Workshop: Les armatures composites internes au béton

Mercredi 27 Novembre

INDURA

23 avenue Condorcet, 69100 VILLEURBANNE

Armature en PRF pour Renforcer la Floride

Presenter: Steven Nolan, P.E.

Senior Structures Design Engineer

Florida Department of Transportation

Member of TRB's AFF80 – Standing Committee on Structural FRP

FRP Reinforcement Deployment in Florida

INDURA
Auvergne-Rhône-Alpes

Speaker Bio: Steven Nolan, P.E.

Registered Professional Engineer in Florida since 2001. Originally from Australia with an engineering degree from the University of New South Wales (Sydney) 1989. A Construction Engineer for a heavy civil contractor for several years before emigrating to the USA in 1996 and joining *FDOT*. Currently leads the implementation of Advanced Materials for Bridge applications within the State Structures Design Office.

Chair of the statewide Structural Advance Materials Technical Advisory Group (SAMTAG), which coordinates deployment and monitoring of the 8 technologies of immediate interest to FDOT including UHPC, FRC, and various BFRP, GFRP & CFRP composite reinforcements. His 23 years with FDOT also includes in-house bridge design; PM structural research projects; development of many of the FDOT precast and prestressed concrete Design Standards; and participation in NCHRP and NIST Technical Panels;

Member of: Transportation Research Board (TRB) AFF80 Committee on Structural FRP; Bridge Engineering Institute's (BEI) International Advisory Committee; fib; reviewer for ASCE Journal of Composite Construction. Provides technical support for FDOT members on AASHTO's T-6 (FRP Composites) and T-10 (Concrete Design) Committees on Bridges and Structures. Co-author and presenter for numerous papers on FRP and Prestressed Concrete related to bridges and coastal structures including most recently: ACI-SDC Forum 46, BEI-2019; TRB (2018-2019); 2018 fib-Congress, ASCE-Florida, IALCCE-2018, IBC-2018; ABC-UTC Conferences (2014-2015); CAMX Conferences (2015-2019); and FDOT Transportation Symposium & Design Training Expo's (2013-2019).

Outline

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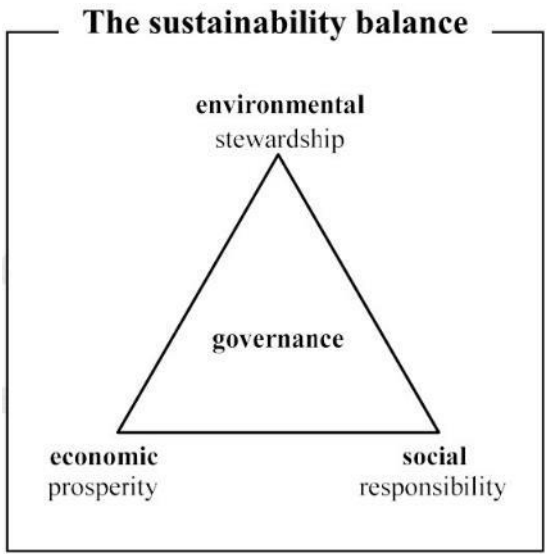
Owner/Designer's perspective

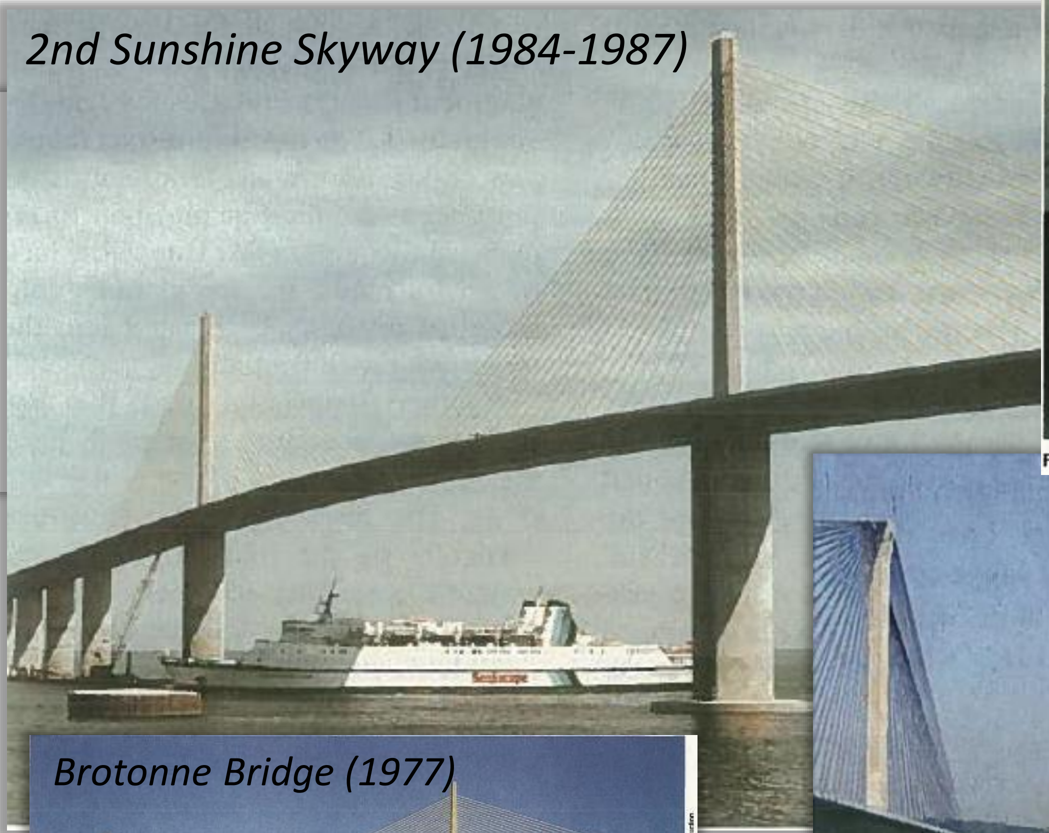
- Historical French-Floridian Bridge Technology Sharing
- Why use FRP rebar for Bridges & Public Infrastructure
- Available Design Guidance & Tools
- Cost Justification (Service Life, LCC, etc.)
- What do we still need?
- Typical Project Examples



Historical French-Floridian Bridge Technology Sharing

1st Sunshine Skyway (1950-1954)

2nd Sunshine Skyway (1984-1987)



Brotonne Bridge (1977)

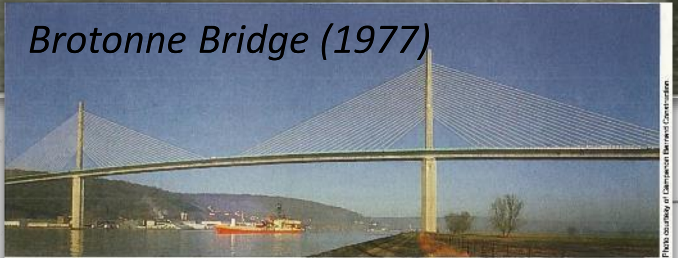
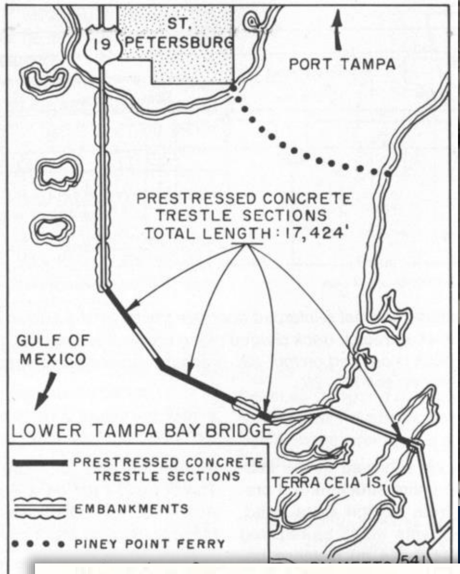


Fig. 13. The Brotonne Bridge is pictured over the Seine River in France.

Fig. 2. Pictured is Eugene Freyssinet.



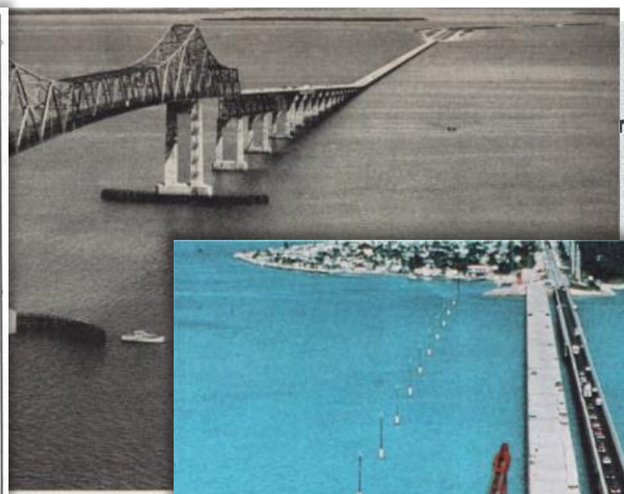


Fig. 1. Pictured is Jean Muller.

Florida Keys Bridges

Until 1978, all precast concrete segmental bridges were built by the balanced or progressive cantilever method, with the exception of smaller overpass structures. The first designs produced by Figg and Muller Engineers were for the Florida Keys bridge replacement program and included the Long Key Bridge, Seven-Mile Bridge, Channel Five Bridge, and Niles Channel Bridge

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

Courtesy: PCI Journal "Jean Muller: Bridge Engineer" (March-April 2006).

Historical French-Floridian Technology Sharing

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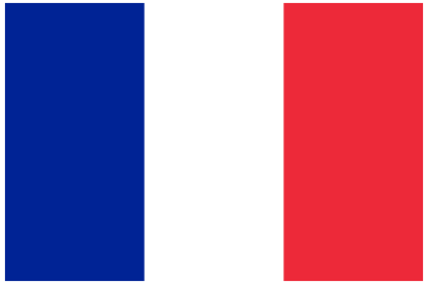

Historical French-Floridian Technology Sharing

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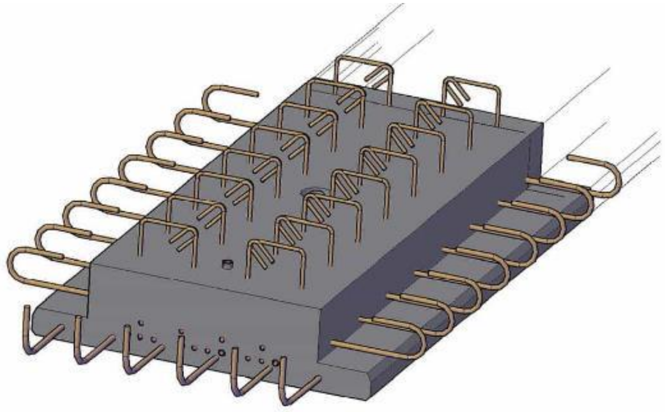
- 2013 FDOT French Study PT-Duct Flexible Filler (wax) Tour

2013 Florida Representatives

- Poutre-Dalles System (PDS) for prestressed-slab units.
  - 2004 FHWA Scan Tour inspired adoption of similar PDS by Minnesota DOT[(1)] in 2005;
  - Later adoption by FDOT in 2013 with a modified concept – Florida-Slab Beam (FSB) - 70 bridges designed to-date.

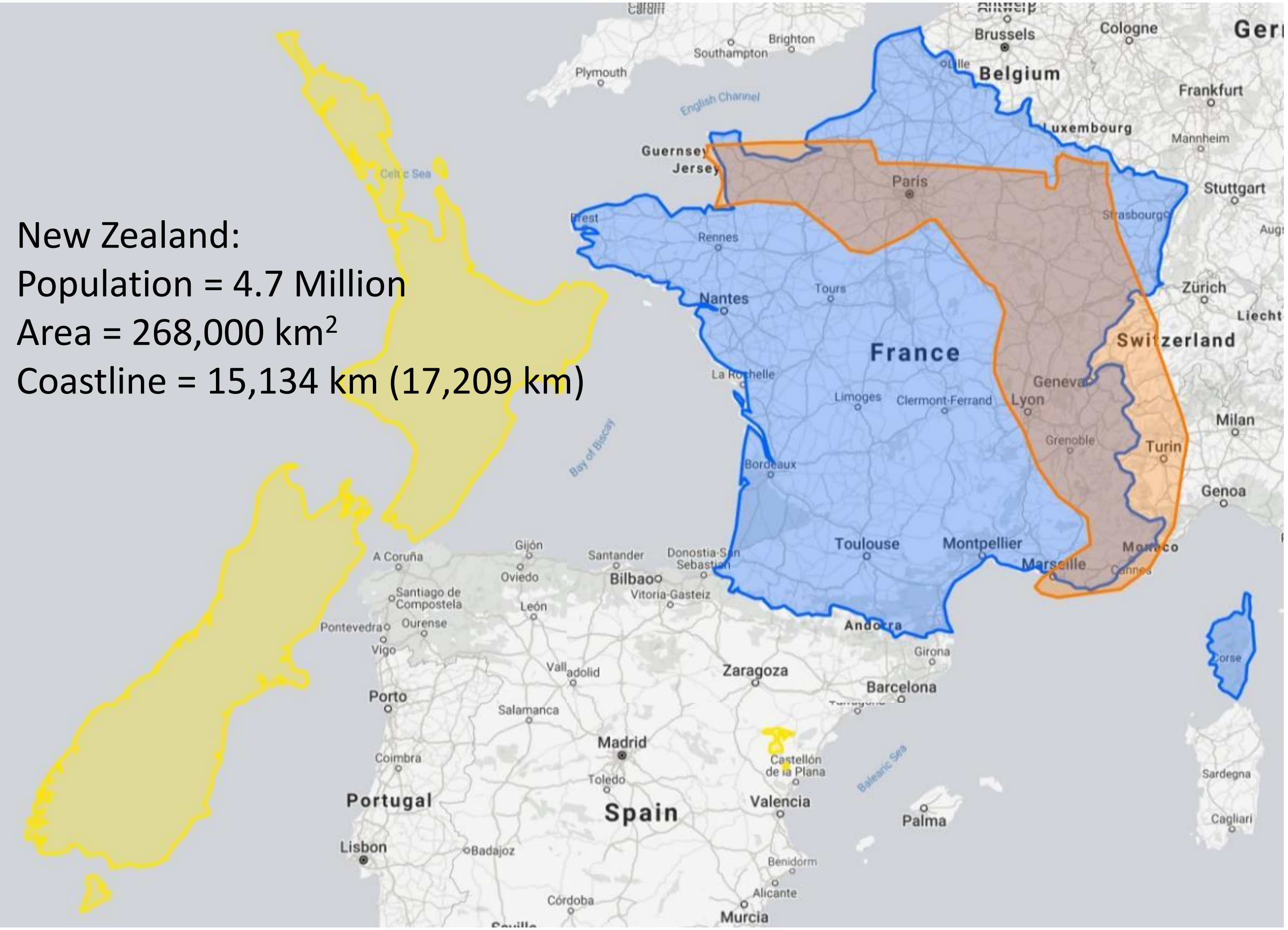


https://www.matiere-tp.com/beam-slab/

Orange Ave (2014)

(1) MnDOT/FHWA Precast Slab System Workshop Summary Report, FHWA, Sept 8, 2005.

France-Florida Comparisons



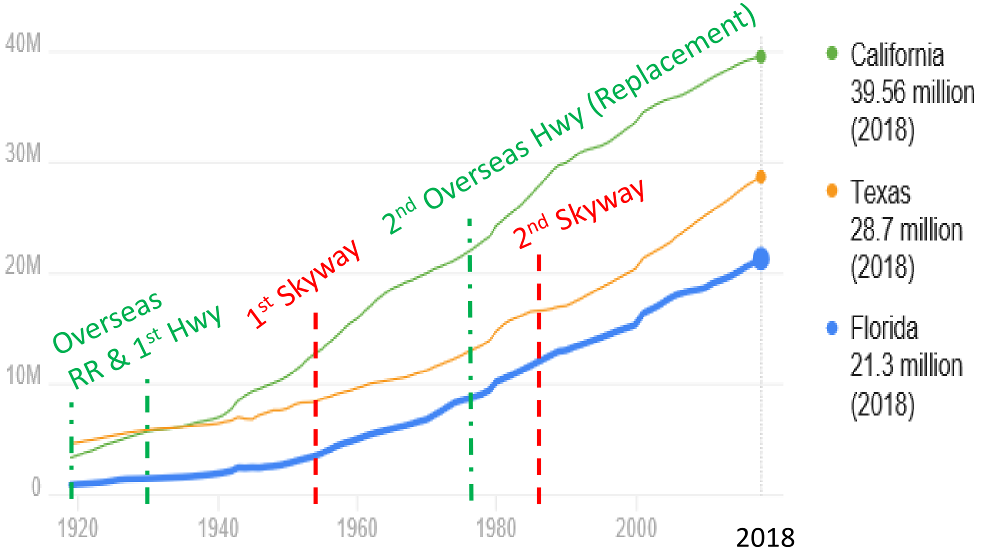
New Zealand:
Population = 4.7 Million
Area = 268,000 km²
Coastline = 15,134 km (17,209 km)

Population:
France = 65 Million
Florida = 21 Million

Area:
France = 643,800 km²
Florida = 170,300 km²

Coastline (shoreline):
France = 4,853 km (7,330 km)[1]
Florida = 2,170 km (13,576 km)[2]

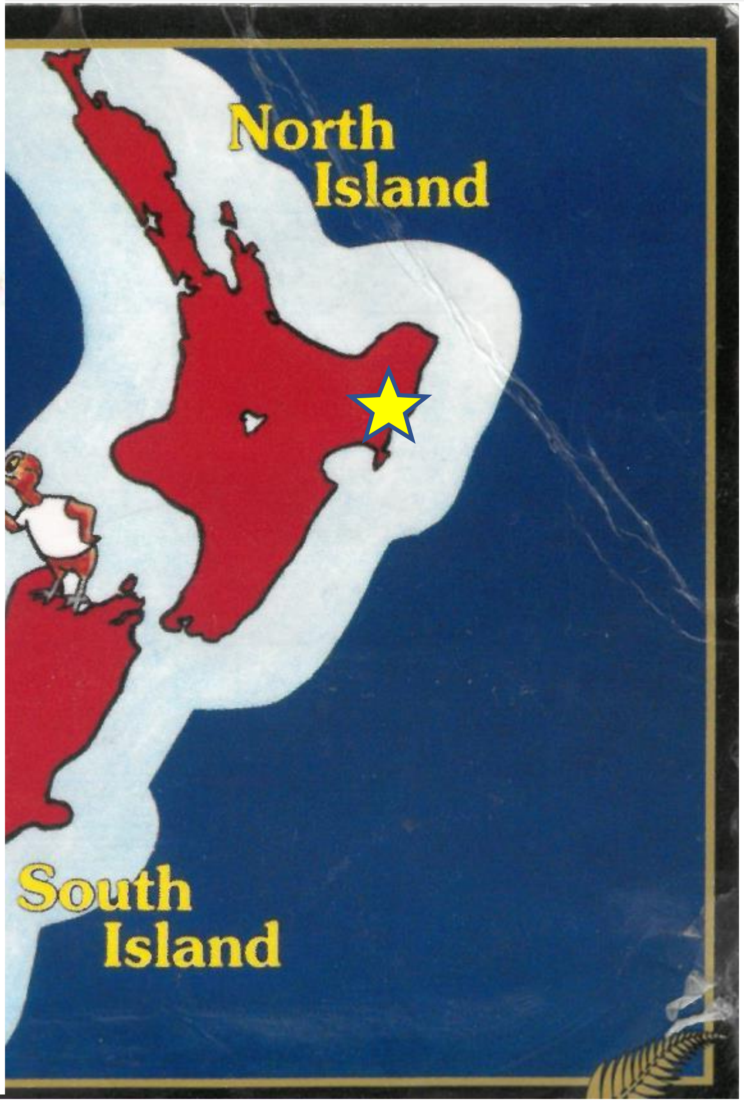
[1] www.wri.org/
[2] NOAA



FLORIDA POPULATION GROWTH

France-Florida-NZ Comparisons

New Zealand:
Population = 4.7 Million
Area = 268,000 km^2
Coastline = 15,134 km (17,20



Florida GFRP-RC Projects

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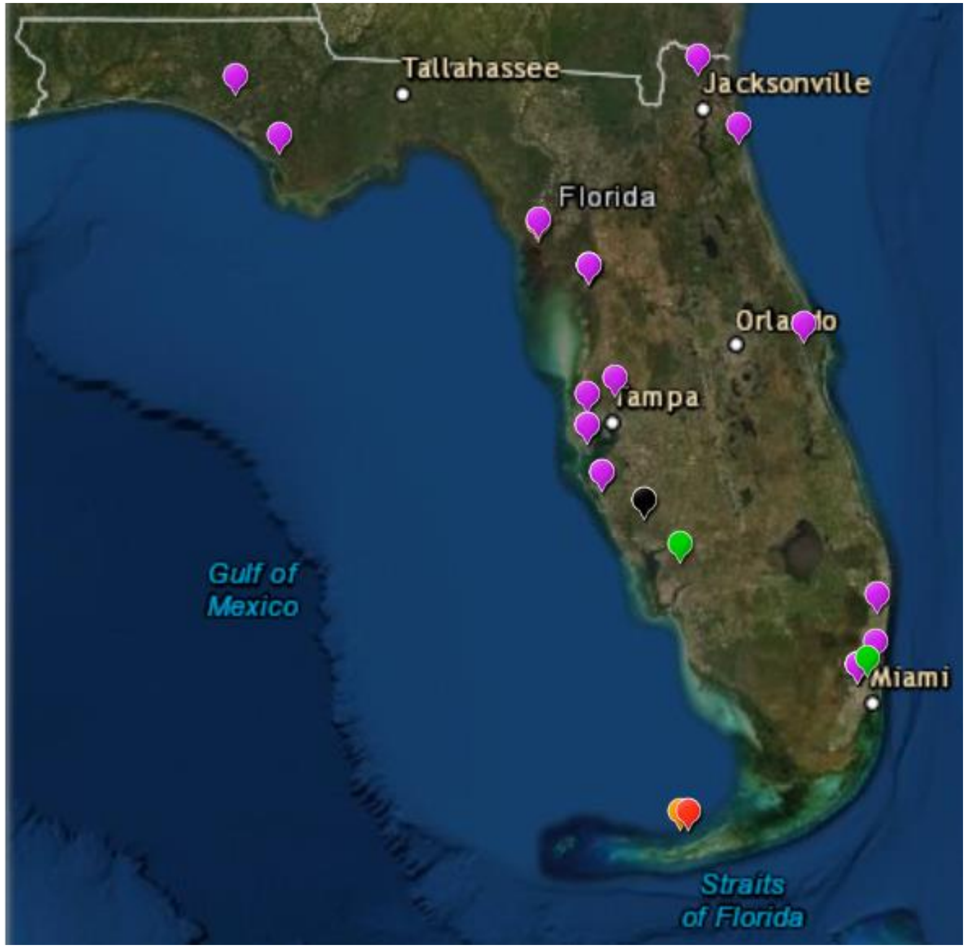
- FRP Rebar Projects
  - GFRP (Glass) Projects
  - CFRP (Carbon) Projects
  - CFRP Prestressed Piles (Index D22600/22600) Projects
  - BFRP (Basalt) Projects
  - CFRP/GFRP Concrete Sheet Piles (Index D22440/22600) Projects
  - Other

Fast-Facts sheets for selected projects available:



- 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

*** completed*

Why use FRP rebar for Bridges and Structures

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- Florida maintains more than 17,000,000 m² (185M ft²) of bridge area
- Florida has more than 6,500 km (4,000 miles) seawall-bulkheads

WebTable 3. Shoreline hardening and population statistics by state (1)

	Hard sheltered shore (km)	Sheltered shore (km)	Hard sheltered shore (%)	Hard open shore (km)	Open shore (km)	Hard open shore (%)	Hard shore (km)	Total shore (km)	Hard shore (%)
Atlantic									
Connecticut	477	1907	25	0	0		477	1907	25
Delaware	287	2163	13	5	45	11	292	2208	13
DC	29	54	53	0	0		29	54	53
Florida*	2694	11 365	24	58	628	9	2752	11 992	23
Gulf									
Alabama							356	2606	14
Florida*							4427	26 383	17

Seven Mile Bridge "New" and Old (Florida Keys)


Jupiter (FL)


Florida Keys


Courtney Campbell Causeway seawall (Tampa Bay)


Gandy Blvd. seawall (Tampa Bay)

(1) Gittman et al. https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/150065

Why? …Inevitability of Corrosion

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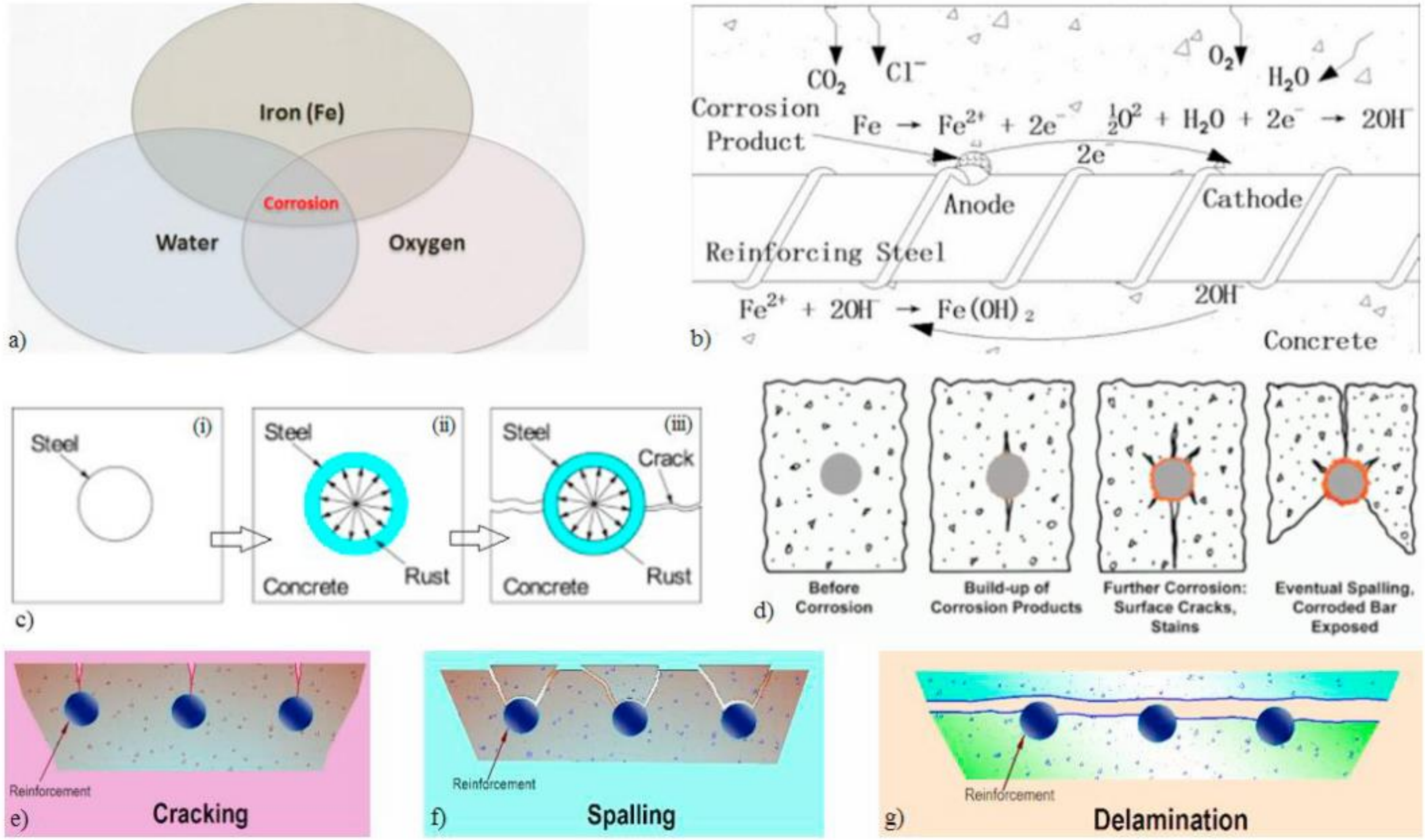
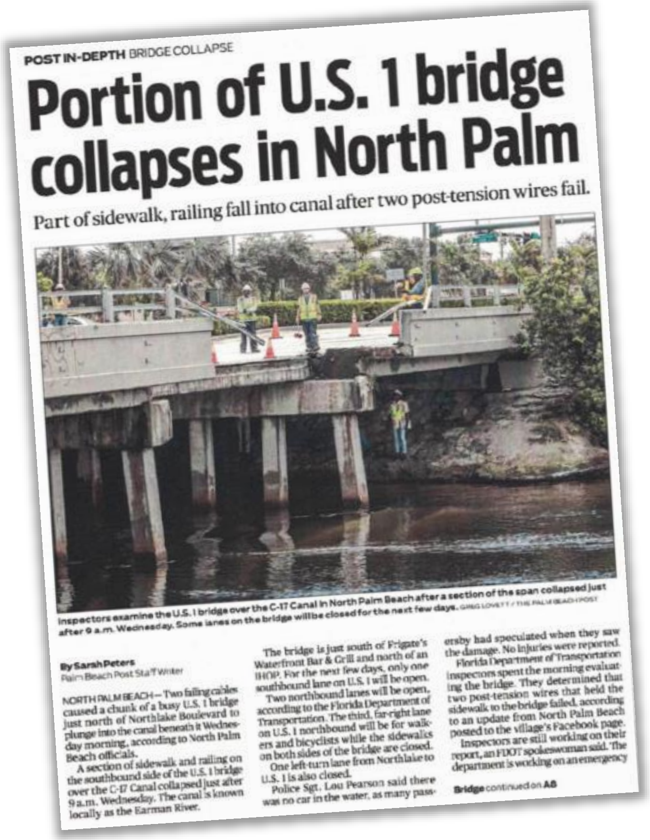


Figure 1. a) Components for corrosion; b) Electro-chemical process of corrosion; c) Generation of stress inside the concrete; d) Evolution of cracks as corrosion progresses; e) Cracks due to corrosion; f) Spalling due to corrosion; g) Delamination due to corrosion.



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.

Inspectors examine the U.S. 1 bridge over the C-17 Canal in North Palm Beach after a section of the span collapsed just after 9 a.m. Wednesday. Some lanes on the bridge will be closed for the next few days. GREG LOVETT / THE PALM BEACH POST

By Sarah Peters
Palm Beach Post Staff Writer

NORTH PALM BEACH — Two failing cables caused a chunk of a busy U.S. 1 bridge just north of Northlake Boulevard to plunge into the canal beneath it Wednesday morning, according to North Palm Beach officials.

A section of sidewalk and railing on the southbound side of the U.S. 1 bridge over the C-17 Canal collapsed just after 9 a.m. Wednesday. The canal is known locally as the Earman River.

The bridge is just south of Frigate's Waterfront Bar & Grill and north of an IHOP. For the next few days, only one southbound lane on U.S. 1 will be open.

Two northbound lanes will be open, according to the Florida Department of Transportation. The third, far-right lane on U.S. 1 northbound will be for walkers and bicyclists while the sidewalks on both sides of the bridge are closed.

One left-turn lane from Northlake to U.S. 1 is also closed.

Police Sgt. Lou Pearson said there was no car in the water, as many passersby had speculated when they saw the damage. No injuries were reported.

Florida Department of Transportation inspectors spent the morning evaluating the bridge. They determined that two post-tension wires that held the sidewalk to the bridge failed, according to an update from North Palm Beach posted to the village's Facebook page.

Inspectors are still working on their report, an FDOT spokeswoman said. The department is working on an emergency

Bridge continued on A8

Figure 1 from: Corrosion Mechanism in Reinforced Concrete (Maia & Alves, 2017)

Why? …Drastic Consequences Demand Different Solutions

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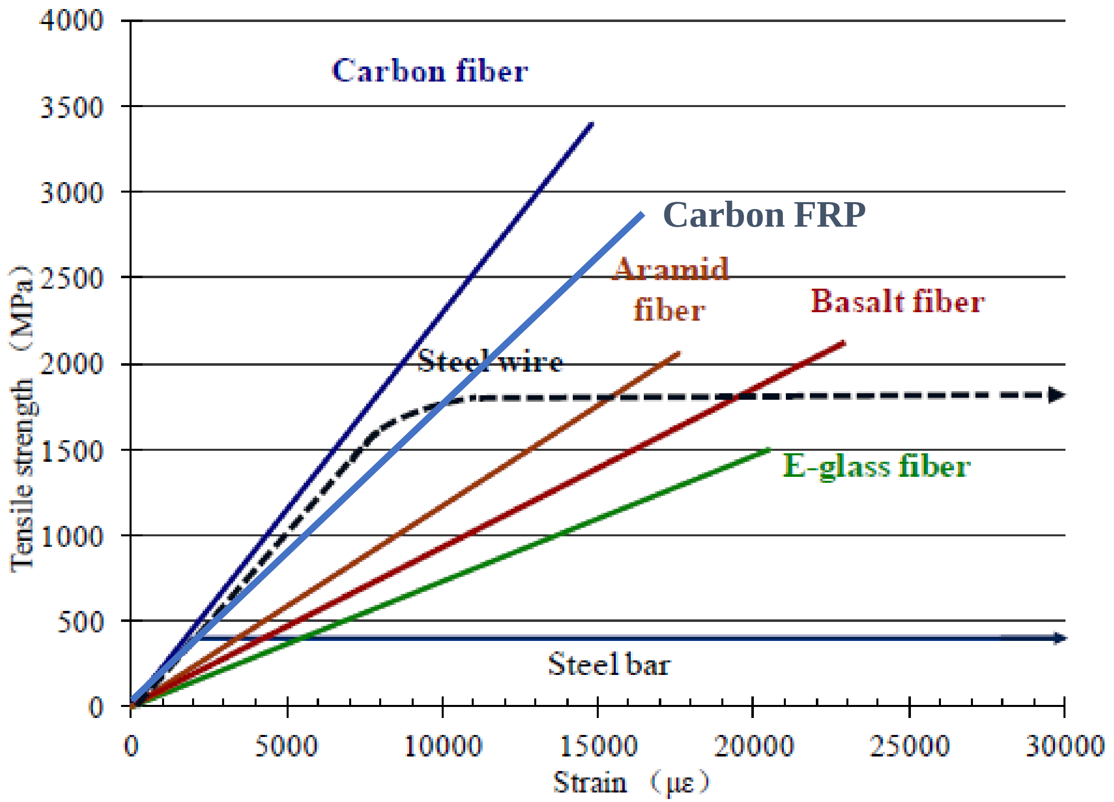
Fiber-Reinforced Polymer (FRP) composites have been successfully utilized for durable bridge applications for more **30+ years worldwide**, demonstrating their ability to provide reduced maintenance cost, extended service life, and significantly increase design durability.

FRP materials of most interest to FDOT (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 rock fiber with epoxy resin systems).*



Available Design Guidance & Tools

- **Mandatory (normative) Specifications**

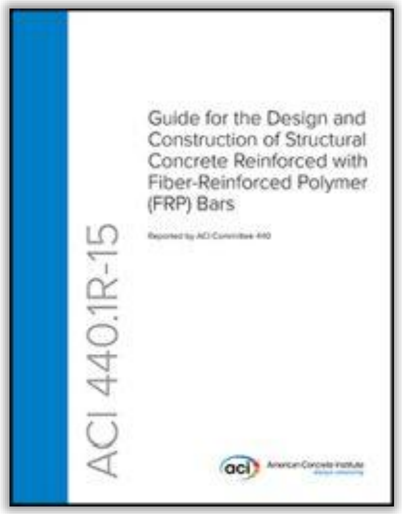
  - Currently there are mostly only Guide Design documents in the USA.

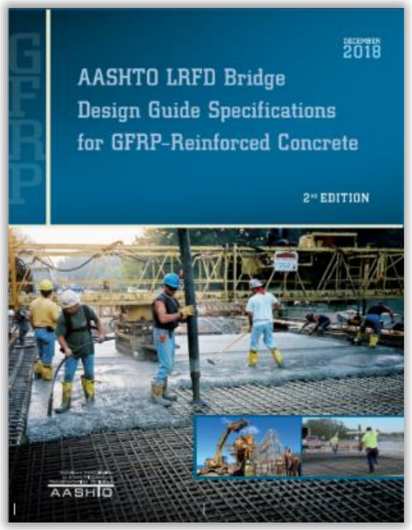
- **Uniform Approval Processes**

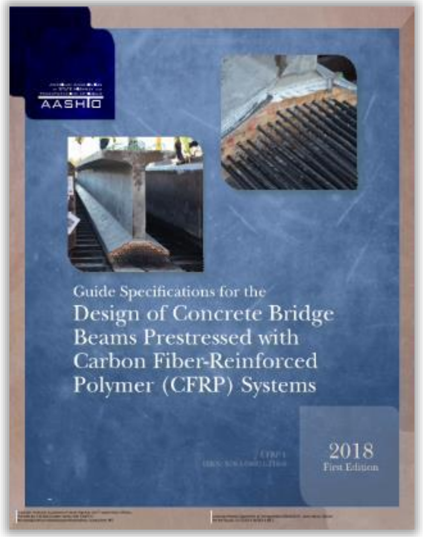
  - Manufacturer Approval vs Product Approval

- **Reliable Design Tools**

  - Commercial vs. Agency based design programs







Available Design Guidance & Tools

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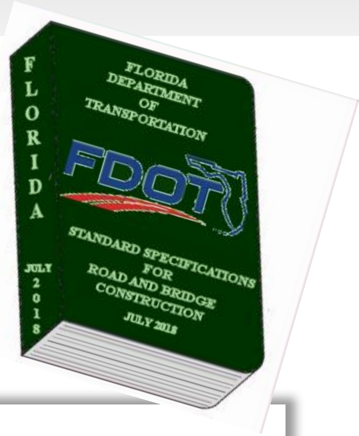
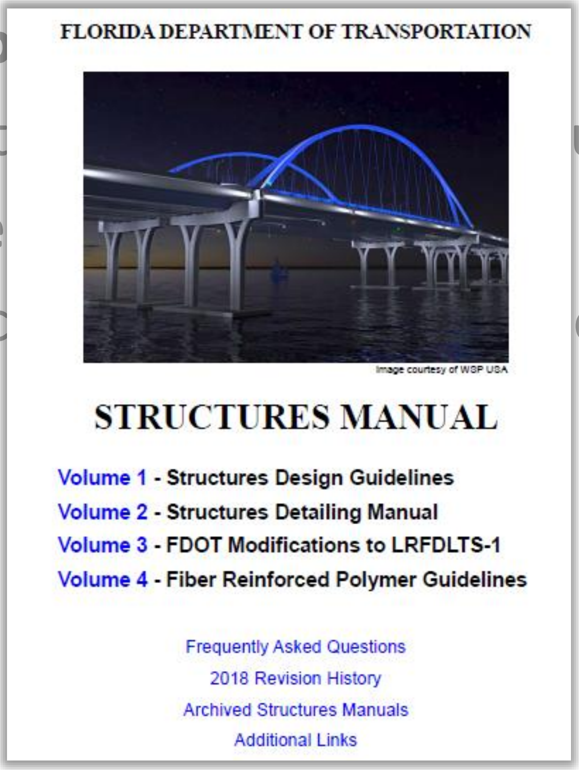
- **Mandatory Specifications needed**
  - Currently there are mostly only **Guide Design** docs in the USA



uct Approval



https://www.fdot.gov/structures/innovation/FRP.shtm

Available Design Guidance & Tools

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- **Uniform Approval Processes** *(National based systems preferred)*

  - Manufacturer Approval vs Product Approval

https://mac.fdot.gov/smoreports

MAC

FDOT

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Fiber Reinforced Polymer Production Facility Listing

ffice, 5007 N.E. 39th Avenue, G

FRP-02 OWENS CORNING (BLYTHEWOOD, SC)

Company: Owens Corning Infrastructure Solutions

Contact: John Amonett **Email:** john.amonett@owenscorning.com

Phone: (419) 819-9739 **Fax:**

Physical Address:

1051 Jenkins Brother
Blythewood, SC 2901

QC Plan Status:

#04 GFRP E
#05 GFRP E
#06 GFRP E
#07 GFRP E
#08 GFRP E

FRP-06 PULTRALL

Company: Pultrall Inc

Contact: ROXANNE FORTIER **Email:** roxanne.fortier@pultrall.com

Phone: (418) 335-3202 ext 231 **Fax:**

Physical Address:

700 9eme rue Nord
Thetford Mines

CANADA

QC Plan Status:

#03 GFRP
#04 GFRP
#05 GFRP
#06 GFRP
#08 GFRP

FRP-12 TUF-BAR INC (EDMONTON CANADA)

Company: Tuf-Bar Inc.

Contact: Nathan Sim **Email:** nathan@tuf-bar.com

Phone: (780) 448-9338 **Fax:**

Physical Address: **Mailing Address:**

5715-76 Avenue 5715-76 Avenue

CANADA CANADA

QC Plan Status: Quality Control Plan ACCEPTED 3/19/2019

#03 GFRP BAR	Glass Fiber Reinforced Polymer Reinforcing for Concrete, #3
#04 GFRP BAR	Glass Fiber Reinforced Polymer Reinforcing for Concrete, #4
#05 GFRP BAR	Glass Fiber Reinforced Polymer Reinforcing for Concrete, #5
#06 GFRP BAR	Glass Fiber Reinforced Polymer Reinforcing for Concrete, #6
#07 GFRP BAR	Glass Fiber Reinforced Polymer Reinforcing for Concrete, #7
#08 GFRP BAR	Glass Fiber Reinforced Polymer Reinforcing for Concrete, #8

FRP-07 PULTRON (DUBAI)

Company: Pultron Composites Ltd

Contact: Bogdan Patrascu **Email:** bogdan@pultron.com

Phone: (714) 880-9533 **Fax:**

Physical Address: **Mailing Address:**

S404 Street
Building 10 Jebel Ali Free Zone South

S404 Street
Building 10 Jebel Ali Free Zone South

UNITED ARAB EMIRATES

QC Plan Status: Quali

#04 GFRP BAR
#05 GFRP BAR
#06 GFRP BAR
#08 GFRP BAR

FRP-08 ATP

Company: ATP

Contact: Aniello Giamundo **Email:** a.giamundo@atp.sa.it

Phone: (811) 948-7131 **Fax:**

Physical Address: **Mailing Address:**

via Campa 34 via Campa 34

ITALY

QC Plan Status:

#03 GFRP B
#04 GFRP B
#05 GFRP B
#06 GFRP B
#08 GFRP B

FRP-14 TUF-BAR INC (ONTARIO CANADA)

Company: Tuf-Bar Inc.

Contact: Jay Christopher **Email:** jay@tufbarcanada.com

Phone: (519) 833-5050 **Fax:**

Physical Address: **Mailing Address:**

7 Erin Park Dr 7 Erin Park Dr

CANADA CANADA

QC Plan Status: Quality Control Plan ACCEPTED 12/11/2017

Available Design Guidance & Tools

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- **Accessible & Reliable Design Tools**

  - Commercial vs. Agency/Institution based design programs

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Box Culvert v4.0 *GFRP-RC in development !*	11/07/2018	Exe (Zip) (Mathcad 15)	Used with FDOT Standard Plan Index 400-289 (formerly Index 289) to design concrete box culverts, wingwalls, headwalls, and cutoff walls in accordance with the AASHTO LRFD Bridge Design Specification.
Prestressed Beam v5.2 *CFRP-PC Beta version ***	11/07/2018	Exe (Zip) (Mathcad 15)	Used with FDOT Standard Plan Index 450-010 to 450-299 (formerly Index 20010 to 20299) to design simple span prestressed beams (Florida-I, AASHTO, Florida Bulb-T, Florida-U, Florida Double-T, Flat Slab, Inverted-T, FSB) in accordance with the AASHTO LRFD Bridge Design Specification.
Bent Cap v1.0 *GFRP-RC included (3b)*	11/07/2018	Exe (Zip) (Mathcad 15)	Analyzes and designs fixed or pinned bent caps, including lateral loads, in accordance with the AASHTO LRFD Bridge Design Specifications.
Retaining Wall v3.3 *GFRP-RC Alpha version ***	11/07/2018	Exe (Zip) (Mathcad 15)	Used with FDOT Standard Plan Index 400-010 (formerly Index 6010) to design and analyze cast-in-place retaining walls in accordance with the AASHTO LRFD Bridge Design Specification.

https://www.fdot.gov/structures/proglib.shtm

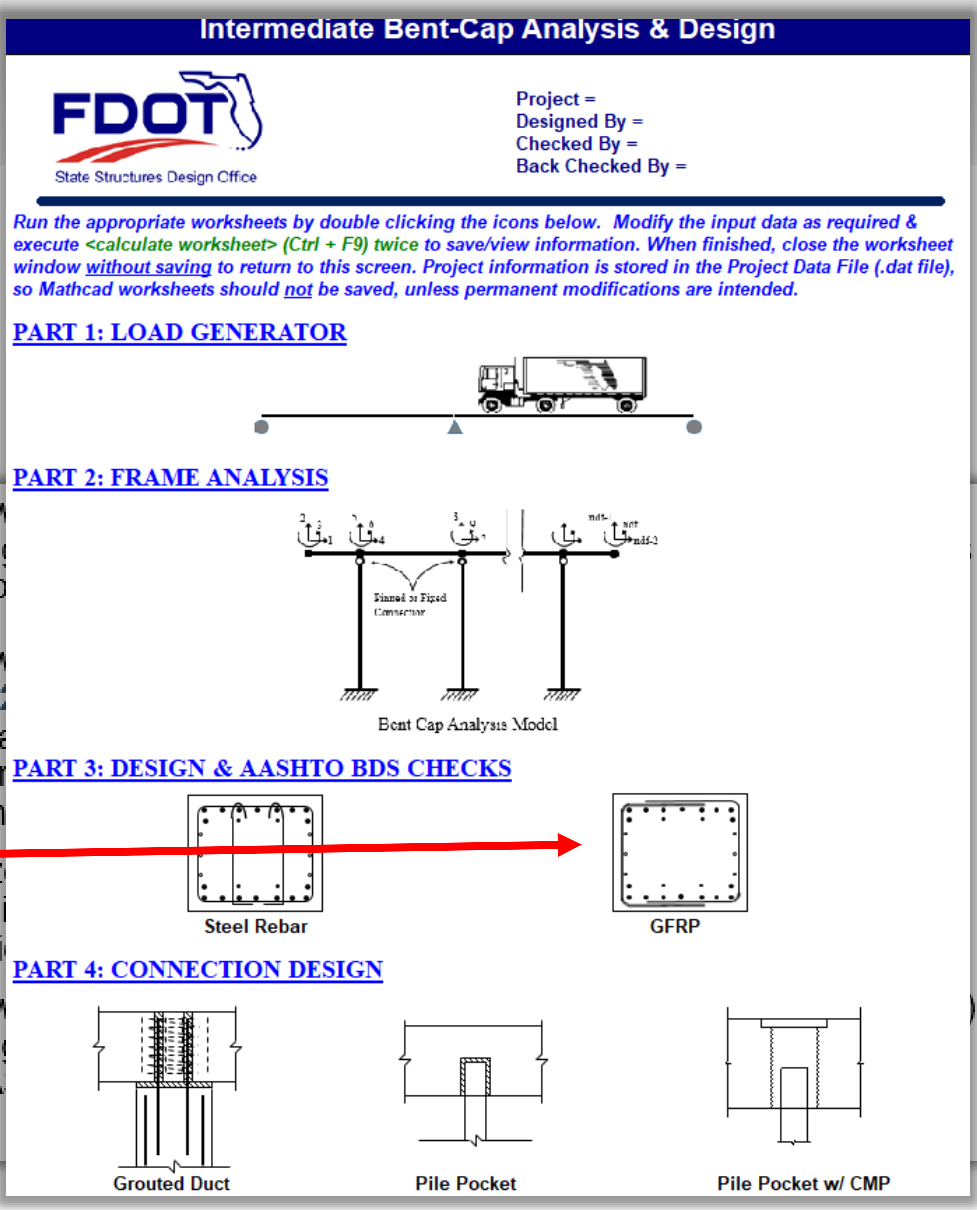
*** Available on request*

Typical GFRP-RC Tools

Projects using Pile-Bent Cap Design Tool:

- 40th Ave NE over Placido Bayou
- Halls River Bridge **
- NE 23rd Ave over Ibis Waterway
- SR-5 (US 41) over North Creek

Box Culvert v4.0	11/07/2018	Exe (Zip) (Mathcad 15)	Used w to desi in acco
Prestressed Beam v5.2	11/07/2018	Exe (Zip) (Mathcad 15)	Used w **Index** (Florida Slab, I Design
Bent Cap v1.0	11/07/2018	Exe (Zip) (Mathcad 15)	Analyz loads, Specifi
Retaining Wall v3.3	11/07/2018	Exe (Zip) (Mathcad 15)	Used w to desi the AA



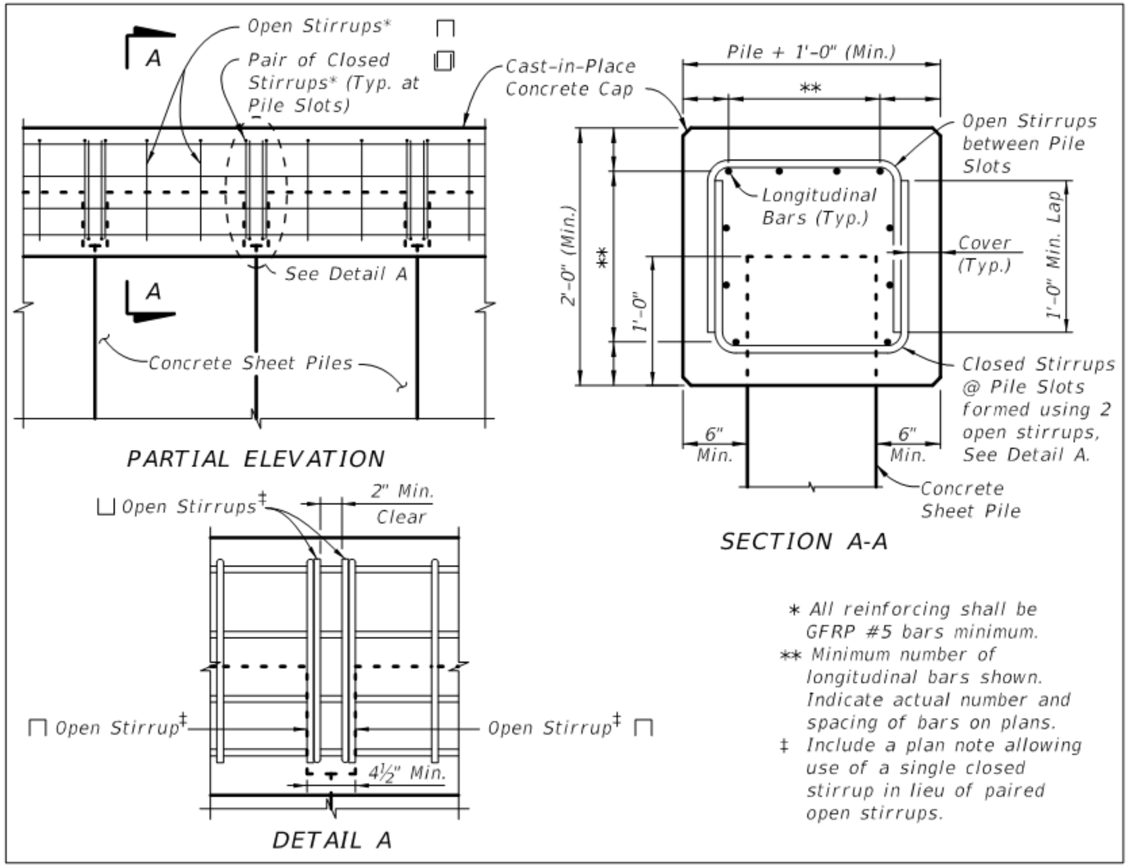
Typical GFRP-RC Applications and Details

Projects using Bulkhead Cap standards:

- Bakers Haulover Cut Bulkhead Replacement **
- Halls River Bridge **
- NE 23rd Ave over Ibis Waterway
- SR-5 (US 41) over North Creek
- SR-30 over St Joe Inlet
- SR-520 over Indian River Bulkhead Rehab
- Sunshine Skyway Seawall Rehabilitation

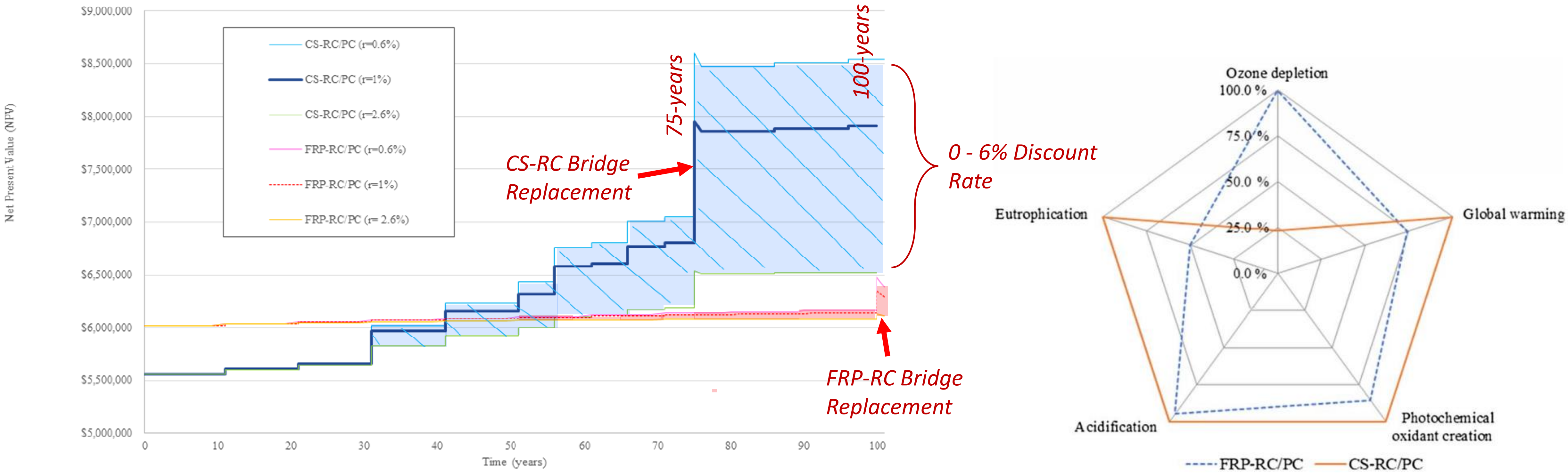
Standard Plans Instructions | Topic No. 625-010-003
Index 455-440 Precast Concrete Sheet Pile Wall (CFRP/GFRP & HSSS/GFRP) | FY 2020-21

Figure 1 Typical Cap Details



Cost Justification (Service Life, LCC, etc.)

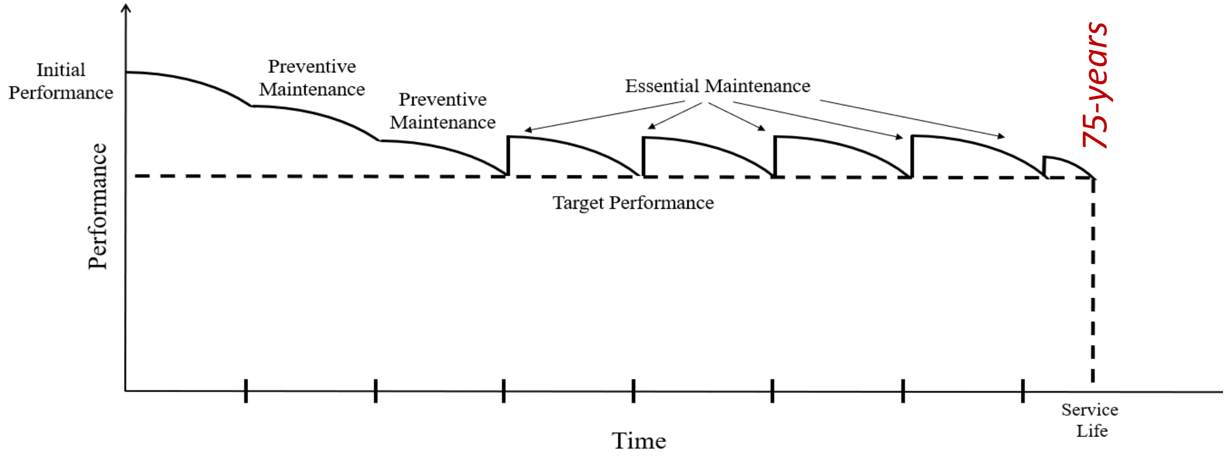
- LCC & LCA also can show the sustainable (economic and environmental) advantage of composite structures in the coastal environment:

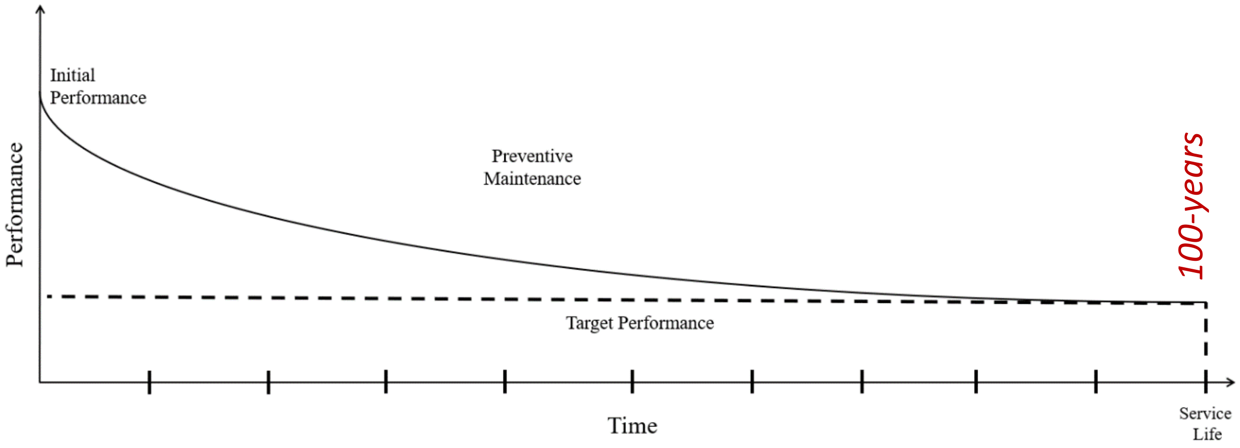


Example LCC & LCA Comparison of Carbon Steel-RC/PC verses FRP-RC/PC bridge *(0.6% Effective Discount Rate),* adapted from Cadenazzi et al. 2019.

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

***Graphs**: 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.*

Cost Justification (Service Life, LCC, etc.) - Younis et al., 2018

INDURA Auvergne-Rhône-Alpes

"Life cycle cost analysis of structural concrete using seawater, recycled concrete aggregate, and GFRP reinforcement", https://doi.org/10.1016/j.conbuildmat.2018.04.183

(Baseline scenario with discount rate = 0.7%)

Table 4
Summary of LCCA results.

Design alternative	Present costs ($/m^2)					LCC ($/m^2)
	Material	Construction	Repair	Reconstruction	End-of-life	
RC1	90	135	183.9	230.7	50.8	690.4
RC2	389	135	24.6	–	37.3	585.9
RC3	174	108	–	–	54.3	336.3

RC1 = Traditional concrete mix with carbon-(black) steel rebar;
RC2 = Traditional concrete mix with SS rebar;
RC3 = Concrete with seawater & RCA with GFRP rebar.

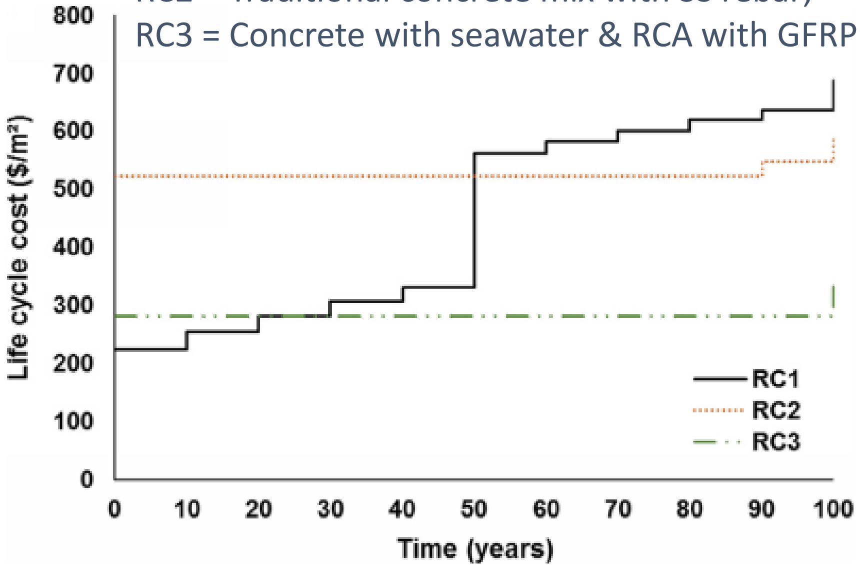


Fig. 5. Life cycle cost results (considering the baseline scenario where r = 0.7% and C = 150% of M).

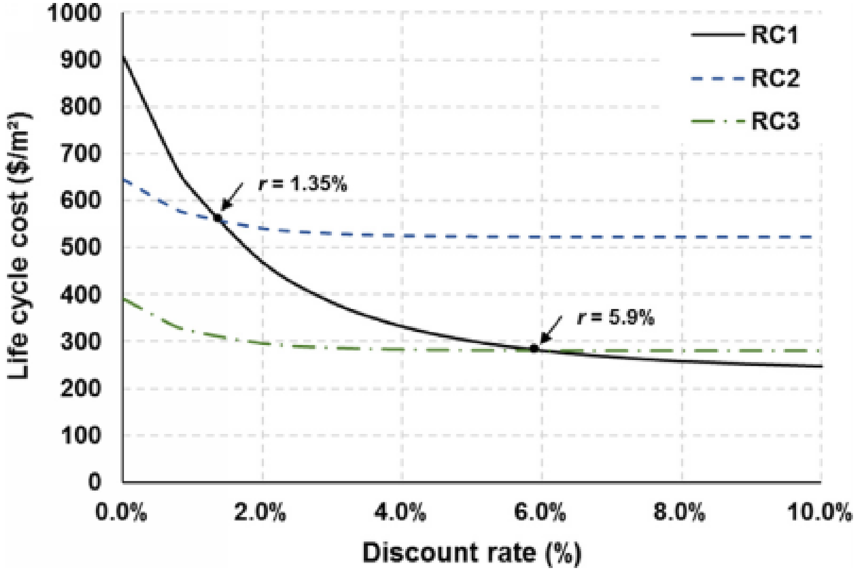


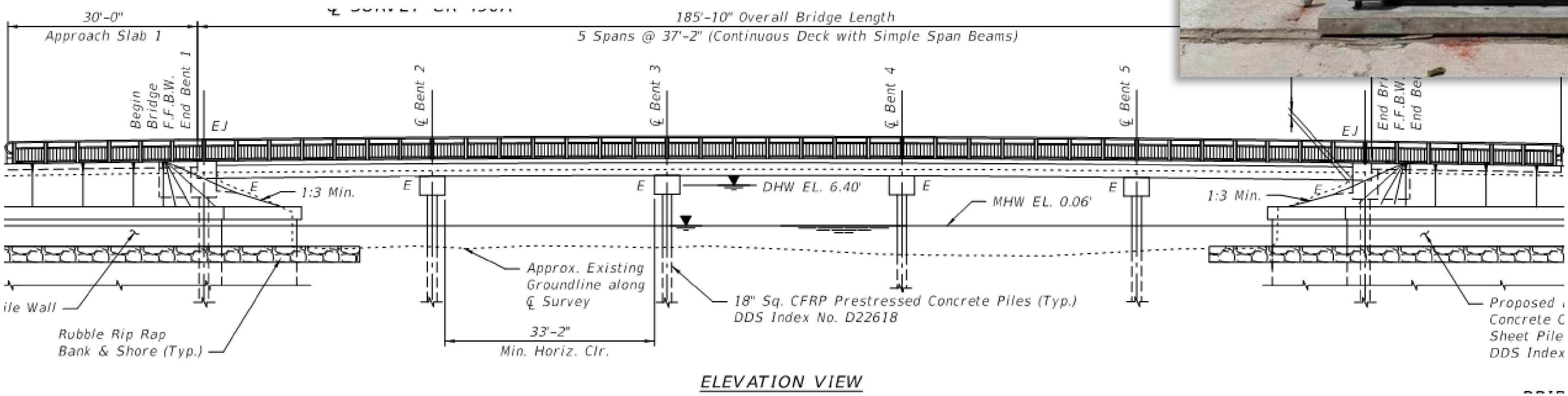
Fig. 6. Sensitivity of LCC results to the discount rate (while C is fixed at 1.5M).

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

- Connections (post-installed anchors – ***ACI 318*** *Chapter 17/****ACI 355.4***)
- Fatigue limits
- Importance of Elastic Modulus
- Bent Bars
- Scalability of production

1700+ Dowel Holes

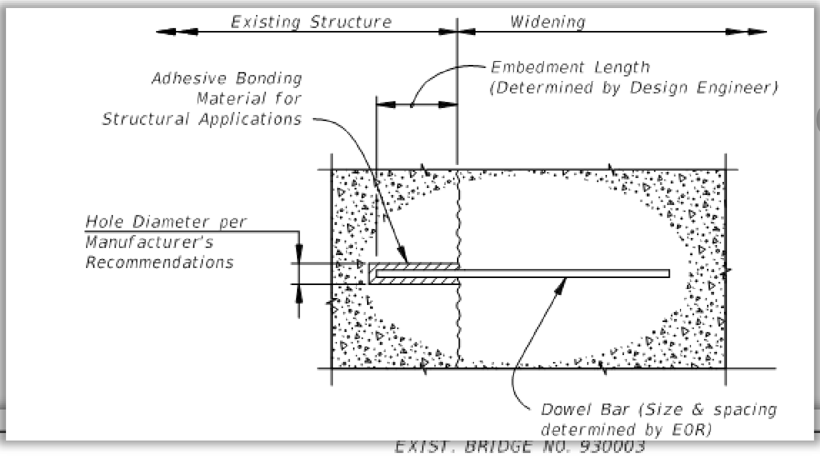
Halls River Bridge - Traffic Railing Retrofit:

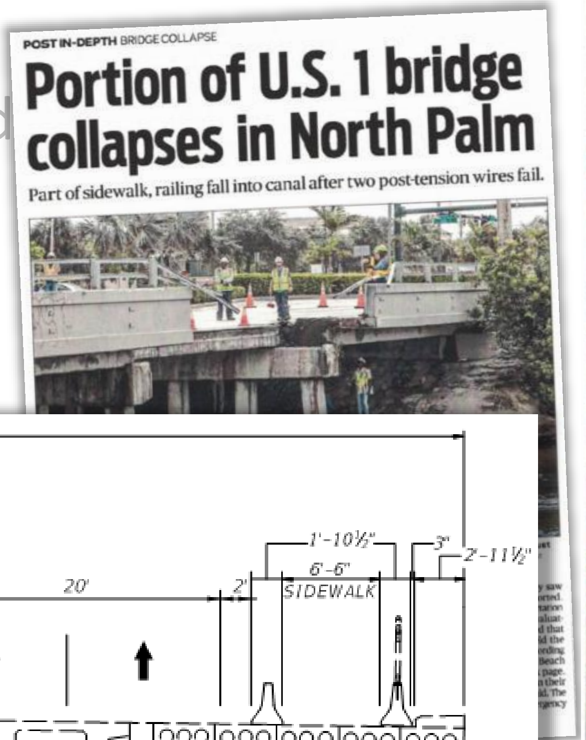


What do we still need? (gaps in design and deployment)

INDURA Auvergne-Rhône-Alpes

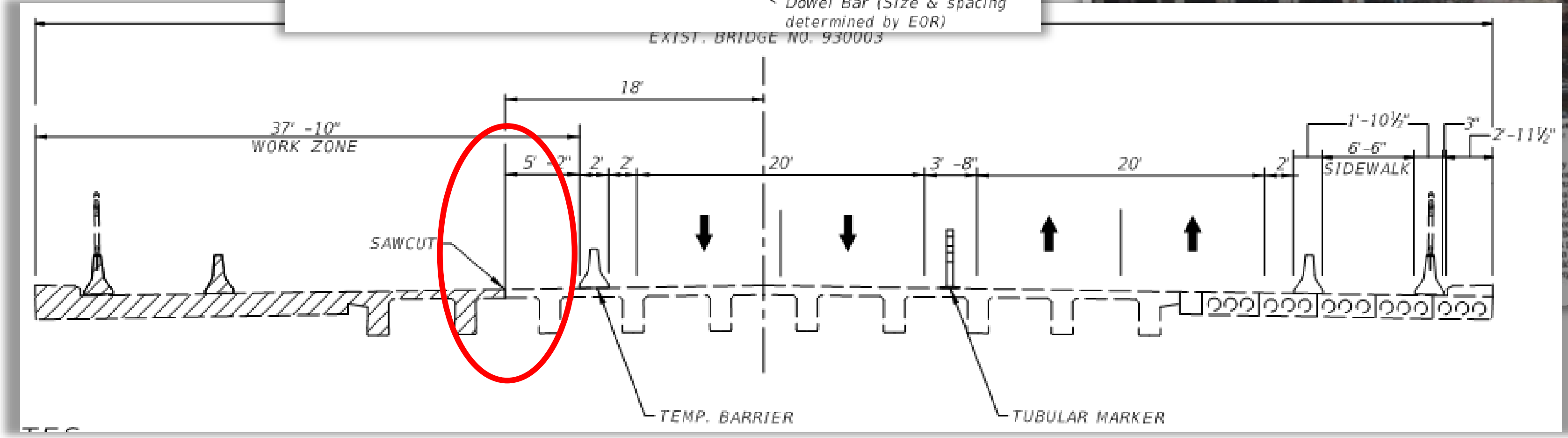
- Connections (post-installed dowels bars – ***ACI 318*** *Chapter 17*/***ACI 355.4***))




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.

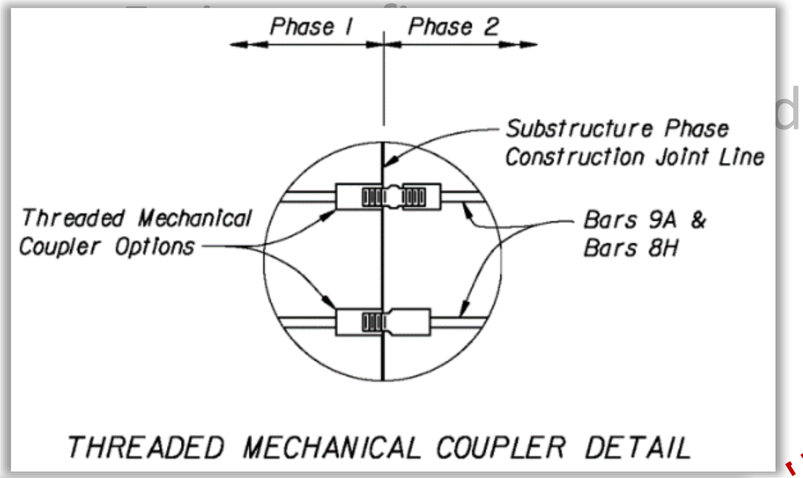


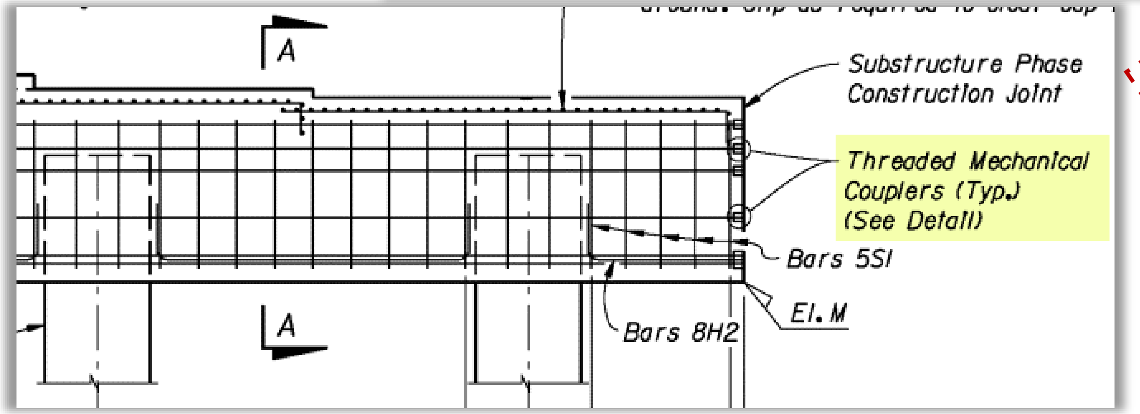
[Lat. 26.8080459, Long.-80.055929]

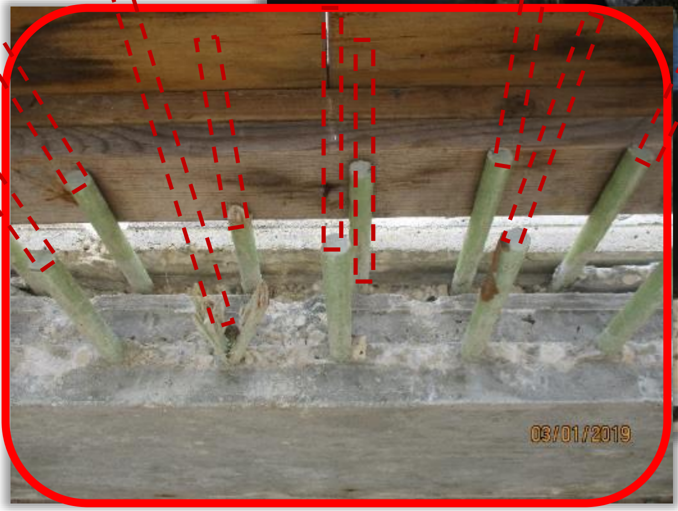
What do we still need? (gaps in design and deployment)

INDURA Auvergne-Rhône-Alpes

- Connections (mechanical couplers)





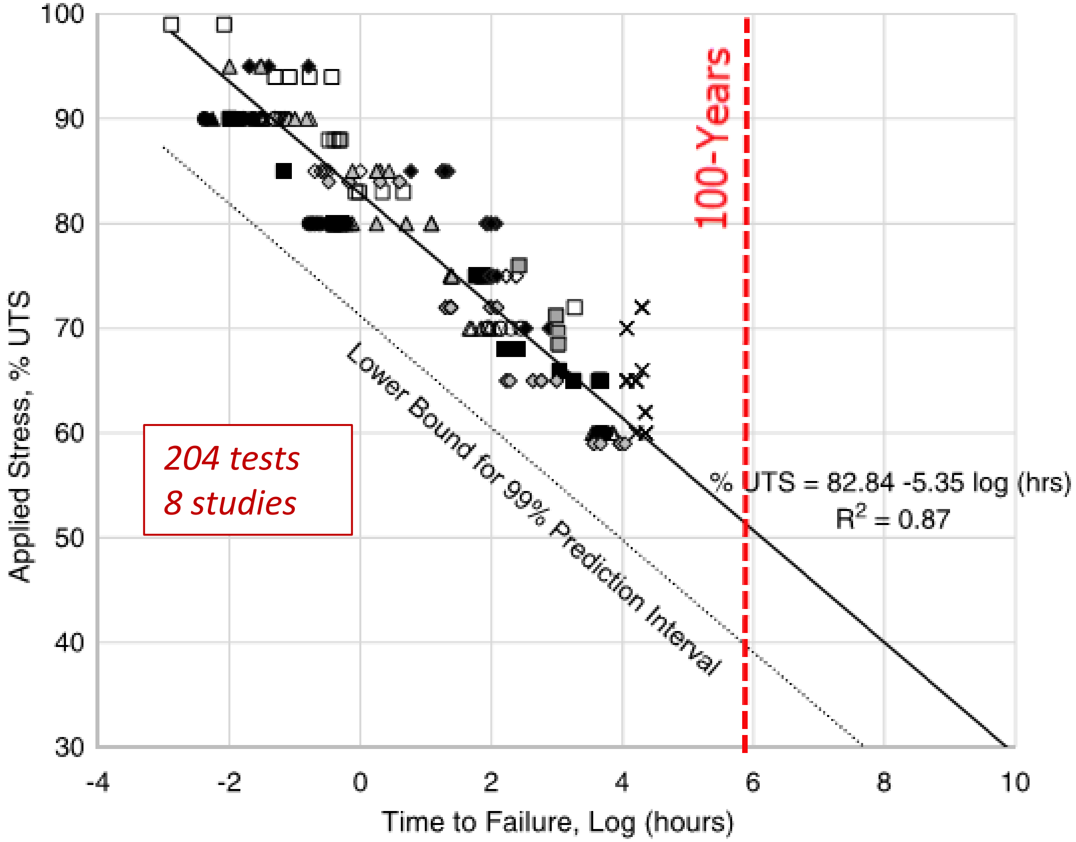


What do we still need? (gaps in design and deployment)

INDURA
Auvergne-Rhône-Alpes

- Connections (coupling, post-installed)
- Fatigue limits - refinement
- Importance of Elastic Modulus
- Bent Bars
- Scalability of production

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.



DOI: 10.1061/(ASCE)CC.1943-5614.0000971.

From: "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)
- Fatigue limits
- Importance of Elastic Modulus
- Bent Bars (thermo-set/plastic)
- Scalability of production

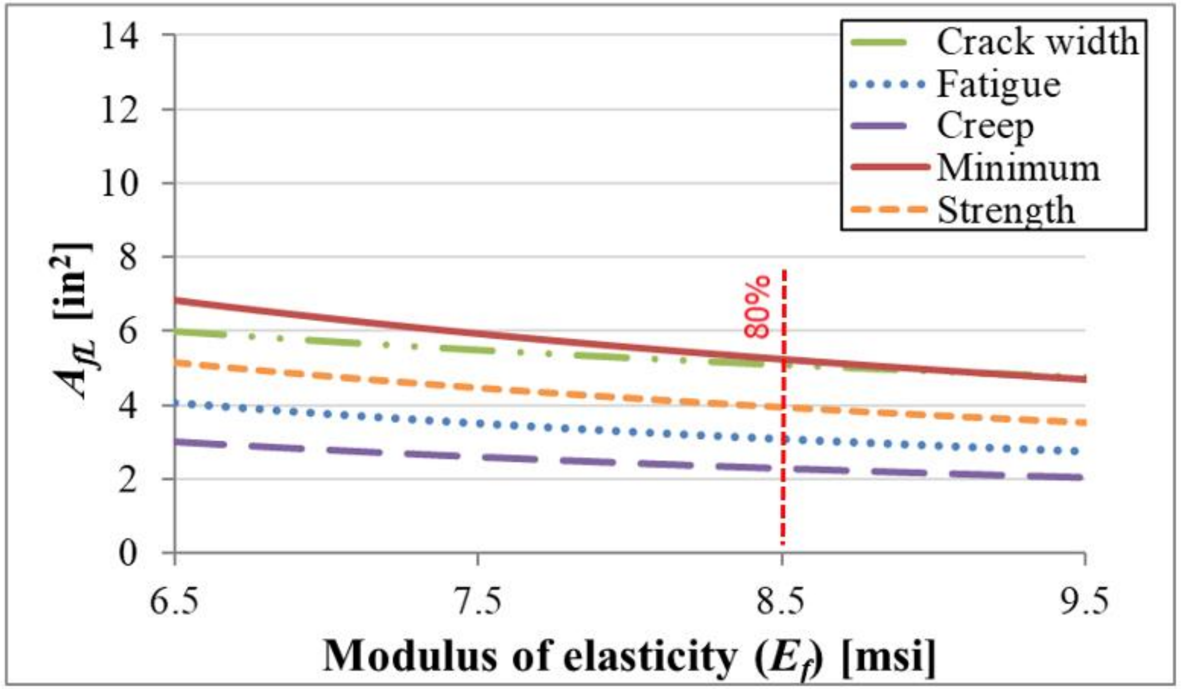


Figure: Parametric analysis of flexural design algorithms per AASHTO GFRP-RC 2nd edition for HRB Bent Cap

From: 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)

Project Examples – Fast Facts Sheets

INDURA
Auvergne-Rhône-Alpes

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.

FDOT

$741,630.00 (Construction Contract)

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

Kisinger Campo & Associates Corp.
Pneumatic Concrete Co, Inc.
JEA Construction Engineering Services
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Kisinger Campo & Associates Corp.
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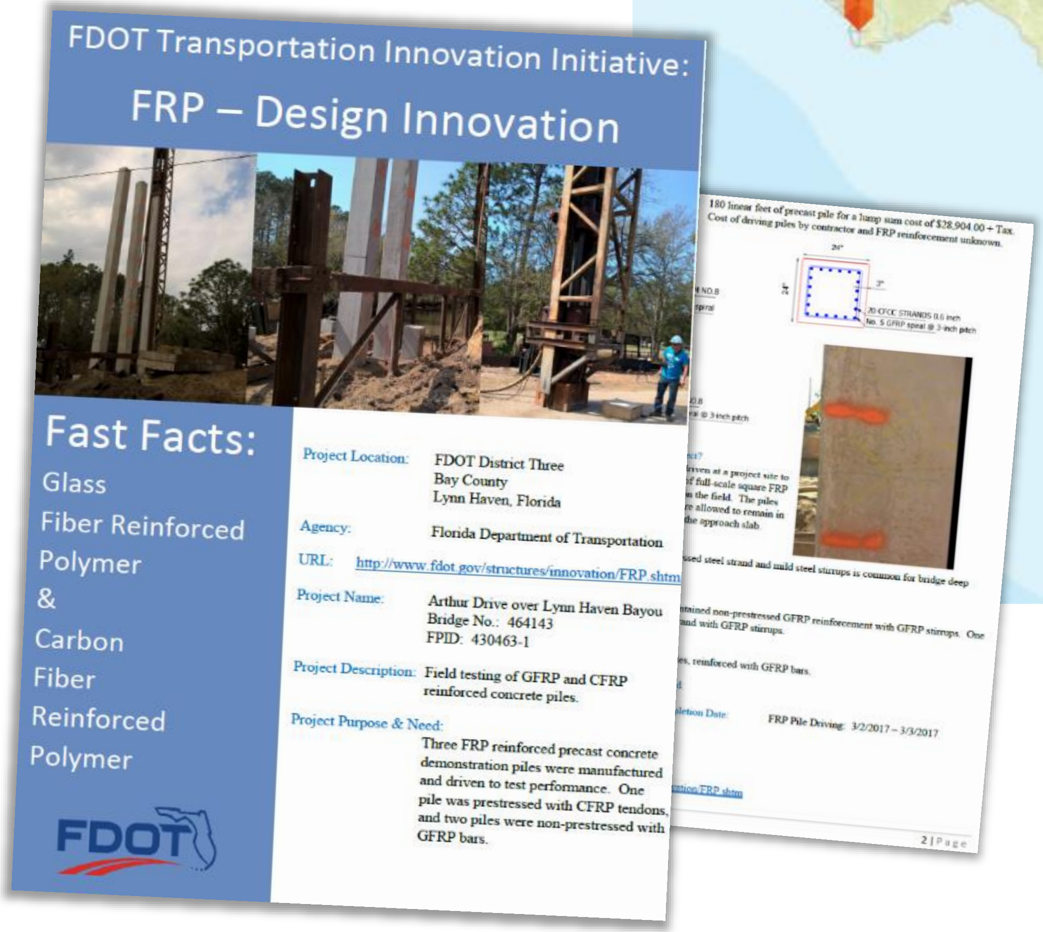

FDOT Transportation Innovation Initiative:

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.

FDOT

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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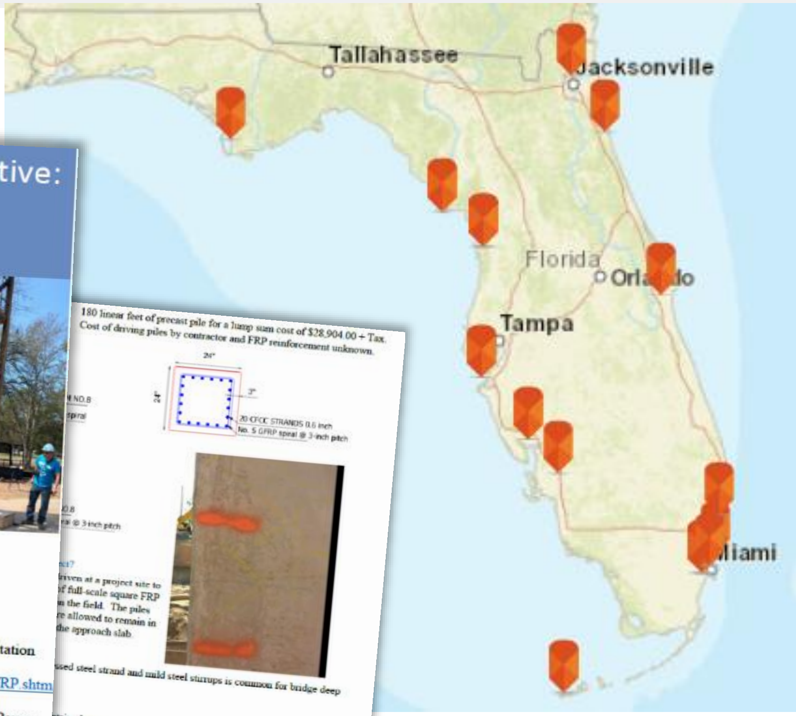

Fast-Facts: https://www.fdot.gov/structures/innovation/FRP.shtm#link9

Project Examples - Port Miami Tunnel Entrance Walls

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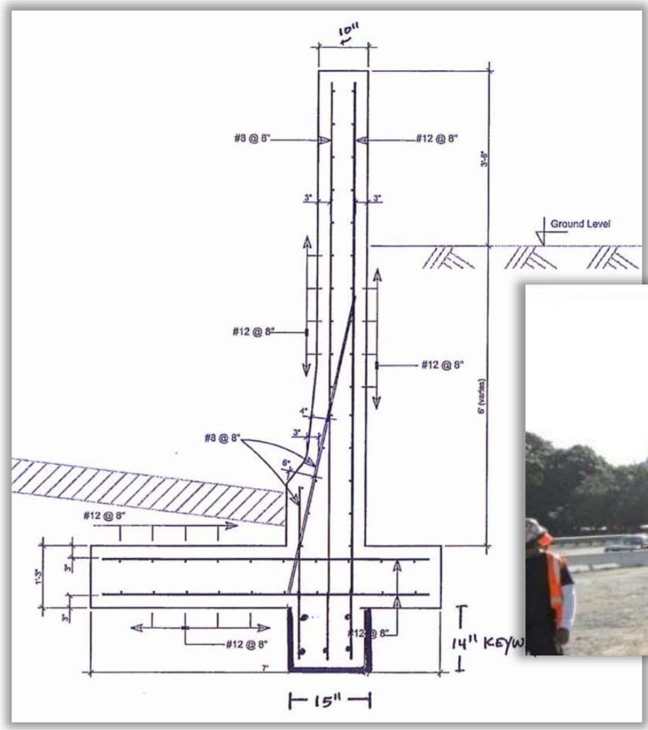
Watson Island, Miami – 2014



Wall 6 under construction & Typical Cross-section of Retaining Walls 5 and 6

[Port Miami Tunnel](#)

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

Project Examples - Innovation Pedestrian Bridge

University of Miami – 2016

Elevation view of Innovation Bridge with FRP reinforcement in the auger-cast-piles, bent-caps, double-tee stems and flanges, deck overlay and curbs.

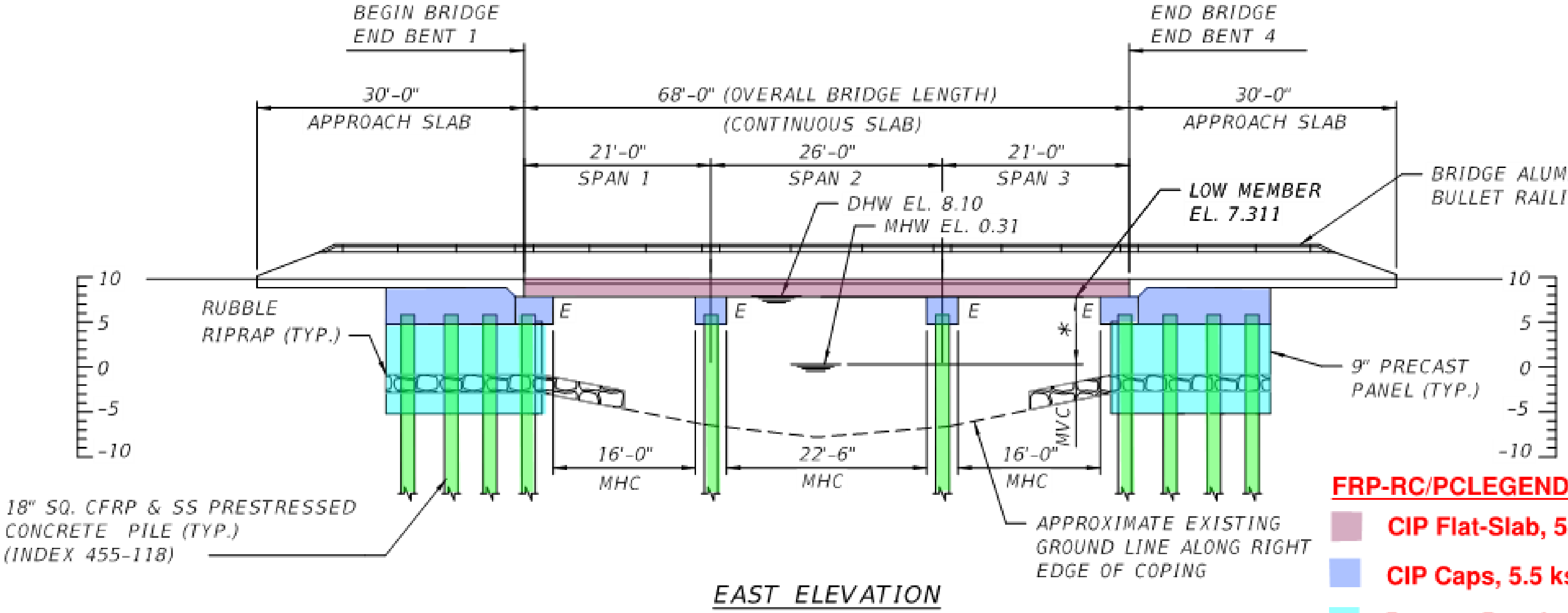
[Innovation Bridge]

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

Project Examples - NE 23rd Ave/Ibis Waterway

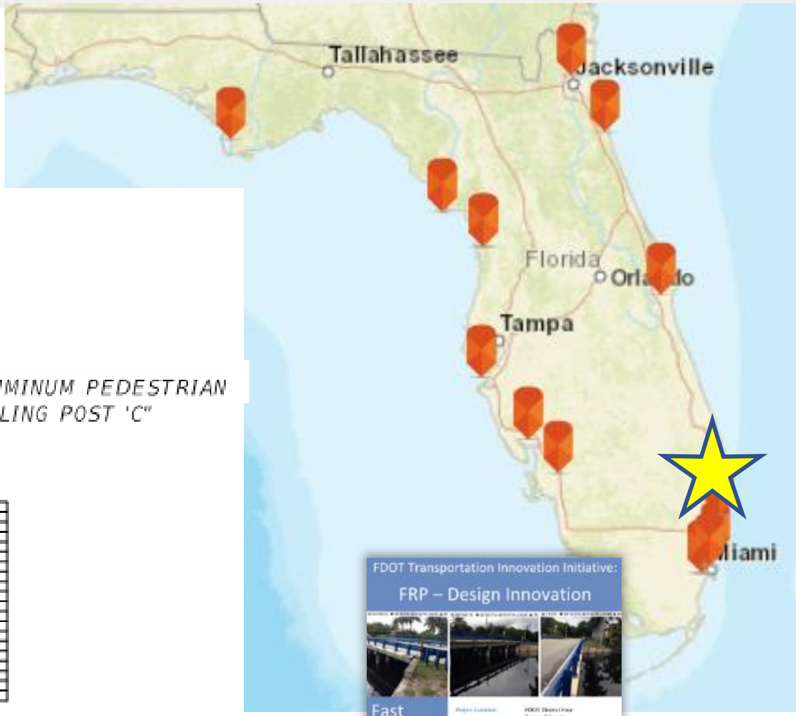
INDURA Auvergne-Rhône-Alpes

CIP continuous flat-slab bridge:



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)



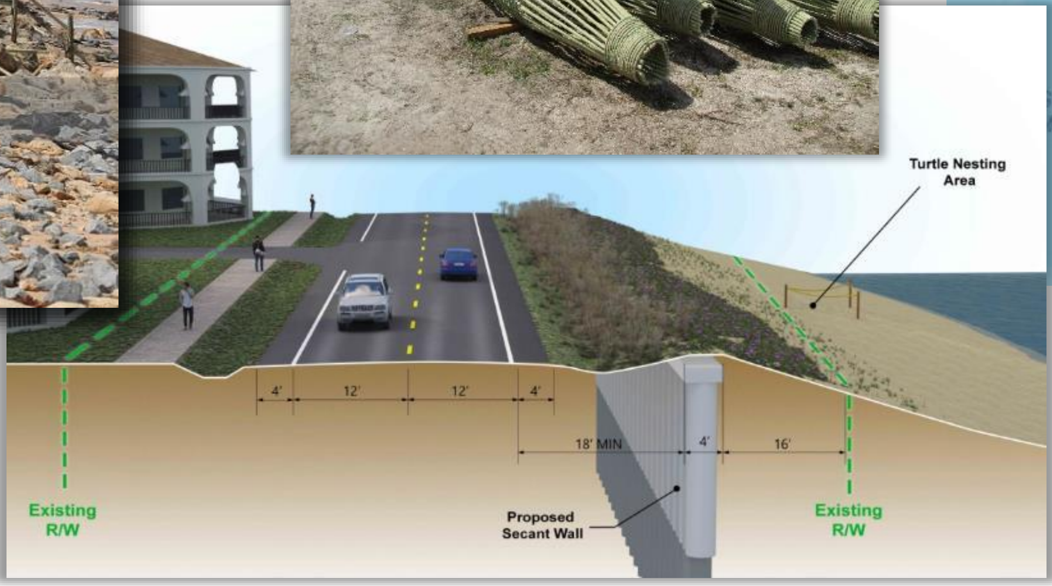
NE 23rd Ave/Ibis Waterway

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

Project Examples - SR-A1A Secant-Pile Seawall

INDURA Auvergne-Rhône-Alpes

Auger-Cast Pile GFRP-RC Secant Wall



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

SR-A1A Flagler Beach Seawall

Project Examples - Halls River Bridge

Homosassa, FL 2017-19 (GFRP-RC & CFRP-PC)

Five-span vehicular bridge

Halls River Bridge

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

Project Examples - Halls River Bridge

INDURA
Auvergne-Rhône-Alpes

Homosassa, FL 2017-2019 (GFRP-RC & CFRP-PC)
Five-span vehicular bridge entirely constructed using corrosion-resistant solutions and mostly FRP reinforcement including:

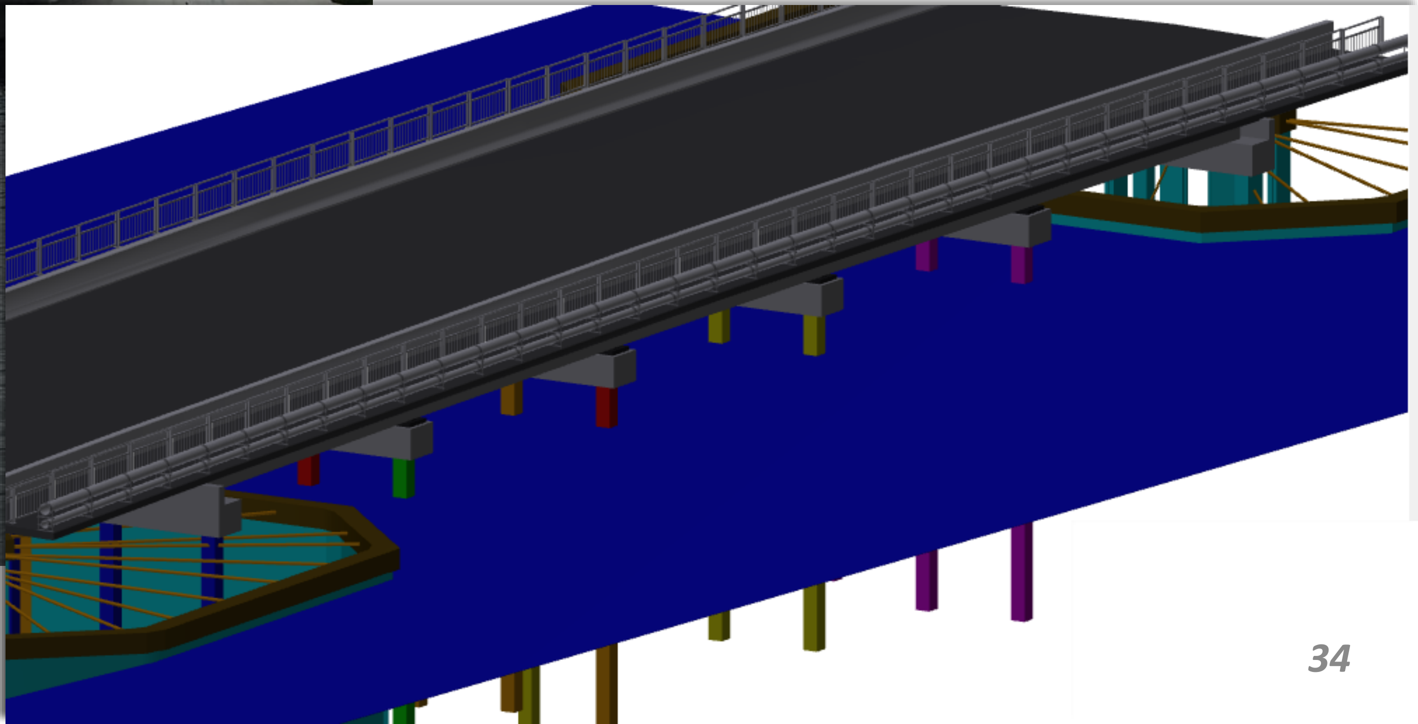
- CFRP-PC bearing piles;
- CFRP-PC/GFRP-RC sheet piles;
- Hybrid HSCS-PC/GFRP-RC sheet piles;
- GFRP-RC bulkhead caps;
- GFRP-RC pile bent caps;
- GFRP-RC bridge deck
- GFRP-RC traffic railings
- GFRP-RC approach slabs
- GFRP-RC gravity wall.

HRB GFRP-RC Bent Cap (2017)


HRB GFRP-RC Deck Casting (2018)

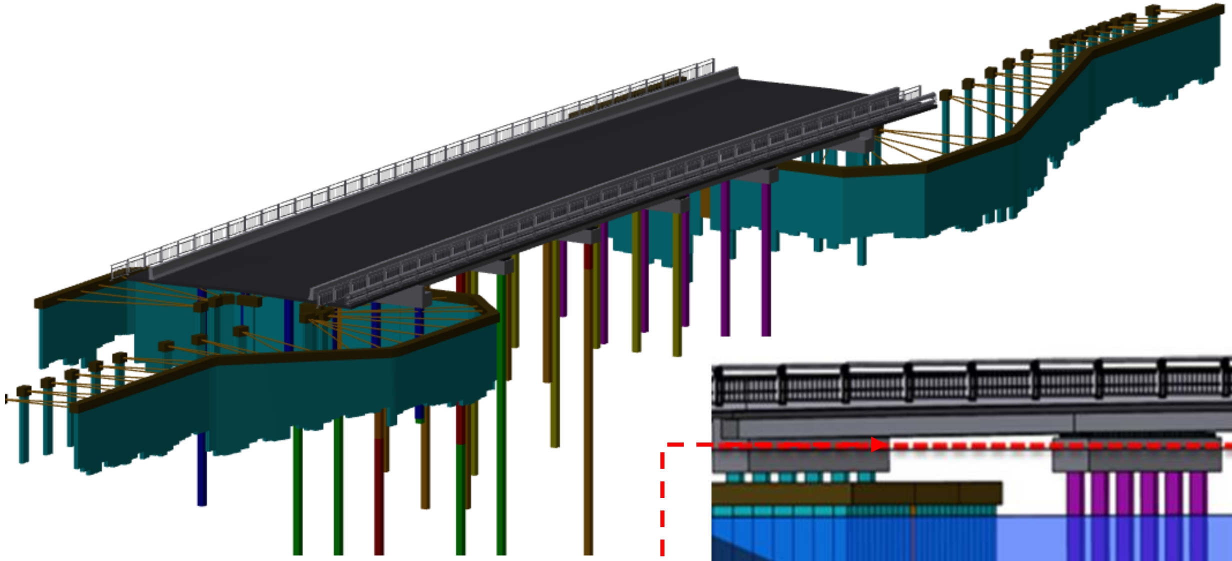
Project Examples - Halls River Bridge

- Halls River Bridge – demonstrating **Durability** thru **FRP materials…**

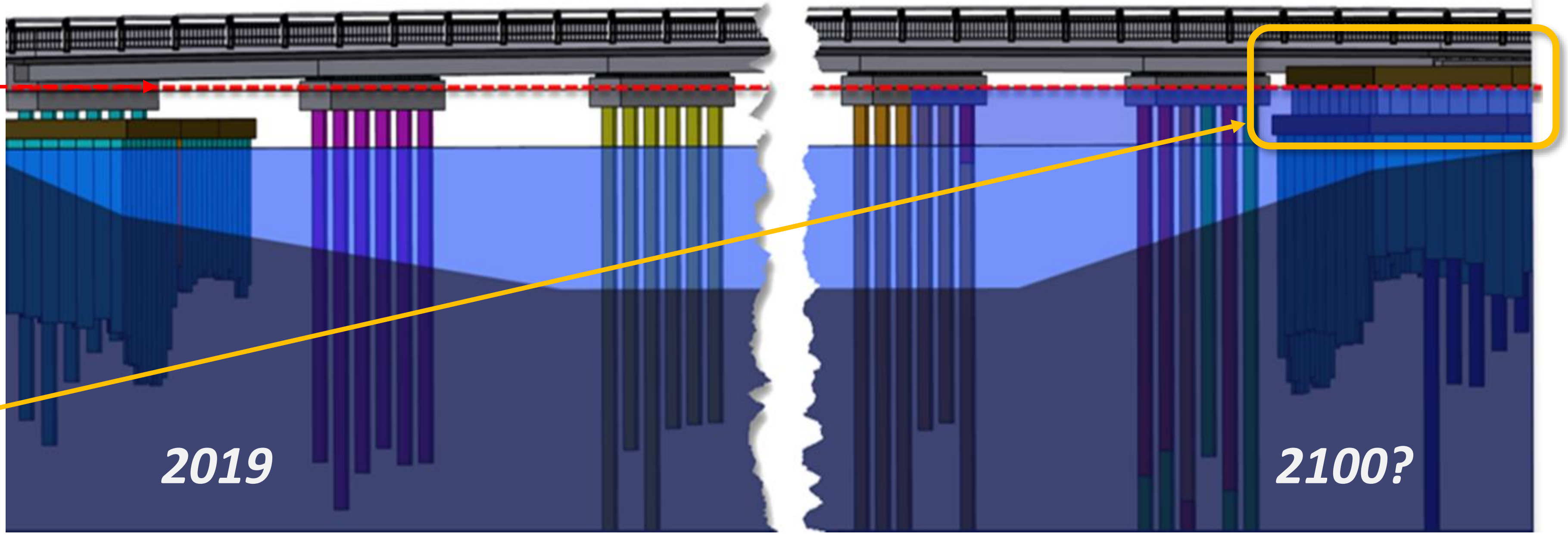


Project Examples - Halls River Bridge

- Halls River Bridge - modelling **Resiliency** thru potential for **Adaption!**



Showing the effect of a 1.8 m (6-ft) RSL



- *Shows current MHW (blue) and 1.8 m projected RSL (dashed redline)*
- *with possible **Adaption Strategy** using 1.5 m raised bulkhead (right-side).*

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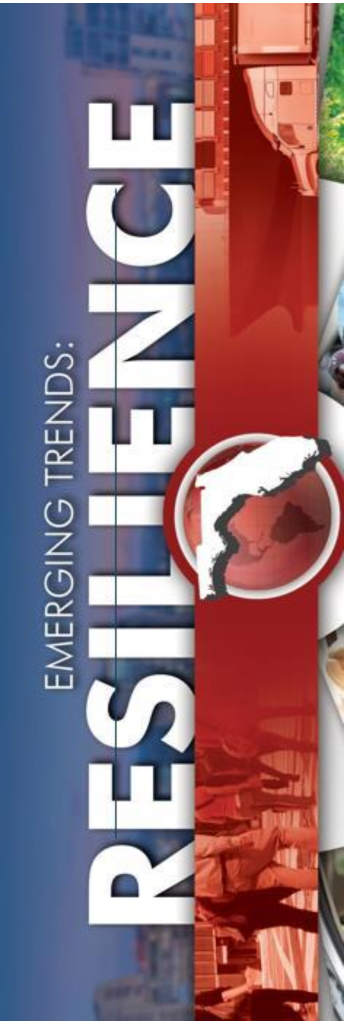

- Florida is the 3rd most populated U.S. state, and our population is expected to increase nearly 30% to 27 million by 2045. To plan for a resilient transportation future, we need to understand important trends and conditions today.
- Florida is the 14th largest economy on the planet (Florida Senate President - Bill Galvano)

What Natural Hazards Impact Our Transportation System?

Nearly **1T0 COASTAL COMMUNITIES** in the U.S. are projected to experience **FLOODING** more than **26 TIMES PER YEAR** by **2035**

In **2018**, **GLOBAL MEAN SEA LEVEL** was **3.2 INCHES ABOVE** the **1993** average

Since 2000, **TIDAL FLOODING** across Florida has **INCREASED BY 352%**

Florida is among the **TOP 10 STATES MOST IMPACTED BY WILDFIRES**

What Types Of Extreme Weather Can Aflect The Mobility Of Floridians?

The amount of **PRECIPITATION** during heavy rainstorms has **INCREASED BY 2T%** in the Southeast over the last **60 years**

By mid-century, the Southeast is expected to experience up to **50 MORE DAYS** per year of temperatures exceeding **90 DEGREES**

Florida has been impacted by **40% OF ALL U.S. HURRICANES**

Approximately **6 MILLION PEOPLE EVACUATED** during Hurricane Irma, **THE LARGEST EVACUATION IN U.S. HISTORY**

Des Questions?

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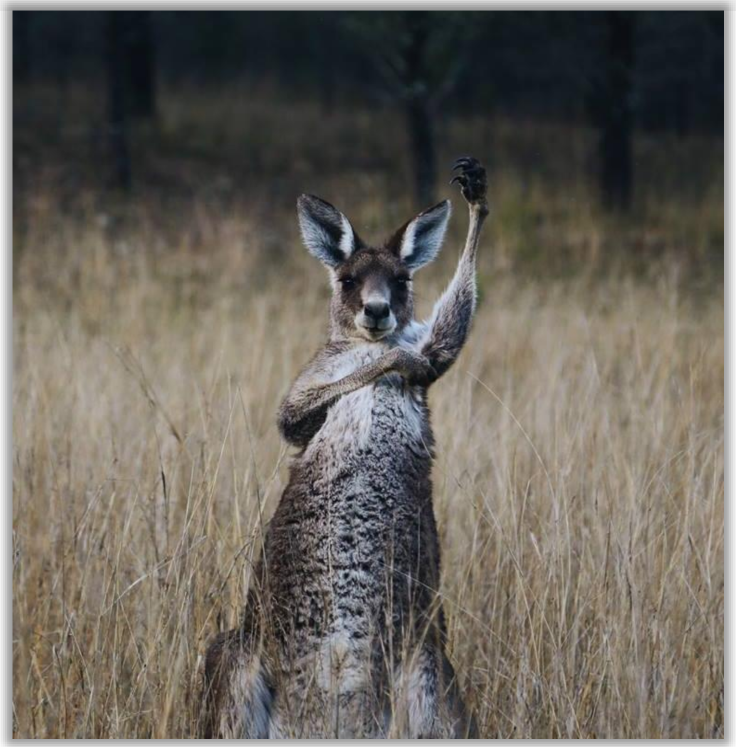
Auvergne-Rhône-Alpes



PHOTOGRAPHER:
CHRIS STEPONAITIS

HALLS RIVER ROAD BRIDGE, HOMOSASSA, FLA.

Submitted by Allan Fadullon, Astaldi Construction

Returning to work after a long weekend last spring, Astaldi's crane operator saw an osprey, a state-protected species, repeatedly landing on the tip of his crane. Astaldi hired Aerial Drone Services by TAS to investigate and document what was going on. "We had to determine whether there was an osprey in a nest with eggs—without disturbing the bird," says drone operator Steponaitis. "We knew this was going to be touchy; we didn't have time to sit around and observe. We did what we had to do and we were out of there." Astaldi shut down work on one end of the bridge and, over the next two weeks, lined up a nest-relocation expert and built a platform for the purpose, but on the day of the move, a hawk ate the egg. Astaldi's lessons learned: Put a flag and a beacon on the tip of the crane and lower the boom over weekends. The delay was covered in the contract, which was extended 19 days.

enr.com January 8/15, 2018 ▪ ENR ▪ 41

FRP Design Contact:

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