UHPC Workshop #3: SDO Design Updates

Presenter: Steve Nolan, P.E.

Date: November 29th, 2023

UHPC Workshop #3 – SDO Design Updates

Pile driving photos coutesy of Cor-Tuf UHPC

1. Introduction
2. FDOT UHPC Structural Research
3. FDOT UHPC Projects to Date
3. FDOT UHPC Pile Standard Development
4. Alabama's H-Pile Research
5. AASHTO Guide Specifications Status
6. Discussion

FDOT Past Research Related to UHPC

- Octagon (SCP) and H-shaped (Durastress) Piles
- ***BDV30-977-34:*** Quantifying the Effect of UHPC Fiber Dispersion and Orientation in Structural Members (FSU/Zhang)
- ***BDV29 977-28:*** Florida Slab Beam Bridge with Ultra-High Performance Concrete Joint Connections (FIU/Garber)
- ***BDV31 977-101:*** Hybrid Prestressed Concrete Bridge Girders Using Ultra-High Performance Concrete (UF/Hamilton)
- ***SRC in-house*** Large Bars Spliced in UHPC for Bridge Substructure Connections (FDOT/Freeman)

FDOT Ongoing & Future Research Related to UHPC

- ***BED30 977-05:*** Acceptable Crack Width Limit got UHPC Structural Members Under Coastal and Marine Environment (FSU/Zhang)
- ***BED30 977-08:*** Assessment and Optimization of the Casting Procedure for UHPC Structural Elements (FSU/Zhang)
- ***BEC96:*** Bond Performance Between Precast UHPC Substrates and Field Cast UHPC Connections (FIU/Garber)
- ***BEC96:*** UHPC Pile Splice Development (FIU/Garber)
- ***SRC23-01:*** Skin Friction Assessment (SRC & SMO)
- Driving Assessment of UHPC Piles (TBA)

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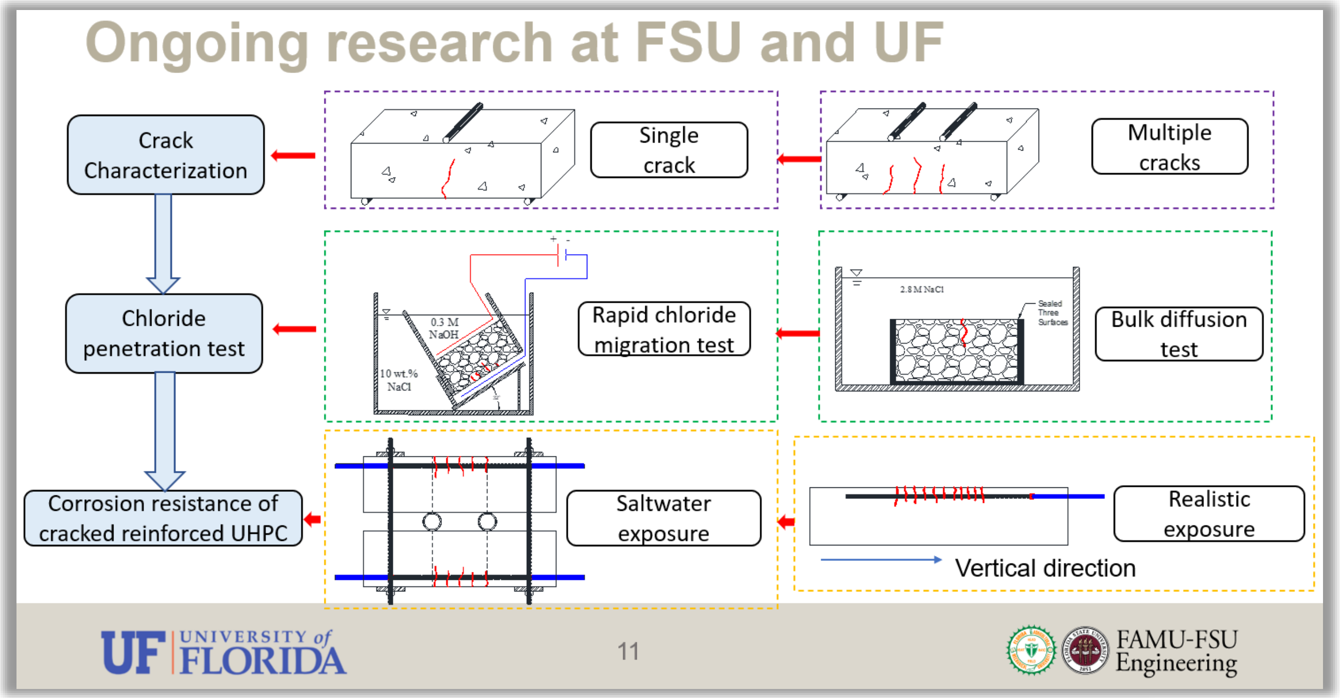
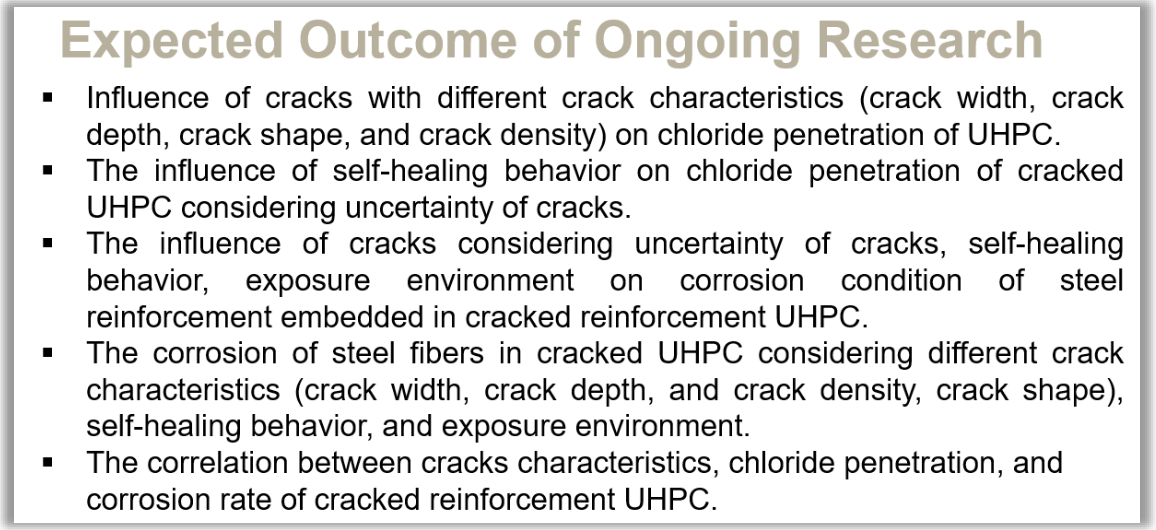


Ongoing research at FSU and UF

Crack Characterization ← Single crack ← Multiple cracks

Chloride penetration test ← Rapid chloride migration test ← Bulk diffusion test

Corrosion resistance of cracked reinforced UHPC ← Saltwater exposure ← Realistic exposure



Expected Outcome of Ongoing Research

- Influence of cracks with different crack characteristics (crack width, crack depth, crack shape, and crack density) on chloride penetration of UHPC.
- The influence of self-healing behavior on chloride penetration of cracked UHPC considering uncertainty of cracks.
- The influence of cracks considering uncertainty of cracks, self-healing behavior, exposure environment on corrosion condition of steel reinforcement embedded in cracked reinforcement UHPC.
- The corrosion of steel fibers in cracked UHPC considering different crack characteristics (crack width, crack depth, and crack density, crack shape), self-healing behavior, and exposure environment.
- The correlation between cracks characteristics, chloride penetration, and corrosion rate of cracked reinforcement UHPC.

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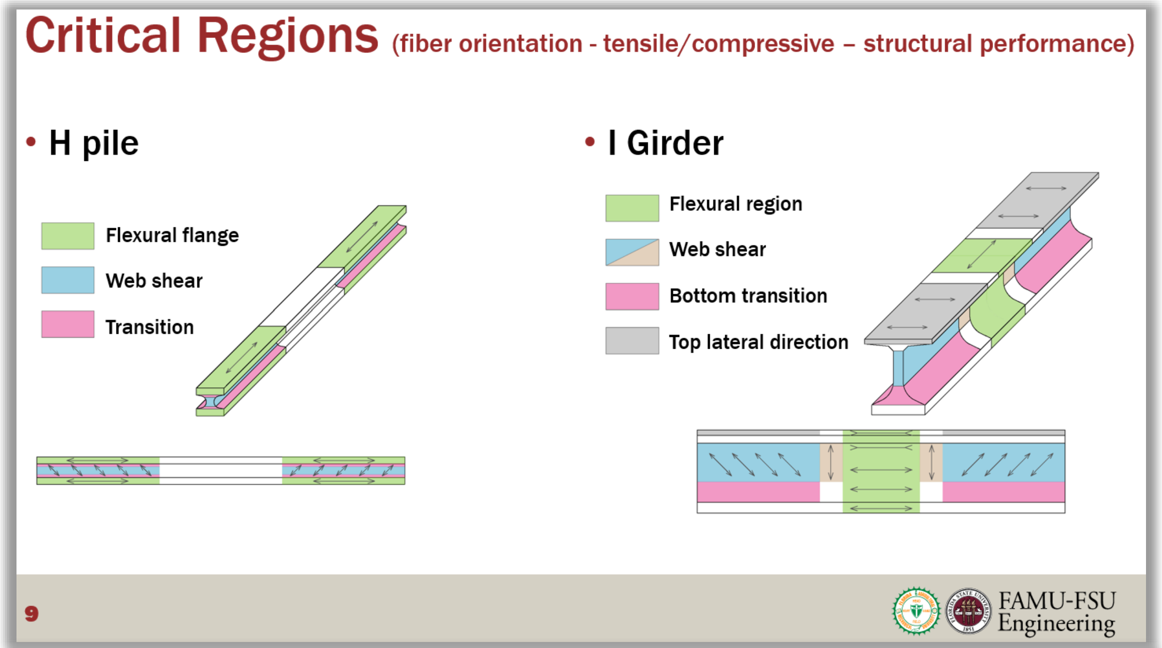


Critical Regions (fiber orientation - tensile/compressive – structural performance)

- H pile

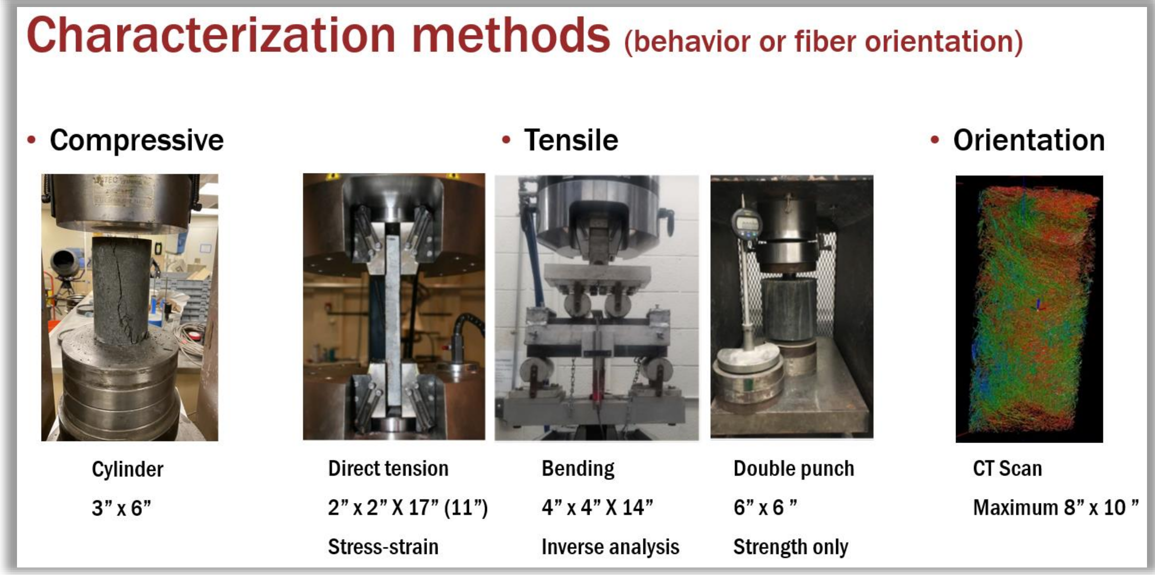
🟩 Flexural flange
🟦 Web shear
🟪 Transition

- I Girder

🟩 Flexural region
🟦 Web shear
🟪 Bottom transition
⬜ Top lateral direction

9

FAMU-FSU Engineering



Characterization methods (behavior or fiber orientation)

- Compressive
- Tensile
- Orientation

Cylinder	Direct tension	Bending	Double punch	CT Scan
3" x 6"	2" x 2" X 17" (11")	4" x 4" X 14"	6" x 6 "	Maximum 8" x 10 "
	Stress-strain	Inverse analysis	Strength only	

FDOT Ongoing & Future Research Related to UHPC

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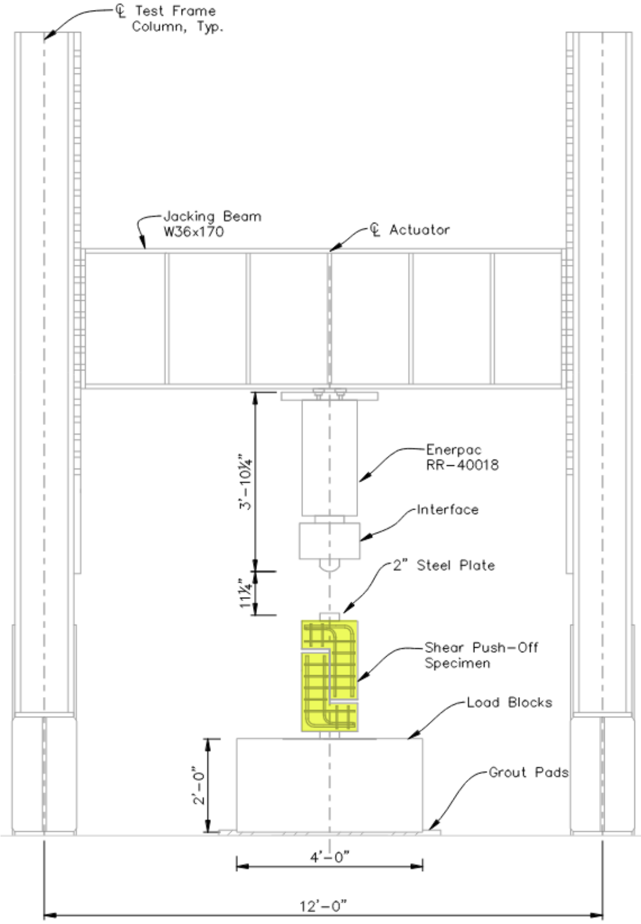

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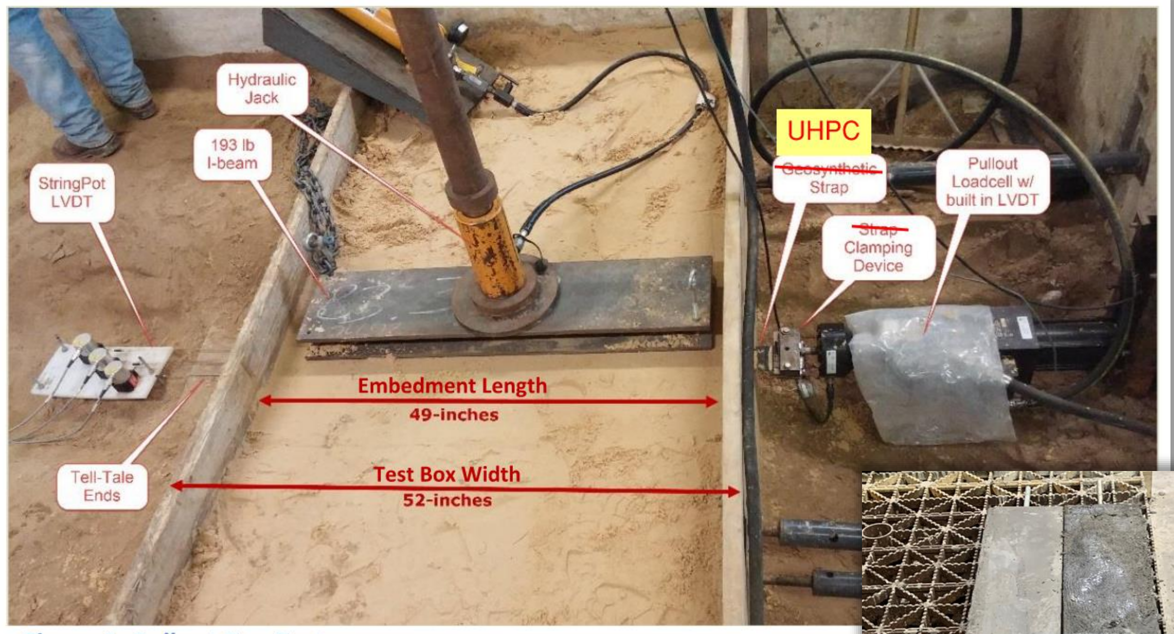
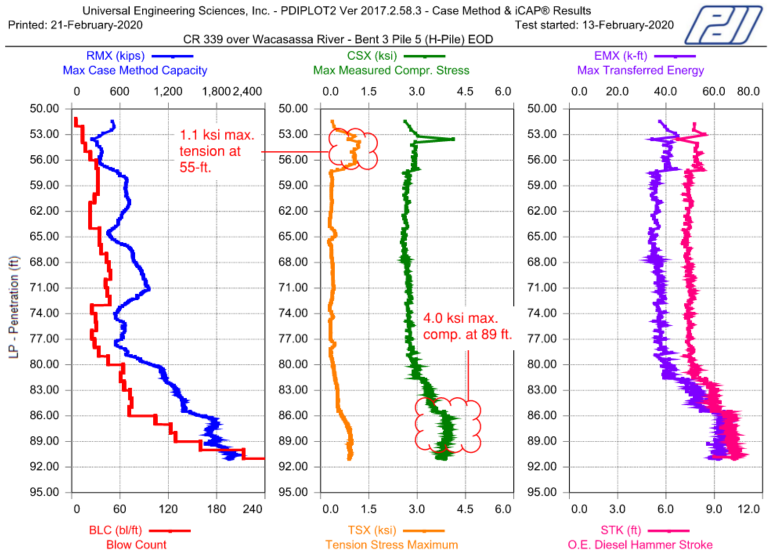


Figure 1: Pullout Box Test



Where you can find UHPC in Florida: DISTRICT 1

- **US 441/Taylor Creek** (437984-1), ***Fast-Facts:*** Longitudinal center joint for dual precast slabs. This was a Contractor redesign (CSIP): *Completed.*
- **US41 over Sunset Waterway** (435390-1) **T4500**, ***Fast Facts:*** Link-slab to use UHPC with BFRP longitudinal bars – *2/27/19 letting, Bid Tabs: Completed.*
- **SR45(US-41) over Roberts Bay** (445941-1), **E1U17**. Sonovoid Joint Rehab with hydro-demolition & UHPC (13 CY) - *Letting 2/07/2022, BidTabs: Completed.*
- **SR25(US-27) NB /Fisheating Creek Overflow** (445925-1), **T1848**. Sonovoid Joint Rehab = 7 x 36' spans x 8 joints (1,900 LF) with hydro-demolition & UHPC (21 CY) - *Letting 12/07/2022, BSN*
- **SR82/Under Canal** (430848-1) – *05/22/24 letting*. FSB without topping & UHPC joints and GRS Abutments – ***status:*** *Final Plans.*
- **Lakeland, New York Ave/Railroad Pedestrian Overpass** (*436656-1), Precast Approach Ramp Slabs - Letting 3/26/2026.* ***status:*** *Phase III Plans*

Where you can find UHPC in Florida: DISTRICT 2

Ultra-high-performance concrete was used for the repair of a midspan spliced U-girder closure pour. Photo: SEMA Construction

- **I-95/JT Butler Interchange**, Curved Spliced U-Beam closure joint repair: *(complete)*
- **SR115 (Arlington Expwy) over Red Bay Branch** (443310-1), T2934. Sonovoid Joint Rehab = 29 x 31’ spans x 8 joint (7,000 LF) with hydro-demo & UHPC (98 CY) – *Letting 12/07/22, BSN*: ***status: under construction***

Where you can find UHPC in Florida: DISTRICT 3

- **I-10 over Flat Creek** (442914-1), **E3S91**, ***Fast-Facts -*** Approach Slab Replacement: Precast w/UHPC longitudinal joint (2.8 CY) – *letting 2/13/2020 (Bid Tabs): Completed 10/21/20.*
- **I-10 over CR268A** (445465-1), **E3T49** ***Fast-Facts -*** Approach Slab Replacement - Precast w/UHPC longitudinal joint (3 CY) – *letting 7/9/2020: Completed 4/13/20.*
- **1-10 over Perdido River** (442913-1), **E3T35**, Approach Slab Replacement: Precast w/UHPC longitudinal joint (3 CY) – *letting 6/11/2020 (Bid Tabs): Complete 6/3/21.*
- **I-10 over Crooked Creek** *(222539-3)* ***E3U40****– Approach Slab Replacement: Precast w/UHPC longitudinal joint – letting 10/14/21 (Bid Tabs), Argos-UHPC: Complete*
- **I-10 over CR 191/Garcon Point Rd** (441588-1/442915-1) **T3787**– Approach Slab Replacement: Precast w/UHPC longitudinal joint – *letting 4/28/21 (BSN), Argos-UHPC: Complete*
- **I-10 over Blackwater** (423591-5) **E3W54** – East Approach Slab Replacement on WB bridge: Precast w/UHPC longitudinal joint (3.0 CY) – *letting 7/13/23 (Bid Tabs), LaFarge-UHPC: Contract Executed.*

Where you can find UHPC in Florida: DISTRICT 4

- **SR 714/Danforth Creek** (430617-1), ***Fast-Facts:*** Sonovoid Rehab, Letting 4/1/16: *Completed 2/21/17.*
- **Henry Kinney Tunnel North Portal Extension** (439714-1) **T4582** – initially UHPC connections between vertical precast panels. *Letting 5/26/21,* *Bid Tabs* – ***status:*** *Redesigned by contractor to avoid UHPC.*

Where you can find UHPC in Florida: DISTRICT 5

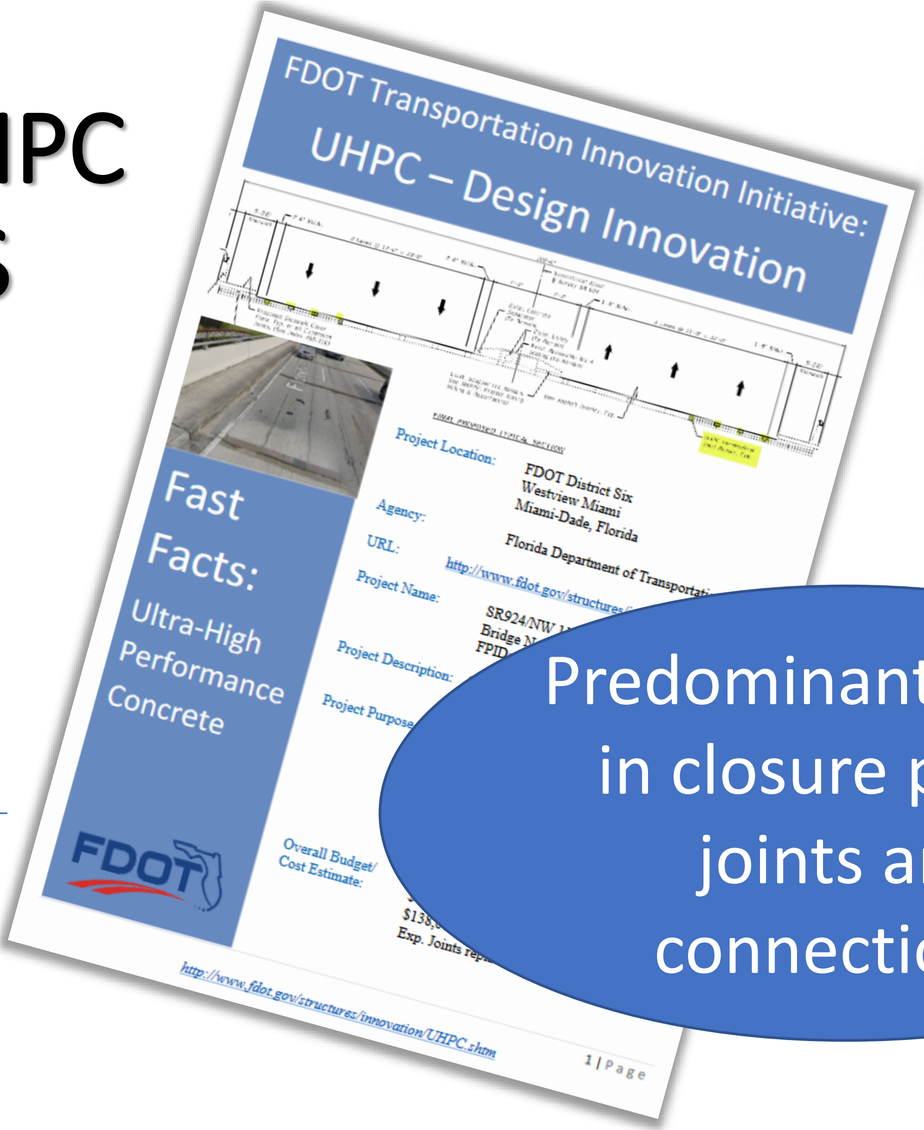
- **I-95 over CR5A** (438321-1), ***Fast-Facts:*** Deck Panel replacements: *Complete 2018.*

Where you can find UHPC in Florida: DISTRICT 6

- **SR 994/Quail Roost Dr./SW 200 St over Canal C-102** (441961-1) **E6M47**, *Let 8/27/20, Bid Tabs, Joint rehab sonovoid slab units (*ceEntek Inc.*):* *Completed 6/3/21.*
- **US-1/Little Duck Key** (436344-2) **E6M59, *Fast-Facts*,** Approach Slab Bridge Expansion Joint Repairs, Letting 2/27/20: *Complete 10/10/20.*
- SR 924/NW 119 St Over Rio Vista Canal (441963-1, lead 439981-1), **T6516**, Sonovoid Bridge Joint Rehab=96 LF, Letting 10/27/21, BidTabs, Steelike UHPC: *Completed 4/28/23*

Where you can find UHPC in Florida… FAST-FACTS

- I-10 over CR268A Approach Slab Replacement
- I-10 over Flat Creek Approach Slab Replacement
- I-95 over CR5A - Precast Deck Panel Replacement
- I-95/JT Butler Interchange Bridge U-Beam Repair
- SR 115/Arlington Expy over Red Bar Branch
- SR25(US27) NB over Fisheating Creek
- SR 714/Danforth Creek - Sonovoid Rehab
- SR 924/NW 119th St over Rio Vista Canal
- SR 994/Quail Roost Dr over Canal C-102
- US1 over Little Duck Key Channel
- US441 over Taylor Creek - Span 12 Replacement
- US41 over Sunset Waterway Link-Slab
- CR339/Waccasassa River Pile Demonstration



FDOT Transportation Innovation Initiative:
UHPC – Design Innovation

Fast Facts:
Ultra-High Performance Concrete

Project Location: FDOT District Six
Westview Miami
Miami-Dade, Florida

Agency: Florida Department of Transportati

URL: http://www.fdot.gov/structures

Project Name: SR924/NW
Bridge N
FPID

Project Description:

Project Purpose

Overall Budget/ Cost Estimate: $138,
Exp. Joints rep

http://www.fdot.gov/structures/innovation/UHPC.shtm

1 | Page

Predominantly used in closure pours, joints and connections.

Prestressed Concrete Pile

https://www.fdot.gov/structures/innovation/uhpc.shtm

FDOT UHPC H-PILE STANDARD DEVELOPMENT

Benefits

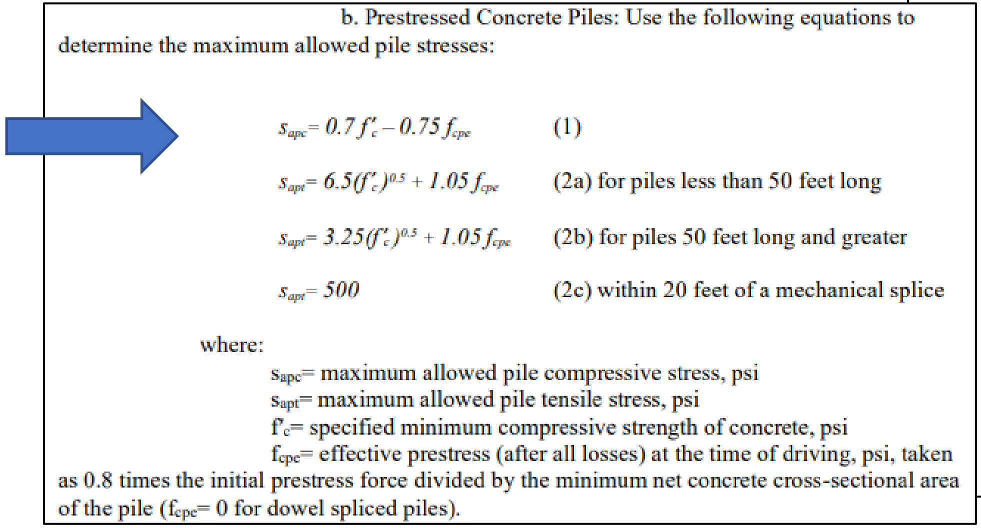
1. **Durability:** Benefit in places where corrosion is an issue (alternative to Standard Piles w/ SS or CFRP strands)
2. **Less Cracking** even with improved installation efficiency.
3. **Lighter weight** members → Reduced shipping and handling costs.
4. **Faster Installation:** Higher compressive and tensile strengths Permits larger driving stresses (using larger hammer and/or stroke)
5. **Fewer Piles**: Greater structural capacity requires a lower number of piles per bridge
6. **Precast Efficiency:** UHPC material is a better fit for a precast construction vs. CIP on-site:
   1. Repetition → Consistency
   2. Better Quality Control
7. **Higher moment** capacity → New possibilities?

Challenges

1. **Cost**
2. Pile **Splicing** (pre-planned or unplanned)
3. "**New**" Material → Material Specifications
   1. Casting Experience
   2. What should the concrete cover be for minimum durability?
   3. **Lack of Data** → Pile driving data, durability data, etc.
4. **Design Criteria** is still under development
   1. Structural Capacity (FHWA/AASHTO)
   2. Geotech Pile Analysis
   3. Scour
5. Determining a practical use for this pile type

FDOT H-PILE STANDARDS

PILE INTERACTION DIAGRAMS



b. Prestressed Concrete Piles: Use the following equations to determine the maximum allowed pile stresses:

$s_{apc} = 0.7f'_c - 0.75f_{cpe}$ (1)

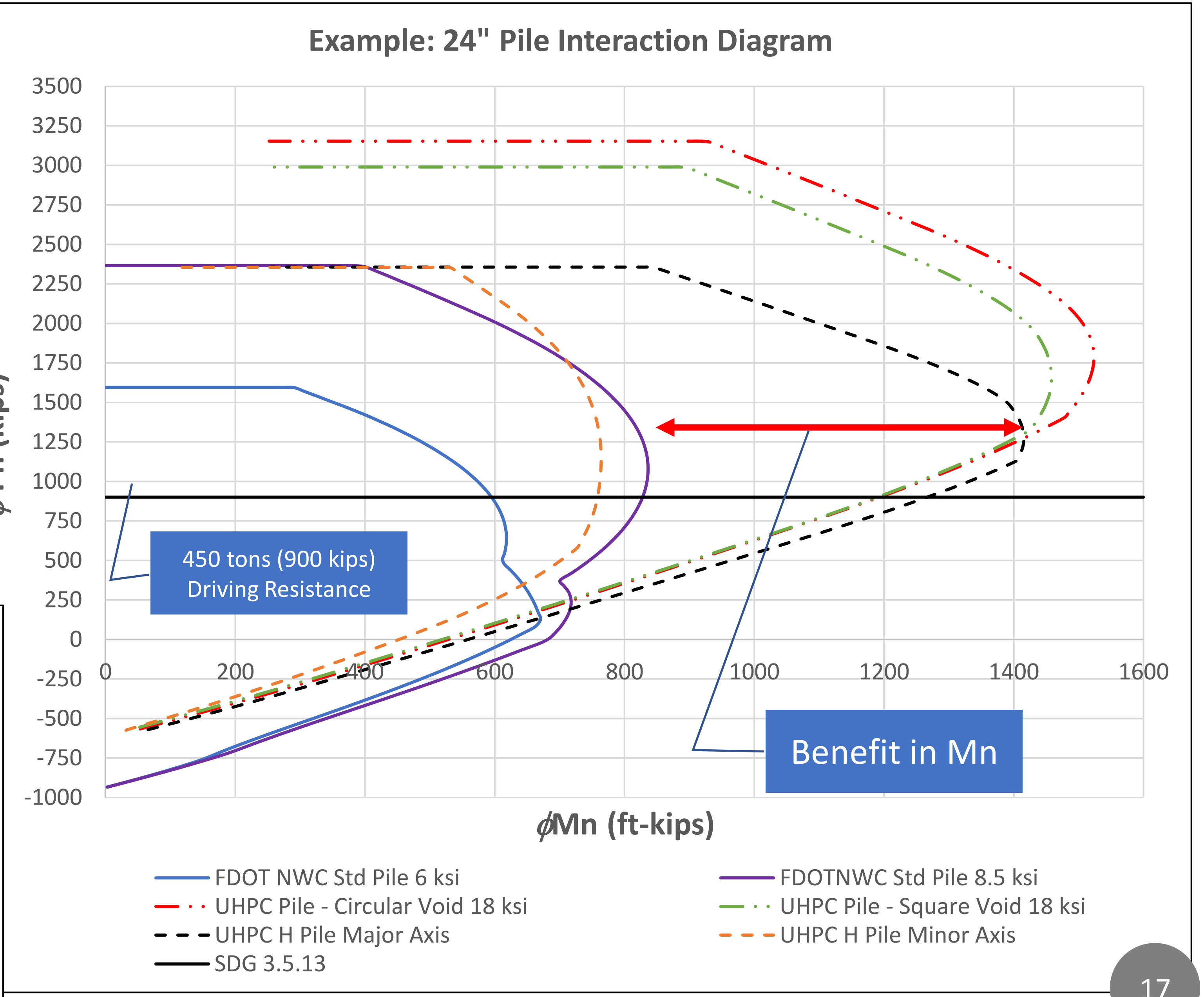
$s_{apt} = 6.5(f'_c)^{0.5} + 1.05f_{cpe}$ (2a) for piles less than 50 feet long

$s_{apt} = 3.25(f'_c)^{0.5} + 1.05f_{cpe}$ (2b) for piles 50 feet long and greater

$s_{apt} = 500$ (2c) within 20 feet of a mechanical splice

where:

s_{apc}= maximum allowed pile compressive stress, psi
s_{apt}= maximum allowed pile tensile stress, psi
f'_c= specified minimum compressive strength of concrete, psi
f_{cpe}= effective prestress (after all losses) at the time of driving, psi, taken as 0.8 times the initial prestress force divided by the minimum net concrete cross-sectional area of the pile (f_{cpe}= 0 for dowel spliced piles).



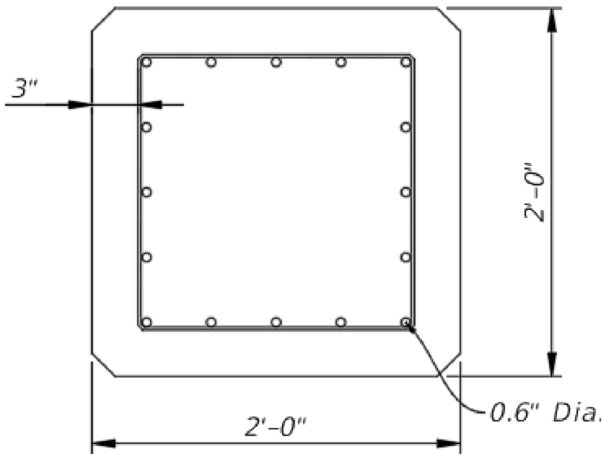
450 tons (900 kips) Driving Resistance

Benefit in Mn

FDOT H-PILE STANDARDS

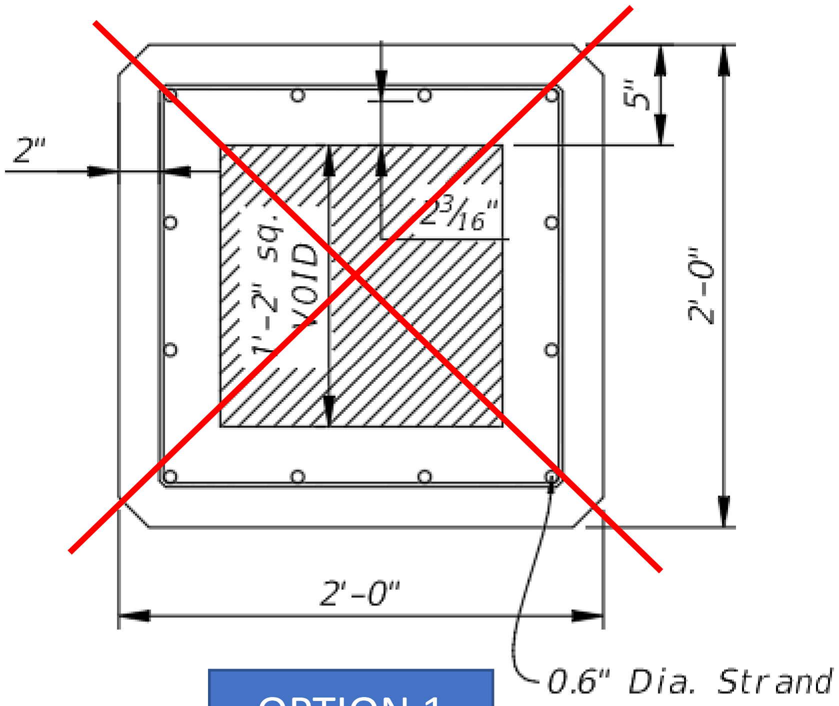
Issues with internal voids:

- Floating void (octagonal pile)
- Possible corrosion path when tying the void form material

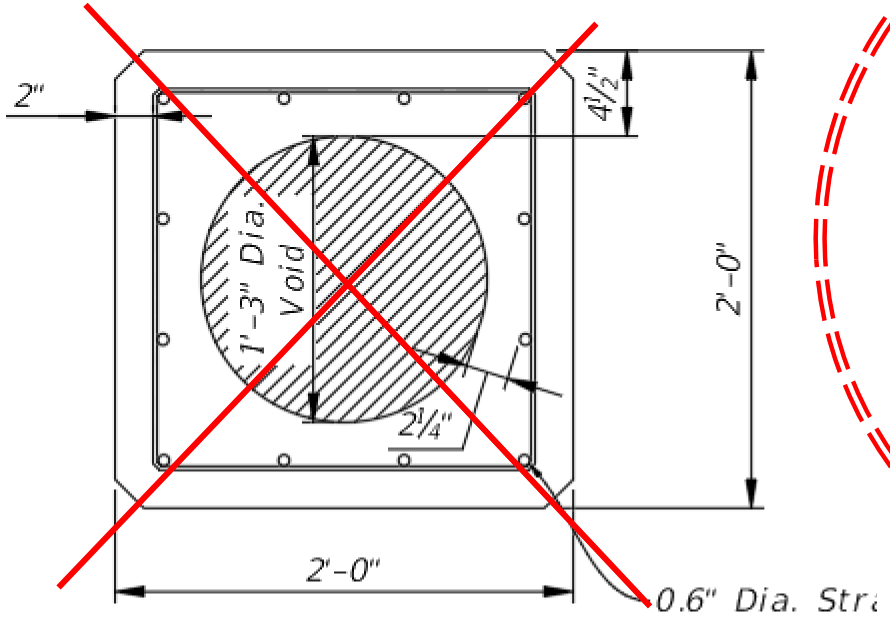


CURRENT FDOT CONCRETE STANDARD PILE

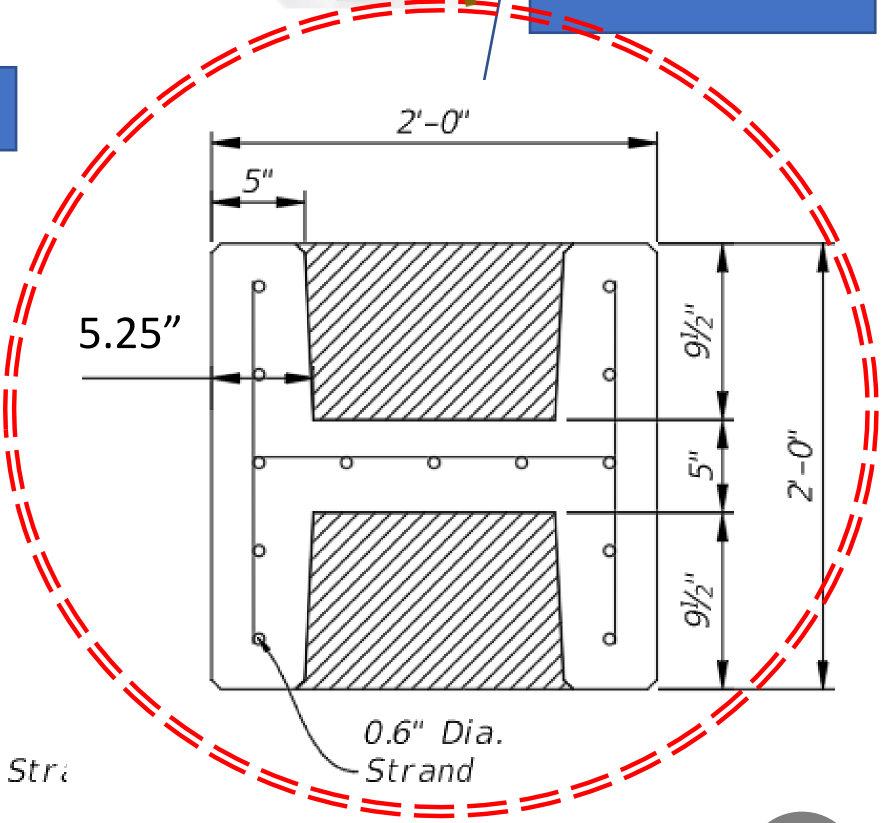
(2) 9.5" x 13" VOIDS ?



OPTION 1

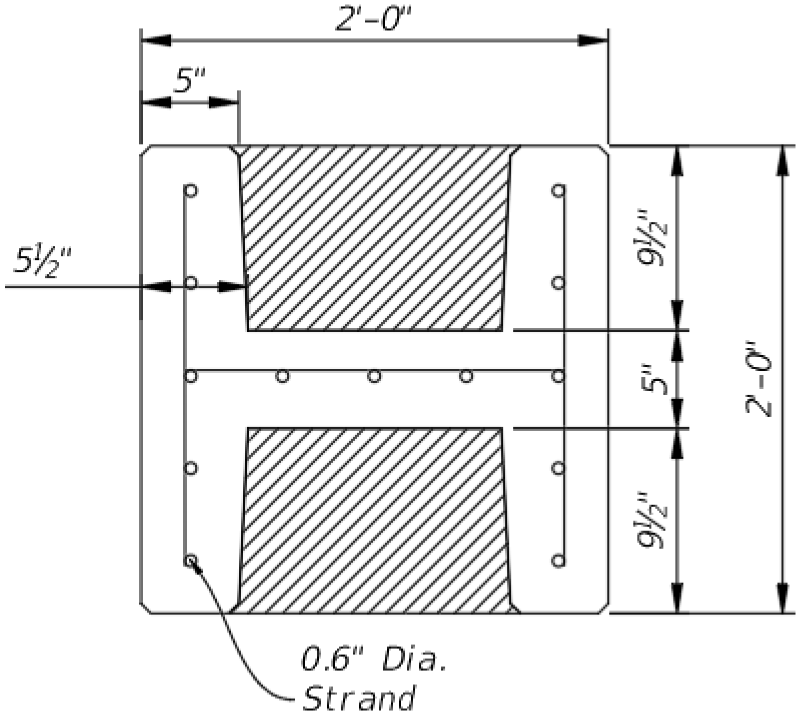


OPTION 2



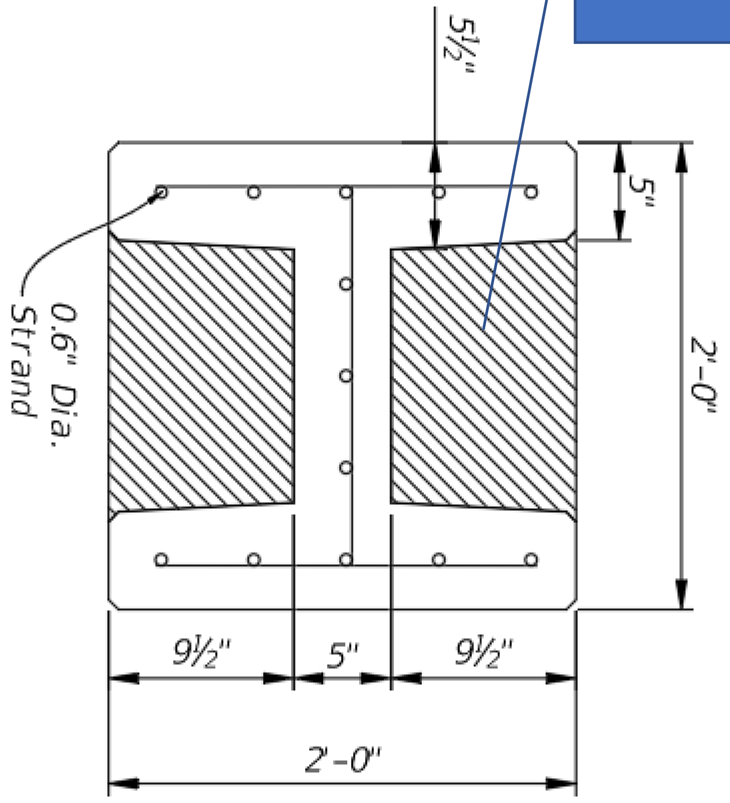
OPTION 3

FDOT H-PILE STANDARDS: FDOT Prototype (CR-339)



INITIAL H-SHAPE

(2) 9.5” x 13” VOIDS

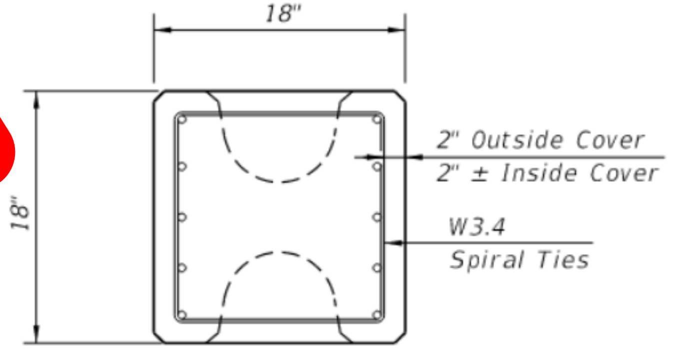


CAST AS AN ‘I’

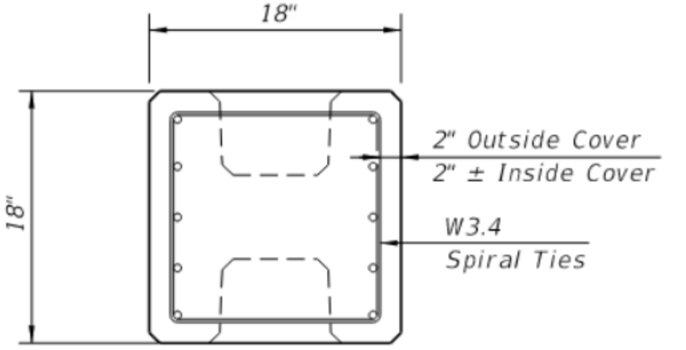
FDOT H-PILE STANDARDS:

18” x 18”

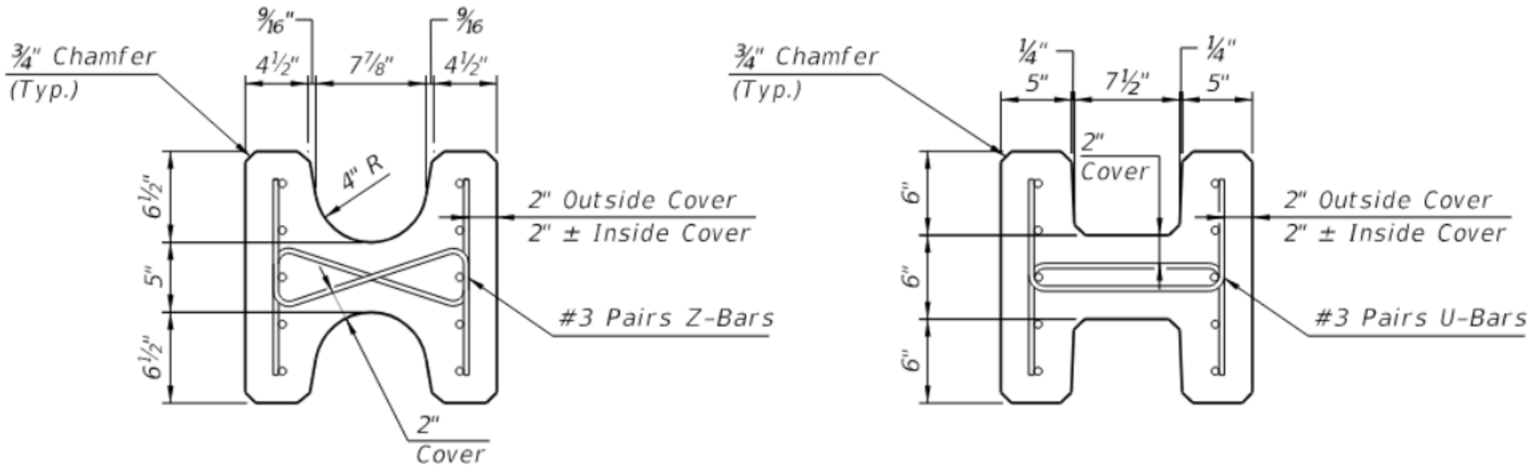
DRAFT



SECTION A-A
(Square Head - Option 1)



SECTION A-A
(Square Head - Option 2)



SECTION B-B
(H-Shape - Option 1)

SECTION B-B
(H-Shape - Option 2)

FDOT H-PILE STANDARDS:

24” x 24”

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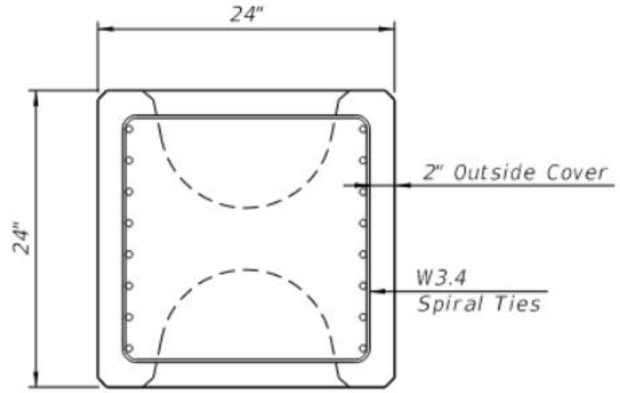

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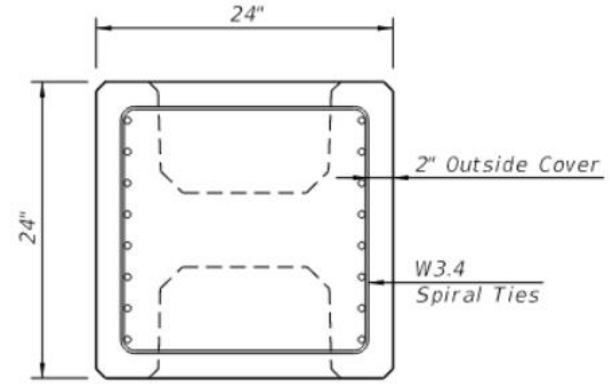

SECTION A-A
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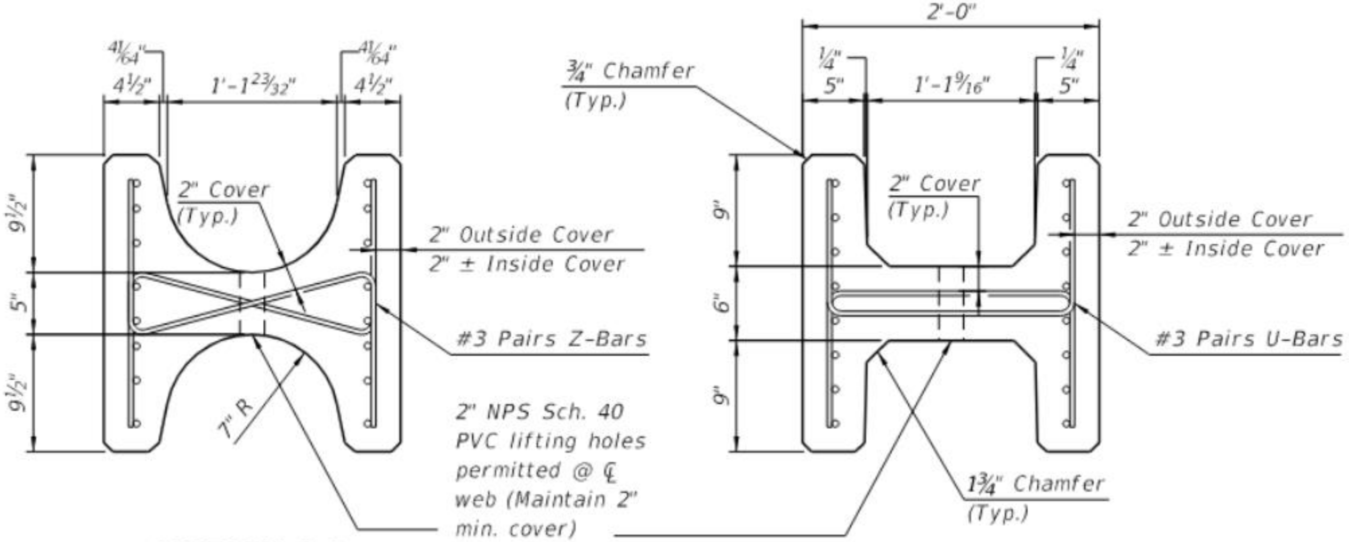

SECTION B-B
(H-Shape - Option 1)

SECTION B-B
(H-Shape - Option 2)

FDOT H-PILE STANDARDS:

24” x 24”

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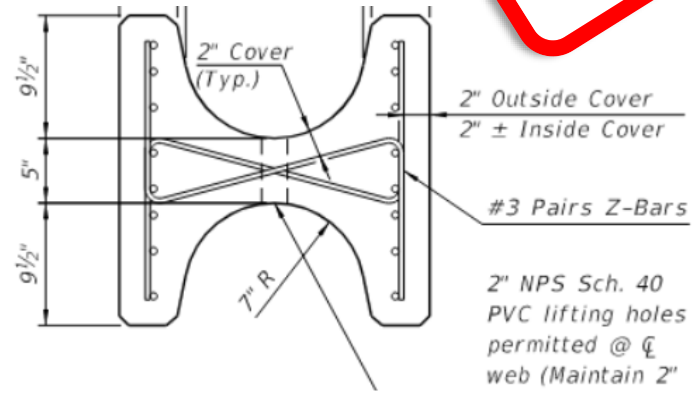
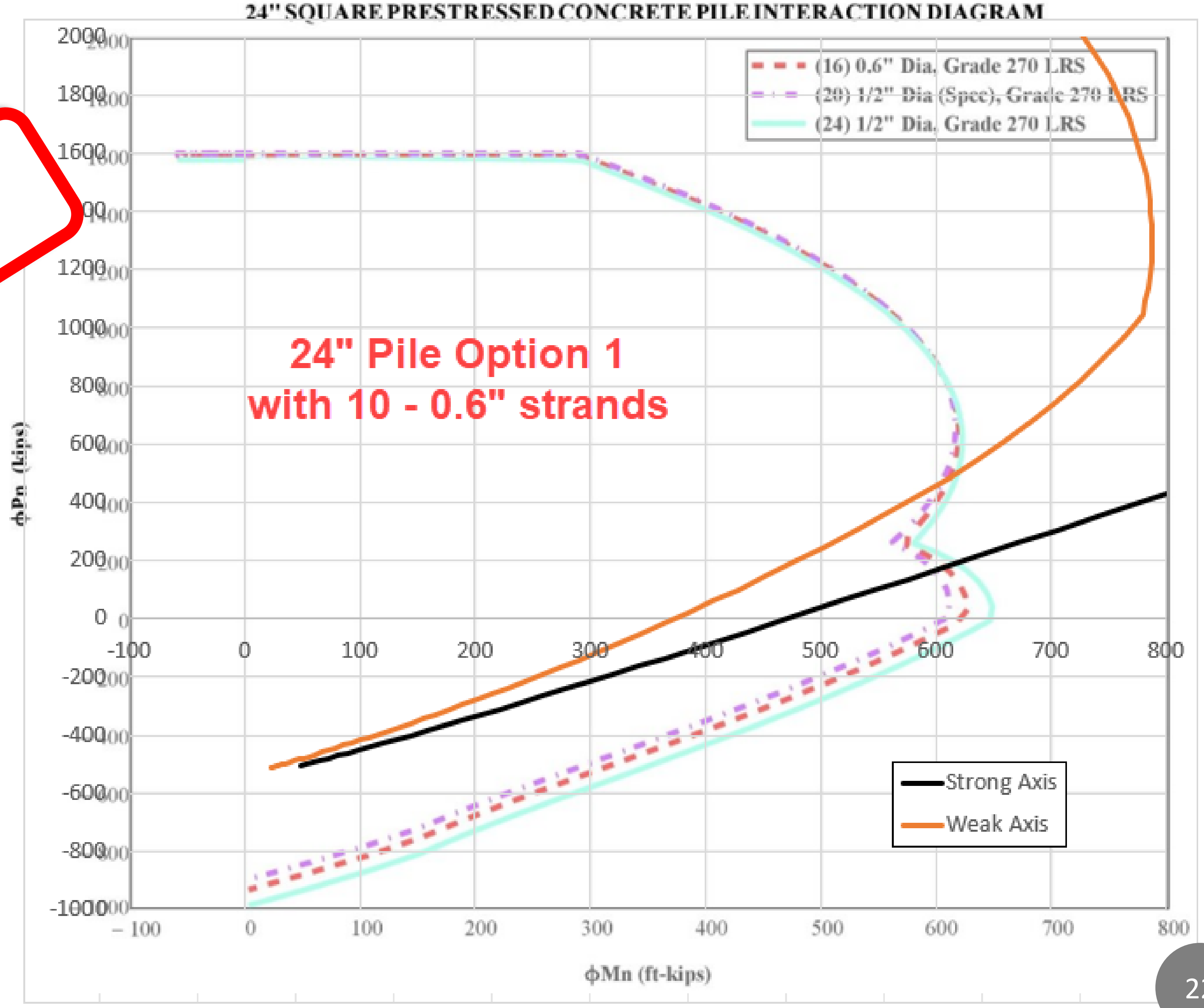


Pile Option 1 - 0.6" Strands

Pile Size	18	24	30
Pile Area (in^2)	231	349.6	473.1
# of Strands	8	10	14
Pull (kip)	44	44	44
f.pi (ksi)	202.8	202.8	202.8
Loss at installation	16.7%	15.4%	15.6%
f.pei (ksi)	169	171.6	171.2
Comp.Stress (ksi)	1.27	1.07	1.1


24" SQUARE PRESTRESSED CONCRETE PILE INTERACTION DIAGRAM

24" Pile Option 1 with 10 - 0.6" strands

FDOT H-PILE STANDARDS:

24” x 24”

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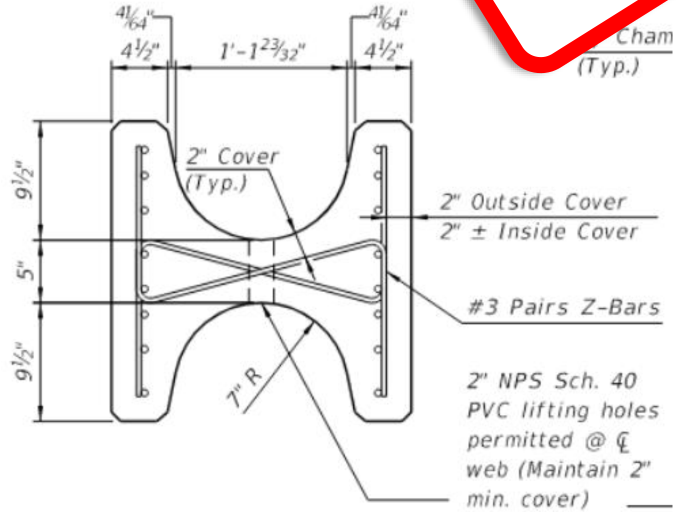
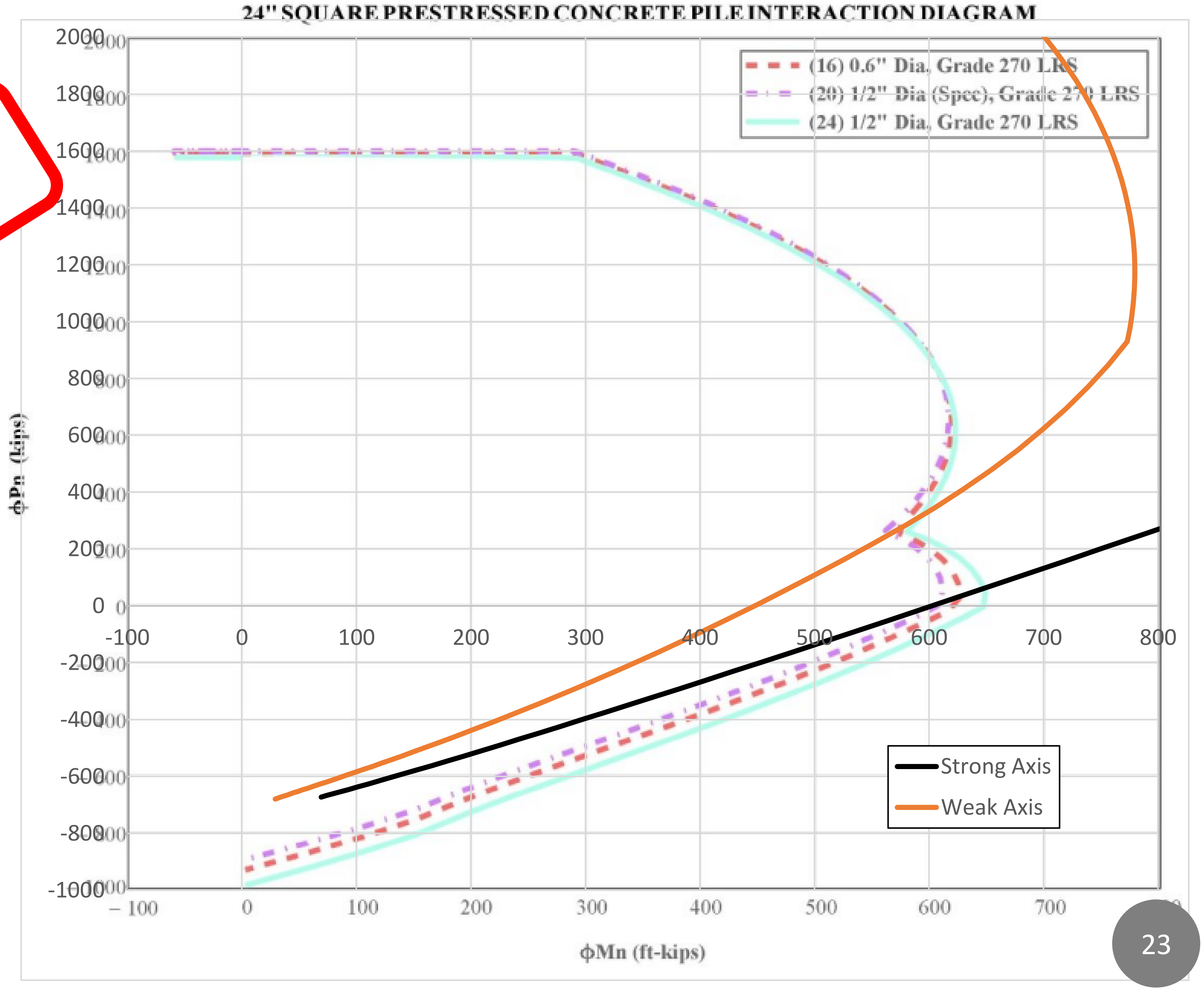


SECTION B-B
(H-Shape - Option 1)

Number of Strands for 1500 psi compression at installation

Pile Size	**18**	**24**	**30**
# of 0.6" Strands	10	16	20
Spacing of Strands (in)	3.35	2.77	2.82
Pull (kip)	43	41	44



FDOT H-PILE STANDARDS:

30” x 30”

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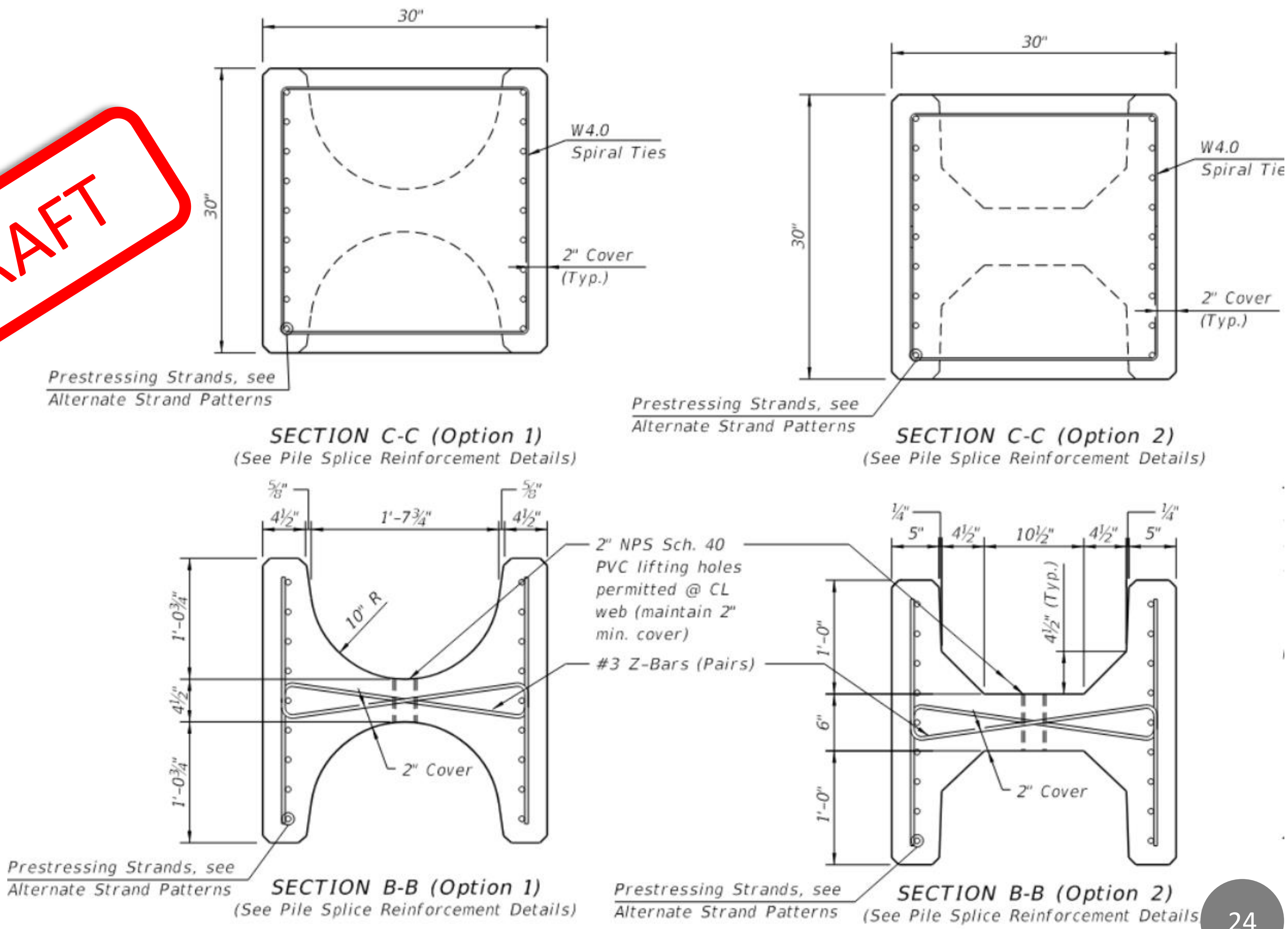


SECTION C-C (Option 1)
(See Pile Splice Reinforcement Details)

SECTION C-C (Option 2)
(See Pile Splice Reinforcement Details)

SECTION B-B (Option 1)
(See Pile Splice Reinforcement Details)

SECTION B-B (Option 2)
(See Pile Splice Reinforcement Details

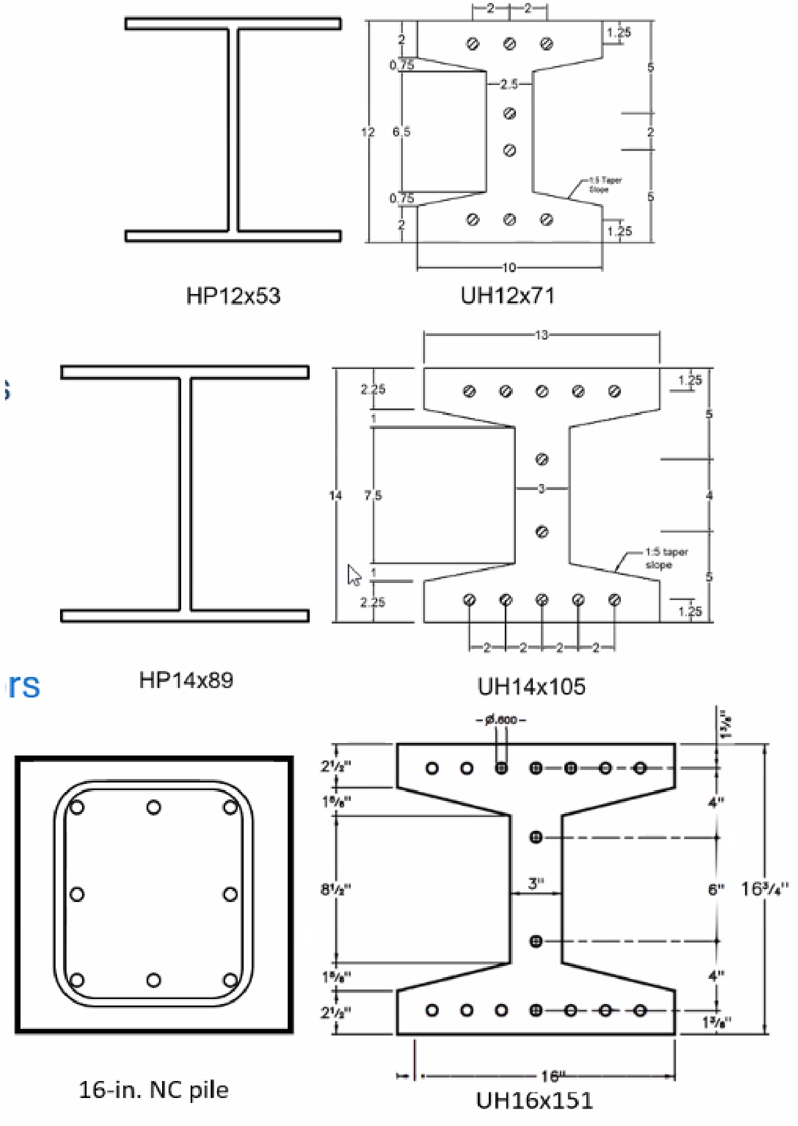
STANDARDIZING UHPC PILES: STATUS…

1. ***Standard Plans*** development *(Index 455-200 series) – Finalizing draft.*
2. ***Material Specifications:* Dev349UHPC & Dev927UHPC** – *Updates pending*
3. ***Materials Manual & FSTMs:***
4. ***Construction Specifications: Section 455- Section B*** – Not started
5. **Design Criteria & *Specifications:***
   - ***a. AASHTO Guide*** *– Approved by COBS, Publication pending.*
   - ***b. SDG Chapter 3 –*** *Not started.*
   - ***c. Soils & Foundation Handbook –*** *Pending research on skin friction & pile driving limits.*
6. **Industry Coordination:**
   - **a. Producers:** Prestressed Concrete Industry (FPCA, Durastress, Standard Concrete, Gate, etc.) – *Ongoing discussions.*
   - **b. Contractors:** FPCA & Leware - Limited discussions.
7. **Research:** LOTS OF RESEARCH going on!
   - a. FDOT Sponsored
   - b. FHWA/AASHTO
   - c. PCI, etc.
8. **District Input:** Possible users, SAMTAG Updates.

H-PILE FABRICATION & TESTING

Alabama Style

Similarities to Dr. Aeliti/FACCA H-Shape cast at Standard Concrete Products (Tampa, FL) 10/26/2022.



H-PILE FABRICATION & TESTING

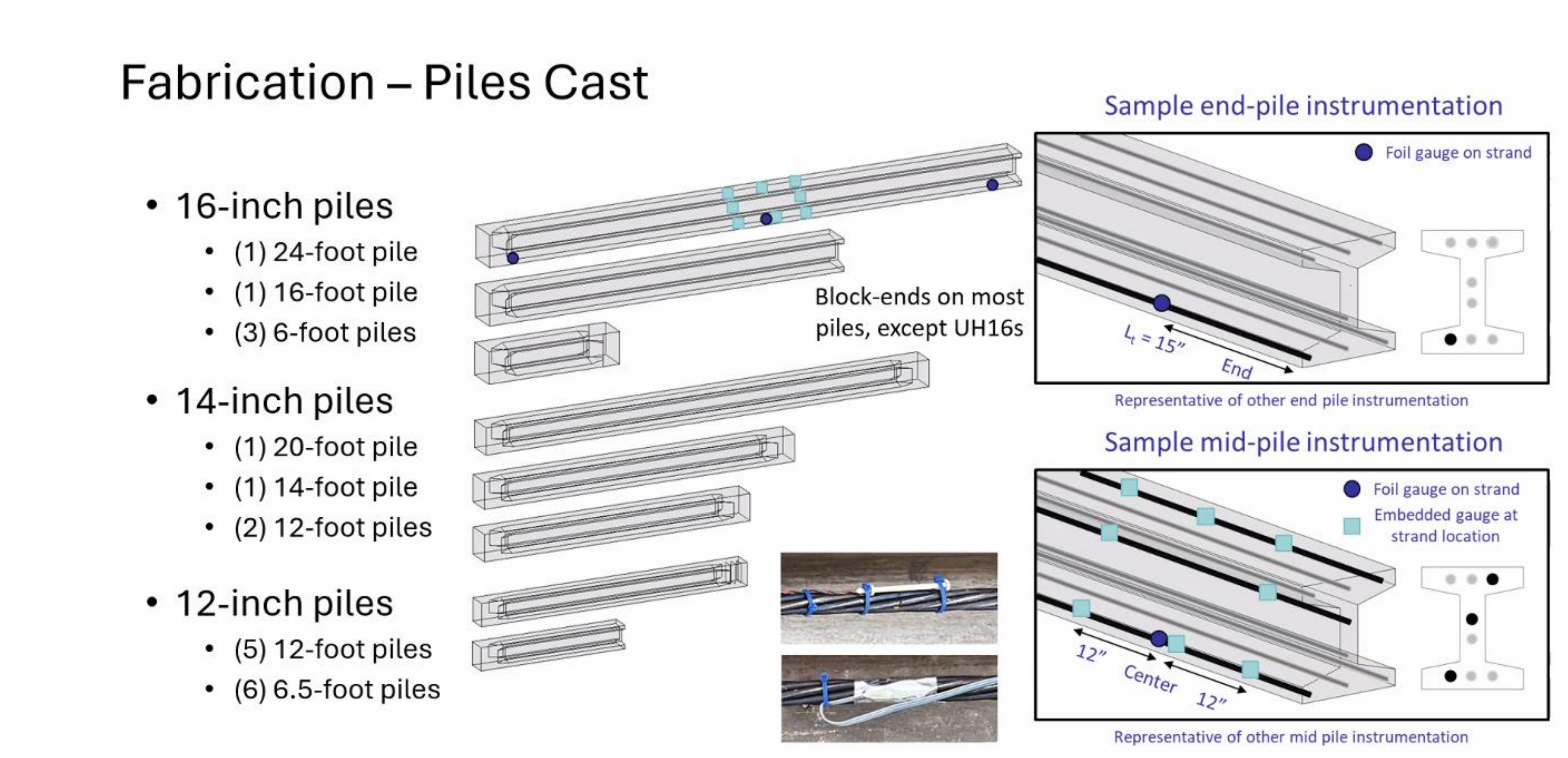
Alabama Style

Dr. Aaleti/FACCA H-Shape Casting
(10/26/2022)

Video Disbaled

H-PILE FABRICATION & TESTING

Alabama Style



Fabrication – Piles Cast

- 16-inch piles
  - (1) 24-foot pile
  - (1) 16-foot pile
  - (3) 6-foot piles
- 14-inch piles
  - (1) 20-foot pile
  - (1) 14-foot pile
  - (2) 12-foot piles
- 12-inch piles
  - (5) 12-foot piles
  - (6) 6.5-foot piles

Block-ends on most piles, except UH16s

Sample end-pile instrumentation

Representative of other end pile instrumentation

Sample mid-pile instrumentation

Representative of other mid pile instrumentation

Source: *Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)*

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UH12s and 14s – Birmingham Plant

UH16s – Tampa Plant

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

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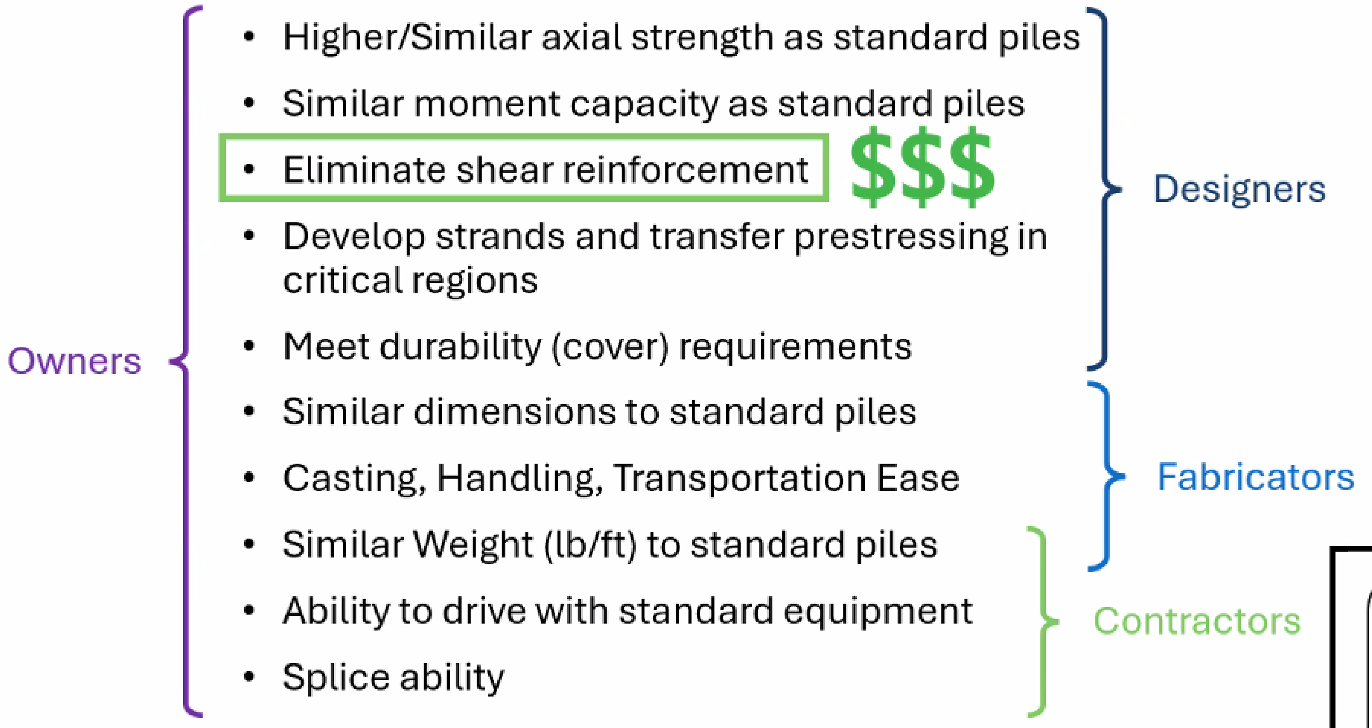
Pile Design Process



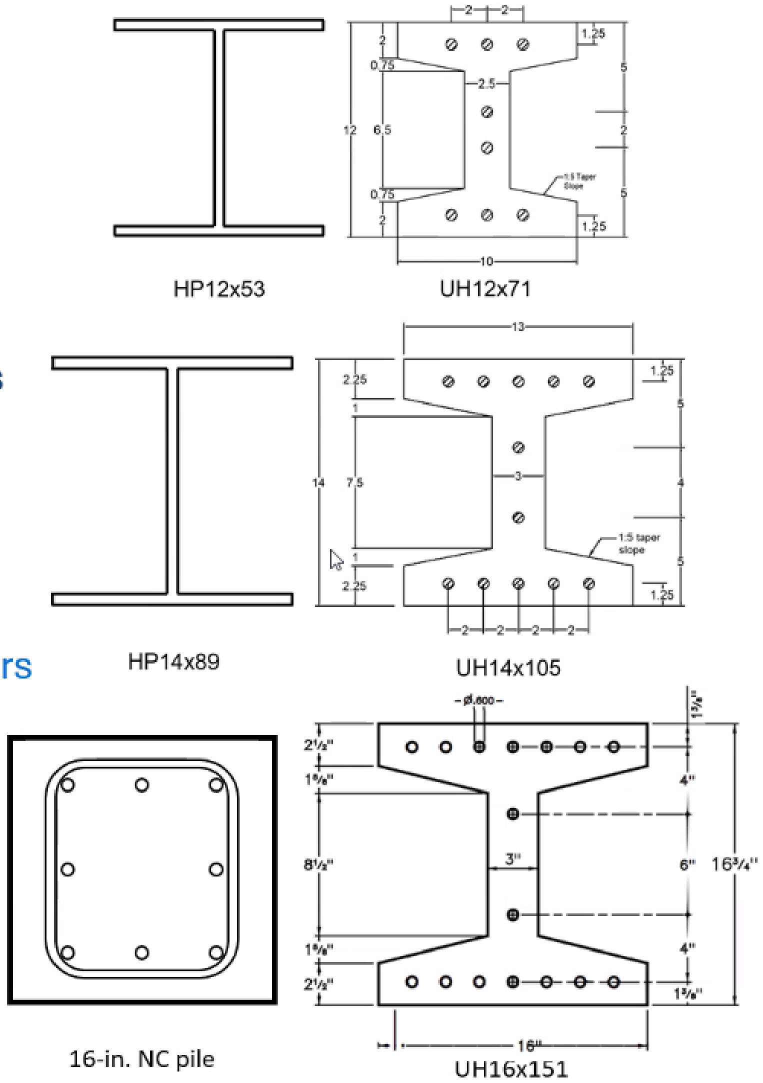
- Higher/Similar axial strength as standard piles
- Similar moment capacity as standard piles
- Eliminate shear reinforcement **$$$**
- Develop strands and transfer prestressing in critical regions
- Meet durability (cover) requirements
- Similar dimensions to standard piles
- Casting, Handling, Transportation Ease
- Similar Weight (lb/ft) to standard piles
- Ability to drive with standard equipment
- Splice ability

Owners

Designers

Fabricators

Contractors



Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

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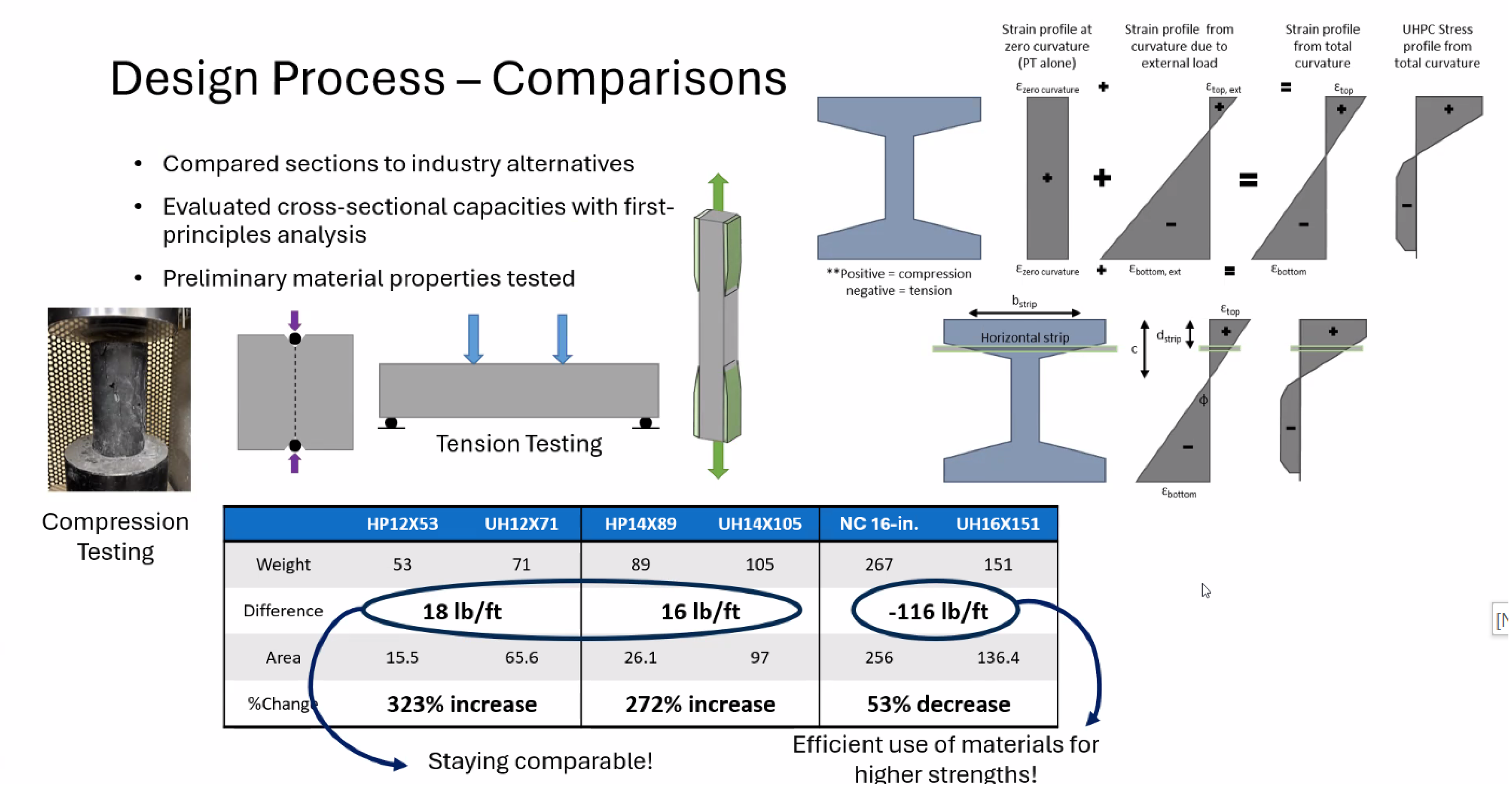

Design Process – Comparisons

- Compared sections to industry alternatives
- Evaluated cross-sectional capacities with first-principles analysis
- Preliminary material properties tested

	HP12X53	UH12X71	HP14X89	UH14X105	NC 16-in.	UH16X151
Weight	53	71	89	105	267	151
Difference	18 lb/ft		16 lb/ft		-116 lb/ft	
Area	15.5	65.6	26.1	97	256	136.4
%Change	323% increase		272% increase		53% decrease	

Staying comparable!

Efficient use of materials for higher strengths!

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

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Detensioning

- Strains measured during detensioning
- Elastic shortening losses
- Transfer length appropriate!

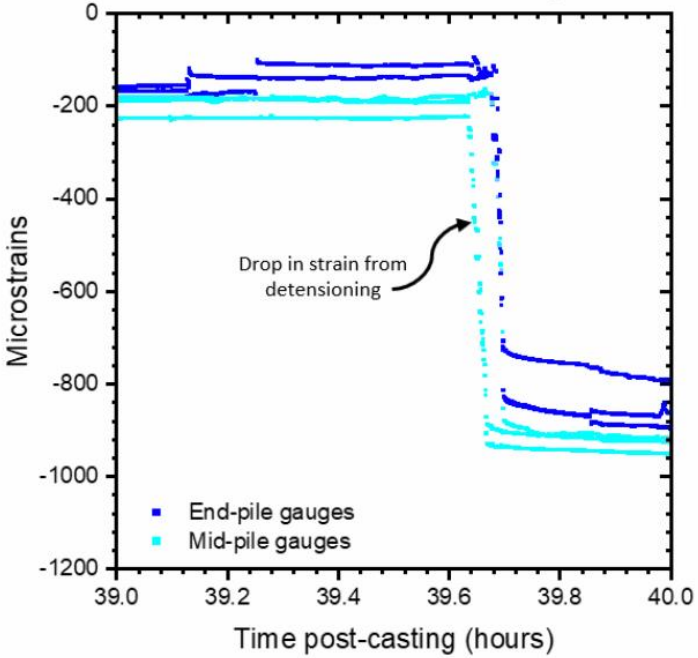
From the field!

$$\Delta f_{pES,strains} = E_{ps} * \boxed{\epsilon_{DT}}$$

$$\Delta f_{pES,AASHTO} = \frac{E_{ps}}{E_{ci}} * f_{pi} * \frac{A_{ps}}{A_t}$$

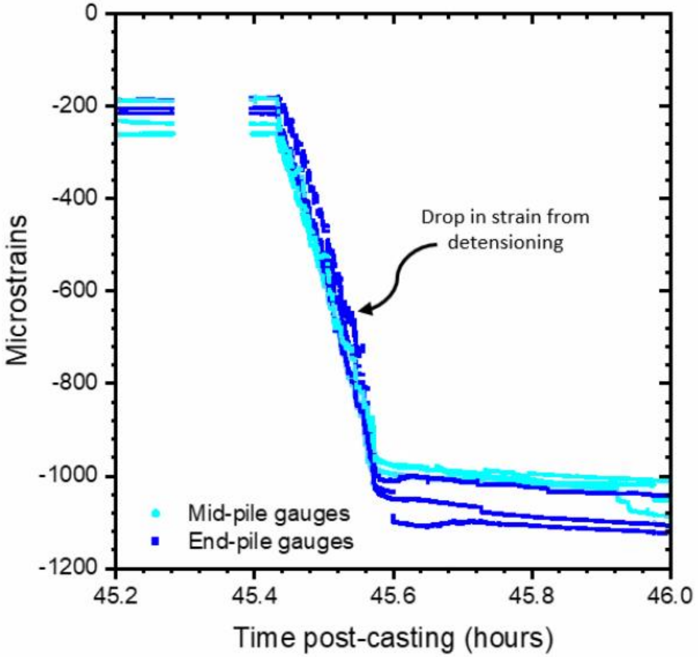
	UH12x71 UH14x105	UH16X151
$\Delta f_{pES,strains}$	22.5 ksi	23.7 ksi
$\Delta f_{pES,AASHTO}$	23.3 ksi	24.7 ksi

UH12s and UH14s Detensioning Strains



Drop in strain from detensioning

UH16s Detensioning Strains



Drop in strain from detensioning

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

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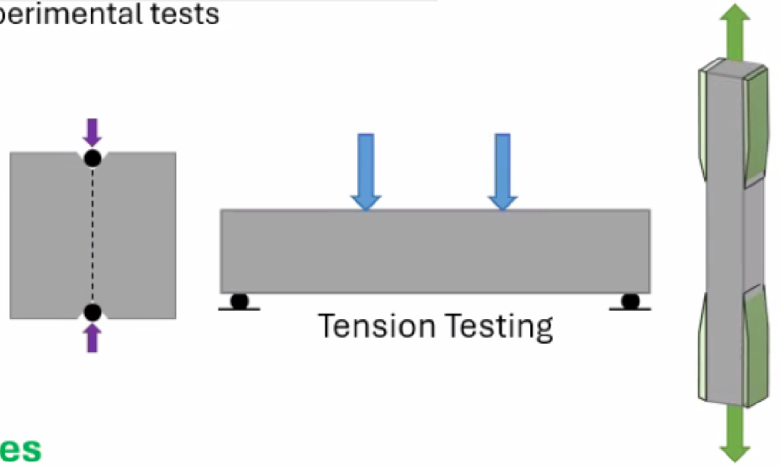
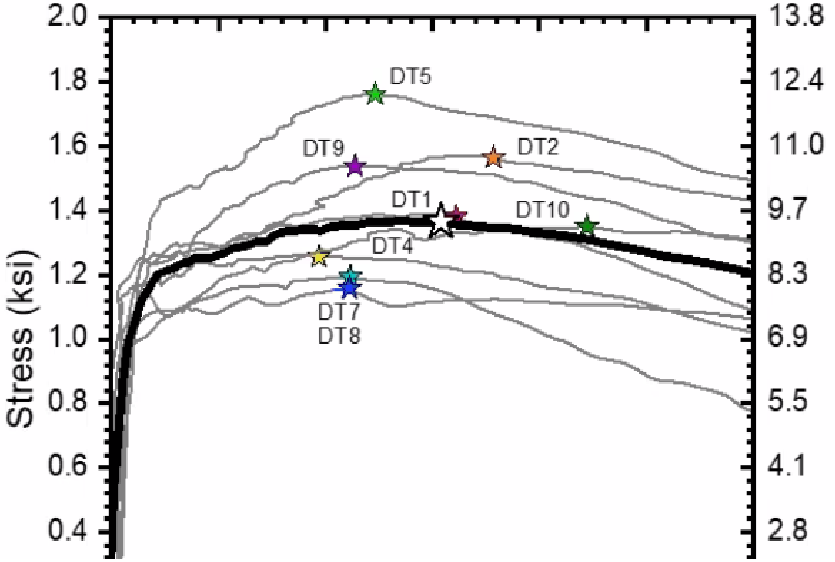
E_{ci} (early strength)	6052 ksi	5385 ksi**
E_c (full-strength)	6974 ksi	6350 ksi

**not from experimental tests

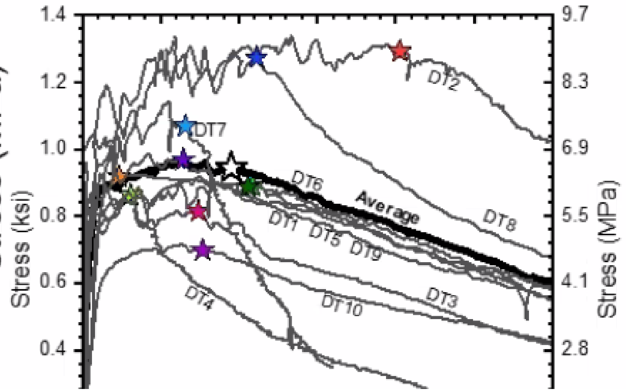
- Compressive strength testing
- Elastic modulus testing at early strength (when possible) and full-strength
- Multiple methods of tension testing



UH12s and UH14s Tension Curves



UH16s Tension Curves



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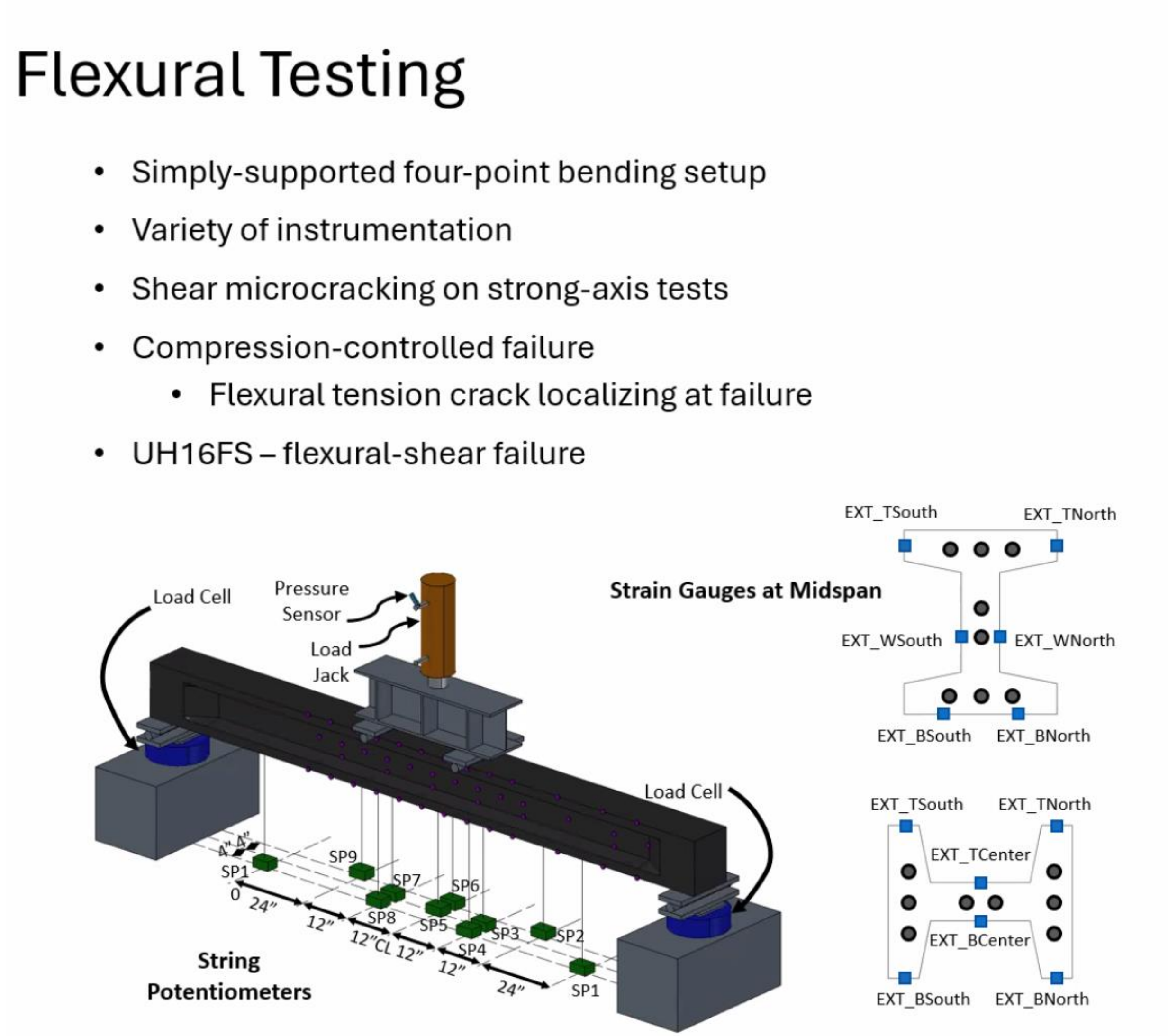
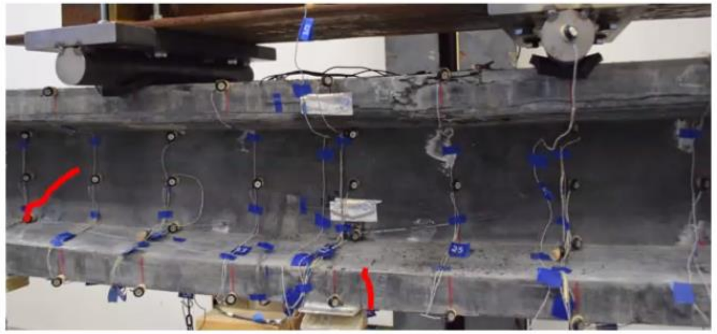
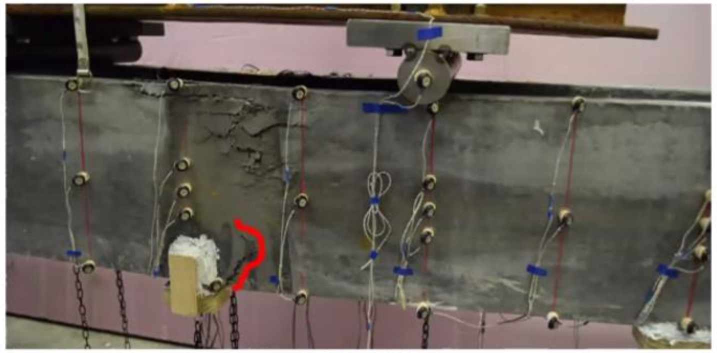


Flexural Testing

- Simply-supported four-point bending setup
- Variety of instrumentation
- Shear microcracking on strong-axis tests
- Compression-controlled failure
  - Flexural tension crack localizing at failure
- UH16FS – flexural-shear failure



UH12FS



UH12FW

UH16FS

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

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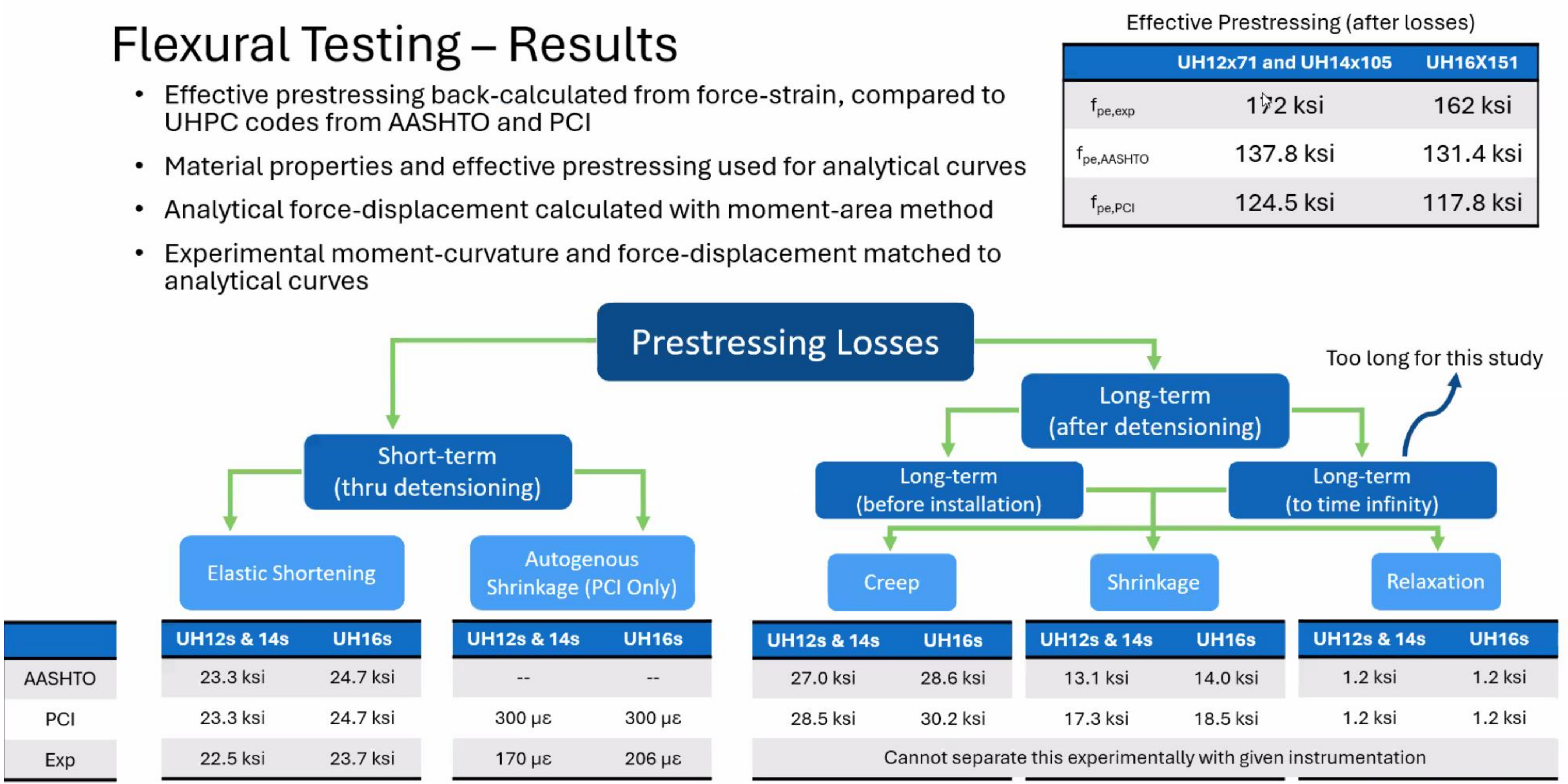

Flexural Testing – Results

- Effective prestressing back-calculated from force-strain, compared to UHPC codes from AASHTO and PCI
- Material properties and effective prestressing used for analytical curves
- Analytical force-displacement calculated with moment-area method
- Experimental moment-curvature and force-displacement matched to analytical curves

Effective Prestressing (after losses)

	UH12x71 and UH14x105	UH16X151
$f_{pe,exp}$	172 ksi	162 ksi
$f_{pe,AASHTO}$	137.8 ksi	131.4 ksi
$f_{pe,PCI}$	124.5 ksi	117.8 ksi

Prestressing Losses

Short-term (thru detensioning)

Long-term (after detensioning)

Long-term (before installation)

Long-term (to time infinity)

Too long for this study

	Elastic Shortening		Autogenous Shrinkage (PCI Only)		Creep		Shrinkage		Relaxation	
	UH12s & 14s	UH16s	UH12s & 14s	UH16s	UH12s & 14s	UH16s	UH12s & 14s	UH16s	UH12s & 14s	UH16s
AASHTO	23.3 ksi	24.7 ksi	--	--	27.0 ksi	28.6 ksi	13.1 ksi	14.0 ksi	1.2 ksi	1.2 ksi
PCI	23.3 ksi	24.7 ksi	300 με	300 με	28.5 ksi	30.2 ksi	17.3 ksi	18.5 ksi	1.2 ksi	1.2 ksi
Exp	22.5 ksi	23.7 ksi	170 με	206 με	Cannot separate this experimentally with given instrumentation					

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

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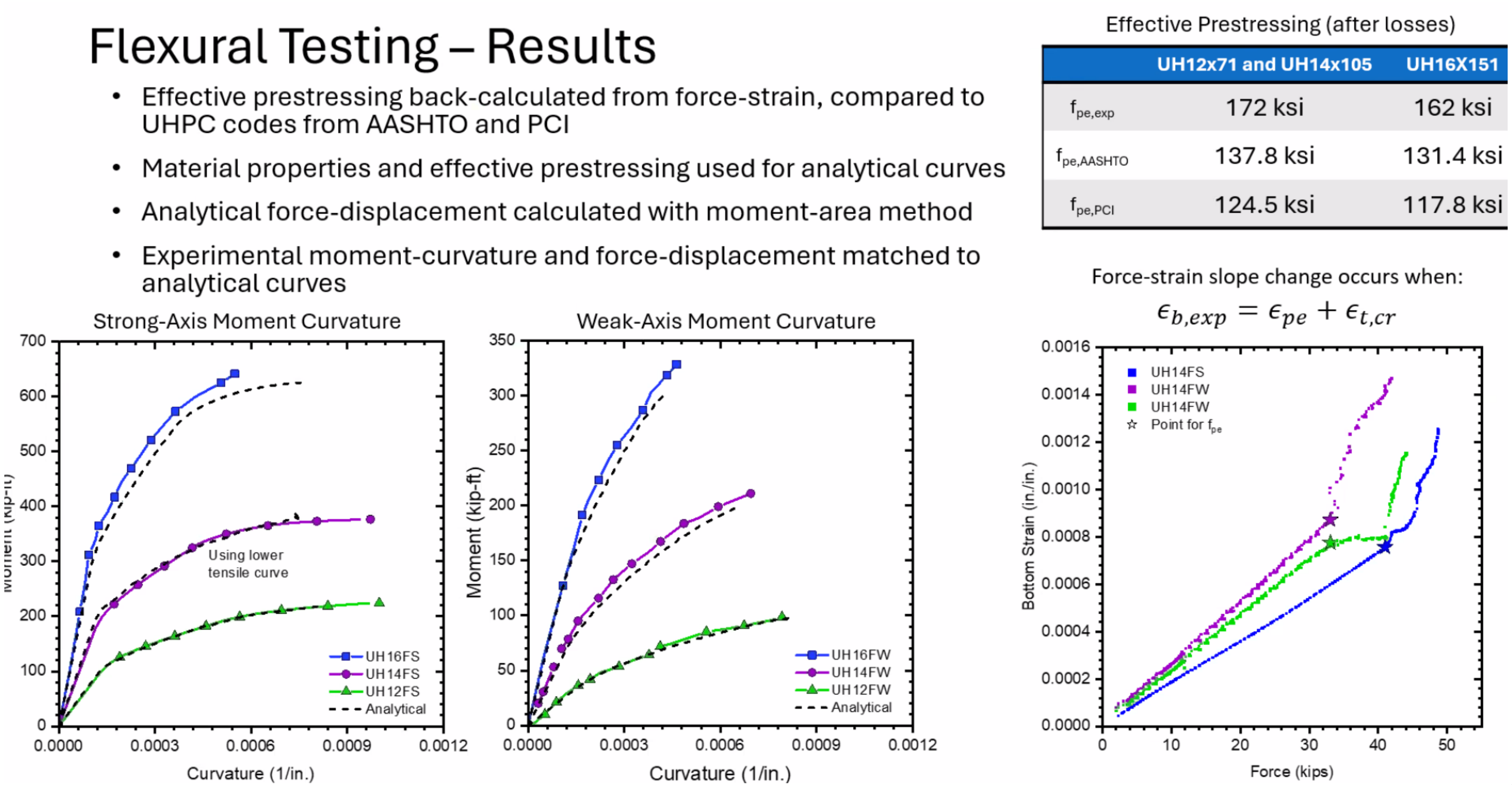

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Force-strain slope change occurs when:

$$\epsilon_{b,exp} = \epsilon_{pe} + \epsilon_{t,cr}$$

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

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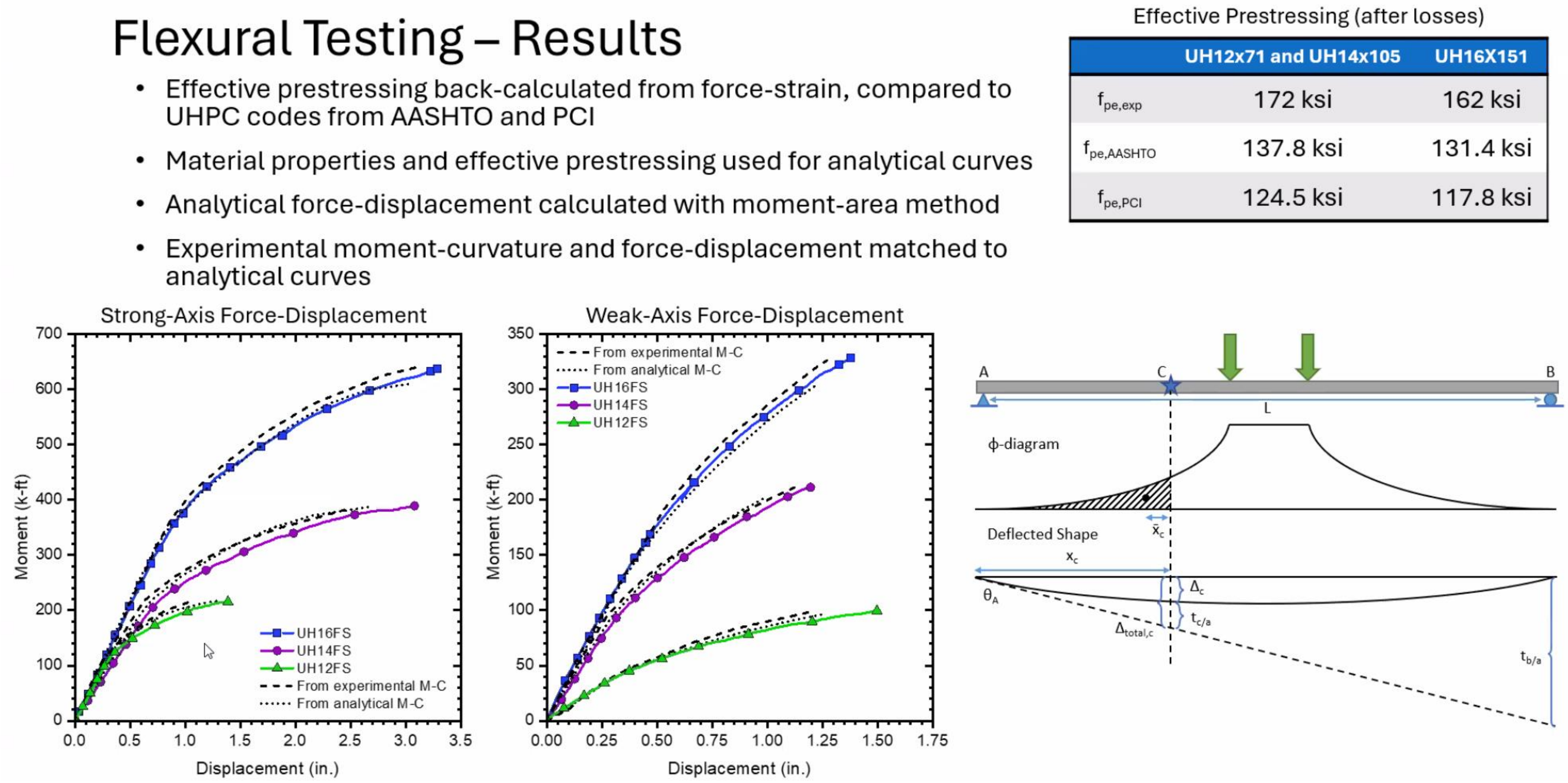

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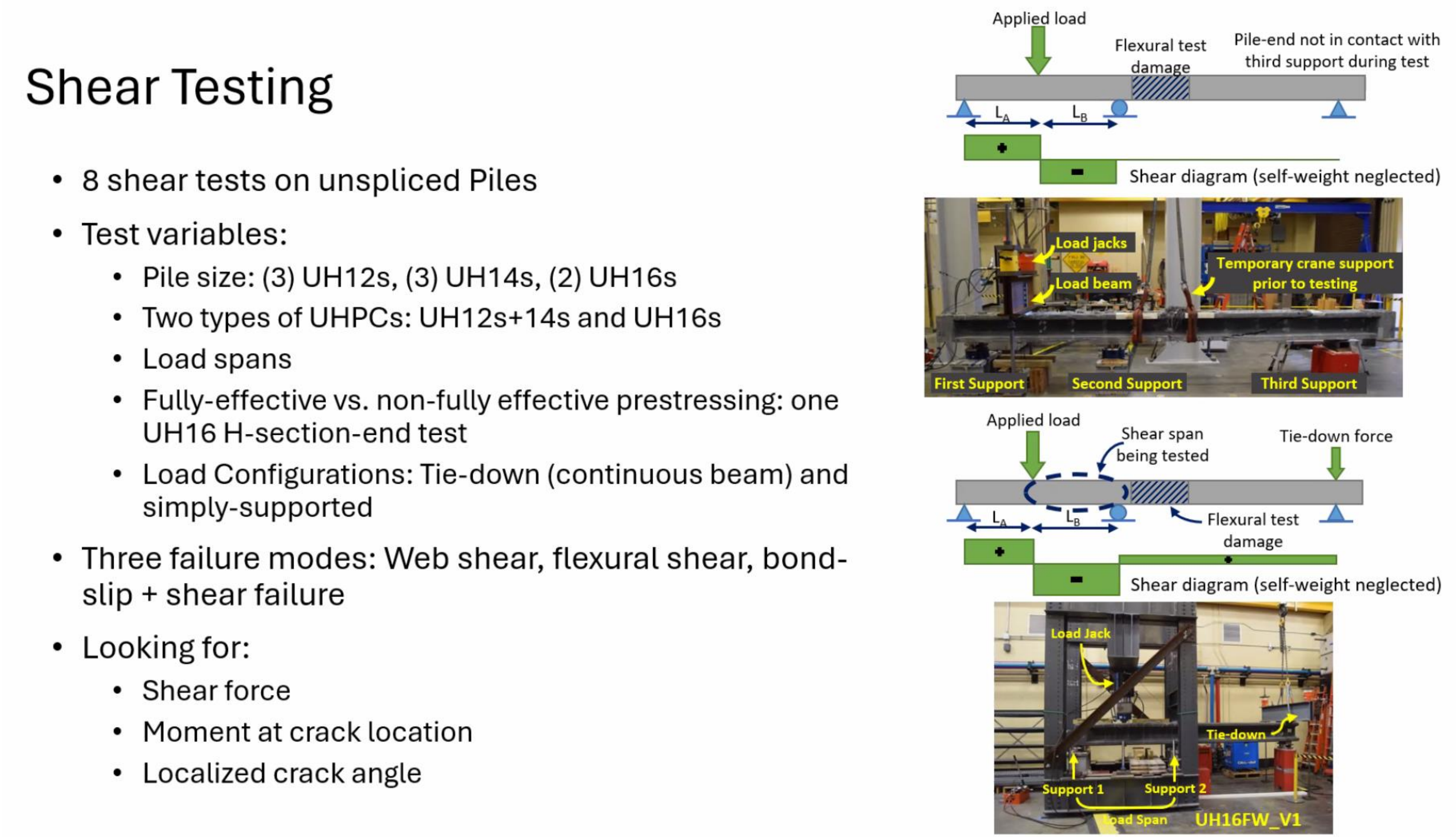

Shear Testing

- 8 shear tests on unspliced Piles
- Test variables:
  - Pile size: (3) UH12s, (3) UH14s, (2) UH16s
  - Two types of UHPCs: UH12s+14s and UH16s
  - Load spans
  - Fully-effective vs. non-fully effective prestressing: one UH16 H-section-end test
  - Load Configurations: Tie-down (continuous beam) and simply-supported
- Three failure modes: Web shear, flexural shear, bond-slip + shear failure
- Looking for:
  - Shear force
  - Moment at crack location
  - Localized crack angle

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

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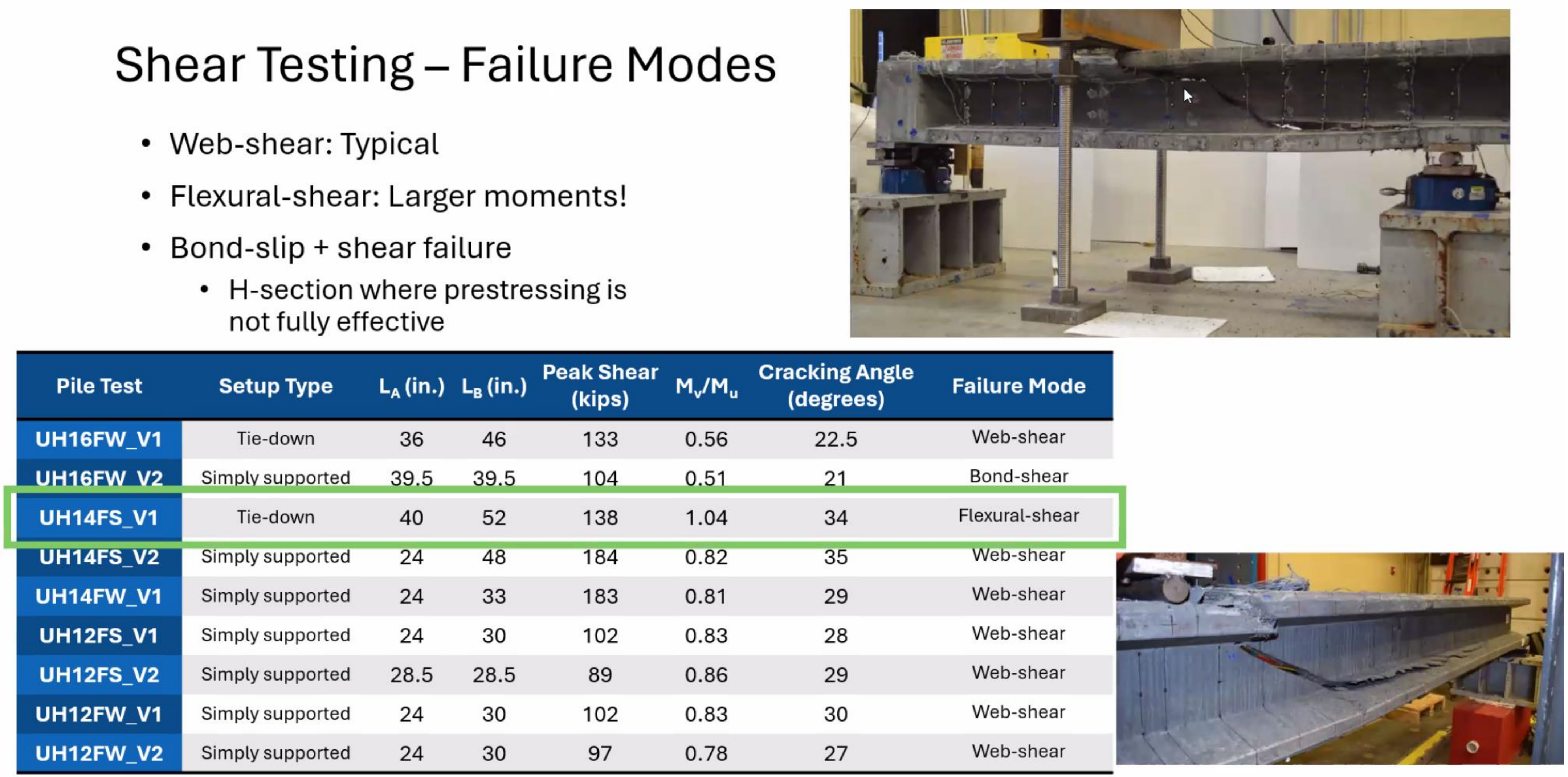

Shear Testing – Failure Modes

- Web-shear: Typical
- Flexural-shear: Larger moments!
- Bond-slip + shear failure
    - H-section where prestressing is not fully effective

Pile Test	Setup Type	L_A (in.)	L_B (in.)	Peak Shear (kips)	M_v/M_u	Cracking Angle (degrees)	Failure Mode
UH16FW_V1	Tie-down	36	46	133	0.56	22.5	Web-shear
UH16FW_V2	Simply supported	39.5	39.5	104	0.51	21	Bond-shear
UH14FS_V1	Tie-down	40	52	138	1.04	34	Flexural-shear
UH14FS_V2	Simply supported	24	48	184	0.82	35	Web-shear
UH14FW_V1	Simply supported	24	33	183	0.81	29	Web-shear
UH12FS_V1	Simply supported	24	30	102	0.83	28	Web-shear
UH12FS_V2	Simply supported	28.5	28.5	89	0.86	29	Web-shear
UH12FW_V1	Simply supported	24	30	102	0.83	30	Web-shear
UH12FW_V2	Simply supported	24	30	97	0.78	27	Web-shear

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

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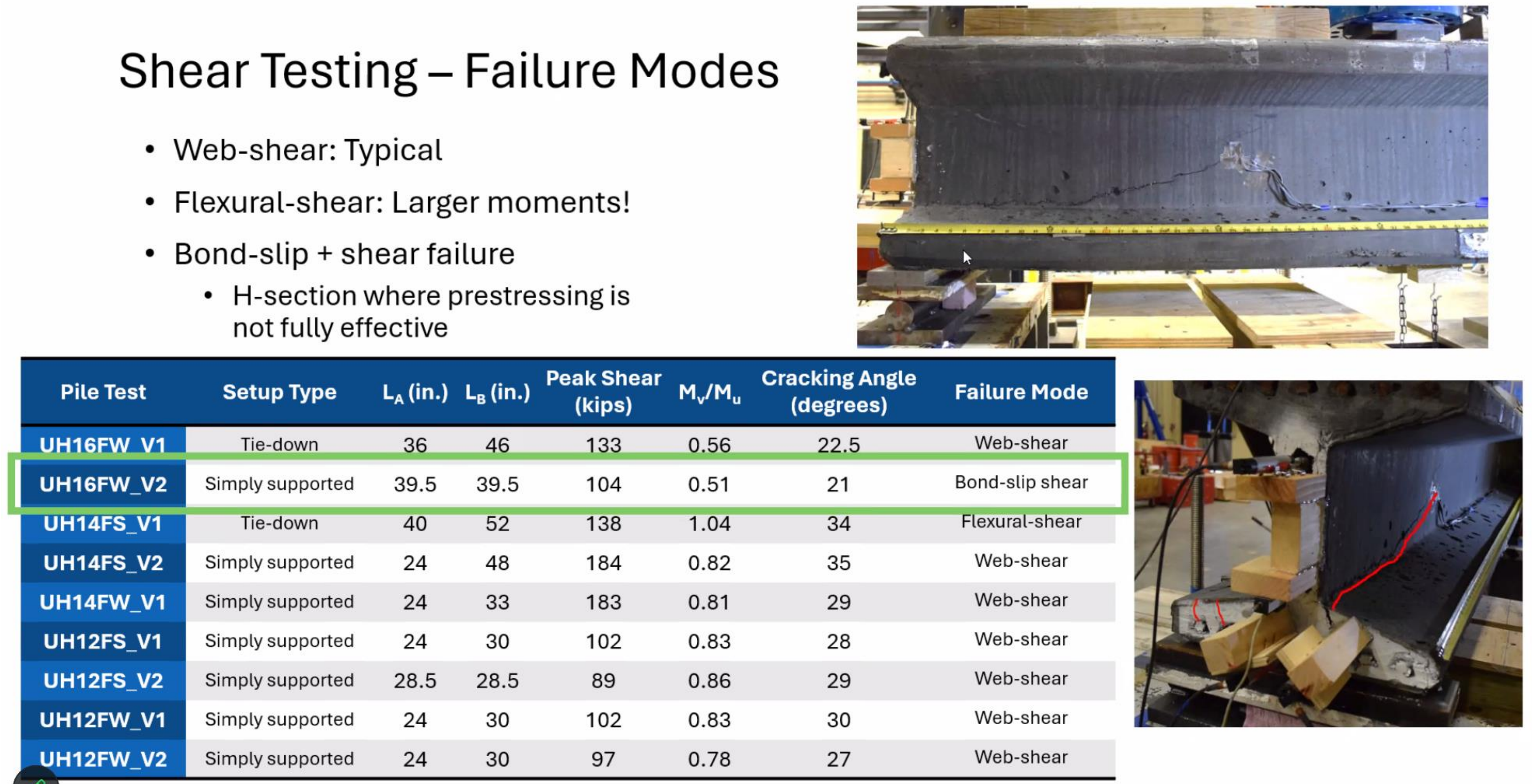

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UH12FS_V2	Simply supported	28.5	28.5	89	0.86	29	Web-shear
UH12FW_V1	Simply supported	24	30	102	0.83	30	Web-shear
UH12FW_V2	Simply supported	24	30	97	0.78	27	Web-shear

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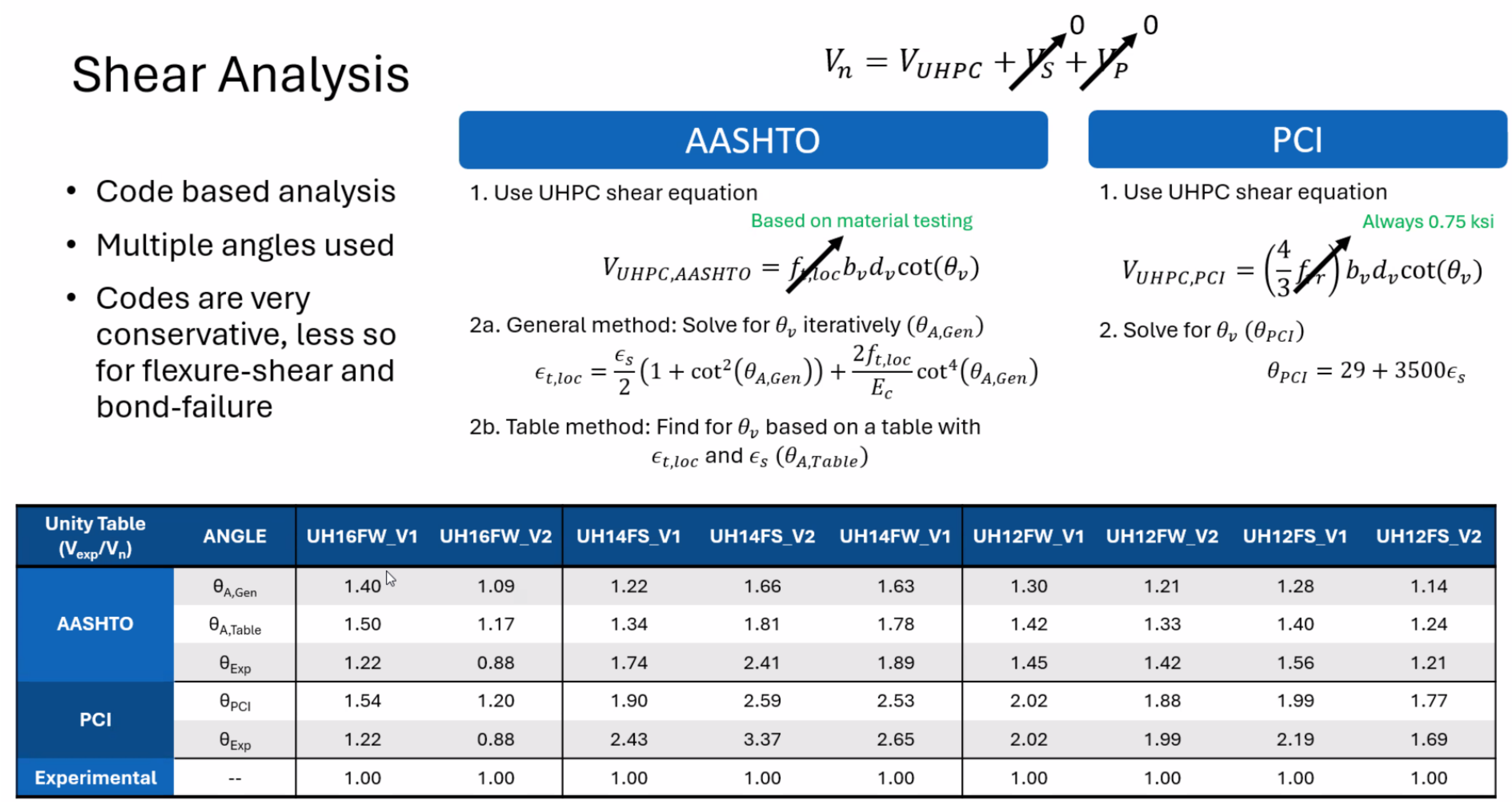


Shear Analysis

$$V_n = V_{UHPC} + \cancelto{0}{V_S} + \cancelto{0}{V_P}$$

- Code based analysis
- Multiple angles used
- Codes are very conservative, less so for flexure-shear and bond-failure

AASHTO

1. Use UHPC shear equation

Based on material testing

$$V_{UHPC,AASHTO} = \cancel{f_{t,loc}} b_v d_v \cot(\theta_v)$$

2a. General method: Solve for θ_v iteratively ($\theta_{A,Gen}$)

$$\epsilon_{t,loc} = \frac{\epsilon_s}{2}\left(1 + \cot^2(\theta_{A,Gen})\right) + \frac{2f_{t,loc}}{E_c}\cot^4(\theta_{A,Gen})$$

2b. Table method: Find for θ_v based on a table with $\epsilon_{t,loc}$ and ϵ_s ($\theta_{A,Table}$)

PCI

1. Use UHPC shear equation

Always 0.75 ksi

$$V_{UHPC,PCI} = \left(\frac{4}{3}\cancel{f_r}\right) b_v d_v \cot(\theta_v)$$

2. Solve for θ_v (θ_{PCI})

$$\theta_{PCI} = 29 + 3500\epsilon_s$$

Unity Table (V_{exp}/V_n)	ANGLE	UH16FW_V1	UH16FW_V2	UH14FS_V1	UH14FS_V2	UH14FW_V1	UH12FW_V1	UH12FW_V2	UH12FS_V1	UH12FS_V2
AASHTO	$\theta_{A,Gen}$	1.40	1.09	1.22	1.66	1.63	1.30	1.21	1.28	1.14
	$\theta_{A,Table}$	1.50	1.17	1.34	1.81	1.78	1.42	1.33	1.40	1.24
	θ_{Exp}	1.22	0.88	1.74	2.41	1.89	1.45	1.42	1.56	1.21
PCI	θ_{PCI}	1.54	1.20	1.90	2.59	2.53	2.02	1.88	1.99	1.77
	θ_{Exp}	1.22	0.88	2.43	3.37	2.65	2.02	1.99	2.19	1.69
Experimental	--	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

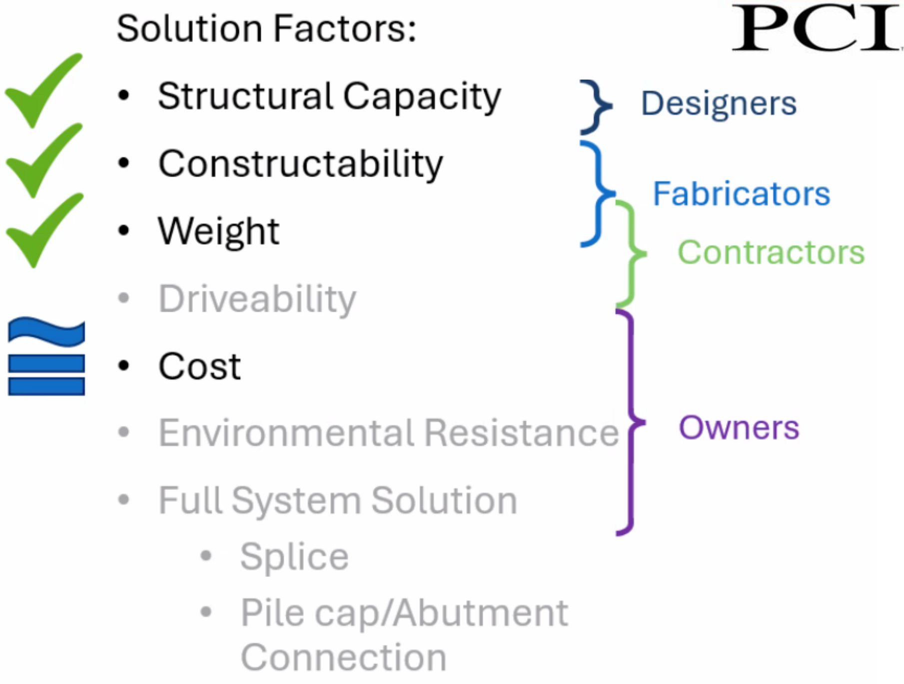
H-PILE FABRICATION & TESTING

Alabama Style

Thank you to the sponsors of these projects!

Pile Design Conclusions

- **The UHPC pile sections developed are viable structural alternatives to current driven piles**
- First principles equations are appropriate for predicting elastic shortening losses
- Long-term prestressing losses according to current standard are conservative
- The flexural behavior of these piles is predicted accurately using first principles with using measured material properties
- Shear failure is unlikely to occur in Pile sections before flexural failure even without transverse reinforcement.
- Current code provisions are sufficiently conservative in predicting shear capacity.

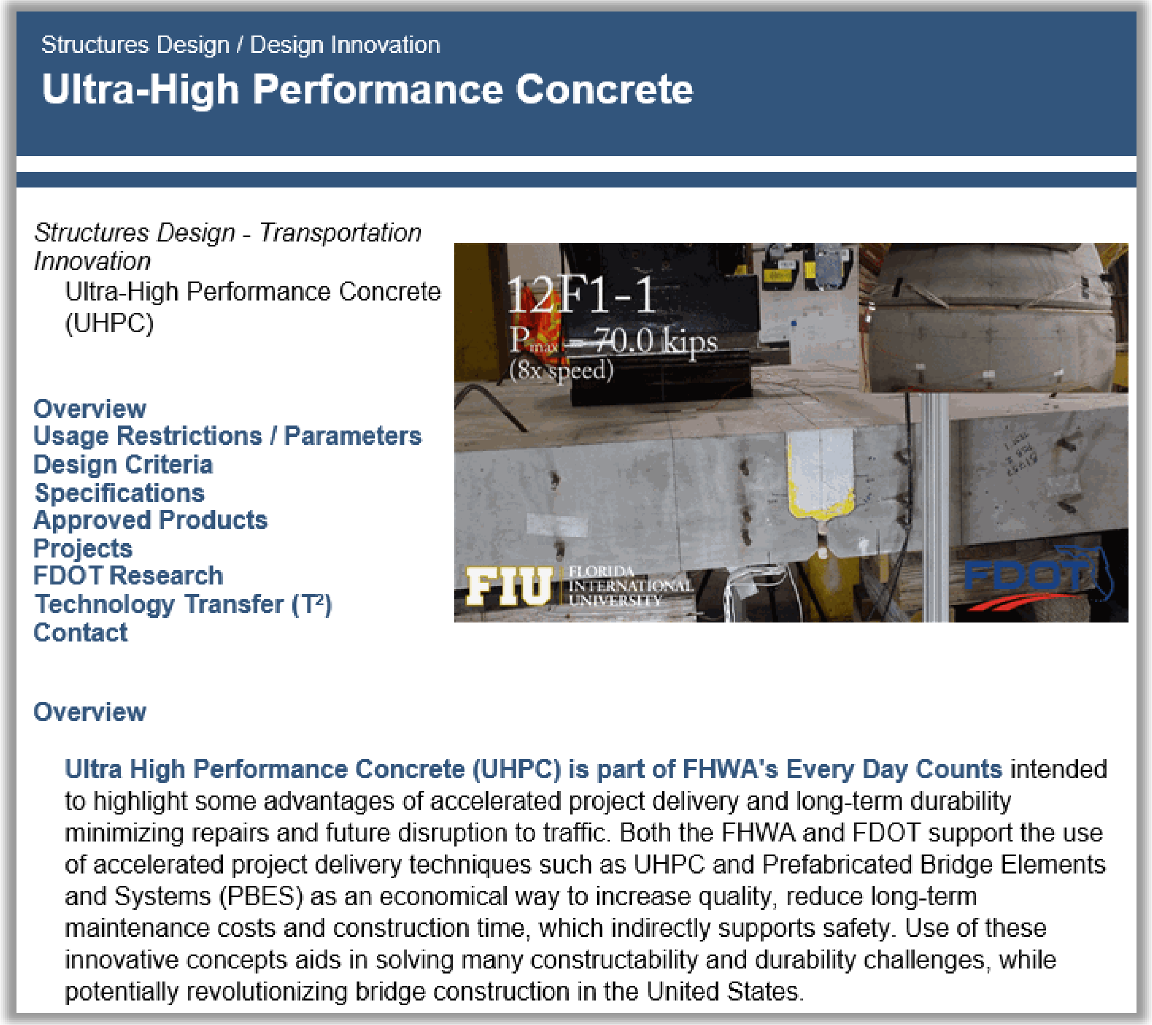


Solution Factors:

- ✓ Structural Capacity
- ✓ Constructability
- ✓ Weight
- Driveability
- ≅ Cost
- Environmental Resistance
- Full System Solution
    - Splice
    - Pile cap/Abutment Connection

Source: Dr. Aaleti PCI/AASHTO UHPC update (11/16/2023)

FDOT & AASHTO UHPC Design Guidance



Structures Design / Design Innovation

Ultra-High Performance Concrete

Structures Design - Transportation Innovation
Ultra-High Performance Concrete (UHPC)

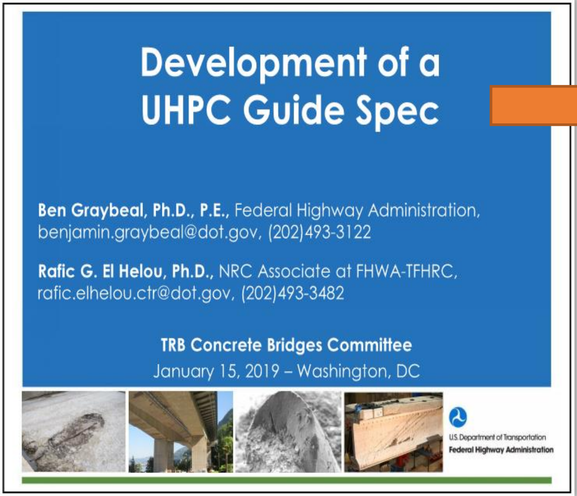
- Overview
- Usage Restrictions / Parameters
- Design Criteria
- Specifications
- Approved Products
- Projects
- FDOT Research
- Technology Transfer (T²)
- Contact

Overview

Ultra High Performance Concrete (UHPC) is part of FHWA's Every Day Counts intended to highlight some advantages of accelerated project delivery and long-term durability minimizing repairs and future disruption to traffic. Both the FHWA and FDOT support the use of accelerated project delivery techniques such as UHPC and Prefabricated Bridge Elements and Systems (PBES) as an economical way to increase quality, reduce long-term maintenance costs and construction time, which indirectly supports safety. Use of these innovative concepts aids in solving many constructability and durability challenges, while potentially revolutionizing bridge construction in the United States.

http://www.fdot.gov/structures/innovation/UHPC.shtm

- **FDOT** ***Developmental Spec*** ***349 & 927;***
- **Transportation Pooled Fund 1434/TPF-5(366);**
- **FHWA** *Guide Specification Development* → ***AASHTO*** *Guide Spec.* *(CBS Approved in May 2023. Publication Pending)*



Development of a UHPC Guide Spec

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TRB Concrete Bridges Committee
January 15, 2019 – Washington, DC

Proposed Draft Version of
AASHTO LRFD GUIDE SPECIFICATION
FOR
STRUCTURAL DESIGN WITH ULTRA-HIGH PERFORMANCE CONCRETE

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APPROVED

QUESTIONS & DISCUSSION

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