FDOT TRANSPORTATION SYMPOSIUM

2020 Webinar Series

FRP-Reinforced and Prestressed Concrete Designer Training (An Introduction)

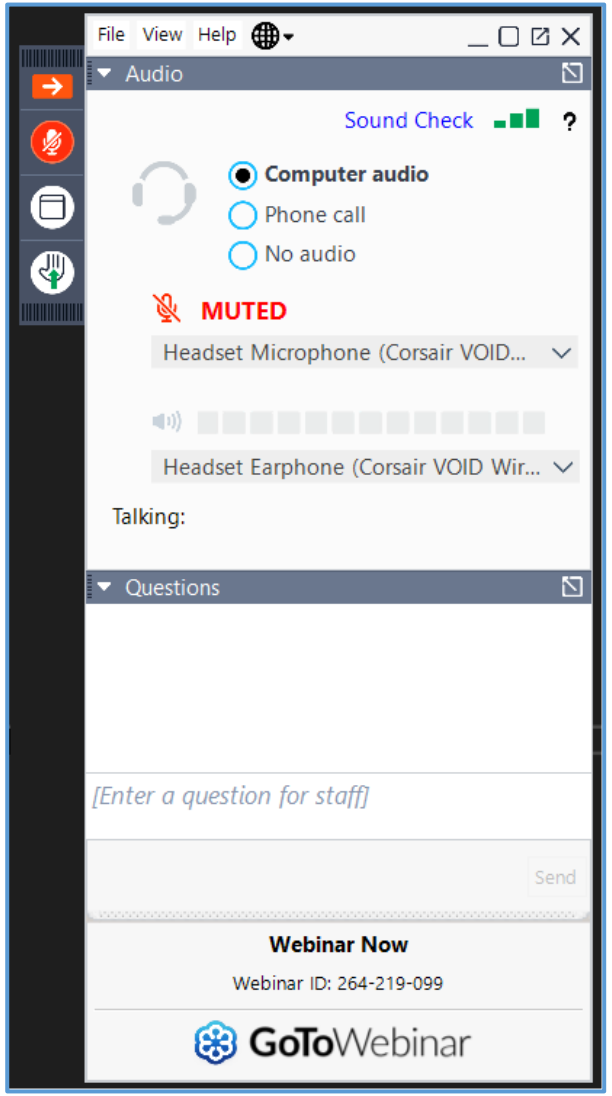
Instructor: Steven Nolan, P.E.

Guest Speakers: Prof. Antonio Nanni & Prof. “DJ” Belarbi



Attendee Questions

- Attendees are automatically muted throughout the webinar.
- Please submit any questions via the questions dialog tool.
- Questions may be answered within the dialog box or may be addressed at the end of the presentation.
- Webinars will be recorded and may be accessed from the Symposium webpage.



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Continuing Education

- Continuing Education credits will be offered to those who attend the live session.
- You must attend the entire session to be eligible for 1.0 hour of Continuing Education credit/Professional Development Hour.
- Attendees will receive their participation certificate via the email address they registered for the GoTo Webinar with.



Overview

The ***FDOT Structures Design Office*** contracted with two universities to collaborate on development one-day training courses for both:

FRP-Reinforced Concrete

&

FRP-Prestressed Concrete Design.

The following presentation is an introduction to the course content, desired outcomes, and delivery methods to entice participants for enrollment beginning in Summer 2020.







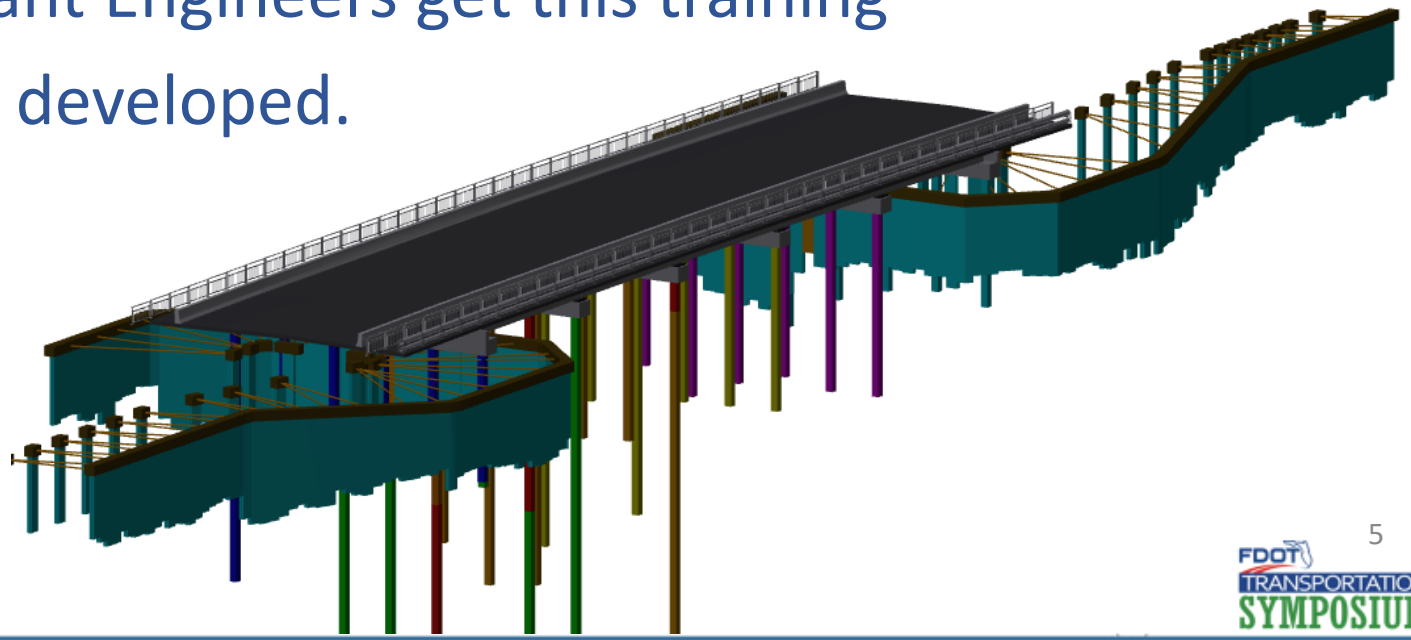


Outline



#3 FDOT Vital Few

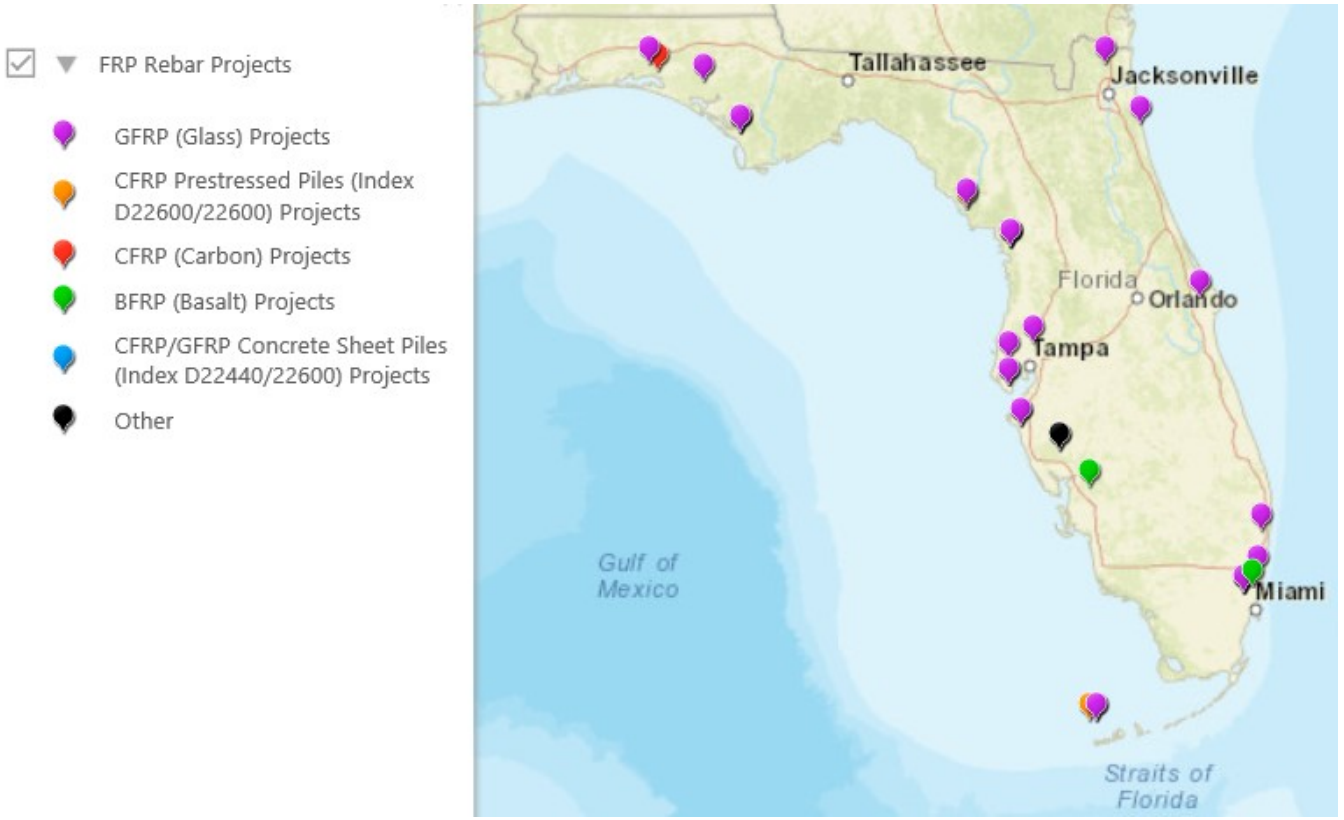
- Is there a need for FRP-RC/PC Training
- What designer guidance and tools are available
- What is FDOT contributing to this need:
  - GFRP-RC Training Overview *(by Prof. Nanni)*
  - CFRP-PC Training Overview *(by Prof. Belarbi)*
- How can Florida DOT & Consultant Engineers get this training
- What other resources are being developed.



Is there a need for FRP-RC/PC Training?

- New ***ASTM*** for GFRP Rebar, *published in 2017*
- New ***AASHTO*** Design Guide Specifications, *published in 2018*
- New ***AASHTO*** Guide for Service Life Design of Highway Bridges, *pending 2020*
- New ***FHWA*** website for Structural Composites, *launched 2020*
- New ***ACI*** 440 Building Code for FRP-RC, *anticipated for 2022*

Current & Completed Projects in Florida

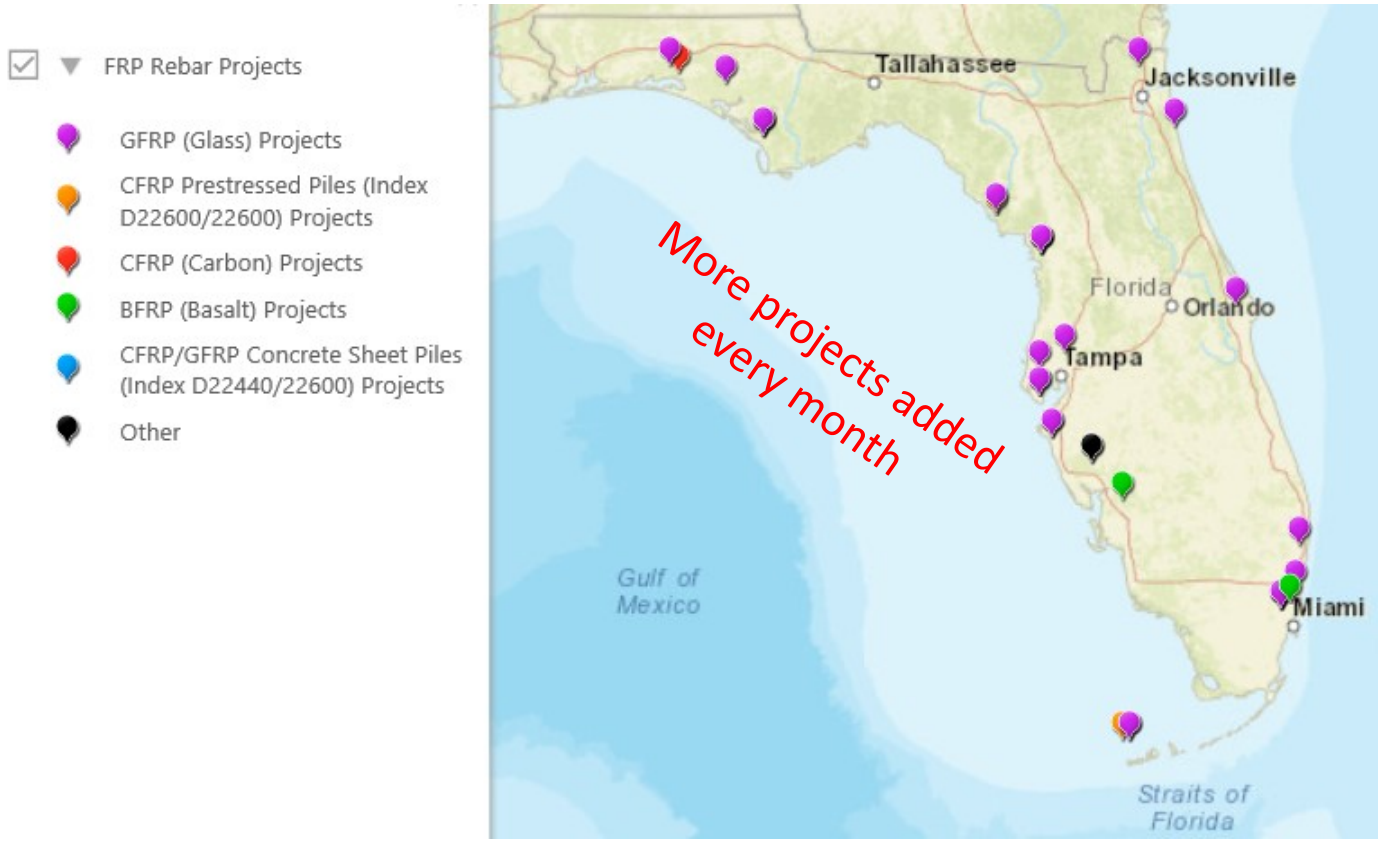


Is there a need for FRP-RC/PC Training

40th Ave NE over Placido Bayou
Arthur Drive over Lynn Haven Bayou **
Bakers Haulover Cut Bulkhead Replacement **
Cedar Key Bulkhead Rehab **
Halls River Bridge **
NE 23rd Ave over Ibis Waterway
PortMiami Tunnel Retaining Walls **
South Maydell Dr over Palm River
SR-A1A Flagler Beach Seawall (Segment 3) **
SR-5 (US-17) over Trout River **
SR-5 (US 41) over Morning Star and Sunset Waterways
SR-5 (US 41) over North Creek
SR-30 over St Joe Inlet
SR-312 over Matanzas River **
SR-520 over Indian River Bulkhead Rehab
Sunshine Skyway Seawall Rehabilitation **
UM Innovation Bridge **
UM Fate Bridge **
UM i-Dock **
US-1 over Cow Key Channel

*** completed*

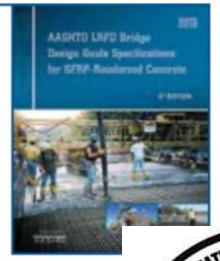
Current & Completed Projects in Florida



What designer guidance and tools are available

AASHTO LRFD BRIDGE DESIGN GUIDE SPECIFICATIONS FOR GFRP-REINFORCED CONCRETE, 2ND EDITION

Item Code: GFRP-2-UL



These guide specifications offer a description of the unique material properties of glass fiber-reinforced polymer (GFRP) composite materials, as well as provisions for the design and construction of concrete bridge decks and railings reinforced with GFRP reinforcing bars. The specifications include information on the advancements in material specifications; new knowledge and field experiences beyond bridge decks and traffic railings; greater consistency with the *AASHTO LRFD Bridge Design Specifications*, 8th Edition; consideration of flexural members, such as girders and bent caps; consideration of substructure and foundation elements, along with compression members; differentiation between the fatigue and creep limit states; and revised shear design methodology. This 2018 2nd edition supersedes the 2009 1st edition. **2018. 122 pp.**

PDF DOWNLOAD Code: GFRP-2-UL | List Price: $135 | Member Price: $100

GUIDE SPECIFICATIONS FOR THE DESIGN OF CONCRETE BRIDGE BEAMS PRESTRESSED WITH CARBON FIBER-REINFORCED POLYMER (CFRP) SYSTEMS, 1ST EDITION

Item Code: CFRP-1-UL

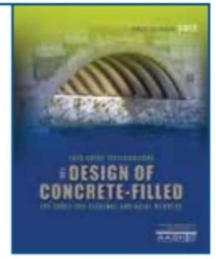


These guide specifications apply to the design of prestressed concrete beams constructed of normal weight concrete and prestressed by carbon fiber-reinforced polymer (CFRP) prestressing systems. **2018. 70 pp.**

PDF DOWNLOAD Code: CFRP-1-UL | List Price: $51 | Member Price: $38

AASHTO LRFD GUIDE SPECIFICATIONS FOR DESIGN OF CONCRETE-FILLED FRP TUBES, 1ST EDITION

Item Code: LRFDFRP-1



These guide specifications present provisions for the analysis and design of concrete-filled fiber-reinforced polymer (FRP) tubes (CFFT) for use as structural components in bridges. Design methodology allows CFFTs to be designed as flexural members, axial compression members, or members subjected to combined flexure and axial compression, in addition to shear. CFFT bridge components may include beams, columns, and piles. **2012. 48 pp.**

PDF DOWNLOAD Code: LRFDFRP-1-UL | List Price: $32 | Member Price: $24
LOOSELEAF Code: LRFDFRP-1 | List Price: $41 | Member Price: $30
LOOSELEAF & PDF COMBO Code: LRFDFRP-1-PUL | List Price: $57 | Member Price: $42

Not discussed here

GUIDE SPECIFICATION FOR SERVICE LIFE DESIGN OF HIGHWAY BRIDGES, 1ST EDITION

Item Code: HBSLD-1



This guide specification is intended to offer design recommendations for agencies wishing to implement service life design principles and detailing recommendations. It was developed to incorporate quantitative approaches, along with proven deemed-to-satisfy provisions, into a single comprehensive design document for implementation on a national level. It also establishes for service life design, while providing opportunities for refinement and expansion, new models capable of simulating deterioration mechanisms become available.

GUIDE SPECIFICATIONS FOR DESIGN OF FRP PEDESTRIAN BRIDGES, 1ST EDITION

Item Code: GSDFPB-1



These guide specifications apply to fiber-reinforced polymer (FRP) composite bridges intended to carry, primarily, pedestrian and bicycle traffic. **2008. 20 pp.**

PDF DOWNLOAD Code: GSDFPB-1-UL | List Price: $27 | Member Price: $20
LOOSELEAF Code: GSDFPB-1 | List Price: $34 | Member Price: $25
LOOSELEAF & PDF COMBO Code: GSDFPB-1-PUL | List Price: $47 | Member Price: $35

Not discussed here

GUIDE SPECIFICATIONS FOR DESIGN OF BONDED FRP SYSTEMS FOR REPAIR AND STRENGTHENING OF CONCRETE BRIDGE ELEMENTS, 1ST EDITION

Item Code: FRPS-1



These guide specifications are intended for the repair and strengthening of reinforced and prestressed highway bridge structural elements using externally bonded fiber-reinforced polymer (FRP) composite systems. **2012. 76 pp.**

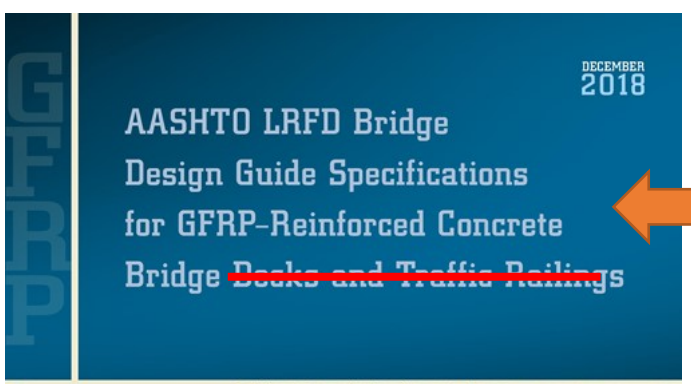
PDF DOWNLOAD Code: FRPS-1-UL | List Price: $47 | Member Price: $35
LOOSELEAF Code: FRPS-1 | List Price: $59 | Member Price: $44
LOOSELEAF & PDF COMBO Code: FRPS-1-PUL | List Price: $83 | Member Price: $61

Not discussed here

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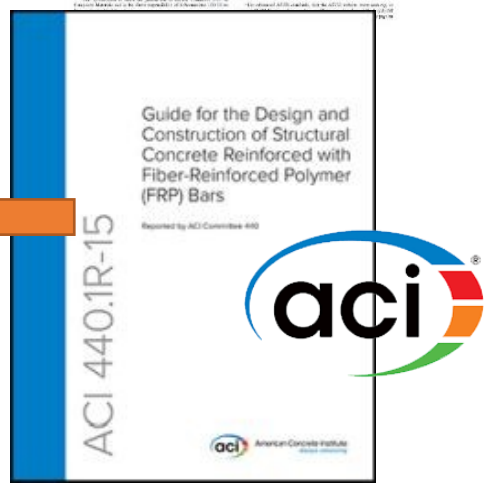
What designer guidance and tools are available

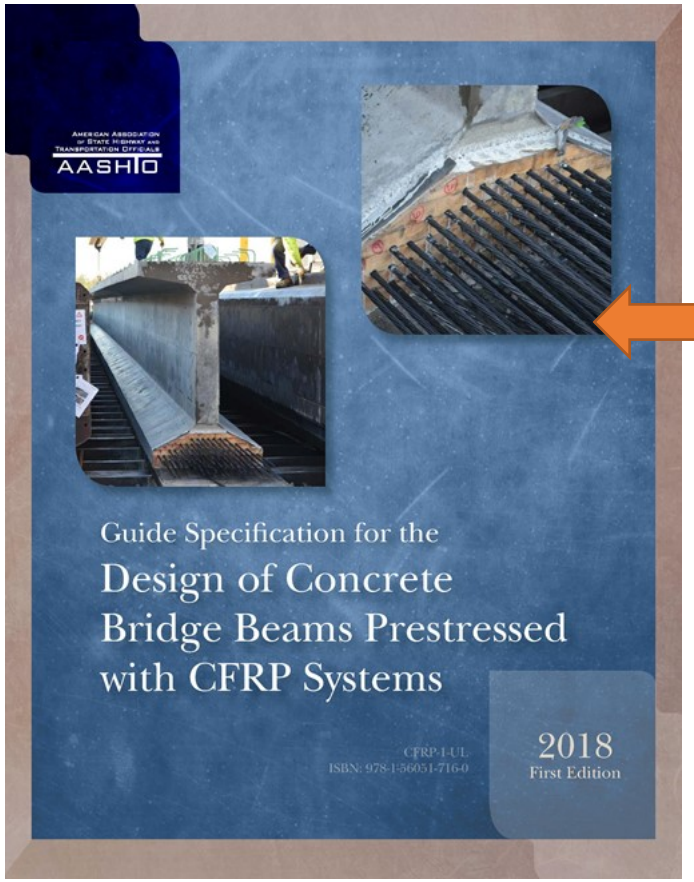
- Design Guide for GFRP-RC
- Design Guide Spec for CFRP-PC













What designer guidance and tools are available

- Design Guidance

FLORIDA DEPARTMENT OF TRANSPORTATION



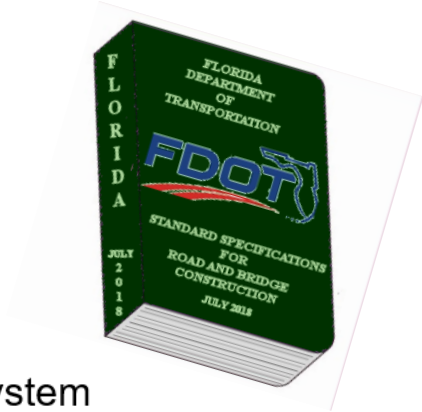
Image courtesy of WSP USA

STRUCTURES MANUAL

Volume 1 - Structures Design Guidelines
Volume 2 - Structures Detailing Manual
Volume 3 - FDOT Modifications to LRFDLTS-1
Volume 4 - Fiber Reinforced Polymer Guidelines

Frequently Asked Questions
2018 Revision History
Archived Structures Manuals
Additional Links

- Materials & Construction



MAC Materials Acceptance and Certification System

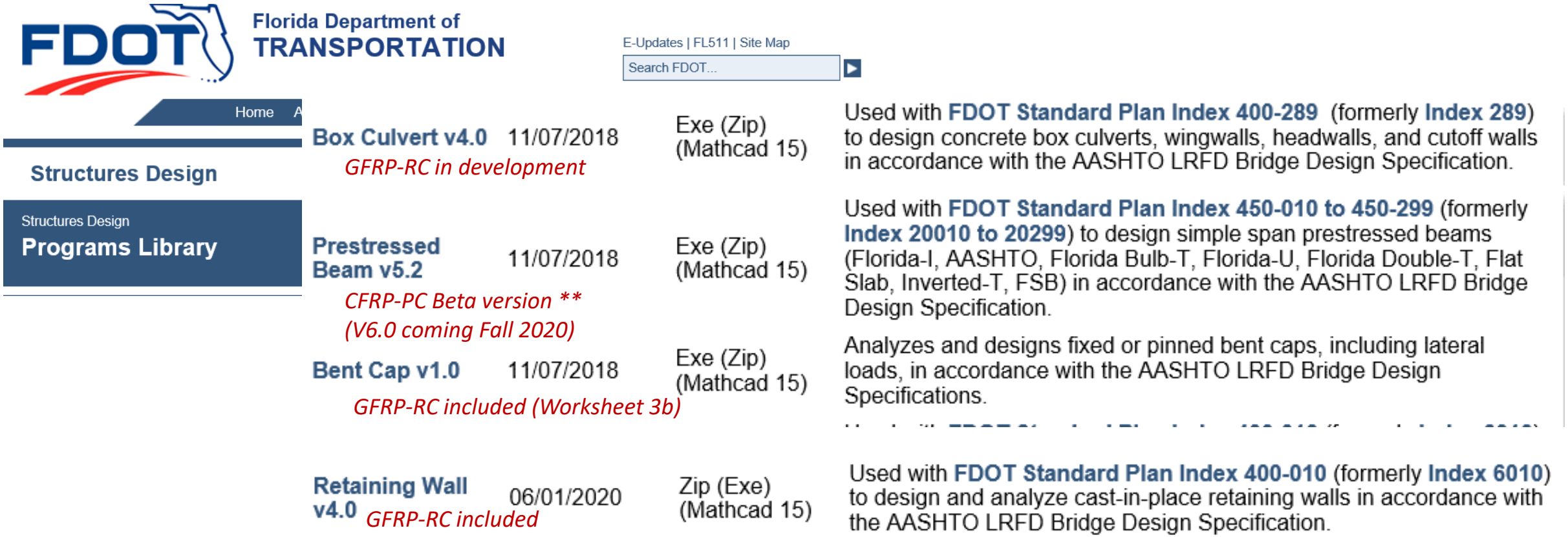
elect Report to View

Production Facility	
Aggregate Production Facility Listing	Lists all Aggregate Production Facilities
All Producers (Excel)	Lists all non-expired Production Facilities in an Excel file
Approved Aggregate Products For Friction Course	Lists all Aggregate Friction Course Products by Geological T
Approved Aggregate Products From Mines or Terminals Listing	Lists Approved Aggregate Products for Mines or Terminals
Approved Products at Expired Mines or Terminals	A summary report to identify Approved Products at Expired Terminals Expired at Mine
Asphalt Production Facility Listing	Lists all Asphalt Production Facilities
Asphalt Recycled Products	Approved Asphalt Recycled Products Report by Plant
Asphalt Targets	A listing of the asphalt gradation and gravity (Gsb) data for A
Cementitious Materials Production Facility Listing	Lists Cementitious Materials Production Facilities
Coatings Production Facility Listing	Lists all Coatings Production Facilities
Fiber Reinforced Polymer Production Facility Listing	Lists all Fiber Reinforced Polymer Production Facilities

FDOT TRANSPORTATION SYMPOSIUM

What designer guidance and tools are available

- FDOT Design Tools



https://www.fdot.gov/structures/proglib.shtm

** Available on request

What designer guidance and tools are available

FDOT Transportation Innovation Challenge

The Department invites you to share your thoughts on ways we can challenge ourselves to be innovative, efficient and exceptional at our **Invitation to Innovation website**

We also invite you to review our Design Office Innovations listed in the links below. Additional innovations will be added as they are identified and developed. If you have any questions, details and contact information are included within the information for each innovation web site.

Structures Design Office

Curved Precast Spliced U-Girder Bridges

Fiber Reinforced Polymer Reinforcing

FRP Members and Structures

Geosynthetic Reinforced Soil Integrated Bridge System

Geosynthetic Reinforced Soil Wall

Prefabricated Bridge Elements and Systems

Segmental Block Walls

Ultra-High Performance Concrete (UHPC)

- FRP-Design Innovation



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

What else is FDOT contributing to this need

- ***TIC*** Technology Transfer
- Predesigned Bearing Pile & Sheet Pile Standards ***(Indexes)***
- ***SDO*** Technical Assistance
- ***SDO*** Plans Review Oversight
- ***FDOT*** STIC Incentive Grant from FHWA for BFRP-RC standards development
- Ongoing ***FDOT*** funded research
- Support to ***TRB AFF80***
- Support to ***AASHTO T-6 & T-10***
- ***…***

Technology Transfer (T^2)

https://www.fdot.gov/structures/innovation/FRP.shtm#link7

2015
- FHWA/NCHRP 20-68
(June 4-5, 2015)

2016
- FDOT-FRP Rebar Ind
(June 15, 2016)
- Composites-Halls Ri
(September 26-29, 20
- CAMX 2016: FDOT-F
(September 29, 2016)
- ACMA-Transportatio
(September 29, 2016)

2017
- FDOT 2017 Winter FF
(February 3, 2017)
- Halls River Bridge Re
(May 2-3, 2017)
- FDOT 2017 Design T
(June 6, 2017)
- International Worksh
(July 18, 2017)
- FES/FICE 2017: The
(August 4, 2017)
- CAMX 2017: Halls Ri
(December 11-14, 201

(January 11-14, 2018)
- FDOT 2018 Winter FRP-RC Workshop and FTBA Construction Conference (February 8-9, 2018)
- International Bridge Conference - Workshop W4 (June 12, 2018):
  - How do I make my bridges more resilient to the damaging effects of natural disasters?
  - Bridge Design Guide Specifications for GFRP-RC
  - Rehabilitation of East Lynn Lake Bridge, WV
  - Beyond Halls River Bridge – FRP-RC/PC Infrastructure Solutions
  - Specifications and Applications of Composite Materials in Bridge Infrastructure in Australia
- FDOT Transportation Symposium (June 18-20, 2018)
  - CFRP & HSSS Strands in Prestressed Concrete Design
  - FRP Beyo
  - Structural

2019
- 2nd Internation
- TRB 2019 Work
- TRB 2019: Bakers Haulover Cut Bridge: Seawall-Bulkhead Rehabilitation and New GFRP-RC Solutions (2019)
- NCBPT 2019: Low Impact Secant-Pile Seawall for protecting SR-A1A along Flagler Beach (Feb 7, 2019)
- FDOT Transportation Symposium (June 3-5, 2019)
  - FRP-RC Design Training (Part 1)
  - FRP-RC Design Training (Part 2)
  - FRP-RC Design Training (Part 3)
- ACI-SDC Forum 46: Agenda, FDOT Presentation (Aug 28, 2019)

2020
- TRB 2019 Workshop 1063 (Jan 12, 2019):
  - Externally Bonded Wraps
  - FRP Design Tools, CBB Implementation & Pedestrian Bridges
- ISACS: Florida
- FDOT Executive Workshop (January 15, 2020)

GFRP-Reinforced Concrete Design for Bridges

Guest Speaker (1): Prof. Antonio Nanni

Inaugural Senior Scholar
Professor and Chair
Department of Civil, Architectural & Environmental Engineering
University of Miami



Biography

Prof. Nanni is a structural engineer interested in construction materials and their structural performance and field application, including monitoring and renewal, with a focus on the sustainability of buildings and civil infrastructure. During the past 30+ years, he has studied concrete and advanced composite-based systems as the principal investigator on a number of projects sponsored by federal and state agencies and private industry. Editor-in-chief of the *Journal of Materials in Civil Engineering* (American Society of Civil Engineers) and serves on the editorial board of other technical journals. He has advised more than 60 graduate students pursuing master's and doctoral degrees in the field, published more than 220 papers in refereed journals, published more than 350 papers in conference proceedings and co-authored two books.

COURSE TOC (Major Topics)

- 1. Introduction & Materials
- 2. Flexure Response
- 3. Shear Response
- 4. Axial, Foundation and Walls
- 5. Case Studies & Field Operations



AASHTO GFRP-Reinforced Concrete Design Training Course

A teaser of what you may expect (in red what will be mentioned today)

	TOPIC	
1	**INTRODUCTION TO FRP-RC**	8:00 (30 min)
1.1	**APPLIED QUESTIONS: Fundamentals**	8.30 (20 min)
1.2	**APPLIED QUESTIONS: Value Engineering**	8.50 (10 min)
2	**THEORY: Flexure Design**	9:00 (50 min)
	Break	9:50 (15 min)
2.1	**APPLIED QUESTIONS: General Fundamentals**	10:05 (20 min)
2.2	**APPLIED EXAMPLE: Deck Design**	10:25 (25 min)
2.3	**APPLIED EXAMPLE: Creep Design Check**	10:50 (10 min)
2.4	**APPLIED EXAMPLE: Min. Reinforcement Design**	11:00 (10 min)
3	**THEORY: Shear Design**	11:10 (30 min)
3.1	**APPLIED QUESTIONS: General Fundamentals**	11:40 (15 min)
	Lunch Break	11:55(50 min)
3.2	**APPLIED EXAMPLE: Bent Cap**	12:45(25 min)
3.3	**SELF STUDY EXAMPLE: Railings**	1:10 (10 min)
4	**THEORY & DESIGN EXAMPLE: Axial Design**	1:20 (50 min)
4.1	**APPLIED QUESTIONS: General Fundamentals**	2:10 (15 min)
4.2	**APPLIED EXAMPLE: Cantilevered Retaining Wall.**	2:25 (30 min)
	Break	2:55 (15 min)
4.3	**SELF STUDY EXAMPLE: Sheet Pile Wall**	3:10 (10 min)
5.1	**Case studies & field operations: NE** 23rd St. Bridge	3:20 (20 min)
5.2	**Case studies & field operations:** Halls River Bridge	3:40 (20 min)
5.3	**Case studies & field operations**: SR-A1A Flagler Beach	4:00 (20 min)
5.4	**Other resources**: Fast Facts	4:20 (20 min)
	End	4:40 pm

Course Learning Objectives

- Know what FRP bars and bends are
- Understand why and where best to use FRP bars as concrete reinforcement
- Learn the fundamental mechanical properties of FRP bars and bends
- Describe the behavior of FRP bars
- Learn the differences between FRP and steel bars
- Describe some major material-based design provisions of concrete members internally reinforced with FRP bars
- Become aware of relevant FRP-RC projects in and out of state



INTRO to FRP-RC: FRP Bar Types

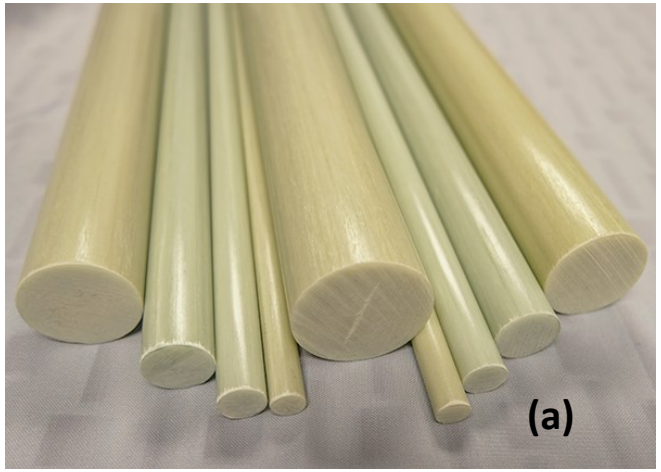
External Surface Types (not standardized)

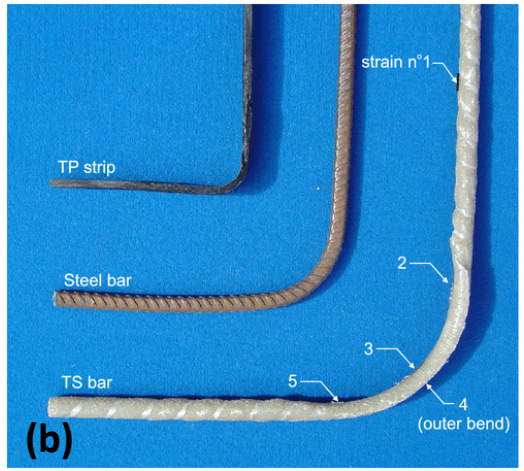
- (A & F) San coated + helically wrapped
- (B) Helically wrapped
- (C) Ribbed
- (D) Sand coated
- (E) Helically grooved

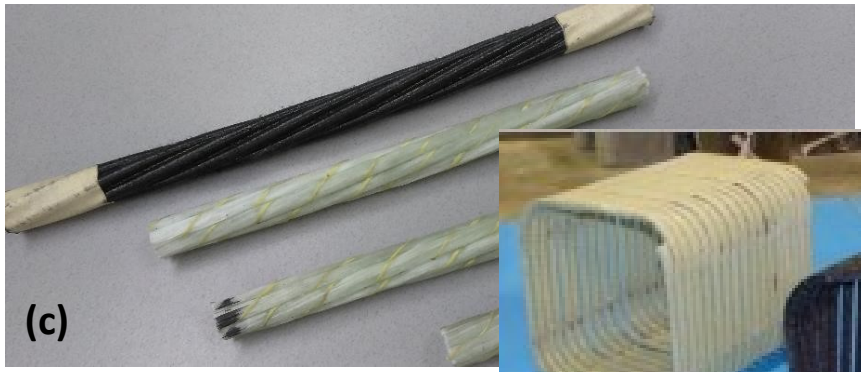


FRP Bar Shapes

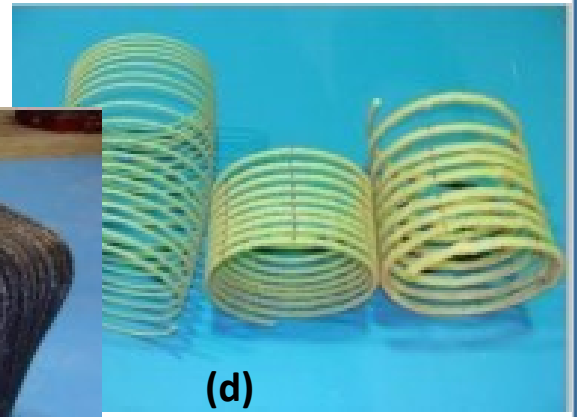
- (a) Round solid bars (smooth for dowels)
- (b) Bent bars
- (c) Twisted strands (for PC)
- (d) Spirals







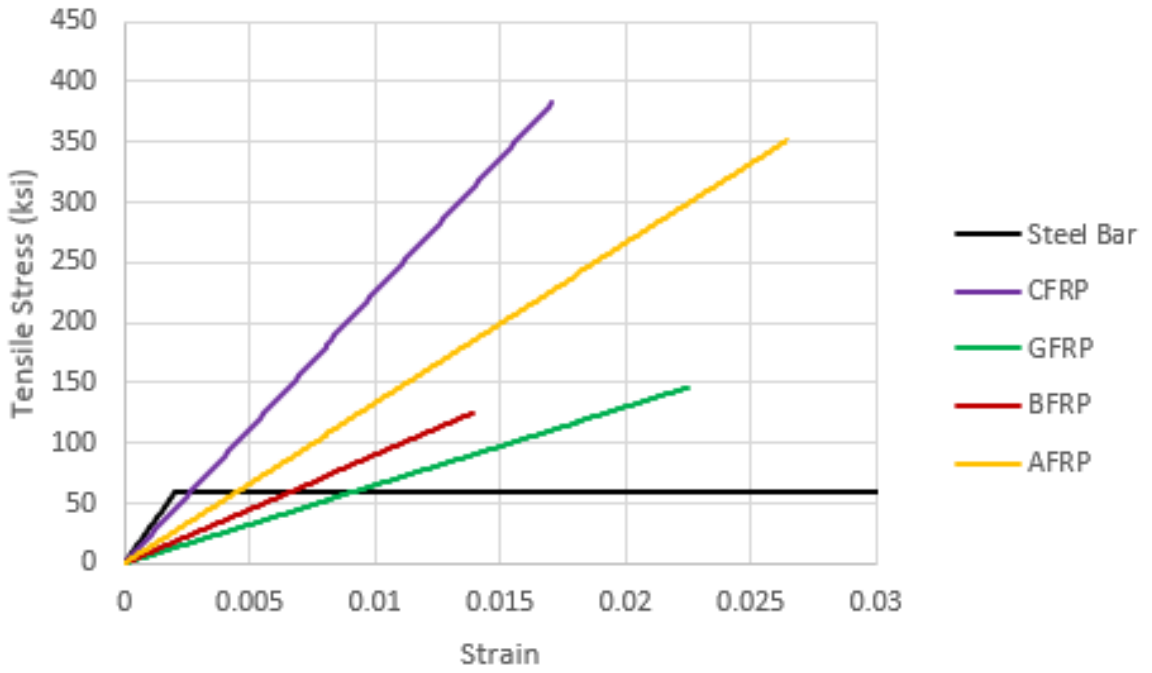




FRP Mechanical Properties

- High strength only in the fiber direction
- Elastic up to failure, stronger, but less stiff than steel
- **Anisotropic** behavior results in lower shear strength and dowel action
- Not ductile: cannot be used in seismic areas, no plastic hinges formed
- Provides less confinement to concrete and has more deflection than steel RC

Tensile Stress-Strain Characteristics



Design Tensile Strength

Design tensile strength and strain are:

$$f_{fu} = C_E f^*_{fu}$$

$$\varepsilon_{fu} = C_E \varepsilon^*_{fu}$$

AASHTO 2.4.2.1-1

Where C_E is an environmental reduction factor from *AASHTO* Table 2.4.2.1-1 (proposed new factors in **ACI** in green)

	Concrete not exposed to earth or weather	Concrete exposed to earth or weather
Carbon	1.0	0.9
Glass	0.9 0.8	0.85 0.70
Aramid	0.9	0.8

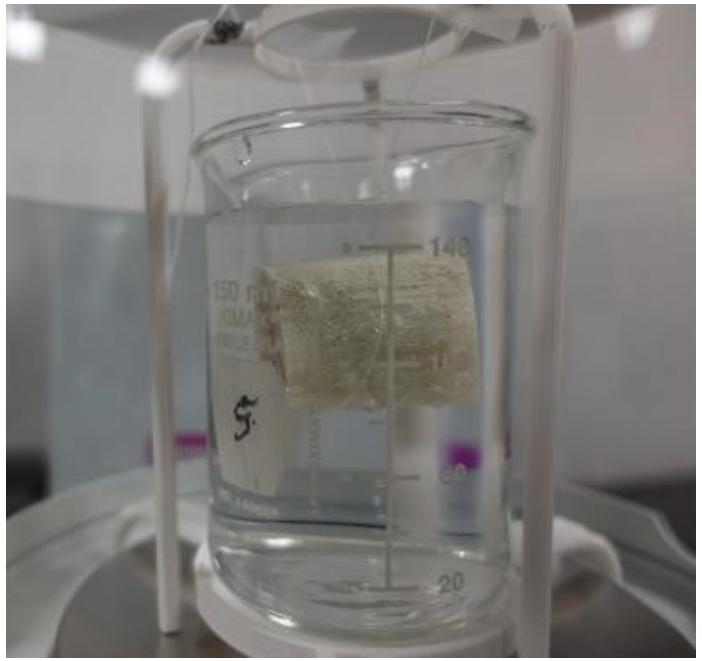
Material Characterization



Moisture absorption
[ASTM D570]



Fiber content
[ASTM D2484]



Cross-sectional area
[ASTM D792]

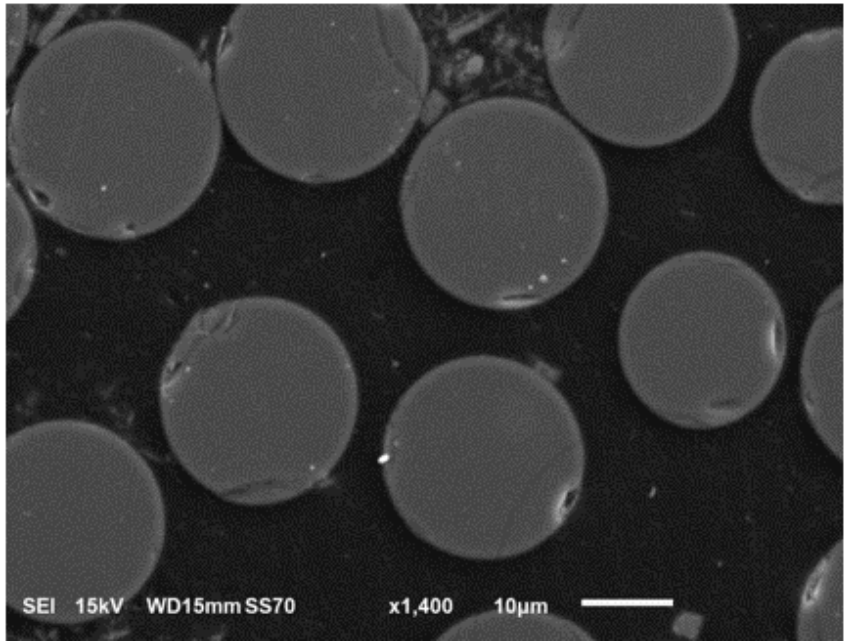
Material Characterization

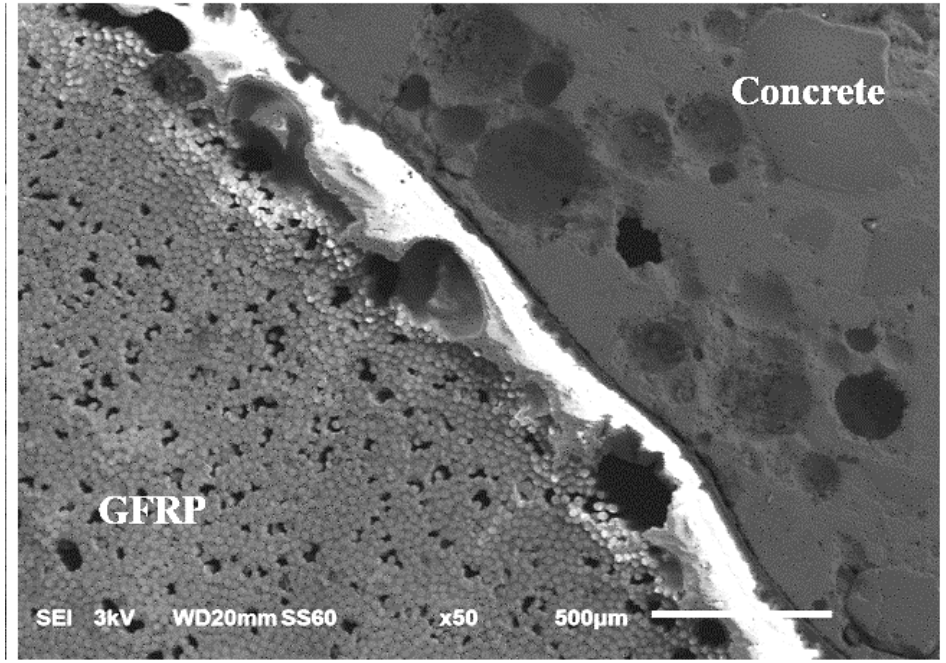




Tensile test
[ASTM D7205]

Durability





Source: Long-term Durability of GFRP Reinforcement in Concrete: A Case Study after 15 Years of Service - O. Gooranorimi, E. Dauer, J. Myers, A. Nanni

NO SIGN OF BOND DEGRADATION NOR LOSS OF CONTACT AND MECHANICAL PROPERTIES AFTER 15 YEARS IN SERVICE

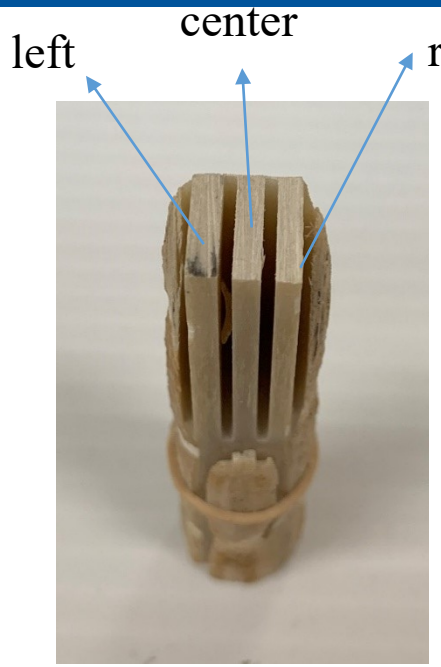
Selected Bridges for ACI-SDC Study on GFRP Durability

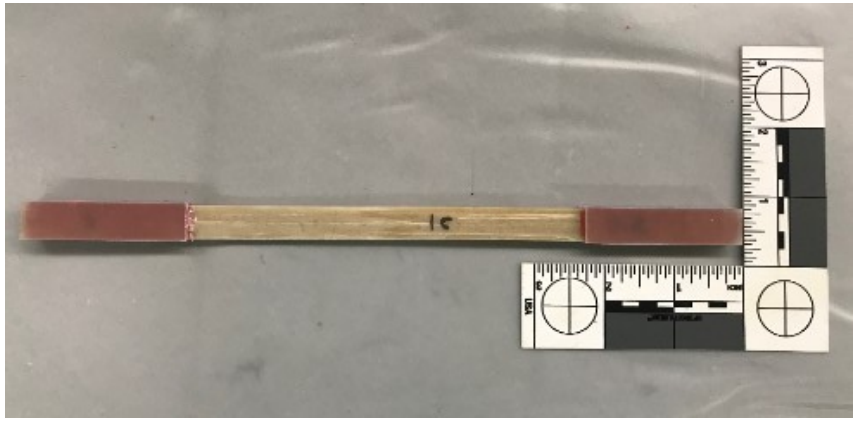
- **Eleven bridges** located across the United States
- Each bridge contains GFRP bars in deck or other location and has been in service for **at least 15 years**



- Gills Creek Bridge (VA)
- O'Fallon Park Bridge (CO)
- Salem Ave Bridge (OH)
- Bettendorf Bridge (IA)
- Cuyahoga County Bridge (OH)
- McKinleyville Bridge (WV)
- Thayer Road Bridge (IN)
- Roger's Creek Bridge (KY)
- Sierrita de la Cruz Creek Bridge (TX)
- Walker Box Culvert Bridge (MO)
- Southview Bridge (MO)

Conclusion for ACI-SDC Study on GFRP Durability





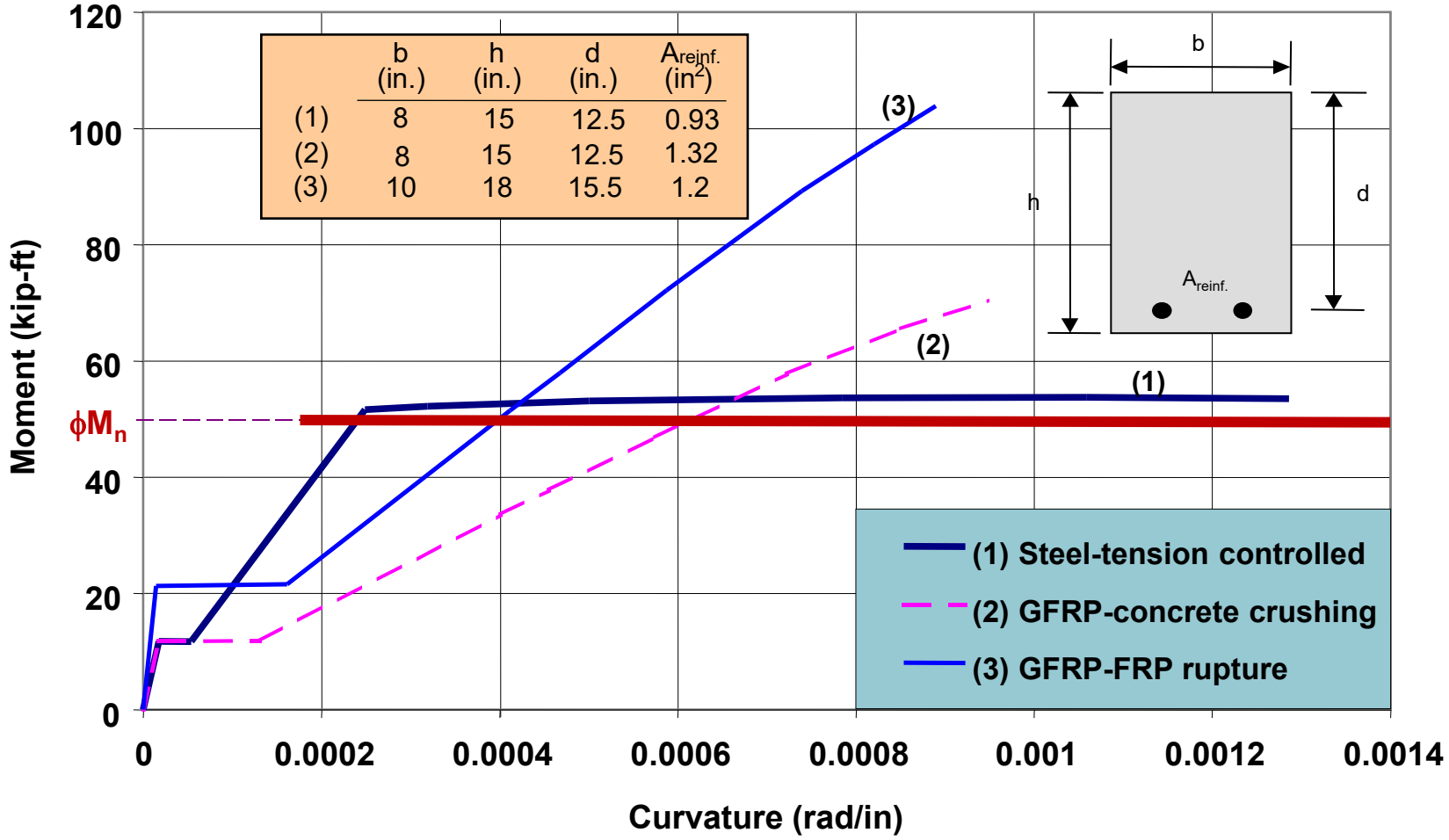


Results indicated reduction in tensile strength of 2.13% over a period of 17 years of service that would correspond to drop in strength of 12.5% over a period of 100 years if the degradation rate is assumed to be linear

Theory – Flexural Design: Table of Contents

- General Considerations
- **Bending Moment Capacity**
- Serviceability
- **Creep Rupture**
- Cyclic Fatigue
- Anchorage and Development
- Special Considerations
- Conclusive Remarks

Moment-Curvature Diagrams



Creep Rupture

Maximum sustained tensile stress in GFRP reinforcement, f_{fs} shall be calculated using **dead loads and live loads** included in **Service I** load combination with live load reduced from **1.0 to 0.2**

$f_{fs} \leq C_c f_{fd}$ maximum sustained tensile stress in GFRP reinforcement, ksi

(***AASHTO 2.5.3-1***)

where:

$$f_{fs} = \frac{n_f d(1-k)}{I_{cr}} M_{s,s}$$

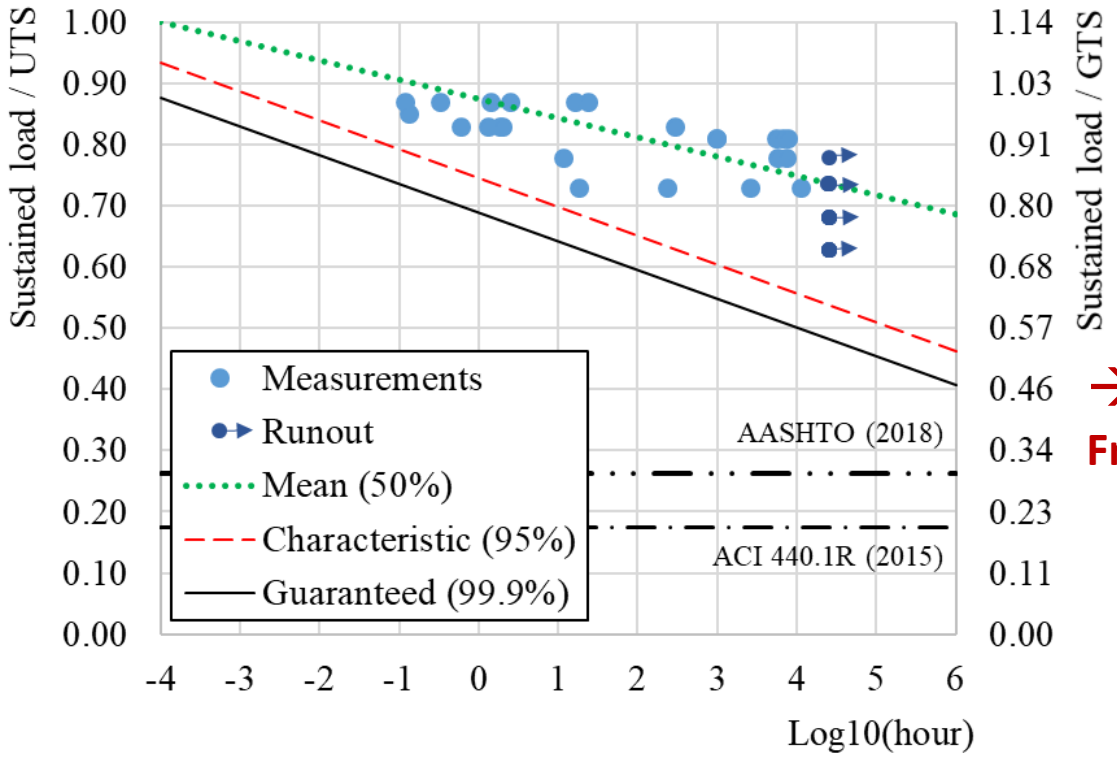
(***AASHTO 2.5.3-2***)

Creep rupture reduction factor, C_c, **shall be equal to 0.3** unless manufacturer can provide a research report following **ASTM D7337**

State-of-the-art in Creep Rupture

Research shows how current limits are conservative and will be raised as technology advances





Specimens not subjected to environmental conditioning

→ **+50%**

From 0.20 to 0.46

Table of Contents – Case Studies

- NE 23rd Avenue Bridge over Ibis Waterway (FPN 434359-1-52-01)
- Halls River Bridge (FPN 430021-1-52-01)
- SR-A1A Flagler Beach (Segment 3), (FPN 440557-7-52-01)
- FDOT Fast Facts

STATE ROAD A1A, FLAGLER BEACH, FL

State Road A1A (SR-A1A) Flagler Beach, FL

Coastal Fortification via Resilient GFRP Secant-Pile Seawall / Bulkhead







GFRP Bar Site-Delivery & Storage

- **Straight bars, bent bars hoops and toe-bent bars**
- Site-storage & protective measures from elements
- Laboratory testing at UM
- Secant-pile construction
- Secant-pile installation
- QC/QA procedures







GFRP Bars - Cage Assemblies







“On-Site” Secant Pile Cage Construction



Concrete Grouting of GFRP Secant-Piles



Cages, delivered to pile-drilling area and ready for installation

Concrete grouting of secant-piles and about 5,000 ft. pile-cap





1,847 Secant-piles installed

Guide Wall Construction for GFRP Secant-Piles & Cap

Secant-piles installed via guide wall form





Flowable-fill placed to complete secant-pile layout locations



Job completed in 4½ months



CFRP-Prestressed Concrete Design for Beams and Piles

Guest Speaker (2): Prof. DJ Belarbi

Distinguished Professor
Department of Civil and Environmental Engineering
University of Houston



Biography

Dr. Abdeldjelil (DJ) Belarbi is a Distinguished Professor of Civil Engineering at the University of Houston. He has taught more than 14 different undergraduate and graduate courses on subjects related to civil and structural engineering. His primary research contributions focus on the constitutive modelling, analytical, and experimental investigations of RC and PC structures. A Fellow of ACI, ASCE, and SEI. In addition to his involvement in ACI 440, he is currently the co-Chair of ACI-440-E (professional development); Chair of ACI-ASCE 445 (Shear and Torsion), member of ACI 341 (Earthquake-Resistant Concrete Bridges) and member of ACI 318-E (Section and Member Strength). The recipient of numerous awards and honors including the 1995 Outstanding Paper Award of the Earthquake Engineering Research Institute (Earthquake Spectra Journal) and the Honorable Mention for Outstanding paper from The Masonry Society.

Florida Department of TRANSPORTATION

UNIVERSITY of HOUSTON
CULLEN COLLEGE of ENGINEERING
Department of Civil & Environmental Engineering

Design of Pretensioned Concrete Bridge Elements with Carbon Fiber-Reinforced Polymer (CFRP) Systems

Abdeldjelil Belarbi, PhD, PE, FACI, FASCE, FSEI
Distinguished Professor
University of Houston
belarbi@uh.edu

FDOT TRANSPORTATION SYMPOSIUM

CORROSION OF PRESTRESSING STRANDS

Prestressed Concrete Elements



Aggressive Environment





Corrosion of Strands



Failure of Structure



http://www.lafargeprecastedmonton.com/anthony-henday-ring-road/img_0983/ ; www.fhwa.gov; https://www.alibaba.com/product-detail/post-tension-concrete-prestressing-steel-pc_60677672453.html

CORROSION RESISTANT STRANDS



Carbon Steel



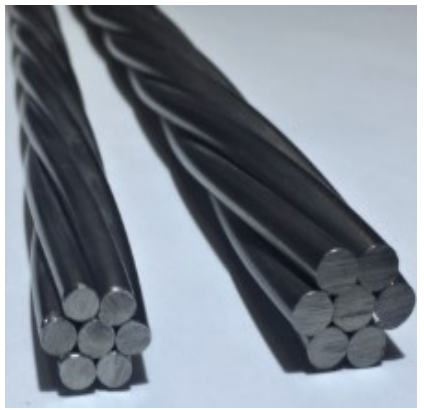
Epoxy Coated Steel



Galvanized Steel

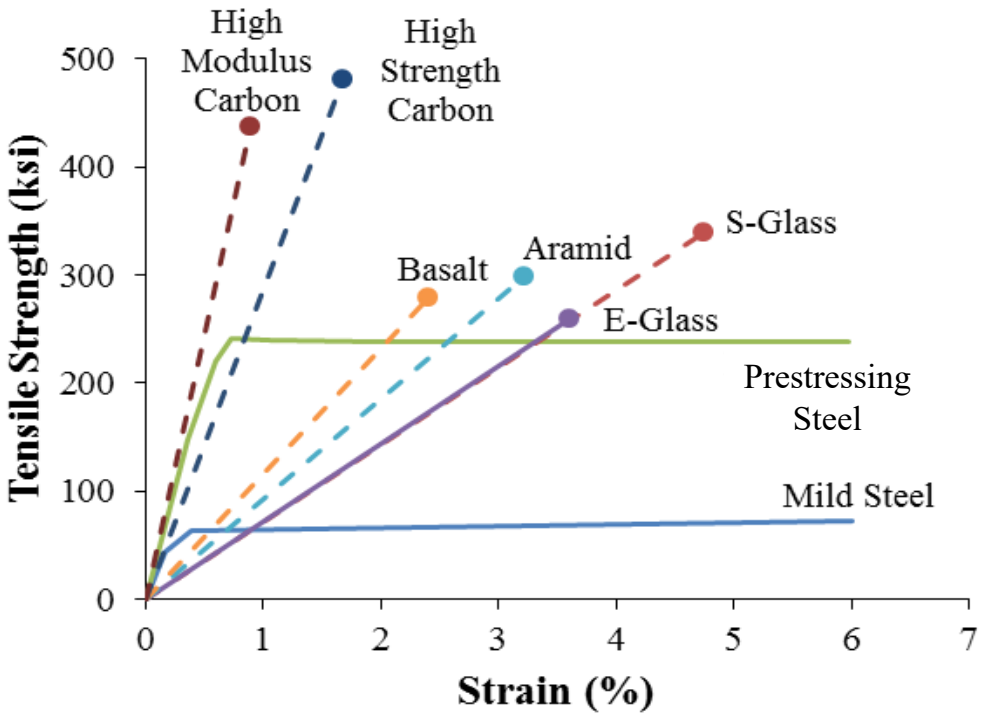


FRP



Stainless Steel

CARBON FIBER REINFORCED POLYMER





CFRP

ADVANTAGES OF CFRP PRESTRESSING



20 years

Carbon Steel Prestressed Bridge





20 years

CFRP Prestressed Bridge





Longer Service Life
Lower Life Cycle Cost

PROJECTS

Halls River Bridge (Florida) - CFRP Prestressed Piles & Sheet Piles











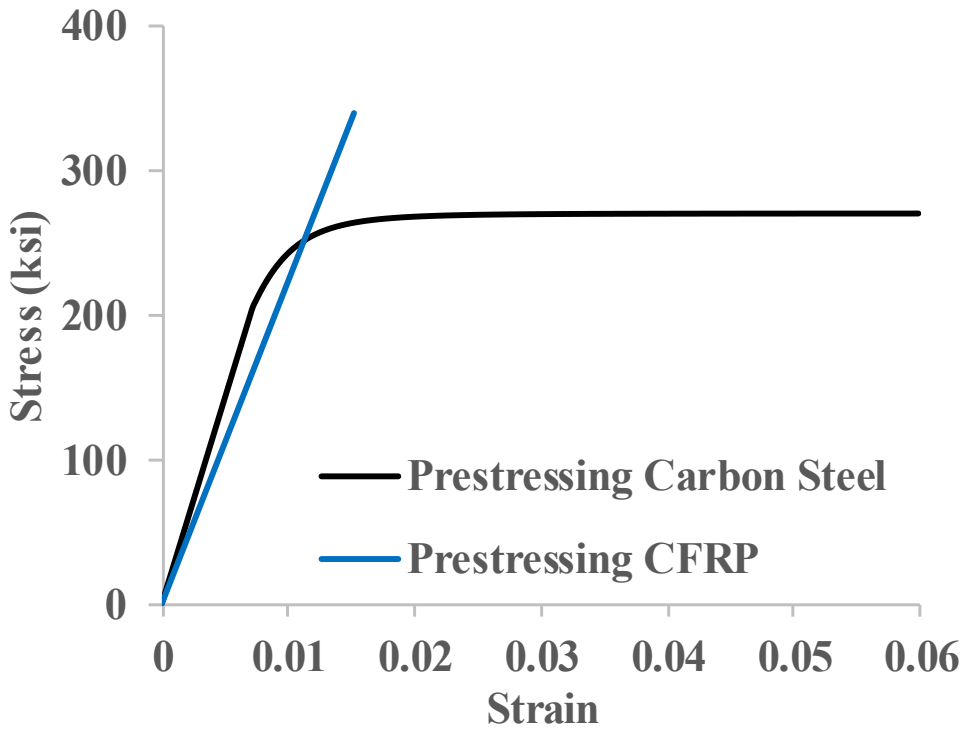




Will Potter (2018), Fiber-Reinforced Polymer (FRP) Development for FDOT Structural Applications

FDOT TRANSPORTATION SYMPOSIUM

PRESTRESSING CFRP VS. CARBON STEEL



Material Specification	AASHTO M203	AASHTO CFRP-1
Steel/CFRP type	1080 carbon steel	CFRP
Grade	250 and 270	340-360
Modulus of elasticity (ksi)	≅ 28,500	18,000-22,500
Total elongation (%)	≥ 3.5	≅ 1.6
Relaxation: (1000 hours @ 80% GUTS)	≤ 3.5%	≤ 5.0%

Different Materials

Behavior

Design Specification



https://blog.tcea.org/instructional-coaching-questions/

RESEARCH ON CFRP PRESTRESSING

NCHRP Report-907: Design of Concrete Bridge Beams Prestressed with CFRP Systems

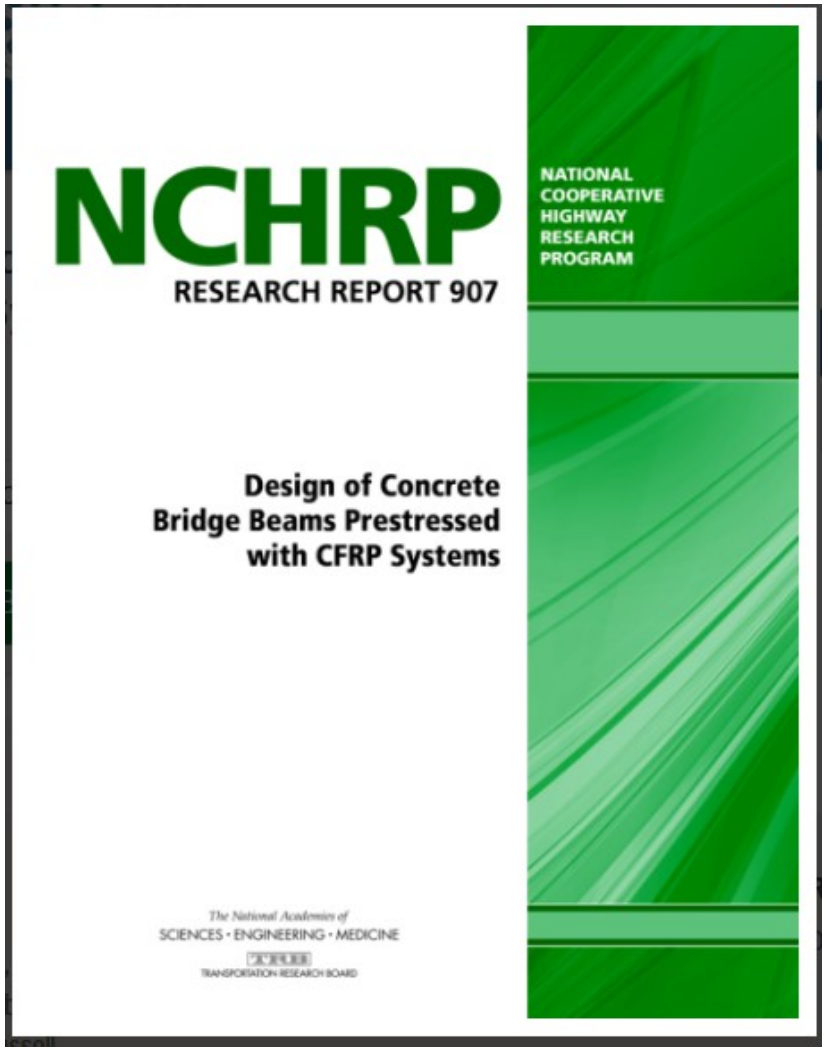
NCHRP NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

UNIVERSITY of HOUSTON





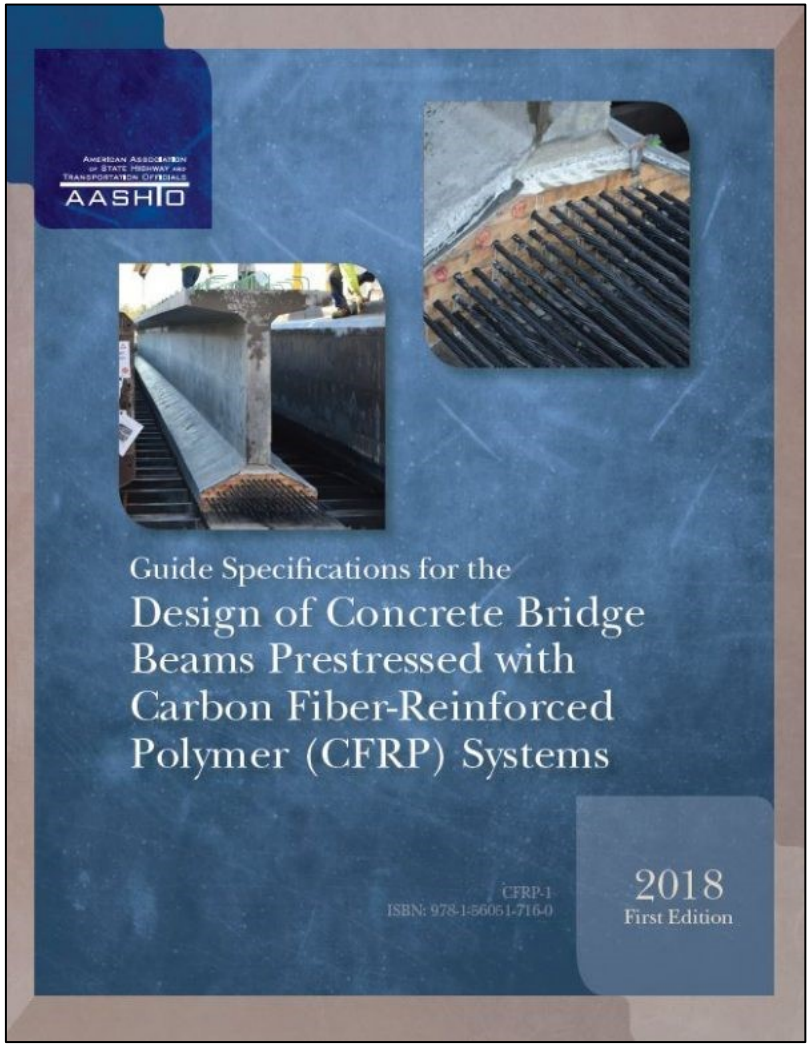




FDOT TRANSPORTATION SYMPOSIUM

DESIGN SPECIFICATION

Guide Specifications for the Design of Concrete Bridge Beams Prestressed with Carbon Fiber-Reinforced Polymer (CFRP) Systems, 1st Edition, 2018



SECTION 1:

GUIDE SPECIFICATIONS FOR THE DESIGN OF CONCRETE BRIDGE BEAMS PRESTRESSED WITH CARBON FIBER-REINFORCED POLYMER (CFRP) SYSTEMS

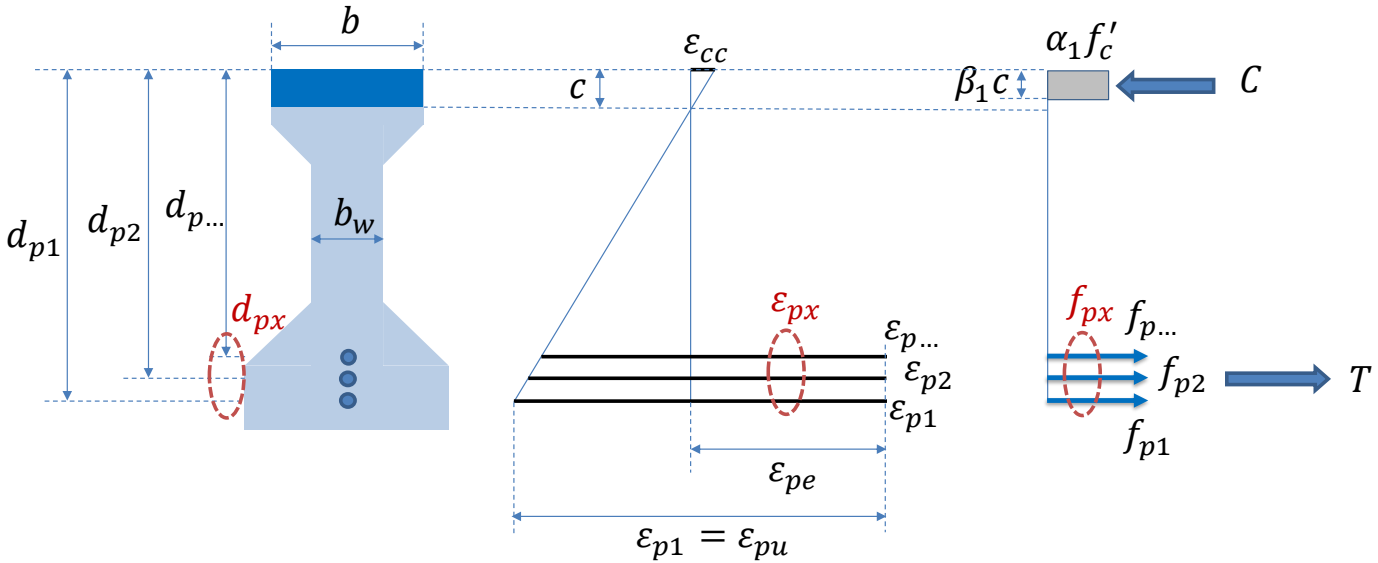
SECTION 2:

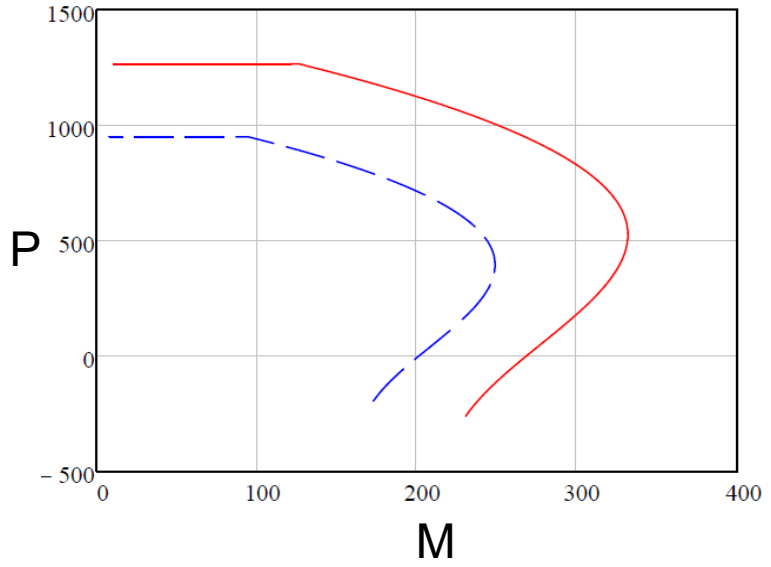
MATERIAL SPECIFICATIONS FOR CARBON FIBER-REINFORCED POLYMER PRESTRESSING CABLES AND BARS

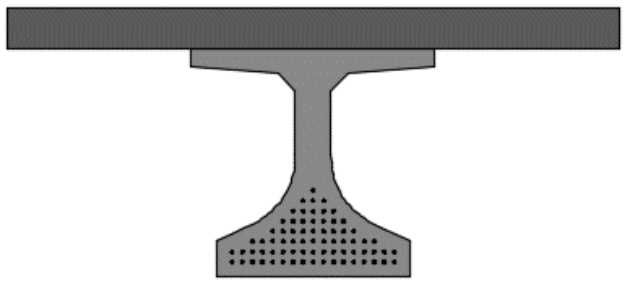
OBJECTIVES OF THIS COURSE

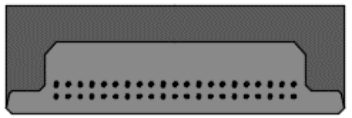
8-Hour Course: Concrete Bridge Elements Prestressed with CFRP Systems

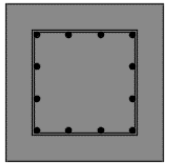
Behavior & Design & Example

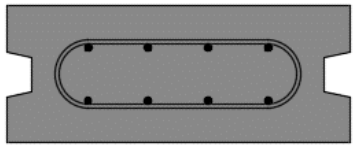












OBJECTIVES OF THIS COURSE

- Identify material properties and stress limitations of prestressing CFRP, as well as short-term and long-term prestress losses
- Explain design procedures of flexural design for pretensioned concrete beams with prestressing CFRP
- Discuss shear design procedures of pretensioned concrete beams with prestressing CFRP
- Describe procedures to construct P-M diagram for prestressed concrete piles with prestressing CFRP
- Illustration design examples of I-Beam, Slab-Beam, prestressed concrete pile, and sheet pile for retaining wall.

LEARNING OUTCOMES

Upon completion of this course, participants will be able to:

- Understand the behavior of pretentioned concrete girder prestressed with CFRP
- Learn about the differences between the designs of pretentioned concrete girders using prestressing CFRP and carbon steel strands
- Estimate both short-term and long-term prestress losses of prestressing CFRP strands in prestressed concrete girders
- Perform flexural and shear designs of pretentioned concrete girders prestressed with CFRP strands
- Analyze and design CFRP prestressed (square and cylinder) concrete piles

REFERENCE CODES/SPECIFICATIONS

- Guide Specifications for the Design of Concrete Bridge Beams Prestressed with Carbon Fiber-Reinforced Polymer (CFRP) Systems, 1st Edition, 2018
- AASHTO LRFD Bridge Design Specifications, 8th Edition, 2017
- FDOT Structures Manual, January 2020
- FDOT Materials Manual
- FDOT Standard Specifications for Road and Bridge Construction, July 2020
- ACI 440.1R Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars, 2015
- ACI 440.4R Prestressing Concrete Structures with FRP Tendons, 2011
- ACI 318 Building Code Requirements for Structural Concrete and Commentary, 2019
- AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete, 2nd Edition, 2018

How can Florida DOT & Consultant Engineers get this training

Coming soon

Attendees should expect an email update this summer!

What other resources are being developed

1. **National Training:**
   - **CFRP-PC Design** - ***NCHRP 20-44*** program for report implementation assistance for CFRP-2, has ***FHWA*** & ***AASHTO*** *T-6* support.
   - **GFRP-RC Design** - not eligible under this program, so *State* ***DOTs*** and ***FHWA*** are working on it.

2. **Guide Specs: *NCHRP 12-121***
   - "Developing AASHTO Specifications for the Use of FRP Auxiliary Reinforcement in Prestressed Concrete Beams and Girders."
     (Expected RFP in late 2020)

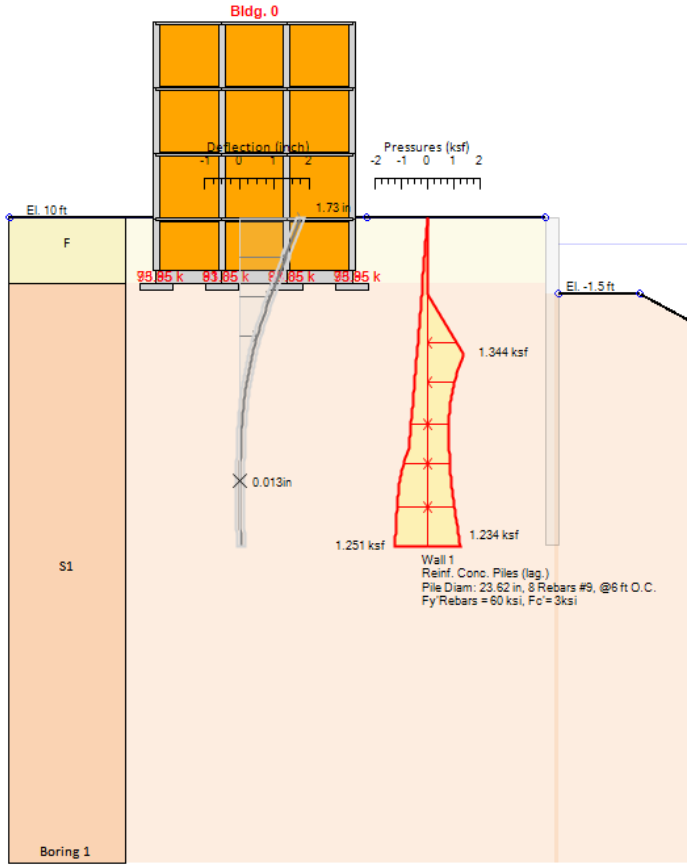
3. **TRB: *Webinar 33 - Advanced Structural Materials for Concrete Bridges***
   - Identified and compared several advanced performance structural materials that may be used on bridges, including CFRP-PC & GFRP-RC
     (Dec. 3, 2019)

3. **Software:** Adaption of FRP analysis or design enhancements:
   - **FBMP** *(BSI) pending*
   - **DeepEx** *(Deep Excavation, LLC) pending*
     - DeepFND 2021: September 2020
     - DeepEX 2021: Jan 2021
     - RC-Solver 2021: Oct. 2020
   - **Michigan DOT/LTU** CFRP-Beam Design Mathcad: *https://mdotjboss.state.mi.us/SpecProv/trainingmaterials.htm* *(also see TRB Webinar 33)*

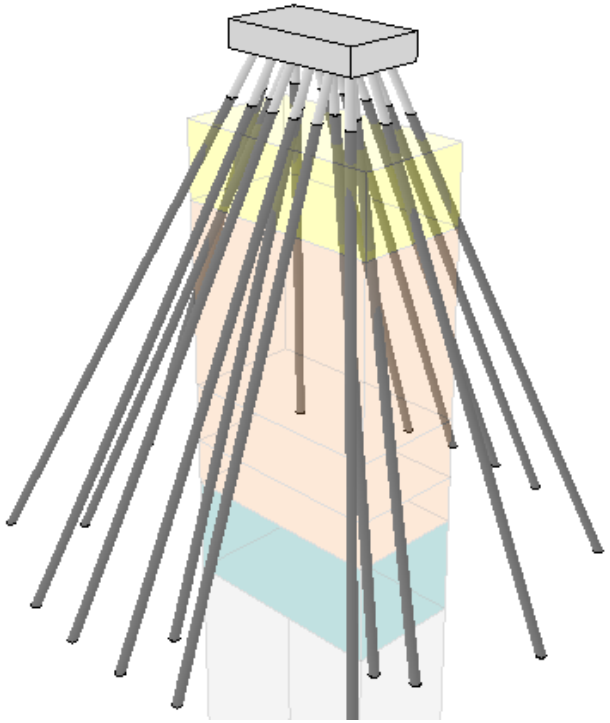


Upcoming 2021 Software Updates
Prestressed and Non-Prestressed GFRP, CFRP

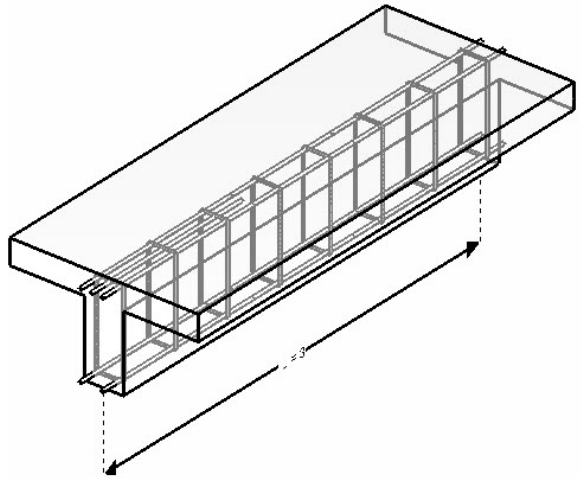
DeepEX
Deep excavations & Bulkheads



DeepFND
Pile & Pile Group Software



RC-Solver
Reinforced Concrete Software



DEEP EXCAVATION
RELIABLE GEOEXPERTISE

What other resources are being developed

4. Design Aids:

- ***SPI-455-101 (piles)***
- ***SPI-455-440 (sheet piles)***
- ***DSP Beam Span Charts (pending)***

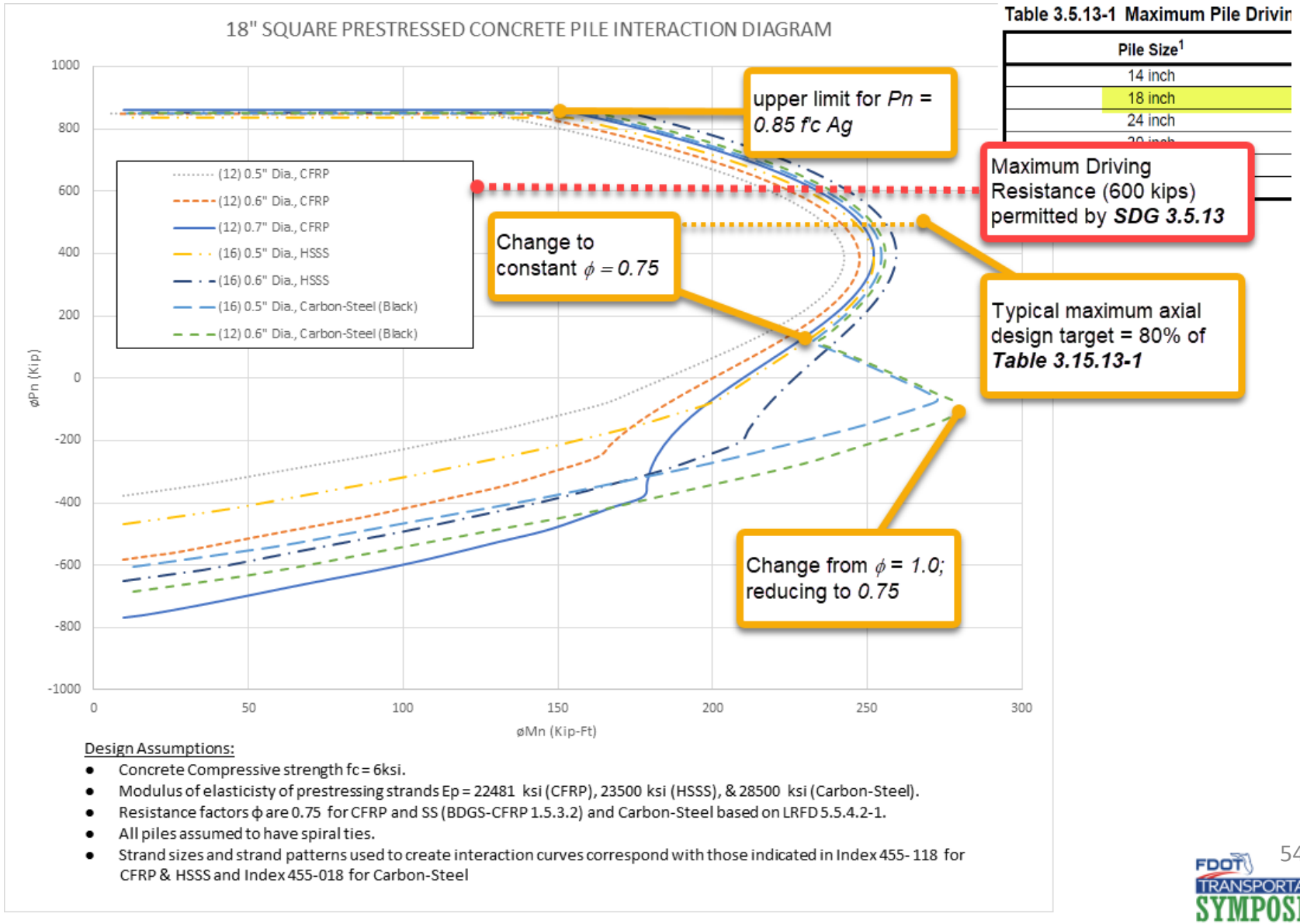
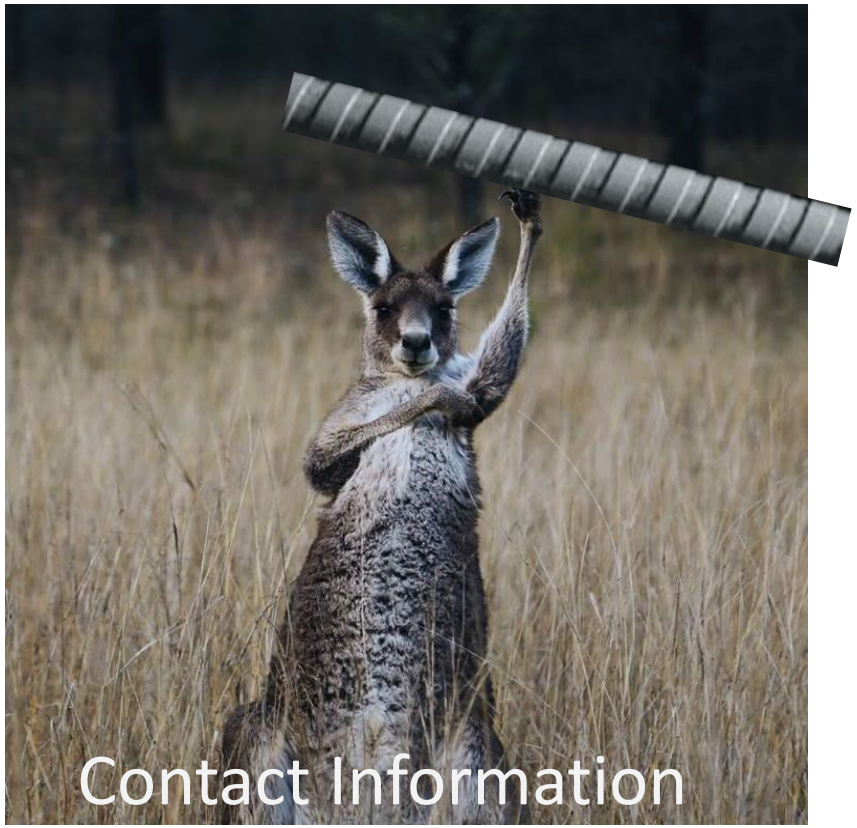


Table 3.5.13-1 Maximum Pile Drivin

Pile Size[1]
14 inch
18 inch
24 inch

Questions



NO text.
NO call.
NOTHING
is worth losing a life over.

PUT IT DOWN
IT'S THE LAW

Steven Nolan, P.E.
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