Third International Interactive Symposium On Ultra-High Performance Concrete (UHPC)

Development of UHPC Prestressed Piles for Florida Bridges in Extremely Aggressive Environments

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Abstract

FDOT has used pretensioned concrete piles for bridge foundations since the early 1950's. In the last decade structural advanced materials have mature to provided designers options for more durable prestressed piles, especially in the splash-zone of marine environments, which are classified as the most extremely aggressive under FDOT guidelines. UHPC is the latest material to emerge as an equivalent or better alternative for existing standardized corrosion-resistant pretensioned piles. Current corrosion-resistant piling utilizing either Carbon Fiber-Reinforced Polymer (CFRP) or High-Strength Stainless-Steel (HSSS) strands and spirals in High Performance Concrete (HPC). UHPC piles pretensioned with carbon-steel strands and spirals (UHPC-PCS) are assumed to have similar durability and potentially greater cost advantages compared to current CFRP-PC and HSSS-PC pretensioned pile designs.

This presentation outlines some of the advantages of UHPC-PCS pretensioned piles identified by FDOT and currently being verified through active research and engineering design. It is anticipated that UHPC-PCS pretensioned pile designs will use bulk materials batched in centralized concrete plants, conventional prestressing materials, and exhibit greater axial and flexural resistance for FDOT standardized 18"x18", 24"x24" and 30"x30" sized piles. This will enable equivalent foundation designs to utilize fewer piles while permitting greater allowable pile driving stresses, thus resulting in faster pile installation and more economical bridge foundations by 2024.

Outline

1. FDOT UHPC Structural Research
2. FDOT UHPC Projects to Date
3. FDOT UHPC Pile Standard Development
4. AASHTO Guide Specifications Status
5. Questions

Pile driving photos coutesy of Cor-Tuf UHPC

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)
- 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)
- 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)
- ***BECxx:*** UHPC Pile Splice Development (FIU/Garber)
- Skin Friction Assessment (SRC & SMO)
- Driving Assessment of UHPC Piles (TBA)

Where you can find UHPC in Florida: DISTRICT 1

- US 441/Taylor Creek (437984-1), ***Fast-Facts:*** Longitudinal center joint for dual precast slabs (Contractor's redesign): *(complete)*
- US41 over Morning Star & Sunset Waterways (435390-1) **T4500**, ***Fast Facts:*** Link-slab to use UHPC with BFRP longitudinal bars – *2/27/19 letting (Bid Tabs)* – ***status:*** *complete.*
- SR45(US-41) over Roberts Bay (445941-1), **E1U17**. Sonovoid Joint Rehab with hydro-demolition & UHPC (13 CY) - *Letting 2/07/2022, BidTabs* - ***status:*** *Under construction 10-3-22.*
- 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) – *04/20/23 letting*. FSB without topping & UHPC joints and GRS Abutments – ***status:*** *Production date 12/12/2022?*
- Lakeland, New York Ave/Railroad Pedestrian Overpass: (*436656-1), Precast Approach Ramp Slabs*, Production 11/08/2024; no *letting date yet.* ***status:*** *Phase II Plans submittal 11/15/22 ?*

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, U-Beam 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 [illegible] 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), Began 2/8/21, complete 6/3/21.*
- *I-10 over Crooked Creek (222539-3) **E3U40**– Approach Slab Replacement: Precast w/UHPC longitudinal joint – letting 10/14/21 (BSN, Bid Tabs), Argos-UHPC: **status**: complete*
- *West Wilson St over Turkey Ck (439390-1), UHPC Alternate B, voided PSU's; letting 10/6/22 – **status:** Env. Permit issues. Changed from replacement to removal (cancelled).*
- *I-10 over CR 191/Garcon Point Rd (441588-1/442915-1) **T3787**– Approach Slab Replacement: Precast w/UHPC longitudinal joint, Argos-UHPC – letting 4/28/21 (BSN): – **status**: Completed early 2023.*

Where you can find UHPC in Florida: DISTRICT 4

- SR 714/Danforth Creek (430617-1), ***Fast-Facts:*** Sonovoid Rehab: *letting 4/1/16 (complete 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)*

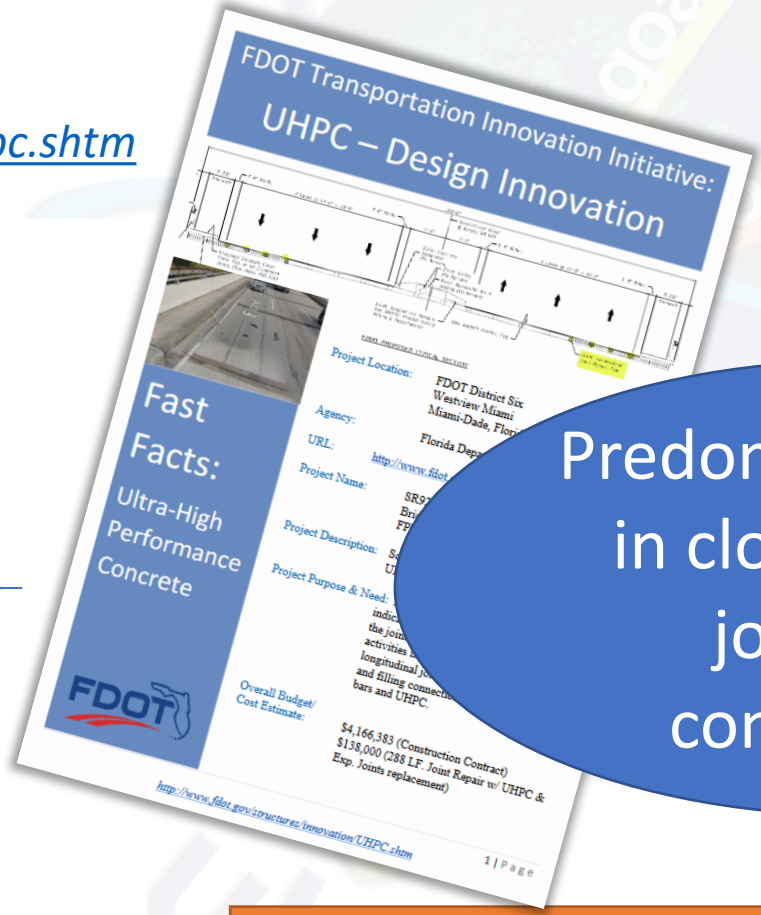
Where you can find UHPC in Florida: DISTRICT 6

- 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. (*complete 6/3/21)*
- Monroe: 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 - ***status:*** *Completion 4/28/23*

Where you can find UHPC in Florida…
FAST-FACTS

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

- 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



Predominantly used in closure pours, joints and connections.

Prestressed Concrete Pile

FDOT UHPC H-PILE STANDARD DEVELOPMENT

Benefits

1. **Durability:** Benefit in places where corrosion is an issue (alternative to Piles w/ SS or CFRP strands)
2. **High moment** capacity → New Alternative!
3. **Lighter weight** members
4. Permit larger driving stresses (using larger hammer and/or stroke) → **Less cracking** & *Potentially* **faster driving** with improve the efficiency.
5. Greater structural capacity → *Potentially* **fewer piles** required per bridge
6. UHPC material is a better fit for a precast construction vs. CIP on-site:
    1. Repetition → Consistency
    2. Better Quality Control

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:

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

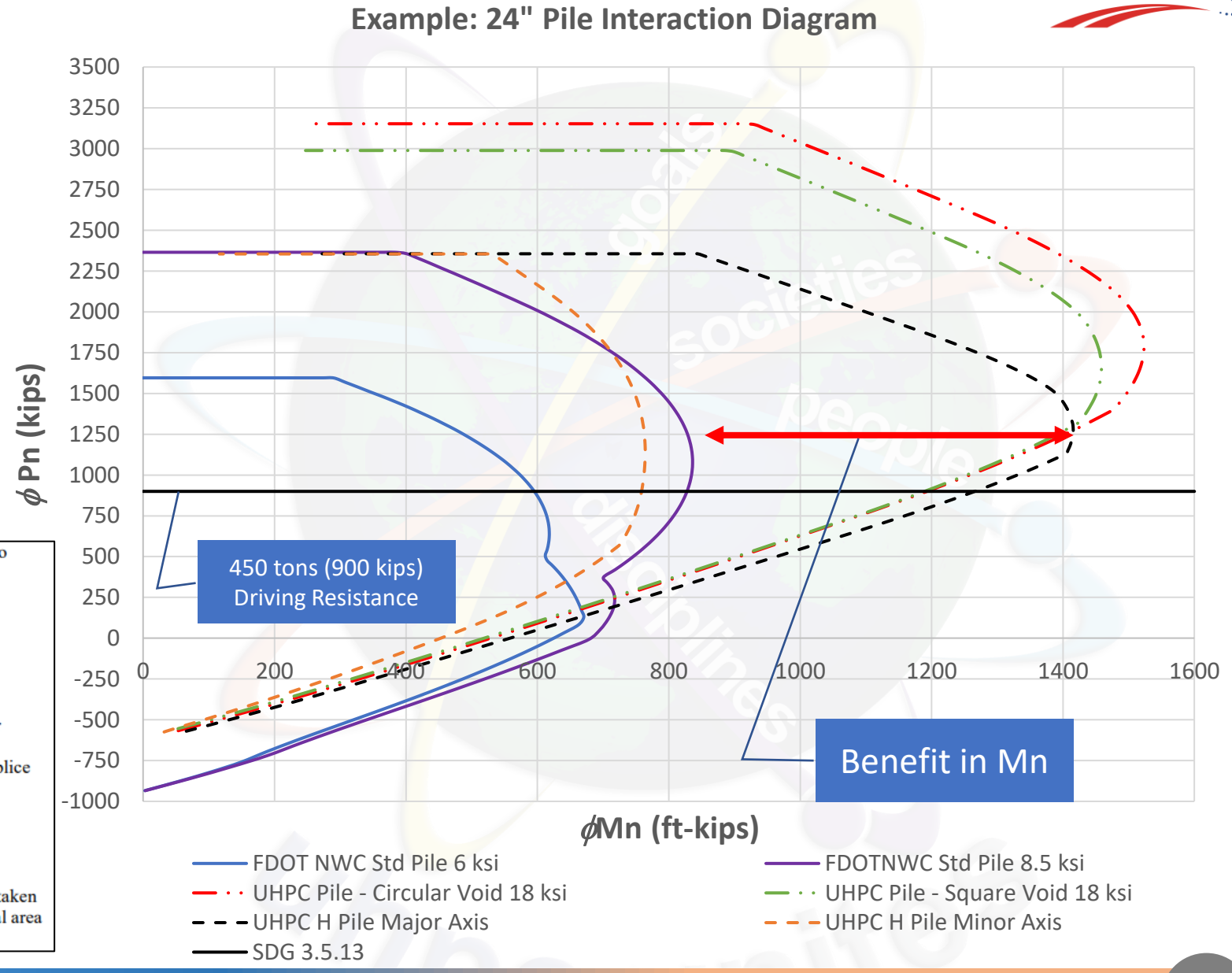
$$s_{apt} = 6.5(f'_c)^{0.5} + 1.05 f_{cpe} \quad (2a) \text{ for piles less than 50 feet long}$$

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

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

where:

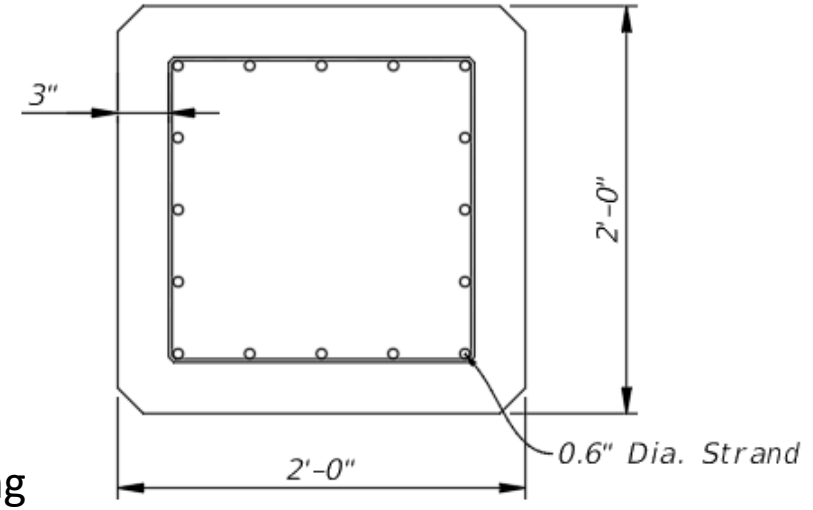
s_{apc} = maximum allowed pile compressive stress, psi
s_{apt} = maximum allowed pile tensile stress, psi
f'_c = specified minimum compressive strength of concrete, psi
f_{cpe} = effective prestress (after all losses) at the time of driving, psi, taken as 0.8 times the initial prestress force divided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



FDOT H-PILE STANDARDS

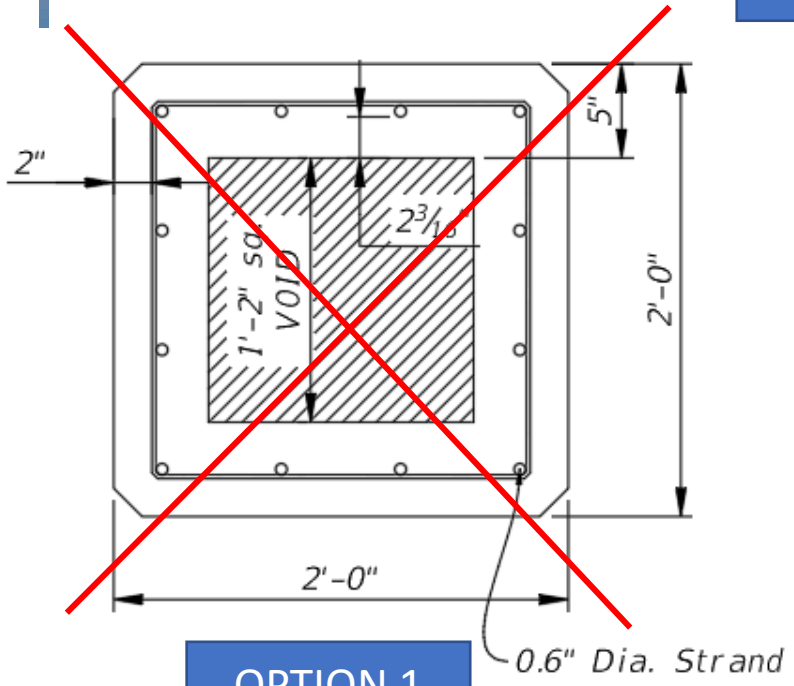
Issues with internal voids:

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

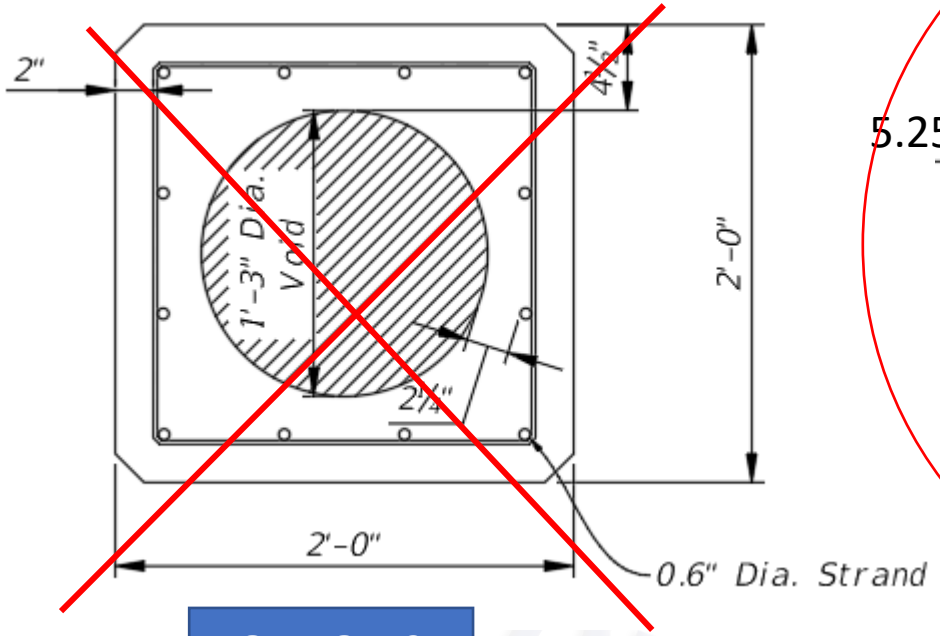


CURRENT FDOT CONCRETE STANDARD PILE

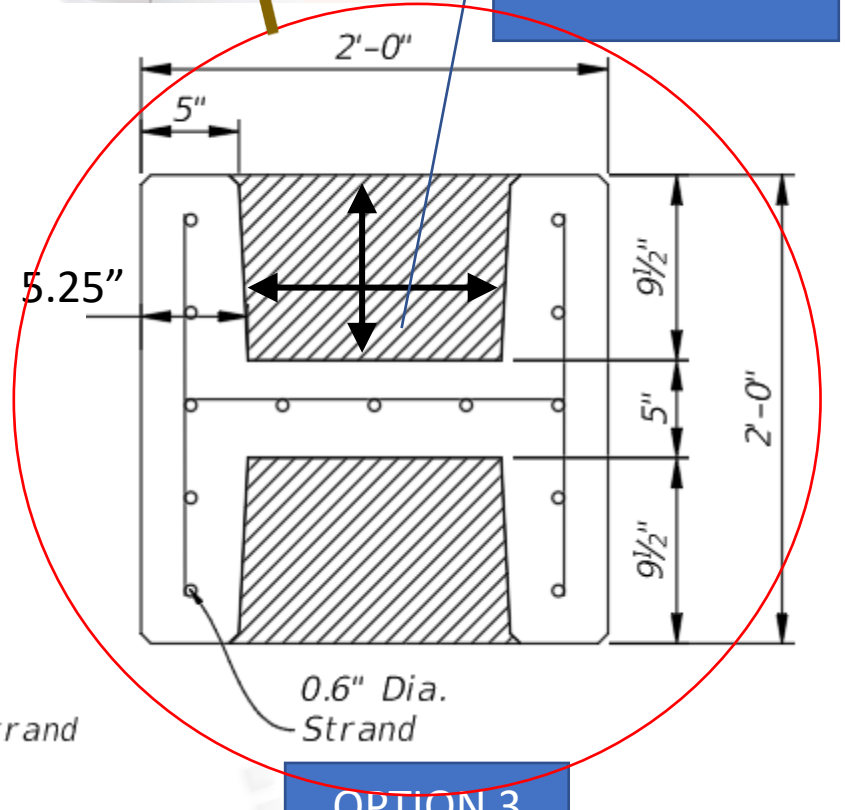
(2) 9.5" x 13" VOIDS ?



OPTION 1



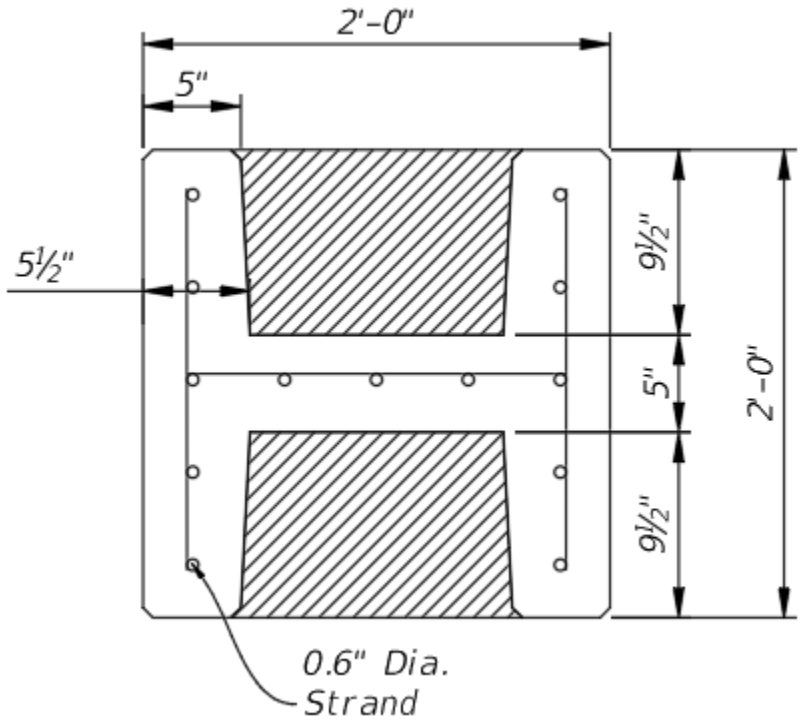
OPTION 2

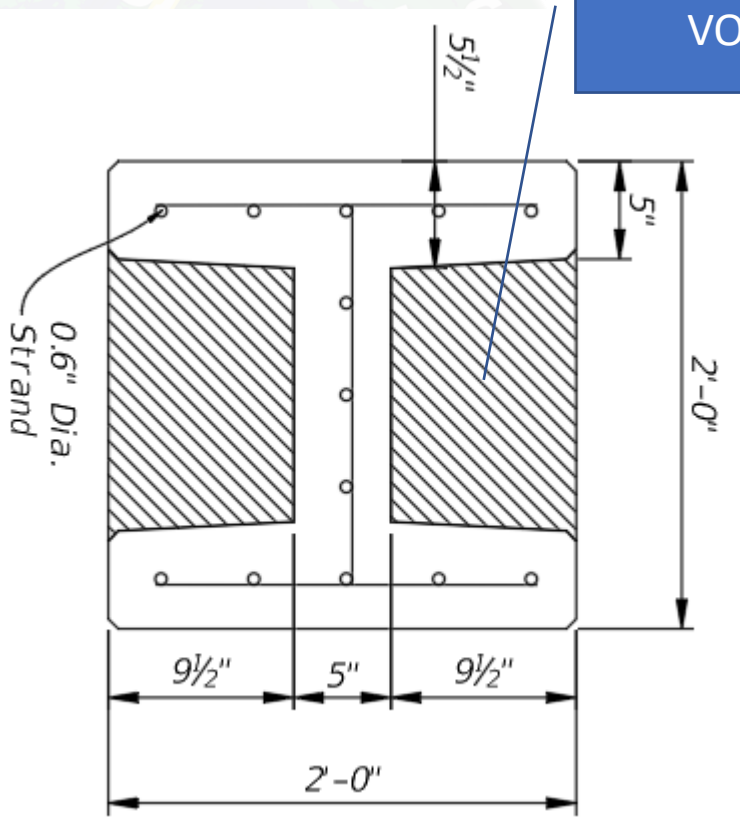


OPTION 3

FDOT H-PILE STANDARDS

FDOT Prototype (CR-339)





(2) 9.5” x 13” VOIDS

INITIAL H-SHAPE

CAST AS AN ‘I’

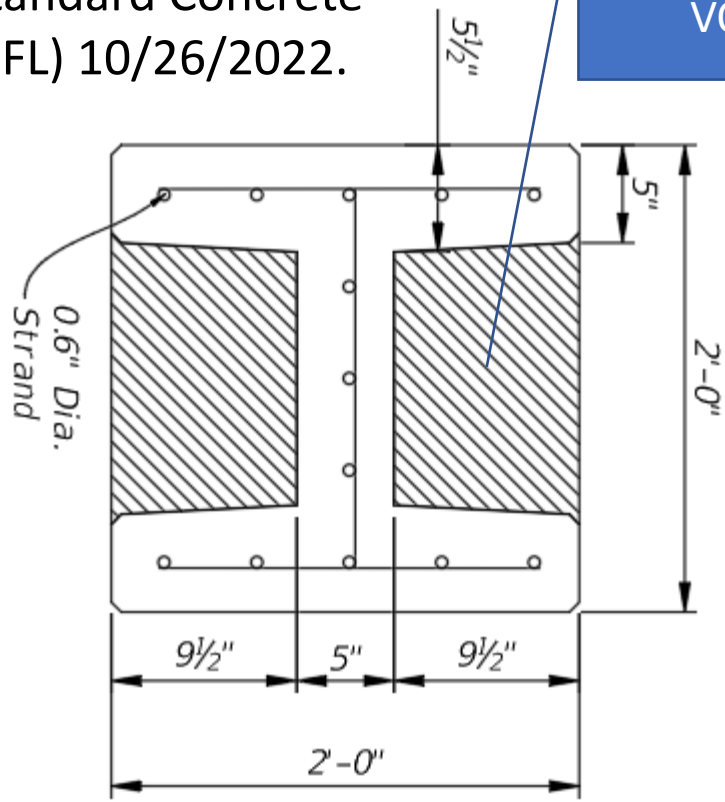
H-PILE STANDARDS

Alabama Style

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

≠

(2) 9.5” x 13” VOIDS



CAST AS AN ‘I’

H-PILE STANDARDS

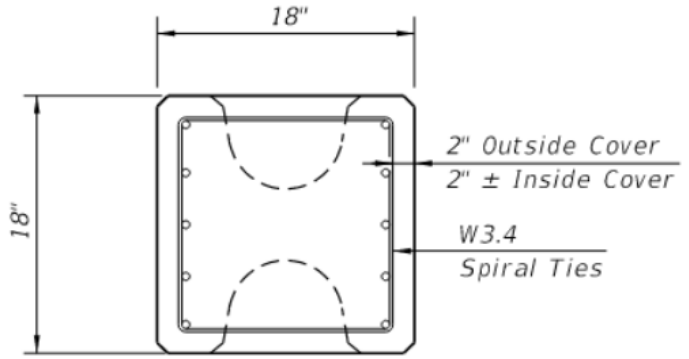
Alabama Style

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

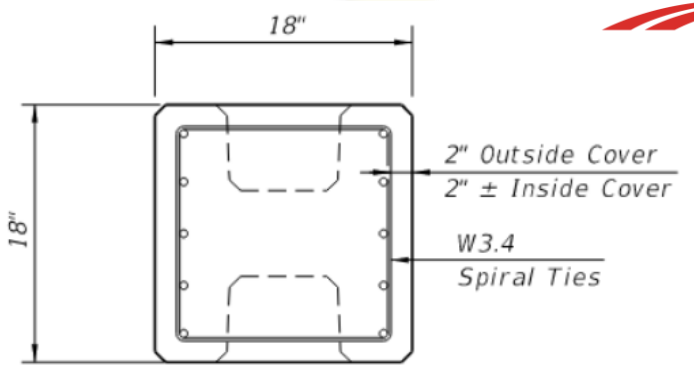
FDOT H-PILE STANDARDS

18” x 18”

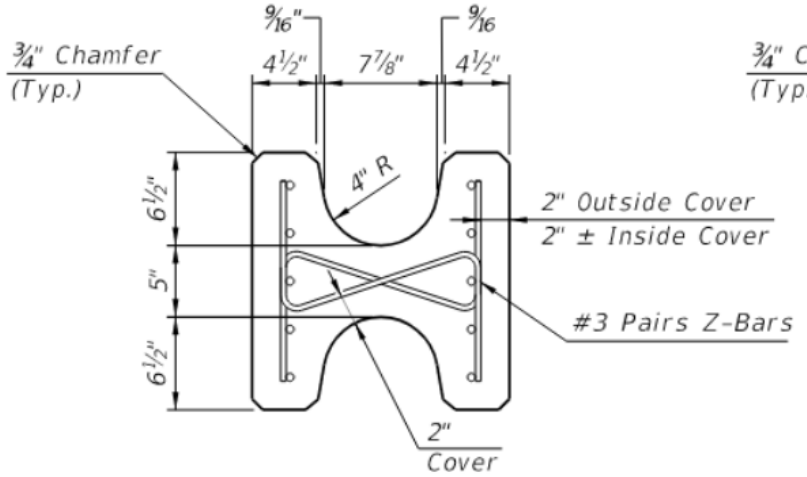
DRAFT



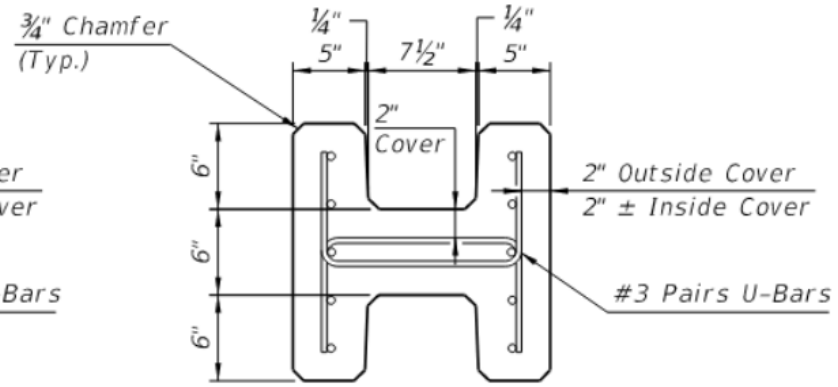
SECTION A-A
(Square Head - Option 1)



SECTION A-A
(Square Head - Option 2)



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

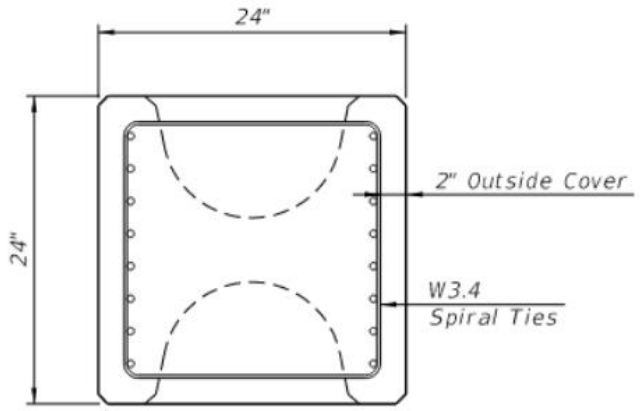


SECTION B-B
(H-Shape - Option 2)

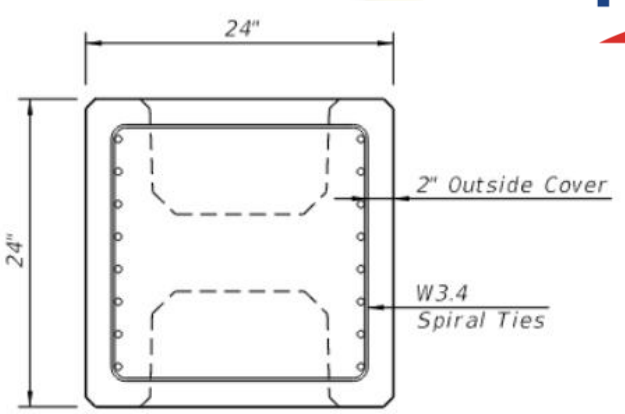
FDOT H-PILE STANDARDS

24” x 24”

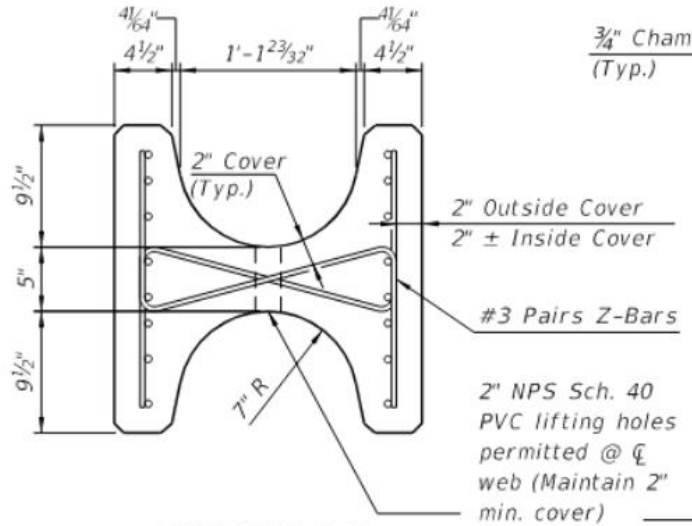
DRAFT



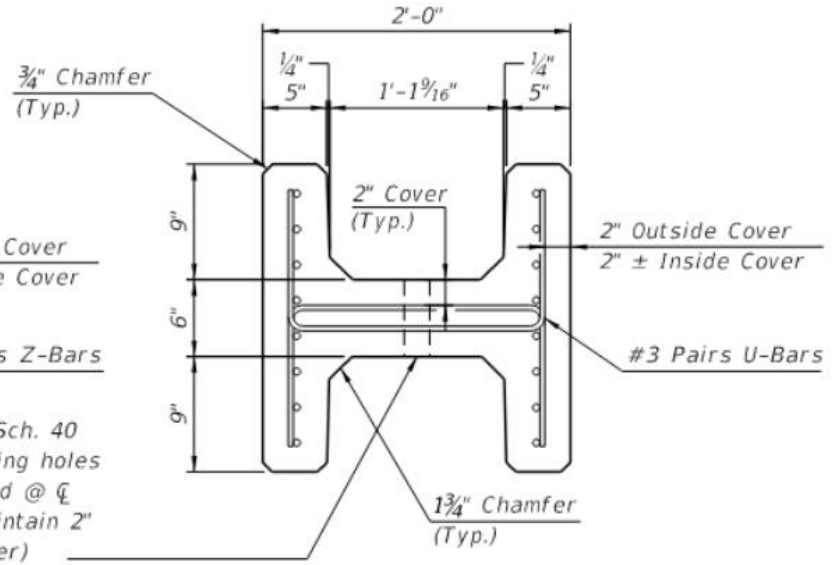
SECTION A-A
(Square Head - Option 1)



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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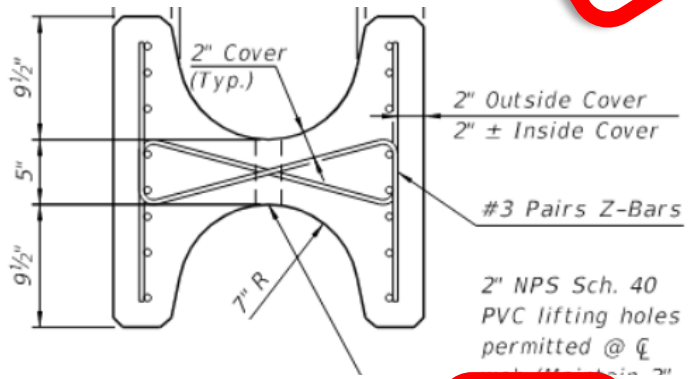
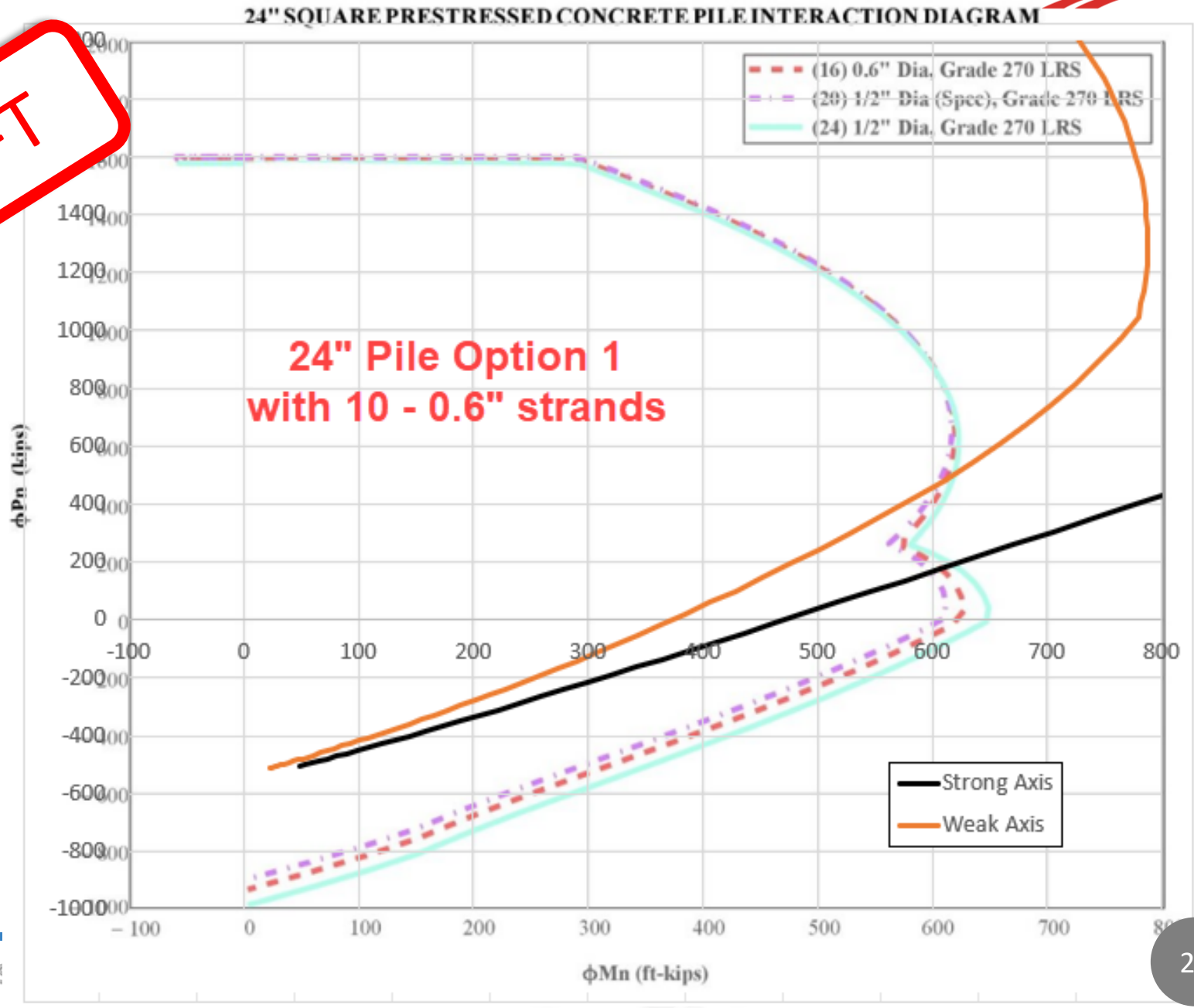


Pile Option 1 - 0.6" Strands

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



FDOT H-PILE STANDARDS

24” x 24”

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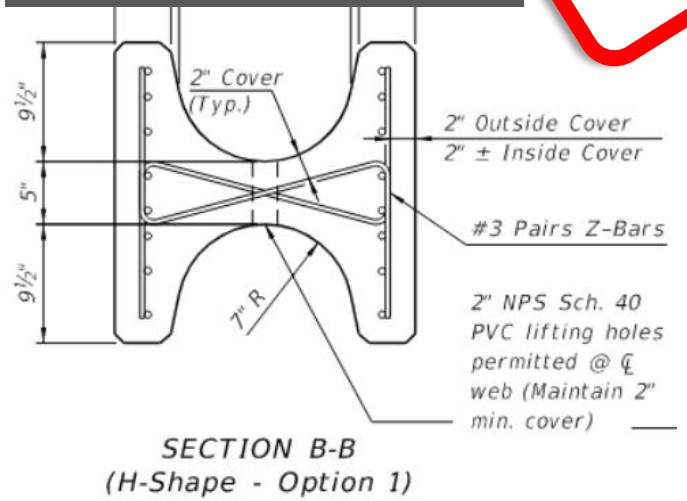
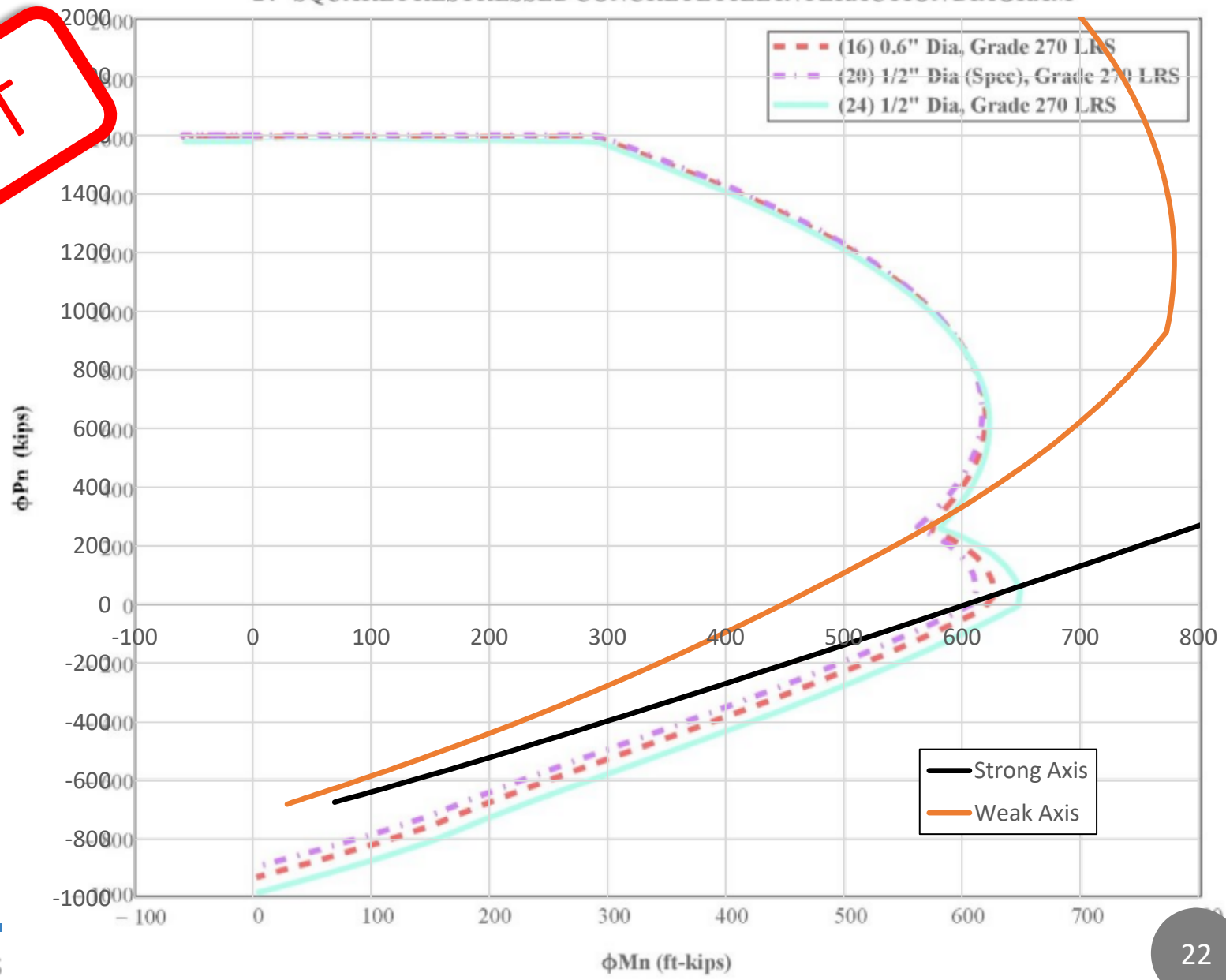


SECTION B-B
(H-Shape - Option 1)

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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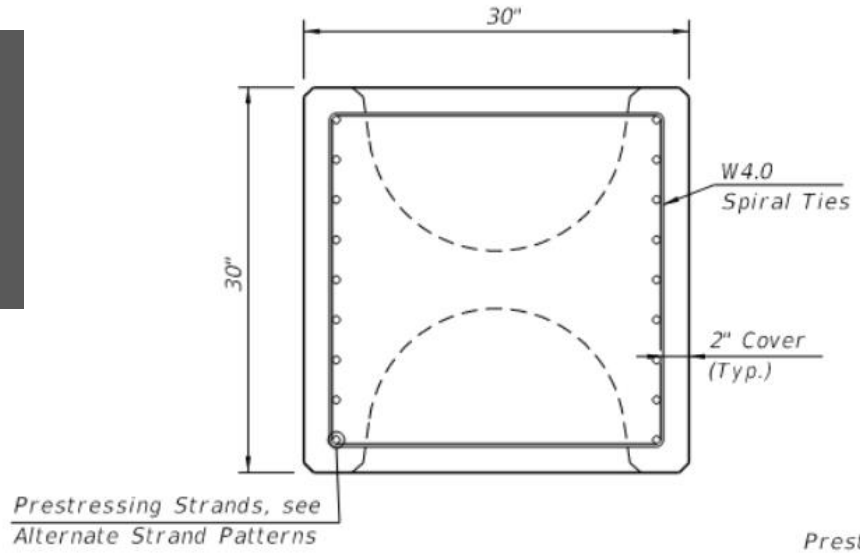
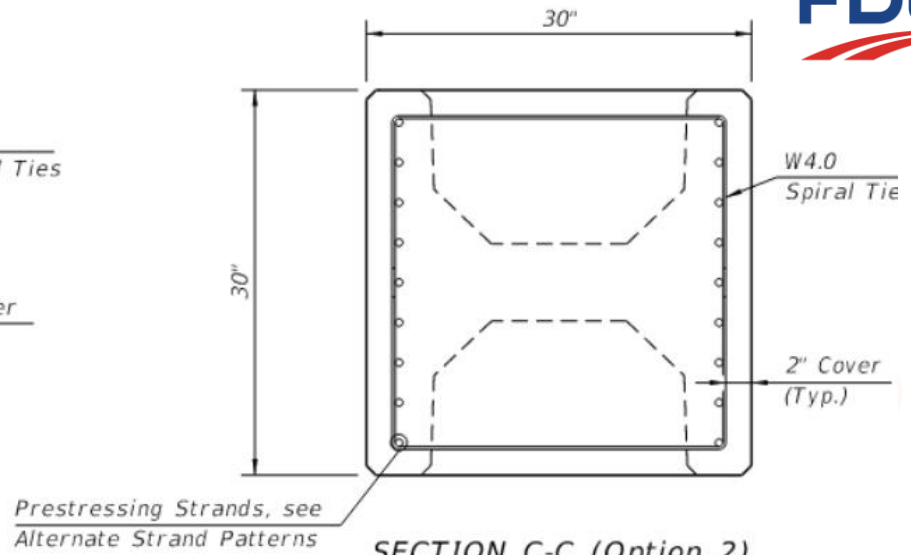
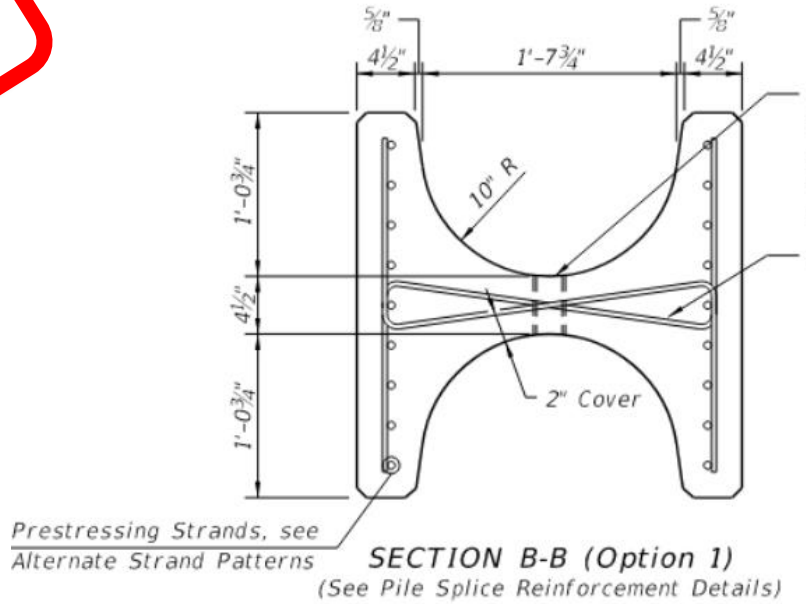


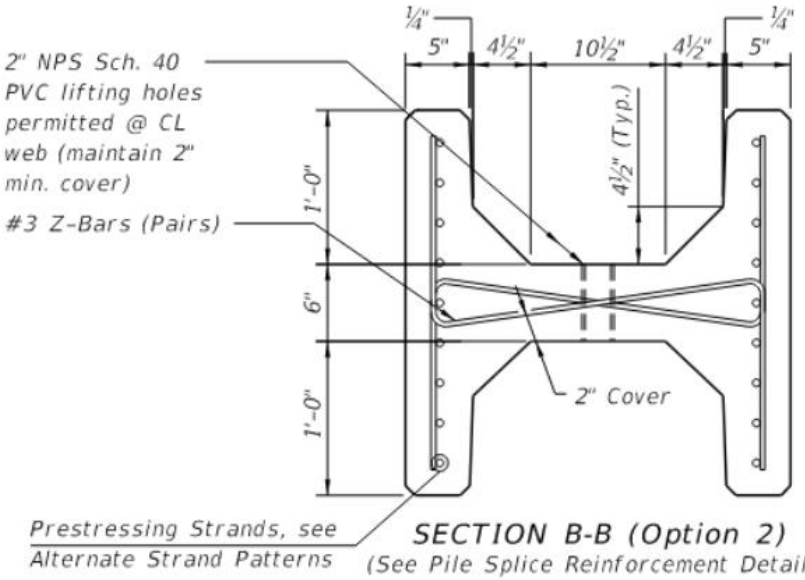
SECTION C-C (Option 1)
(See Pile Splice Reinforcement Details)



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



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

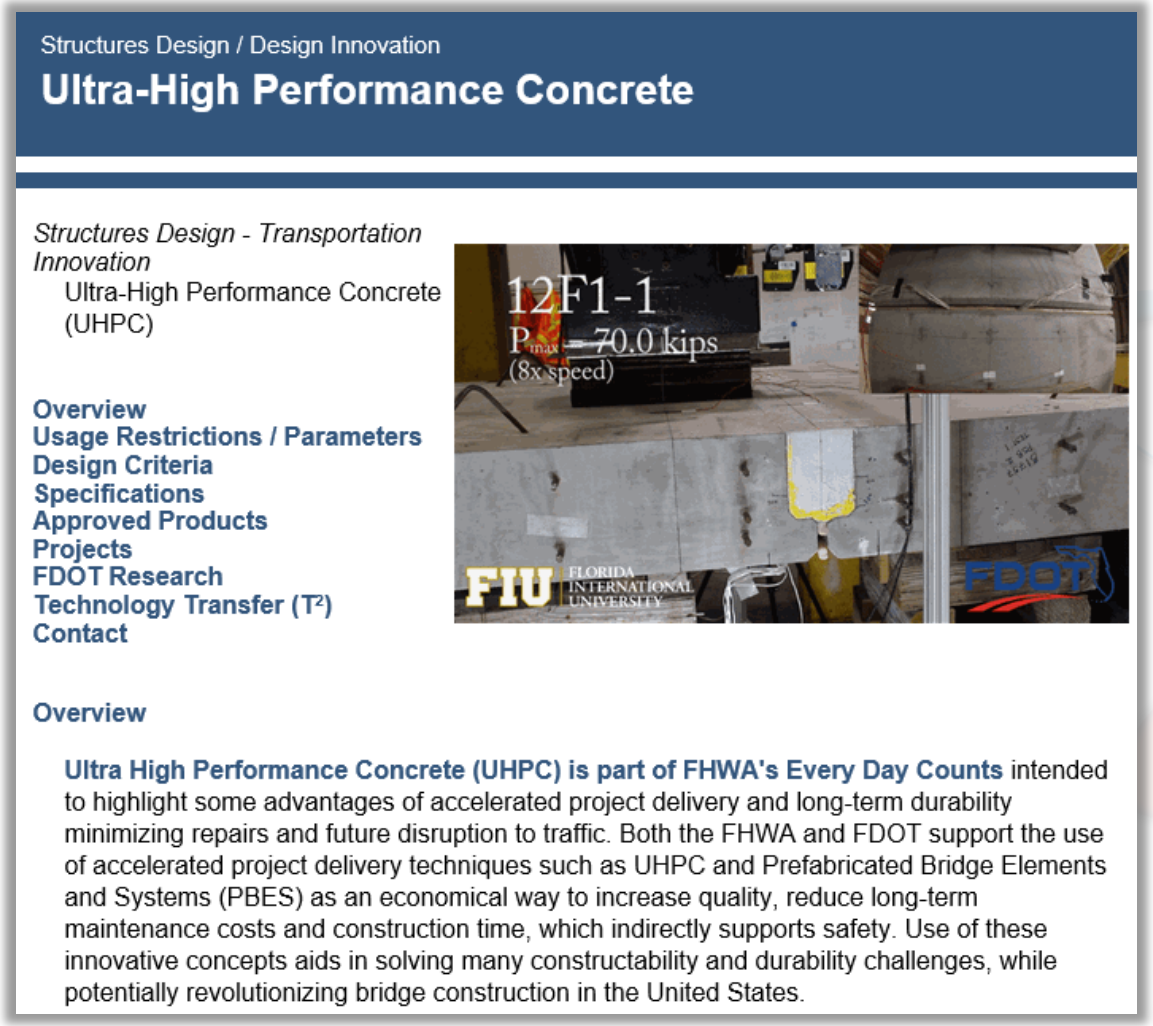


SECTION B-B (Option 2)
(See Pile Splice Reinforcement Details)

STANDARDIZING UHPC PILES: ACTIVE STEPS…

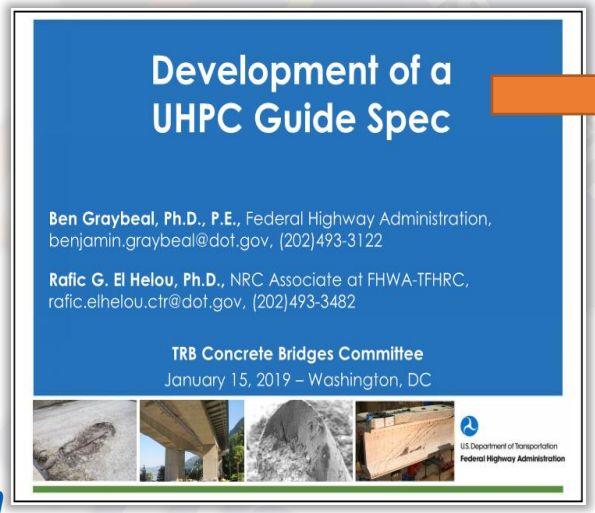
1. Working on Draft ***Standard Plans***
2. Need to update Material ***Specifications (Dev349UHPC & Dev927UHPC)*** and ***Materials Manual?***
3. Need to update Construction ***Specifications (Section 455- Section B)***
4. Need to update Design Criteria & *Specifications* ***(AASHTO Guide, SDG Chapter 3, S&FH)***
5. Working with Prestressed Concrete Industry (FPCA, Durastress, Standard Concrete, Gate, etc.)
6. Will meet with Contractors
7. Research…A LOT OF RESEARCH going on!
   a. FDOT Sponsored
   b. FHWA/AASHTO
   c. PCI, etc.

FDOT & AASHTO UHPC Design Guidance



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

- **FDOT *Developmental Spec* 349;**
- **Transportation Pooled Fund** 1434/TPF-5(366);
- **FHWA** *Guide Specification Development* → ***AASHTO*** *Guide Spec.*
  (CoBS Balloted in May 2023)



QUESTIONS & DISCUSSION