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Innovative UHPC Mixing and Placing Techniques for the Repair of Three Illinois Bridges



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Agenda

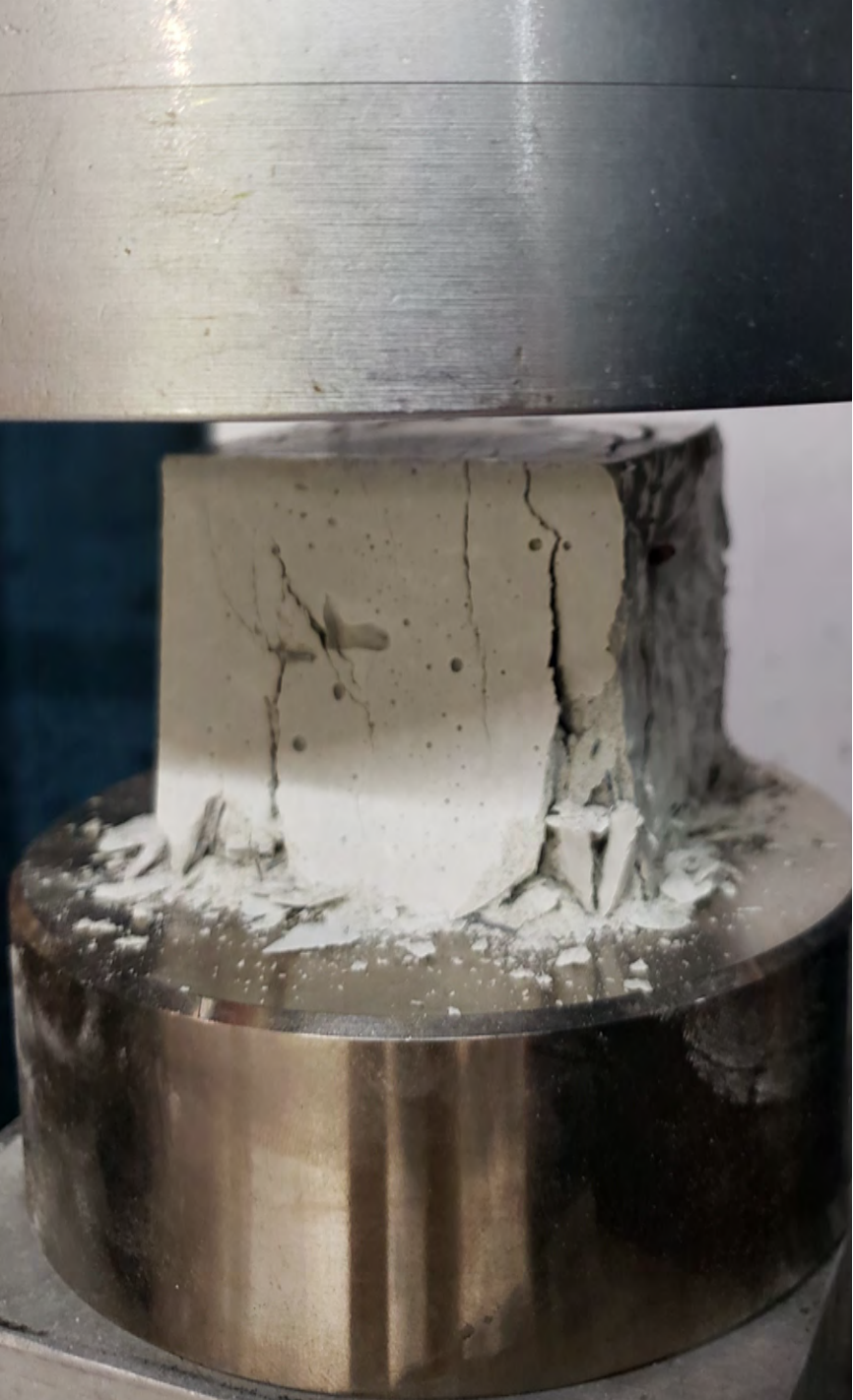
- 1. UHPC Introduction**
- 2. Project Overview**
- 3. Repair Approach**
 - Traditional UHPC Construction Practices
 - Innovative UHPC Construction Techniques
- 4. Lessons Learned**
- 5. Summary**

UHPC Introduction



What is UHPC?

- Cementitious fiber-reinforced composite
- Largest particle is fine sand $\leq 0.5\text{mm}$ diameter
- Highly flowable, self-consolidating
- Water-cementitious material ratio < 0.25 vs. $0.40-0.60$
- Advantageous mechanical and durability properties



UHPC Mechanical Performance

- 22,000 psi compressive strength vs. 4,000 psi
- ≥ 750 psi tensile strength vs. 0-200 psi
- 600 psi bond to conventional concrete vs. 0?
- Strain hardening to $\geq 0.0035 \mu\epsilon$ tension vs. brittle



UHPC Durability Performance

- Rapid Chloride Test (ASTM C1202)
 - ≤ 250 coulombs permeability vs. 1,000-4,000
- Chloride Ion Diffusion Coefficient (ASTM C1556)*
 - $2 \times 10^{-13} \text{ m}^2/\text{s}$
 - $2 \times 10^{-12} \text{ m}^2/\text{s}$ for high-performance concrete (HPC)
 - $2 \times 10^{-11} \text{ m}^2/\text{s}$ for conventional concrete
 - No corrosion on rebar with 3/8-inch cover in UHPC samples left for 10 years at mean tide in northern Maine

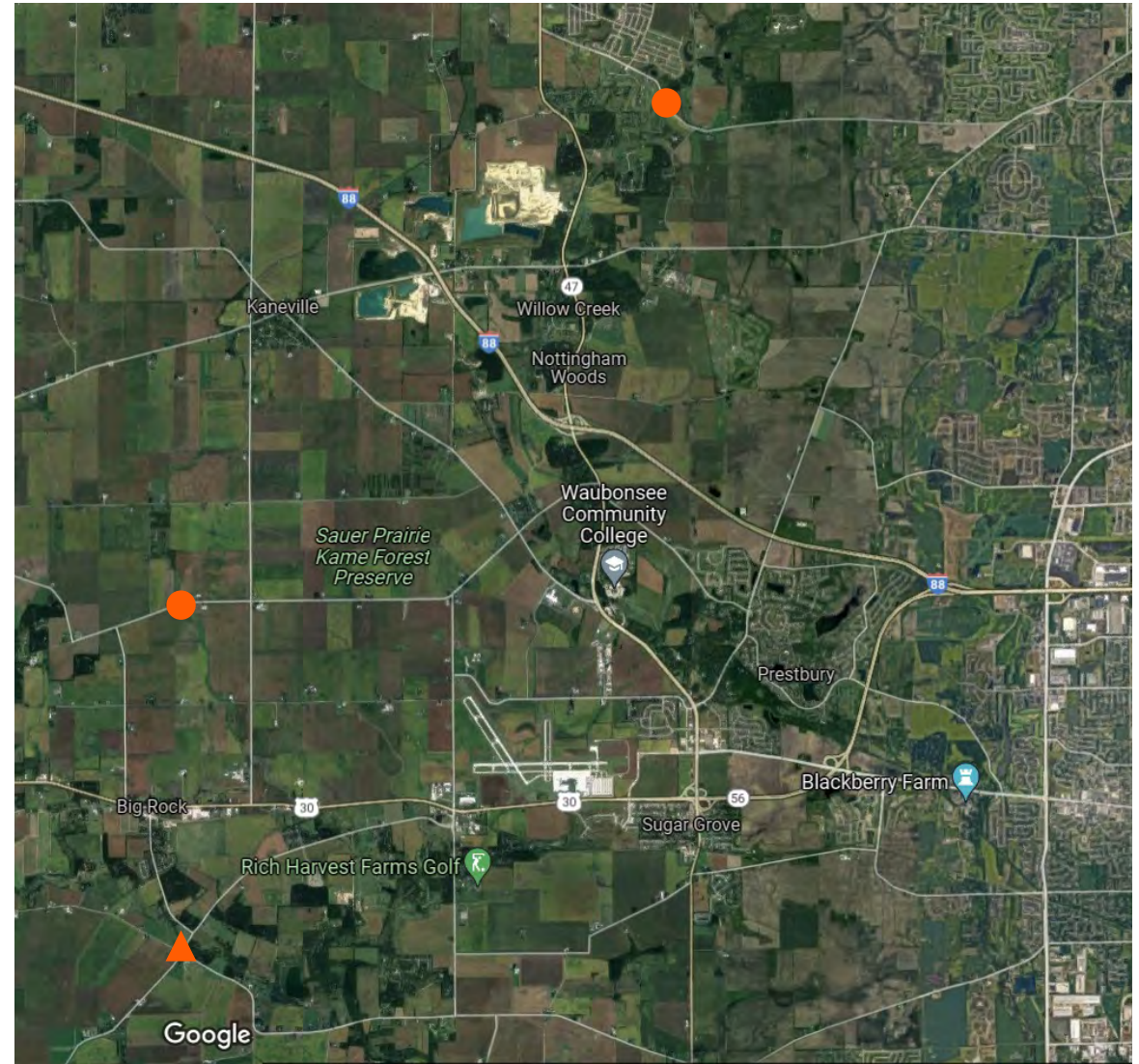
* Source: FHWA Report FHWA-HRT-06-103
Material Property Characterization of Ultra-High Performance Concrete

Project Overview

Project Overview

Repair of Three Bridges

- Kane County, IL
- About 50 miles west of Chicago
- All bridges within 15 miles of each other
- Two box beam bridges with failing connections ●
- One bridge deck rehabilitation ▲



Source: Google

Scott Road Bridge over Welch Creek

Condition Prior to Repair

- Side-by-side box beams
- 75-feet long, 30-feet wide
- Asphalt overlay
- Reflective cracking in overlay
- Failure of box beam grouted keyways



Source: Google

Hughes Road Bridge over Blackberry Creek

Condition Prior to Repair

- Side-by-side box beams
- 85-feet long, 40-feet wide
- Concrete overlay
- Reflective cracking in overlay
- Failure of box beam grouted keyways



Source: Google

Granart Road Bridge over Big Rock Creek

Condition Prior to Repair

- 140-feet long, 50-feet wide
- Concrete deck
- Cracking of deck



Source: Google

Scott and Hughes Road Bridges Repair Approach

Scott and Hughes Box Beam Keyway Repairs

Demolition

- Removal of overlays
- Excavation and widening of keyway connections
- Exposure of box beam rebar
- V-shaped connection edges



Source: Kane County DOT

Scott and Hughes Box Beam Keyway Repairs

Repair

- New rebar stirrups link the box beam rebar across the connections
- Connections filled with UHPC
- Only the 3rd and 4th applications of UHPC for box beam connection repair



Granart Road Bridge Repair Approach

Granart Road Bridge Deck Rehabilitation

Demolition

- Hydrodemolition of deck surface



Granart Road Bridge Deck Rehabilitation

Repair

- 1.5-inch UHPC overlay



UHPC Deck-Level Connections Traditional Practices

Traditional Practice: Mixing

- Rent Specialty Mixers
- 0.6 CY Maximum Capacity
- Multiple Mixers
- Generators Required



Vertical shaft high-shear mixers

Source: FHWA

Traditional Practice: Top Forming



Traditional Practice: Overfill



Traditional Practice: Grind Overfill



UHPC Overlays Traditional Practices

Traditional Practice: Mixing

- Rent Specialty Mixers
- 14 CY Capacity
- Multiple Mixers
- Generators Required



Horizontal shaft high-shear mixers

Source: NJDOT

Traditional Practice: Transporting

- Concrete Buggies



Discharging UHPC from concrete buggy in front of overlay screed

Source: NJDOT

Traditional Practice: Curing

- Curing Compound
- Plastic Sheeting
- Hold-downs



Plastic sheeting over UHPC overlay with wind blowing underneath

Source: WSP

Traditional Practice: Curing

What Can Go Wrong

- Wind blows under sheeting
- Wind blows sheeting into live traffic
- Sheeting or hold-downs leave deep impressions
- Workers leave deep footprints attempting to adjust hold-downs



Impressions in final grinded and grooved surface from sheeting

Source: WSP

Scott and Hughes Box Beam Keyway Repairs

Innovative Mixing and Placing Techniques

Scott and Hughes Box Beam Keyway Repairs

UHPC Mixing

- UHPC mixed in a locally available standard ready-mix truck
- Up to 6 CY mixed per batch
 - Discharged as fast as contractor could place it
- Eliminated:
 - Shipping of specialty mixers
 - Multiple mixers
 - Large generators



Mixing UHPC in standard ready-mix truck

Scott and Hughes Box Beam Keyway Repairs

UHPC Mixing

- Leftover material from overlay project was used on one occasion on Hughes Road Bridge
- Batch was mixed 15 miles away and driven to bridge
- UHPC in truck was still workable more than 1.5 hours after mixing
- Reduced significant material waste
- Saved time by eliminating mixing of a batch



Delivering UHPC in standard ready-mix truck

Scott and Hughes Box Beam Keyway Repairs

UHPC Install

- No top forms
- Connections cast flush with deck along high edge
 - No trapped air
- Edge form along low edge



Placing UHPC in longitudinal connections with no top forms

Scott and Hughes Box Beam Keyway Repairs

UHPC Curing and Finishing

- Curing compound used for curing
- Eliminated grinding
 - Due to placement of asphalt overlay, the minimal overfills along the low edges were allowed to remain



Cured Connections

Source: Kane County DOT

Granart Road Bridge UHPC Overlay

Innovative Mixing and Placing Techniques

Granart Road Bridge UHPC Overlay

UHPC Mixing

- UHPC mixed in a locally available standard ready-mix truck
- Up to 5 CY mixed per batch
 - Discharged as fast as contractor could place it
- Eliminated:
 - Shipping of specialty mixers
 - Multiple mixers
 - Large generators



Discharging UHPC directly from ready-mix truck

Granart Road Bridge UHPC Overlay

UHPC Transport / Discharge

- UHPC discharged directly to the deck from the ready-mix truck
- Eliminated:
 - Concrete buggies
 - Buggy operators
 - Waste generated by transferring UHPC to buggies
- Accelerated placement
- Similar to ready-mix concrete discharge



Directly discharging UHPC onto bridge deck in front of screed.

Granart Road Bridge UHPC Overlay

UHPC Transport / Discharge

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Directly discharging UHPC onto bridge deck in front of screed.

Granart Road Bridge UHPC Overlay

UHPC Curing

- No plastic sheeting used to to cure overlay (only curing compound)
- Eliminated risks of:
 - Wind blowing under sheeting
 - Wind blowing sheeting into live traffic
 - Impressions in overlay from sheeting or hold-downs
 - Footprints in overlay from workers adjusting sheeting



Curing UHPC overlay without plastic sheeting.

Granart Road Bridge UHPC Overlay

Finished Project

- Overlay surface was grinded



Completed project

Lessons Learned

Lessons Learned

- Mockups are essential. The closer a mockup represents actual project conditions the better, especially for UHPC overlays.
 - Contractor gets to practice and tune methods, including screed forward speed and vibration intensity for overlays.
 - UHPC supplier gets understanding of overlay consistency needs.
- Contractors should follow past successful UHPC practices rather than assumptions.
 - Place UHPC overlays from low to high
 - Properly seal forms
 - Keep a clean site

Summary

Summary

Innovative UHPC Mixing Techniques:

- UHPC was mixed in standard, locally available ready-mix trucks
 - Up to 6 CY batch sizes for connections
 - Up to 5 CY batch sizes for overlay
 - Partial batch transported from one bridge to another, reducing waste and saving time
 - UHPC remained workable in truck up to 1.5 hours after mixing

Summary

Innovative UHPC Placing Techniques (connections):

- No top forming
 - No trapped air
 - Eliminated grinding

Innovative UHPC Placing Techniques (overlay):

- UHPC directly discharged from truck to deck
 - Accelerated work, reduced labor, reduced waste
- Cured without plastic sheeting
 - Eliminated many risks associated with sheeting

Summary

Conclusions:

This was the contractor's first time working with UHPC, which created some challenges. However, with guidance that the UHPC supplier shared from other contractors' successful approaches, the contractor was ultimately able to successfully place UHPC for connections and overlays on the three bridges.

The multiple innovations for mixing and placing UHPC helped accelerate portions of the contractor's work, reduced waste, and reduced the contractor's costs.

Questions?

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