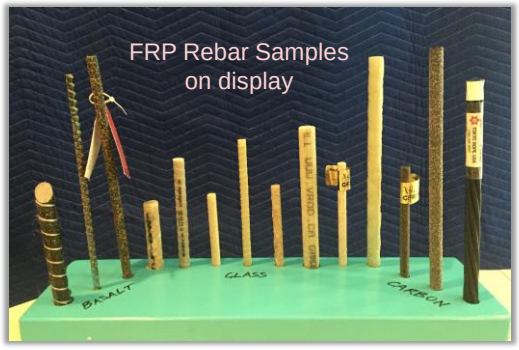
FDOT Executive Workshop
January 15, 2020

Fiber-Reinforced Polymer Deployment for Corrosion-Free Bridges



Steven Nolan, P.E. (Steven.Nolan@dot.state.fl.us)
State Structures Design Office

1

Why use FRP rebar for Bridges and other Structures?

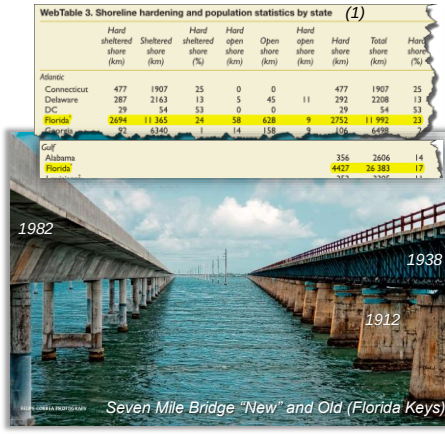
- Failure of structures exposed to aggressive environments is often corrosion of the steel reinforcement;
- Chlorides from air-borne salt or seawater penetrate concrete and reach steel rebar:
  - ✓ Via concrete porosity
  - ✓ Via cracks
- Corrosion is also accelerated by carbonation of concrete that lowers the pH;

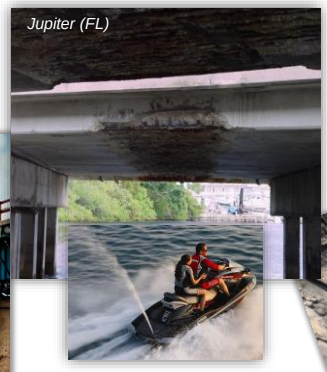
+ Low electro-magnetic interference;
+ Lower ownership costs.

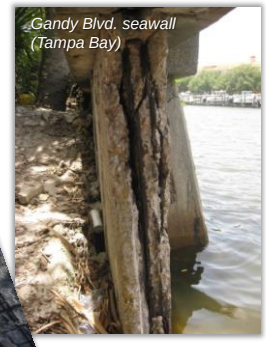
2

Why use FRP rebar for Bridges and other structures

- Florida maintains more than 150 million sq.ft. of bridge area *(7007 FDOT bridges[2]);*
- Florida has more than 4,000 miles seawall-bulkheads[3].







(1) Gittman et al. (2015) https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/150065
(2) FDOT Bridge Inventory - 2019 Annual Report
(3) Estimates from Gittman et al. (2015)

3

3

Why? …Inevitability of Corrosion

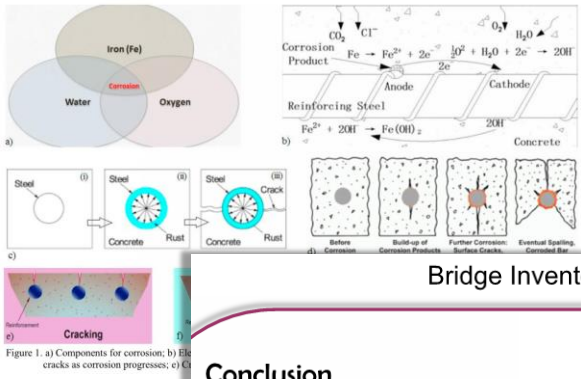


Figure 1. a) Components for corrosion; b) Ele... cracks as corrosion progresses; e) C...

Figure 1 from: Corrosion Mechanism in Reinforced Concrete(from Maia & Alves, 2017)


POST IN-DEPTH BRIDGE COLLAPSE

Portion of U.S. 1 bridge collapses in North Palm

Part of sidewalk, railing fall into canal after two post-tension wires fail.

Bridge Inventory — 2019 Annual Report (2)

(2) https://fdotwww.blob.core.windows.net/sitefinity/docs/default-source/maintenance/str/bi/florida_bridge_inventory_2019_annual_report.pdf

Conclusion

Florida's bridges are generally in good condition, with those maintained by the FDOT in better condition than those maintained by local governments or others. The most serious threat to bridges in Florida is the corrosion of steel reinforced concrete substructures in coastal regions. Much has been learned in recent years about corrosion in marine environments, affecting material specifications and design practices that helps new bridges built today. However, the older bridges in the coastal regions are beginning to require careful evaluation and extensive corrective actions. On-going re-

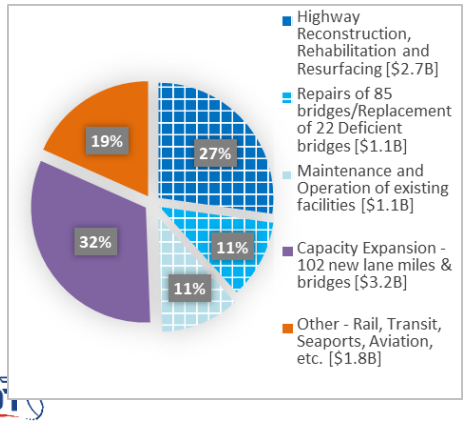
4

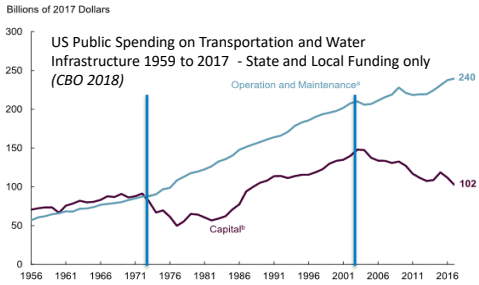
4

Why? …some Infrastructure Facts

Florida DOT Transportation Budget FY 2019/2020

- 49% for combined Maintenance, Operations, Repair, Rehabilitation and Deficient Bridge Replacement (hatched areas).





"Reduce the life cycle cost of infrastructure by 50% by 2025 and foster the optimization of infrastructure investments for society"

www.ASCEgrandchallenge.com

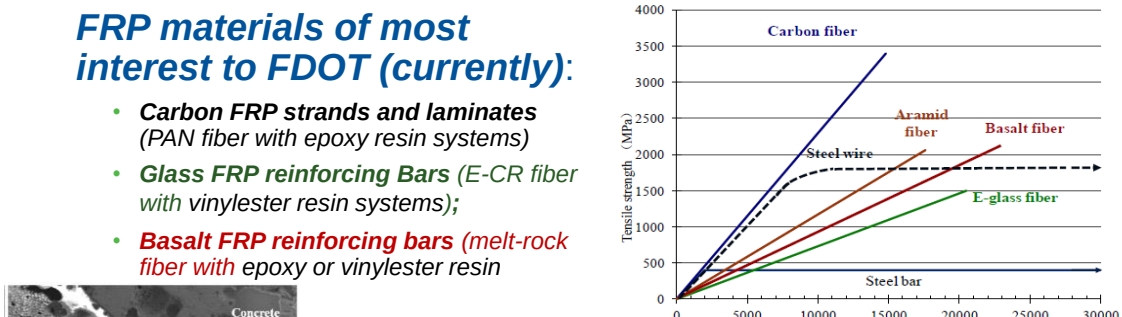
5

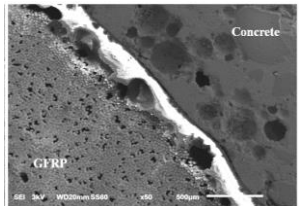
Why? …Drastic Consequences → Different Solutions

FRP composites have been utilized for durable bridge applications for more 30+ years, demonstrating their ability to provide reduced maintenance cost, extended service life, and significantly increase design durability.

FRP materials of most interest to FDOT (currently):

- ***Carbon FRP strands and laminates*** *(PAN fiber with epoxy resin systems)*
- ***Glass FRP reinforcing Bars*** *(E-CR fiber with vinylester resin systems);*
- ***Basalt FRP reinforcing bars*** *(melt-rock fiber with epoxy or vinylester resin*





FDOT's Fiber-Reinforced Polymer Deployment Train

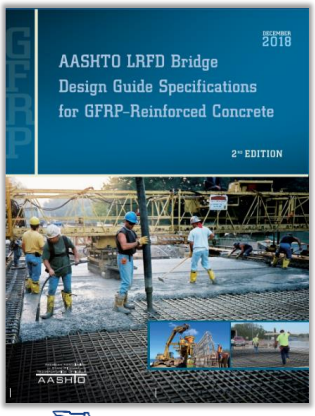
External FRP Laminate Repairs	Fender Systems	CFRP-PC	GFRP-RC	Composite Bridge Girders	BFRP-RC
1990's	*2000's*	*2015*	*2016*	*2016*	*2020*

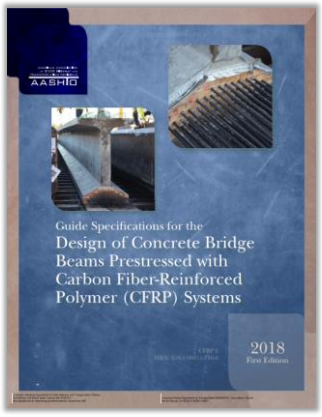
6

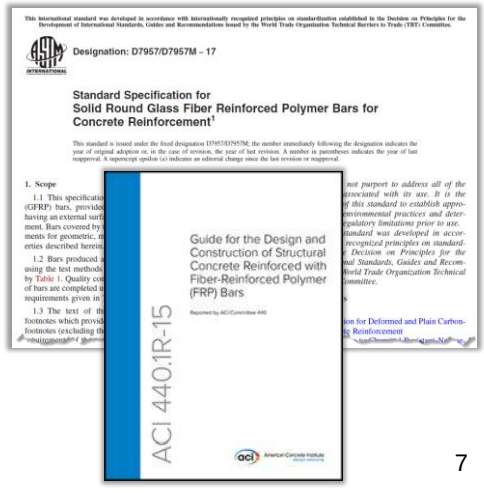
Availability of Design Guidance & Tools

- **Design and Construction Specifications**

  - Now available for rebar & strand (also shapes - tubes, beams & plates for Pedestrian Bridges etc.)

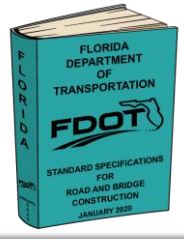


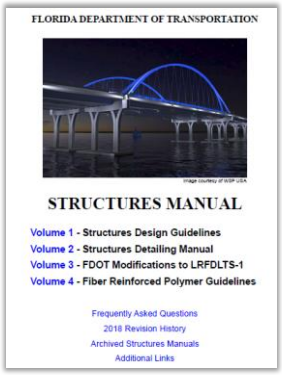




Availability of Design Guidance & Tools

- **FDOT Guidance, Specs and Approval Lists:**

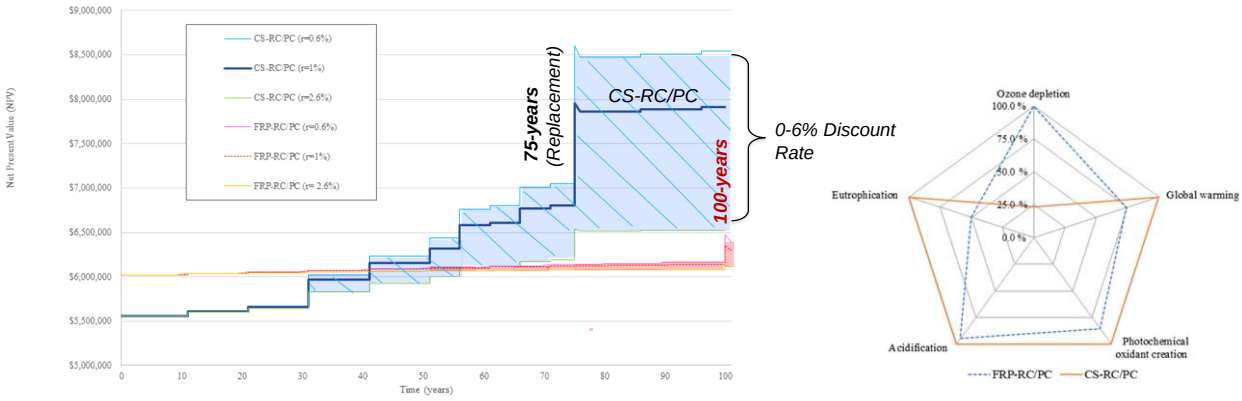




https://www.fdot.gov/structures/innovation/FRP.shtm

Cost Justification (Service Life, LCC, etc.)

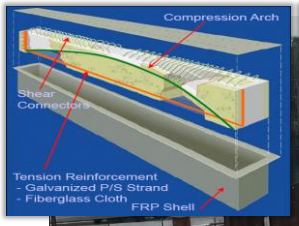
Life-Cycle Cost (LCC) analysis & LCA can show the sustainable (economic and environmental) advantage of FRP structures in the coastal environment:

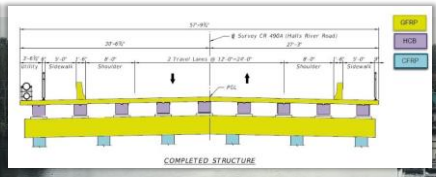


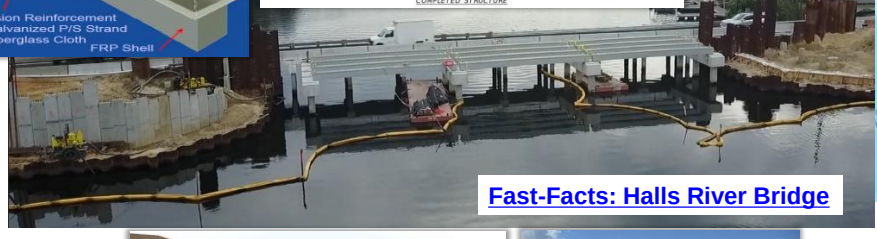
Example LCC & LCA Comparison of Carbon Steel-RC/PC verses FRP-RC/PC bridge *(adapted from Cadenazzi et al. 2019)*

9

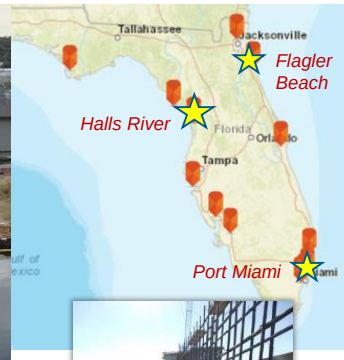
Project Examples & Fast-Facts







Fast-Facts: Halls River Bridge



Fast-Facts: SR-A1A Flagler Beach Seawall

Fast-Facts: Port Miami Tunnel

10

Extra Slides, if needed for later follow up.

11

11

Project Fast Facts

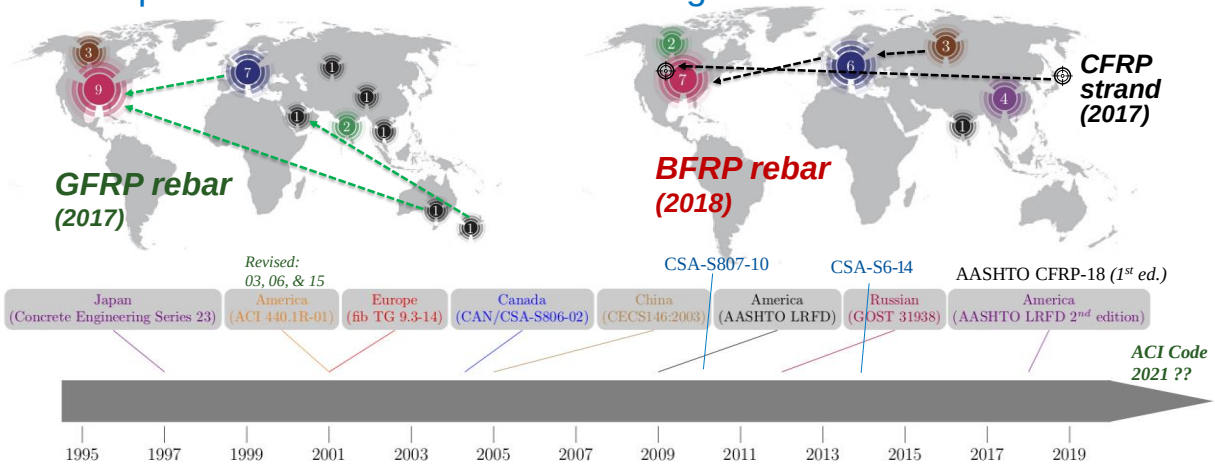
Fast-Facts: https://www.fdot.gov/structures/innovation/FRP.shtm#link9

12

12

Availability of Design Guidance & Tools

Development of worldwide Manufacturing and FRP-RC/PC Guidelines



From FDOT Research Projects ***BDV30 977-18*** *(GFRP)* and ***BDV30 986-01*** *(BFRP)* - FAMU-FSU/UM

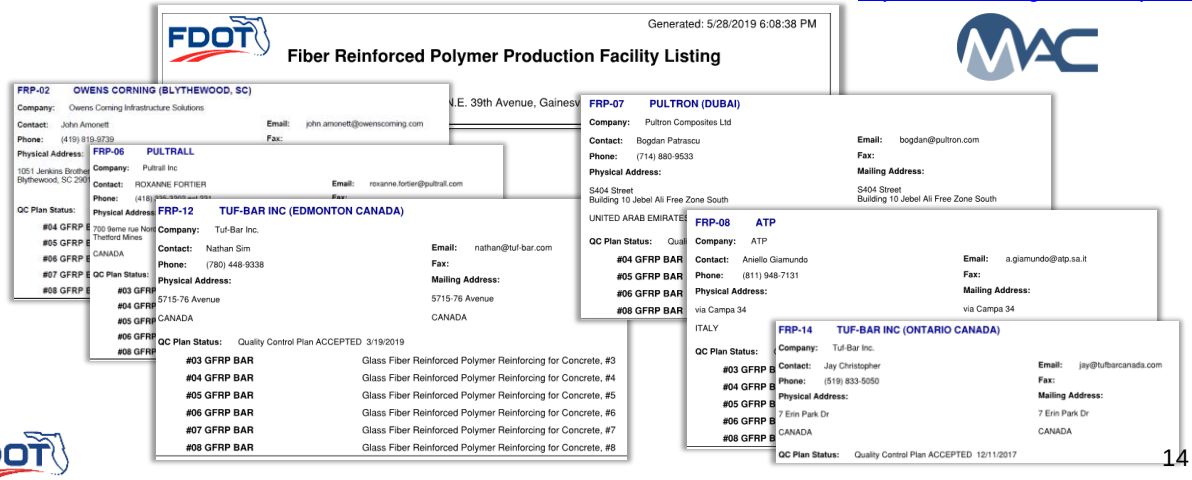
13

13

Availability of Design Guidance & Tools

- **Uniform Approval Processes**
  - Producer Approval vs Product Approval (APL)

https://mac.fdot.gov/smoreports

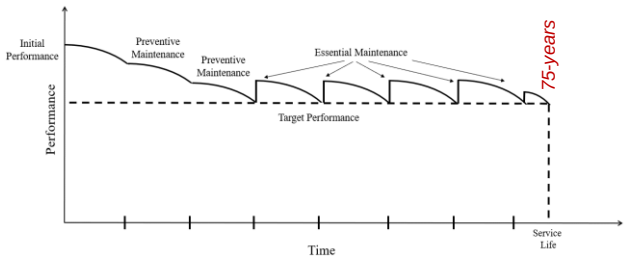


14

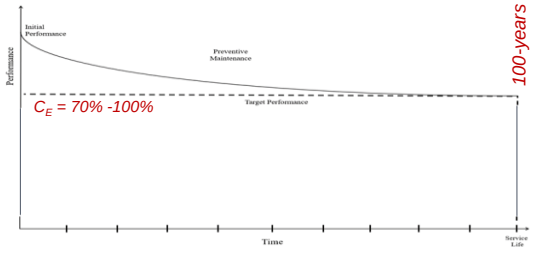
14

Cost Justification (Service Life, LCC, etc.)

LCC & LCA also can show the sustainable (economic and environmental) advantage of composite structures in the coastal environment:



CS-RC/PC alternative



FRP-RC/PC alternative

Charts: Cadenazzi, T., Dotelli, G., Rossini, M., Nolan, S., and A. Nanni. (2019). Cost and Environmental Analyses of Reinforcement Alternatives for a Concrete Bridge. Structure and Infrastructure Engineering.

15