IOWA STATE UNIVERSITY

# Infrastructure Enhancement Utilizing Ultra-High Performance Concrete Bridge Deck Overlay

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Presented at:
2017 Mid-Continent Transportation Research Symposium
Ames, IA
August 16-17, 2017

# Presentation Outline

- Introduction
- Relevant Past Research
- Implementation on Mud Creek Bridge
- Delamination Assessment
- Experimental Test Specimens
- Experimental Test Setup
- Experimental Results
- Conclusions

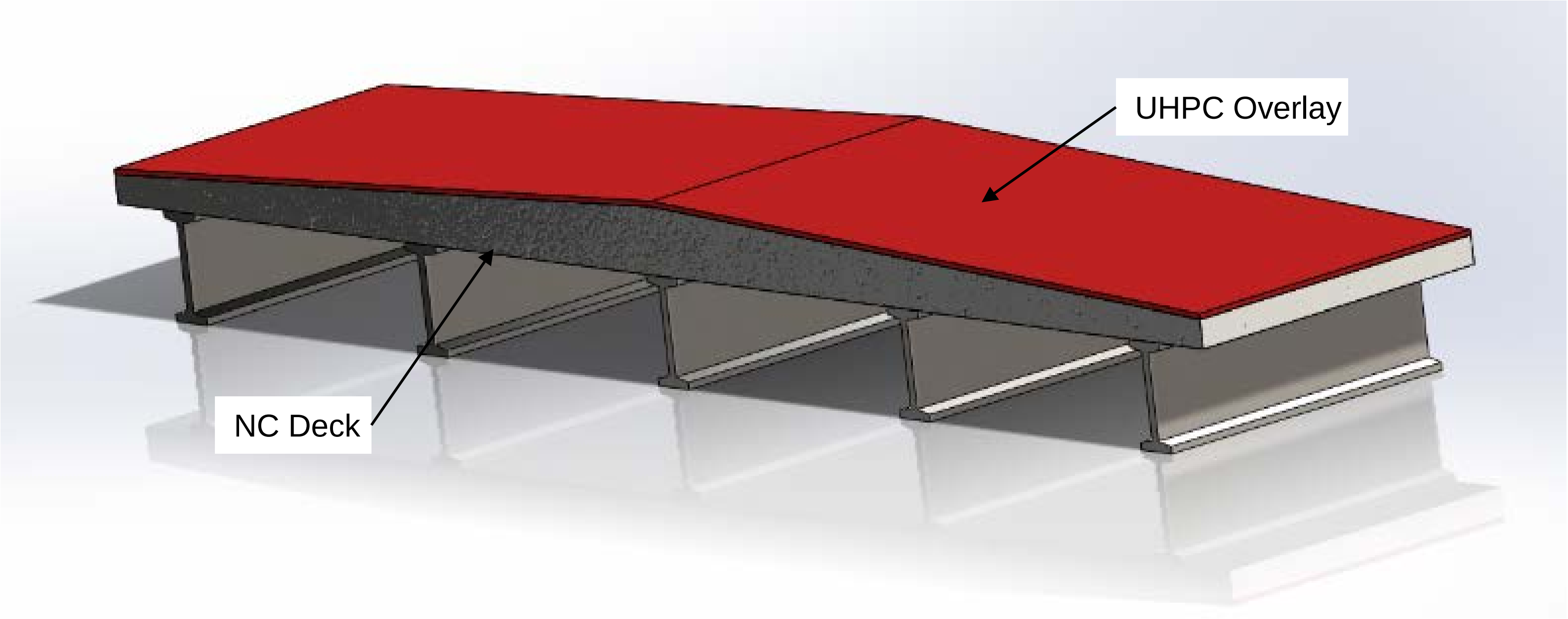
# Introduction

- Most common bridge deterioration:
  - Cracking on the deck surface → water and chloride infiltration into the core concrete → corrosion damage to steel reinforcement → further damage to the structure
  - Worsened by the impact of freeze-thaw cycles
- Potential retrofit or preventive solution:

**Thin overlay layer of highly durable, self-consolidating, ultra-high performance concrete (UHPC) integrally on top of the normal concrete (NC) deck**

# Introduction

UHPC Bridge Deck Overlay

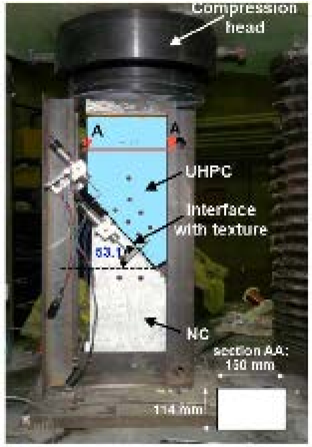


# Relevant Past Research

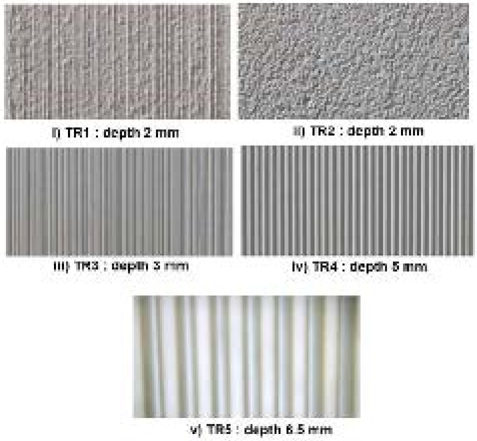
- Through 60 slant shear tests and 4 flexural tests, a minimum interface roughness of 0.08 in (2 mm) is needed so that adequate bond between UPHC and NC can be ensured (Test at ISU)
- Flexural bond test also showed that for specimens with roughened surface, the failure occurred in the NC but if the surface was not roughened, the failure occurred at the bond between UHPC and NC (Tests at ISU and Clemson University)

# Relevant Past Research

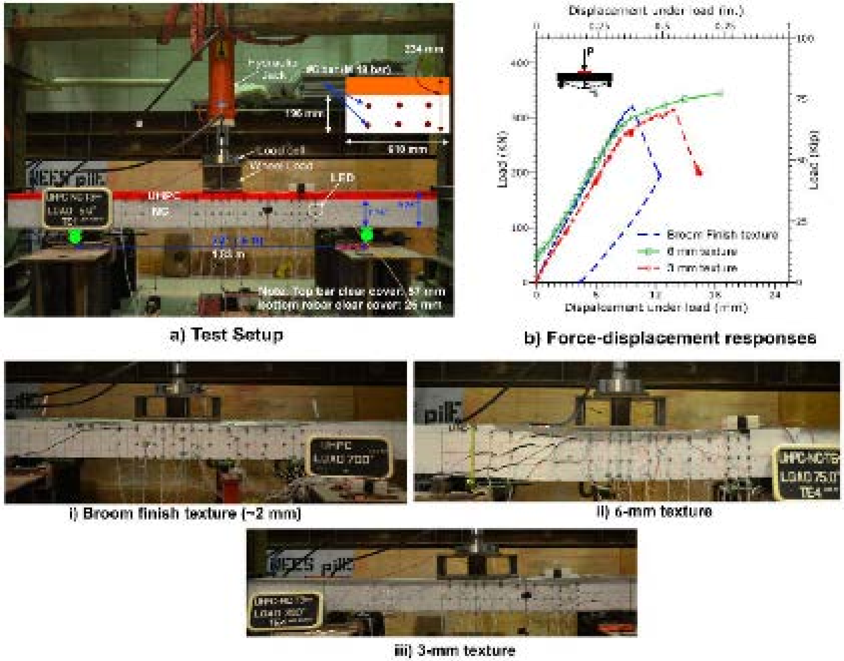
## Tests at Iowa State University



a) Slant shear test setup



b) Texture details



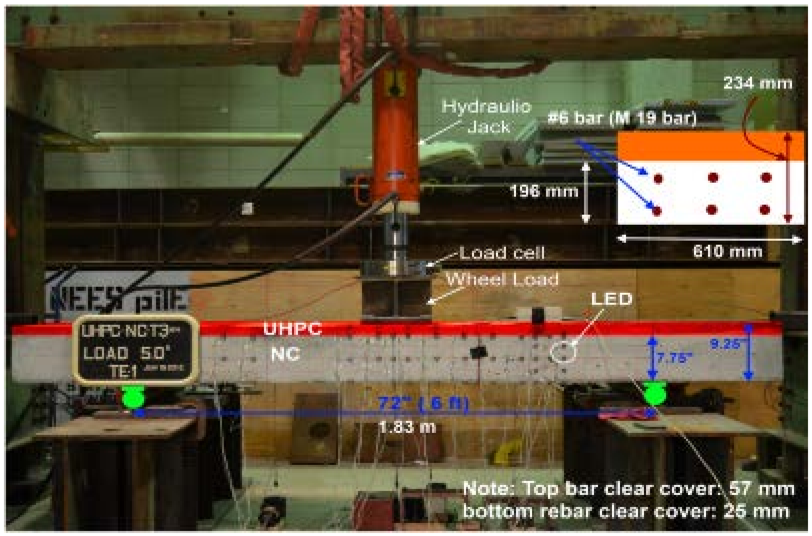
c) Shear failure in the composite deck specimens at ultimate load

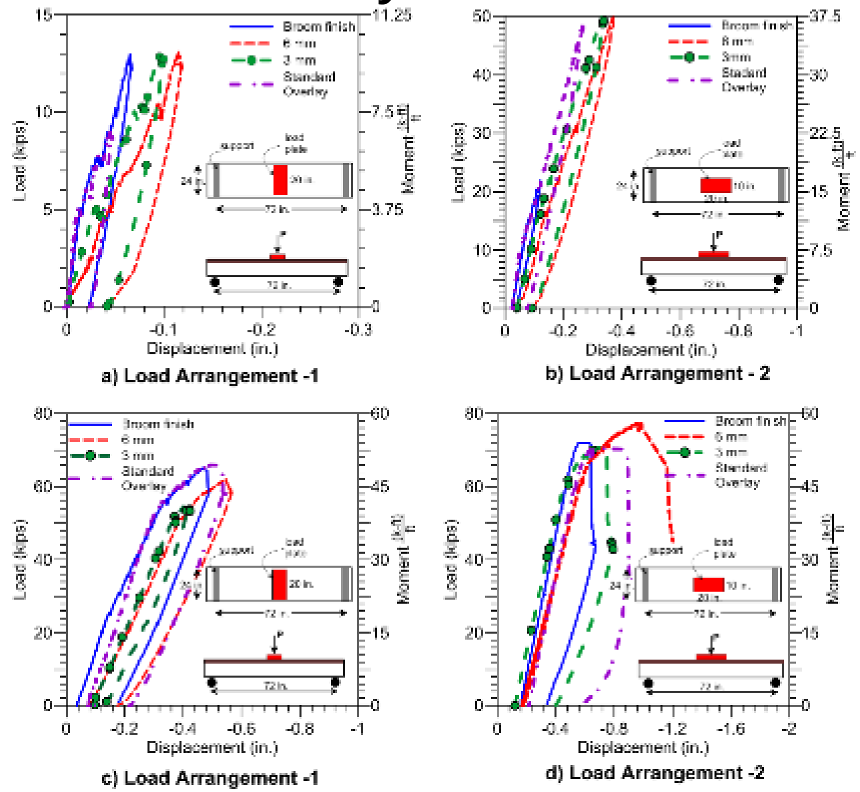
# Relevant Past Research

- Several static tests were previously carried out at ISU
- 4 cases tested: (a) broom finish surface roughness, (b) 6 mm surface roughness, (c) 3 mm surface roughness, and (d) standard overlay surface roughness
- The results from these tests showed that surface roughness affects the bond strength of the interface and 6 mm surface roughness provided the highest strength among the 4 cases

# Relevant Past Research

## Tests at Iowa State University



# Implementation on Mud Creek Bridge

PILOT PROJECT

- Before Overlay

- After Overlay

Built in the mid-1960s in Buchanan County, IA. The bridge is 100 ft long and 28 ft wide with 5% superelevation

# Delamination Assessment

- Once the UHPC overlay is placed, it is difficult to monitor any potential delamination at the interface
- Need a time-efficient, reliable, and repeatable non-destructive evaluation (NDE) technique to assess the delamination potential at the UHPC-NC interface
- Several pull-off tests were carried out to evaluate the NDE results

# Delamination Assessment

- Selection of non-destructive evaluation method

Applicability of NDE Techniques for Different Inspection Tasks

| Tools | Surface Cracks | Internal cracks | Delamination | Internal voids (large) | Rebar condition | Rebar cover/ location | Uniformity (strength or density) |
|---|---|---|---|---|---|---|---|
| Visual inspection | F | N | N | N | N | N | N |
| Infrared | N | P | G | F | N | P | N |
| GPR | N | F | F | F | N | G | P |
| UPV-tomography | P | F | P | G | N | P | G |
| Impact–echo | P | P | G | F | N | P | G |
| Impulse response | N | F | N | F | N | N | N |
| Radiography | P | F | P | G | F | G | G |

Technique applicability rated on the following scale: G = good, F = fair, P = poor and N = not appropriate

Reference: Popovics, J. S., "NDE Techniques for Concrete and Masonry Structures," *Progress in Structural Engineering and Materials*, 5 (2), 2003, pp. 49-59.

# Delamination Assessment

- Thermal camera was mounted on top of a car
- Some potential delamination areas identified
- Limitations exist, but manageable


# Delamination Assessment

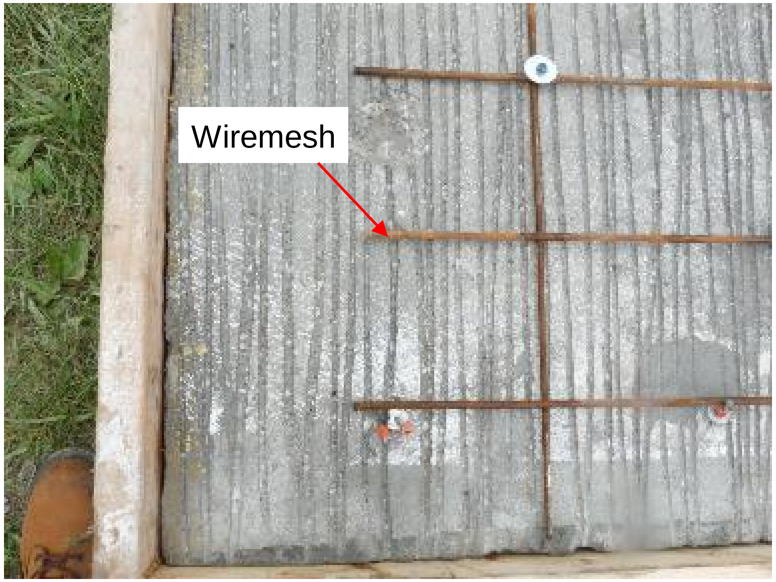
- Pull-off test
- Delamination was not found at UHPC-NC interface but within NC deck

# Test Specimens

- Three slab specimens were cut from a larger concrete deck used in a previous project, representing regular concrete bridge deck
- The size of each slab specimen was 2 ft by 8 ft, the thickness of the slab was 9 in
- The measured concrete strength for the slabs was 6.6 ksi. The rebar yield strength was 75 ksi with an ultimate strength of 100 ksi. The UHPC compressive strength was 17 ksi and the tensile strength was 1.3 ksi.

# Test Specimens

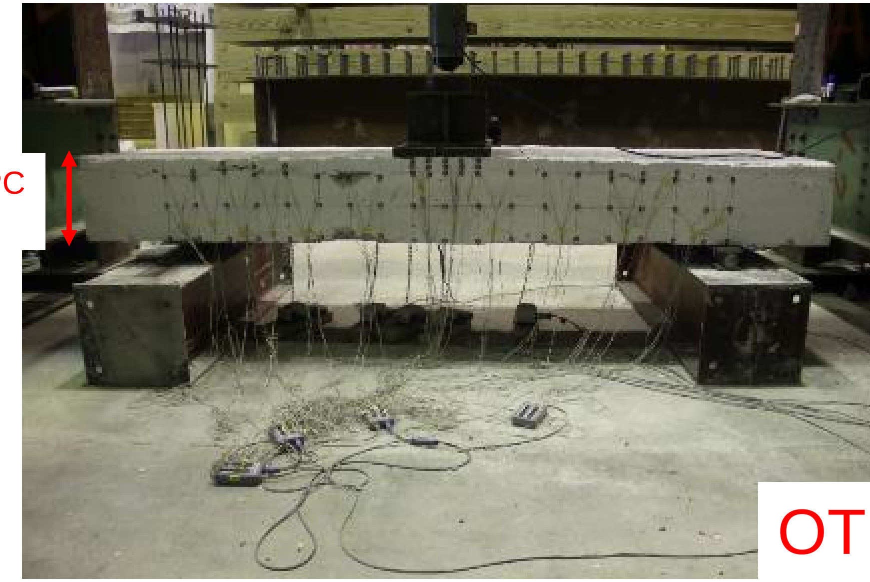
- Slab specimens were brought to the construction site and overlaid with UHPC

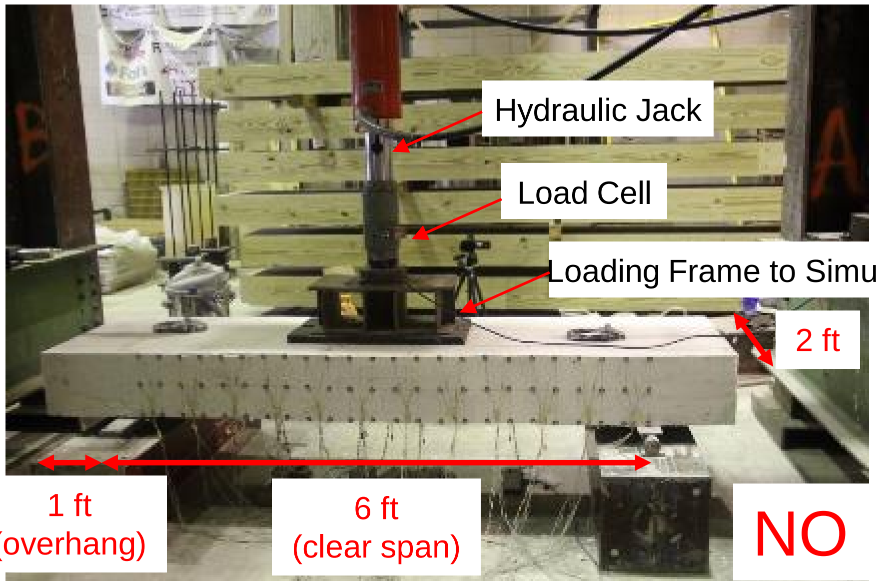



# Test Specimens

- Three specimens were tested:
  - NC slab only, no UHPC overlay (NO)
  - NC slab with UHPC overlay on top to represent positive moment (OT)
  - NC slab with UHPC overlay on bottom to represent negative moment (OB)

# Test Setup

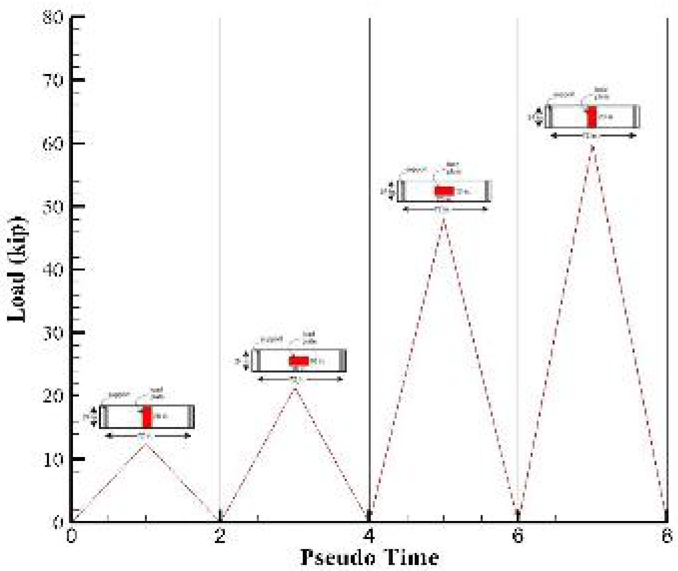

1.5 in UHPC
9 in NC
OT

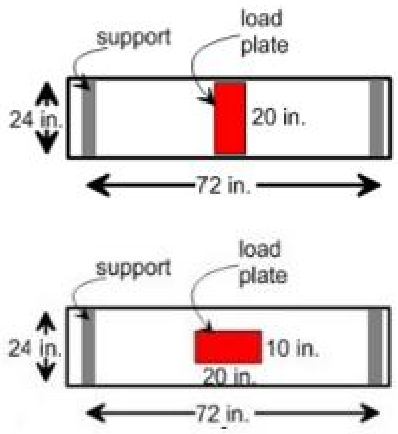

Hydraulic Jack
Load Cell
Loading Frame to Simulate Wheel Load
2 ft
1 ft
(overhang)
6 ft
(clear span)
NO


OB

# Test Setup

- Loading was applied in 4 loading steps with 2 load orientations
- Specimens were subjected to loads that ultimately cause failure in shear or interface debonding



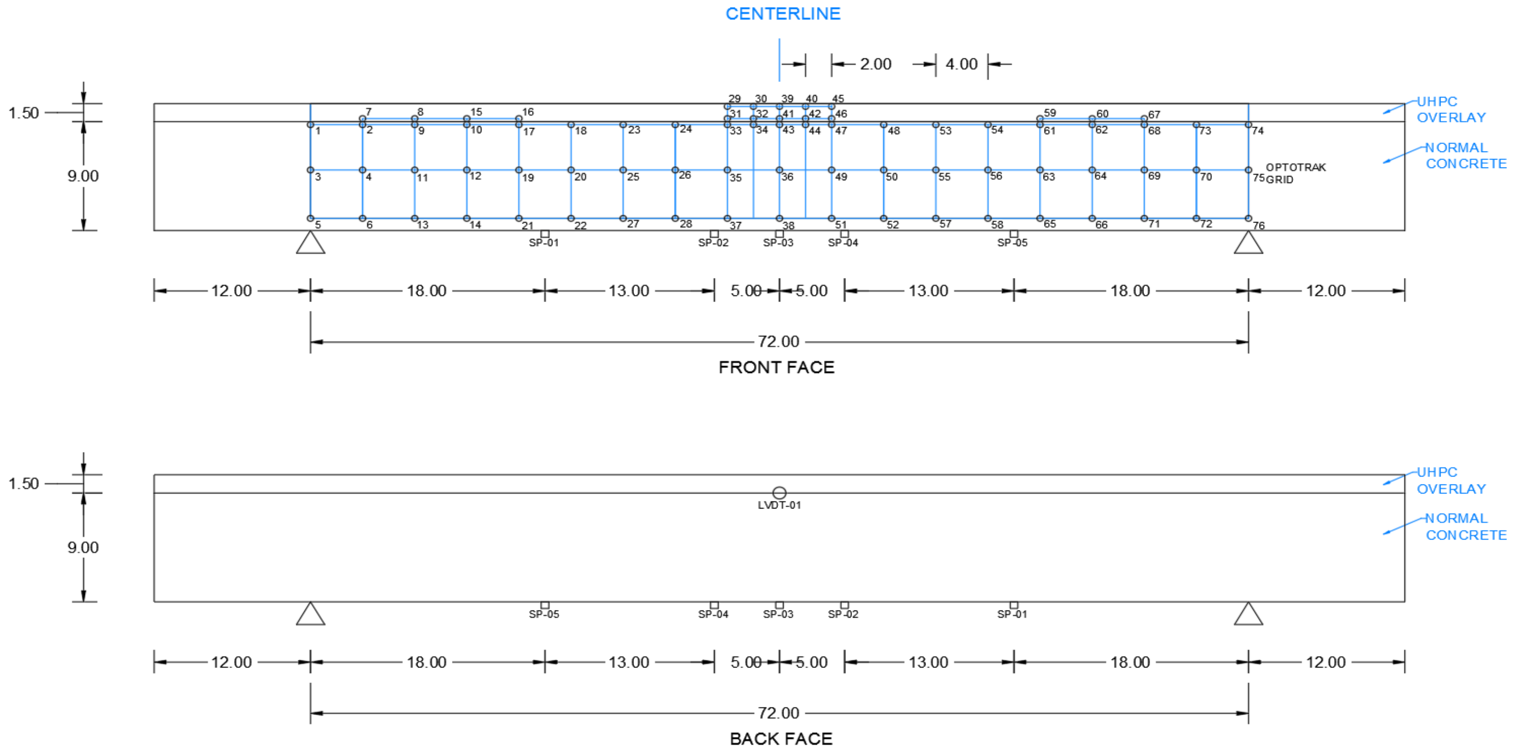




Load Orientation 1

Load Orientation 2

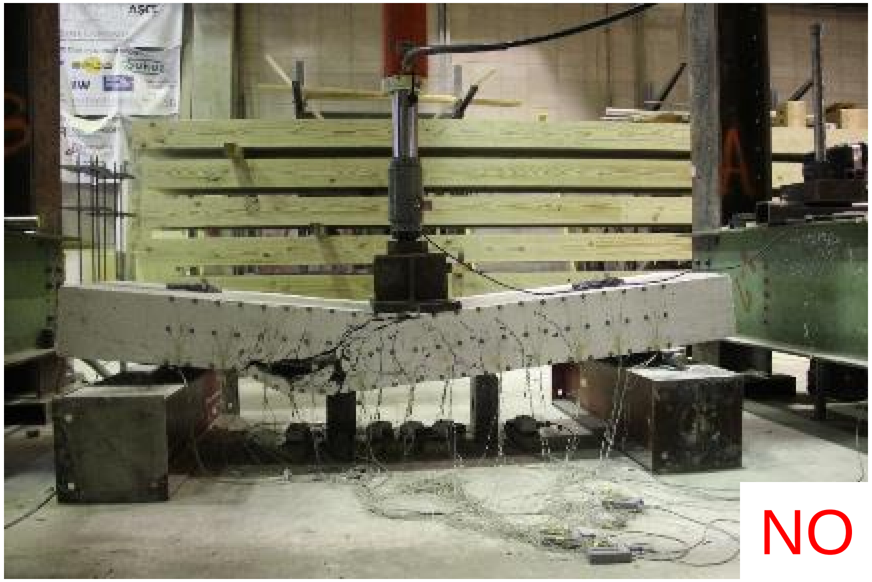
# Test Setup

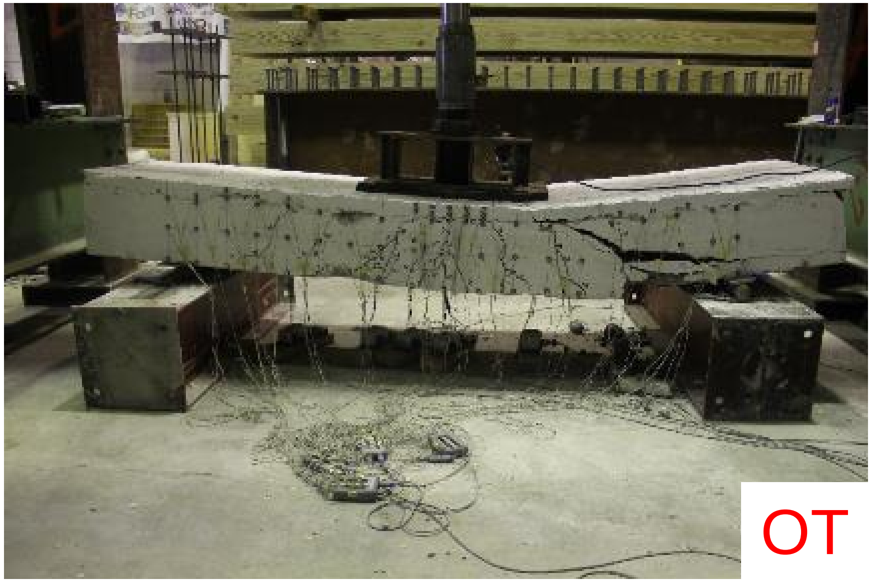
- Instrumentation layout (example Case OT)

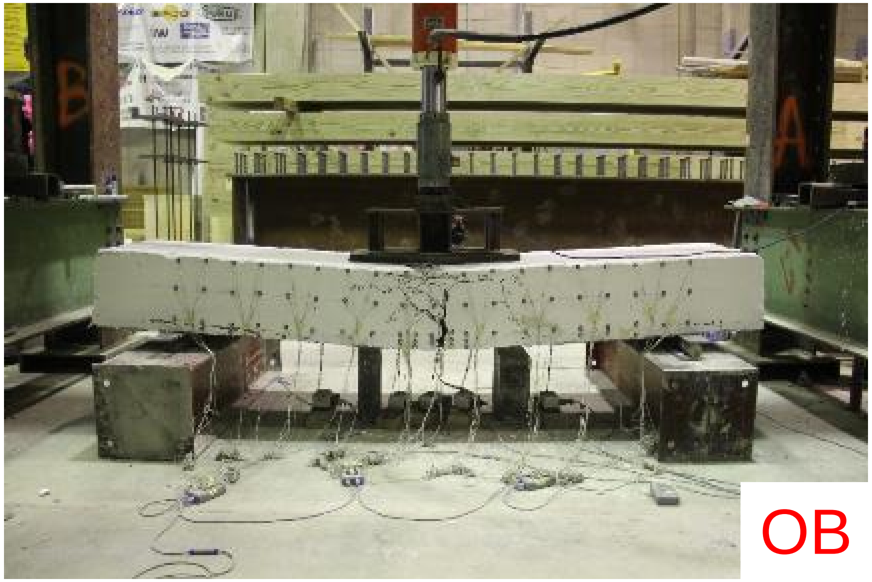


# Results

- Specimens at failure

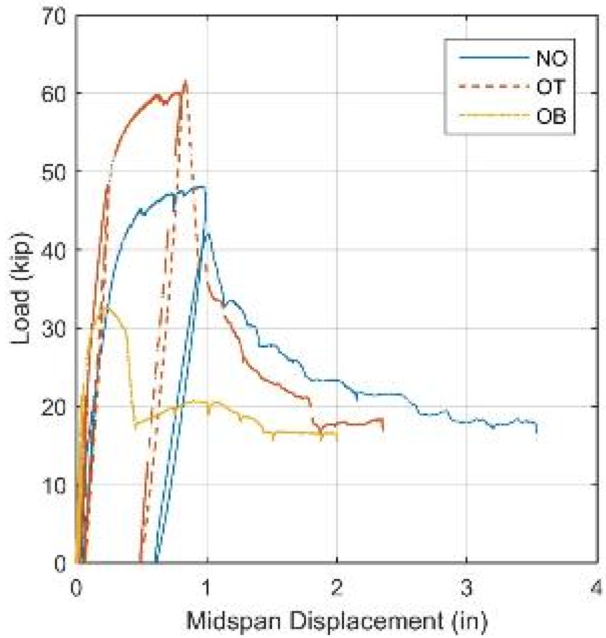

NO


OT


OB

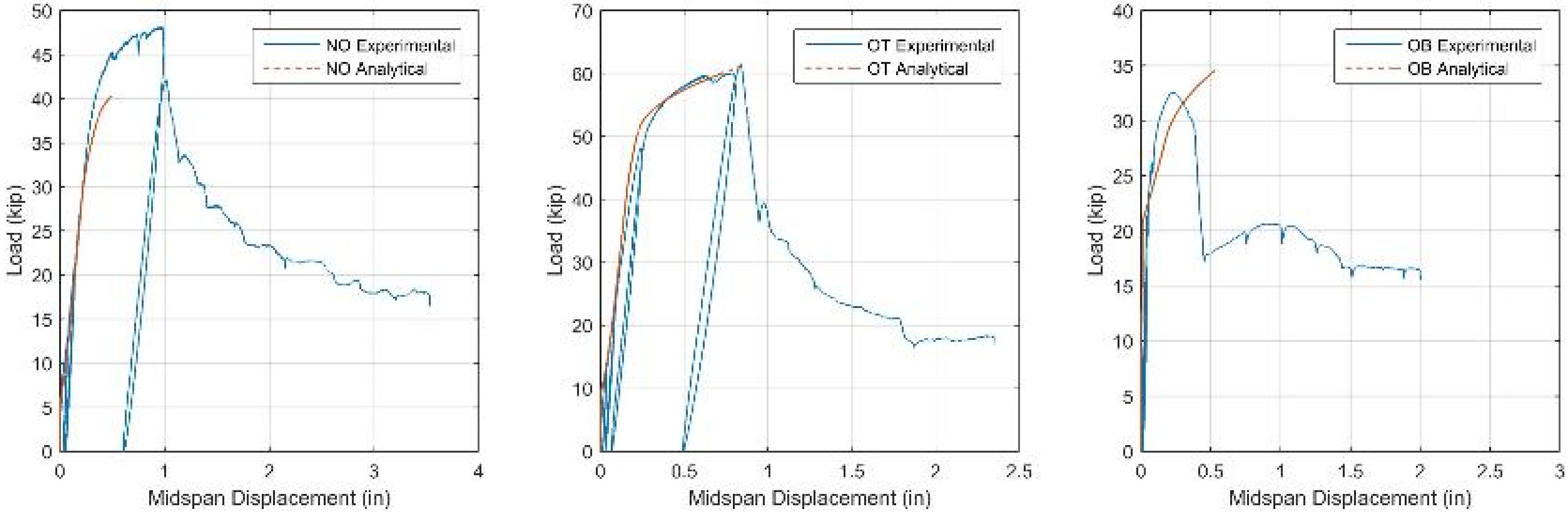
# Results

- UHPC overlay increases the stiffness and load capacity (strength) by 28% in positive moment region
- In negative moment region, the failure load is lower as expected



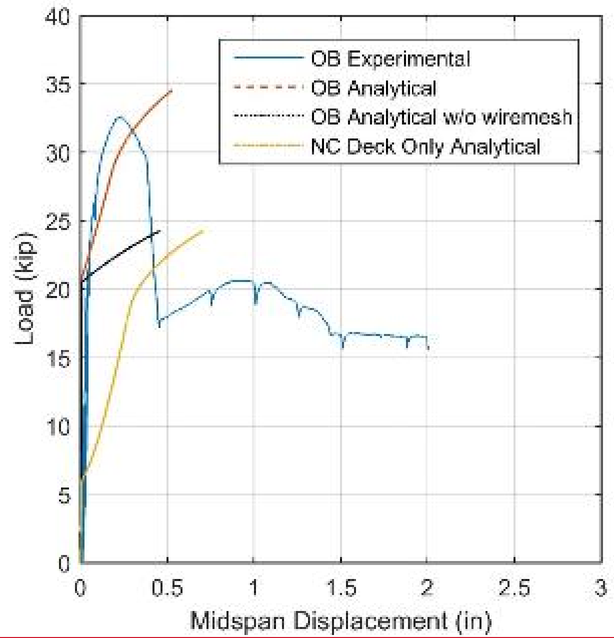
# Results

- Analytical results show good agreement with the experimental results
- Discrepancies may be caused by actual vs. assumed properties



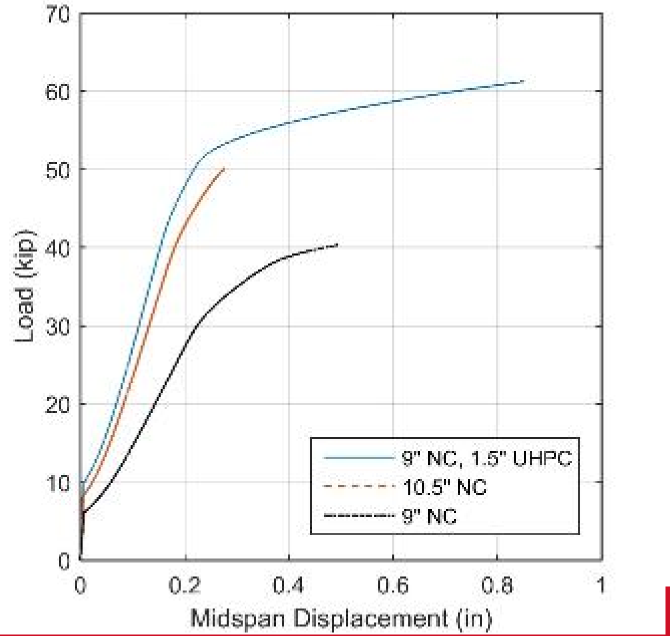
# Results

- For negative moment region, when compared with NC deck only, UHPC overlay also provided additional stiffness and strength
- Contribution of wiremesh is proportional to the area



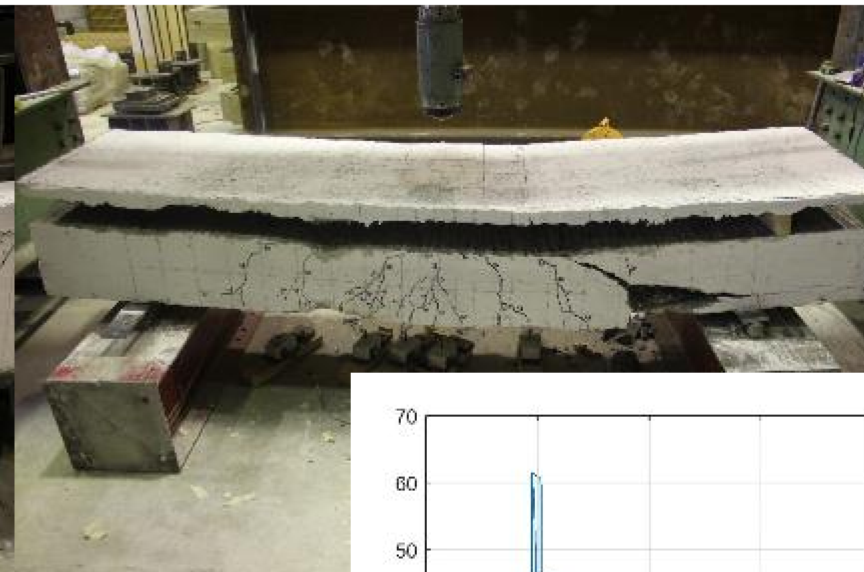
# Results

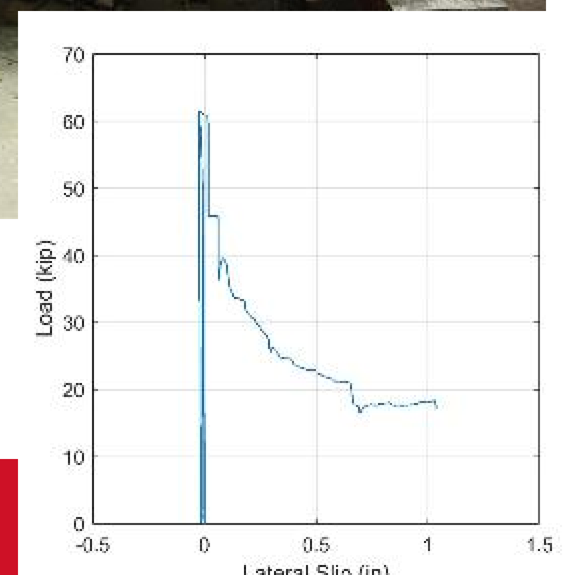
- The additional strength provided by UHPC overlay is due to:
  - Increase in height
  - Increase in compressive strength



# Results

- Overlay debonding due to insufficient surface roughness





# Conclusions

- UHPC overlay is a simple and cost-effective alternative solution to improve bridge deck performance, which in turn will enhance infrastructure performance
- Potential delamination areas can be identified using infrared imaging, which is a non-destructive method
- For Mud Creek Bridge, no delamination was found at the UHPC-NC interface, only within NC deck (pre-existing condition)

# Conclusions

- Based on the laboratory tests, the UHPC overlay was found to increase the stiffness and strength of the NC deck; the strength increase was found to be approximately 28%
- A proper surface roughness is necessary to create good bond at the UHPC-NC interface that will ensure sufficient shear strength is achieved

# Acknowledgments


- Federal Highway Administration
- Iowa Department of Transportation
- Iowa Highway Research Board
- Buchanan County Secondary Roads Department
- Lafarge Holcim
- Drs. Richard Wood and Zhigang Shen, University of Nebraska - Lincoln