TRB ANNUAL MEETING, (WASHINGTON DC.) JANUARY, 2019

Session 1114 - Monday 1/14/2019, 8:00-9:45 am

Bakers Haulover Cut Bridge: Seawall-Bulkhead Rehabilitation and New GFRP-RC Solutions

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FDOT

Outline

1. Defining the problem… Are Composites the solution?
2. Existing BHC Seawall System(s)
3. New BHC Seawall-Bulkhead Design
4. Construction & Lessons Learned
5. New Challenges – *SLR, Extreme Weather, Sustainability, Increased Durability Expectations*
6. New Solutions – *SEACON, GFRP-PC*
7. Improving of Creep-Rupture limits
8. Where do we go from here?

What is the Problem?

Need for New Solutions for Corrosion Durability and Sustainability

Avoiding corrosion *"concrete cancer"*

- GFRP or SS rebar
- CFRP or HSSS prestressing strand

i. Cost-Benefit Analysis Justification, LCA/LCC;

ii. Durability = Long Service Life;

iii. Challenges & Mitigating Risks

- Acquisition Cost
- New material systems;
- Limited suppliers/competition;
- Unfamiliar design criteria;
- Unfamiliar construction practices.

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

Courtney Campbell Causeway, seawall (Tampa Bay)

Gandy Blvd. seawall, (Tampa Bay)

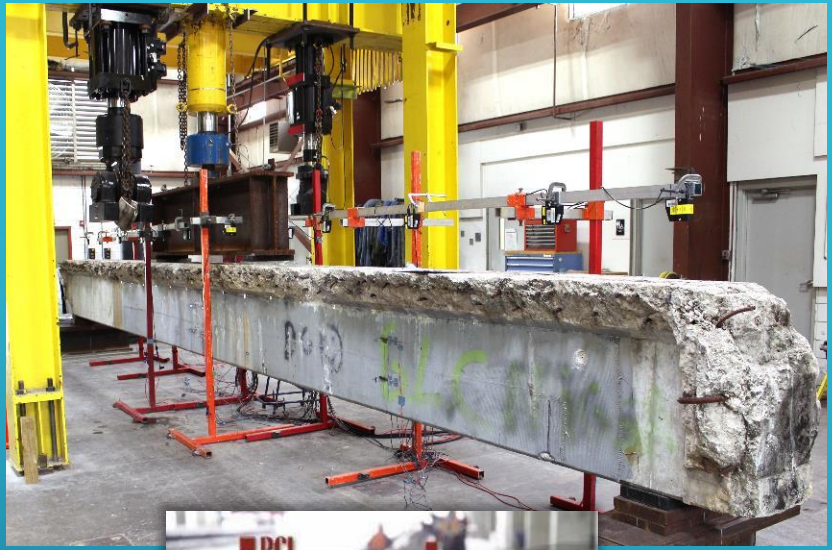
Are Composites the Solution?

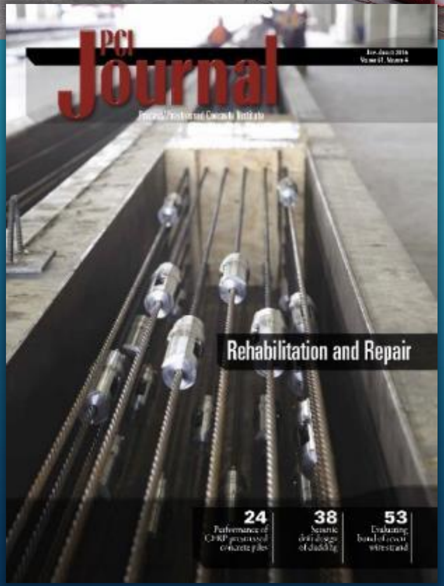
FDOT Research Efforts

- Service Life Enhancement thru Durability:

1992	Feasibility of Fiberglass Pretensioned Piles in a Marine Environment	Sen, R.	USF
1995	Active Deformation Control of Bridges with AFRP Cables	Arockiasamy, M.	FAU
1995	Durability of CFRP Pretensioned Piles in a Marine Environment – Phase II	Sen, R.	USF
1997	Mechanical and Microscopy Analysis of CFRP Matrix Composite Materials	Garmestani, H.	FAMU/FSU
1997	FRP Composite Column and Pile Jacket Splicing	Mirmiran, A.	UCF
1997	An Analytical and Experimental Investigation of Concrete Filled FRP Tubes	Mirmiran, A.	UCF
1997	Flexural Reliability of RC Bridge Girders Strengthened with CFRP Laminates	Okeil, A.	UCF
1998	Studies of CFRP Prestressed Concrete Bridge Columns and Piles in Marine Environment	Arockiasamy, M.	FAU
1999	LRFD Flexural Provisions for PSC Bridge Girders Strengthened with CFRP Laminates	El-Tawil, S.	UCF
2000	Investigation of Fender Systems for Vessel Impact	Yazdani, N.	FAMU/FSU
2001	Design of Concrete Bridge Girders Strengthened with CFRP Laminates	El-Tawil, S.	UCF
2003	Hybrid FRP-Concrete Column	Mirmiran, A.	NC State
2004	CFRP Repair of Impact Damaged Bridge Girders	Hamilton, T	UF
2009	Thermo-Mechanical Durability of CFRP Strengthened RC Beams	Mackie, K	UCF
2011	Testing of Trelleborg Structural Plastics	Wagner, D.	FDOT

Are Composites the Solution?





FDOT Research Efforts (Cont.)

2012	The Repair of Damaged Bridge Girders with CFRP Laminates	El-Safty, A.	UNF
2014	Investigation of CFCC in Prestressed Concrete Piles	Roddenberry, M.	FAMU/FSU
2015	Repair of Impact Damaged Utility Poles with FRP, Phase II	Mackie, K.	UCF
2015	Use of CFRP Cable for Post-Tensioning Applications	Mirmiran, A.	FIU
2017	Durability Evaluation of Florida's FRP Composite Reinforcement for Concrete Structures	Hamilton, T.	UF
2018	Bridge Girder Alternatives for Extremely Aggressive Environments	Brown, J.	ERAU
2018	Degradation Mechanisms and Service Life Estimation of FRP Concrete Reinforcements	El-Safty, A.	UNF
2018	Testing, Evaluation, and Specification for Polymeric Materials used for Transportation Structures	El-Safty, A.	UNF
2018	Performance Evaluation of GFRP Reinforcing Bars Embedded in Concrete Under Aggressive Environments	Kampmann, R.	FAMU/FSU
2019	Inspection and Monitoring of Fabrication and Construction for the West Halls River Road Bridge Replacement	Roddenberry, M.	FAMU/FSU
2021	Evaluation of GFRP Spirals in Corrosion Resistant Concrete Piles	Jung, S.	FAMU/FSU
2021	Development of GFRP Reinforced Single Slope Bridge Rail	Consolazio, G.	UF
2019	Performance Evaluation, Material and Specifications for Basalt FRP Reinforcing Bars Embedded in Concrete (STIC)	Kampmann, R. Roddenberry, M.	FAMU/FSU
2021	Testing Protocol and Material Specifications for Basalt Fiber Reinforced Polymer Bars	Kampmann, R. Tang, Y	FAMU/FSU

Seawall-Bulkhead Development in Florida

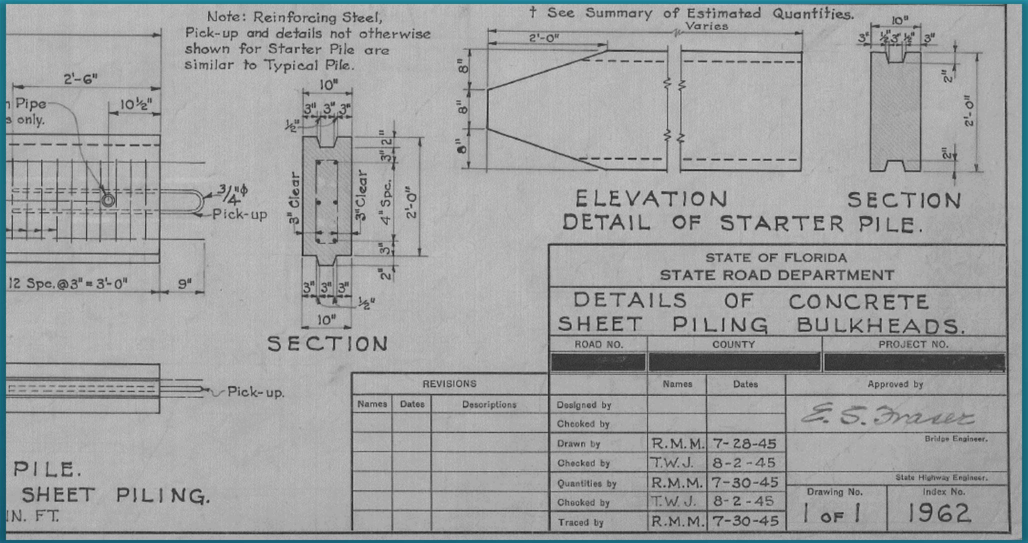
for the Built-Environment...

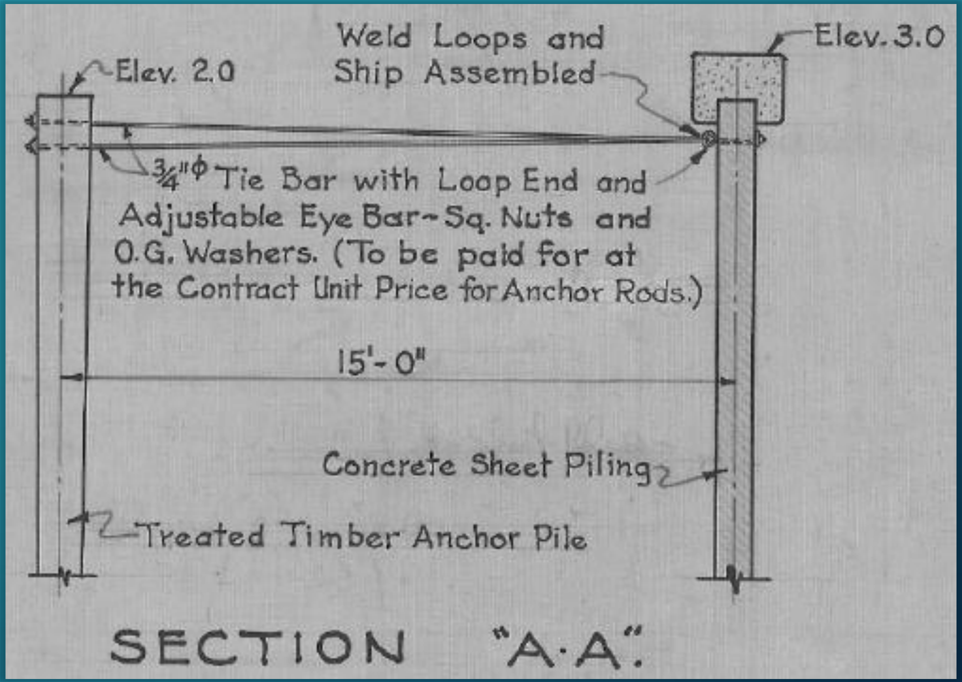
Davis Islands, PCA Concrete Piles Pub., pg.70 (1951)

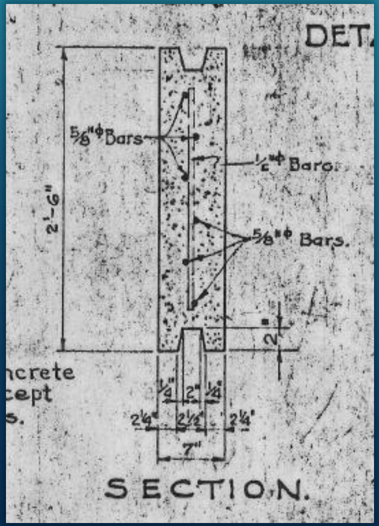
(*Photographs courtesy of the Burgert Bros.*)

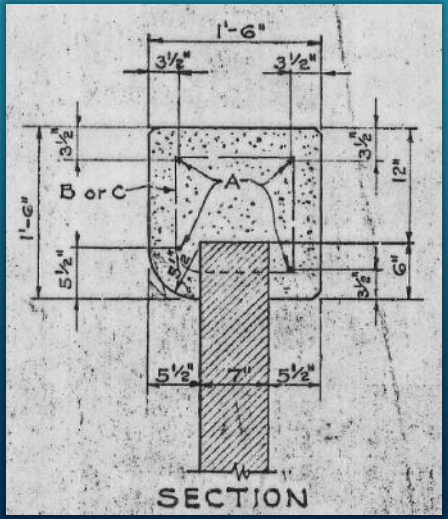
Seawall-Bulkhead Development in Florida

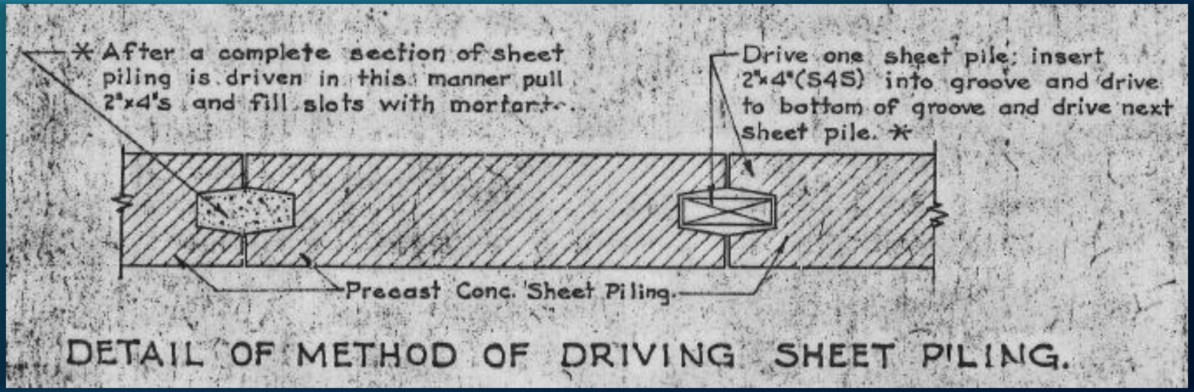
Reinforced Concrete: since 1920's











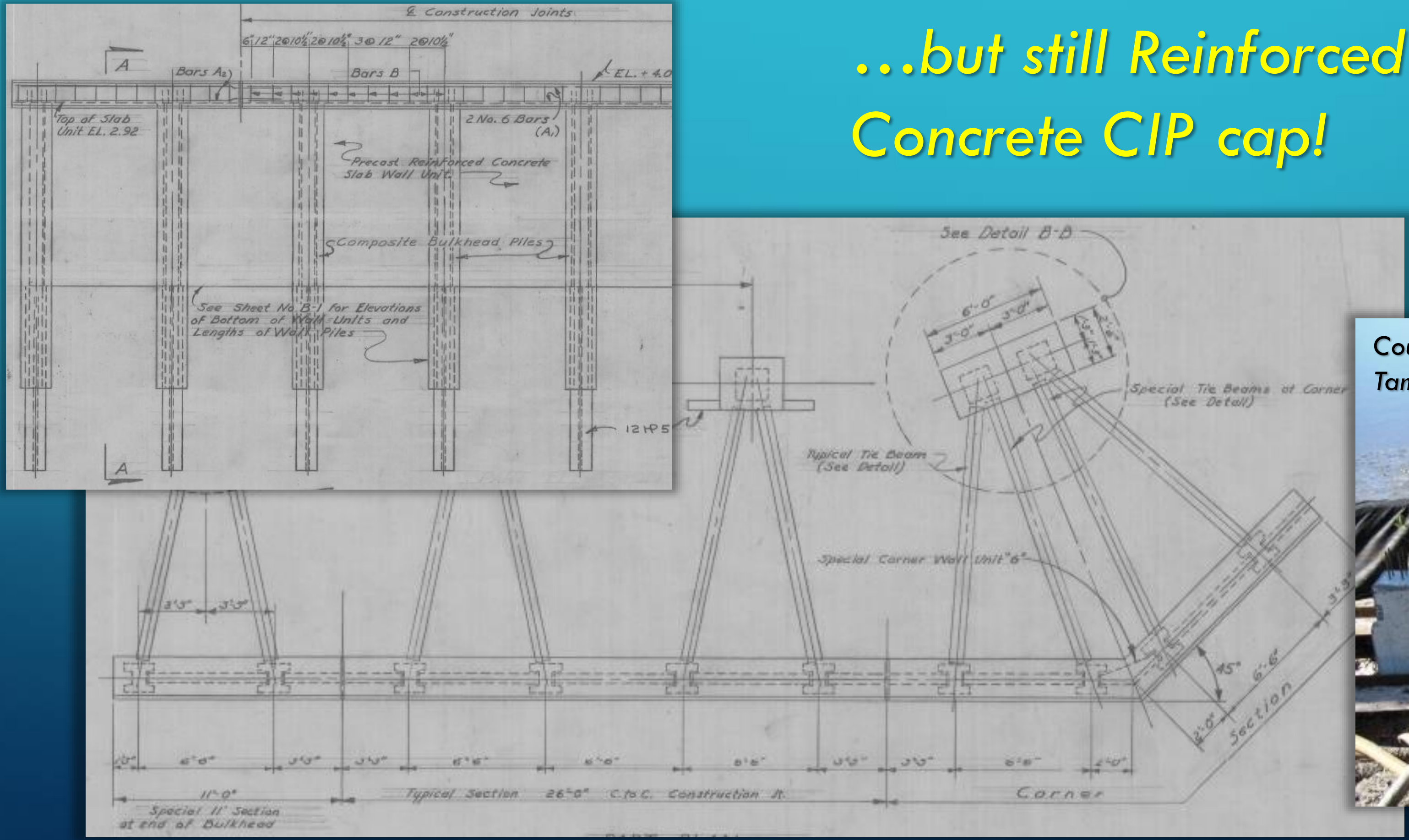
Images from 1945 (Index 1962) & 1946 (Index 2039) Standards.
Florida State Road Dept. (FDOT)

Seawall-Bulkhead Development in Florida

Prestressed Concrete:

- Soldier Piles in the 1950's
- Sheet Piles in the 1970's *…better,*

…but still Reinforced Concrete CIP cap!



Replace corroded RC seawalls.
Tampa Bay, FDOT (2011)

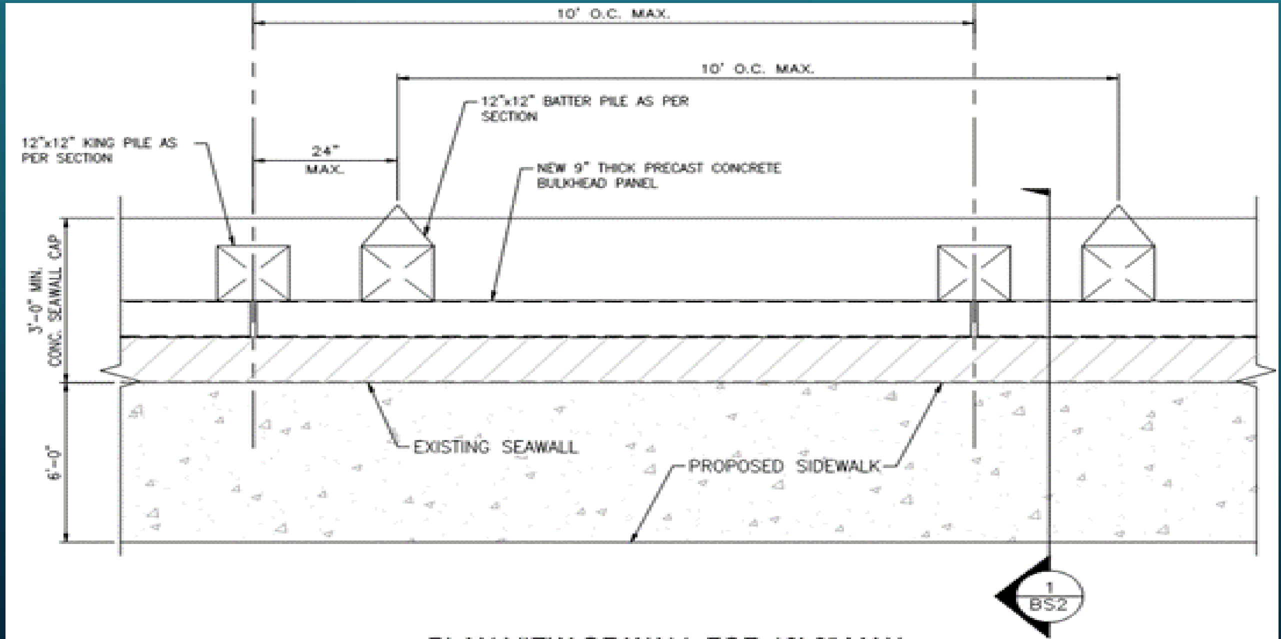
Courtney Campbell Causeway,
Tampa Bay, FDOT (2011)

Seawall-Bulkhead Development in Florida

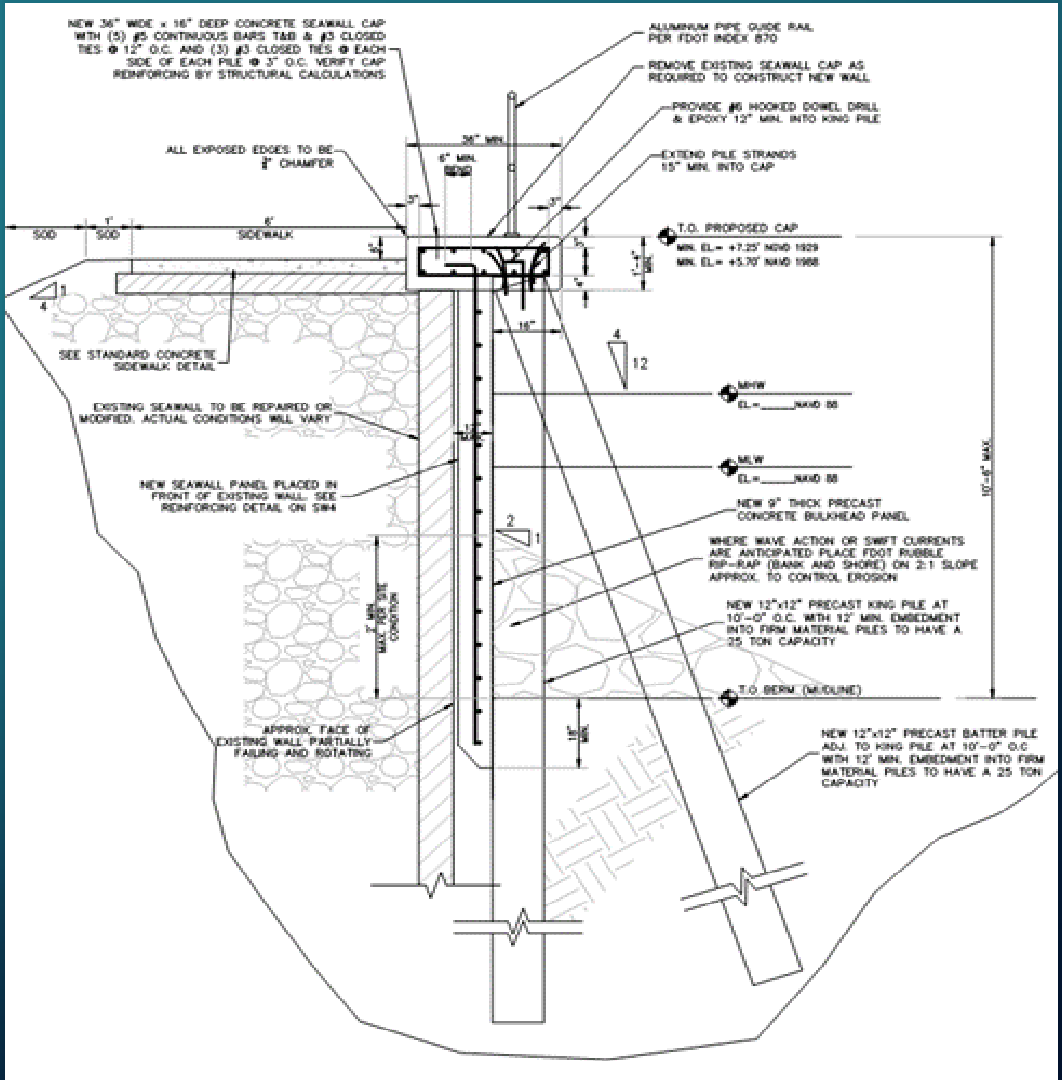
Prestressed Concrete (Miami-Dade):

- Soldier Piles in the 1950's & 60's
- Still using RC panels in between…

…similar durability challenges



PLAN VIEW OF WALL FOR 10'-0" MAX.
RETAINED FILL BEHIND WALL



SEAWALL SECTION 1
FOR RETAINED FILL NOT TO EXCEED 10'-0" DEPTH

Miami Beach Public Works Manual (2015)

Seawall-Bulkhead Development in Florida

CFRP Prestressing, since 2014 *…best ?*

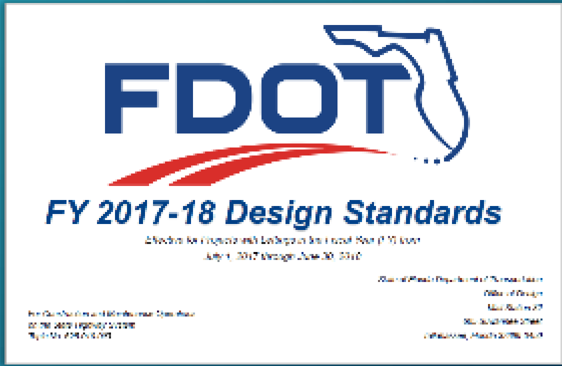
i. Design criteria for prestressing – ***Fiber Reinforced Polymer Guidelines*** **(FRPG)** – Chapter 3;

ii. ***Developmental*** Index D22440 *(Nov. 2014)*

- (Halls River Bridge demonstration project);

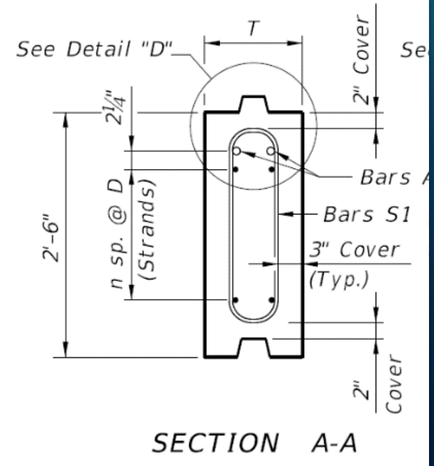
iii. FDOT ***FY2017-18 Design Standards*** *(Nov. 2016)*

- Index 22440 series *(now Index 455-100 series FY10-20)*;
- CFRP prestressing strands & GFRP stirrups;
- Stainless Steel prestressed/reinforced alternative.



Vibro-hammer installation at Halls River Bridge FDOT (2017)

CFCC prior to stressing at Gate Precast (2016)



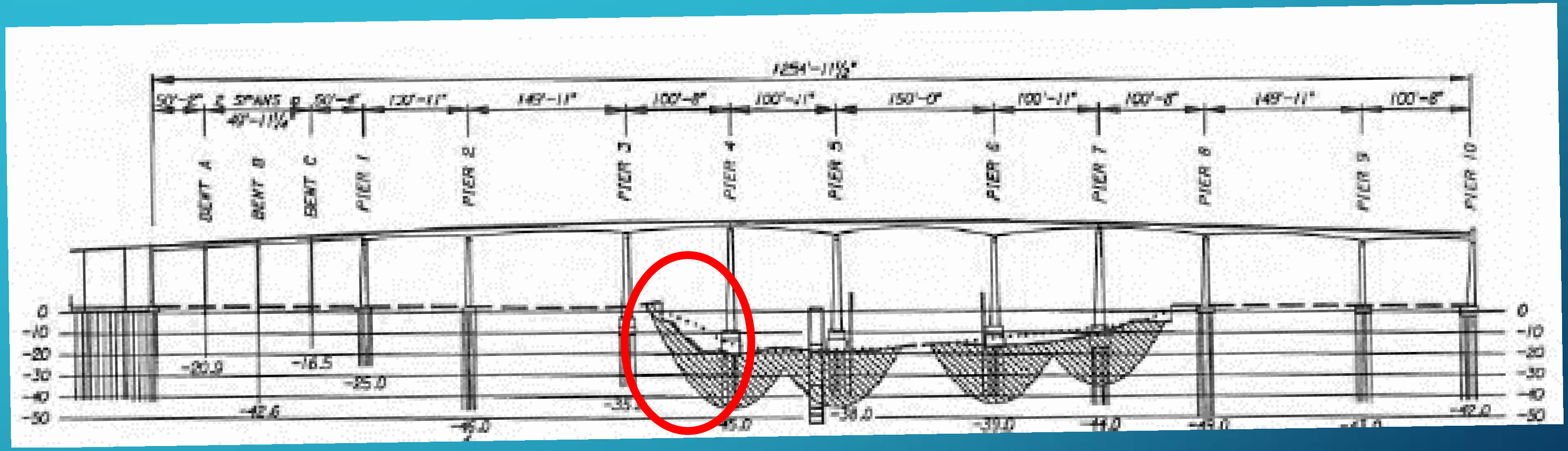
GFRP Stirrups ties to CFRP strands (2016)

Existing BHC Bulkhead System(s) at BHC Project

Pile & Panel (north wall) Prestressed Sheet Pile (south wall):

…both in severely corroded condition

Soldier Pile & Panel System (original 1948): Extensive corrosion damage in splash zone



Prestressed Sheet Pile System (rebuilt 1970's): Extensive corrosion damage in splash zone

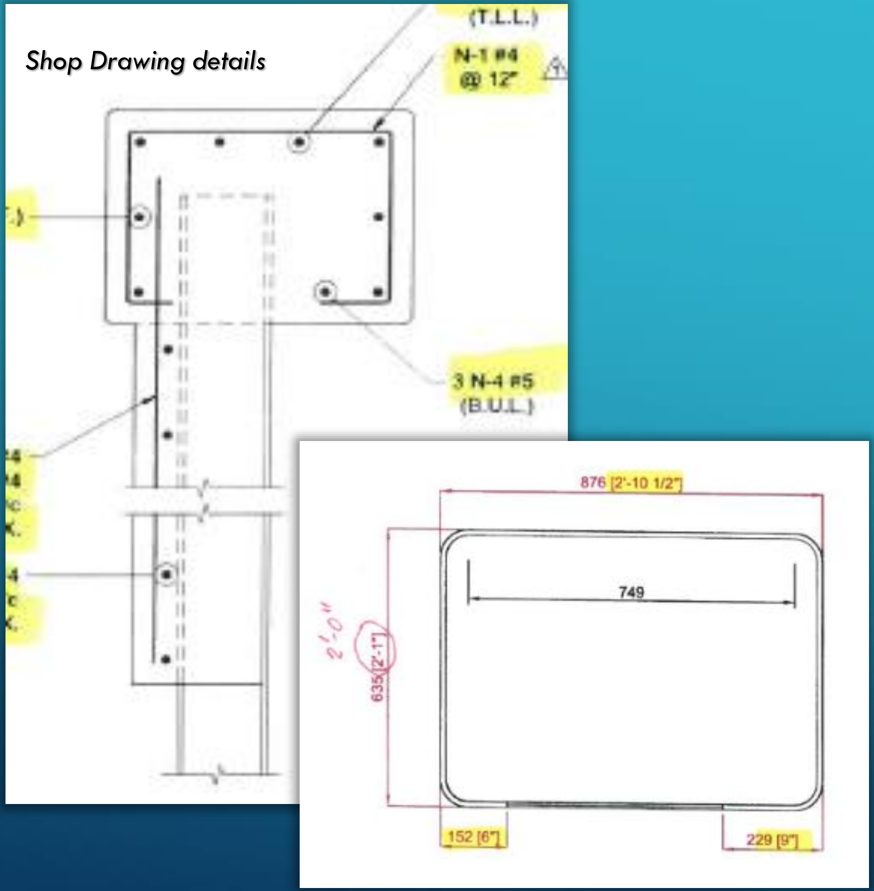
Adjacent properties to Southwest with one section recently repaired (2014 county approval)

Bridge site looking Southwest (courtesy: BPA Consulting Eng.)

New Seawall-Bulkhead System at BHC

Selected Alternative: *…Steel Sheet Piles with GFRP-RC facia*

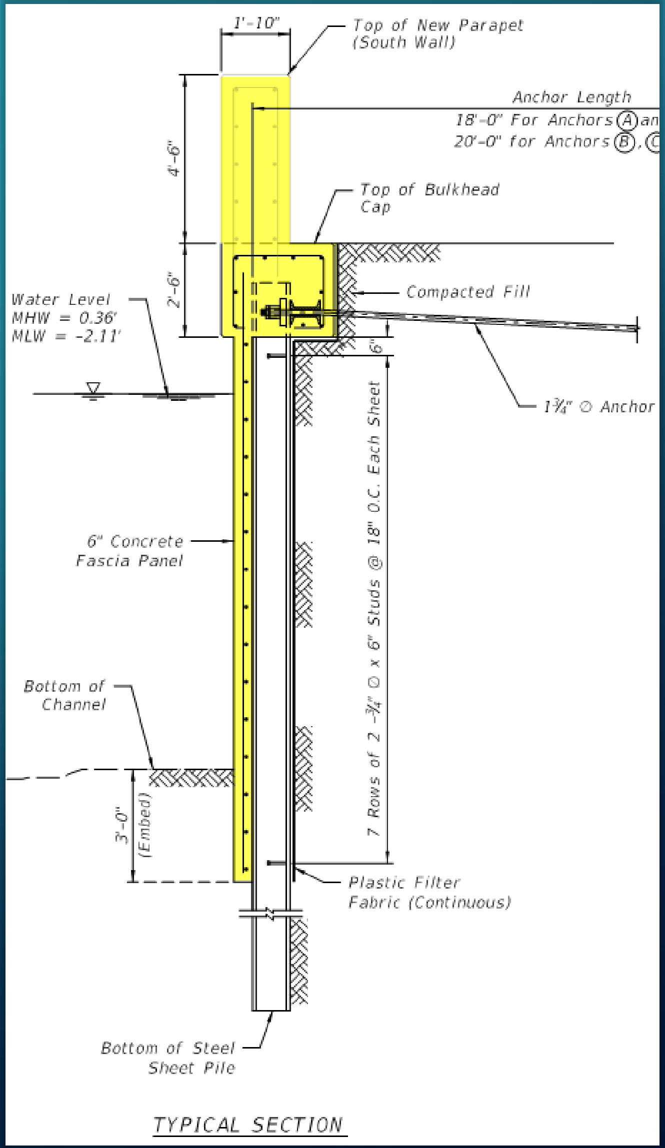
Shop Drawing details




Bulkhead wall cap GFRP reinforcement in place


Hoisting GFRP rebar mat for placement in form

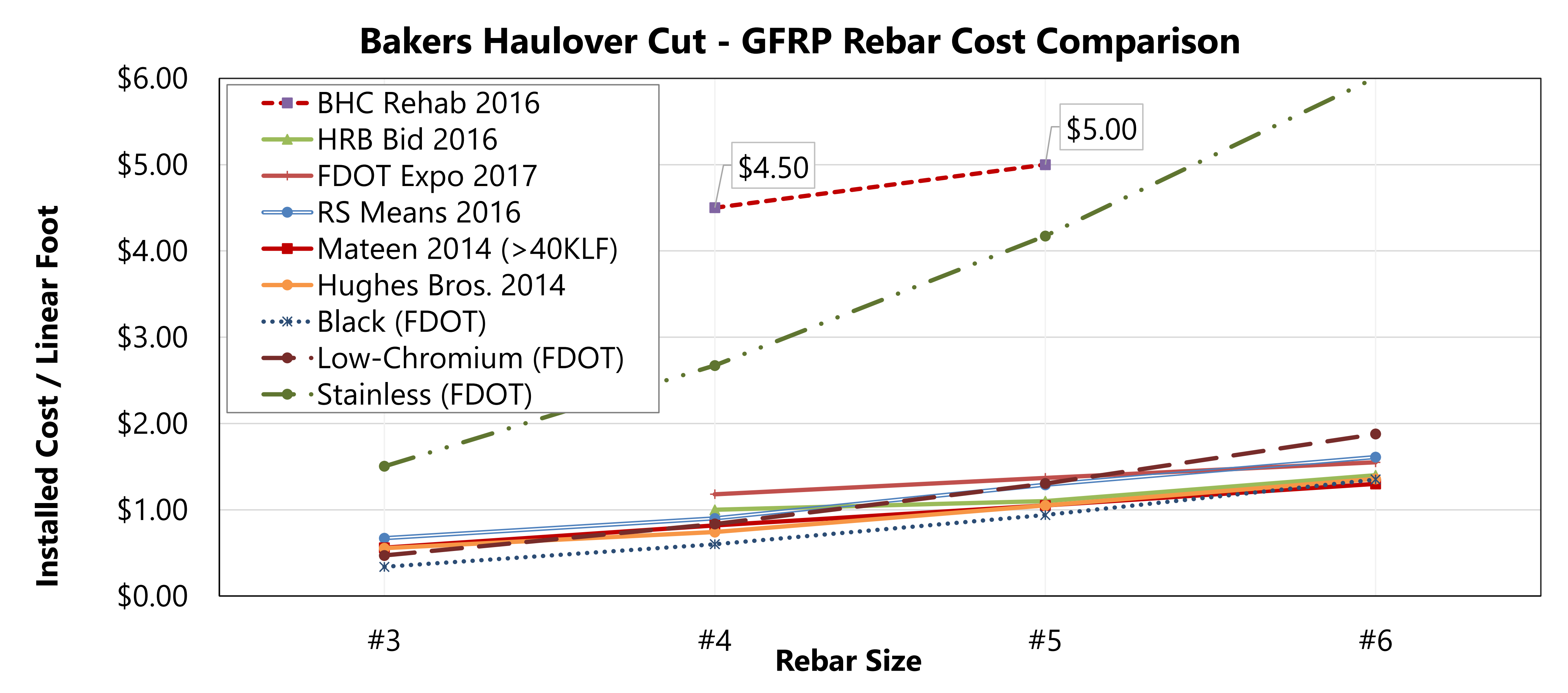

Divers placing GFRP mat in forms



914-415-104	FIBER REINFORCED POLYMER BAR #4	BULKHEAD CAP, PARAPET & FASCIA PANEL	LF	12,199.32
914-415-105	FIBER REINFORCED POLYMER BAR #5	BULKHEAD CAP, PARAPET & FASCIA PANEL	LF	7,071.14

New Seawall-Bulkhead System at BHC

Selected Alternative: *…Steel Sheet Piles with GFRP-RC facia*



914-415-104	FIBER REINFORCED POLYMER BAR #4	BULKHEAD CAP, PARAPET & FASCIA PANEL	LF	12,199.32
914-415-105	FIBER REINFORCED POLYMER BAR #5	BULKHEAD CAP, PARAPET & FASCIA PANEL	LF	7,071.14

New Challenges

SLR, Extreme Weather, Sustainability, Increased Durability Expectations

Photos from Hurricane Matthew (2016)

New Challenges

SLR, Extreme Weather, Sustainability, Increased Durability Expectations

(a) Hurricane Damage along A1A (*2008*)
(b) Hurricane Sandy damage along A1A in Fort Lauderdale *(Photo: Susan Stocker, Sun Sentinel, 2012)*.
(c) Hurricane Mathew damage along A1A Flagler Beach, (*2016*)
(d) Brickell Ave under water during Hurricane Irma *(2017)*

New Solutions

Reviving an old system with new material - Post and Panel with FRP-RC/PC

2 new FDOT projects in design:

1. SE 23rd Ave Bridge Replacement
2. US 41 over North Creek replacement
3. Possibly… Barracuda Blvd. over Indian River North

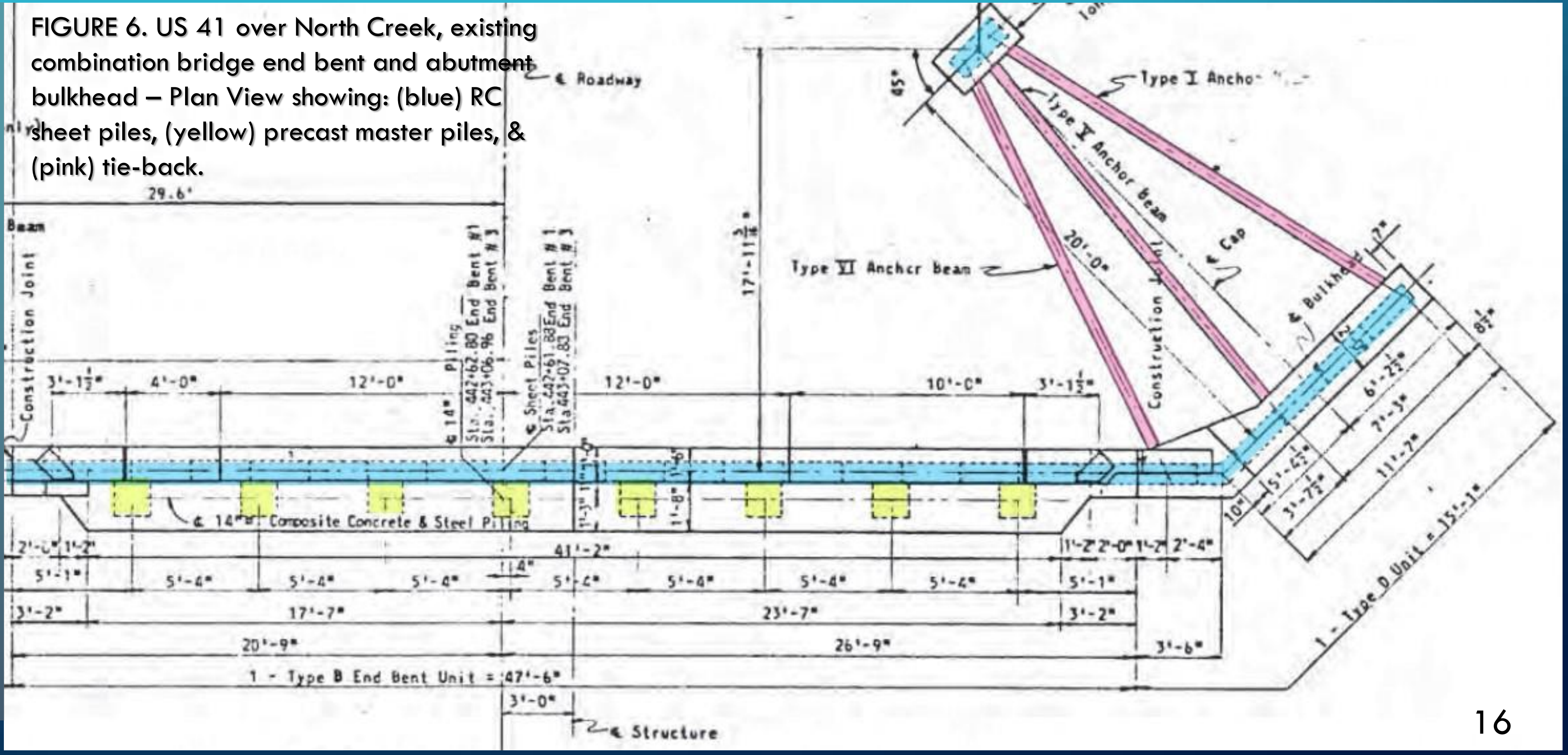
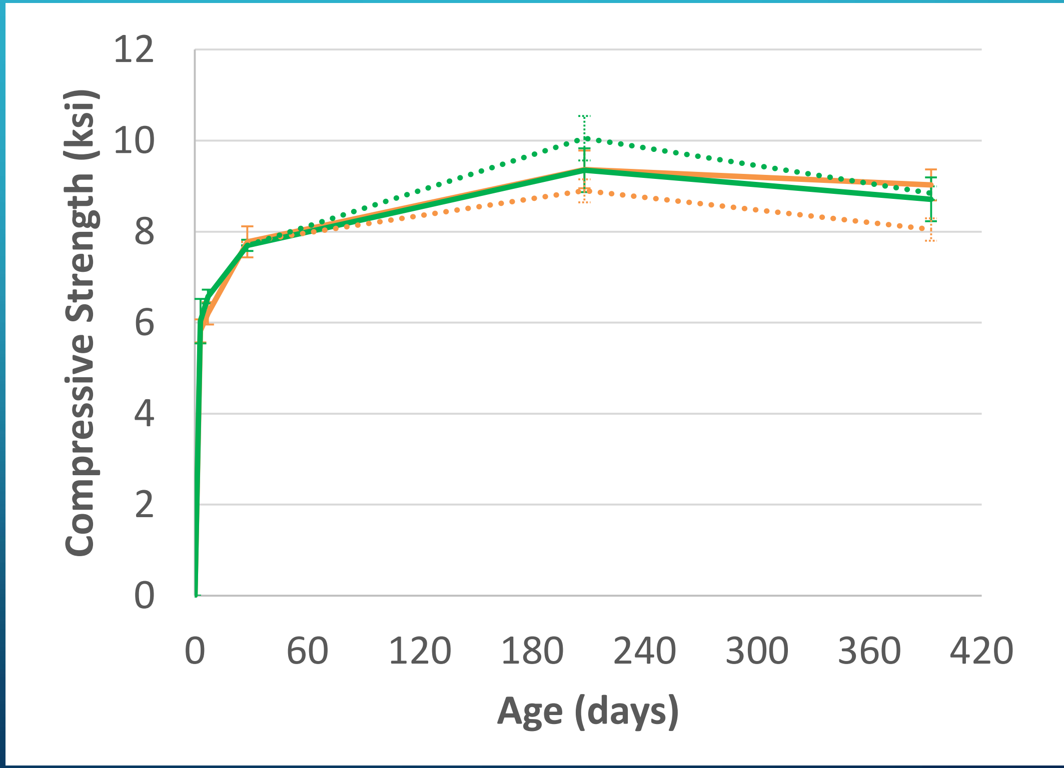


FIGURE 6. US 41 over North Creek, existing combination bridge end bent and abutment bulkhead – Plan View showing: (blue) RC sheet piles, (yellow) precast master piles, & (pink) tie-back.

New Solutions

SEACON…

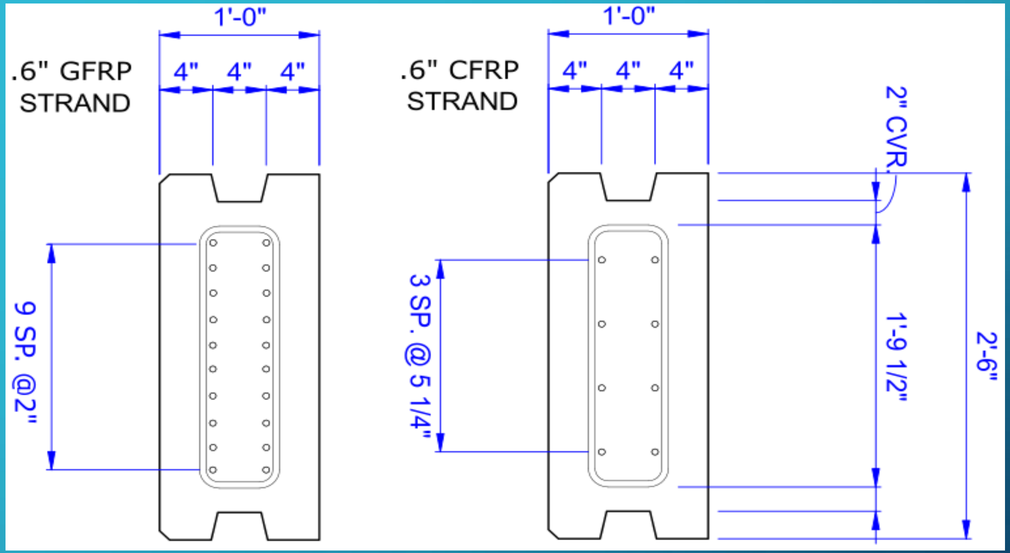
Sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement



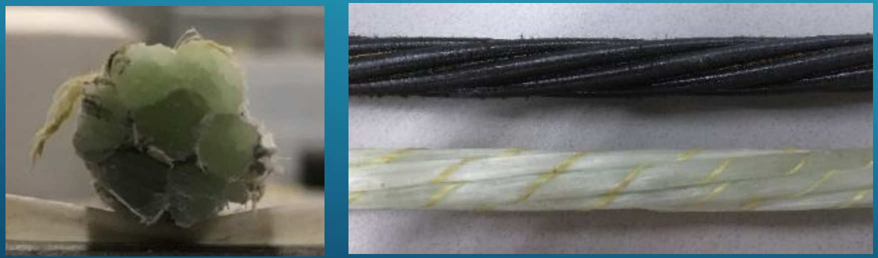
New Solutions

IDEA Project - *MILDGLASS*

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



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



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

(a) & (b) Tensioning apparatus for CFRP; versus (c) standard steel HSCS chucks, for GFRP.

New Solutions

- Affordable higher modulus GFRP $\geq$ 65 GPa (9,000+ ksi)
- Adhoc continuous stirrups;
- STIC 2018 Incentive Project
  – *Basalt-FRP Rebar Standardization*

STIC State Transportation Innovation Councils

"Develop standard (guide) design specification, and standard material and construction specifications for basalt fiber-reinforced polymer (BFRP) bars for the internal reinforcement of structural concrete"

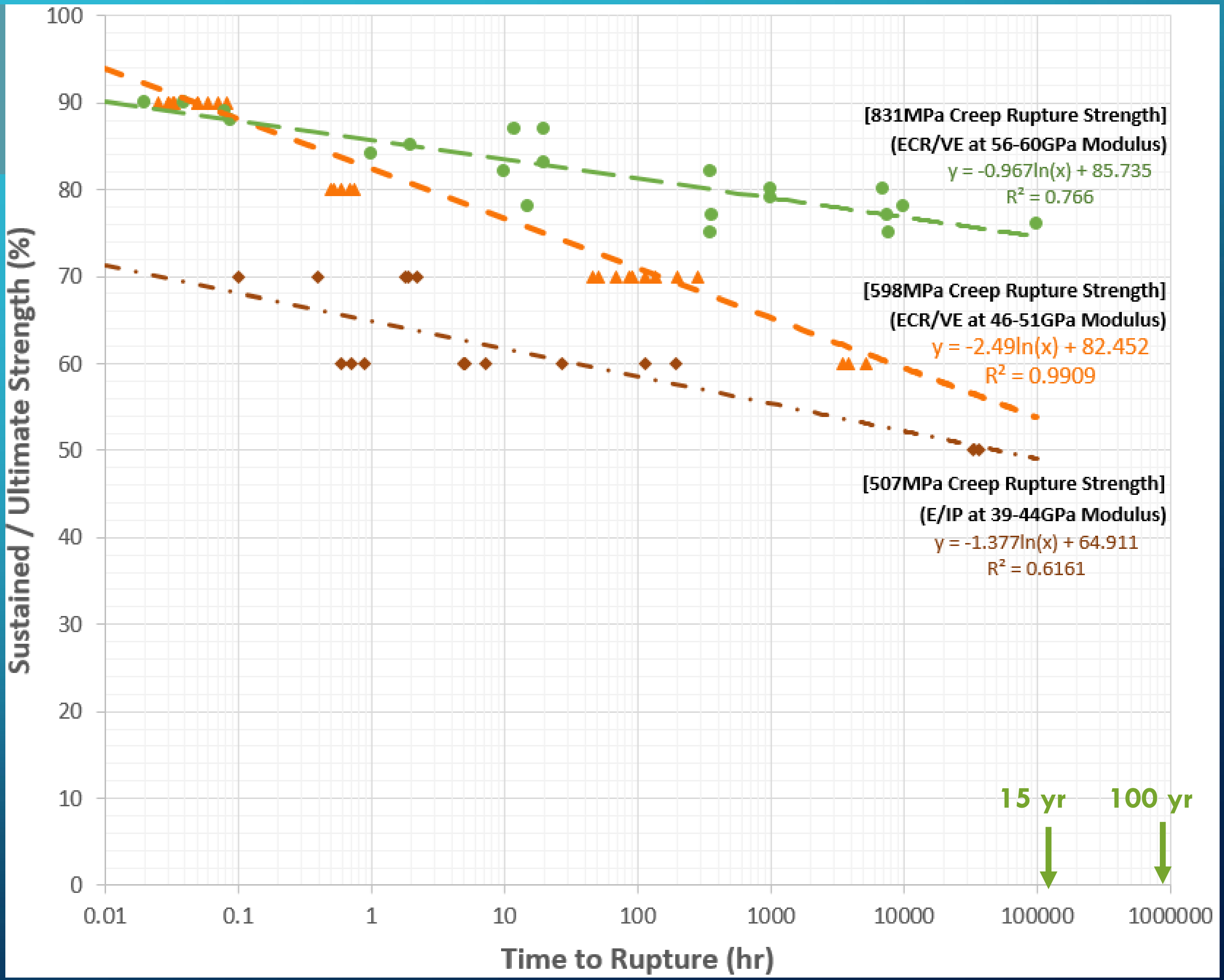
Photo courtesy of Don Smith, RAW Energy Materials (2019)

Why Improve Creep-Rupture Limits?

Enhance AASHTO Specifications and Extend Bridge Service Life

ACI 440.3R B.8 GFRP Creep Rupture Accelerated Testing

1. ACI 440.1R limits the allowable sustained stress for traditional GFRP;
2. Creep rupture limit recently improved C_C = 0.2 to 0.3 in AASHTO BDGS-2;
3. ASTM D7957 GFRP rebar of ECR glass fiber in vinyl ester shows improved creep rupture limit.

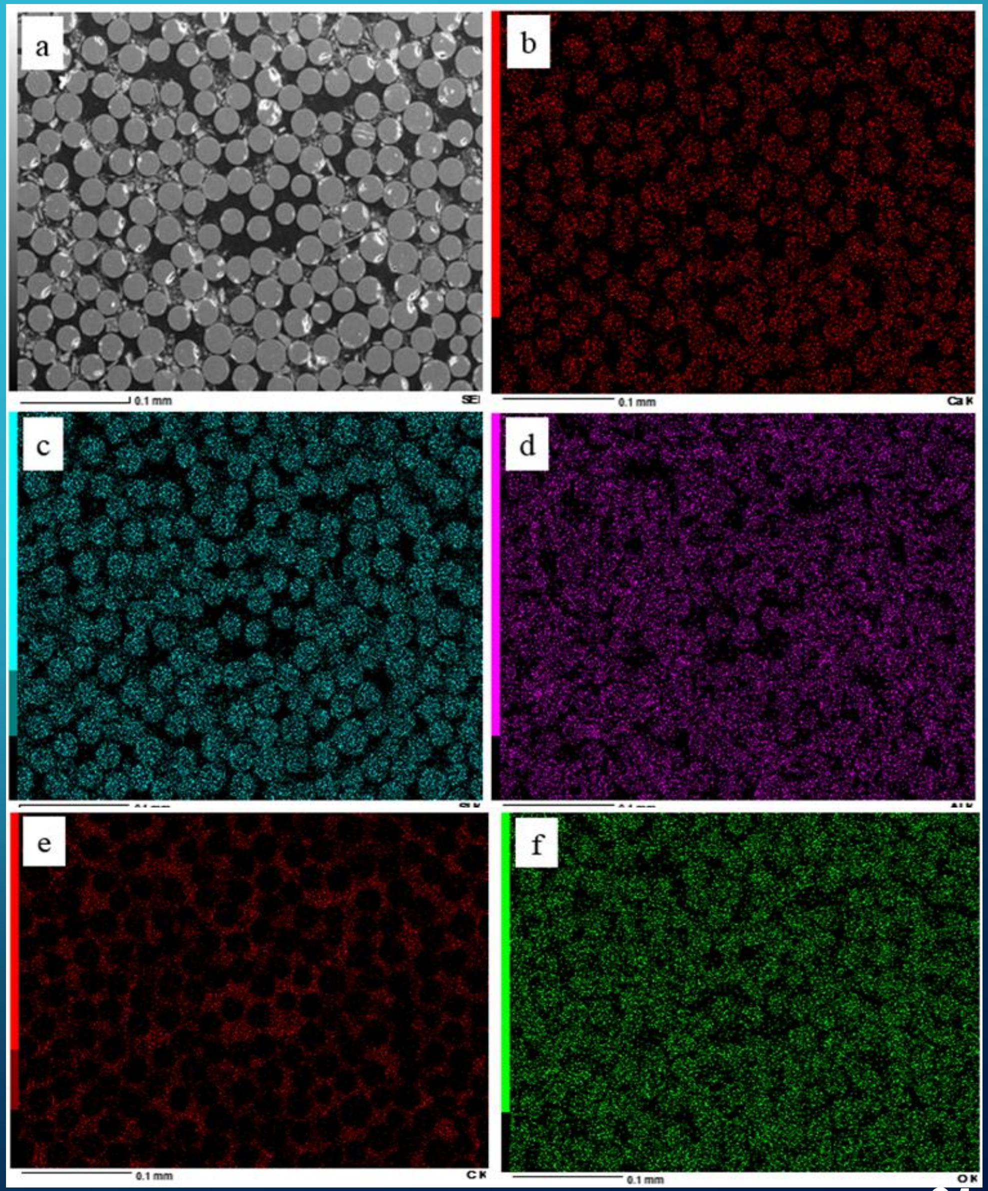


Why Improve Endurance Limits?

Validate With Bridge Service Life

Bridge Core Extraction of 15+ Year GFRP Rebar Samples

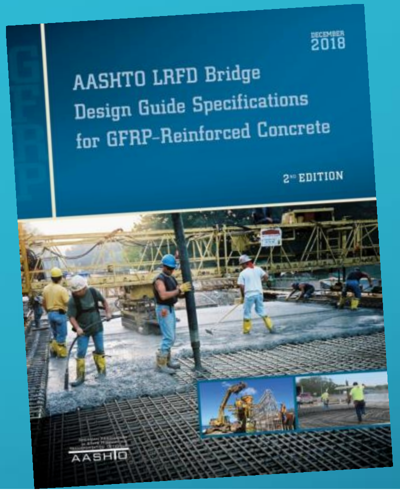
1. Negligible impact in mechanical properties and chemical composition of GFRP fiber and matrix SEM/EDX (300x image fiber, Ca, Si, Al, C, O)
2. GFRP rebar durability in corrosive environments better than predicted by accelerated test methods 0.85 C_E

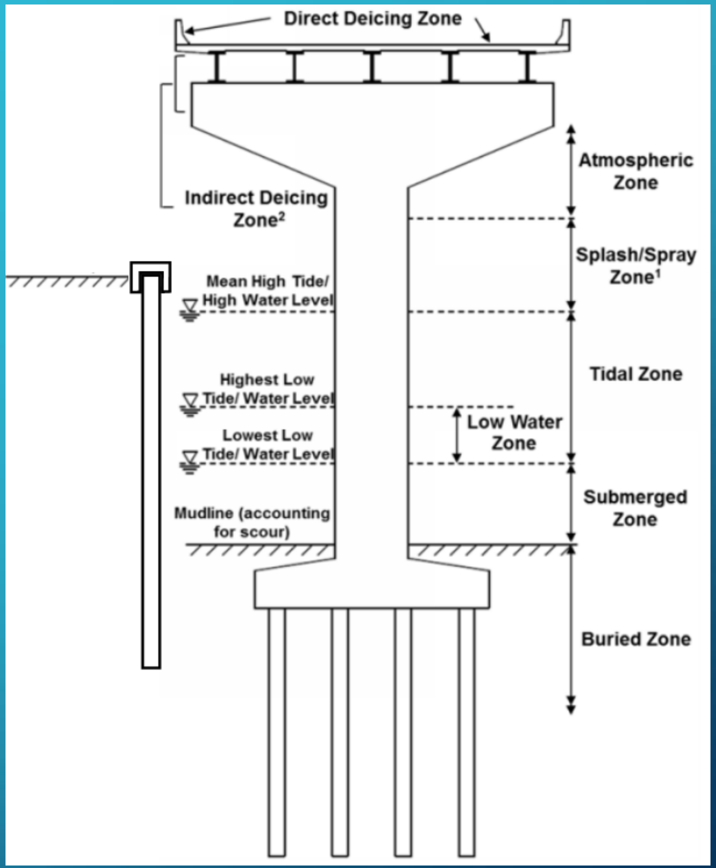


Where do we go from here?

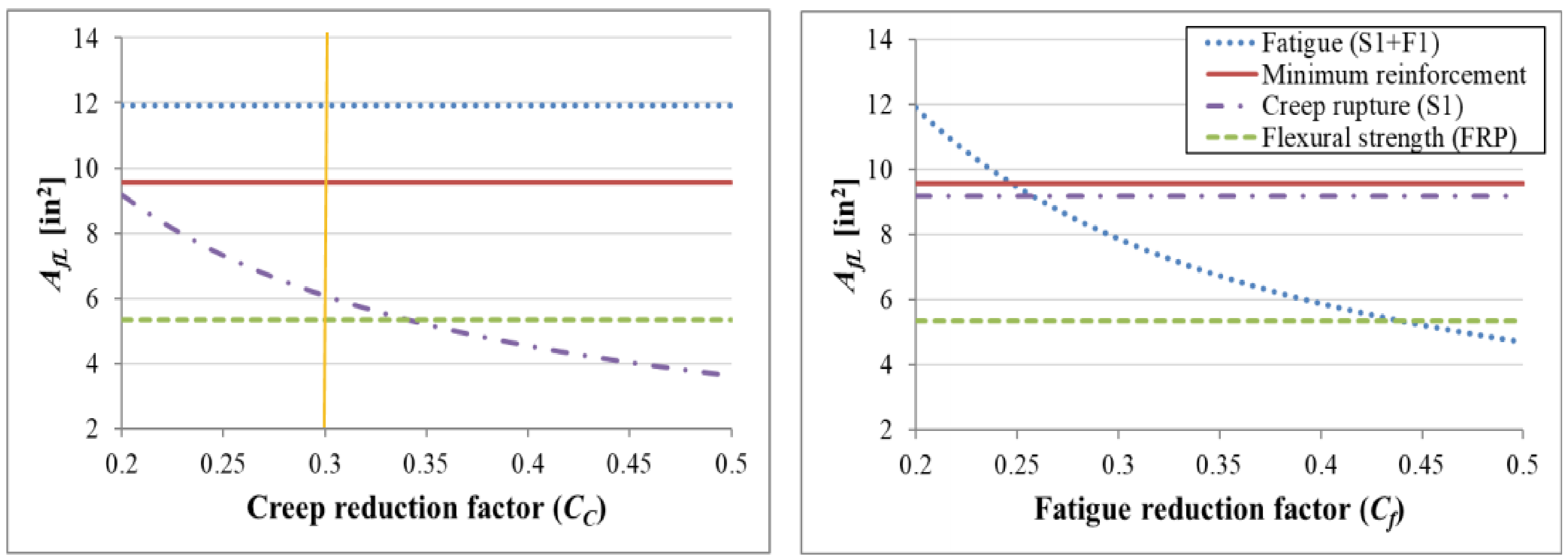
Recommend Endurance Limits to Meet AASHTO LRFD Bridge Design Specification Reliability Requirements

1. Design Limit Refinements
2. Durability Model Refinements
3. GFRP Service Life Design for Tidal and Submerged Concrete Structures
4. Life-Cycle Cost Guidance





Micro-Exposure Zones proposed under NCHRP Project 12-108 for Service Life Design



Proposal to improve endurance limits for 125-year service life and also develop a simple short duration QA verification test method

QUESTIONS ??

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FDOT's Fiber-Reinforced Polymer Deployment Train

GFRP Prestressing ? → BFRP Reinforcing Bars → GFRP Reinforcing Bars → CFRP Prestressing → Navigation Fender Systems → External FRP Laminate Repairs