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EVALUATION AND ANALYSIS OF DECKED BULB-T BEAM BRIDGES

"Experimental Investigation, Numerical analysis, Field Deployment, & Current/Future Research"

by

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Transportation Pooled Fund Program (MI, OR, MN, IA & WI)
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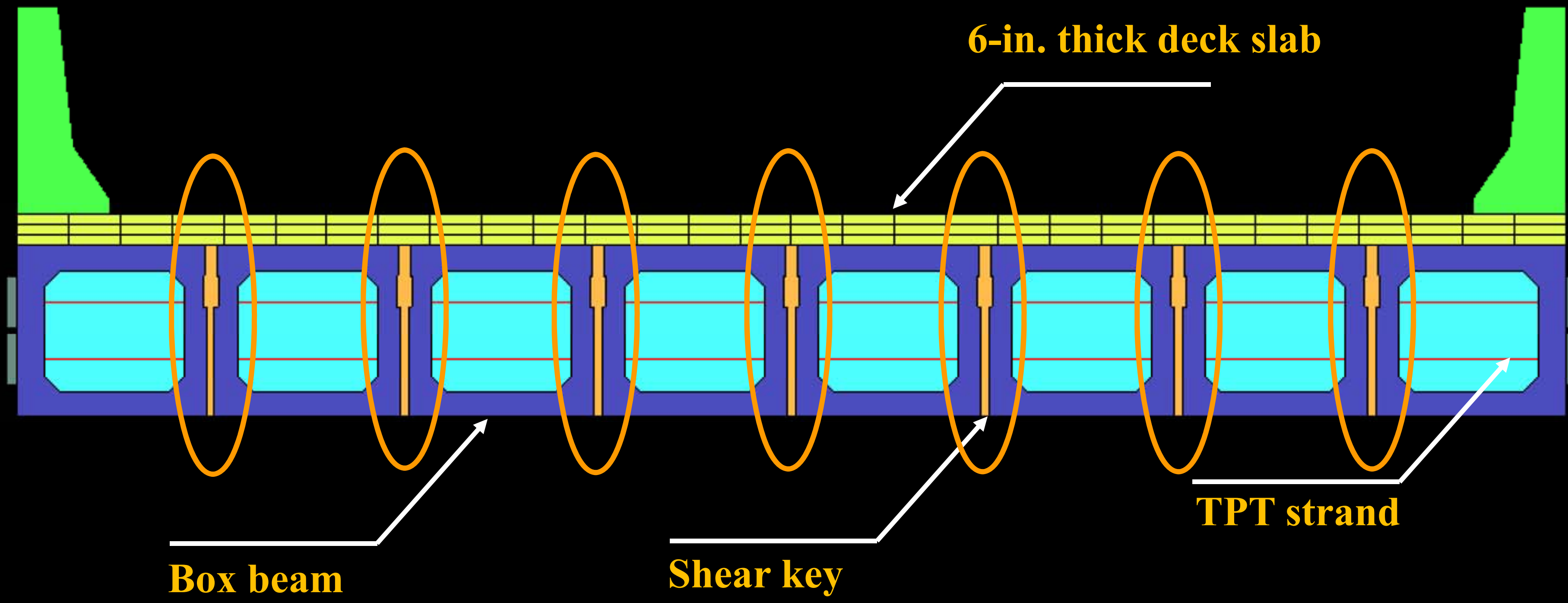
Subjects

- Statement of the Problem
- Experimental Investigation
- Numerical Investigation
- Field Deployment
- Ongoing Research Projects
- Future Research Projects

Statement of the Problem

Commonly used side-by-side box beam bridge system



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Statement of the Problem

Deterioration of side-by-side box beam bridge system

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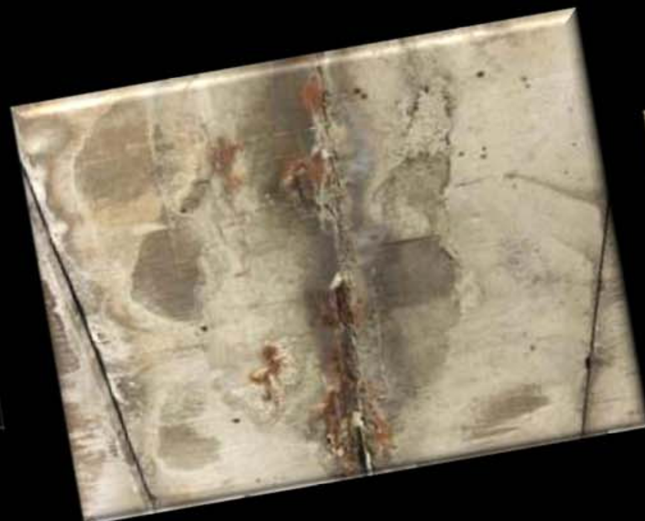
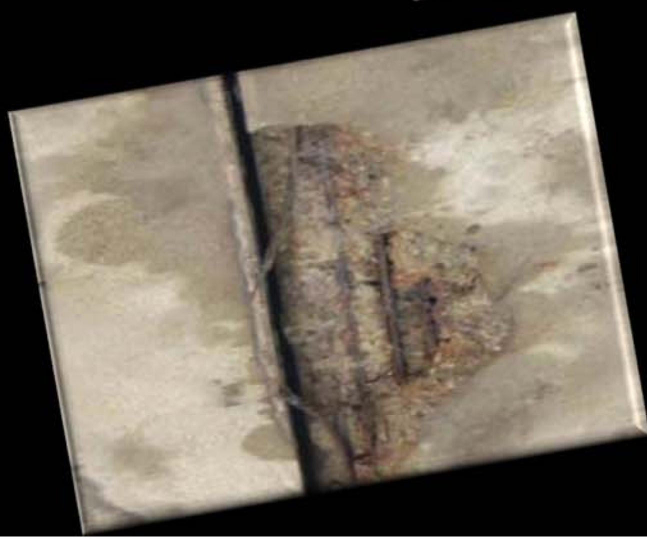
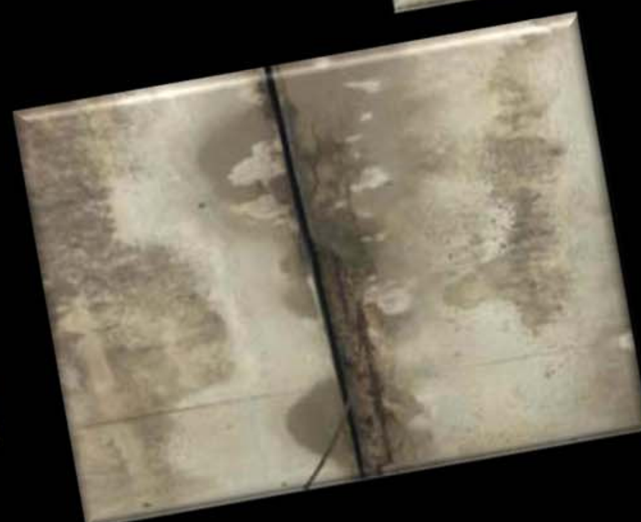
Deterioration of side-by-side box beam bridge system







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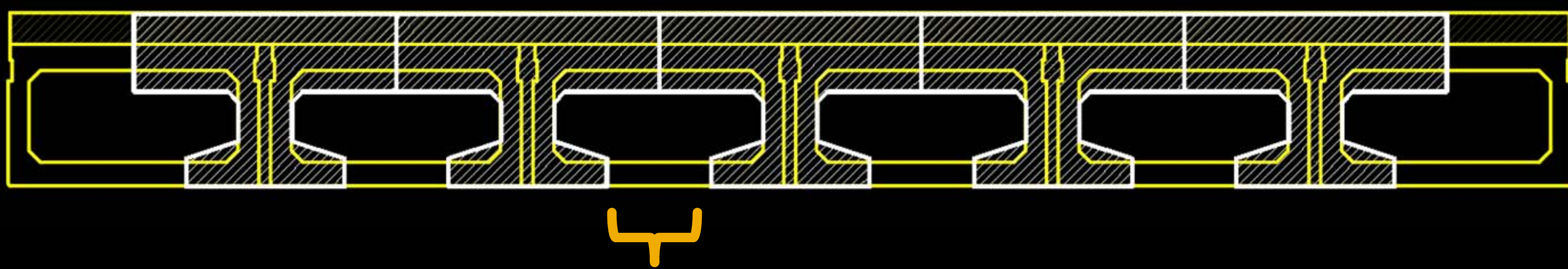
Research Scope

Alternative for side-by-side box beam bridge system

Decked bulb T beam bridge system

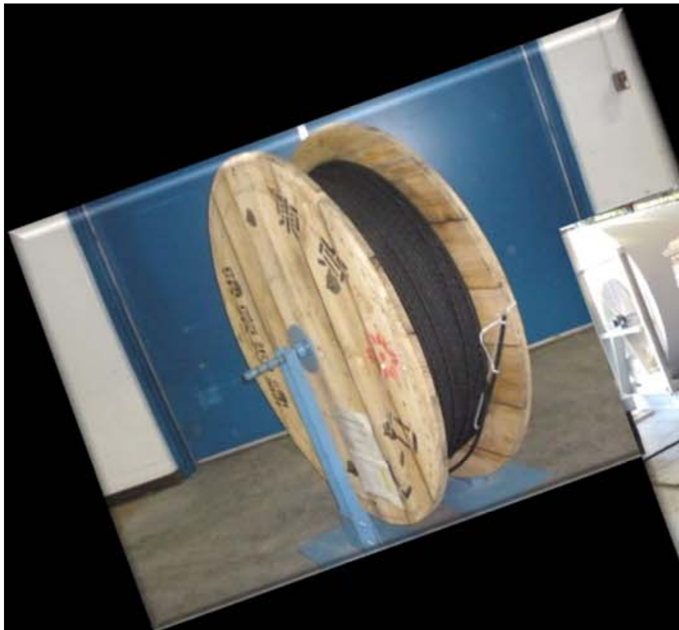


Space for inspection

~~Steel Reinforcement~~ → FRP Reinforcement

~~Non-shrink grout~~ → UHPC for shear key joints

CFCC Reinforcement



Classification	7-wire strand
Diameter	0.6 in.
C.S. area	0.179 in.^{2}
Guaranteed strength	340 ksi
Ultimate strength	424 ksi
Elastic modulus	21,610 ksi
Ultimate elongation	2 %

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Components of Decked Bulb T beam Bridge Model

- *Four prestressing strands/beam*
- *Initial prestressing force = 33 kip/strand (132 kip/beam)*

UHPC shear key

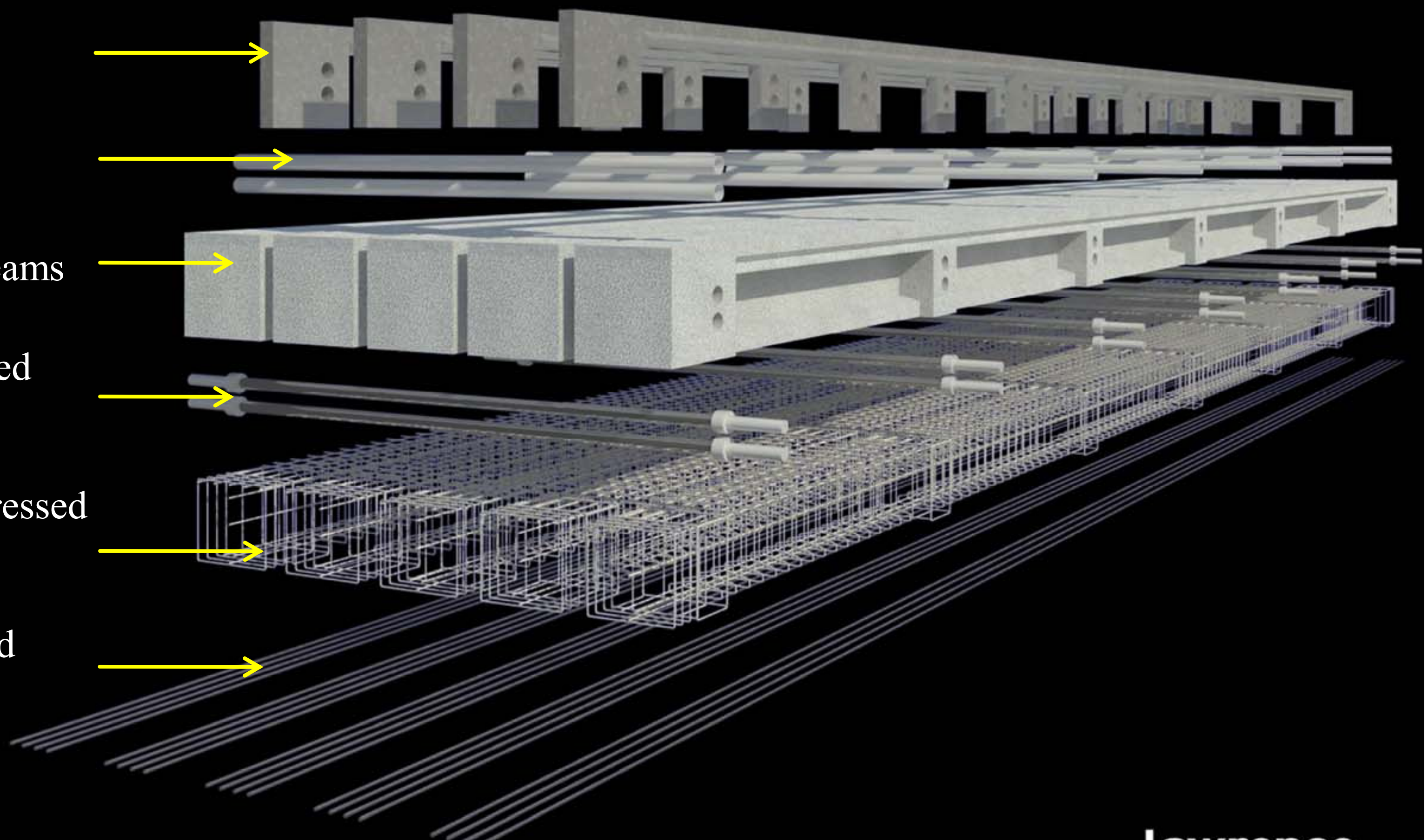
Post-Tension Ducts

7,000 psi Concrete beams

1″ (1x7) post-tensioned CFCC strands

3/8″ (1x7) non-prestressed CFCC strands

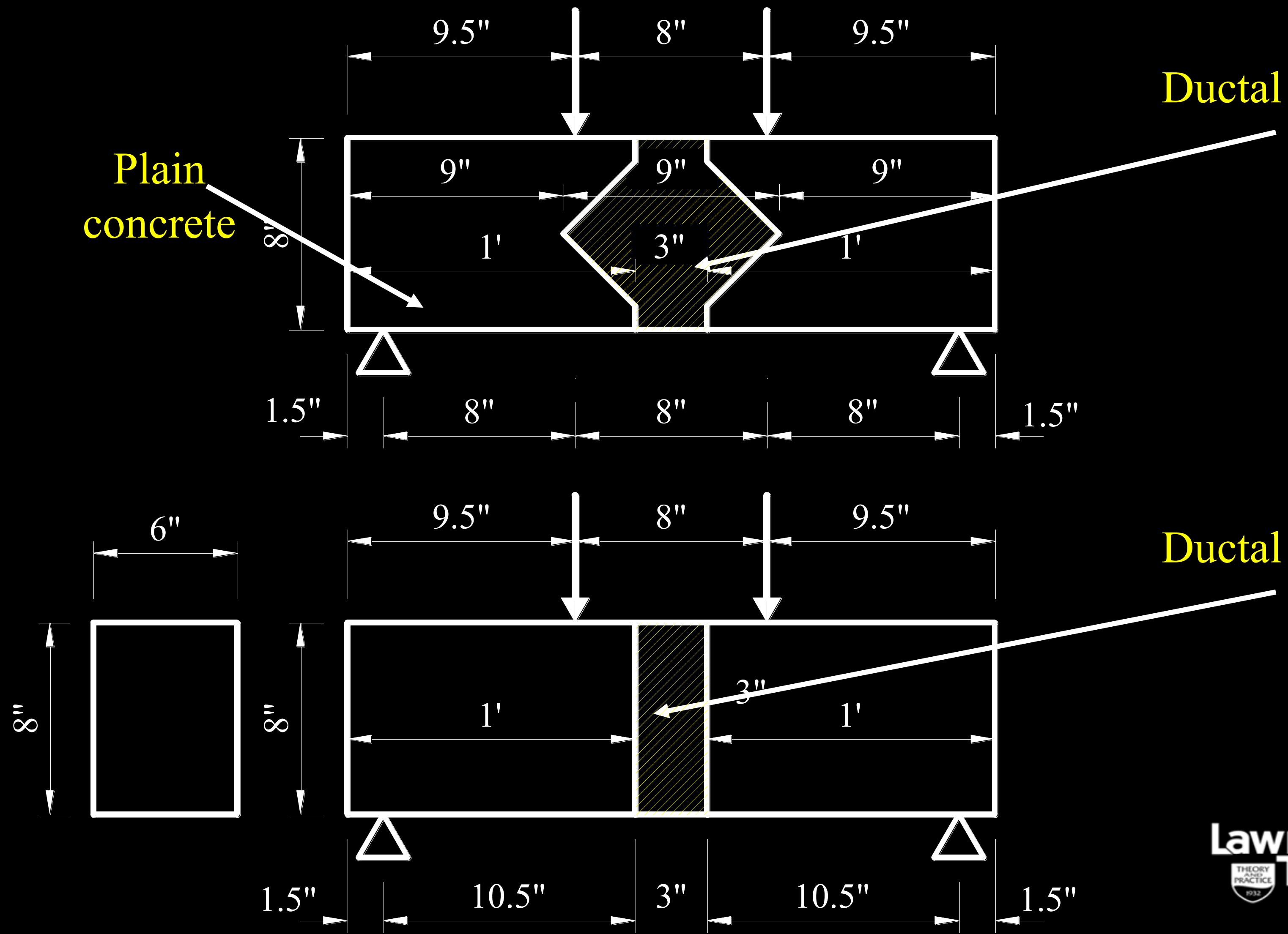
0.6″ (1x7) prestressed CFCC strands



Ultra High Performance Concrete (UHPC) for Shear Keys

ASTM Testing for UHPC

ASTM C78- Flexural strength of concrete



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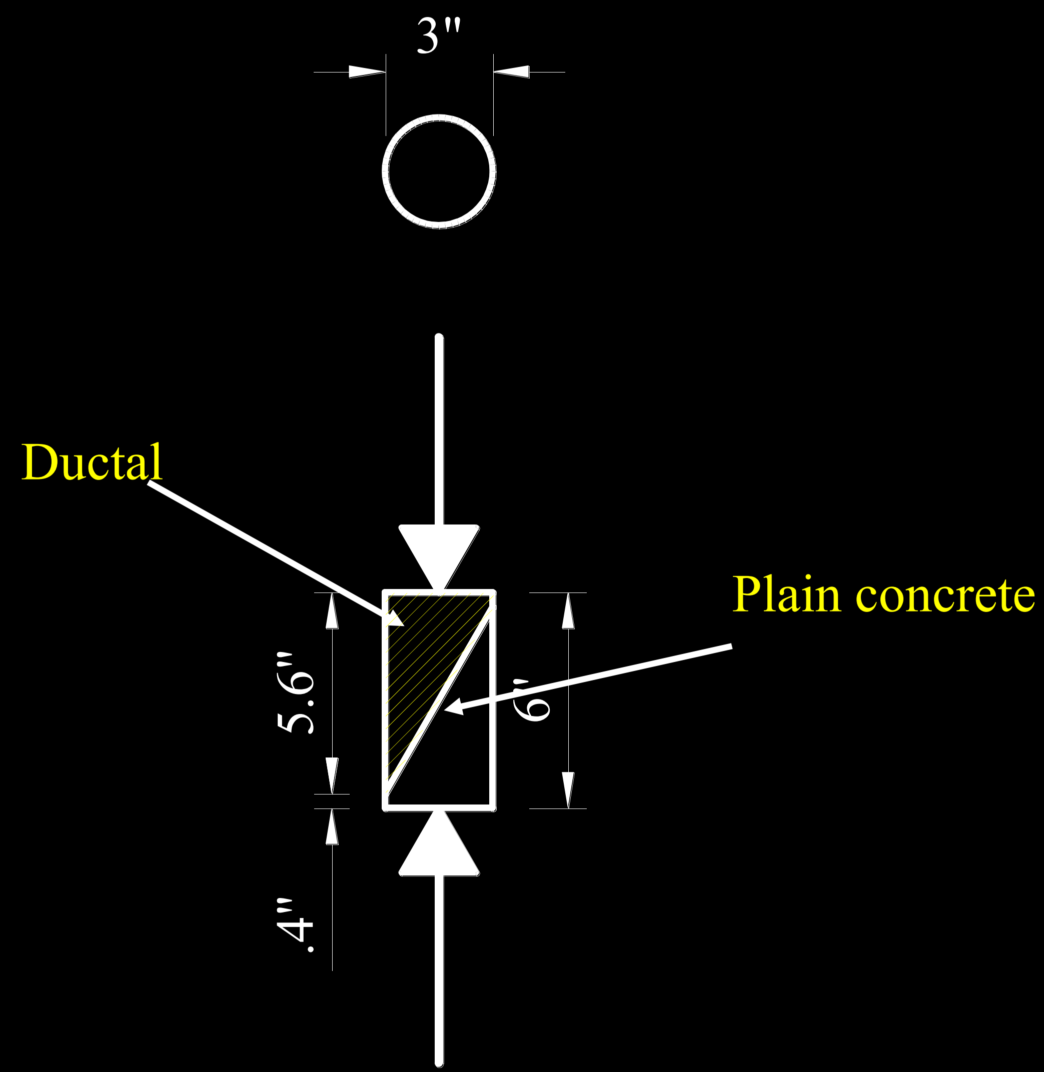
ASTM C78- Flexural Strength of Concrete

Failure Load = 14.61 kips, failure stress = 930 psi

ASTM Testing for UHPC

ASTM C1042- Bond strength by slant shear test



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ASTM C1042- Slant Shear Test

Concrete

UHPC

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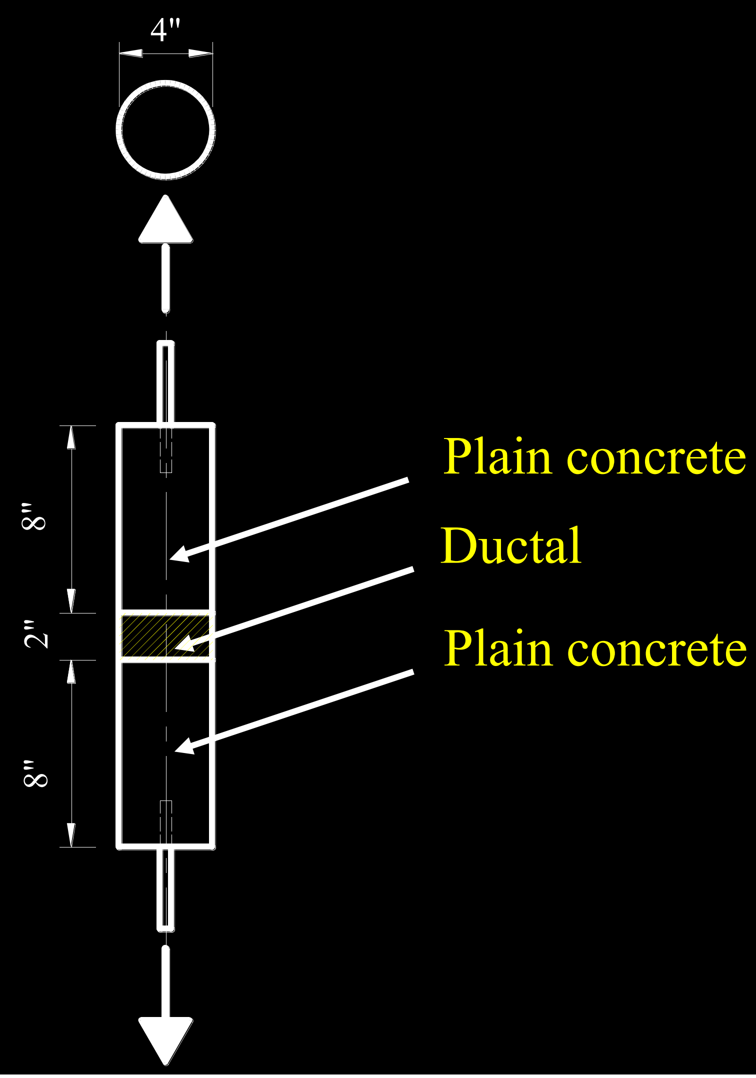
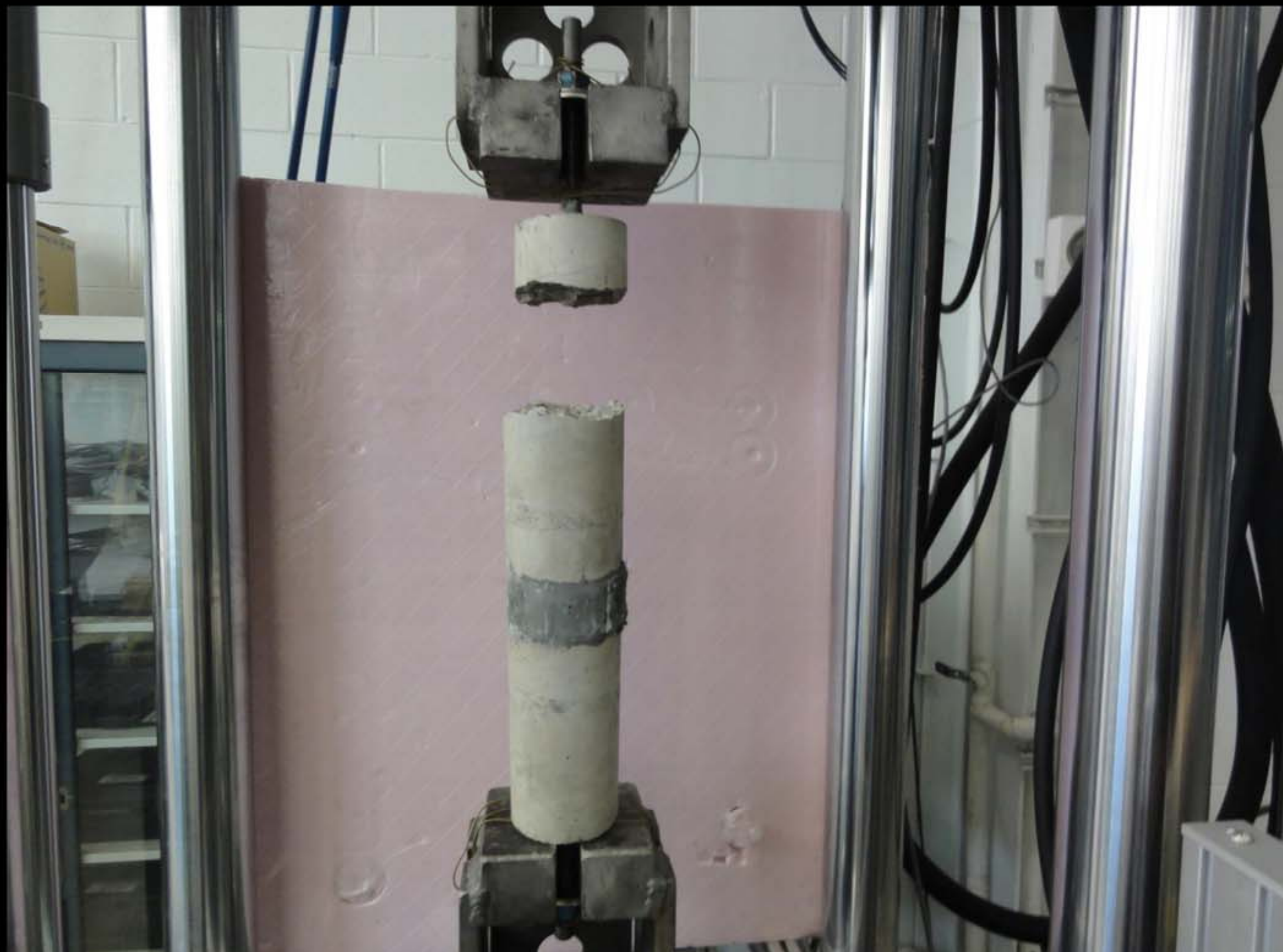
ASTM Testing for UHPC

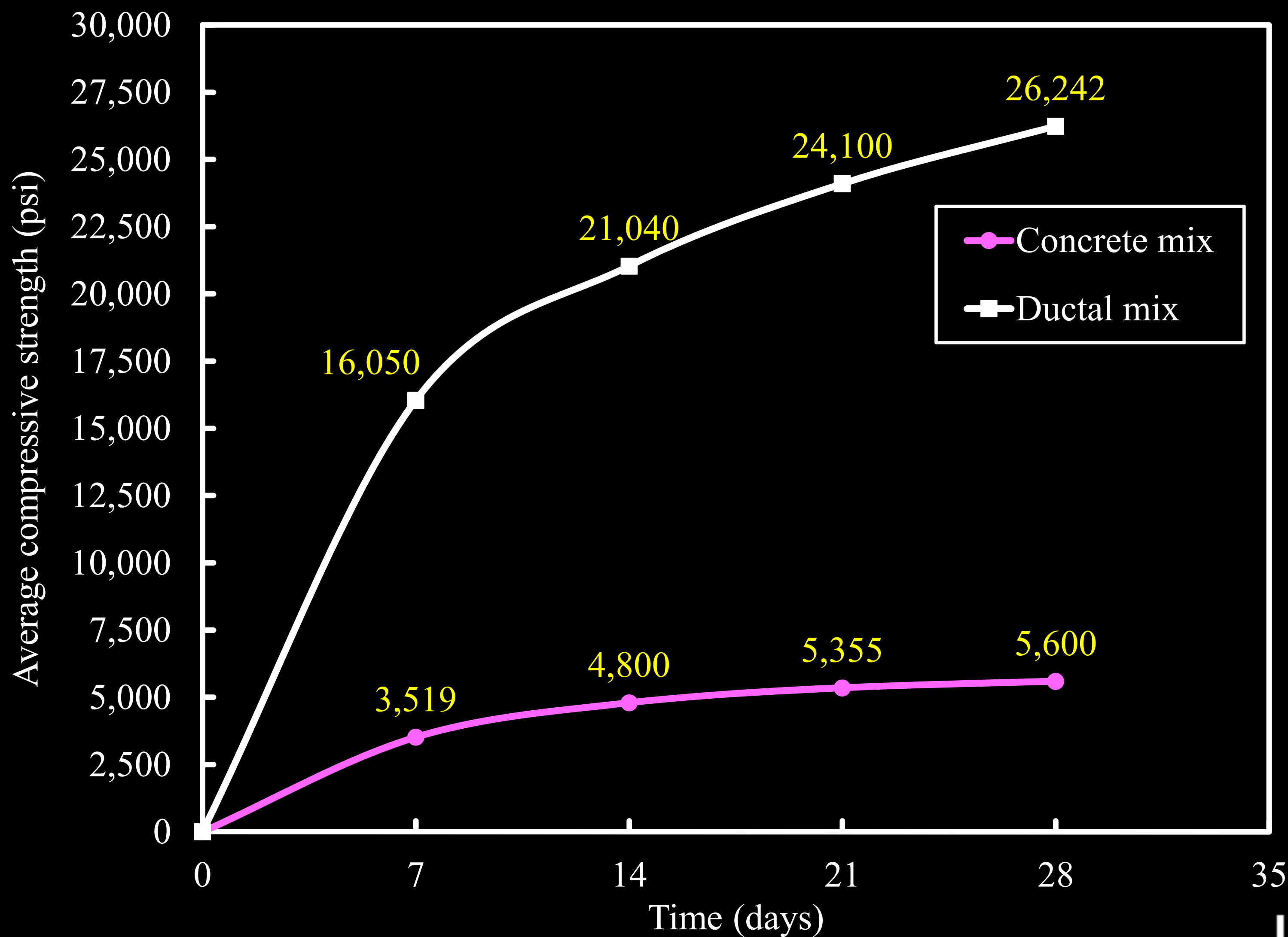
ASTM C1583- Bond strength by direct tension



ASTM C1583- Pull-off Test



Compressive Strength of UHPC vs. Regular-mix Concrete



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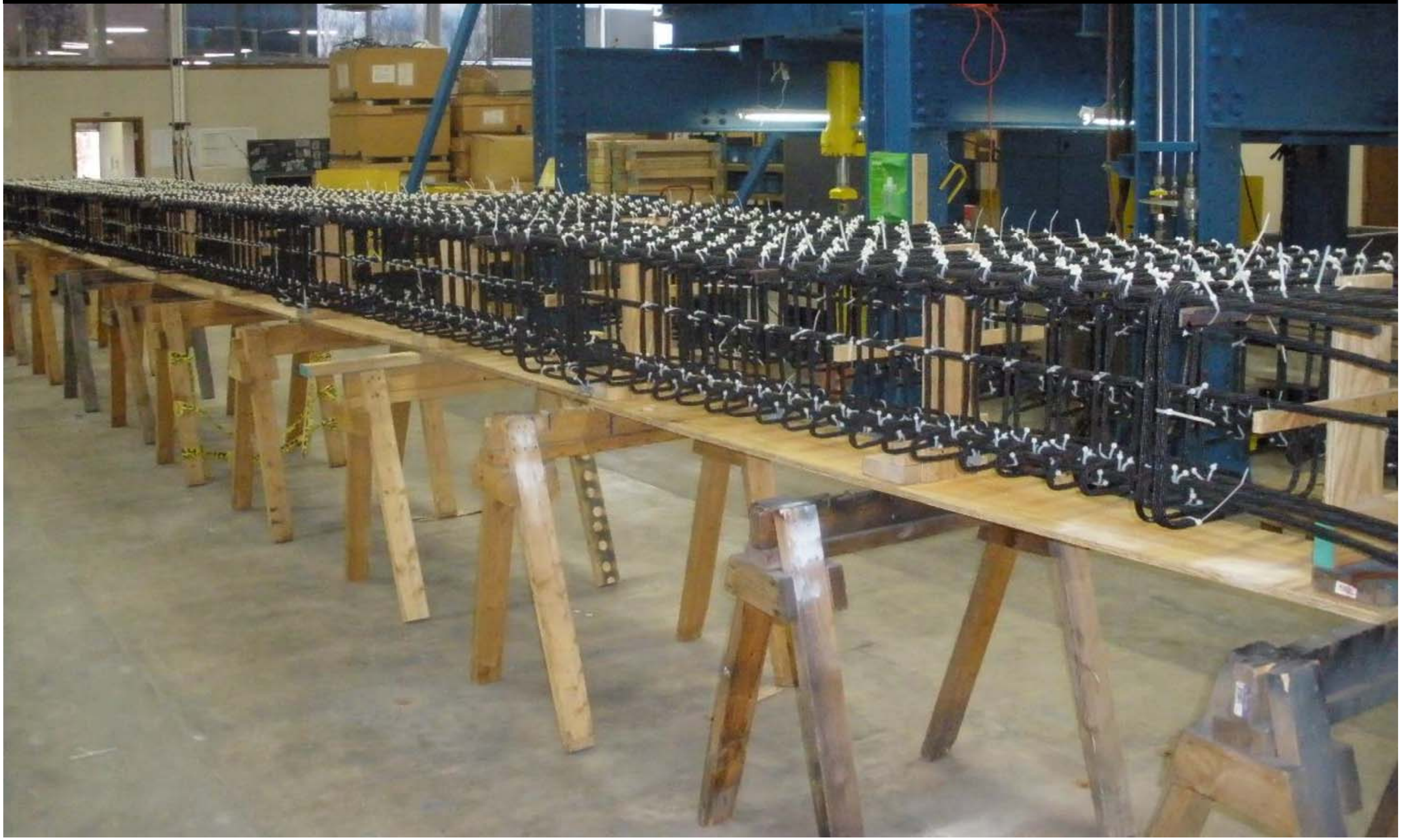
Reinforcement Cages

Completed CFCC reinforcement cage (non-prestressing strands & stirrups)

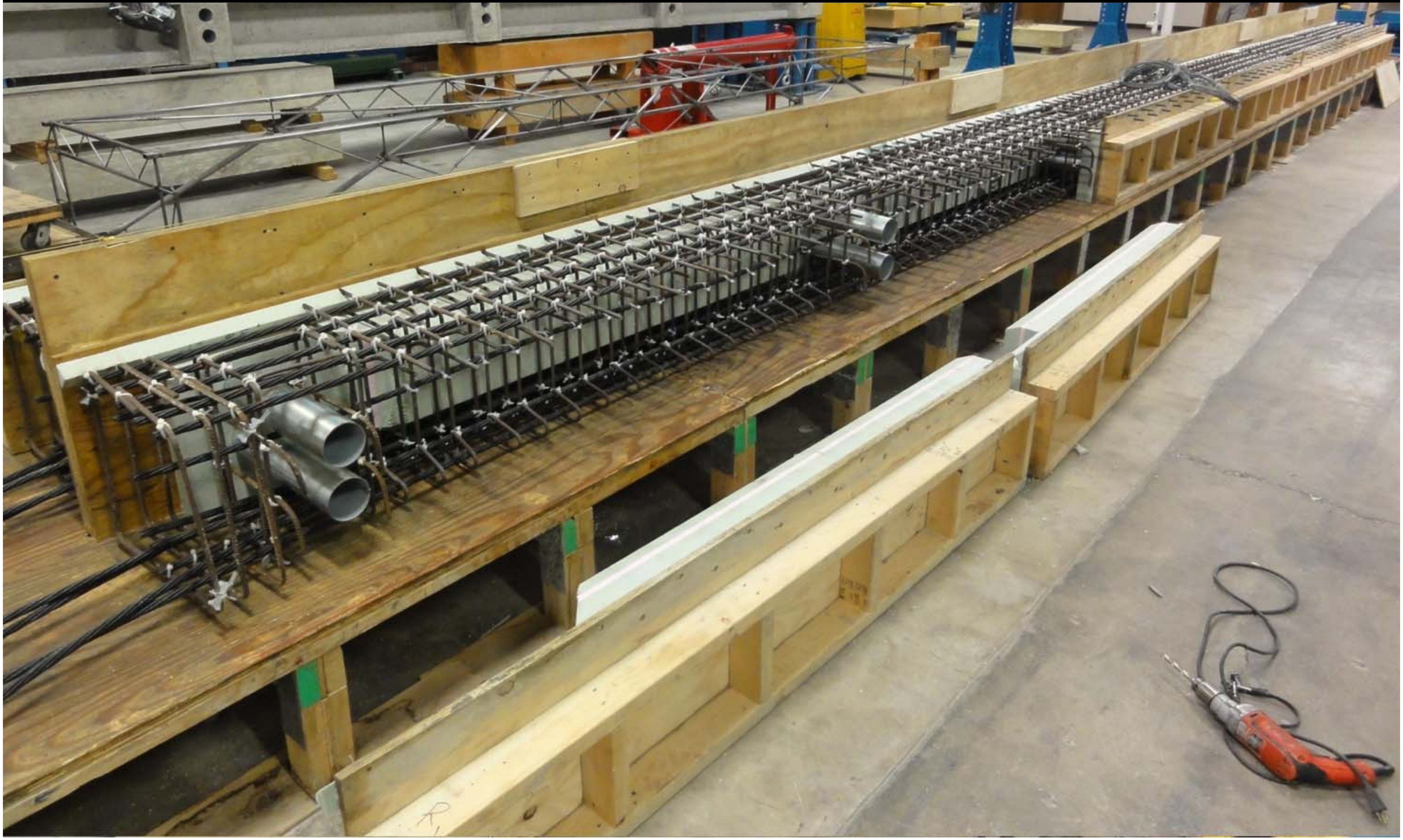


Reinforcement Cages of DBT Beams for Bridge Model

Completed cage for interior beam (non-prestressed strands & stirrups)

Placing Reinforcement Cages in Formwork

Attaching exterior sides of formwork



Development of Couplers for CFCC Strands

Concrete Finishing, Curing, & Side Formwork Removal


Finishing the surface


Wet curing for 7 days


Removing sides of formwork

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Prestress Release

Building Formwork for Shear Key Joints

Pouring Shear Key Joints

Covering & Curing Shear Key Joints

Applying Transverse Post-tensioning CFCC Strands

Flexural Testing of Under-Reinforced CFCC Beam (Video)

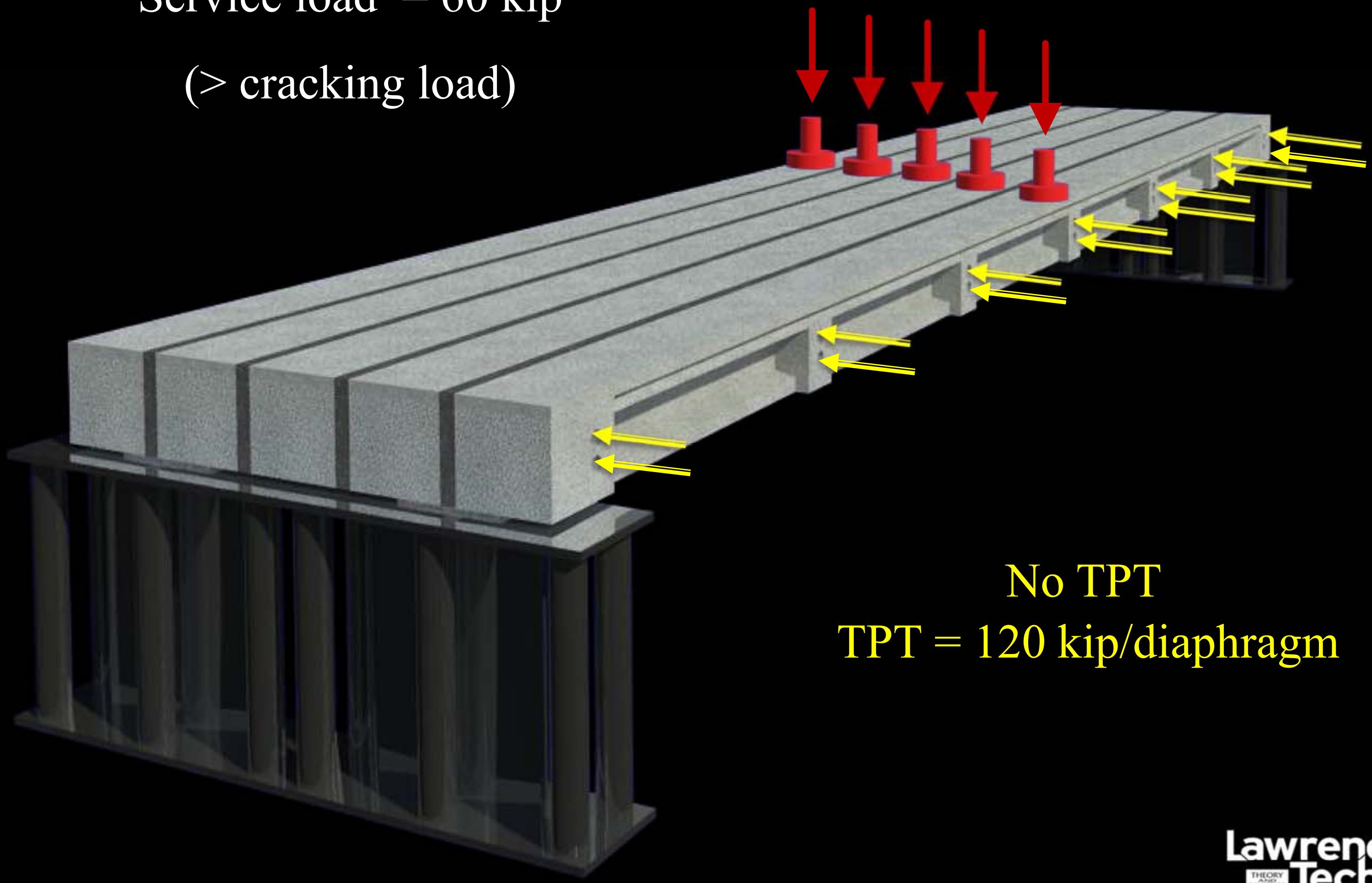
Play Video

Failure of Under-Reinforced CFCC Beam

Post-crack Limit State Testing of the Bridge Model

Service load = 60 kip

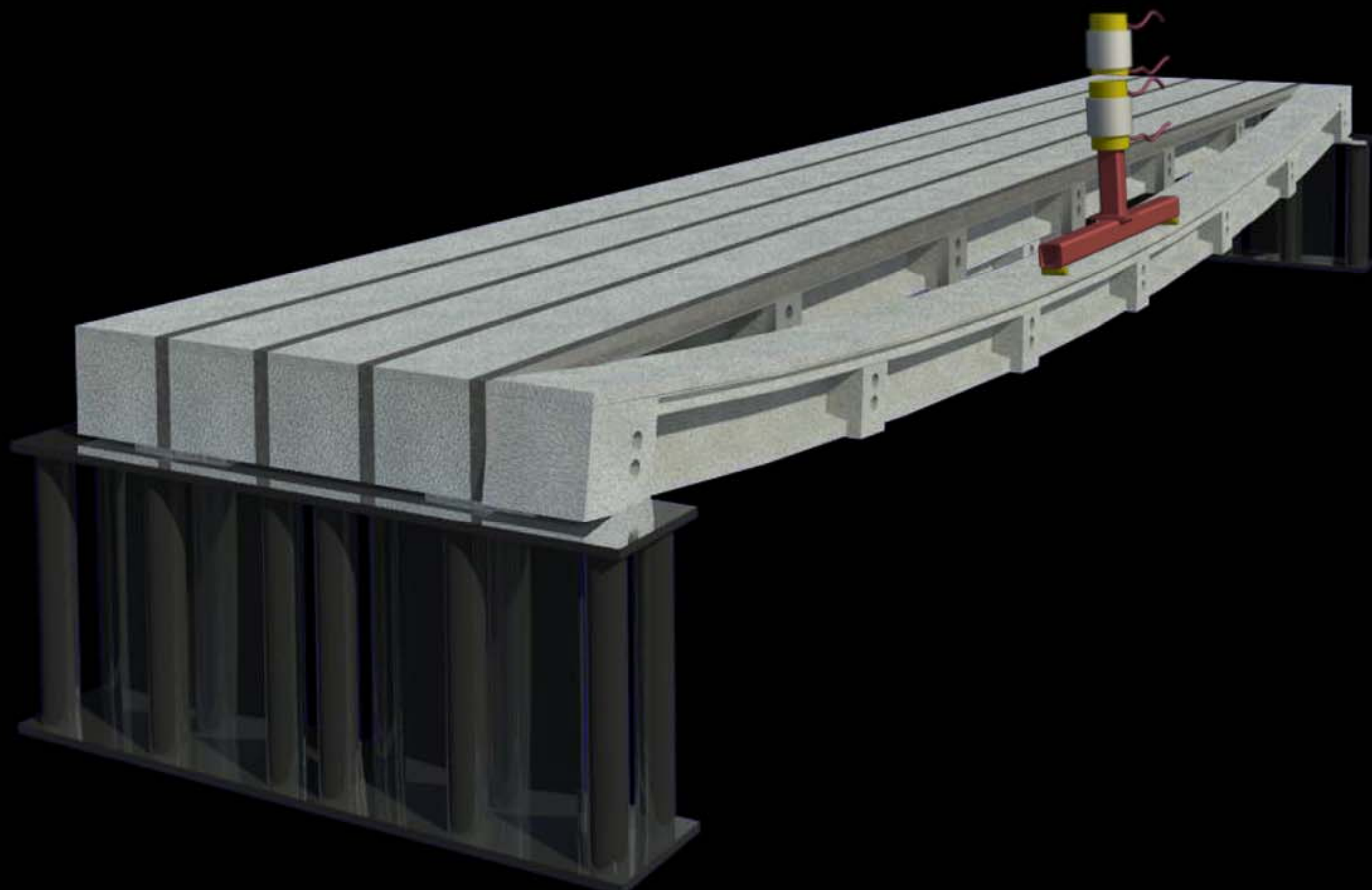
(> cracking load)



No TPT

TPT = 120 kip/diaphragm

Shear Key Testing



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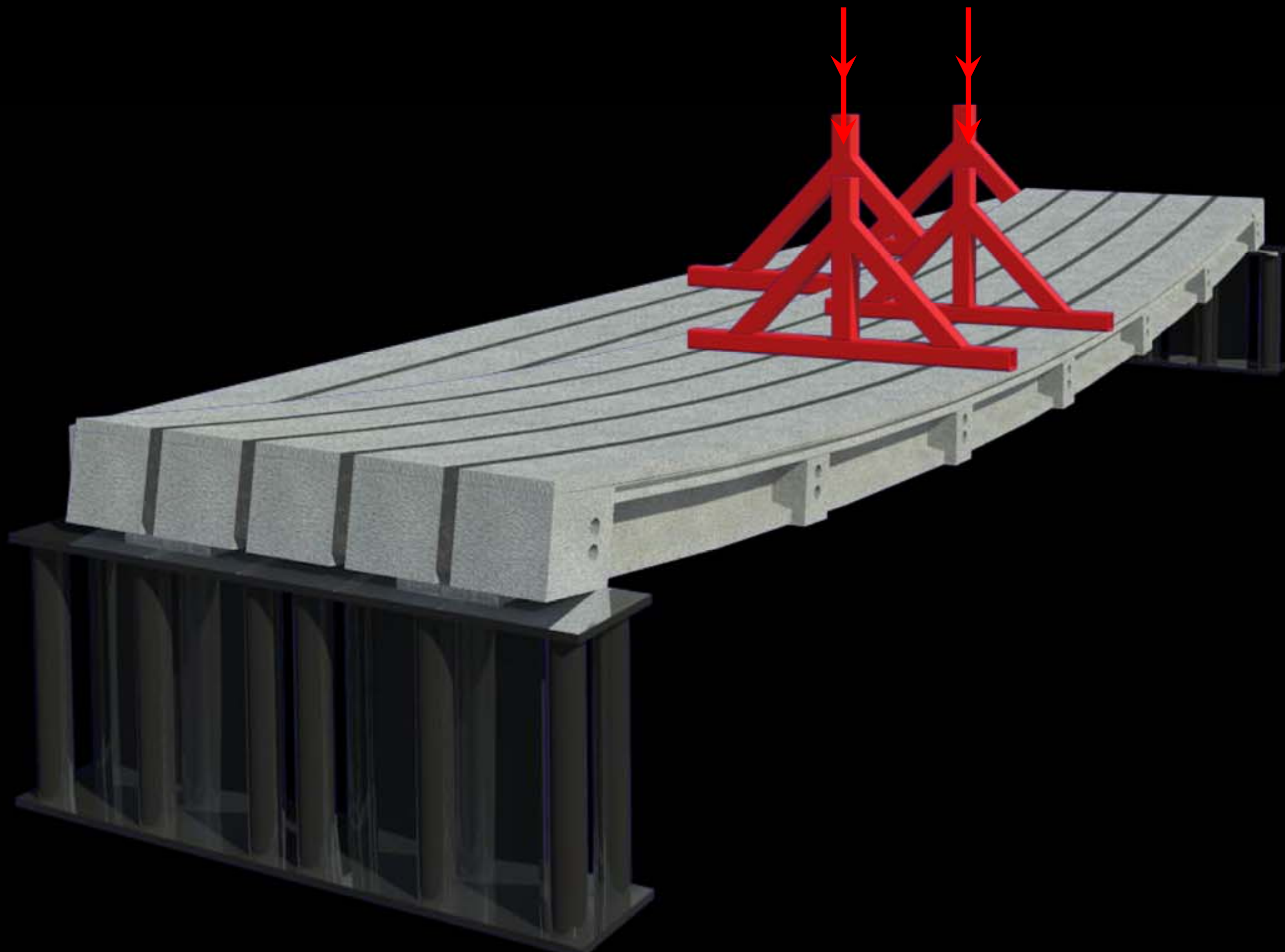
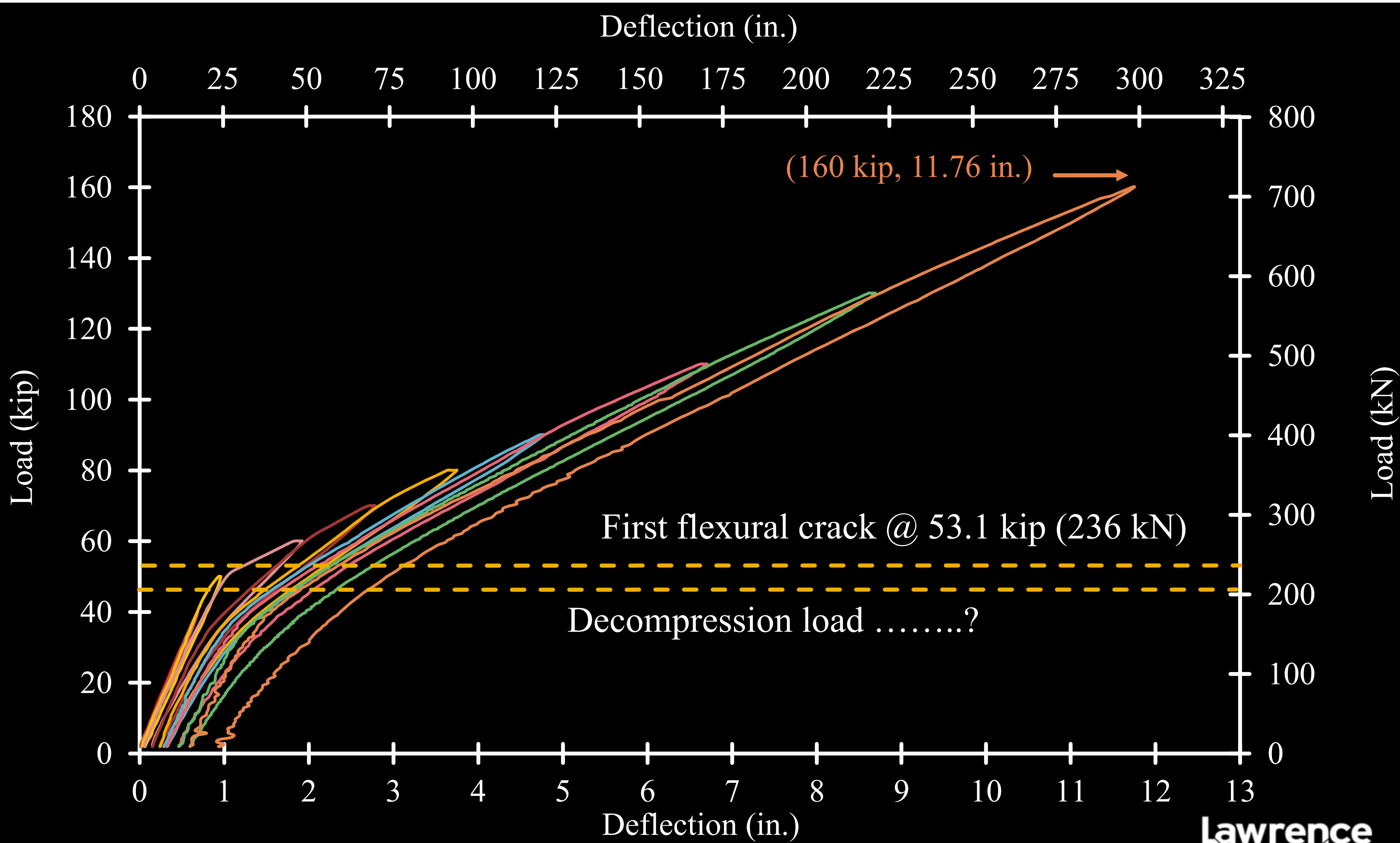
Testing Shear Key Connection

Strength Limit State Testing



Load cycles Under Four-Point-Loading

Load cycles Under Four-Point-Loading



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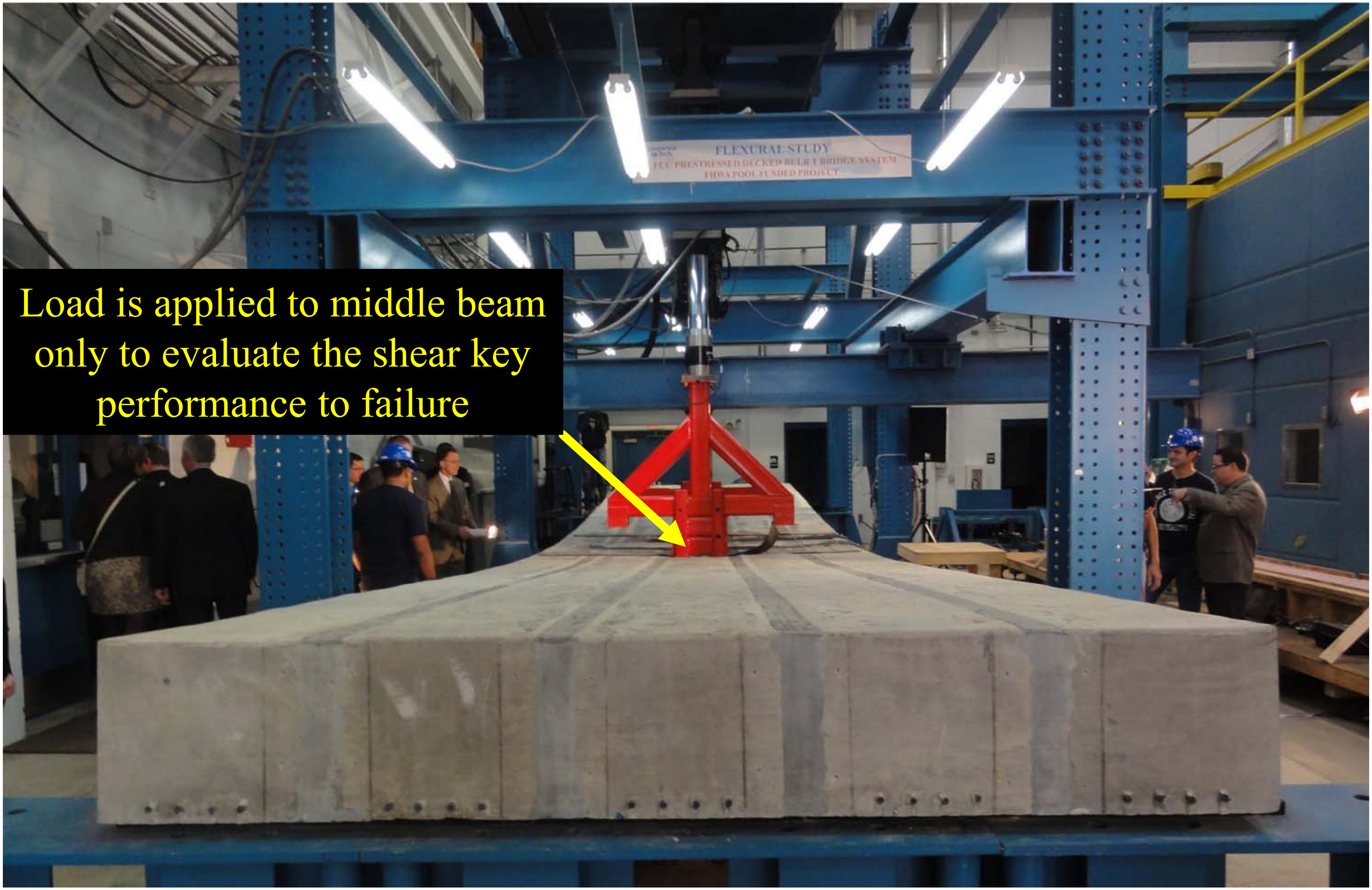
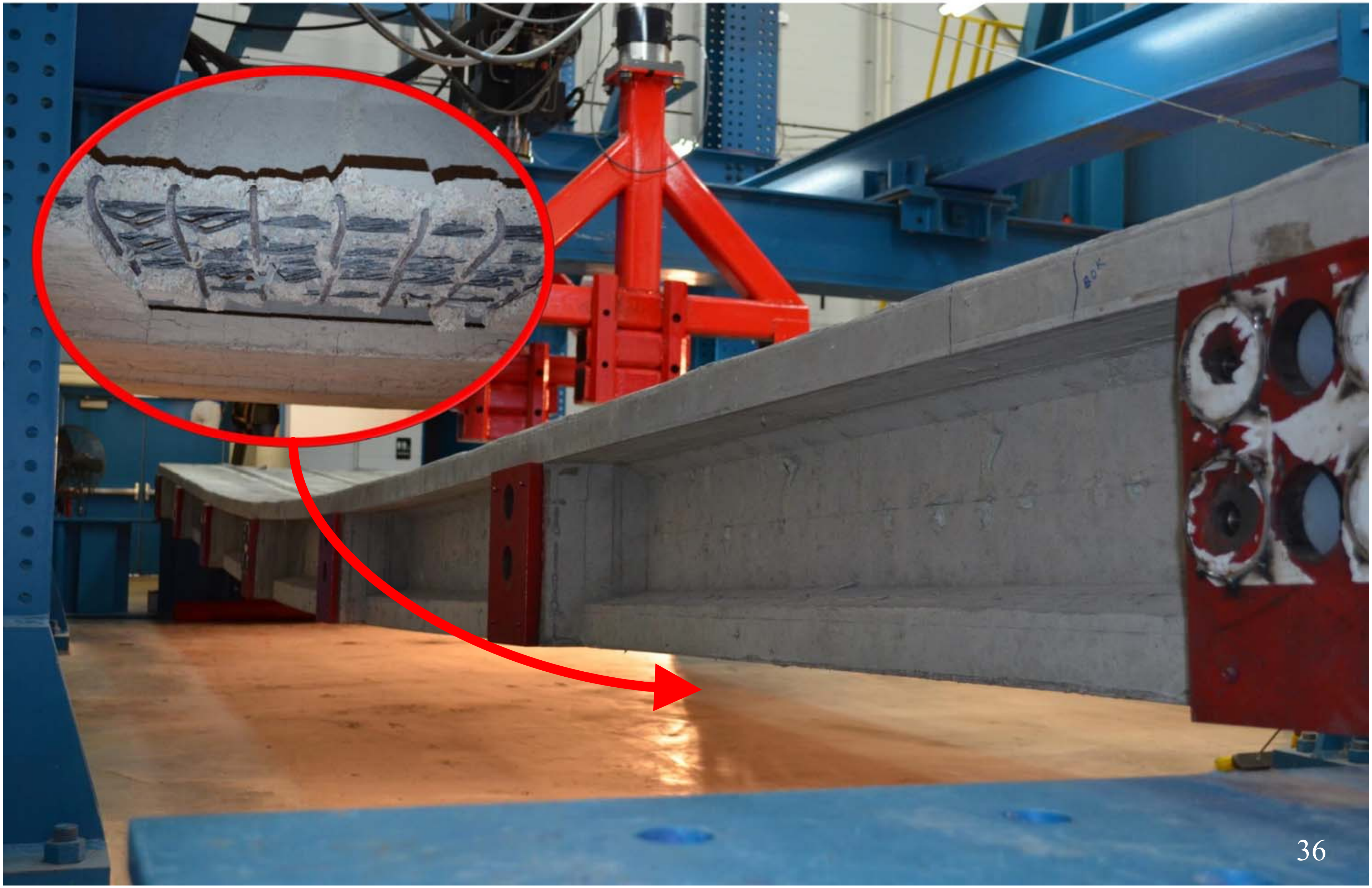
Strength Limit State Testing of Bridge Model

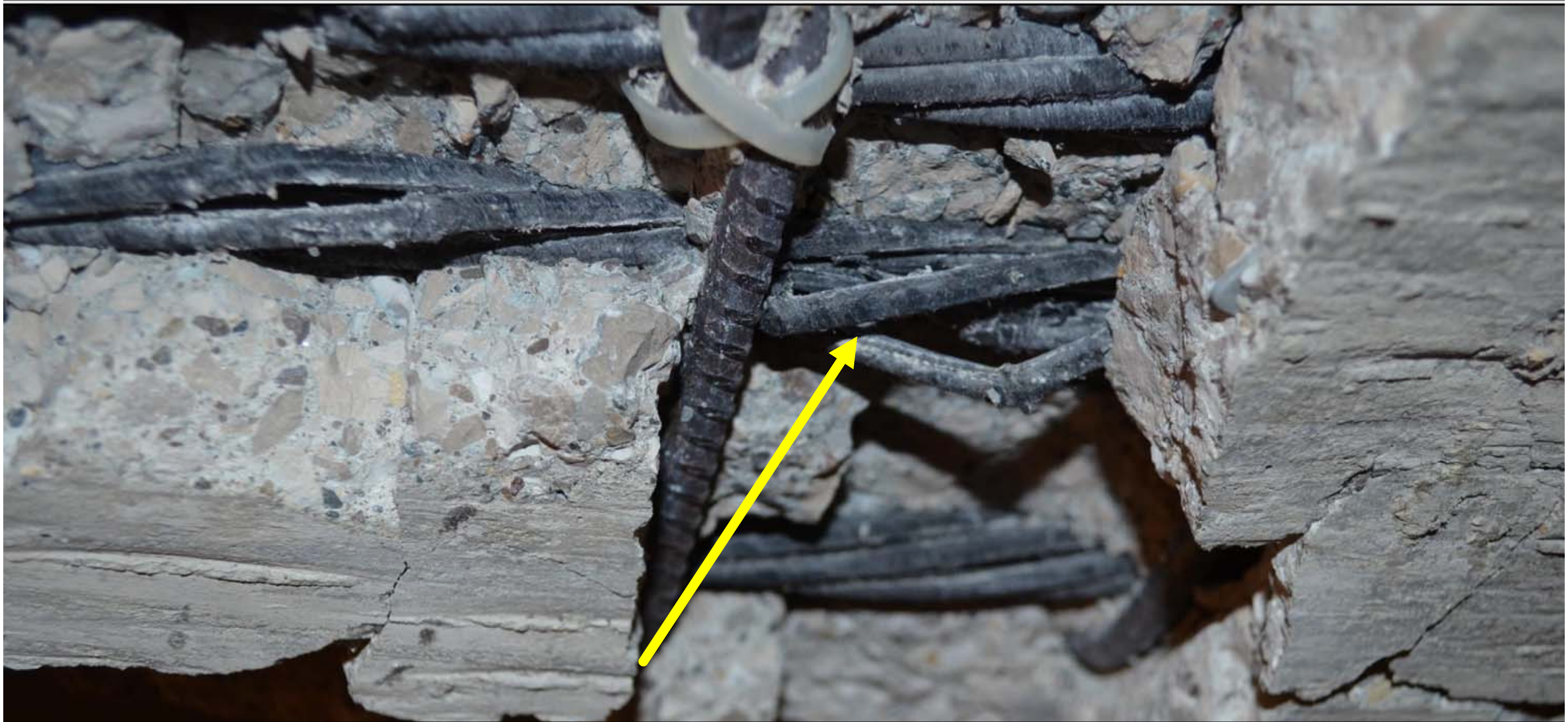


Load is applied to middle beam only to evaluate the shear key performance to failure

Failure of Bridge Model



Failure of Bridge Model



Rupture of CFCC strands at load of 220 kip > anticipated failure load based on the test of single beam (5 × 40.81 = 204 kip)

Separation of the middle beam and failure of UHPC shear key joint could not be achieved before the flexural failure of bridge beams

Failure of Bridge Model

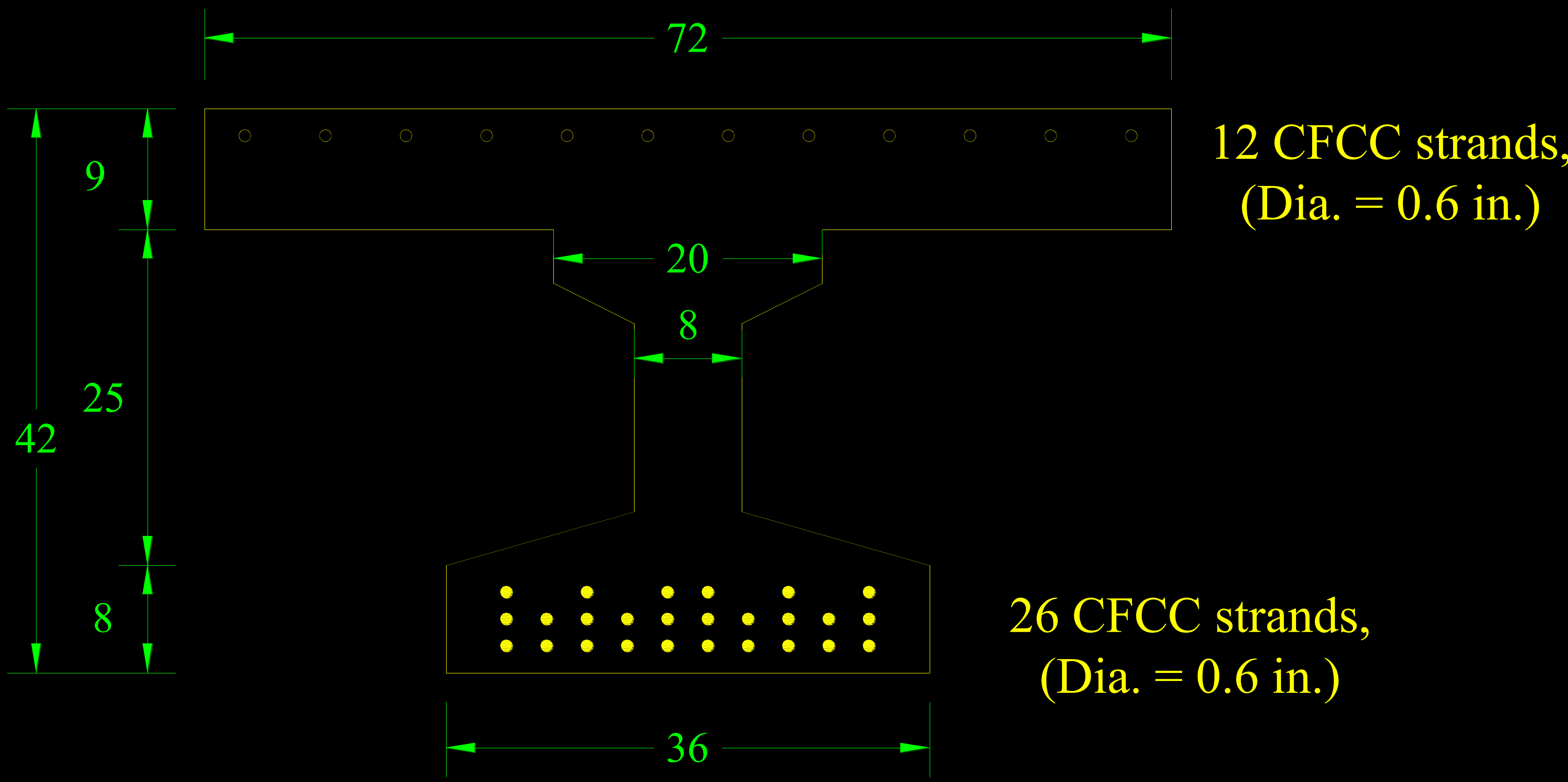
Play Video

Findings of Experimental Investigation

Decked bulb T beam bridge system:

- Decked bulb T beam (DBTB) bridge system offers a **practical alternative** to side-by-side box beam bridge system.
- It promotes **faster construction**, **easier inspection**, & **lesser maintenance** work compared with side-by-side box beam bridges
- The lack of cast-in-place deck slab does not seem to have any **adverse effect** on the bridge system. Even without TPT, **uniform load distribution** was maintained until failure.

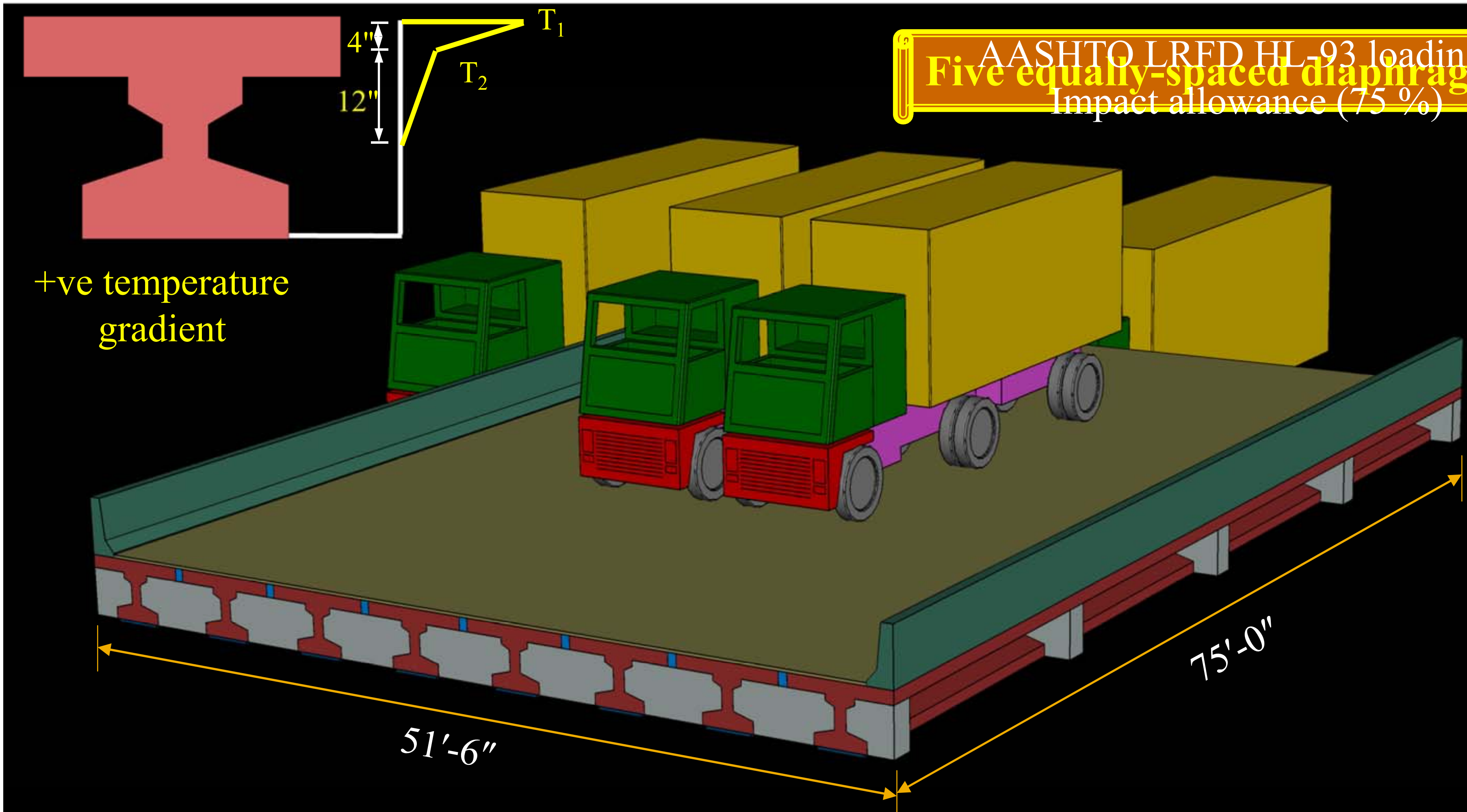
Beam Cross Section for 75-ft-span DBTB Bridge Models



Loading & Traffic Locations

AASHTO LRFD HL-93 loading + Impact allowance (75 %)

Five equally-spaced diaphragm

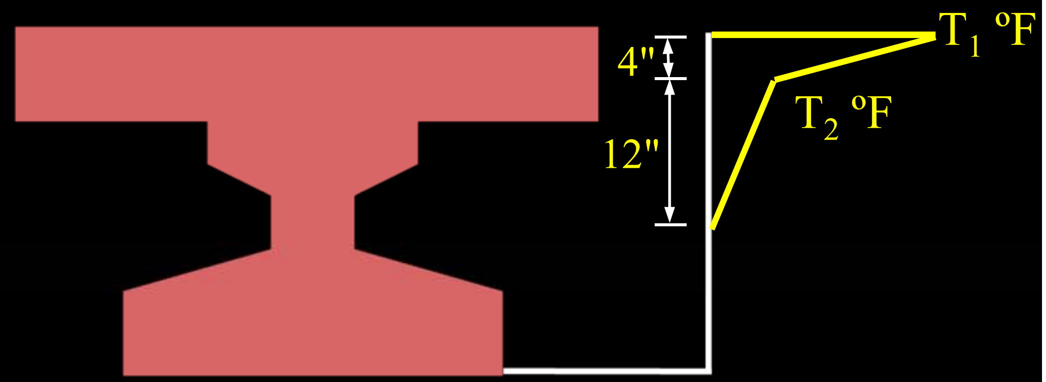


Truck Location III

Multiple Presence Factor (AASHTO LRDF 3.6.1.1.2) = 1.0

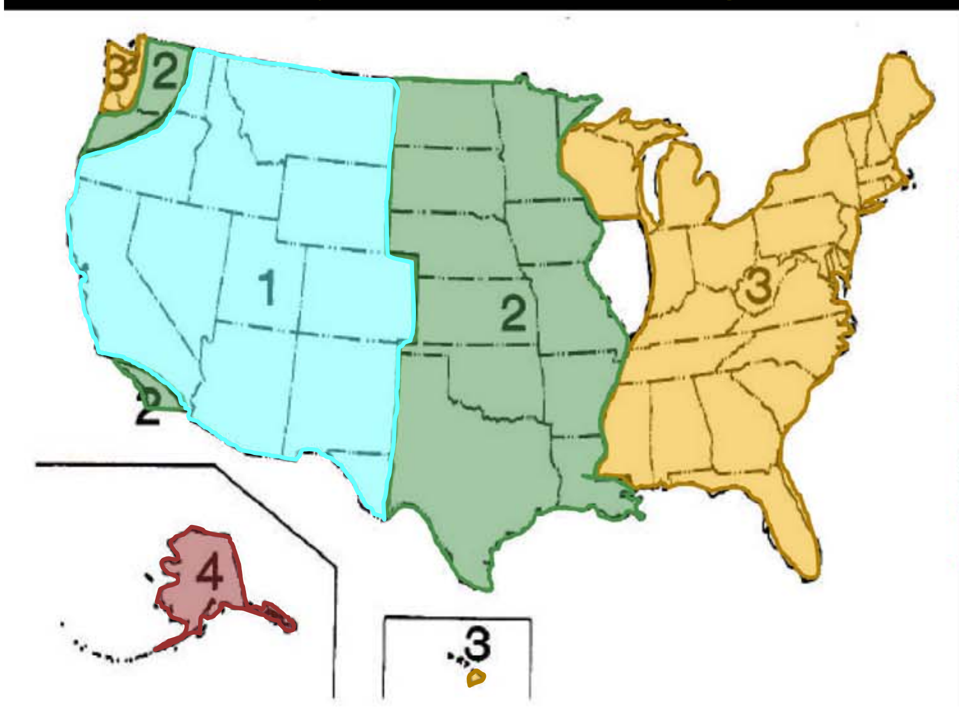
Positive Temperature Gradient (AASHTO LRFD 3.12.3)

- *Perform analysis for one zone*
- *Verify results for other zones*



+ve temperature gradient

Four zones for Temperature gradient



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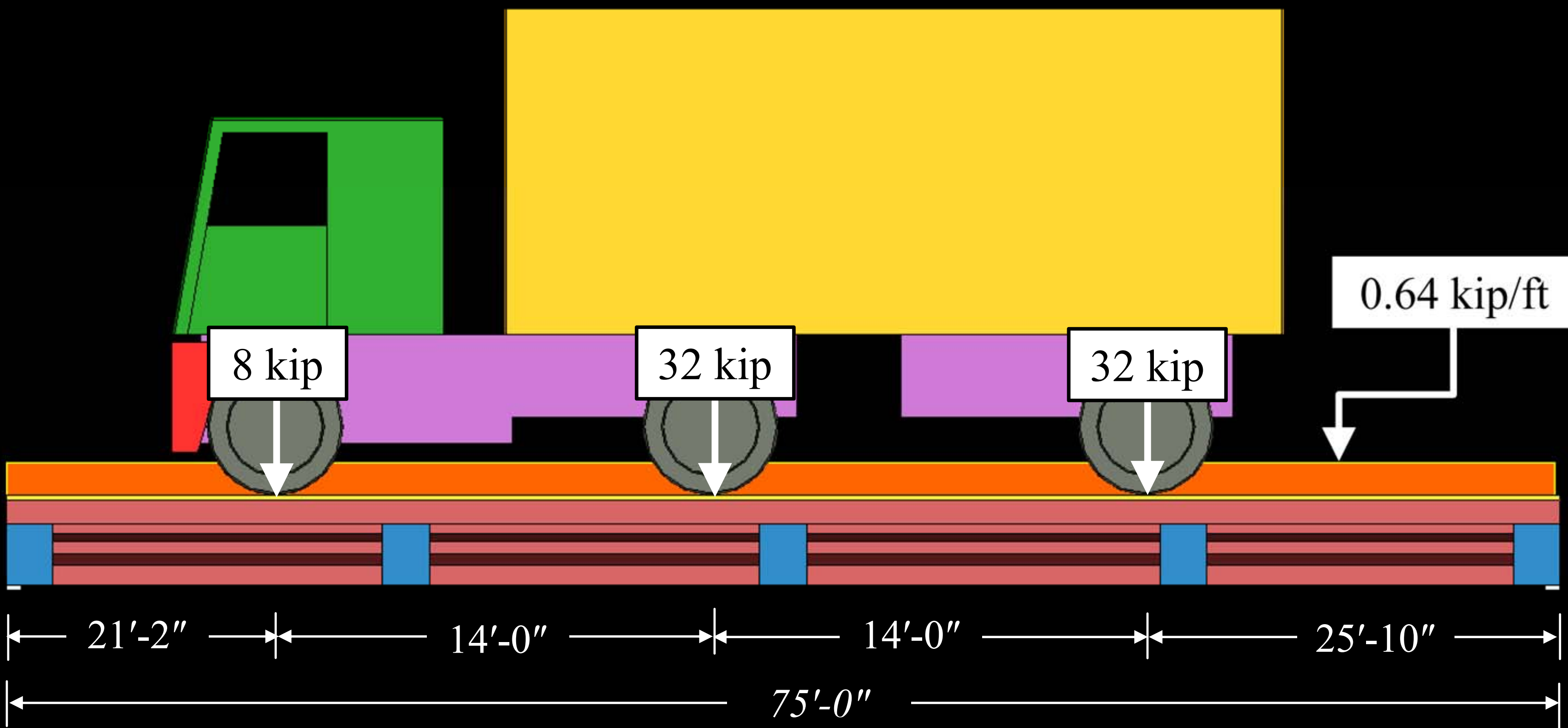
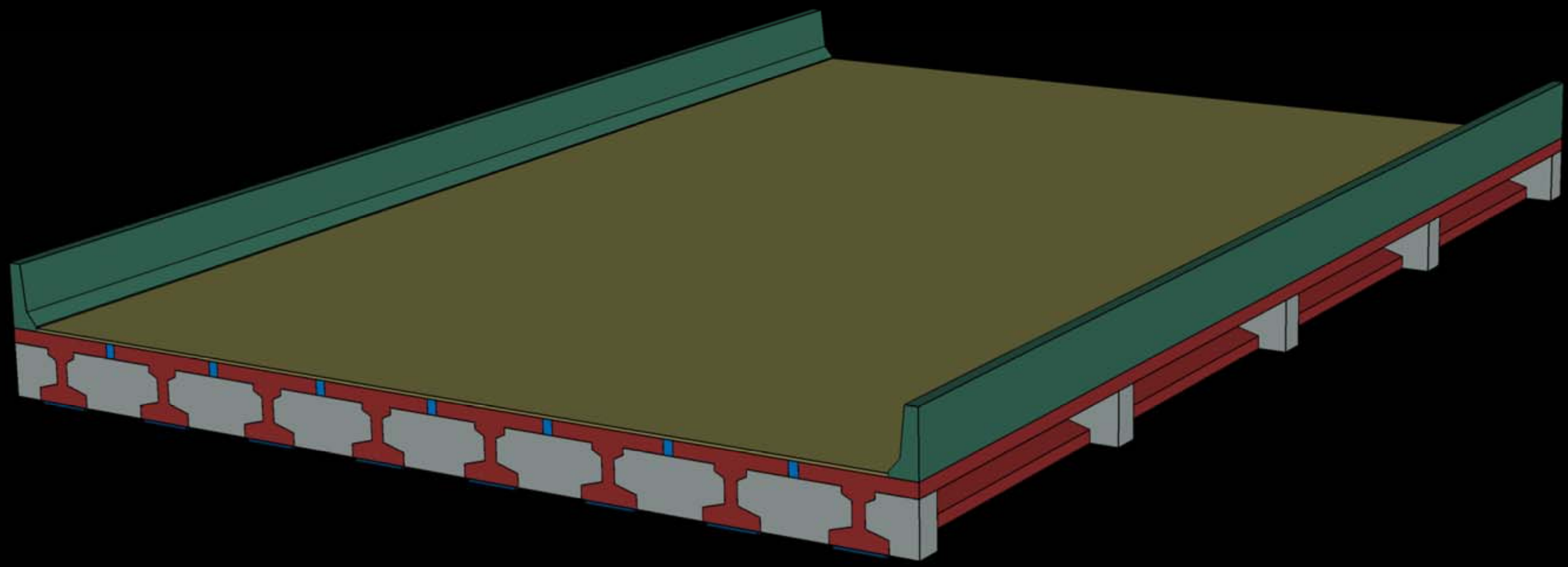
HL-93 Vehicular Loading (AASHTO LRFD 3.6.1.2.2)



Dynamic allowance for deck joints (AASHTO LRDF 3.6.2.1) = 75%

Case of 0° Skew Angle

Two end diaphragms & three equally spaced intermediate diaphragm



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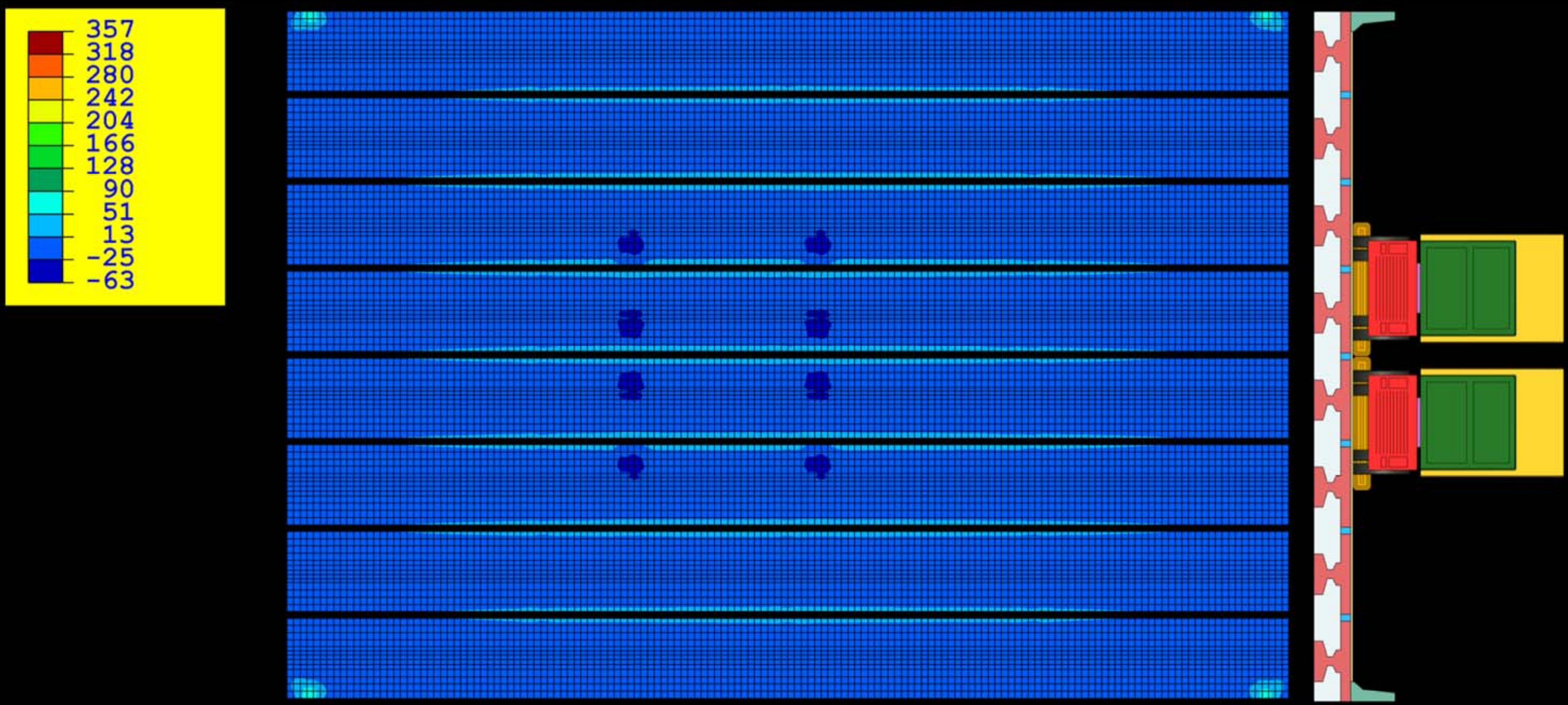
Decked Bulb T Beam Bridge (Span = 75′, width = 51.5′, Skew = 0°)

Maximum principal stresses in deck flange after adding AASHTO HL-93 (Location III)

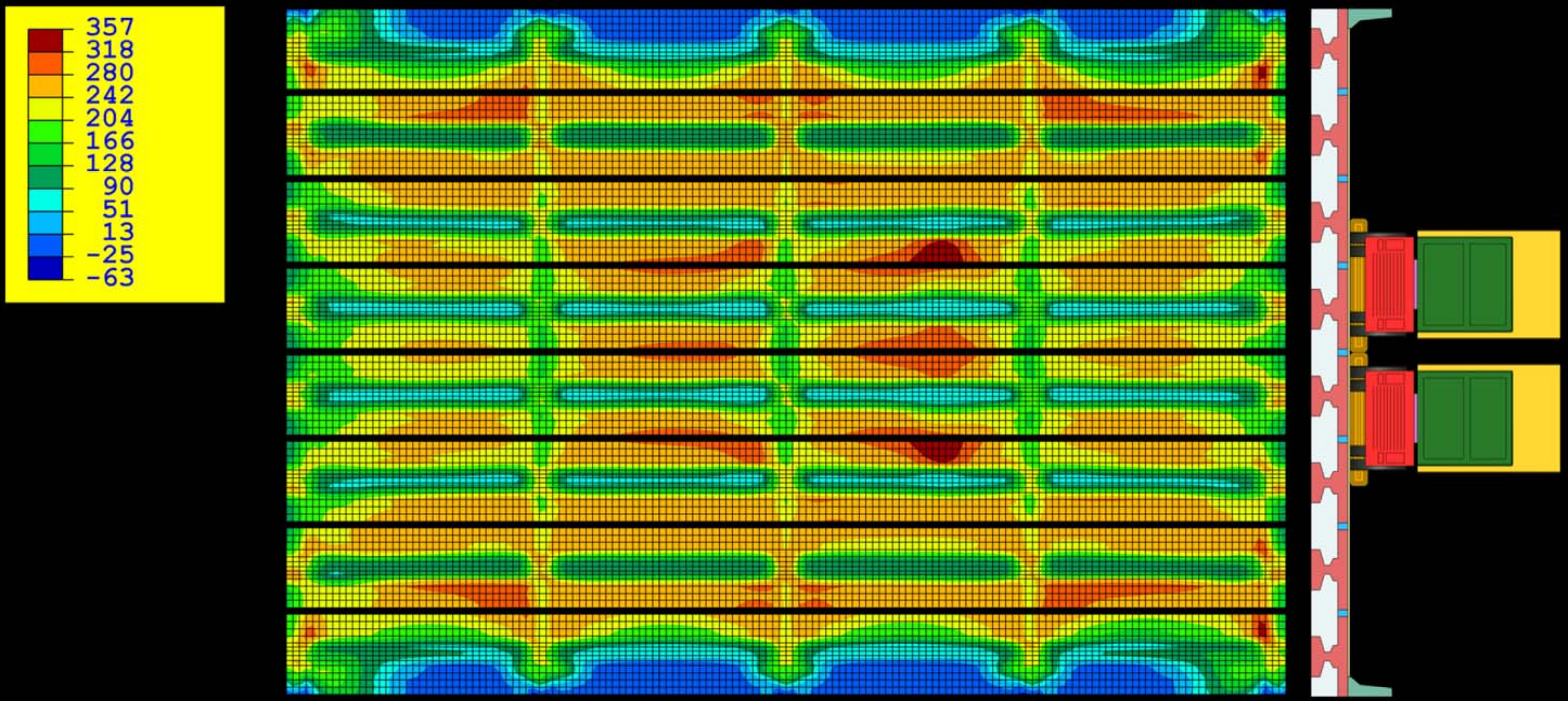


Deck flange top surface

Maximum principal stresses < 608 psi (No cracks)

Decked Bulb T Beam Bridge (Span = 75′, width = 51.5′, Skew = 0°)

Maximum principal stresses in deck flange after adding AASHTO HL-93 (Location III)



Deck flange bottom surface

Maximum principal stresses < 608 psi (No cracks)

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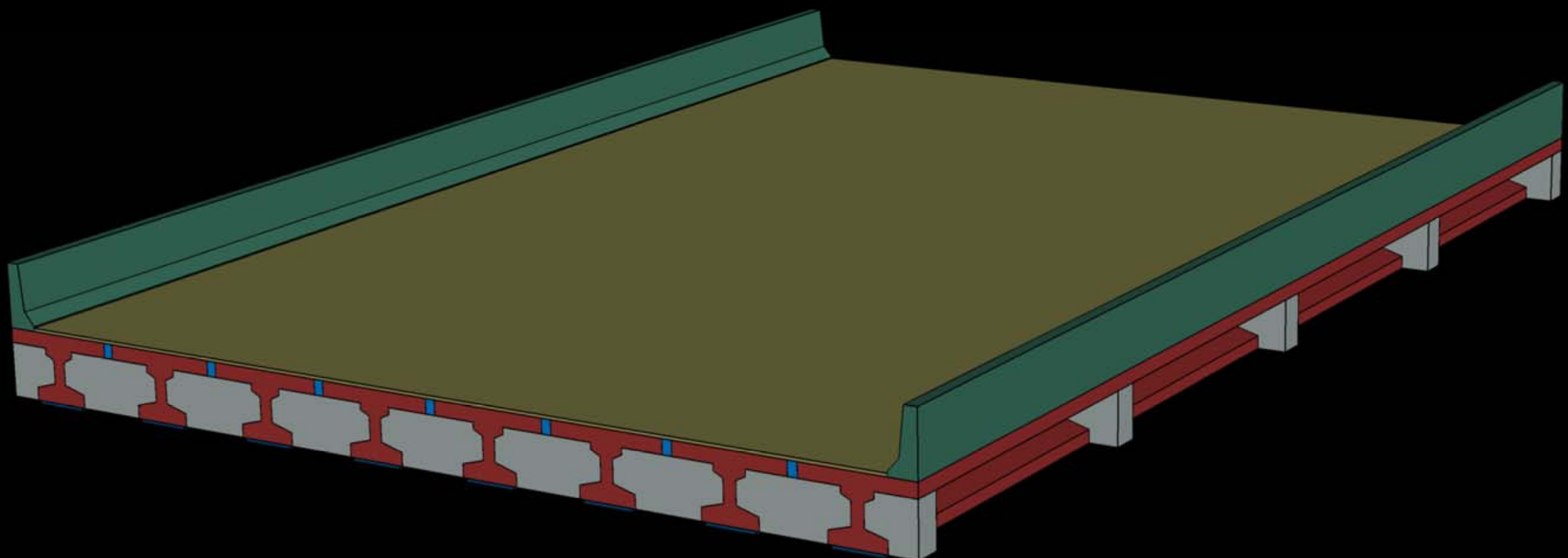
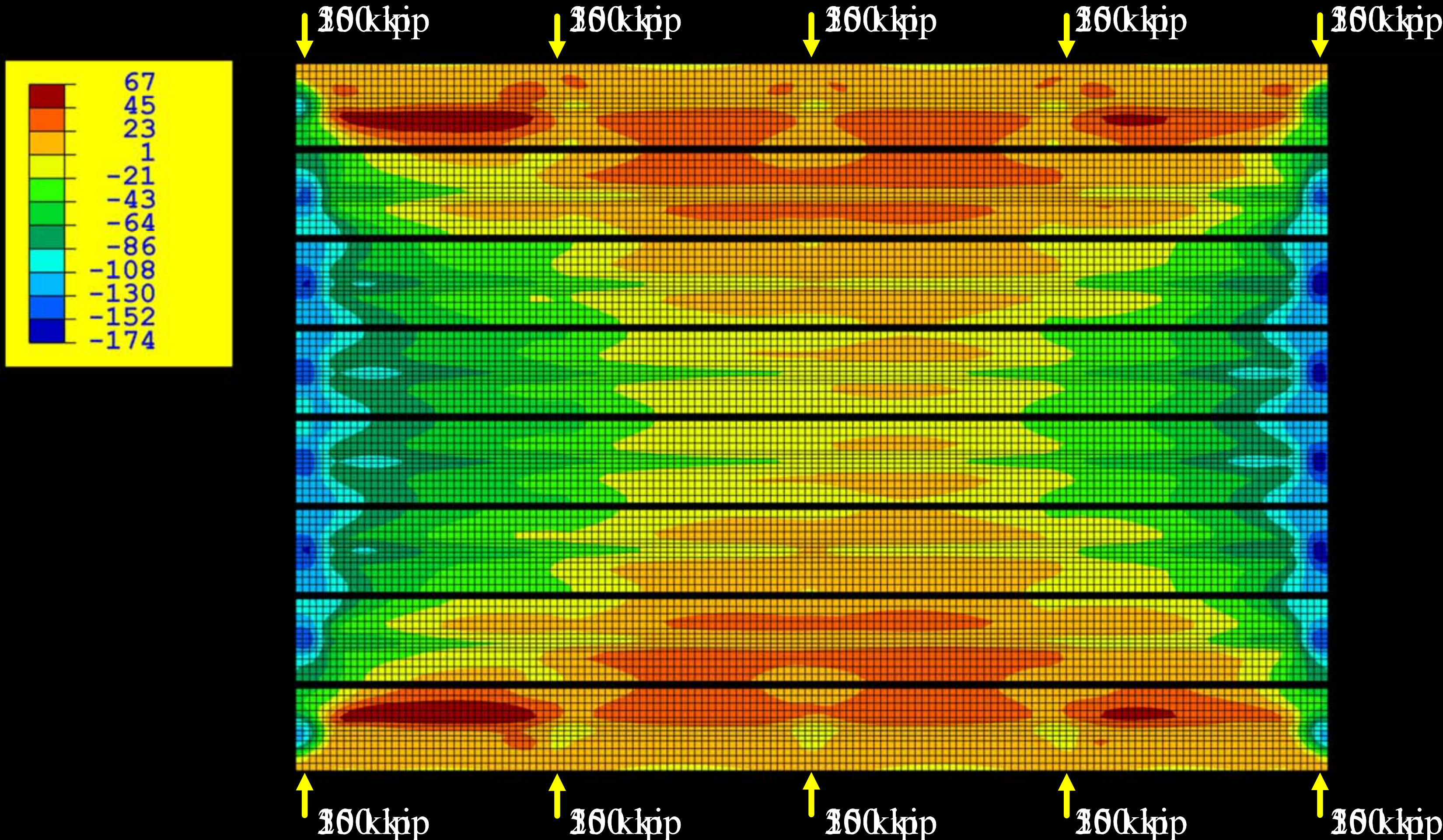
Effect of TPT Force (0 Skew Angle)

Two end diaphragms & three equally spaced intermediate diaphragm



Decked Bulb T Beam Bridge (Span = 75′, width = 51.5′, Skew = 0°)

Transverse stresses in deck flange after applying TPT force of 150 kip/diaphragm



Deck flange top surface

Subjects

- Statement of the Problem
- Experimental Investigation
- Numerical Investigation
- Field Deployment
- Ongoing Research Projects
- Future Research Projects

Current M-86 Bridge Over Prairie Creek

Images from Google Earth

Bridge was originally built in 1923, and was re-built at the present site in 1938-1939

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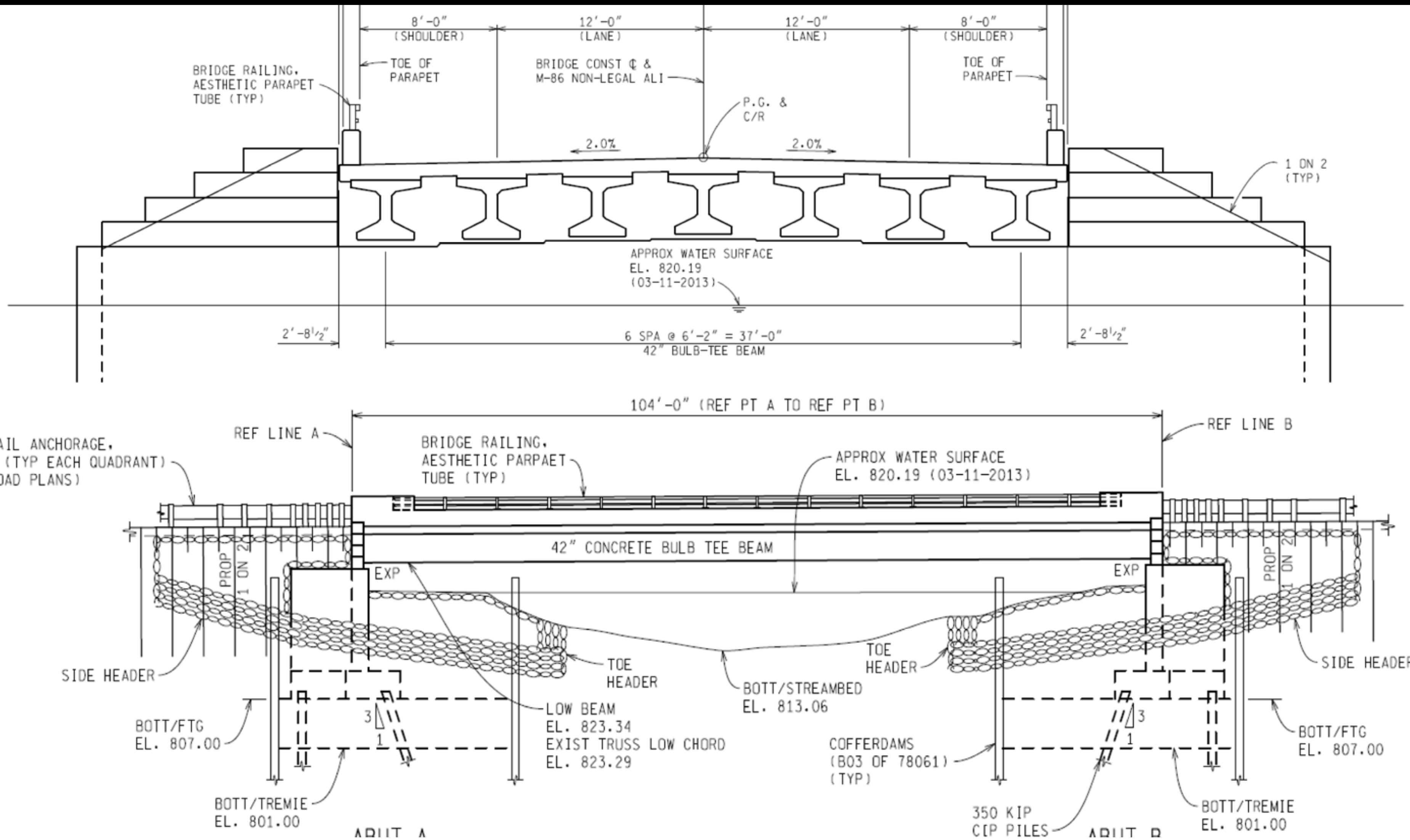
New M-86 Bridge Over Prairie Creek (B01-67032)

New Bridge is designed as precast bulb T beams prestressed with CFCC strands with 9.0-in.-thick cast-in-place reinforced concrete deck slab.



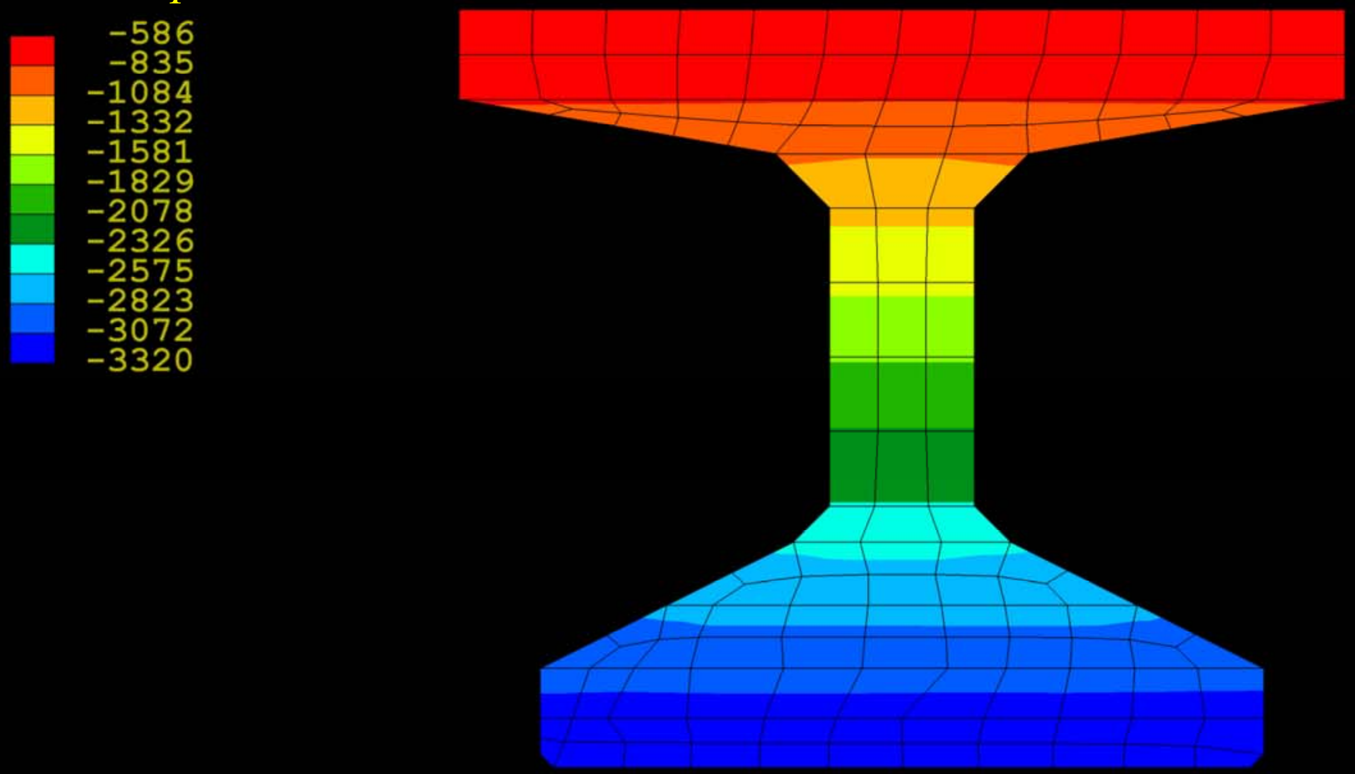
Numerical/MathCad Analysis of M-86 Bridge Over Prairie Creek

- Single beam immediately after transfer (no deck)
- Ultimate capacity of a single beam (with deck)
- Analysis of complete bridge model
  - Traffic Loads
  - Temp. Gradient
  - Hot weather
  - Cold weather

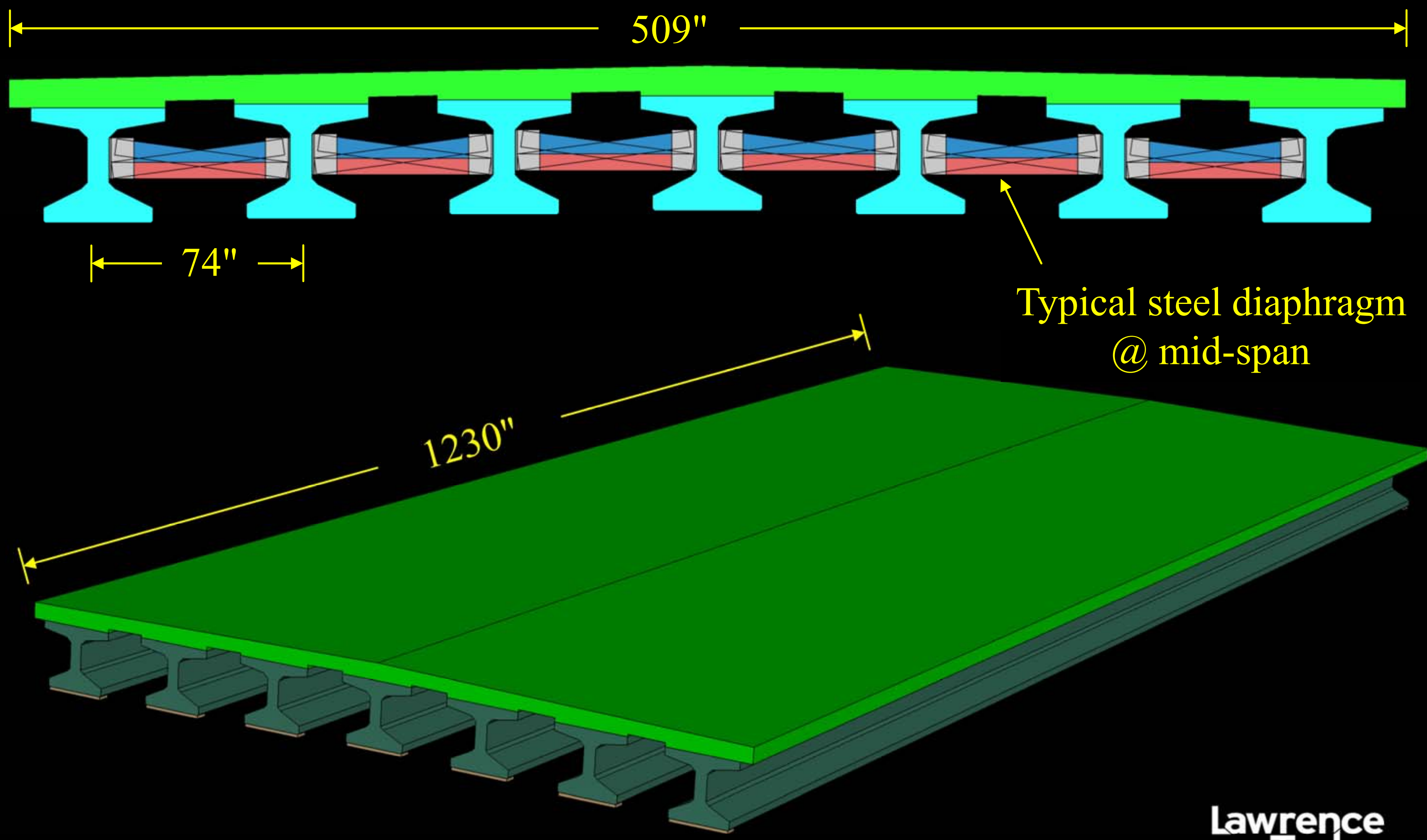
Single Beam Immediately after Transfer

Longitudinal stresses in the beam @ mid-span (prestressing & self-weight)

Stresses in psi



Analysis of Complete Bridge Model



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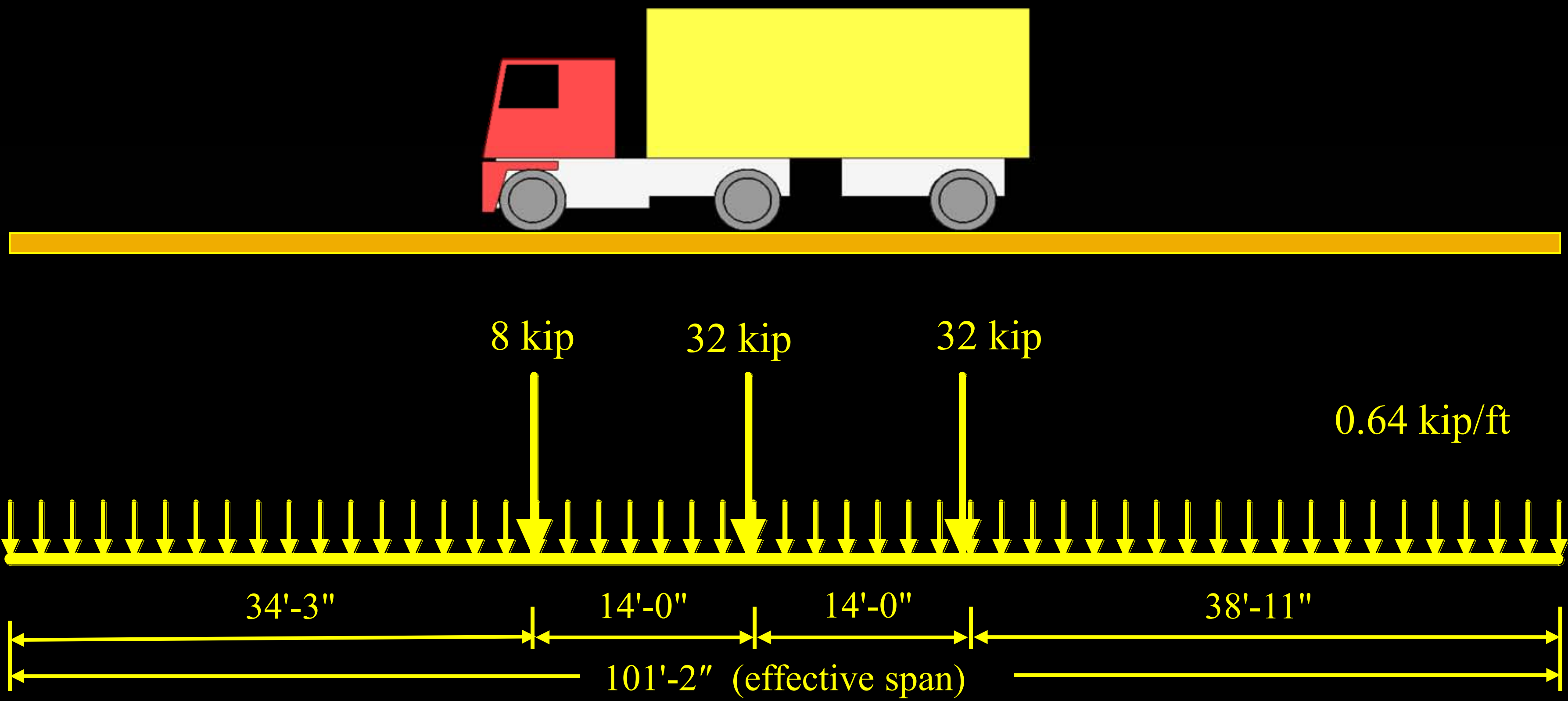
Modified AASHTO HL-93 Vehicular Loading (Truck Loading)

Modification factor = 1.2

Impact Allowance = 1.33



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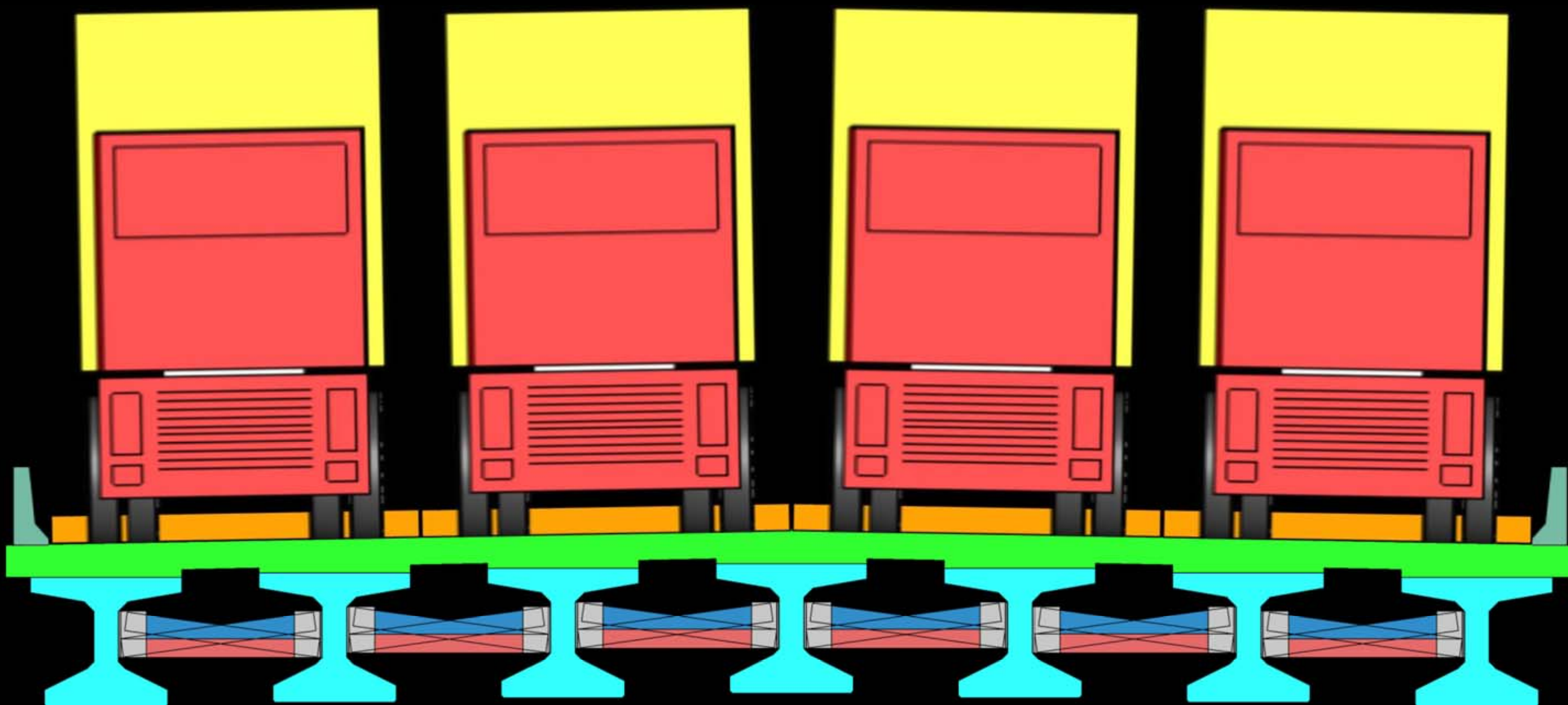
Location of Truck Loading across the Width of the Bridge

Location IV

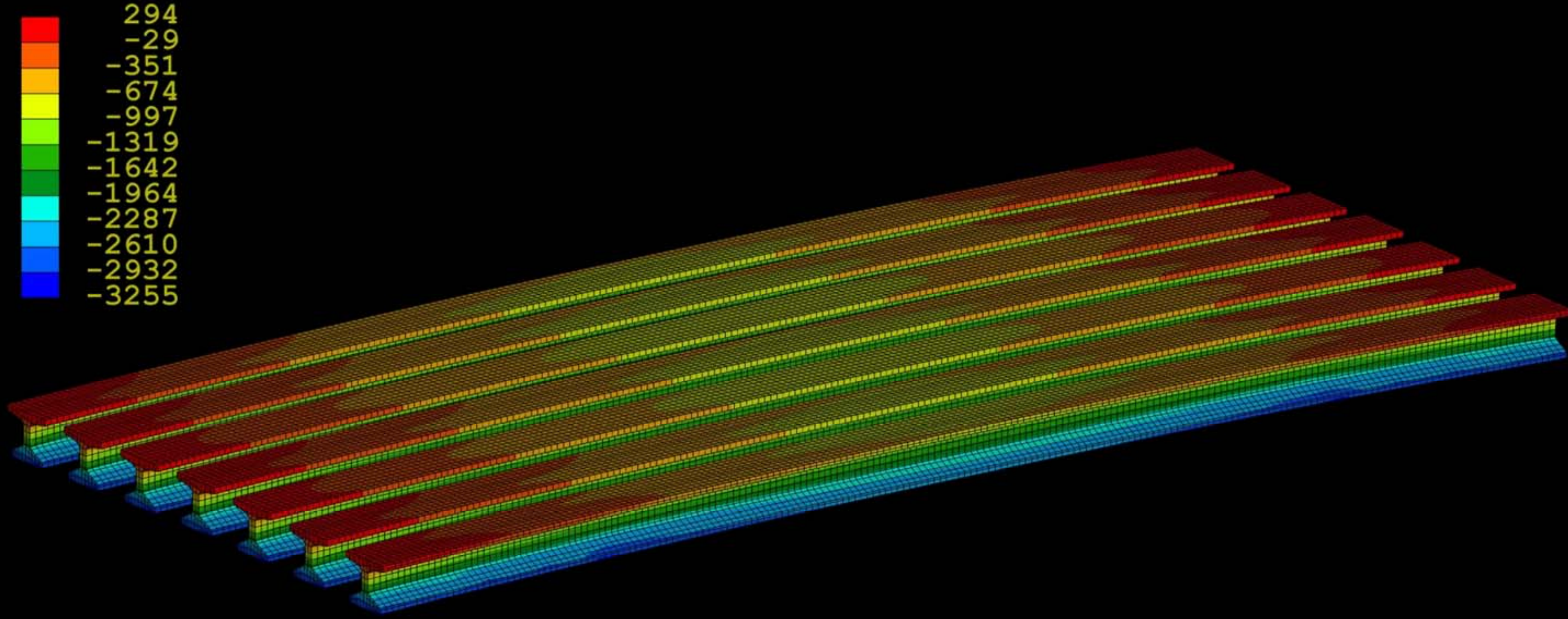


Longitudinal Stresses in Bridge Beams after All Losses

Longitudinal stresses in the beam @ mid-span due to:

Final prestressing + Beams self-weight

Stresses in psi



- *Final prestressing stress = 143.85 ksi (25.75 kip/strand)*
- *Concrete compressive strength = 8 ksi*

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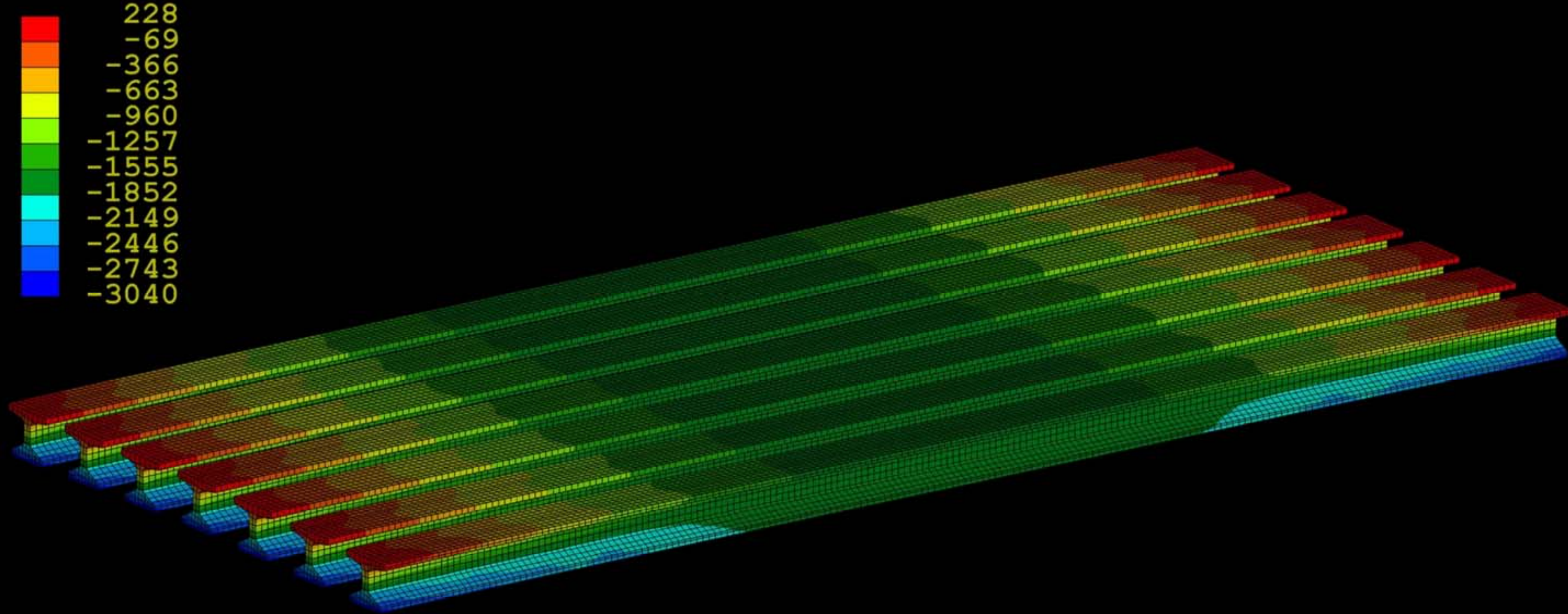
Longitudinal Stresses in Bridge Beams

Longitudinal stresses in the beam @ mid-span due to:

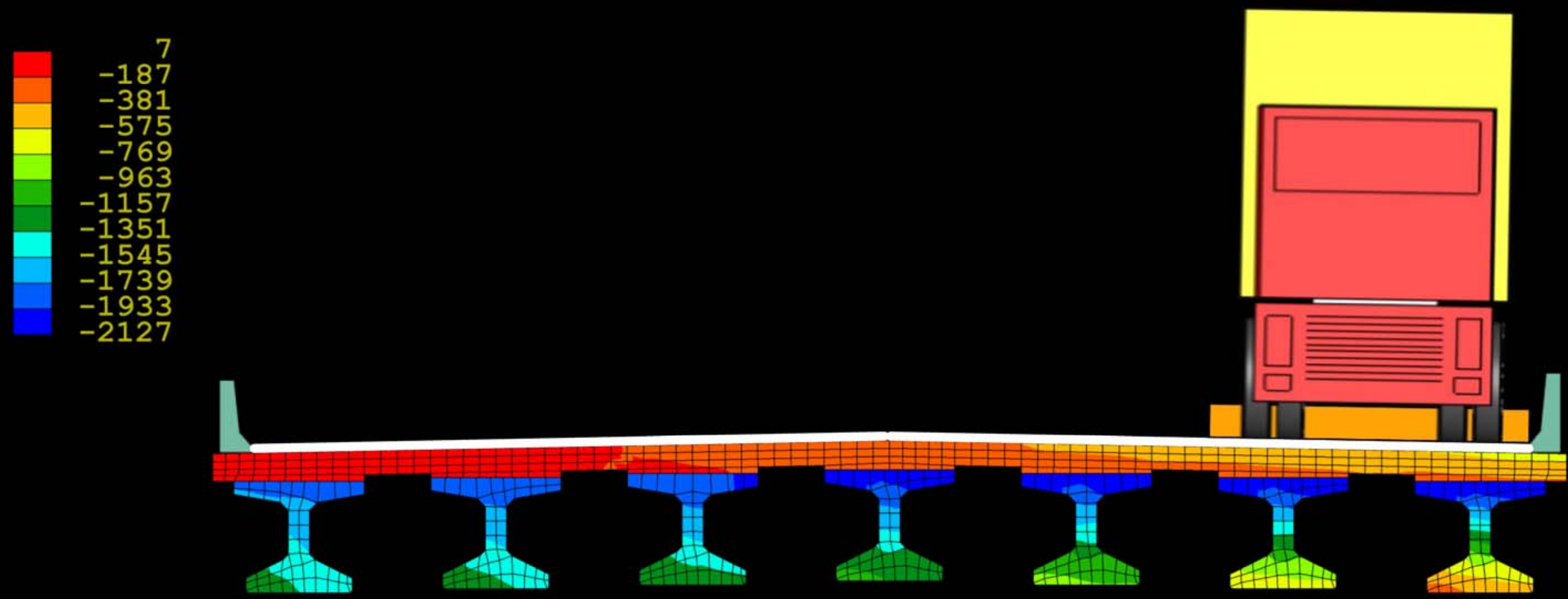
Final prestressing + Beams self-weight + **SIP + Haunch + Slab self-weight + Diaph.**



Stresses in psi

Extreme Hot Weather (100 °F) & Traffic Load

Stresses in psi



Longitudinal stresses in the beam @ mid-span due to:

Final prestressing + Beams self-weight + SIP + Haunch + Self-weight of slab + Diaph.

Superimposed dead loads (barriers + future wearing surface)

Extreme hot weather effect according to AASHTO LRFD 3.12.2.2 Procedure B

HL-93 Vehicular loading @ Location I × 1.2 × 1.33 × 1.2

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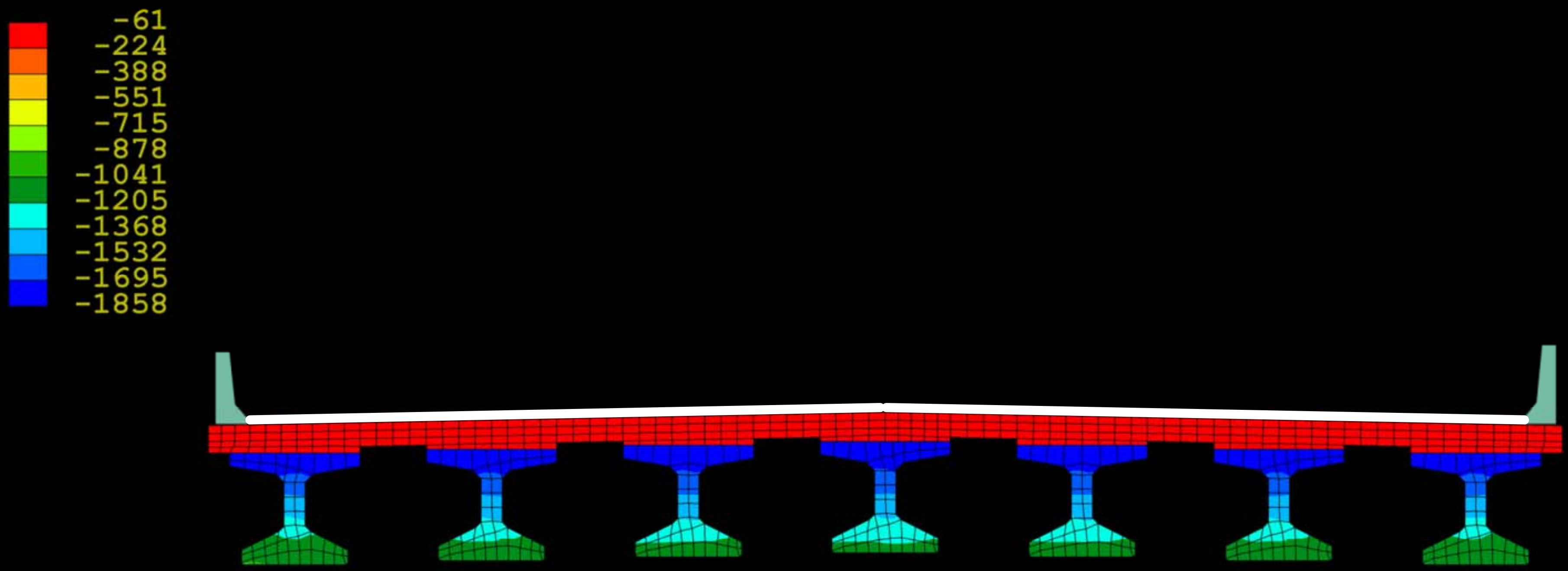
Extreme Cold Weather (-10 °F) & Traffic Load

Stresses in psi



Longitudinal stresses in the beam @ mid-span due to:

Final prestressing + Beams self-weight + SIP + Haunch + Self-weight of slab + Diaph.

Superimposed dead loads (barriers + future wearing surface)

Extreme cold weather effect according to AASHTO LRFD 3.12.2.2 Procedure B

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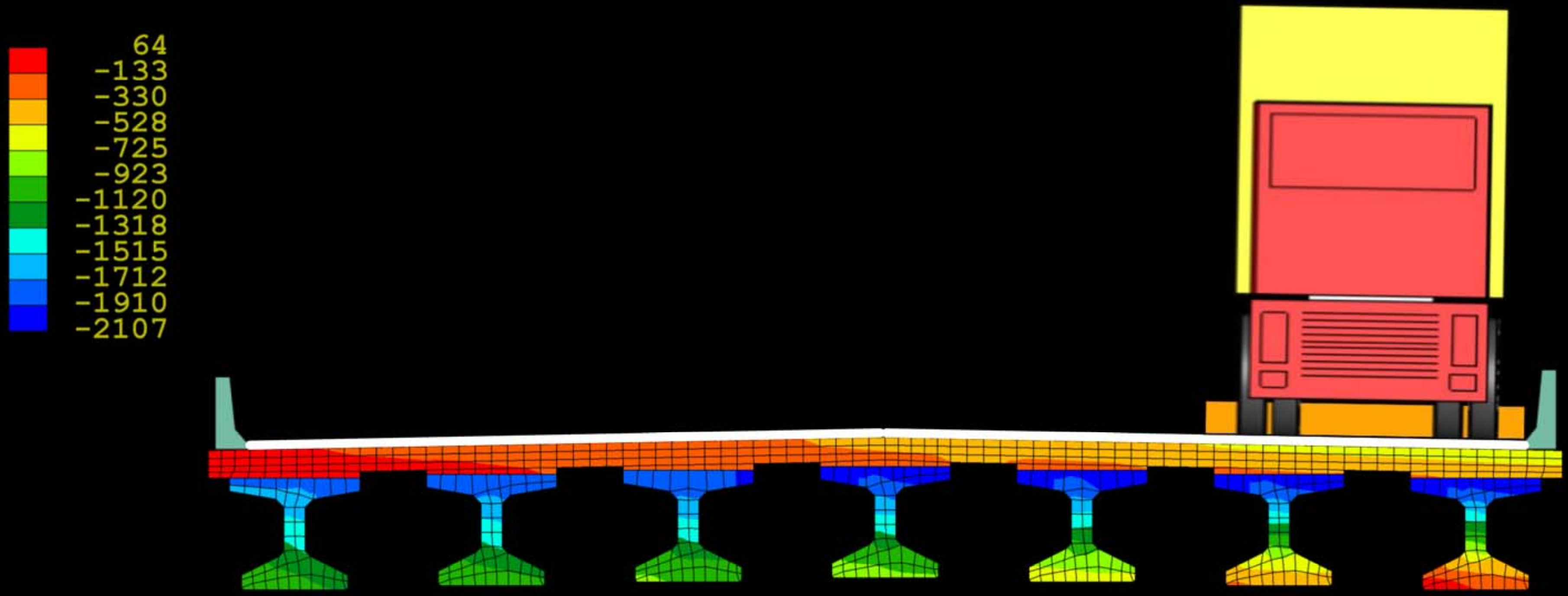
Extreme Cold Weather (-10 °F) & Traffic Load

Stresses in psi



Longitudinal stresses in the beam @ mid-span due to:

Final prestressing + Beams self-weight + SIP + Haunch + Self-weight of slab + Diaph.

Superimposed dead loads (barriers + future wearing surface)

Extreme cold weather effect according to AASHTO LRFD 3.12.2.2 Procedure B

HL-93 Vehicular loading @ Location I × 1.2 × 1.33 × 1.2

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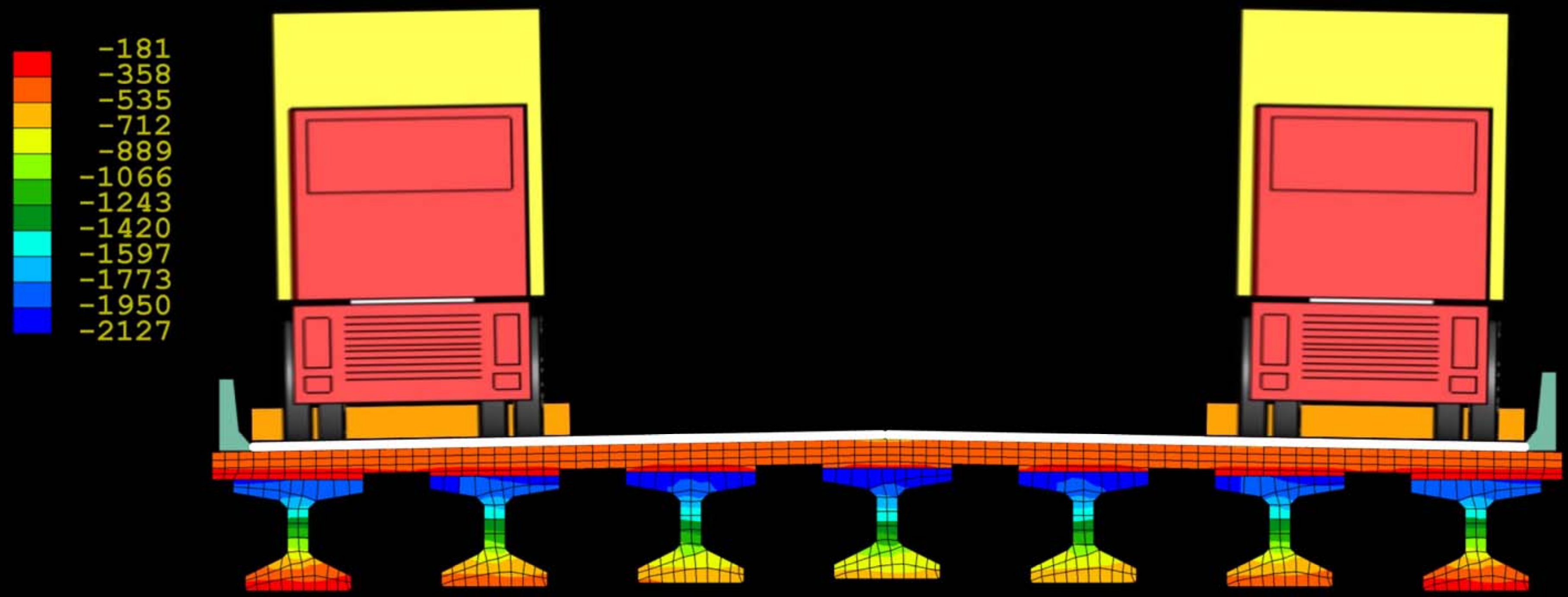
Extreme Cold Weather (-10 °F) & Traffic Load

Stresses in psi



Longitudinal stresses in the beam @ mid-span due to:

Final prestressing + Beams self-weight + SIP + Haunch + Self-weight of slab + Diaph.

Superimposed dead loads (barriers + future wearing surface)

Extreme cold weather effect according to AASHTO LRFD 3.12.2.2 Procedure B

HL-93 Vehicular loading @ Location II × 1.0 × 1.33 × 1.2

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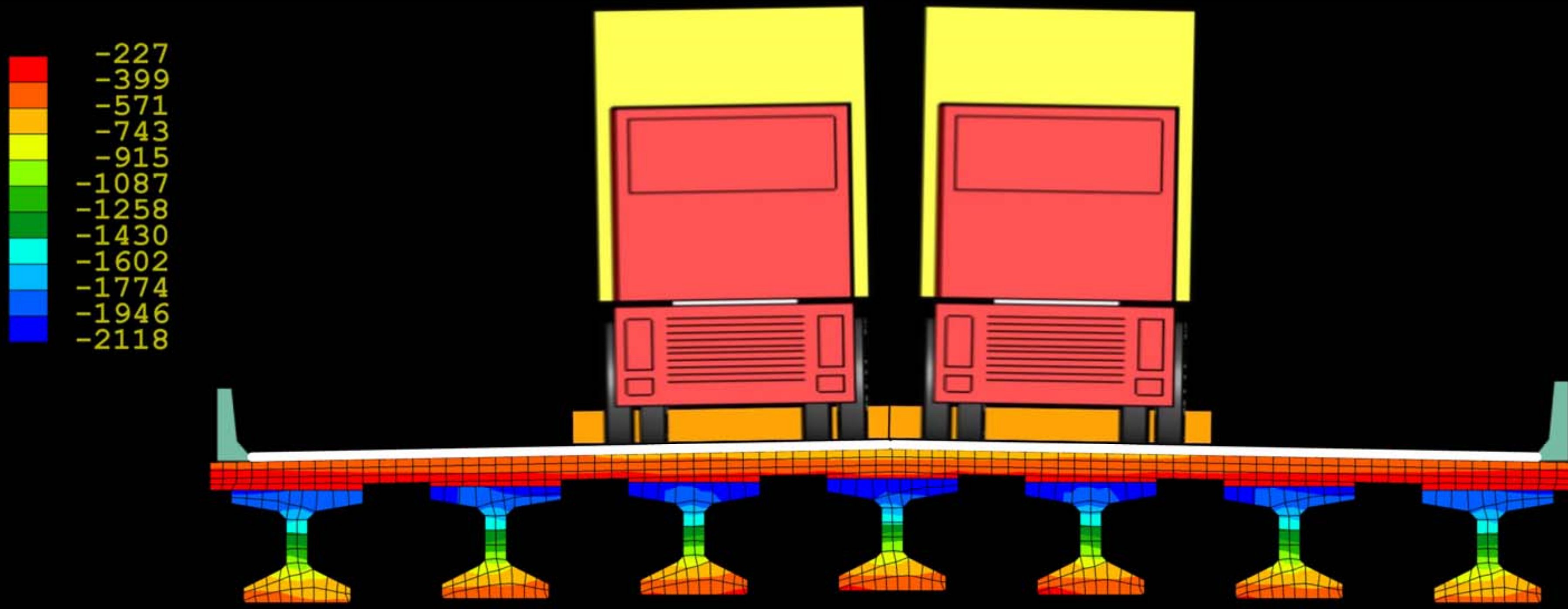
Extreme Cold Weather (-10 °F) & Traffic Load

Stresses in psi



Longitudinal stresses in the beam @ mid-span due to:

Final prestressing + Beams self-weight + SIP + Haunch + Self-weight of slab + Diaph.

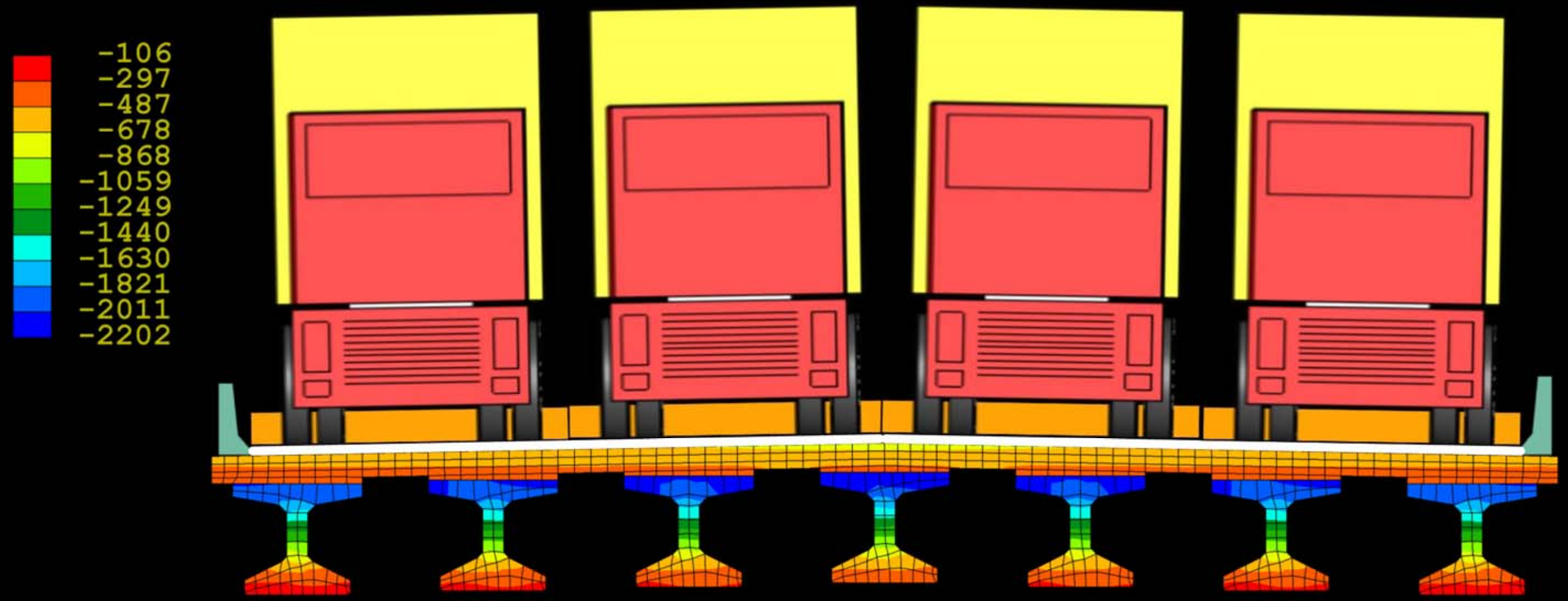
Superimposed dead loads (barriers + future wearing surface)

Extreme cold weather effect according to AASHTO LRFD 3.12.2.2 Procedure B

HL-93 Vehicular loading @ Location III × 1.0 × 1.33 × 1.2

Extreme Cold Weather (-10 °F) & Traffic Load

Stresses in psi



Longitudinal stresses in the beam @ mid-span due to:

Final prestressing + Beams self-weight + SIP + Haunch + Self-weight of slab + Diaph.

Superimposed dead loads (barriers + future wearing surface)

Extreme cold weather effect according to AASHTO LRFD 3.12.2.2 Procedure B

HL-93 Vehicular loading @ Location IV × 0.65 × 1.33 × 1.2

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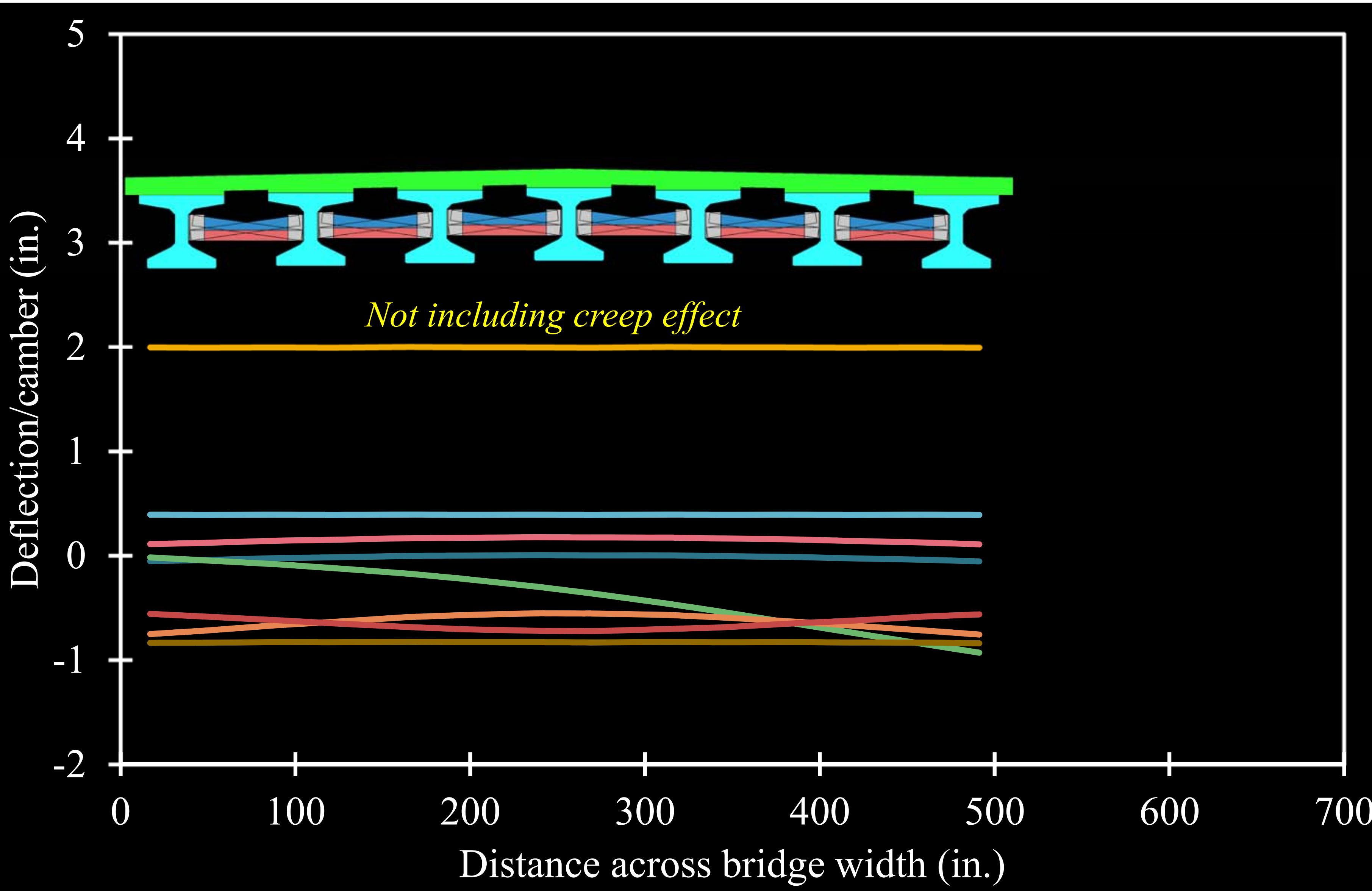
Deflection, Extreme Cold (-10 °F) & Traffic Load



Ongoing Research Project

Verifications for the CFRP design values including creep rupture, prestress level, & long-term losses

Appropriate stress levels and strength reduction factors for CFRP strands considering creep rupture & long-term losses

Experimental verification for material resistance for: bond fatigue, fire damage, severe environmental conditions

Design methodologies/criteria and empirical equations for inclusion in MDOT Bridge Design Manual (including details for Bridge design Guide)

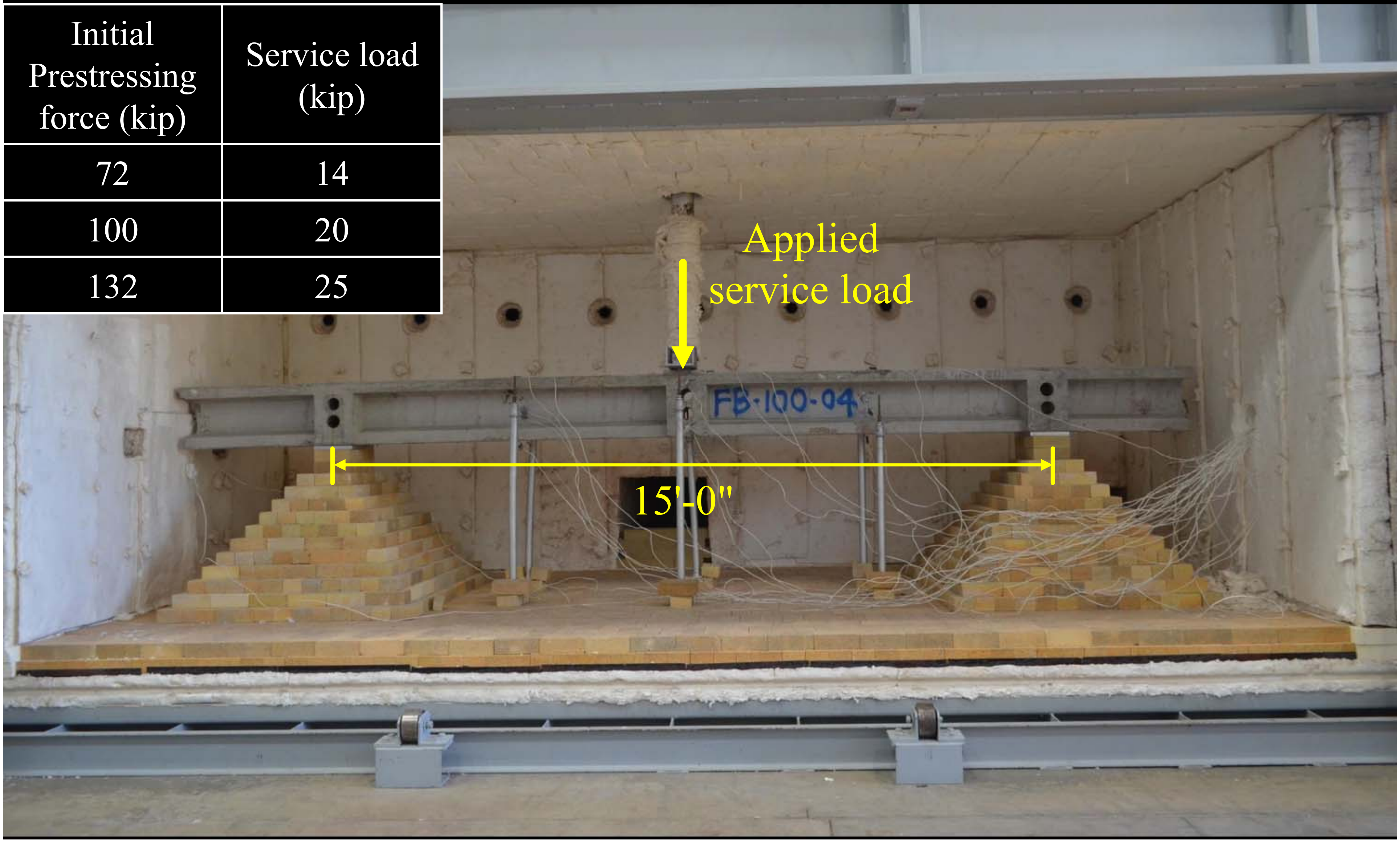
Design guide specifications in LRFD format for inclusion in MDOT Bridge Design Manual (including details for Bridge Deign Guide)

CFRP MathCAD design tool calculations

Fire Testing of Prestressed CFCC Beams

CFCC prestressed decked bulb T beam under fire/loading event (ASTM E119)

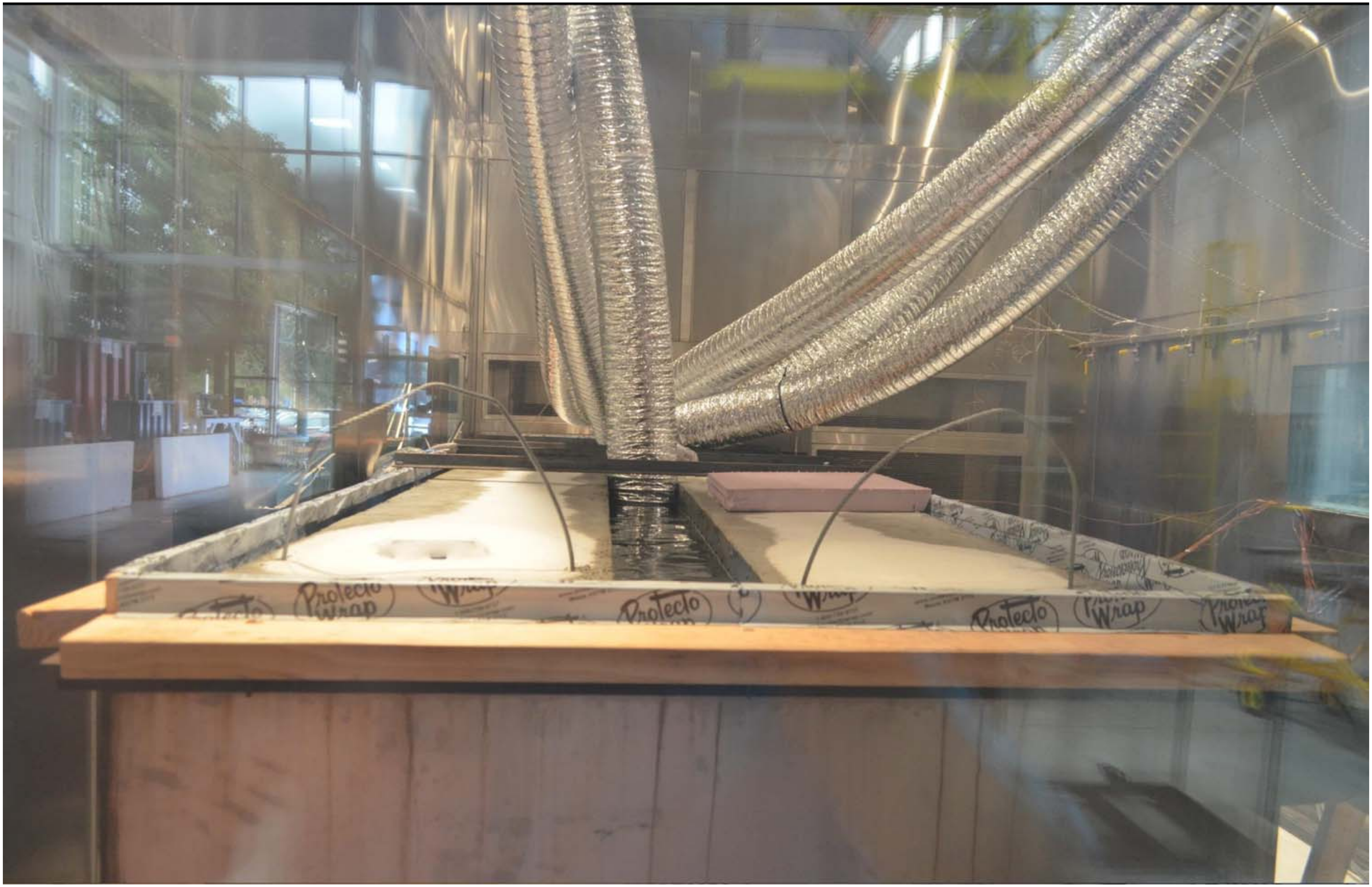
Initial Prestressing force (kip)	Service load (kip)
72	14
100	20
132	25



Beams under Fire (C100-20-3, Video)

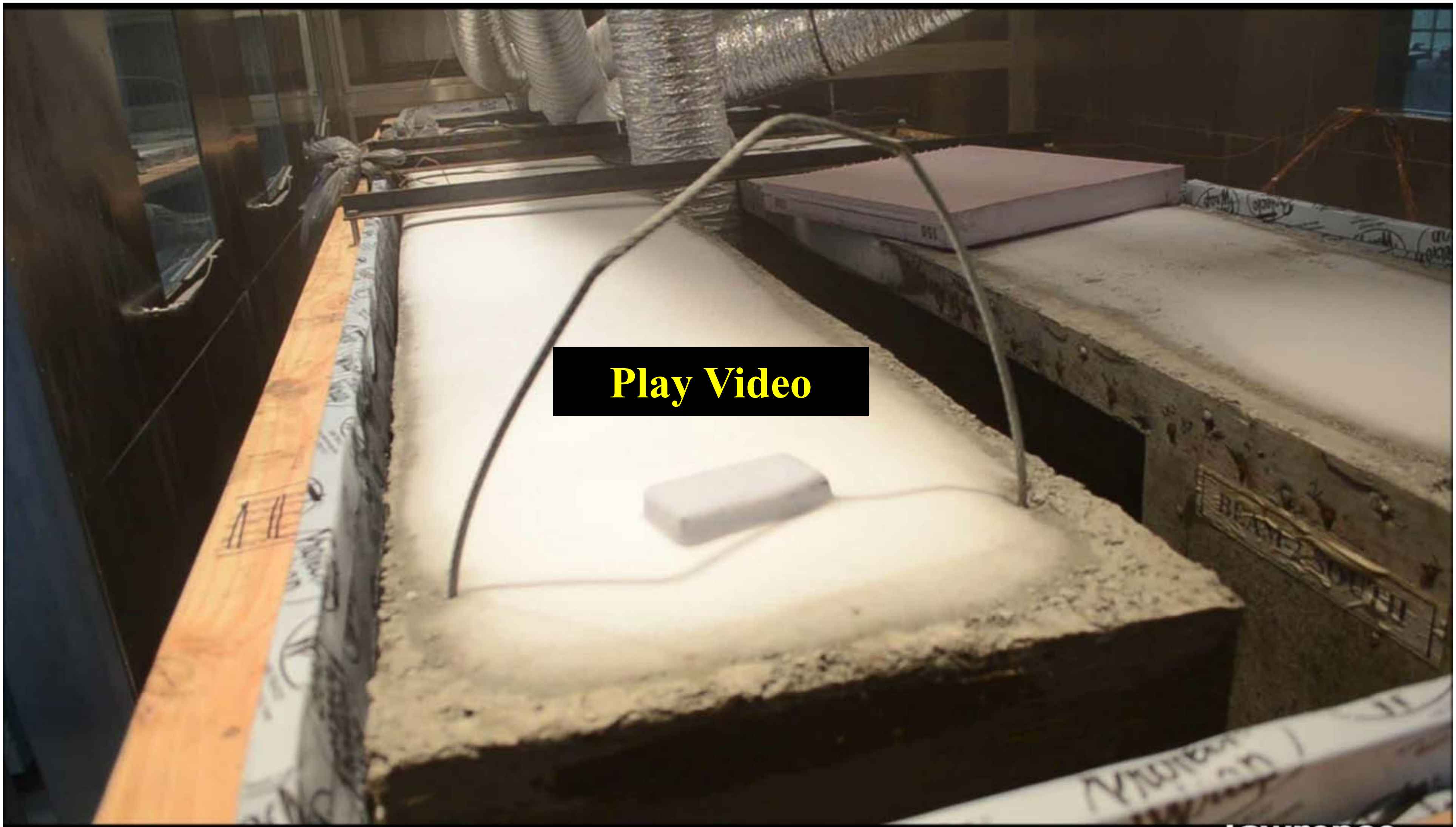
Play Video

Freeze & Thaw Cycles of Four Beams (ASTM C666)



Freeze and Thaw Cycles of Post-Tensioned CFCC Strands

Freeze and Thaw Cycles (Video)



Play Video

Monitoring of MDOT bridge inventory with CFRP

Double T beam

Bridge Street Bridge, Southfield (2001)

Side-by-side box beam

Pembroke over M-39, Detroit (2011)

Side-by-side box beam

M-50 over NSRR, Jackson (2012)

Spread box beam

M-102 over Plum Creek, Southfield (2013/2014)

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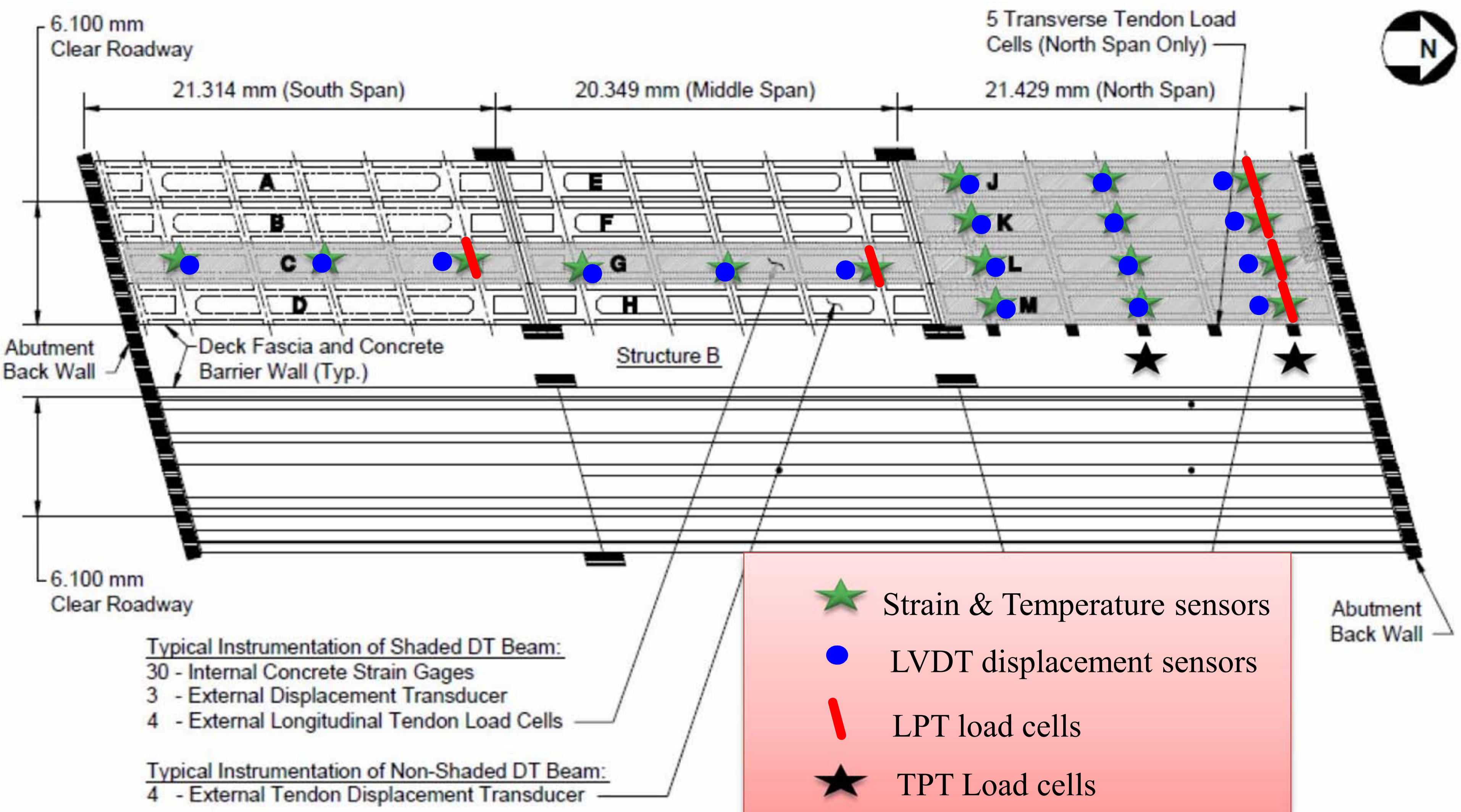
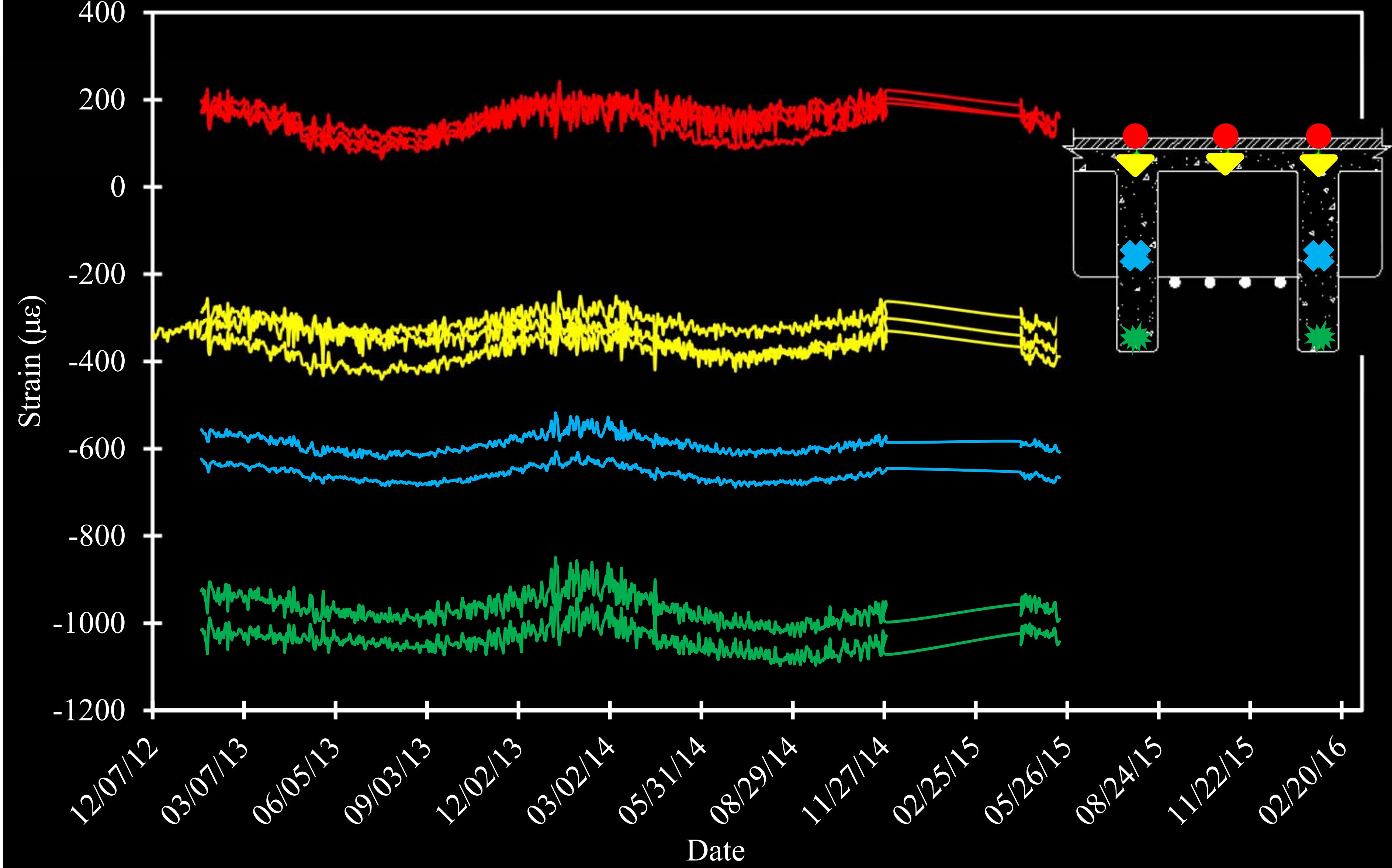
Sensors in Double T Beam Bridge (Structure B)



VWSGs @ Mid-span of Beam J



0.7-in. CFCC Strands

Diameter (in.)	**0.68**
Area (in.^{2})	0.234
Guaranteed load (kip)	78.7
Elastic modulus (ksi)	22,626
Average ultimate strength (ksi)	451
Average ultimate strain (%)	2.0
Average breaking load (kip)	105.6
Construction	1×7

Thank you