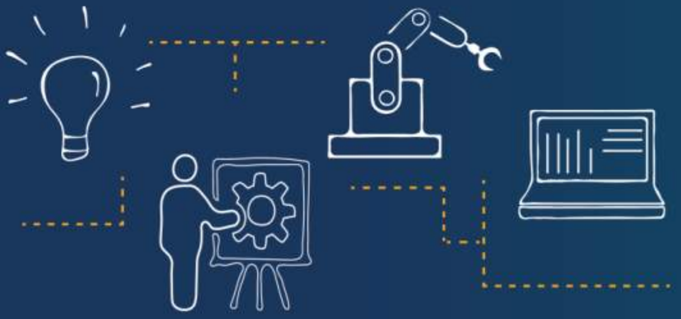
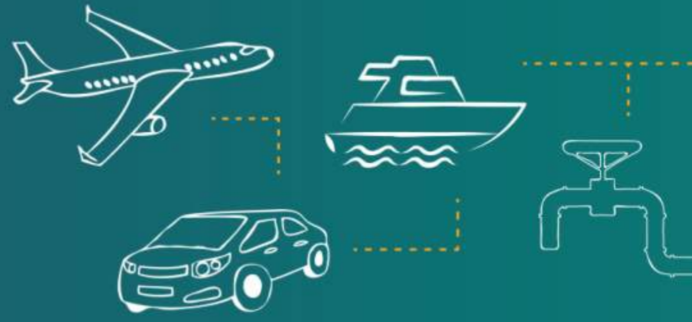


A NEW CAMX
FOR A NEW TIME



COMBINED STRENGTH. UNSURPASSED INNOVATION

CAMX
THE COMPOSITES AND ADVANCED MATERIALS EXPO

SEPTEMBER 21-24

A VIRTUAL EXPERIENCE

2020

Tim Lattner, P.E.

- Florida Native – Born in Fort Pierce, FL
- B.S. Civil Engineering, UCF
- Experience
  - 5 years in Design, Director, FDOT
  - 9 years in Maintenance, Director, FDOT
  - 11 years in Construction, FDOT and Private
    - Various roles from Inspector to Project Engineer
    - Widening and reconstruction, Bridge and resurfacing projects

Game Changing Infrastructure Challenges: New Solutions & Opportunities

Tim Lattner, P.E.
Director, Office of Design
Florida Department of Transportation

FDOT

CAMX
THE COMPOSITES AND ADVANCED MATERIALS EXPO
September 21-24, 2020 / www.theCAMX.org

PREFACE

Game Changing Infrastructure Challenges: New Solutions & Opportunities

Expectations for infrastructure service-life and asset maintenance strategies have changed significantly since the Interstate Act was signed into law in 1956. The resulting expressways eliminated at grade crossings substantially increasing the nation's bridge inventory. Originally no target service-life expectations were specifically set, but by the 1970's observations from fatigue damage failures forced engineers to consider the number of heavy truck wheel load cycles – selecting 50 years as the design life. In the late 1990's with the recognition of a growing inventory maintenance challenge, AASHTO set the minimum design life to 75 years.

Most recently the AASHTO Committee on Bridges and Structures approved publication of a new Guide Specification for 2020 that assigns three target service-life limits (75-, 100-, and 150-years). In recent years, Florida DOT interest in innovation and application of materials like FRP composites has led to many successful installations with the objective of building better with better materials. This presentation will provide an overview of FDOT research and implementation using FRP composites and attendees will learn about FDOT's vision for the future for transportation infrastructure.

LEARNING OBJECTIVES

Game Changing Infrastructure Challenges: New Solutions & Opportunities

i. Describe the common infrastructure durability challenges typical faced by highway agency owners.

ii. Identify emerging solutions for infrastructure applications and potential opportunity areas for the composites industry.

iii. List recent successful Florida infrastructure applications with composites solutions.

OUTLINE

Game Changing Infrastructure Challenges: New Solutions & Opportunities

- Historic Overview
- Background on Florida's Bridges & Structures
- How is Florida leveraging composites for Infrastructure
- Lessons Learned
- What does the future hold for composites in Florida

In the Beginning….

- **Bold ideas**, such as the "transcontinental highway" had been around since the 1890's:

"The whole scheme would carry with it something that would inspire the entire Nation. It not any new scheme; it is not any new idea. It was the idea of Jefferson and Madison and Gallatin and many other great men who helped to start the national Road which led through Pennsylvania, Ohio and Indiana, and reached as far as the Mississippi River.
(General Roy Stone)

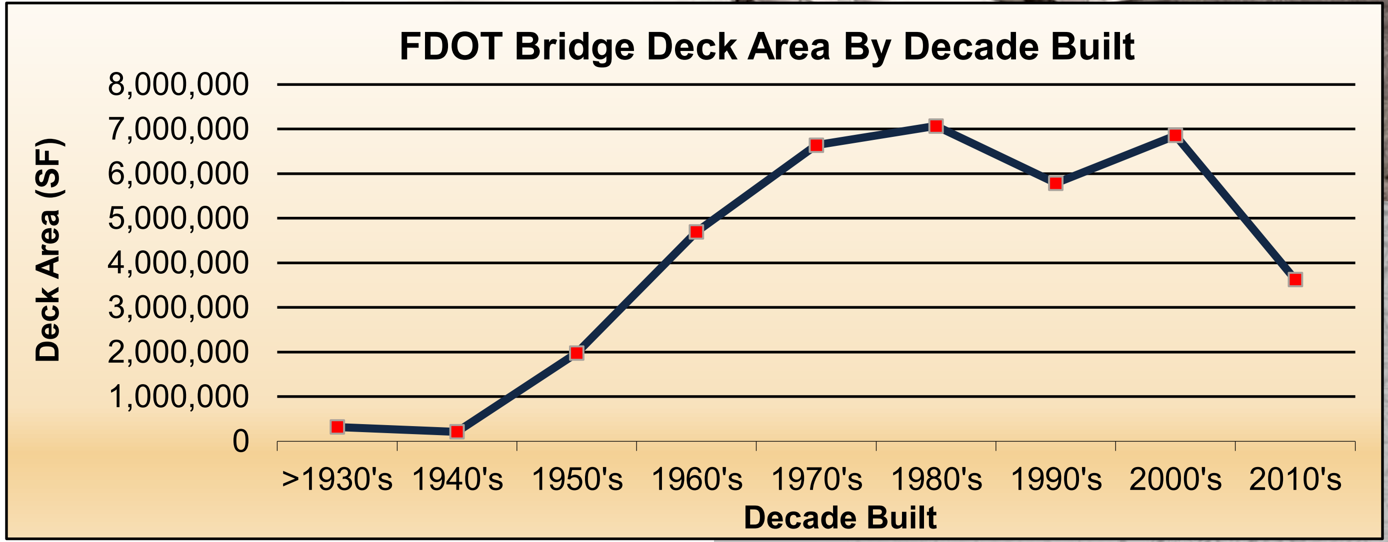
FDOT Bldg. 1966

- **1914** Old Trails Road Assoc. plan
- **1915** FL State Road Dept. born.
- **1917** Florida roadmap network.
- **1956** National Interstate and Defense Highways Act signed.
- **1993** Last time the federal gasoline tax was raised *(18.4 cents/gal)*

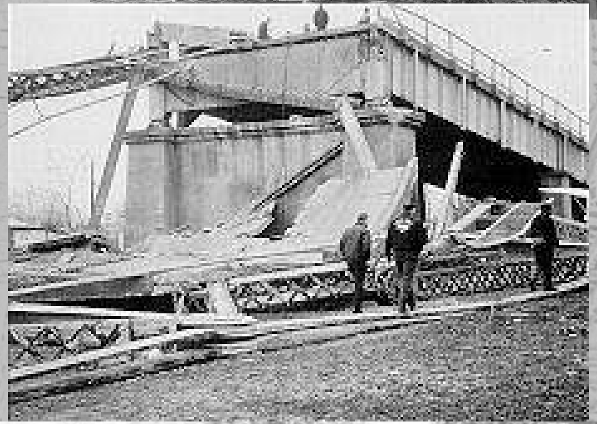
https://www.fhwa.dot.gov/infrastructure/trails.cfm

… thru the Interstate Era ...

- **1969** the State Road Dept. becomes the ***Florida Department of Transportation*** (FDOT)
- Interstate construction accelerates along with **prestressed concrete** and **steel girder** technologies



… accidents & mistakes happen, lessons are learned…

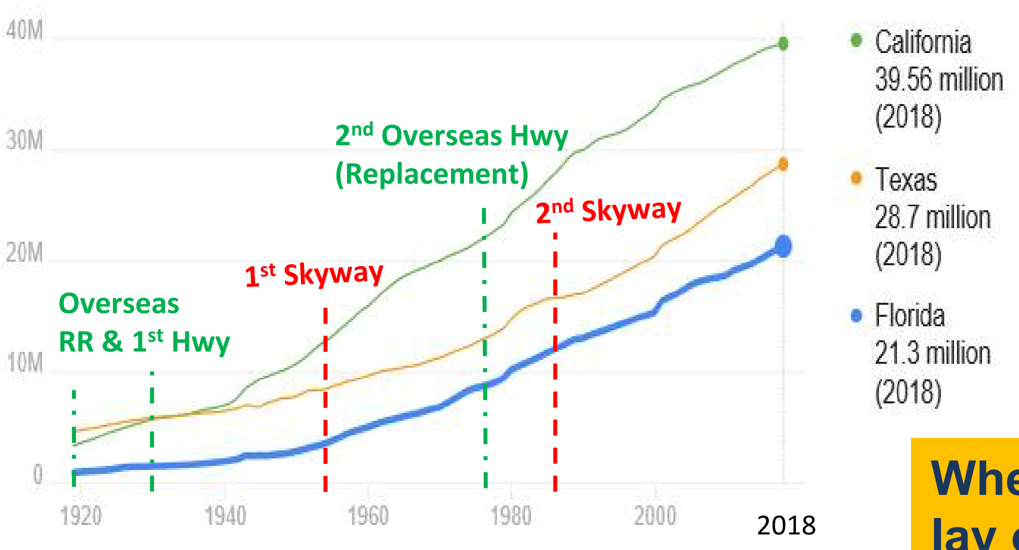


- **1940** Tacoma Narrows (WA) – *high strength/low stiffness*
- **1967** Silver Bridge (OH) – *high strength/fatigue/corrosion/low redundancy*
- **1983** I-95/Mianus River (CT) – *fatigue/corrosion/low redundancy*
- **2007** I35W Mississippi Rv (MN) – *buckling at high strength slender connection plate*

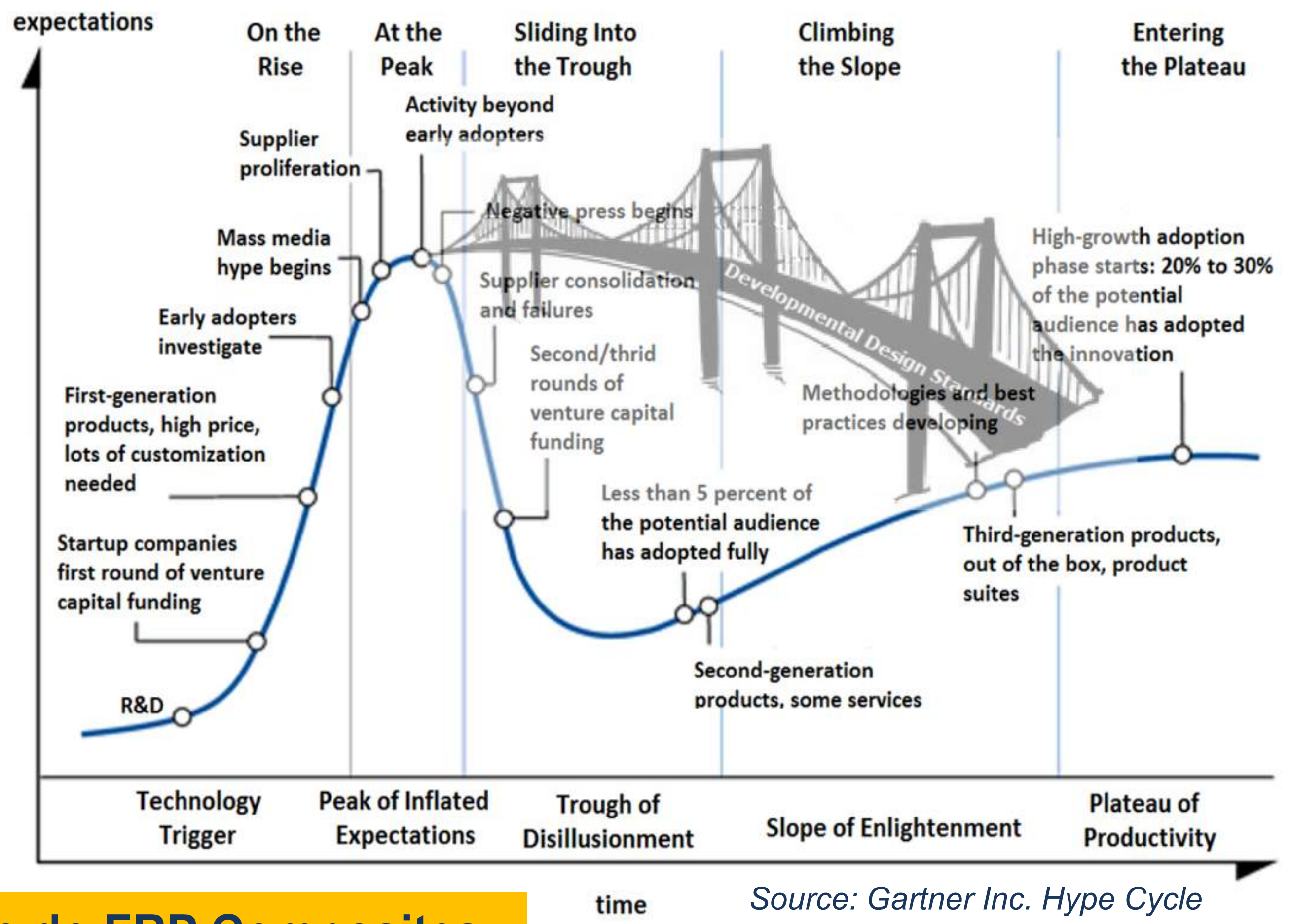
Many of these issues are also applicable to FRP Composites design solutions

…into the 21st Century ?

- Bridging the gap between ***innovation*** and ***institutional adoption***



FLORIDA POPULATION GROWTH



Source: Gartner Inc. Hype Cycle

Where do FRP Composites lay on this chart for infrastructure?

Historical Structural Technology Firsts in Florida Bridges…

When did FRP Composites make this list?

- **1954** 1^{st} Sunshine Skyway – Post-Tension Beams in Trestle Approach Spans
- **1955** Precast/Prestressed Concrete Institute begins in Florida
- **1965** Sebastian Inlet – Drop-in Lightweight Concrete Prestressed Span
- **1978** Long Key & Seven Mile Bridge – Segmental Box
- **1979** Chipola Nursery Rd/1-10 – 1^{st} Splice I-Girder
- **1987** 2^{nd} Sunshine Skyway Bridge - 1200 ft. Segmental Cable-Stay
- **1989** Dames Point Bridge - 1300 ft. Cable-Stay

Fig. 1. Long Key Bridge — A precast segmental, post-tensioned, span-by-span structure. (Courtesy of Figg and Muller Engineers Inc., Designer)

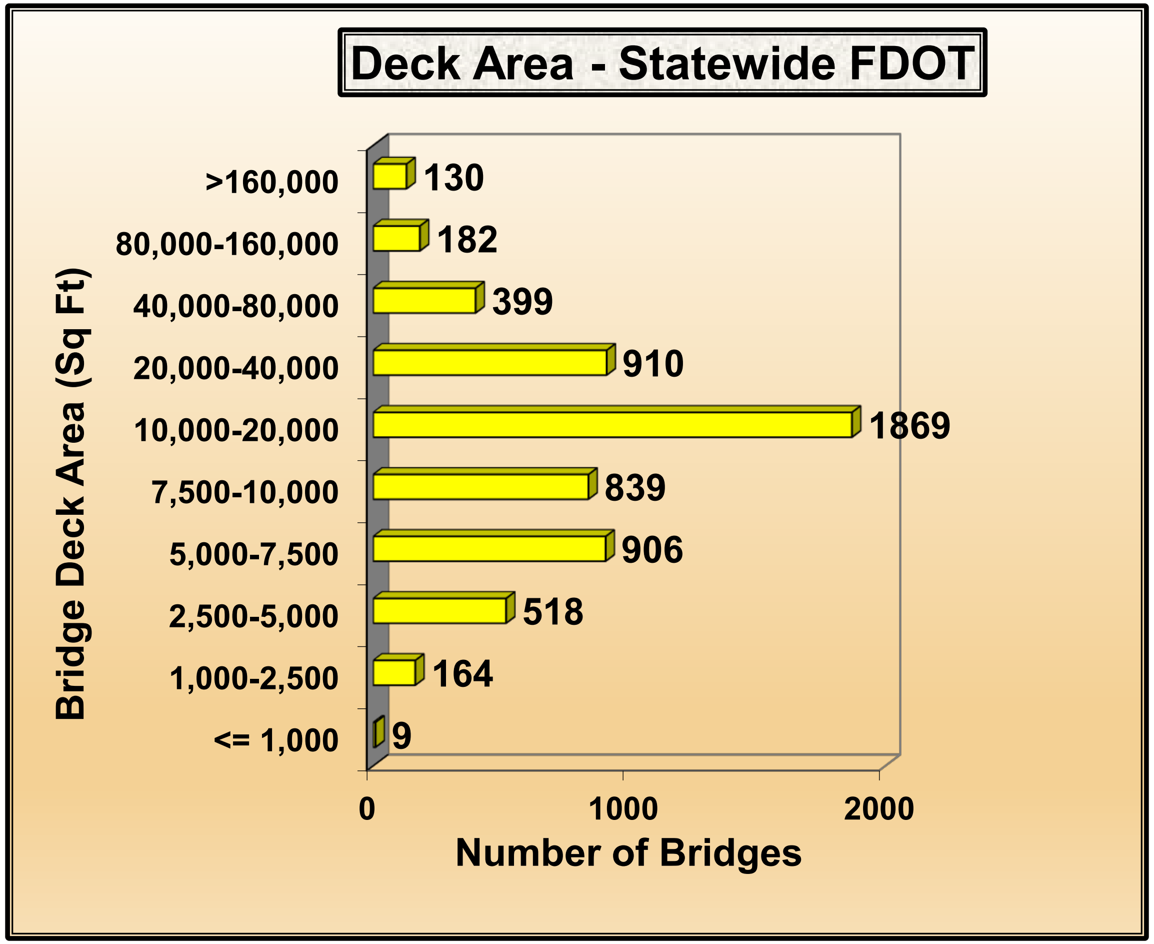
FRP Structural Technology Firsts for Florida Bridges and Structures...

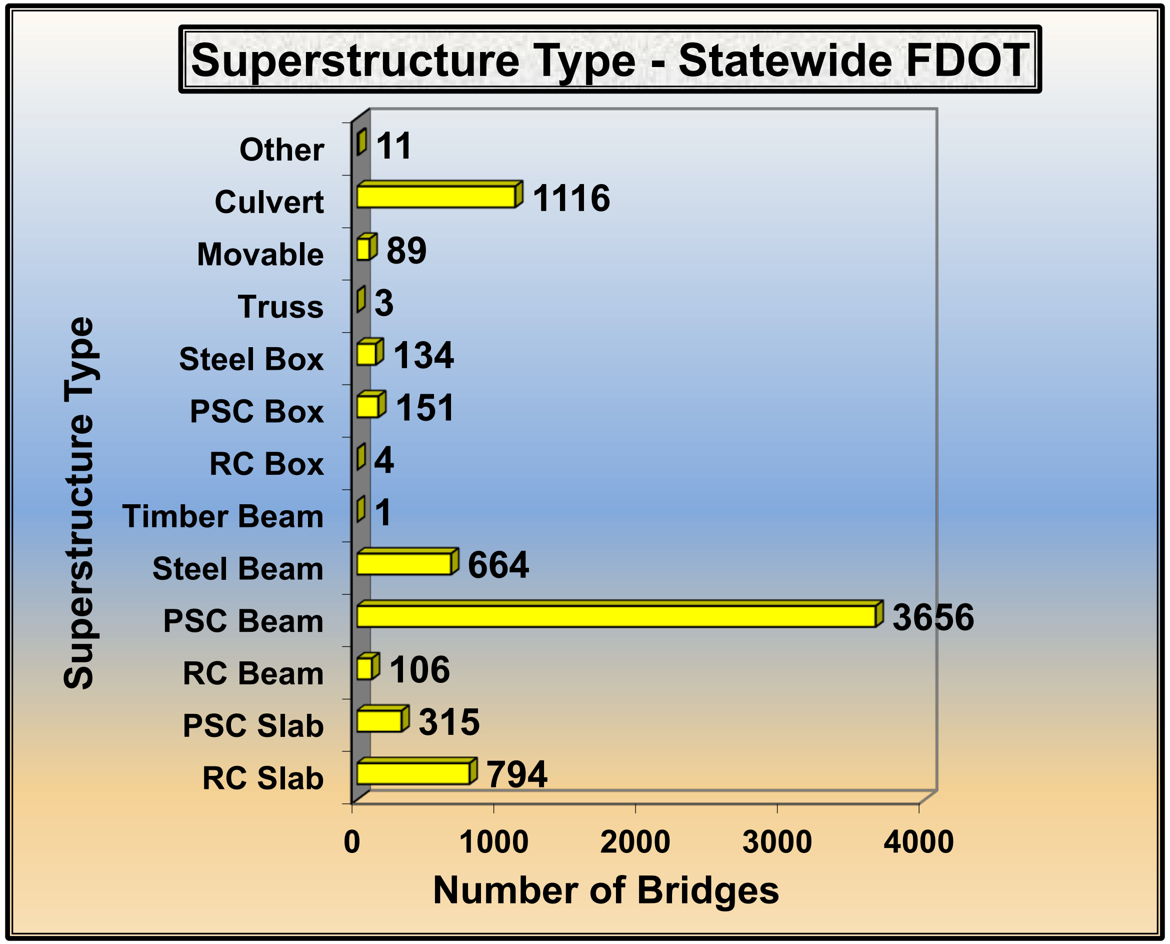
- **1980's** 1st GFRP bridge beam strengthening
- **1990's** 1st CFRP bridge beam strengthening
- **2006** 1st FRP fender system Specs & Standard Index issued.
- **2011** IROX I-75: 1st RC drainage structures using BFRP
- **2014** PortMiami: Tunnel approach retaining walls 5 & 6 use BFRP-RC *(slide #46)*
- **2015** University of Miami: CFRP-Prestress Double-T Innovation Bridge *(slide #47)*
- **2016-19** Halls River: FDOT 1st complete FRP-PC/RC/HCB bridge *(slide #48+)*
- **2018** Skyplex Blvd: 1st Concrete Filled FRP Tube Arch Bridge *(slide #31)*
- **2019** US41/North Creek & NE 23rd/Ibis Waterway: 1st 2-span & 3-span cast-in-place GFRP-RC Flat-Slab bridges, and soldier pile precast panels *(slide #53-54)*

Taking stock of our Infrastructure...

- FDOT's Structures Inventory
  - 12,529 bridges in the State of Florida
  - 7,044 bridges maintained by FDOT
  - 150,227,048 SF of deck area
  - 5,485 maintained by others (County, City, Federal)
  - 2,143,163 SY of noise barrier wall
  - 379.22 miles of retaining wall
  - 72.8 miles of seawall

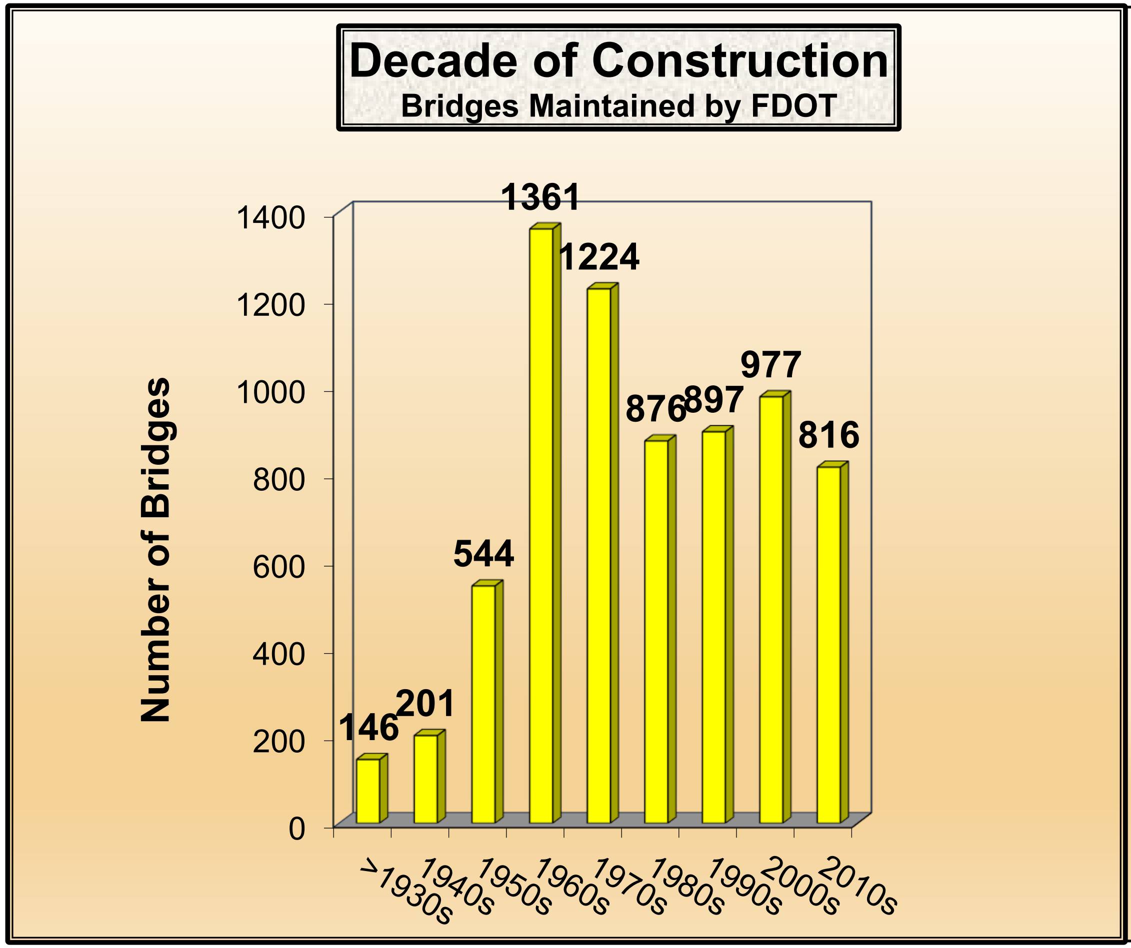
Florida's Bridges

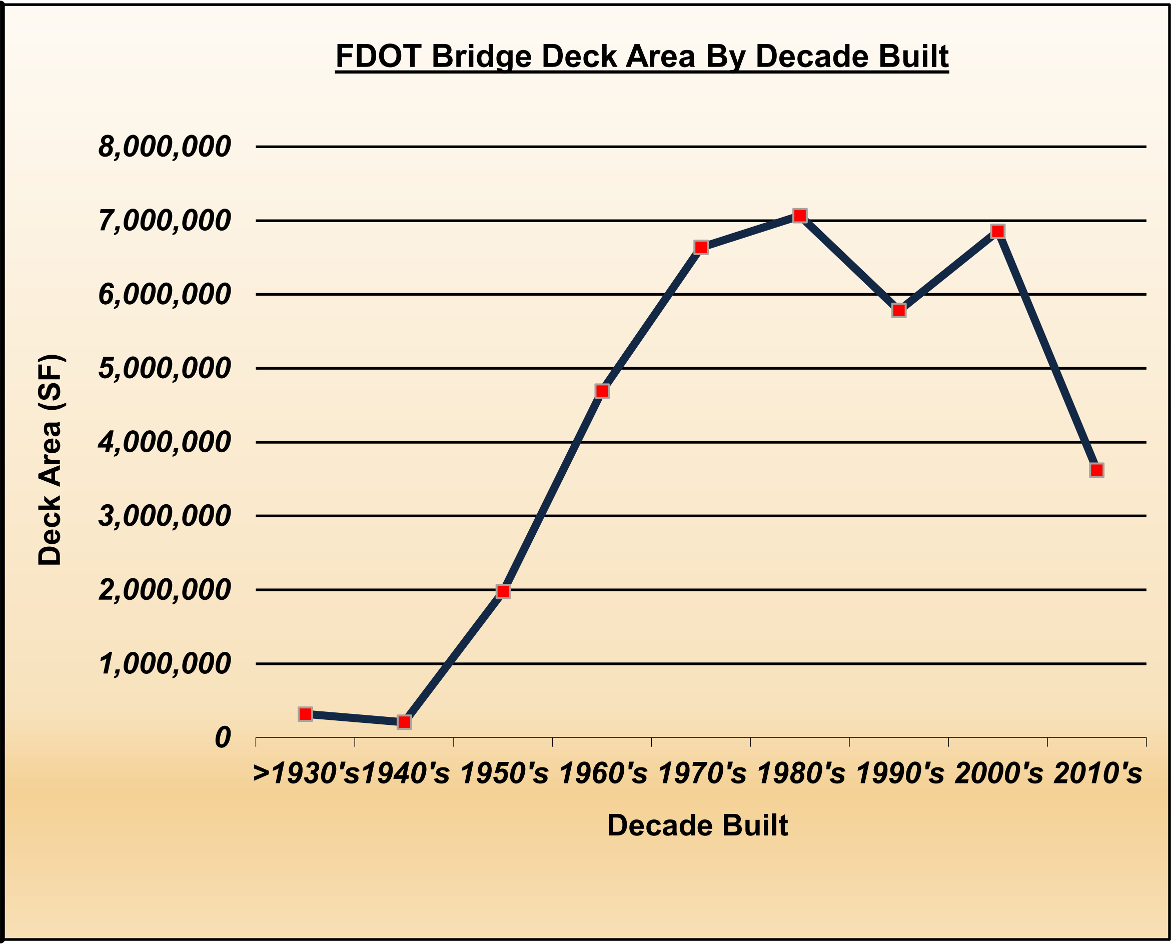




Source: 2020 FDOT Bridge Maintenance Annual Report

Florida's Bridges





Source: [2020 FDOT Bridge Maintenance Annual Report]

Florida's Bridges

Age of Bridges

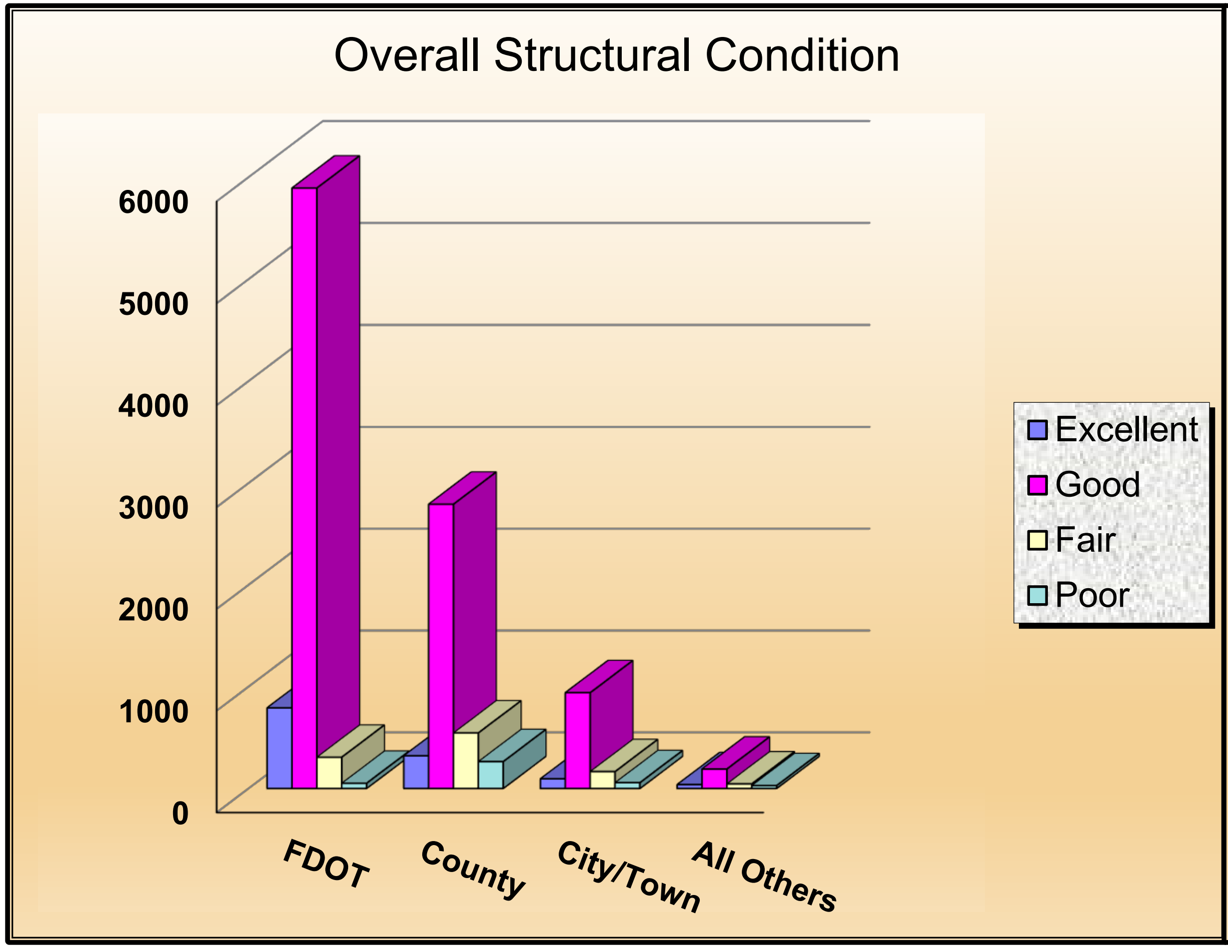
While the industry is now designing bridges to last for 75 years, most bridges built in the past were designed for a service life of 50 years. Looking at bridge age is the most common and simplest method of forecasting long-term budget requirements. This might lead one to conclude that bridges constructed before 1960 are at the end of the service life. Fortunately, advances in material science, design practices, and construction methods, along with a generally favorable climate, inspection and maintenance practices have contributed in many bridges functioning well past their original design life, despite the tremendous growth in traffic volume over the years. The strategy of bridge maintenance is to leverage these advances using an aggressive maintenance program to extend the useful life of the bridges, thereby minimizing the need to replace a large number of bridges within a short time period (see Table 1).

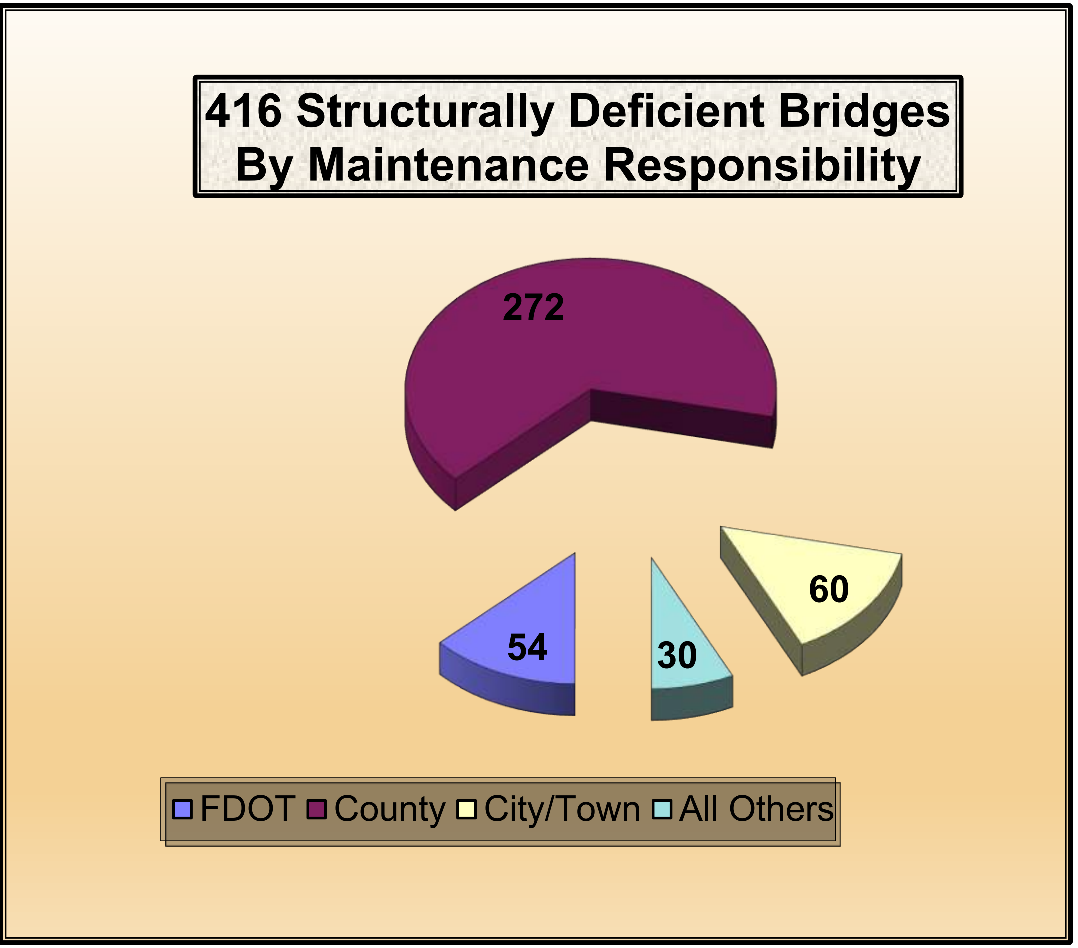
Source: 2020 FDOT Bridge Maintenance Annual Report

Florida’s Bridge Program

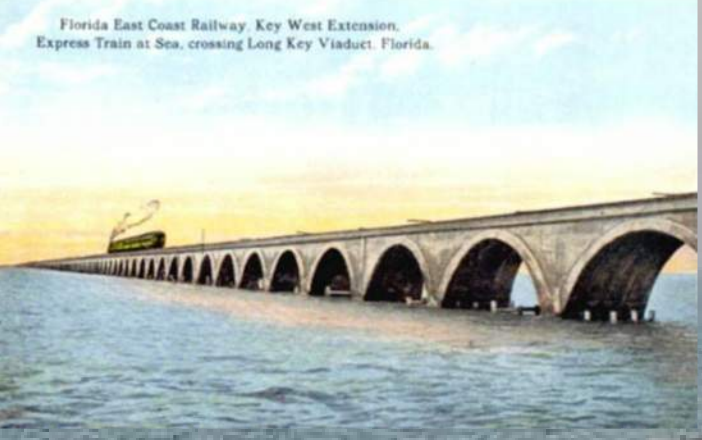
- FDOT has a robust bridge maintenance program
  - $13 Million spent annually on routine bridge maintenance
  - Programmed for bridge repair/replacement
    - FY 20/21 - $470.7M
    - FY 21/22 - $382.5M
    - FY 22/23 - $152.4M
    - FY 23/24 - $324.2M
    - FY 24/25 - $156.3M

Florida's Bridge Condition





… Then and Now …



“New” Seven-Mile-Bridge, (Florida Keys)

- Henry Flagler’s Overseas Railroad constructed 1905-1912.
- Damage beyond repair by 1935 Hurricane.
- Converted to Overseas Highway in 1938.
- New adjacent highway constructed in 1970’s – 1980’s.
- Many of these “Florida Keys” bridges are ready for major rehabilitation or replacement.

"Corrosion-Resistant High-Performance Materials" (CR-HPM)

Florida Department of
TRANSPORTATION

Safety, Innovation, Mobility, Attract, Retain & Train

E-Updates | FL511 | Site Map | Translate

Search FDOT...

Home | About FDOT | Careers | Contact Us | Maps & Data | Offices | Performance | Projects

Office of Design

Office of Design / Design Innovation

Design Innovation

Office of Design
Florida's Transportation Engineers

The Florida Department of Transportation (FDOT) continually strives to enhance all areas of its operations. In support of these efforts, the department recently moved into a bold new era for innovative ideas, research and accelerated implementation. Success will depend on our ability to carefully evaluate or implement the products and services provided to the users of Florida's transportation system. Our goal is to utilize newly developed technology or employ creative thinking to generate greater value for every transportation dollar invested.

After researching and evaluating many innovative ideas, the Central Office has developed a list of concepts, products and services that may be the best solution to the project's needs or design challenges. Some items on the list are completely developed, and only need tailoring to your project. We encourage you to propose one or more of these innovations for project specific solutions with confidence of approval by the Districts. Other items are not fully detailed and will require coordination with and approval by the District's Design Office. Many of these innovations have been successfully implemented in other states and countries. Not all projects benefit from these innovations and the Department is not advocating the general use of new products or designs where an economical well proven solution exists and is the most appropriate solution for the situation.

FDOT Transportation Innovation Challenge

The Department invites you to share your thoughts on ways we can challenge ourselves to be innovative, efficient and exceptional at our **Invitation to Innovation website**

Structures Design Office

- Curved Precast Spliced U-Girder Bridges
- Fiber Reinforced Polymer Reinforcing
- FRP Members and Structures
- Geosynthetic Reinforced Soil Integrated Bridge System
- Geosynthetic Reinforced Soil Wall
- Prefabricated Bridge Elements and Systems
- Segmental Block Walls
- Ultra-High Performance Concrete (UHPC)
- **+ Stainless-Steel Prestressing Strand & Rebar**

Non-Corrosive

Corrosion-Resistant

Florida’s Bridge Condition

Structures Design Guidelines
1 - General Requirements

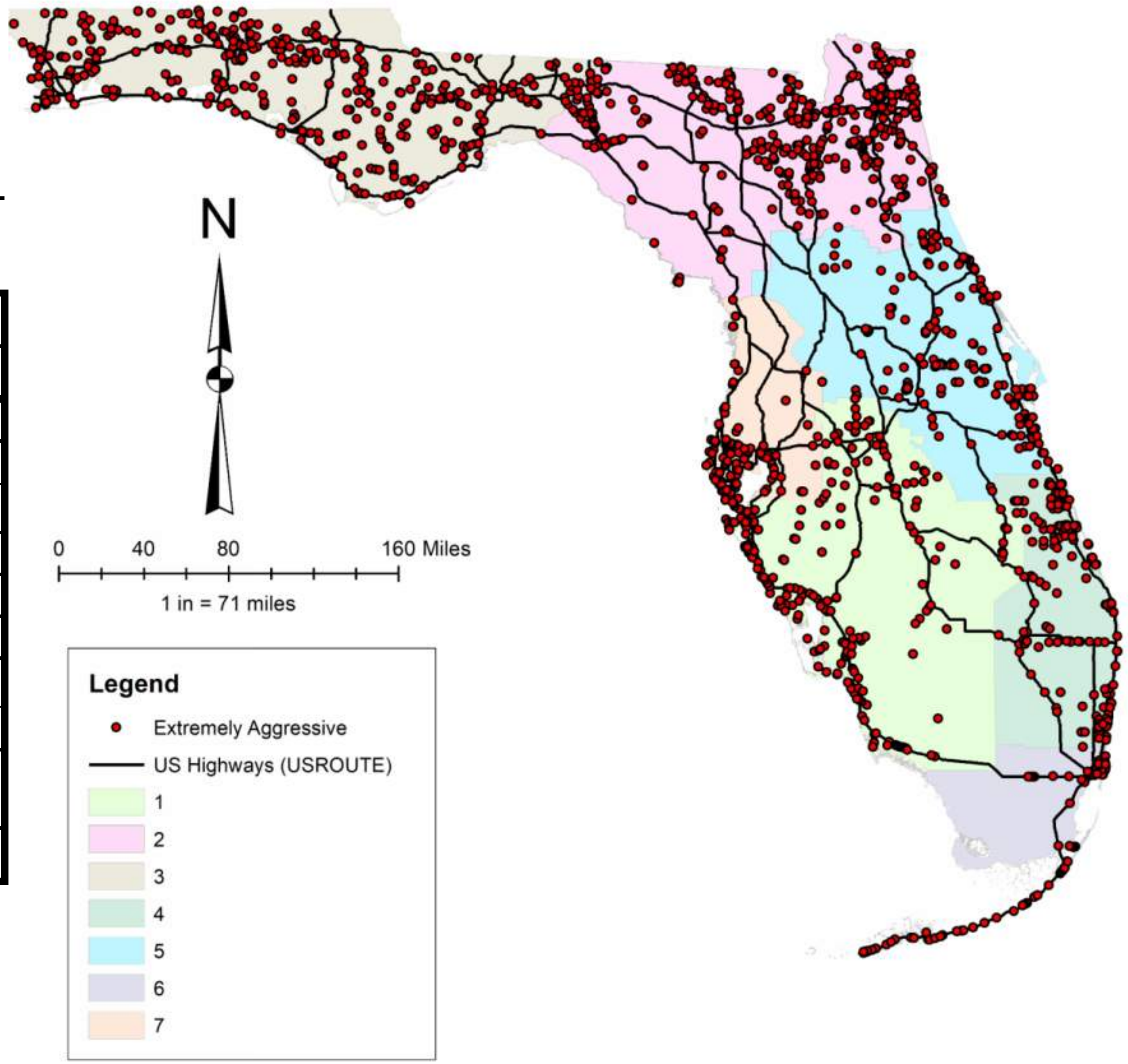
Topic No. 625-020-018
January 2020

Table 1.3.2-1 Criteria for Substructure Environmental Classifications

Classification	Environmental Condition	Units	Steel		Concrete	
			Water	Soil	Water	Soil
Extremely Aggressive (If any of these conditions exist)	pH		< 6.0		< 5.0	
	Cl	ppm	> 2000		> 2000	
	SO_4	ppm	N.A.		> 1500	> 2000
	Resistivity	Ohm-cm	< 1000		< 500	
Slightly Aggressive (If all of these conditions exist)	pH		> 7.0		> 6.0	
	Cl	ppm	< 500		< 500	
	SO_4	ppm	N.A.		< 150	< 1000
	Resistivity	Ohm-cm	> 5000		> 3000	
Moderately Aggressive	This classification must be used at all sites not meeting requirements for either slightly aggressive or extremely aggressive environments.					

pH = acidity ($-\log_{10}H^+$; potential of Hydrogen), Cl = chloride content, SO_4 = Sulfate content.

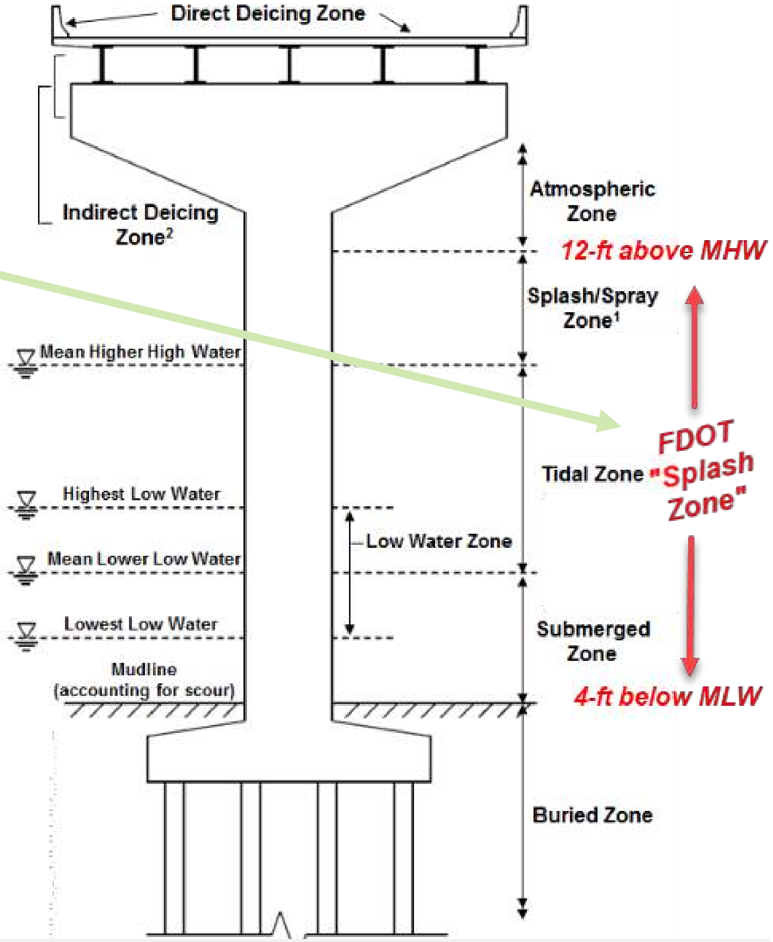
2. Superstructure: Any superstructure located within 2,500 feet of any coal burning industrial facility, pulpwood plant, fertilizer plant, or any other similar industry classify as Moderately Aggressive. All others classify as Slightly Aggressive.



Why use CR-HPM for Bridges and other Structures?

- An **aggressive environment** would be the portion of a structure in or near salt or brackish water, and the portions of the structure in the "***splash zone***". This would include the undersides of decks or slabs with low clearances over salt or brackish water. There may be special cases where additional areas of the bridge may be considered an **aggressive environment** with similar effects as marine environments.
- **FDOT** bridges classified in an **aggressive environment**:
  - 1,534 Bridges
  - 68,857,118 SF Deck or about 46%

Figure 131—University Boulevard Bridge

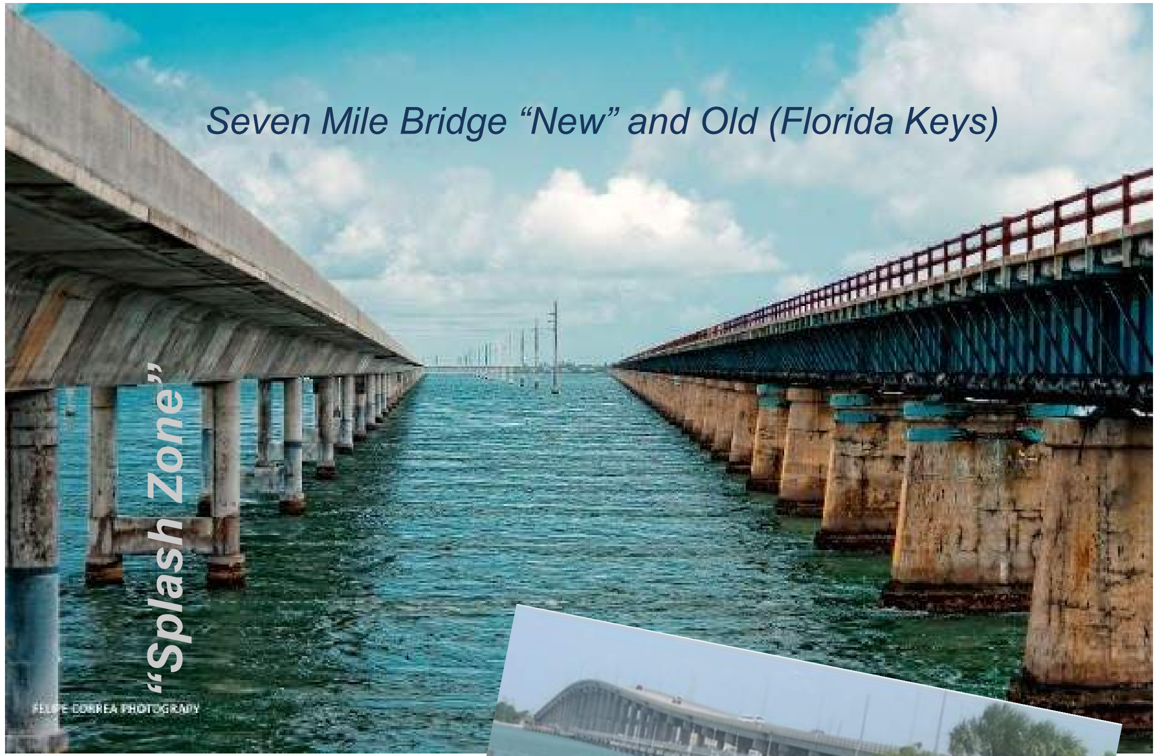


Source: AASHTO. 2020, Guide Specification for Service Life Design of Highway Bridges (1st Edition).

Figure 2.2.1.2-1—Micro Environment Exposure Zones

Why use CR-HPM for Bridges and other Structures?

- Aggressive environments also include:
  - Areas where people fishing from a bridge may dump containers with salt or brackish water
  - Bridges near boat ramps where salt or brackish water draining from boats may fall on bridges after they have been removed from the water



Report: BDV31 977-01
(University Blvd Bridge, 2011)

Figure 136—High tide inundation of (a) spans

Figure 220—Corroded steel reinforcement in the north end of Girder 3-1

Why use CR-HPM for Bridges and other Structures?

- Aggressive environments also include:
  - Areas subject to spray from jet skis.
  - In northern Florida there has been a move to place salt after winter storms. If this becomes a more common occurrence, consideration may be given to including these.

Why use CR-HPM for Bridges and other Structures?

- But there are several other reasons FRP repairs and strengthening are necessary:
  - Over-height truck impacts.
  - In sufficient detailing past practice for shear strength.

BDV31 977-01: Figure 227—Girder damage from vehicle impact in July of 2001

Where do FRP solutions fit for Infrastructure?

- Repair & strengthening.
- New construction as internal reinforcement for concrete.
- New construction structural FRP members.
- New construction with fully FRP structural system.

FRP Reported Firsts

- 1st FRP rebar – early 1970's - USA
  - 2nd company, more R&D – early 1980's
  - Bridges – 1980's – Japan
- 1st FRP dowel bar in concrete pavements – USA – 1977 (dug-up in 1985)
- 1st FRP Vehicular Bridge – China – 1982
- 1st FRP Pedestrian Bridge – China – 1986
- 1st FRP tendon, prestressing – 1986
  - Germany
- 1st FRP Glulam beams – USA – early 1990's
- 1st FRP Strengthening System
  - Experimental work, 1978, Germany
  - 1st application, RC columns, 1980's, Japan
  - 1st application, flexural strengthening of RC bridges, 1987
- 1st Bridge "Wind Fairing" – USA – 2003
- …and more to come


The wedge shaped wind fairing used on the Bronx-Whitestone Bridge

Source: John Busel to MA-DOT (2011)

ACMA American Composites Manufacturers Association

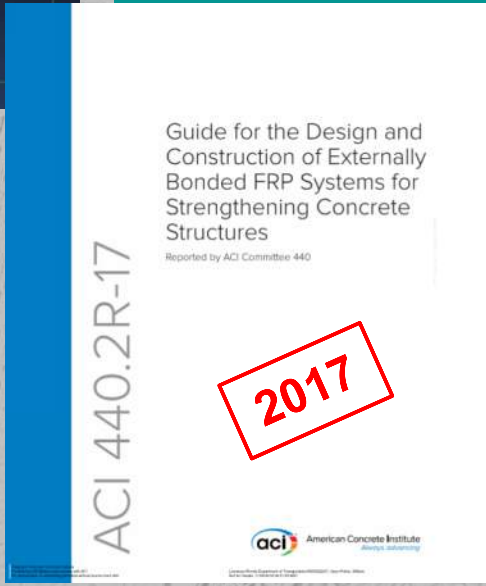
Where do FRP solutions fit for Infrastructure?

- Repair & strengthening.

NCHRP 20-07/Task 428 [Active]

Update of the 2012 AASHTO Guide Specification for Design of Bonded FRP Systems for Repair
[NCHRP 20-07 (Research for AASHTO Standing Committee on Highways)]

Project Data	
Funds:	$130,000
Staff Responsibility:	Amir N. Hanna
Research Agency:	University of Kentucky Research Foundation
Principal Investigator:	Issam Harik
Effective Date:	9/3/2019
Completion Date:	12/2/2020



Where do FRP solutions fit for Infrastructure?

- Repair & strengthening.

Florida Department of Transportation Research

Durability Evaluation of Florida's Fiber-Reinforced Polymer (FRP) Composite Reinforcement for Concrete Structures

March 2017

FDOT

Project Number
BDV31-977-01

Project Manager
David P. Wagner
FDOT Structures Office

Principal Investigator
H. R. Hamilton
University of Florida

Current Situation

Fiber-reinforced polymer (FRP) composites, when applied to concrete bridge structures, are proven to increase strength and stiffness. They may also mitigate corrosion of the steel reinforcement in concrete members by reducing diffusion of chlorides into concrete. However, in the past, these repairs have been viewed as a very temporary bandage, and their durability has generally been evaluated using accelerated or theoretical methods. Long-term field exposure data which would help to determine the validity of accelerated testing are not readily available.

Research Objectives

University of Florida researchers evaluated the long-term effectiveness of FRP repairs on a number of Florida bridges.

Project Activities

The replacement of three Florida bridges ... times by overheight trucks and subsequently repaired with FRP composites.

Source: Hamilton, et al. 2017, Durability Evaluation of Florida's Fiber-Reinforced Polymer (FRP) Composite Reinforcement for Concrete Structures, UF & FDOT.

Table 7—Summary of survey responses

Bridge No.	Location	Repair Date	FRP	FRP source	Inspection reports?	Load test?
790035	Volusia County	2007	Wet layup CFRP	Unknown	Y	Y
570017	District 3	2015	Wet layup CFRP	Unknown	Y	N
570018	District 3	2015	Wet layup CFRP	Unknown	Y	N
110070	SR 91 NB over CR 561	2009	Wet layup CFRP	TREX Wrap TEC3-10U	Y	N
110074	Bridges Road over SR 91	2005	Wet layup CFRP	MAS-2000	Y	N
920027	CR 530 WB over SR 91	2010	Wet layup CFRP	TREX Wrap TEC3-10U	Y	N
920075	Ramp A over SR 91	2005	Wet layup CFRP	MAS-2000	Y	N
930144	45th Street over SR 91	2007	Wet layup CFRP	TREX Wrap TEC3-20C	Y	N
930144	45th Street over SR 91	2004	Wet layup CFRP	BASF MBrace CF160	Y	Y
930148	PGA Blvd Ramp over SR 91	2004	Wet layup CFRP	BASF MBrace CF160	Y	Y
104320	Phillips Lane, Hillsborough County	2001	Wet layup CFRP	Unknown	Y	Y
104323	Dickman Road, Hillsborough County	2014	Wet layup CFRP	Mapei	Y	N
104422	Durant Road, Hillsborough County	2013	Wet layup CFRP	Mapei MapeWrap C Bi-Ax 230	Y	N

Pre-2001 & Post-2015 projects pending

Where do FRP solutions fit for Infrastructure?

- Repair & strengthening.
- New construction as internal reinforcement for concrete:
  - **Glass FRP rebar** & **Carbon FRP strands** with improving mechanical properties
  - **Basalt FRP rebar** & possible prestressing applications

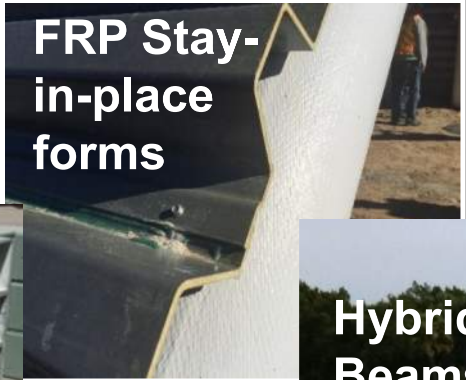
Where do FRP solutions fit for Infrastructure?

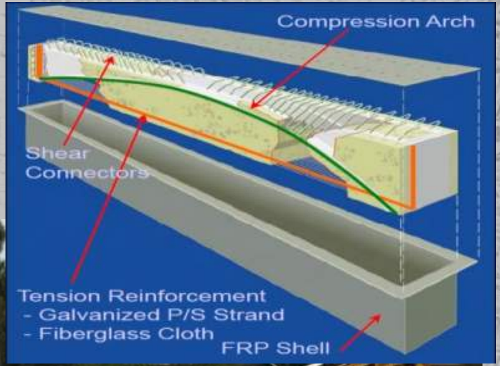
- New construction structural FRP members.

  - Composite Bridge Beams

  (Pultruded, VARTM, Molded & Built-up composite members)

  - Hybrid systems *(HCB, Concrete-Filled FRP Tubes…)*

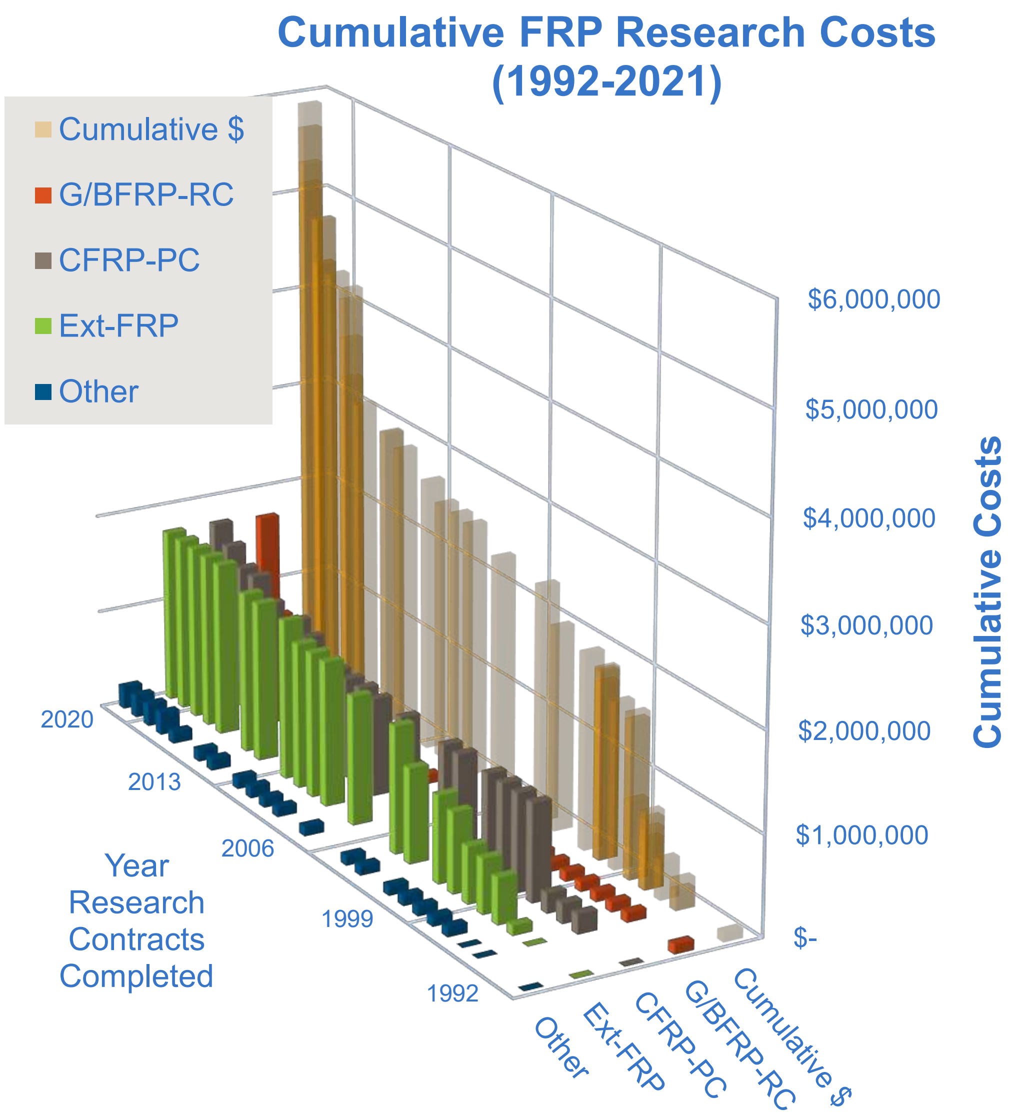




Where do FRP solutions fit for Infrastructure?

- New construction with fully FRP structural system.
  - **Hybrid systems** *(Concrete-Filled FRP Tubular Arch Bridge)*
  - **Full FRP Systems** *(Fenders, Ped. Trusses)*

FDOT FRP Research

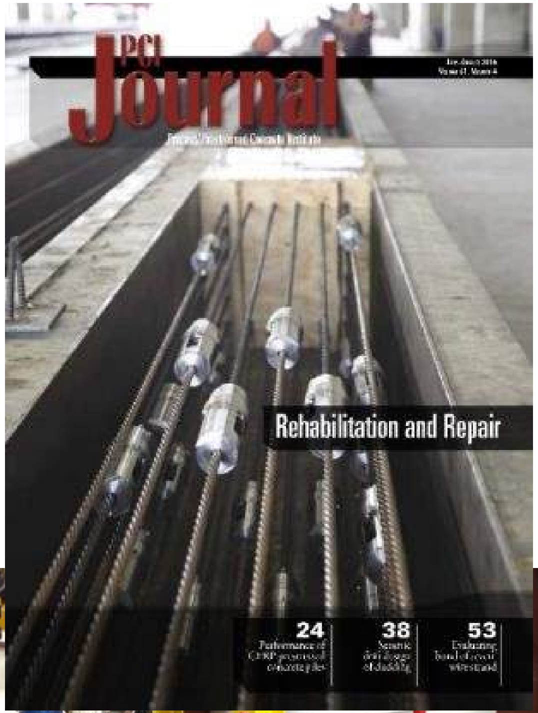


1992	Feasibility of Fiberglass Pretensioned Piles in a Marine Environment	Sen, R.	USF
1995	Active Deformation Control of Bridges with AFRP Cables	Arockiasamy, M.	FAU
1995	Durability of CFRP Pretensioned Piles in a Marine Environment – Phase II	Sen, R.	USF
1997	Mechanical and Microscopy Analysis of CFRP 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
1998	Analysis and Modeling of Fiber-Wrapped Columns and Concrete-Filled Tubes	Shahawy, M.	FDOT
1999	LRFD Flexural Provisions for PSC Bridge Girders Strengthened with CFRP Laminates	El-Tawil, S.	UCF

FDOT FRP Research

1999	Behavior of Reinforced Concrete Beam-Column Retrofitted with Composite Wrapping Systems	Chaallal, O.	FDOT
2000	Effect of Concrete Strength on the Performance of FRP Wrapped RC Column Under Combined Axial-Flexure Loading	Chaallal, O.	FDOT
2000	Behavior of Axially Loaded Short Rectangular Columns Strengthened with CFRP Composite Wrapping	Chaallal, O.	FDOT
2000	Investigation of Fender Systems for Vessel Impact	Yazdani, N.	FAMU/ FSU
2000	Short-Term Tensile Strength of CFRP Laminates for Flexural Strengthening of Concrete Girders	Okeil, A.	UCF
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
2007	Testing Bridge Decks with Near-Surface mounted FRP Bars Embedded in Cement Based Grout	Hamilton, T	UF
2009	Thermo-Mechanical Durability of CFRP Strengthened RC Beams	Mackie, K	UCF

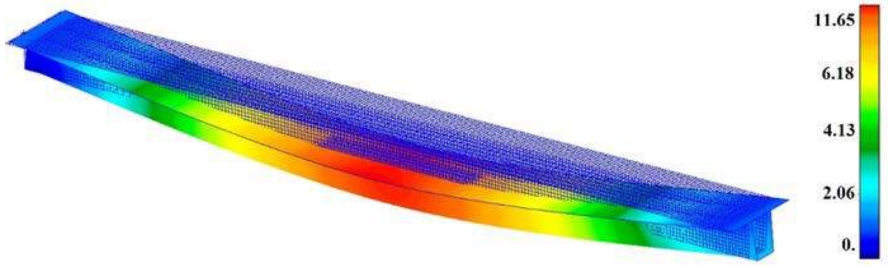
FDOT FRP Research



1999 CFRP repaired girder (Indian River)

2010	Testing Precast Piles with Carbon Fiber Reinforced Polymer Mesh	Abalo, V.	FDOT
2011	Testing of Trelleborg Structural Plastics	Wagner, D.	FDOT
2011	Testing of Trelleborg Structural Plastics	Wagner, D.	FDOT
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	Use of CFRP Cable for Post-Tensioning Applications	Mirmiran, A.	FIU
2015	Repair of Impact Damaged Utility Poles with FRP, Phase II	Mackie, K.	UCF
2017	Durability Evaluation of Florida's FRP Composite Reinforcement for Concrete Structures	Hamilton, T.	UF
2018	Testing, Evaluation, and Specification for Polymeric Materials used for Transportation Structures	El-Safty, A.	UNF
2018	Degradation Mechanisms and Service Life Estimation of FRP Concrete Reinforcements	El-Safty, A.	UNF

FDOT FRP Research



2018	Bridge Girder Alternatives for Extremely Aggressive Environments	Brown, J.	ERAU
2018	Performance Evaluation of GFRP Reinforcing Bars Embedded in Concrete Under Aggressive Environments	Kampmann, R.	FAMU/ FSU
2019	Performance Evaluation, Material and Specifications for Basalt FRP Reinforcing Bars Embedded in Concrete	Kampmann, R. Roddenberry, M.	FAMU/ FSU
2020	Basalt FRP-FRC Link-Slab Demonstration Project Monitoring (STIC-Phase 1)	El-Safty, A.	UNF
2020	Inspection and Monitoring of Fabrication and Construction for the Halls River Bridge Replacement	Roddenberry, M.	FAMU/ FSU
2020	HSSS Strands and Lightweight Concrete for Pretensioned Concrete Girders (w/ Shear & Confinement Rebar)	Roddenberry, M.	FAMU/ FSU
2021	Testing Protocol and Material Specifications for Basalt Fiber Reinforced Polymer Bars (Long-term Durability Modelling)	Kampmann, R. Tang, Y	FAMU/ FSU
2021	Evaluation of GFRP Spirals in Corrosion Resistant Concrete Piles	Jung, S.	FAMU/ FSU
2021	Development of GFRP Reinforced Single-Slope Railing	Consolazio, G.	UF
2021	Epoxy Dowelled Pile Splice Evaluation & Testing	Mehrabi, A.	FIU

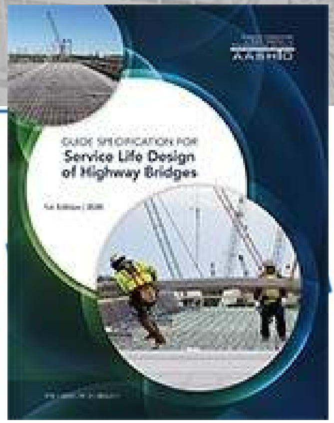
Durable Solutions and Life Cycle Cost Evaluation

- Service Life Expectations for Structures
  - 50 years *(AASHTO LFD < 1993)*
  - 75 years *(AASHTO LRFD > 2007)*
  - 100 or 150 years? *(HBSLD-1, 2020)*

GUIDE SPECIFICATION FOR SERVICE LIFE DESIGN OF HIGHWAY BRIDGES, 1ST EDITION

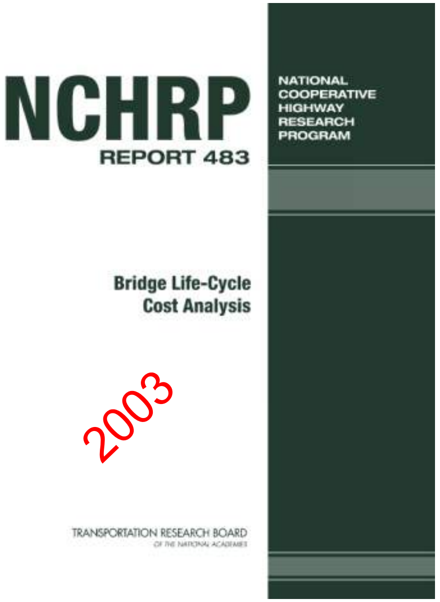
Item Code: HBSLD-1

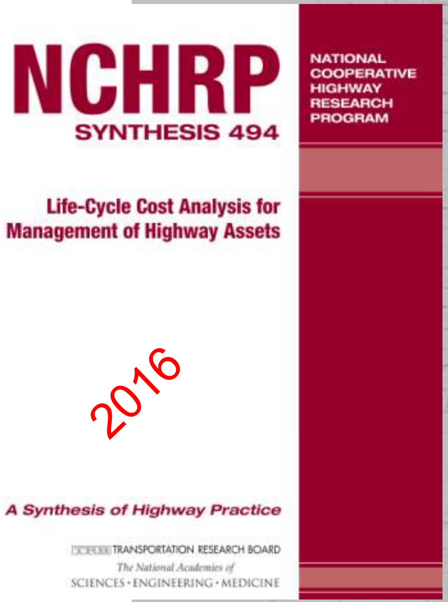
This guide specification is intended to offer design recommendations for agencies wishing to implement service life design principles and detailing recommendations. It was developed to incorporate quantitative approaches, along with proven deemed-to-satisfy provisions, into a single comprehensive design document for implementation on a national level. It also establishes a framework for service life design, while providing opportunities for refinement and expansion, especially as new models capable of simulating deterioration mechanisms become available.



2020

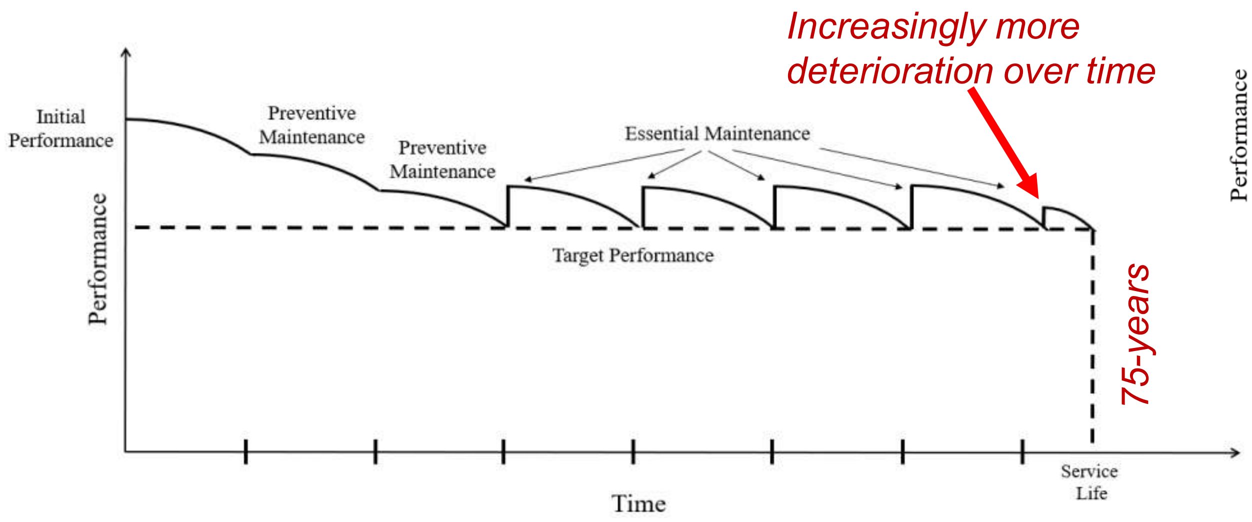
- Life Cycle Cost policies & comparisons



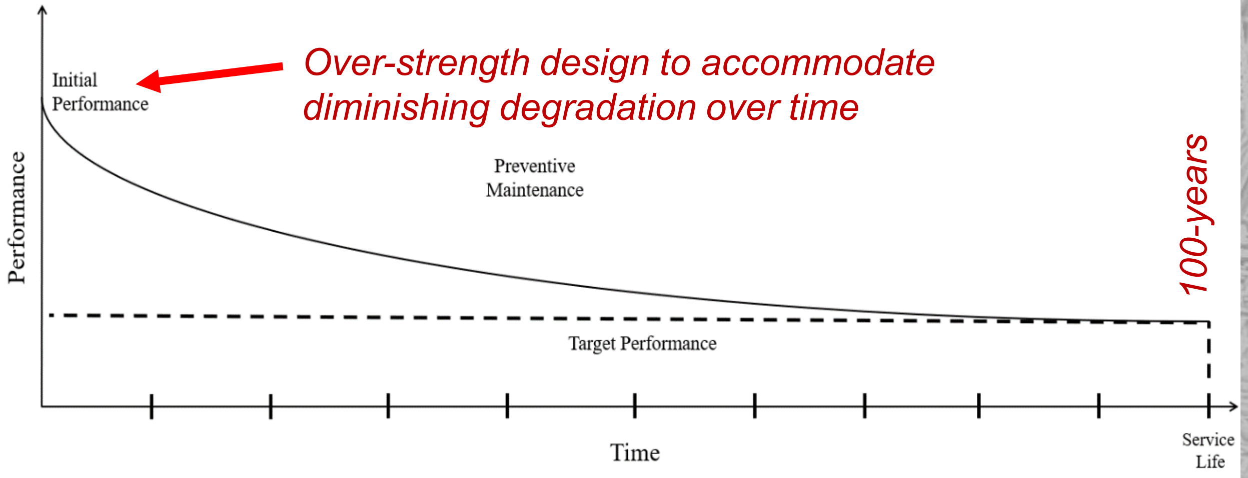


Cost Justification (Service Life, LCC, etc.)

- LCC & LCA also can show the sustainable (economic and environmental) advantage of composite structures in the coastal environment:



CS-RC/PC alternative



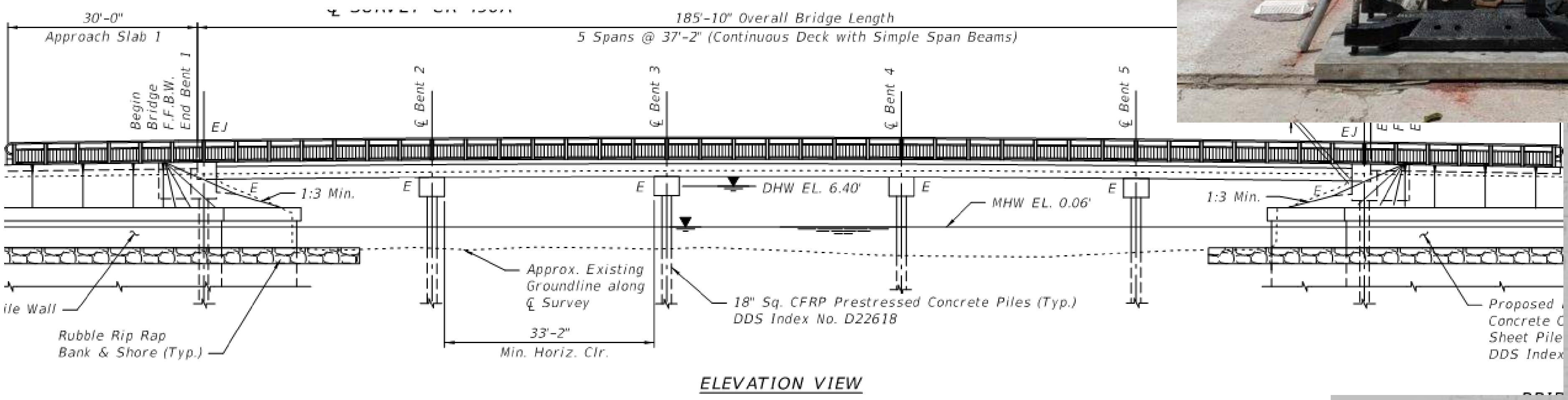
FRP-RC/PC alternative

Source: Cadenazzi, T., Dotelli, G., Rossini, M., Nolan, S., and A. Nanni. (2019). Cost and Environmental Analyses of Reinforcement Alternatives for a Concrete Bridge. Structure and Infrastructure Engineering.

What do we still need?
(gaps in design and deployment)

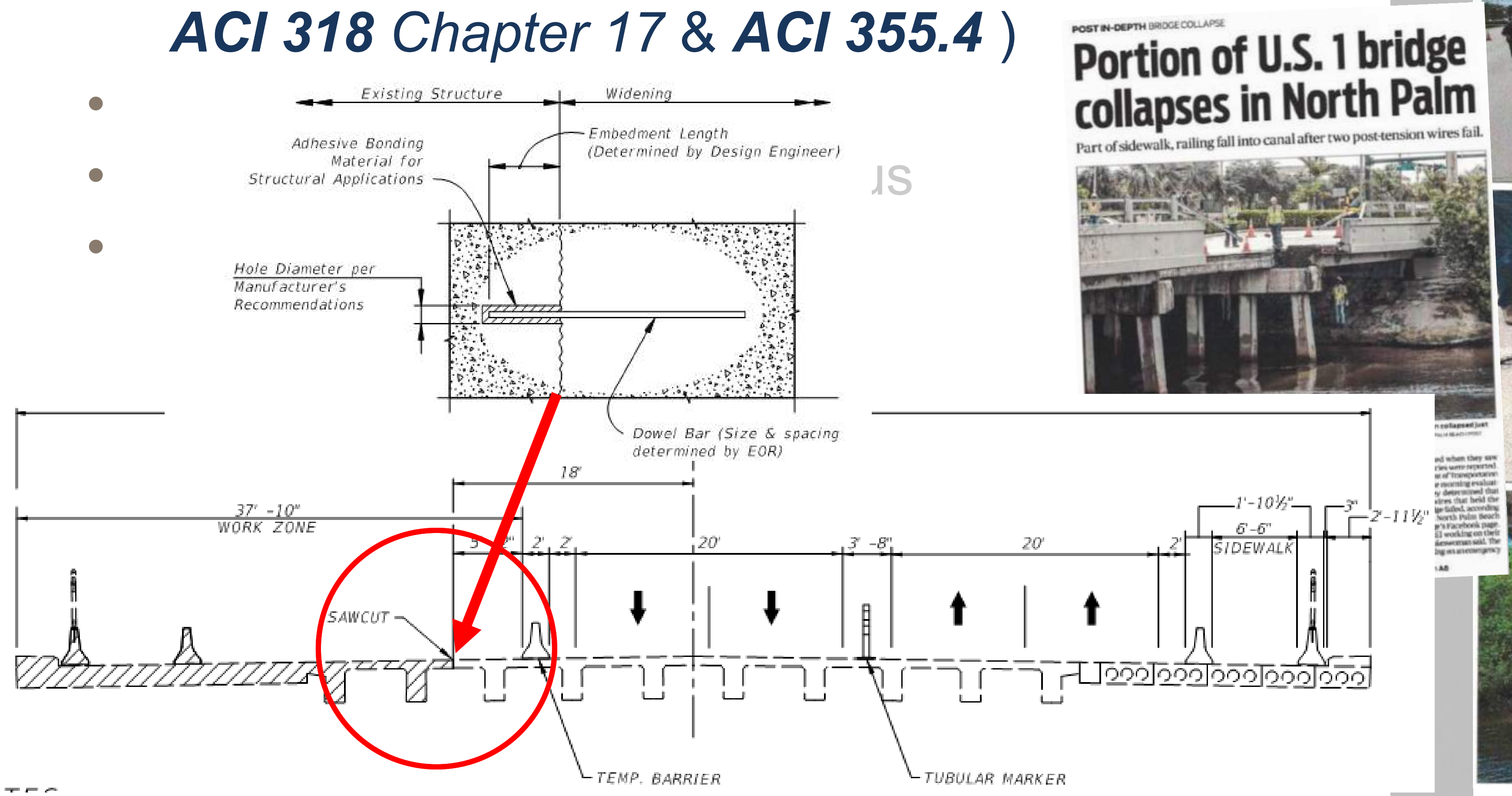
- Connections (post-installed anchors & coupling)
- Creep rupture & Fatigue limits
- Importance of Elastic Modulus
- Bent Bars
- Scalability of production ?

1700+
Dowel Holes



What do we still need?
(gaps in design and deployment)

- Connections (post-installed anchors – ***ACI 318*** *Chapter 17* & ***ACI 355.4***)
-
-
-



POST IN-DEPTH BRIDGE COLLAPSE

Portion of U.S. 1 bridge collapses in North Palm

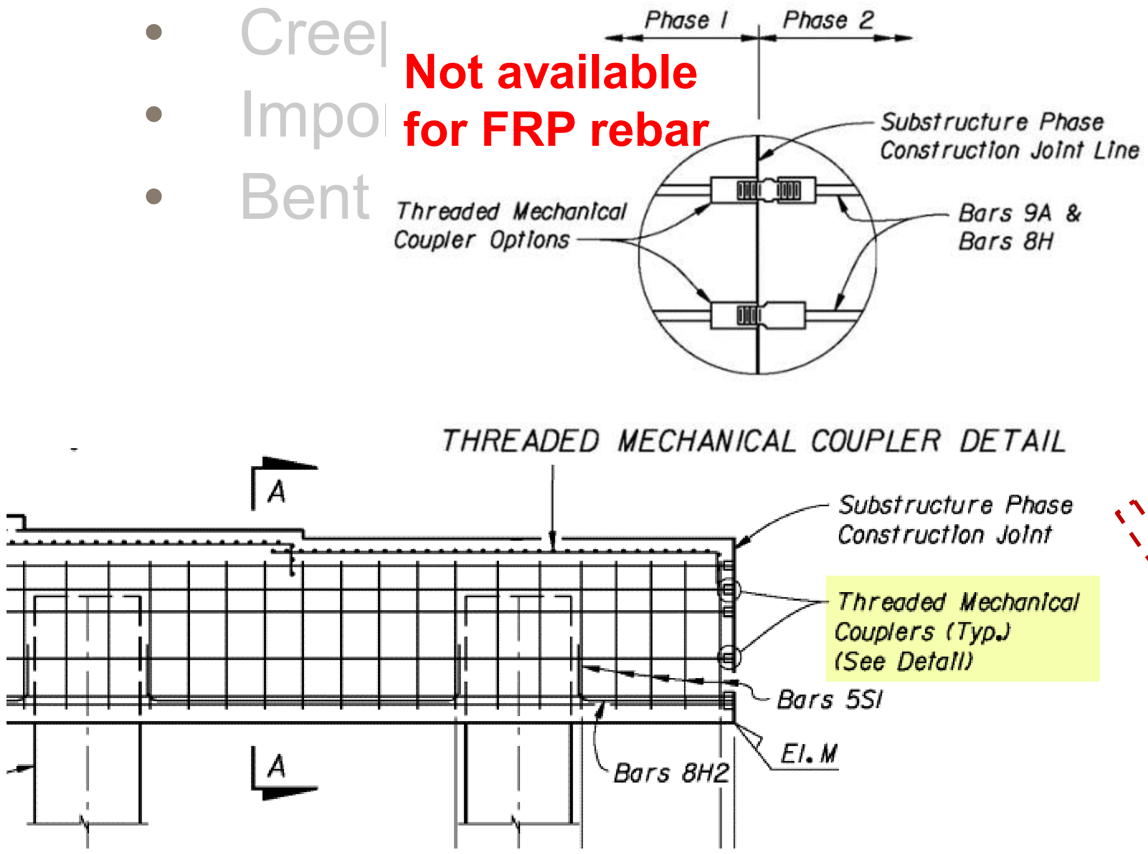
Part of sidewalk, railing fall into canal after two post-tension wires fail.

[Lat. 26.8080459, Long.-80.055929]

What do we still need?
(gaps in design and deployment)

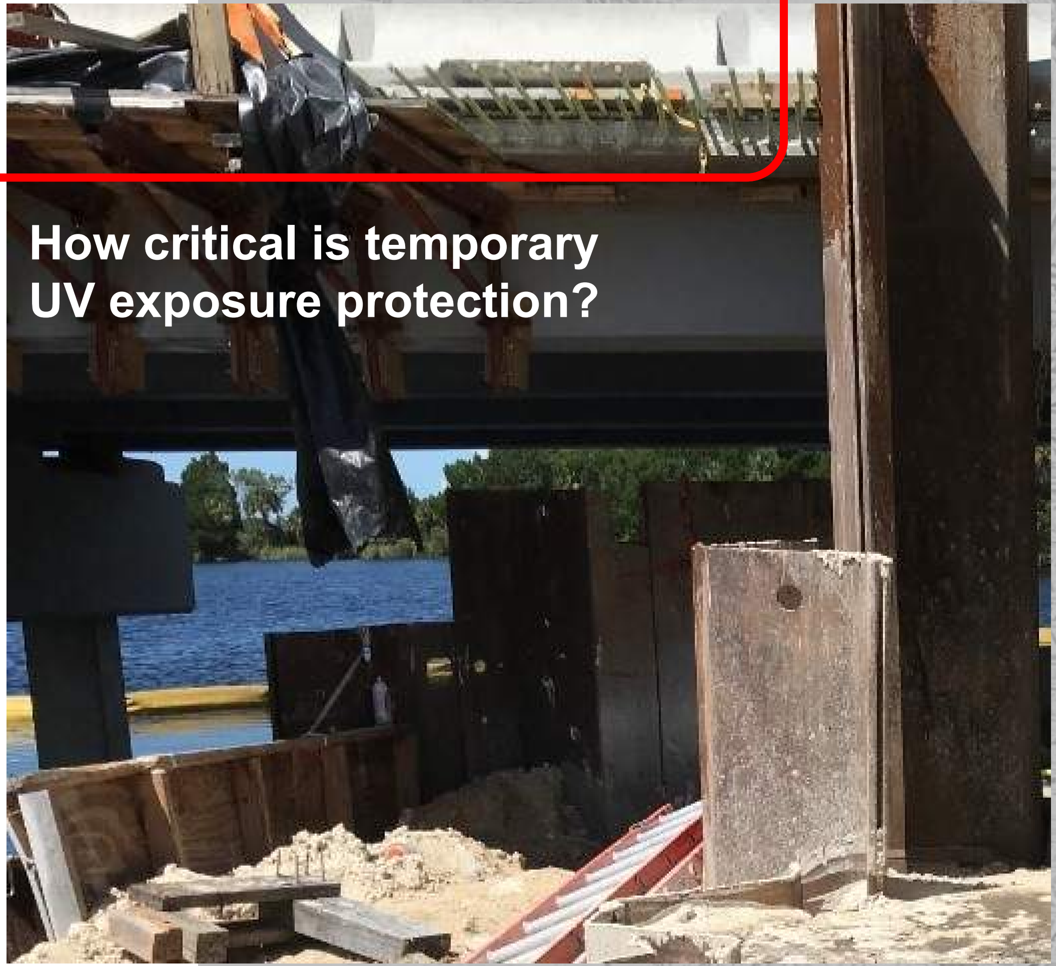
- Connections (mechanical couplers)
- Cree
- Impo
- Bent

Not available for FRP rebar



What do we still need?
(gaps in design and deployment)

- Connections (lap splicing for phased construction)
-
-
-



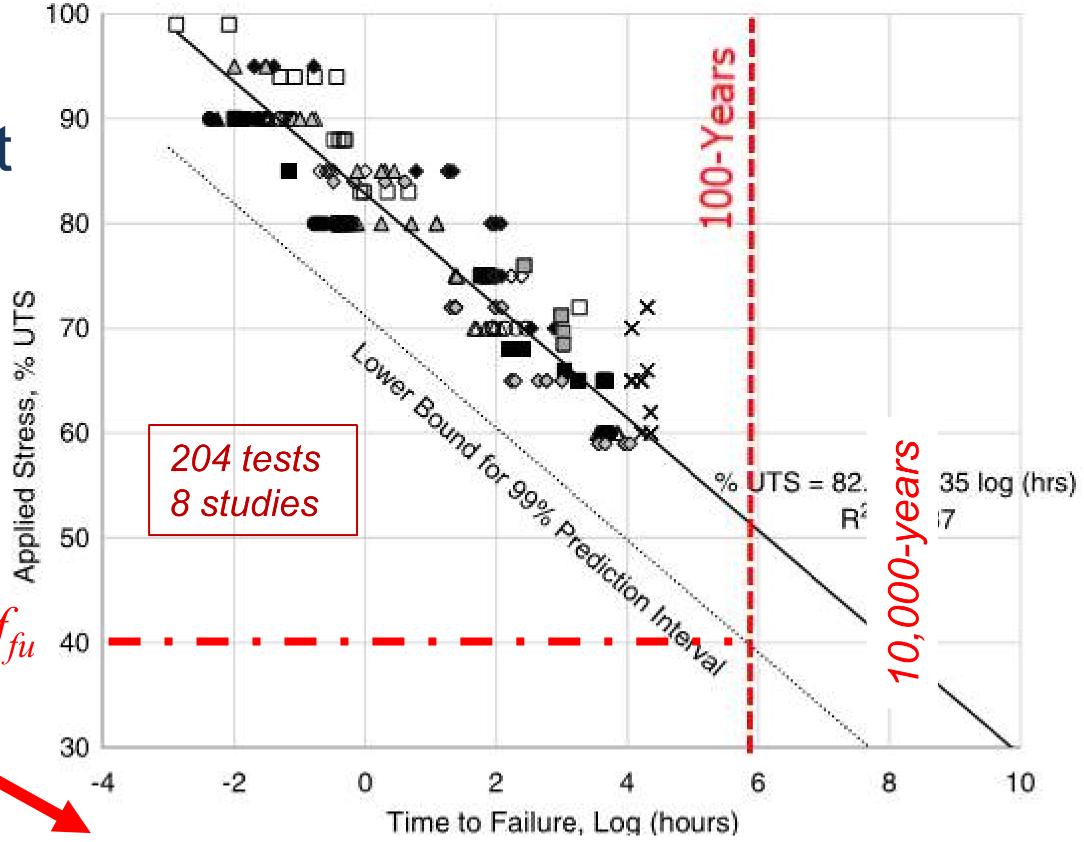
What do we still need? (gaps in design and deployment)

- Connections (coupling, post-installed)
- Creep rupture & Fatigue limits - refinement
- Importance of Elastic Modulus
- Bent Bars

recommended creep-rupture stress limit $(0.30 f_{fu})$ can also be applied for limiting the fatigue stresses in GFRP-reinforced elements subjected to fatigue cyclic loads owing to the similarity between the fatigue and creep-rupture strengths of FRP bars (GangaRao et al. 2006; Rostasy et al. 1993). Additional studies on the fatigue behavior of GFRP bars, however, are essential to support future adjustments of the stress limit.

$\times\, C_E = 0.21 f_{fu}$

$0.40 f_{fu}$



Source: “Creep-Rupture Limit for GFRP Bars Subjected to Sustained Loads”, (2019)
B.Benmokrane, V.L.Brown, K.Mohamed, A.Nanni, M.Rossini, Carol Shield (ASCE-JCC)

What do we still need? (gaps in design and deployment)

- Connections (coupling, post-installed)
- Creep rupture & Fatigue limits
- Importance of Elastic Modulus
- Bent Bars (thermo<u>set</u> vs. thermo-<u>plastic</u>, & quality)

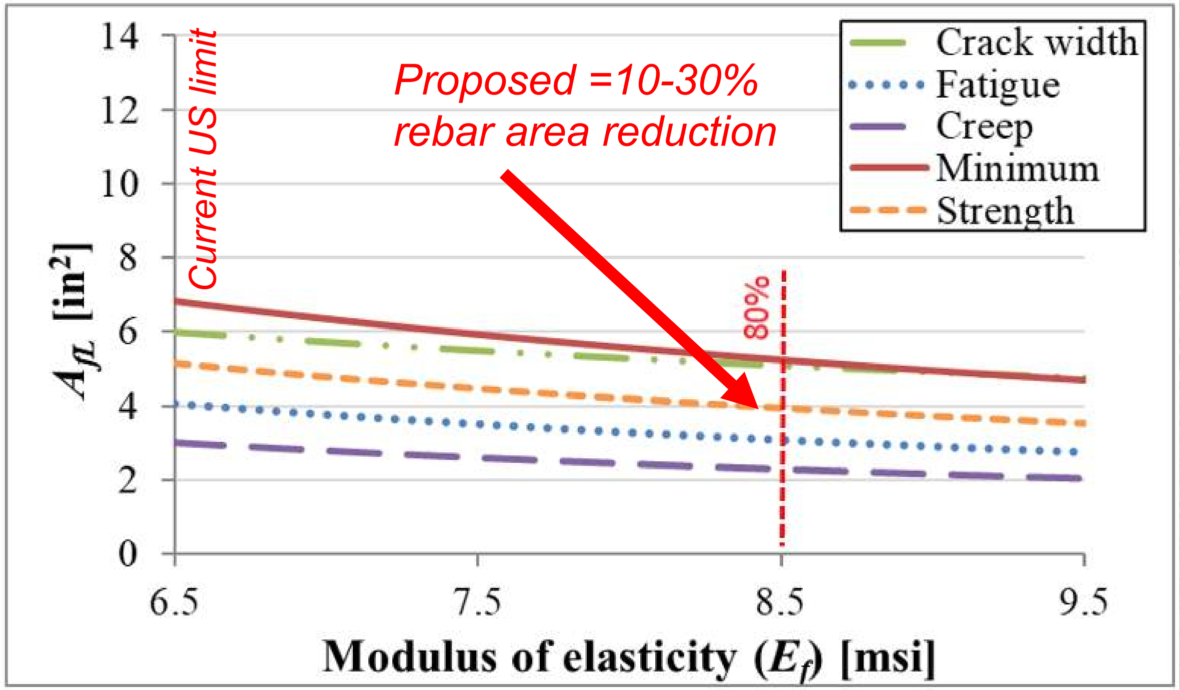


Chart: Parametric analysis of flexural design requirements per AASHTO GFRP-RC 2nd edition for HRB Pile Bent Cap

Source: M.Rossini, F.Matta, S.Nolan and A.Nanni, extended abstract *"Overview of Proposed AASHTO Design Specifications for GFRP-RC Bridges 2nd Edition using Case-Specific Parametric Analysis"* (2017)

Current & Completed Projects in Florida

(new construction excluding fender systems)

- 40th Ave NE over Placido Bayou ++
- Arthur Drive over Lynn Haven Bayou **
- Bakers Haulover Cut Bulkhead Replacement **
- Cedar Key Bulkhead Rehab **
- Halls River Bridge **
- NE 23rd Ave over Ibis Waterway +
- PortMiami Tunnel Retaining Walls **
- South Maydell Dr over Palm River +
- SR-A1A Flagler Beach Seawall (Segment 3) **
- SR-5 (US-17) over Trout River **
- SR-5 (US 41) over Morning Star and Sunset Waterways **
- SR-5 (US 41) over North Creek +
- SR-30 over St Joe Inlet +
- SR-312 over Matanzas River **
- SR-520 over Indian River Bulkhead Rehab **
- Sunshine Skyway Seawall Rehabilitation **
- UM Innovation Bridge **
- UM Fate Bridge **
- UM i-Dock **
- US-1 over Cow Key Channel +

GFRP (Glass) Projects

CFRP Prestressed Piles (Index D22600/22600) Projects

CFRP (Carbon) Projects

BFRP (Basalt) Projects

CFRP/GFRP Concrete Sheet Piles (Index D22440/22600) Projects

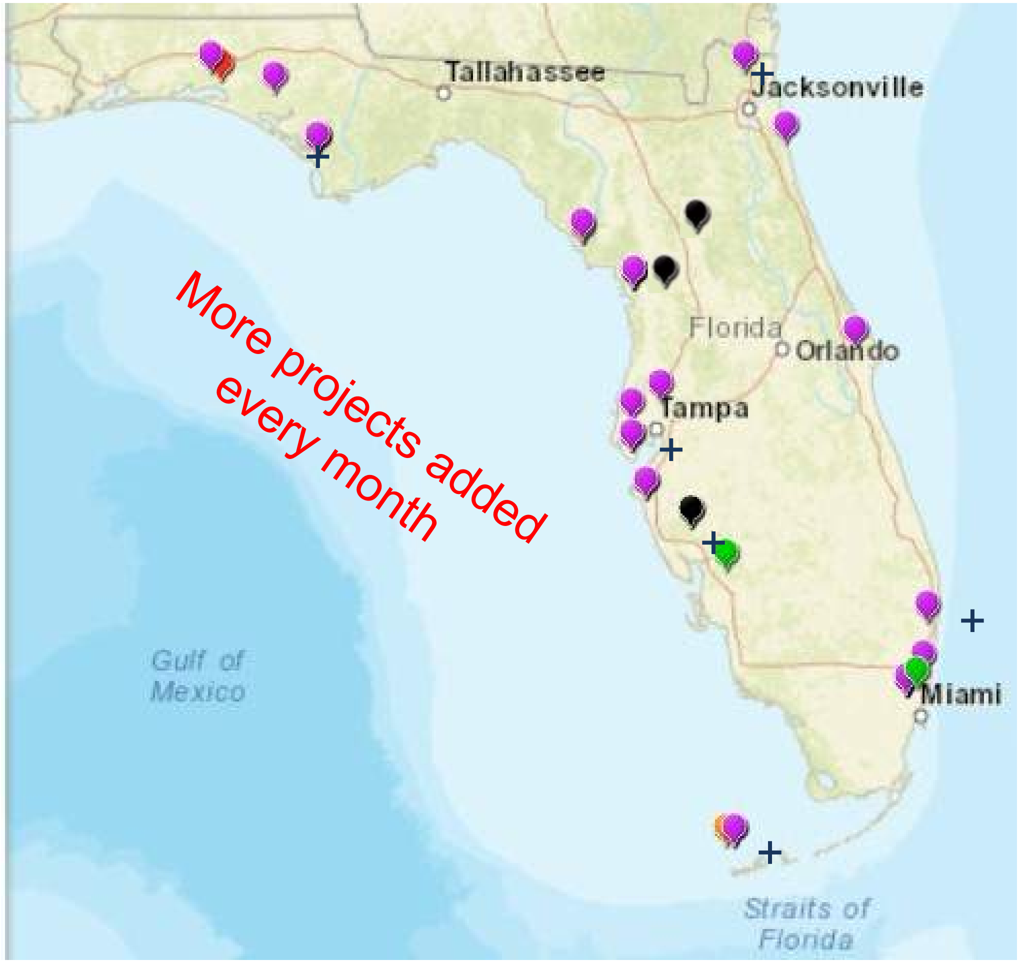
Other

(only includes HCB, CFFT, FRP boardwalk)

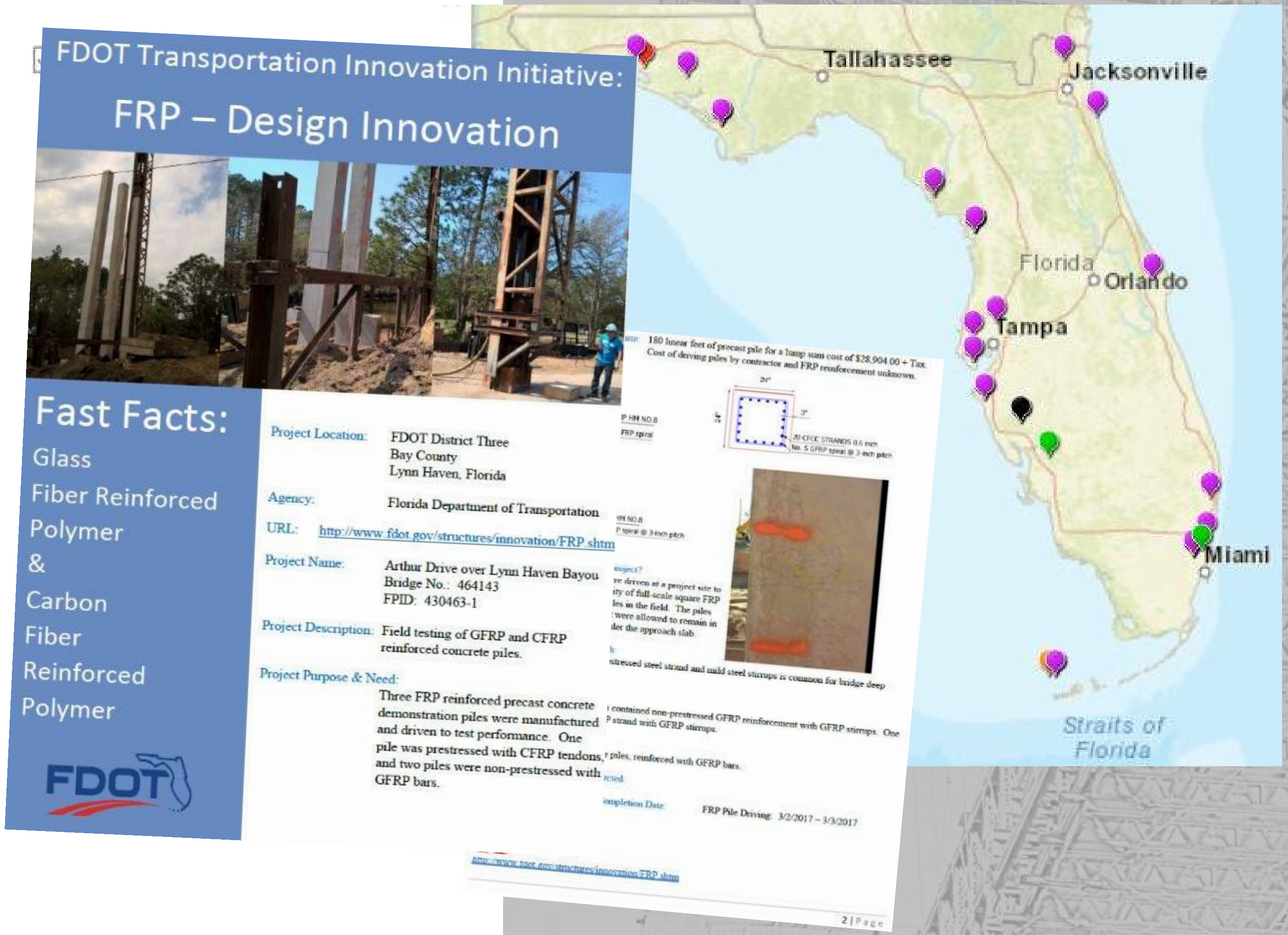
++ *under bid*

\+ *under construction*

** *completed*



Project Examples – Fast Facts Sheets

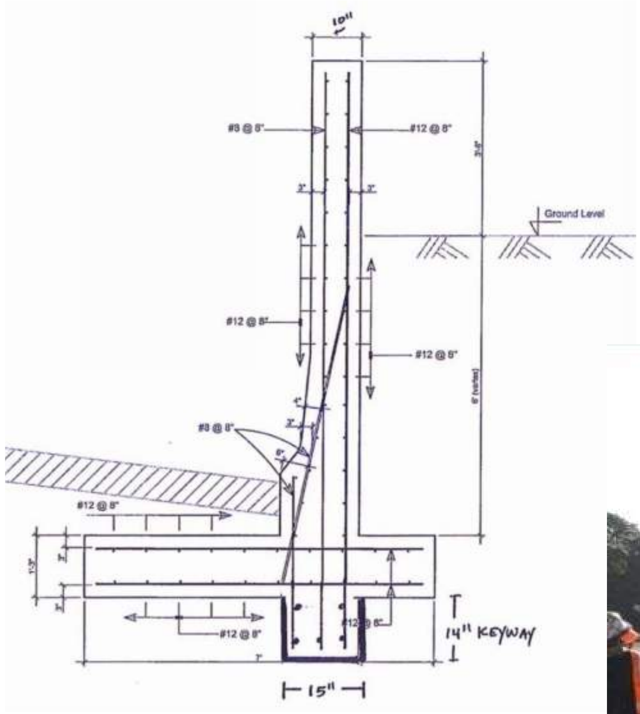


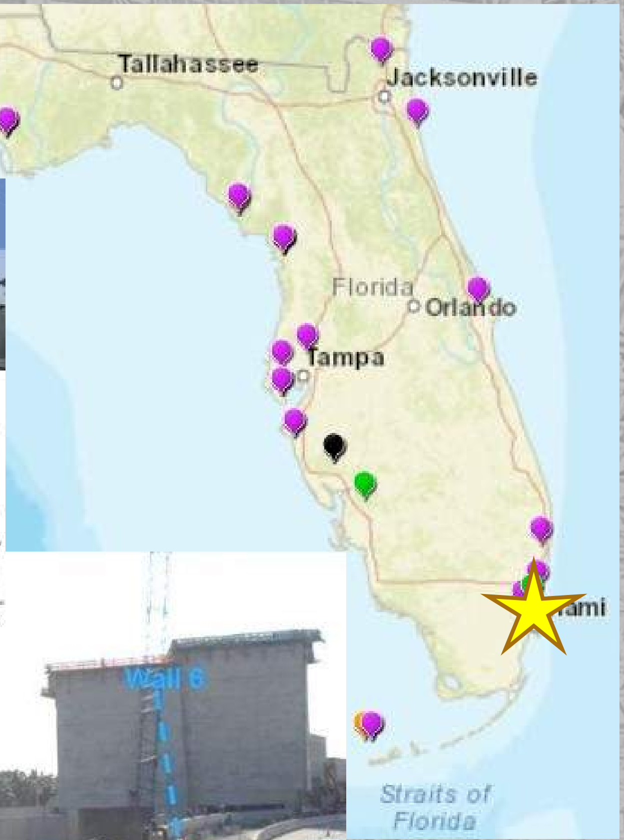
Fast-Facts: https://www.fdot.gov/structures/innovation/FRP.shtm#link9

Project Examples - Port Miami Tunnel Entrance

Watson Island, Miami – 2014

- Retaining Walls 5 & 6



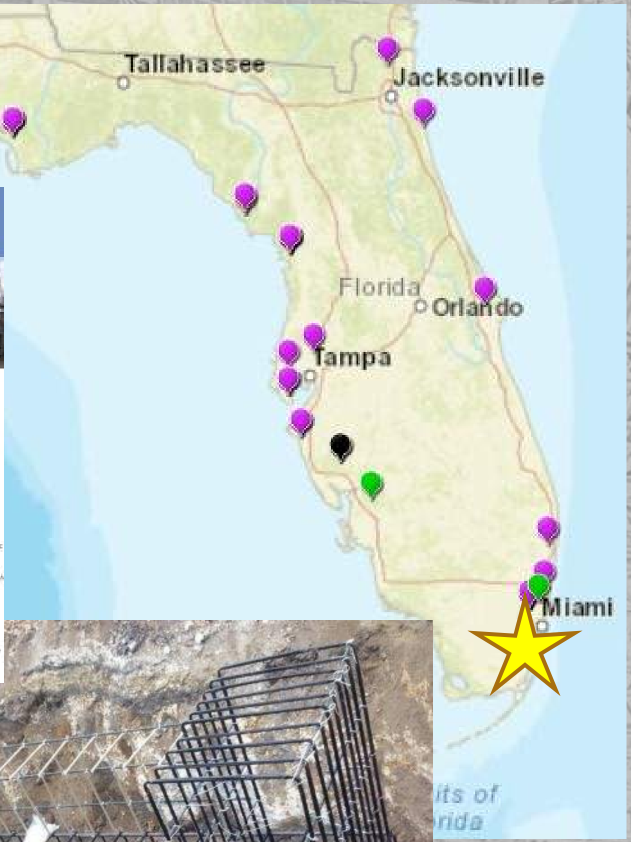


Wall 6 under construction & Typical Cross-section using **Basalt** FRP rebar

Project Examples - Innovation Pedestrian Bridge

University of Miami – 2016

- Single-span pedestrian bridge



Innovation Bridge with **Basalt, Glass & Carbon** FRP reinforcement in the auger-cast-piles, bent-caps, double-tee stems and flanges, deck overlay and curbs.

Project Examples - Halls River Bridge

Entire Bridge and Seawalls - 2017 to 2019

- Five-span vehicular bridge

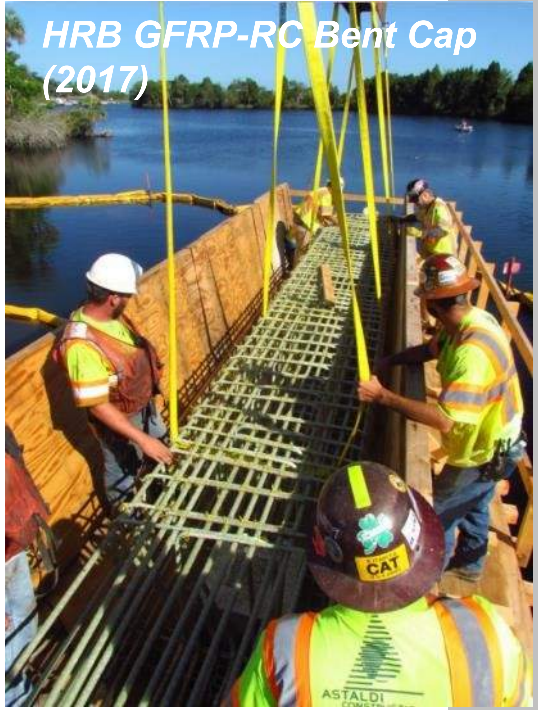
HRB - Phase III construction, July 2019

Project Examples - Halls River Bridge

Homosassa, FL 2017-2019 (GFRP-RC & CFRP-PC)

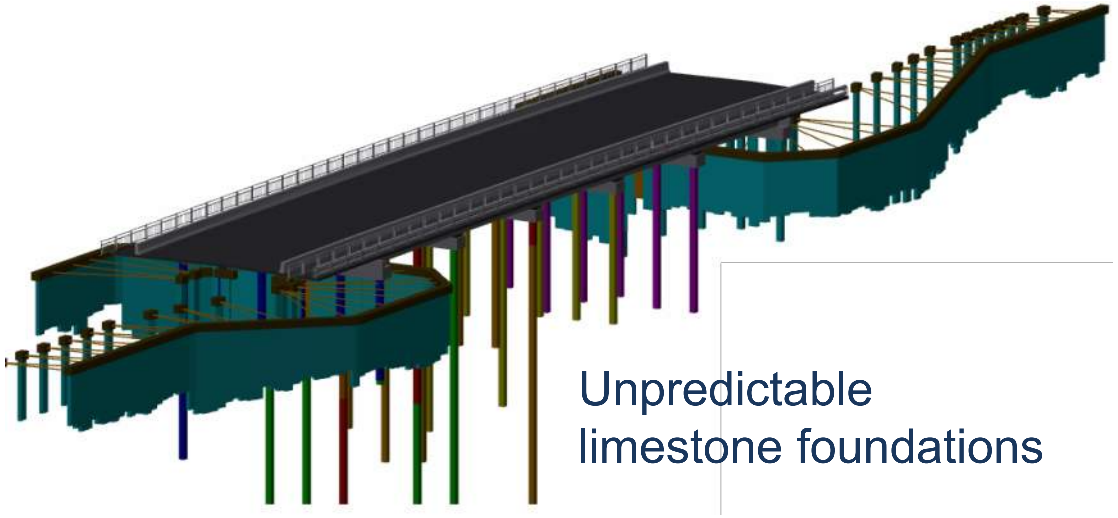
- Five-span vehicular bridge entirely constructed using corrosion-resistant solutions that were mostly FRP reinforcement including:

1) CFRP-PC bearing piles
2) CFRP-PC/GFRP-RC sheet piles
3) Hybrid Steel-PC/GFRP-RC sheet piles;
4) GFRP-RC bulkhead caps
5) GFRP-RC pile bent caps
6) GFRP-RC bridge deck
7) GFRP-RC traffic railings
8) GFRP-RC approach slabs
9) GFRP-RC gravity wall.

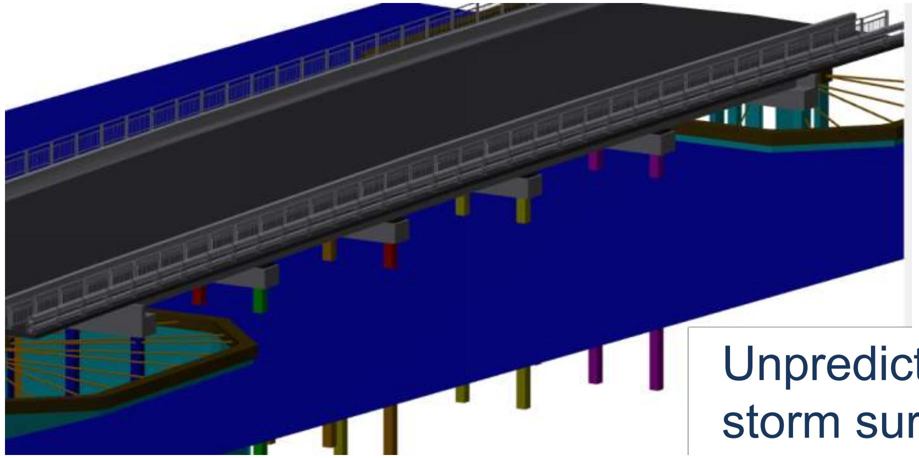


Project Examples - Halls River Bridge

- Demonstrating **Durability** & **Resiliency** thru **FRP materials…**



Unpredictable
limestone foundations

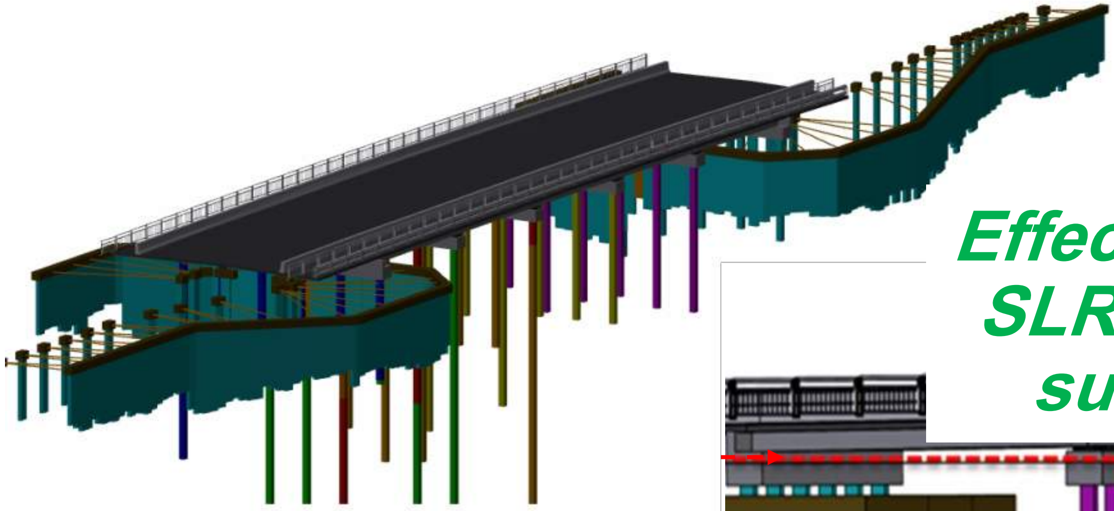


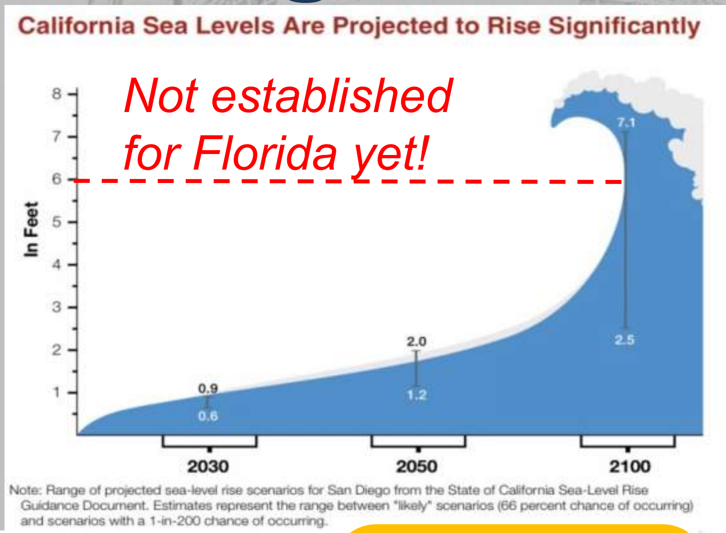
Unpredictable future
storm surge & sea-levels

HRB completed Nov. 2019

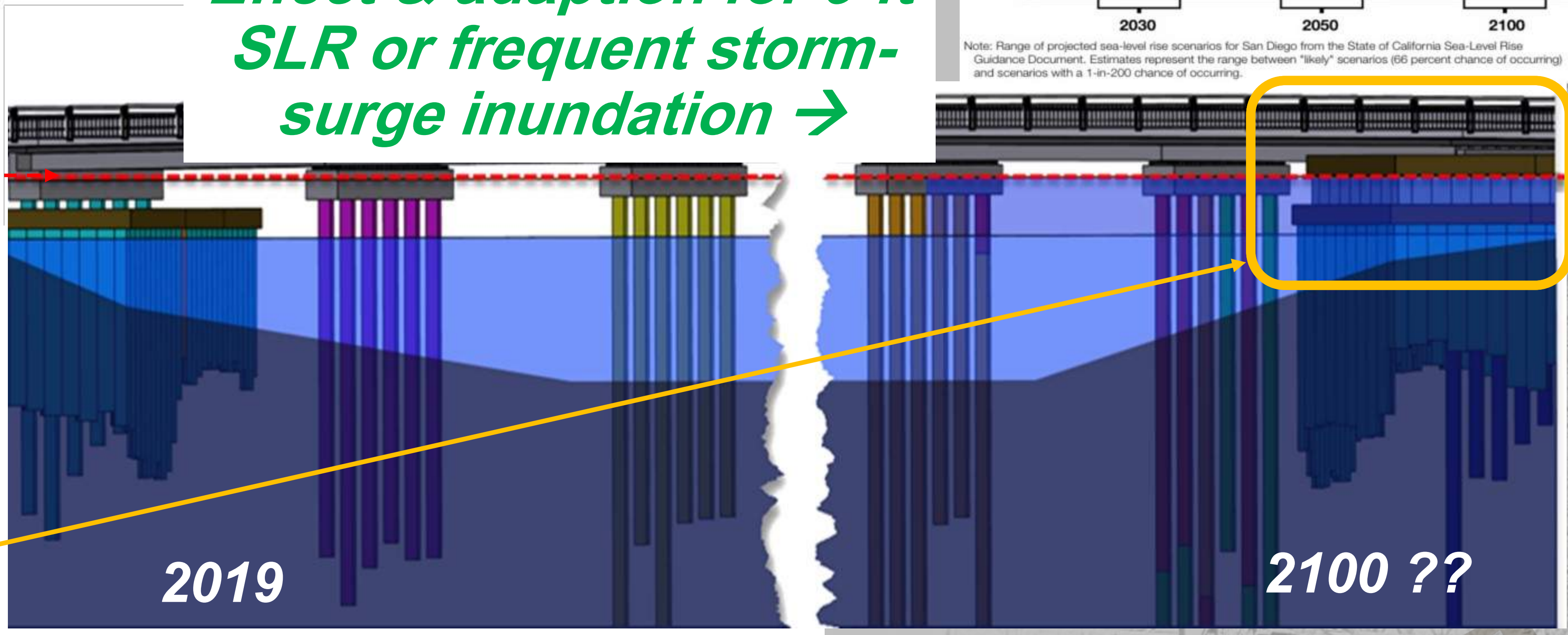
Project Examples - Halls River Bridge

- **Resiliency** thru providing the potential for **Adaption!**





Effect & adaption for 6-ft SLR or frequent storm-surge inundation →

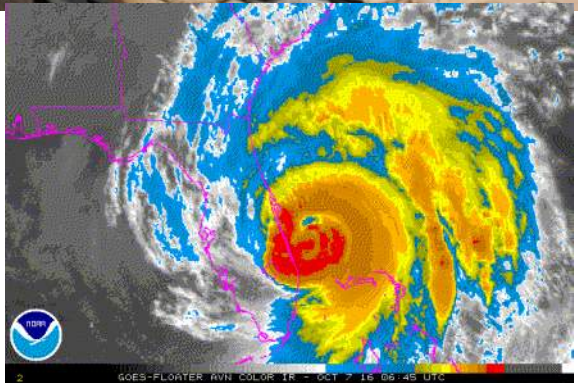


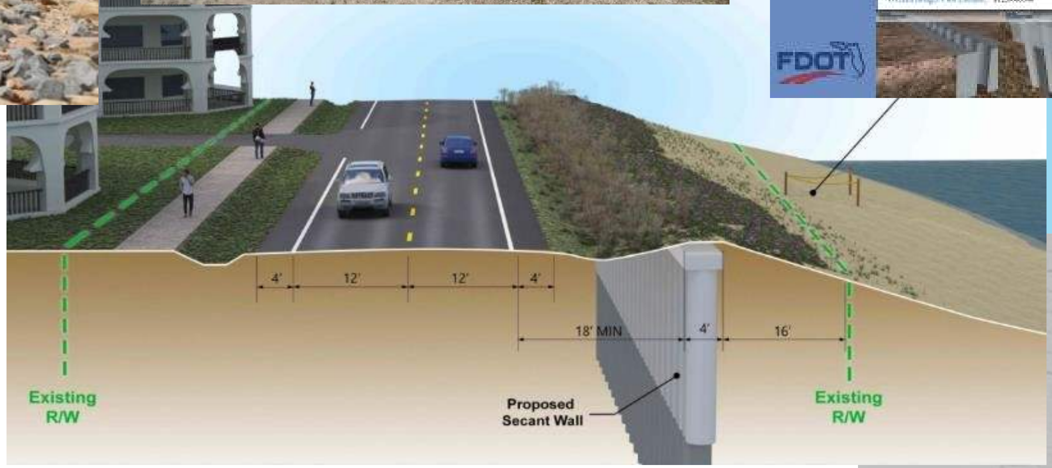
- *Shows current MHW (blue) and 6-ft. projected SLR (dashed redline)*
- *with possible **Adaption Strategy** using 1.5 m raised bulkhead (right-side).*

Project Examples - SR-A1A Secant-Pile Seawall

Auger-Cast Secant Pile Wall - 2019

- **Resiliency** thru robust **Design**






FDOT Transportation Innovation Initiative:

FRP – Design Innovation

Fast Facts:

Glass Fiber Reinforced Polymer

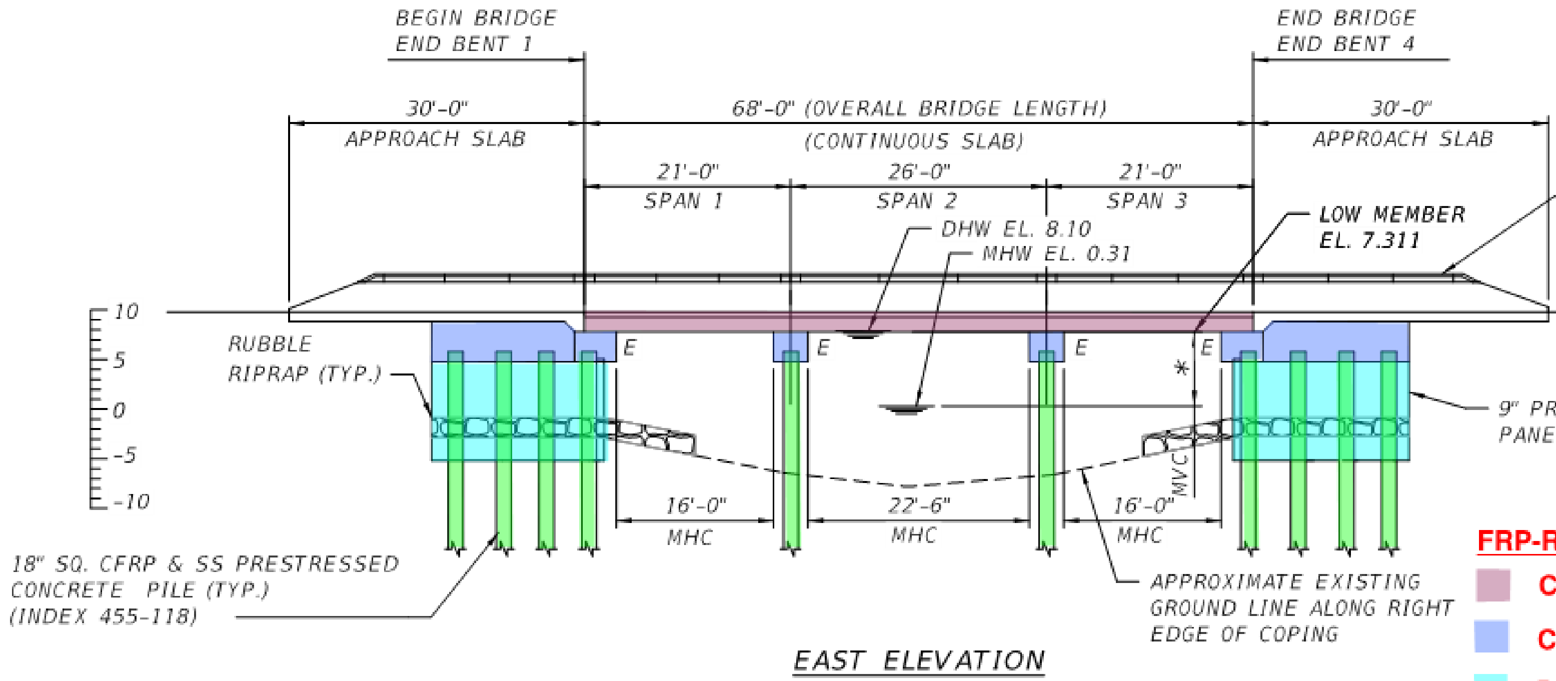
FDOT

Project Examples - NE 23rd Ave/Ibis Waterway

CIP continuous flat-slab bridge – 2020

- **Resiliency** thru robust **Design**

Glass FRP reinforcement & **Carbon** FRP strands, prestressed piles, bent-caps, walls and deck flat-slab.



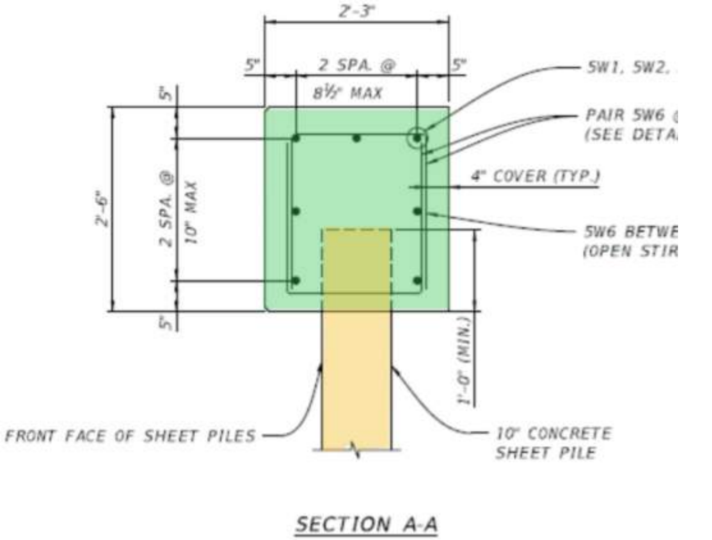
FRP-RC/PCLEGEND

- CIP Flat-Slab, 5.5 ksi (1.5" cover)
- CIP Caps, 5.5 ksi (3" cover)
- Precast Panels, 5.5 ksi (2" cover)
- PS Piles, 6 ksi (3" cover)

Other Projects Under Construction

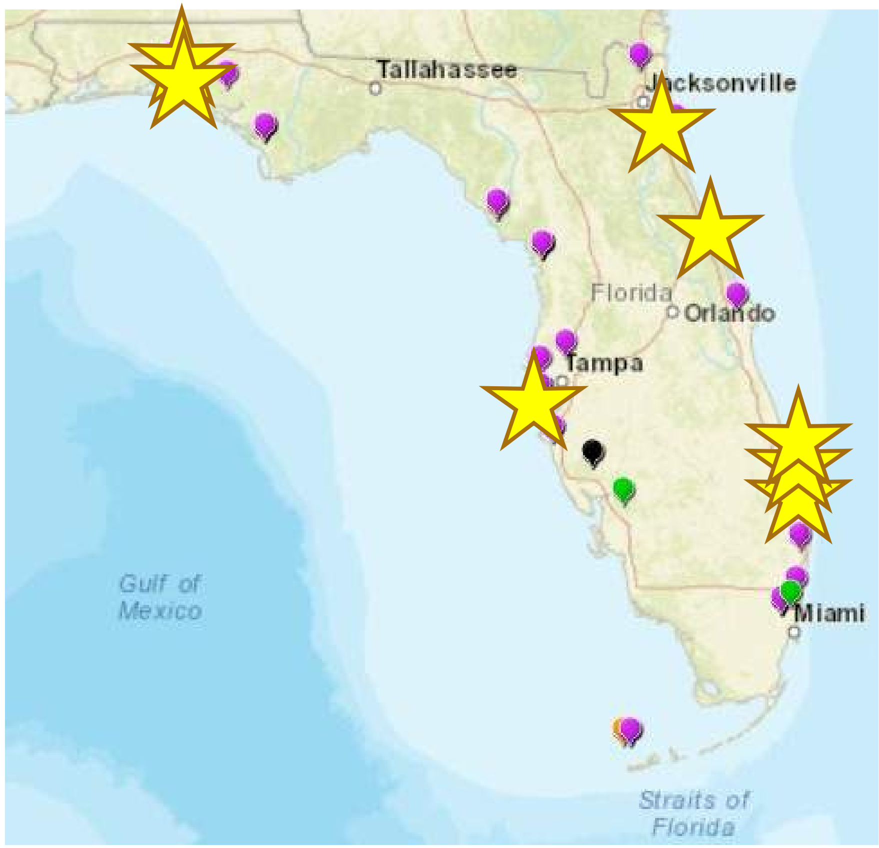
- Bridge Superstructures (US-1/Cow Key Channel, US41/North Creek, Link-Slabs, 40th Ave NE/Placido Bayou)

- Bridge Foundations (South Maydell Dr.)
- Seawalls (SR30/St Joe Bay Inlet, Pinellas Bayway E)



Example New Projects in Design

- Low-level Pedestrian Piers -
  - SR-A1A North Bridge/Indian River Lagoon, US-1/Jupiter Inlet;
- Prestressed Bridges
  - SR82/Earman Canal, Barracuda Ave/North Indian Lagoon, CR30A/Western Lake, Kings St/San Sebastian River;
- CIP Bridges –
  - West Wilson St/Turkey Creek;
- Bridge Foundations –
  - St. Petersburg, 4th St over Big Island Gap



Lessons Learned from the Real World

- Designer Issues
  - Lack of designer training, software tools, and national consensus design codes.
- Material & Testing Issues
  - Costs for FRP rebar supply to public agencies are typically higher since no centralized certification standards for manufacturers, so additional testing and approvals are invoked by individual agencies.
- Constructability Issue
  - Unit $$ for FRP rebar can be very high for small quantities due to the one-size project testing requirements.
  - Many construction contractors do not understand the lead times involved for FRP products.
  - Higher modulus of elasticity can improve competitiveness of GFRP vs. other corrosion-resistant solutions.
  - Stirrup bends and closed shapes or multiple bends still not standardized.
  - Tie-wire (plastic ties are slower, more expensive, and less secure)
  - Coupling of bars for phased construction is essential for broader deployment or will rely on SS solutions.
  - Adhesive anchors are often needed, but not codified for FRP rebar. Field proof testing/gripping is a challenge, especially for bent bars.
  - Shear reinforcing requires much closer spacings and often multiple legs overlapping causing rebar congestion.
  - Non-metallic (corrosion-resistant) lifting devices for heavy civil components are not readily available.
  - Replacement of easily damaged bars/parts in the field is a common need.
  - ***Change is hard… but inevitable !***

THANK YOU
FOR WATCHING

CAMX
THE COMPOSITES AND ADVANCED MATERIALS EXPO

SEPTEMBER 21-24
A VIRTUAL EXPERIENCE
2020