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

Michael McDonagh, P.E., P.Eng.
Vice President, Eng. & Projects
Steelike, Inc.

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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 ≤ 0.5mm 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 ≥ 0.0035 με tension vs. brittle
UHPC Durability Performance

• Rapid Chloride Test (ASTM C1202)
  • $\leq 250$ coulombs permeability vs. 1,000-4,000

• Chloride Ion Diffusion Coefficient (ASTM C1556)*
  • $2 \times 10^{-13}$ m$^2$/s
  • $2 \times 10^{-12}$ m$^2$/s for high-performance concrete (HPC)
  • $2 \times 10^{-11}$ m$^2$/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
Traditioal Practice: Mixing

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

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

Source: Kane County DOT
Granart Road Bridge UHPC Overlay

Innovative Mixing and Placing Techniques
Granart Road Bridge UHPC Overlay

**UHPC Mixing**

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- Up to 5 CY mixed per batch
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- 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

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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 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
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?

Michael McDonagh, PE, P.Eng.
Vice President, Engineering & Projects
Steelike, Inc.
(215) 388-4445
Michael@Steelike.com