Industrial Advisory Board (IAB) Meeting

May 26, 2021

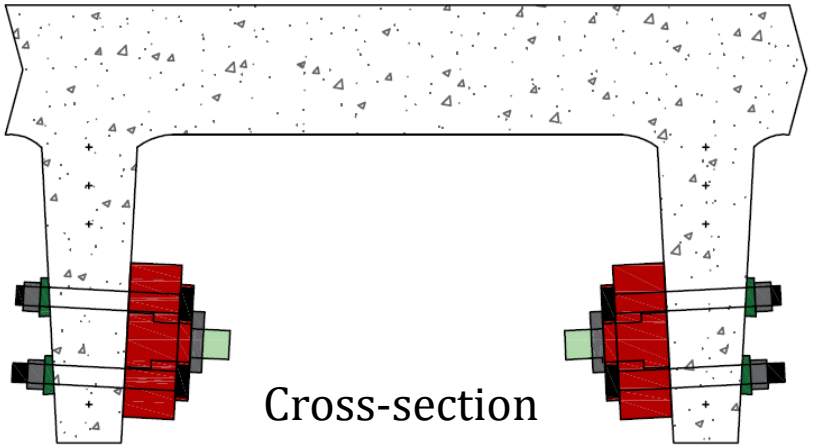
CICI-14
Prestressed MF-FRP Repair of Deteriorated PC Bridge Beams

Sheng-Hsuan (Mike) Lin - PhD Candidate

Project Goals and Objectives

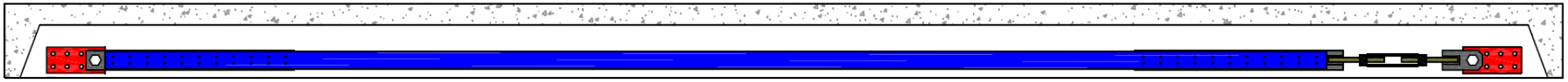
- Design a flexural strengthening system for PC beams using prestressed MF-FRP system and understand its long-term behavior.
- Develop procedures to analyze the full behavior and capacity.
- Apply the retrofitted system on in-service bridges and conduct long-term monitoring.
- Quantify the behavior of shear deteriorated C-channel beam.

Introduction



Cross-section

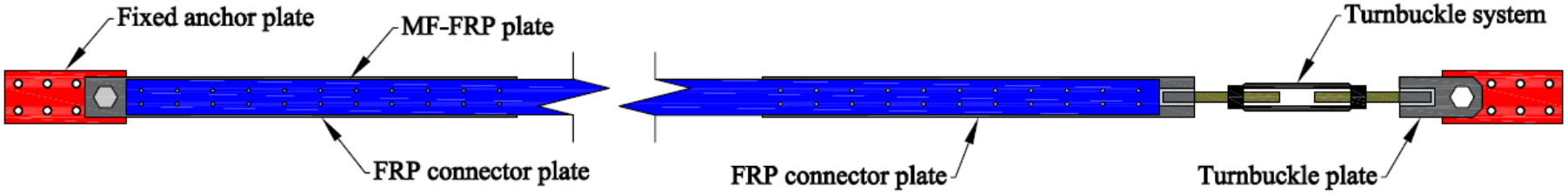
22-bolt pattern with 0.5 in. diameter bolts



Elevation View

Dead-end

Live-end

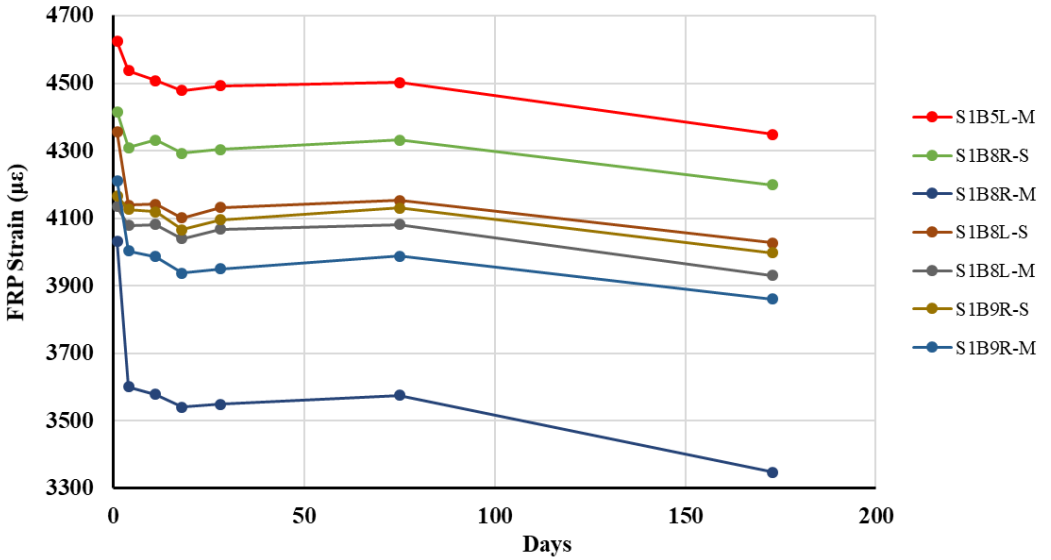


Field Application – Sampson County Bridge

Current Condition

- Repair installed in November 2020.
- After 6 months in service
  - Retrofit remains in good condition

- Built in 1966
- 3-spans, C-channel Beam
- Current status: Open for service
- Load Posting: 16/22



FRP Strain vs In-Service Days

Field Application – Wake County Bridge

- Built in 1967
- 3-spans, C-channel Beam
- Current status: Open
- Load Posting: 5/0

- Plan to repair three stems with loss of bottom prestressing strand.

Shear Deteriorated C-channel Beam

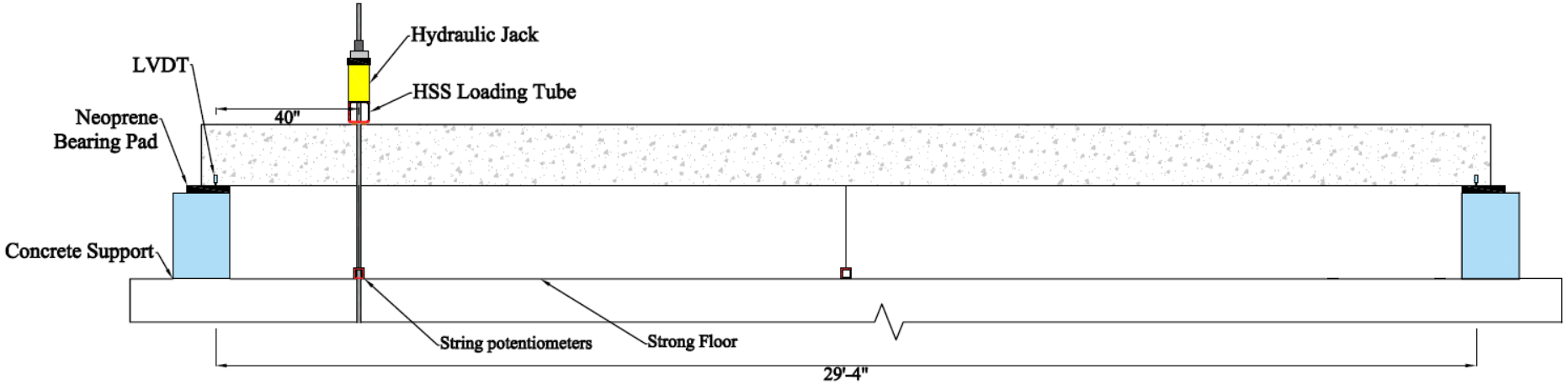
- Concrete spalled
- Prestressing strand corroded
- Shear capacity concern

Different Shear Deterioration and Test Setup

Undamaged

Intermediate Damage

Severe Damage



Failure Mode and Shear Capacity

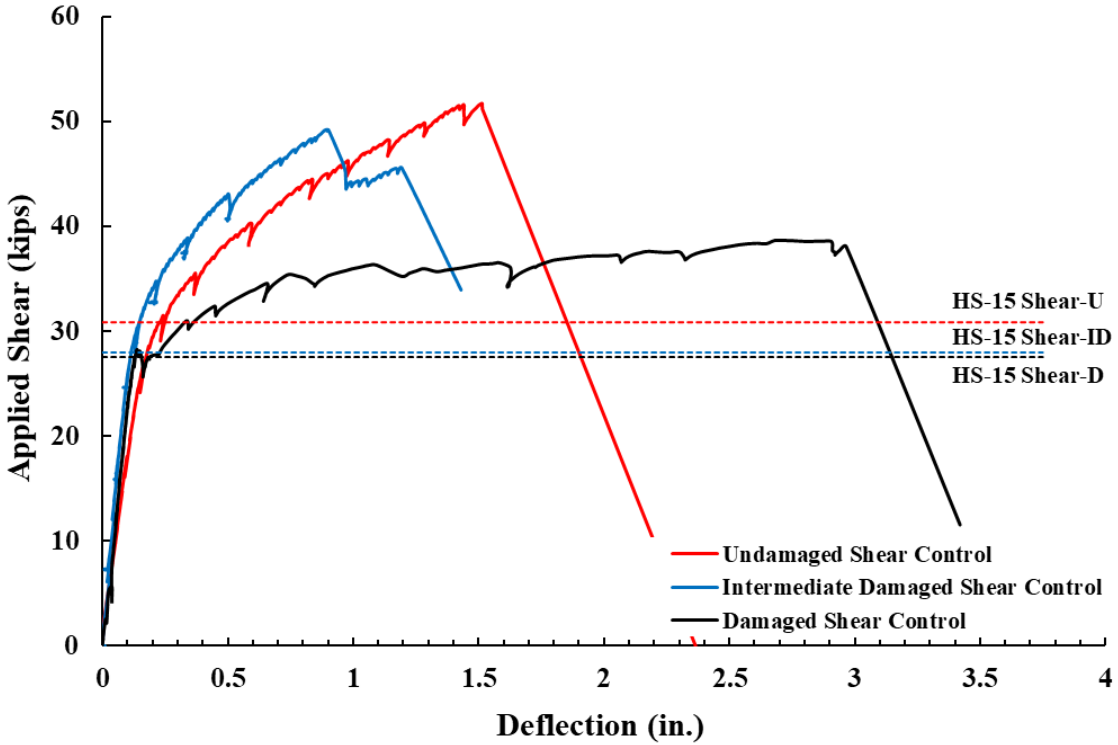
Intermediate Damage: 49.2 kips

Undamaged: 51.8 kips

Severe Damage: 38.7 kips

Experimental Results

Beam No.	Specimen ID	Max. Applied Force (kips)	Measured Disp. at Max. Applied Force (in.)	Total Span (in.)	Shear Span (in.)	Applied Shear Force at Shear Span (kips)	Failure Modes	Predicted Shear Capacity, V_n (kips)	$V_{u,exp,}/V_n$ (%)
1	C-U-S2	57.0	4.72	352	40	50.5	Flexure and Shear	49.2	103
1	C-DS-S1	45.4	2.71	268	40	38.7	Shear	39.8	97
2	C-U-S1	58.4	1.51	352	40	51.8	Shear	49.2	105
2	C-IDS-S1	57.4	0.90	280	40	49.2	Shear	TBD.	TBD.

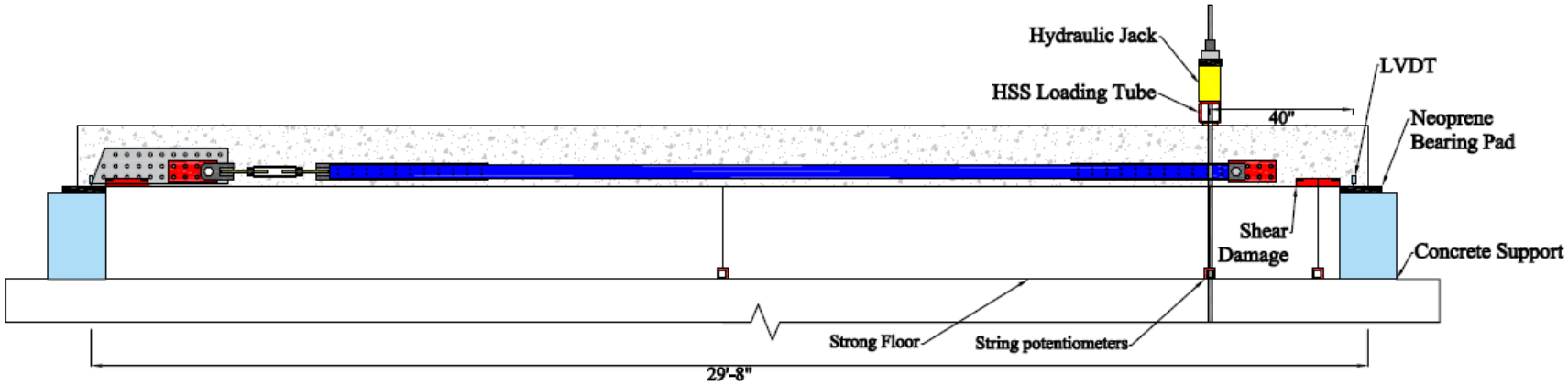


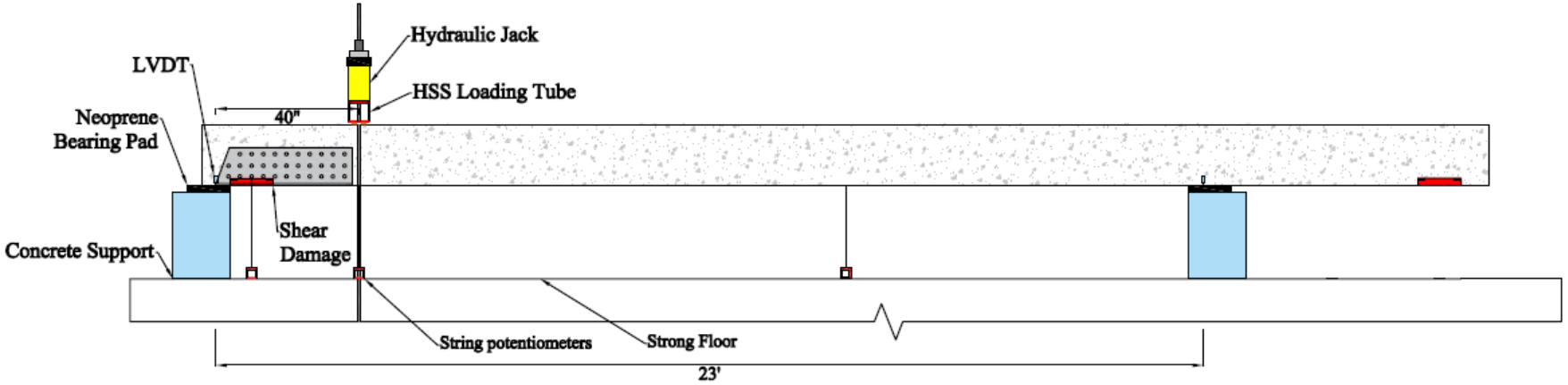
Outcomes

- MF-FRP system remains in good condition on an in-service bridge 6 months after repair allowing the bridge to remain open until the future replacement.
- The prestressed MF-FRP retrofitted system is planned to be installed on third bridge in NC.
- The beam shear capacity has been quantified.

Future work

- Application of MF-FRP system to shear and flexure deteriorated beams.

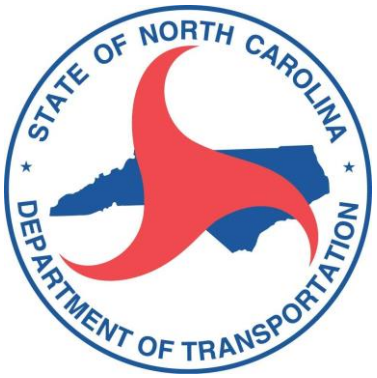




Please Complete the LIFE Form

Project Name: Prestressed MF-FRP Repair of Deteriorated PC Bridge Beams

Project Number: CICI-14



Center for Integration of Composites into Infrastructure

Industrial Advisory Board (IAB) Meeting

May 26, 2021

CICI-15

Design and Repair of Prestressed Concrete Dapped End Beams

Mohammad Qambar – PhD Student

PI: Gregory Lucier

Co-PI: Rudolf Seracino, Giorgio Proestos

Introduction

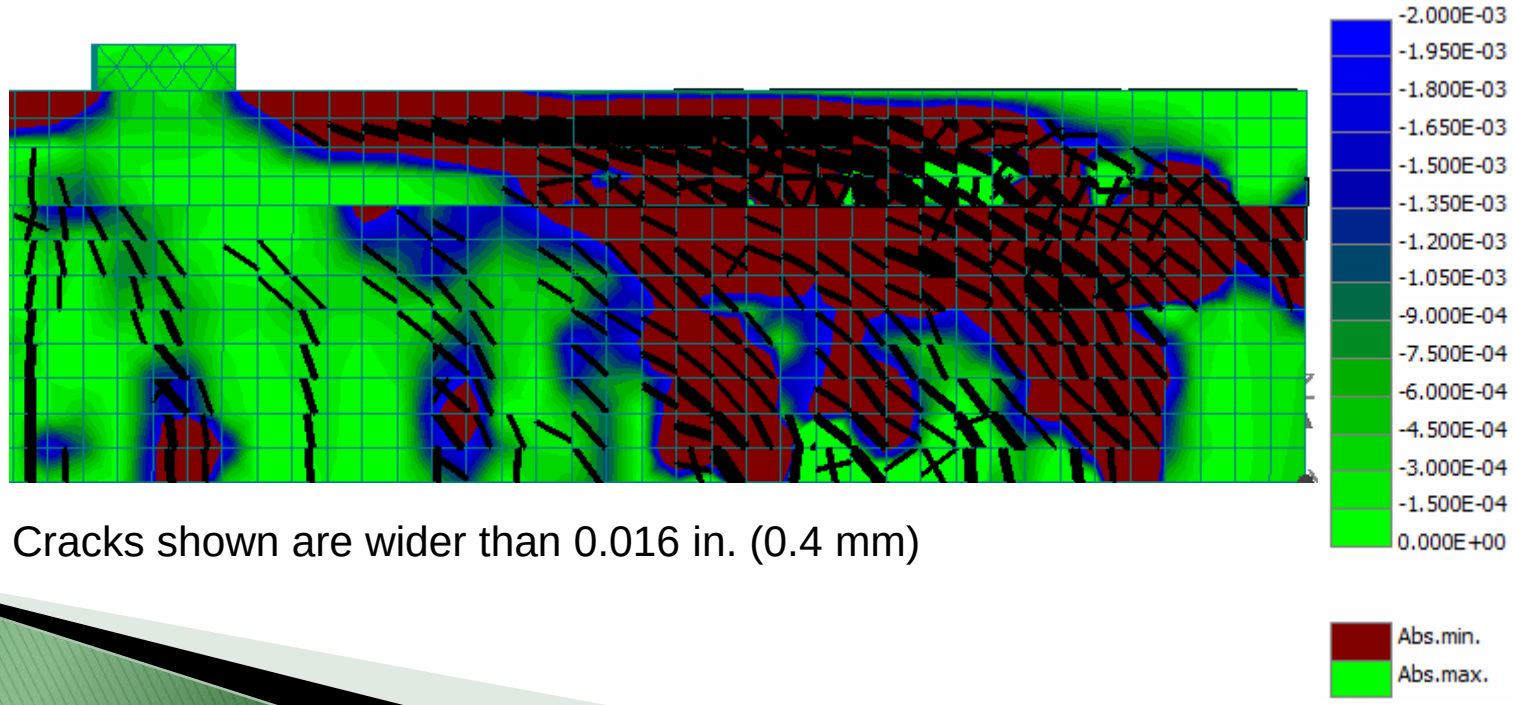
- Dapped ends are a common end condition that allow for a reduced floor thickness, and thus, reduce the floor-to-floor height.
  - Lead to significant economic savings for producers.

Project Goals and Objectives

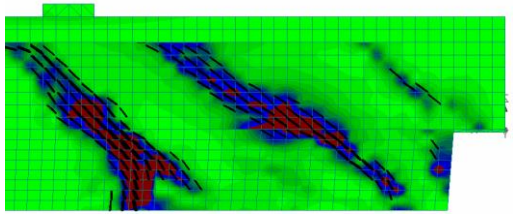
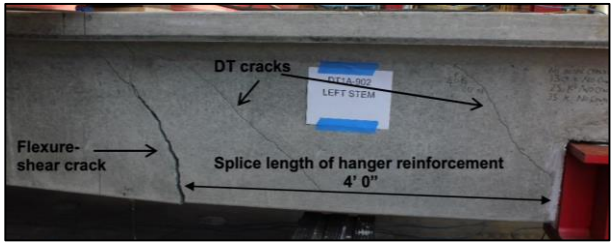
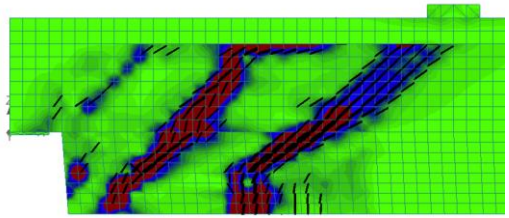
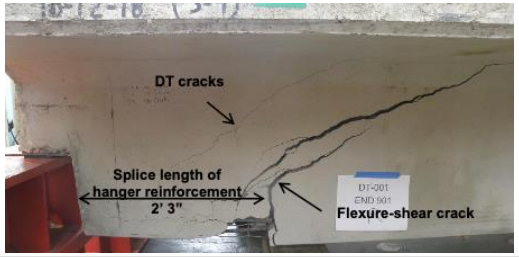
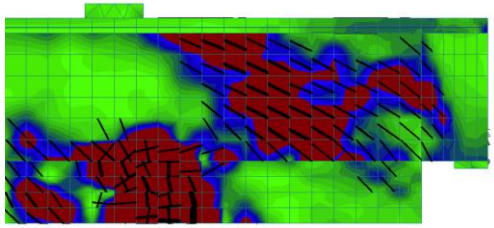
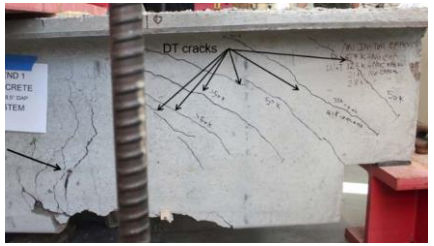
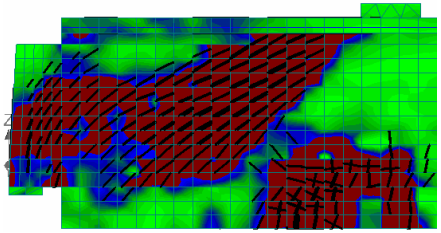
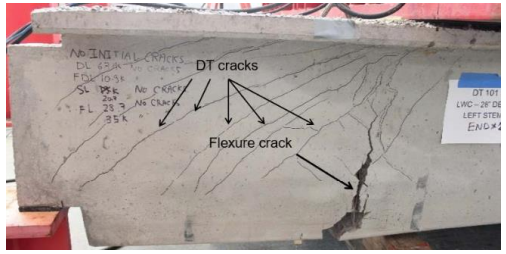
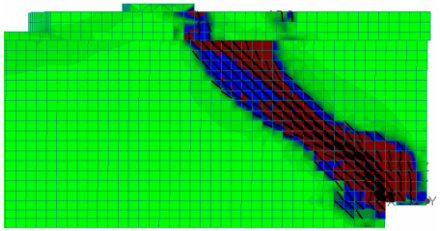
- Dapped Ends Project Goals:
  - Lightweight concrete
  - Prestressing in the nib
  - Hanger steel bend radius
  - Daps versus notches
  - Investigate composite repair techniques for dapped end members

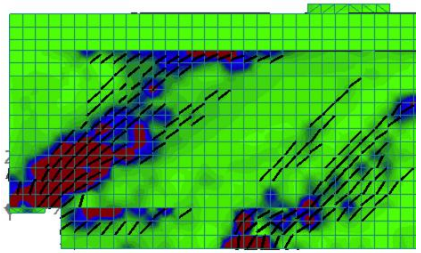
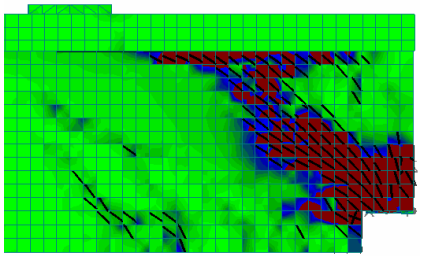
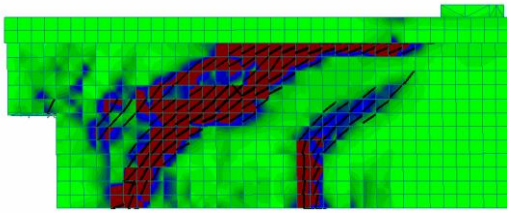
Progress

- Finalize validating finite-element models (LWC, bond models, etc.)
- Finalized test matrix
- Finalized design of four test specimens
- Finalized test setup.



Cracks shown are wider than 0.016 in. (0.4 mm)

Parameter	V_{exp} (kips)	V_{FEM} (kips)	Test/ FEM	FEM Failure Mode	Actual Failure Mode
Prestressing in the Nib	62	56	1.10		
	56	50	1.12		
LWC	57	56	1.01		
	65	67	0.97		
Notched	131	126	1.03		

Parameter	V_{exp} (kips)	V_{FEM} (kips)	Test/ FEM	FEM Failure Mode	Actual Failure Mode
Deep Members	204	182	1.12		
	179	170	1.05		
	67	62	1.08		

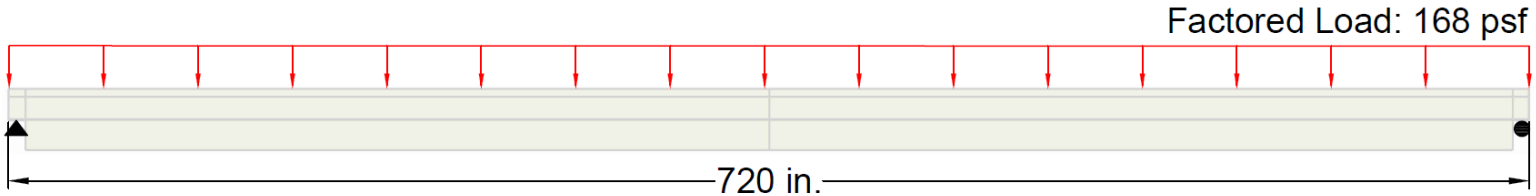
Test/Predicted Average	1.06
COV	5.14%

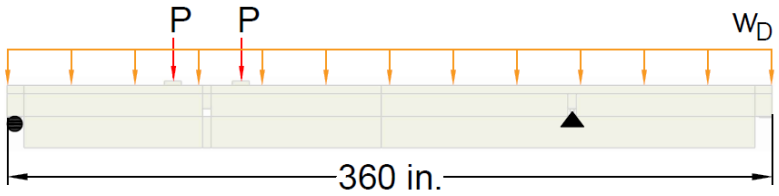
Experimental Test Matrix

Parameter	Number of Tests
Prestressing in the Nib	4
Daps and Notches	8
Hanger Bend Radius	4
Lightweight Concrete	6
Deep Tees	2
Repairs of Dapped End Members	4*
Total	28

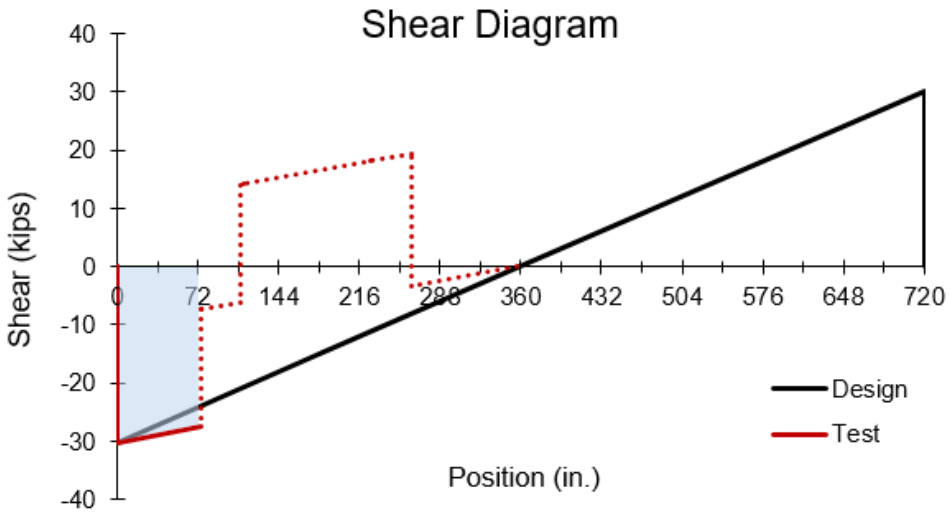
*TBD once failure modes of different specimens are observed.

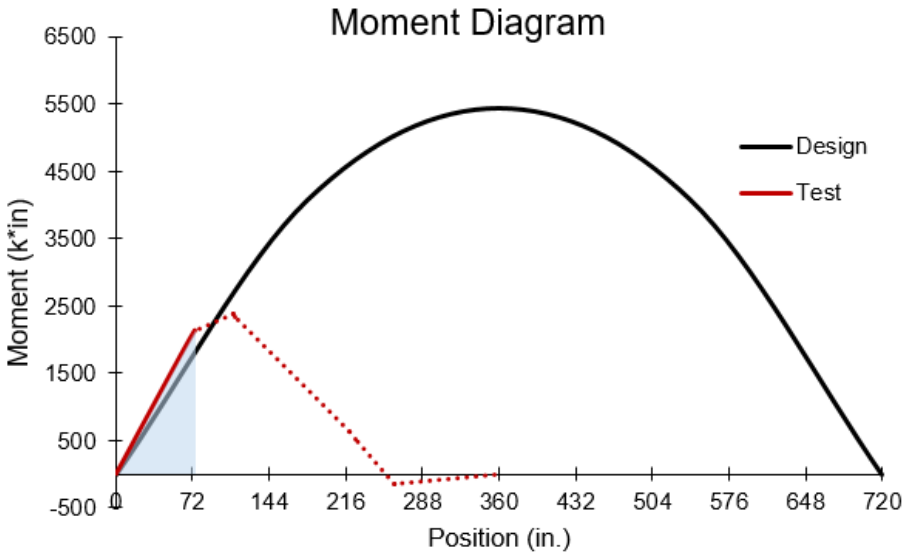
Test Setup





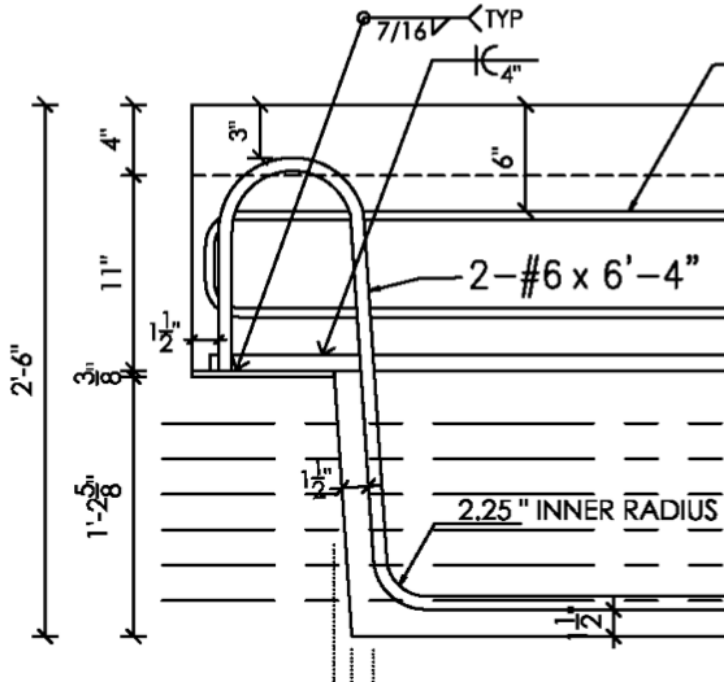
P = 20.2 kips
Dead Load = 83.9 psf





Ongoing Work/Future work

- Experimental Work
  - Testing the four designed specimens.
  - Testing the repaired members.
- Design work
  - Finalize the design of the remaining 24 tests
- Design Guidelines and Reports



Please Complete the LIFE Form

Project Name: Design and Repair of Prestressed Concrete Dapped End Beams

Project Number: CICI-15

PCI
Precast/Prestressed Concrete Institute

Center for Integration of Composites into Infrastructure

Virtual Industrial Advisory Board (IAB) Meeting

May 26, 2021

CICI-16

Creep Behavior of CFRP Wythe Connectors

Gregory Lucier, Ph.D. – Research Associate Professor, NCSU
Francisco De Caso, Ph.D. – Research Associate Professor, UM

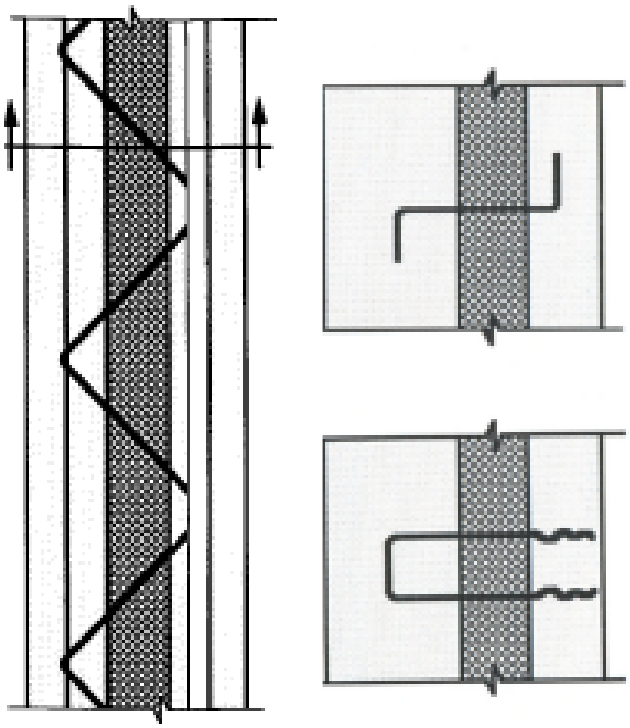
Need and Industrial Relevance

- Precast concrete sandwich wall panels are common structural elements that can provide high levels of thermal and structural efficiency.
- Performance depends on an efficient wythe connection that joins two layers of concrete through a rigid insulating core.

Need and Industrial Relevance

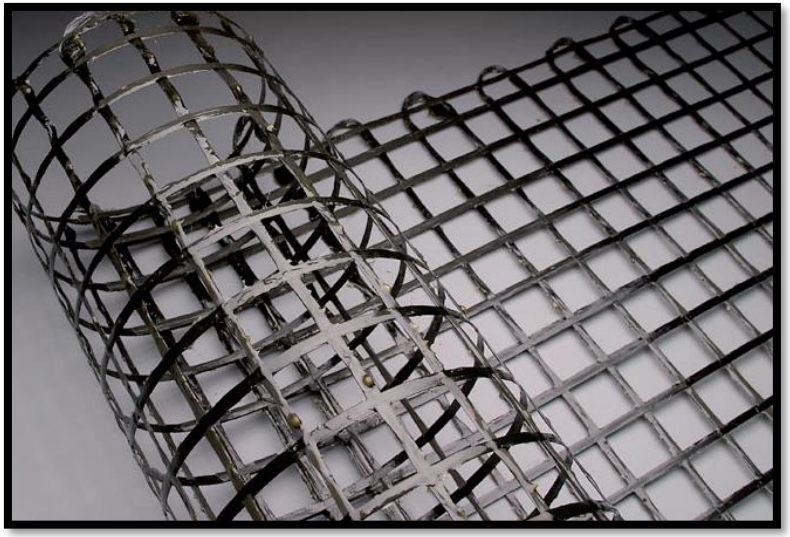
Typical Shear Mechanisms:

- Steel truss connectors
  - Thermally inefficient
- Steel tie connectors
  - Thermally and structurally inefficient
- Concrete solid zones
  - Thermally inefficient

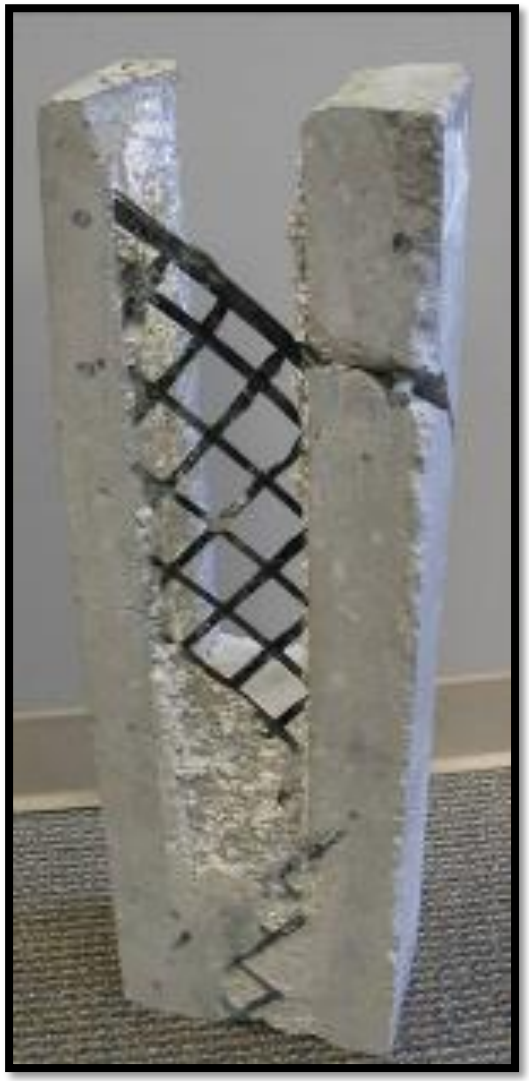


Need and Industrial Relevance

CFRP Shear Grid



- Orthogonal CFRP Grid
- Cut at a 45-degees to develop a truss action
- Provides composite action
- Structurally and thermally efficient



Project Goals and Objectives

- Measure the creep performance of the CFRP grid connection using standard “push specimens” loaded for 1 year.
- Test loaded specimens to failure after 1 year of loading.
- Test control specimens to failure before and after the 1 year period.
- Determine the appropriate design values that should be considered to account for creep in service.

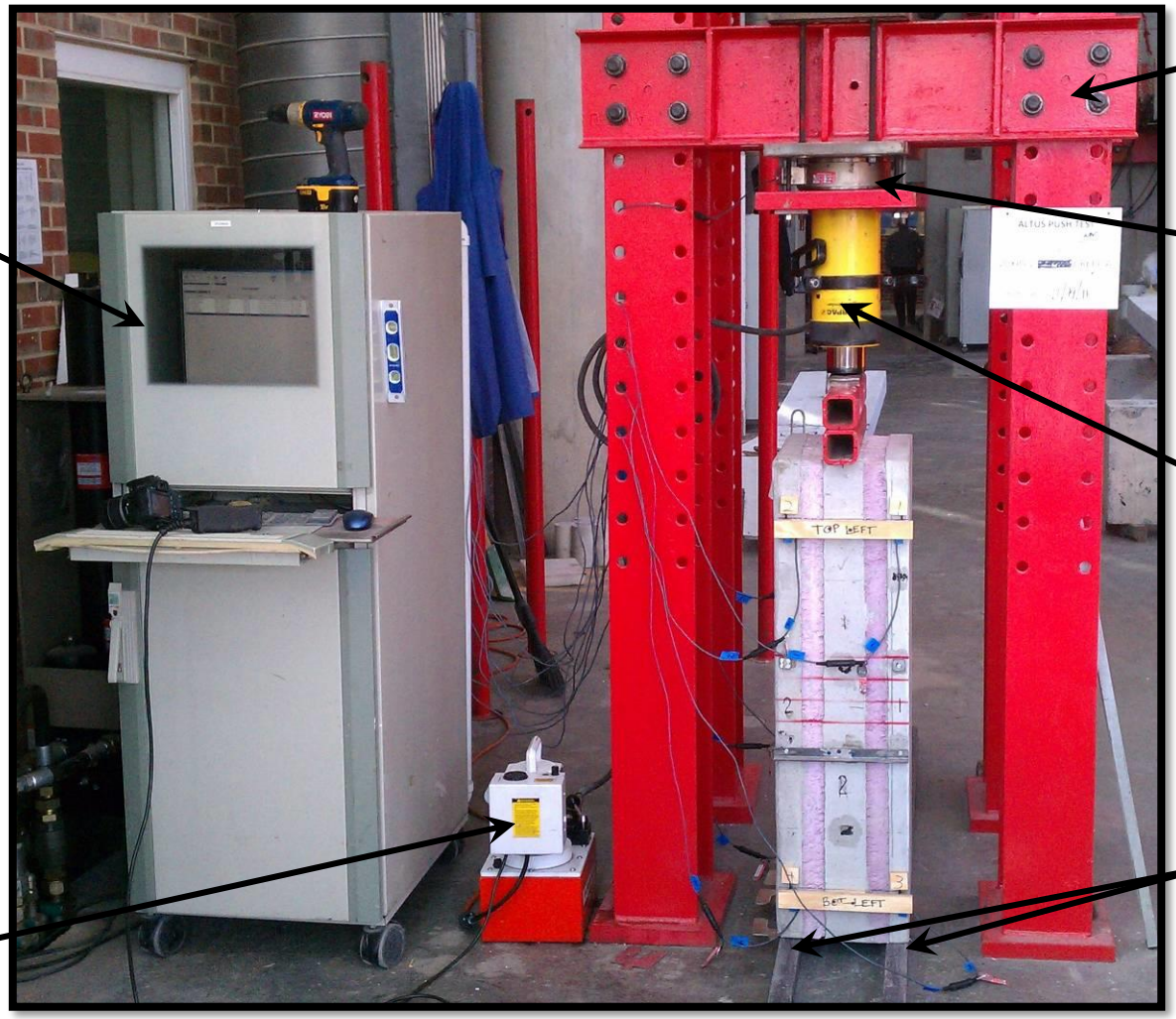
Preliminary Work – Underway

- Develop a testing matrix and test setup.
- Evaluate existing codes and design guidelines.
- Design test specimens and have them fabricated.

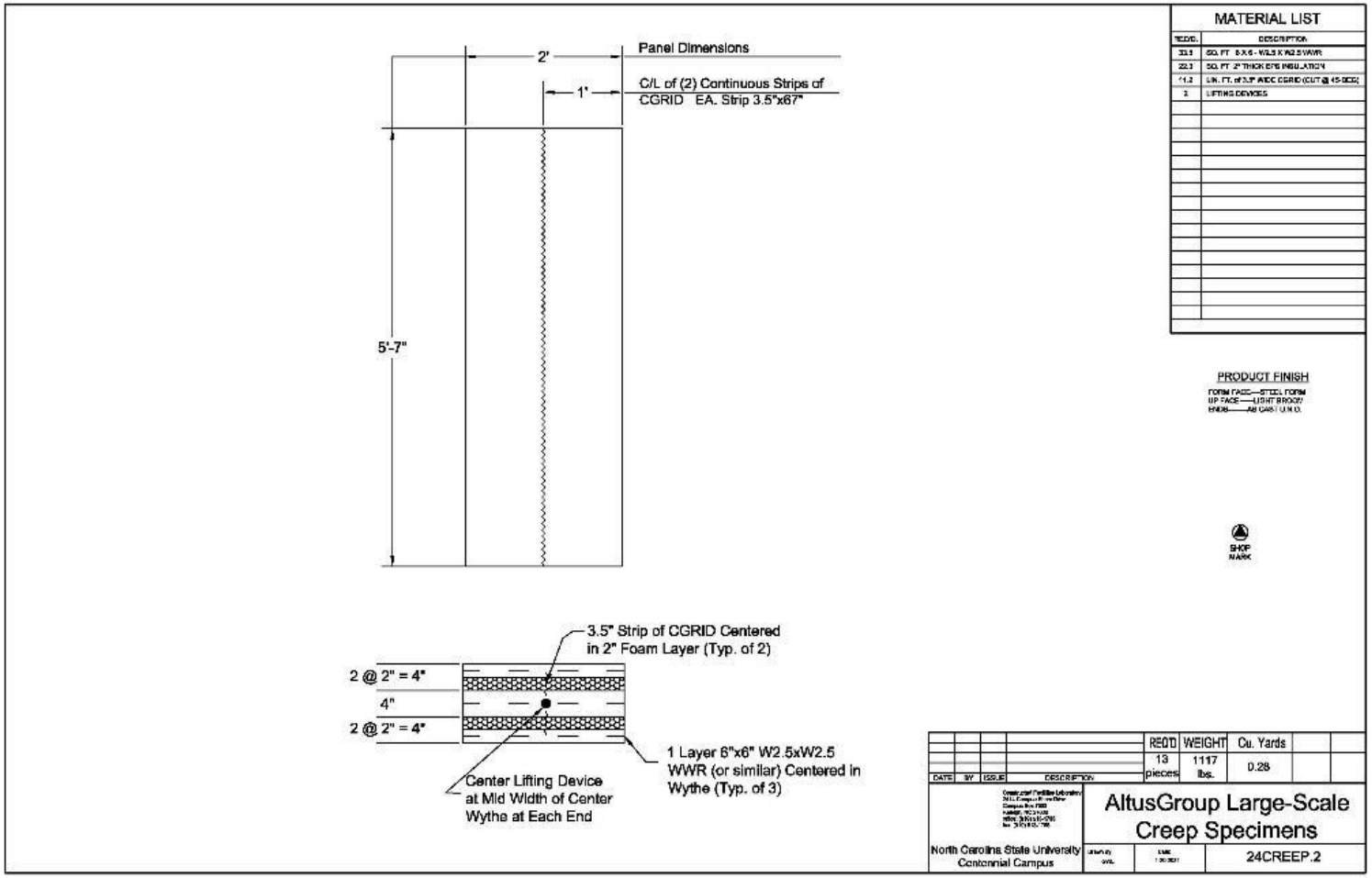
- Project official start date = January 2021 (Delayed until April due to limited precast production capacity).

- Specimens have been designed and produced.

Prior “Push Test” Specimens:



Specimens Designed:



Specimens Produced and Delivered:

Please Complete the LIFE Form

Project Name: Creep Behavior of CFRP Wythe Connectors

Project Number: CICI-16