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FRP Constructability Issues and Coordination

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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

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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***, and ***NATM works.***

FRP in Tunneling

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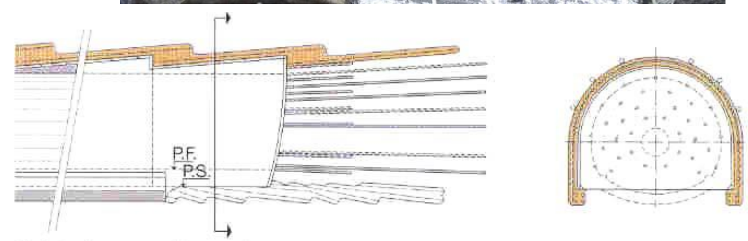
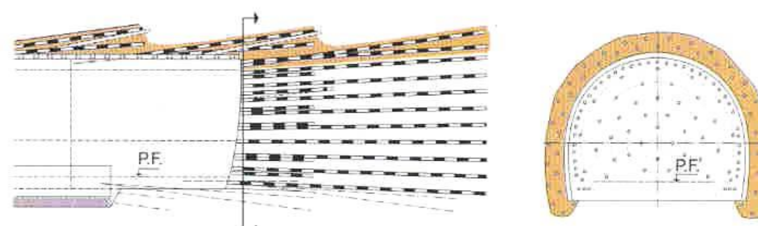
- Use of 'Soft Eye' in breakthroughs of Tunnel Boring Machines (TBMs) in stations/shafts.
- Use of Glass FRP reinforcements for tunnel face strengthening in soft ground NATM tunnels works.



Solution by means of jet-grouting

Silty sands and sandy silts



Solution by means of FGT + FGT

Clayey silts and silty clays

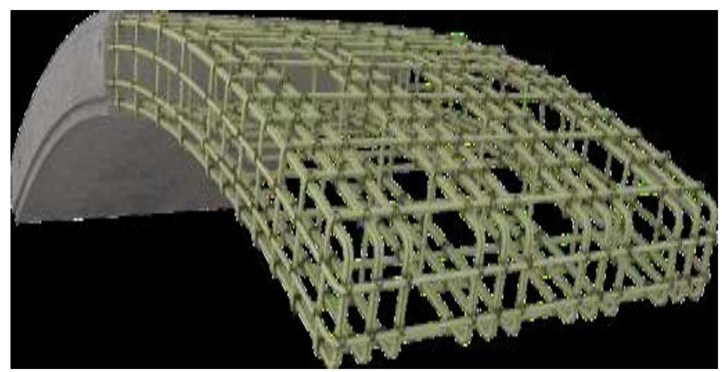
FRP in Permanent Works

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

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FLORIDA TRANSPORTATION BUILDERS' ASSN. INC. 1933 FTBA

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Construction Considerations

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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

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- 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

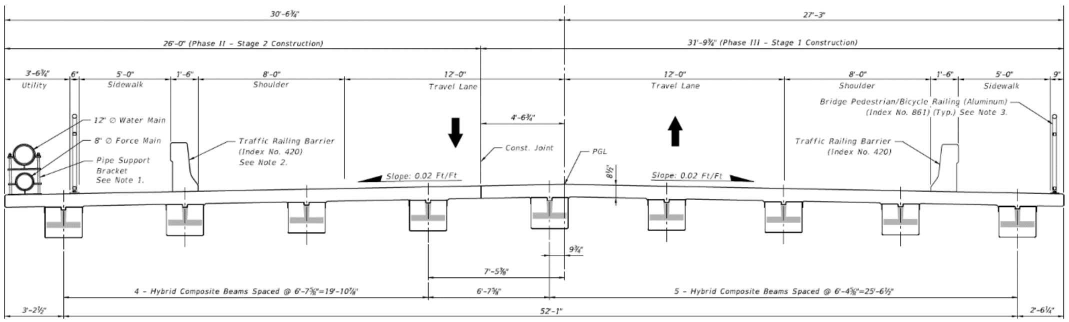
Advantages:

- 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

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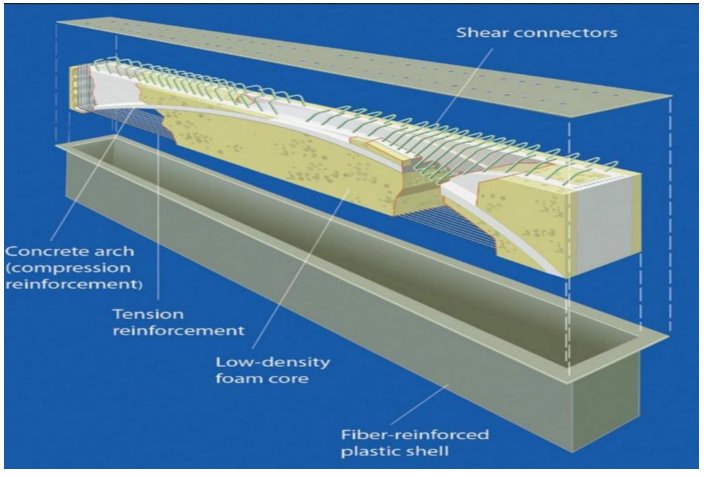
- FRP reinforcement for main deck slab
- Hillman Composite Beams (HCB)
- Carbon FRP reinforcements and pre-stressing for 18”piles
- Precast concrete sheet piles with carbon FRP reinforcements and pre-stressing
- Precast concrete sheet piles with external FRP reinforcements and central steel pre-stressing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

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

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  - SEACON
  - Concrete mixtures
  - Lab testing

SEACON Project

- 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

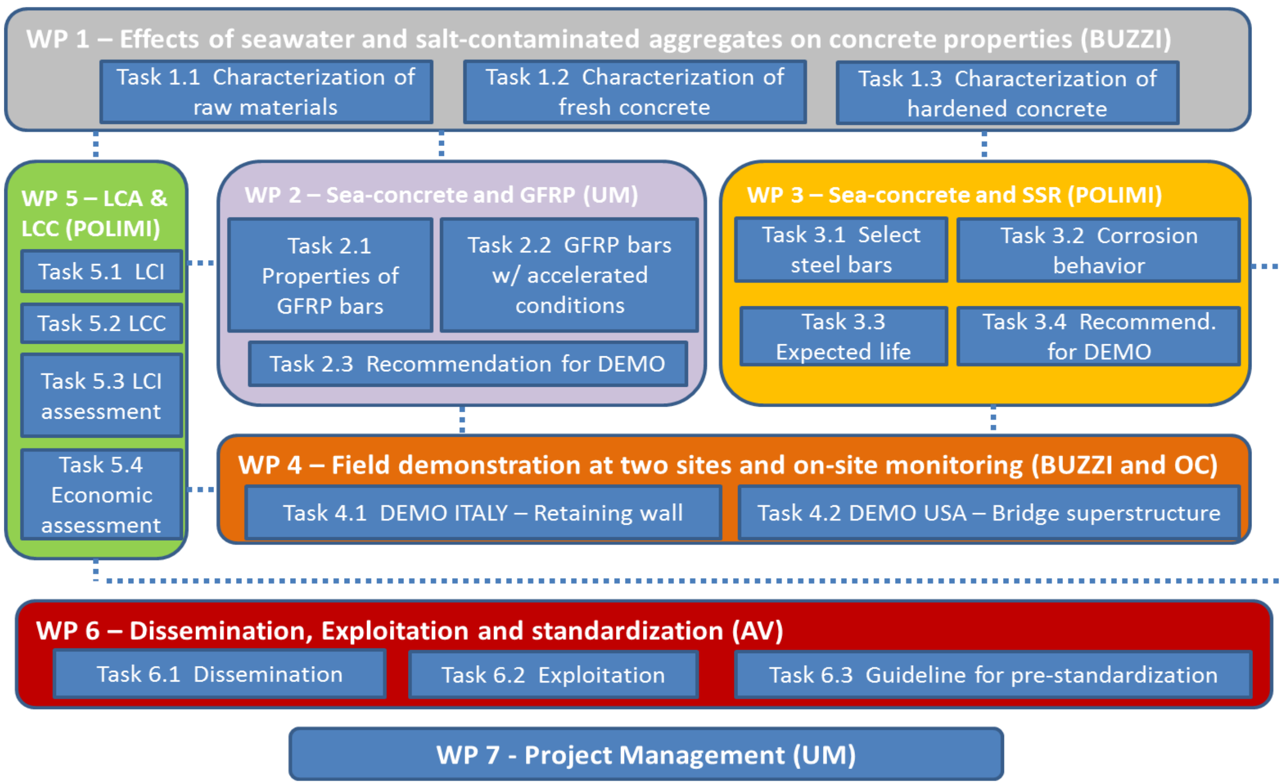
- University of Miami (UM)
- Owens Corning (OC)
- ATP srl (ATP)
- Politecnico di Milano (POLIMI)
- Buzzi Unicem (BUZZI)
- Acciaierie Valbruna (AV)

Collaborators

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

SEACON Project

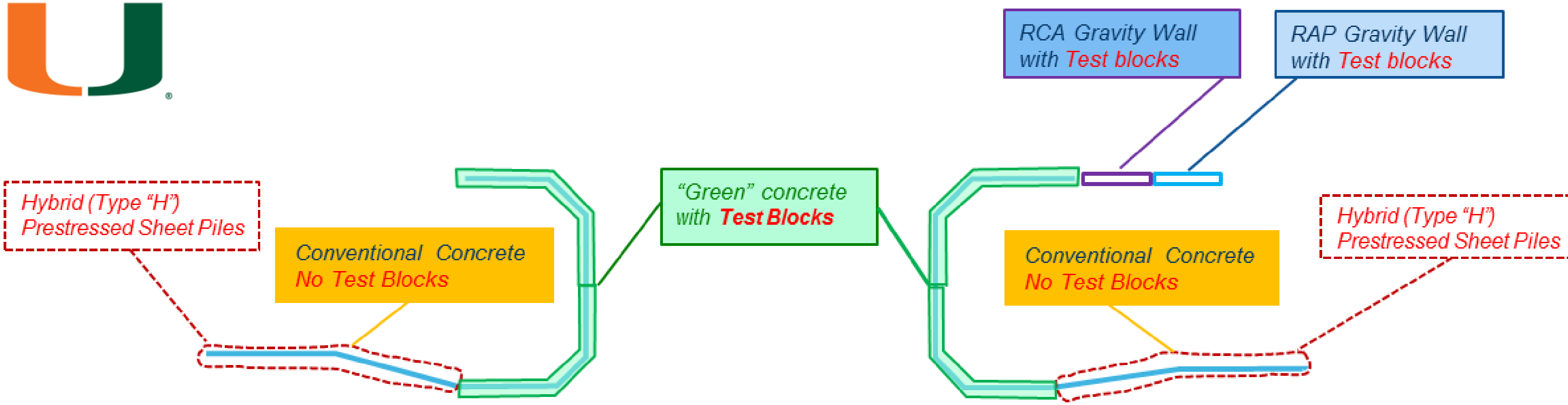
This project titled "Sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement" or SEACON was funded under the aegis of the European research program called Infravation (**seacon.um-sml.com**)



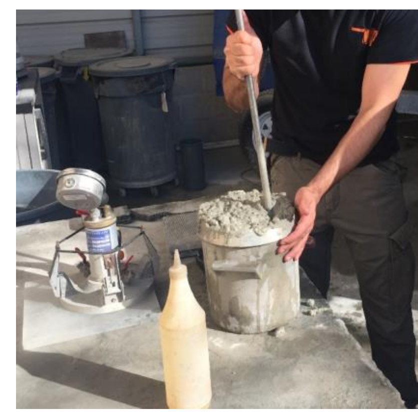
SEACON Project - Objectives

- 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)

Halls River Bridge Concrete Mixtures

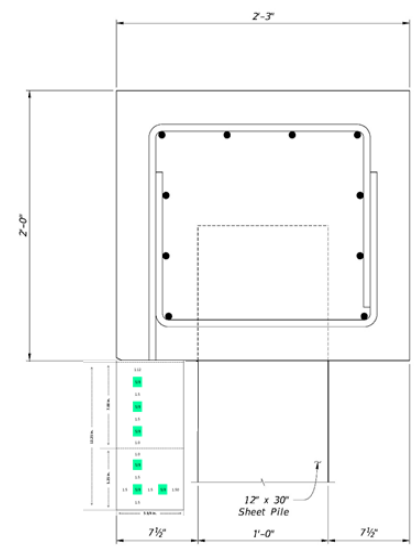


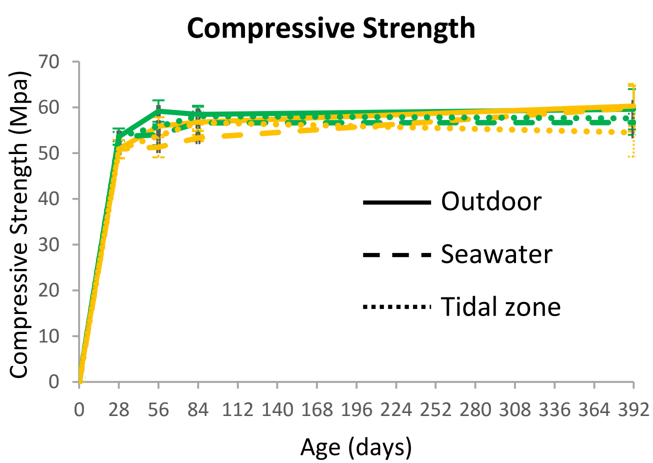
1. Conventional Concrete (Class IV)
2. Green Concrete
3. Concrete with Recycled Concrete Aggregate (RCA)
4. Concrete with Recycled Asphalt Pavement (RAP)
5. White Cement Concrete (Class IV)
6. 60% Slag Concrete (Class IV)



Green Concrete

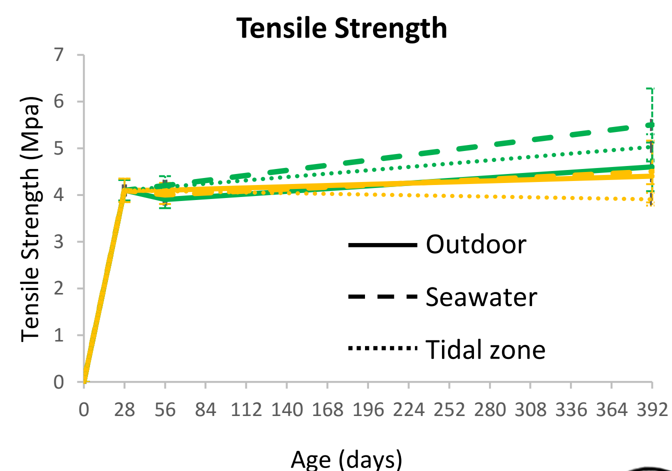
- Bulkhead caps and test blocks
- Test blocks with Glass, Basalt and Carbon FRP reinforcement
- Proportion of Class IV but fresh water replaced with seawater by 100%.
- Retarding agent to offset acceleration effect of chlorides
- Long-term durability is comparable to conventional concrete





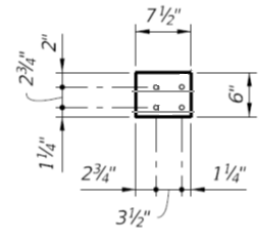
Conventional Concrete

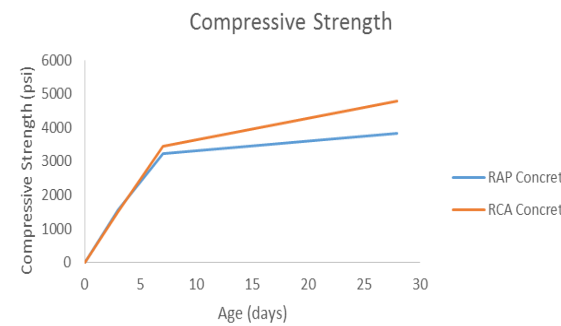
Green Concrete

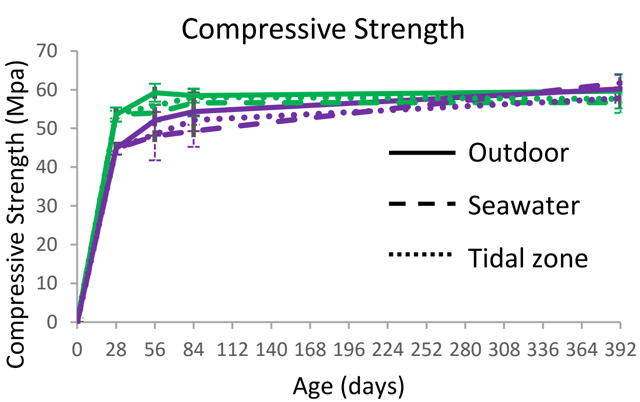


RCA and RAP Concrete

- 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

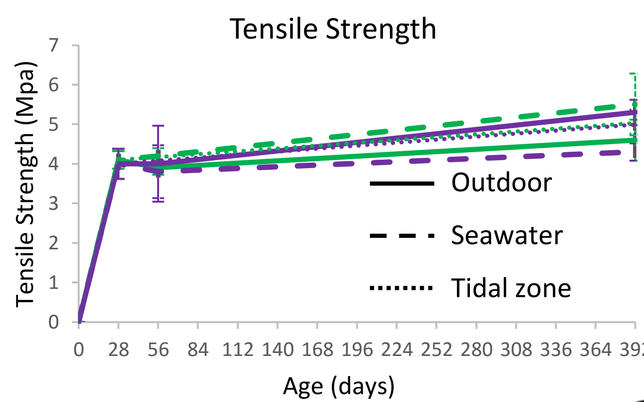






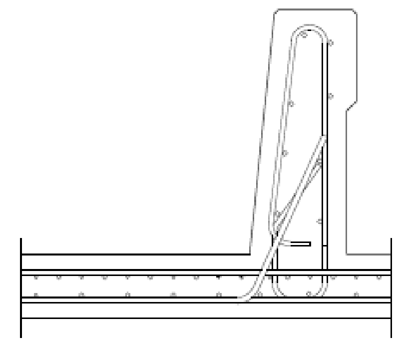
Conventional Concrete

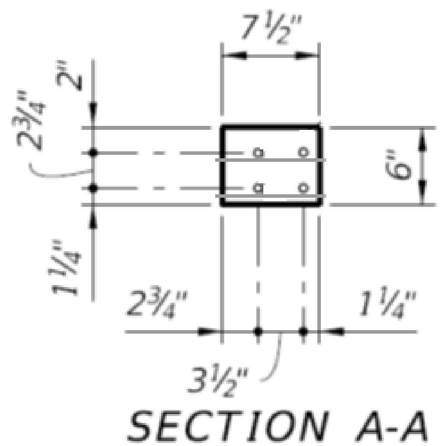
RCA Concrete

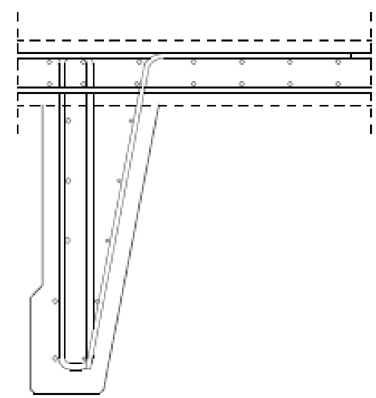


White-cement and 60%-slag concretes

- 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





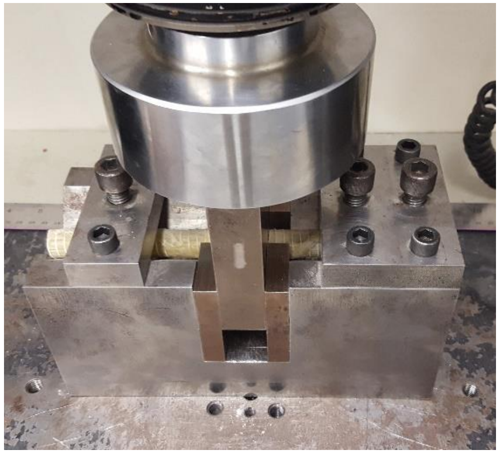


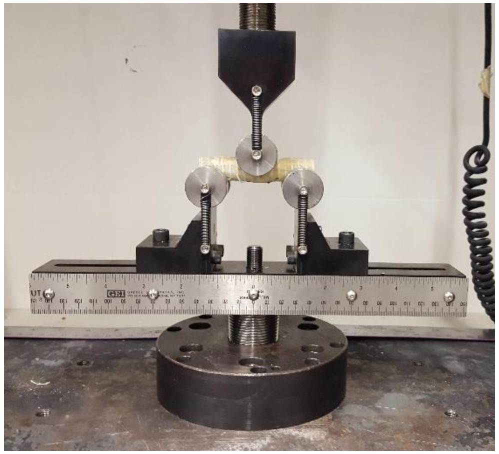
Lab Testing: Durability of GFRP bars embedded in Green Concrete

- 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

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





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