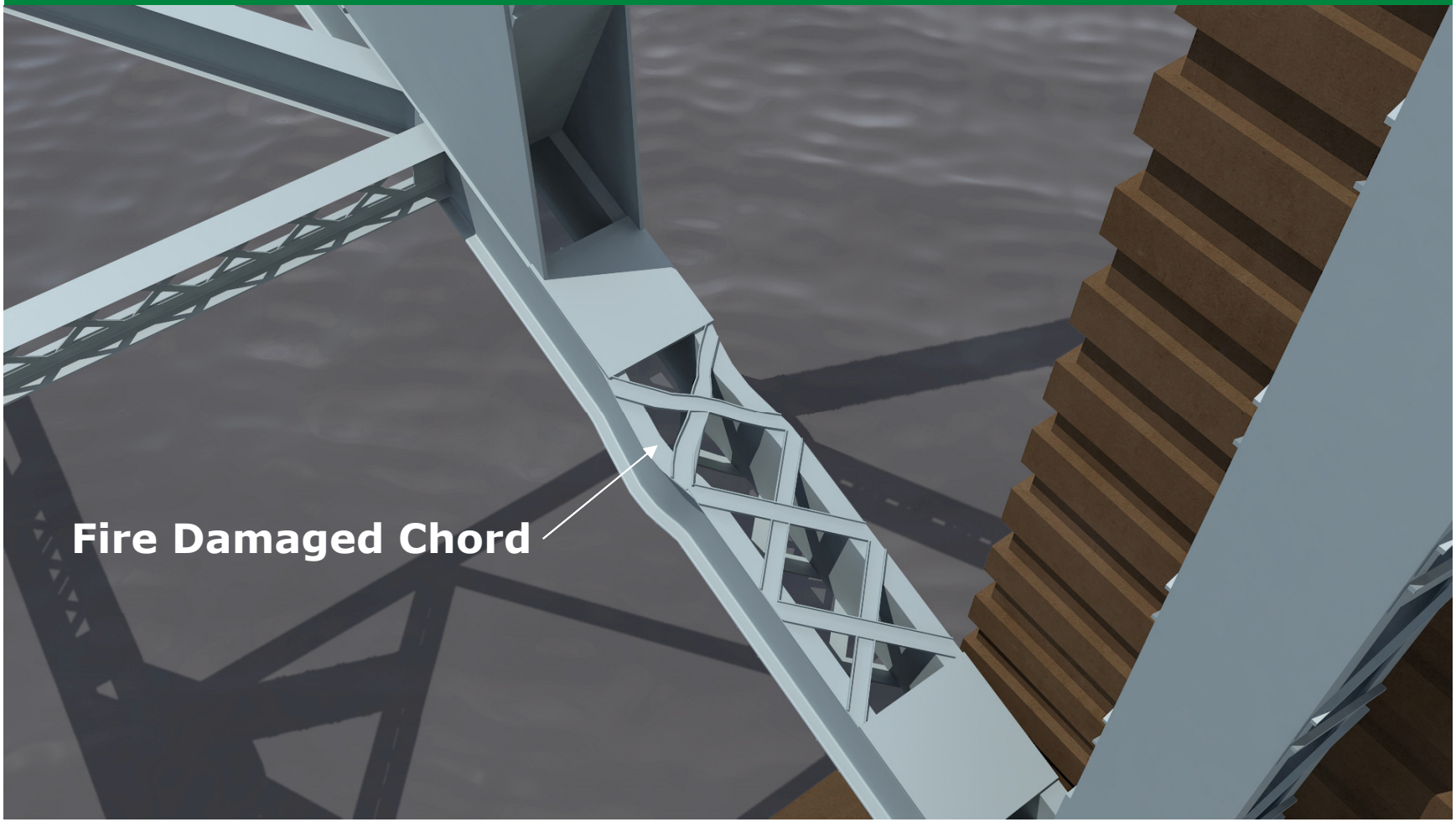


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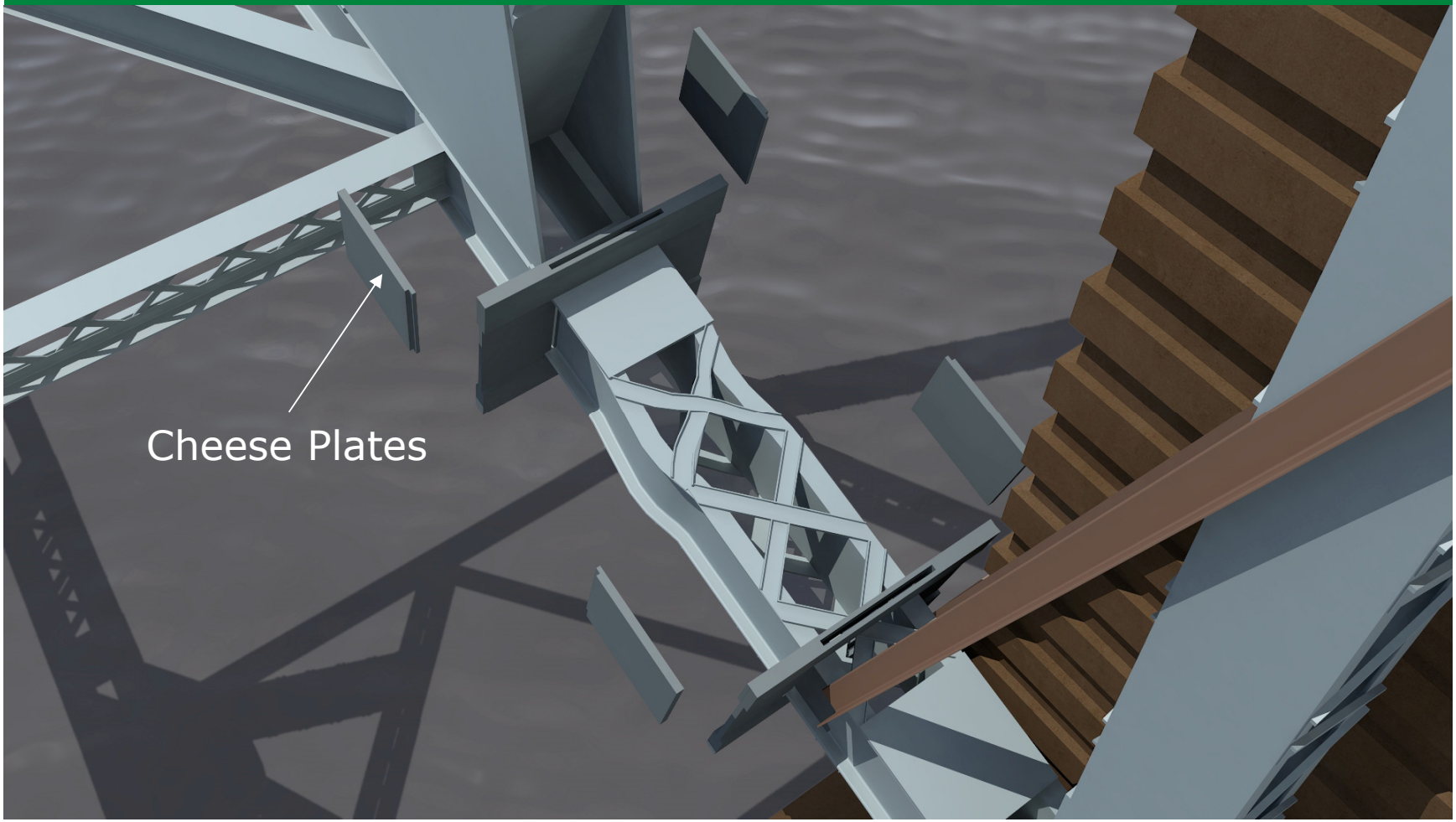


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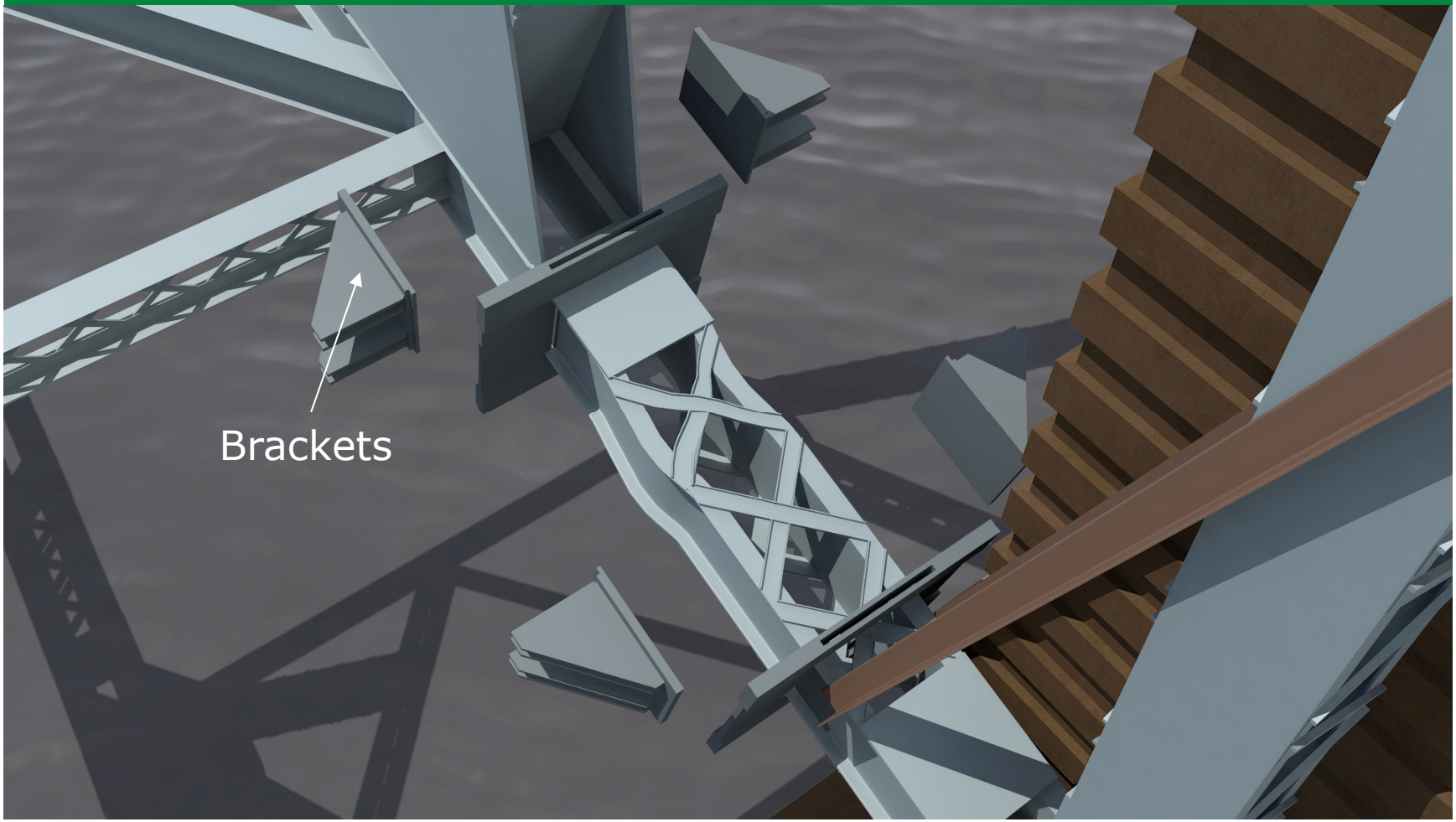


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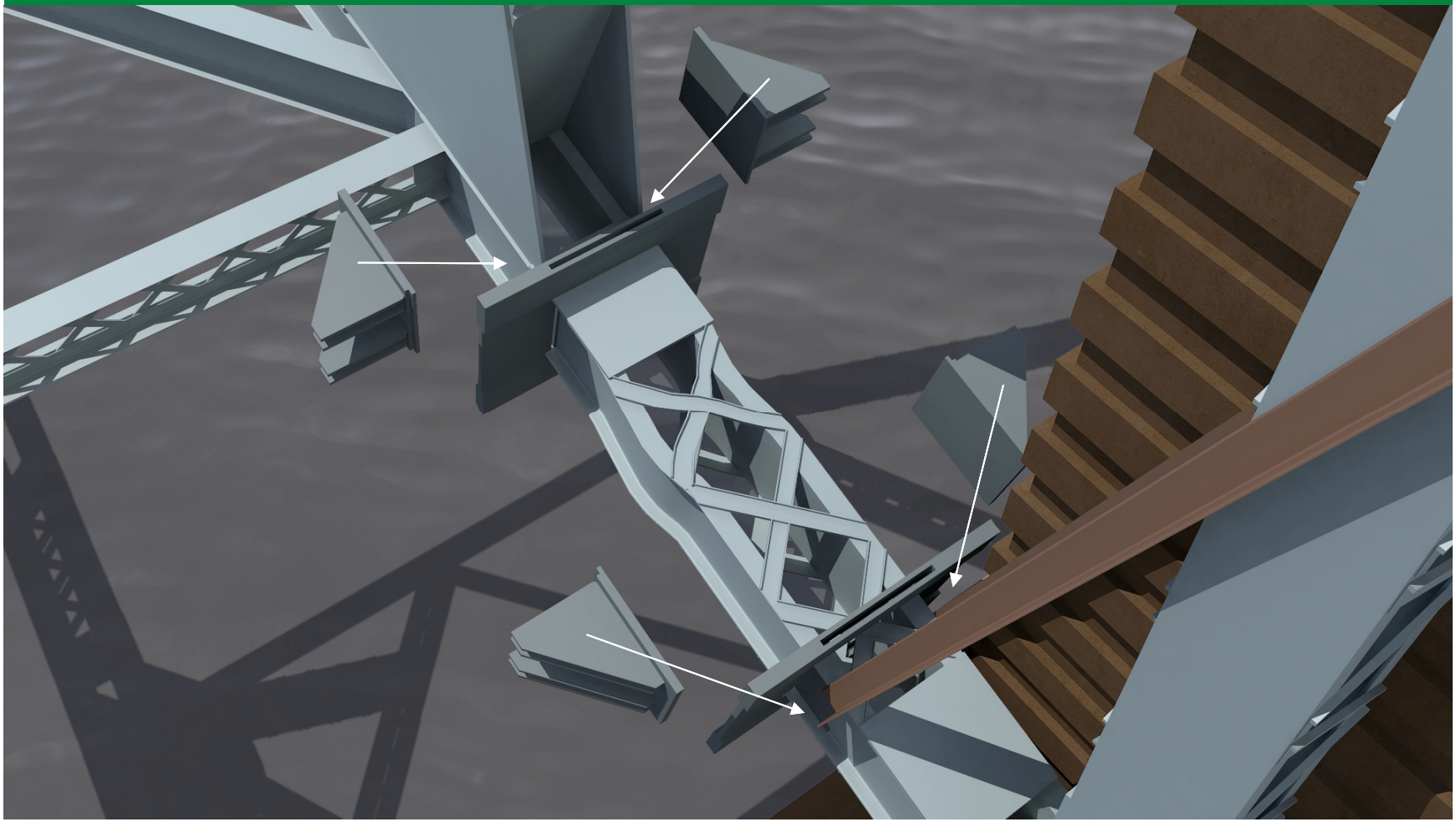

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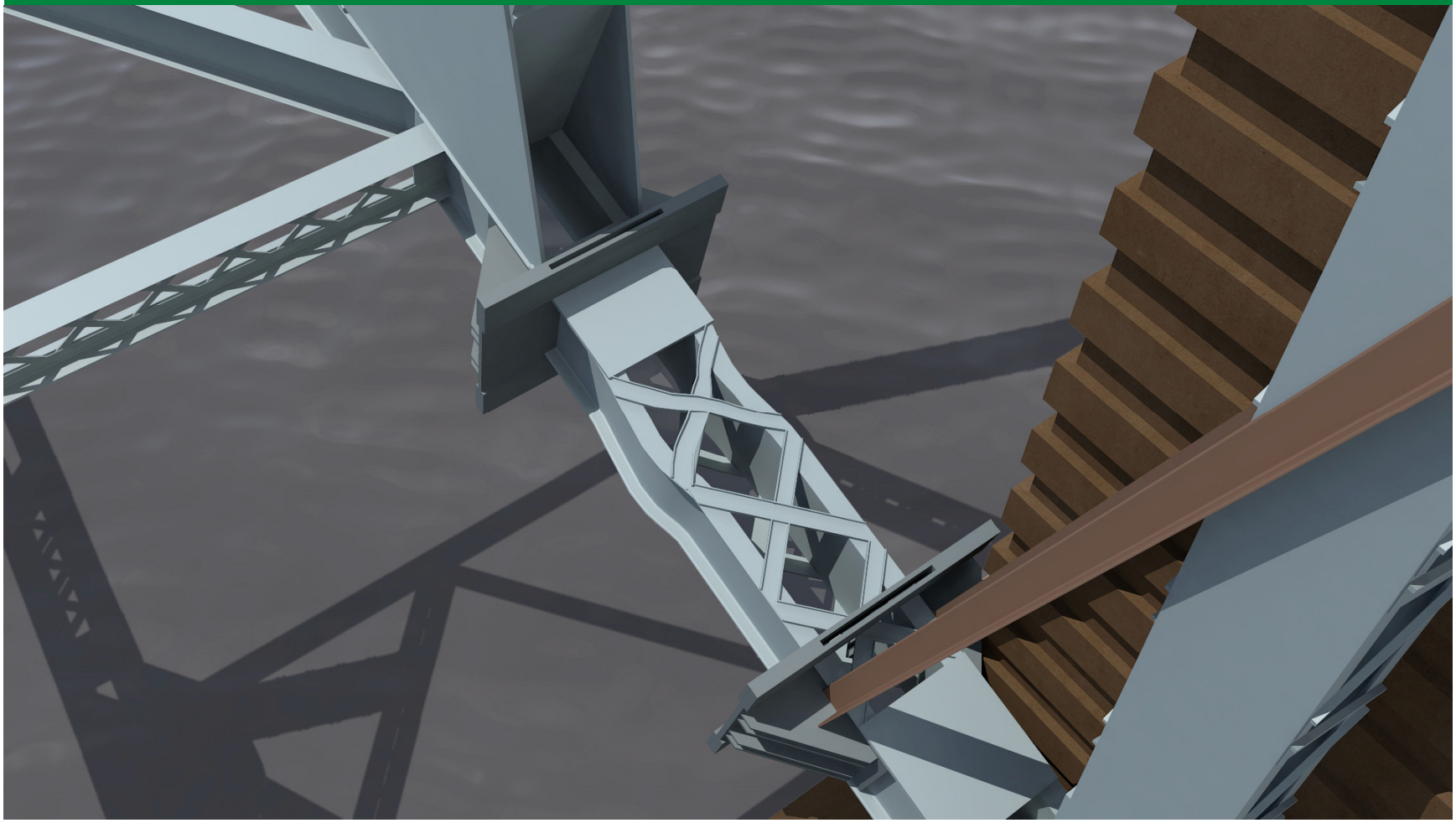

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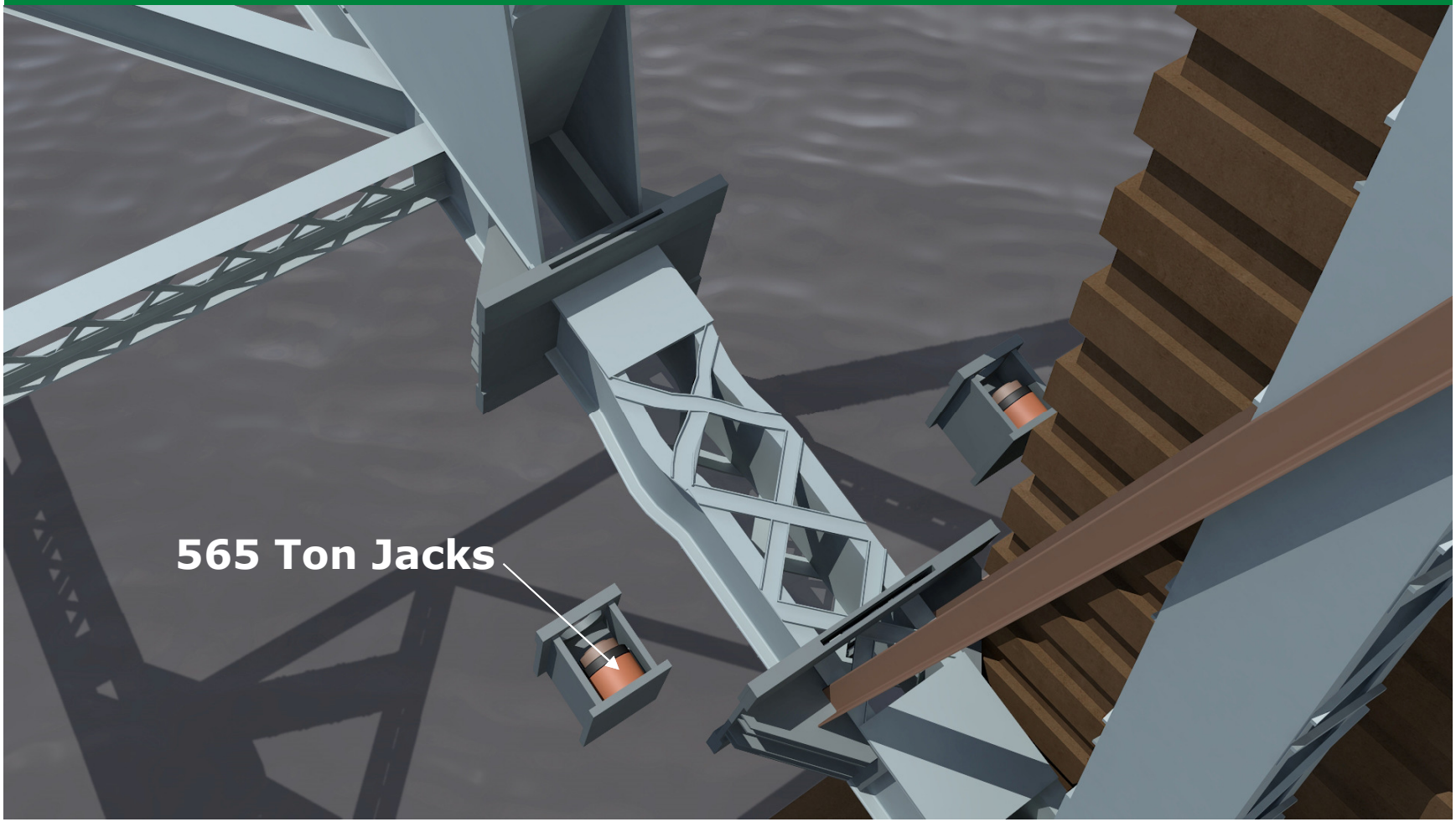


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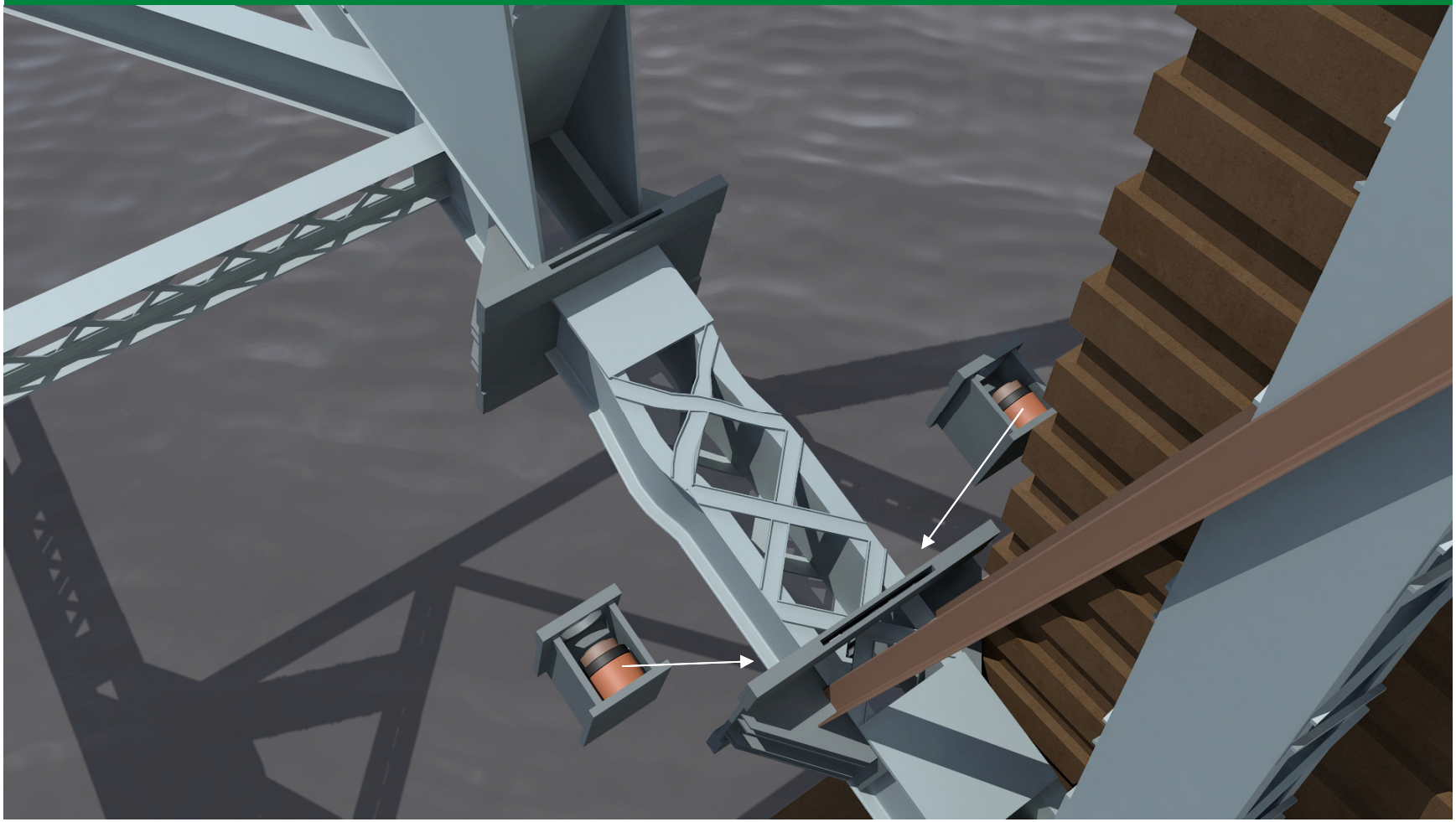

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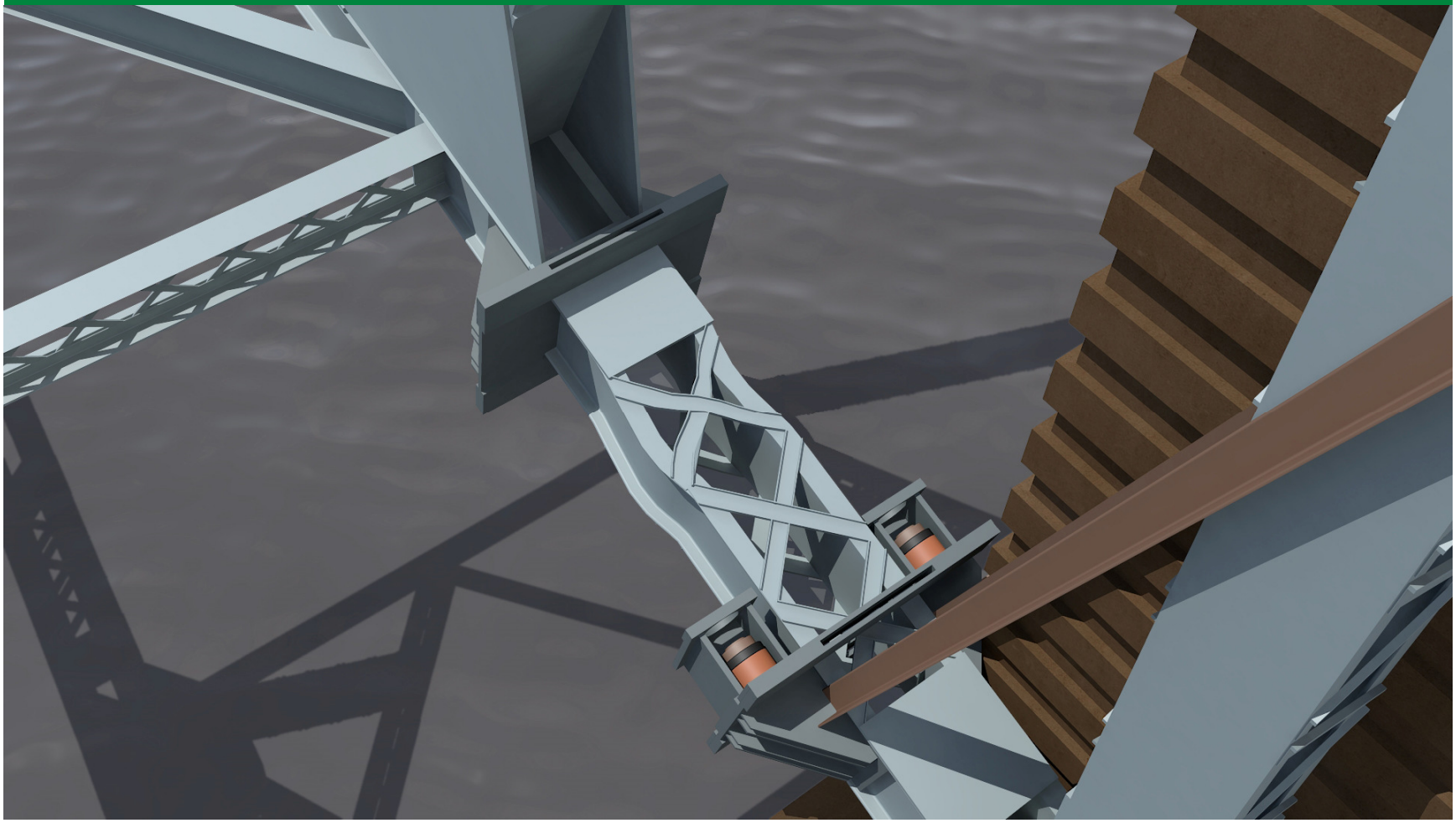

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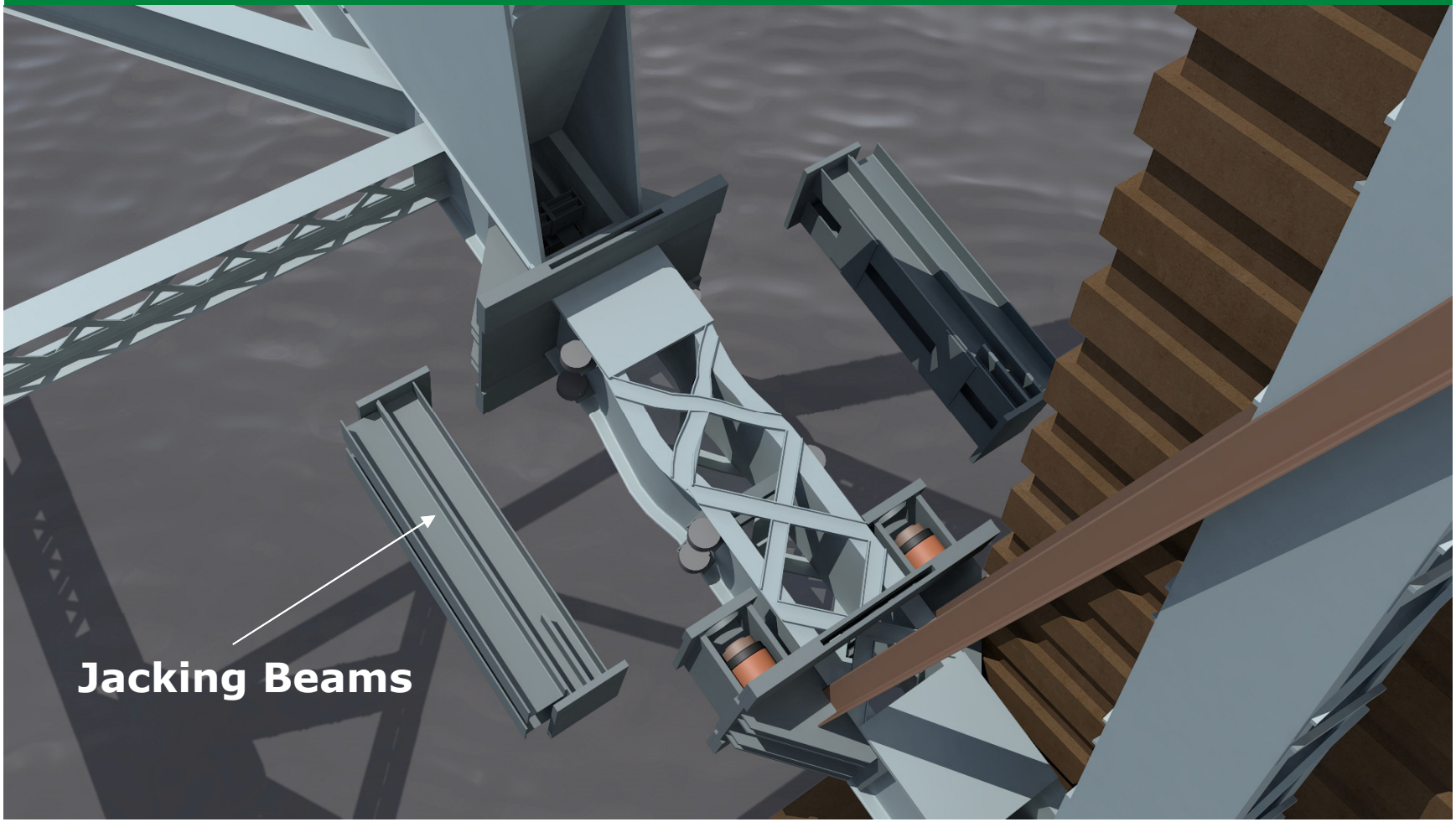


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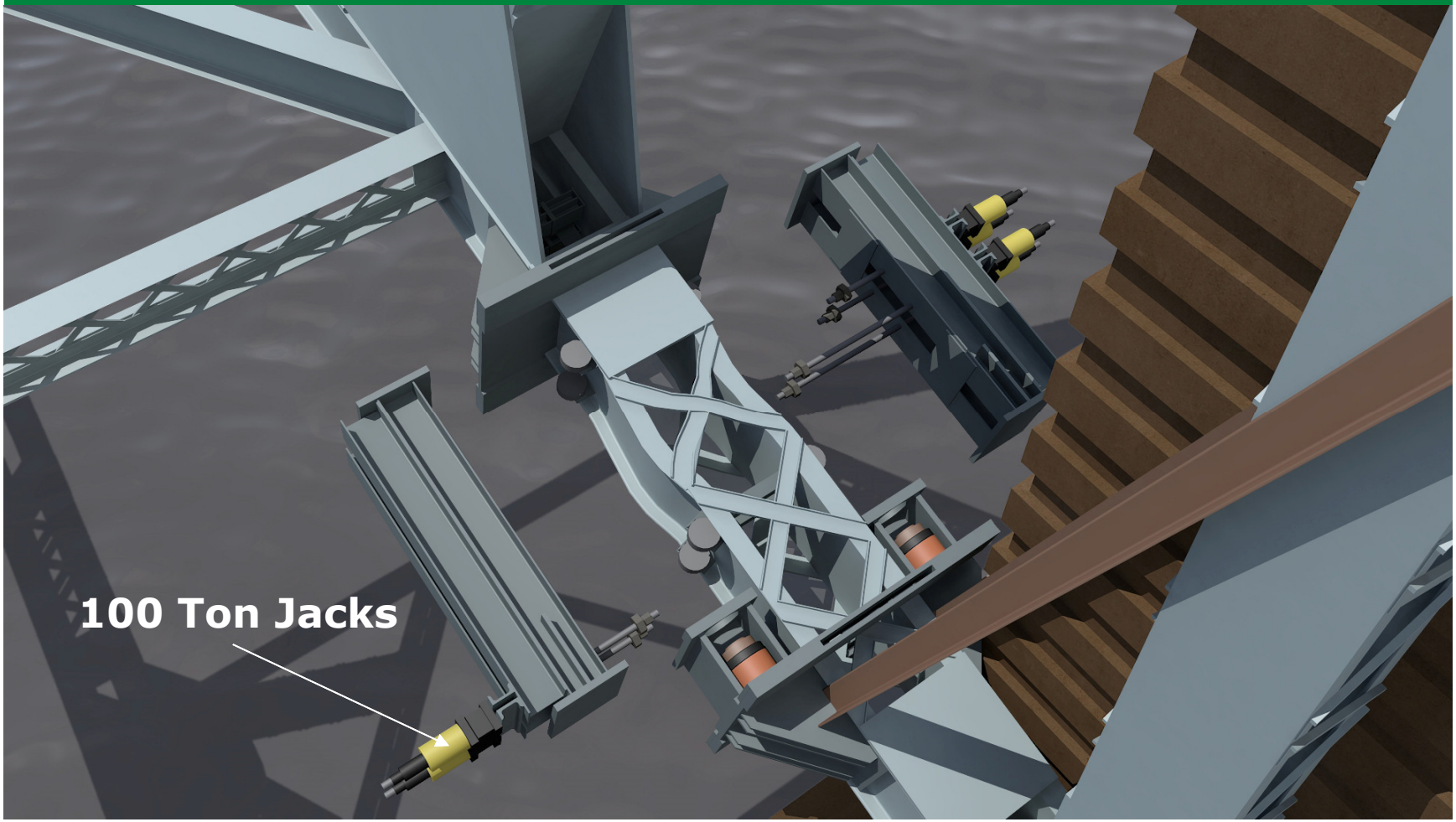


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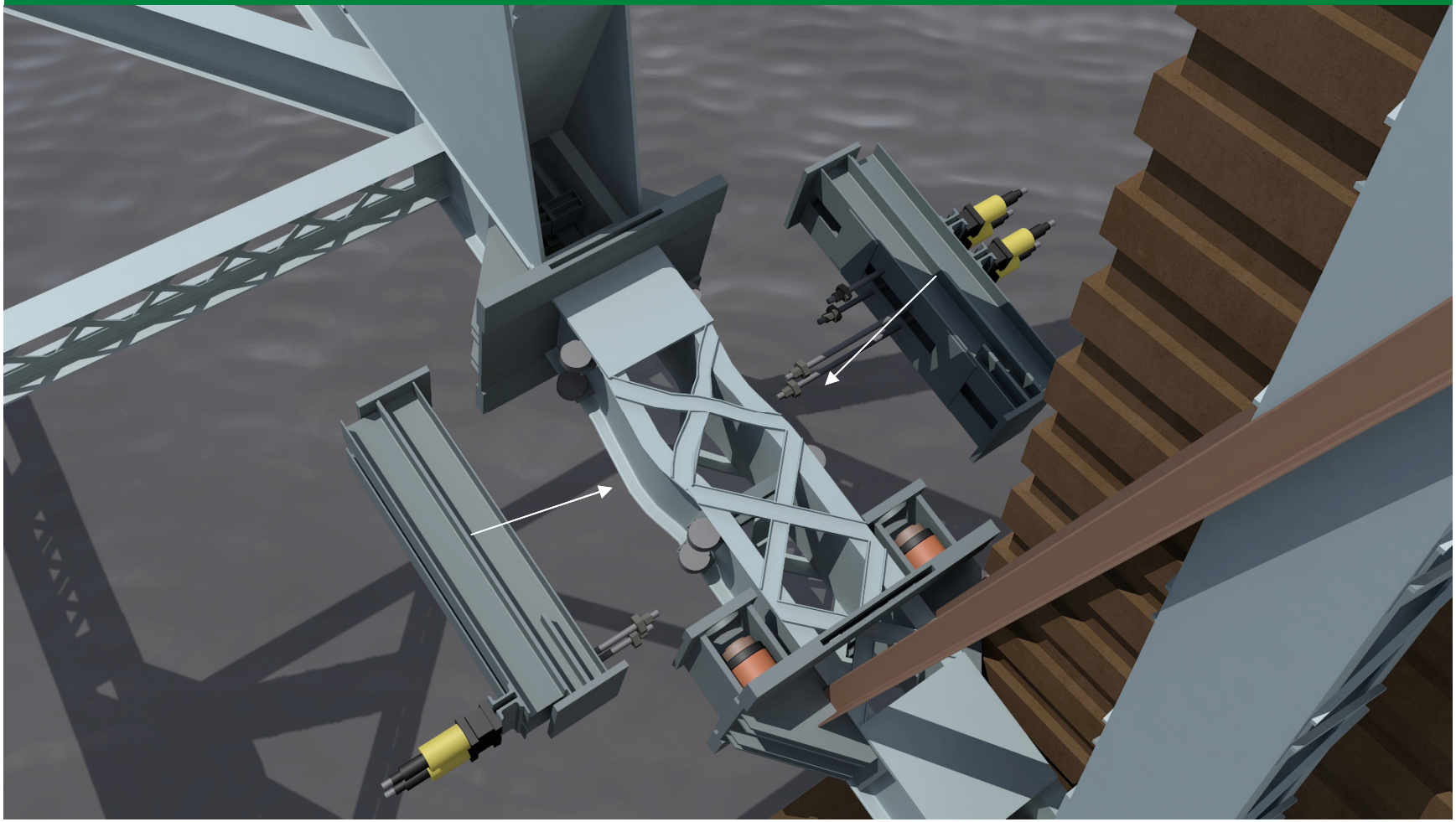

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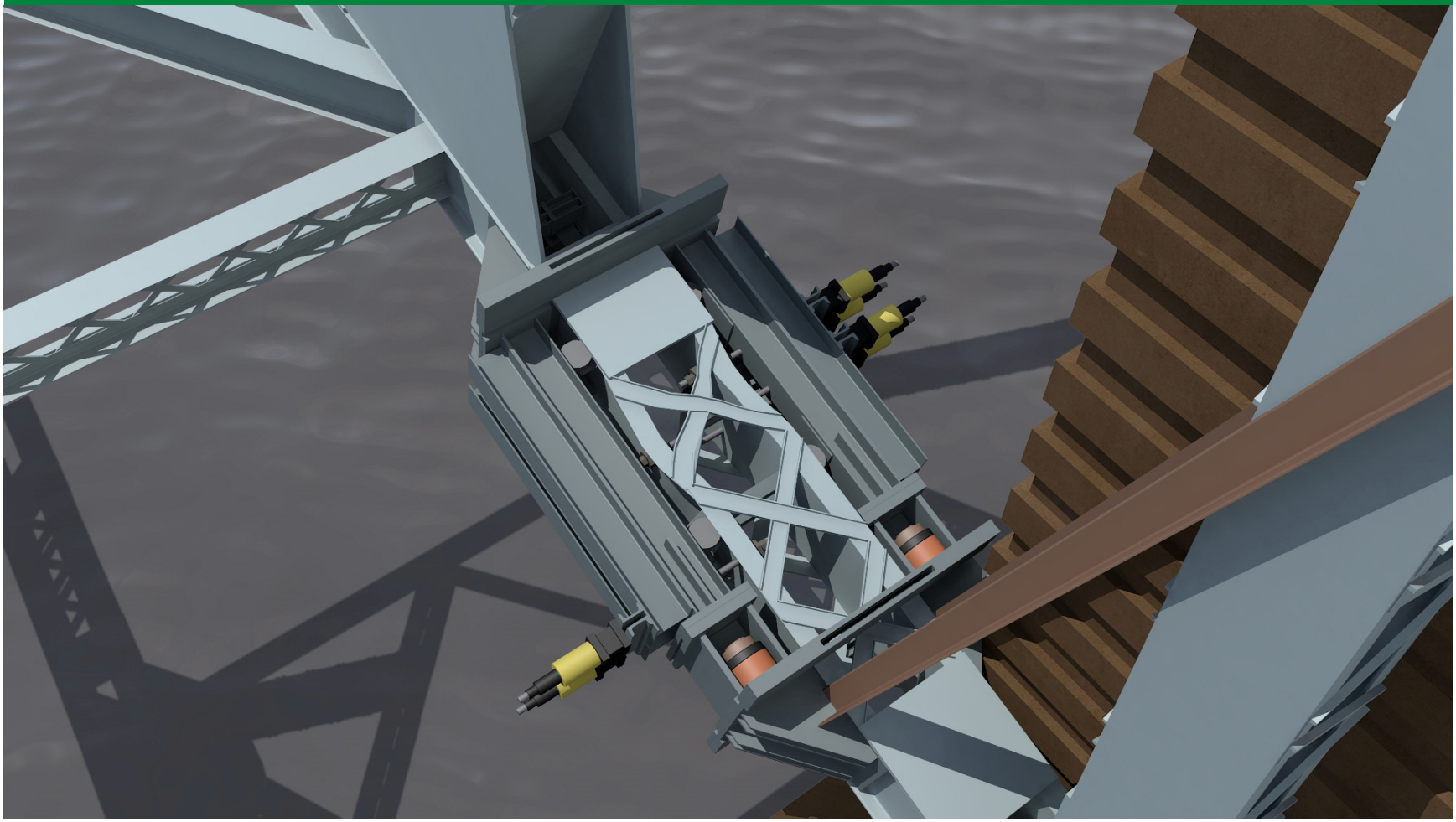

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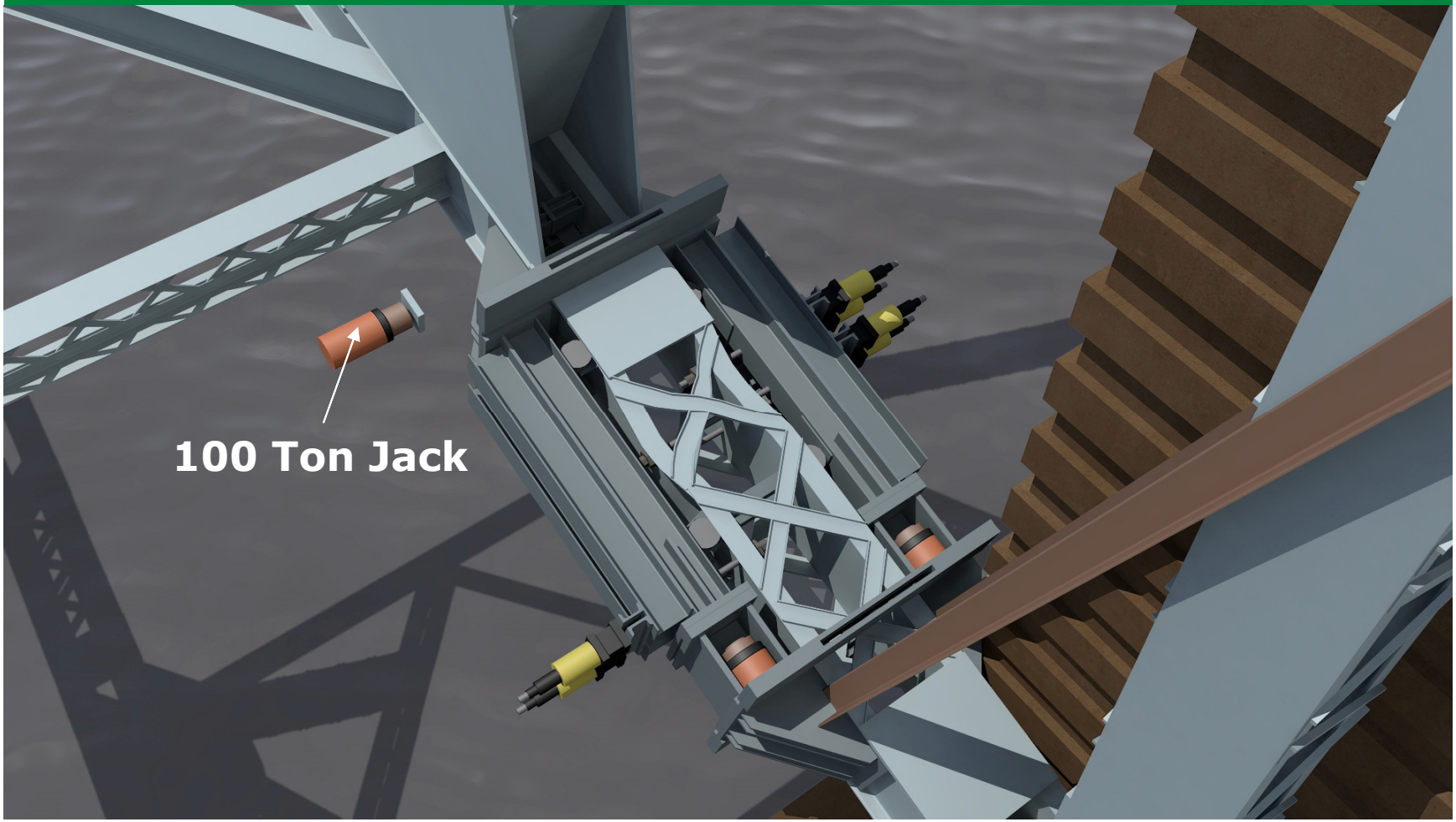


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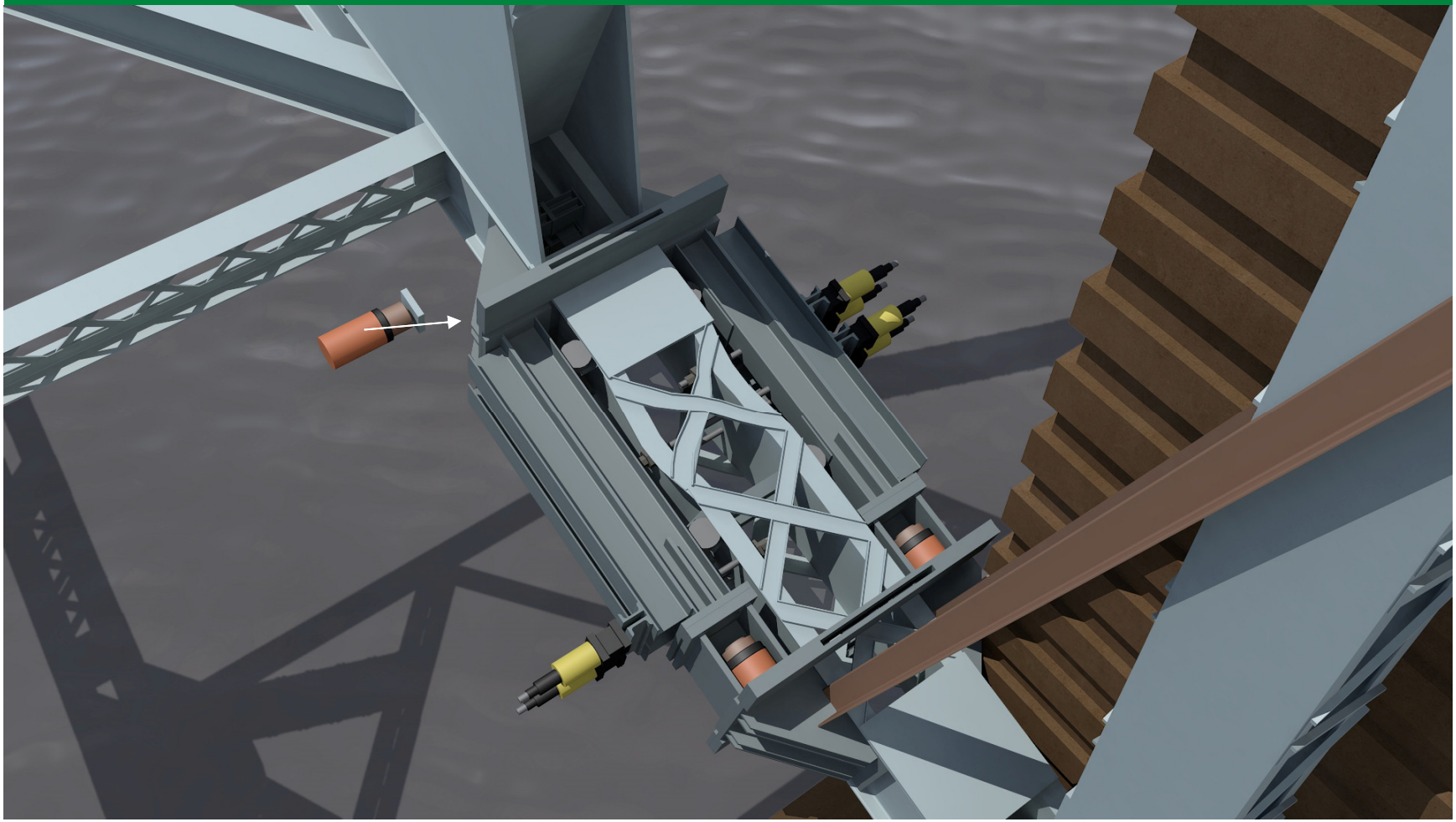

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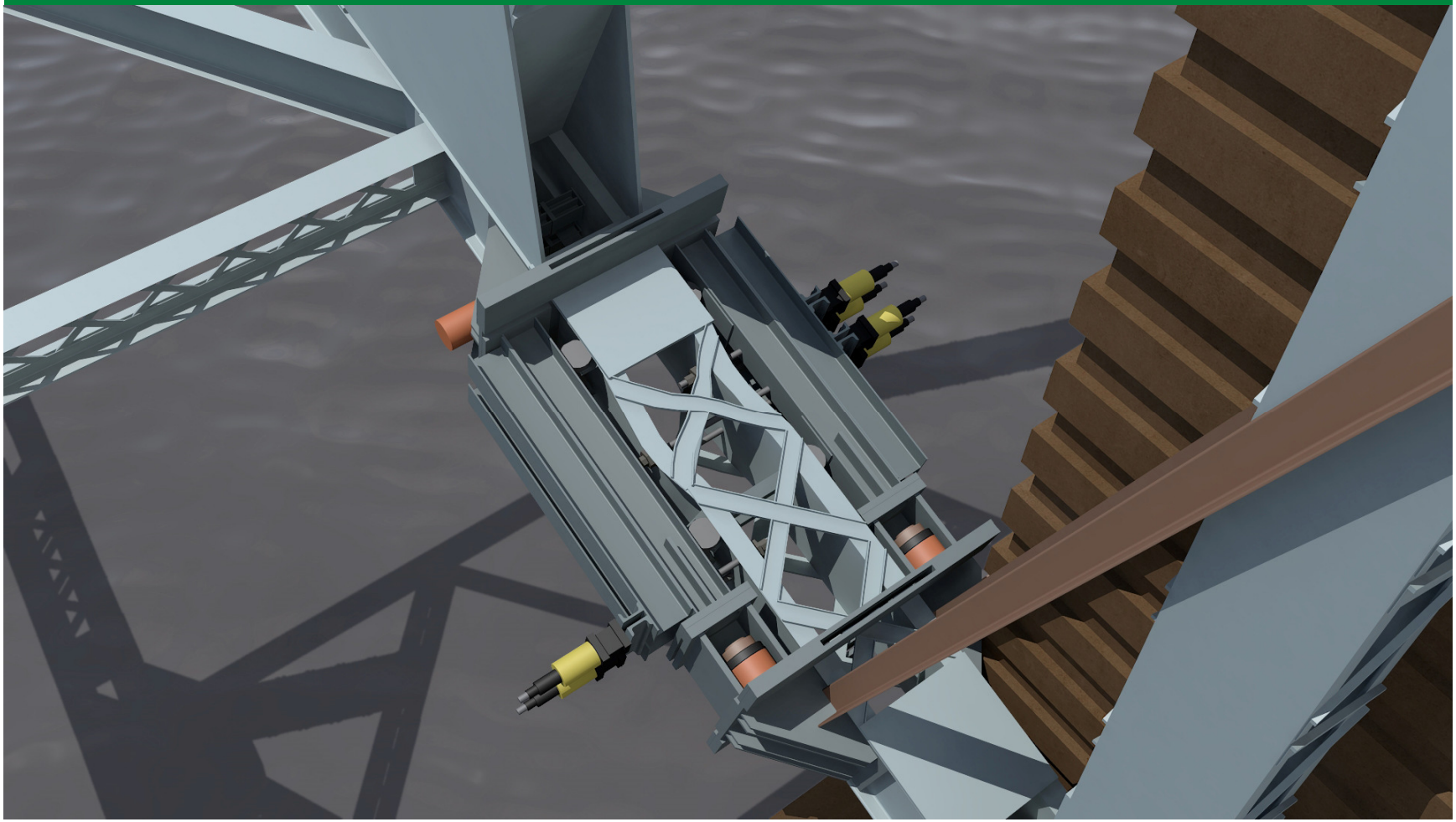

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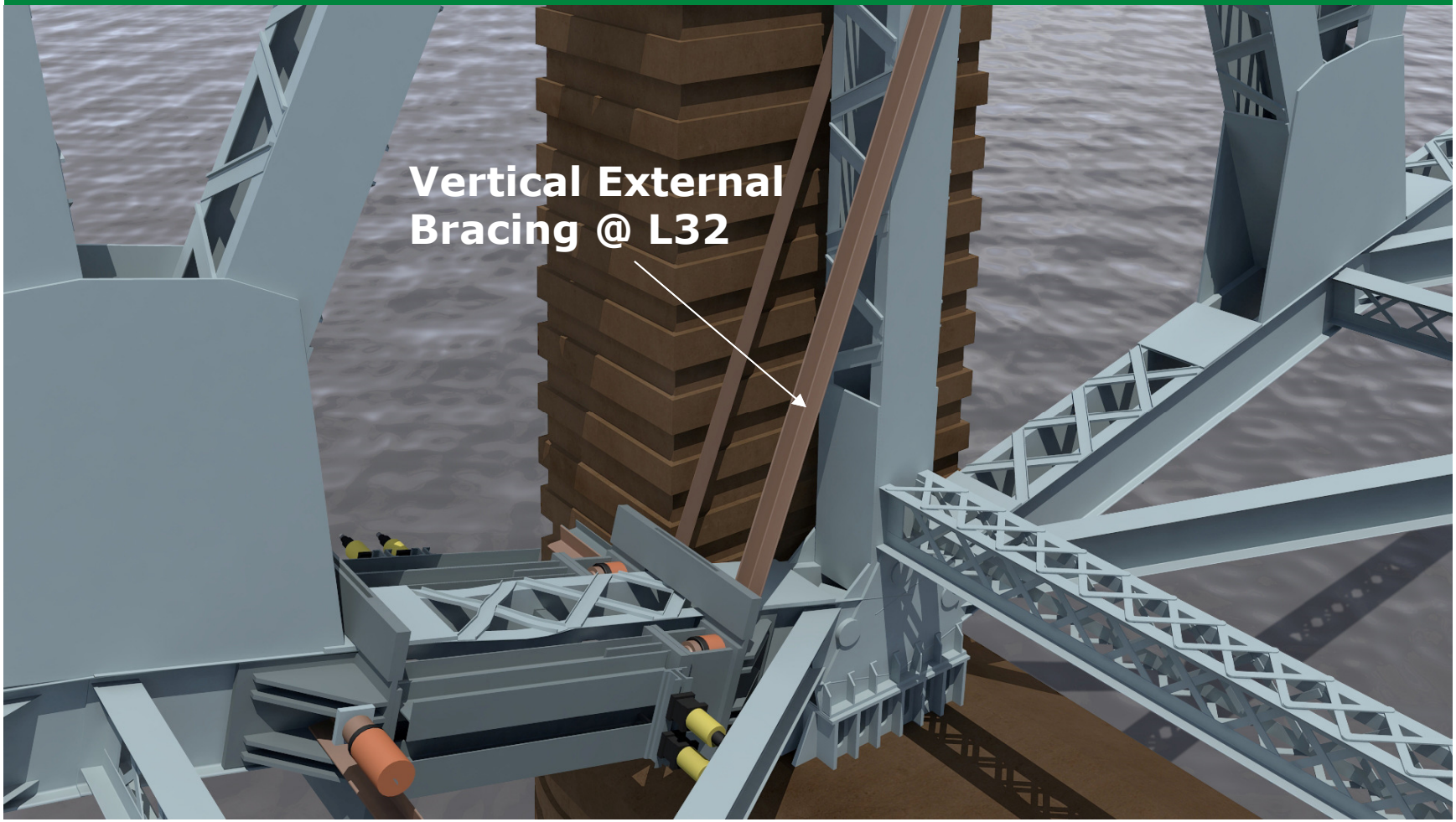


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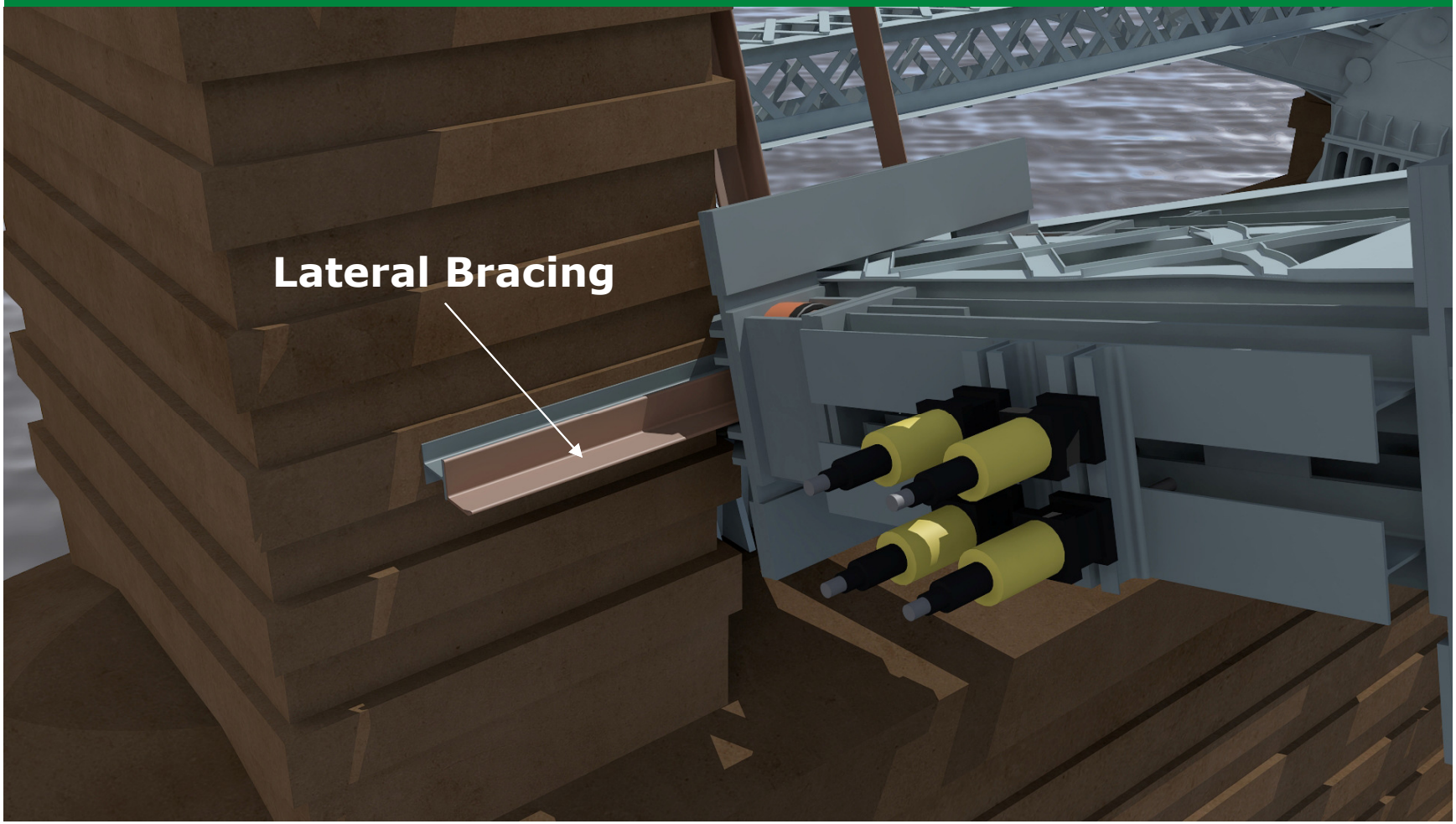


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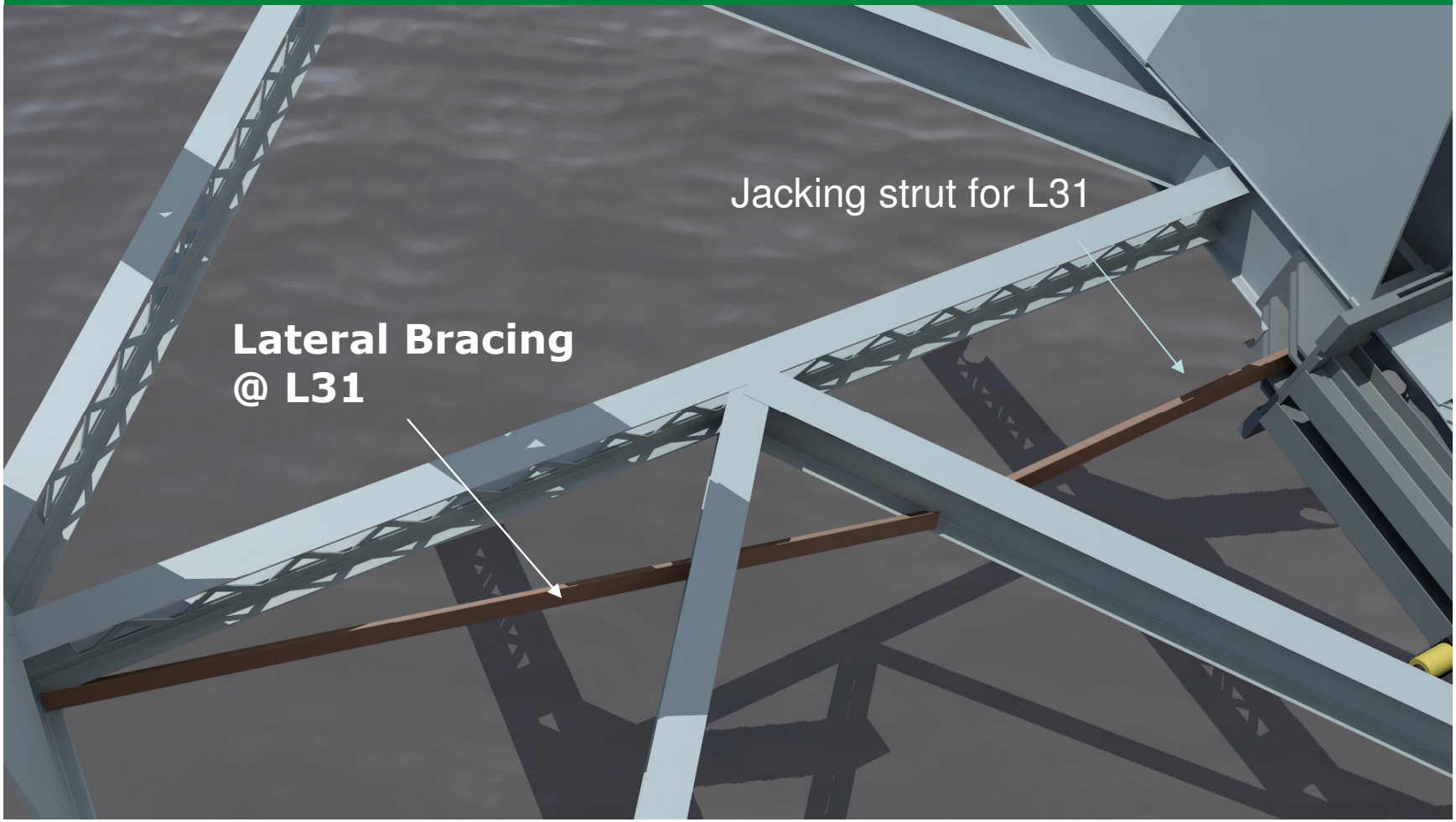


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- Repairs began on Sunday night, September 4th by removing rivets and replacing them with temporary A325 bolts.
- 200 Bolts were replaced, 4 at a time, 1 in each corner of the damaged lower chord.

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Rivet removal

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# A490s Bolt ROCAP Testing

Bolt issues – procurement, cracks, testing

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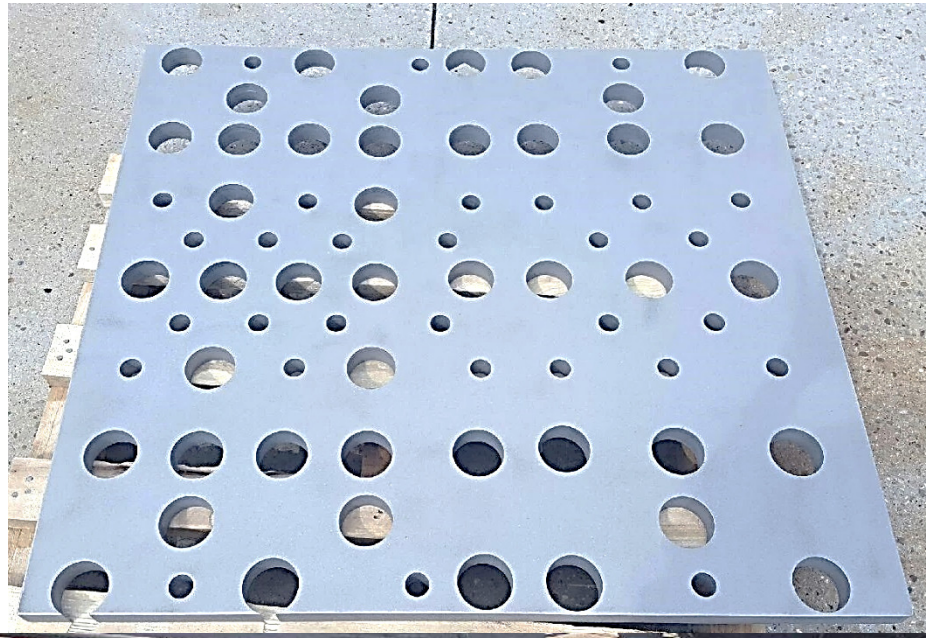
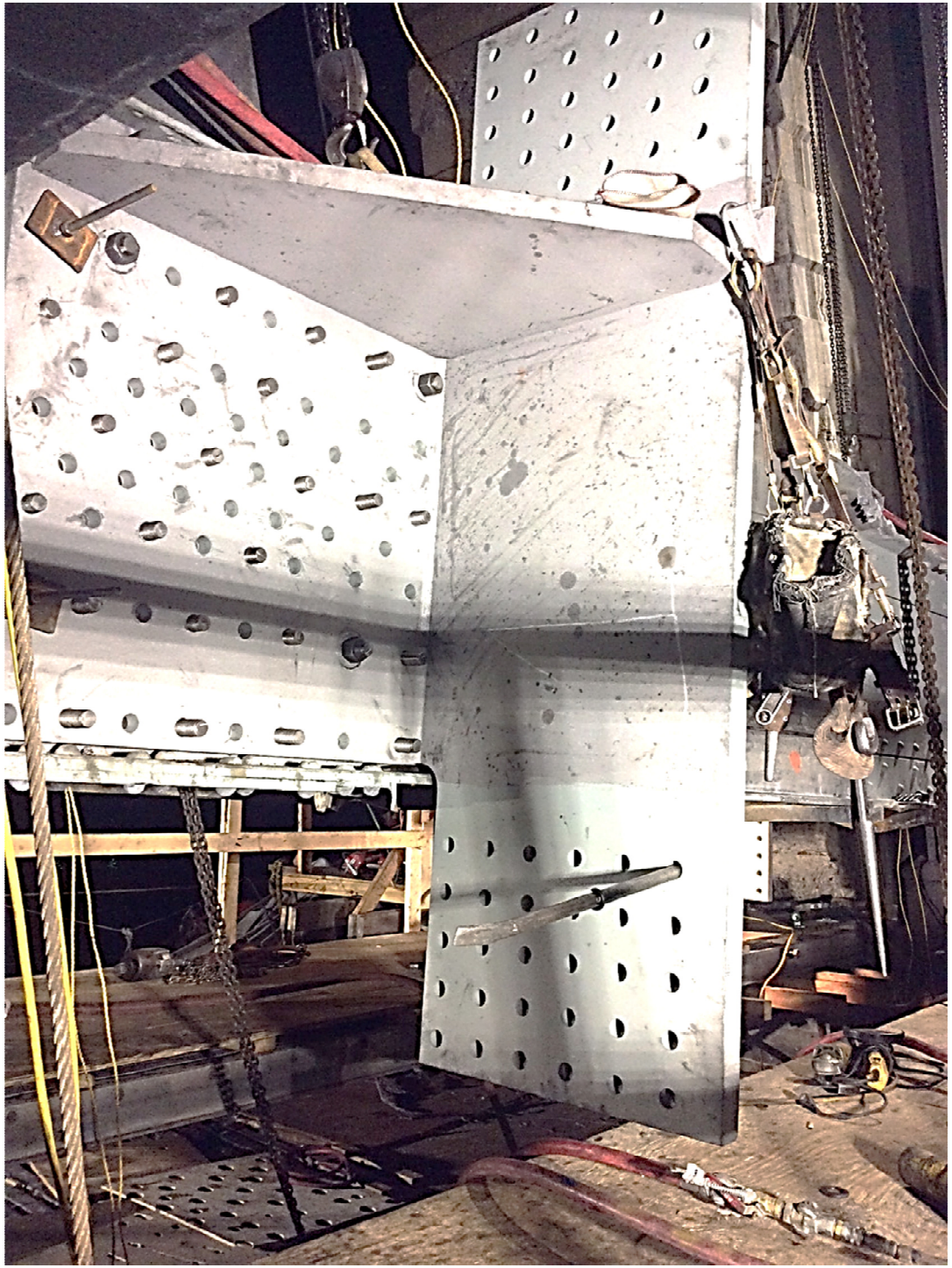
Cheese plate



Jacking
frame pieces



Jacking Brackets from fab. Shop w/ only ¼ stiffeners, permitted bolt tensioning.

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Jacking assembly continue – torque verification of bolts at bottom plate, L31 and L32

# Field Welding of Bracket Stiffeners

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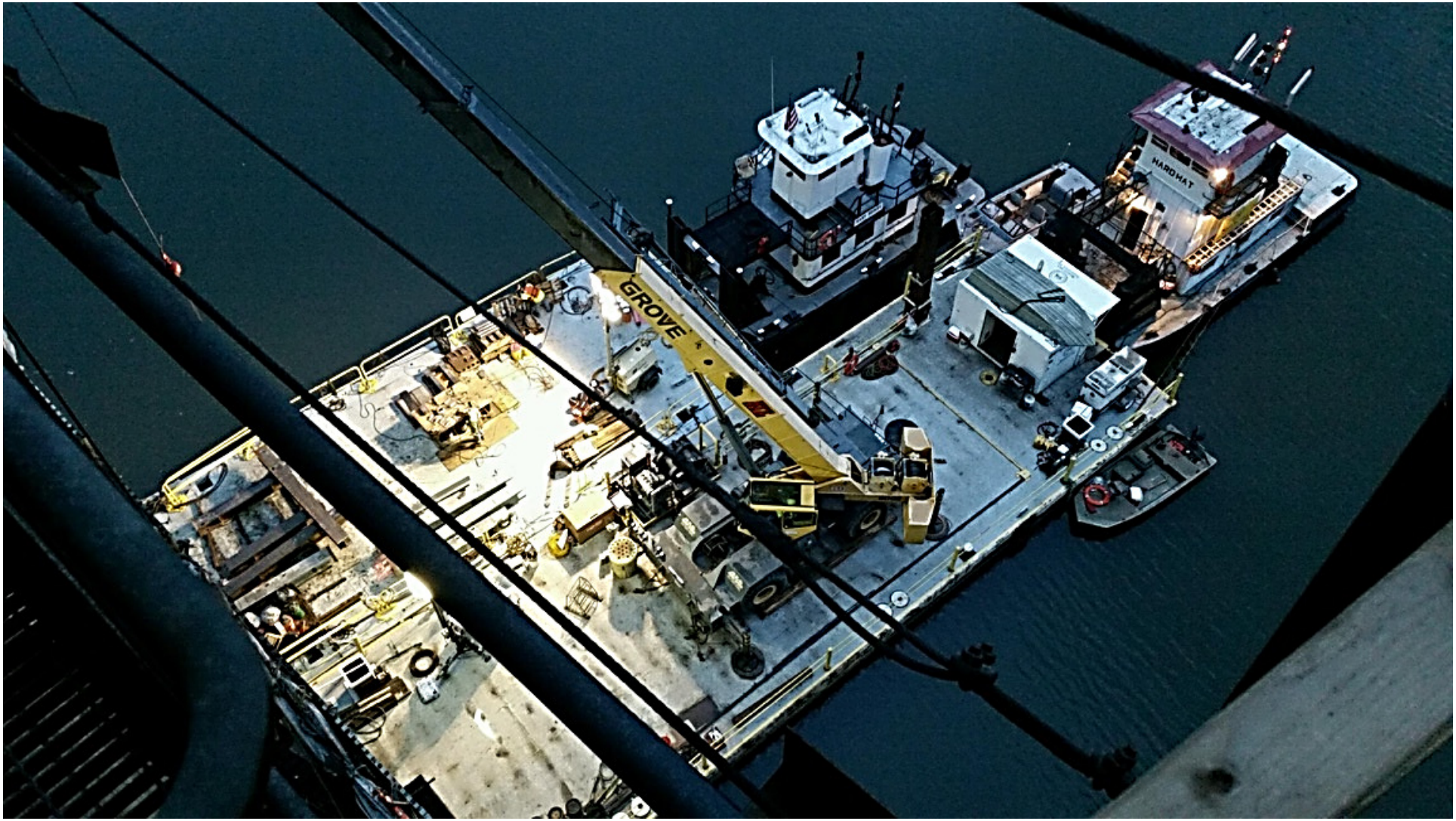


- 3 Barges & tugs:
  - delivery barge, crane barge for material delivery.
  - 3rd barge & crane on shore to receive over the road deliveries

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- Jacking box
- 4 – 565 T Jacks

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# Evolving Design…

- 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

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# Evolving Design… (cont.)

- 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

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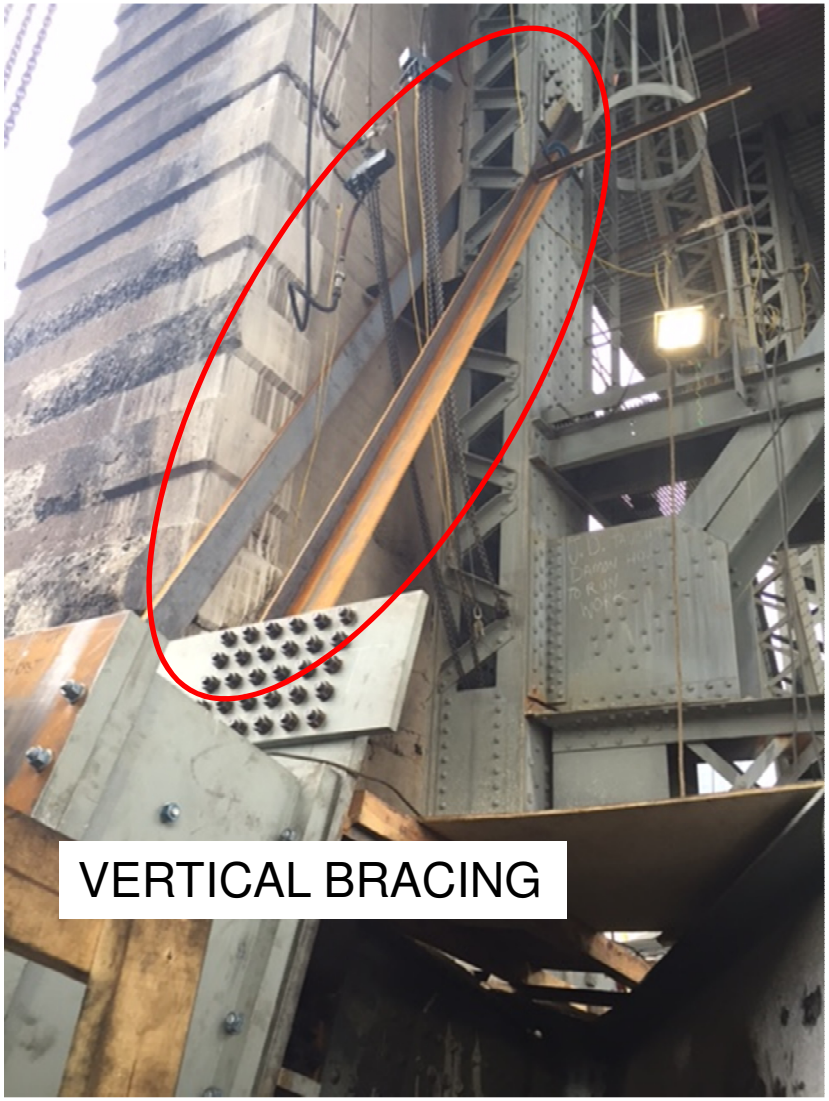
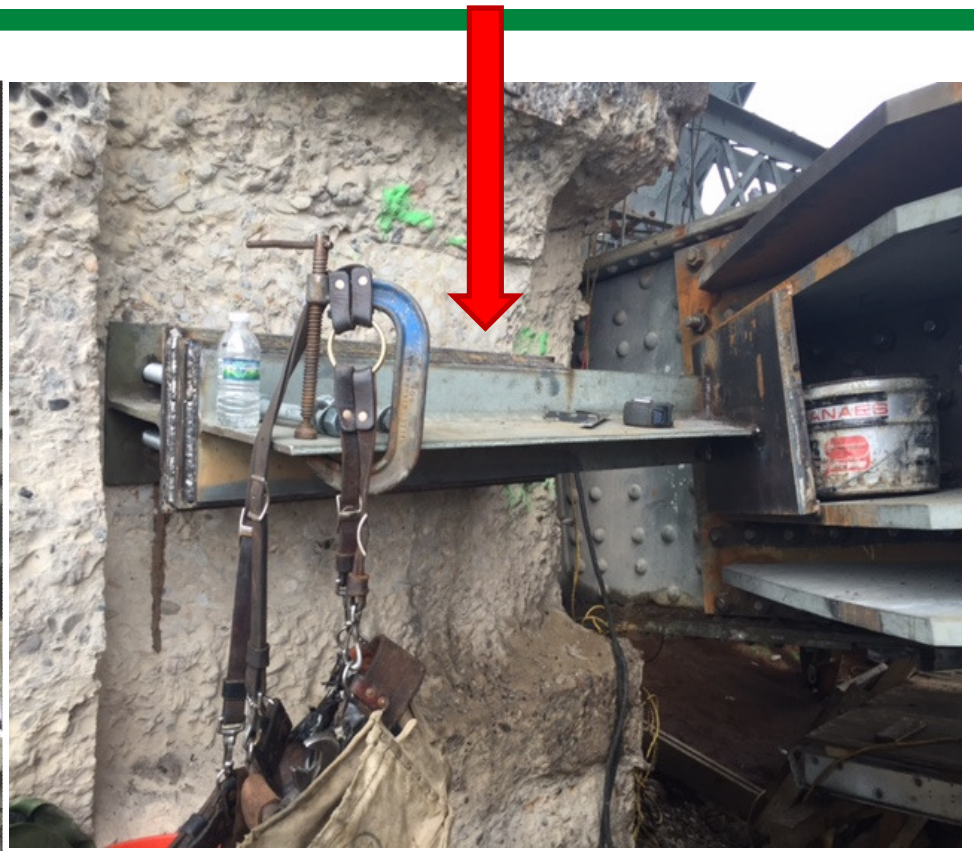
# External Bracing @ L32



VERTICAL BRACING



LATERAL BRACING

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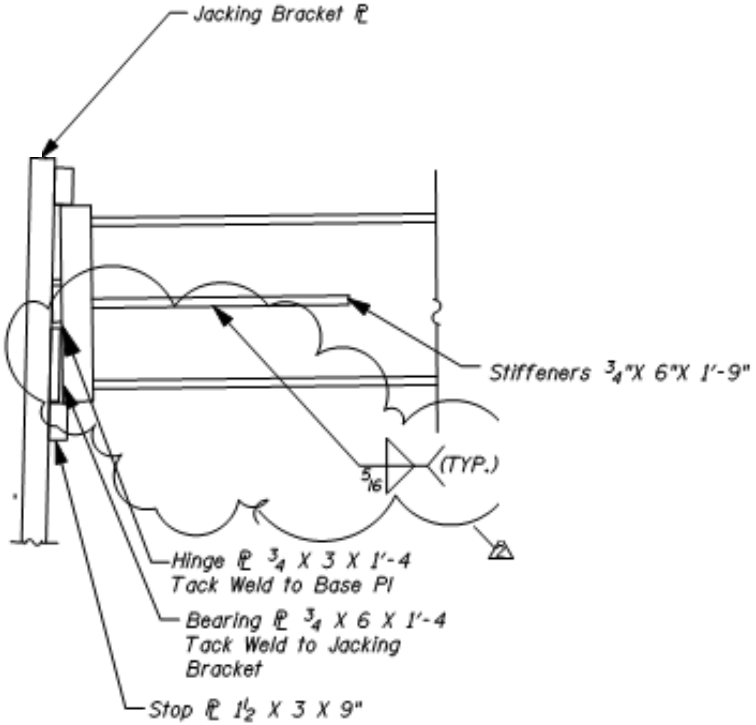
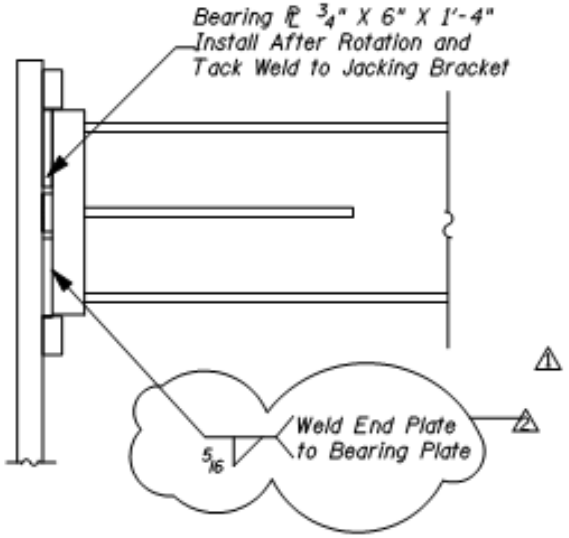
# "Poor Boy's Hinge"

- 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)




(AFTER ROTATION)

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# L31 Lateral Jacking Strut & Brace to East Truss

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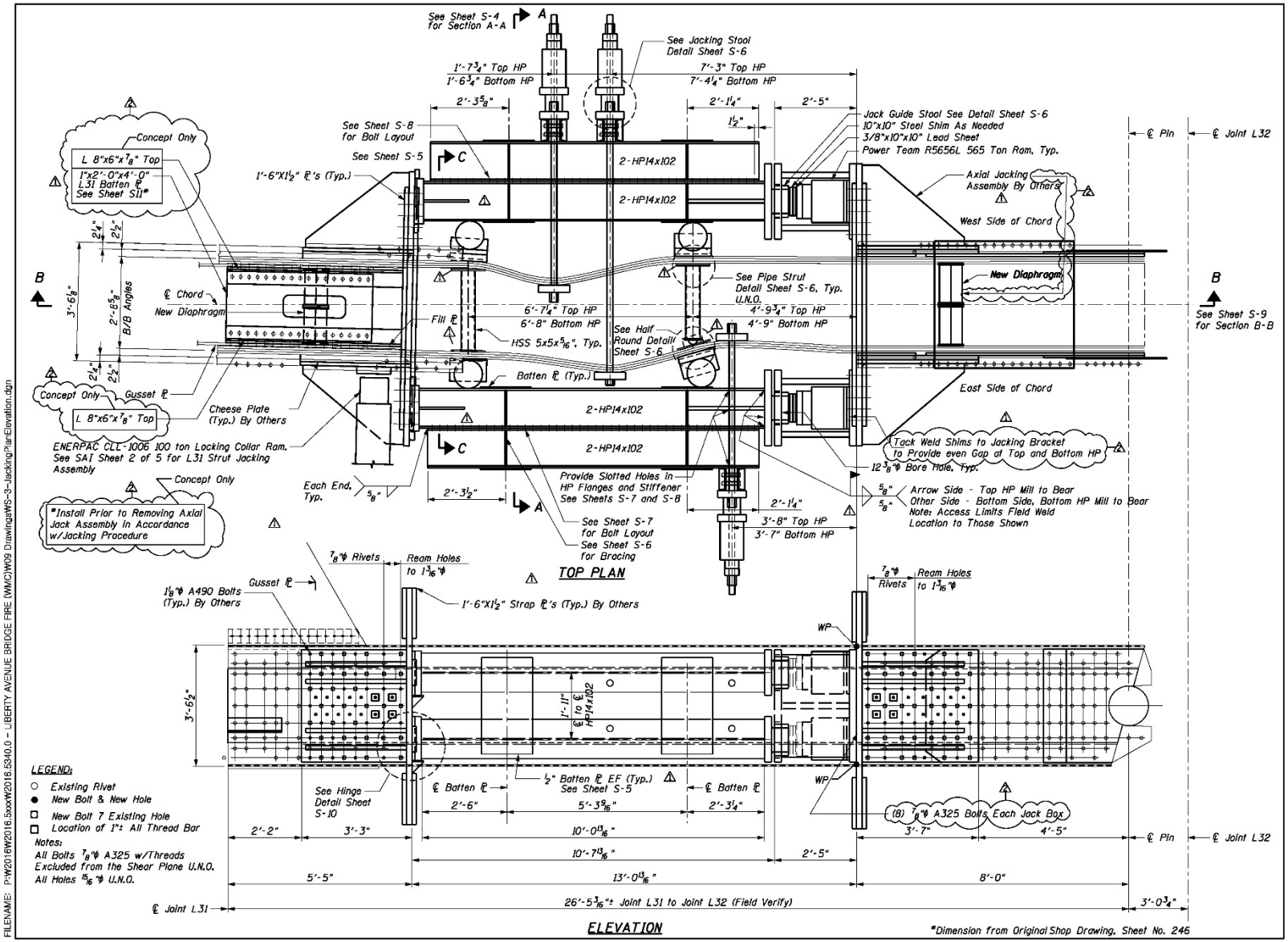


DATE: 9/22/2016
FILENAME: P:\W2016\W2016.5xxx\W2016.5340.0 - LIBERTY AVENUE BRIDGE FIRE (WMC)\W09 Drawings\WS-3-Jacking\PlanElevation.dgn


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Seal

COMMONWEALTH OF PENNSYLVANIA REGISTERED PROFESSIONAL WILLIAM J. NUGENT ENGINEER No. PE061436

9/22/16

Consultants

Project

Liberty Bridge
L31-L32 West Truss
Retrofit

Owner

PennDOT District 11-0

| Mark | Date | Description |
|---|---|---|
| 2 | 9/22/16 | Review Comments |
| 1 | 9/20/16 | Review Comments |

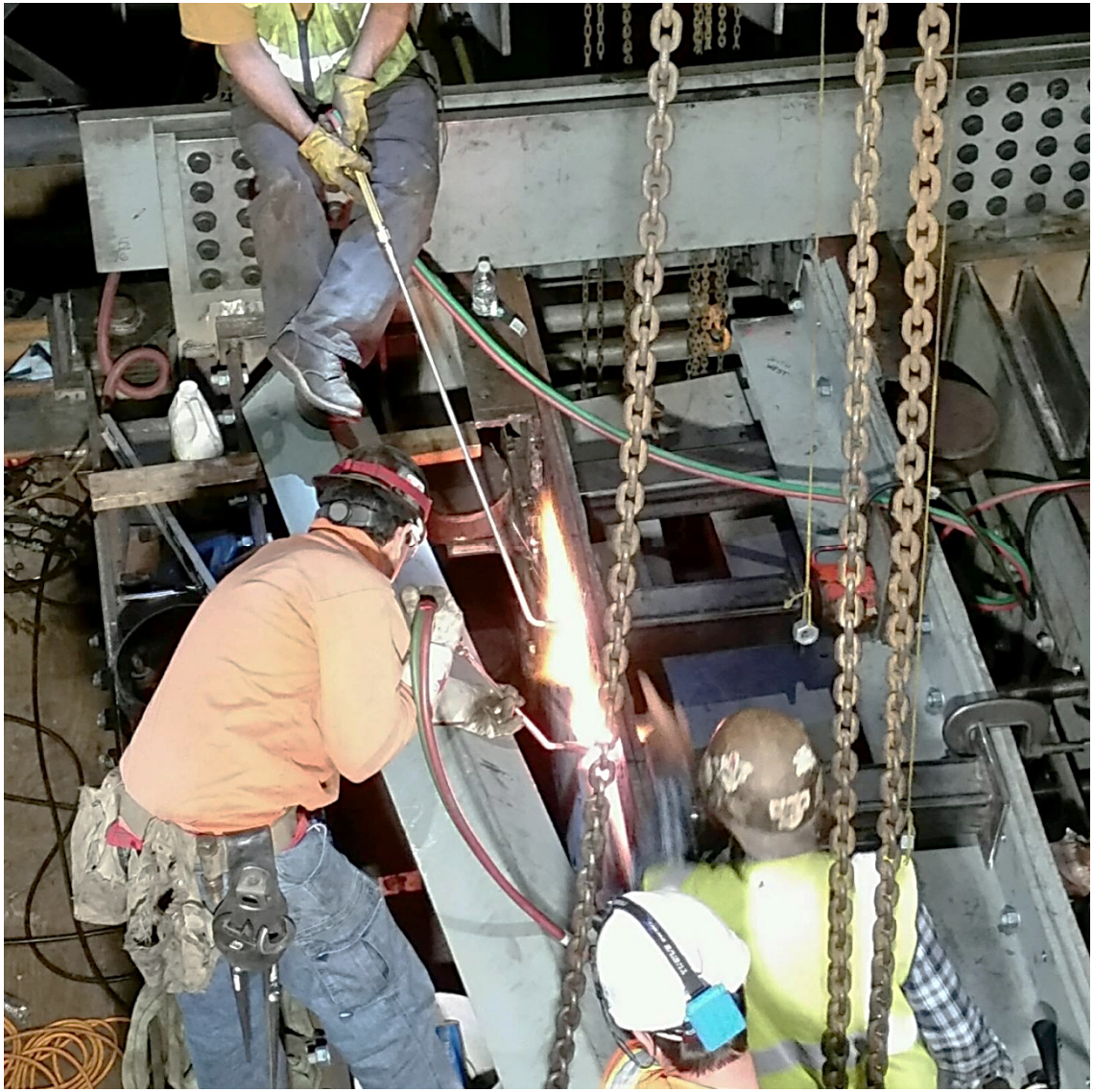
| | |
|---|---|
| Project No. | 2016.5340 |
| Date | 9/22/2016 |
| Drawn | IMG |
| Checked | MWJ |
| Scale | NTS |

JACKING DETAILS

Sheet Title

Sheet No. S-3

# Heat Straightening



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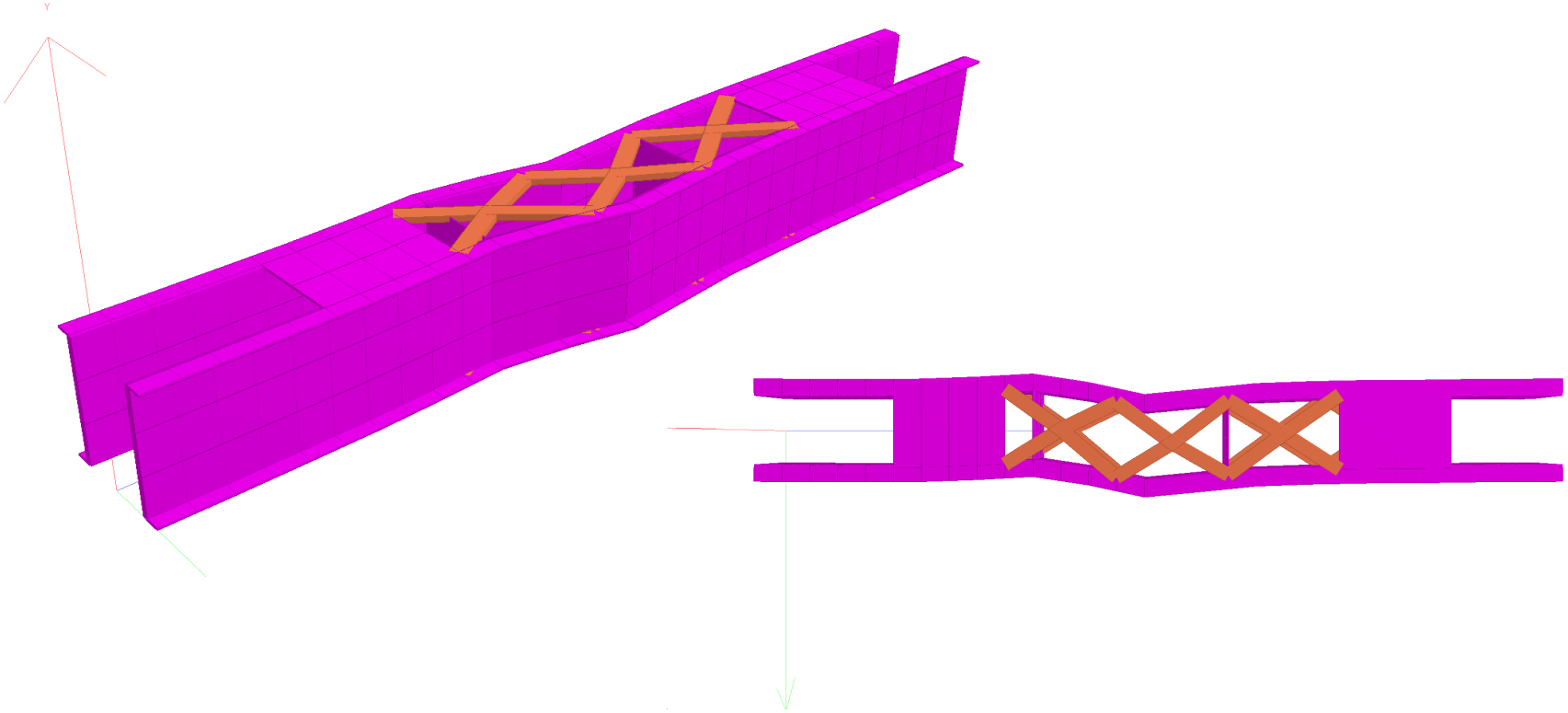
# Bottom Chord Model

Apply 1000 kips without removing stiffeners
Average longitudinal displacement of 0.05”



- Out-of-Plane Deformations

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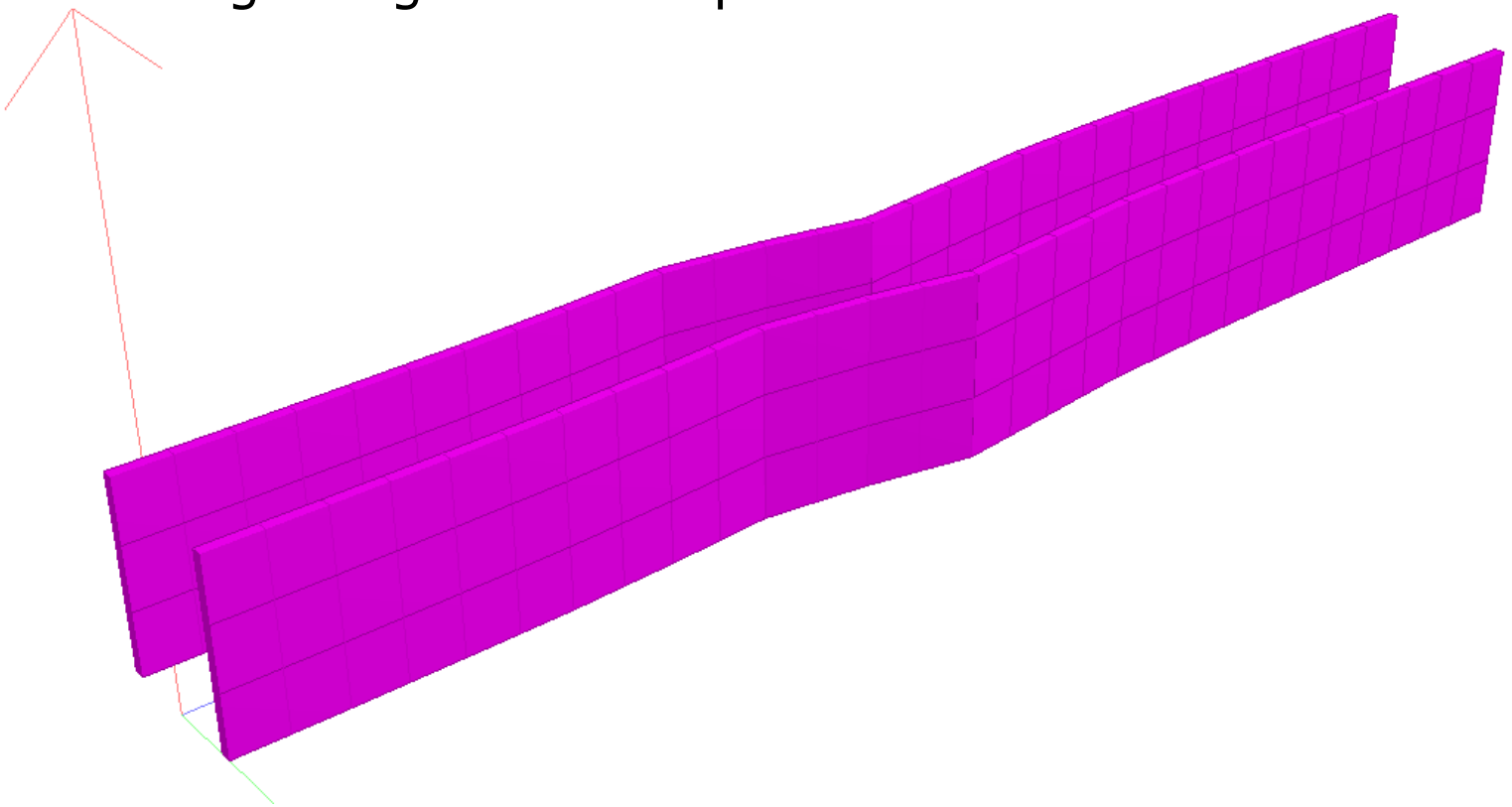
# Bottom Chord Model

- 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)

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# 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

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# 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)

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# Lehigh University Strain Gages


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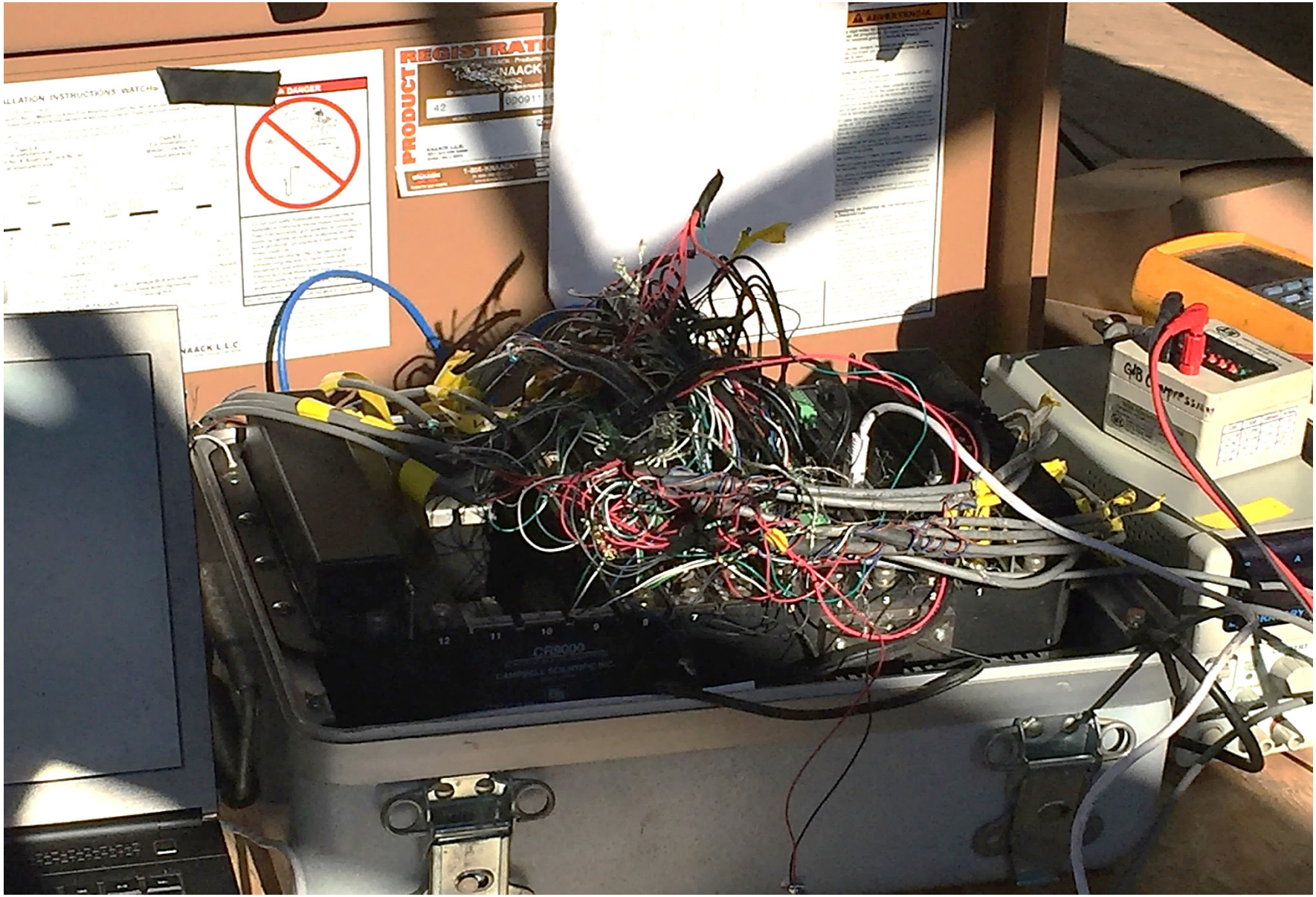
# Lehigh University Strain Gages




# Lehigh’s wires for monitoring strain gauges

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# M&M 3D Model for load re-distribution


- L31L32 length measurements
- Strain gage data dump
  - stiffness refinements
- Continually refining 3D models as jacking progresses

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# Steel Temperature check, Friday 9/23/16

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- Command Center
- Incident Mgmt. Plan

# Command Center

Saturday, September 24th

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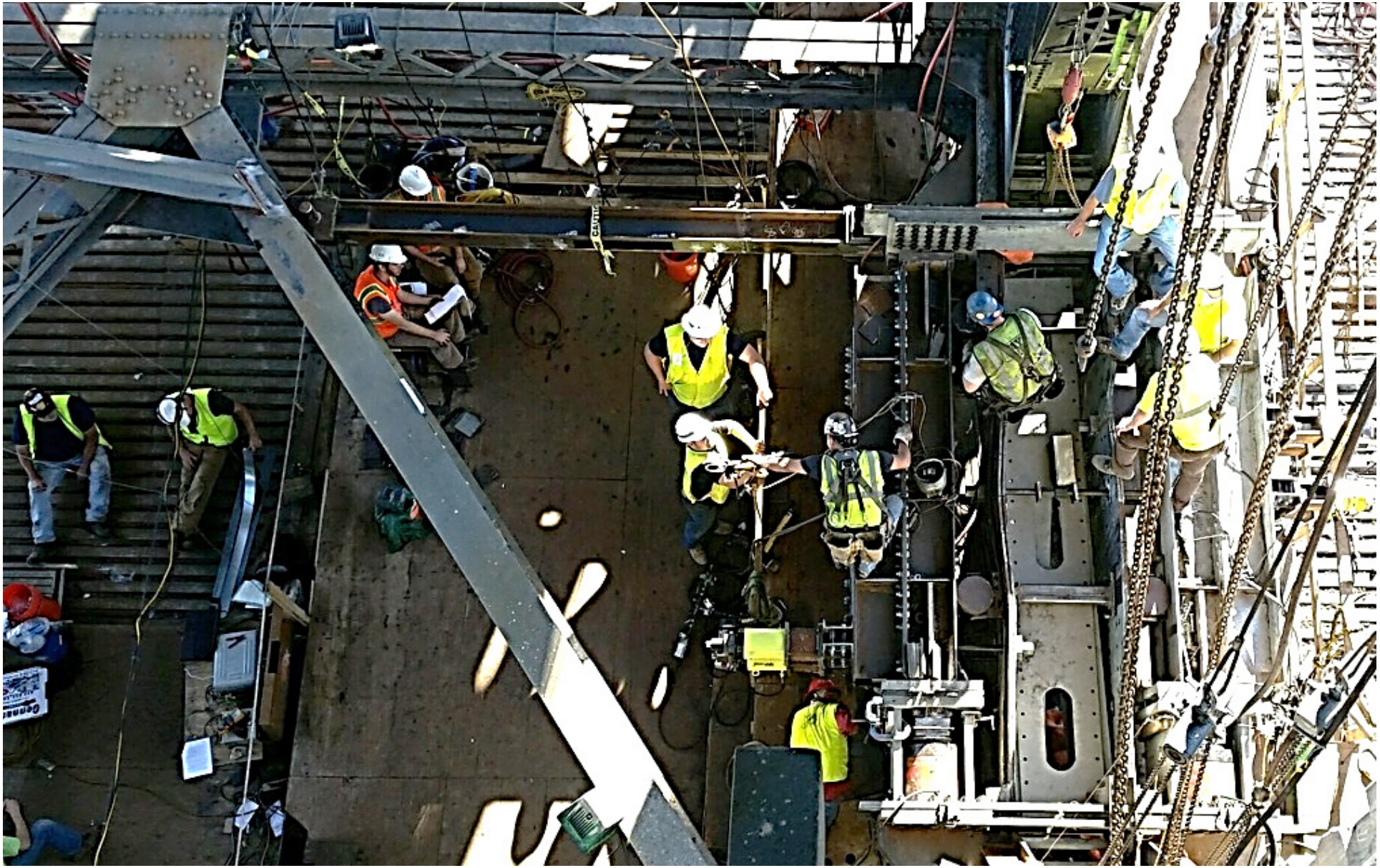

Saturday, September 24th

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Damaged Diaphragms

Saturday,
September 24th at

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# Lacing removed

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Accelerated delivery system

# Saturday Lunch!

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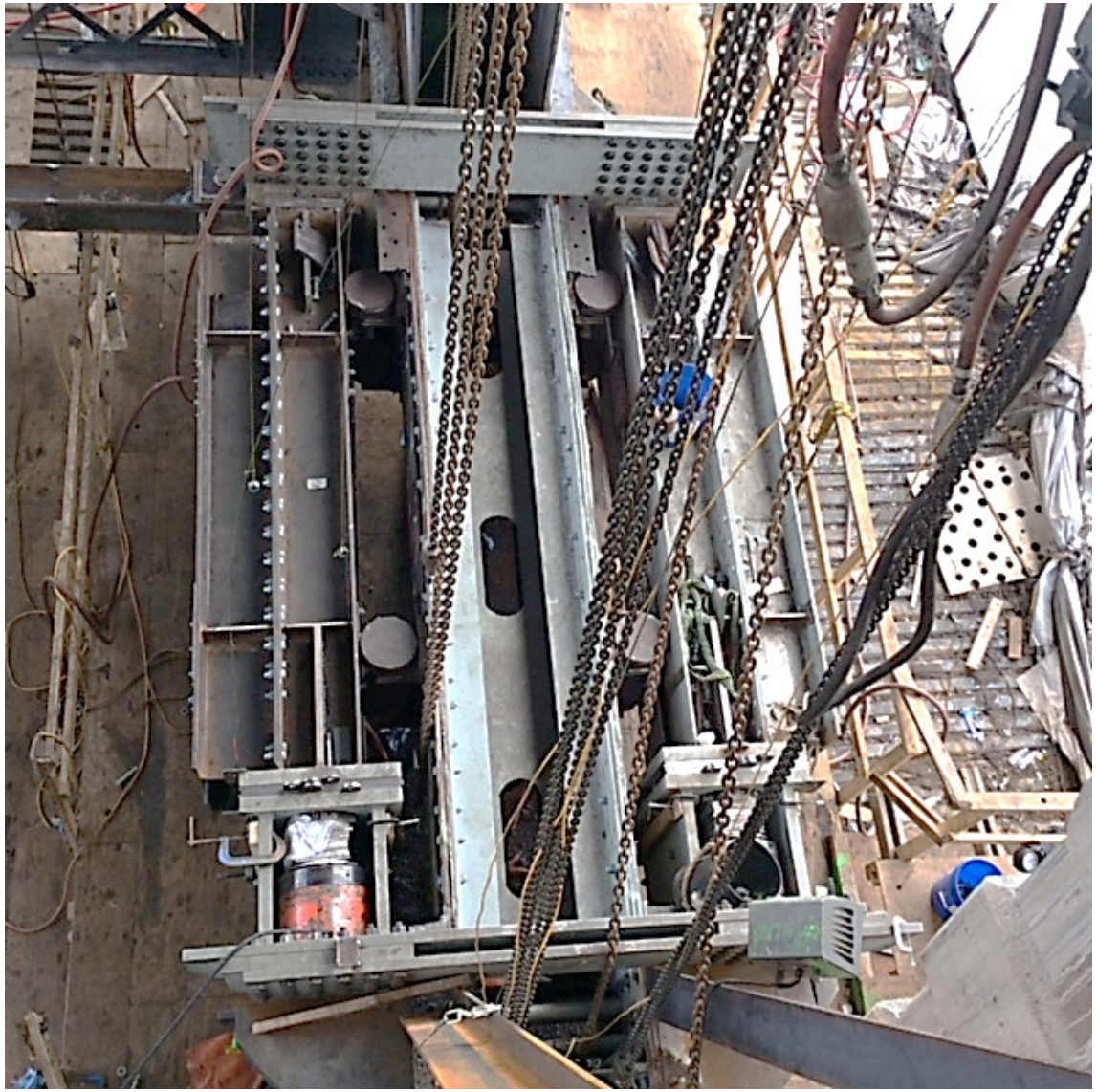
Cross bracing starting to straighten

# Temporary Repair



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# Temporary Repair

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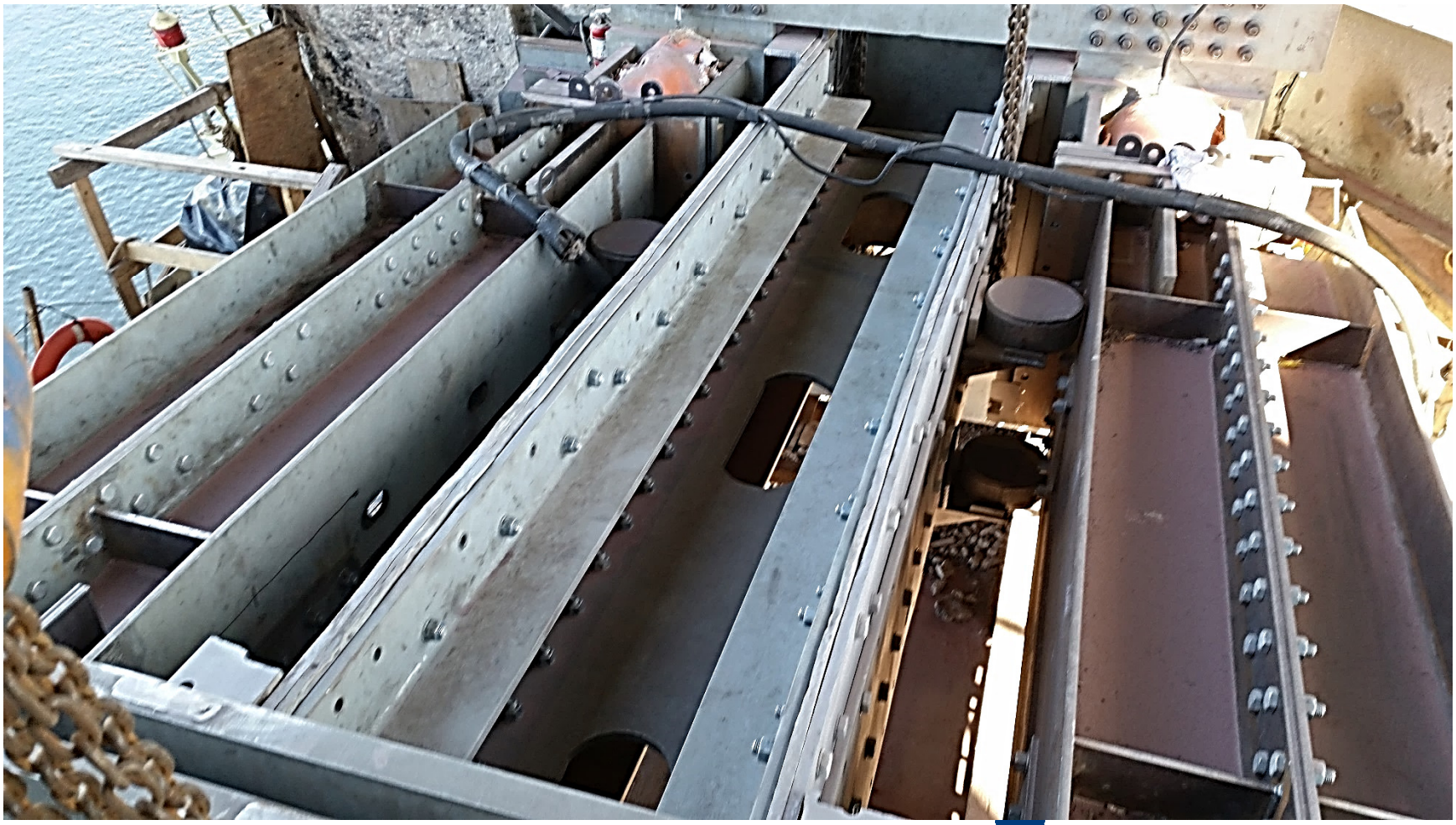
# Temporary Repair



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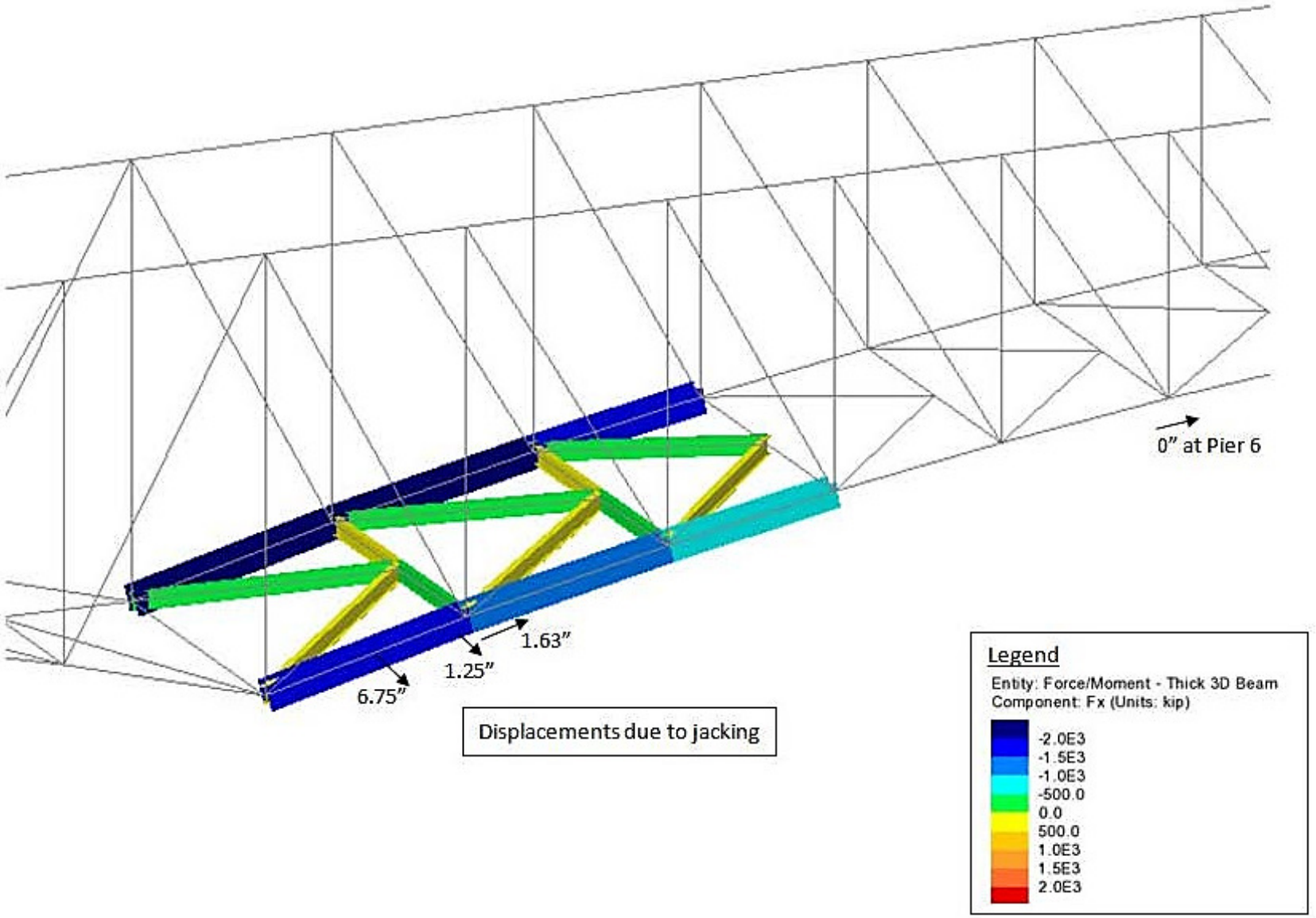
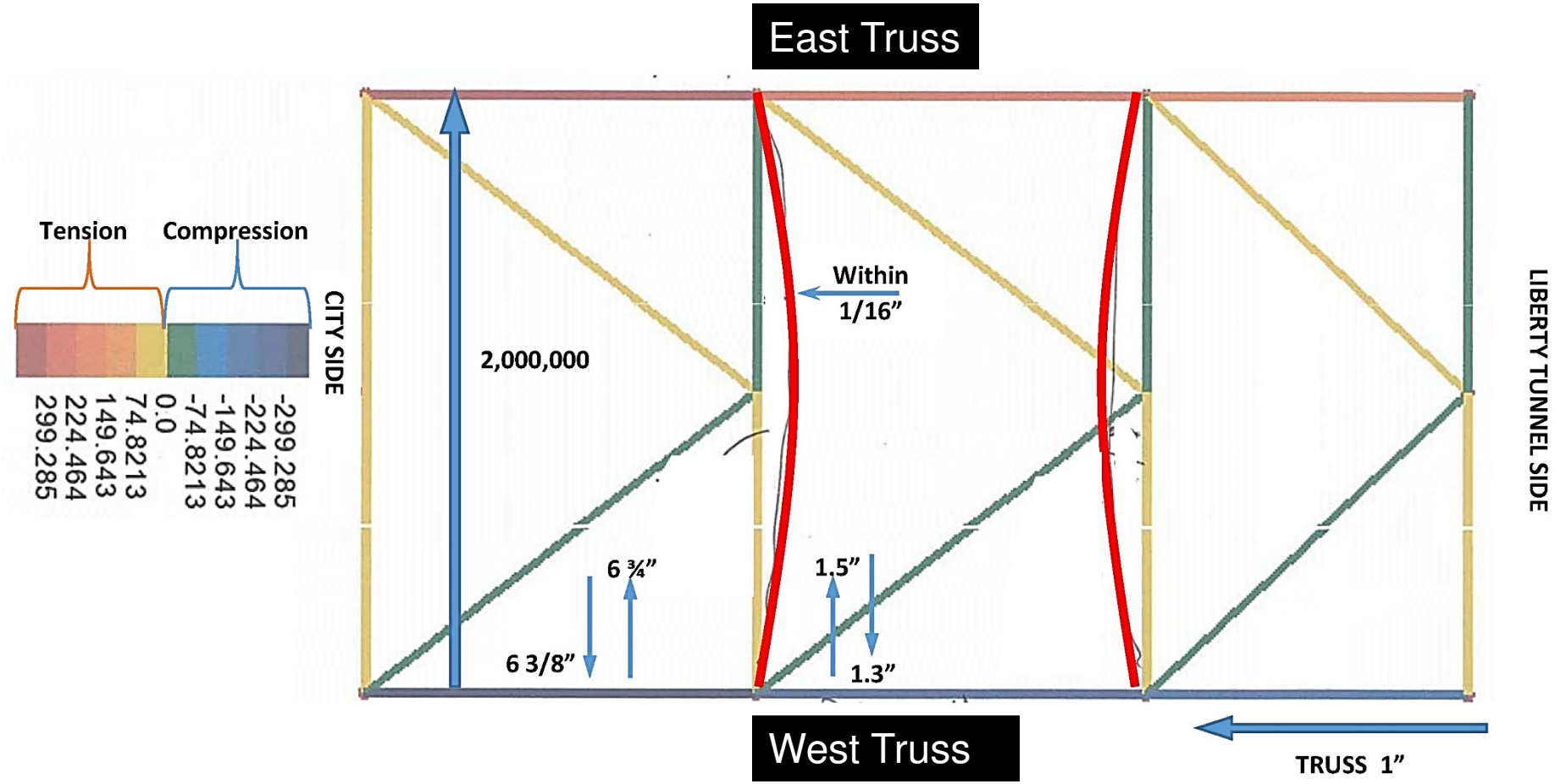
# Temporary Repair

# Post Jacking – Restored Displacement of 1.63”



# M&M 2D Drawing

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# Bridge opened to traffic with 9 ton restriction


At 3:30pm, September 26th

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# Weigh Station on Bridge

# Tuesday Morning – 9/27/16

- 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

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# 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

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# 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 conducted.

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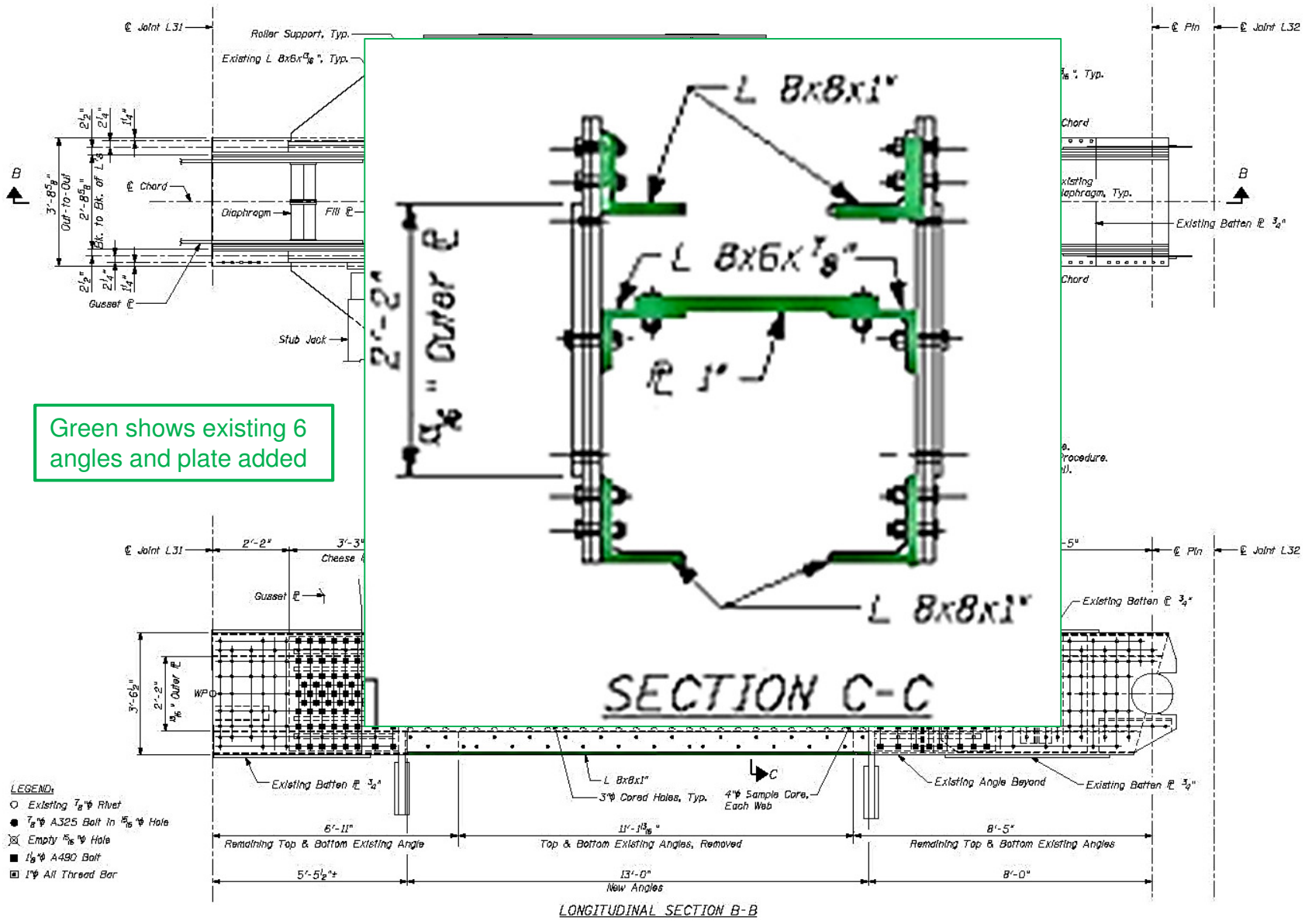
# Stage I: Final Repair L31L32

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WILLIAM J. NUGENT
PROFESSIONAL ENGINEER
COMMONWEALTH OF PENNSYLVANIA

10/17/16

Liberty Bridge
L31-L32 West Truss
Retrofit

PennDOT District 11-0

| Mark | Date | Description |
|---|---|---|

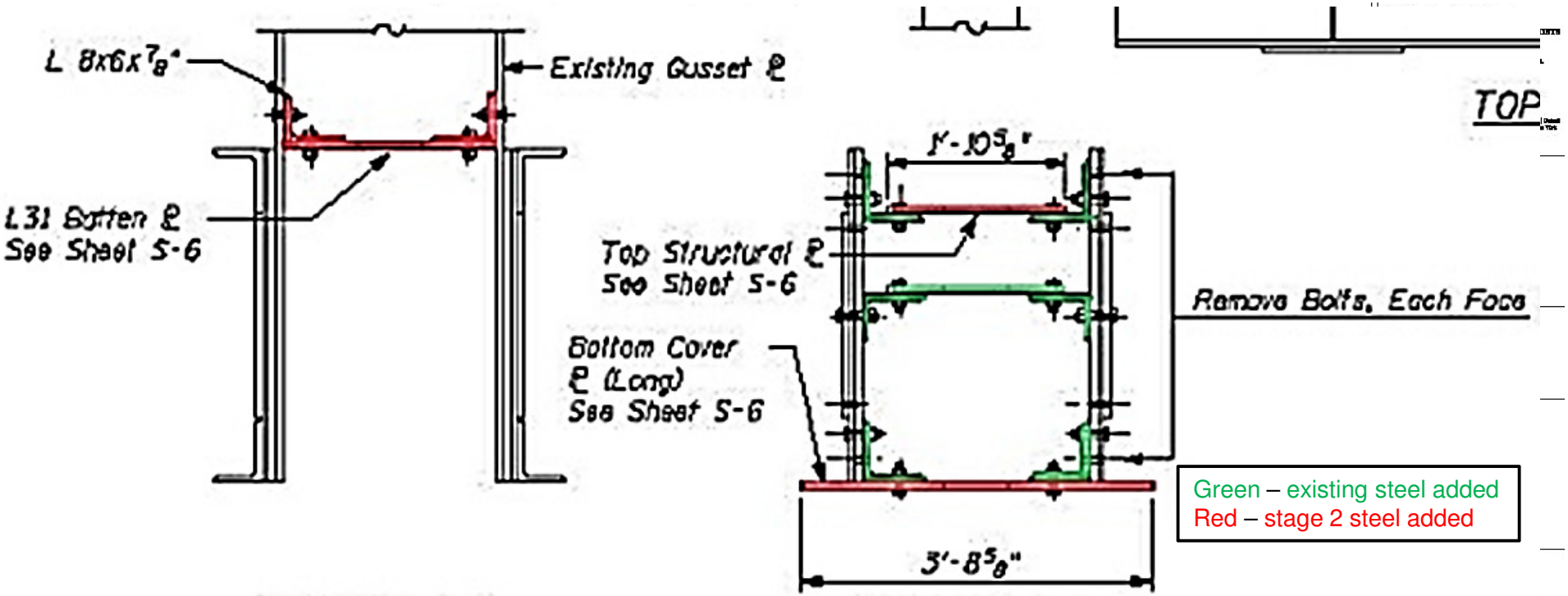
Project No. 2016.6342
Date 10/17/2016
Drawn BKB
Checked JCM
Scale NTS

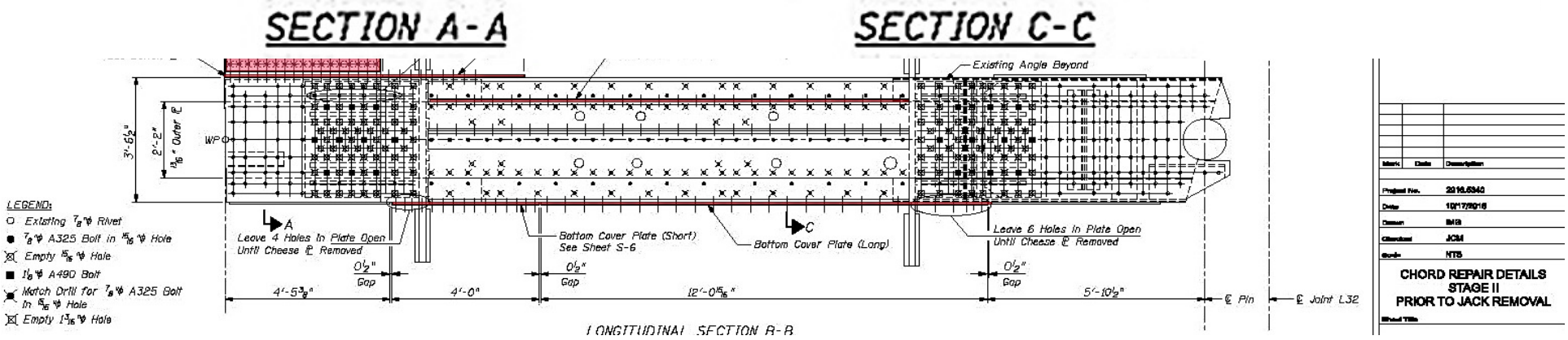
CHORD REPAIR CONDITION AFTER JACKING STAGE I

S-2

# Post Jacking Work - Final Repair L31L32 – Stage II

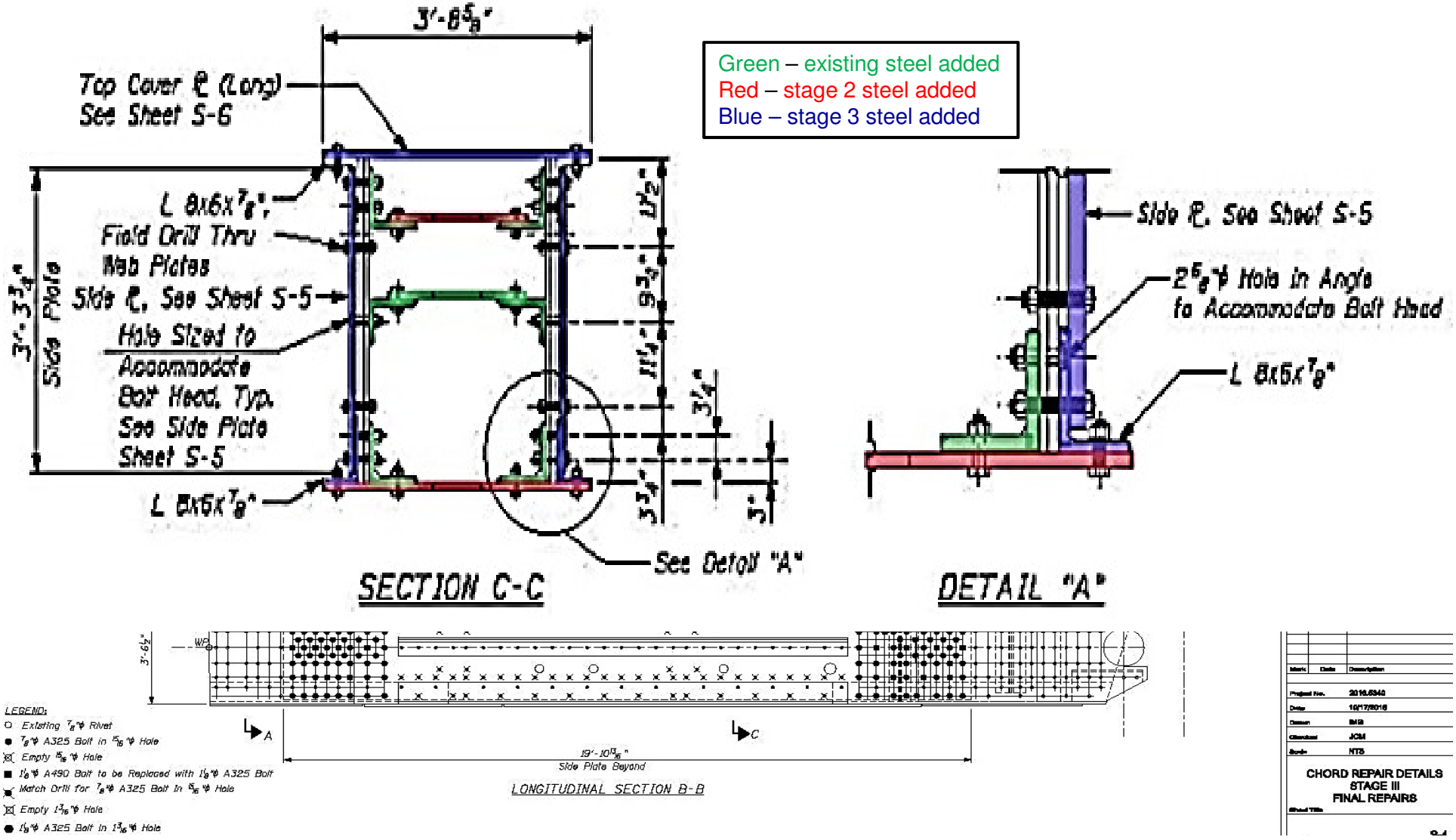
- Angles on gusset, L31 Batten, Top Structural, Bottom Cover Short & Long, Top cover Short



# Post Jacking Work - Final Repair L31L32 –Stage III

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



# Final Repair L31L32

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# Key Contributors




























# 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
- Jason Zang, P.E.

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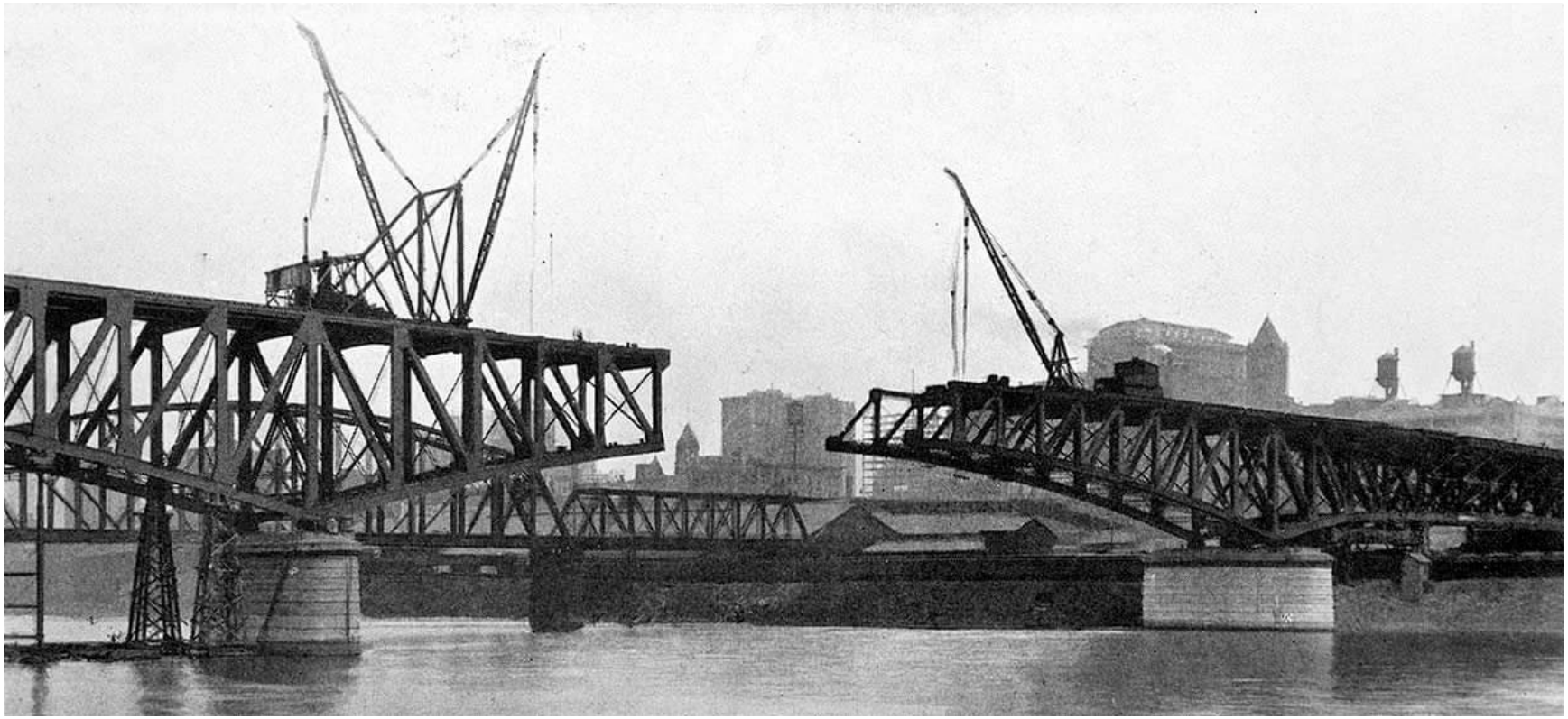
# Any Questions



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