Innovative Structural Research & Demonstration Project implementation by the Florida DOT

GFRP rebar for deck & substructure of Halls River Bridge (2017-19)
GFRP Secant-Pile Shaft cages for A1A-Flagler Beach seawall (2019)
UHPC-PC H-Pile for CR-339 demonstration (2020)
CFRP-PC FSB’s US-1/Cow Key span replacements (2020)

Prepared By: Will Potter & Steven Nolan
FDOT State Structures Design Office
Summary:
Florida DOT is privileged to have its own Structures Research Center (SRC) to assist in-house engineers, or contracted universities, and occasionally commercial producers with full scale structural element testing for applied research and demonstration purposes. Due to limited resources these activities are focused on mission critical activities often associated with innovative structural materials or systems.

Independent but cognizant of these activities, the Structures Design Office oversees a Design Innovation initiative which develops and monitors design guidance and demonstration projects for deployment of innovative structural materials and systems. This presentation will highlight some of the recent applied research coordinated by the SRC, outline the FDOT’s innovative structural material implementation, and highlight some of the early demonstration projects.

Speakers:  FDOT State Structures Design Office (Tallahassee)

*Will Potter, P.E.: Assistant State Structures Design & Manager of Structures Research Center*

*Steven Nolan, P.E.: Senior Structures Design Engineer*
Innovative Structural Research at FDOT

Florida’s History with Innovation and Research

Fig. 26. Typical Tampa Bay beam

Fig. 21. Location map of Lower Tampa Bay Bridge

Fig. 25. Demonstration test of 100-ft (30.5 m) long prestressed channel slab at R. H. Wright & Son, Fort Lauderdale, Florida.
Marcus H. Ansley FDOT Structures Research Center

Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
Structures Research Center Capabilities

- 11 Full Time Staff
  - 4 Engineers, 6 Technicians and 1 Admin Assistant
- 110-ft x 50-ft Strong Floor
- Outdoor Pendulum Facility
- Bridge Load Testing Program

Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
Ultra-High-Performance Concrete (UHPC)

Florida Slab Beam with 6” Concrete Deck

Florida Slab Beam with UHPC Closure Pour
Florida Slab Beam w/ UHPC Joints

Strength Testing to Evaluate Overall Joint Integrity

Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
Objective

- Evaluate the effectiveness of UHPC to contribute to the structural performance of prestressed girders
- Reduce or eliminate visible end-region cracking
Hybrid Prestressed Concrete Girder with UHPC

Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
• Collaborate with Florida Precaster’s to evaluate and test all UHPC Piling and Beam Concepts
• Florida is fortunate to have 2 Precaster’s that have UHPC mixes and willing to contribute to the state of knowledge
UHPC Industry Collaboration
UHPC Box Beam

Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
Carbon Fiber and High-Strength Stainless Steel Prestressed Piling

- Constructability
- Strength and Behavior Evaluation
  - Flexure
  - Shear
  - Transfer/Development Length
- Drivability
- Implementation
  - Standard Plans (455 series)
## Corrosion Resistant/Free Prestressed Piling

<table>
<thead>
<tr>
<th></th>
<th>Duplex 2205 Alloy</th>
<th>ASTM A416 PC Strand</th>
<th>CFRP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diameters (in)</strong></td>
<td>0.375 to 0.7*</td>
<td>0.375 to 0.7</td>
<td>0.375 to 0.7**</td>
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<tr>
<td><strong>Tensile Strength (ksi)</strong></td>
<td>240</td>
<td>250, 270, 300+</td>
<td>300+</td>
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<tr>
<td><strong>Elongation @ UTS</strong></td>
<td>≥ 1.4% (1.4-2.0)</td>
<td>≥ 3.5% (5.0-7.0)</td>
<td>≥ 1.2%</td>
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<tr>
<td><strong>Relaxation</strong></td>
<td>&lt; 2.5%</td>
<td>&lt; 2.5%</td>
<td>&lt; 6.0%</td>
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<tr>
<td><strong>Elastic Modulus (ksi)</strong></td>
<td>24,500</td>
<td>28,500</td>
<td>≥ 17,000</td>
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</table>

### Standard Plans

<table>
<thead>
<tr>
<th>Plan Number</th>
<th>Description</th>
<th>Document Number</th>
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<tbody>
<tr>
<td>455-101</td>
<td>Square CFRP and SS Prestressed Concrete Piles - Typical Details and Notes</td>
<td>22600</td>
</tr>
<tr>
<td>455-102</td>
<td>Square CFRP and SS Prestressed Concrete Pile Splices</td>
<td>22601</td>
</tr>
<tr>
<td>455-112</td>
<td>12&quot; Square CFRP and SS Prestressed Concrete Pile</td>
<td>22612</td>
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<tr>
<td>455-114</td>
<td>14&quot; Square CFRP and SS Prestressed Concrete Pile</td>
<td>22614</td>
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<td>455-118</td>
<td>18&quot; Square CFRP and SS Prestressed Concrete Pile</td>
<td>22618</td>
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<td>455-124</td>
<td>24&quot; Square CFRP and SS Prestressed Concrete Pile</td>
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<td>455-130</td>
<td>30&quot; Square CFRP and SS Prestressed Concrete Pile</td>
<td>22630</td>
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<td>455-154</td>
<td>54&quot; Precast/Post-Tensioned CFRP and SS Concrete Cylinder Pile</td>
<td>22654</td>
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<tr>
<td>455-160</td>
<td>60&quot; Prestressed CFRP and SS Concrete Cylinder Pile</td>
<td>22660</td>
</tr>
<tr>
<td>455-400</td>
<td>Precast Concrete Sheet Pile (Conventional)</td>
<td>SPI</td>
</tr>
<tr>
<td>455-440</td>
<td>Precast Concrete Sheet Pile (CFRP/GFRP and HSSS/GFRP)</td>
<td>SPI</td>
</tr>
</tbody>
</table>

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Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
High-Strength Stainless Steel Prestressing
- Flexural Applications -

Duplex 2205

Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
High-Strength Stainless Steel Prestressing
- Flexural Applications -

Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
High-Strength Stainless Steel Prestressing
- Flexural Applications -
FRP Pile Splices (Unforeseen/Preplanned)
FRP Pile Splices (Unforeseen/Preplanned)

Testing based on comparison with conventional splices
Variables included:
• Splice dowel material (CFRP/GFRP/Steel)
• Splice length/method
  • Unforeseen or Preplanned
• Strand material
GFRP Spirals in Prestressed Piling

Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
Agency Initiatives

Innovative Structural Research & Demonstration projects by the Florida DOT (2021)
Innovative Structural Materials Implementation

- Why
- What
- How

Innovative Structural Research & Demonstration Project implementation by the Florida DOT (2021)
Why? Bridge Durability & Structural Advancement

- **Durability** needs – low-maintenance, extended service-life, cost-effective solutions, reducing work zones.

- **Structural** needs – Inspectable, repairable, robust, extended span lengths (light-weighting and/or high-strength & high-endurance):
  - HSSS-Prestressed Concrete (**2205 Duplex SS**)
  - CFRP-Prestressed Concrete (**Carbon strands**)
  - FRP-Reinforced Concrete (**Glass & Basalt**)
  - Ultra-High Performance Concrete (**UHPC**)
  - Light-weight Concrete or FRP (** Longer spans and/or less shipping cost**)

Highly Corrosion-Resistant (HCR)

Structural Advancement

Innovative Structural Research & Demonstration Project implementation by the Florida DOT (2021)
Why use HCR materials for Bridges & Structures

- Florida maintains more than 150 million sq.ft. of bridge area \( 7044 \text{ FDOT bridges}^2 \);  
- Florida has more than 4,000 miles seawall-bulkheads\(^3\).

(2) FDOT Bridge Inventory – 2020 Annual Report  
(3) Estimates from Gittman et al. (2015)  

*Innovative Structural Research & Demonstration Project implementation by the Florida DOT*
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;

+ FRP has low electro-magnetic interference (for electronic tolling)
+ FRP has low electrical conductivity (eliminates stray current corrosion)
+ FRP, SS & UHPC have lower ownership costs.
Why use HCR materials for Bridges & Structures

Source (1): 2020 FDOT Bridge Maintenance Annual Report

Age of Bridges (1)

While the industry is now designing bridges to last for 75 years, most bridges built in the past were designed for a service life of 50 years. Looking at bridge age is the most common and simplest method of forecasting long-term budget requirements. This might lead one to conclude that bridges constructed before 1960 are at the end of the service life. Fortunately, advances in material science, design practices, and construction methods, along with a generally favorable climate, inspection and maintenance practices have contributed in many bridges functioning well past their original design life, despite the tremendous growth in traffic volume over the years. The strategy of bridge maintenance is to leverage these advances using an aggressive maintenance program to extend the useful life of the bridges, thereby minimizing the need to replace a large number of bridges within a short time period (see Table 1).

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

Bridge Inventory — 2019 Annual Report (2)

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-


Innovative Structural Research & Demonstration Project implementation by the Florida DOT (2021)
Florida DOT Transportation Budget
FY 2019/2020
➢ ~50% for combined Maintenance, Operations, Repair, Rehabilitation and Deficient Bridge Replacement (hatched areas).

> Highways Reconstruction, Rehabilitation and Resurfacing [$2.7B]
> Repairs of 85 bridges/Replacement of 22 Deficient bridges [$1.1B]
> Maintenance and Operation of existing facilities [$1.1B]
> Capacity Expansion - 102 new lane miles & bridges [$3.2B]
> Other - Rail, Transit, Seaports, Aviation, etc. [$1.8B]

Tent. FY 2021/22
[$1B ?]
(89/18)
 [$0.5B]

www.ASCEgrandchallenge.com

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

Innovative Structural Research & Demonstration Project implementation by the Florida DOT (2021)
What? Bridge Durability & Structural Advancement

“invitation-to-innovation”
https://www.fdot.gov/agencyresources/innovation/default.shtm

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
Bridge Durability & Structural Advancement

Where are HCR material systems used in Bridges & Structures?

Innovative Structural Research & Demonstration Project implementation by the Florida DOT (2021)
How? Bridge Durability & Structural Advancement

- How do we bridge the gap between innovation and institutional adoption and keep up with our FTP needs?

Where does HCR technology lay on this chart for FDOT Bridge & Structures?

Where we are now?

Source: Gartner Inc. Hype Cycle
LCC & LCA can show the sustainable (economic and environmental) advantage of composite structures in the coastal environment:

Current CS-RC/PC process

HCR-RC/PC alternative

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

Example LCC Comparison of Carbon Steel-RC/PC verses FRP-RC/PC bridge
(adapted from Cadenazzi et al. 2019)
How do we encourage more Local Agency & District innovation participation?

1. **Schedule** is always a challenge – *seems its always “too early” or “too late”*.

2. **Construction** is not the ideal time to propose innovative material alternates, but often that is what industry must default too thru the CSI process – *engineering cost and schedule risk is passed on to the contractor*.

3. **Implementation** at the beginning of the consultant’s Design Contract is too slow → *3-6 years before construction complete*.

→ Need a more **nimble** and **equitable** process!

Innovative Structural Research & Demonstration Project implementation by the Florida DOT (2021)
What could a more nimble and equitable process look like?

- **Nimble** – encourage alternate designs post-BDR & during procurement of contractor.

- **Equitable** – (1) Pay for the design of recognized innovative alternates upfront (Design-Innovation) in addition to conventional design (~ADAB) = “Low-Bid” (A);
  - (2) Bid alternates recognize the life-cycle cost benefits = “Best Value Bid” (A+D)

- **Incentivize** – For “Cost Savings Initiatives” (CSI ~VE) proposals using select higher-performing materials (eg. Design-Innovation) → Give up DOT portion of savings – no sharing.

- **Empower other Stakeholders** – cost adjustment and schedule extensions until institutionalized.
Negative effects of a more nimble and equitable process?

• **Nimble** – mistakes due to new procedures & doing more with the same or less?

• **Equitable** – cost & time increase for design and/or construction.

• **Incentives** – less cost sharing with the Department.

• **Empowering other Stakeholders** – loss of owner control.
Positive outcomes of a more nimble and equitable process?

• **Nimble** – more responsive to innovation and scalable deployment, can bring new business to the State if the market is seen as more open than other places.

• **Equitable** – all solutions are evaluated based on value.

• **Incentives** – makes the DOT look more progressive to industry & public & can develops new industries!

• **Empowering other Stakeholders** – more buy-in or “ownership” of the implementation challenges by others.
Project Fast-Facts

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

Innovative Structural Research & Demonstration Project implementation by the Florida DOT (2021)
Project Fast-Facts

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

- CFRP Secant-Pile Shaft cages for A1A-Flagler Beach seawall (2019)
- CFRP-PC FSB’s US-1/Cow Key: 3 full span replacements (2020)
Project Fast-Facts

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

Innovative Structural Research & Demonstration Project implementation by the Florida DOT (2021)

- UHPC 30" H-Pile CR339, Taylor County
- UHPC Link Slab, US41 over Sunset Waterway (2020)

250' simple span pending?
Questions

The Grades are in:

- C- (Infrastructure)

Missouri:
24,494 bridges, 8.8% of which were structurally deficient in 2019

Bridge Conditions by Year