



North Carolina State University

Site Director: Dr. Sami Rizkalla

Associate Director: Dr. Rudi Seracino

Date: February 1st, 2011

NC STATE UNIVERSITY

Industrial Collaborators

- ▶ AltusGroup, Inc.
- ▶ Freyssinet, Inc.
- ▶ Fyfe Company, LLC
- ▶ Grancrete, Inc.
- ▶ Martin Marietta Composites
- ▶ Nippon Steel Materials Co., Ltd.

Potential Members

- ▶ Korea Institute of Construction Technology (KICT)
- ▶ Millikan & Company
- ▶ KPFF, Inc.

Ongoing Projects

- ▶ NCSU-1. Rapid FRP Repair of Damaged Reinforced Concrete Columns
- ▶ NCSU-2. 3-D FRP Sandwich Panels with Corrugated Sheets for Bridge Decks
- ▶ NCSU-3. Innovative Bonding and Fibers for Strengthening Concrete Structures
- ▶ NCSU-4. Innovative FRP Shear Transfer Mechanism for Precast Prestressed Concrete Sandwich Panels
- ▶ NCSU-5. FRP Anchorage Systems for Strengthening Infill Masonry Structures

(Please complete LIFE forms for these projects)

Rapid FRP Repair of Damaged Reinforced Concrete Columns

Project Number: NCSU-1

- ▶ PI: Dr. Rudi Seracino
- ▶ Industrial Collaborator: Fyfe Company, LLC
- ▶ Student: Amy Byrum
(Hao Hu & Ty Rutledge)
- ▶ Overview:
Develop rapid FRP repair techniques for damaged RC columns with buckled and/or ruptured longitudinal reinforcing steel.
- ▶ Budget: \$25,000

Rapid FRP Repair of Damaged Reinforced Concrete Columns

Project Number: NCSU-1

▶ Motivation

- **Rapidly** restore lost strength and ductility of damaged RC columns
- Currently, FRP repair not permitted when longitudinal bars are not straight

▶ Research Plan

- Phase I – Confined Cylinder Tests
- Phase II – Full-Scale Column Repair



Rapid FRP Repair of Damaged Reinforced Concrete Columns

Project Number: NCSU-1

► Phase I

- Cylinder Tests with 3 parameters
 1. FRP Material
 2. Core Material
 3. Adhesive

- Direct axial compression in order to determine confined stress-strain properties



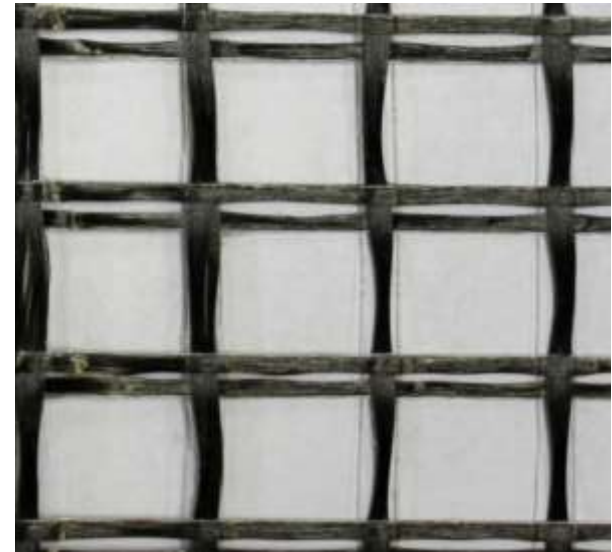
► Phase I - Repair System Design

Types of FRP



Carbon Fiber Reinforcing Fabric

- Unidirectional



Open Weave Basalt Fabric

- 0/90 bidirectional

► Phase I - Repair System Design

Core Material

PC Concrete

- 5000 psi

Rapid Curing Cementitious Patching Material

- 4500 psi
- Initial set in 3-5 minutes



Adhesive

Regular Epoxy

- 7 – day full cure

Rapid Cure Epoxy

- 48 minute gel time

Cementitious Bonding Matrix

- 50 min workability time
- Interlocks fibers

► Phase I - Repair System Design

Material Tests

- Tensile Properties of Composites and Epoxies (ASTM D3039 and ASTM D638)
- Tensile Properties of Basalt Cementitious Alternative and Dry Fibers



Rapid FRP Repair of Damaged Reinforced Concrete Columns

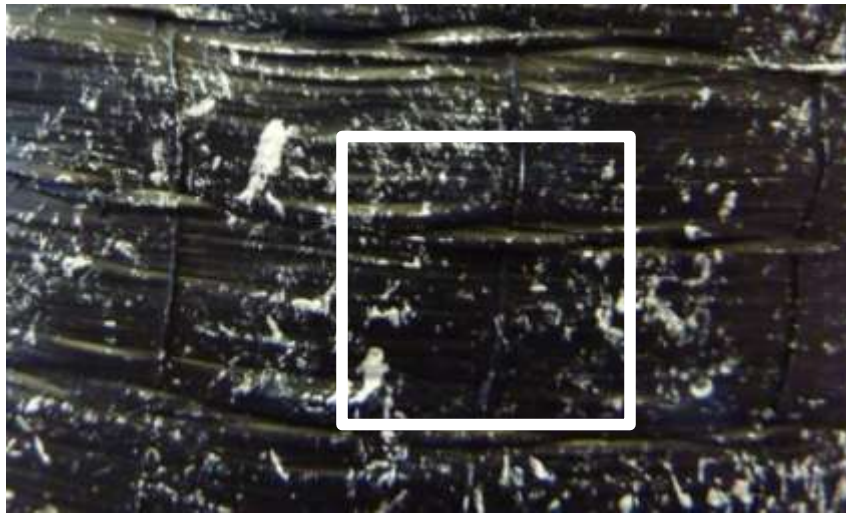
Project Number: NCSU-1

► Phase I - Test Matrix

Core Material	Control (No Wrap)	CFRP & 7-day Epoxy	CFRP & Rapid Cure Epoxy	Basalt & Bonding Matrix
PC Concrete	3	1 layer 3 layers	1 layer 3 layers	1 layer 3 layers
Rapid Patch Material	3	1 layer 3 layers	1 layer 3 layers	1 layer 3 layers



- ▶ Phase I – Continuous Strain Field Measurement
 - Particle Image Velocimetry (PIV)
 - Benefits



Speckle Pattern



- ▶ Phase I \longrightarrow Phase 2
- Compare data with existing confinement models
- Use proposed model to optimize design for wrapping damaged columns



► Future Work - Phase II (Column Repair)

“Moderately Damaged”

- **Buckled** reinforcing bars
- Remove loose concrete
- Replace damaged concrete
- Apply repair system design



“Severely Damaged”

- **Ruptured** reinforcing bars
- Remove loose concrete
- **Add longitudinal reinforcement in concrete cover**
- Replace damaged concrete
- Apply repair system design



Rapid FRP Repair of Damaged Reinforced Concrete Columns

Project Number: NCSU-1



LIFE Form Completion

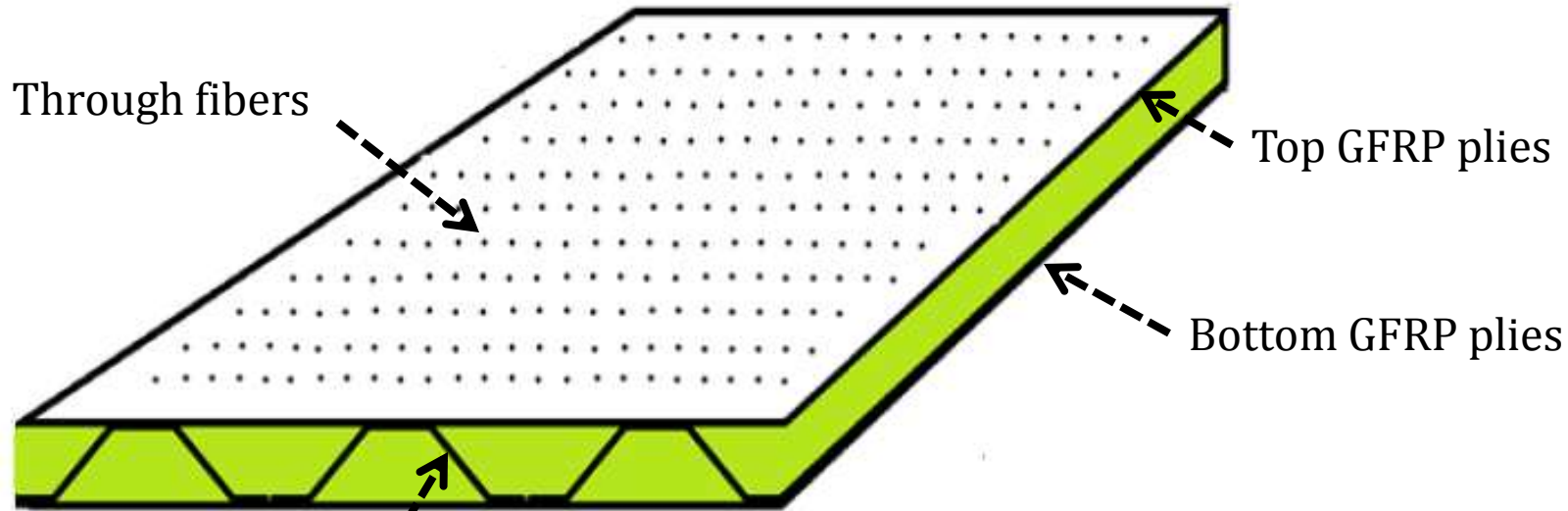
3-D FRP Sandwich Panels with Corrugated Sheets for Bridge Decks

Project Number: NCSU-2

- ▶ PI: Dr. Sami Rizkalla
- ▶ Industrial Collaborator: Martin Marietta Composites
- ▶ Graduate Student: Gautam Sopal
- ▶ Objective: To Study the behavior of new 3-D GFRP sandwich panels with corrugated sheets under various loading conditions
- ▶ Budget: \$50,000

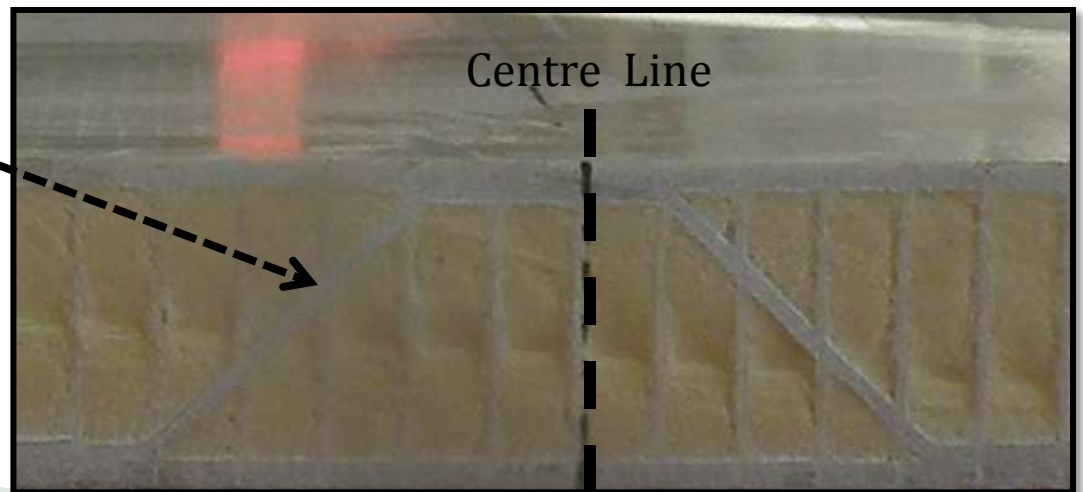
3-D GFRP Sandwich Panels with Corrugated Sheets for Bridge Decks

Project Number: NCSU-2

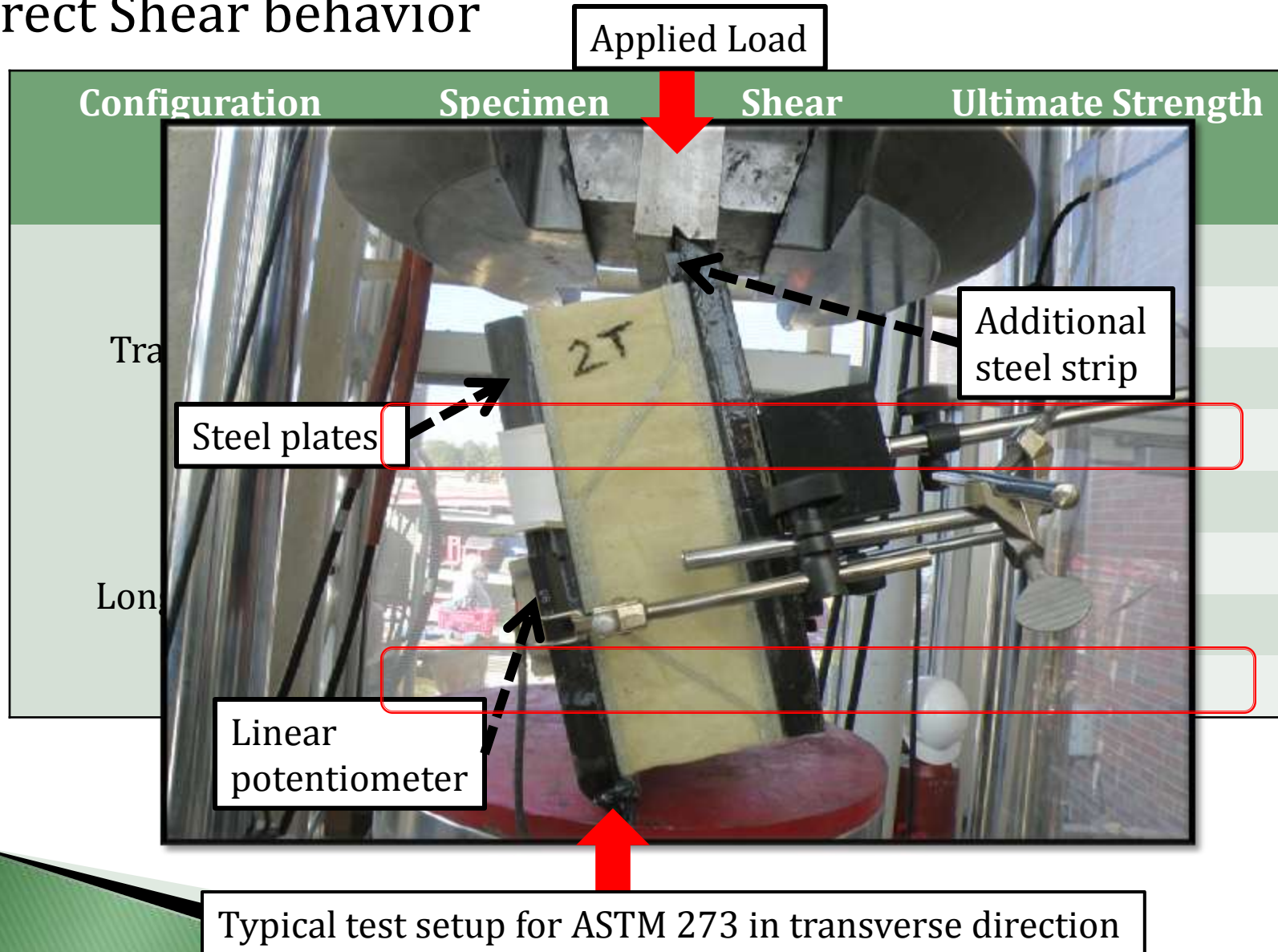


- ▶ 3-D GFRP Sandwich Panel with corrugated sheets

Additional corrugated sheets



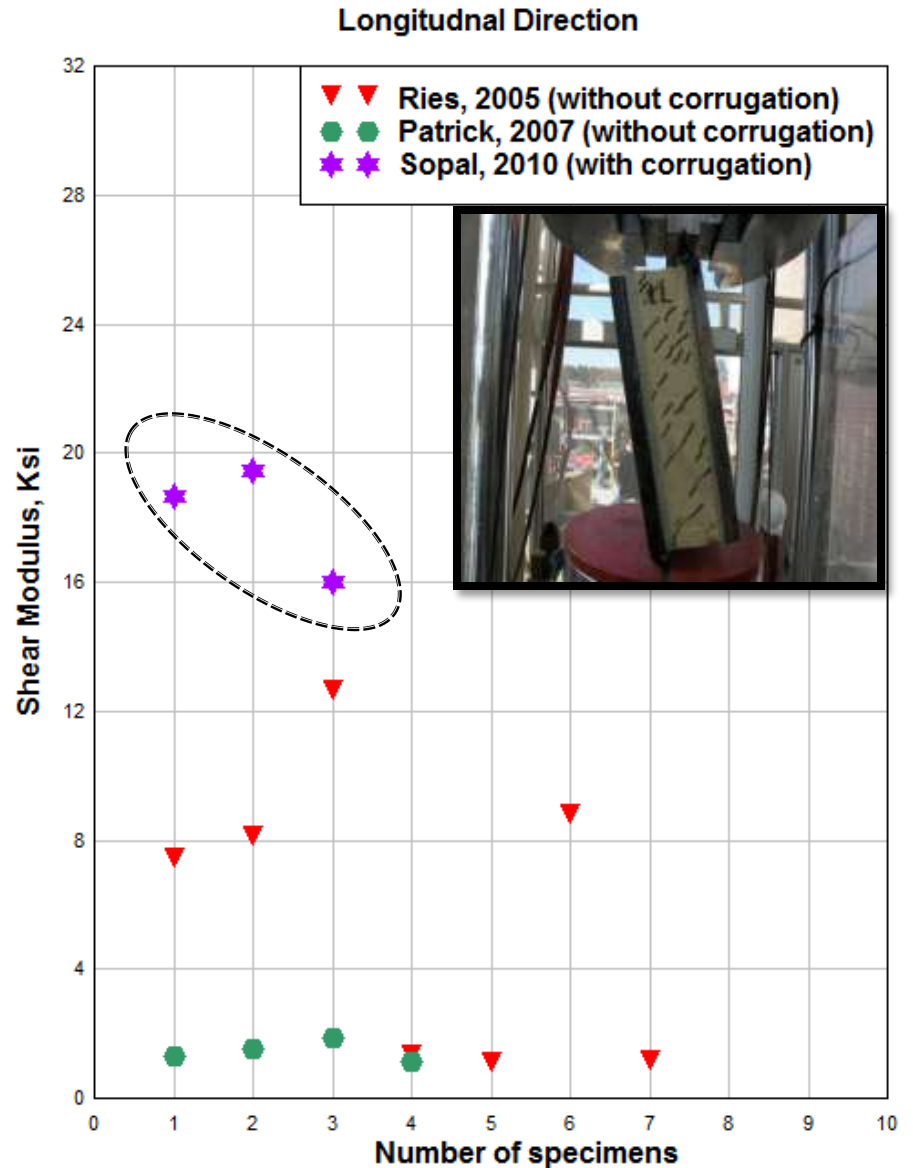
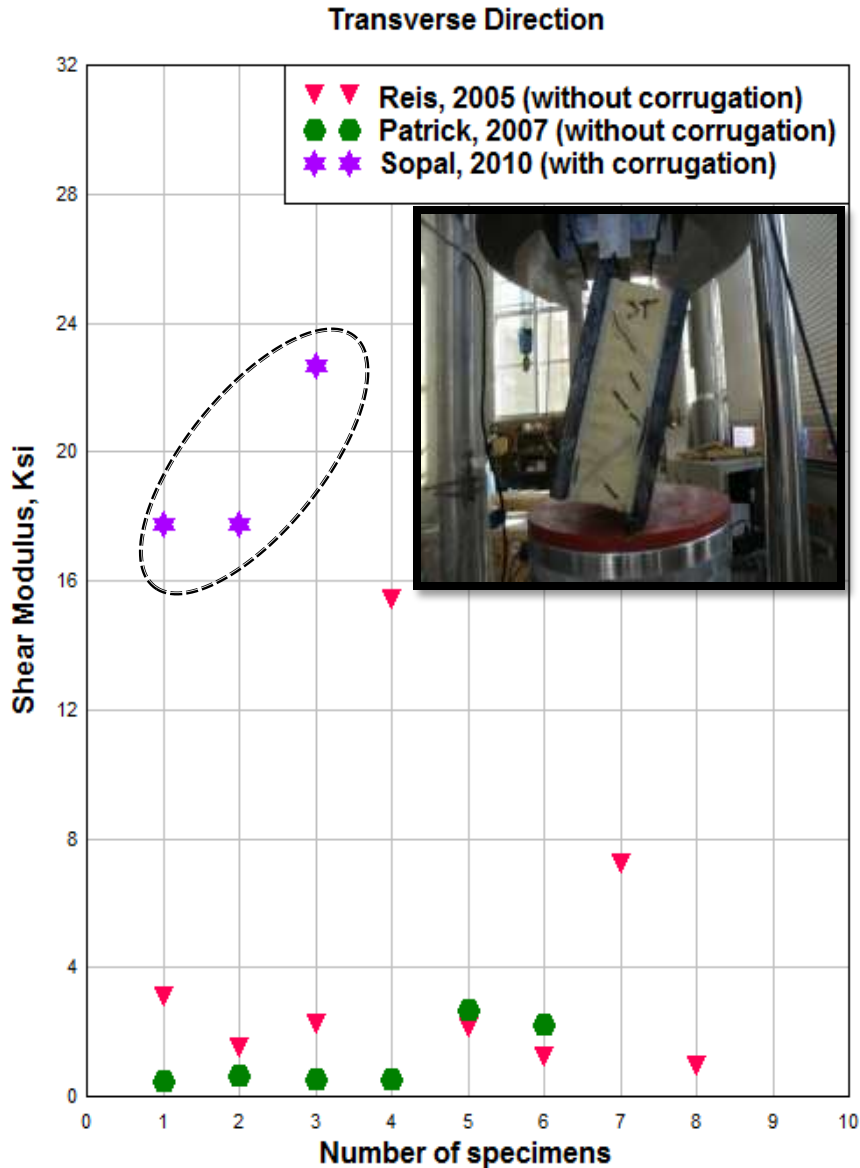
► Direct Shear behavior



3-D GFRP Sandwich Panels with Corrugated Sheets for Bridge Decks

Project Number: NCSU-2

► Direct Shear behavior

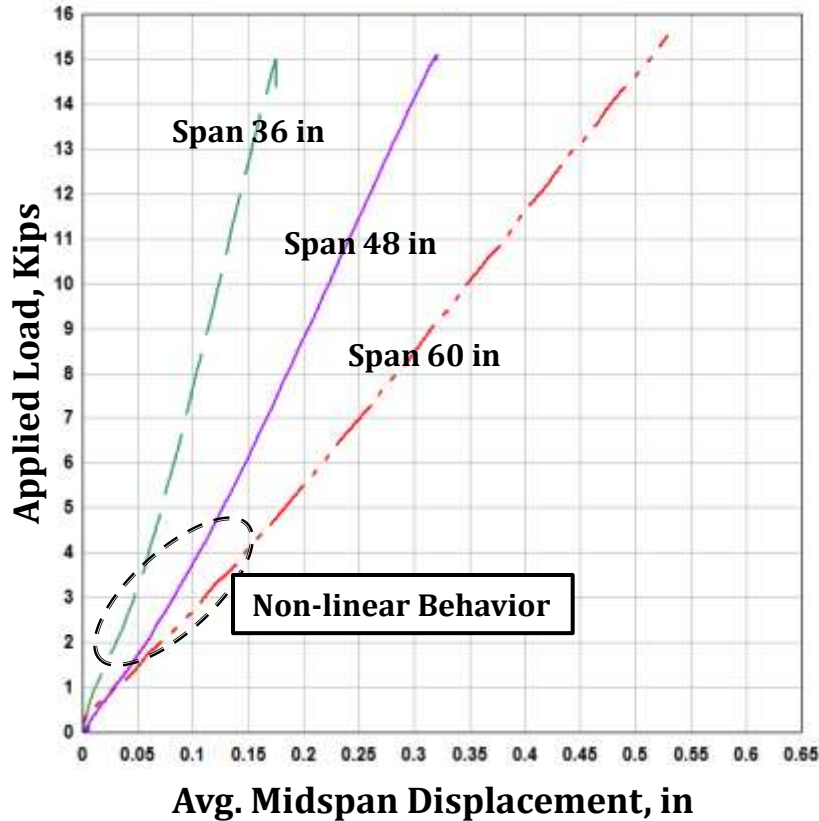


3-D GFRP Sandwich Panels with Corrugated Sheets for Bridge Decks

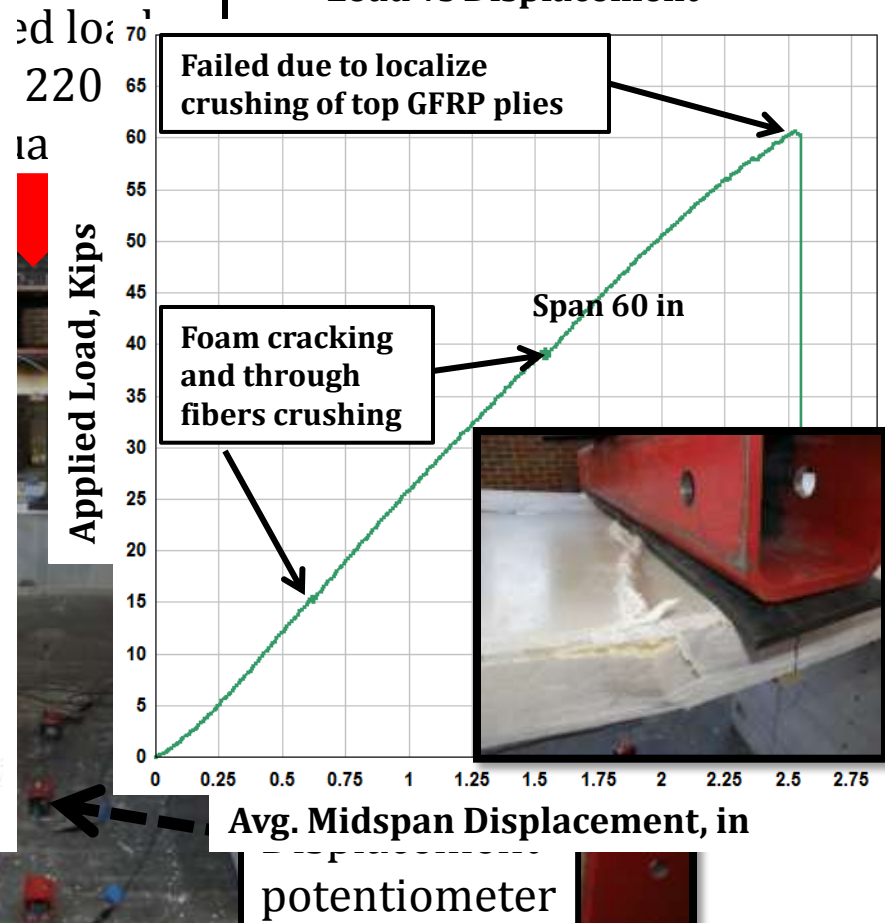
Project Number: NCSU-2

► One way flexural behavior

Load vs Displacement



Load vs Displacement



Typical test setup evaluating one way flexural behavior

3-D GFRP Sandwich Panels with Corrugated Sheets for Bridge Decks

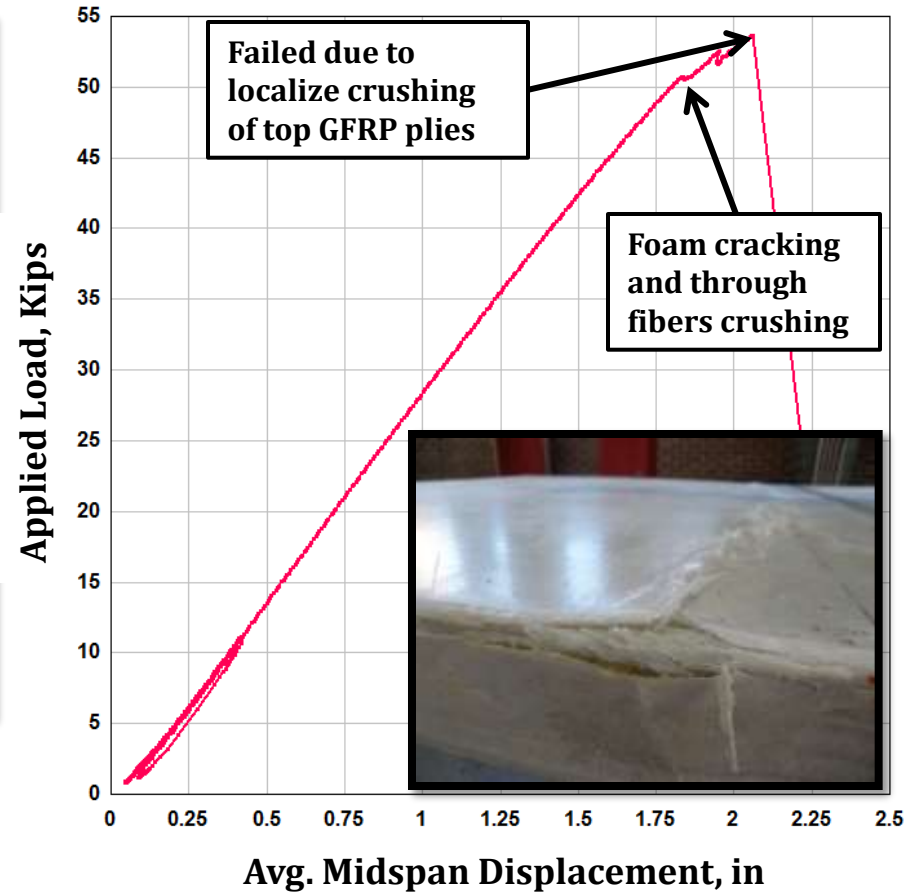
Project Number: NCSU-2

▶ Two way flexural behavior



Typical test setup evaluating two way flexural behavior

Load vs Displacement



3-D GFRP Sandwich Panels with Corrugated Sheets for Bridge Decks

Project Number: NCSU-2

► Shear behavior

Direct Shear results

Configuration	Avg. Ultimate Shear stress (psi)
Transverse	247
Longitudinal	200

$$\tau = \frac{VQ}{Ib} = 196.6 \text{ psi}$$

Where,

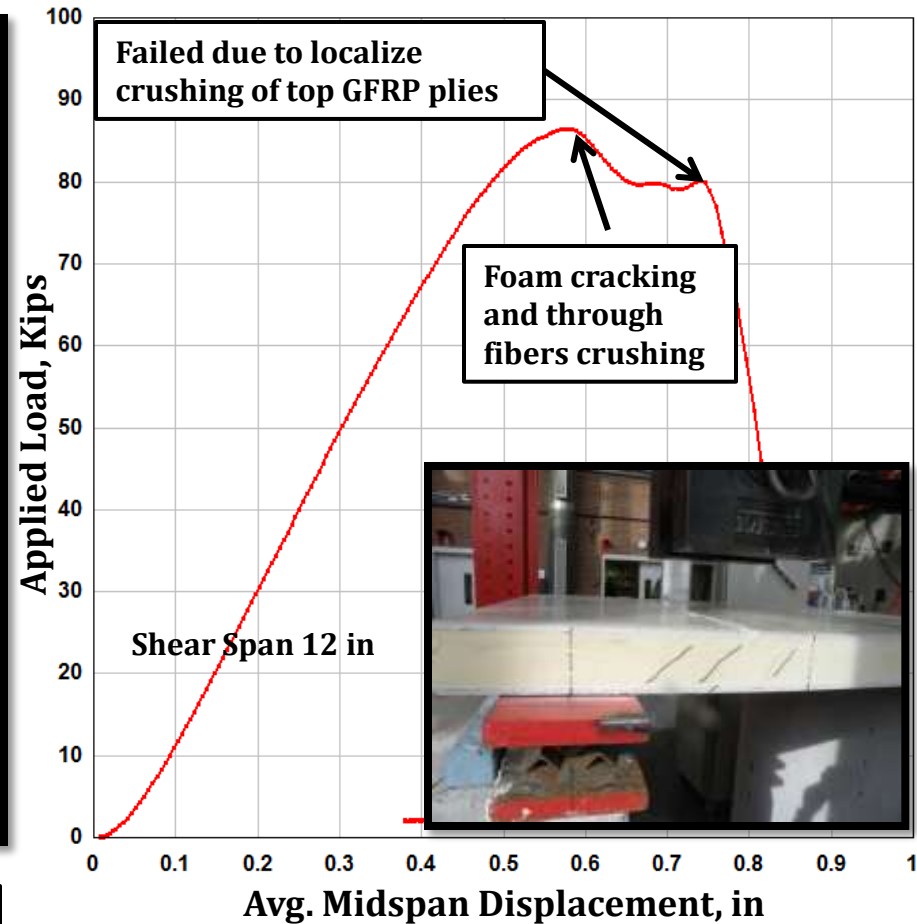
V= Experimental shear force = 43.5 Kips

Q = 1st moment of inertia = 2.1 in³

I = Moment of inertia = 10.1 in⁴

b = width of the section = 46 in

Load vs Displacement



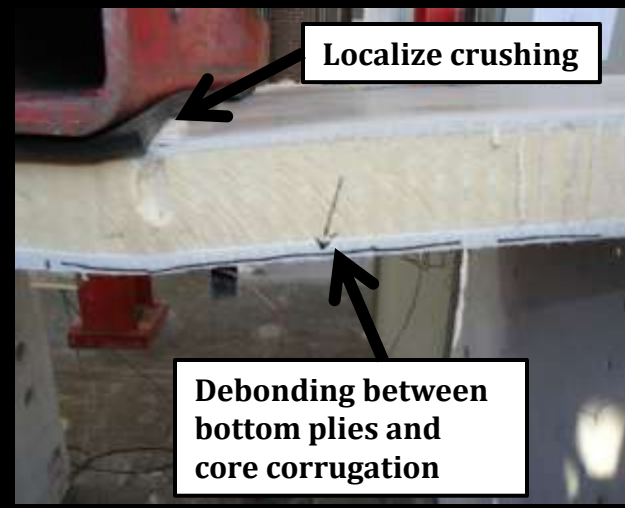
3-D GFRP Sandwich Panels with Corrugated Sheets for Bridge Decks

Project Number: NCSU-2

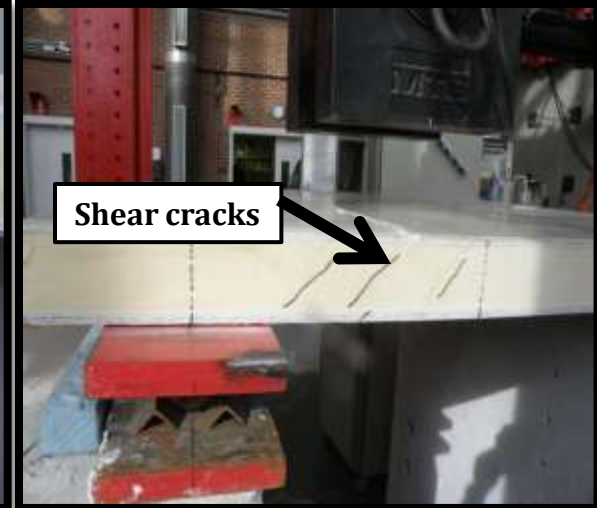
► Failure Modes



- Direct shear behavior



- One way and two way flexure behavior

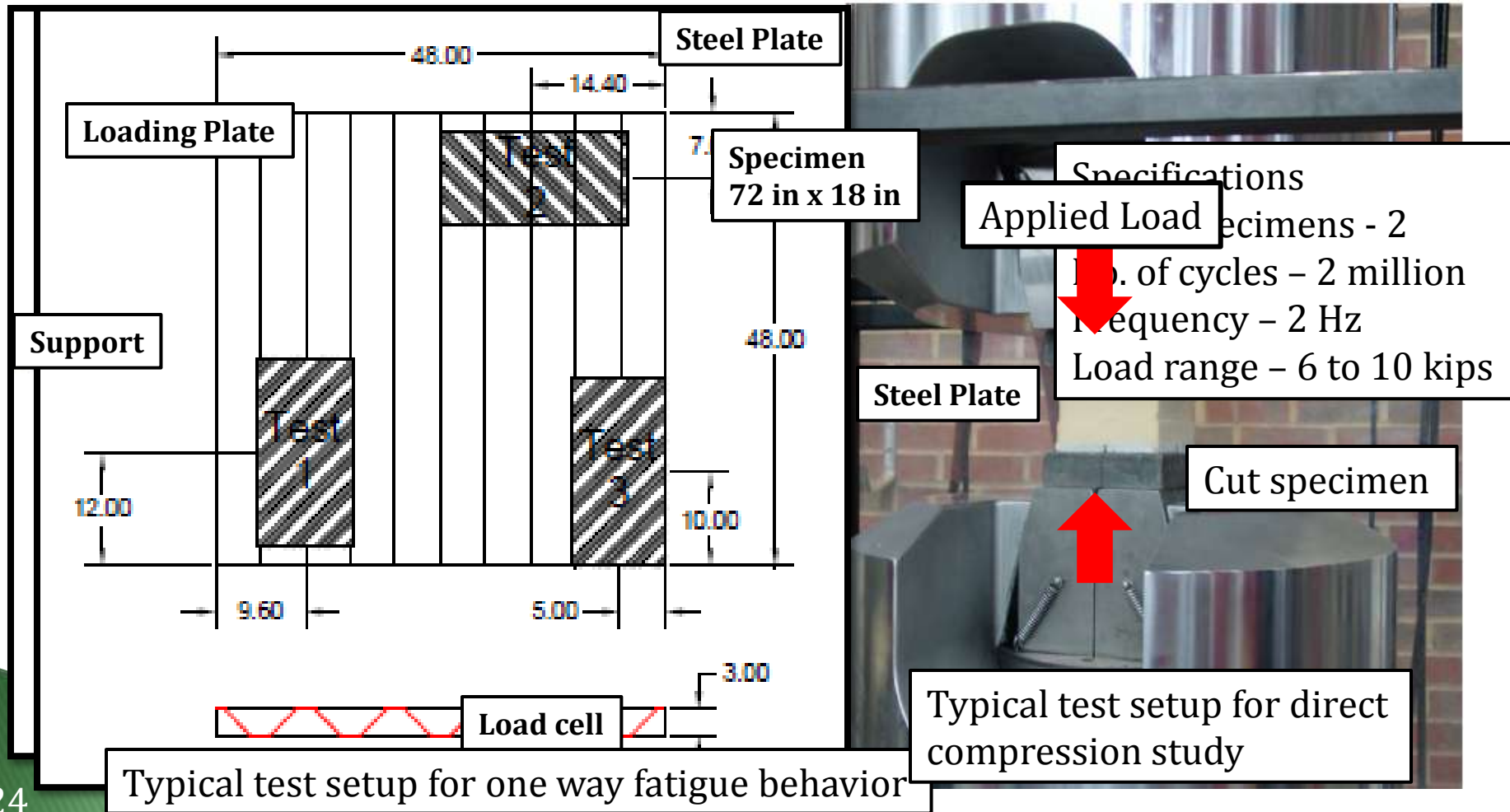


- Shear behavior



► Future experiments

One way fatigue behavior Direct compression behavior



- ▶ Preliminary conclusions
 - ▶ Panels failed under required failure modes
 - ▶ Increased shear strength and shear modulus
 - ▶ Perfectly linear and elastic behavior towards failure
 - ▶ Localize crushing of top GFRP plies
 - ▶ Bottom GFRP plies remained undamaged

- ▶ Future study
 - ▶ Quantify the effect of core corrugation
 - ▶ Compare the fundamental characteristics
 - ▶ Determine the possible degradation under cyclic loading
 - ▶ Calibrate specific analysis approach
 - ▶ Develop simple design guidelines

3-D FRP Sandwich Panels with Corrugated Sheets for Bridge Decks

Project Number: NCSU-2



LIFE Form Completion

Innovative Bonding and Fibers for Strengthening Concrete Structures

Project Number: NCSU-3

- ▶ PI: Dr. Sami Rizkalla
- ▶ Industrial Collaborators : Grancrete, Inc., Nippon Steel Materials Co., Ltd., Fyfe Company, LLC, Freyssinet, Inc.
- ▶ Graduate Students: Adolfo Obregon-Salinas, Benjamin Mielke, Brian Mielke
- ▶ Objective: Investigate the effectiveness of various fiber strengthening systems using different adhesive materials.
- ▶ Budget: \$125,000

► Repair and Strengthening of Concrete Structures Using Grancrete/FRP System

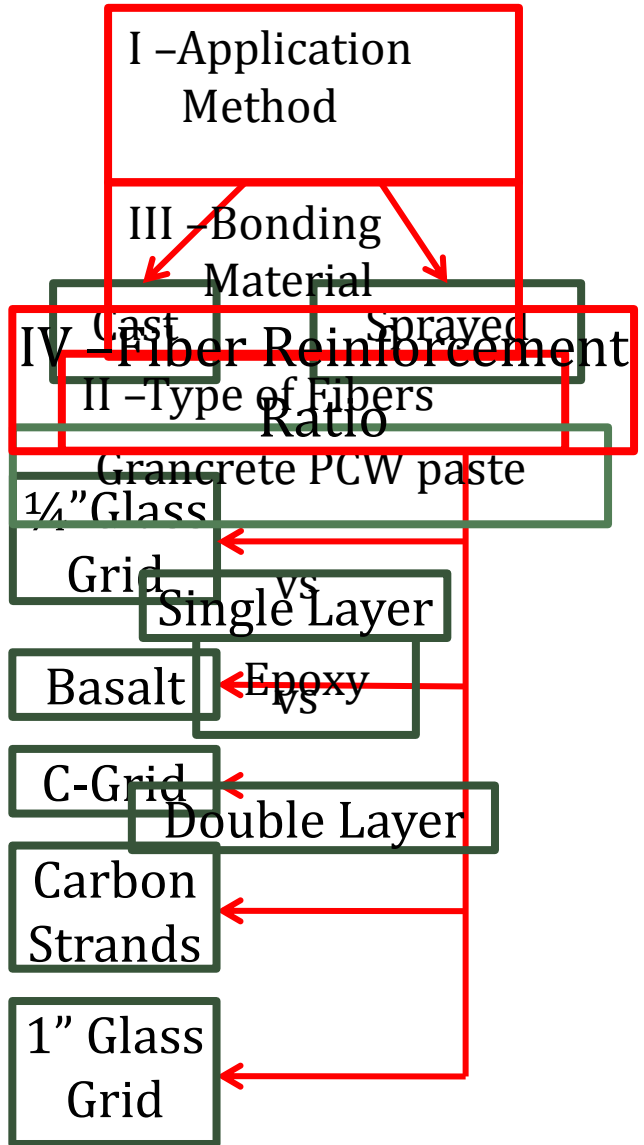
○ Parameters

- Application Method
- Type of Fiber
- Adhesive Material
- Fiber Reinforcement Ratio



► Test Matrix

Cast	Type of Fiber	Adhesive Material	Layers of Fiber	Application Method	Specimen ID	
1	NONE	NONE	NONE	NONE	Control - 1	
	Glass Fibers (small 1/4" grid)	Grancrete PCW Paste	1 Layer	Cast	GS-G-1-C	
		Epoxy		Sprayed	GS-G-1-S	
	Basalt Grid	Grancrete PCW Paste	1 Layer	Cast	B-G-1-C	
		Epoxy		Sprayed	B-G-1-S	
		Grancrete PCW Paste	2 Layers	Cast	B-E-1-C	
				Cast	B-G-2-C	
	2	NONE	NONE	NONE	NONE	Control - 2
Glass Fibers (Large 1" grid)		Grancrete PCW Paste	1 Layer	Cast	GL-G-1-C	
		Epoxy		Cast	GL-E-1-C	
C-Grid		Grancrete PCW Paste	1 Layer	Cast	CG-G-1-C	
		Epoxy		Cast	CG-E-1-C	
Carbon Strand Sheet		Grancrete PCW Paste	1 Layer	Cast	CS-G-1-C	
		Epoxy		Cast	CS-E-1-C	
		Grancrete PCW Paste	2 Layers	Cast	CS-G-2-C	
3		NONE	NONE	NONE	NONE	Control - 3
		Basalt Grid	Grancrete PCW Paste	1 Layer	Cast	B-G-1-C
	Epoxy		2 Layers	Cast	B-G-2-C	
			2 Layers	Cast	B-E-2-C	
	Carbon Strand Sheet	Grancrete PCW Paste	1 Layer	Cast	CS-G-1-C	
		Epoxy	2 Layers	Cast	CS-G-2-C	
			2 Layers	Cast	CS-E-2-C	
	C-Grid	Grancrete PCW Paste	2 Layers	Cast	CG-G-2-C	
Total number of slabs					24	

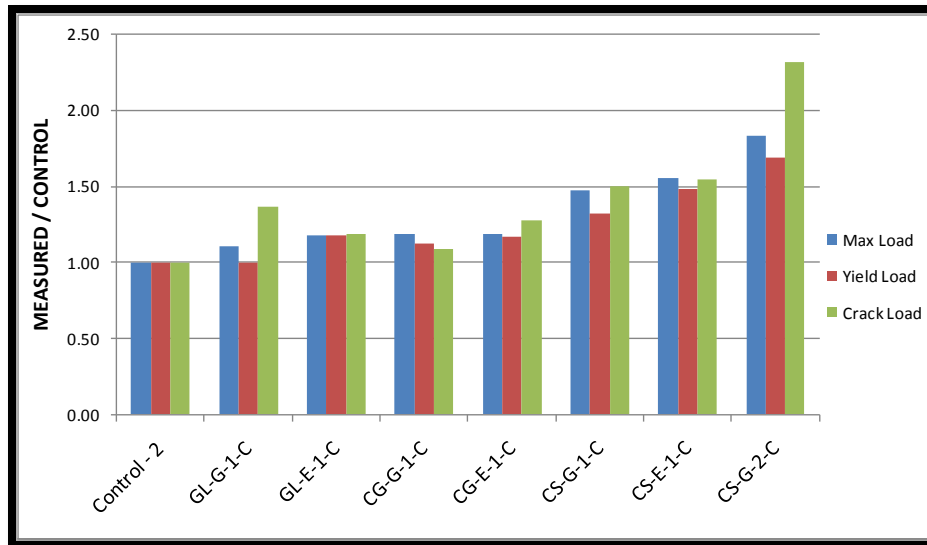


► Test Results

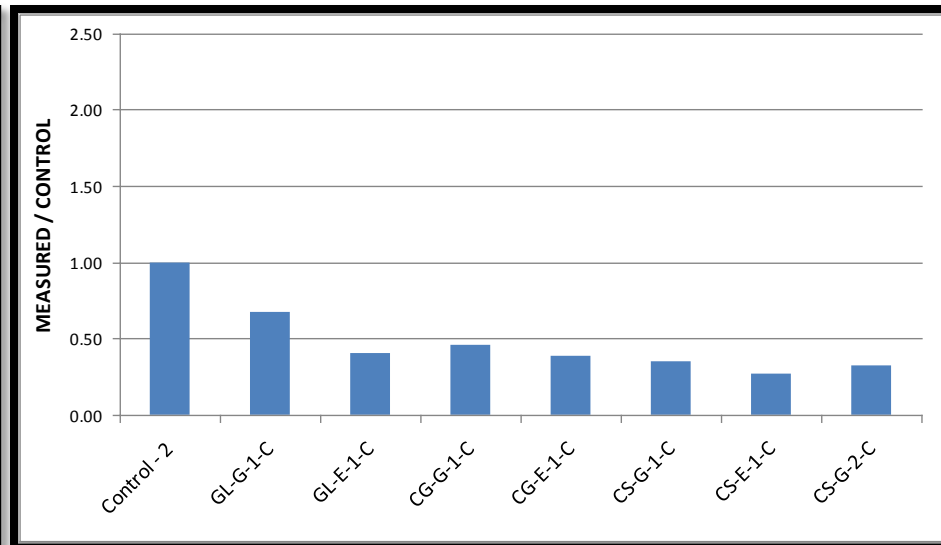
SLAB ID	CRACKING		YIELD		MAX LOAD (kips)	DEFLECTION AT 85% MAX LOAD (in)	DUCTILITY	FAILURE MODE
	Load (kips)	Deflection (in)	Load (kips)	Deflection (in)				
CAST #1								
Control - 1	2.51	0.06	11.90	0.94	13.49	4.85*	5.18*	Concrete Crushing
GS-G-1-C	4.40	0.13	13.24	0.97	15.54	4.50	4.62	Fiber Rupture
GS-G-1-S	3.92	0.09	13.51	0.99	16.23	6.46	6.55	Fiber Rupture
GS-E-1-C	4.61	0.12	15.30	1.02	17.96	3.41	3.33	Fiber Rupture
B-G-1-C	4.62	0.10	13.35	0.88	16.09	6.98	7.92	Concrete Crushing
B-G-1-S	3.42	0.07	13.01	0.93	14.76	6.02*	6.44*	Concrete Crushing
B-E-1-C	4.30	0.09	14.70	0.91	16.22	3.91	4.32	Fiber Rupture
B-G-2-C	4.43	0.07	13.53	0.81	15.74	6.07	7.53	Concrete Crushing
CAST #2								
Control - 2	2.20	0.07	12.30	1.12	12.66	5.46	4.89	Concrete Crushing
GL-G-1-C	3.00	0.12	12.30	1.15	14.02	3.78	3.30	Fiber Rupture
GL-E-1-C	2.61	0.08	14.51	1.20	14.88	2.35	1.97	Fiber Rupture
CG-G-1-C	2.40	0.06	13.81	1.17	15.00	2.62	2.24	Fiber Rupture
CG-E-1-C	2.81	0.10	14.41	1.26	14.99	2.40	1.91	Fiber Rupture
CS-G-1-C	3.30	0.09	16.30	1.34	18.68	2.30	1.72	Fiber Rupture
CS-E-1-C	3.40	0.08	18.20	1.36	19.69	1.82	1.34	Fiber Rupture
CS-G-2-C	5.10	0.11	20.80	1.22	23.21	1.93	1.58	Concrete Crushing
CAST #3								
Control - 3	2.50	0.05	12.30	1.05	13.10	5.26	5.03	Concrete Crushing
B-G-1-C	3.11	0.06	12.71	1.02	13.33	6.65	6.54	Concrete Crushing
B-G-2-C	3.10	0.07	12.90	1.07	14.97	4.12	3.85	Concrete Crushing
B-E-2-C	3.40	0.10	15.40	1.20	17.29	3.07	2.55	Fiber Rupture
CS-G-1-C	4.21	0.09	17.45	1.23	21.11	2.30	1.88	Fiber Rupture
CS-G-2-C	5.01	0.11	21.31	1.36	26.12	2.63	1.93	Concrete Crushing
CS-E-2-C	4.30	0.11	23.61	1.39	27.21	2.05	1.47	Fiber Rupture
CG-G-2-C	3.91	0.09	15.30	1.15	18.28	3.25	2.82	Fiber Rupture

* Test stopped before reaching 85% of maximum load. Maximum recorded deflection used instead.

► Typical Test Results



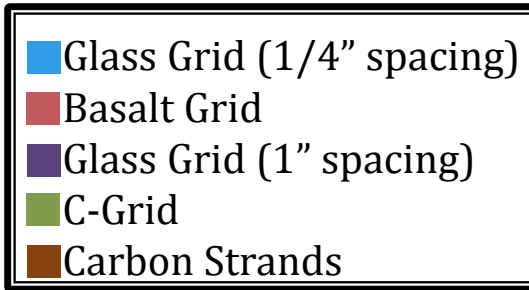
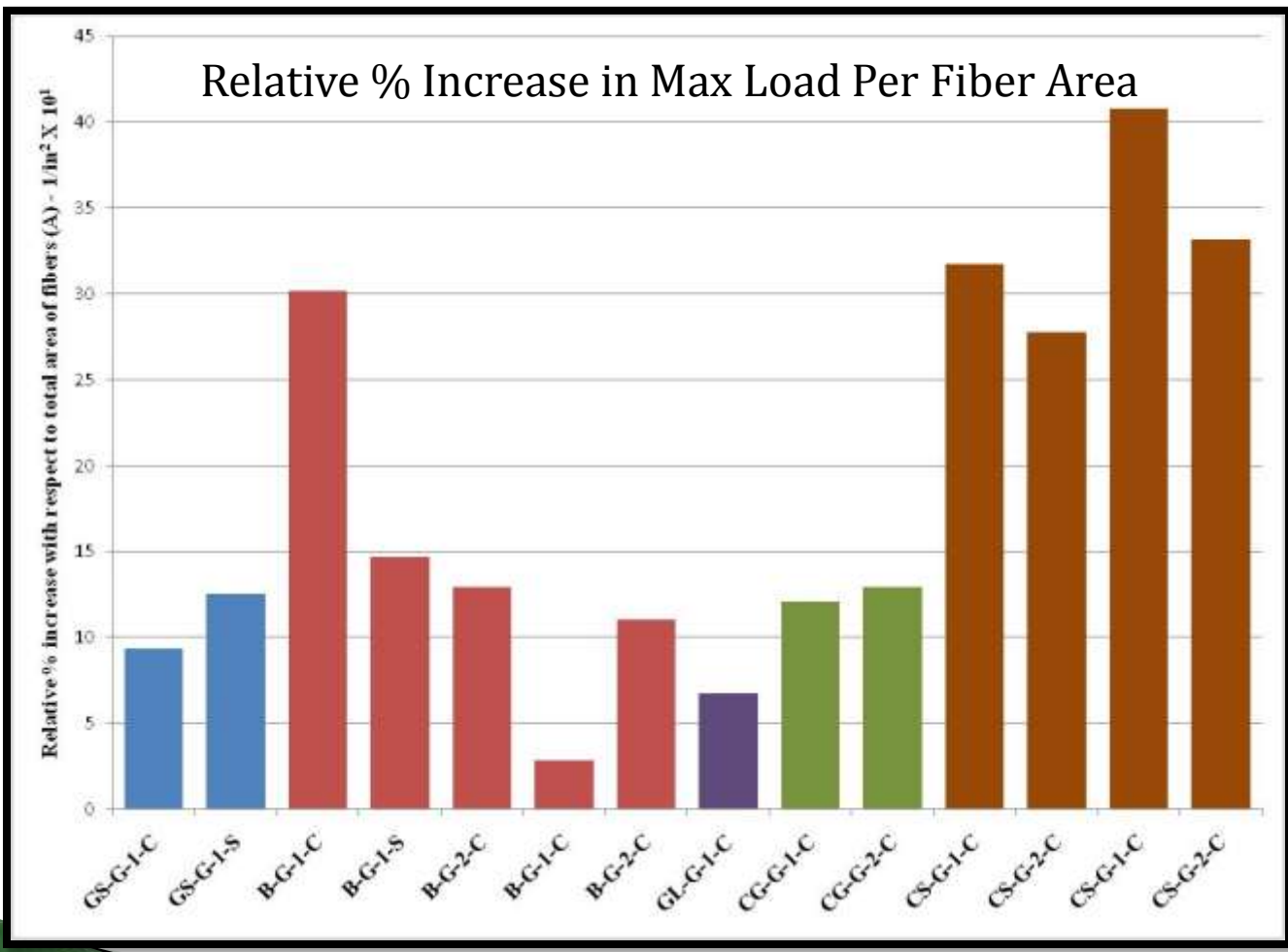
Load at different stages



Ductility

Data dimensionalized with respect to the control specimen

▶ Test Results



► Effects

◦ Method of Application

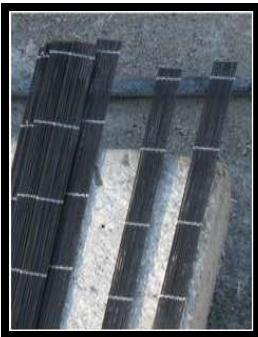
- No major differences observed
- Both methods adequate for FRP application
 - Spray – Positive moment regions →
 - Cast – Negative moment regions ↓



► Effects

○ Type of Fibers

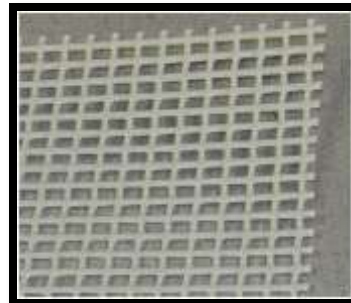
- All fibers increased load capacity
 - Basalt quality control
- Fibers with high tensile strength and modulus increase load capacity and decrease ductility
- Fiber grids with small spacing may cause localized debonding



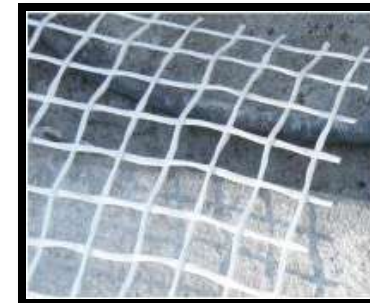
Carbon Strand



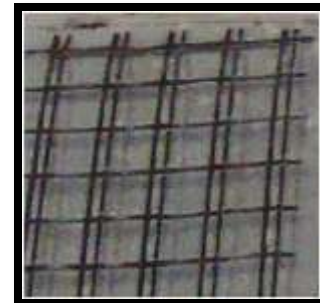
Carbon-Grid



0.25" Glass Grid



1" Glass Grid

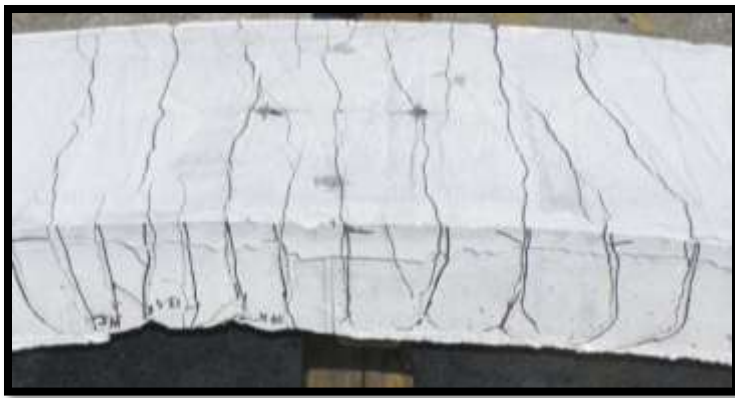


Basalt Grid

► Effects

○ Bonding Material

- Epoxy had slightly higher load capacity
- Epoxy caused fibers to rupture at a single crack
- Grancrete had slightly higher deflection and ductility
- Grancrete forms well distributed flexural cracks



Grancrete



Epoxy

► Effects

○ Fiber Reinforcement Ratio

- Higher reinforcement ratio increases flexural capacity
- Higher reinforcement ratio reduces ductility



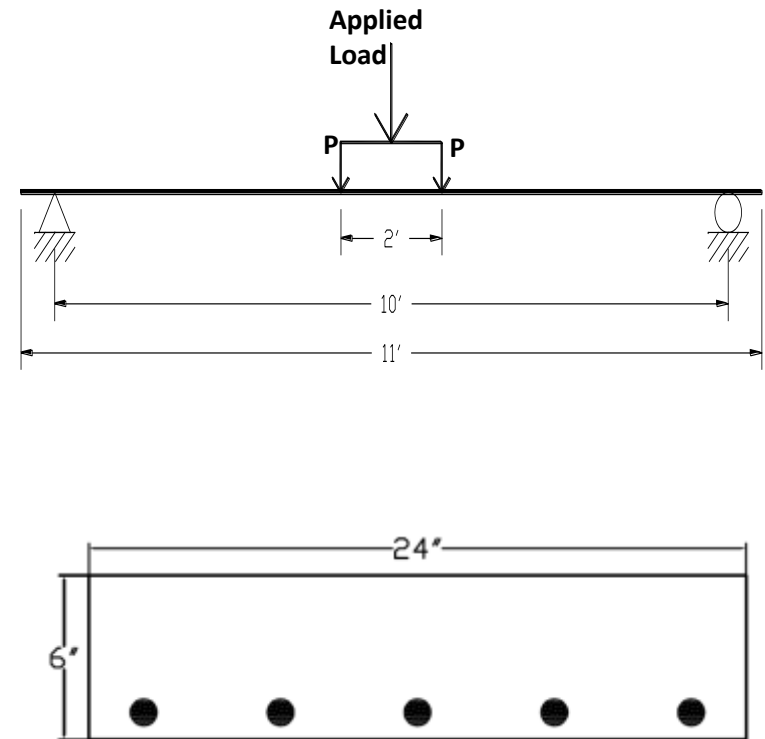
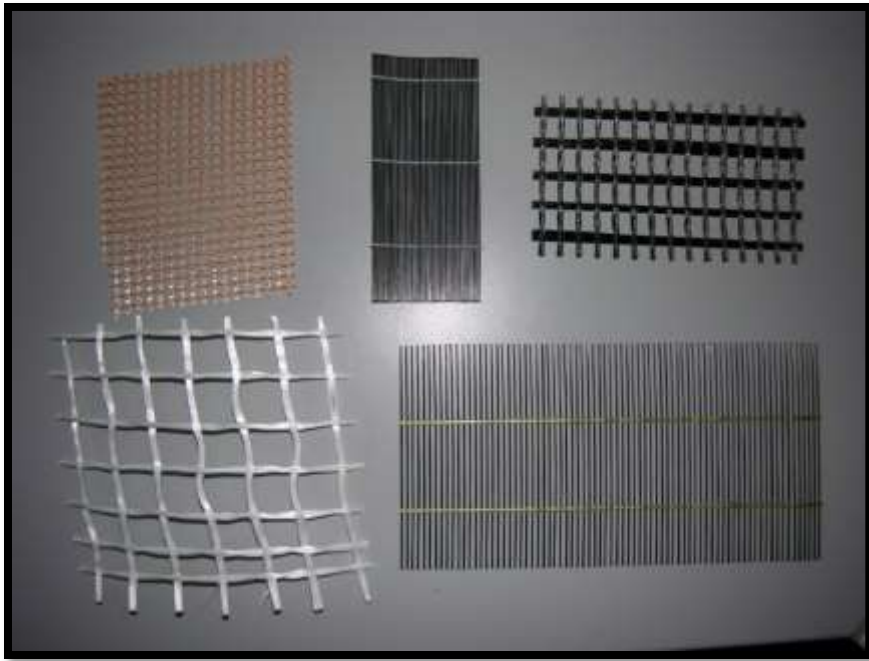
1 Layer Carbon Strands



2 Layers Carbon Strands

► Work In Progress

- I. Advanced Fiber Strengthening Systems for Concrete Structures



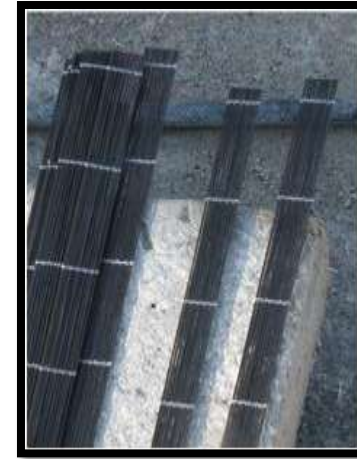
► Materials to be Investigated

◦ Fibers

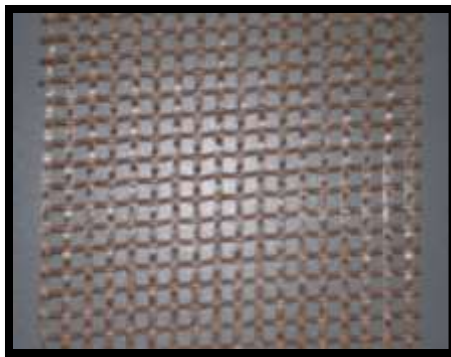
- Carbon Strand
- Carbon Grid
- Glass Grid

◦ Adhesive

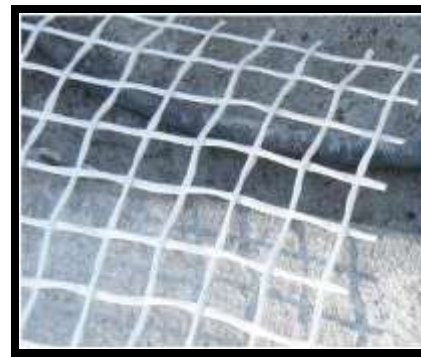
- Epoxy
- Cementitious Bonding Matrix
- Grancrete



Carbon Strand



0.25" Glass Grid



1" Glass Grid



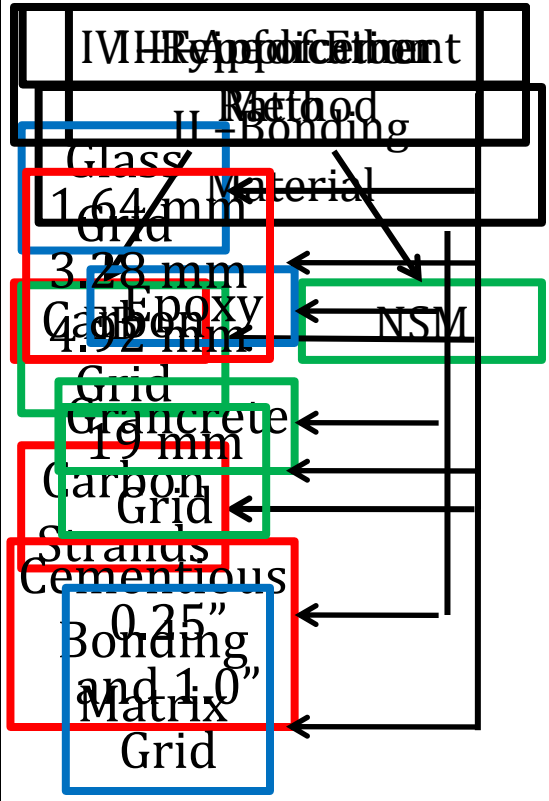
Carbon-Grid

Innovative Bonding and Fibers for Strengthening Concrete Structures

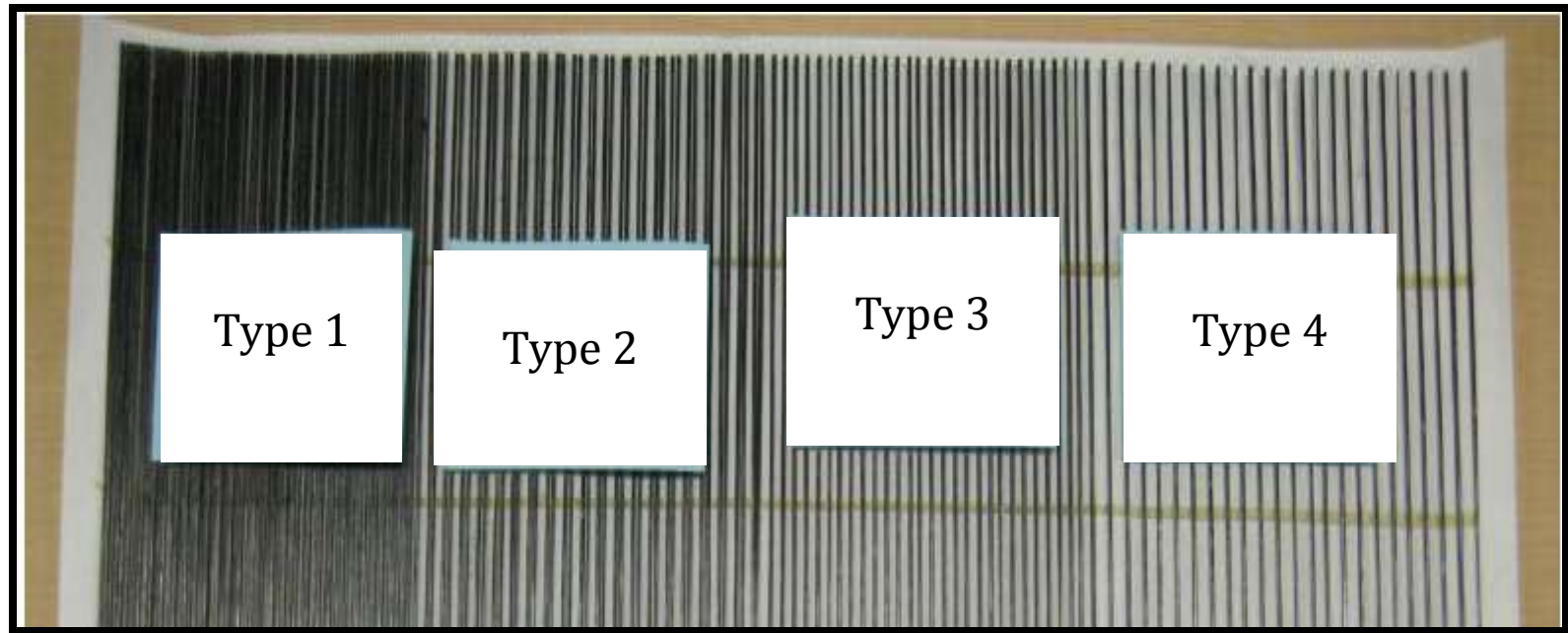
Project Number: NCSU - 3

▶ Test Matrix

Specimen ID	Fiber Details	Adhesive	Application	Reinforcement Ratio	No. of Specimens
CONTROL	NONE	NONE	NONE	NONE	2
HT-E-E	High Tensile Carbon Strand	Epoxy	Externally Bonded (EB)	1.64 mm	1
HT-G-E-1		Grancrete	EB	1.64 mm	1
HT-G-E-3			EB	3.28 mm	1
HT-G-E-4			EB	4.92 mm	1
HT-G-NSM			NSM	-----	1
HM-E-E	High Modulus Carbon Strand	Epoxy	EB	1.64 mm	1
HM-G-E-1		Grancrete	EB	1.64 mm	1
HM-G-E-3			EB	3.28 mm	1
HM-G-E-4			EB	4.92 mm	1
HM-G-NSM			NSM	-----	1
C-E-E	Carbon Grid	Epoxy	EB	19 mm Grid	1
C-G-E		Grancrete	EB	19 mm Grid	1
C-C-E		Cementious Bonding Matrix	EB	19 mm Grid	2
G-G-0.25	Glass Grid	Grancrete	EB	0.25 inch Grid	1
G-G-0.5		Grancrete	EB	1.0 inch Grid	1
Total Number of Slab Specimens					18



► Reinforcement Ratio for Carbon Strands

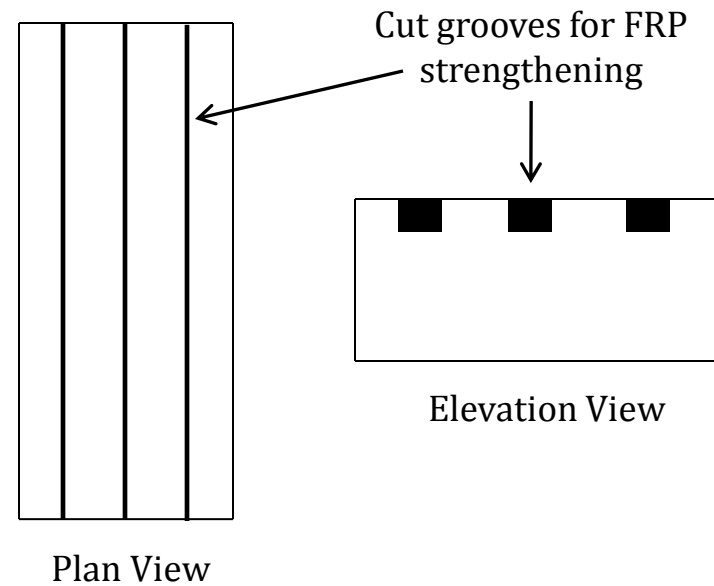


Type (HT)	Center-Line to Center-Line Spacing
Type 1	1.64mm
Type 2'	1.94/3.28 mm(alternate)
Type 3	3.28 mm
Type 4	4.92 mm

► Different Application Techniques



Externally Bonded (EB)



Near Surface Mounted (NSM)

▶ Work in Progress

- II. CFRP Strengthening System for Reinforced Concrete Structures



▶ Motivation

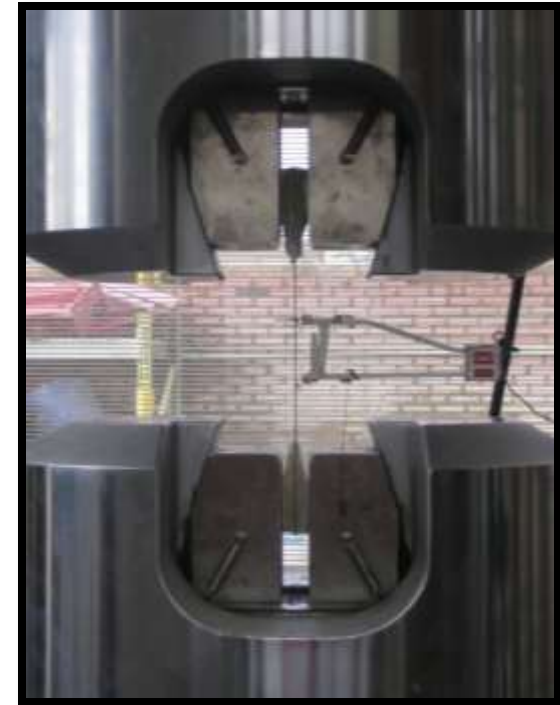
- Experimental study of innovative CFRP sheet strengthening system for RC structures
 - Phase I - Physical and Mechanical Properties and Aging
 - Tensile Properties
 - Creep (Tensile)
 - Glass transition temperature
 - Void Content
 - Coefficient of Thermal Expansion
 - Interlaminar Shear Strength
 - Phase II - Large Specimen Testing
 - RC beams in flexure and shear
 - RC slabs in flexure
 - RC columns in axial compression

► Physical and Mechanical Properties and Aging

Witness Panels

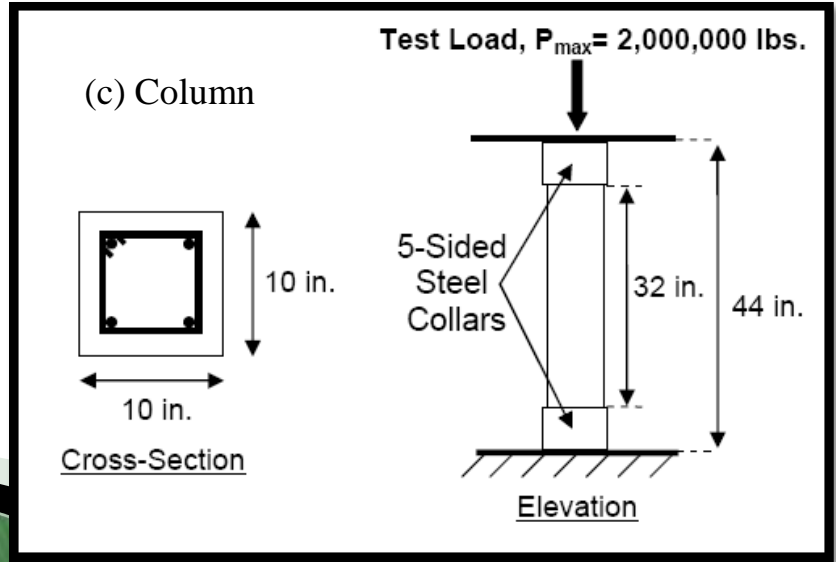
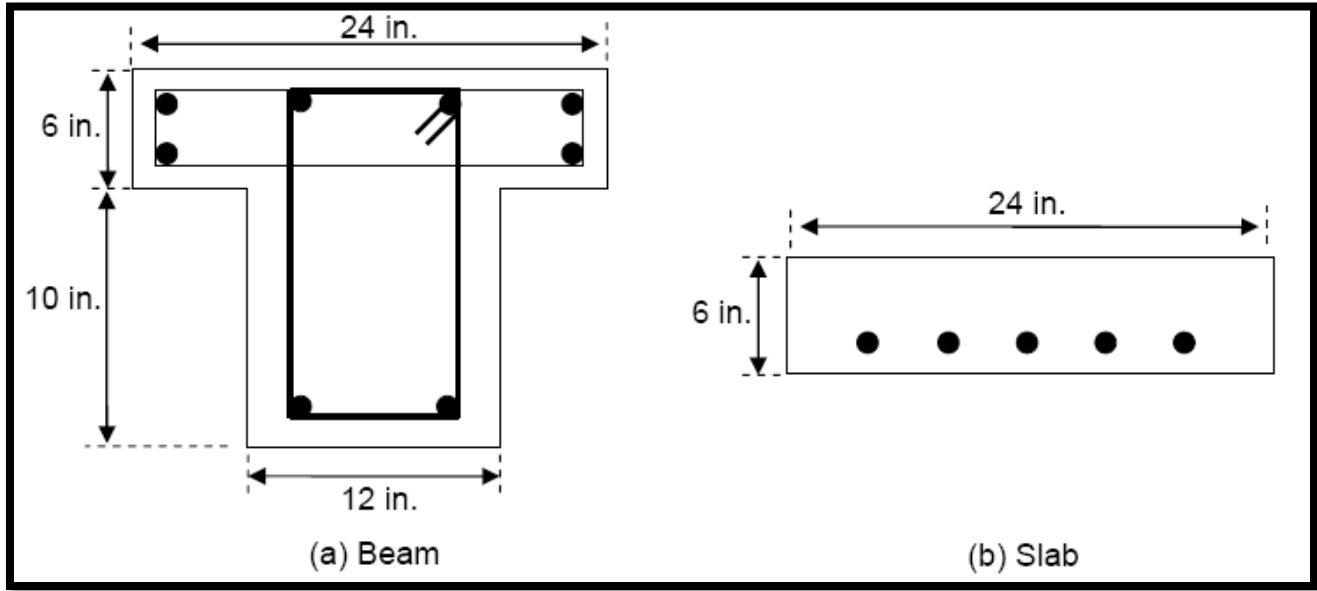


Coupon Specimens



Testing Tensile Properties

► Large Specimen Testing



▶ Test Matrix – Beams and Slabs

<u>Type</u>	<u>Group</u>	<u>Specimen</u>	<u>Limit State Configuration</u>	<u>Strengthening</u>	<u>Concrete Strength</u>
Beam: T- Shaped Cross-section	1	1.1	Flexure	None	High
	1	1.2	Flexure	A	High
	1	1.3	Flexure	B	High
	2	2.1	Flexure	None	Low
	2	2.2	Flexure	A	Low
	2	2.3	Flexure	B	Low
	3	3.1	Shear	None	High
	3	3.2	Shear	A	High
	3	3.3	Shear	B	High
	4	4.1	Shear	None	Low
	4	4.2	Shear	A	Low
	4	4.3	Shear	B	Low
Slab: Rectangular Cross-section	5	5.1	Flexure	None	High
	5	5.2	Flexure	A	High
	5	5.3	Flexure	B	High
	6	6.1	Flexure	None	Low
	6	6.2	Flexure	A	Low
	6	6.3	Flexure	B	Low

▶ Test Matrix – Columns

<u>Column Specimen</u>	<u>Limit State Configuration</u>	<u>Strengthening</u>	<u>Concrete Strength</u>
1	Compressive	None	High
2	Compressive	A	High
3	Compressive	B	High
4	Compressive	None	Low
5	Compressive	A	Low
6	Compressive	B	Low

Innovative Bonding and Fibers for Strengthening Concrete Structures

Project Number: NCSU-3



LIFE Form Completion

Innovative FRP Shear Transfer Mechanism for Precast Prestressed Concrete Sandwich Panels

Project Number: NCSU-4

- ▶ PI: Dr. Sami Rizkalla
- ▶ Industrial Collaborator: AltusGroup, Inc.
- ▶ Graduate Students: Greg Bunn
- ▶ Overview : Investigate the fundamental properties of a unique CFRP shear transfer mechanism.
- ▶ Budget : \$50,000

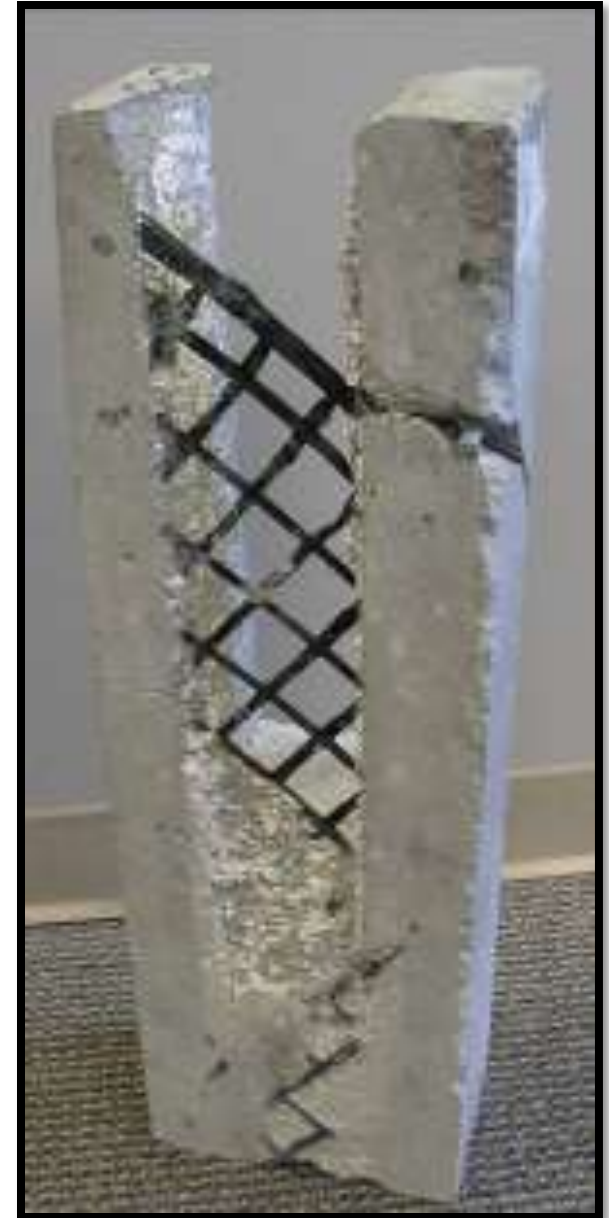
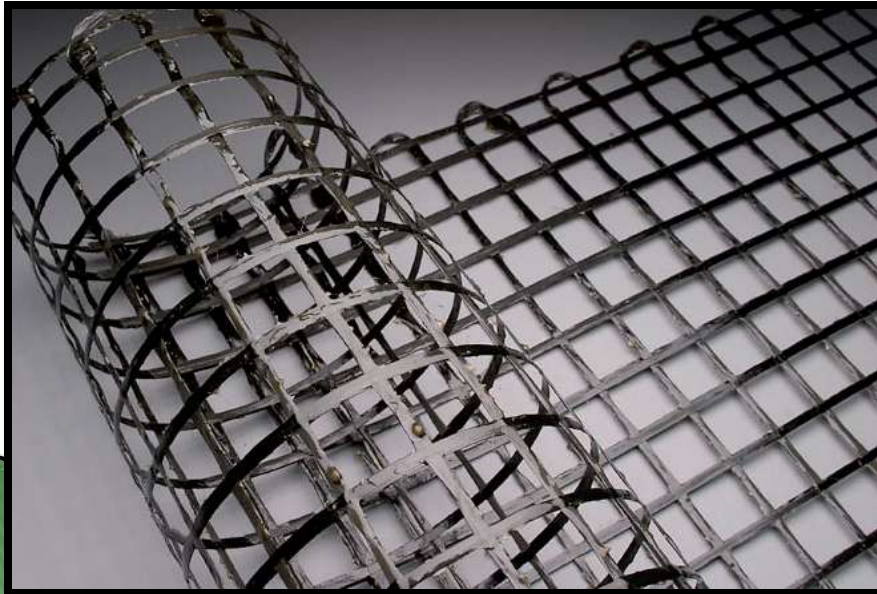
Introduction

- ▶ Precast, reinforced, and prestressed concrete sandwich panels have been produced for over 50 years.
- ▶ Panels are typically load bearing and provide insulating value.



CFRP Shear Grid

- ▶ Provides up to 100% composite action by transferring all forces across the insulation that separates the two wythes of concrete through truss action.
- ▶ Creates a more thermally efficient building envelope.



EPS



- ▶ Expanded Polystyrene Insulation (EPS) –
 - Closed-cell Insulation
 - Manufactured by “expanding” a polystyrene polymer

XPS



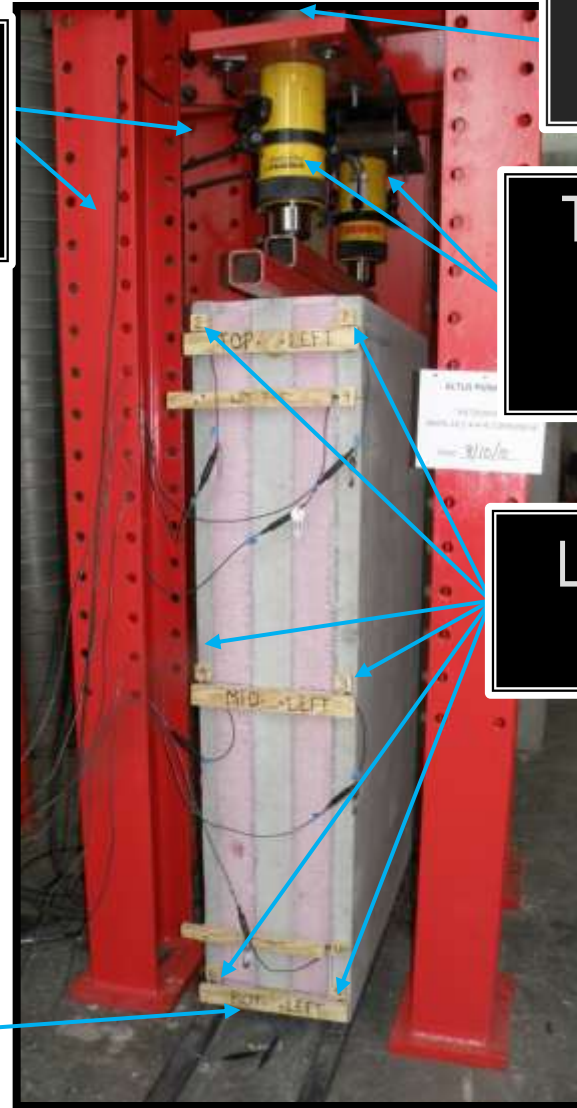
- ▶ Extruded Polystyrene Insulation (XPS) –
 - Rigid Insulation
 - Manufactured using and extrusion process of polystyrene polymer

Push Test Setup

Dual Reaction Frames



Outer Wythes Supported



150 Kip Load Cell

Two - 60 ton Hydraulic Jacks

Linear Pots

Testing Parameters

Insulation Type	
EPS	XPS

Insulation Thickness	
EPS	XPS
2"	2"
4"	4"
6"	
8"	

Panel Width
24"
36"
48"
72"

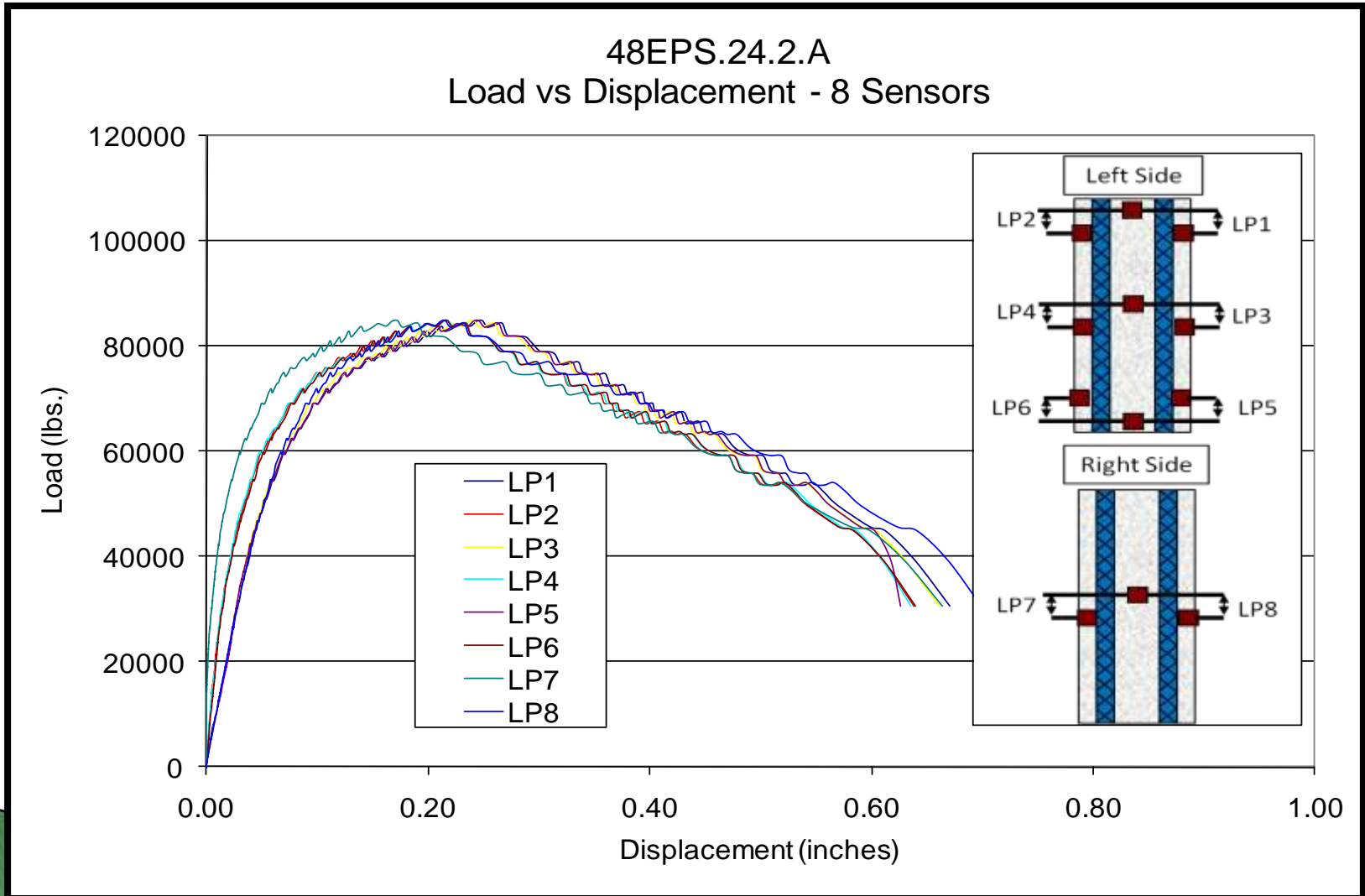
CGRID Spacing
12"
18"
24"
36"

Insulation Concrete Interface
Bonded - Typical Practice
Debonded - Plastic Sheets Breaking Bond

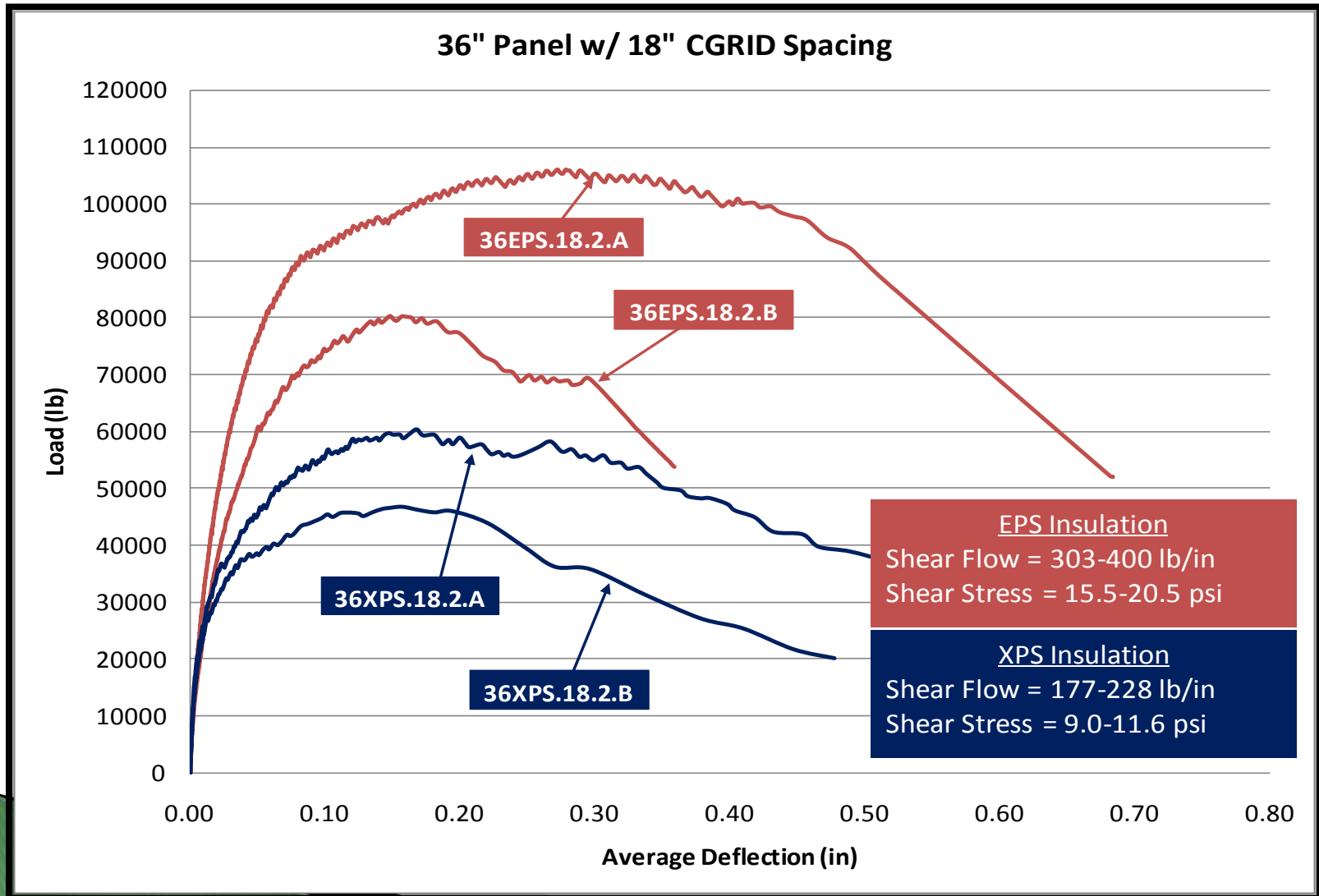
CGRID Continuity
No Gap
6" Gap

CGRID Orientation
Vertical
Transverse

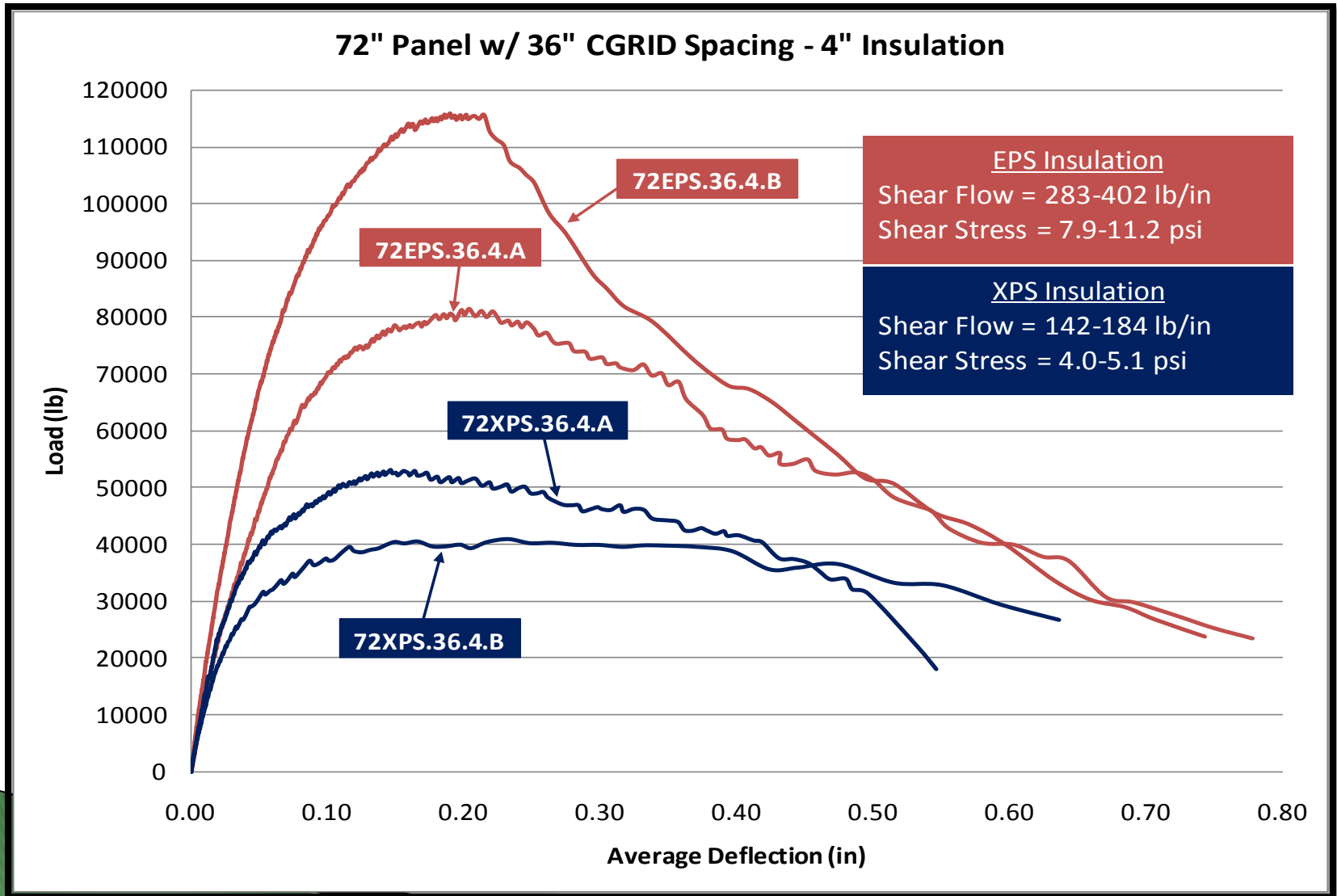
Typical Push Test Results



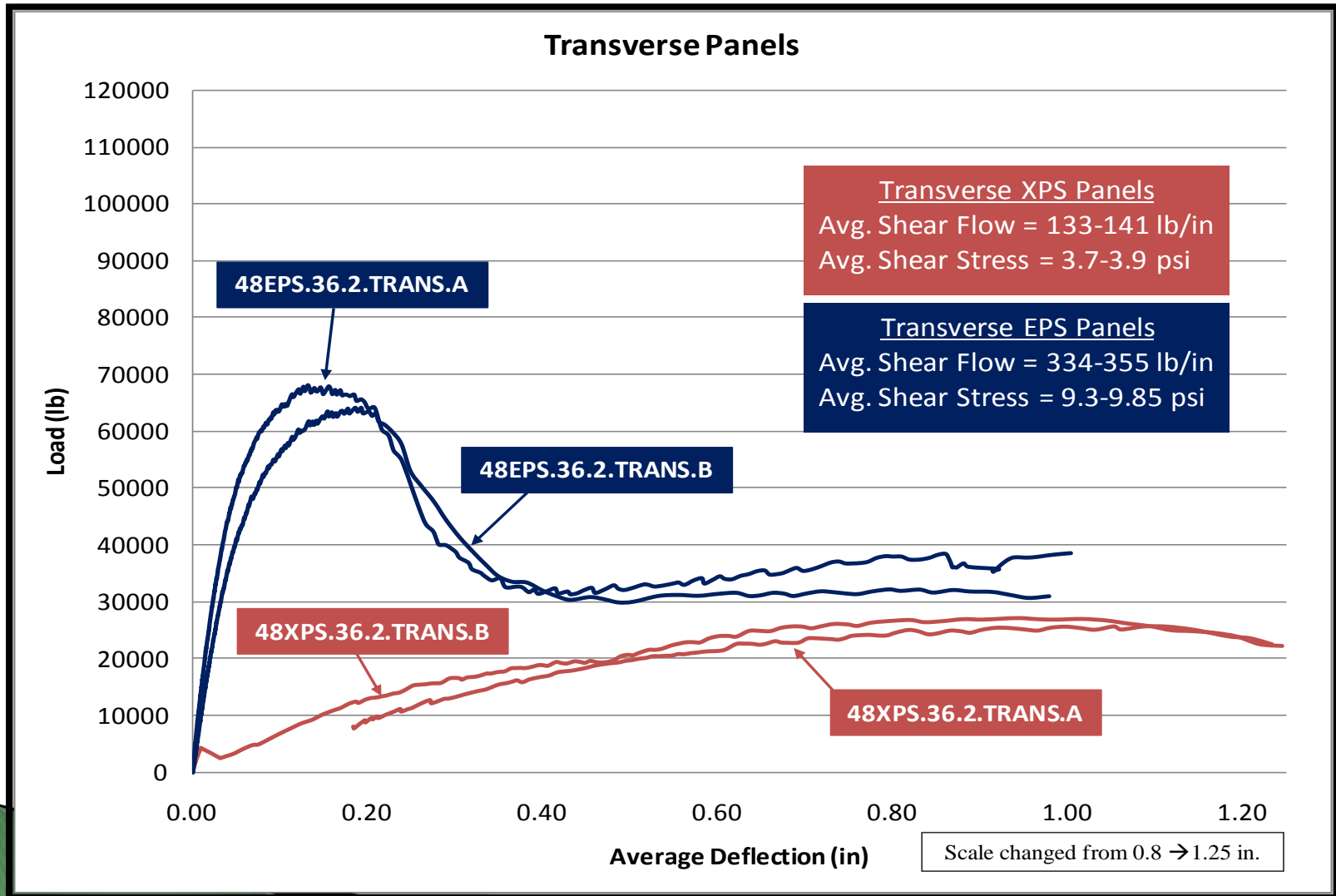
2" XPS vs 2" EPS



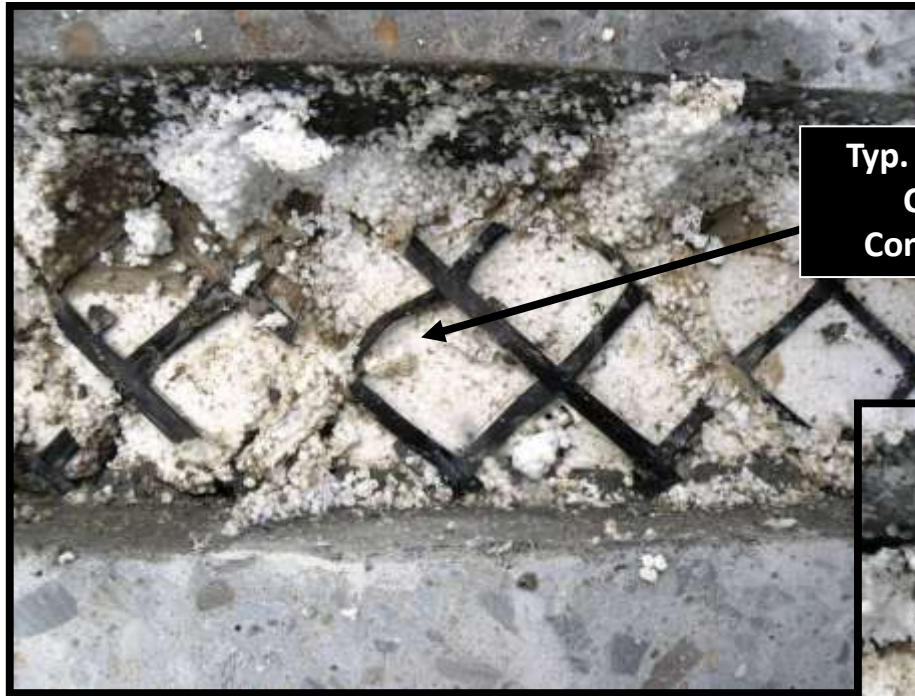
4" XPS vs 4" EPS



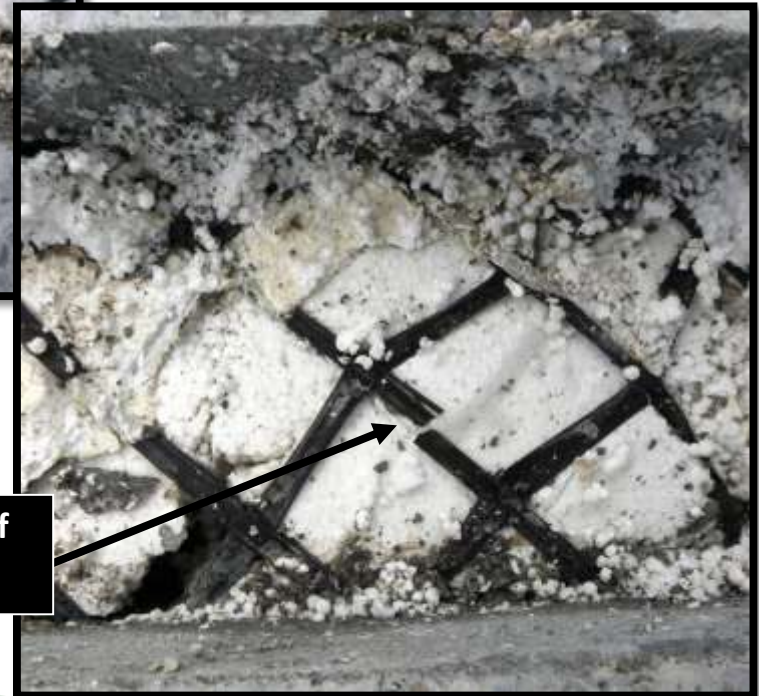
2" XPS vs 2" EPS w/ Transverse CGRID



Typical Failure Mode



Typ. Buckling of
Cords in
Compression

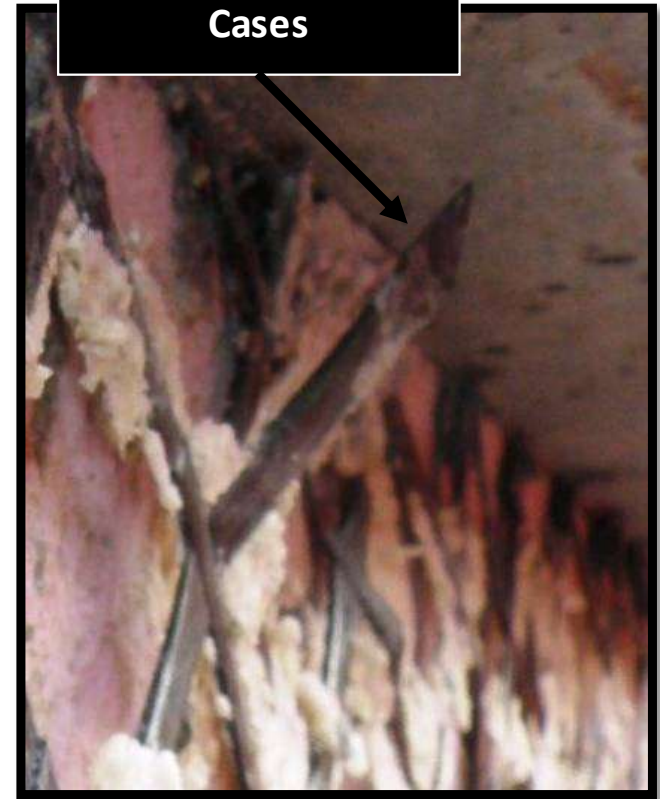


Typ. Rupturing of
Cords in Tension

Typical Failure Mode

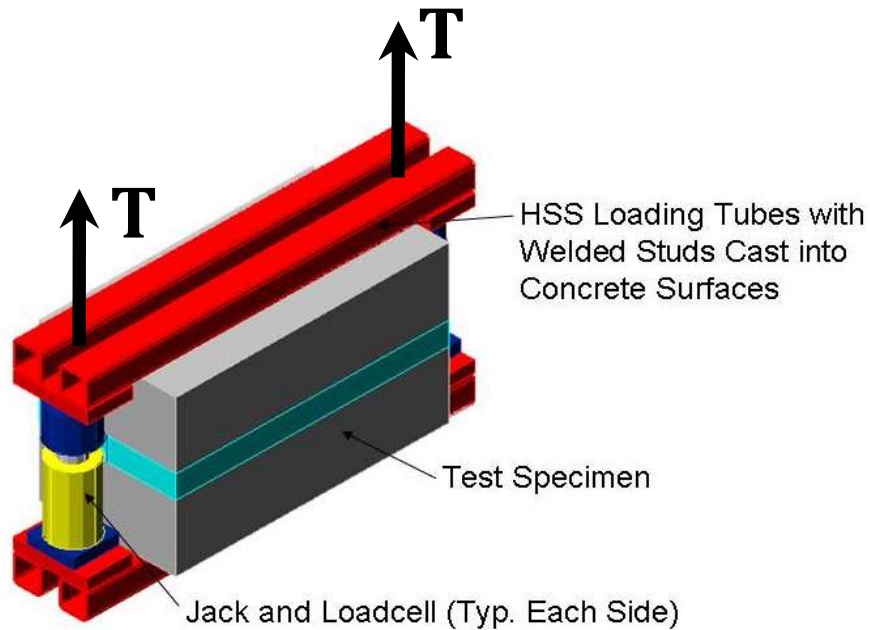


Typ. Rupturing of
Cords in Tension

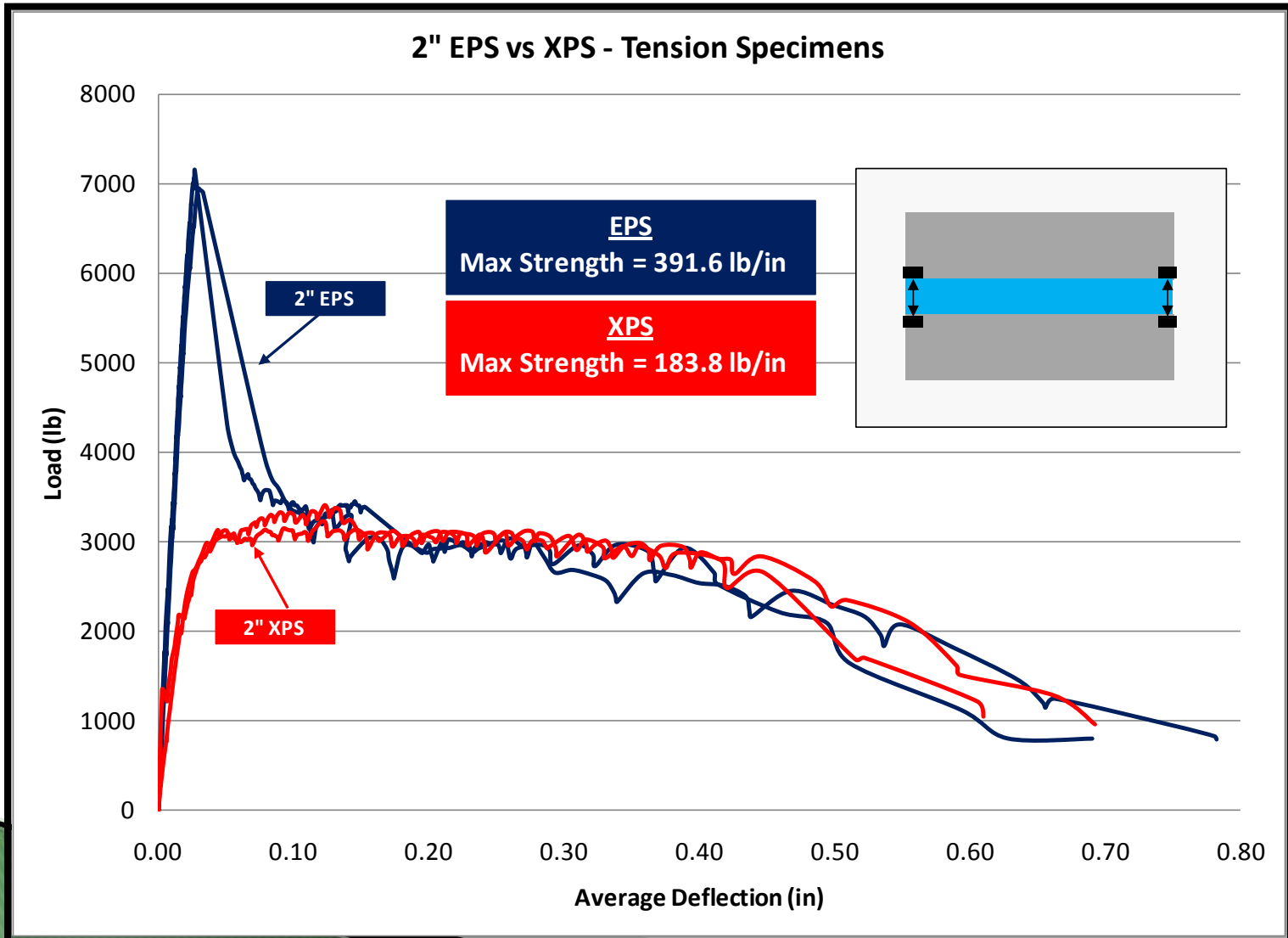


Observed Pull-Out
of CGRID in Some
Cases

Direct Tension Tests on Concrete/Insulation Specimens

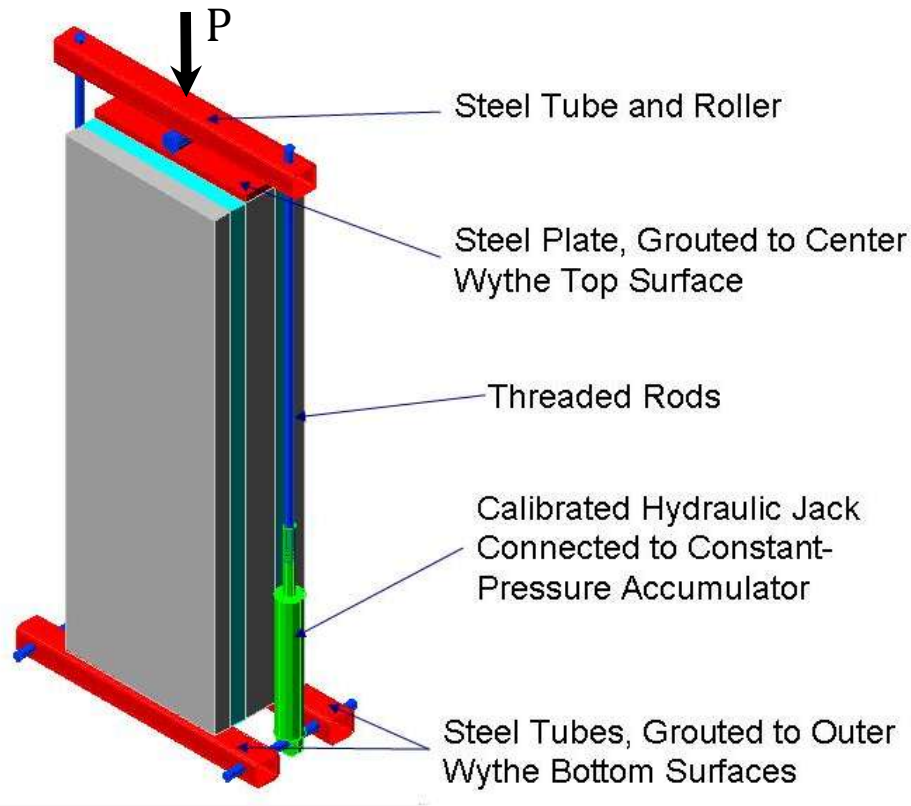


Tension Test Results – 2" Insulation

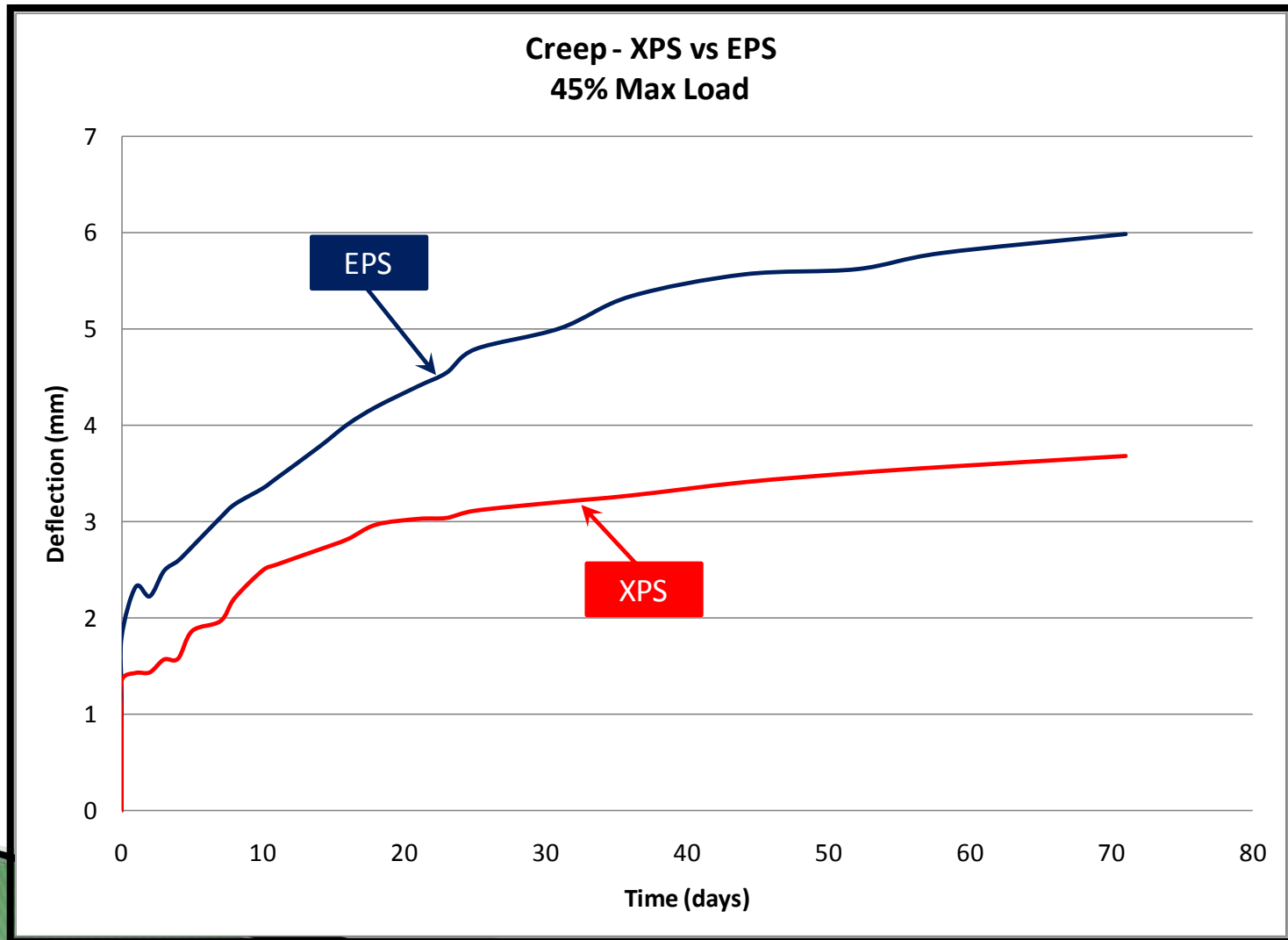


Creep Tests on Altus Wall Panels 1 Year

Isometric View



Creep Data : Testing in Progress



Conclusions

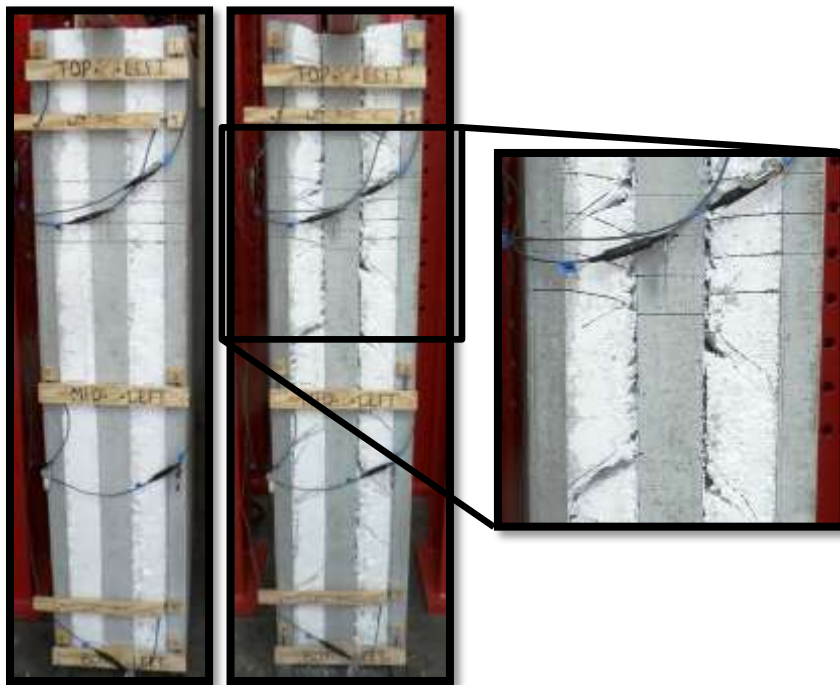
- ▶ EPS insulation exhibits greater shear capacity.
- ▶ XPS panels rely primarily on the CGRID reinforcement.
- ▶ Increasing the thickness of EPS tends to have a negative effect on the shear capacity.
- ▶ Increasing thickness of XPS seems to have minimal effect.
- ▶ Tension tests exhibited similar behavior.

Future Work

- ▶ Analyze test data to provide design guidelines for use of CGRID as a shear transfer mechanism in precast concrete wall panels.
- ▶ Investigate the effect of freeze/thaw cycling on composite action.
- ▶ Complete 1 year creep testing – In progress.
- ▶ Explore the use of other FRP and insulation types in wall panels.

Innovative FRP Shear Transfer Mechanism for Precast Prestressed Concrete Sandwich Panels

Project Number: NCSU-4



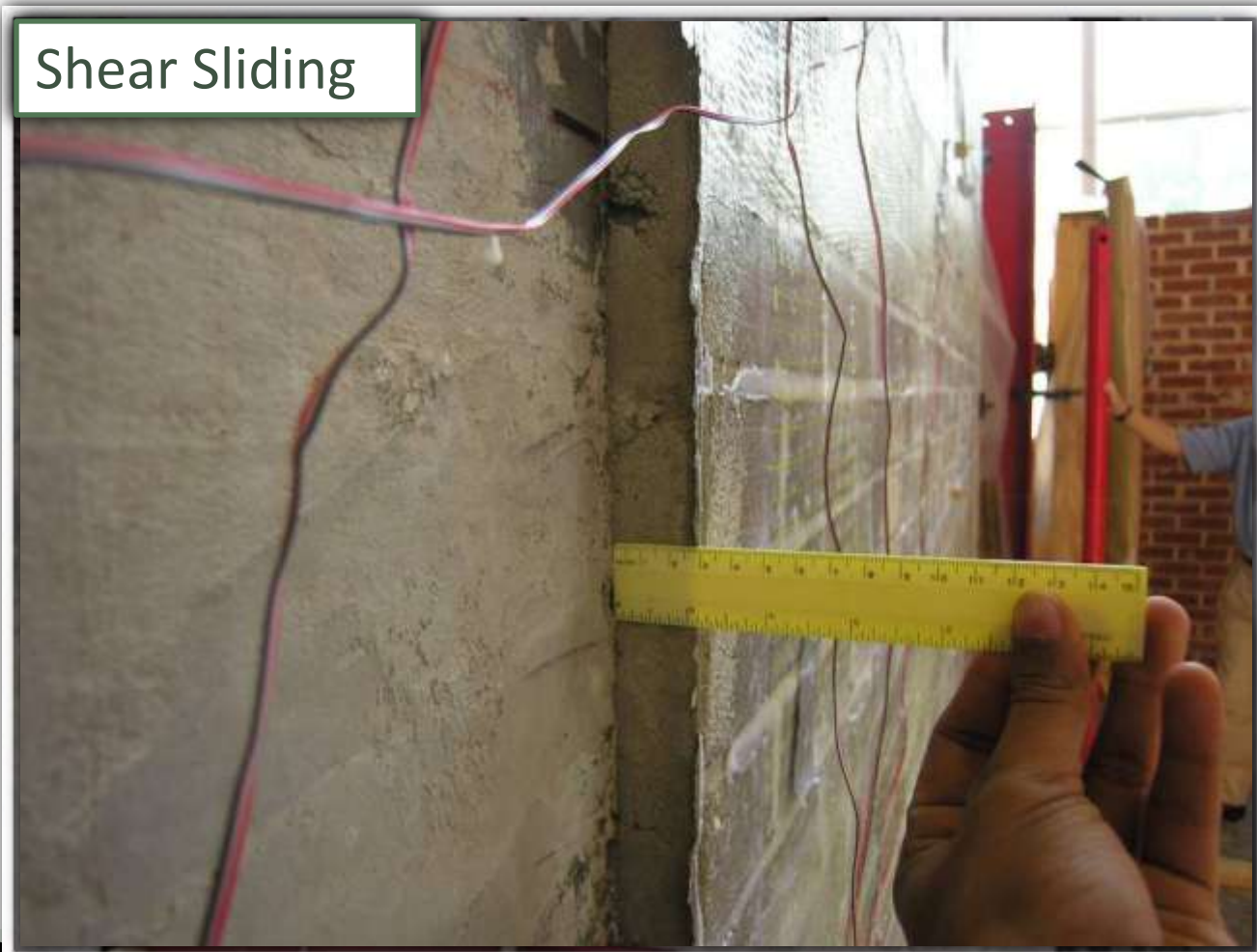
LIFE Form Completion

FRP Anchorage Systems for Strengthening Infill Masonry Structures

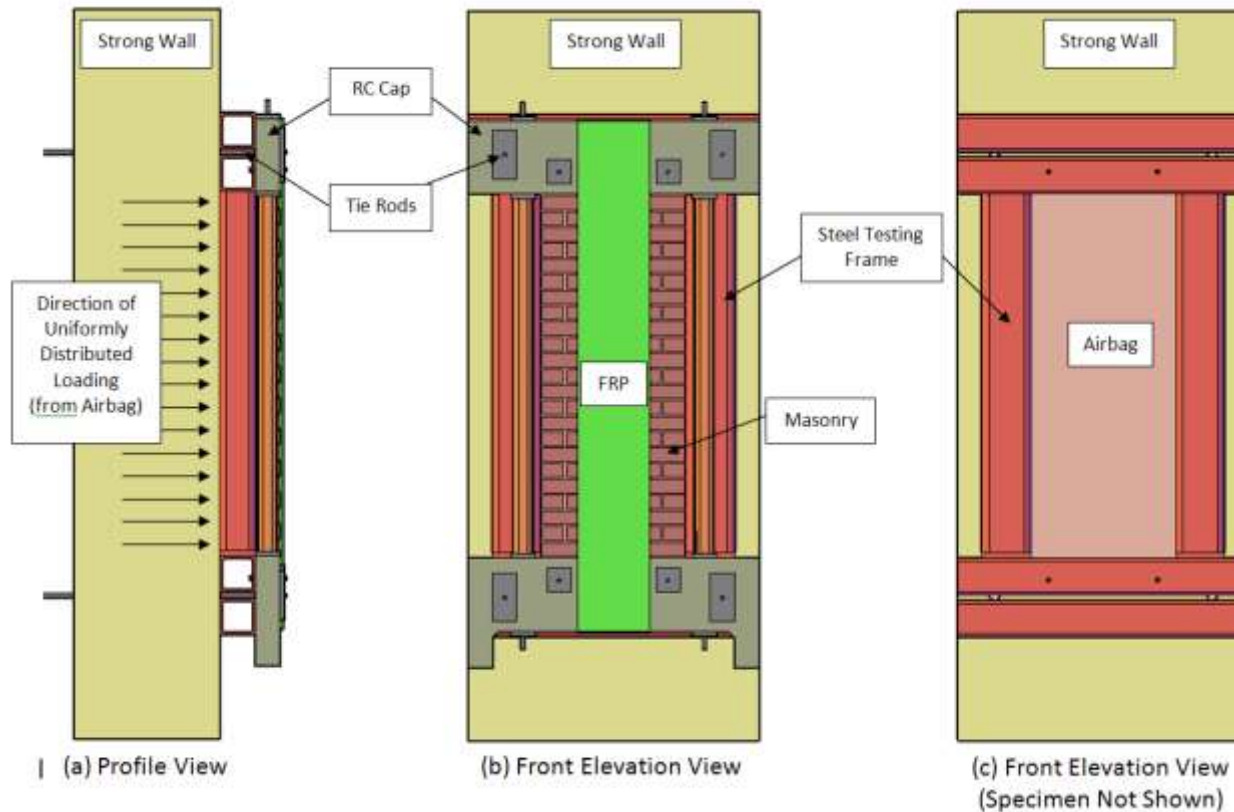
Project Number: NCSU-5

- ▶ PI: Dr. Sami Rizkalla & Dr. Tamon Ueda
- ▶ Industrial Collaborators: Fyfe Company, LLC & Nippon Steel Materials Co., Ltd.
- ▶ Graduate Students: Dillon Lunn & Shohei Maeda
- ▶ Objective: Explore the performance of innovative FRP anchorage systems for strengthening of masonry infill walls
- ▶ Budget: \$50,000

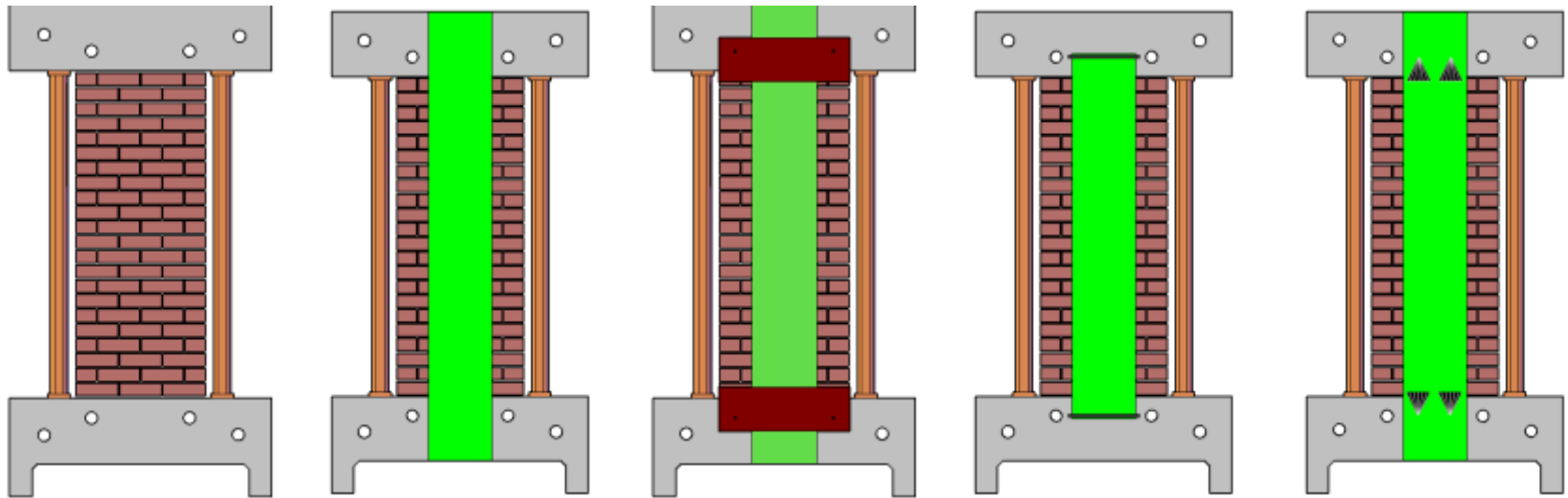
► Motivation



► Test Setup



► FRP Anchorage Systems



Control

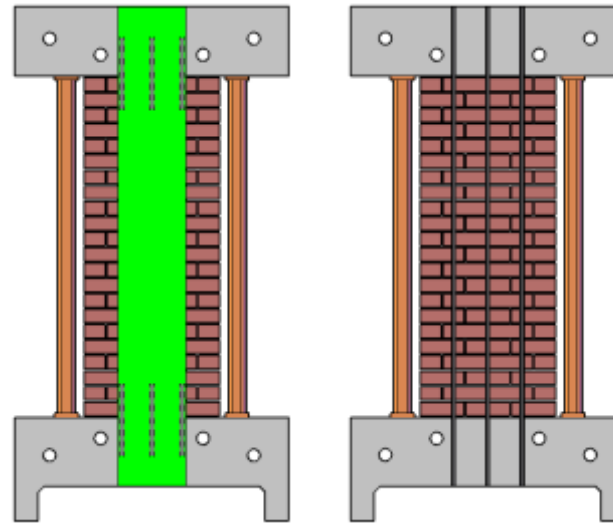
Overlap

Mechanical

Embedded Bar

Fiber Anchor

► FRP Anchorage Systems



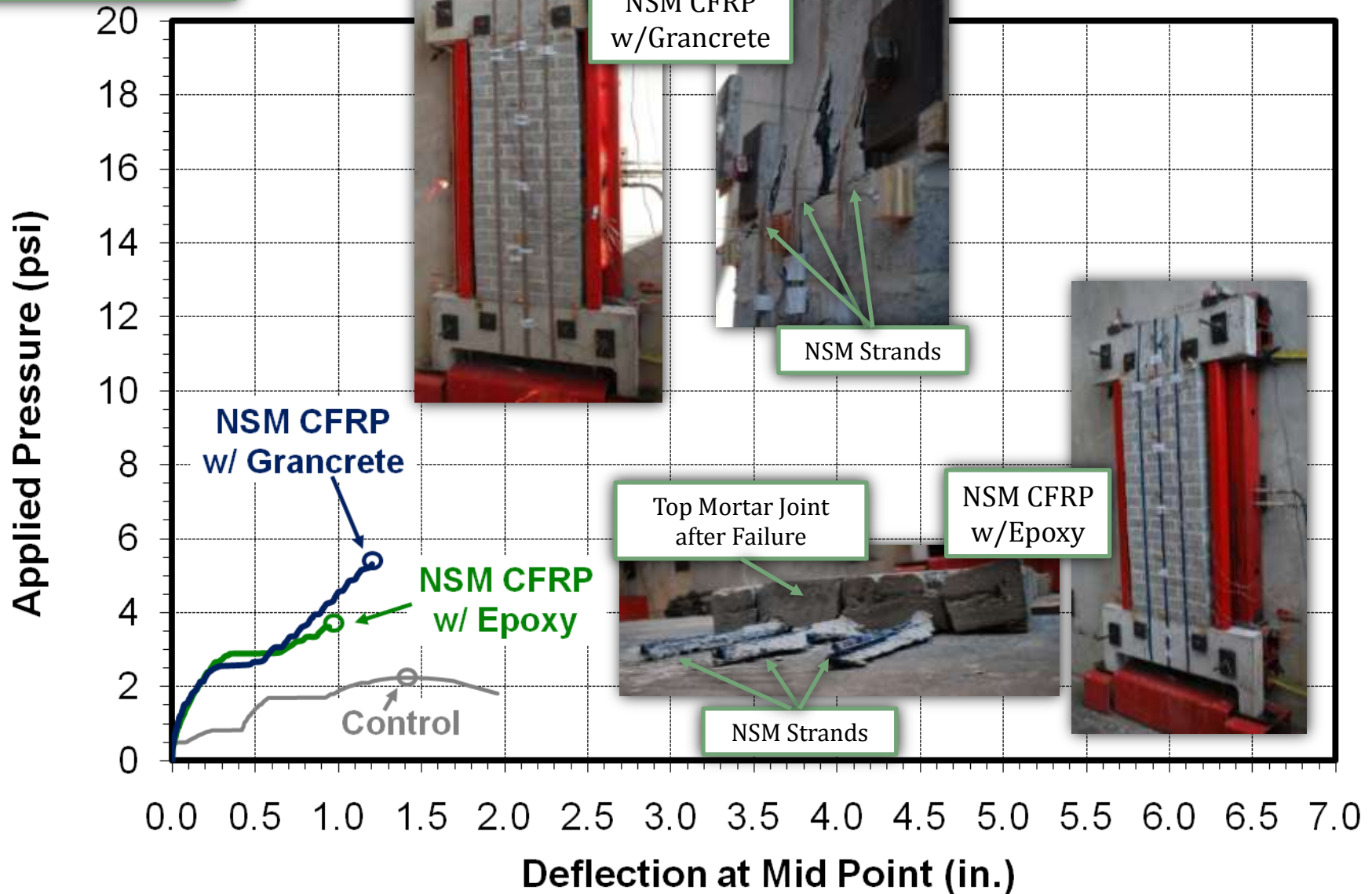
Shear Key

Near Surface
Mounted

FRP Anchorage Systems for Strengthening Infill Masonry Structures

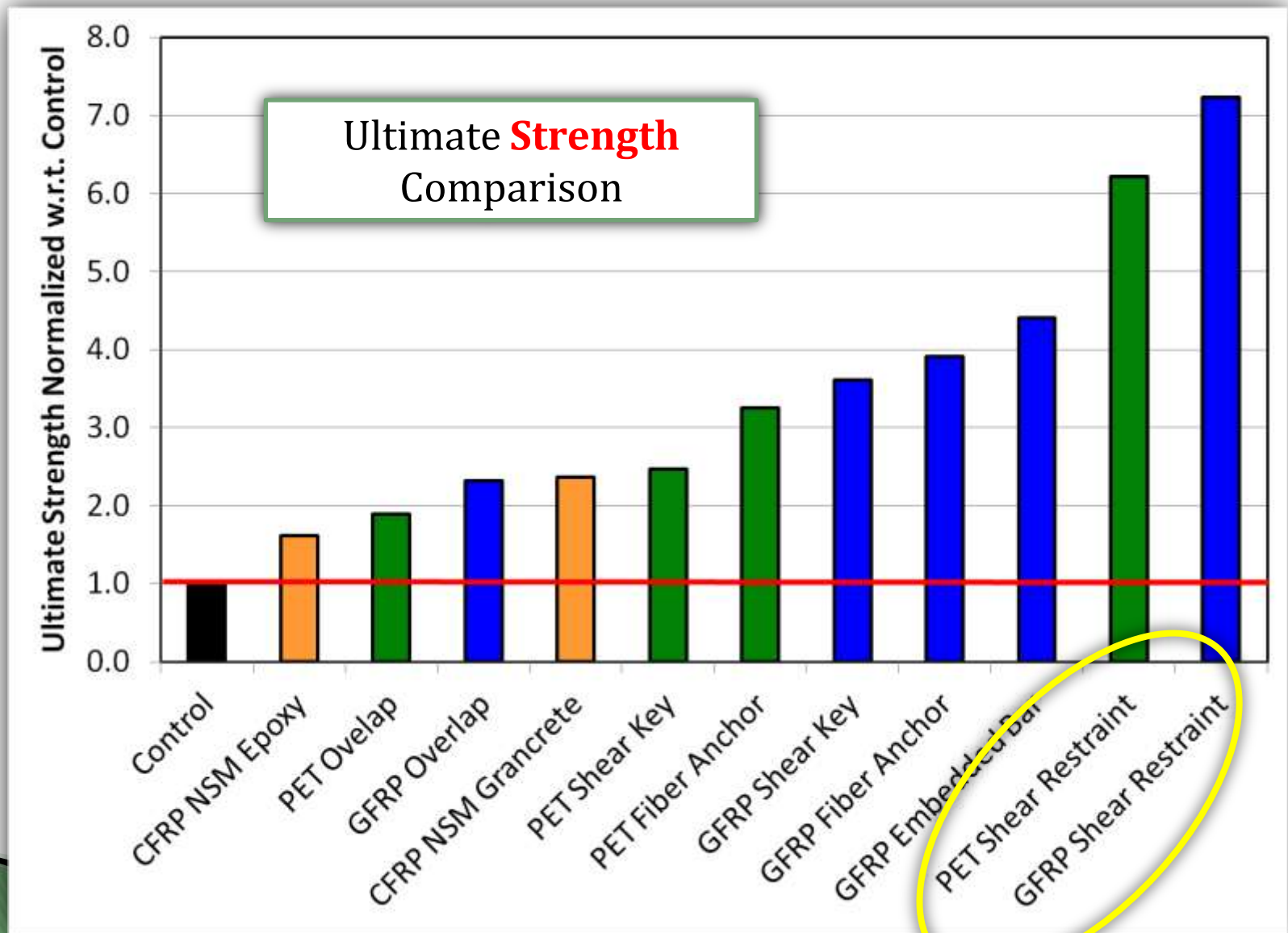
Project Number: NCSU-5

NSM CFRP



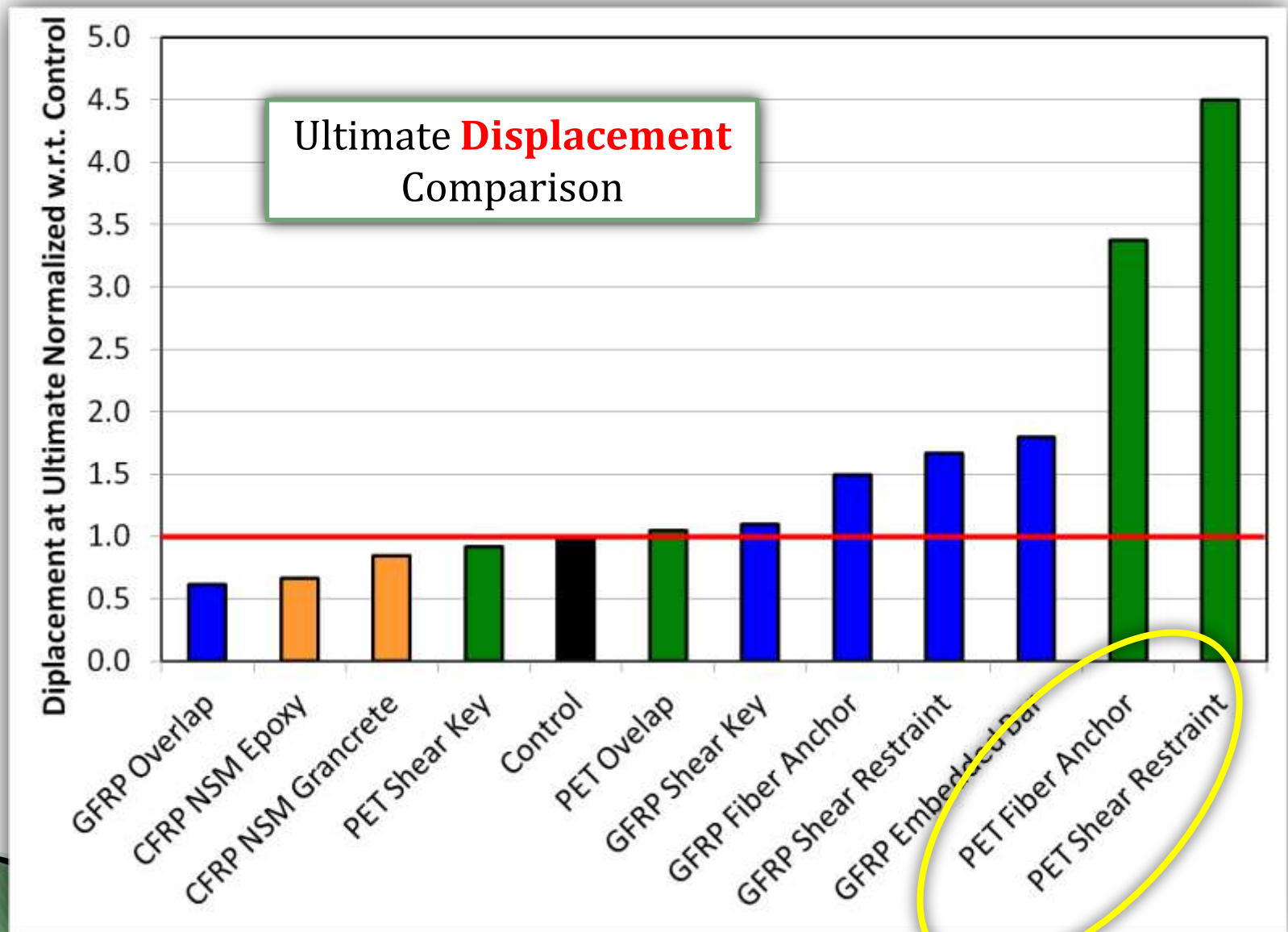
FRP Anchorage Systems for Strengthening Infill Masonry Structures

Project Number: NCSU-5



FRP Anchorage Systems for Strengthening Infill Masonry Structures

Project Number: NCSU-5



▶ Future Work

- Non-Linear Finite Element Analysis
 - Material non-linearity
 - Geometric non-linearity

▶ Conclusions

- Increase in **strength** of between **1.6 to 7.2 times** the control
- Change in **displacement** capacity ranged between **0.6 to 4.5 times** the control
- **Mode of failure** closely related to **type of anchorage**
- **GFRP** typically provided **greater strength**, while **PET** provided **greater ductility**

FRP Anchorage Systems for Strengthening Infill Masonry Structures

Project Number: NCSU-5



LIFE Form Completion

Motion to Accept a New Member

Move to accept the Korea Institute of Construction Technology (KICT) as a member of the NSF I/UCRC “Center for Integration of Composites into Infrastructure (CICI)” for the period of Feb 1, 2011 to June 30, 2013. The research project that will be undertaken is the “Use of FRP for Innovative Insulated Concrete Sandwich Panels”.

PI: Dr. Sami Rizkalla

Graduate Student: Greg Bunn