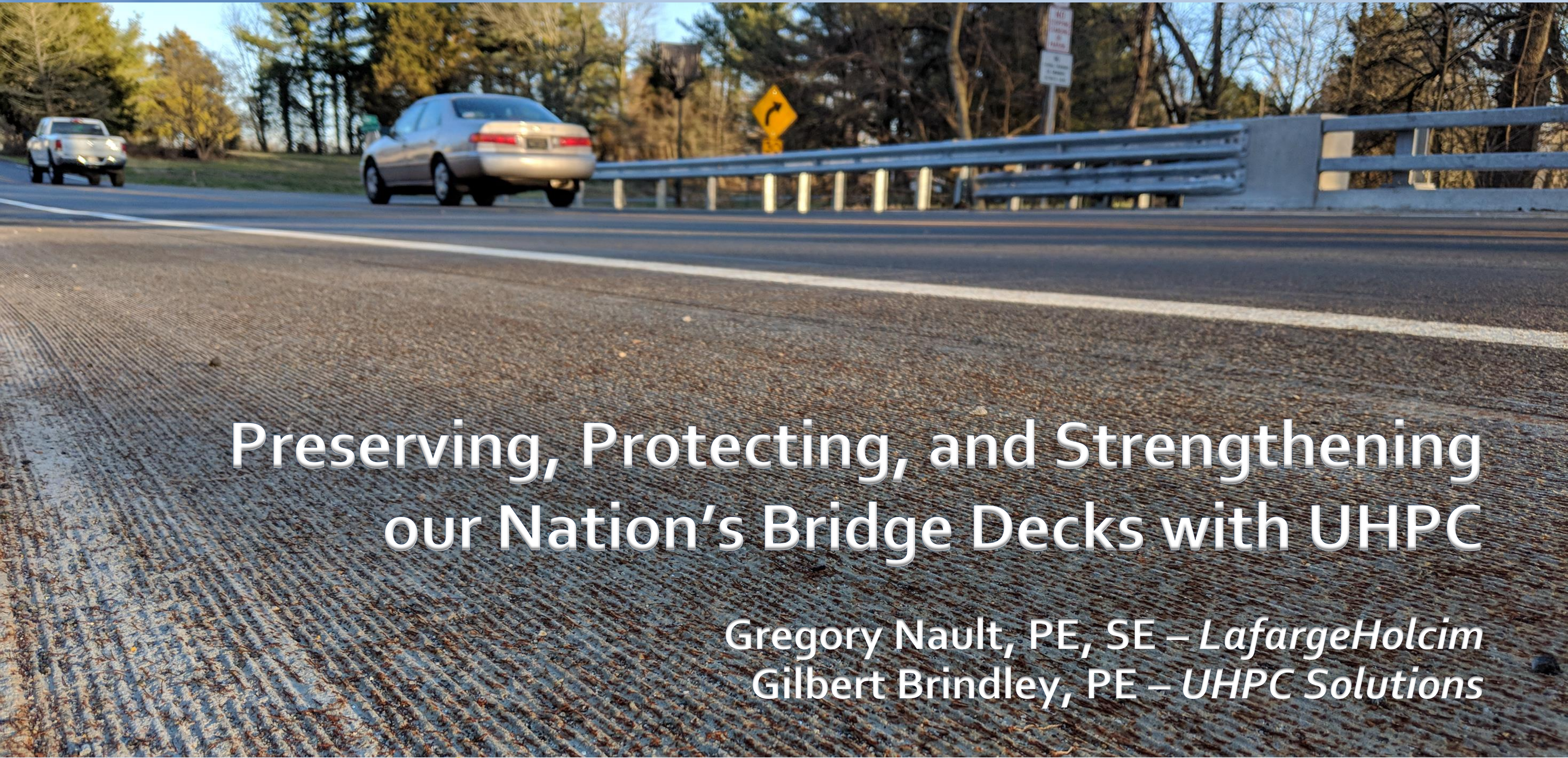


Preserving, Protecting, and Strengthening our Nation's Bridge Decks with UHPC

Gregory Nault, PE, SE – *LafargeHolcim*
Gilbert Brindley, PE – *UHPC Solutions*

UHPC: Ultra-High Performance Concrete

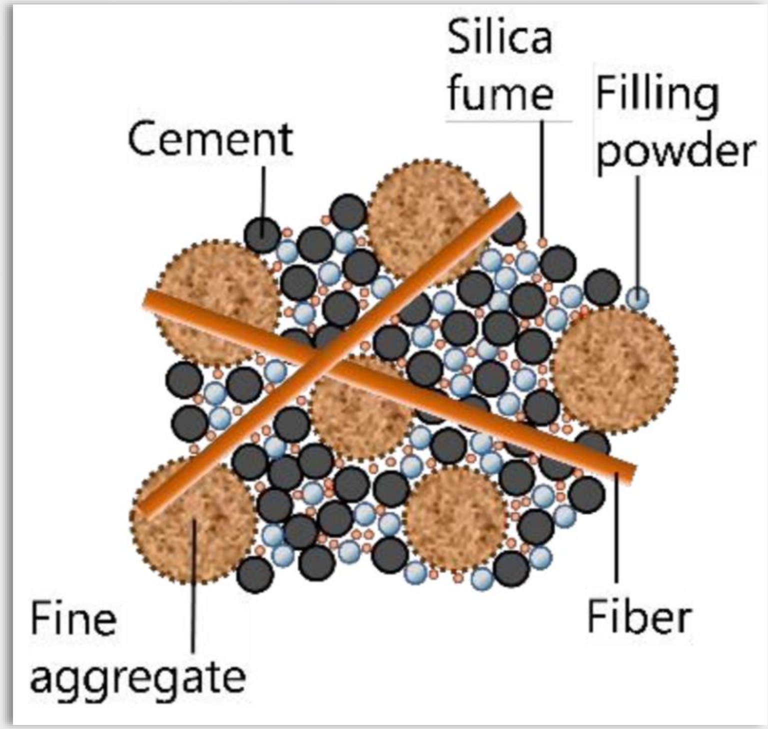
"UHPC is a cementitious composite material composed of an optimized gradation of granular constituents, a water-to-cementitious materials ratio less than **0.25**, and a high percentage of discontinuous internal fiber reinforcement. The mechanical properties of UHPC include compressive strength greater than **21.7 ksi** (150 MPa) and sustained post-cracking tensile strength greater than **0.72 ksi** (5 MPa)."

FHWA

UHPC PROPERTIES

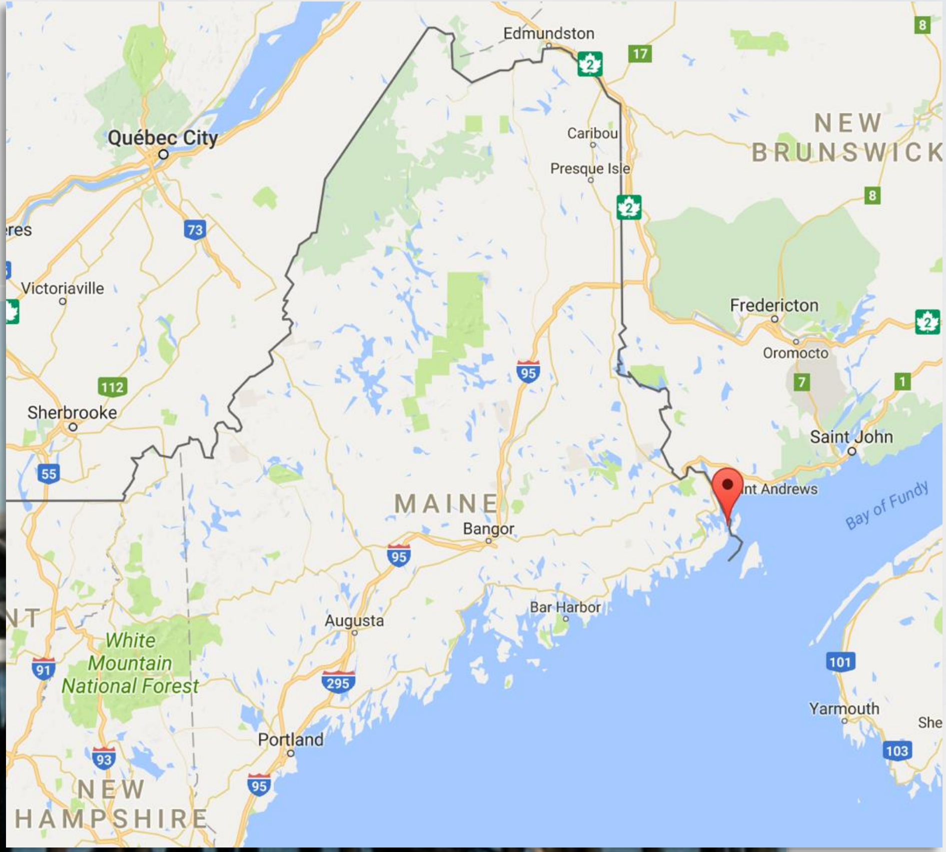
Property	Value
Unit weight	158 lb/ft^3 (2,535 kg/m^3)
Modulus of elasticity	7,500–8,500 ksi (52–59 GPa)
Compressive strength	25–32 ksi (170–220 MPa)
Post-cracking tensile strength	1.0–1.5 ksi (7.0–10.3 MPa)
Chloride ion penetrability (ASTM C1202-12)(4)	Very low to negligible

Material Constituents



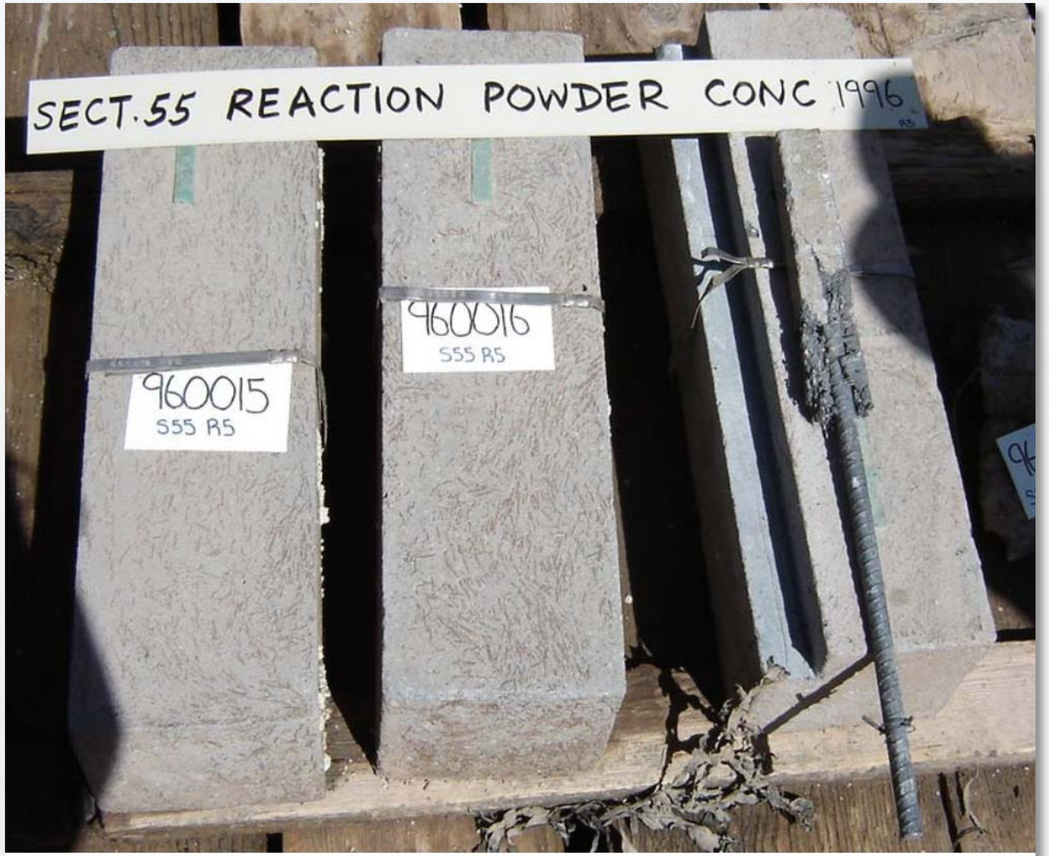
W/C Ratio < 0.25

Treat Island, ME – USACE

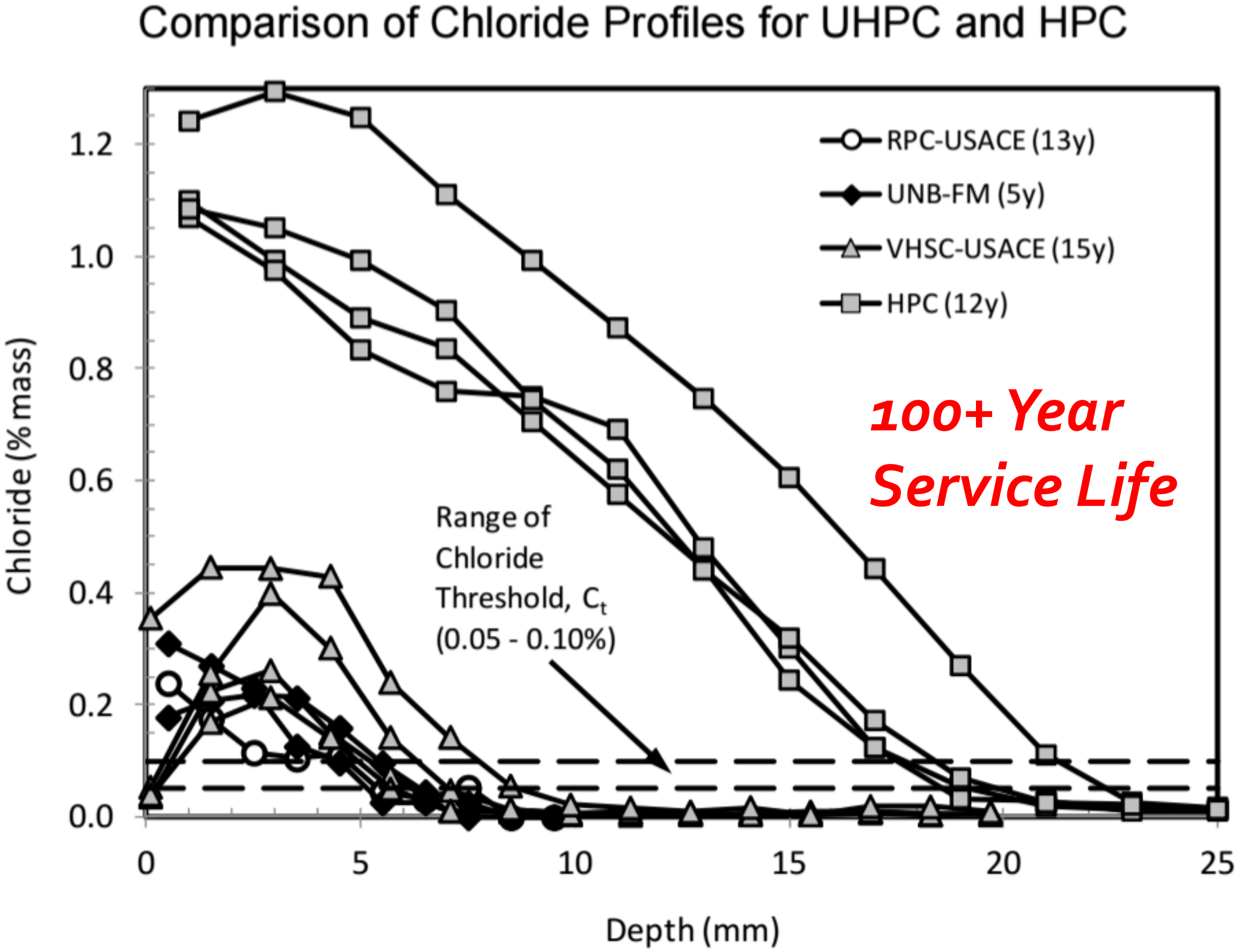


Longest Running UHPC Durability Study (20+ years)

Chloride & Freeze/Thaw Resistance



In 2006 – Rebar at 10-mm (3/8-inch) cover removed from one of the 10-year-old beams



UHPC COVER REQUIREMENTS

Table 4.202 — Values of minimum cover $c_{min,dur}$ requirements with regard to durability for reinforcement steel compliant with EN 10080

Environmental requirement for $c_{min,dur}$ (mm)							
Structural class	Exposure class according to Table 4.1						
	X0	XC1	XC2/XC3	XC4	XD1/XS1	XD2/XS2	XD3/XS3
S1	-	5	5	10	10	15	15
S2		5	10	10	15	15	20
S3		5	10	15	15	20	20
S4		10	15	15	20	20	20
S5		10	15	20	20	20	25
S6		15	20	20	20	25	25

NF P 18-710

BRIDGE DECK DAMAGE

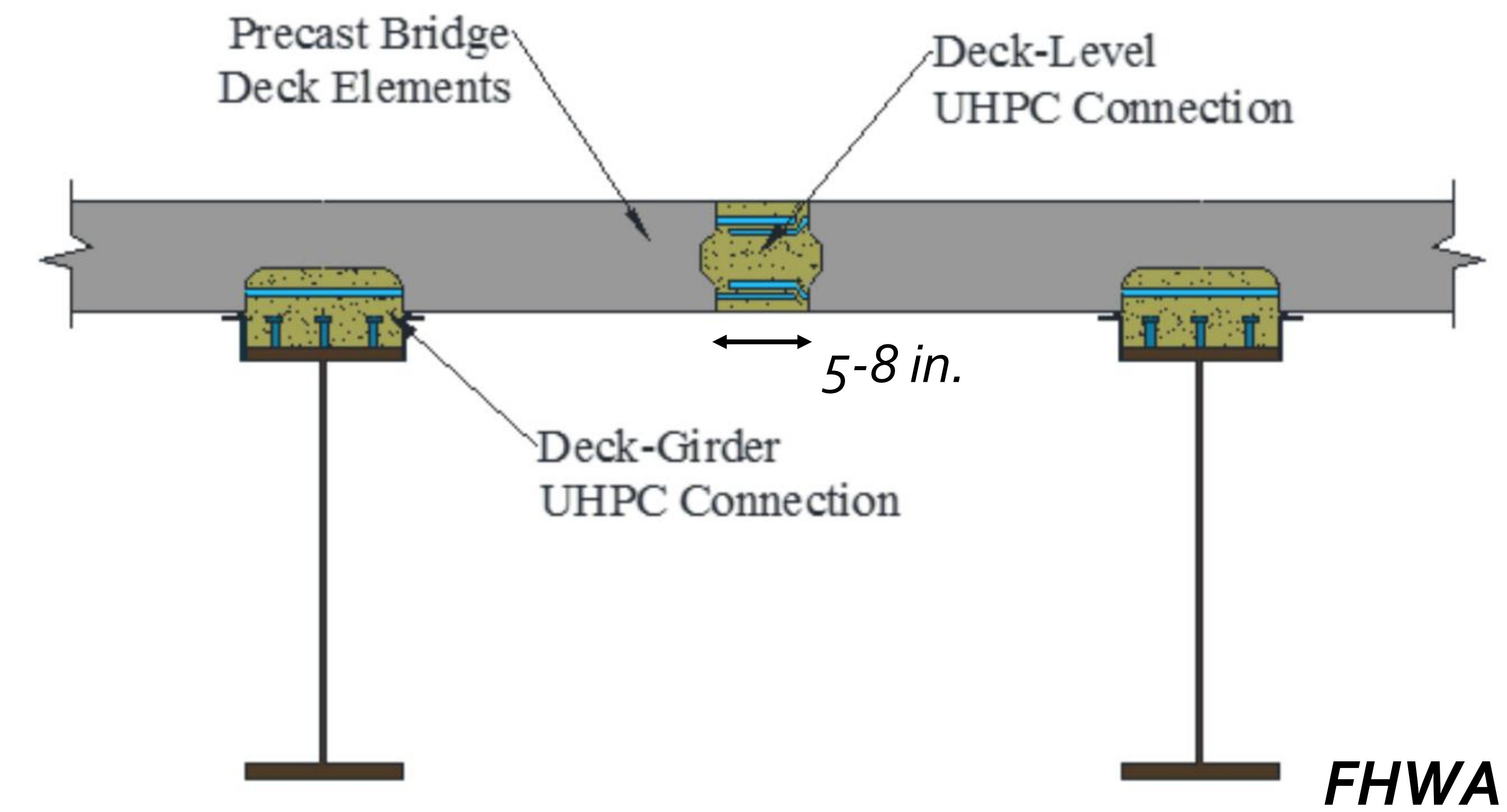
TYPICAL DETERIORATION MECHANISMS

Cracking
(shrinkage, ASR, loading)

Spalling
(freeze/thaw, carbonation, corrosion)

Corrosion
(chloride/acid penetration)

PBE + UHPC CONNECTIONS



FHWA PUBLICATIONS – UHPC CONNECTIONS

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.

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Guidance

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 $\geq 3d_b$.

For lap splices of straight lengths of deformed steel reinforcement, the lap-splice length, ℓ_s, shall be at least $0.75\ell_d$.

- ❖ Embedment > $8d_b$
- ❖ Lap Splice > $0.75 \times 8d_b$

TECHBRIEF

Adjacent Box Beam Connections: Performance and Optimization

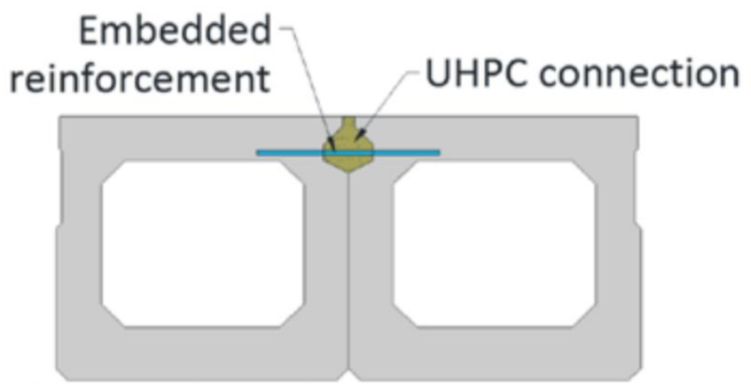
FHWA Publication No.: FHWA-HRT-17-094

Ben Graybeal, HRDI-40, (202) 493-3122, benjamin.graybeal@dot.gov.

This document is a technical summary of the Federal Highway Administration (FHWA) report, *Box Beam Bridges: Testing of Conventional Grout and Ultra-High Performance Concrete Connection Details* (FHWA-HRT-17-093).[1]

Introduction

Precast, prestressed concrete adjacent box beams are widely used in short- and medium-span bridges in the United States. However, a recurring issue with this type of bridge is the deterioration of shear key connections resulting in substandard performance of the overall bridge system. This research



(c) Partial-Depth UHPC Connection

provide specific guidance for the design or construction of

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Ductal® UHPC Products

PRODUCT DATA SHEET

JS1000

Ductal®

LAFARGE Building better cities™

JS1000

Field-cast UHPC closure pour solutions for prefabricated bridge element connections

DESCRIPTION:
Ductal® JS1000 is an ultra-high performance concrete (UHPC) that offers superior strength, durability, ductility, and bond capacity compared to conventional and high performance concretes and grouts. Composed of an optimized gradation of fine granular particles and a water-to-cementitious ratio less than 0.25, Ductal® is denser than conventional concrete giving it a discontinuous pore structure that attributes to remarkable imperviousness and durability against liquid ingress, chloride penetration, freeze-thaw, abrasion, scaling, chemical attack, alkali reactivity, and carbonation.

Internally reinforced with millions of discrete steel fibers (2% by volume, typ.), Ductal® JS1000 is extremely strong in compression and flexible in bending. Cracking is controlled and maintained at microscopic levels, ensuring impermeability and long-term durability against adverse conditions, aggressive agents and environments.

APPLICATIONS:
Ductal® JS1000 is primarily used as a closure pour material to connect prefabricated structural elements on-site. Its fluidity, strength, and enhanced bond properties make it ideal for this application; enabling engineers and contractors to create optimized, durable designs using precast systems. Typical applications include: beam haunch connections and connections between Precast Deck Panels, Deck Bulb-Tees, Next D Beams, and Adjacent Box Beams for bridge structures. Other applications include: link slabs, expansion joint headers, and pier jackets.

TYPICAL MATERIAL PROPERTIES
In accordance with ASTM C1856 / C1856M.
Material and curing conditions at 73°F (23°C) and 50% R.H.(1)

Density	150 - 160 lb/ft³ (2,400 – 2,565 kg/m³)	
Flow	7 to 10 in. (175 to 250 mm) diameter without visible sign of fiber segregation	
Working Time / Set Time	approx. 120 min. / 15 to 18 hrs	
Compressive Strength(2)	> 14 ksi (100 MPa)(3)	at 4 days (4,5)
Compressive Strength(2)	> 21 ksi (150 MPa)	at 28 days
Tensile Strength(6)	> 725 psi (5 MPa)	at 28 days
Modulus of Elasticity	> 6,500 ksi (45 GPa)	at 28 days
Long-term Shrinkage	< 800 microstrain	at 28 days
Chloride Ion Penetrability	< 250 coulombs (very low)	at 56 days
Freeze -Thaw Resistance	> 96% RDM	at 300 cycles

(1) Field results may differ depending on mixing/test methods, equipment used, temperature, and site/curing conditions.
(2) Compression tests are performed on 3 in. x 6 in. (75 mm x 150 mm) cylinders with ends ground flush prior to testing.
(3) 14 ksi (100 MPa) is the typical minimum compressive strength required before application of design live load for most closure pour applications; consult the Engineer or Project Specifications to verify.
(4) 4 days or less is typical when the ambient curing temperature is greater than 60°F (16°C). For colder temperatures, an accelerating admixture may be required to obtain 14 ksi (100 MPa) in 4 days.
(5) For 14 ksi (100 MPa) compressive strength in 12-36 hours, consider using rapid-set Ductal® JS1212.
(6) This test measures the sustainable, post-cracking, direct tension strength of a mix with 2% (by volume) steel fibers.

PRODUCT DATA SHEET

JS1212

Ductal®

LAFARGE Building better cities™

JS1212

Field-cast Rapid-Set UHPC closure pour solutions for Accelerated Bridge Construction

DESCRIPTION:
Ductal® JS1212 is a rapid-set ultra-high performance concrete (UHPC) that offers superior strength, durability, ductility and bond capacity, compared to conventional and high performance concretes and grouts. Composed of an optimized gradation of fine granular particles and a water-to-cementitious ratio less than 0.25, Ductal® is denser than conventional concrete giving it a discontinuous pore structure that attributes to remarkable imperviousness and durability against liquid ingress, chloride penetration, freeze-thaw, abrasion, scaling, chemical attack, alkali reactivity, and carbonation.

Internally reinforced with millions of discrete steel fibers (2% by volume, typ.), Ductal® JS1212 is extremely strong in compression and flexible in bending. Cracking is controlled and maintained at microscopic levels, ensuring impermeability and long-term durability against adverse conditions, aggressive agents and environments.

APPLICATIONS:
Ductal® JS1212 is primarily used as a rapid-set closure pour material to connect prefabricated structural elements on-site to accelerate a project's construction schedule. Similar to Ductal® JS1000, its fluidity, strength, and enhanced bond capability make it ideal for this application, enabling engineers and contractors to create optimized, durable designs using precast systems. Ductal® JS1212, however, can reach the required design strength in as little as 12 hours (when supplemented with external heat during initial cure). Typical applications include: connections between Precast Deck Panels, Deck Bulb-Tees, Next D Beams, and Adjacent Box Beams for bridge structures.Other applications include: link slabs, expansion joint headers, and pier jackets.

TYPICAL MATERIAL PROPERTIES
In accordance with ASTM C1856 / C1856M.
Material and curing conditions at 73°F (23°C) and 50% R.H.(1)

Density	150 - 160 lb/ft³ (2,400 – 2,565 kg/m³)	
Flow	7 to 10 in. (175 to 250 mm) diameter without visible sign of fiber segregation	
Working Time / Set Time	approx. 45 min. / 2 to 3 hrs	
Compressive Strength(2)	> 12 ksi (80 MPa)	at 12 hours(3)
Compressive Strength(2)	> 14 ksi (100 MPa)(4)	at 36 hours(5)
Compressive Strength(2)	> 19 ksi (130 MPa)(6)	at 28 days
Compressive Strength(2)	> 21 ksi (150 MPa)	at 56 days
Tensile Strength(7)	> 725 psi (5 MPa)	at 28 days
Modulus of Elasticity	> 6,500 ksi (45 GPa)	at 28 days
Long-term Shrinkage	< 800 microstrain	at 28 days
Chloride Ion Penetrability	< 500 coulombs (very low)	at 56 days
Freeze -Thaw Resistance	> 96% RDM	at 300 cycles

(1) Field results may differ depending on mixing/test methods, equipment used, temperature, and site/curing conditions.
(2) Compression tests are performed on 3 in. x 6 in. (75 mm x 150 mm) cylinders with ends ground flush prior to testing.
(3) 12 ksi (80 MPa) in 12 hours is only achievable if external heat is provided to raise the internal curing temperature of the material to greater than 120°F (49°C).
(4) 14 ksi (100 MPa) is the typical minimum compressive strength required before application of design live load for most closure pour applications; consult the Engineer or Project Specifications to verify.
(5) 36 hours or less is typical when the ambient curing temperature is greater than 60°F (16°C).
(6) A reduced 28 day strength (compared to Ductal® JS1000) is common due to the acceleration of the initial strength gain.
(7) This test measures the sustainable, post-cracking, direct tension strength of a mix with 2% (by volume) steel fibers.

PRODUCT DATA SHEET

TX1000

Ductal®

LAFARGE Building better cities™

TX1000

Field-cast UHPC structural overlay solutions

DESCRIPTION:
Ductal® TX1000 is an ultra-high performance concrete (UHPC) that offers superior strength, durability, water tightness, excellent bond, ductility and allows thinner overlays compared to conventional concretes. Composed of an optimized gradation of fine granular particles and a water-to-cementitious ratio less than 0.25, Ductal® is denser than conventional concrete giving it a discontinuous pore structure that attributes to remarkable imperviousness and durability against liquid ingress, chloride penetration, freeze-thaw, abrasion, scaling, chemical attack, alkali reactivity, and carbonation.

Internally reinforced with discrete steel fibers (min. of 3.25% by volume), Ductal® TX1000 is extremely strong in compression and flexible in bending. Cracking is controlled and maintained at microscopic levels, ensuring impermeability and long-term durability against adverse conditions, aggressive agents and environments.

APPLICATIONS:
Ductal® TX1000 is a thixotropic mix which allows it to hold a slope up to 10%, making it ideal for all types of bridge deck configurations. The material has an initial fluidity that allows placement with vibration (such as a concrete paver). This will produce a smooth finish, maintain shape and hold the slope when the consolidation process is completed. Its fluidity, strength and enhanced bond capability make it ideal for overlay applications, thereby enabling engineers and contractors to create optimized, durable designs.

MECHANICAL PROPERTIES at 28 days(1) (Use appropriate factors for design)

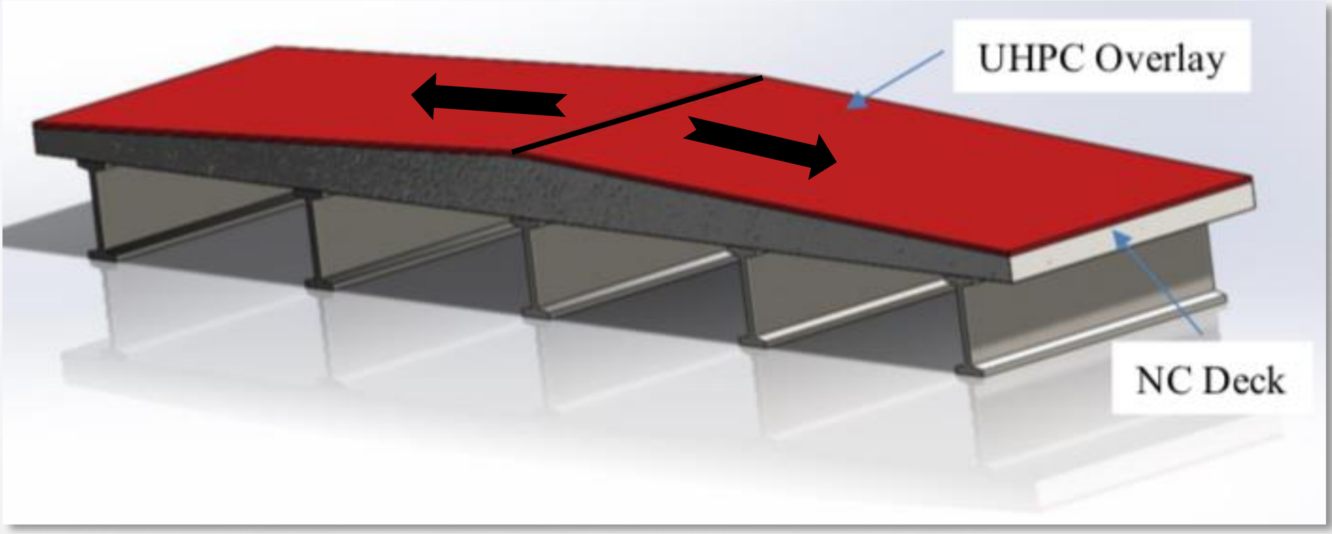
Elastic tensile strength	f_{Utek}	1,160 psi	8.0 MPa
Tensile strength	f_{Utuk}	1,300 psi	9.0 MPa
Strain when the tensile strength is reached	e_{Utu}	0.38%	
Compressive strength	f_{Uck}	18 ksi	120 MPa
Modulus of Elasticity	E_{Um}	6,500 ksi	45 GPa

(1) Field results may differ depending on mixing/test methods, equipment used, temperature, and site/curing conditions.

THIXOTROPIC BEHAVIOR

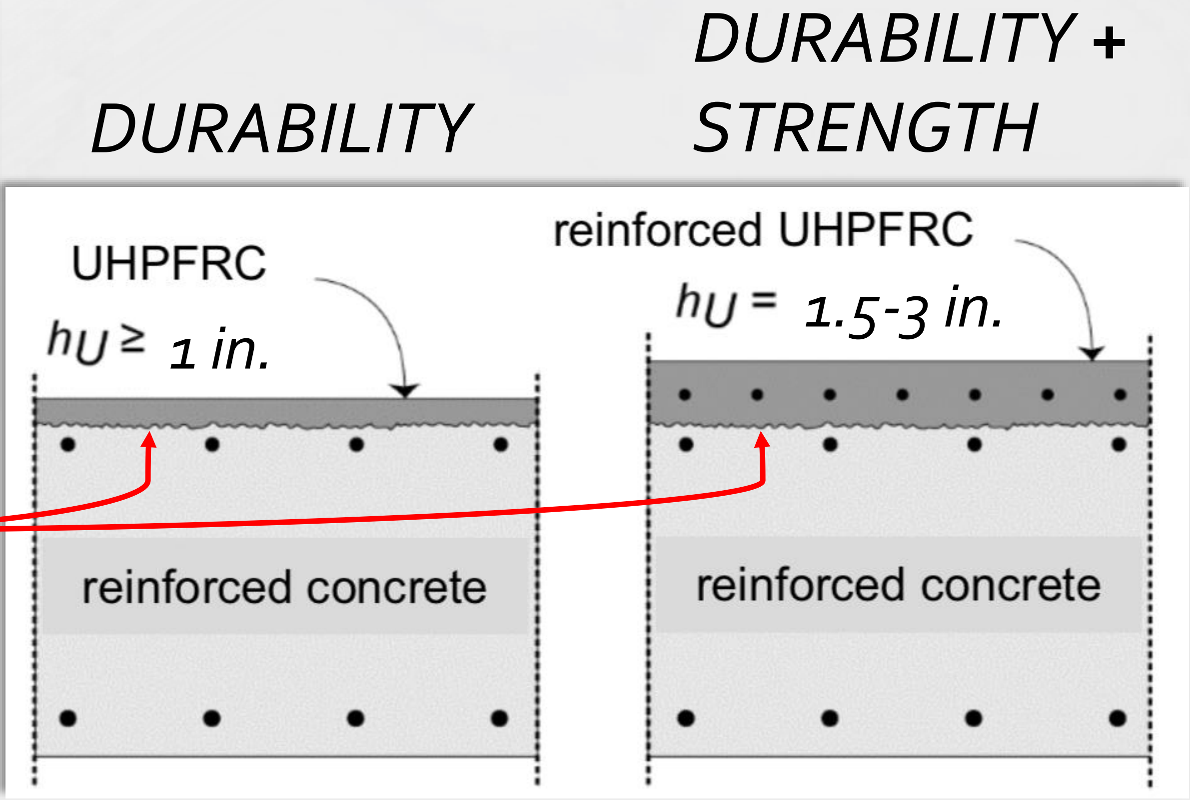
For overlays, the rheology must be adjusted from self-leveling to rheo-thinning behavior (thixotropic)

UHPC OVERLAY CONCEPT



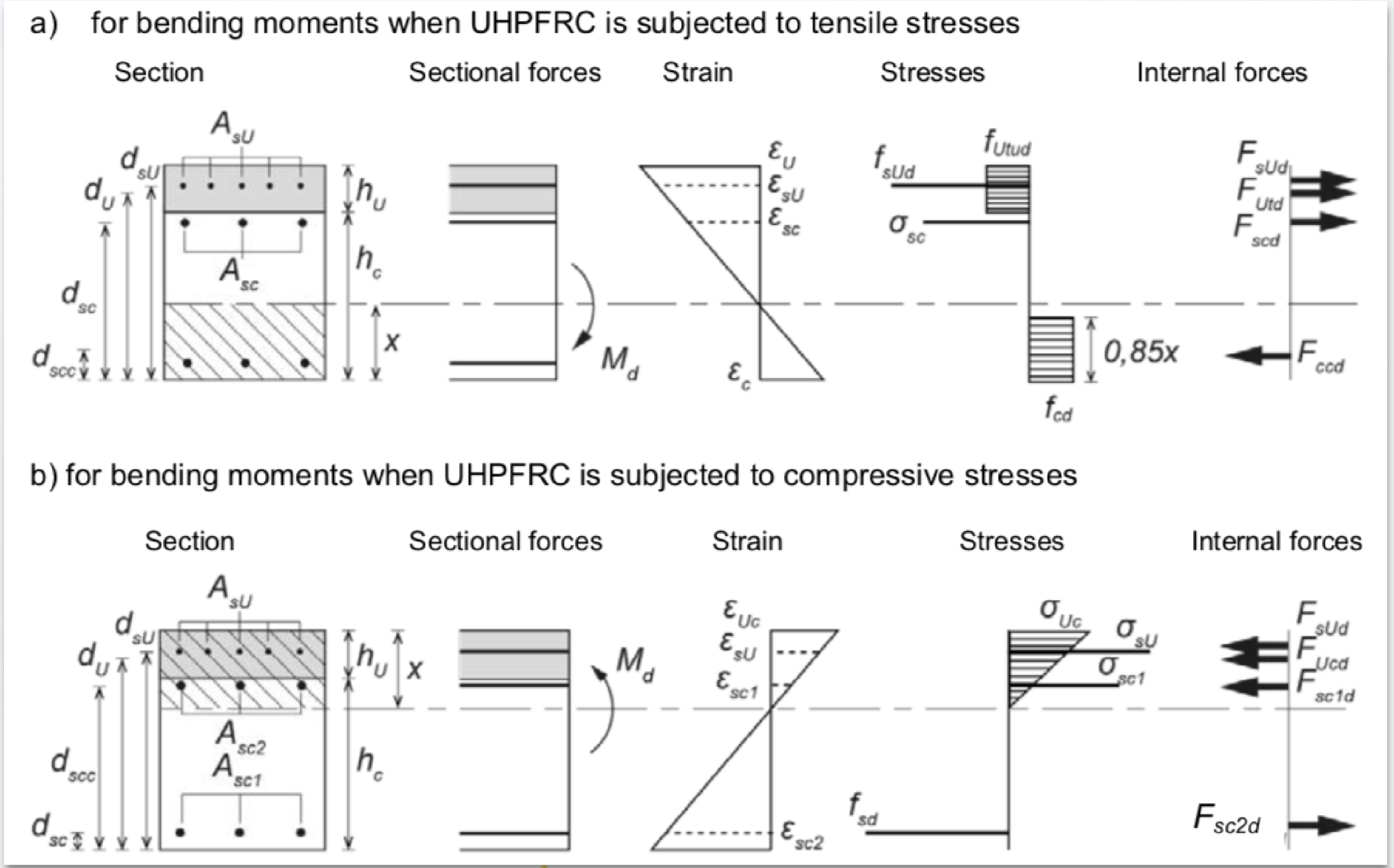
Structurally Composite Bond

Remove existing contaminated & deteriorated concrete surface before placing UHPC overlay.



Basic configurations of the UHPFRC-concrete composite construction method

UHPC DESIGN



MCS MAINTENANCE CONSTRUCTION SÉCURITÉ
INSTITUT D'INGÉNIERIE CIVILE

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Recommendation:

Ultra-High Performance Fibre Reinforced Cement-based composites (UHPFRC)

Construction material, dimensioning und application

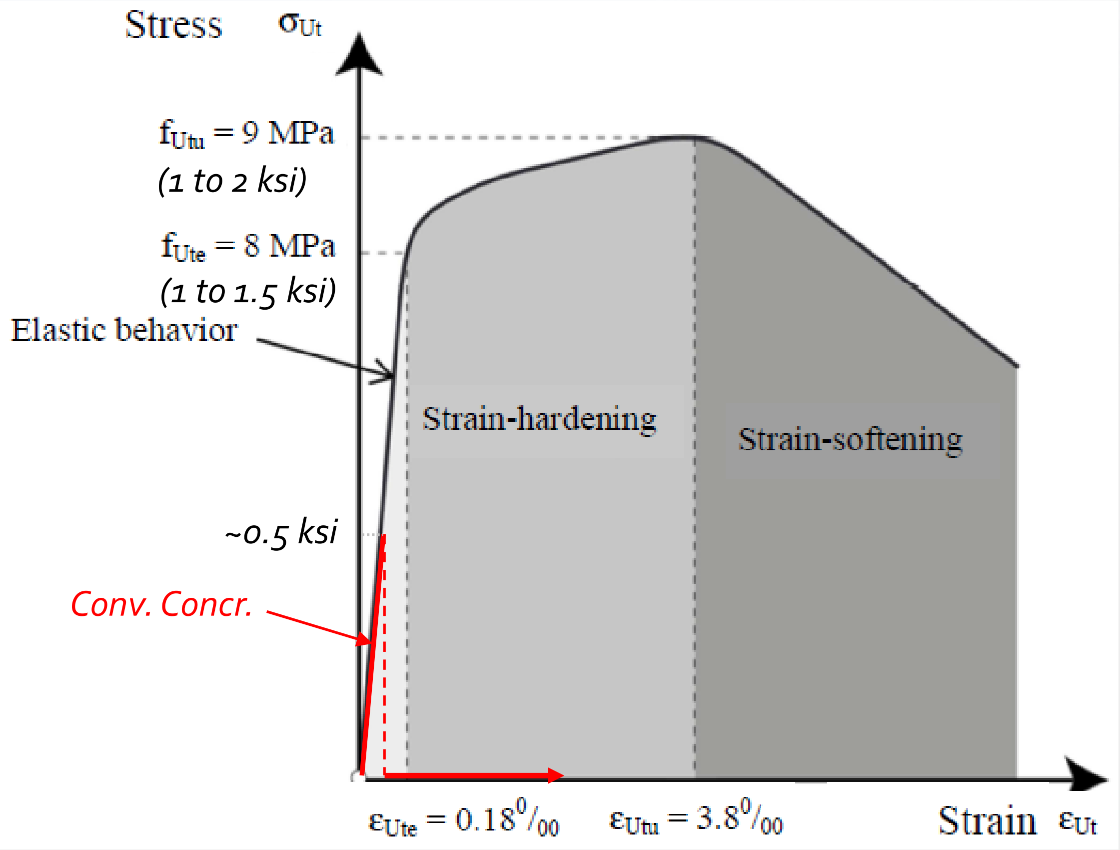
English translation of the Technical Leaflet SIA 2052 with adaptations

For internal use

MCS-EPFL Lausanne, Switzerland, 17 April 2016

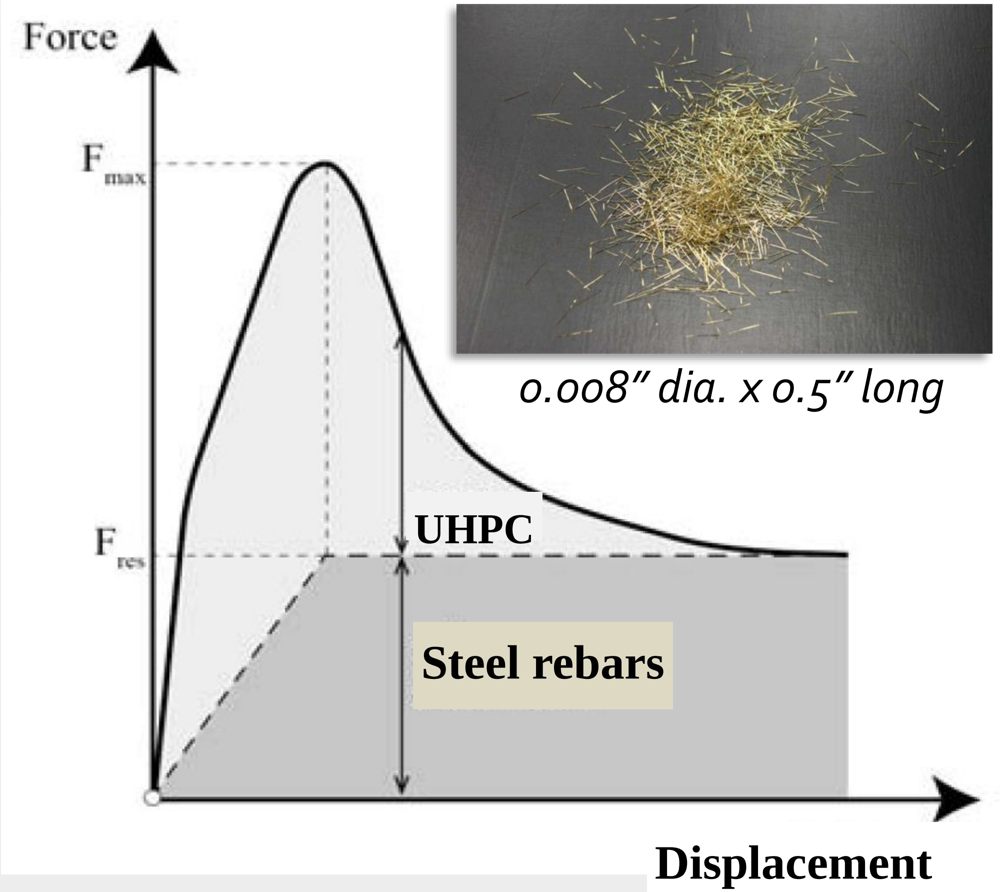
Adress:
EPFL-Swiss Federal Institute of Technology
MCS-Maintenance, construction and safety of structures
Station 18
CH-1015 Lausanne, Switzerland

TENSILE BEHAVIOR



w/ 3.25% steel fiber reinforcement (no rebar)

Steel Fibers



0.008" dia. x 0.5" long

PUBLICATIONS – UHPC OVERLAY

TECHNOTE

Ultra-High Performance Concrete for Bridge Deck Overlays

FHWA Publication No.: FHWA-HRT-17-097

FHWA Contacts: Ben Graybeal, HRDI-40, 202-493-3122, benjamin.graybeal@dot.gov; Zach Haber, HRDI-40, 202-493-3469, zachary.haber@dot.gov

Introduction

There is urgent need for effective and durable rehabilitation solutions for deteriorated highway bridge decks. Deck deterioration is commonly caused by a combination of vehicle loading, freeze–thaw degradation, cracking, delamination of cover concrete, and/or corrosion of internal reinforcement. Deteriorated bridge decks are commonly rehabilitated using overlays depending on the cause of deck deterioration, available budget, and desired service life of the rehabilitated structure. Common overlay materials include conventional concretes, high-performance concretes (HPCs), latex-modified concretes (LMCs), asphalt with waterproofing membranes, and polymer-based materials. The performance objectives of bridge deck overlays include protecting the underlying deck and reinforcement from contaminates, providing additional strength and stiffness to the deck system, and extending the service life of the overall structure.

One emerging solution for bridge deck rehabilitation is thin, bonded ultra-high performance concrete (UHPC) overlays. As an overlay material, UHPC can provide both structural strengthening and protection from ingress of contaminates using a 1-inch (25-mm) to 2-inch (51-mm) layer of material. This minimizes required material volume and can minimize additional dead load on the bridge structure compared with some traditional overlay solutions. The concept and use of UHPC overlays has been researched in Europe and has been deployed on more than 20 European bridges.[1]

This TechNote introduces UHPC as a potential solution for bridge deck overlays. A brief review of the history and development of UHPC is presented, followed by a summary of the properties that make UHPC a viable overlay solution. A laboratory investigation on the tensile bond strength of a UHPC specially formulated for overlay applications is then presented. This investigation provides a comparison between UHPC and LMC overlays using different substrate materials and surface preparations. Lastly, this TechNote highlights the findings of a field study and subsequent

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Field Testing of an Ultra-High Performance Concrete Overlay

PUBLICATION NO. FHWA-HRT-17-096 SEPTEMBER 2017

U.S. Department of Transportation
Federal Highway Administration

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

Use of Ultra-High-Performance Concrete for Bridge Deck Overlays

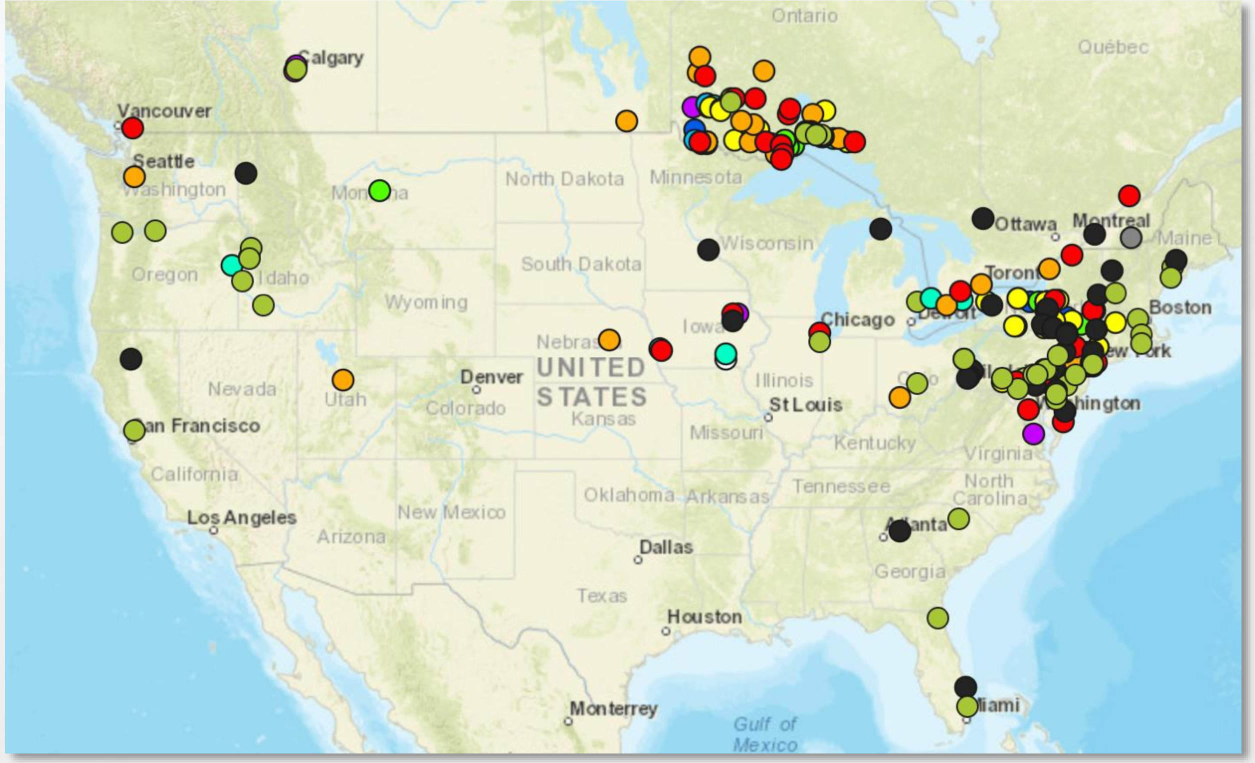
Final Report
March 2018

BRIDGE ENGINEERING CENTER

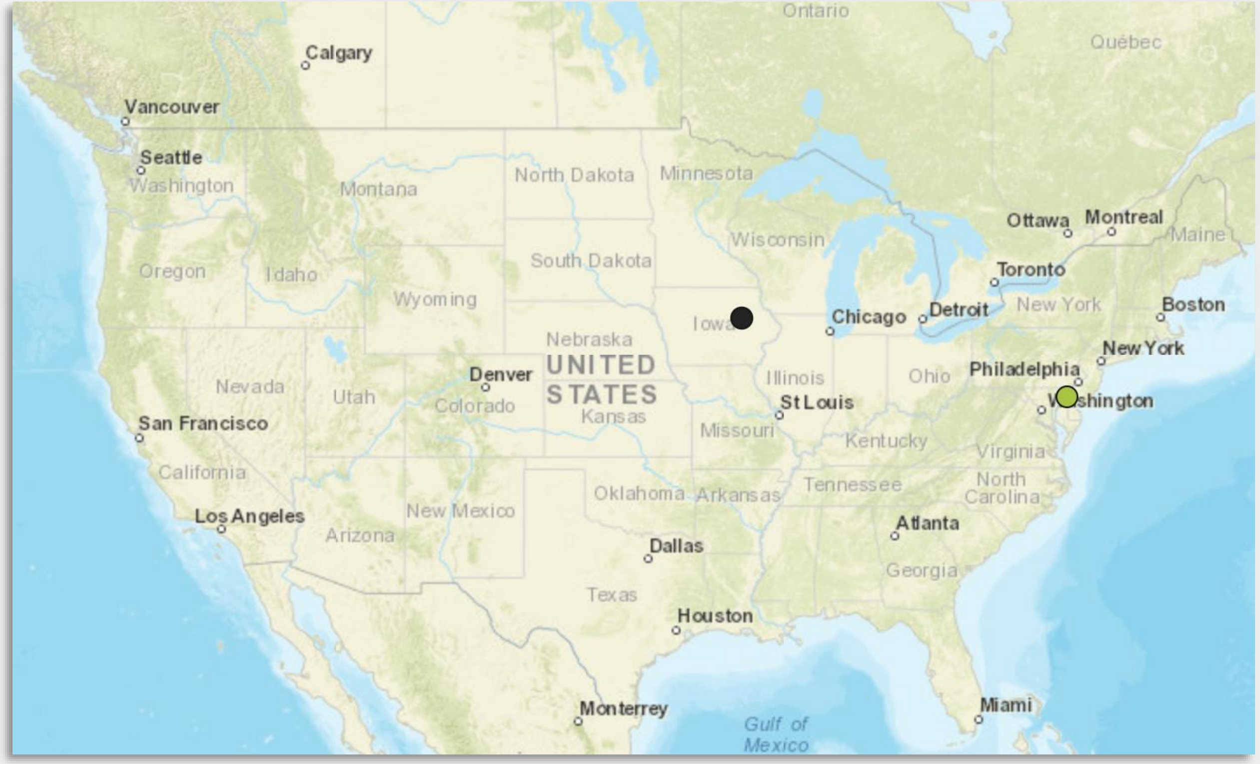
IOWA STATE UNIVERSITY
Institute for Transportation

Sponsored by
Iowa Highway Research Board
(IHRB Project TR-683)
Iowa Department of Transportation
(InTrans Projects 16-573 and 16-574)
Federal Highway Administration

COMPLETED UHPC BRIDGE PROJECTS

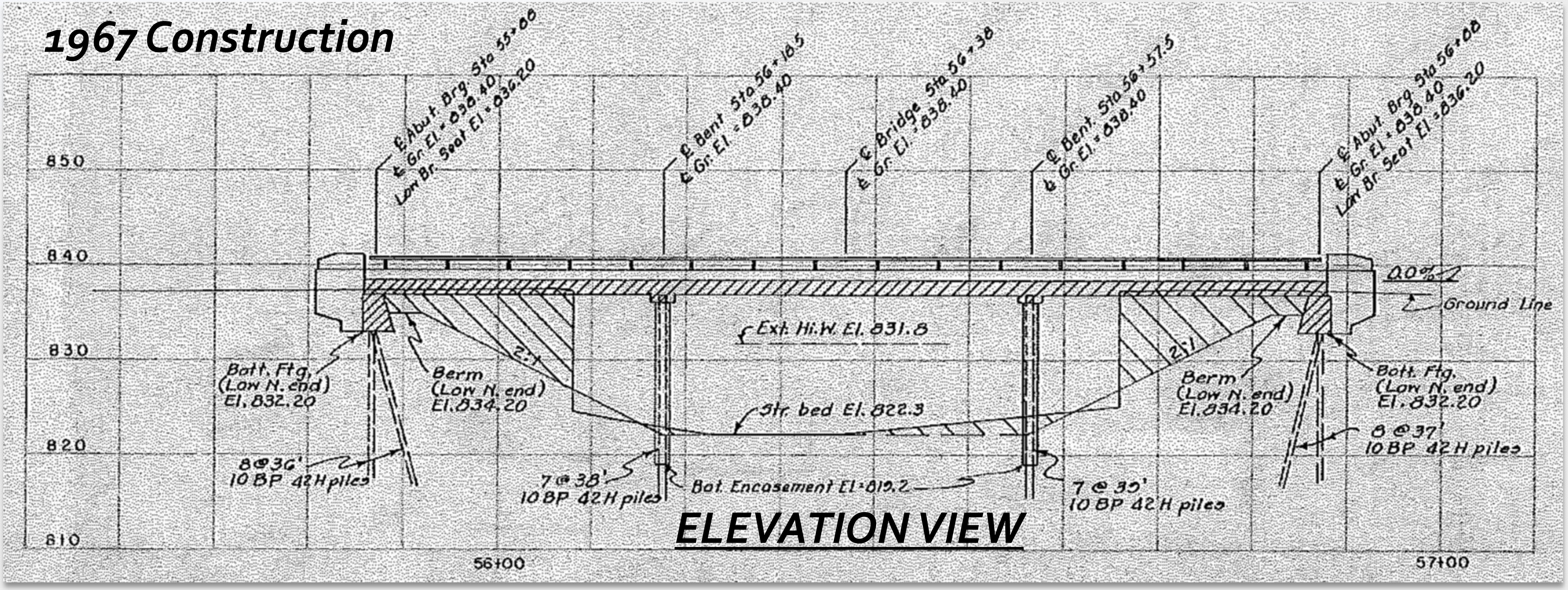


All UHPC Applications (200+)



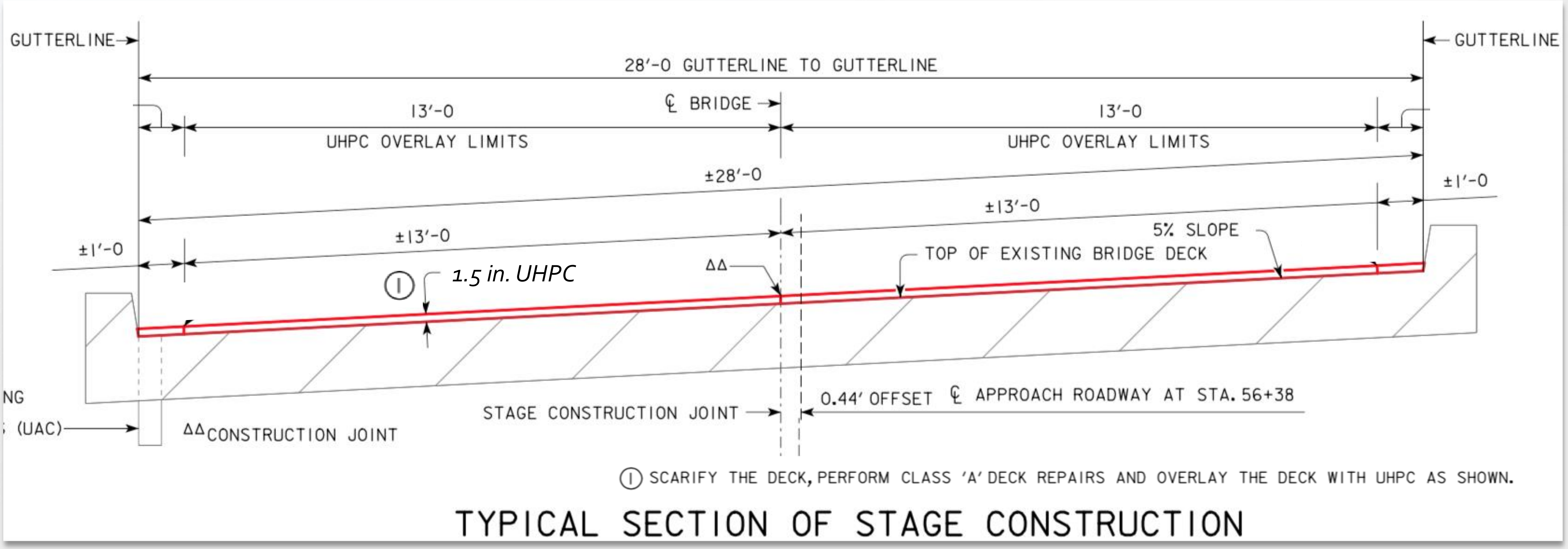
UHPC Overlay (2)

MUD CREEK BRIDGE, IOWA



EXISTING BRIDGE

PROPOSED UHPC OVERLAY REHAB



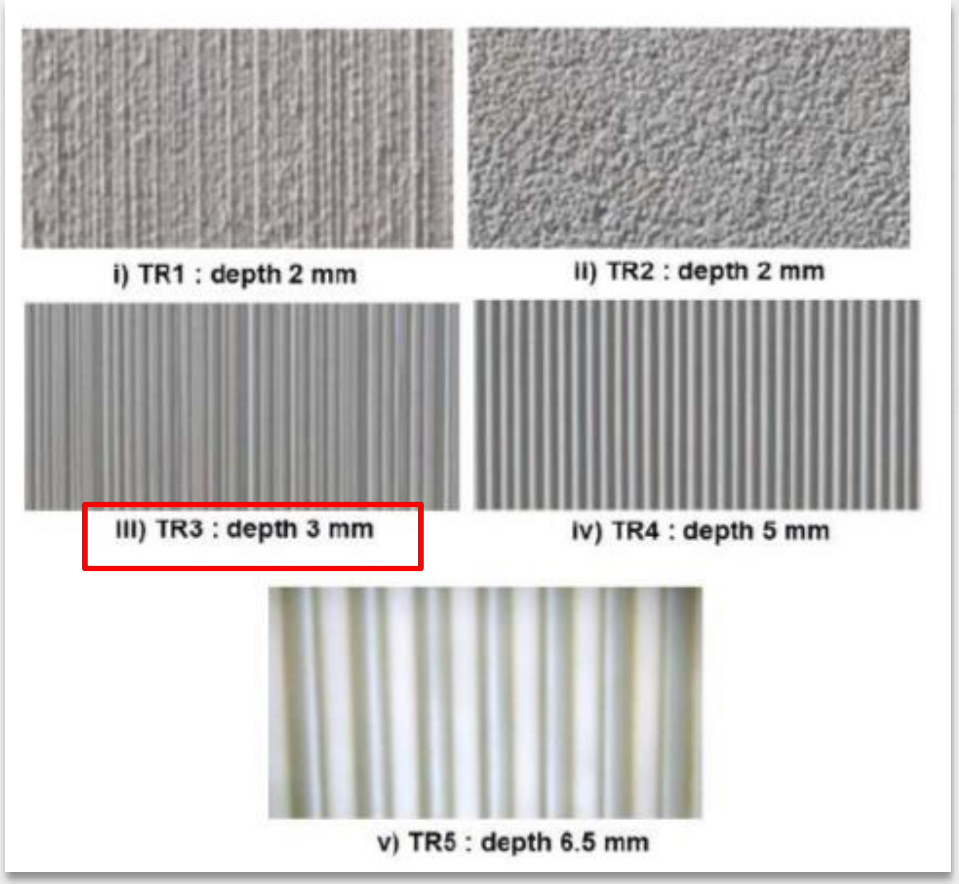
PRE-CONSTRUCTION MOCK-UP

Preparing for UHPC Placement

SURFACE PREP

- Roughened Surface
  - **Milling**
  - Hydro Demolition
- Saturated Surface

ROUGHENED SURFACE



Study by Iowa State University

ON-SITE MIXING

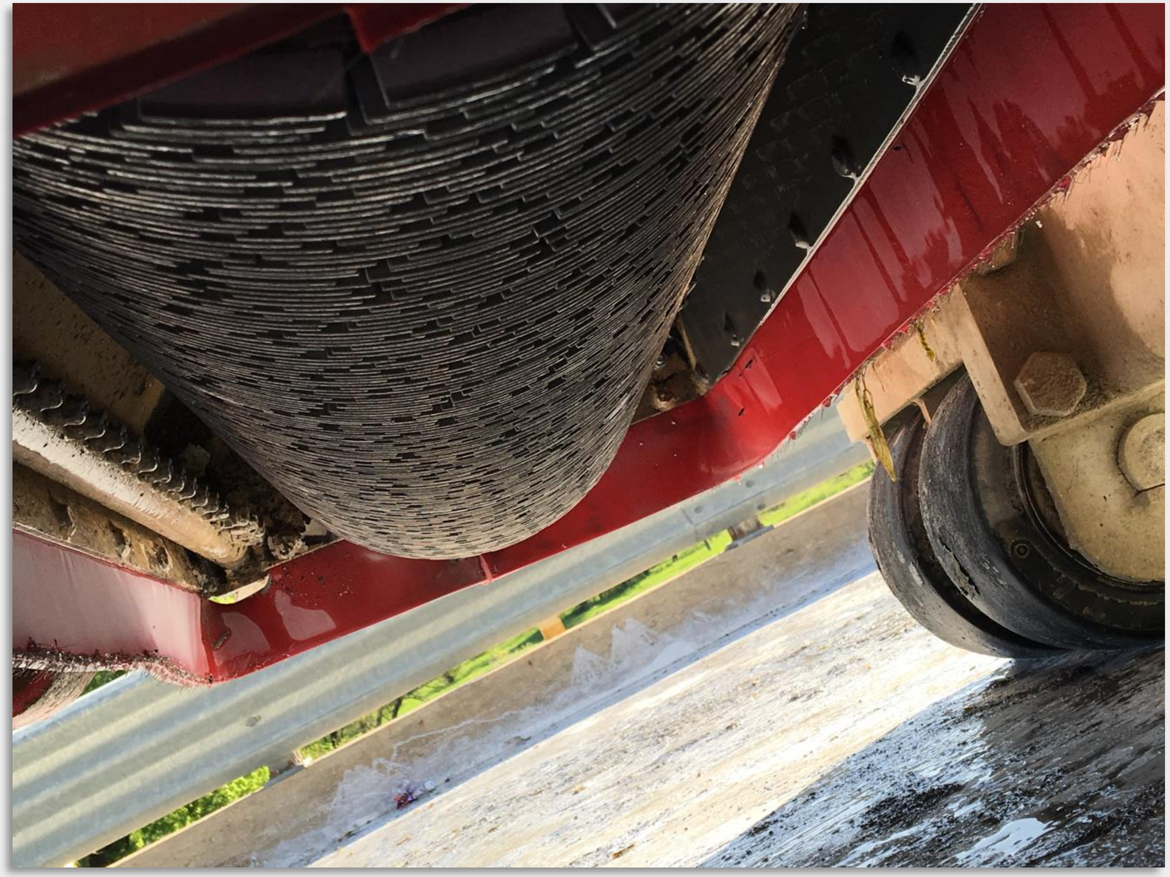
On-Site QC Testing

MATERIAL PLACEMENT

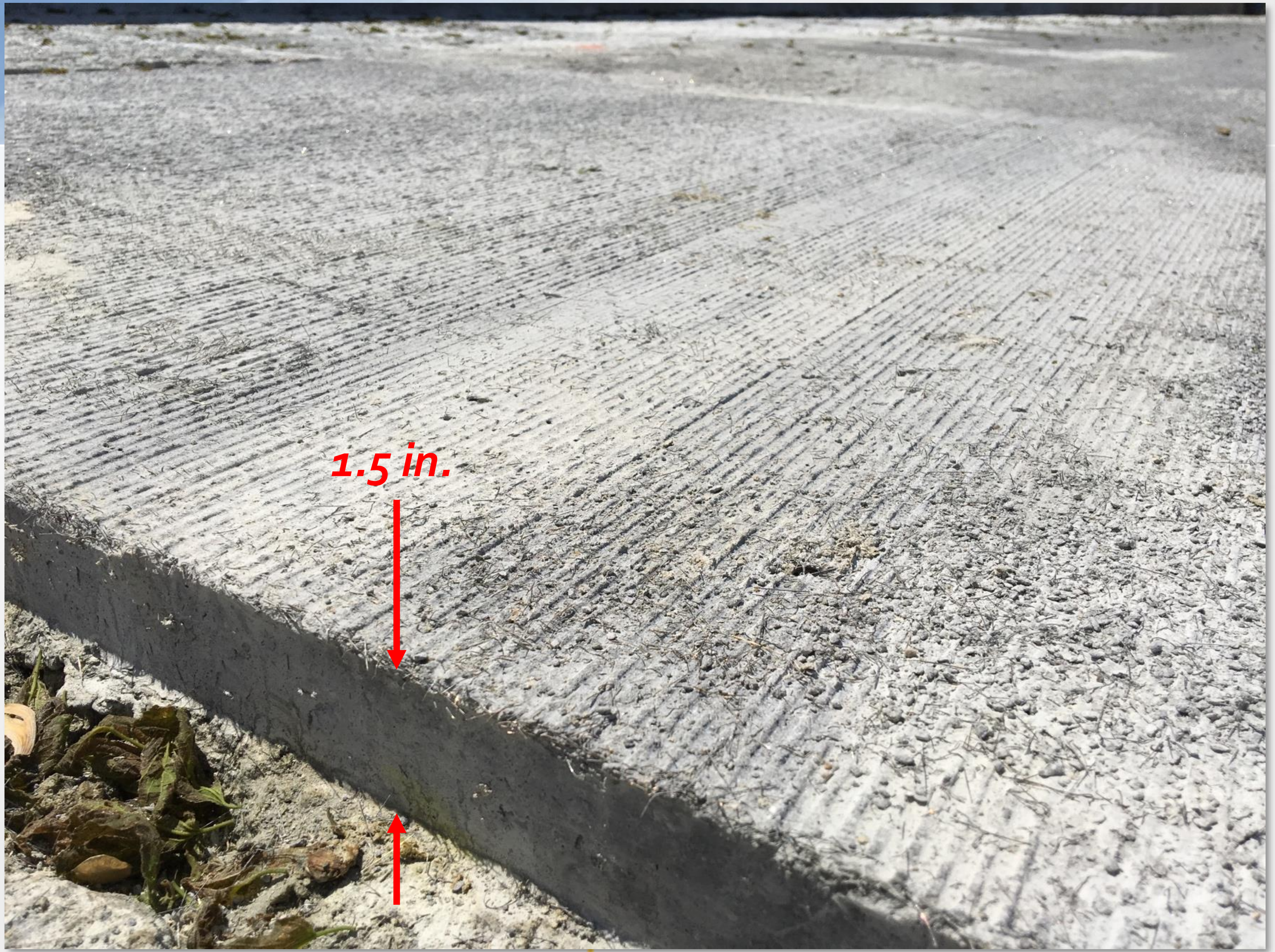
CURING – STAGE I


Poured May 16, 2016
Poured May 11, 2016

MILLING MACHINE

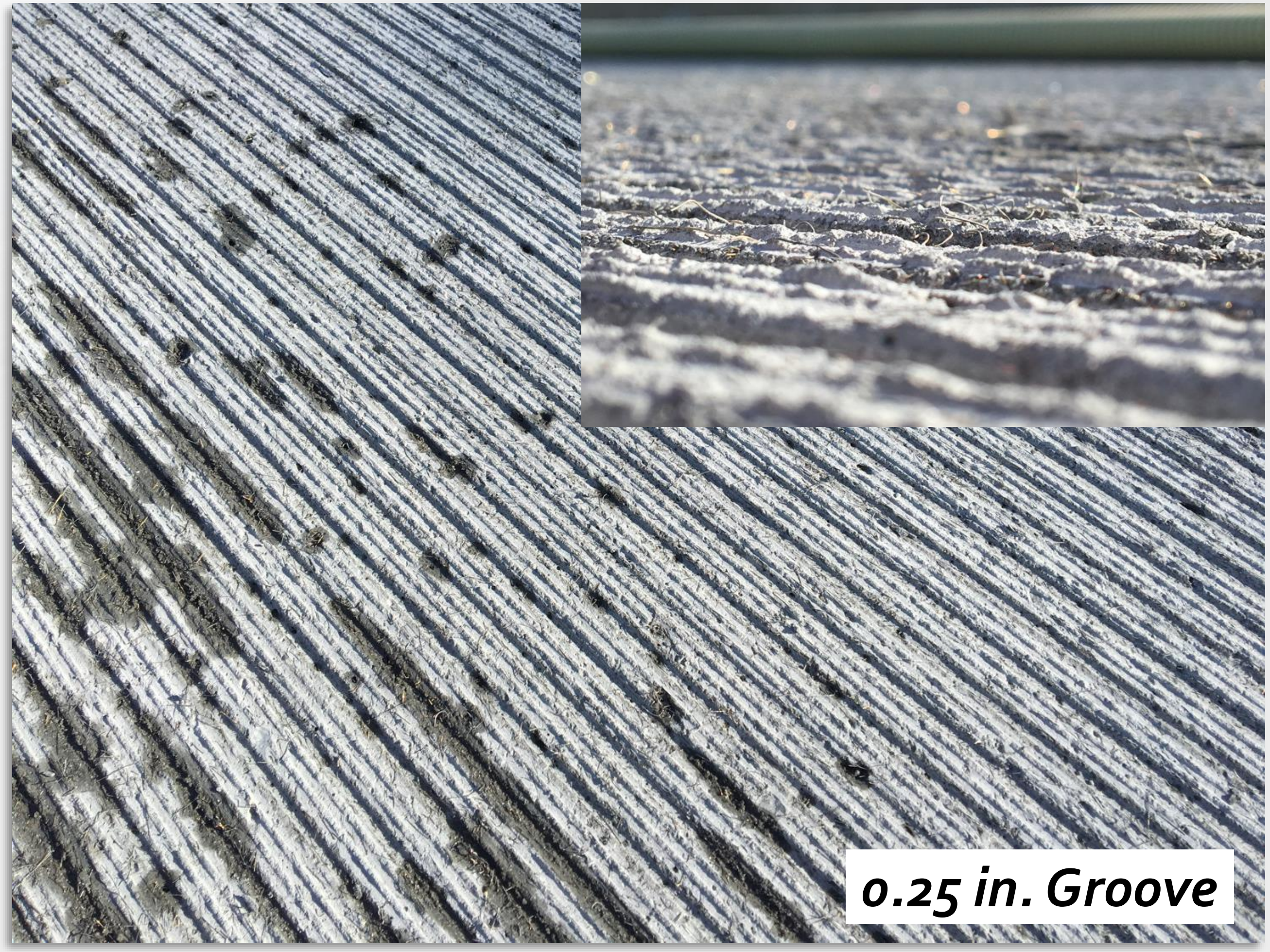


SURFACE GRINDING


1.5 in.


Milled Surface

SURFACE GROOVING




May 19, 2016
0.25-in. Milled Surface
w/ 0.25-in. Grooved Finish

RIDING SURFACE – 1 YR LATER

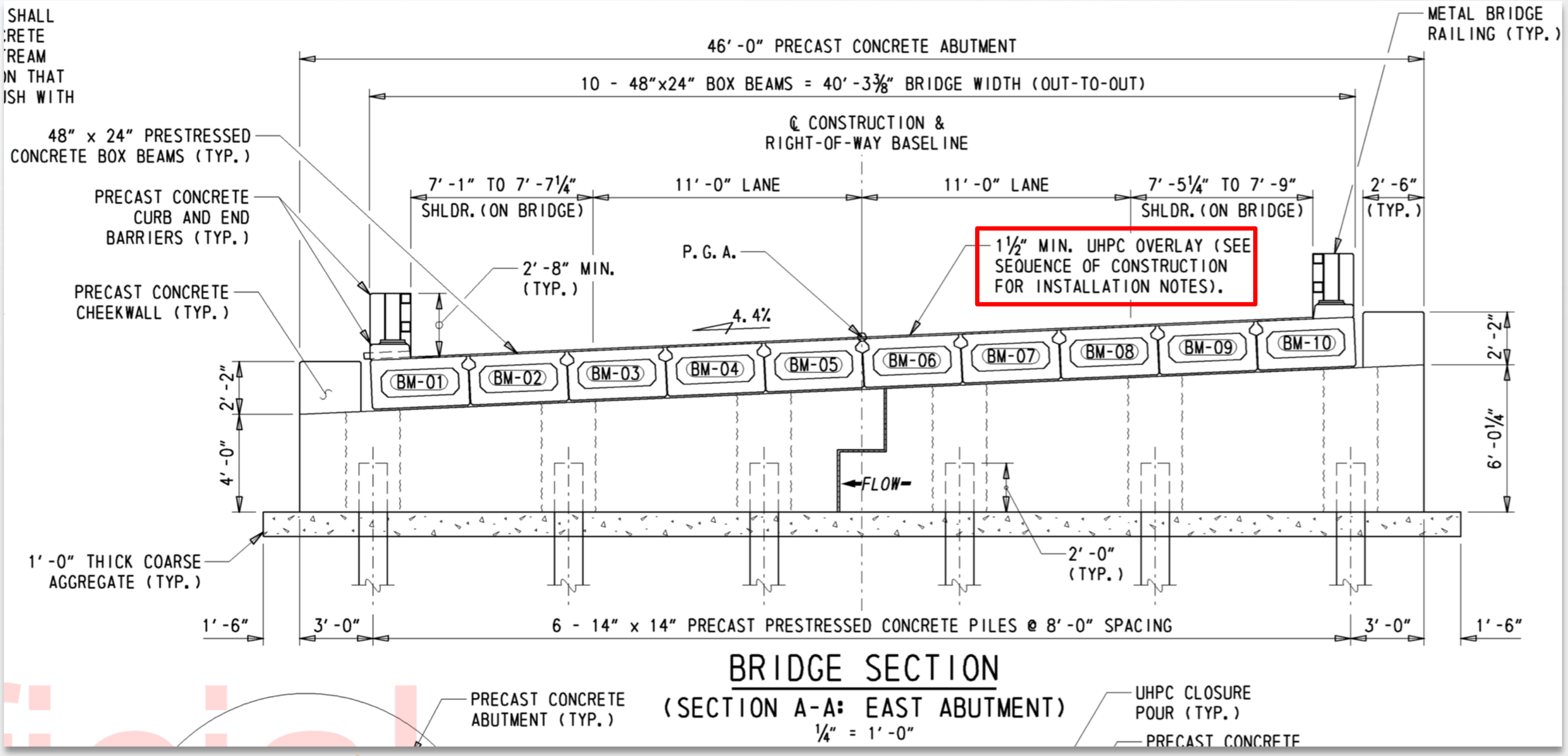
COMPLETED BRIDGE

Project Stats

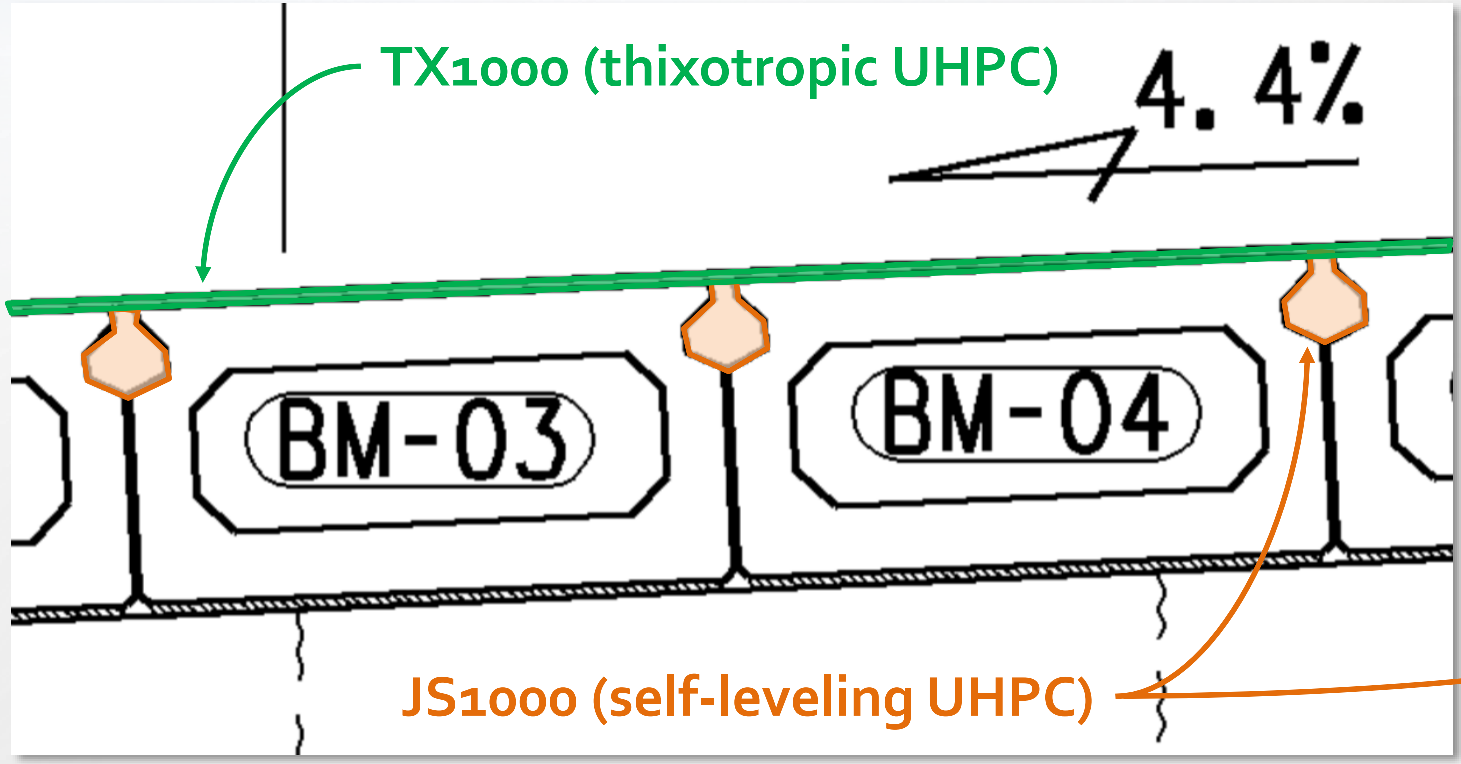
- 102' L x 28' W Superstructure
  = 2,856 SF of Bridge Deck
- 16 CY of UHPC for Overlay
- 1.75 in. thick UHPC overlay w/ 0.25 in. grind + 0.25 in. groove
- Increased Negative Moment Capacity of Bridge by **33%**
- Increased Positive Moment Capacity of Bridge by **16%**

BLACKBIRD CREEK BRIDGE, DELAWARE

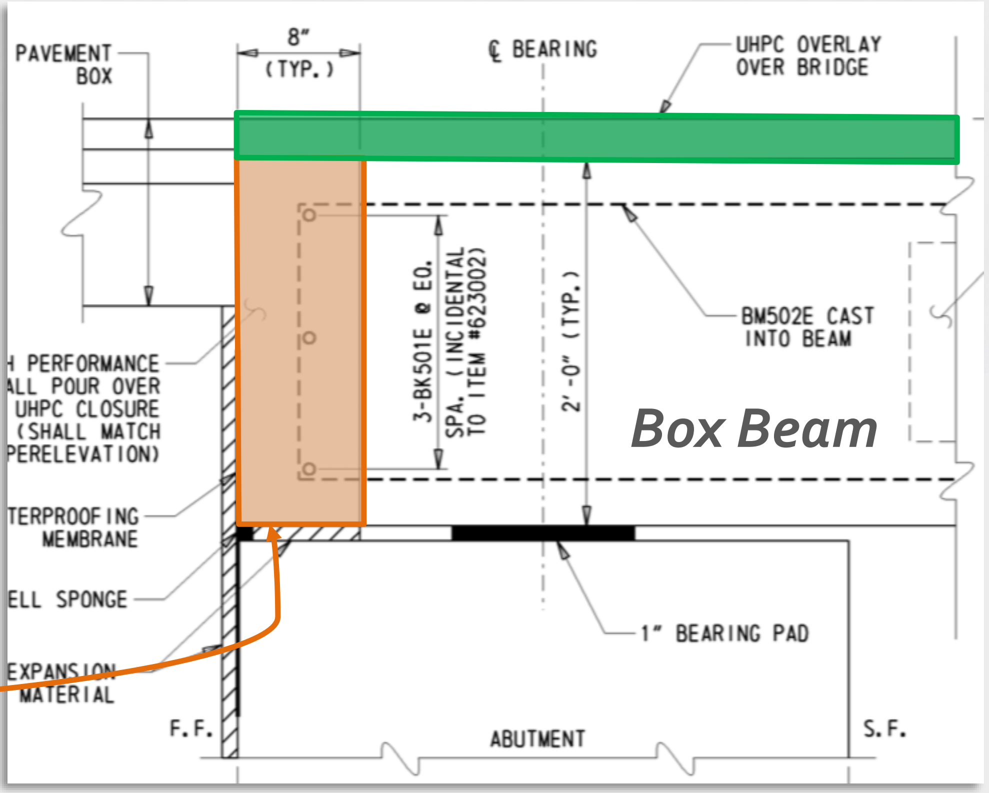
PROPOSED SUPERSTRUCTURE



UHPC APPLICATIONS

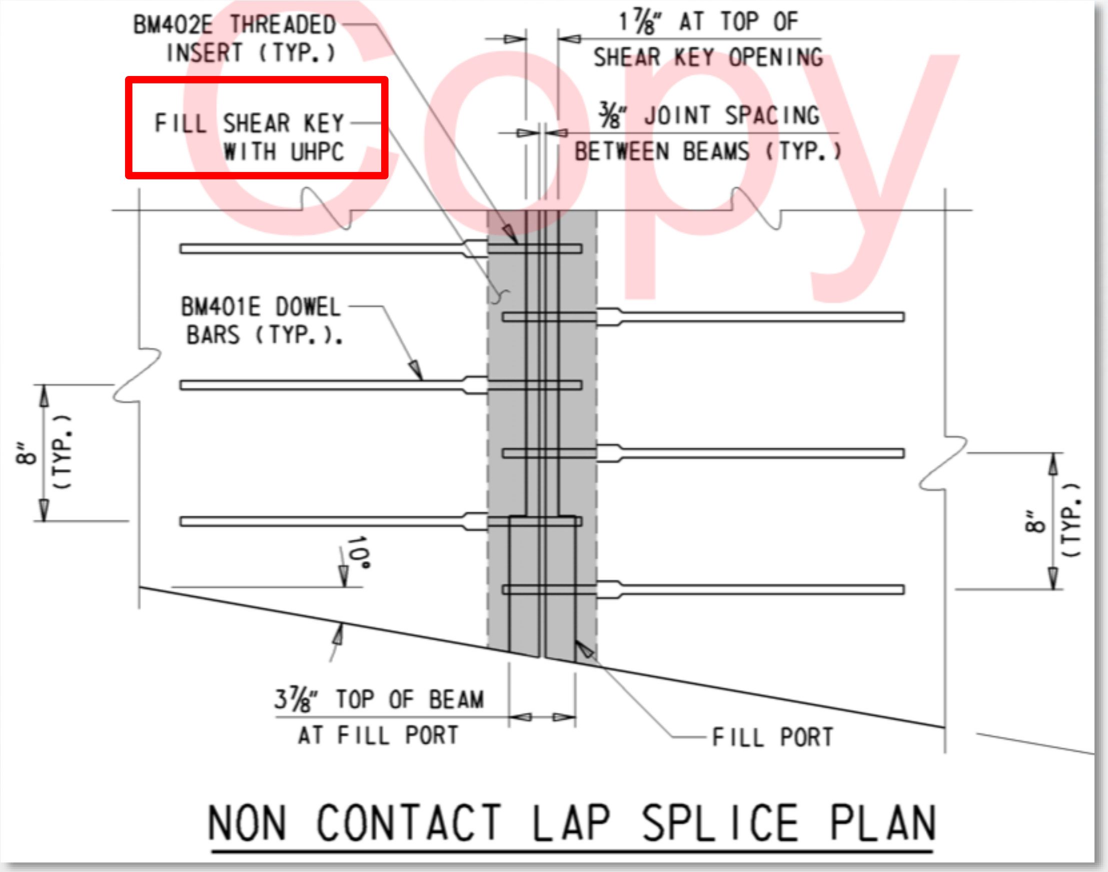


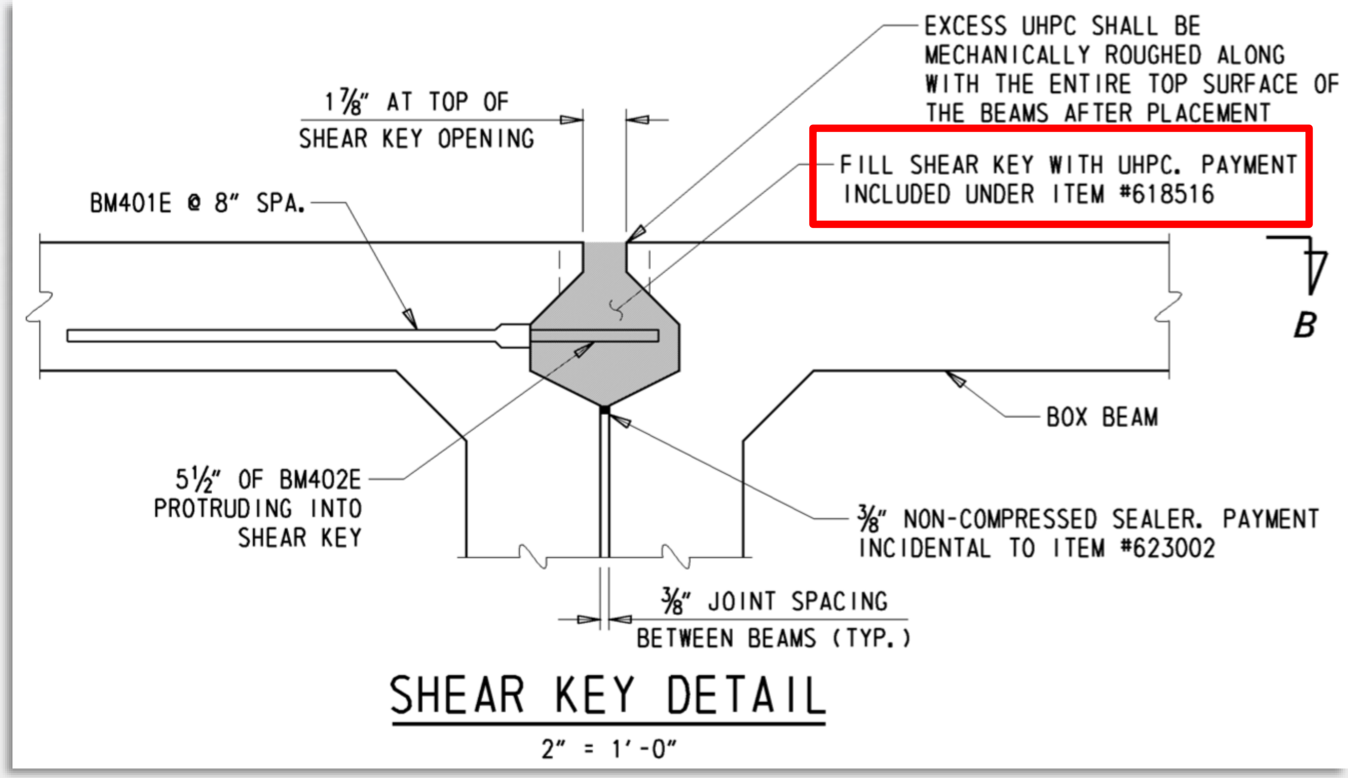
PARTIAL SECTION VIEW



ELEVATION END VIEW

JOINT DETAIL






CAT


CATERPILLAR
CAT
CAT

PRE-CONSTRUCTION MOCK-UP

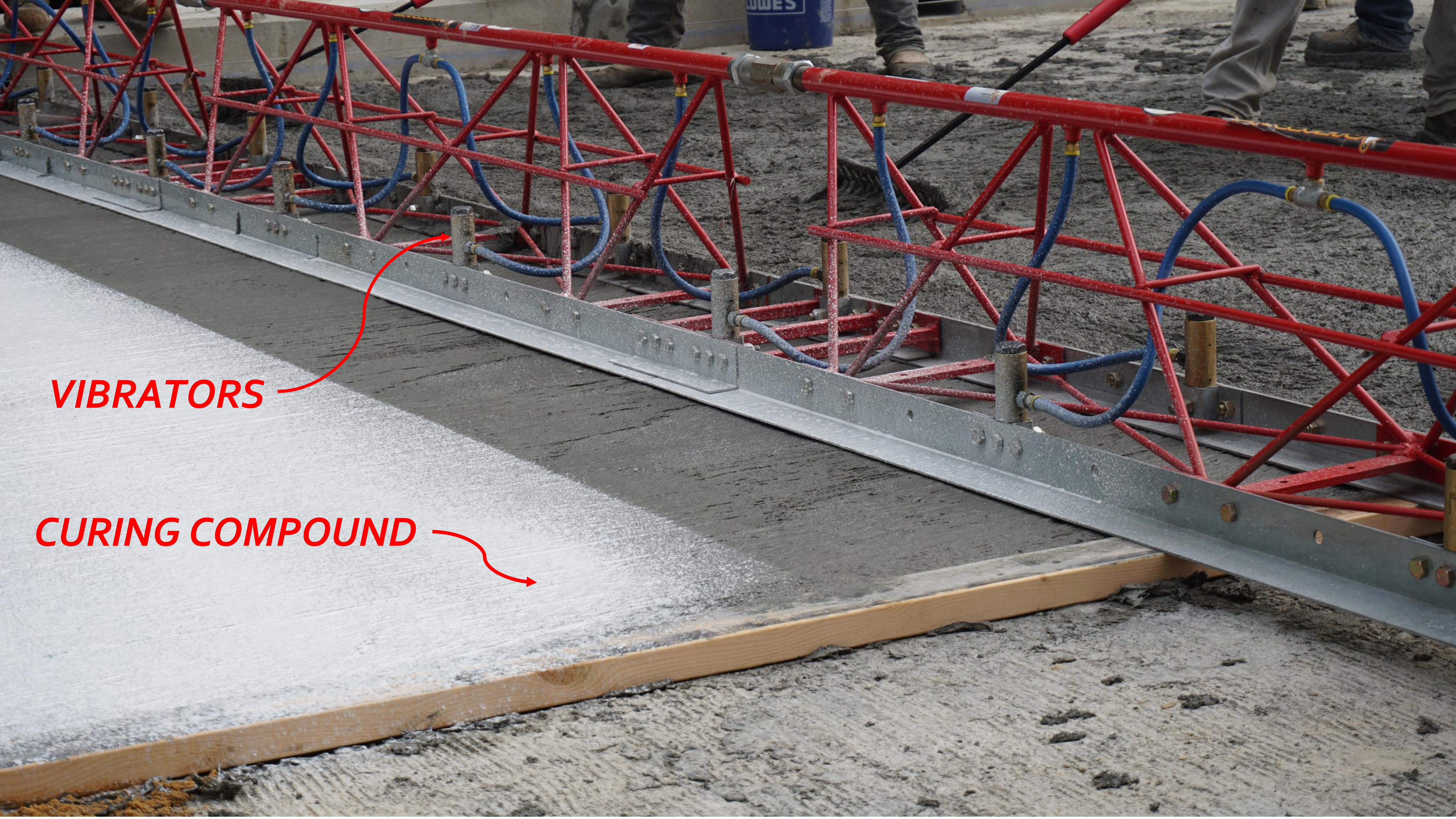
July 20, 2017


CAT

SURFACE PREPARATION

Two 0.65 Cubic Yard (0.5 CM) Capacity High-Shear Mixers
Max. Output = 4 CY per Hour


WBH-21
MQ
WHITEMAN


VIBRATORS
CURING COMPOUND
LOWES


CURE UNDER PLASTIC FOR 2-3 DAYS
Poured August 24, 2017

FINAL UHPC RIDING SURFACE

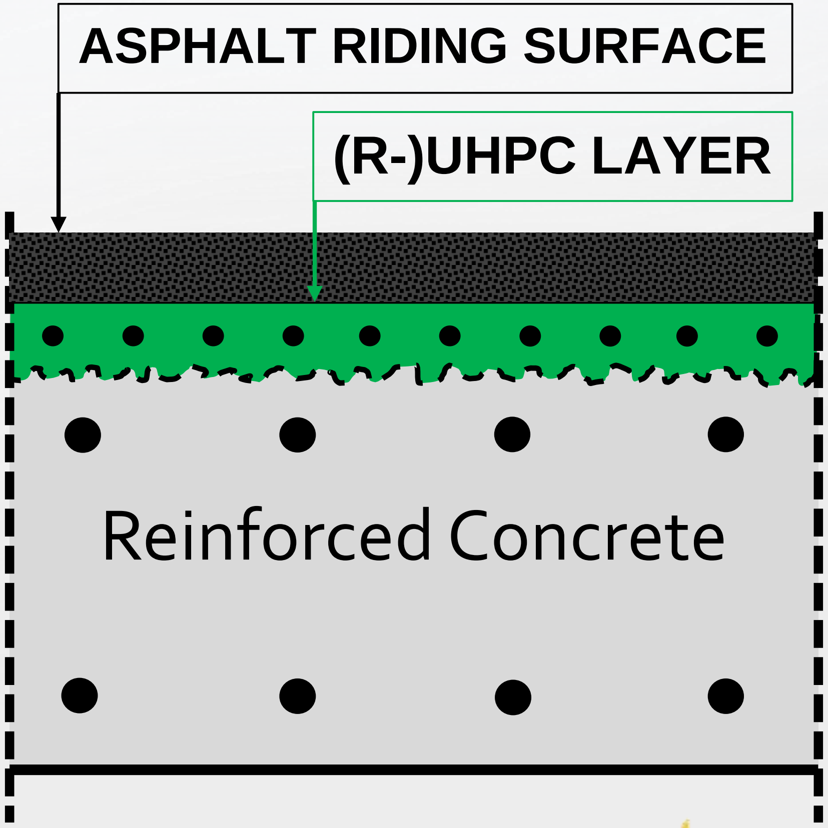
COMPLETED BRIDGE

Project Stats

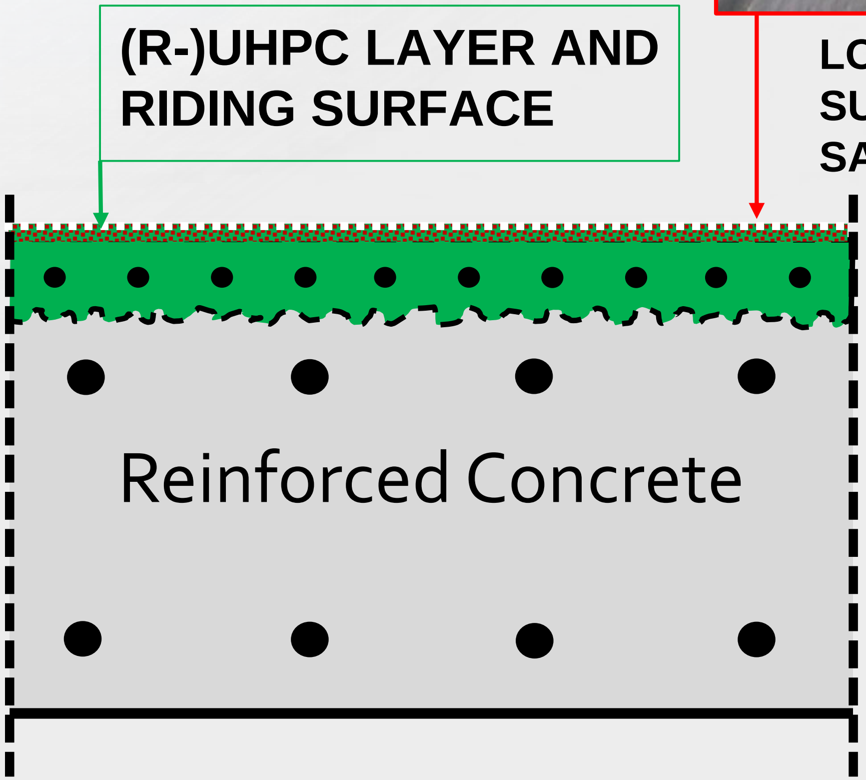
- 52' L x 40' W Superstructure
  = 2,080 SF of Bridge Deck
- 8 CY UHPC for joints and b.w.
- 10 CY UHPC for overlay
- 1.75 in. Overlay w/ 0.25 in. Mill
- Overlay Bid = ~$9,500 / CY
  = $44 per SF
- Pricey!? Yes…but cost will come down as more projects develop.
- And remember…you are investing in a **maintenance-*free*** deck for the LIFE of the bridge.

SOLUTIONS FOR RIDING SURFACE

EU-VERSION

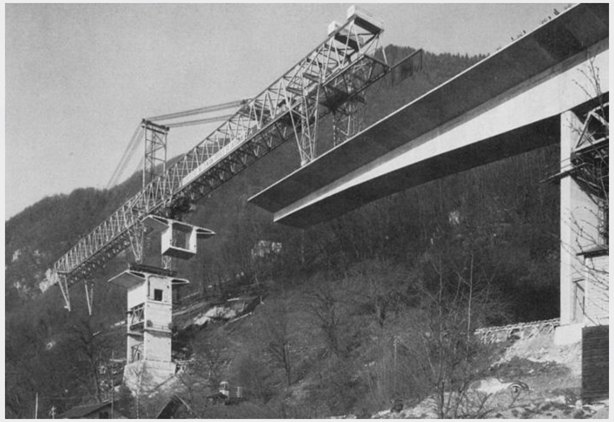


US-VERSION



LONGITUDINAL GROOVES ON THE SURFACE ALLOW FOR TRACTION, SAFETY, AND NOISE REDUCTION.

CHILLON VIADUCTS, SWITZERLAND



- Two 1.3 miles long bridges (spans between 302 and 341 ft.)
- Built in the 1960s (Monument) by prestressed segmental construction with epoxy-glued joints
- Vital to transportation infrastructure

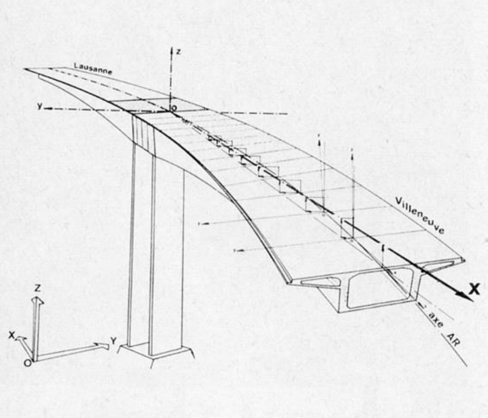


Fig. 11. — Portique à géométrie variable. Définition des systèmes d'axes.

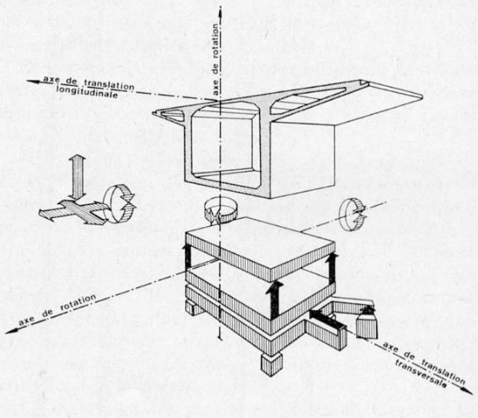
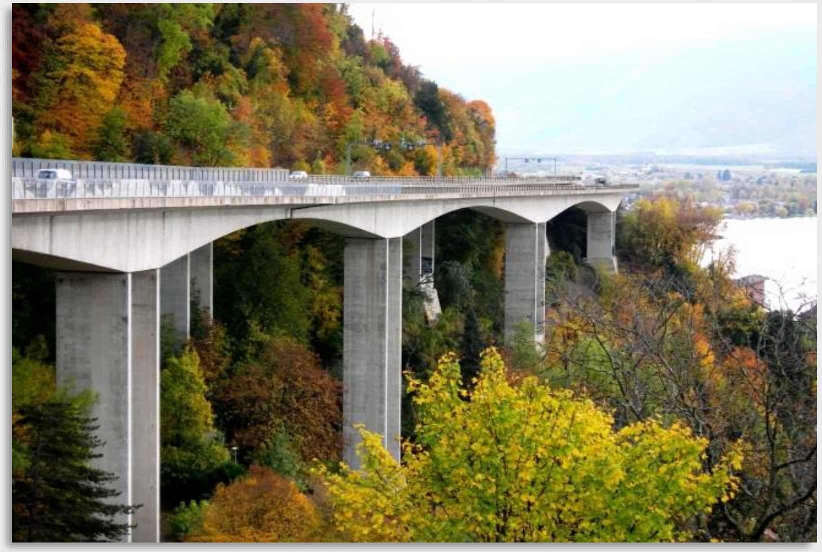


Fig. 12. — Portique à géométrie variable. Principe d'orientation d'un voussoir-moule.

BRIDGE EVALUATION

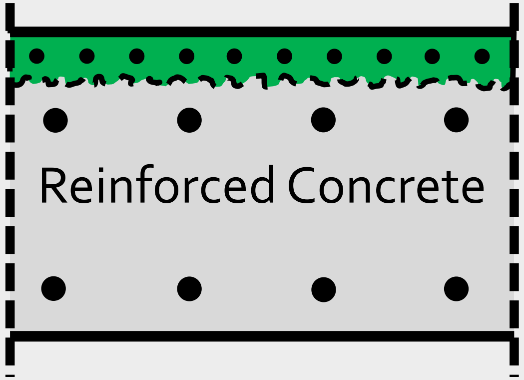


- Expert Evaluation in 2011:
  - Structural capacity of the bridge deck was at service load
  - Main failure: punching of wheel loads through 7 in. thin deck slab
- Further investigations in 2012:
  - early signs of alkali-aggregate reaction (AAR)
  - deterioration of concrete compressive strength
  - insufficient structural safety at ULS and unacceptable performance under service loads

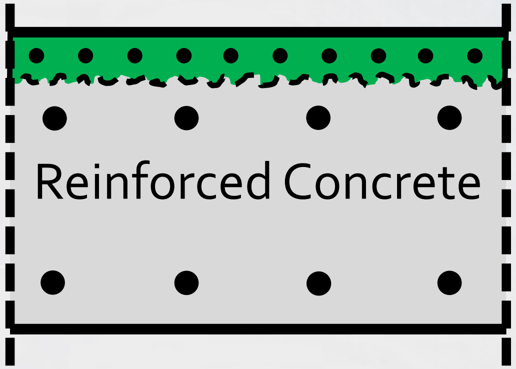
Possible Solutions

1. Demolition and rebuild of historic structure (expensive)
2. Conventional concrete rehabilitation (increase in dead load)
3. Extensive external prestressing (not possible AAR)

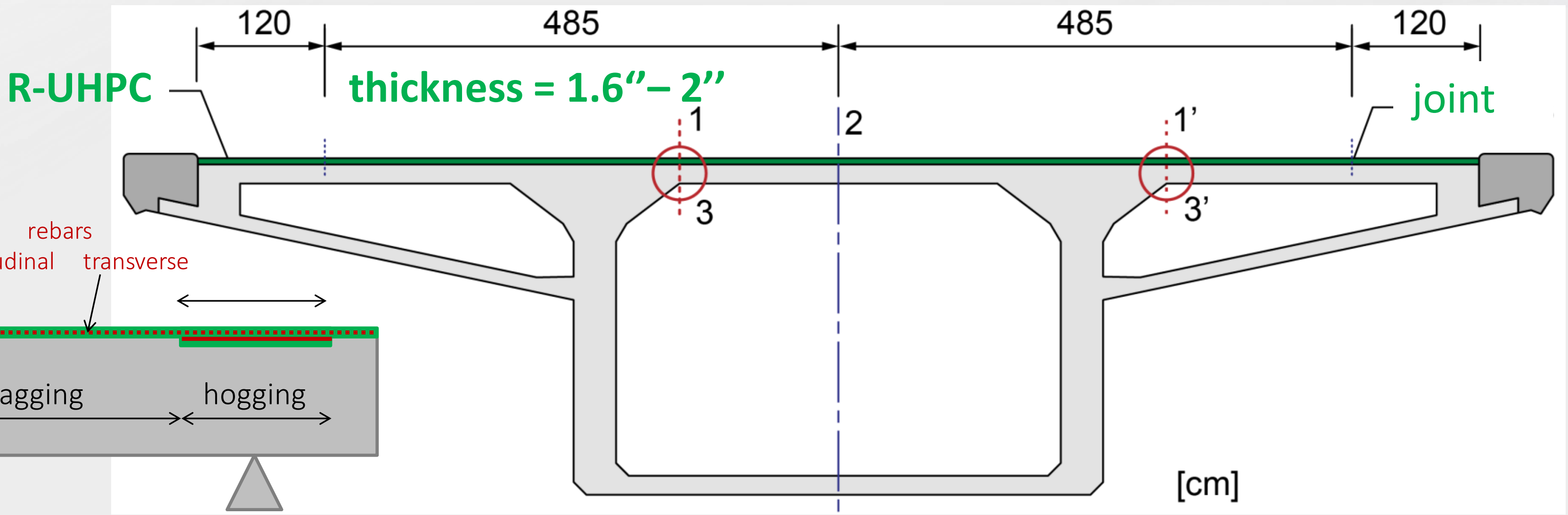
➢ **UHPC layer to strengthen the bridges capacity by approximately 40% and increase durability of structure**

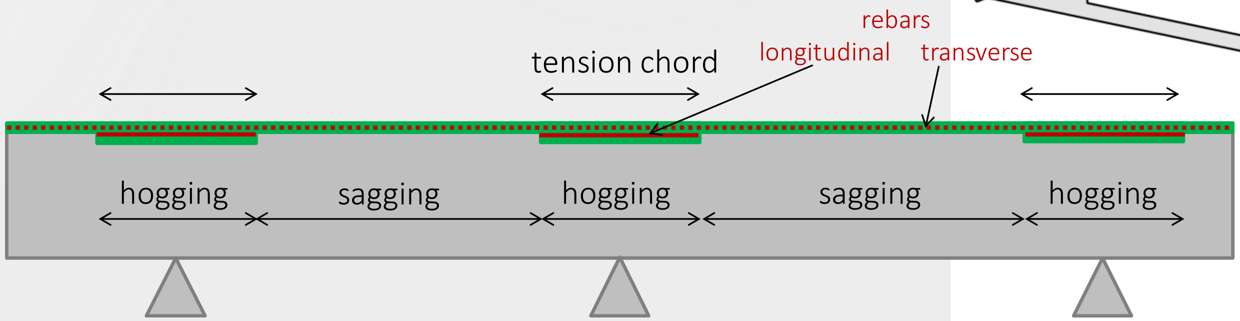


R-UHP(FR)C REPAIR SOLUTION

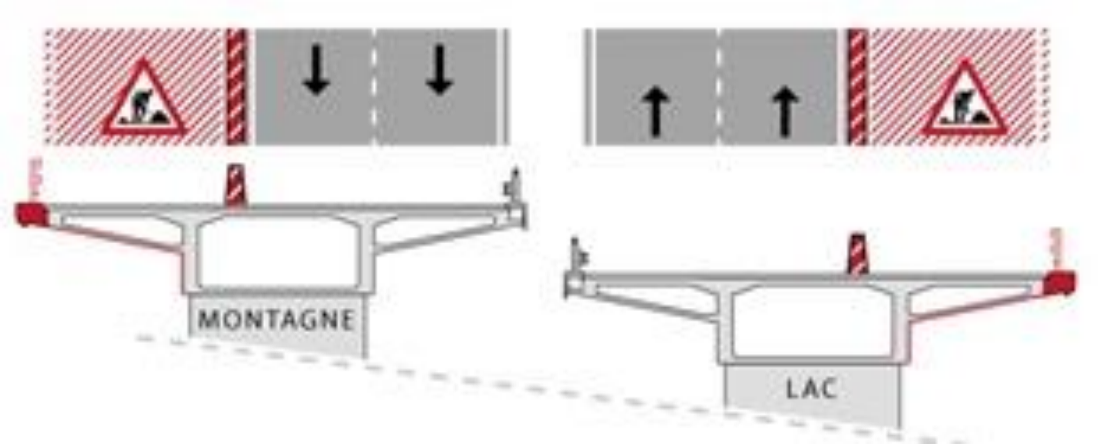


- 1.6 – 2 inch UHPC layer
  (with rebars in the transverse direction and in the longitudinal direction only in the area of hogging (i.e. negative) moments)
  - strengthening of deck slab in the transverse direction: bending, shear and fatigue
  - increase in stiffness and strength in the longitudinal direction
  - waterproofing of slab (slow down the rate of AAR by protecting concrete from water ingress)
  - no increase in dead load
  - lower intervention cost
  - short duration (ABC)

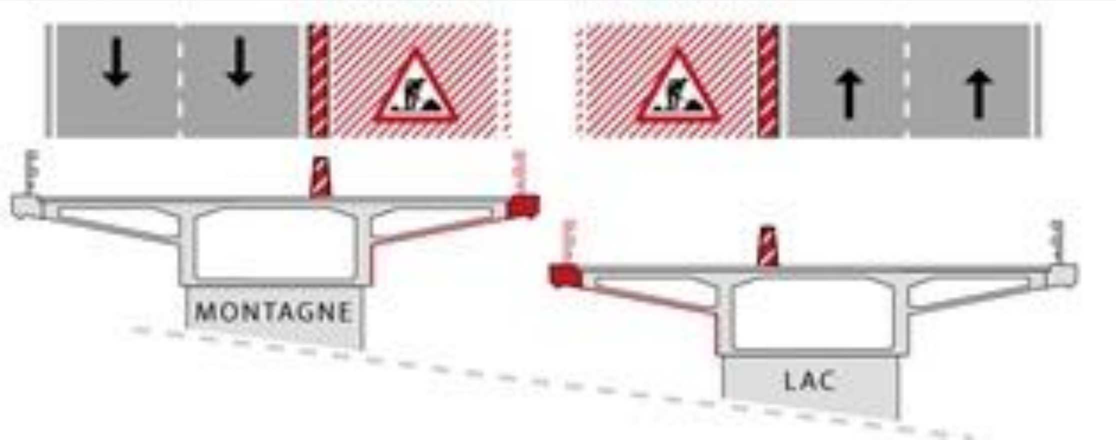




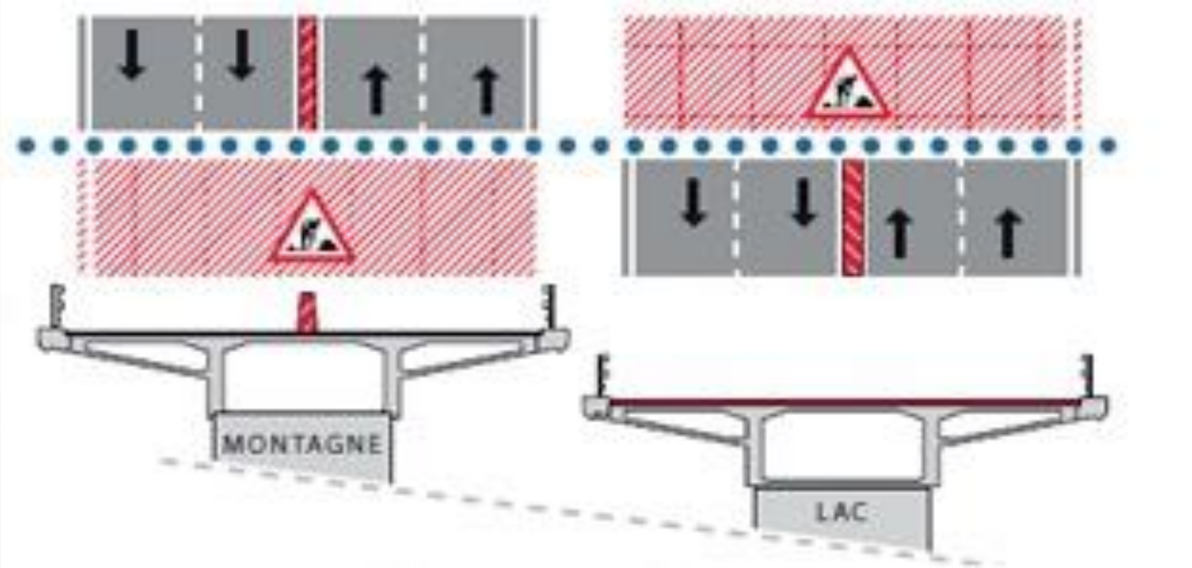
PHASE I – CURB and GIRDER RESTORATION



Construction Staging

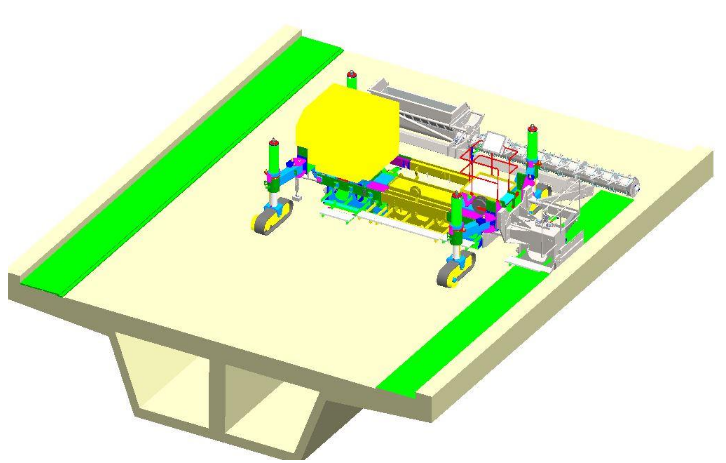


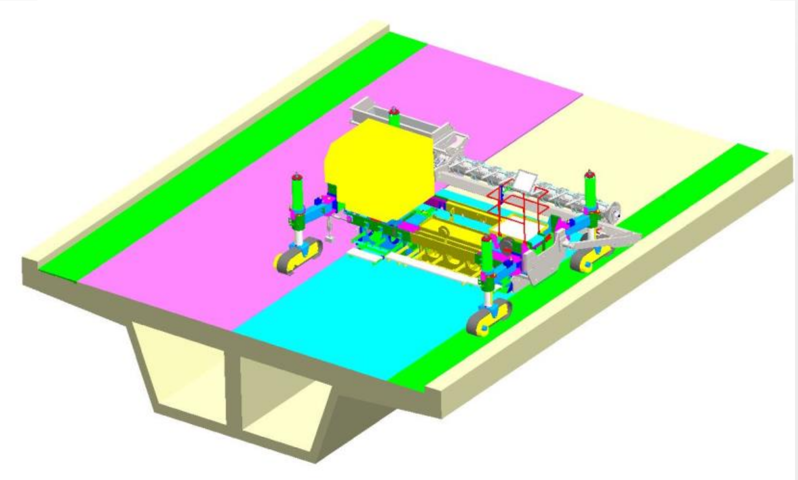
PHASE II – ROADWAY PAVING with UHPC



Construction Staging

Bridge to stay open to traffic at all times (only partial closing)



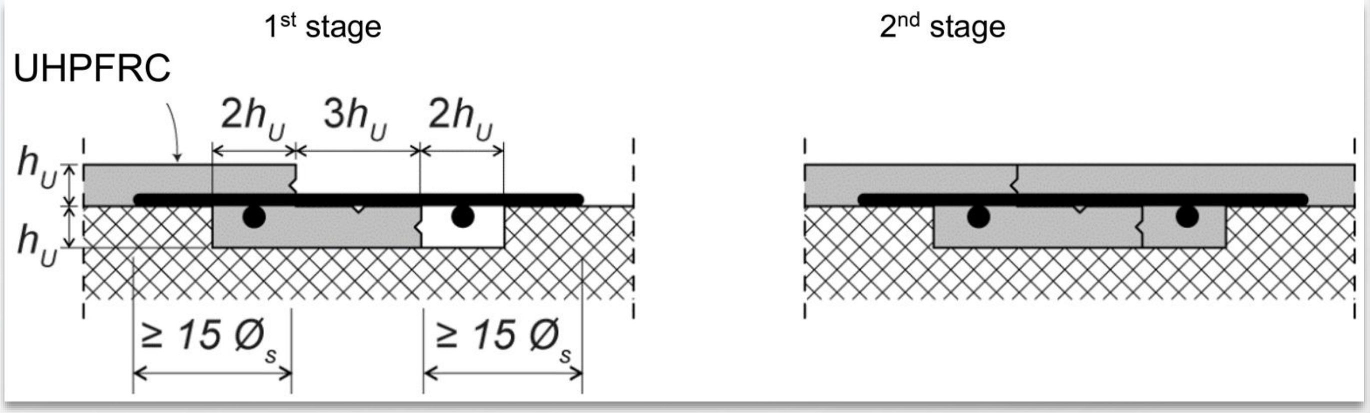



WALO


WALO


WALO

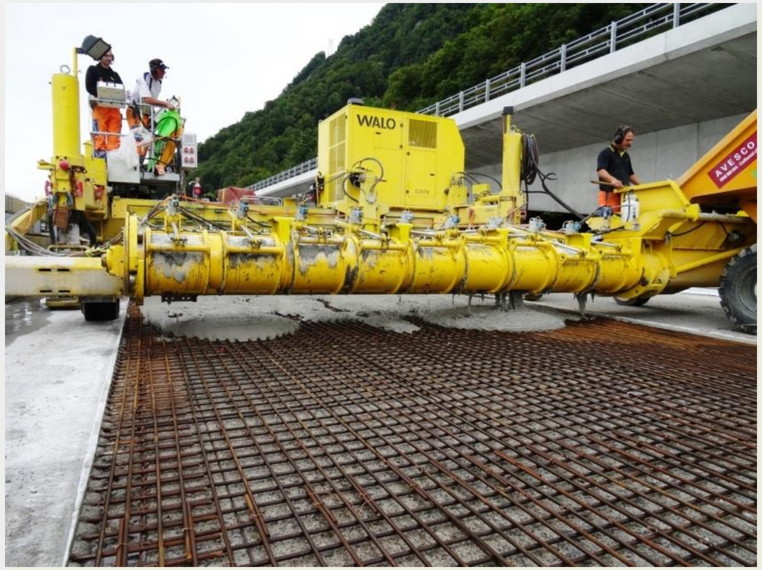
UHPC CONSTRUCTION JOINT




WALO
AVESCO

WALO

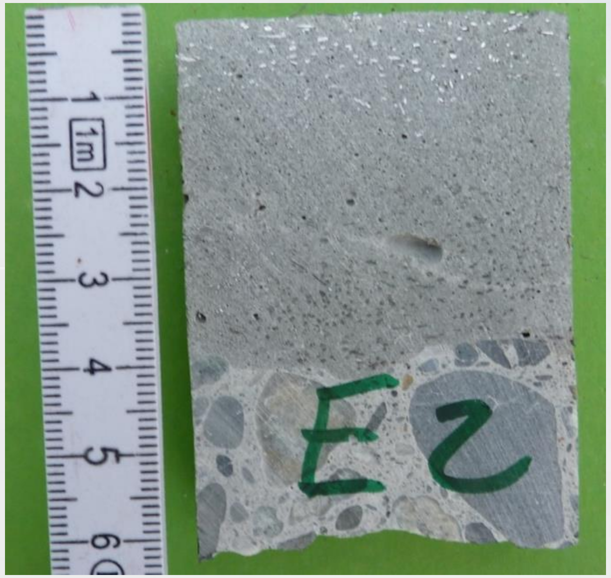
MAXIMUM SLOPE = 7%
WALO

WALO

WALO
AVESCO

CURING
WALO

PROJECT SUMMARY

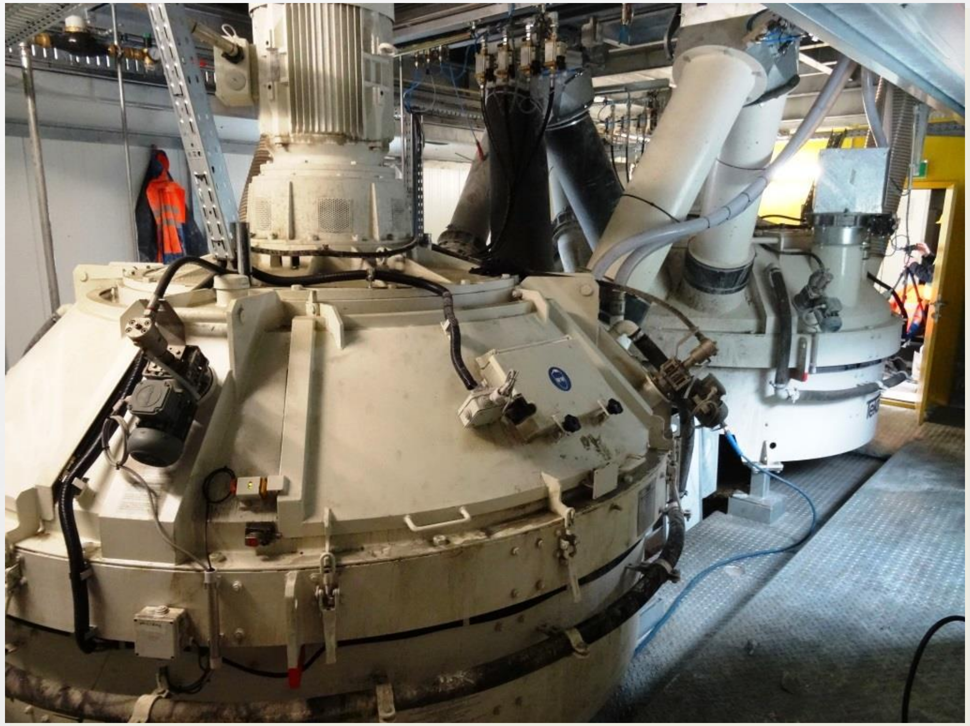
- 50,000 m^2 - 550,000 ft^2
- 3,200 cy (2400 m^3) of UHPFRC (**DUCTAL®**)
- Maximum daily output 120 cy (92 m^3)
- Duration: 2 x 30 days (2014 & 2015)
- Intervention Cost ≈ 230 \$/m^2 ≈ 22 \$/ft^2
- Additional repair on deck underside with conventional shotcrete



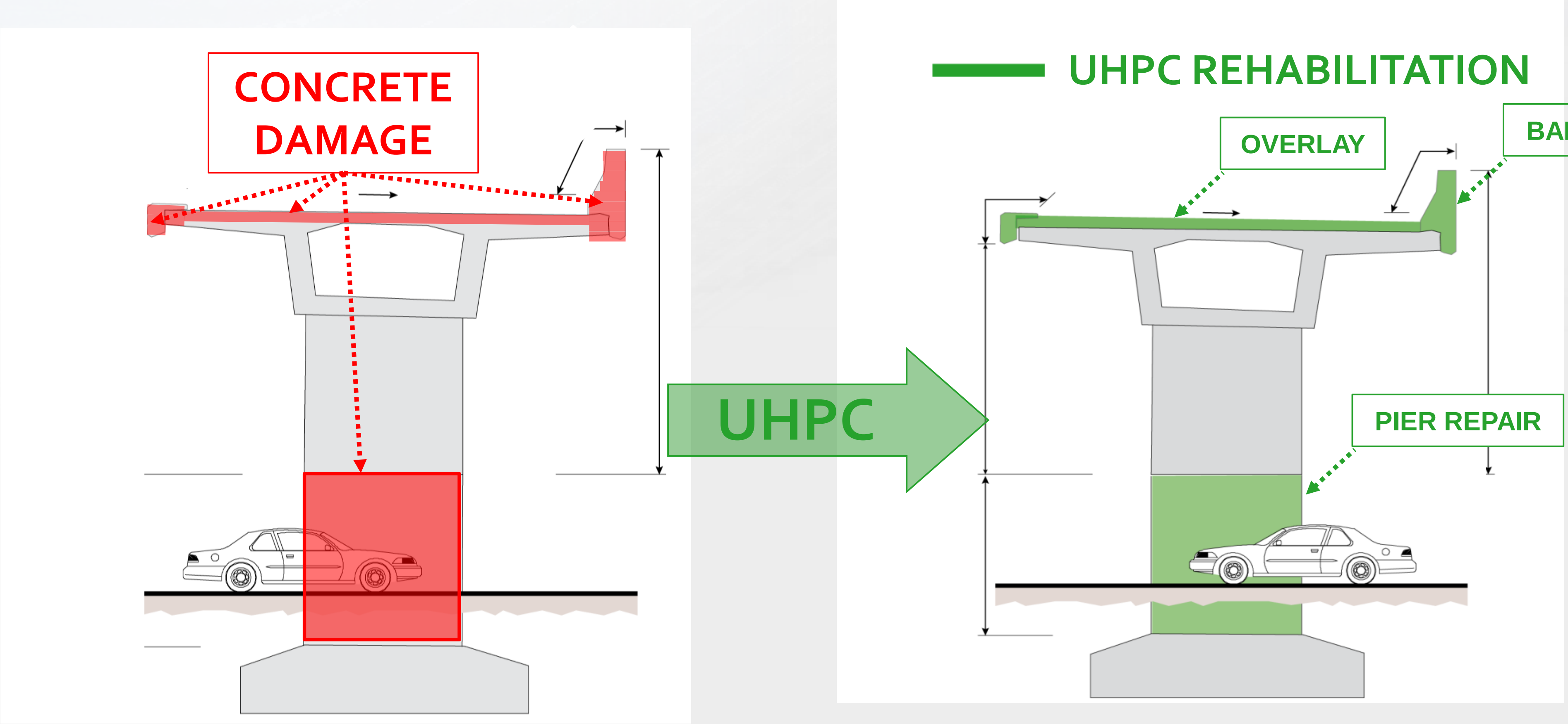
Bond Behavior UHPC-NSC

UHPC ON-SITE BATCHING PLANT

UHPC BATCH PLANT

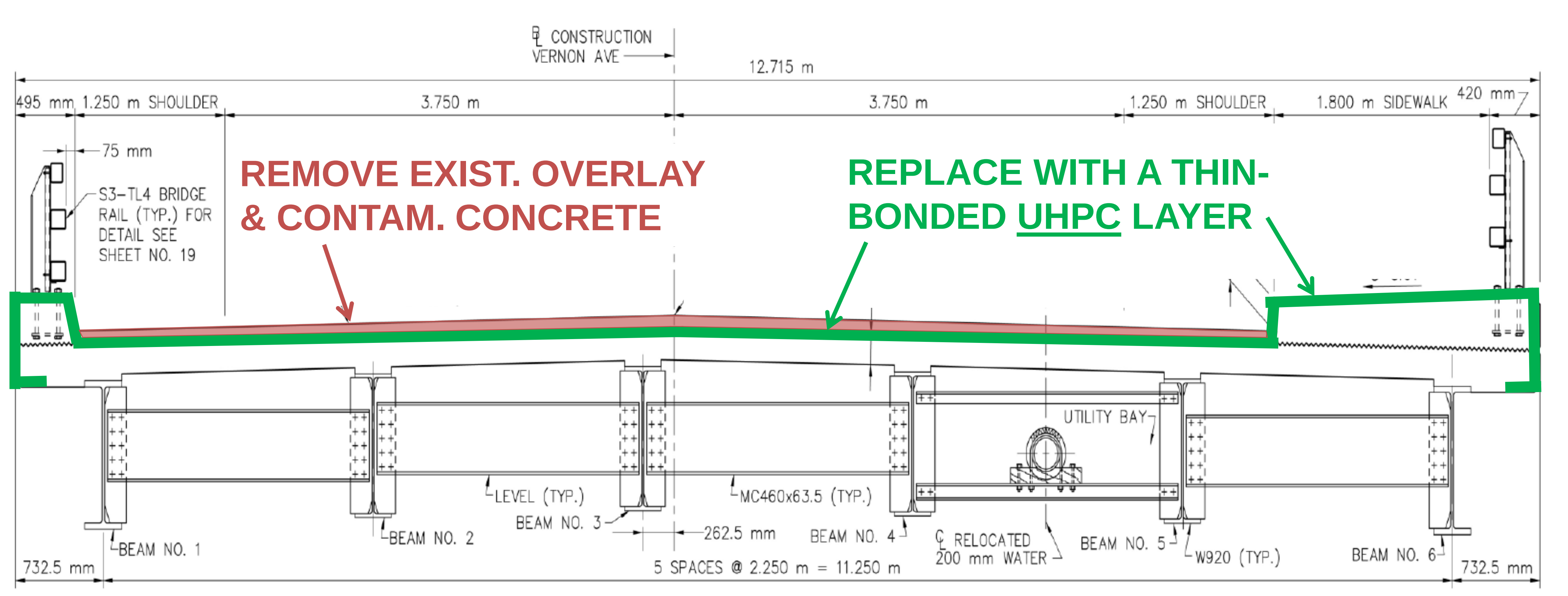


UHPC REHABILIATION STRATEGY



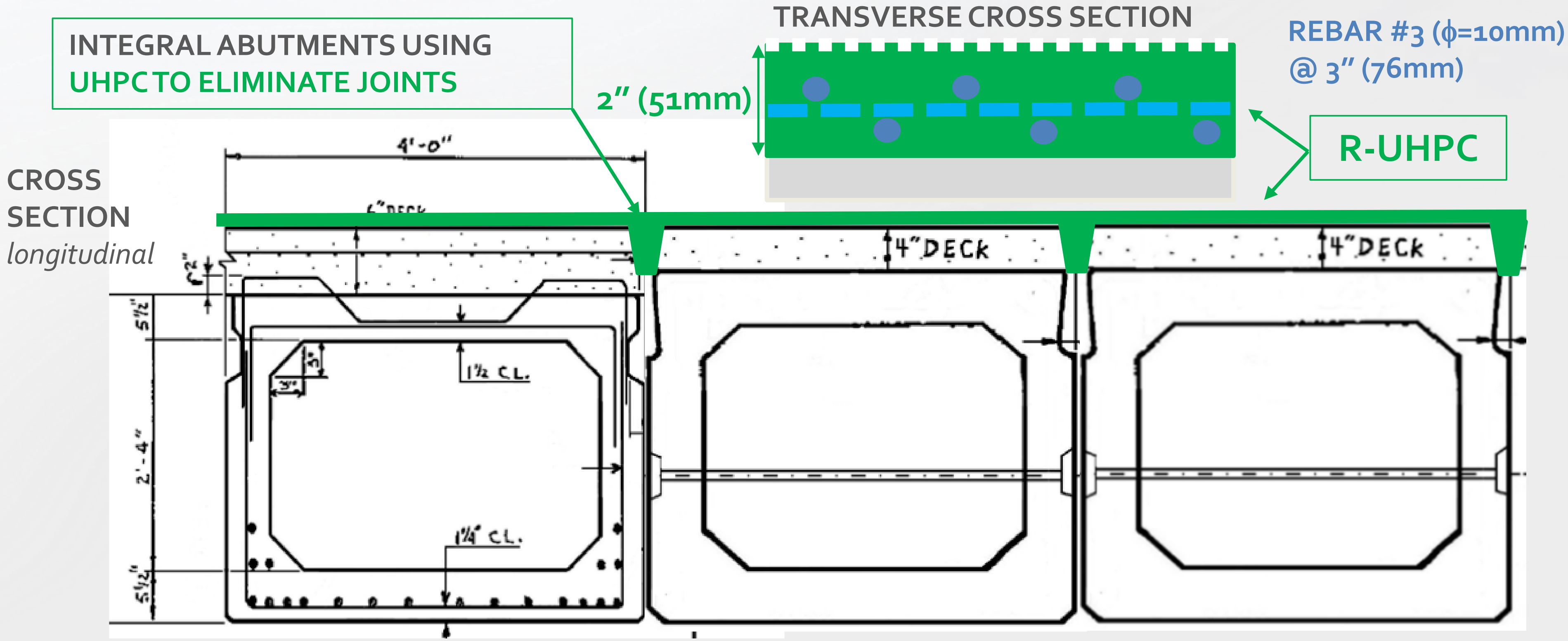
Increase structural capacity of bridges in a faster and more cost-efficient way!

REPAIR EXAMPLE – STEEL GIRDER BRIDGE



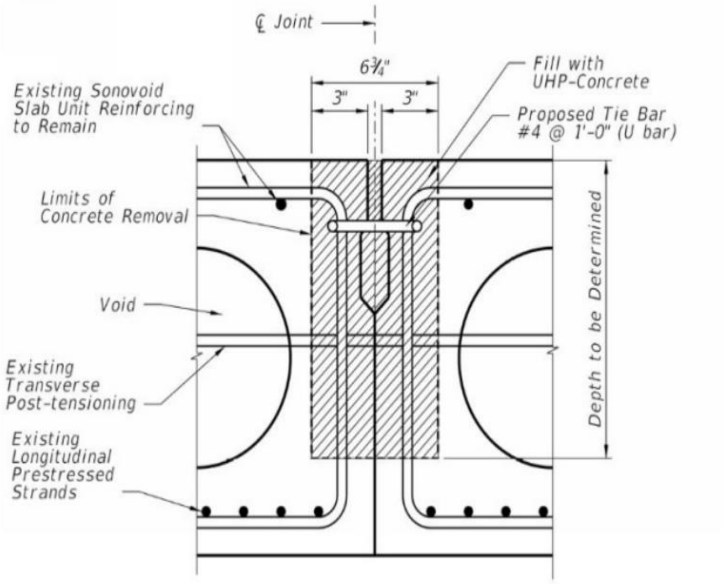
UHPC for the rehabilitation of steel or prestressed concrete girder bridges

REPAIR EXAMPLE – BOX GIRDER BRIDGE



UHPC for the rehabilitation of hollow box girder bridges

Florida Voided Slab Joint Repair



SLAB UNIT CONNECTION DETAIL USING UHP-CONCRETE

Florida DOT Rehabilitation of SR-714
at Danforth Creek in Fall 2016

Florida DOT

COST COMPARISON

Table 1. Approximate cost of different overlay solutions compared with bridge deck replacement.

Overlay Type	Overlay Thickness, Inches (mm)	Cost, $/ft² ($/m²)
HPC*	1–5 (25–127)	17–25 (183–269)
Low slump concrete*	1.5–4 (38–102)	13–19 (140–204)
LMC*	1–5 (25–127)	18–39 (193–419)
Asphalt with a membrane*	1.5–4 (38–102)	3–8 (32–86)
Polymer-based*	0.13–6 (3–152)	10–17 (107–183)
Non-proprietary UHPC	1–2 (25–52)	3–6 (32–64)†
Proprietary UHPC	1–2 (25–52)	9–18 (97–184)‡
Rehabilitation of the Chillon Viaduct (Switzerland) using a proprietary UHPC overlay	1.6 (40)**	20 (215)**
Bridge deck replacement*	n/a	43–53 (462–570)

*Data collected from Krauss et al. (2009).[5] The costs shown reflect average values from low and high ranges.
**Data collected from Brühwiler et al. (2015).[7] Price reflects cost of material and installation.
†Price reflects material cost only, assumes UHPC cost of $1,000 per cubic yard.
‡Price reflects material cost only, assumes UHPC cost of $3,000 per cubic yard.
n/a = not applicable.

Blackbird Creek Bridge, US

Cost = $44 per SF

- 1.75” overlay (w/o rebar)
- 10 cubic yards of UHPC
- 2,080 SF Bridge Deck

Chillon Viaduct, SUI

Cost = $22 per SF

- 1.8” avg. overlay (w/ rebar)
- 3,200 cubic yards of UHPC
- 550,000 SF Bridge Deck

Future Projects

Cost = $25-40 per SF ??

- Depends on overlay thickness and size of project (i.e. deck area)

TO LEARN MORE…

WEDNESDAY
April 11

10:00 AM TO 12:00 PM	Crystal Ballroom D & E	**C6 DECK PRESERVATION ACTIONS** *MODERATOR: Larry O'Donnell, Federal Highway Administration* **20 Years of Hydrodemolition of Bridge Decks in Missouri** *Pat Martens, Bridge Preservation and Inspection Services* **WSDOT Bridge Deck Preservation Program** *DeWayne Wilson, Washington DOT* ➡ **Ultra-high Performance Concrete for Bridge Deck Overlays** *Zachary Haber, Federal Highway Administration* **Silane's the First Defense in Bridge Preservation** *Tim Woolery, Advanced Chemical Technologies*

TECHNOTE

Ultra-High Performance Concrete for Bridge Deck Overlays

FHWA Publication No.: FHWA-HRT-17-097

FHWA Contacts: Ben Graybeal, HRDI-40, 202-493-3122, benjamin.graybeal@dot.gov; Zach Haber, HRDI-40, 202-493-3469, zachary.haber@dot.gov

Introduction

There is urgent need for effective and durable rehabilitation solutions for deteriorated highway bridge decks. Deck deterioration is commonly caused by a combination of vehicle loading, freeze–thaw degradation, cracking, delamination of cover concrete, and/or corrosion of internal reinforcement. Deteriorated bridge decks are commonly rehabilitated using overlays depending on the cause of deck deterioration, available budget, and desired service life of the rehabilitated structure. Common overlay materials include conventional concretes, high-performance concretes (HPCs), latex-modified concretes (LMCs), asphalt with waterproofing membranes, and polymer-based materials. The performance objectives of bridge deck overlays include protecting the underlying deck and reinforcement from contaminates, providing additional strength and stiffness to the deck system, and extending the service life of the overall structure.

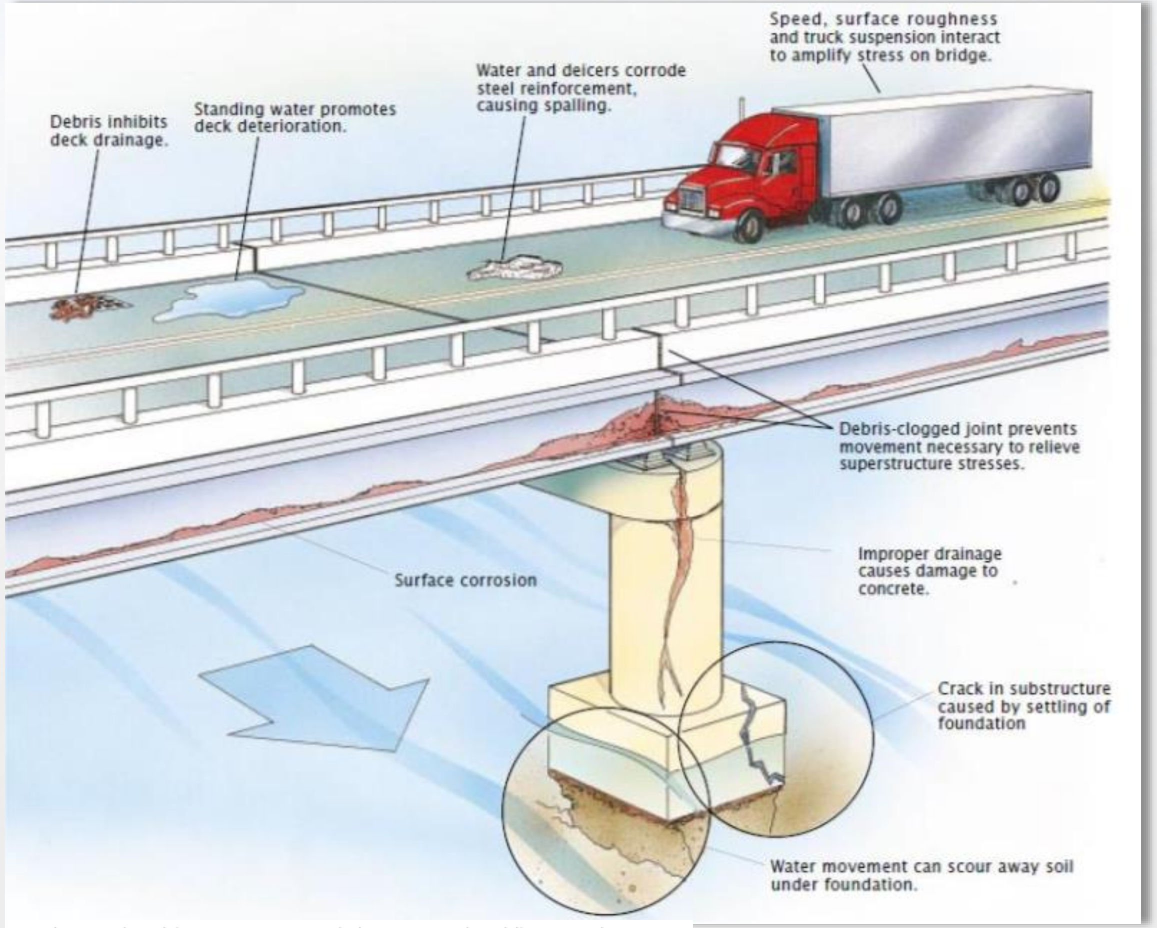
One emerging solution for bridge deck rehabilitation is thin, bonded ultra-high performance concrete (UHPC) overlays. As an overlay material, UHPC can provide both structural strengthening and protection from ingress of contaminates using a 1-inch (25-mm) to 2-inch (51-mm) layer of material. This minimizes required material volume and can minimize additional dead load on the bridge structure compared with some traditional overlay solutions. The concept and use of UHPC overlays has been researched in Europe and has been deployed on more than 20 European bridges.[1]

This TechNote introduces UHPC as a potential solution for bridge deck overlays. A brief review of the history and development of UHPC is presented, followed by a summary of the properties that make UHPC a viable overlay solution. A laboratory investigation on the tensile bond strength of a UHPC specially formulated for overlay applications is then presented. This investigation provides a comparison between UHPC and LMC overlays using different substrate materials and surface preparations. Lastly, this TechNote highlights the findings of a field study and subsequent

U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike, McLean, VA 22101-2296
www.fhwa.dot.gov/research

OTHER UHPC SOLUTIONS



Dunker and Rabbat 1993, Copyright 1993 Scientific American, Inc.

- ➢ UHPC OVERLAY
- ➢ UHPC JOINT HEADERS
- ➢ UHPC LINK SLABS
- ➢ UHPC CONNECTIONS
- ➢ UHPC BEAM END ENCASEMENT
- ➢ UHPC PIER JACKETS

VISIT OUR BOOTHS!

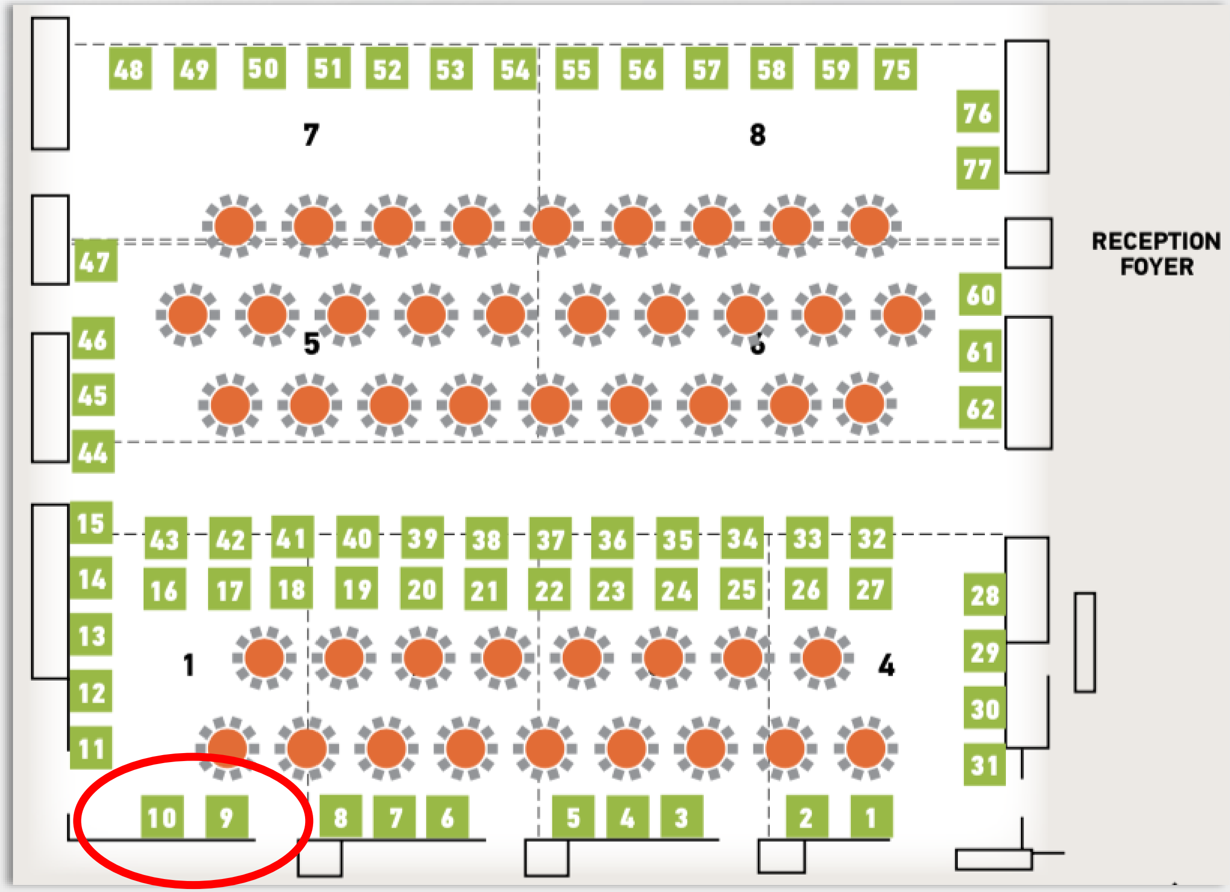
#9 – UHPC Solutions

UHPC SOLUTIONS
NORTH AMERICA

#10 – LafargeHolcim

Ductal

A technology of
LafargeHolcim



QUESTIONS?

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