Advancements in FRP composite usage for Highway Infrastructure in Florida

Steven Nolan, P.E.
Senior Structures Design Engineer
Florida Department of Transportation

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Biography:
Steve has worked for the FDOT since 1996 and is a registered Professional Engineer in Florida. He currently leads the Advanced Materials for Structures initiatives within the State Structures Design Office and includes FRP composites, High-Strength Stainless Steel strands, Fiber-Reinforced Concrete, and Ultra-High Performance Concrete materials. In his 24 years with FDOT he has worked with in-house bridge design and developed many of the Department’s precast and prestressed concrete Standards. He is an active member of the Transportation Research Board’s AFF80/AKB10 Committee on Structural Composites/Innovative Highway Structures; the Bridge Engineering Institute’s Scientific Advisory Panel; and a reviewer for several engineering journals. Steven has co-authored and presented numerous papers on FRP and prestressed concrete related to bridges and coastal structures.
ABSTRACT

Advancements in FRP composite usage for Highway Infrastructure in Florida

FDOT has been involved in researching composite FRP’s since the late 1980’s. This research led to successful project applications beginning in the 1990’s for bridge structure repair and strengthening typically required due to either corrosion and/or truck impact damage and continues to evolve today.

Broad use of composite FRP structures for new construction began in the 2000’s with navigational fender systems that are used to guide vessels and protect bridge piers. Later research and demonstration of lightweight applications for bridge deck panel evaluation and other minor structural components. Hybrid composite beams coupling FRP and concrete are now gaining acceptance and have been showcased on a few Florida structures, bolstered by the success of other state DOTs. The broadest implementation for new construction applications is with composite rebar starting in the 2010’s and the progressing to prestressed concrete applications by mid-decade. Other ancillary structures find use of composites under new construction in minor applications but the reinforced & prestressed concrete are currently receiving the most attention with broadening of fiber types and resin systems.

A robust framework for manufacturer approval and product verification, coupled with standard specification and design guidance is evolving. Proliferation of design practices and partnering with other state and infrastructure stakeholders is consider key to driving further development of innovation and delivering cost effective solutions that can succeed at an infrastructure scale and within the existing culture of the construction industry. This presentation will walk thru FDOT’s journey and provide some insights on what a successful value proposition for the future could entail.
OUTLINE

1. The Value Proposition
2. Expanding Range of Product Solutions
3. Recent Full-Scale Testing Examples
4. Implementation Tools for Designers, Contractors, & Owners

5. Projects Examples
6. Lessons Learned from the Real World
7. Forecasting the Future
Advancements in FRP composite usage for Highway Infrastructure in Florida

The Value Proposition –
Structural Advancement & Durability
(Resilience & Sustainability)

1. High Tensile Strength
2. Low Unit Weight
3. High Durability (corrosion-free)
4. Innovative Technology Development
5. Local/Regional Manufacturing Opportunities
6. Low Carbon Footprint?
The Value Proposition

Durable Solutions and Life Cycle Cost Benefits

• Service Life Expectations for Structures
• Alternative Design Strategies
• Life Cycle Cost policy and comparisons
Advancements in FRP composite usage for Highway Infrastructure in Florida

**Taking stock of our Bridge & Structures Infrastructure**

- **FDOT’s Structures Asset Inventory (2019/20)**
  - 12,529 bridges in the State of Florida
  - 7,044 bridges maintained by **FDOT**
  - 150,227,048 SF of deck area
  - 5,485 maintained by others (County, City, Federal)
  - 2,143,163 SY of noise barrier wall
  - 379.22 miles of retaining wall
  - 72.8 miles of seawall

- **FDOT bridges classified in an aggressive environment:**
  - 1,534 Bridges
  - 68,857,118 SF Deck
  or about 46%
FRP material systems used in FDOT’s Highway Bridges & Structures

1. FRP-Prestressed Concrete (PC):
   - Prestressed Beams - CFRP strands, GFRP/BFRP auxiliary rebar
   - Bearing Piles – CFRP strands, spirals, & splice dowels, (GFRP/BFRP? auxiliary rebar )
   - Sheet Piles - CFRP strands, GFRP (BFRP ? submerged) stirrups

2. FRP-Reinforced Concrete (RC):
   - CIP Decks & Flat-Slab Bridges - GFRP (BFRP now allowed)
   - Seawalls – GFRP (submerged)
   - Bulkhead Caps – GFRP/BFRP
   - Retaining Walls - GFRP/BFRP
   - Drainage Structures/Box Culverts – (no recent examples)

3. FRP Elements (MS):
   - Fenders, Piles, HCBs, Pedestrian Structures

4. Maintenance Repair & Rehabilitation (MR&R)
   - Externally Bonded Repairs (CFRP wrap & laminates, GFRP ?)
   - Pile Jackets (Cathodic Protection w/ GFRP shells, FRP dowels & bars)

*Advancements in FRP composite usage for Highway Infrastructure in Florida*
Expanding Range of Reliable FRP Materials & Structural Solutions

i. GFRP rebar & improved properties
ii. BFRP rebar implementation
iii. Improving CFRP strand & bar performance and economy
iv. Pultruded & Molded Structural Components
Expanding Range of Reliable FRP Materials & Structural Solutions

i. GFRP rebar & improved properties

**Elastic Tensile Modulus**

✓ Smaller bars =
  - Higher strength
  - Better crack control
  - Better fit-up *(especially for bent bars bend radius must be ≥ 3 bar diameters)*

✓ Less bars *(reducing congestion)*
✓ Higher allowable shear stresses
✓ Lower deflections

*Why is this important for FDOT?*

← Improves efficiency in design requiring either
Expanding Range of Reliable FRP Materials & Structural Solutions

i. GFRP rebar & improved properties

**Tensile Strength:**

- ✓ Smaller bars =
  - **better fit-up**
  - x higher stress - larger crack widths
  - x higher fatigue stresses
  - x higher sustained loads

- ✓ Less bars - reduces congestion
- x Greater deflections?
- x Great surface bond stress demands
  - May need higher bond strength standard (>> 1.1 ksi)

*Figure: Different types of FRP [Fu et al. 2019]*

*Advancements in FRP composite usage for Highway Infrastructure in Florida*
Expanding Range of Reliable FRP Materials & Structural Solutions

i. GFRP rebar & improved properties

ii. BFRP rebar implementation

932-3.2 Bar Sizes and Loads: The sizes and loads of FRP reinforcing bars shall meet the requirements in Table 3-1. The measured cross-sectional area, including any bond enhancing surface treatments, shall be determined according to Table 3-2.

<table>
<thead>
<tr>
<th>Bar Size Designation</th>
<th>Cross-Sectional Area (in²)</th>
<th>Minimum Guaranteed Tensile Load (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.085</td>
<td>6.1</td>
</tr>
<tr>
<td>3</td>
<td>0.161</td>
<td>13.2</td>
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<tr>
<td>4</td>
<td>0.263</td>
<td>21.6</td>
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<tr>
<td>5</td>
<td>0.388</td>
<td>29.1</td>
</tr>
<tr>
<td>6</td>
<td>0.539</td>
<td>40.9</td>
</tr>
<tr>
<td>7</td>
<td>0.713</td>
<td>54.1</td>
</tr>
<tr>
<td>8</td>
<td>0.913</td>
<td>66.8</td>
</tr>
<tr>
<td>9</td>
<td>1.137</td>
<td>82.0</td>
</tr>
<tr>
<td>10</td>
<td>1.385</td>
<td>98.2</td>
</tr>
</tbody>
</table>

Expansions in FRP composite usage for Highway Infrastructure in Florida
Expanding Range of Reliable FRP Materials & Structural Solutions

i. GFRP rebar & improved properties
ii. BFRP rebar implementation
iii. Improving CFRP strand & bar performance and economy
iv. Pultruded & Molded Structural Components

Table 1-2
Typical Sizes and Loads of CFRP Prestressing Strands and Bars

<table>
<thead>
<tr>
<th>Type</th>
<th>Nominal Diameter (in)</th>
<th>Nominal Cross Sectional Area (in²)</th>
<th>Nominal Ultimate Load (P_u) (kips)</th>
<th>Nominal Ultimate Tensile Stress (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Strand - 5.0mm Ø</td>
<td>0.20</td>
<td>0.02540</td>
<td>9.1</td>
<td>364.00</td>
</tr>
<tr>
<td>7-strand - 7.95mm Ø</td>
<td>0.310</td>
<td>0.04850</td>
<td>17.8</td>
<td>374.00</td>
</tr>
<tr>
<td>7-strand - 10.85mm Ø</td>
<td>0.434</td>
<td>0.090</td>
<td>33.12</td>
<td>367.56</td>
</tr>
<tr>
<td>Single Strand - 9.5mm Ø</td>
<td>0.38</td>
<td>0.110</td>
<td>35.0</td>
<td>318.00</td>
</tr>
<tr>
<td>7-strand - 12.5mm Ø</td>
<td>0.49</td>
<td>0.1178</td>
<td>43.34</td>
<td>370.47</td>
</tr>
<tr>
<td>Single Strand - 12.7mm Ø</td>
<td>0.50</td>
<td>0.196</td>
<td>59.0</td>
<td>301.00</td>
</tr>
<tr>
<td>7-strand - 15.2mm Ø</td>
<td>0.60</td>
<td>0.179</td>
<td>66.24</td>
<td>369.44</td>
</tr>
<tr>
<td>19-strand - 20.5mm Ø</td>
<td>0.81</td>
<td>0.220</td>
<td>111</td>
<td>229.00</td>
</tr>
<tr>
<td>7-strand - 17.2mm Ø</td>
<td>0.68</td>
<td>0.234</td>
<td>86.679</td>
<td>370.538</td>
</tr>
</tbody>
</table>
Expanding Range of Reliable FRP Materials & Structural Solutions

i. GFRP rebar & improved properties
ii. BFRP rebar implementation
iii. Improving CFRP strand & bar performance and economy
iv. Pultruded & Molded Structural Components
Recent Full-Scale Testing and Research on Beams and Piles

i. GFRP Pile prestressing, spirals and dowel splicing
Recent Full-Scale Testing and Research on Beams and Piles

i. GFRP Pile prestressing, spirals and splicing
ii. FRP Shear and Confinement Rebar – Beams & Slabs
iii. Durability Sampling and Testing of Submerged Rebar

Gate Precast, FL (2017)  
Halls River Bridge, FL (2017)  
Durastress, FL (2019)
Recent Full-Scale Testing and Research on Beams and Piles

i. GFRP Pile prestressing, spirals and splicing

ii. FRP Shear and Confinement Rebar – Beams & Slabs

iii. Durability Sampling and Testing in Wet Environments

Ongoing Project:
BE694
Advancements in FRP composite usage for Highway Infrastructure in Florida

Higher-Performance Materials

Implementation Tools for Designers, Contractors, & Owners

Non-Corrosive

The Florida Department of Transportation (FDOT) continually strives to enhance all areas of its operations. In support of these efforts, the department recently moved into a bold new era for innovative ideas, research, and accelerated implementation. Success will depend on our ability to carefully evaluate and implement the products and services provided to the users of Florida's transportation system. Our goal is to utilize newly developed technology or employ creative thinking to generate greater value for every transportation dollar invested.

After researching and evaluating many innovative ideas, the Central Office has developed a list of concepts, products and services that may be the best solution to the project's needs or design challenges. Some items on the list are completely developed, and only need tailoring to your project. We encourage you to propose one or more of these innovations for project specific solutions with confidence of approval by the Districts. Other items are not fully detailed and will require coordination with and approval by the District's Design Office. Many of these innovations have been successfully implemented in other states and countries. Not all projects benefit from these innovations and the Department is not advocating the general use of new products or designs where an economical well proven solution exists and is the most appropriate solution for the situation.

FDOT Transportation Innovation Challenge

Highly Corrosion-Resistant

Advancements in FRP composite usage for Highway Infrastructure in Florida

"Higher-Performance Materials"

Structures Design Office

Curved Precast Spliced U-Girder Bridges

Fiber Reinforced Polymer Reinforcing

FRP Members and Structures

Geosynthetic Reinforced Soil Integrated Bridge System

Geosynthetic Reinforced Soil Wall

Prefabricated Bridge Elements and Systems

Segmental Block Walls

Ultra-High Performance Concrete (UHPC)

+ Stainless-Steel Prestressing Strand & Rebar
Implementation Tools for Designers, Contractors, & Owners

i. FRP Designer Training

ii. Structural Design and LCC Tools

iii. Technology Transfer Participation

https://www.fdot.gov/structures/innovation/FRP.shtm#link7 (2020)
Implementation Tools for Designers, Contractors, & Owners

i. FRP Designer Training

ii. Structural Design and LCC Tools
   • New construction:
     – Glass FRP rebar & Carbon FRP strands with improving mechanical properties
     – Basalt FRP rebar & possible prestressing applications
     – Composite Bridge Beams (Pultruded, VARTM, Molded & Built-up composite members)
     – Hybrid systems (HCB, Concrete-Filled FRP Tubes...)

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Implementation Tools for Designers, Contractors, & Owners

i. FRP Designer Training

ii. Structural Design and LCC Tools

• New construction:
• Repair & strengthening.
# Implementation Tools for Designers, Contractors, & Owners

## i. FRP Designer Training

- **CFRP-PC Beta version** *(V6.0 coming 2021)*
  - **Prestressed Beam v5.2**
    - Exe (Zip) (Mathcad 15)
    - 11/07/2018

## ii. Structural Design and LCC Tools

- **GFRP-RC in development**
  - **Box Culvert v4.0**
    - Exe (Zip) (Mathcad 15)
    - 11/07/2018

- **GFRP-RC included** *(Worksheet 3b)*
  - **Bent Cap v1.0**
    - Exe (Zip) (Mathcad 15)
    - 11/07/2018

## iii. Technology Transfer Participation

- **GFRP-RC included**
  - **Retaining Wall v4.0**
    - Zip (Exe) (Mathcad 15)
    - 06/01/2020

**Available on request**

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**CFRP** → **GFRP** (Worksheet 3b) → **FDOT Design Software**

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**FDOT Standard Plan Index 400-289** *(formerly Index 289)* to design concrete box culverts, wingwalls, headwalls, and cutoff walls in accordance with the AASHTO LRFD Bridge Design Specification.

**FDOT Standard Plan Index 450-010 to 450-299** *(formerly Index 20010 to 20299)* to design simple span prestressed beams (Florida-I, AASHTO, Florida Bulb-T, Flat Slab, Inverted-T, FSB) in accordance with the AASHTO LRFD Bridge Design Specification.

Analyzes and designs fixed or pinned bent caps, including loads, in accordance with the AASHTO LRFD Bridge Design Specifications.

**FDOT Standard Plan Index 400-010** *(formerly Index 6010)* to design and analyze cast-in-place retaining walls in accordance with the AASHTO LRFD Bridge Design Specification.
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Implementation Tools for Designers, Contractors, & Owners

i. FRP Designer Training
ii. Structural Design and LCC Tools
iii. Technology Transfer Participation

Other Design Software:
Adaption for FRP analysis or design enhancements:

- FBMP (BSI) added Jan. 2021 (see newsletter)
- DeepEx (Deep Excavation, LLC)
- FRPpro™ emerging tools
- Michigan DOT/LTU CFRP-Beam Design Mathcad: https://mdotboss.state.mi.us/SpecProv/trainingmaterials.htm (also see TRB Webinar Dec 3, 2019)
- …
Implementation Tools for Designers, Contractors, & Owners

i. FRP Designer Training
ii. Structural Design and LCC Tools
iii. Technology Transfer Participation


Advancements in FRP composite usage for Highway Infrastructure in Florida
Implementation Tools for Designers, Contractors, & Owners

i. FRP Designer Training

ii. Structural Design and LCC Tools

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)

Advancements in FRP composite usage for Highway Infrastructure in Florida
Implementation Tools for Designers, Contractors, & Owners

i. FRP Designer Training
ii. Structural Design and LCC Tools
iii. Technology Transfer Participation
Implementation Tools for Designers, Contractors, & Owners

iii. Technology Transfer Participation:

1. Research & Bridge Code Development:
   - **TRB AKB30 & AASHTO COBS T-6 & T-10**

2. National Training – **AASHTO COBS T-6 & TRB ABK10**:
   - **CFRP-PC Design** - Under NCHRP 20-44 program for report implementation assistance for CFRP-1, has FHWA & AASHTO T-6 support.
   - **GFRP-RC Design** - not eligible under this program, so State DOTs and FHWA are working on it.

3. AASHTO Guide Specs Review Panels:
   - **NCHRP 12-121**: Developing Specs for FRP Auxiliary Reinf. in PC Girders. (2020-2022)

4. **CAMX**
   - 2016, 2017, 2018, 2019, 2020 (Featured Speaker/Panel)

5. **International**:
   - International Workshop on GFRP Bars for Concrete Structures (2017, 2019, 2021)
   - Lyon (FR) LMC²/AFGC GFRP-RC workshop (2019)
   - International Bridge Conference (2018 FRP Workshop)

6. TRB Annual Meetings:
   - Committee Meeting participation AFF30, AFF80
   - FRP Workshops: 2019 & 2020
   - Technical Sessions: 2018, 2019, & 2021

7. TRB 2019 Webinar - Advanced Structural Materials for Concrete Bridges:

8. ACI coordination (informal)
   - 343 & 440 Committees (Bridge & FRP) 2020 Fall Convention
   - Strategic Development Council – Forum 46 (2019)

9. State Level Engagement:
   - FTBA/Contractors (2017 & 2018)
## Recent Completed Projects

- **Arthur Drive over Lynn Haven Bayou**
- **Bakers Haulover Cut Bulkhead Replacement**
- **Cedar Key Bulkhead Rehab**
- **Key West Bight Ferry Terminal Extension**
- **Halls River Bridge**
- **PortMiami Tunnel Retaining Walls**
- **South Maydell Dr over Palm River**
- **SR-A1A Flagler Beach Seawall (Segment 3)**
- **SR-5 (US-17) over Trout River Rehab**
- **SR-5 (US 41)/Morning Star and Sunset link-slabs**
- **SR-45 (US 41) over North Creek**
- **SR-312 over Matanzas River Rehab**
- **SR-520 over Indian River Bulkhead Rehab**
- **Sunshine Skyway Seawall Rehab & Extension**
- **UM Innovation Bridge**
- **UM Fate Bridge superstructure**
- **UM i-Dock**
- **US-1 over Cow Key Channel FSB’s**

## Current Projects

- **4th St at Big Island Gap**
- **40th Ave NE over Placido Bayou**
- **Barracuda Blvd over Canal Bradano**
- **Bayway Structure-E Seawall Cap**
- **Bimini Dr over Duck Key Canal**
- **CR30A over Western Lake**
- **Jupiter Federal Observation Platform**
- **NE 23rd Ave over Ibis Waterway**
- **S. Maydell Dr/Palm River Bulkhead**
- **SR-A1A over Myrtle Creek and Simpson Creek**
- **SR-A1A N. Bridge Observation Platform**
- **SR 404 & 528 Indian & Banana Rivers Rehab**
- **SR5 over Oyster Creek**
- **SR 5/US 1 over Earman River Canal**
- **SR-30 over St Joe Inlet**
- **SR-112/I-195 Westshore waterway**
- **Village of North Bay Seawall**
- **West Wilson St over Turkey Creek**

[https://www.fdot.gov/structures/innovation/FRP.shtm](https://www.fdot.gov/structures/innovation/FRP.shtm)

* bulkhead/seawall only
** piling/substructure only
*** complete bridge

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**Advancements in FRP composite usage for Highway Infrastructure in Florida**

More projects added every month
FRP Structural Member (MS) systems used in Florida’s Highway Bridges & Structures

Recent Completed Projects

- Acosta Bridge fender replacement *
- Bayway Structure-E fender *
- US-331/Choctawhatchee Bay fender wales
- Halls-River Bridge - Hybrid Composite Beams
- Howard Frankland Bridge NB fender *
- Ocala Water-Recharge Park Boardwalk ***
- Skyplex Blvd - Composite Arch Bridge **
- SR-A1A/Sisters Creek fender *
- SR-A1A/Blue Heron fender replacement *
- SR-3 over Barge Canal fender replacement *
- SR-44 over Indian River fender replacement *
- SR 714/South Fork St Lucie River *

Current & Future Projects

- Bimini Dr over Duck Key Canal ? **
- CR510 3-Sided Culvert-Bridge ? **
- Marco Island Winter Berry Bridge
- I-10/Apalachicola River Fender replace *
- Jax. Main St Bridge Fender rehab *
- SR-40 over Halifax River fender replacement *
- SR-292 Perdido Key/ICWW fender replacement *
- SR-520 over Indian River fender replacement *
- US-192 over Indian River fender replacement *
- SR-401 over Barge Canal fender replacement *
- SR-518 over Indian River fender replacement *

Recent Completed Projects

- Ocala Water-Recharge Park, FL (2018-19)
- Halls River Bridge, FL (2017-19)
- Skyplex Blvd, FL (2018-19)

Current & Future Projects

- Bimini Dr over Duck Key Canal ? **
- CR510 3-Sided Culvert-Bridge ? **
- Marco Island Winter Berry Bridge
- I-10/Apalachicola River Fender replace *
- Jax. Main St Bridge Fender rehab *
- SR-40 over Halifax River fender replacement *
- SR-292 Perdido Key/ICWW fender replacement *
- SR-520 over Indian River fender replacement *
- US-192 over Indian River fender replacement *
- SR-401 over Barge Canal fender replacement *
- SR-518 over Indian River fender replacement *

Typical Fender System

https://www.fdot.gov/structures/innovation/frpms

* complete fender system
** FRP concrete filled arch
*** FRP pedestrian structure

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**FRP Maintenance Repairs & Rehabilitation (MR&R) used on Florida’s Highway Bridges & Structures**

**Recent Completed Projects**
- Numerous since 1990’s.
- We do not actively track

**Current & Future Projects**
- Identified during the biennial bridge inspection program – typically corrosion related.
- Emergency repairs from over-height vehicle impacts

![Recent Completed Projects](image1.png)
- University Blvd. FL.
  - (repaired in 1990’s & 2000’s, replaced 2015)

![Recent Completed Projects](image2.png)
- Jupiter Beach, FL.
  - (scheduled for replacement)

![Recent Completed Projects](image3.png)
- Chaffee Rd, FL.
  - (repaired multiple times & finally replaced)

![Recent Completed Projects](image4.png)
- 03/24/2007

Figure 136—High tide inundation of (a) spans

Figure 220—Corroded steel reinforcement in the north end of Girder 3-1

Figure 227—Girder damage from vehicle impact in July of 2001
Recently Completed Projects (RC/PC)

i. Bridge Superstructures (US-1/Cow Key, US-41 Link-Slabs)

ii. Bridge Foundations (NE23rd Ave/Ibis)

iii. Seawalls (SR-A1A@Flagler Beach, Sunshine Skyway South)
Projects Under Construction (RC/PC)

i. Bridge Superstructures (US41/North Creek, SR-105 Link-Slabs, 40th Ave NE/Placido Bayou)

ii. Bridge Foundations (NE23rd Ave, Maydell Dr.)

iii. Seawalls (SR30/St Joe Bay Inlet, Pinellas Bayway E)
Advancements in FRP composite usage for Highway Infrastructure in Florida

New Projects in Design (RC/PC & MS)

i. Pedestrian Piers & Fenders (North Bridge, Jupiter Beach)

ii. Prestressed Bridges (Earman Canal, Barracuda, 30A)

iii. CIP Bridges (Turkey Creek)

iv. Bridge Foundations (4th St over Island Gap)
New Projects in Design (RC/PC)

i. Pedestrian Piers & Fenders (North Bridge, Jupiter)

ii. Prestressed Bridges (Earman Canal, Barracuda, 30A)

i. CIP Bridges (Turkey Creek)

ii. Bridge Foundations (4th St over Big Island Passage)
New Projects in Design (RC/PC)

i. Pedestrian Piers & Fenders (North Bridge, Jupiter)

ii. Prestressed Bridges (Earman Canal, Barracuda, 30A)

iii. CIP Bridges (Turkey Creek)

iv. Bridge Foundations (4th St over Big Island Gap)
New Projects in Design (RC/PC)

i. Pedestrian Piers & Fenders (North Bridge, Jupiter)
ii. Prestressed Bridges (Earman Canal, Barracuda, 30A)
iii. CIP Bridges (Turkey Creek)
iv. Bridge Foundations
   (4th St over Big Island Gap)
Lessons Learned from the Real World

i. Designer Issues
   • Lack of designer training, software tools, and national consensus design codes.

ii. Material & Testing Issues
   • Costs for FRP rebar supply to public agencies are typically higher since no centralized certification standards for manufacturers, so additional testing and approvals are invoked by individual agencies.

iii. Constructability Issue
   1. Unit costs for FRP rebar are very high for small quantities due to the project testing requirements.
   2. Many construction contractors do not understand the lead times involved for FRP rebar.
   3. Higher modulus of elasticity can improve competitiveness of GFRP vs. other corrosion-resistant solutions.
   4. Stirrup bends and closed shapes or multiple bends still not standardized.
   5. Tie-wire (plastic ties are slower, more expensive, and less secure)
   6. Coupling of bars for phased construction is essential for broader deployment or will rely on SS solutions.
   7. Adhesive anchors are often needed, but not codified for FRP rebar. Field proof testing/gripping is a challenge, especially for bent bars.
   8. Shear reinforcing requires much closer spacings and often multiple legs overlapping causing rebar congestion
   9. Non-metallic lifting devices for heavy civil components are not available
   10. Replacement of easily damaged bars in the field is a common need
Advancements in FRP composite usage for Highway Infrastructure in Florida

Forecasting the Future

- **new Federal “Push Factor”**
- **Industry “Push Factors”**
  - Closing the infrastructure Gap: Shared goal of reducing infrastructure life cycle costs by 50% by 2025
  - Sustainability

- **State/Owner “Pull Factors”**
  - Reducing Asset Management Risk: limit need for corrosion related repairs, MOT, etc.
  - Benefits from Enlarging the Market: increase supply chain security, regional manufacturing opportunity, etc.

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President-elect Biden is working to make far-reaching investments in:

- **Infrastructure**: Create millions of good, union jobs rebuilding America’s crumbling infrastructure – from roads and bridges to green spaces and water systems to electricity grids and universal broadband – to lay a new foundation for sustainable growth, compete in the global economy, withstand the impacts of climate change, and improve public health, including access to clean air and clean water.

- **Innovation**: Drive dramatic cost reductions in critical clean energy technologies, including battery storage, negative emissions technologies, the next generation of building materials, renewable hydrogen, and advanced nuclear – and rapidly commercialize them, ensuring that those new technologies are made in America.

[https://buildbackbetter.gov/priorities/](https://buildbackbetter.gov/priorities/)
QUESTIONS?

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