Behavior of UHPC Connections Between Precast Bridge Deck Elements

A Joint NYSDOT-FHWA-IowaDOT Research Effort — TPF-5(217)

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What is Ultra-High Performance Concrete?

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

Cementitious Powder
Fine Filler Materials
Steel Fibers
Superplasticizer
Water
UHPC Properties: Some Ballpark Values

- Compressive Strength – 18 to 35 ksi
- Modulus of Elasticity – 6200 to 8000 ksi
- Creep Coefficient – 0.3 to 0.8
- Sustained Tensile Capacity – 0.9 to 1.5 ksi or more
- Rapid Chloride Permeability – 20 to 350 Coulombs
- Freeze/Thaw Resistance – RDM > 95%
Important Points

- Fiber-reinforced cementitious composite
- Strength is impressive
  ...durability is extraordinary.
- Cost (by volume) is high
  - Consider optimized use
  - Consider life-cycle costs
  - Increased familiarity and competition will help
TURNER-FAIRBANK HIGHWAY RESEARCH CENTER

UHPC Solutions
π-Girder

- Modular Decked Bridge Component for:
  - Rapid Construction
  - Reduced Structure Weight
  - Long-term Durability
π-Girder

- Fabrication, Testing, Deployment Complete
- 33 inch deep section spans 87 feet
- Family of girders under development
π-Girder Research Reports Available

- Structural Behavior of a Prototype UHPC Pi-Girder
  - National Technical Information Service Report # PB2009-115495

- Structural Behavior of a 2\textsuperscript{nd} Generation UHPC Pi-Girder
  - National Technical Information Service Report # PB2009-115496
UHPC Waffle Slab

Detail 1-1
Cross Section

- 2.5 in.
- 5.5 in.
- 3 in.
- 0.5 in. prestressing strands

Plan

- 24 in.
- 8 ft.
- 8 in.
- 2.5 in.
- 5.5 in.

Plan

- 38 ft.

- 5 girders @ 8 ft. spacing

- UHPC deck panel

- Grout filled pocket
UHPC Waffle Slab Bridge Deck

Bridge over Little Cedar Creek
Wapello County, Iowa

Prestressed I-girders
Precast UHPC Waffle Slabs
Field-Cast UHPC Joints b/t Modular Components

Construction during 2010

Panel Fabrication at Coreslab Structures, Omaha Nebraska

Test Panels Currently Under Test at Iowa State Univ.

Test Panel Photo Courtesy of Iowa State University
Mars Hill Bridge
Wapello County, Iowa

Jakway Bridge
Buchanan County, Iowa

Cat Point Creek Bridge
Richmond County, Virginia

U.S. UHPC Highway Bridges
Cat Point Creek Bridge
Rt. 624 over Cat Point
Richmond County, Virginia
Cat Point Creek Bridge

Virginia 45” Bulb Tee
Statement of Problem

- Prefabricated components can:
  - Accelerate construction
  - Increase quality and safety
  - Enhance Durability
- But…
  Prefabricated components require connections.
- Connections tend to be:
  - Difficult to Construct
  - Expensive
  - Less Durable
Solution: Rethink the Connection

• Goals:
  – Simplify construction
  – Minimize expense
  – Increase mechanical strength
  – Increase durability

• What we need:
  – Strong, Durable Material
  – Good Bond to Concrete
  – Good Bond to Rebar

Greater Than Prefab!
Concept: UHPC Connection

• Use rebar splice connection as the starting point
• UHPC mechanical properties allow:
  – Reduced width through shortened development length
  – Reduced cracking through higher strengths
  – Reduced interface cracking through good cementitious bond
• UHPC durability properties allow:
  – Greatly reduced permeability and enhanced longevity

Simple, field-cast splice connection between precast concrete components
Field-Cast UHPC Properties

- Compressive Strength → 18 to 25 ksi
- Modulus of Elasticity → 6200 to 6500 ksi
- Creep Coefficient → 0.8
- Sustained Tensile Capacity → 0.9 ksi or more
- Rapid Chloride Permeability → 350 Coulombs
- Freeze/Thaw Resistance → RDM > 100%

Source: FHWA Report FHWA-HRT-06-103
Material Property Characterization of Ultra-High Performance Concrete
UHPC Modular Connections

SR 31 over Canandaigua Outlet
Lyons, New York

SR 23 over Otego Creek
Oneonta, New York
Field-Cast Connections for Modular Components
UHPC Joint Testing Project

- NYSDOT
  - Already deploying UHPC closure pours
  - Supplied test specimens

- FHWA-TFHRC
  - Significant experience w/ UHPC R&D
  - Provided majority of funding

- Iowa DOT
  - Provided supplemental funding

Transportation Pooled Fund Program
UHPC Joint Testing Project

- 6 specimens fabricated
  - Four 8” decks and Two 6.3” decks
- Fabrication Process:
  - Precast Panels
  - Sandblast Interface
  - Field-Cast UHPC
- Testing ongoing for 9 months
  - Cyclic testing below static cracking
  - Cyclic testing above static cracking
  - Static loading to flexural failure
UHPC Joint Testing

Simulating Deck Panel Cxn

Simulating DBTee Cxn

84.7"  6'-0"

7'-0"

8"

6.3"
UHPC Joint Testing

- Joint Designs Investigated
  - Hairpins, headed bars, and straight bars
  - Epoxy coated, galvanized, and black bars
- Load Levels
  - Uncracked cycling  Does interface debond?
  - Cracked cycling  Interface debond?  Rebar debond?
## UHPC Transverse Joint Testing

<table>
<thead>
<tr>
<th>Panel</th>
<th>Peak Cyclic Load</th>
<th>Rebar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16 kip</td>
<td>21.3 kip</td>
</tr>
<tr>
<td>8E</td>
<td>8.9M</td>
<td>5.2M</td>
</tr>
<tr>
<td>8G</td>
<td>2.1M</td>
<td>5.8M</td>
</tr>
<tr>
<td>8B</td>
<td>2.1M</td>
<td>5.2M</td>
</tr>
<tr>
<td>8H</td>
<td>2.0M</td>
<td>5.1M</td>
</tr>
</tbody>
</table>

- No Interface Debonding
- No Leakage
- Midspan Flexural Cracking at Higher Loads
UHPC Transverse Joint Testing

Precast Panel  
UHPC  
Precast Panel

Wheel Patch Above Here

7’ between Simple Supports

7’ Wide Specimen

Panel 8G – After 5.8 Million Cycles to 21.3 kips
UHPC Transverse Joint Testing

Precast Panel

UHPC

Precast Panel

0.005” (0.13 mm) crack

0.003” (0.08 mm) crack

0.001” (0.03 mm)

UHPC structural cracks tend to measure approximately 0.0002” (0.005 mm)

Panel 8G – After 5.8 Million Cycles to 21.3 kips
### UHPC Longitudinal Joint Testing

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<td></td>
<td>16 kip</td>
<td>21.3 kip</td>
</tr>
<tr>
<td>6H</td>
<td>2.0M</td>
<td>7.0M</td>
</tr>
<tr>
<td>6B</td>
<td>0.06M *</td>
<td>5.5M+</td>
</tr>
</tbody>
</table>

- Overload to 70 kip…major cracking

- No Leakage
- 6H: No interface debond
- 6B: No rebar debond
UHPC Longitudinal Joint Testing

Panel 6H – After 7.0 Million Cycles to 21.3 kips

Wheel Patch Above Here

Precast Panel

6’ Span

8’ Wide

Precast Panel

UHPC
UHPC Longitudinal Joint Testing

Panel 6H – After 7.0 Million Cycles to 21.3 kips
UHPC Longitudinal Joint Testing

Panel 6B – After 70 kip Overload and 5.5 Million Cycles to 21.3 kips

Crack Map
- Precast Panel
- UHPC
- Interface

No interface crack widening over 5.5+ million cycles
UHPC Joint Testing

- Remainder of Project
  - Complete cyclic testing
  - Load panels to failure (monotonic increasing loads)
  - Autopsy of panels
- Experimental work complete by May 2010
- Report complete by June 30, 2010
UHPC Joint Testing

- Important Observations to Date
  - Good interface bond performance between HPC and UHPC
  - Perpendicular cracks do not turn and run along interface
  - HPC cracks intersecting UHPC become many tight UHPC cracks
  - Overload + cyclic loading has not debonded rebar in joint

- Bottom Line: *UHPC connections have performed very well.*
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