FRP Constructability
Issues and Coordination

Sergio Notarianni, Director of Engineering, Astaldi
Antonio Nanni, Professor, University of Miami
Outline

- Astaldi’s Experience with FRP
- Construction Considerations
  - Procurement & Lead times
  - Site Storage and logistics
  - Construction Challenges
  - Advantages/Disadvantages – Contractor’s View
- Halls River Bridge Project
  - Project Description
  - Status
- UM activities at Halls River Bridge
  - SEACON
  - Concrete mixtures
  - Lab testing
Experience with FRP

• More than 20 years using FRP:

<table>
<thead>
<tr>
<th>Astaldi’s Recent Projects using FRP</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro Copenhagen, Phase 1 &amp; 2 - Denmark</td>
<td>Metro Milan Line 5 Bignami - Garibaldi, Italy</td>
</tr>
<tr>
<td>Metro Brescia, Italy</td>
<td>Metro Naples Line 1, Piscinola - Centro Direzionale, Italy</td>
</tr>
<tr>
<td>Metro Genoa, Italy</td>
<td>Metro Rome Line C, Italy Phase 1 and Phase 2</td>
</tr>
<tr>
<td>Metro Milan Line 4, Italy</td>
<td>Metro Warsaw, Poland</td>
</tr>
<tr>
<td>Metro Milan Line 5, San Siro - Garibaldi, Italy</td>
<td>Rome-Naples HSR, Italy</td>
</tr>
</tbody>
</table>

• Astaldi’s use of FRP, has been predominately for mechanized tunneling, and NATM works.
FRP in Tunneling

- Use of ‘Soft Eye’ in breakthroughs of Tunnel Boring Machines (TBMs) in stations/shafts.
- Use of Glass FRP reinforcements for tunnel face strengthening in soft ground NATM tunnels works.

FRP for New Construction
In recent years, the improvement in materials and testing have allowed FRP to make the jump from ‘temporary works’ to ‘permanent works’.

- Concrete Tunnel Linings/Segments with FRP.
- LRT Track Beds - Mitigation of Stray Current Corrosion
- Reinforced Concrete Structures in marine environments.
- Reinforced Structures subject to harsh environment – cold weather climates.
Concrete Tunnel Segments

Benefits of FRP

- Less reinforcements requirements due to reduced concrete cover.
- Higher durability - no issues with spalling caused by oxidization of steel rebar.
- Higher durability - no corrosions caused by stray currents from DC distribution lines, railway systems, substations, among other sources.
- Normal Concrete Mixes Designs- no specific requirements for specialized mixes and relevant testing.
Site Storage and Logistics

- Transportation and storage usually in containers – avoids mishandling of rebar and protection from direct sunlight.
- Light weight of FRP rebar make it easy to man handle all sizes and lengths minimizing H&S issues.
Construction Challenges

- Lift of prefabricated FRP cages
- Splicing of rebar to ensure safe lifting.
- Concrete issues due to light weight of rebar.
- NO FLAME – no heat sources allowed near FRP bars.
- Fragility of rebar
Construction Challenges

- Lift of prefabricated FRP cages
- Splicing of rebar to ensure safe lifting.
- Concrete issues due to light weight of rebar.
- NO FLAME – no heat sources allowed near FRP bars.
- Fragility of rebar
Construction Challenges

- Lift of prefabricated FRP cages
- Splicing of rebar to ensure safe lifting.
- Concrete issues due to light weight of rebar.
- NO FLAME – no heat sources allowed near FRP bars.
- Fragility of rebar
Construction Considerations

Procurement & Lead Time

➢ Procurement must consider lead time for manufacturing and shipping.

➢ Design becomes critical

➢ Procurement of additional quantities of FRP bars to ensure immediate replacements in case of damages on site.

➢ QA/QC - additional verifications at manufacturing plant needed prior to shipment to mitigate risk of delays due to non compliances of materials arriving on site.
Construction Considerations

Site Storage and Logistics

- Additional Storage requirements needed on site
- Specific lifting plans needed for large prefabricated cages.
- Weight of bars is ¼ of black steel, making it easy to handle and increases productivity rebar placing.
Construction Challenges

• Trained labor required to ensure correct fixing and minimize risk of damages and movement of reinforcements during concreting operations.

• Specialized lifting plans required for prefabricated cages.

• Splicing of FRP bars complicated and time consuming.
Construction related issues

**GFRP vs Black Steel**

Advantages:
- Reduced concrete cover requirements
- Labor Savings during Installation
- Concrete Properties less stringent

Disadvantages:
- Higher Costs of Materials
- Specific Storage and Site Logistics
- Additional Contingency Qty’s required
- Specific lifting plans required
- QA/QC - additional verifications at manufacturing plant
- Risk of movement of GFRP during concreting
- Fragile – easily damaged. Specialized training of labor.
- Splicing details for prefabricated cages
Halls River Bridge

- Situated in Citrus County and consists of the replacement of the existing. The bridge section is a two 12’ lane width, 8’ shoulder and 5’ sidewalk in each direction.
- The proposed bridge is being constructed using Composite Beams, pre-stressed piles using carbon tendons and FRP reinforcement for bridge deck.
- Two-stage construction method is envisaged, partial demolition of the existing bridge structure, construction of a portion of the new bridge, demolition of the remaining existing bridge structure and the completion of the new bridge.
PROJECT FEATURES

• FRP reinforcement for main deck slab
• Hillman Composite Beams (HCB)
• Carbon FRP reinforcements and pre-stressing for 18” piles
• Precast concrete sheet piles with carbon FRP reinforcements and pre-stressing
• Precast concrete sheet piles with external FRP reinforcements and central steel pre-stressing tendons.
PROJECT STATUS

Commencement of Works January 2017

Current ongoing activities:
• Preconstruction Deliverables
• Temporary roads and site preparation.
• QC plan and Shop Drawings
• ADVANCED PROCURMENT
  • GATE PRECAST (USA) for piles and sheet piles
  • ATP (ITA) for FRP reinforcement for bridge deck
  • TOKYO ROPE (JAP) for pre-stressing strands for piles and sheet piles
  • HCB (USA) for composite beams

<table>
<thead>
<tr>
<th>MATERIALS</th>
<th>START PLACEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>PILES</td>
<td>3/3/2017</td>
</tr>
<tr>
<td>SHEET PILES</td>
<td>2/15/2017</td>
</tr>
<tr>
<td>HCB</td>
<td>4/6/2017</td>
</tr>
<tr>
<td>REINFORCEMENT</td>
<td>3/28/2017</td>
</tr>
</tbody>
</table>
Outline

- Astaldi’s Experience with FRP
- Construction Considerations
  - Procurement & Lead times
  - Site Storage and logistics
  - Construction Challenges
  - Advantages/Disadvantages – Contractor’s View
- Halls River Bridge Project
  - Project Description
  - Status
- UM activities at Halls River Bridge
  - SEACON
  - Concrete mixtures
  - Lab testing

FRP for New Construction
On October 1, 2015, a consortium of six partners and three collaborators led by the University of Miami started a 2.5-year research project.

**Partners**
- University of Miami (UM)
- Owens Corning (OC)
- ATP srl (ATP)
- Politecnico di Milano (POLIMI)
- Buzzi Unicem (BUZZI)
- Acciaierie Valbruna (AV)

**Collaborators**
- Florida DOT (FDOT)
- Pavimental (PV)
- Titan America (TT)
SEACON Project

This project titled “Sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement” or SEACON was funded under the aegis of the European research program called Infravation (seacon.um-sml.com)

WP 1 – Effects of seawater and salt-contaminated aggregates on concrete properties (BUZZI)
  - Task 1.1 Characterization of raw materials
  - Task 1.2 Characterization of fresh concrete
  - Task 1.3 Characterization of hardened concrete

WP 5 – LCA & LCC (POLIMI)
  - Task 5.1 LCI
  - Task 5.2 LCC
  - Task 5.3 LCI assessment
  - Task 5.4 Economic assessment

WP 2 – Sea-concrete and GFRP (UM)
  - Task 2.1 Properties of GFRP bars
  - Task 2.2 GFRP bars w/ accelerated conditions
  - Task 2.3 Recommendation for DEMO

WP 3 – Sea-concrete and SSR (POLIMI)
  - Task 3.1 Select steel bars
  - Task 3.2 Corrosion behavior
  - Task 3.3 Expected life
  - Task 3.4 Recommend. for DEMO

WP 4 – Field demonstration at two sites and on-site monitoring (BUZZI and OC)
  - Task 4.1 DEMO ITALY – Retaining wall
  - Task 4.2 DEMO USA – Bridge superstructure

WP 6 – Dissemination, Exploitation and standardization (AV)
  - Task 6.1 Dissemination
  - Task 6.2 Exploitation
  - Task 6.3 Guideline for pre-standardization

WP 7 - Project Management (UM)
SEACON Project - Objectives

• Make it clear that chlorides do not damage concrete properties (i.e., workability, strength development, durability)

• Assess the durability performance and economic impact resulting from the use of chloride contaminated aggregates, high chloride content cement and seawater in structural concrete

• Validate suitable reinforcement alternatives (i.e., improved stainless steel reinforcement (SSR) and GFRP)

• Demonstrate technology by means of two real-size field prototypes in two countries (Italy and Florida)
1. Conventional Concrete (Class IV)
2. Green Concrete
3. Concrete with Recycled Concrete Aggregate (RCA)
4. Concrete with Recycled Asphalt Pavement (RAP)
5. White Cement Concrete (Class IV)
6. 60% Slag Concrete (Class IV)
Green Concrete

- Bulkhead caps and test blocks
- Test blocks with Glass, Basalt and Carbon FRP reinforcement
- Proportion of Class IV but fresh water replaced with seawater by 100%.
- Retarding agent to offset acceleration effect of chlorides
- Long-term durability is comparable to conventional concrete

**Compressive Strength**
- Outdoor
- Seawater
- Tidal zone

**Tensile Strength**
- Outdoor
- Seawater
- Tidal zone
RCA and RAP Concrete

- Used in gravity walls
- Test blocks with GFRP, BFRP, and CFRP bars
- Non-structural concrete with 28-day minimum $f'_c$ of 2,500 psi
- 20% of natural aggregate replaced with RCA and RAP
- Long-term durability comparable to conventional concrete

Compressive Strength

- Outdoor
- Seawater
- Tidal zone

RCA Concrete

Conventional Concrete

Tensile Strength

- Outdoor
- Seawater
- Tidal zone
White-cement and 60%-slag concretes

- White-cement and 60%-slag concretes for traffic railings reinforced with GFRP
- Three 12-ft specimens for pendulum test
- FRP reinforced test blocks for performance monitoring
Lab Testing: Durability of GFRP bars embedded in Green Concrete

- **Green** concrete beams with GFRP bars exposed to accelerated conditioning
- No degradation in physio-mechanical properties of embedded GFRP bars
Durability of GFRP reinforcement embedded in Green Concrete

<table>
<thead>
<tr>
<th>Mechanical and physical properties</th>
<th>Pristine bars (CV%)</th>
<th>Extracted bars (CV%)</th>
<th>Mix A Conventional</th>
<th>Mix B Green</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength (ksi)</td>
<td>164.2 (2.2)</td>
<td>170 (2.1)</td>
<td>170.1 (0.1)</td>
<td></td>
</tr>
<tr>
<td>Tensile chord modulus of Elasticity (Msi)</td>
<td>7.65 (3.5)</td>
<td>8.3 (1.1)</td>
<td>8.2 (2.5)</td>
<td></td>
</tr>
<tr>
<td>Horizontal shear strength (ksi)</td>
<td>5.2 (3)</td>
<td>4.9 (4.2)</td>
<td>5.4 (9.2)</td>
<td></td>
</tr>
<tr>
<td>Transverse shear strength (ksi)</td>
<td>26.3 (5.2)</td>
<td>25 (3.5)</td>
<td>23 (4.9)</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

• Even if not iconic in its aesthetics and geometry, **Halls River Bridge (HRB)** is a truly unique and remarkable project to demonstrate the deployment of innovation

• **HRB** design, construction, monitoring and research will allow for the validation of the proposed technologies helping FDOT (and other agencies) to assess feasibility implications and develop specifications/standards

• **HRB** as a test-bed for collaboration among FDOT, private sector and academia is truly a landmark
FRP Deployment for New Construction

Steven Nolan, P.E.
State Structures Design Office
(Structures Standards Group)
Outline

• Fender Systems
• Internal Reinforcement
• FRP for Pretensioning
• Construction Specifications
• Design Standards
• Design Guidance
• Where are we heading...
• FDOT Current Projects Status
Leveraging the most benefit from FRP for FDOT

i. Why composites:
   • Avoiding corrosion -
     • GFRP rebar
     • CFRP prestressing strand
     • Polymeric piling durability & toughness

ii. Durability/Service Life;

iii. Cost-Benefit;

iv. Challenges - Mitigating Risks
   • New Material Systems;
   • Limited suppliers/competition;
   • Unfamiliar design criteria;
   • Unfamiliar construction practices.

FRP for New Construction
Fender Systems

**OLD:**
Timber and/or Concrete

**NEW:**
FRP Composite Systems

Fender System Piles and Wales:
- FDOT **Spec. 471 & 973**
- New Approved Producers List (now FRP Production Facilities) requirements in **MM 12.1 (Jan. 2015)**
- New **Structures Detailing Manual** - Chapter 24 (Jan. 2015)


Courtesy of: Creative Pultrusions, Inc. (2014)


Courtesy of Garcia Bridge Engineers (2013)
Fender Systems

Materials:
- Thermoset Pultruded & Thermoplastic Structural Shapes

(photographs) D. Troutman; Creative Pultrusions Inc., Polymeric Bridge Fender Piles and Wales.

FRP for New Construction
Fender Systems

Progressive Development:

• 2006 – 2011, Predesigned FRP Systems under Index 21910 (Heavy Duty) & Index 21920 (Medium Duty)

• 2011 – 2015: Preset pile spacing under Index 21900, Contractor/Vendor designs tailored for navigation channel barge population generic;

• 2015+: Customized Contractor/Vendor configuration and designs tailored for navigation channel barge population based on Structures Manual.
Fender Systems

Resources:

i. Fender System “Polymeric” Piles and Wales (Design Standards – Index 21900 series, since 2006);
ii. FDOT Specifications 471 & 973;
iii. Approved Products List (APL) for Wales (and Piles for projects bid prior to July 2015);
iv. Fiber Reinforced Polymer Production Facility Listing via Materials Manual – Section 12.1 (Piles for new projects bid since July 2015 lettings);
v. Custom designed systems – Structures Design Guidelines (SDG) – Section 3.14 design criteria (new projects bid since July 2015 lettings);
Internal Reinforcement for Concrete Structures
GFRP and CFRP Reinforcing Bars

Permitted use for:

- Approach Slabs;
- Bridge Decks and Bridge Deck overlays;
- Cast-in-Place Flat Slab Superstructures;
- Pile Bent Caps, Pier Columns and Caps not in direct contact with water;
- Traffic Railings;
- Pedestrian/Bicycle Railings;

Example bar-surface types:
- a) Ribbed
- b) Sand-coated
- c) Helically wrapped and sand-coated

(photographs) Hughes Bros. GFRP Bars.
GFRP and CFRP Reinforcing Bars
(cont.)

Permitted use for (cont.):

- Retaining Walls, Noise Walls and Perimeter Walls;
- MSE Wall Panels;
- MSE Wall Copings;
- Bulkhead Copings;
- Concrete Sheet Piles
- Drainage Structures.

(photograph) Hughes Bros. GFRP Bars in retaining walls.

(photograph) FDOT, 2015. GFRP Bars in bulkhead cap – Cedar Key.
Challenges with GFRP & CFRP

Rebar \((Spec.~Section~932)\):

- No field of FRP bars;
- Fabricate bent FRP bars to the required shape;
- FRP bars must be shielded from prolonged exposure to UV light.
- No thermal or shear cutting of FRP bars;
- Tie using plastic coated wire or zip ties;
- No mechanical couplers;
- Paid for by the linear foot based on bar size (not weight).

(photograph) Hughes Bros. FRP Protection.

(photograph) Hughes Bros. Coated tie wire.
Challenges with FRP Bar Bending Details (cont.)

- Combinations of single bars for complex shapes
CFRP Prestressing Strands

Permitted use for:

- Prestressed concrete piles;
- Concrete sheet piles

(photographs) FDOT. CFRP Strands in Piles.
Challenges with CFRP Strands (Spec. Section 933):

- Use self-consolidating concrete only;
- No flame or shear cutting of CFRP strand;
- Tie using plastic coated wire or zip ties;
- Spirals for CFRP reinforced piling must also be CFRP;
- Headers must be wood, or steel with rubber grommets.
- Coupling to steel strand tails for stressing.
Specifications:

a) Standard Specifications (effective July 2016):
   • Implemented previous FRP Developmental Specifications.
   • 400 Concrete Structures – Fiber Reinforced Polymer Reinforcing;
   • 410 Precast Concrete Box Culvert;
   • 415 Reinforcing for Concrete;
   • 450 Precast Prestressed Concrete Construction – Fiber Reinforced Polymer (FRP);
   • 932 Nonmetallic Accessory Materials for Concrete Pavement and Concrete Structures;
   • 933 Prestressing Strand;

b) Previous Developmental Specifications:
   • Dev400FRP, Dev410FRP, Dev415FRP, Dev450FRP, Dev932FRP, Dev933FRP

(Photograph) Hughes Bros.
Design Standards:

a) FY2017-18 Design Standards:
   • Index 22600 series – Square CFRP & SS Prestressed Concrete Piles;
   • Index 22440 – Precast Concrete CFRP/GFRP & HSS/GFRP Sheet Pile Wall

b) Developmental Design Standards:
   • Index D6011c – Gravity Wall – Option C (GFRP reinforced);
   • Index D21310 – Pultruded FRP Bar Bending Details;
   • Index D22420 – GFRP reinforced 32” F-Shape Traffic Railing;
   • Index D22900 – GFRP reinforced Approach Slab;

FRP for New Construction
Design Guidance

FDOT Structures Manual

1. Design criteria –
   a) Fiber Reinforced Polymer Guidelines (FRPG – Vol.3)
   b) Structures Design Guidelines (SDG – Vol.1);

2. Detailing criteria – Structures Detailing Manual (SDM-Vol.2);

Where are we heading?

Possible expanded applications of FRP Internal Reinforcement:

• Initially Glass FRP (GFRP) reinforcement;
• Investigating Basalt FRP (BFRP) reinforcing;
• Investigation feasibility of CFRP Prestressing for low-level bridges over saltwater for beams/slabs;
• Development of GFRP closed stirrups (continuous – filament winding) for greater product efficiency.
• Resolution of GFRP durability in submerged applications for bridges.
FDOT Projects Status

1. **Cedar Key Bulkhead Cap Rehab.**
   - FPID 432194-1 construction completed June 2006; SMO monitoring.

2. **Halls River Bridge Replacement**
   - Construction started 1/9/17;
   - Astaldi Construction Corp.

3. **Bakers Haulover Cut Bridge Rehab.**
   - Contractor started mobilizing to site;
   - Kiewit Infrastructure South Co.

4. **Skyway South Rest Area Seawall Rehab.**
   - Design Build Procurement;
   - Anticipated Award Date 02/8/2017;
Questions ??

FDOT Contact Information:

**Structures Design Office:**
Rick Vallier, P.E. (FRP Coordinator)
(850) 414-4290
Rick.Vallier@dot.state.fl.us

Steven Nolan, P.E. (Standards Coordinator)
(850) 414-4272
Steven.Nolan@dot.state.fl.us

**State Materials Office:**
Chase C. Knight, PhD. (FRP Coordinator)
(352) 955-6642
Chase.Knight@dot.state.fl.us

Ivan Lasa, B.S.C.E. (Corrosion Lab.)
(352) 955-2901
Ivan.Lasa@dot.state.fl.us

FRP for New Construction
Halls River Bridge Replacement – Example FRP Project Application

Mamun Siddiqui, P.E.
Cristina Suarez
1. Project Overview
2. Design Challenges
3. Design References - Specs and Standards
4. Construction
5. Lessons Learned
Project Overview – Corrosion Issues

Severe Pile Damage

Pile Damage

Beam Damage

FRP for New Construction
District 7 (FY 02/03 to Present)

- 54 Total projects:
  - 20 Steel
  - 34 Concrete

24% Other Repairs
76% Corrosion Repair

$2.4M per Project

Source: FDOT D7 District Structures Maintenance Office (DSMO)
Project Overview – Prevention Methods

• New Concrete Structures
  • Adequate Concrete Cover
  • Concrete Quality
  • Alternative Reinforcements
    • Corrosion Inhibiting Admixtures

• Existing Concrete Structures
  • Pile Jacket
  • FRP Wrapping
  • Cathodic Protection

- Epoxy
- Galvanized
- ECR
- Z-bar
- FRP
- Stainless
- MMFX
FRP for New Construction

Project Overview - Background Info

- **Relevant Information**
  - Demonstration Project - First of its kind in Florida
  - Category II Structure - D7 Structures In-house Design

- **Sole Source Items**
  - Hybrid Composite Beam (HCB) - *HC Bridge Company*
  - Carbon Fiber Composite Cable (CFCC) - *Tokyo Rope Mfg. Company Ltd.*

- **Contractor Bid**
  - $6.016 Million (Overall Project Cost)
  - $4.06 Million – Structures
    - Bridge $2.35M / Sheet Pile Walls $1.71M
  - Roadway, Utility etc.

- **Funding** – FHWA

- **Construction Date:** January 09, 2017
Project Overview - Background Info

- Owner
- Maintaining Agency

- Bi-Annual Inspection
- Design and Build Proposed Bridge
Project Overview – Existing Bridge

EXISTING SECTION THRU BRIDGE DECK
Project Overview – Existing and Proposed Bridge
Project Overview – Proposed Bridge
FRP Materials

FRP for New Construction
Design Challenges: FRP VS Steel Reinforcing

• Direct substitution between FRP and steel reinforcement is not possible,

• Modulus of elasticity much lower than steel,

• FRP reinforced concrete sections do not show ductility,

• Safety against failure for FRP is higher than the conventional steel,
Design References

Codes, Standards and References

ACI 440.1R-15
Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinforced Polymer (FRP) Bars
Reported by ACI Committee 440

AASHTO LRFD Bridge Design Guide Specifications for FRP Reinforced Concrete Bridge Decks and Traffic Railings

FLORIDA DEPARTMENT OF TRANSPORTATION
FIBER REINFORCED POLYMER GUIDELINES (FRPG)
FDOT STRUCTURES MANUAL
VOLUME 4
JANUARY 2016

2016 FDOT Design Standards
For Construction and Maintenance Operations on the State Highway System

Specifications and Estimates/Specifications/
Materials Manual Section 12.1, Volume II
FIBER REINFORCED POLYMER COMPOSITES
Section 12.1, Volume II

FRP for New Construction
Design References

[Image of two books on reinforced concrete with FRP bars]
Hybrid Composite Beam (HCB) – Manuals and References

Hybrid-Composite Beam (HCB®) Design and Maintenance Manual

TECHNICAL SPECIAL PROVISION

FOR

SECTION T450 - FURNISHING & INSTALLING HYBRID-COMPOSITE BEAMS

FINANCIAL PROJECT ID: 430021-1-52-01

The official record of this Technical Special Provision has been electronically signed and sealed using a Digital Signature as required by Rule 61G 15-23.004. F.A.C. Printed copies of this document are not considered signed and sealed and the signature must be verified on an electronic copies.

Professional Engineer: Mamunur Rashid Siddiqui, P.E.
Date: March 3, 2016
Firm License No.: 70094
Firm Name: FDOT
Firm Address: 11201 N McKinley Dr.
City: Tampa, State: FL, Zip code: 33612
Certificate of Authorization: N/A.
Pages: 1-13
Materials

Hybrid Composite Beam (HCB)
Fiber Reinforced Polymer (FRP) Reinforcing

So how does it work?

GFRP Rebar is made of Glass Fibers embedded in Polymeric Resin

- Fibers provide strength and durability
- Resin holds fibers together, transfers load between fibers and protects from abrasion/environment
Fiber Reinforced Polymer (FRP) Reinforcing

Pros:

- Corrosion Resistance
- High Strength
- Lightweight
- Fatigue Endurance

Cons:

- High Initial Cost
- Brittle Failure
Construction Coordination

• Construction coordination is key
• Quick resolution of issues
• Construction coordination includes:
  • Pre-construction planning
  • Safety coordination and management
  • RFI, RFM program implementation and resolution
  • Quality assurance and control
  • Material control and procurement support
  • Field contract administration
  • Inspection coordination
Construction

EXISTING STRUCTURE REMOVAL (INTERMEDIATE BENTS)

PHASE II - STAGE 1

FRP for New Construction
Construction

PHASE II - STAGE 2
(Intermediate Bent Shown, End Bent Similar)

PHASE III - STAGE 1
Construction

COMPLETED BRIDGE SECTION
Hybrid Composite Beam – Fabrication

HYBRID COMPOSITE BEAMS

STANDARD CONCRETE BEAMS
Hybrid Composite Beam – *Handling and Storage*

**HYBRID COMPOSITE BEAMS**

**STANDARD CONCRETE BEAMS**

*FRP for New Construction*
Construction

Hybrid Composite Beam – Transportation

HYBRID COMPOSITE BEAMS
Union St., Maine
(4 - 70 ft. beams @ 9 kips = 36 kips total)

PRESTRESSED SLAB BEAMS
Gospel Island, Florida
(2 - 39 ft. beams @ 25 kips = 50 kips total)
Construction

Hybrid Composite Beam – Installation

HYBRID COMPOSITE BEAMS
PRESTRESSED SLAB BEAMS
Construction Photos

FRP for New Construction
FRP Rebar

FRP Bars are vulnerable to surface damage

<table>
<thead>
<tr>
<th>Checklist: Handling and Storage of FRP Rebars</th>
</tr>
</thead>
<tbody>
<tr>
<td>☑ Store bars in a clean environment</td>
</tr>
<tr>
<td>☑ Protect bars against:</td>
</tr>
<tr>
<td>☑ UV radiation</td>
</tr>
<tr>
<td>☑ High temperature</td>
</tr>
<tr>
<td>☑ Damaging chemicals</td>
</tr>
<tr>
<td>☑ Lift bundles of bars with care</td>
</tr>
<tr>
<td>☑ Do not shear bars when cutting</td>
</tr>
</tbody>
</table>

**SAFETY** Work gloves should be worn at all times

*In addition to typical safety precautions and procedures*
Construction

CFRP Prestressed Piles

• FDOT Research
  • Lab Testing
  • Field Testing

• Production
  • Similar to Conventional Piles
  • Handling of CFRP

• Installation
  • Driving Method and Behavior similar to Conventional Piles

• Performance
  • Strength and Capacity similar to Conventional Piles
Monitoring

• 3rd Party Monitoring
  • HCB Beams
  • CFRP & GFRP Reinforcement

• Monitoring Phases
  • Fabrication
  • Construction
  • Performance (6 months, 1 & 2 Years - Post Construction)

• Test Blocks
  • Sheet Pile Wall Cap and Gravity wall
  • 3 Composite Materials- GFRP, CFCC and Basalt
  • Green Concrete

• Load Test
Monitoring

Test Blocks

Materials
- CFRP
- GFRP
- Basalt
Lessons Learned

• To develop standard details and specifications
• Design for Phase Construction
• Rebar arrangement – no mechanical coupler
• Lead time, Sole source of CFCC (Tokyo Rope)
• HCB QA/QC plan
Summary

• Demonstration Project with Innovative Materials – First in Florida
  ✓ Superstructure: Hybrid Composite Beams; GFRP Bars: Deck, Barriers & Approach Slabs
  ✓ Substructure: CFRP Pre-stressed Piles; Bent Caps: GFRP Bars
  ✓ Sheet Pile Walls: CFRP/GFRP Sheet Piles; Wall Cap: GFRP Bars

• Contractor Bid Cost - $6.016 Million (Structures = $4.06 Million)
  • Bridge Cost = $218 / sq. ft.
    (Conventional Construction = $166 / sq. ft.)

• Accelerated Construction
  • Lighter Materials – Beams and Rebar
  • Faster Transportation and Delivery – reduced construction time
QUESTIONS