massDOT Transportation Innovation CONFERENCE

Accelerated Construction of an Unbraced Network Tied Arch Bridge

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U.S. Department of Transportation Federal Highway Administration

Agenda

- Welcome & Introductions
- Background & Site Constraints
- Network Arch Design & Details
- ABC Considerations
- Bridge Construction & Move
- Q&A

BUREAU of BRIDGES and STRUCTURES

Welcome and Introductions

Mike LaViolette, P.E., P.Eng.
National Bridge Practice Leader

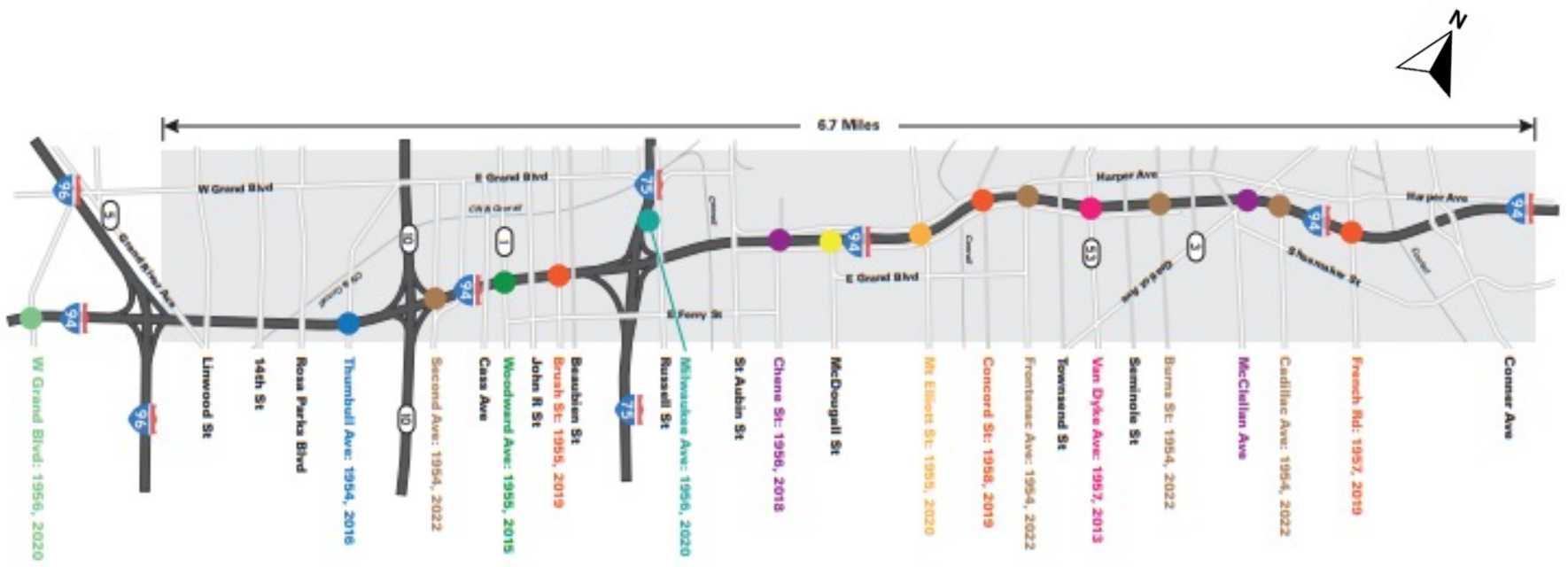
Charlie Swanson, P.E.
New England Bridge and Structures Section Leader

I-94 Modernization Project

Background & Site Constraints

Arch Bridge Concept Inception

- MDOT's Advance Bridge Project Goals:
  - Replace 8 critical bridges in advance of the full corridor reconstruction
  - Utilize Accelerated Bridge Construction (ABC) methods
  - Construct a signature structure in the corridor



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Second Avenue Bridge – Network Tied Arch

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Why a tied arch span?

- This design provides flexibility:
  - Eliminates the need for a median pier and a future pier shift during the corridor reconstruction
  - Allows adjustment of freeway alignment shift (up to 40 ft)
  - Shallower structure reduces profile grade increase on 2nd Ave
  - Provides aesthetic highlight for entire corridor

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Second Avenue Bridge Construction

- Skewed, unbraced network tied-arch
  - First bridge of this type in the US
  - Skewed to accommodate frontage roads and adjacent properties
  - Unbraced - There are no lateral bracing members between the arch ribs.
  - Network refers to the orientation of cables, they will be crossed from the top of the arch to the part of the structure supporting traffic.
  - Tied-arch -the ends of the arch rib are “tied” so they cannot spread laterally as the weight of the concrete deck, vehicles and pedestrians are applied.

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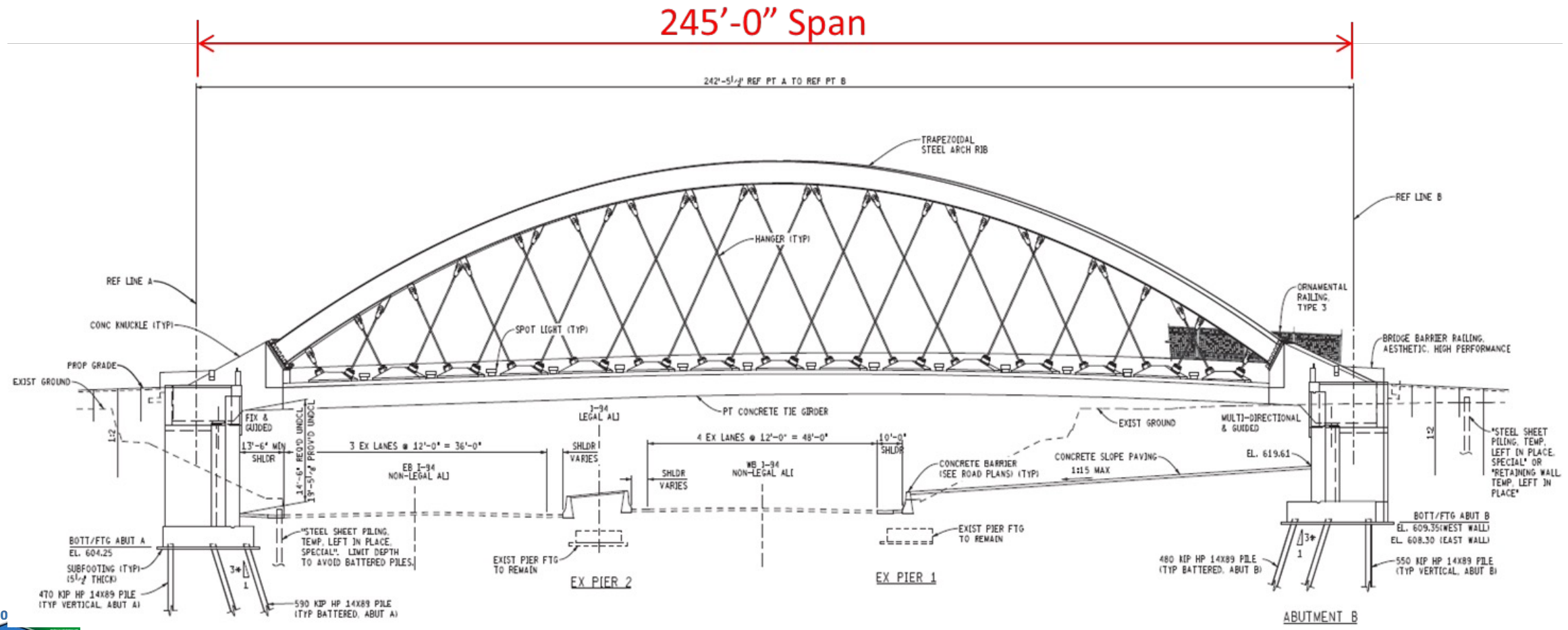
Site Constraints and Staging Area

I-94 Viewpoint at Second Avenue

I-94 Modernization Project

Network Tied Arch Design & Details

Second Avenue Bridge – Network Tied Arch



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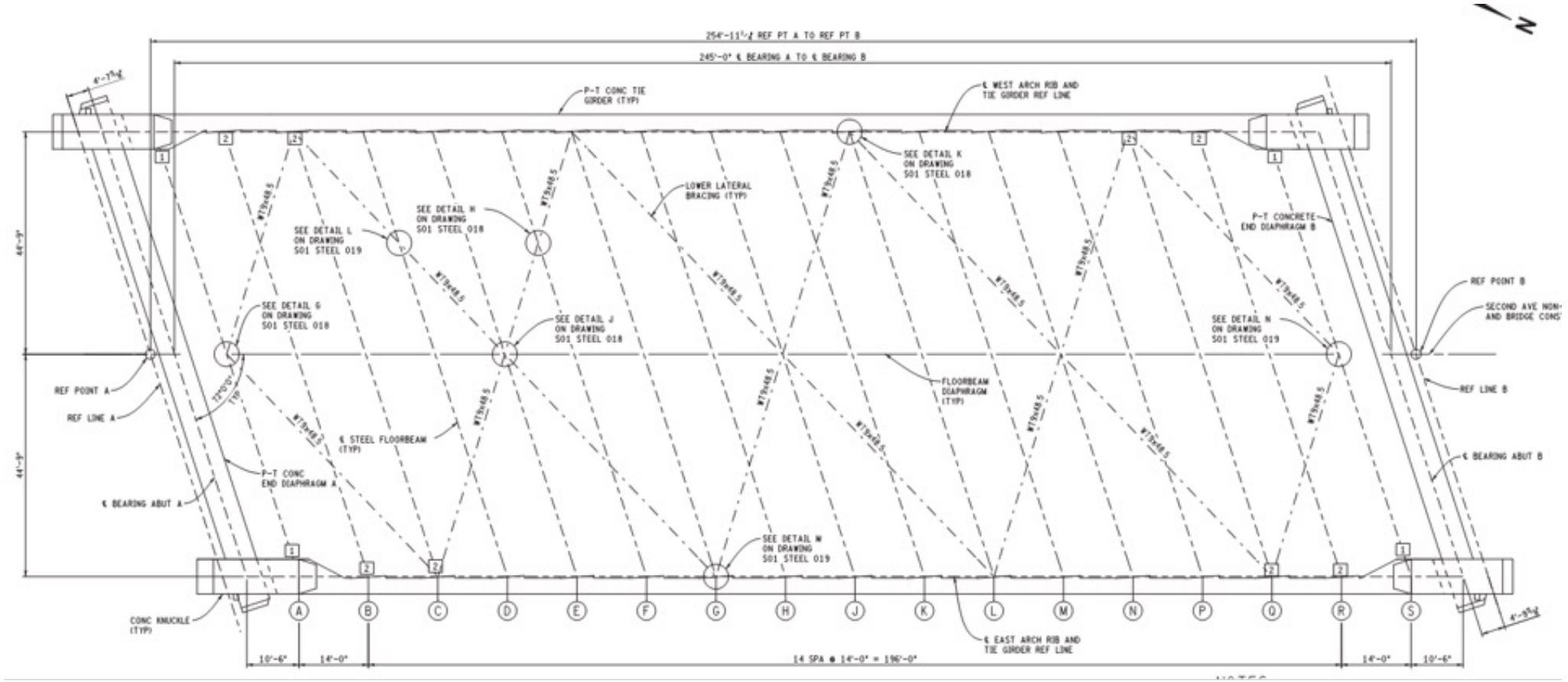
Framing Plan



Skew = 18 degrees and asymmetrical vertical curve

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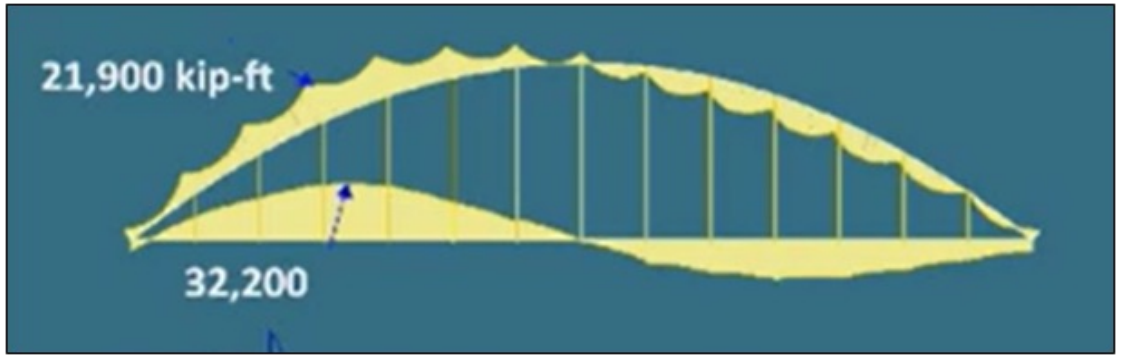
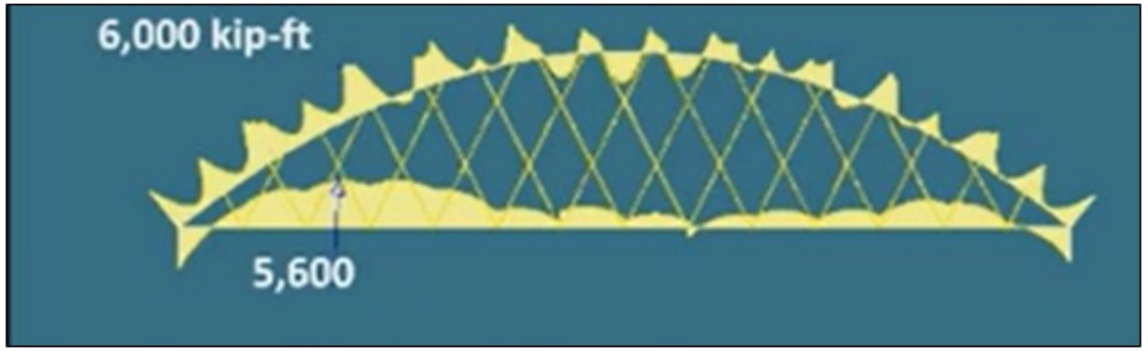
Network Arch Advantages

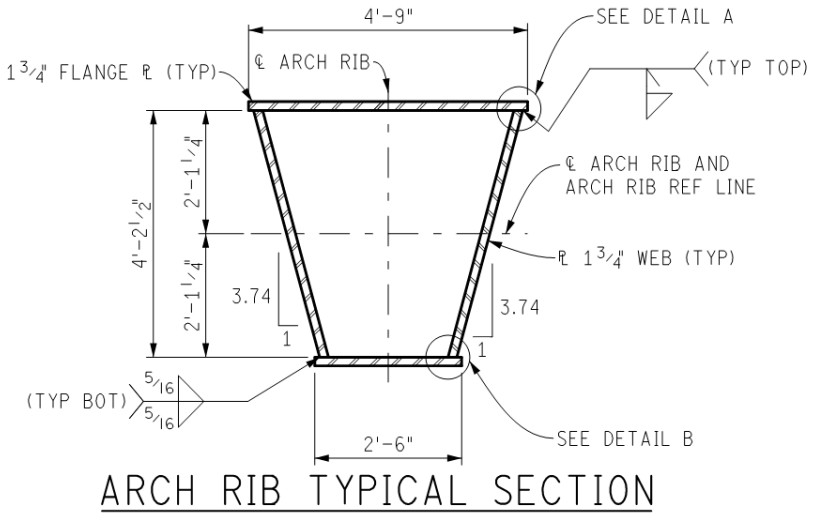
- Network arch is more efficient than traditional tied arch structure
- Inclined hangers greatly reduce arch rib moment and shear forces
- Increased stiffness vs. vertical hangers
  - Dead and live load deflections approx. 1/10 of vertical hanger systems
- Increased redundancy with more efficient members





Credit: Gregor Wollman - HNTB

Arch Rib Details



ARCH RIB TYPICAL SECTION

Hangers

- 3 1/8” dia. ASTM A586 Structural Strand
- Class A Coating Inner Wires
- Class C Coating Outer Wires

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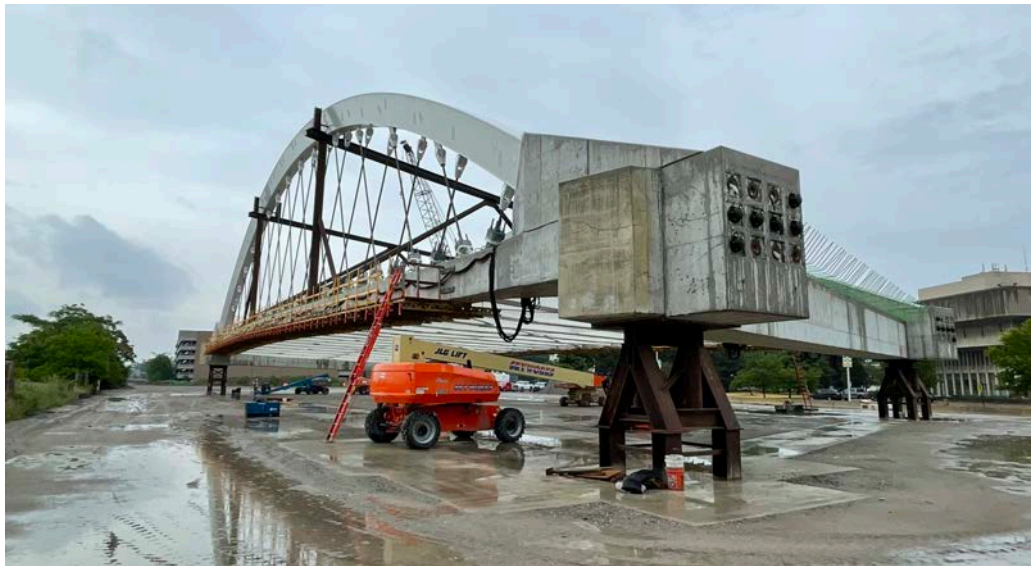
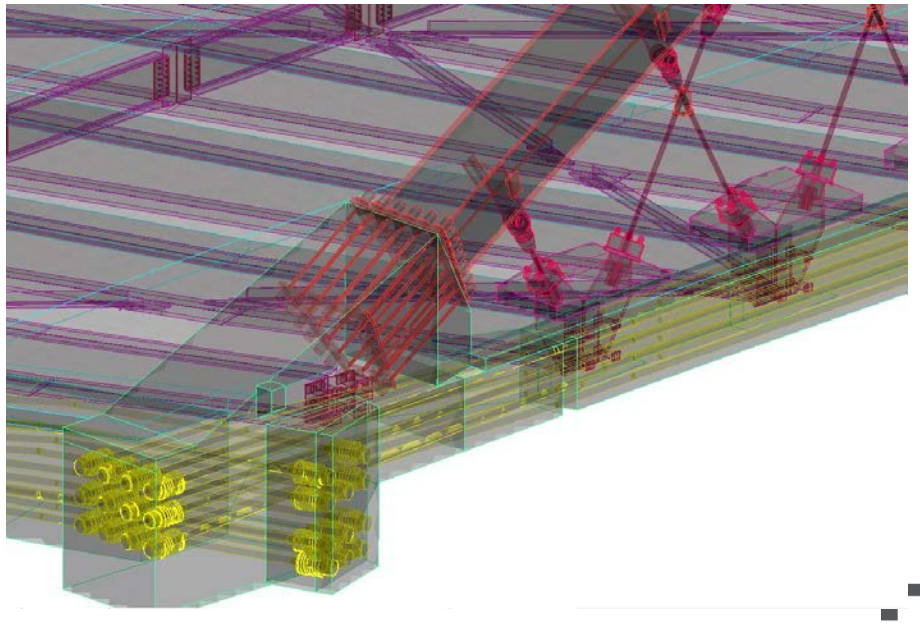
Post-Tensioning Details

- Tie Girders:
  - 12 – 19 strand tendons (0.6” dia.)
- End Diaphragms:
  - 11 – 19 strand tendons (0.6” dia.)
- Knuckle Base Plate:
  - 20 - 1 3/8” Grade 150 PT Bars





I-94 Modernization Project

ABC Considerations

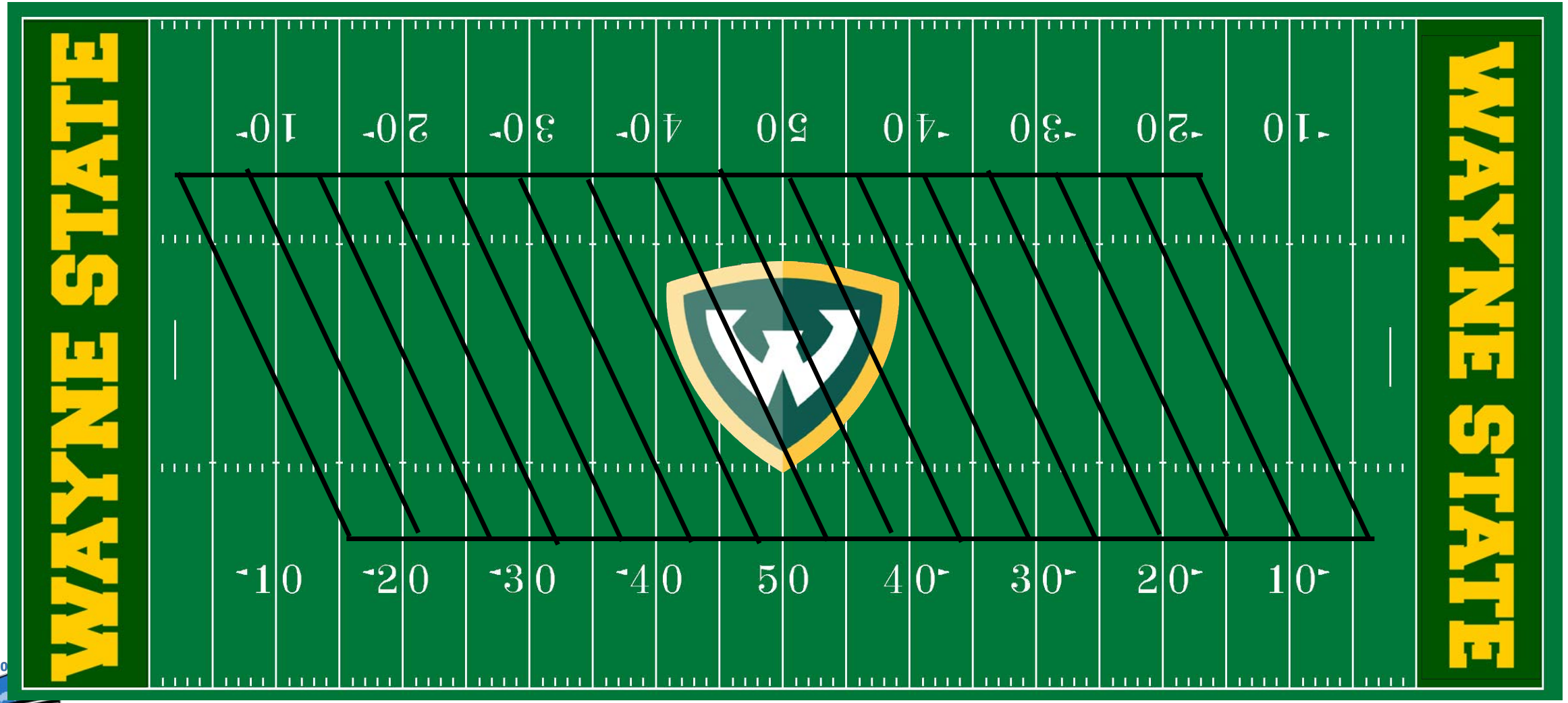
ABC Alternatives Considered

- Offsite full assembly and SPMT move
- Offsite skeleton assembly and SPMT move ✓
- Arch

Self-Propelled Modular Transporters (SPMTs) are a sophisticated flatbed trailer system supported by multiple independently controlled axles.

Second Avenue Bridge Size Comparison

Span 245’, Width 96’6”, Skew 18 degrees



Industry Outreach During Structure Study Phase

- First web meeting – designer presentation on project constraints
- Series of confidential, one-on-one meetings with individual heavy-lift contractors
- Identify feasible bridge move methods
- Establish basis of design

ALE SMARTER, SAFER, STRONGER

BIGGE Established 1916 CRANE and RIGGING CO.

BARNHART

EMMERT INTERNATIONAL

FAGIOLI

MAMMOET

sarens group

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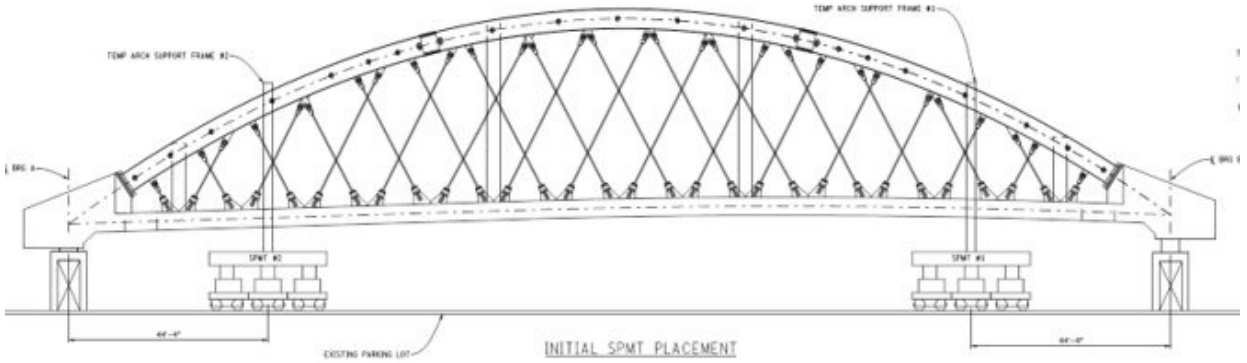
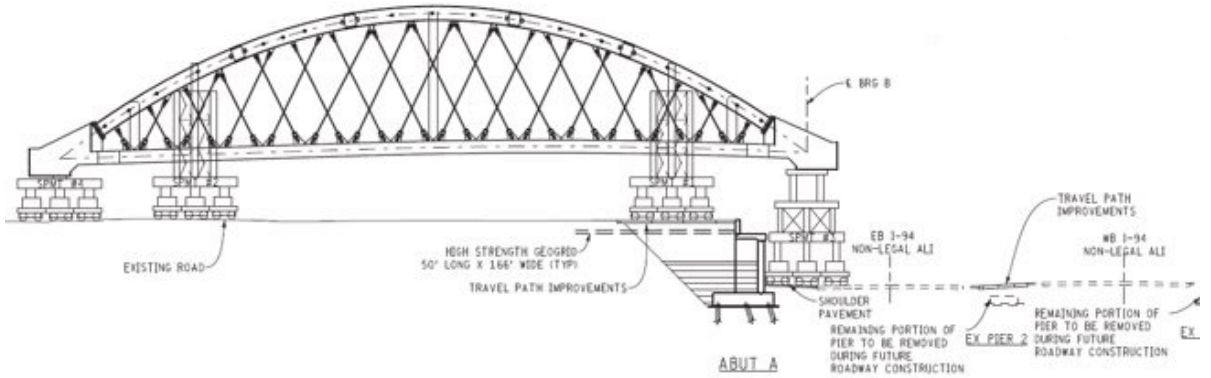
I-94 Modernization Project

Construction Engineering

Assumed Erection Analysis

- Design phase assumed an erection sequence based on industry outreach
  - SPMT's located inboard of knuckles
  - Handoff to SPMT's for I-94 launch
  - Temporary end diaphragms
  - Used to approximate locked-in construction stresses
  - Drove permanent structure geometry
- Special provision requiring contractor to furnish analysis and erection plan consistent with means and methods





Proposed Erection Analysis

- SPMT's located under each knuckle along CL Bearing
- End diaphragms poured prior to move
- Skidding system to transfer bridge to SPMT's on I-94
- Erection plans and calculations totaled nearly 1,700 pages

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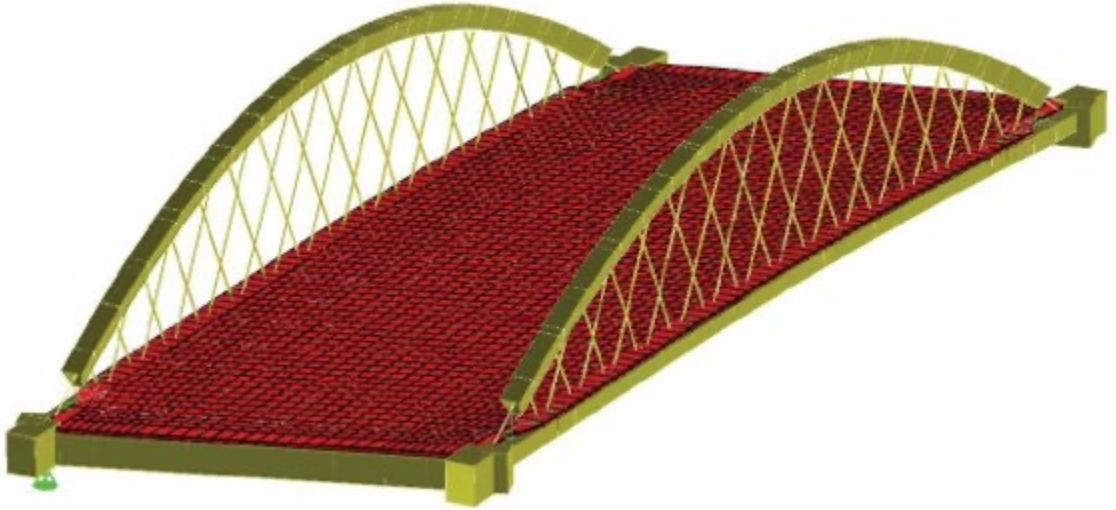
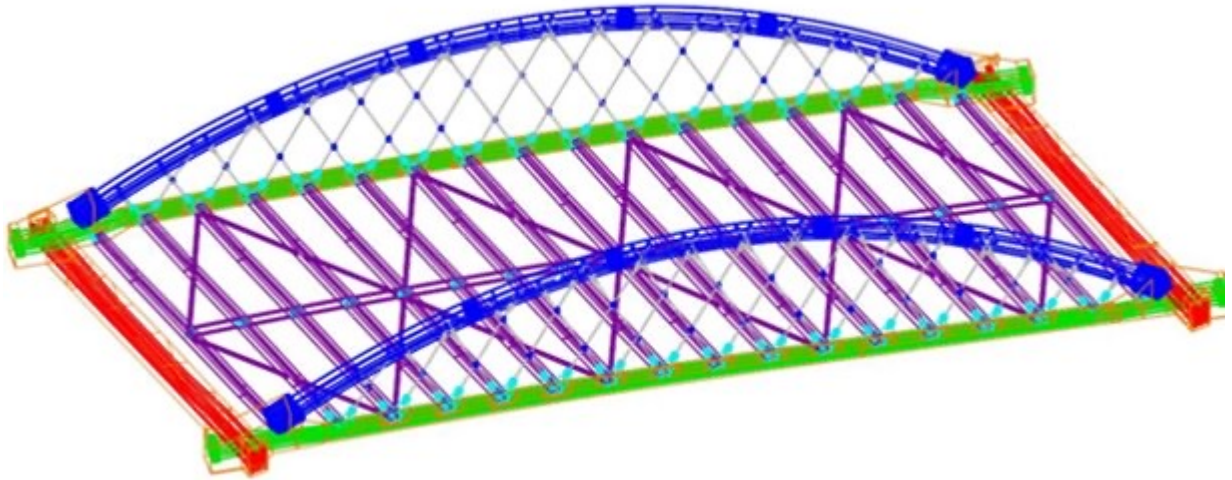
Analysis Reviewers

- Multiple reviews of erection and move analysis
  - Engineer of Record
  - MDOT construction and materials staff
  - Independent Peer Review Engineer
- Collaborative effort with Erection Engineer to reduce risk and resolve concerns

Finite Element Modeling

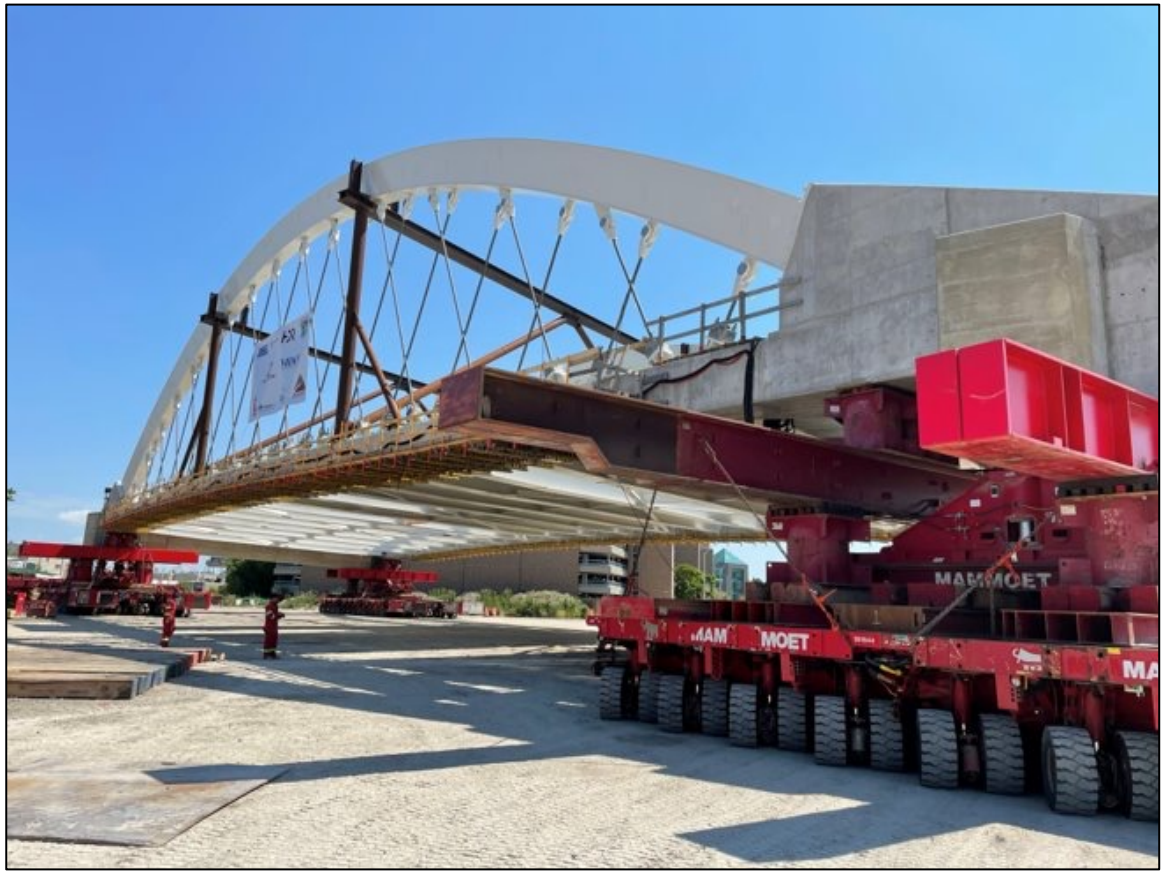
- Total of three independent models and calculations developed
  - Erection Engineer
  - Engineer of Record
  - Independent Peer Review Engineer
- Concurrence between models obtained prior to acceptance





Bridge Move Preparation

- Bridge Move Document
  - Move Procedure
  - Schedule
  - Safety Procedures
  - Communication Plan / Contact Info
  - Equipment
  - Drawings & Calculations
  - Monitoring Plan
  - Crowd Control Plan
- Pre-move meeting one month prior with stakeholders and Contractor



I-94 Modernization Project

Bridge Construction & Move

Floor System Assembly – Fall 2020

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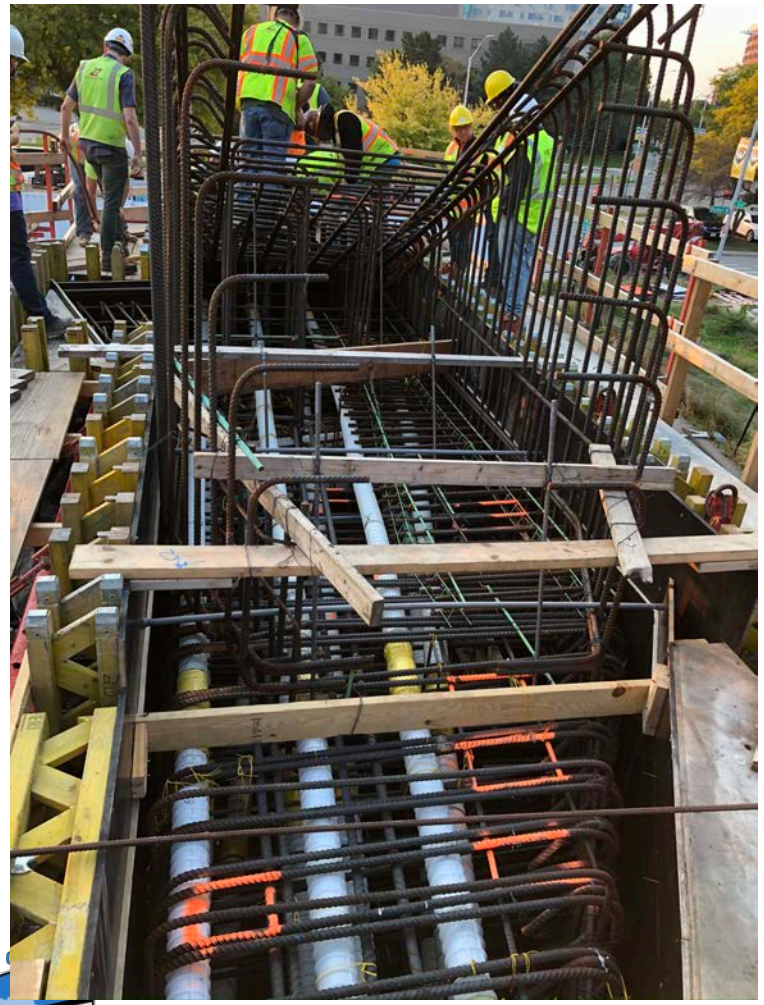
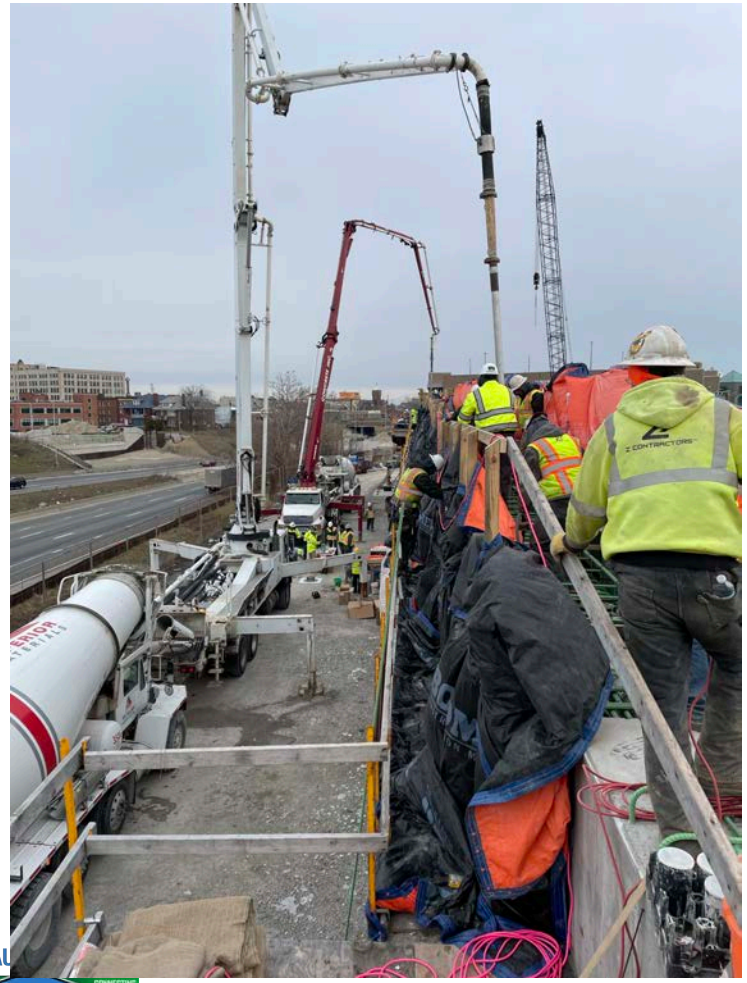
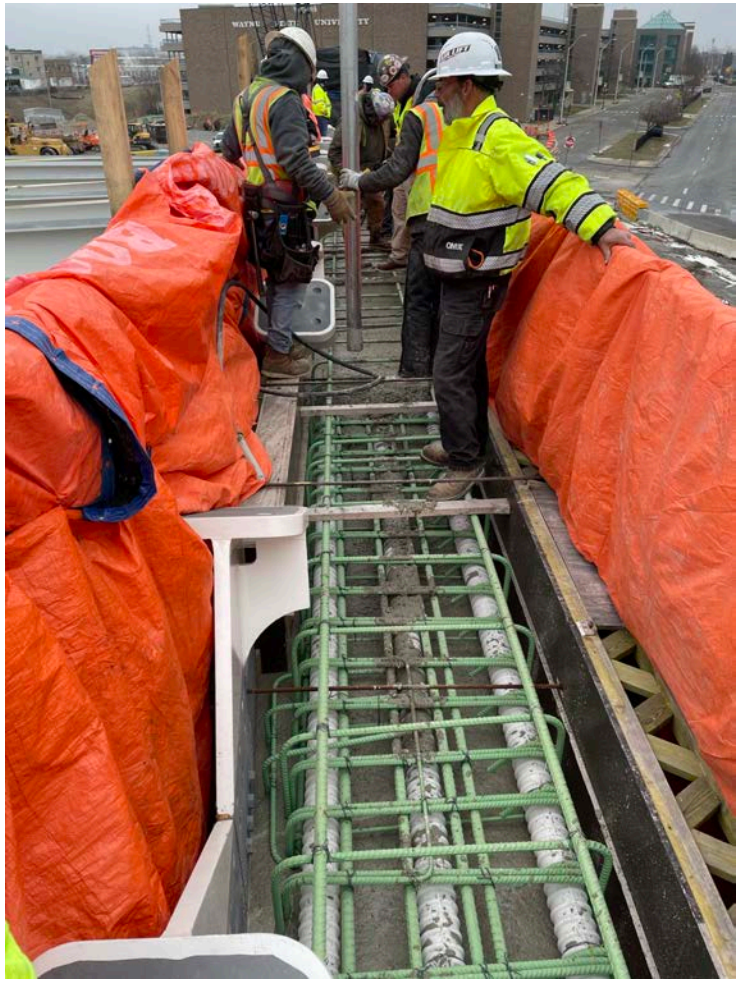
Tie Girder and Knuckle Mockup

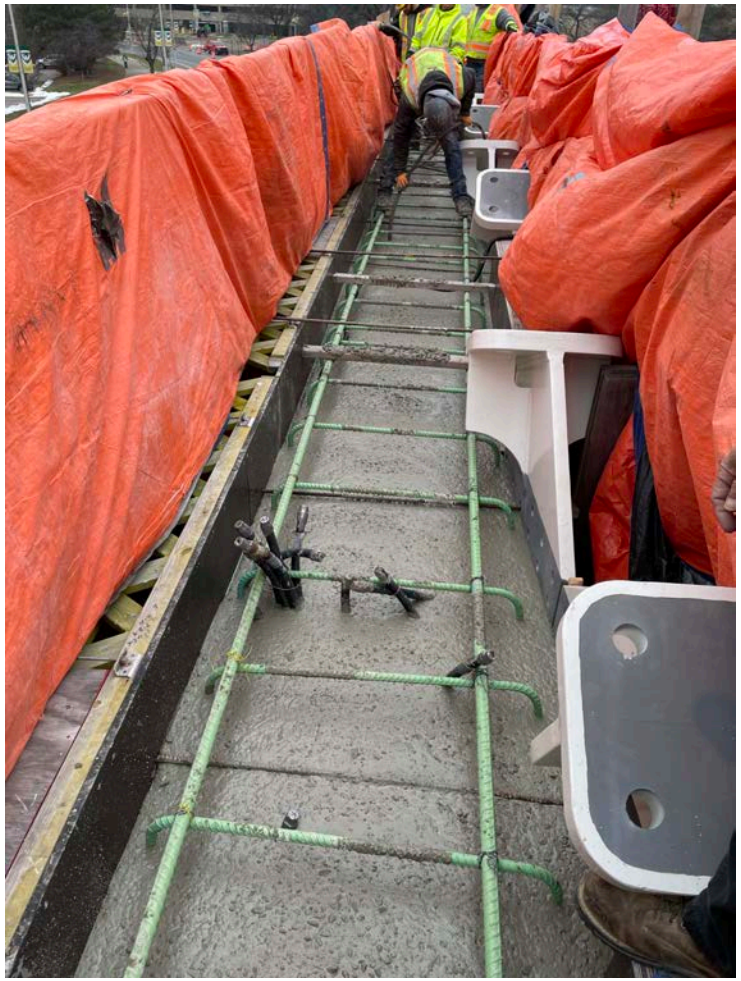


BUREAU of SPANNING SAFELY EFFICIENTLY and STRUCTURES

Tie Girder Concrete Placement







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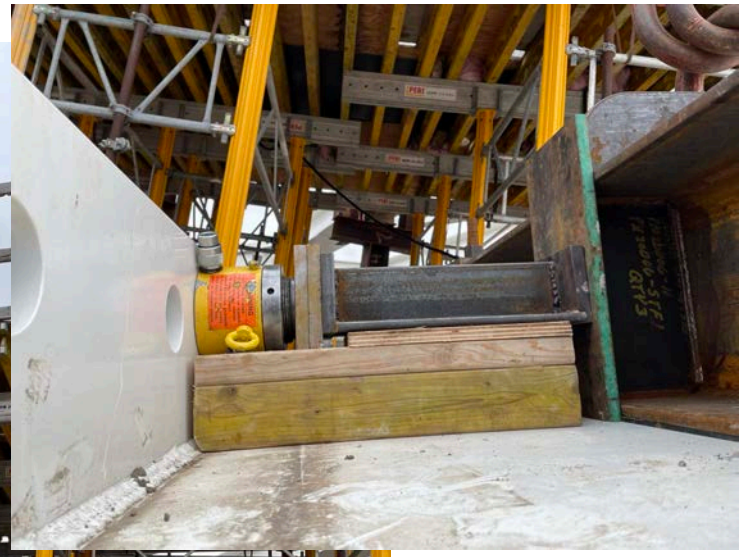
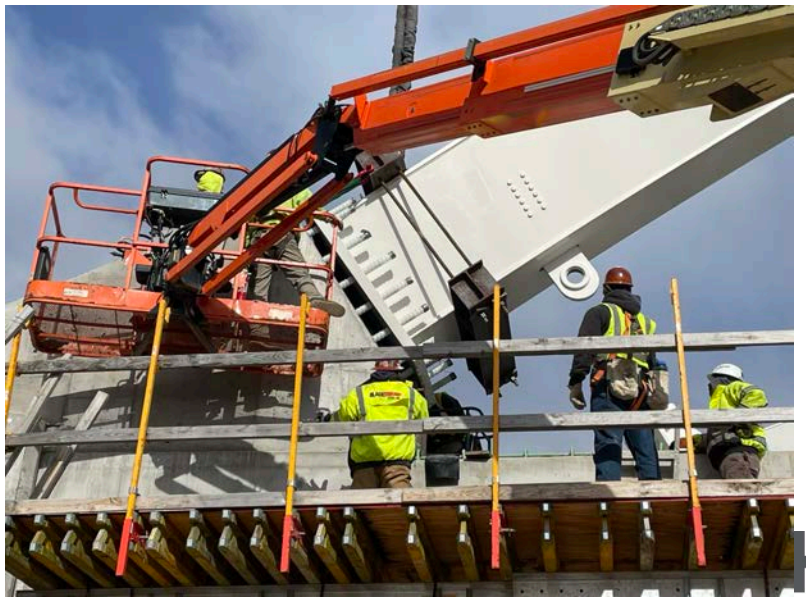
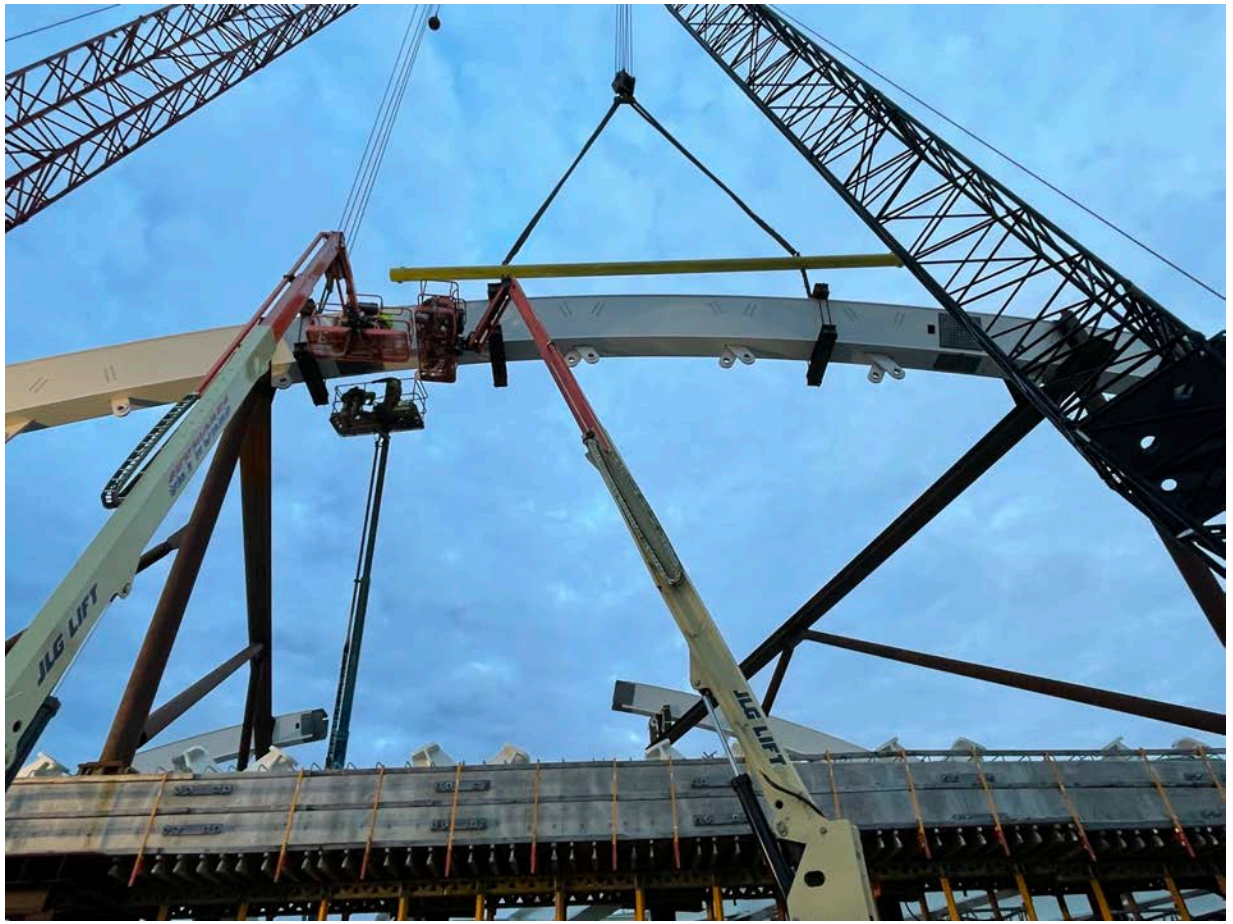
Arch Erection





Arch Erection



Arch Erection

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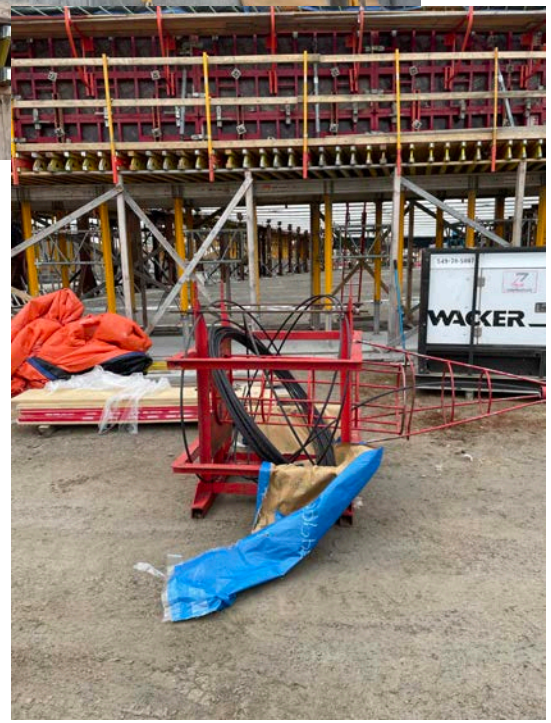
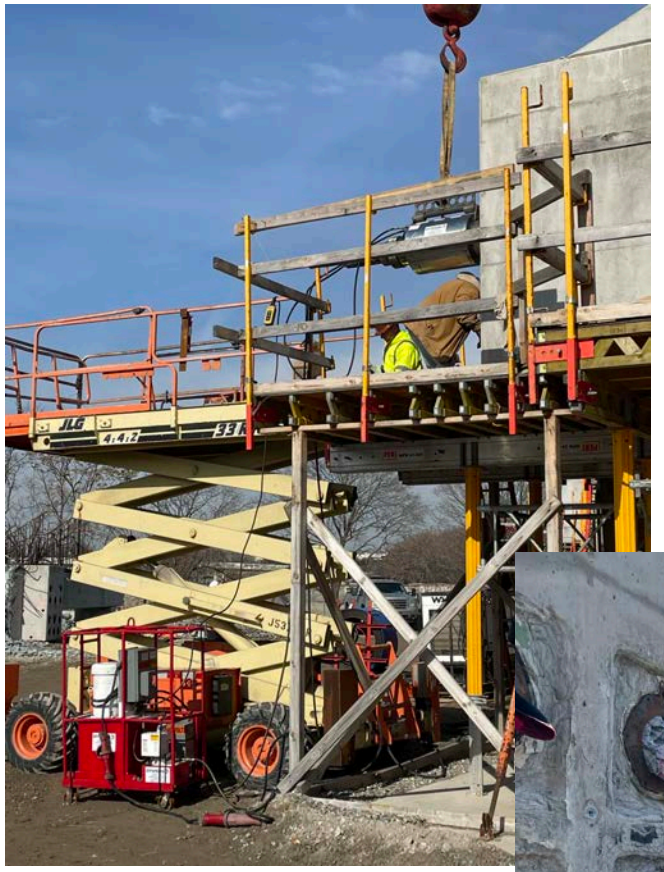
Post-Tensioning (Stage 1)





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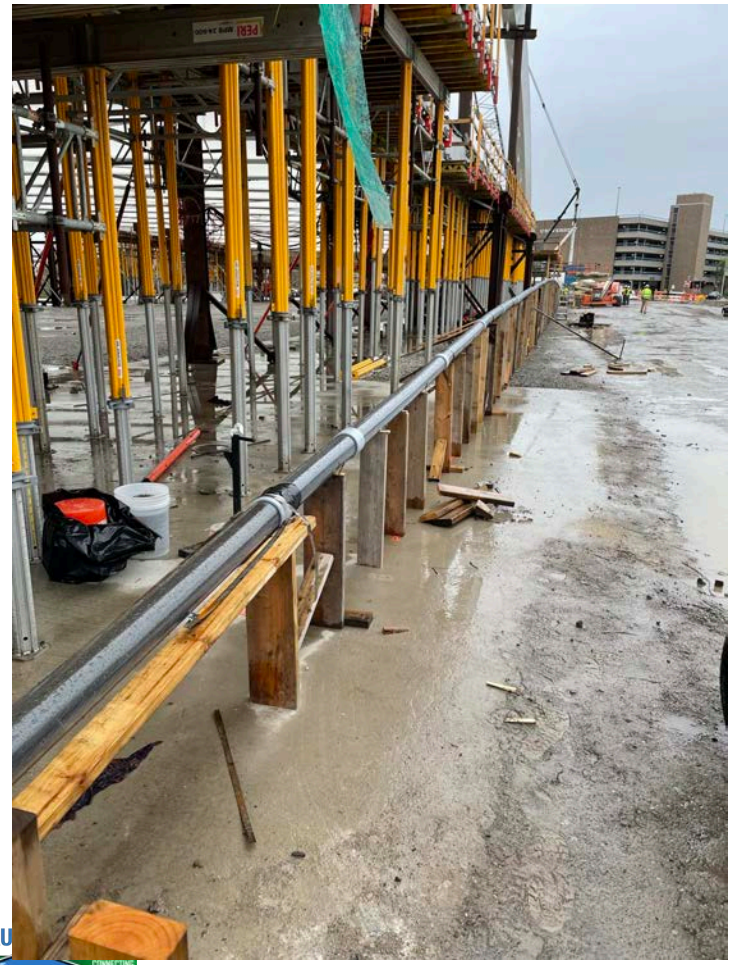
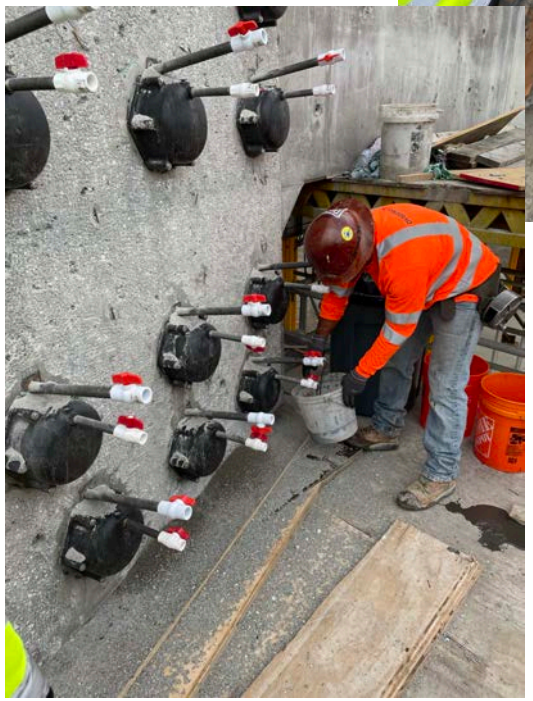
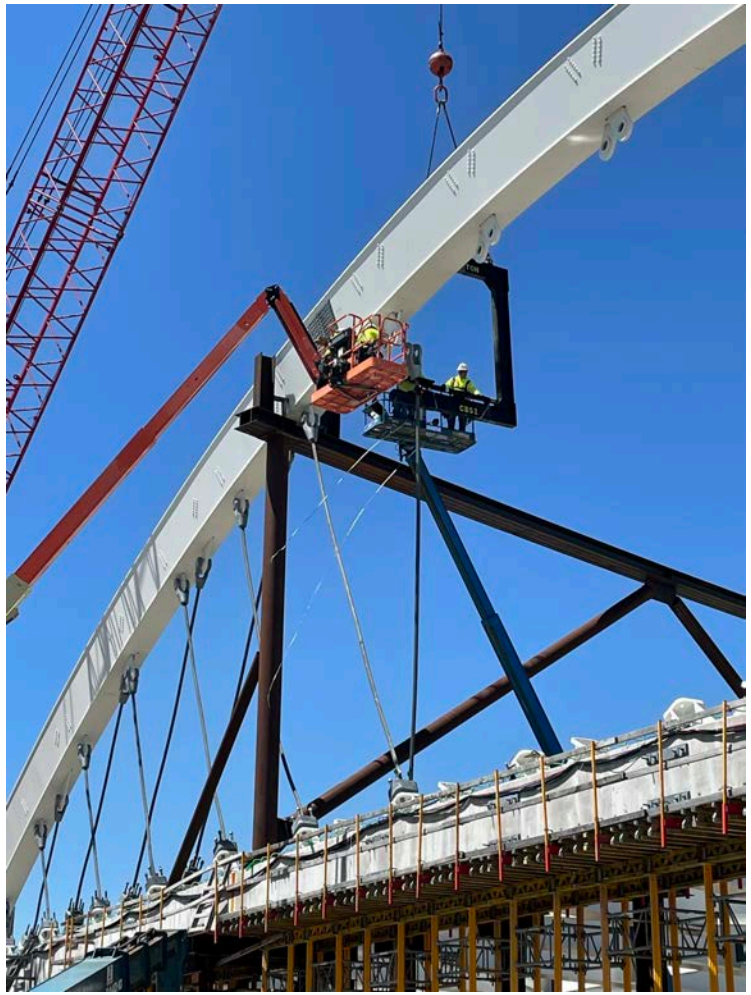
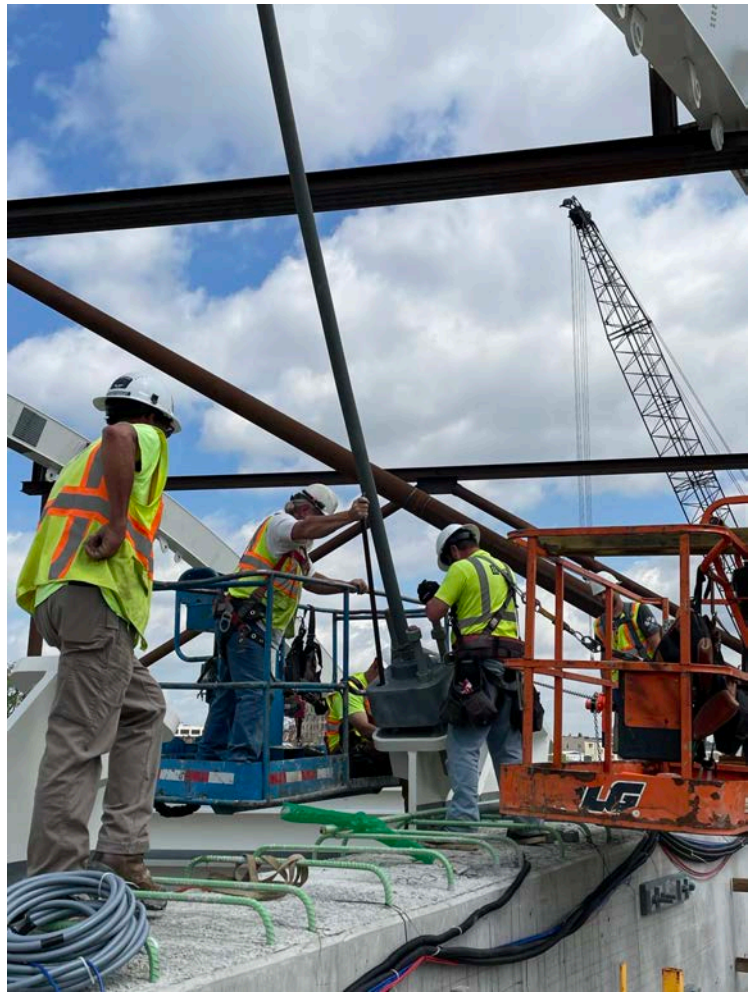
Grouting





Hanger Installation





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SAFELY
EFFICIENTLY
and STRUCTURES

Hanger Adjustments/Verifications (July 6th & 7th, 2022)

Heavy Movers Arrive (July 6th-8th, 2022)

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HDR

Initial Lift and Temp Support Removal (July 14th, 2022)

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Initial Lift and Temp Support Removal (July 14th, 2022)

Initial Lift and Temp Support Removal (July 14th, 2022)

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Mobilize SPMTs (July 15th, 2022)

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Loading SPMTs (July 16th, 2022)

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Final Preparation for Move (July 18th, 2022)

BUREAU SPANNING CONNECTING SAFELY EFFICIENTLY and STRUCTURES

Final Preparation for Move (July 18th, 2022)

- Monitoring System:
  - Crossed Wires
  - Survey Prisms
  - Total Station

First Move (July 19th, 2022)

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First Move (July 19th, 2022)

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First Move (July 19th, 2022)

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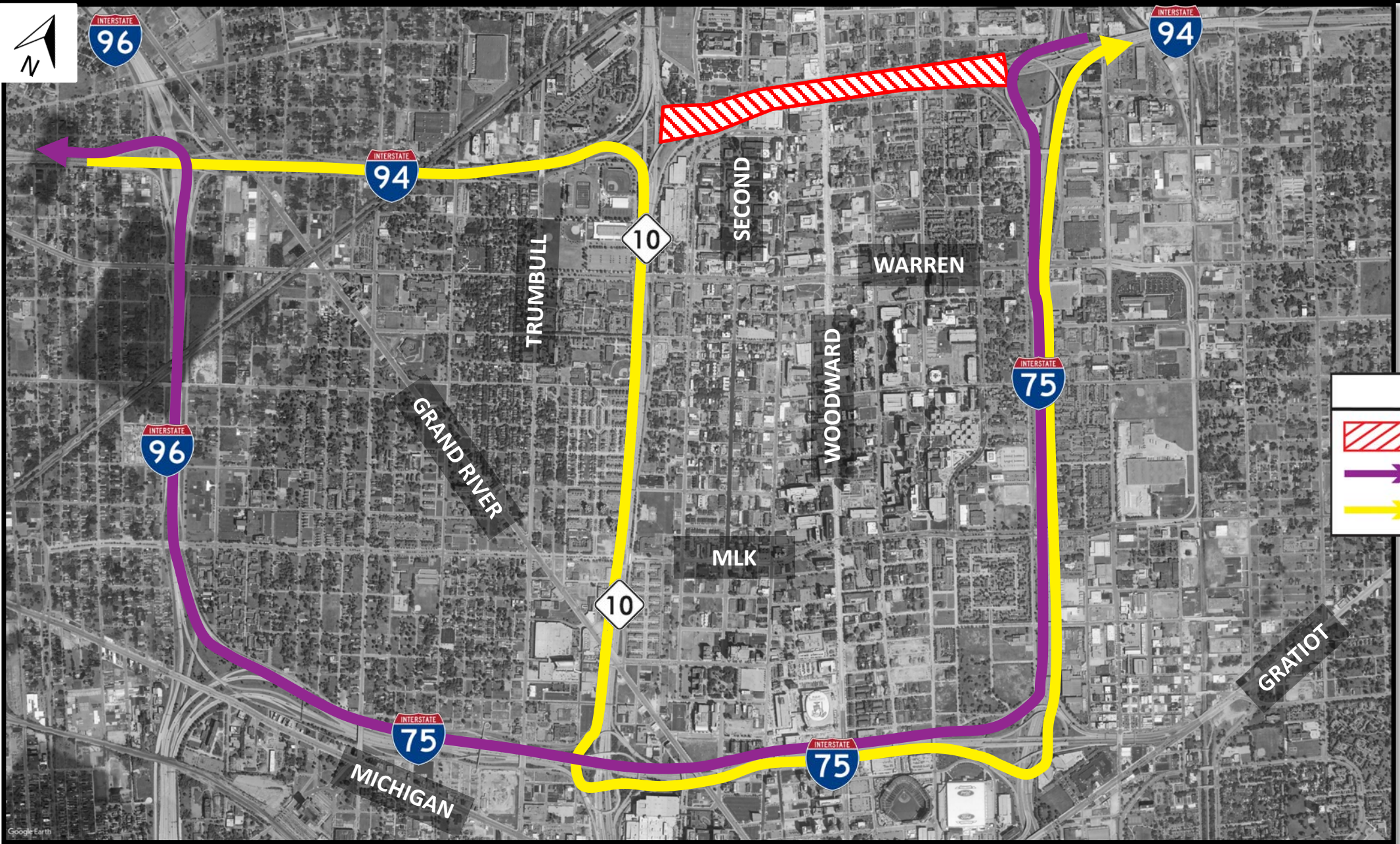
I-94 Full Closure For Bridge Move



The Handoff (July 23rd, 2022)

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Crossing I-94 (July 24th, 2022)

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Crossing I-94 (July 24th, 2022)

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Transfer to Abutments (July 25th, 2022)

BUREAU of BRIDGES and STRUCTURES

Transfer to Abutments (July 25th, 2022)

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Remove SPMTs and Begin Lowering (July 26th, 2022)

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MDOT Michigan Department of Transportation

Lowering to Bearings (July 27th, 2022)

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Welding the Bearings (July 28th, 2022)

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Key to Success is Collaboration

MDOT Michigan Department of Transportation

HDR

TETRA TECH

HNTB

PARSONS

Z CONTRACTORS

JSE JANSSEN & SPAANS ENGINEERING

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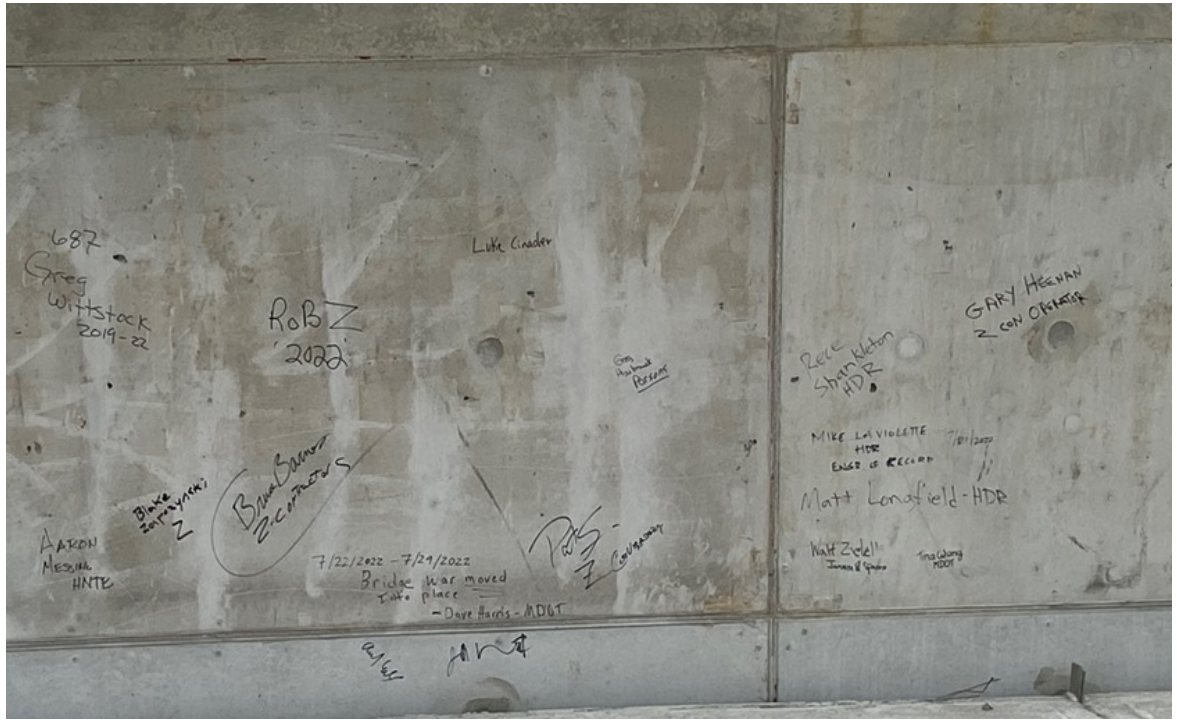
End Diaphragm Signing



Timelapse Video of Bridge Move

I-94 Modernization Project

Conclusions

Conclusions

- ABC projects can be done using D/B/B but might be a better fit for alternative delivery such as CMGC or PDB
- Constructing a mock-up of complex components provides opportunity to address challenges prior to work on permanent structure
- Independent peer review of complex bridge designs is invaluable
- Collaboration between MDOT, design team and contractor remain key to successful project

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Conclusions

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I-94 Modernization Project

Q & A Session

MDOT

Accelerated Construction of Unbraced Network Tied Arch Bridge

Second Avenue Bridge Move – Concept to Construction

INTERSTATE 94

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May 3, 2023