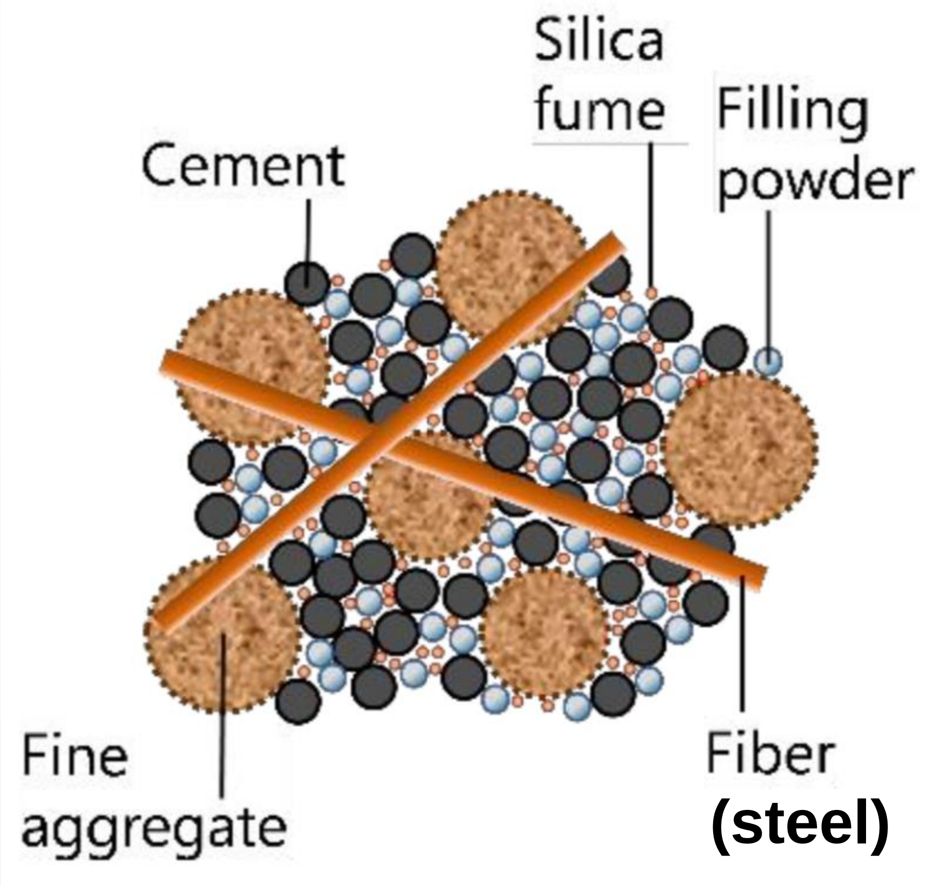
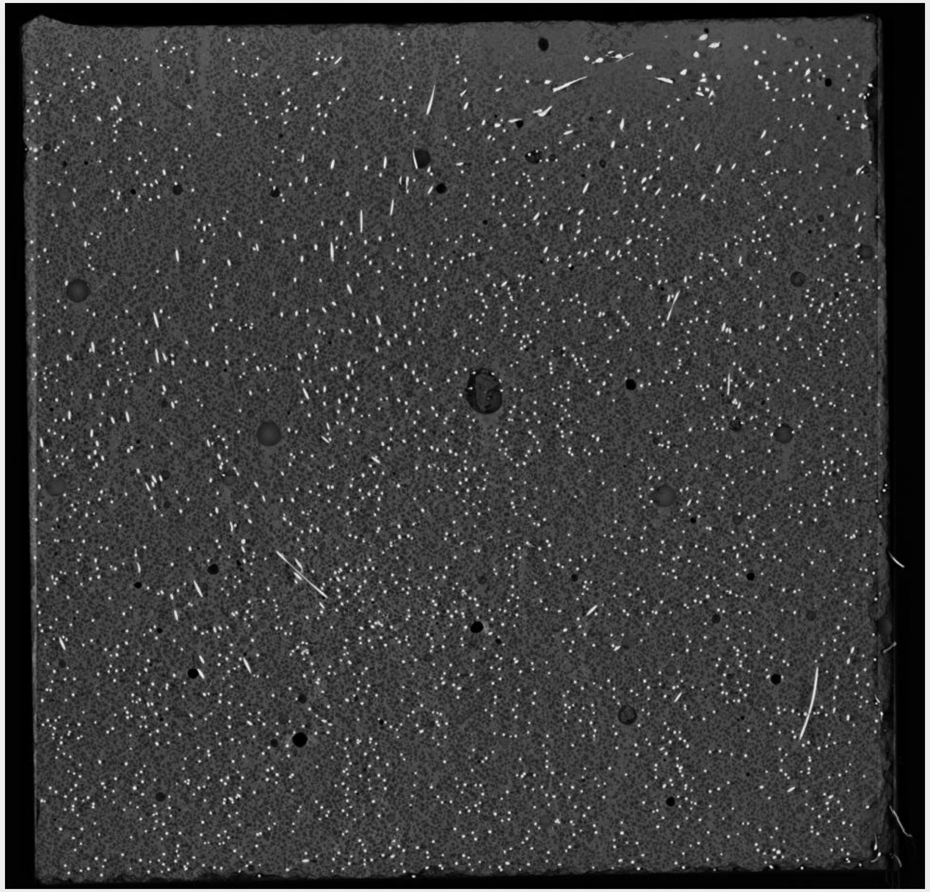
UHPC Overlay Solutions

Gregory Nault, PE, SE – *LafargeHolcim*

Ultra-High Performance (Fiber-Reinforced) Concrete



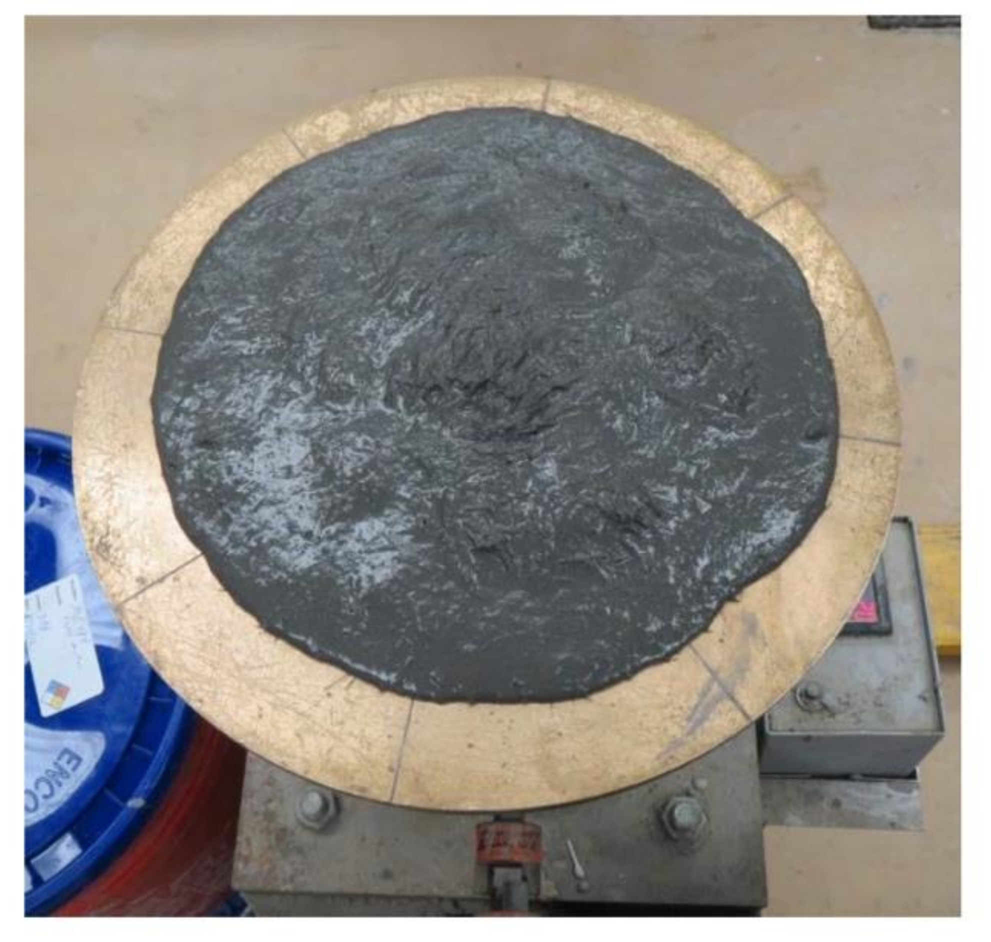
WATER (w/c < 0.3)
+
SUPERPLASTICIZER




JS1000


JS1212

“Self-Leveling”



“Thixotropic”

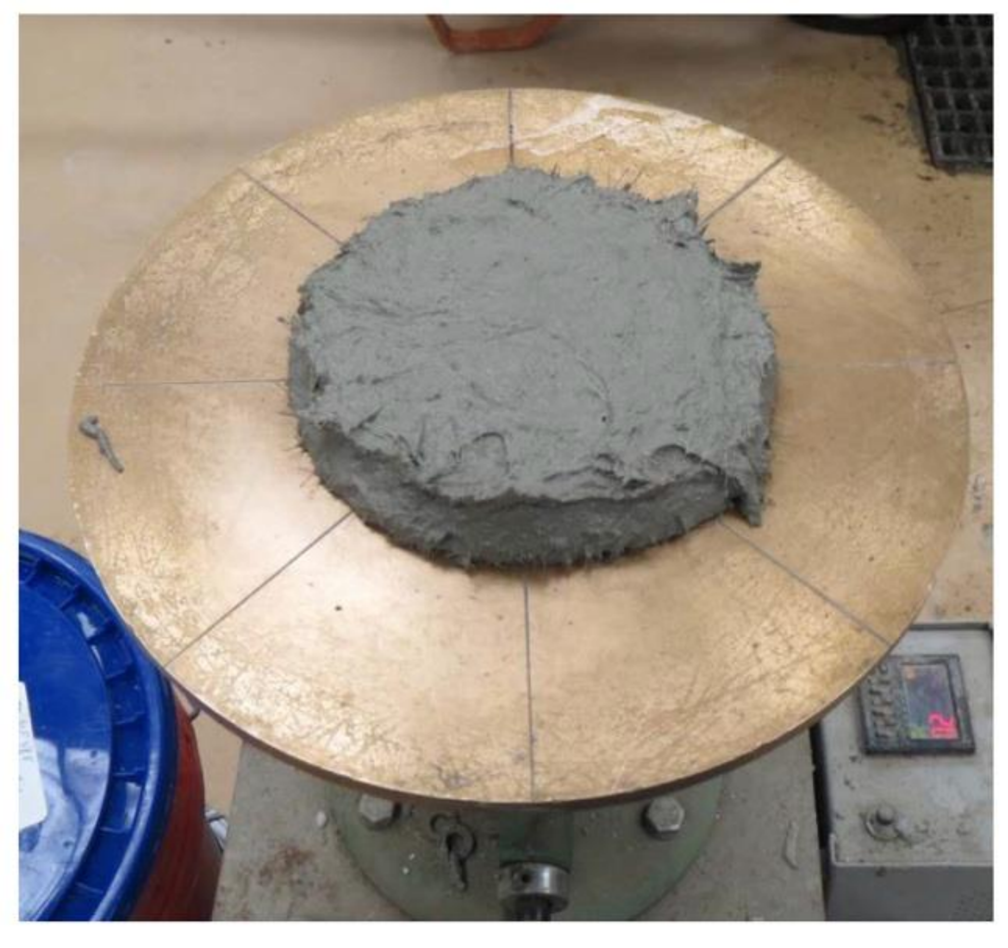
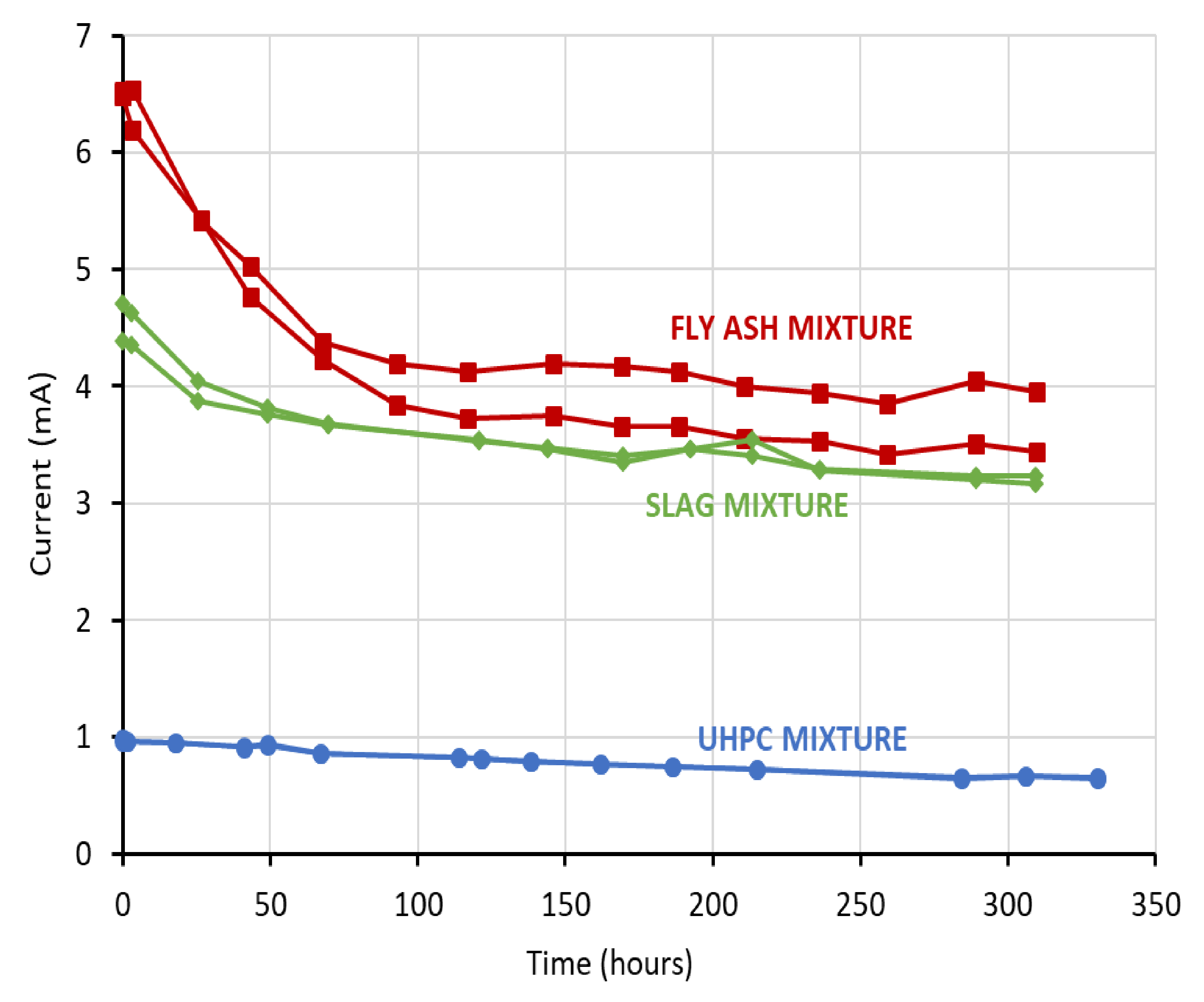
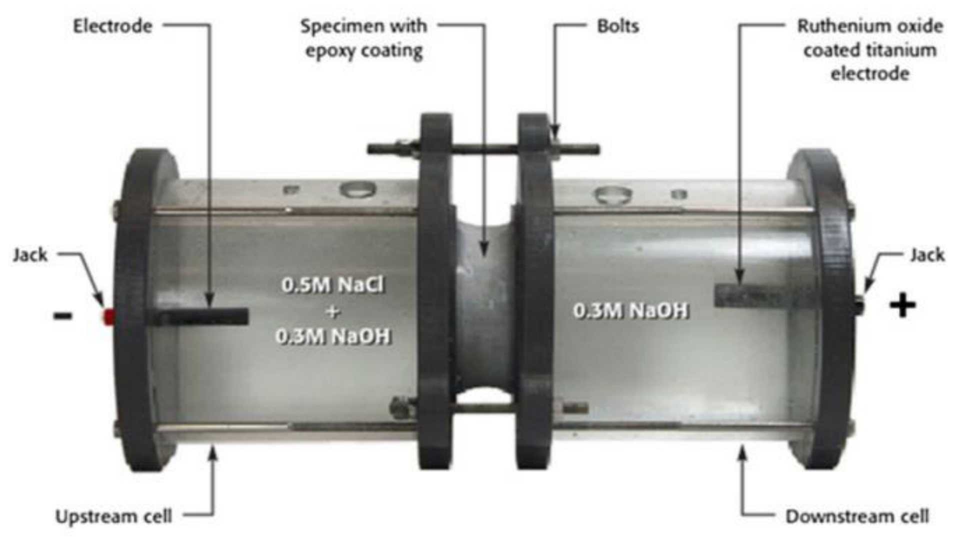


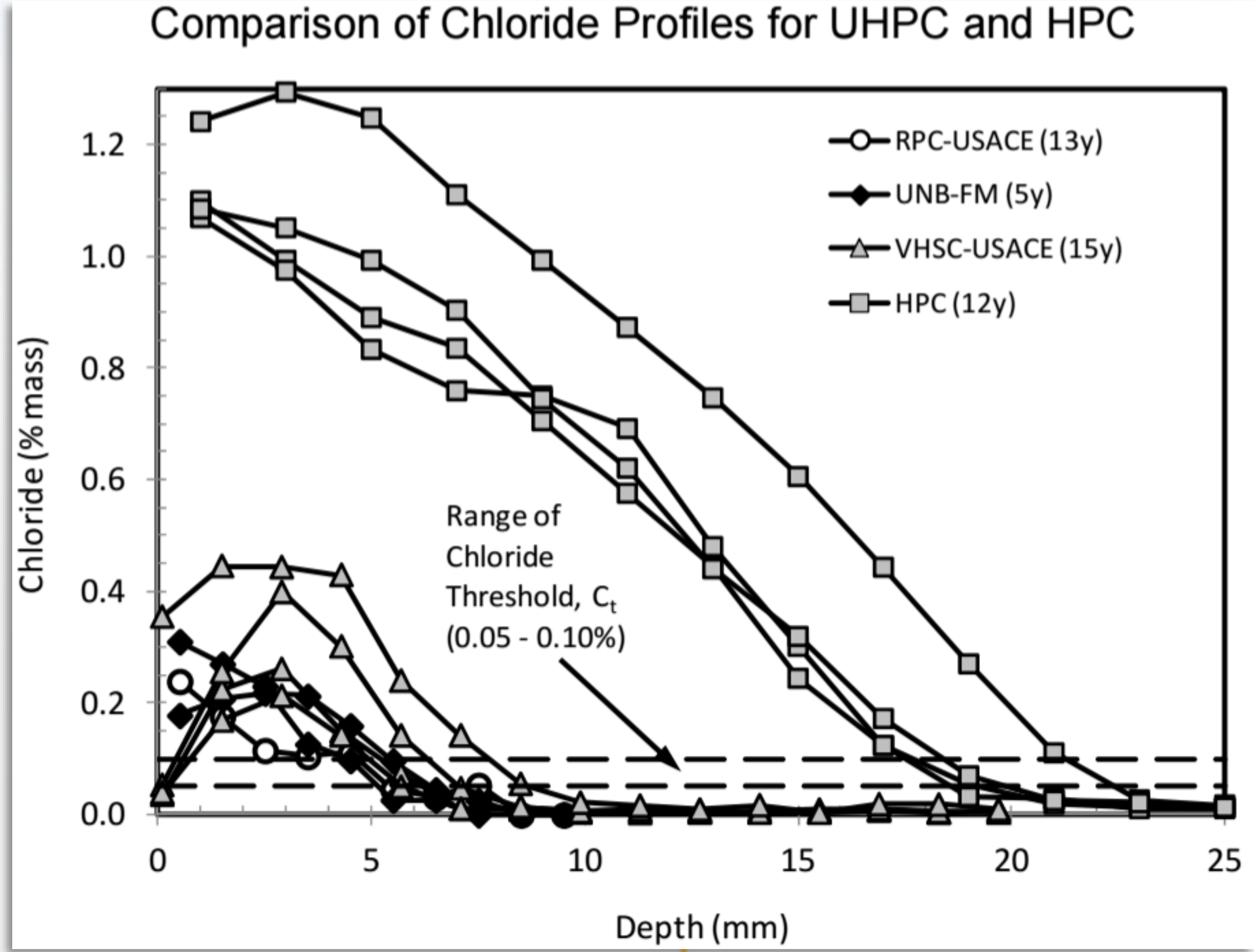
Table 2. Material tests commonly applied to UHPC used in field-cast connections.

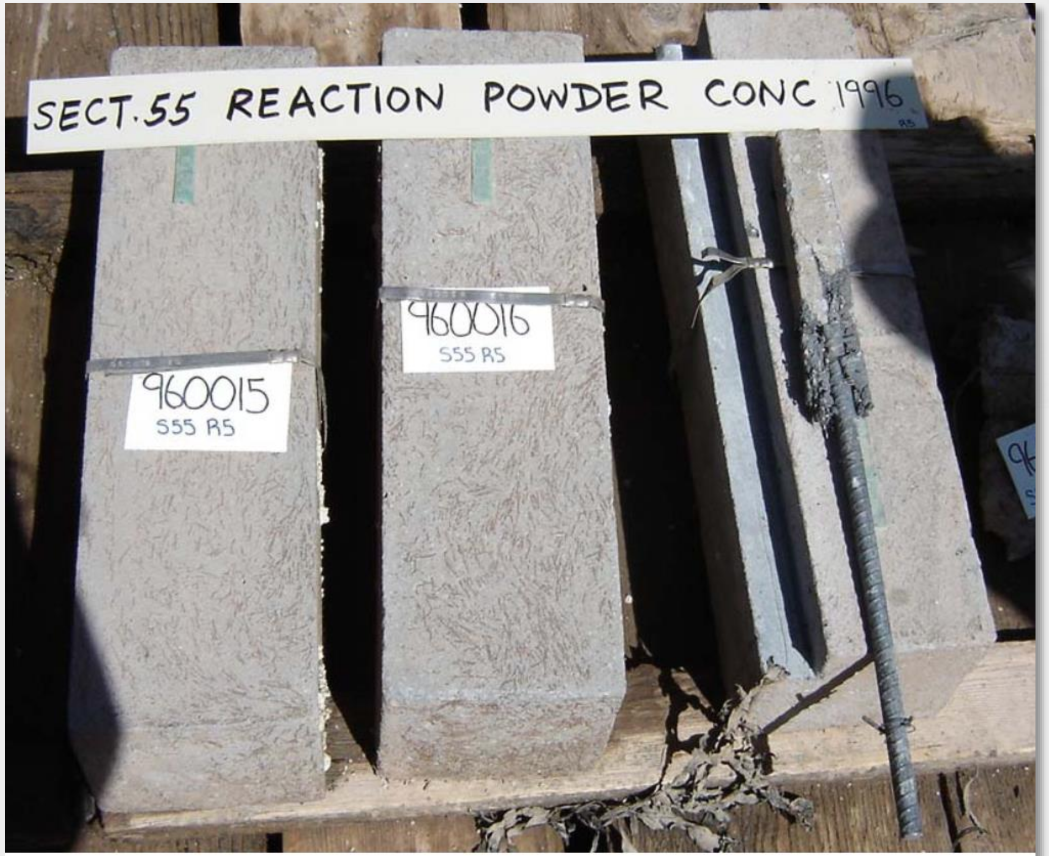
Test Method	ASTM	Material Vetting	QA/QC	QA/QC Frequency	Acceptance Criteria
Flow	C1856 (C1437 mod.)	Yes	Yes	Once per mix	• Flow range from 7 to 10 inches (178 to 254 mm).
Compressive strength	C1856 (C39 mod.)	Yes	Yes	At least once per 25 yd^3 (19 m^3) or once per 12-hour shift	• >14 ksi (97 MPa) after 4 days.[a] • >17.5 ksi (120 MPa) after 28 days. • >14 ksi (97 MPa) before application of construction or live loads.
Chloride ion penetrability	C1856 (C1202)[b]	Yes	Not common	N/A	• ≤500 coulombs by 28 days.
Freeze–thaw resistance	C1856 (C666A mod.)	Yes	Not common	N/A	• RDM ≥ 90 percent after 300 cycles.
Shrinkage	C1856 (C157 mod.)	Yes	Not common	N/A	• ≤800 microstrain at 28 days. • Consider curing scenarios.


FLY ASH MIXTURE
SLAG MIXTURE
UHPC MIXTURE
Current (mA)
Time (hours)
0
1
2
3
4
5
6
7
0
50
100
150
200
250
300
350


Electrode
Specimen with epoxy coating
Bolts
Ruthenium oxide coated titanium electrode
Jack
Jack
-
+
0.5M NaCl + 0.3M NaOH
0.3M NaOH
Upstream cell
Downstream cell

USACE Durability Testing





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

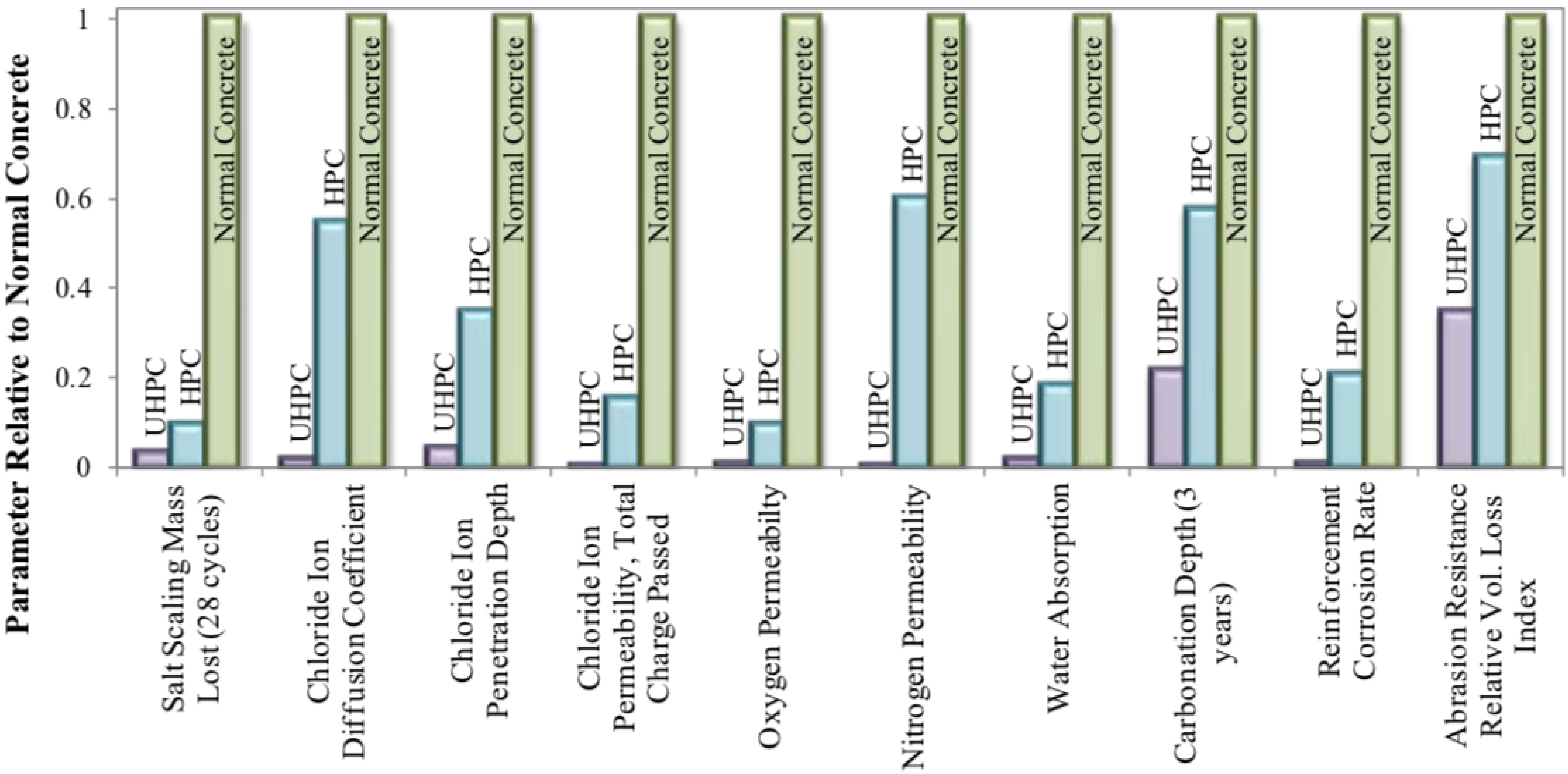


Figure 4. Chart. Durability properties of UHPC and HPC with respect to normal concrete (lowest values identify the most favorable material.[26]

French standard

NF P 18-710
16 April 2016

Classification index: **P 18-710**

National addition to Eurocode 2 — Design of concrete structures: specific rules for Ultra-High Performance Fibre-Reinforced Concrete (UHPFRC)

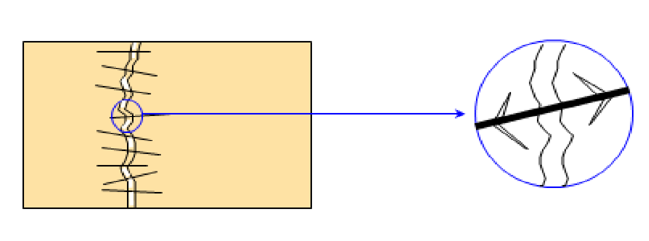
Table 4.202 — Values of minimum cover $c_{min,dur}$ requirements with regard to durability for reinforcement steel compliant with EN 10080

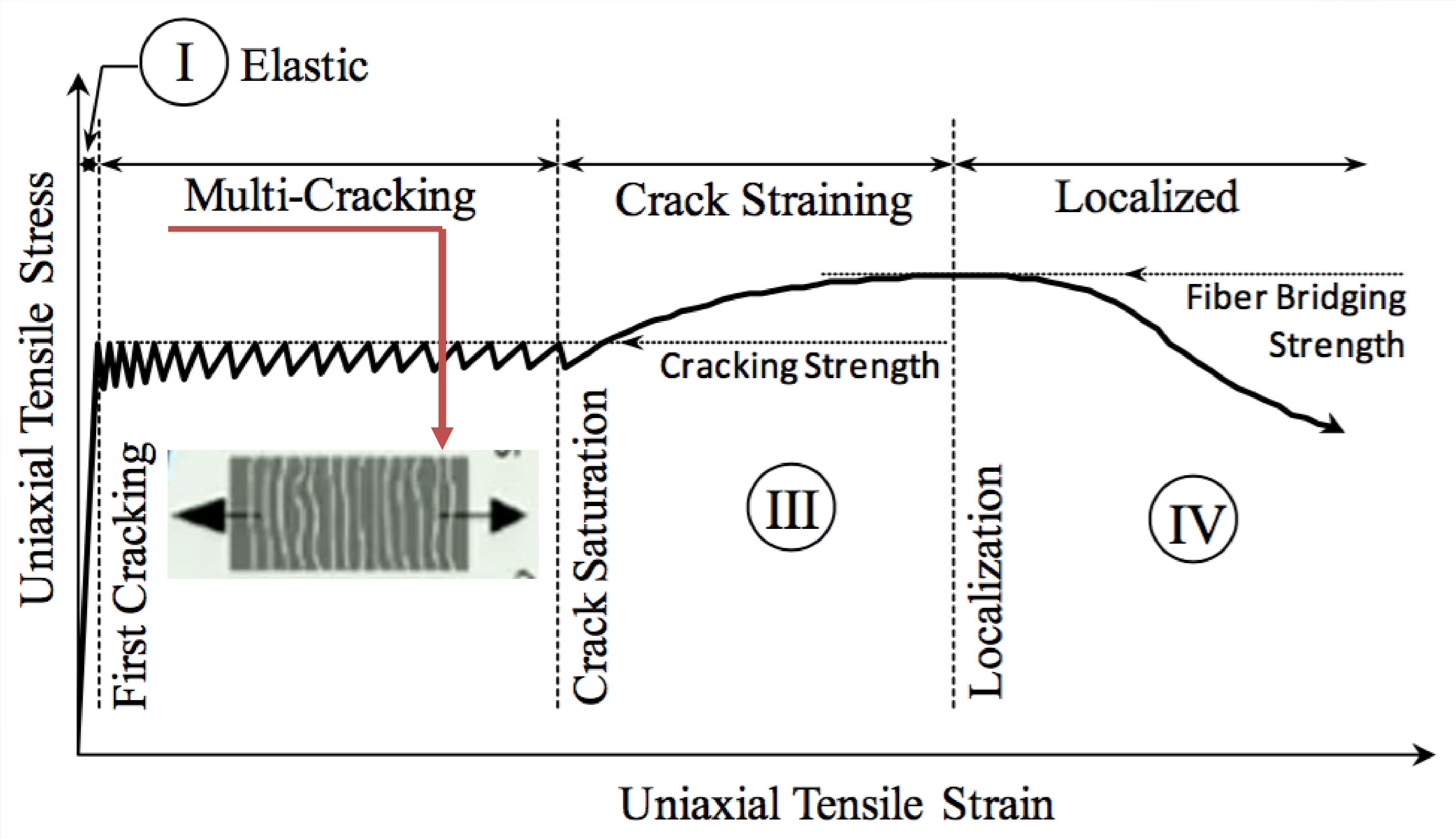
Environmental requirement for $c_{min,dur}$ (mm)							
Structural class	Exposure class according to Table 4.1						
	X0	XC1	XC2/XC3	XC4	XD1/XS1	XD2/XS2	XD3/XS3
S1	-	5	5	10	10	15	15
S2		5	10	10	15	15	20
S3		5	10	15	15	20	20
S4		10	15	15	20	20	20
S5		10	15	20	20	20	25
S6		15	20	20	20	25	25

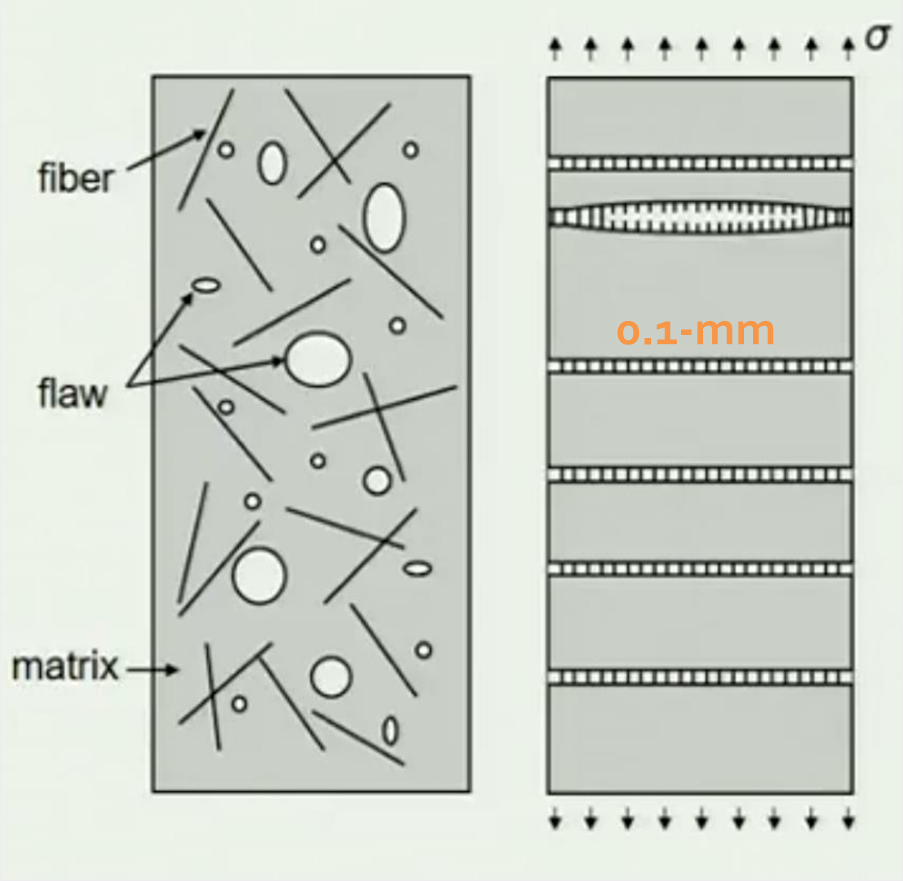
Table 6 — Performance-based requirement

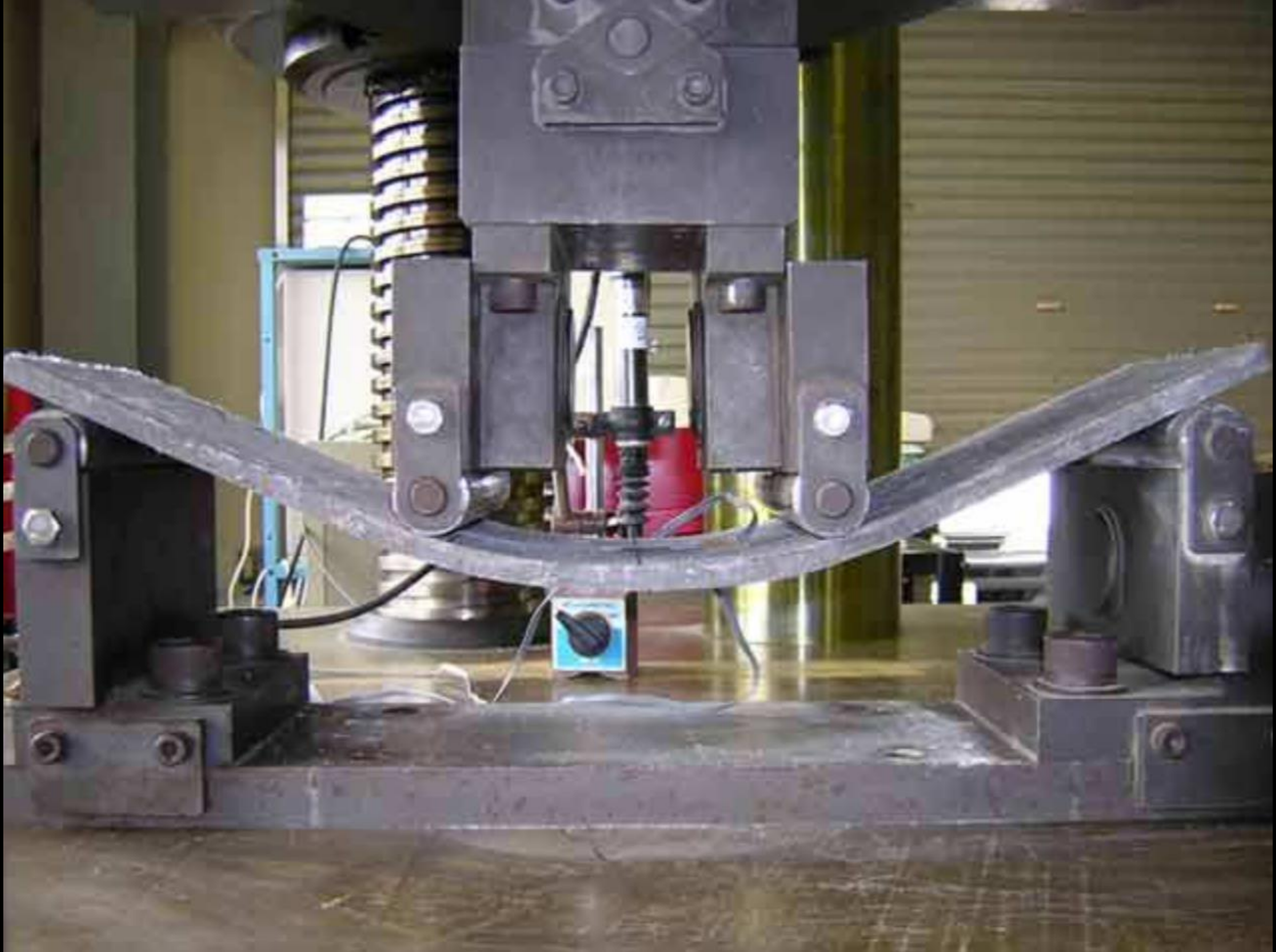
Exposure class	DWL(a)	Requirement
XC1, XC2, XC3, XC4	50 years	-
	100 years	-
	150 years	Dp+, Dg+
XS1, XS2, XD1, XD2, XF2	50 years	-
	100 years	-
	150 years	Dp+, Dc+, Dg+
XF1, XF3	50 years	-
	100 years	-
	150 years	-
XS3, XD3	50 years	-
	100 years	Dp+, Dc+
	150 years	Dp+, Dc+, Dg+
XF4	50 years	-
	100 years	Dp+, Dc+, Dg+
	150 years	Dp+, Dc+, Dg+ and specific study

Tensile Behavior









TYPICAL BRIDGE DECK

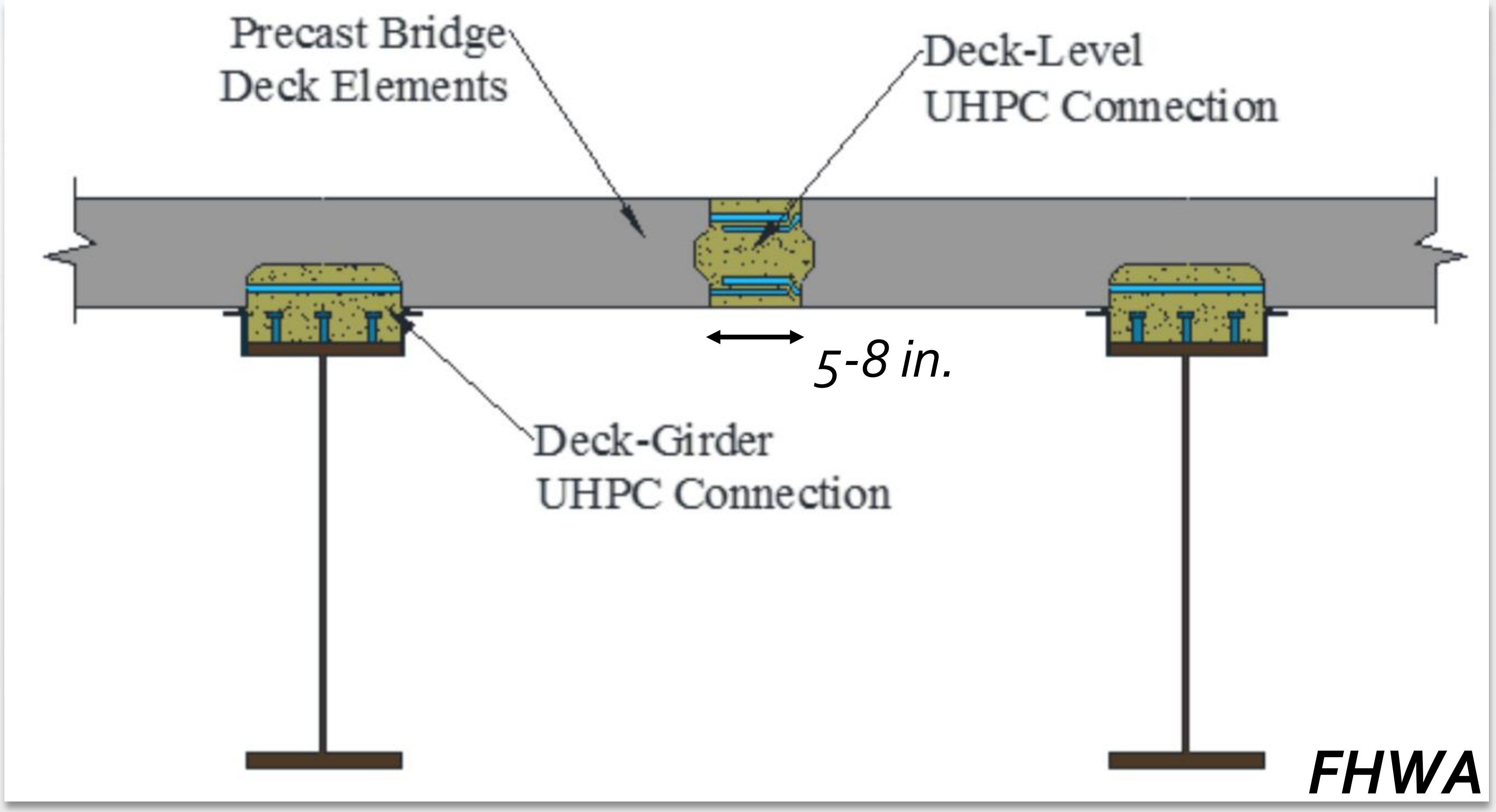
TYPICAL DETERIORATION MECHANISMS

Cracking
(shrinkage, ASR, loading)

Spalling
(freeze/thaw, carbonation, corrosion)

Corrosion
(chloride/acid penetration)

PBE + UHPC CONNECTIONS



TECHNOTE

Design and Construction of Field-Cast UHPC Connections

FHWA Publication No: FHWA-HRT-19-011

FHWA Contact: Ben Graybeal, HRDI-40, ORCID: 0000-0002-3694-1369, 202-493-3122, benjamin.graybeal@dot.gov

This document is an update to *Design and Construction of Field-Cast UHPC Connections* (FHWA-HRT-14-084).

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 ideal for use in new solutions to pressing concerns about highway-infrastructure deterioration, repair, and replacement.[1,2] The use of field-cast UHPC details that connect prefabricated structural elements in bridge construction has captured the attention of bridge 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 advancements in superplasticizers, dry-constituent gradation, fiber reinforcements, and supplemental cementitious materials, UHPC outperforms 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. In general, 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]

An alternative name for UHPC is ultra-high performance fiber-reinforced concrete (UHPFRC).

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Common UHPC Connections 5
Design of Field-Cast Connections 13
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Construction Engineer Inspection 29
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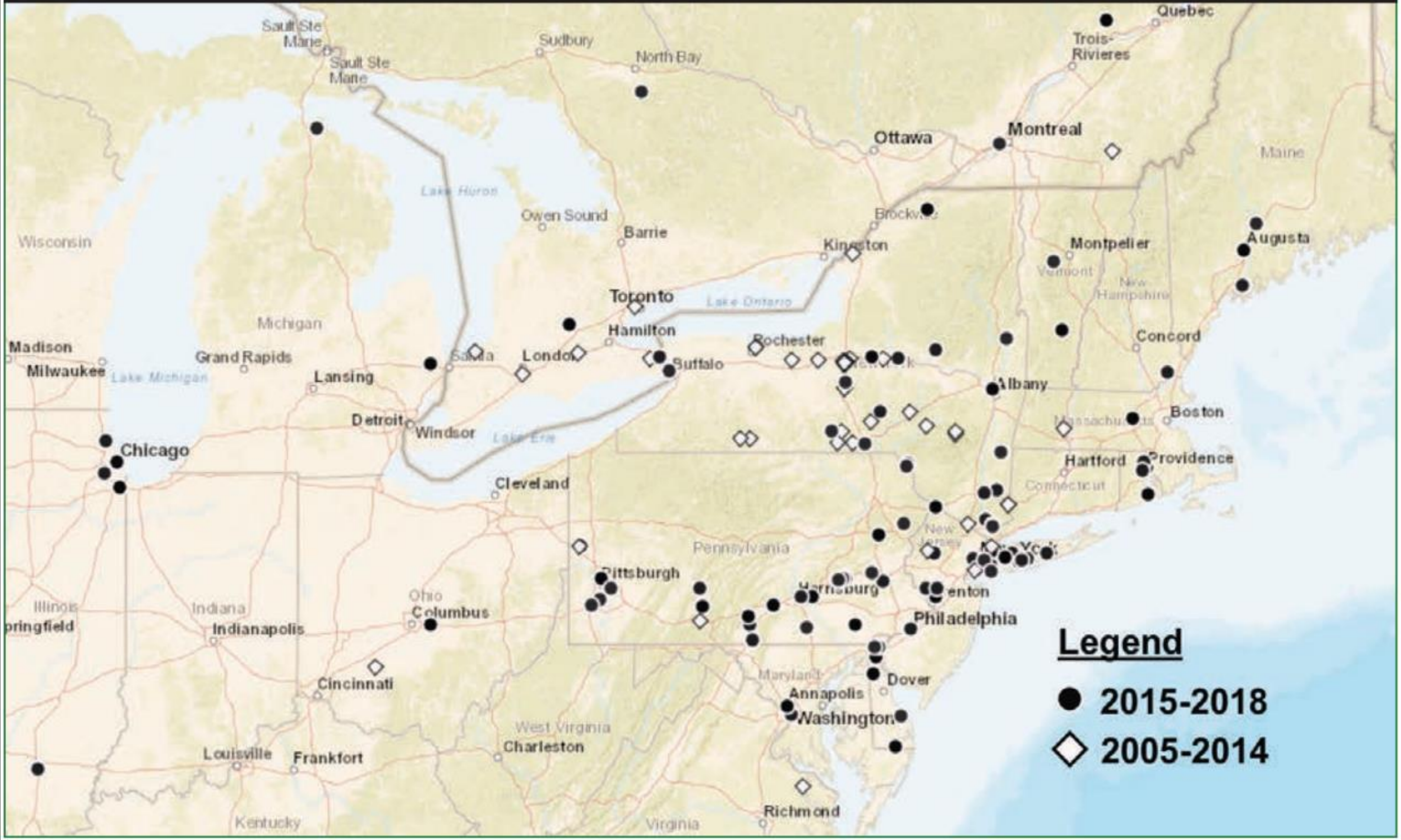
Conclusion 40

U.S. Department of Transportation
Federal Highway Administration

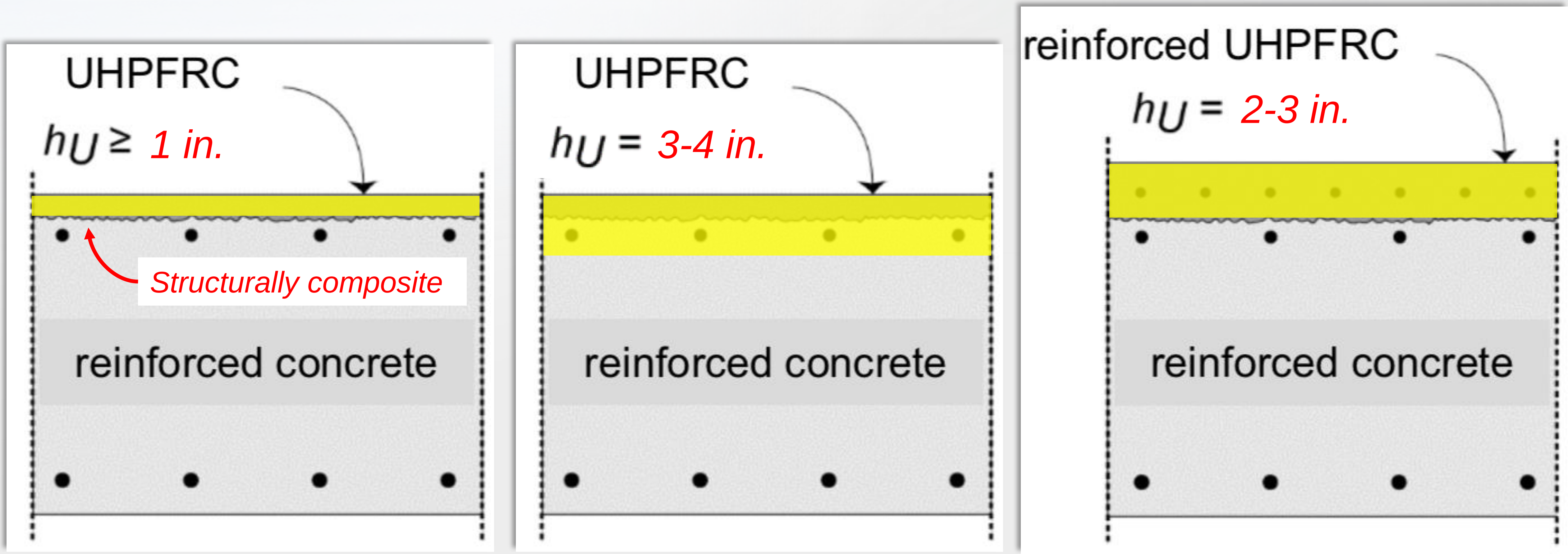
Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike, McLean, VA 22101-2296
www.fhwa.dot.gov/research

Figure 36. Map. Deployments of UHPC in bridges across the northeast United States.



TYPICAL BRIDGE DECK

UHPC "Overlay" Concepts



(1) (2) (3)

Iowa (2016)
Mud Creek

- 1st UHPC overlay in the U.S.
- Rehab & strengthening of exist. concrete bridge
- 1.5″ thick UHPC overlay
- 2,800 square feet
- 13 cubic yards Ductal®
- Two stage installation
- Studies by FHWA and Iowa State University

Delaware (2017)
Blackbird Creek

- 1st UHPC overlay in DE
- New construction – adjacent box beams w/ UHPC joints & overlay
- 1.5″ thick UHPC overlay
- 2,080 square feet
- 10 cubic yards Ductal®
- Two stage installation

Iowa (2018)
Floyd River

- 2nd UHPC overlay in Iowa
- Multi-span deck rehab
- 2″ thick UHPC overlay
- 17,650 square feet
- 110 cubic yards Ductal®
- Multi-phase installation
- 1st project in U.S. to use large-scale equipment

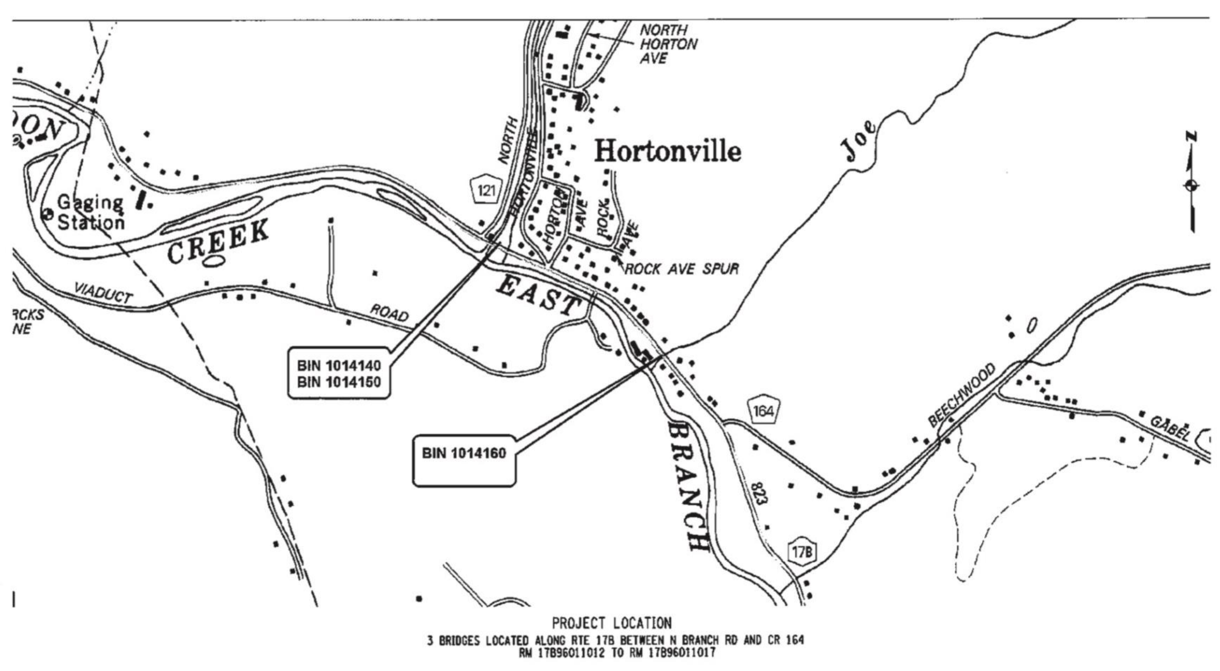
Delaware (2019)
Little Heaven

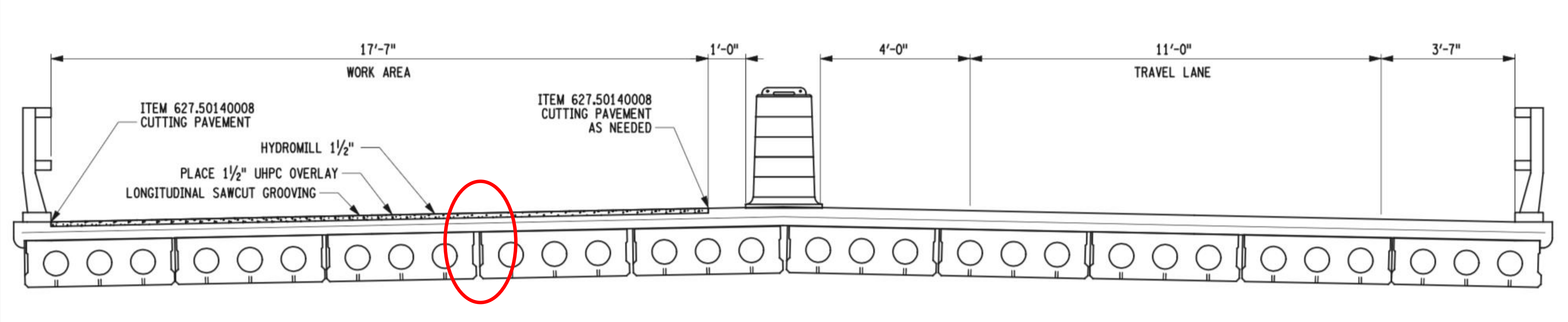
- 2nd UHPC overlay in DE
- Remediation for two (2) new bridge decks
- 2-3″ thick UHPC overlay
- 2 x 5,500 square feet
- 95 cubic yards Ductal®
- Three stage installation per bridge

New York (2019)

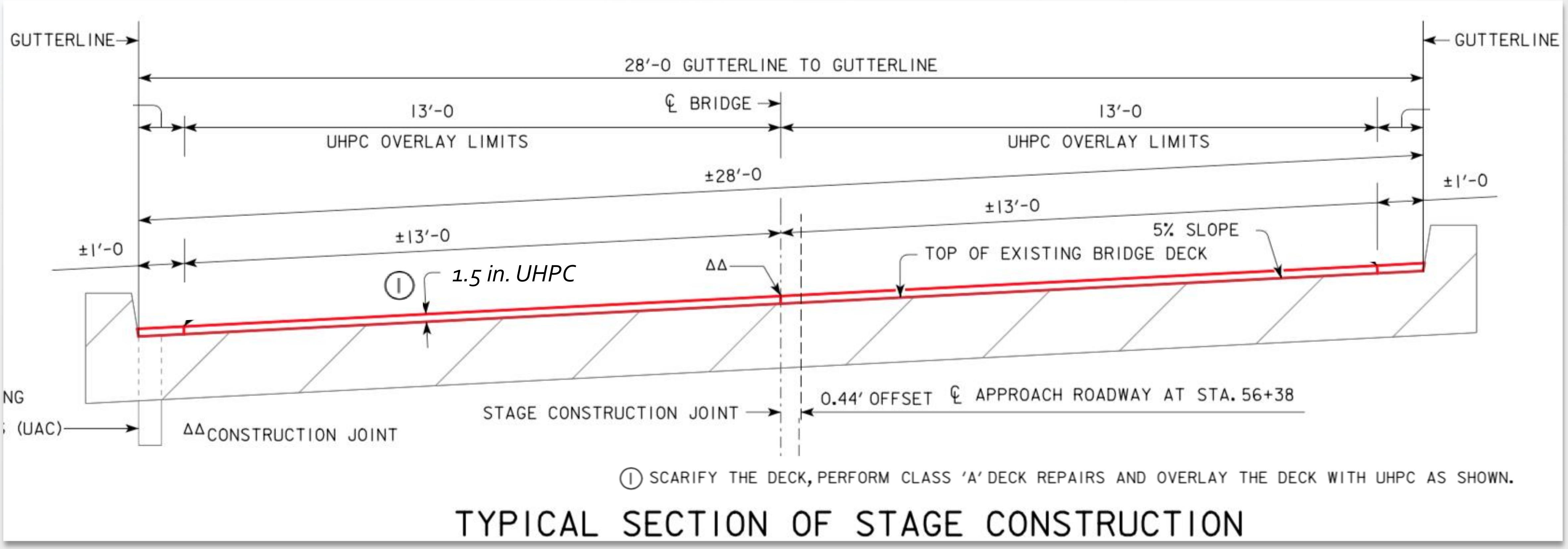
Hortonville

- 1st UHPC overlay project in New York State
- Rehab of three (3) exist. concrete slab bridges
- 1.5" thick UHPC overlay
- 3,300 + 1,900 + 1,100 = 6,300 tot. square feet
- 40 cubic yards Ductal®





MUD CREEK, IA (2016)

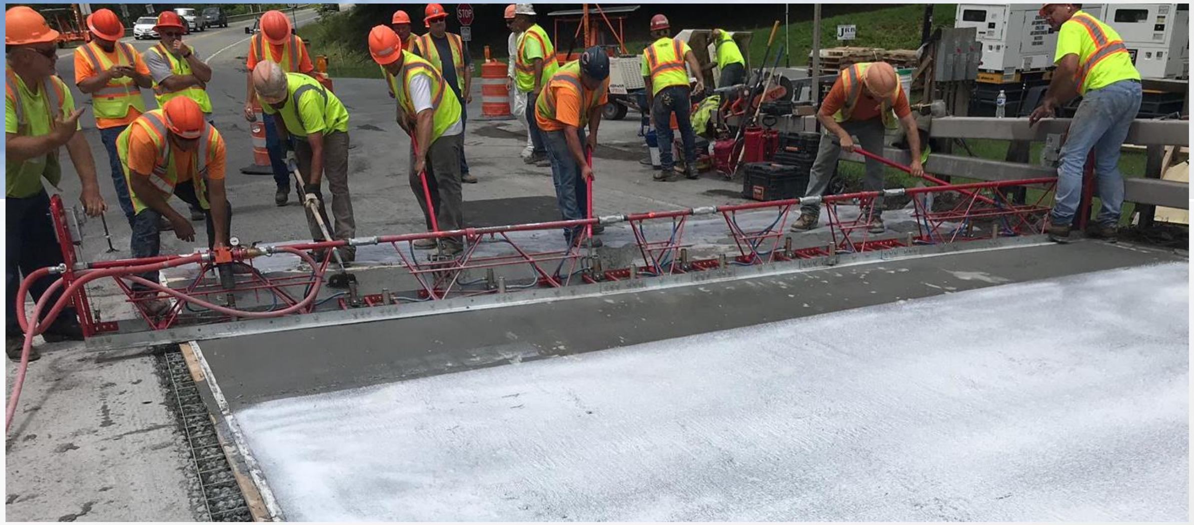


SURFACE PREP

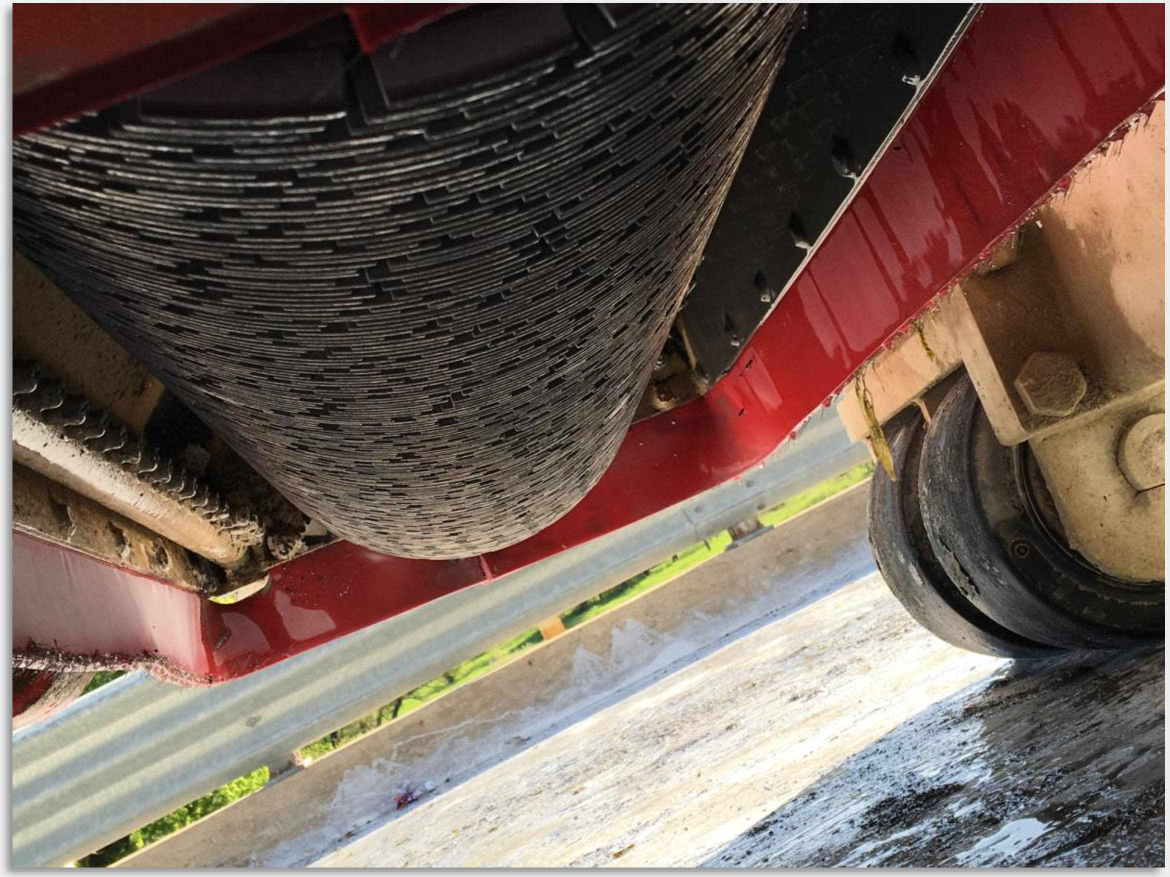
Mill (3-mm min.) *vs* *Hydro-demolition*

Mixing Equipment

Placing Equipment

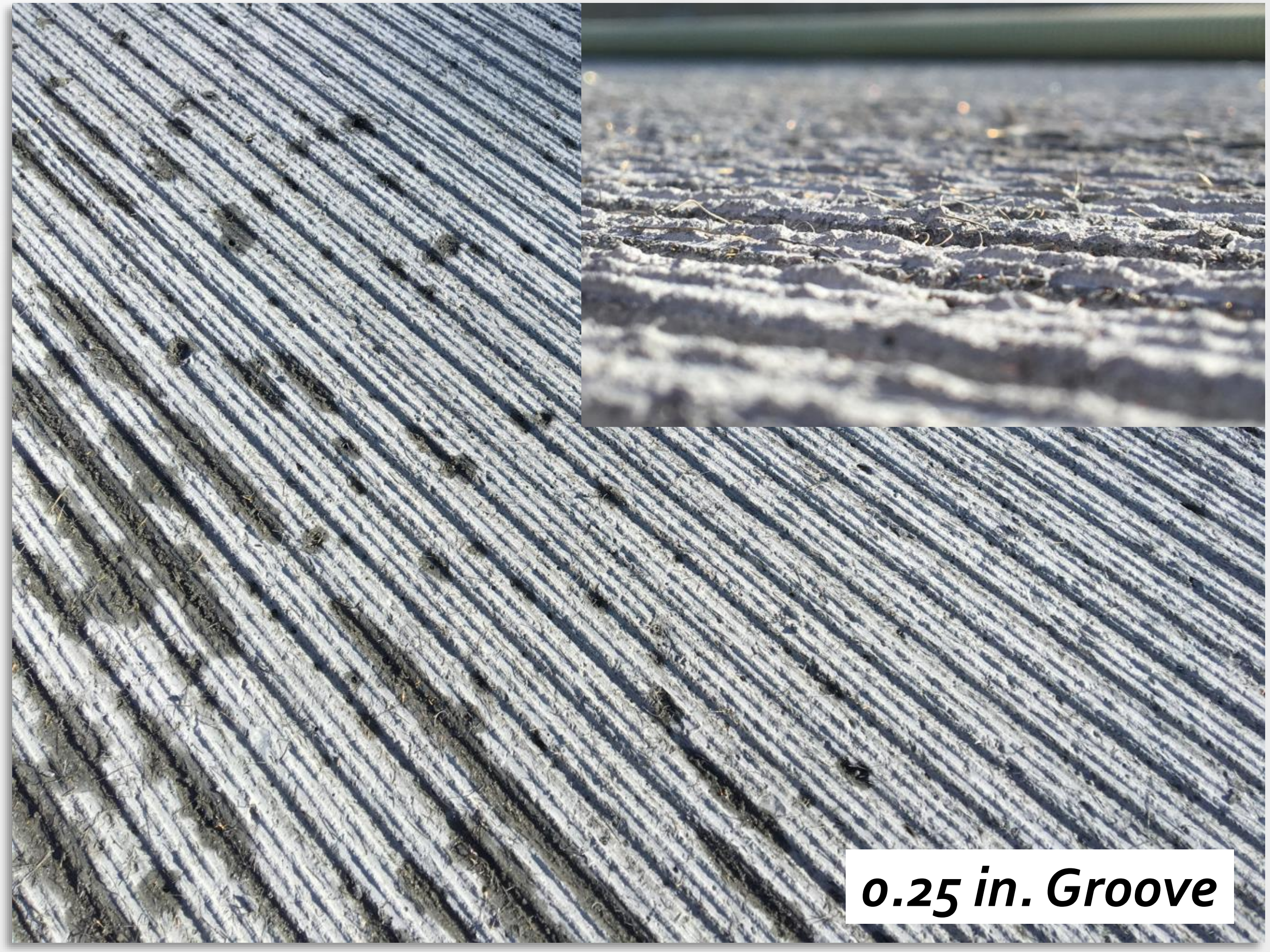


MILLING MACHINE
(pre- and/or post- placement)



SURFACE MILLING

SURFACE GROOVING

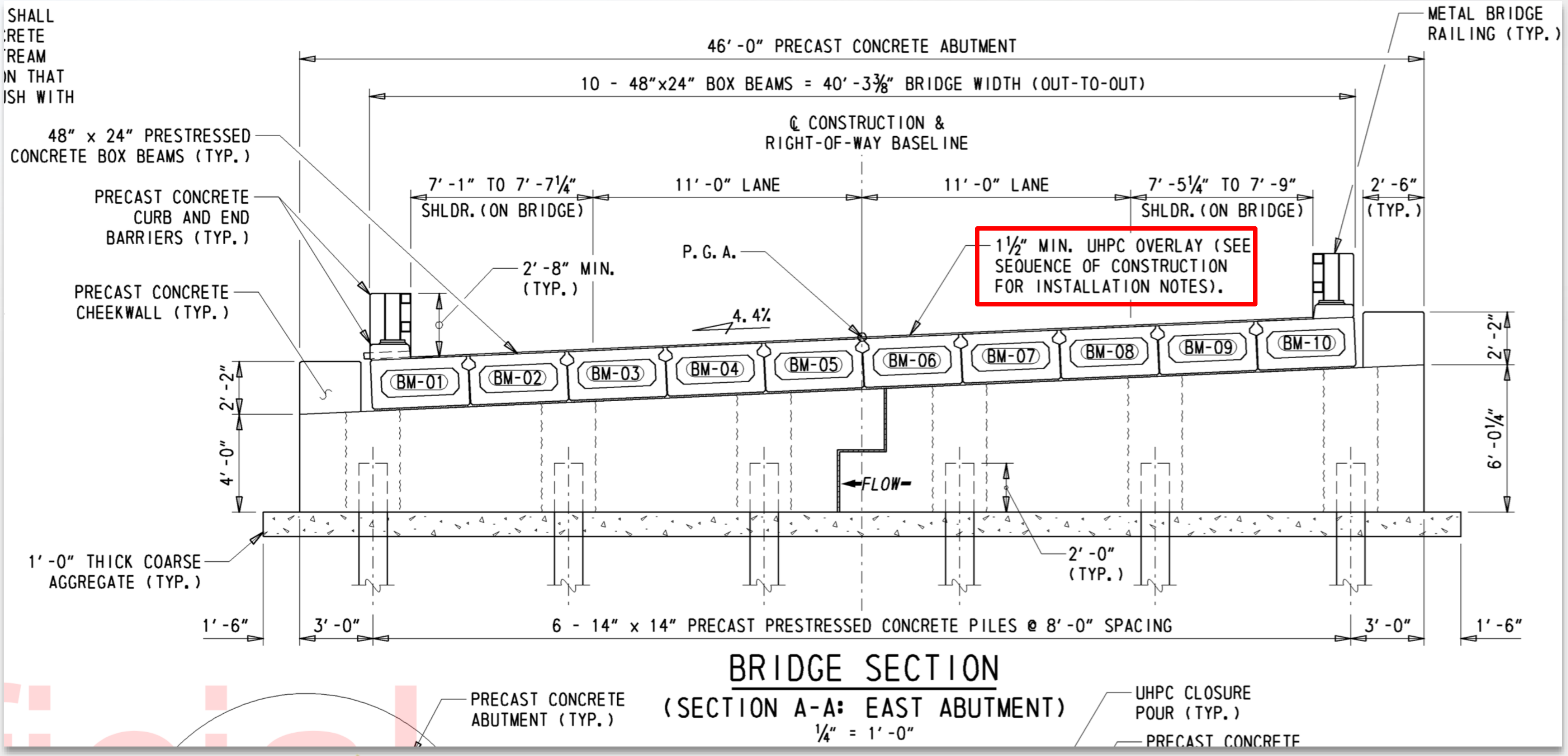



May 19, 2016
0.25-in. Milled Surface
w/ 0.25-in. Grooved Finish

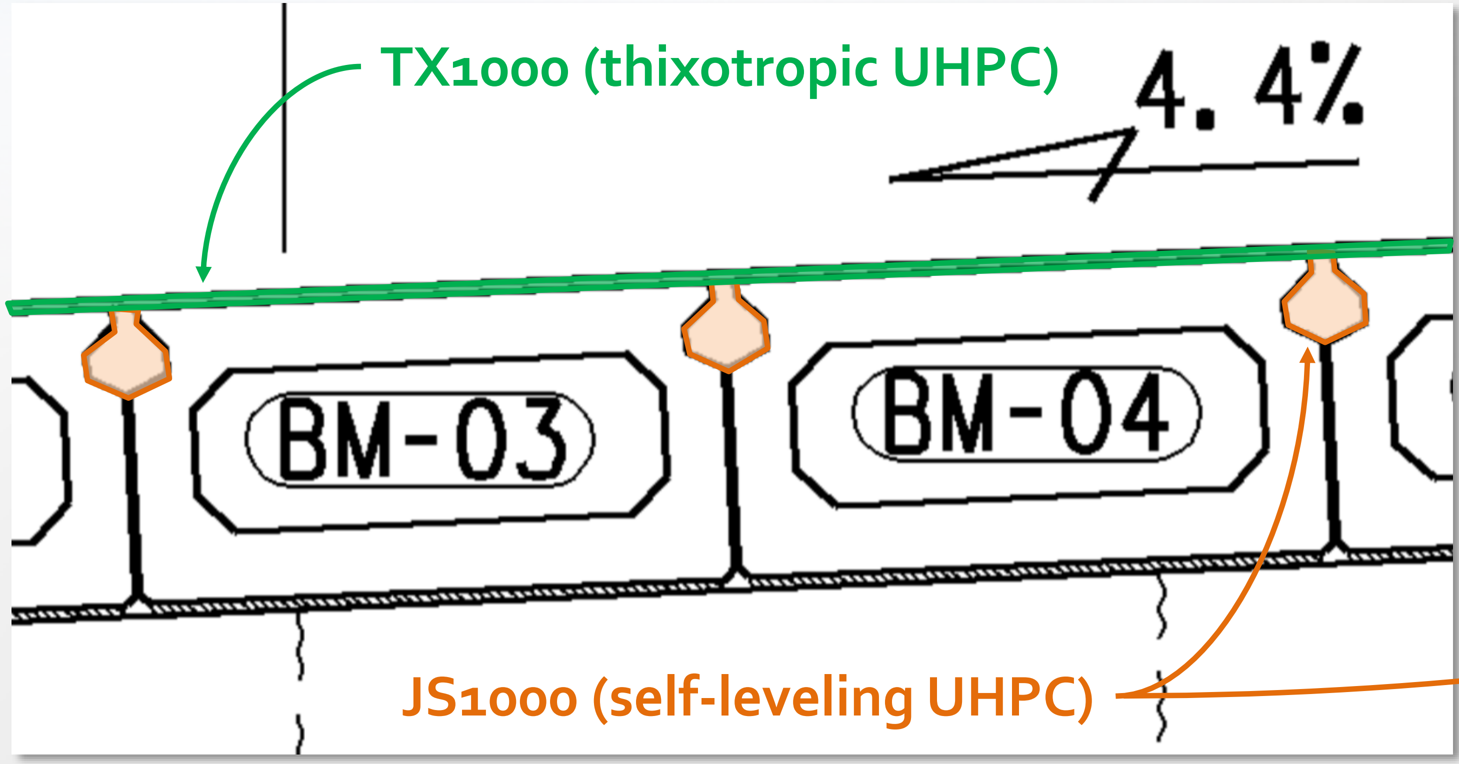
RIDING SURFACE – 1 YR LATER

BLACKBIRD CREEK BRIDGE, DELAWARE

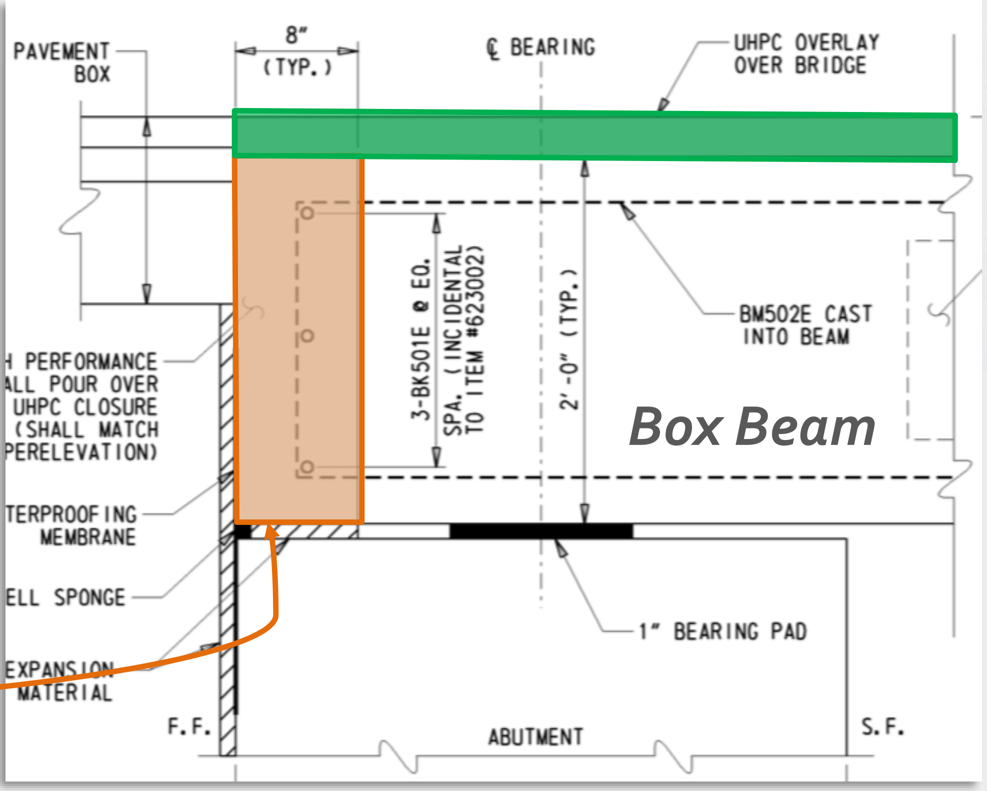
PROPOSED SUPERSTRUCTURE



UHPC USAGE



PARTIAL SECTION VIEW



ELEVATION END VIEW


CAT


CAT

PRE-CONSTRUCTION MOCK-UP


CAT

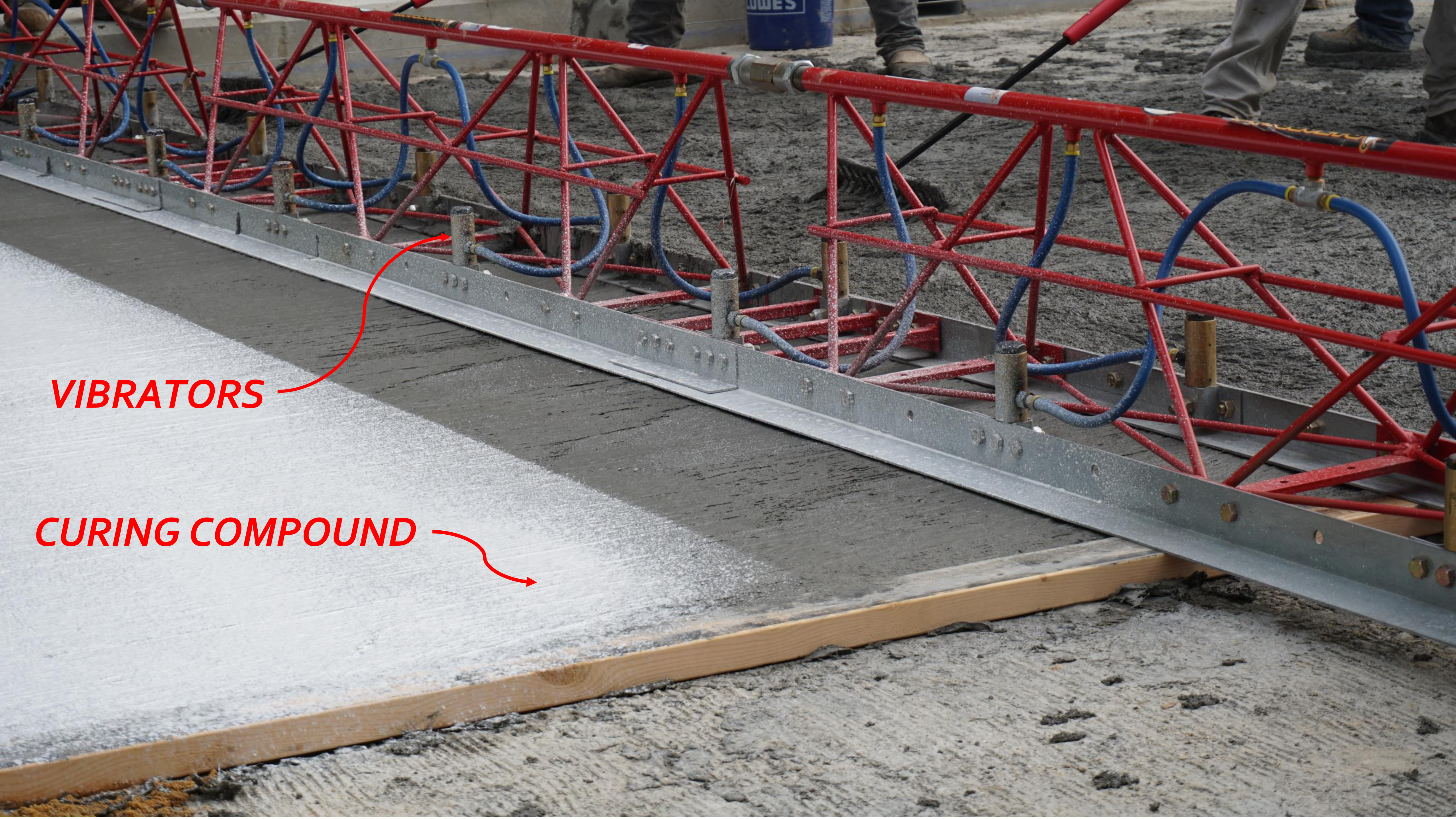
SURFACE PREPARATION

UHPC Ingredients

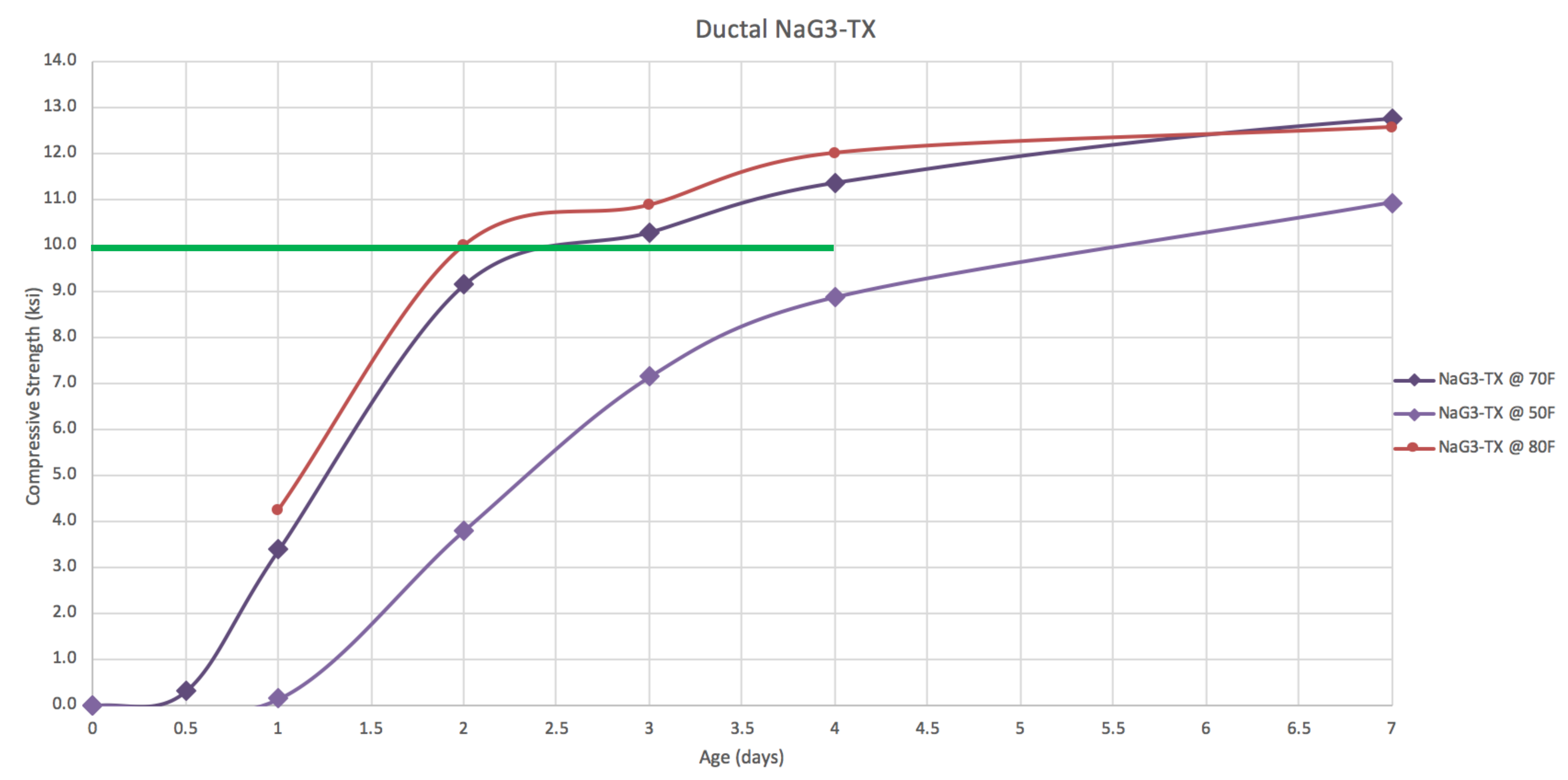
Two 0.65 Cubic Yard (0.5 CM) Capacity High-Shear Mixers
Max. Output = 4 CY per Hour


ZACK
EXCAVATING INC.
DRAMIX
DEERE
GEHL


WHITEMAN
WBH-21
MQ
WHITEMAN


VIBRATORS
CURING COMPOUND


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



CURE UNDER PLASTIC FOR 2-3 DAYS

Poured August 24, 2017


ZACK

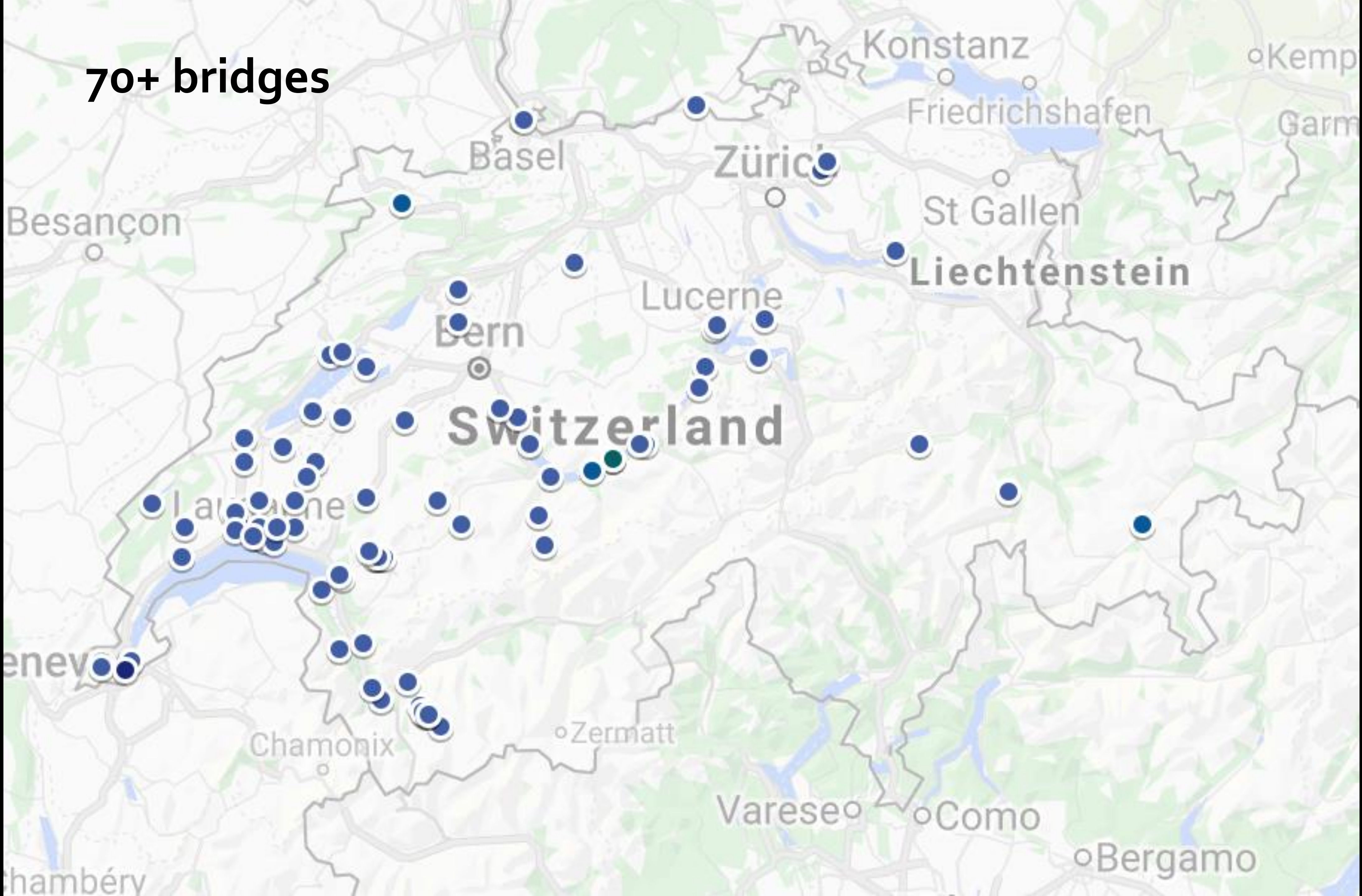
FLOYD RIVER, IA (2018)

WALO
WALO USA

LITTLE HEAVEN, DE (2019)

HORTONVILLE, NY (2019)

70+ bridges



Konstanz
Kemp
Friedrichshafen
Garm
Basel
Zürich
Besançon
St Gallen
Liechtenstein
Lucerne
Bern
Switzerland
Lausanne
Genev
Chamonix
Zermatt
Varese
Como
Bergamo
Chambéry


WALO

CHILLON BRIDGE SECTION

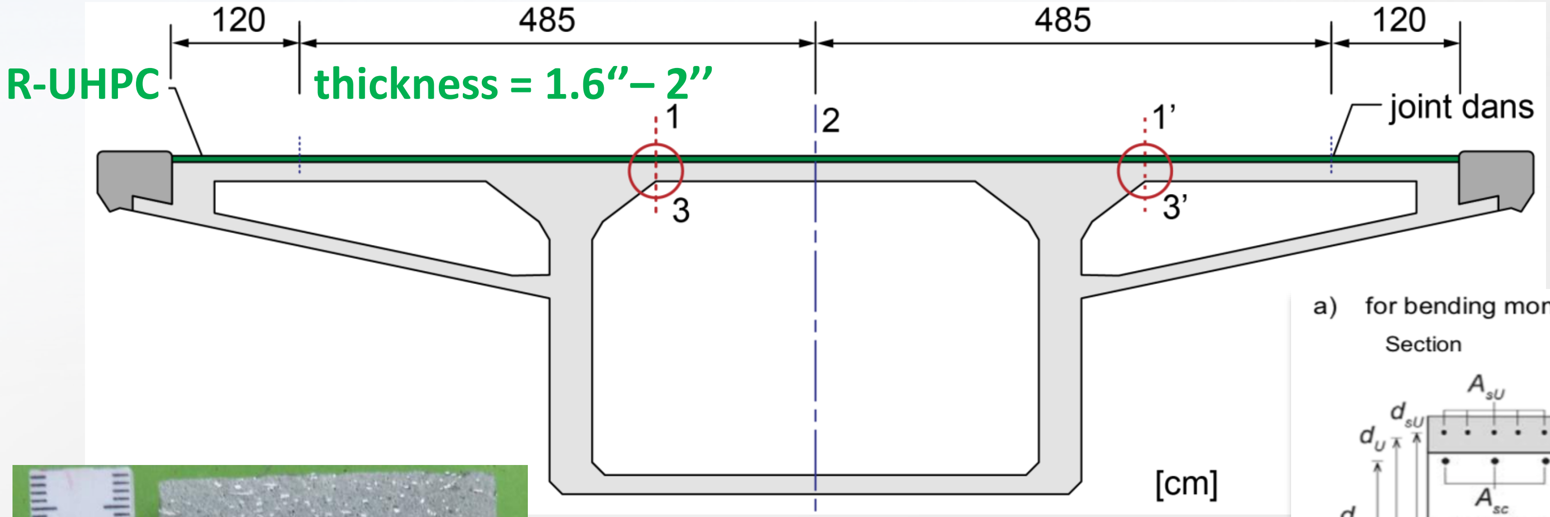
MCS MAINTENANCE CONSTRUCTION SÉCURITÉ
INSTITUT D'INGÉNIERIE CIVILE

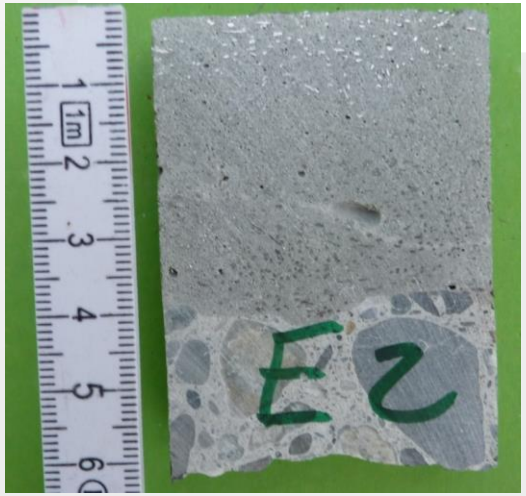
EPFL ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

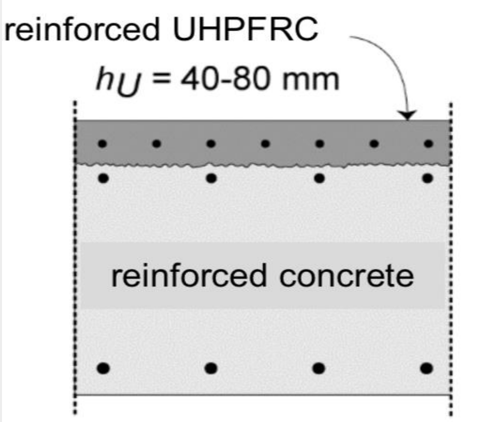
Recommendation:

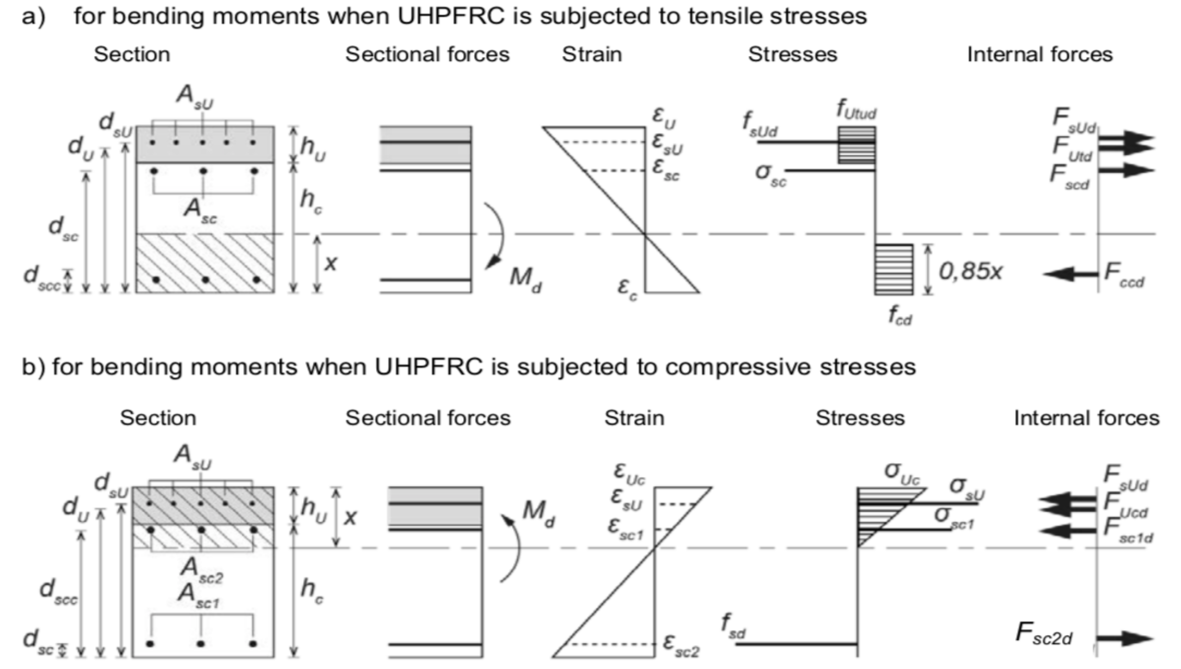
Ultra-High Performance Fibre Reinforced Cement-based composites (UHPFRC)

Construction material, dimensioning und application

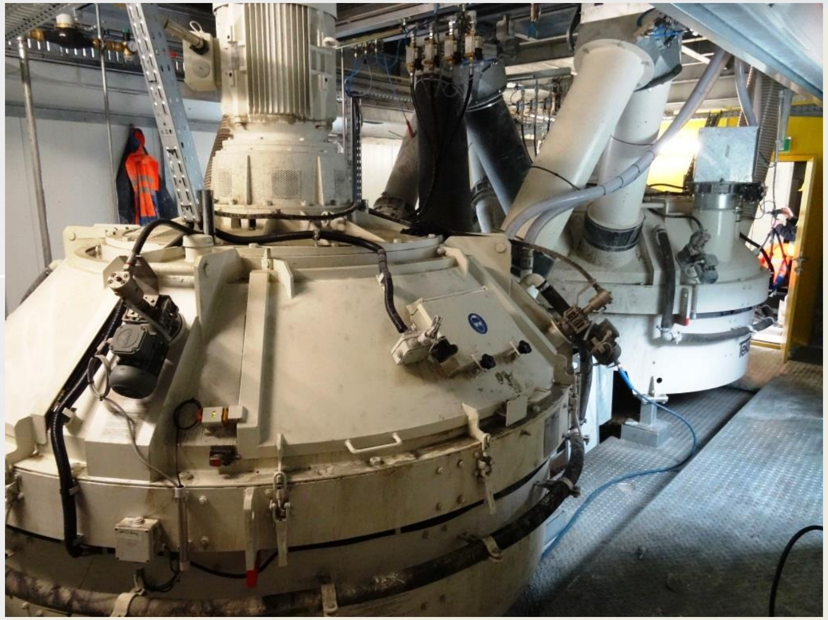








Large-Scale Batching



UPCOMING UHPC OVERLAYS

- Delaware (3)
- New Mexico (1)
- New Jersey (5)
- New York (3)
- Commodore Barry Br. (demo)
- other

TO LEARN MORE…

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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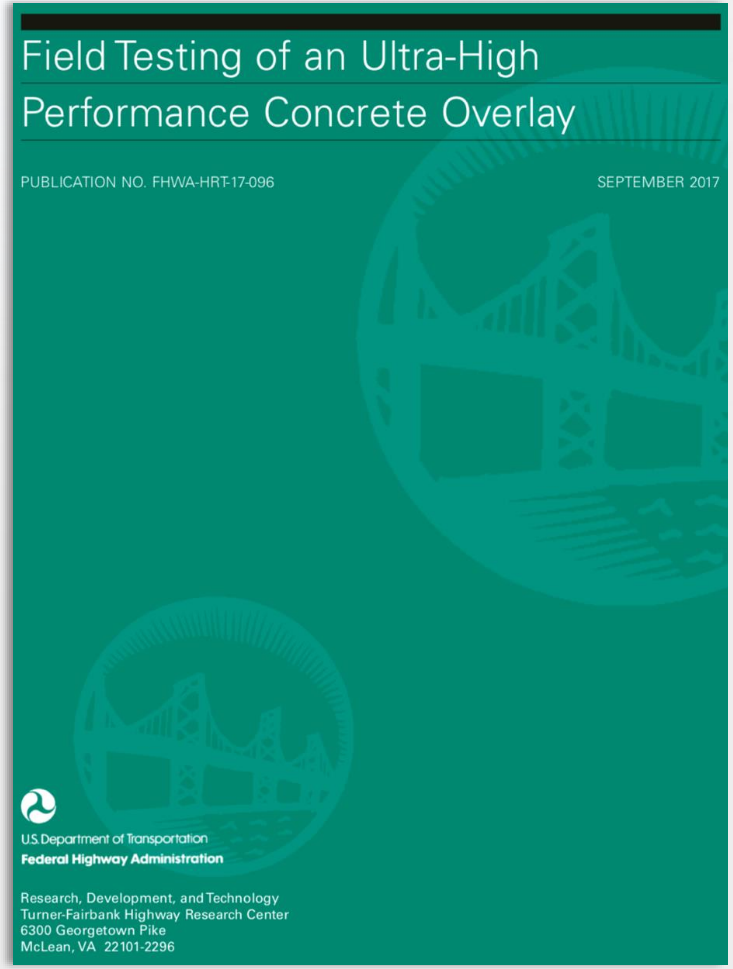
Federal Highway Administration

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



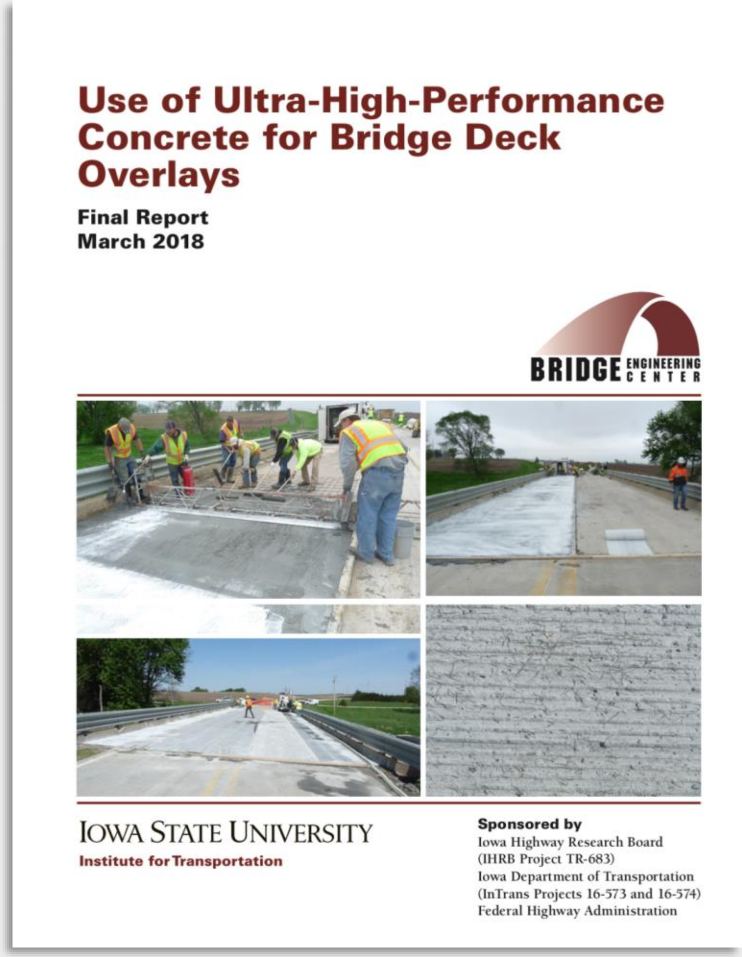
Field Testing of an Ultra-High Performance Concrete Overlay

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



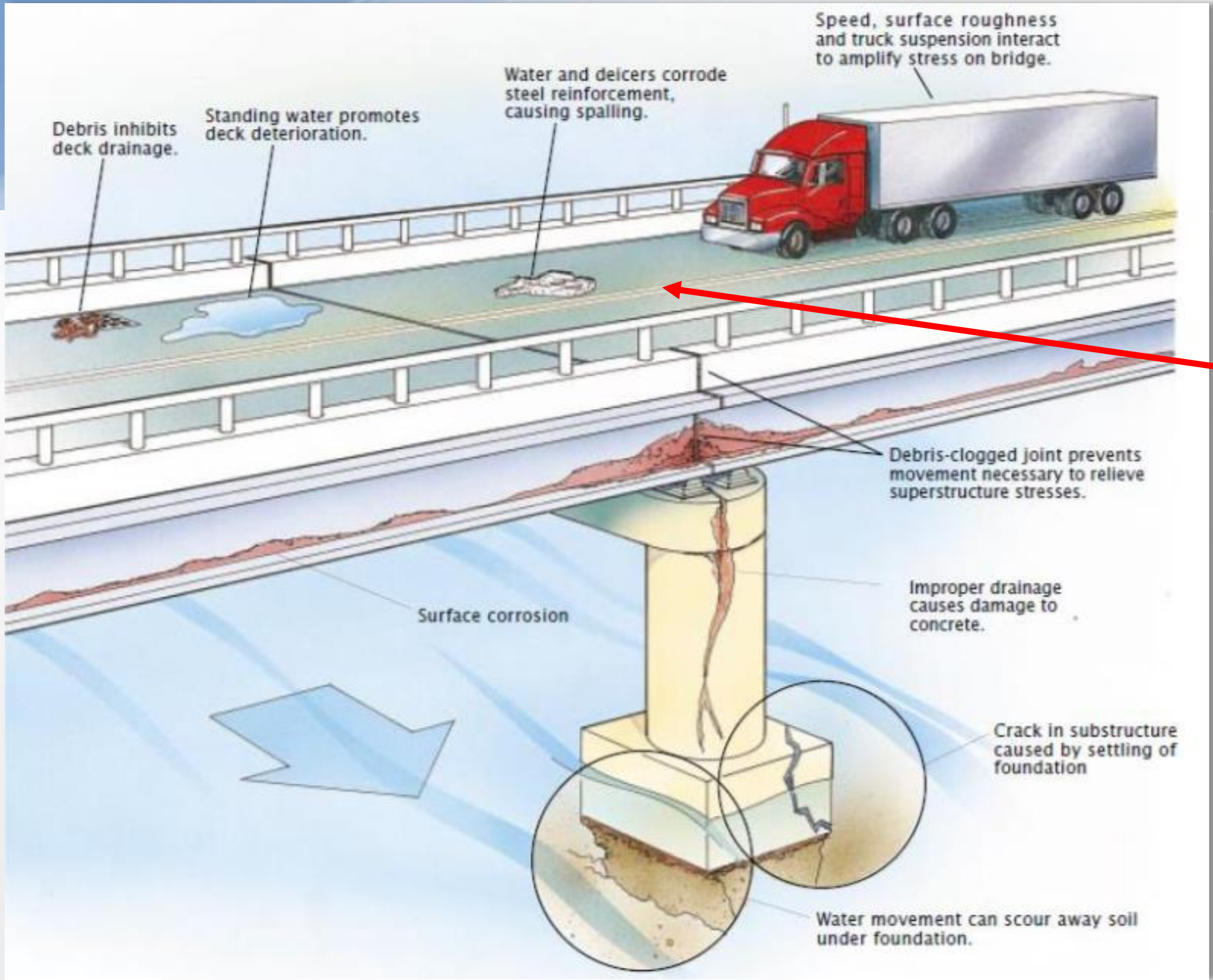
Use of Ultra-High-Performance Concrete for Bridge Deck Overlays

Final Report
March 2018

BRIDGE ENGINEERING CENTER

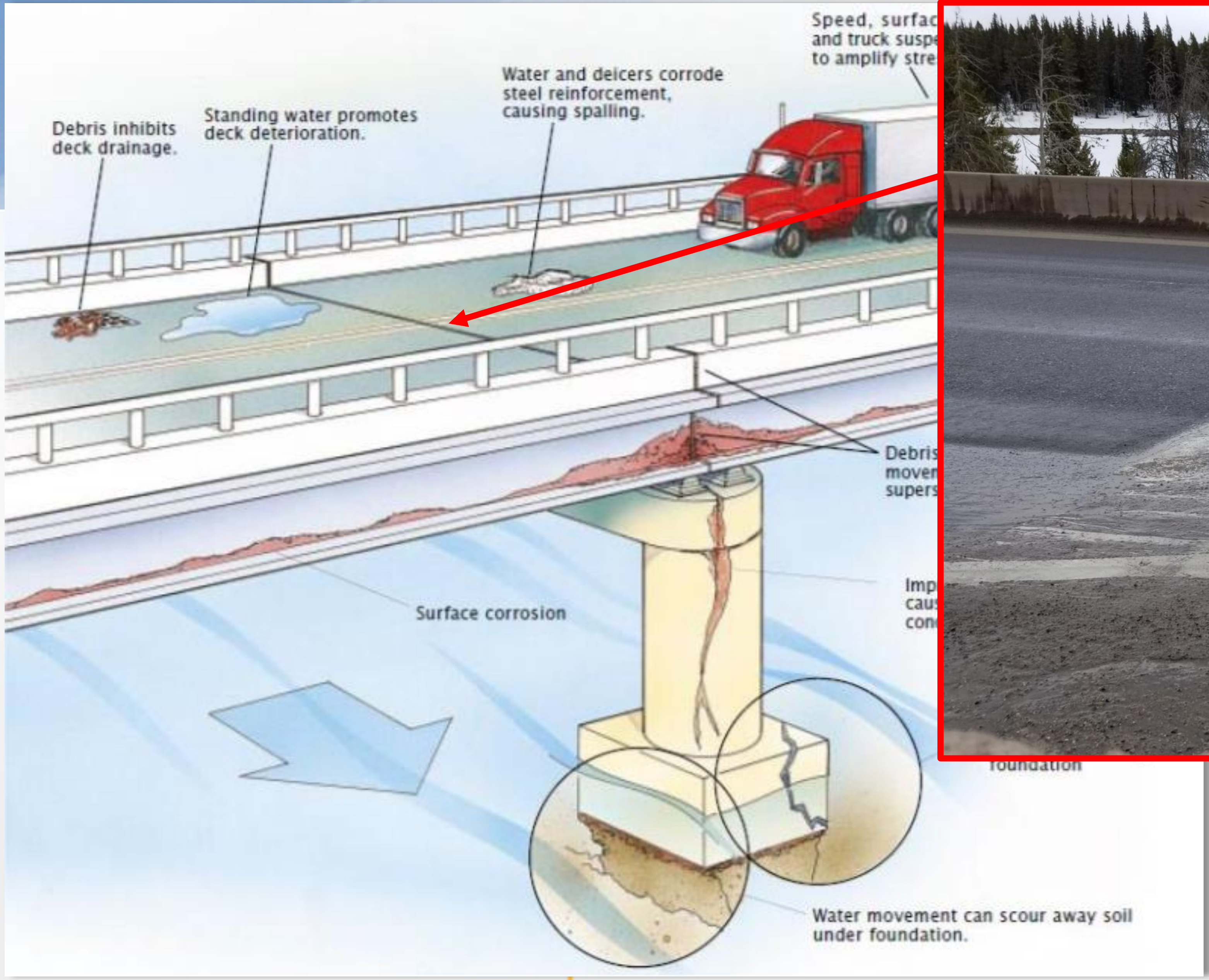
IOWA STATE UNIVERSITY
Institute for Transportation

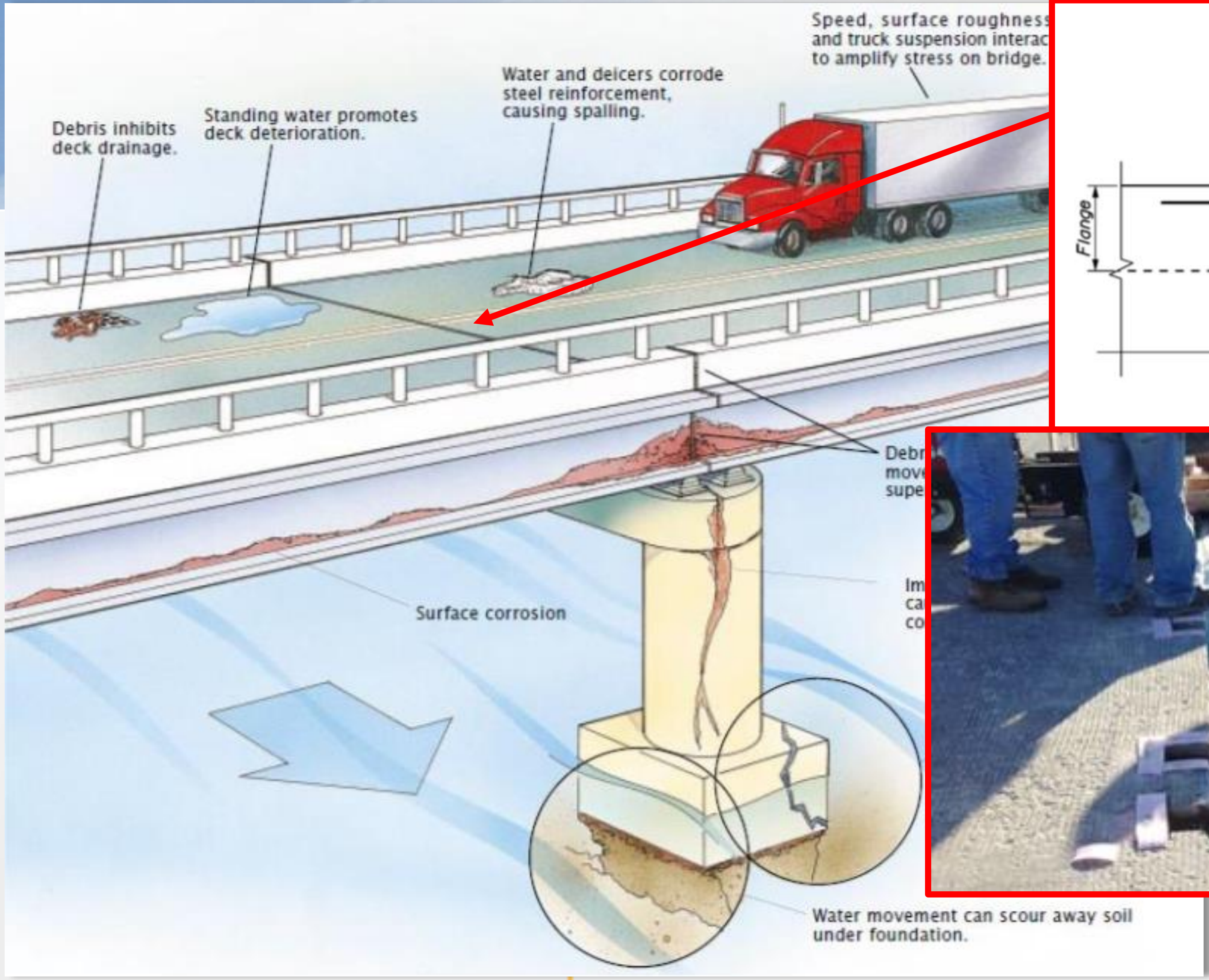
Sponsored by
Iowa Highway Research Board
(IHRB Project TR-683)
Iowa Department of Transportation
(InTrans Projects 16-573 and 16-574)
Federal Highway Administration

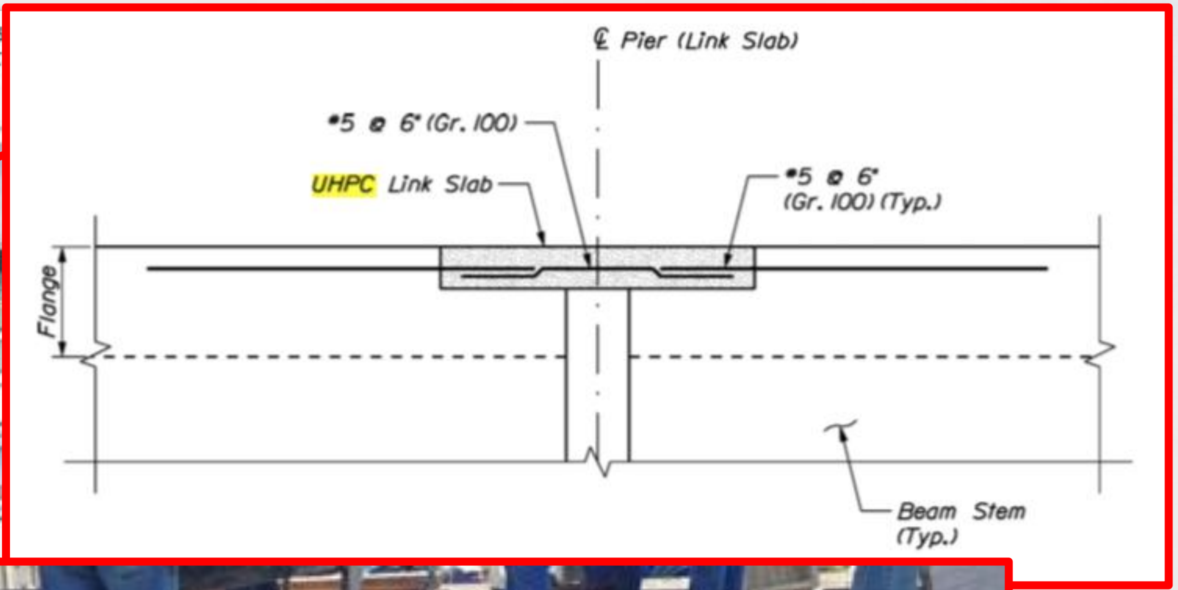


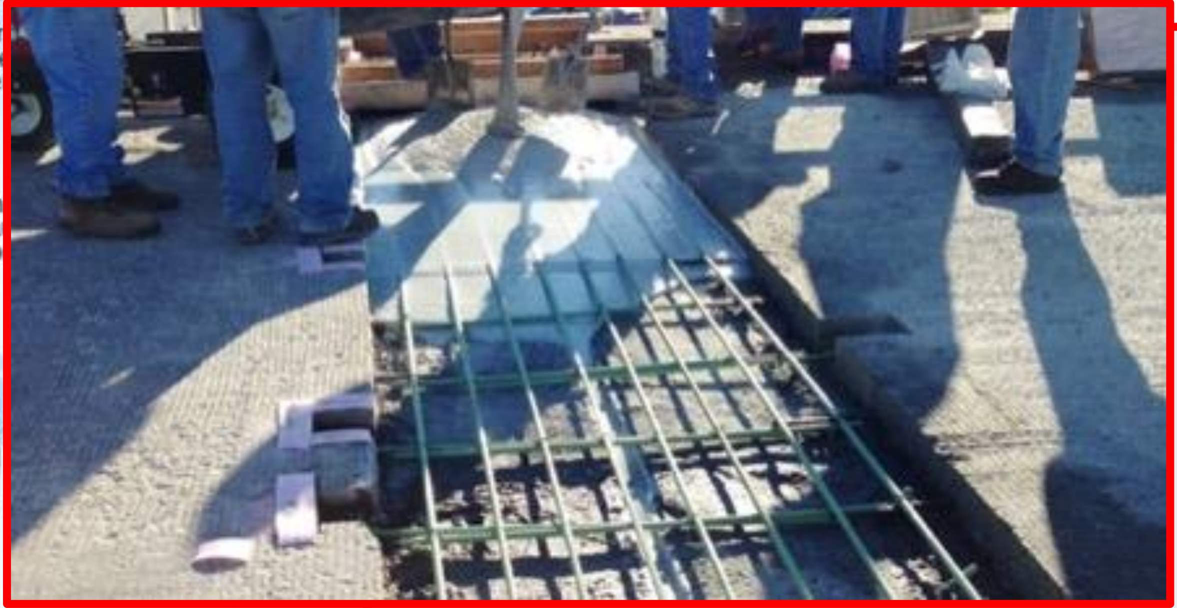
Other Solutions

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


Water and deicers corrode
steel reinforcement,
causing spalling.
Standing water promotes
deck deterioration.
Debris inhibits
deck drainage.
Surface corrosion
Water movement can scour away soil
under foundation.


Speed, surface roughness
and truck suspension interac
to amplify stress on bridge.
Water and deicers corrode steel reinforcement, causing spalling.
Debris inhibits deck drainage.
Standing water promotes deck deterioration.
Surface corrosion
Water movement can scour away soil under foundation.


℄ Pier (Link Slab)
#5 @ 6" (Gr. 100)
UHPC Link Slab
#5 @ 6" (Gr. 100) (Typ.)
Flange
Beam Stem (Typ.)



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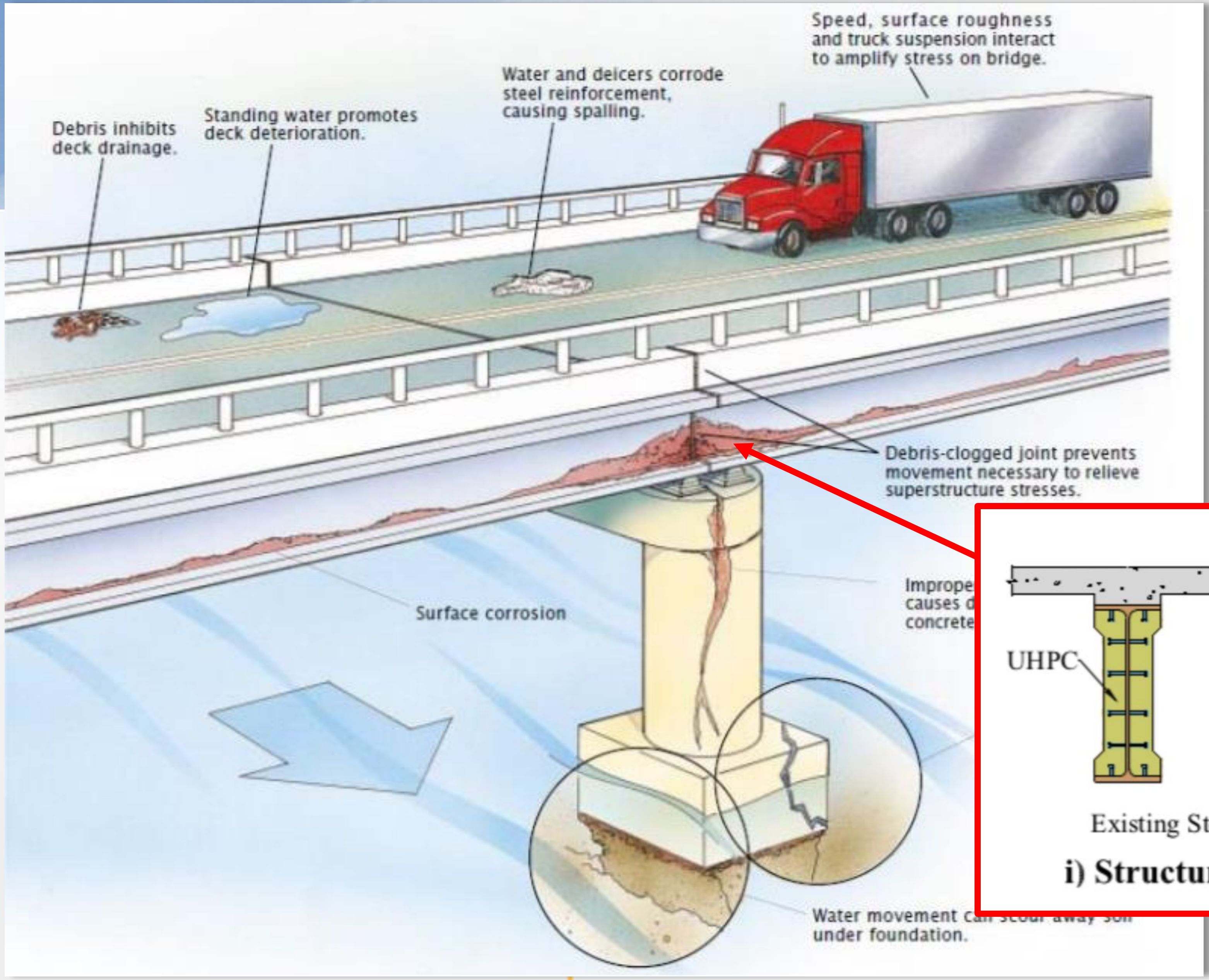
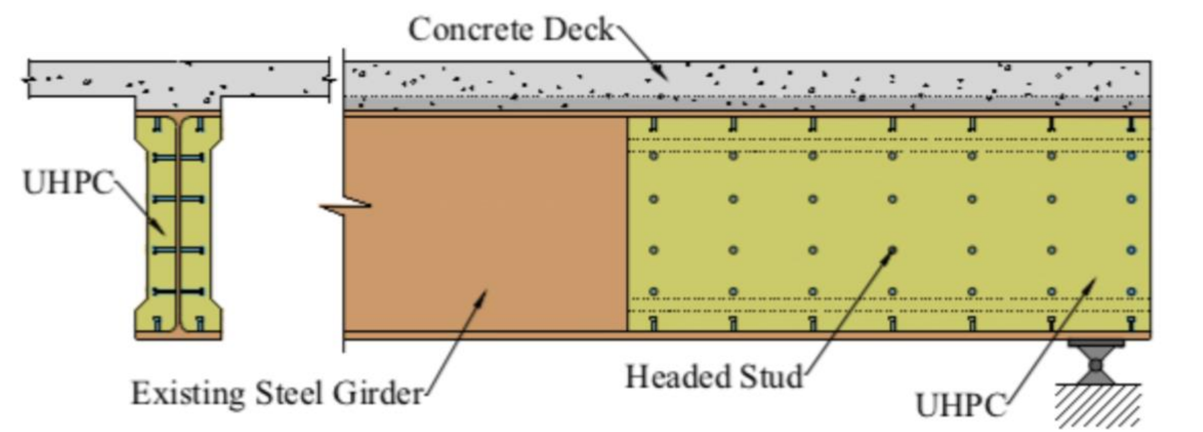
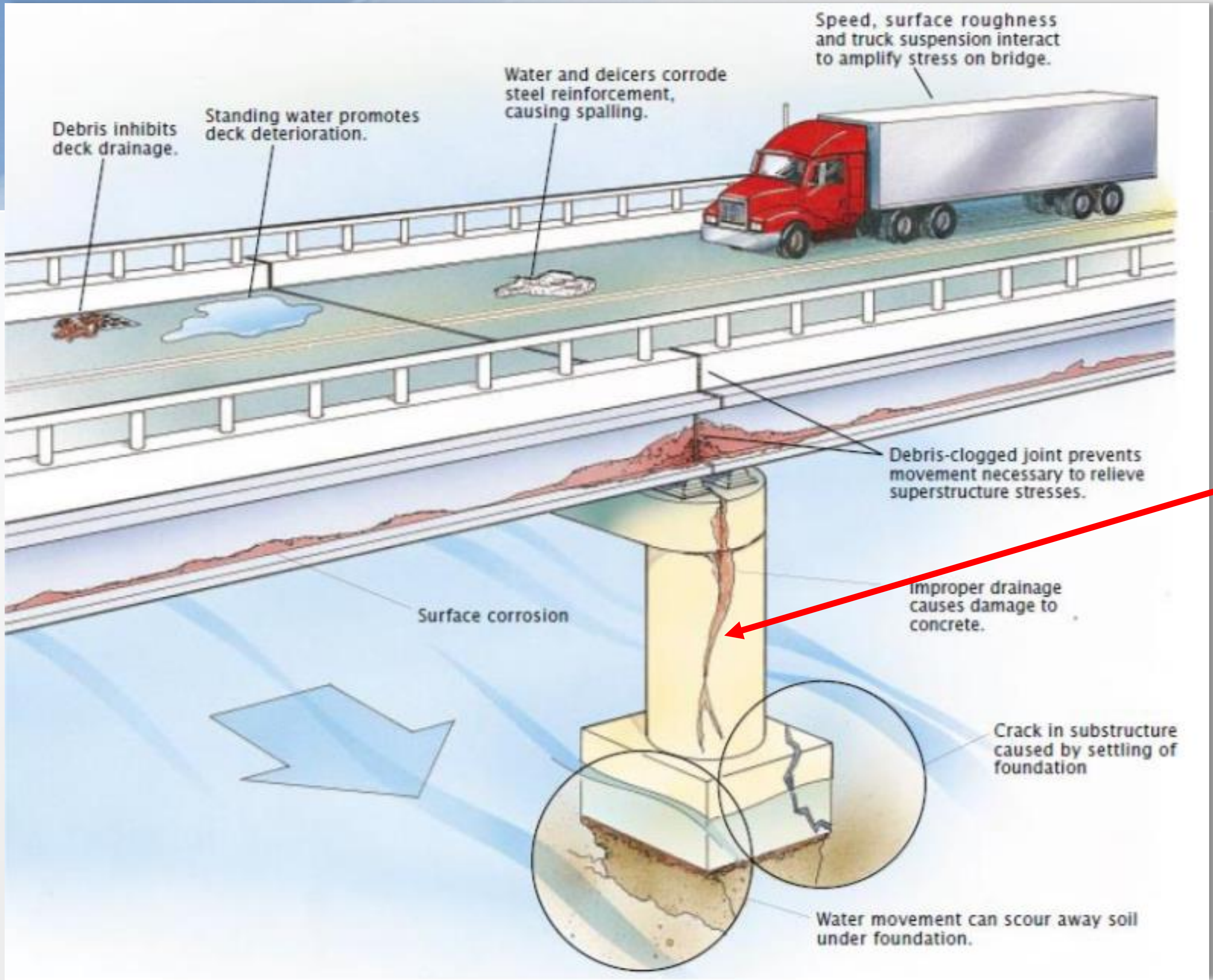
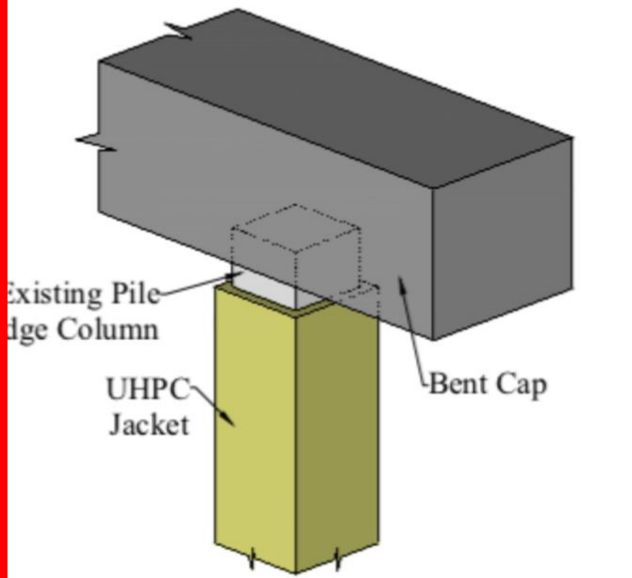




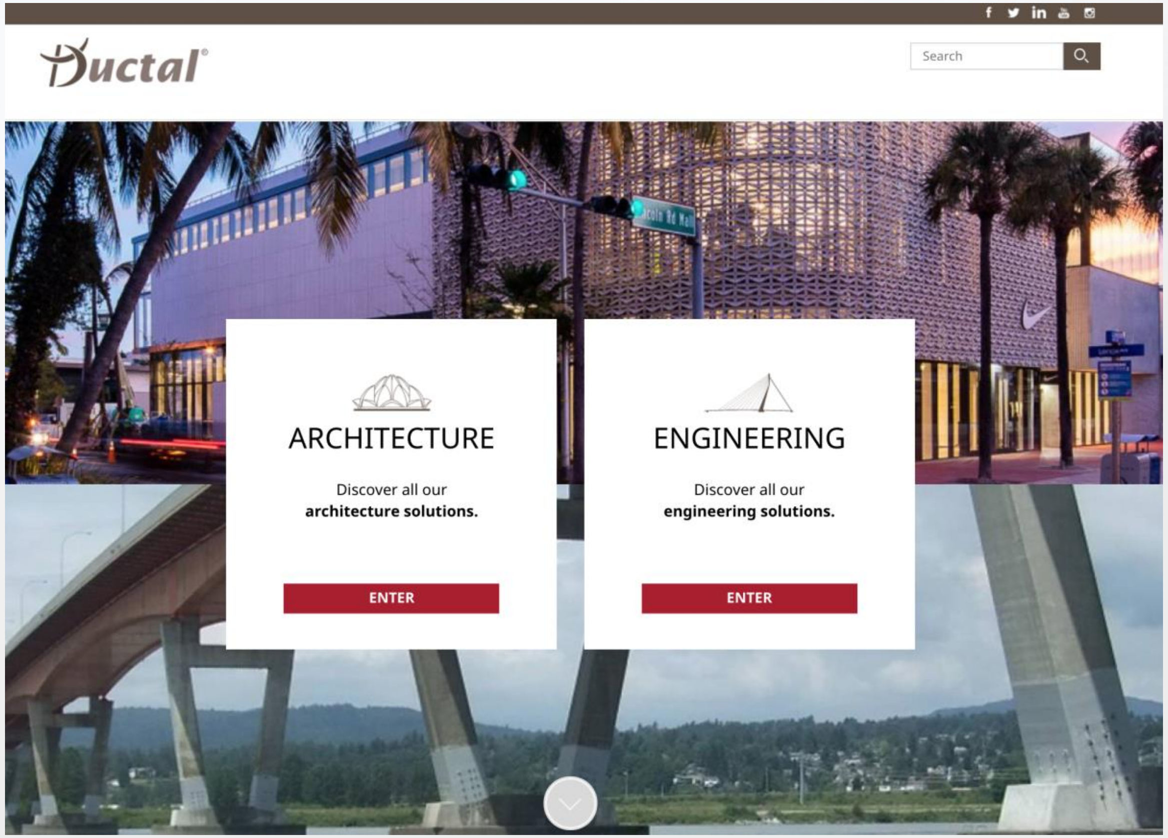
i) Structural Strengthening of Deteriorated Steel Girders

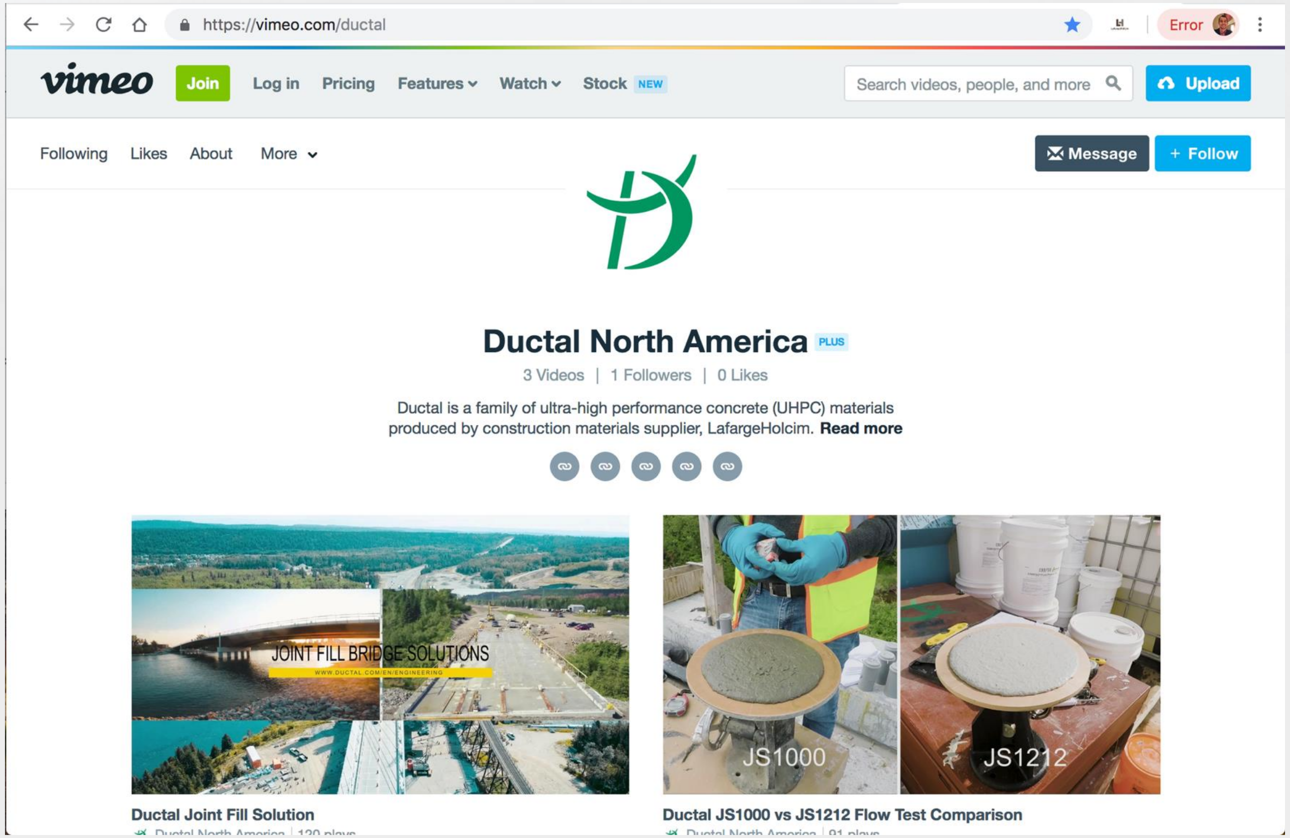




k) Structural Strengthening Column / Pile Elements www.ductal.com

www.vimeo.com/ductal





Any questions?

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