
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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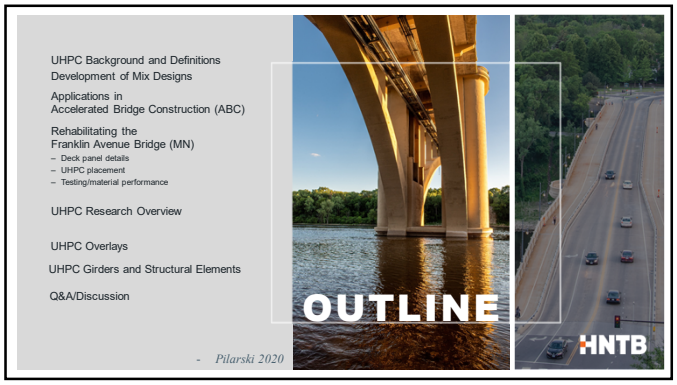
UHPC Background and Definitions
Development of Mix Designs
Applications in
Accelerated Bridge Construction (ABC)
Rehabilitating the
Franklin Avenue Bridge (MN)
– Deck panel details
– UHPC placement
– Testing/material performance
UHPC Research Overview
UHPC Overlays
UHPC Girders and Structural Elements
Q&A/Discussion
OUTLINE
- Pilarski 2020
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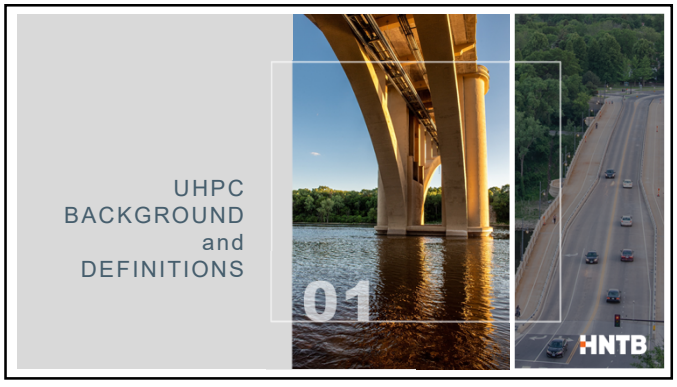
UHPC
BACKGROUND
and
DEFINITIONS
01
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UHPC HISTORY

1970s/80s — Developed in Europe

1990s — In-use in Canada

early **2000s** — Introduced to the U.S.

Deployments | FHWA (dot.gov)

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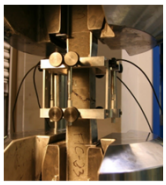
UHPC DEFINITION

- 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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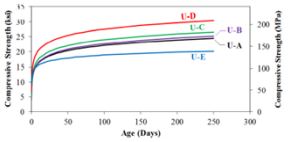
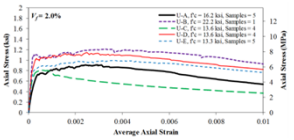
COMMERCIAL AND NON-PROPRIETARY UPHC MIX DESIGNS



Compressive strength gain trendlines for UHPCs with 2 percent fiber.



Comparison of average tensile stress-strain response for 2.0 percent fiber volume.

- *Haber et al, 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)

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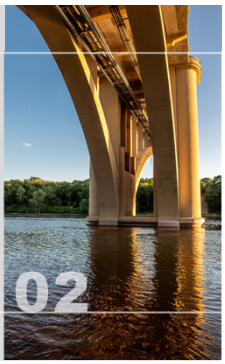
RE-HABILITATING the FRANKLIN AVENUE BRIDGE



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UHPC on the FRANKLIN AVE BRIDGE

1st
UHPC application in Minnesota

2nd
largest application of UHPC in the USA at the time of placement

350
panels connected with UHPC

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DUCTAL JS1000 UHPC MIX

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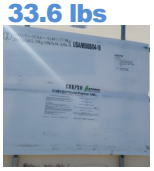
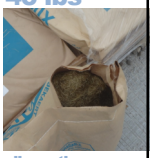
UHPC MIX PROPORTIONS

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

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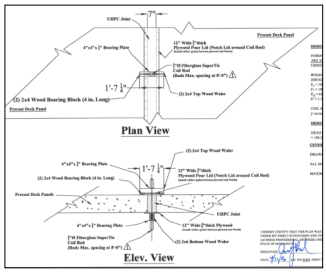
UHPC FORMING
Longitudinal closure pour



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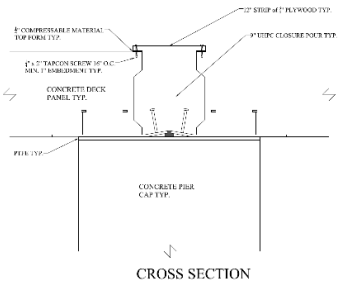
UHPC FORMING
Transverse closure pour

Franklin Ave - 9" Transverse UHPC Closure Pour Formwork



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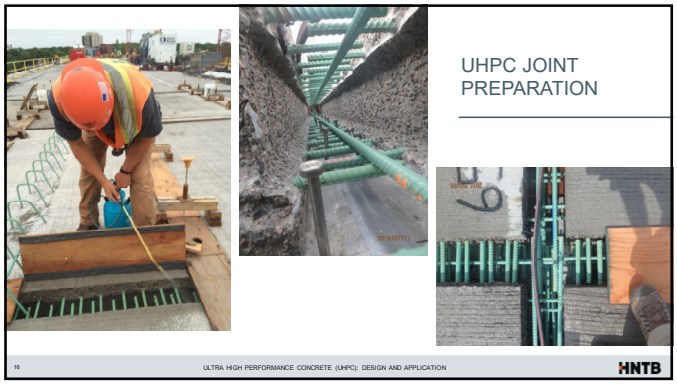
UHPC JOINT
PREPARATION
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ULTRA HIGH PERFORMANCE CONCRETE (UHPC): DESIGN AND APPLICATION
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Hennepin
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Franklin Bridge Restoration
F.W. Cappelen Memorial Bridge
Paul Backer, Hennepin County
Travis Konda and Mario Ratnaraj, HNTB Corporation
08/03/2016

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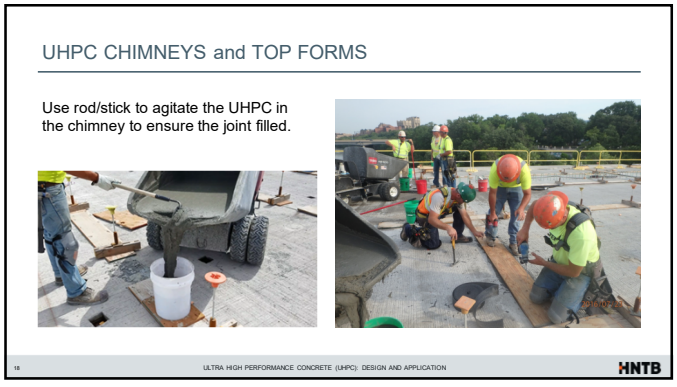
UHPC CHIMNEYS and TOP FORMS
Use rod/stick to agitate the UHPC in the chimney to ensure the joint filled.
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ULTRA HIGH PERFORMANCE CONCRETE (UHPC): DESIGN AND APPLICATION
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UHPC QA/QC

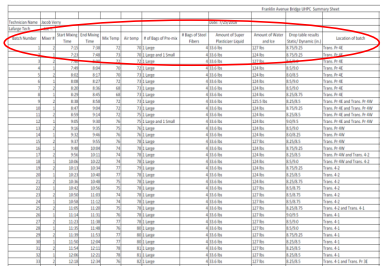
Temperature
Mix, ambient, water

Timing
Start and end of mix

Quantity
Premix, water, super plasticizer and discontinuous steel fiber

Drop/Flow table test
Static and Dynamix

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



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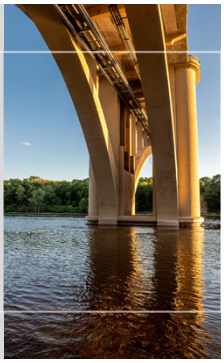
#1

LESSONS LEARNED

Always over pour ¼" high



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ULTRA HIGH PERFORMANCE CONCRETE (UHPC): DESIGN AND APPLICATION
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#2
LESSONS LEARNED
UHCP can break
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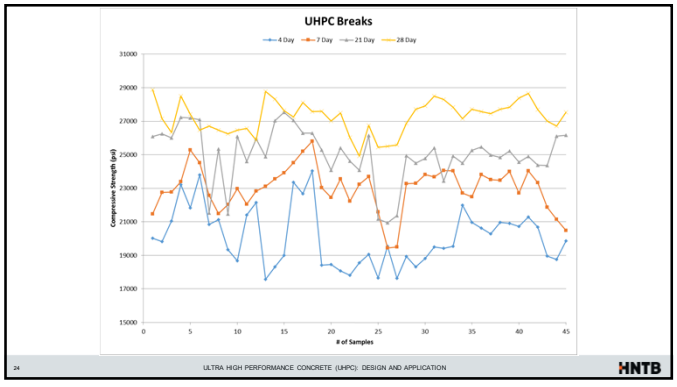
UHPC Breaks
4 Day
7 Day
21 Day
28 Day
Compressive Strength (psi)
# of Samples
24
ULTRA HIGH PERFORMANCE CONCRETE (UHPC): DESIGN AND APPLICATION
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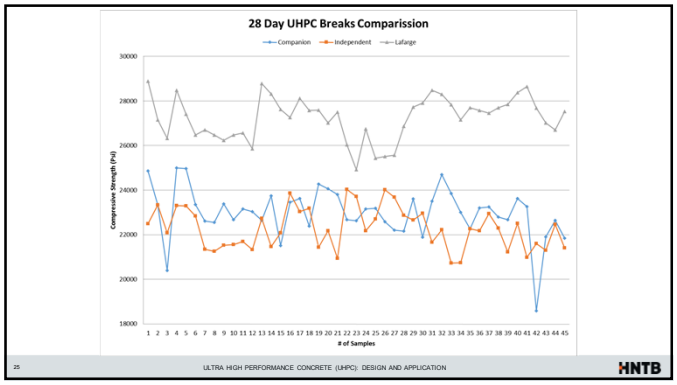
28 Day UHPC Breaks Comparission
Companion
Independent
Lafarge
Compressive Strength (Psi)
# of Samples
25
ULTRA HIGH PERFORMANCE CONCRETE (UHPC): DESIGN AND APPLICATION
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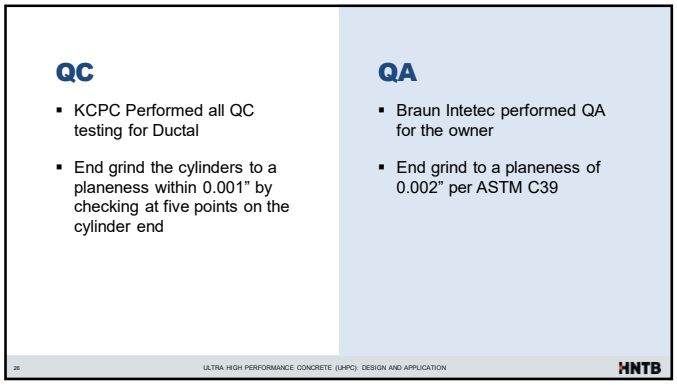
QC
KCPC Performed all QC testing for Ductal
End grind the cylinders to a planeness within 0.001" by checking at five points on the cylinder end
QA
Braun Intetec performed QA for the owner
End grind to a planeness of 0.002" per ASTM C39
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ULTRA HIGH PERFORMANCE CONCRETE (UHPC): DESIGN AND APPLICATION
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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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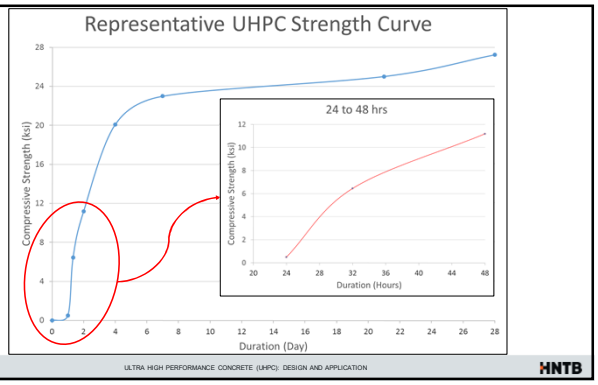

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MODIFICATION to SPECIFICATION

"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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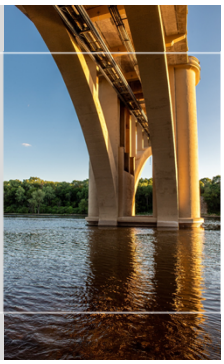
LESSONS LEARNED

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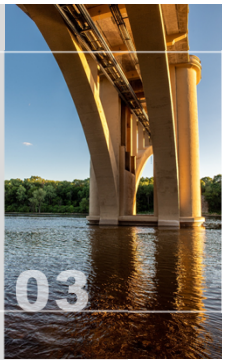
- UHPC Overlays
- UHPC Girder End Repairs
- UHPC Girders
  - Pi Girders
  - U-Beams
  - Pre-stressed UHPC Girders

DEVELOPING UHPC APPLICATIONS

03



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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 down to the pier.

Credit: Aneek E. Zoghi and Alexandra Hass, University of Connecticut

- *FHWA 2022*
- *McMullen 2019*
- *Nelson 2022*

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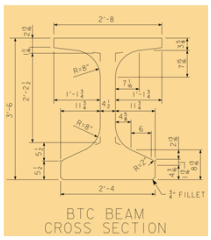
UHPC GIRDER APPLICATIONS

MARS HILL BRIDGE



- *Wipf et al, 2011*

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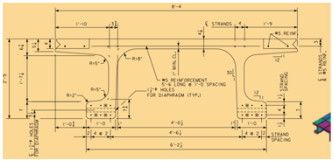
UHPC GIRDER APPLICATIONS

PI GIRDERS



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

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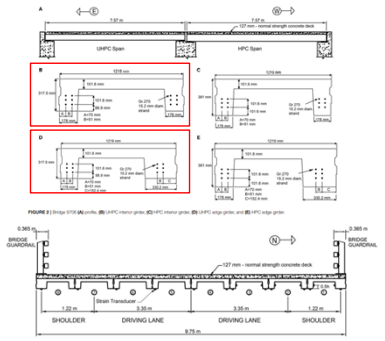
UHPC GIRDER APPLICATIONS

PI GIRDERS



- *Alahmari et al, 2019*

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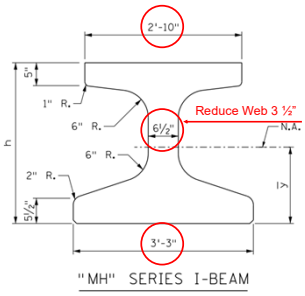
UHPC GIRDER APPLICATIONS MNDOT



- *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,I., 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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