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)

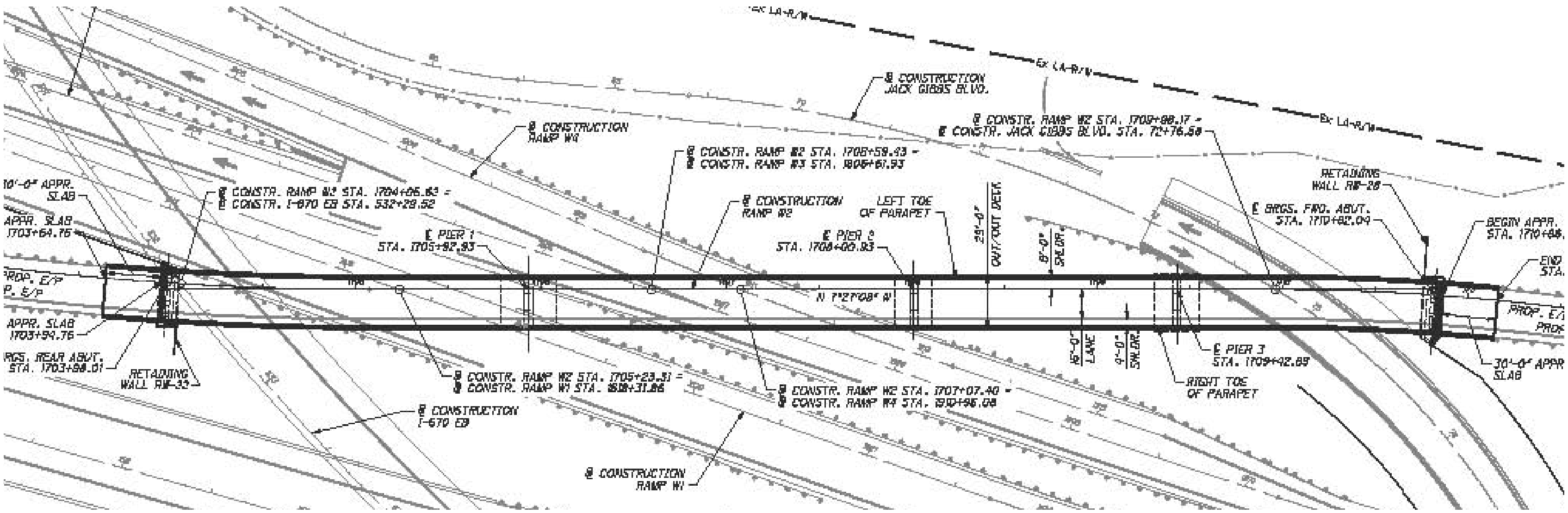
3D Modeling Transportation Infrastructure:

- Zoo Interchange, Milwaukee, WI

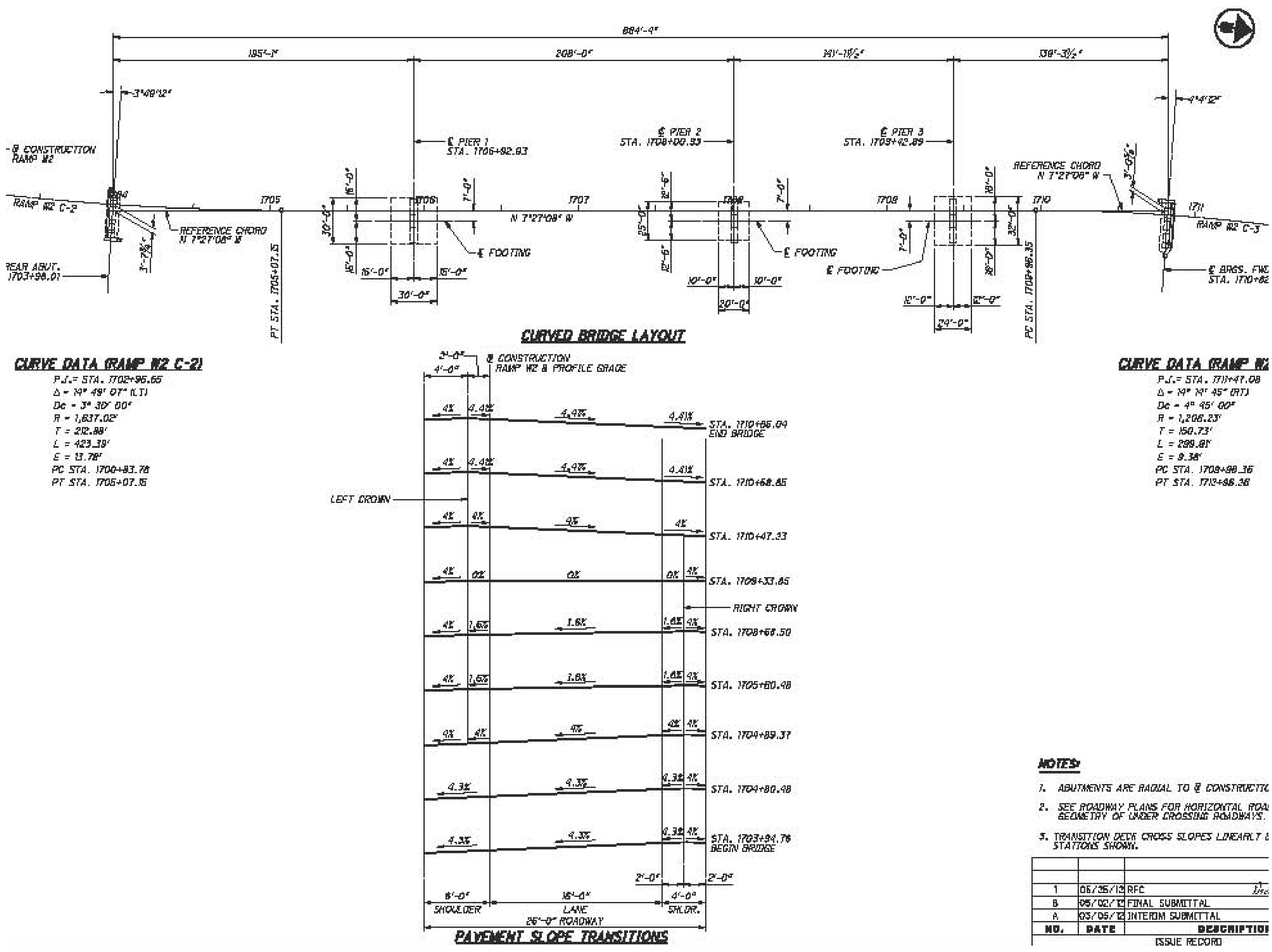
  Chris Johnson (20 minutes)

Questions: (5 minutes)

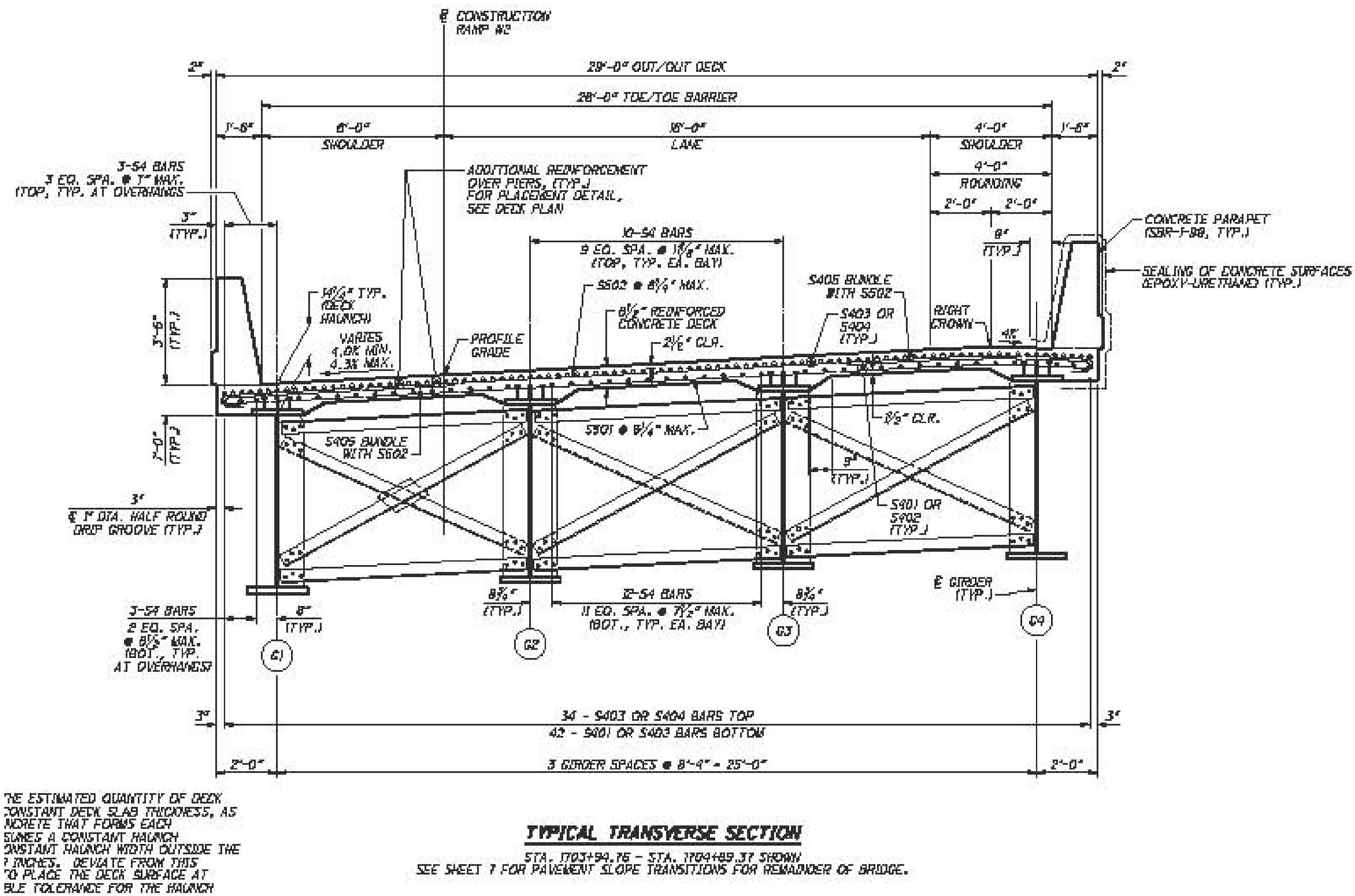
Bridge 13B Plan



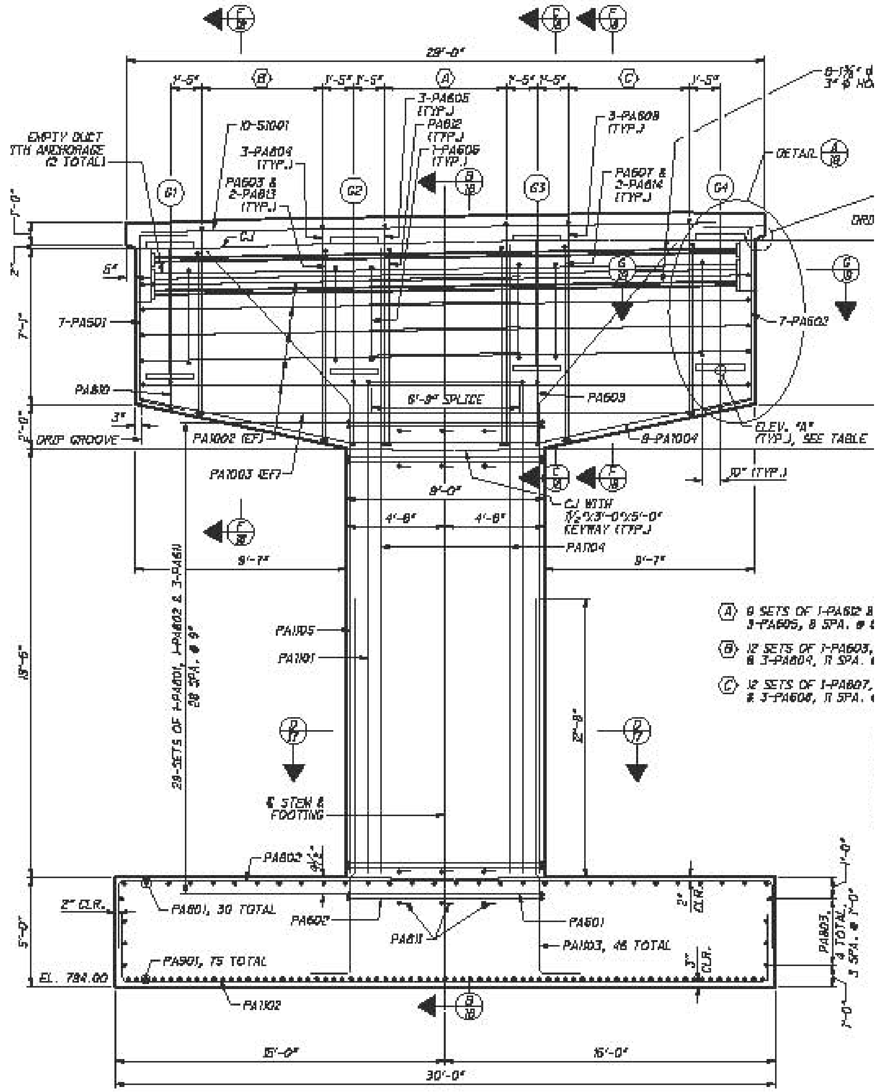
Bridge 13B Plan



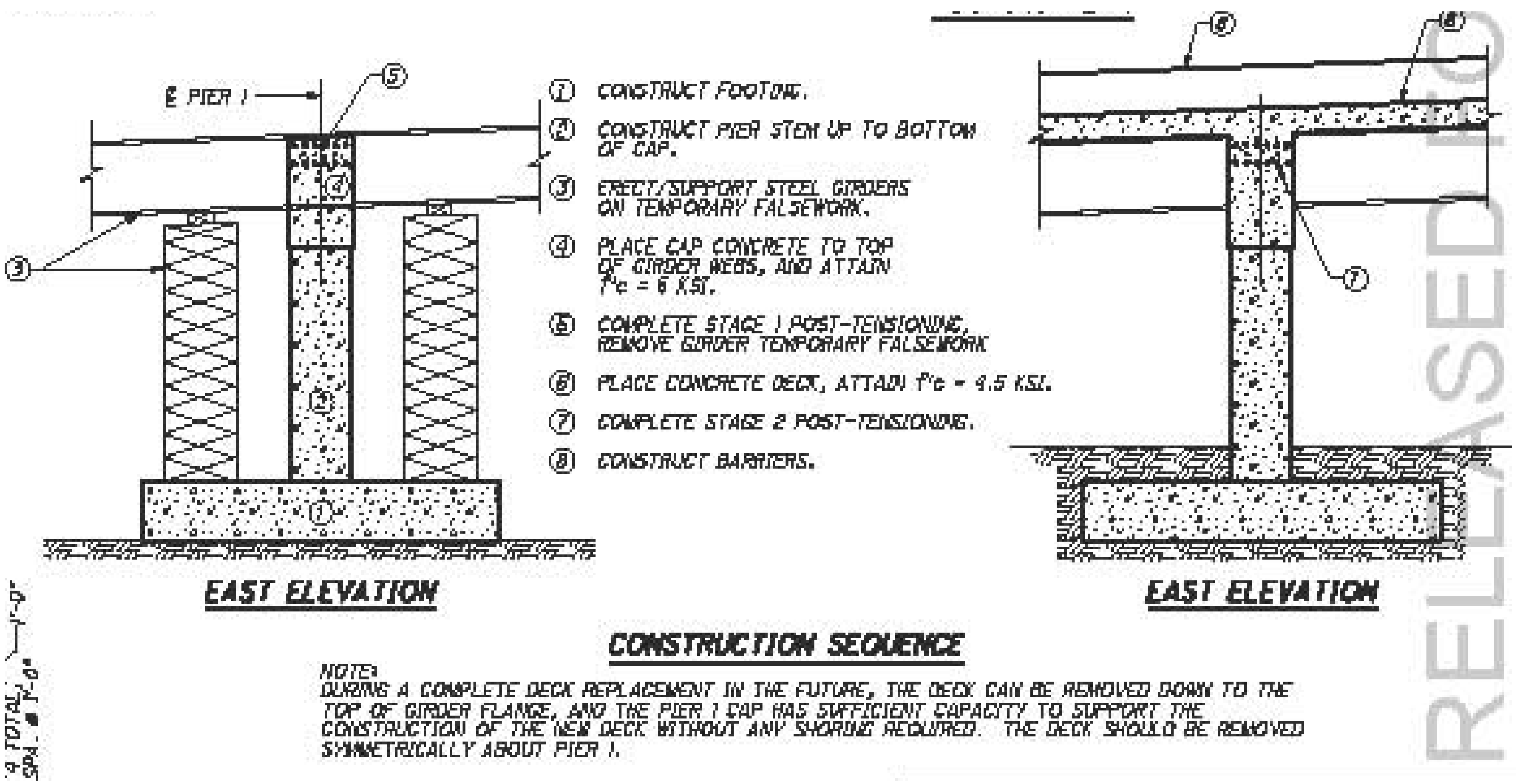
Bridge 13B Bridge Cross-Section



Bridge 13B Integral Pier Cap



Bridge 13B Construction Staging



Bridge 13B Details

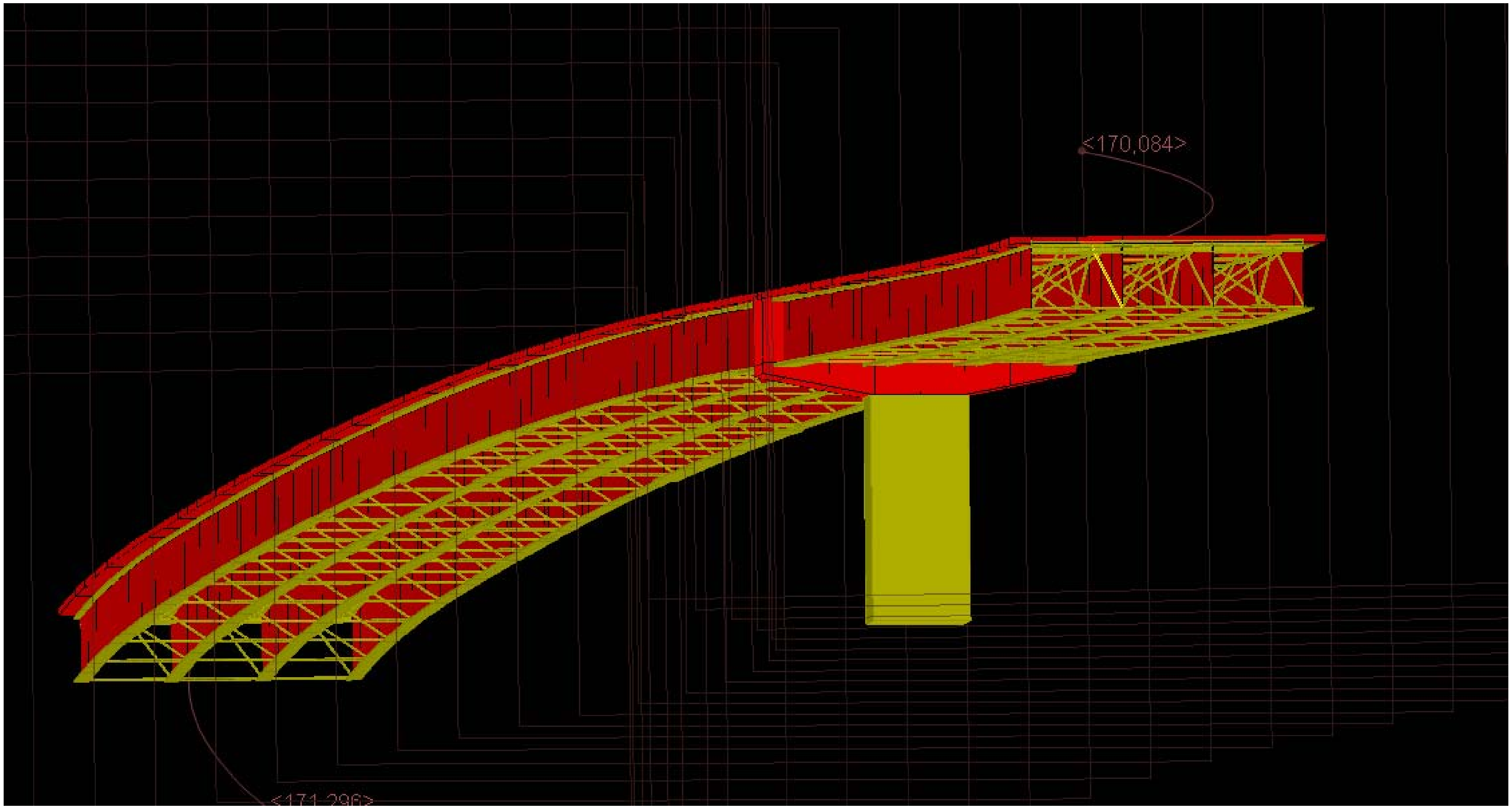
- Reverse horizontal Curvature
- Deck Cross-slope variation
- Integral Pier Cap
- Construction Stages

Bridge 13B Integral Pier Cap

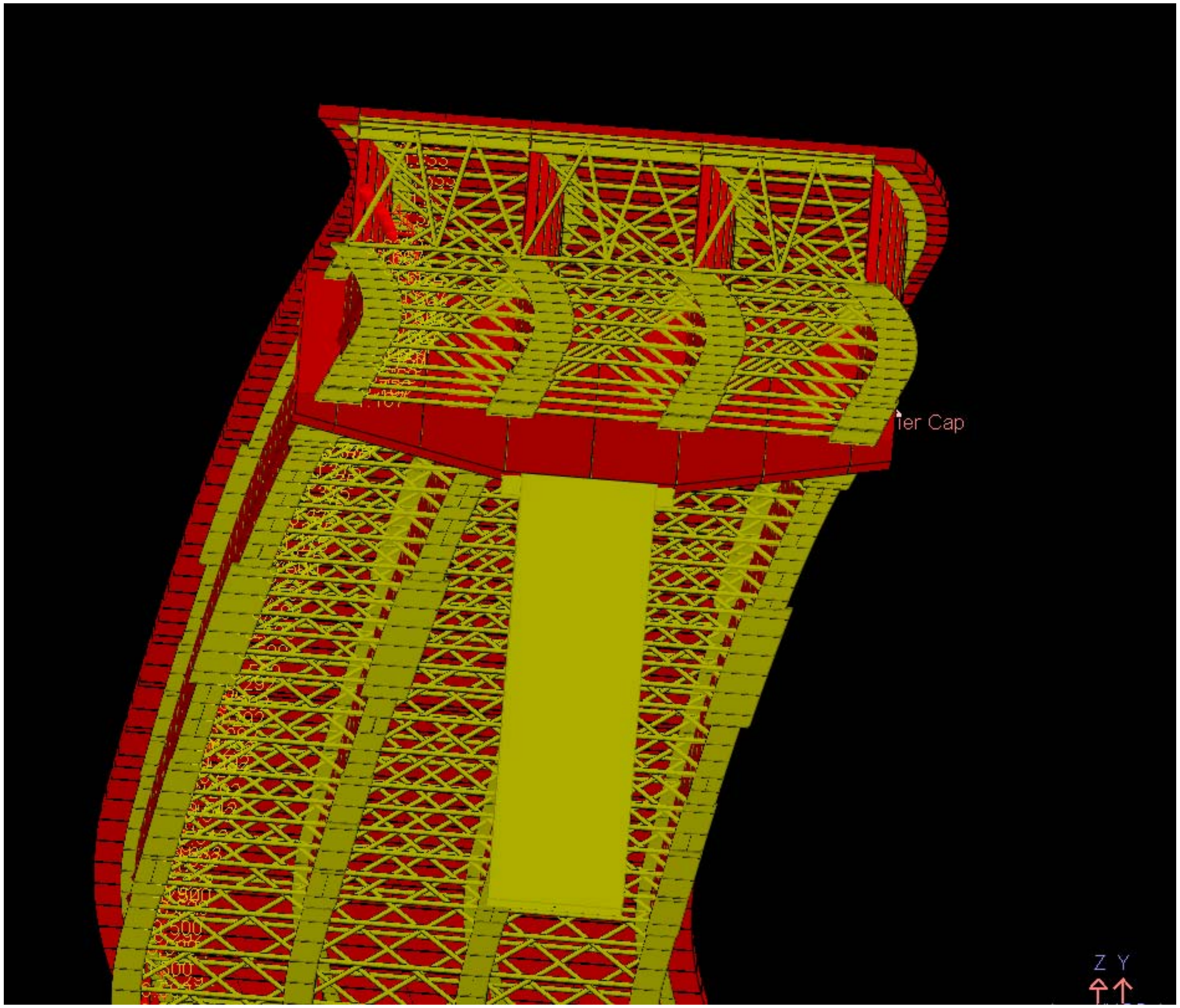
Bridge 13B

Bridge 13B

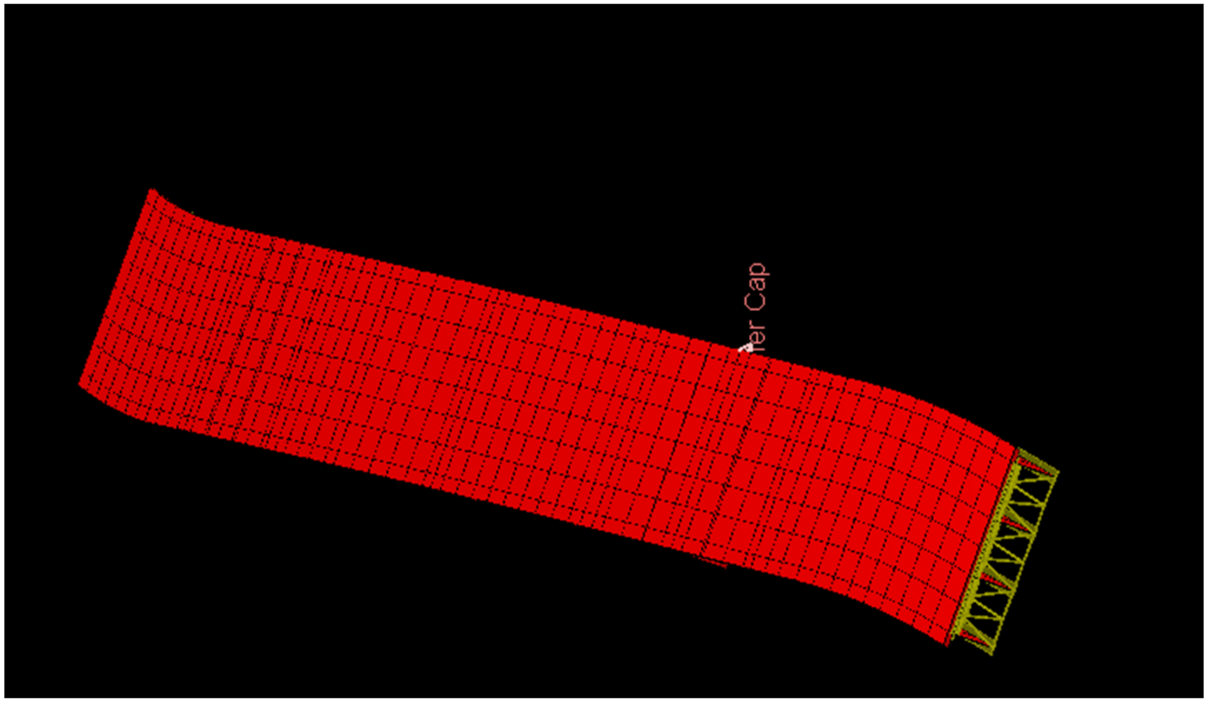
3D Structural Model



3D Structural Model



3DStructural Model



Temporary Support at Integral Pier Cap

Freestanding Arch Bridge
Hastings, MN

April 14, 2015

Iowa DOT 3D Design and Modeling
for Highway Structures Workshop

CH2MHILL

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)

The Braced Arch

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

The Braced Arch

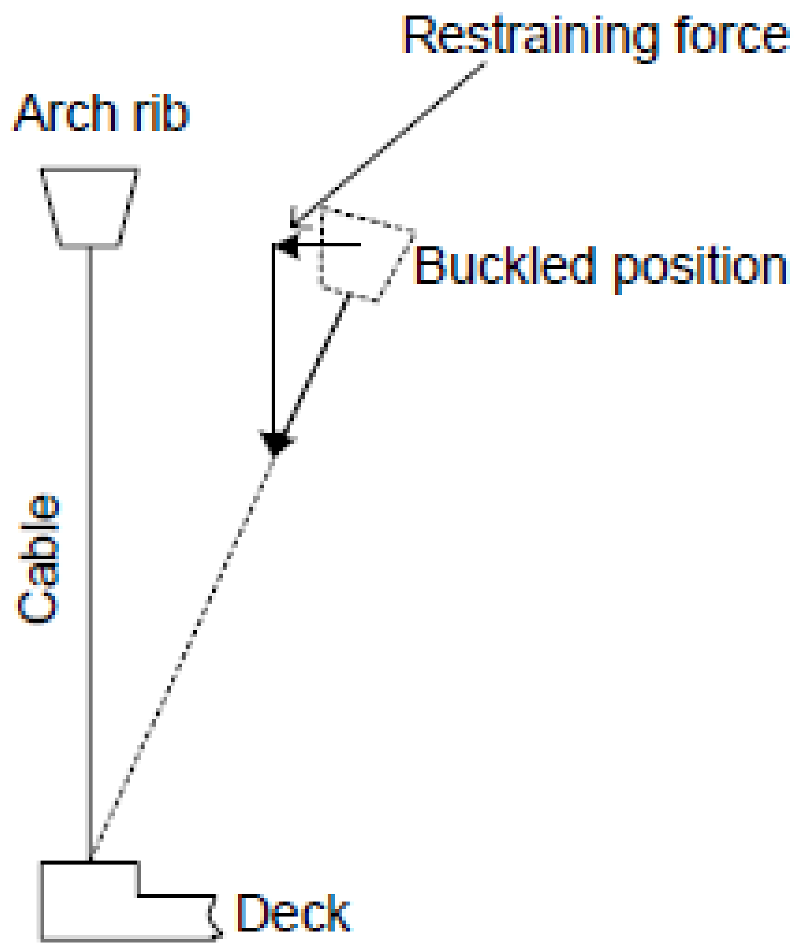
- Two arch ribs braced together
  - Laterally stiff (stable)

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

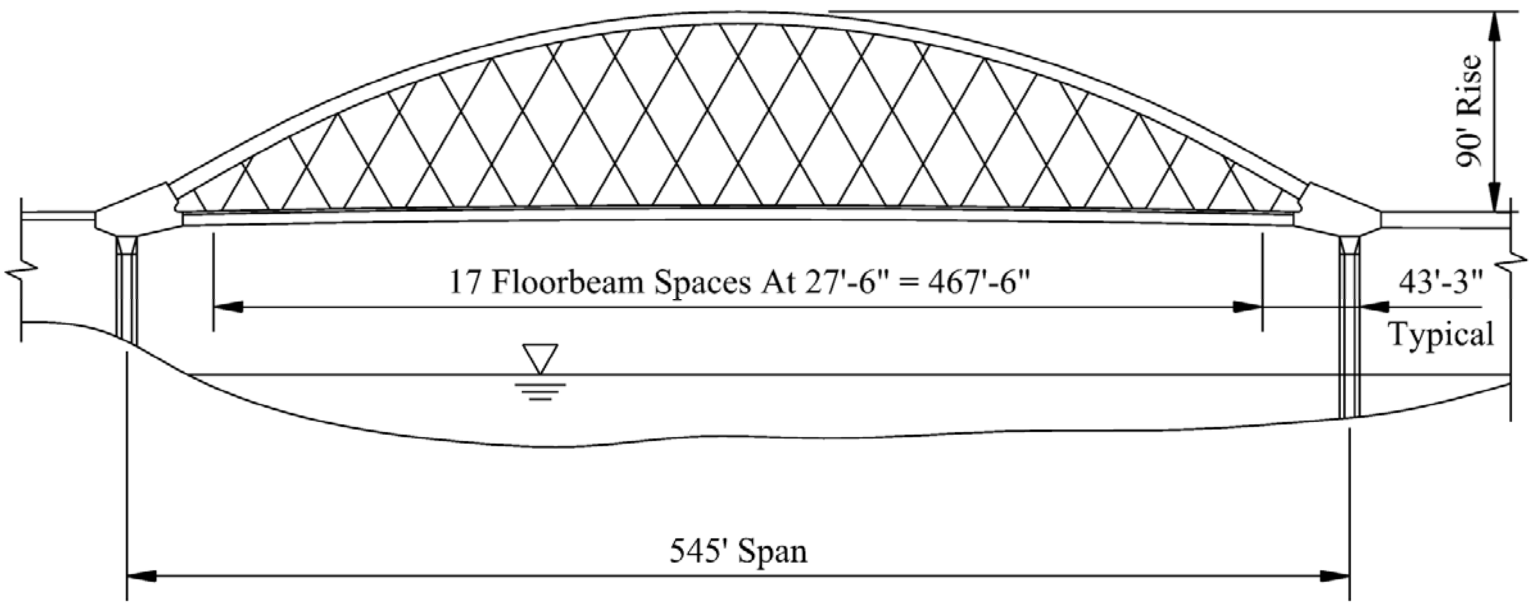


New STH 16 Bridge at Hastings

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

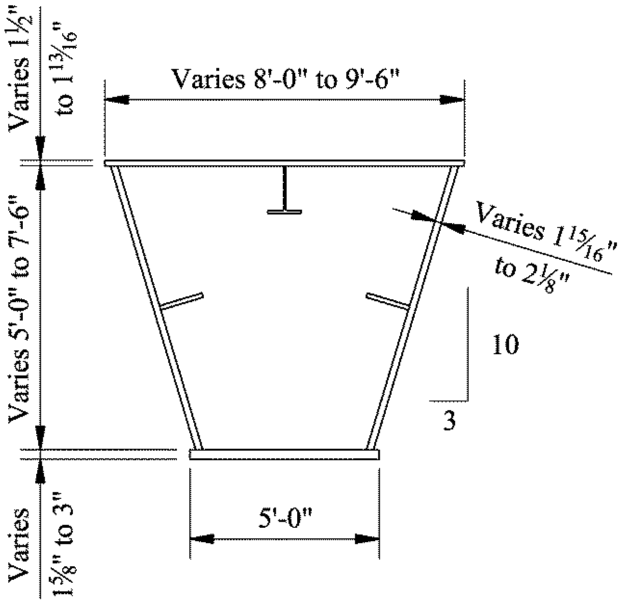
New STH 16 Bridge at Hastings

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



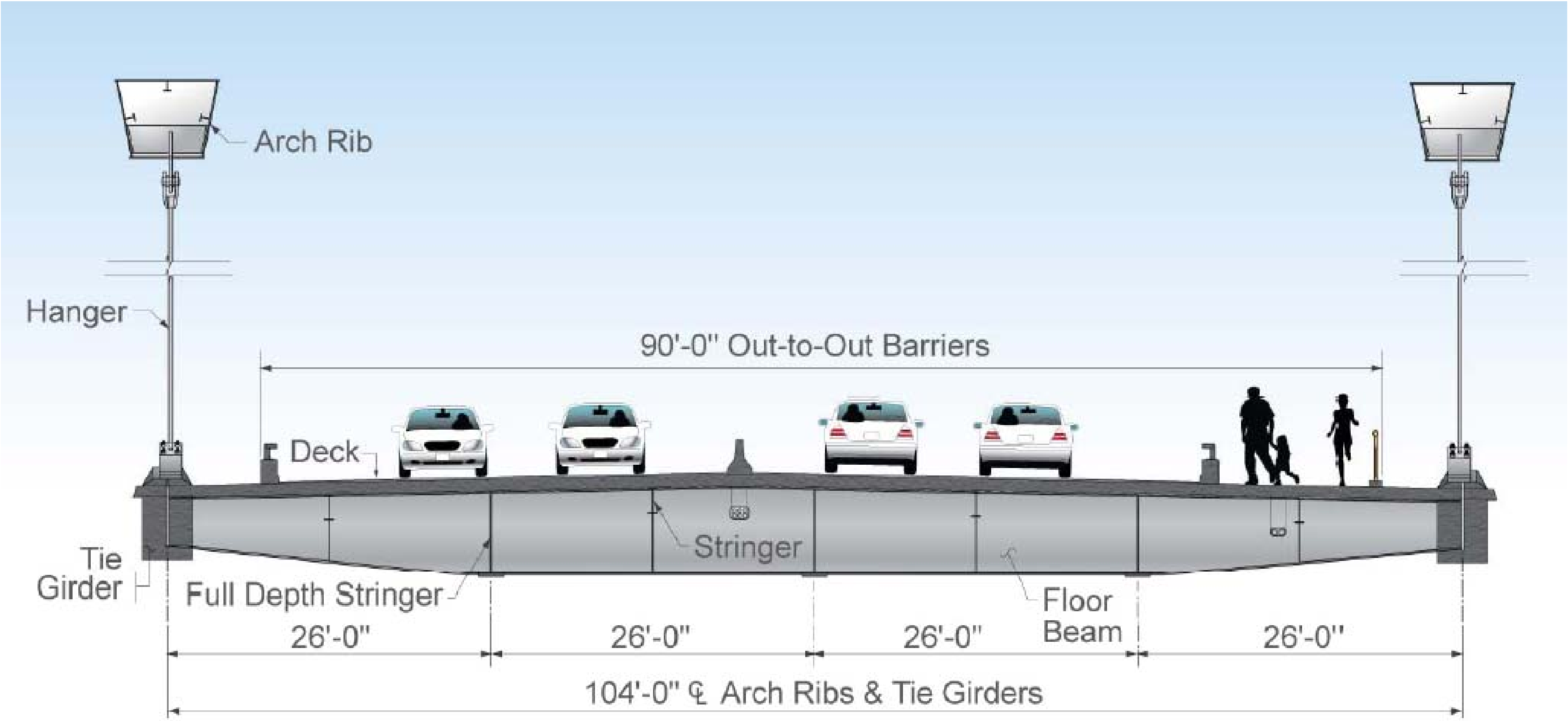
New STH 16 Bridge at Hastings

- Nonprismatic trapezoidal steel box ribs
- Diagonal hanger network



New STH 16 Bridge at Hastings

- Typical Section



4D Staged Construction Model

- Why model 3D geometry?
  - Eccentric tie girders and hangers
  - Unsymmetric piers/foundations
- Why model time (4^{th} 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

4D Staged Construction Model

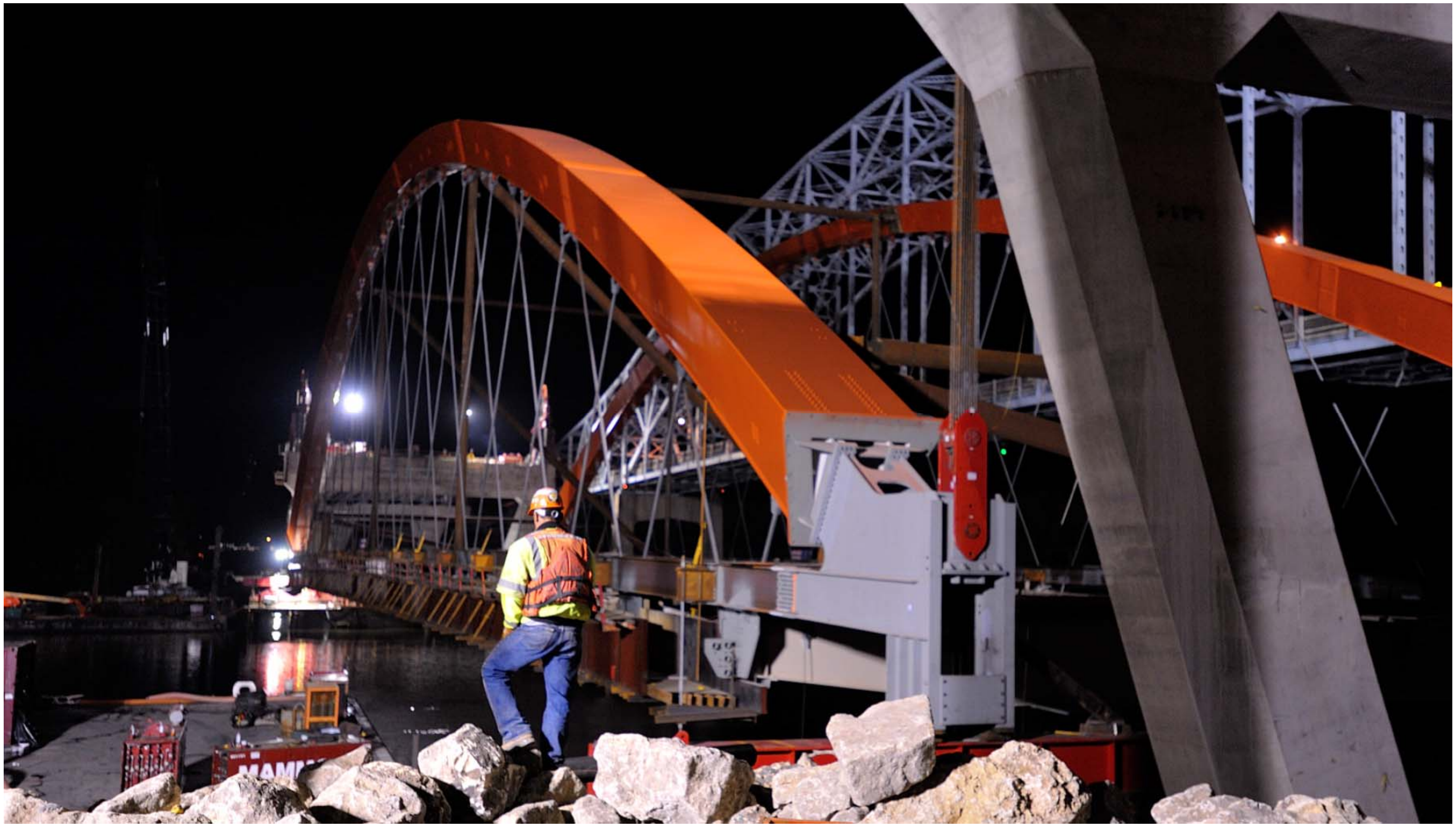
- Transfer onto barges using SPMT's

4D Staged Construction Model

- Barge upriver

4D Staged Construction Model

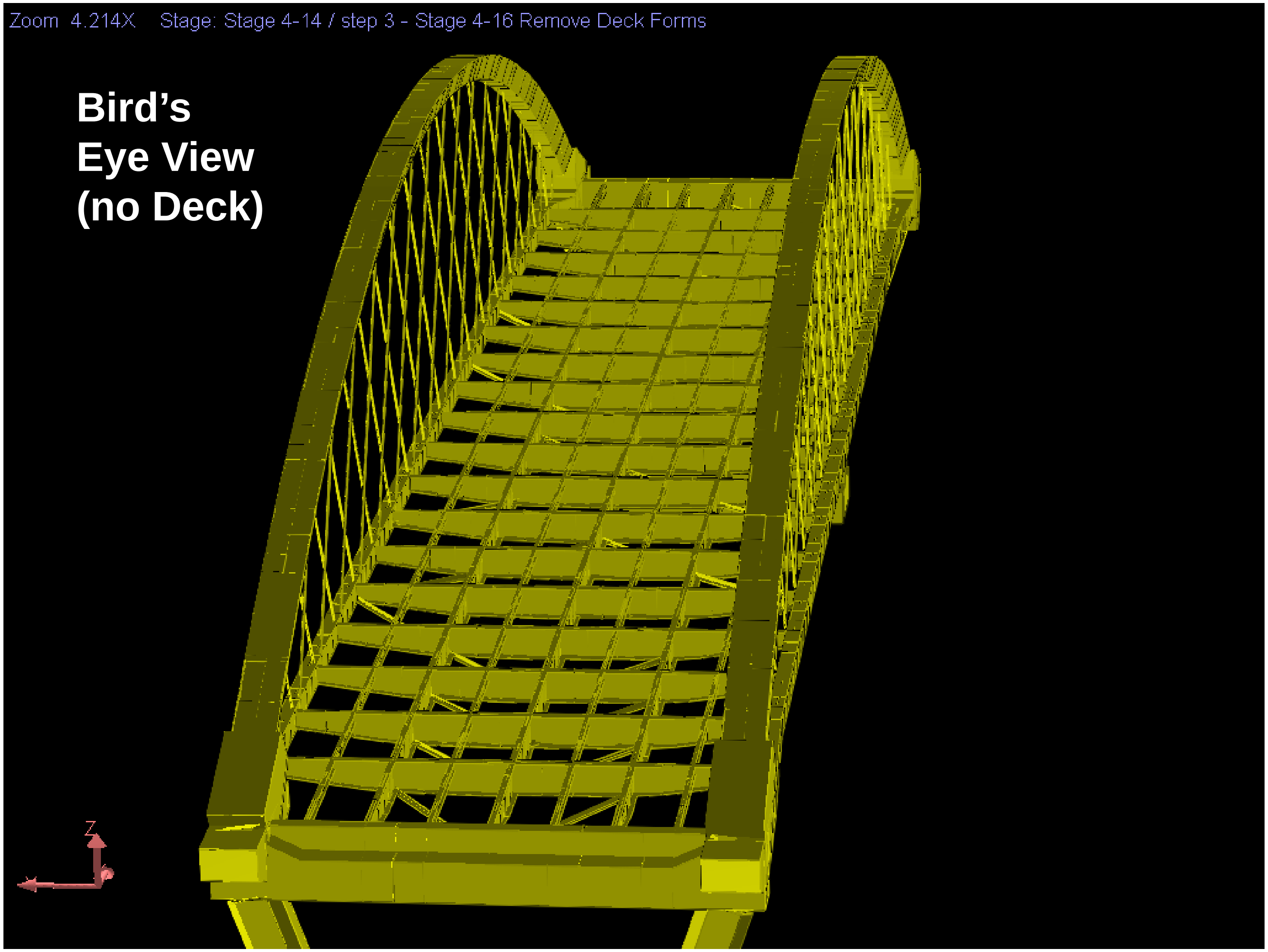
- Lift preassembled span into place



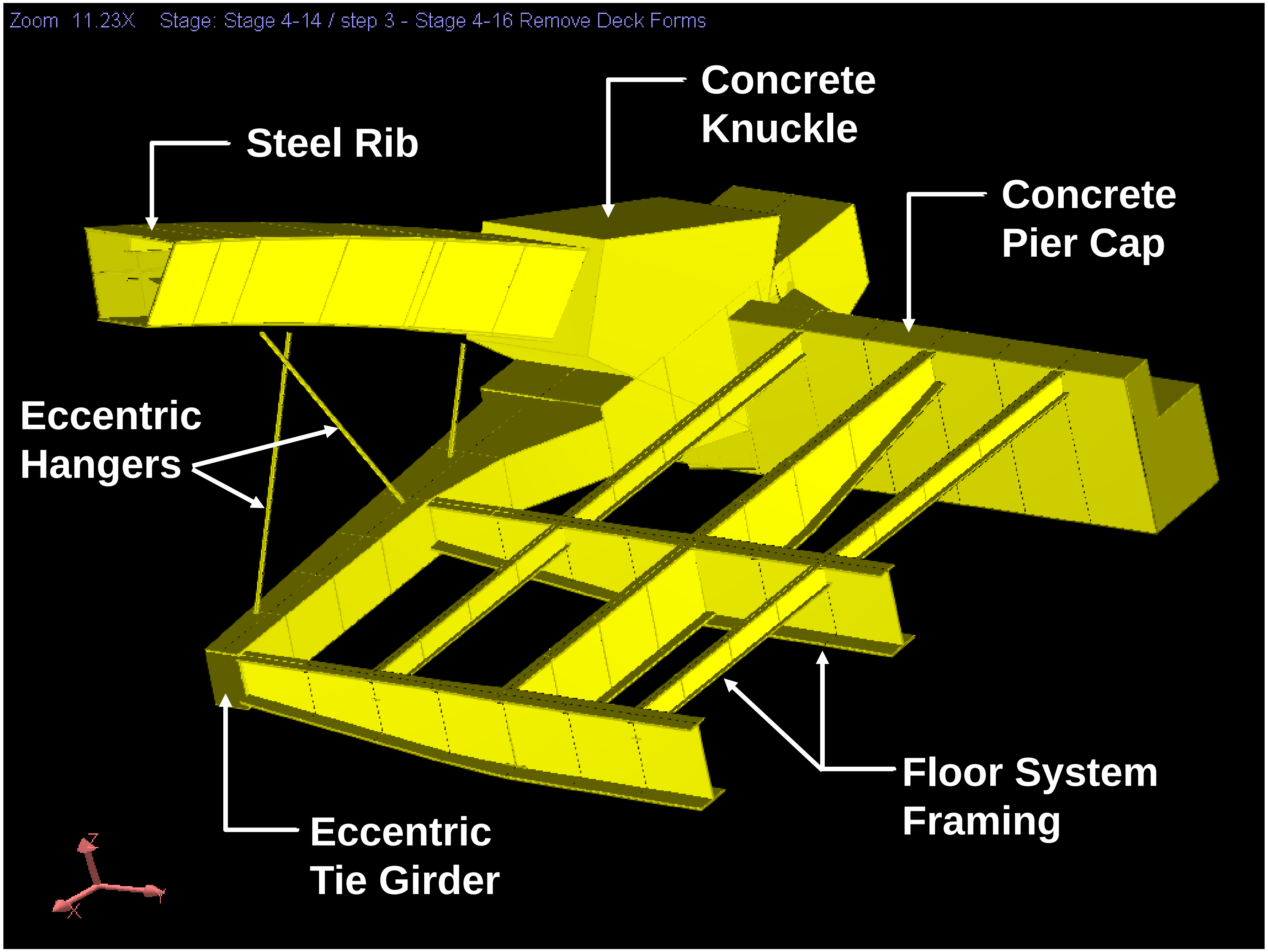
4D Staged Construction Model

- Construct post-tensioned ties and deck

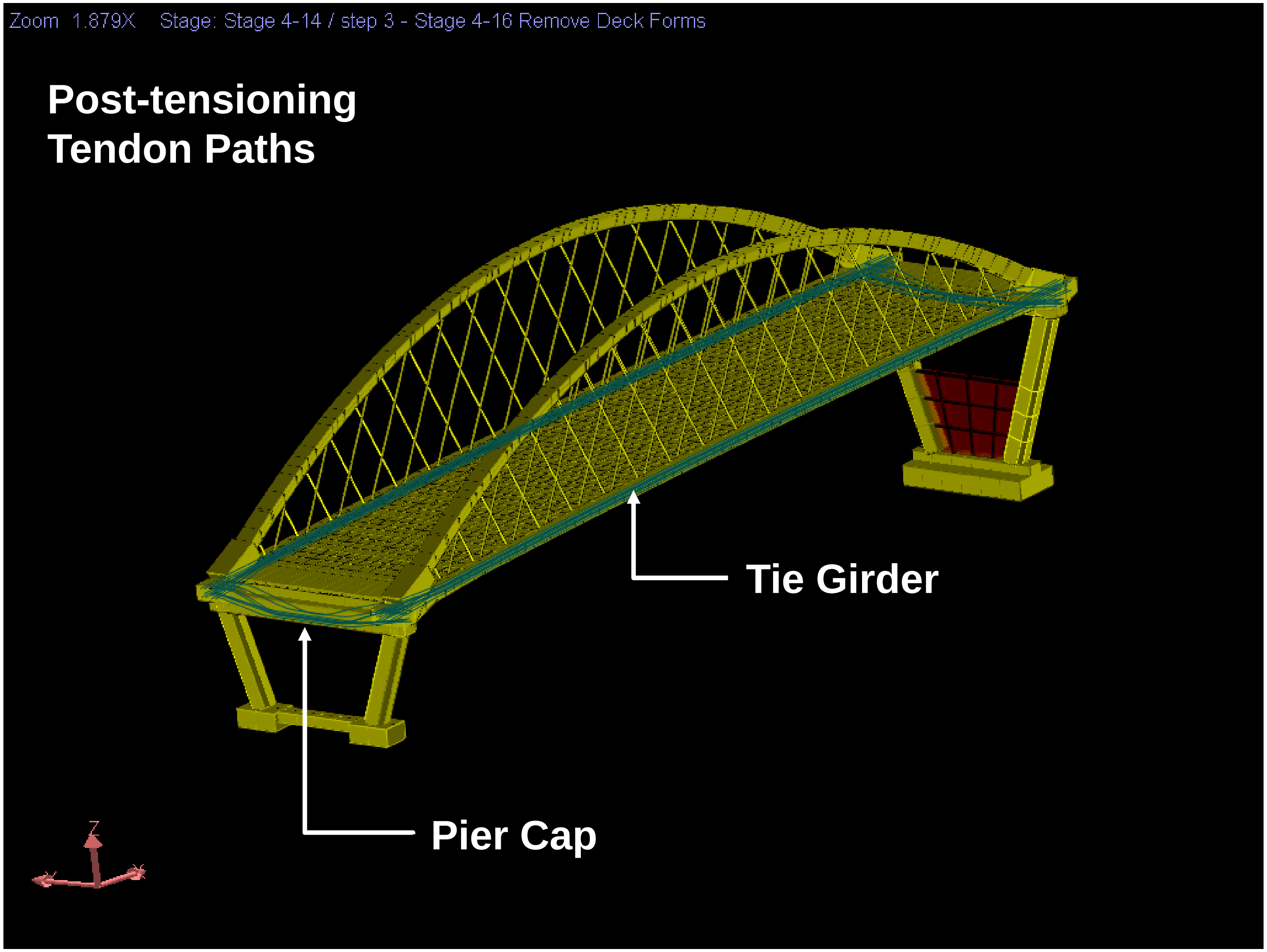
4D Staged Construction Model



4D Staged Construction Model

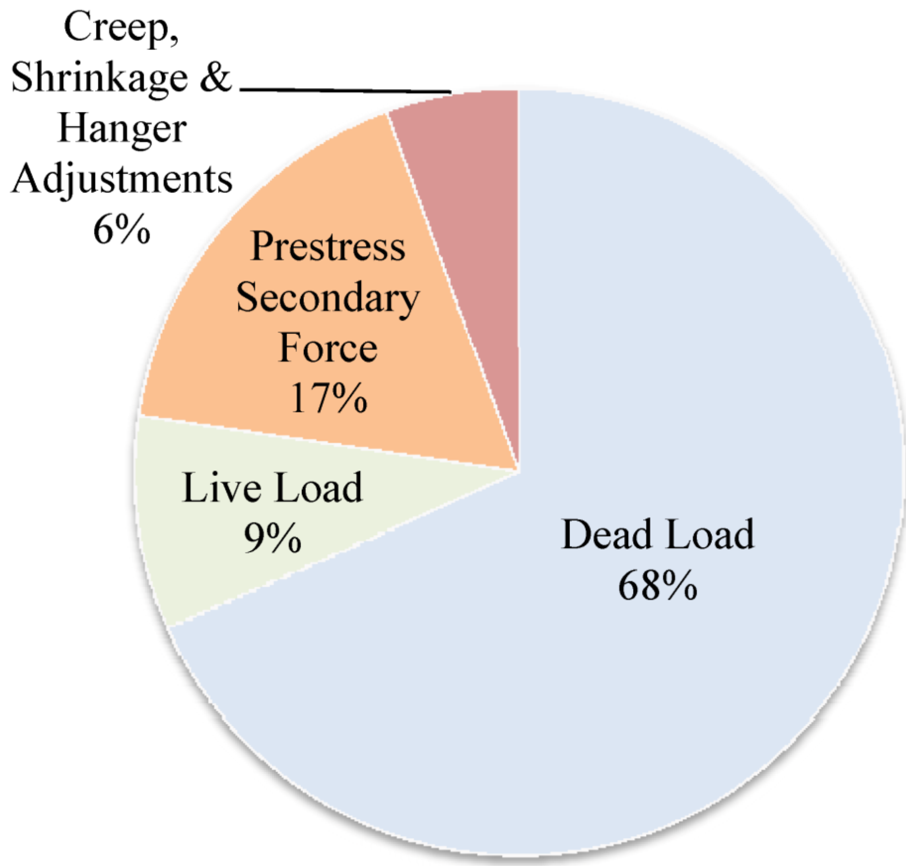


4D Staged Construction Model



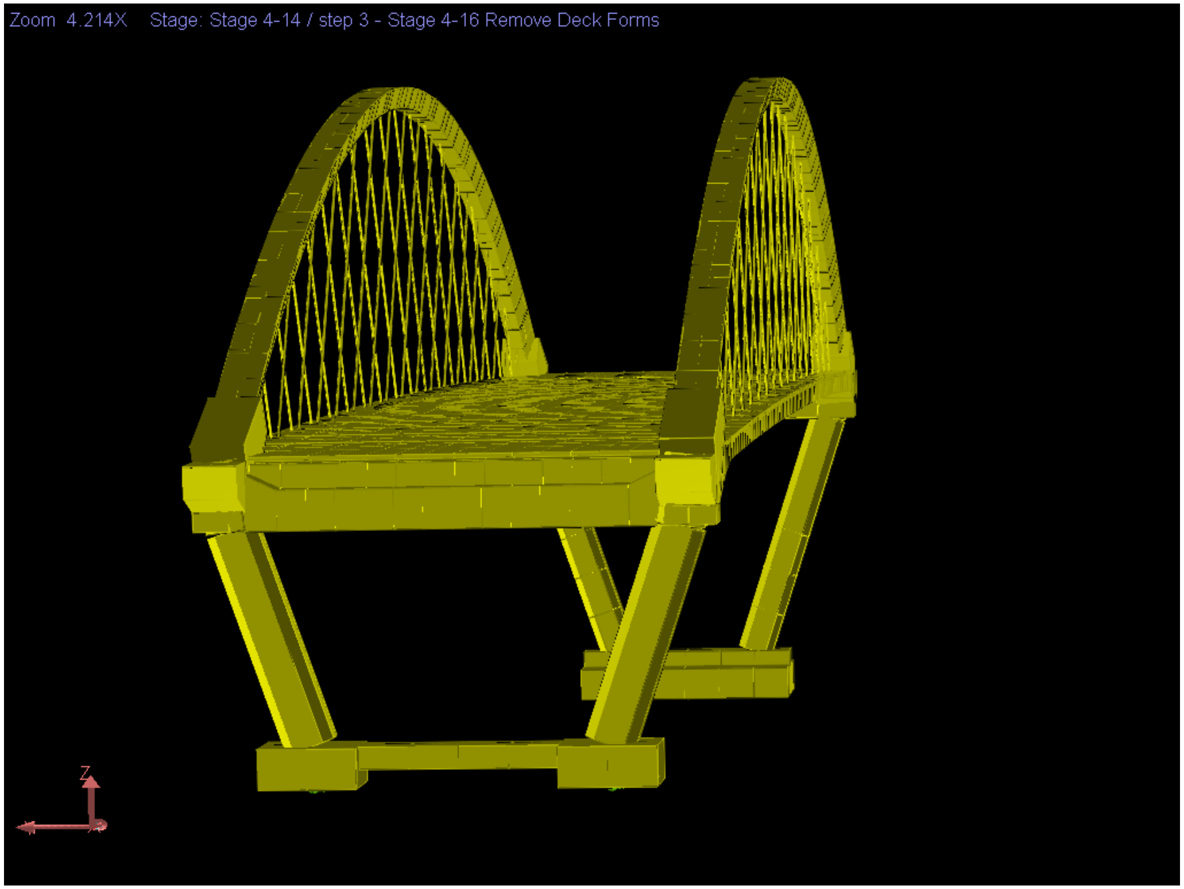
Insights from 4D Model Analysis

- 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



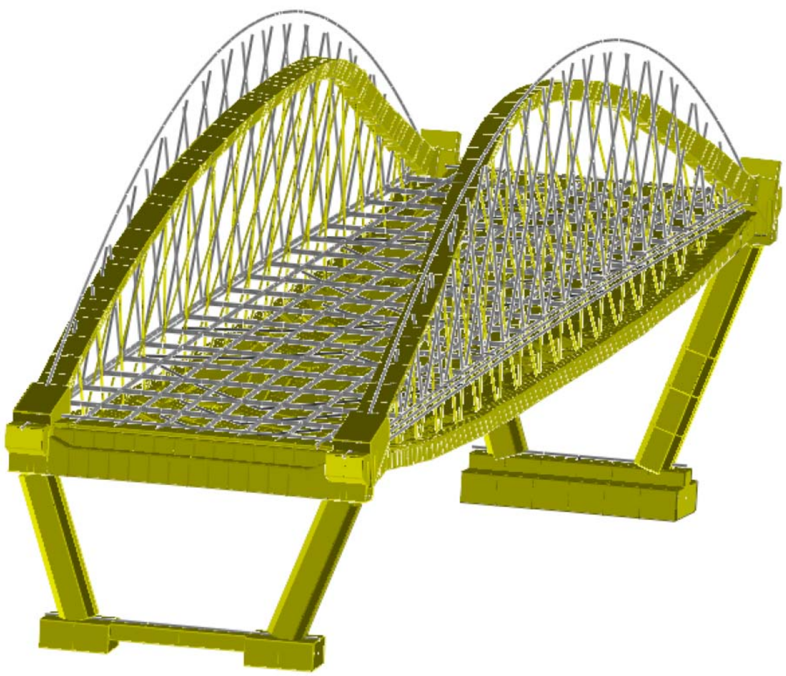
Insights from 4D Model Analysis

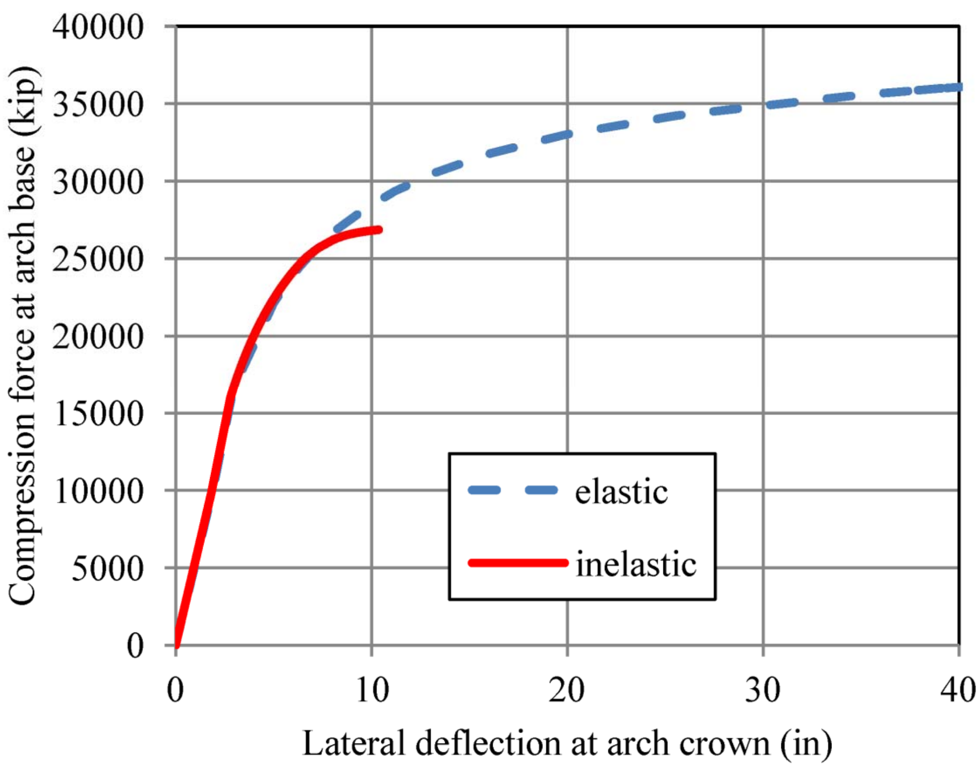
- Eccentric tie girders cause ribs to move inward
  - 1” from dead load
  - ¾” from creep over 100 years



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