FDOT Activities and Experiences Using FRP Composites

Will Potter
Florida Department of Transportation
-The Need-
Why FRP Composites?
Avoiding Corrosion

• Durability/Service Life
• Cost/Benefit Analysis
• Mitigating Risks
Repair and Strengthening Operations

- Impact Damage
- Corrosion Damage
- Load Changes
- Defects
Bridge Fender Systems
Florida’s FRP History

- What’s Next
- BFRP Reinforcing Bars
- Composite Bridge Girders
- GFRP Reinforcing Bars
- CFRP Prestressed Piles
- Navigation Fender Systems
- External FRP Laminate Repairs
- FRP Bridge Deck
<table>
<thead>
<tr>
<th>Year</th>
<th>Title of Research Effort</th>
<th>Author</th>
<th>Institution</th>
</tr>
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<tbody>
<tr>
<td>1992</td>
<td>Feasibility of Fiberglass Pretensioned Piles in a Marine Environment</td>
<td>Sen, R.</td>
<td>USF</td>
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<td>1995</td>
<td>Active Deformation Control of Bridges with AFRP Cables</td>
<td>Arockiasamy, M.</td>
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<td>1995</td>
<td>Durability of CFRP Pretensioned Piles in a Marine Environment – Phase II</td>
<td>Sen, R.</td>
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<tr>
<td>1995</td>
<td>Mechanical and Microscopy Analysis of CFRP Matrix Composite Materials</td>
<td>Garmestani, H.</td>
<td>FAMU/FSU</td>
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<td>1997</td>
<td>FRP Composite Column and Pile Jacket Splicing</td>
<td>Mirmiran, A.</td>
<td>UCF</td>
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<td>1997</td>
<td>An Analytical and Experimental Investigation of Concrete Filled FRP Tubes</td>
<td>Mirmiran, A.</td>
<td>UCF</td>
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<td>1997</td>
<td>Flexural Reliability of RC Bridge Girders Strengthened with CFRP Laminates</td>
<td>Okeil, A.</td>
<td>UCF</td>
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<td>1997</td>
<td>Studies of CFRP Prestressed Concrete Bridge Columns and Piles in Marine Environment</td>
<td>Arockiasamy, M.</td>
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<td>1998</td>
<td>LRFD Flexural Provisions for PSC Bridge Girders Strengthened with CFRP Laminates</td>
<td>El-Tawil, S.</td>
<td>UCF</td>
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<tr>
<td>2000</td>
<td>Investigation of Fender Systems for Vessel Impact</td>
<td>Yazdani, N.</td>
<td>FAMU/FSU</td>
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<td>2001</td>
<td>Design of Concrete Bridge Girders Strengthened with CFRP Laminates</td>
<td>El-Tawil, S.</td>
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<td>2003</td>
<td>Hybrid FRP-Concrete Column</td>
<td>Mirmiran, A.</td>
<td>NC State</td>
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<td>2004</td>
<td>CFRP Repair of Impact Damaged Bridge Girders</td>
<td>Hamilton, T</td>
<td>UF</td>
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<td>2009</td>
<td>Thermo-Mechanical Durability of CFRP Strengthened RC Beams</td>
<td>Mackie, K</td>
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<tr>
<td>2011</td>
<td>Testing of Trelleborg Structural Plastics</td>
<td>Wagner, D.</td>
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## FDOT Research Efforts Continued...

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<th>Year</th>
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<tbody>
<tr>
<td>2012</td>
<td>The Repair of Damaged Bridge Girders with CFRP Laminates</td>
<td>El-Safty, A.</td>
<td>UNF</td>
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<td>2014</td>
<td>Investigation of CFCC in Prestressed Concrete Piles</td>
<td>Roddenberry, M.</td>
<td>FAMU/FSU</td>
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<td>2015</td>
<td>Repair of Impact Damaged Utility Poles with FRP, Phase II</td>
<td>Mackie, K.</td>
<td>UCF</td>
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<td>2015</td>
<td>Use of CFRP Cable for Post-Tensioning Applications</td>
<td>Mirmiran, A.</td>
<td>FIU</td>
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<tr>
<td>2017</td>
<td>Durability Evaluation of Florida’s FRP Composite Reinforcement for Concrete Structures</td>
<td>Hamilton, T.</td>
<td>UF</td>
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<td>2018</td>
<td>Bridge Girder Alternatives for Extremely Aggressive Environments</td>
<td>Brown, J.</td>
<td>ERAU</td>
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<td>2018</td>
<td>Degradation Mechanisms and Service Life Estimation of FRP Concrete Reinforcements</td>
<td>El-Safty, A.</td>
<td>UNF</td>
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<td>2018</td>
<td>Performance Evaluation of GFRP Reinforcing Bars Embedded in Concrete Under Aggressive Environments</td>
<td>Kampmann, R.</td>
<td>FAMU/FSU</td>
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<tr>
<td>2019</td>
<td>Inspection and Monitoring of Fabrication and Construction for the West Halls River Road Bridge Replacement</td>
<td>Roddenberry, M.</td>
<td>FAMU/FSU</td>
</tr>
<tr>
<td>2019</td>
<td>Performance Evaluation, Material and Specifications for Basalt FRP Reinforcing Bars Embedded in Concrete (STIC)</td>
<td>Kampmann, R. Roddenberry, M.</td>
<td>FAMU/FSU</td>
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<tr>
<td>2021</td>
<td>Evaluation of GFRP Spirals in Corrosion Resistant Concrete Piles</td>
<td>Jung, S.</td>
<td>FAMU/FSU</td>
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<td>2021</td>
<td>Development of GFRP Reinforced Single Slope Bridge Rail</td>
<td>Consolazio, G.</td>
<td>UF</td>
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<tr>
<td>2021</td>
<td>Testing Protocol and Material Specifications for Basalt Fiber Reinforced Polymer Bars</td>
<td>Kampmann, R. Tang, Y</td>
<td>FAMU/FSU</td>
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</table>
CFRP Repair and Strengthening

• Currently reference ACI 440.2R w/ modifications
  • Structures Design Manual – Volume 4 – Section 4
• Research and installations performed since the early 1990’s
• Considered routine practice for given applications
• Repairs have been re-evaluated after 10 to 15 years of service with positive results.
• Detailing is critical to ensuring adequate performance and longevity.
Bridge Navigation Fender Systems

- 2011-2015 – Preset spacings under Standard Plans with Contractor/Vendor designs
- 2015+ - Customized Contractor/Vendor configuration and design
GFRP Bridge Deck

10/2009
8-9/2009
6/2012
12/2011
10/2010
CFRP Prestressed Piling and Sheet Piling

• CFRP Pretensioned Piling
  • Standard Plans Index – 455-100 series
• CFRP Pretensioned Sheet Piling
  • Standard Plans Index – 455-440
• Continuing to learn and refine the detailing practices...
GFRP Reinforcing Bars

• Recent implementation effort
• Several projects under construction and more to come
• Initial low risk implementation effort with a broaden effort envisioned
Composite Bridge Girders

- Continuing to evaluate the appropriate implementation methods...
Guidance Documents

• Design Criteria
• Detailing Criteria
• Standard Plans
• Specifications
  • Material and Construction
• Materials Manual
FDOT Structures Manual
Design Criteria and Detailing Manual

- Structures Design Guidelines
- Fiber Reinforced Polymer Guidelines
- Referenced Guides
# Standard Plans

## Structures Foundations

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tr>
<td>455-101</td>
<td>Square CFRP and SS Prestressed Concrete Piles - Typical Details and Notes</td>
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<tr>
<td>455-102</td>
<td>Square CFRP and SS Prestressed Concrete Pile Splices</td>
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<td>455-112</td>
<td>12” Square CFRP and SS Prestressed Concrete Pile</td>
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<td>455-114</td>
<td>14” Square CFRP and SS Prestressed Concrete Pile</td>
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<td>455-118</td>
<td>18” Square CFRP and SS Prestressed Concrete Pile</td>
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<td>455-124</td>
<td>24” Square CFRP and SS Prestressed Concrete Pile</td>
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<td>455-130</td>
<td>30” Square CFRP and SS Prestressed Concrete Pile</td>
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<td>455-154</td>
<td>54” Precast/Post-Tensioned CFRP and SS Concrete Cylinder Pile</td>
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<td>455-160</td>
<td>60” Prestressed CFRP and SS Concrete Cylinder Pile</td>
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## Fiber Reinforced Polymer Fender Systems

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<th>Code</th>
<th>Description</th>
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<tr>
<td>471-030</td>
<td>Fender System - Prestressed Concrete Piles and FRP Wales</td>
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## Structures Foundations - Sheet Pile Wall

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<th>Code</th>
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<tr>
<td>455-400</td>
<td>Precast Concrete Sheet Pile Wall (Conventional)</td>
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<tr>
<td>455-440</td>
<td>Precast Concrete Sheet Pile Wall (CFRP/GFRP &amp; HSSS/GFRP)</td>
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</table>

[https://www.fdot.gov/design/standardplans/SPRBC.shtm](https://www.fdot.gov/design/standardplans/SPRBC.shtm)
Developmental Standards (Plans)

Developmental Standard Plans
• Issued to implement new technologies in a limited trial fashion on an as-needed or an as-available basis.

WALL SYSTEMS

<table>
<thead>
<tr>
<th>Certification</th>
<th>Gravity Wall - Option C (GFRP Reinforced)</th>
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<tbody>
<tr>
<td>Statement</td>
<td>Permitted Projects FPID No(s): 430021-1</td>
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FIBER REINFORCED POLYMER BAR BENDING DETAILS

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<th>Certification</th>
<th>FRP Bar Bending Details</th>
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FRP REINFORCED TRAFFIC RAILINGS RAILINGS

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<tr>
<th>Certification</th>
<th>Traffic Railing (32&quot; F Shape - GFRP Reinforced)</th>
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<td>Statement</td>
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FRP REINFORCED APPROACH SLABS

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<tr>
<th>Certification</th>
<th>Approach Slab - GFRP Reinforced (Flexible Pavement Approach)</th>
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</table>

https://www.fdot.gov/roadway/DS/Dev.shtm
Construction and Material Specifications

• Construction
  • 105 – Contractor Quality Control (FRP Producers)
  • 400 – Concrete (FRP Bar)
  • 415 – Reinforcing for Concrete (FRP Bar)
  • 450 – Precast Prestressed Concrete Construction (FRP Bars/Strand)
  • 471 – FRP Fender Systems (Design criteria and construction considerations)

• Materials
  • 932 – Nonmetallic Accessory Materials for Concrete Pavement and Concrete Structures (GFRP and CFRP Bars)
  • 933 – Prestressing Strand (CFRP Strand material)
  • 973 – FRP Composite Structural Shapes (material and fabrication requirements)
Material and Producer Requirements

- State Materials Office Oversight Role:
  - Material Specification
  - Sampling and Testing Requirements
  - Quality Control Program – Production Facility Approvals
  - Conduct and Facilitate Materials Research
CFRP Girder Bearing Repair
Halls River Bridge
Halls River Bridge

Completed Phase I

Phase I

HCB Arch Casting

GFRP Deck Reinforcement
Bakers Haulover
Cut Bridge Rehab.

Prestressed Sheet Pile System (rebuilt 1970's):
Extensive corrosion damage in splash zone

Divers placing GFRP rebar mat in forms
Light-weight for easy handling
Bulkhead wall cap GFRP reinforcement in place
Completed view of North Wall
Skyway Rest Area
Seawall
(Cap Rehab.)
Bridge Substructure (Rehab)
Looking Forward... New Projects in 2019

• SR A1A Secant-Pile Seawall – 11/6/18 contractor awarded
• NE 23rd Ave/Ibis Waterway – 2/27/19 letting
• US 41 over Morning Star & Sunset Canal – 2/27/19 letting
• US 41 over North Creek – 7/31/19 letting
• US 1 over Cow Key channel, 6 Span Replacement – 10/21/19 letting
• Pensacola Beach Pedestrian Tunnels (3) – Design 100% (city project)
Looking Forward... New Projects in 2019

- **SR A1A Secant-Pile Seawall** – 11/6/18 contractor awarded

  - Proposed Secant Wall Concept Rendering
  - 2006 Emergency Contract Wall
  - SR A1A damage after Hurricane Matthew (2016)
Looking Forward... New Projects in 2019

• NE 23rd Ave/Ibis Waterway – 2/27/19 letting
Looking Forward... New Projects in 2019

- **US 41 over Morning Star & Sunset Canal – 2/27/19 letting**
  - GFRP-RC link-slab (shown)
  - GFRP-UHPC link-slab (similar)
Looking Forward... New Projects in 2019

• US 41 over North Creek – 7/31/19 letting

GFRP-RC Flat Slab and Traffic Railing
Looking Forward... New Projects in 2019

- **US 1 over Cow Key channel, 6-span replacement** – 10/21/19 letting
Looking Forward... New Projects in 2019

- Pensacola Beach Pedestrian Tunnels (3) – Design 100% (city project)
Looking Forward...

**Priority Focus Areas:**
- Continue efforts to improve design and construction guidance
- Investigate new concepts for efficiencies and competition
- Construction & Maintenance guidance for inspection and repair for FRP systems
- Continue coordination with AASHTO and ACMA to develop design codes and test protocols. FDOT is very active in the future development of FRP.

**Promote: Confidence, Competency, Consistency & Codification**
- *Use it where you need it!*

**2018 FDOT-FRP Industry Workshop Strategic Goals**
Questions

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