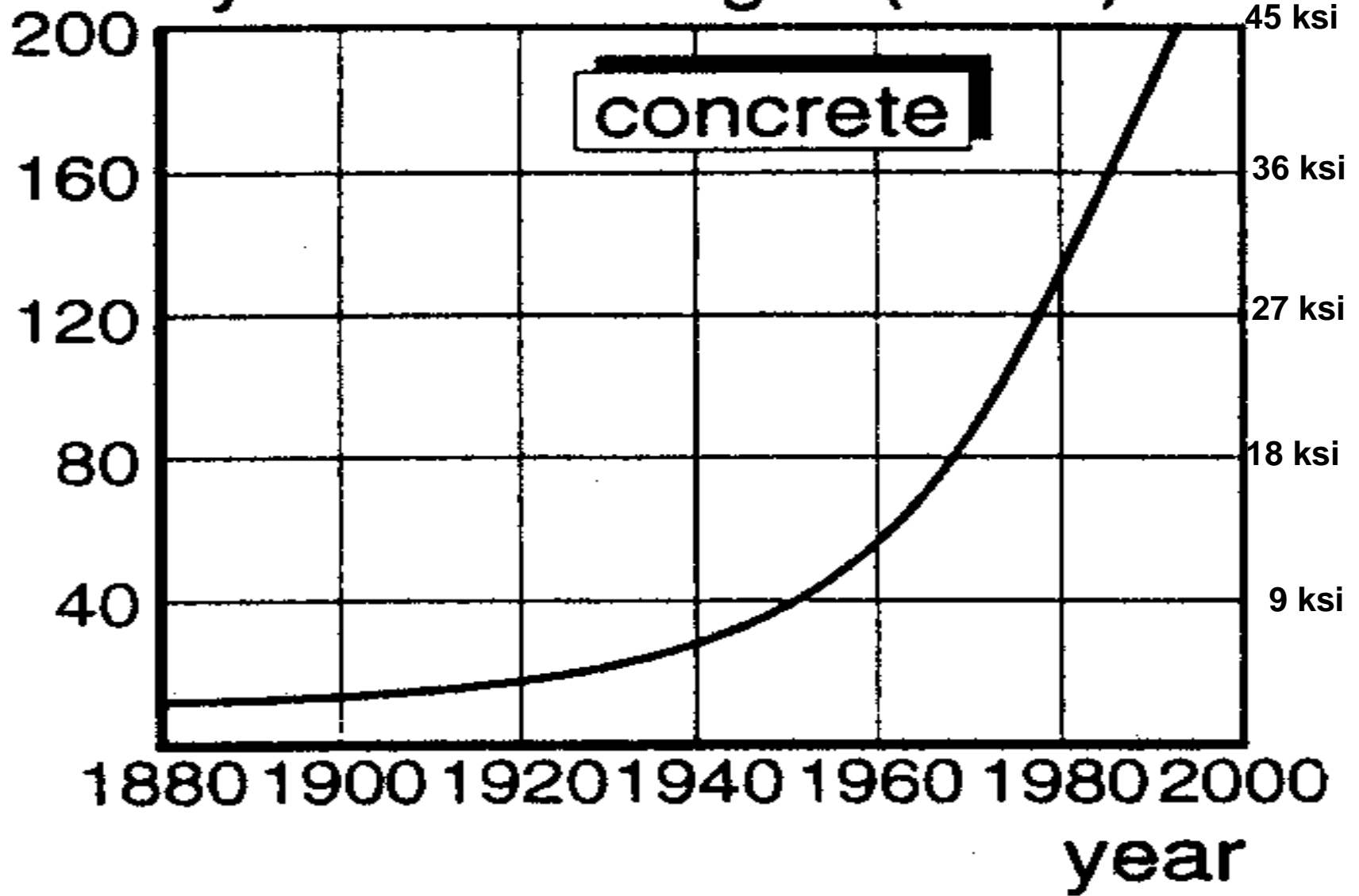


Protecting Bridge Decks with UHPC

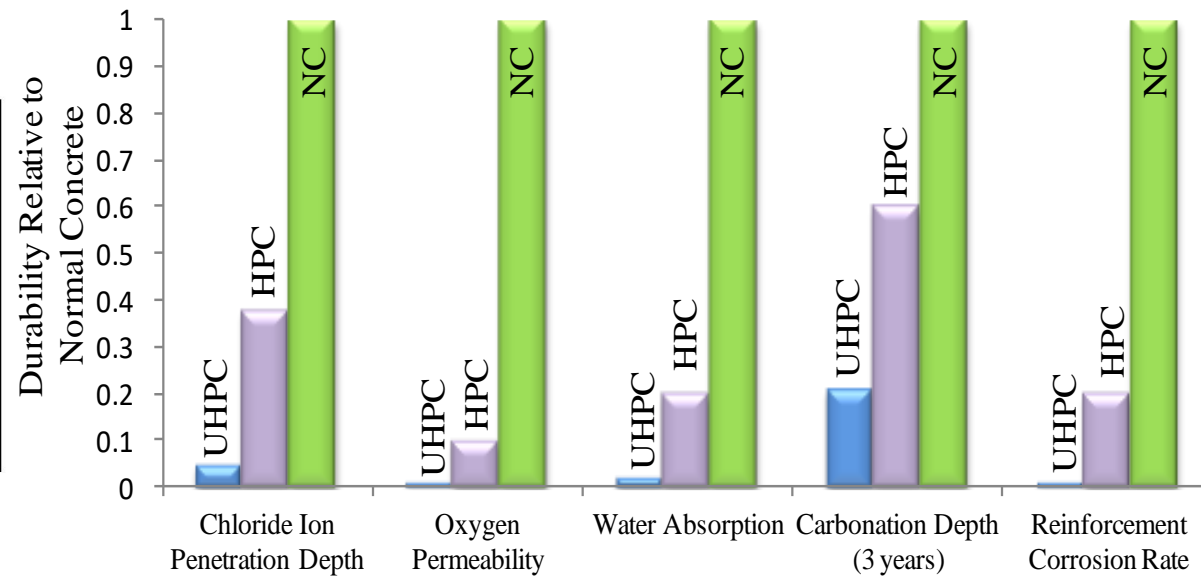
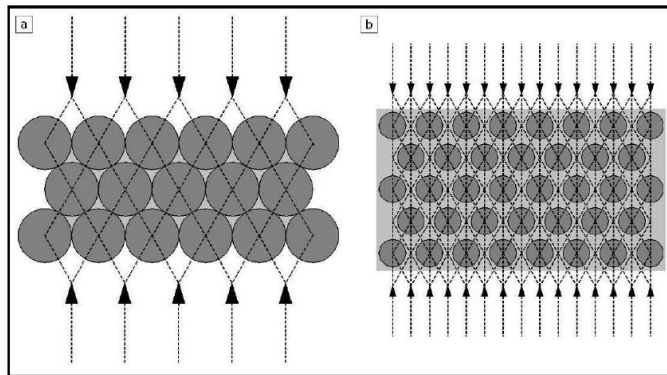
Sri Sritharan

Wilkinson Chair of Interdisciplinary Engineering

cylinder strength (MPa)

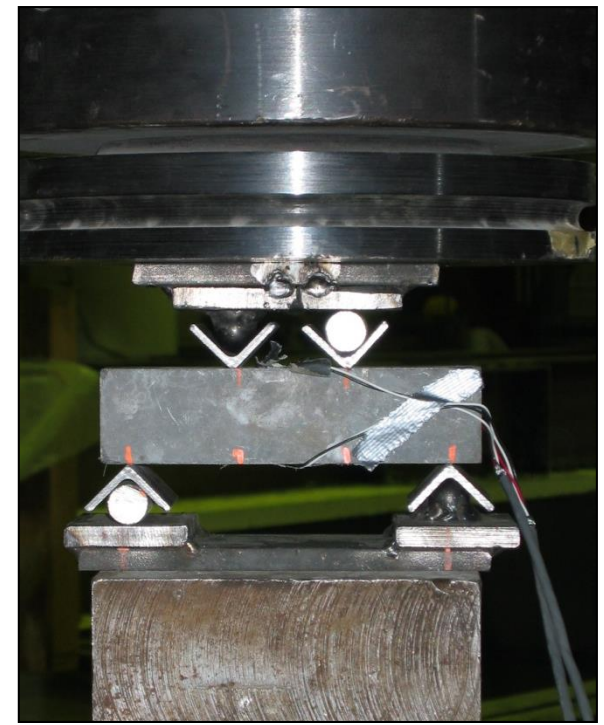


Ultra-High Performance Concrete (UHPC)



Waraven 2002

Material Behavior



Parameter	Average Value
Linear elastic limit of longitudinal strain, e_c	0.0032 in/in
Compressive strength, f'_c	25.6 ksi (177 MPa)
Elastic modulus, E_{RPC}	8000 ksi (55 GPa)
Poisson's ratio, ν	0.18

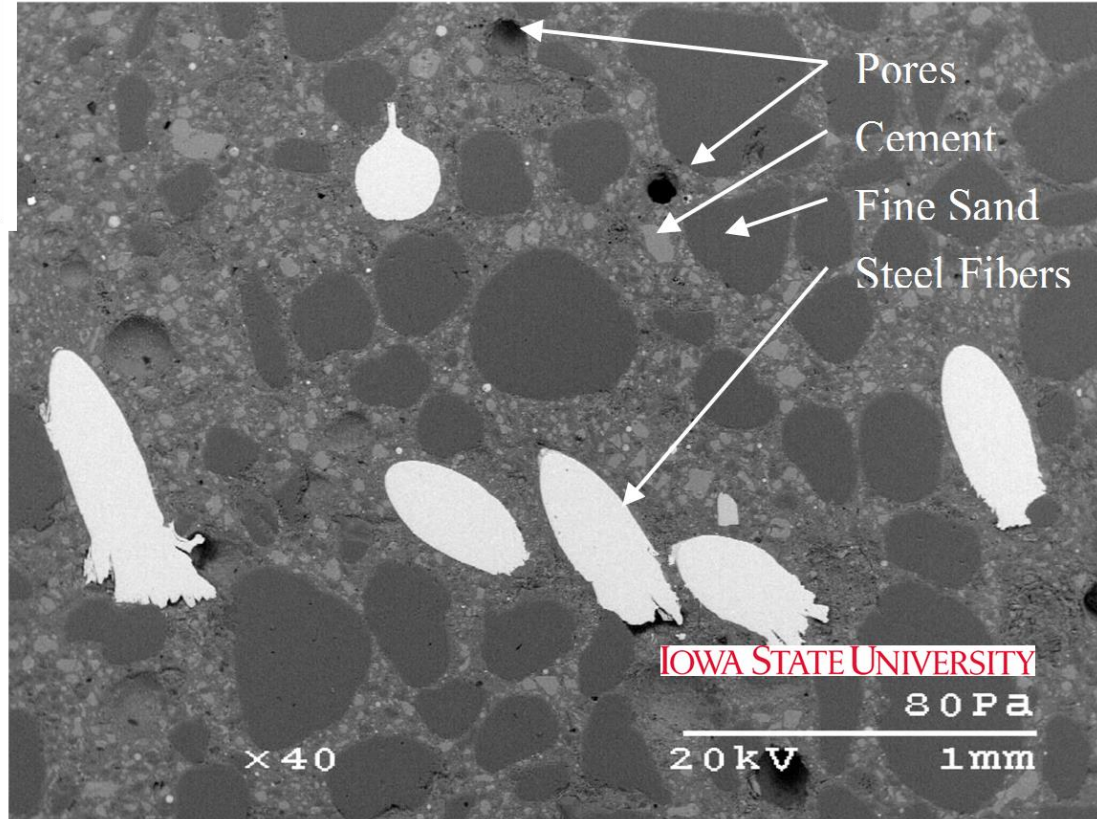
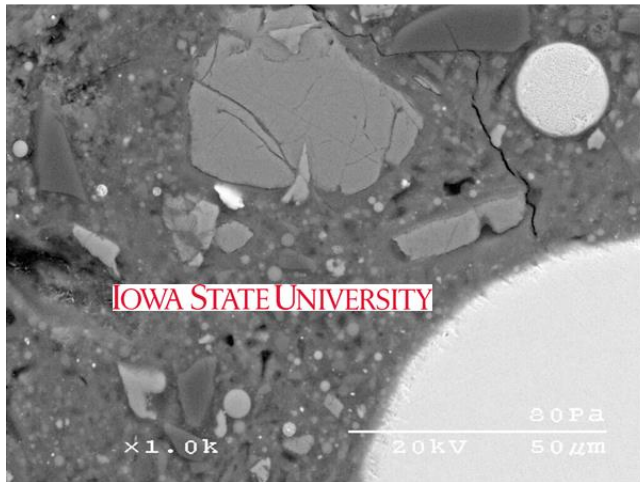
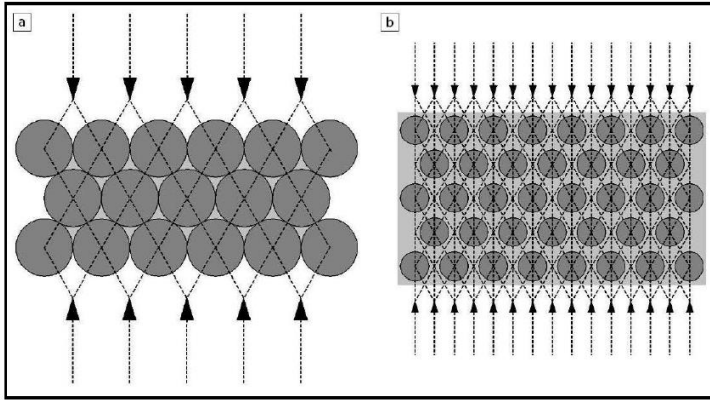
UHPC vs. UPC vs. NC

- Optimized, fiber-reinforced , heat-treated UHPC
- High Performance Concrete
- Normal Concrete

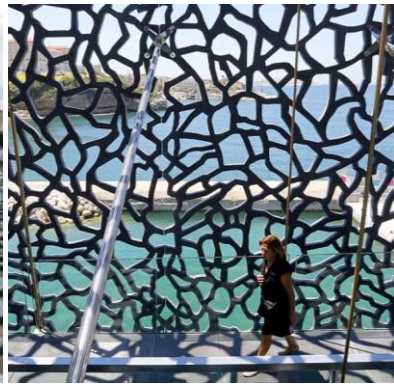
Property	UHPC	HPC	Normal Concrete
Compressive Strength	26-30 ksi (179-207 MPa)	12-18 ksi (82-124 MPa)	4-8 ksi (28-55 MPa)
Tensile Strength	1.7 ksi (12 MPa)	0.8-0.9 ksi (5-6 MPa)	0.3-0.7 ksi (2-5 MPa)
Elastic Modulus	8000 ksi (55 GPa)	4800-6400 ksi (33-44 GPa)	3600-5100 ksi (25-35 GPa)

Typical Constituents

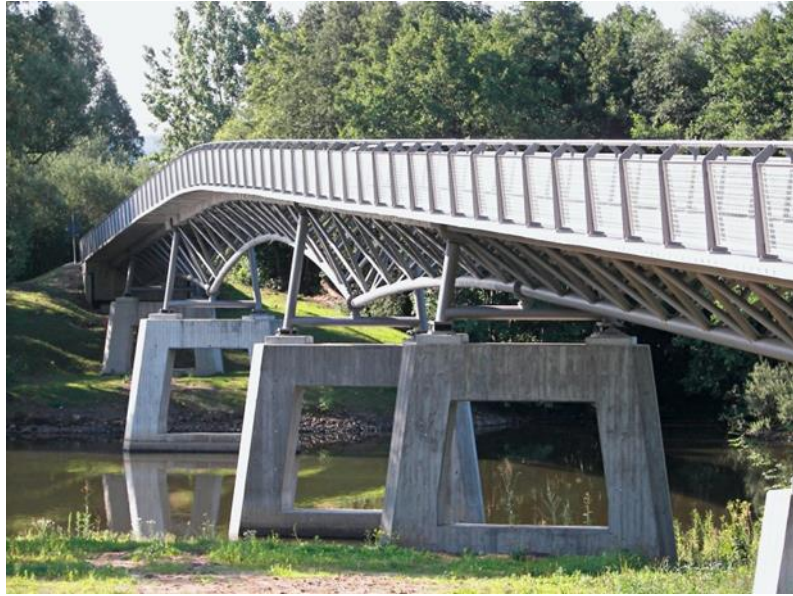
Component	Weight /m ³ (kg)	Mass ratio/cement	Volume fraction
Sand	92.1	1.43	38.8%
Cement	62.9	1.00	22.7%
Silica Fume	20.8	0.33	10.6%
Crushed Quartz	19.3	0.30	8.1%
Fibers	14.0	0.22	2.0%
Superplasticizer	1.3	0.02	1.4%
Water	14.7	0.23	16.5%



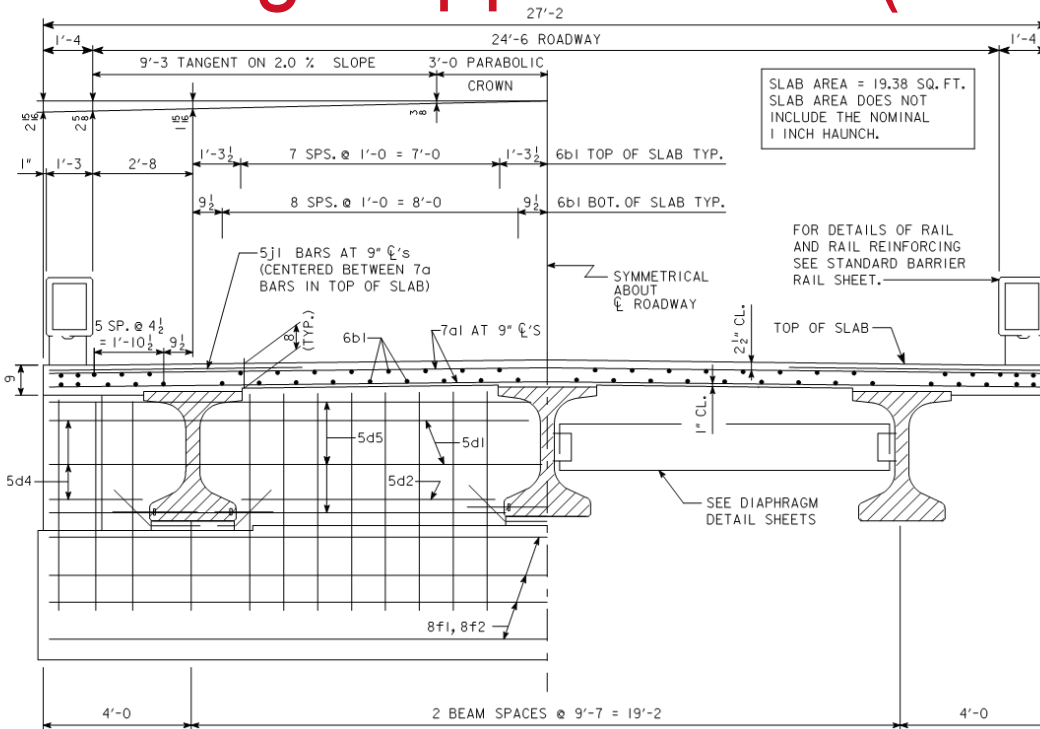
Design Requires Innovation



Bridges



Bridge Applications (U.S.)



Wapello County, IA
2005



Bridge Applications (U.S.)



National Problem



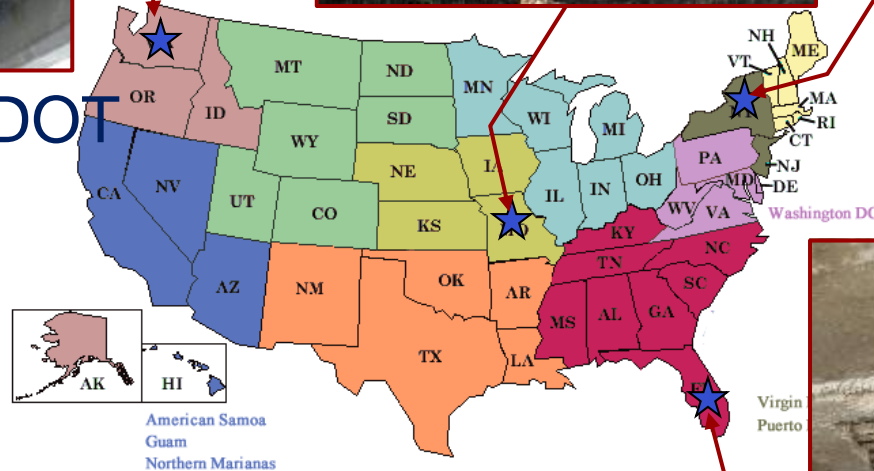
Washington DOT



Missouri DOT



NY DOT



Florida DOT

In 2015, FHWA estimated that \$200 to \$300 billion dollars is needed to rehabilitate or replace all structurally deficient bridges in the nation, and \$123 billion dollars is required to repair them.

Current Approach

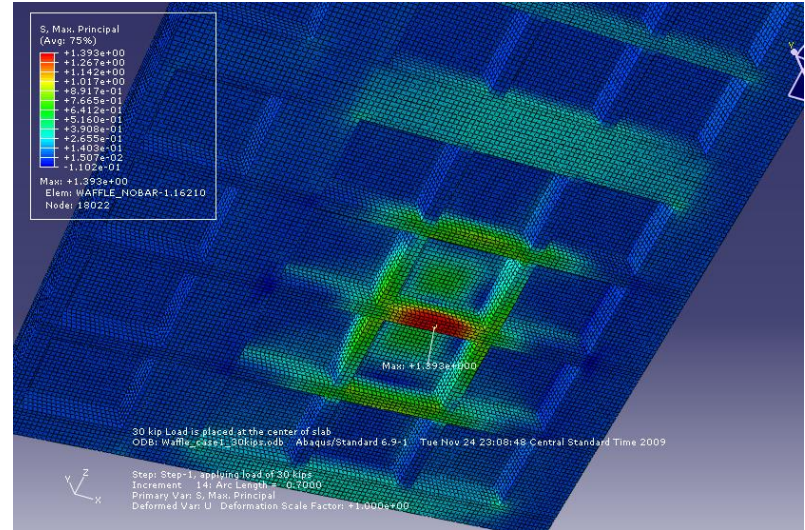


Deck repair/rehabilitation

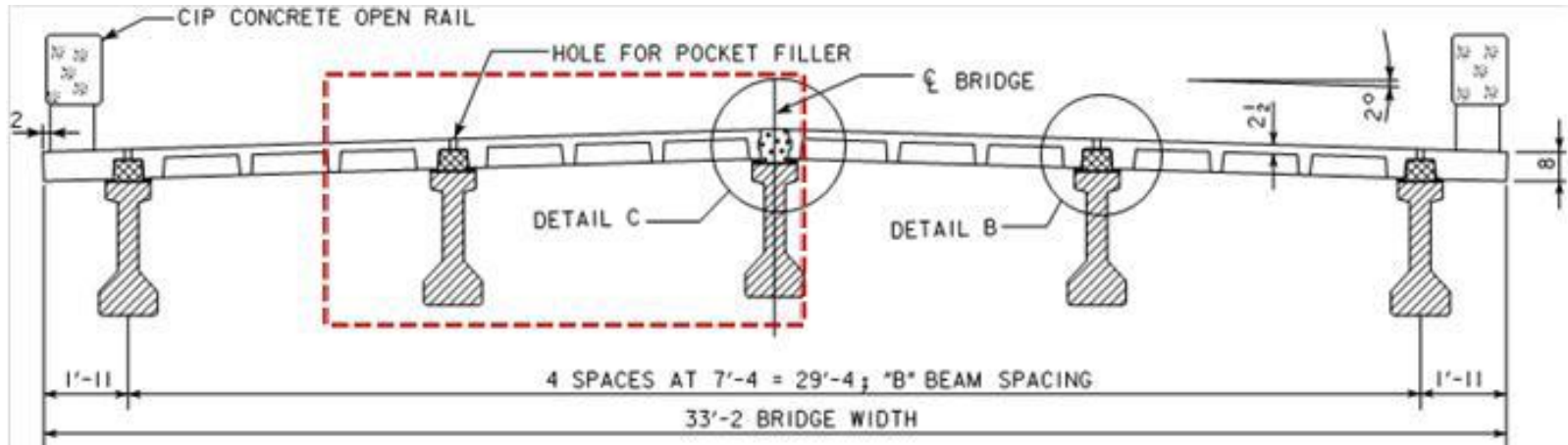


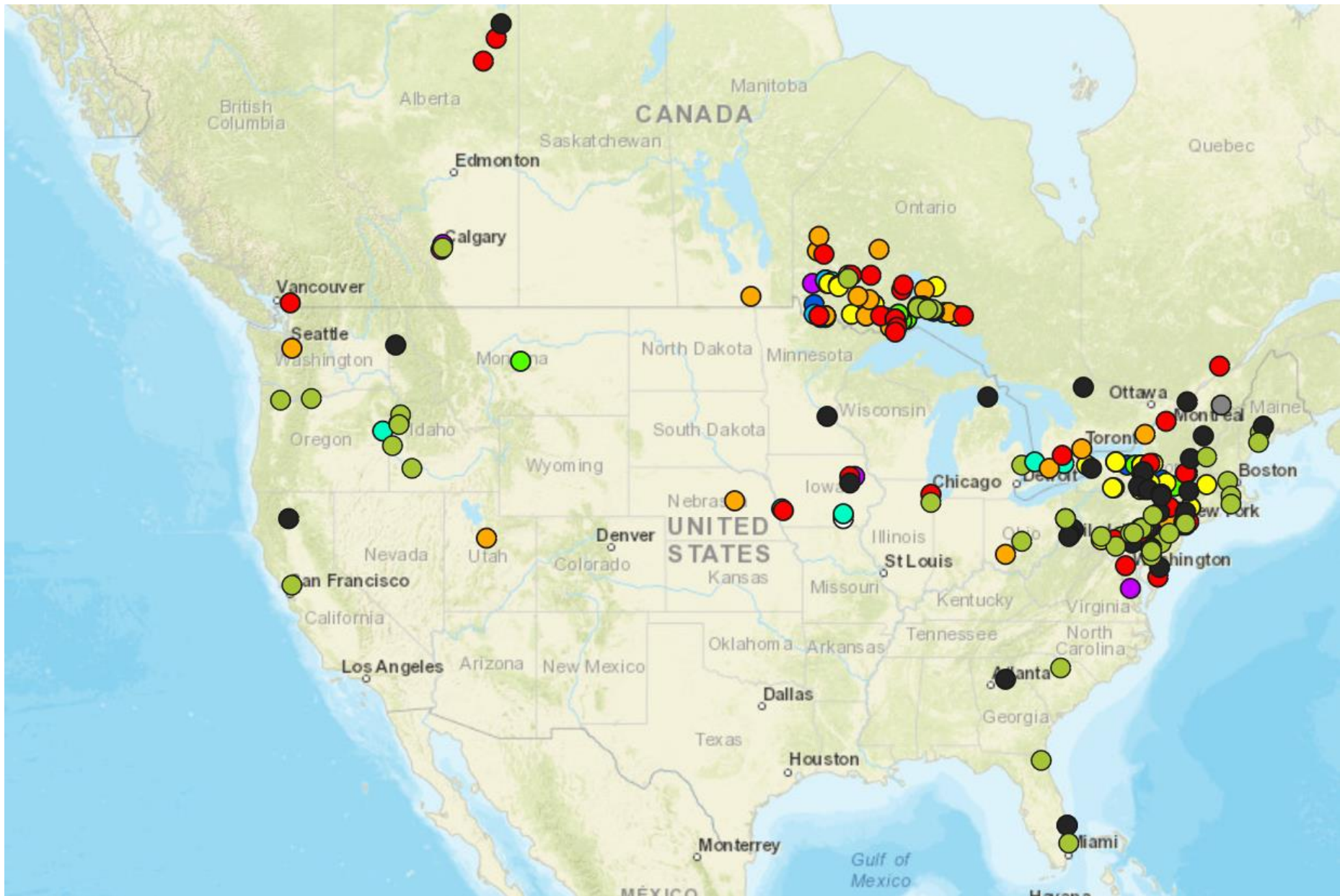
Deck replacement

UHPC Waffle Deck System - 2011

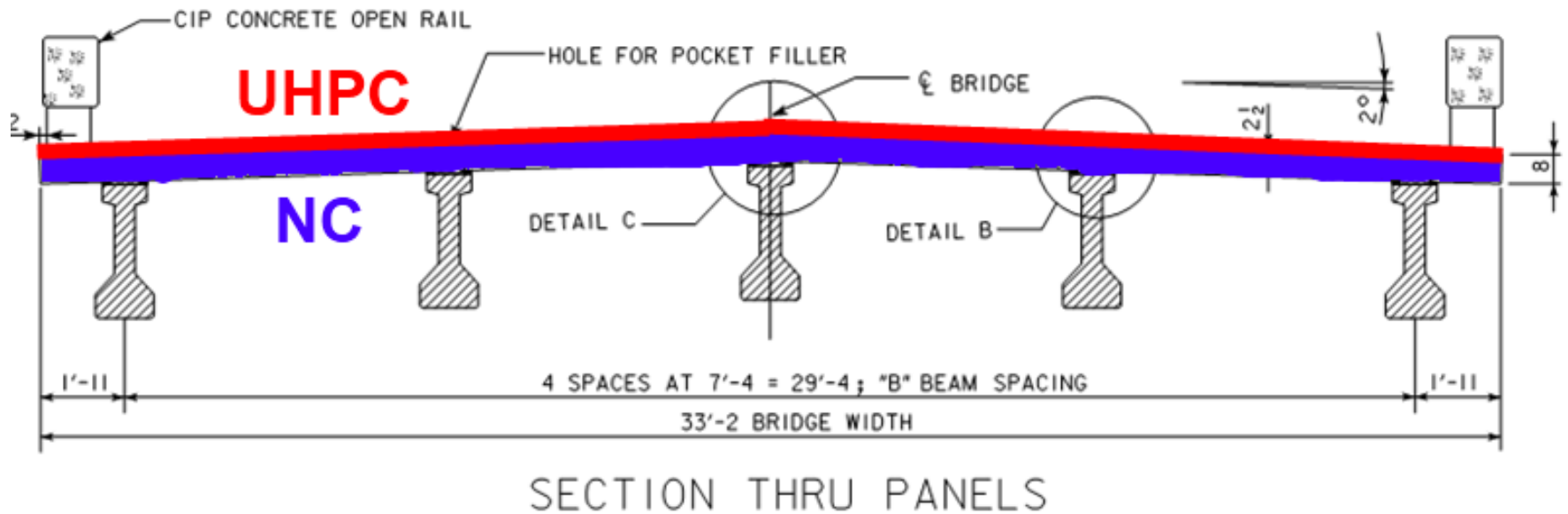


Waffle Deck





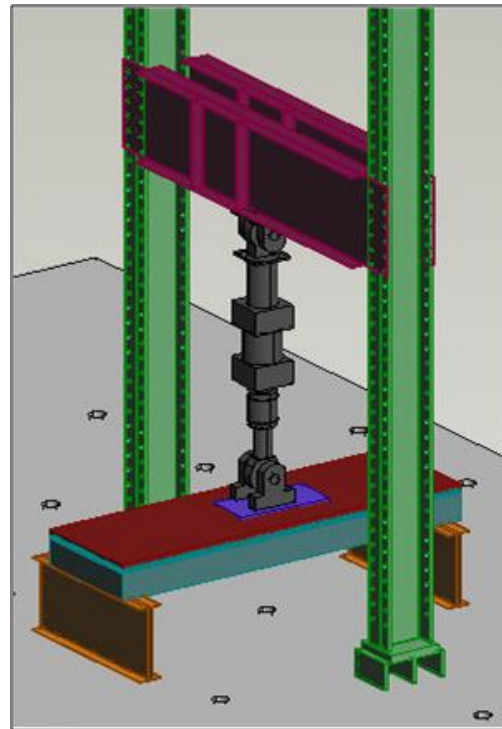
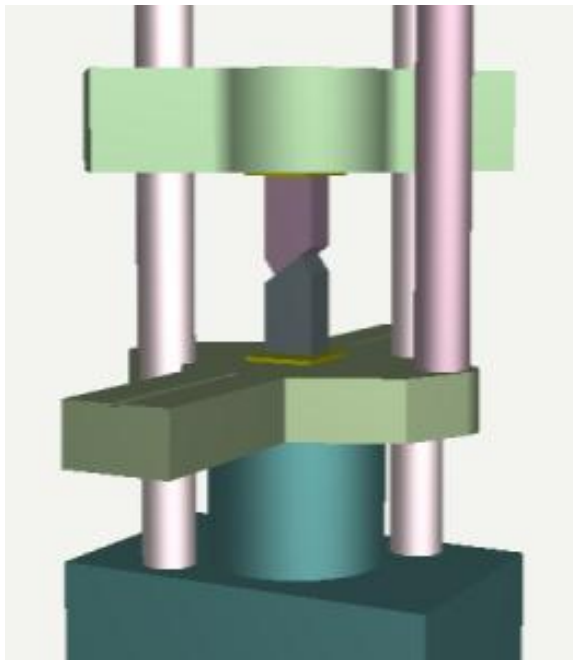
The Overlay Concept



No mechanical connection!

Trials and Testing

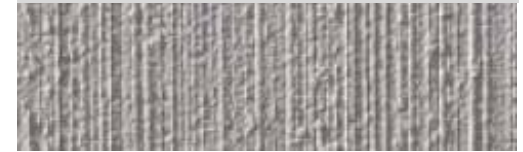
- **Slant Shear Test** – to characterize the shear friction behavior between the UHPC and NC surfaces
- **Small-Scale Slab Tests** – Establish & validate suitable details for UHPC-NC composite deck system.



Texture depth = 2 mm



Texture depth = 2 mm



Texture depth = 3 mm



Texture depth = 5 mm

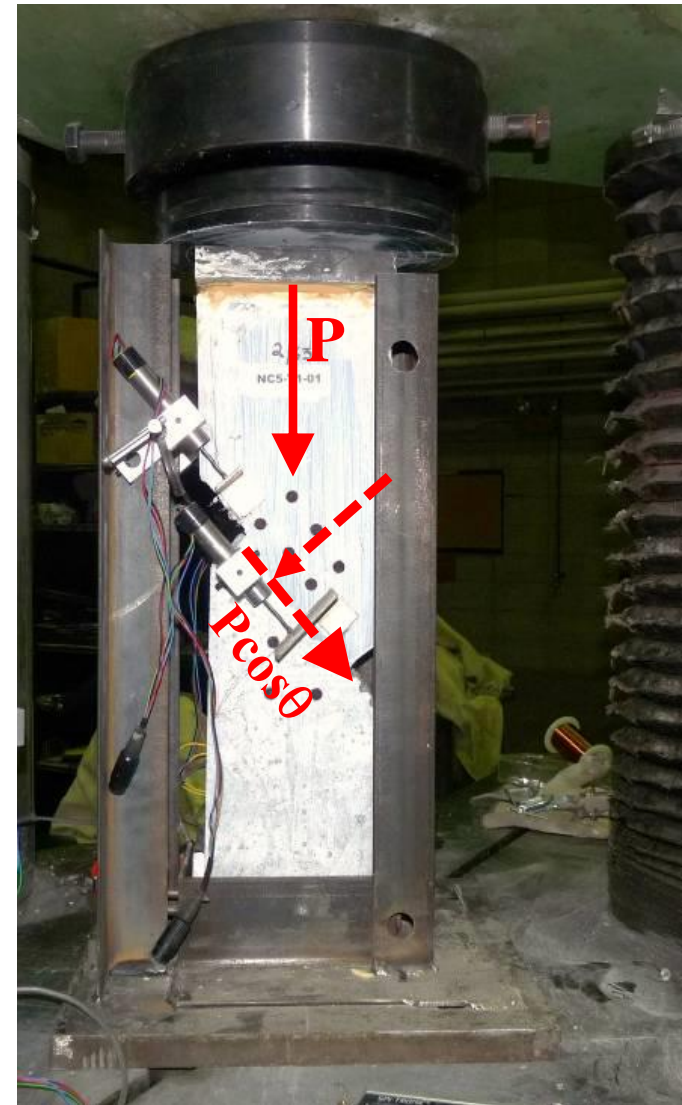


Texture depth = 6.5 mm



Test Setup

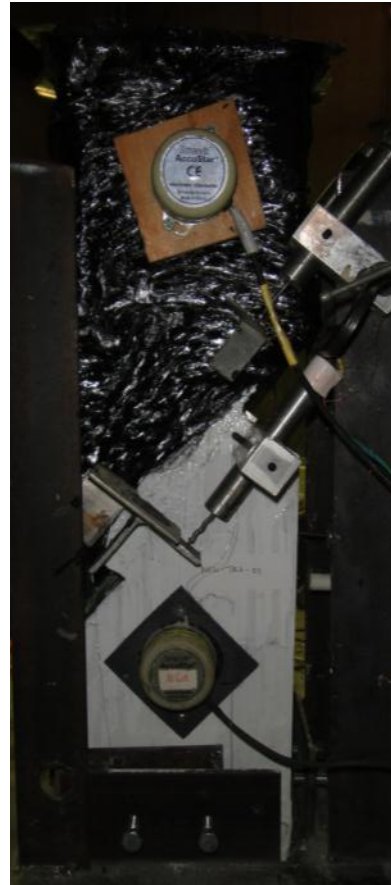
- Standard Setup using 4 by 6 rectangular specimen
- Factors considered:
 - surface roughness (5 textures)
 - concrete strength (5 ksi, 6.4 ksi and 7.5 ksi)
 - curing condition (Heat treated or Wet UHPC)



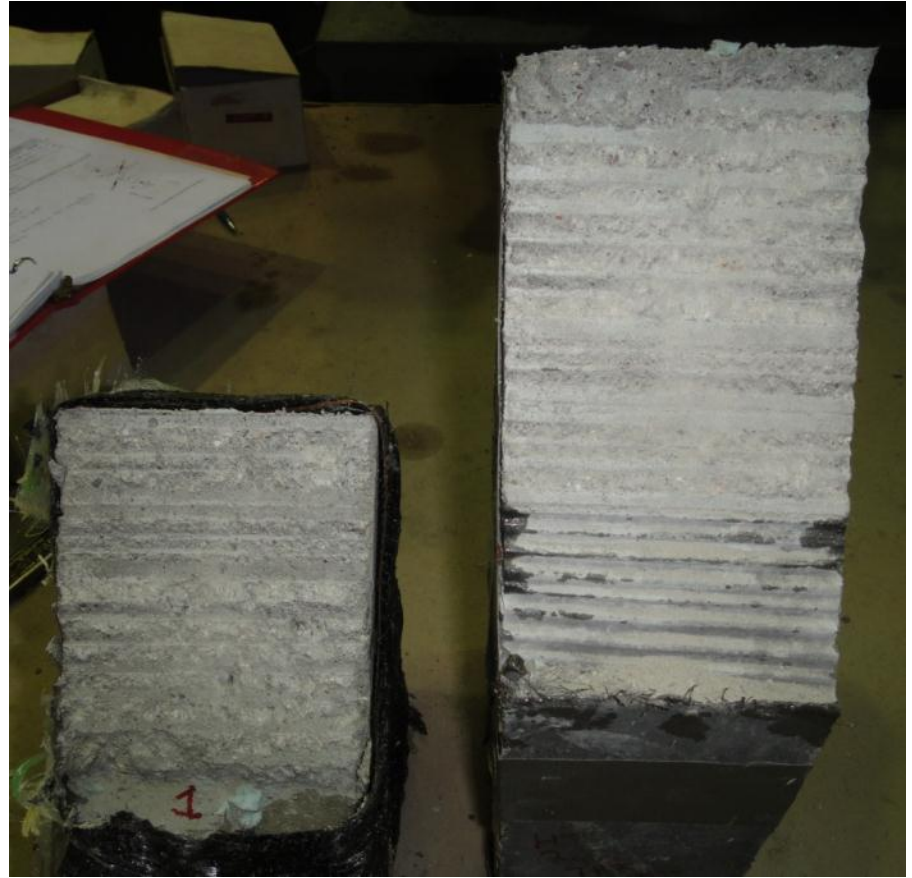
Failure Models



Crushing of NC



Wrap NC with FRP

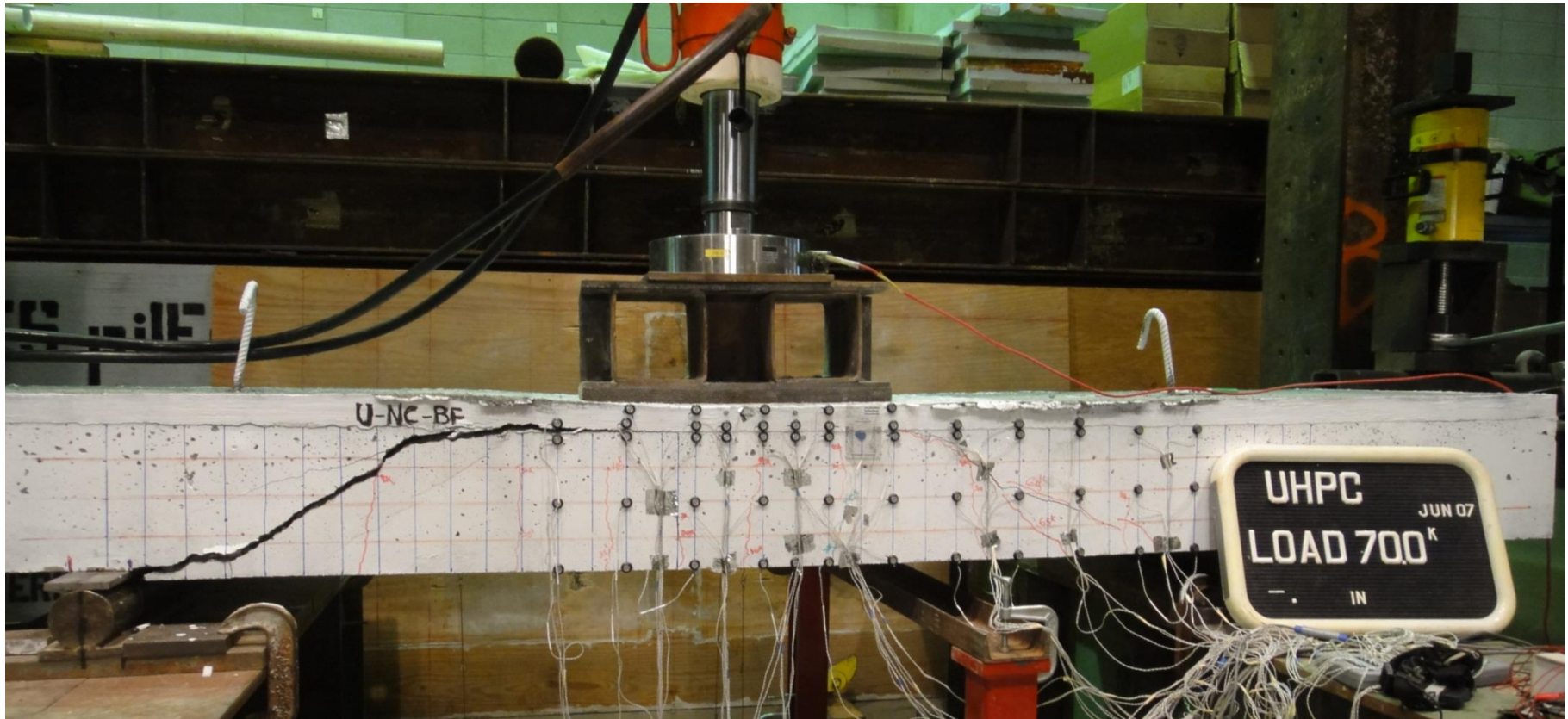


Sliding of the specimens

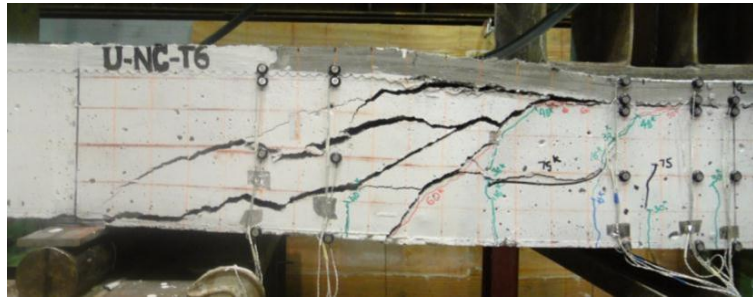
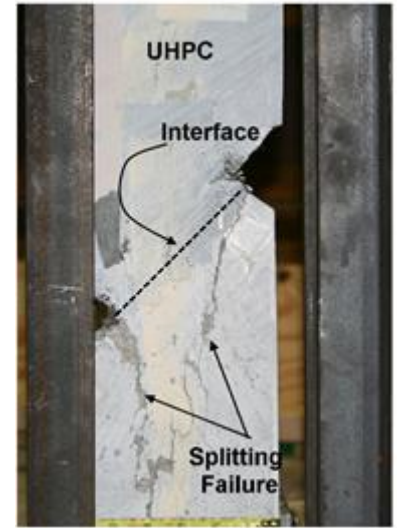
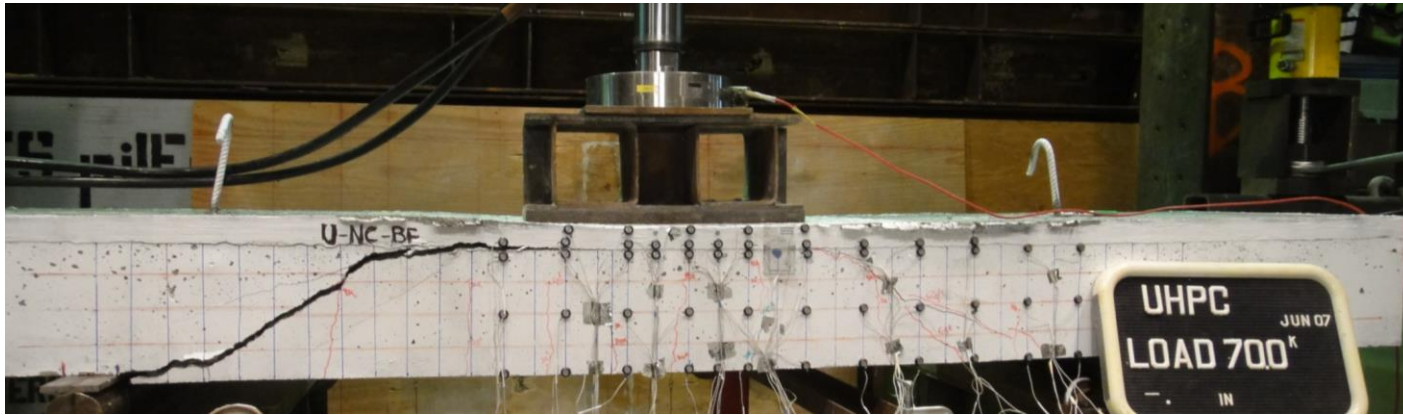
Test Matrix

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
UHPCCh-NC5	5 textures (3 per texture)	Wet NC on Heat treated UHPC	5 ksi

UHPC-NC Deck (Broom Finish – 2 mm)



Trials and Testing





First Application



Flyod River Bridge, Sheldon, IA



Improving Efficiency and Quality



Partnership

Field Casting



Flyod River Bridge



Cost Reduction

- Reducing the UHPC overlay construction cost will increase broader use of the technology
- Current research focusses on reducing the cost of UHPC overlay mix
- Ongoing partnership with WALO focusses on reducing the construction cost
- Goal – reduce the construction cost by at least 25%

Tech Transfer



Brandon, IA

Sheldon, IA



Partnership

- Iowa DOT; District 3
- Cramer & Associates
- Walo USA
- Lafarge-Holcim
- Iowa State University

- Posillico Inc.
- GOMACO

- Multiple projects are being explores

Conclusions

- UHPC overlay concept has been successful and become niche area for use of UHPC
 - There is already significant interest from many DOTs to utilize the technology: New Mexico, Delaware, California, New York, New Jersey, South Dakota, Montana, ...
- UHPC overlay research continues to place Iowa in the forefront of UHPC research and field implementation
- Ongoing research will continue to work towards reducing the cost of UHPC overlay



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