Infravation
An Infrastructure Innovation Programme

2017 FES/FICE 101st ANNUAL CONFERENCE

The Halls River Bridge - perspective of owner/designer, contractor and researcher

(August 4, 2017)

Elisha Masséus, P.E. (FDOT D6 Structures Design Office)

Gianbattista Mazzocchi (Astaldi Construction Corporation)

Michelle Roddenberry, Ph.D., P.E. (FAMU-FSU College of Engineering)

Antonio Nanni (University of Miami)

Outline

Part I - HRB: Corrosion Free Design with FRP Composites

Part II - Constructing HRB

Part III - Production of Prefabricated Elements for HRB

Part IV - HRB as a Demonstrator of an International Project

This is a four-speaker presentation offering different perspectives. The Halls River bridge replacement project started on January 9, 2017 with completion expected by the end of the year. Even though not an iconic structure in terms of aesthetic and geometry, it is a landmark construction because of the material systems and technology adopted for the first time by FDOT. As for many of the Florida bridges, both superstructure and substructure are classified as extremely aggressive due to Halls River's chloride concentrations and the close proximity of the superstructure to the water. The use of non-corrosive fiber reinforced polymer (FRP) bars, stirrups and strands as the concrete reinforcement and prestressing tendons is an efficient method to address the long-term durability. FRP reinforcement are used in cast-in-place concrete bulkhead caps, pile caps, wing-walls, back-walls, deck, traffic barriers, and approach slabs. FRP strands are used in piles and sheet piles.

Infravation
An Infrastructure Innovation Programme

The Halls River Bridge – perspective of owner/designer, contractor and researcher

Part I – HRB: Corrosion Free Design with FRP Composites

August 4, 2017

Elisha Masséus, P.E.

FDOT D6 Structures Design Office

Outline

- Why FRP Reinforcement?
- Project Overview
- Composite Materials
- References, Codes and Specifications

Why FRP Reinforcement?

Infravation
An Infrastructure Innovation Programme

Avoid corrosion "concrete cancer"


Gandy Blvd. seawall, (Tampa Bay)


New and Old Seven-Mile-Bridge, (Florida Keys)

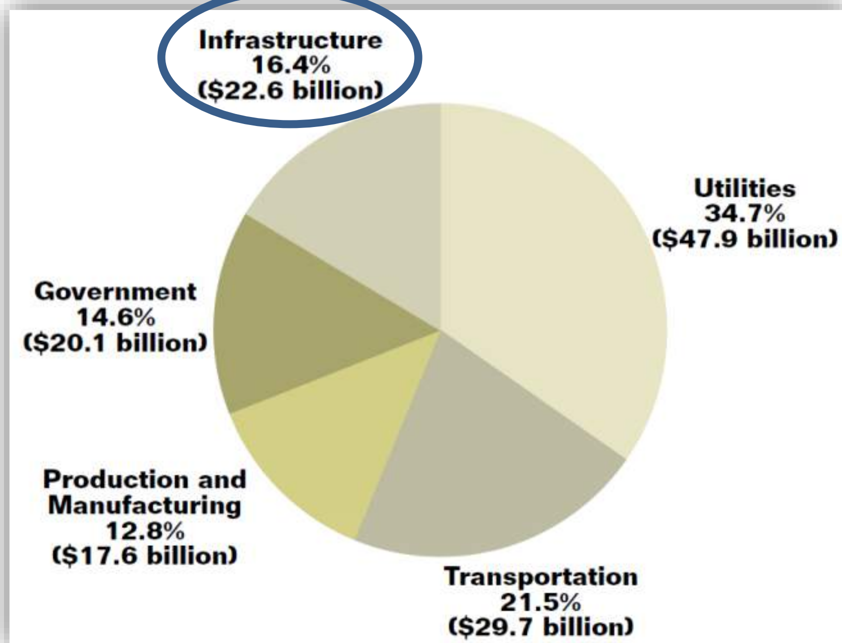

Courtney Campbell Causeway, seawall (Tampa Bay)

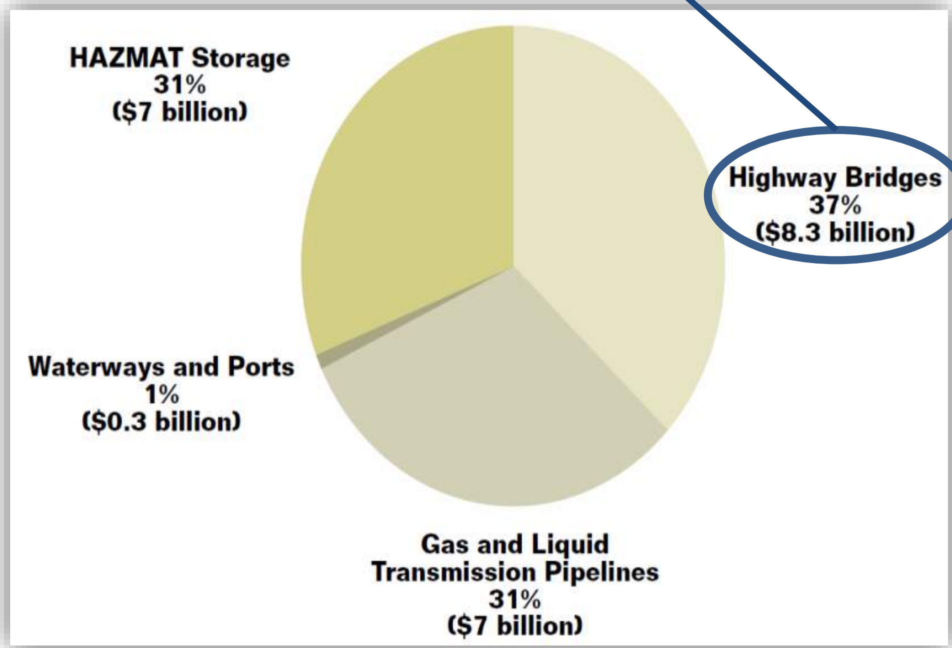
Why FRP Reinforcement?

Costs of Corrosion (United States)

Infrastructure - 16.4% ($22.6 billion)

Hwy Bridges - 37% ($8.3 billion)



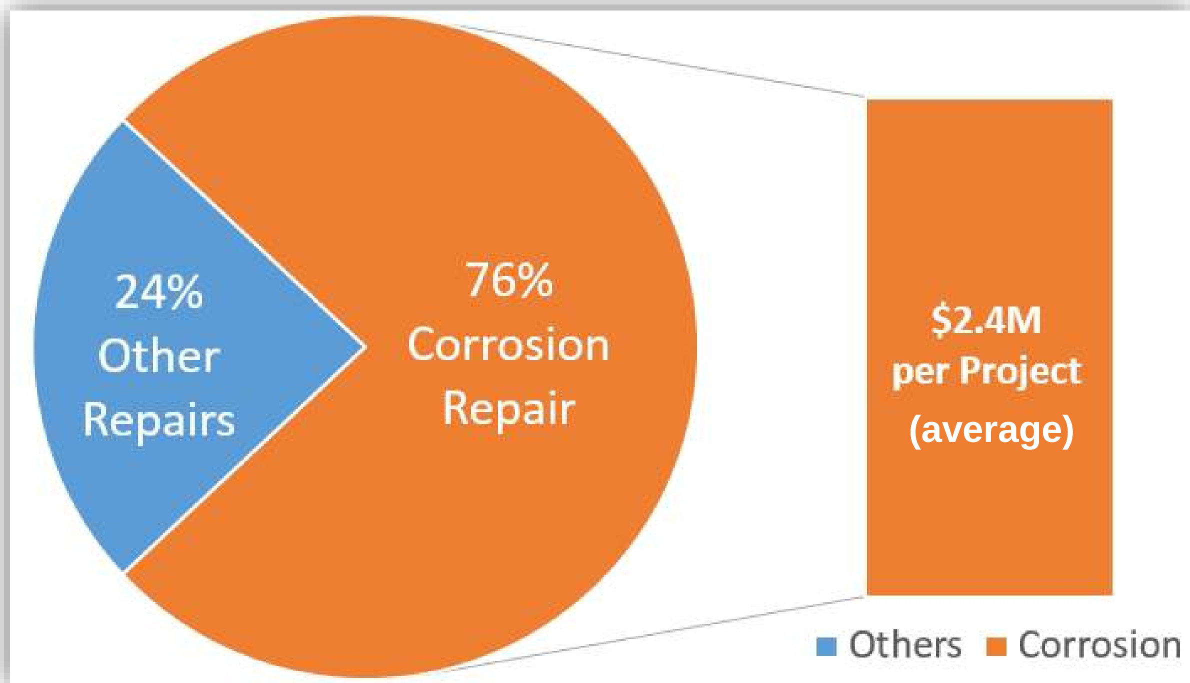


https://www.nace.org/uploadedFiles/Publications/ccsupp.pdf

Why FRP Reinforcement?

Costs of Corrosion - FDOT District 7

- FY 02/03 to 12/13
- 54 bridge projects studied (20 steel, 34 concrete)



Source: FDOT D7 District Structures Maintenance Office & T.Y. Lin

Project Overview

Infravation
An Infrastructure Innovation Programme

Two **alternatives to carbon steel** as concrete reinforcement for **corrosion resistance** on FDOT projects are:

Stainless Steel
- Bar (Spec. 931)
- Strand – HSSS (Spec. 933)

FRP Reinforcement
- Bar – GFRP (Spec. 932)
  CFRP (Spec. 932)
- Strand – CFRP (Spec. 933)

Extremely aggressive superstructure and substructure

Halls River Bridge Project

Project Overview

Infravation
An Infrastructure Innovation Programme

Demonstration Project with Innovative Materials – First in Florida

- ✓ Superstructure: Hybrid Composite Beams; GFRP Bars: Deck, Wingwall, Backwall, Barriers & Approach Slabs
- ✓ Substructure: CFCC Prestressed Piles; Bent Caps: GFRP Bars
- ✓ Sheet Pile Walls: CFCC/GFRP Sheet Piles; Wall Cap: GFRP Bars

Accelerated Construction

- Lighter Materials – Beams and Rebar
- Faster Transportation and Delivery
- reduced construction time

Estimated Project Cost - $6.1 Million **(Structures = $4.06 Million)**

- Bridge Cost = **$218 / sq. ft.**

  (Conventional Construction = **$166 / sq. ft.**)

Project Overview

Infravation
An Infrastructure Innovation Programme

Owner and Maintaining Agency

Design and Bi-Annual Inspection

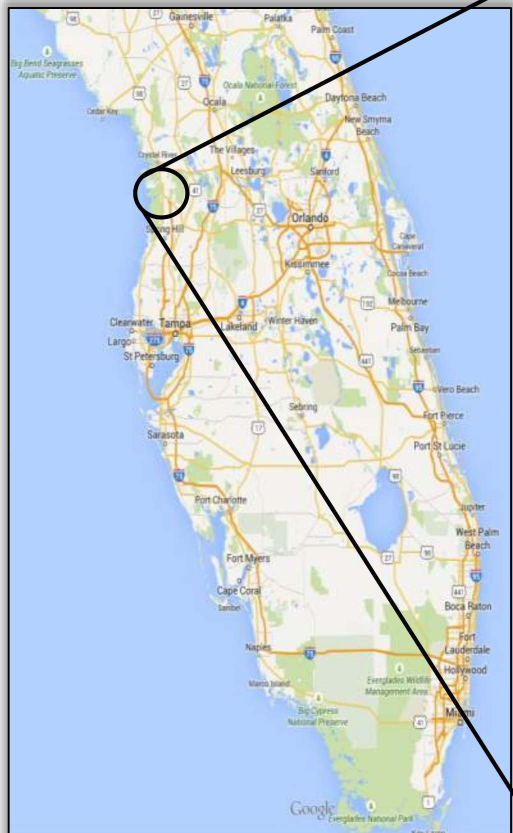
Funding and Oversight

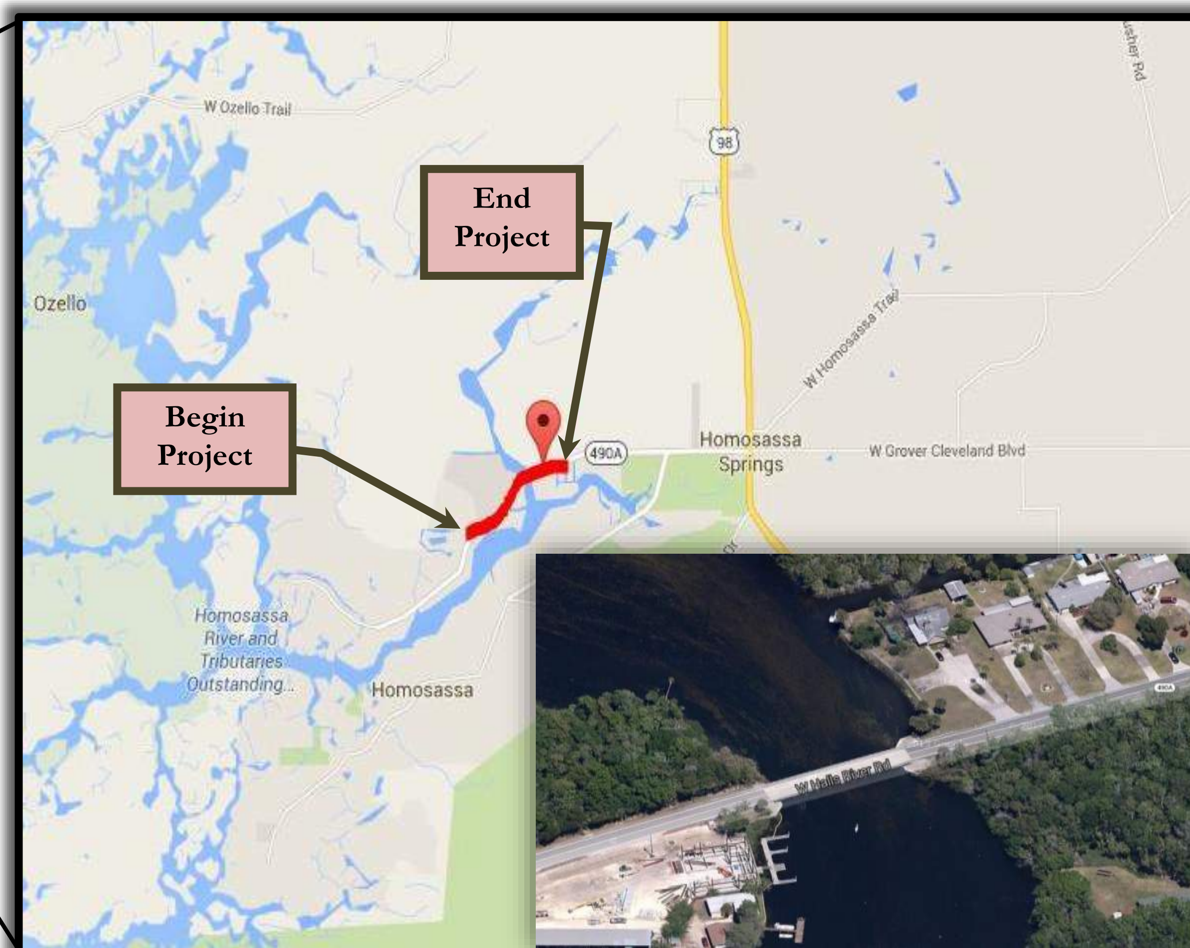
Collaboration and Research

Project Overview

Infravation
An Infrastructure Innovation Programme

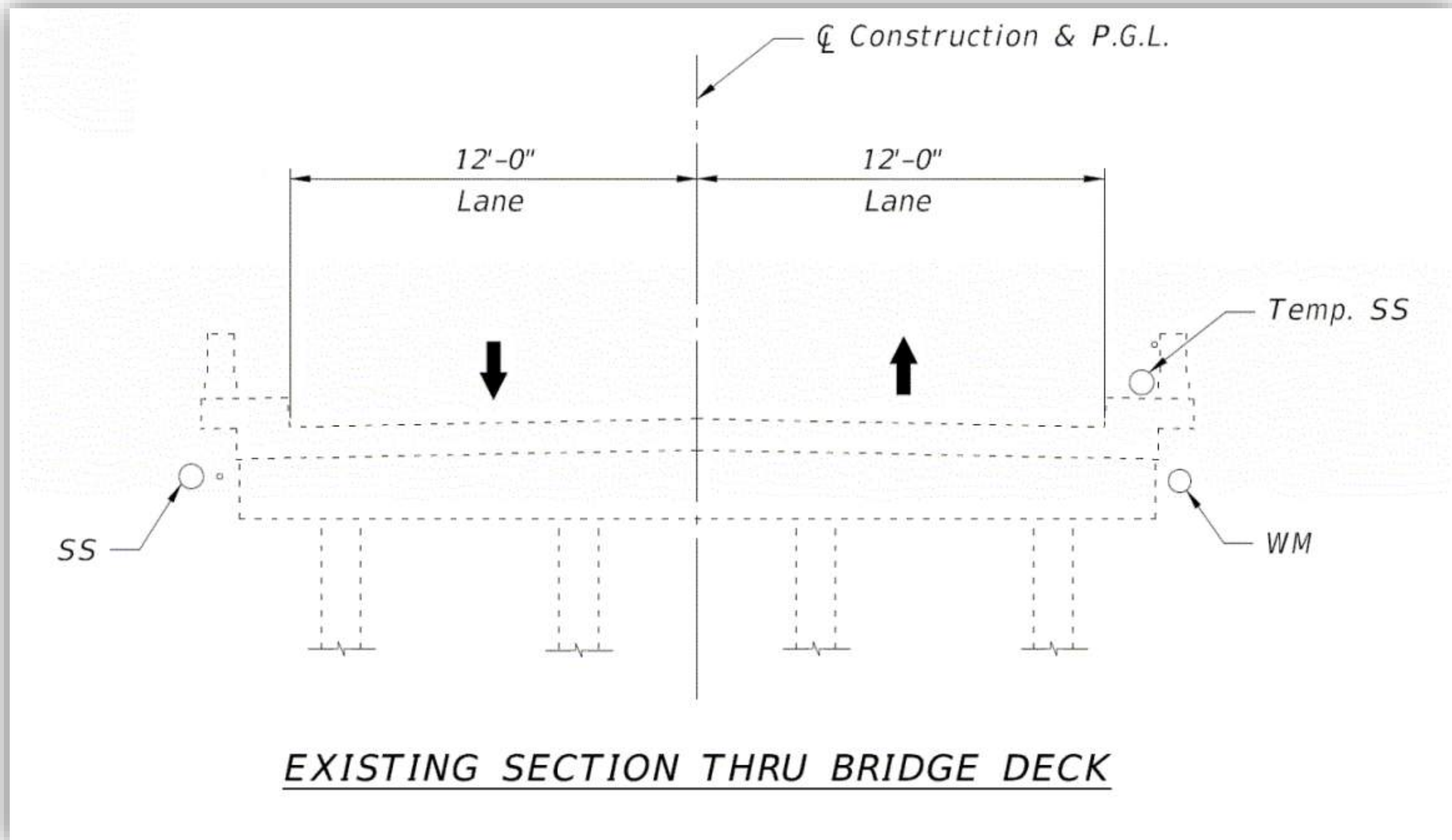
Location





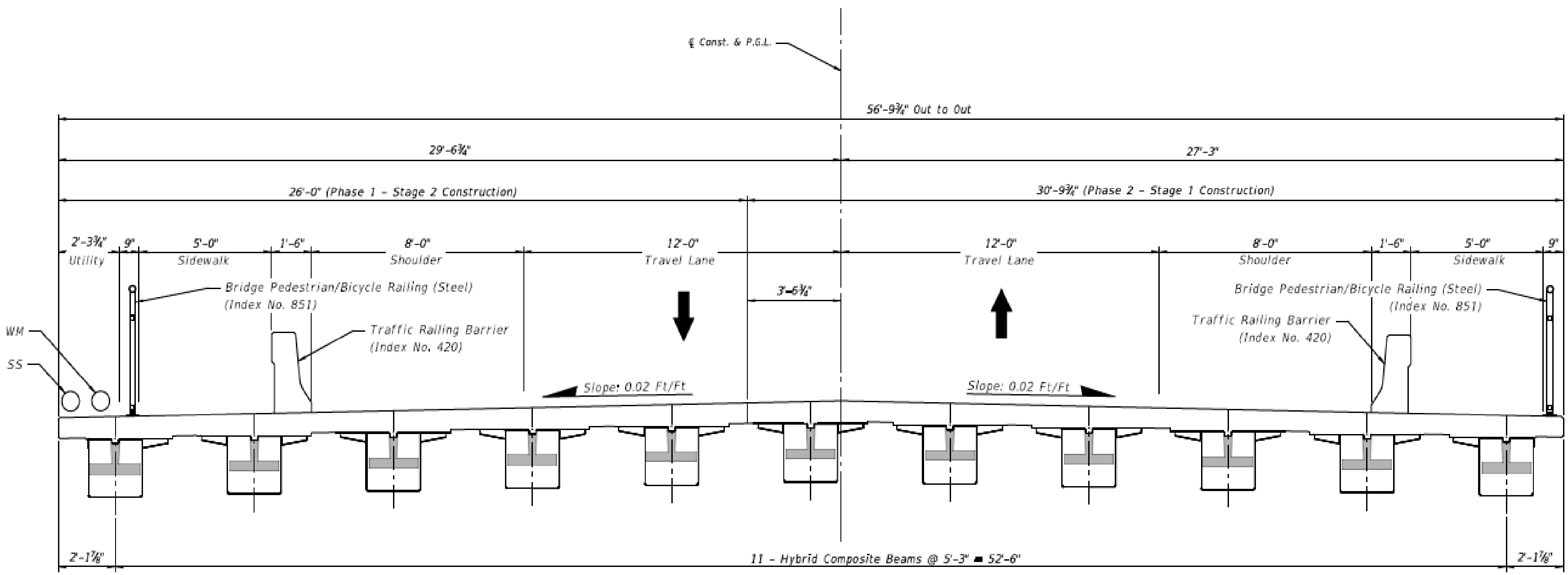
Project Overview

Existing Cross Section



Project Overview

Proposed Cross Section



TYPICAL SECTION THRU BRIDGE DECK

Infravation
An Infrastructure Innovation Programme

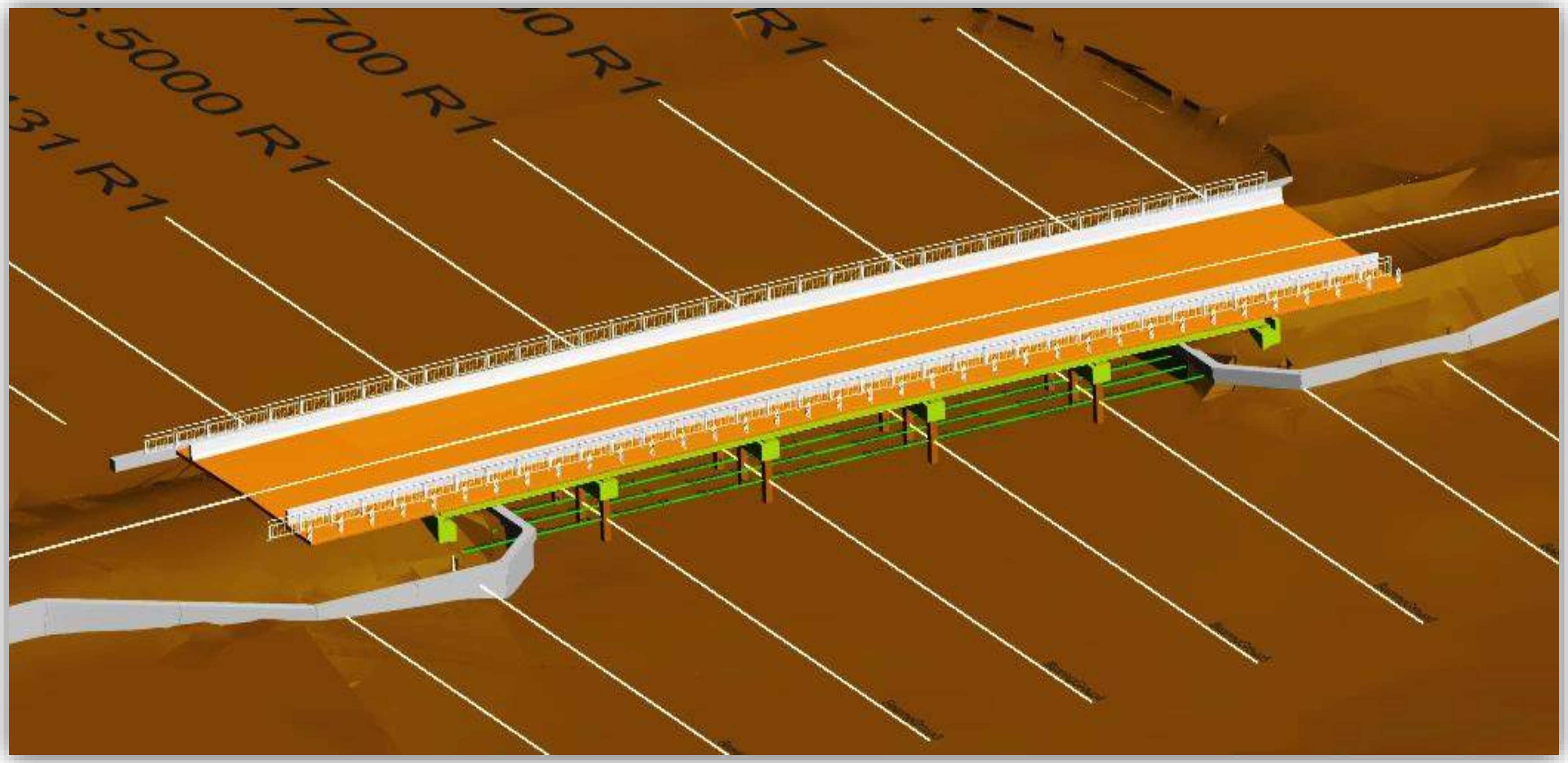
Project Overview

Existing Bridge

Project Overview

Infravation
An Infrastructure Innovation Programme

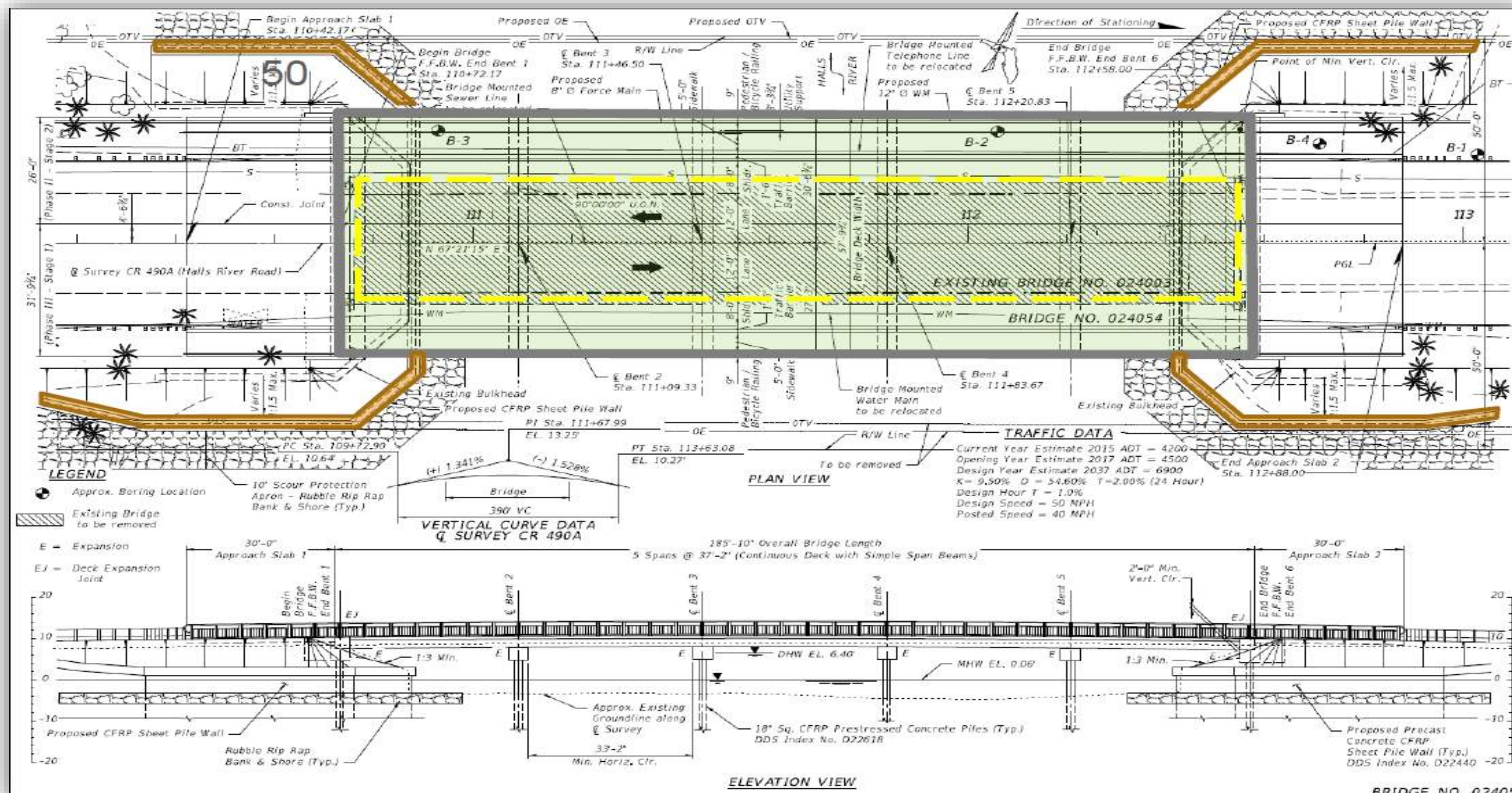
Proposed Bridge



Project Overview

Infravation
An Infrastructure Innovation Programme

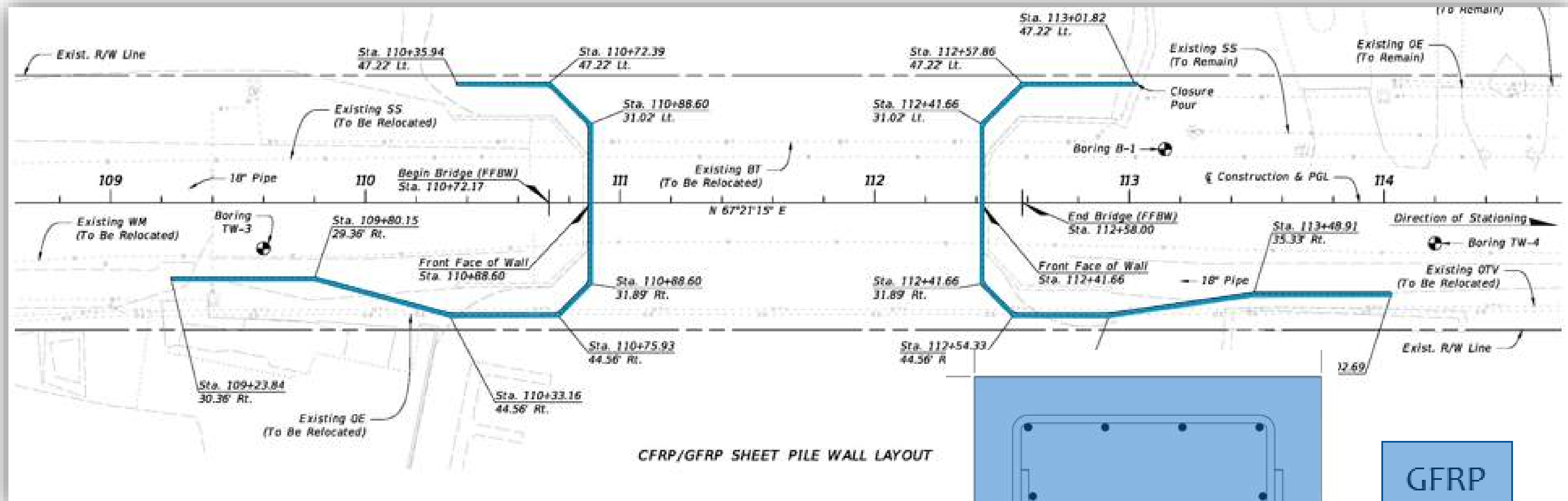
Proposed Bridge Plan and Elevation View

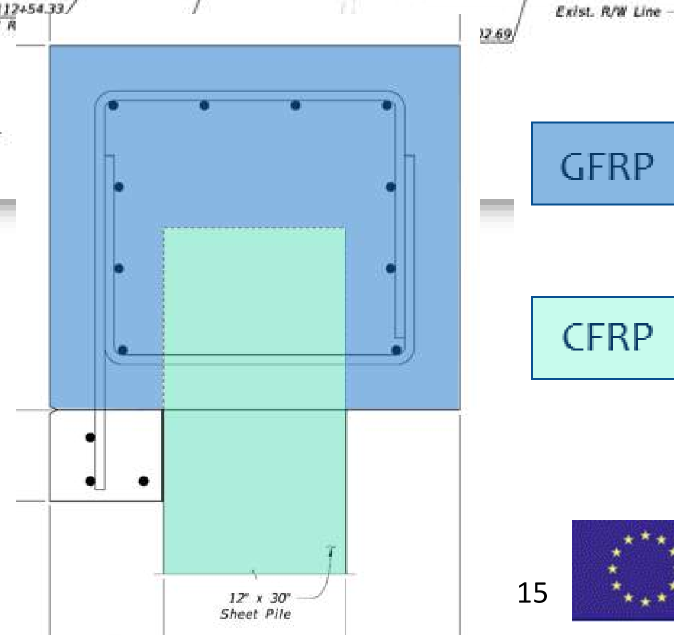


Infravation
An Infrastructure Innovation Programme

Project Overview

Proposed CFRP/GFRP Sheet Pile Walls

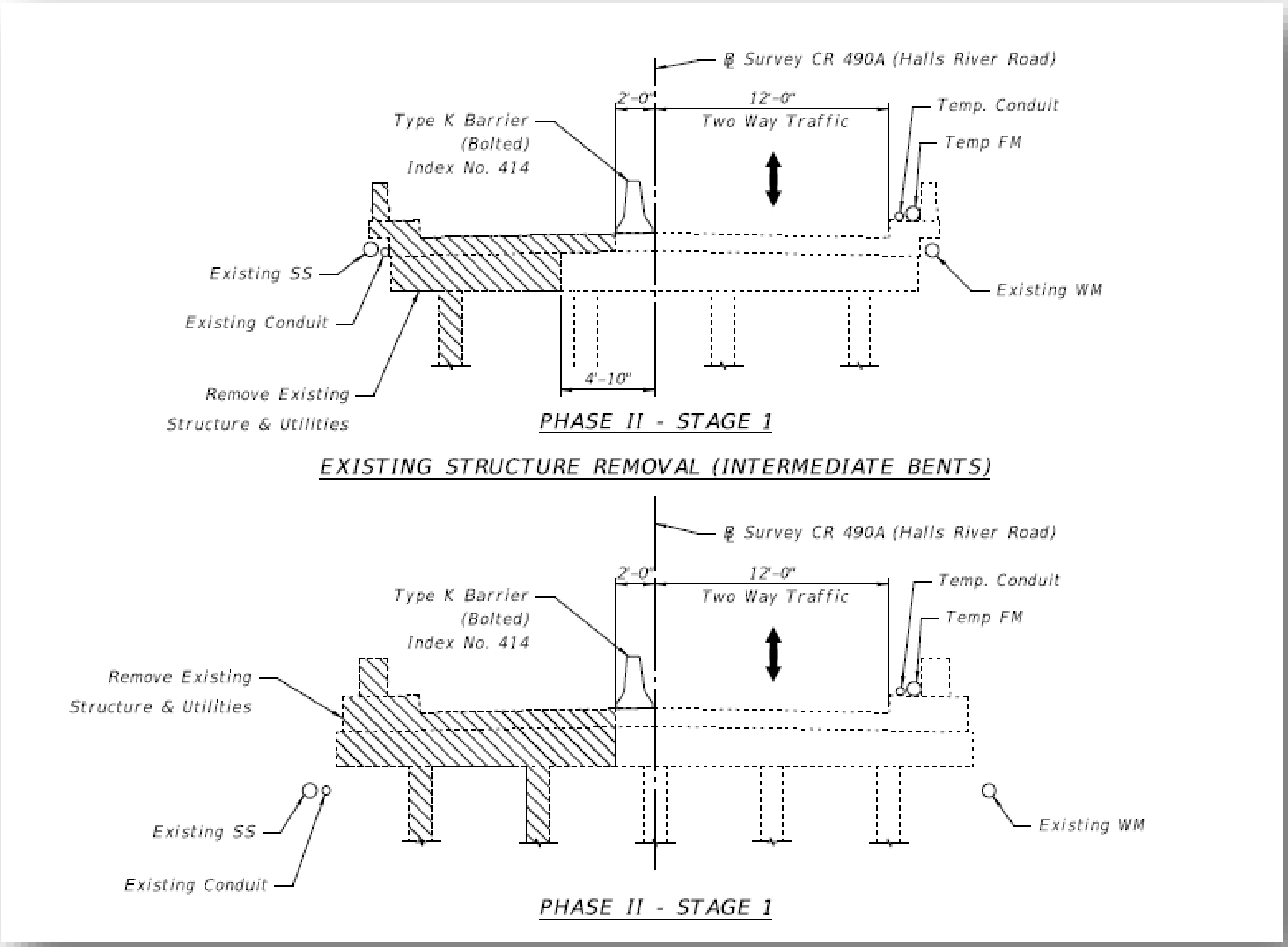




Project Overview

Infravation
An Infrastructure Innovation Programme

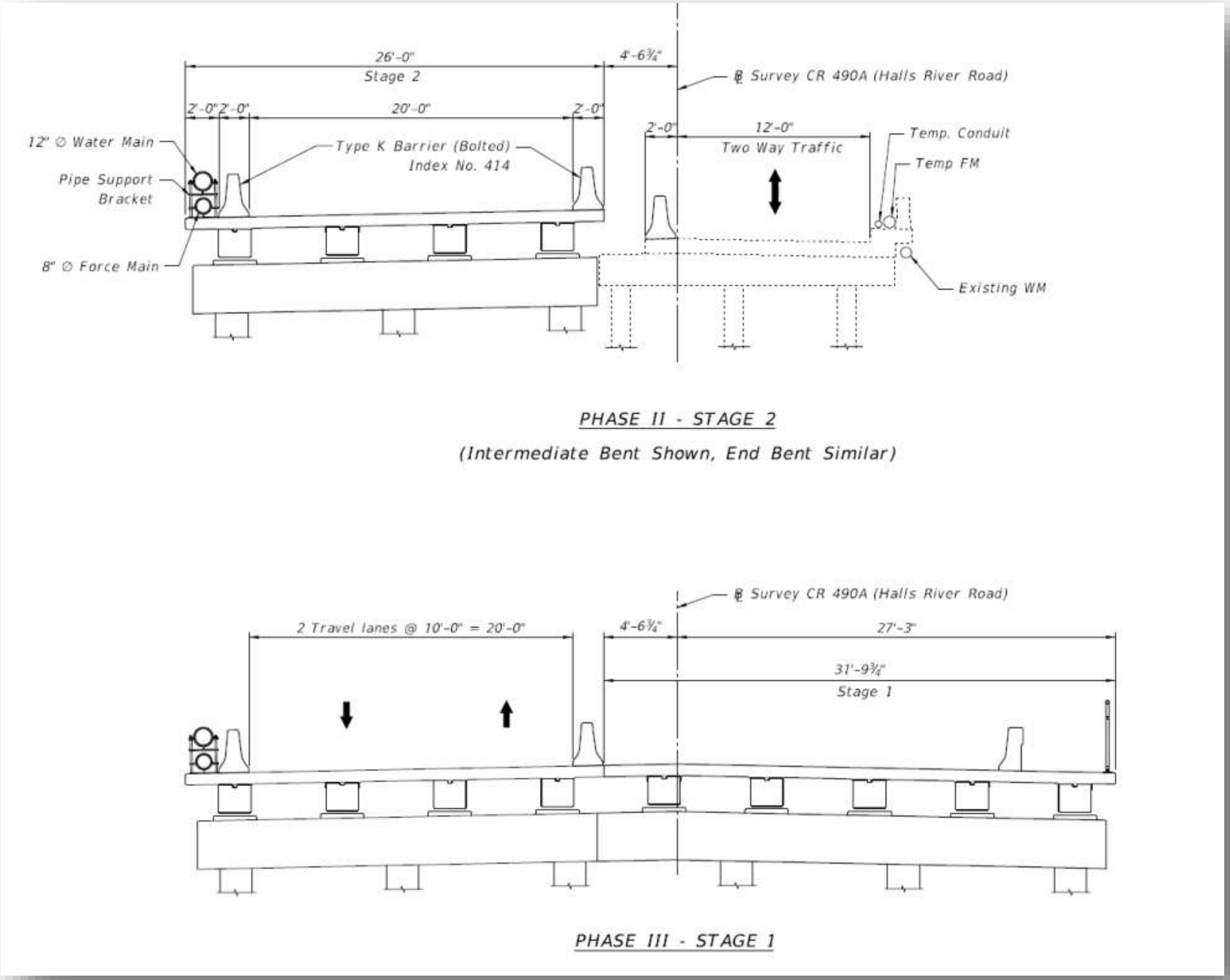
Construction



Project Overview

Infravation
An Infrastructure Innovation Programme

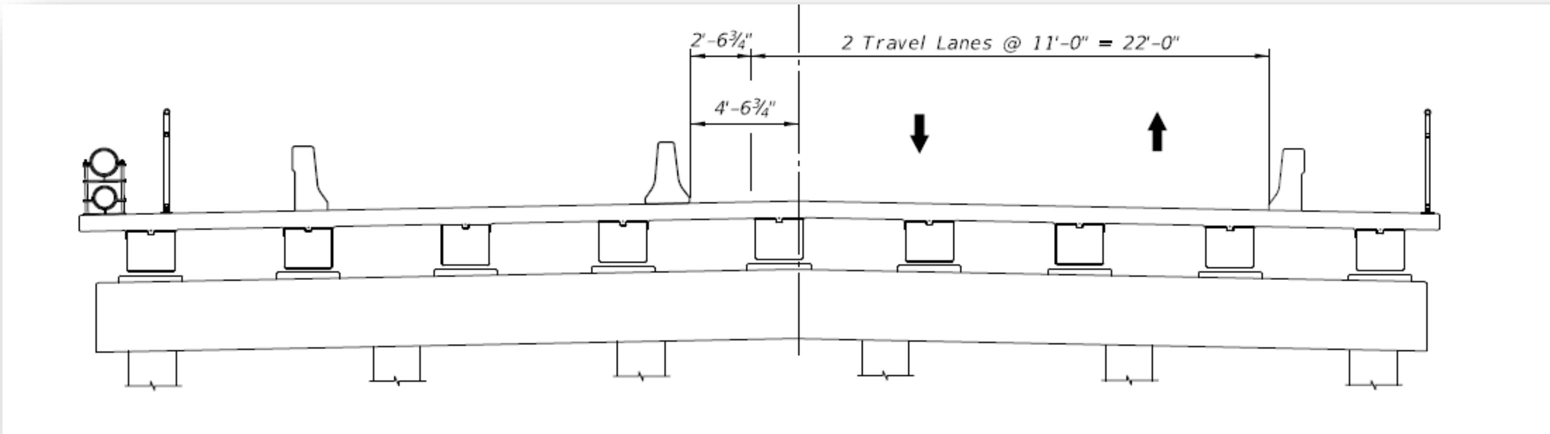
Construction

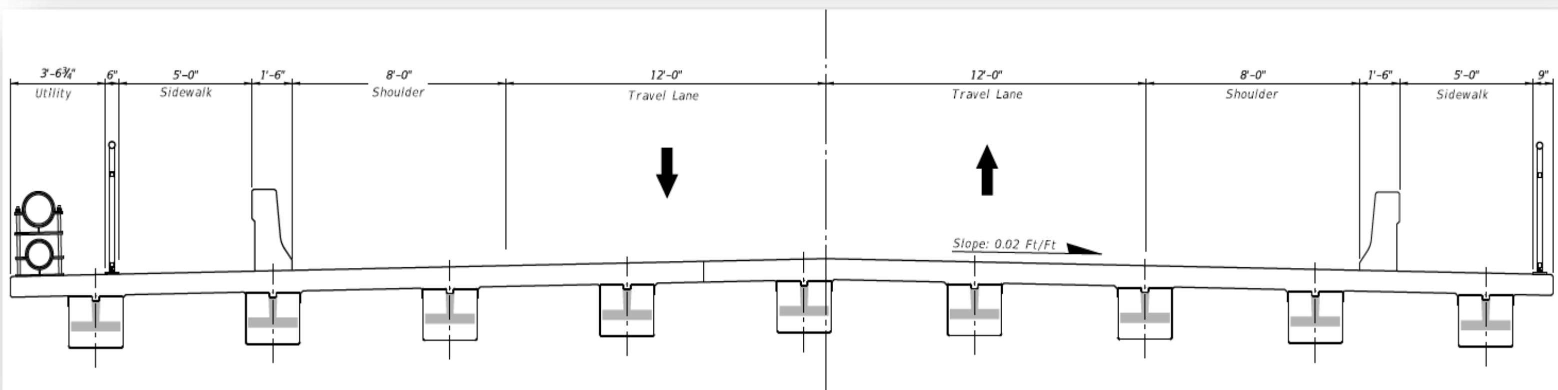


Project Overview

Infravation
An Infrastructure Innovation Programme

Construction





Composite Materials

Glass Fiber Reinforced (GFRP) Bars

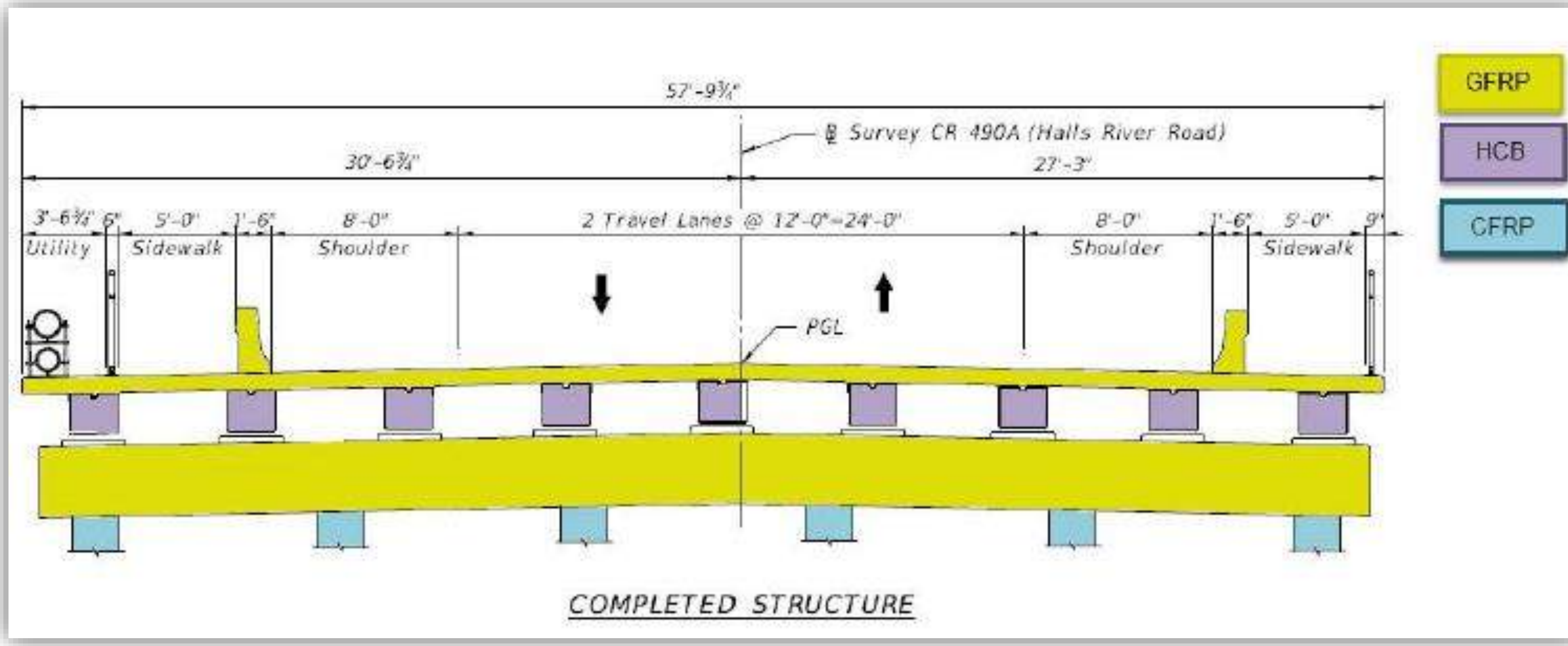
Carbon Fiber Composite Cables (CFCC)

Hybrid Composite Beams (HCB)

Composite Materials

Infravation
An Infrastructure Innovation Programme

Halls River Bridge FRP Components



Composite Materials

Precast Prestressed Concrete Piles

- 18" Steel Reinforced : **$ 80 / ft**
- 18" CFCC Reinforced : **$ 122 / ft**

(bid cost was $150)

Precast Prestressed Sheet Piles

- 12"x30" Steel Reinforced : **$ 120 / ft**
- 12"x30" CFCC Reinforced : **$ 144 / ft**

(bid cost was $265)

Prestressed Slab Beams

$ 300 / ft

Hybrid Composite Beams

$ 428 / ft

(bid cost was $330)

Bridge Life-Cycle Cost

Infravation
An Infrastructure Innovation Programme

Composite Materials

Cost Comparison (Installed Price)

Bar Size	Nominal Diameter	Average Unit Costs of Three Bidders on the Halls River Bridge Project		FDOT Structures Manual for BDR Cost Estimating	
		GFRP Bar	CFRP Bar	Grade 60 Steel Bar	Stainless Steel
#4	0.500"	$1.18 / LF	$7.99 / LF	$0.60 / LF	$2.72 / LF
#5	0.625"	$1.37 / LF	$8.34 / LF	$0.94 / LF	$4.19 / LF
#6	0.750"	$1.55 / LF	-	$1.35 / LF	$5.98 / LF
#8	1.000"	$2.54 / LF	-	$2.40 / LF	$10.74 / LF

Note: There is not 1:1 substitution of FRP for steel bars.
Black steel bar based on $0.90 / lb for all bar sizes.
Stainless steel bar based on $4.00 / lb for all bar sizes.

Bridge Life-Cycle Cost

Composite Materials

Infravation
An Infrastructure Innovation Programme

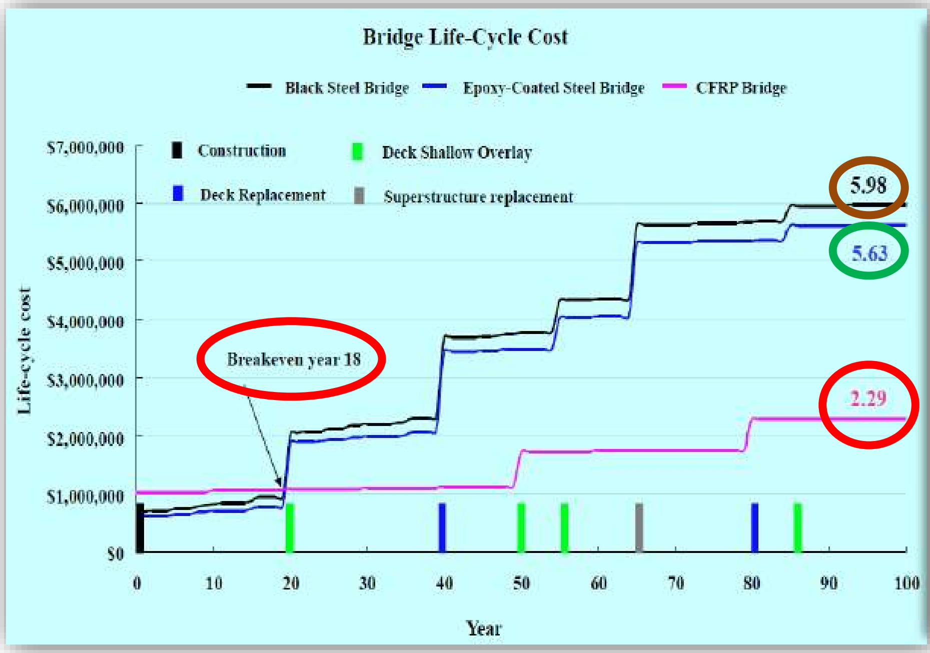
Example

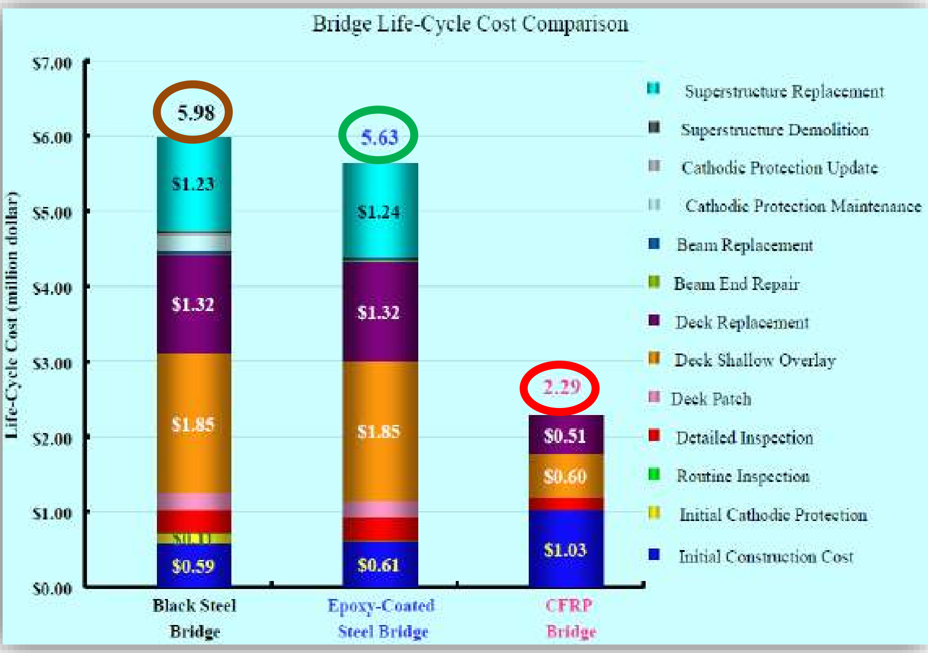
Bridge Life-Cycle Cost

CFRP: $2.29 Million — *Breakeven yr 18*

Epoxy-Coated: $5.63 Million

Black Steel: $5.98 Million





Source: Ohio Bridge Design Conference presentation, "New Generation of Sustainable CFRP Prestressed Concrete Highway Bridges" (Dr. Nabil Grace, 2014)

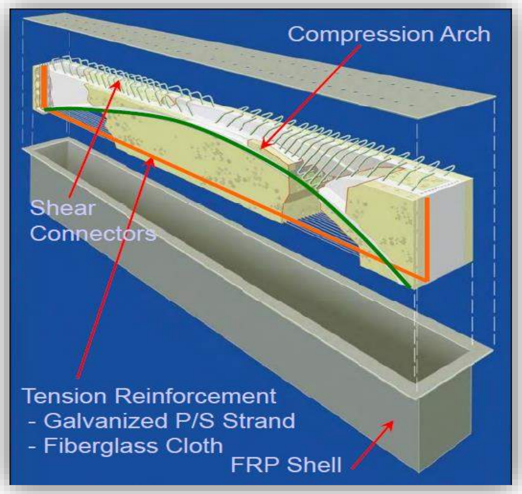
Composite Materials – HCB

HCB = Hybrid Composite Beam

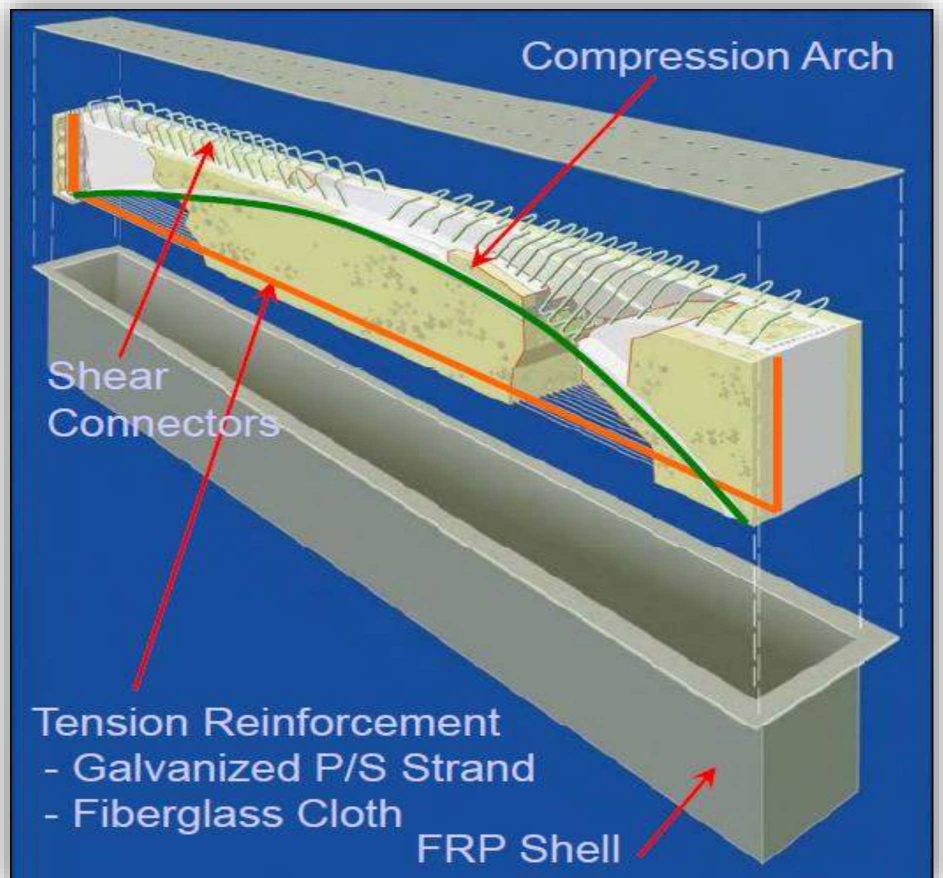
"Tied Arch in A Fiberglass Box"

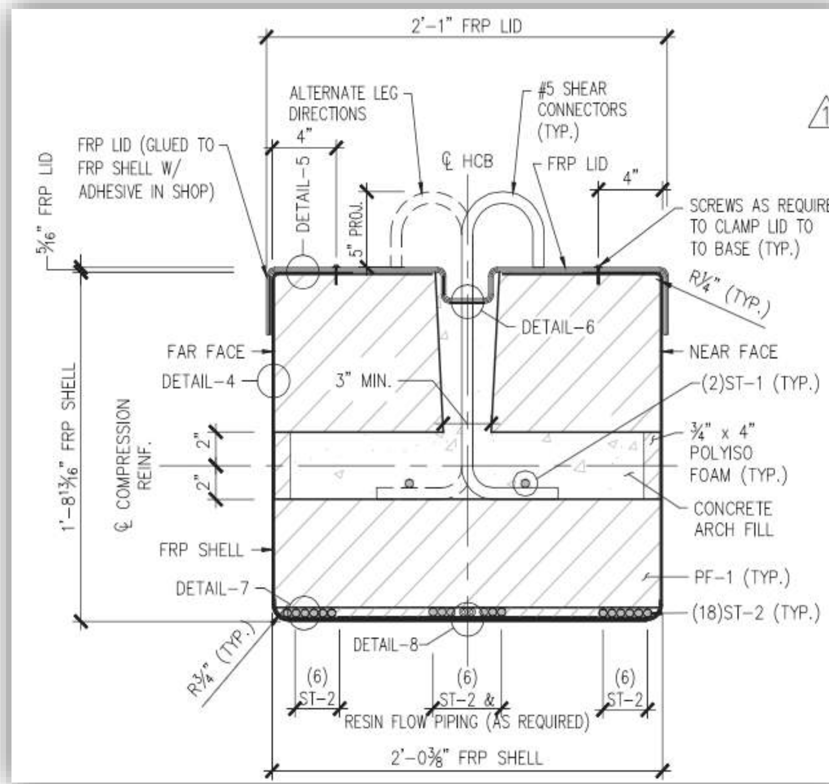
A structural member using several different building materials resulting in a cost effective composite beam designed to be stronger, lighter, and more corrosion resistant

- Compression Arch (SCC Concrete)
- Tension Reinforcement
- FRP Shell
  - Galvanized P/S Strand
  - Fiberglass Cloth
- Galvanized Shear Connectors



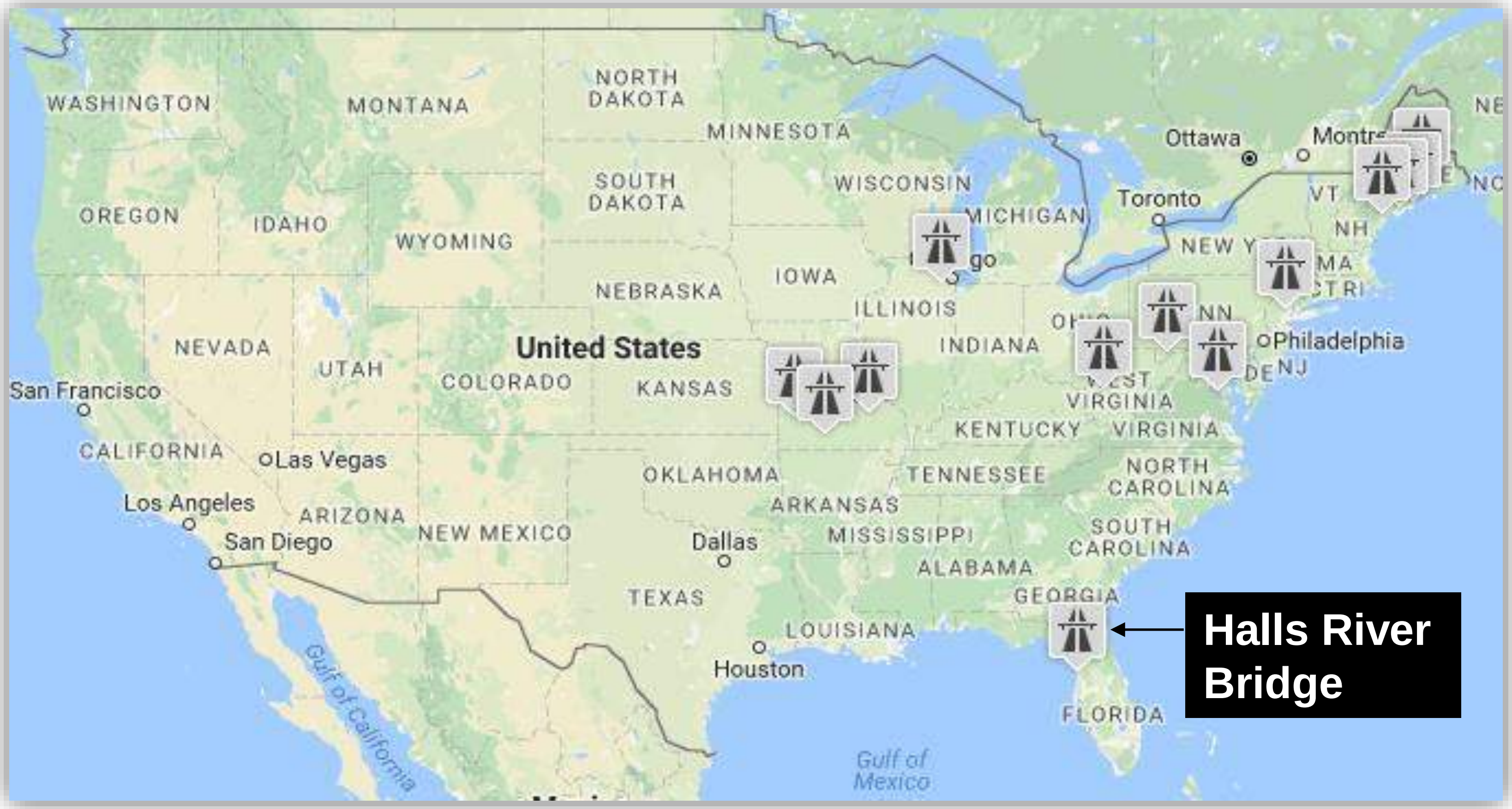
Composite Materials – HCB





Composite Materials – HCB

FRP Materials – HCB



Source: Hillman Composite Bridge , Inc.

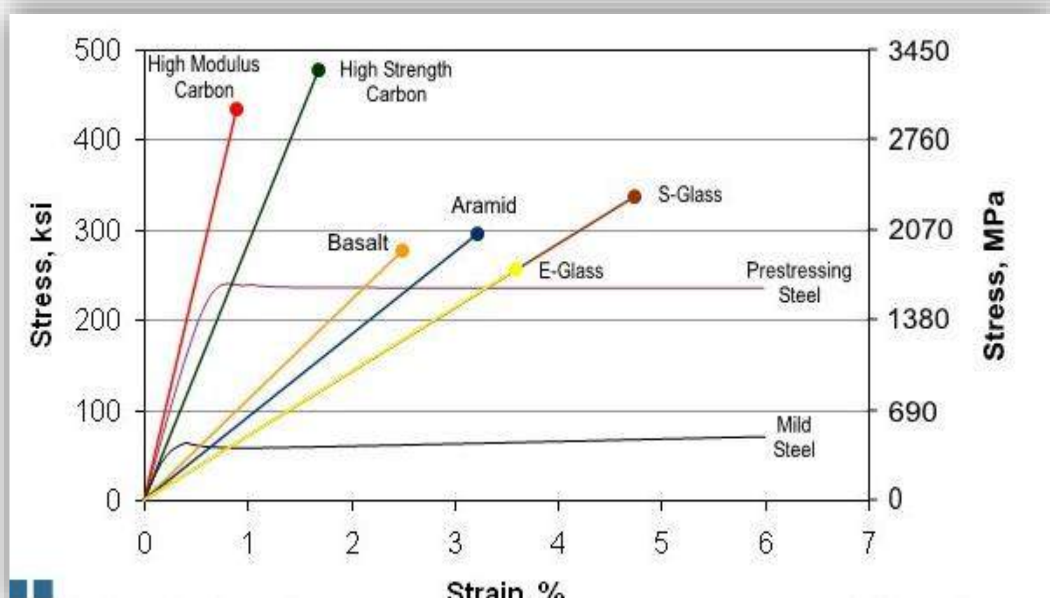
Infravation
An Infrastructure Innovation Programme

Composite Materials – FRP bars

Fiber Reinforced Polymer (FRP) Reinforcing

Pros:
- Corrosion Resistance
- High Strength
- Lightweight
- Fatigue Endurance

Cons:
- High Initial Cost
- Brittle Failure



http://www.build-on-prince.com/frp-reinforcement.html#sthash.w7HfVILh.dpbs

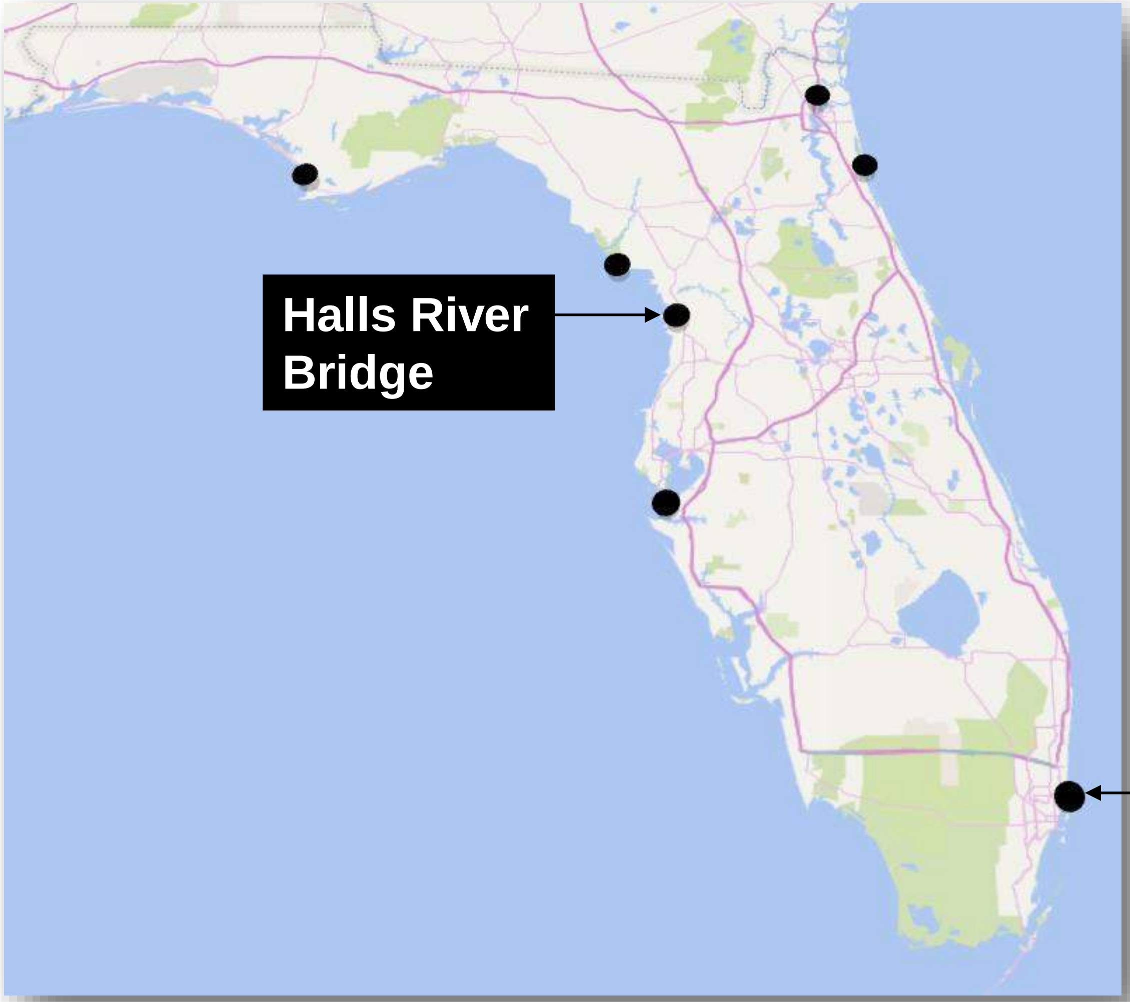
Bar type	Yield strength f_y or tensile strength f_{fu}, ksi (MPa)	Modulus of elasticity, ksi (GPa)
Steel	60 (414)	29,000 (200)
GFRP	80 (552)	6000 (41.4)
AFRP	170 (1172)	12,000 (82.7)
CFRP	300 (2070)	22,000 (152)

Composite Materials – FRP Decks

Source: University of Miami – College of Engineering

Composite Materials – GFRP Reinforcing

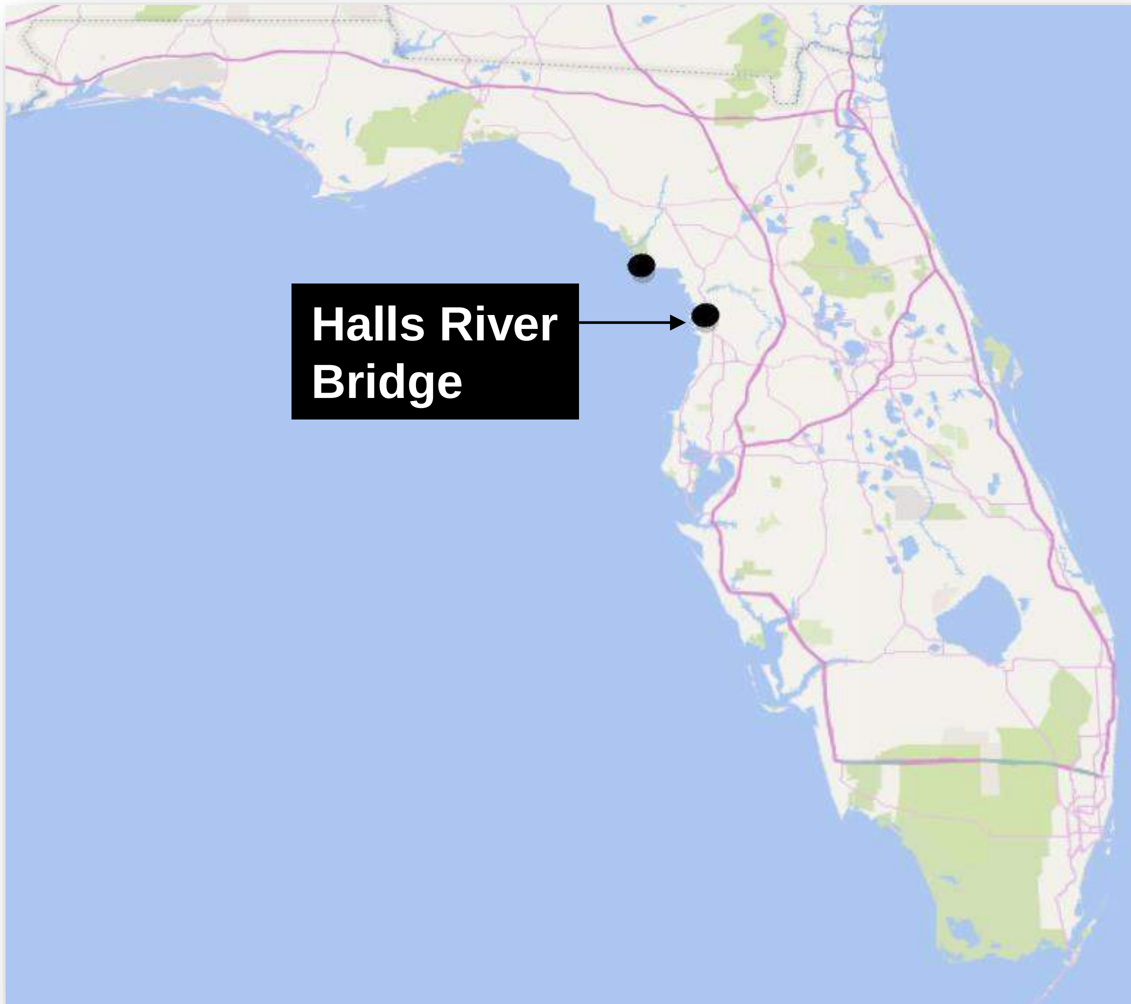
Infravation
An Infrastructure Innovation Programme



Source: FDOT Structures Design Office

Composite Materials – CFRP/GFRP Piles

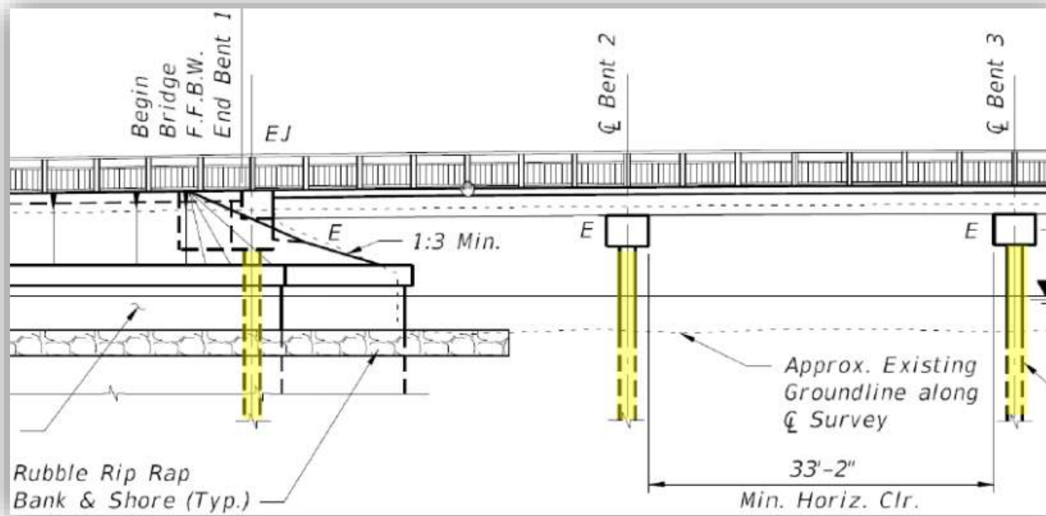
Infravation
An Infrastructure Innovation Programme

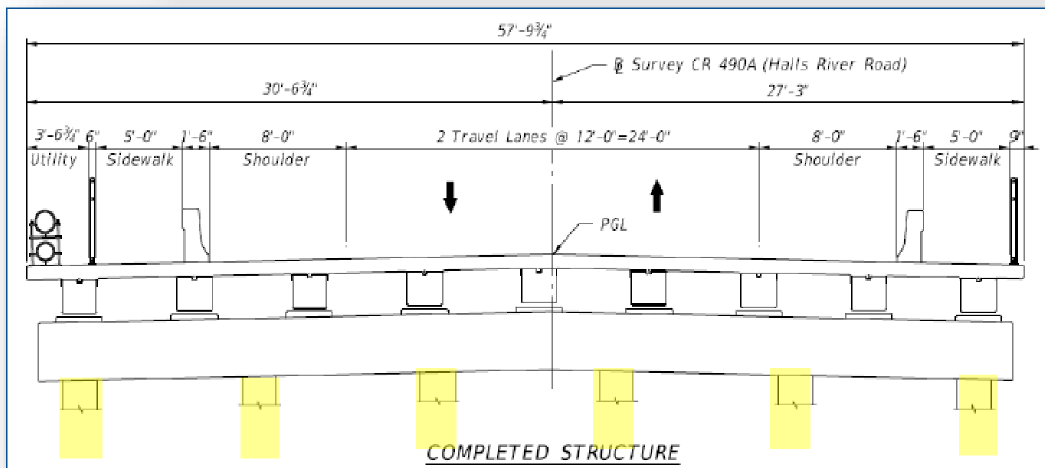


Source: FDOT Structures Design Office

Composite Materials – Bearing Piles

- 18”x18” Square Concrete Prestressed Piles;
- 6 Piles per End Bents;
- 6 Piles per Intermediate Bents;
- Total 36 piles, (test pile lengths 55’ to 70’)





Composite Materials – Bearing Piles

Infravation
An Infrastructure Innovation Programme

Structures Manual Vol. 4 – Fiber Reinforced Polymer Guidelines (FRPG).

- Overall commentary on FRP;
- Specific design criteria, plan content and Specification requirements;
- Design review requirements;
- Approval of use process;
- Permitted uses for each type of FRP.

Standardization

i. Square CFRP Prestressed Bearing Piles

ii. ***Developmental*** Index D22600 & D22618 (*now conventional* ***Design Standards***)

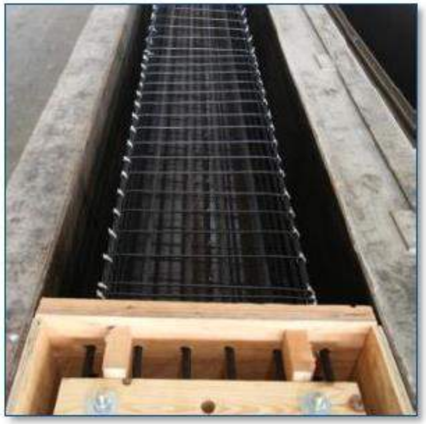
Development Basis

i. Research at FAMU/FSU

Design Criteria - ***ACI 440.4R***

FDOT Material Specifications – (**Dev**) **932** & **933**

Usage Criteria – **SDG** 3.5.1



(photograph) FDOT. *Wooden Headers For CFRP Strands.*

(photograph) FDOT. *CFRP Pile Casting with SCC.*

Composite Materials – Bearing Piles

Infravation
An Infrastructure Innovation Programme

Roddenberry M, Mtenga P, Joshi K, (2014). "Investigation of Carbon Fiber Composite Cables (CFCC) in Prestressed Concrete Piles", FAMU-FSU College of Engineering, for FDOT Project BDK83-977-17, April 2014.

http://www.dot.state.fl.us/structures/structuresresearchcenter/Final%20Reports/2014/FDOT-BDK83-977-17-rpt.pdf

Iyer, S. L., 1995, "Demonstration of Advanced CompositeCables for use as Prestressing in Concrete WaterfrontStructures," Final report submitted to U.S. Army Corps of Engineers, Construction Engineering Research Laboratory, Champaign, Ill., Nov.

Arockiasamy, M., and Amer, A., 1998, "Studies on CFRP Prestressed Concrete Bridge Columns and Piles in Marine Environment," Final Report Submitted to FDOT, Tallahassee, Fla., July.
http://www.fdot.gov/structures/structuresresearchcenter/Final%20Reports/1998/B-9076%20-%20Final%20Rpt.pdf

Schiebel, S., and Nanni, A., 2000, "Axial and Flexural Performance of Concrete Piles Prestressed with CFRP Tendons," *Proceedings of the Third International Conference on Advanced Composite Materials in Bridges and Structures (ACMBS3)*, Ottawa, Canada, Aug., pp. 471-478

Composite Materials - Sheet Piles

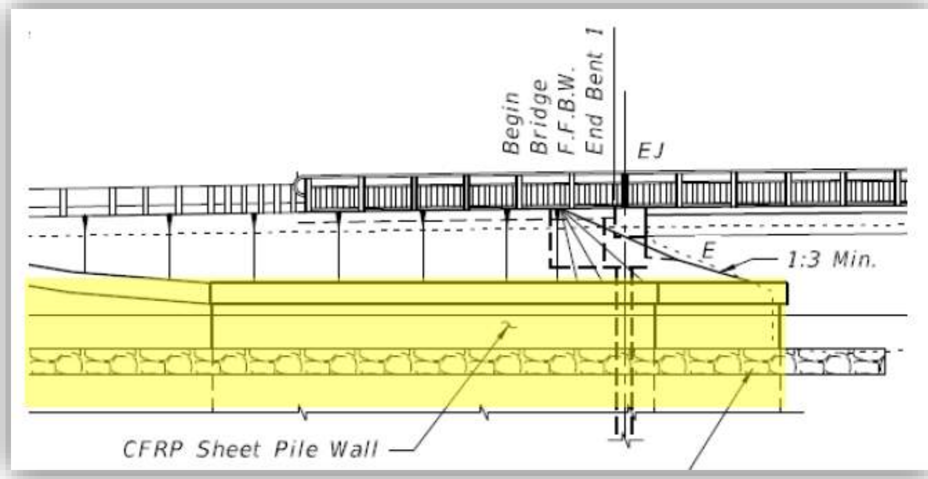
Infravation
An Infrastructure Innovation Programme

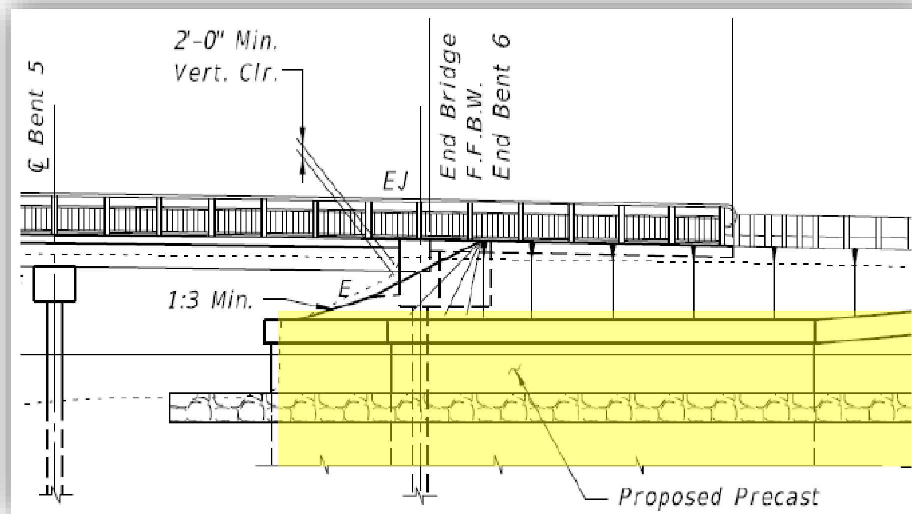
Sheet Piles:

- 12” x 30” Concrete Prestressed Sheet Section;
- 8 CFRP prestressing strands ;
- GFRP #4 stirrups and #5 supplemental reinforcing;
- Lengths vary 24’ to 29’;
- Total 235 piles (12 corner piles)

Caps:

- 24” x 27” Concrete Section;
- GFRP #5 stirrups and #5 longitudinal reinforcing;
- Total Length 575’
- Integral Test Blocks





Composite Materials – Sheet Piles

Design Criteria - ***ACI 440.1R*** & ***440.4R***

FDOT ***Material Specifications*** for strands and bars

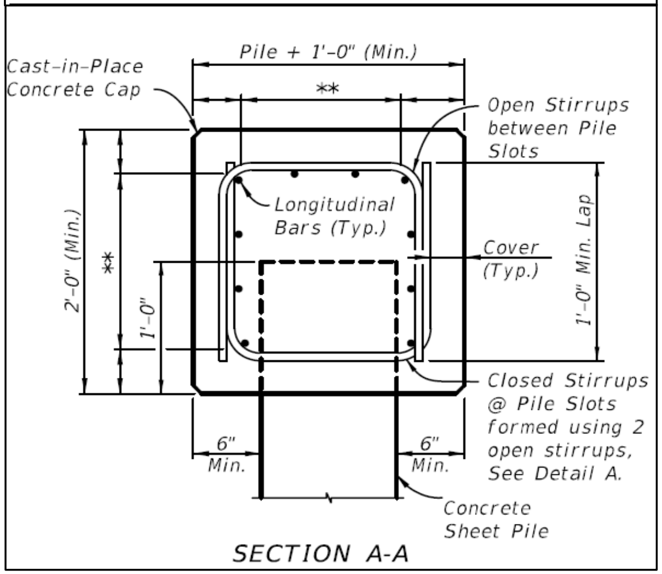
FRP Bars – ***Section 932 (Dev)***

FRP Strands - ***Section 933 (Dev)***

Standardization

i. CFRP/GFRP Prestressed Concrete Sheet Piles (***Index D22440***)
ii. GFRP-RC Bulkhead Cap (***FDOT Instructions – IDDS-22440,*** *see Figure 1 below*)
iii. GFRP-RC Guidelines (***Structures Manual*** –Vol. 4 ***Fiber-Reinforced Polymer Guidelines***)

Figure 1 Typical Cap Details



Composite Materials –Approach Slabs

Infravation
An Infrastructure Innovation Programme

General

i. 30ft length
ii. GFRP reinforcement

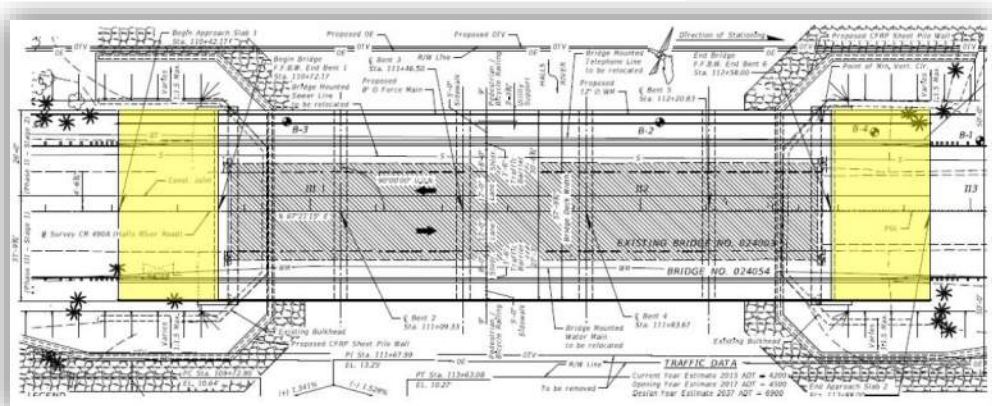
Structural System

i. ***Developmental Design Standard*** Index D22900

Design Criteria

i. ***ACI 440.1R / AASHTO Guide Spec.*** *(without service limit state checks) – For slab-on-grade neither may not be applicable.*
ii. Emulates FDOT standard Approach Slab (*Index 20900*)

FDOT Material Specifications – ***Section 932 (Dev)***



Composite Materials –Traffic Railings

General

- *i.* ***DDS*** Index D22420 - GFRP-RC 32” F-Shape
- ii. Supplemental plan details required for post-installed anchorage (north side).

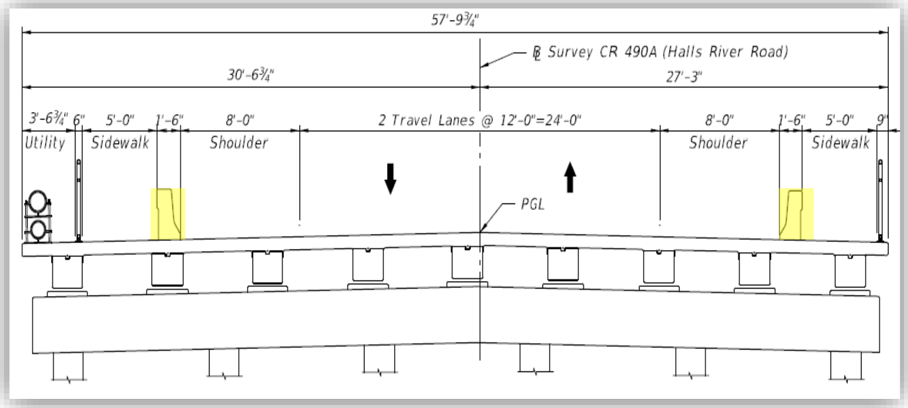
Similar crash tested designs

- i. Pultrall (V-Rod), Schoeck (ComBAR), & Temcorp (TemBar): MASH TL-5, 42" Safety-Shape
- ii. GFRP Adhesive Anchor Pullout Tests by Hilti/Canadian Researchers.

Design Criteria

- *i.* ***AASHTO Guide Spec.***
- ii. NCHRP Report 350 (but MASH pending)

FDOT Material Specifications - ***Dev932***



References, Codes and Specifications

Technical Special Provision

TECHNICAL SPECIAL PROVISION

FOR

SECTION T450 - FURNISHING & INSTALLING HYBRID-COMPOSITE BEAMS

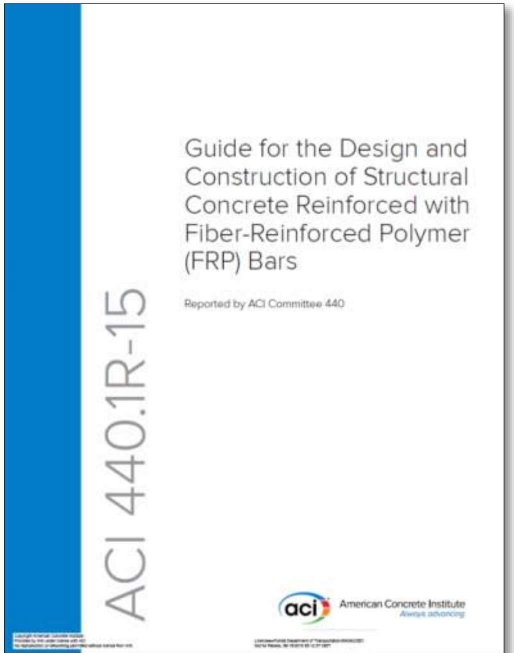
FINANCIAL PROJECT ID: 430021-1-52-01

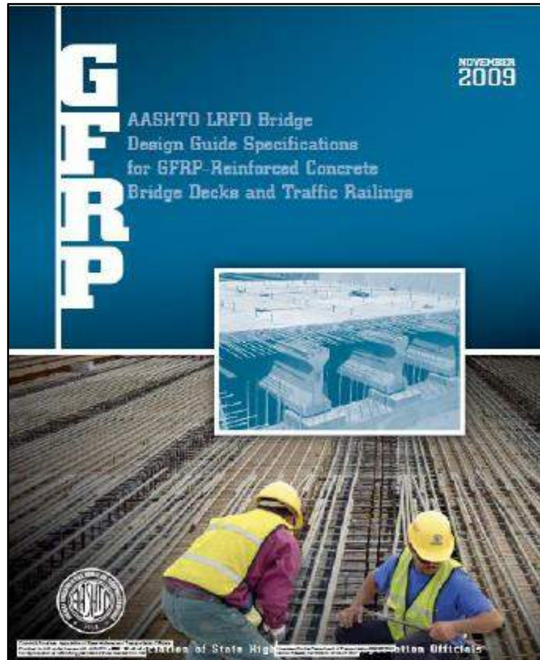
Design & Maintenance Manual

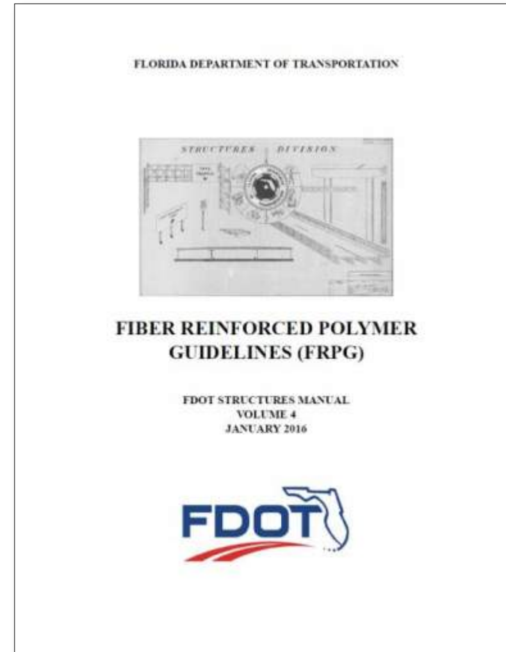
Hybrid-Composite Beam (HCB®)
Design and Maintenance Manual

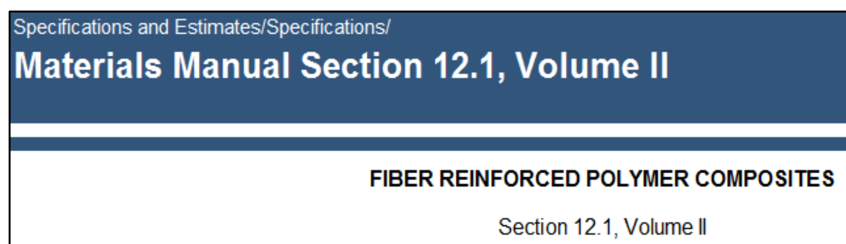
Field Installation Manual

References, Codes and Specifications








Specifications and Estimates/Specifications/

Materials Manual Section 12.1, Volume II

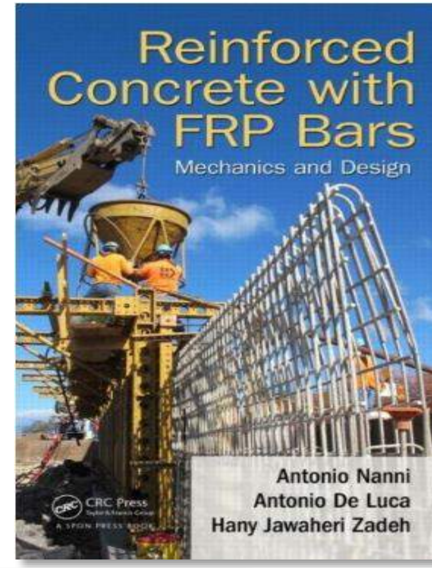
FIBER REINFORCED POLYMER COMPOSITES

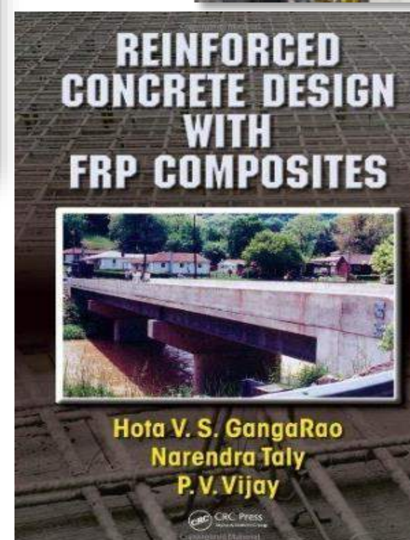
Section 12.1, Volume II

References, Codes and Specifications

FDOT Developmental Standards:

- Pultruded FRP Bar Bending Details (**Index *D21310***)
- 18” CFRP Prestressed Piles (***Index D22618***)
- CFRP Prestressed Piles Splices (***Index D22601***)
- CFRP/GFRP Sheet Piles Walls (***Index D22440***)
- Traffic Railing - GFRP Reinforced (***Index D22420***)
- Approach Slab – GFRP Reinforced (***Index D22900***)





Infravation
An Infrastructure Innovation Programme

References, Codes and Specifications

FDOT research and field implementation of FRP materials is ongoing and design recommendations continue to evolve.

Completion Date	Title	Researcher	Institution	Research No.
5/31/2018	Performance Evaluation of GFRP Reinforcing Bars Embedded in Concrete Under Aggressive Environments	R. Kampmann	FSU	BDV30 977-18
3/31/2018	Degradation Mechanisms and Service Life Estimation of FRP Concrete Reinforcements	A. El Safty	UNF	BDV34 977-05
4/16/2014	Investigation of Carbon Fiber Composite Cables (CFCC) in Prestressed Concrete Piles	M. Roddenberry, P. Mtenga	FSU	BDK83 977-17
11/30/1998	Studies on Carbon FRP (CFRP) Prestressed Concrete Bridge Columns and Piles in Marine Environment	M. Arockiasamy	FAU	B-9076
8/1/1995	Durability of CRFP Pretensioned Piles in Marine Environment Volume II	R. Sen	USF	0510642

http://www.fdot.gov/research

References, Codes and Specifications

Unless otherwise stated within the FRPG, the **use of FRP composites requires approval** of the State Structures Design Office.

Obtain concept approval before proceeding with any design effort.

After concept is approved, submit the design to the State Structures Design Office for review.

PPM 26.3.2: Structures with any component designed using FRP composite materials is a Category 2 Structure.

With prior approval by State Structures Design Engineer

Without prior approval by State Structures Design Engineer

- **GFRP/CFRP** reinforcing bars used for **expansion joints in junction slabs** when paired with a keyed joint
- **CFRP/GFRP Prestressed Concrete Bearing Pile**
  Design Standards (22600 Series)
- **CFRP/GFRP Prestressed Concrete Sheet Pile Wall**
  Design Standard 22440

Infravation
An Infrastructure Innovation Programme

References, Codes and Specifications

Structures Design

Structures Design / Design Innovation

Fiber Reinforced Polymer Reinforcing

Structures Design - Transportation Innovation

Fiber Reinforced Polymer (FRP) Reinforcing Bars and Strands

Overview
Usage Restrictions / Parameters
Design Criteria
Specifications
Standards
Producer Quality Control Program
Technology Transfer (T^2)
Contact

Contact Information

Charles E. Boyd, P.E.
Assistant State Structures Design Engineer
Phone: (850) 414-4275
e-mail: Charles.Boyd@dot.state.fl.us

Rick Vallier, P.E.
Structures Design Engineer
Phone: (850) 414-4290
e-mail: Rick.Vallier@dot.state.fl.us

http://www.fdot.gov/structures/innovation/FRP.shtm

Summary

- New vehicular bridge using FRP materials (1st in FL)
- Category 2 Structure
- Design:
  - FDOT D7 Structures Design Office (Bridge)
  - American Consulting (Bulkhead/Seawall)
  - FDOT SDO Design Standards Group (Developmental Standards)
- FHWA oversight and funding
- Long-term monitoring by FDOT, FAMU-FSU, and UM/SEACON

QUESTIONS?

Bridge EOR: Mamunur Siddiqui, P.E. (FDOT D7 SDO)

Bulkhead/Seawall EOR: Richard Hunter, P.E. (ACE)

FDOT Developmental Standards: Steven Nolan, P.E. (FDOT SDO)

FDOT Contact Information:

Mamunur Siddiqui, P.E. (EOR)
FDOT D7 Structures Office
813.975.6093
Mamunur.Siddiqui@dot.state.fl.us

Steven Nolan, P.E. (Standards Coordinator)
FDOT Structures Design Office
850.414.4272
Steven.Nolan@dot.state.fl.us

Rick Vallier, P.E. (FRP Coordinator)
FDOT Structures Design Office
850.414.4290
Rick.Vallier@dot.state.fl.us

Chase C. Knight, PhD. (Composite Specialist)
FDOT State Materials Office
352.955.6642
Chase.Knight@dot.stat.fl.us

The Halls River Bridge – perspective of owner/designer, contractor and researcher

Part II – Constructing HRB

August 4, 2017

Gianbattista Mazzocchi

Astaldi Construction Corporation

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

Astaldi's Experience with FRP

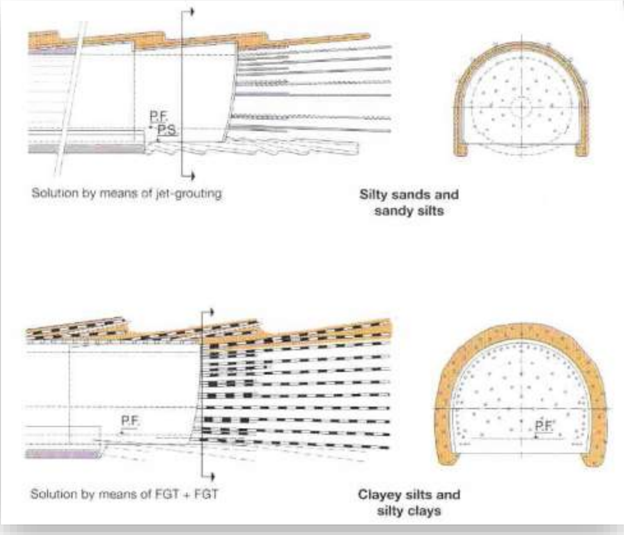
- More than 20 years using FRP:

Astaldi's Recent Projects using FRP	
Metro Copenhagen,Phase 1 & 2 - Denmark	Metro Milan Line 5 Bignami - Garibaldi, Italy
Metro Brescia. Italy	Metro Naples Line 1, Piscinola - Centro Direzionale, Italy
Metro Genoa, Italy	Metro Rome Line C, Italy Phase 1 and Phase 2
Metro Milan Line 4, Italy	Metro Warsaw, Poland
Metro Milan Line 5, San Siro - Garibaldi, Italy	Rome-Naples HSR, Italy

Astaldi's use of FRP, has been predominately for **mechanized tunneling**.

Astaldi's Experience with FRP

- 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.



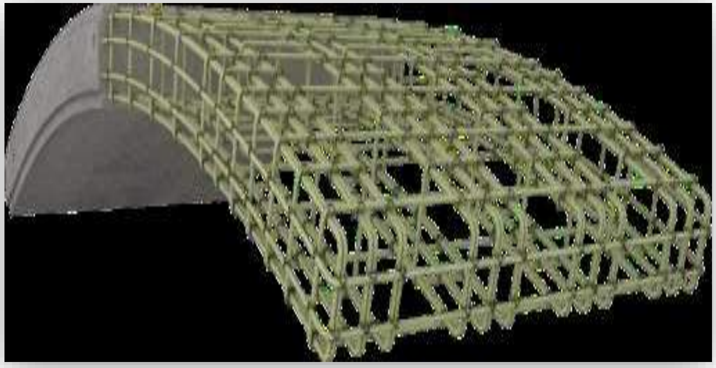
Astaldi's Experience with FRP

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.*

Astaldi's Experience with 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



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.

ASTALDI

Construction Considerations

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 Considerations

Site Storage and Logistics

- Additional Storage requirements needed on site
- Need to be protected from extended exposure to direct sunlight.

Construction challenges

- Trained labor required to ensure correct fixing and minimize risk of damages and movement of reinforcements during concreting operations.
- Splicing of rebar to ensure safe lifting of the cages (time consuming).

Construction Considerations

Construction challenges

- Concrete issues due to light weight of rebar.
- NO FLAME – no heat sources allowed near FRP bars.
- Fragility of the rebar during vibration.

Construction Considerations

Advantages:

- Highly resistant to corrosion
- Tensile strength greater than steel
- Weighs only one quarter as steel
- It is transparent to magnetic fields and radar frequencies
- GFRP has low electrical and thermal conductivity
- Reduced concrete cover requirements
- Labor Savings during Installation
- Concrete Properties less stringent

Construction Considerations

Disadvantages:

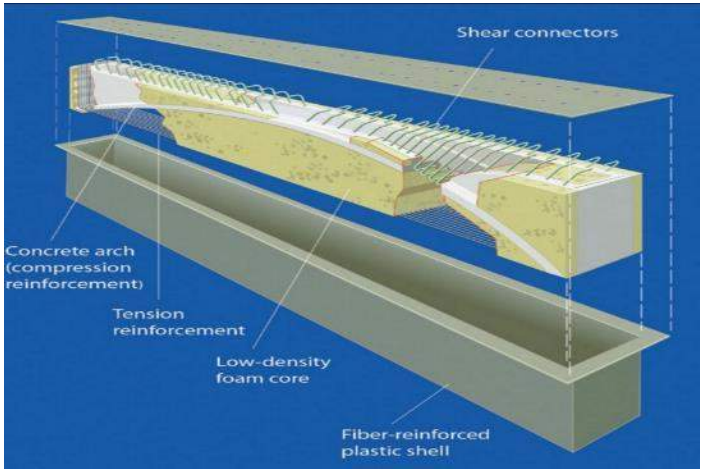
- Higher Costs of Materials
- Additional Contingency Qty's required
- Specific Storage and Site Logistics
- Specific lifting plans required
- QA/QC - additional verifications at manufacturing plant
- Risk of movement of GFRP during concreting
- Fragile – easily damaged. Specialized training of labor.
- 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 Description

- 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 pre-stressing and Glass FRP reinforcing
- GFRP for all the cast in place structures.



Project Status

Commencement of Works January 2017

Current ongoing activities (PHASE II):

- Construction Deliverables
- Advanced procurement
  - 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
- Pile driving
- Assembling GFRP bent
- Bent forming and pouring
- Beams installation

MATERIALS	START PLACEMENT
PILES	3/3/2017
SHEET PILES	2/15/2017
HCB	4/6/2017
REINFORCEMENT	3/28/2017

Project Status

- CFRP Pile Driving



Project Status

- Pile splices IB-2

Project Status

- Pile spices IB-2

Project Status

- Osprey Nest Relocation

Project Status

ASTALDI

- Osprey Nest Relocation

Project Status

- CFRP/GFRP Sheet piles installation

Project Status

- CFRP/GFRP Sheet piles installation

Project Status

- Assembling GFRP bent cages

Project Status

6 man-power can complete a bent cap in 4 hours and 30 minutes

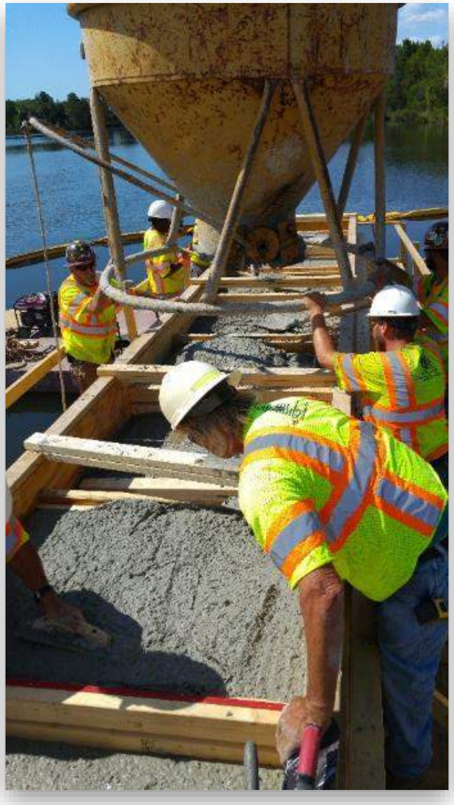



- Placing GFRP Reinforcing

Project Status

- Bent forming and pouring






Project Status

ASTALDI

- Beams Installation


Thank You!
aerial
Innovations

The Halls River Bridge – perspective of owner/designer, contractor and researcher

Part III – Production of Prefabricated Elements for HRB

August 4, 2017

Michelle Roddenberry, Ph.D., P.E.

FAMU-FSU College of Engineering

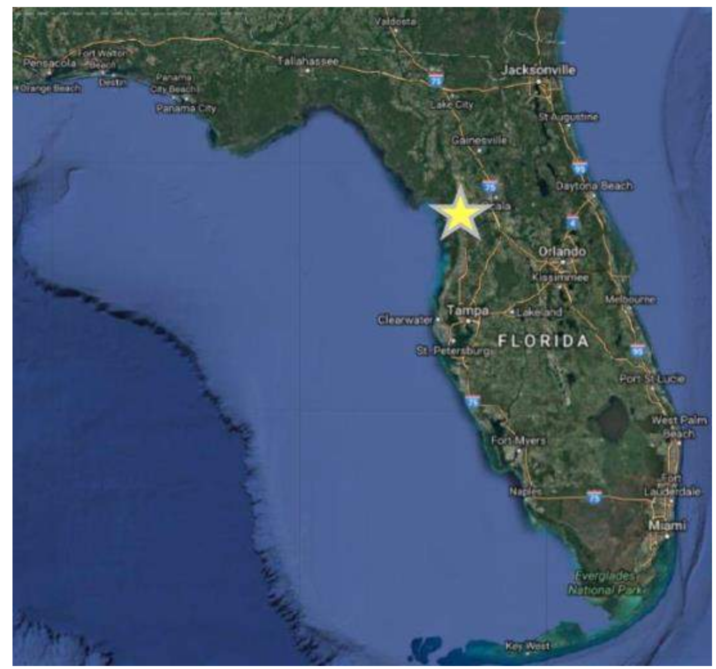
Principal Investigator

Research Sponsor

Research Partner

Project Overview

- FRP reinforced concrete demonstration project
- Improve durability
- Expect longer service life and lower maintenance liability



Objectives

- Verify the ability of experimental features within an extremely aggressive environment to increase the overall life of the bridge along with decreasing the associated maintenance costs
- Prove validity of experimental features for future use of these products

Main Tasks

- Observe and document the fabrication activities
- Document the construction activities
- Document the quality of the constructed bridge
- Measure the performance of the in-service bridge by monitoring and durability testing
- Identify and quantify material degradation of concrete and FRP in sheet pile wall caps
  - End of construction
  - 6 months
  - 1 year
  - 2 years

CFCC Pile Driving

Halls River Bridge
Homosassa Springs, FL

CFCC Pile Driving

CFCC/GFRP 18” Splice Piles

CFCC/GFRP 18” Splice Piles

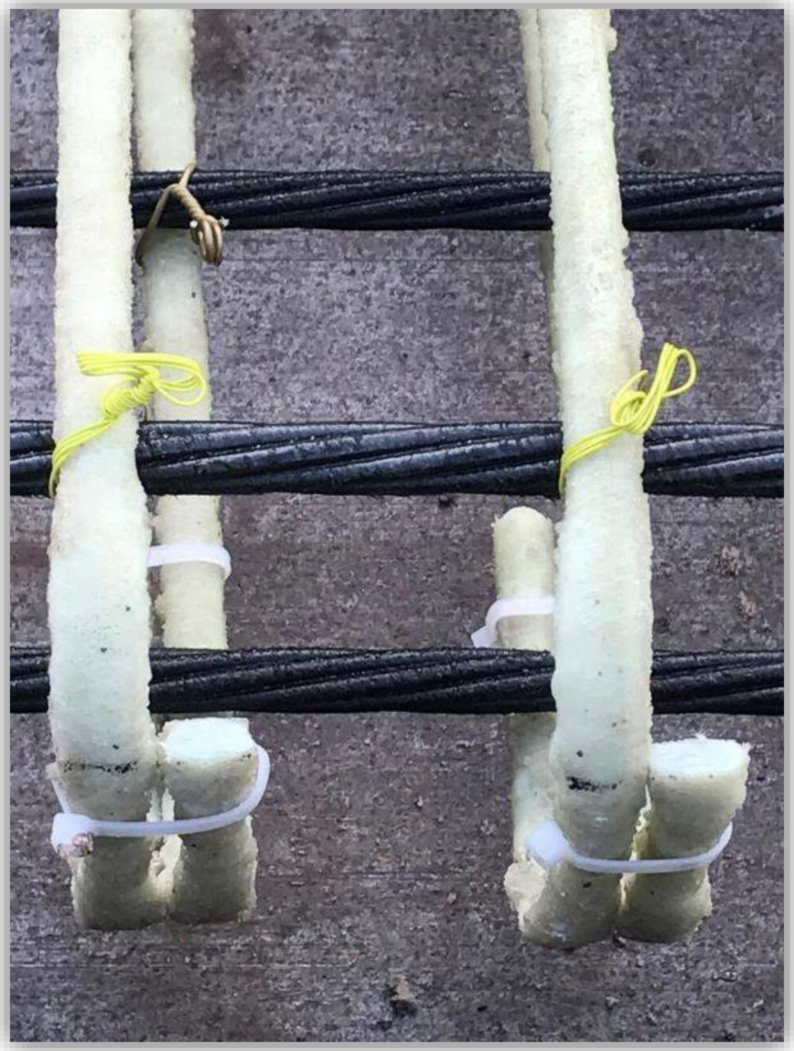
CFCC/GFRP 18” Splice Piles

CFCC/GFRP 18” Splice Piles

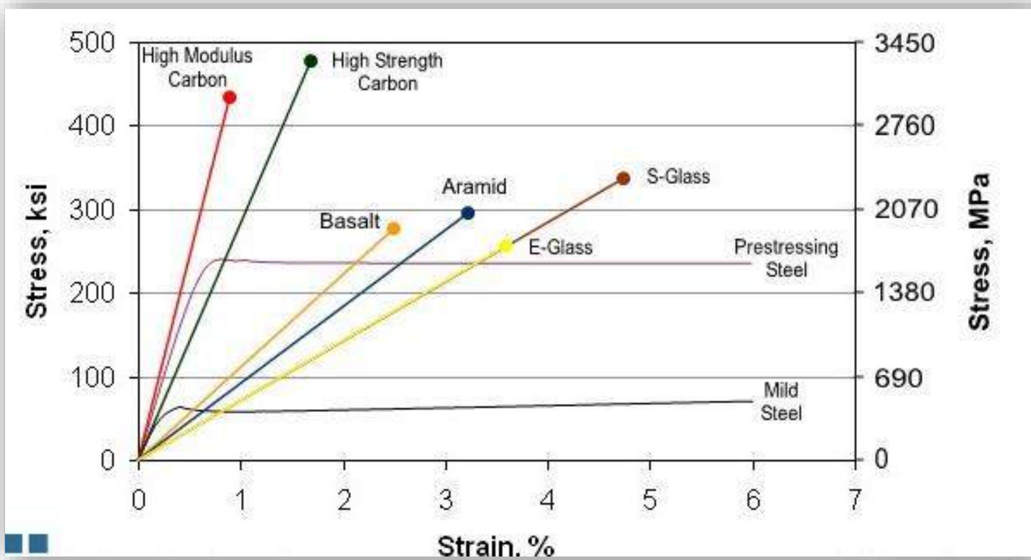
CFCC Prestressed Sheet Piles

Gate Precast Company
Jacksonville, FL

CFCC Prestressed Sheet Piles

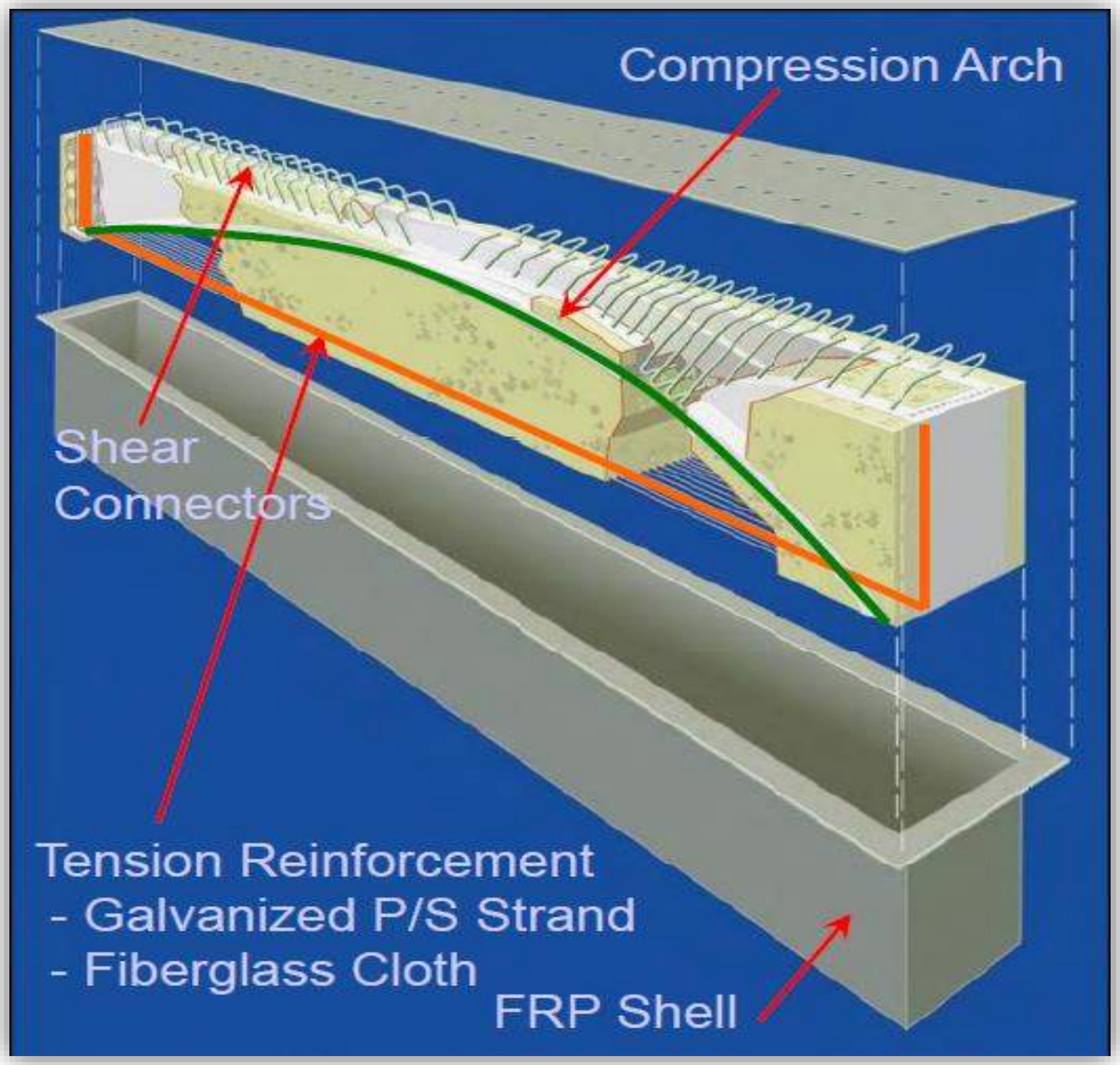


CFCC Prestressed Sheet Piles

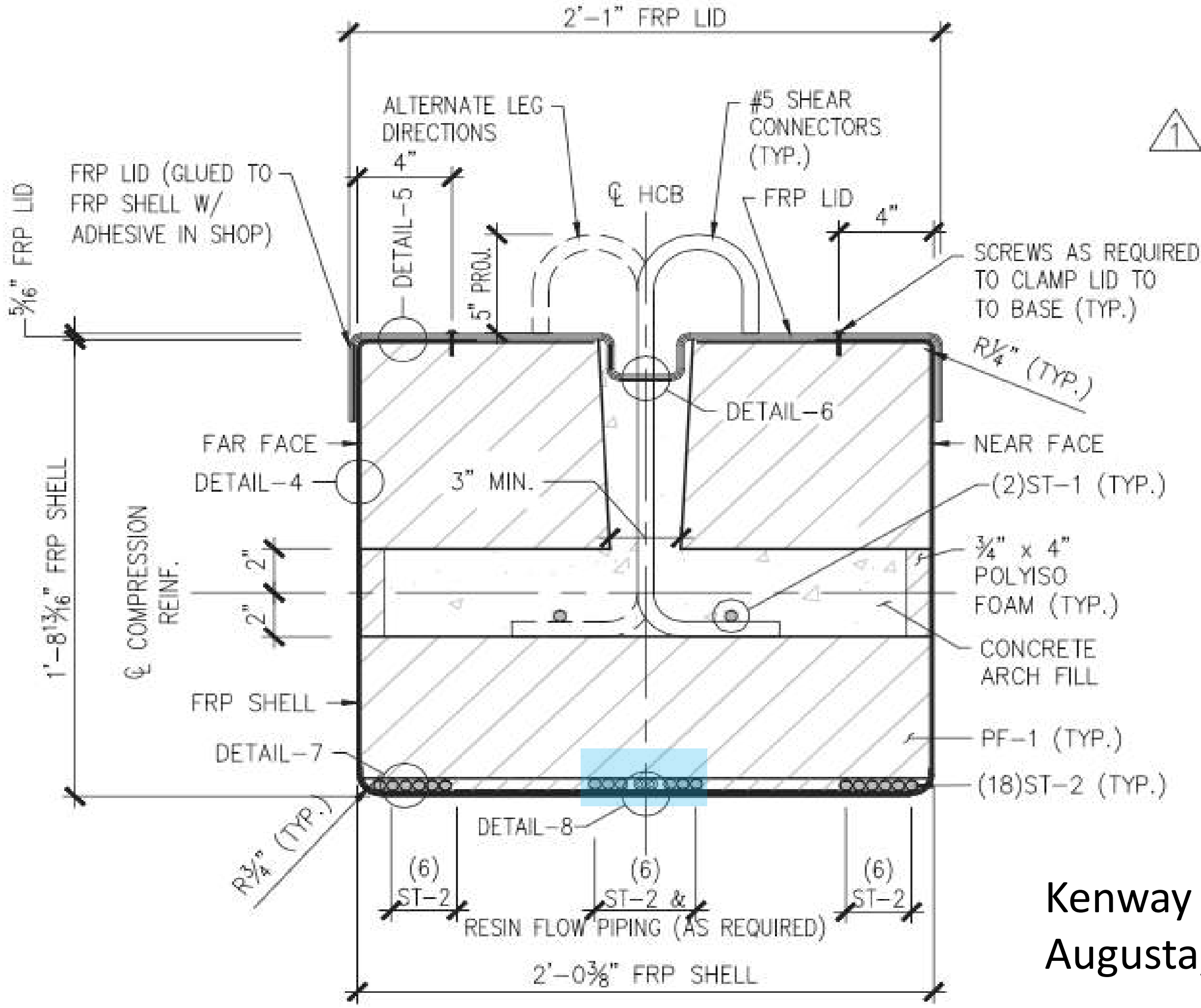


CFCC Prestressed Sheet Piles

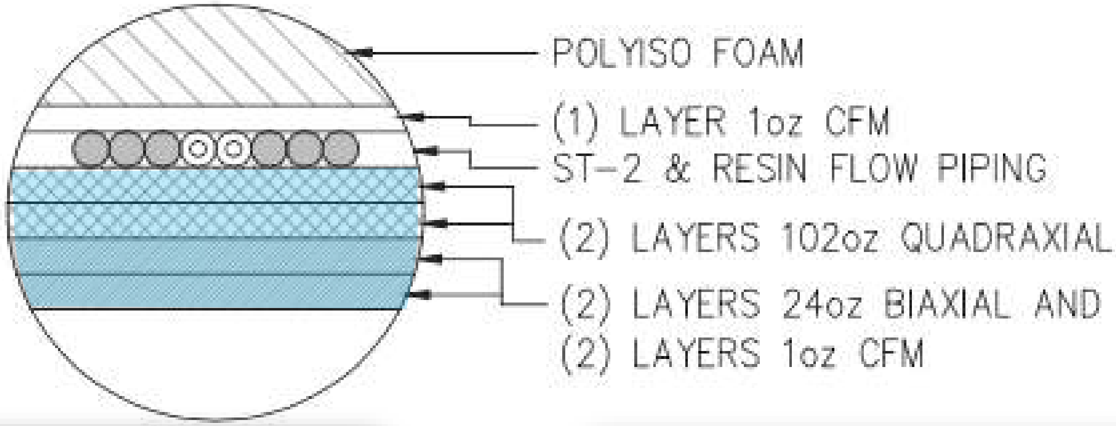
Hybrid Composite Beam (HCB)



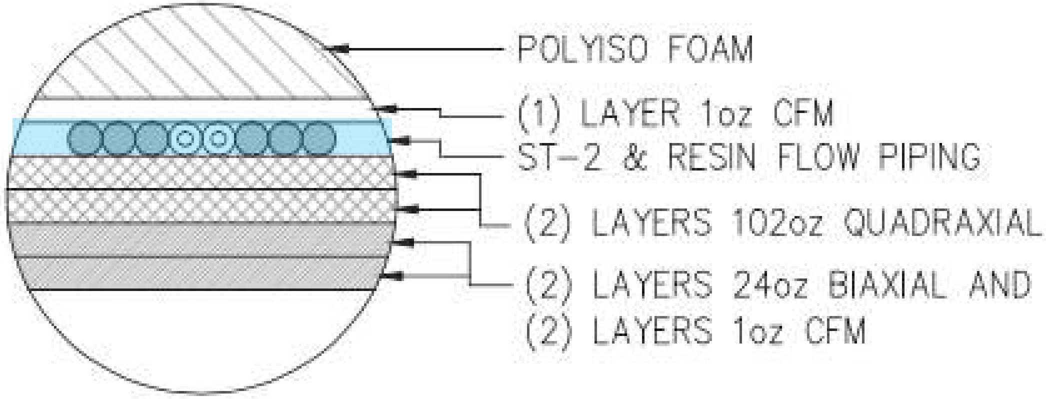
Hybrid Composite Beam (HCB)

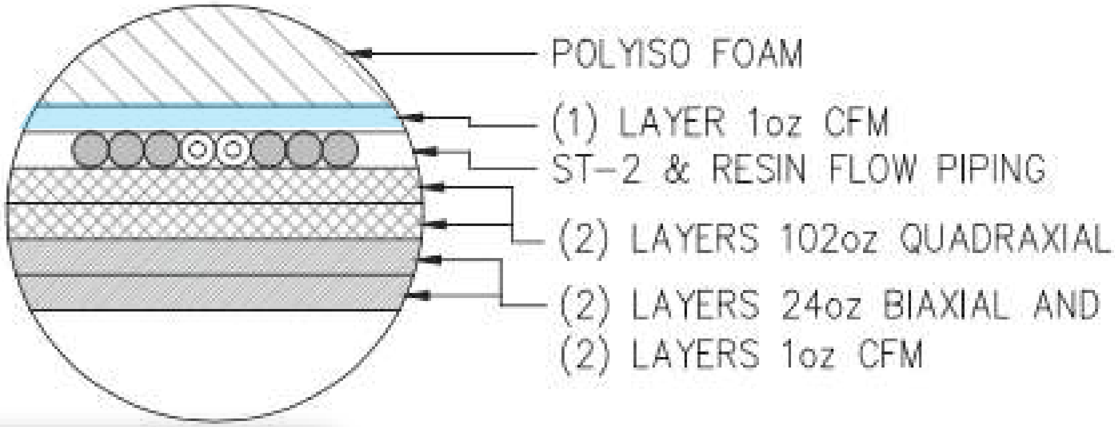


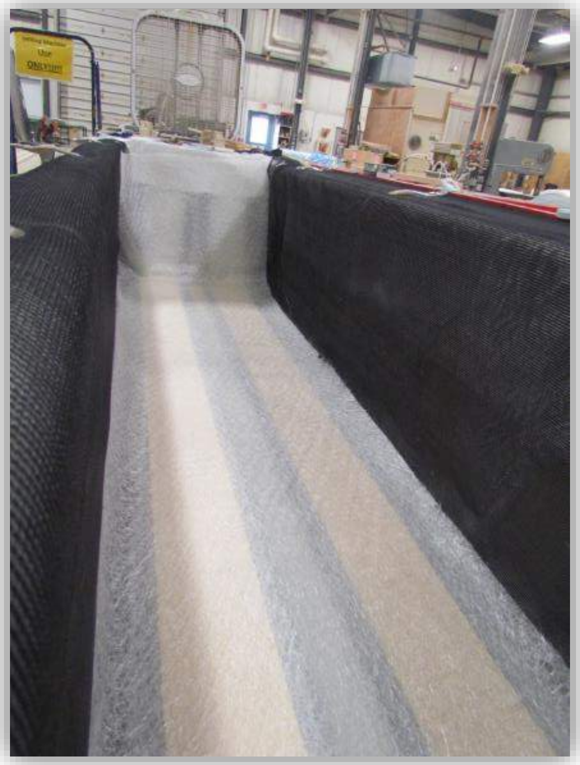
Kenway Corporation
Augusta, ME

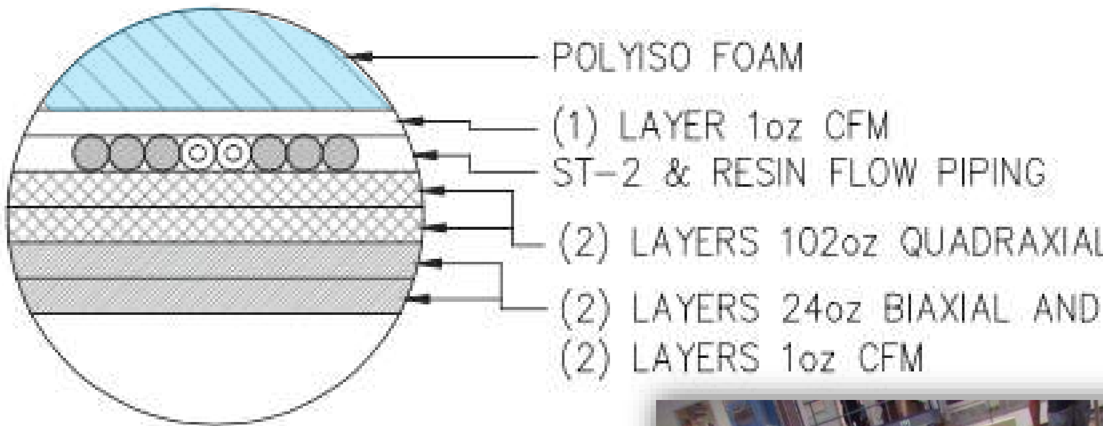


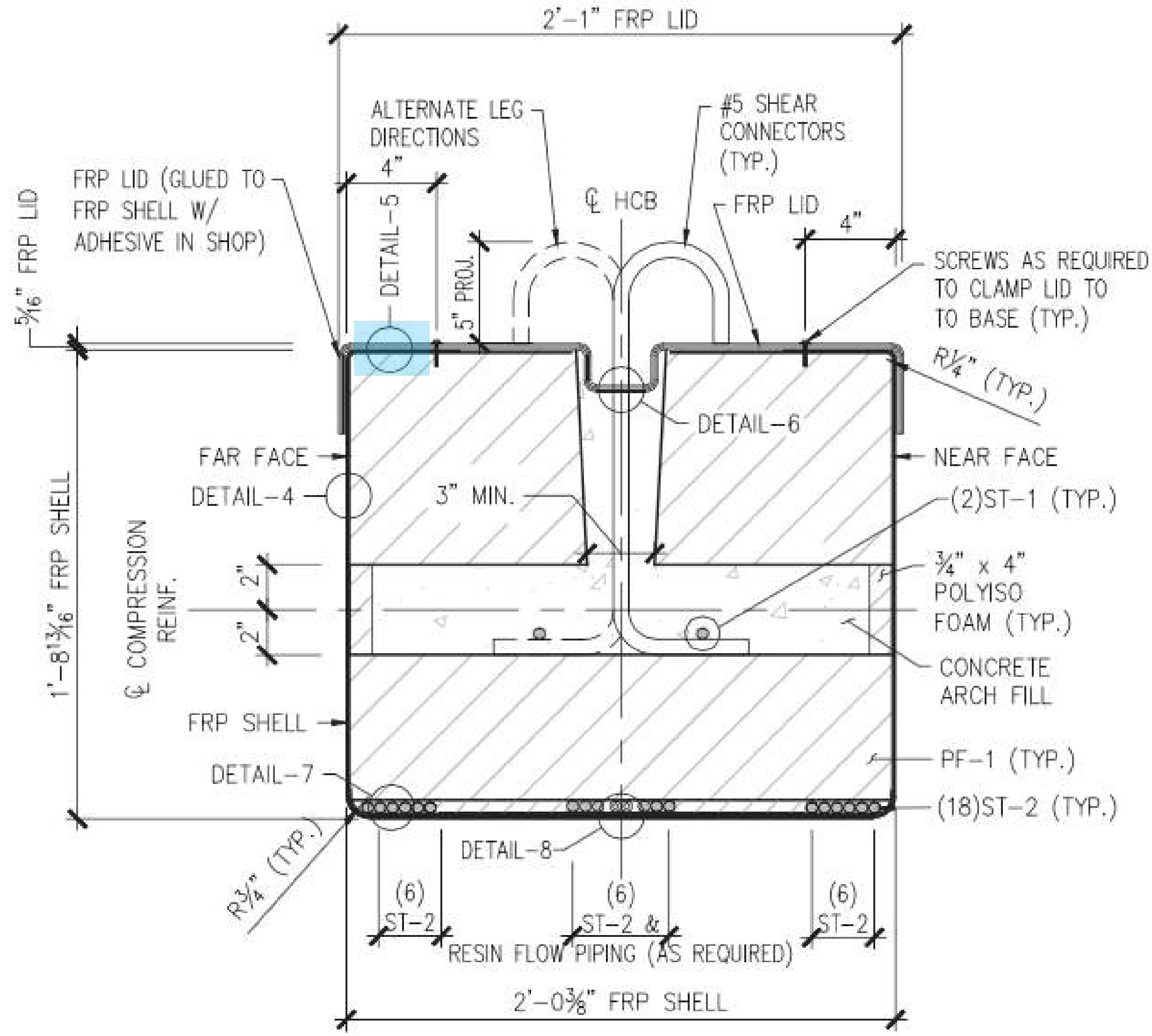
POLYISO FOAM
(1) LAYER 1oz CFM
ST-2 & RESIN FLOW PIPING
(2) LAYERS 102oz QUADRAXIAL
(2) LAYERS 24oz BIAXIAL AND
(2) LAYERS 1oz CFM

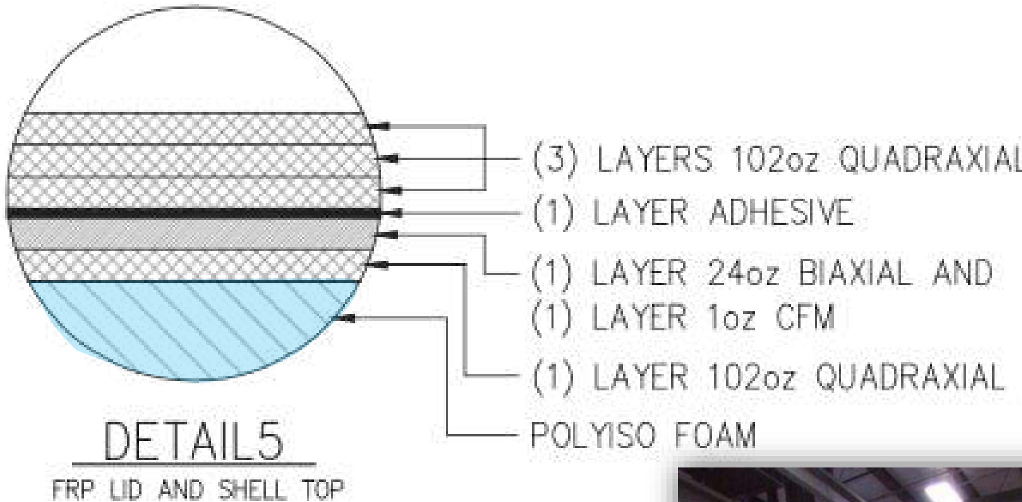

POLYISO FOAM
(1) LAYER 1oz CFM
ST-2 & RESIN FLOW PIPING
(2) LAYERS 102oz QUADRAXIAL
(2) LAYERS 24oz BIAXIAL AND
(2) LAYERS 1oz CFM

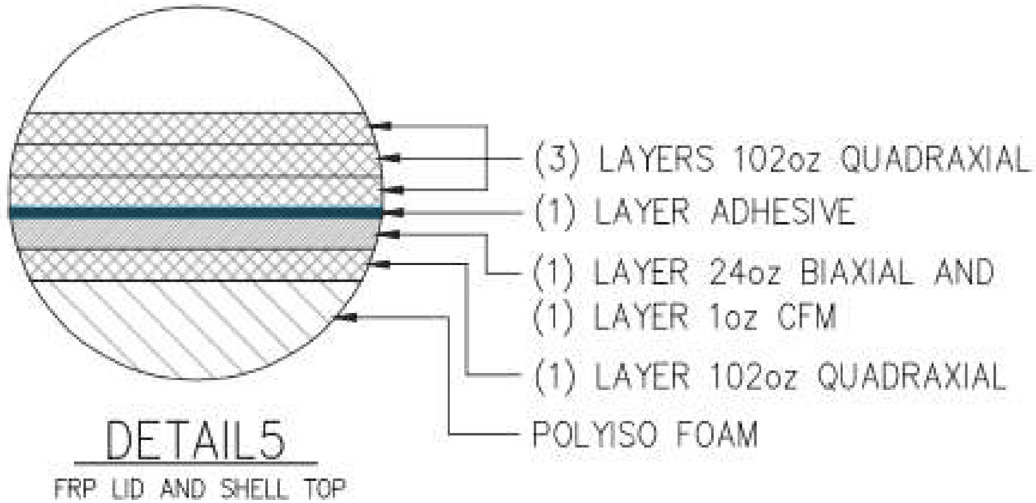

POLYISO FOAM
(1) LAYER 1oz CFM
ST-2 & RESIN FLOW PIPING
(2) LAYERS 102oz QUADRAXIAL
(2) LAYERS 24oz BIAXIAL AND
(2) LAYERS 1oz CFM




POLYISO FOAM
(1) LAYER 1oz CFM
ST-2 & RESIN FLOW PIPING
(2) LAYERS 102oz QUADRAXIAL
(2) LAYERS 24oz BIAXIAL AND
(2) LAYERS 1oz CFM

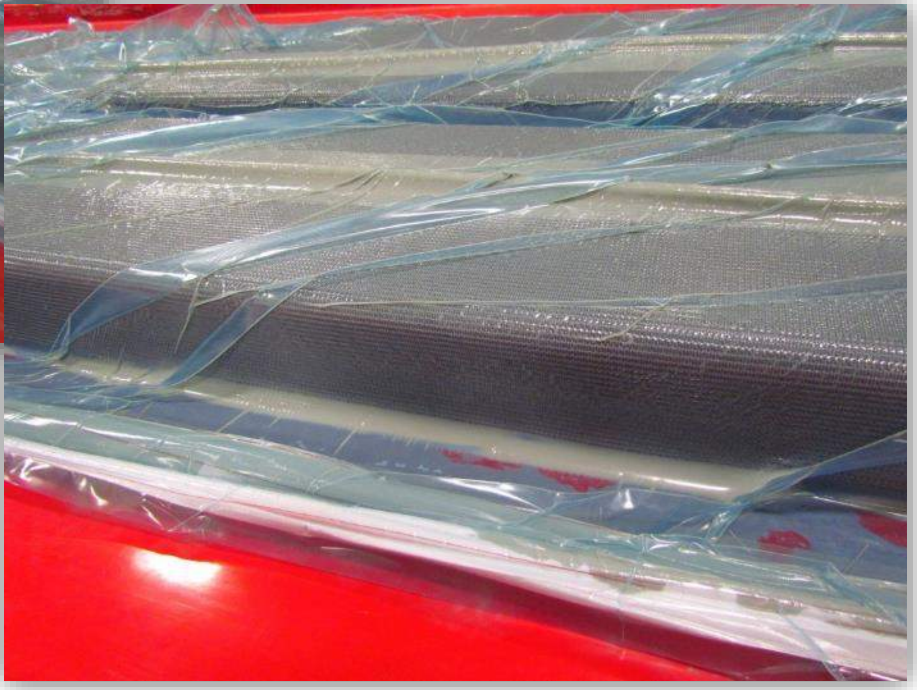

2'-1" FRP LID
ALTERNATE LEG DIRECTIONS
#5 SHEAR CONNECTORS (TYP.)
FRP LID (GLUED TO FRP SHELL W/ ADHESIVE IN SHOP)
4"
DETAIL-5
℄ HCB
FRP LID
4"
5/16" FRP LID
5" PROJ.
SCREWS AS REQUIRED TO CLAMP LID TO TO BASE (TYP.)
R1/4" (TYP.)
DETAIL-6
FAR FACE
NEAR FACE
DETAIL-4
3" MIN.
(2)ST-1 (TYP.)
3/4" x 4" POLYISO FOAM (TYP.)
2"
2"
℄ COMPRESSION REINF.
1'-8 13/16" FRP SHELL
CONCRETE ARCH FILL
FRP SHELL
PF-1 (TYP.)
DETAIL-7
(18)ST-2 (TYP.)
R3/4" (TYP.)
DETAIL-8
(6) ST-2
(6) ST-2 &
RESIN FLOW PIPING (AS REQUIRED)
(6) ST-2
2'-0 3/8" FRP SHELL


(3) LAYERS 102oz QUADRAXIAL
(1) LAYER ADHESIVE
(1) LAYER 24oz BIAXIAL AND
(1) LAYER 1oz CFM
(1) LAYER 102oz QUADRAXIAL
POLYISO FOAM
DETAIL5
FRP LID AND SHELL TOP


(3) LAYERS 102oz QUADRAXIAL
(1) LAYER ADHESIVE
(1) LAYER 24oz BIAXIAL AND
(1) LAYER 1oz CFM
(1) LAYER 102oz QUADRAXIAL
POLYISO FOAM
DETAIL5
FRP LID AND SHELL TOP


HRB 18
05

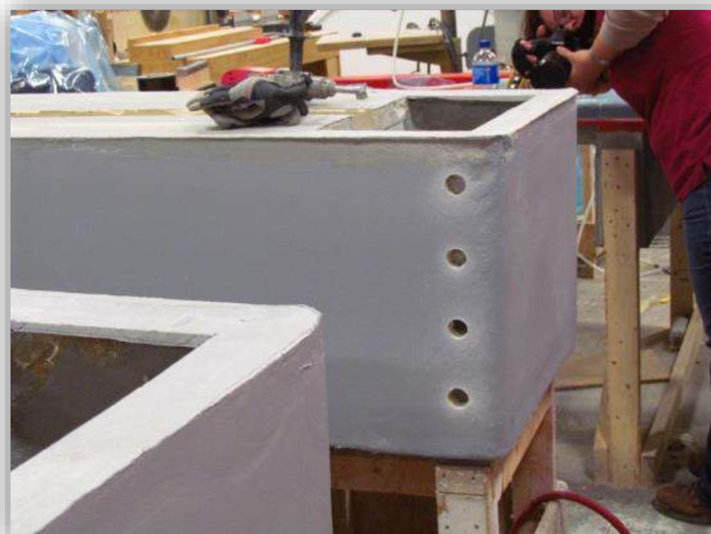
Lid Resin Infusion



Lid Preparation

Shell Resin Infusion

Shell Preparation



Reinforcement

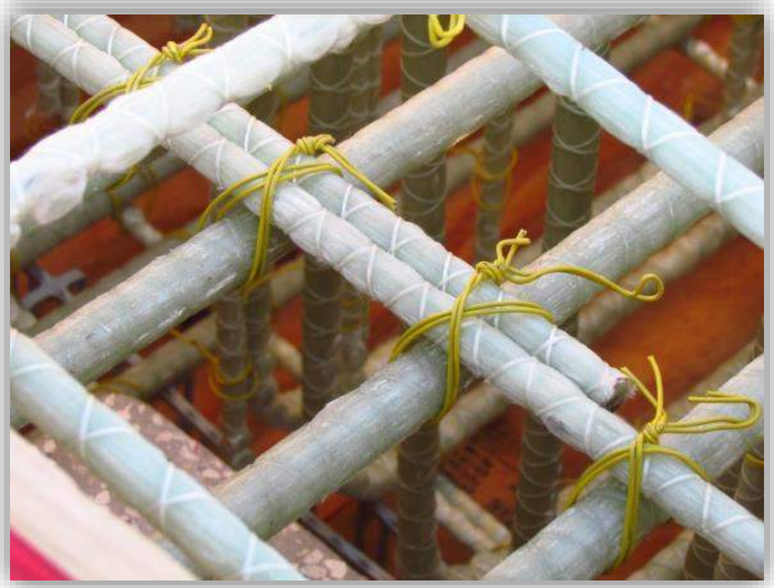
Storage & Shipping

HCB Concrete Arch Casting

HCB Concrete Arch Casting

Completed HCB

GFRP-Reinforced Pier Caps



GFRP-Reinforced Pier Caps

HCBs on Pier Caps

Environmental Aspects

Infravation
An Infrastructure Innovation Programme

The Halls River Bridge – perspective of owner/designer, contractor and researcher

Part IV - HRB as a Demonstrator of an International Project

August 4, 2017

Antonio Nanni
University of Miami

Table of Contents

Halls River Bridge

- Outline of SEACON Project
- Bridge elements directly related to SEACON
- Support work for HRB

Outline of SEACON Project

- Introduction
- Background
- Work Packages (WPs)

Introduction (critical issues)

Infravation
An Infrastructure Innovation Programme

- Cement production contributes 5% of annual anthropogenic global CO_2
- Concrete industry uses more than 500 million gallon of fresh water annually
- Aggregate is mined from the earth, either dug out of pits or blasted out of quarries. Mining has many significant environmental impacts
- In many countries, sand is being extracted at a rate far greater than its renewal and having a major impact on rivers, coastal and marine ecosystems

Introduction (challenges)

Infravation
An Infrastructure Innovation Programme

- Potential alternatives to concrete constituents:
  - Seawater
  - High chloride content cement (CKD)
  - Recycled Concrete Aggregate (RCA) and Recycled Asphalt Pavement (RAP)
- Using seawater in concrete is prohibited by standards and codes due to associated risks of steel reinforcement corrosion. But seawater concrete could be combined with noncorrosive reinforcement

Background

- 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

- 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 (www.infravation.net)

Consortium Membership

Infravation
An Infrastructure Innovation Programme

Partners

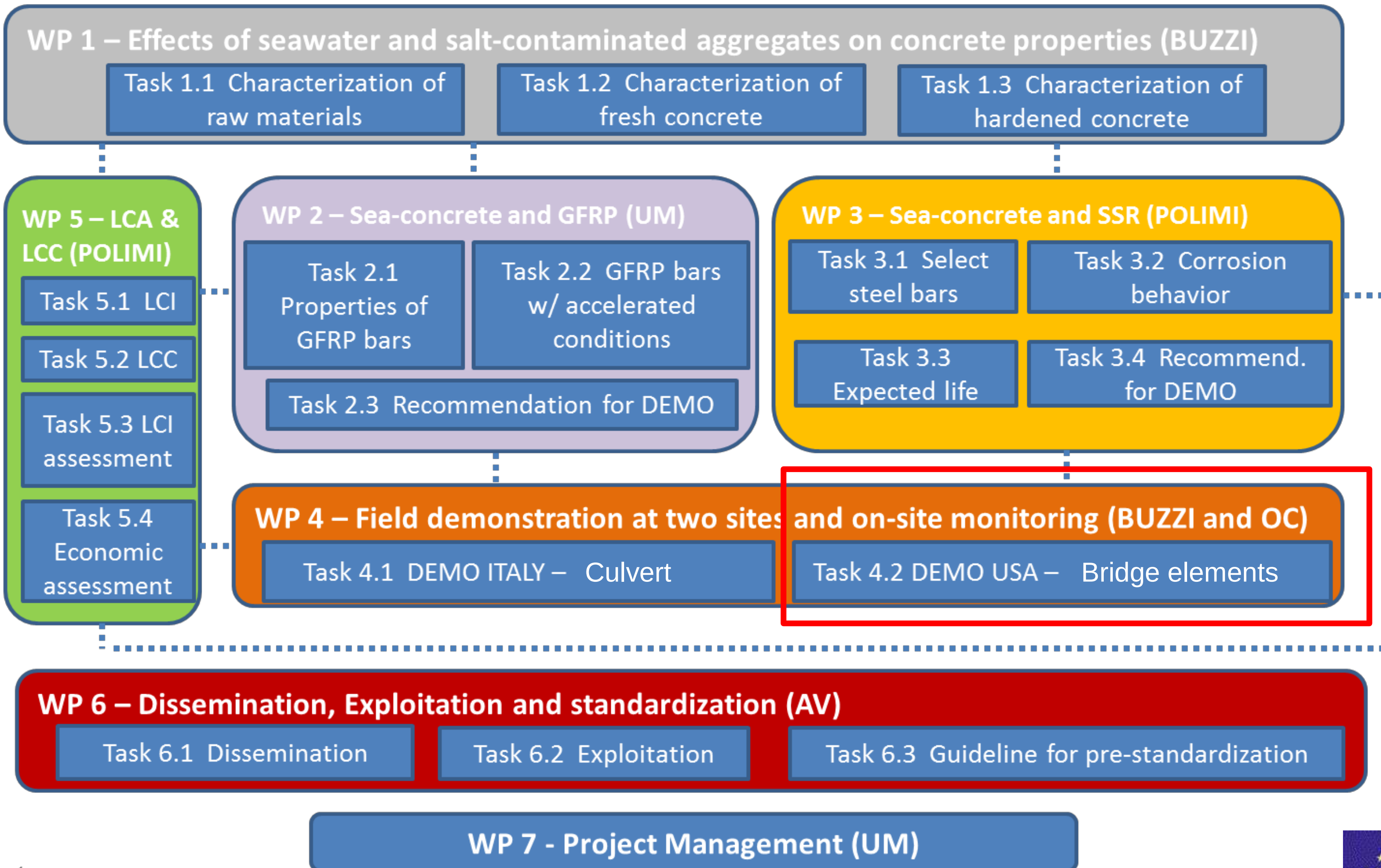
- University of Miami (UM)
- ATP srl (ATP)
- Politecnico di Milano (POLIMI)
- Owens Corning (OC)
- Buzzi Unicem (BUZZI)
- Acciaierie Valbruna (AV)

Collaborators

- Florida DOT (FDOT)
- Pavimental (PV)
- Titan America (TT)

WPs, Tasks and Their Relationships

Infravation
An Infrastructure Innovation Programme

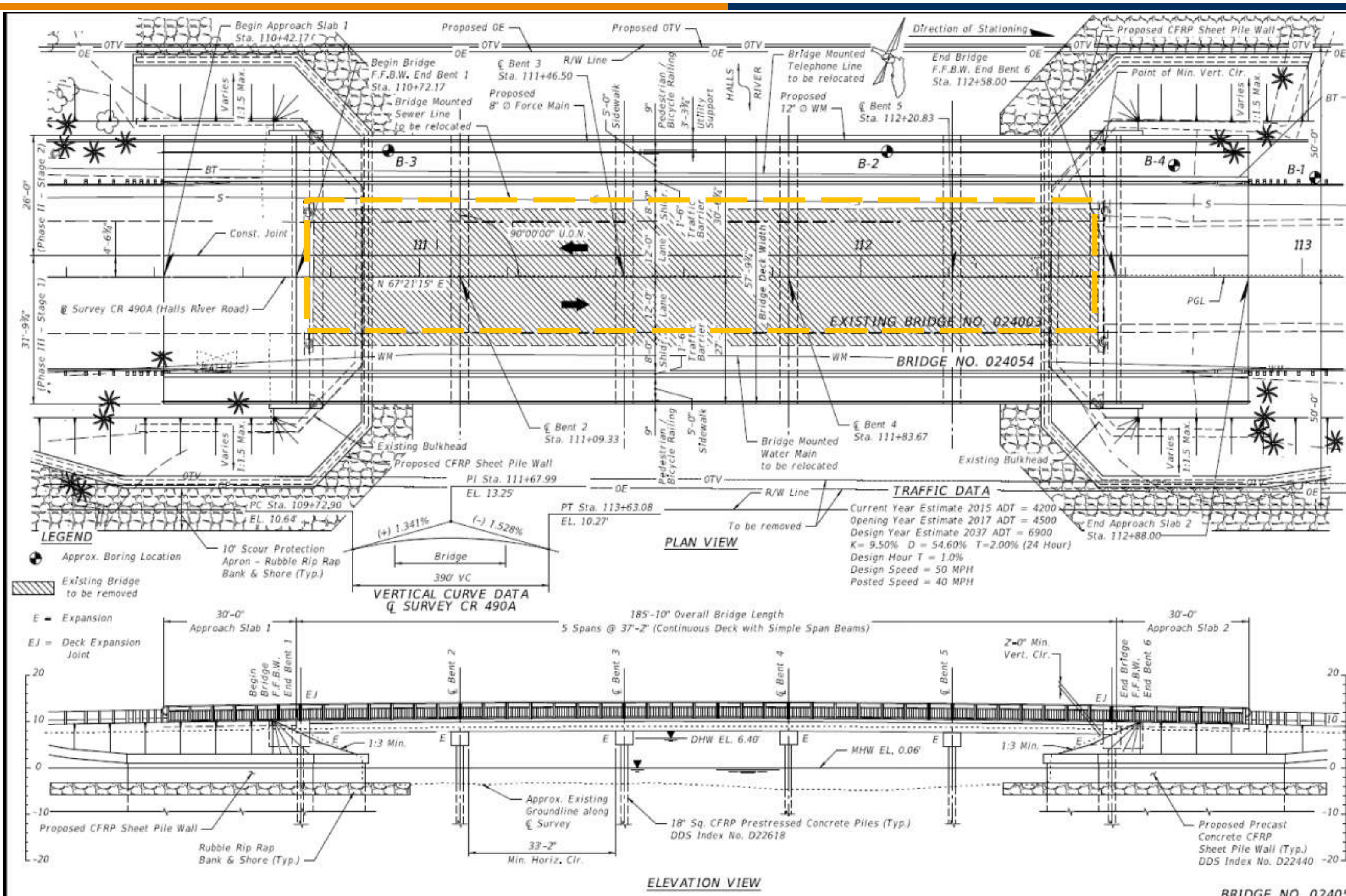


SeaCon

Bridge Elements Related to SEACON

- Bulkhead caps and test blocks
- Retaining walls
- Traffic railings

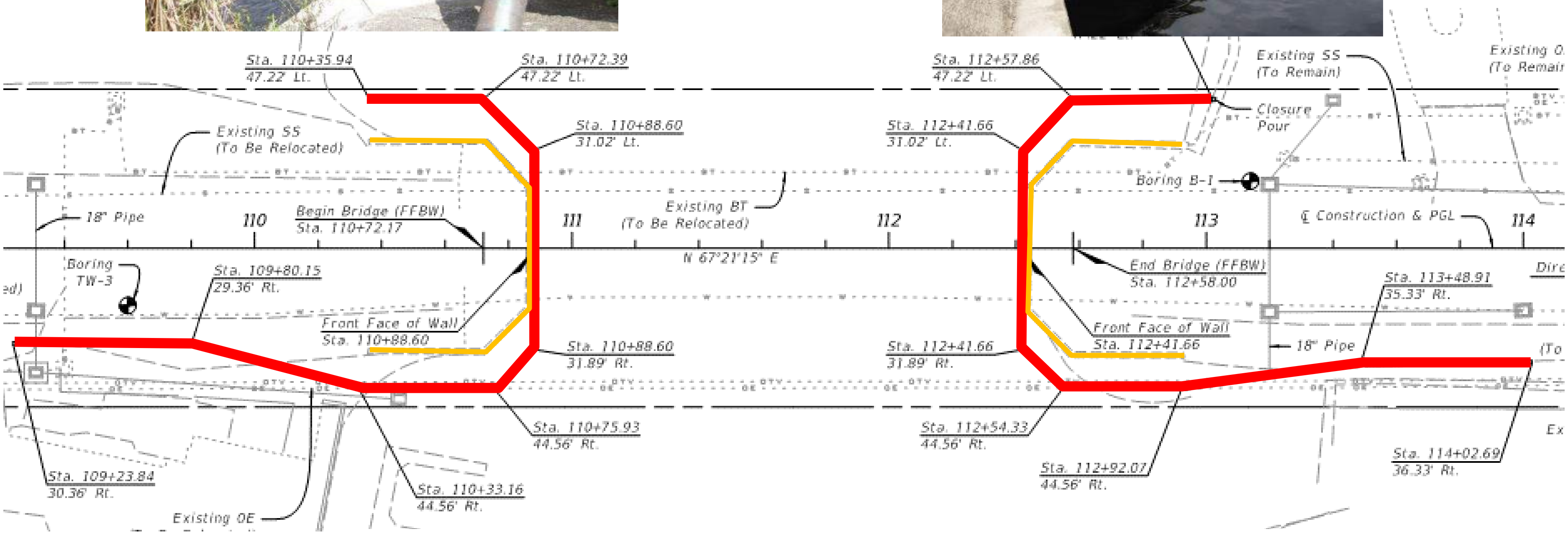
Halls River Bridge Replacement



Existing (orange) and New Layout

Halls River Bridge Replacement

Infravation
An Infrastructure Innovation Programme

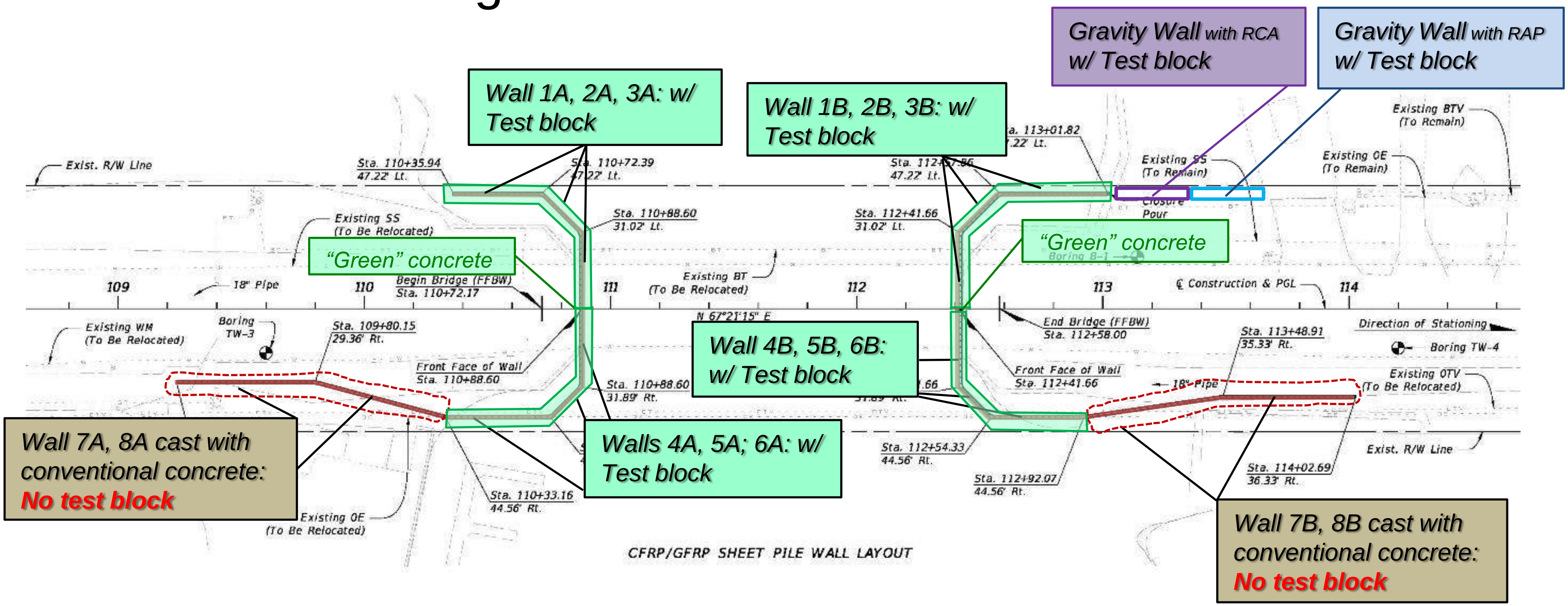


Existing (orange) and New Bulkhead (red) Layout

Bulkhead Cap for Sheet Pile Walls

Infravation
An Infrastructure Innovation Programme

"Green" concrete (i.e., SEACON concrete) uses seawater for mixing



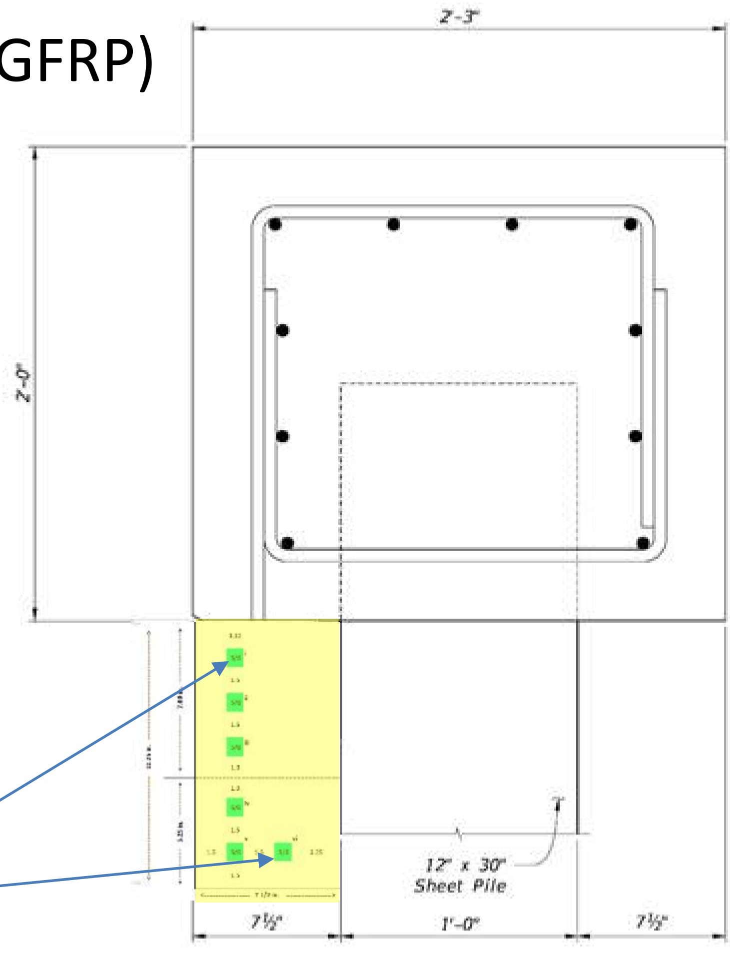
Total wall cap length: 575 LF

Total test block length: 395 LF

Bulkhead Cap Test Blocks

(with BFRP/CFRP/GFRP)

Bulkhead cap and test block are to be cast monolithically with same concrete mix



SECTION A-A

Six FRP bars for lab testing

Legend: Test block to be removed at different ages

Gravity Walls (with GFRP & RAP or RCA)

Infravation
An Infrastructure Innovation Programme

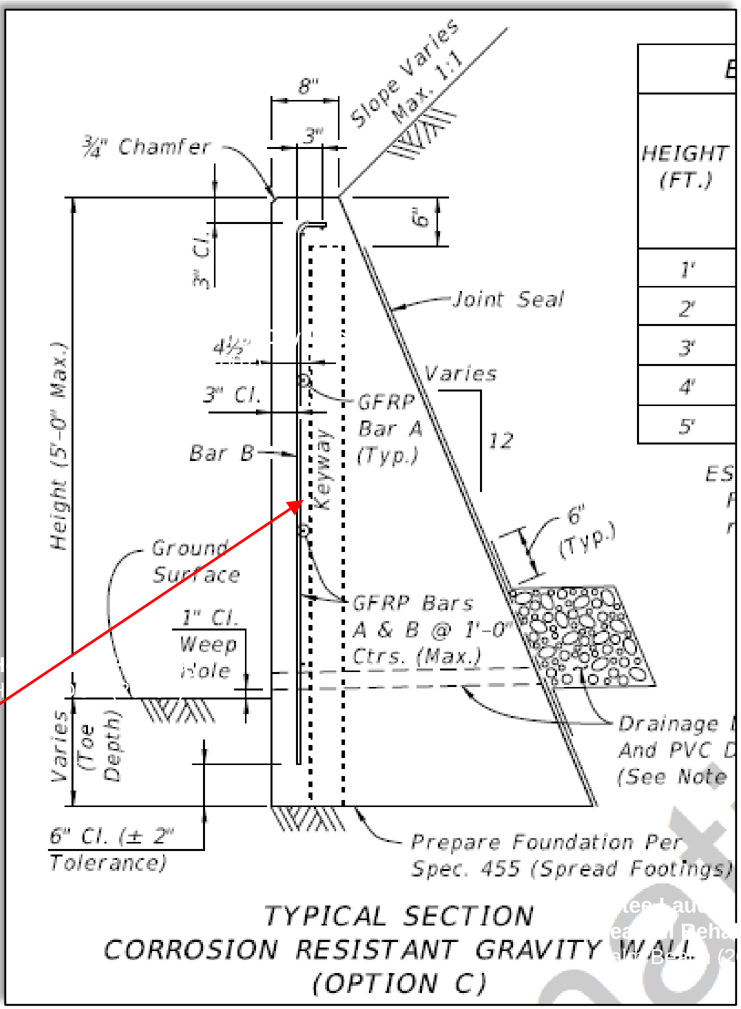
Mix Design Criteria:

FDOT Material Specifications ***–347*** (RAP)

Dev347 (RCA – *project specific*)

Challenges:

i. Consistent aggregate gradation envelope for alternate source substitution
ii. Relevant performance based specifications



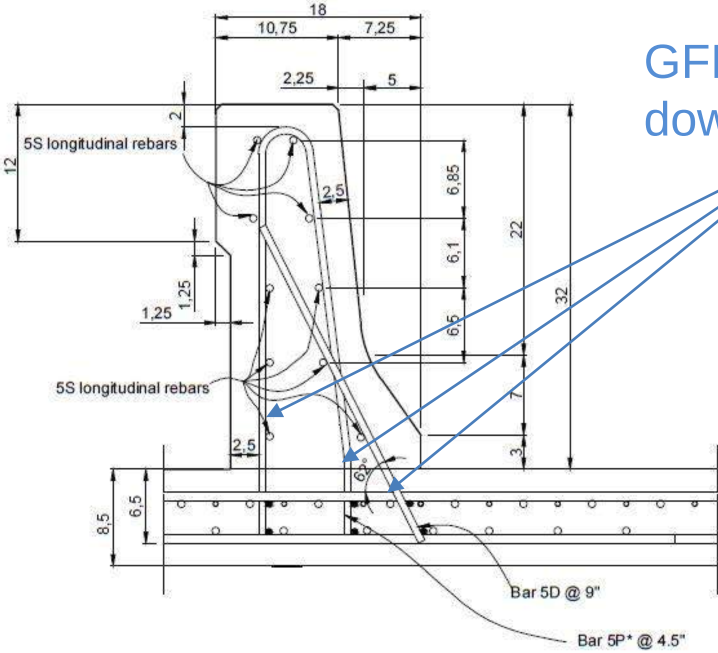
GFRP bar

Traffic Railings

Infravation
An Infrastructure Innovation Programme

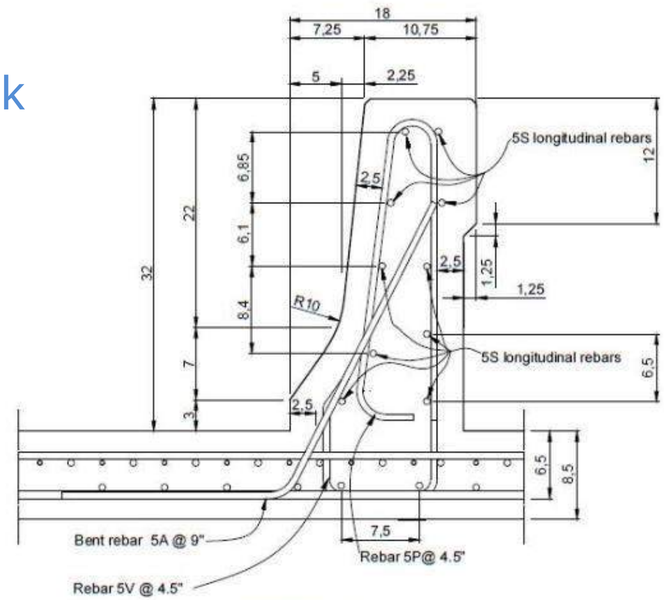
North Side – constructed on existing deck

South Side – constructed with deck



SECTION A-A
TYPICAL SECTION THRU TRAFFIC RAILING

GFRP bars doweled into deck



SECTION A-A
TYPICAL SECTION THRU TRAFFIC RAILING

Concrete mixtures with: a) white cement; and, b) blend of slag and fly ash

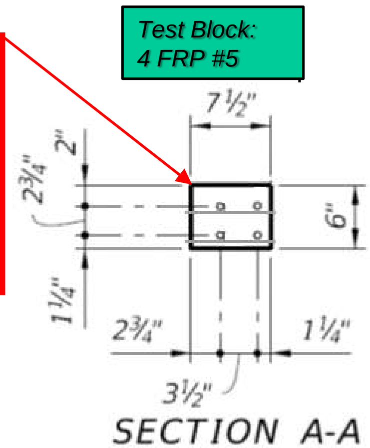
SEACON Test Matrix

Infravation
An Infrastructure Innovation Programme

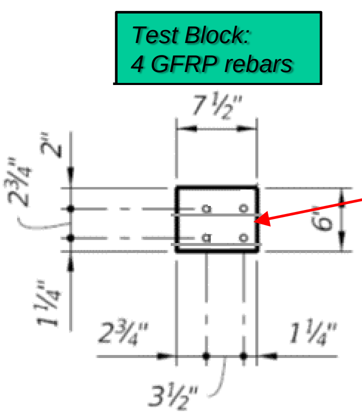
- RCA & RAP Gravity Walls

<u>24 test blocks of each RCA and RAP concrete mixes</u>

4 GFRP #5 rebar (half the blocks cast with conventional RCA and RAP mixes & half with green RCA and green RAP mixes)



- White Cement & Slag Blend Traffic Railings



<u>12 test blocks of each WHITE CEMENT and SLAG BLEND concrete mixes</u>

Test blocks with 4 GFRP rebar

(All blocks cast separately not attached to walls or railings)

Support Work for HRB

- Design and characterization of concrete mixtures
- Durability of SEACON concrete
- Durability of embedded GFRP bars in SEACON

Support Work for **Halls River Bridge**

Infravation
An Infrastructure Innovation Programme

Non-standard structural and non-structural concrete mixtures for HRB were designed by UM and approved by FDOT

- Structural:
  - Class IV 5500 psi
  - Green class IV 5500 psi (bulk head caps)
  - 100% white cement class IV 5500 psi (railings)
  - 60% slag class IV 5500 psi (railings)
- Non-structural
  - RCA (gravity wall)
  - RAP (gravity wall)
  - Green RCA (research)
  - Green RAP (research)

Support Work for **Halls River Bridge**

Infravation
An Infrastructure Innovation Programme

- Aggregate properties examined:
  a) Particle size distribution by sieve analysis
  b) Specific gravity
  c) Water absorption
  d) Bulk density and voids
  e) Total sulfate and chloride content
  f) -200 ratio (material finer than 200 sieve)
- Seawater chemical composition was evaluated
- Seawater, RCA and RAP delivered to Argos (concrete provider) readymix plant in Brooksville, FL

Durability of SEACON

Infravation
An Infrastructure Innovation Programme

Specimens cast from two different concrete mixes:

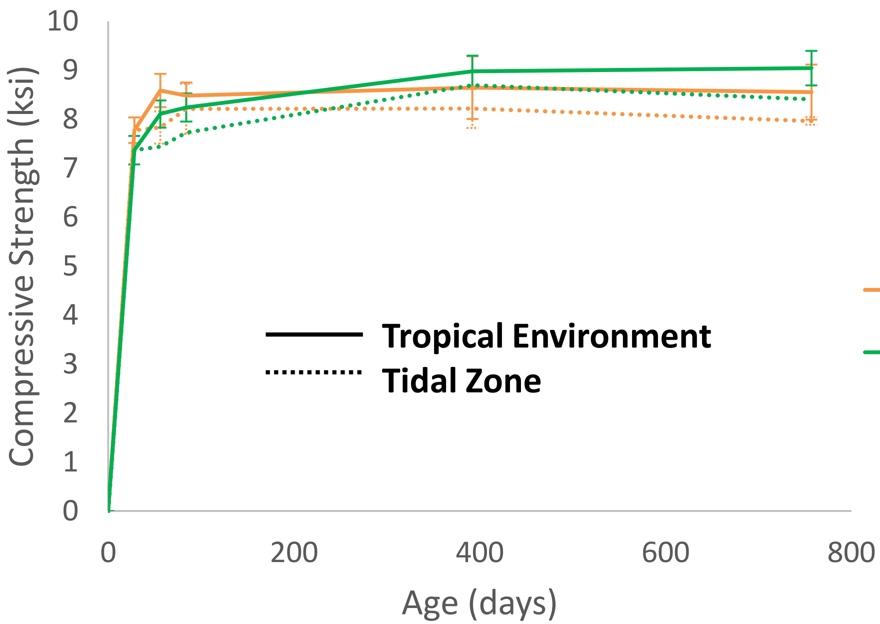
i. Mix A: benchmark conventional concrete mix

ii. Mix B: proportions identical to Mix A, but tap-water replaced with seawater from Key Biscayne Bay

Materials (lb./yd^3)	**Mix A**	**Mix B**
Cement (type I – II)	560	560
Fly ash (class F)	140	140
Fresh water	283	-
Sea water	-	283
Coarse aggregate (#57 stone)	1750	1750
Fine aggregate (silica sand)	1032	1032
Fresh Properties		
Slump (in.)	4	4
Density (lb./ft^3)	146.8	147.2
Air Content (%)	1.3	1

Durability of SEACON (Phase I)

Cylinder Compressive Strength



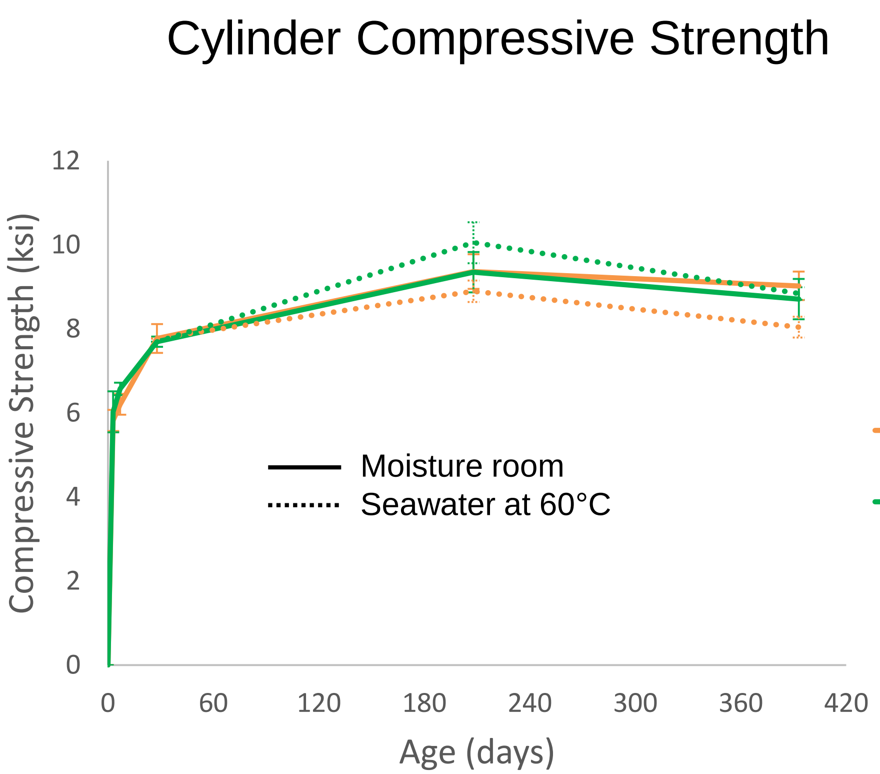
Mix A :Conventional Concrete

Mix B :Seawater Concrete

Subtropical Environment of Miami, FL

Tidal Zone at Key Biscayne, FL

Durability of SEACON (Phase II)



Seawater Immersion

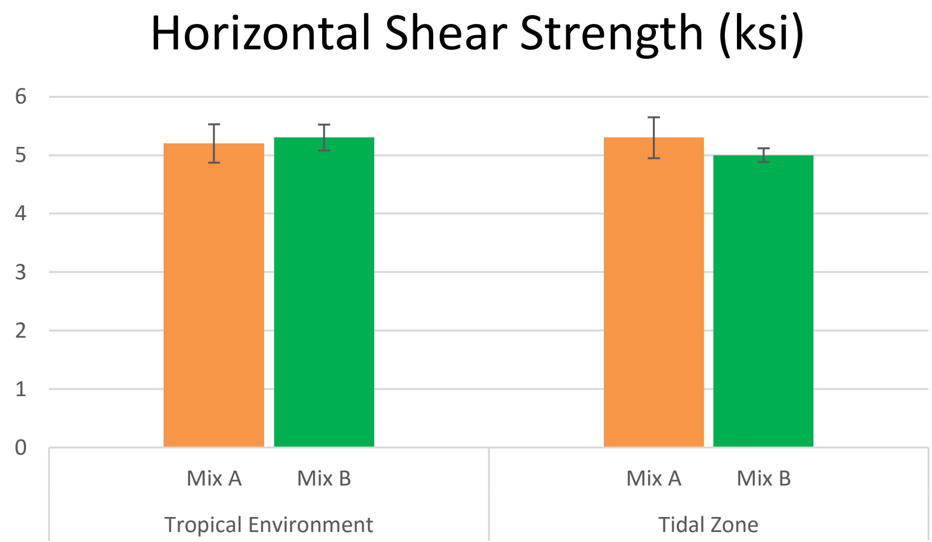
Mix A :Conventional Concrete

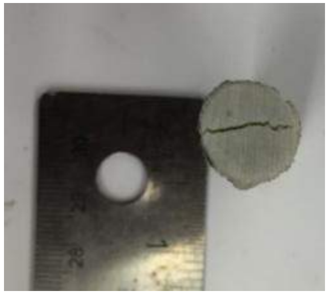
Mix B :Seawater Concrete

Moisture room

Durability of Embedded GFRP Bars

Phase I : GFRP bars extracted from 1-year old concrete cylinders to study residual mechanical properties

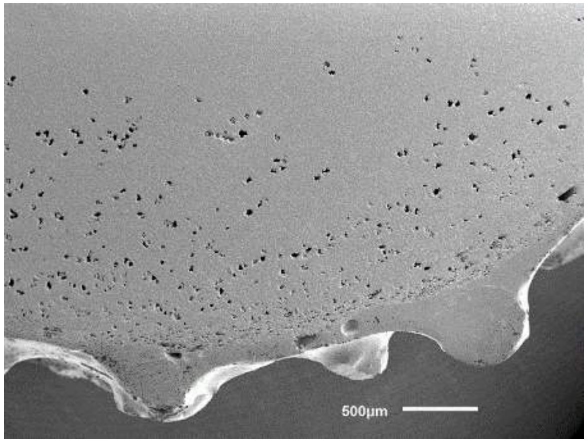




Durability of Embedded GFRP Bars

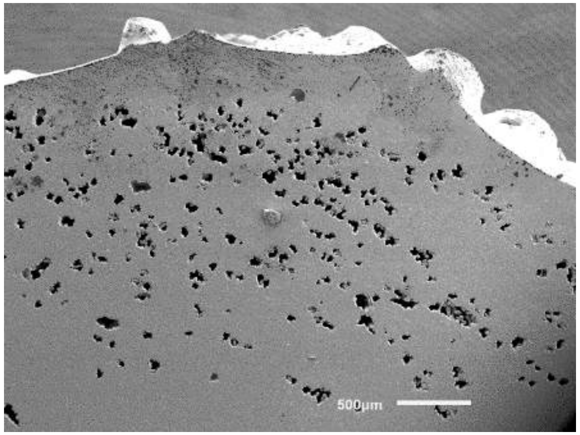
Infravation
An Infrastructure Innovation Programme

SEM imaging to evaluate potential degradation of GFRP microstructure and GFRP-concrete interface. Images were taken from the edges of extracted GFRP bars prone to degradation

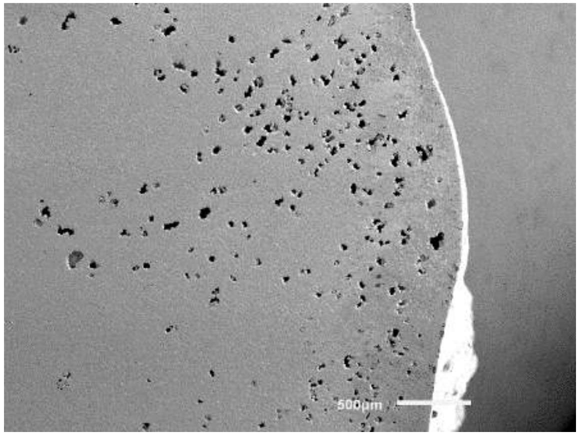


Pristine Bar

Mix A (Conventional Concrete)



Mix B (Seawater Concrete)



Durability of Embedded GFRP Bars

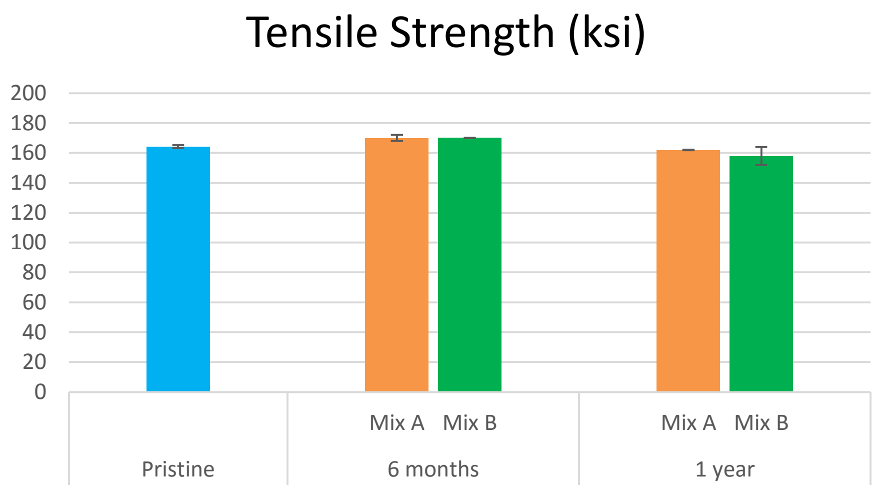
Phase II : GFRP bars embedded in concrete beams with cross section replicating test blocks from bulkhead cap of **Halls River Bridge**.

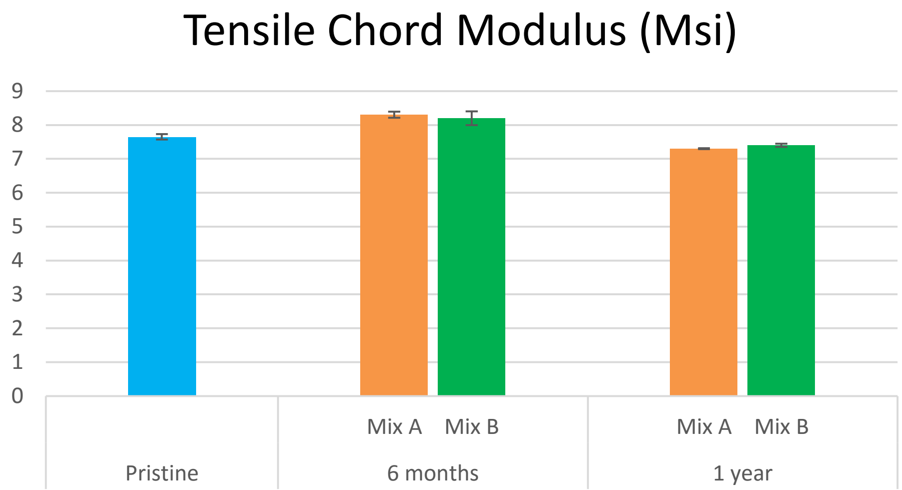
Beams exposed to accelerated conditioning (seawater at 60°C) for a year and GFRP bars extracted every 6 months and tested for:

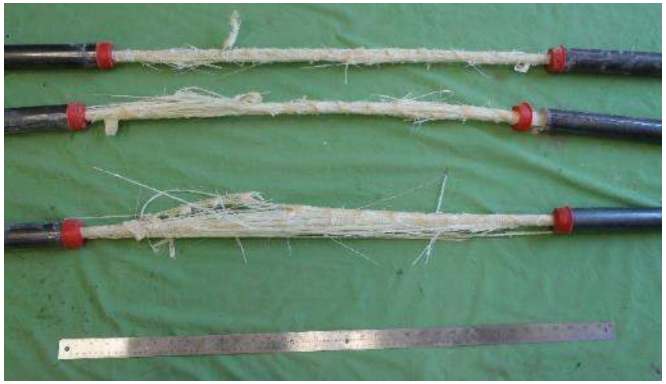
I. Tensile properties including tensile chord modulus
II. Horizontal and transverse shear strengths

GFRP microstructure and its interface with concrete also examined using SEM imaging

Durability of Embedded GFRP Bars



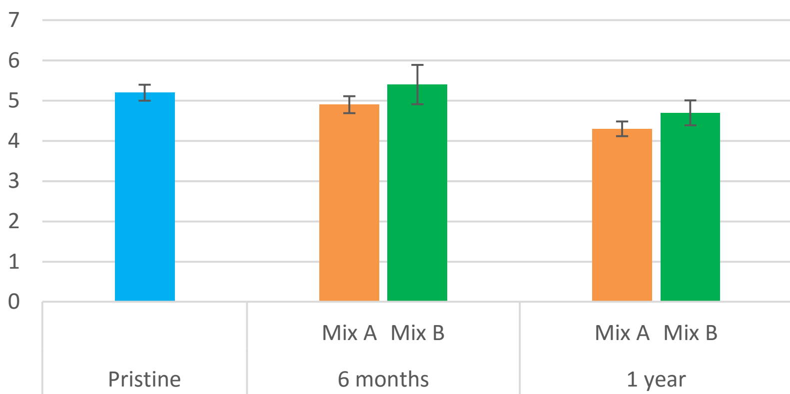




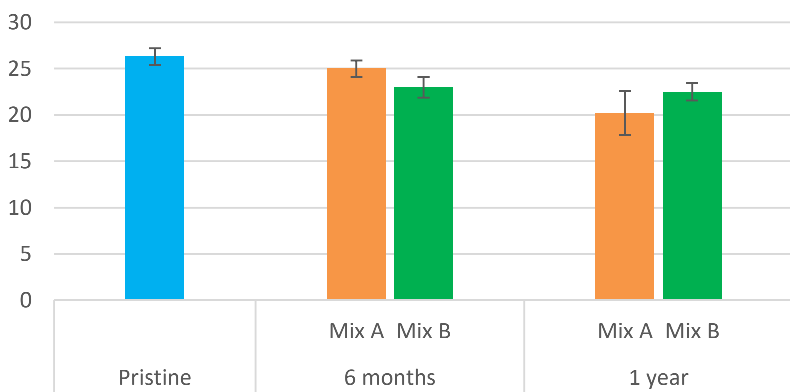
Durability of Embedded GFRP Bars

Infravation
An Infrastructure Innovation Programme

Horizontal Shear Strength (ksi)



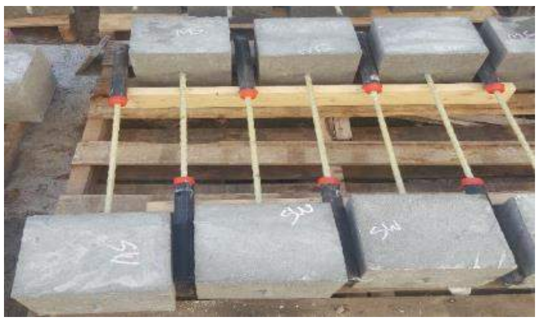
Transverse Shear Strength (ksi)

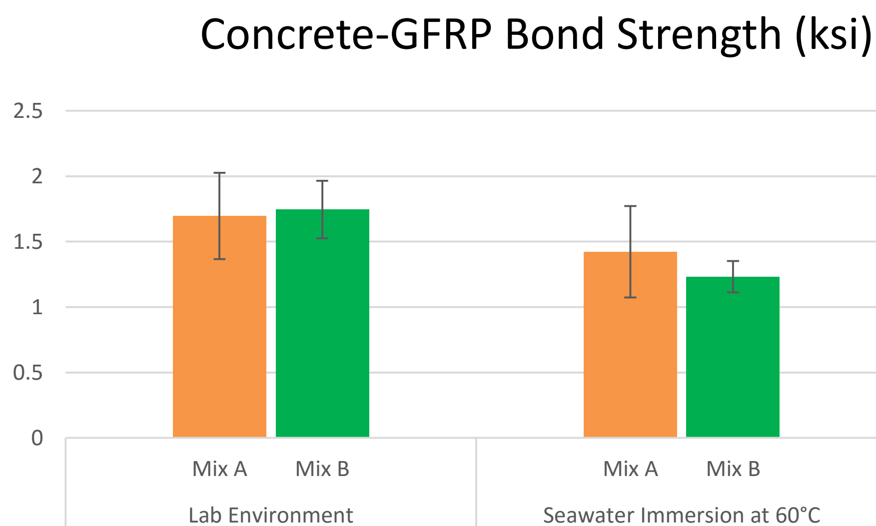


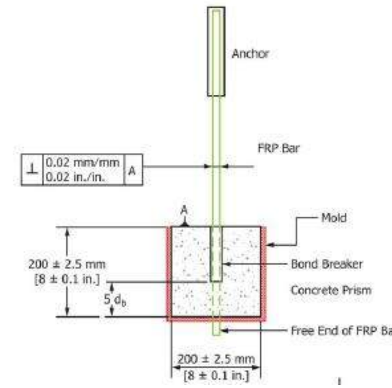
Durability of Embedded GFRP Bars

Infravation
An Infrastructure Innovation Programme

The relative bond between GFRP rebars and concrete was experimentally determined by pullout testing (ACI 440.3R)



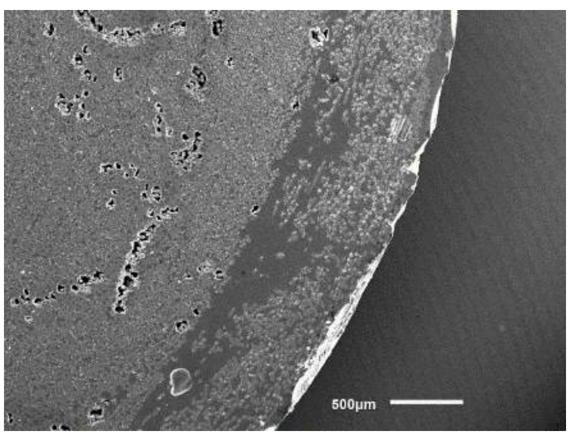


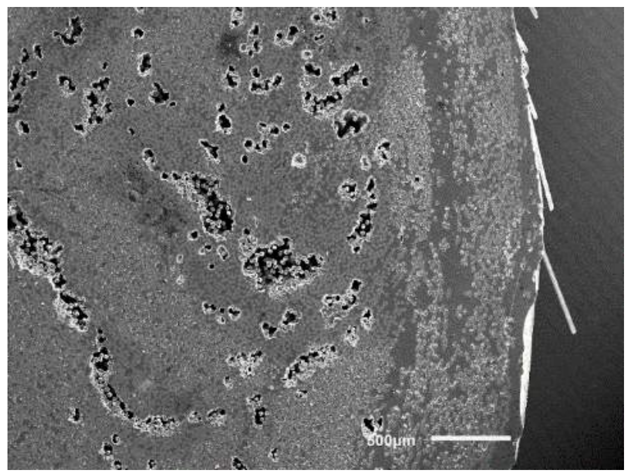


Durability of Embedded GFRP Bars

SEM is being used to evaluate potential degradation at GFRP microstructure and GFRP-concrete interface. The edge of extracted GFRP bars which is prone to degradation was imaged

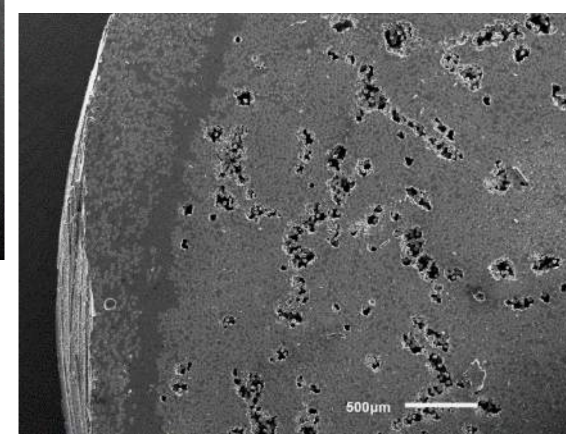
Mix A (Conventional Concrete)





Pristine

Mix B (Seawater Concrete)



Conclusions

- HRB a landmark bridge not only for Florida, but the nation and the world
- HRB as an opportunity to validate new technology and allow FDOT to deploy it in the immediate future
- HRB as the testbed for sustainability:
  - Fresh and hardened properties of SEACON evaluated
  - Mechanical behavior of SEACON after exposure to different aging conditions comparable to conventional concrete
  - Residual mechanical and physical properties of embedded GFRP bars aged in different environments show no degradation
  - Microstructure of embedded GFRP bars shown unaltered using SEM imaging

Presenters' Contact Information

Assistant District Structures Design Engineer
Elisha Masséus, P.E.
(305) 470-5444
Elisha.Masseus@dot.state.fl.us

FAMU-FSU College of Engineering
Michelle Roddenberry, Ph.D., P.E.
(850) 410-6125
mroddenberry@fsu.edu

Astaldi Construction Corporation
Gianbattista Mazzocchi (Project Engineer)
(305) 284-3391
g.mazzocchi@astaldi.com

University of Miami
Antonio Nanni, Ph.D., P.E.
(305) 284-3391
nanni@miami.edu

Other Team Members

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

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

Design 7 Structures Office / EOR
Mamun Siddiqui, P.E. (Designer)
(813) 975-6093
Mamunur.Siddiqui@dot.state.fl.us

State Materials Office
Chase C. Knight, Ph.D.
(352) 955-6642
Chase.Knight@dot.state.fl.us


Thank you!
aerial
Innovations