CAMX2020 Featured Panel – Infrastructure “Building Bridges Along the Atlantic”

Wednesday, September 23, 2020

**Description:** Recent bridge design and construction projects will be highlight showing the willingness of transportation agencies along the east coast of North America to embrace the use of FRP for more than just rehabilitation and strengthening. With a focus on improved Life Cycle Cost and reduced maintenance liability this panel will discuss the needs of the infrastructure community to integrate Composites reliably and economically into their business practices particularly for concrete structures.
OUTLINE

• Moderator: Antonio Nanni, PhD. PE. (University of Miami)
• Speaker 1: Darrell Evans, PE. (PEI Dept. of Transportation, Infrastructure & Energy)
• Speaker 2: Wayne Frankhauser Jr., PE (Maine Dept. of Transportation)
• Speaker 3: Steven Nolan, PE. (Florida Dept. of Transportation)
• Speaker 4: Chase Knight, PhD. PE. (Florida Dept. of Transportation)
• Speaker 5: Steve McNamara, (ANZAC CONTRACTORS, INC.)
Using ACM’s for Internal Reinforcement in Prince Edward Island, Canada

Darrell Evans, P.Eng.
A/Asst. Director, Capital Projects
PEI Dept. of Transportation, Infrastructure & Energy
Darrell J. Evans, P.Eng.

- Graduate of the Technical University of Nova Scotia (TUNS) Class of ’95.
- Private Sector for 5 years (consulting).
- Public sector for 20 years.
- Transportation structures main focus.
- Instrumental in application of ACM’s for transportation infrastructure in PEI.
- Responsible for asset management within PEI.
Prince Edward Island, Canada

• Here we are on the east coast of Canada.
• Smallest Province.
• 5660 km² (2190 mi²) of land area
• 5600 km (3480 mi) natural waterways
• 5600 km of roadway network.
Structures Map

- 1400 “structures”
- 289 bridges
- 1111 buried type.
Island Definition

- Surrounded by salt water (about 34 ppt)
- Florida hovers around 36 ppt
Creates some Issues
Seasonal variations

- Four Seasons
  - Almost Winter
  - Winter
  - Still Winter, and
  - Construction

- Or, in layman’s speak:
  - Fall
  - Winter
  - Spring
  - Summer
Fantastic Summer (Construction) Season

- Up to 30° C (86° F)
- Humidex up to 40° C (104 ° F)
Fantastic Winter Season too!

- This is 2015
- Total accumulation of 4.5 metres (≈ 15 ft.)
- Down to -20°C (-4°F)
- Wind chill down to -40°C (-40°F)
Winter Maintenance

- Salt.
- Salt brine, salt pellets, salt/sand blend.
- Salt, salt, salt (NaCl).
Leads to more issues.
Use of GFRP in TIE’s Infrastructure

• Began in 2002 using GFRP wraps on timber piles to extend the service life of our timber bridge infrastructure.
• To date, over 20 bridge rehabilitations conducted in this fashion.
• We will continue to use this method of repairs as half of our bridge inventory is timber.
• Also used in rehab of AASHTO PCC girder (shear strengthening).
Use of GFRP as Primary Reinforcement

- We were invited to sit on a national committee on ACM’s in 2004.
- During this exposure, we developed an interest in GFRP reinforcement.
- Test results seemed very positive based on samples taken from various locations across Canada, with differing applications.
- Initial costs appeared somewhat high; but, should be reviewed against life cycle costing.
- Philosophy was to try it, see how the design and construction community reacts to new methods and monitor over the long term.
Structures with GFRP as Primary Reinforcement

- Shaded areas represent deck and substructure.
- All others are just deck. T&B
- Represents about 7% of bridge inventory.
- Plan on another 10 structures within the next 4 years.
- Green shaded is full-depth pre-cast deck post-tensioned together (albeit with steel).
- Orange is using GFRP ties for the formworks.

<table>
<thead>
<tr>
<th>Bridge</th>
<th>No. of Spans</th>
<th>Super structure</th>
<th>Horiz. Align.</th>
<th>Total Length (m)</th>
<th>Ft.</th>
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<td>Straight</td>
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TOTAL DECK LENGTH
1087 3566
How much GFRP can we stuff into a bridge?
Can’t use it everywhere.

• Recognize that it doesn’t fit all scenarios.
• Pre-cast arches for example, use WWM which they can bend into any radius they require.
• Timber bridges (why bother)
• Retrofits or extensions.
• Also, where we require ductility (Diaphragms)
Issues
Issues

• Designer inexperience (know your material – detailing – code limitations).
• Contractor inexperience (know your limitations – placement and cutting- UV degradation).
• Supplier resources (engineering and technical support for the end user - competitiveness).
• Repairs due to external damage.
• End of life disposal (sustainability)
• These are all solvable.
Thank you!
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Durable Bridges – An Owner’s Perspective
Wayne Frankhauser, PE
Bridge Program Manager
Maine Department of Transportation
OUTLINE

1. Building better bridges
2. FRP solutions
3. Challenges to the widespread use of composites
Background

- MaineDOT owns and manages 2,750 bridges and minor spans
- 2020-21-22 Work Plan
  - 148 Bridge Projects – Estimated Cost: $545 million
  - Unmet need of $67 million per year to maintain bridges in good condition
- Can’t build our way out – need to focus on preservation and building longer lasting bridges
- MaineDOT has been using composites for nearly 20 years
- Strong support from the UMaine Advanced Structures and Composites Center and the composite industry
Building Better Bridges

Harsh conditions cause reoccurring deterioration – Coastal environment, deicing chemicals, and freeze-thaw cycles.

➢ Piers deteriorate in splash zone and from leaky joints
➢ Decks deteriorate and spall
➢ Backwalls and bridge seats crumble
➢ Bridge bearings freeze up
➢ Bridge drains corrode
➢ Painted steel beams rust and are expensive to paint
Building Better Bridges

Can we do better?

– Better maintenance and preservation
– Better bridge detailing and construction practices
– Bridge type selection
– The use corrosion resistant materials

Some of these solutions will have a higher upfront costs
FRP Solutions

FRP Bridge Systems

- Composite Arch Bridge System
- HC Beams
- CT Girder System

Composite Arch System
on the Caribou Connector
(2011)
54’ 2” span x 12’ rise
Standard practice to include
as an option on projects where
appropriate
FRP Solutions

HC Beams
Boothbay, Barters Island Bridge (2012)
8 spans, 540’ long
CT Girder System
Hampden, Twin Bridge (2020)
75' span
FRP Solutions

CT Girder System
GFRP Reinforcing

• MaineDOT has used nearly 500,000 LF of GFRP in the last 3 years
• Standard practice to use GFRP straight bars, and stainless bent bars, in our bridge decks
• Average cost for GFRP close to black bar
FRP Solutions

Composite Drains

• Standard practice for new bridges
FRP Solutions

FRP Pile Wrap

York, Rices Bridge

Repair of the epoxy coated pipe pile bent piers built in 2005
Other FRP Applications

- FRP pile
- FRP culvert invert lining
- FRP fenders
- FRP fairing
- CFCC prestressing and post-tensioning
- Carbon fiber strand in cable stay
Challenges

• Education
• Specifications
• Industry support
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INFRASTRUCTURE FEATURED PANEL DISCUSSION
Wednesday, September 23, 2020
2:25 pm – 3:40 pm EDT

Building Bridges Along the Atlantic
- A Florida Structural Perspective

Steven Nolan, P.E.
Senior Structures Design Engineer
Lead: Advanced Materials for Structural Durability & Resiliency
OUTLINE

1. What are the Needs?
2. What are our Options?
3. What are the Benefits?
4. What are some Challenges that need Solving?
What Are the Needs?

- Florida maintains over 166 million sq.ft. of bridge area
- Florida has more than 4,000 miles seawall-bulkheads

**Seven Mile Bridge “New” and Old (Florida Keys)**

- 1912
- 1938
- 1982
- Cow Key Channel 1976 & 1983

**Jupiter (FL)**

- Seven Mile Bridge “New” and Old (Florida Keys)
- Gandy Blvd. seawall (Tampa Bay)
- Courtney Campbell Causeway (Tampa Bay)

**WebTable 3. Shoreline hardening and population statistics by state**

<table>
<thead>
<tr>
<th>State</th>
<th>Hard sheltered shore (km)</th>
<th>Hard sheltered shore (%)</th>
<th>Hard open shore (km)</th>
<th>Hard open shore (%)</th>
<th>Total shore (km)</th>
<th>Hard shore (%)</th>
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<td>13455</td>
<td>24</td>
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<td>26386</td>
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</table>

**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 substrates 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 research will help ensure the durability and longevity of these critical infrastructure elements.

(1) FDOT Bridge Inventory - 2020 Annual Report
(2) Estimates from Gittman et al. (2015)
**What are our Options?**

1. Glass & Basalt FRP rebar for concrete structures
2. Carbon FRP strand and spirals for prestressed members
3. Pultruded, Wound & Molded FRP Structural Components
4. FRP Laminates and Wraps for rehabilitation & strengthening
What Are the Benefits?

1. Reduced repair & rehabilitation
   - No corrosion
2. Longer asset life and replacement frequency
3. Potential reuse of foundations
5. Lighter weight materials
   - Worker safety
   - Strengthening of existing structures or decrease design loads
6. Sustainability benefits
   - Materials have improved LCA over conventional reinforcing
   - Reduce cement content needed or even geopolymer low alkalinity concretes
What Are the Challenges that need Solving?

- Connections – Coupling, Anchoring, Lifting Devices
- Bent bars – Consistency, Scaling, & Performance
- Supply chain efficiency & Contractor expectations
What Are some Challenges that need Solving?

- Connections – Coupling, Anchoring
- Bent bars – Consistency, Scaling, & Performance
- Supply chain efficiency & Contractor expectations
- LCC Policy, Standards, & Design tools

Published: Sept. 2020

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Building Bridges Along the Atlantic
- A Florida Materials Perspective

Chase Knight, PhD, P.E.
State Corrosion & Composite Materials Engineer
1. How does FDOT approve specified FRP materials for infrastructure?

2. What are our Quality Control expectations?

3. How can a new/novel FRP product or material get approved for use?

4. What do we worry about?
How does FDOT approve specified FRP materials for infrastructure? – Uniform Approval Processes

• Limited U.S. consensus standards for FRP products and recognized manufacturer certification programs:
  i. Develop FDOT Specifications as an interim measure.
  ii. Develop FDOT Sampling and Test Methods (FSTMs), if necessary.

• FRP Producer Approval or Product Approval (APL)?
  i. “widgets” go on the APL.
  ii. Most FRP products require more nuanced review, approval and monitoring = Producer QC Plan Approval by FDOT.
  iii. Similar to Prestressed Concrete Plant approval, but no in-plant inspectors at this time - Auditing is an option - Industry or AASHTO certification program could be desirable.
Limited U.S. consensus standards for FRP products and recognized manufacturer certification programs:

i. Develop **FDOT Specifications** as an interim measure or supplemental requirements, such as highlighted in the example below:

932-3 Fiber Reinforced Polymer (FRP) Reinforcing Bars.  
932-3.1 General: Obtain FRP reinforcing bars from producers currently on the Department’s Production Facility Listing. Producers seeking inclusion on the list shall meet the requirements of Section 105.

Use only solid, round, thermoset basalt fiber reinforced polymer (BFRP), glass fiber reinforced polymer (GFRP) or carbon fiber reinforced polymer (CFRP) reinforcing bars. Bars shall be manufactured using pultrusion, variations of pultrusion, or other suitable processes noted in the producer’s Quality Control Plan, subject to the approval of the State Materials Office (SMO). For BFRP and CFRP bars only vinyl ester or epoxy resin systems are permitted. For GFRP, use only bars manufactured using vinyl ester resin systems and glass fibers classified as E-CR or R that meet the requirements of ASTM D578.
Uniform Approval Processes

- FRP Producer Approval = Materials Acceptance & Certification

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Fiber Reinforced Polymer Production Facility Listing

**FRP-02**
Company: Owens Corning Infrastructure Solutions
Contact: John Amoretti
Phone: (419) 819-4739
Physical Address: 1561 Jenkins Brothers Blvd, Blytheindhoven, SC 29016

**FRP-05**
Company: Pultrall Inc
Contact: Roxanne Fortier
Phone: (418) 332-5200
Physical Address: Pultrall Inc, 755 Sir Francis Drake Blvd, San Rafael, CA 94903

**FRP-06**
Company: Pultron Composites Ltd
Contact: Bogdan Patreseu
Phone: (714) 630-1234
Physical Address: 7821 S 4480 W, Bldg 10, Freeport, IL 61032

**FRP-12**
Company: Tuf-Bar Inc
Contact: Nathan Stry
Phone: (760) 442-9338
Physical Address: Tuf-Bar Inc, 5715 SE, Avenue 1, Silver Spring, MD 20902

**FRP-07**
Company: Pultron Inc
Contact: Nathan Stry
Phone: (760) 442-9338
Physical Address: 5715 SE, Avenue 1, Silver Spring, MD 20902

**FRP-08**
Company: GFRP Bar
Contact: Nathan Stry
Phone: (760) 442-9338
Physical Address: GFRP Bar, 5715 SE, Avenue 1, Silver Spring, MD 20902

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Glass Fiber Reinforced Polymer Reinforcing for Concrete, #3
Glass Fiber Reinforced Polymer Reinforcing for Concrete, #4
Glass Fiber Reinforced Polymer Reinforcing for Concrete, #5
Glass Fiber Reinforced Polymer Reinforcing for Concrete, #6
Glass Fiber Reinforced Polymer Reinforcing for Concrete, #7
Glass Fiber Reinforced Polymer Reinforcing for Concrete, #8

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**FRP-08**
Company: ATP
Contact: Aniello Giamundo
Phone: (811) 548-7131
Physical Address: via Campa 34, ITALY

**FRP-14**
Company: Tuf Bar Inc
Contact: Jay Christopher
Phone: (519) 833-5050
Physical Address: 7 Erin Park Dr, Clinton, ON K0C 1J0

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**FRP-07**
Company: Pultron Inc
Contact: Nathan Stry
Phone: (760) 442-9338
Physical Address: 5715 SE, Avenue 1, Silver Spring, MD 20902

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Glass Fiber Reinforced Polymer Reinforcing for Concrete, #6
Glass Fiber Reinforced Polymer Reinforcing for Concrete, #7
Glass Fiber Reinforced Polymer Reinforcing for Concrete, #8

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Building Bridges Along the Atlantic
### What are the Quality Control expectations?

#### Uniform Approval Processes

**DIVISION I**

**GENERAL REQUIREMENTS AND COVENANTS**

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How can a new/novel FRP product or material get approved for use? – Uniform Approval Processes

• Unique product (widget) that fits a Department Need – Innovative Products List (IPL)

• Standard products (widgets) that the Department needs – Approved Product List (APL)
  ➢ [https://fdotwp1.dot.state.fl.us/ApprovedProductList/Specifications](https://fdotwp1.dot.state.fl.us/ApprovedProductList/Specifications)

• Novel or Project Specific Need – Technical Special Provision (TSP)
  ➢ Work with District Specs Office and Project Manager

• Materials/Construction Process that is not mature – Developmental Specification
  ➢ [https://www.fdot.gov/programmanagement/otherfdotlinks/developmental/default.shtm](https://www.fdot.gov/programmanagement/otherfdotlinks/developmental/default.shtm)

• Standard Materials/Construction Process (institutionalized acceptance) – FDOT Standard Specifications for Road and Bridge Construction (Specs)
  ➢ [https://www.fdot.gov/programmanagement/implemented/specbooks/default.shtm](https://www.fdot.gov/programmanagement/implemented/specbooks/default.shtm)
What do we worry about? - CPR&T

- **Consistency** – Creating a level “playing field” and setting clear expectations $\rightarrow$ *uniform processes and standards.*

- **Predictability** – Mechanical and Durability $\rightarrow$
  - *Improvement can lead to more efficiency in design reduction factors with the same level of confidence.*

- **Repeatable/Reliability** – Builds confidence with owners, inspectors, contractors, and ultimately the public taxpayers $\rightarrow$
  - *can lead to reduced inspection and testing requirements.*

- **Traceability** – When “stuff” happens, we need to be able to find out why, and where else this could be a problem. e.g.$\rightarrow$
  - *PT Grout “Chloride contamination (2002-10)”, and then later “Soft”.*
  - *Polymer adhesive-anchor creep failure from Boston Tunnel ceiling collapse*
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N.E. 23rd Avenue Bridge [IBIS-Waterway]
Prestressed GFRP-Piles & GFRP-RC Seawall

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INNOVATIVE GFRP-BRIDGE CONCEPTS

1. Prestressed and Driven GFRP-Piles with Monitoring.


INNOVATION AND LAYOUT

- First of its kind, currently under construction, GFRP-RC 3-Span continuous Flat-Slab Bridge and first Soldier-Pile Bulkhead-Seawall with GFRP-RC Precast-Panels, in the State of Florida, USA.
BRIDGE - REPLACEMENT VIA GFRP

BRIDGE - PILE DRIVING PHASE

The IBIS Waterway Bridge Pile-Driving included the driving of GFRP-RC Piles. Relative “hard” soil conditions and powerline locations challenged the driving.
IBIS-Waterway Bridge GFRP placement at Intermediate-Bents atop Prestressed GFRP-RC driven Piles. Cage-Construction with GFRP bars is fast and efficient, due to lightweight and is also corrosion resistant.
GFRP REINFORCED END-BENTS

IBIS-Waterway Bridge GFRP placement at End-Bents atop Precast Seawall- Panels, and at Intermediate-Bents
GFRP LESSONS LEARNED

• Correct scheduling of FRP/GFRP/BFRP bar deliveries is critical
• Verify and check Shop-Drawings (Dimensions, Angles, Splices)
• For Structural Tie-Backs verify that slotted block-outs are designed for the corresponding angles of installation in both the vertical and horizontal plane (to easily accommodate the GFRP)
• Anticipate some bar-breakage and order some additional bars
• The lightweight and high strength of GFRP bars makes it easy to work with and improves installation efficiency by more than 52% 
• The use of GFRP bars allows for less expensive Mix-Designs
CONCLUSIONS & RECOMMENDATIONS

- There is a strong case for use of FRP/GFRP/BFRP in structural concrete exposed to corrosive environment.
- Economics of FRP comparable to steel upfront and return on investment is higher on a life cycle cost analysis basis.
- GFRP anisotropic and linear elastic up to failure.
- Specifications and Design Guides exist.
- Accessible design tools exist for design professionals.
- Prestressed GFRP-RC Piles were successfully driven.
IBIS-WATERWAY

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