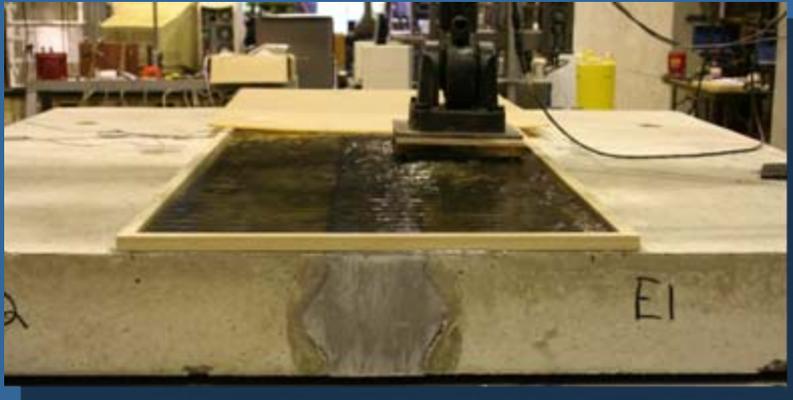




# Behavior of UHPC Connections Between Precast Bridge Deck Elements

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



PI: Benjamin A. Graybeal, Ph.D., P.E.  
Research Structural Engineer  
Federal Highway Administration  
202-493-3122  
[bgraybeal@dot.gov](mailto:bgraybeal@dot.gov)





# 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

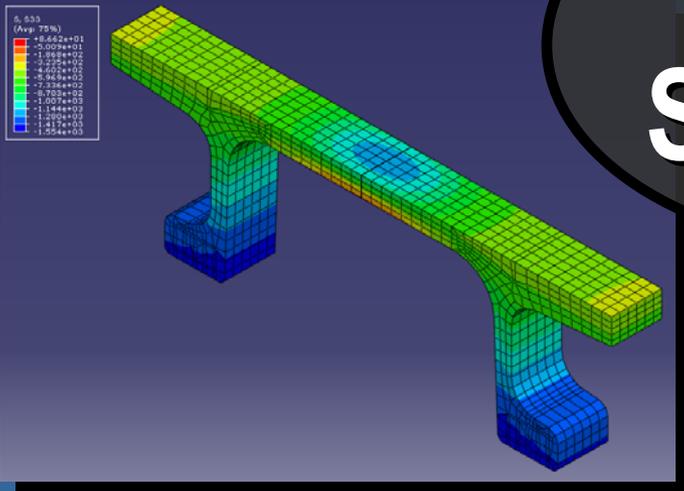
- **Fiber-reinforced cementitious composite**
- **Strength is impressive**  
    ...durability is extraordinary.
- **Cost (by volume) is high**
  - Consider optimized use
  - Consider life-cycle costs
  - Increased familiarity and competition will help



# TURNER-FAIRBANK HIGHWAY RESEARCH CENTER



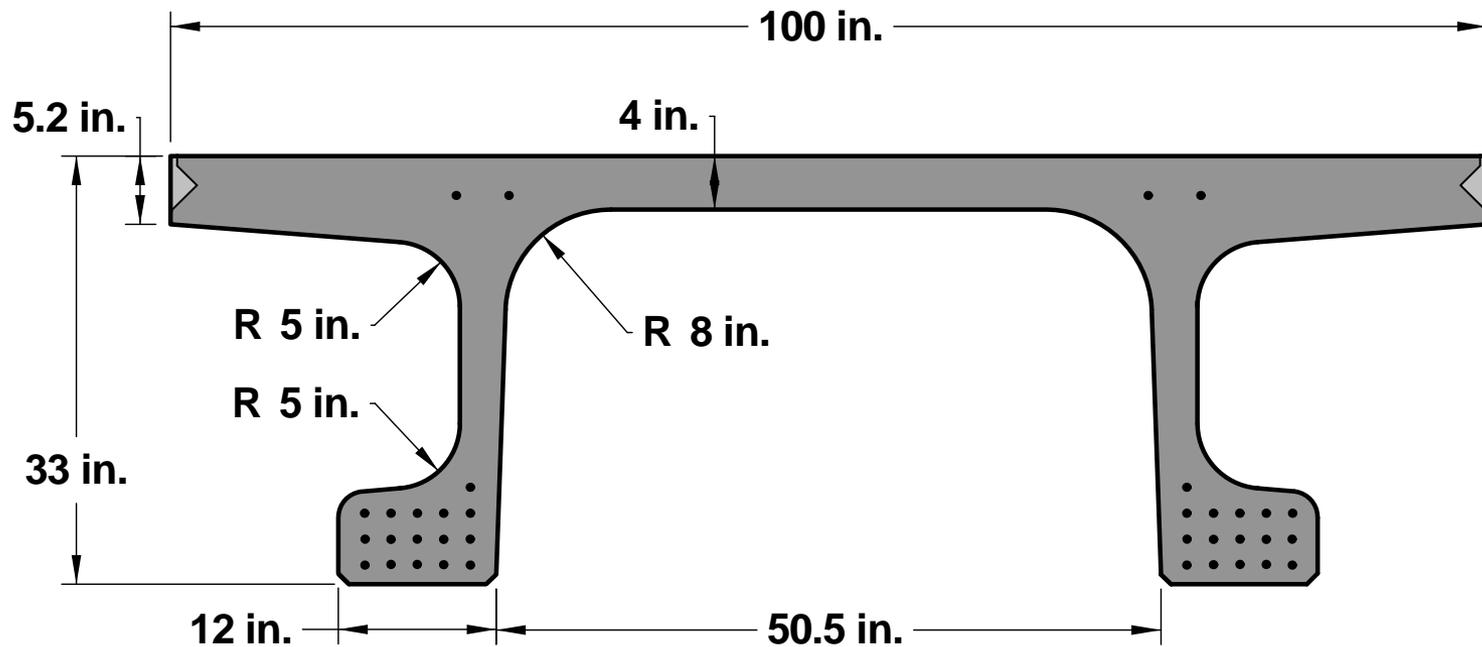
## UHPC Solutions





# $\pi$ -Girder

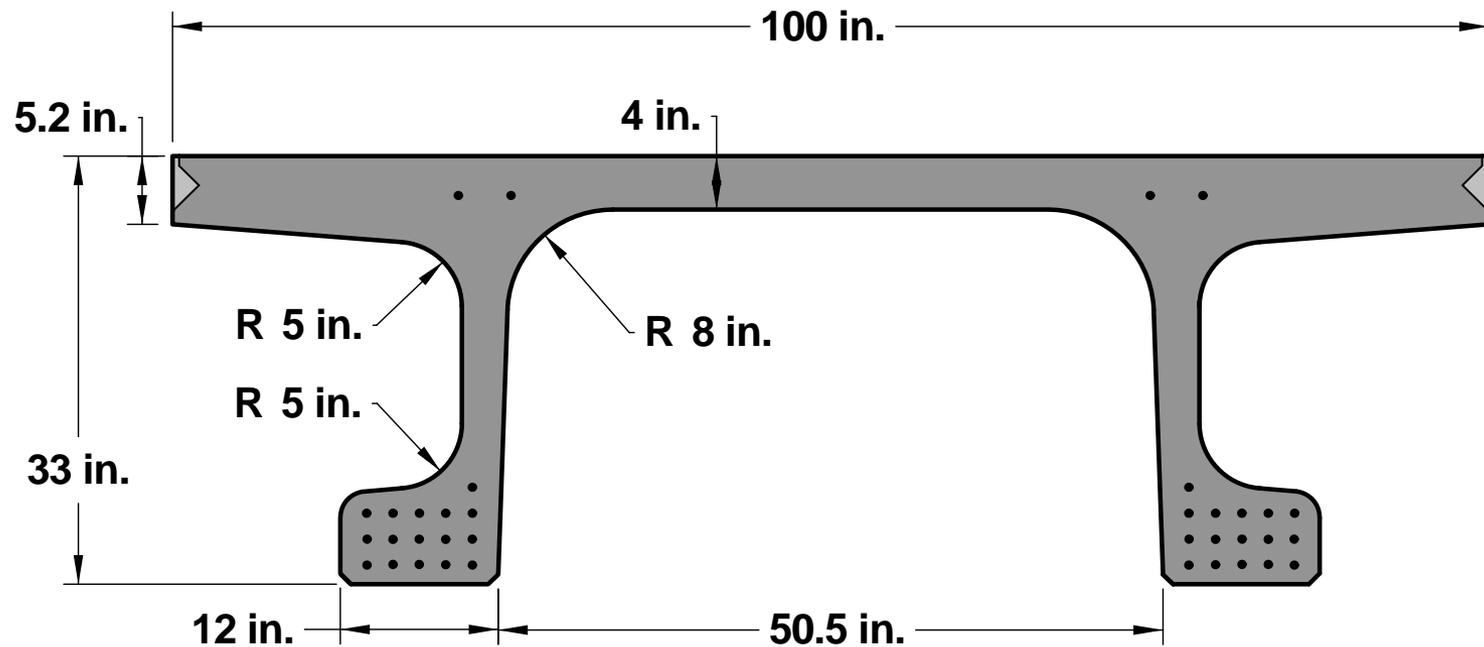
- Modular Decked Bridge Component for:
  - Rapid Construction
  - Reduced Structure Weight
  - Long-term Durability





# $\pi$ -Girder

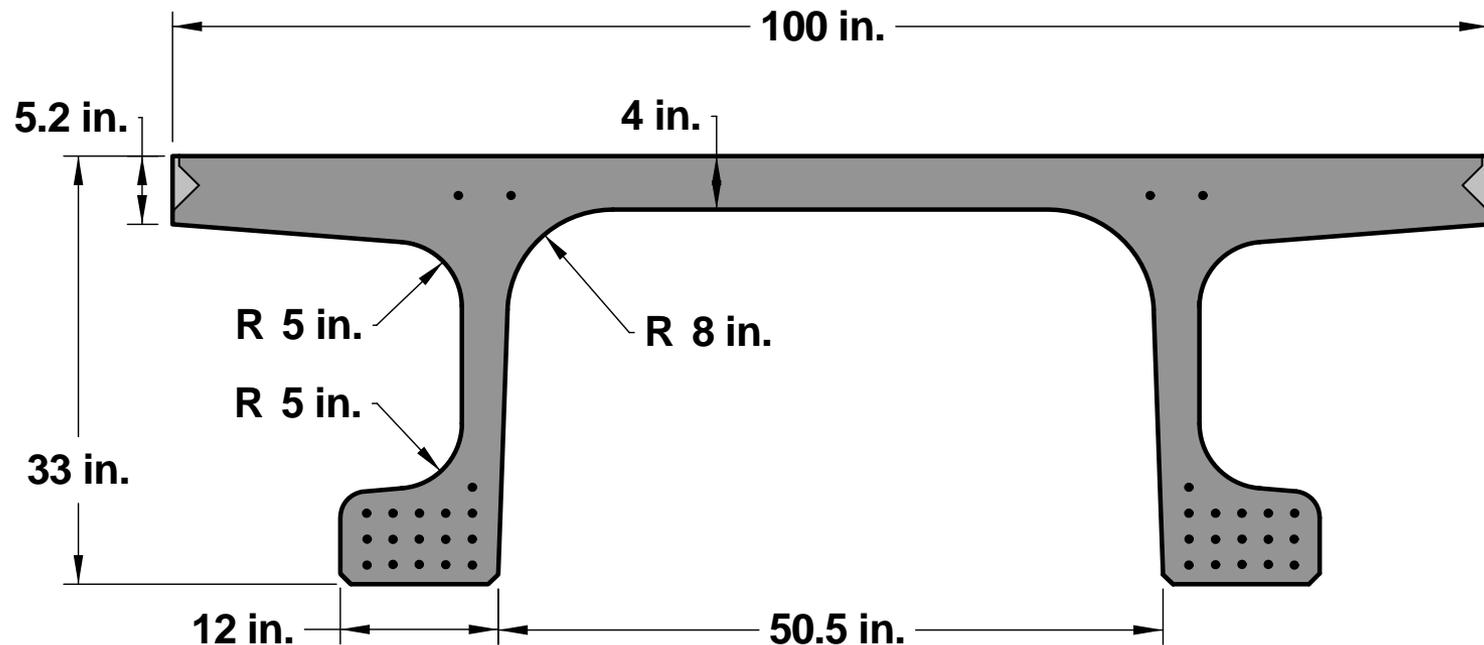
- Fabrication, Testing, Deployment Complete
- 33 inch deep section spans 87 feet
- Family of girders under development



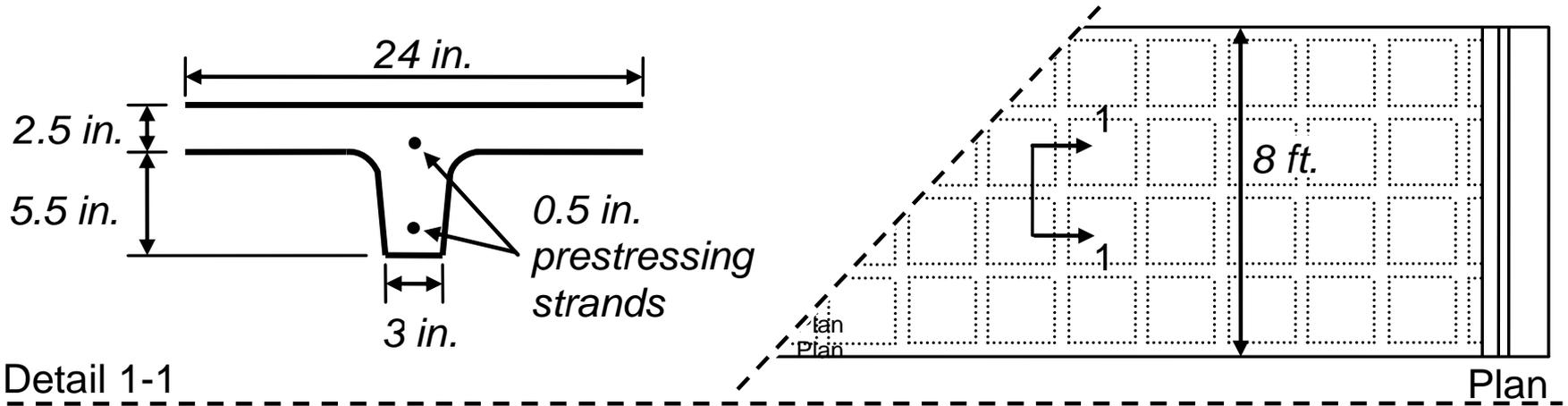


# $\pi$ -Girder Research Reports Available

- Structural Behavior of a Prototype UHPC Pi-Girder
  - National Technical Information Service Report # PB2009-115495
- Structural Behavior of a 2<sup>nd</sup> Generation UHPC Pi-Girder
  - National Technical Information Service Report # PB2009-115496



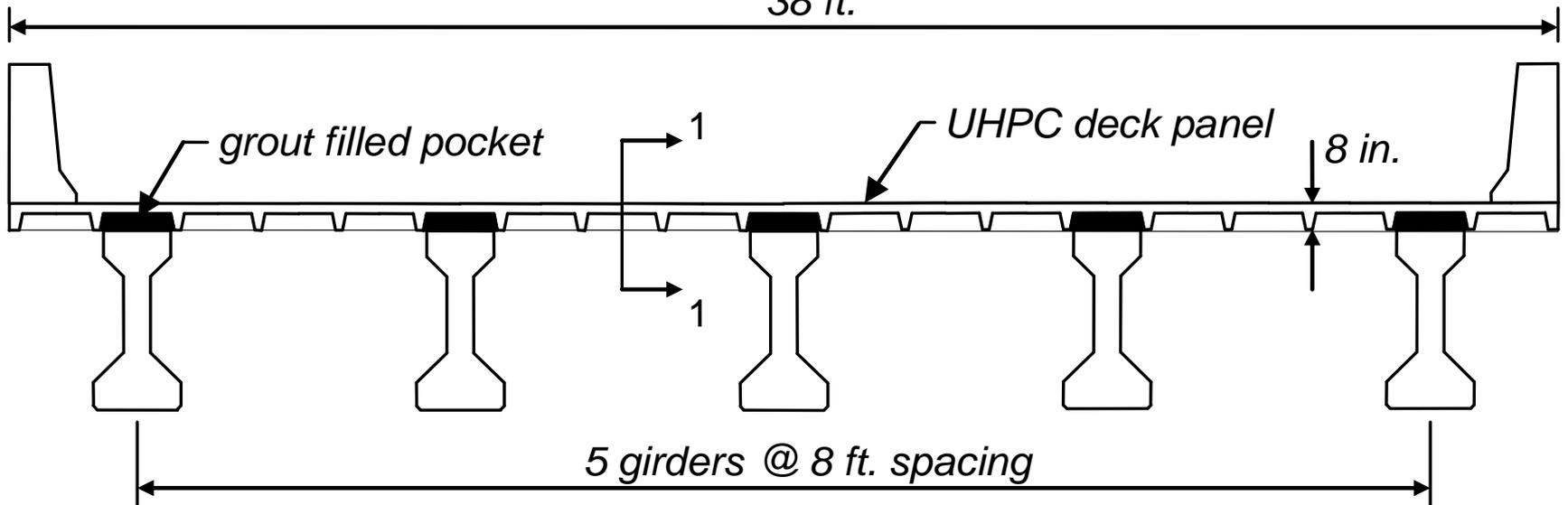
# UHPC Waffle Slab



Detail 1-1

Cross Section

38 ft.



# 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**

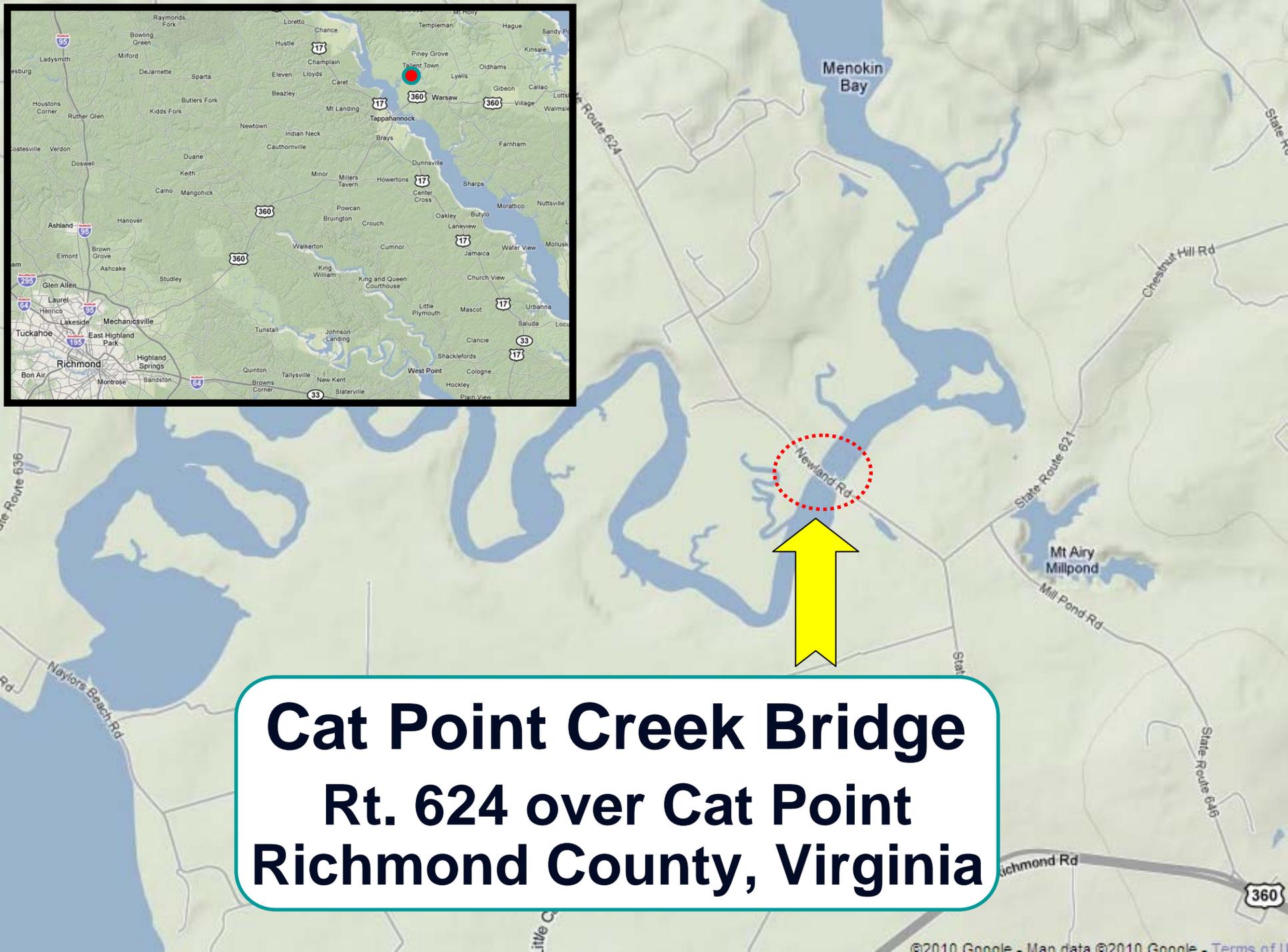
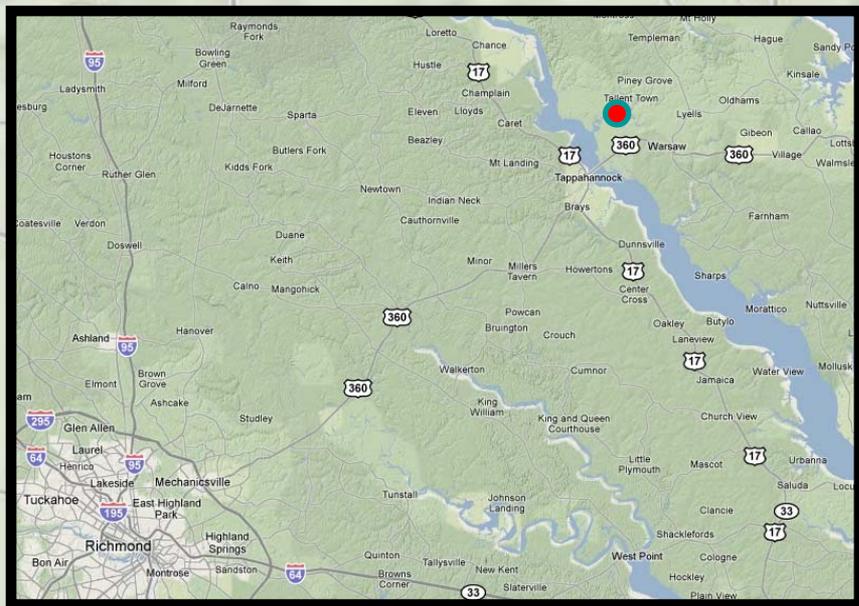


**Jakway Bridge  
Buchanan County, Iowa**

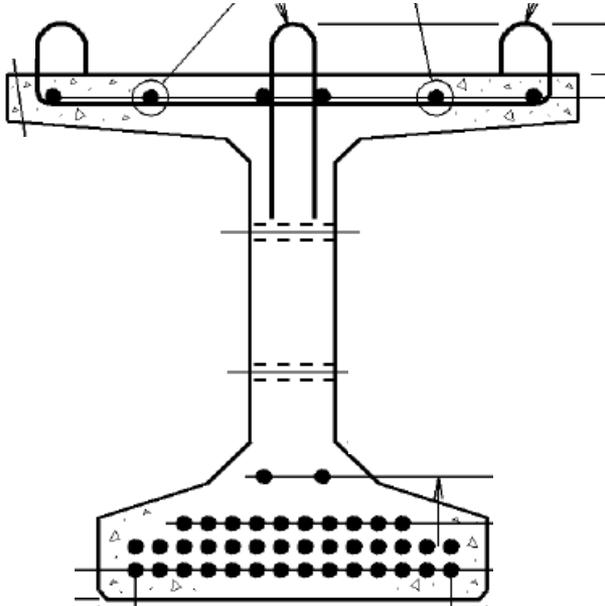
**Cat Point Creek Bridge  
Richmond County, Virginia**



# **U.S. UHPC Highway Bridges**



**Cat Point Creek Bridge  
Rt. 624 over Cat Point  
Richmond County, Virginia**



## Virginia 45" Bulb Tee



Cat Point Creek Bridge





## **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
- } **Greater Than Prefab!**
- **What we need:**
    - Strong, Durable Material
    - Good Bond to Concrete
    - Good Bond to Rebar





## **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***



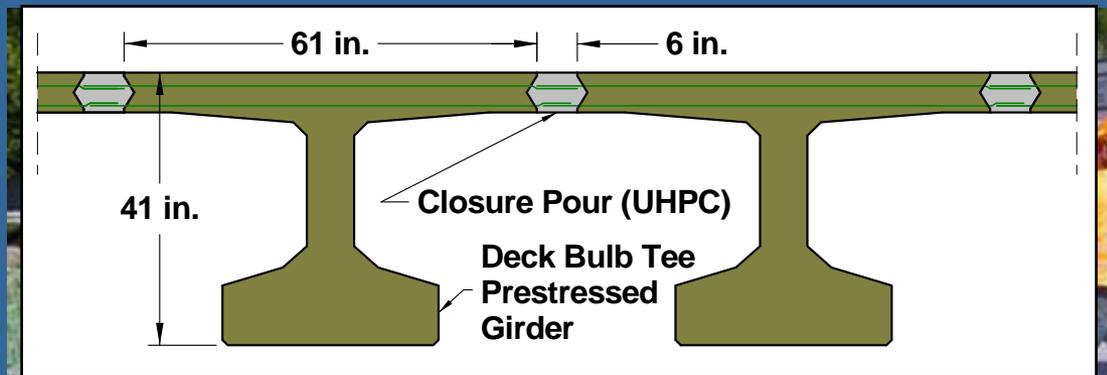


## Field-Cast UHPC Properties

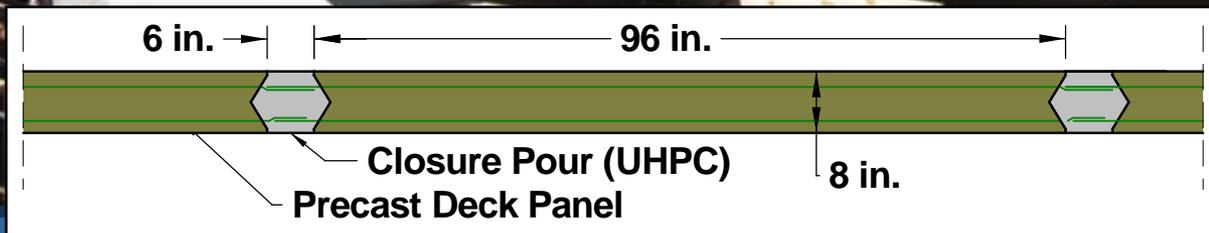
- **Compressive Strength** → 18 to 25 ksi
- **Modulus of Elasticity** → 6200 to 6500 ksi
- **Creep Coefficient** → 0.8
- **Sustained Tensile Capacity** → 0.9 ksi or more
- **Rapid Chloride Permeability** → 350 Coulombs
- **Freeze/Thaw Resistance** → RDM > 100%



# 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





# 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



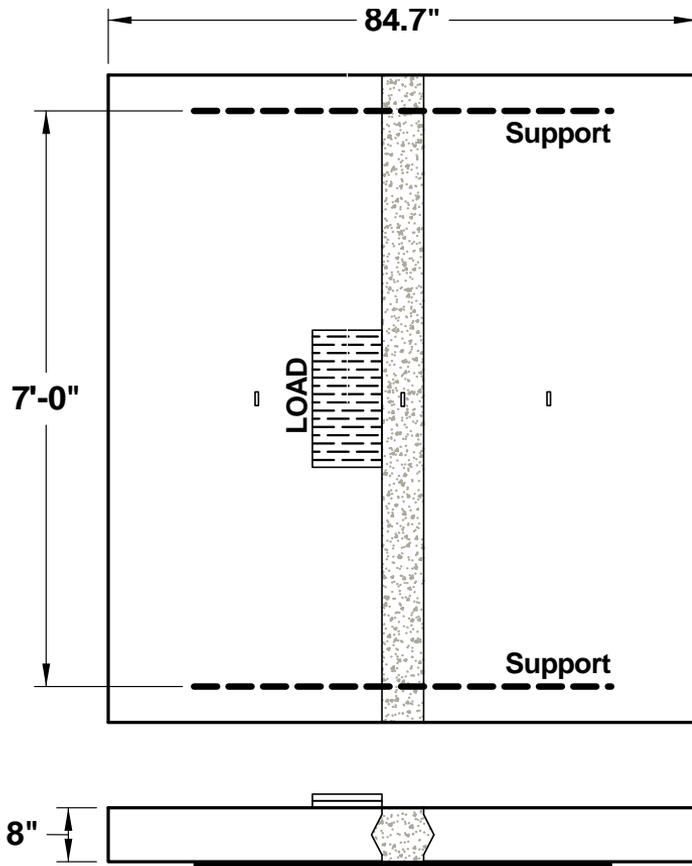
# TURNER-FAIRBANK HIGHWAY RESEARCH CENTER



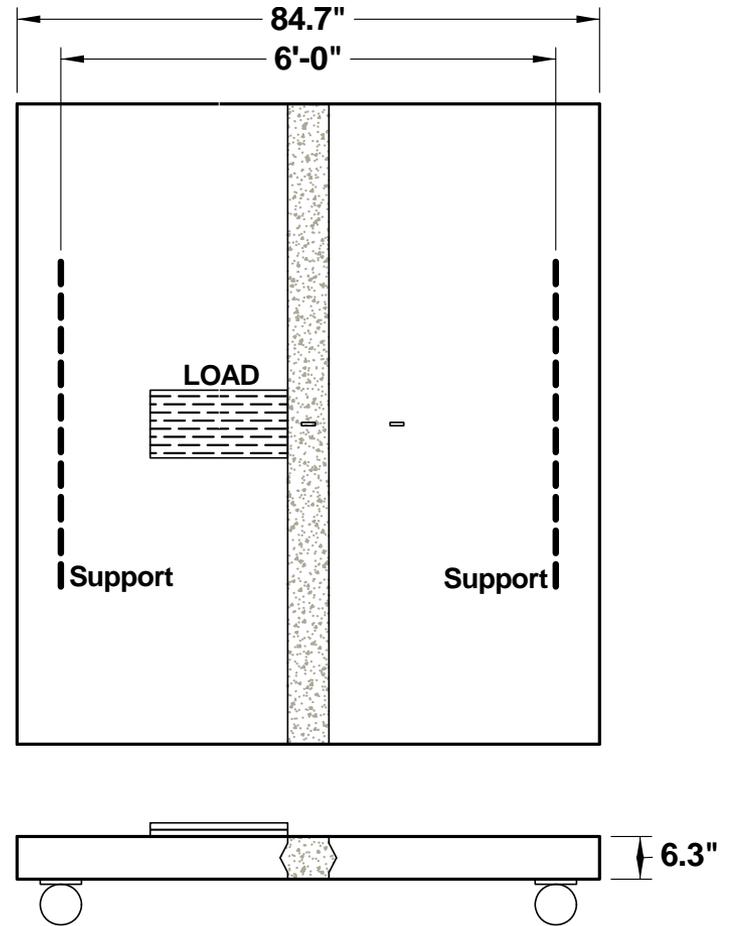


# UHPC Joint Testing

## Simulating Deck Panel Cxn



## Simulating DBTee Cxn





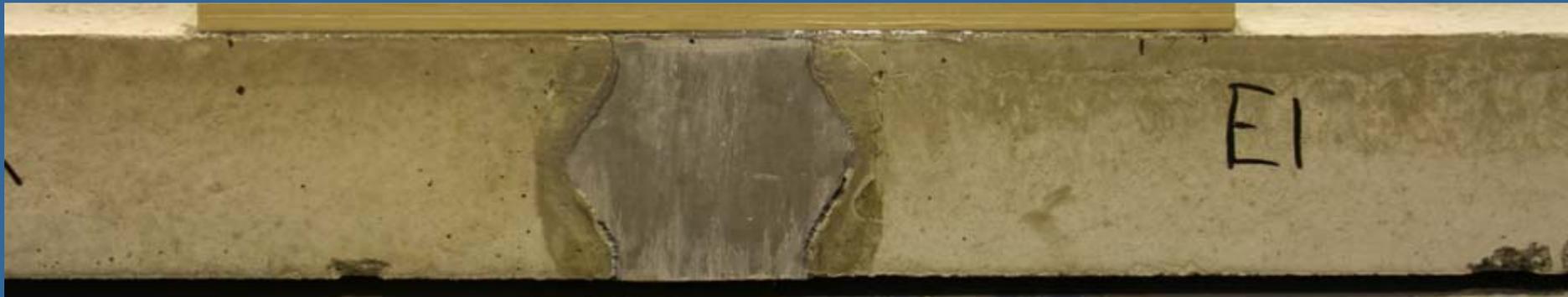
# UHPC Joint Testing

- **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

Panel	Peak Cyclic Load		Rebar
	16 kip	21.3 kip	
8E	8.9M	5.2M	#4 epoxy-coated hairpins
8G	2.1M	5.8M	#5 straight galvanized bars
8B	2.1M	5.2M	#5 straight black bars
8H	2.0M	5.1M	#5 headed black bars



- **No Interface Debonding**
- **No Leakage**
- **Midspan Flexural Cracking at Higher Loads**

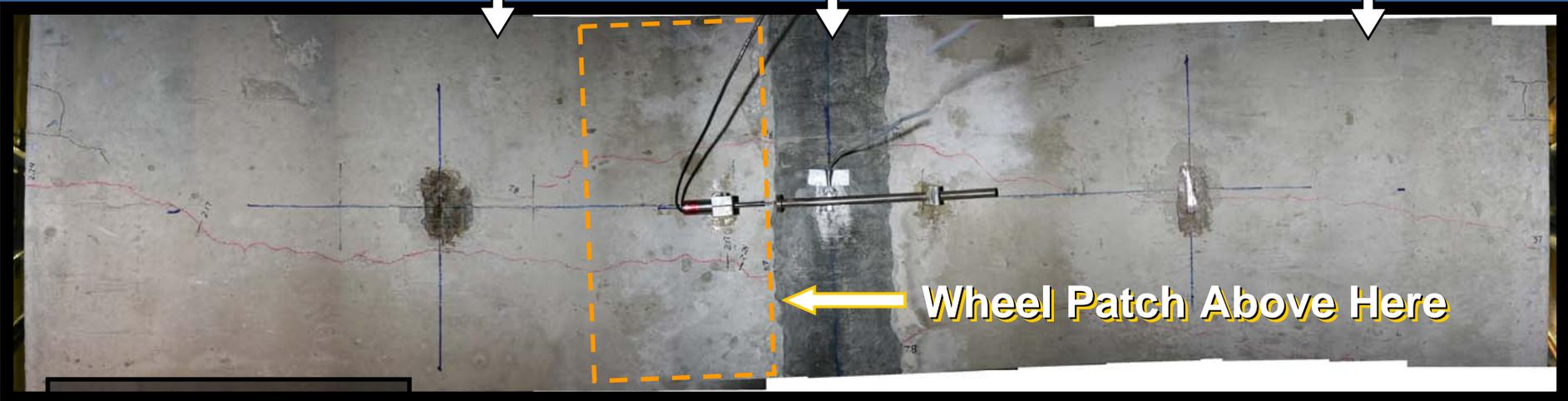


# UHPC Transverse Joint Testing

Precast Panel

UHPC

Precast Panel



Wheel Patch Above Here

7' between Simple Supports

7' Wide Specimen

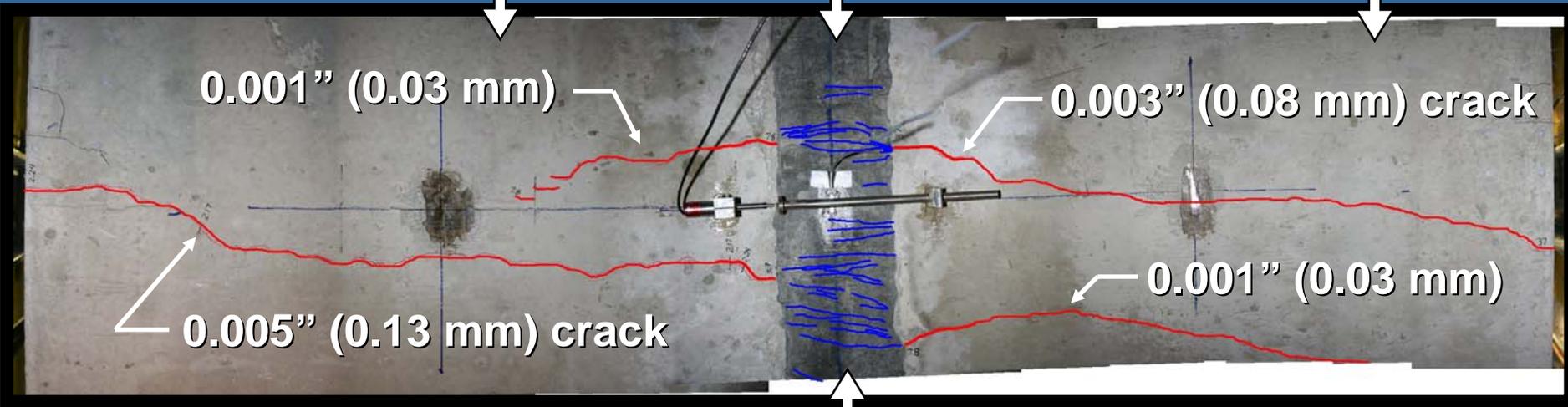


# UHPC Transverse Joint Testing

Precast Panel

UHPC

Precast Panel



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

Panel	Peak Cyclic Load		Rebar
	16 kip	21.3 kip	
6H	2.0M	7.0M	#5 headed black bars
6B	0.06M *	5.5M+	#5 straight black bars

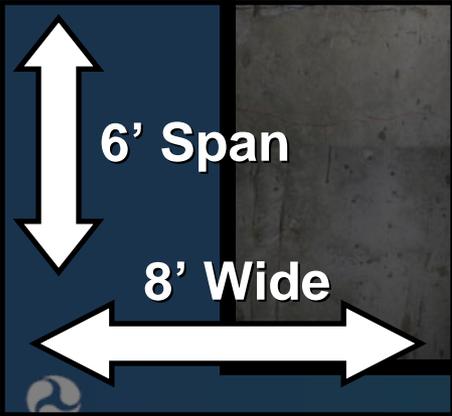
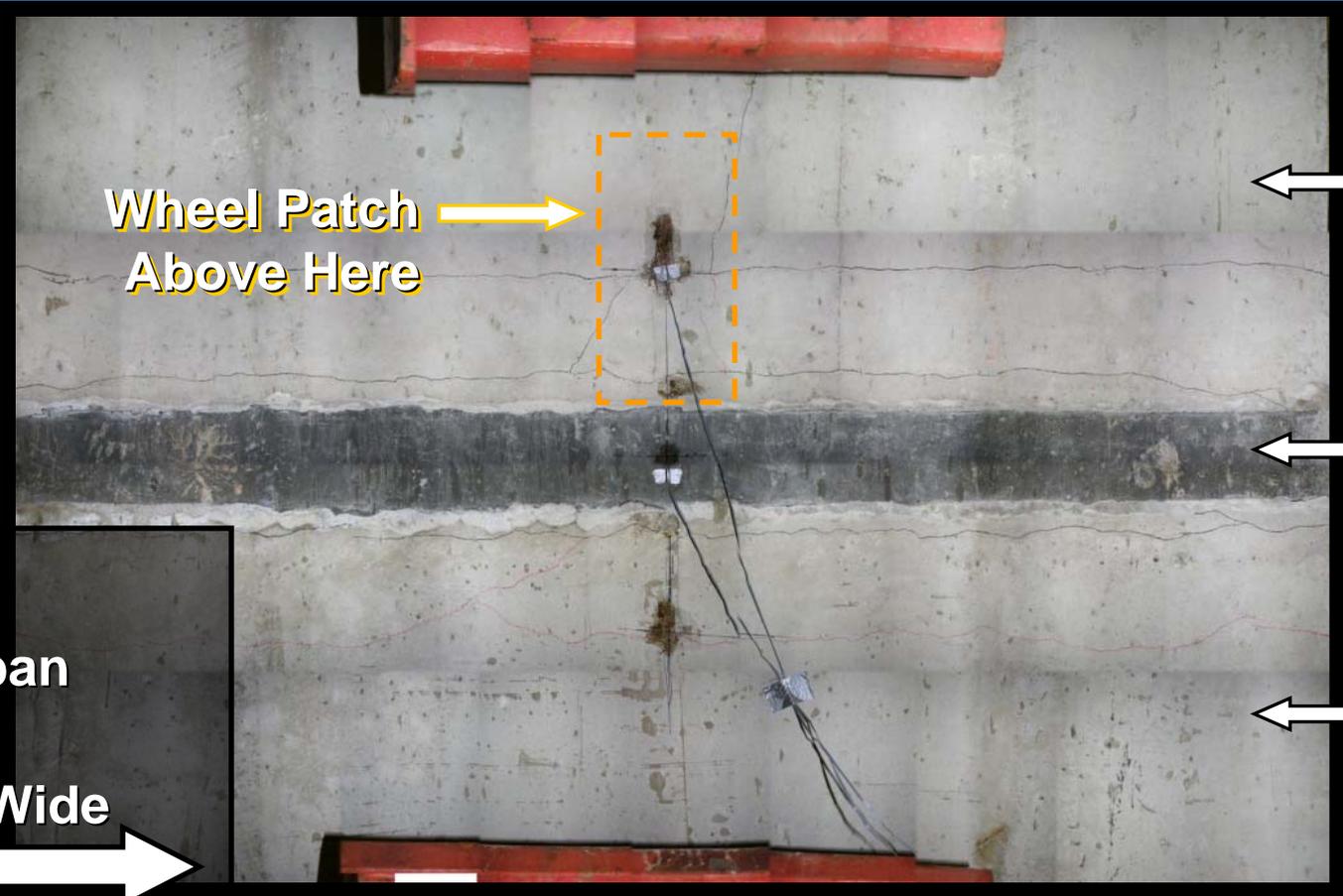

**Overload to 70 kip...major cracking**



- No Leakage
- 6H: No interface debond
- 6B: No rebar debond



# UHPC Longitudinal Joint Testing



Precast Panel

UHPC

Precast Panel

Panel 6H – After 7.0 Million Cycles to 21.3 kips



# UHPC Longitudinal Joint Testing

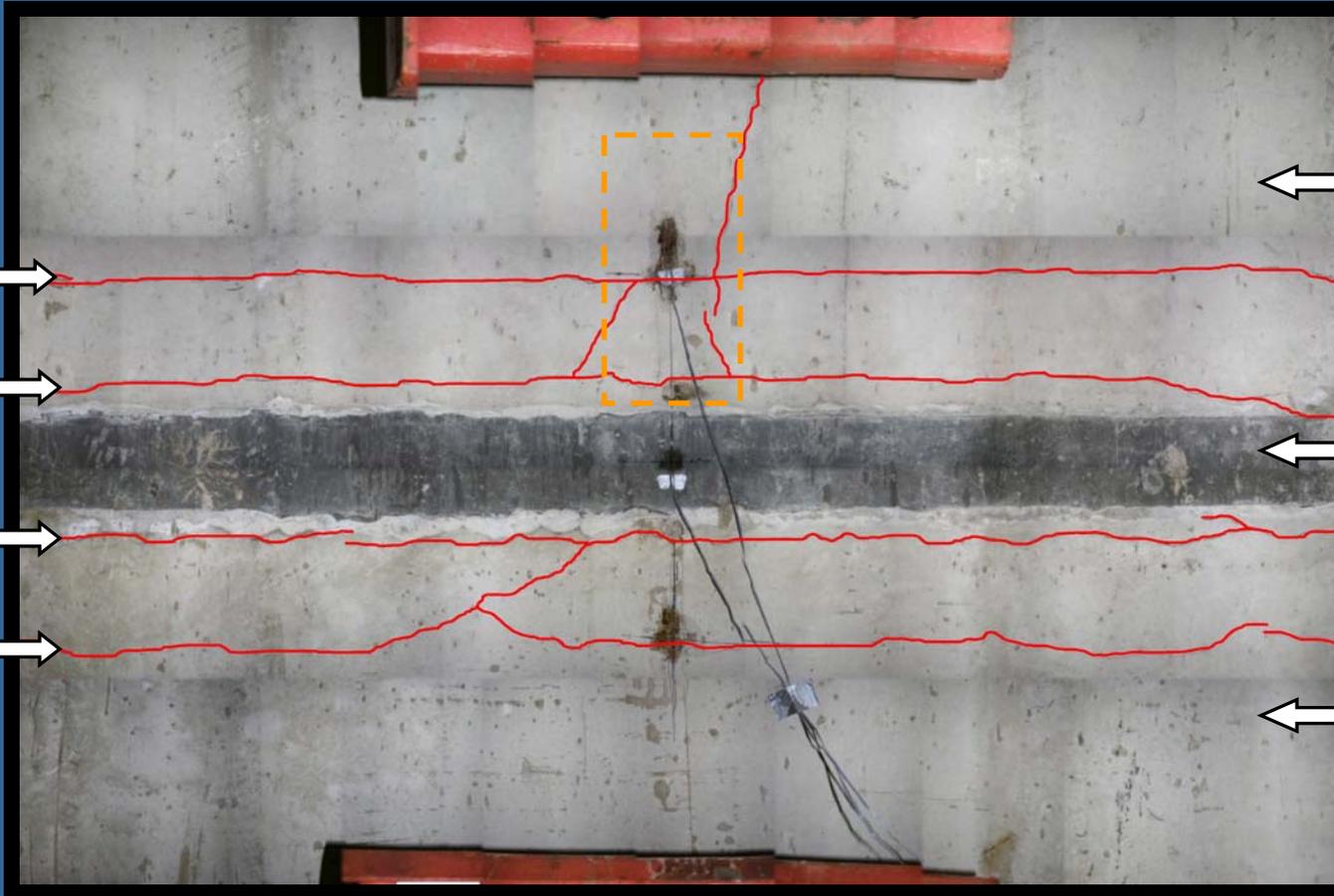
Ave.  
Crack  
Widths

0.006"

0.004"

0.005"

0.004"



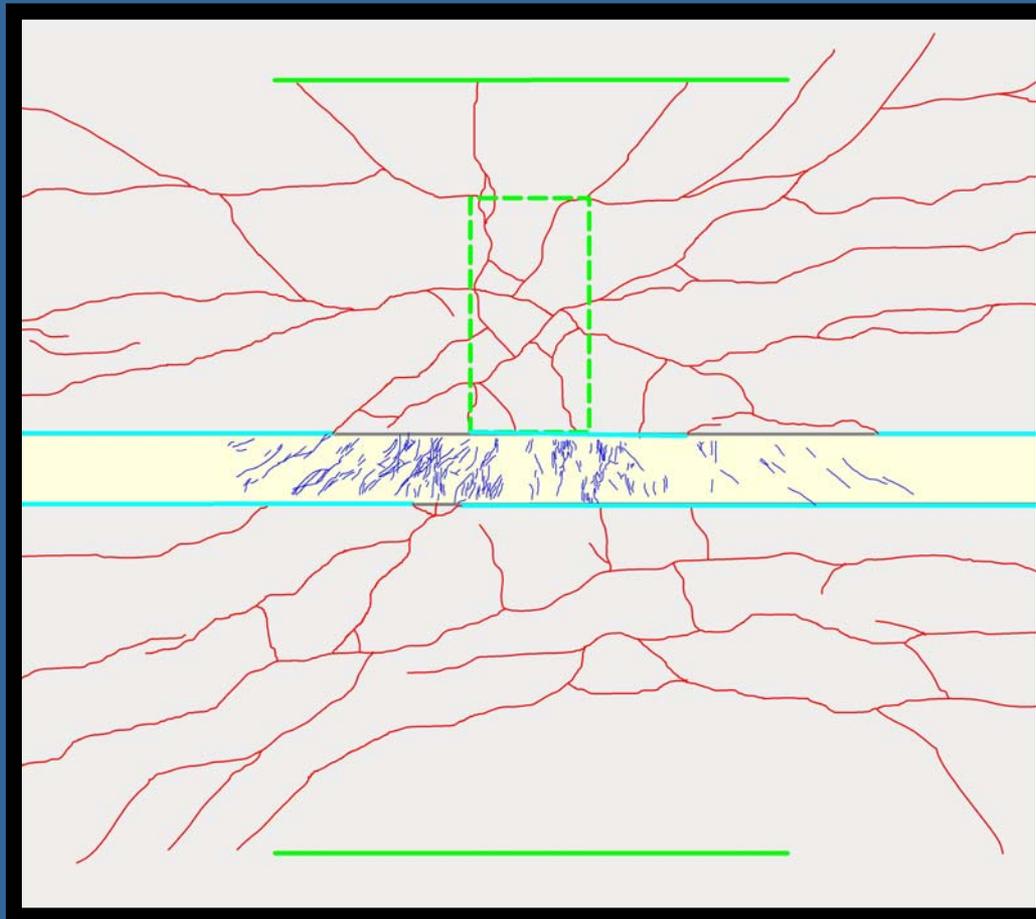
← Precast  
Panel

← UHPC

← Precast  
Panel



# UHPC Longitudinal Joint Testing



## Crack Map

- Precast Panel
- UHPC
- Interface

*No interface crack widening over 5.5+ million cycles*

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





## 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

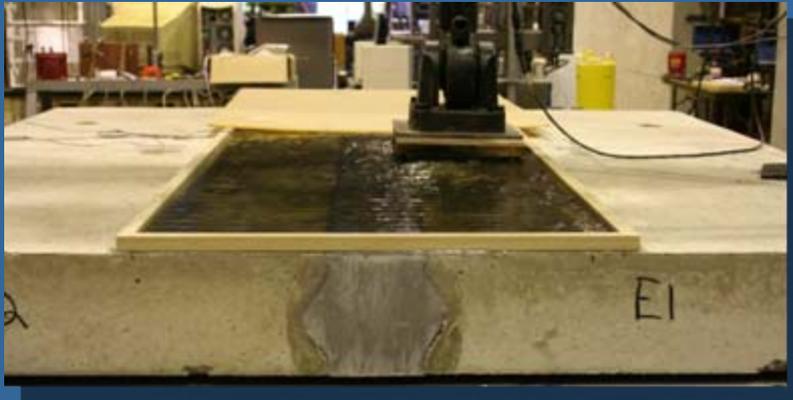
- **Important Observations to Date**
  - Good interface bond performance between HPC and UHPC
  - Perpendicular cracks do not turn and run along interface
  - HPC cracks intersecting UHPC become many tight UHPC cracks
  - Overload + cyclic loading has not debonded rebar in joint
- **Bottom Line:** *UHPC connections have performed very well.*





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