Emergency Repair of the Hernando de Soto Bridge

TSITE Spring Meeting
May 18, 2022

Today’s Speakers

Ted Kniazewycz, PE, F. ASCE

Director | Structures Division

Michael Welch, PE

Director | Region 4 Operations

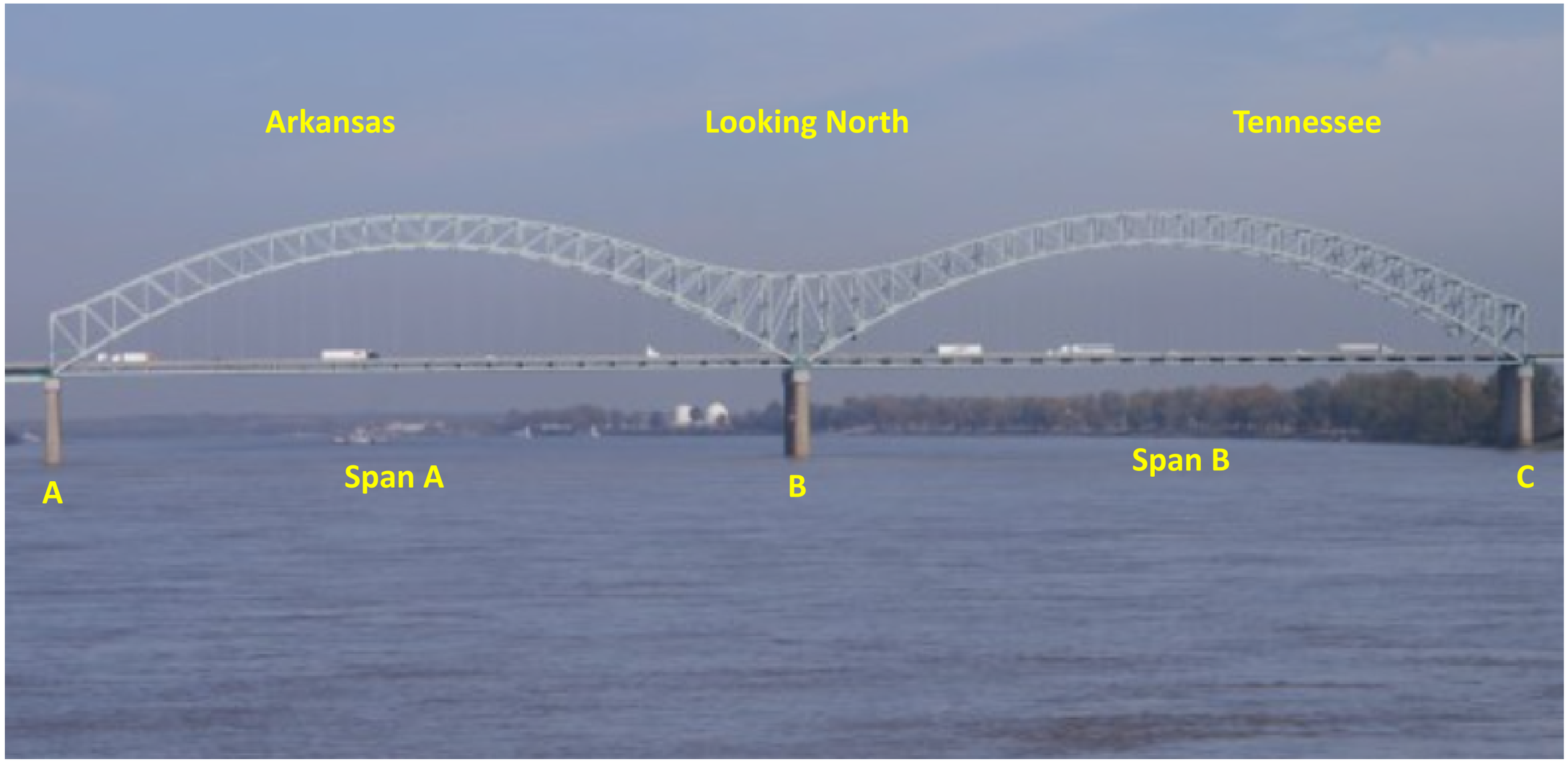
TDOT Department of Transportation

TN

TDOT

Department of Transportation

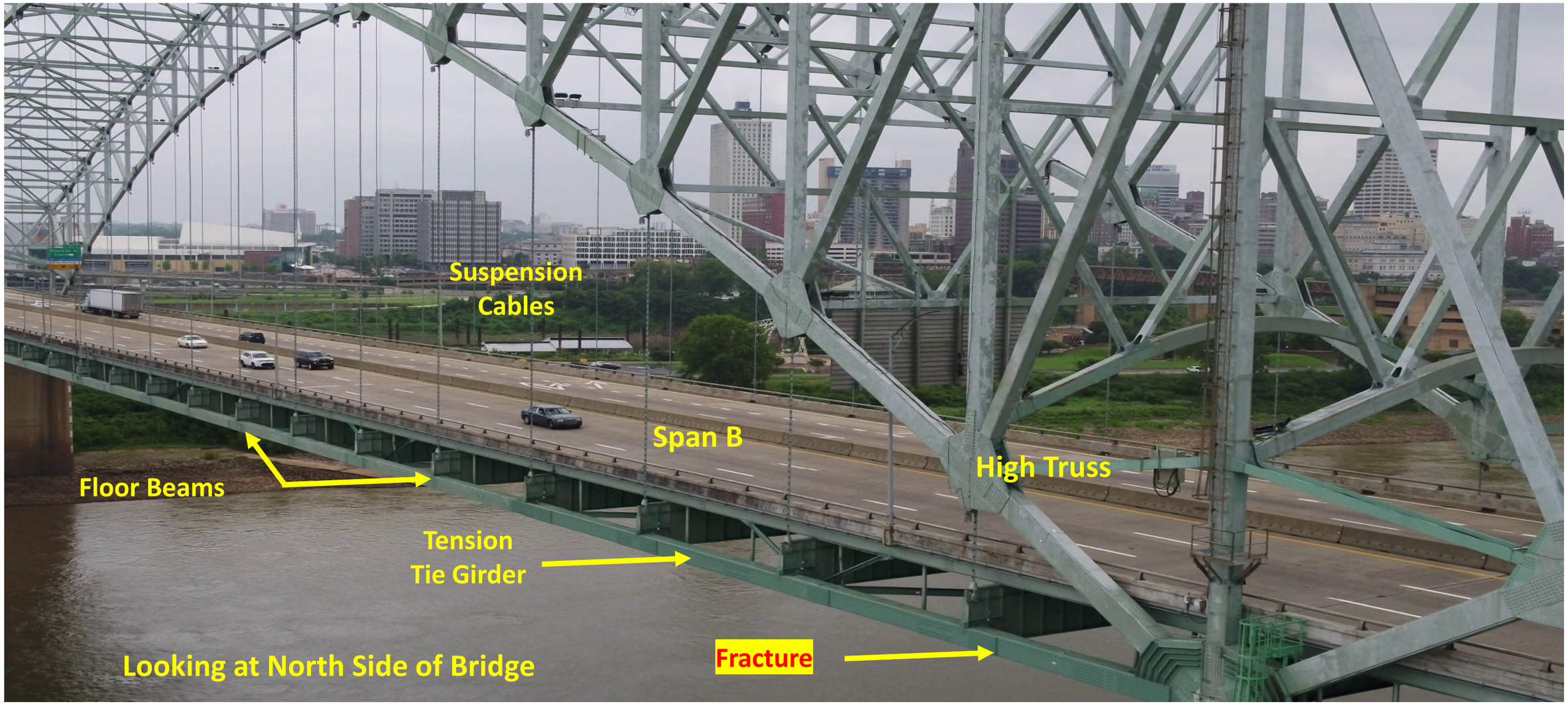
Interstate 40 Hernando de Soto Bridge



Bridge History

- Hernando de Soto
- Constructed 1967-1973
  - Opened August 2, 1973
- Two Span Continuous Tied Arch Bridge
  - 2 – 900ft spans
  - 109ft above the water
  - Designed by Hazlett and Erdall

Interstate 40 Hernando de Soto Bridge



Agenda - *Swift and Critical Decisions*

- Immediate Closure

- Three-Phase Approach
  - Assess / Stabilize the Structure
  - Repair of the Fracture
  - Inspect and Assess the rest of the Tie Girder

- Fracture Analysis

- Lessons Learned

Immediate Response

Early Actions in the days immediately following the critical find

Timeline of Events

Day 0

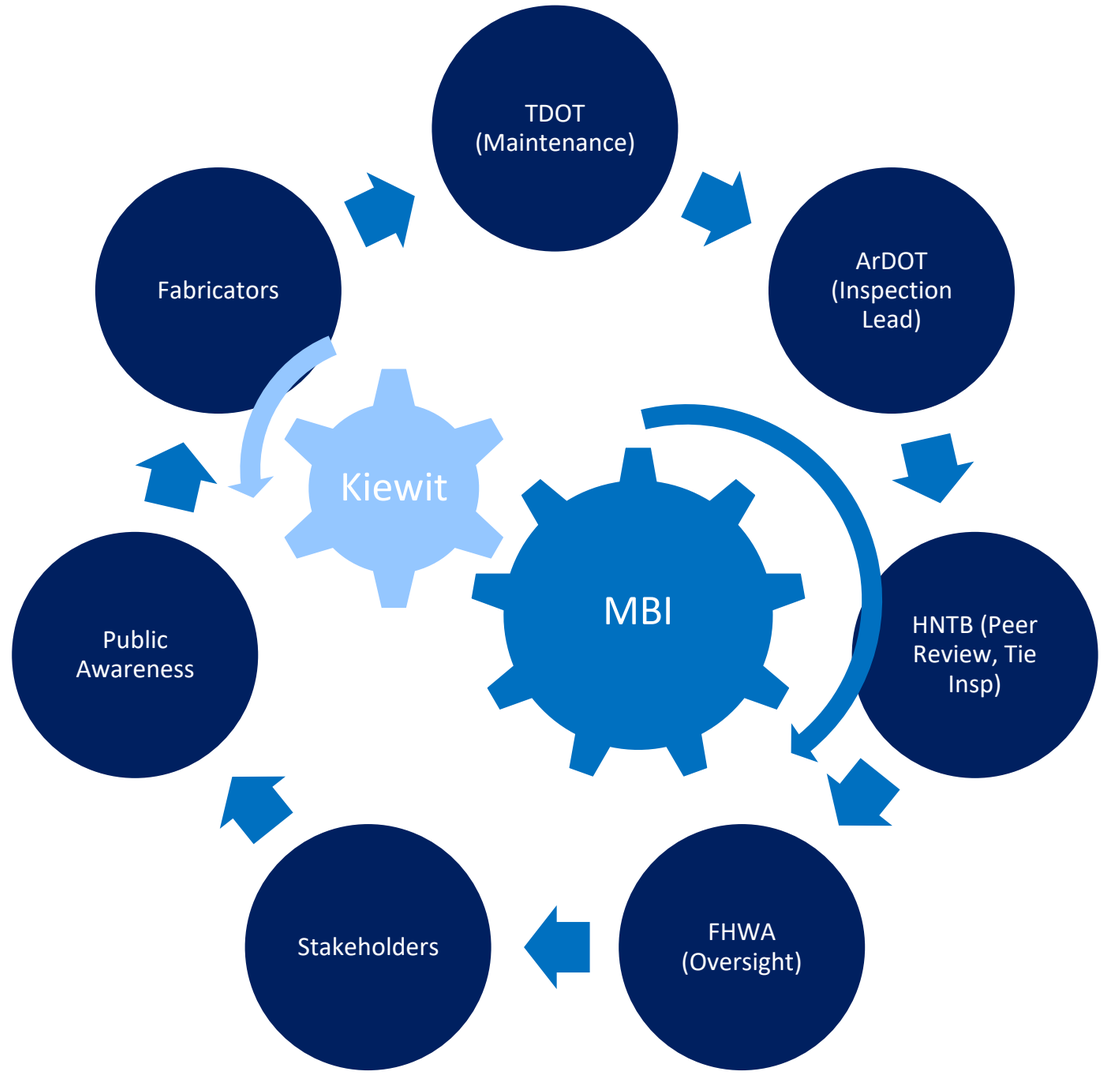
- TDOT has responsibilities for repair project development
  - Selected Michael Baker International on Tuesday - May 11th
    - Qualification
    - Related Project Experience (Sherman Minton Bridge on I-64)
    - Availability of Team and Equipment (Inspection Staff on-site)
    - Contractual Relationship with TDOT was already in place
  - Initial task was to evaluate bridge in current state
  - Develop preliminary plan to stabilize structure
  - Work with CM on approach to complete fracture repair

- TDOT and ArDOT collaborated on a three-phase approach
  - Evaluate for resumption of river traffic
  - Evaluate and complete repairs for initial fracture
  - Evaluate existing bridge tension members and complete any repairs needed to open bridge

Critical Startup Activities

Day 1+

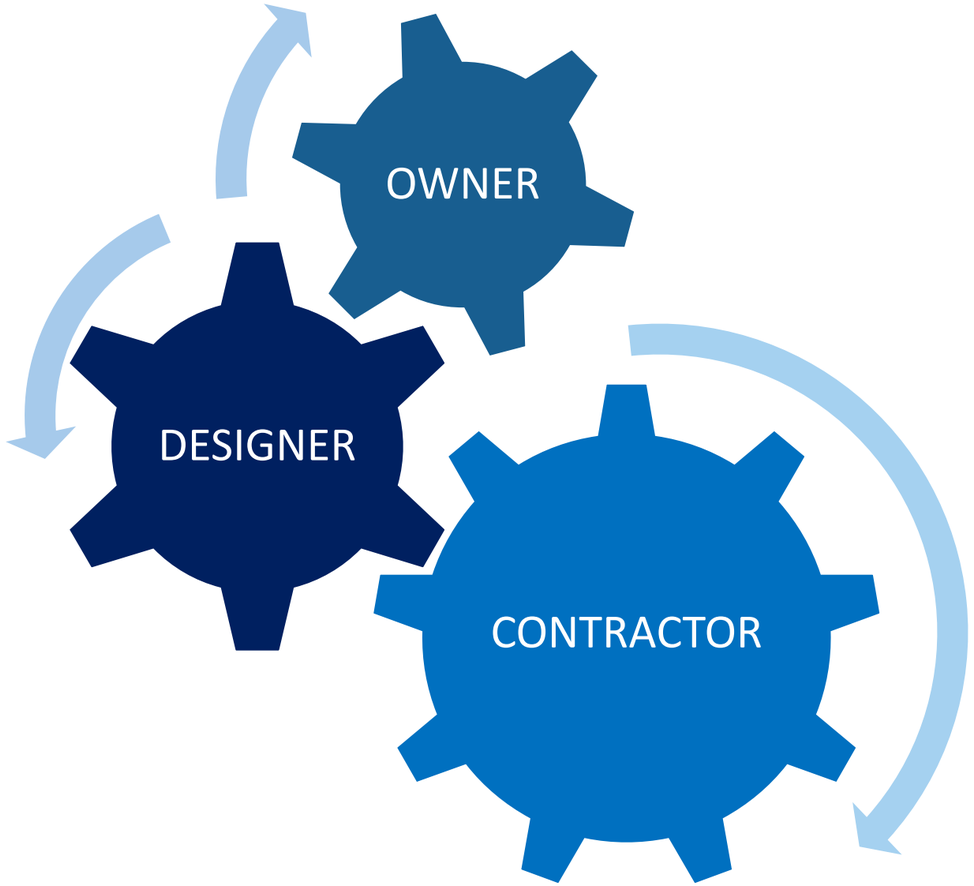
- Communication IS Critical
  - 9:00 AM - Detailed design call
    - (DOT Engineers, Consultants, Contractor)
  - 1:00 PM – Media and Social Media updates issued
  - 3:00 PM – Project status call
    - (DOT's leadership, USCG, design and contractor)
  - 3:30 PM – Traffic update call
    - local EMS, USCG, DOT's
  - 4:00 PM – Engineering & Construction update
    - with partner agencies
- Daily Work Summaries



CM/GC Procurement

Day 1+

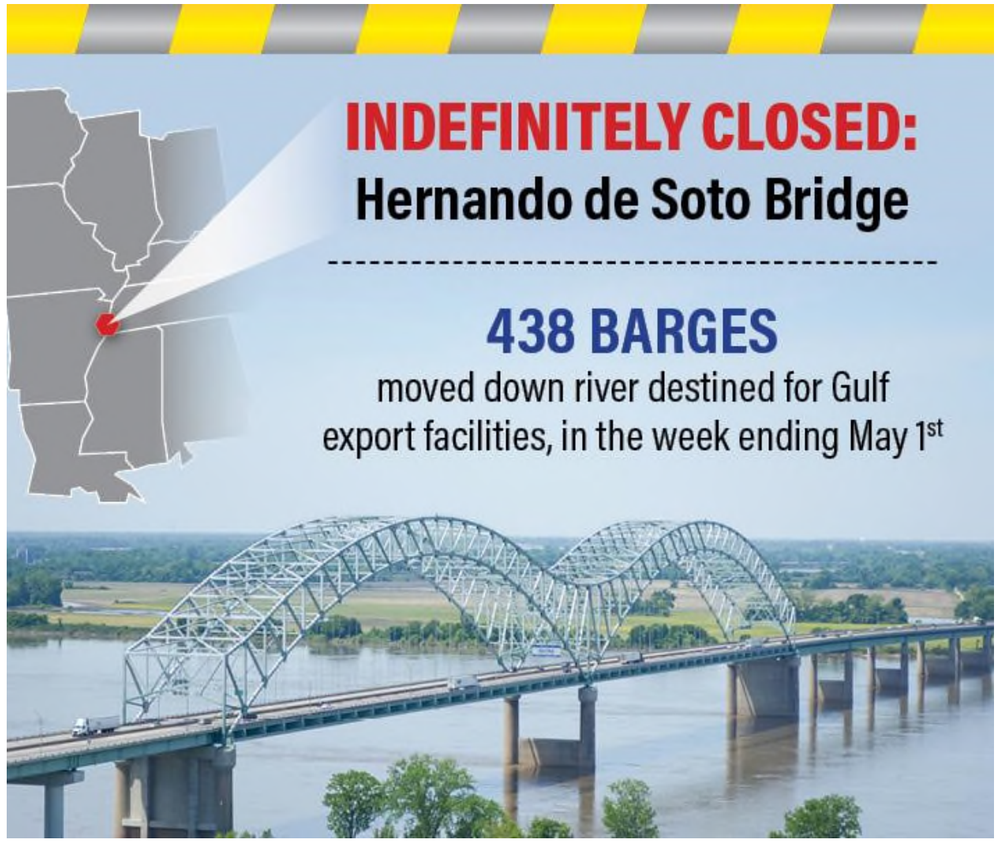
- Repair Project – CM/GC Contractor Selection Process
  - o Advertised on Friday - May 14th
  - o 8 Contractors were invited to provide submit interest packages
  - o Preliminary plating plans were provided as part of the invitation
  - o Selection of CM/GC was based on the following
    - Qualification
    - Related Project Experience
    - Availability of Team and Equipment
    - Approach on Repair Options



Impact on Traveling Public

Day 1

- Interstate Traffic
  - 60,000 vehicle ADT
  - 2-3 hour backups
  - Estimated $2.4M/day impact to trucking industry
- Mississippi River
  - 470,323 short tons of freight every day
  - soybeans, distillate fuel oil and corn



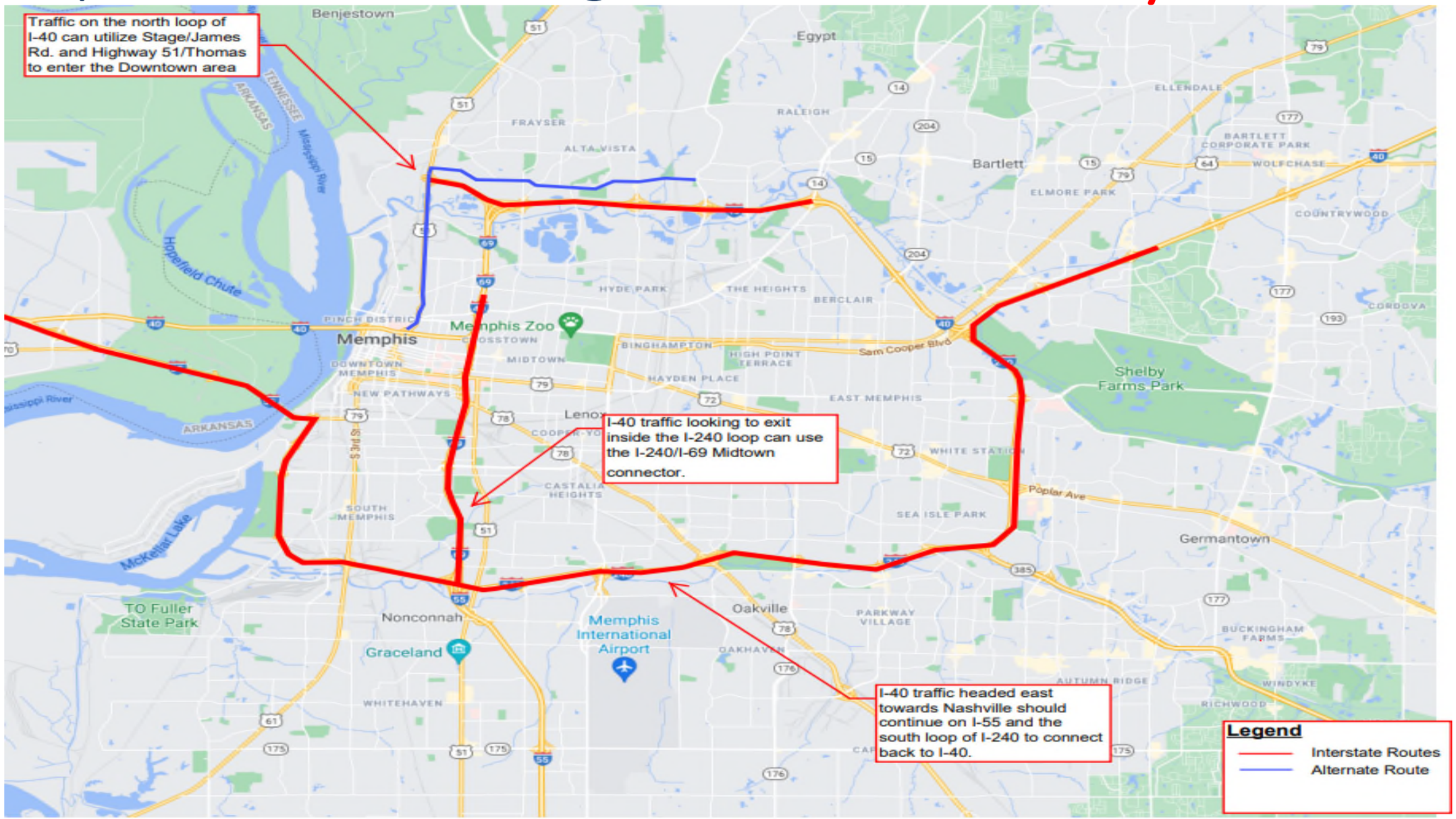
Inspection Efforts

- Supplemental Review of I-55 bridge to ensure safety and reliability.

- Used Drones to access key areas without disrupting traffic

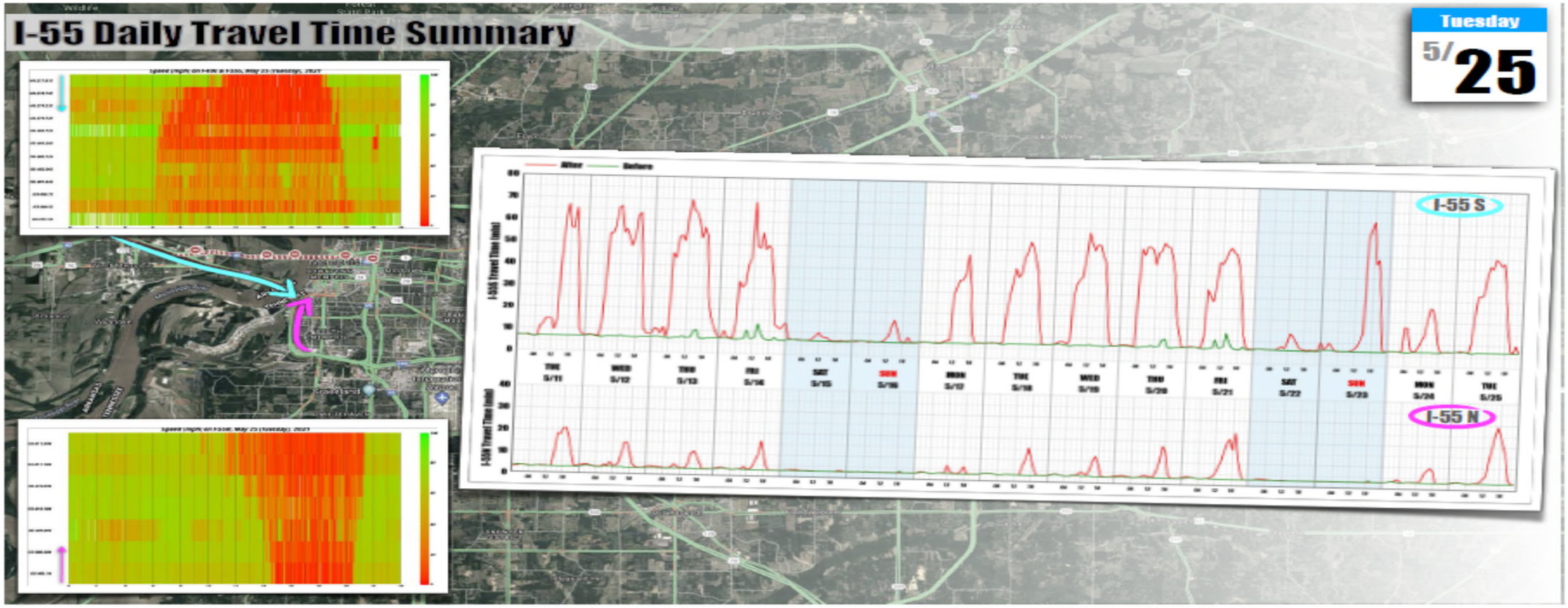
Impact on Traveling Public

Day 1



Interstate 40 Detour

- Increased travel times have occurred in both Arkansas and Tennessee to reach state lines.



To keep I-55 bridge open, HELP is stationed on each end of the bridge 24/7.

Interstate 40 Detour

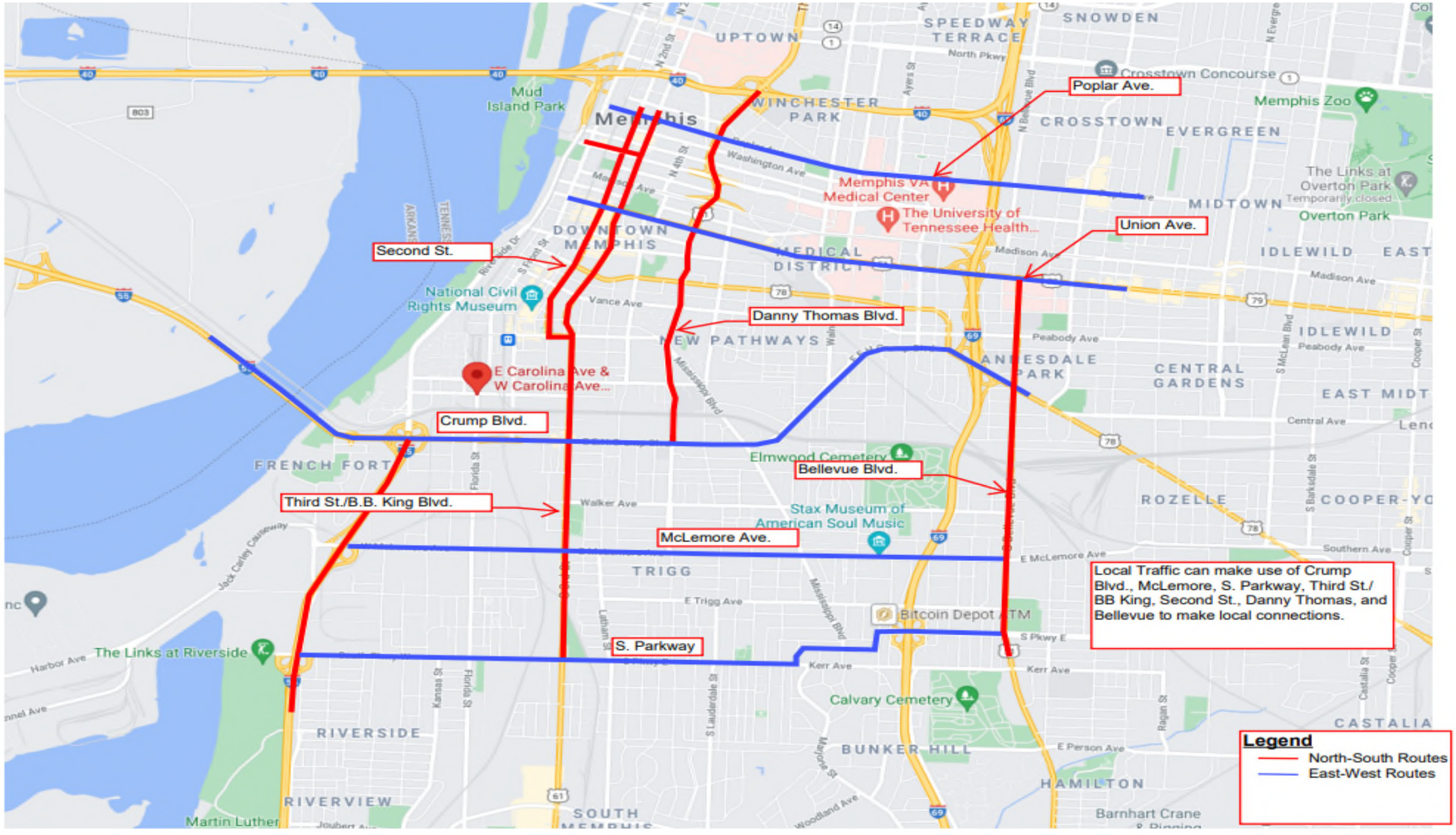
- Crump interchange has congestion points in both the south and northbound directions.
  - Northbound – 2 lane cloverleaf style ramp
  - Southbound – 1 lane section (ramp)

- Daily meetings with COM, FHWA, ARDOT and other agencies reviewing data, monitoring traffic, etc.
  - Closed some access to I-55, modified signage and striping.
  - Widened southbound lane to accommodate 2 lanes of traffic.

- Opening I-40 from I-40/I-240 midtown interchange back to Danny Thomas (SR 3/Exit 1C and 1D)

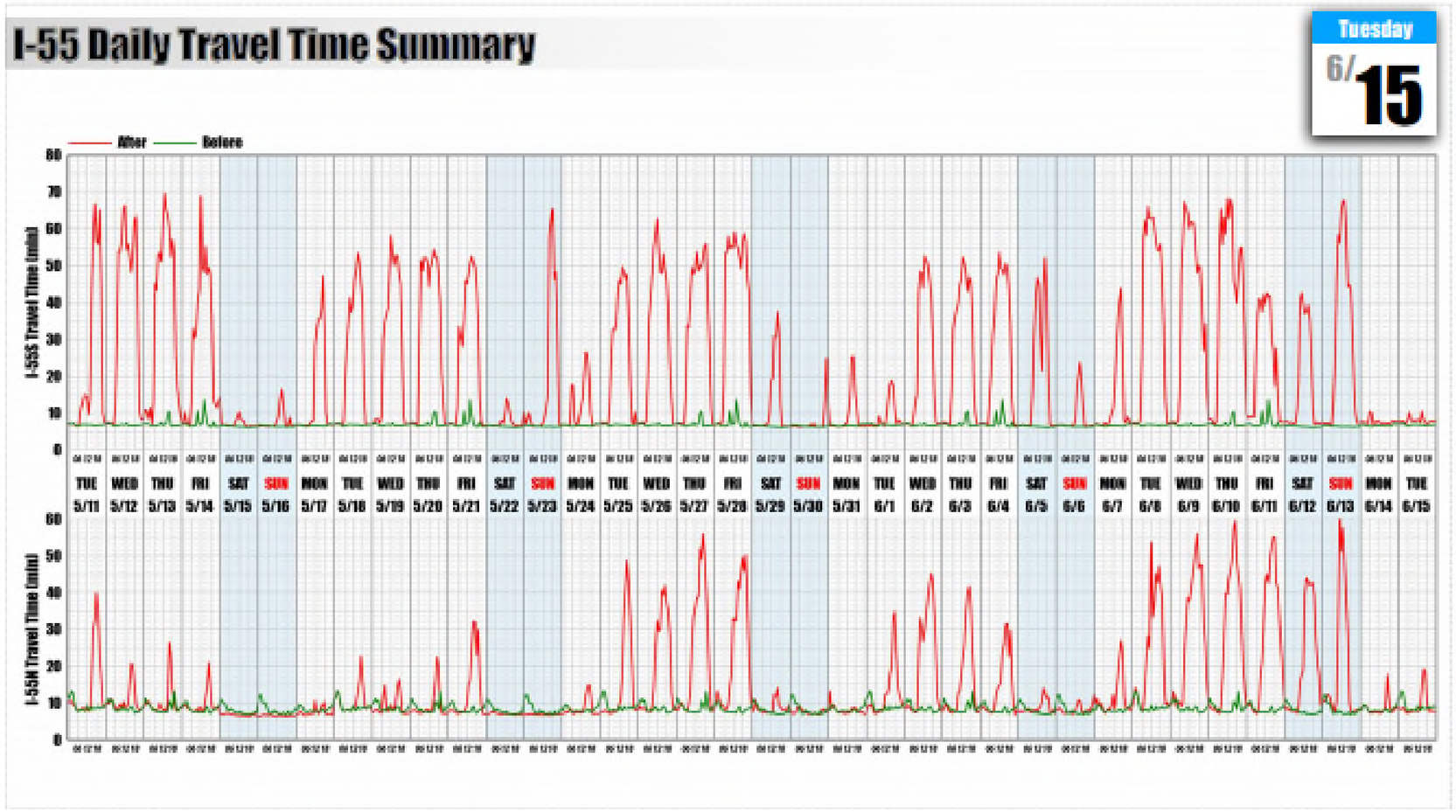
Impact on Traveling Public

Day 1



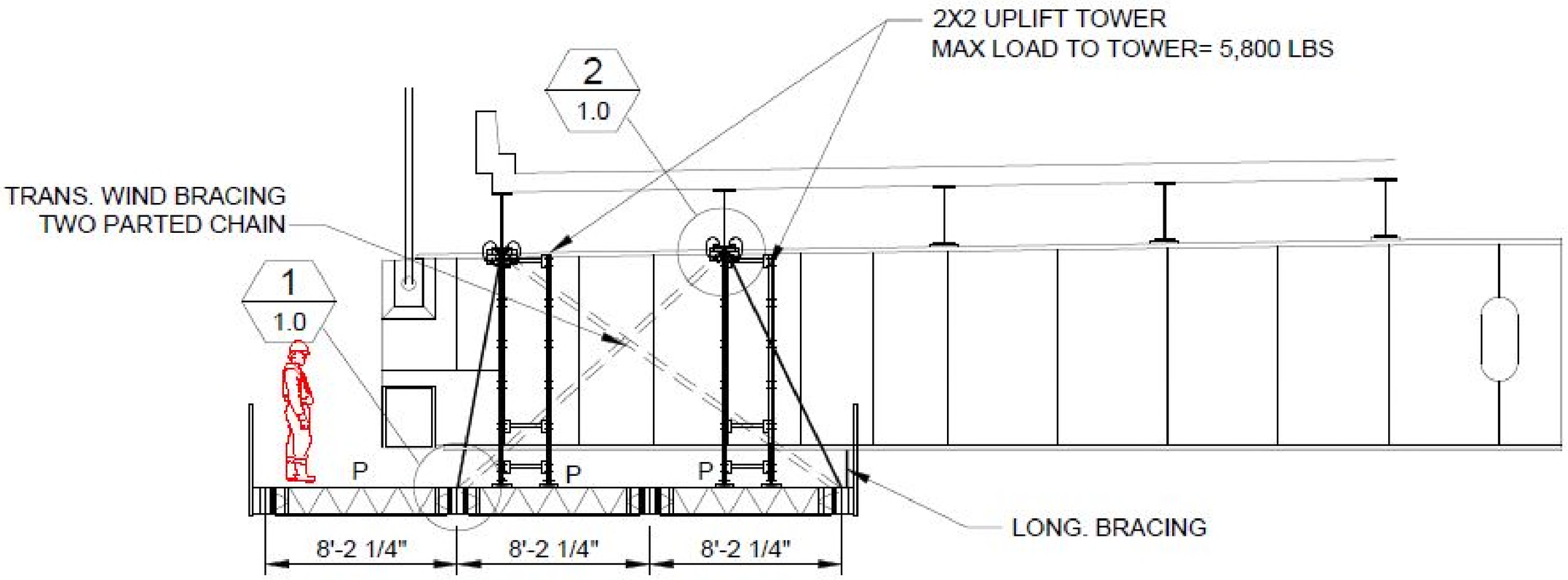
Interstate 40 Detour

- Travel Times after Crump Interchange Modifications



Interstate 40 Hernando DeSoto Bridge

Installing Work Platform



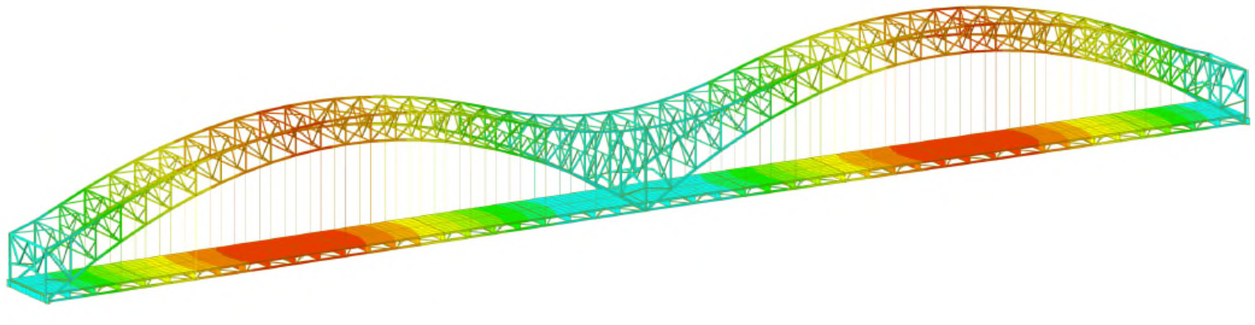
Interstate 40 Hernando DeSoto Bridge

Installing Work Platform

Timeline of Events

Day 1+

- TDOT & ArDOT supplied bridge data to MBI
  - Plans, Shop Drawings & Weld Inspection Report (TDOT)
  - Inspection Reports (ArDOT)
  - Approved development of Phase 1 plating plans & model development



Propagation of Fracture

- TDOT did not ask for recommendations on safety/risk. **Day 2**
- MBI provides FEA model results to TDOT
  - TDOT does a risk assessment using model data, historic photos & former staff
  - Construction photos suggest favorable sequence of loading during construction **Day 3**
  - **TDOT provides risk evaluation to USCG who opens river to traffic.**

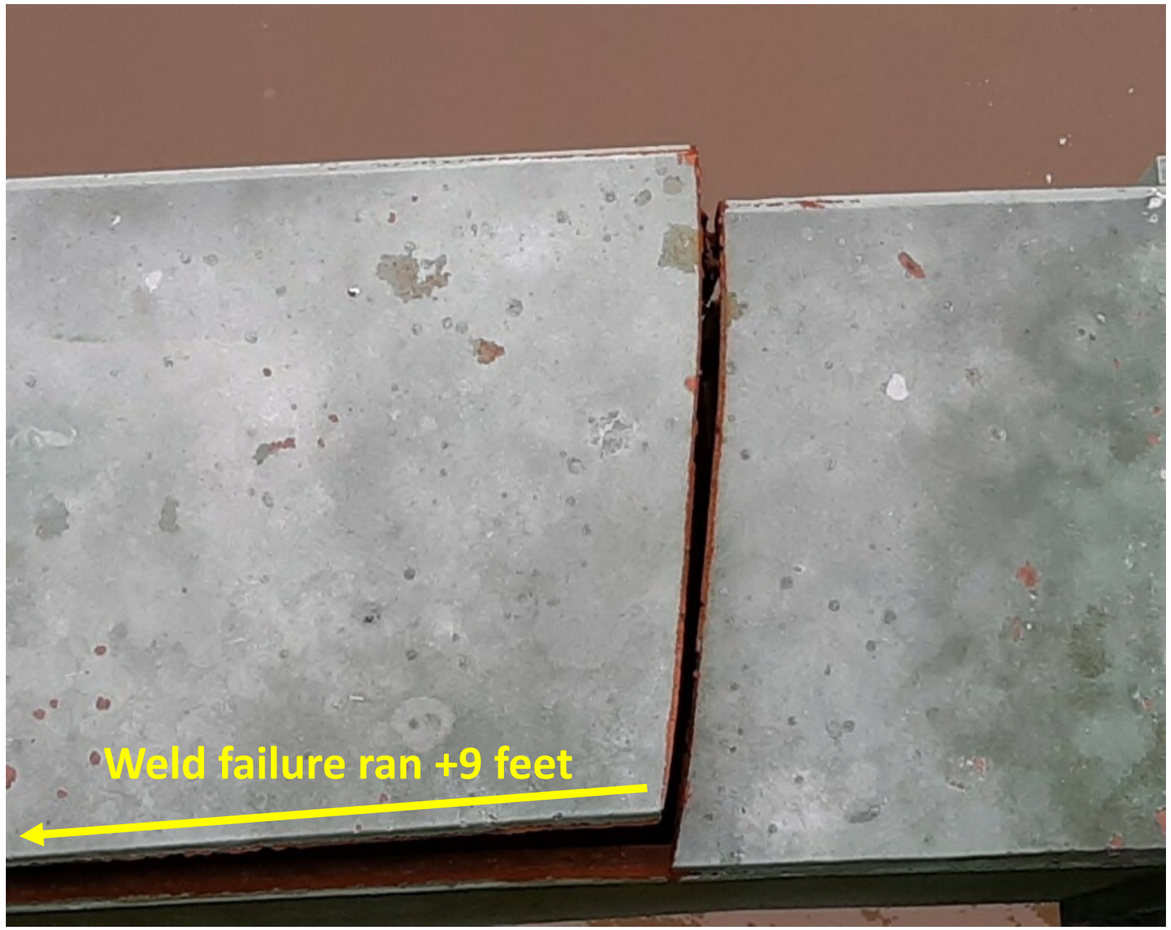
Media Attention on Inspection

- Reports of Prior Fracture
- Traffic Snarls
- TDOT Media Coordination

"It's so simple and so shocking to see a literal split in a steel beam on which millions of pounds of pressure and countless thousands of lives depend."

Sec. of Transportation Pete Buttigieg, while touring the Hernando de Soto Bridge

Fracture Details

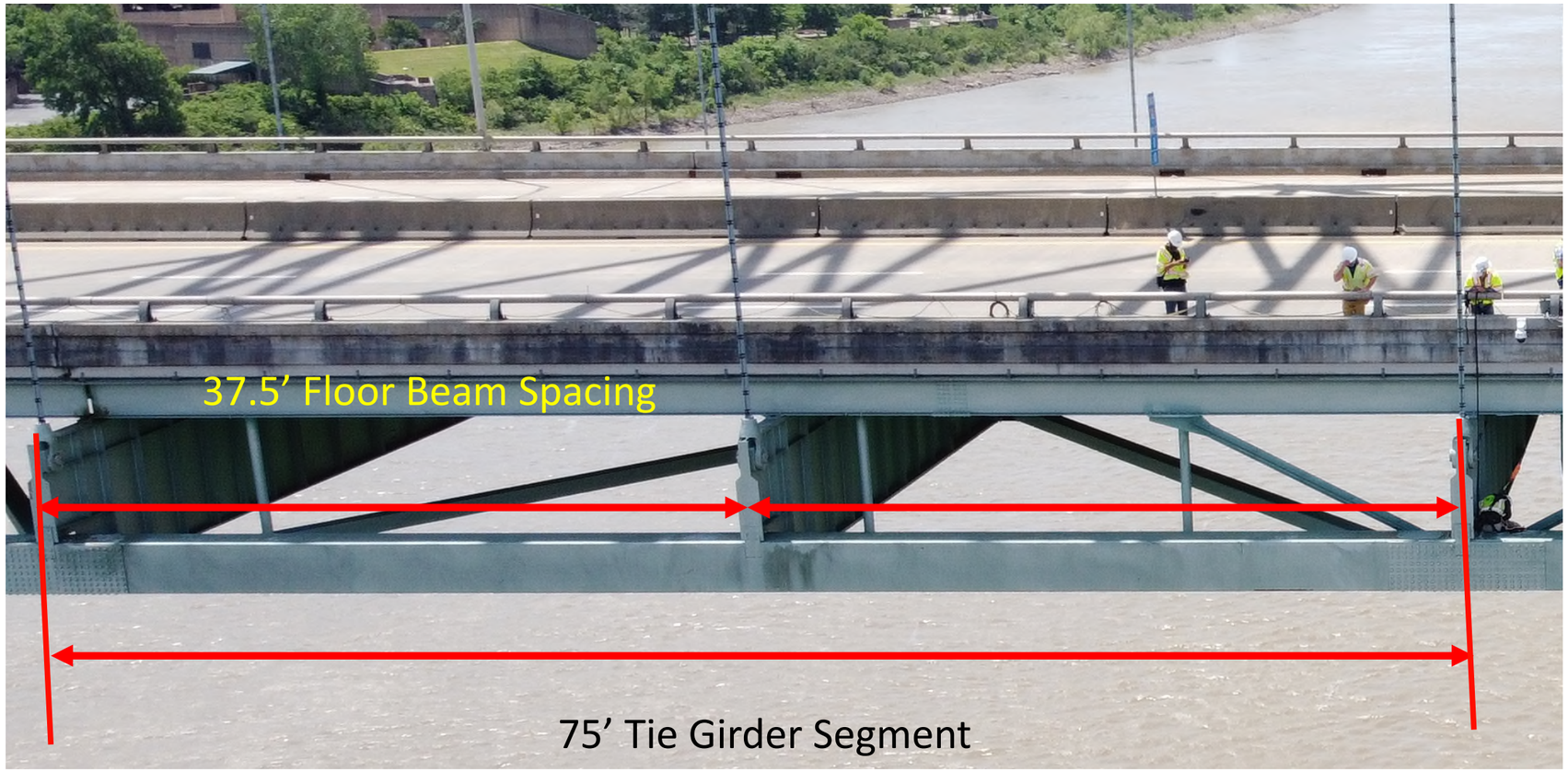


Phase 1 Repairs

Stabilizing the Structure

Phase 1: Stabilize the Structure

- Design Challenges for Phase 1 –
  - 100 ksi plate in tie girder and select high truss members
  - Thin (1.375”) plate sections limited bolting options due to net section limitations
  - Geometry (twist) of current tie girder impacted plating design



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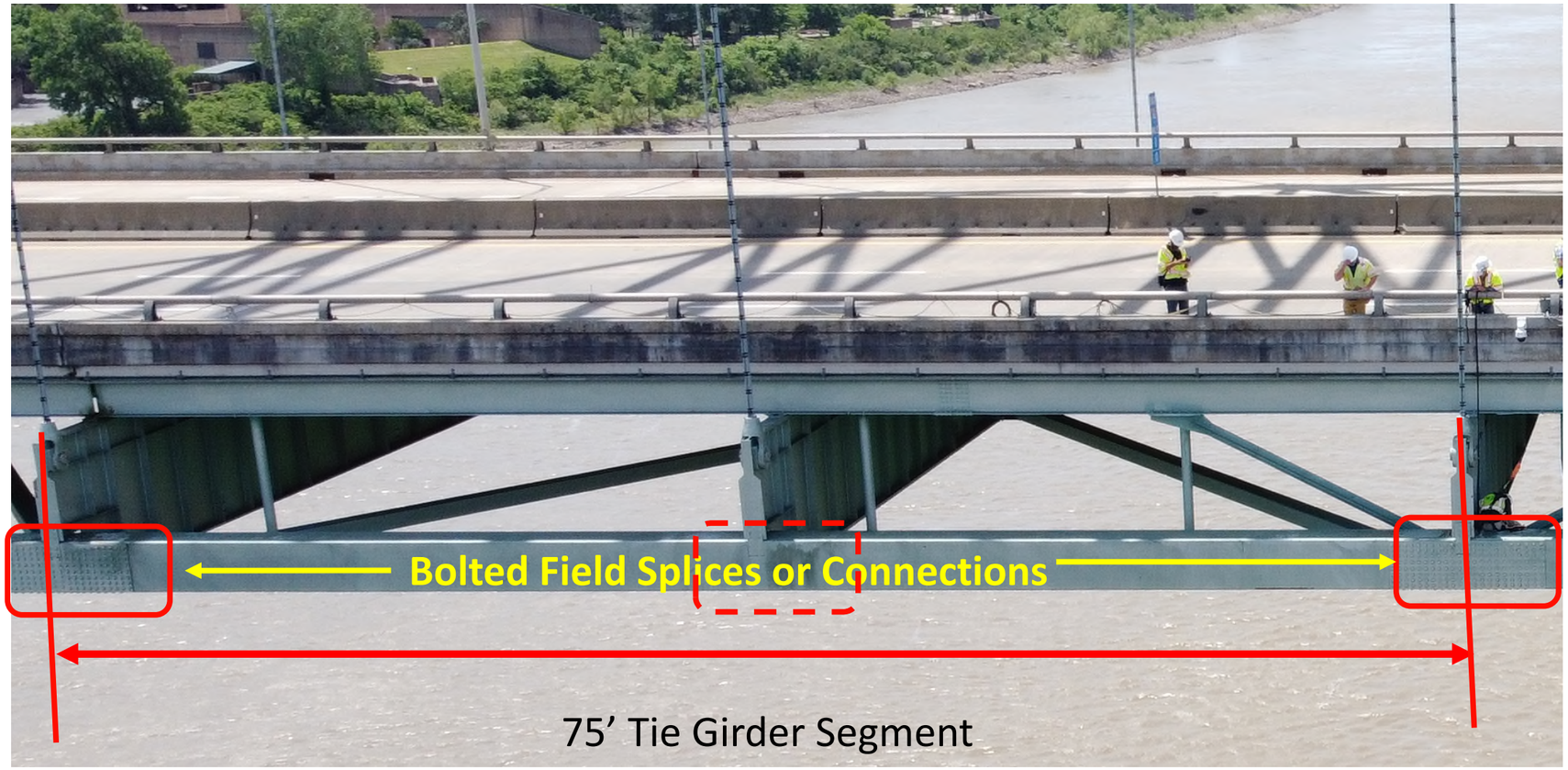

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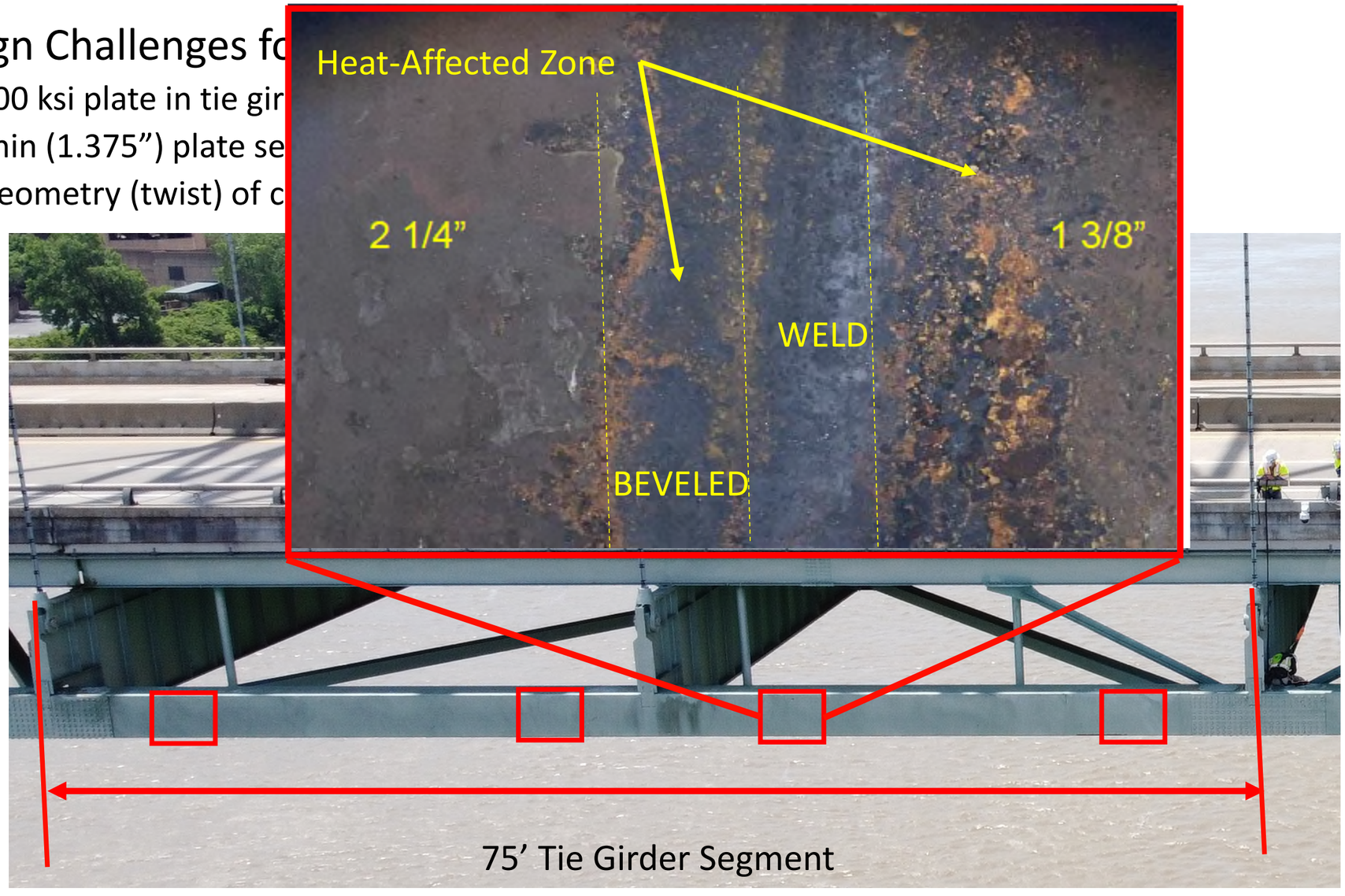
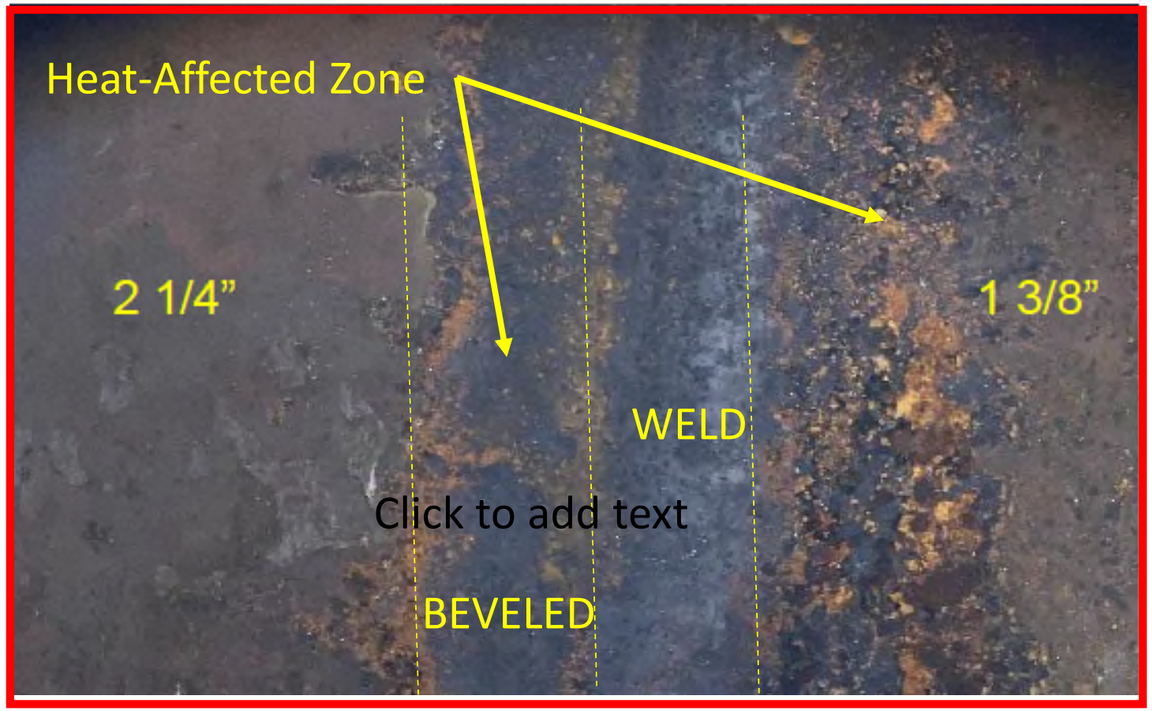
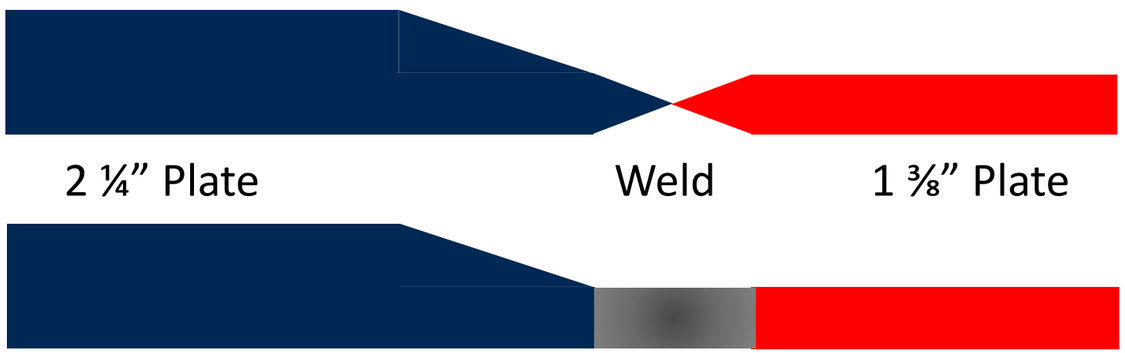


Phase 1: Stabilize the Structure



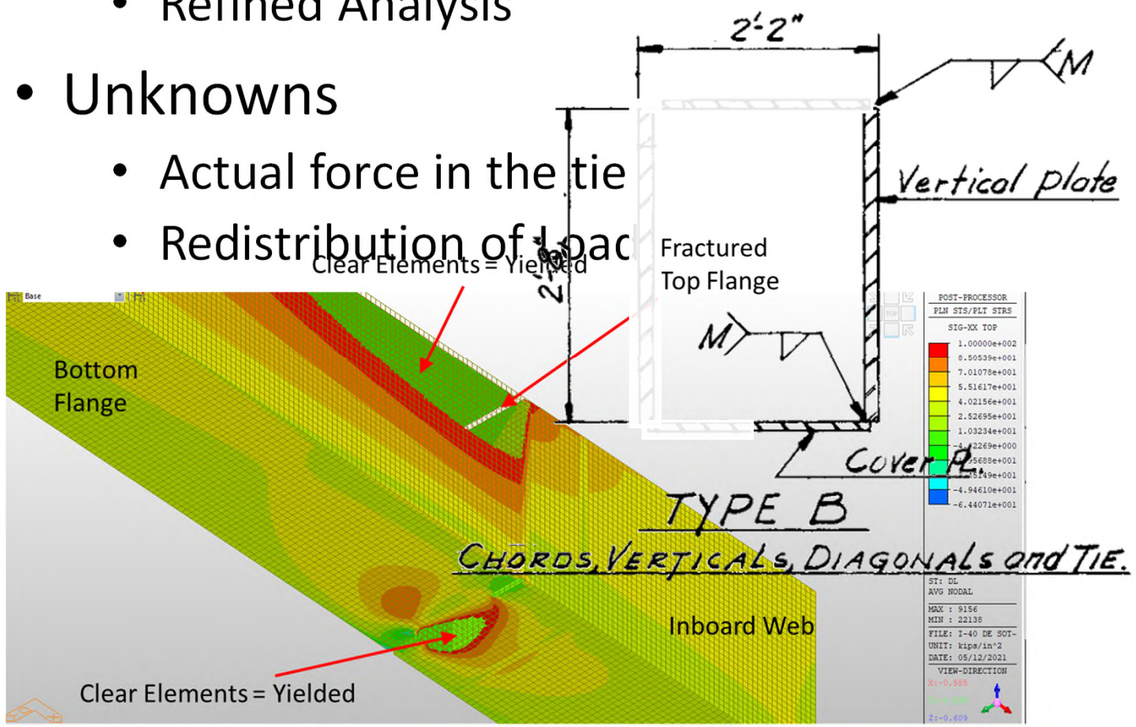
Inside Surface of Tie Girder Box Section



Outside Surface of Tie Girder Box Section

How Bad is it?

- T1 steel = 100 ksi (+)
  - P/A design = 38ksi
- Fracture 113 in2 -> 51.5in2 (**45%!**)
  - P/A after Fracture = 83ksi
- Eccentric Loading
  - Refined Analysis
- Unknowns
  - Actual force in the tie
  - Redistribution of Load



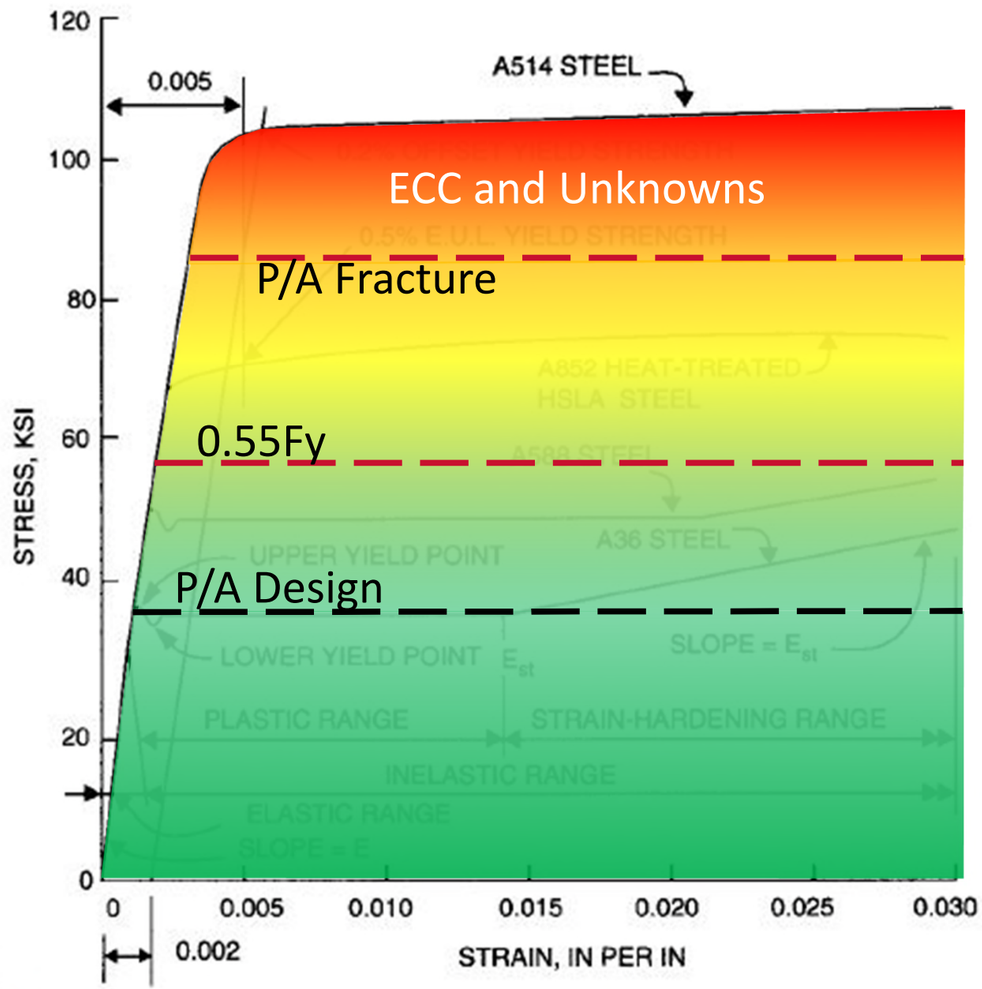
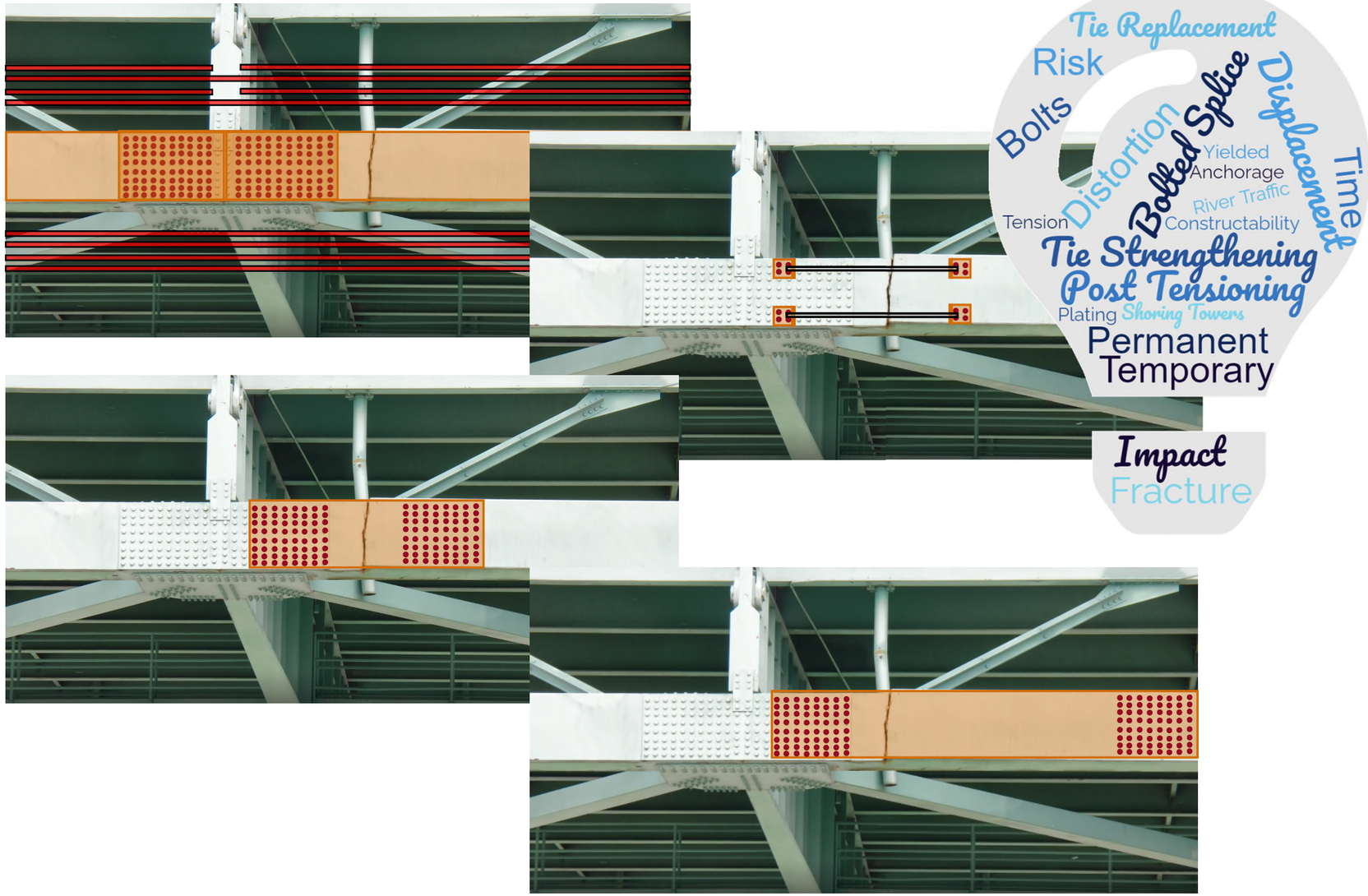


FIGURE 1.4 Partial stress-strain curves for structural steels strained through the plastic region into the strain-hardening range. (*From R. L. Brockenbrough and B. G. Johnston, USS Steel Design Manual, R. L. Brockenbrough & Associates, Inc., Pittsburgh, Pa., with permission.*)

Phase 1: Stabilize the Structure

How do you fix it?

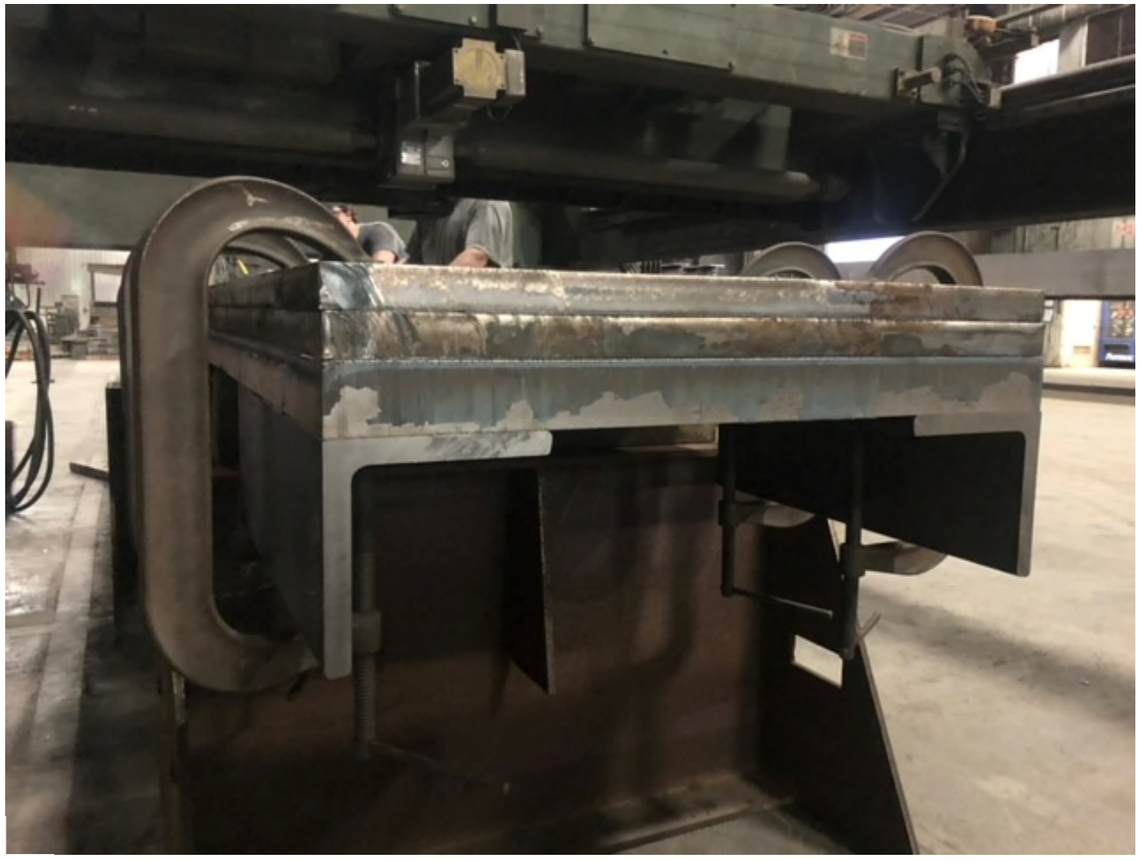
- Permanent Fix
  - *Duration too long*
- Shoring Towers
  - *Navigation / Duration*
- Temporary PT
  - *High Loads*
  - *Long lead time / fabrication*
- Adjacent Splice
  - *Distortion of the box*
- Lengthen Splice
  - Showed promise



Phase 1: Stabilize the Structure

Availability

- Initial contact with several fabricators looking for plate availability
- HPS 70W in stock and able to be used for the repairs
- 2+” Thickness? Length?
- <u>You can’t install what you can’t get!</u>



Stupp Bridge in Bowling Green, KY

Phase 1: Fabrication

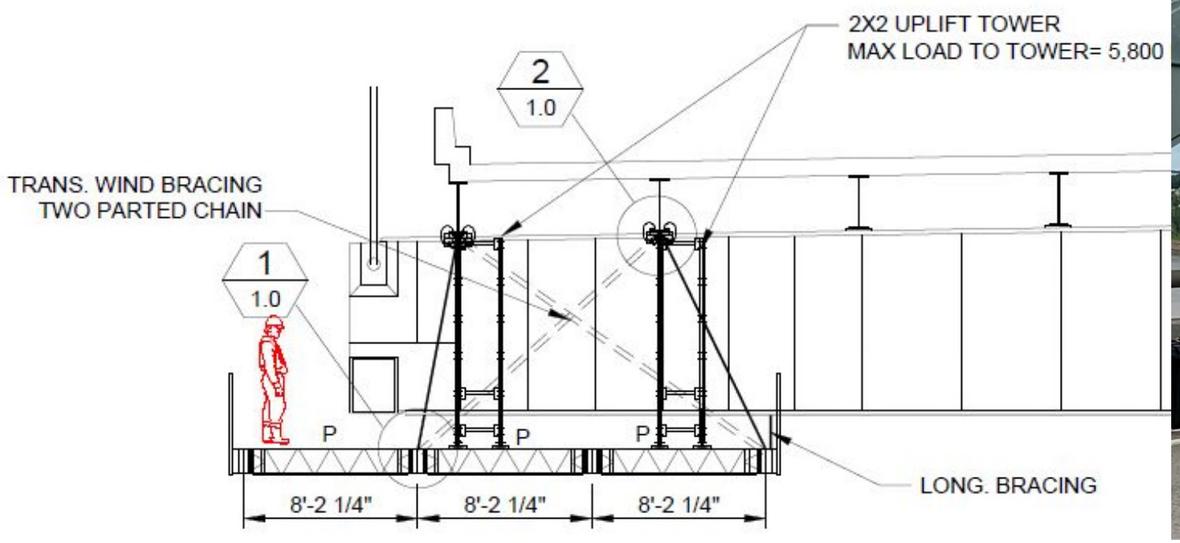
Fabrication

- **DAY 6** - Design Finalized 5/18
- **DAY 8 -** Shop drawings created and approved 5/20
- **DAY 10 -** Fabrication began 5/21
- **DAY 11 -** TDOT maintenance picked up the steel 5/22

Phase 1: Stabilize the Structure

Construction

- Trucks come from west end of the bridge
- Use chain fall to move plates on Span 2 and into place
- No work barges or river access was used during the duration of the project



Phase 1: Plate Installation

- Kiewit Infrastructure began installing the plates Saturday, May 22nd. **Day 11**
- Phase 1 plate installation was completed on Tuesday, May 25th. **Day 14**
- Completing Phase 1 allowed for starting the Phase 3 inspection work

Phase 3: Inspect & U/T all welds

Day 15

- 484 tie girder weld locations + statistical sample of welds on high truss.
- Phased Array and single beam UT were used – required paint removal.
- More details later

Phase 2 Repairs

Long term remediation of the fractured section

Phase 2 Repair Design

Day 0

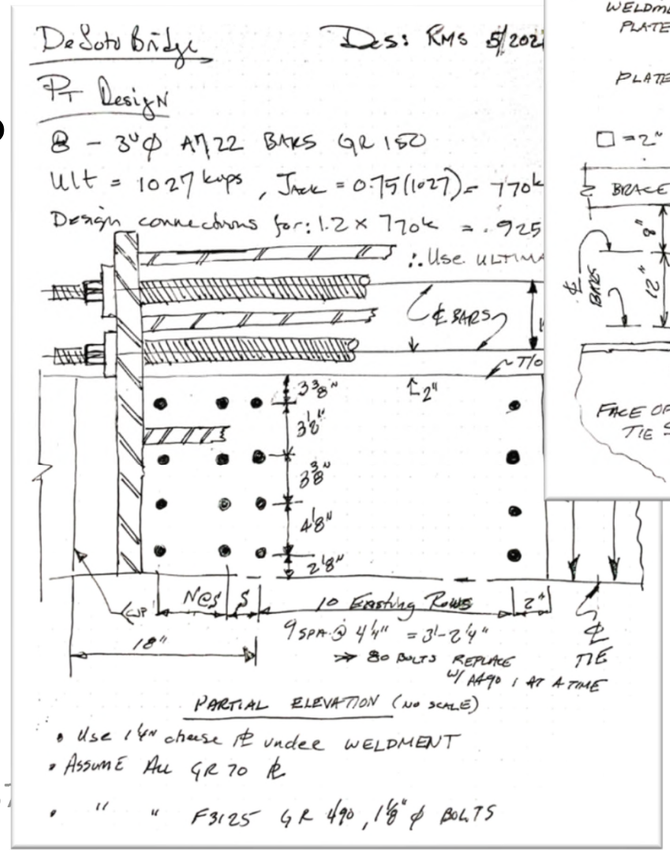
Initial Calc 8:44 PM on 5/11

Design Philosophy

- Preserve capacity of original tie
- How much post-tensioning ?
- How much of the gap do we need to close?
- Effects on Secondary Members?
- How effective will the Post-Tensioning actually be?

Multiple concepts considered

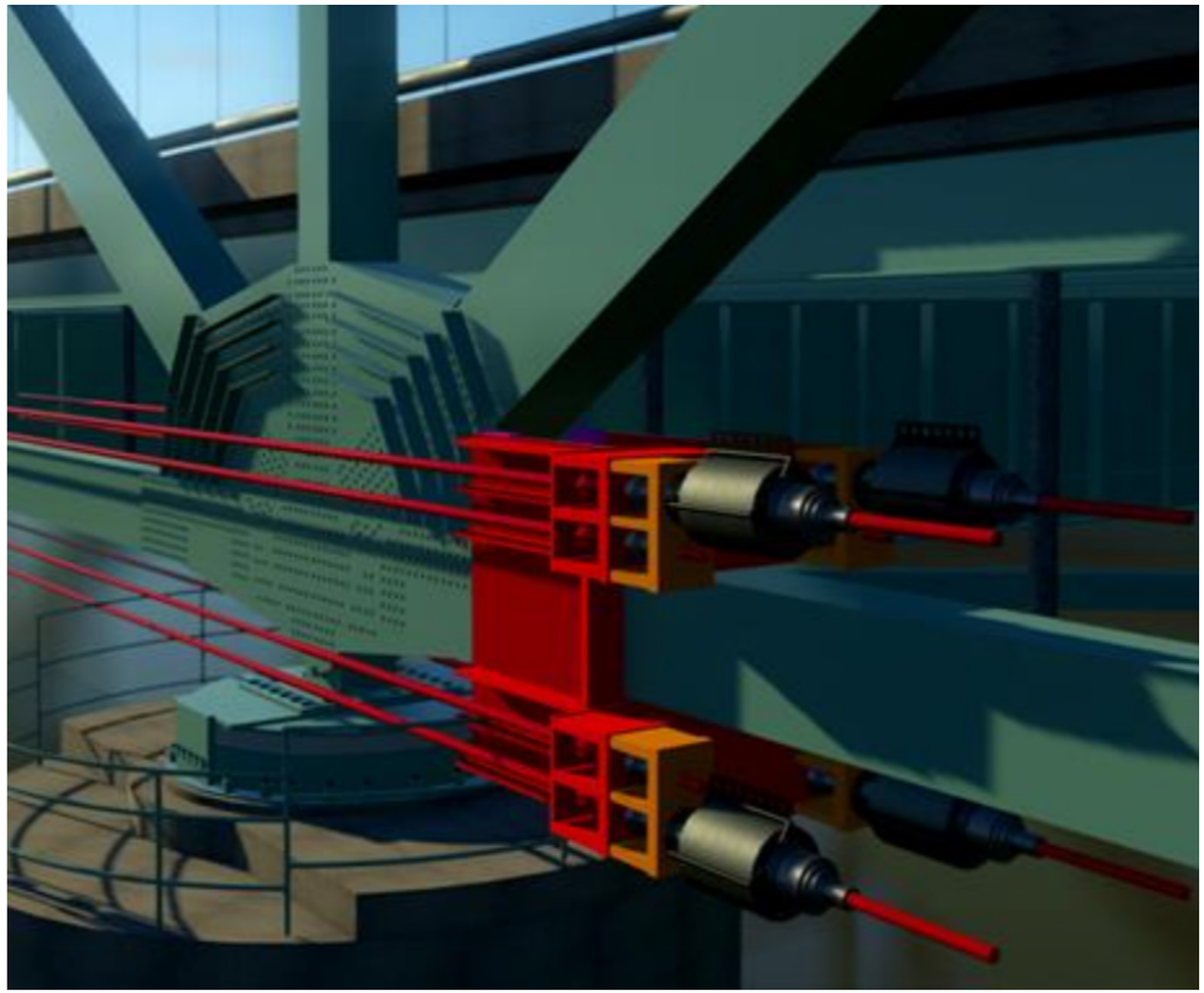
- Ultimately, load path to the tie girder dictated design



Post-Tensioning System Design

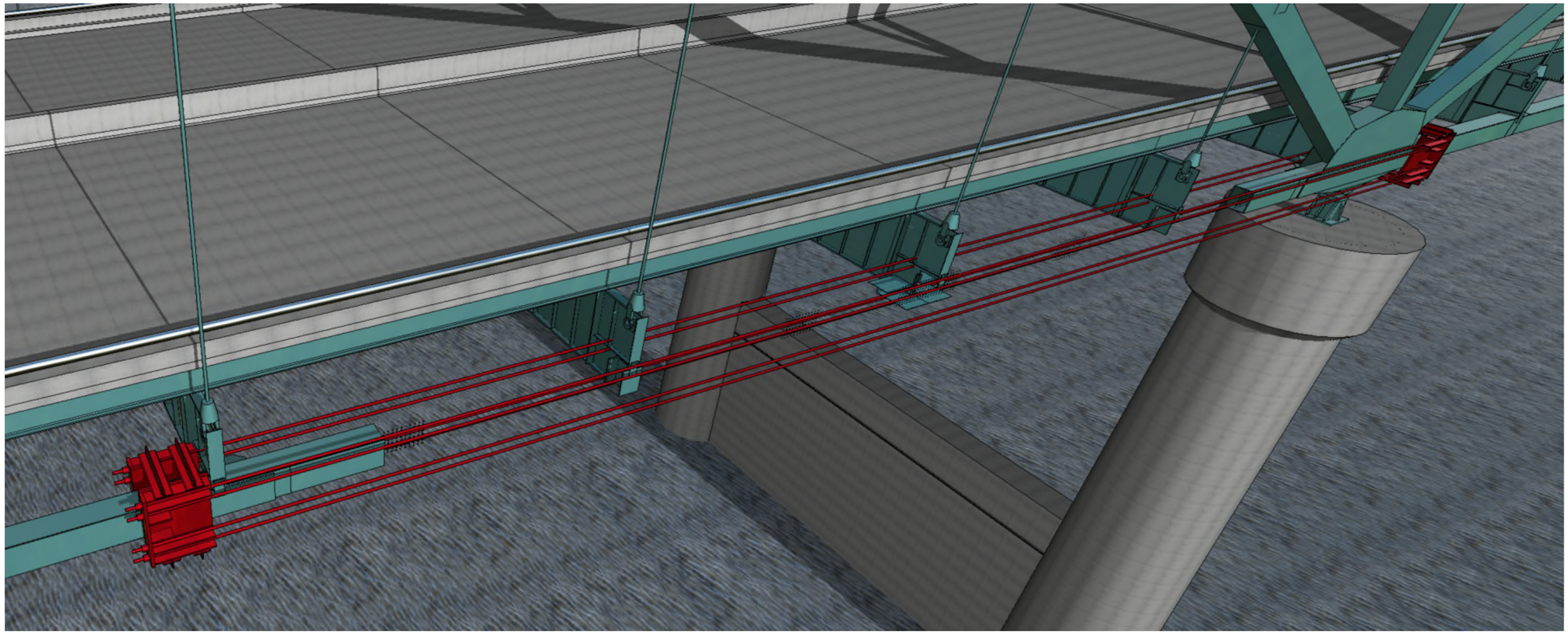
P/T System

- 8 - Cold-rolled 150 ksi 3” diameter PT bars
- Allowance for fitment/eccentric loads
- Staged PT
- Monitoring Plan including direct force measurement

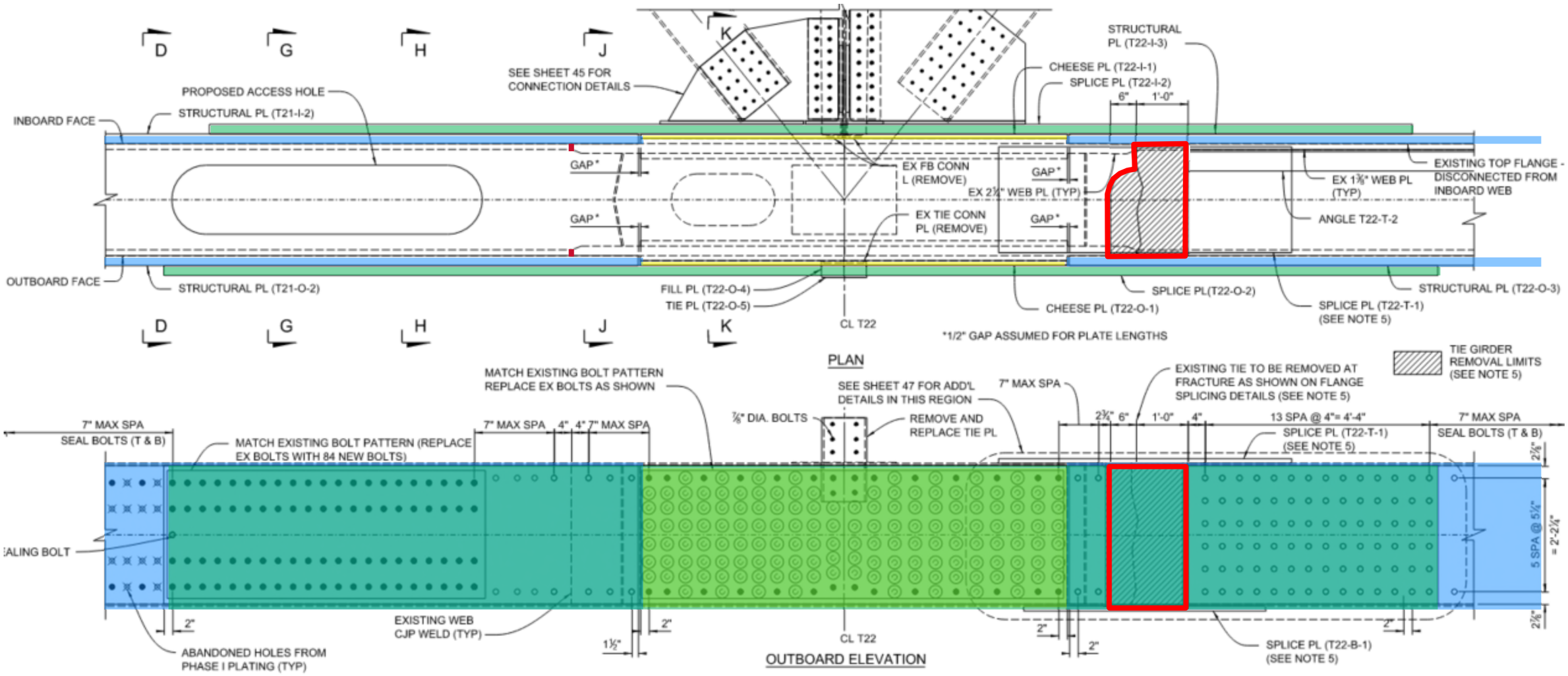


Tie Girder Complete Replacement

- Initial direction: completely remove the old/fractured tie
- End Result: Cut out Fracture and Plate back to connections

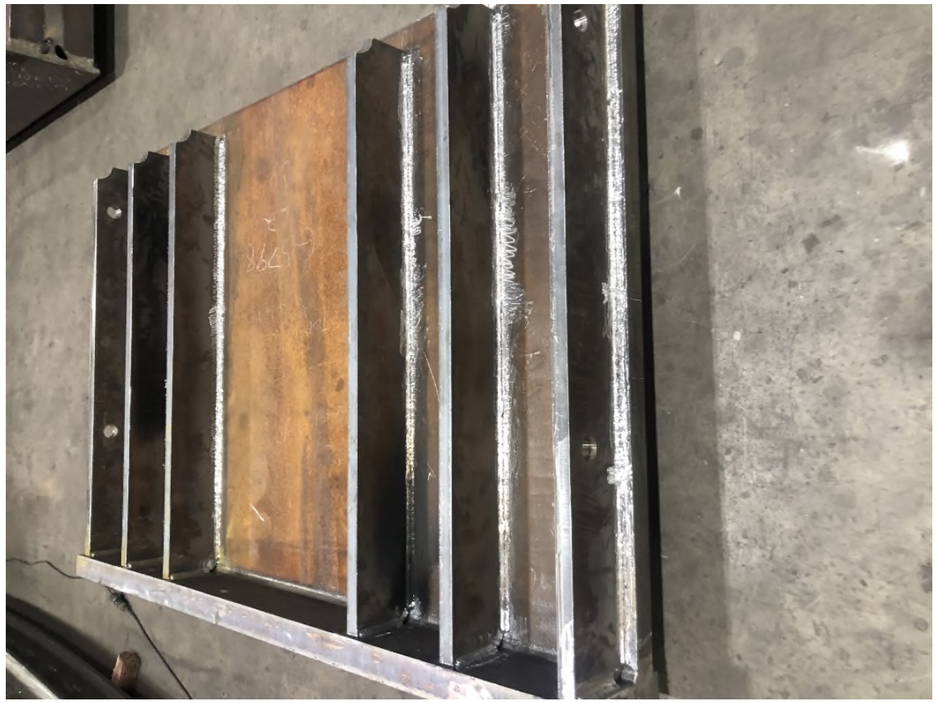


Phase 2 – Plating T22



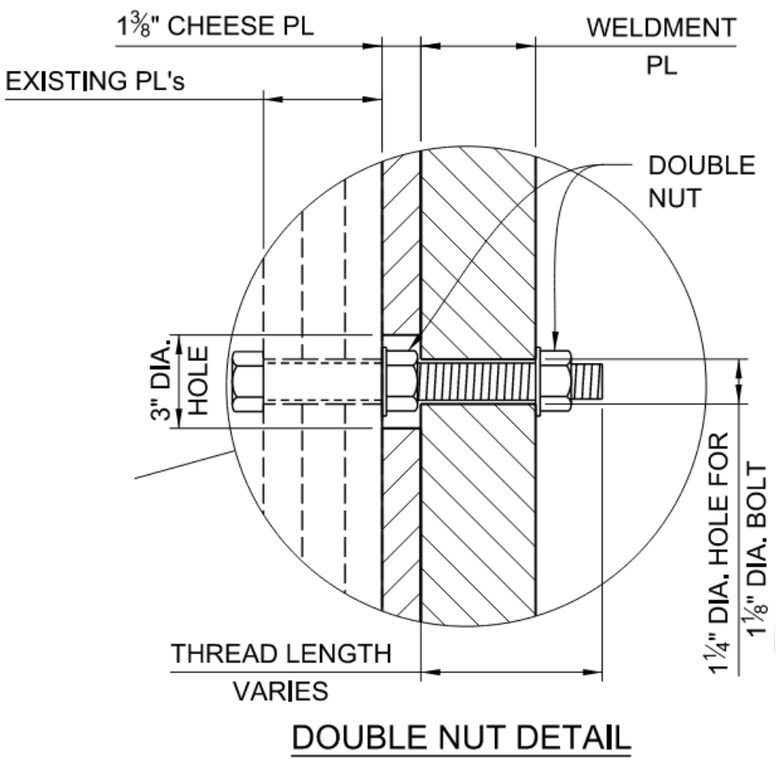
Phase 2: PT Weldment Fabrication

- **Each weldment is 8 foot tall and 20,000 pounds**
- **Fabricated by G&G Steel in Russellville, Alabama**
- **Weldments were delivered to the job site June 11th** **Day 31**

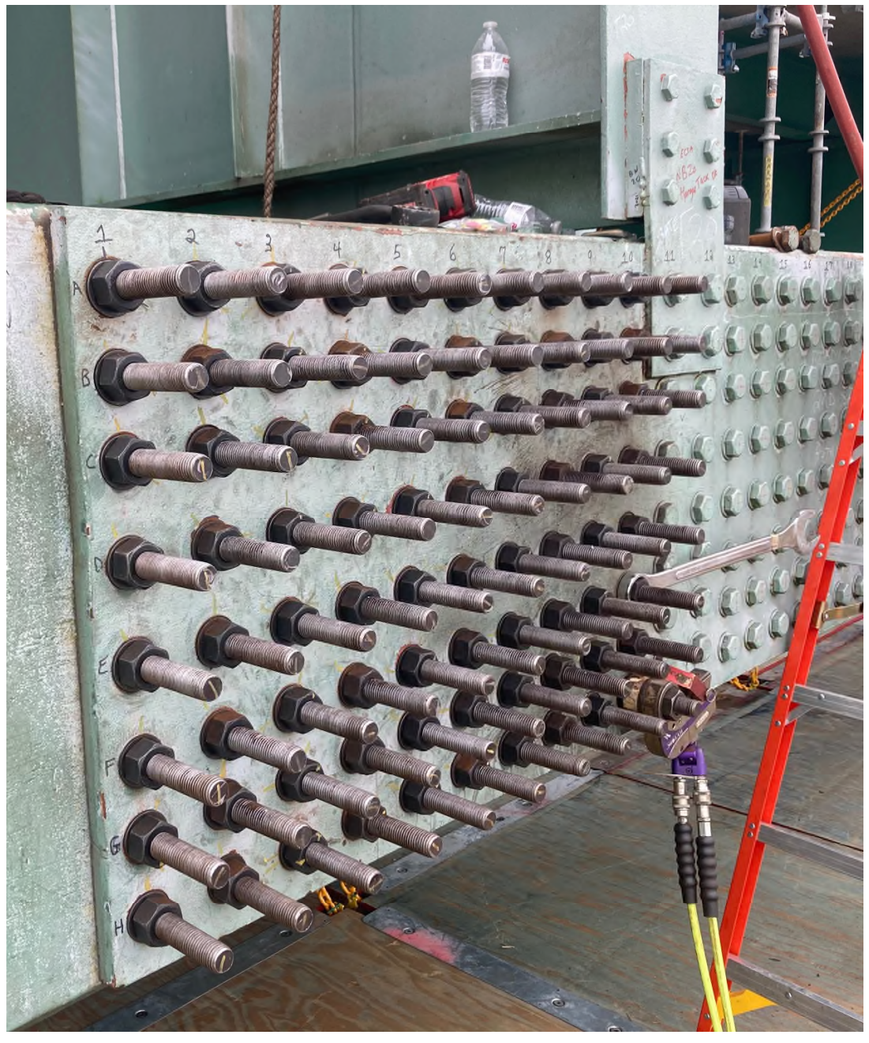


Cheese Plate & Double Nut

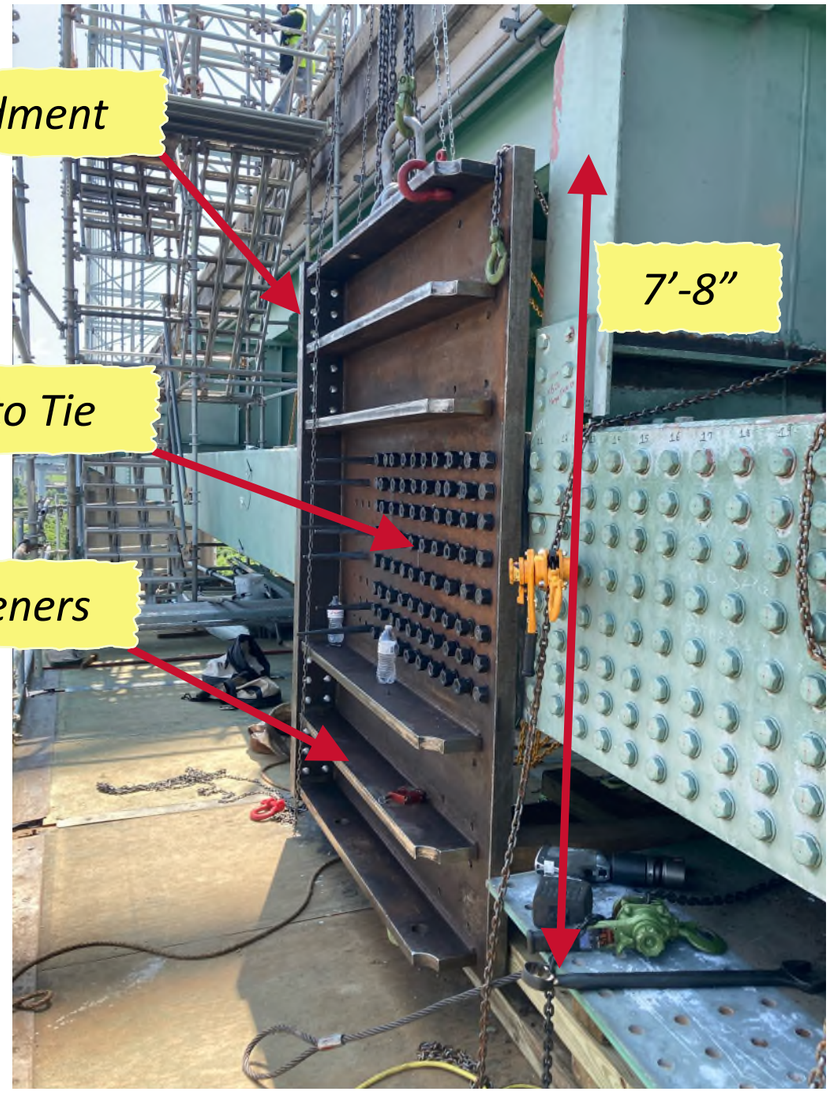
Day 32

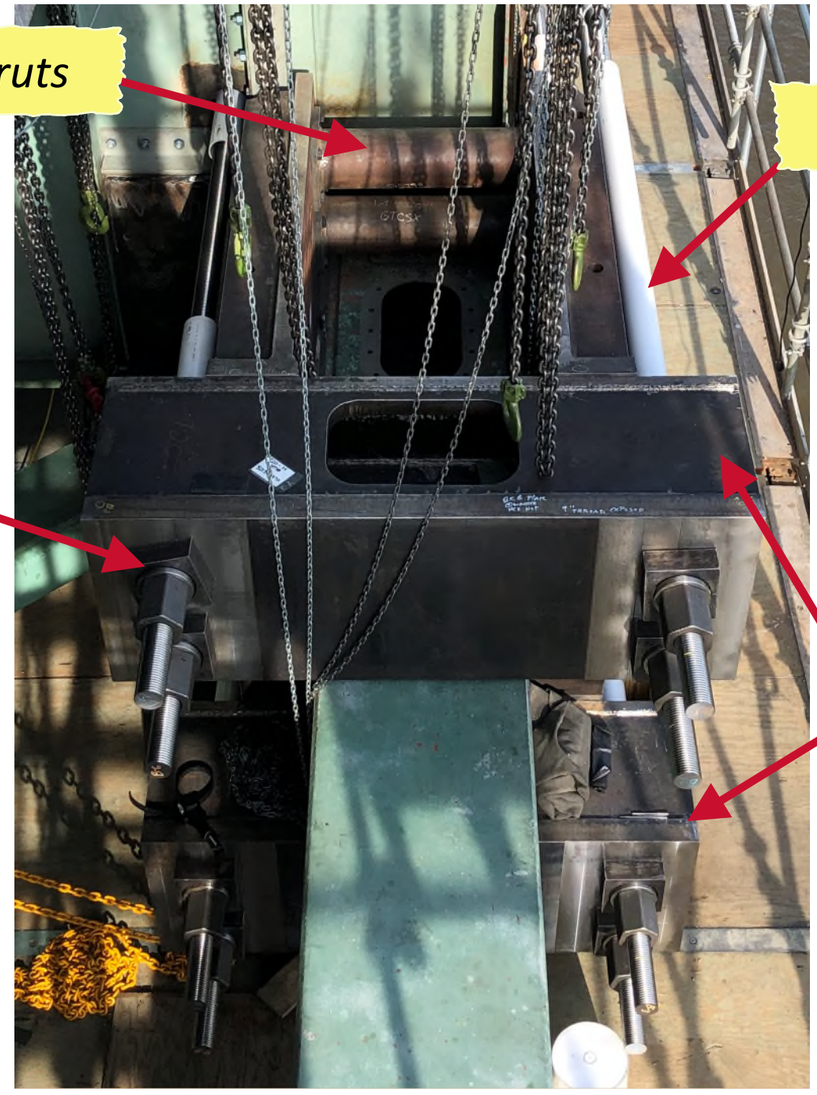


DOUBLE NUT DETAIL



Post Tensioning Anchorage Day 32





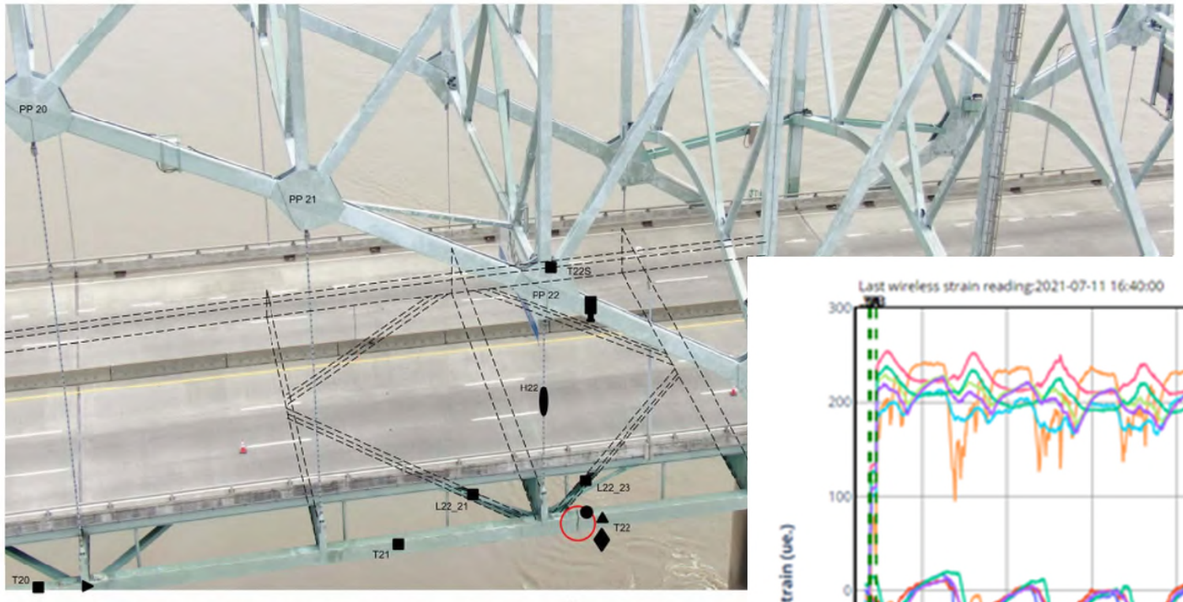
Stressing

Day 42

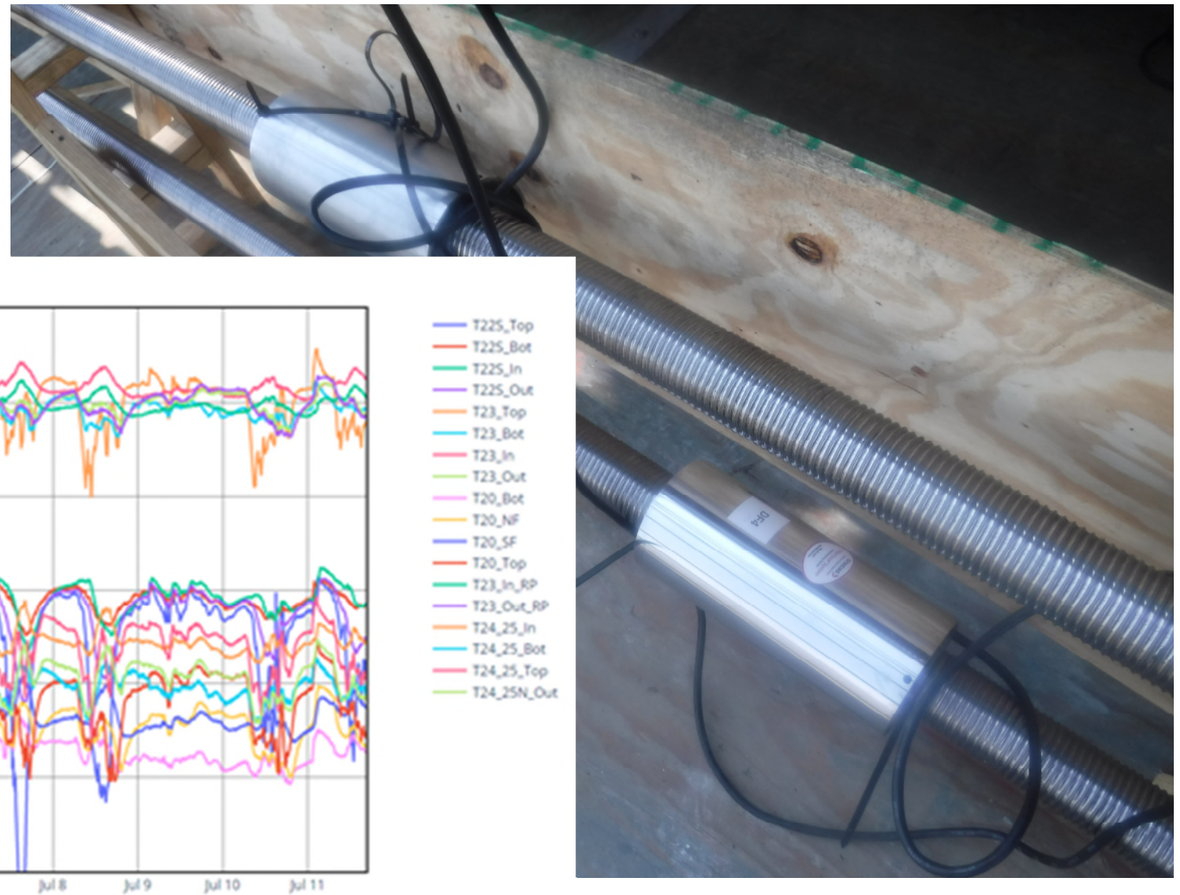
PT Stressing began Sunday, June 20th and was completed June 22nd

PT Monitoring

Strain Gauges

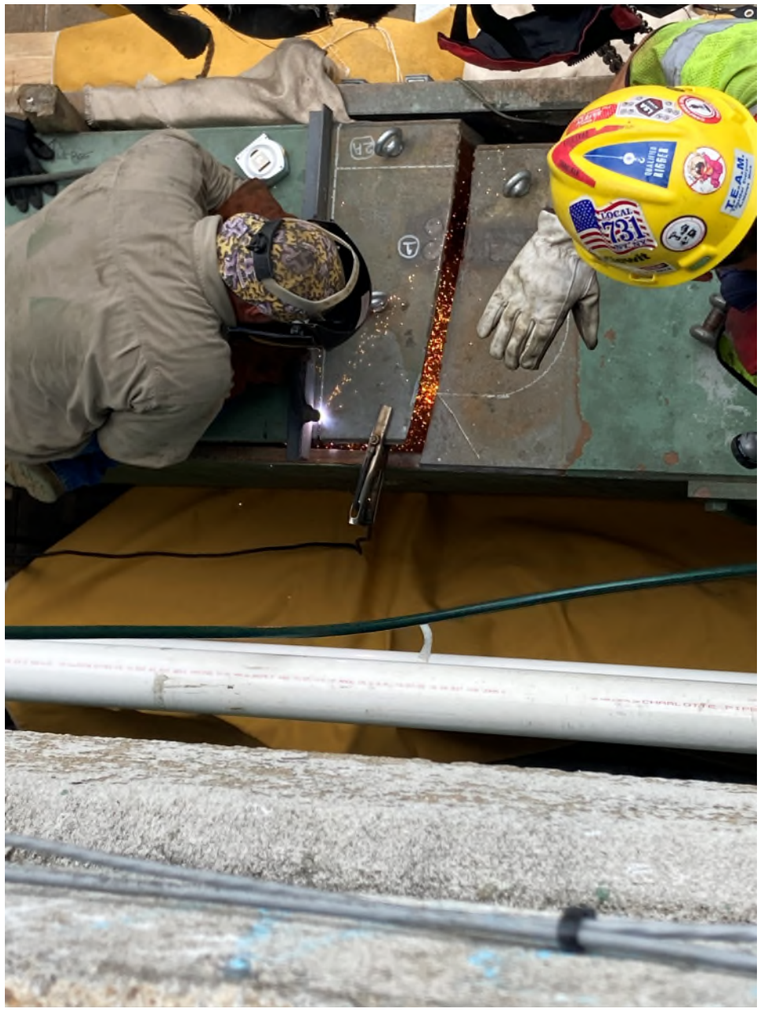


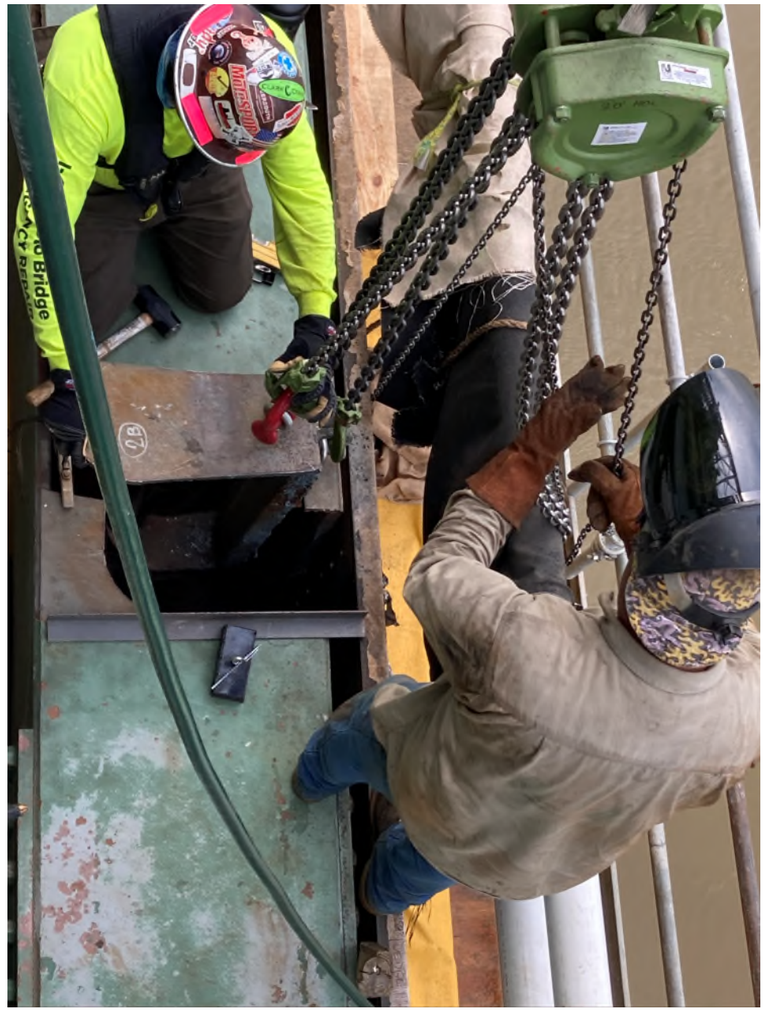
Dyna Force Sensors



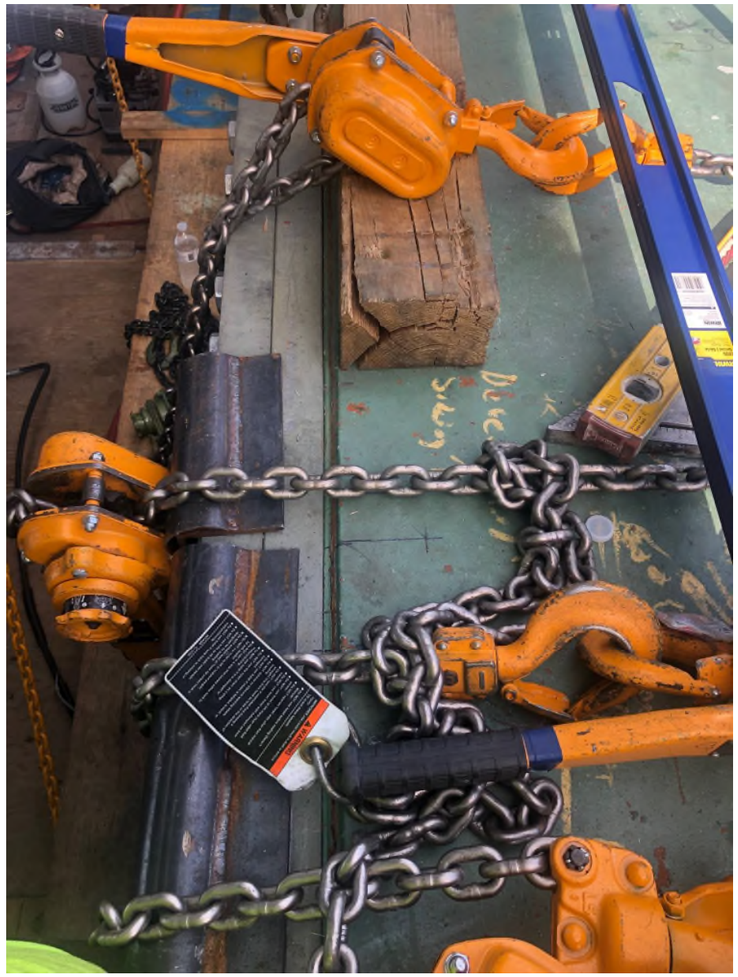
Removing the Fracture

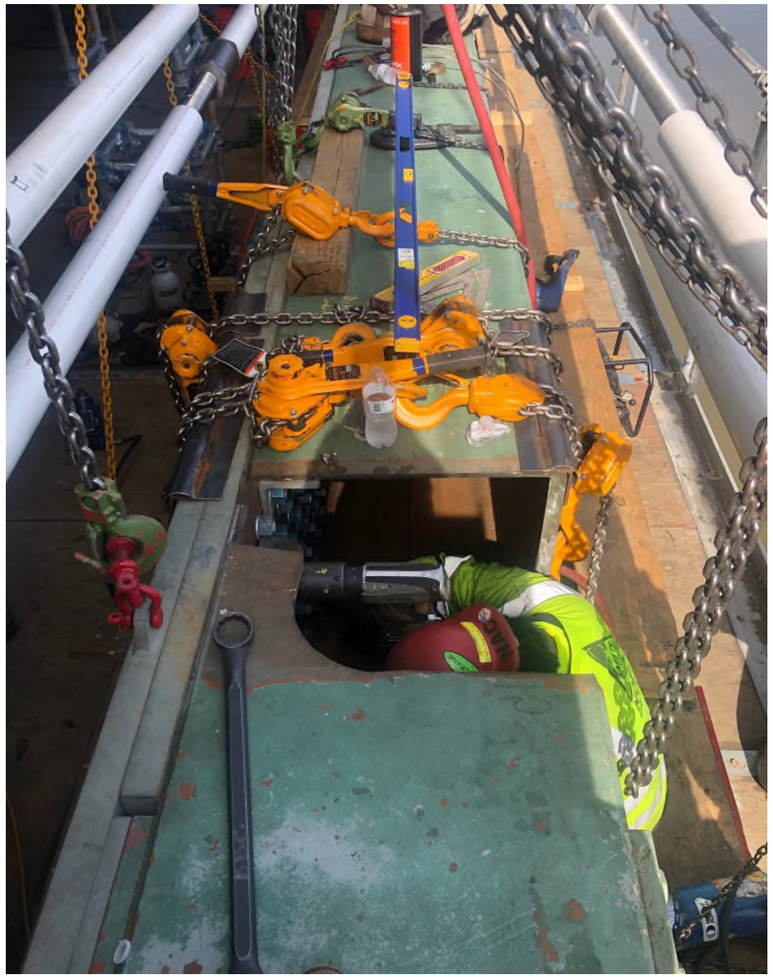
Day 43





Squaring of the Box





Phase 2 Completion

- Final Painting
- Phase 2 Complete

Phase 3 Repairs

Inspection, Testing, and Repair for long-term reliability

Phase 3 – Inspection

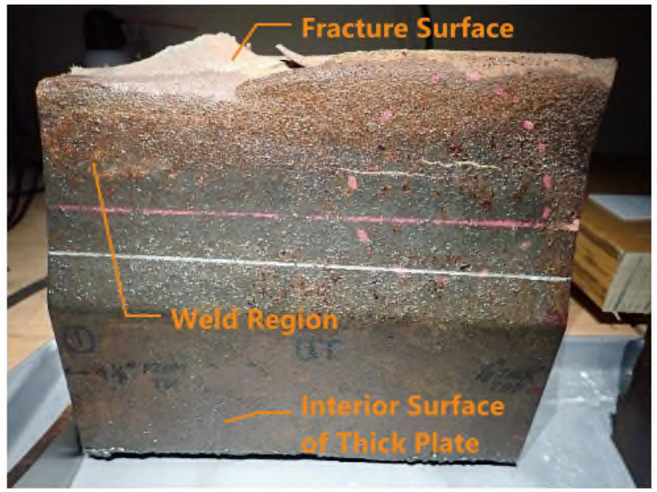
Day 15 - Day 59

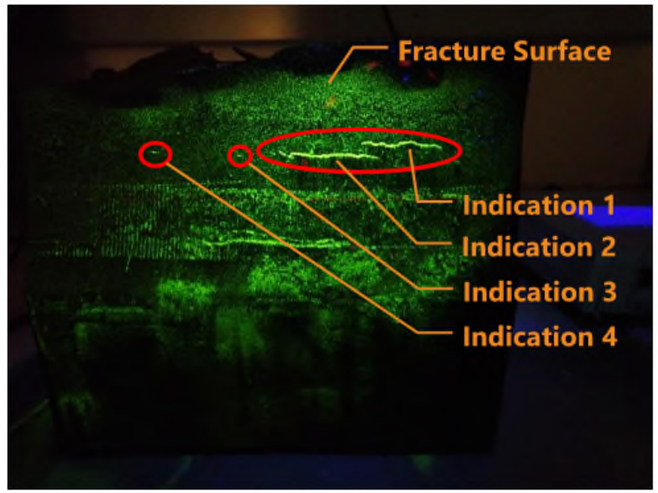
- Full Penetration Butt Weld detail typical throughout structure
  - Potential for similar defects
  - Prevent future failure
- Arch Tie Members and Hanger Pins (Approx. 500 welds)
  - HNTB contracted CAN-USA
  - June 1st to June 23rd
- Arch Truss Members (Sampling)
  - MBI contracted Fickett
  - June 7th to June 11th and June 23rd to 25th

NDT Inspection of Arch Rib Member

Phase 3 – PAUT Recalibration

- WJE Examination of Fracture
  - Verify CAN-USA system setup sensitivity as QA/QC measure
  - Utilize confirmed defects from extracted fractured section for PAUT data reinterpretation
  - Not much data available for ASTM A514 Steel
- WJE concluded CAN-USA original setup accurate for data collection
- CAN-USA identified additional 17 rejectable welds for a grand total of 46





WJE Recalibration Testing

(WJE PAUT Calibration and Verification Testing Memo)

Fracture Analysis

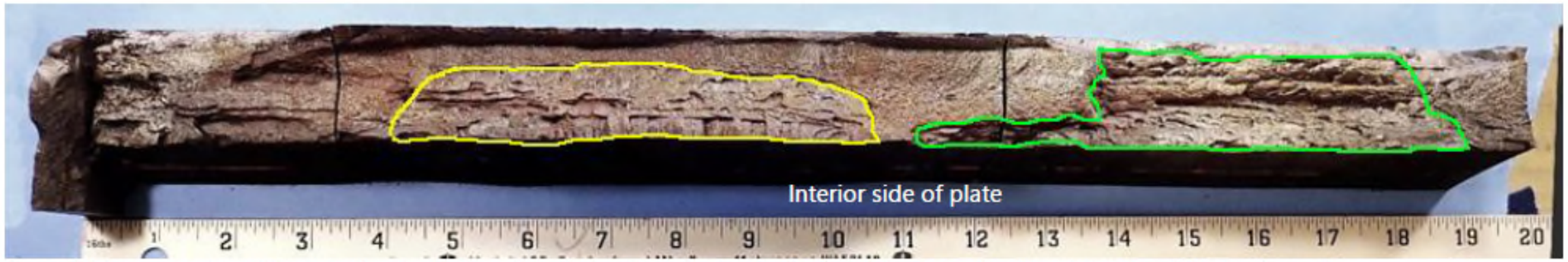


Figure 20. Lower portion of fracture showing Primary Preexisting Crack Region (yellow) and the Secondary Preexisting Crack Region (green).

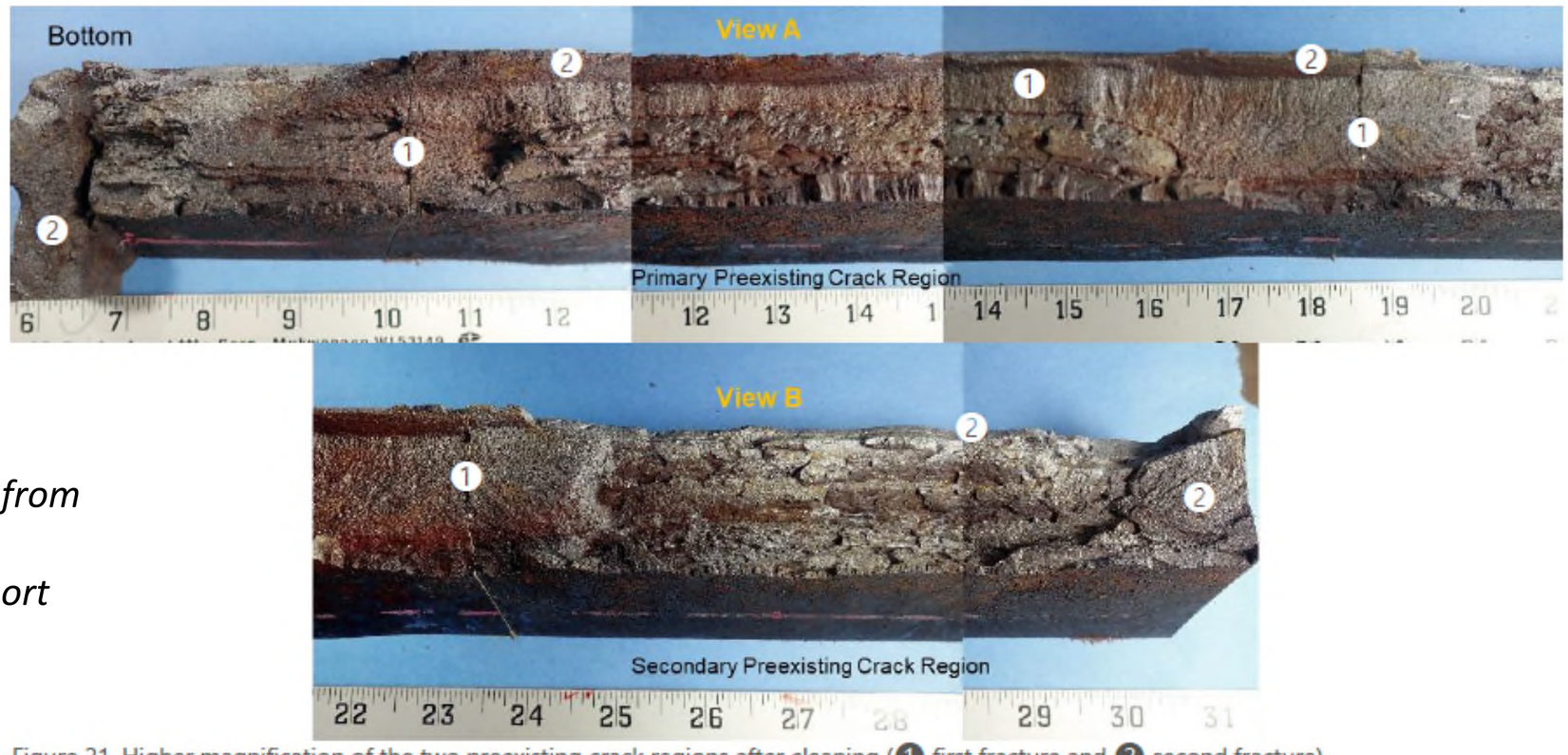


Figure 21. Higher magnification of the two preexisting crack regions after cleaning (❶ first fracture and ❷ second fracture).

Figures obtained from WJE Fracture Investigation Report

Fracture Analysis

Figures obtained from WJE Fracture Investigation Report

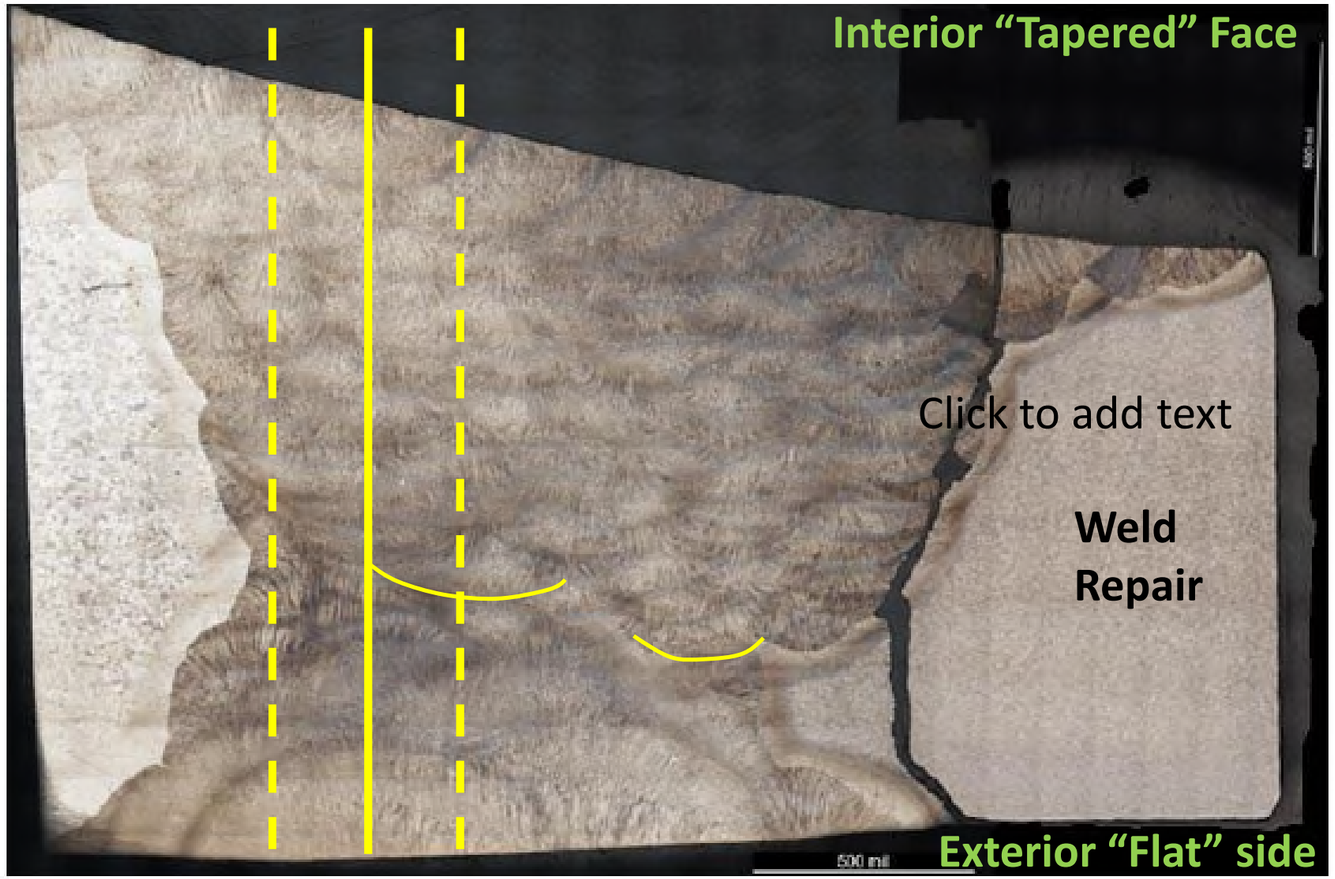


Figure 39. Primary preexisting crack weld profile.

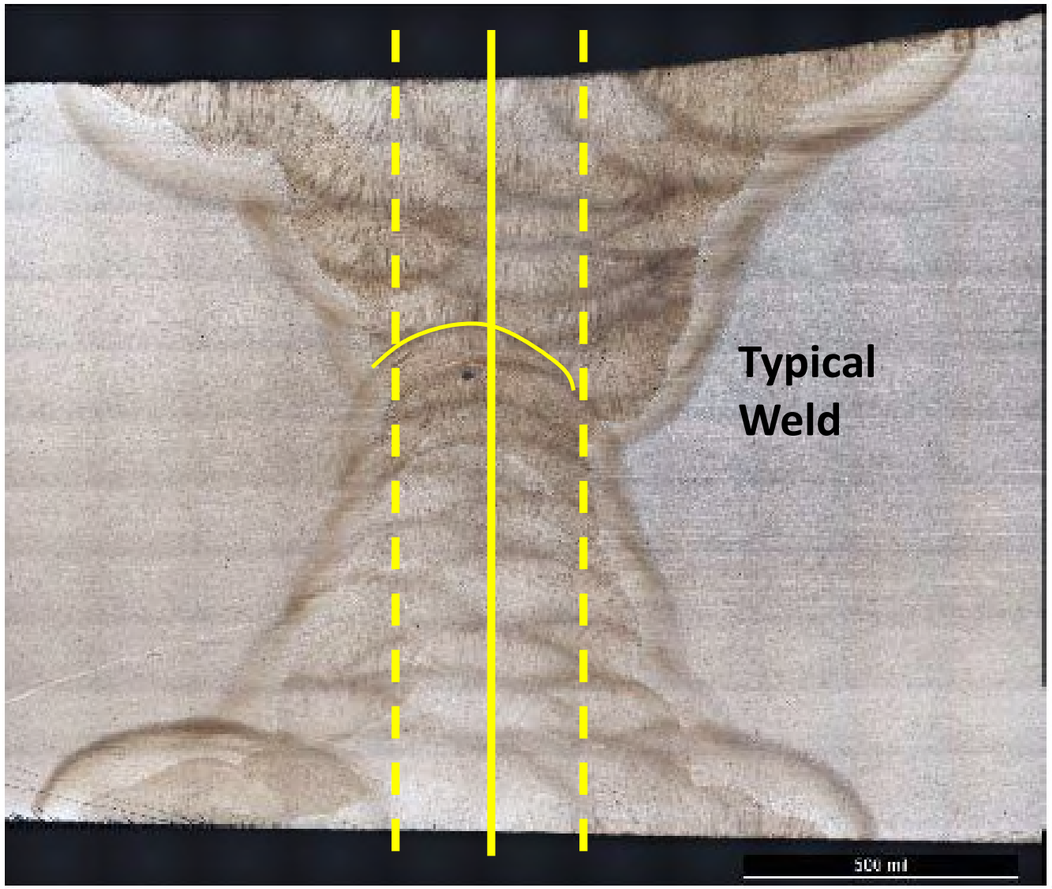


Figure 40. Core Sample SA008E weld profile.

Fracture Analysis

Figures obtained from WJE Fracture Investigation Report

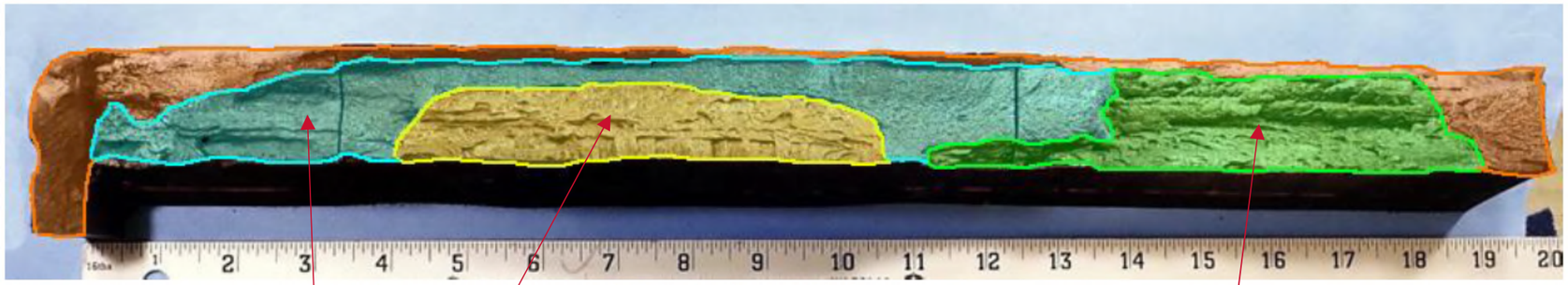


Figure 61. Lower portion of fracture, color-coded to indicate failure sequence.

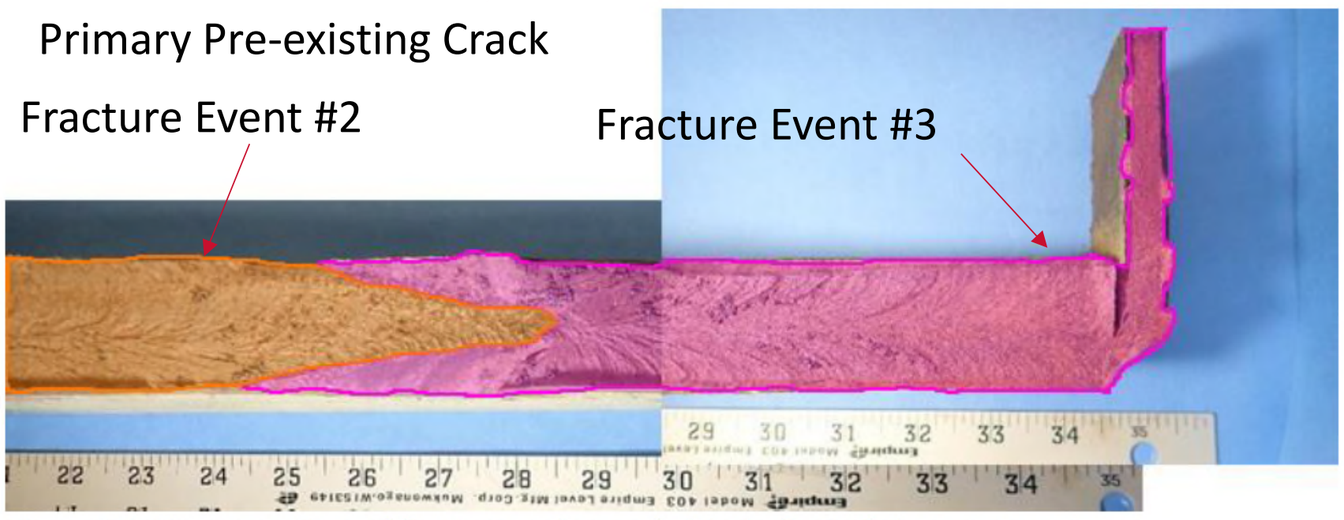
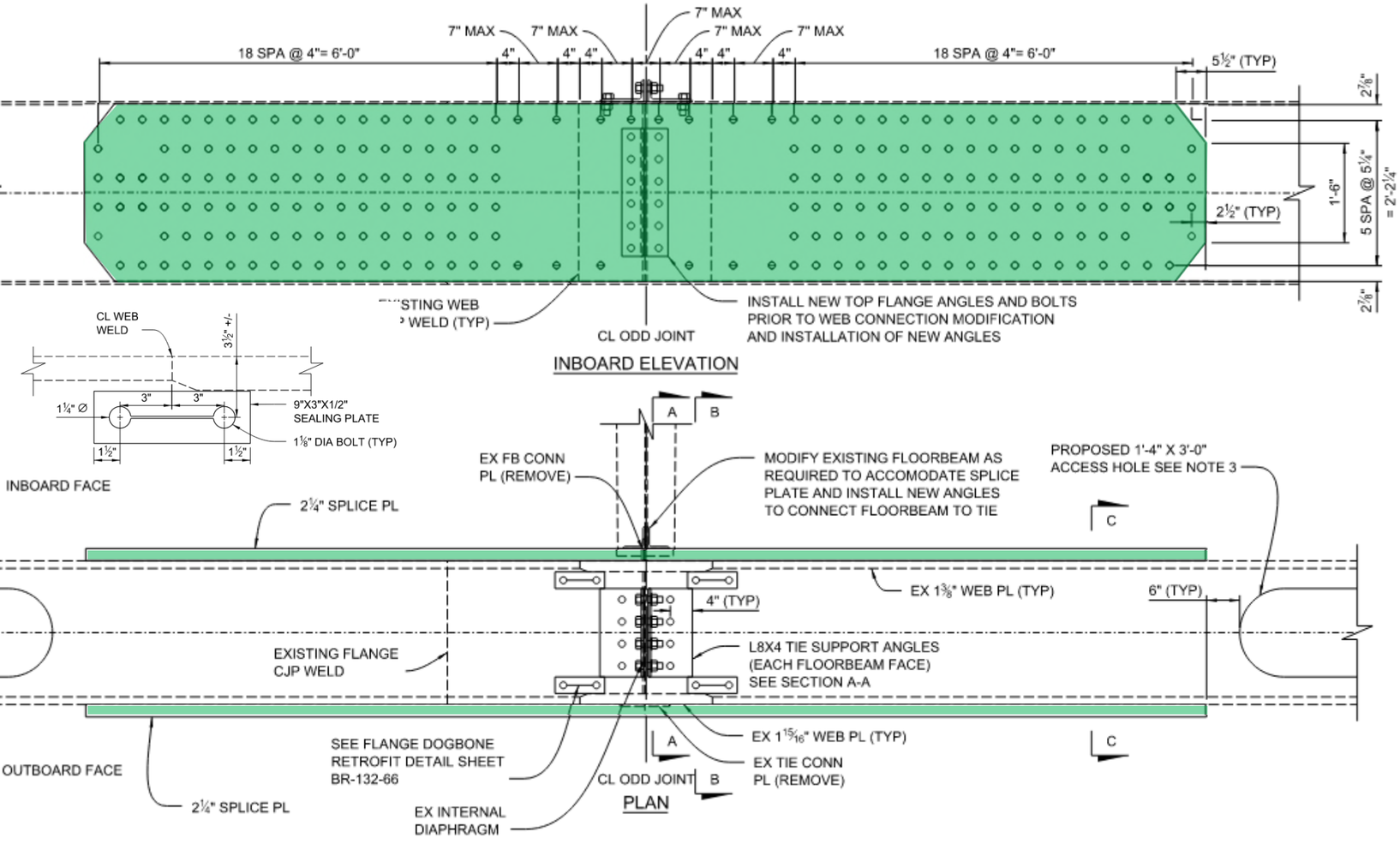


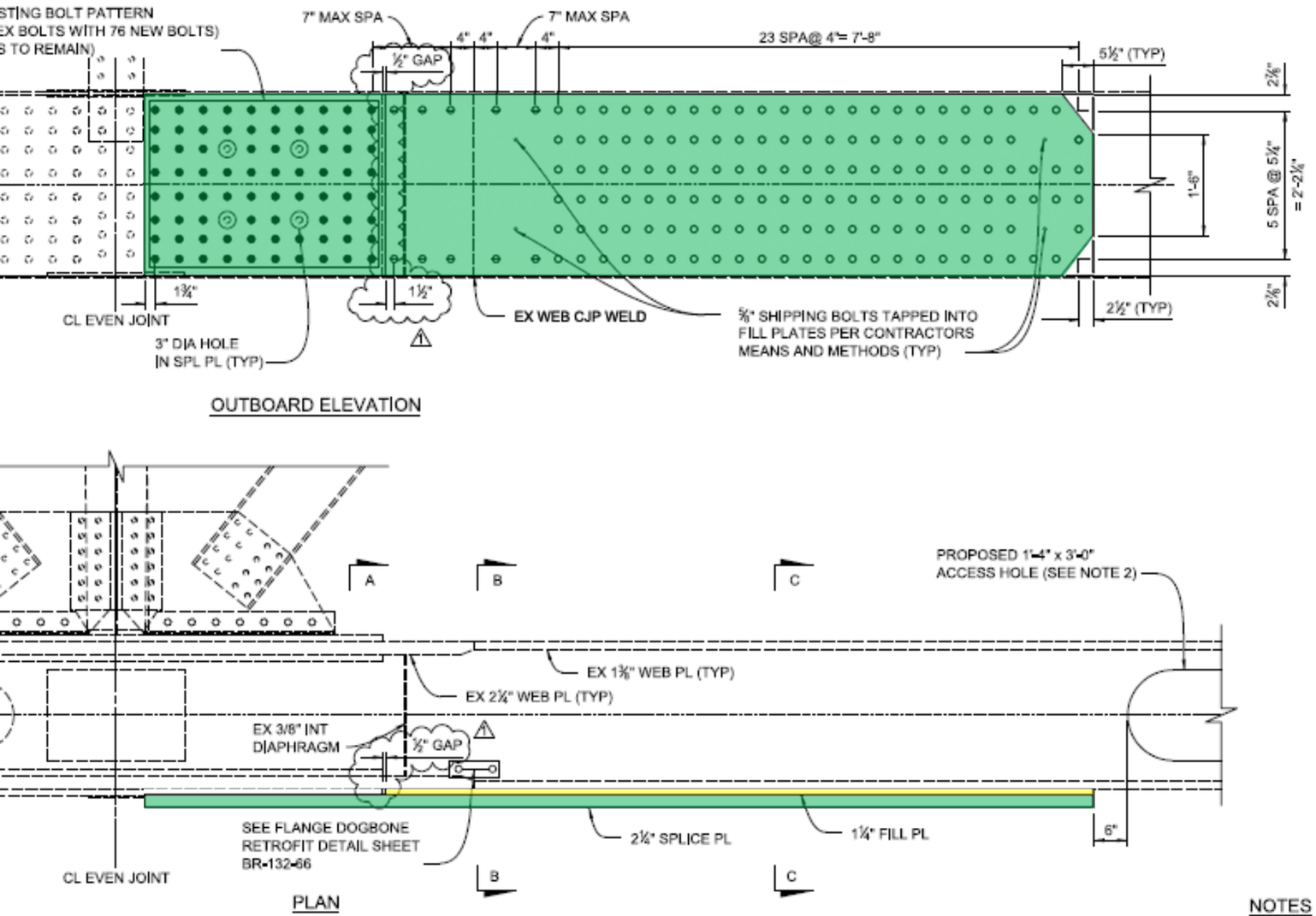
Figure 62. Upper portion of fracture, color-coded to indicate failure sequence.

Phase 3 – Repair Types (Typical Odd)



[Plating with “Dogbone” (17 locations)]

Phase 3 – Repair Types (Typical Even)



Phase 3 – Bridge Reopening

Westbound
August 2nd

Arkansas

Tennessee

Eastbound
July 31st

Lessons Learned

Keys to success

Lessons Learned

- Collaboration
  - Everyone with a Common Goal
  - Commitment of every single team member!
- Communication
  - Internal and Externally
  - Many moving pieces and parts
- CM/GC Benefits
  - Risk Reduction
  - Improved Constructability
  - Material Procurement / Schedule
  - Contractor Risk Sensitivity

By the Numbers

PHASE 1

30,000 LBS
of structural steel redundancy plating to stabilize the Tie Girder

448
Temporary bolts required to install the plates

Total Repair Cost = $9.7M

PHASE 2

108,000 LBS
of structural steel redundancy plating added to the Tie Girder

Over 4,400
Permanent Bolts used to connect the plates

1,424 Feet
of 3” diameter High-strength Post tensioning rods utilized in the repair procedure

1.2Million +
Pounds of tension removed from the fractured section and put on the composite section

PHASE 3

17 Welds
were plated for a total of 78,000 LBS of structural steel

Over 4,000
Permanent Bolts used to connect the plates

1,202 ft
of welds inspected and tested in the 472 but welds of Tie Girders

29
Additional weld defects ground or cored out

Questions ?