INNOVATIVE UHPC-NORMAL CONCRETE COMPOSITE BRIDGE DECK

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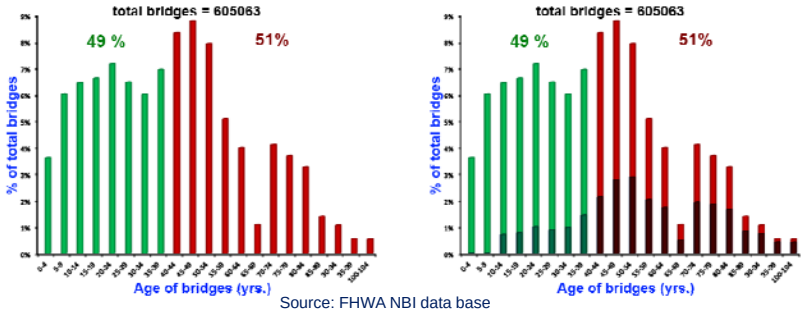
Outline

- Background
- UHPC-NC Composite Deck System
- Experimental Testing
- Analytical Modeling
- Conclusions

Current State of Bridge Infrastructure

- 51 % of U.S. bridges were built over 40 yrs. ago (typical design life 50 yrs.)
- 24 % (11 % + 13%) of U.S bridges are structurally deficient or functionally obsolete



Source: FHWA NBI data base

What does this mean?

- Need technologies to rapidly replace bridges (e.g., ABC)
- Increase longevity of bridges
- Need to replace 15000 bridges/yr

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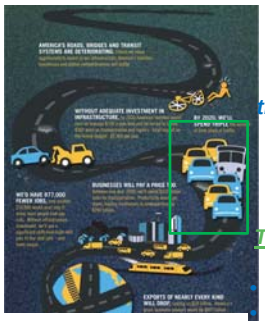
ASCE Observations…



300 % increase in amount of time stuck in traffic

Transportation issues

- ***Congestion***
- ***Safety***

Need Economical Solutions!

Source: *American Society of Civil Engineers*

Primary Cause

Washington DOT

Missouri DOT

NY DOT

Florida DOT

Bridge Deck Deterioration !!

What is the current practice?

- *Deck rehabilitation/repair*
- *Bridge Deck Replacement*

The Challenge is ….

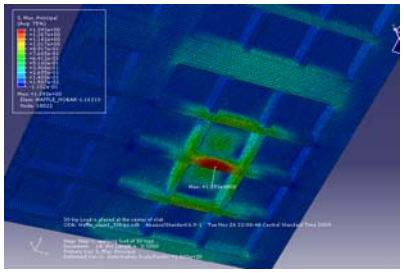
- Improve the poor rating of Bridges
  - Deck Deterioration (Durability)
  - Inadequate capacity
- Rapid replacement and Durable (100 yrs.)

we can address this by …

- ***Using High-performance materials such as UHPC* in developing bridge deck systems**

UHPC Waffle Deck System

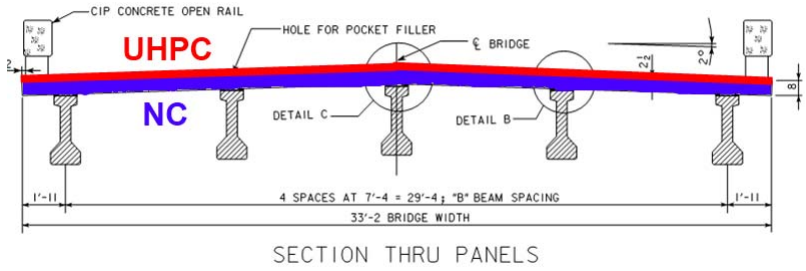
- UHPC two-way ribbed bridge deck panel
- UHPC waffle deck design is developed jointly by Iowa State University, Coreslab, and Iowa DOT



- Capacity > 165 kips
- Higher cost compared to normal concrete deck !!

UHPC-NC Composite deck Alternative

- A composite bridge deck with a thin layer of UHPC overlaying a Normal Strength Concrete (NC) slab

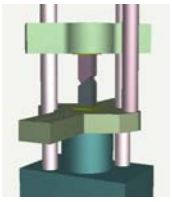


SECTION THRU PANELS

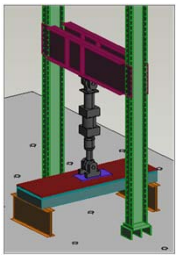
Composite action is Critical !

Experimental Program

Slant Shear Test – to characterize the shear friction behavior between the UHPC and NC surfaces

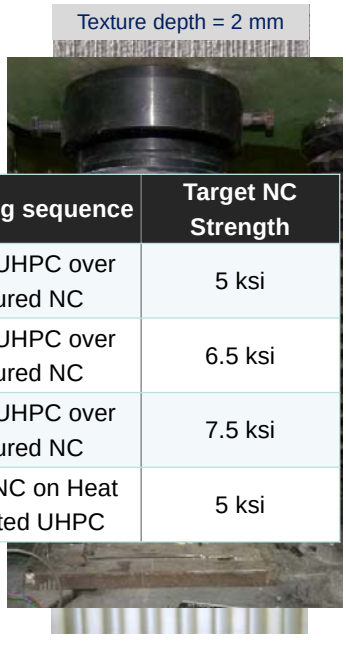


Small-Scale Slab Tests – Establish & validate suitable details for UHPC-NC composite deck system.



Slant Shear Test

- Standard Setup using 4 by 6 rectangular specimen
- Total of 60 tests

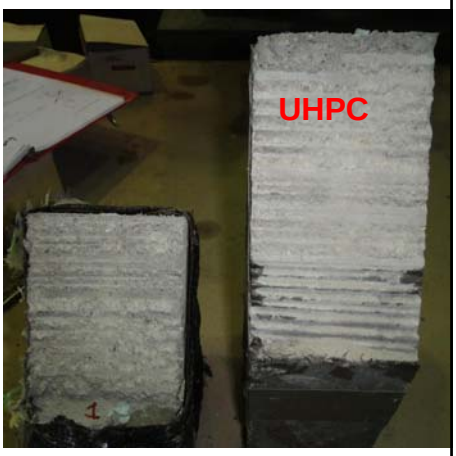


Test type	Texture (# of specimens)	Casting sequence	Target NC Strength
UHPCw-NC5	5 textures (3 per texture)	Wet UHPC over Cured NC	5 ksi
UHPCw-NC7	5 textures (3 per texture)	Wet UHPC over Cured NC	6.5 ksi
UHPCw-NC10	5 textures (3 per texture)	Wet UHPC over Cured NC	7.5 ksi
UHPCh-NC5	5 textures (3 per texture)	Wet NC on Heat treated UHPC	5 ksi

Failure modes

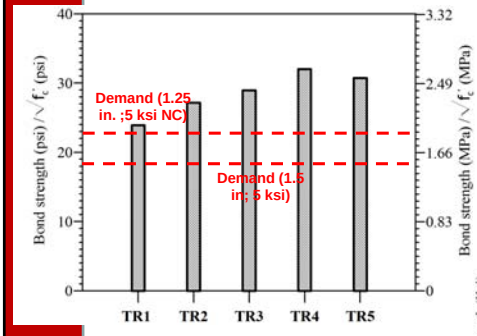
Crushing of NC

Wrap NC with FRP

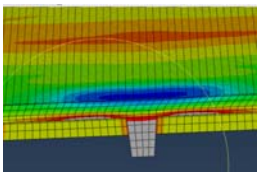


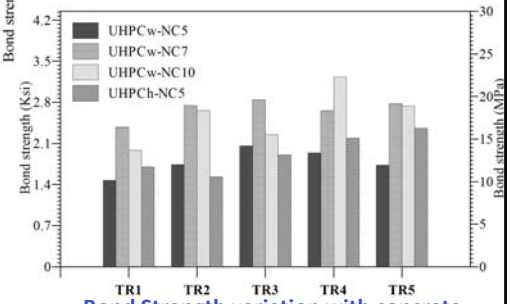
Sliding of the specimens

Summary of Results



Normalized Bond Strength for texture

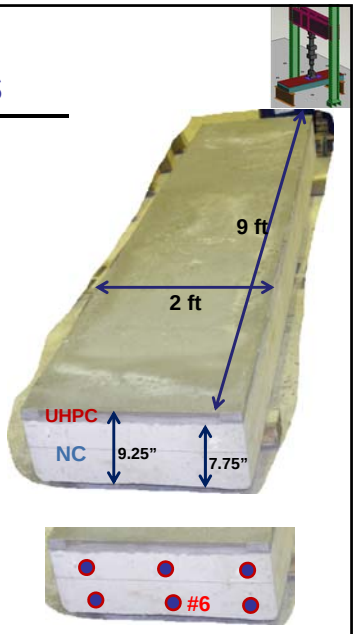




Bond Strength variation with concrete strength and texture

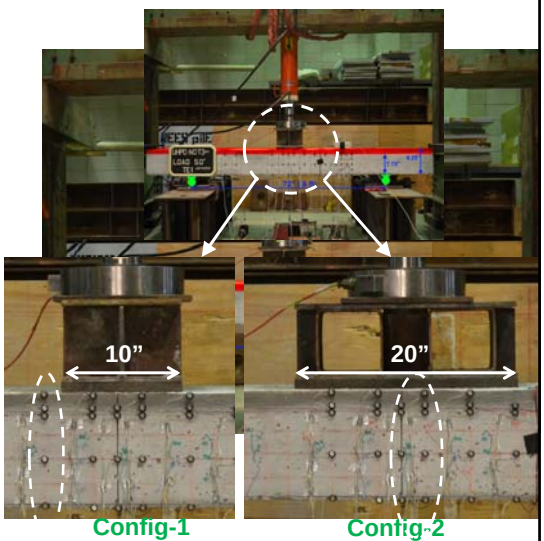
Small Scale Slab Tests

- Four Tests (3 different Textures – *broom finish, 3 mm, 5.5 mm* and standard overlay)
- 9 ft long, 2 ft wide strip from typical Iowa DOT bridge Deck
- 1.5 in. thick UHPC overlay
- Used 4 ksi standard concrete deck mix for Normal Concrete (NC)

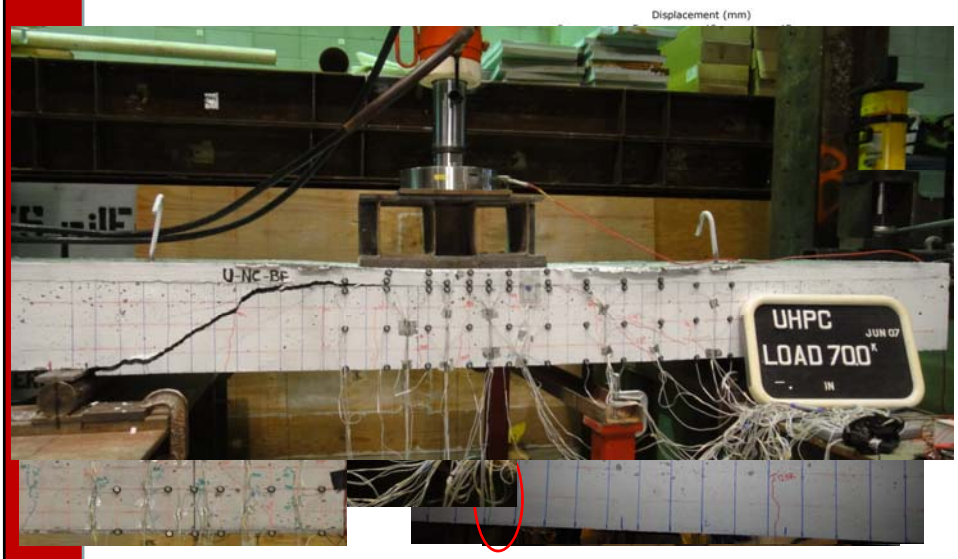


Test Setup

- Single point bending
- Used 10” x 20” wheel load plate
- Load plate in Two Configurations
- State-of-the–art 3-D measurement system

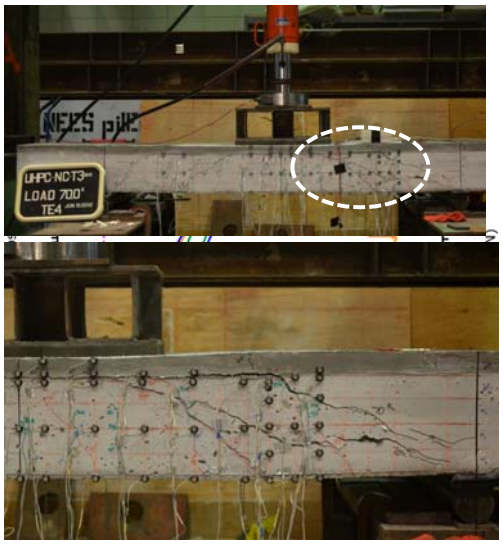


UHPC-NC Deck (Broom Finish – 2mm)



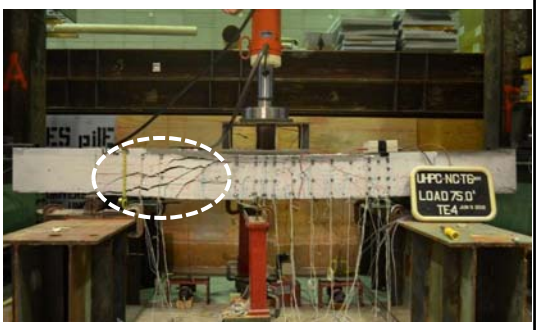
UHPC-NC Deck (3 mm)

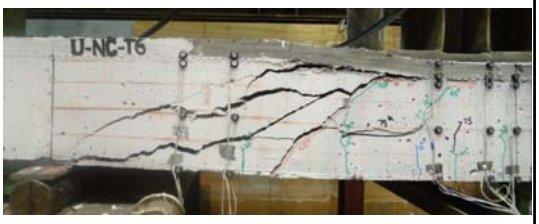
- Max. load applied = 72 kips (~ 4.5 x service load)
- Max. moment = 108 kip-ft
- Specimen failed in **Shear**, with failure started normal concrete.
- No delamination of the interface till failure.



UHPC-NC Deck (6 mm)

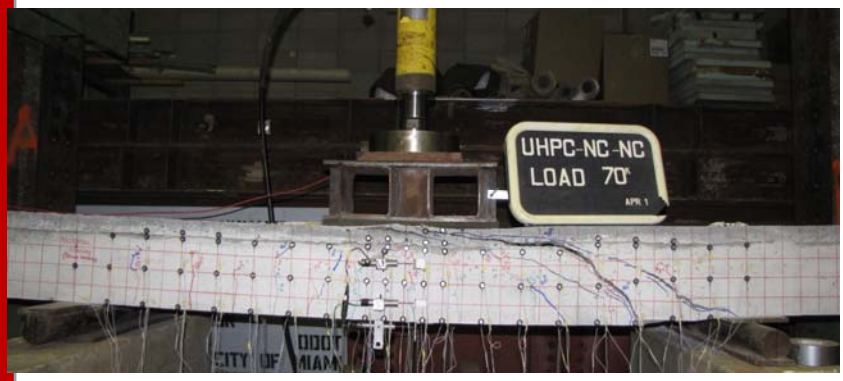
- Max. load applied = 75 kips (~ 4.7 x service load)
- Max. moment = 112.5 kip-ft
- Specimen failed in **Shear**, with failure started normal concrete.
- No delamination of the interface till failure.



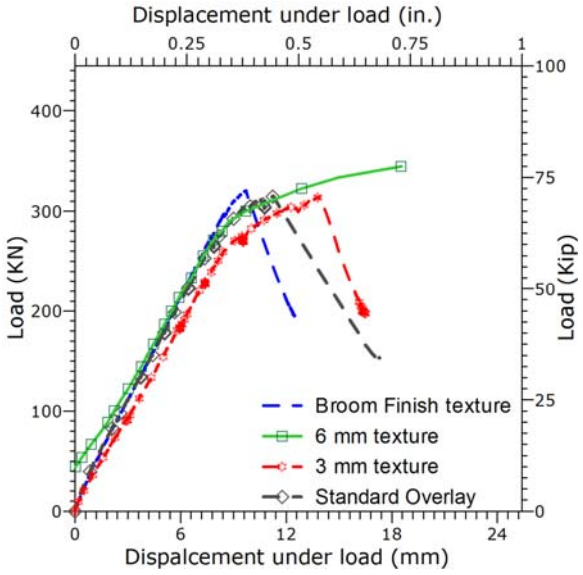


Standard Overlay

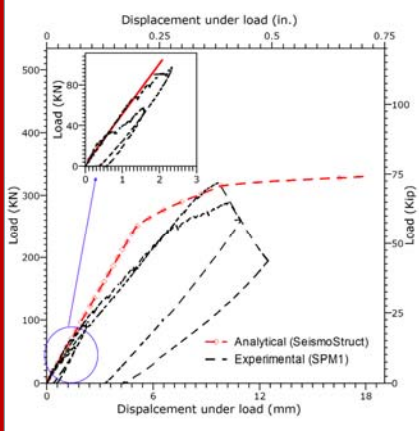
- Specimen failed in **Shear**, with failure starting at normal concrete.
- Max. Load applied = 70 kips
- Sudden Failure and small residual strength



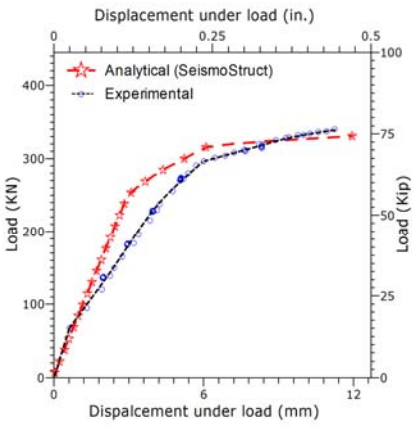
Force-displacement Response



Comparison with Analytical Results



a) Broom finish texture



b) 6 mm texture

Field Application

- Crowning
- Maintain slope
- Able to do crowning

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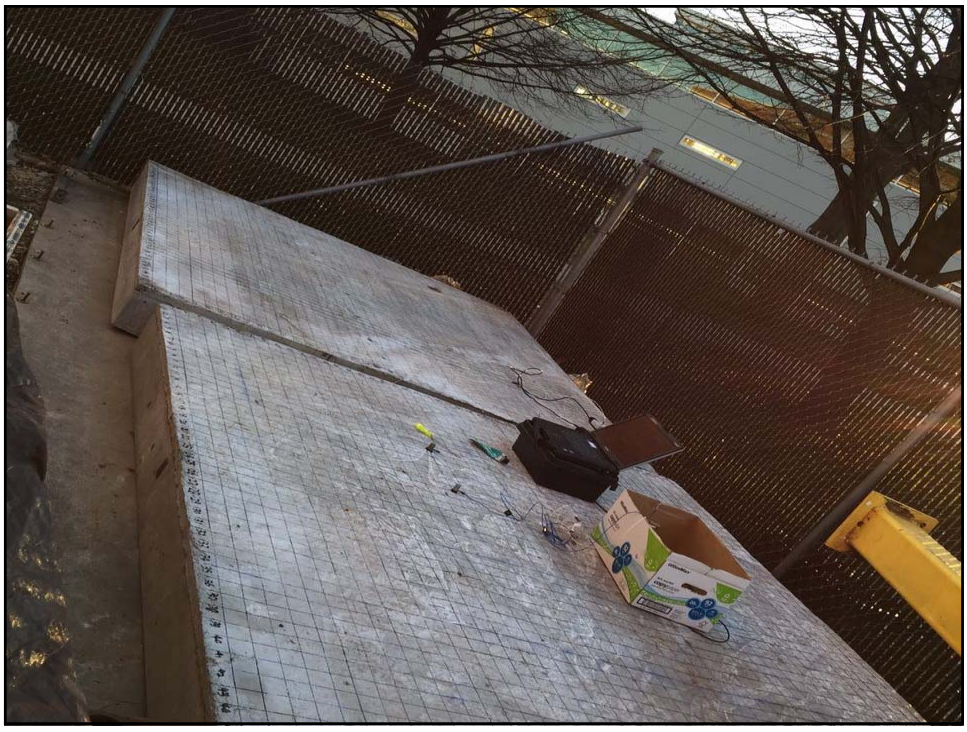

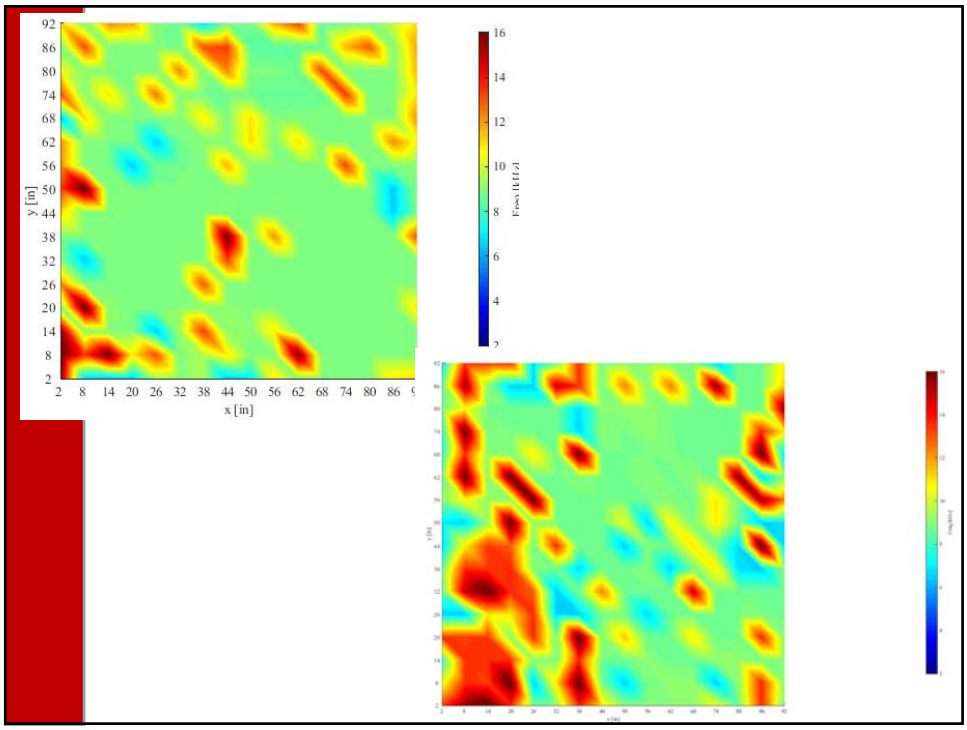
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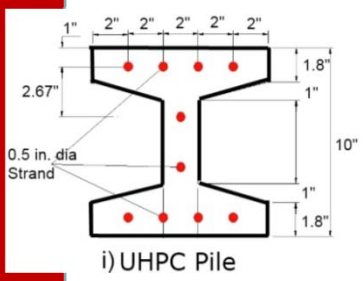
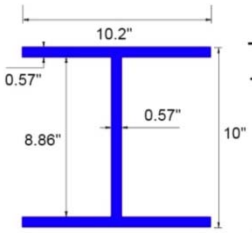
Design Guide for Precast UHPC Waffle Deck Panel System including Connections

UHPC Pile



i) UHPC Pile

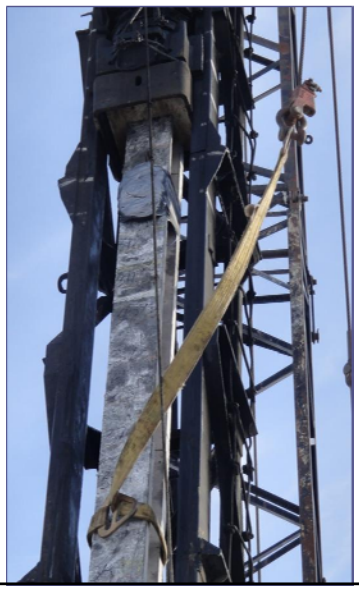


ii) HP 250 x 85

Property	HP 250 x 85	UHPC pile
Total Area (cm^2)	108	366
Weight (kg/m)	85.1	90.9
Moment of Inertia (mm^4)	1.22×10^8	3.31×10^8
Stiffness (E I) ($N.mm^2$)	2.25×10^{13}	1.83×10^{13}

- *Field splice
- *Connection to pile cap/abutment
- *Driving method

Pile Driving



Conclusions

- Based on the slant-shear tests, a minimum roughness of 2 mm would be sufficient to develop adequate bond strength between UHPC and NC interface under combined shear and compression loading.
- The bond strength between UHPC and NC increases with the increase in interface roughness and concrete strength. The casting sequence did not have any significant influence on the bond strength.
- Based on the flexural tests on composite slabs, it is clear that UHPC can be used as a durable overlay in bridge decks
- For field application, a 3 mm minimum roughness for the UHPC and NC interface is recommended.

Conclusions (contd..)

- The composite section behavior can be accurately calculated using analytical models with fiber-based beam elements.
- Given the durability concerns resulting from deterioration of bridge decks that begins at the top of the deck, an economical solution to mitigate this problem would be use UHPC as an overlay.