

Presentation Outline

4D Structural Analysis and Design:

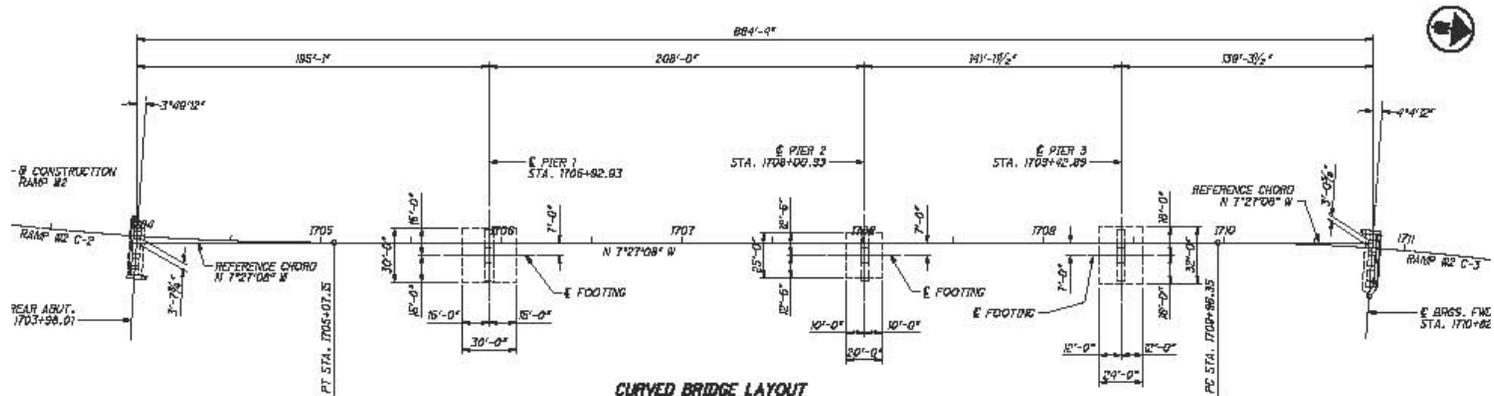
- **Bridge 13B, I71/670, Columbus, OH**
Anthony Peterson, PE (15 minutes)
- **Hwy. 61 Bridge over the Mississippi River, Hastings, MN**
Randy Thomas, PE (20 minutes)

3D Modeling Transportation Infrastructure:

- **Zoo Interchange, Milwaukee, WI**
Chris Johnson (20 minutes)

Questions: (5 minutes)

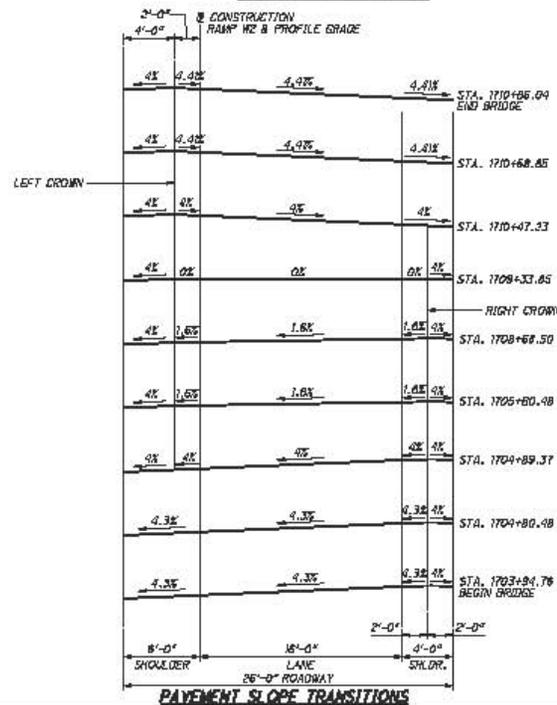
Bridge 13B Plan



CURVE DATA (RAMP #2 C-2)

P.I. = STA. 1702+96.66
 $\Delta = 34^\circ 49' 07''$ (I.T.)
 $D_c = 3^\circ 30' 00''$
 $R = 1,637.02'$
 $T = 212.88'$
 $L = 423.39'$
 $E = 13.78'$
 PC STA. 1700+83.78
 PT STA. 1705+07.15

CURVED BRIDGE LAYOUT



CURVE DATA (RAMP #2)

P.I. = STA. 1711+47.08
 $\Delta = 34^\circ 31' 45''$ (I.T.)
 $D_c = 4^\circ 45' 00''$
 $R = 1,206.23'$
 $T = 150.73'$
 $L = 299.81'$
 $E = 8.34'$
 PC STA. 1708+88.36
 PT STA. 1713+66.36

NOTES

1. ABUTMENTS ARE RADIAL TO @ CONSTRUCTION
2. SEE ROADWAY PLANS FOR HORIZONTAL ROAD GEOMETRY OF UNDER CROSSING ROADWAYS.
3. TRANSITION DECK CROSS SLOPES LINEARLY @ STATIONS SHOWN.

NO.	DATE	DESCRIPTION
1	05/26/13	RFC
B	05/02/13	FINAL SUBMITTAL
A	03/05/12	INTERIM SUBMITTAL

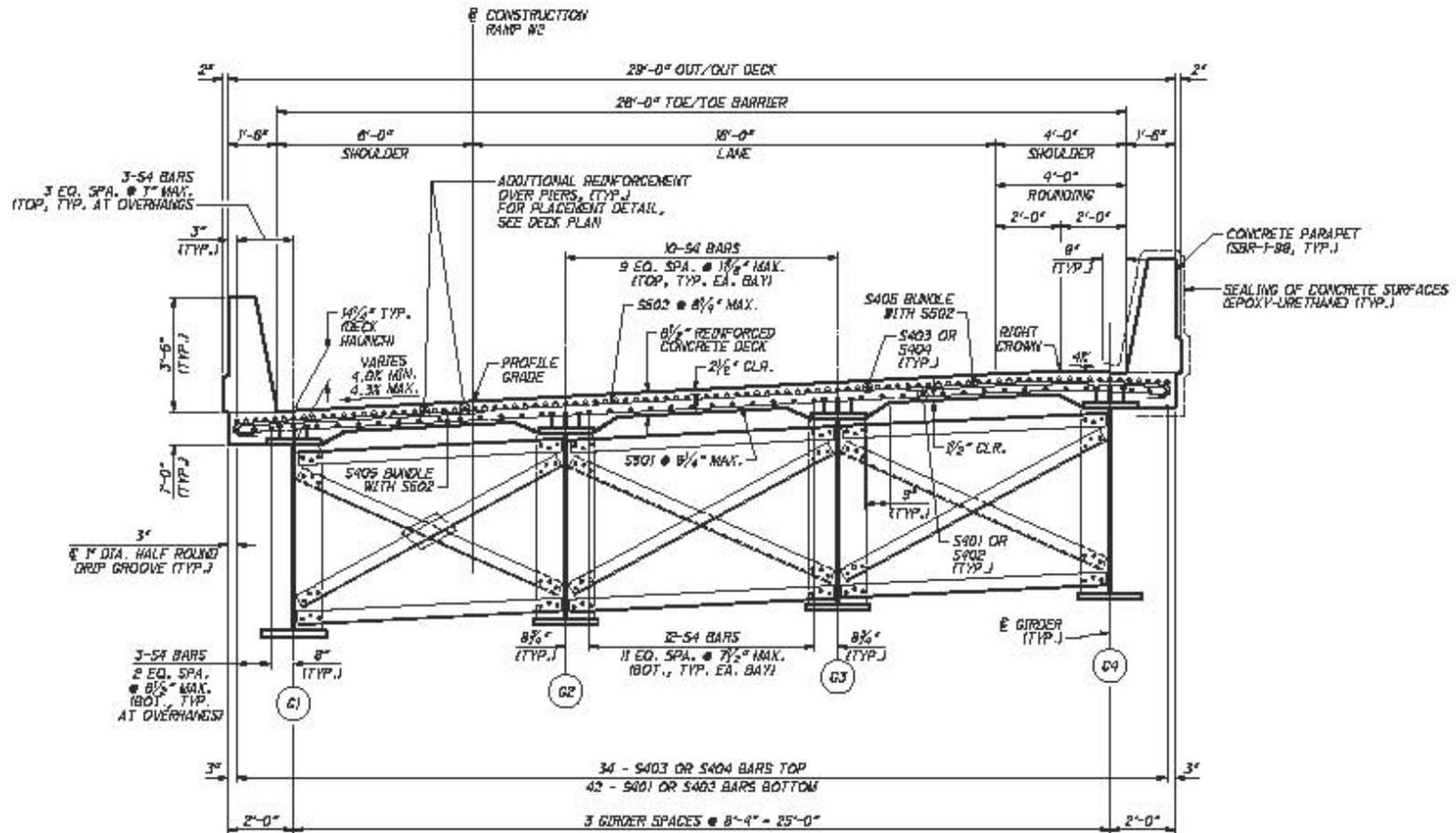
ISSUE RECORD

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Bridge 13B Bridge Cross-Section



THE ESTIMATED QUANTITY OF DECK CONSTANT DECK SLAB THICKNESS, AS NOTED THAT FORMS EACH BAY'S A CONSTANT HAUNCH CONSTANT HAUNCH WIDTH OUTSIDE THE 7 INCHES. DEVIATE FROM THIS TO PLACE THE DECK SURFACE AT BLE TOLERANCE FOR THE HAUNCH

TYPICAL TRANSVERSE SECTION

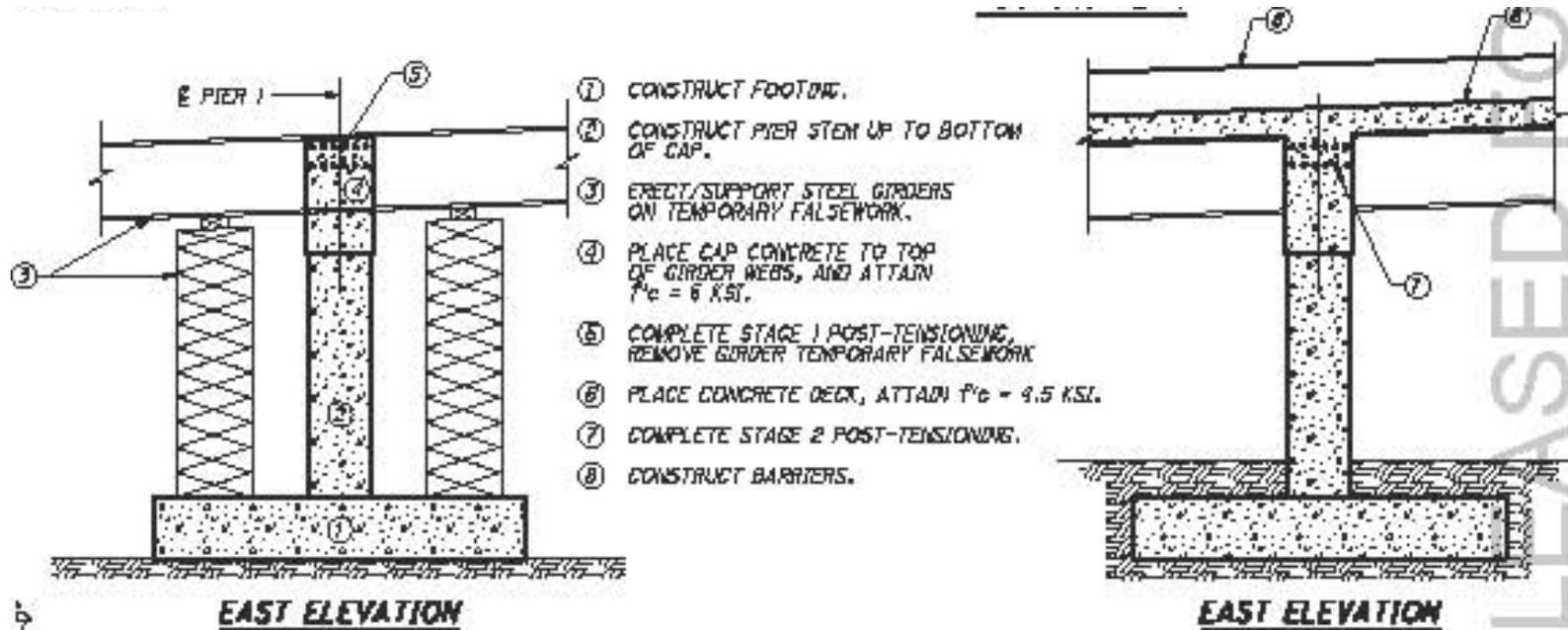
STA. 1703+94.75 - STA. 1704+89.37 SHOWN
SEE SHEET 7 FOR PAVEMENT SLOPE TRANSITIONS FOR REMAINDER OF BRIDGE.

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Bridge 13B Construction Staging



CONSTRUCTION SEQUENCE

NOTE:
 DURING A COMPLETE DECK REPLACEMENT IN THE FUTURE, THE DECK CAN BE REMOVED DOWN TO THE TOP OF GIRDER FLANGE, AND THE PIER 1 CAP HAS SUFFICIENT CAPACITY TO SUPPORT THE CONSTRUCTION OF THE NEW DECK WITHOUT ANY SHORING REQUIRED. THE DECK SHOULD BE REMOVED SYMMETRICALLY ABOUT PIER 1.

TOTAL SPAN 1'-0"

Bridge 13B Details

- Reverse horizontal Curvature
- Deck Cross-slope variation
- Integral Pier Cap
- Construction Stages

Bridge 13B Integral Pier Cap



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Bridge 13B



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Bridge 13B

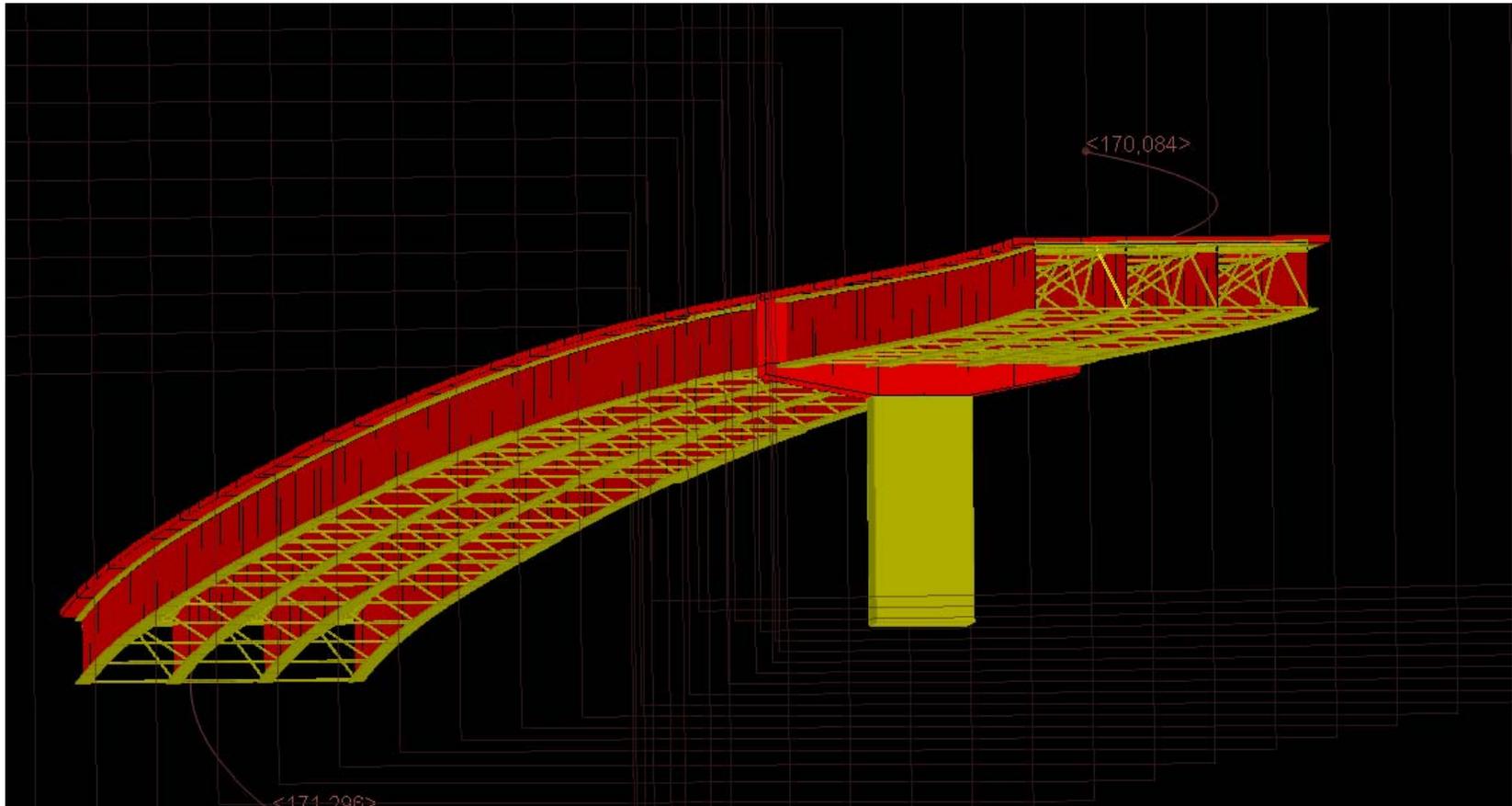


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3D Structural Model

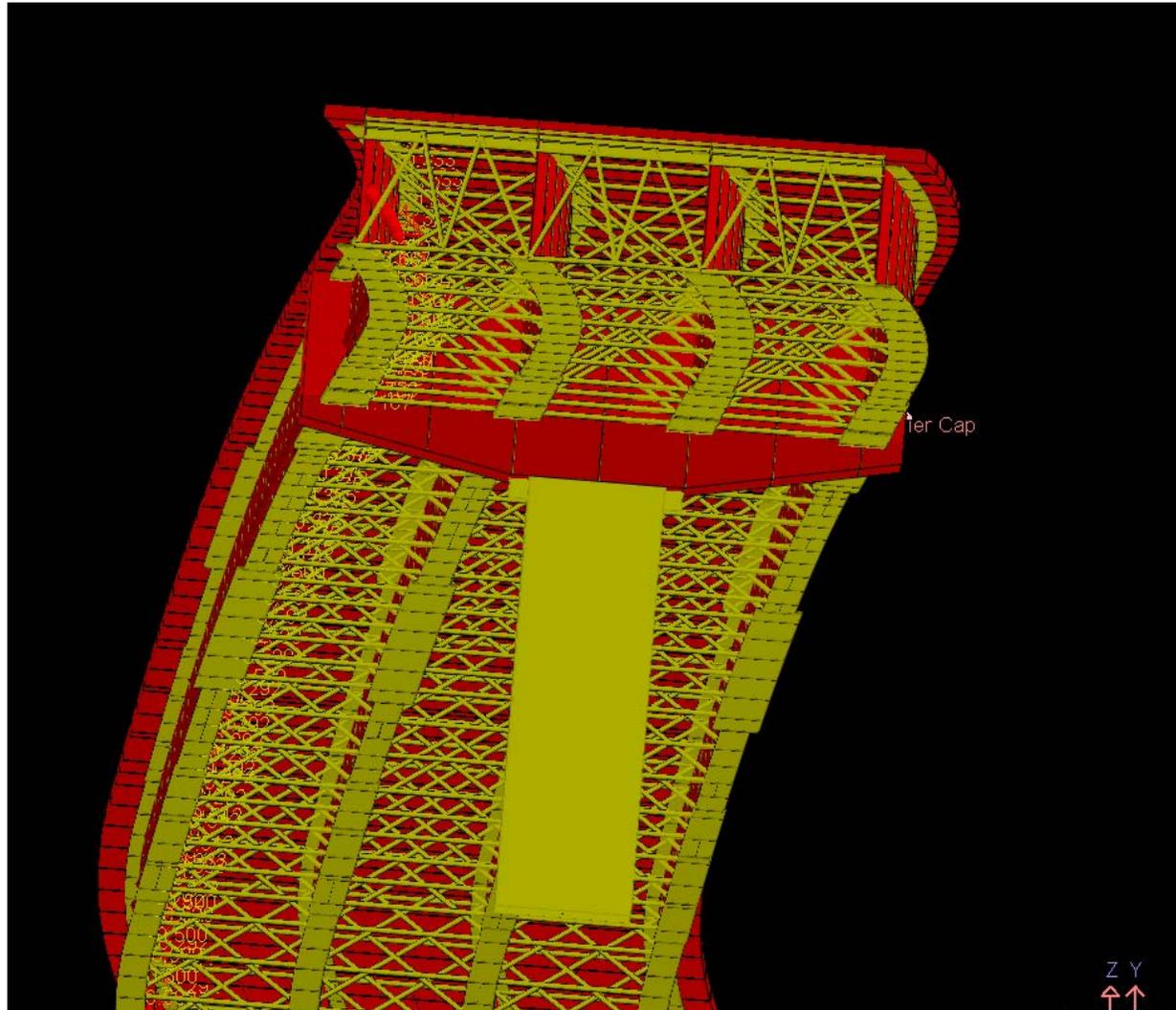


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3D Structural Model

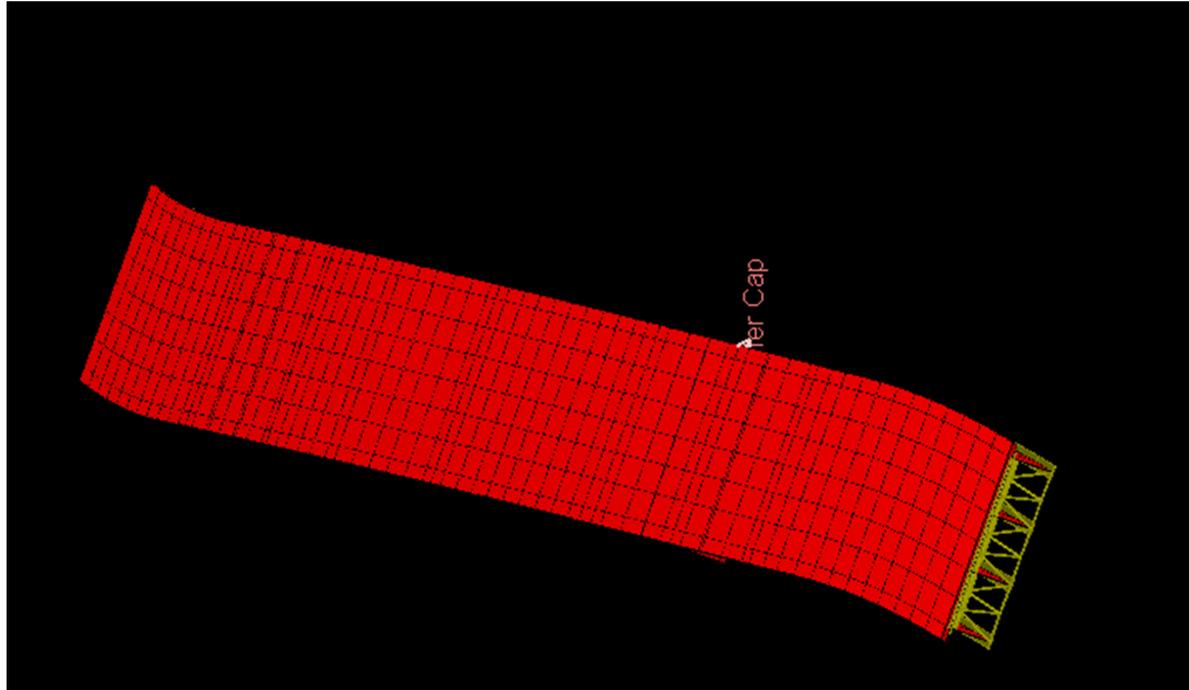


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3D Structural Model



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Temporary Support at Integral Pier Cap



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Freestanding Arch Bridge Hastings, MN



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Presentation Outline

- Braced vs. Unbraced Steel Arch
- Hastings Bridge Geometry & Staging
- Why 4D Analysis?
- Insights Gained from 4D Modeling & Analysis

The Braced Arch

- Traditional Steel Arch Bridge Forms
 - Deck Arch (True Arch)



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The Braced Arch

- Traditional Steel Arch Bridge Forms
 - Through Arch (Tied Arch)



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The Braced Arch

- Two arch ribs braced together
 - Laterally stiff (stable)



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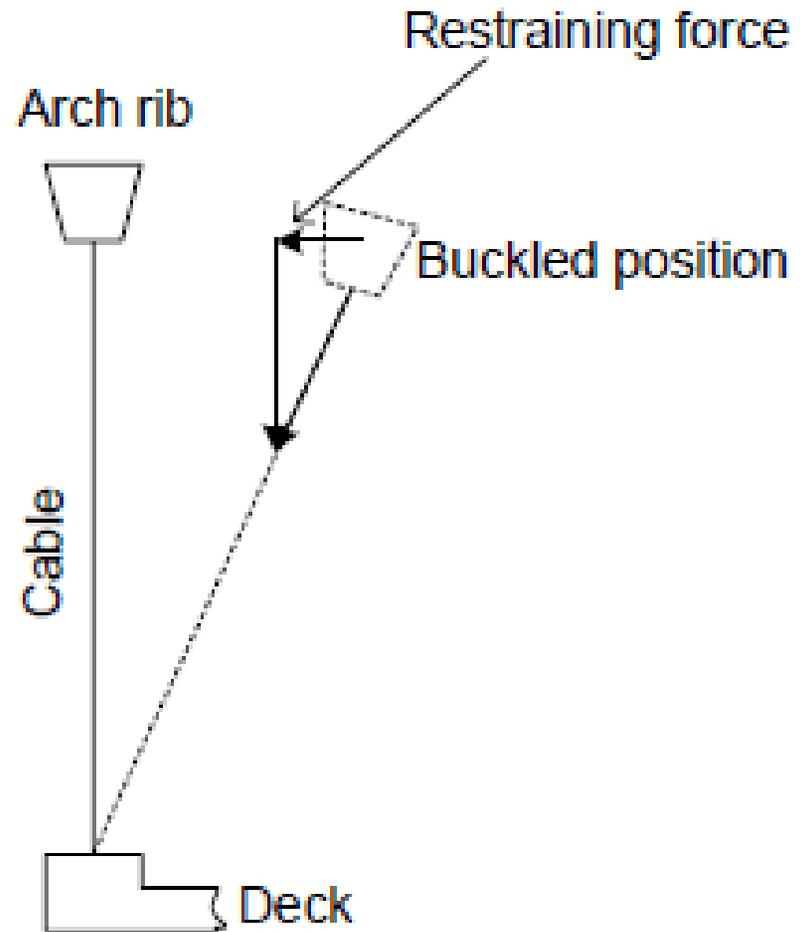
The Unbraced Arch

- aka Freestanding Arch
- Rotation fixed at base
- Uncommon in bridges
- Laterally Flexible



The Unbraced Arch

- Deck suspended on cables
- Stiff deck anchors cables
- Lateral buckling triggers cable restorative force
- Diagonal cable network stabilizes in-plane buckling

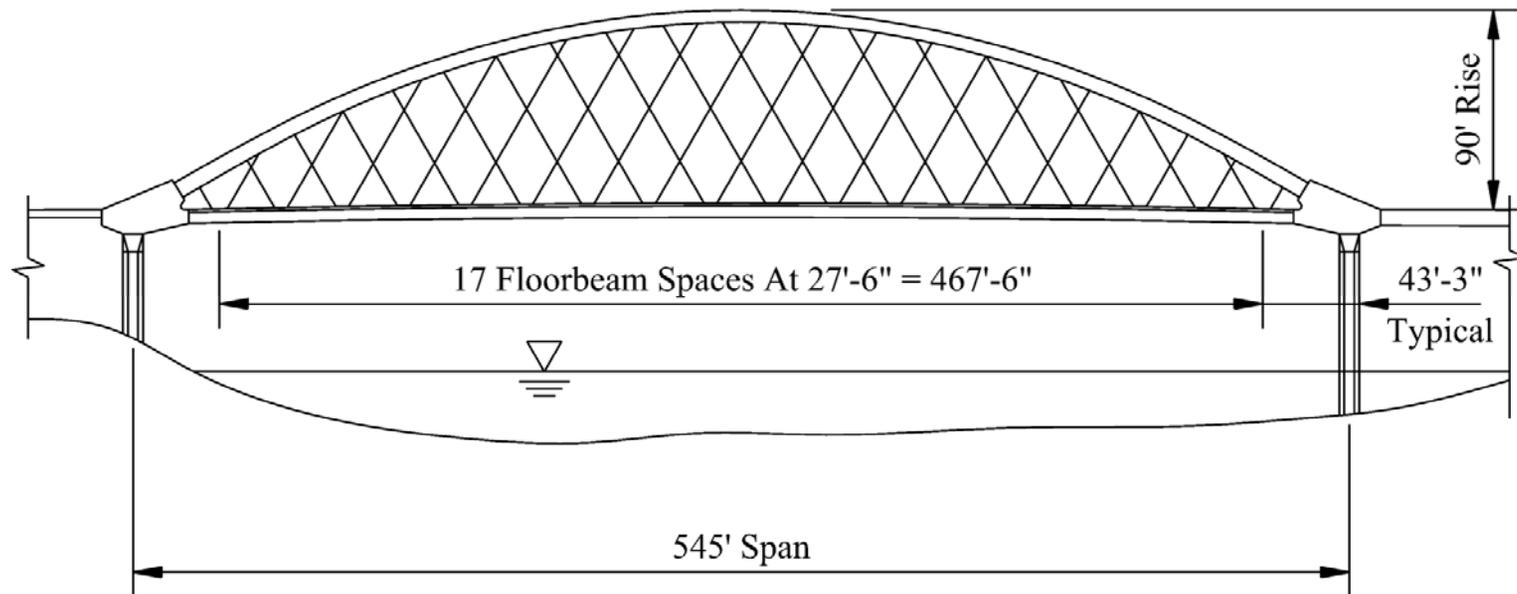


New STH 16 Bridge at Hastings

- Location: Mississippi River, near Minneapolis
- Owner: MnDOT
- Builder: Lunda-Ames
- Designer: Parsons
- Independent Design Check: CH2M HILL
- Construction Oversight: HNTB

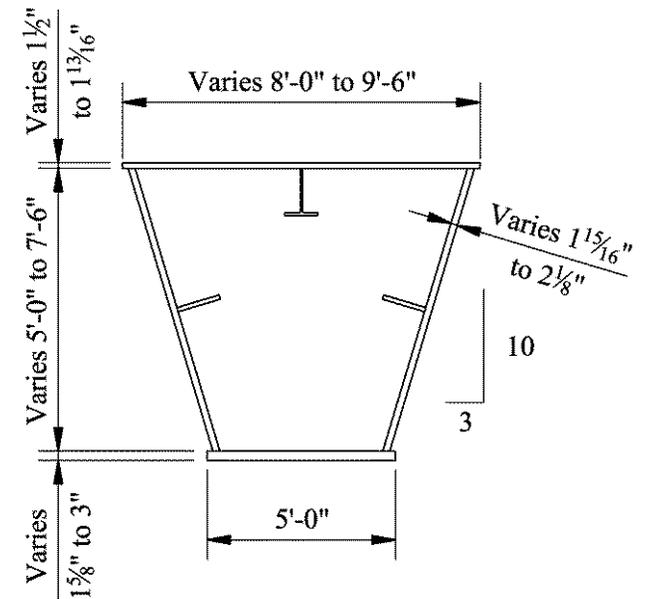
New STH 16 Bridge at Hastings

- 545-foot span freestanding tied arches
- Post-tensioned concrete tie girders
- Complex construction sequence



New STH 16 Bridge at Hastings

- Nonprismatic trapezoidal steel box ribs
- Diagonal hanger network



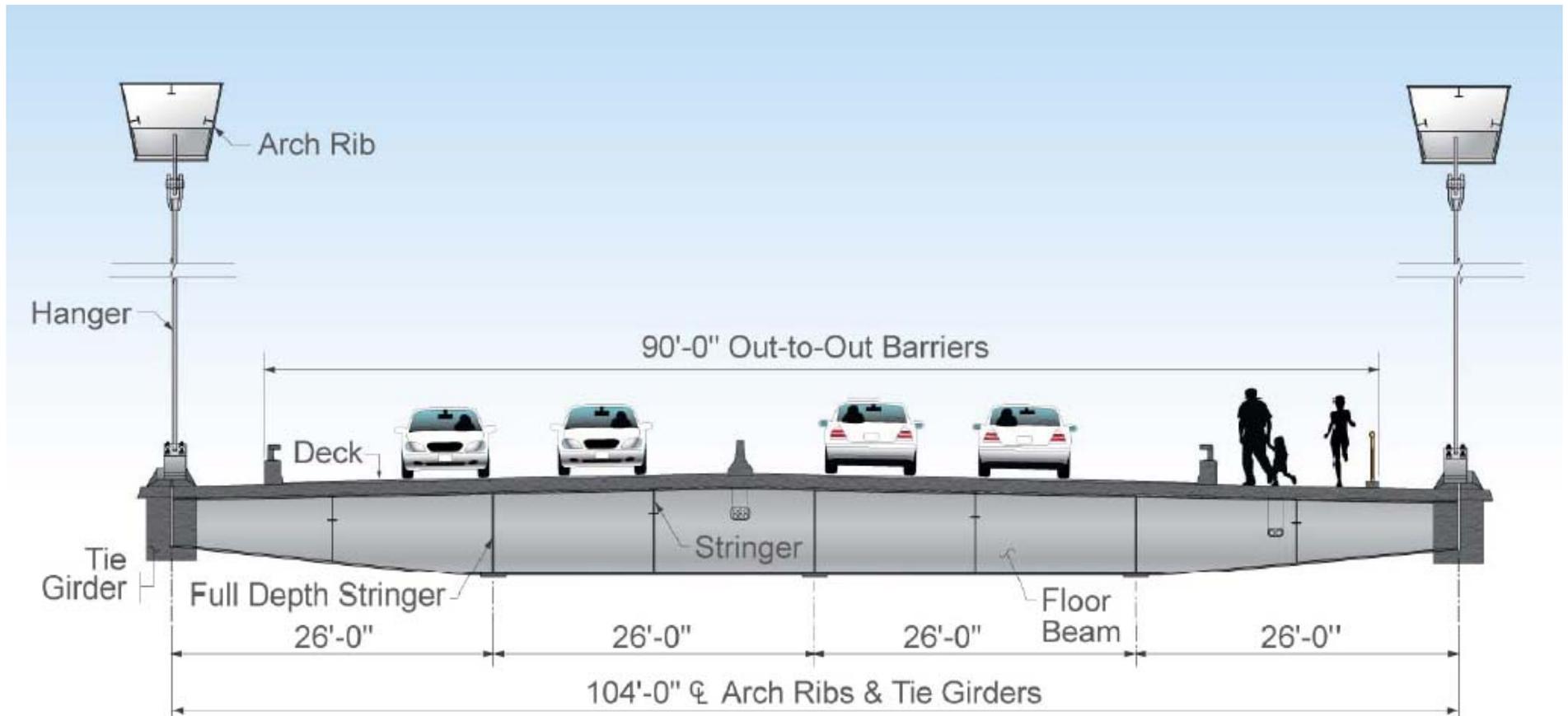
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New STH 16 Bridge at Hastings

■ Typical Section



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4D Staged Construction Model

- Why model 3D geometry?
 - Eccentric tie girders and hangers
 - Unsymmetric piers/foundations
- Why model time (4th D)?
 - Complex construction sequence
 - Temporary tie girders
 - Multiple stages of post-tensioning
 - Hanger and connection adjustments
 - Time-dependent material behavior

4D Staged Construction Model

- Steel erected on falsework in staging yard



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4D Staged Construction Model

- Transfer onto barges using SPMT's



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4D Staged Construction Model

- Barge upriver



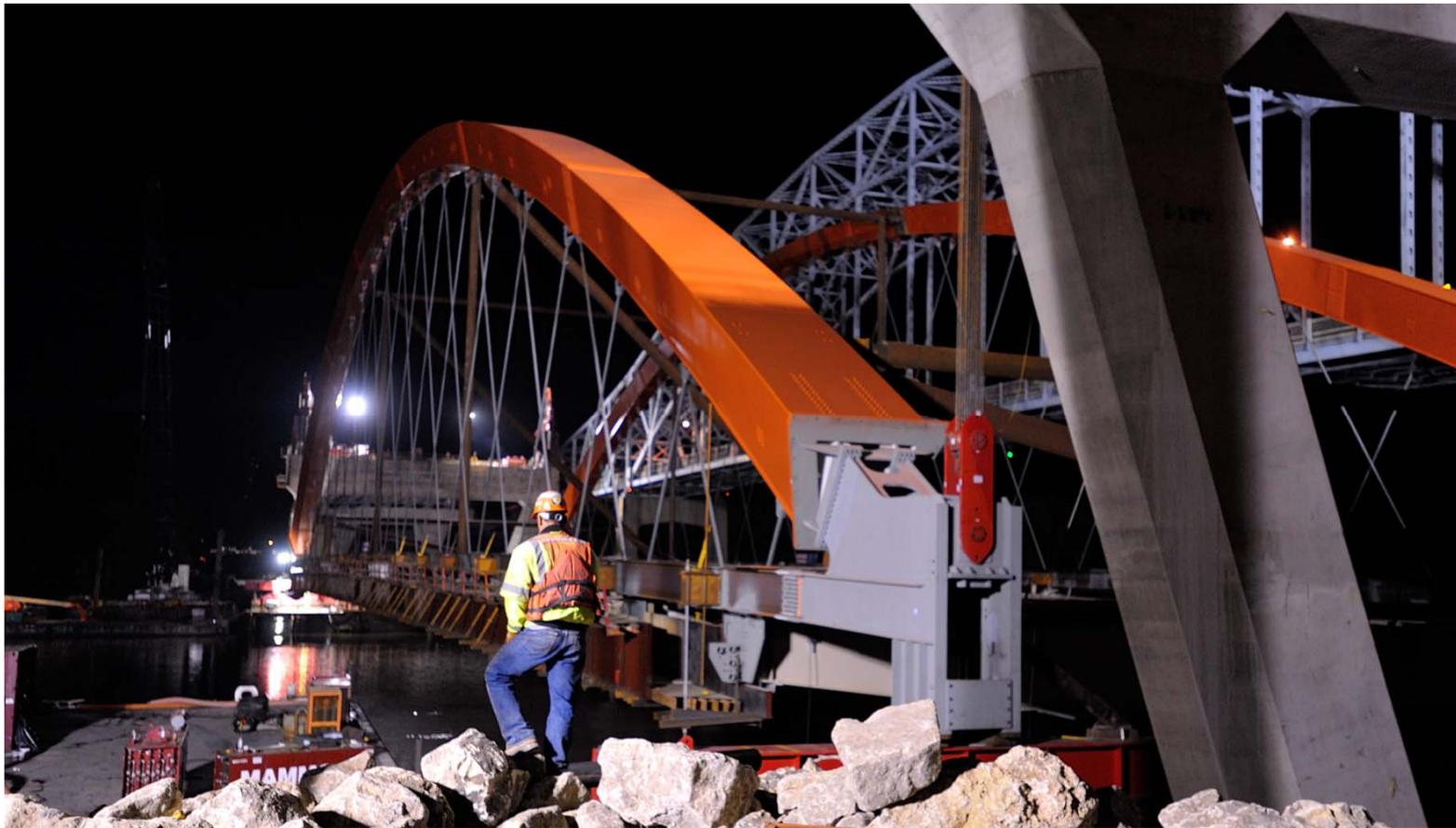
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4D Staged Construction Model

- Lift preassembled span into place



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4D Staged Construction Model

- Construct post-tensioned ties and deck



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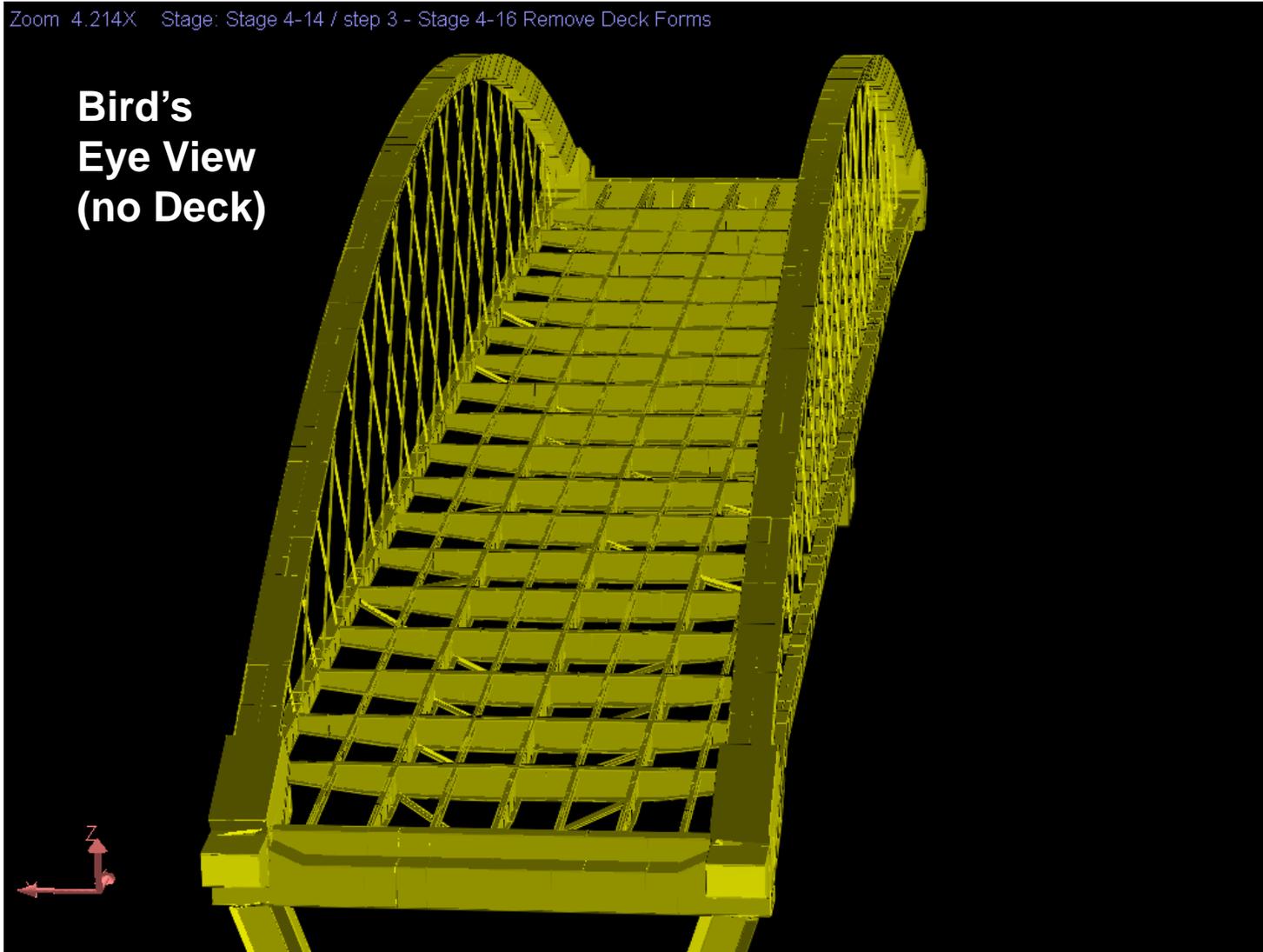
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4D Staged Construction Model

Zoom 4.214X Stage: Stage 4-14 / step 3 - Stage 4-16 Remove Deck Forms

**Bird's
Eye View
(no Deck)**

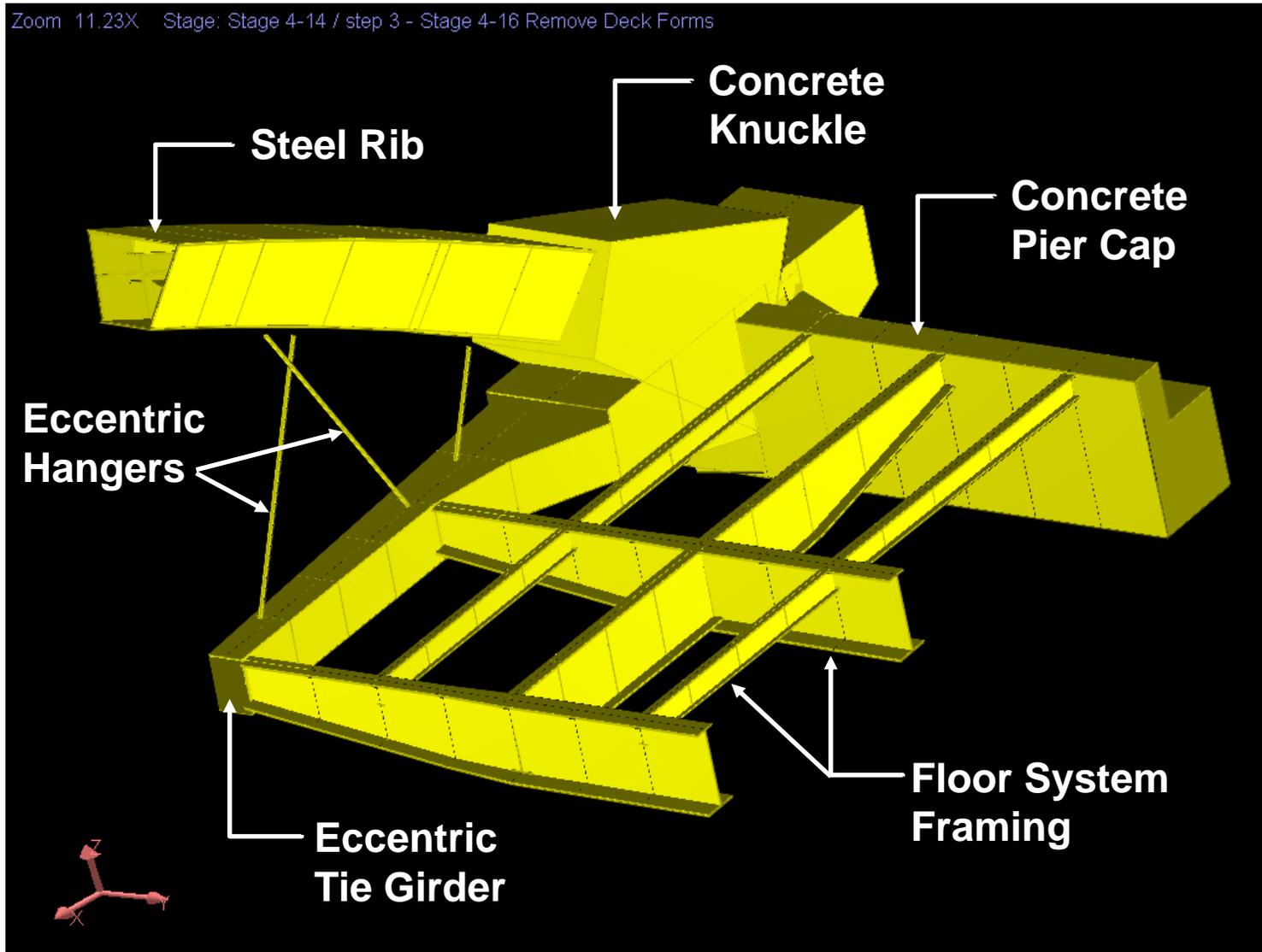


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4D Staged Construction Model



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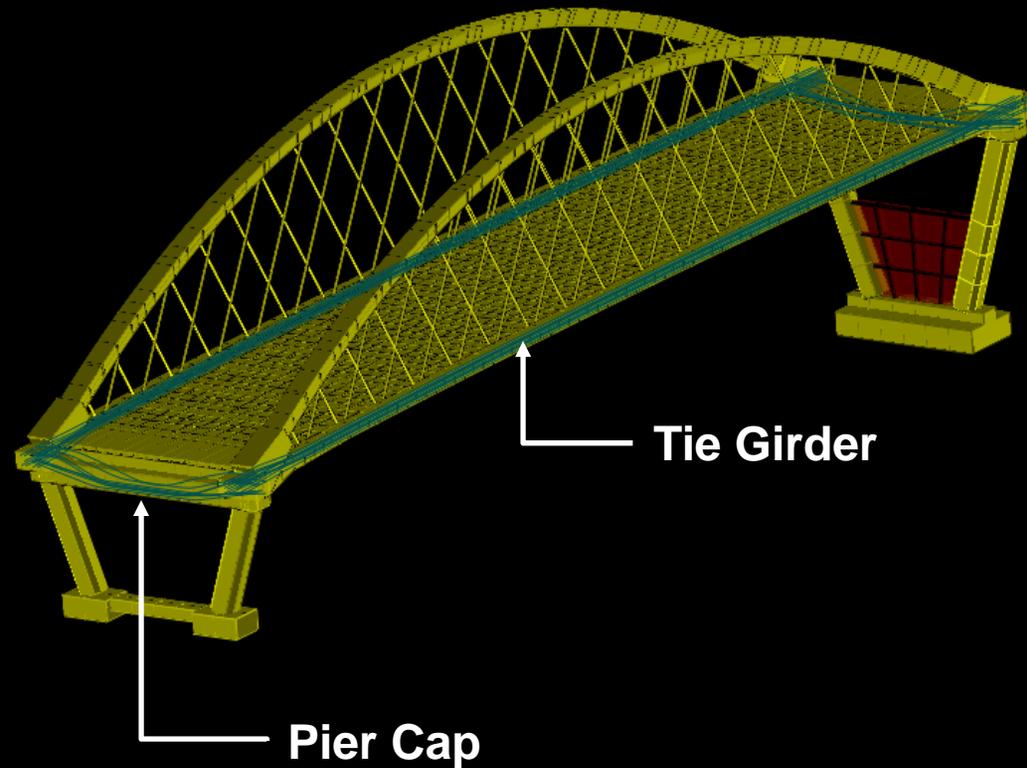
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4D Staged Construction Model

Zoom 1.879X Stage: Stage 4-14 / step 3 - Stage 4-16 Remove Deck Forms

Post-tensioning Tendon Paths



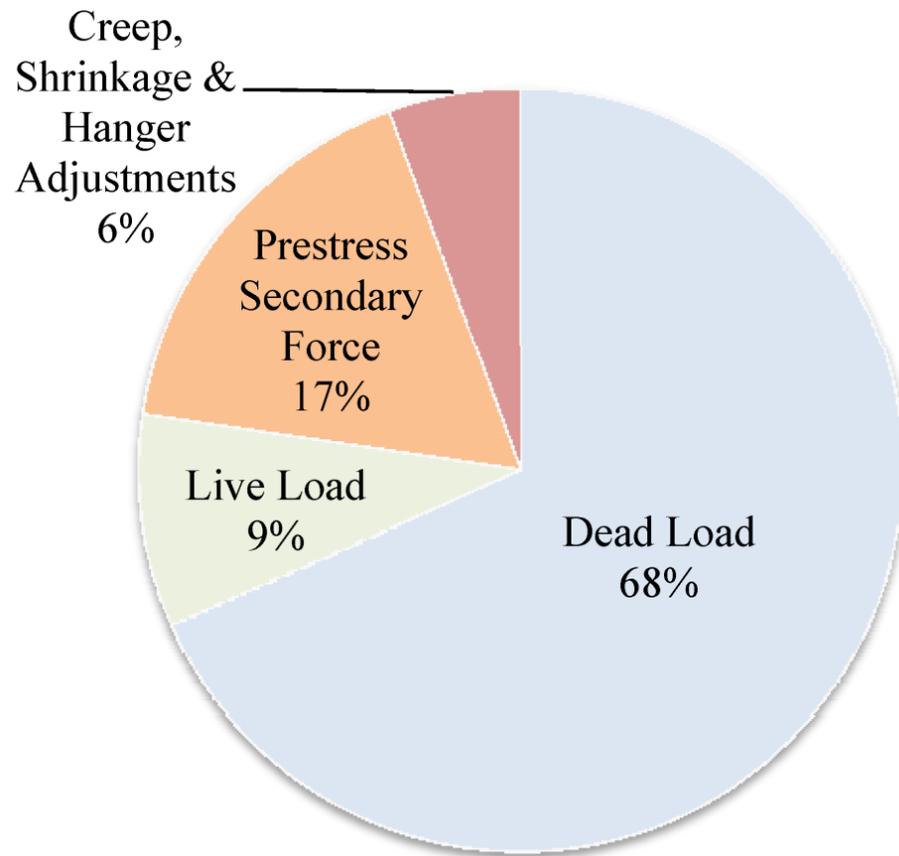
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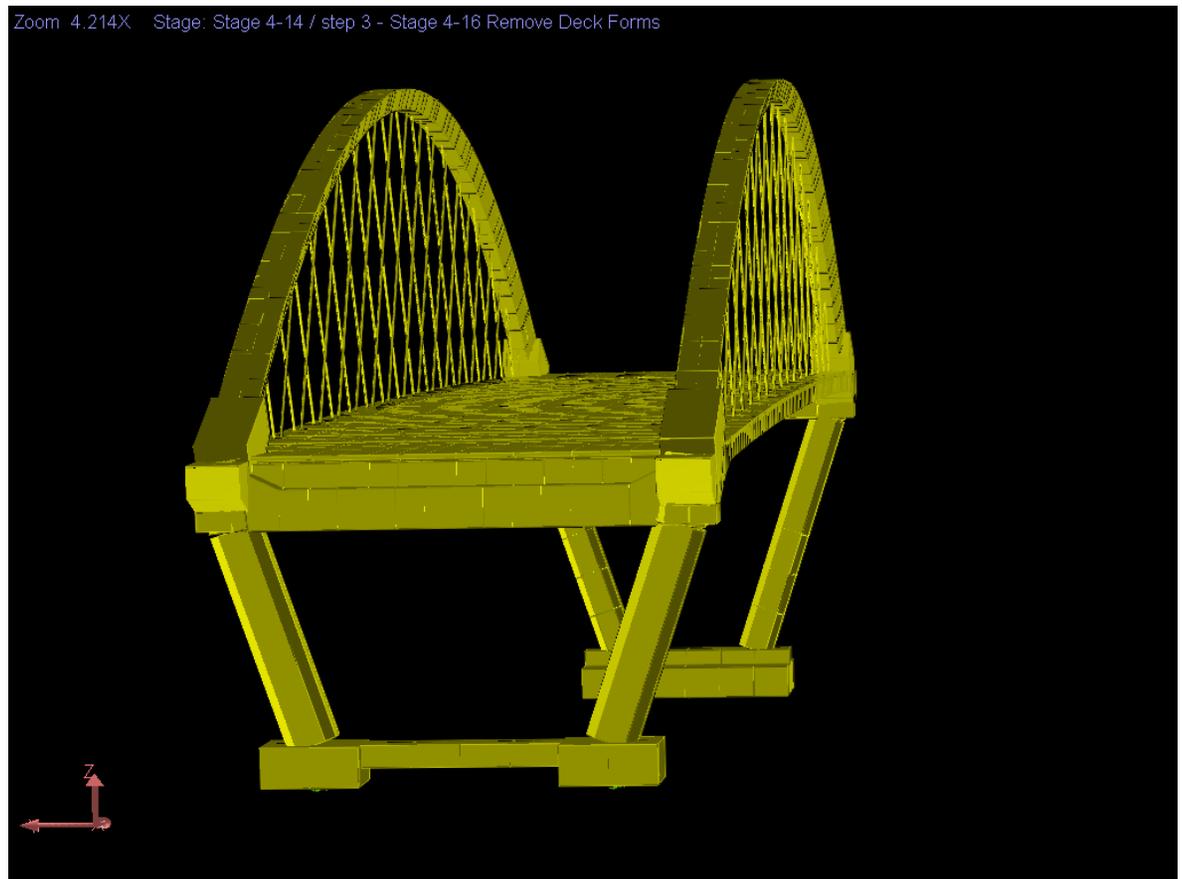
Insights from 4D Model Analysis

- Maximum factored rib compression = 15,850 kips at end of 100-year service life
- 23% from non-gravity loads (CR, SH, PS, EL)
- Staging is important for capturing initial state of stress



Insights from 4D Model Analysis

- Eccentric tie girders cause ribs to move inward
 - 1" from dead load
 - $\frac{3}{4}$ " from creep over 100 years



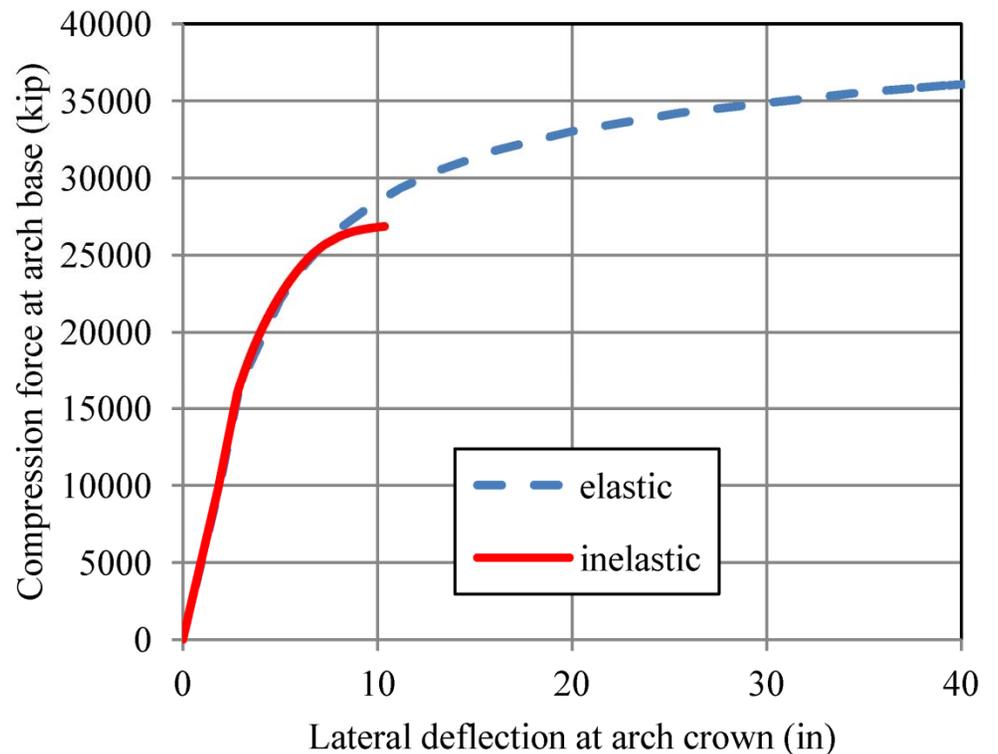
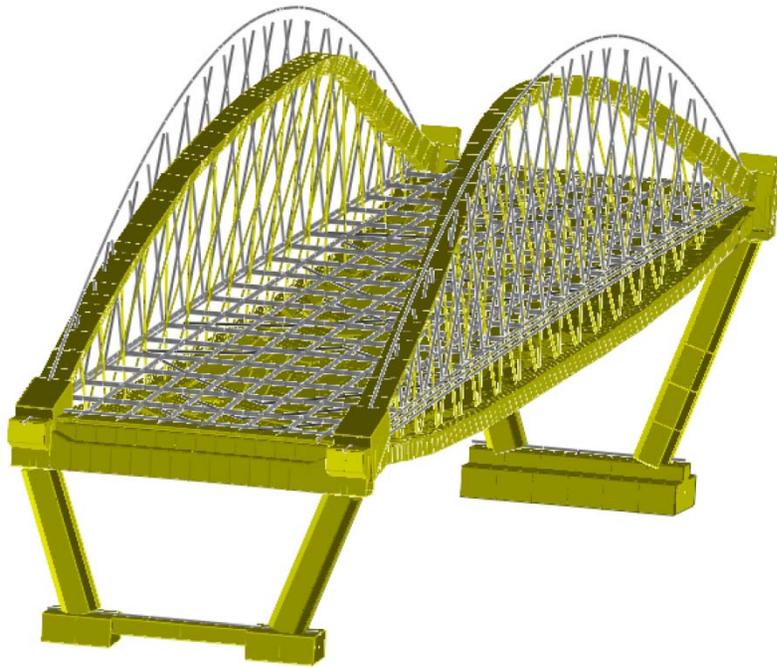
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Insights from 4D Model Analysis

- Inelastic Buckling Load = 27,000 kips



Insights from 4D Model Analysis

- The base 4D model was adapted for many uses not covered in this presentation
 - Evaluation of stability during erection
 - Fracture scenario simulations
 - Framing system live load analysis
 - Redecking analysis
 - Barge impact analysis
 - Wind analysis
 - Tendon loss/repair simulations

Conclusions

- 3D geometry model essential for capturing asymmetric and eccentric loading effects
- Time-dependent model essential for capturing staging (boundary condition changes) and material nonlinearities
- 4D model simulation provides robust analysis and confidence in design of prototypical bridge