Accelerating Construction using Pre-fabricated Bridge Elements Connected with UHPC

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LafargeHolcim – Ductal®

2017 UTC Spotlight Conference: Rebuilding and Retrofitting the Transportation Infrastructure

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U.H.P.C. – Ultra-High Performance Concrete

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).

– FHWA

Typical UHPC Composition

TABLE 1 Typical Composition of Field-Cast UHPC Mix

Material	Amount [kg/m^3 (lb/yd^3)]		Percentage by Weight
Portland cement	712 (1,200)		28.6
Fine sand	1,020 (1,720)		41.0
Silica fume	231 (390)		9.3
Ground quartz	211 (355)		8.5
Superplasticizer	30 (51)		1.2
Steel fibers	156 (263)	**2% by Vol.**	6.2
Water	130 (218)		5.2

Typical UHPC Properties

Property	Value
Unit weight	158 lb/ft^3 (2,535 kg/m^3)
Modulus of elasticity	7,500–8,500 ksi (52–59 GPa)
Compressive strength	25–32 ksi (170–220 MPa)
Post-cracking tensile strength	1.0–1.5 ksi (7.0–10.3 MPa)
Chloride ion penetrability (ASTM C1202-12)[(4)]	Very low to negligible

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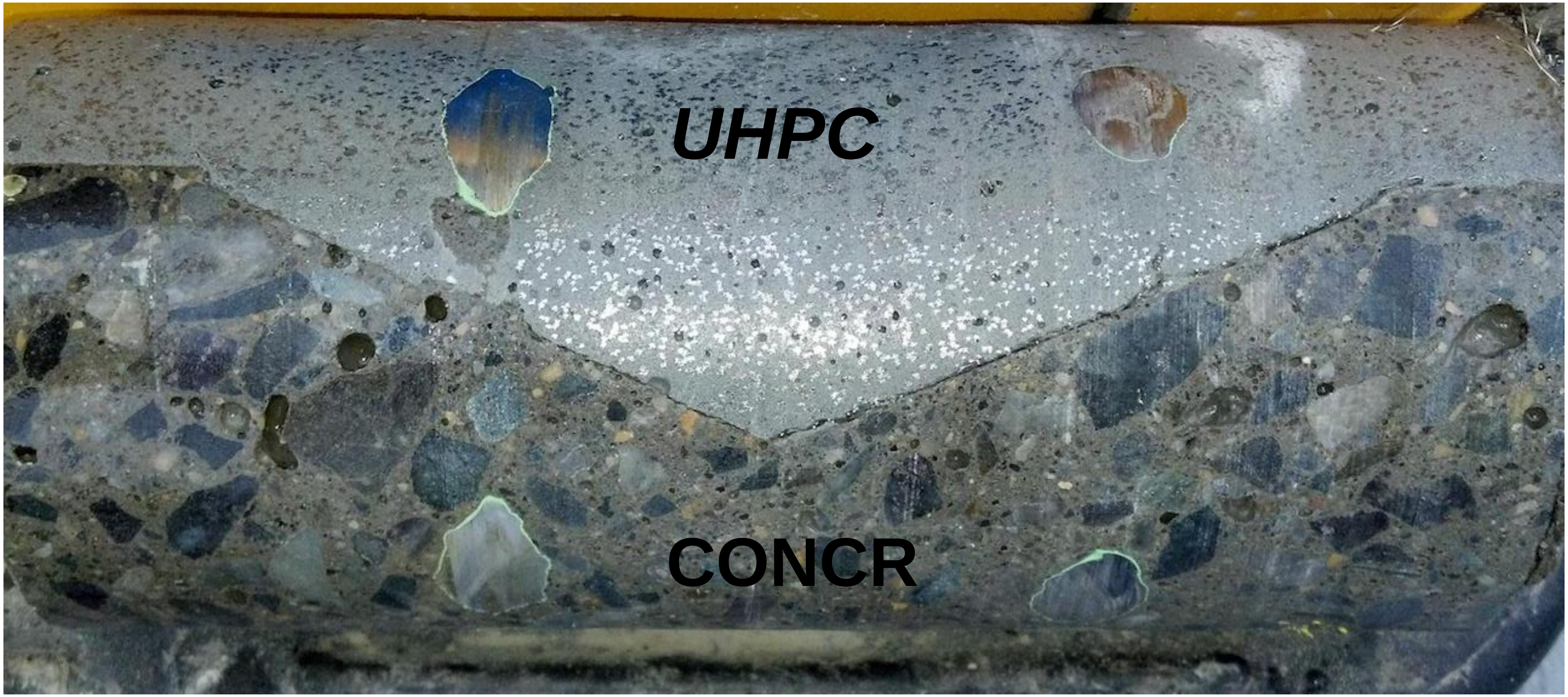
UHPC Cross-Section

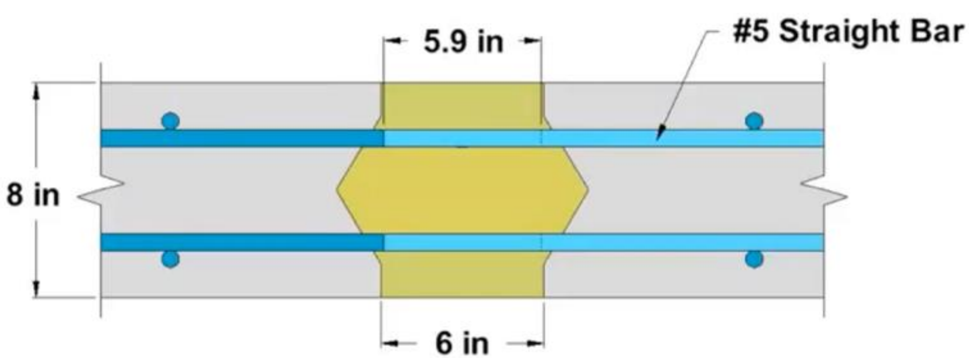


Why UHPC for Connections?

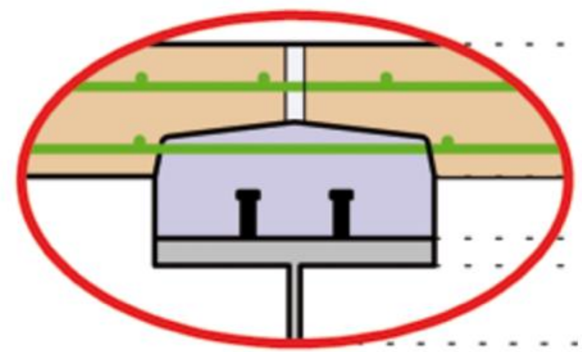
Speed. The mechanical properties of UHPC allow for redesign of common connection details in ways that promote both ease and speed of construction.

Simplicity. UHPC connections are inherently less congested, simplifying fabrication and assembly.

Performance. Field-cast UHPC between prefabricated bridge elements results in robust connections that can provide better long-term performance than connections constructed by conventional methods.



Straight Bar Connection w/ UHPC



Girder Haunch w/ UHPC

UHPC Mix Designs

PRODUCT DATA SHEET

JS1000

Ductal®

LAFARGE
Building better cities™

JS1000

field-cast joint fill solutions for precast deck panel bridges

Ductal® JS1000 offers a combination of superior properties including strength, durability, fluidity and increased bond capacity. By utilizing these superior properties in conjunction with precast deck panels, engineers can create optimized solutions for advanced precast bridge deck systems – with simplified fabrication and installation processes.

Reinforced with steel fibers, Ductal® JS1000 is significantly stronger than conventional concrete and performs better in terms of abrasion and chemical resistance, freeze-thaw, carbonation and chloride ion penetration.

Because of its optimized gradation of the raw material components, Ductal® is also denser than conventional concrete. This "denseness", along with nanometer sized non-connected pores throughout its cementitious matrix, attributes to its remarkable imperviousness and durability against adverse conditions or aggressive agents.

PHYSICAL PROPERTIES

Characteristic Values for Design							
		Test Data					
		Mean		Standard Deviation		Design Values	
		MPa	psi	MPa	psi	MPa	psi
Compression		140	20,000	10	1,400	100	14,500
Flexural		30	4,300	5	700	-	-
Direct Tension	f_t	8	1,160	1	145	5	725
		GPa	ksi	GPa	ksi	GPa	ksi
Youngs Modulus		50	7,200	2	300	45	6,500

PRODUCT DATA SHEET

JS1212
Rapid Strength

Ductal®

LAFARGE
Building better cities™

JS1212

field-cast joint fill solutions for Accelerated Bridge Construction (ABC)

Ductal® JS1212 offers a combination of superior properties including rapid strength, durability, fluidity and increased bond capacity. By utilizing these superior properties in conjunction with precast deck panels, engineers can create optimized solutions for advanced precast bridge deck systems – with simplified fabrication and installation processes. Compressive strengths of 12 ksi may be attained in 12 hours with 49°C (120°F) curing.

Reinforced with steel fibers, Ductal® JS1212 is significantly stronger than conventional concrete and performs better in terms of abrasion and chemical resistance, freeze-thaw, carbonation and chloride ion penetration.

Because of its optimized gradation of the raw material components, Ductal® is also denser than conventional concrete. This "denseness", along with nanometer sized non-connected pores throughout its cementitious matrix, attributes to its remarkable imperviousness and durability against adverse conditions or aggressive agents.

PHYSICAL PROPERTIES

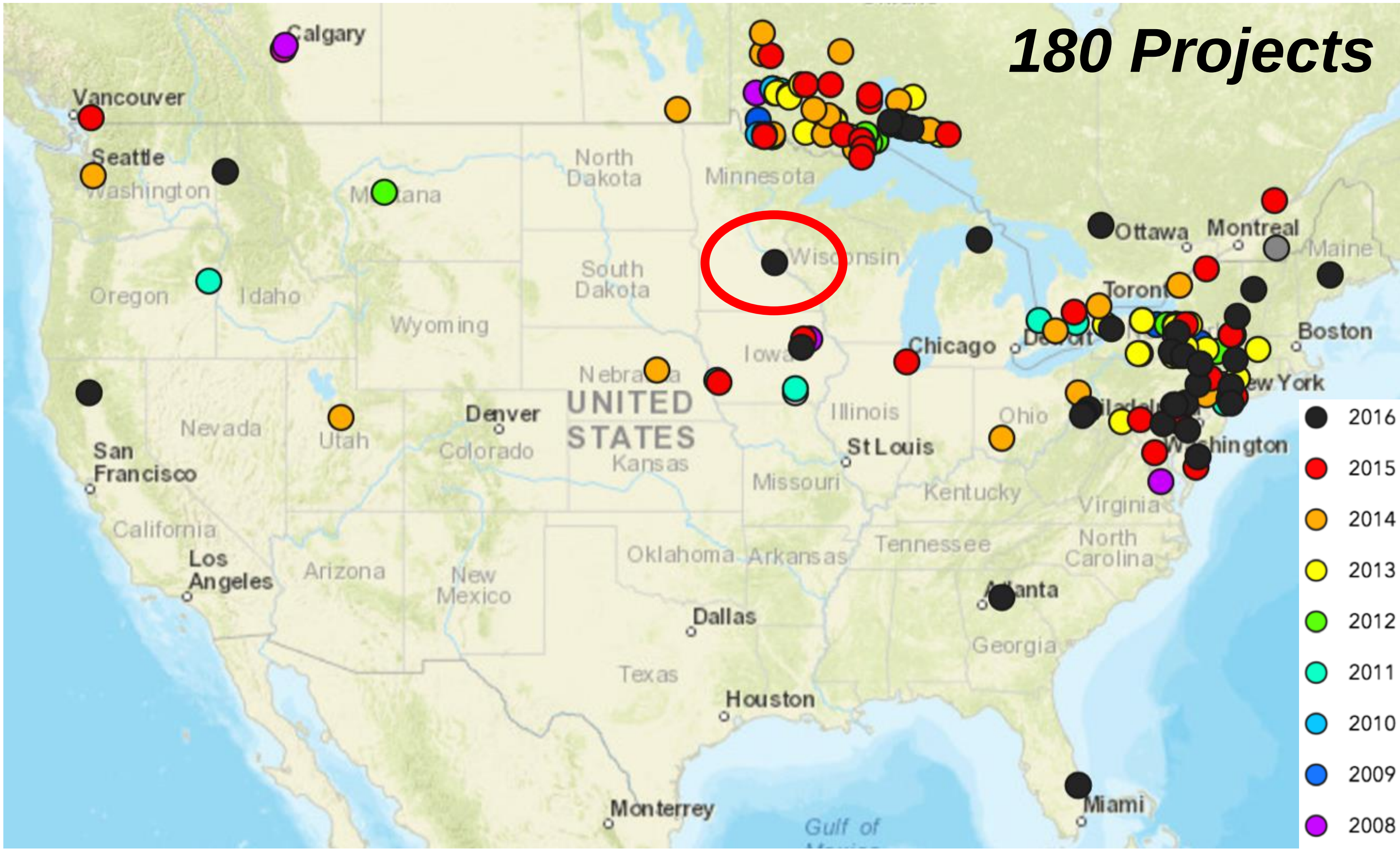
Characteristic Values for Design							
		Test Data					
		Mean		Standard Deviation		Design Values	
		MPa	psi	MPa	psi	MPa	psi
Compression		140	20,000	10	1,400	100	14,500
Flexural		30	4,300	5	700	-	-
Direct Tension	f_t	8	1,160	1	145	5	725
		GPa	ksi	GPa	ksi	GPa	ksi
Youngs Modulus		50	7,200	2	300	45	6,500

Project Case Studies

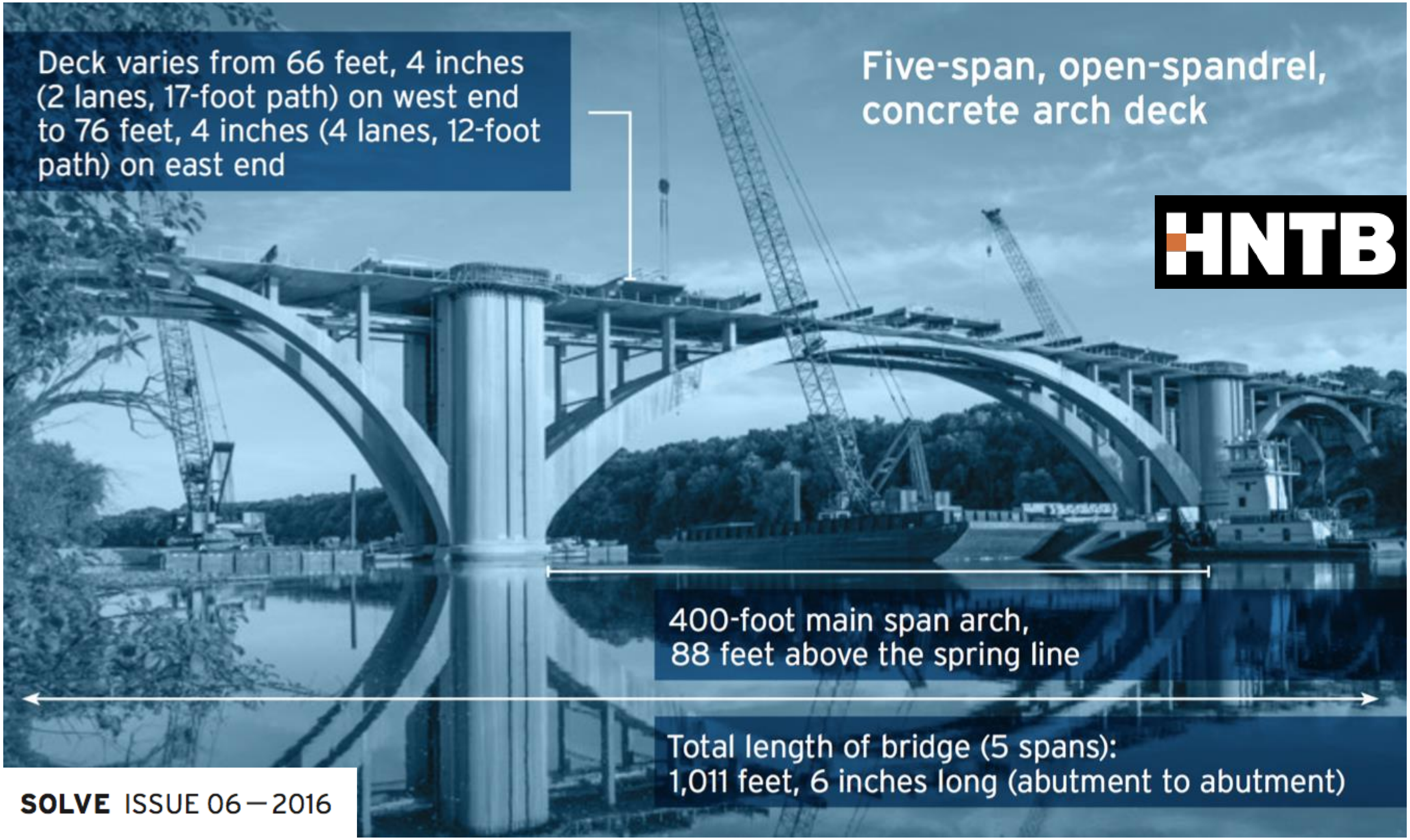
1. **Franklin Avenue Bridge over Mississippi River, Minneapolis**
   - *Deck Rehabilitation, 2016*

2. **U.S. Route 30 Bridge over Bessemer Avenue, Pittsburgh**
   - *Superstr. Replacement, 2016*

Completed Projects



Franklin Avenue Bridge



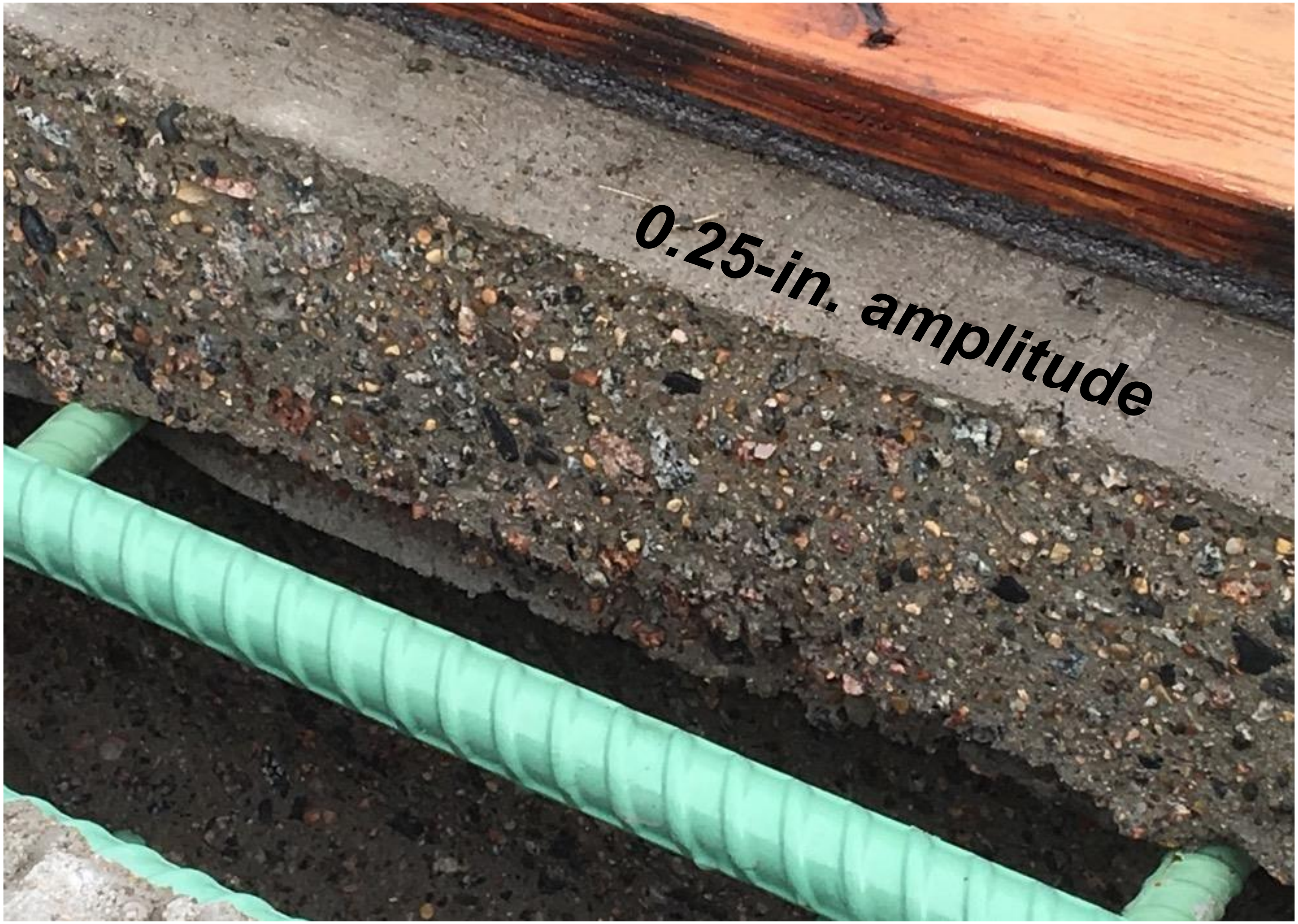
New Precast Cap Beam

New Precast Deck Panels

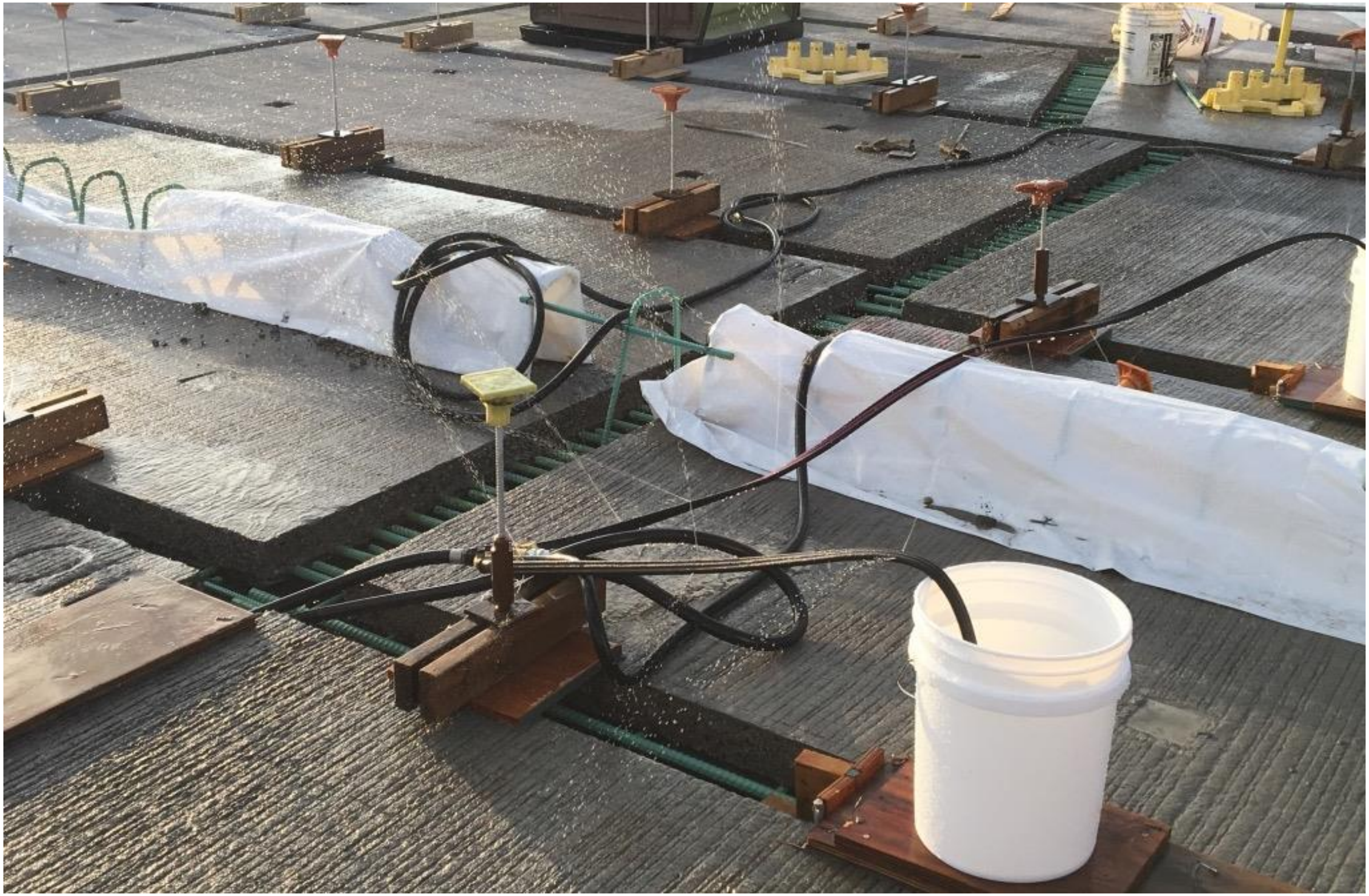
Underside View

Joint Details for UHPC

Exposed Aggregate Finish



Pre-Wetting Joints to SSD



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New Deck Panel Layout

Joint Forms – Ready for UHPC

0.5 CM Mixers & Generator

Premix Bag & Steel Fibers

Quality Control – Typ. Flow Test

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JS1000 UHPC Placement

20-min. per batch

2-hr. working time

Top Forms w/ Buckets

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UHPC Joint Before Grinding

UHPC Joint After Grinding

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Completed Bridge Deck

FHWA / EDC Write-Up

every day counts
An Innovation Partnership with States

Ultra-High Performance Concrete Connections

PROJECT CASE STUDY

Rapid Rehabilitation of a Mississippi River Crossing

Project Background

The Franklin Avenue Bridge is an open-spandrel concrete arch bridge that is currently listed on the National Register of Historic Places and is a City of Minneapolis Landmark. When it opened in 1923, the bridge's 400-foot central arch spanning the Mississippi River was the longest reinforced concrete arch in the world.

In the early 1970s, a major renovation changed many of the bridge's ornamental details, eliminated overlooks, and added a new, wider deck. In 2007, a structural investigation revealed that the bridge was structurally sound but in need of rehabilitation. Many concrete elements, especially those located near expansion joints, were deteriorating and warranted extensive repair, including concrete repair on the substructure and full deck and spandrel cap beam replacement.

Project Approach

An accelerated bridge construction (ABC) approach using prefabricated bridge elements and systems (precast deck panels, spandrel cap beams, and ornamental railings) was selected after considering the needs of users at the bridge's location in downtown Minneapolis, where it connects two major pedestrian and bike corridors neighboring the University of Minnesota. Offsite prefabrication of the panels meant significantly less bridge closure time and need for detours. It also allowed closure to be timed for the summer months when many university students would be out of town.

The Franklin Avenue Bridge is a historic crossing in downtown Minneapolis, MN, heavily used by drivers, pedestrians, and cyclists. Hennepin County used UHPC connections between precast deck panels to help accelerate the bridge's rehabilitation in 2016.

This case study presents the experience of Hennepin County, Minnesota, in using field-cast ultra-high performance concrete (UHPC) connections between prefabricated bridge elements to rehabilitate the historic Franklin Avenue Bridge.

Officially named the F.W. Cappelen Memorial Bridge in honor of its designer, the 1,000-foot span's recent rehabilitation was the second-largest project in the United States to date to employ field-cast UHPC connections between precast bridge deck panels.

Using precast panels allowed construction crews to remove and replace the entire deck within a 17-week timeframe, and using UHPC for the connections simplified the construction activities and increased the quality of the completed structure.

What is UHPC?

Ultra-high performance concrete, or UHPC, is a steel-fiber reinforced, portland cement-based material that has superior mechanical and durability properties compared to conventional concrete. Its fresh properties, oftentimes including self-consolidation, allow it to be an ideal match for field construction with prefabricated components.

Precast Panels and UHPC

- Connection preparation is critical, including 1/4" amplitude exposed aggregate finish on connection interfaces.
- SSD all connection surfaces early and just prior to pour. One of the most effective ways to ensure an SSD condition is met is to design the formwork to provide access, such as a removable top form.
- Bulkhead locations should be accurately located on the deck panel forms prior to the panel concrete pour. At each of these locations, a vertical recessed groove should be pre-formed into the panel UHPC key-way during the panel pour. The pre-formed groove will then accommodate a bulkhead form during the UHPC pour process.
- At bulkheads or construction joints between UHPC pours, the previous pour must be roughed prior to placing new UHPC. If not, a cold joint will be formed, creating potential for leakage at the bulkhead interface.
- Mix temperature is critical (never to exceed 85°F). Maintaining a mix temperature below 80°F is preferred. On this project, chilled water and ice were critical in lowering the mix temperature. The contractor was encouraged to provide the ice, although this was not spelled out in the specification.
- A small percentage of the connections in an isolated area were observed to leak following a heavy rainstorm and prior to the methacrylate installation. This was attributed to the mix temperature at placement being 80-90°F and also to possibly driving buggies over the connections before they attained the needed strength. As evidenced by the large majority of the bridge deck, leak-free performance can be obtained if the construction is completed according to plan.
- Detailed as-built surveying of reinforcement prior to casting panels is essential to avoid reinforcement conflicts when panels are installed.
- The contractor must design forms/ties so that reinforcement conflicts are not created by their choice of forms.
- The fit of panels to transverse beams, especially at sliding joints, needs to be well designed. Construction tolerances need to consider shims or other practical adjustment methods.

Available Resources

EDC-4 Ultra-High Performance Concrete Connections for Prefabricated Bridge Elements
https://www.fhwa.dot.gov/innovation/everydaycounts/edc_4/uhpc.cfm

Design and Construction of Field-Cast UHPC Connections (FHWA-HRT-14-084)
http://www.fhwa.dot.gov/publications/research/infrastructure/structures/14084/14084.pdf

Ultra-High Performance Concrete: A State-of-the-Art Report for the Bridge Community (FHWA-HRT-13-060)
https://www.fhwa.dot.gov/publications/research/infrastructure/structures/hpc/13060/13060.pdf

Acknowledgements: Photos and project details for this case study provided as a courtesy by Hennepin County and HNTB Corporation.

For additional information about this EDC Initiative, please contact:

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Every Day Counts (EDC), a State-based initiative of FHWA's Center for Accelerating Innovation, works with State, local and private sector partners to encourage the adoption of proven technologies and innovations aimed at shortening and enhancing project delivery.

U.S. Department of Transportation
Federal Highway Administration

FHWA-17-CAI-004

www.fhwa.dot.gov/everydaycounts

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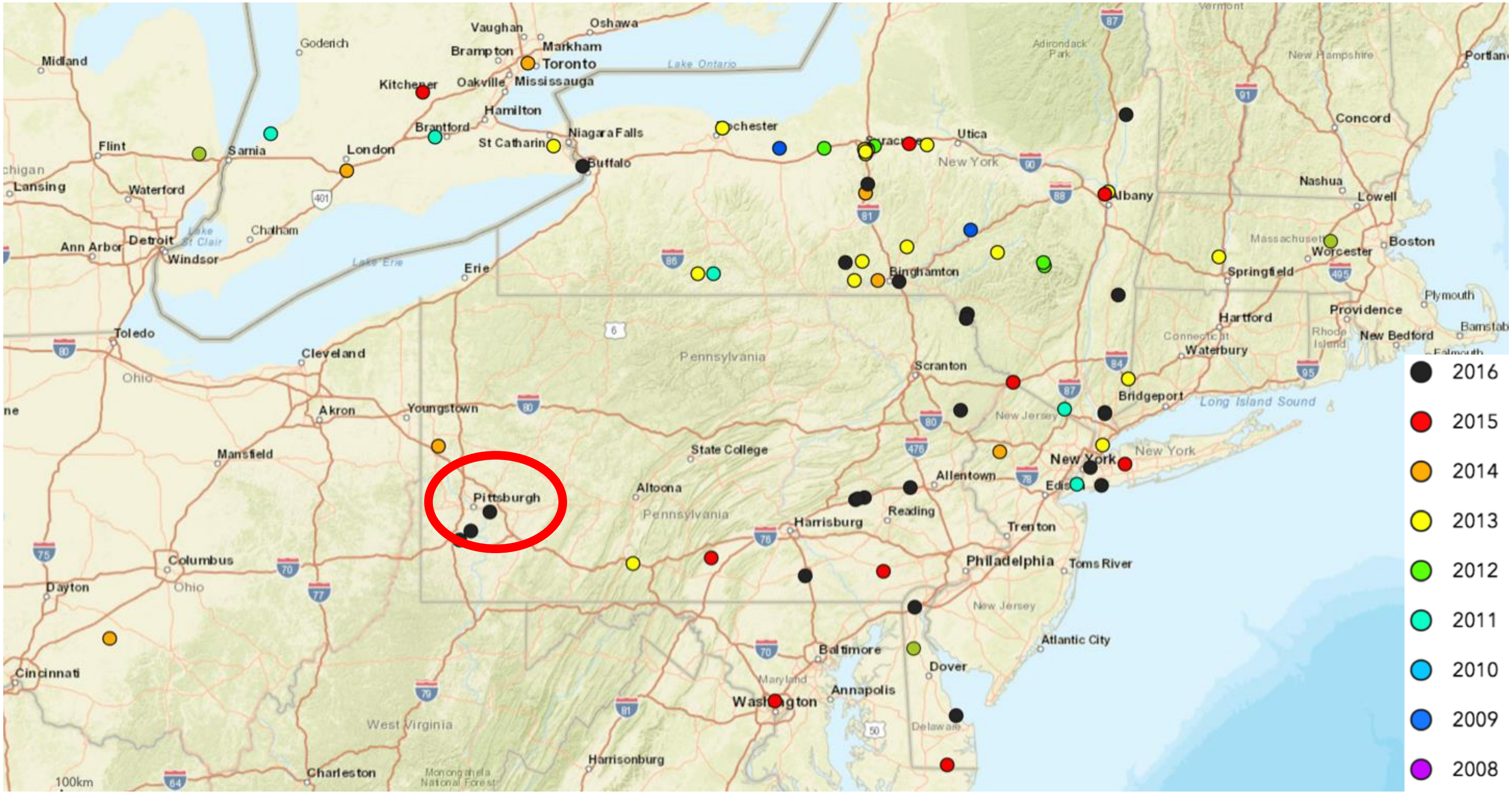
FIU Webinar


FIU
Accelerated Bridge Construction Center
FLORIDA INTERNATIONAL UNIVERSITY
ABC Rehabilitation of Historic Franklin Avenue Bridge
Nancy Daubenberger, P.E., Division Director, Engineering Services, Minnesota DOT;
Bala Sivakumar, P.E., Lead Designer (ABC), HNTB;
Travis Konda, Ph.D., P.E., Construction Engineer, HNTB
Webinar held on 01/19/2017

Completed Projects – NE



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Existing Bridge – US Rte 30

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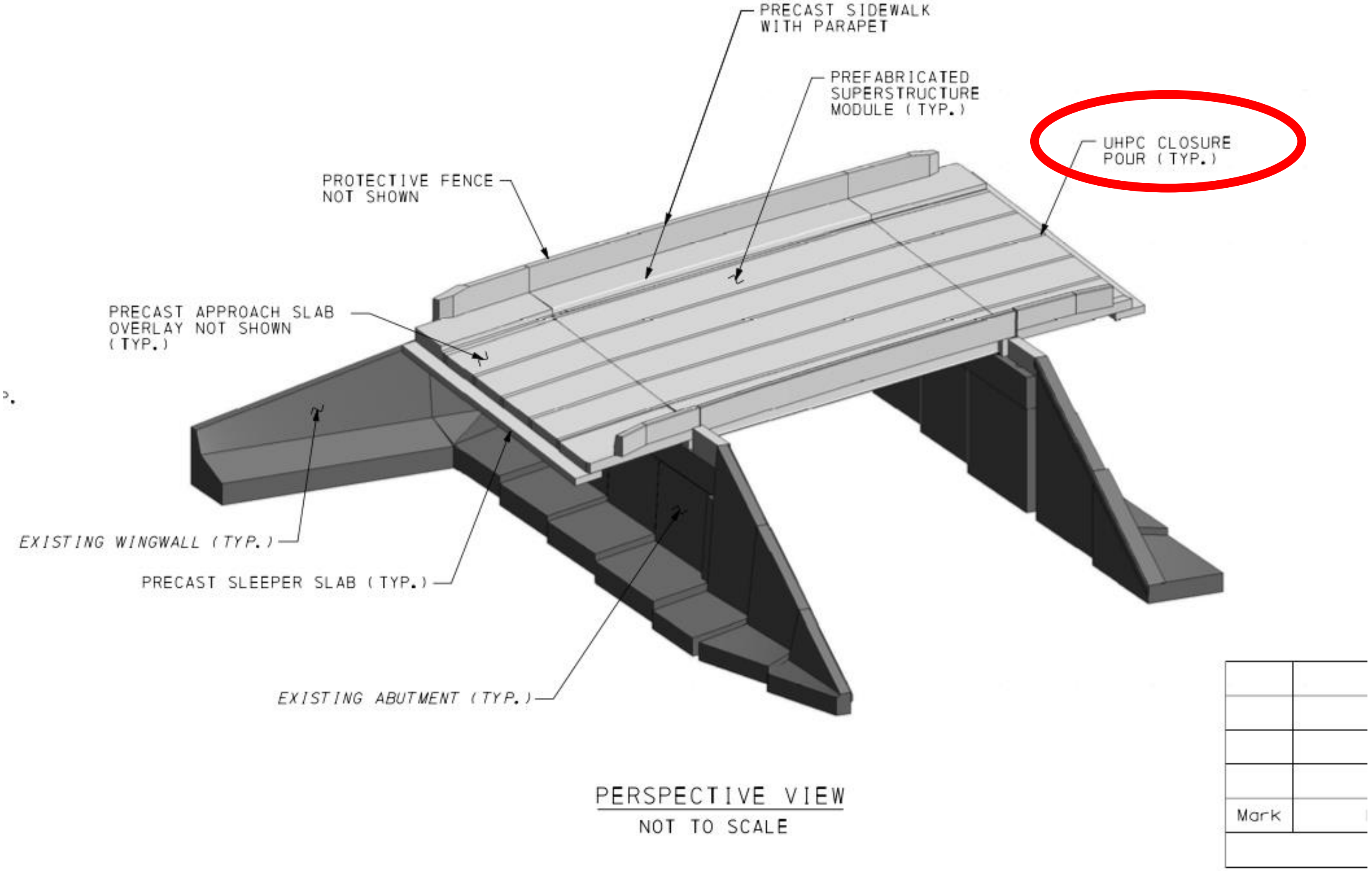
Existing Bridge

3D Model of New Superstructure



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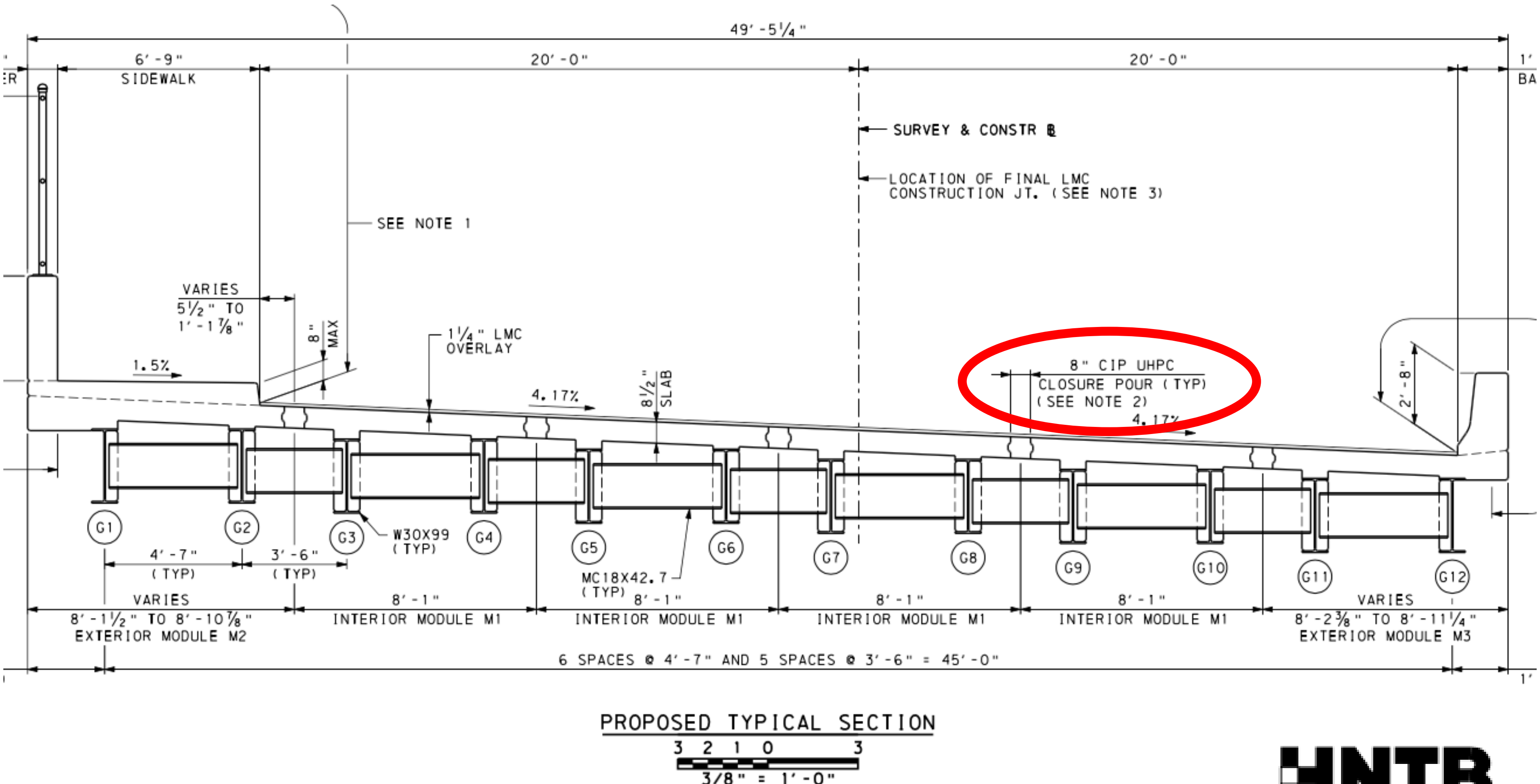
Typical Bridge Section



HNTB

6 Prefabricated Modules

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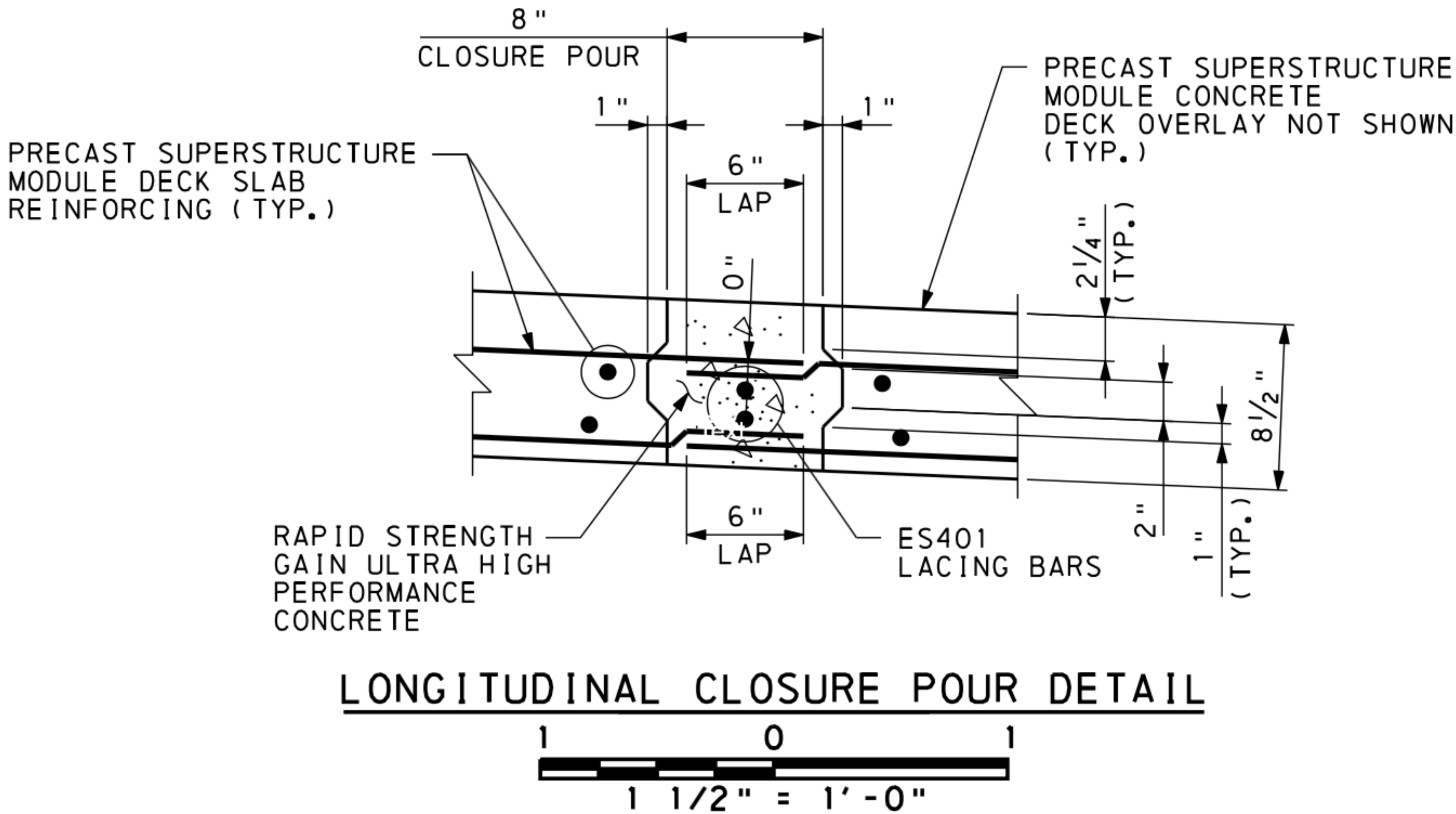
Closure Pour Detail



New Precast Riser Block

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Exterior Module Installation

Quality Control

Flow Test

LAFARGE DUCTAL®

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Chicago, IL 60631 USA
www.lafargeholcim.com www.ductal.com

QUALITY CONTROL TEST RESULTS

Project: Route 30 over Bessemer Rd. Pittsburgh, PA
Client: Brayman Construction Co.
Weather: Cloudy

Date: May 22, 2016
Tech Rep: JR AR
Mix Type: JS1212

Total Amount Batched: 19.285

Batch #	Mixer ID	Time		Mix Temp	Ambient	Flow		Lot #	Comments
		Start	Finish	Finish	Temp	Static	Dynamic		
1	L	3:53 PM	4:06 PM	78	63	8.50	9.00	DXVI J1099G1	
2	R	4:02 PM	4:13 PM	78	63	9.25	9.75	DXVI J1099F2	
3	L	4:09 PM	4:22 PM	80	63	8.75	9.25	DXVI J1099F3	
4	R	4:21 PM	4:33 PM	80	63	8.75	9.25	DXVI J1099I1	
5	L	4:27 PM	4:45 PM	79	63	8.75	9.25	DXVI J1099I2	
6	R	4:45 PM	4:56 PM	79	63	8.75	9.25	DXVI J1099H2	
7	L	4:52 PM	5:03 PM	82	63	8.75	9.25	DXVI J1099H3	
8	R	5:01 PM	5:12 PM	81	63	8.50	9.00	DXVI J1099E2	
9	L	5:12 PM	5:24 PM	80	62	8.75	9.25	DXVI J1099E4	
10	R	5:20 PM	5:34 PM	82	62	8.50	9.00	DXVI J1099H3	
11	L	5:30 PM	5:41 PM	80	62	8.50	9.00	DXVI J1099G2	
12	R	5:42 PM	5:53 PM	81	62	8.75	9.25	DXVI J1099F4	
13	L	5:50 PM	6:02 PM	79	62	8.50	9.00	DXVI J1099F1	
14	R	6:00 PM	6:14 PM	82	62	8.50	9.00	DXVI J1099E3	
15	L	6:08 PM	6:21 PM	81	62	8.75	9.25	DXVI J1099C3	
16	R	6:19 PM	6:29 PM	81	62	8.50	9.00	DXVI J1099I4	
17	L	6:31 PM	6:43 PM	82	61	8.75	9.25	DXVI J1099H4	
18	R	6:42 PM	6:54 PM	81	61	9.00	9.50	DXVI J1099B1	
19	L	6:54 PM	7:06 PM	82	61	8.75	9.25	DXVI J1099D4	
20	R	7:01 PM	7:13 PM	83	61	8.75	9.25	DXVI J1099B2	
21	L	7:11 PM	7:26 PM	82	59	8.75	9.25	DXVI J1099D2	
22	R	7:18 PM	7:34 PM	82	58	8.75	9.25	DXVI J1099D1	
23	L	7:30 PM	7:44 PM	81	57	8.75	9.25	DXVI J1099E1	
24	R	7:39 PM	7:56 PM	84	57	8.75	9.25	DXVI J1099D3	
25	L	7:49 PM	8:02 PM	81	56	8.75	9.25	DXVI J1099C4	
26	R	8:05 PM	8:17 PM	83	56	8.75	9.25	DXVI J1099A3	
27	R	8:52 PM	9:04 PM	82	56	8.75	9.25	DXVI J1099A2	Cylinders Cast
28	R	9:09 PM	9:20 PM	81	56	8.75	9.25	DXVI J1099A1	
29	R	9:40 PM	9:52 PM	83	56	8.75	9.25	DXVI J1099A4	
30									

UHPC Performance Specs & Testing Standards

PROPOSAL Report - Project 27267

Special Provision: 00 - a35730 Ultra High Performance Concrete, Accelerated

Addendum:

Action:

Item(s) Associated:

Header:
ULTRA HIGH PERFORMANCE CONCRETE, ACCELERATED

Provision Body:

DESCRIPTION - This work is the batching, transporting, placing, finishing, and curing of Ultra High Performance Concrete (UHPC) to connect pre- cast structural elements. UHPC is a cementitious composite material composed of an optimized gradation of granular constituents, a water-to-cement ratio less than 0.25, and a high percentage of discontinuous internal fiber reinforcement.

MATERIAL - The material shall be a self-leveling, self-consolidating cementitious UHPC containing a well-graded matrix of fibers so as to provide ductility in bending and an ultra-low permeability. All of the components of the UHPC mixture shall be supplied by a single material manufacturer with a minimum of five years of experience in manufacturing and the commercial supply of UHPC. The UHPC shall attain a minimum compressive strength of 12 ksi in 12 hours using accelerated heat curing. Use Medium Heat Treatment to accelerate curing. Medium Heat temperatures not to exceed 120ºF

a. Ultra High Performance Concrete Mixture. Produce mix using either a premixed ultra-high performance composite material with the manufacturer's recommended steel fibers and admixtures that is certified as specified in Section 106.03(b) or a combination of the following:

- Cement - Section 701
- Fine Aggregate - Section 703.1 except the maximum nominal size is not to exceed 0.024".
- Pozzolan - Section 724.4
- Admixture - Section 711.3
- Steel Fibers - ASTM A 820, Type 1, cold drawn high-carbon steel with a minimum tensile strength of 290,000 psi. Minimum steel fiber content shall be 2% of the mix's dry volume.
- Water - Section 720.1, if concrete temperatures rise above 8°0F, ice cubes maybe required to decrease mix temperatures.

Produce a UHPC mixture meeting the following properties:

Table A. UHPC Expected Properties

Description	Test Method	Acceptance Criteria
Compressive Strength	ASTM C39	≥ 12,000 psi
Compressive Strength	PTM 604, 28 days	21,700 psi
Long-Term Shrinkage	ASTM C157; initial reading after set	≤ 766 microstrain
Prism Flexural Tensile toughness	ASTM C1018; 12 in. span	I30 ≥ 48
Freeze-Thaw Resistance	ASTM C 666 / AASHTO T 161 (600 cycles)	Relative Dynamic Modulus of Elasticity >96%
Rapid Chloride Permeability	ASTM C 1202 / AASHTO T 277	≤ 250 coulombs
Chloride Ion Penetration	AASHTO T 259; ½" depth	< 0.1183 lbs./ cy

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ASTM INTERNATIONAL

Designation: C1856/C1856M – 17

NEW!

Standard Practice for Fabricating and Testing Specimens of Ultra-High Performance Concrete[1]

This standard is issued under the fixed designation C1856/C1856M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers procedures for fabricating and testing specimens in the laboratory and the field using a representative sample of ultra-high performance concrete (UHPC), for the purpose of determining the properties of the material. This practice is applicable to UHPC with a specified compressive strength of at least 120 MPa (17 000 psi), with nominal maximum size aggregate of less than 5 mm [¼ in.] and a flow between 200 and 250 mm [8 and 10 in.] as measured by the modified flow table test described in Section 6.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 If required results obtained from another standard are not reported in the same system of units as used by this standard, it is permitted to convert those results using the conversion factors found in the SI Quick Reference Guide (**1**).[2]

1.4 *The text of this standard references notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.*

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. [WARNING—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to exposed skin and tissue upon prolonged exposure.[3] Hand protection should be worn when handling UHPC.]*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[4]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field
C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens
C42/C42M Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C125 Terminology Relating to Concrete and Concrete Aggregates
C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
C191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
C219 Terminology Relating to Hydraulic Cement
C230/C230M Specification for Flow Table for Use in Tests of Hydraulic Cement
C341/C341M Practice for Preparation and Conditioning of Cast, Drilled, or Sawed Specimens of Hydraulic-Cement Mortar and Concrete Used for Length Change Measurements
C469/C469M Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression
C512/C512M Test Method for Creep of Concrete in Compression
C666/C666M Test Method for Resistance of Concrete to Rapid Freezing and Thawing
C944/C944M Test Method for Abrasion Resistance of Concrete or Mortar Surfaces by the Rotating-Cutter Method

[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.61 on Testing for Strength.

Current edition approved May 15, 2017. Published June 2017. DOI: 10.1520/C1856_C1856M-17.

[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

[3] See section on Safety Precautions, *Manual of Aggregates and Concrete Testing, Annual Book of ASTM Standards, Vol. 04.02.*

[4] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

UHPC Placement

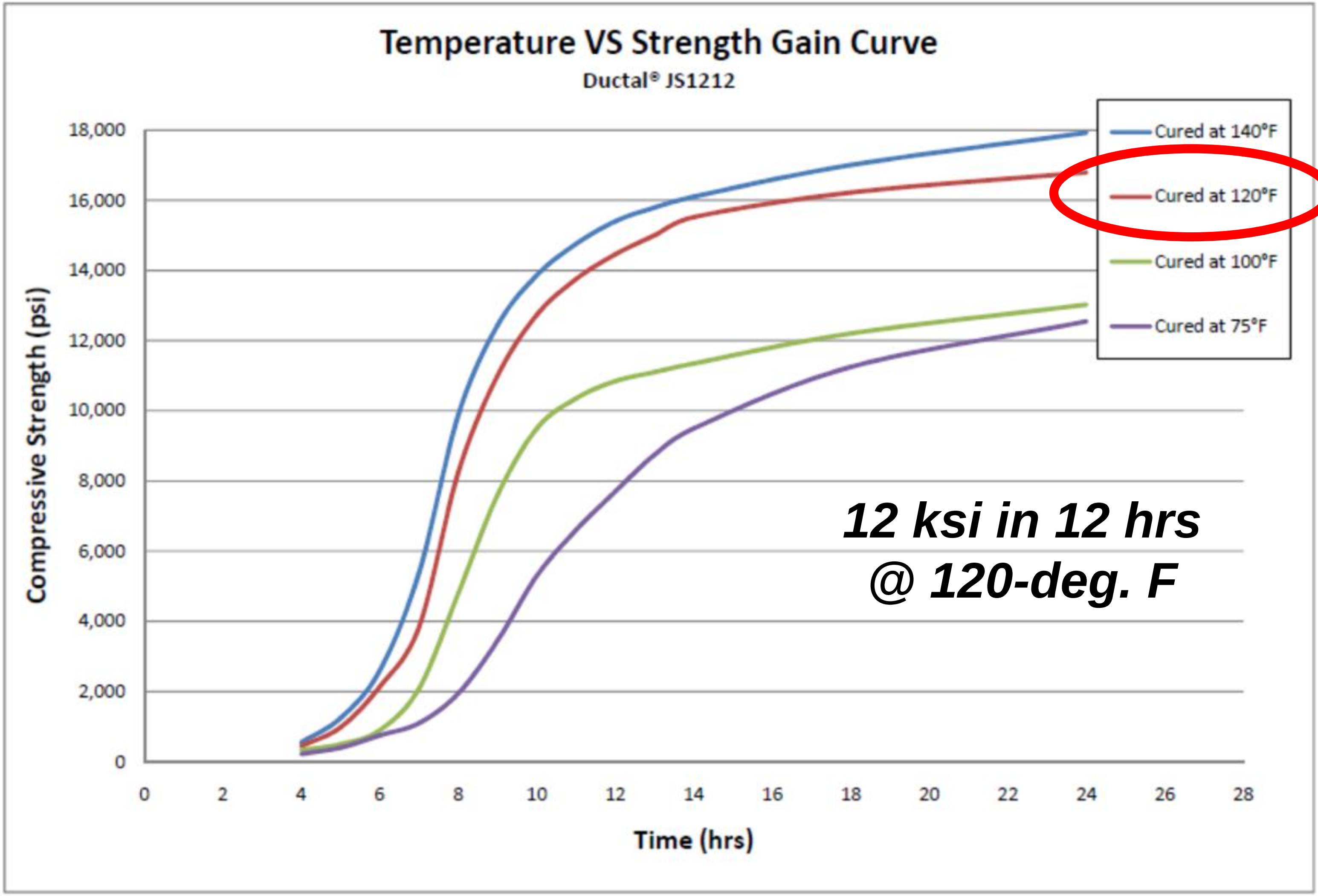
UHPC rep. on-site

Ductal® JS1212

1-hr. working time

Heat Enclosure

JS1212 – UHPC Rapid Curing



Engineer's ABC Schedule

Activity	Duration (hrs)
Superstructure & approach roadway removals, backfill excavation	8
Substructure saw-cutting and removal	6
Install precast abutment caps	8
Install superstructure modules	8
Install approach slabs	4
Place UHPC closure pours	5
Cure time for UHPC	12
Total Duration (ABC)	**51 Hrs**

Actual Closure: Fri. 9pm – Mon. 6am ***57-hr.***

Completed Bridge

New Bridge – Underside

Time Lapse Video

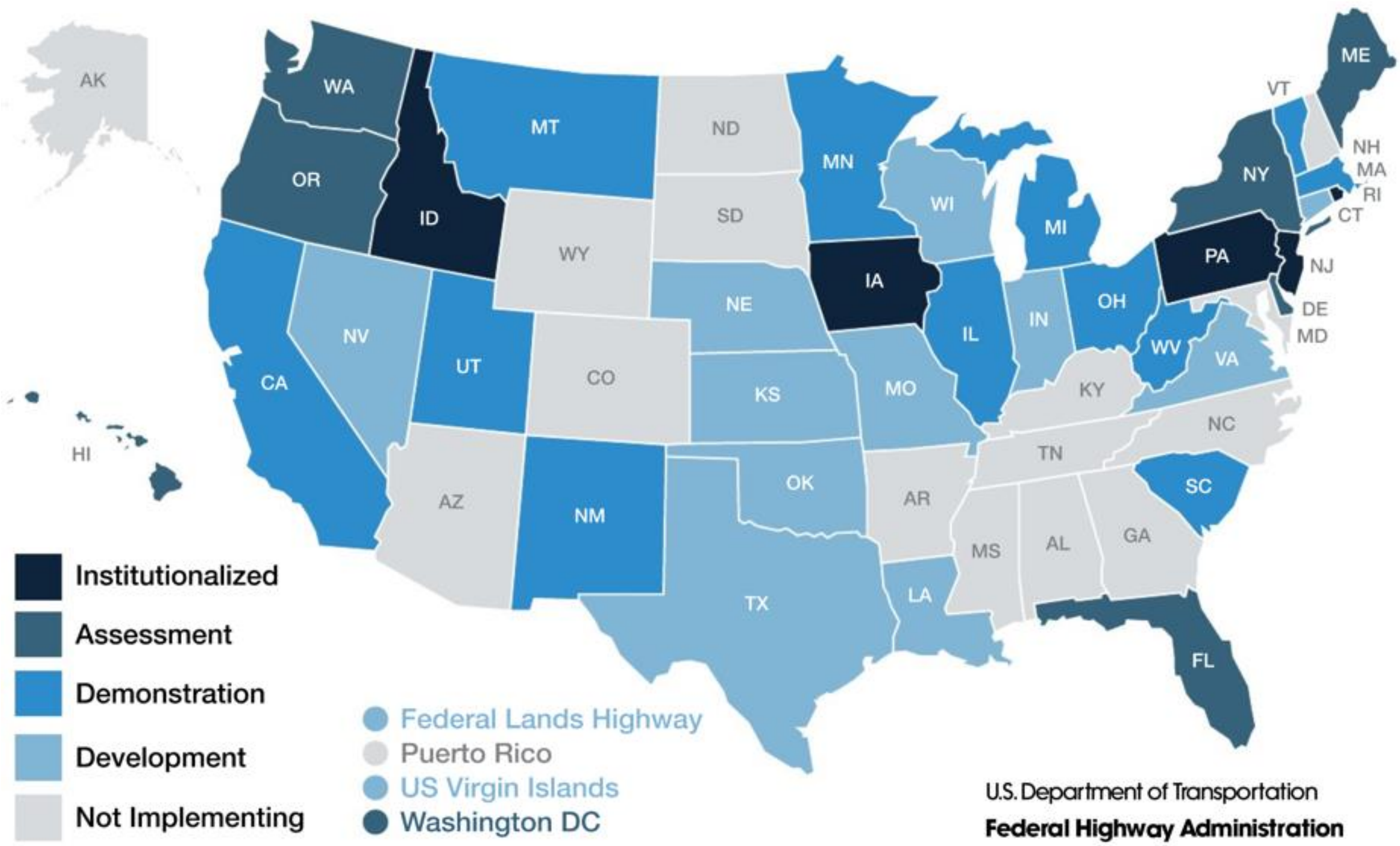
https://www.youtube.com/watch?v=0VMMq0fNWjg

FIU Webinar

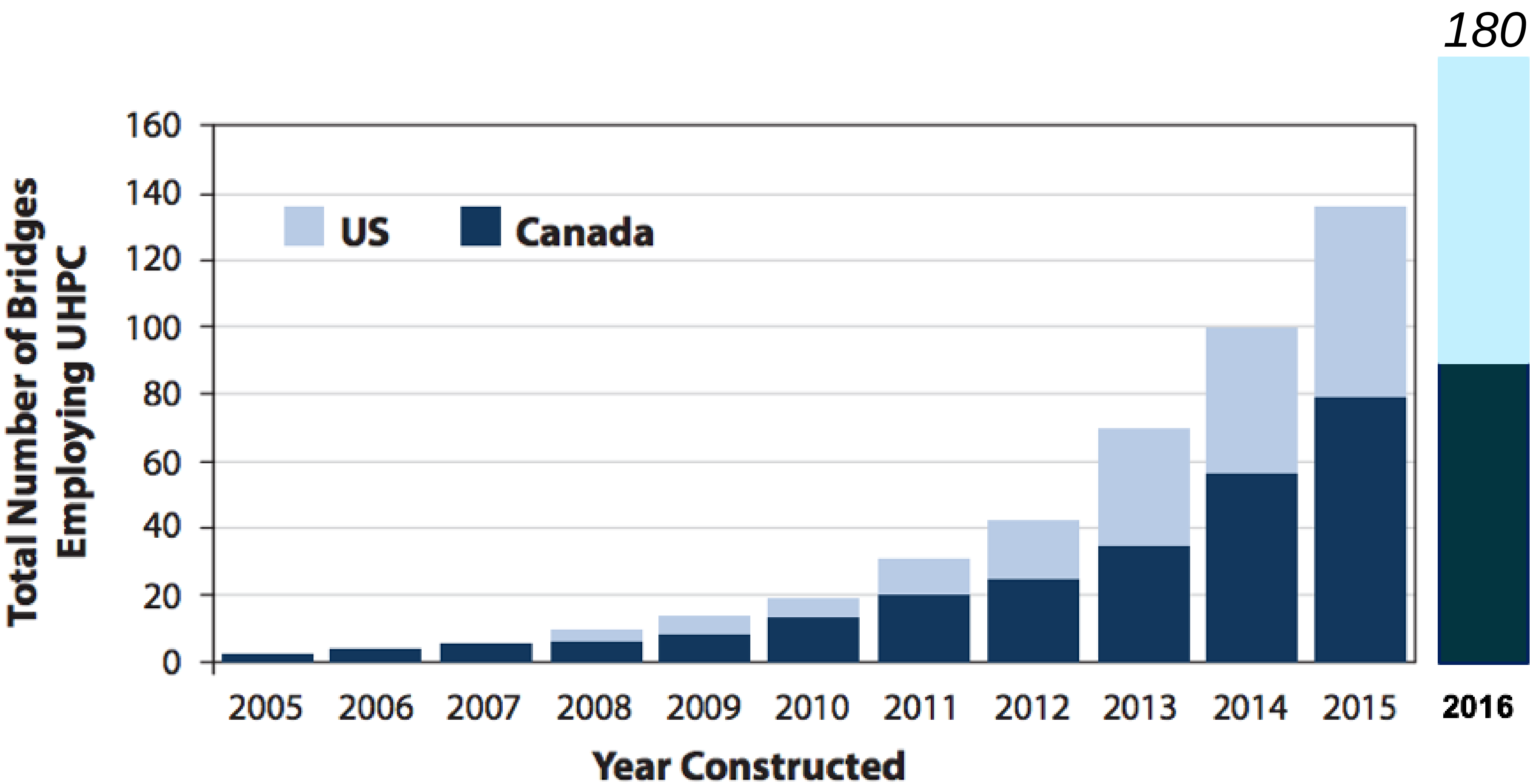

FIU
Accelerated Bridge Construction Center
FLORIDA INTERNATIONAL UNIVERSITY
PennDOT SR 30 over Bessemer Avenue Bridge Replacement
in One Weekend
Louis J. Ruzzi, P.E., PennDOT District 11-0 Bridge Engineer, Pittsburgh area;
John Myler, PennDOT Assistant Construction Engineer, District 11-0;
Bala Sivakumar, P.E., Vice President, Director-Special Bridge Projects, HNTB
Webinar held on 08/25/2016

EDC-3 Final Report

Current (December 2016)



UHPC Project Growth



FHWA / EDC UHPC Webinars

Webinar Topic	Tentative Speakers	Date and Time
1. Introduction to UHPC	Characteristics of UHPC – EDC UHPC Team	March 7, 2017 1 pm – 2:30 pm EST Recorded Version
2. Why UHPC for Prefabricated Bridge Element Connections?	Overview – EDC UHPC Team Superstructure Connections – Iowa DOT Substructure Connections – NYSDOT	April 4, 2017 1 pm – 2:30 pm EST Recorded Version
3. Structural Design, Detailing, and Specifying UHPC for Prefabricated Bridge Element Connections (PBEC)	Overview – EDC UHPC Team Lessons Learned – Iowa State University Franklin Ave. Bridge Rehab Project – MNDOT & Hennepin County	May 9, 2017 1 pm – 2:30 pm EST Recorded Version
4. Construction, Inspection and Quality Assurance of UHPC Connections	Overview – EDC UHPC Team NYSDOT I-81 Case Study Contractor Perspectives on UHPC	June 6, 2017 1 pm – 2:30 pm EST Recorded Version
5. UHPC Implementation Stories	UHPC Implementation –DelDOT UHPC Implementation –GDOT	July 11, 2017 1 pm – 2:30 pm EST Recorded Version
6. Pulaski Skyway– Owner's Perspective	Project Overview – EDC UHPC Team Owner's Perspective and Lessons Learned –NJDOT	August 15, 2017 1 pm – 2:30 pm EST Recorded Version

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FHWA – UHPC Design TechNote

TECHNOTE

Design and Construction of Field-Cast UHPC Connections

FHWA Publication No: FHWA-HRT-14-084

FHWA Contact: Ben Graybeal, HRDI-40, 202-493-3122, benjamin.graybeal@dot.gov

Introduction

Advancements in the science of concrete materials have led to the development of a new class of cementitious composites called ultra-high performance concrete (UHPC). UHPC exhibits mechanical and durability properties that make it an ideal candidate for use in developing new solutions to pressing concerns about highway infrastructure deterioration, repair, and replacement.[1,2] Field-cast UHPC details connecting prefabricated structural elements used for bridge construction have proven to be an application that has captured the attention of owners, specifiers, and contractors across the country. These connections can be simpler to construct and can provide more robust long-term performance than connections constructed through conventional methods.[3] This document provides guidance on the design and deployment of field-cast UHPC connections.

UHPC

UHPC is a fiber-reinforced, portland cement-based product with advantageous fresh and hardened properties. Through the appropriate combination of advancements in superplasticizers, dry constituent gradation, fiber reinforcements, and supplemental cementitious materials, UHPC is able to deliver performance that far exceeds conventional concrete. Developed in the late 20th century, this class of concrete has emerged as a capable replacement for conventional structural materials in a variety of applications.

The Federal Highway Administration (FHWA) defines UHPC as follows:

> 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).[1] UHPC has a discontinuous pore structure that reduces liquid ingress, significantly enhancing durability compared to conventional concrete.[2]

TABLE OF CONTENTS:

[1]The tensile behavior of UHPC may generally be defined as "strain-hardening," a broad term defining concretes in which the sustained post-cracking strength provided by the fiber reinforcement is greater than the cementitious matrix cracking strength. Note that the post-cracking tensile strength and strain capacity of UHPC is highly dependent on the type, quantity, dispersion, and orientation of the internal fiber reinforcement.

U.S. Department of Transportation
Federal Highway Administration
www.fhwa.dot.gov/research

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike, McLean, VA 22101-2296

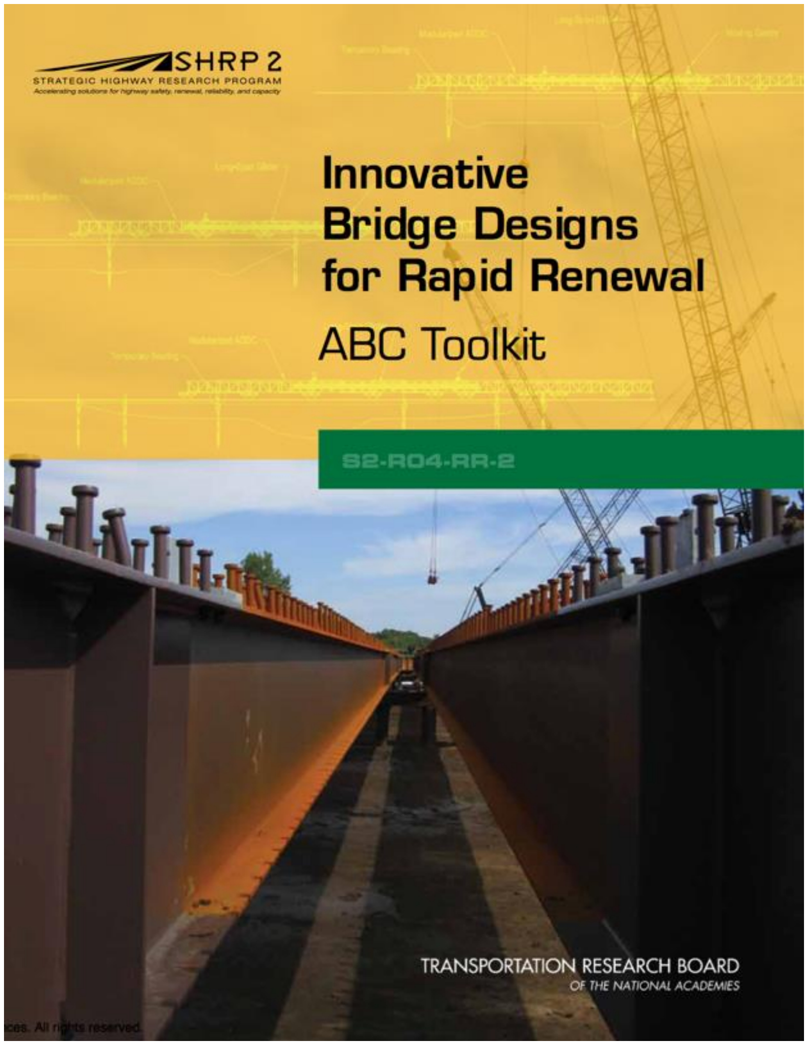
Design of Field-Cast UHPC Connection Details

The following section provides guidance for the structural design of UHPC connection details. This guidance is based on concrete materials and structural engineering research that has been conducted on UHPC-class materials. Guidance is provided in the left column while corresponding commentary is provided in the right column.

Embedment Length of Deformed Steel Reinforcement

Guidance	*Commentary*
The minimum embedment length of deformed steel reinforcement, ℓ_d, shall be taken as $8d_b$ for No. 8 bar and smaller with f_y (yield strength of reinforcing bars) less than or equal to 75 ksi (517 MPa) when the following conditions are met: • Field-cast UHPC with 2-percent (by volume) steel fiber reinforcement and a compressive strength of at least 14 ksi (97 MPa). • Cover $\geq 3d_b$.	Research has demonstrated that deformed steel reinforcement can be developed within comparatively short embedment lengths.[14] An embedment length of $8d_b$ is sufficient for most common reinforcement configurations, including the use of epoxy-coated reinforcement. Increased confinement of the bar, increased compressive strength of the UHPC, and/or decreased bar stress demand can allow shorter embedment lengths. A compressive strength of 14 ksi (97 MPa) is defined here to facilitate use of UHPC in accelerated construction when early application of construction loads to newly completed connections is advantageous. The final compressive strength of UHPC is normally greater than 22 ksi (152 MPa).
The minimum embedment length of deformed steel reinforcement meeting the above conditions with 75 ksi (517 MPa) $< f_y \leq$ 100 ksi (689 MPa) shall be taken as $10d_b$.	The increased stress and strain demand of high-strength reinforcement necessitates an increase in the embedment length.
The minimum embedment length of deformed steel reinforcement with $f_y \leq$ 100 ksi (689 MPa) and with $2d_b \leq$ minimum cover $< 3d_b$ shall be increased by $2d_b$.	A decrease in the cover results in reduced confinement of the bar and thus an increase in the embedment length.

SHRP2 – ABC Toolkit



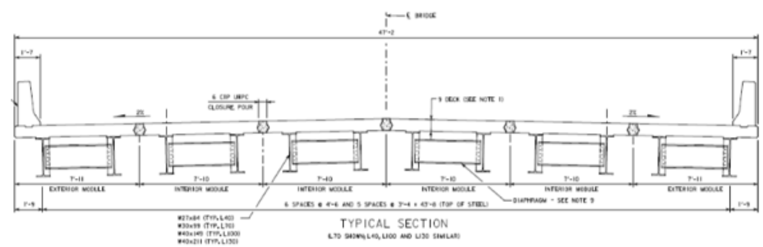
CONCRETE DECKED STEEL GIRDER DESIGN FOR ABC

This document shows the procedure for the design of a steel girder bridge with precast deck element for use in a rapid bridge replacement design in Accelerated Bridge Construction (ABC). This sample calculation is intended as an informational tool for the practicing bridge engineer. These calculations illustrate the procedure followed to develop a similar design but shall not be considered fully exhaustive.

This sample calculation is based on the *AASHTO LRFD Bridge Design Specifications* (Fifth Edition with 2010 interims). References to the *AASHTO LRFD Bridge Design Specifications* are included throughout the design example. AASHTO references are presented in a dedicated column in the right margin of each page, immediately adjacent to the corresponding design procedure.

An analysis of the superstructure was performed using structural modeling software. The design moments, shears, and reactions used in the design example are taken from the output, but their computation is not shown in the design example.

BRIDGE GEOMETRY:



Design member parameters:

Deck Width:	$w_{deck} := 47ft + 2in$	C. to C. Piers:	$Length := 70ft$
Roadway Width:	$w_{roadway} := 44ft$	C. to C. Bearings	$L_{span} := 67ft + 10in$
Skew Angle:	$Skew := 0deg$	Bridge Length:	$L_{total} := 3 \cdot Length = 210\,ft$
Deck Thickness	$t_d := 10.5in$	Stringer	W30x99
Haunch Thickness	$t_h := 2in$	Stringer Weight	$w_{s1} := 99plf$
Haunch Width	$w_h := 10.5in$	Stringer Length	$L_{str} := Length - 6 \cdot in = 69.5\,ft$
Girder Spacing	$spacing_{int} := 3ft + 11in$	Average spacing of adjacent beams. This value is used so that effective deck width is not overestimated.	
	$spacing_{ext} := 4ft$		

N-ABC Conference – 12/2017

Many presentations include UHPC topics!

PRE-CONFERENCE WORKSHOPS - PRELIMINARY

A series of workshops will be held the day before the conference on Wednesday, December 6, 2017.

W-04: Ultra-High Performance Concrete Connections for Prefabricated Bridge Elements

8:00 a.m. to 12:00 p.m.

Field-cast UHPC details connecting prefabricated bridge elements have proven to be an application that has captured the attention of owners, specifiers, and contractors across the U.S. These connections can be simpler to construct and can provide more robust long-term performance than connections constructed through conventional methods. This workshop will introduce attendees to this technology including background on UHPC, details on connection design, specification and construction considerations, as well as examples of deployed applications.

Speakers (invited): Benjamin Graybeal, FHWA; Mark Leonard, FHWA; Zachary Haber, Genex Systems LLC

2IISUHPC Symposium – 2019

Thank You

Questions?