Forecasting the FRP Future for FDOT Highway Bridges & Structures

Presenter: Steven Nolan, P.E. (FDOT State Structures Design Office)

Jan. 25th 10:00 AM - 11:30 AM EST
Forecasting the FRP Future for FDOT Highway Bridges & Structures

1. The Value Proposition
2. How does FRP align with Florida’s Transportation Plan
3. FRP Material Systems used in Florida
4. FDOT Design Guidance, Specs, & Tools
5. Life-Cycle Cost analysis
6. Forecasting the Future
7. Technology Transfer & Future Development

Also see **IW-GFRPCS2** Case Study #4: “FDOT GFRP-RC Market Size Estimate for Cast-In-Place Concrete by 2020”
The Value Proposition - structural advancement, durability & sustainability

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

How does FRP align or complement the (draft) 2045 Florida Transportation Plan?
The Value Proposition - structural advancement, durability & sustainability

A. relevant Key Strategies for Infrastructures:
   • Address long-term costs
   • Adaptability
   • Advanced Materials
   • …
The Value Proposition - structural advancement, durability & sustainability

2045 Florida Transportation Plan

B. relevant Key Objectives:
   • Maintain Assets in good repair
   • Increase Resilience
   • Quality Infrastructure
   • ...
The Value Proposition - structural advancement, durability & sustainability

2045 Florida Transportation Plan

C. relevant Goals:
- Agile
- Resilient
- Quality infrastructure

Goal: Agile, Resilient, and Quality Infrastructure.

Florida’s emphasis continues to expand from maintaining existing infrastructure to providing agile, resilient, and quality infrastructure. Our infrastructure will adapt to changing customer needs, business models, mobility options, technologies, and energy sources. Our infrastructure will be designed to withstand and recover from potential risks such as extreme weather events and climate trends. Our definition of infrastructure also is broader – it’s not just concrete and steel, but also the communications backbone, sensors, and other technologies that enable the system to function.

Florida will place a high priority on identifying risks to its transportation system and the customers that use it. Florida will incorporate these risks into planning and management decisions.

To learn more about infrastructure in Florida, visit The FDOT Source Book.

- Pavement Condition
- Bridge Condition
- Maintenance Rating

"Input needed: Click here to review draft strategies that help get us closer to this goal. Leave a Comment in the box above and let us know your thoughts."

TRBAM 2021 - Forecasting the FRP Future for FDOT Highway Bridges & Structures
The Value Proposition - structural advancement, durability & sustainability

Cost : Benefit ???
FRP material systems used in FDOT’s Highway Bridges & Structures

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

* bulkhead/seawall only
** piling/substructure only
*** complete bridge
FRP structural member 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 *

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

https://www.fdot.gov/structures/innovation/frpms
FRP Design Guidance, Specs, & Tools: Florida DOT

“High-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

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 or 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

The Department invites you to share your thoughts on ways we can challenge ourselves to be innovative, efficient and exceptional at our Invitation to Innovation website.
FRP Design Guidance, Specs, & Tools: Florida DOT

- Mandatory Specifications
- Uniform Approval Processes
  - Manufacturer Approval vs. Product Approval
- Design Tools

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https://www.fdot.gov/structures/innovation/
### Prestressed Concrete (CFRP-PC) Design & Construction Standards

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<th>Structures Foundations</th>
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<td><strong>455-001</strong></td>
<td><strong>Certification Statement</strong></td>
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<td>Square Prestressed Concrete Piles - Typical Details and Notes</td>
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<td><strong>455-101</strong></td>
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<tr>
<td>Square CFRP and SS Prestressed Concrete Piles - Typical Details and Notes</td>
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<td>54&quot; Precast/Post-Tensioned CFRP and SS Concrete Cylinder Pile</td>
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<td>60&quot; Prestressed CFRP and SS Concrete Cylinder Pile</td>
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<td>Precast Concrete Shear Pile (Conventional)</td>
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<tr>
<td>Precast Concrete Shear Pile (CFRP/GFRP and HSSS/GFRP)</td>
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FRP Design Guidance, Specs, & Tools: Florida DOT

Reinforced Concrete (RP-RC) Design & Construction Standards

**FRP REINFORCED TRAFFIC RAILINGS RAILINGS**

**D22420**
Traffic Railing (32” F Shape - GFRP Reinforced)

Certification Statement
Permitted Projects FPID No(s): 430021-1

**FRP REINFORCED APPROACH SLABS**

**D22900**
Approach Slab - GFRP Reinforced (Flexible Pavement Approach)

Certification Statement
Permitted Projects FPID No(s): 430021-1

**Concrete Structures**

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<th>Description</th>
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<td>D6011c</td>
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FRP Design Guidance, Specs, & Tools: Florida DOT +

- Mandatory Specs
- Uniform Approval Processes
  - Manufacturer Approval vs. Product Approval
- Design Tools – Structural software

Other’s Design Software:
Adaption of FRP analysis or design enhancements:

- FB-MultiPier (BSI) CFRP-PC available in Jan. 2021
- Michigan DOT/LTU CFRP-Beam Design Mathcad: https://mdotjboss.state.mi.us/SpecProv/trainingmaterials.htm (also see TRB Webinar Dec 3, 2019)
- DeepEx (Deep Excavation, LLC) available
- FRPpro™ pending
- ...

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LCC Design Guidance & Tools: AASHTO/NCHRP/ASCE

- Mandatory Specs
- Uniform Approval Processes – Manufacturer Approval vs. Product Approval
- Design Tools – SLD & LCC Guides

- Service Life Expectations for Structures
  - 50 years (AASHTO LFD < 1993)
  - 75 years (AASHTO LRFD > 2007)
  - 100 or 150 years? (HBSLD-1, 2020)

- Life Cycle Cost policies & comparisons

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LCC Design Guidance & Tools: USDOT/NIST

- Mandatory Specs
- Uniform Approval Processes
  - Manufacturer Approval vs. Product Approval
- Design Tools – LCC software
  
  https://www.nist.gov/services-resources/software/bridgelcc

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FRP-RC Evaluation of Durability: ACI selected Bridges

- **Eleven bridges** located across the United States in 2017-18
- Each bridge contains GFRP bars in deck or other location and has been in service for **at least 15 years**

- Gills Creek Bridge (VA)
- O’Fallon Park Bridge (CO)
- Salem Ave Bridge (OH)
- Bettendorf Bridge (IA)
- Cuyahoga County Bridge (OH)
- McKinleyville Bridge (WV)
- Thayer Road Bridge (IN)
- Roger’s Creek Bridge (KY)
- Sierrita de la Cruz Creek Bridge (TX)
- Walker Box Culvert Bridge (MO)
- Southview Bridge (MO)
- Pearl Harbor Dry Dock #4 (HI)

FRP-RC Evolution from Durability Research

• **Environmental Reduction Factors** will be relaxed (~20-25%) for GFRP 100-year+

• **BFRP** rebar will be broadly adopted, sooner rather than later, if recent import tariffs are rescind (~30%)

• **B&G-FRP** rebar design stiffness and strength will be significantly increase (~20-25%)

• **B&G-FRP** creep rupture limits will increase (20~30%), so partial/mild prestressing will become feasible.

• **Thermoplastic resin** FRP rebar will become predominant for bent bars

• **Sustainability** will become more important, so

• **FRP synergy** with recycled aggregates, seawater, & by-product SCM’s will be advantageous.

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Life-Cycle Cost analysis

• Comparisons and synergies
  • Economics is in the eye of the beholder
  • Save now, $$$ later or $$$ now adaption later
  • Use realistic discount rates:
    (i) recognizing long-term investment using government bonding rates – highway/bridge construction inflation rates (NHCCI) = < 1%

Idiom: “Penny wise and pound foolish”
Life-Cycle Cost analysis

- Comparisons and synergies
  - Conventional-RC with periodic Repair & Rehabilitation


TRBAM 2021 - Forecasting the FRP Future for FDOT Highway Bridges & Structures
Life-Cycle Cost analysis

- Future enhancements or needs
  - Highly Corrosion-resistant solutions
  - Improvement of Probabilistic techniques

Cadenazzi at al. (2021), “Evaluation of Probabilistic and Deterministic Life-Cycle Cost Analyses for Concrete Bridges Exposed to Chlorides”. Journal of Cleaner Production (pending)
Forecasting the Future

• new Federal “Push Factor”

https://buildbackbetter.gov/priorities/

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.

• Industry “Push Factors”

- Closing the infrastructure Gap: Shared goal of reducing infrastructure life cycle costs by 50% by 2025

• 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.
Technology Transfer & Future Development

• Strategies
  • Seek to inform, not to persuade... *Inception!*
  • Recognize that it is easier to do nothing than to change
  • Encourage ownership of the challenges...

• Engagement and Education
  • Need for mentorship of future designers
  • Foster passion and curiosity
  • Engineers can learn best, by doing
Technology Transfer & Future Development

- **8th International Conference on Advanced Composite Materials in Bridges and Structures (ACMBS-VIII)**
  **Person-contact:** Professor Brahim Benmokrane, University of Sherbrooke,
  E-mail: brahim.benmokrane@usherbrooke.ca

- **Third International Workshop on GFRP Bars for Concrete Structures (IW-GFRP-3)**
  - **Workshop Theme:** ‘Advances in concrete reinforcement’
  **Person-contact:** Professor Brahim Benmokrane, University of Sherbrooke,
  E-mail: brahim.benmokrane@usherbrooke.ca
Conclusions

• Seek to inform, not to persuade
• Be good custodians for public infrastructure
• Get familiar... FRP is here to stay as an essential tool for our future!
Questions ???

Contact Information:

Steven Nolan, P.E.
State Structures Design Office
Florida Department of Transportation
Email: steven.nolan@dot.state.fl.us
Website: https://www.fdot.gov/design/Innovation/