Applications of Ultra-High-Performance Concrete and Prefabricated Concrete Elements in Accelerated Bridge Construction

2018 Virginia Concrete Conference

March 2, 2018

HNTB

Bardia Emami, PE

Outline

Projects

- IADOT - Keg Creek ABC Bridge Replacement
- VDOT - Piney Run ABC Bridge Replacement

UHPC

- General Features
- Concerns about UHPC
- Other UHPC Applications

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Keg Creek Bridge Rapid Replacement - IADOT

- SHRP2 R04 ABC Demonstration Project #1
- ABC 14 Day Road Closure
- Total Prefabricated Bridge Elements and Systems (PBES)
- 3-span bridge
- Jointless construction
- Predecked steel beam (with option for PS girders)

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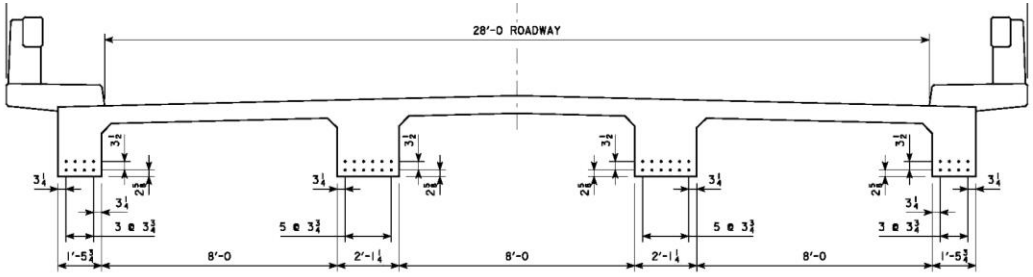
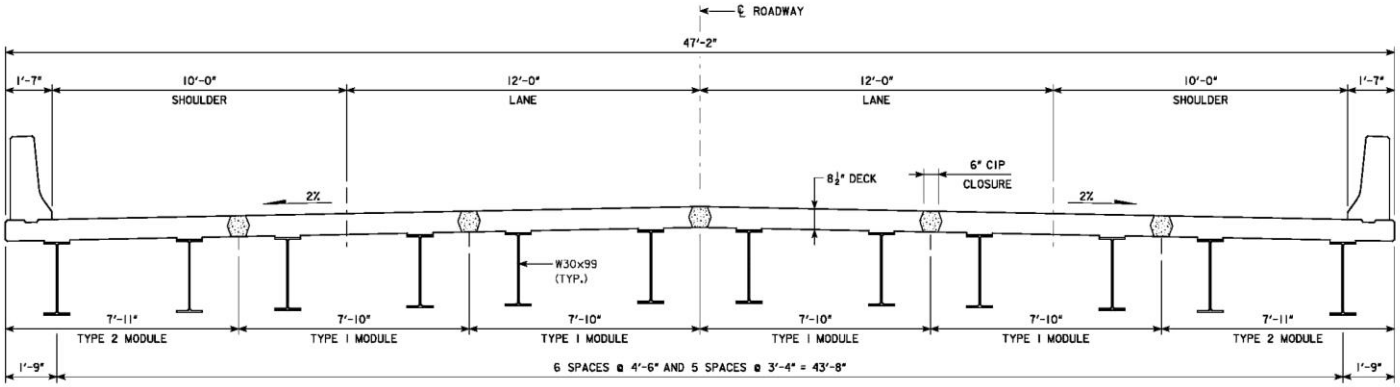
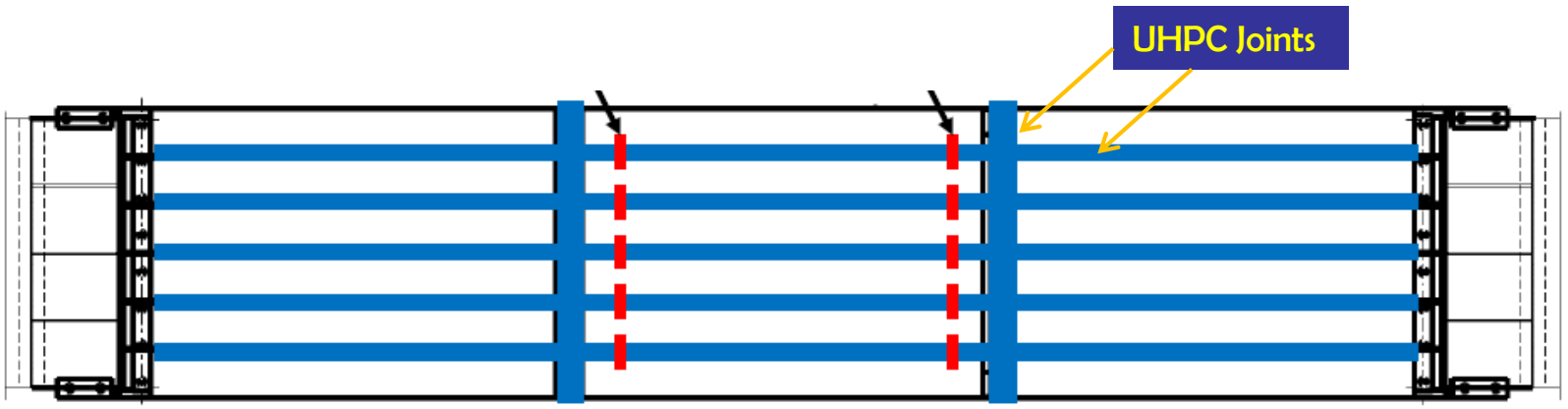
Cross-Sections / Plan

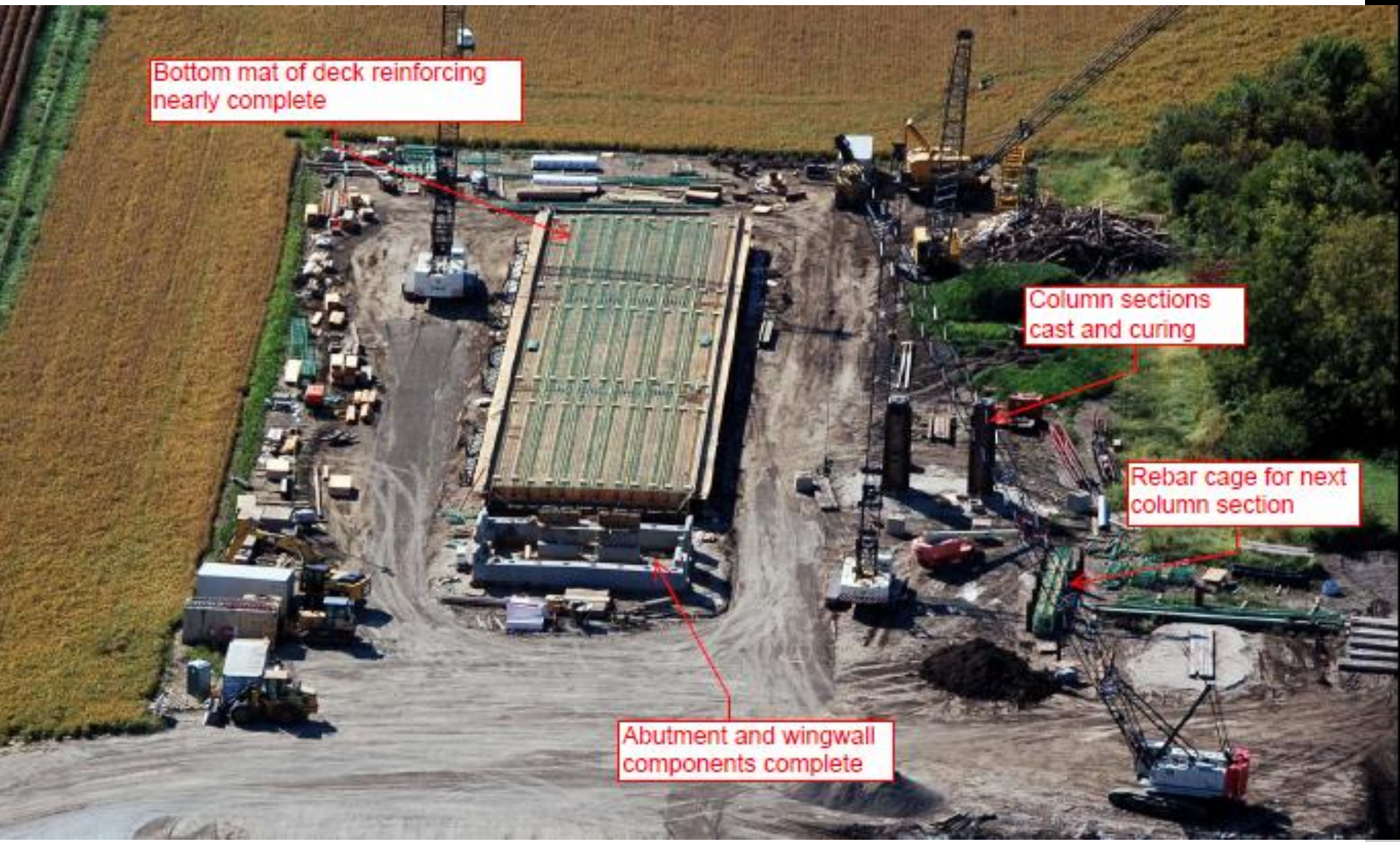


EXISTING CROSS SECTION AT CENTERLINE



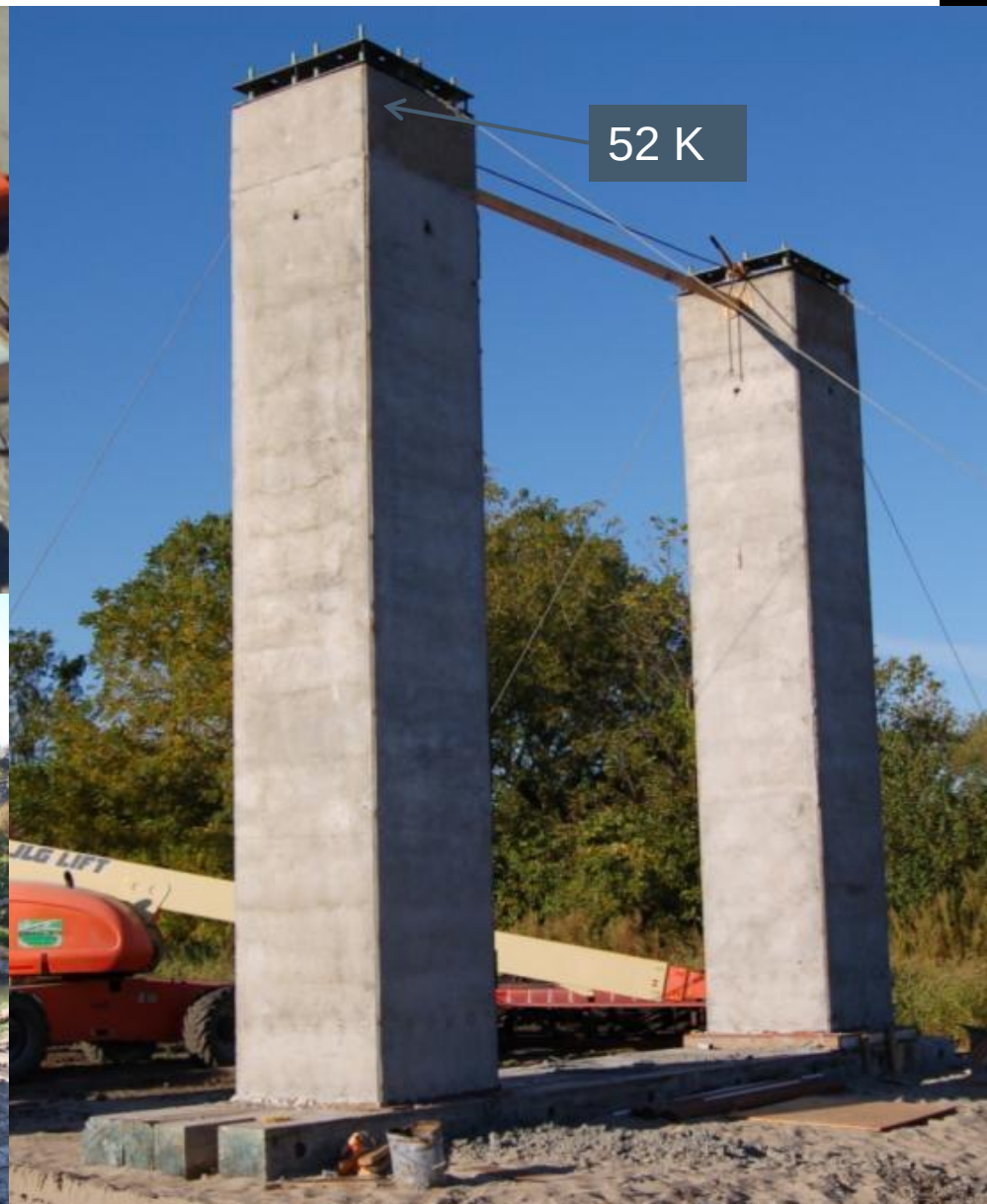


Prefabrication Yard Adjacent to Bridge



Prefabrication Yard Adjacent to Bridge

Prefabrication of Abutments and Piers



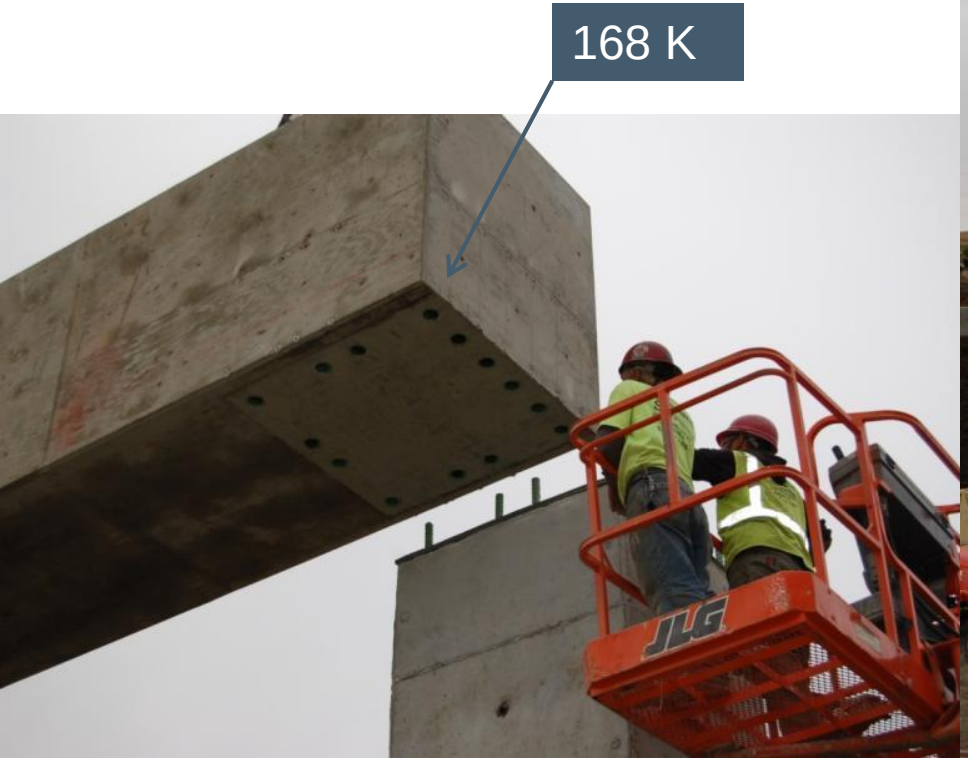
Day 1 - Rapid Demolition

- One day demolition
- Two hydraulic breakers
- Crane with wrecking ball

Days 3 & 4 - Precast Abutment Assembly

Day 5 - Precast Pier Assembly

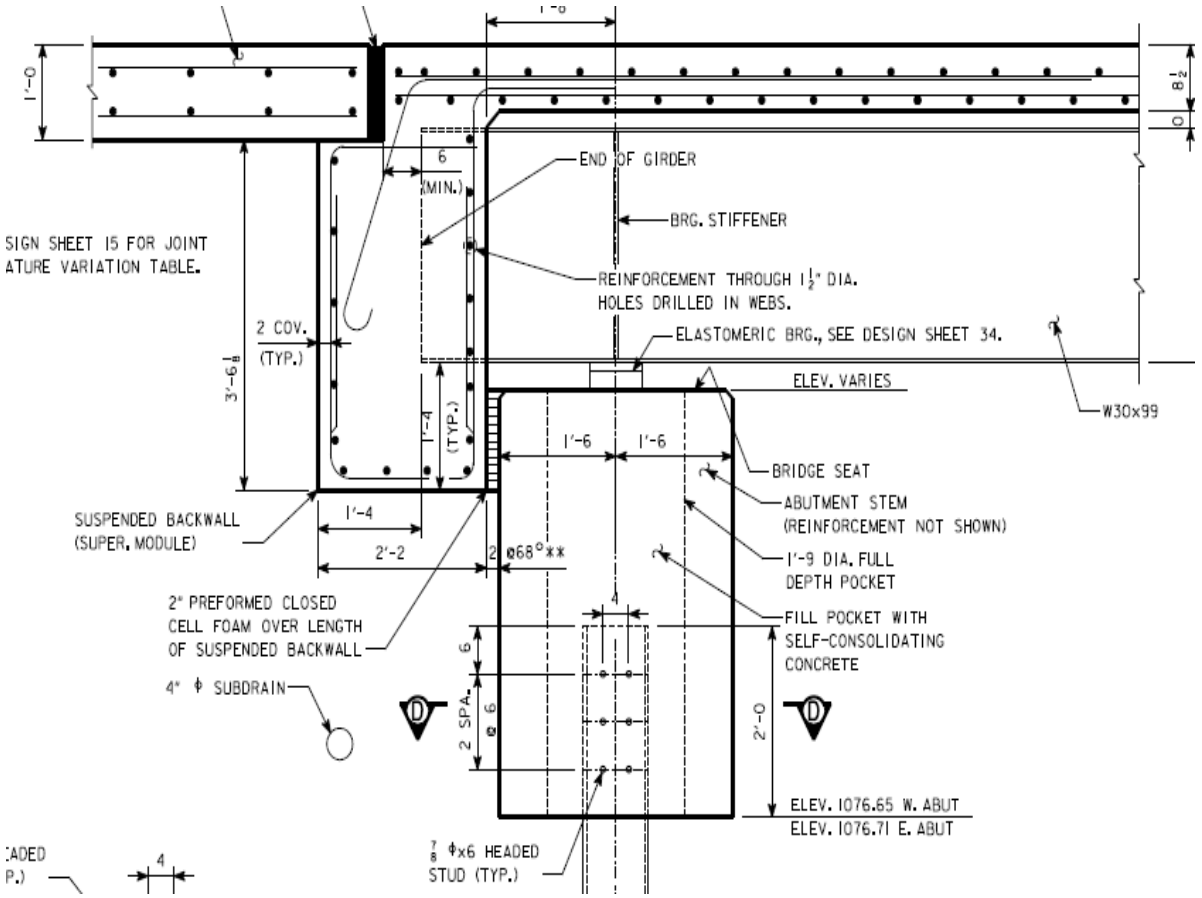
- Pier caps: 168 kips
- Required two 110 ton cranes to lift into place



Days 7 and 8 - Superstructure Elements

Days 7 and 8 - Superstructure Elements

Days 7 and 8 - Semi-Integral Abutment



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Day 10 – UHPC Deck Closure Pours

Transverse UHPC Joints

Longitudinal UHPC Joints

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Day 13 - Deck Riding Surface

- No open deck joints
- Integral wearing surface (no overlay)
- Extra ½ inch for grinding for smooth riding surface

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Keg Creek Bridge Rapid Replacement - IADOT

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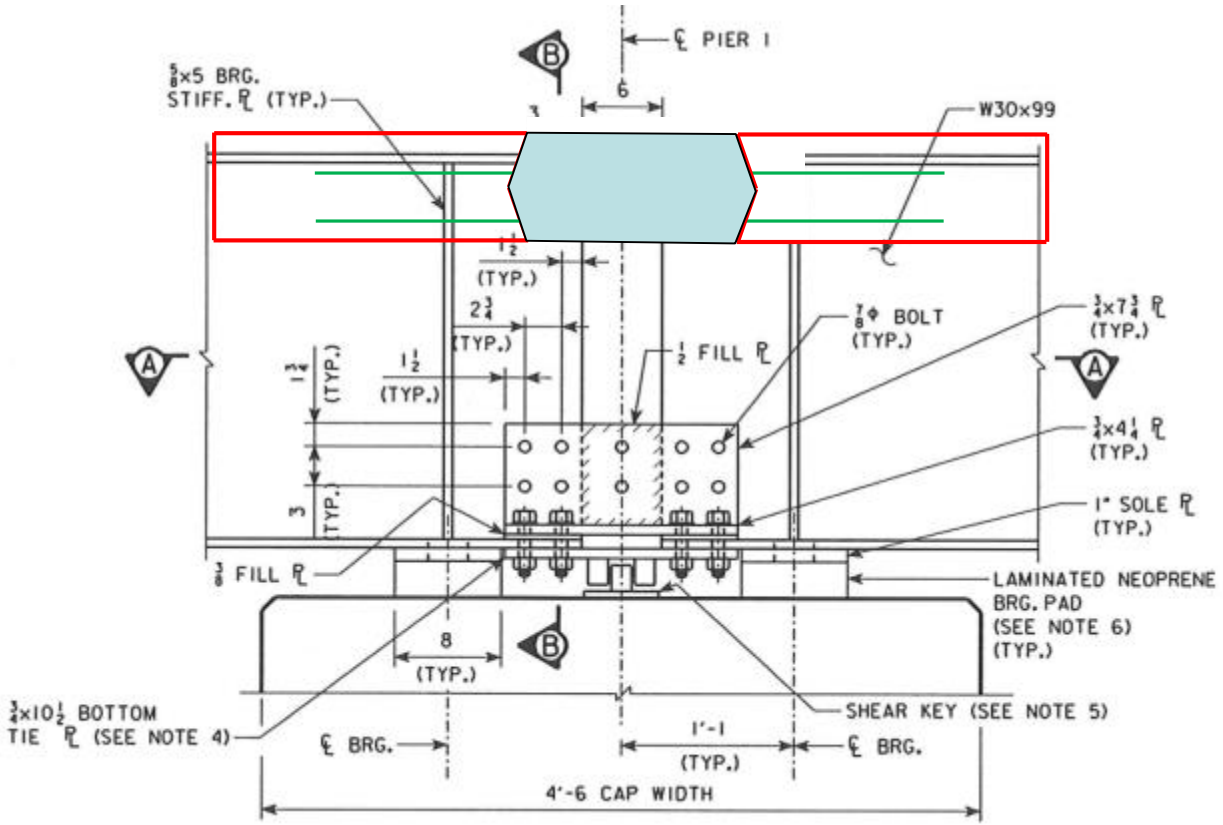
Concrete Material Highlights

- UHPC joint reinforced to carry the full LL tension
- First use of UHPC for transverse joints over pier



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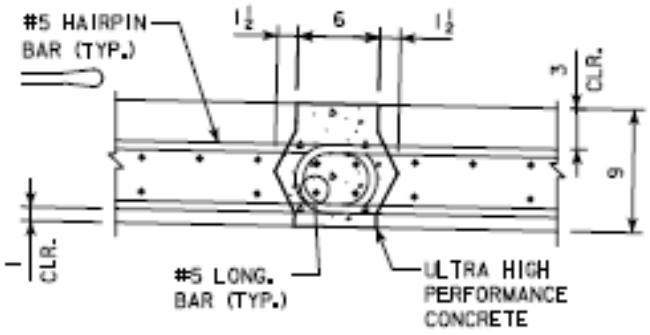
Concrete Material Highlights

- UHPC
- Full moment transfer
- No post-tensioning
- 6 in. wide



LONGITUDINAL CLOSURE POUR DETAIL

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Concrete Material Highlights

- 5,000 psi HPC in prefabricated elements
- HES SCC at abutment closure pours and full depth pockets
- No post-tensioning

Self Consolidating Concrete Joints

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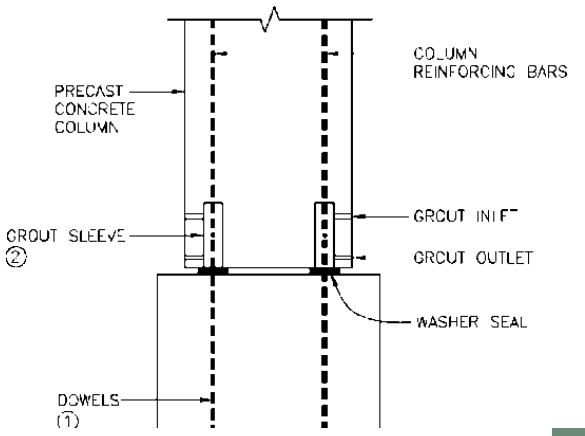
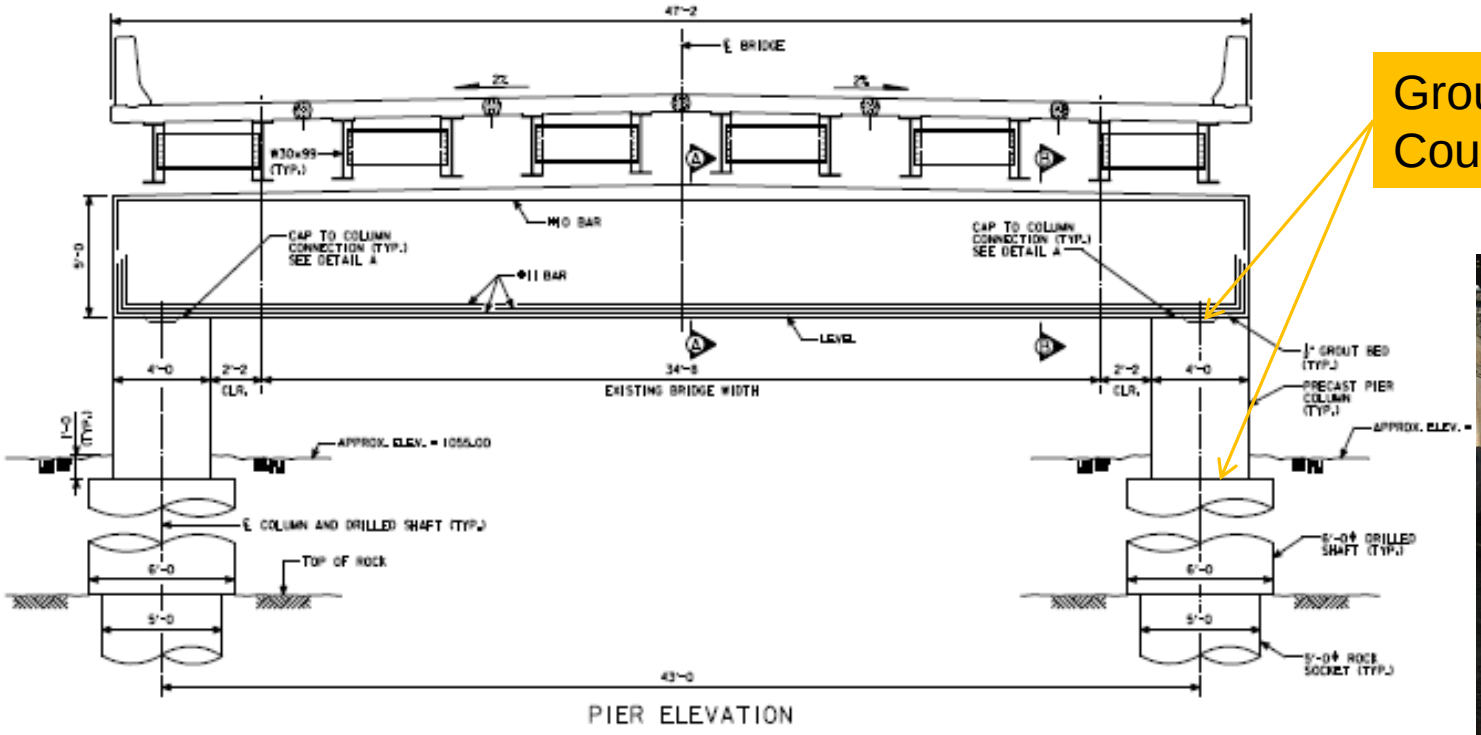
Concrete Material Highlights

- Grouted Splice Couplers
- Low seismic zone





Grouted Splice Couplers

ABC Seismic Connections

Column-to-Cap Connection Type	Seismic Design Category
Grouted Splice Sleeve[1]	A, B, C
Grouted Duct[2]	A, B, C, D
Cap Pocket[2]	A, B, C, D

1. NCHRP 12-74 has recommended use for limited-ductility applications only.

2. NCHRP 12-74 tested both a limited-ductility and a full-ductility cap pocket connection.

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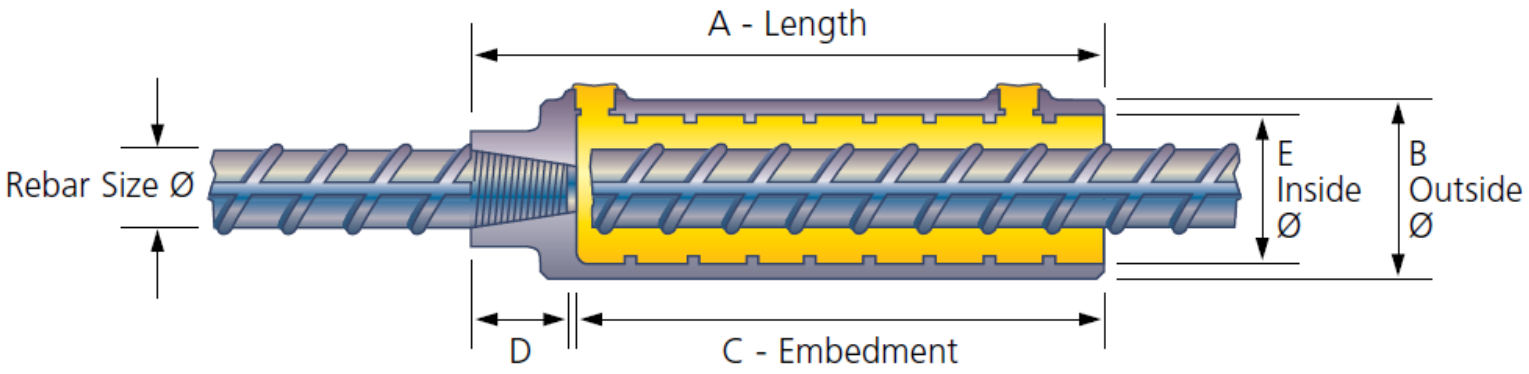
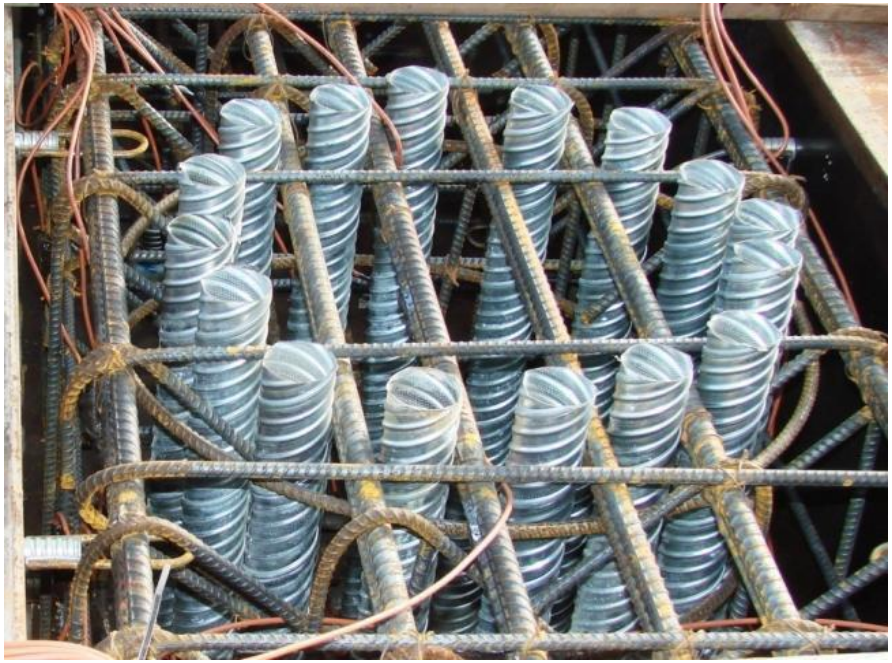
ABC Seismic Connections

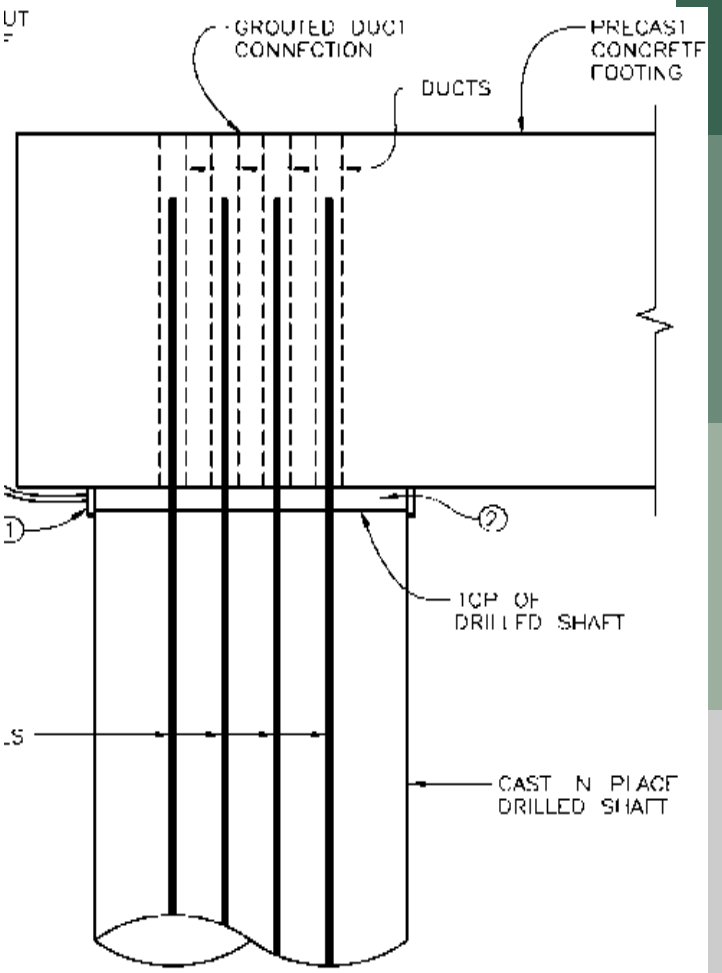
- Grouted Couplers
  - Fast assembly
  - Limited ductility
  - Suitable for low to moderate seismic zones



ABC Seismic Connections

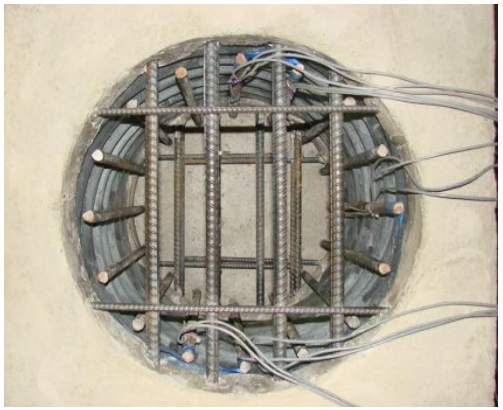
- Grouted Duct
  - Full ductility
  - Suitable for high seismic zones

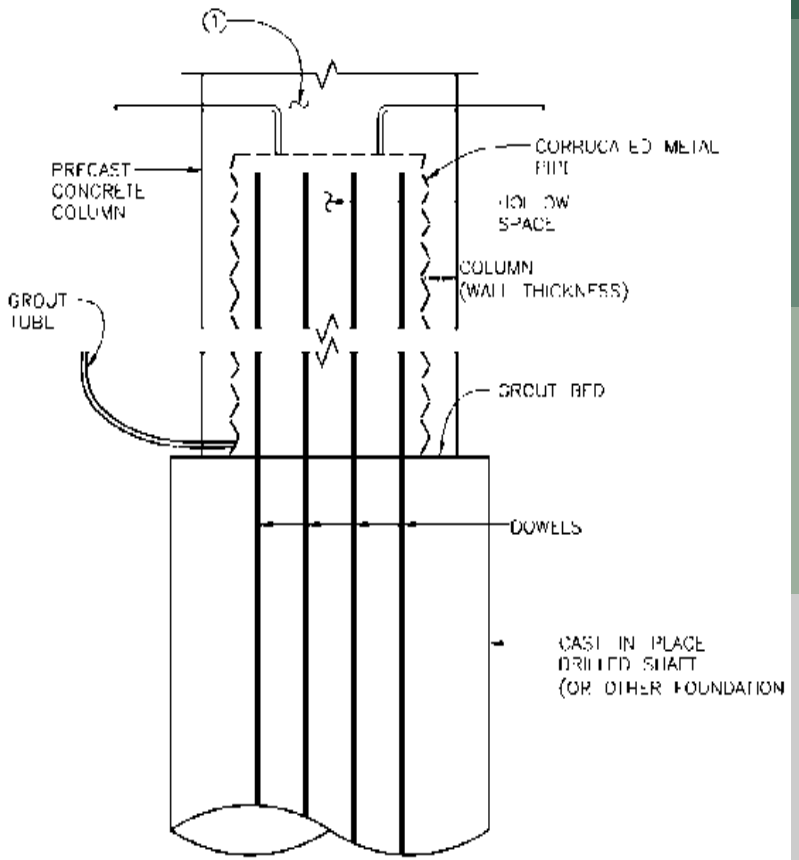




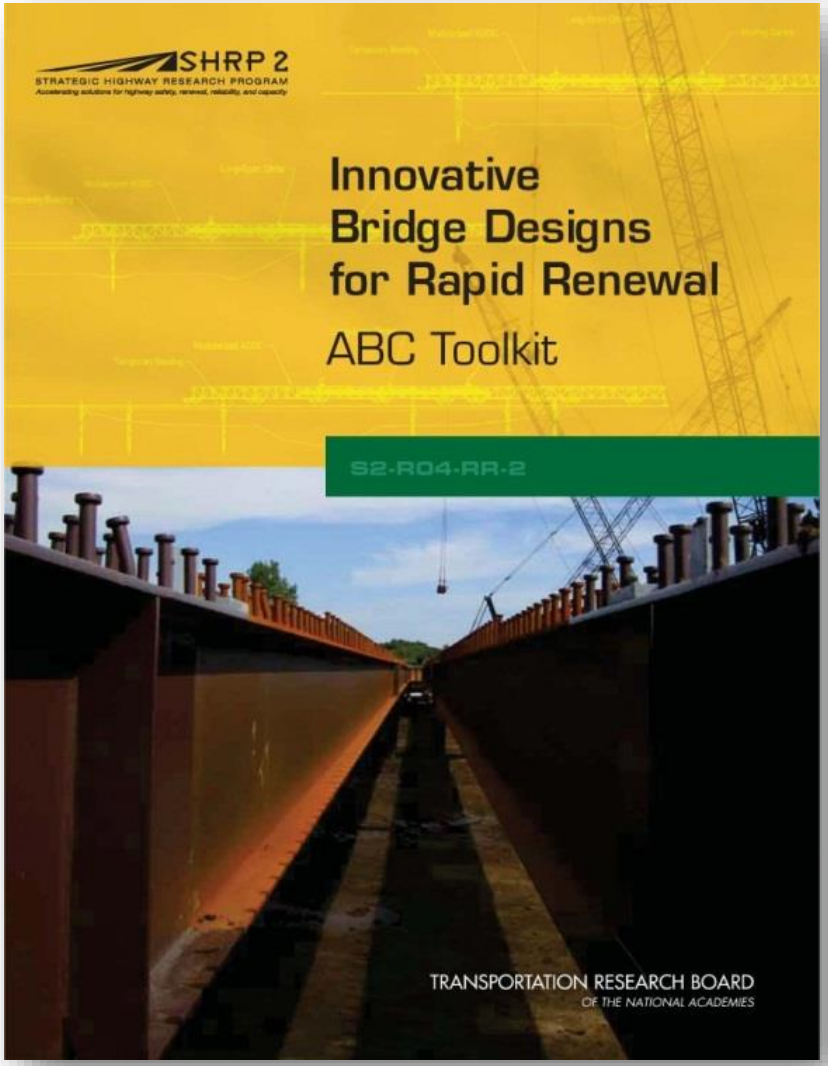
ABC Seismic Connections

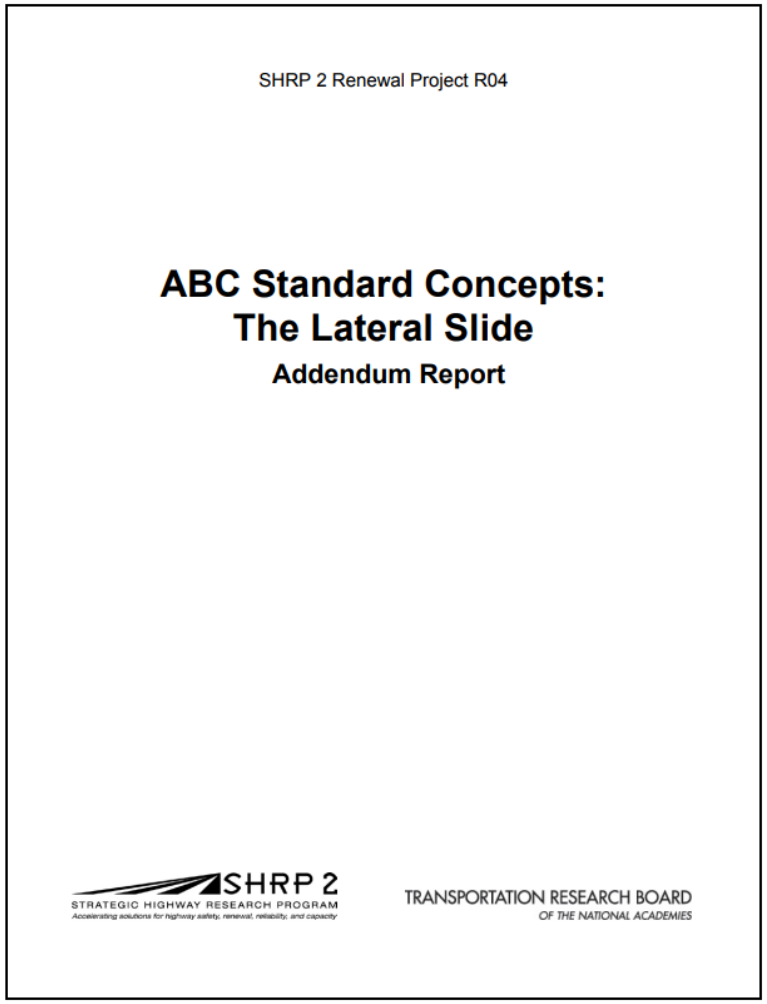
- Cap Pockets
  - Full ductility
  - Suitable for high seismic zones





ABC Toolkit and References





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VDOT Route 681 over Piney Run – Fairfax, VA

- Existing structure:
  - Single-span bridge
  - ADT = 6,200
  - Single Lane
  - High number of accidents
  - Bridge Length = 19’

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VDOT Route 681 over Piney Run – Fairfax, VA

- Major flood damage at approaches in 2006, 2008 and 2011

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VDOT Route 681 over Piney Run – Fairfax, VA

- Proposed bridge preliminary design in 2015
- ABC 10-day road closure to minimize traffic impact
- Prefabricated Bridge Elements
- 50’ long bridge with improved hydraulic opening
- 2-lanes of traffic and a 6’ raised sidewalk
- Retaining walls and 100’ long reinforced concrete approach slabs as flood protection measure
- Improved approach sight distance

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VDOT Route 681 over Piney Run – Fairfax, VA

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VDOT Route 681 over Piney Run – Fairfax, VA

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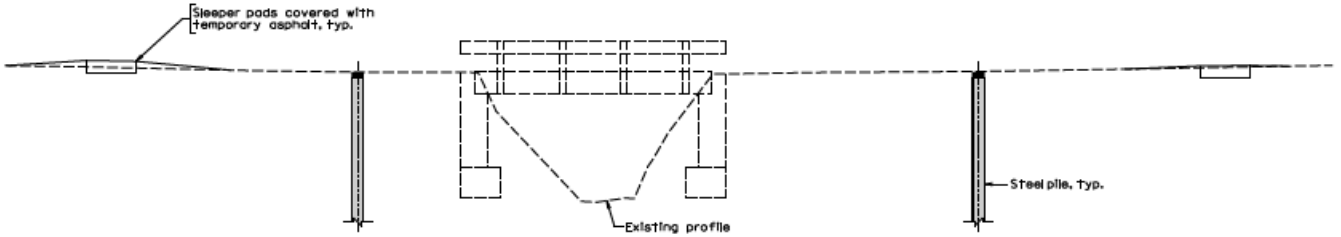
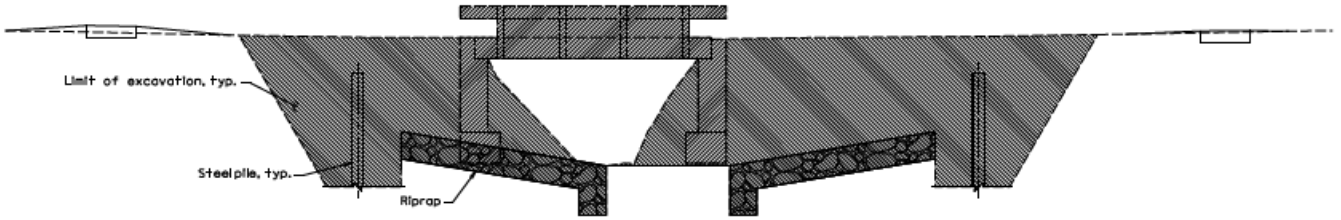
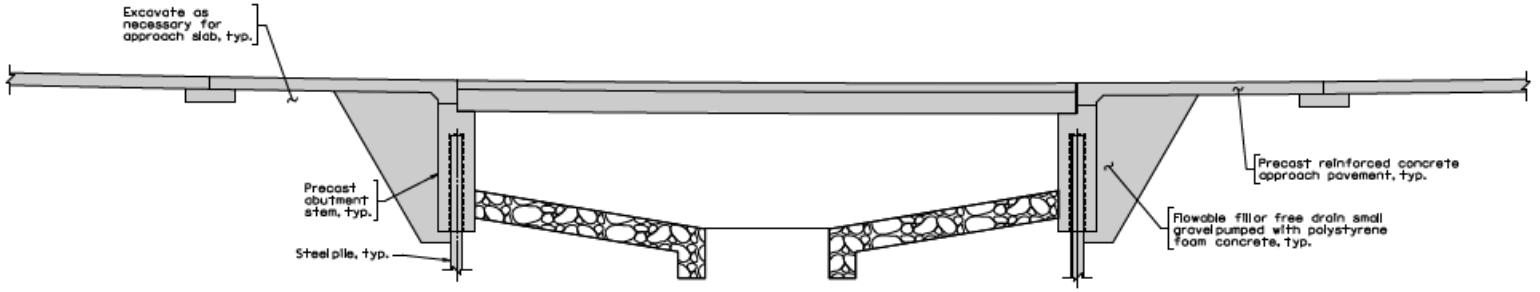
VDOT Route 681 over Piney Run – Fairfax, VA



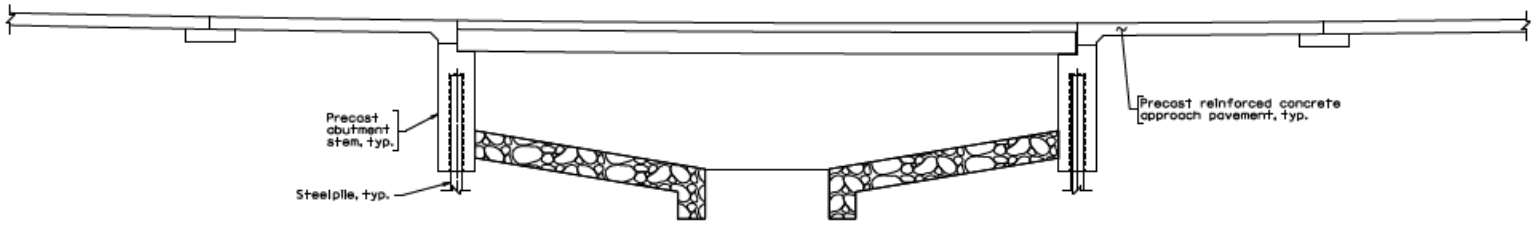
CONSTRUCTION STAGE I (PRIOR TO ROAD CLOSURE)



CONSTRUCTION STAGE II (DURING ROAD CLOSURE)

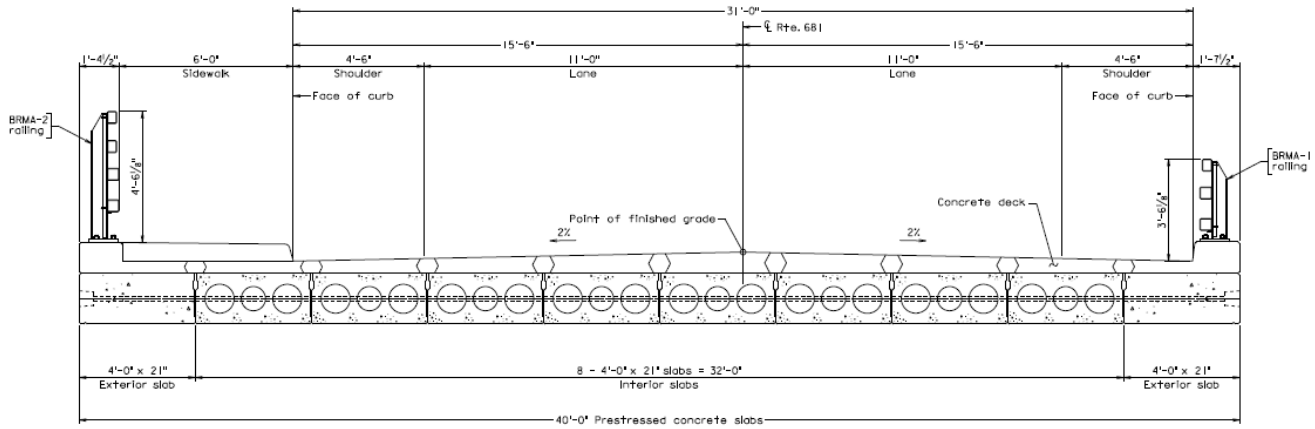


CONSTRUCTION STAGE III (DURING ROAD CLOSURE)

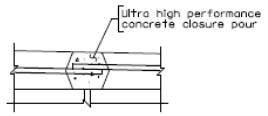


FINAL ELEVATION

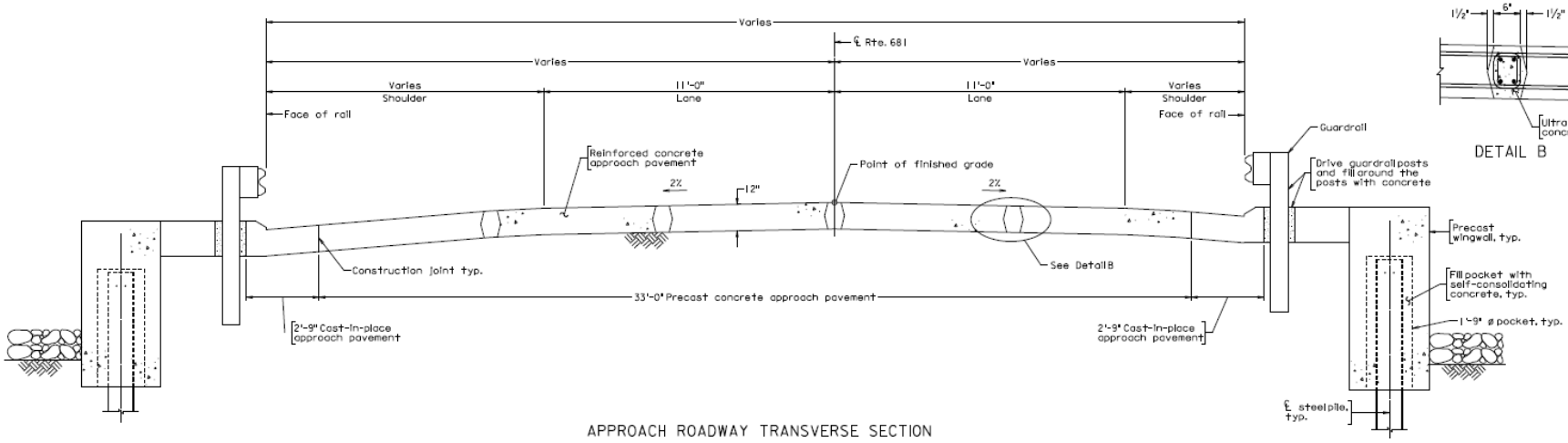
VDOT Route 681 over Piney Run – Fairfax, VA



BRIDGE TRANSVERSE SECTION



DETAIL A



APPROACH ROADWAY TRANSVERSE SECTION

DETAIL B

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What is UHPC?

Typical Composition of UHPC

Constituent	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

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UHPC – General Features

- Compressive Strength: 20 ksi to 32 ksi
- High tensile capacity: 0.75 ksi to 1.5 ksi
- Flexural strength: 3 ksi to 7 ksi
- Early strength: 10 ksi to 12 ksi in 12 hours
- Very low creep and shrinkage
- Higher ductility
- Highly durable: Lower 100-yr life cycle cost
- Impermeability: Almost no carbonation and penetration of Chloride

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UHPC – General Features

- Self Consolidating: Vibrating will result steel fiber settlement
- Bondable to any type of existing concrete surface
- Abrasion resistance: Similar to natural rock
- Short lap length: FHWA publication - 5” lap for #5
- Workable up to an hour
- Highly flowable and castable (as low as 5/8” thick)
- Self leveling: Flows up to 10 ft
- No post-tensioning is required

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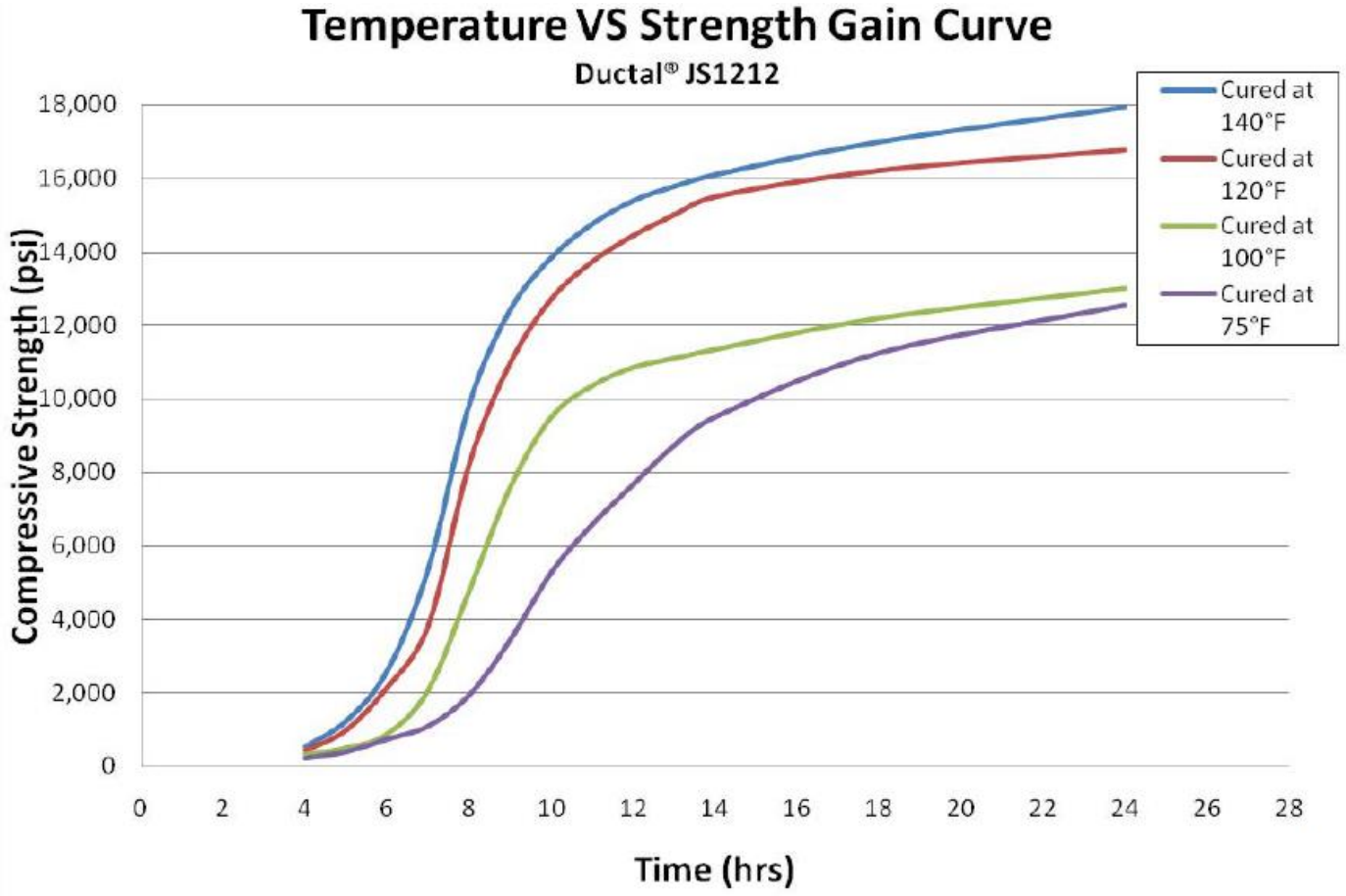
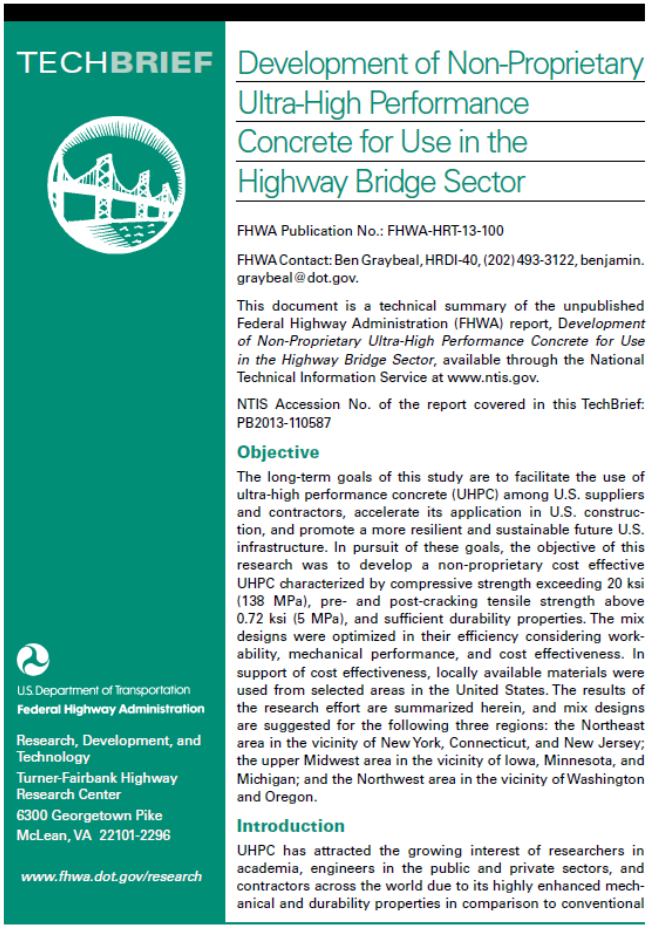
UHPC – General Features



Source: Ductal®

Concerns about UHPC

- Proprietary products
  - FHWA Memorandum
  - Performance based specification
  - Non-proprietary mix design
  - Sole source issue
- Domestic source
- Forming and casting



TECHBRIEF

Development of Non-Proprietary Ultra-High Performance Concrete for Use in the Highway Bridge Sector

FHWA Publication No.: FHWA-HRT-13-100

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

This document is a technical summary of the unpublished Federal Highway Administration (FHWA) report, *Development of Non-Proprietary Ultra-High Performance Concrete for Use in the Highway Bridge Sector*, available through the National Technical Information Service at www.ntis.gov.

NTIS Accession No. of the report covered in this TechBrief: PB2013-110587

Objective

The long-term goals of this study are to facilitate the use of ultra-high performance concrete (UHPC) among U.S. suppliers and contractors, accelerate its application in U.S. construction, and promote a more resilient and sustainable future U.S. infrastructure. In pursuit of these goals, the objective of this research was to develop a non-proprietary cost effective UHPC characterized by compressive strength exceeding 20 ksi (138 MPa), pre- and post-cracking tensile strength above 0.72 ksi (5 MPa), and sufficient durability properties. The mix designs were optimized in their efficiency considering workability, mechanical performance, and cost effectiveness. In support of cost effectiveness, locally available materials were used from selected areas in the United States. The results of the research effort are summarized herein, and mix designs are suggested for the following three regions: the Northeast area in the vicinity of New York, Connecticut, and New Jersey; the upper Midwest area in the vicinity of Iowa, Minnesota, and Michigan; and the Northwest area in the vicinity of Washington and Oregon.

Introduction

UHPC has attracted the growing interest of researchers in academia, engineers in the public and private sectors, and contractors across the world due to its highly enhanced mechanical and durability properties in comparison to conventional

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

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Concerns about UHPC

- Cost


VTRC
Virginia Transportation Research Council

Evaluation of High-Performance Fiber-Reinforced Concrete for Bridge Deck Connections, Closure Pours, and Joints

http://www.virginiadot.org/vtrc/main/online_reports/pdf/17-r15.pdf

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Bridge Designer
FIGG Bridge Group

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Virginia Transportation Research Council

MICHAEL C. BROWN, Ph.D., P.E.
Associate Director
Virginia Transportation Research Council

Final Report VTRC 17-R15

VIRGINIA TRANSPORTATION RESEARCH COUNCIL
530 Edgemont Road, Charlottesville, VA 22903-2454
www.VTRC.net

Concrete Type	Approximate cost ($/yd$^{3)}$)
Regular Concrete	100
Proprietary UHPC (low volume)	2,000
Non-proprietary UHPC	850
Non-proprietary UHPC (without fiber reinforcement)	500
HPFRC - Engineered Cementitious Composite (ECC)	300
Epoxy Grout	5,000
Portland Cement Grout	1,500

Concerns about UHPC

- Aesthetics concern

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Other UHPC Applications

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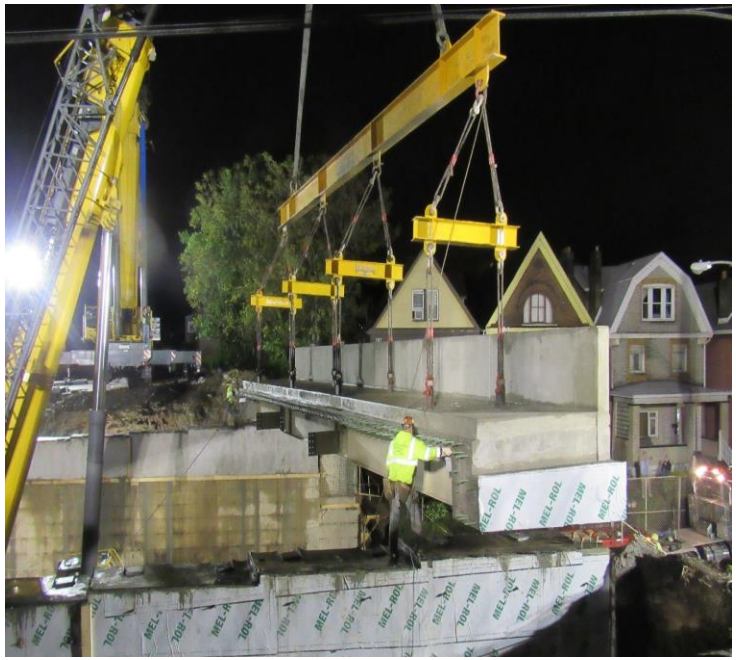
UHPC Connections in Precast Deck Panels

- 2017 Virginia Concrete Conference: Deck Panels and UHPC Joints – David Liu, PhD, PE, SE



PennDOT Route 30 over Bessemer Ave
Superstructure Replacement in 57 hours

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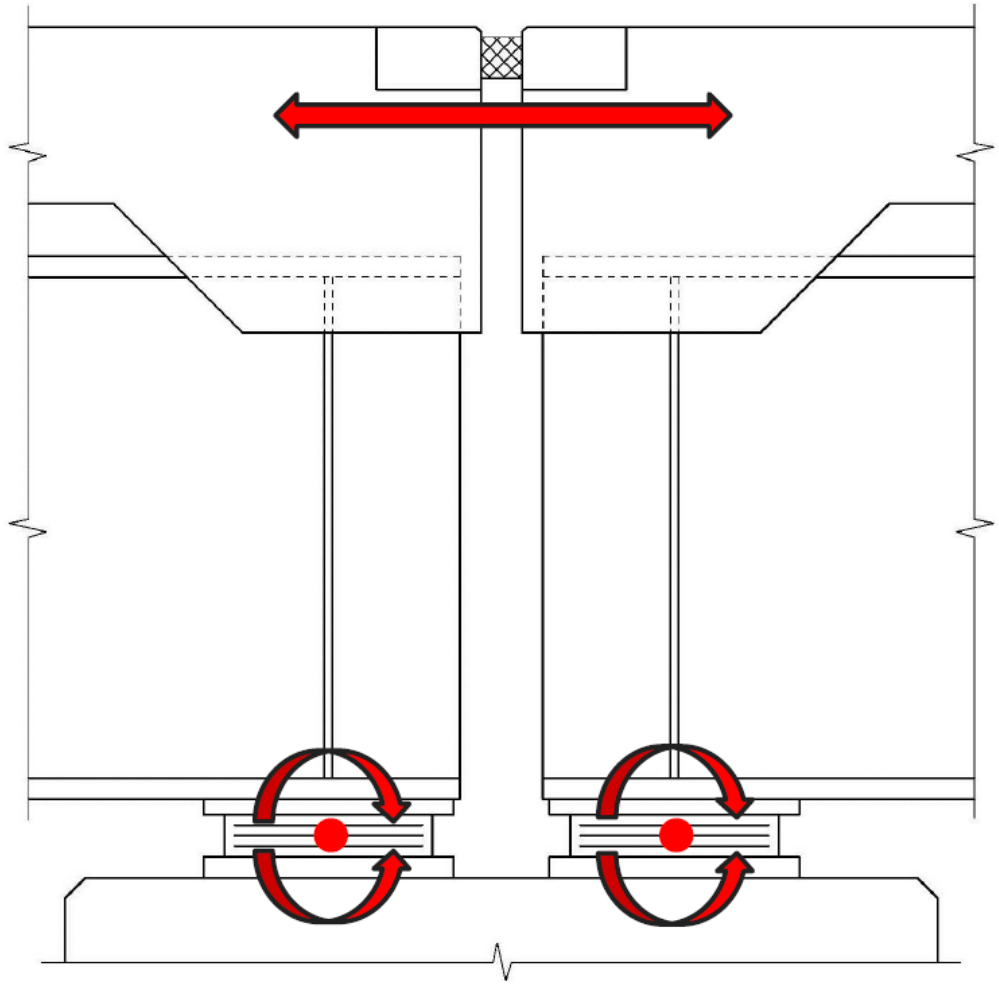
NYDOT Link Slab



Deck Joint

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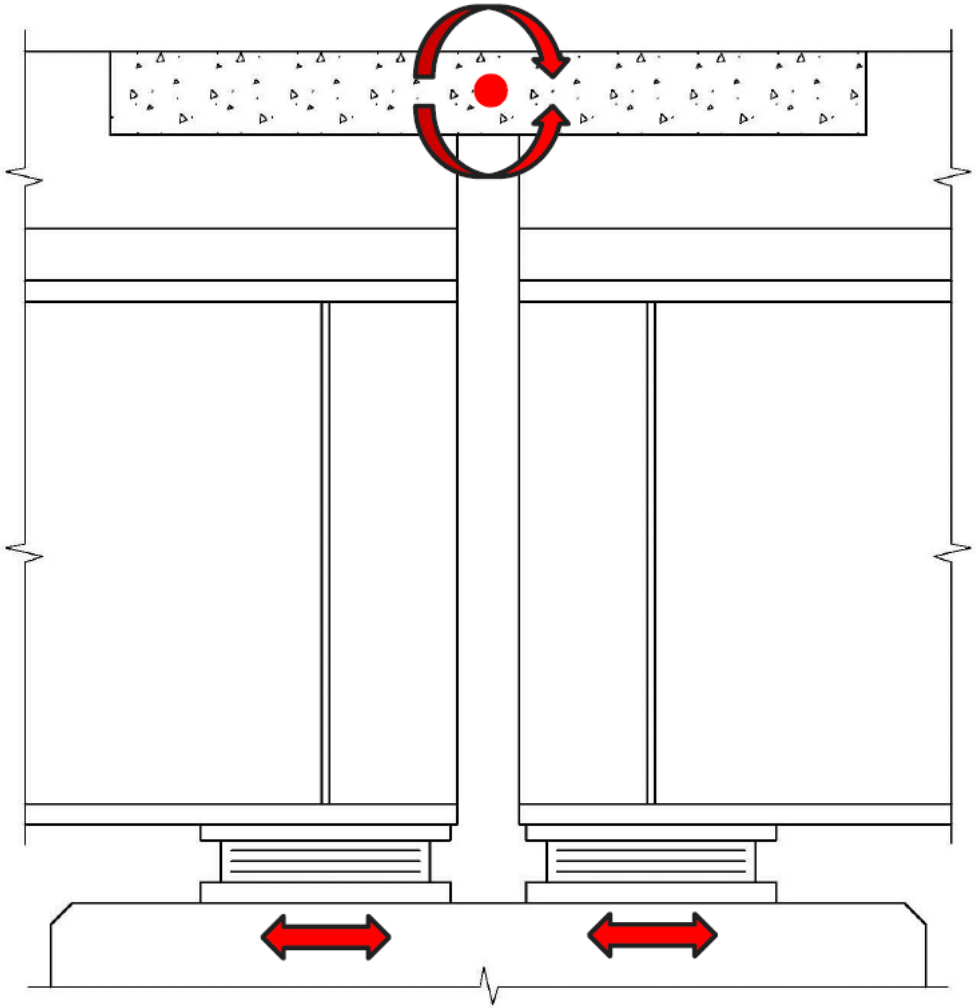
Source: 2017 NYDOT UHPC Workshop

NYDOT Link Slab



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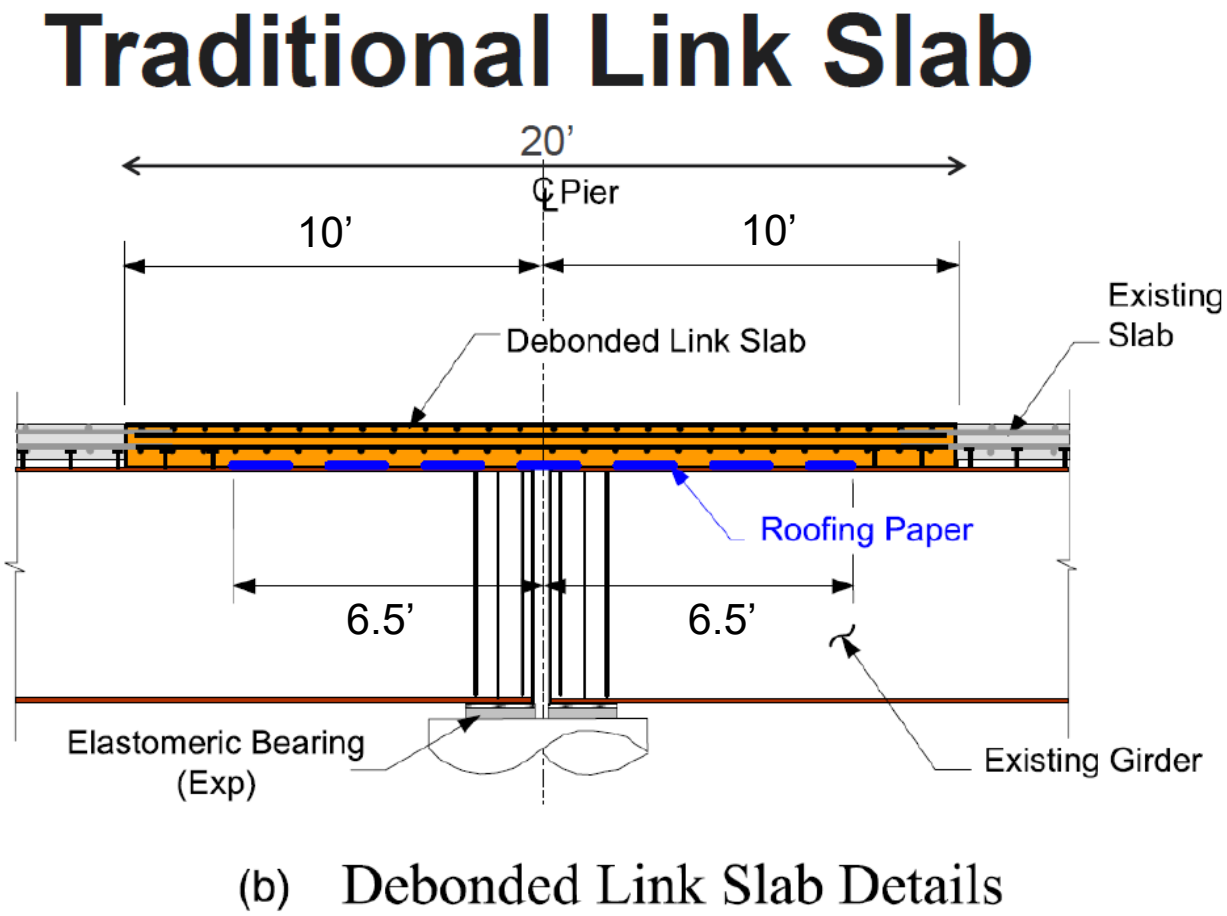
Source: 2017 NYDOT UHPC Workshop

NYDOT Link Slab



(b) Debonded Link Slab Details

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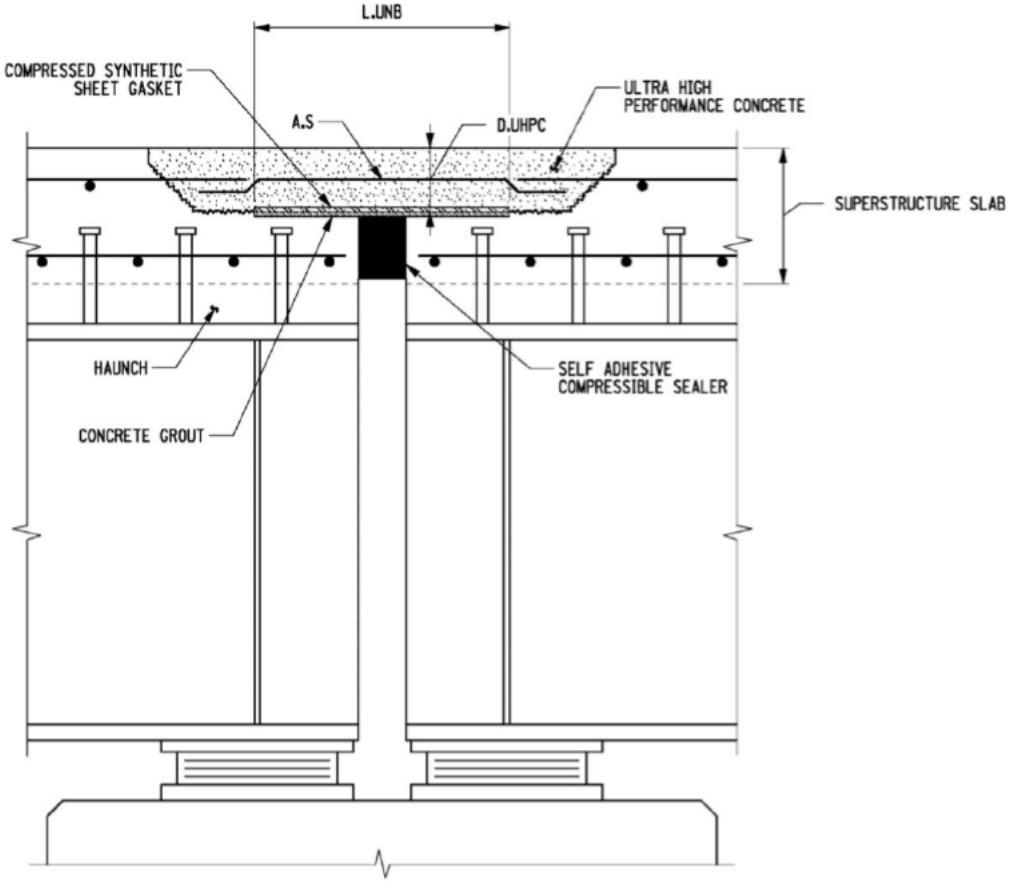
Source: 2017 NYDOT UHPC Workshop

NYDOT Link Slab

UHPC Link Slab



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Source: 2017 NYDOT UHPC Workshop

NYDOT Link Slab

Traditional vs. UHPC

Traditional

- HP Concrete
- Full depth
- 5% of span + anchor
- Heavily reinforced
- Low material cost
- High rotational restraint
- Average durability
- CIP deck replacement

UHPC

- UHP Concrete
- Partial depth - 4"
- Approx. 2’ - 3’ long
- Nominal long. reinf.
- High material cost
- Minimal rotational res.
- High durability
- Precast deck/joint replacement

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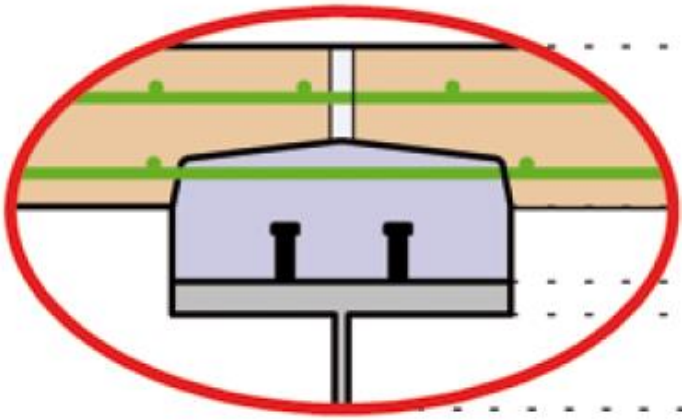
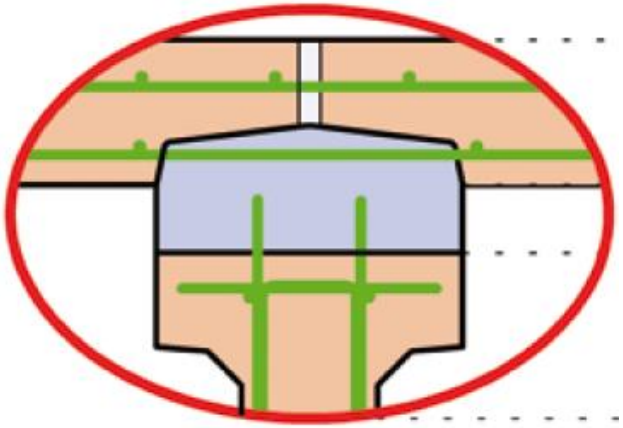
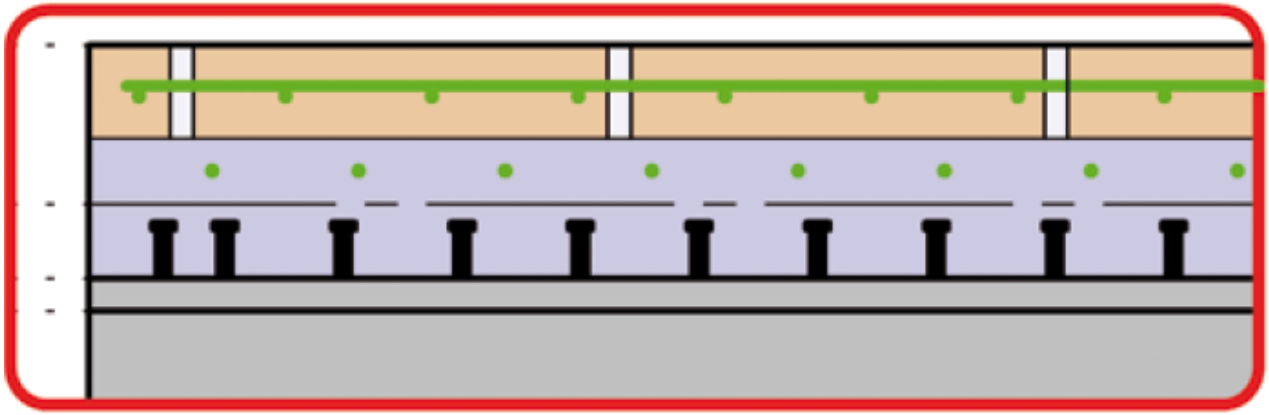
Source: 2017 NYDOT UHPC Workshop

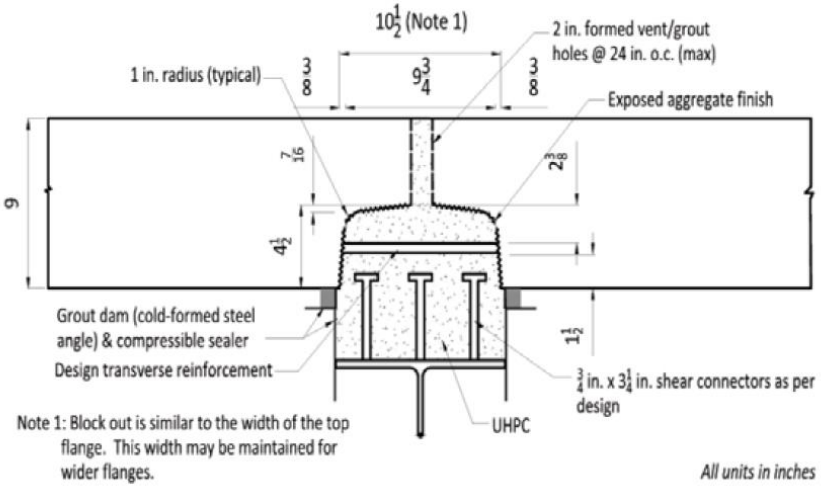
Precast Deck Connections to Girders
Hidden Pockets with UHPC







Precast Concrete Deck with Hidden Pockets
Kosciuszko Bridge - NYSDOT



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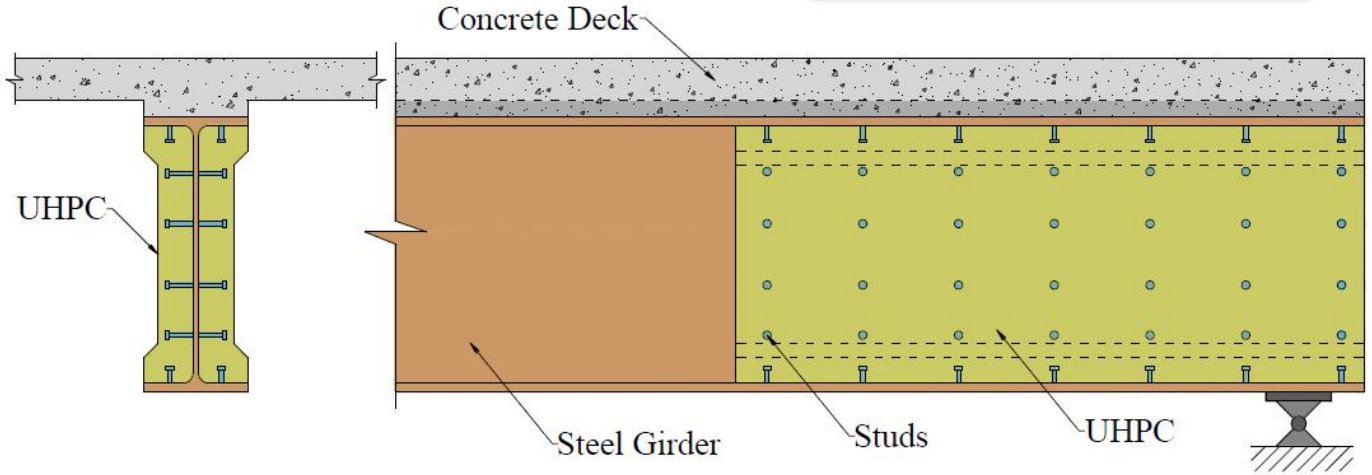
Girder End Repair



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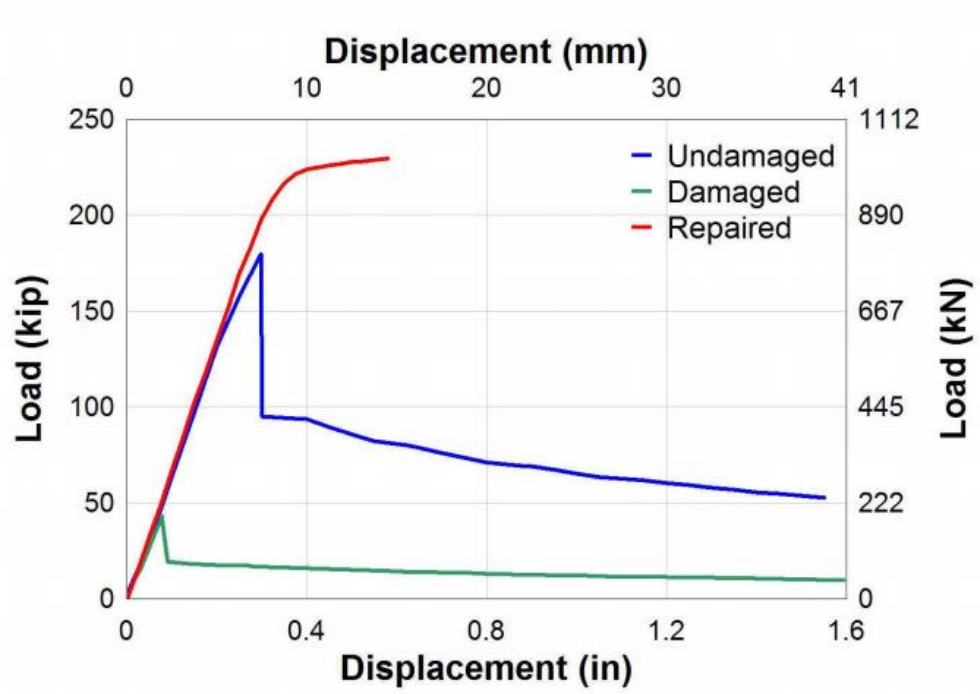
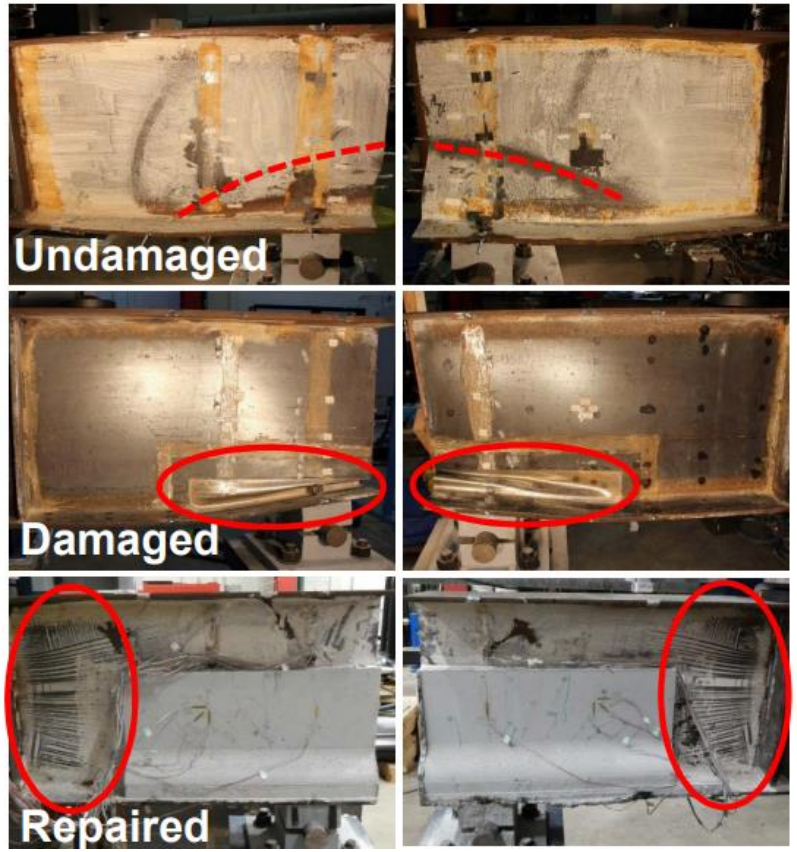
Source: 2016 FDOT FHWA Design Training

Girder End Repair





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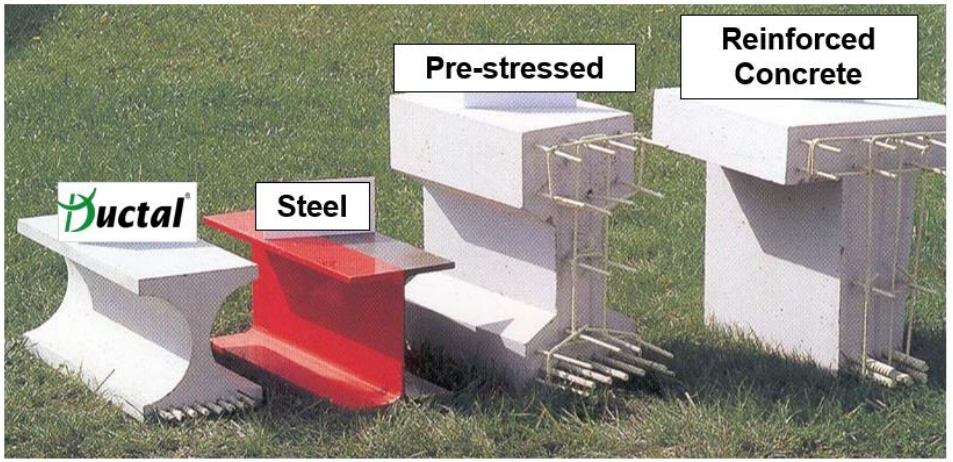
Source: 2017 UCONN UHPC workshop

Concrete Girder Using UHPC

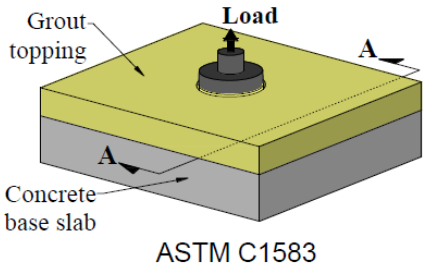
- Long span shallow concrete girder
  - Minimize superstructure depth (50% reduction)
  - Shorter fabrication duration (no vibration, early strength and no mid steel reinforcement)
  - No stirrups and higher number of strands
  - Eliminate piers



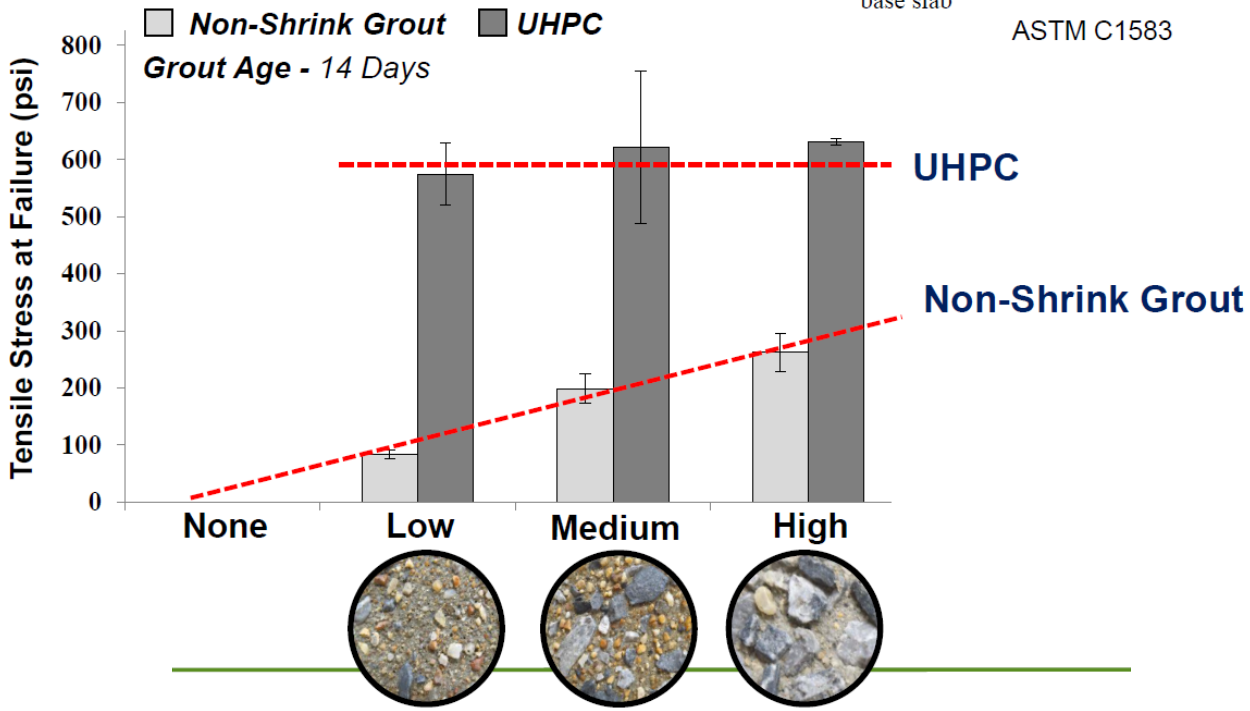
	Mass (weight) of Beams			
lbs/lineal ft.	94	75	313	355

Source: Ductal® Repair/Retrofit Solutions

Bondable Interface – Alternative to grout and overlay



ASTM C1583



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Source: 2016 FDOT FHWA Design Training

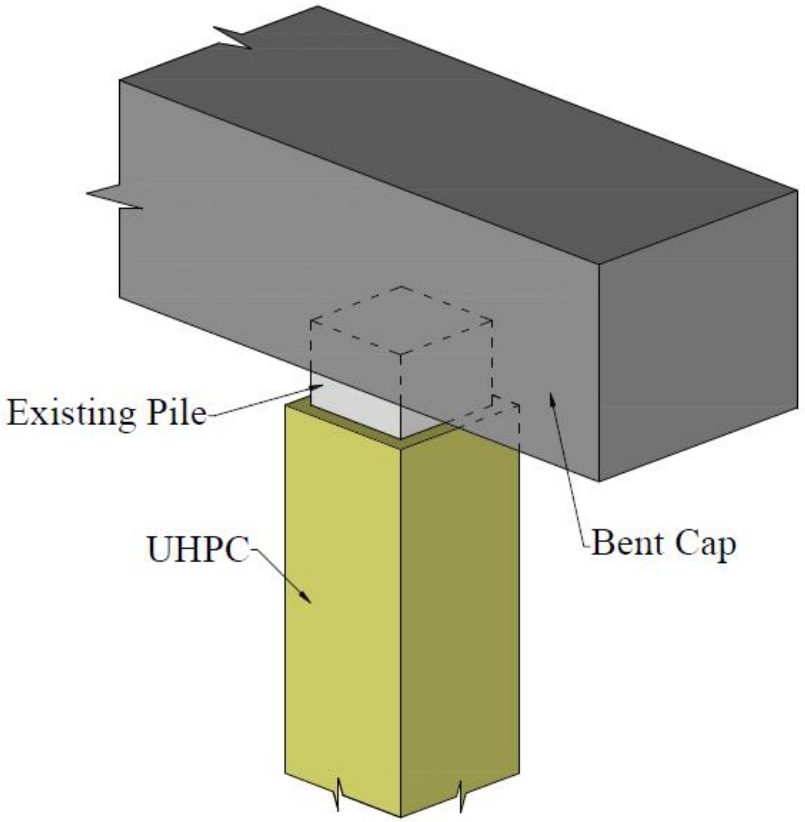
Seismic Retrofit

Mission Bridge – Pier Retrofit, Mission, BC

Source: Ductal® UHPC

Concrete Pile Retrofit

Nace.org



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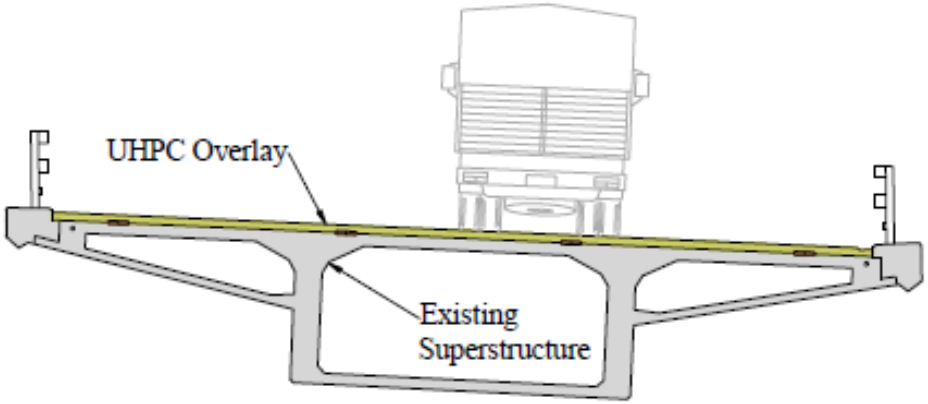
Source: 2016 FDOT FHWA Design Training

Deck Overlay

- 1-in to 2’-in bonded overlay
- Harsh environments, waterproofing & strengthening



- 1.6” thick overlay
- $20/ft^2

Chillon Bridge Repair Project, Switzerland

HNTB

Source: FHWA Field testing of UHPC overlay

Deck Overlay

- 60% increase in the moment and shear capacity

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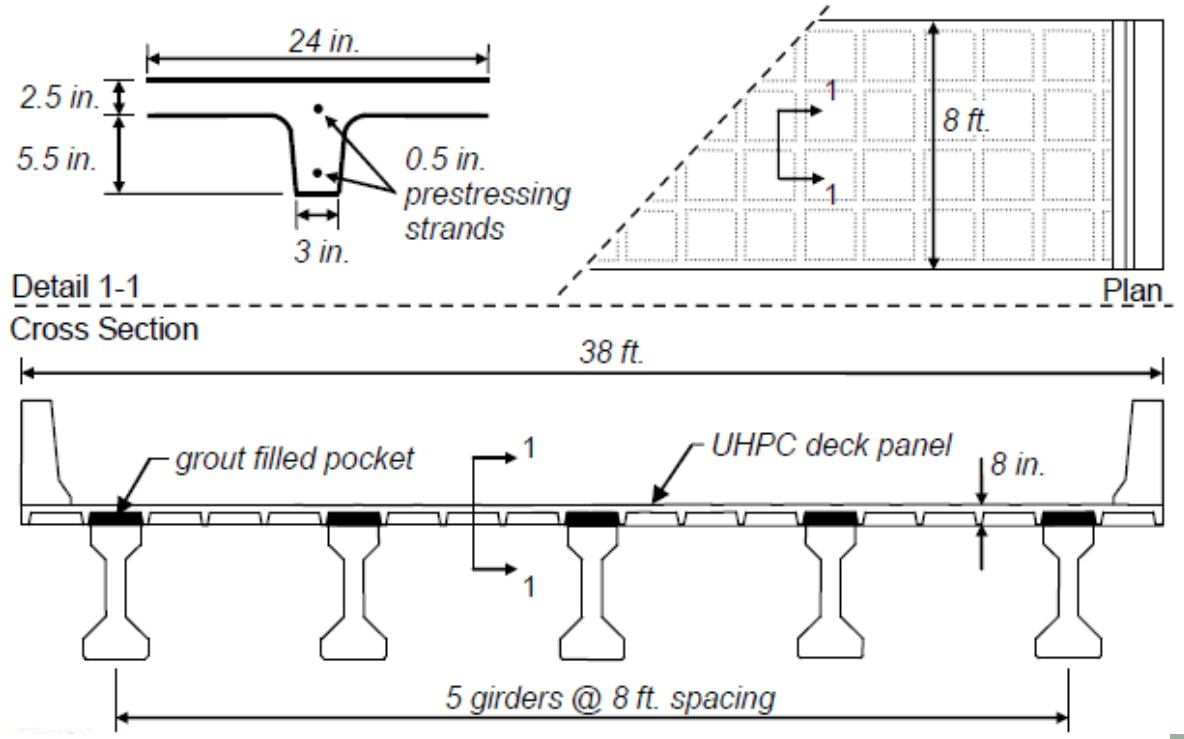
Source: Ductal® Repair/Retrofit Solutions

Precast waffle deck bridge panels



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Source: FHWA UHPC for PBE Connections

Questions?

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