Beyond Halls River Bridge: FRP-RC/PC Infrastructures Solutions

Steven Nolan, Felix Padilla, Sam Fallaha, Chase Knight
Overview

1. Halls River Bridge progress
2. Goals for broader Deployment
3. Specifications
4. Design Tools
5. Project Identification & Delivery
6. Uniform Standards
7. Advancement
Halls River Bridge progress
Halls River Bridge progress
Halls River Bridge challenges
Goals for Broader Deployment

1. Stewardship
2. Confidence
3. Competency
4. Consistency
5. Codification
Goals for Broader Deployment

Strategic Workplan items

1. Endurance Limits
2. Endurance Characteristic Curves and Testing
3. Establishing Consistency
4. Increasing Material Property Qualification Thresholds and Design Limits
5. Cost Estimating
   a. OC initiative for ACMA FRP-RMC
   b. FDOT SDG Chapter 9 update
6. Bar Bends
   a. Complex Shapes
   b. FDOT Index D21310
7. Minimum Bar Sizes for Design Elements
8. Life-Cycle Cost Guidance
9. Minimum Concrete Class

Top 5 Long-Term Goals
- Stewardship
- Confidence
- Competency
- Consistency
- Codification

Participants/Collaborators

2018 FDOT-FRP Industry 2nd Winter Workshop
Safe Deployment of FRP-RC/PC for Structural Reinforcement
- Next Generation Infrastructure (eliminating the threat of steel corrosion)

http://www.fdot.gov/structures/Innovation/FDOT%202018%20Winter%20FRP-RC%20Workshop/Default.shtm
1. **Stewardship**

- Use FRP where it makes sense;
- Maximize material efficiency;
- Identify resources for exploitation.
Goals for Broader Deployment

1. Stewardship

2. Confidence
   - Build Stakeholder confidence;
   - Supply Chain security.
Goals for Broader Deployment

1. Stewardship
2. Confidence
3. Competency
   • Designer qualifications/training;
   • Design Tools
   • Contractor & Inspector guidance
4. **Consistency**

- Material reliability;
- Encourage improved QC;
- Simplified verification testing;
- Bent Bar improvement and capabilities
Goals for Broader Deployment

4. Consistency

5. Codification

- Establish “Roadmap” for AASHTO adoption;
- Coordination with ACI 440;
- Coordination with international authoritative committees.
Specifications - GFRP


• To be voted (06/26/2018) by AASHTO Committee T6 for adoption.
Specifications - CFRP


- To be voted (06/26/2018) by AASHTO Committee T6 for adoption.
Specifications – BFRP

STIC Incentive Project – BFRP-RC Standardization


FDOT #443377-1; Research Project BDV30 986-01

- Develop standard specifications for basalt fiber-reinforced polymer (BFRP) bars for the internal reinforcement of structural concrete.

https://www.fhwa.dot.gov/innovation/stic/state_innovation.cfm
Specifications – FDOT stuff

1. **Structures Manual** – Vol. 4 *(FRPG)*
2. Construction **Specs.** *(Division II)*
3. Materials **Specs.** *(Division III)*
4. **Production Facility Approvals**
5. **Standard Plans** *(SP)*
   - SP Instructions *(SPI)*
1. Design Programs
   - CFRP-PC Beams
   - GFRP-RC Flat-Slab
   - GFRP-RC Bent Cap
   - Retaining Walls soon!

2. SPI “Design Aids”


4. Under development
   - LCC Analysis Guidance
   - Cost Estimating Guidance
1. Currently includes:
   - Active and Completed FRP-RC/PC projects;

2. Plans to add:
   - Bridge beam repair/strengthening projects (20+ year history of wet-layup repairs)
   - FRP-Fender Systems
   - HSSS projects

https://fdot.sharepoint.com/sites/FDOT-Design/Structures/SpecialProjects/Lists/FRP%20Rebar%20Project/AllItems.aspx
1. Environment Driven
   - Durability/Magnetic Transparency/LCC

2. Optional precast alternatives
   - Encourage stakeholder buy-in

3. Desire for multiple suppliers
   - Redundancy & Supply chain security

4. Simplify design process/workflow

5. Minimize change for Contractors
   - Business as usual…almost
Uniform Standards

- **BDGS-GFRP 2nd Ed.** refers to **ASTM D7957-17** for material specifications
  - Only vinylester GFRP / epoxy GFRP round bars allowed
  - Role separation and eased certification

- Design of GFRP-RC bridge elements follows structure of Bridge Design Specifications for steel-RC/PC (**AASHTO-BDS-17, 8th Ed.**).
  - Same language and integration
  - Familiar environment for the practitioner
Uniform Standards (cont.)

• **Inputs** from existing guidelines/codes:
  - **ACI 440.1R-15** “Guide for the Design and Construction of Structural Concrete Reinforced with Fiber Reinforced Polymer Bars”
  - **CSA S6-14** Section 16 “Canadian Highway Bridge Design Code: Fibre-Reinforced Structures”

• **Coordination** with next-edition (where possible)
  - **ACI 440-19** “Building Code Requirements for Structural Concrete Reinforced with GFRP Bars” (under dev.)
  - **CSA S6-19** Section 16 “Canadian Highway Bridge Design Code: Fibre Reinforced Structures” (under dev.)
## Uniform Advancement

<table>
<thead>
<tr>
<th></th>
<th>AASHTO 2\textsuperscript{nd} 2018</th>
<th>AASHTO 1\textsuperscript{st} 2009</th>
<th>ACI 440.1R 2015</th>
<th>CSA 2014</th>
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\( \Phi \) = \text{Res. Fact.} \quad \text{conc.} = \text{Concrete} \quad \text{frp} = \text{FRP} \quad \text{shear} = \text{Shear} \quad \text{Environmental reduction} \quad \text{Creep rupture reduction} \quad \text{Fatigue reduction} \quad \text{Bond reduction} \\
\text{Crack width limit [in.]} \\
\text{(1) ACI 440.5-08 Table 3.1; (2) Characteristic Strength}
2nd Ed. updates reflect:

- Rationally defined creep rupture and fatigue load demands
- Separated Creep $C_c$ and Fatigue $C_f$ and aligned to CSA-14 (0.20 to 0.25) – **Now we need to additional study to improve these still conservative limits!**
Advancement (cont.)

2nd Ed. updates reflect:

- Performances of ASTM-certified materials and increase Compression-Controlled Flexural Resistance $\Phi_C$ aligned to AASHTO BDS-17 (0.65 to 0.75);

Now need to:

1. Rationally increase Tension-Controlled Flexural Resistance $\Phi_t$ (0.55 to 0.75 ?), and
2. Increase Elastic Modulus…

Figure C2.5.5.2-1 – Variation of $\phi$ with Tensile Strain at Failure, $\varepsilon_{ft}$, in GFRP Reinforcement
1. Elastic modulus is a game-changer.

2. Increment shall not come from mere sectional area enlargement.

3. Need to operate within ASTM D7957-17 boundaries.

4. Improve quality of the manufacturing process to answer market demand: stiffness, bond performances, durability.
**Bridge Bearing Pile Standards**

<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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<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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<tr>
<td>455-160</td>
<td>60” Prestressed CFRP and SS Concrete Cylinder Pile</td>
</tr>
</tbody>
</table>

**Alternate Strand Patterns**

- 16 - 0.6” Ø, CFRP 7-Strand, at 42 kips
- 16 - ½” Ø, CFRP Single-Strand, at 41 kips
Concrete Sheet Pile Bulkhead Standards

<table>
<thead>
<tr>
<th>Structures Foundations - Sheet Pile Wall</th>
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<tbody>
<tr>
<td>455-400</td>
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<tr>
<td>455-440</td>
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</table>
Secant Piles seawall on SR A1A
Advancement (cont.) - Footings

Waterline footings in saltwater – need big bars!
Advancement (cont.) - Bent Cap

Projects:

- Halls River Bridge Replacement (Homosassa)
- NE 23rd Ave/Ibis Waterway (City of Lighthouse Point)
- Barracuda Blvd (New Smyrna)
- Maydell Dr. (Tampa)
- 40th Ave. N (St Petersburg)
- iDock (Miami)
Advancement (cont.) - **Girders**

**Projects:**

- Halls River Bridge = **HCB’s** (Homosassa)
- NE 23rd Ave/Ibis Waterway = **Flat-Slab** (City of Lighthouse Point)
- US1 over Cow Key Channel = **FSB hybrid** (Key West)
- Maydell Dr. = **FSB’s** ? (Tampa)
- 40th Ave. N = **FSB’s** (St Pete.)
1. FHWA's Innovations Deserving of Exploratory Analysis (IDEA)

- GFRP Prestressing - MILDGLASS (University of Miami);

(a) & (b) CFRP strand failed during tensioning; (c) cracking following strands release.

(a) GFRP strand prototype cross section; (b) compared to a CFRP alternative.

(a) GFRP-PC sheet pile concept (b) CFRP-PC sheet pile design for Halls River Bridge
1. **FHWA's Innovations Deserving of Exploratory Analysis (IDEA)**

- GFRP Prestressing - MILDGLASS (University of Miami);

**Pull test load:**
(a) Displacement diagrams;
(b) Pull strength at varying twist per meter;
(c) Creep displacement over initial value;
(d) Creep rupture logarithmic regression
2. *Next* Innovation Deserving of Exploratory Analysis…
   - BFRP Prestressing (perhaps)
Structural Advance Materials - TAG Mission:

- Advance the safe implementation and broad deployment of innovative structural materials through advisement to the Structures Technical Advisor Group (TAG) and coordination with national and international specification development organization representatives...

Members are to support District Structures Design Engineers make informed choices:

1 ~ Champion & 1 ~ Backup from each District Structures Office
2 ~ Consultants - structures design community
2 ~ State Materials Office materials experts
2 ~ State SDO facilitators & coordinators
1 ~ Structures Research Center representative
   ~ Friends of the TAG (Collaborators)

...future Construction and Maintenance representatives?
Questions?

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**FDOT’s Fiber-Reinforced Polymer Deployment Train**

- **BFRP**
- Composite Bridge Girders
- **GFRP-RC**
- **CFRP-PC**
- Fender Systems
- External FRP Laminate Repairs