



**Ultra High Performance Concrete:
Design and Application**

HNTB

Travis Konda, PE, SE, CCM
Associate HNTB Fellow

Mario Ratnaraj, PE
Project Engineer



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UHPC Background and Definitions
Development of Mix Designs
Applications in Accelerated Bridge Construction (ABC)
Rehabilitating the Franklin Avenue Bridge (MN)
- Deck panel details
- UHPC placement
- Testing/material performance

UHPC Research Overview

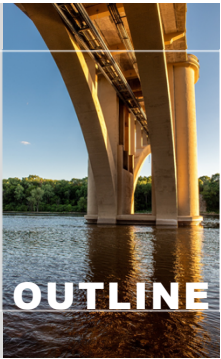

UHPC Overlays

UHPC Girders and Structural Elements

Q&A/Discussion

OUTLINE

- Pilarski 2020

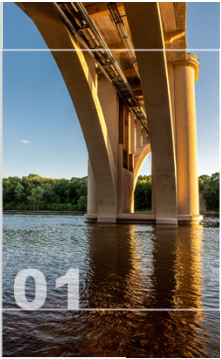




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UHPC
BACKGROUND
and
DEFINITIONS

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UHPC HISTORY

1970s/80s	1990s	early 2000s
Developed in Europe	In-use in Canada	Introduced to the U.S.




[Deployments | FHWA \(dot.gov\)](#)

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UHPC DEFINITION

- No universally-accepted definition
- FHWA developed definition



UHPC is a cementitious composite material composed of an optimized gradation of granular constituents, a water-to-cementitious materials ratio less than 0.25, and a high percentage of discontinuous internal fiber reinforcement. The mechanical properties of UHPC include compressive strength greater than 21.7 ksi (150 MPa) and sustained post-cracking tensile strength greater than 0.72 ksi (5 MPa). UHPC has a discontinuous pore structure that reduces liquid ingress, significantly enhancing durability compared to conventional concrete. (Graybeal 2014a)


- Haber et al, 2018

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UHPC COMPONENTS

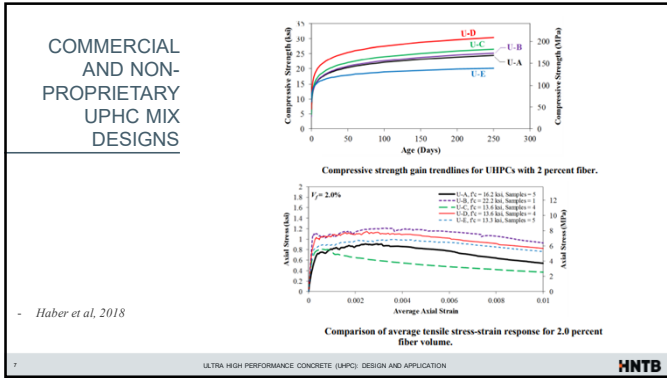
- Fine Sand and smaller particles
- Portland Cement
- Supplemental Cementitious Materials
- Admixtures
- Fibers, (typically steel)
- Water



- Haber et al, 2018
- Leonard 2018

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UHPC – ABC APPLICATIONS

- Properties conducive to connect Prefabricated Bridge Elements and Systems
- Accelerated Bridge Construction – UHPC
- Entry Point for UHPC usage
- Florida International University – Accelerated Bridge Construction
- [Home - Accelerated Bridge Construction \(fiu.edu\)](http://Home-Accelerated Bridge Construction (fiu.edu))

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ABC UHC ACCELERATED BRIDGE CONSTRUCTION UNIVERSITY TRANSPORTATION CENTER

FIU FLORIDA INTERNATIONAL UNIVERSITY

2022 INTERNATIONAL ACCELERATED BRIDGE CONSTRUCTION CONFERENCE Fully In-Person Conference December 7-9, 2022, Miami FL

About Us Monthly Webinar 2021 In-Depth Web Training Archive

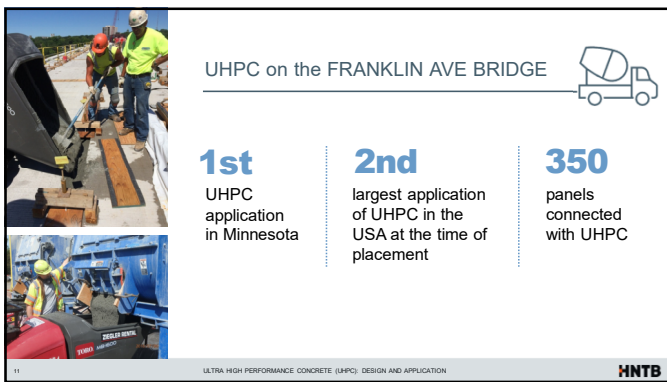
ULTRA HIGH PERFORMANCE CONCRETE (UHPC) DESIGN AND APPLICATION

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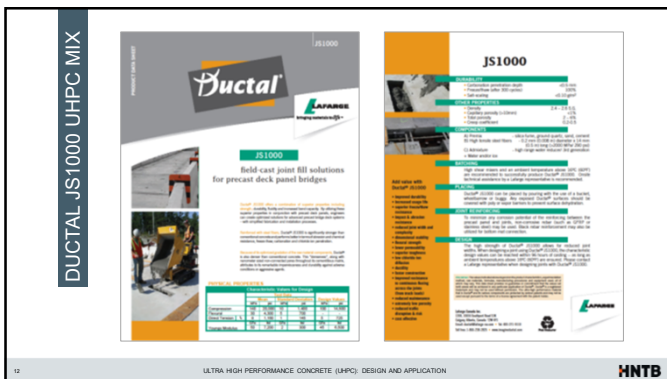
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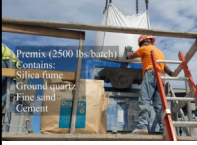




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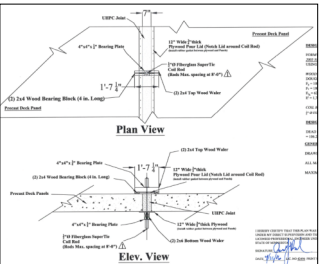
UHPC MIX PROPORTIONS

2500 lbs	124 lbs	33.6 lbs	45 lbs
			
premix	water	superplasticizer	discontinuous steel fiber

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UHPC FORMING Longitudinal closure pour



Plan View

Elev. View

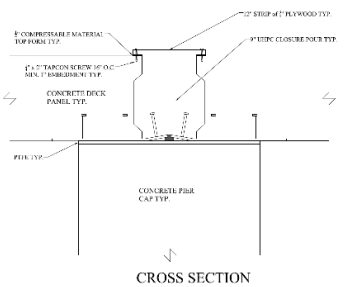


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Franklin Ave • 9" Transverse UHPC Closure Pour Formwork

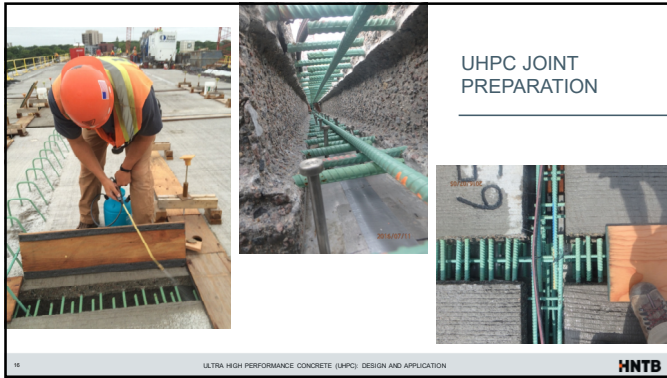
UHPC FORMING Transverse closure pour



CROSS SECTION

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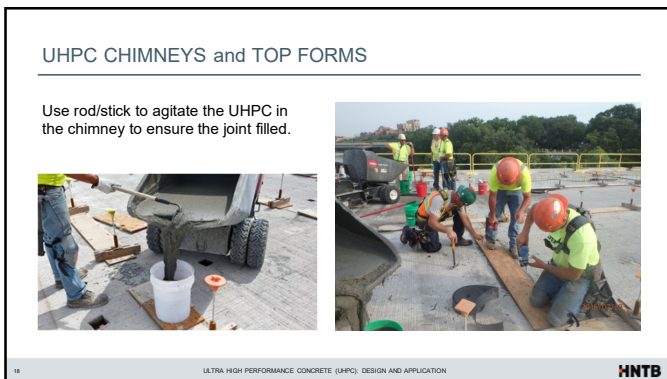
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UHPC QA/QC

Temperature
Mix, ambient, water

Timing
Start and end of mix

Quantity
Premix, water, super plasticizer and discontinuous steel fiber

Drop/Flow table test
Static and Dynamic

Compressive strength
at 4, 7, 21, and 28 days

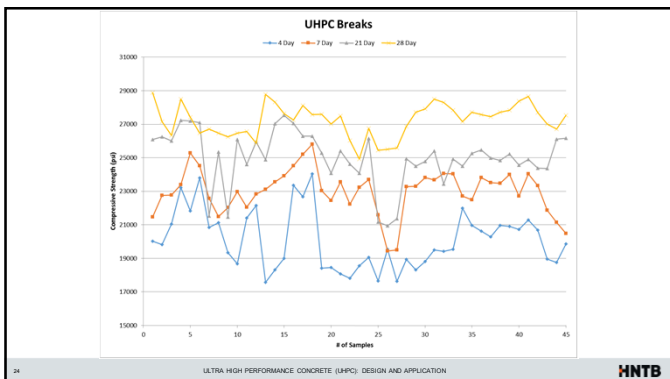
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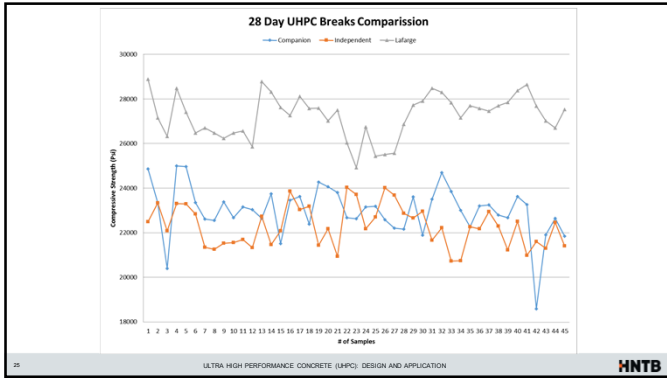
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QC

- KCPC Performed all QC testing for Ductal
- End grind the cylinders to a planeness within 0.001" by checking at five points on the cylinder end

QA

- Braun Intetec performed QA for the owner
- End grind to a planeness of 0.002" per ASTM C39

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#3

LESSONS LEARNED

Language in specification

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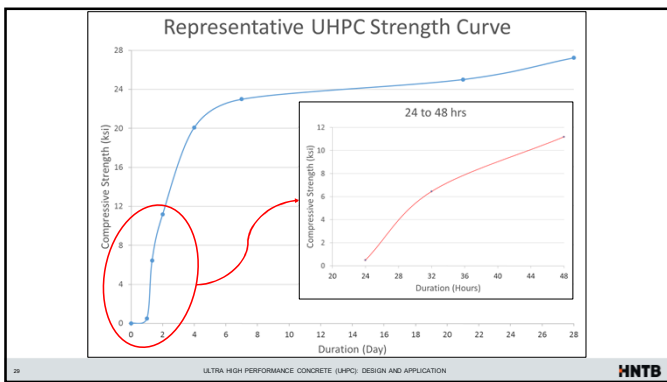
MODIFICATION to SPECIFICATION

“ Contractor shall keep the water under 55 degree F and substitute ice cubes for water limiting the mix temp to 80 degree F. ”
(Only during summer/hot weather condition)

“ Contractor shall not drive any equipment (construction equipment, buggies, etc.) over joints less than 48 hours old (or min strength of xxx psi). ”

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MODIFICATION to SPECIFICATION

“ Contractor shall submit pouring sequence that avoids driving on UHPC that has been placed in the past XX hours or min strength of xxx psi. ”


“ Bulkhead joint shall be roughed prior to placing UHPC. ”
If not, cold joint will be formed; creating the potential for leakage at the bulkhead interface.

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LESSONS LEARNED

- Select formwork that has a removable top form to ensure the joint is pre wet
- Ensure SSD condition is met immediately ahead of the pour
- Importance of preplanning
 - Test pours/Mockup
 - Scanning Tours
- When you are at 60% or 90% of final design phase, we recommend sending a draft copy of the UHPC specification to the producer for comment




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- UHPC Overlays
- UHPC Girder End Repairs
- UHPC Girders
 - PI Girders
 - U-Beams
 - Pre-stressed UHPC Girders

DEVELOPING UHPC APPLICATIONS


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UHPC BRIDGE DECK OVERLAYS



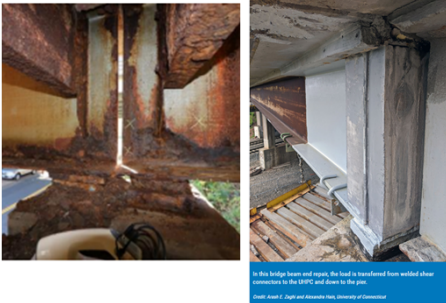
- Graybeal 2018
- Nop 2021

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UHPC GIRDER END REPAIRS



In this bridge beam end repair, the load is transferred from welded shear connectors to the UHPC and across the full span.
Credit: Mark J. Jager and Alexander Hoot, University of Connecticut

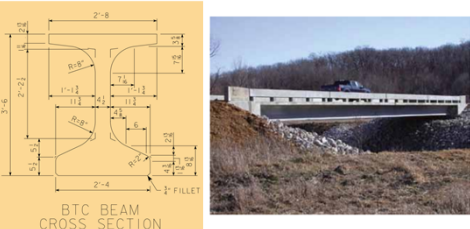
- FHWA 2022
- McMullen 2019
- Nelson 2022

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UHPC GIRDER APPLICATIONS

MARS HILL BRIDGE



BTC BEAM CROSS SECTION

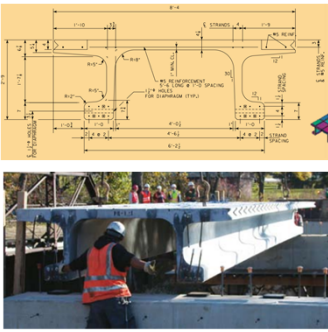
- Wipf et al, 2011

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UHPC GIRDER APPLICATIONS

PI GIRDERS



- Wipf et al, 2011
- Keierleber et al, 2010

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UHPC GIRDER APPLICATIONS

PI GIRDERS

FIGURE 1 Bridge (A) UHPC deck, (B) UHPC interior girder, (C) UHPC interior girder, (D) UHPC edge girder, and (E) UHPC edge girder

0.365 m BRIDGE SIDEWALK 0.365 m BRIDGE SIDEWALK
1.22 m SHOULDER 3.35 m DRIVING LANE 3.35 m DRIVING LANE 1.22 m SHOULDER
8.78 m

127 mm - normal strength concrete deck

Alahmari et al, 2019

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UHPC GIRDER APPLICATIONS

MNDOT

2'-10"

1" R_w

6" R_w

6" R_w

2" R_w

5/8" R_w

6 1/2"

Reduce Web 3 1/2"

N.A.

3'-3"

"MH" SERIES I-BEAM

Western, 2022
MnDOT 2021
El-Helou 2019

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SUMMARY/ QUESTIONS

- Developing AASHTO Design Guide Specifications
- Growing Catalog of Mix Designs
- Optimized Sections
- Multiple Applications

QUESTIONS

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"Properties and Behavior of UHPC-Class Materials." Haber, Z. B., De la Varga J., Graybeal, B. A., Nakashoji, B. and El-Helou R. (March 2018) Office of Infrastructure Research and Development, Federal Highway Administration, 6300 Georgetown Pike, McLean, VA 22101-2296.


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Nelson, N. (2022, May 13). Personal communication [Personal interview].

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