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# BASALT FRP-RC STANDARDIZATION FOR FLORIDA DOT STRUCTURES

Steve Nolan, Chase Knight, Raphael Kampmann

FDOT

FAMU-FSU Engineering

# Paper 229: Basalt FRP-RC Standardization for Florida FDOT Structures

**Abstract**:
Fiber-reinforced polymer bars are emerging as a viable economical solution to eliminate corrosion degrading of reinforced concrete (RC) structures caused by chloride attack in both coastal and cold weather locations. The corrosion mechanism is similar in these divergent environments due to the presence of chlorides: within seawater along the coastal fringe of 20 states; and within deicing chemicals used in most of the other US states. Significant improvements in manufacturing techniques and resin matrix materials have occurred in recent years enabling exploitation of the superior properties of Basalt FRP rebar that is now available. The Canadian Standards Association will shortly be adopting BFRP rebar for concrete structures in their next update to the Canadian Highway Bridge Design Code. FDOT under their Transportation Design Innovation initiative is committed to providing resilient, sustainable, cost effective and scalable solutions to the aging infrastructure challenge. The provision of multiple material options for corrosion-resistant rebar is foreseen as a positive development to encourage competition, further innovation and provide a redundant supply chain for FRP materials, especially as wider deployment occurs. A significant amount of inferior BFRP products are reportedly now available on the world market due to the lack of standards, underlying the need and urgency for establishing robust standards in the US. This paper describes the need and development of standard (guide) design specifications, and standard material and construction specifications for basalt fiber-reinforced polymer (BFRP) bars for the internal reinforcement of structural concrete on FDOT projects.

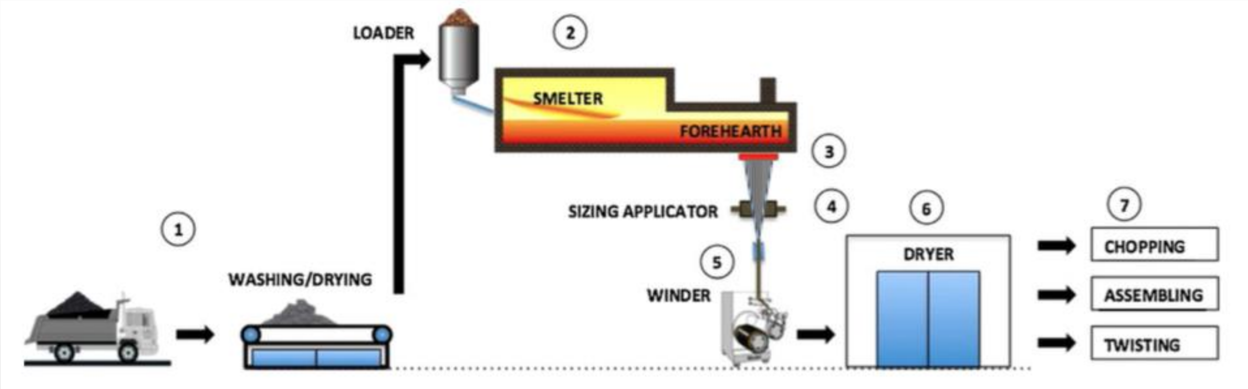
# Introduction

- Fiber-reinforced polymer bars are emerging as a viable economical solution to eliminate corrosion
- Paul Dh`e first produced basalt fibers in the United States, in 1923 (Dh´e, 1923; Colombo et al., 2012), however the technology did not gain traction in the US due to initial production difficulties and more profitable opportunities with glass fibers.
- Specifically, after the manufacturing process for glass fibers was successfully industrialized in Toledo, Ohio, by Games Slayter in 1933 (Slayter, 1938)
- The major fiber producers in the US abandoned basalt fiber research in favor of glass products (Faruk et al., 2017).
- Extensive research on basalt fibers was later conducted in the former Soviet Union, during the cold war (Jamshaid and Mishra, 2016), for military purposes in a search for ballistic resistant textiles.
- After the Soviet Union collapse in 1991, these research projects were declassified (in 1995) and released for civilian applications.
- Most basalt fiber producing companies are still located in countries that use to be associated with the Eastern Bloc (Zych and Wojciech, 2012).

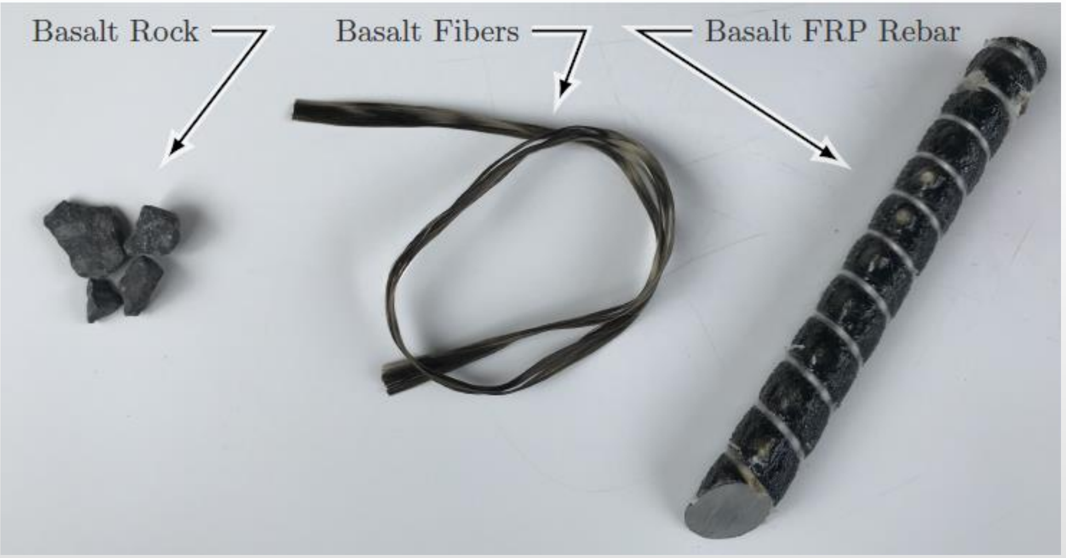
# Basalt FRP Rebar Manufacturing

Significant improvements in FRP manufacturing techniques and resin matrix materials have occurred in recent years enabling exploitation of the superior properties of Basalt FRP rebars.

Epoxy based resins are the preference for BFRP due to improved durability and mechanical performance




Continuous basalt fiber production process (Ipbuker et al., 2014)



# Standards for BFRP-RC

- A significant amount of BFRP products are reportedly now available on the world market, with a wide range of performance properties due to the lack of uniform standards.
- This highlights the need and urgency for establishing robust standards in the US to ensure reliability and instill confidence in asset owners and designers.
- Some significant progress has already been completed for developing a US based code of practice using the current GFRP rebar Guide Specifications as a framework (AASHTO 2018, ACI 2015).


from ***BDV30 986-01*** (FDOT/FAMU-FSU/UM)

# Standards for BFRP-RC

**FHWA State Transportation Innovation Council (STIC) Incentive Project, 2018 – 2019**

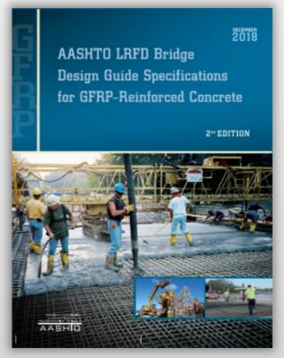
- FDOT under FRP Innovation Initiative received a grant to Standardization of BFRP Rebar (STIC-0004-00A): (https://www.fdot.gov/structures/innovation/FRP.shtm).
- A goal is to provide multiple material options (including the adoption of BFRP) for corrosion-resistant rebar, to encourage market competition, product innovation; and provide a redundant supply chain of FRP materials as wider deployment occurs.
- Includes development of standard design (guide) specifications, and standard material and construction specifications for BFRP rebars for 2020 adoption.

STIC
State Transportation Innovation Councils

***FHWA Project: STIC-0004-00A (2018-2019)***

# Standards for BFRP-RC

1. **ICC-ES AC454:** “Fiber-Reinforced Polymer Bars for Internal Reinforcement of Concrete Members”, approved 2016 - *includes BFRP.*
2. **ACI 440. 1R**: “Guide for the design and Construction of Structural Concrete Reinforced with FRP Bars". *1st Edition in 2001, 2nd Edition in 2003, 3rd Edition in 2006, 4th Edition in 2015, Design Code (ACI 318 in 2020). Will not address BFRP.*
3. **ASTM D7957-17**: “Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement“. *1st Edition 2017 - Does not address BFRP.*
4. **CAN/CSA-S807**: “Specifications for Fibre Reinforced Polymers". *1st Edition in 2010, 2nd Edition in 2019 - Will include BFRP.*
5. **CAN/CSA S6**: "Canadian Highway Bridge Design Code", Section 16 "Fibre Reinforced Polymers (FRP) Structures". *1st Edition in 2000, 2nd Edition in 2006, Supplement S1 in 2010, 3rd Edition in 2014, 4th Edition in 2019 - Will include BFRP.*
6. **AASHTO LRFD**: “ Bridge Design Guide Specifications for GFRP-Reinforced Concrete Bridge Decks and Traffic Railings“. *1st Edition in 2009, 2nd Edition 2018; - Does not address BFRP.*

# Standards for BFRP-RC

7. **FDOT Construction and Materials Specifications:** Section 932-3 "Fiber Reinforced Polymer (FRP) Reinforcing Bars" *Will include BFRP for 2020.*

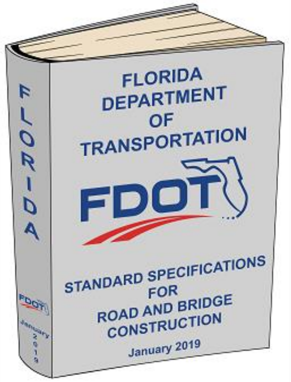



**Table 2A**
**Grades of FRP straight bars and grids corresponding to their minimum modulus of elasticity, GPa**

| Designation | Grade I | | Grade II | | Grade III | |
|---|---|---|---|---|---|---|
| | Individual bars | Bars in a grid | Individual bars | Bars in a grid | Individual bars | Bars in a grid |
| AFRP | 50 | 40 | 70 | 60 | 90 | 80 |
| BFRP | 50 | 40 | 60 | 50 | 70 | 60 |
| CFRP | 80 | 70 | 110 | 100 | 140 | 130 |
| GFRP | 40 | 30 | 50 | 40 | 60 | 50 |

**Fig. 1**. Proposed grades of FRP bars per CAN/CSA S807-19 public review copy.

# Standards for BFRP-RC

## FYI - other available International Material Specifications and Design Codes for Concrete Structures Reinforced with FRP Bars

**SP295 Russian Code of Practice (2017) 2018.12.01 English translation available.**

GOST 13015-2003 Reinforced Concrete and Concrete Produ
Requirements. Rules for Acceptance, Marking, Transportation and

GOST 31938-2012 Fibre-Reinforced Polymer Bar for Concr
Specifications

GOST 32492-2015 Fibre-Reinforced Polymer Bar For Concrete R
of Structural and Thermo-Mechanical Characteristics

GOST 27751-2014 Reliability for Constructions and Foundations.

Code of Practice SP 295.1325800.2017 Concrete Structures Reinforced with Fibre-Reinforced Polymer Bars. Design Rules
*SP (Code of Practice) of 11.07.2017 No. 295.1325800.2017*
*Used from 12.01.2018*

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63.13330 .

**5.2 Performance standards and design characteristics of composite fibre-reinforced polymer bars**

5.2.1 For reinforcement of structures the following types of composite fibre-reinforced polymer bars meeting the requirements of GOST 31938 shall be used:

- glass fibre reinforced polymer (GFRP);
- basalt fibre reinforced polymer (BFRP);
- carbon fibre reinforced polymer (CFRP);
- aramid fibre reinforced polymer (AFRP);
- hybrid fibre reinforced polymer (HFRP).

# Standards for BFRP-RC

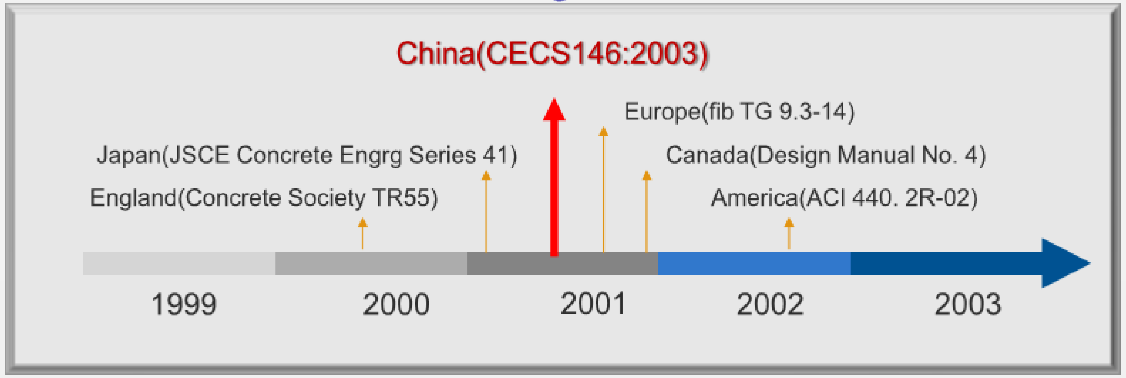
## FYI - other available International Material Specifications and Design Codes for Concrete Structures Reinforced with FRP Bars

### FRP Design Standard —— China's First FRP Standard


In 1998, the first applied technical standard of FRP was developed in China.

CECS146:2003 *Technical specification for strengthening concrete structures with carbon fiber reinforcea polymer laninate*

**Compilation time of the first FRP specification in the major countries and regions of the world**




An overview of research, development and application of FRP for civil infrastructure in China

**Angela Wei Liu**
**Nanjing Fenghui Composite Material Co.,Ltd**

**In collaboration with**
**Nanjing Tech University**

2017

CAMX

**JG/T406-2013** ***Class frbre reinforced plastics rebar for civil engineering***

**JG/T351-2012** ***Fiber reinforced composite bars***

**GB50608-2010** ***Technical code for infrastructure appliaction of FRP composites***

# Standards for BFRP-RC

## BFRP Bars in Florida *(FDOT Spec 932-3, similar to ASTM D7957)*

Table 3-1
Sizes and Tensile Loads of FRP Reinforcing Bars

| Bar Size Designation | Nominal Bar Diameter (in) | Nominal Cross Sectional Area (in²) | Measured Cross-Sectional Area (in²) | | Minimum Guaranteed Tensile Load (kips) | |
|---|---|---|---|---|---|---|
| | | | Minimum | Maximum | *BFRP and* GFRP Bars | CFRP Bars |
| 2 | 0.250 | 0.049 | 0.046 | 0.085 | 6.1 | 10.3 |
| 3 | 0.375 | 0.11 | 0.104 | 0.161 | 13.2 | 20.9 |
| 4 | 0.500 | 0.20 | 0.185 | 0.263 | 21.6 | 33.3 |
| 5 | 0.625 | 0.31 | 0.288 | 0.388 | 29.1 | 49.1 |
| 6 | 0.750 | 0.44 | 0.415 | 0.539 | 40.9 | 70.7 |
| 7 | 0.875 | 0.60 | 0.565 | 0.713 | 54.1 | - |
| 8 | 1.000 | 0.79 | 0.738 | 0.913 | 66.8 | - |
| 9 | 1.128 | 1.00 | 0.934 | 1.137 | 82.0 | - |
| 10 | 1.270 | 1.27 | 1.154 | 1.385 | 98.2 | - |

$E_f \geq 6{,}500$ ksi  $E_f \geq 18{,}000$ ksi

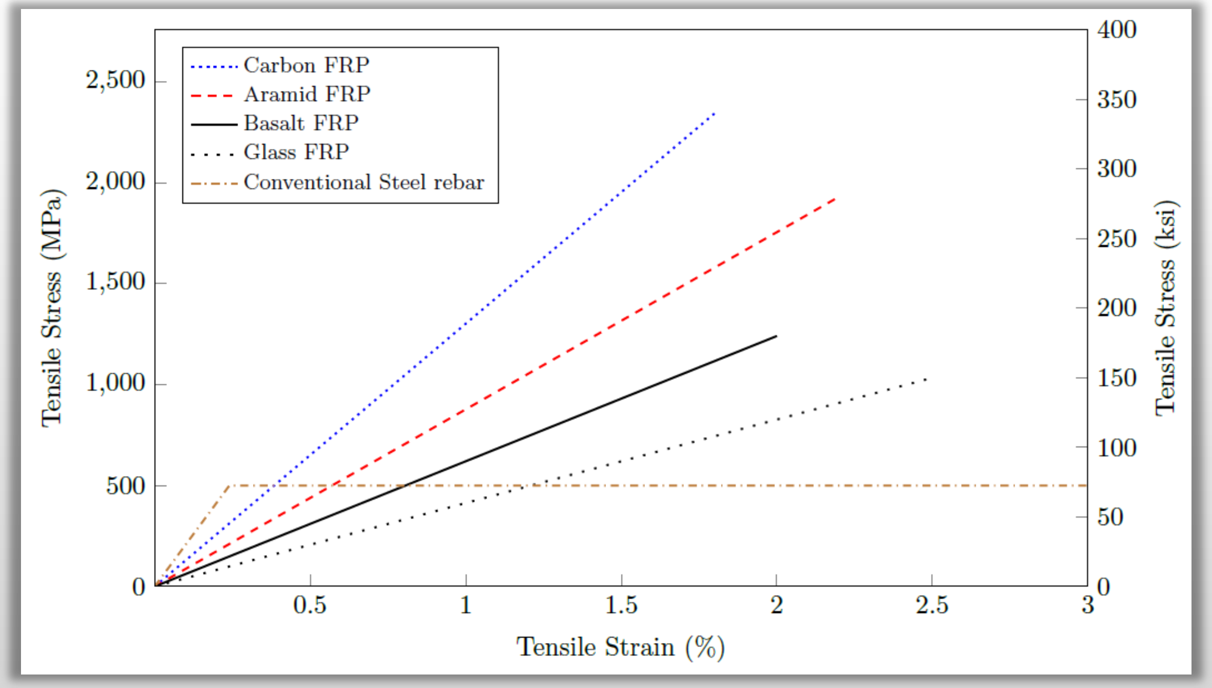
# Standards for BFRP-RC



## Improving FRP Bars in North America

Basalt FRP Bars (High Modulus and High Strength)

1. *Guaranteed Tensile strength up to 200 ksi (1,400 MPa)*
2. *Modulus of elasticity up to 9,000+ ksi (64+ GPa)*

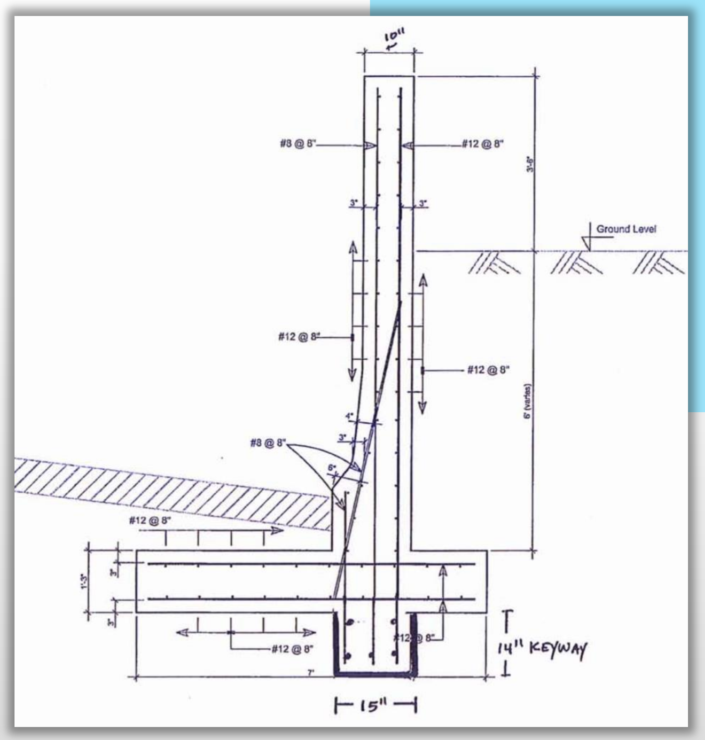

from ***BDV30 986-01*** (FDOT/FAMU-FSU/UM)

# BFRP-RC Structures in Florida

Some recent examples of structures that have been successfully constructed with BFRP rebar in Florida, are summarized below:

## Port Miami Tunnel Entrance Walls (Watson Island)
## Miami – 2014



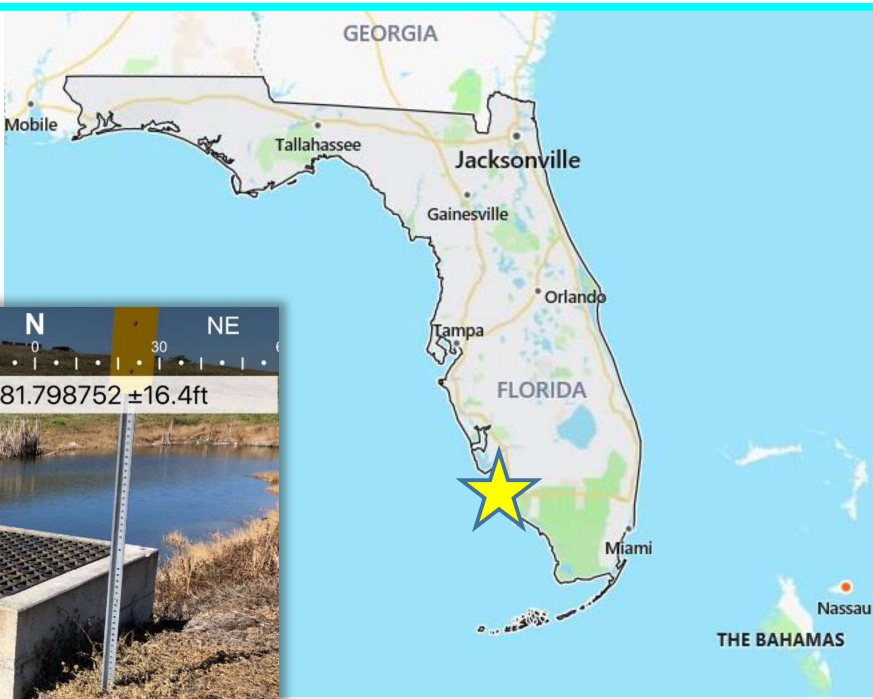


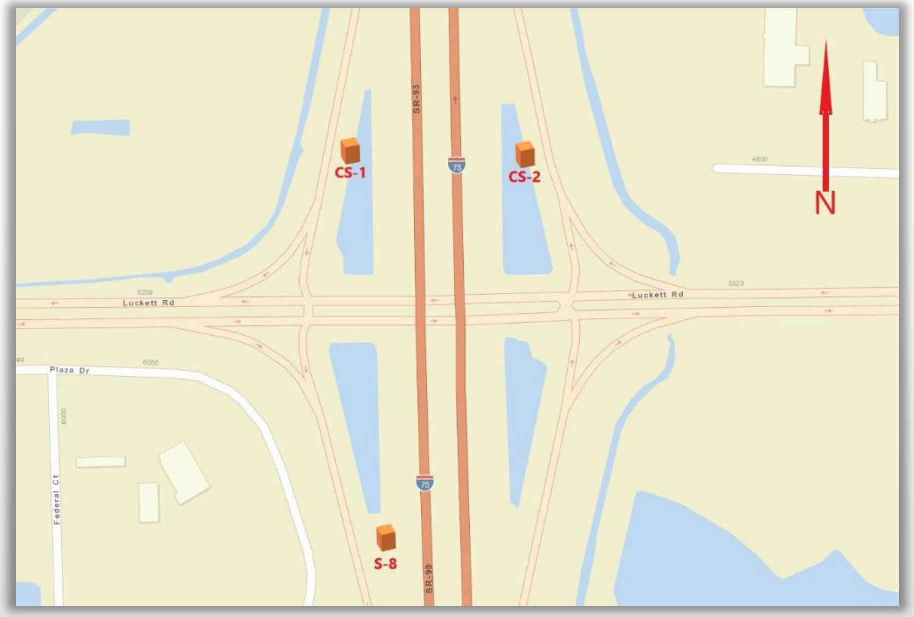

Wall 6 under construction & Typical Cross-section of Retaining Walls 5 and 6

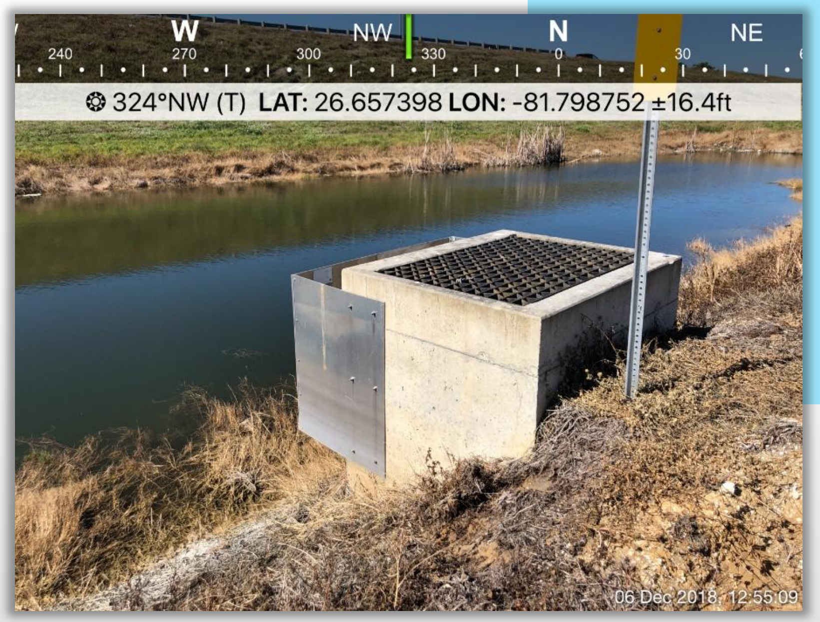
Port Miami Tunnel Fast-Facts:
https://www.fdot.gov/structures/innovation/FRP.shtm#link9

# BFRP-RC Structures in Florida

## IROX Drainage Structures, Lee County - 2014



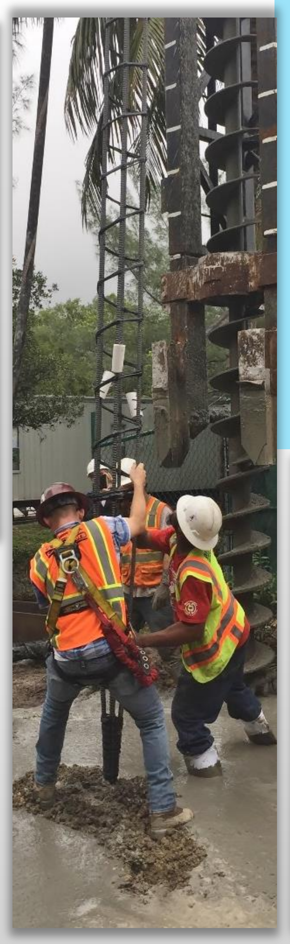

**(a)** Plan view locations of 3 retention pond overflow structures; **(b)** Photograph of structure CS-2.

# BFRP-RC Structures in Florida

## Innovation Pedestrian Bridge, Miami – 2016 & i-Dock, Miami - 2019

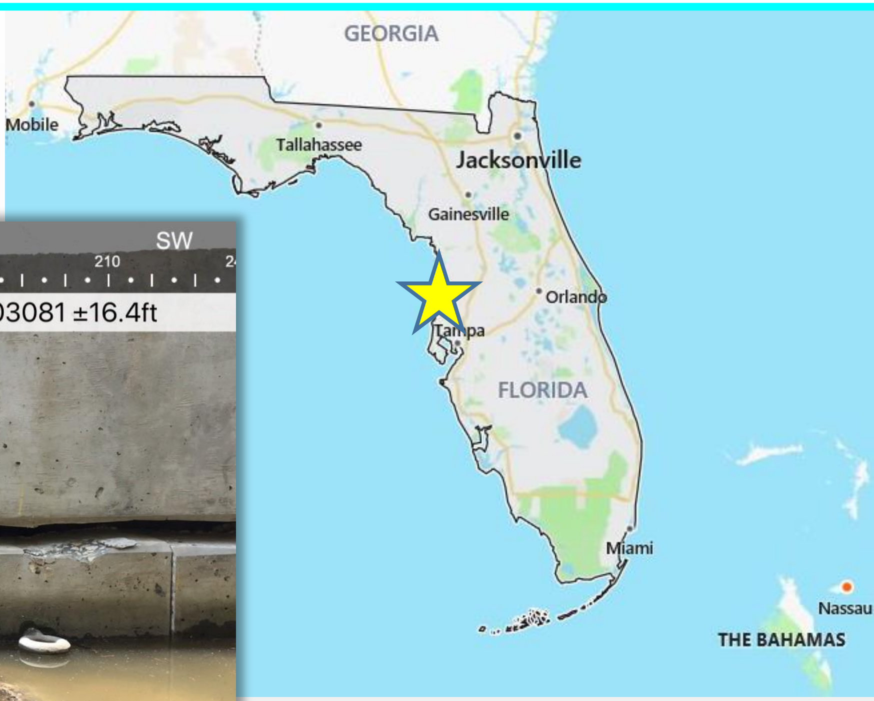
Elevation view of Innovation Bridge with BFRP reinforcement in the auger-cast-piles, bent-caps, double-tee stems and flanges, deck overlay and curbs.

Innovation Bridge & I-Dock Fast-Facts
https://www.fdot.gov/structures/innovation/FRP.shtm#link9




# BFRP-RC Structures in Florida

## Halls River Bridge, Homosassa – 2018


Typical position of test blocks: (a) High tide at HRB (test bock outlined); (b) 6-month Benchmark test blocks cut and ready for extraction (July 2018)

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

# Conclusion

- Several demonstration projects in Florida, and others around the world, have shown the versatility and practicality of BFRP rebar for structural applications.
- Commercial manufacturers have exhibited the capacity to accommodate a variety of geometric challenges and respond to asset owner's needs.
- Researchers have validated the mechanical properties, and while durability research continues, the current limits in the available GFRP-RC guide specifications appear appropriately conservative
- LCC analysis can currently be utilized by designers to show the benefits of FRP-RC alternatives,
- Future refinement of the durability models can provide additional economy, encourage industry innovation, and provide increasing sustainability.

# Questions

## Lead Researcher

***Raphael Kampmann PhD***

*FAMU-FSU College of Engineering*

*Tallahassee, FL.*

*kampmann@eng.famu.fsu.edu*

## FDOT Design Contacts:

***Steven Nolan, P.E.***

*FDOT State Structures Design Office,*

*Tallahassee, FL.*

*Steven.Nolan@dot.state.fl.us*

## FDOT Materials and manufacturing:

***Chase Knight, Ph.D, P.E.***

*State Materials Office,*

*Gainesville, FL.*

*Chase.Knight@dot.state.fl.us*