Florida's Fiber-Reinforced Polymer (FRP) initiatives for Bridges

Steve Nolan, P.E. (FDOT State Structures Design Office)

Overview

1. A Brief History of FRP in Florida's Bridges
2. US Highway Innovation and Incentive Programs
3. US FRP Specifications
4. Specification Harmonization
5. Florida's Design Tools
6. Recent & Future Advancements
7. Example FRP Elements & Projects
8. Principles for Broader Deployment

History of FRP in Florida's Bridges

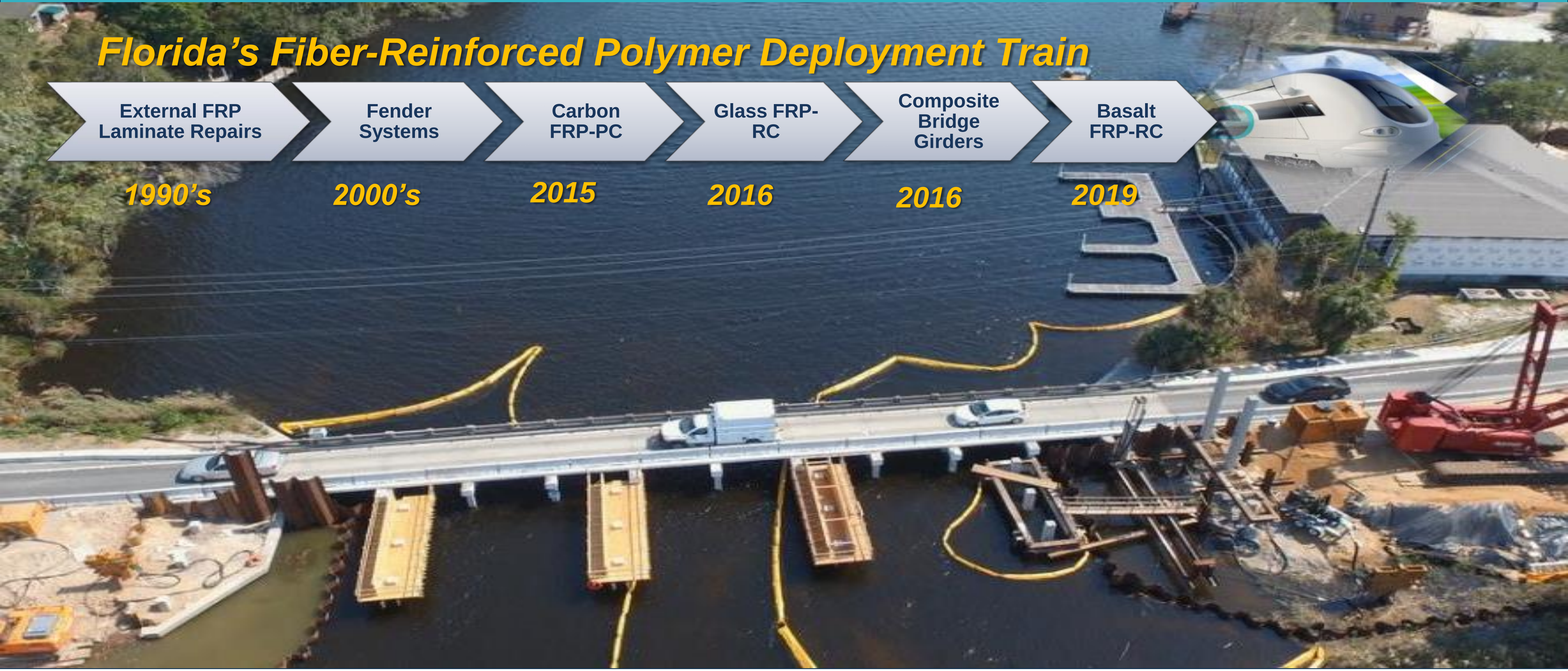


Photo Courtesy of Astaldi Construction Corp.
– Halls River Bridge under construction (FDOT FRP-RC/PC & HCB Demonstration project), April 2017.

History of FRP in Florida - Repair/Strengthening Operations

Florida's Fiber-Reinforced Polymer Deployment Train

External FRP Laminate Repairs

1990's

Now considered routine practice for some applications

Florida DOT currently references **ACI 440.2R**-08 (with modifications); **AASHTO Guide Spec.** (2012) is also available.

History of FRP in Florida - Need for Corrosion Protection

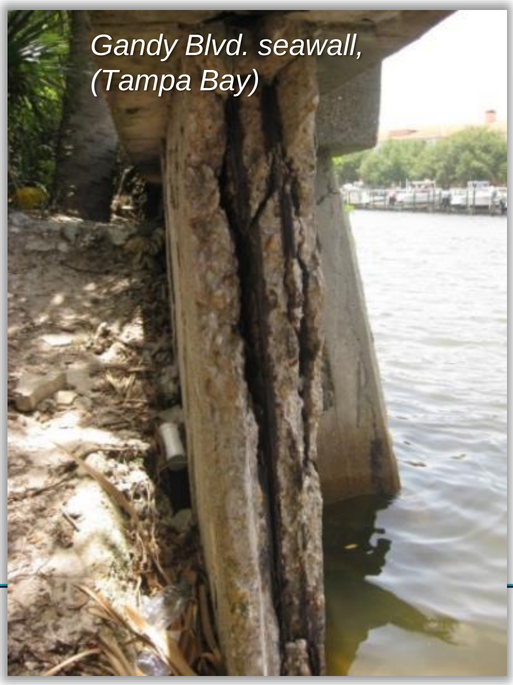
Florida's Fiber-Reinforced Polymer Deployment Train

External FRP Laminate Repairs

1990's *2000's*

- FRP can increase Durability
- Extend maintenance-free Service-Life
- Mitigate long-term Risks

Old St. George Island Bridge Piling



Gandy Blvd. seawall, (Tampa Bay)

Courtney Campbell Causeway, seawall (Tampa Bay)

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

History of FRP in Florida - Bridge Fender Systems

Florida's Fiber-Reinforced Polymer Deployment Train

External FRP Laminate Repairs	Fender Systems				
1990's	*2000's*				

Fully implemented on Florida Department of Transportation projects.

FRP systems strongly recommended - see ***SDG 3.14*** and [DS] ***Index 21930*** *or* [SP] ***Index 415-030***)

(Photos Courtesy of Creative Pultrusion)

History of FRP in Florida – Carbon FRP-PC

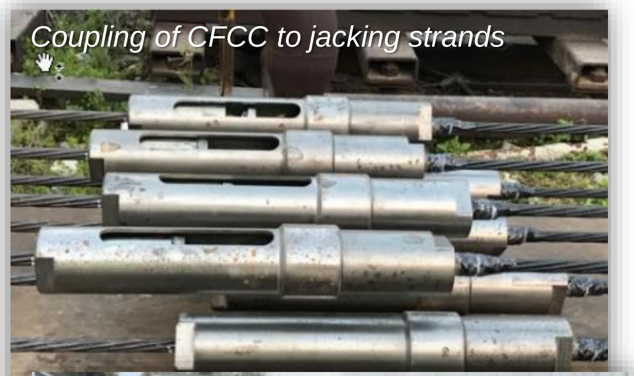
Florida's Fiber-Reinforced Polymer Deployment Train

External FRP Laminate Repairs → Fender Systems → **Carbon FRP-PC** → → →

1990's — 2000's — 2015


Gate Precast (2017)


Halls River Bridge 18"x18" bearing piles (2017)


Coupling of CFCC to jacking strands


CFCC strands for HRB sheet piles (2017)

- Carbon FRP-PC Bearing Piles
- Carbon FRP-PC/Glass FRP-RC Sheet Piles

History of FRP in Florida – Carbon FRP-PC & Glass FRP-RC

Florida's Fiber-Reinforced Polymer Deployment Train

External FRP Laminate Repairs → Fender Systems → Carbon FRP-RC → Glass FRP-PC

1990's | 2000's | 2015 | 2016

- CFRP-PC Bearing Piles
- CFRP-PC/GFRP-RC Sheet Piles
- GFRP Caps, Deck, App. Slab…


Gate Precast (2017)


Halls River Bridge 18"x18" bearing piles (2017)


Coupling of CFCC to jacking strands


CFCC strands for HRB sheet piles (2017)

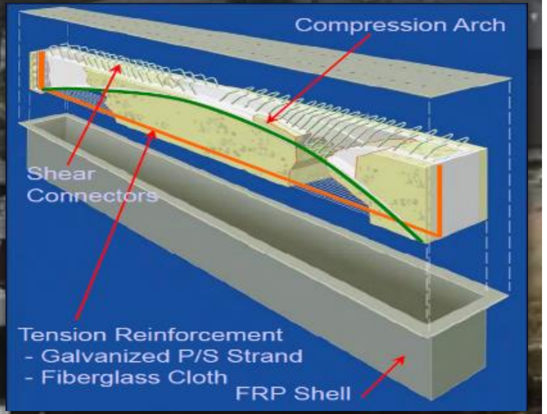

HRB GFRP-RC Bent Cap (2017)

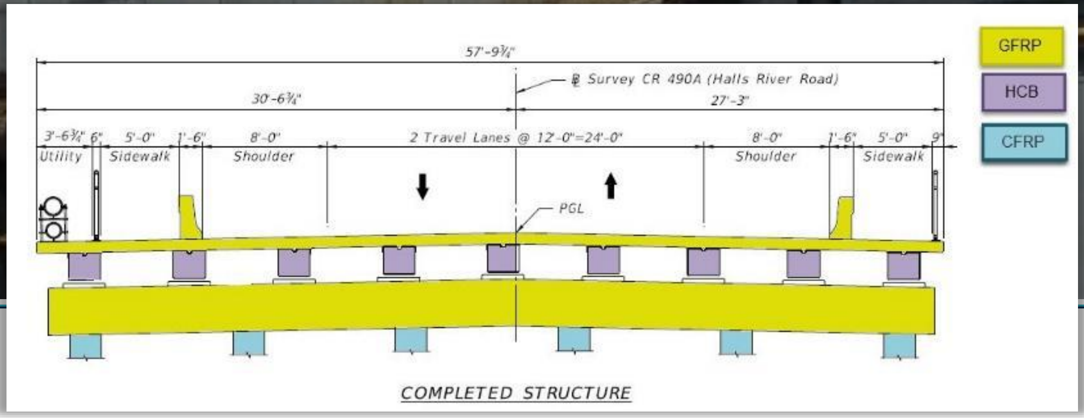

HRB GFRP-RC Deck Casting (2018)

History of FRP in Florida – Composite Bridge Girders

Florida's Fiber-Reinforced Polymer Deployment Train

External FRP Laminate Repairs	Fender Systems	Carbon FRP-RC	Glass FRP-PC	Composite Bridge Girders	
1990's	2000's	2015	2016	2016	






HRB GFRP-RC Diaphragms for HCB's (2018)


HRB Hybrid Composite Beams (2017)

History of FRP in Florida – Composite Bridge Girders (cont.)

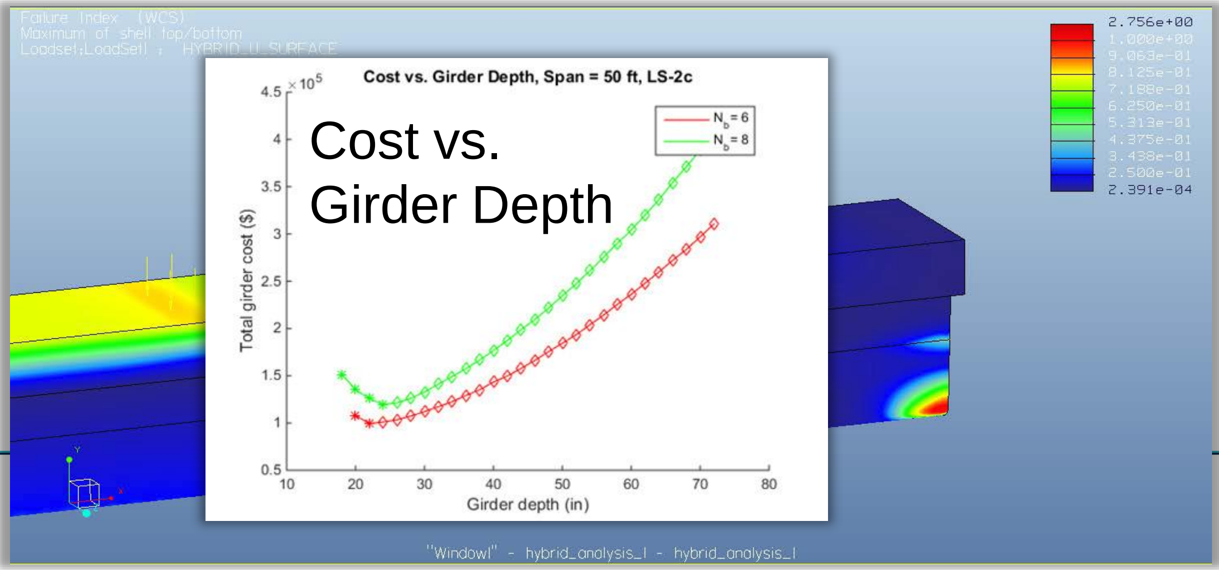
Florida's Fiber-Reinforced Polymer Deployment Train

External FRP Laminate Repairs	Fender Systems	Carbon FRP-RC	Glass FRP-PC	Composite Bridge Girders	
1990's	2000's	2015	2016	2016+	

- Non-Proprietary Composite Bridge Girder

Completion Date	Title (Full Report)	Principal Investigator	University / Agency	Project Manager	Contract No. (Summary)
1/31/2018	[Bridge Girder Alternatives for Extremely Aggressive Environments]()	Brown, Jeff	Embry-Riddle Aeronautical Univ.	Potter, William	[BDV22 977-01]()

FRP girders await the next step in construction of this bridge.



History of FRP in Florida – Basalt FRP-RC

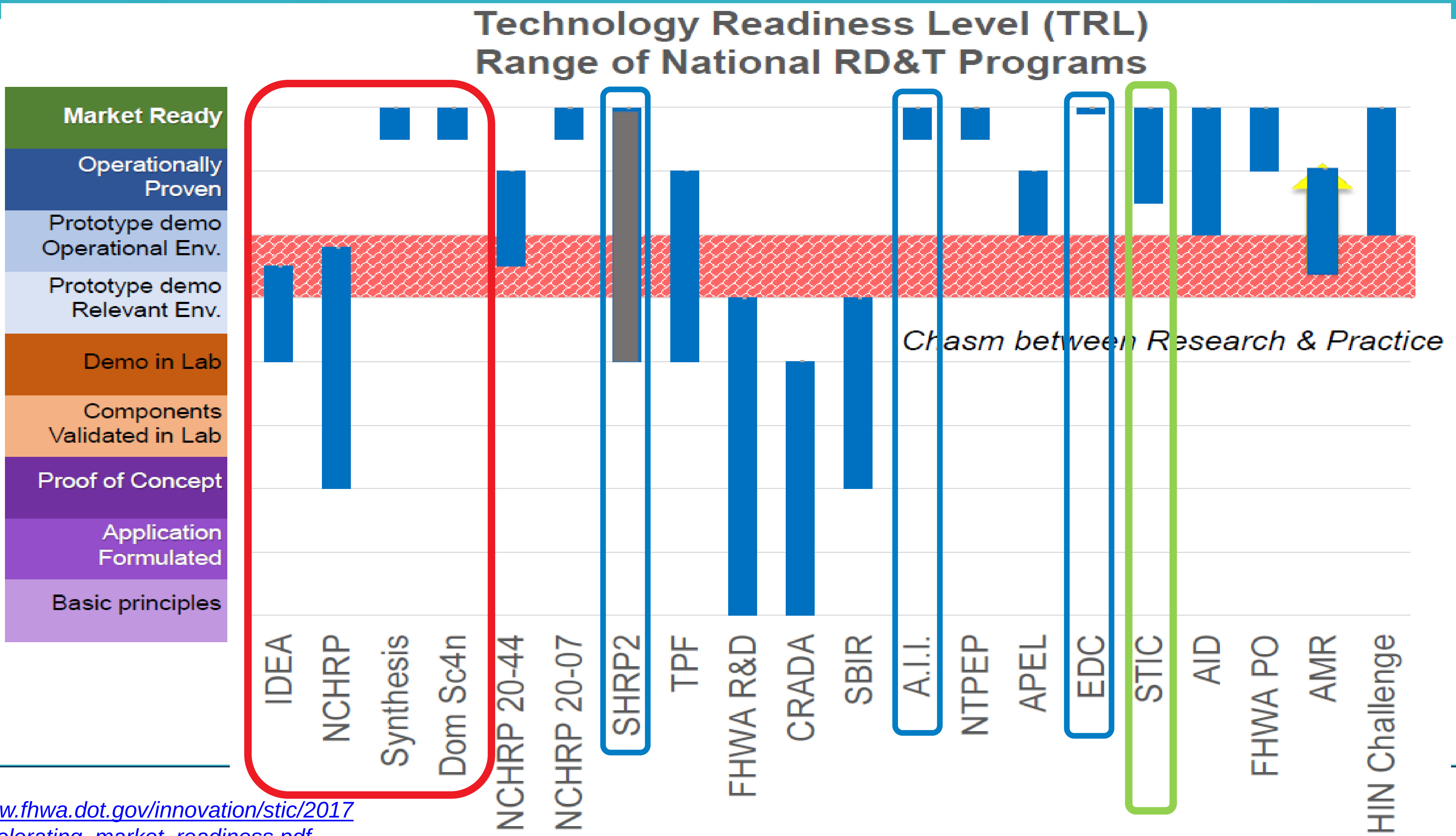
Florida's Fiber-Reinforced Polymer Deployment Train

External FRP Laminate Repairs	Fender Systems	Carbon FRP-RC	Glass FRP-PC	Composite Bridge Girders	Basalt FRP-RC
1990's	2000's	2015	2016	2016	2019

STIC Incentive Project – BFRP-RC Standardization

- Develop ***Standards*** & ***Specifications*** for basalt fiber-reinforced polymer (BFRP) bars for the internal reinforcement of structural concrete. (US$100,000 FHWA grant)

US Highway Innovation and Incentive Programs



Source:
https://www.fhwa.dot.gov/innovation/stic/20171019_accelerating_market_readiness.pdf

US Highway Innovation and Incentive Programs

STIC Excellence Award Forward *(April 2018)***:**

“America's highway community faces significant challenges: an aging infrastructure, growing traffic volumes and limited staffing and funding resources. Widespread use of innovation and enhanced business processes is essential to meeting customer needs and increasing the efficiency of project delivery.

Initiatives such as ***Every Day Counts***, the second ***Strategic Highway Research Program (SHRP2)*** Implementation Assistance Program, the ***AASHTO Innovation Initiative***, and others are designed to promote innovations and support the highway community in putting them into practice. Whether through training, workshops, demonstrations, technical assistance or incentive funding, **the result of these initiatives is rapid technology transfer and accelerated deployment of innovation across the nation…**”

https://www.fhwa.dot.gov/innovation/stic/2018_stic_excellence_award.pdf

US Highway Innovation and Incentive Programs

Every Day Counts (EDC):

FHWA: PBES → ABC, UHPC, *GRS-IBS…*

Strategic Highway Research Program (SHRP2):

TRB, ***AASHTO*** & ***FHWA:***

- Prefabricated Elements-PBES (R04 Report & Toolkit)
- Service Life Design for Bridges (R19A)
- Service Limit State Design Guide Spec./Toolkit (R19B)

AASHTO Innovation Initiative (A.I.I):

AASHTO: Carbon Fiber-Reinforced Polymer Strands

US Highway Innovation and Incentive Program - NCHRP

NCHRP:

[Report 503](#) *(2003): Application of FRP Composites to the Highway Infrastructure*

- *Dr. Dennis Mertz (lead author) – "Lack of a clear signal of intent or encouragement from government agencies undermines FRP suppliers' confidence in the viability of a long-term market…"*

[Synthesis 512](#) *(2017): Use of Fiber-Reinforced Polymers in Highway Infrastructure*

- *State-of-the-art review*

[US Scan Team Report 13-03](#) *(2017): Advances in FRP Composite Transportation Infrastructure*

- *NCHRP 20-68A program*

http://www.domesticscan.org/13-03-leading-practices-in-use-of-fiber-reinforced-polymer-frp-composites-in-transportation-infrastructure

US Highway Innovation and Incentive Program - IDEA...

Ideas Deserving of Exploratory Analysis (IDEA):

NCHRP (TRB & AASHTO):

- Glass FRP Prestressing Strand (MILDGLASS-2018)

Innovative Bridge Research and Construction (IBRC):

FHWA (1998-2006): FRP Bridges are to be revisited and an update report on status issued;

Innovative Bridge Research and Deployment (IBRD):

FHWA (2006-2017): US 90 over Little River - PBES Bent Caps (used ***SHRP2 R04 Toolkit*** for guidance). FDOT since developed a Mathcad Design Program which includes GFRP-RC elements.

What else is there… (ASCE Grand Challenge)

- *"Reduce the life cycle cost of infrastructure by 50 percent by 2025 and foster the optimization of infrastructure investments for society"*

Together we can close the infrastructure gap!

www.ascegrandchallenge.com

What else is there… (nationally / internationally)

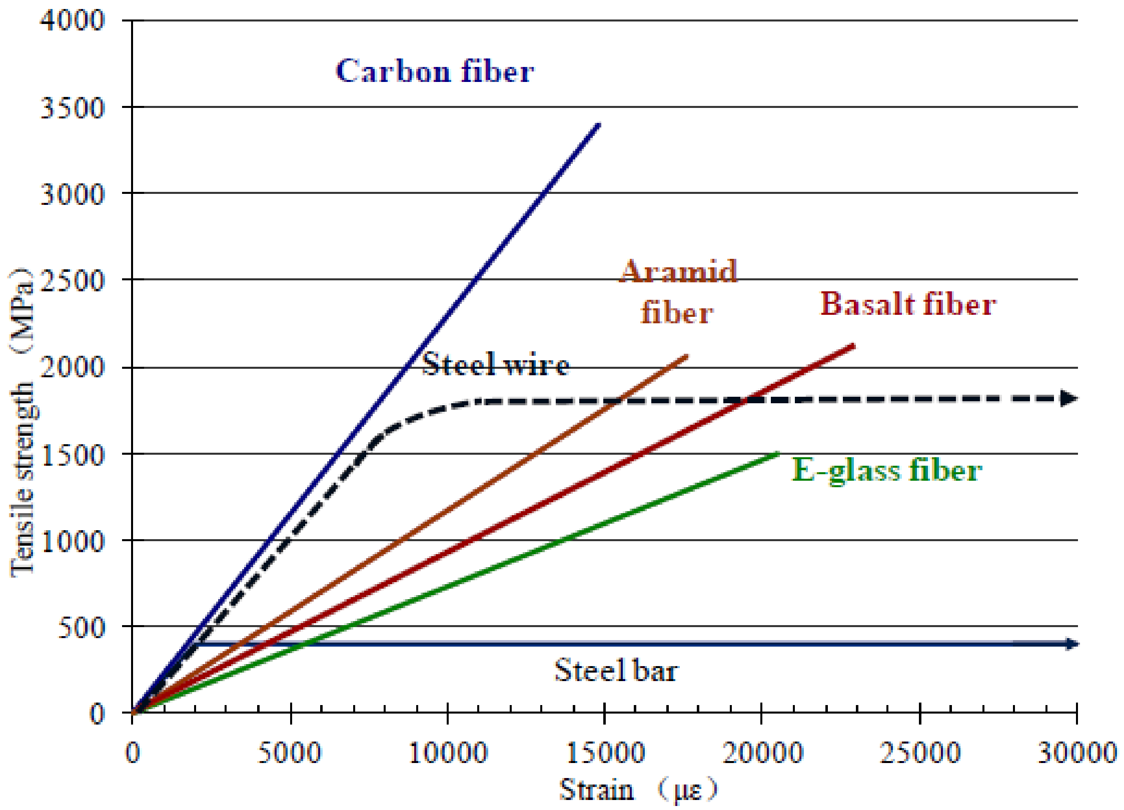
FDOT participation in related technical organizations:

- ***AASHTO Committee on Bridge and Structures – T6 FRP*** *(Member: William Potter)*
- ***TRB AFF80*** *– Structural Fiber Reinforced Polymers (Members: Potter, Fallaha & Nolan)*
- ***ACMA*** *– Transportation Structures Council & FRP Rebar Manufacturers Council (liaisons → John Busel)*
- ***ACI 440*** *– (liaison → Prof. Nanni)*
- ***CICI*** *- (liaison --> Prof. Nanni & Dr. Liang)*
- ***Canadian Standards Association*** *(liaison → Prof. Benmokrane)*
- ***Jiangsu Composite Society*** *???*

What is of most interest… (in Florida)

FRP materials of most interest (currently):

- ***Carbon FRP strands and laminates*** *(PAN fiber with epoxy or vinyl-ester resin systems)*
- ***Glass FRP reinforcing Bars*** *(E-CR fiber with vinyl-ester resin systems)**;***
- ***Basalt FRP reinforcing bars*** *(melt fiber with epoxy resin systems).*

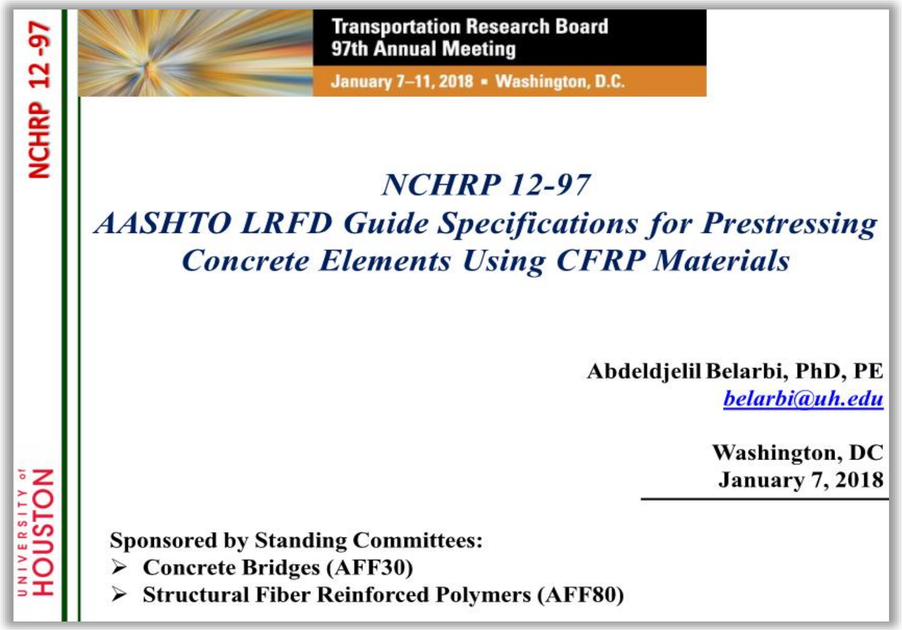


Typical stress-strain relationships of different FRPs compared to steel bars (Zhishen et al., 2012)

Design Specifications – Carbon FRP-PC

***AASHTO's* 1st Edition for prestressed concrete with FRP strands *Bridge Design Guide Specifications (BDGS:CFRP-PC)*.**

- Approved 06/28/2018 by ***AASHTO Committee on Bridges and Structures*** (thru ***T-6*** sponsorship).



NCHRP 12-97

Transportation Research Board
97th Annual Meeting
January 7–11, 2018 • Washington, D.C.

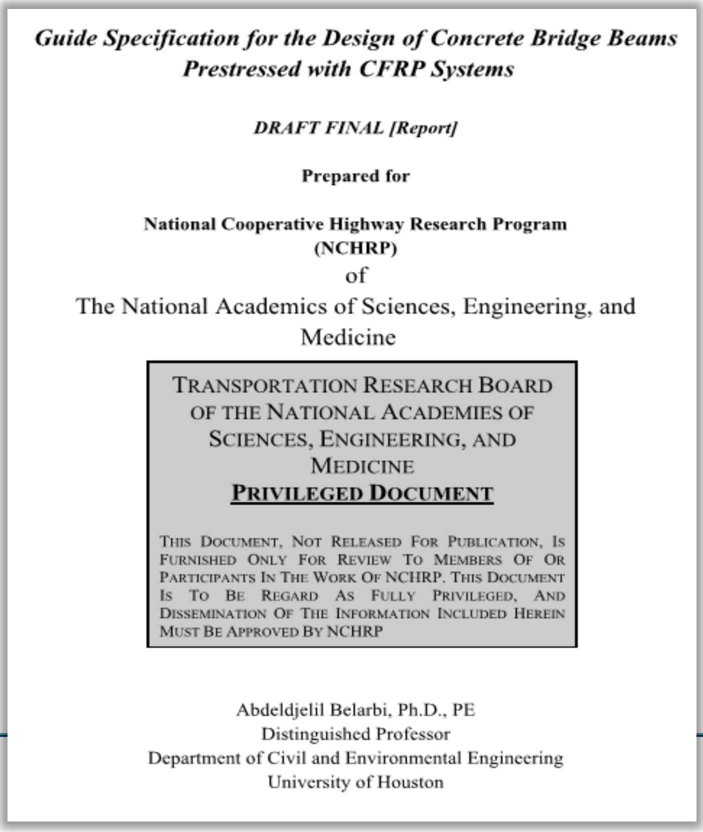
NCHRP 12-97
AASHTO LRFD Guide Specifications for Prestressing Concrete Elements Using CFRP Materials

Abdeldjelil Belarbi, PhD, PE
belarbi@uh.edu

Washington, DC
January 7, 2018

Sponsored by Standing Committees:
- Concrete Bridges (AFF30)
- Structural Fiber Reinforced Polymers (AFF80)

UNIVERSITY of HOUSTON



Guide Specification for the Design of Concrete Bridge Beams Prestressed with CFRP Systems

DRAFT FINAL [Report]

Prepared for

National Cooperative Highway Research Program (NCHRP)
of
The National Academies of Sciences, Engineering, and Medicine

TRANSPORTATION RESEARCH BOARD OF THE NATIONAL ACADEMIES OF SCIENCES, ENGINEERING, AND MEDICINE
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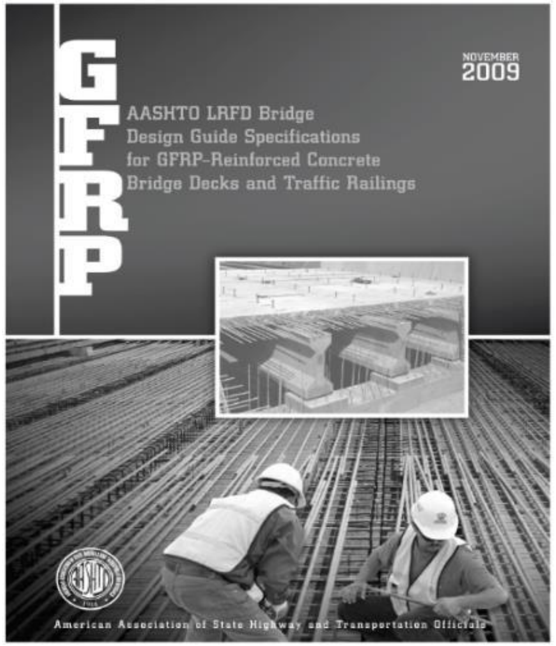
Abdeldjelil Belarbi, Ph.D., PE
Distinguished Professor
Department of Civil and Environmental Engineering
University of Houston

Design Specifications – Glass FRP-RC

AASHTO's *1st Edition* **on decks and railings has now been updated to a complete *Bridge Design Guide Specification (BDGS:GFRP-RC) 2nd Edition*.**

- Approved 06/28/2018 by ***AASHTO Committee on Bridges and Structures*** (thru ***T-6*** sponsorship).



2018

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

TABLE OF CONTENTS

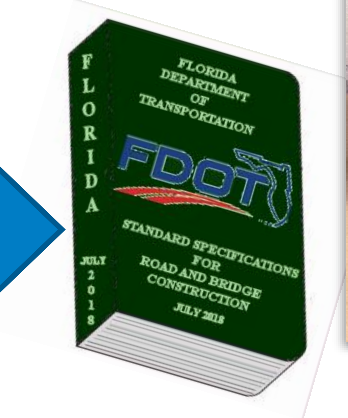
Design & Material Specifications – BFRP *(in progress)*

STIC Incentive Project – BFRP-RC Standardization

FHWA Project: STIC-004-A *(April 2018 - Dec 2019; US$125,000)*

FDOT #443377-1; *includes* ***Research Project BDV30 986-01***

- Develop standard specifications for basalt fiber-reinforced polymer (BFRP) bars for the internal reinforcement of structural concrete.



https://www.fhwa.dot.gov/innovation/stic/state_innovation.cfm

Testing & Material Specifications – BFRP *(in procurement)*

Testing Protocol and Material Specifications for Basalt Fiber Reinforced Polymer Bars

Advertisement #: DOT-RFP-19-9032-KW *(Proposals due Nov. 11, 2018; ≤US$250,000)*

FDOT State Materials Office, *complements* ***BDV30 986-01***

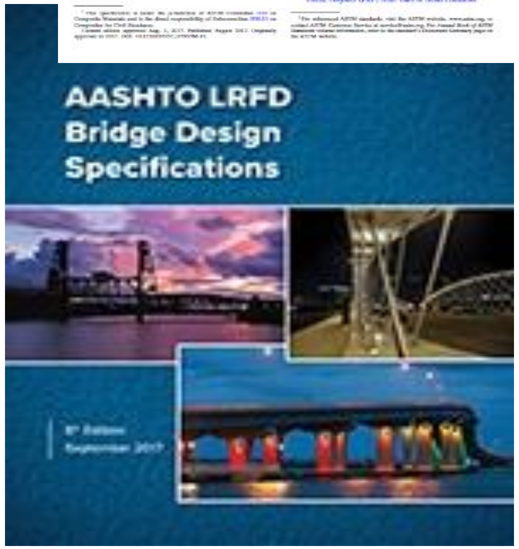
1. Establish minimum level of purity as well as the fiber property minimum requirements (including strength and resistance to chemicals) and corresponding composition ranges, paralleling ASTM D578 Standard Specification for Glass Fiber Strands.
2. Establish acceptable formulations and/or classes of sizing chemicals that are compatible with basalt fibers and that will form effective interfacial bonding to select resin matrices;
3. Identify the resin matrix that will provide highest performance when combined with appropriately sized basalt fibers to produce BFRP reinforcing for concrete

http://www.myflorida.com/apps/vbs/vbs_www.ad_r2.view_ad?advertisement_key_num=142944

Specification Harmonization – GFRP-RC

- ***BDGS-GFRP 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



Specification Harmonization – GFRP-RC *(cont.)*

- **Inputs** 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"*

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

Specification Harmonization – GFRP-RC *(cont.)*

	AASHTO-GS 2nd 2018	*AASHTO-GS 1st* 2009	*ACI 440.1R* 2015 *(19)*	*CSA* 2014 *(19)*	
f_{fu}^*	99.73	99.73	99.73	**95.0** [(1)]	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 ***(0.30)***	0.25 ***(0.30)***	*Creep rupture reduction*
C_f	**0.25**	**0.20**	0.20	0.25	*Fatigue reduction*
C_b	**0.80**	**0.70** [(2)]	0.70 [(2)]	**1.0**	*Bond reduction*
w	**0.028**	**0.020 or 0.028**	0.020 to 0.028	0.020 ?	Crack width limit [in.]
$c_{c,stirrups}$	1.5	1.50	2.0 [(3)]	1.5	Clear cover [in.]
$c_{c,slab}$	1.0	0.75 to 2.0	0.75 to 2.0 [(3)]	1.5	Clear cover [in.]

[(1)] *Characteristic Strength;* [(2)] *$1/k_b$;* [(3)] ***ACI 440.5-08** Table 3.1;* ***(19)** proposed for 2019 updates*

Specification Harmonization – CFRP-PC

	AASHTO-BDS 8th 2018 (steel only)	*AASHTO-GS 1st* 2018	*ACI 440.4R* 2002 (11)	*CSA* 2014 *(19)*	
f_{fu}^{*}	99.73	99.73	99.73		Strength percentile
Φ_C	0.75	**0.75**	0.65		Res. Factor concrete failure
Φ_T	1.00	0.75	0.85		Res. Factor FRP failure
Φ_S	0.75	0.75			Res. Factor shear failure
C_E	1.00	1.00 (internal)	0.9 (from 440.1R)		*Environmental reduction*
C_{Ci}	0.75_j / 0.70_{serv}	**0.70_j / 0.65_{serv}**	**0.60**		*Creep rupture reduction*
C_f	0.45	**18 ksi**			*Fatigue reduction / stress*
C_b	n/a	n/a			*Bond reduction*
w	n/a	n/a			Crack width limit [in.]
$c_{c,stirrups}$	-	-			Clear cover [in.]
$c_{c,strand}$	-	3.5 d_b			Clear cover

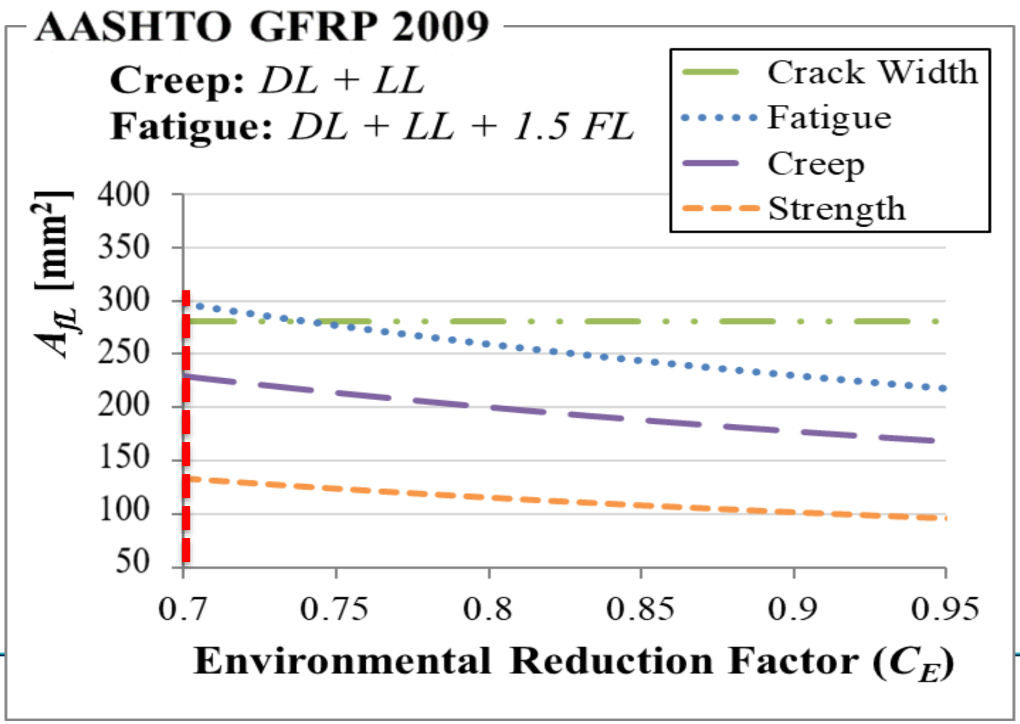
[1] *Characteristic Strength; (19) proposed for 2019 updates*

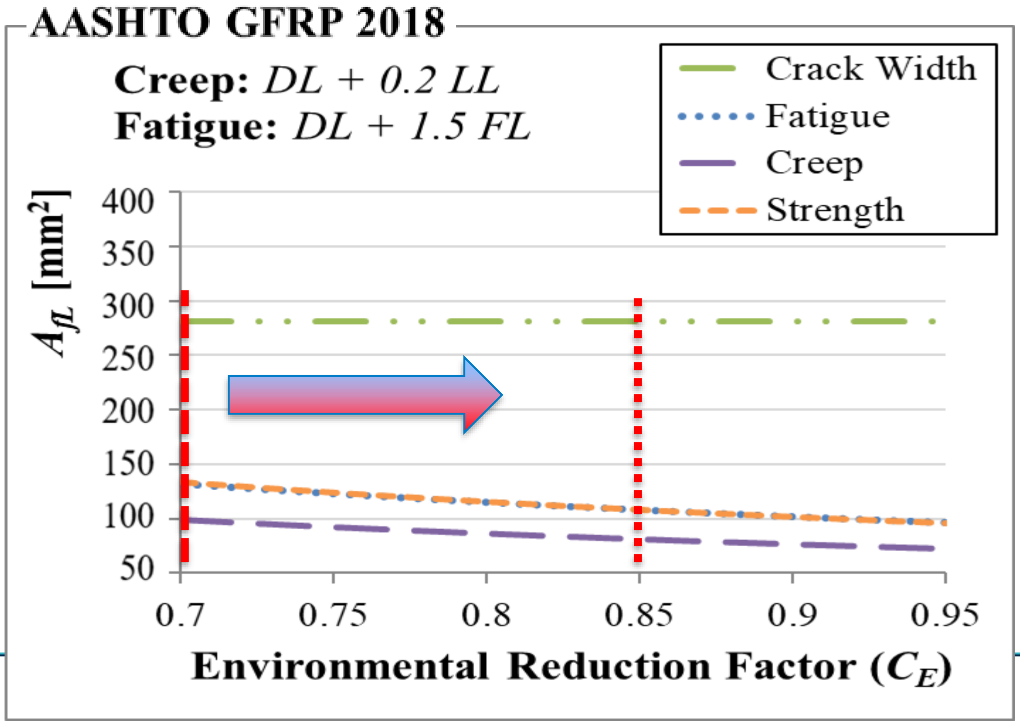
Recent Advancement - GFRP-RC Specs

2nd *Ed.* updates reflect:

- Rationally defined creep rupture and fatigue load demands
- Separated ***Creep*** C_c and ***Fatigue*** C_f and aligned to *CSA-14* (0.20 to **0.30**) –

Need additional study to improve these conservative limits!





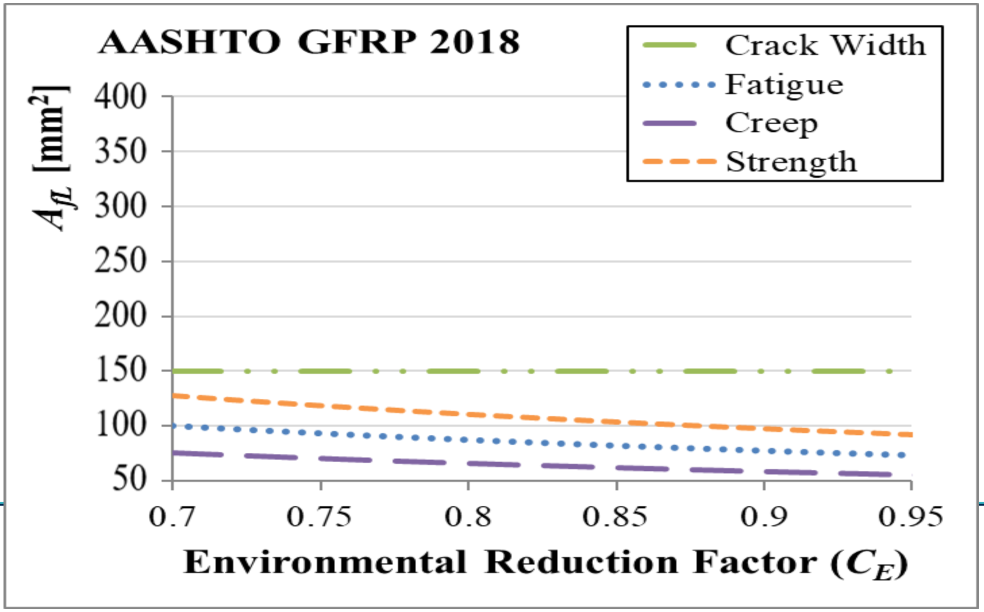
Recent Advancement (cont.) - GFRP-RC Specs

2nd *Ed.* updates reflect:

- Performances of ***ASTM***-certified materials and increase **Compression-Controlled** Flexural Resistance $\boldsymbol{\Phi_c}$ alignment to ***AASHTO BDS-17*** (0.65 to **0.75**);
- Reduced increased Bond Factor $\boldsymbol{C_b}$ (= 1/$\boldsymbol{k_b}$) and max. crack width to 0.028 inches.

Now need to:

1. *Rationally increase **Tension-Controlled** Flexural Resistance $\boldsymbol{\Phi_t}$ (**0.55** to **0.75 ?**), and*
2. *Increase the minimum **Elastic Modulus**…*



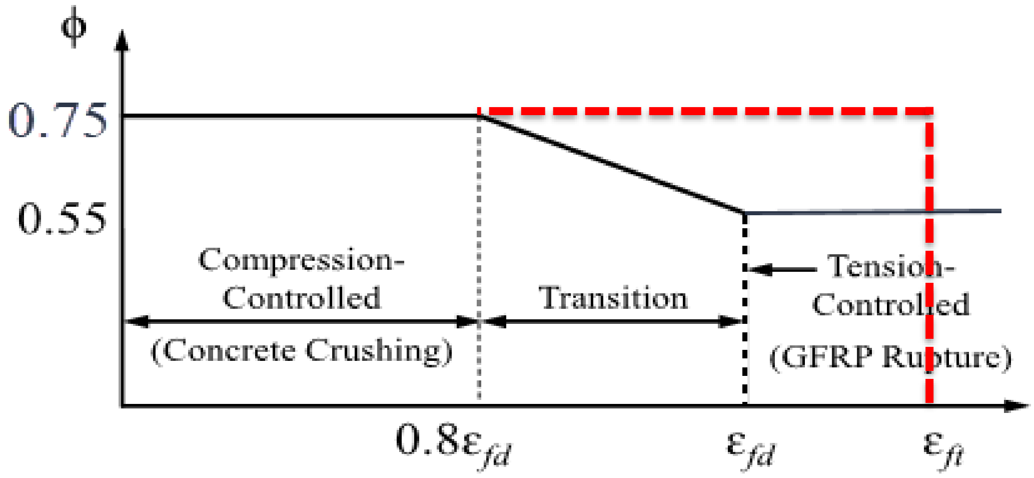
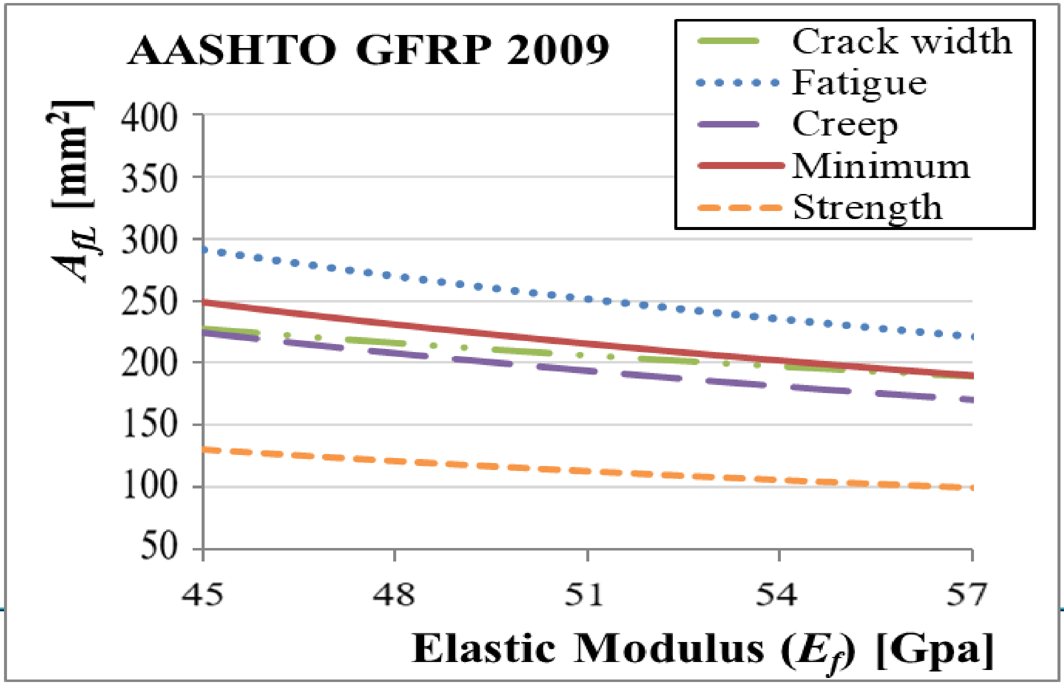
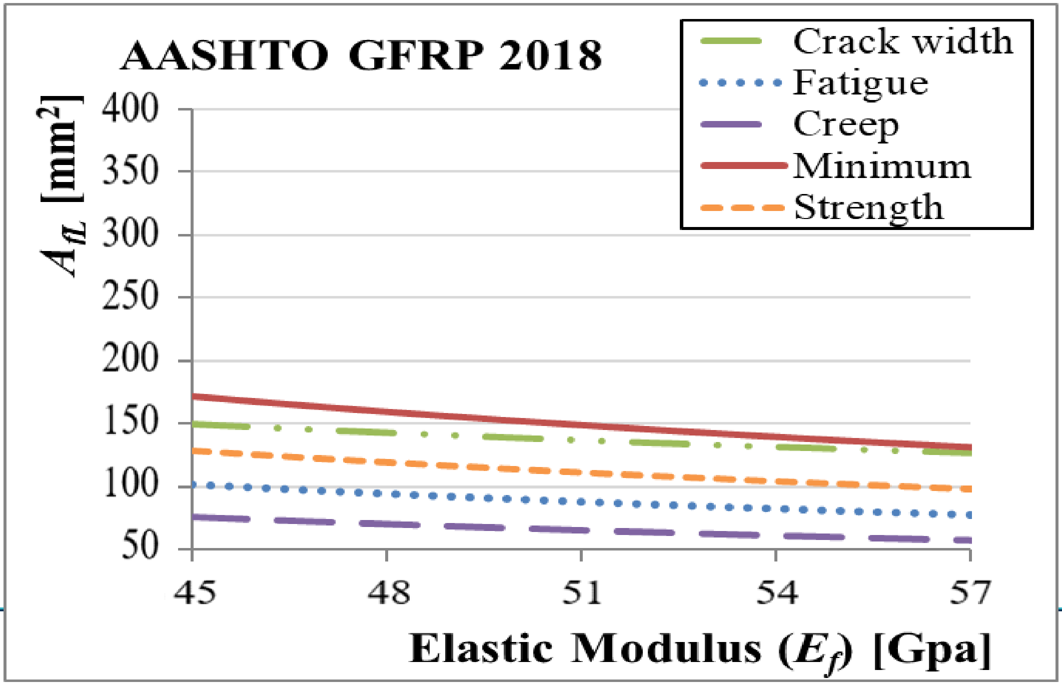


Figure C2.5.5.2-1 – Variation of ϕ with Tensile Strain at Failure, ε_{ft}, in GFRP Reinforcement

Future Advancement (cont.) - GFRP-RC Specs

1. Elastic modulus is a game-changer.
2. Increment shall not come from mere sectional area enlargement.
3. Need to operate within ***ASTM D7957-17*** boundaries.
4. Improve quality of the manufacturing process to answer market demand: stiffness, bond performances, durability.





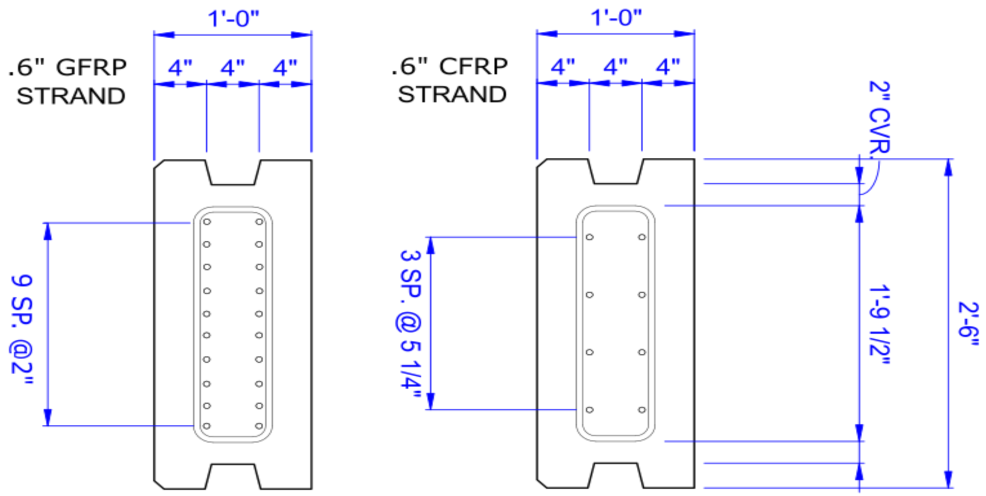
Future Advancement – GFRP-PC twisted strand

1. *NCHRP's* Innovations Deserving of Exploratory Analysis *(IDEA)*

- GFRP Prestressing - **MILDGLASS** *(University of Miami)*;

(a) & (b) CFRP strand failed during tensioning; (c) cracking following strands release.

(a) GFRP strand prototype cross section; (b) compared to a CFRP alternative.

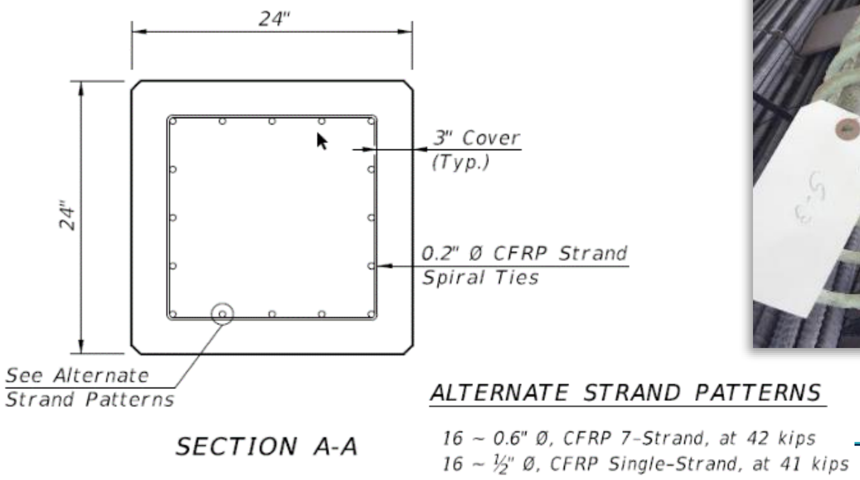


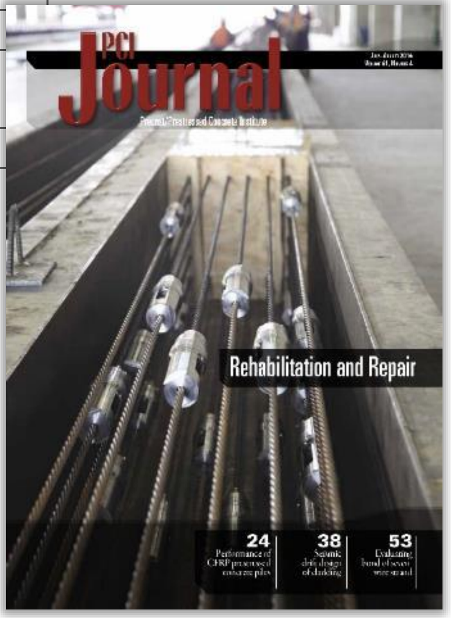
(a) GFRP-PC sheet pile concept (b) CFRP-PC sheet pile design for Halls River Bridge

Standardized Elements - Piles

Bridge Bearing Pile Standards

455-101		Square CFRP and SS Prestressed Concrete Piles - Typical Details and Notes
455-102		Square CFRP and SS Prestressed Concrete Pile Splices
455-112		12" Square CFRP and SS Prestressed Concrete Pile
455-114		14" Square CFRP and SS Prestressed Concrete Pile
455-118		18" Square CFRP and SS Prestressed Concrete Pile
455-124		24" Square CFRP and SS Prestressed Concrete Pile
455-130		30" Square CFRP and SS Prestressed Concrete Pile
455-154		54" Precast/Post-Tensioned CFRP and SS Concrete Cylinder Pile
455-160		60" Prestressed CFRP and SS Concrete Cylinder Pile





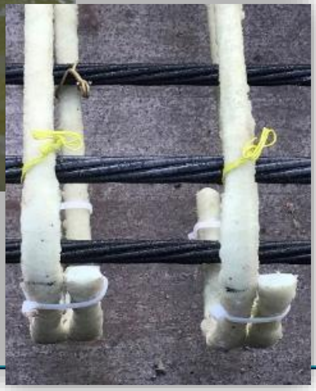
Standardized Elements - Seawall-Bulkheads

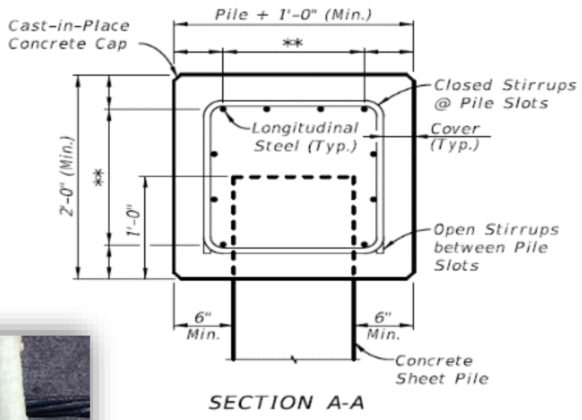
Concrete Sheet Pile Bulkhead Standards

HRB Sheet Pile Installation

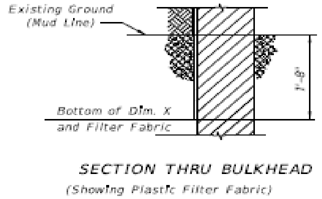
	Structures Foundations - Sheet Pile Wall
455-400	Precast Concrete Sheet Pile Wall (Conventional)
455-440	Precast Concrete Sheet Pile Wall (CFRP/GFRP & HSSS/GFRP)

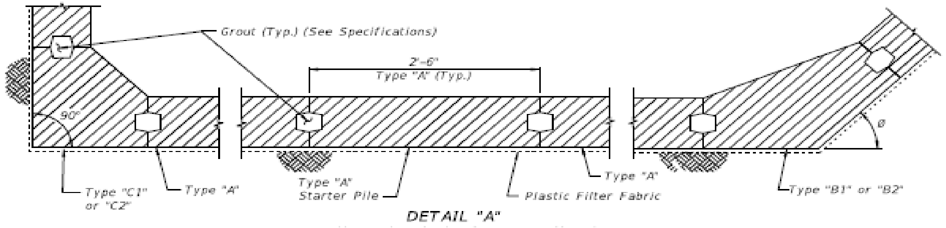
Traditional RC Bulkhead





Traditional RC Bulkhead Cap

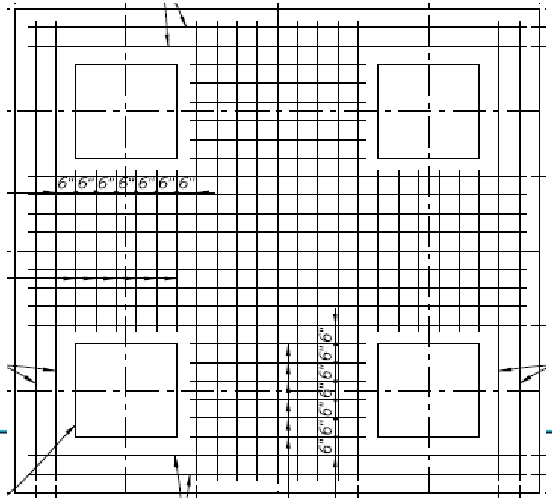


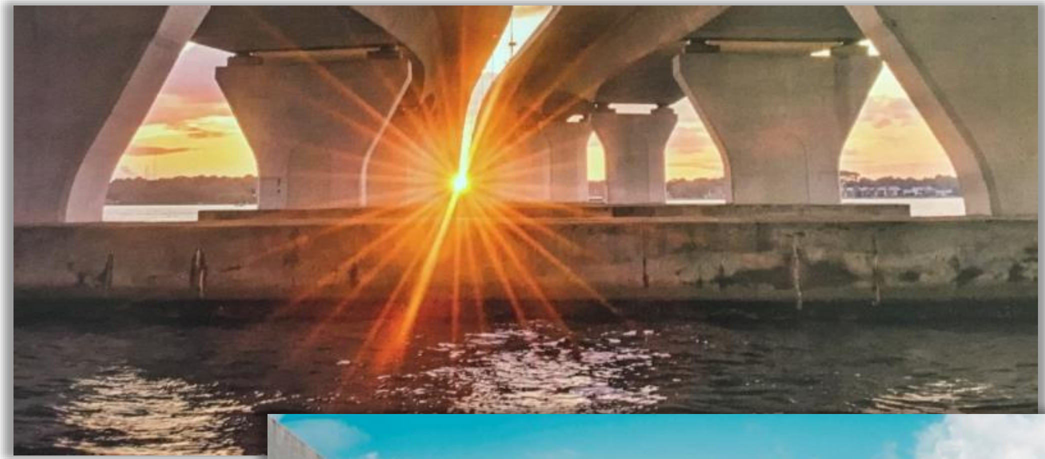


Future Elements - Substructures

Waterline footings & columns in saltwater – *need big bars for this!*

#10 bars recognized in
ASTM D7957;
Will need #11 bars in future;
May also need #14 bars?





Example Projects for - Bridge Piles

Bridge Bearing Pile Projects

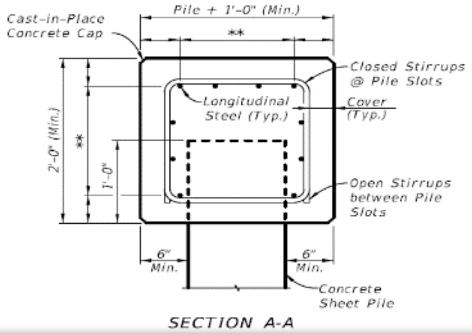
- Halls River Bridge (Homosassa)
- NE 23rd Ave/Ibis Waterway (City of Lighthouse Point)
- C Street Bridge (Cedar Key)
- Barracuda Blvd (New Smyrna)
- 40th Ave. N (St Petersburg)
- iDock (Miami)
- Maydell Dr. (Tampa) ?

Example Projects for - Seawall-Bulkheads

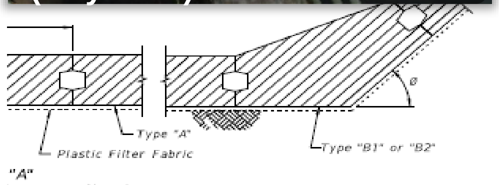
Concrete Sheet Pile Bulkhead Projects

HRB Sheet Pile Walls (2017-18)

- SR24/Channel 3 (Cedar Key)
- Halls River Bridge (Homosassa)
- Bakers Haulover Cut (Miami)
- Skyway Rest Area (Manatee Co.)
- Pinellas Bayway – Structure E
- NE 23rd Ave/Ibis Waterway (City of Lighthouse Point)
- Barracuda Blvd (New Smyrna)
- Maydell Dr. (Tampa)
- 40th Ave. N (St Petersburg)



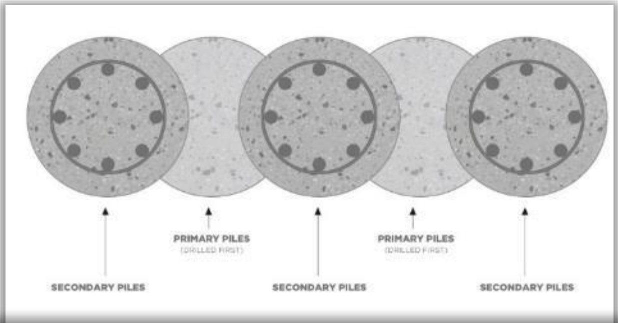
Skyway Rest Area Rehab. (May 2018)



Example Projects for - Seawall-Bulkheads

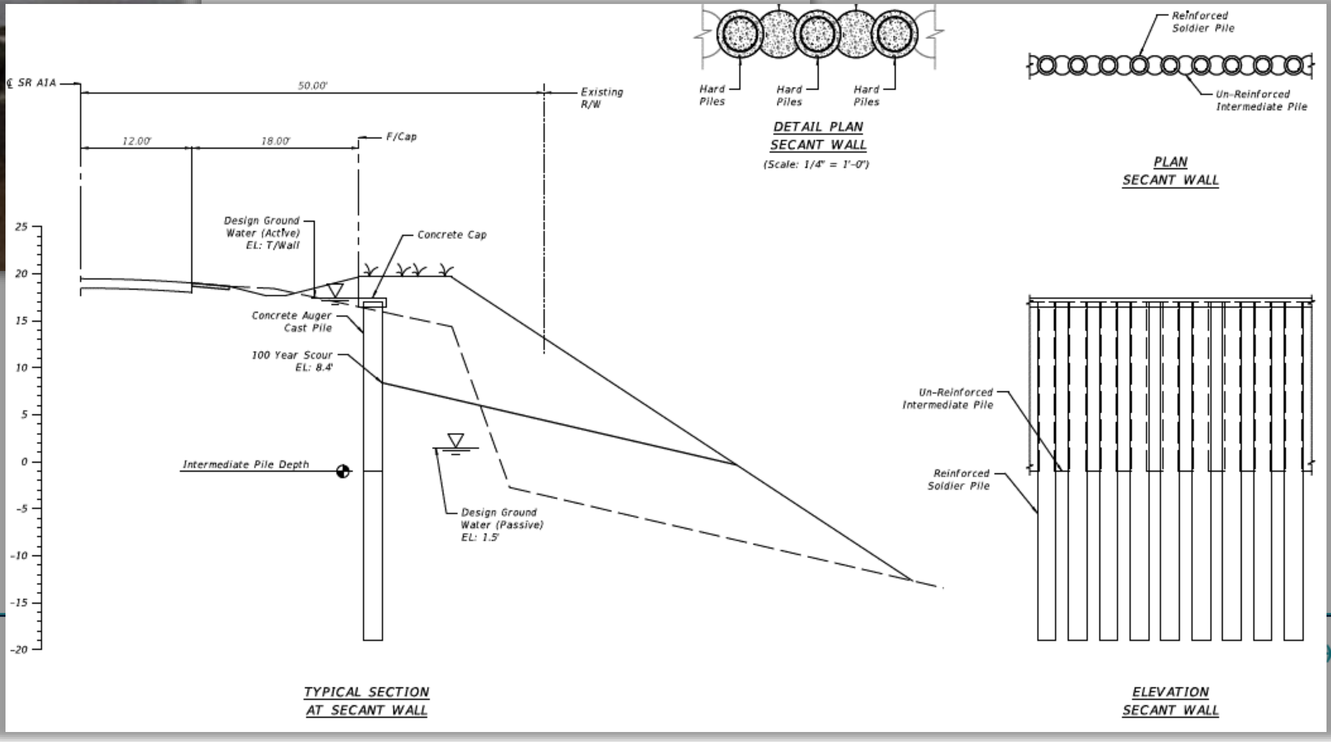
Secant Piles seawall on SR A1A


SR A1A damage after Hurricane Matthew (2016)




GFRP Pile cages (Hughes Bros.)

Secant Wall Concept Rendering

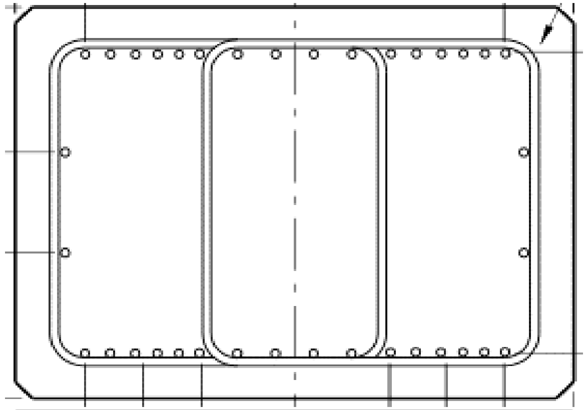


Examples Projects for – Bridge Pile Bent Caps

Projects:

- Halls River Bridge (Homosassa)
- NE 23rd Ave/Ibis Waterway (City of Lighthouse Point)
- Barracuda Blvd (New Smyrna)
- iDock (Miami)
- Maydell Dr. (Tampa)?
- 40th Ave. N (St Petersburg)?

HRB GFRP-RC Pile Caps (2017)



Typical Section from HRB Plans

iDock pile bent caps GFRP rebar cages,Coreslab (2018)

Hurricane Irma damage of boat docks (2017)

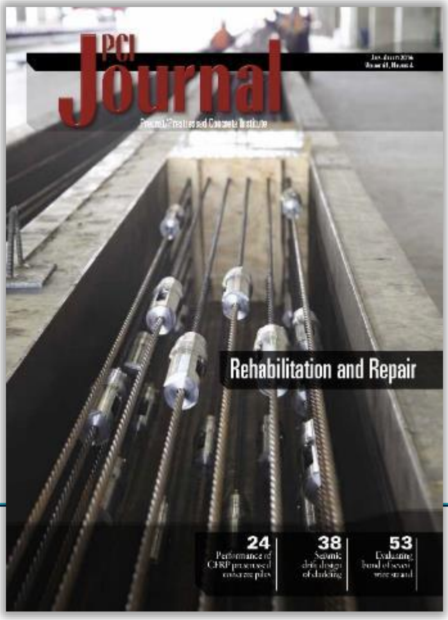
Example Projects for - Girders/Slab-Beams

Projects:

- Halls River Bridge = **HCB's** (Homosassa)
- NE 23rd Ave/Ibis Waterway = **Flat-Slab** (City of Lighthouse Point)
- US-1 over Cow Key Channel = **FSB CFRP/GFRP** (Key West)
- 40th Ave. N = **FSB's** ? (St Petersburg)
- Maydell Dr. = **FSB's** ? (Tampa)


HCB's set on GFRP-RC Pile Caps


CFRP/GFRP combined



Project Identification & Delivery

1. **Environmental condition driven**
   - Durability (corrosion-resistant)/Magnetic Transparency/LCC
2. **Optional precast alternatives**
   - Encourage stakeholder buy-in
3. **Desire for multiple suppliers**
   - Redundancy & Supply chain security
4. **Simplify design process/workflow**
5. **Minimize change for Contractors**
   - Business as usual…almost

Principles for Broader Deployment

1. Stewardship
2. Confidence
3. Competency
4. Consistency
5. Codification

NCHRP Report 503 (2003) identified 11 elements for a draft strategic plan as follows:

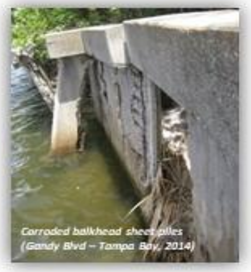
1. Buy-in from all strategic plan participants;
2. Acceptance, implementation, and revision of the strategic plan;
3. The means to oversee and manage the strategic plan;
4. A study of the relative costs of FRP versus traditional materials;
5. A database of practical infrastructure-based FRP knowledge;
6. Generic bridge-specific material specifications;
7. Generic bridge-specific design and evaluation methodologies;
8. Generic bridge-specific inspection and repair methods;
9. Training on FRP composite materials for practicing engineers;
10. Education on FRP composite materials for graduate civil engineers; and
11. Continuation of FHWA's Innovative Bridge Research and Construction (IBRC) program.

Principles for Broader Deployment

Participants/Collaborators

Top 5 Long-Term Goals

- Stewardship
- Confidence
- Competency
- Consistency
- Codification

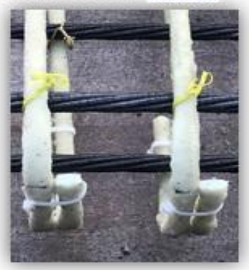


2018 FDOT-FRP Industry 2nd Winter Workshop

Safe Deployment of FRP-RC/PC for Structural Reinforcement

- *Next Generation Infrastructure*

(eliminating the threat of steel corrosion)



2018 Strategic Workplan items

1. **Endurance Limits**
2. **Endurance Characteristic Curves and Testing**
3. **Establishing Consistency**
4. **Increasing Material Property Qualification Thresholds and Design Limits**
5. **Cost Estimating**
   a. OC initiative for ACMA FRP-RMC
   b. FDOT SDG Chapter 9 update
6. **Bar Bends**
   a. Complex Shapes
   b. FDOT Index D21310
7. **Minimum Bar Sizes for Design Elements**
8. **Life-Cycle Cost Guidance**
9. **Minimum Concrete Class (strength)**

http://www.fdot.gov/structures/Innovation/FDOT%202018%20Winter%20FRP-RC%20Workshop/Default.shtm

Principles for Broader Deployment

1. Stewardship

- Responsible use of public funds = specify FRP where it makes sense;
- Maximize material efficiency = strive for constant improvement;
- Identify additional technical resources for exploitation = getting outside of our "silos".

Bakers Haulover Cut GFRP-RC Bulkhead Cap (2017-18)

US 17 over Trout River
GFRP-RC Substructure Rehab. (2016)

Principles for Broader Deployment

1. Stewardship
2. **Confidence**
   - Build Stakeholder confidence = *owners, designers, contractors, suppliers, inspectors*;
   - Supply Chain security = *redundancy, scalability, sustainability.*

Principles for Broader Deployment

1. Stewardship
2. Confidence
3. **Competency**

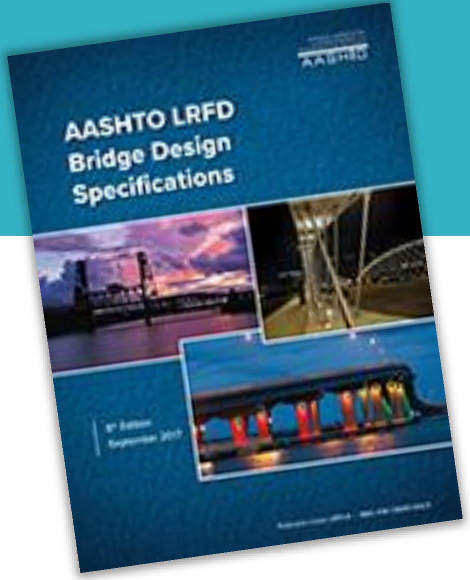
- Designer qualifications/training *= all minor bridge consultants;*
- Design Tools *= calculations & estimates;*
- Contractor & Inspector guidance *= CPAM & training.*

Principles for Broader Deployment

4. Consistency

- Material reliability *= data gathering and curation;*
- Encourage improved QC *= improved reliability;*
- Simplified verification testing *= improved reliability and efficiency;*

Principles for Broader Deployment



4. Consistency

5. Codification

- Establish **“Roadmap”** for ***AASHTO LRFD BDS*** adoption;
- Coordination with ***CBS T-6***, ***T-10***, & ***ACI 440***;
- Coordination with other national and international authoritative committees = ***TRB’****s AFF80*, ***CSA***, *Jiangsu Composite Society?*

Actions for Broader Deployment – IW-GFRPCS2

Second International Workshop on GFRP Bars for Concrete Structures *(Jan 15-16th, 2019)*

Workshop Theme: "Advances in concrete reinforcement"

Goal of Workshop: *Defining a path to broadly implement FRP bar for safe, economical and resilient concrete structures. Non-corrosive FRP rebars are an effective alternative to steel reinforced concrete, with a market estimated at $600M (2017). This workshop is geared for stakeholders involved in concrete construction, including owners, manufactures, installers, distributors, engineers, architects, and state and city/local officials. The workshop aims to define a path to fully implement FRP bar for concrete structures.*

https://iw-gfrpcs2registration.azurewebsites.net/

Thank you for your attention

Florida's Fiber-Reinforced Polymer "Deployment Train"

External FRP Laminate Repairs	Fender Systems	Carbon FRP-PC	Glass FRP-RC	Composite Bridge Girders	Basalt FRP-RC
1990's	*2000's*	*2015*	*2016*	*2016*	*2019*