Florida Slab Beam (FSB) with Ultra-High Performance Concrete (UHPC) Joint Connections

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Outline

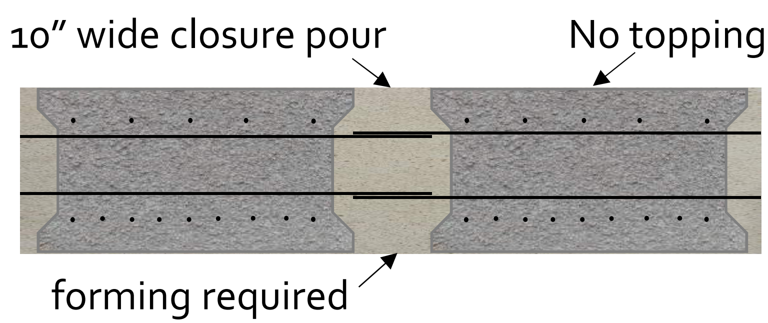
- Background
  - Slab Beams
  - Florida Slab Beam (FSB)
  - Ultra-High Performance Concrete (UHPC)
- Objectives
- Supporting Tasks
- Current Progress

Background

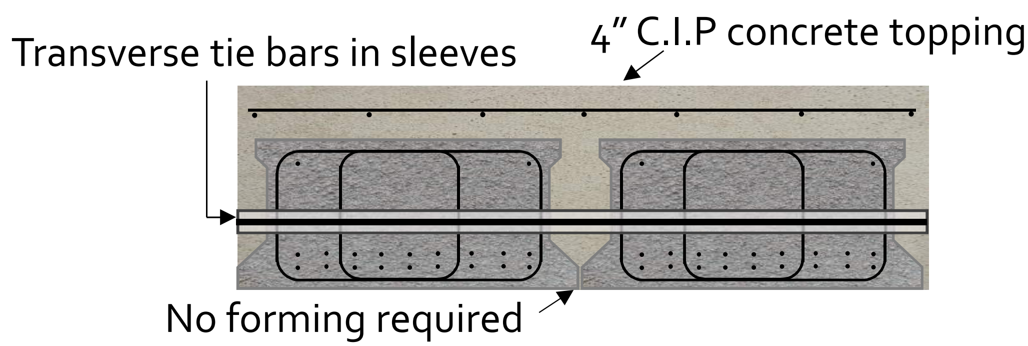
Slab Beams

Slab beams have been used in construction since prestressing began in the US

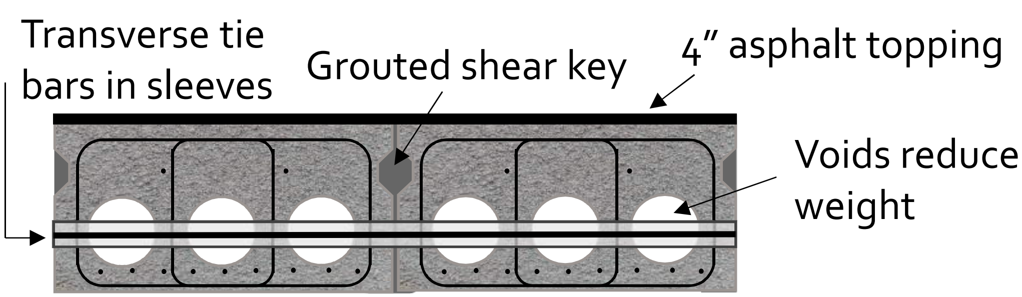
Prestressed Rectangular Slab Units (1955)



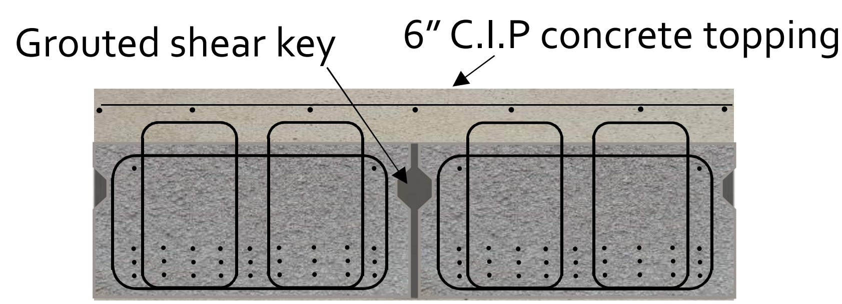
Prestressed Keyed Slab Units (1958)



Prestressed Voided Slab Units – Sonovoids (1959)



Prestressed Slab Units – PSU (2008)



Background

Slab Beams – Performance

There have been some issues observed with previously used slab beams

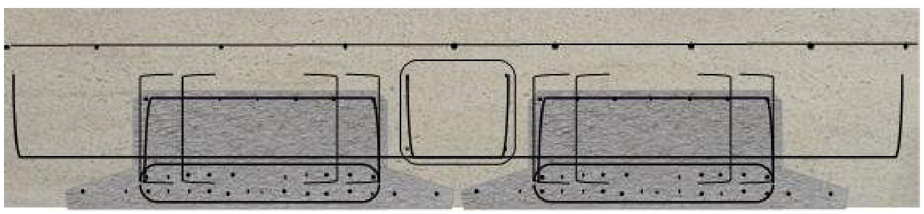
Bridge over Danforth Creek near West Palm Beach, FL (Spring 2018)

Background

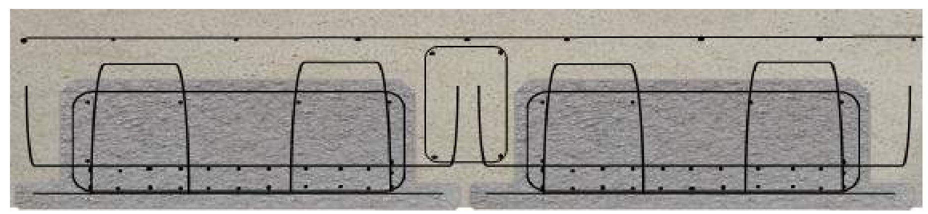
Slab Beams

Poor performance of previous systems led to development of alternate systems

Precast Composite Slab Span System – PCSS (2005)



Florida Slab Beam – FSB (2015)



These systems require field placement of large reinforcement

Background

Ultra-High Performance Concrete (UHPC)

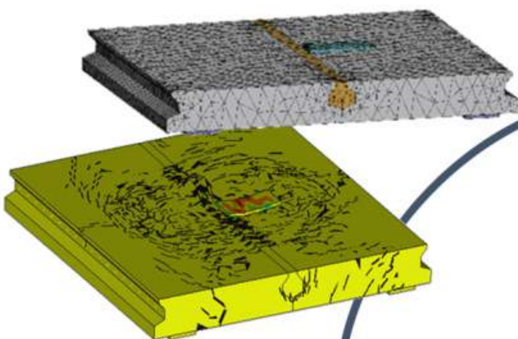
Property	***Range***	
Compressive Strength (f'_c)	20 to 30 ksi	140 to 200 MPa
Tensile Cracking Strength (f_r)	0.9 to 1.5 ksi	6 to 10 MPa
Modulus of Elasticity (E_c)	6,000 to 10,000 ksi	40 to 70 GPa

Source: https://www.fhwa.dot.gov/research/resources/uhpc/

Research Objectives

- Develop cross-section and joint region detail for short- to medium-span bridges for use with accelerated construction
- Assess strength and fatigue performance of cross-section and joint
- Recommend fabrication procedures, on-site construction practices, and erection tolerances

Methodology



Literature Review

Review all available research and field applications for UHPC joints and short-span bridge solutions.

(Tasks 1 and 2)

Analytical Program

Develop and analyze modified sections/joints and their impact on design through numerical analysis and parametric study.

(Tasks 2, 3 and 6)

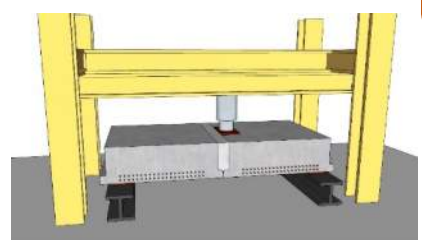
Refine Numerical Models

Optimize Developed Section

Experimental Program

Evaluate and refine developed sections through small- and full-scale testing.

(Tasks 4 and 5)



Supporting Tasks

1. Literature Review (short-span bridge options, joint details, current practices)
2. Conceptually and Analytically Develop FSB Design Standards and UHPC Joint Details
3. Conceptually and Analytically Develop FSB for 75-ft. Single Span with UHPC Joints
4. Small-Scale Joint Testing
   a) Develop and Evaluate Alternative FSB and UHPC Connection Details and Testing Protocol
   b) Develop Construction Documents for Beam Fabrication
   c) Fabricate Small-Scale Specimens for Strength and Fatigue Testing
   d) Strength Testing of Small-Scale Specimens
   e) Fatigue Testing of Small-Scale Specimens

Supporting Tasks (continued)

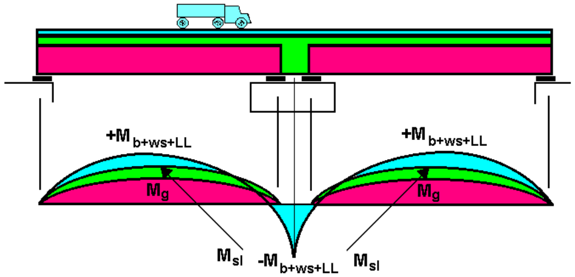
5. Full-Scale Specimen Testing
   a) Develop and Evaluate Alternative FSB Details and Testing Protocol
   b) Develop Construction Documents for Beam Fabrication
   c) Fabricate Full-Scale Specimens for Strength and Fatigue Testing
   d) Strength Testing of Full-Scale Specimens
   e) Fatigue Testing of Full-Scale Specimens
6. Conceptually and Analytically Develop FSB Detail as a Continuous Span
7. Draft Final Report and Closeout Teleconference
8. Final Report

Task 1 – Literature Review

Objectives

- Short-span bridge solutions
- Longitudinal and transverse joints (non-UHPC and UHPC)

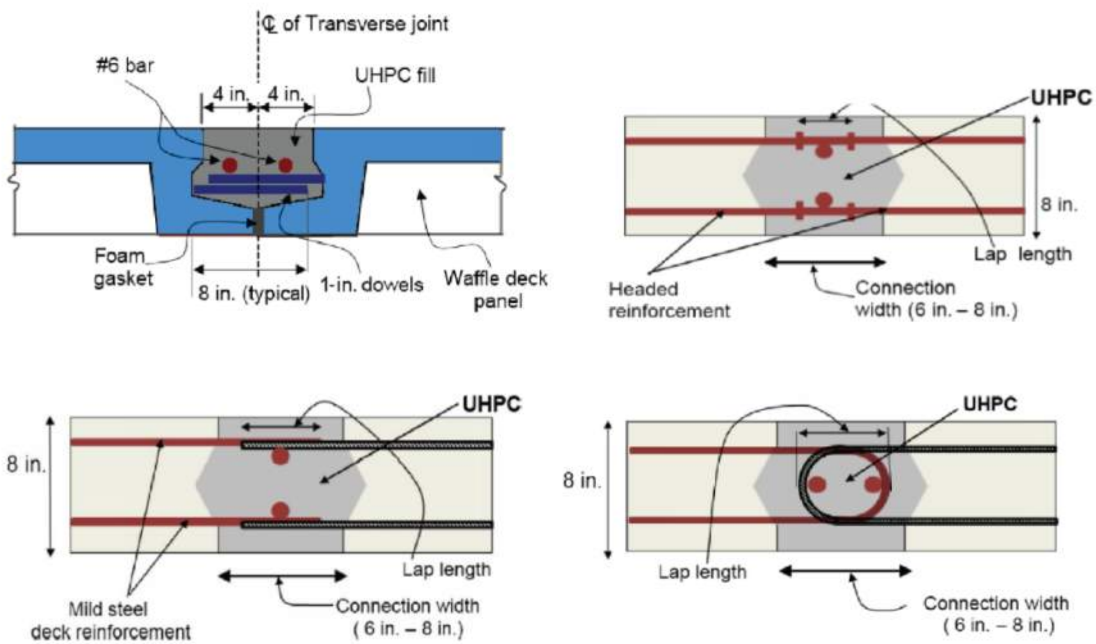
- Current practice with UHPC joints
- SDCL in prestressed concrete bridges



Task 1 – Literature Review

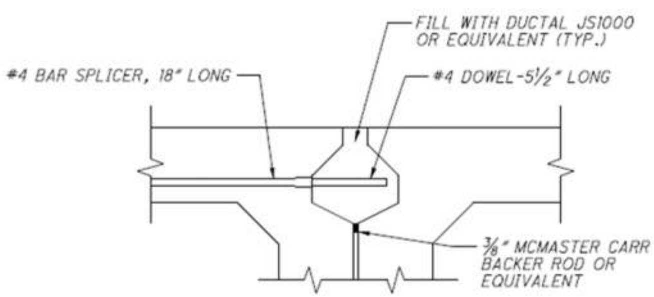
Longitudinal and Transverse Joints (UHPC)

Full-Depth Deck Connections



(Aeleti and Sritharan, 2014)

Adjacent Box-Beam Connections



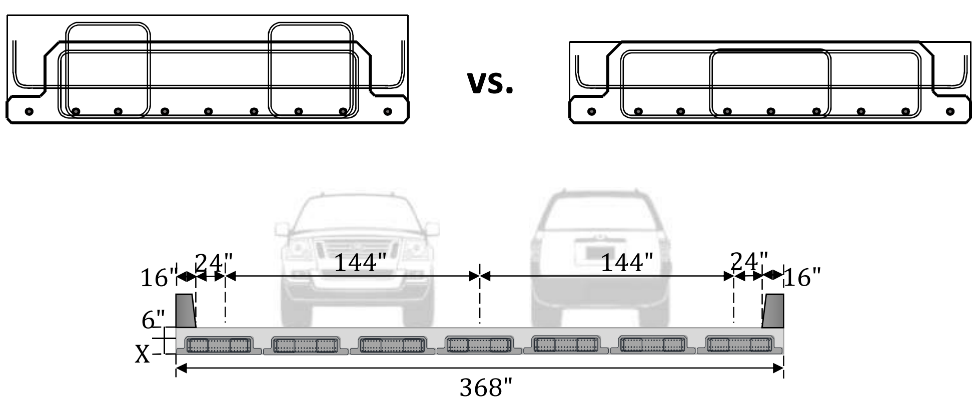
(Graybeal FHWA)

Task 2 – Section and Joint Development

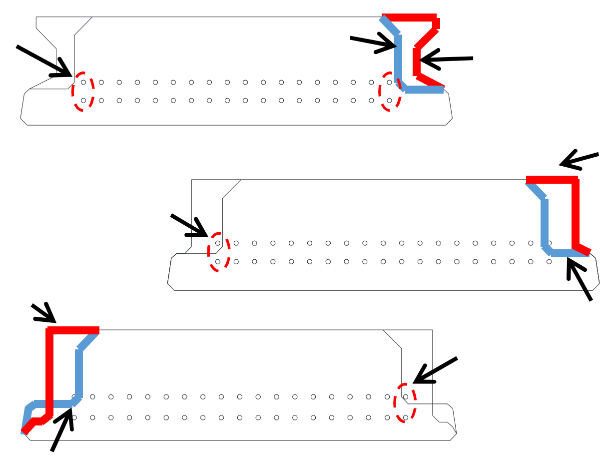
Objectives

- Feasible span lengths for beams without CIP deck
- Preliminary joint and section designs

Feasible span lengths



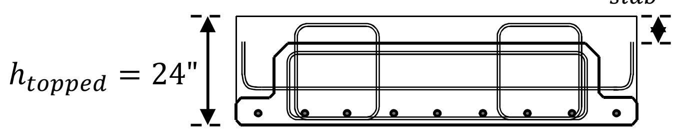
Modified section and joint



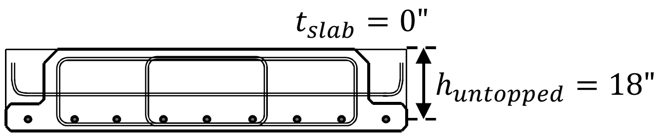
Task 2 – Section and Joint Development

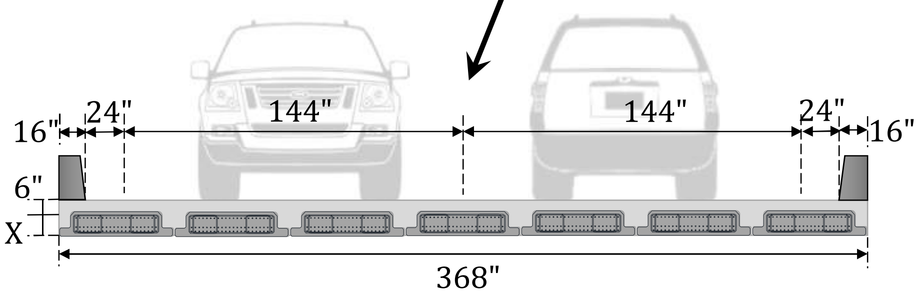
Feasible Span Lengths

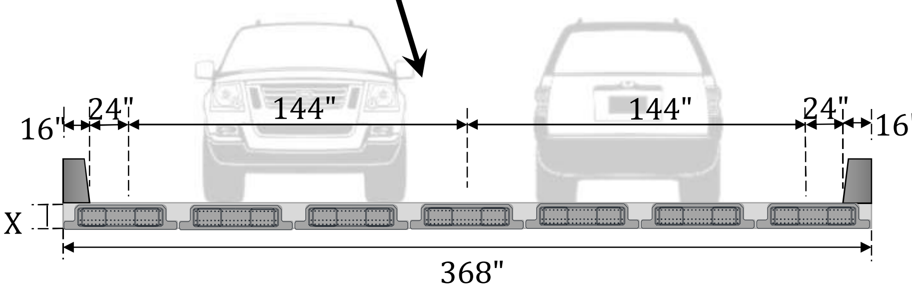
Current Design



Modified for ABC







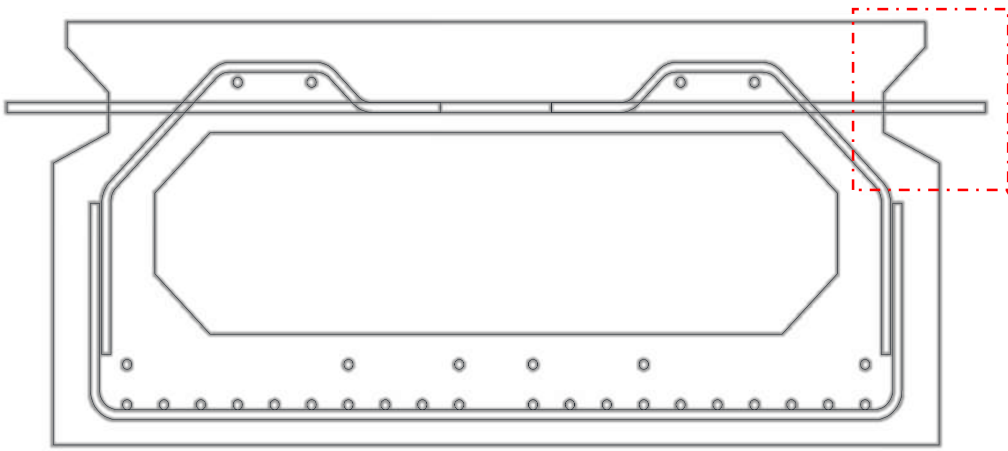
$$L_{max,topped} = 61'$$

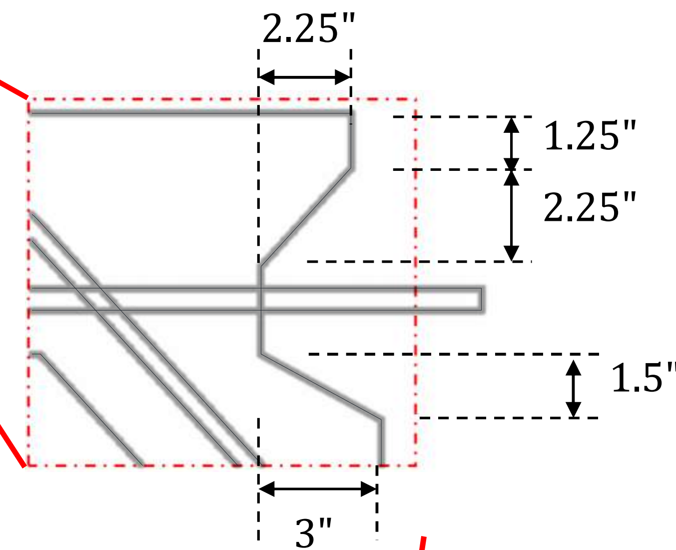
$$L_{max,untopped} = 55'$$

Task 2 – Section and Joint Development

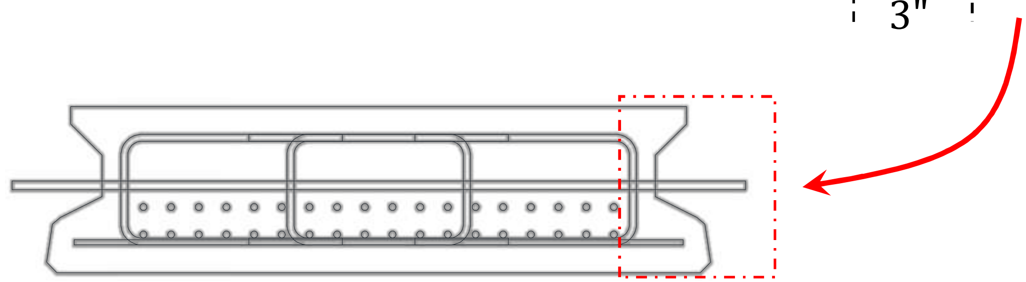
Development of Joint Details

<u>Option 1 – Box Beam Joint Integration</u>





Joint 1 – Integrated Box Beam Joint:

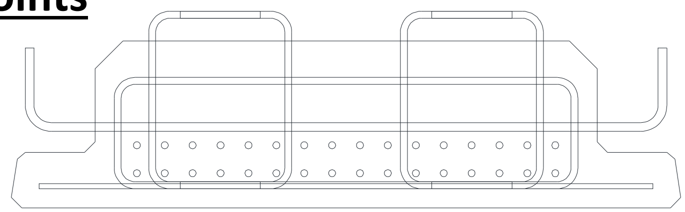


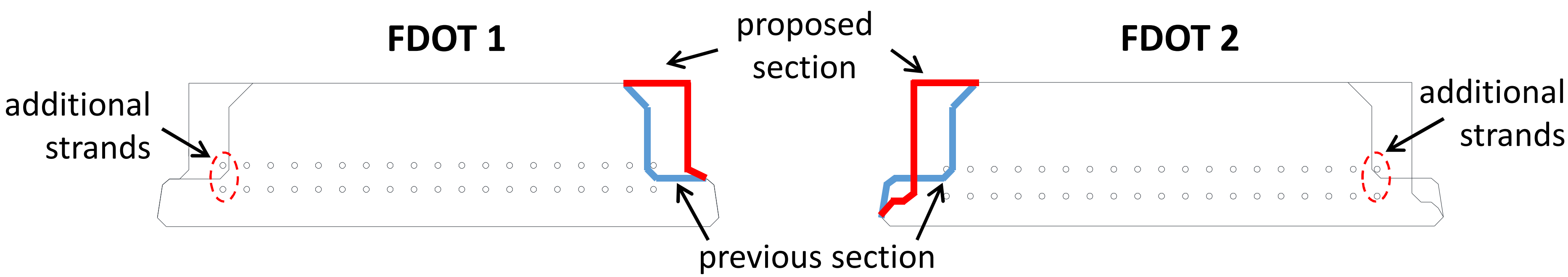
Task 2 – Section and Joint Development

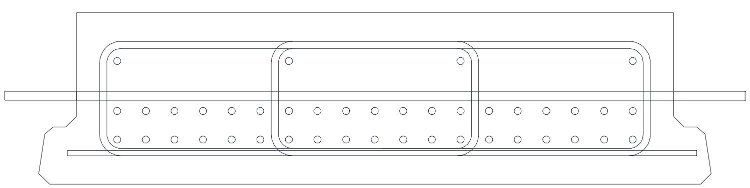
Development of Joint Details

<u>Options 2 and 3 – FDOT Joints</u>

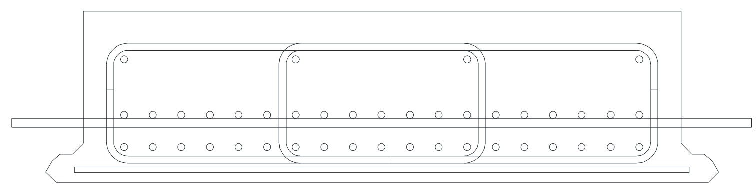
Original FSB Section:







Joint 2 – No Shear Key (4" lip)



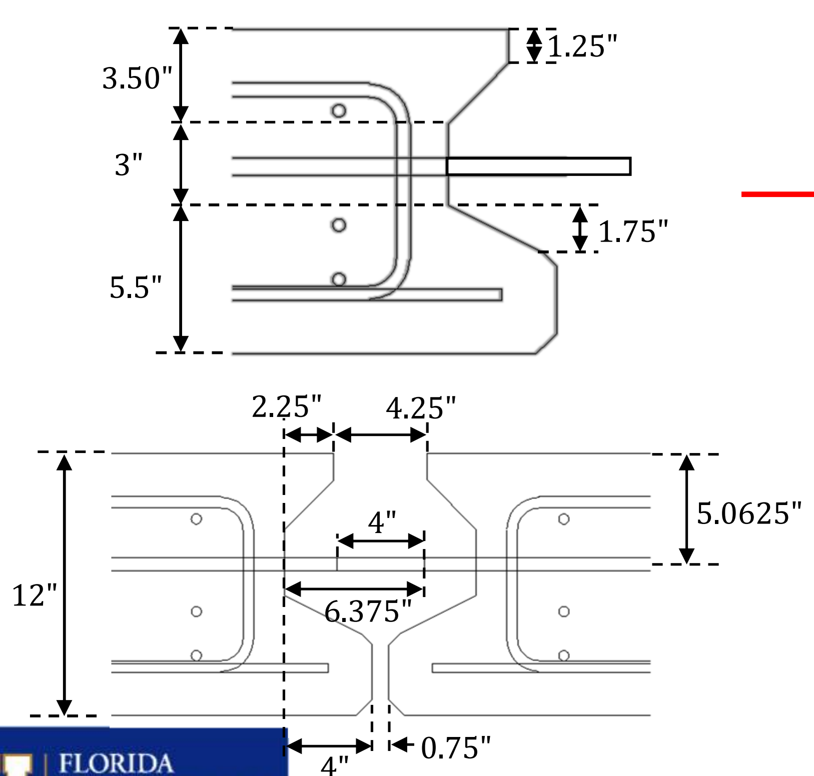
Joint 3 – No Shear Key (2" lip)

Task 2 – Section and Joint Development

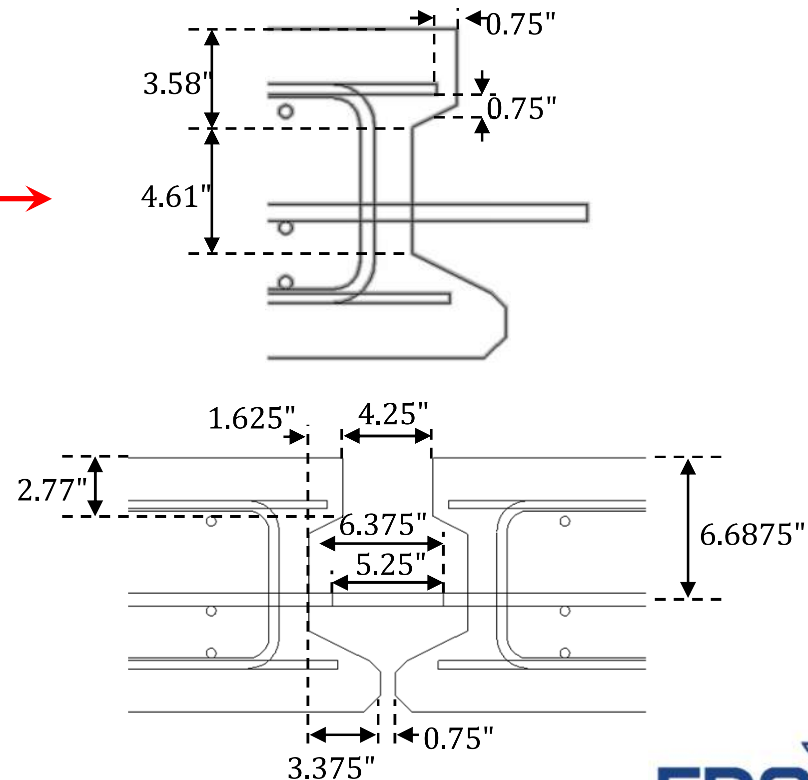
Development of Joint Details

Options 4 – Modified Box Beam Joint

Joint 1 – Integrated Box Beam Joint



Joint 4 – Modified Box Beam Joint

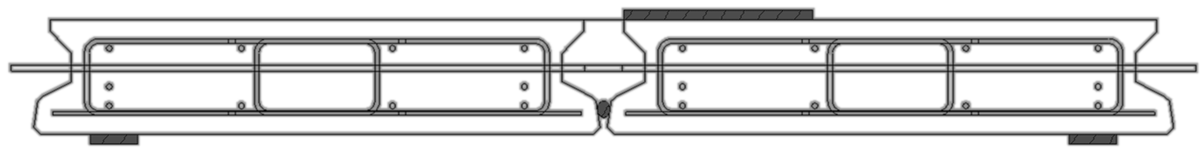


(Note this joint was developed after some testing in Task 4)

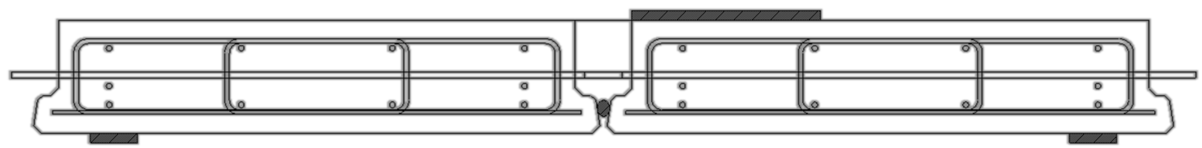
Task 2 – Section and Joint Development

Development of Joint Details

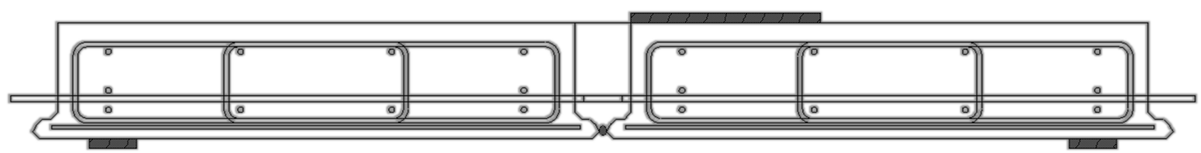
Joint 1 – Integrated Box Beam Joint:



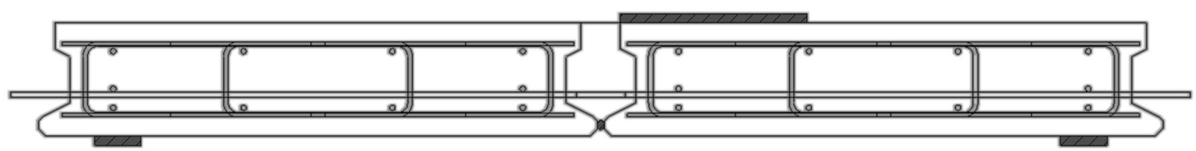
Joint 2 – No Shear Key (4" lip):



Joint 3 – No Shear Key (2" lip):



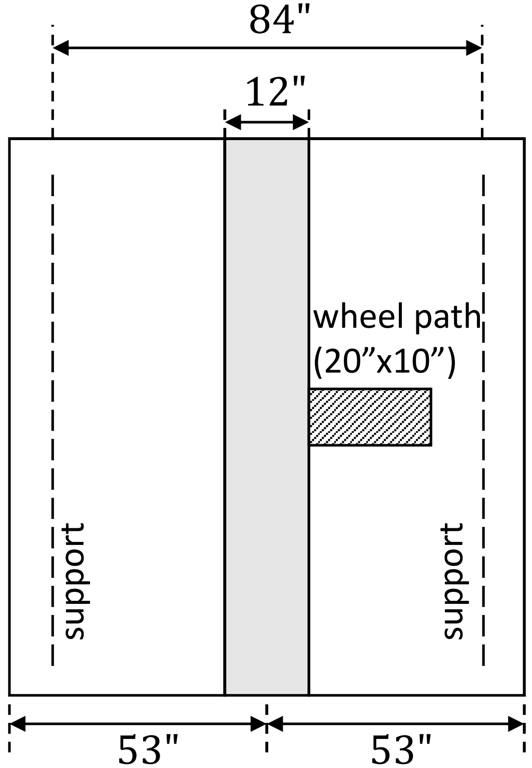
Joint 4 – Modified Box Beam Joint:



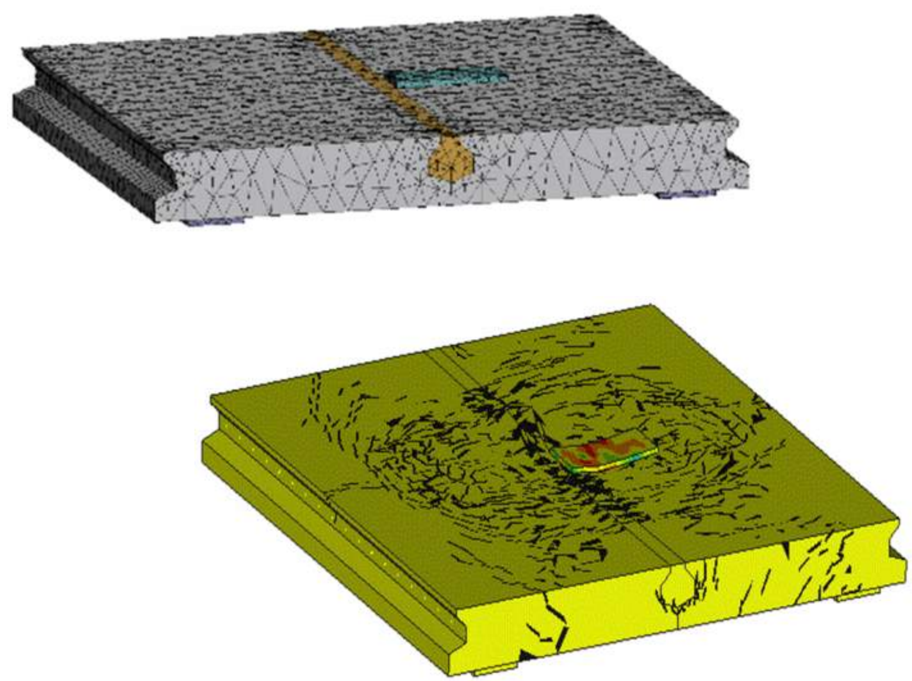
Task 2 – Section and Joint Development

Numerical Modeling of Joint Details

Experimental Setup



Numerical Model

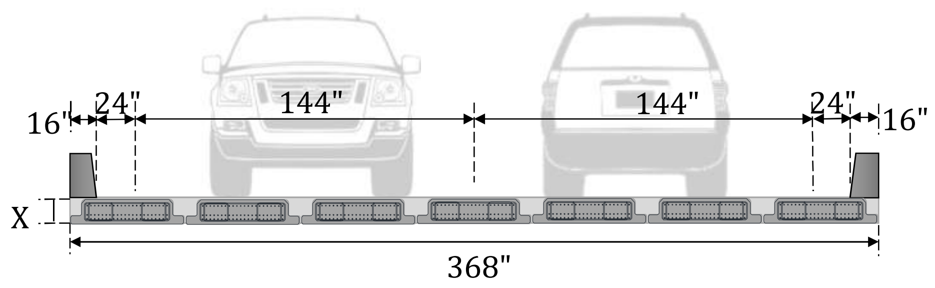


Task 3 – FSB for 75-ft. Span

Objectives

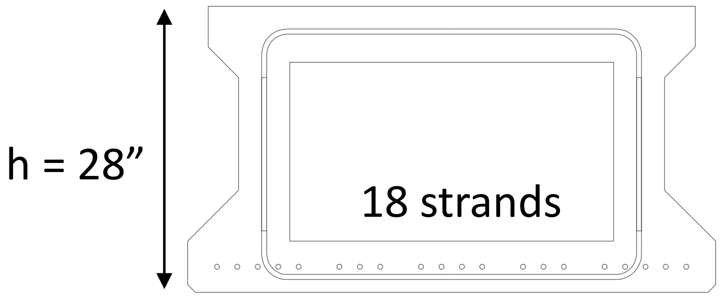
Determine options for 75-ft. span

- No CIP deck
- Adaptable for ABC projects (UHPC Joint)
- High notoriety

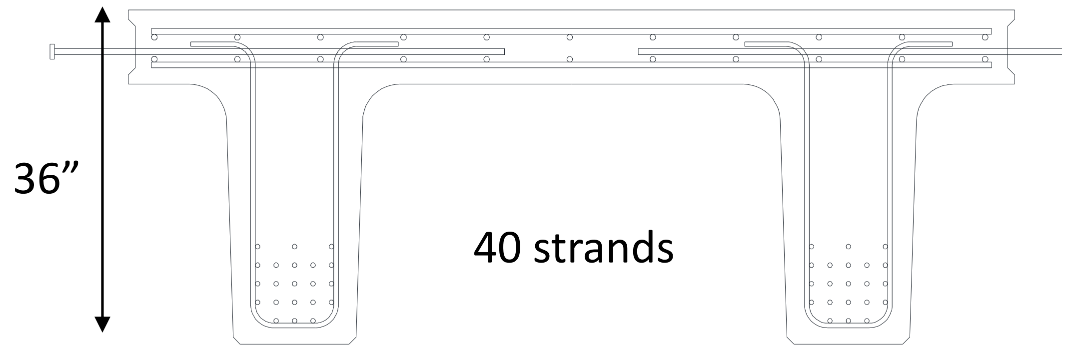


Task 3 – FSB for 75-ft. Span

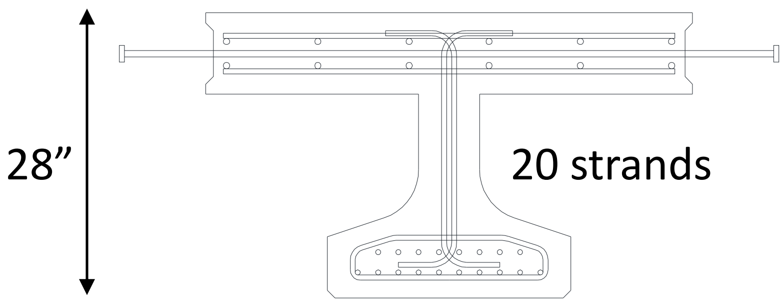
Section Options



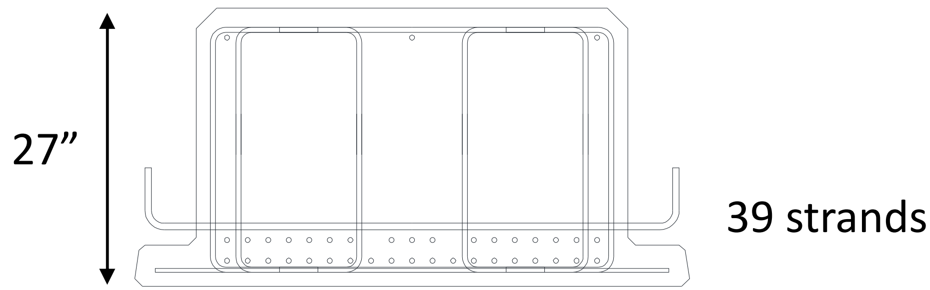
Box Beam



NEXT D Beam



Pre-Topped Florida Inverted-T Beam



Modified Florida Slab Beam

Task 3 – FSB

Section Options

Box Beam and Pre-Topped Florida Inverted-T are the most efficient sections

Section Type:	*Texas 4B28*	*NEXT D 96*	*Pre-Topped FIT*	*FSB 27x53*
depth [in]	28	36	28	27
width [in]	48	96	48	53
0.6” diameter strands for 75’ length	18	40	20 (4*)	39 (3**)
A [in^2]	678.8	1,562	635.4	1,176
I_{xx} [in^4]	68,745	176,674	77,574	74,098
y_t [in]	14.38	12.97	11.02	13.99
y_b [in]	13.62	23.03	16.98	13.01
weight [k/ft]	0.707	1.627	0.661	1.225
ρ (efficiency)	0.517	0.379	0.652	0.351

$$\rho = \frac{I}{A y_b y_t} = \frac{r^2}{y_b y_t}$$

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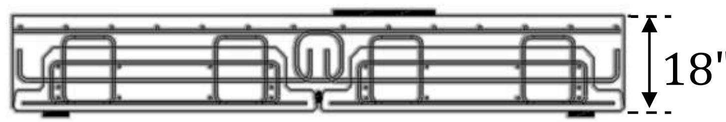
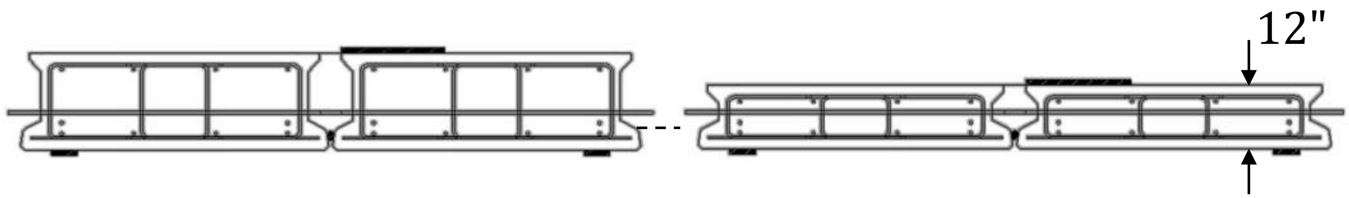
Task 4 – Joint Testing Program

Preliminary Test Specimens

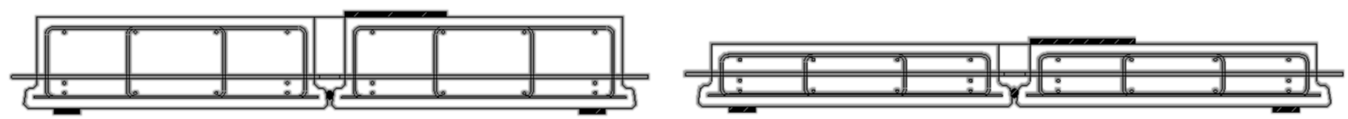
Slab Beam w/CIP Deck:



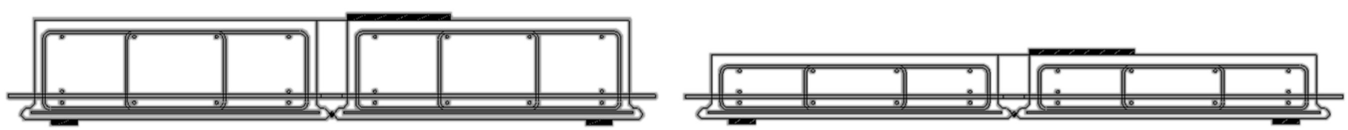
Joint 1 – Integrated Box Beam Joint:



Joint 2 – No Shear Key (4" Lip):



Joint 3 – No Shear Key (2" Lip):



Joint 4 – Modified Box Beam Joint:

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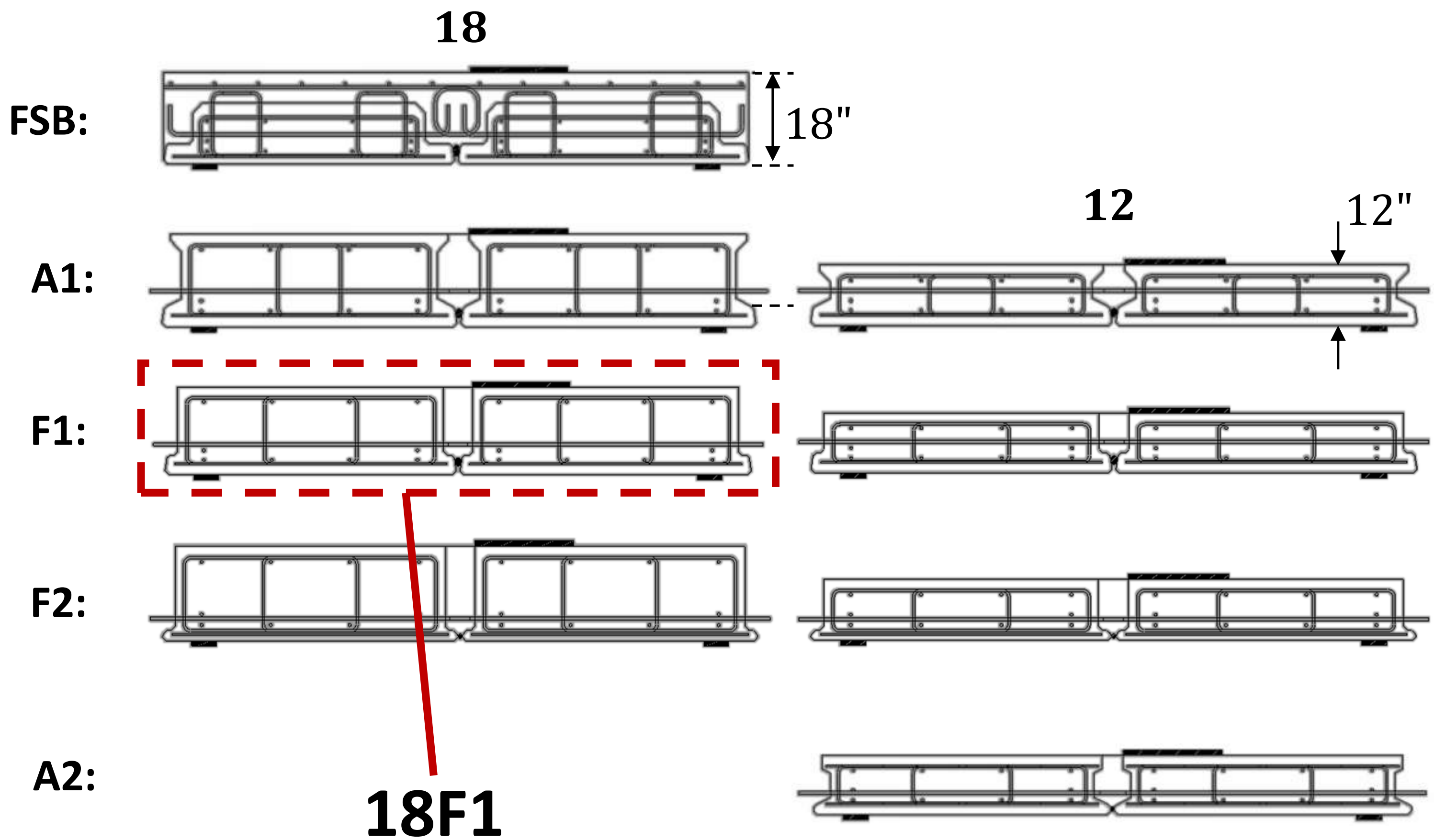
Task 4 – Joint Testing Program

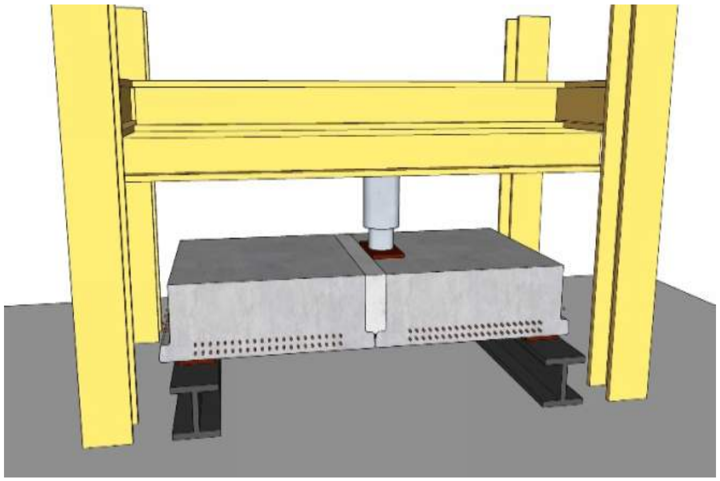
Preliminary Test Specimens – Naming Convention

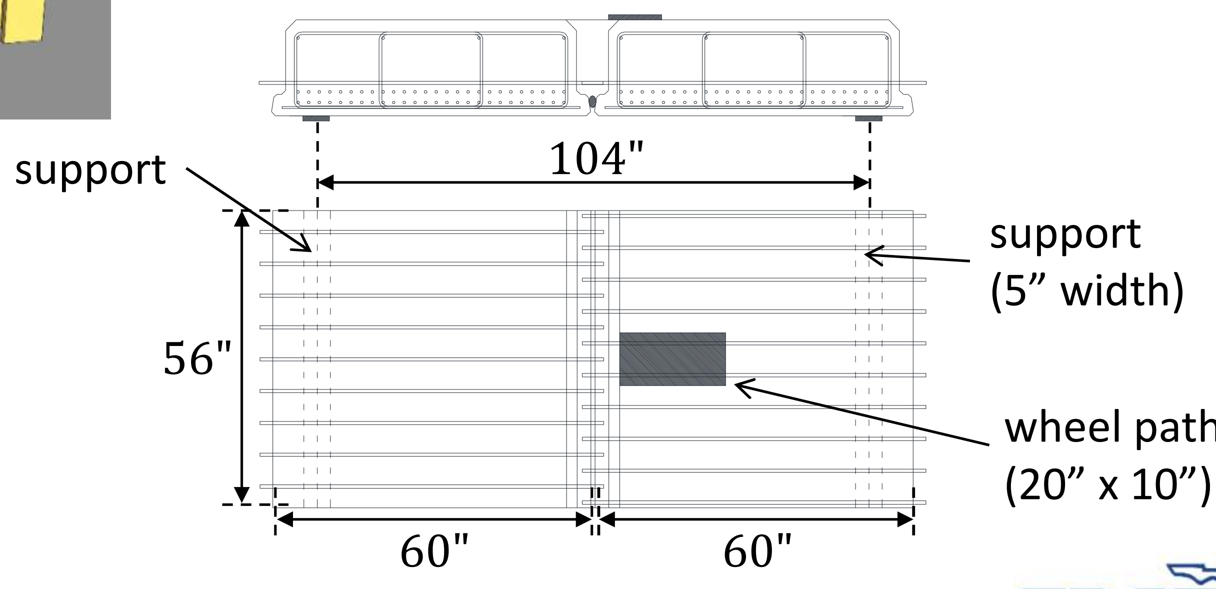


Note: 2 tests were performed on each specimen

Task 4 – Joint Testing Program

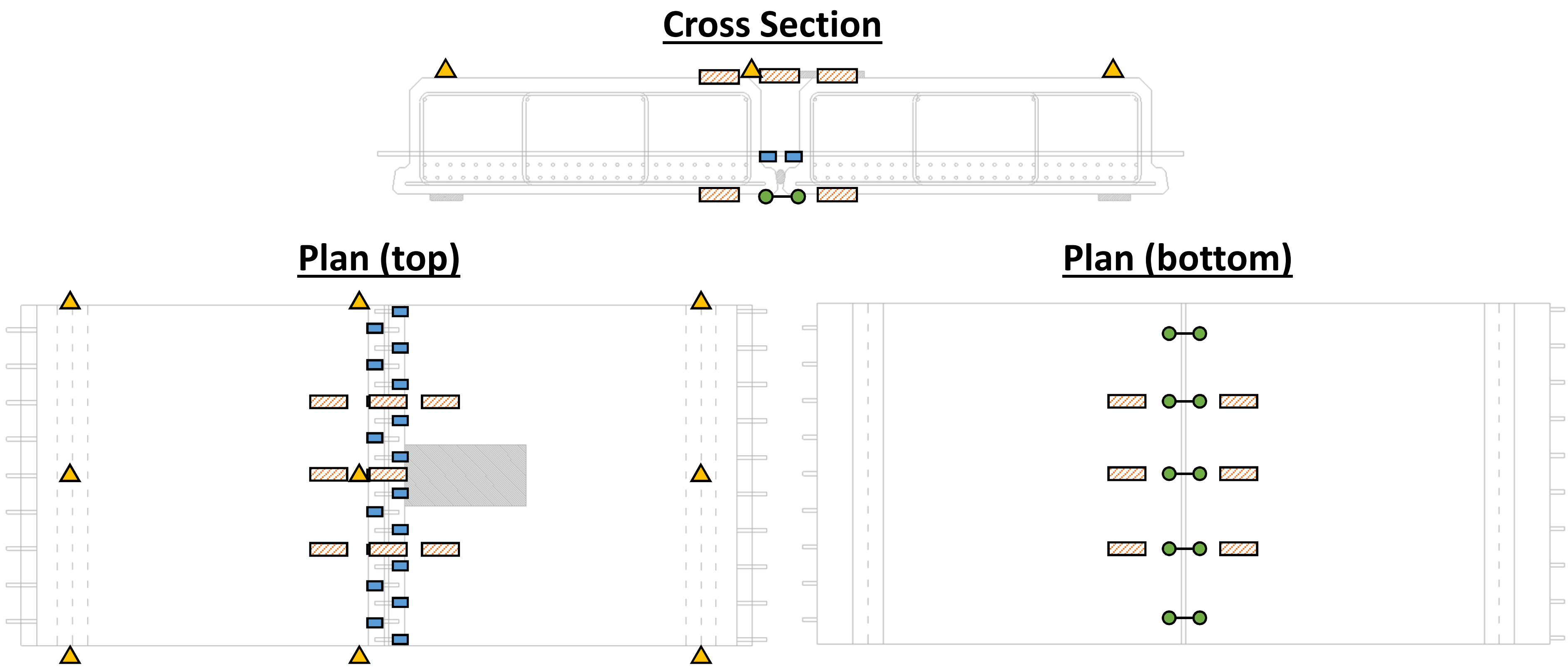
Test Setup





Task 4 – Joint Testing Program

Instrumentation Schedule



Legend

- Concrete surface gauge
- Rebar strain gauge
- Crack opening gauge
- Laser displacement transducer

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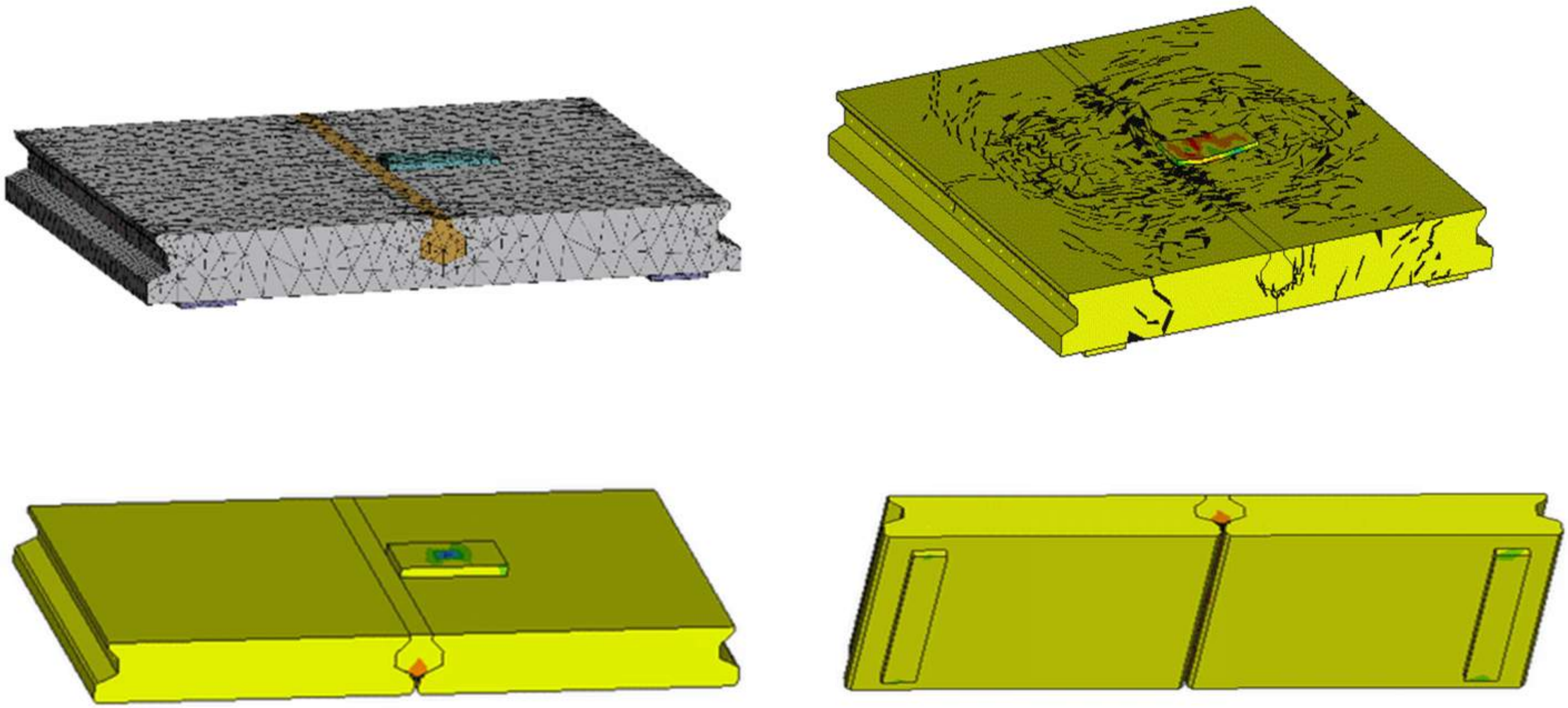
Task 4 – Joint Testing Program

Numerical Modeling



Task 4 – Joint Testing Program

Specimen Fabrication

Specimen Reinforcement

Concrete Pour

Finished Cast

Surface Raked Finish

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Task 4 – Joint Testing Program

Specimen Fabrication


Delivered Specimens


Beam w/CIP Deck Cast


UHPC Mixing


UHPC Joint Cast

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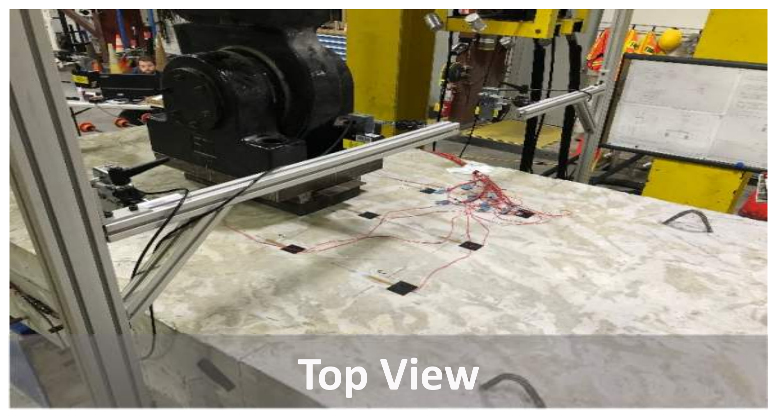
Task 4 – Joint Testing Program

Specimen in Test Setup

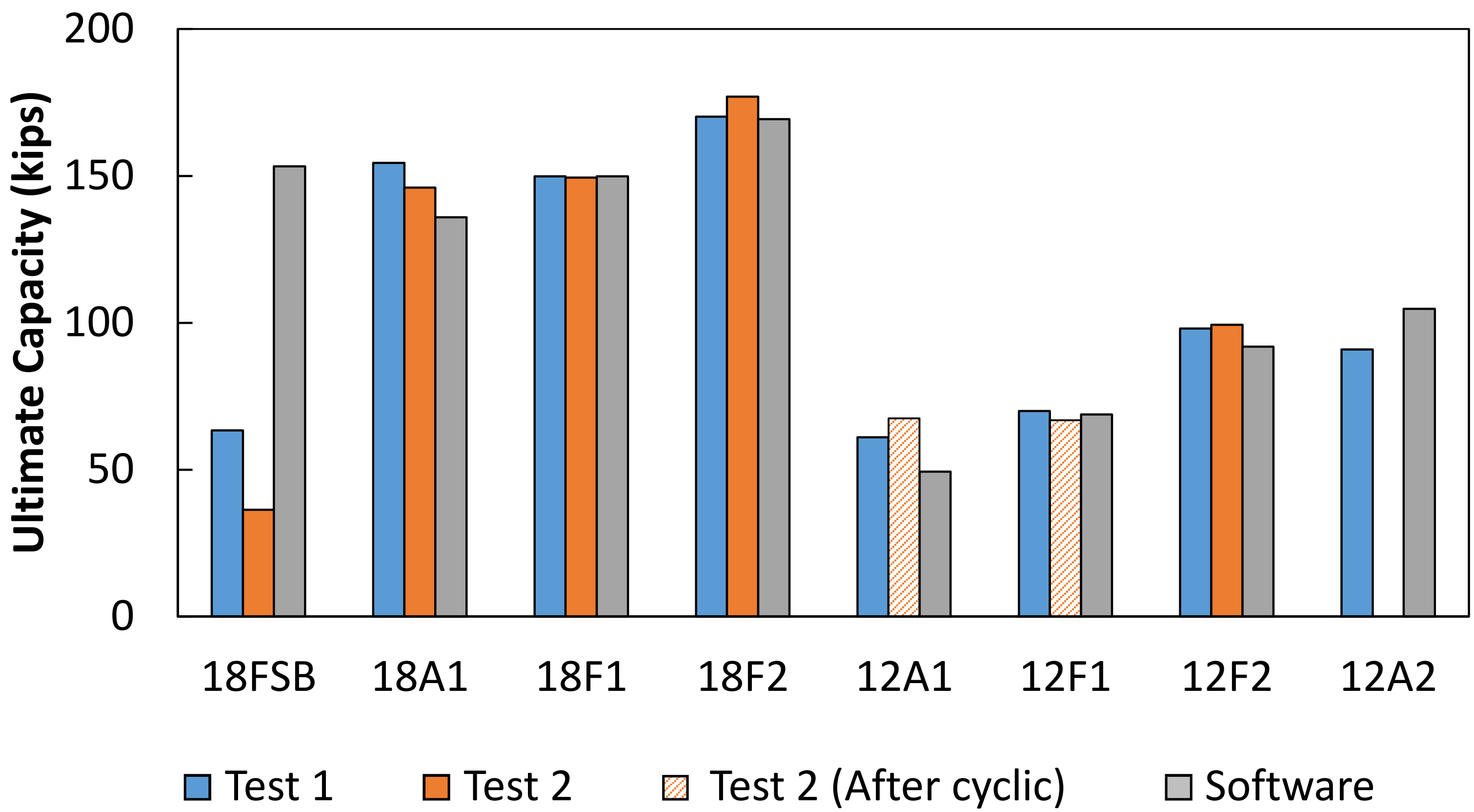
Side View


Bottom View


Top View

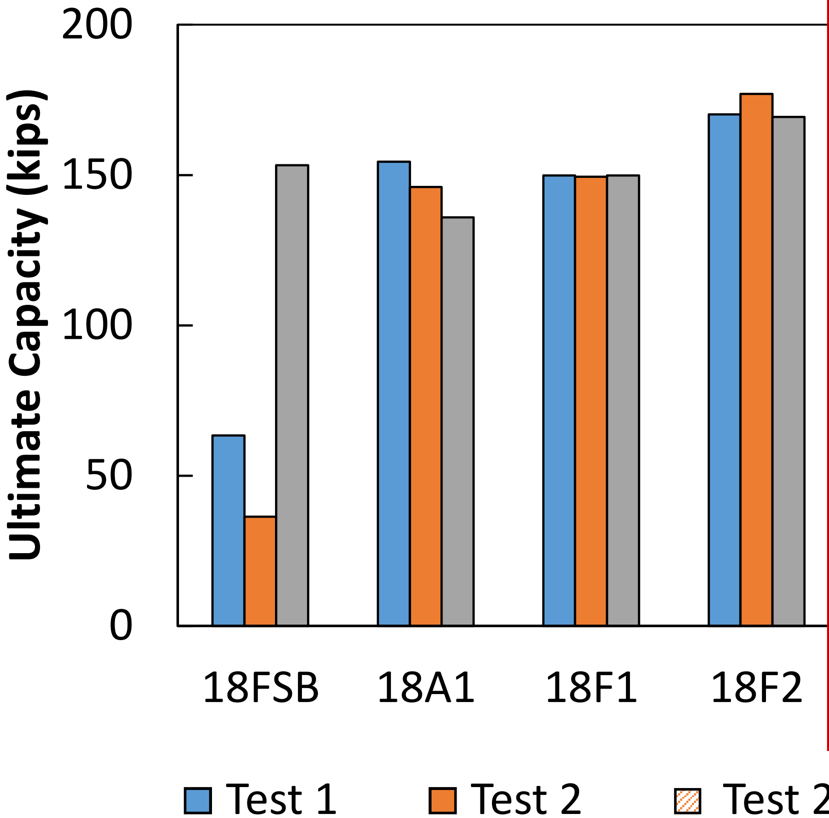
Task 4 – Joint Testing Program

Experimental Results



Task 4 – Joint Testing Program

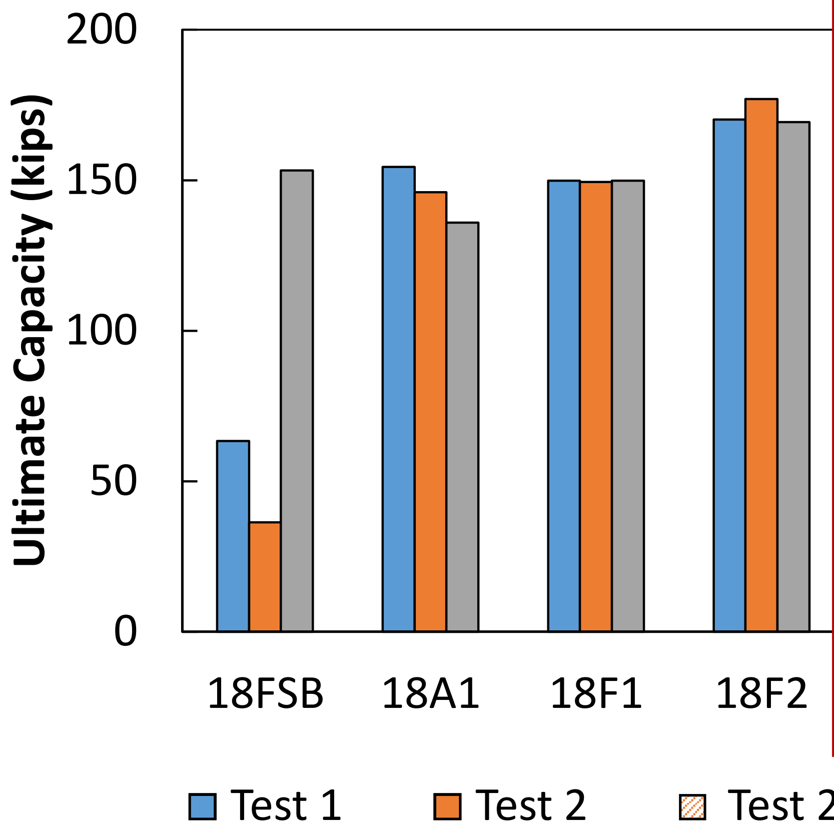
Experimental Results

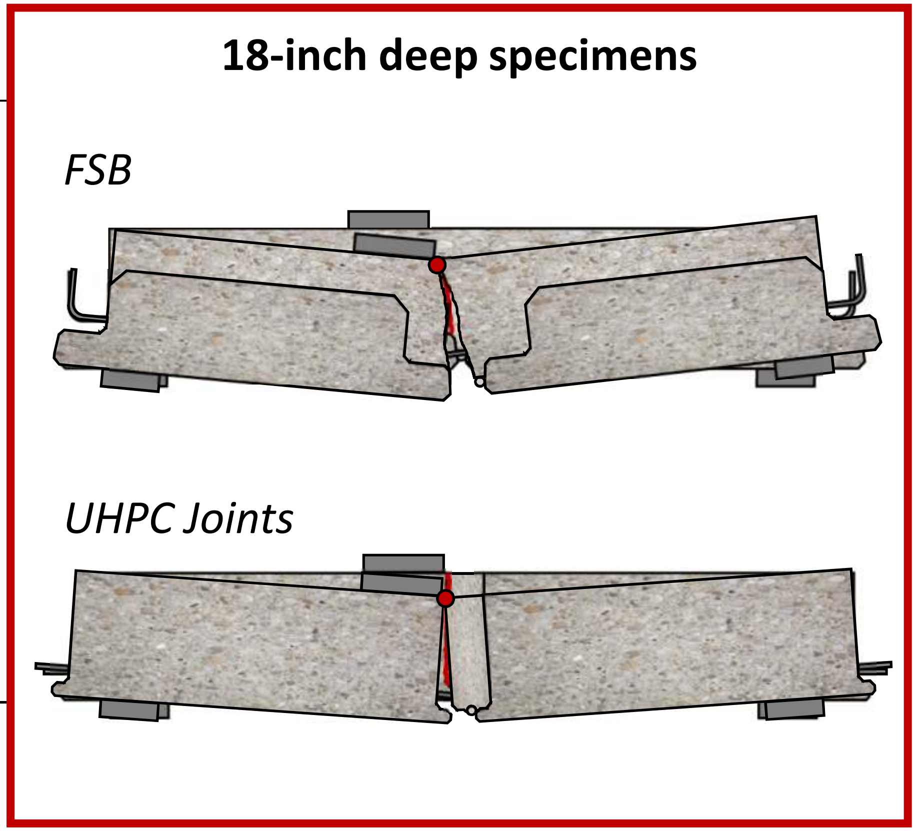


18-inch deep specimens

Task 4 – Joint Testing Program

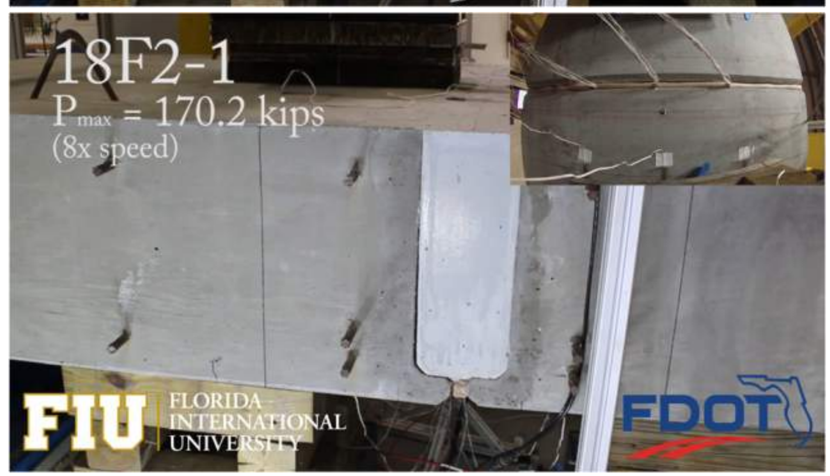
Experimental Results





Task 4 – Joint Testing Program

Experimental Testing – 18” Specimens



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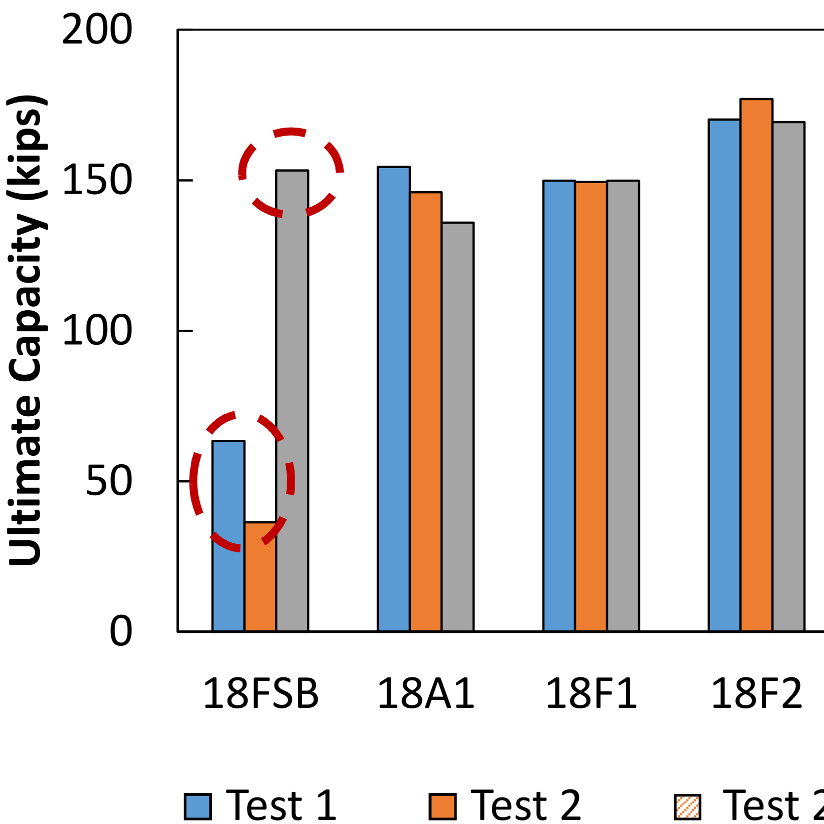
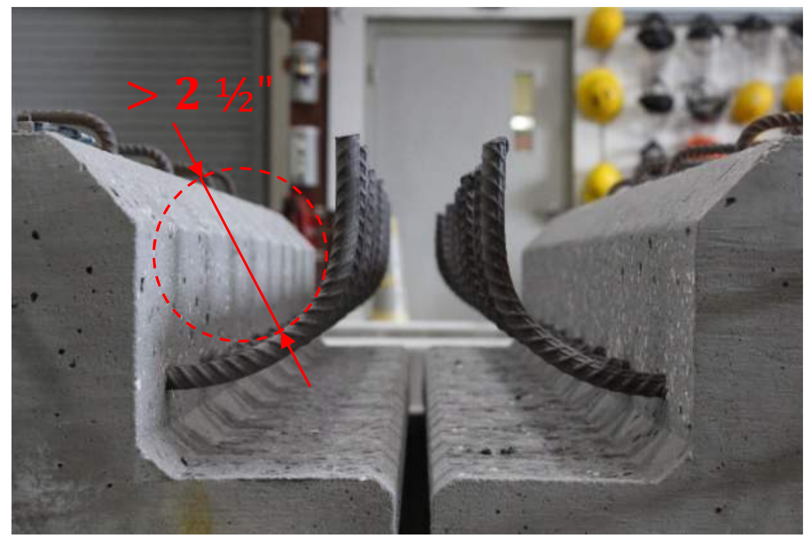
Task 4 – Joint Testing Program

Experimental Results



18-inch deep specimens

- Current FSB joint failed much lower than expected



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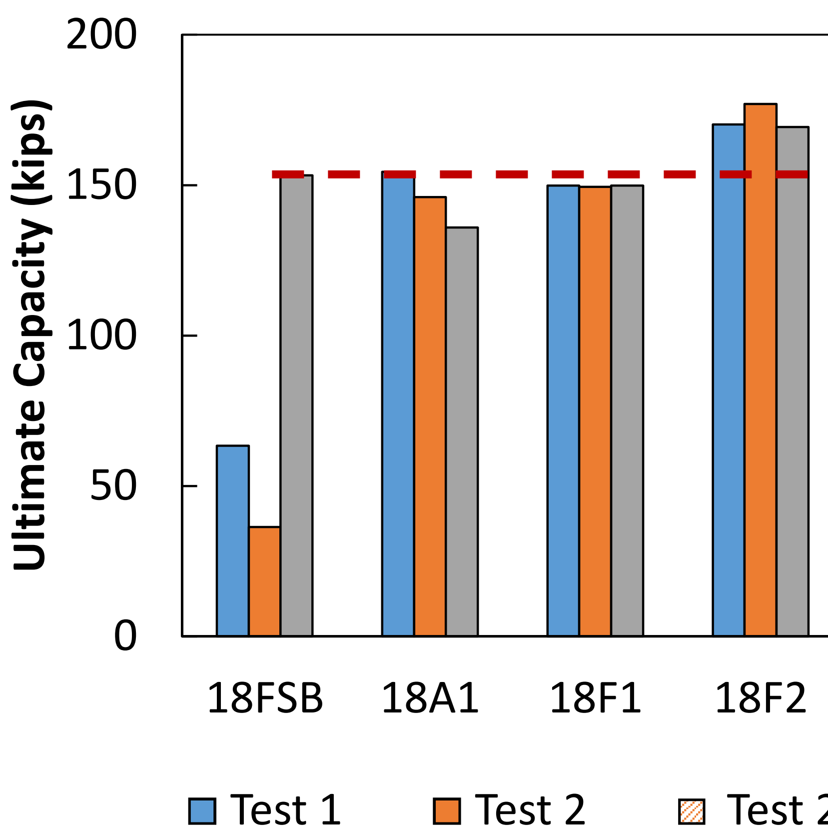
Task 4 – Joint Testing Program

Experimental Results



18-inch deep specimens

- Current FSB joint failed much lower than expected
- Modified UHPC joints had similar ultimate capacities to current FSB

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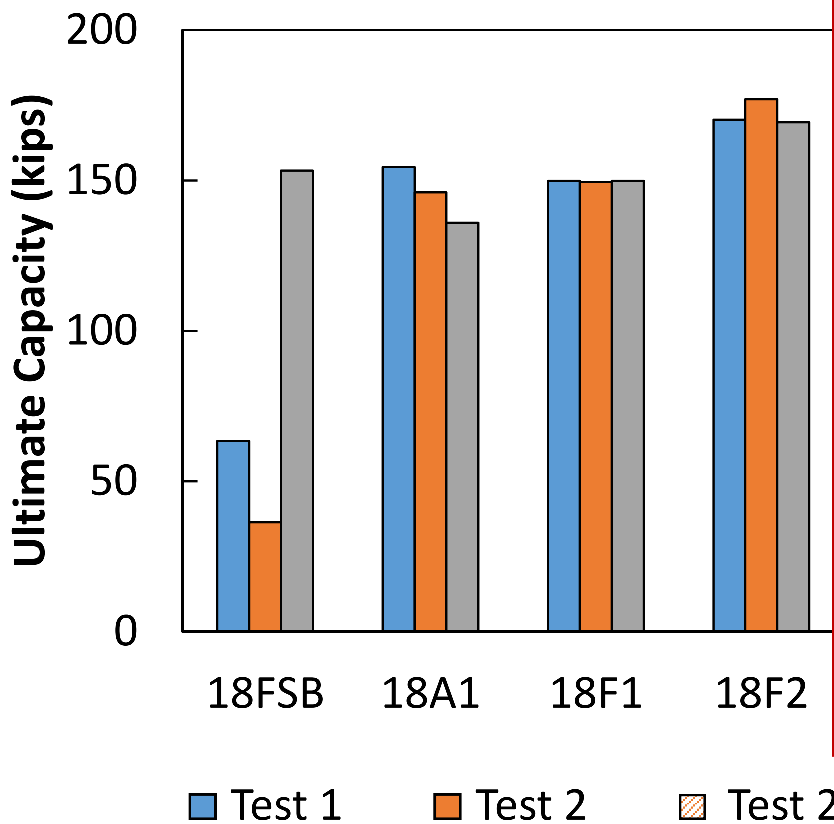
Task 4 – Joint Testing Program

Experimental Results

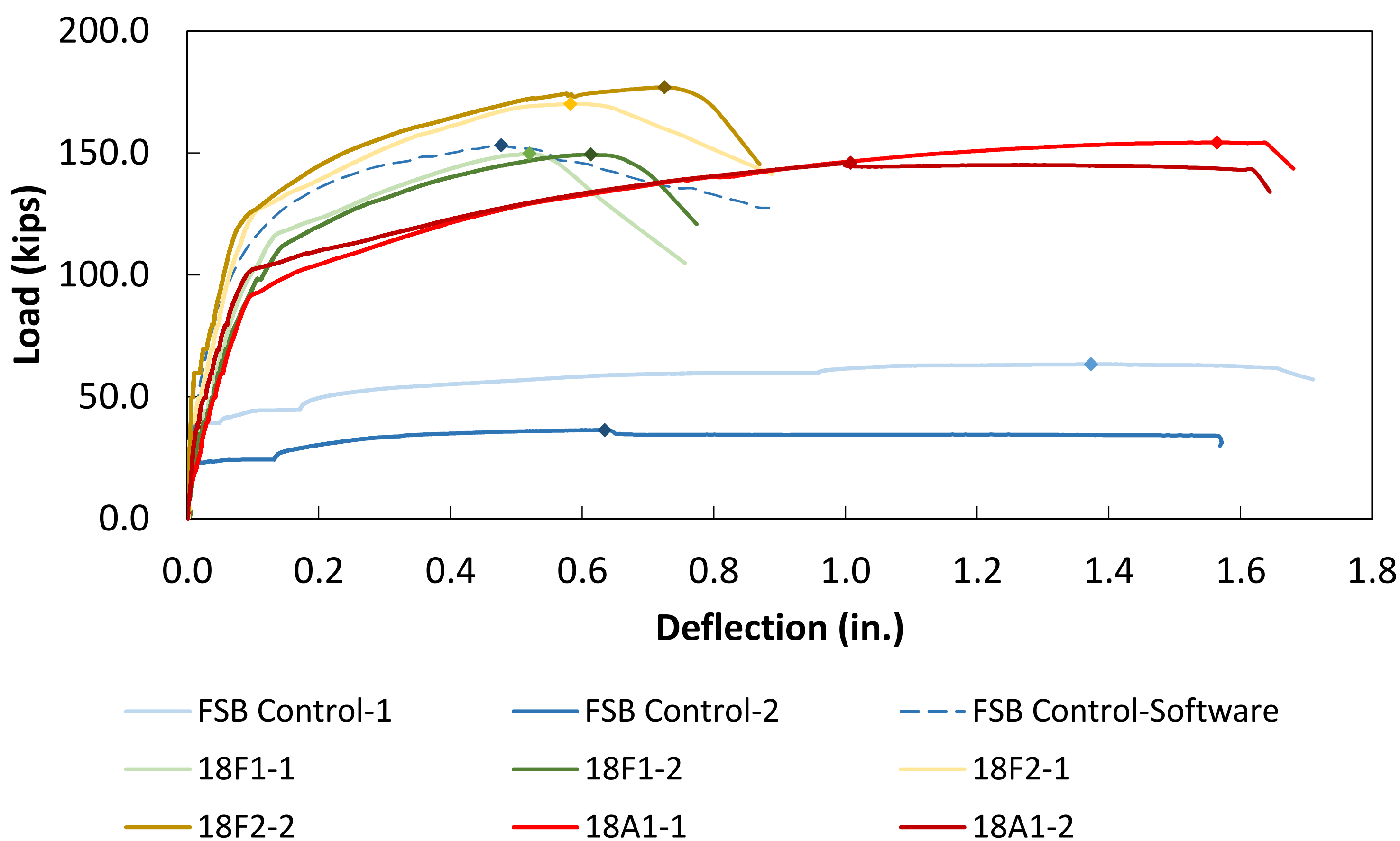


18-inch deep specimens

- Current FSB joint failed much lower than expected
- Modified UHPC joints had similar ultimate capacities to current FSB
- Joint 18A1 had the largest ductility among all the joints

Task 4 – Joint Testing Program

Experimental Results



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Task 4 – Joint Testing Program

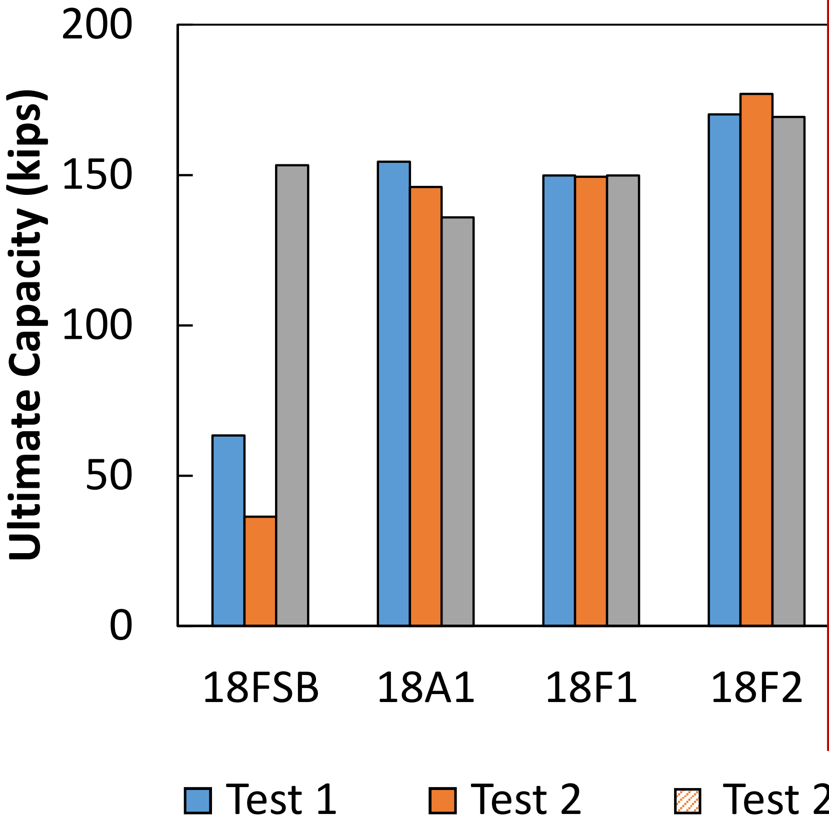
Experimental Results

18-inch deep specimens

- Current FSB joint failed much lower than expected
- Modified UHPC joints had similar ultimate capacities to current FSB
- Joint 18A1 had the largest ductility among all the joints
- Sandblasted joint finish was not sufficient for achieving desired bond

Task 4 – Joint Testing Program

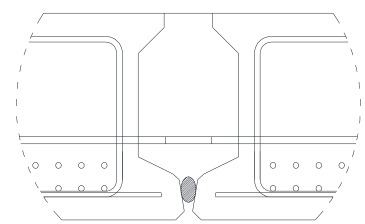
Experimental Results



18-inch deep specimens

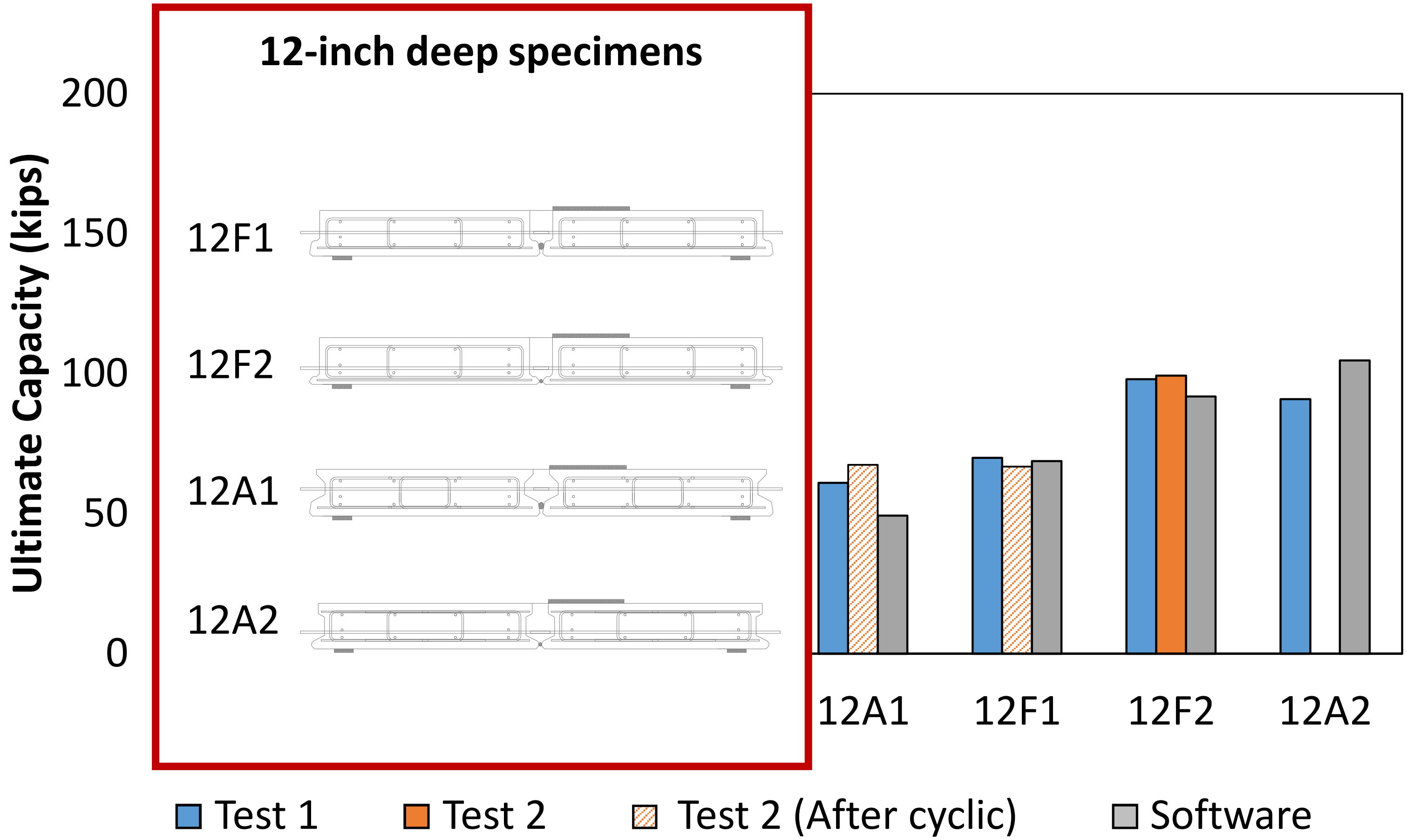
- Current FSB joint failed much lower than expected
- Modified UHPC joints had similar ultimate capacities to current FSB
- Joint 18A1 had the largest ductility among all the joints
- Sandblasted joint finish was not sufficient for achieving desired bond

Best Performance
18A1



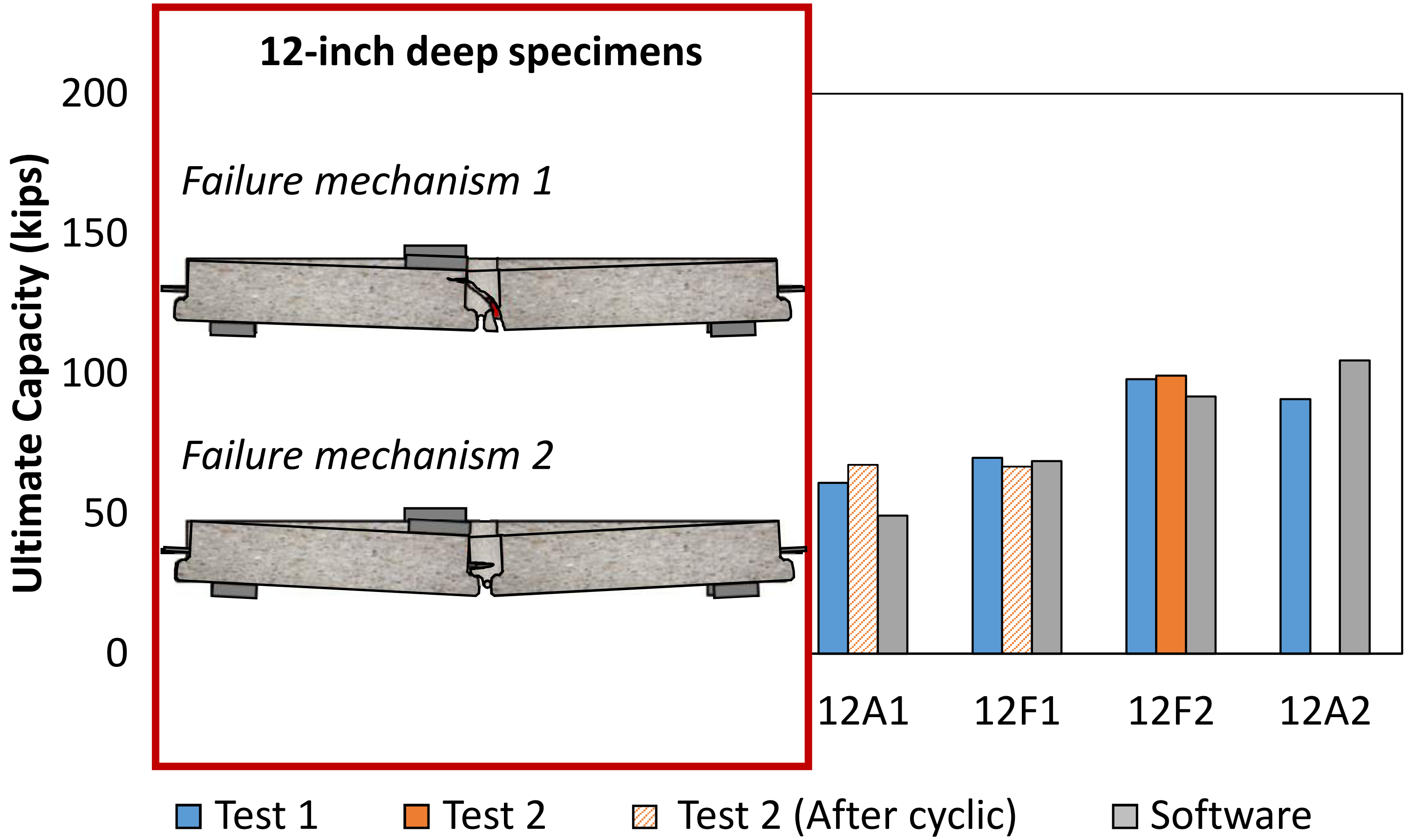
Task 4 – Joint Testing Program

Experimental Results



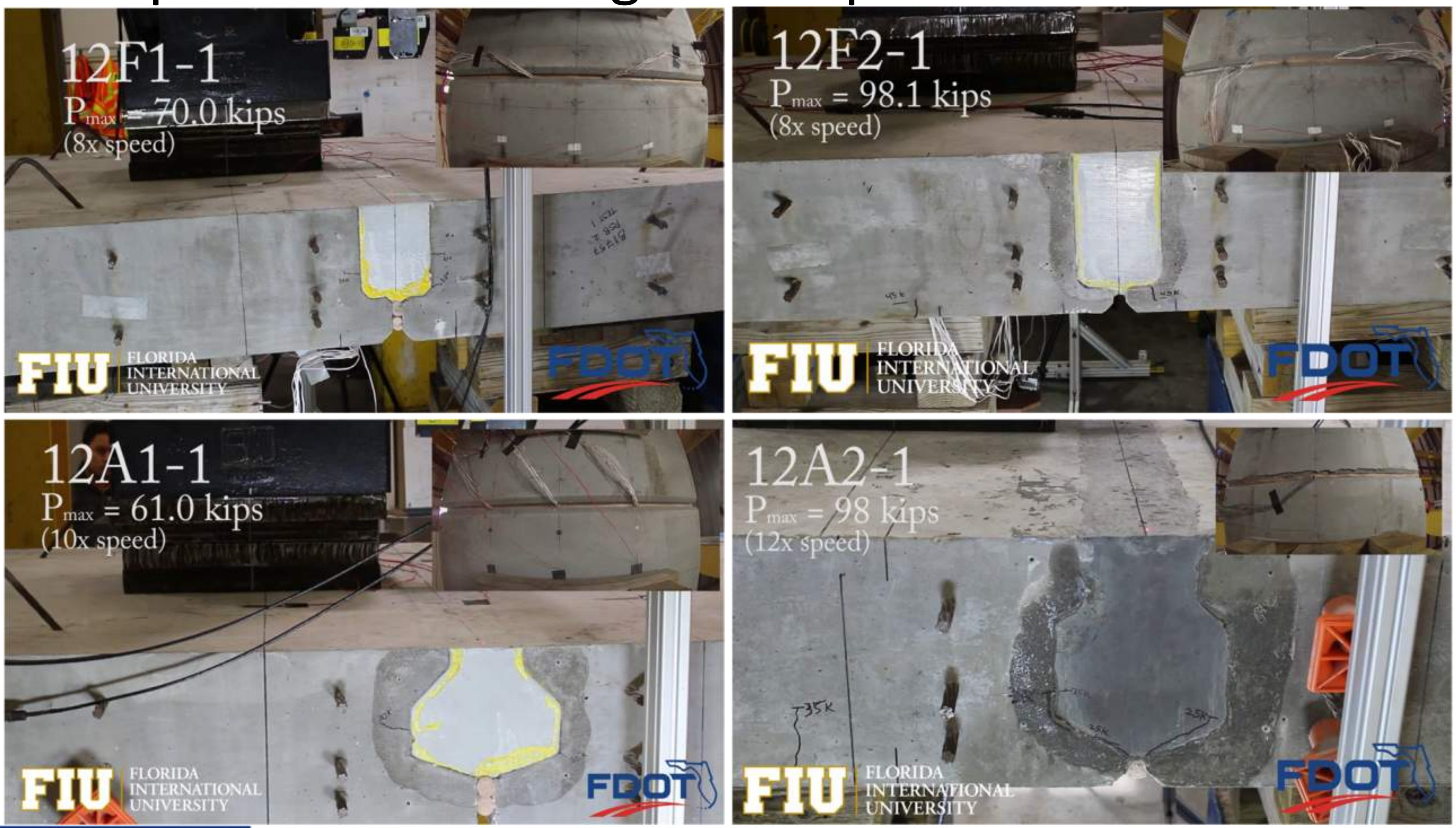
Task 4 – Joint Testing Program

Experimental Results



Task 4 – Joint Testing Program

Experimental Testing – 12" Specimens

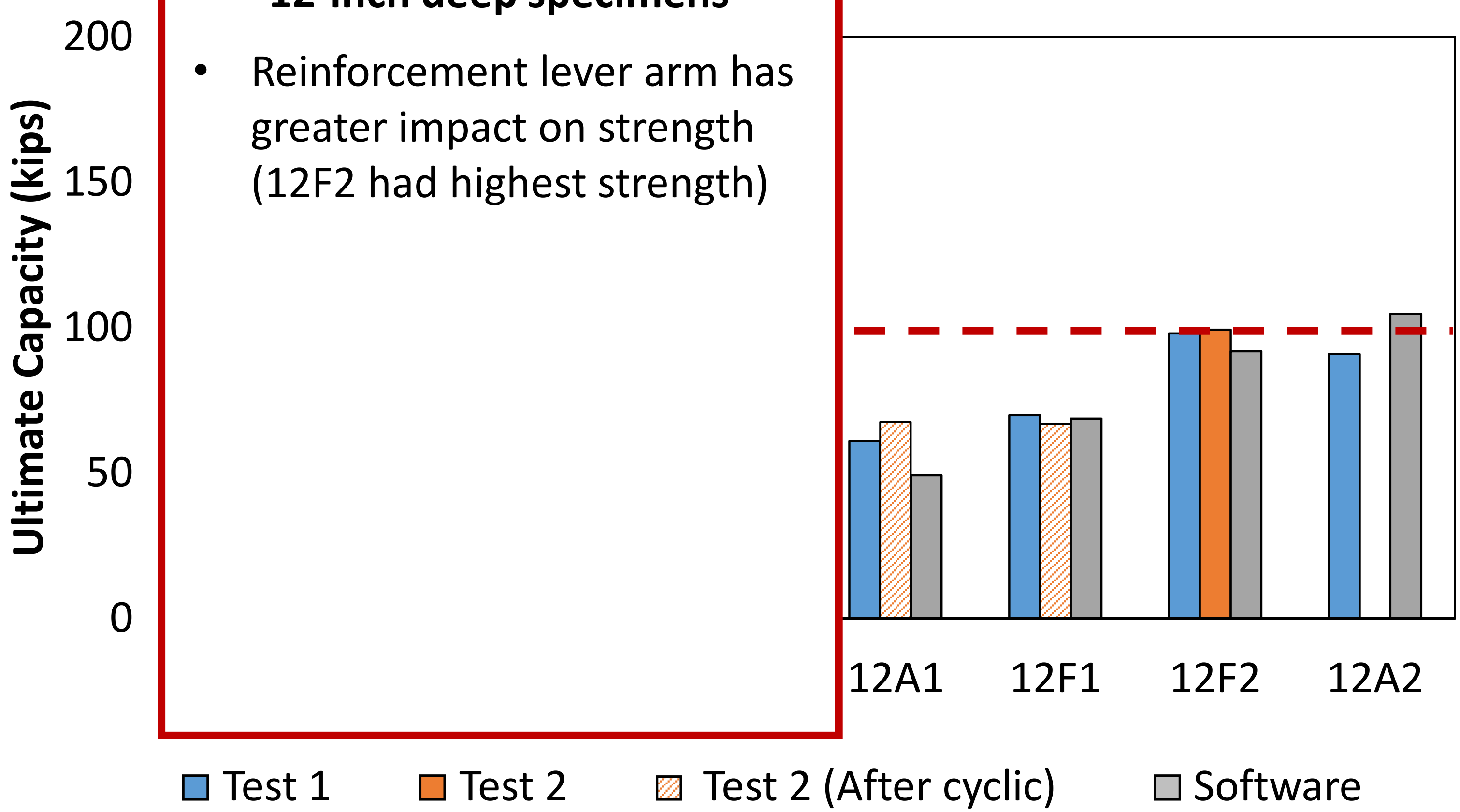


Task 4 – Joint Testing Program

Experimental Results

12-inch deep specimens

- Reinforcement lever arm has greater impact on strength (12F2 had highest strength)



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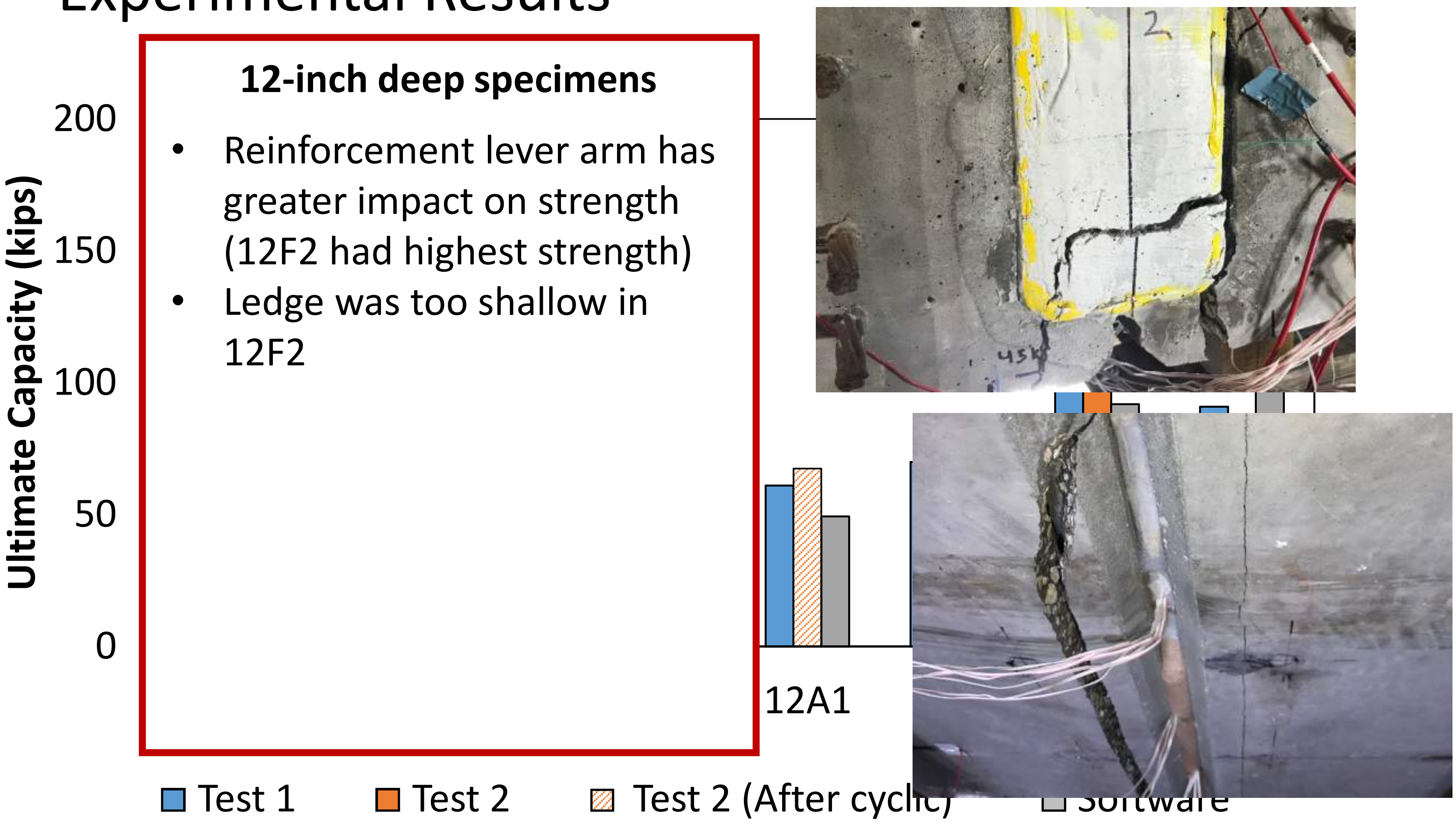
Task 4 – Joint Testing Program

Experimental Results

12-inch deep specimens

- Reinforcement lever arm has greater impact on strength (12F2 had highest strength)
- Ledge was too shallow in 12F2

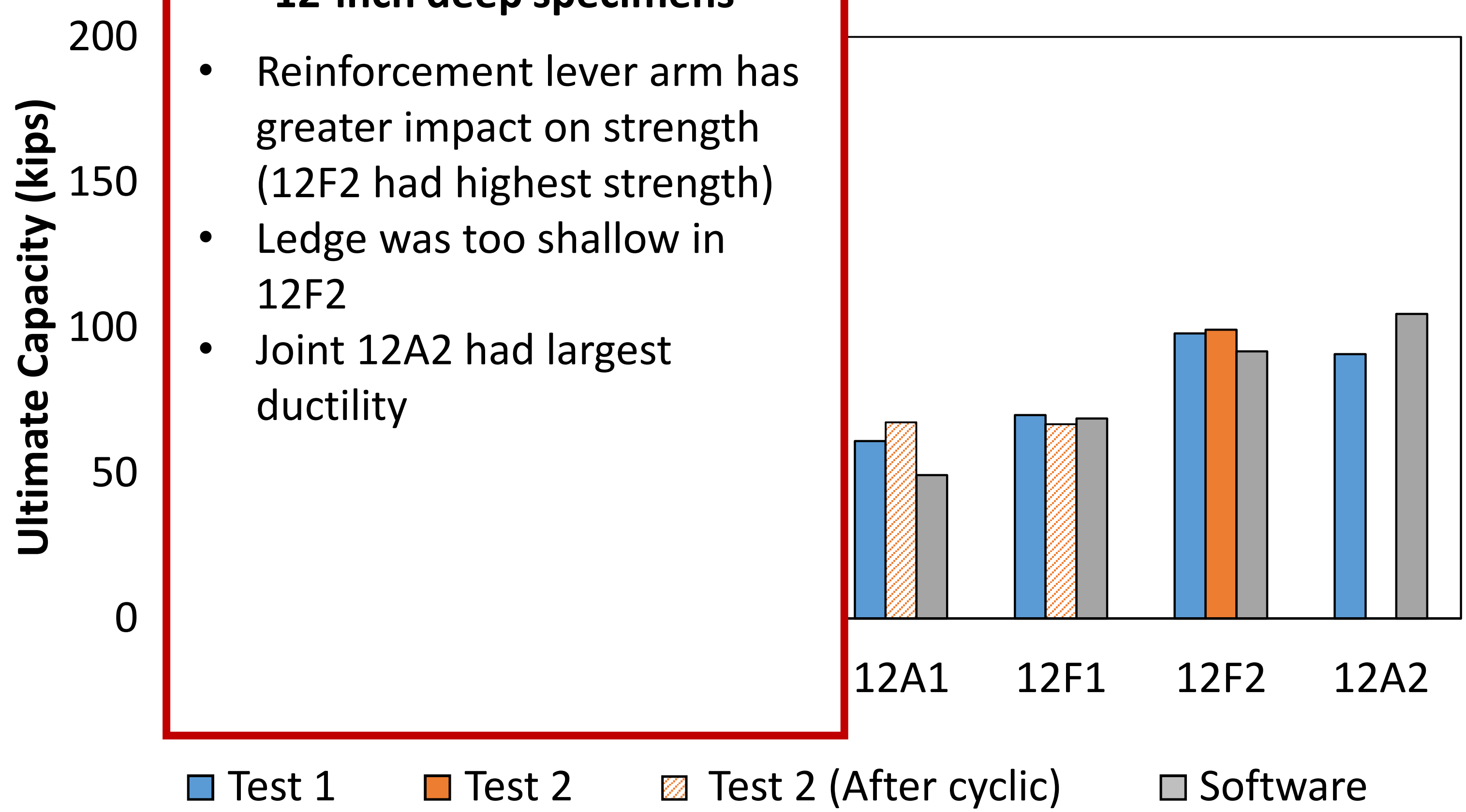


Task 4 – Joint Testing Program

Experimental Results

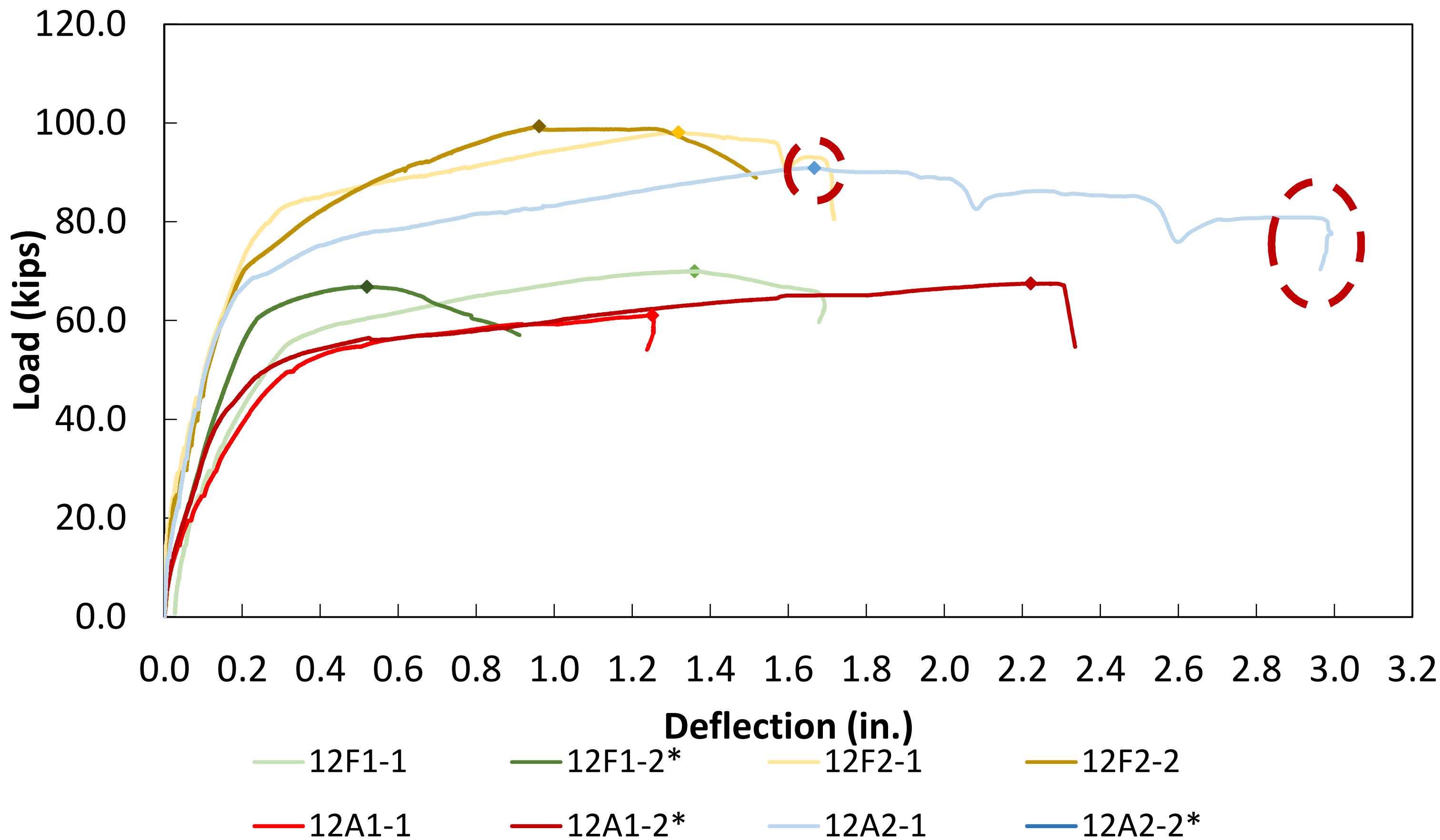
12-inch deep specimens

- Reinforcement lever arm has greater impact on strength (12F2 had highest strength)
- Ledge was too shallow in 12F2
- Joint 12A2 had largest ductility



Task 4 – Joint Testing Program

Experimental Results



Task 4 – Joint Testing Program

Experimental Results

12-inch deep specimens

- Reinforcement lever arm has greater impact on strength (12F2 had highest strength)
- Ledge was too shallow in 12F2
- Joint 12A2 had largest ductility
- Better finish with paste retarder

Sandblasting

Paste Retarder

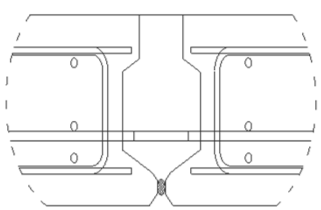
Task 4 – Joint Testing Program

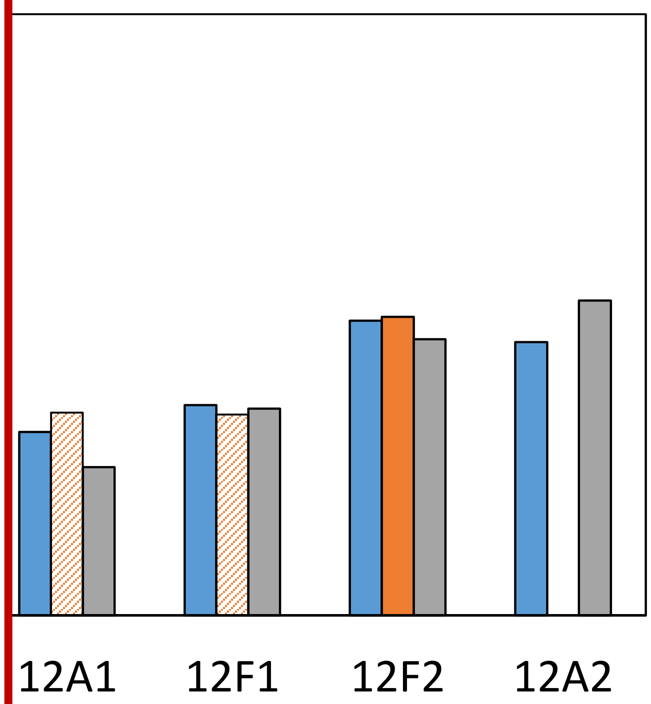
Experimental Results

12-inch deep specimens

- Reinforcement lever arm has greater impact on strength (12F2 had highest strength)
- Ledge was too shallow in 12F2
- Joint 12A2 had largest ductility
- Better finish with paste retarder

Best Performance
12A2





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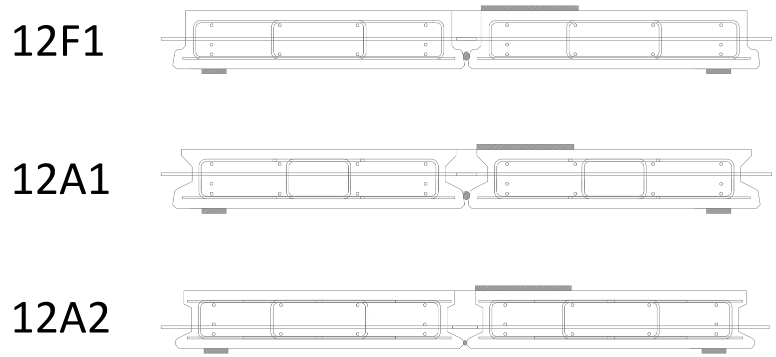
Task 4 – Joint Testing Program

Fatigue Testing



Loading type	Load Range Steps	Lower Limit Load	Upper Limit Load	Frequency	# Cycles	Testing Days
Fatigue	1 - Calibration	2 kip	12.64 kip	1 Hz	200,000	3
	2 – Under Cracking Performance	2 kip	12.64 kip	1 Hz	900,000	12
	3 – After Cracking Performance	19 kip	31 kip	1 Hz	900,000	11
Strength	4 – Overload Performance	0 kip	100 % Failure Load	N/A	N/A	1

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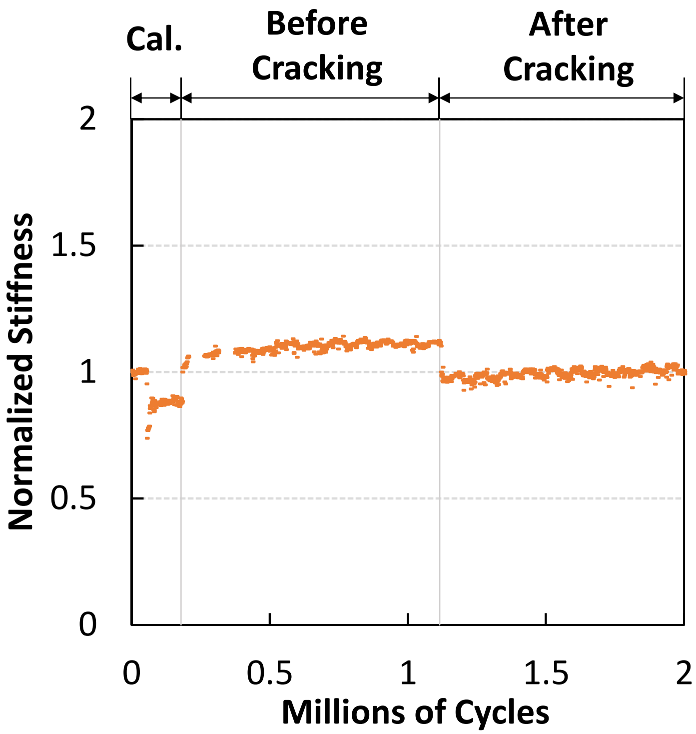
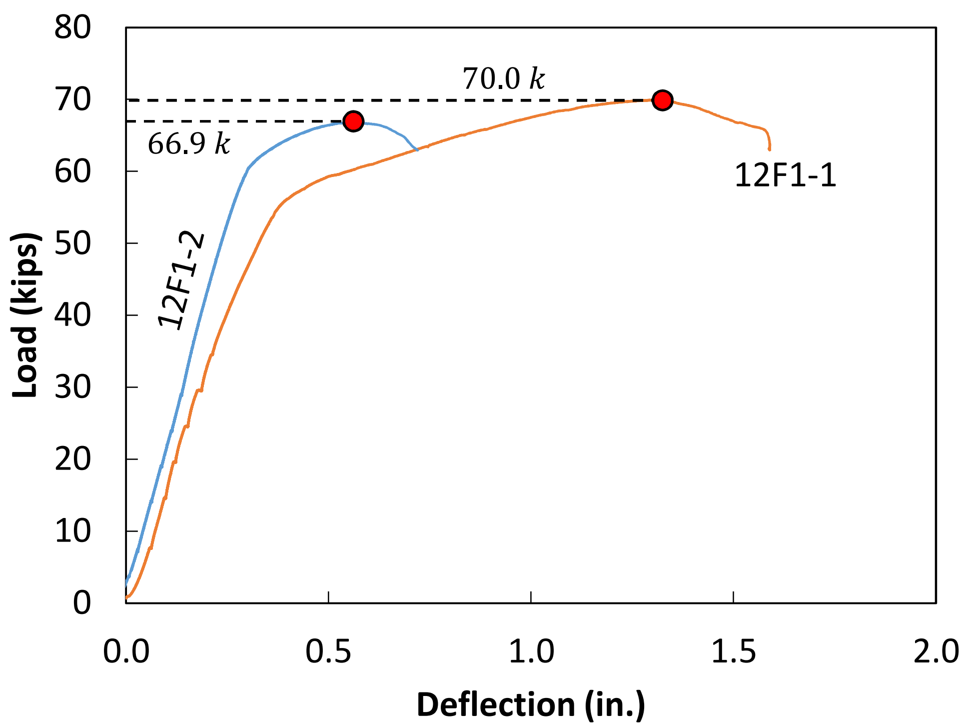
Task 4 – Joint Testing Program

Fatigue Testing





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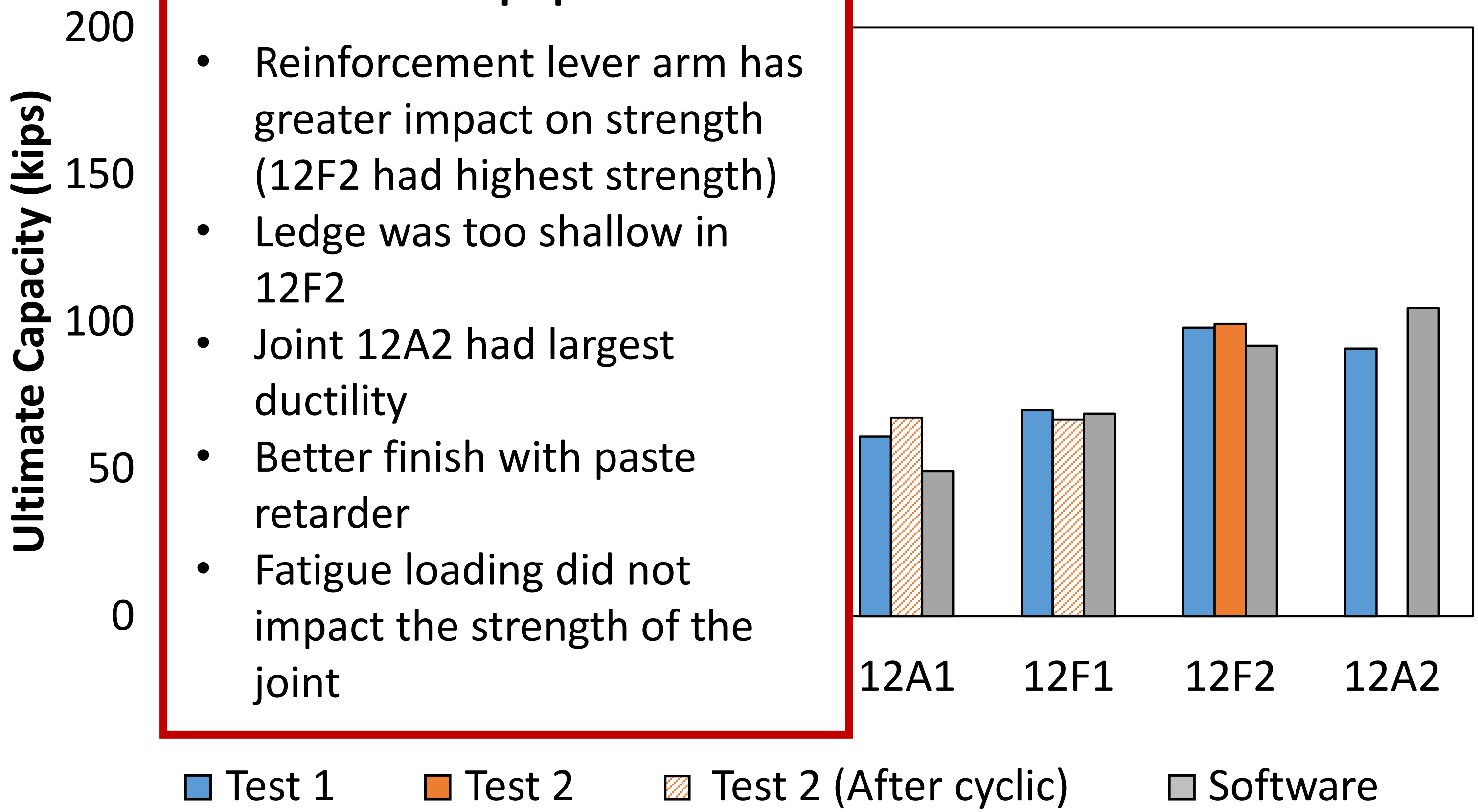
Task 4 – Joint Testing Program

Experimental Results

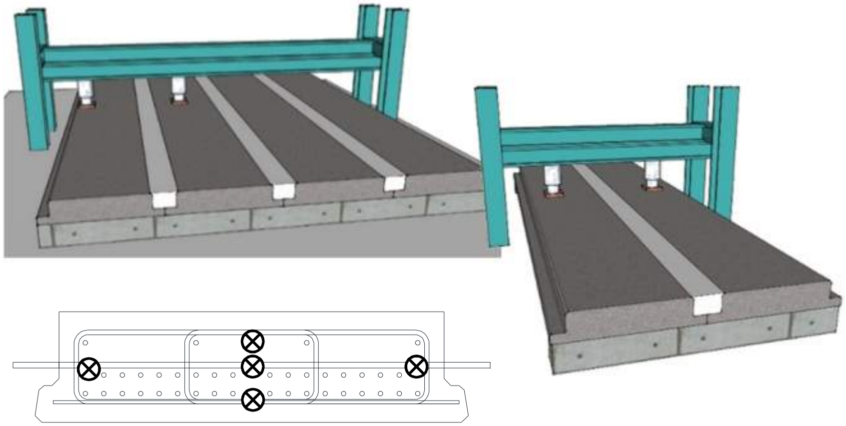
12-inch deep specimens

- Reinforcement lever arm has greater impact on strength (12F2 had highest strength)
- Ledge was too shallow in 12F2
- Joint 12A2 had largest ductility
- Better finish with paste retarder
- Fatigue loading did not impact the strength of the joint

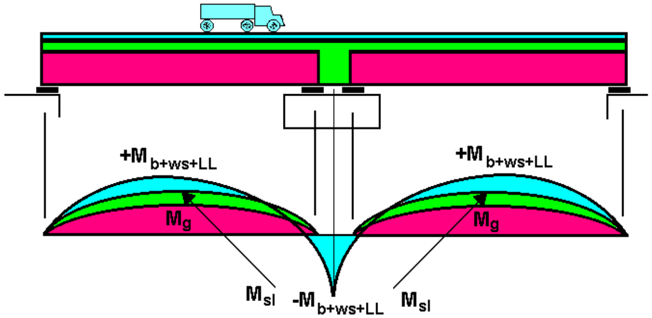


Future Work

- **Task 5** - Full-Scale Beam Testing
- **Task 6** - Conceptually and Analytically Develop FSB Detail as a Continuous Span
- **Task 7** - Draft Final Report and Closeout Teleconference
- **Task 8** - Final Report



Proposed VWG schedule for full-scale specimens



Thank You

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Florida International University