RC 2018 XVII Reunión del CONCRETO

El evento del Cemento, el Concreto y los Prefabricados

RC 2018 XVII Reunión del CONCRETO

El evento del Cemento, el Concreto y los Prefabricados

Estructuras de concreto con refuerzos no metálicos

Antonio Nanni

University of Miami and American Concrete Institute

USA

Todo el Concreto está en Asocreto

American Concrete Institute
Always advancing

ACI is …

a technical and educational society dedicated to improving:

- design
- construction
- maintenance
- repair

One of the world's largest sources of concrete knowledge

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- **Applications in Florida**
  - ✓ FDOT application and UM R&D
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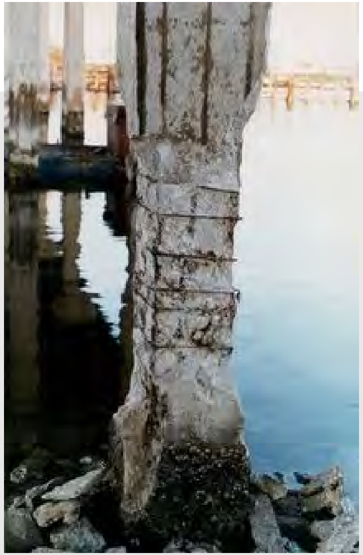
  - ✓ Acknowledgements

FRP = Fiber Reinforced Polymer

PROBLEM STATEMENT

- Failure mechanism for structures exposed to aggressive environments is often corrosion of the steel reinforcement
- Chlorides from de-icing salts or seawater penetrate concrete and reach steel
  - ✓ Via cracks
  - ✓ Via concrete permeability
- Corrosion is accelerated by carbonation of concrete that lowers the pH



SERVICE LIFE OF STRUCTURES GREATLY REDUCED BY CORROSION

STATE OF THE PRACTICE

Picture: Courtesy of TxDOT

Traditional corrosion mitigation efforts center on keeping chlorides from getting to reinforcing steel or simply delaying diffusion their time

- Admixtures
- Increase Concrete Cover
- Alter Concrete Mix
- Membranes & Overlays
- Epoxy-coated, Galvanized or Stainless Steel

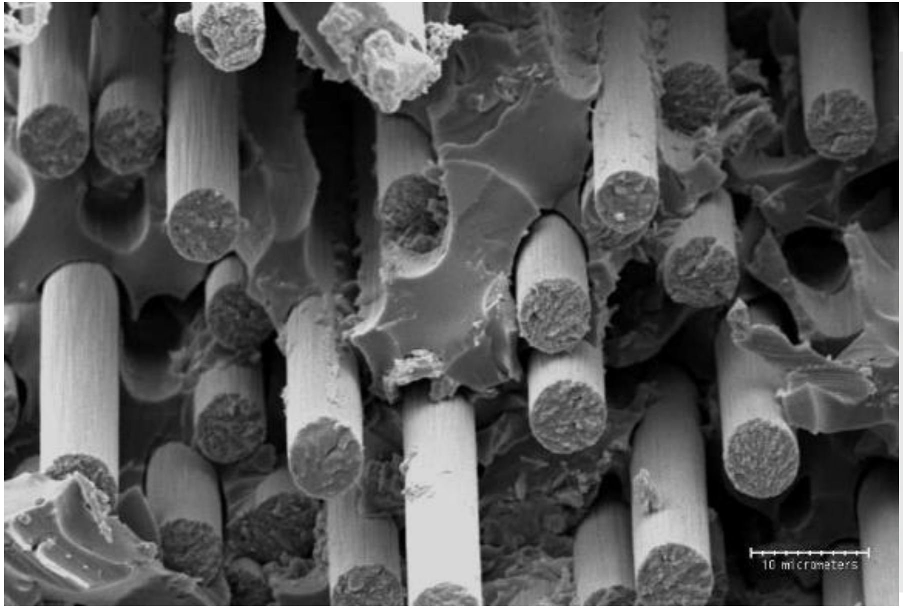
DELAYING THE SYMPTOMS RATHER THAN CURING THE DISEASE

STATE OF THE PRACTICE

INSTEAD OF MITIGATION WHY NOT ELIMINATE THE PROBLEM?

SIMPLE SOLUTION TO GET AN EXTENDED SERVICE LIFE

WHAT IS GFRP?

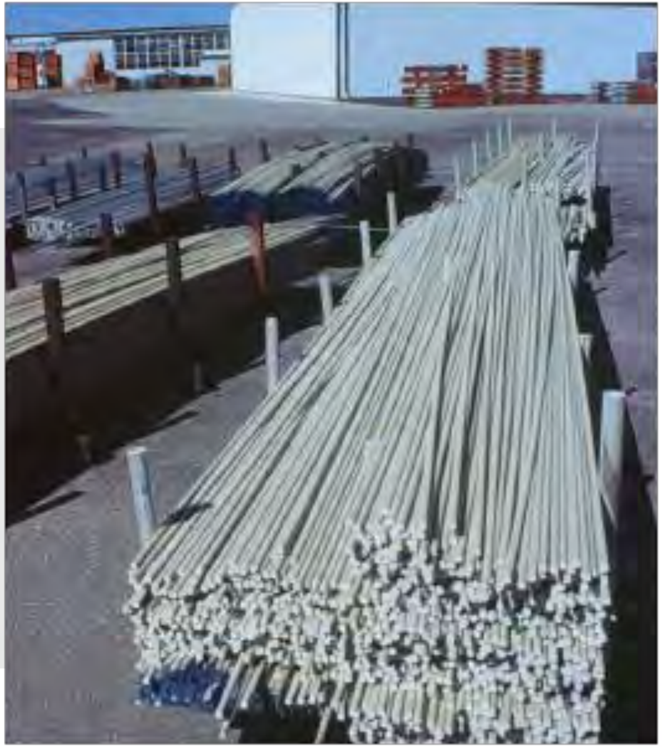


- **Fiber** - Structural element
  - E-CR Glass
- **Matrix** - Binder
  - Vinyl Esther

GLASS FIBER REINFORCED POLYMER

WHERE SHOULD FRP BE USED?

- Any concrete member susceptible to:
  - ✓ Steel corrosion by chlorides
  - ✓ Low concrete pH
- Any concrete member requiring non-ferrous reinforcement due to
  - ✓ Electro-magnetic considerations
  - ✓ Thermal non-conductivity
- Where machinery will "consume" RC member (i.e., mining and tunneling)



ALTERNATIVE TO EPOXY, GALVANIZED AND STAINLESS STEEL REBAR

MINING AND TUNNELING

GFRP bars as temporary reinforcing for TBM (Tunnel Boring Machine) construction

CIVIL ENGINEERING APPLICATIONS

- Seawalls, Piles and Piers
- Marine Structures
- Bridge Decks and Traffic Railings
- Approach Slabs
- Barrier and Retaining Walls
- Culverts
- Sewage Tunneling
- Parking Garages
- Buildings

READY FOR PRIME TIME

- Structure design defined by ACI & AASHTO
- Rebar properties defined by ASTM D7957
- 500+ installations in US & Canada
- Traditional procurement & construction methods

Source: I-635 Bridge over State avenue Kansas City study. 2014 ACI 440.1R-06, AASHTO Load Resistance Design Factors 2009, ACMA RMC presentations

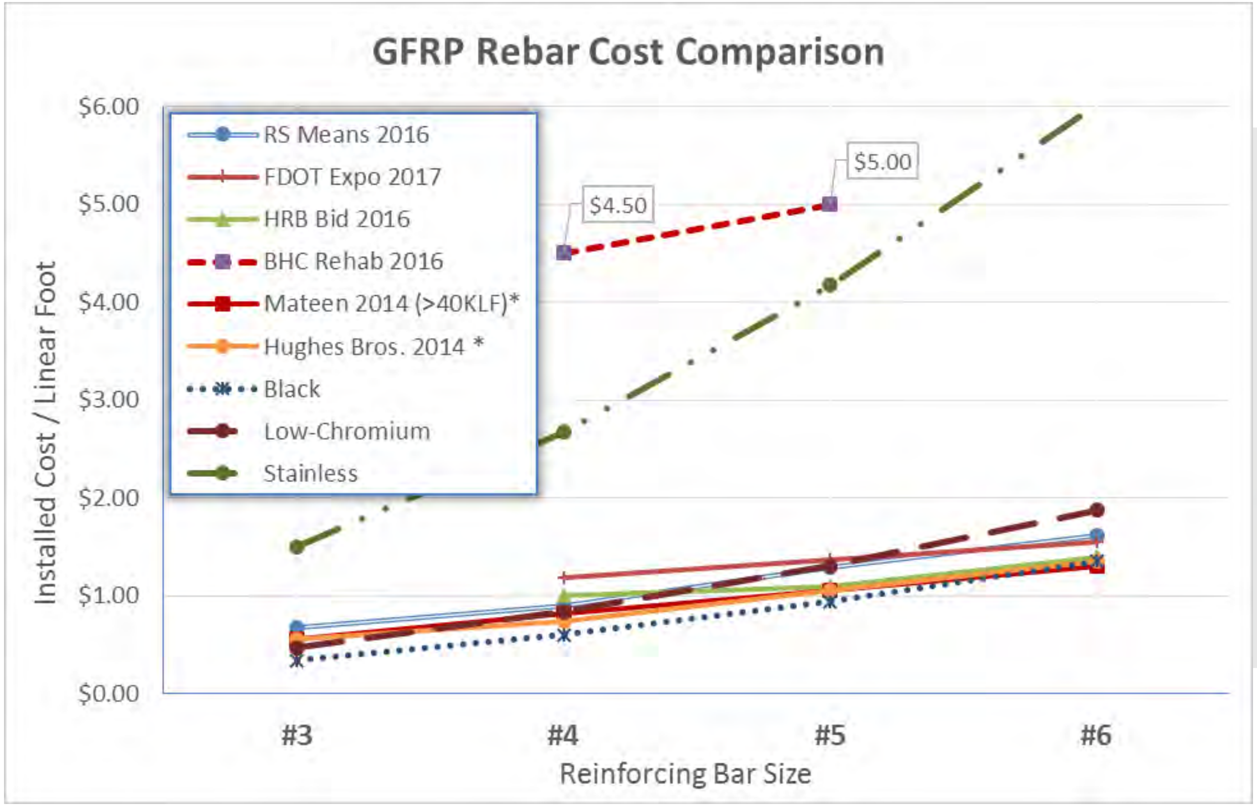
REPLACING TRADITIONAL MATERIALS WITH INNOVATIVE AND COST EFFECTIVE MATERIALS

KEY BENEFITS

- Corrosion Resistant
- High strength-to-weight ratio
- Ease of application & installation
- ¼ the weight of steel
- Transparent to magnetic fields and radar frequencies
- Electrically and thermally non-conductive

FIRST COST IS COMPARABLE WITH EPOXY COATED STEEL

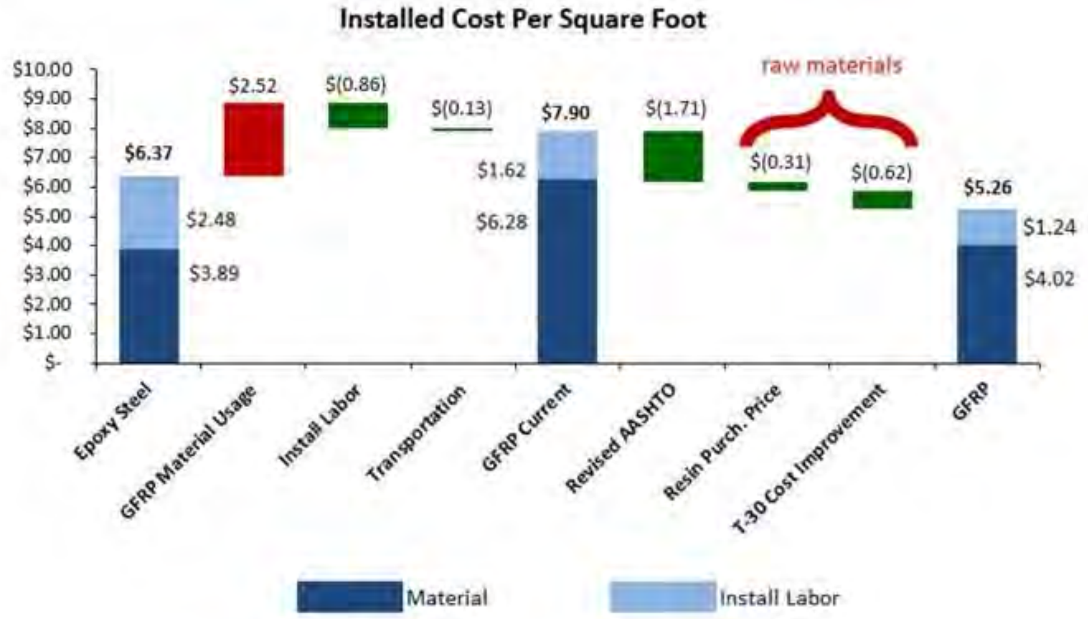
COST COMPARISONS



Bid Tabulation for GFRP reinforcing on Bakers Haulover Cut (BHC) bridge rehabilitation project in Miami-Dade County compared to materials (Black, Low-Chromium & Stainless Steel), other estimates and Halls River Bridge project bids

COST COMPARISONS

COST COMPARISON GFRP v. STEEL



Source: Owens Corning estimates based on research and interviews

Bridge deck construction costs

Comparison being verified now with input from manufacturers, designers and contractors for bridges under construction in Ohio

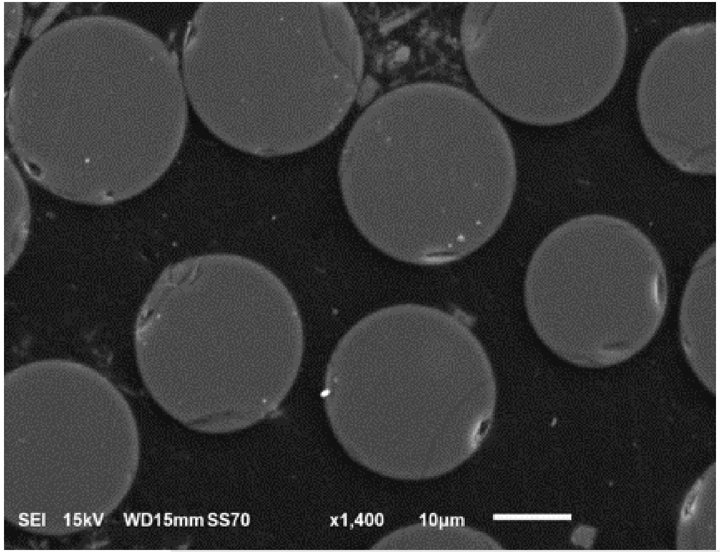
COST COMPARISON WITH EPOXY COATED STEEL

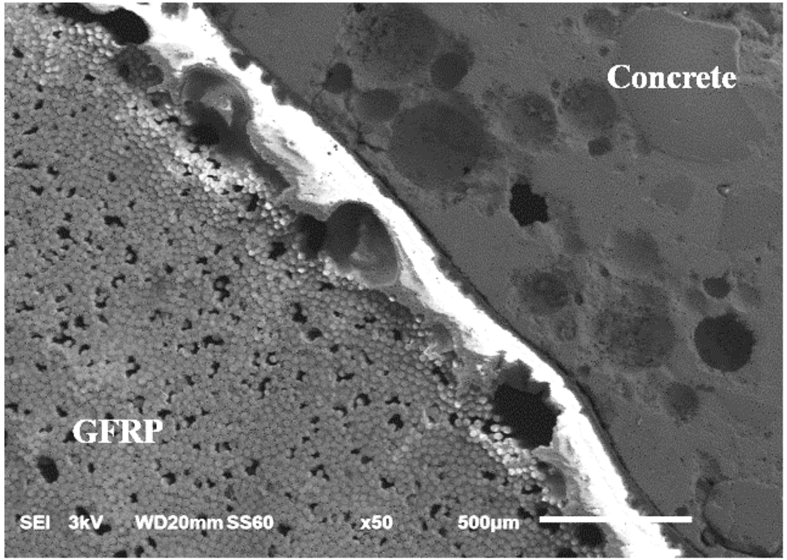
PROVEN HISTORICAL DURABILITY

Samples extracted from bottom surface of culvert boxes of Walker and deck of the Southview bridges (1999 construction date)

GFRP coupons properly prepared and polished for microscopic examination and mechanical tests

PROVEN HISTORICAL DURABILITY



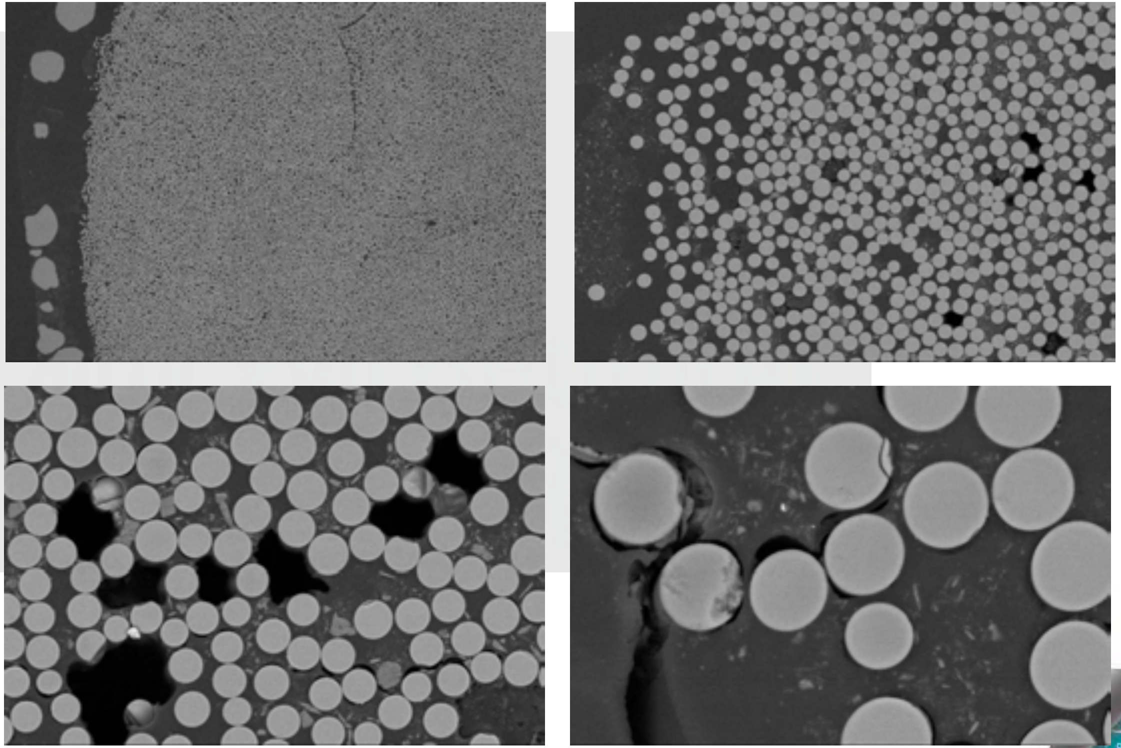


Source: Long-term Durability of GFRP Reinforcement in Concrete: A Case Study after 15 Years of Service - O. Gooranorimi, E. Dauer, J. Myers, A. Nanni

NO SIGN OF BOND DEGRADATION NOR LOSS OF CONTACT AND MECHANICAL PROPERTIES AFTER 15 YEARS IN SERVICE

Gills Creek GFRP bar samples - SEM analysis

- Extracted from Gills Creek bridge
- Core 4 bar 2
- SEM
  - Zeiss SEM
  - EHT = 20.00 kV
  - WD = 8.5, 9.0 mm
  - NTS BSD

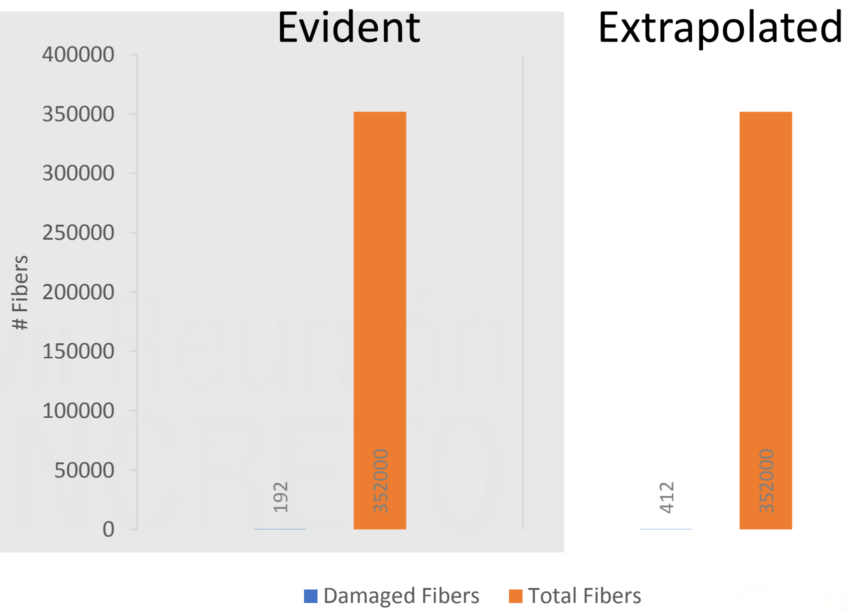


PROVEN HISTORICAL DURABILITY

Estimation of affected fibers – Gills Creek

Fibers being negatively affected by concrete environment after 15 years in service: **0.05 to 0.12 %** of total fibers. Much less than predicted by accelerated test methods. Negligible impact on mechanical properties

- Fibers evidently affected (**192 out of 352,000**) estimated from counting fibers with obvious signs of damage (possibly affected fibers: **412 out of 352,000**)



Affected fibers on outer edge of bar

CONSTRUCTABILITY ADVANTAGES




TRANSPORATION	HANDLING	INSTALLATION	SAFETY
• Fit more than twice material in one shipment • Use lighter mechanical equipment to unload	• Half number of trips from storage to site • More durable than epoxy coating	• Faster placement due to lightweight • Reduce rework with labeling	• Reduced risk score for lifting activities • Reduced number of slips, trips, falls

Source: Owens Corning estimates based on research and interviews

Reduced Overall System Cost

CONSTRUCTION PECULIARITIES

- Lap splices longer
- Tying with plastic coated wire
- Handling same as epoxy-coated steel
- Tie mat down in a few areas
- Support chairs at 2/3rd conventional spacing
- Watch for abrasion
- Bid by foot rather than pound
- May need multiple pick-up points

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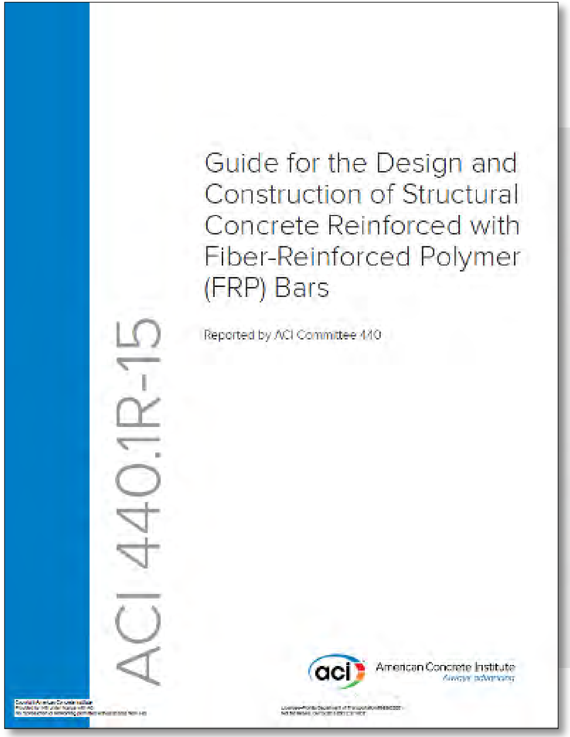
HOW TO SPECIFY



Guide for the Design and Construction of Structural Concrete Reinforced with Fiber-Reinforced Polymer (FRP) Bars

Reported by ACI Committee 440

ACI 440.1R-15

American Concrete Institute
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ACI 440.5-08

Specification for Construction with Fiber-Reinforced Polymer Reinforcing Bars

An ACI Standard

Reported by ACI Committee 440

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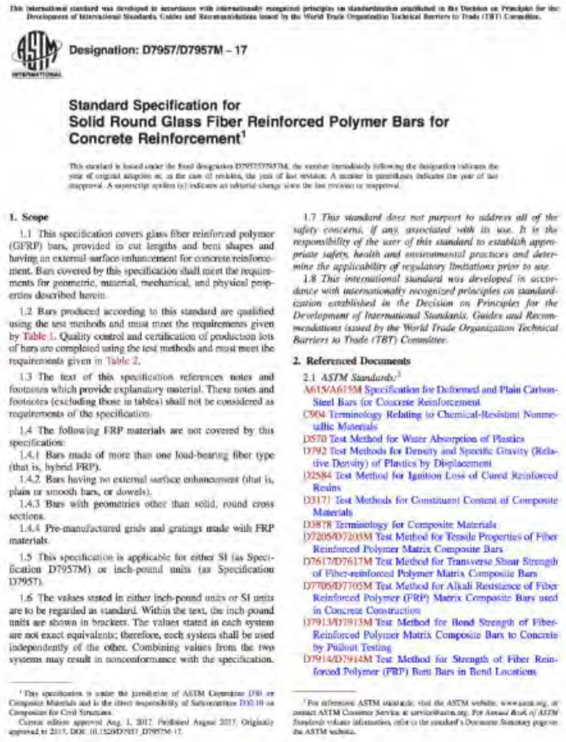


This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: D7957/D7957M – 17

Standard Specification for
Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement[1]

This standard is issued under the fixed designation D7957/D7957M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers glass fiber reinforced polymer (GFRP) bars, provided in cut lengths and bent shapes and having an external surface enhancement for concrete reinforcement. Bars covered by this specification shall meet the requirements for geometric, material, mechanical, and physical properties described herein.

1.2 Bars produced according to this standard are qualified using the test methods and must meet the requirements given by Table 1. Quality control and certification of production lots of bars are completed using the test methods and must meet the requirements given in Table 2.

1.3 The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables) shall not be considered as requirements of the specification.

1.4 The following FRP materials are not covered by this specification:

1.4.1 Bars made of more than one load-bearing fiber type (that is, hybrid FRP).

1.4.2 Bars having no external surface enhancement (that is, plain or smooth bars, or dowels).

1.4.3 Bars with geometries other than solid, round cross sections.

1.4.4 Pre-manufactured grids and gratings made with FRP materials.

1.5 This specification is applicable for either SI (as Specification D7957M) or inch-pound units (as Specification D7957).

1.6 The values stated in either inch-pound units or SI units are to be regarded as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

1.7 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health and environmental practices and determine the applicability of regulatory limitations prior to use.

1.8 This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

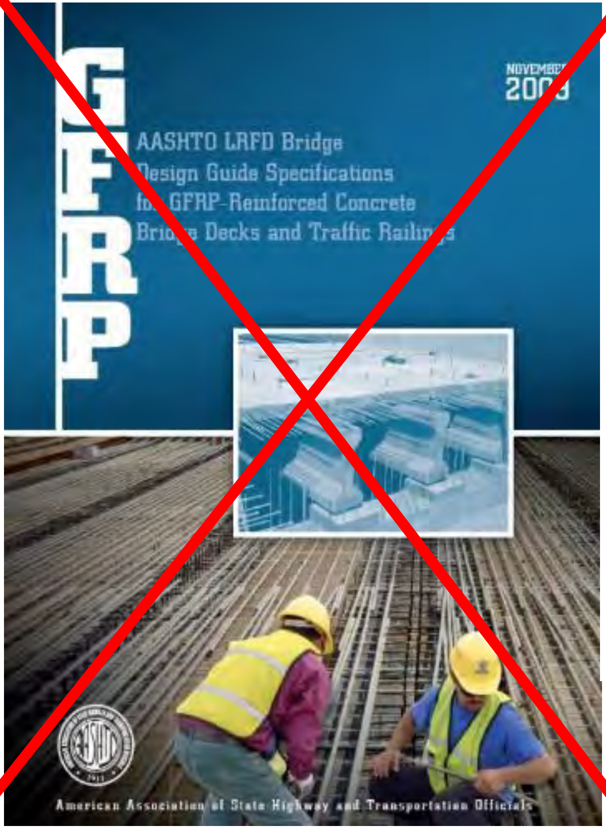
A615/A615M Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
C904 Terminology Relating to Chemical-Resistant Nonmetallic Materials
D570 Test Method for Water Absorption of Plastics
D792 Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
D2584 Test Method for Ignition Loss of Cured Reinforced Resins
D3171 Test Methods for Constituent Content of Composite Materials
D3878 Terminology for Composite Materials
D7205/D7205M Test Method for Tensile Properties of Fiber Reinforced Polymer Matrix Composite Bars
D7617/D7617M Test Method for Transverse Shear Strength of Fiber-reinforced Polymer Matrix Composite Bars
D7705/D7705M Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction
D7913/D7913M Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing
D7914/D7914M Test Method for Strength of Fiber Reinforced Polymer (FRP) Bent Bars in Bend Locations

[1] This specification is under the jurisdiction of ASTM Committee D30 on Composite Materials and is the direct responsibility of Subcommittee D30.10 on Composites for Civil Structures.
Current edition approved Aug. 1, 2017. Published August 2017. Originally approved in 2017. DOI: 10.1520/D7957_D7957M-17.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

SPECIFYING AND CONSTRUCTION WITH GFRP BARS

HOW TO DESIGN FOR TRANSP. STRUCTURES



2018

AASHTO LRFD BRIDGE DESIGN GUIDE SPECIFICATIONS FOR GFRP REINFORCED CONCRETE – 2ND EDITION

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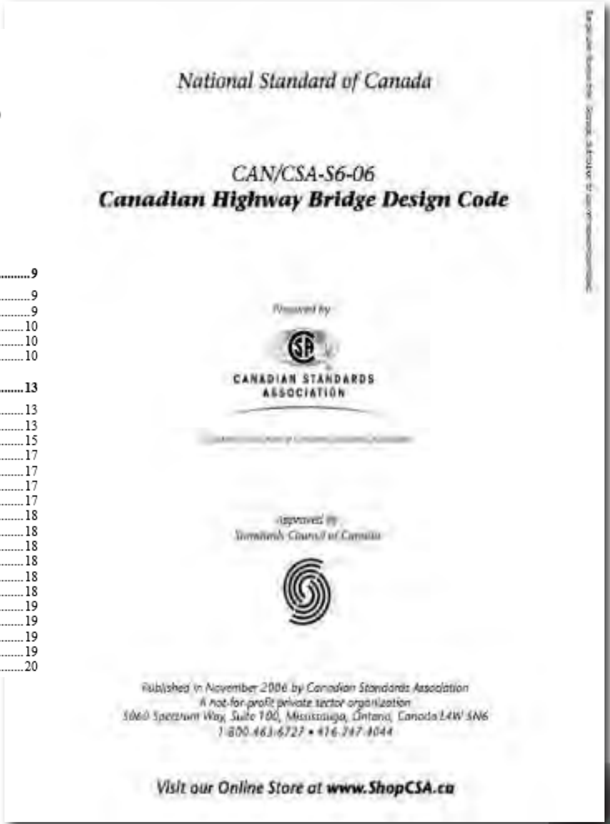
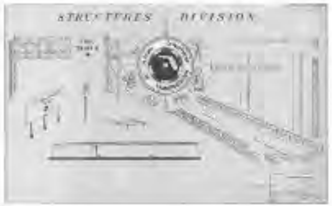


HOW TO SPECIFY IN FLORIDA

FLORIDA DEPARTMENT OF TRANSPORTATION



FIBER REINFORCED POLYMER GUIDELINES (FRPG)

FDOT STRUCTURES MANUAL
VOLUME 4
JANUARY 2016

FDOT

Specifications and Estimates/Specifications/

Materials Manual Section 12.1, Volume II

FIBER REINFORCED POLYMER COMPOSITES

Section 12.1, Volume II

Structures Design

Structures Design / Design Innovation

Fiber Reinforced Polymer Reinforcing

Structures Design - Transportation Innovation

Fiber Reinforced Polymer (FRP) Reinforcing Bars and Strands

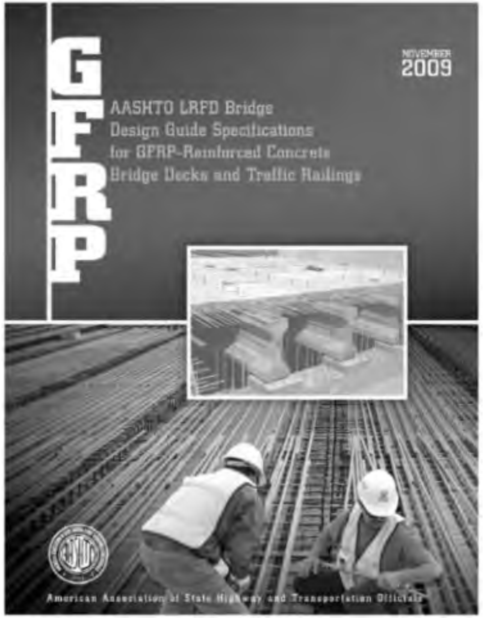
- Overview
- Usage Restrictions / Parameters
- Design Criteria
- Specifications
- Standards
- Producer Quality Control Program
- Technology Transfer (T^2)
- Contact

EXISTING GUIDELINES IN NORTH AMERICA

- **AASHTO →** GFRP-1 and GFRP-2 2018
- **ACI →** 440.1R-15
  440.3R-12
  440.5-08 and 440.6-08
  440.9R-15
- **FDOT →** 932
- **CAN/CSA →** S06-15
  S806-12
  S807-10

AASHTO DESIGN SPECS FOR GFRP-RC BRIDGES

- From 1st Ed. on decks and railings to complete **Bridge Design Specifications** (**BDS-**GFRP)
- Approved on 06/28/2018 by AASHTO for adoption



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AASHTO LRFD
BRIDGE DESIGN GUIDE SPECIFICATIONS
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APPROACH AND RELEVANCE

- **Harmonize** with national (ACI, ASTM and AASHTO-BDS) and international (CSA) specifications.
  - Ease design/deployment
  - Ease certification
  - Enlarge market
- **Update** existing provisions to reflect better materials and manufacturing, and new research findings.
  - Make design more efficient
- **Expand** provisions to include all members of a bridge.
  - Allow the design of a bridge entirely GFRP-RC

CONTENTS COMPARISON

Chapter/Section AASHTO 2nd	AASHTO 2nd 2018	AASHTO 1st 2009	ACI 440.1R 2015	CSA 2014
2. Concrete Structures				
• Flexural elements	x	x	x	x
• Compression	X			
• Shear	x	x	x	x
• Torsion	X			
3. Decks	x	x		x
4. Substructures	X			
5. Railings	x	x		x
6. Mat. & Construction	x	x	x	x

CRITICAL DESIGN PROVISIONS

Capacity provisions

$$f_{fd} = \boldsymbol{C_E}\, f_{fu}^{*}$$

GFRP Design Strength

$$M_n = \begin{cases} \Phi_C\, A_f f_f \left(d - \dfrac{0.8\,x}{2}\right) & \varepsilon_c = \varepsilon_{cu} \\ \Phi_T\, A_f \boldsymbol{f_{fd}} \left(d - \dfrac{0.8\,x}{2}\right) & \varepsilon_c = \varepsilon_{fd} \end{cases}$$

Flexural Resistance

$$V_n = \Phi_S\,(V_c + V_f)$$

Shear Resistance

CRITICAL DESIGN PROVISIONS

Serviceability provisions

$$f_{f,c} = C_c \, C_E \, f_{fu}$$

GFRP Creep Rupture Strength

$$f_{f,f} = C_f \, C_E \, f_{fu}$$

GFRP Fatigue Strength

$$s \leq 1.15 \, C_b \frac{E_f w}{f_f} - 2.5 \, c_c$$

Spacing for Crack Control

CRITICAL DESIGN PARAMETERS - COMPARISON

	AASHTO 2nd 2018	AASHTO 1st 2009	ACI 440.1R 2015	CSA 2014	
f_{fu}^*	99.73	99.73	99.73	95.0	Strength percentile
Φ_C	0.75	0.65	0.65	0.75	Res. Fact. concr. failure
Φ_T	0.55	0.55	0.55	0.55	Res. Fact. FRP failure
Φ_S	0.75	0.75	0.75	0.75	Res. Fact. shear failure
C_E	0.70	0.70	0.70	1.0	*Environmental reduction*
C_C	0.30	0.20	0.20	0.25	*Creep rupture reduction*
C_f	0.25	0.20	0.20	0.25	*Fatigue reduction*
C_b	0.80	0.70	0.70	1.0	*Bond reduction*
w	0.7	0.5	0.7 to 0.5	0.5	Crack width limit [mm]
$c_{c,stirrups}$	40	40	50(1)	40	Clear cover [mm]
$c_{c,slab}$	25	20 to 50	20 to 50(1)	40	Clear cover [mm]

(1) ACI 440.5-08 Table 3.1

HARMONIZATION: ASTM & AASHTO-BDS

- 2nd Ed. Refers to **ASTM D7957-17** for material specifications
  - Only vinyl ester GFRP / epoxy GFRP round bars allowed
  - Role separation and eased certification
- Design of GFRP-RC bridge elements follows structure of Bridge Design Specifications for steel-RC/PC (**AASHTO-BDS-17, 8th Ed.**).
  - Same language and integration
  - Familiar environment for the practitioner

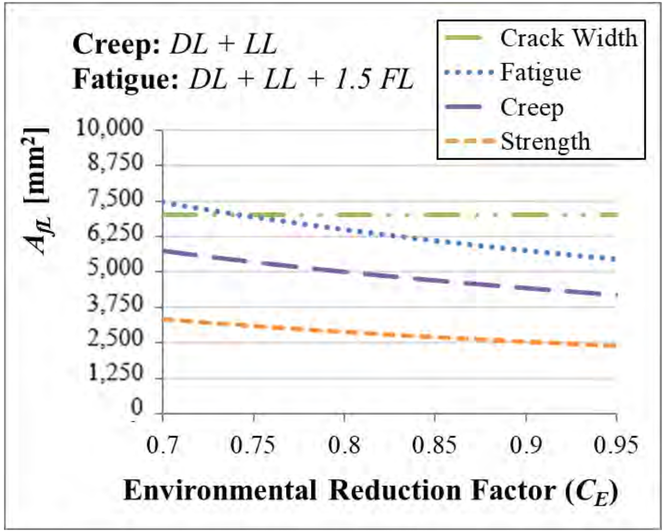
HARMONIZATION: ACI & CSA-CHBDC

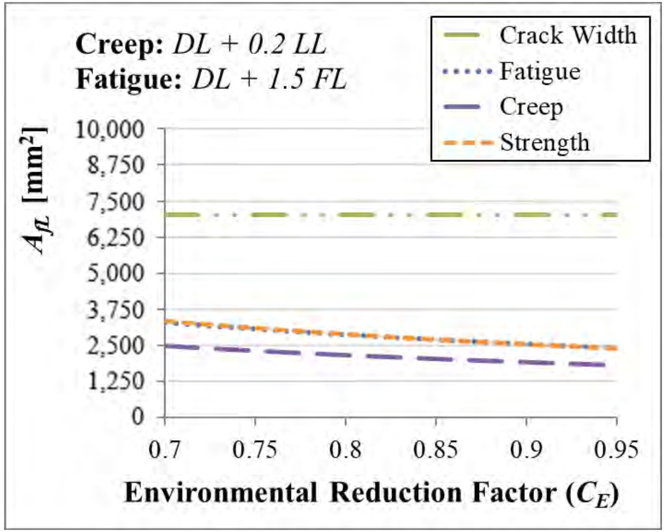
- <u>Inputs</u> from existing guidelines/codes:
  - **ACI 440.1R-15** *"Guide for the Design and Construction of Structural Concrete Reinforced with Fiber Reinforced Polymer Bars"*
  - **CSA S6-14 Section 16** *"Canadian Highway Bridge Design Code: Fibre-Reinforced Structures"*

- <u>Coordination</u> with next-edition (where possible)
  - **ACI 440-19** *"Building Code Requirements for Structural Concrete Reinforced with GFRP Bars"* (under dev.)
  - **CSA S6-19 Section 16** *"Canadian Highway Bridge Design Code: Fibre Reinforced Structures"* (under dev.)

UPDATE: CREEP RUPTURE & FATIGUE (DEMAND)

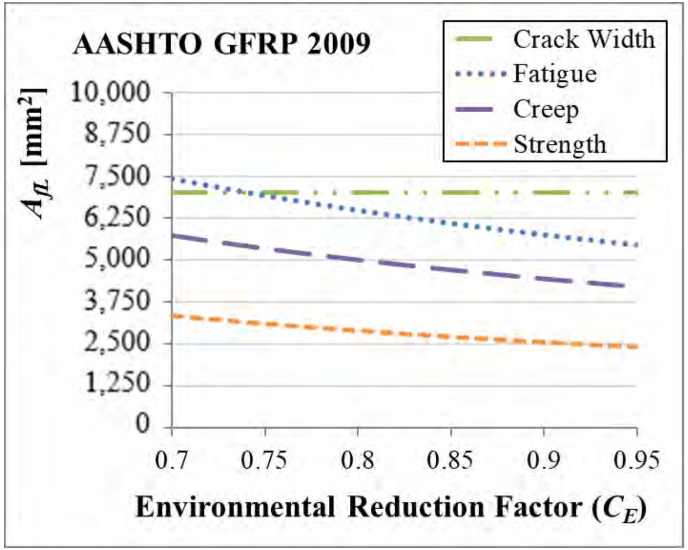
- Rationally defined creep rupture and fatigue load demands
- Only a portion of the **live load** considered **sustained load for creep rupture** calculations
- **Dead load** added to **fatigue load for cyclic fatigue** calculations. Accounts for static/cyclic fatigue coupling

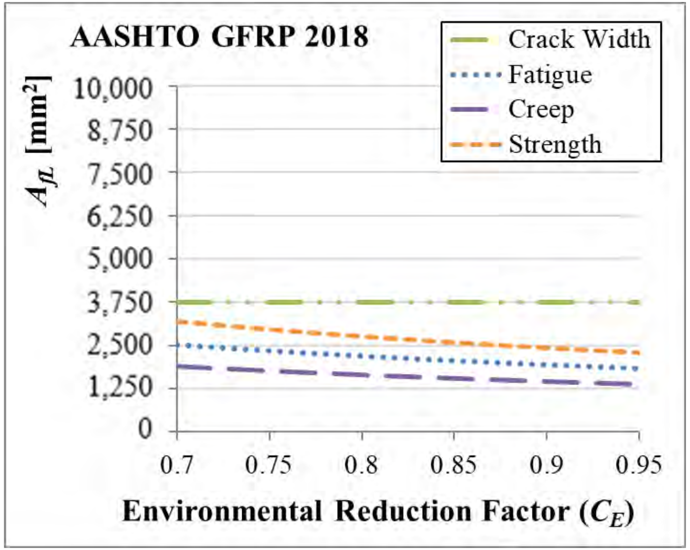




UPDATE: FLEXURAL PARAMETERS (RESISTANCE)

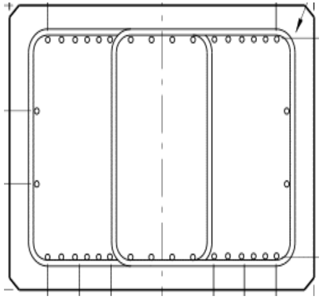
- Updates reflect performances of **ASTM**-certified materials
- **Flexural resistance Φ_C** aligned to **AASHTO BDS-17** (0.65 to **0.75**)
- **Creep** C_c & **fatigue** C_f separated & aligned to **CSA-14** (0.2 to **0.3** & **0.25**)
- **Crack width** w limit aligned to **ACI 440-19** (0.5 to **0.7 mm**)

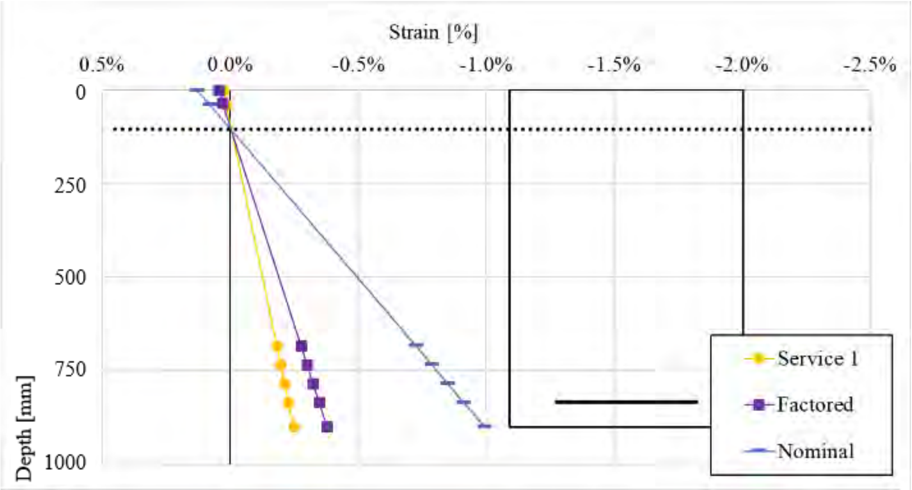




EXPAND: GFRP-RC **BENT CAP**

- Reference Project: ***Halls River Bridge Replacement***.
- Steel-RC 6 Ø25
- GFRP-RC-1st 16 Ø25 **(+ 166%)** not covered in 1st Ed.
- **GFRP-RC-2nd 9 Ø25 (+ 50%)**

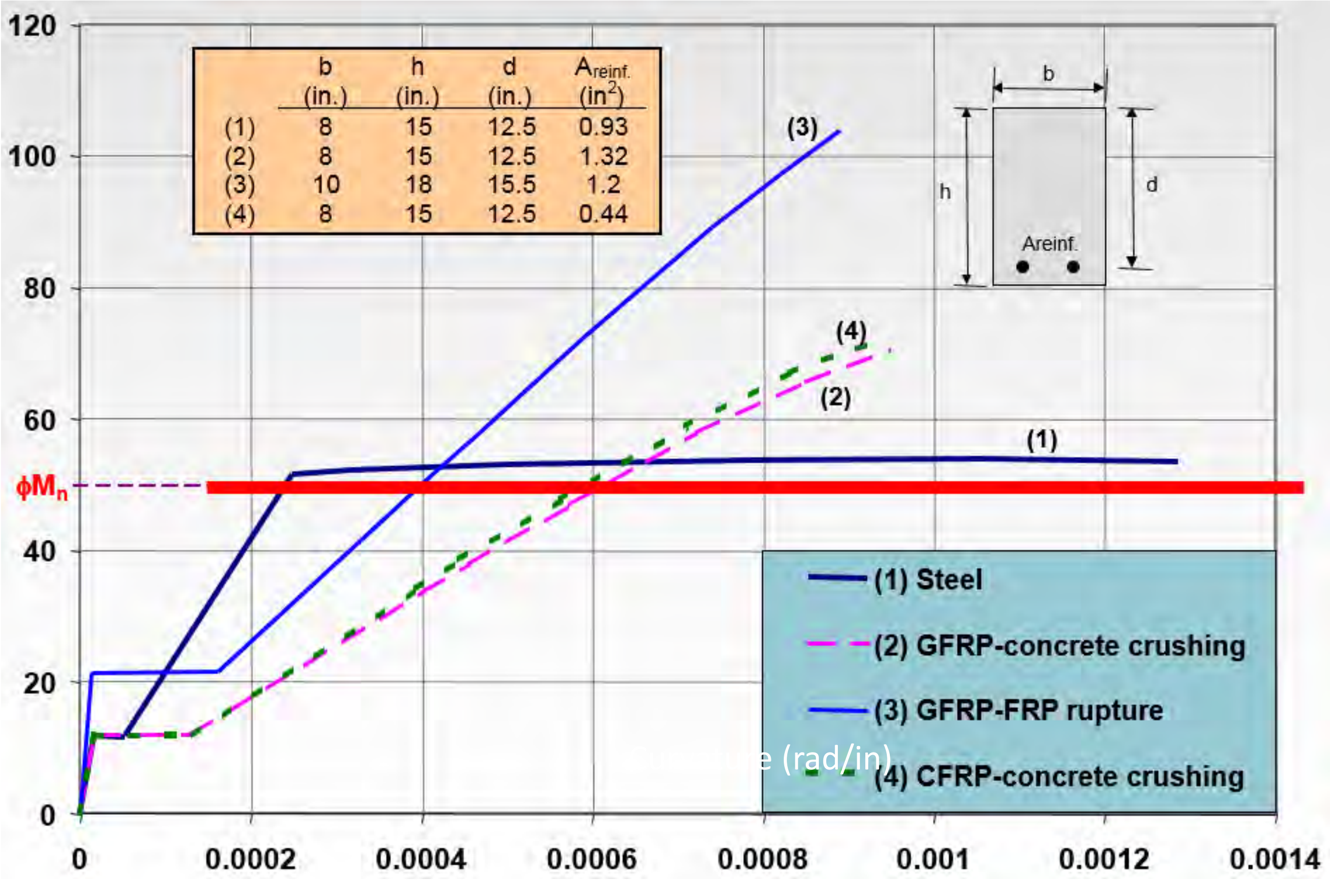




DESIGN CONSIDERATIONS

- **Flexure**
  - Similar to Steel RC members
  - Load factors from AASHTO
  - No ductility
  - Lower ϕ factor
  - Two failure modes allowed

MOMENT - CURVATURE RELATIONSHIP



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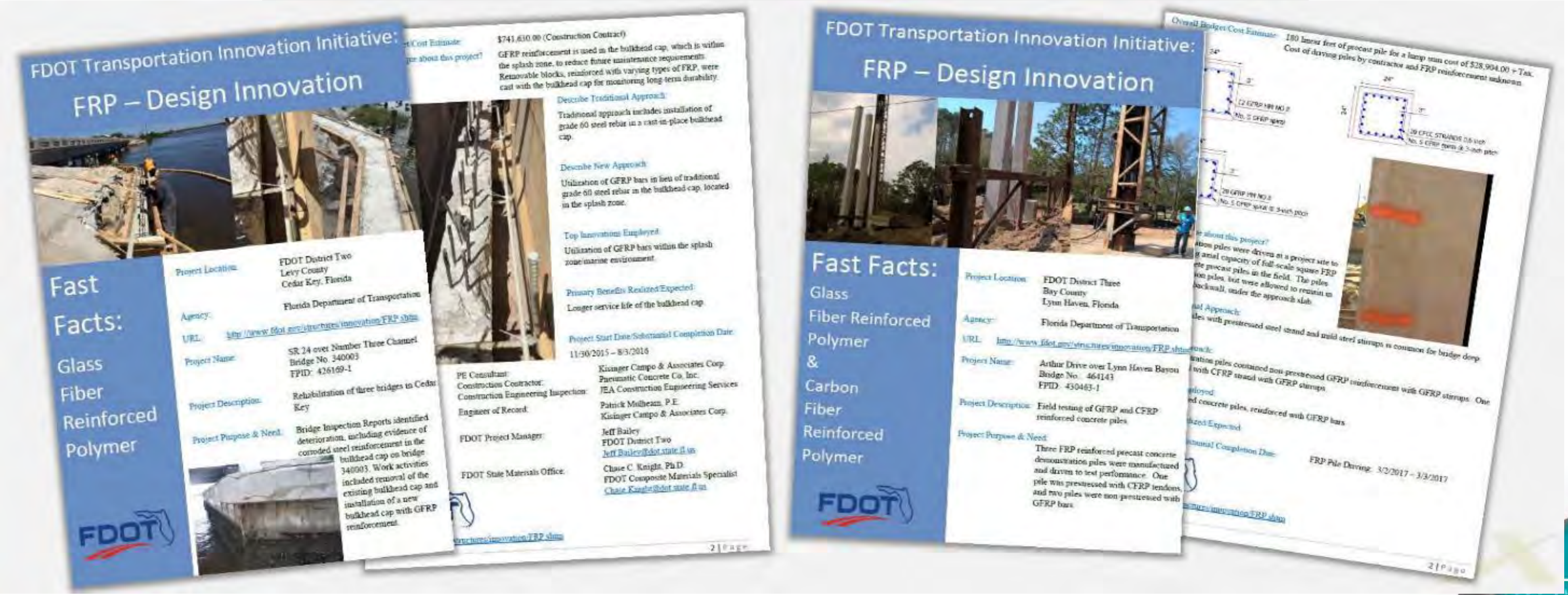
  - ✓ Durability of GFRP Bars
  - ✓ Construction Issues
- Guides, Codes and Specifications
  - ✓ Design of GFRP Reinforced Concrete Structures
  - ✓ AASHTO Guide Ed. 2
- Applications in Florida
  - ✓ FDOT application and UM R&D
- Conclusions
  - ✓ Acknowledgements

APPLICATIONS in FLORIDA

Source for FL transportation projects is:

FDOT Transportation Innovation Initiative: FRP – Design Innovation



FDOT Transportation Innovation Initiative:
FRP – Design Innovation

Fast Facts:
Glass
Fiber
Reinforced
Polymer

Project Location:	FDOT District Two Levy County Cedar Key, Florida
Agency:	Florida Department of Transportation
URL:	http://www.fdot.gov/structures/innovation/FRP.shtm
Project Name:	SR 24 over Number Three Channel Bridge No. 340003 FPID: 426169-1
Project Description:	Rehabilitation of three bridges in Cedar Key
Project Purpose & Need:	Bridge Inspection Reports identified deterioration, including evidence of corroded steel reinforcement in the bulkhead cap on bridge 340003. Work activities included removal of the existing bulkhead cap and installation of a new bulkhead cap with GFRP reinforcement.

Cost Estimate:	$741,630.00 (Construction Contract)
…about this project?	GFRP reinforcement is used in the bulkhead cap, which is within the splash zone, to reduce future maintenance requirements. Removable blocks, reinforced with varying types of FRP, were cast with the bulkhead cap for monitoring long-term durability.
Describe Traditional Approach:	Traditional approach includes installation of grade 60 steel rebar in a cast-in-place bulkhead cap.
Describe New Approach:	Utilization of GFRP bars in lieu of traditional grade 60 steel rebar in the bulkhead cap, located in the splash zone.
Top Innovations Employed:	Utilization of GFRP bars within the splash zone/marine environment
Primary Benefits Realized/Expected:	Longer service life of the bulkhead cap
Project Start Date/Substantial Completion Date:	11/30/2015 – 8/3/2016
PE Consultant: Construction Contractor: Construction Engineering Inspection:	Kisinger Campo & Associates Corp. Pneumatic Concrete Co. Inc. JEA Construction Engineering Services
Engineer of Record:	Patrick Mulhearn, P.E. Kisinger Campo & Associates Corp.
FDOT Project Manager:	Jeff Bailey FDOT District Two Jeff.Bailey@dot.state.fl.us
FDOT State Materials Office:	Chase C. Knight, Ph.D. FDOT Composite Materials Specialist Chase.Knight@dot.state.fl.us

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FDOT Transportation Innovation Initiative:
FRP – Design Innovation

Fast Facts:
Glass
Fiber Reinforced
Polymer
&
Carbon
Fiber
Reinforced
Polymer

Project Location:	FDOT District Three Bay County Lynn Haven, Florida
Agency:	Florida Department of Transportation
URL:	http://www.fdot.gov/structures/innovation/FRP.shtm
Project Name:	Arthur Drive over Lynn Haven Bayou Bridge No.: 464143 FPID: 430463-1
Project Description:	Field testing of GFRP and CFRP reinforced concrete piles
Project Purpose & Need:	Three FRP reinforced precast concrete demonstration piles were manufactured and driven to test performance. One pile was prestressed with CFRP tendons, and two piles were non-prestressed with GFRP bars.

Overall Budget/Cost Estimate: 180 linear feet of precast pile for a lump sum cost of $28,904.00 + Tax. Cost of driving piles by contractor and FRP reinforcement unknown.

FRP Pile Driving: 3/2/2017 – 3/3/2017

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APPLICATIONS in FLORIDA

Bridge Substructure

Fast Facts: Glass Fiber Reinforced Polymer

Project Location:	FDOT District Two Duval County Jacksonville, Florida
Agency:	Florida Department of Transportation
URL:	http://www.fdot.gov/structures/innovation/FRP.shtm
Project Name:	US-17 (SR-5) Over Trout River Bridge No. 720011 FPID: 426169-1
Project Description:	Bridge Substructure Rehabilitation
Project Purpose & Need:	Bridge Inspection Reports identified concrete deterioration in the substructure. Work activities included removal of existing Pile Jackets and installation of new Pile Jackets and Pier Footing Jackets with Impressed Current Cathodic Protection (ICCP). Glass Fiber Reinforced Polymer (GFRP) dowels and reinforcement were used in select locations.

FDOT

Source for FL projects is:
FDOT Transportation
Innovation Initiative:
FRP – Design Innovation

APPLICATIONS in FLORIDA

Fast Facts:

Glass Fiber Reinforced Polymer

Project Location: FDOT District Six
Miami-Dade County
Bal Harbour, Florida

Agency: Florida Department of Transportation

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

Project Name: SR-A1A/Collins Avenue over Haulover Cut Bridge Rehabilitation
Bridge No. 870071
FPID: 433378-1

Project Description: Bridge and Bulkhead Rehabilitation

Project Purpose & Need: District Six Bridge Maintenance identified repairs that included bridge coatings and replacing the deteriorated concrete bulkhead retaining wall on both sides of the Haulover Cut channel. Work activities included replacing the existing bulkhead walls with a steel sheet pile wall system that included a reinforced concrete cap and a protective concrete fascia panel over the steel sheets. GFRP reinforcement was used in the concrete cap and fascia panels.

FDOT

Bridge and Bulkhead Rehab

APPLICATIONS in FLORIDA

Bridge Replacement

The Halls River Bridge (HRB)

Fast Facts:

Glass Fiber Reinforced Polymer
&
Carbon Fiber Reinforced Polymer
&
Hybrid Composite Beam

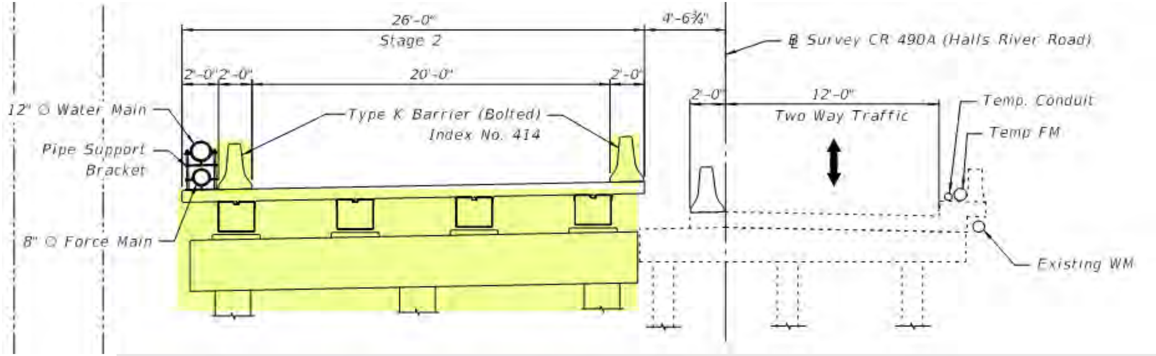
FDOT

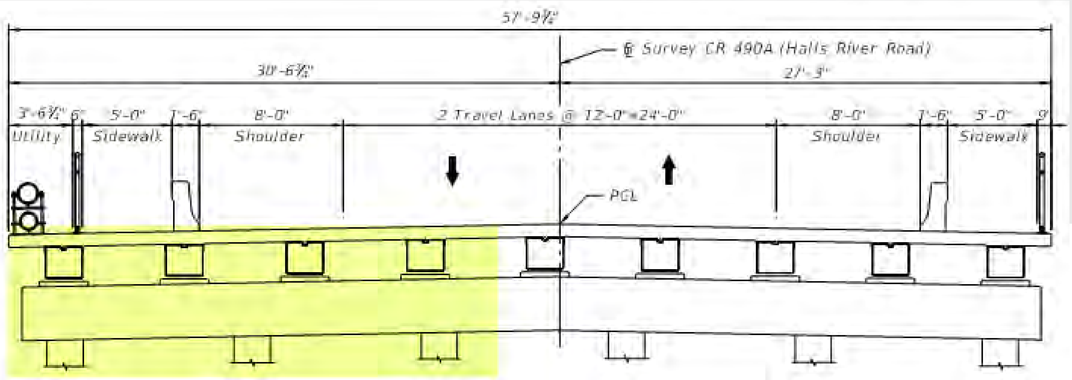
Project Location:	FDOT District Seven Citrus County Homosassa Spring, Florida
Agency:	Florida Department of Transportation
URL:	http://www.fdot.gov/structures/innovation/FRP.shtm
Project Name:	CR-490A Halls River Road over Halls River Bridge No. 024054 FPID: 430021-1-52-01
Project Description:	Bridge Replacement
Project Purpose & Need:	The existing bridge was functionally obsolete and listed on the Citrus County Bridge Replacement Program. The purpose of this project is to increase capacity and improve safety of the existing transportation facility.
Overall Budget/Cost Estimate:	$6,015,645.00 (Construction Contract)

Todo el Concreto está en Asocreto

APPLICATIONS in FLORIDA

Continued: HRB Project Details





COMPLETED STRUCTURE

APPLICATIONS in FLORIDA

Continued: HRB Project Details

Six-man crew can complete bent cap in 4 hours and 30 minutes

APPLICATIONS in FLORIDA

Continued: HRB Project Details

Positioning of GFRP Cage

APPLICATIONS in FLORIDA

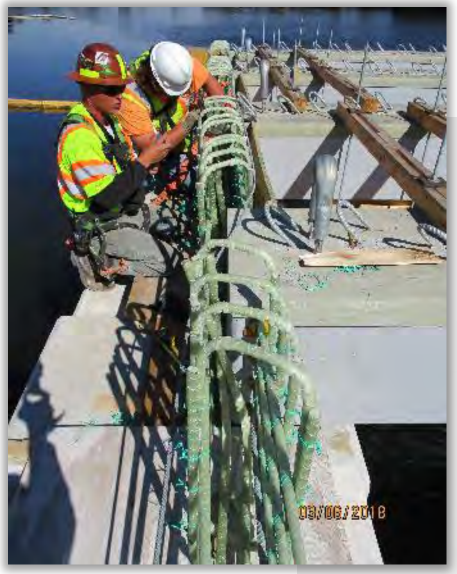
Continued: HRB Project Details

Bent forming and pouring



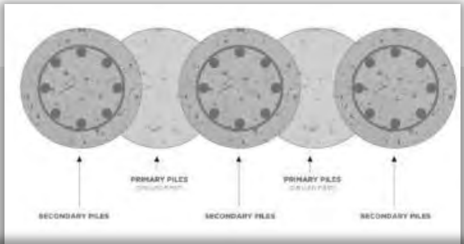

APPLICATIONS in FLORIDA

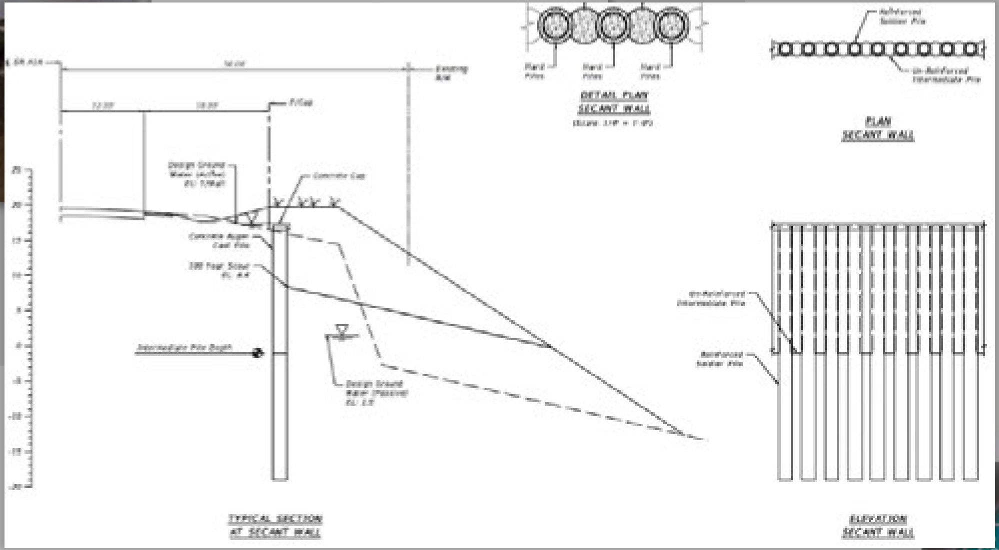
Continued: HRB Project Details



FUTURE FDOT PROJECT - SEAWALL-BULKHEADS

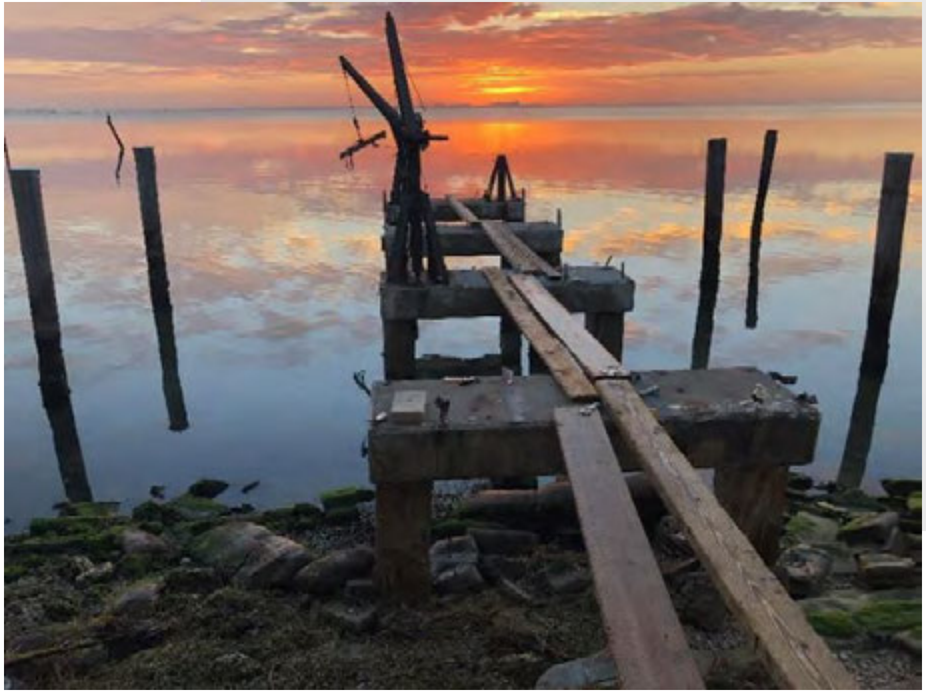
Secant Piles seawall on SR A1A





EXISTING DOCK

Existing Condition: dock damaged by Hurricane Irma



PROPOSED DOCK - IDOCK

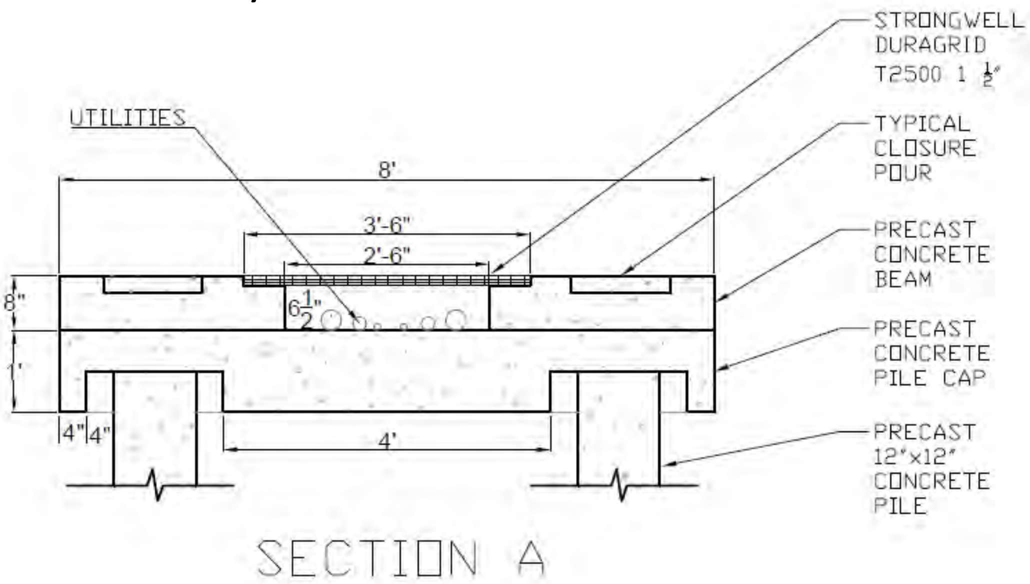
Precast Elements all using FRP reinforcement only:

- 8 Piles: 24’x1’x1’
- 4 Pile Caps: 8’x2.5’x1’
- 8 Slabs:

  1 unit of 144”x33”x8”

  1 unit of 132”x33”x8”

  6 units of 120”33”x8”

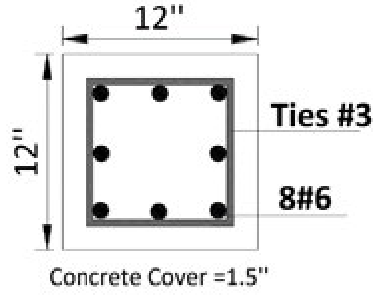


RC PILES

Precast piles reinforced with **GFRP**

4 types of piles:

- Type A: 6#6 with spirals
- Type B: 6#6 with square ties
- Type C: 6#8 with spirals
- Type D: 6#8 with square ties

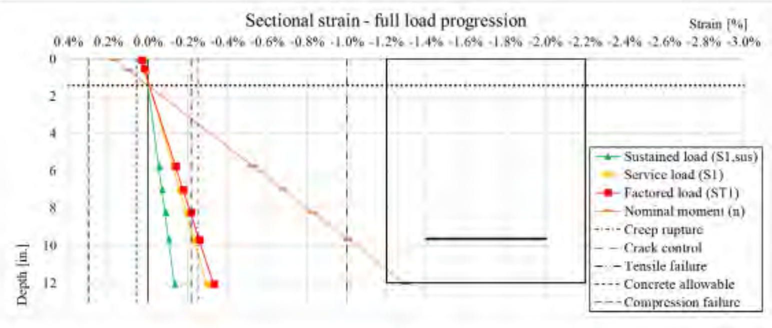


RC PILE CAPS

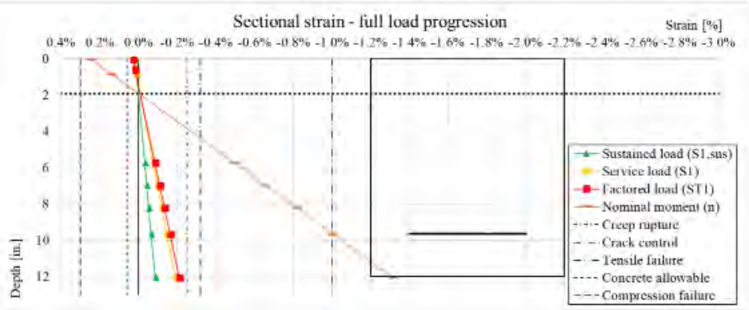
Precast pile cap reinforced with **GFRP**

- Top: 6#6
- Bottom: 2#6 and 4#4
- Sides: 3#4 C-shaped
- Stirrups: #3 @ 6”

Flexure Design



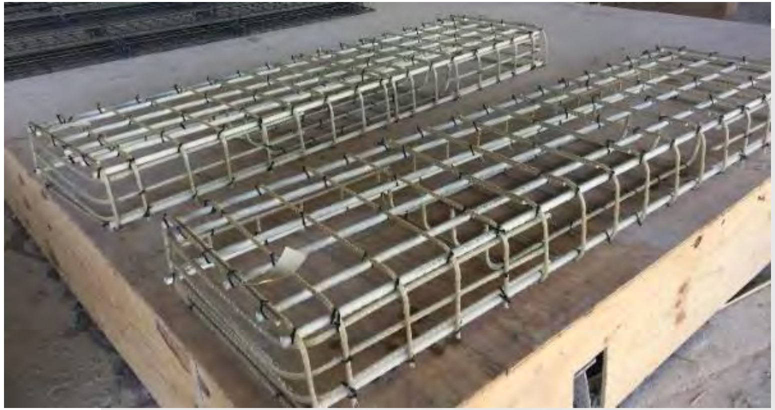
Positive moment at midspan from gravity and pedestrian loads



Negative moment at midspan from uplift loads

RC PILE CAP

Cages and cages inside formwork with block-outs



RC SLABS

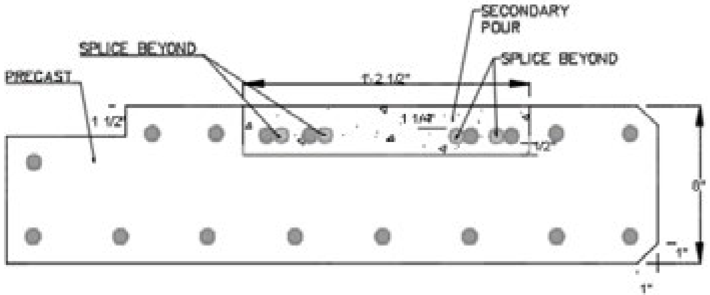
Precast slabs reinforced with **BFRP**

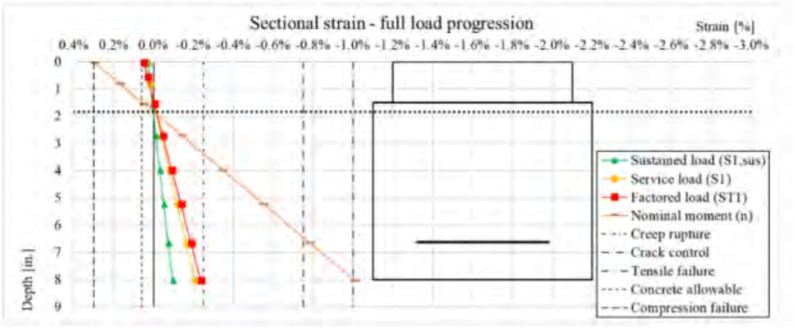
- Top: 4#6 and mesh
- Bottom: 8#6 and mesh
- Joints:

    4#6 top

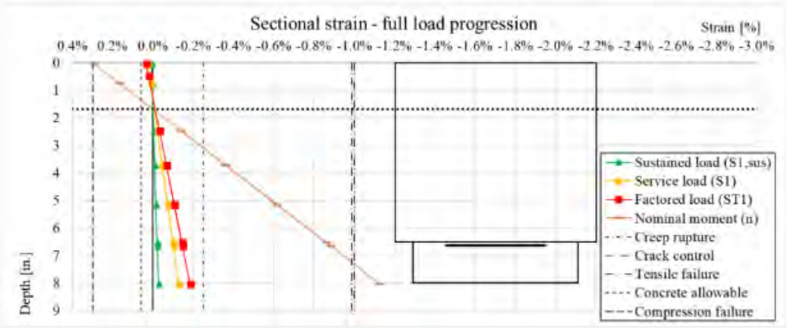
    2#4 from piles

Flexure Design





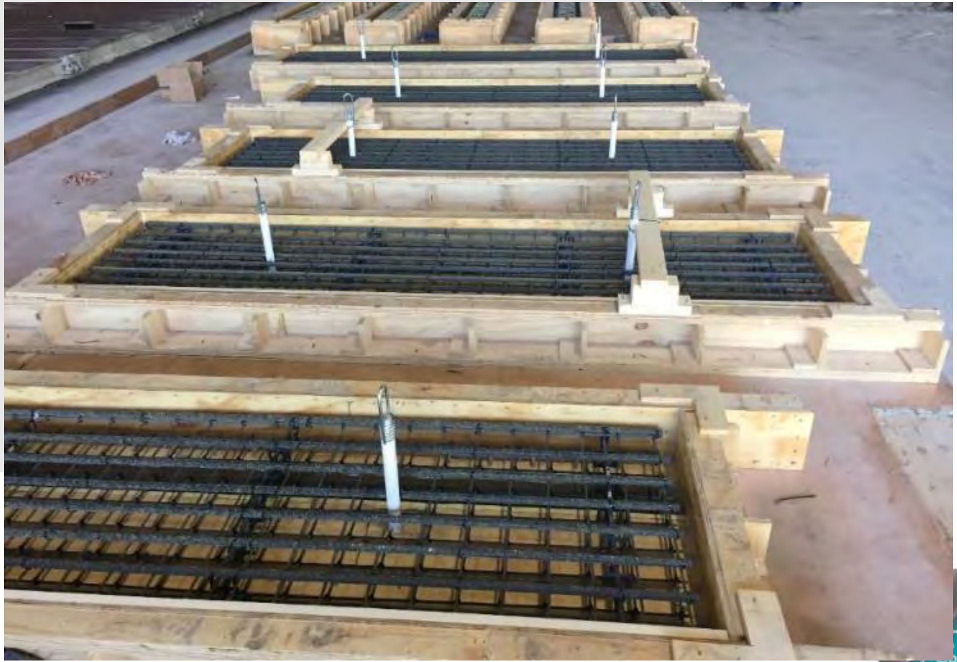
Positive moment at midspan from gravity and pedestrian loads



Negative moment at midspan from uplift loads

RC SLABS

Cages and cages inside formwork with lift points



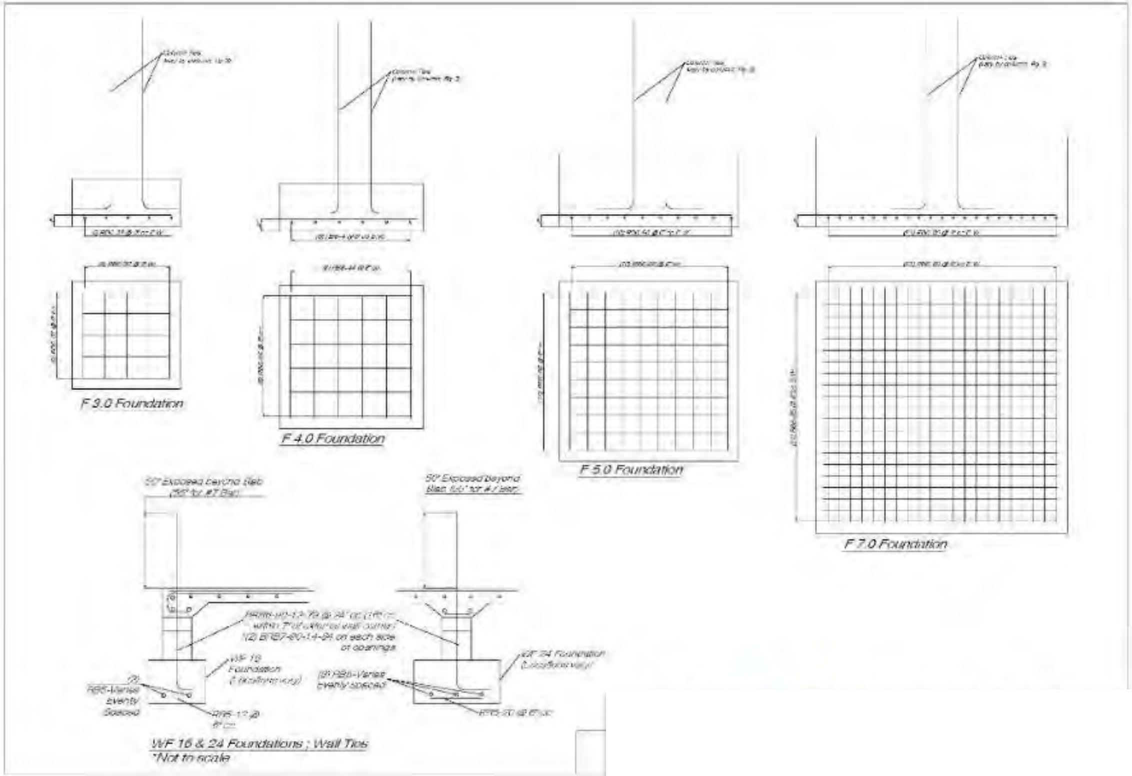
COMPLETE ELEMENTS AT PRECASTER

Slabs, caps and piles

CASA SEAMOUR - THE SITE

Berry Island, Bahamas

CASA SEAMOUR - FOUNDATION PLANS



CASA SEAMOUR - CONCRETE AND BARS

Shipment of supersacks and GFRP from Miami

CASA SEAMOUR - EXCAVATION AND CAGES

CASA SEAMOUR - FOUNDATION POUR

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CONCLUSIONS

- Complete set of guides, test methods and standards are available for GFRP bars
- Many bridges and ancillary structures have been built with GFRP bars and are performing well
- Non-proprietary solution, traditional supply chain acquisition & installation available
- Extended service life of GFRP reinforced concrete
- Practices adopted for corrosion protection are unnecessary with GFRP reinforcement

ACKNOWLEDGEMENTS

American Concrete Institute Ambassador Program

National Science Foundation (NSF) Industry/University Center for Integration of Composites into Infrastructure (**CICI**) under Grant IIP-1439543

Infravation under grant 31109806.005-**SEACON**

Thank U and Questions?

GFRP cage for TBM launch pad – Santa Lucia tunnel, Italy