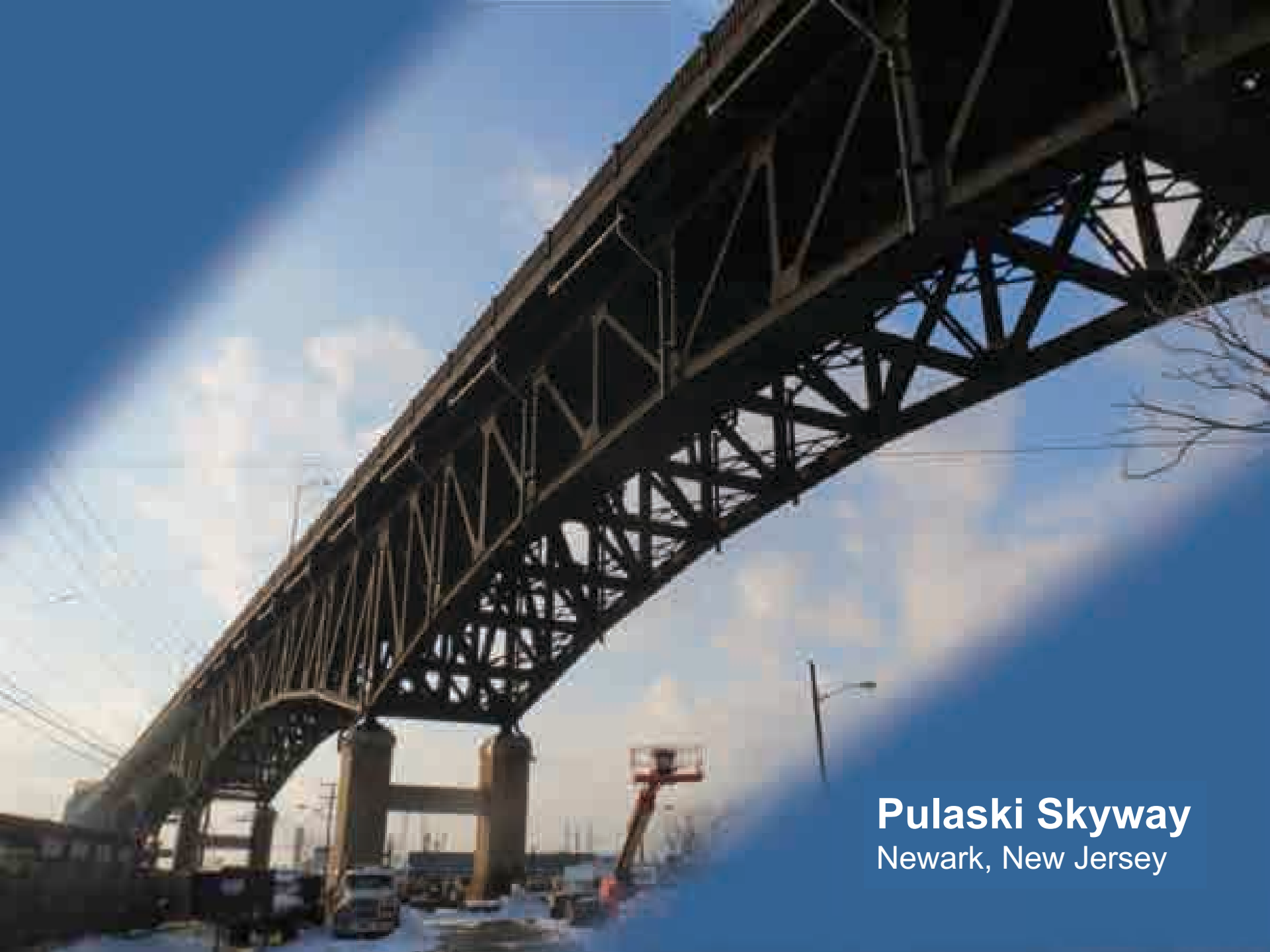


UHPC CONNECTIONS: A Path to Accelerated Construction and Enhanced Bridge Performance

Ben Graybeal, Ph.D., P.E.
Team Leader – Bridge & Foundation Engineering
Federal Highway Administration
202-493-3122
benjamin.graybeal@dot.gov





Pulaski Skyway
Newark, New Jersey

Name	Year
Mars Hill Bridge, Wapello County, IA	2006
Route 624 over Cat Point Creek, Richmond County, VA	2008
Jakway Park Bridge, Buchanan County, IA	2008
State Route 31 over Canandaigua Outlet, Lyons, NY	2009
State Route 23 over Otego Creek, Oneonta, NY	2009
Little Cedar Creek, Wapello County, IA	2011
Fingerboard Road Bridge over Staten Island Expressway, NY	2011-2012
State Route 248 over Bennett Creek, NY	2011
U.S. Route 30 over Burnt River and UPRR bridge, OR	2011
U.S. Route 6 over Keg Creek, Pottawatomie County, IA	2011
Ramapo River Bridge, Sloatsburg, NY	2011
State Route 42 Bridges (2) near Lexington, NY	2012
State Route 31 over Putnam Brook near Weedsport, NY	2012
I-690 Bridges (2) over Peat Street near Syracuse, NY	2012
I-690 Bridges (2) over Crouse Avenue near Syracuse, NY	2012
I-481 Bridge over Kirkville Road near Syracuse, NY	2012
Windham Bridge over BNSF Railroad on U.S. Route 87 near Moccasin, MT	2012
State Route 12 over Spring Brook near Greene, NY	2013
State Route 10 over Webster Brook near Dehli, NY	2013
State Route 38 over Wilson Creek near Newark, NY	2013
State Route 962G over U.S. Route 17 in Owego, NY	2013
State Route 907W over U. S. Route 1 in Pelham, NY	2013
State Route 2 Bridges (2) over SR9 in Colonie, NY	2013
I-81 Bridges (2) over E Castle St in Syracuse, NY	2013
I-81 Bridges (2) over E Calthrop Ave in Syracuse, NY	2013
I-84 Bridges (2) over Dingle Road in Southeast, NY	2013
I-690 Westbound over Onandaga Creek in Syracuse, NY	2013
I-690 over N. Salina Street in Syracuse, NY	2013
SR1004 over Cove Creek in Everett, PA	2013
Northampton St. over Manhan River in Easthampton, MA	2013
Sollars Road over Lees Creek in Washington Court House, OH	2014
SR0288 over Wampum Run in Wampum, PA	2014
I-81 Bridges (2) over Preble Road in Preble, NY	2014

Bridges in Service in the U.S.

UHPC RESEARCH AT TFHRC

Vertically Integrated Research

- Material Performance
- Component Performance
- Structural Performance



UHPC RESEARCH AT TFHRC

Vertically Integrated Research

- Material Performance
- Component Performance
- Structural Performance

Developing Solutions



UHPC Resources



UHPC

UHPC
Connections



UHPC
State-of-
the-Art

UHPC
Memo



FHWA UHPC Website

- <https://www.fhwa.dot.gov/research/resources/uhpc/>
- Web Search: ***UHPC FHWA***
- *Overview, Research Projects, Bridges, Publications*



What is Ultra-High Performance Concrete?

- Advanced cementitious composite material
- High strength, high stiffness
- Exceptional durability
- Internal steel fiber reinforcement for added ductility
- Self-consolidating

150+ MPa Compression
5+ MPa Tension
Fiber Reinforced
Self-Consolidating
Low Permeability

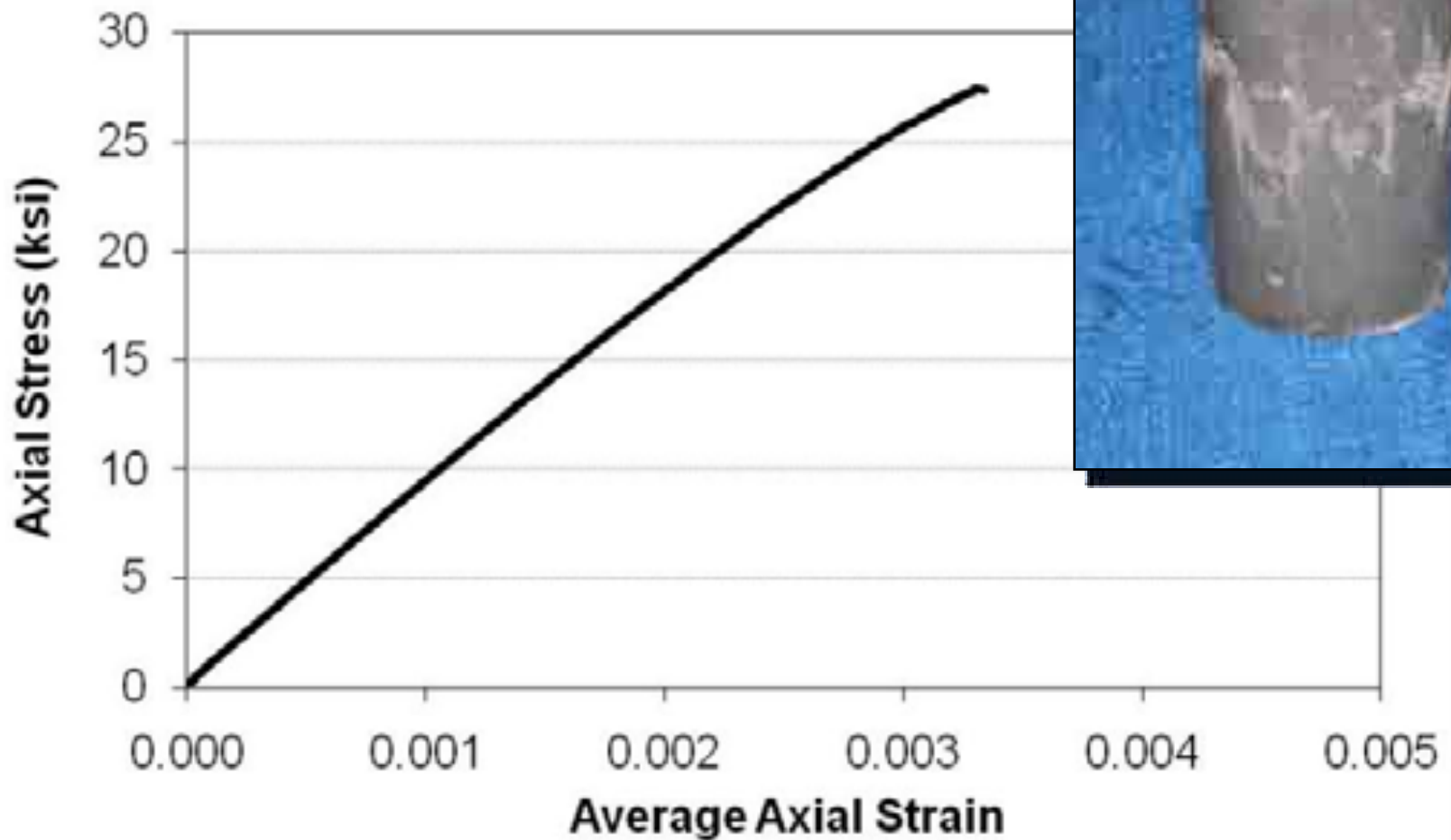


Typical Composition of UHPC

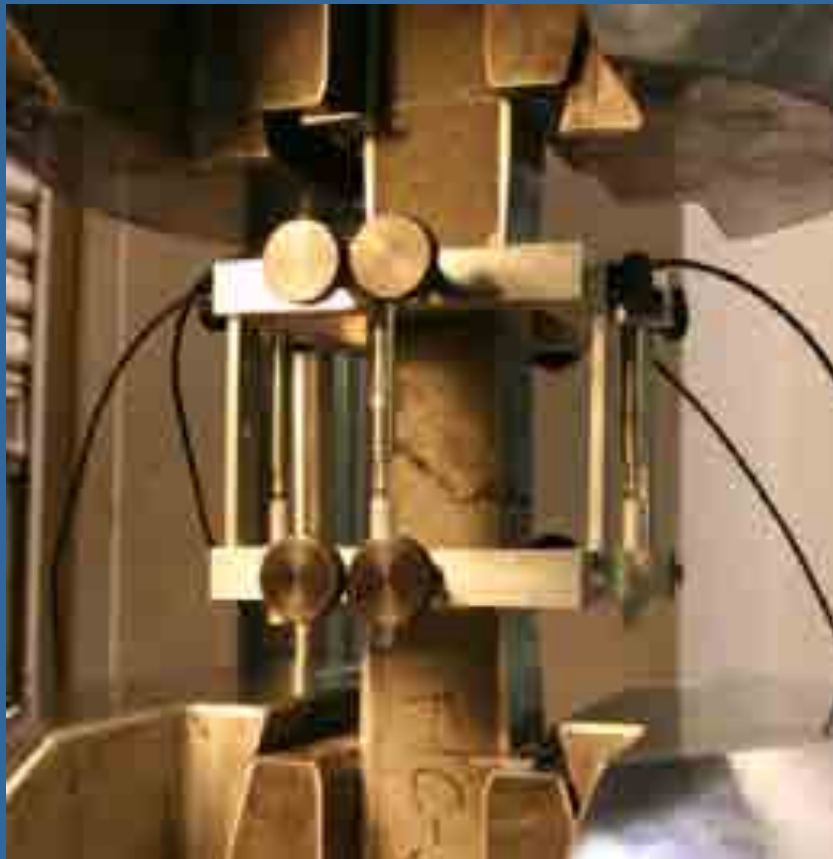
Material	Amount	% by Weight
Portland Cement	1200 lb/yd ³	28.5
Silica Fume	390 lb/yd ³	9.3
Ground Quartz	355 lb/yd ³	8.5
Fine Sand	1720 lb/yd ³	41.0
Steel Fibers*	263 lb/yd ³	6.3
Superplasticizer	51 lb/yd ³	1.2
Water	218 lb/yd ³	5.2



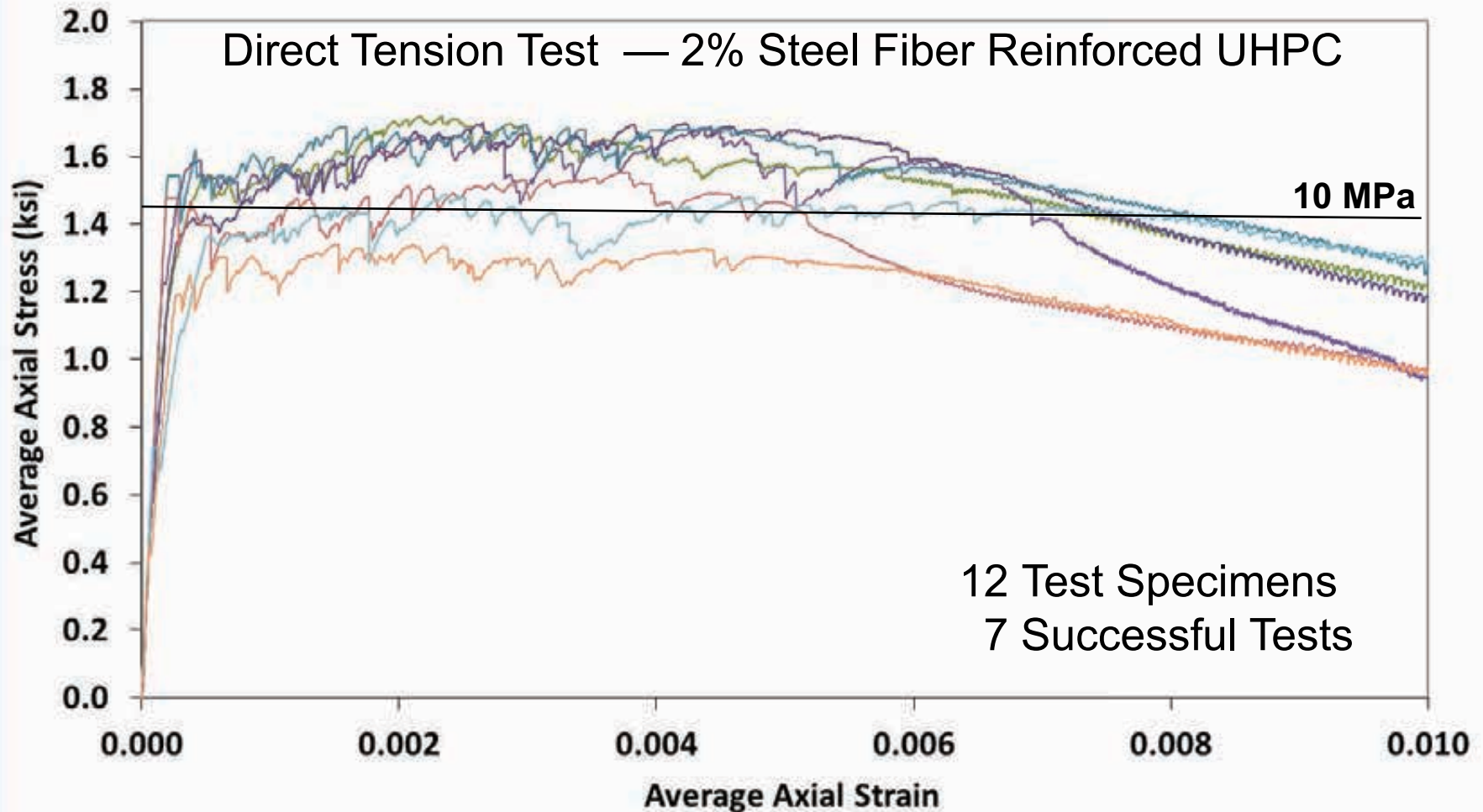
Compression Behavior



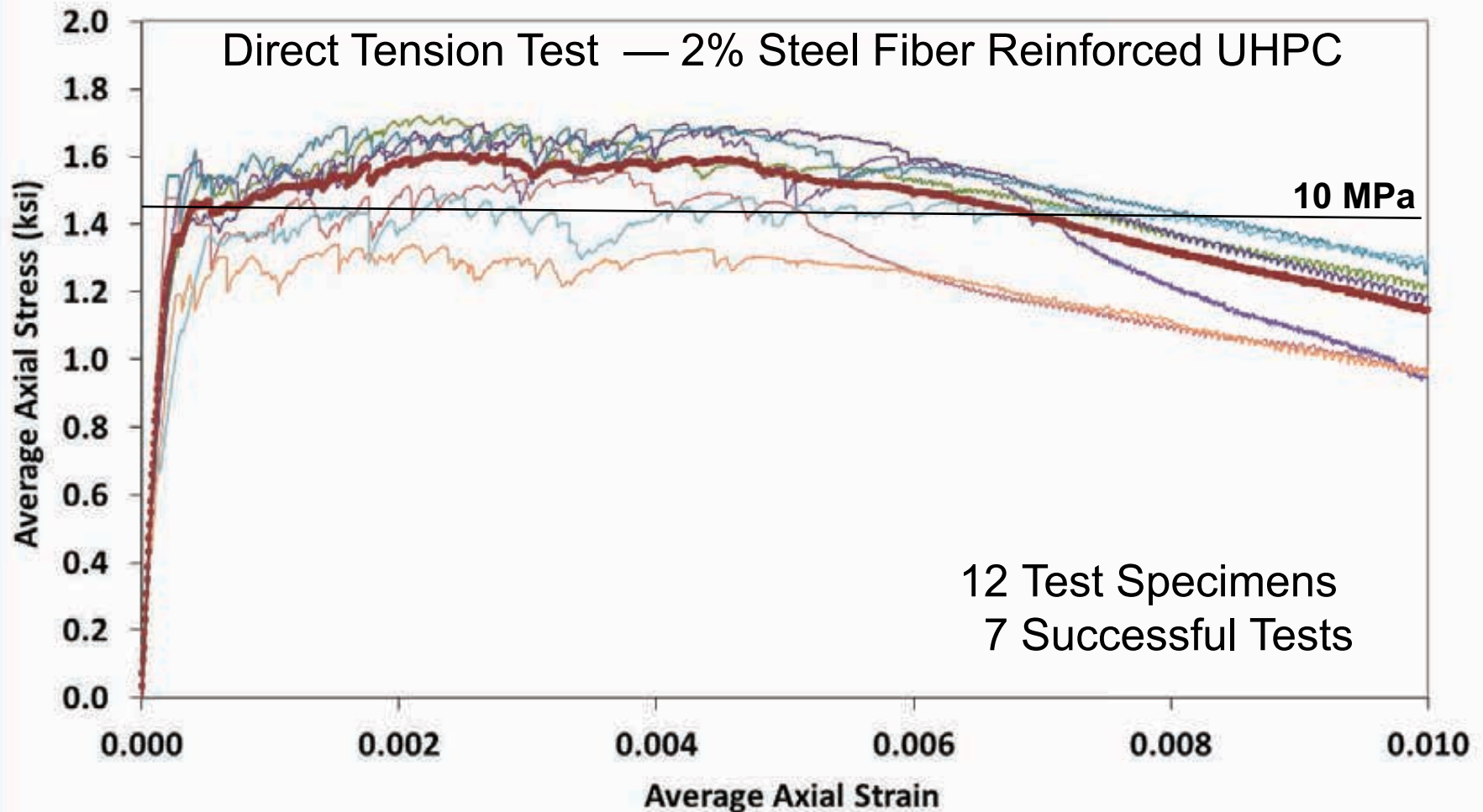
Tensile Stress-Strain Response of UHPC



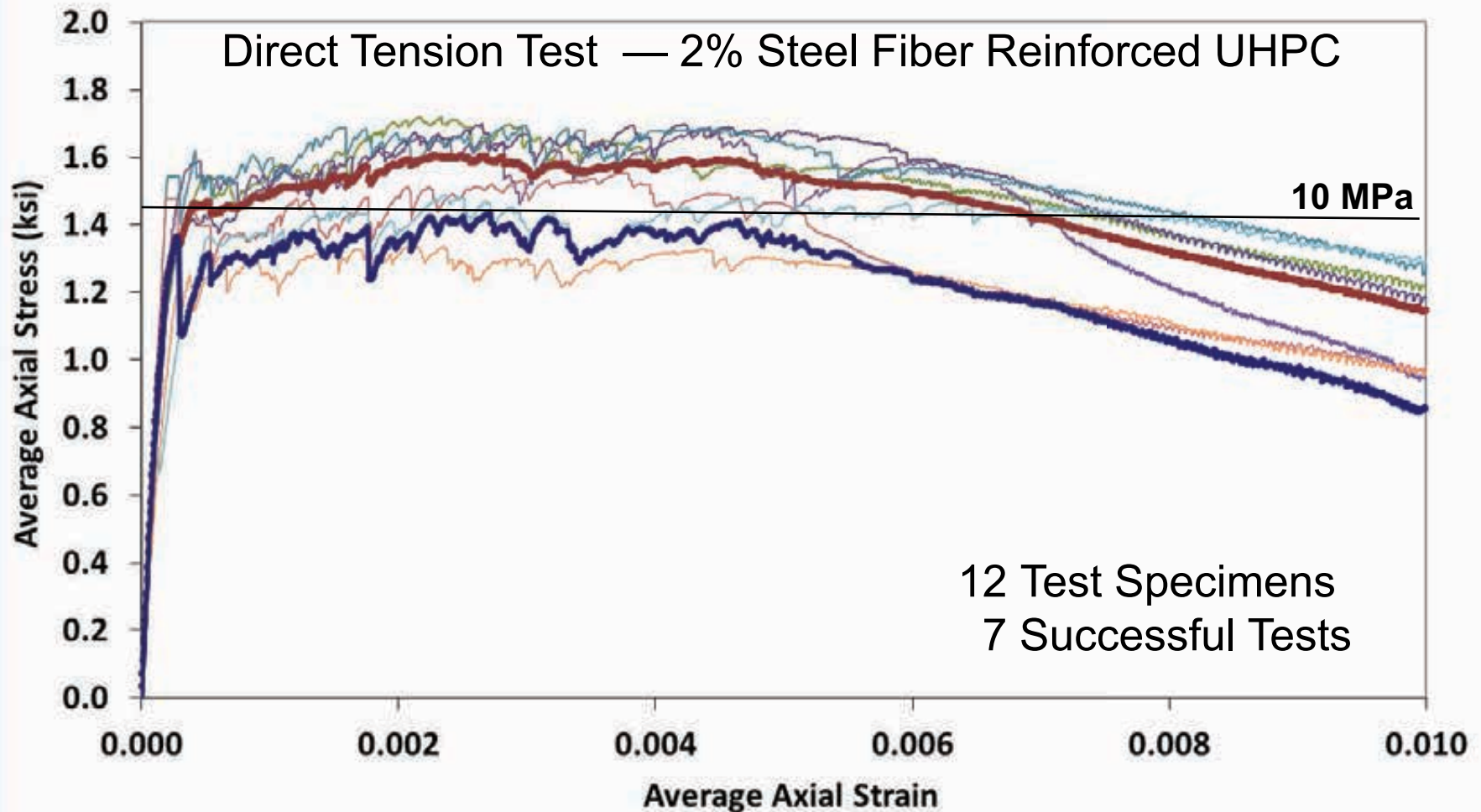
Tensile Stress-Strain Response of UHPC



Tensile Stress-Strain Response of UHPC



Tensile Stress-Strain Response of UHPC



UHPC Considerations: Materials

- Strength Testing
- Flow Testing
- Bonding Surface
- Riding Surface
- Material Specification



UHPC Considerations: Materials

- **Strength Testing**
- **Flow Testing**
- **Bonding Surface**
- **Riding Surface**
- **Material Specification**
 - **ASTM C39**
 - **Faster Load Rate (150 psi/sec)**
 - **Cylinders or Cubes**
 - **Grind Ends of Cylinders**



UHPC Considerations: Materials

- Strength Testing
- **Flow Testing**
- Bonding Surface
- Riding Surface
- Material Specification
 - **ASTM C1437**
 - **Mini Slump Cone**
 - **Measure Spread**



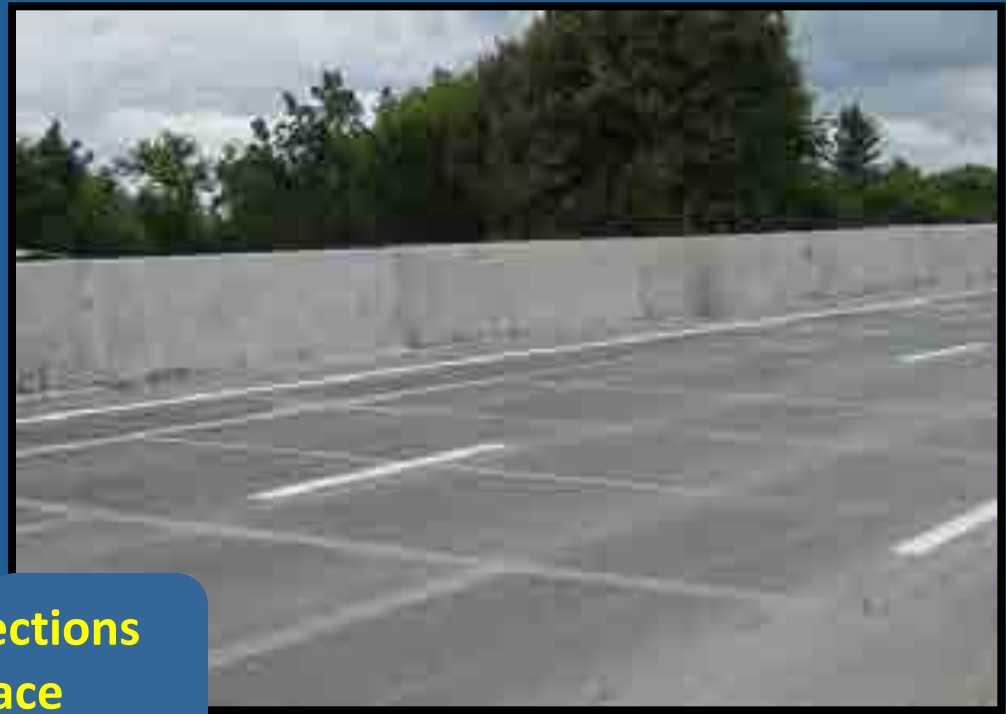
UHPC Considerations: Materials

- Strength Testing
- Flow Testing
- **Bonding Surface**
- Riding Surface
- Material Specification
 - **Rough Interface**
 - **Exposed Aggregate**
 - **Wet Interface**
 - **Prewet before casting**



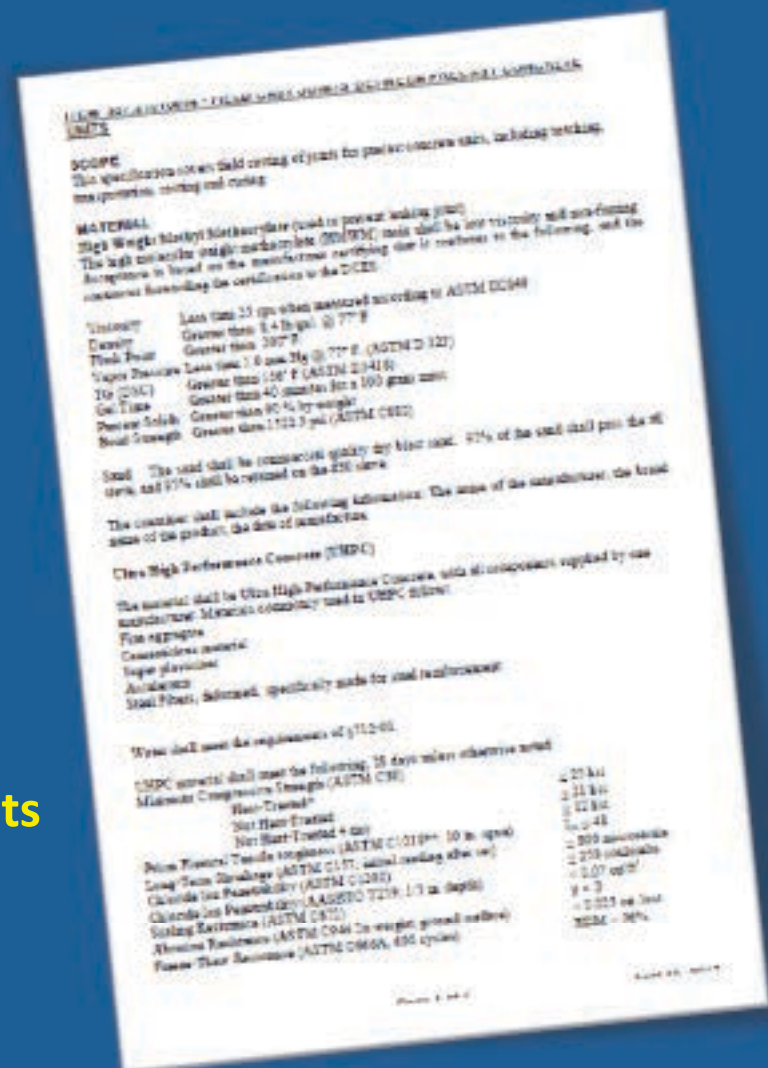
UHPC Considerations: Materials

- Strength Testing
 - Flow Testing
 - Bonding Surface
 - **Riding Surface**
 - Material Specification
- **Overpour Connections**
 - **Grind Deck Surface**



UHPC Considerations: Materials

- Strength Testing
- Flow Testing
- Bonding Surface
- Riding Surface
- **Material Specification**
 - Performance Spec
 - NYSDOT example
 - Approved Proprietary Material
 - Common on 1st Deployments



PBE CONNECTIONS

- **Must be:**
 - Robust, Ductile, Durable
- **Frequently:**
 - Emulative



PBE CONNECTIONS

- **Must be:**
 - Robust, Ductile, Durable
- **Frequently:**
 - Emulative

- **What we need:**
 - Strong, Durable Material
 - Good Bond to Concrete
 - Good Bond to Rebar
 - Self Consolidating
 - Sustained Tensile Strength
 - Short Development Length



PBE CONNECTIONS

- What we need:
 - Strong, Durable Material
 - Good Bond to Concrete
 - Good Bond to Rebar
 - Self Consolidating
 - Sustained Tensile Strength
 - Short Development Length

Solution:

UHPC



UHPC CONNECTIONS: WHERE?

- Accelerated Bridge Construction
- PBE w/o Post-Tensioning
- Robust, Durable Bridge System
- Rural Locations w/o Reliable Ready-Mix
- Owners Interested in Innovation



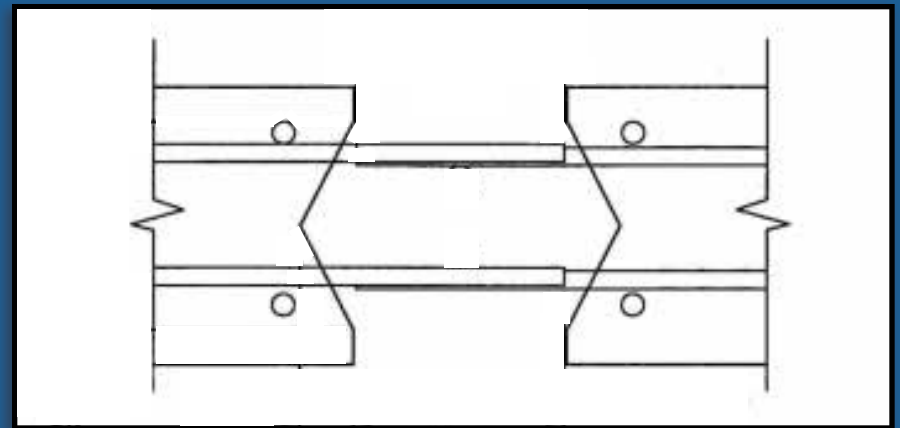
UHPC CONNECTIONS

- Deck-to-Deck
- Deck-to-Girder
- Column-to-Footing/Cap
- Girder-to-Girder
- Deck-to-Barrier
- Deck-to-Expansion Joint

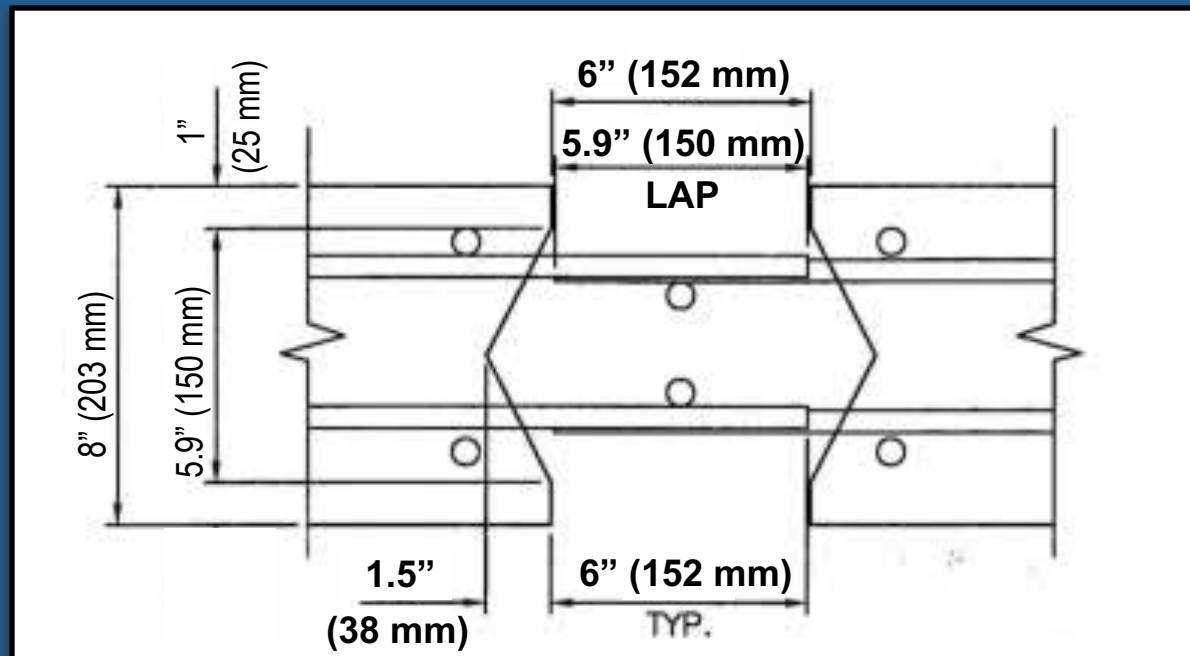


FIELD-CAST “SPLICE” CONNECTIONS

- Simple Lap-Splice Cxn
- Smaller Grout Volumes
- Shortened Bar Lengths
- Emulates Monolithic Component



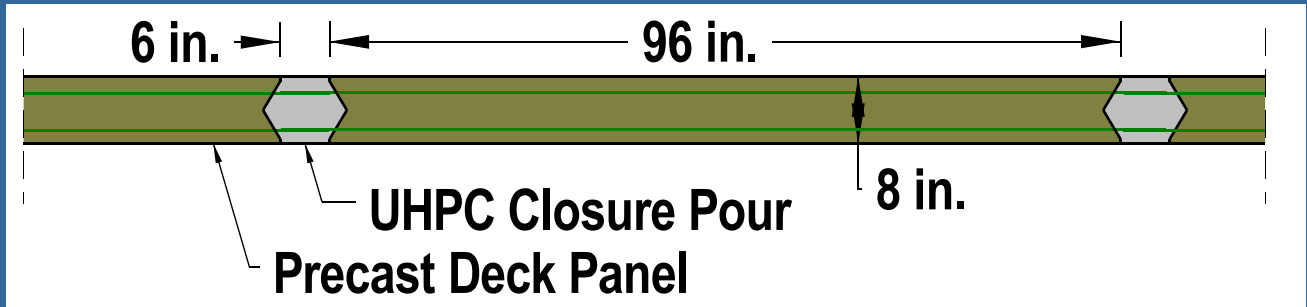
SLAB/PLATE/DECK CONNECTIONS W/ UHPC



Field-Cast, Non-Contact Lap Splice Connection

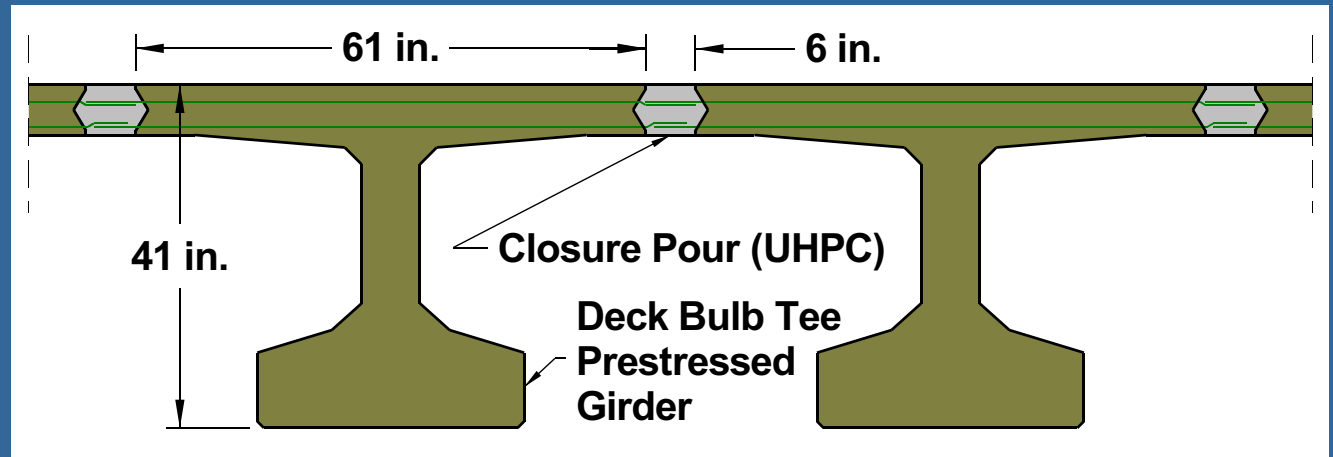


FIELD-CAST "SPLICE" CONNECTIONS



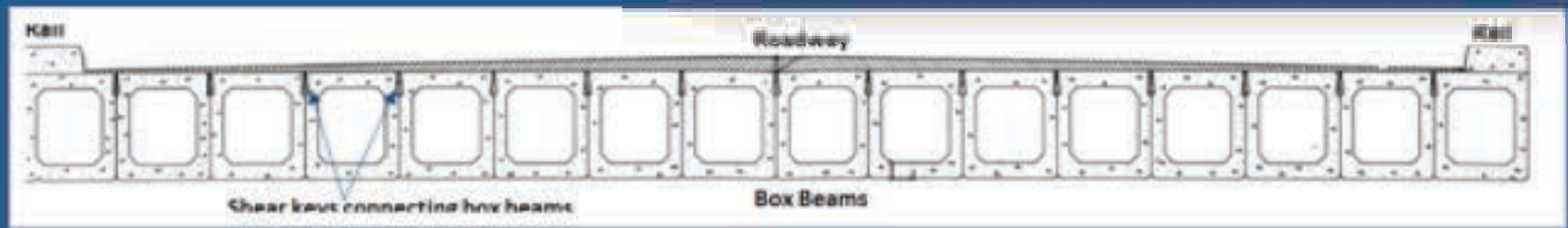
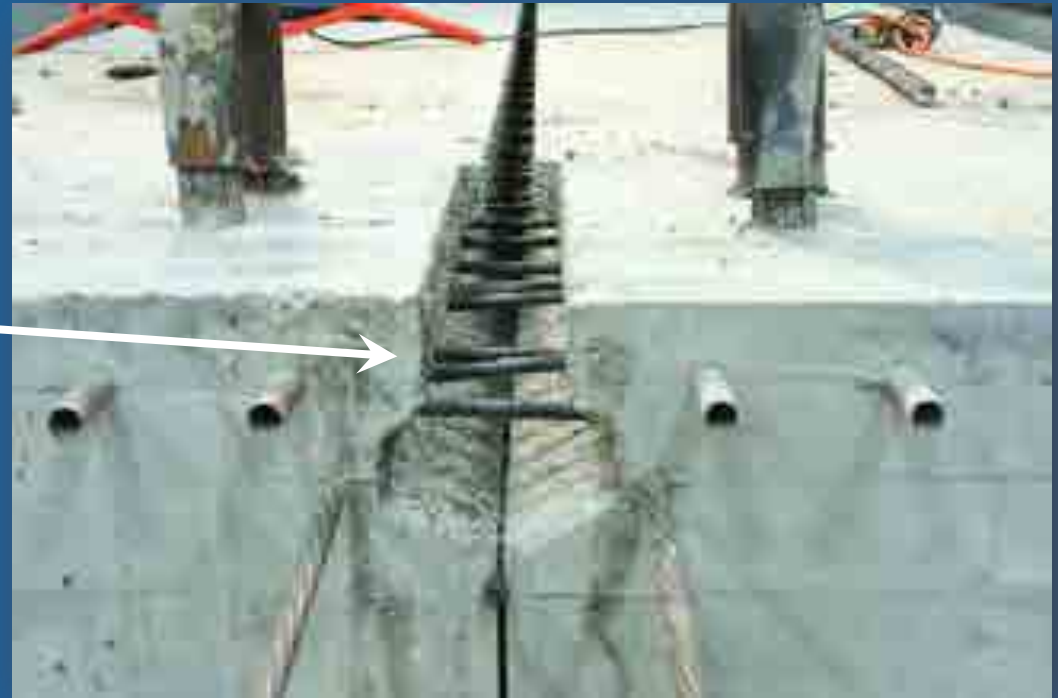
Precast Deck Panels and Slabs

Deck Bulb Tee Girders

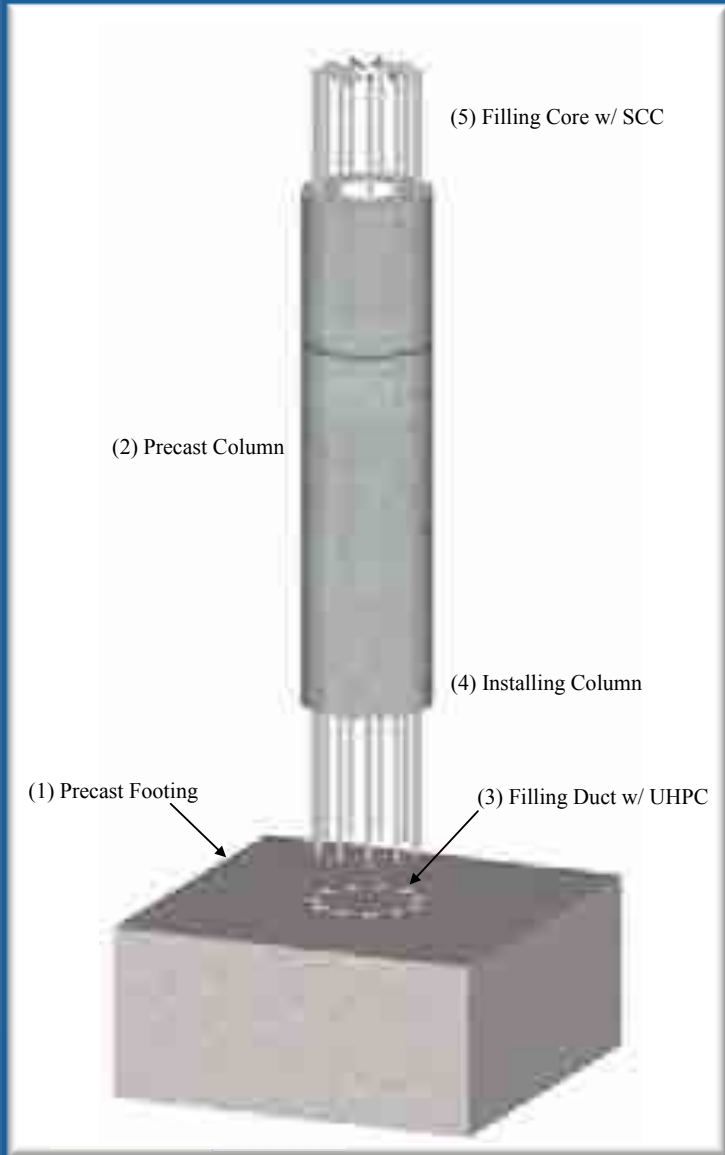


ADJACENT BOX BEAM CONNECTIONS

No. 4 rebar lap splice
(No Post-Tension needed)

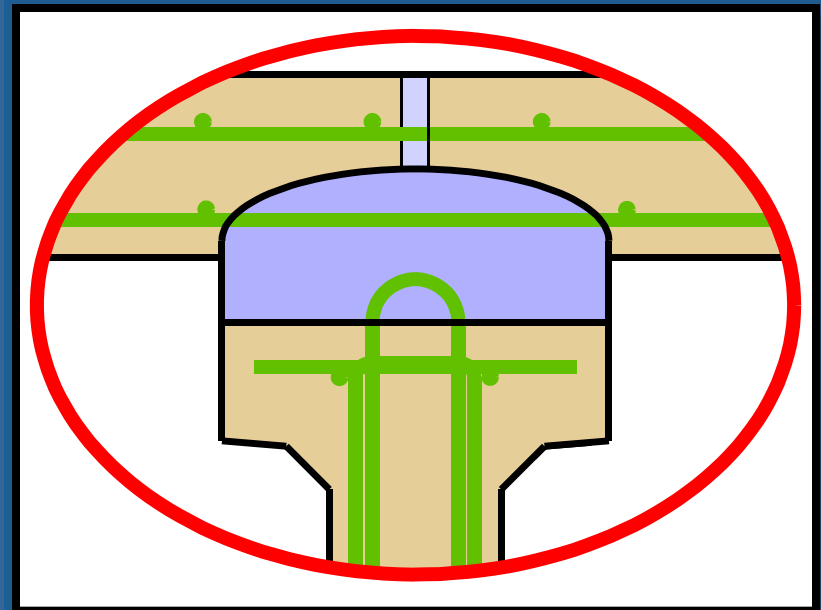


COLUMN-TO-FOOTING/CAP CONNECTIONS

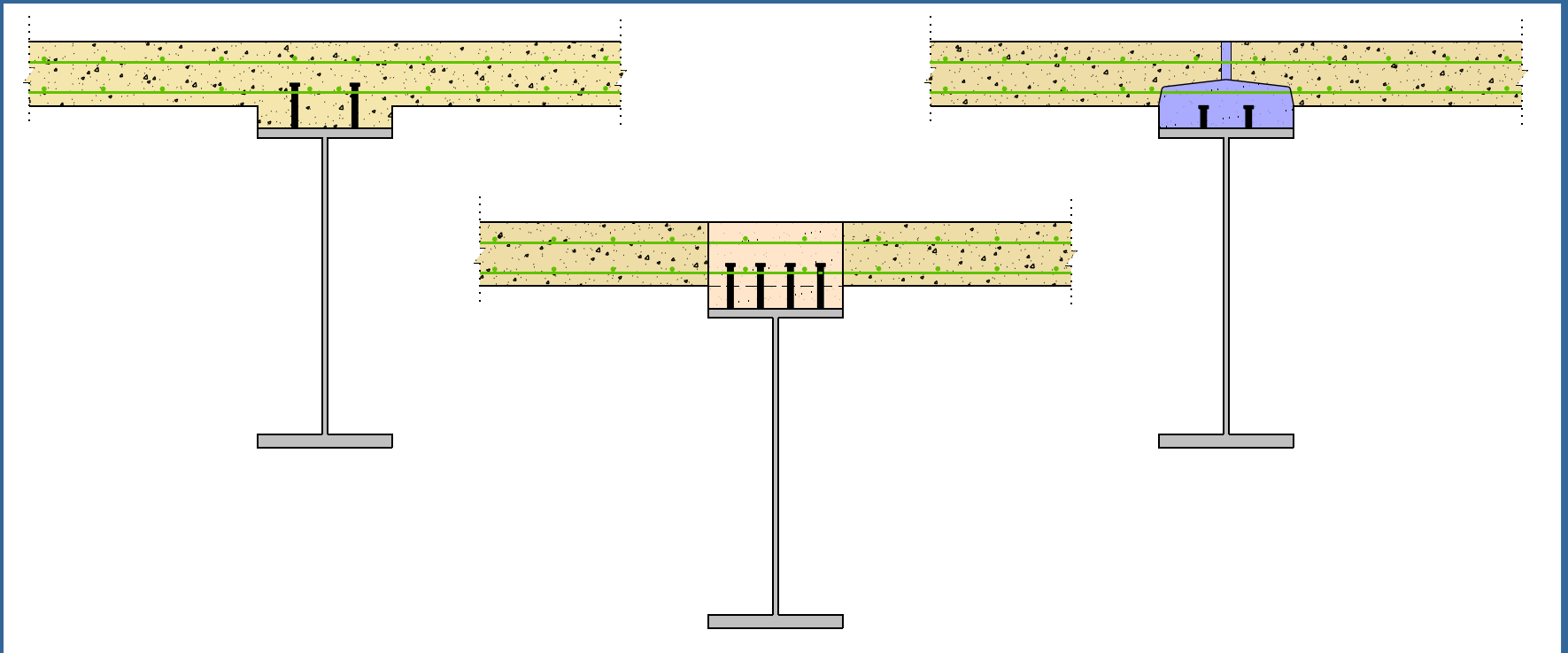


FIELD-CAST DECK-TO-GIRDER CONNECTIONS

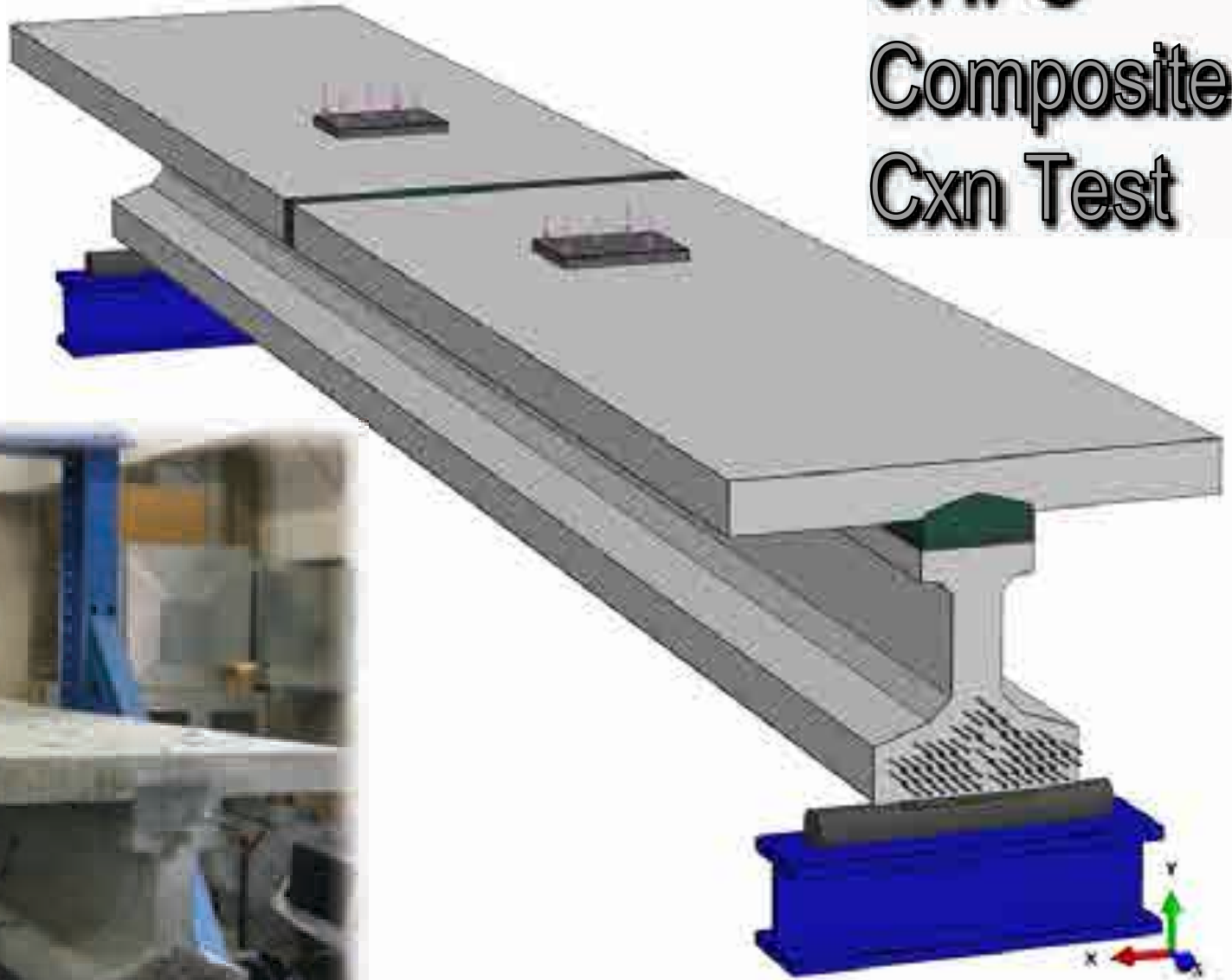
- Simple Connection
- No Interference
- Hidden Connection
- Emulates Cast-in-Place



FIELD-CAST “INTERFACE” CONNECTIONS



UHPC Composite Cxn Test



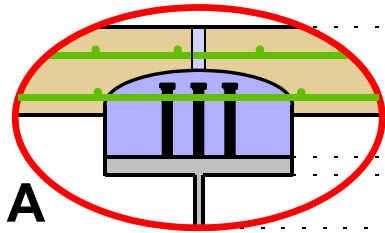
UHPC Composite Connection



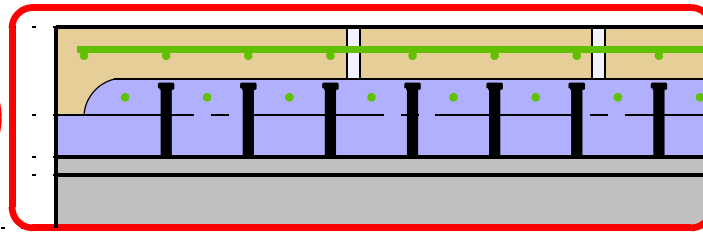
Steel Girder Connection



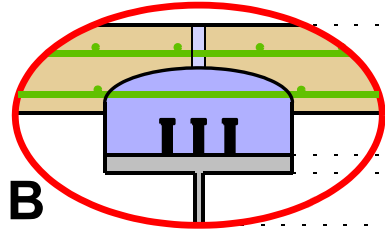
Concrete Girder Connection



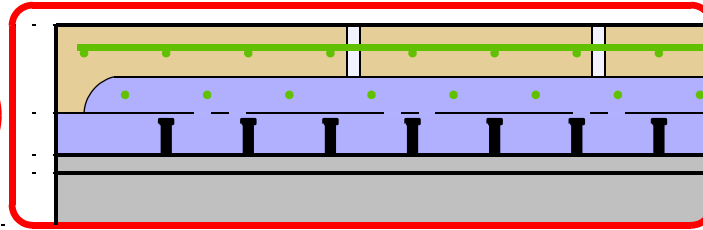
A



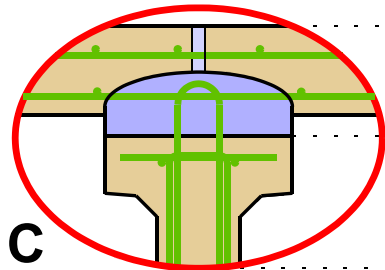
← Precast Deck
← Grout
← Steel Girder



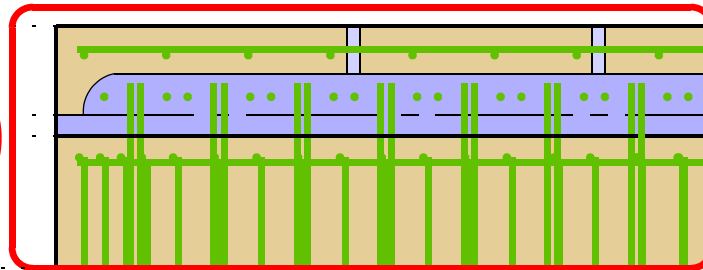
B



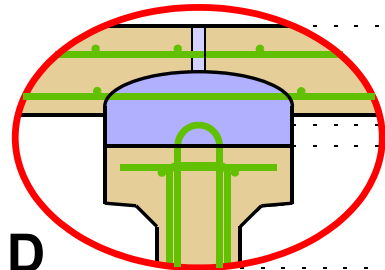
← Precast Deck
← UHPC
← Steel Girder



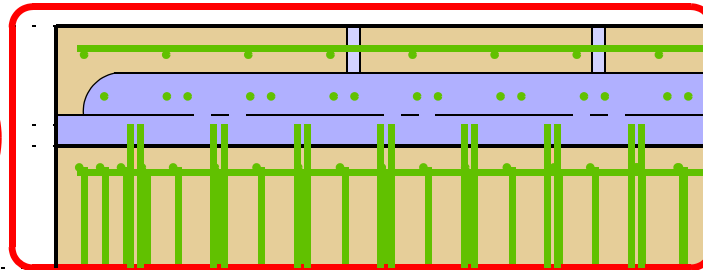
C



← Precast Deck
← Grout
← Concrete Girder



D



← Precast Deck
← UHPC
← Concrete Girder

PBES INNOVATION



PBES INNOVATION

I-81 in Syracuse NY — August 2013

Acknowledgements:

NY Accelerated Bridge Program

NYSDOT

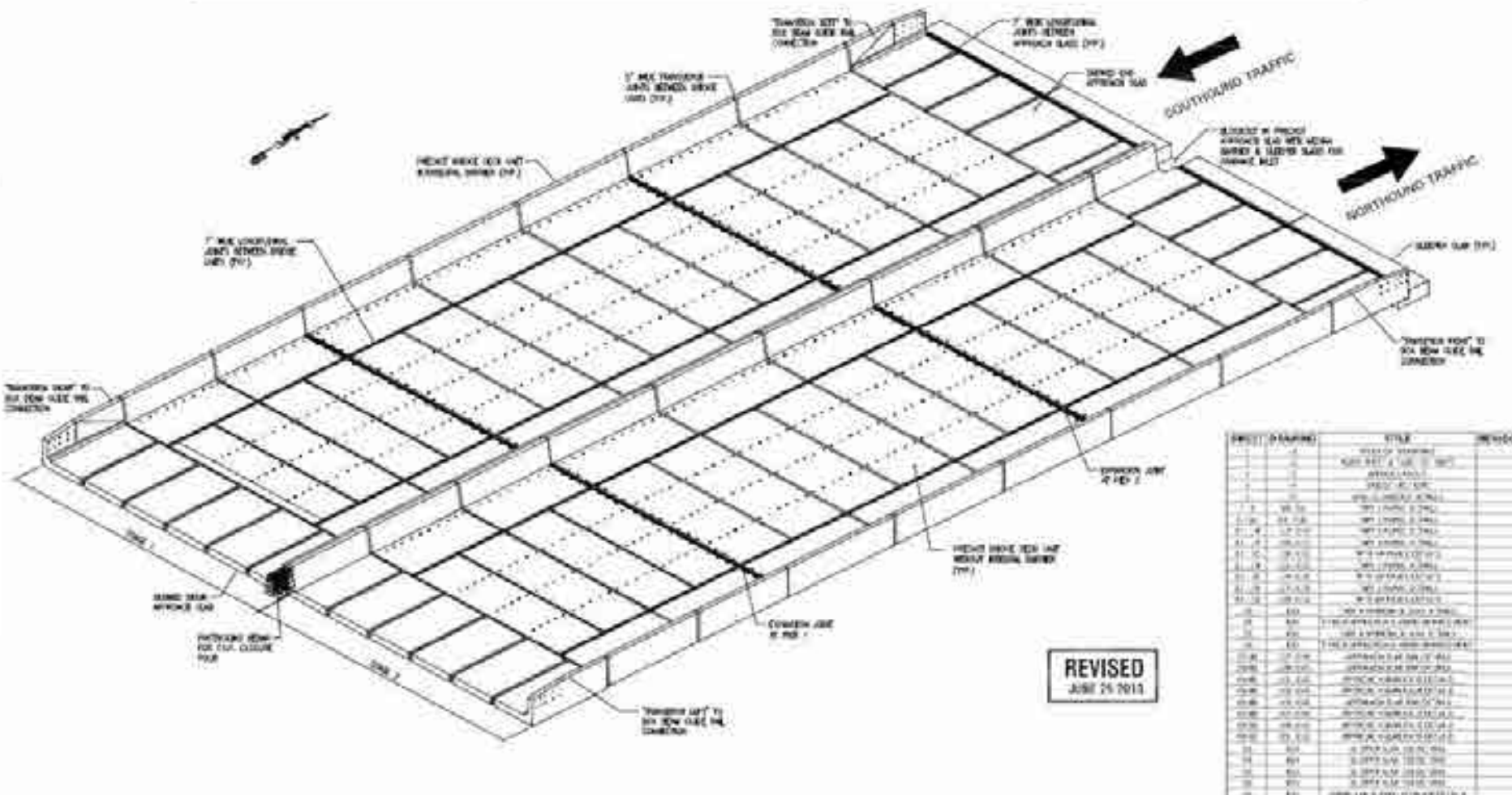
Fort Miller Group, Inc.

Slate Hill Constructors, Inc.

Economy Paving Company, Inc.



I-81 OVER EAST CALTHROP AVENUE



REVISED
JUNE 25 2013

REV#	DATE	TITLE	DESCRIPTION
1	01/15/13	ISSUE FOR BIDDING	
2	01/22/13	ADD SET & USE OF SET	
3	01/22/13	APPROVALS	
4	01/22/13	PROJ. NO. 13	
5	01/22/13	PROJ. NO. 13	
6	01/22/13	PROJ. NO. 13	
7	01/22/13	PROJ. NO. 13	
8	01/22/13	PROJ. NO. 13	
9	01/22/13	PROJ. NO. 13	
10	01/22/13	PROJ. NO. 13	
11	01/22/13	PROJ. NO. 13	
12	01/22/13	PROJ. NO. 13	
13	01/22/13	PROJ. NO. 13	
14	01/22/13	PROJ. NO. 13	
15	01/22/13	PROJ. NO. 13	
16	01/22/13	PROJ. NO. 13	
17	01/22/13	PROJ. NO. 13	
18	01/22/13	PROJ. NO. 13	
19	01/22/13	PROJ. NO. 13	
20	01/22/13	PROJ. NO. 13	
21	01/22/13	PROJ. NO. 13	
22	01/22/13	PROJ. NO. 13	
23	01/22/13	PROJ. NO. 13	
24	01/22/13	PROJ. NO. 13	
25	01/22/13	PROJ. NO. 13	
26	01/22/13	PROJ. NO. 13	
27	01/22/13	PROJ. NO. 13	
28	01/22/13	PROJ. NO. 13	
29	01/22/13	PROJ. NO. 13	
30	01/22/13	PROJ. NO. 13	
31	01/22/13	PROJ. NO. 13	
32	01/22/13	PROJ. NO. 13	
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45	01/22/13	PROJ. NO. 13	
46	01/22/13	PROJ. NO. 13	
47	01/22/13	PROJ. NO. 13	
48	01/22/13	PROJ. NO. 13	
49	01/22/13	PROJ. NO. 13	
50	01/22/13	PROJ. NO. 13	

M.B.T.

Project Name:
40000000 for Calthrop Avenue Bridge
01/22/13 10:54:01 AM

APPROVED	EE PLAN NO.	DATE	CONTRACT NO.	SHEET NO.	TOTAL SHEETS		I-81 OVER EAST CALTHROP AVENUE CITY OF SYRACUSE
Michael A. Tamm, P.E.	01/22/13	01/22/13	D262027				
City of Syracuse	2101 & 2102	2101 & 2102	2101 & 2102	2101 & 2102	2101 & 2102	1. 2101 & 2102 2. 2101 & 2102 3. 2101 & 2102 4. 2101 & 2102 5. 2101 & 2102 6. 2101 & 2102 7. 2101 & 2102 8. 2101 & 2102 9. 2101 & 2102 10. 2101 & 2102 11. 2101 & 2102 12. 2101 & 2102 13. 2101 & 2102 14. 2101 & 2102 15. 2101 & 2102 16. 2101 & 2102 17. 2101 & 2102 18. 2101 & 2102 19. 2101 & 2102 20. 2101 & 2102 21. 2101 & 2102 22. 2101 & 2102 23. 2101 & 2102 24. 2101 & 2102 25. 2101 & 2102 26. 2101 & 2102 27. 2101 & 2102 28. 2101 & 2102 29. 2101 & 2102 30. 2101 & 2102 31. 2101 & 2102 32. 2101 & 2102 33. 2101 & 2102 34. 2101 & 2102 35. 2101 & 2102 36. 2101 & 2102 37. 2101 & 2102 38. 2101 & 2102 39. 2101 & 2102 40. 2101 & 2102 41. 2101 & 2102 42. 2101 & 2102 43. 2101 & 2102 44. 2101 & 2102 45. 2101 & 2102 46. 2101 & 2102 47. 2101 & 2102 48. 2101 & 2102 49. 2101 & 2102 50. 2101 & 2102	

REVISIONS

NYSDOT Requirements

- **Complete redecking**
- **10-day max closure**
- **No overlay...Grinding OK**
- **Prefabricated Barriers**
- **May use UHPC connections**
- **Exposed aggregate interfaces**



Precaster and General Contractor Developed the Details of the System

- **Element Weight < 15 tons**
- **Element Length < 26 feet**
- **No Prestressing or PT**
- **Inverted Cast w/ Integrated Barrier**
- **Exposed Aggregate**
- **UHPC Connections**
- **1/2" Sacrificial Surface...Ground**







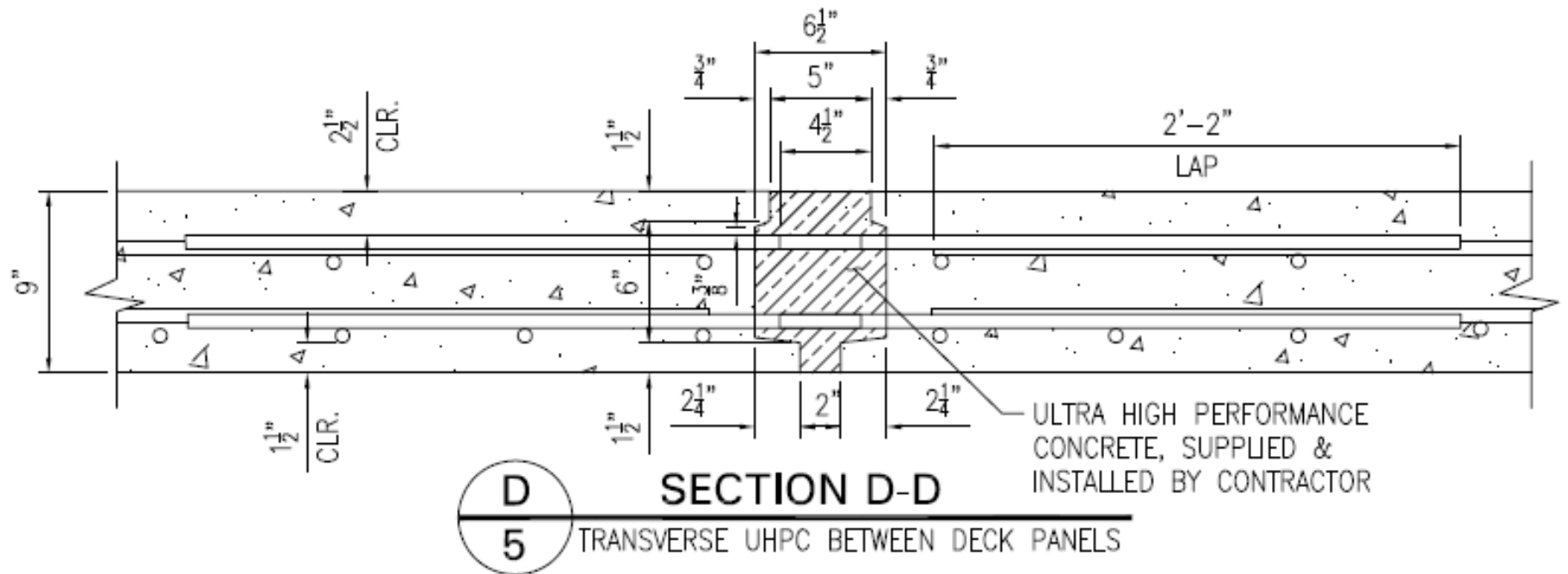




Deck-to-Deck Connection



Deck-to-Deck Connection



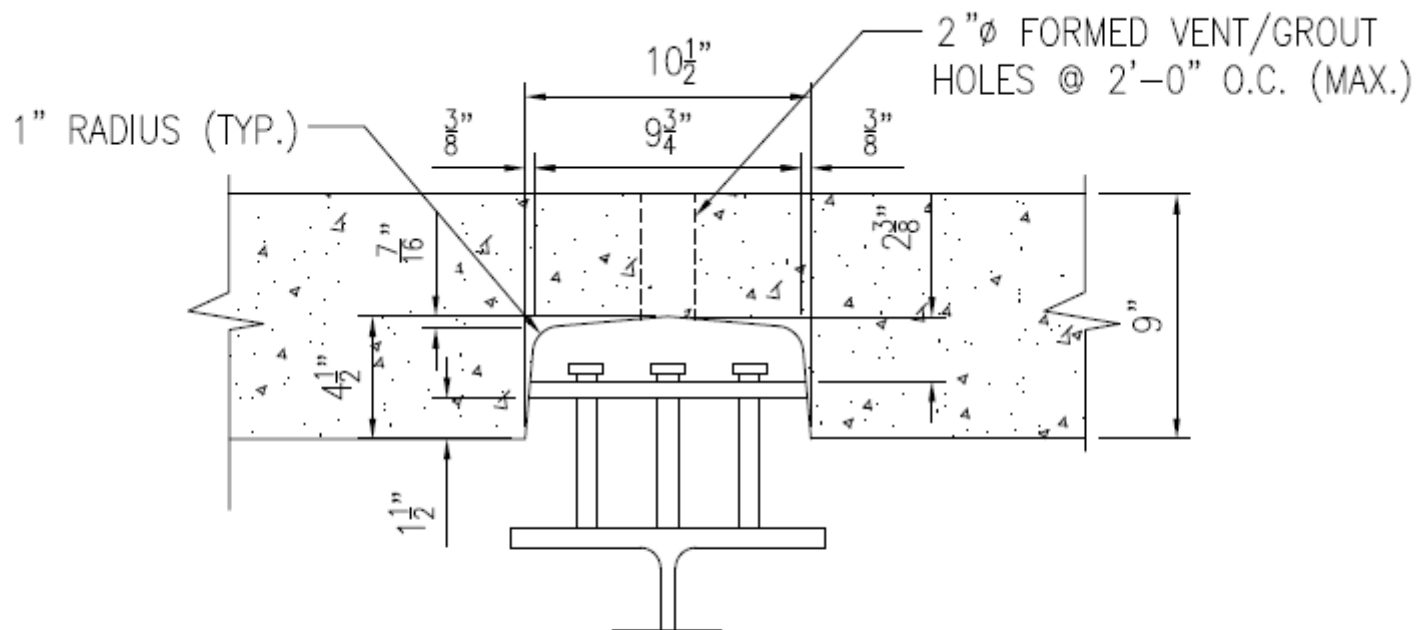
Deck-to-Deck Connection



Deck-to-Girder Connection



Deck-to-Girder Connection



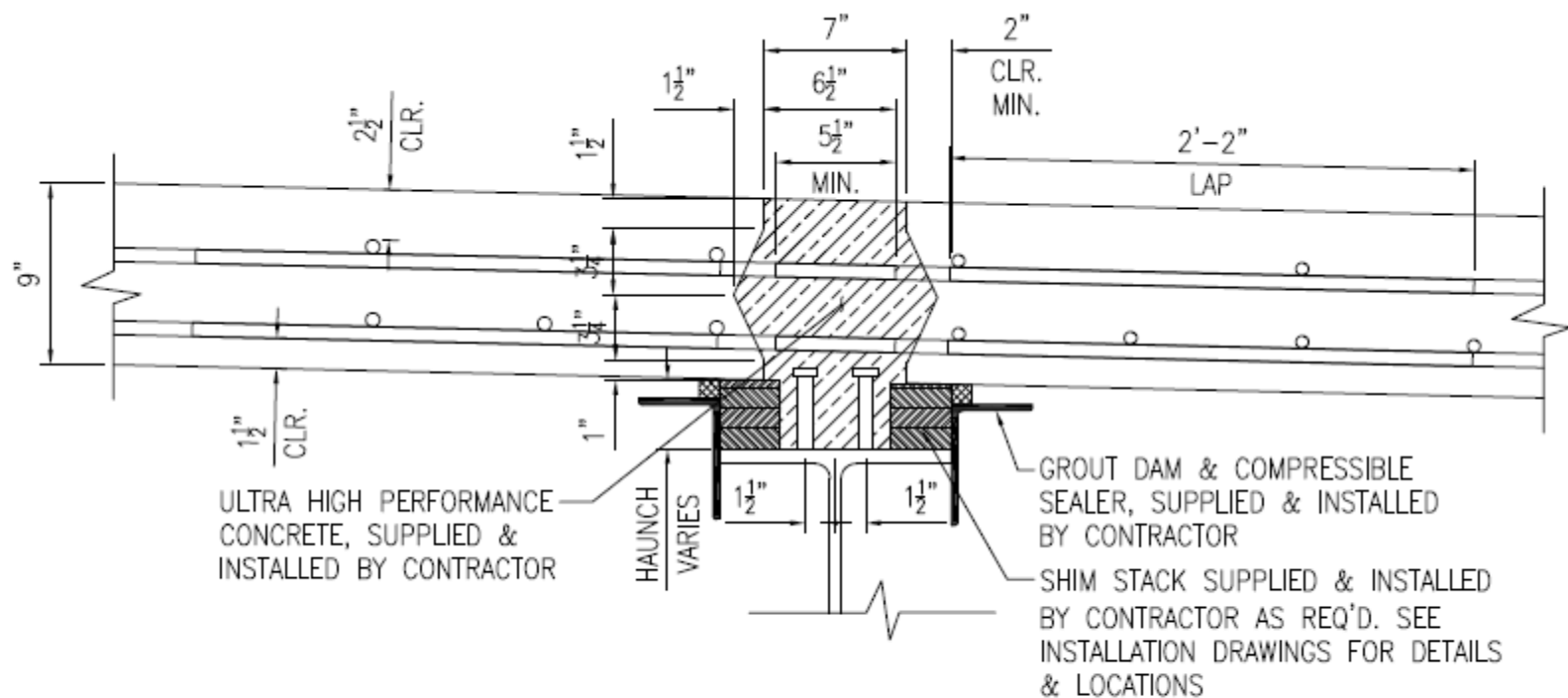
E SECTION E-E

5 NON-SHRINK GROUT JOINT
OVER INTERIOR BEAMS

Deck-to-Girder Connection

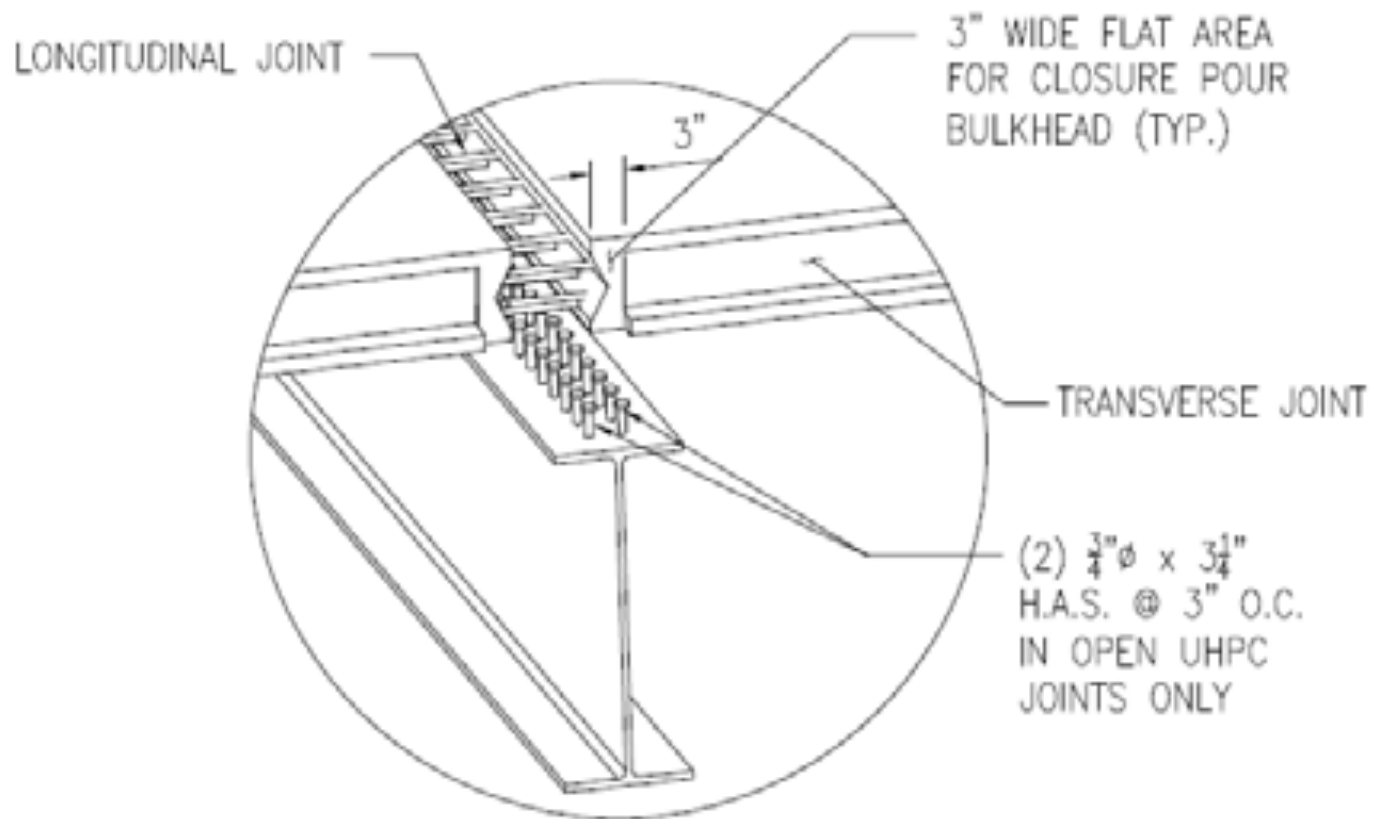


Deck-to-Girder Connection



C
5 SECTION C-C
 LONGITUDINAL UHPC JOINT OVER BEAMS

Deck-to-Girder Connection



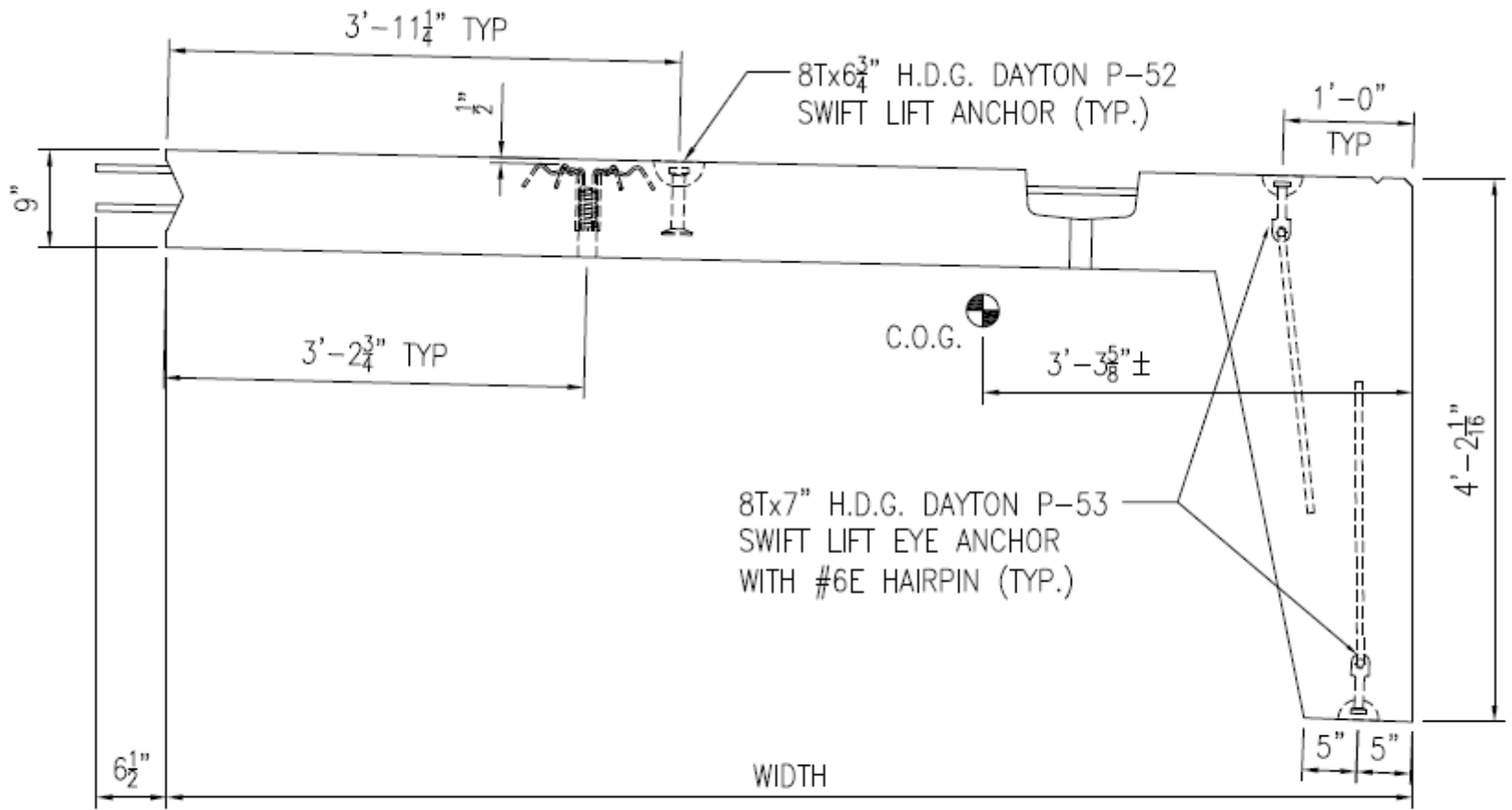
ISOMETRIC VIEW-INTERIOR JOINT

NOTE: ALL SURFACES IN JOINT TO BE EXPOSED AGGREGATE

Deck-to-Girder Connection



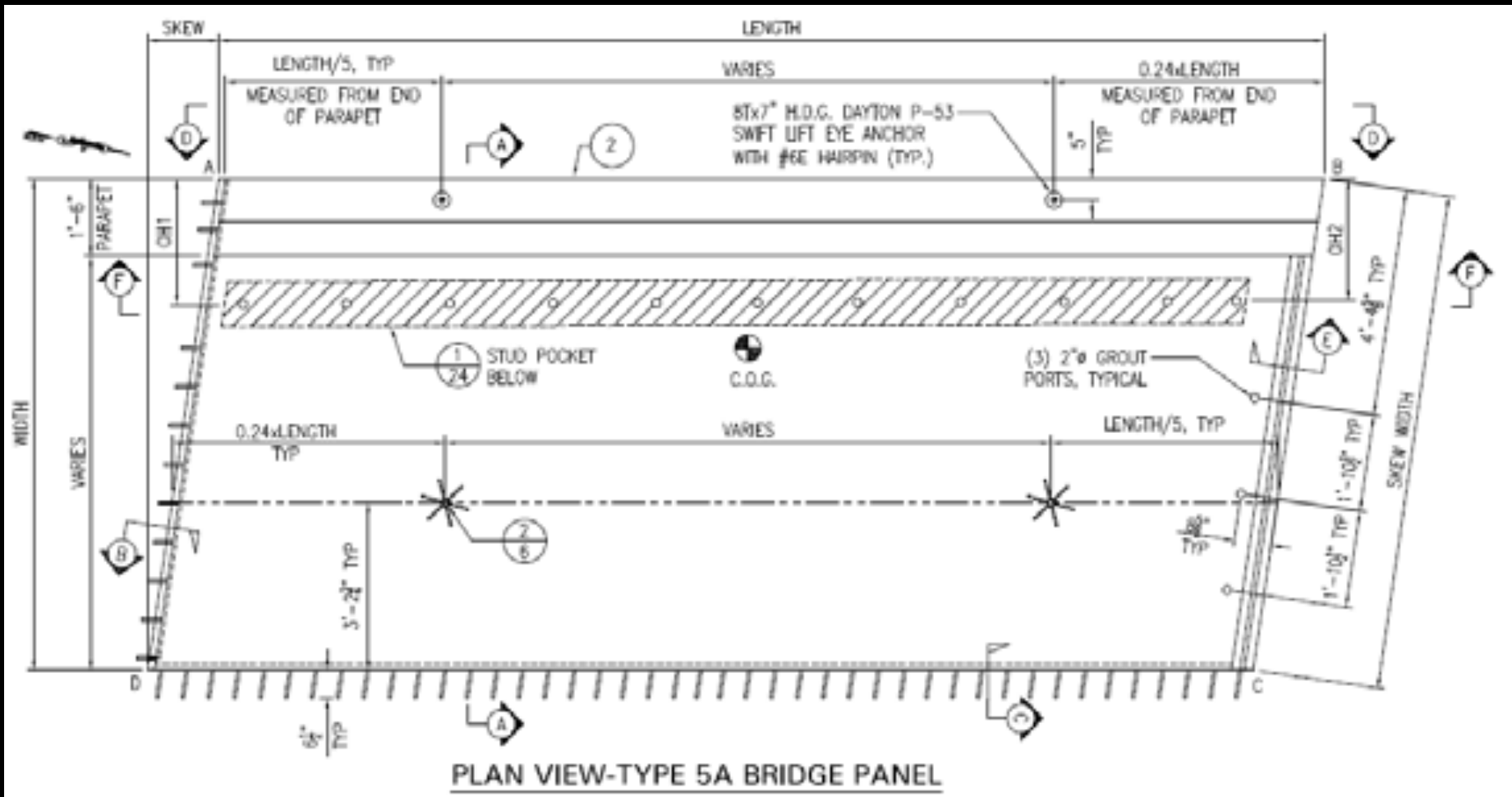
Deck-Barrier Components



FORM STRIPPING SECTION F-F

TYPE 6 BRIDGE PANELS

Deck-Barrier Components



Deck-Barrier Components





Field-Cast UHPC

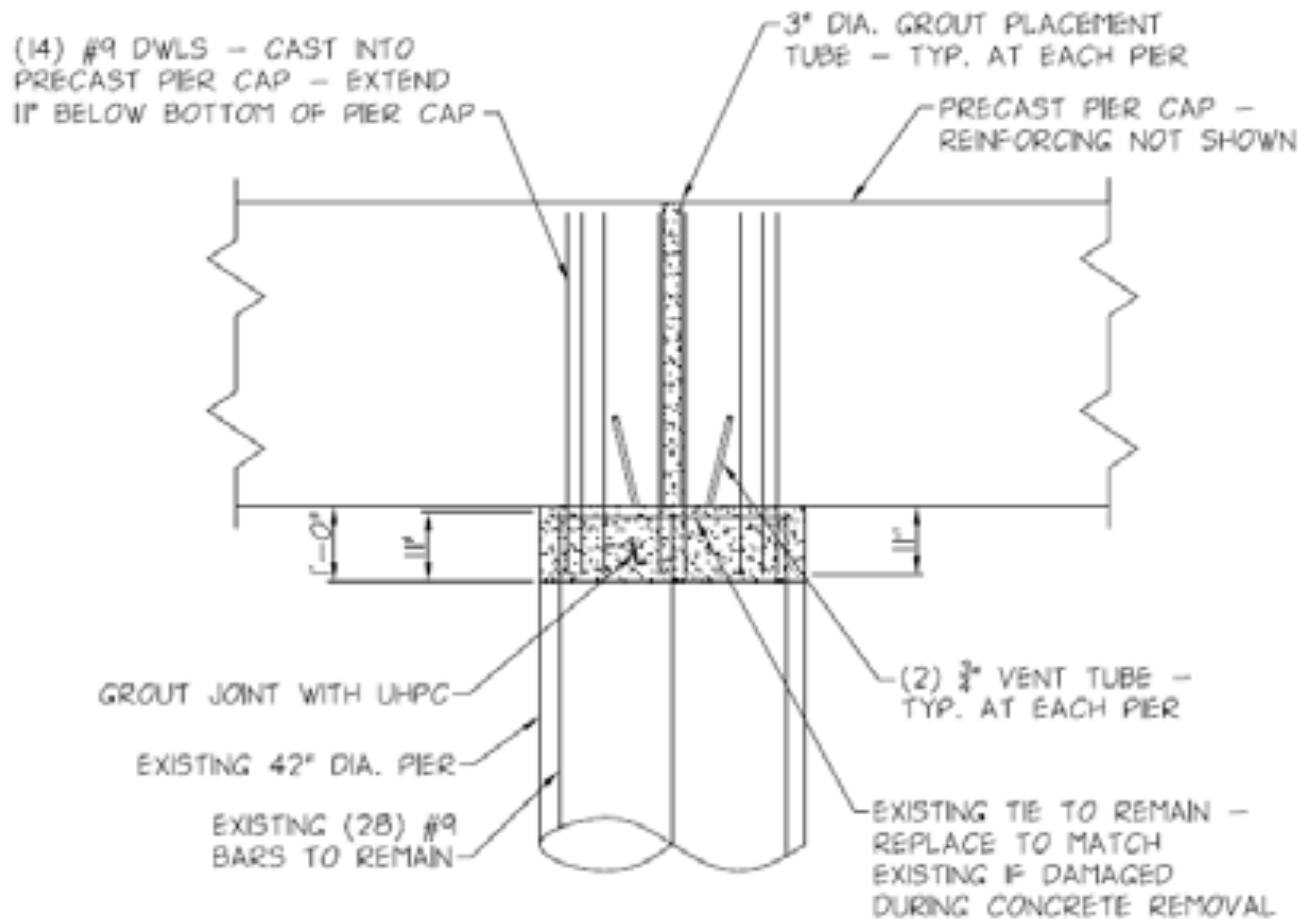
PBES INNOVATION

Other Interesting Concepts



A photograph showing a large, flat concrete surface, likely a link slab, with a white concrete wall in the background. The concrete has a textured, slightly uneven appearance. A black rounded rectangle is overlaid at the bottom of the image, containing the text "Link Slab" in white.

Link Slab



Column-to-Cap Connection

Federal Highway Administration
Every Day Counts
Innovation Initiative



UHPC FOR PBE IN EDC3



UHPC CONNECTIONS: A Path to Accelerated Construction and Enhanced Bridge Performance

Ben Graybeal, Ph.D., P.E.

Team Leader – Bridge & Foundation Engineering
Federal Highway Administration

202-493-3122

benjamin.graybeal@dot.gov



GUIDANCE ON USE OF UHPC CONNECTIONS

- FHWA document HRT-14-084
 - Design guidance
 - Construction guidance
 - Case Studies
- Publication within 3 months
- Layout/Printing Underway



Introduction to UHPC

- NHI Innovations Webinars – November 18, 2010 and April 21, 2011
- FIU ABC Webinar – September 29, 2011
- TechNote: UHPC
 - FHWA HRT-11-038
 - Aimed at DOTs and practitioners
 - General information on casting, curing, testing, applications, inspection, etc.
 - Web Search:
UHPC TechNote



UHPC State-of-the-Art Report

- FHWA HRT-13-060
 - 300+ references
 - 600+ item bibliography
 - Materials, Performance, Design, Applications, Outlook
 - Web Search:
UHPC State of the Art



FHWA UHPC Memo – 12 Feb 2014

- Buy America re: Fibers
- Availability
- Proprietary Products
- Example Special Provision (NYSDOT)



NON-PROPRIETARY UHPC

- Full Report on Study Results
- Report: NTIS PB2013-110587
- TechBrief: FHWA HRT-13-100



TECHNOTE: UHPC CONNECTIONS

- FHWA HRT-12-038
 - Aimed at DOTs and practitioners
 - General information on field-cast use of UHPC
 - Web Search:
UHPC Connections TechNote



DECK-LEVEL UHPC CONNECTIONS

- Full Report on Study Results
- Report: NTIS PB2011-101995
- TechBrief: FHWA HRT-11-022



FHWA UHPC Research and Development Program

Select References as of October 2014

Field-Cast UHPC Connections for Modular Components

- Graybeal, B., "Ultra-High-Performance Concrete Connections for Precast Concrete Bridge Decks," *PCI Journal*, V. 59, No. 4, Fall 2014, pp. 48-62.
- Graybeal, B., "Construction of Field-Cast Ultra-High Performance Concrete Connections," FHWA Report HRT-12-038, April 2012, 8 pp.
- Graybeal, B., "Ultra-High Performance Concrete Composite Connections for Precast Concrete Bridge Decks," NTIS Report No. PB 2012-107569, May 2012, 109 pp.
- Graybeal, B., "Behavior of Ultra-High Performance Concrete Connections Between Precast Bridge Deck Elements," *Proc., Concrete Bridge Conference*, Phoenix, Arizona, February 2010, 13 pp.
- Graybeal, B., "Behavior of Field-Cast Ultra-High Performance Concrete Bridge Deck Connections Under Cyclic and Static Structural Loading," NTIS Report No. PB2011-101995, Nov. 2010, 106 pp.
- Graybeal, B., "Fatigue Response of an Ultra-High Performance Concrete Field-Cast Bridge Deck Connection," *Proc., 2011 Transportation Research Board Conference*, Washington D.C., January 2011, 12 pp.
- Swenty, M., and Graybeal, B., "Effects of Early Age Differential Displacements on Concrete-Bar Bond in the Connections of Staged Constructions," *Materials and Structures*, August 2014, 12 pp.
- Graybeal, B., "Splice Length of Prestressing Strands in Field-Cast UHPC Connections," *Materials and Structures*, March 2014, 9 pp.

UHPC Pi-Girder Research

- Graybeal, B., "Structural Behavior of a 2nd Generation Ultra-High Performance Concrete Pi-Girder," NTIS Report No. PB2009-115496, Nov. 2009, 114 pp.
- Graybeal, B., "Structural Behavior of a Prototype Ultra-High Performance Concrete Pi-Girder," NTIS Report No. PB2009-115495, Nov. 2009, 145 pp.
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UHPC I-Girder Research

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