Florida Bridges and Structures for 100+ Years’ Service with FRP Composites

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Contributing Partners:
Abstract

Recent applications for new construction using Fiber-reinforced Polymer (FRP) composites is expanding in Florida. This presentation will highlight projects from 2018/2019 that utilize a variety of FRP materials for construction of new highway infrastructure applications including: Basalt-FRP & Glass-FRP reinforcing bars for concrete bridge structures; Carbon-FRP prestressed bridge beams; FRP structural shapes and pilings. Recent publication of Glass-FRP and Carbon-FRP Guide Specifications by the American Association of State Highway Officials (AASHTO) have enabled expanded and streamlined deployment of these innovative materials in highway infrastructure. Additional research and evaluation is ongoing to refine these standards and improve the economy of FRP composite structures. Brief case studies on three bridges and three non-bridge infrastructure applications exceeding $25M construction.

The bridge case-studies involve cast-in-place continuous slabs, prestressed slab and girder bridge applications (including coupling FRP elements with Ultra-High Performance Concrete). The non-bridge applications include: precast and cast-in-place retaining walls and seawalls; and thermoset piling and structural shape elements for various in-water structures.

Life-Cycle Cost (LCC) analysis can range from simple to complex depending on the desired level of precision and effort. Three levels of analysis are presented for use by designers during the Bridge Alternatives Development process for selecting the final design option:

- Level 1 – Basic (Average Acquisition Cost per Year);
- Level 2 – Intermediate (Stepwise LCC for discrete construction and maintenance);
- Level 3 – Advanced (Probabilistic analysis of stepwise methodology).

These strategies for a tiered LCC approach using increasing levels of complexity will be presented with selected application to some of the case study projects.
Key Topics

• The Value Proposition of FRP for Bridges and Marine Structures;
• Authoritative resources, guidelines, and specifications;
• Example Projects from Florida 2018-2020;
• Ongoing Applied Research and Future Opportunities;
• Challenges to the Manufacturing Industry.
The Value Proposition of FRP for Bridges and Marine Structures

• Durability vs. Cost (repair and replacement);
• Extended Service-Life vs. Cost (LCC & LCA);
• Reliability vs. Cost. (Quality is an investment);
• Embracing the competition (and taking a larger piece of the pie).
Value Proposition…

• Mostly motivated by corrosion durability concerns…

**FIGURE 2**
**INFRASTRUCTURE ($22.6 BILLION)**

- HAZMAT Storage 31% ($7 billion)
- Highway Bridges 37% ($8.3 billion)
- Waterways and Ports 1% ($0.3 billion)
- Gas and Liquid Transmission Pipelines 31% ($7 billion)

Annual cost of corrosion in the infrastructure category.


**FDOT Budget FY 2018-19**

- Other Transportation $5.6B
- New Construction $3.11B
- Maintenance $1.69B
- Rest of Budget $76.6B

Value Proposition...

- Florida is ranked 2\textsuperscript{nd} behind Alaska in the longest US coastline.
Value Proposition…

• Extended Service-Life vs. cost (LCC & LCA);

Value Proposition…

• Embracing the competition (and taking a larger piece of the pie).

Value Proposition…

- Environmental implications (LCA);

Authoritative resources, guidelines, and specifications

• AASHTO for Concrete Structures (GFRP-RC & CFRP-PC Guide Specs);
• AASHTO & ASCE FRP Composite Structures (various Guide Specs);
• CSA for Concrete Structures (S807 & S6)
• National & International harmonization;
• FDOT’s Implementation Strategy (Design, Manufacturer Approval, Construction);
Authoritative resources...

- AASHTO for Concrete Structures (GFRP-RC & CFRP-PC Guide Specs)
• AASHTO & ASCE FRP Composite Structures (various Guide Specs)
Authoritative resources…

• CSA for Concrete Structures (S806, S807 & S6)
Authoritative resources…

• National Harmonization (Example GFRP-RC):

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<td>50</td>
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<td>$c_{c,\text{slab}}$</td>
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**To be finalized**
Authoritative resources, guidelines, and specifications

• Development Worldwide of major FRP-RC/PC Guidelines:
Authoritative resources, guidelines, and specifications

- FDOT’s Implementation Strategy (Design, Manufacturer Approval, Construction);
Authoritative resources, guidelines, and specifications

- FDOT’s Implementation Strategy (Design, Manufacturer Approval, Construction);

https://mac.fdot.gov/smoreports
Example Projects from Florida 2018-2020

1) NE 23rd Ave over Ibis Waterway
2) US1 over Cow Key Channel
3) US41 Pedestrian Bridge Link-Slabs
4) SR-A1A Secant-Pile Seawall
5) I-dock Biscayne Bay
6) Recharge-Water Park Boardwalks
7) Skyplex Composite Arch Bridge
Example Project 1: NE 23rd Ave/Ibis Waterway

Historical Hurricanes Passing within 50 nmi of the project site (1842-2015) (Source: https://coast.noaa.gov/hurricanes/)

Pile Jackets at End Bents
NE 23rd Ave/Ibis Waterway

- First GFRP-RC 3-span continuous flat-slab bridge in Florida. First soldier pile bulkhead-seawall with GFRP-RC precast panels.
Example Project 2: US1/Cow Key Channel

Figure 2: Deterioration on Underside of Slab Units of Spans 3 and 4 (Bridge No 900086)
US1/Cow Key Channel

- FRP eliminates need for additional concrete cover, additives, and waterproofing.
- CFRP Prestressing and GFRP Reinforcing with no reduction in AASHTO tensile stresses.
Example Project 3: SR-A1A Secant-Pile Seawall

Project Background:
• Historical erosion issues due to hurricane impacts
• Provide a long term, permanent solution to protect A1A roadway. A wall design was needed to protect roadway in the most vulnerable areas
• Governor’s commitment – accelerated acquisition, design, & construction schedule

2006 Emergency Contract Wall
SR-A1A Secant-Pile Seawall

- N. 18th St. to Osprey Dr.
- 4920 ft of beach along E. Flagler Beach
- Wall constructed along entire limits of segment 3
SR-A1A Secant-Pile Seawall

Concept and Design
SR-A1A Secant-Pile Seawall

Construction Process:
Example 4: Ocala Water-Recharge Park Boardwalks

- Ocala’s water recharge park to have ‘cutting edge’ technology
  - 1,700 Linear Feet of boardwalk and viewing platforms spanning over 3 reclaimed water filtration ponds. Creating a city park and learning center.
Ocala Water-Recharge Park Boardwalks

Installation Process

Pile Driving 5”x 5” Composite Sections

Installing the Bonded Stringer Sections
Ocala Water-Recharge Park Boardwalks

Installation Process

Installing the Bonded Bearers and Stringer Sections
Ocala Water-Recharge Park Boardwalks

A completed pond walk-over. Waiting to flood the cell
Example Project 5: I-Dock on Biscayne Bay

Project Background:
• 2018 Condition:
  – Existing dock damaged by Hurricane Irma (2017)
I-Dock on Biscayne Bay

SECTION A

TIES #3
8#6

Concrete Cover = 1.5"

12"

12"

12"

STONGWELL
DURAGRIDENT
T2500 1 3/4"

TYPICAL
CLOSURE
POUR

PRECAST
CONCRETE
BEAM

PRECAST
CONCRETE
PILE CAP

PRECAST
12"x12"
CONCRETE
PILE
I-Dock on Biscayne Bay

Installation Process
Example Project 6:
US41 Pedestrian Bridges Link-Slabs

- SR-5 (US 41) over Morning Star (FRP rebar – FRC)
- SR-5 (US 41) over Sunset Waterways (FRP rebar – UHPC)
US41 Pedestrian Bridge Link-Slabs

- Elimination of expansion joint maintenance, and better transfer of lateral load
- Utilization of low modulus GFRP bars and fibers in concrete

Plan view of Morning Star bridge
Example 7: Skyplex Composite Arch

- Easy to built, innovative solution
Ongoing Applied Research and Future Opportunities

• Mild Prestressing for Concrete applications of low-cost FRP-PC elements;
• Refined Durability and Endurance Modeling;
• Ultra-High Performance Concrete (UHPC) and FRP; rebar/prestressing;
• Hybrid systems and Other synergistic combinations.
MILDGLASS: NCHRP-IDEA #207

Possible Benefits:

• Concept: GFRP Mild Prestressing
• Limits cracking and splitting at release
• Safe pulling with traditional techniques
• Targets Coastal Structures
• Experience Highest corrosion
• Requires Lowest prestress
Structural Tests at U-Houston

- Cross Section 10x30 inches
- Length: 20 feet
- Prestress: 36-41% GTS
- Conf. A: 16 GFRP No.4 at 10-kip
- Conf. B: 16 GFRP No.5 at 13-kip
- Conf. C: 8 GFRP No.5 at 13-kip
Ongoing Applied Research and Future Opportunities

• Refined Durability and Endurance Modeling;
Ongoing Applied Research and Future Opportunities

• Refined Durability and Endurance Modeling
  – Creep rupture knock-down factor = 0.46
  – ~50% more than 0.30 recommended by AASHTO

Fig. 10. Sustained load versus logarithmic time-to-failure for batch M13(1).

Fig. 11. Sustained load versus logarithmic time-to-failure for batch M13(2).
Ongoing Applied Research and Future Opportunities

• Ultra-High Performance Concrete (UHPC) and FRP; rebar/prestressing;

https://fotwww.blob.core.windows.net/sitefinity/docs/default-source/structures/innovation-docs/iw-gfrpcs2-casestudypapers.pdf?sfvrsn=57af4e3_2
Ongoing Applied Research and Future Opportunities

- Ultra-High Performance Concrete (UHPC) and FRP; rebar/prestressing;
Challenges to the Manufacturing Industry

- Product Certification
- Instilling Asset Owner Confidence in Quality
- Scalability for Mainstream Infrastructure?
QUESTIONS?

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

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