Implementation of UHPC Decked I-Beam in Ontario, Canada

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Presentation Outline

- Background
- Design
- Fabrication
- Testing

Background

- Part of PCI study on the Implementation of UHPC Structural Elements for Bridges and Buildings (PI: eConstruct USA).

Implementation of Ultra-High Performance Concrete in Long-Span Precast Pretensioned Elements for Concrete Buildings and Bridges

Phase II Report
September 15, 2021

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Participating Steel Formwork Companies:

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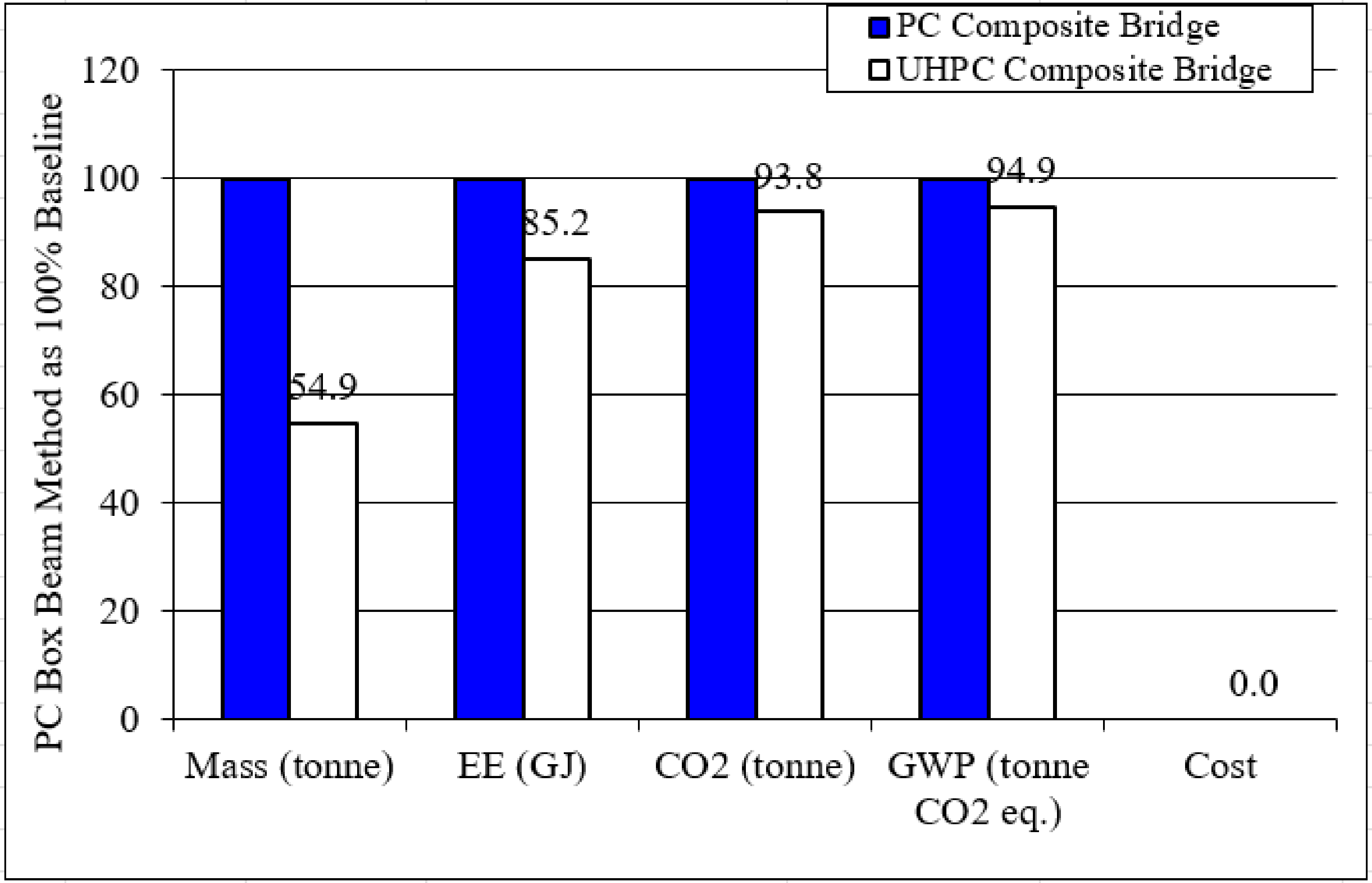
Environmental Impact: PC Box Beam vs UHPC NUDIB



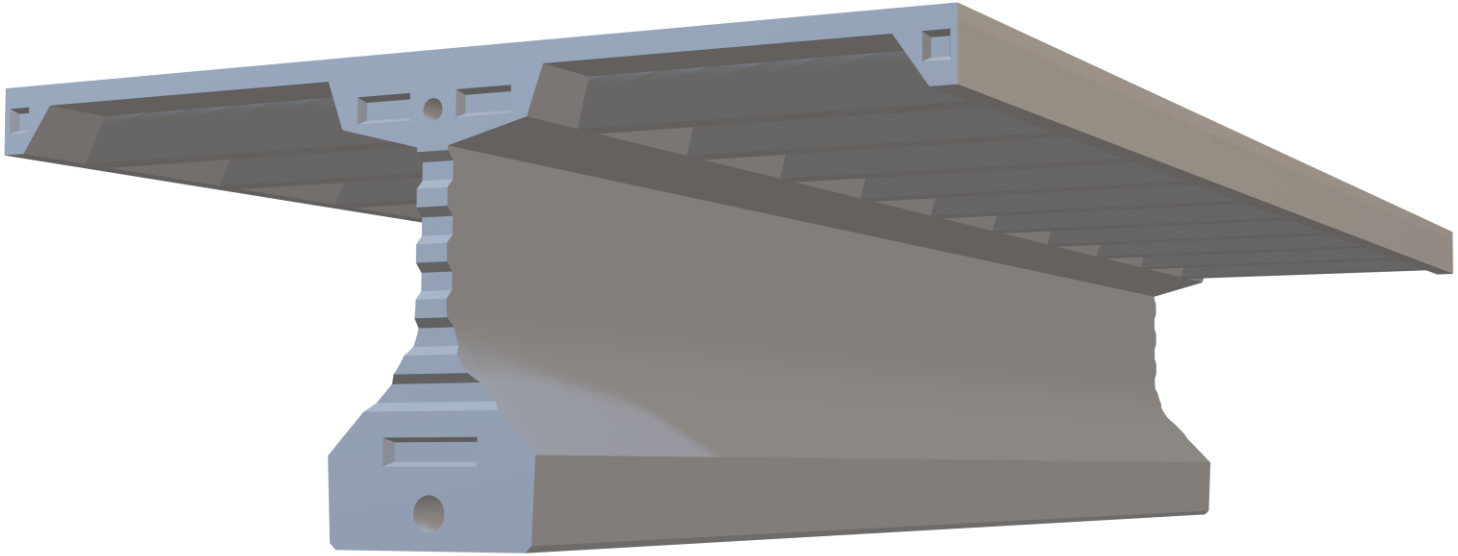
Based on Voo & Foster in 2020, which showed an expected Service life for the UHPC bridge girders Of 340 years.

UHPC Decked I-Beam Development

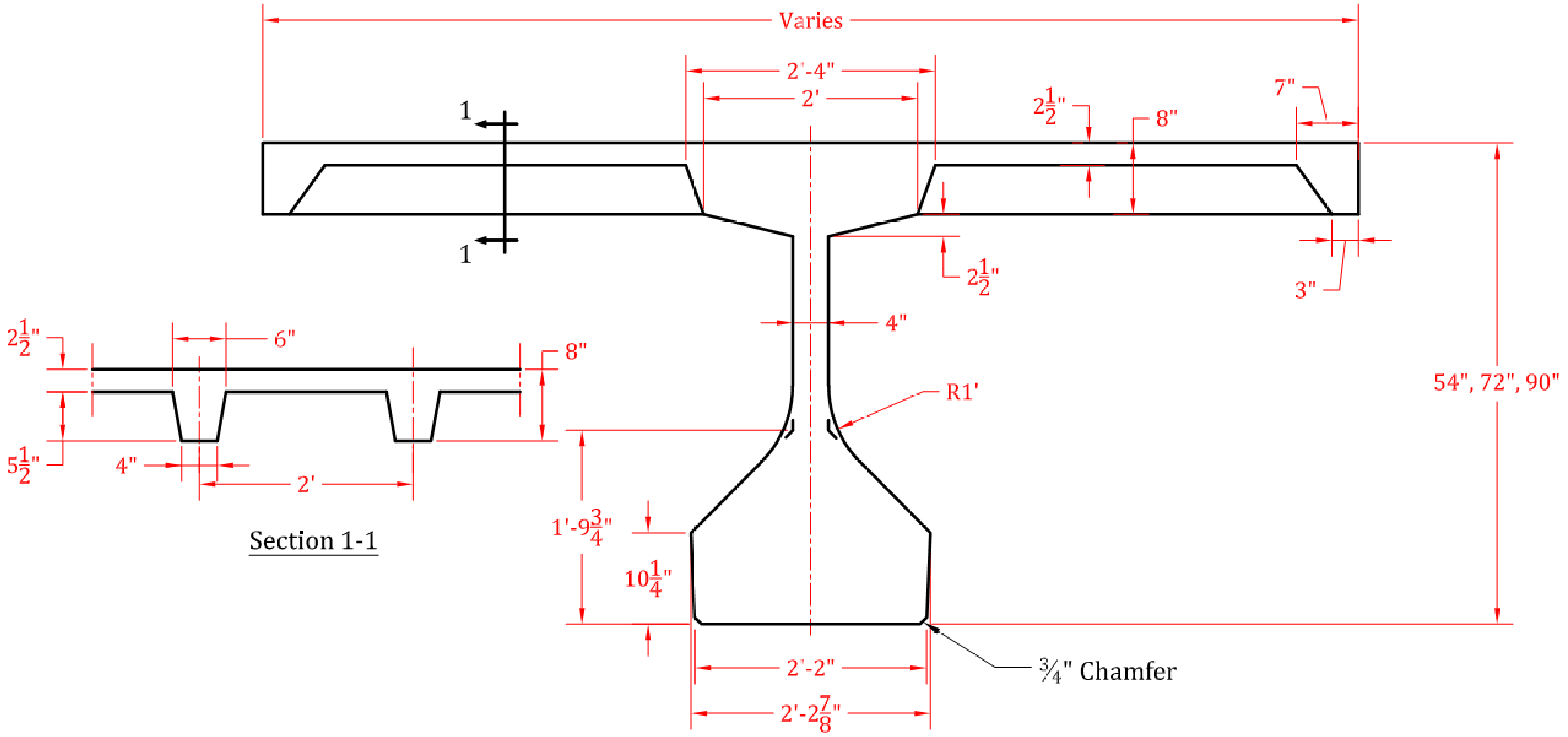
- The girder cross section shape was developed by e.construct USA, (Dr. Maher Tadros, Mr. Adam Sevenker, Dr. Mostafa Aboelkhier)
- It was optimized to meet the following criteria
  - Accelerated bridge construction (ABC), using the least number of precast pieces and minimizing cast-in-place usage.
  - Superior durability against freeze-thaw cycling and saltwater contamination
  - Superior tensile strength
  - Least concrete volume while maintaining satisfactory stiffness

Three-Dimensional View of Beam

Product can be pretensioned, or segmentally post-tensioned.



Cross Section Dimensions

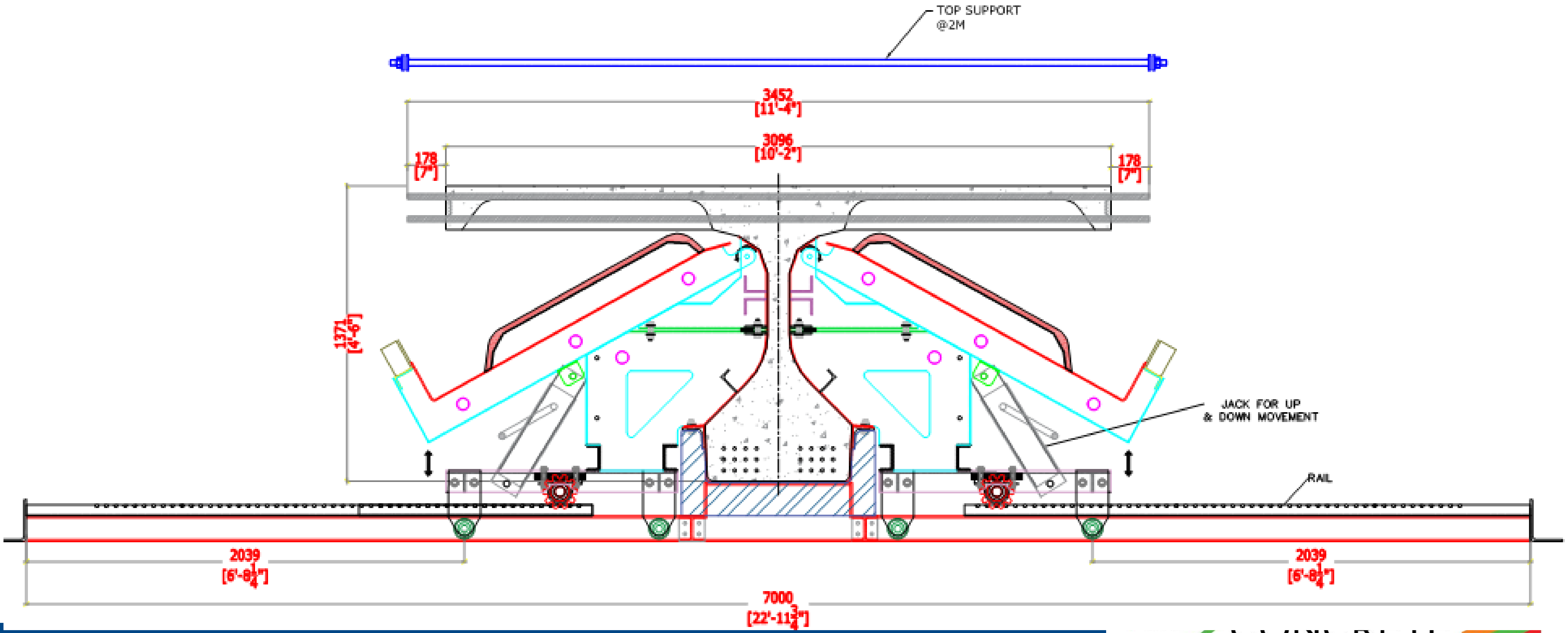


Challenges of Use of Decked I-Beam with Ribbed Top Flange

- Forms are more complicated than with conventional I-beams. But this is a one-time cost.
- Crown requires sloping beams at 2%
- Flange to flange connection requires that the flange edges be totally aligned. Possible to use a clamping mechanism.
- Full 8 in. (200 mm) thickness may be needed for ends of skew bridges. The forms must be designed to allow for void form removal.
- UHPC beams connected at the site with a UHPC CIP closure strip produce a challenging vertical cold joint.

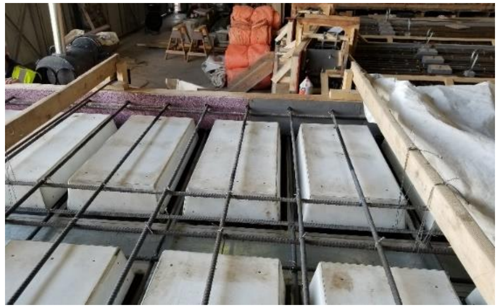
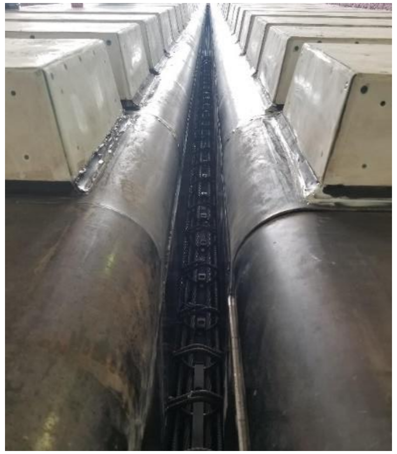
Forming Concept

Courtesy Kessab Steel, Dubai, UAE

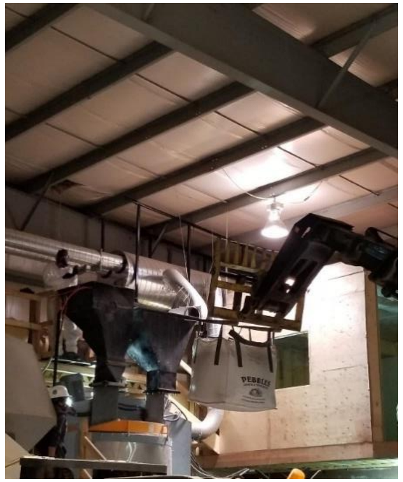


Girder Form and Reinforcement

- The formwork materials included steel, plastic, and roughened Styrofoam
- Formwork was pre-heated to a minimum of 10 ºC (50 ºF)
- Temperature sensors were attached to some bars


Dura® UHPC Batching



- High shear Skako mixer (0.4 m^3 (0.5 yd^3)) and two pan mixers (0.15 m^3 (0.2 yd^3)
- Batch ready every **20-25** minutes
- Ice and workability admixture were used to maintain flowability

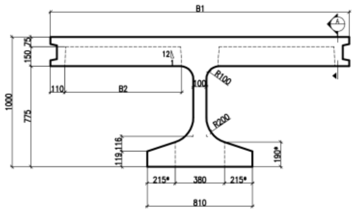
Batching Sequence

- Add dry powder, mix, then water and chemicals – mix
- Add fibers after flowability is assured
- Discharge using traditional buckets
- Stack batches and deliver to mold

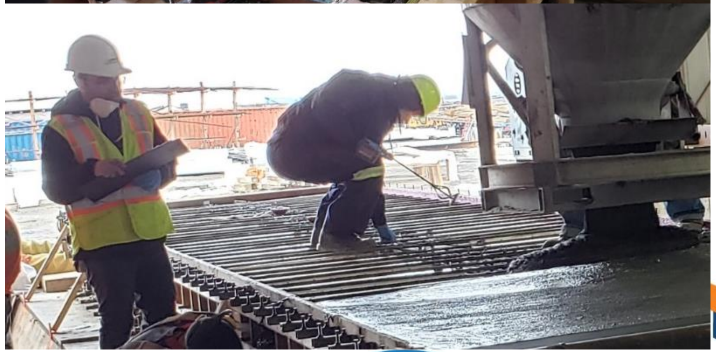
Concrete Placement

- A special chute was built to convey the materials from the bucket to the lower bell and the web
- While the material was discharged, vibration was externally applied from both sides of the web, to aid flow
- The exposed UHPC surface was immediately covered with wet burlap

Placement-Continued



- After concrete filled the web and bottom flange, pouring of the deck started
- Vibration for a short period was applied under each waffle to ensure the entire waffle section and key were filled
- Excess material was levelled with a spiked roller
- While waiting for the next bucket, the exposed surface was agitated using a paint drill bit

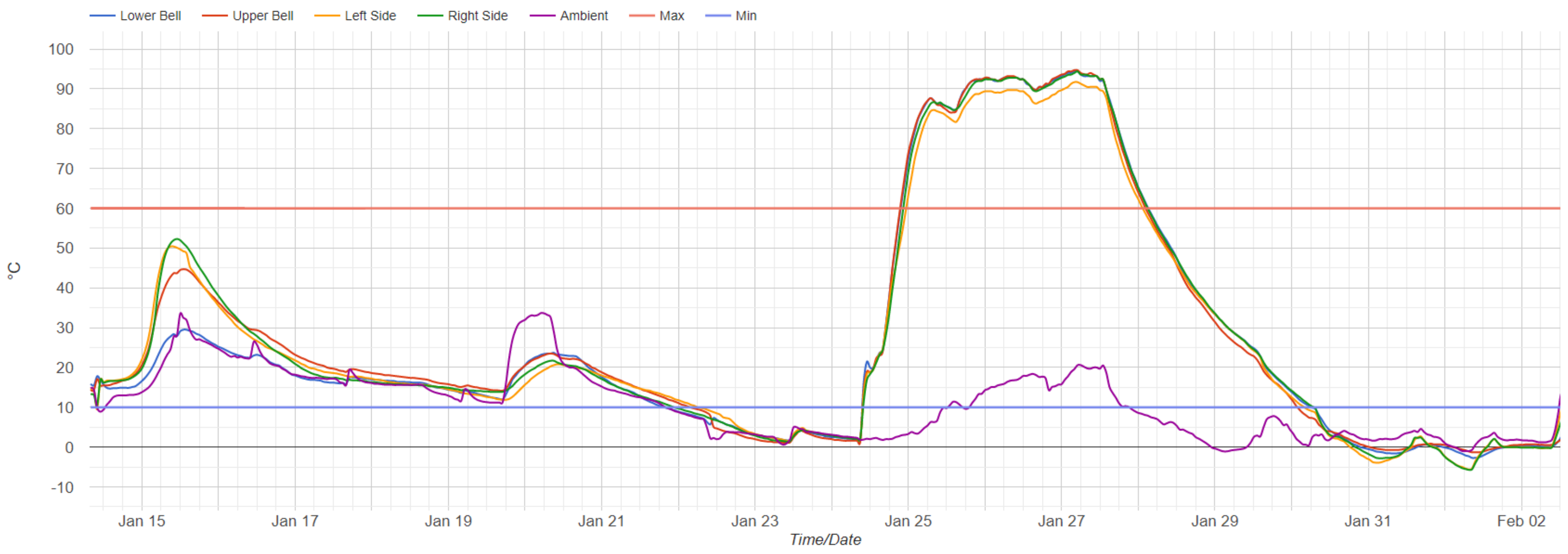


Deck Finish

- Fine ribbed rubber matting sheets were placed on the surface after levelling
- Then a heavy steel roller was moved back and forth on top of the rubber matting, to force the concrete to fill the rubber ribs
- The rubber matting ribs were oriented parallel to the traffic direction

Steam Curing

Curing & Post-CuringTemperature Profile



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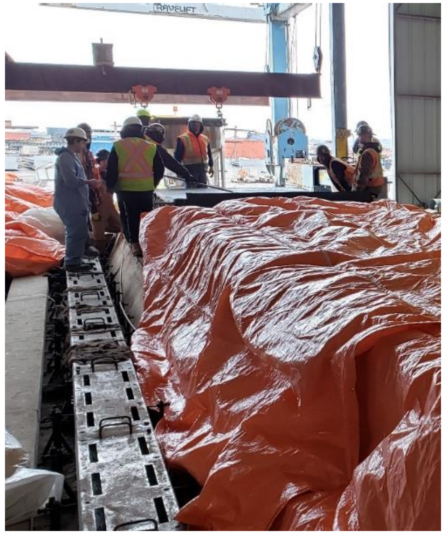
Quality Control



- After thermal curing, the DIB girder was covered with an isolated tarp
- A total of 144 cylinders and 15 prisms were molded from 8 different batches
- Specimens were generally taken from a combination of two or more batches
- The cylinders and prisms were left to cure with the product
- Testing at local Ontario CCIL certified lab, WJE Chicago and NCSU

Testing at North Carolina State University

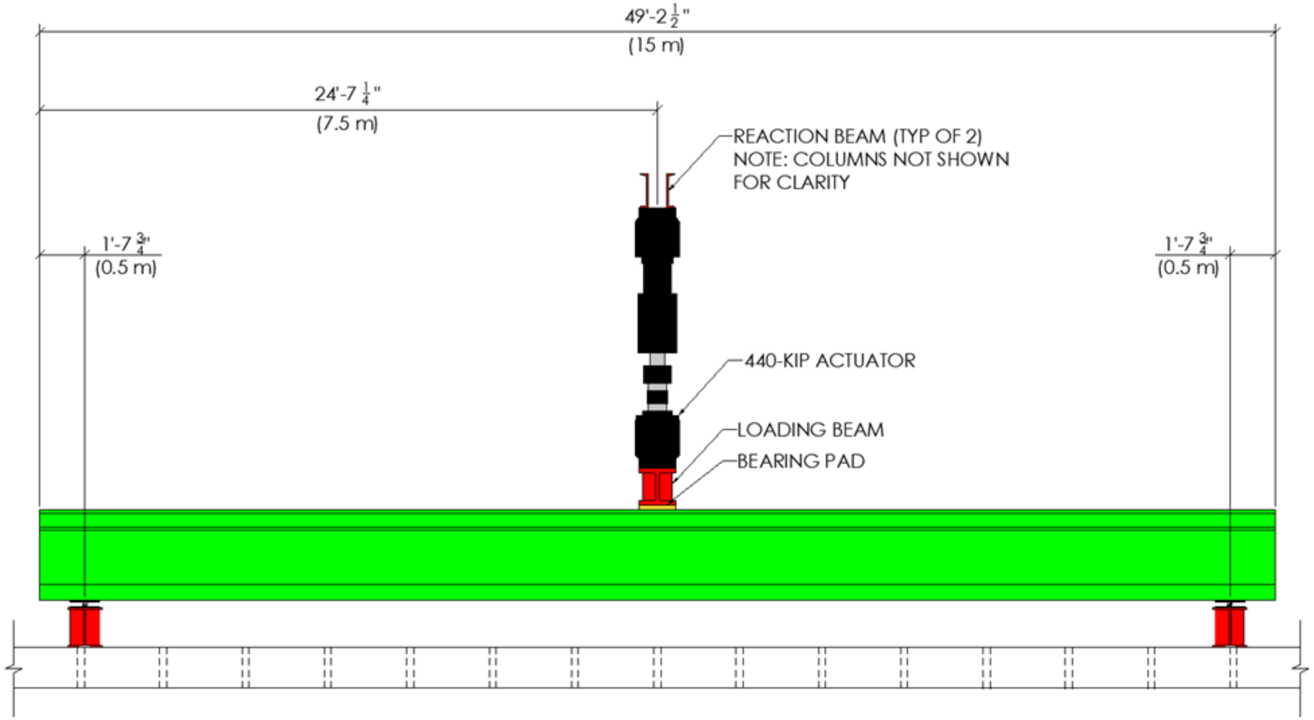
Girder Shipped on February 21, 2020

FACCA Inc. in Ruscom, Ontario, Canada

NC State Univ. in North Carolina, USA

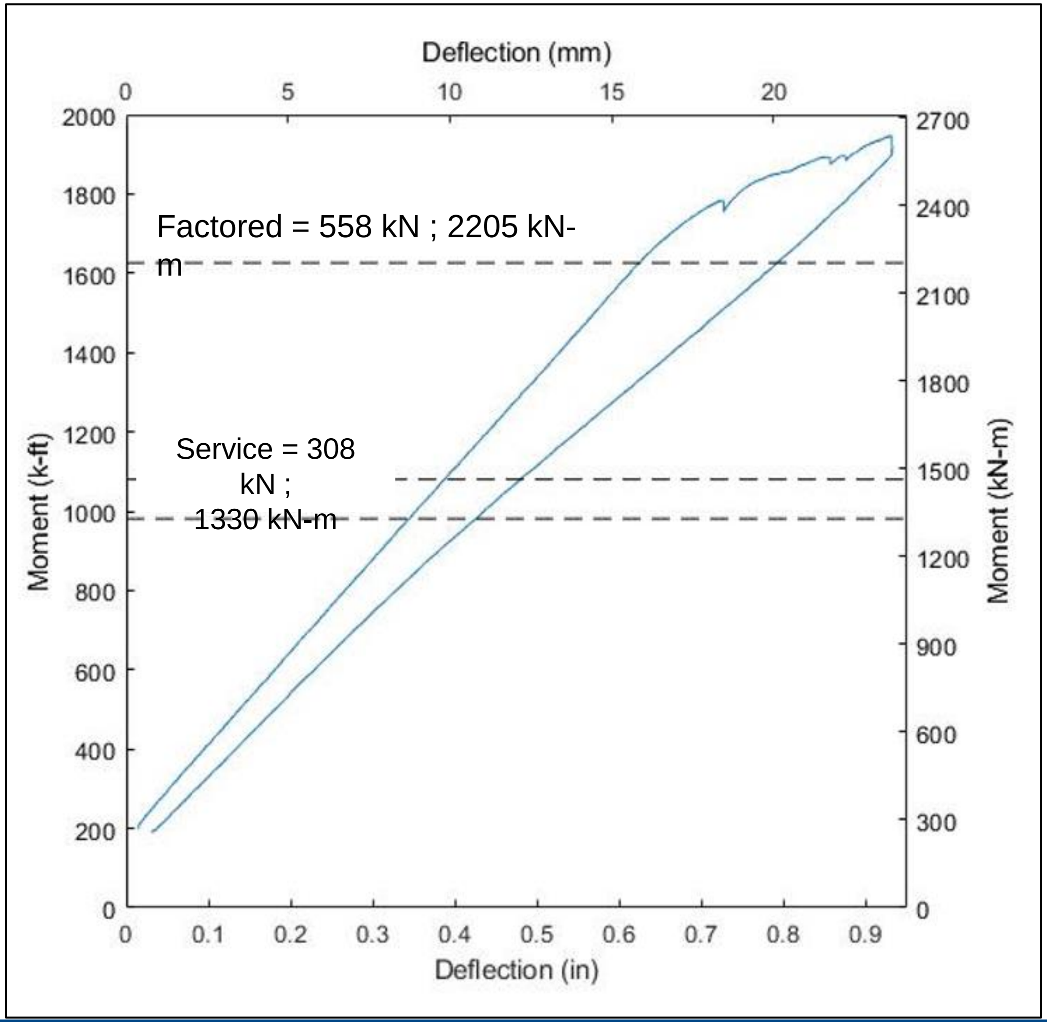
Flexure Testing

Goal: Verify flexural behavior. Stop the test prior to excessive damage so the beam ends can be tested in shear.



Flexure Testing

Source: NCSU

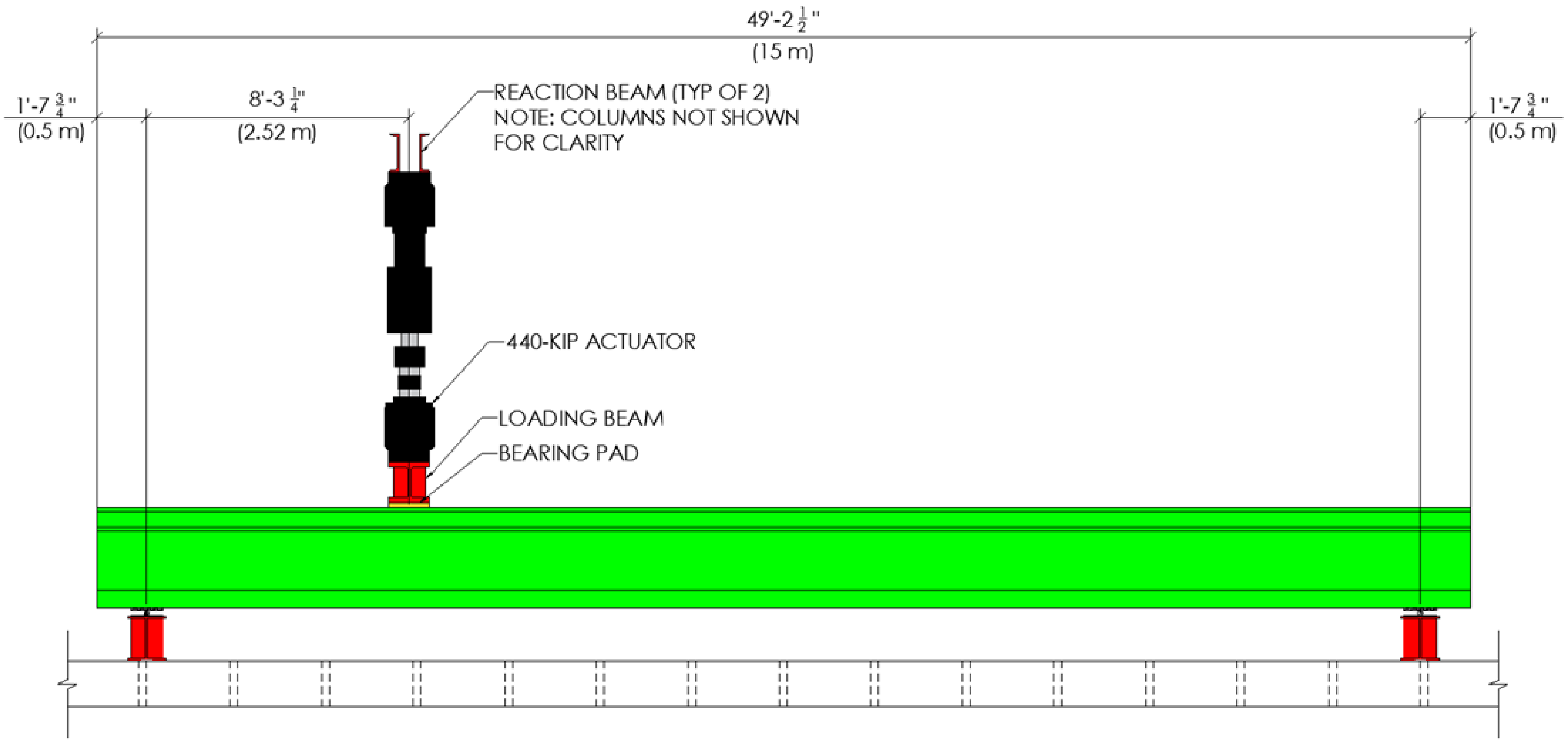


Service = 308 kN (69 kips)
Factored = 558 kN (125 kips)
Theoretical Cracking = 591 kN
Experimental Cracking = 578 kN

Test was stopped and unloaded after reaching 689 kN (155 kips), with no visible damage.

Theoretical Capacity = 875 kN (197 kips)

Shear Testing

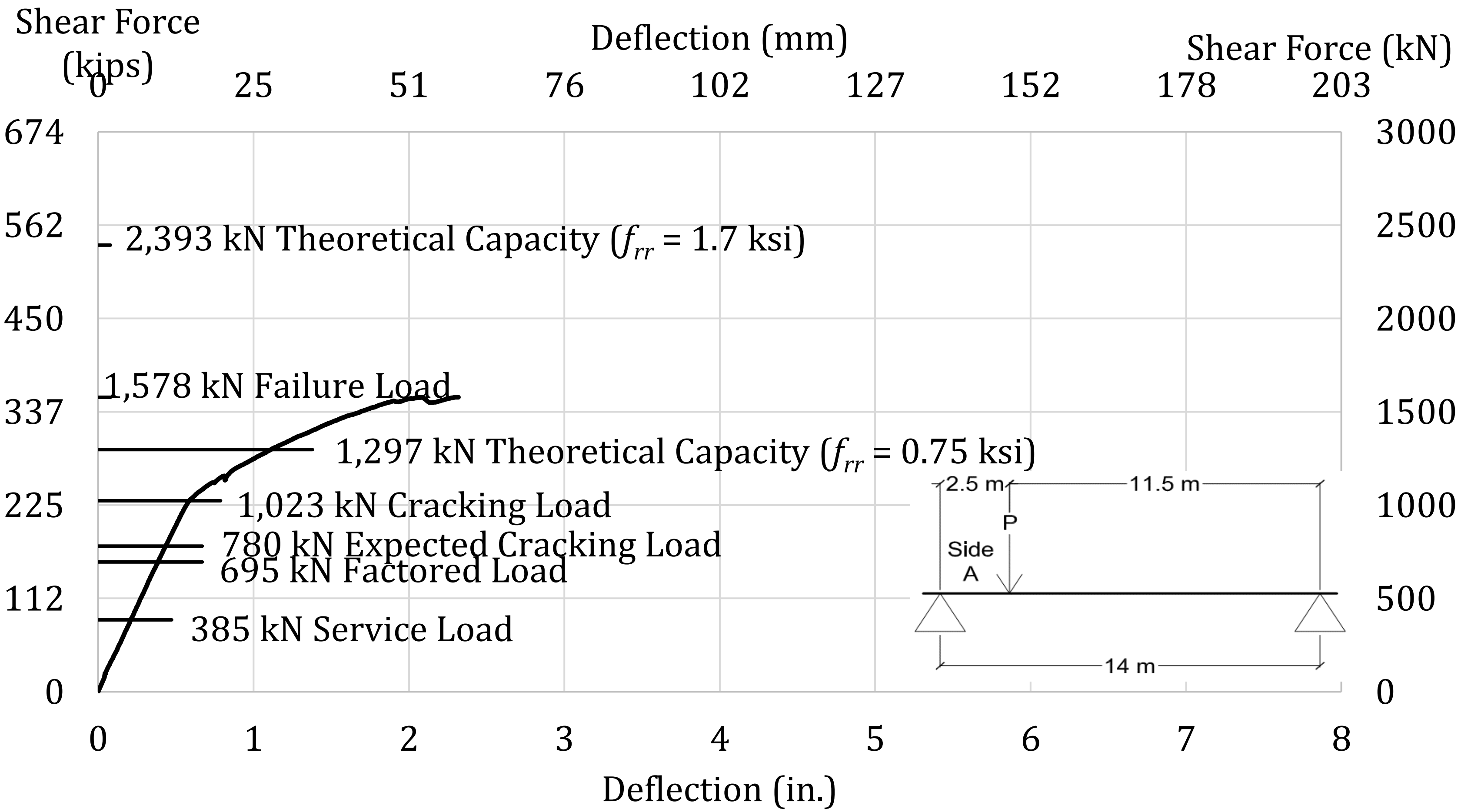


Goal: Verify behavior to failure on both sides of the beam.

One side with steel stirrups (US #5 bar at 250mm)

Other side with no stirrups (UHPC only).

Shear Testing – Side with No Stirrups



Source: NCSU

Shear Testing – Side with No Stirrups

Source: NCSU

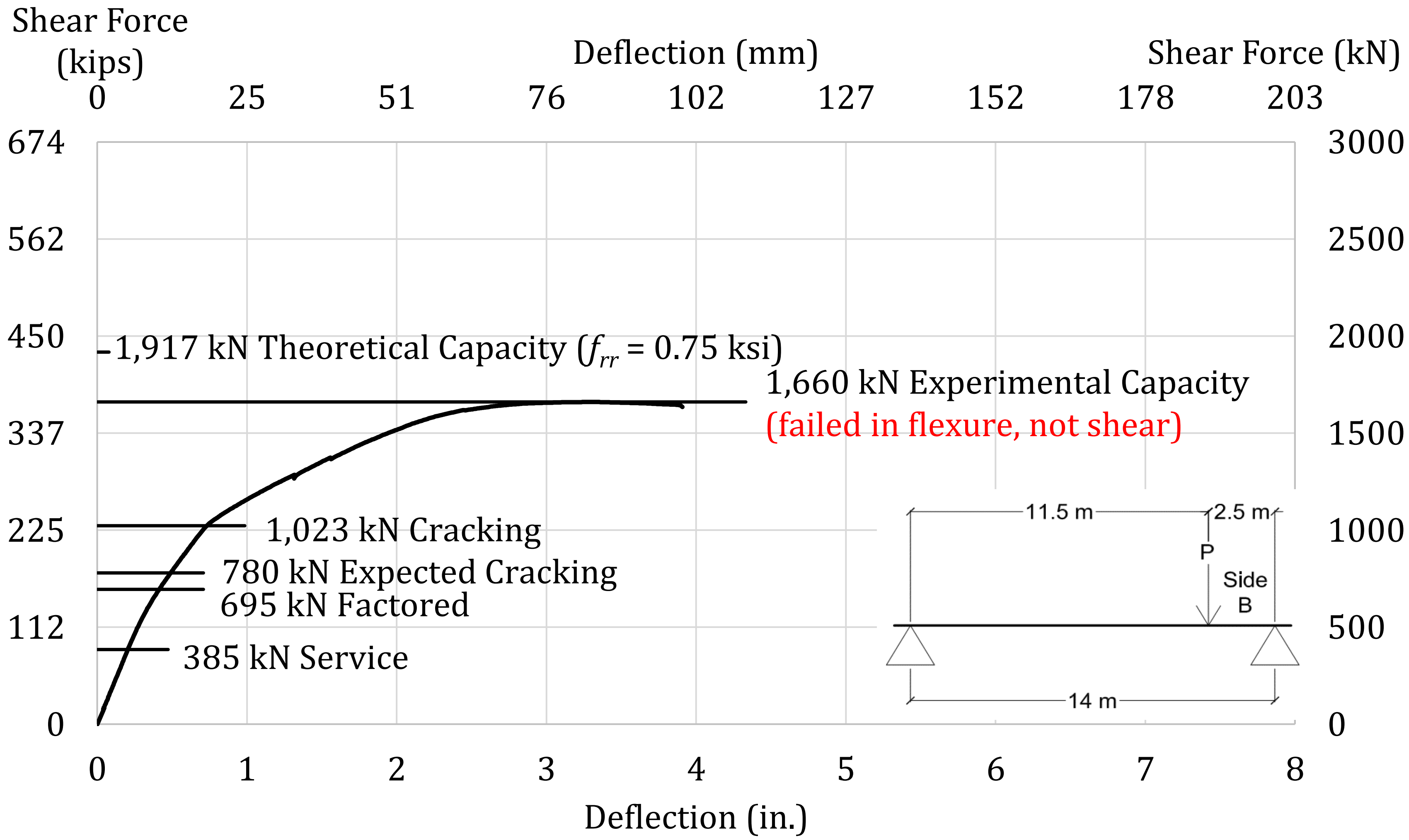
Steel fibers bridge the crack at peak load

Shear Testing – Side with No Stirrups (Video)

Source: NCSU

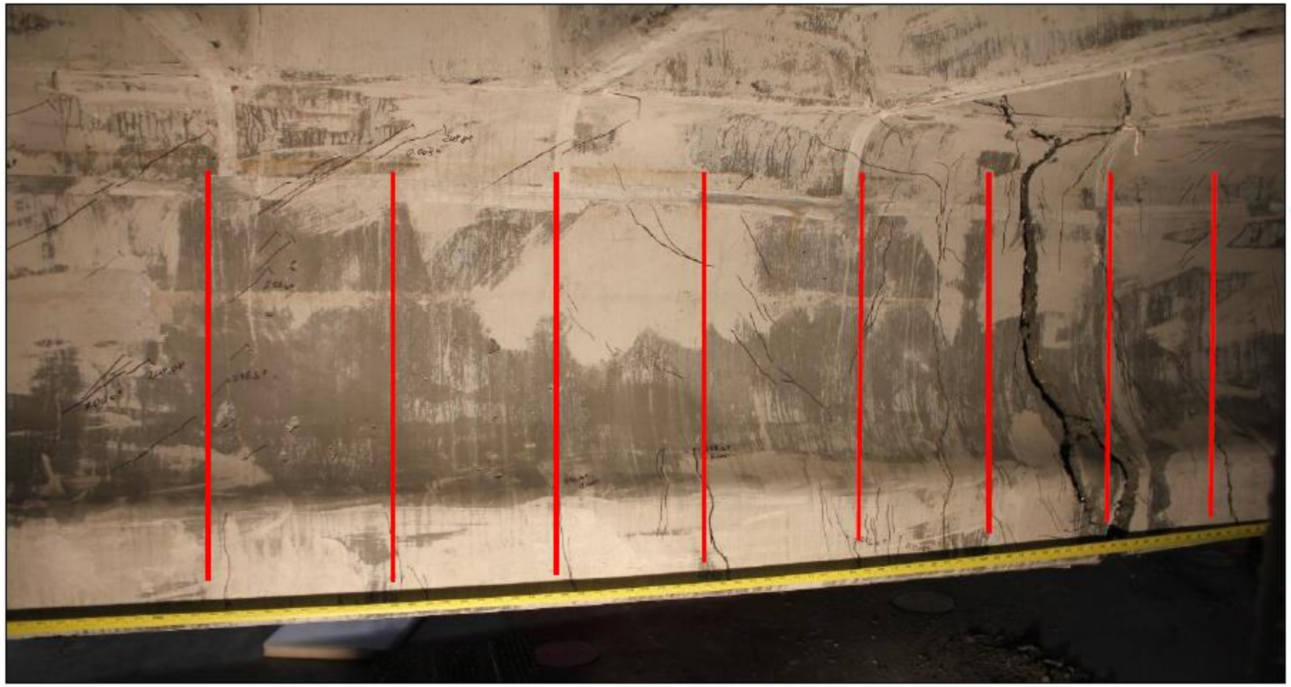
Shear Testing – Side with Stirrups (#5 @ 10”)

Source: NCSU

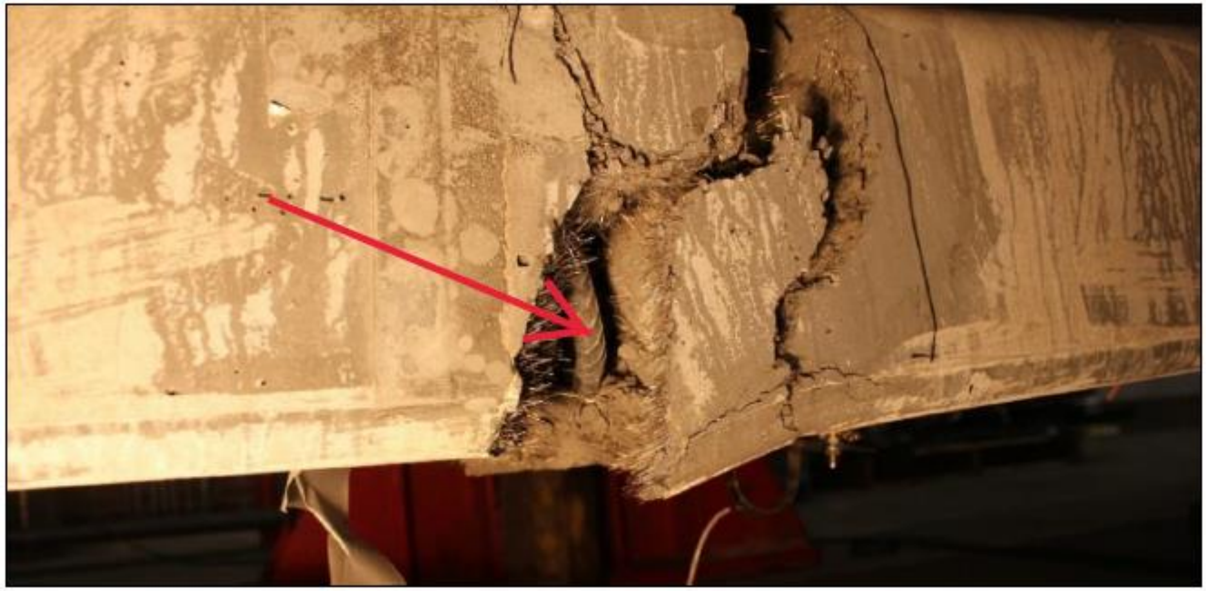


Shear Testing – Side with Stirrups (#5 @ 10")

Source: NCSU



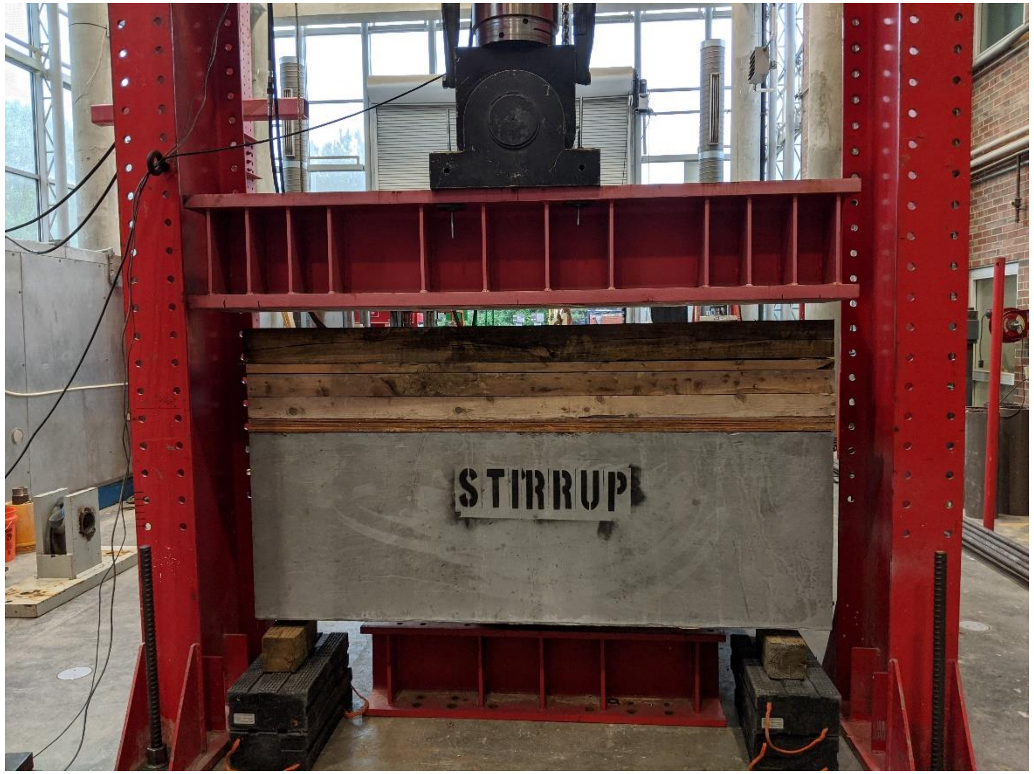
Flexural cracks at each stirrup (red lines = stirrup locations)



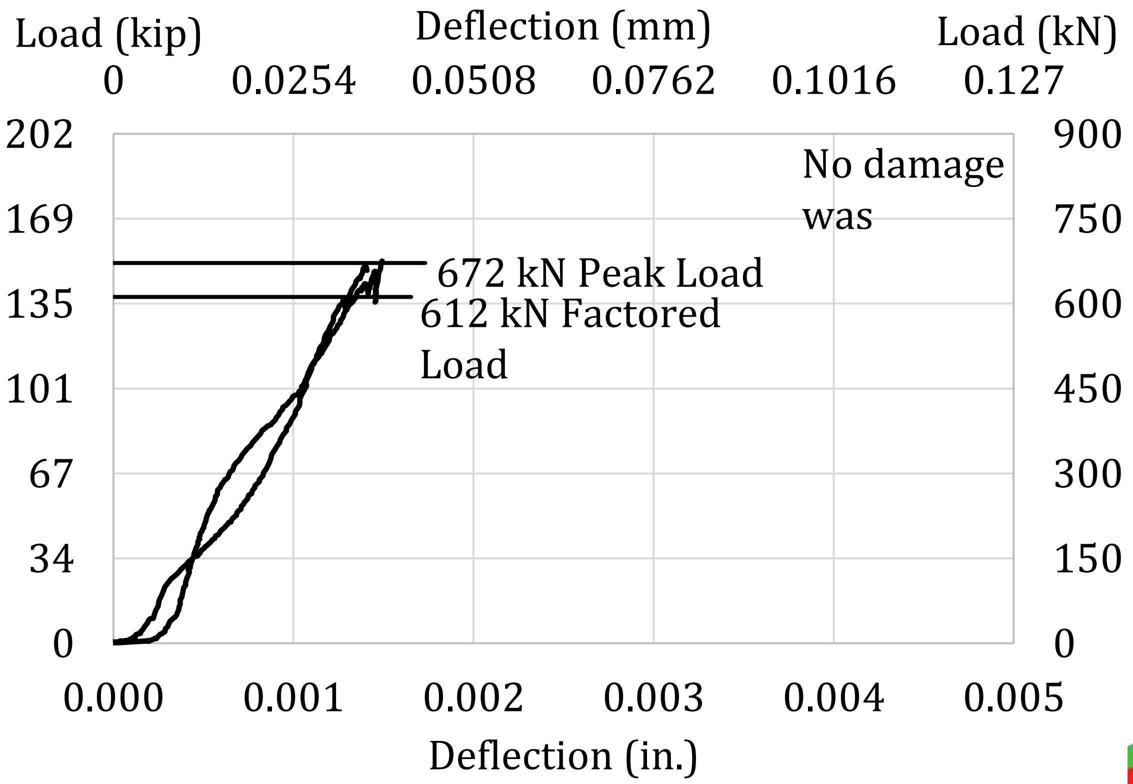
Close view of failure location showing stirrup

Shear Testing – Side with Stirrups (Video) Source: NCSU

Semi-Integral Diaphragm Test



Source: NCSU



University of Nebraska Test Results

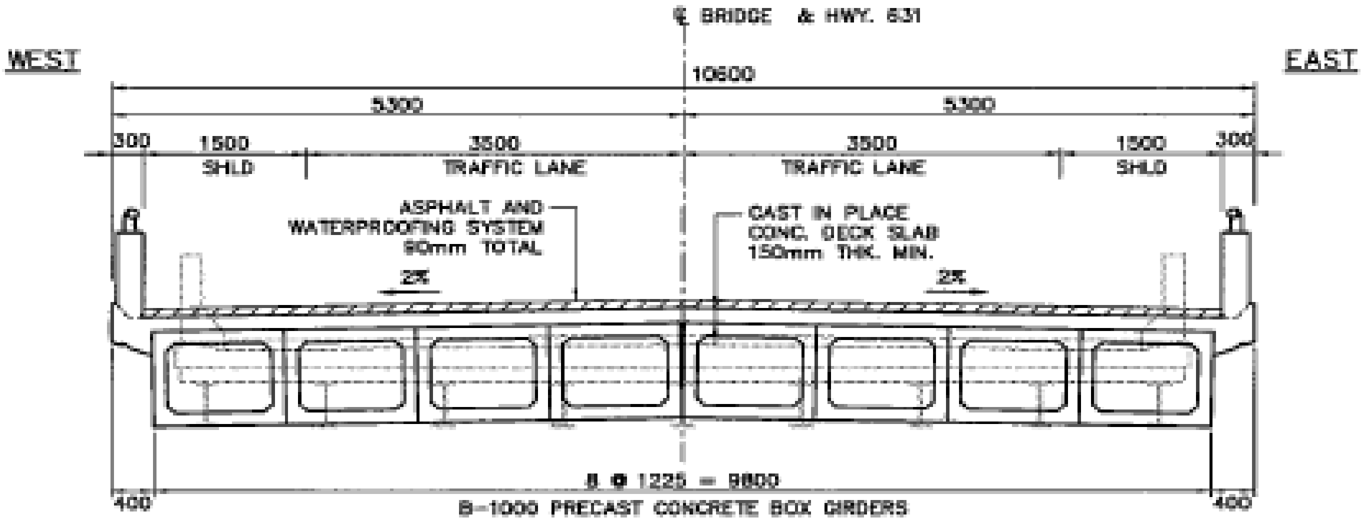
- Please see separate presentation by Drs. Morcous and Tadros.
- Results confirm conservative design.
- Results are consistent with NC State University results.

What is next? Potential New Project in Ontario

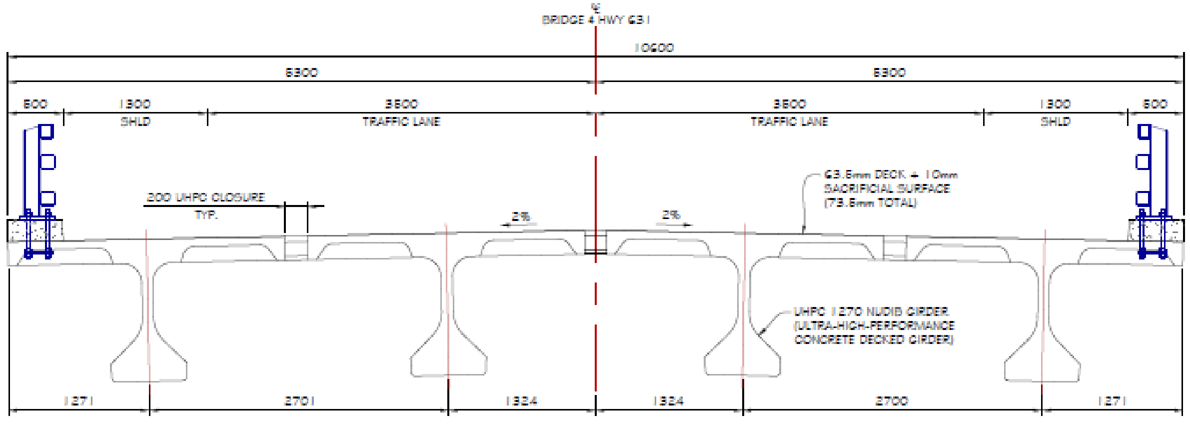
- Converted from conventional concrete adjacent boxes to UHPC DIB

What’s next ?

Note: Preliminary details subject to further review if considered by the client



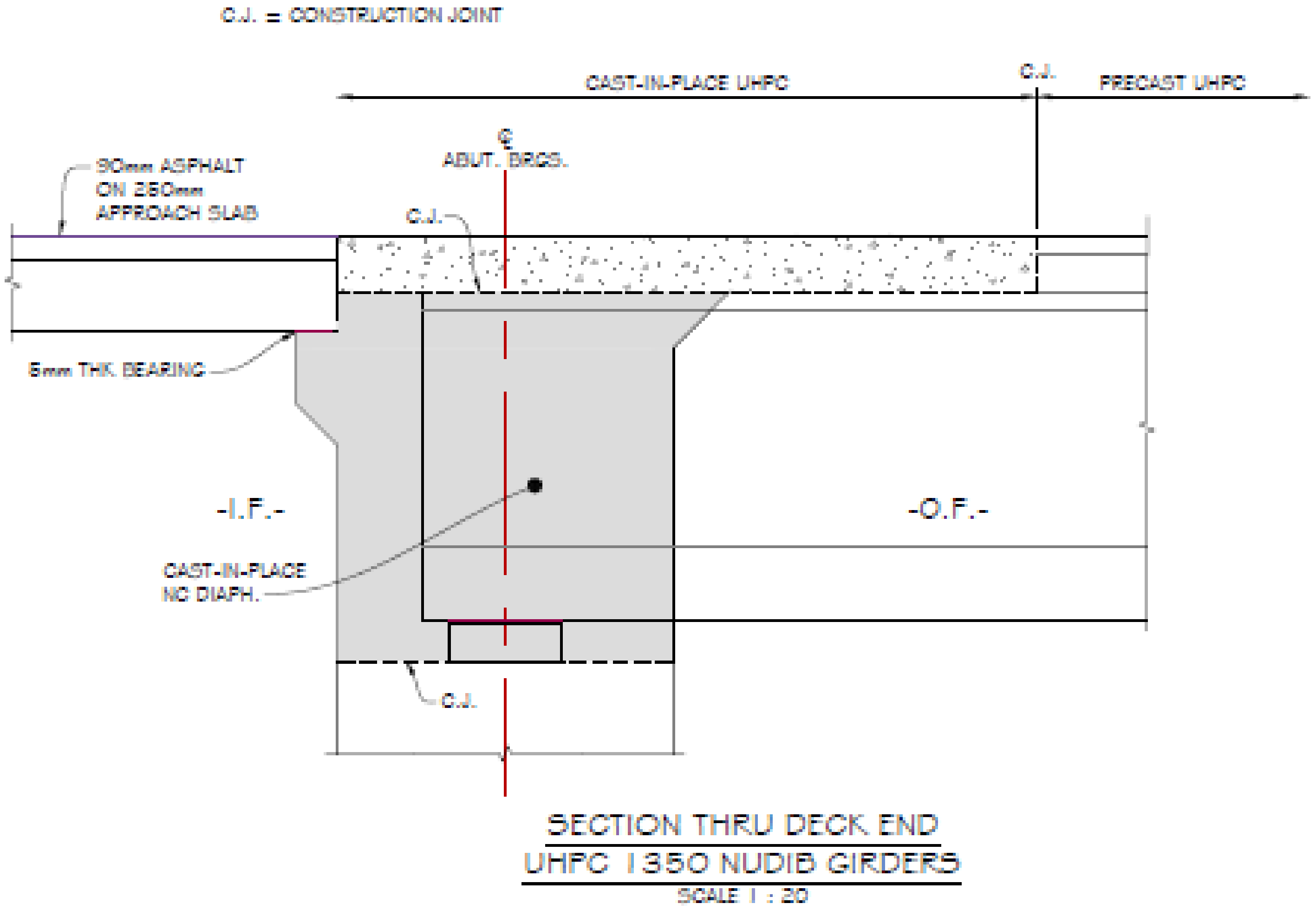
As-tendered design



SECTION THRU DECK
UHPC 1270 NUDIB GIRDERS

UHPC NUDIB alternative
With TL4 3-tube railing

Integral abutments



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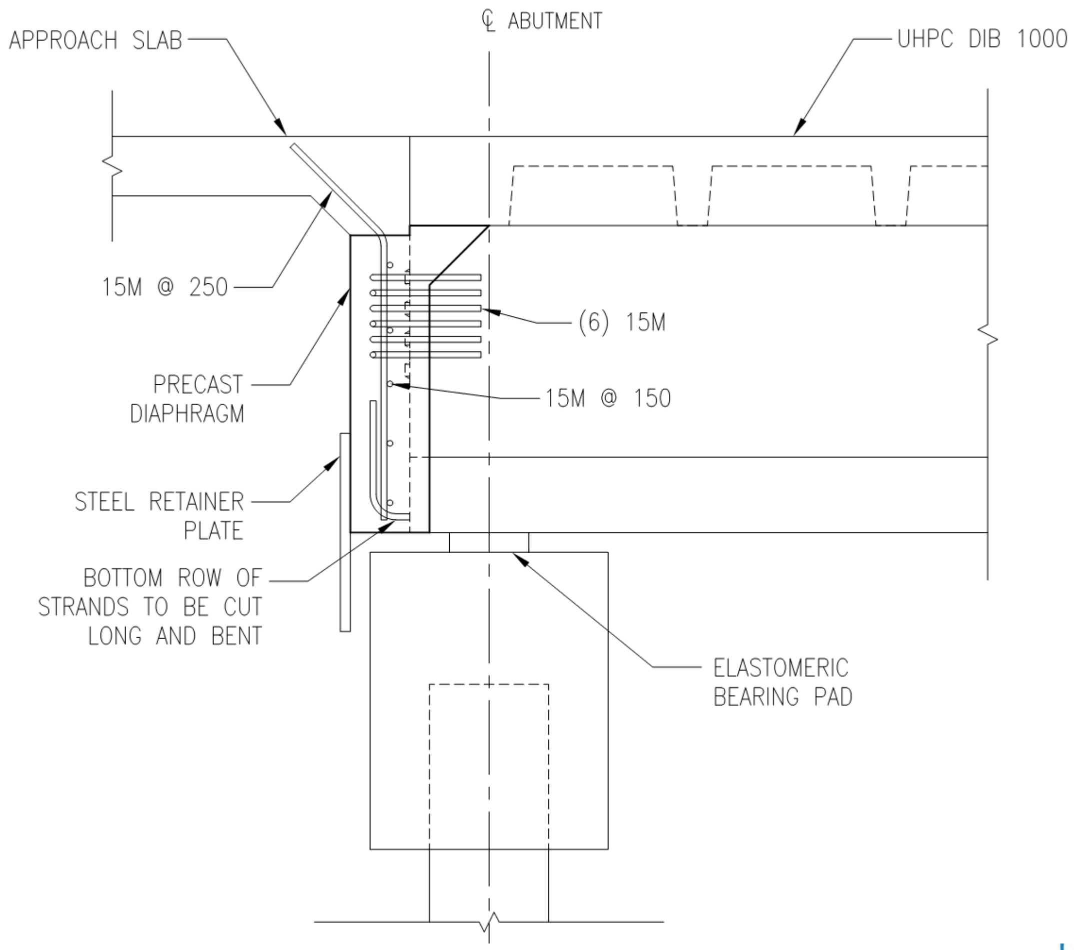
Semi-Integral Diaphragm Option



Conclusions

- Use of precast UHPC is environmentally responsible and cost effective
- Structural products can be produced in current precasting facilities with minor equipment modification
- Quality control must be a top priority
- Excellent structural performance in full scale testing by 2 universities
- Testing demonstrated conservative design.
- Eliminate discrete mild steel shear reinforcement using a narrow 4 inch (100 mm) web

Thank You

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