CAMX

THE COMPOSITES AND ADVANCED MATERIALS EXPO

September 26–29, 2016: Conference / September 27–29, 2016: Exhibits
Anaheim Convention Center / Anaheim, California

COMBINED STRENGTH.
UNSURPASSED INNOVATION.

INDUSTRY LEADERS COMPOSITES ADVANCED MATERIALS EDU

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PRODUCED BY
ACMA
American Composites Manufacturers Association
SAMPE

Fiber-Reinforced Polymer Deployment for Florida DOT Structural Applications

(for new construction)

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THE COMPOSITES AND ADVANCED MATERIALS EXPO
Anaheim Convention Center | Anaheim, California, USA

SUMMARY

Florida Department of Transportation (***FDOT***) recently embarked on a series of innovations under their ***Invitation for Innovation*** initiative (now ***Innovation Rising***), one of which focused on Fiber-Reinforced Polymer (FRP) deployment for structural applications.

The goal was to improve durability, encourage innovation and investment in the FRP transportation infrastructure market and ultimately reduce life-cycle costs and improve performance. This presentation describes the motivation, incubation, implementation and monitoring that support this initiative. One of the key strategies identified by the FDOT for successful deployment of this FRP effort was standardization, tempered with flexibility to accommodate customization while leveraging the enhanced properties of manufactured FRP products.

The intention is to instill confidence in the stakeholders [1] while economizing the final product under a lowest-cost bid procurement system typically encumbered on State Transportation Agencies.

[1] Stakeholders include: Owners; Designers; Inspectors; FRP Manufacturers; Precast Concrete Producers; and Construction Contractors.

The continuing challenge is to accommodate the diametrically opposed strategies of standardization and customization.

Four ***FDOT*** standardized FRP structural systems in various stages of deployment will be discussed:

1. **Bridge Navigation Fender Systems**;
2. **CFRP Prestressed Concrete Bearing Piles**;
3. **CFRP Prestressed/GFRP Reinforced Concrete Sheet Piles**;
4. **GFRP Reinforced Concrete Bulkhead/Seawall Caps**.

Additionally, one bridge replacement project [2] and three seawall rehabilitation projects will be presented, utilizing these standardized elements, plus additional GFRP reinforced concrete components including: **foundations, approach slabs, bridge deck** and **traffic railings**.

[2] Monitoring of this project will be undertaken as part of the field demonstration portion (WP4) of the ***Infravation-SEACON*** *research project. In addition to the bridge and seawall components, 570 feet of removable test beams with four different types of FRP reinforcing (carbon strand, carbon bar, glass bar and basalt bar) will be located in the splash-zone of this marine environment and periodically removed for testing to verify the degradation models that are assumed for FRP reinforced concrete design under* ***ACI 440.1R****.*

Key Topics

Topic #1: Standardization vs. Customization for FDOT
[10 slides]

Topic #2: Leveraging the most benefit from FRP for FDOT
[7 slides]

Topic #3: Bridge Navigation Fender Systems
[4 slides]

Topic #4: CFRP Prestressed Concrete Bearing Piles
[4 slides]

Topic #5: CFRP/GFRP Reinforced Concrete Sheet Piles
[5 slides]

Topic #6: GFRP Reinforced Concrete Bulkhead/Seawalls
[9 of slides]

Topic #7: Project Examples
[23 slides]

Topic #1

Standardization vs. Customization for FDOT

i. FDOT standardization for transportation infrastructure:
   - Design Criteria;
   - Material Specifications;
   - Construction Specifications;
   - Design Drawings;

ii. Approved Products List (***APL***);

iii. Approved Producers List (Producers with Accepted QC Programs);

iv. Customized designs by producers (APL vs QCP inclusion);

v. Customized designs by Consultant Engineers:
   - Engineer of Record during design (Design-Bid-Build);
   - Contractor proposal (Design-Bid-Build);
   - Design-Build projects.

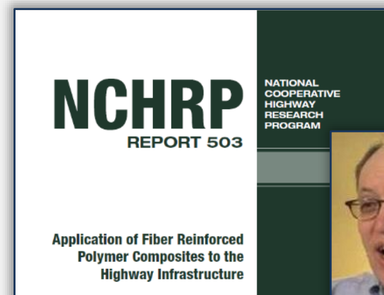
Topic #1

Standardization vs. Customization for FDOT

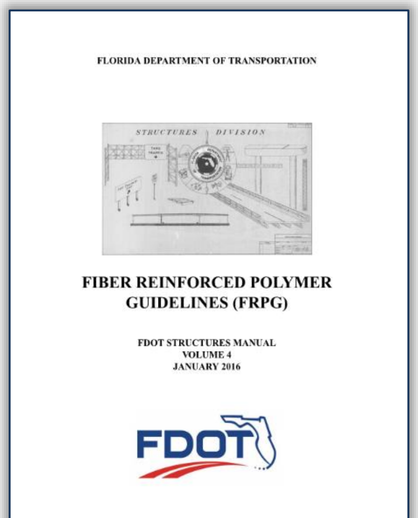
i. FDOT standardization for transportation infrastructure:

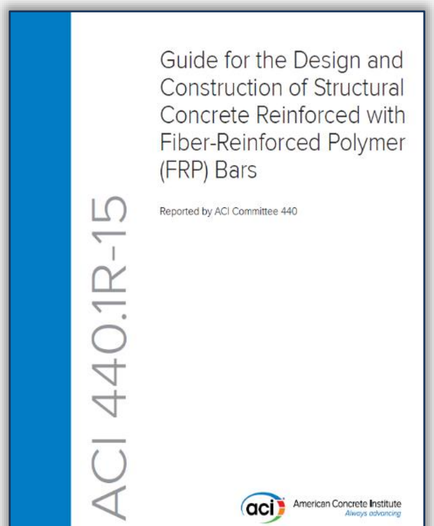
- Design Criteria:
  - FDOT ***Structures Manual*** (Vol.4) – ***FRPG;***
  - ***ACI*** 440.1R-15 and ***ACI*** 440.4R-04/11;
  - ***AASHTO*** GFRP Guide Specification;
- Material Specifications:
  - FDOT Standard Specifications 900 series;
  - ASTM WK43339; (subcommittee D30.10);
- Construction Specifications
  - FDOT ***Standard Specifications*** - 400 series;
- Standard Design Drawings/Plans:
  - FDOT ***Design Standards***
  - FDOT ***Developmental*** ***Design Standards***

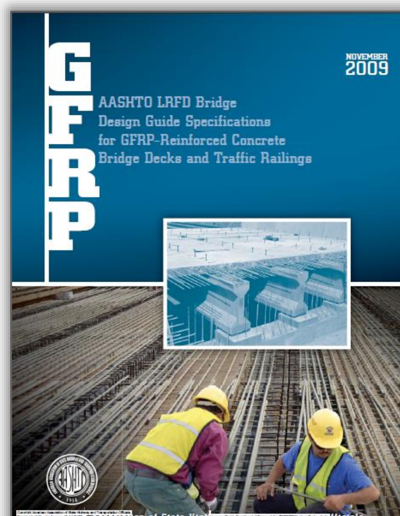
ASTM INTERNATIONAL
Helping our world work better

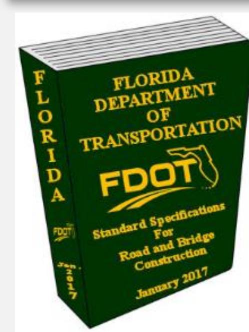


Dr. Dennis Mertz, P.E.,
(lead author)
Professor of Civil and Environmental Engineering;
Director of the Center for Innovative Bridge Engineering at the University of Delaware.









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Topic #1

Standardization vs. Customization for FDOT

Extracts from *NCHRP Report 503* – Section 1, (2003):

Lack of Encouragement from Government Agencies

The government has the ability to encourage, limit, and even foreclose entry of industries into government-funded programs with procurement regulations, training, and similar items. To date, the U.S. government has provided sporadic support of FRP applications in highway construction, but has made no indication of full support in the future. Lack of a clear signal of intent or encouragement from government agencies undermines FRP suppliers' confidence in the viability of a long-term market.

Bridge Design Objectives

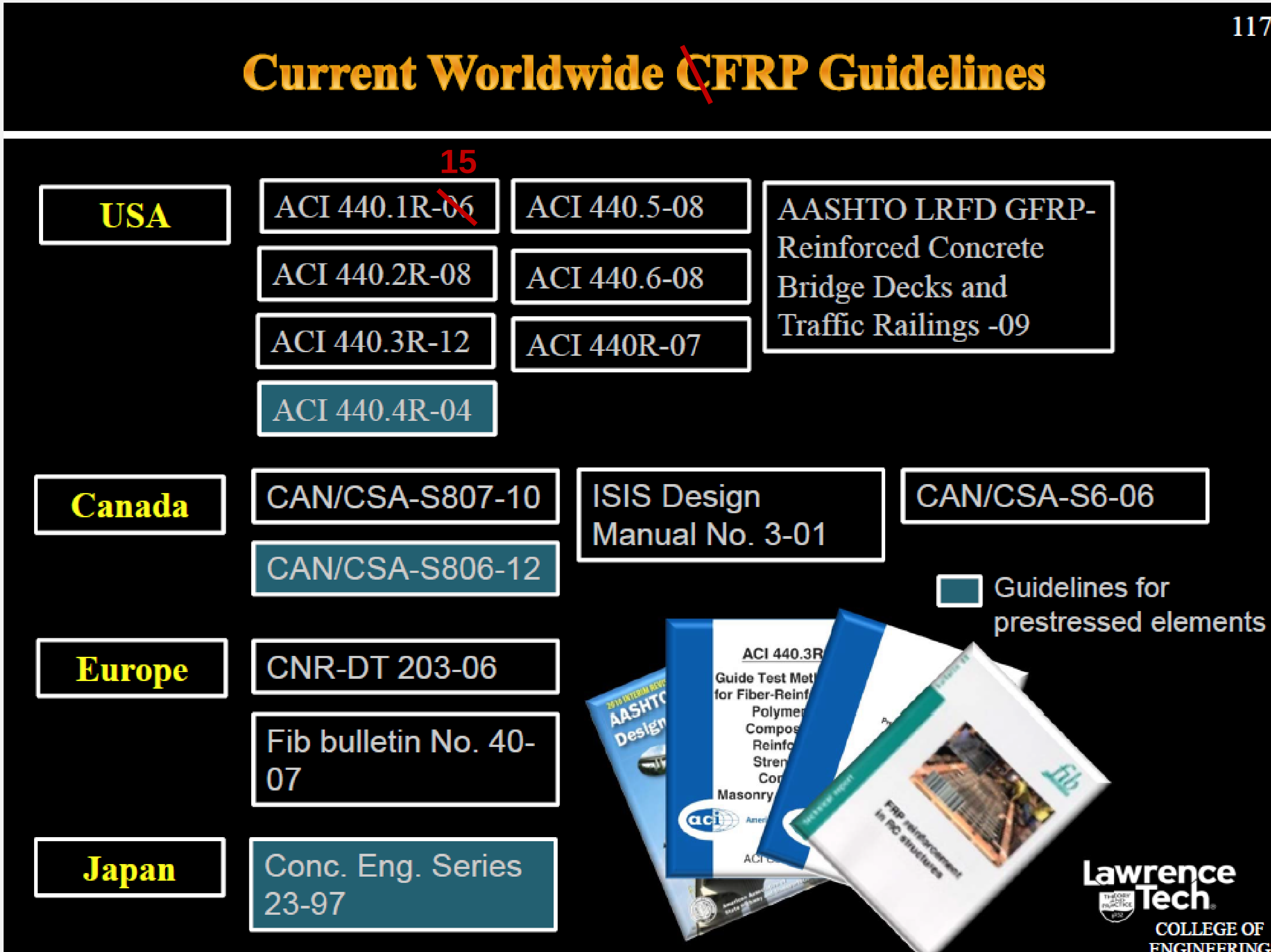
The culture of the FRP composite materials industry must adapt to the culture of the bridge community for FRP composites to be successfully implemented. The bridge community has no pressing need to adapt to using FRP composites; FRP composites are not required to design bridges. For the most part, bridge designers believe that the bridges they design of concrete, steel, and/or wood are performing adequately. The only area in which improvement may be desired is in bridge durability. FRP composites' potential for more durability and greater cost-effectiveness in terms of lifecycle costs may open the door to the bridge-construction industry.

White Paper 5: FRP Composites as Internal Reinforcement of Concrete Components

…Unfortunately, the increased initial cost of FRP internal reinforcement may be a disadvantage as enhanced traditional-material applications with lower life-cycle costs are developed. Designers looking further into the future warn of the foolhardiness of merely replacing one material with another. They suggest that the components should be redesigned to better use the new material's enhanced attributes. This may be the case for internal reinforcement of concrete components with FRP composite materials.

Topic #1

Standardization vs. Customization for FDOT

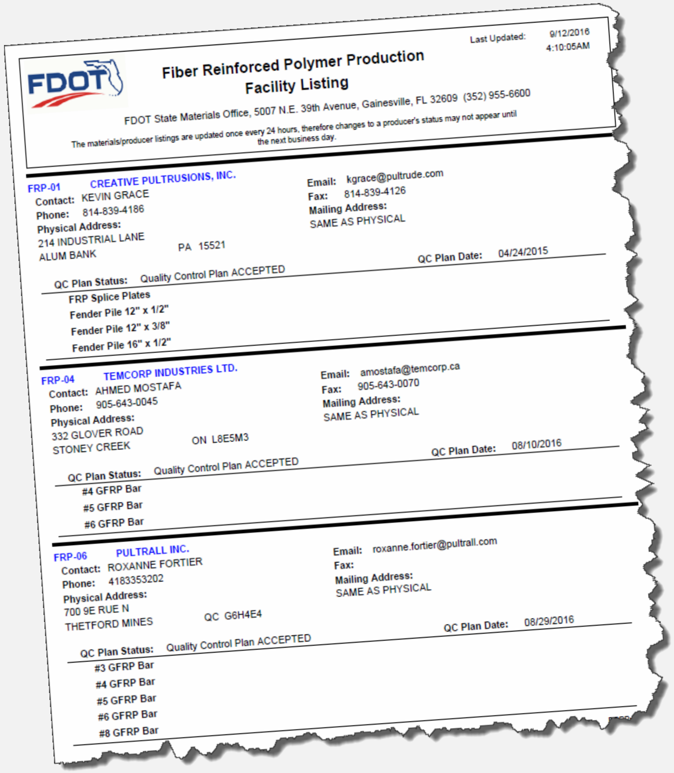


Source:
Ohio Bridge Design Conference
presentation, "New Generation of Sustainable CFRP Prestressed Concrete Highway Bridges", slides 25-26. (Dr. Nabil Grace, 2014)

Topic #1

Standardization vs. Customization for FDOT

ii. Approved Products List ([***APL***]);
iii. Approved Producers List ([Producers with Accepted QC Programs]);
iv. Customized designed by producers (***APL*** vs. ***QC Plan*** inclusion);
v. Customized design by Consulting Engineers*
   - During design (Design-Bid-Build);
   - Contractor proposals: Design-Bid-Build (by Contract or ***CSIP***);
   - Contractor proposals: Design-Build projects (by ***RFP*** or ***ATC***)



FDOT

Fiber Reinforced Polymer Production Facility Listing

Last Updated: 9/12/2016 4:10:05AM

FDOT State Materials Office, 5007 N.E. 39th Avenue, Gainesville, FL 32609 (352) 955-6600

The materials/producer listings are updated once every 24 hours, therefore changes to a producer's status may not appear until the next business day.

FRP-01 CREATIVE PULTRUSIONS, INC.
Contact: KEVIN GRACE
Phone: 814-839-4186
Physical Address:
214 INDUSTRIAL LANE
ALUM BANK PA 15521
Email: kgrace@pultrude.com
Fax: 814-839-4126
Mailing Address:
SAME AS PHYSICAL
QC Plan Status: Quality Control Plan ACCEPTED
QC Plan Date: 04/24/2015
FRP Splice Plates
Fender Pile 12" x 1/2"
Fender Pile 12" x 3/8"
Fender Pile 16" x 1/2"

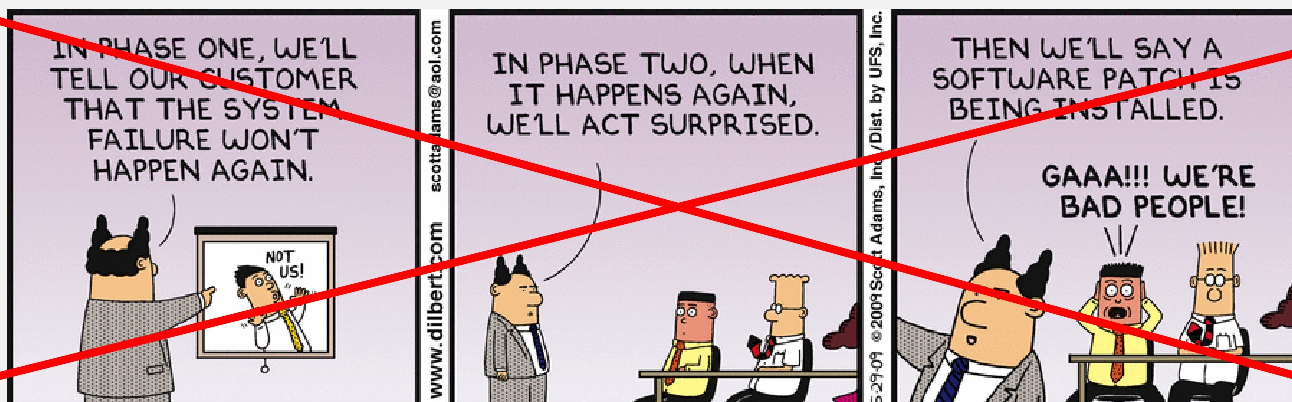
FRP-04 TEMCORP INDUSTRIES LTD.
Contact: AHMED MOSTAFA
Phone: 905-643-0045
Physical Address:
332 GLOVER ROAD
STONEY CREEK ON L8E5M3
Email: amostafa@temcorp.ca
Fax: 905-643-0070
Mailing Address:
SAME AS PHYSICAL
QC Plan Status: Quality Control Plan ACCEPTED
QC Plan Date: 08/10/2016
#4 GFRP Bar
#5 GFRP Bar
#6 GFRP Bar

FRP-06 PULTRALL INC.
Contact: ROXANNE FORTIER
Phone: 4183353202
Physical Address:
700 9E RUE N
THETFORD MINES QC G6H4E4
Email: roxanne.fortier@pultrall.com
Fax:
Mailing Address:
SAME AS PHYSICAL
QC Plan Status: Quality Control Plan ACCEPTED
QC Plan Date: 08/29/2016
#3 GFRP Bar
#4 GFRP Bar
#5 GFRP Bar
#6 GFRP Bar
#8 GFRP Bar

* *Qualifications meeting **Florida Administrative Code** Rule 14-75*
CSIP = Contractor Savings Initiative Proposal
RFP = Request For Proposal
ATC = Alternative Technical Proposal

Topic #1

…and effective Implementation thru Technology Transfer (guided T^2)



Topic #1

Technology Transfer (T^2)

NCHRP Report 768 (2014):

10 key components provide practitioners with a "roadmap" through a guided T^2 process:

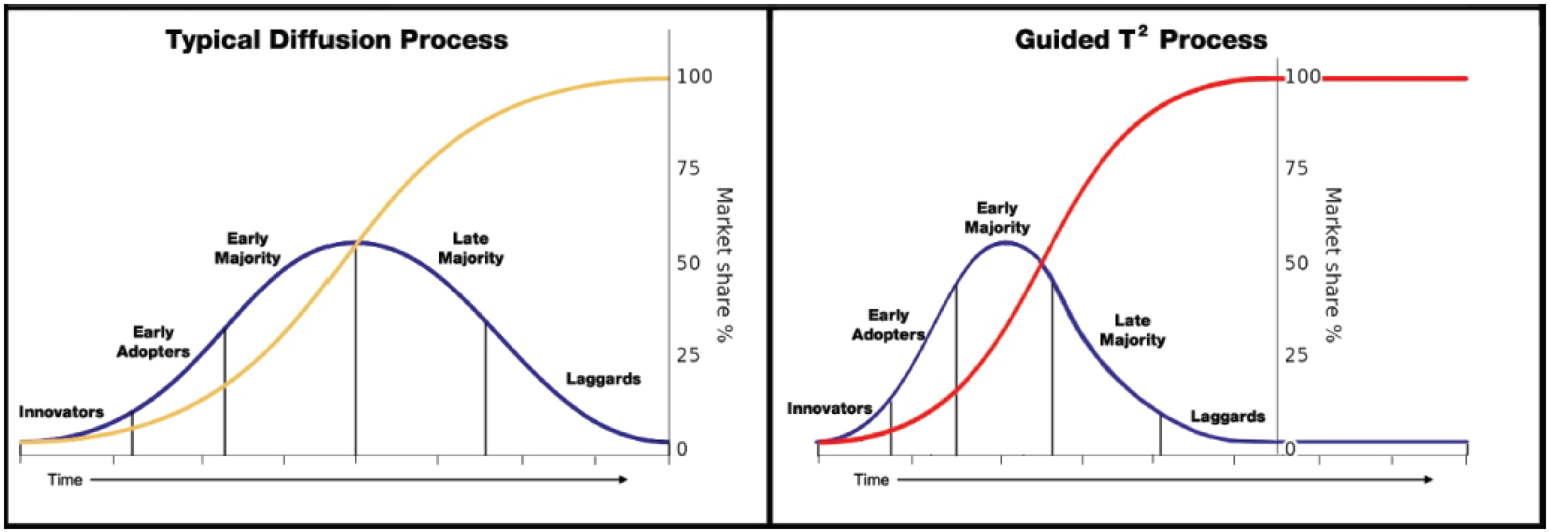
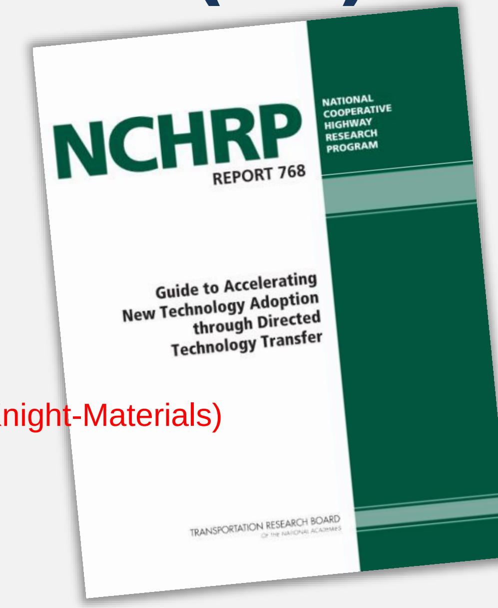


Figure 1-2. Conceptual representation of the intent of guided T^2.

Topic #1

Technology Transfer (T^2)

NCHRP Report 768 (2014):



10 key components provide practitioners with a "roadmap" through a guided T^2 process:

1. Address societal and legal issues;
2. Have an effective champion; (Rick Vallier-Structures / Chase Knight-Materials)
3. Engage decision makers;
   - FDOT-FHWA Corrosion-Resistant Rebar Seminar – 07/17/12;
   - FRP Rebar Industry-FDOT Workshop – 06/15/16;
   - ACMA-Transportation Structures Council - CAMX 9/29/16;
4. Develop a T^2 plan; (Developmental Design Standards Reports, Roadmap for FRP Deployment...)
5. Identify, inform, and engage stakeholders; (***Invitation to Innovation***, FDOT-SRC Research Update webinars, FDOT Design Training Expo, …)
6. Identify and secure resources; (***Structures Manual-FRPG***, Developmental Specs. & ***DDS***)
7. Conduct demonstrations/showcases; (Halls River Bridge, Haulover Cut Rehab. - 2017)
8. Educate, inform, and provide technical assistance;
   - FTBA/FDOT Construction Conference - Feb. 2017;
   - Halls River Workshop – May 2017;
   - FDOT Design Expo – June 2017;
9. Evaluate progress; (***SEACON***, FDOT Monitoring Project 430021-1-62-03)
10. Reach [wider] deployment decision; (***Design Standards***)

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Topic #1

Technology Transfer (T^2)

FDOT-SDO's: Design Technology Section (Standards Group):

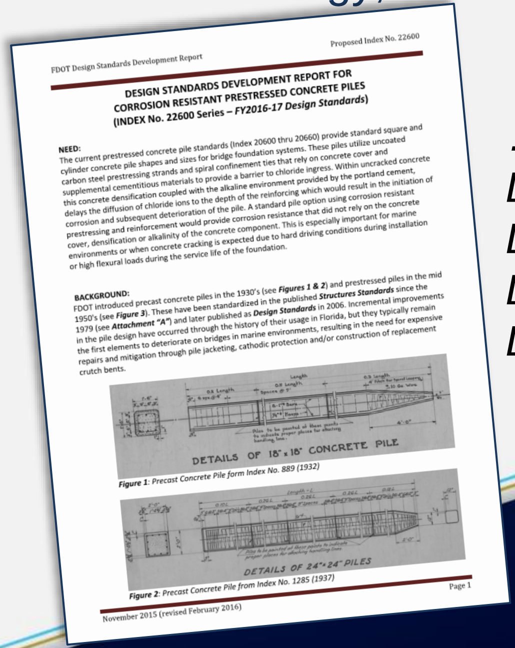
***Developmental Design Standards** (**DDS**)* are our primary tool for guided T^2 implementation.

- Rapid deployment;
- Open access but controlled usage (*DDS website*);
- Nimble change process;
- Customizable when necessary for project specific challenges;
- Tracking and monitoring.

http://www.dot.state.fl.us/rddesign/DS/Dev.shtm

***Design Standards Development Reports (DSDR's)** are a complementary tool useful in assisting deployment:*

- Identify needs;
- Proposes solutions;
- Proposes implementation strategy;



FDOT Design Standards Development Report — Proposed Index No. 22600

DESIGN STANDARDS DEVELOPMENT REPORT FOR CORROSION RESISTANT PRESTRESSED CONCRETE PILES (INDEX No. 22600 Series – *FY2016-17 Design Standards*)

NEED:
The current prestressed concrete pile standards (Index 20600 thru 20660) provide standard square and cylinder concrete pile shapes and sizes for bridge foundation systems. These piles utilize uncoated carbon steel prestressing strands and spiral confinement ties that rely on concrete cover and supplemental cementitious materials to provide a barrier to chloride ingress. Within uncracked concrete this concrete densification coupled with the alkaline environment provided by the portland cement, delays the diffusion of chloride ions to the depth of the reinforcing which would result in the initiation of corrosion and subsequent deterioration of the pile. A standard pile option using corrosion resistant prestressing and reinforcement would provide corrosion resistance that did not rely on the concrete cover, densification or alkalinity of the concrete component. This is especially important for marine environments or when concrete cracking is expected due to hard driving conditions during installation or high flexural loads during the service life of the foundation.

BACKGROUND:
FDOT introduced precast concrete piles in the 1930's (see ***Figures 1 & 2***) and prestressed piles in the mid 1950's (see ***Figure 3***). These have been standardized in the published ***Structures Standards*** since the 1979 (see ***Attachment "A"***) and later published as ***Design Standards*** in 2006. Incremental improvements in the pile design have occurred through the history of their usage in Florida, but they typically remain the first elements to deteriorate on bridges in marine environments, resulting in the need for expensive repairs and mitigation through pile jacketing, cathodic protection and/or construction of replacement crutch bents.

***Figure 1**: Precast Concrete Pile form Index No. 889 (1932)*

***Figure 2**: Precast Concrete Pile from Index No. 1285 (1937)*

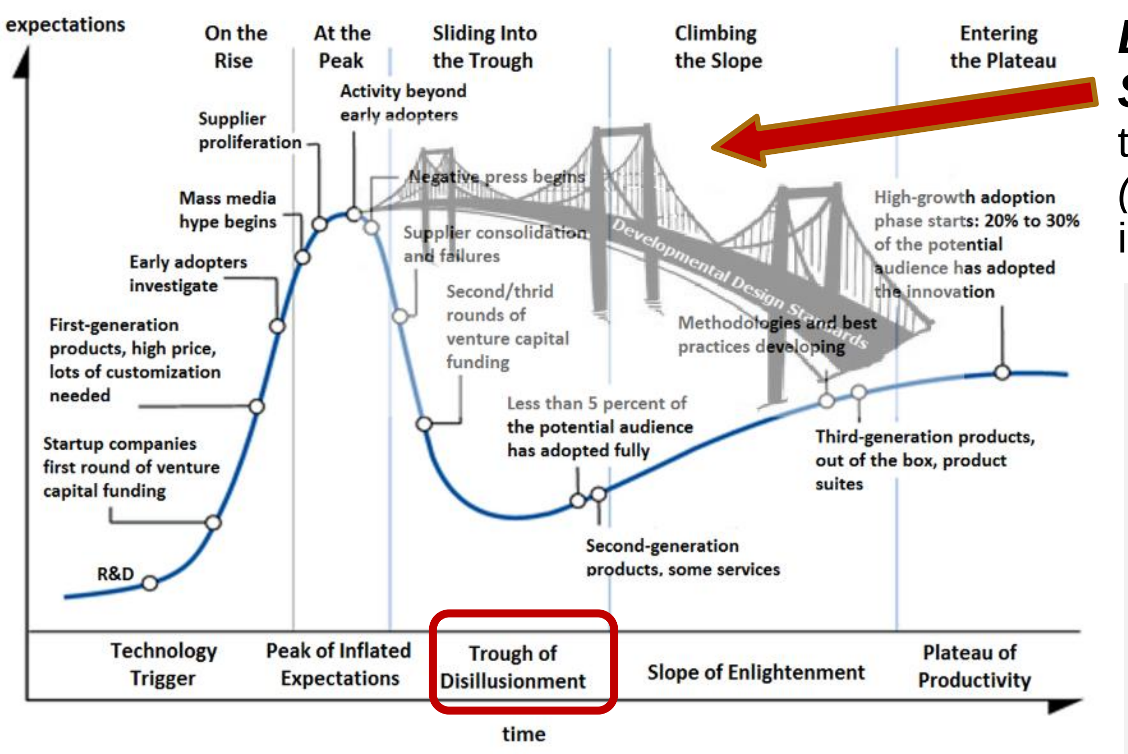
Page 1

November 2015 (revised February 2016)

…
DSDR-22420
DSDR-22440
DSDR-22600
DSDR-22900

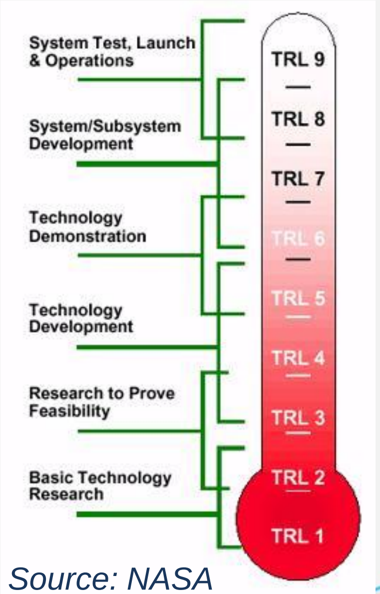
Topic #1

Technology Transfer (T^2)

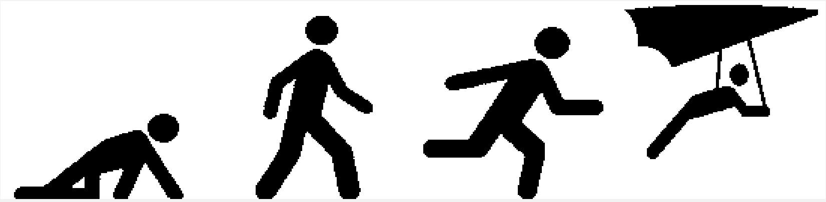


Source: Gartner Inc. Hype Cycle

Developmental Design Standards (***DDS***) can bridge the *"Trough of Disillusionment" (or Valley of Death)* for effective implementation!



Source: NASA



Research (TRL 1-3) → Demonstration Project (TRL 4-5) → Developmental (*DDS*) Index (TRL 6-8) → Design Standard Index (TRL 9)

Topic #2

Leveraging the most benefit from FRP for FDOT

i. Why composites:
  - Avoiding corrosion *"concrete cancer"*
    - GFRP rebar
    - CFRP prestressing strand
  - Polymeric piling durability & toughness

ii. Cost-Benefit Analysis;

iii. Durability/Service Life;

iv. Mitigating Risks
  - New Material Systems;
  - Limited suppliers/competition;
  - Unfamiliar design criteria;
  - Unfamiliar construction practices.

New and Old Seven-Mile-Bridge, (Florida Keys)

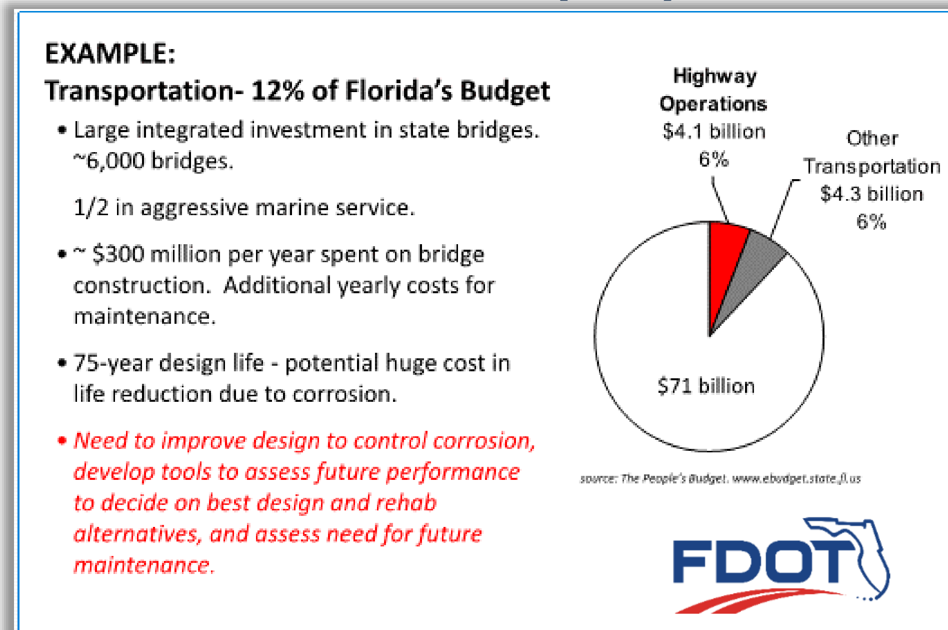
Courtney Campbell Causeway, seawall (Tampa Bay)

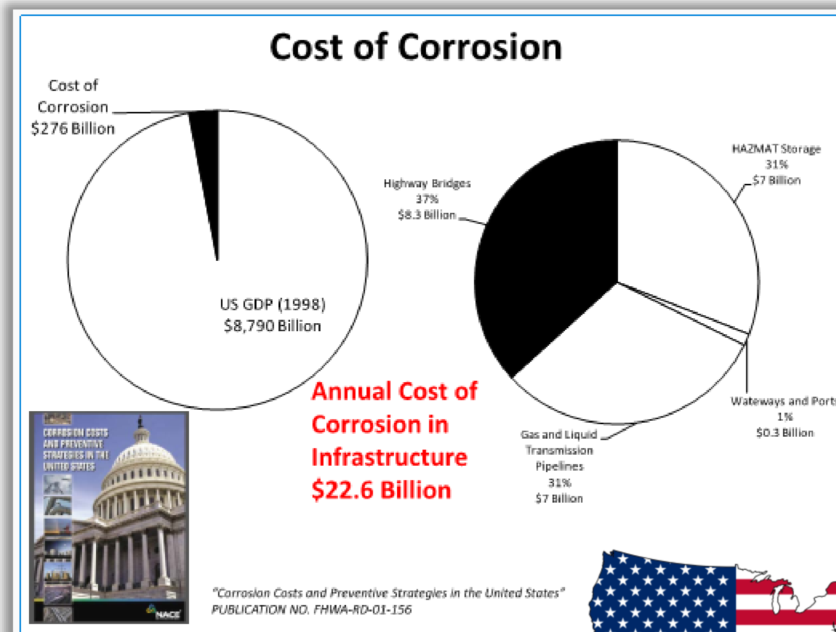
Gandy Blvd. seawall, (Tampa Bay)

Topic #2

Leveraging the most benefit from FRP for FDOT

- Example costs of corrosion ($$)





https://www.nace.org/uploadedFiles/Publications/ccsupp.pdf

Chart: FY 2012-2013 http://www.floridafirstbudget.com/
(FY 2015-16: Total = $78B, Hwy.Op. = $5.6B, Other = $4.4)
from TRB webinar "[Controlling Corrosion of Infrastructure Systems](#)" – K. Lau & M. O'Reilly, August 2016.

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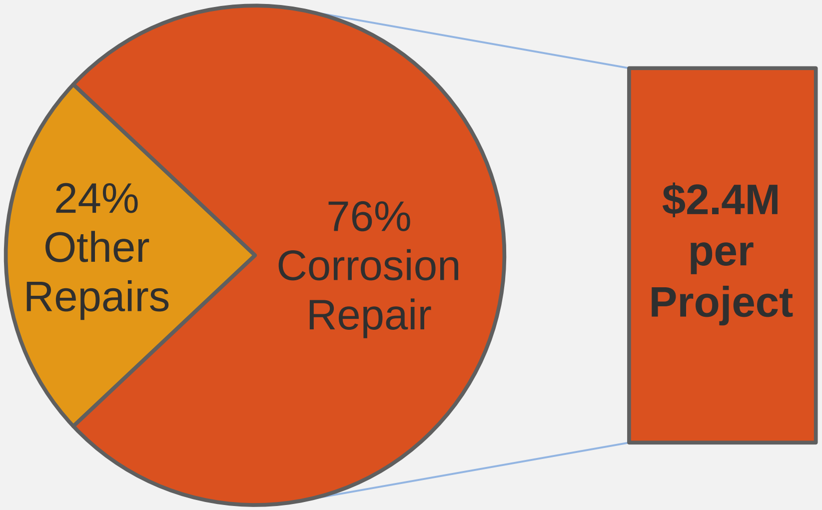
Topic #2

Leveraging the most benefit from FRP for FDOT

- Example costs of corrosion (District 7)

  - Repair cost of bridges in District 7 *(FY 2002/03 to 2012/13)*
  - 54 Bridge projects studied (20 Steel Bridges and 34 Concrete Bridges)

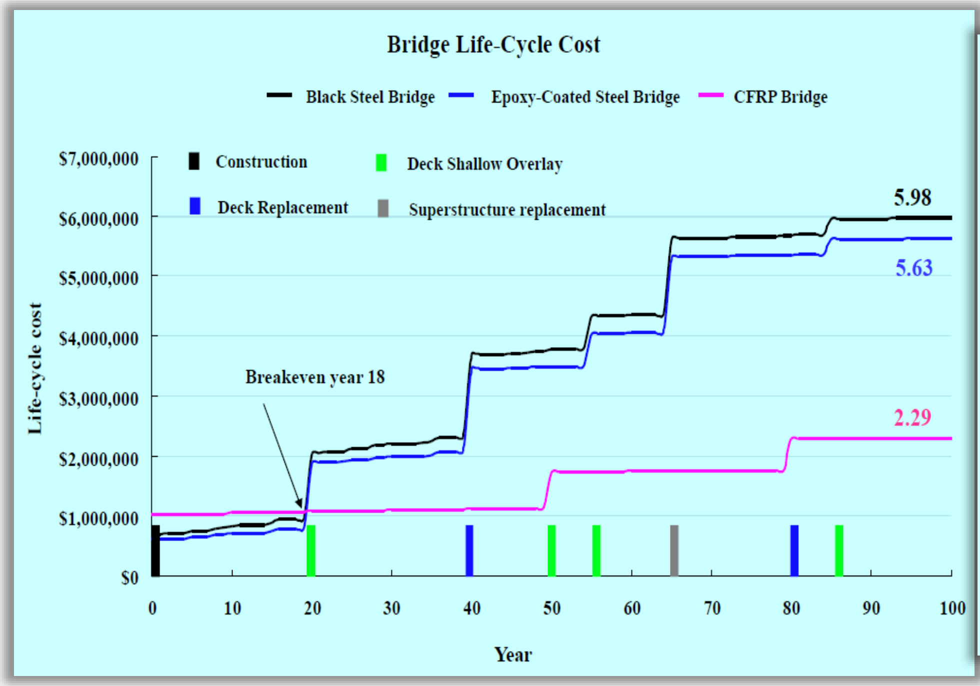


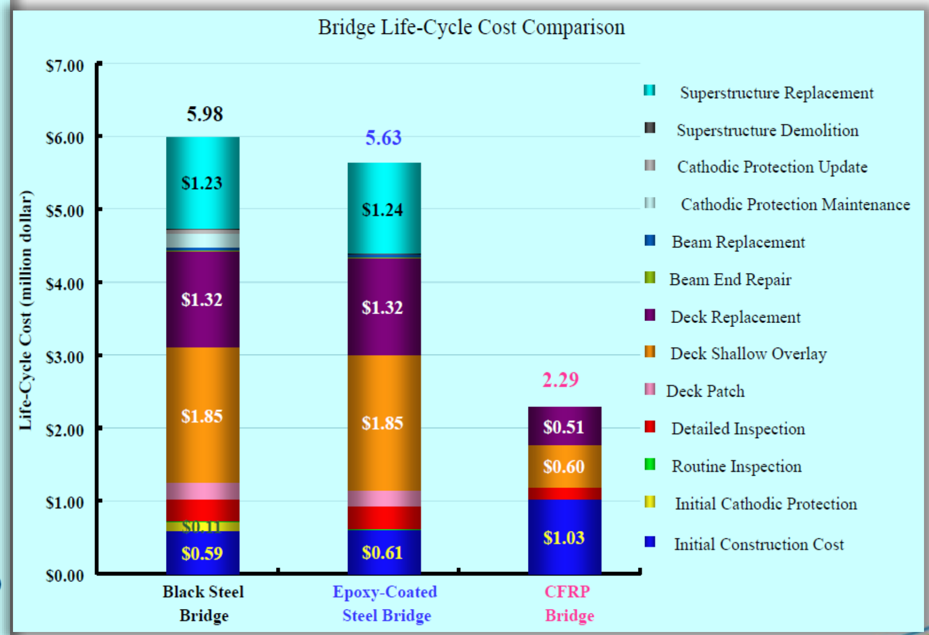
Source: FDOT D7 District Structures Maintenance Office & T.Y. Lin

Topic #2

Leveraging the most benefit from FRP for FDOT

- Bridge Life-Cycle Cost





Source: ***Ohio Bridge Design Conference presentation****, "New Generation of Sustainable CFRP Prestressed Concrete Highway Bridges", slides 25-26. (Dr. Nabil Grace, 2014)*

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Topic #2

Leveraging the most benefit from FRP for FDOT

- Service Life Enhancement thru Durability:
  - 50 years under ***AASHTO Standard Specification for Highway Bridges*** (1970's??? - 2002)
  - 75 years under ***AASHTO LRFD Bridge Design Specification*** (1994 – present)
  - 100 years +, ***SHRP2-R19A-RW-1*** "Bridges for Service Life beyond 100 Years: Innovative Systems, Subsystems and Components" *(Design Guide for Bridges for Service Life , Publication S2-R19A-RW-2, Section 3.2.2.10 FRP) 2013.*

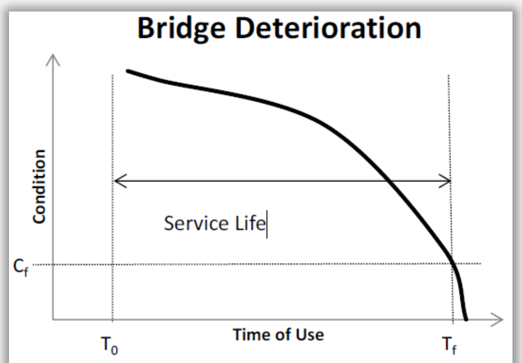


Figure 1.11. An example of bridge deterioration curve.

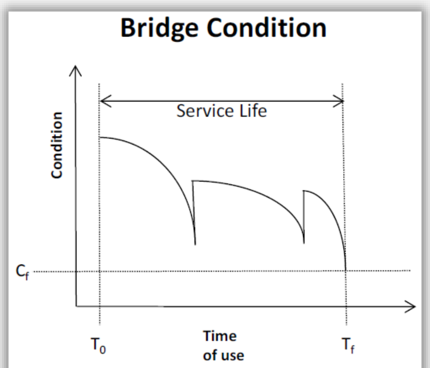
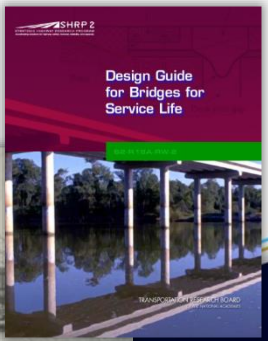


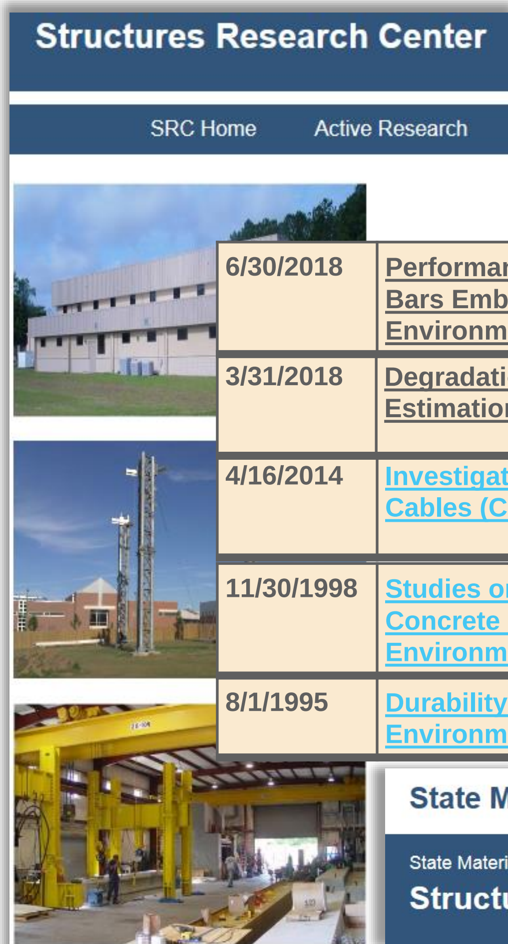
Figure 1.12. Bridge condition life cycle.

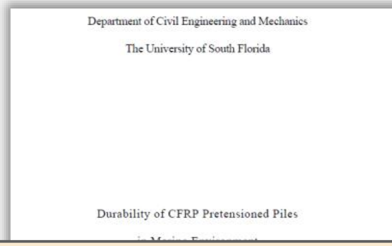


Topic #2

Leveraging the most benefit from FRP for FDOT

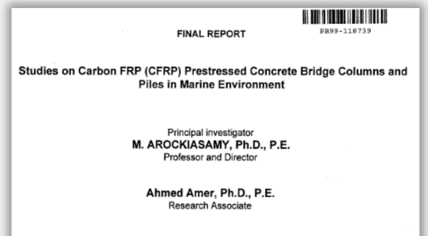
- Service Life Enhancement thru Durability:




Department of Civil Engineering and Mechanics

The University of South Florida

Durability of CFRP Pretensioned Piles


FINAL REPORT

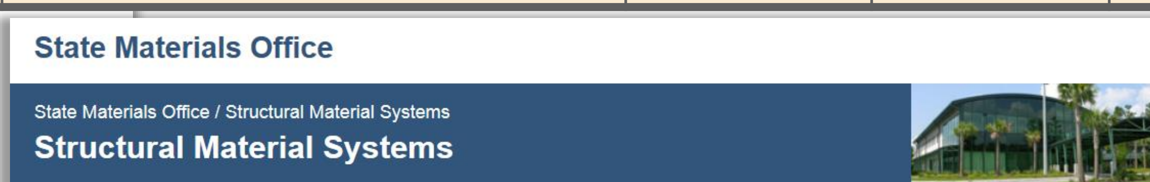
PB99-118739

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

Principal investigator
M. AROCKIASAMY, Ph.D., P.E.
Professor and Director

Ahmed Amer, Ph.D., P.E.
Research Associate

6/30/2018	Performance Evaluation of GFRP Reinforcing Bars Embedded in Concrete Under Aggressive Environments	R. Kampmann	Florida State University	BDV30 977-18
3/31/2018	Degradation Mechanisms and Service Life Estimation of FRP Concrete Reinforcements	A. El Safty	University of North Florida	BDV34 977-05
4/16/2014	Investigation of Carbon Fiber Composite Cables (CFCC) in Prestressed Concrete Piles	M. Roddenberry, P. Mtenga	Florida State University	BDK83 977-17
11/30/1998	Studies on Carbon FRP (CFRP) Prestressed Concrete Bridge Columns and Piles in Marine Environment	M Arockiasamy	Florida Atlantic University	B-9076
8/1/1995	Durability of CFRP Pretensioned Piles in Marine Environment Volume II	R. Sen	University of South Florida	0510642



Topic #2

Leveraging the most benefit from FRP for FDOT

- Mitigating Risks
  - ✓ New Material Systems;
  - ✓ Limited suppliers/competition;
  - ✓ Unfamiliar design criteria;
  - ✓ Unfamiliar construction practices.

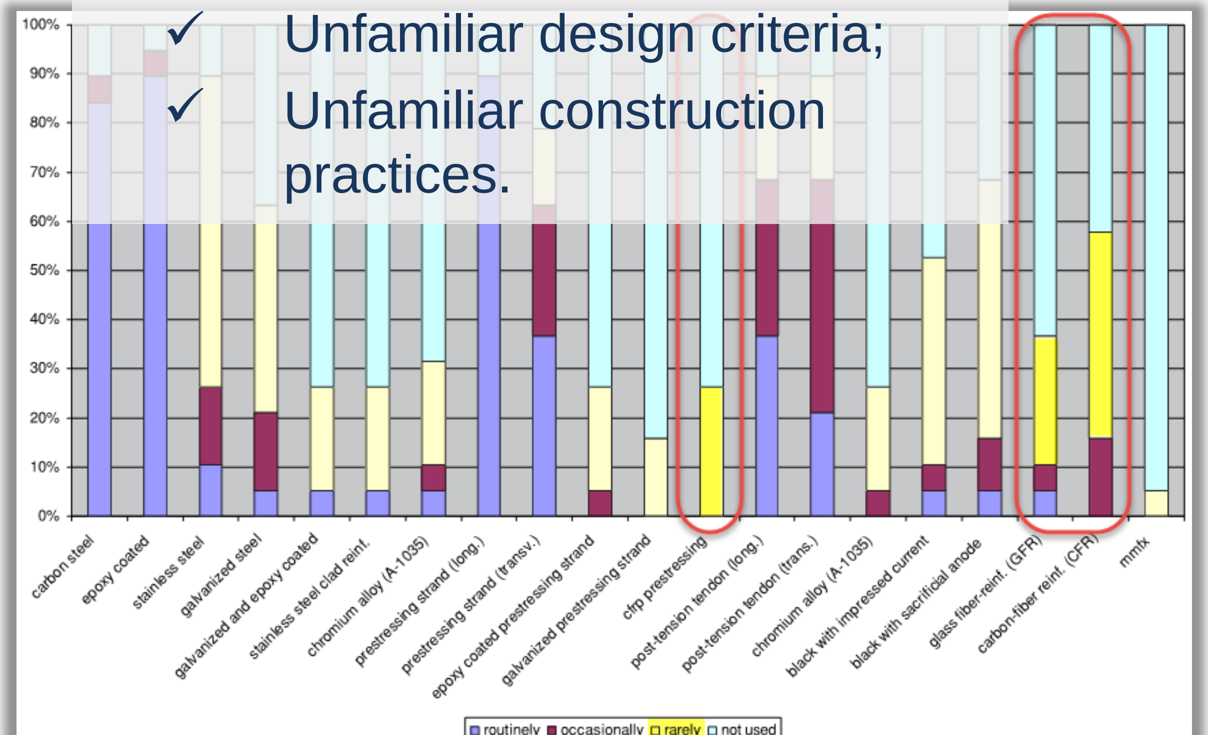
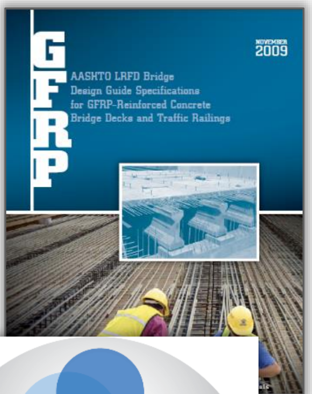


Figure 3.6. Survey results for type of reinforcement used.

Source: SHRP2-R19A-RW-1



Topic #3

Bridge Navigation Fender Systems

i. Fender System "Polymeric" Piles and Wales (***Design Standards*** *– Index 21900 series,* since 2006);

ii. FDOT ***Specifications*** *471 & 973;*

iii. Approved Products List (***APL***) for Wales *(and Piles for projects bid prior to July 2015)*;

iv. Producers with Accepted QC Programs via ***Materials Manual*** *– Section 12.1 (new projects bid since July 2015 lettings)*;

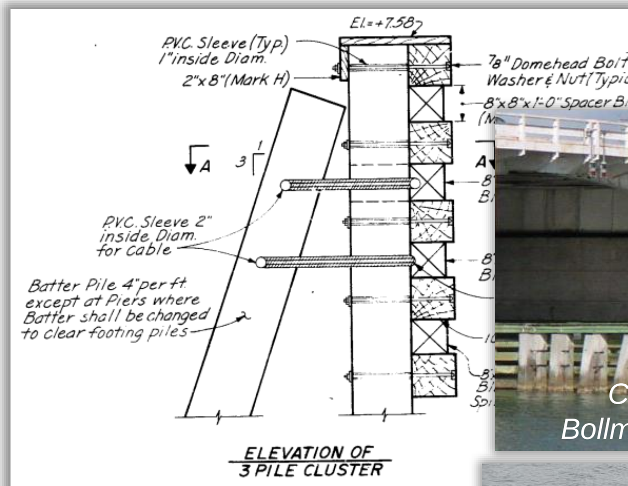
v. Custom designed systems – ***Structures Design Guidelines*** ***(SDG)*** – *Section 3.14* design criteria *(new projects bid since July 2015 lettings)*;

vi. ***Structures Detailing Manual*** ***(SDM)*** *- Chapter 24 (updated Jan 2015).*

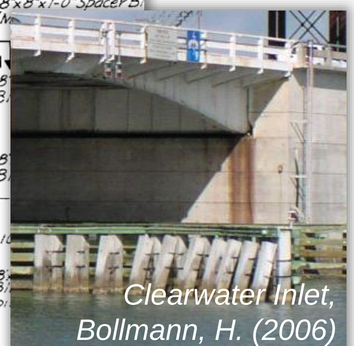
Topic #3

Bridge Navigation Fender Systems

<u>OLD</u>:
Timber and/or Concrete



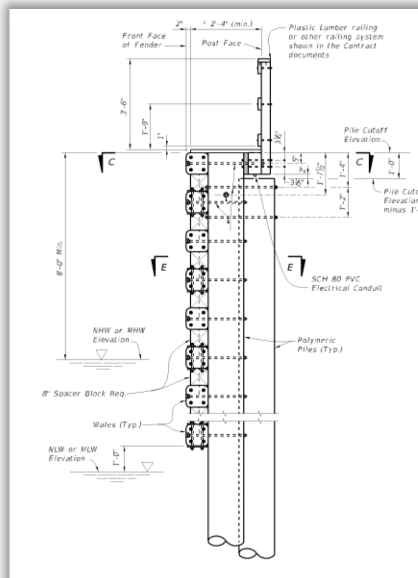
I-95/I-595 Interchange (1984)

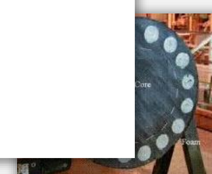

Clearwater Inlet, Bollmann, H. (2006)


Yazdani, N. (2000)

<u>NEW</u>:
FRP Composite Systems


Courtesy of: Creative Pultrusions, Inc.

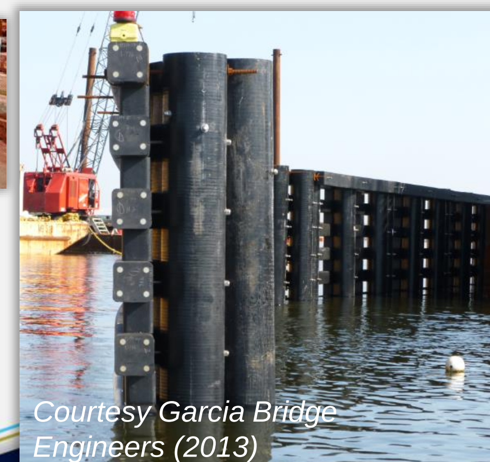




Fender System Piles and Wales:

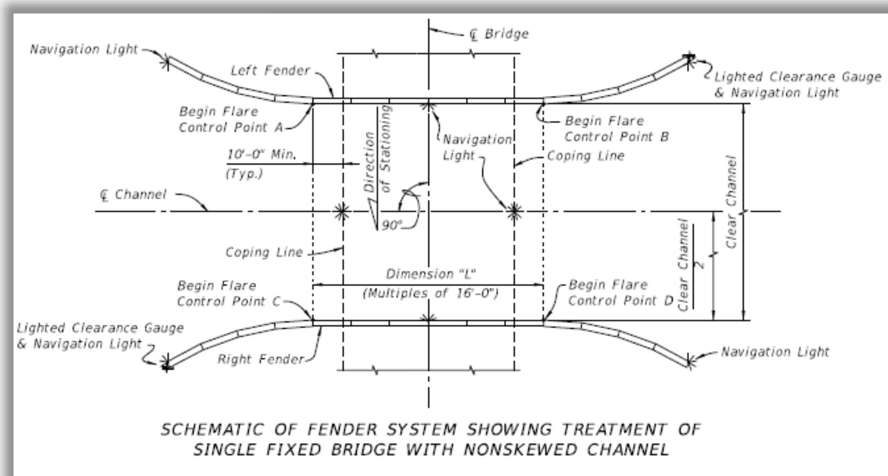
- FDOT <u>***Spec.***</u> ***471 & 973***
- New <u>Approved Producers List</u> requirements in ***MM 12.1*** *(Jan. 2015)*
- New ***Structures Detailing Manual*** - Chapter 24 *(Jan. 2015)*

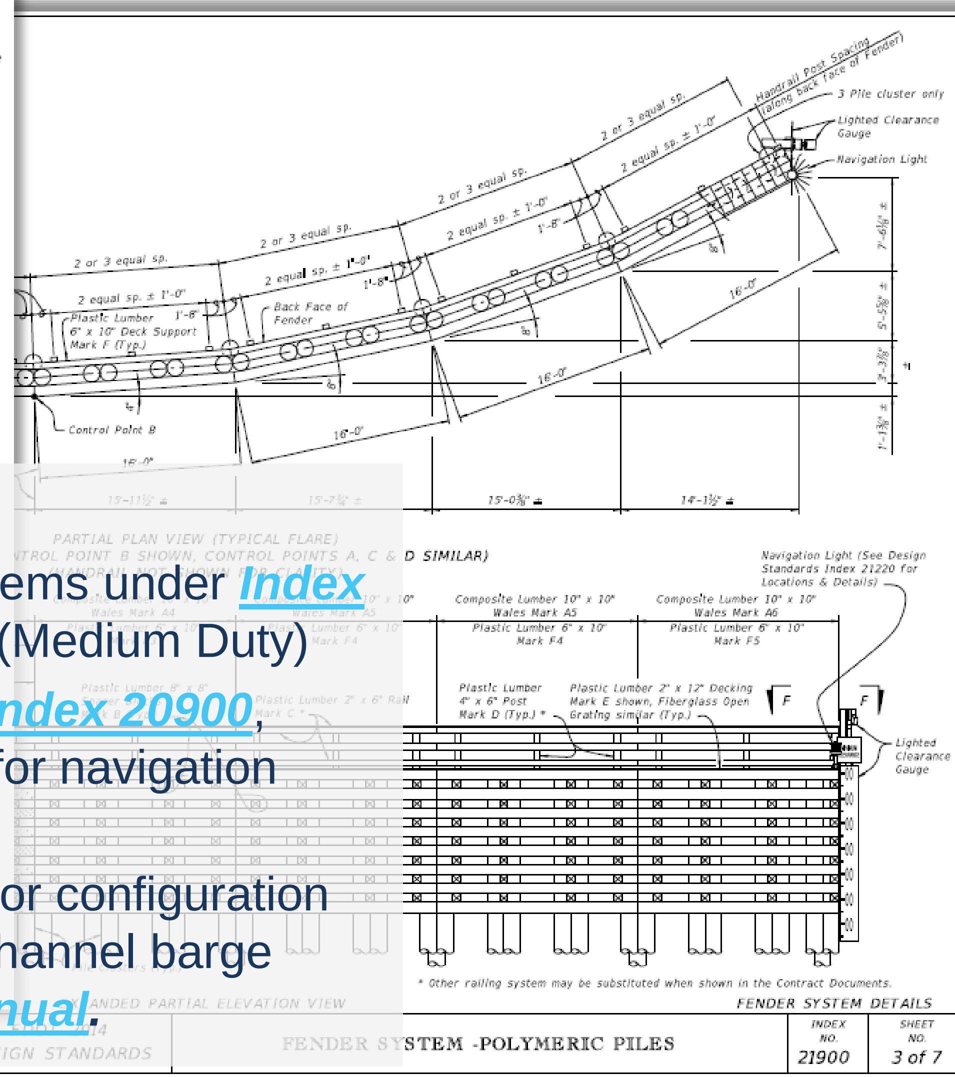

Creative Pultrusions Inc. (2014)


Courtesy Garcia Bridge Engineers (2013)

Topic #3

Bridge Navigation Fender Systems





NEW (cont.)

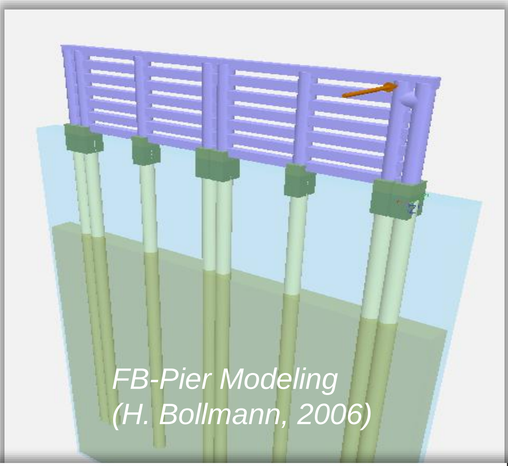
- 2006 – 2011, Predesigned FRP Systems under ***Index 21910*** (Heavy Duty) & ***Index 21920*** (Medium Duty)
- 2011 – 2015: Preset spacing under ***Index 20900***, Contractor/ Vendor designs tailored for navigation channel barge population generic;
- 2015+: Customized Contractor/Vendor configuration and designs tailored for navigation channel barge population based on ***Structures Manual***.

Topic #3

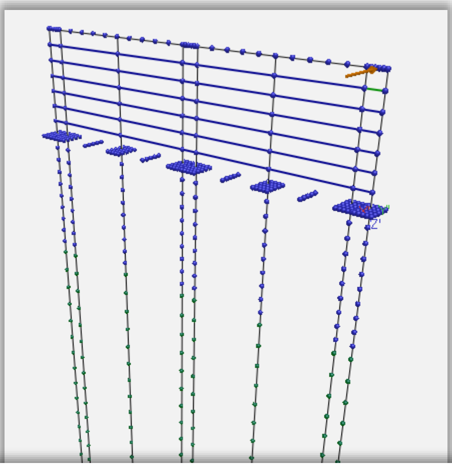
Bridge Navigation Fender Systems

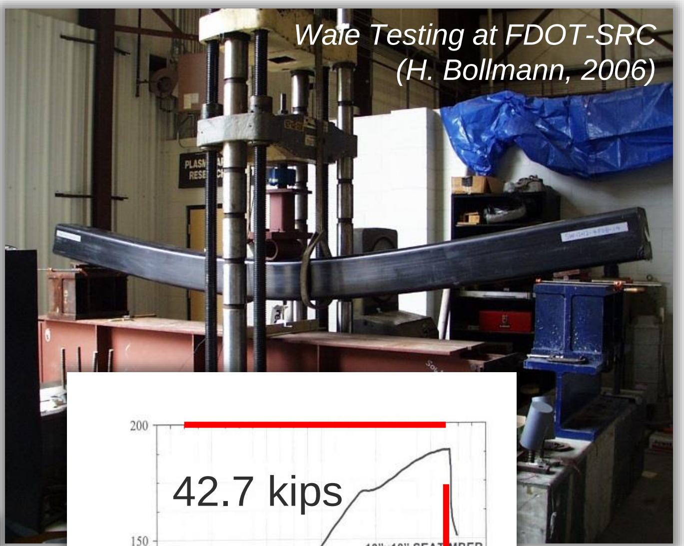
Fender System Design

- New ***Structures Design Guidelines*** - *Section 3.14* *(Jan. 2015)*

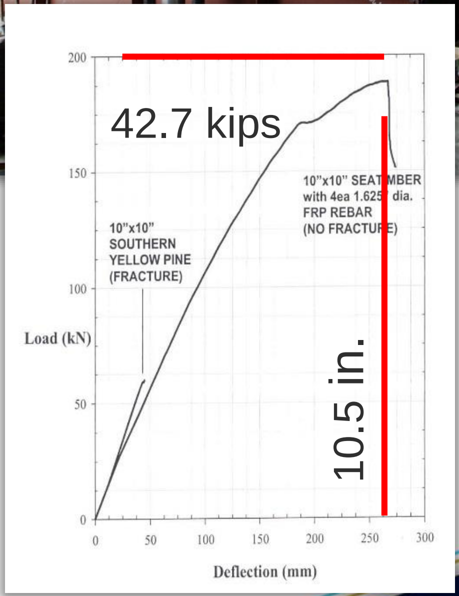


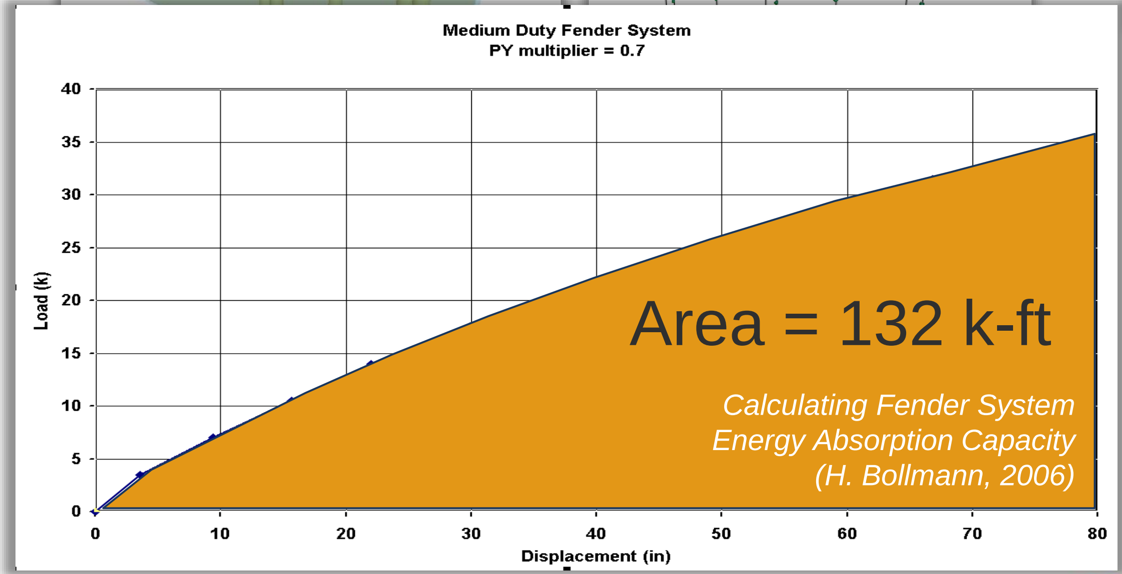
FB-Pier Modeling (H. Bollmann, 2006)





Wale Testing at FDOT-SRC (H. Bollmann, 2006)





Calculating Fender System Energy Absorption Capacity (H. Bollmann, 2006)

Topic #4

CFRP Prestressed Concrete Bearing Piles

i. Research project BDK-83-977-17;

ii. FDOT ***Specifications*** *933 (CFRP Prestressing Strand);*

iii. ***Developmental*** Index D22600 series *(Effective Nov. 2014)*

- Halls River Bridge demonstration project Index D22618;

iv. FDOT ***FY2016-17 Design Standards*** *(Effective July 2010)*

- Index 22600 series;
- CFRP(CFCC) prestressing strands and spirals;
- CFRP bar pile splices;
- HSSS prestressed/reinforced alternative;
- ***Structures Design Bulletin*** *15-10*.

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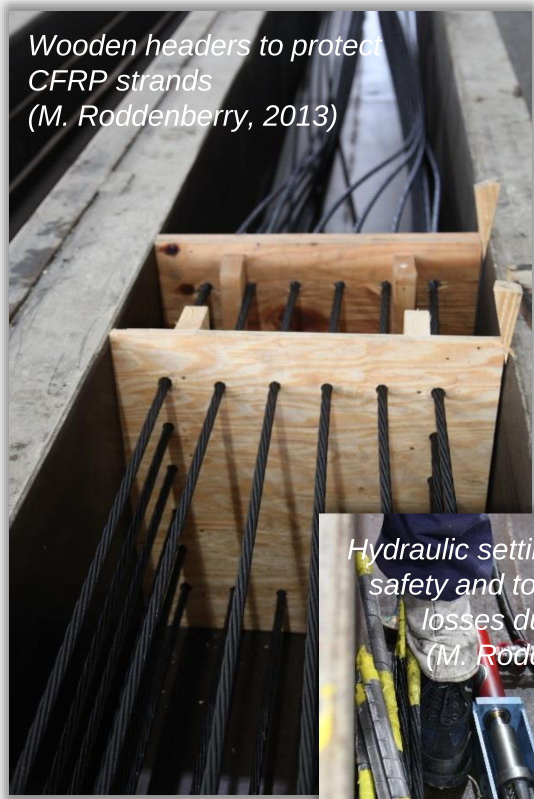
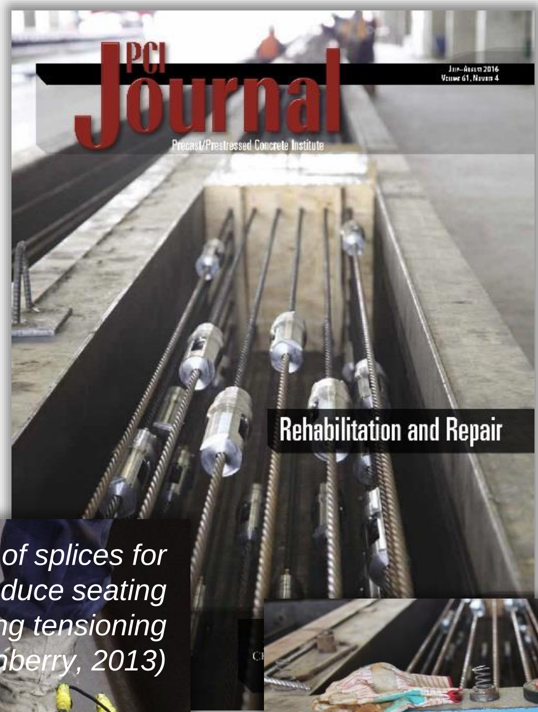
THE COMPOSITES AND ADVANCED MATERIALS EXPO

Topic #4

CFRP Prestressed Concrete Bearing Piles



Wooden headers to protect CFRP strands (M. Roddenberry, 2013)



Use of Self-Consolidating Concrete to avoid strand damage from vibrators (M. Roddenberry, 2013)

Hydraulic setting of splices for safety and to reduce seating losses during tensioning (M. Roddenberry, 2013)

Coupling with steel strands for jacking and anchoring (M. Roddenberry, 2013)

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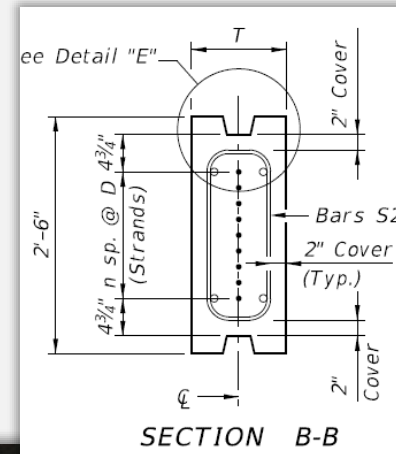
Topic #4

CFRP Prestressed Concrete Bearing Piles (and more...)

i. Exploring “hybrid” solutions

Bespoke [1]

- FRP Grids for confinement with steel strands (galvanic corrosion ?)
- SS spirals/CFCC (galvanic corrosion ?)
- GFRP spirals & bespoke[1] reinforcing



Carbon grid with circular strand pattern (W. Potter, 2013)

Prefabricated Auger-Cast-Pile FRP cages (Claura, et.al, 2015)

Bespoke [1]

[1] Bespoke (custom) FRP Reinf: RE-CAST Webinar: https://mstedu.webex.com/mstedu/ldr.php?RCID=457e3e65ae2430f7828746828643f85c

Topic #4

CFRP Prestressed Concrete Bearing Piles (…and more)

ii. Possible synergistic solutions

- Sustainable concrete
  - Cement without chloride limits would allow use of solid waste as kiln fuel (co-generation), and use of by-products (kiln dust) back to clinker;
  - Unwashed sea-sand to preserve freshwater resources;
  - Saltwater usage to preserve freshwater resources;
  - Chloride contaminated RCA;

- Combination with FRC for stiffness and crack control in non-prestressed applications

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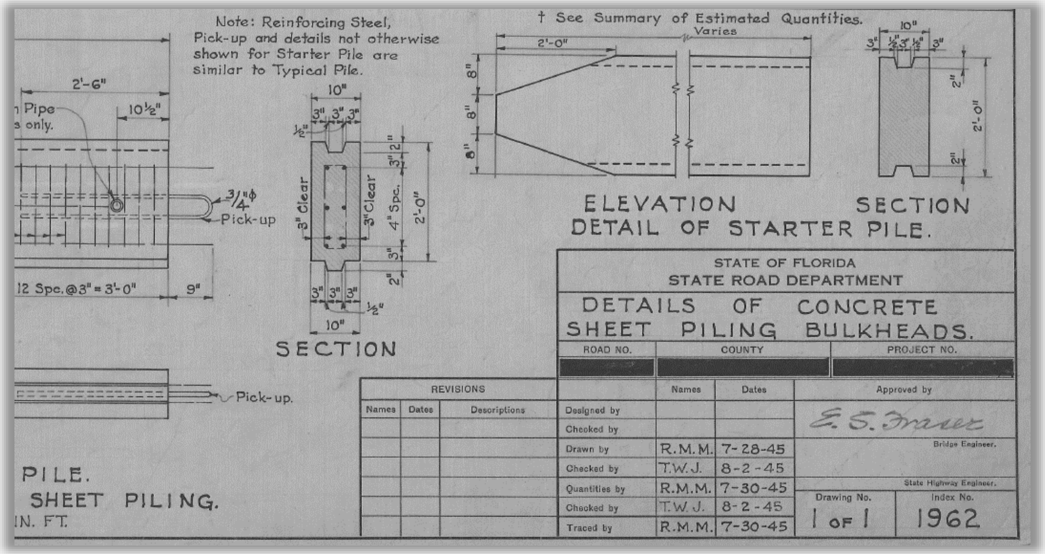
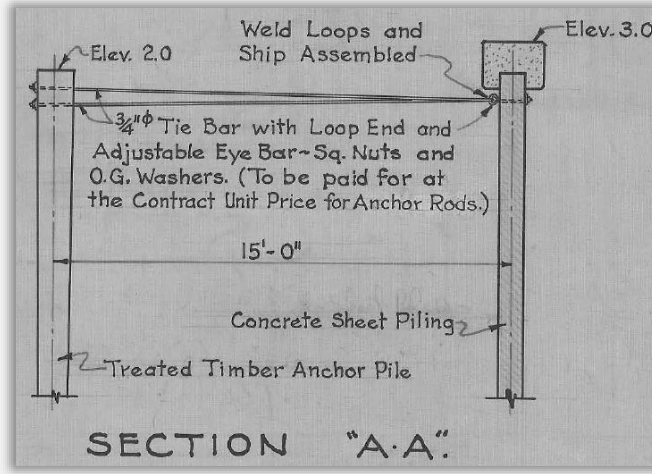
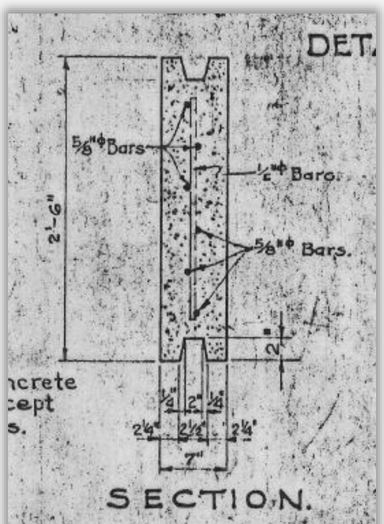
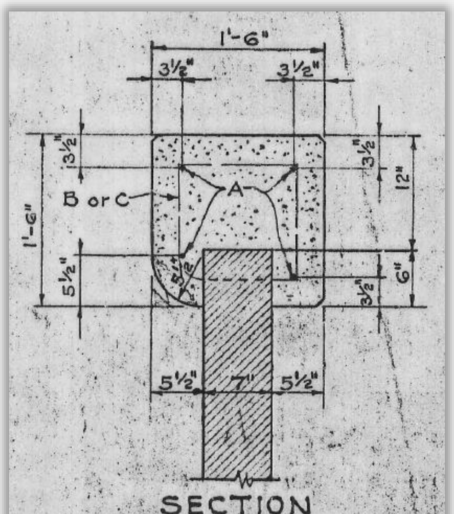
Topic #5

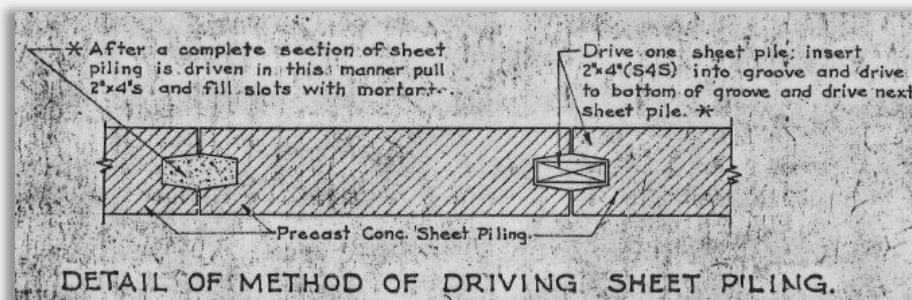
Concrete Sheet Piles
(Historical examples, RC since 1920's)











Images from 1945 (Index 1962) & 1946 (Index 2039) Standards.
Florida State Road Dept. (FDOT)

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Topic #5

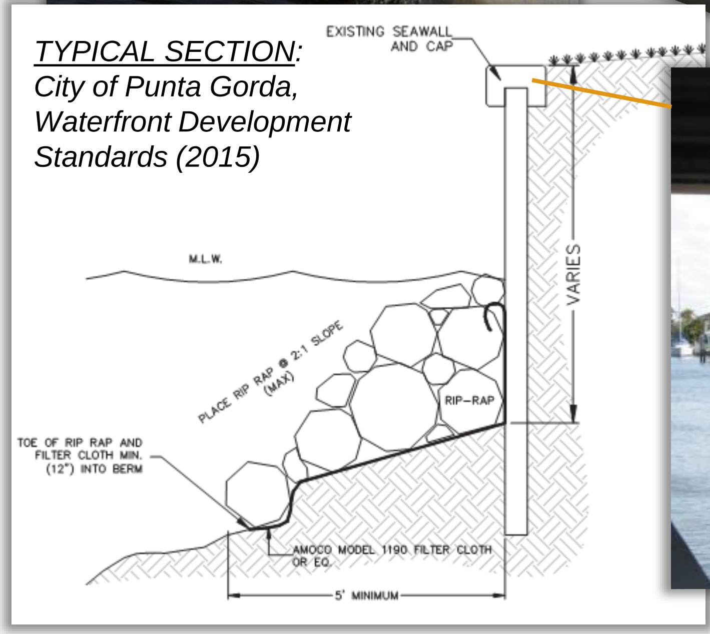
Concrete Sheet Piles
(Historical examples, RC since 1920's)

Bulkhead toe failure

Bulkhead wall panel failure

Bulkhead tie-back failure

TYPICAL SECTION: City of Punta Gorda, Waterfront Development Standards (2015)



Photos: Courtesy City of Punta Gorda, Waterfront Property Owners Manual (2010)

Topic #5

Prestressed Concrete Sheet Piles (Current, since mid-1950's)*...better*

Courtney Campbell Causeway, FDOT (2011)

Courtney Campbell Causeway, Tampa Bay, FDOT (2011)

Courtney Campbell Causeway, Tampa Bay, FDOT (2011)

Replace corroded RC seawalls. Tampa Bay, FDOT (2011)

Topic #5

CFRP Prestress/GFRP Reinf. Concrete Sheet Piles*…best?*

i. Design criteria for prestressing – ***Fiber Reinforced Polymer Guidelines*** ***(FRPG)*** – *Chapter 3*;

ii. ***Developmental*** Index D22440 *(Nov. 2014)*

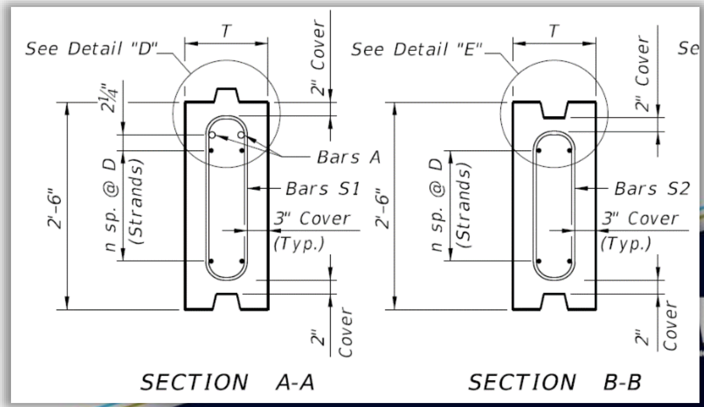
- (Halls River Bridge demonstration project);

iii. FDOT ***FY2017-18 Design Standards*** *(Nov. 2016)*

- Index 22440 series;
- CFRP prestressing strands & GFRP stirrups;
- Stainless Steel prestressed/reinforced alternative.

FRP REINFORCED PILES				
D22440 Certification Statement	Precast Concrete CFRP/GFRP Sheet Pile Wall Permitted Projects FPID No(s): 430021-1-52-01, 432194-1, 435815-1	Steve Nolan	IDDS-D22440	CEL-D22440-CSPSA CEL-D22440-CSPDA CEL-D22440-CSPC

Developmental Design Standards webpage extract.



Topic #6

Concrete Bulkhead/Seawalls

RESEARCH COMMUNICATIONS RESEARCH COMMUNICATIONS

Engineering away our natural defenses: an analysis of shoreline hardening in the US

Rachel K Gittman[1*†], F Joel Fodrie[1], Alyssa M Popowich[2], Danielle A Keller[1], John F Bruno[3], Carolyn A Currin[4], Charles H Peterson[1], and Michael F Piehler[1]

Rapid population growth and coastal development are primary drivers of marine habitat degradation. Although shoreline hardening or armoring (the addition of concrete structures such as seawalls, jetties, and groins), a byproduct of development, can accelerate erosion and loss of beaches and tidal wetlands, it is a common practice globally. Here, we provide the first estimate of shoreline hardening along US Pacific, Atlantic, and Gulf of Mexico coasts and predict where future armoring may result in tidal wetland loss if coastal management practices remain unchanged. Our analysis indicates that 22 842 km of continental US shoreline – approximately 14% of the total US coastline – has been armored. We also consider how socioeconomic and physical factors relate to the pervasiveness of shoreline armoring and show that housing density, gross domestic product, storms, and wave height are positively correlated with hardening. Over 50% of South Atlantic and Gulf of Mexico coasts are fringed with tidal wetlands that could be threatened by future hardening, based on projected population growth, storm frequency, and an absence of coastal development restrictions.

Front Ecol Environ 2015; 13(6): 301–307, doi:10.1890/150065

Although coastal regions constitute less t… Earth's land area, coastal habitats (e… tidal wetlands; Figure 1) rank among the … natural resources globally (MA 2005). Ove… the human population lives within 100 k…

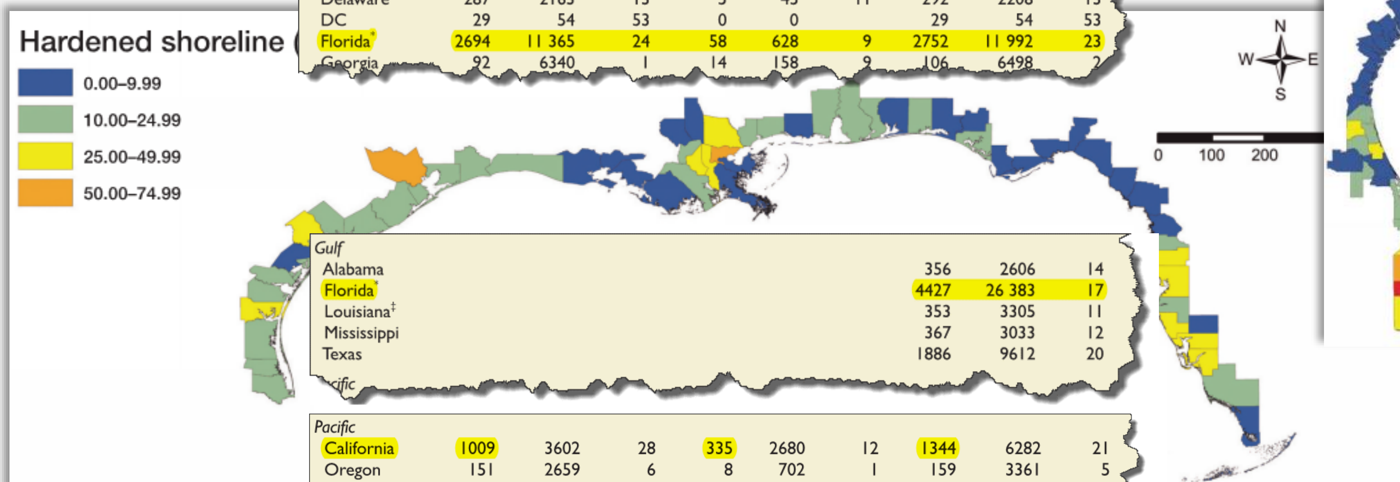
WebTable 2. Summary of shoreline hardening estimates for continental US coasts

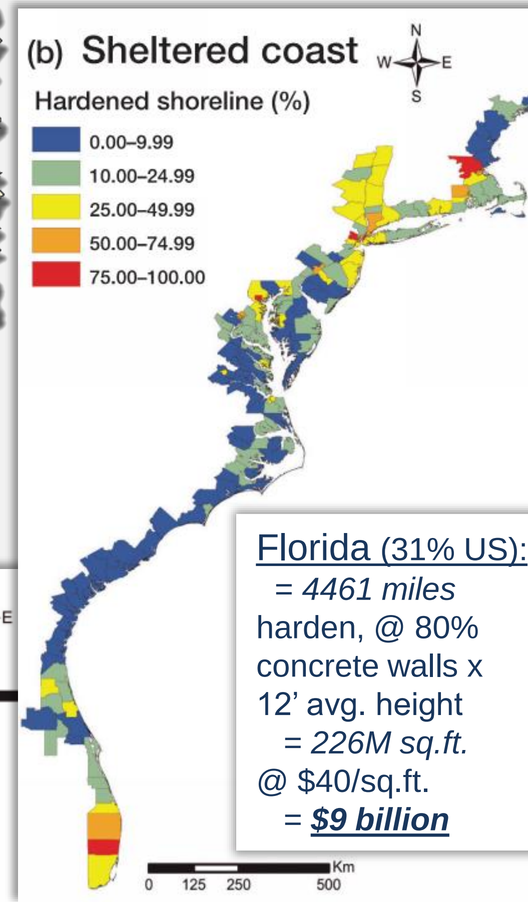
Region	Total shoreline (km)	Hardened shoreline (km)	Hardened (%)
Atlantic	99 494	12 923	13
Sheltered	93 848	12 425	13
Open	5646	498	9
Gulf of Mexico*†	44 939	7390	16
Pacific	15 735	2529	16
Sheltered	12 026	2182	18
Open	3709	348	9
Total	160 168	22 842	14

Notes: *The Gulf of Mexico shoreline could not be divided into "Open" …

WebTable 3. Shoreline hardening and population statistics by state

	Hard sheltered shore (km)	Sheltered shore (km)	Hard sheltered shore (%)	Hard open shore (km)	Open shore (km)	Hard open shore (km)	Hard shore (km)	Total shore (km)	Hard shore (%)
Atlantic									
Connecticut	477	1907	25	0	0		477	1907	25
Delaware	287	2163	13	5	45	11	292	2208	13
DC	29	54	53	0	0		29	54	53
Florida*	2694	11 365	24	58	628	9	2752	11 992	23
Georgia	92	6340	1	14	158	9	106	6498	2
Gulf									
Alabama							356	2606	14
Florida*							4427	26 383	17
Louisiana‡							353	3305	11
Mississippi							367	3033	12
Texas							1886	9612	20
Pacific									
California	1009	3602	28	335	2680	12	1344	6282	21
Oregon	151	2659	6	8	702	1	159	3361	5
Washington	1022	5765	18	5	327	1	1027	6092	17





Florida (31% US):
= *4461 miles*
harden, @ 80%
concrete walls x
12' avg. height
= *226M sq.ft.*
@ $40/sq.ft.
= ***$9 billion***

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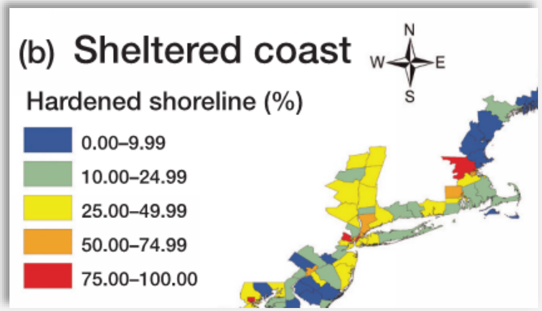
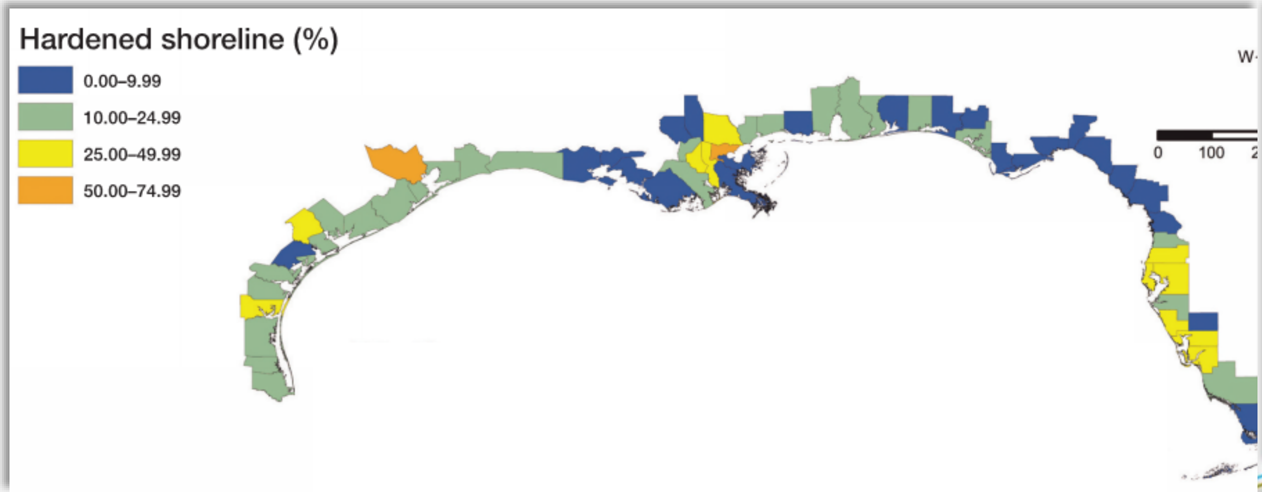
Topic #6

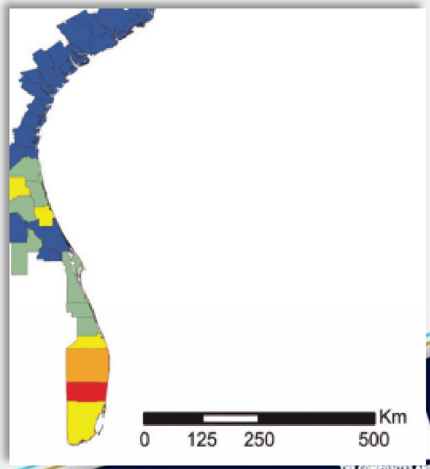
Concrete Bulkhead/Seawalls

Florida Municipal Examples:

City of Miami Beach = 60+ miles
City of Miami = 10+ miles
City of Punta Gorda = 124 miles
Marco Island = 200+ miles
Fort Lauderdale = 200+ miles
Tampa Bay Area = ??? (*Davis Islands 11.5 miles*)
Monroe Co. (2003) = 222 miles residential canals
(*rubble or bulkhead*)







Topic #6

Concrete Bulkhead/Seawalls

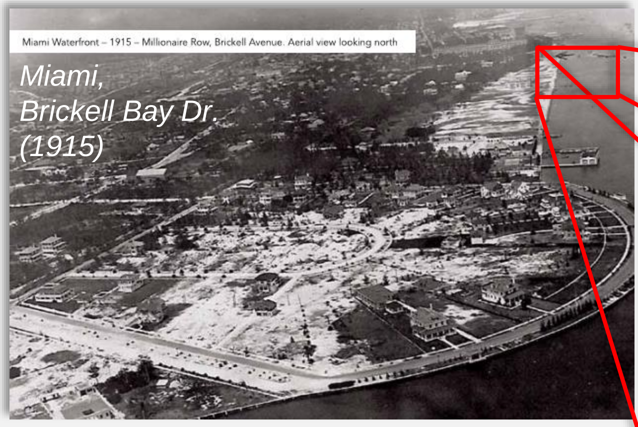

Brickell Key (Burlingame Is.,1928)

Typical Examples (Miami):

Fisher Island	(1919)	= 2.4 mile
Brickell Key	(1920's-70's)	= 1.1 mile
Dodge Island	(1950's)	= 4.2 miles
Key Biscayne	(1950's-70's)	= 8 miles


Fisher Island (1920's)


Fisher Island (2015)



Miami, Brickell Bay Dr. (1915)


island marine
Photo - Nov 2011

The Mackle Company developed the middle of Key Biscayne in the 1950's


Miami, Brickell Bay Dr. Google © (2015)


Miami, Key Biscayne (2015)


Brickell Key, (Claughton Is., 1972)

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Topic #6

Concrete Bulkhead/Seawalls

Typical Examples:

Marco Island ("The Platinum Coast", Collier Co. – 1960's)

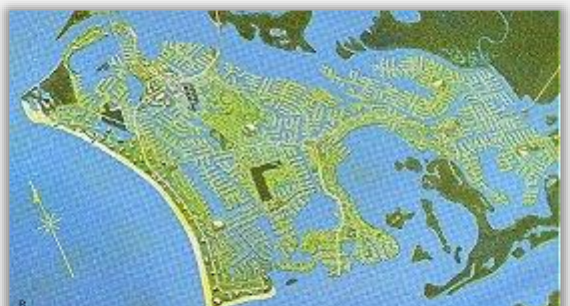
~ 200 miles

http://www.themacklecompany.com/femjrstorypublic/16-deltona-marcoisland.htm

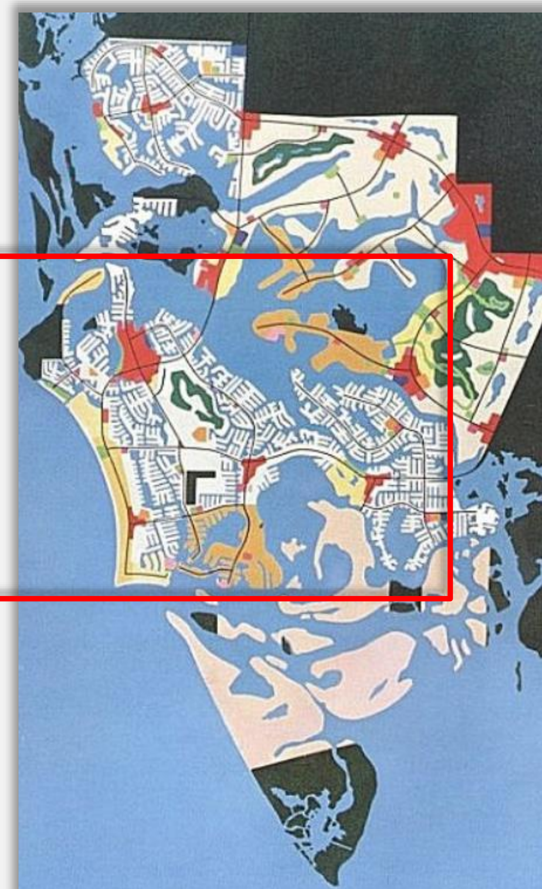
Under the direction of Bill O'Dowd and Earl Cortright Sr. a high production sea-wall operation - refining the processes developed at Key Biscayne, Pompano and Port Charlotte - was planned. Land based drag lines along with water based dredges would do the major earth moving.

Marco Island progress, 1967.
(Image courtesy of the Mackle Company)

Marco Island 1964, and early residents!
(Images courtesy of the Mackle Company)



Marco Island showroom scale model, 1965.
(Image courtesy of the Mackle Company)



Marco Master Plan, 1969.
(Image courtesy of the Mackle Company)

Topic #6

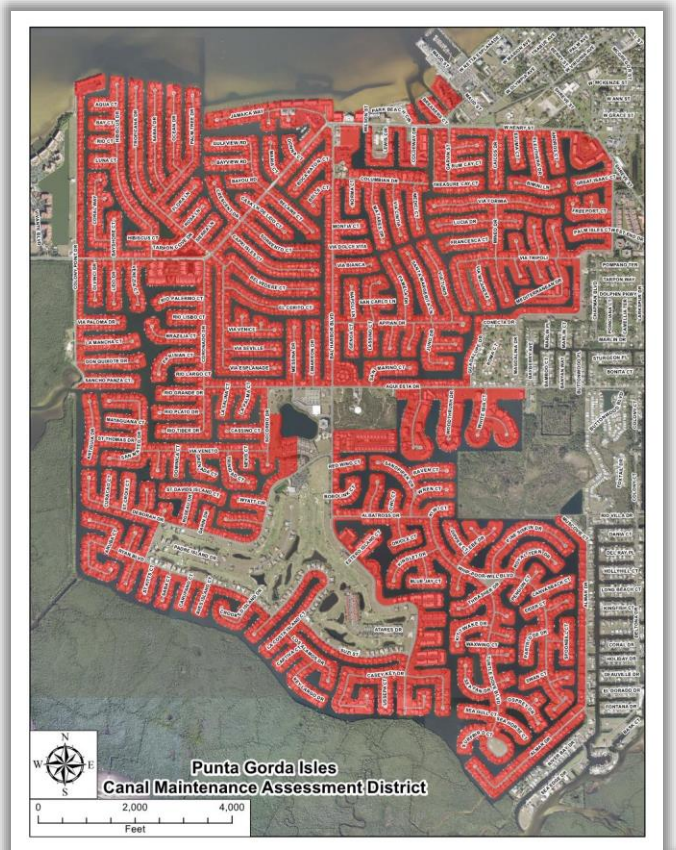
Concrete Bulkhead/Seawalls

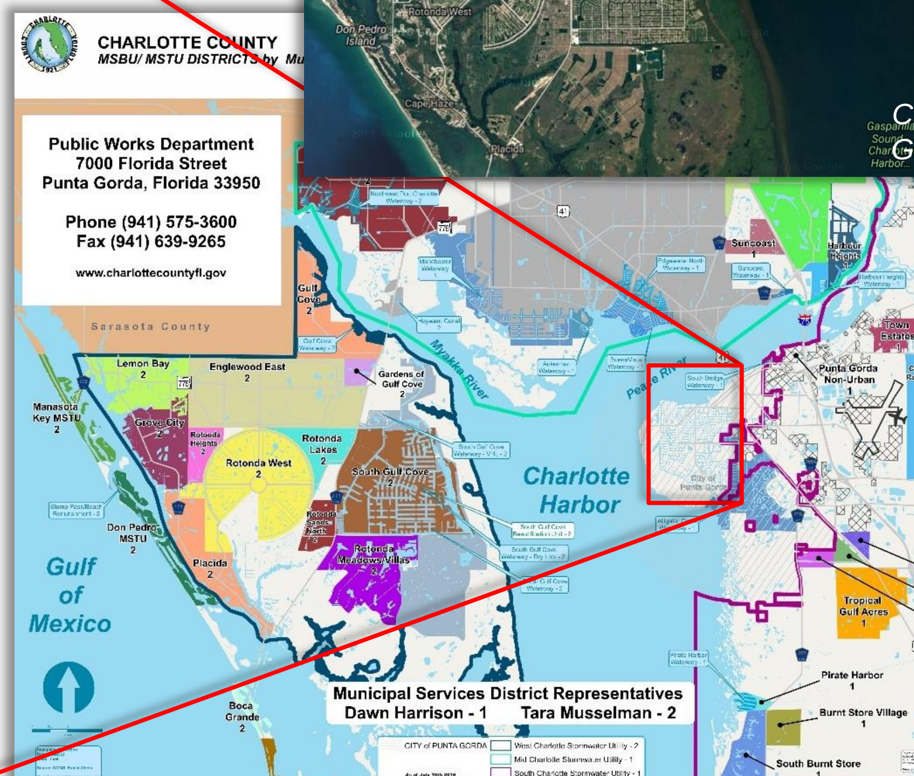
Typical Examples:

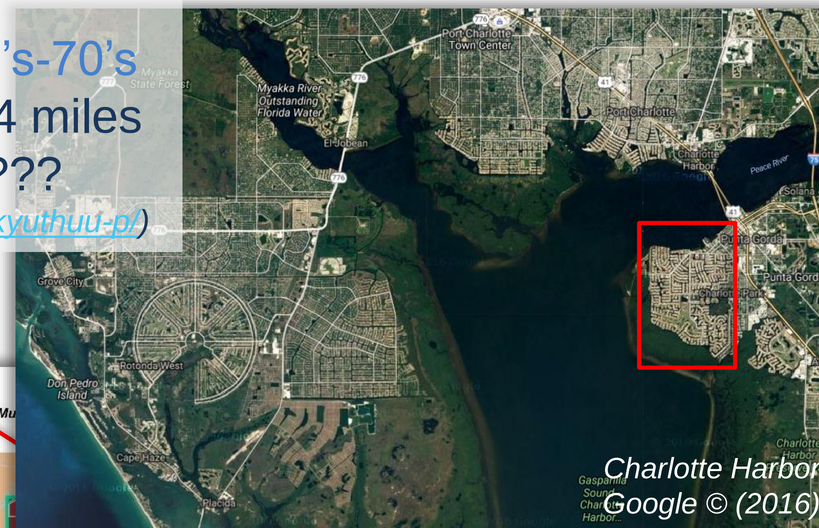
City of Punta Gorda (Punta Gorda Isles 1960's-70's & Burnt Store Isles 1970's-80's) = 124 miles

Charlotte Co. (MSBU-Waterway Districts) = ???

(MMFX article*: http://mmfxsteelcorporation.cmail2.com/t/t-l-hydhdjl-klkyuthuu-p/*)







Topic #6

Concrete Bulkhead/Seawalls

Typical Examples:

Davis Islands (Tampa – 1920's) = 11.5 miles

Davis Shores (St. Augustine 1920's - 60's) = 2 miles


Davis Islands (1924)

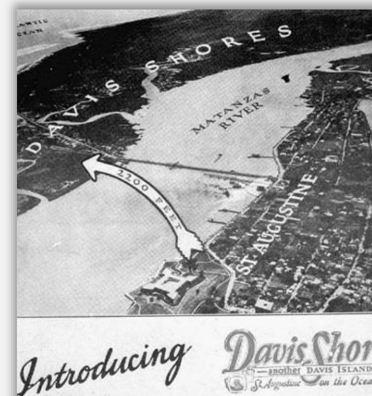

Davis Islands (1925)


Davis Islands (1926)


Davis Islands, Dredge-and-fill (1926)


Davis Islands, PCA Concrete Piles Pub., pg.70 (1951)


Davis Islands, Adalia Ave (1926)



North Davis Shores is part of a larger "City Beautiful" project that developer D. P. Davis sought to create on the island in the 1920s soon after the success of Davis Island in Tampa. The City Beautiful concept included stately plazas, embellished boulevards, waterside promenades, prominent public statues, fountains and memorials.

If it had not been for the Florida real estate bust during the Great Depression and the disappearance of the developer, the project would have outshone his other examples of

Topic #6 **Concrete Bulkhead/Seawalls**

Typical Examples:

Pinellas county (Tampa Bay, 1910's – 1960's)

"The 'finger island' frenzy - the dredging of islands just wide enough for a cul-de-sac road and houses on either side—reached its heyday between the mid-1940s and 1960s. During this period, developers throughout the Tampa Bay region reaped the riches of a second land boom" ([1] James Anthony Schnur, 2015)

Dredging operations transformed Boca Ciega Bay along Redington Beach and Madeira Beach. (Image courtesy of Archives and Library, Heritage Village) [1]

Dredging operations transformed Paradise Island and the Yacht Club Estates along the Treasure Island Causeway during the 1950s. (Image courtesy of Archives and Library, Heritage Village) [1]

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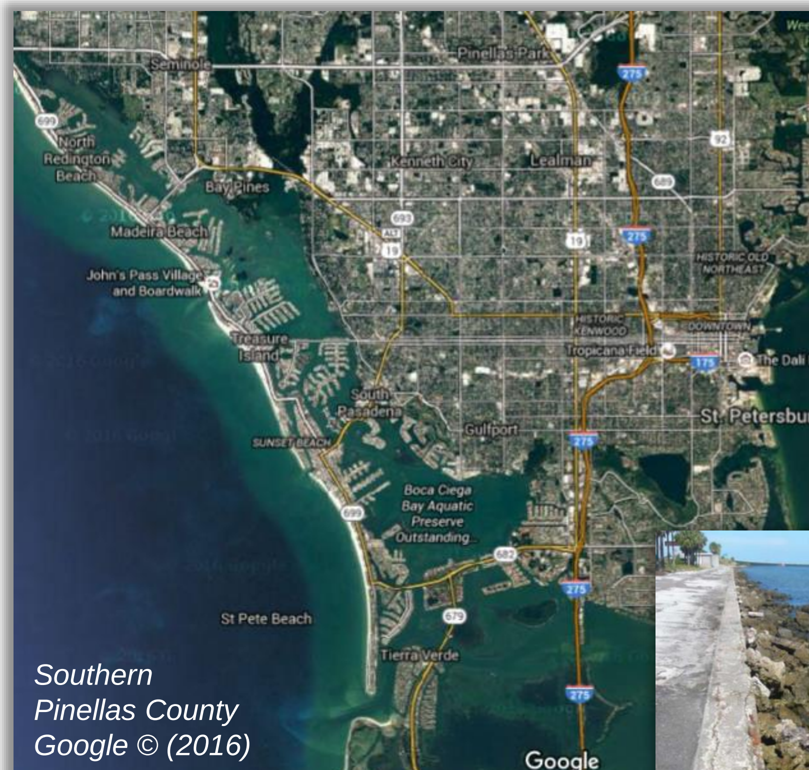
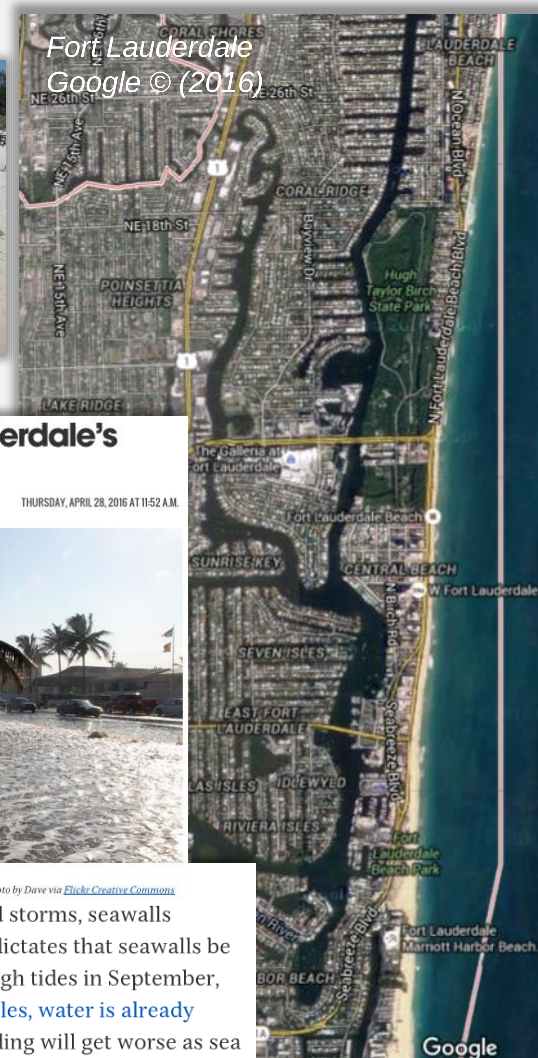
Topic #6

Concrete Bulkhead/Seawalls





Scientists Wary of Fort Lauderdale's Proposed Seawall Plan

BY JESS SWANSON

THURSDAY, APRIL 28, 2016 AT 11:52 A.M.

Sea level rise experts think the city's plan to raise seawalls won't be enough.

Photo by Dave via Flickr Creative Commons

Original story:

Fort Lauderdale has over 200 miles of seawalls. During high tides and storms, seawalls protect properties from coastal flooding. Currently, a city ordinance dictates that seawalls be no higher than five and a half feet. But during King Tides, the really high tides in September, the seawalls are not cutting it. In coastal communities like Las Olas Isles, water is already washing over them and nearly flooding homes. Experts fear this flooding will get worse as sea level is predicted to rise.

It is estimated to cost a property owner anywhere from $10,000 to $125,000 to raise an existing seawall or completely replace a 100-foot seawall. With four miles of public seawalls, it can cost the city as much as $26 million to replace its seawalls. Slap worries about spending

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Topic #6

GFRP Reinforced Concrete Bulkhead/Seawall - Caps

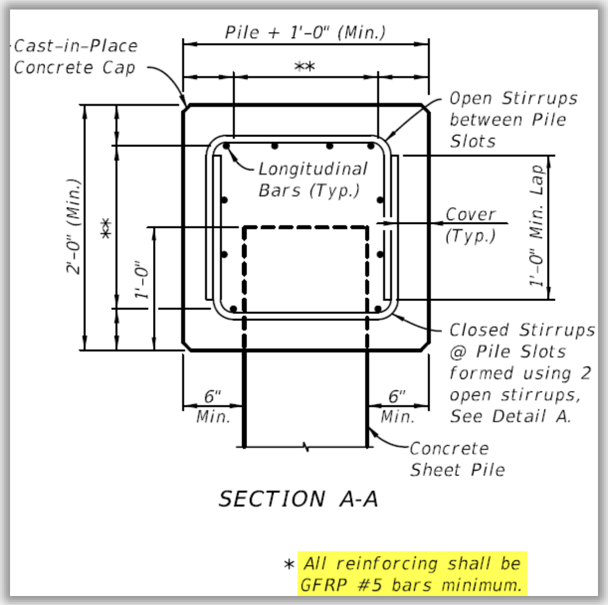
i. C-I-P concrete cap for concrete sheet pile walls;

ii. FDOT **_Specifications_** *415 & 932* *(GFRP rebar)*

iii. Approved Producers List requirements via **_Materials Manual_** *– Section 12.1* *(Jan 2015);*

iv. Design criteria for rebar – **_Fiber Reinforced Polymer Guidelines_** ***(FRPG)*** *– Chapter 2;*

v. Standard detailing - **_Structures Detailing Manual_** ***(SDM)*** *- Chapter 19.5.1 and special GFRP Instructions* **_IDDS_**_-D22440_ *(Jan 2015).*



Topic #7

Project Examples

i. Other States Overview

ii. Halls River Bridge Replacement Project
   - Letting 6/15/2016 (FPID 430021-1-52-01)
   - FDOT 2015 Design Expo Presentation
   - FDOT 2016 Design Expo Presentation

iii. Cedar Key SR24 Bulkhead Rehab.
   - Construction completed June 2016 (FPID 432194-1-52-01)
   - Construction Project Overview

iv. Bakers Haulover Cut Bridge Bulkhead Rehab.
   - Letting 6/15/2016 (FPID 432194-1-52-01)

v. Skyway South Rest Area Seawall Rehab.
   - Design-Build contract E1P44 (FPID 438528-1-52-01)
   - Advertisement 04/11/2016

Topic #7-i

Project Examples – *Non-FDOT (CFRP Strands)*

Prestressing bed with carbon-fiber-composite cable strands/spirals for piles for the Nimmo Parkway bridge in Virginia.

AASHTO Innovation Initiative

CFCC projects			
Project	**State**	**Year**	**Application**
Pembroke bridge over Southfield Freeway	Michigan	2011	Beam/posttensioned
M 102 bridges over Plum Creek, Southfield	Michigan	2013/14	Beam/pretensioned
Interstate 94 bridges over Lapeer Road, Port Huron	Michigan	2014/15	Beam/posttensioned
Kittery overpass bridge over State Route 234	Maine	2014	Beam/pretensioned
Nimmo Parkway bridge	Virginia	2014	Precast concrete pile/pretensioned
Route 49 bridge over Aaron's Creek	Virginia	2015	Beam/pretensioned
KY 70 bridge over Stoner Creek, Taylor County	Kentucky	2014	Beam/pretensioned
Innovation Bridge at University of Miami	Florida	2016	Beam/pretensioned
Note: CFCC = carbon-fiber-composite cable.			

PCI Journal, K.Ushijima et.al, "Field deployment of carbon-fiber-reinforced polymer in bridge applications", (Sept-Oct 2016).

CAMX THE COMPOSITES AND ADVANCED MATERIALS EXPO

Topic #7-i

Project Examples – *in the USA (FRP Rebar)*

67 Bridges – 27 States

not comprehensive

Colorado	2
Connecticut	1
Florida	8
Georgia	2
Indiana	1
Iowa	2
Kansas	1
Kentucky	2
Mass	1
Maine	4
Michigan	2
Minnesota	1
Missouri	6
Nebraska	1

New Hampshire	1
New York	3
North Carolina	1
Ohio	4
Oregon	1
PA/NJ	1
Pennsylvania	1
Texas	3
Utah	2
Vermont	1
Virginia	1
West Virginia	9
Wisconson	3

*

Applications		
Deck only	Deck, parapet, barrier, enclosure, and/or sidewalk	Parapet, barrier, enclosure, and/or sidewalk
54	8	3

John Busel-ACMA, "Fiber Reinforced Polymer (FRP) Composite Rebar" presentation, (FDOT-GFRP Rebar Workshop, June 15, 2016).*

Topic #7-i

Project Examples – *Non-FDOT (FRP Decks)*

The following are notable FRP bridge decks** and FRP bridges constructed in the United States listed in ***NCHRP Report 503*** (2003):

- INEEL Bridge, Idaho (1995);
- No-Name Creek Bridge, Kansas (1996);
- Magazine Ditch Bridge, Delaware (1997);
- Laurel Lick Bridge, West Virginia (1997);
- Wickwire Run Bridge, West Virginia (1997);
- Tech 21 Bridge, Ohio (1997);
- Tom's Creek Bridge, Virginia (1997);
- Washington Schoolhouse Road Bridge, Maryland (1998);
- Bridge 1-351, Delaware (1998);
- Milltown Bridge, Delaware (1998);
- Wilson's Bridge, Pennsylvania (1998);
- Bennet's Bridge, New York (1998);
- Laurel Run Road Bridge, Pennsylvania (1998);

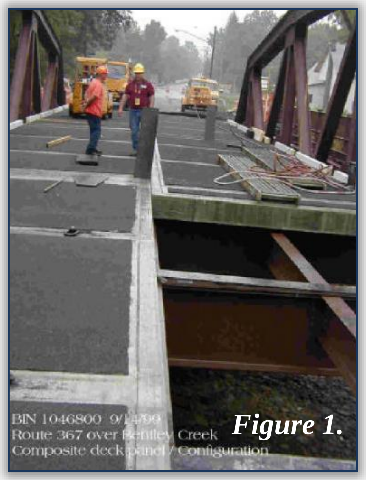


Figure 1.

- Crawford County Bridges (2), Kansas (1999);
- Woodington Run Bridge, Ohio (1999);
- Greensbranch Bridge, Delaware (1999);
- Bentley's Truss Bridge, New York (1999) – ***Figure 1***;
- Schroon River Truss Bridge, New York (2000);
- Market Street Bridge, West Virginia (2000);
- Kings Stormwater Canyon Bridge, California (2000);
- Salem Avenue Bridge, Ohio (2000); and
- Westbrook Road Bridge (1st of Ohio Project 100), Ohio (2000).

** Most of the decks used to date have been made out of either pultruded sections (e.g., honeycomb-shaped, trapezoidal, or double-web I-beams) or slabs made using a vacuum-assisted resin infusion process. Several have been made by hand with a wet lay-up process. Most of the bridges have a thin polymer concrete wearing surface, although sometimes asphalt is used.

CAMX THE COMPOSITES AND ADVANCED MATERIALS EXPO

Topic #7-ii

Project Example – *Halls River Bridge Replacement Project*

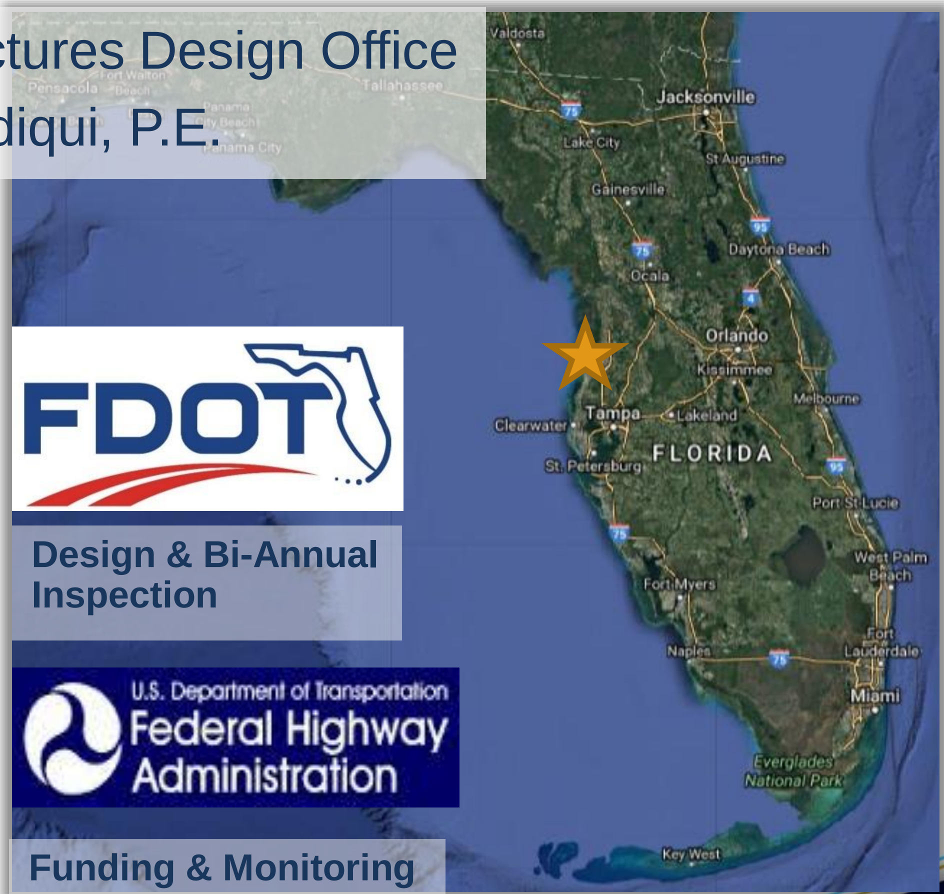
Designer: FDOT District 7 Structures Design Office

Structures EOR: Mamunur Siddiqui, P.E.

- Project Overview
- Design
- Materials
- Monitoring

Owner & Maintaining Agency

Collaboration Research

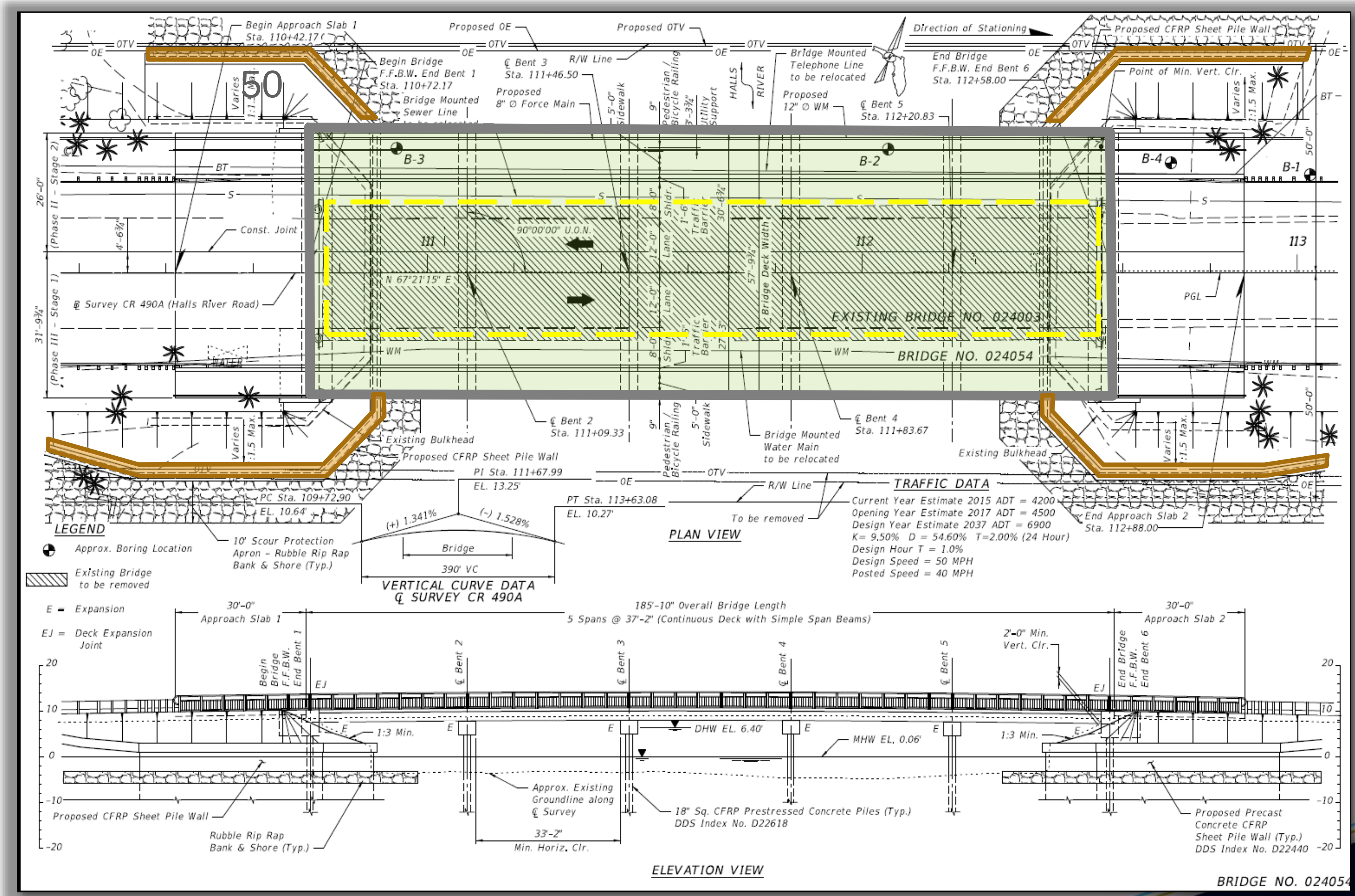


Design & Bi-Annual Inspection

Funding & Monitoring

Topic #7-ii

Project Example – *Halls River*

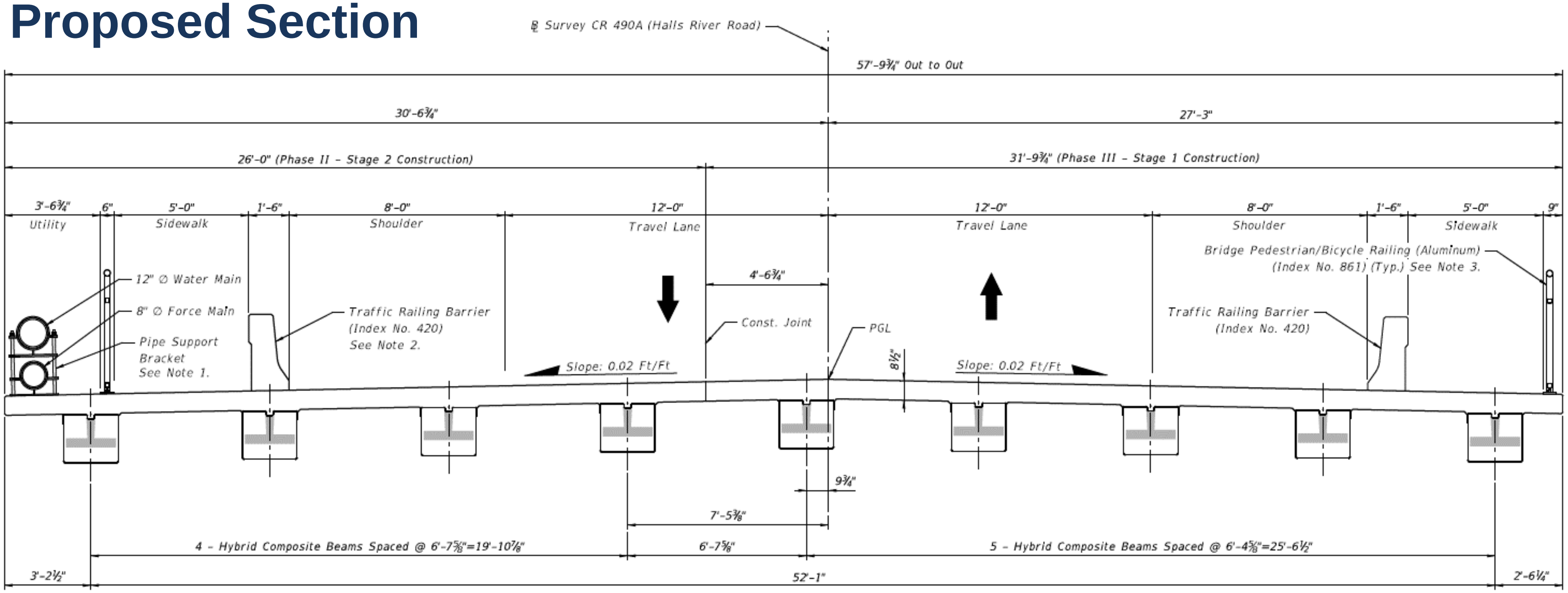


Existing and Proposed Layout

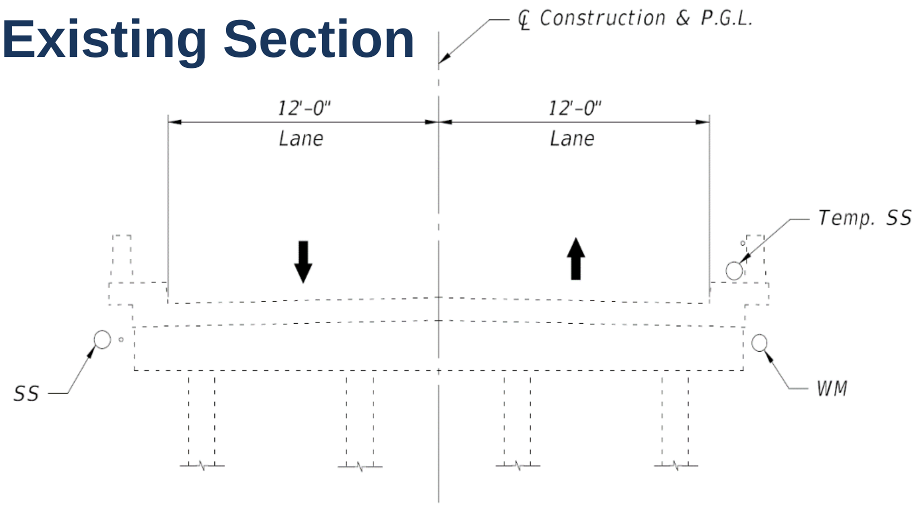
Topic #7-ii

Project Example – *Halls River*

Proposed Section



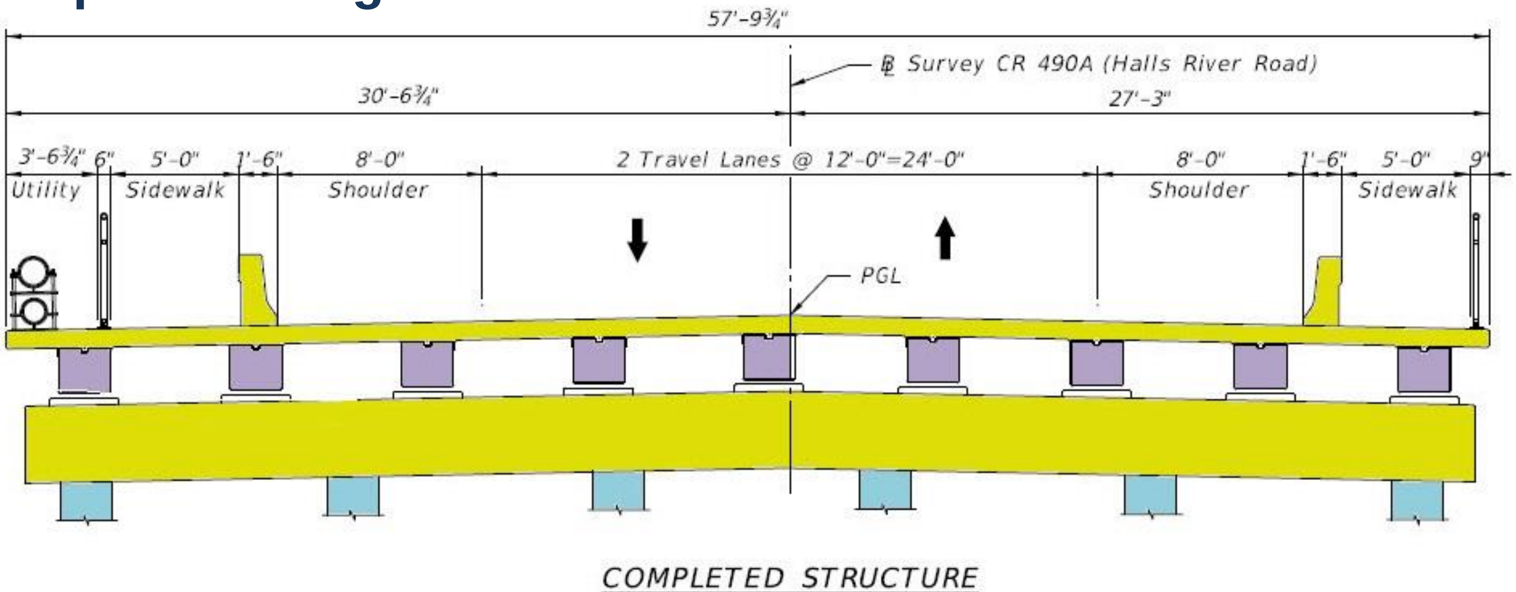
Existing Section



Topic #7-ii

Project Example – *Halls River*

Proposed Bridge Section

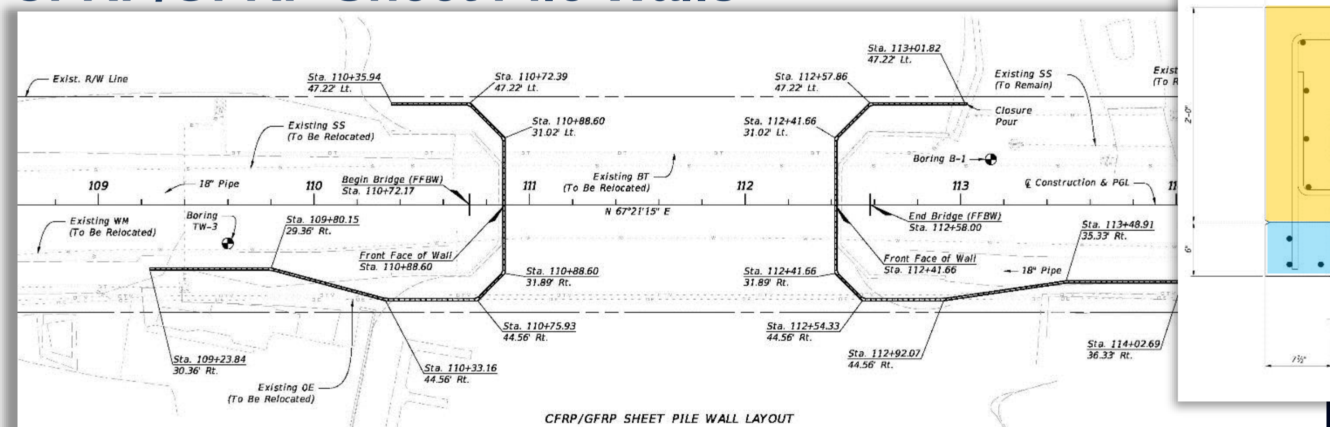


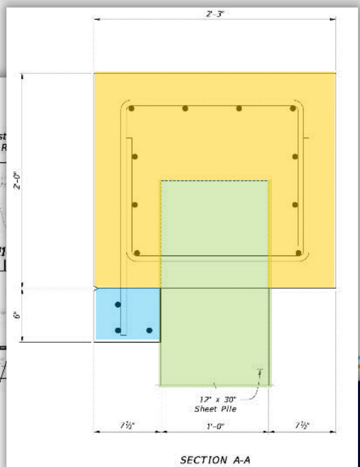
GFRP

HCB

CFRP

CFRP/GFRP Sheet Pile Walls





GFRP

CFCC

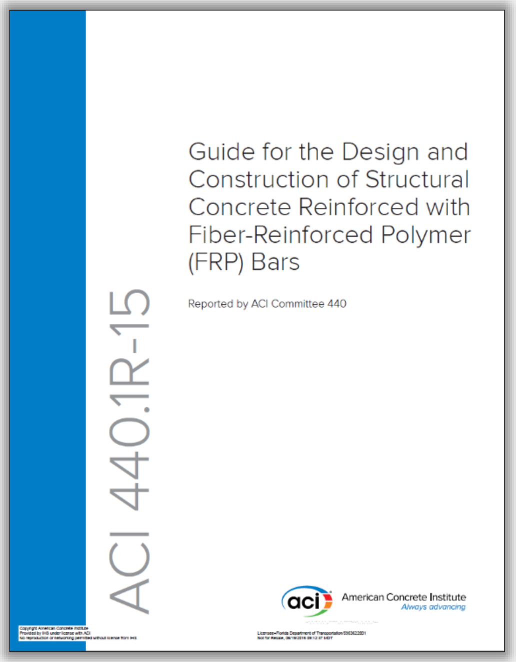
Test Blocks

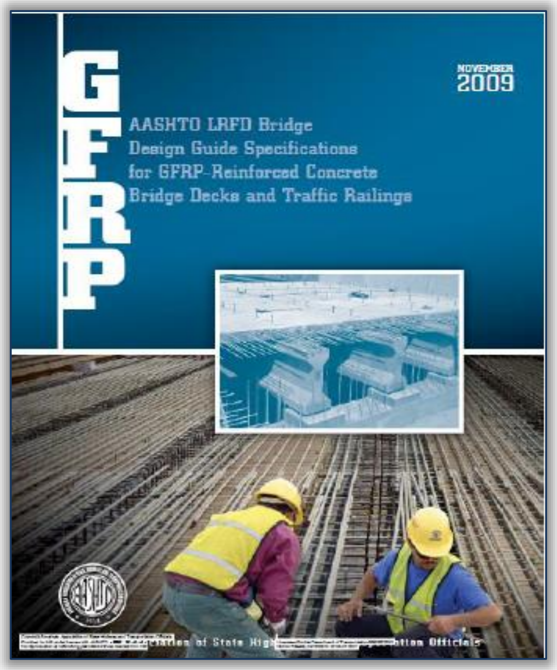
CAMX THE COMPOSITES AND ADVANCED MATERIALS EXPO

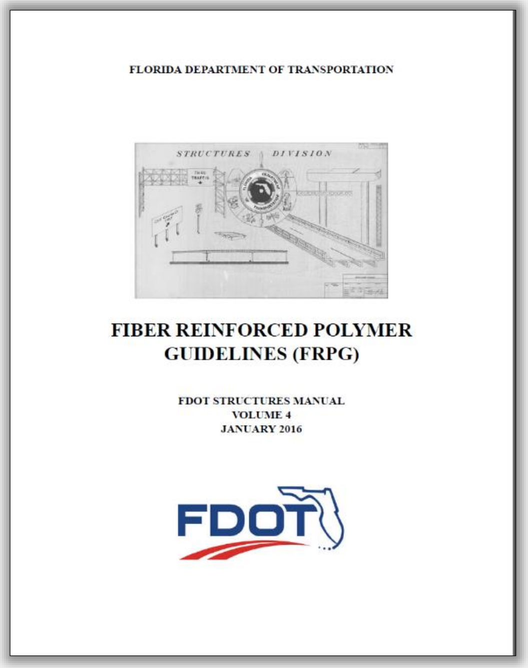
Topic #7-ii

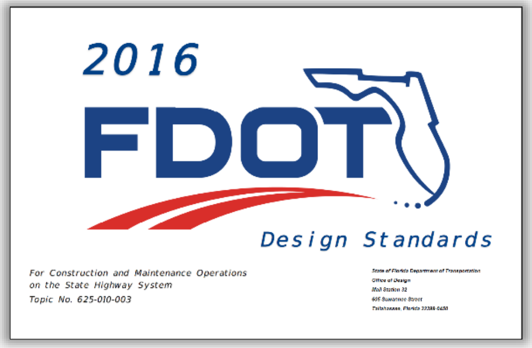
Project Example – *Halls River*

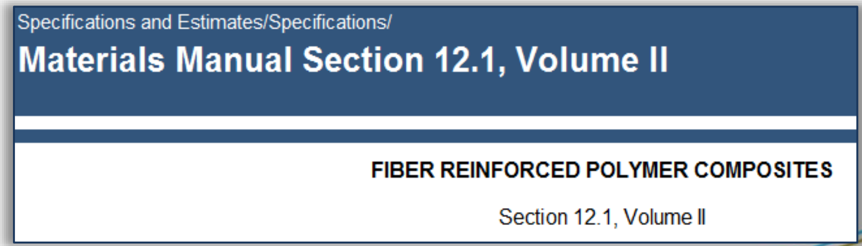
Codes, Standards and References











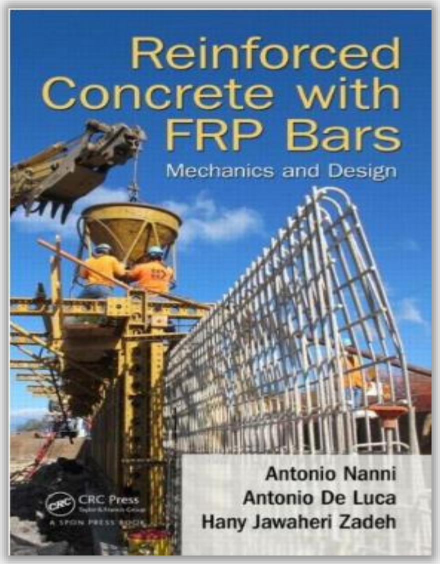
Topic #7-ii

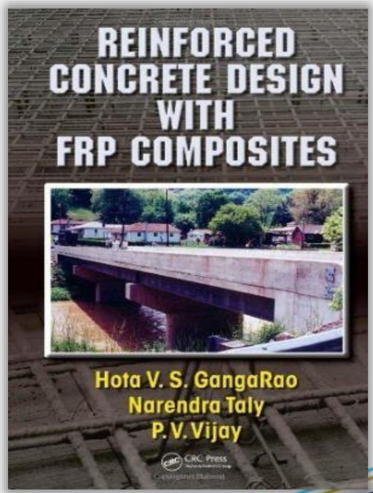
Project Example – *Halls River*

Codes, Standards and References (cont'd)

FDOT Developmental Standards:

- Pultruded FRP Bar Bending Details (**Index *D21310***)
- 18" CFRP Prestressed Piles (***Index D22618***)
- CFRP Prestressed Piles Splices (***Index D22601***)
- CFRP/GFRP Sheet Piles Walls (***Index D22440***)
- Traffic Railing - GFRP Reinforced (***Index D22420***)
- Approach Slab – GFRP Reinforced (***Index D22900***)





Topic #7-ii

Project Example – *Halls River*

Hybrid Composite Beam (HCB) – Manuals and References

Hybrid-Composite Beam (HCB®)
Design and Maintenance Manual

RTE 205 (RIDGE RD.)
Over Tide Mill Stream, Westmoreland Co
State Project No.: 0205-096-101, B601
Federal Aid Project No.: BR-096-6(015)
NBIS No. 27818

Prepared for
The Virginia Department of Transportatio

John R. Hillman, PE, SE
HCB, Inc.

TECHNICAL SPECIAL PROVISION

FOR

SECTION T450 - FURNISHING & INSTALLING HYBRID-COMPOSITE BEAMS

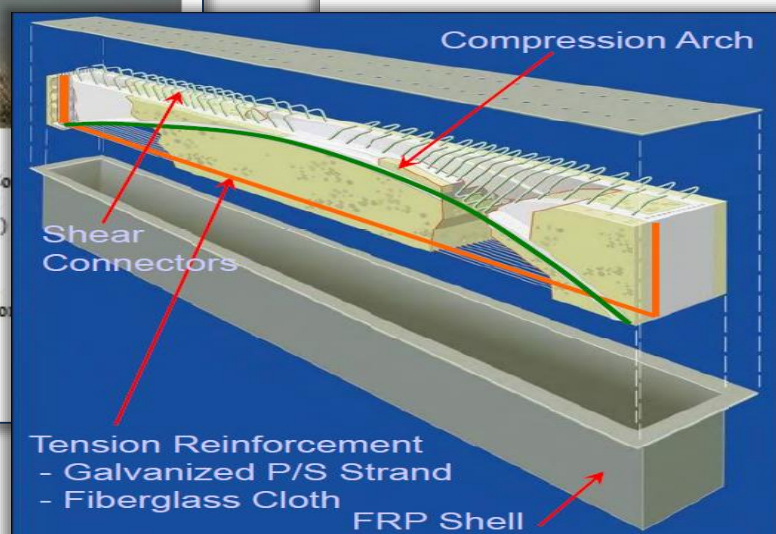
FINANCIAL PROJECT ID: 430021-1-52-01

n electronically signed and sealed
F.A.C. Printed copies of this
ure must be verified on an electronic

Mamunur Rashid Siddiqui, P.E.

4

N McKinley Dr.
, Zip code: 33612
ation: N/A.



CAMX THE COMPOSITES AND ADVANCED MATERIALS EXPO

Topic #7-ii

Project Example – *Halls River*

Fiber Reinforced Polymer (FRP) Reinforcing

Pros:

- Corrosion Resistance
- High Strength
- Lightweight
- Fatigue Endurance

Cons:

- High Initial Cost
- Brittle Failure

Cost Comparison:

#6 Steel Rebar : **$ 1.40/ft.**

#6 GFRP Rebar : **$ 1.60/ft.**

188,815 ft.
+ Sheet Pile Stirrups
+Traffic Railings

0914-415-104	FIBER REINFORCED POLYMER REINFORCING, #4 GFRP BAR	22916.000
0914-415-105	FIBER REINFORCED POLYMER REINFORCING, #5 GFRP BAR	59962.000
0914-415-106	FIBER REINFORCED POLYMER REINFORCING, #6 GFRP BAR	86486.000
0914-415-108	FIBER REINFORCED POLYMER REINFORCING, #8 GFRP BAR	17471.000

Steel Bars

GFRP Bars

Project Example – *Halls River*

Cost Comparison

Precast Prestressed Concrete Piles

- 18” Steel Reinforced : **$ 80 / ft**
- 18” CFCC Reinforced : **$ 122 / ft**

(bid cost was $150)

Prestressed Concrete Piles

Precast Prestressed Sheet Piles

- 12”x30” Steel Reinforced : **$ 120 / ft**
- 12”x30” CFCC Reinforced : **$ 144 / ft**

(bid cost was $265)

Prestressed Sheet Piles

0455- 14- 24	CONCRETE SHEET PILING, 12" X 30" WITH FRP STRAND AND REINFORCING	LF				6251.000
0455- 34- 23	PRESTRESSED CONCRETE PILING, 18" SQ W/FRP OR STAINLESS STEEL STRAND AND REINFORCING	LF				1634.000
0455-143- 23	TEST PILES-PRESTRESSED CONCRETE, 18" SQ W/ FRP STRAND AND REINFORCING	LF				255.000

CAMX
THE COMPOSITES AND ADVANCED MATERIALS EXPO

Project Example – *Halls River*

Cost Comparison

Prestressed Slab Beams

$ 300 / ft

Hybrid Composite Beams

$ 428 / ft

(bid cost was $330)

CAMX
THE COMPOSITES AND ADVANCED MATERIALS EXPO

Topic #7-ii

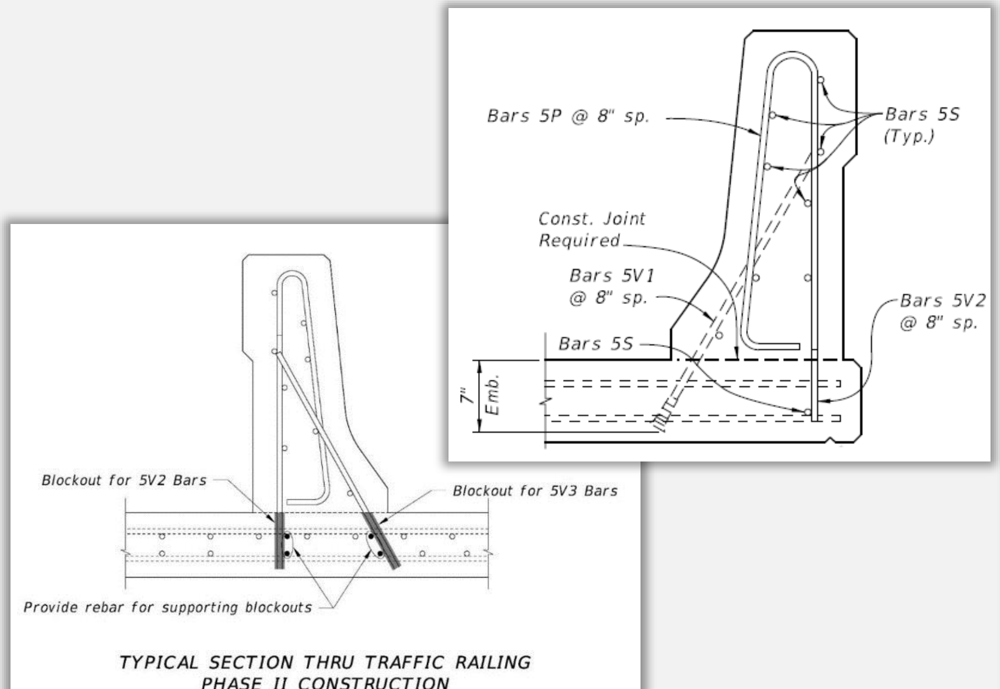
Project Example – *Halls River*

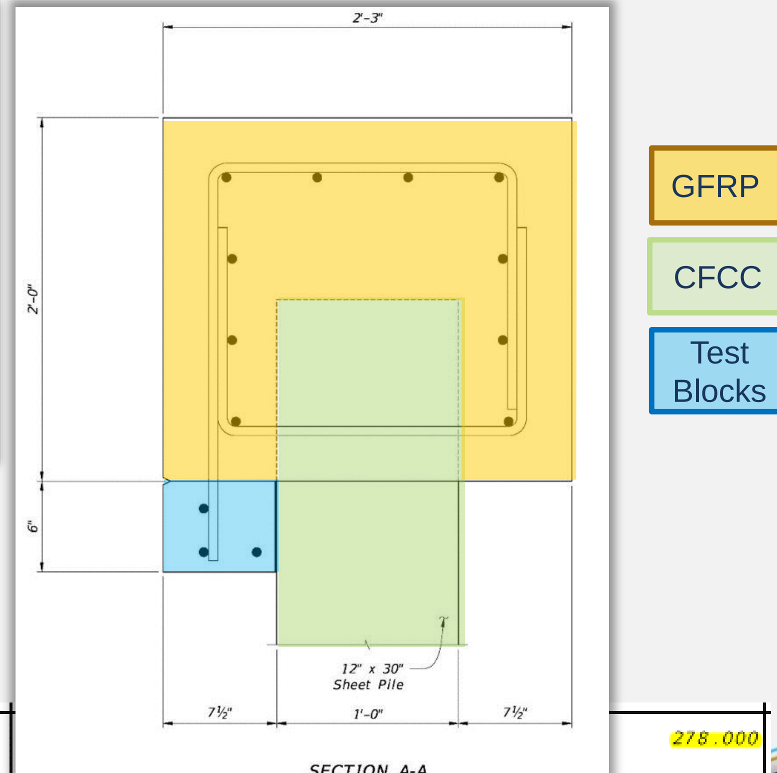
GFRP Barrier Reinforcement

(Post Installed for Phase Construction)

Monitoring Test Blocks

(To be periodically removed from under Bulkhead Cap)





0914-415-204	FIBER REINFORCED POLYMER REINFORCING, #4 CARBON FIBER REINFORCING BAR	LF	278.000
0914-415-205	FIBER REINFORCED POLYMER REINFORCING, #5 CARBON FIBER REINFORCING BAR	LF	256.000
0914-415-305	FIBER REINFORCED POLYMER REINFORCING, #5 BASALT FIBER REINFORCING BAR	LF	614.000
0915-450- 21	HYBRID COMPOSITE BEAM, 21" T-SHAPE	LF	1624.000
0916-521- 1	CONCRETE TRAFFIC RAILING- BRIDGE, 32" F-SHAPE GFRP REQUIRED	LF	492.000

Project Example – *Halls River*

Summary:

- **Demonstration Project with Innovative Materials –** First in Florida
  - ✓ Superstructure: Hybrid Composite Beams; GFRP Bars: Deck, Wingwall, Backwall, Barriers & Approach Slabs
  - ✓ Substructure: CFCC Prestressed Piles; Bent Caps: GFRP Bars
  - ✓ Sheet Pile Walls: CFCC/GFRP Sheet Piles; Wall Cap: GFRP Bars

– **Estimated Project Cost - $6.1 Million (Structures = $3.7 Million)**
  – Bridge Cost = **$221 / sq. ft.**
  (Conventional Construction = **$166 / sq. ft.**)

– **Accelerated Construction**
  – Lighter Materials – Beams and Rebar
  – Faster Transportation and Delivery
  – reduced construction time

Project Example – *Cedar Key SR24 Bulkhead Rehabilitation*

Designer: Kisinger Campo & Associates Corp. (Tampa)

Structures EOR: Patrick Mulhearn

- Replacement of bulkhead cap with GFRP reinforced concrete;
- Addition of Test Blocks on underside of cap with three types of GFRP rebar surface treatments;
- FDOT State Materials Office to perform periodic sampling and monitoring.

Design

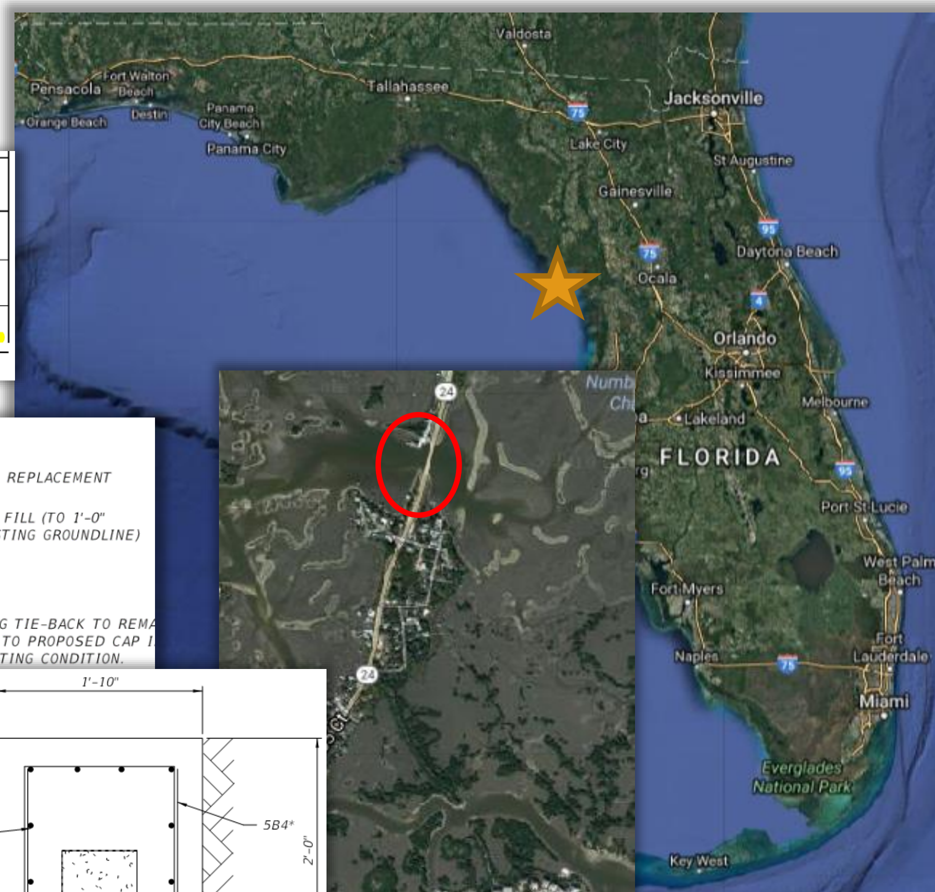
Owner & Maintaining Agency (Bi-Annual Inspection)

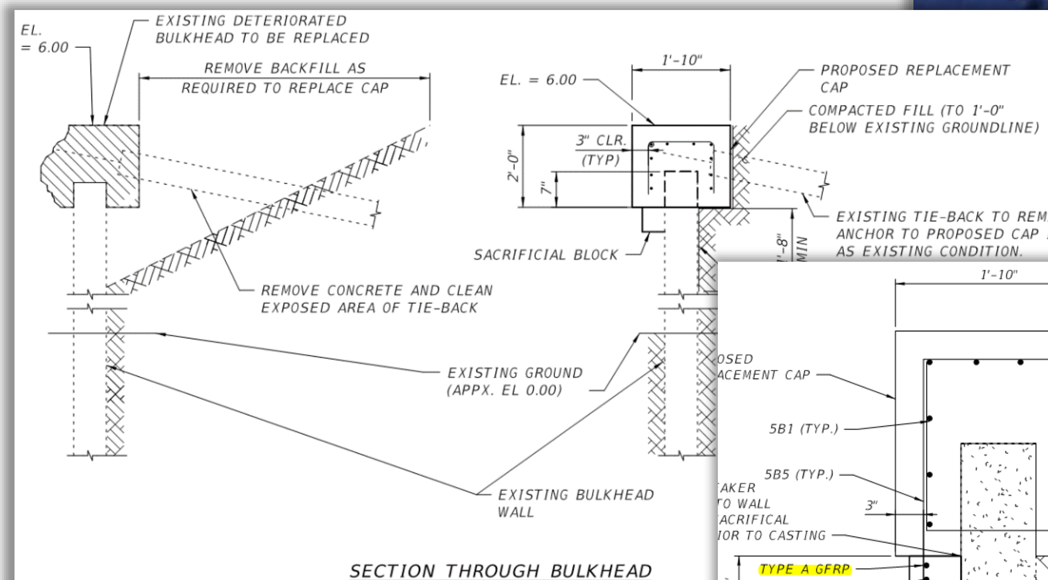
Funding

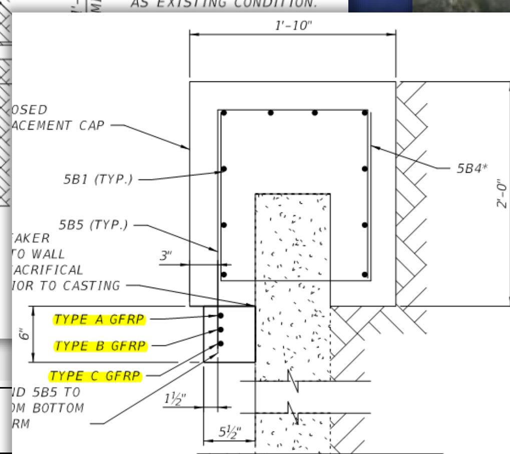
Project Example – *Cedar Key*
SR24 Bulkhead Rehabilitation

GFRP BAR TYPE CHART	
TYPE A	SIZE 5 GFRP BAR COATED WITH GRANULAR MATERIAL AND WITH SURFACE INDENTATIONS/DEFORMATIONS CREATED BY HELICAL WRAPPING.
TYPE B	SIZE 5 GFRP BAR COATED WITH GRANULAR MATERIAL AND WITHOUT SURFACE INDENTATIONS/DEFORMATIONS.
TYPE C	SIZE 5 GFRP BAR COATED WITH POLYMER (NO GRANULAR COATING) AND WITH SURFACE INDENTATIONS/DEFORMATIONS CREATED BY SHAPING THE POLYMER COATING (NO EXTERNAL WRAPPING).

TABLE APPLIES ONLY TO REBAR IN SACRIFICIAL BLOCK



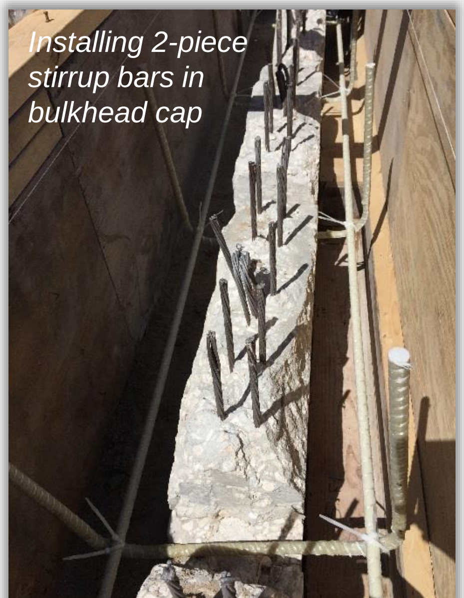


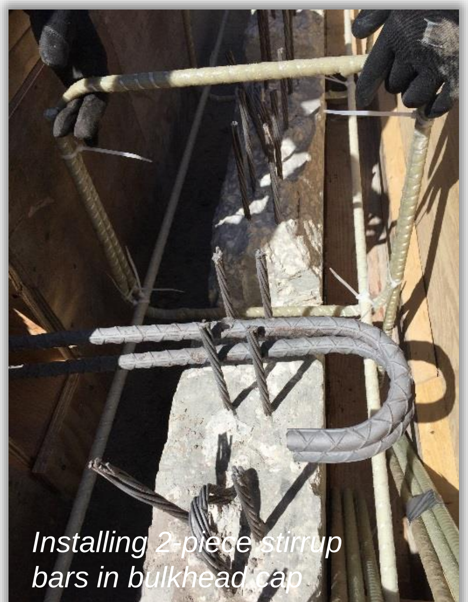


914-415-105	GLASS FIBER REINFORCING POLYMER BAR		
	ADS	LF	5088
	ED	LF	131

Topic #7-iii

Project Example – *Cedar Key*
SR24 Bulkhead Rehabilitation


Installing 2-piece stirrup bars in bulkhead cap

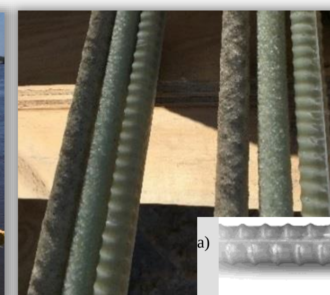

Installing 2-piece stirrup bars in bulkhead cap


Plastic zip-ties for securing GFRP rebar

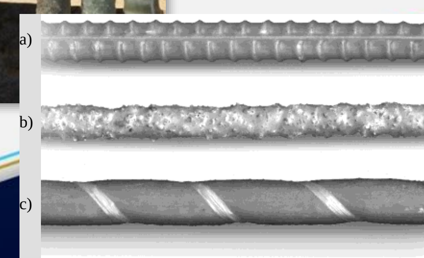

Curing concrete bulkhead cap prior to form removal


Temporary UV protection for bulkhead cap reinforcing


Forming bulkhead cap



3 bar-surface types:
a) Ribbed
b) Sand-coated
c) Helically wrapped and sand-coated



Project Example – *Bakers Haulover Cut Bridge Bulkhead Replacement*

Designer: Bolton Perez & Associates (Miami)

Structures EOR: Joaquin Perez

- GFRP Reinforced concrete facing, cap and parapet on a steel sheet pile wall;
- No test blocks.

Bolton Perez & Associates
Consulting Engineers

Design

FDOT

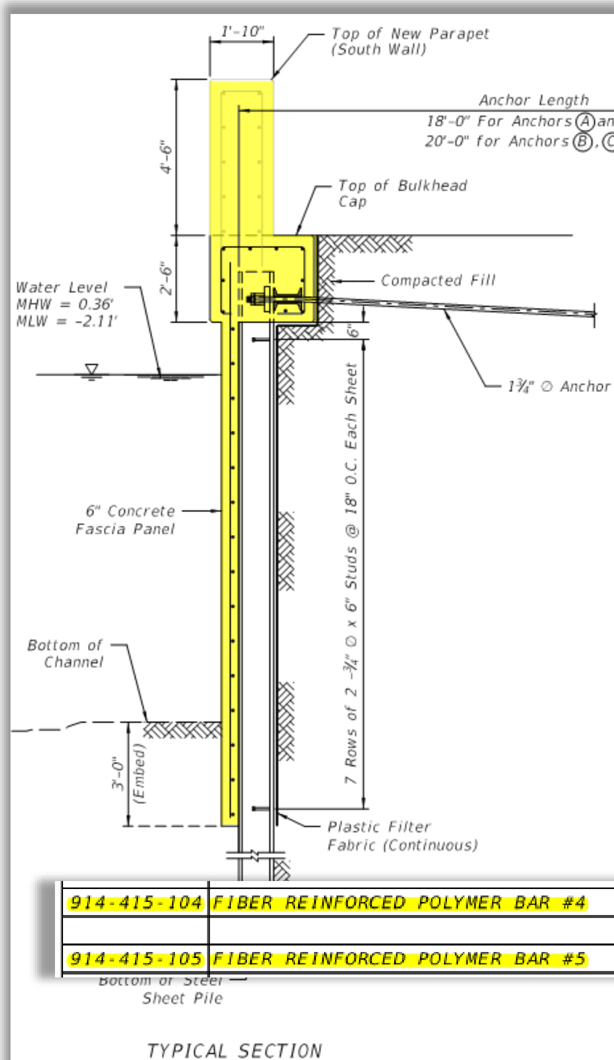
Owner & Maintaining Agency (Bi-Annual Inspection)

U.S. Department of Transportation
Federal Highway Administration

Funding

Topic #7-iv

Project Example – *Bakers Haulover Cut Bridge Bulkhead Replacement*



914-415-104	FIBER REINFORCED POLYMER BAR #4	BULKHEAD CAP, PARAPET & FASCIA PANEL	LF	12,199.32
914-415-105	FIBER REINFORCED POLYMER BAR #5	BULKHEAD CAP, PARAPET & FASCIA PANEL	LF	7,071.14

Project Example – *Skyway South Rest Area Seawall Rehabilitation*

Designer: *TBD*

Structures EOR: *TBD*

- **<u>FPID 437973-1, South Rest Area Site</u>**:
  - The existing seawall and handrail shall be raised
  - Extend the seawall southward 285' from the end.
  - Fill behind the seawall to provide for a grassed area and grade for drainage.
  - Metallic reinforcement is not allowed.
  - Non-metallic Reinforcement must meet design criteria and specification
  - Incorporate existing sheet pile, tie-back rods and deadman anchors.
- **<u>FPID 438528-1, Seawall:</u>**
  - **R**emove and replace the existing seawall cap.
  - Metallic reinforcement is not allowed.
  - Incorporate existing sheet pile, tie-back rods and deadman anchors...

Source: Request for Proposal (Revised August, 2016)

(Design-Build)

FDOT

Owner & Maintaining Agency (Bi-Annual Inspection)

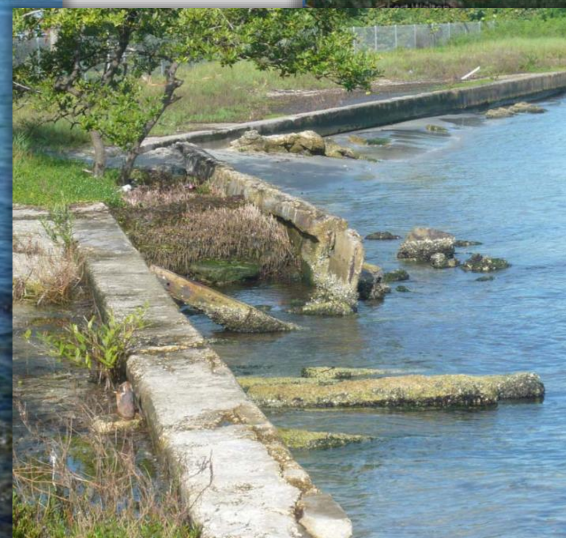
U.S. Department of Transportation Federal Highway Administration

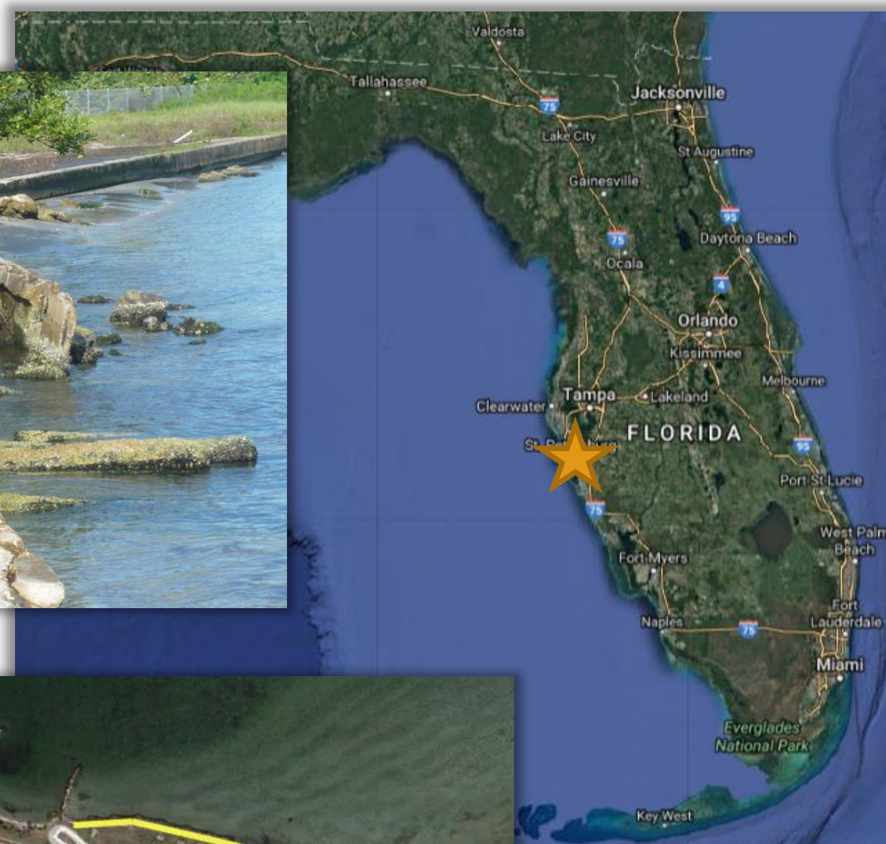
Funding

Topic #7-v

Project Example 4 – *Skyway South Rest Area Seawall Rehabilitation*

Cracking of existing seawall bulkhead cap





Limits of seawall bulkhead cap replacement

Limits of seawall bulkhead cap replacement near Rest Area

CAMX THE COMPOSITES AND ADVANCED MATERIALS EXPO

Questions ??

FDOT Contact Information:

Structures Design Office:
Steven Nolan, P.E. (Standards Coordinator)
(850) 414-4272
Steven.Nolan@dot.state.fl.us

Structures Design Office:
Rick Vallier, P.E. (FRP Coordinator)
(850) 414-4290
Rick.Vallier@dot.state.fl.us

State Materials Office:
Chase C. Knight, PhD.
(352) 955-6642
Chase.Knight@dot.state.fl.us

Design 7 Structures Office:
Mamun Siddiqui, P.E. (Designer)
(813) 975-6093
Mamunur.Siddiqui@dot.state.fl.us

FDOT's Fiber-Reinforced Polymer Deployment Train

??? → Composite Bridge Girders → GFRP Reinforcing Bars → CFRP Prestressed Piles → Navigation Fender Systems → External FRP Laminate Repairs