FDOT TRANSPORTATION SYMPOSIUM

CFRP & HSSS Strands in Prestressed Concrete Design

Vickie Young and Ge Wan

AGENDA

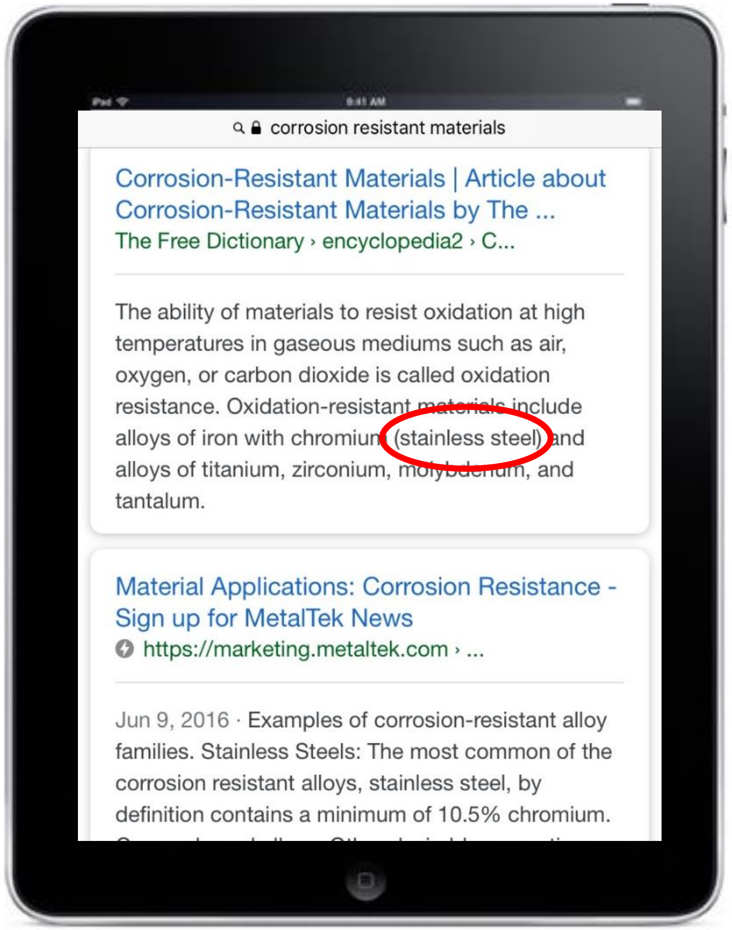
- PART 1: Corrosion Resistant Materials in Prestressed Concrete
- PART 2: High Strength Stainless Steel (HSSS) Strands
- PART 3: Carbon Fiber Reinforced Polymer (CFRP) Strands

PART 1:
Corrosion Resistant Materials in Prestressed Concrete

AGENDA

1. Introduction
2. Codes & Manuals & References
3. FDOT Current Policy

What are Corrosion Resistant Materials (CRM)?



Stainless Steel → CRM ← Fiber Reinforced Polymers (FRP)

- Glass (GFRP)
- Carbon (CFRP)

Introduction

- Focus of this Presentation is limited to Stainless Steel & FRP for:

1. **Reinforcing Bars**
2. **Prestressing Strands**

- For more information on GFRP & CFRP & Other Innovative Materials
  - Tuesday at 4:20 pm → Structural Advanced Materials for Florida's Transportation Infrastructure
  - Wednesday at 10:05 am → FRP – Beyond Halls River Bridge

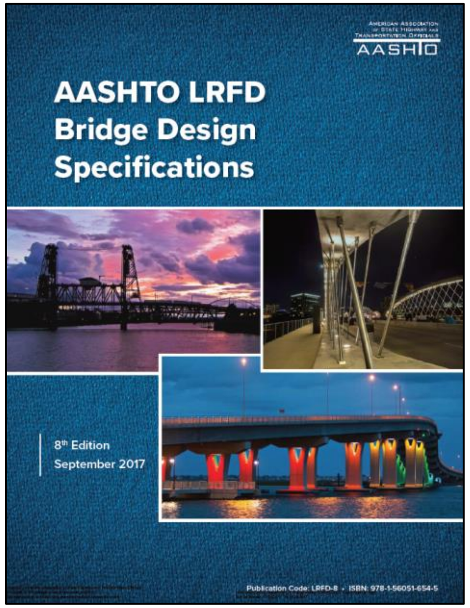
Introduction - Using CRM in Prestressed Concrete Components

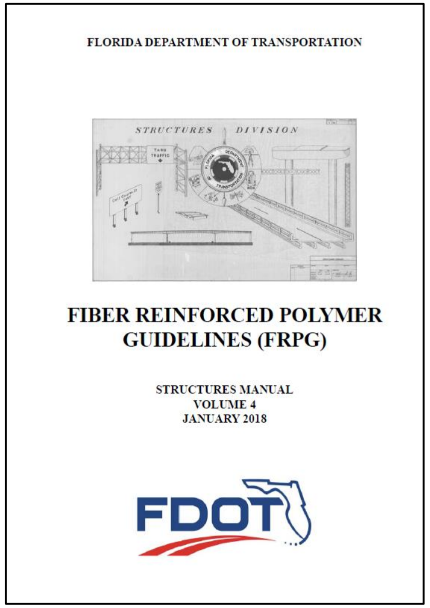
- Benefits
  - Lower life cycle costs including reduced Maintenance Costs
  - Reduced concrete cover (FRP)
  - Longer structure life

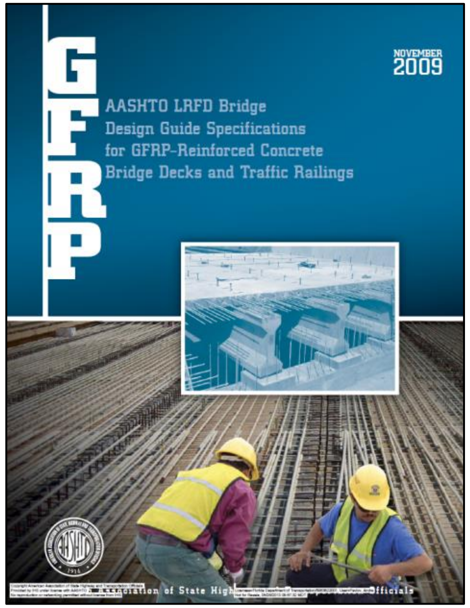
- Disadvantages
  - Higher Initial Cost (Both HSSS & FRP)
  - Availability & Time (Both HSSS & FRP)
  - Dissimilar metals (CFRP)
  - FRP bars <u>cannot</u> be Field Bent

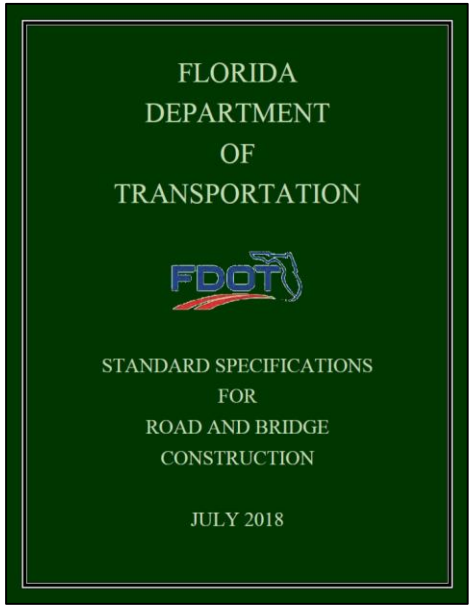
Codes & Manuals & References

1. Structures Manual – *Volumes 1 & 4*
2. AASHTO LRFD *Bridge Design Specifications*
3. AASHTO LRFD *Bridge Design Guide Specifications for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings*
4. FDOT *Standard Specifications for Road and Bridge Construction*









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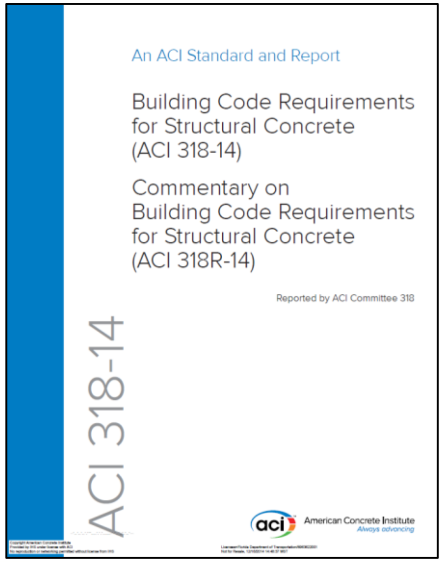
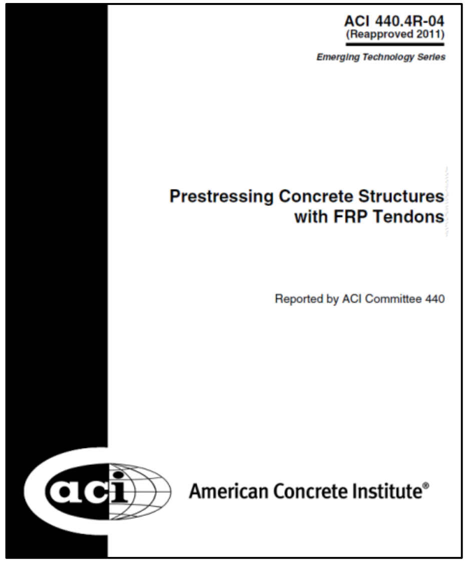
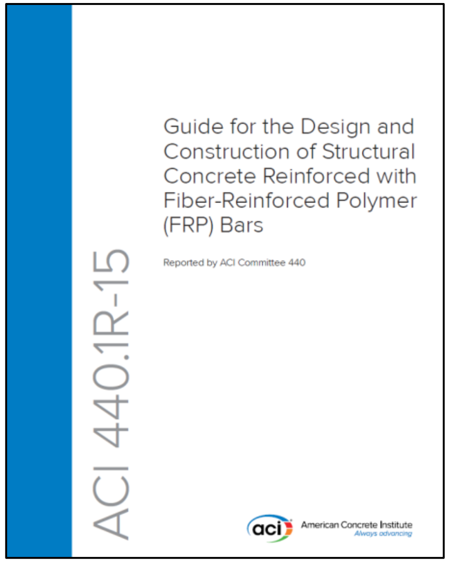
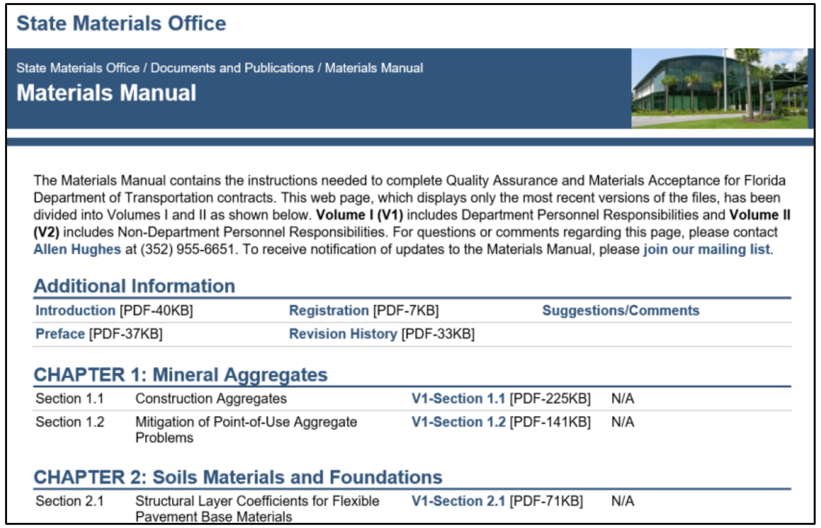
Codes & Manuals & References

5. FDOT Materials Manual
6. ACI 440.1 *Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars*
7. ACI 318 *Building Code Requirements for Structural Concrete*
8. ACI 440.4 *Prestressing Concrete Structures with FRP Tendons*









State Materials Office

State Materials Office / Documents and Publications / Materials Manual

Materials Manual

The Materials Manual contains the instructions needed to complete Quality Assurance and Materials Acceptance for Florida Department of Transportation contracts. This web page, which displays only the most recent versions of the files, has been divided into Volumes I and II as shown below. **Volume I (V1)** includes Department Personnel Responsibilities and **Volume II (V2)** includes Non-Department Personnel Responsibilities. For questions or comments regarding this page, please contact **Allen Hughes** at (352) 955-6651. To receive notification of updates to the Materials Manual, please **join our mailing list**.

Additional Information

Introduction [PDF-40KB]	**Registration** [PDF-7KB]	**Suggestions/Comments**
Preface [PDF-37KB]	**Revision History** [PDF-33KB]	

CHAPTER 1: Mineral Aggregates

Section 1.1	Construction Aggregates	**V1-Section 1.1** [PDF-225KB]	N/A
Section 1.2	Mitigation of Point-of-Use Aggregate Problems	**V1-Section 1.2** [PDF-141KB]	N/A

CHAPTER 2: Soils Materials and Foundations

Section 2.1	Structural Layer Coefficients for Flexible Pavement Base Materials	**V1-Section 2.1** [PDF-71KB]	N/A

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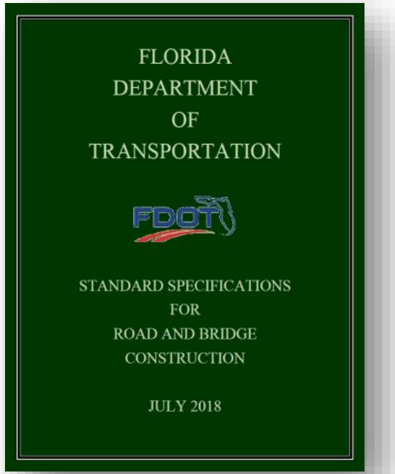
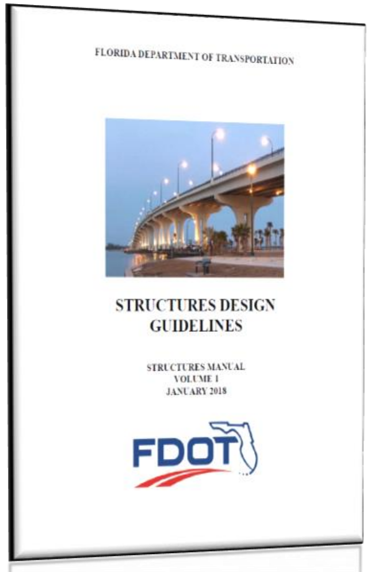
FDOT POLICY





Strand Types:

1. *Carbon Steel Strands*
2. *Stainless Steel Strands*
3. *Carbon Fiber Reinforced Polymer Strands (CFRP)*

Table 3.5.1-1 Concrete Pile Size and Material Requirements

Pile Location			Minimum Square Pile Size (inches): Vehicular Bridges	Minimum Square Pile Size (inches): Pedestrian Bridges & Fishing Piers	Minimum Cylinder Pile Diameter (inches)	Material Properties for All Pile Sizes[1]: Strand Type	Material Properties for All Pile Sizes[1]: Spiral Type	Material Properties for All Pile Sizes[1]: Reinforcing Bar Type
Pile Bents	On land or in water in environments that are Extremely Aggressive due to chlorides	Widenings	24[2]	18	54	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931
		New Construction	24[3]	18[3]	54[3]	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931
			18	14	54	CFRP, Spec 933	CFRP, Spec 932	CFRP, Spec 932
						Stainless steel, Spec 933	Stainless steel, Spec 931	Stainless steel, Spec 931
	On land or in water in all other environments		18	14	54	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931
Footings	In water (waterline or mudline) in environments that are Extremely Aggressive due to chlorides		24[2]	18	54	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931
	On land or in water (waterline or mudline) in all other environments		18	14	54	Carbon steel, Spec 933	Carbon steel, Spec 931	Carbon steel, Spec 931

A. Prestressed Concrete Piling; cost per linear foot (furnished and installed)

Size of Piling	Driven Plumb or 1" Batter[1]	Driven Battered[1]
18-inch w/ carbon steel strand[2]	$90	$125
24-inch w/ carbon steel strand[2]	$100	$140
30-inch w/ carbon steel strand[2]	$150	$210
18-inch w/ CFRP or Stainless Steel Strand	$135	$160
24-inch w/ CFRP or Stainless Steel Strand	$150	$210
30-inch w/ CFRP or Stainless Steel Strand	$225	$280

1 When silica fume, metakaolin or ultrafine fly ash is used, add $6 per LF to the piling cost.

2 When heavy mild steel reinforcing is used in the pile head, add $250.

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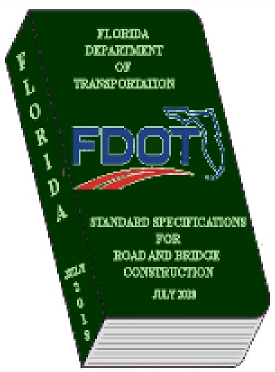

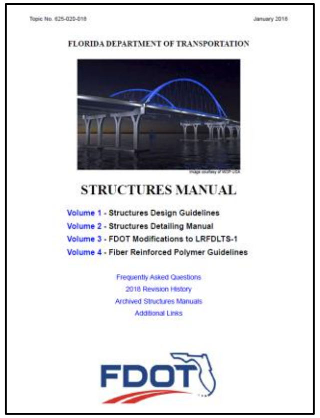

HSSS

- Bars
  - Use following steel reinforcing for concrete design with prior approval from the SDO:
    - ASTM A955 Grade 60 or 75, or ASTM A276, UNS S31603 or S31803 deformed stainless steel bar
- Strands
  - The stainless steel strands for prestressing concrete members shall be a high strength stainless steel (HSSS) conforming to the chemical requirements of ASTM A276, UNS S31803 or S32205 (Type 2205) and the mechanical and dimensional requirements of ASTM A416, except the minimum ultimate tensile strength shall be 240 ksi.

CFRP

- Bars
  - GFRP and CFRP reinforcing bars may be used in the following concrete components when approved by the SSDE:
    - Approach Slabs, & Bridge Decks and Overlays
    - Cast-in-Place Flat Slab Superstructures
    - Pile Bent Caps not in direct contact with water
    - Pier Columns and Caps not indirect contact with water
    - Retaining Walls, Noise Walls, Perimeter Walls
    - Traffic Railings & Pedestrian/Bicycle Railings
    - Bulkheads and Bulkhead Copings
    - MSE Wall Panels & Copings
    - Drainage Structures
- Strands
  - Obtain CFRP prestressing strands from producers currently on the Department’s Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

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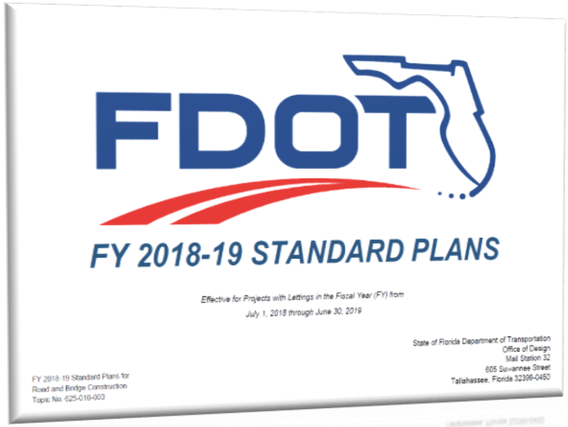
FDOT

FY 2018-19 STANDARD PLANS

Effective for Projects with Lettings in the Fiscal Year (FY) from
July 1, 2018 through June 30, 2019

State of Florida Department of Transportation
Office of Design
Mail Station 32
605 Suwannee Street
Tallahassee, Florida 32399-0450

FY 2018-19 Standard Plans for
Road and Bridge Construction
Topic No. 625-010-003

455-101		Square CFRP and SS Prestressed Concrete Piles - Typical Details and Notes	22600	SPI
455-102		Square CFRP and SS Prestressed Concrete Pile Splices	22601	
455-112		12" Square CFRP and SS Prestressed Concrete Pile	22612	
455-114		14" Square CFRP and SS Prestressed Concrete Pile	22614	
455-118		18" Square CFRP and SS Prestressed Concrete Pile	22618	
455-124		24" Square CFRP and SS Prestressed Concrete Pile	22624	
455-130		30" Square CFRP and SS Prestressed Concrete Pile	22630	
455-154		54" Precast/Post-Tensioned CFRP and SS Concrete Cylinder Pile	22654	SPI
455-160		60" Prestressed CFRP and SS Concrete Cylinder Pile	22660	SPI

Standard Plans

- *455-101 Square CFRP and SS Prestressed Concrete Piles Series*
- *455-440 Precast Concrete Sheet Pile Wall (CFRP/GFRP & HSSS/GFRP)*

Developmental Standard Plans

- D21310 *FRP Bar Bending Details*
- D22420 *Traffic Railing (32" F Shape – GFRP Reinforced)*
- D22440 *Precast Concrete CFRP/GFRP Sheet Pile Wall*
- D22900 *Approach Slab – GFRP Reinforced*

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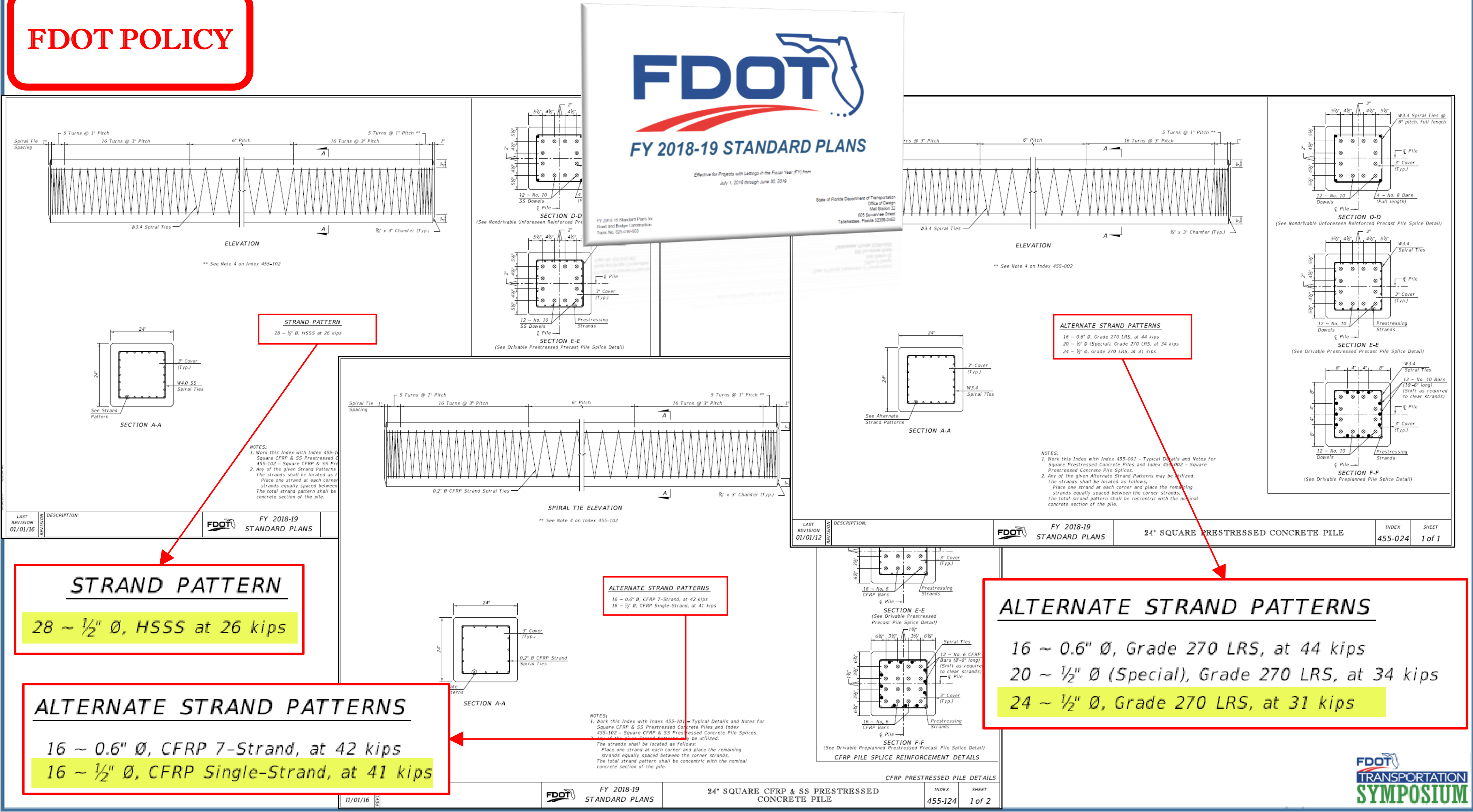
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FY 2018-19 STANDARD PLANS
Effective for Projects with Lettings in the Fiscal Year (FY) from July 1, 2018 through June 30, 2019
ELEVATION
SECTION A-A
SECTION D-D
SECTION E-E
SECTION F-F
SPIRAL TIE ELEVATION
STRAND PATTERN
28 ~ ½" Ø, HSSS at 26 kips
ALTERNATE STRAND PATTERNS
16 ~ 0.6" Ø, CFRP 7-Strand, at 42 kips
16 ~ ½" Ø, CFRP Single-Strand, at 41 kips
ALTERNATE STRAND PATTERNS
16 ~ 0.6" Ø, Grade 270 LRS, at 44 kips
20 ~ ½" Ø (Special), Grade 270 LRS, at 34 kips
24 ~ ½" Ø, Grade 270 LRS, at 31 kips
24" SQUARE PRESTRESSED CONCRETE PILE
INDEX 455-024
SHEET 1 of 1
24" SQUARE CFRP & SS PRESTRESSED CONCRETE PILE
INDEX 455-124
SHEET 1 of 2
CFRP PILE SPLICE REINFORCEMENT DETAILS
CFRP PRESTRESSED PILE DETAILS
FY 2018-19 STANDARD PLANS
FDOT TRANSPORTATION SYMPOSIUM

PART 2:
High Strength Stainless Steel (HSSS) Strands

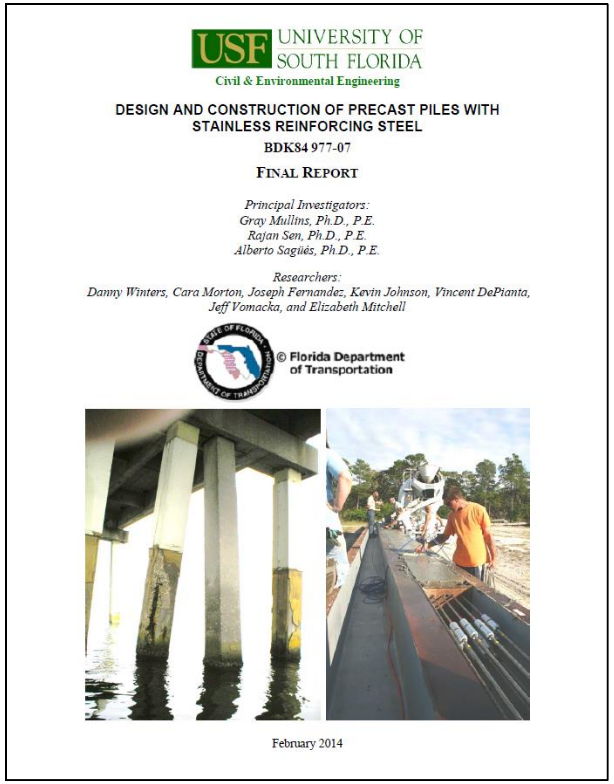
AGENDA

1. Research
2. Design Considerations
3. Projects

Previous Research

Design and Construction of Precast Piles with Stainless Steel Reinforcing

- ❑ Done USF in 2014
- ❑ Additional Follow Up Testing done by FDOT SRC 2017 – 2018
- ❑ Research Project Objective:
  - ❑ Evaluate 3 Different Stainless Steel Materials to identify a suitable Stainless Steel Strand
  - ❑ Grade 316 SS, XM-29 & Duplex 2205
- ❑ Testing & Evaluation Included:
  - ❑ Structural Capacity
  - ❑ Long-term Relaxation
  - ❑ Corrosion Resistance
  - ❑ Field Fabrication
  - ❑ Cost Comparison
- ❑ Final Conclusions & Recommendations:
  - ❑ Use Duplex 2205


USF UNIVERSITY OF SOUTH FLORIDA
Civil & Environmental Engineering

DESIGN AND CONSTRUCTION OF PRECAST PILES WITH STAINLESS REINFORCING STEEL

BDK84 977-07

FINAL REPORT

Principal Investigators:
Gray Mullins, Ph.D., P.E.
Rajan Sen, Ph.D., P.E.
Alberto Sagüés, Ph.D., P.E.

Researchers:
Danny Winters, Cara Morton, Joseph Fernandez, Kevin Johnson, Vincent DePianta, Jeff Vomacka, and Elizabeth Mitchell

Florida Department of Transportation

February 2014

Table (1) Mechanical properties of strands

Mechanical properties	Carbon Steel	2205	XM-29	316
Diameter *(in)*	0.507	0.504	0.515	0.497
Area (in^2)	0.155	0.152	0.158	0.151
Ultimate Tensile Strength *(ksi)*	289.65	264.43	238.13	189.75
Ultimate strain %	7.6	2.3	2.0	2.5
Elastic modulus *(ksi)*	28,732	25,000	22,546	21,541

Ongoing Research

Stainless Steel Strands for Pretensioned Concrete Girders

- ❑ Done by FSU with support from:
  - ❑ Structures Research Center for Structural Testing
  - ❑ Structures Materials Office for Material Testing
- ❑ Research Project Objective:
  - ❑ Strength
  - ❑ Ductility
  - ❑ Deformability
  - ❑ Evaluate Shear Using CRM Bars
- ❑ Material Testing:
  - ❑ 0.6” Diameter Low Relaxation Stainless Steel Strands
- ❑ Structural Testing:
  - ❑ Testing AASHTO Type II Girders with 0.6” Diameter HSSS Strands
  - ❑ Stainless Steel Bars for Shear Reinforcement
  - ❑ GFRP Bars for Shear Reinforcement

Task #	Task Description	Status
n/a	Kickoff Meeting	✔
1	Design Proposed Girders for Testing	✔
2	Testing & Instrumentation Plans	✔
3	Fabricated Girders and Field Evaluation	
4	Flexural Testing	
5	Evaluate Test Data & Provide Design & Detailing Guidelines	
6	Shear Testing	
7	Evaluate Test Data & Provide Design & Detailing Guidelines	
8 - 9	Lightweight Concrete Testing	N/A
10	Draft and Final Reports	

FDOT

FAMU-FSU College of Engineering

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Ongoing Research

Stainless Steel Strands for Pretensioned Concrete Girders

❑Research Project Objective In Depth, Verify the Following:

Initial Stress

- Carbon Steel Strand → 270 ksi @ 75%
- **SS Strand → 240 ksi @ 65%**

Cracking Moment

- Carbon Steel Strand → Mcr or 1.33Mu
- **SS Strands → 1.1Mcr or 1.5Mu**

**Adjusted due to lower ductility*

Elongation

- Carbon Steel Strand → 3.5%
- **SS Strand → ~ 1.5%**

Note: Minimum Acceptable Values to be included in the Specifications

Allowable Tension

- Carbon Steel → $0.19\sqrt{f`c}$ or $0.0948\sqrt{f`c}$
- **SS Strands → $0.0948\sqrt{f`c}$ or 0 ksi**

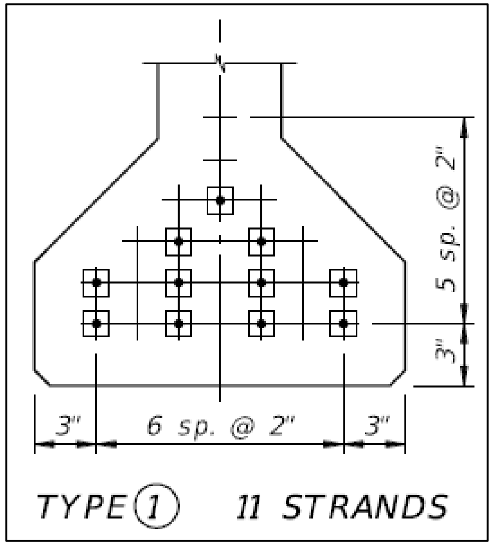
**To compensate for Lower Elastic Modulus*

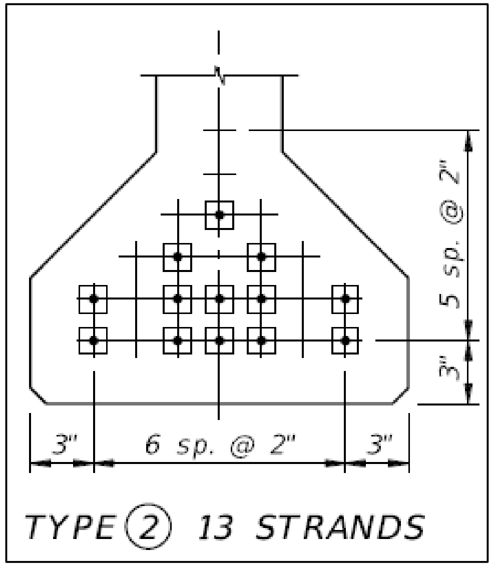
Ongoing Research

Stainless Steel Strands for Pretensioned Concrete Girders

- Testing Matrix:

	Strand Type			End Zone Reinforcement		
Girder Designation	A416	Stainless Steel	Number of Strands	Steel	GFRP	Stainless Steel
A1	X		11	X		
A2	X		11		X	
A3	X		11			X
B2		X	11		X	
B3		X	11			X
C1		X	13	X		
C2		X	13		X	
C3		X	13			X





FDOT FAMU-FSU College of Engineering

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Ongoing Research

Stainless Steel Strands for Pretensioned Concrete Girders

- ❑SRC has 6,000 ft of 0.6” SS Strand
- ❑Material Testing Performed:
  - ❑ASTM A1061 – Tensile Tests for Mechanical Properties
  - ❑ASTM A1061 – Tensile Tests Using Conventional Wedge Grips
  - ❑ASTM A1081 – Tensile Tests to Evaluate Bond
- ❑Results → Stay Tuned…

Aspire Magazine

Spring 2018 Issue, 2 articles were published regarding Stainless Steel Strands:

1. *Structural Design Using Stainless Steel Strands*
2. *Production of Prestressed Concrete Piles Using Stainless Steel Strand*

Louisiana

	AASHTO M 203	Stainless Steel
Steel type	1080 carbon	2205 stainless
Grade	250 and 270	250
Total elongation	> 3.5%	1.2% to 2.0%
Relaxation: 1000 hours @ 80% GUTS	< 3.5%	< 3.5%
Modulus of elasticity	28,500 ksi*	24,500 ksi*

Note: Data from www.sumidenwire.com/products/stainless-steel-pc-strand.

GUTS = guaranteed ultimate tensile strength.

**Nominal value—actual value may vary with manufacturer's production lot.*

Comparison of Material Properties for Types of Strands

Strand Material	Minimum Tensile Strength f_{pu}, ksi	Elastic Modulus E, ksi
2205 Stainless Steel Grade 250[a]	250	25,500
1080 Carbon Steel Grade 270[b]	270	28,600

Current Design Considerations

Red Text is the information for the 0.6" dia. strand currently at FDOT SRC

- *Strength:*
  - Ultimate Tensile Strength = 240 ksi per Specification Section 933 (250 ksi mill cert)
- *Ductility:*
  - Elongation ≈ 1.5% (1.9% mill cert)
- *Elastic Modulus:*
  - Modulus of Elasticity ≈ 25,000 ksi (24,400 ksi mill cert)
- *Once Research is Complete, Guidance On the Following:*
  - Initial Stress (65% of ultimate)
  - Cracking Moment
  - Allowable Tension

Projects

- Airport Road at Daughtry Bayou, Levy County
  - 24” Sq. PCP with Stainless Steel Strand and Reinforcing

- Gulf Boulevard at Lewis Pass, Levy County
  - 24” Sq. PCP with Stainless Steel Strand and Reinforcing

PART 3:
Carbon Fiber Reinforced Polymer (CFRP) Strands

AGENDA

1. Tensile Behavior of CFRP Strands
2. Beams Prestressed with CFRP Systems
3. Design Guidance
4. Design Considerations
5. Design Example

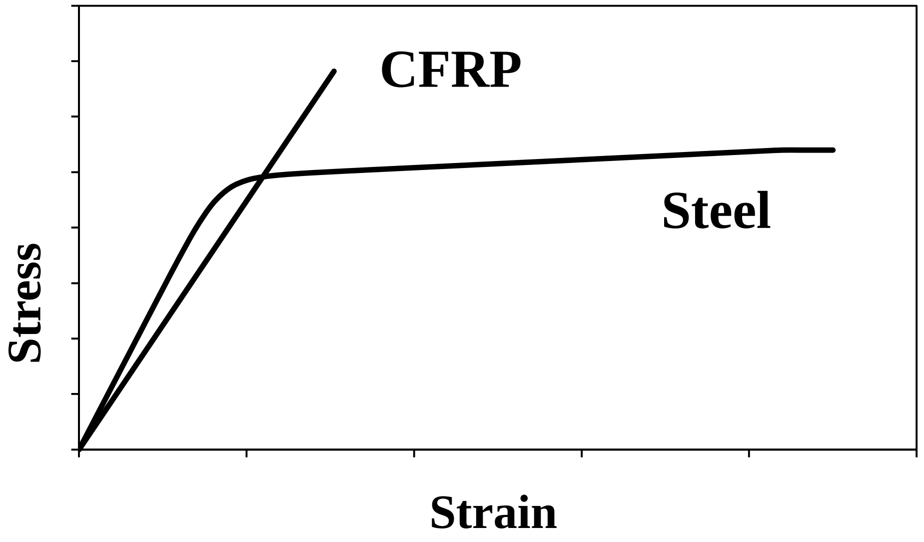
Why CFRP strands?

- FDOT Structures Design Innovation
- Fiber Reinforced Polymer (FRP) Bars and Strands
  - Glass (GFRP) Basalt (BFRP) Carbon (CFRP)

- AASHTO Innovation Initiative
- Advantages of CFRP Strands
  - Superior corrosion resistance
  - Light weight and flexible
  - High tensile strength
  - Good creep and fatigue resistance

[Tokyo Rope]

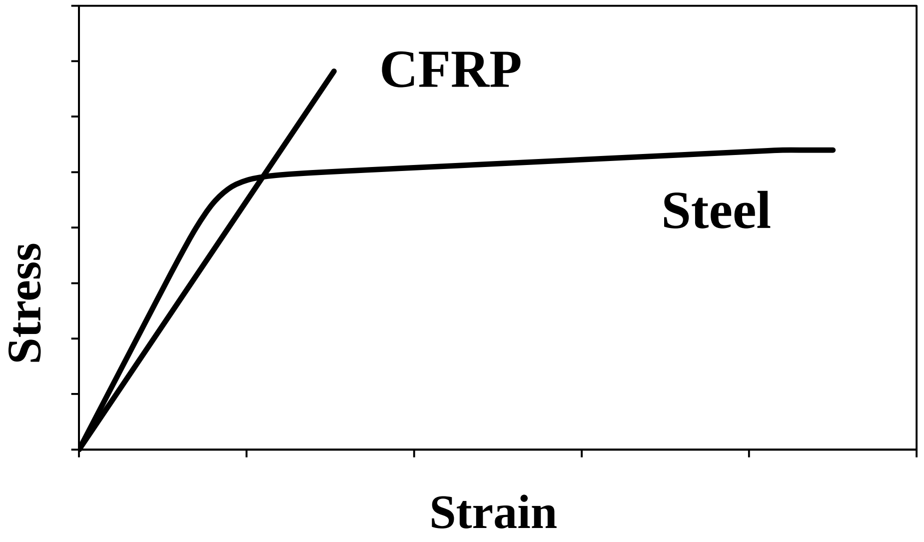
Tensile Behavior of CFRP Systems



- No plastic behavior before rupture
- The tensile strength and stiffness are dependent on:
  - Fiber content

    Fiber mass fraction ≥ 70% [FDOT Specs Section 933]
  - Rate of curing
  - Manufacturing process
  - Manufacturing quality control

Tensile Behavior of CFRP Strands



- Typical values for the tensile strength:

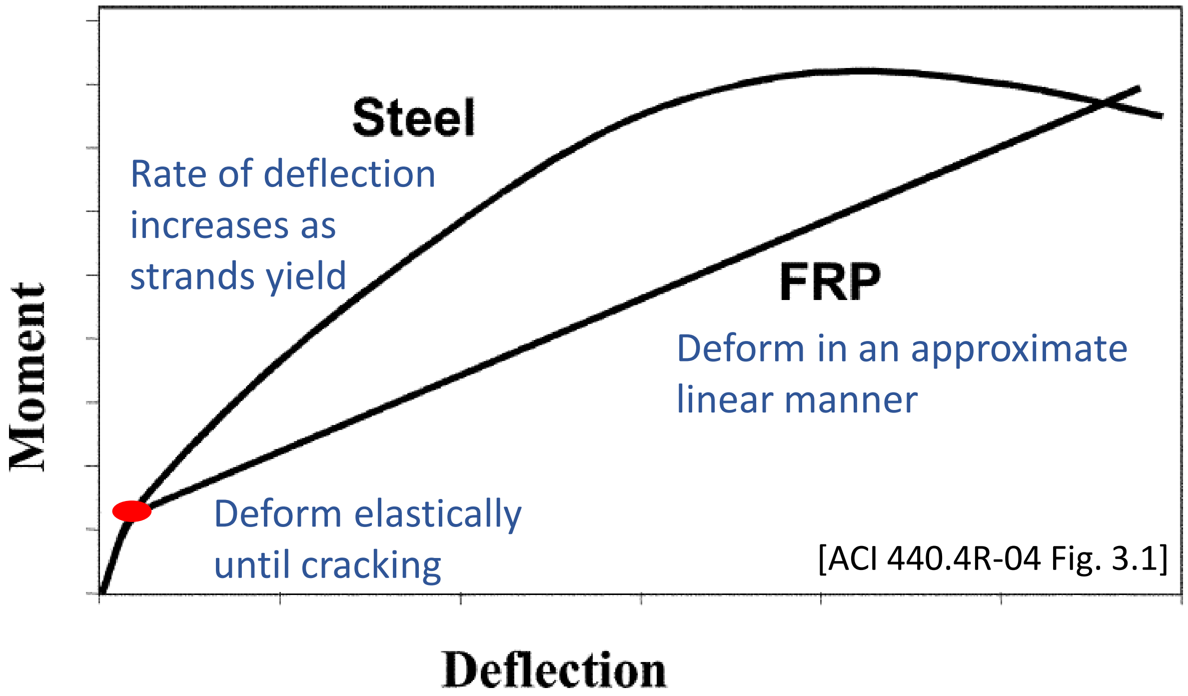
Table 1-1
Typical Sizes and Loads of CFRP Prestressing Strands and Bars

Type	Nominal Diameter (in)	Nominal Cross Sectional Area (in^2)	Nominal Ultimate Load (P_u) (kips)	Nominal Ultimate Tensile Stress (ksi)
Single Strand - 5.0mm Ø	0.20	0.030	9	300
7-strand - 7.5mm Ø	0.30	0.050	17	340
7-strand - 10.5mm Ø	0.41	0.090	32	356
Single Strand - 9.5mm Ø	0.38	0.110	35	318
7-strand - 12.5mm Ø	0.49	0.118	41	347
Single Strand - 12.7mm Ø	0.50	0.196	59	301
7-strand - 15.2mm Ø	0.60	0.179	61	341
19-strand - 20.5mm Ø	0.81	0.320	71	222
7-strand - 17.2mm Ø	0.68	0.234	79	338
19-strand - 25.5mm Ø	1.00	0.472	105	222
19-strand - 28.5mm Ø	1.12	0.621	134	216
37-strand - 35.5mm Ø	1.40	0.916	189	206
37-strand - 40.0mm Ø	1.57	1.240	270	218

[FDOT Specs Section 933]

- Typical values for the modulus of elasticity: 17,000 to 25,000 ksi.
  - 18,000 ksi minimum [FDOT Specs Section 933]

Beams Prestressed with CFRP Strands



- Lower modulus of elasticity
- Lack of traditional ductility
- Acceptable deformability can be achieved

Design Guidance

PROPOSED AASHTO LRFD BRIDGE DESIGN GUIDE SPECIFICATIONS AND MATERIAL SPECIFICATIONS

FOR

CONCRETE BRIDGE BEAMS PRESTRESSED WITH CARBON FIBER-REINFORCED POLYMER SYSTEMS

DRAFT

NCHRP 12-97

Proposed AASHTO LRFD Bridge Design Guide Specifications and Material Specifications for Concrete Bridge Beams Prestressed with Carbon Fiber-Reinforced Polymer Systems

NCHRP NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

UNIVERSITY of HOUSTON

Abdeldjelil Belarbi, PhD, PE
belarbi@uh.edu

AASHTO

T-6 (*FRP Composites*)

Design Considerations - Prestressing

- Stress Limitations for Prestressing CFRP
  - Immediately prior to transfer (f_{pbt}): $0.70\ f_{pu}$
  - At service limit state after all losses (f_{pe}): $0.65\ f_{pu}$

- Prestress Losses

$$\Delta f_{pT} = \Delta f_{pES} + \Delta f_{pLT} + \Delta f_{pTH}$$

  - Elastic shortening (Δf_{pES})

$$\Delta f_{pES} = \frac{E_f}{E_{ct}} f_{cgp}$$

  - Long-term shrinkage and creep of concrete, and relaxation of CFRP (Δf_{pLT})

$$\Delta f_{pR} = \left(0.019\left(\frac{f_{pt}}{f_{pu}}\right) - 0.0066\right)\log(24t) \times f_{pu}$$

  - Temperature change (Δf_{pTH})

$$\Delta f_{pTH} = \Delta T(\alpha_{f,l} - \alpha_c)E_f \geq 0$$

Design Considerations - Prestressing

- Development of Prestressing CFRP
  - Transfer length

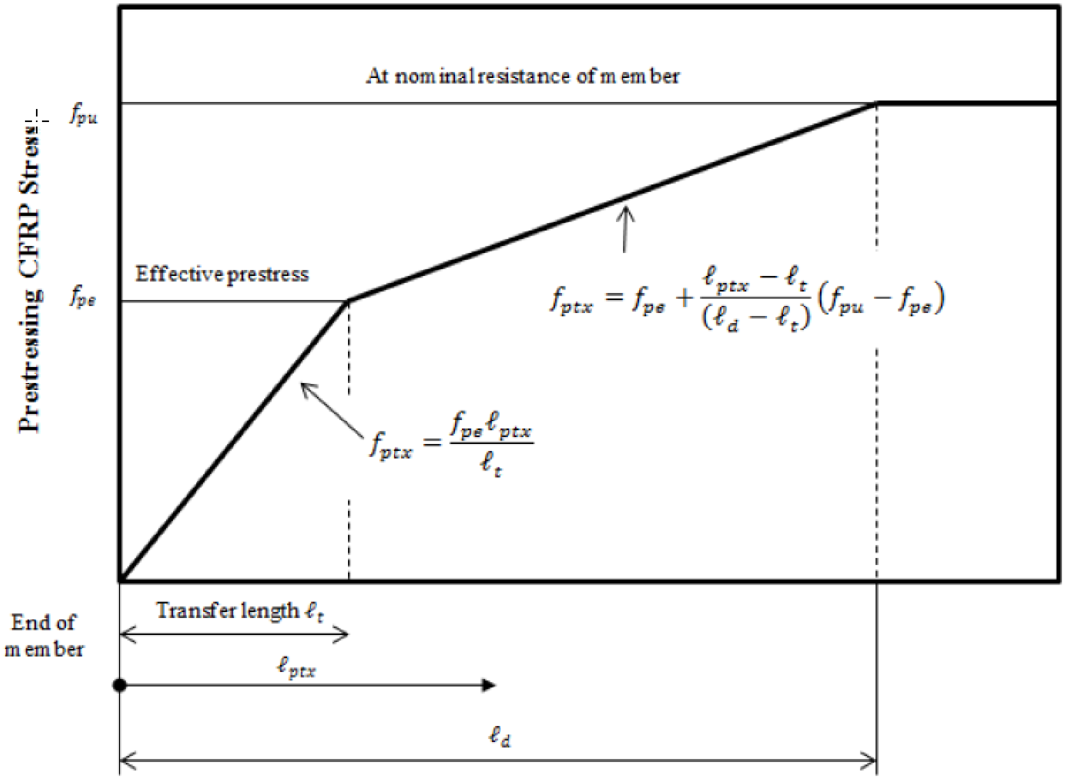
$$\ell_t = \frac{f_{pbt} d_b}{\alpha_t {f'_{ci}}^{0.67}}$$

  - Flexural bond length

$$\ell_b = \frac{(f_{pu} - f_{pe}) d_b}{\alpha_d {f'_c}^{0.67}}$$

  - Development length

$$l_d = lt + lb$$



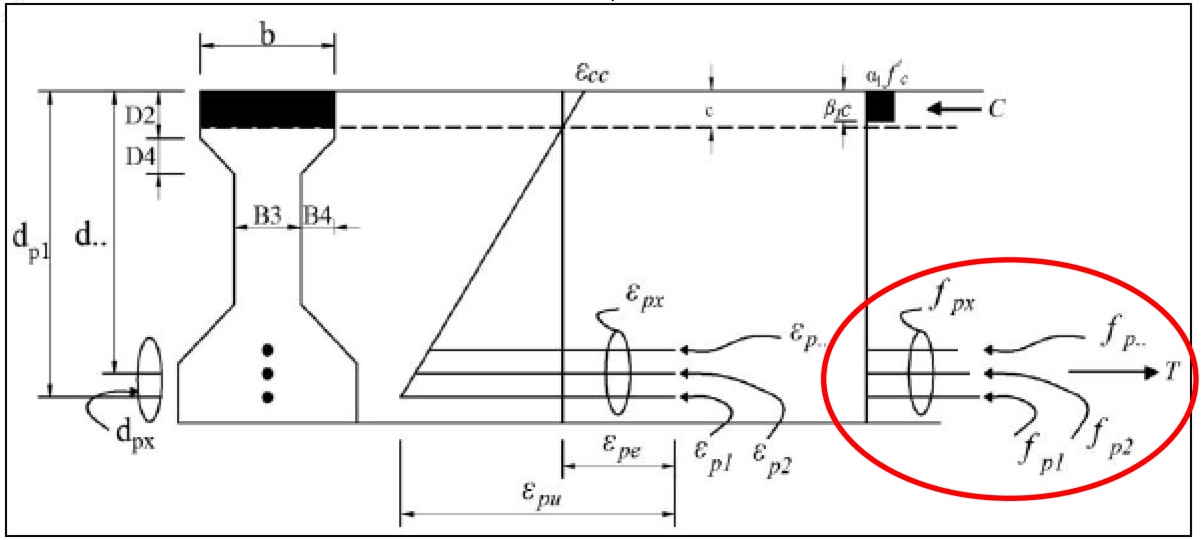
Design Considerations - Service

- Concrete Stresses
  - Article 5.9.2.3 of the AASHTO LRFD Bridge Design Specifications

Allowable stress at transfer of prestress (before losses)	**(ksi)**	
(a) Extreme fiber stress in compression	$0.65f'_{ci}$	
(b) Extreme fiber stress in tension except (c)	$0.0948\sqrt{f'_{ci}}$	
(c) Extreme fiber stress in tension at ends	$0.24\sqrt{f'_{ci}}$	
Allowable stress under service load (after losses)	**(ksi)**	
(a) Extreme fiber stress in compression due to prestress plus sustained loads	$0.45f'_c$	
(b) Extreme fiber stress in compression due to prestress plus total loads	$0.60f'_c$	
(c) Extreme fiber stress in precompressed tensile zone – moderate corrosion	$0.19\sqrt{f'_c}$	[FDOT SM Vol.4]
– severe corrosion	$0.0948\sqrt{f'_c}$	→ $0.19\sqrt{f'_c}$

Design Considerations - Strength

- General Procedure
  - The design principles are based upon equilibrium and strain compatibility.



[NCHRP 12-97]

- Resistance Factors
  - 0.75 for tension controlled (CFRP rupture)
  - 0.75 for compression controlled (concrete crushing)

Design Example

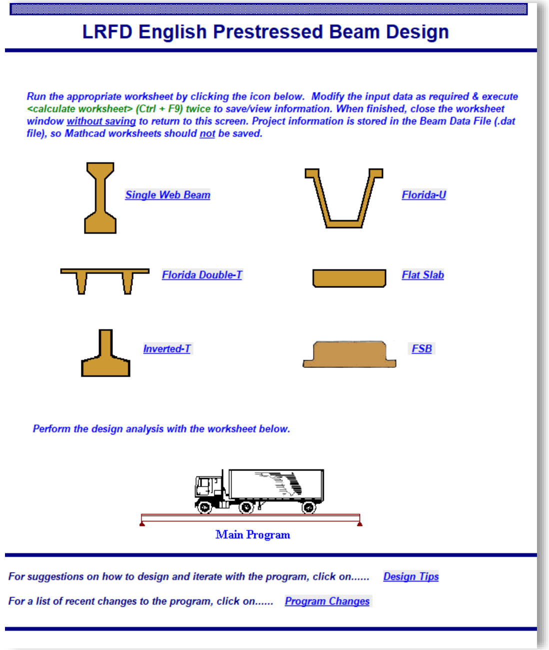
PROPOSED AASHTO LRFD BRIDGE DESIGN GUIDE SPECIFICATIONS AND MATERIAL SPECIFICATIONS

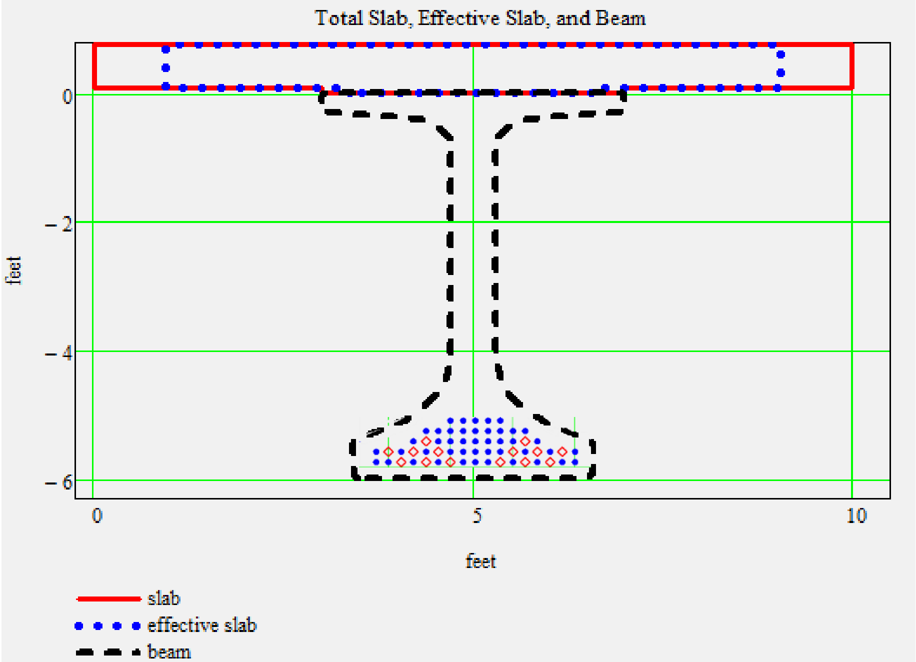
FOR

CONCRETE BRIDGE BEAMS PRESTRESSED WITH CARBON FIBER-REINFORCED POLYMER SYSTEMS

NCHRP 12-97

Proposed AASHTO LRFD Bridge Design Guide Specifications and Material Specifications for Concrete Bridge Beams Prestressed with Carbon Fiber-Reinforced Polymer Systems





- FIB 72 @ 10’ spacing, 155’ span, moderately aggressive
- See [Standard Plans Instructions of Index 450-072]for full list of design assumptions

Design Example

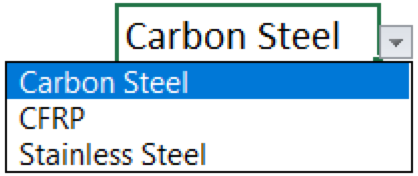
	Low Relaxation Steel	CFRP	CFRP
Diameter, d_b	0.6 inch	0.6 inch	
Area, A_{ps}	0.217 sq. inch	0.179 sq. inch	
Modulus of elasticity, E_p	28,500 ksi	22,400 ksi	
Ultimate tensile stress, f_{pu}	270 ksi	341 ksi	
Yield strength, f_{py}	243 ksi (90% f_{pu})	n/a	
Jacking stress, f_{pj}	202.5 ksi (75% f_{pu})	238.7 ksi (70% f_{pu})	
Effective stress after losses, f_{pe}	171.3 ksi (15% f_{pu})	203.5 ksi (14.7% f_{pu})	
Effective prestressing force per strand	37.2 kips	36.4 kips	
Total number of strands	59	59	62
Service stress checks	OK	OK	OK
Strength I flexural demand, M_u	16239 kip*ft		
Nominal flexural capacity, M_n	19280 kip*ft	20972 kip*ft	21880 kip*ft
Factored flexural capacity, ϕM_n	19280 kip*ft (ϕ =1.00)	15729 kip*ft (ϕ =0.75)	16410 kip*ft (ϕ =0.75)

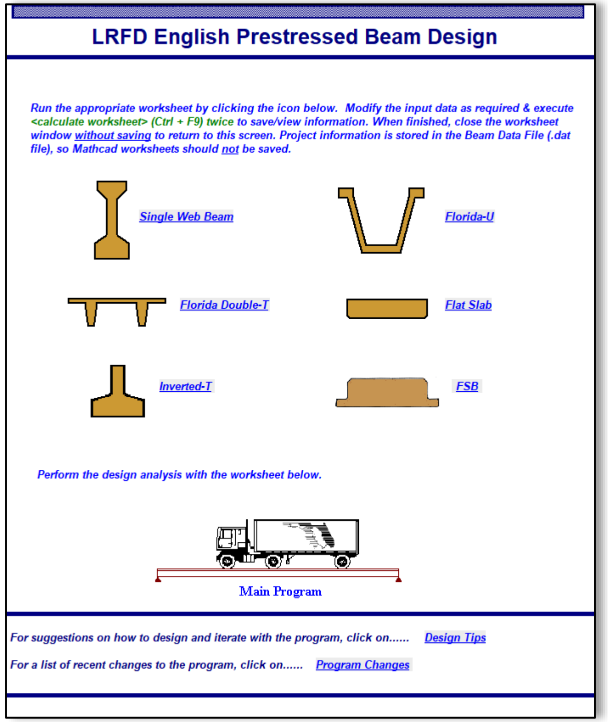
Summary

- Why CFRP and HSSS strands?
  - Corrosion resistance
  - Lower life cycle costs, including reduced maintenance and rehabilitation work
  - Comparable performance to steel in the finished product in terms of load carrying capacity, constructability, and other factors
- FDOT has implemented Specifications, Design Criteria and Guidelines
- Standard Plans to use both CFRP and HSSS strands in Prestressed Concrete Piles and Sheet Piles were released in 2016

Summary

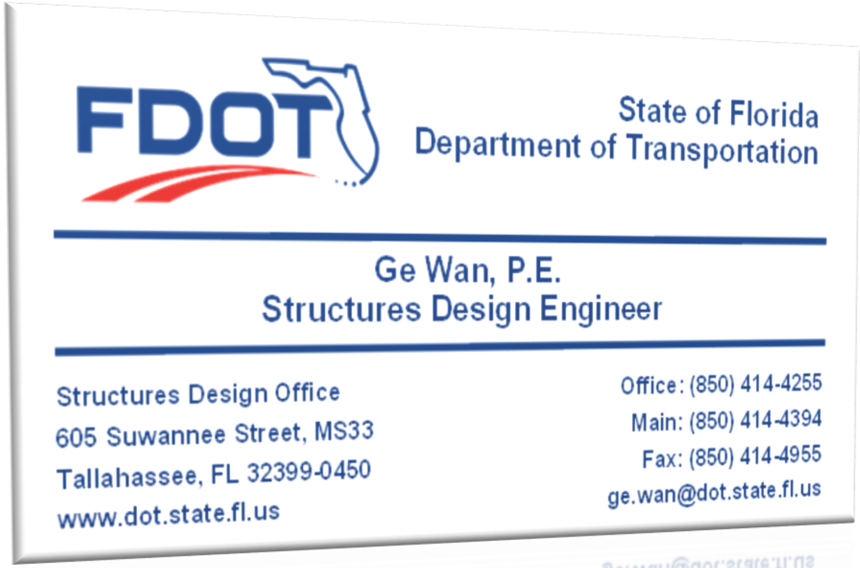
- What’s coming:
  - Implementation of CFRP and HSSS Strands for PS Concrete Girders
  - Once implemented, the Beam Program will be modified to select one of the following strand types:

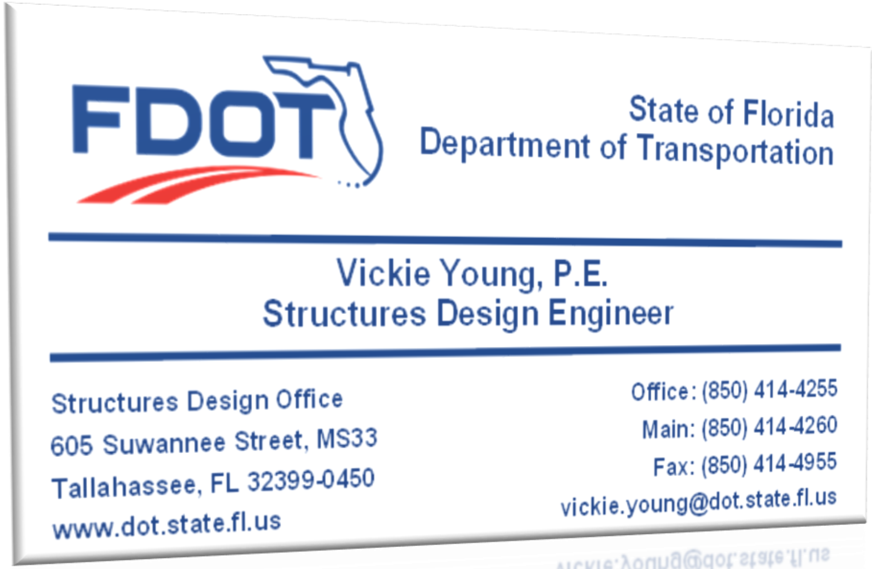




FDOT TRANSPORTATION SYMPOSIUM

Thank You!





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