

Orlando, FL

November 7-8, 2024



2024 TRANSPORTATION SYMPOSIUM



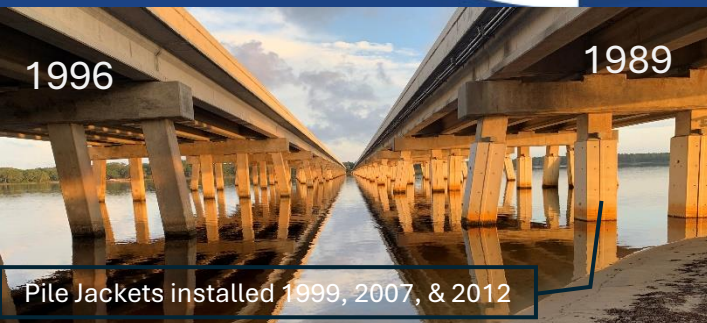
FRP Reinforced Concrete Structures: 10-year update, Lessons Learned, and Emerging Best Practices (Nov, 2024)

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District 7 Structures Design Office (Tampa, FL.)



Objectives

What is a symposium?

Symposiums are organized, often large-scale meetings, that bring together experts, researchers, practitioners, and professionals. The purpose of a symposium is to discuss and exchange knowledge, research findings, and insights on a particular topic or theme.



- Highlight the improvements in FRP Reinforced and Prestressed Concrete since 2014, including:
 - Structural design practices and standards
 - Materials specifications, testing, and qualification
 - Construction including representative projects
- Provide Lessons Learned during both design and construction.
- Highlight latest research and planned improvements future implementation.



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1. Design: Practices and Standards for FRP-RC/PC.
2. Materials: Specifications, Testing, and Qualification.
3. Construction: Example Projects & Lessons Learned.

Background:

- FDOT introduced guidance for the implementation of Fiber-Reinforced Polymer-Reinforced and Prestressed Concrete (FRP-RC & FRP-PC) at the **2014 Design Training Expo**. We highlighted the planned release of **Standard Specifications, Structures Manual, and Materials Manual** updates, and the early design work for the seminal demonstration project - Halls River Bridge.
- Reflecting on 10 years of implementation and the evolution of design guidance, standard specifications and plans, many projects have now been successful completed and continue to be monitored with the goal of improving the state-of-the-practice and cost efficiency.

Way Way Back: CFRP Prestressing Strand

- CFCC: Developed in Japan with first prestressed bridge application in 1988

II. APPLICATIONS OF CFCC



CFCC has been used in over 300 civil engineering projects .



1. Concrete Structures (PC and RC)
2. Cable for Stay Cable Bridges
3. Ground Anchors
4. Other (Architectures)

II. APPLICATIONS OF CFCC



1. CONCRETE STRUCTURES (PRE-TENSIONING)

Shinmiya Bridge 1988.10 in Japan

World's first PC bridge with CFRP tendon



Former Bridge



Bottom side of the bridge After 20-year life]

SYMPOSIUM

Way Back: CFRP Prestressing Strand

- CFCC: First USA bridge application in Michigan in 2001 – Post-Tensioning

TOKYO ROPE INTERNATIONAL

Former Bridge after 20-year life




(Steel Reinforcing)

New Shinmiya Bridge after 23-year life





(2011)

TOKYO ROPE INTERNATIONAL

1. CONCRETE STRUCTURES (TRANSVERSE POST-TENSIONING & EXTERNAL TENDON)

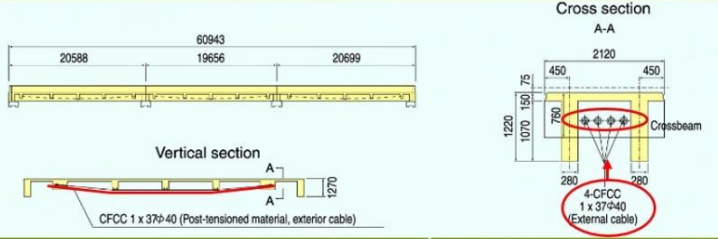
Bridge Street Bridge May. 2001 in Southfield, Michigan
 Funded by FHWA and MDOT **United States's first bridge constructed using CFRP**



Transverse Cables

TPT
 CFCC 1 × 37 40.0φ : 9.2 m × 10 tendons,
 9.4 m × 7 tendons
 CFCC 1 × 19 21.8φ : 9.0 m × 6 tendons

External Tendons
 CFCC 1 × 37 40.0φ : 16.8 m × 24 tendons,
 17.0 m × 30 tendons



Vertical section

CFCC 1 × 37φ40 (Post-tensioned material, exterior cable)

Cross section A-A

4-CFCC 1 × 37φ40 (External cable)

External Cables

Back a Decade: CFRP Prestressing Strand

- 2012 (Maine) & 2012-13 (Virginia)

TOKYO ROPE INTERNATIONAL

1. CONCRETE STRUCTURES (TRANSVERSE POST-TENSIONING)

Little Pond Bridge Aug. 2012 in Fryeburg, Maine
Bridge Length : 133' - 6" , Bridge Width : 49' - 4.5"
TPT CFCC 1 × 37 40φ : 50' - 10" (15.5 m) × 20 tendons



Navigation icons: back, forward, search, refresh, close

TOKYO ROPE INTERNATIONAL

1. CONCRETE STRUCTURES (PRESTRESSED CONCRETE PILE)

NIMMO PARKWAY in Virginia 2 Test Piles, 16 Piles 2012&2013



24" square pile
16 strands: CFCC 1 × 7 15.2mm
Spiral: CFCC U 5.7mm



Navigation icons: back, forward, search, refresh, close

Back a Decade : CFRP Prestressing Strand

- 2014 (Louisiana) & 2016 (Maine)

1. CONCRETE STRUCTURES (POST-TENSIONING) TOKYO ROPE INTERNATIONAL

I-10 New Orleans East Girder Repairs May. 2014 in Louisiana

External tendon: CFCC 1 × 7 17.2φ

2 tendons/girder × 6 girders = 12 tendons

2. CABLE-STAYED BRIDGE (STAY CABLE) TOKYO ROPE INTERNATIONAL

Penobscot Narrow Bridge July. 2007 in Maine

PROSPECT PYLON 1 - ELEVATION

CFCC

CFCC length

- 100 m × 2 strands
- 210 m × 2 strands
- 310 m × 2 strands

Back span 480'

Main span 1161'

Back a Decade : Launched FRP Innovation Webpage

- 2014 FDOT (Invitation to Innovation)

WELCOME TO THE STRUCTURES DESIGN OFFICE

Office Manager: Will Potter, P.E. – State Structures Design Engineer

The Structures Design Office provides design guidance and technical assistance for structural, geotechnical, mechanical and electrical issues related to structural design and construction. The Structures Design Office is 1 of 3 divisions under the **Office of Design**, along with **Roadway Design**, and the **CADD Office**.

Most Requested

- Current Structures Manual
- Current e-Book
- Structures Design Software Downloads
- Documents and Publications

Structures Divisions

- Structures Criteria Website
- Structures Standard Plans Website
- Structures Design Software Website
- Structures Research Center Website
- Geotechnical Website
- Innovations Website
- Plans Review Website
- Design Examples

Structures Design Office

Contact: [Steven Nolan, P.E.](mailto:Steven.Nolan@fdot.com) | Phone: (850) 414-4272

- Curved Precast Spaced U-Girder Bridges
- Fiber-Reinforced Polymer Reinforcing (Bars & Strands)
- Fiber-Reinforced Polymer Members and Structures
- Geo-synthetic Reinforced Soil Integrated Bridge System
- Segmental Block Walls (SBW)
- Geo-synthetic Reinforced Soil (GRS) Wall
- Ultra-High Performance Concrete (UHPC)

Fiber Reinforced Polymer Reinforcing

Structures Design - Transportation Innovation
 Fiber Reinforced Polymer (FRP)
 Reinforcing Bars and Strands

- [Overview](#)
- [Usage Restrictions / Parameters](#)
- [Design Criteria](#)
- [Specifications](#)
- [Standards](#)
- [Producer Quality Control Program](#)
- [Projects](#)
- [Technology Transfer \(T²\)](#)
- [FDOT Research](#)
- [Contact](#)

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CFRP Prestressing Strand & more... at FDOT



8/1/1992

Feasibility of Fiberglass Pretensioned Piles in a Marine Environment

Sen, Rajan (USF)

8/1/1995

Durability of CFRP Pretensioned Piles in Marine Environment Volume II

Sen, Rajan (USF)

11/30/1998

Studies on Carbon FRP (CFRP) Prestressed Concrete Bridge Columns and Piles in Marine Environment

Arockiasamy, M. (FAU)



TRANSPORTATION SYMPOSIUM

Design: Practices and Standards for FRP-RC/PC



VS.



2024 TRANSPORTATION SYMPOSIUM

FRP Reinforced Concrete Structures:
10-year update, Lessons Learned, and
Emerging Best Practices

Steven Nolan, P.E.

State Structures Design Office, FDOT (Tallahassee)



FRP Reinforced Concrete Design

Presented in 2017 by:

Rick Vallier, P.E.

Updates in 2024 by:

Steven Nolan, P.E.

TRANSPORTATION
SYMPOSIUM

2017 vs. 2024 FRP Reinforced Concrete Outline



A. FRP Reinforcing Bars

B. Research

C. Structures Manual

~~D. Design Standards~~

~~E. Developmental Design
— Standards~~

~~E. Standard Specifications~~

~~F. Challenges~~

A. Reinforcing Bars

Spec. 932-4.2 Bar Sizes and Loads

Table 932-8
Sizes and Tensile Loads of FRP Reinforcing Bars

Bar Size Designation	Nominal Bar Diameter (in)	Nominal Cross Sectional Area (in ²)	Measured Cross-Sectional Area (in ²)		Minimum Guaranteed Tensile Load (kips)			
			Minimum	Maximum	BFRP & GFRP Bars (Type 0)	BFRP & GFRP Bars (Type III)	CFRP (Type II) Single & 7-Wire Strands	CFRP (Type I) Bars
2.1-CFRP	0.21	0.028	0.026	0.042	-	-	7.1	-
2	0.250	0.049	0.046	0.085	6.1	7.4	-	10.3
2.8-CFRP	0.280	0.051	0.048	0.085	-	-	13.1	-
3	0.375	0.11	0.104	0.161	13.2	16.0	-	20.9
3.8-CFRP	0.380	0.09	0.087	0.134	-	-	23.7	-
4	0.500	0.20	0.185	0.263	21.6	27.9	-	33.3
5	0.625	0.31	0.288	0.388	29.1	40.8	-	49.1
6	0.750	0.44	0.415	0.539	40.9	57.3	-	70.7
6.3-CFRP	0.630	0.19	0.184	0.242	-	-	49.8	-
7	0.875	0.60	0.565	0.713	54.1	75.8	-	-
7.7-CFRP	0.770	0.29	0.274	0.355	-	-	74.8	-
8	1.000	0.79	0.738	0.913	66.8	94.9	-	-
9	1.128	1.00	0.934	1.159	82.0	115.0	-	-
10	1.270	1.27	1.154	1.473	98.2	138.7	-	-
11	1.410	1.56	1.500	1.700	105.8	160.0	-	-



A. Reinforcing Bars



Characteristics of FRP Reinforcement:

- Polymer resin matrix relatively weak:
 - Bond force is transferred through resin to fibers.
 - Shear resistance is considered relatively weak ($\sim 60\%$).
- Low compressive strength of FRP:
 - Design **contribution** of FRP reinforcement to resist compression is ~~not recommended~~ **ignored**.
- Modulus of elasticity is low:
 - Due to lower stiffness (6.5 msi & 8.7 msi), serviceability often controls the design.
- Creep-rupture threshold is low (~~25%~~ $30\% f_u$):
 - Sustained high tension can cause fibers to fail after a period of time
 - GFRP is considered more susceptible than CFRP ($70\% f_u$).

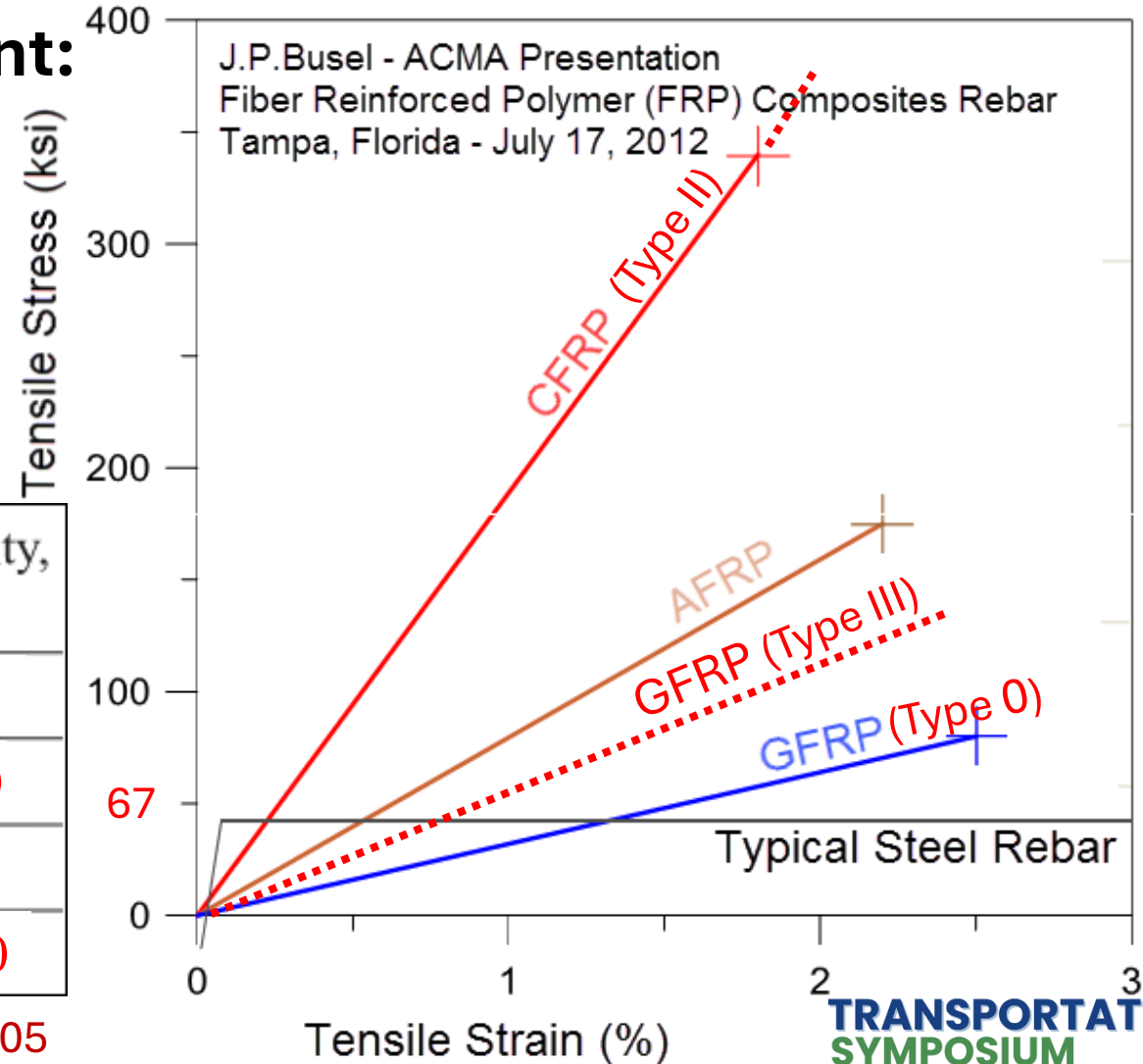
A. Reinforcing Bars

Characteristics of FRP Reinforcement:

- Linear Elastic to Failure
- No Yielding (but higher strain at 60 ksi)
- Higher Ultimate Strength
- Lower Strain at Failure

Bar type	Yield strength f_y or tensile strength f_{tu} , ksi	Modulus of elasticity, ksi
Steel	60	29,000
GFRP (Type 0)	80 to 120	6,000 6,500
AFRP (Type III)	170 105 to 150	12,000 8,700
CFRP (Type II)	300	22,000 22,480

From ~~ACI 440.1R-15~~ FDOT Spec 932-4, ASTM D7957 & D8505



A. Reinforcing Bars

FRP Bar Mechanical Characteristics Influenced By: Pre-Construction

- Manufacturing Process (*FDOT MM Chapter 12.1*)
- Rate of Curing
- Quality and Quantity of Constituents

Construction and Post-Construction

- Moisture (*current limitation on BFRP in submerged marine environments. See FRPG 2.1*)
- Ultraviolet Exposure (*Spec. 416 limits on exposure*)
- Elevated Temperature (*Fire < T_g*)
- Alkaline, Acidic, Saline Solutions ($C_E = 0.70$)



A. Reinforcing Bars

Characteristics of FRP Reinforcement:

- Endurance time in fire or elevated temperature less than for steel **for anchorage zones (*ACI 440-H is working on criteria*)**:
 - Reinforcement type, aggregate type, and concrete cover will influence fire performance
 - Tensile, compressive, and shear properties of the resin material diminish as temperature approaches the glass transition temp. (***T_g***)

Property	Test Method	Requirement
Glass Transition Temperature (<i>T_g</i>)	ASTM E1640 (DMA)	$\geq 230^{\circ}\text{F}$
	or ASTM E1356 (DSC)	$\geq 212^{\circ}\text{F}$

Specification 932-4 <https://www.fdot.gov/programmanagement/specs.shtm>

A. Reinforcing Bars

Characteristics of FRP Reinforcement:

- Life cycle costs ~~likely~~ lower where steel corrosion is a concern (*see HRB*).
- SCMs (HRPs) for corrosion protection ~~are~~ may not be needed:
 - Silica Fume • Ultrafine Fly Ash
 - Metakaolin • ~~Calcium Nitrite~~
- Transportation costs are lower and handling easier for FRP due to light weight (*~25%*).
- Concrete cover reduction is allowed (*see FRPG Table 2.2*).



A. Reinforcing Bars

Bent Bars Characteristics:

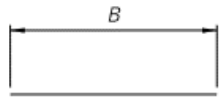
- FRP is pultruded from thermoset resin (*viable thermoplastic resins are emerging*)
- FRP is fabricated with bends (*thermoplastic and olefin resin will allow controlled thermal bending – [NCHRP IDEA-207](#) validated this*):
 - Sharp bends can be manufactured, but avoided due to potential **low stress** failure.
 - Bend Radius / Bar Diameter ≥ 3 .
 - Tail Length = 12 x Bar Diameter.
 - Field bending not permitted.
- ~~Developmental Design~~ **Standard**



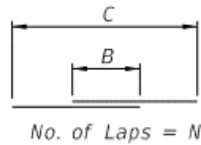
Plan Index 415-010 D21310 Bar Bending Details

A. Reinforcing Bars

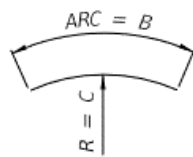
From ~~Developmental Design Standard~~ **Plans Index D21310 415-010:**
(renumbering to match steel bar bending Index)



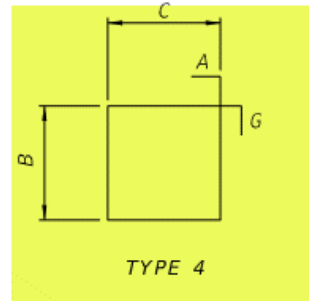
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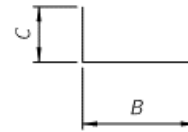
TYPE 2



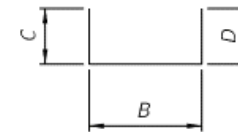
TYPE 3



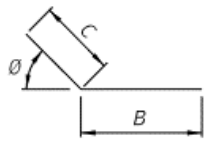
TYPE 4



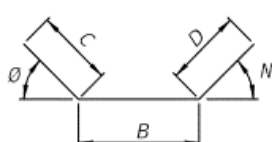
TYPE 10



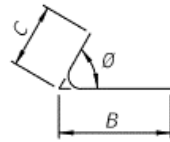
TYPE 11



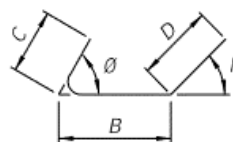
TYPE 12



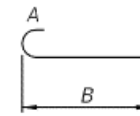
TYPE 13



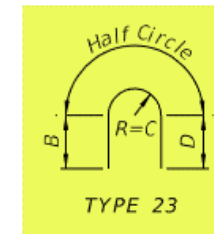
TYPE 14



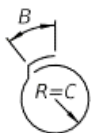
TYPE 15



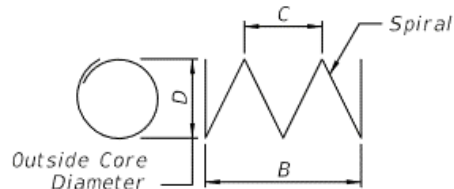
TYPE 17



TYPE 23



TYPE 24

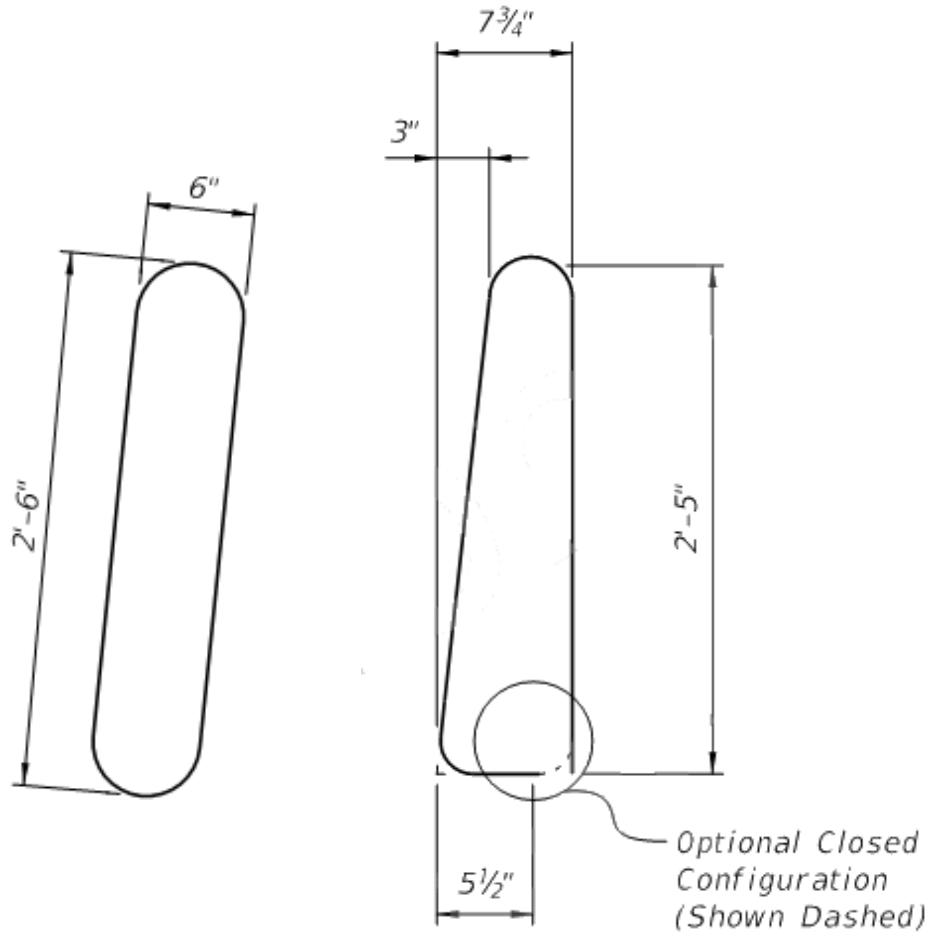


TYPE 39

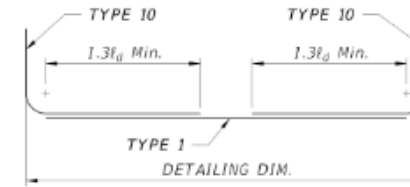
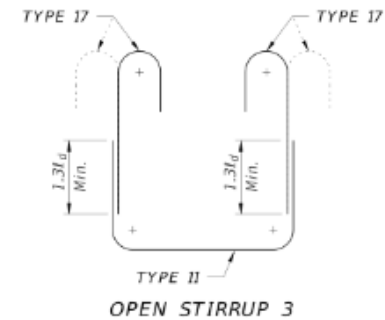
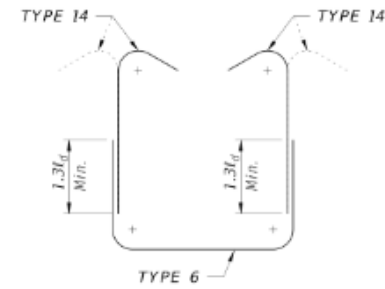
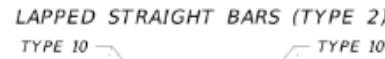
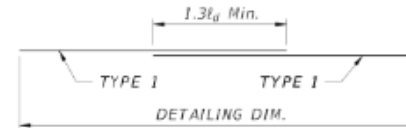
HOOK DETAILS				
BAR SIZE	D	180° HOOKS		90° HOOKS
		A OR G	J	A OR G
#3	2 1/4"	5"	3"	6"
#4	3"	6"	4"	8"
#5	3 3/4"	7"	5"	10"
#6	4 1/2"	8"	6"	1'-0"
#7	5 1/4"	10"	7"	1'-2"
#8	6"	11"	8"	1'-4"
STYLE		1		3

A. Reinforcing Bars

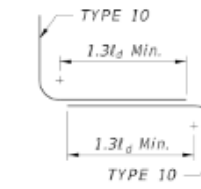
Complex Shapes:



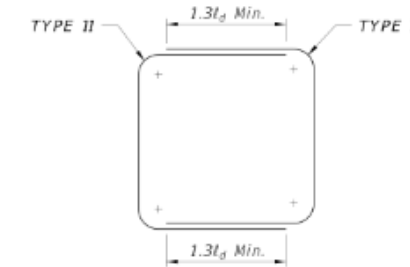
Design Aids



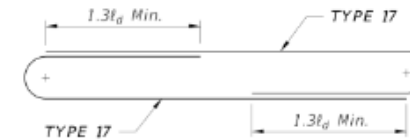
LONG LEG U SHAPE



Z BAR SHAPE



CLOSED STIRRUP 1



CLOSED STIRRUP 2

NOTE: See Developmental Standard D415-010 for referenced Single Bar Bending Types.

A. Reinforcing Bars

Cost Comparison (Installed Price)

Bar Size	Nominal Diameter	Average Unit Costs HRB (3-bids) / **		FDOT Structures Manual for BDR Cost Estimating / **	
		GFRP Bars 2016	GFRP Bars 2023	Grade 60 Steel	Stainless-Steel
#4	0.500"	\$1.18 / LF	\$1.90 / LF	\$0.60 1.11 / LF	\$2.72 5.25 / LF
#5	0.625"	\$1.37 / LF	\$2.29 / LF	\$0.94 1.74 / LF	\$4.19 8.09 / LF
#6	0.750"	\$1.55 / LF	\$2.71 / LF	\$1.35 2.51 / LF	\$5.98 11.54 / LF
#8	1.000"	\$2.54 / LF	\$4.04 / LF	\$2.40 4.45 / LF	\$10.74 20.73 / LF

Note: There is not 1:1 substitution of FRP for steel bars. ** 2023 FDOT Bid Avg.

Black steel bar based on **\$1.67**** ~~\$0.90~~ / lb for all bar sizes.

Stainless steel bar based on **\$7.72**** ~~\$4.00~~ / lb for all bar sizes.

A. Reinforcing Bars

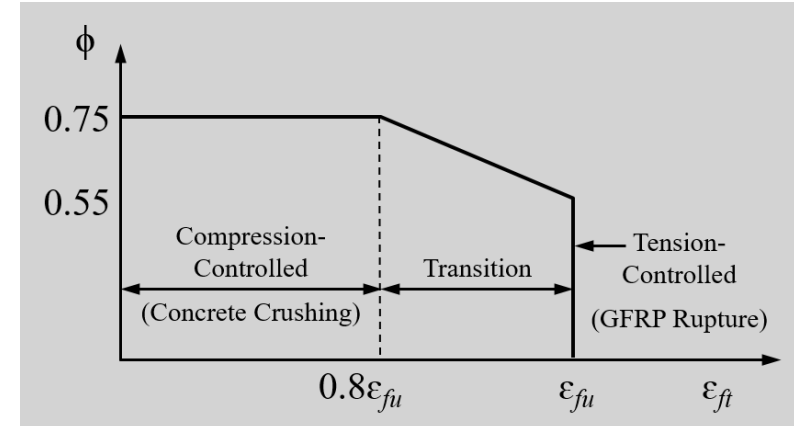
Flexural Strength Design Philosophy

Steel Reinforced Concrete Design

- Tension-Controlled Behavior
- Yielding of Steel Prior to Concrete Crushing Provides Ductility and Warning of Distress **through extensive cracking and deformation**

FRP Reinforced Concrete Design

- Tension-Controlled Behavior
 - FRP Rupture ($\phi = 0.55$)
- Compression-Controlled Behavior
 - Concrete Crushing prior to FRP Rupture ($\phi = \del{0.65} 0.75$)
- Margin of Safety is Higher than for Steel Reinforced Design



A. Reinforcing Bars

Design Assumptions

- Plane sections remain plane
- Flexural strength using equivalent rectangular concrete stress distribution
- Compressive strain in concrete assumed to be 0.003
- Tensile strength of concrete is ignored
- Perfect bond exists between concrete and FRP reinforcement
- Tensile behavior of FRP reinforcement is linear elastic until failure
- Compressive strength of FRP reinforcement is ignored

B. FDOT Research

Research and field implementation of FRP materials is **ongoing** and design recommendations **continue to evolve and improved**.

Completed	Title	Researcher	Institution	Research No.
Nov. 2018	Performance Evaluation of GFRP Reinforcing Bars Embedded in Concrete Under Aggressive Environments	R. Kampmann	FAMU-FSU	BDV30 977-18
April 2019	Degradation Mechanisms and Service Life Estimation of FRP Concrete Reinforcements	A. El Safty	UNF	BDV34 977-05
6/30/2019	<u>Performance Evaluation of Basalt Fiber Reinforced Polymer (BFRP) Reinforcing Bars Embedded in Concrete</u>	R. Kampmann	FAMU-FSU	BVD30 986-01
April 2022	<u>Epoxy Dowel Pile Splice Evaluation</u> with FRP Bars	A. Mehrabi	FIU	BDV29 977-52
Dec. 2020	<u>“Stainless Steel Strands and Lightweight Concrete for Pretensioned Concrete Girders”</u> (w/ GFRP shear stirrups)	M. Roddenberry	FAMU-FSU	BDV30 977-27 (Report A)
07/30/2022	<u>Improving Testing Protocol and Material Specifications for Basalt Fiber Reinforced Polymer Bars</u>	R. Kampmann	FAMU-FSU	BE694

B. FDOT Research - Completed and In-progress

Research and field implementation of FRP materials is ongoing **and expanding...**

Completion Date	Title	Researcher	Institution	Research No.
08/29/2022	<u>Development of GFRP Reinforced Single Slope Bridge Rail</u>	G. Consolazio	UF	BDV31 977-110
12/31/2023	<u>Evaluation of Glass Fiber Reinforced Polymers (GFRP) Spirals in Corrosion Resistant Concrete Piles</u>	S. Jung	FAMU-FSU	BDV30 977-27
Feb. 2025	FSBs With Stainless Steel Strands and GFRP Shear Reinforcement	M. Roddenberry	FAMU-FSU	BED30 977-09
April 2025	<i>Waterline Pile Cap Footings for Bridges using Large Diameter FRP Reinforcing – Material Characterization and Design</i>	A. Nanni	UM	BEE76 977-01
May 2025	<i>HRB Extraction and Physio-Mechanical Testing of FRP Reinforcing Bars from 5-year-old Seawater Concrete Test Blocks on Halls River Bridge Bulkhead</i>	F. De Caso	UM	BEE76 977-02

C. FDOT Structures Manual

FDOT Design Criteria for FRP:

Topic No. 625-020-018

FDOT Structures Design Office
Topic No: 625-020-018

January 2017

FLORIDA DEPARTMENT OF TRANSPORTATION



2024 Structures Manual
Effective January 1, 2024

FDOT 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**

Vol. 1 – SDG

- Bearing Piles – 3.5
- Fender Systems – 3.14
- Structural FRC– 3.17
- BDR Cost Estimating – 9.2
 - Bearing Piles
 - Sheet Pile

Vol. 2 – SDM

- Fender Systems – 24

Vol. 4 – FRPG

- Reinforcing Bars – 2
- Strands – 3
- Strengthening – 4
- Pultruded Shapes – 5
- VIP Shapes – 6
- Thermoplastic Shapes – 7

**TRANSPORTATION
SYMPOSIUM**

C. FDOT Structures Manual

FDOT Design Criteria for using FRP Composites:

The Structures Manual implements *basic design guidelines* for FRP composites in specific applications.

As is the case with all structural materials, the engineer must practice the *appropriate standard of care* when designing components using FRP composites.



C. FDOT Structures Manual

Volume 4 - Fiber Reinforced Polymer Guidelines (*FRPG*)

Unless otherwise stated within the *FRPG*, the **use of FRP composites requires approval** of the State Structures Design Office.

Obtain concept approval before proceeding with any design effort.

After concept is approved, submit the design to the State Structures Design Office for review.

FDM 121.3.2: “Any component designed using Fiber Reinforced Polymer (FRP) composite materials *except components in the Standard Plans*” is designated as **Category 2 Structure**.

C. FDOT Structures Manual

Volume 4 - Fiber Reinforced Polymer Guidelines (FRPG) – Section 2:

Permitted use when approved by the SSDE:

- Approach Slabs
- Bridge Decks & Bridge Overlays
- Cast-in-Place Flat Slab Superstructure
- Pile Bent Caps ~~not in direct contact with water~~
- Pile Jackets
- Pier Columns and Caps ~~not in direct contact with water~~
- Retaining Walls, Noise Walls, Perimeter Walls
- ~~○ Traffic Railings~~
- Pedestrian/Bicycle Railings
- Bulkheads and Bulkhead Copings
- MSE Wall Panels **and Copings**
- Drainage Structures
- **Dowel Bars for Exp. Joints**

Note: Other locations will be considered on a case-by-case basis.

C. FDOT Structures Manual

FDOT Structures Manual – Vol. 4 FRPG 2.3

Concrete Cover Requirements in Extremely Aggressive Environments

Component	FRP Cover Requirements	Steel Cover Requirements
External Surface Cast Against Earth	3 in.	4.5 in.
Box Culverts	2.5 2 in.	3 in.
C.I.P. Cantilever Retaining Walls	2.5 2 in.	3 in.
MSE Walls	2 1.5 in.	3 in.
Bulkheads and Sheet Pile Caps	3 2 in.	4 in.

See **FDOT Structures Manual** for cover requirements for other components.

<http://www.fdot.gov/structures>

C. FDOT Structures Manual

GFRP/CFRP Reinforcing Bars – Section 2 – Design Criteria

Design **concrete members** with FRP reinforcement according to:

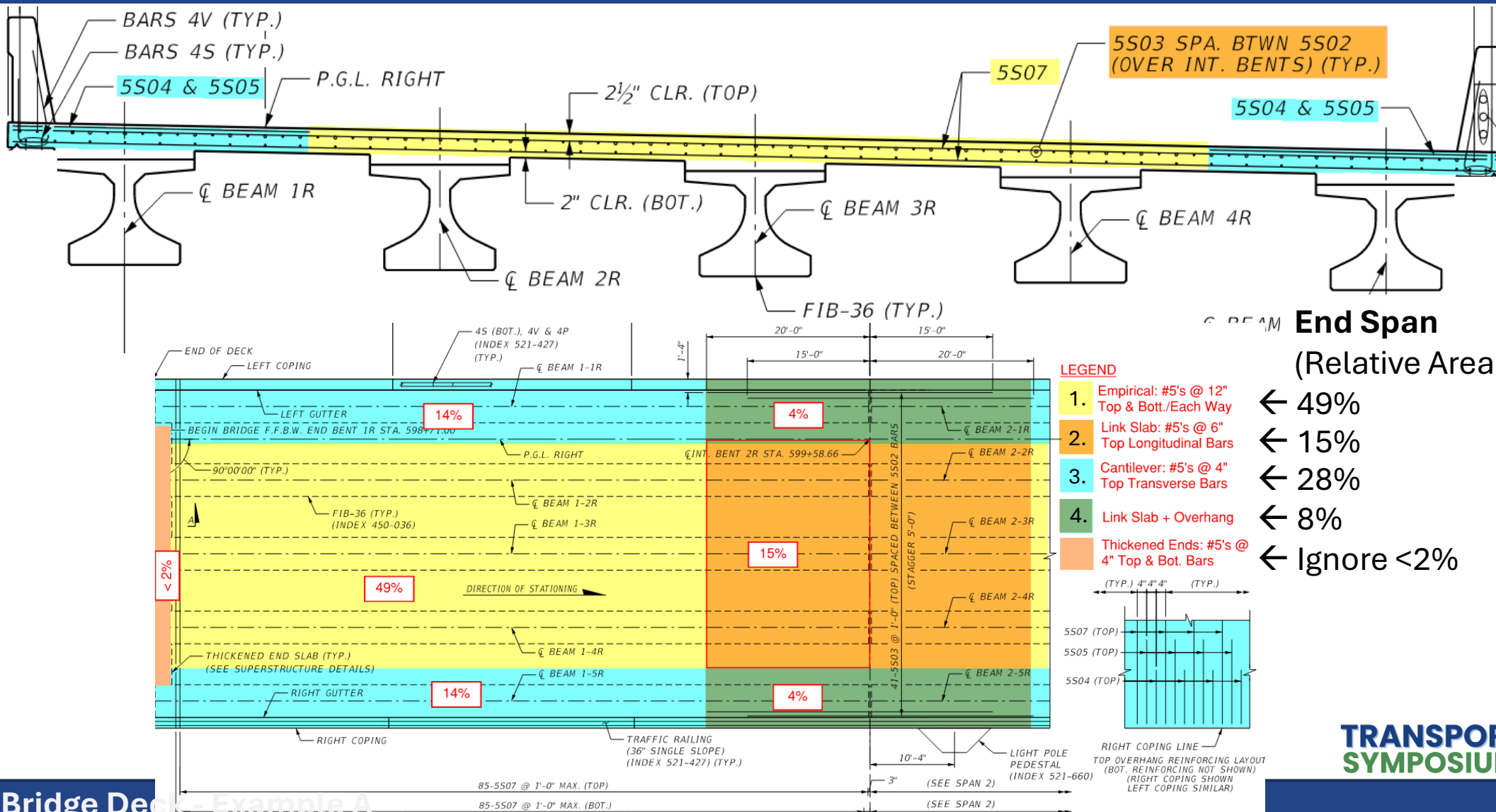
- *AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete* ~~ACI 440.1 Guide for the Design and Construction of Structural Concrete Reinforced with FRP Bars.~~
- *AASHTO Guide Specification for the Design of Concrete Bridge Beams Prestressed with CFRP Systems.* ~~ACI 440.4 Prestressing Concrete Structures with FRP Tendons~~

Design **Bridge Decks** according to:

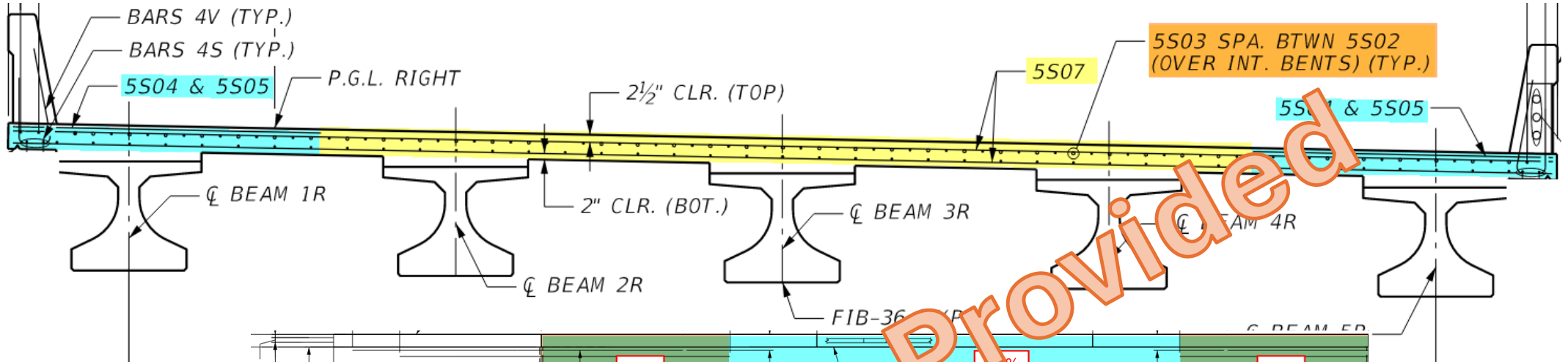
- *AASHTO LRFD Bridge Design Guide Specifications for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings (2nd Edition)*

Use FRP Mechanical Properties per FDOT Section 932-4.

Comparison of Rebar Qty. – Bridge Deck Example A

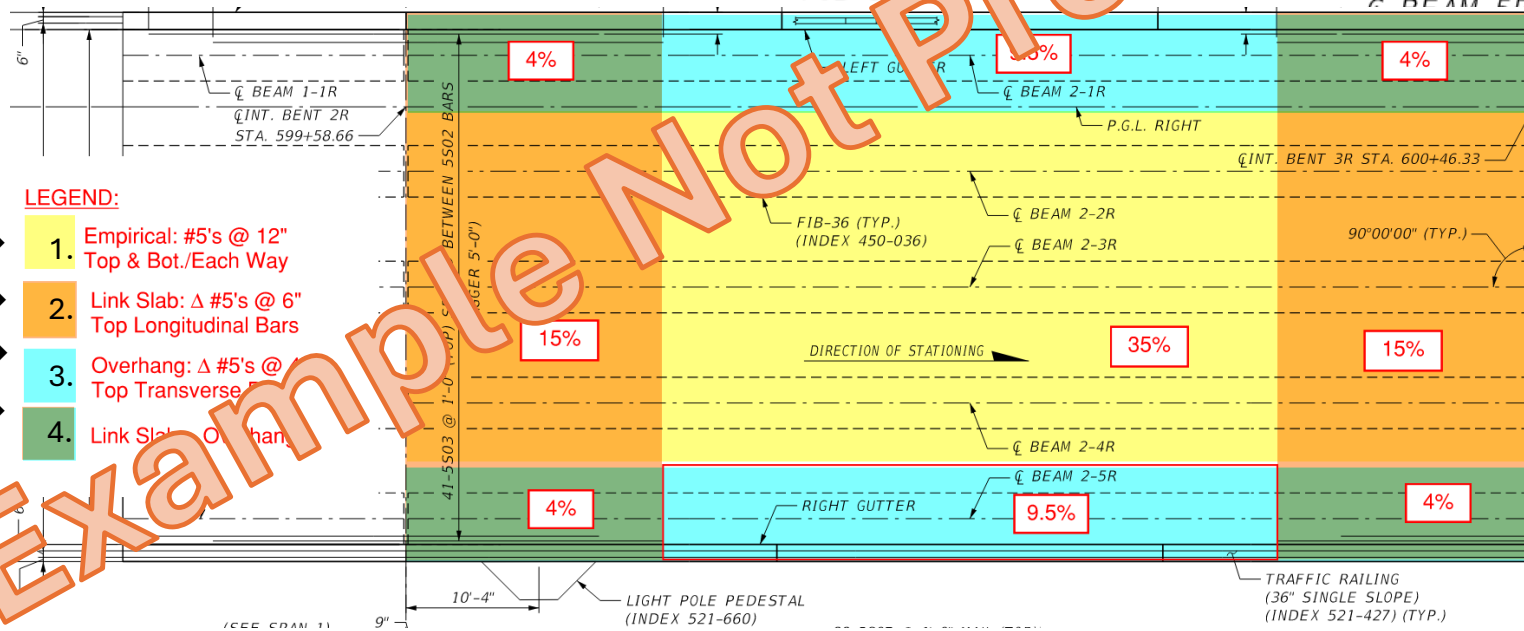


Comparison of Rebar Qty. – Bridge Deck Example B



Interior Span (Relative Areas):

- LEGEND:**
- 35% → 1. Empirical: #5's @ 12" Top & Bot./Each Way
 - 30% → 2. Link Slab: Δ #5's @ 6" Top Longitudinal Bars
 - 19% → 3. Overhang: Δ #5's @ Top Transverse
 - 16% → 4. Link Slab: Overhang



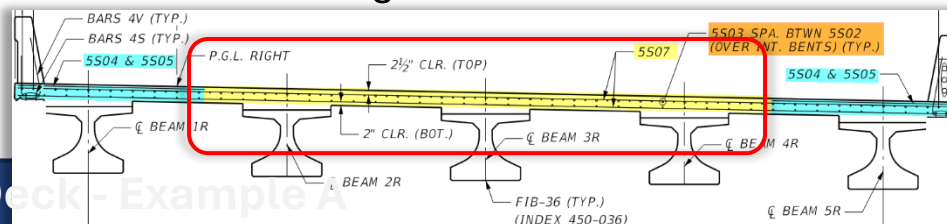
Comparison of Material Qty. – Deck Area 1 (Example A)

Convention CS-RC (ASTM A615):

- Thickness = 8”
- Concrete Cover = 2”
- Flexural Depth (#5’s) $d = 5.7”$
- Empirical (AASHTO-BDS): Bottom layers = #5’s @ 13.8” ($0.27 \text{ in}^2/\text{ft}$); Top layers = #4’s @ 13.3” ($0.18 \text{ in}^2/\text{ft}$)
- Empirical (FDOT): #5’s @ 12” **
- Total Rebar (AASHTO): $A_s = 0.90 \text{ in}^2/\text{ft}^2$;
(FDOT): $A_s = 1.24 \text{ in}^2/\text{ft}^2$

GFRP-RC (ASTM D8505-23):

- Thickness = 7” $\rightarrow \Delta_{\text{vol.}} = -12\%$; $\Delta_{\text{weight}} = -15\%$
- Concrete Cover = 1”
- Flexural Depth (#5’s) $d = 5.7”$
- Empirical (AASHTO-GSG): ** Bottom transverse layer = #5’s @ 6.5” (0.83%)
Other 3-layers = #5’s @ 12” (0.35%)
- Total Rebar: $A_f = 1.50 \text{ in}^2/\text{ft}^2 \text{ deck}$
 $\rightarrow \Delta_{\text{volume}} \text{ (AASHTO)} = +67\%$; $\Delta_{\text{weight}} = -58\%$
 $\rightarrow \Delta_{\text{volume}} \text{ (FDOT)} = +21\%$; $\Delta_{\text{weight}} = -70\%$



Interior Section

TRANSPORTATION SYMPOSIUM

** Minimum bar size and spacing governs

Comparison of Material Qty. – Deck Area 2 (Example A)

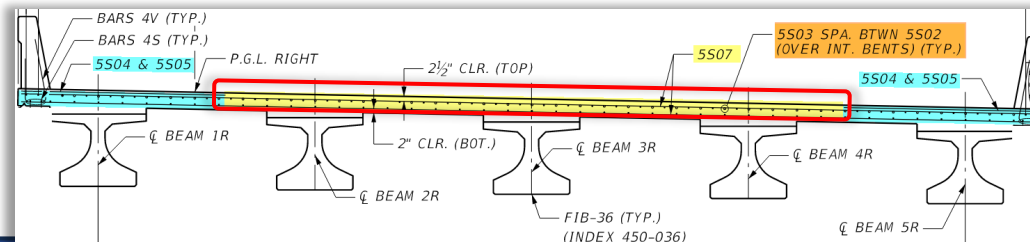
Convention CS-RC (ASTM A615):

- Thickness = 8"
- Concrete Cover = 2"
- Flexural Depth (#5's) $d = 5.7"$
- Empirical (AASHTO): Bottom layers = #5's @ 13.8" ($0.27 \text{ in}^2/\text{ft}$); Top transverse = #4's @ 13.3" ($0.18 \text{ in}^2/\text{ft}$); + Top long. = #5's @ 6" ($0.62 \text{ in}^2/\text{ft}$)
- Empirical (FDOT): 3-layers @ #5's @ 12" ** ($0.31 \text{ in}^2/\text{ft}$);
- Total Rebar (AASHTO): $A_s = 1.34 \text{ in}^2/\text{ft}^2$
(FDOT): $A_s = 1.55 \text{ in}^2/\text{ft}^2$

Link-Slab Section

GFRP-RC (ASTM D8505-23):

- Thickness = 7" → $D_{vol.} = -12\%$; $D_{weight} = -15\%$
- Concrete Cover = 1"
- Flexural Depth (#5's) $d = 5.7"$
- Empirical (FDOT/AASHTO-GSG): ** Bottom transverse = #5's @ 6.5" ($0.83\% = 0.57 \text{ in}^2$); Other 2-layers = #5's @ 12" ($0.35\% = 0.31 \text{ in}^2$); + Top long. = #5's @ 6" ($0.62 \text{ in}^2/\text{ft}$)
- Total Rebar: $A_f = 1.81 \text{ in}^2/\text{ft}^2$
→ $\Delta_{vol.} \text{ (AASHTO)} = +35\%$; $\Delta_{weight} = -66\%$
→ $\Delta_{vol.} \text{ (FDOT)} = +17\%$; $\Delta_{weight} = -71\%$



** Minimum bar size and spacing governs

Comparison of Material Qty. – Deck Area 3 (Example A)

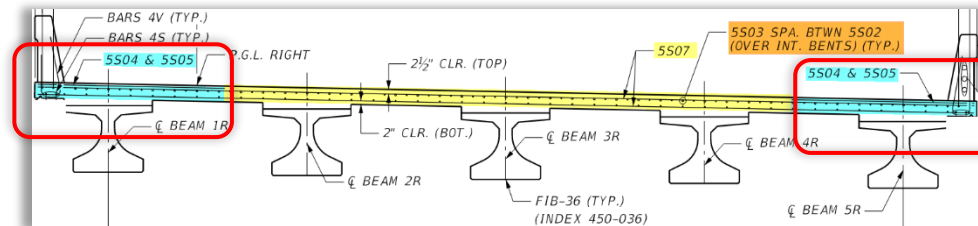
Convention CS-RC (ASTM A615):

- Thickness = 8"
- Concrete Cover = 2"
- Flexural Depth (#5's) $d = 5.7"$
- Empirical (AASHTO-BDS): 2~Bot. layers = #5's @ 13.8" ($0.27 \text{ in}^2/\text{ft}$); Top long. = #4's @ 13.3" ($0.18 \text{ in}^2/\text{ft}$); Top transv. = #4's + #5's @ 4" ($0.82 \text{ in}^2/\text{ft}$).
- Empirical (FDOT): 3-layers #5's @ 12" ** ($0.31 \text{ in}^2/\text{ft}$); Top Transv. = #5's @ 4" ($0.93 \text{ in}^2/\text{ft}$).
- Total Rebar (AASHTO): $A_s = 1.54 \text{ in}^2/\text{ft}^2$;
(FDOT): $A_s = 1.86 \text{ in}^2/\text{ft}^2$.

Overhangs (midspan)

GFRP-RC (ASTM D8505-23):

- Thickness = 7" → $\Delta_{vol.} = 88\%$; $\Delta_{weight} = 85\%$
- Concrete Cover = 1"
- Flexural Depth (#5's) $d = 5.7"$
- Empirical (AASHTO-GSG): Bot. ** transv. = #5's @ 6.5" ($\geq 0.83\% = 0.57 \text{ in}^2$); 2~long. layers = #5's @ 12" ($\geq 0.35\% = 0.31 \text{ in}^2$); Top transv. = #5's @ 4" ($0.93 \text{ in}^2/\text{ft}$).
- Total Rebar: $A_f = 2.12 \text{ in}^2/\text{ft}^2 \text{ deck}$
→ $\Delta_{volume} \text{ (AASHTO)} = +38\%$; $\Delta_{weight} = -66\%$
→ $\Delta_{volume} \text{ (FDOT)} = +14\%$; $\Delta_{weight} = -72\%$



TRANSPORTATION
SYMPOSIUM

** Minimum bar size and spacing governs

Comparison of Material Qty. – Deck Area 4 (Example A)

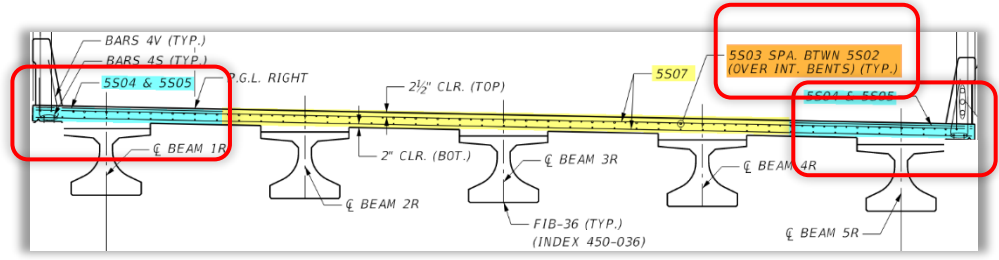
Convention CS-RC (ASTM A615):

- Thickness = 8”
- Concrete Cover = 2”
- Flexural Depth (#5’s) $d = 5.7$ ”
- Empirical Overhang + Link-Slab (AASHTO-BDS):
 2~Bot. layers = #5’s @ 13.8” ($0.27 \text{ in}^2/\text{ft}$); Top long. = #4’s & #5’s @ 6.7” ($0.46 \text{ in}^2/\text{ft}$); Top transv. = #4’s + #5’s @ 4” ($0.82 \text{ in}^2/\text{ft}$).
- Empirical-Link (FDOT): 2~Bot. layers #5’s @ 12” ** ($0.31 \text{ in}^2/\text{ft}$); Top Transv. = #5’s @ 4” ($0.93 \text{ in}^2/\text{ft}$). Top long. = #5’s @ 6” ($0.62 \text{ in}^2/\text{ft}$).
- Total Rebar (AASHTO): $A_s = 1.82 \text{ in}^2/\text{ft}^2$;
 (FDOT): $A_s = 2.17 \text{ in}^2/\text{ft}^2$.

Overhangs @ Link-Slab

GFRP-RC (ASTM D8505-23):

- Thickness = 7” $\rightarrow \Delta_{\text{vol.}} = -12\%$; $\Delta_{\text{weight}} = -15\%$
- Concrete Cover = 1”
- Flexural Depth (#5’s) $d = 5.7$ ”
- Empirical Overhang + Link-Slab (AASHTO-GSG):
 Bot. ** transv. = #5’s @ 6.5” ($\geq 0.83\% = 0.57 \text{ in}^2$); Bot. long. = #5’s @ 12” ($\geq 0.35\% = 0.31 \text{ in}^2$); Top transv. = #5’s @ 4” ($0.93 \text{ in}^2/\text{ft}$). Top long. = #5’s @ 6” (0.62 in^2)
- Total Rebar: $A_f = 2.69 \text{ in}^2/\text{ft}^2$ deck)
 $\rightarrow \Delta_{\text{volume}} \text{ (AASHTO)} = +48\%$; $\Delta_{\text{weight}} = -67\%$
 $\rightarrow \Delta_{\text{volume}} \text{ (FDOT)} = +24\%$; $\Delta_{\text{weight}} = -69\%$



Comparison of Material Quantities – Example A Summary

Convention CS-RC (ASTM A615):

• **Example A** (End Span Rebar)

- Empirical (AASHTO): $A_s = 0.49 \cdot 0.90 + 0.15 \cdot 1.34 + 0.28 \cdot 1.54 + 0.08 \cdot 1.82 = 1.22 \text{ in}^2/\text{ft}^2$

- Empirical (FDOT): $A_s = 0.49 \cdot 1.24 + 0.15 \cdot 1.55 + 0.28 \cdot 1.86 + 0.08 \cdot 2.17 = 1.53 \text{ in}^2/\text{ft}^2$

GFRP-RC (ASTM D8505-23):

• **Example A** (End Span Rebar)

- Empirical (both): $A_s = 0.49 \cdot 1.50 + 0.15 \cdot 1.81 + 0.28 \cdot 2.12 + 0.08 \cdot 2.69 = 1.82 \text{ in}^2/\text{ft}^2$

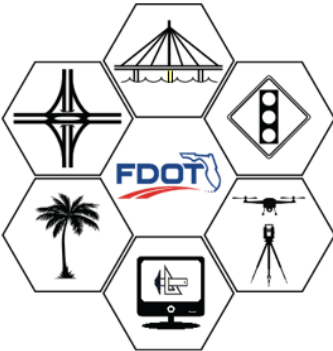
Concrete $\rightarrow \Delta_{vol.}$ (AASHTO) = -12%; Δ_{weight} = -15% for GFRP-RC

Rebar $\rightarrow \Delta_{volume}$ (AASHTO) = +49%; Δ_{weight} = -63 %.

Rebar $\rightarrow \Delta_{volume}$ (FDOT) = +19%; Δ_{weight} = -70 %.

TRANSPORTATION
SYMPOSIUM

Comparison of Rebar Qty. – Pile Bent Cap Example C




FDOT 2022 Webinar Series
TRANSPORTATION SYMPOSIUM

GFRP Reinforced Concrete Design for Pile Bent Caps

Steven Nolan, P.E. – State Structures Design Office

October 19, 2022



10/20/2022

GFRP Reinforced Concrete Design for Pile Bent Caps

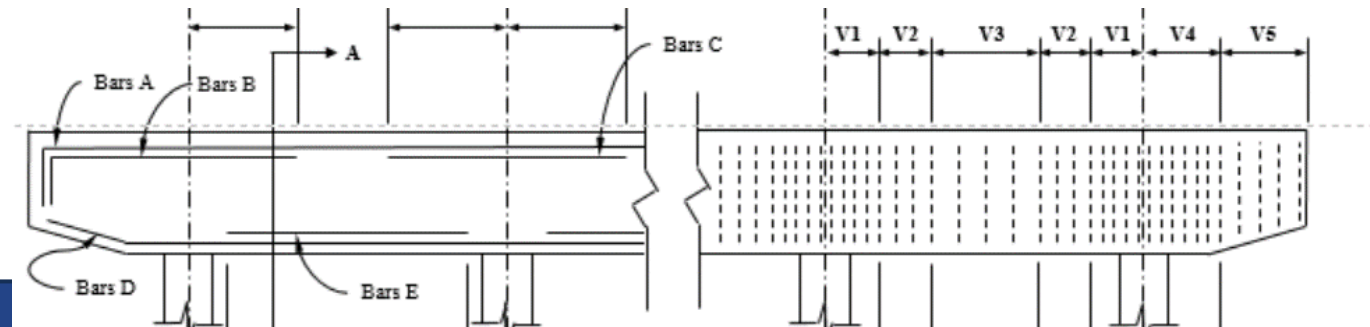
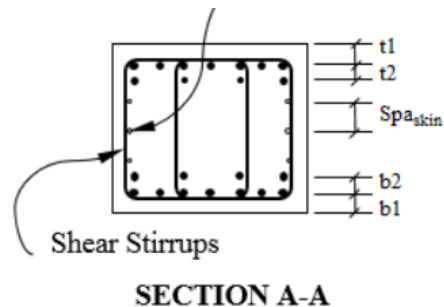
Presentation

TRANSPORTATION SYMPOSIUM

Design Example for Pile Bent Cap Summary

- Comparison of different design alternates for **5-piles @ 9-ft spacing (Example 1) – Higher Modulus GFRP Rebar ($E_f = 6,500$ psi to $8,700$ psi for future enhancements to ASTM D7957)**

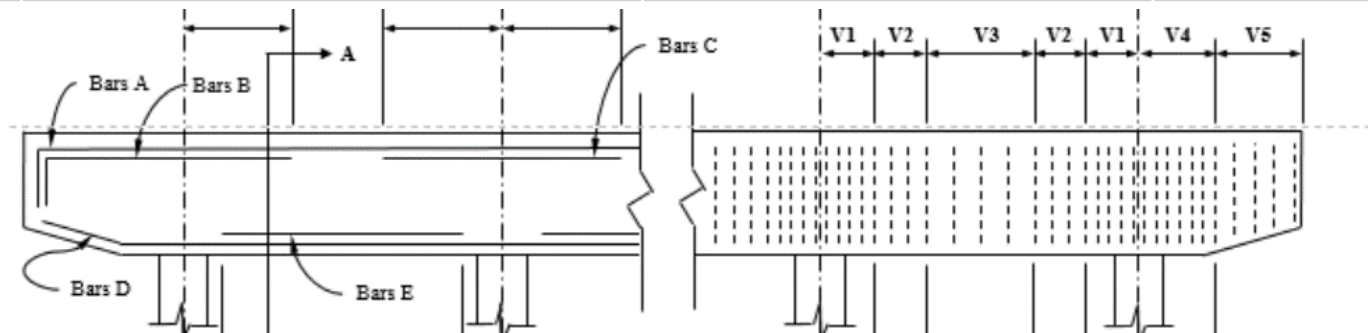
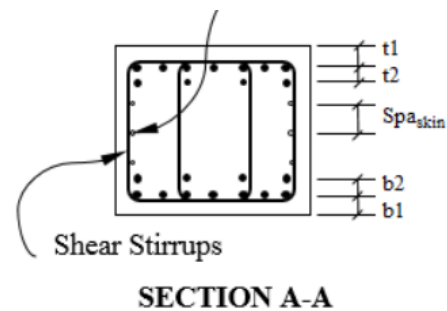
Rebar Location	GFRP-RC (Type 0) 3-ft Deep Cap ($E_f = 6,500$ ksi)	GFRP-RC 3-ft Deep Cap ($E_f = 7,250$ ksi)	GFRP-RC (Type III) 3-ft Deep Cap ($E_f = 8,700$ ksi)
Bars A - Flexural Top	6 ~ #8's ($A_f = 4.7$ in ²)	7 ~ #7's ($A_f = 4.2$ in ²)	6 ~ #7's ($A_f = 3.6$ in ²)
Bars D & E - Flexural Bottom	8 ~ #8's ($A_f = 6.3$ in ²)	7 ~ #8's ($A_f = 5.5$ in ²)	6 ~ #8's ($A_f = 4.7$ in ²)
Bars V3 - Shear Stirrups	4-legs #5 at 11" sp. ($A_f = 1.4$ in ² /ft)	4-legs #5 at 13" sp. ($A_f = 1.1$ in ² /ft)	4-legs #4 at 10" sp. ($A_f = 1.0$ in ² /ft)



Design Example for Pile Bent Cap Summary

- Comparison of different design alternates for 5-piles @ 9-ft spacing (Example 1)

Rebar Location	GFRP-RC (Type 0) 3-ft Deep Cap	Δ_{volume} Type 0 or (Type III)	Steel-RC 3-ft Deep Cap
Bars A - Flexural Top	6 ~ #8's ($A_f = 4.7 \text{ in}^2$)	+80% or (+38%)	6 ~ #6's ($A_s = 2.6 \text{ in}^2$)
Bars D & E - Flexural Bottom	8 ~ #8's ($A_f = 6.3 \text{ in}^2$)	+50% or (+12%)	7 ~ #7's ($A_s = 4.2 \text{ in}^2$)
Bars V3 - Shear Stirrups	4-legs #5 at 11" sp. ($A_f = 1.4 \text{ in}^2/\text{ft}$)	+75% or (+25%)	4-legs #4 at 12" sp. ($A_s = 0.8 \text{ in}^2$)



Construction: Example Projects & Lessons Learned

Projects with Fast-Facts Sheet

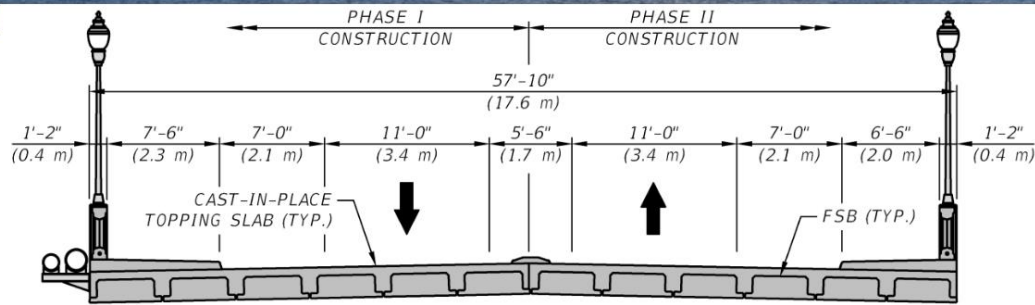
- [4th St North over Big Island Gap \(D7\)](#) – *In-house Design.*
- [40th Ave NE over Placido Bayou \(D7\)](#)
- [Arthur Drive over Lynn Haven Bayou \(D3\)](#)
- [Bakers Haulover Cut Bulkhead Replacement \(D6\)](#)
- [Bimini Dr Bridge on Duck Key \(D6\)](#)
- [Cedar Key Bulkhead Rehab \(D2\)](#)
- [Halls River Bridge \(D7\)](#) – *In-house Design.*
- [Key West Bight Ferry Terminal Extension \(D7\)](#)
- [NE 23rd Ave over Ibis Waterway \(D6\)](#)
- [PortMiami Tunnel Retaining Walls \(D6\)](#)
- [South Maydell Dr over Palm River \(D7\)](#)
- [SR-A1A Flagler Beach Seawall \(Segment 3\) \(D5\)](#)
- [SR-A1A over Myrtle Creek and Simpson Creek \(D2\)](#)
- [SR-5 \(US-17\) over Trout River \(D2\)](#)
- [SR-5 \(US 41\) over Morning Star and Sunset Waterways \(D1\)](#)
- [SR-30 over St Joe Inlet \(D3\)](#)
- [SR-45 \(US 41\) over North Creek \(D1\)](#)
- [SR 112/I-195 Over Westshore Waterway \(D5\)](#)
- [SR-312 over Matanzas River \(D2\)](#)
- [SR-520 over Indian River Bulkhead Rehab \(D5\)](#)
- [Sunshine Skyway Seawall Rehabilitation \(D7\)](#)
- [UM Innovation Bridge](#)
- [UM Fate Bridge](#)
- [UM I-Dock](#)
- [US-1 over Cow Key Channel \(D6\)](#)

Upcoming Bridge and Seawall Projects

- D2: [US1/King St over San Sebastian River \(437428-1\)](#)
- D2: [St. Augustine A1A/Avenida Menendez Seawall replacement \(428271-2\)](#)
- D2: CR 357 over Shired Creek ([437402-1](#))
- D3: CR30A over Western Lake ([443331-1](#))
- D3: CR30B/Indian Lagoon ([441185-2](#))
- D3: CR 372/Surf Road over Otter Creek Rise ([442951-1](#))
- D4: US 1/Jupiter Federal Observation Platform ([428400-2](#))
- D4: SR-A1A North Causeway Bridge Observation Platform ([429936-2](#))
- D4: 17th St/Indian River, East End-Vero ([446106-2](#))
- D4: [SR 5/US 1 Over Earman River \(442891-1\)](#) – *In-house Design.*
- D5: SR-A1A Seawalls - Flagler Beach & Nth Volusia Co. ([452443-1](#) & [452444-1](#))
- D5: Barracuda Blvd New Smyrna ([437935-1](#)) – *In-house Design.*
- D5: 5th Street over Yacht Club Cut ([437936-1](#))
- D5: US1 over Pellicer Ck ([447118-1](#))
- D6: FKOSH Bridge Replacement... ([448206-1](#) & [448207-1](#))

Construction: D7 Example Project

- **40th Ave NE over Placido Bayou (FPID: 443600-1)**



- **4th St North over Big Island Gap (FPID: 430500-1)**



In-house Design

**TRANSPORTATION
SYMPOSIUM**

4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Bridge Location

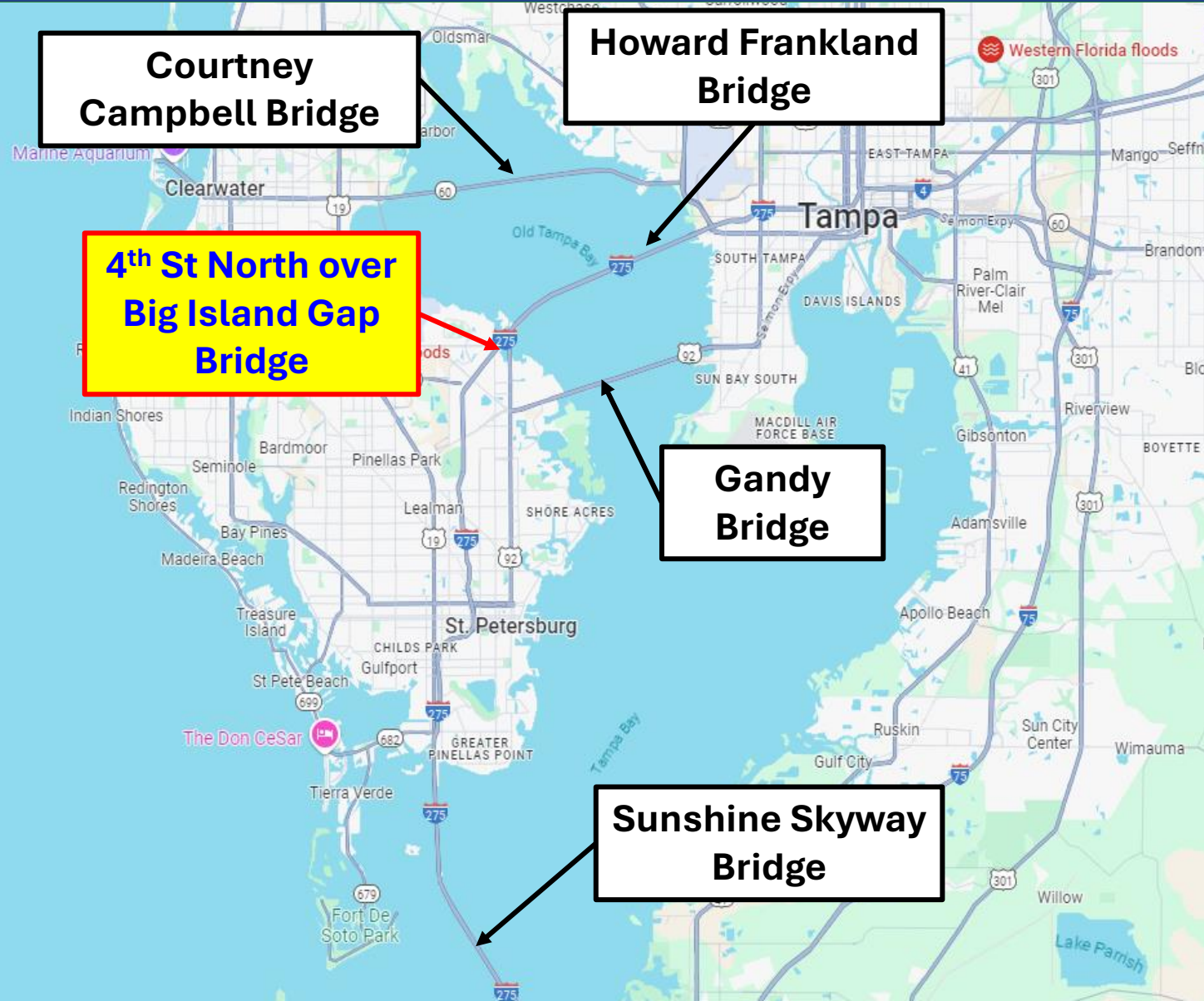
OLD BRIDGE



**Courtney
Campbell Bridge**

**Howard Frankland
Bridge**

**4th St North over
Big Island Gap
Bridge**



**Gandy
Bridge**

**Sunshine Skyway
Bridge**

NEW BRIDGE



4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project

Existing Bridges



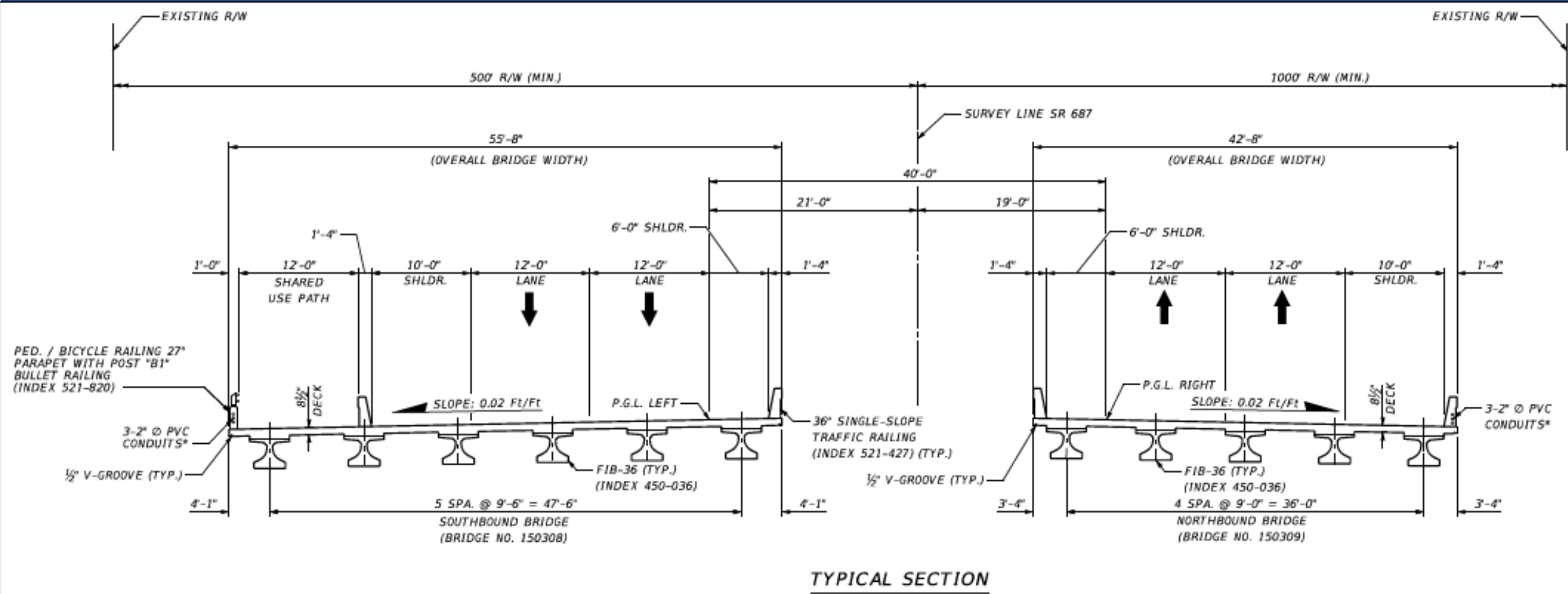
4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project

Existing Bridges – Pile Jackets

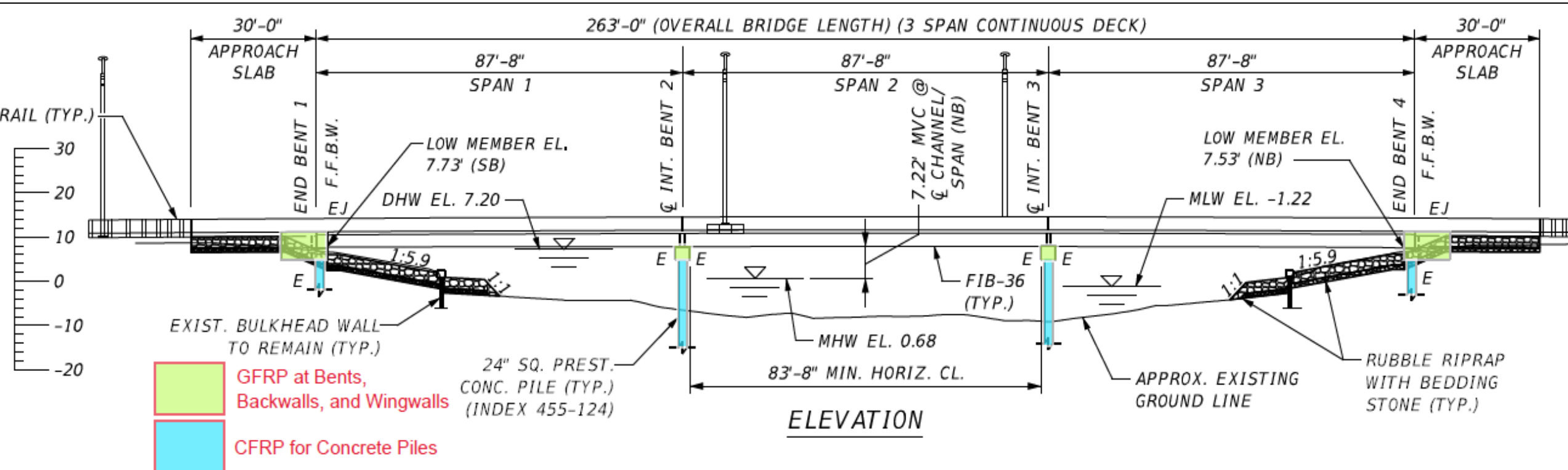


Construction: D7 Example Project New Bridges – Typical Section



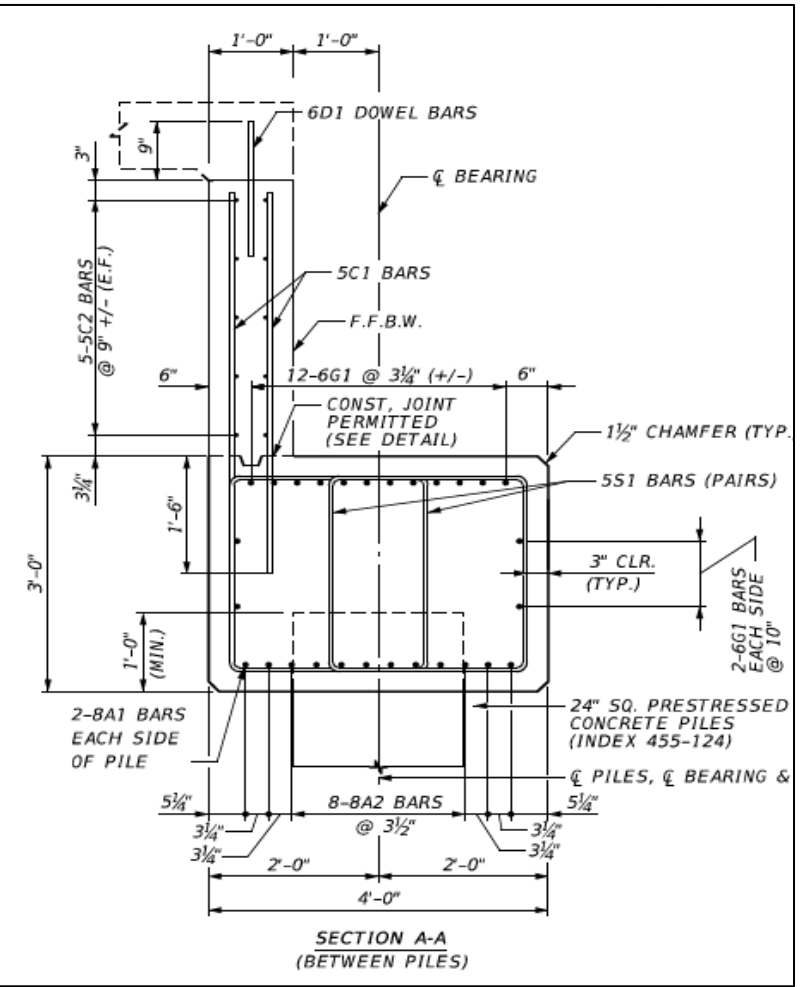
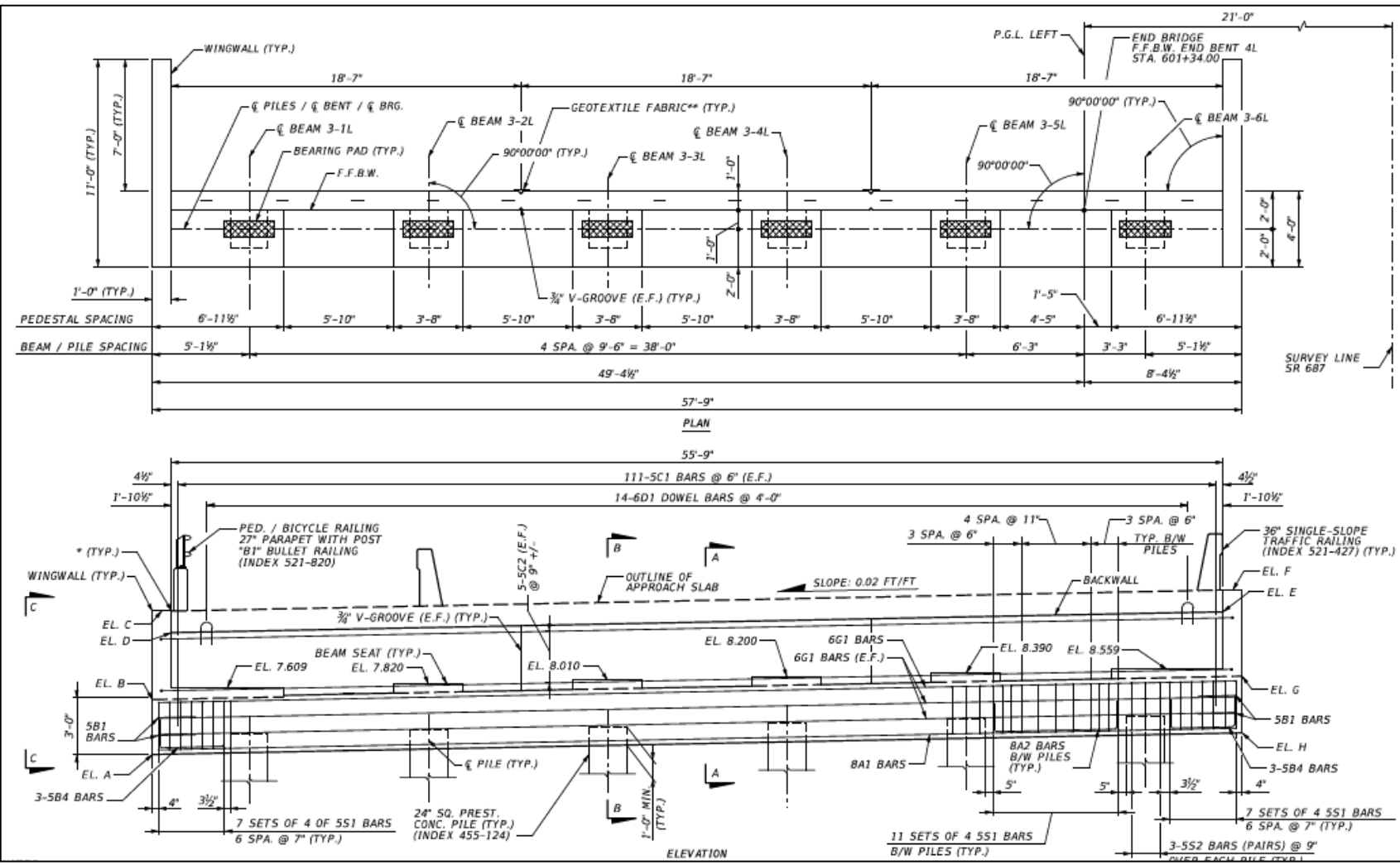
TYPICAL SECTION

Construction: D7 Example Project New Bridge – Elevation View



Construction: D7 Example Project

End Bent – Plan & Elevation / Details



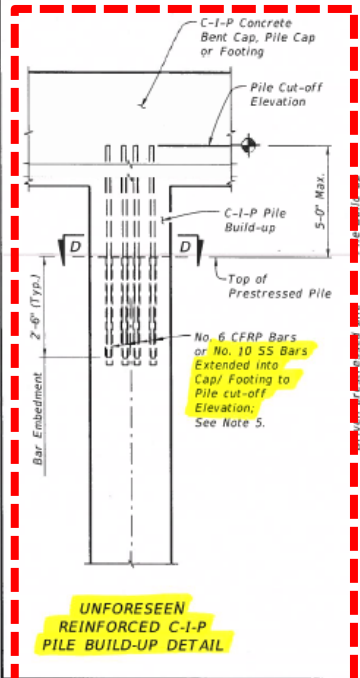
4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Pile Installation & Pile Crack Repair

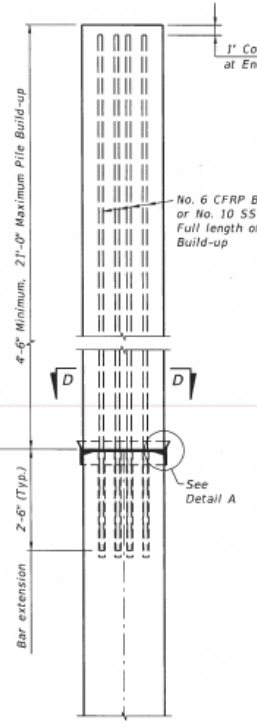


Construction: D7 Example Project Pile Splice Build-Up Detail

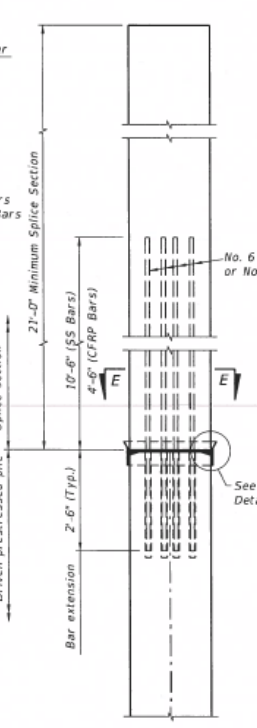
NOTES:
1. For Sections D-D, & E-E, see Index 455-112, 455-114, 455-118, 455-124 or 455-130 for applicable concrete pile size and Pile Splice Reinforcement Details.
2. Prestressing strands, spiral ties and/or reinforcement are not shown for clarity.
3. In cases where pile splices are desired due to length limitations in shipping and/or handling, the "Drivable Preplanned Prestressed Precast Splice Detail" shall be used.
4. When preformed dowel holes are utilized, the 1" spiral tie pitch shall be continued to 4'-0" below the head of the pile. See Index 455-118, 455-124. Preformed holes shall utilize either removable forming material or stay-in-place corrugated galvanized steel ducts. Stay-in-place ducts shall be fabricated from galvanized sheet steel meeting the requirements of ASTM A653, Coating Designation G90, 26 gauge. Ducts shall be 1½" diameter for CFRP Bars, and 2" diameter for SS Bars with a minimum corrugation (rib) height of 0.12 in. Ducts shall be fabricated with either welded or interlocked seams. Galvanizing of welded seams will not be required.
5. For tension piles where top of Prestressed Pile is less than 3 feet below Pile Cut-off Elevation, extend No. 6 CFRP Bars or No. 10 SS into cap beyond Pile Cut-off Elevation to achieve development as approved by the Engineer.



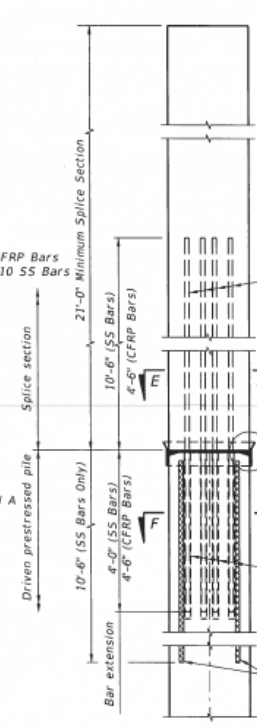
UNFORESEEN REINFORCED C-I-P PILE BUILD-UP DETAIL



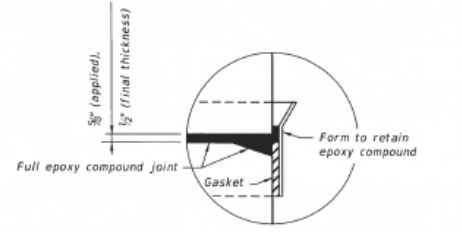
NONDRIVABLE UNFORESEEN REINFORCED PRECAST PILE BUILD-UP DETAIL



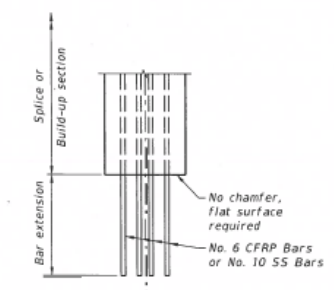
DRIVABLE UNFORESEEN PRESTRESSED PRECAST PILE SPICE DETAIL



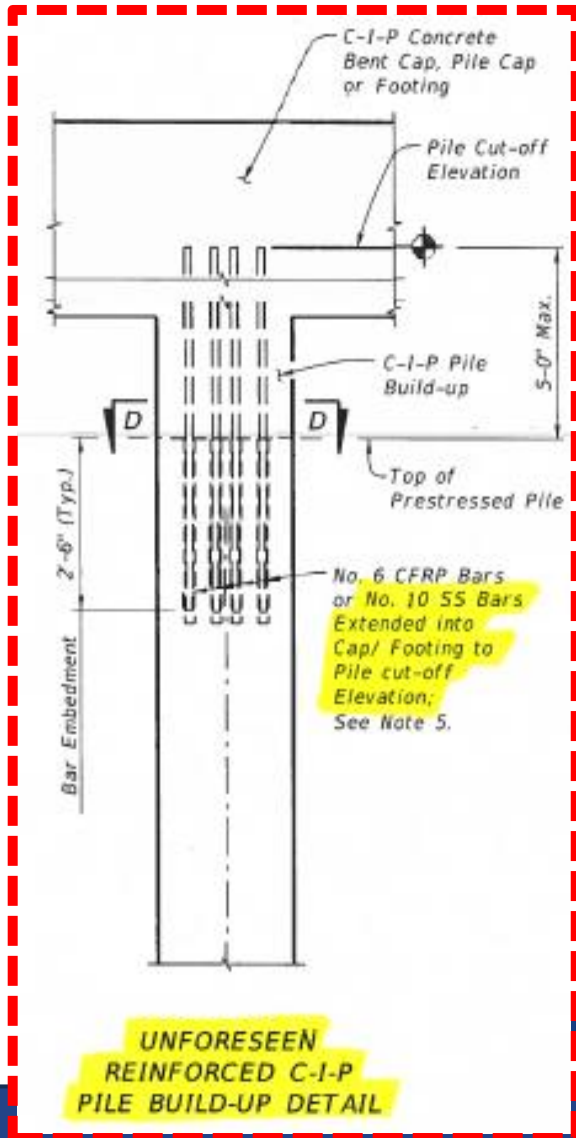
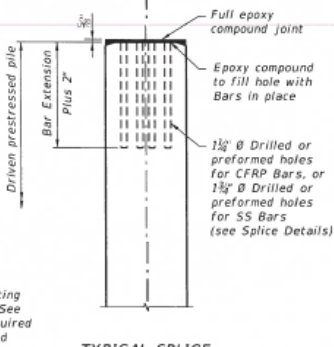
DRIVABLE PREPLANNED PRESTRESSED PRECAST PILE SPICE DETAIL



DETAIL A



TYPICAL SPICE BEFORE BONDING



UNFORESEEN REINFORCED C-I-P PILE BUILD-UP DETAIL

4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Pile Splice Build-Up Construction



4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Pile Splice Build-Up Construction



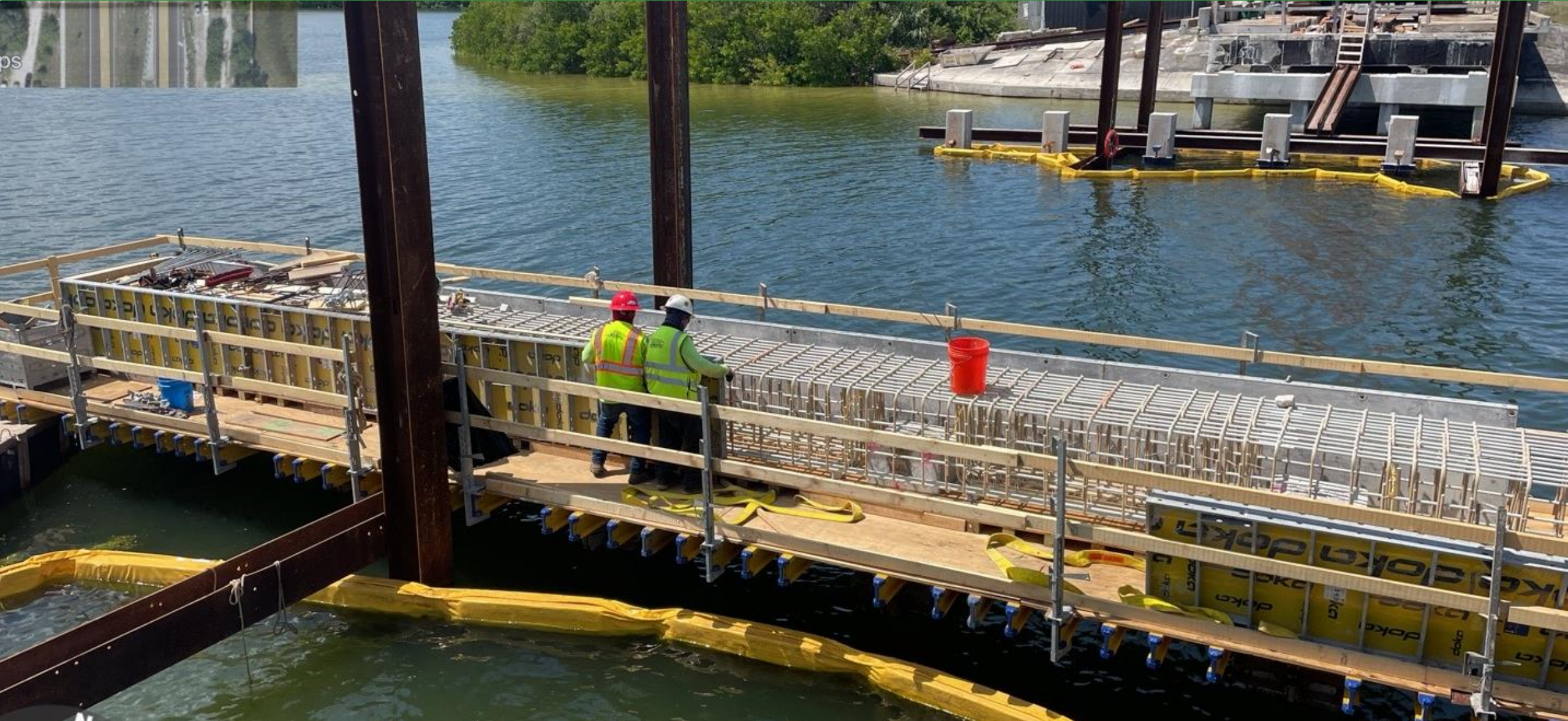
4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Cap, Backwall & Wingwall Construction



4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Cap, Backwall & Wingwall Construction



4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Cap, Backwall & Wingwall Construction



4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project

SB FIB-36 Placement (Span 2)



4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project

SB FIB-36 Placement (Span 2)



4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Cap, Backwall & Wingwall Construction



4th St North over
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(430500-1)

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4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Cap, Backwall & Wingwall Construction



4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project Cap, Backwall & Wingwall Construction



4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project

Hurricane – Storm Surge



Hurricane Idalia
Category 4 Hurricane
August 30, 2023

4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project

Hurricane – Storm Surge



Hurricane Idalia

Category 4 Hurricane

August 30, 2023

**TRANSPORTATION
SYMPOSIUM**

4th St North over
Big Island Gap
(430500-1)

Construction: D7 Example Project

Completed Bridge – November 2023



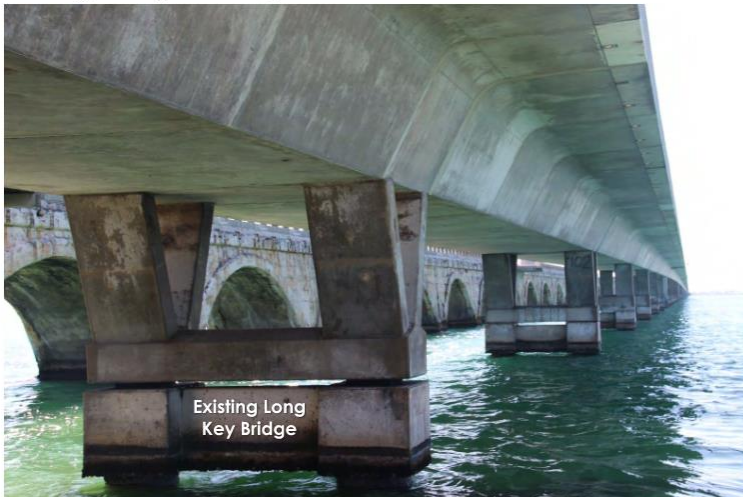
Future Construction: D6 Example Projects

- Long Key Bridge Replacement ([448206-1](#) & [448207-1](#))

- Seven Mile Bridge Replacement ([448207-1](#))

FDOT SR 5/US 1 LONG KEY BRIDGE OVER LONG KEY CHANNEL PD&E STUDY | FPID 448206-1-22-01 | ETDM 14451
 DISTRICT 6 ALTERNATIVE BRIDGE REINFORCEMENT COORDINATION MEETING

Long Key Bridge Facts



Existing Long Key Bridge

Part of the 110-mile Florida Keys National Scenic Highway / All-American Road

Also known as the Dante B. Fascell Bridge

- Year Constructed:** 1981
- Bridge Type:** Precast Segmental Box Bridge
- Vertical Clearance:** 25.54 feet
- Horizontal Clearance:** 111.0 feet
- Bridge Length:** 12,152 feet (2.3 miles)
- Travel Lanes:** Two 12-foot travel lanes
- Shoulders:** 6-foot paved shoulders on both sides of the bridge also function as undesignated bicycle lanes
- Sidewalks:** No existing sidewalks

ARDURRA HDR

Seven Mile Bridge

SR 5/US 1/OVERSEAS HIGHWAY SEVEN MILE BRIDGE OVER MOSER CHANNEL
 PROJECT DEVELOPMENT AND ENVIRONMENT STUDY

Ad # 24639 | FM# 448207-1-22-01

SMB
 Seven Mile Bridge

Letting Date: 03/15/2027

Letting Date: 03/11/2030

**TRANSPORTATION
 SYMPOSIUM**

Construction: D5 Example Projects

- SR-A1A Seawalls - Flagler Beach & Nth Volusia Co. ([452443-1](#) & [452444-1](#))

- Barracuda Blvd over Canal Bradano ([437935-1](#)) *In-house Design*

Financial Project Identification (FPID) Nos.: 452443-1 & 452444-1

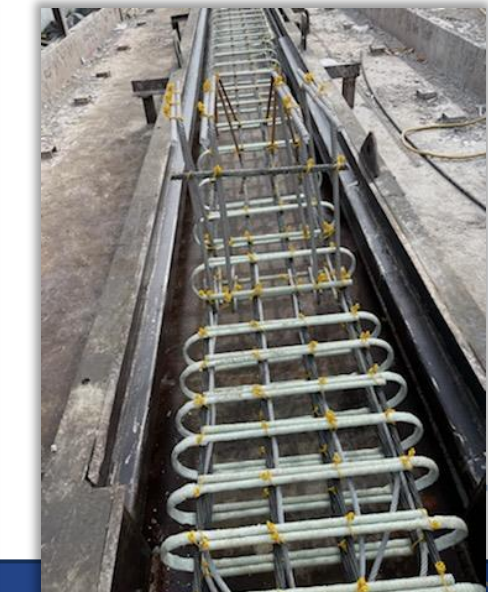
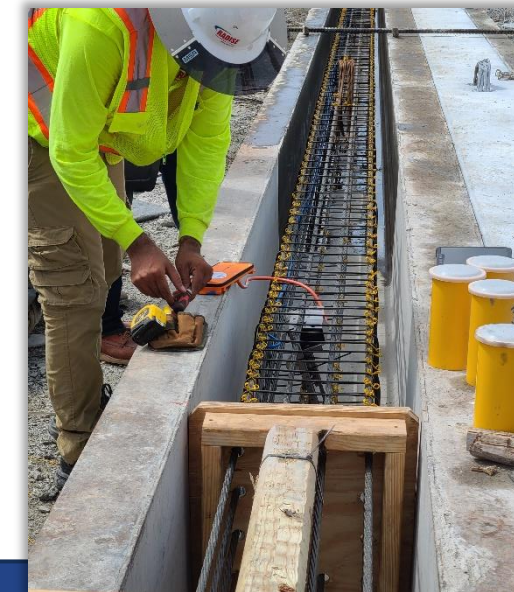
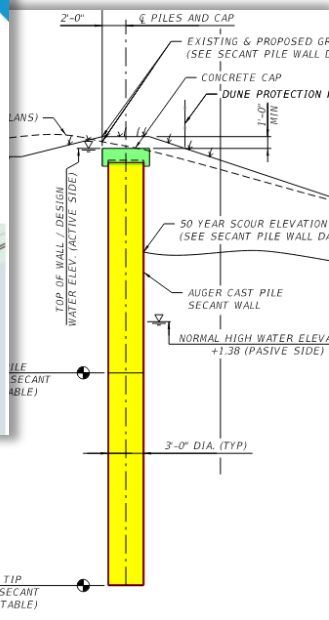
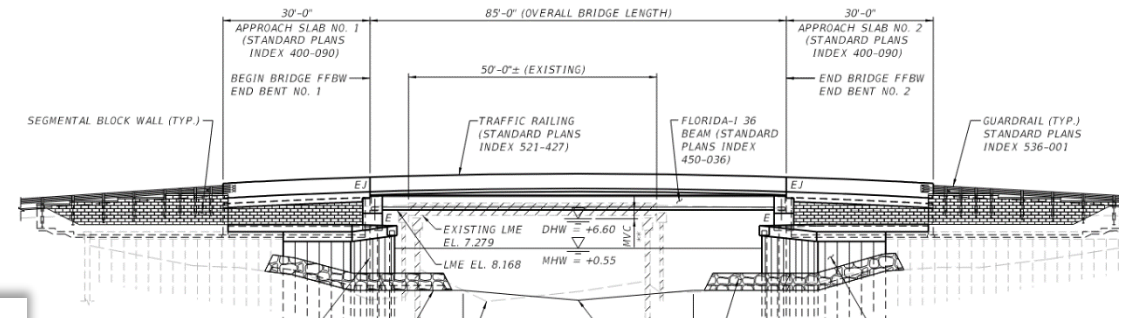
S.R. A1A RESILIENCY PROJECT

Construction Update

The Florida Department of Transportation (FDOT) is set to start construction on the first of two buried seawalls along State Road (S.R.) A1A. The first wall will extend from one-half mile north of Highbridge Road in Volusia County to South Central Avenue in Flagler County. Work is expected to begin in February 2024 at the north end of the seawall in

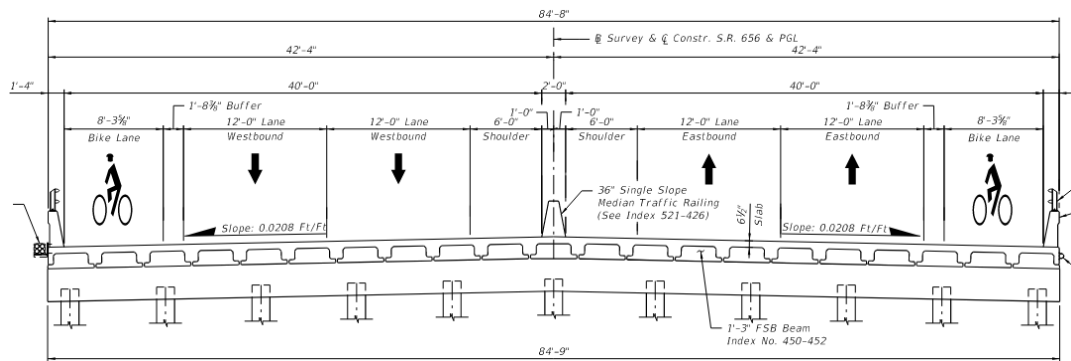
SECTION A-A

3'-0" DIA. PRIMARY SECANT PILE (TYP) (REINFORCED)
4" OVERLAP (TYP)
3'-0" DIA. INTERMEDIATE PILE (TYP) (UN-REINFORCED)

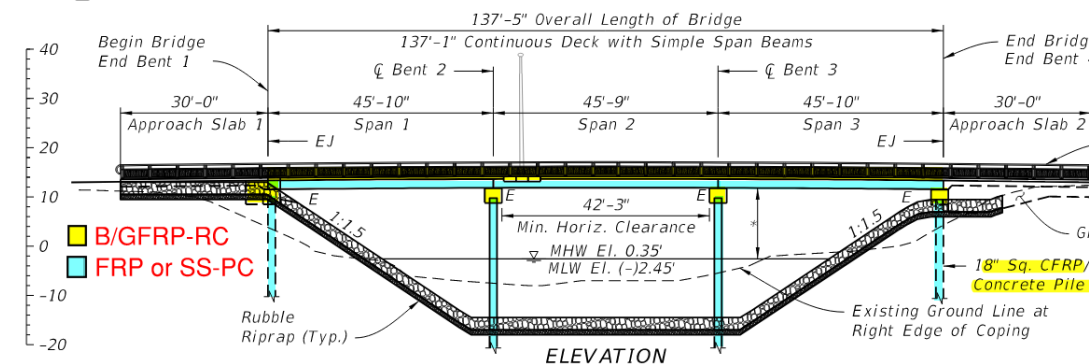
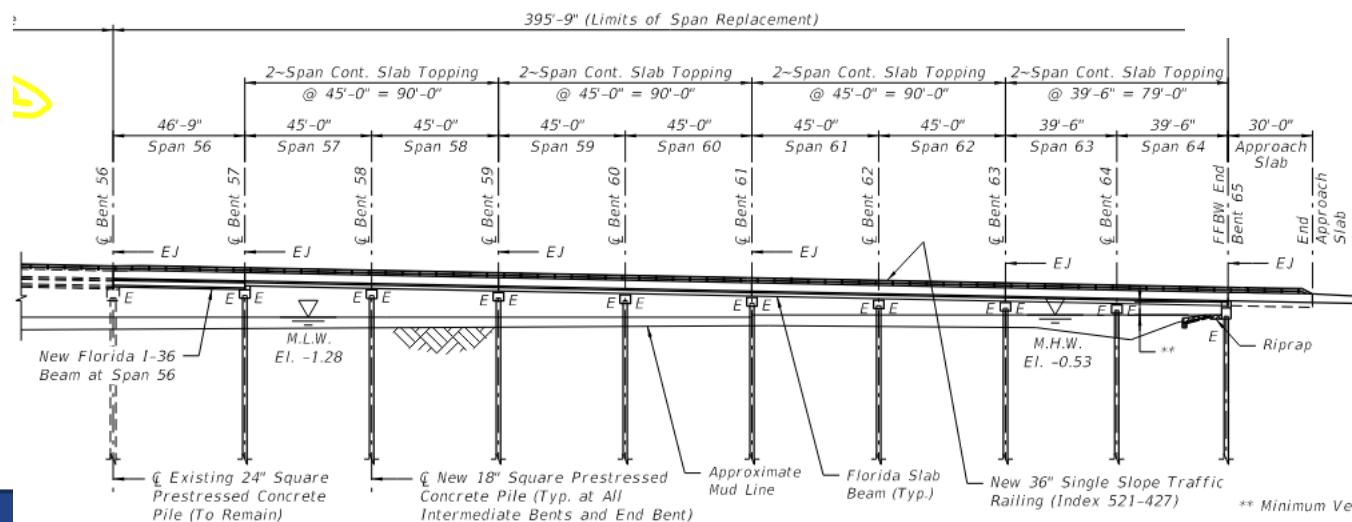
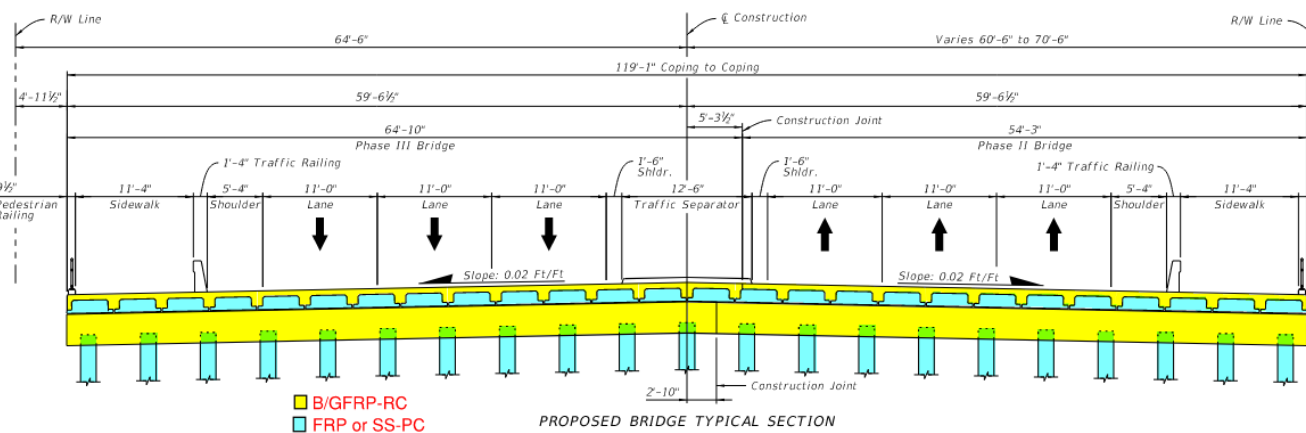


Construction: D4 Example Projects

- 17th St/Indian River, East End-Vero (446106-2)



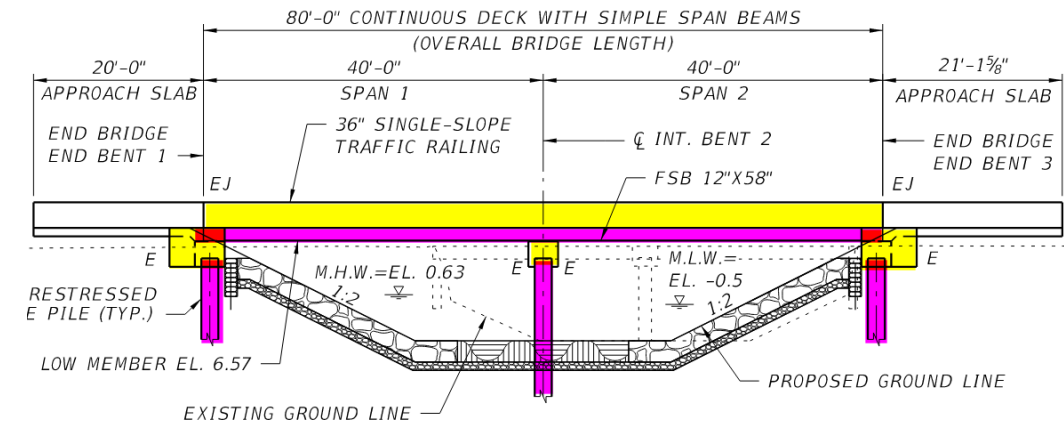
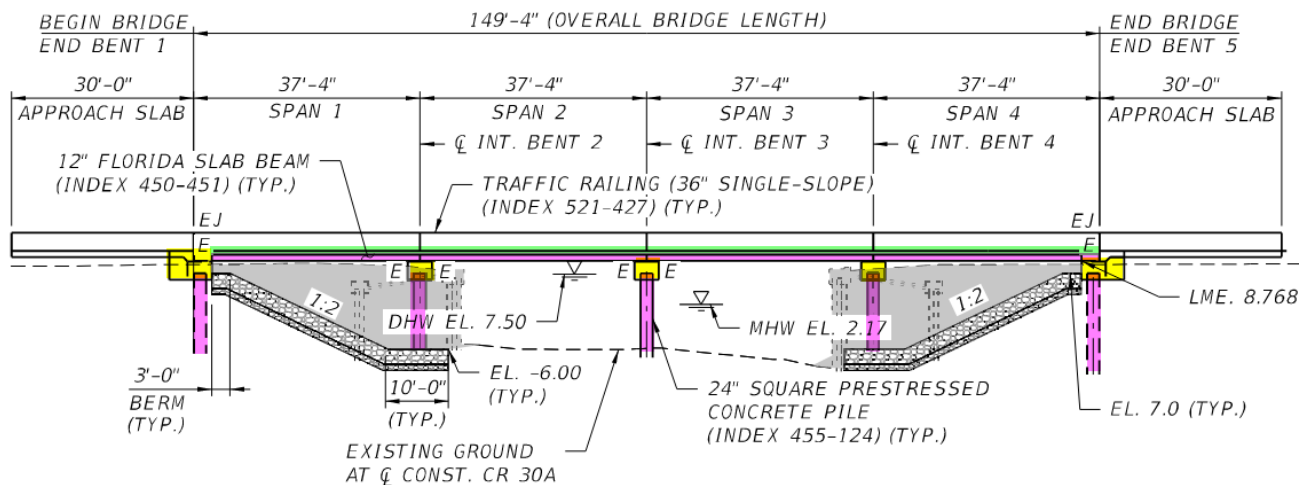
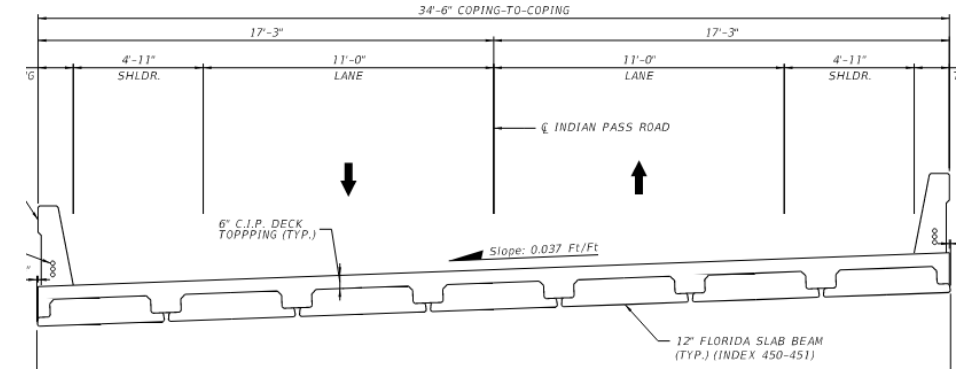
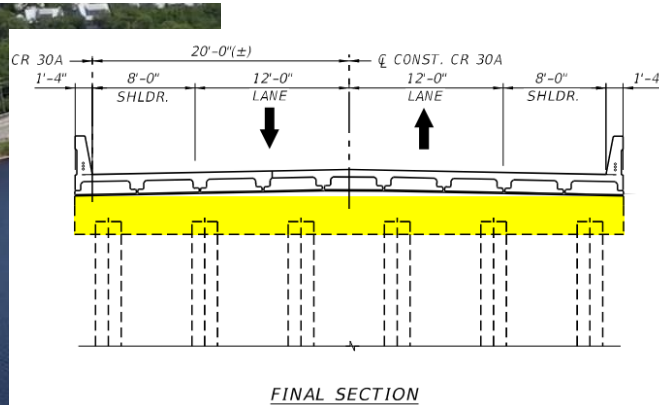
- SR 5/US 1 Over Earman River (442891-1) *In-house Design*



Construction: D3 Example Projects

- CR30A over Western Lake ([443331-1](#))

- CR30B/Indian Lagoon ([441185-2](#))



Future Construction: D2 Example Projects

- US1/King St over San Sebastian River (437428-1)

- St. Augustine A1A/Avenida Menendez Seawall Replacement (428271-2)

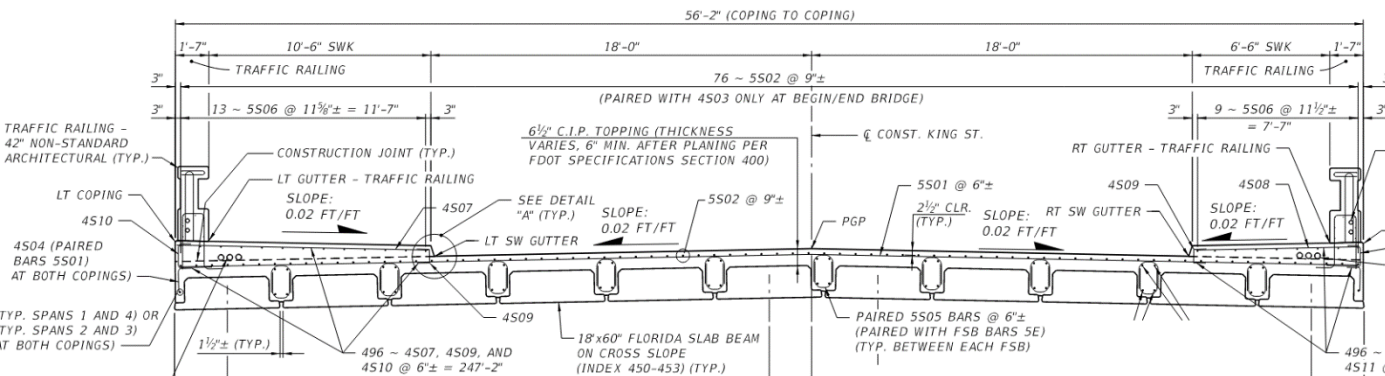
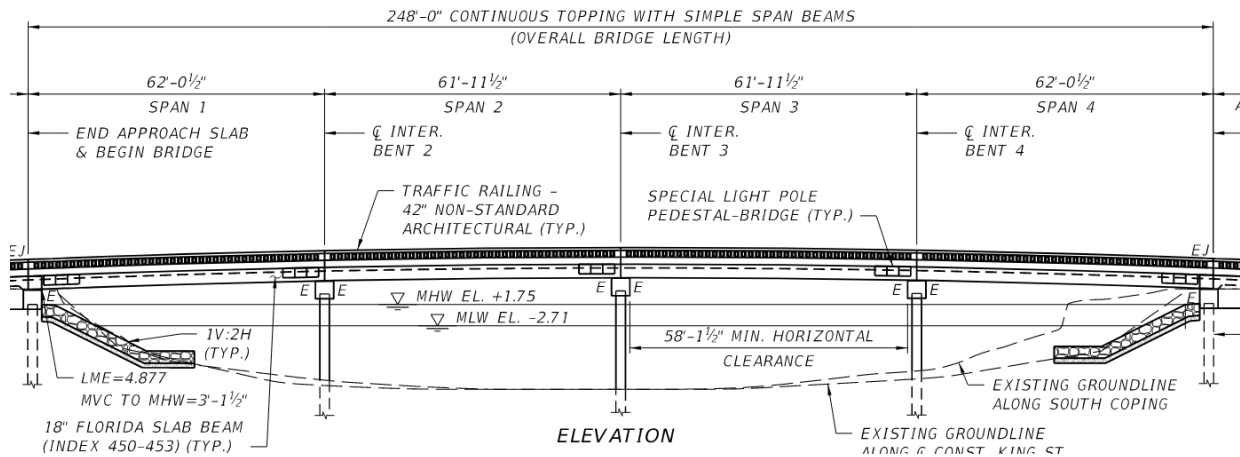
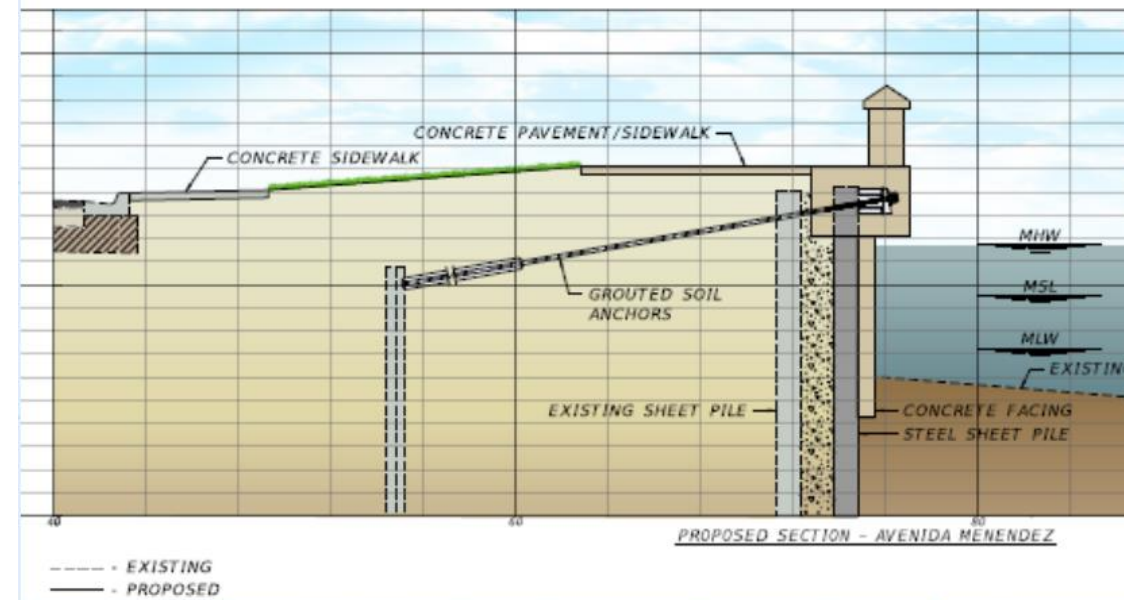


Figure 2 - Proposed Bulkhead Typical Section



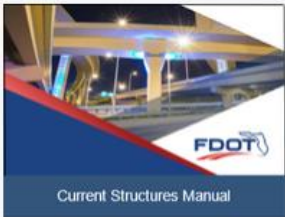
More Info: FRP RC/PC Design Innovation Webpage

WELCOME TO THE STRUCTURES DESIGN OFFICE

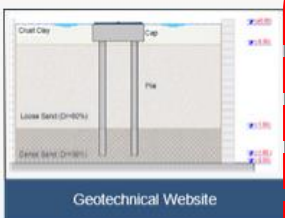
Office Manager: Will Potter, P.E. – State Structures Design Engineer

The Structures Design Office provides design guidance and technical assistance for structural, geotechnical, mechanical and electrical issues related to structural design and construction. The Structures Design Office is 1 of 3 divisions under the **Office of Design**, along with **Roadway Design**, and the **CADD Office**.

Most Requested

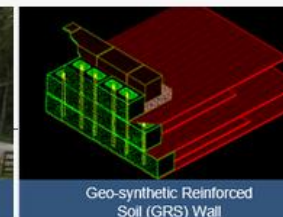


Structures Divisions



Structures Design Office

Contact: [Steven Nolan, P.E.](#) Phone: (850) 414-4272



Fiber Reinforced Polymer Reinforcing

Structures Design - Transportation Innovation
Fiber Reinforced Polymer (FRP)
Reinforcing Bars and Strands

- [Overview](#)
- [Usage Restrictions / Parameters](#)
- [Design Criteria](#)
- [Specifications](#)
- [Standards](#)
- [Producer Quality Control Program](#)
- [Projects](#)
- [Technology Transfer \(T²\)](#)
- [FDOT Research](#)
- [Contact](#)

TRANSPORTATION SYMPOSIUM



NO text.

NO call.

NOTHING

is worth losing a life over.



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Florida Dept. of Transportation

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Website: <https://www.fdot.gov/design/Innovation/>





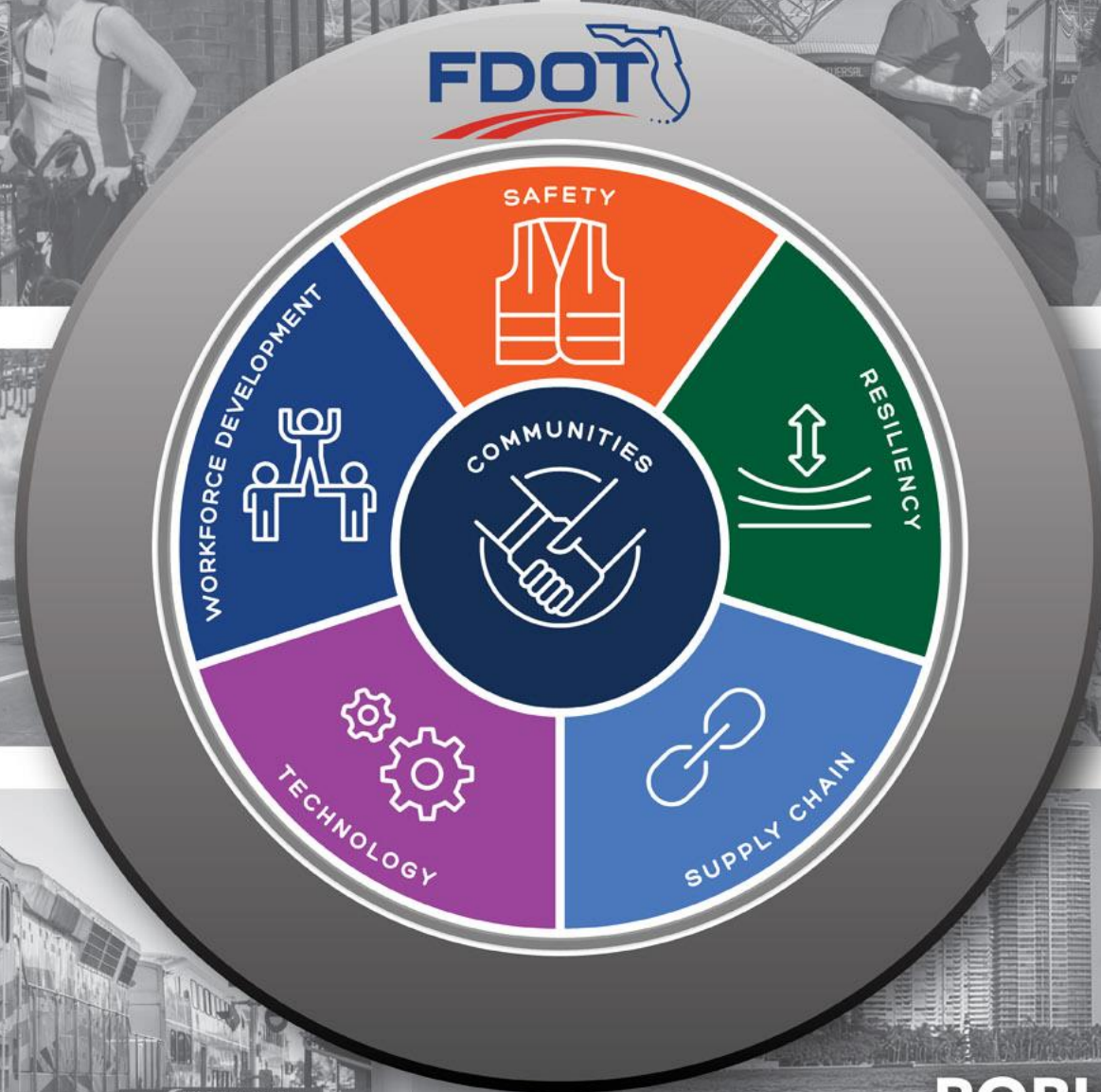
SAFETY



COMMUNITIES



WORKFORCE DEVELOPMENT



RESILIENCY



TECHNOLOGY



ROBUST SUPPLY CHAIN

Extra Slides