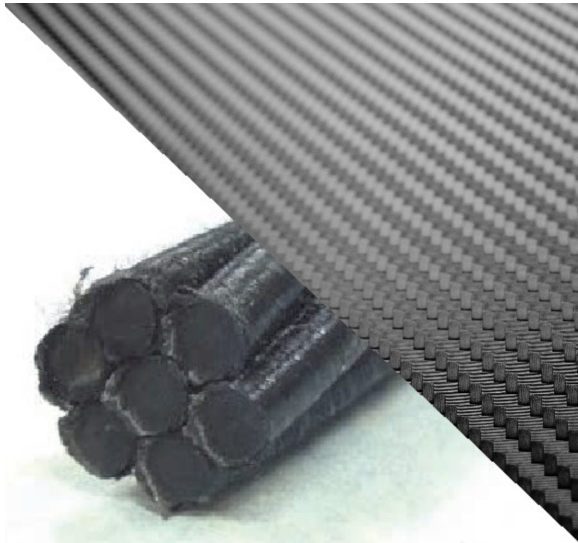
2021 TRB ANNUAL MEETING
Transportation Research Board

100TH Annual Meeting
A Virtual Event
January 2021

Structural Advanced Materials Implementation in Florida's Concrete Bridges

Presenter: Steven Nolan, P.E. (FDOT State Structures Design Office)

Jan. 12 10:00 AM - 1:00 PM EST



Structural Advanced Materials Implementation in Florida's Concrete Bridges

1. **Introduction of current needs in bridge durability & structural advancement**
2. **UHPC: CIP Connections, Precast/Prestressed members**
3. **HSSS-PC: Prestressed Beams & Piles in EAE**
4. **CFRP-PC: Prestressed Beams & Piles in EAE**
5. **FRP-RC: CIP & Precast Elements, Auxiliary Reinforcing**
6. **Managing Implementation Challenges and LCC strategies**

1.

Introduction of current needs in bridge durability & structural advancement.

- **Durability** needs – low-maintenance, extended service-life, cost-effective solutions.
- **Structural** needs – Inspectable, repairable, robust, extended span lengths (light-weighting and/or high-strength & high-endurance)
  - UHPC
  - HSSS-Prestressed Concrete
  - CFRP-Prestressed Concrete
  - FRP-Reinforced Concrete *(using Glass & Basalt rebar)*
  - Light-weight Concrete & Fiber-Reinforced *(not discussed today)*

2.

UHPC Design guidance & standards documents

Design Guidance, Specs, and Design tools

- Mid-2021 implementation
- Interim Guidance webpage for **Design Innovation**

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)

Structures Design

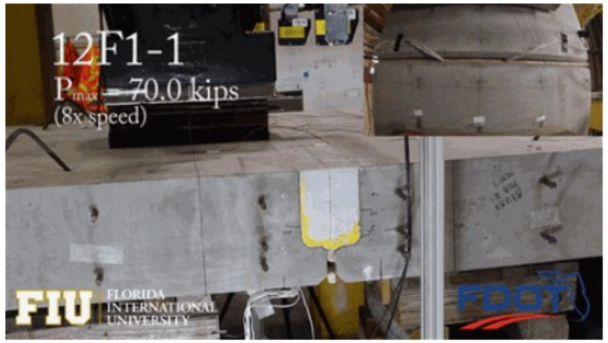
https://www.fdot.gov/structures/innovation/uhpc.shtm

Structures Design / Design Innovation

Ultra-High Performance Concrete

Structures Design - Transportation Innovation
Ultra-High Performance Concrete (UHPC)

Overview
Usage Restrictions / Parameters
Design Criteria
Specifications
Approved Products
Projects
FDOT Research
Technology Transfer (T²)
Contact



UHPC Design guidance & standards documents

- Interim Guidance webpage for **Design Innovation**

  Projects:

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

Fast-Facts sheets for selected projects are listed below:

- **I-10 over CR268A Approach Slab Replacement**
- **I-10 over Flat Creek Approach Slab Replacement**
- **I-95 over CR5A - Precast Deck Panel Replacement**
- I-95/JT Butler Interchange Bridge U-Beam Repair
- **SR 714/Danforth Creek - Sonovoid Rehab**
- **US1 over Little Duck Key Channel**
- **US441 over Taylor Creek - Span 12 Replacement**
- **US41 over Sunset Waterway Link-Slab**


FDOT Transportation Innovation Initiative:
UHPC – Design Innovation

Fast Facts: Ultra-High Performance Concrete

Project Location: FDOT District Four, Palm City, Martin County, Florida

Agency: Florida Department of Transportation

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

Project Name: SR714/Martin Downs Blvd over Danforth Ck. Bridge Nos. 890134 & 890135 FPID: 430617-1

Project Description: Sonovoid PSB longitudinal joint repairs with UHPC.

Project Purpose & Need: 2014 Bridge Inspection Report identified numerous reflective cracks in the asphalt overlay, indicating separation of the sonovoid units at the joints between the units. Bridge work activities involved hydro-demolition of longitudinal joints between PSB precast units and filling connections with supplemental tie bars and UHPC.

Overall Budget/ Cost Estimate: $1,176,116 (Construction Contract) $ 204,880 (522 LF. Joint Repair w/ UHPC)

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Overall Budget/Cost Estimate: $399,878 (Construction Contract)

What was unique about this project? First UHPC for connection proposed by Contractor for span replacement/repair in Florida.

Describe Traditional Approach: Traditional approach includes using hooked and lacing reinforcing bars within wider closure pours using high early strength concrete.

Describe New Approach: Utilization of short length straight #4 bar lap splices with 4" overlap using UHPC closure pour. The precast deck units were also cast with the overhangs and concrete railing attached, prior to placement.

Top Innovations Employed: Utilization of UHPC connections for rapid replacement (weekend) of damaged/deteriorated span.

Primary Benefits Realized/Expected: More robust and longer service life from precast deck slabs and UHPC connections. Short closure time for highway bridge lane (5/11/18 – 5/13/18).

Project Start Date/Substantial Completion Date: 4/9/2018 – 6/11/2018

Affiliations:	PE Consultant:	WSP USA, Inc.
	Construction Contractor:	Cone & Graham, Inc.
	Construction Engineering Inspection:	WSP USA, Inc.
Project Contacts:	Engineer of Record:	Timothy A. Deland, P.E. WGI, West Palm Beach, FL.
	FDOT Project Manager:	Richard Clements FDOT Brevard Operations Richard.Clements@dot.state.fl.us

http://www.fdot.gov/structures/innovation/UHPC.shtm

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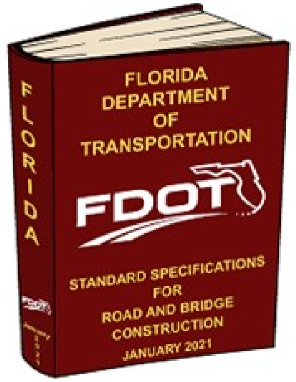
UHPC Design guidance & standards documents

- Developmental Materials & Construction Specifications

STRUCTURES		
Ultra-High-Performance Concrete -	Jose Armenteros	Dev349UHPC Project List
Prepackaged Ultra-High-Performance Concrete Provide the material requirements for ultra-high-performance concrete. NOTE: Use with Dev 349UHPC	Jose Armenteros	Dev927UHPC Project List



https://www.fdot.gov/programmanagement/otherfdotlinks/developmental/default.shtm

UHPC Design guidance & standards documents

- Research Activities

Completed Research:

- ***BDV31 977-94:*** **Requirements for Use of Field-Cast, Proprietary UHPC in Florida Structural Applications** – ***Final Report*** *7/8/19*

Ongoing Research Activities:

- ***In-house SRC*****:** Spliced Columns with larger bars #8 to #11 (Freeman), Final report early 2021
- ***BDV29 977-28:*** FSB Bridge with UHPC Joint Connections (FIU) – 1st round testing completed; 6 new beams cast (2 tests) with only bottom reinforcement in joint; Cyclic SDLC testing
- ***BDV31-977-105:*** Requirements for nonproprietary *"UHPC Use in Florida Structural Applications"*
- ***BDV31-977-101:*** Hybrid Prestressed Concrete Bridge Girders using UHPC *(Potter) –Final report submitted*

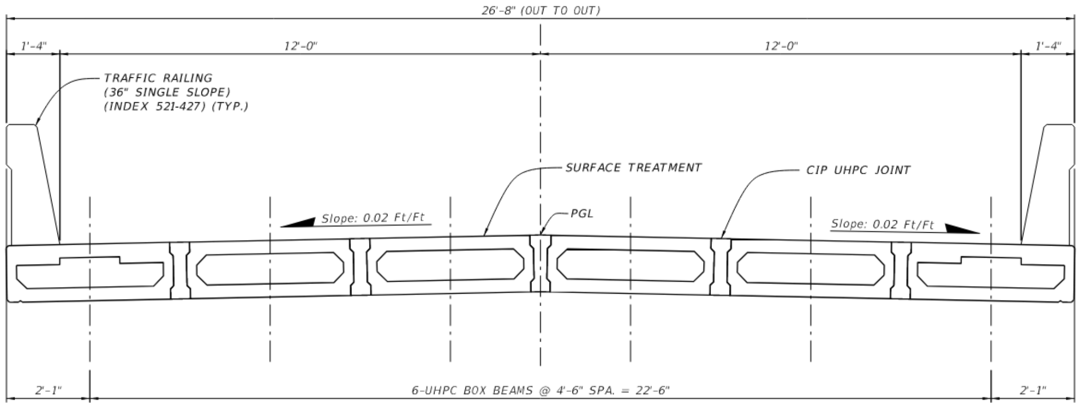
UHPC Design guidance & standards documents

• Research Activities

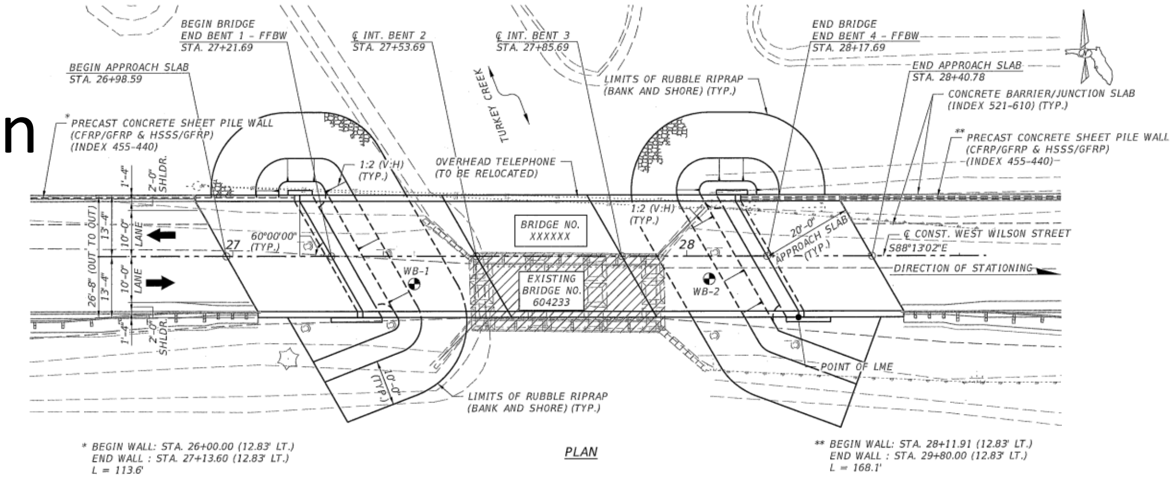
- **Precaster 1:**
  - First UHPC octagonal pile tested at SRC in April 2018 another one waiting
  - Hollow-Box Beam from SCP. Testing 2~ 47’ beams in flexure completed
  - 3x20’ lengths of Waffle Deck & 60’ AASHTO Type II Beam, cast on 06/17/20 tested in Oct 2020 at SRC for resistance of all 3 interface shear connection systems.
- **Precaster 2:**
  - 14” sq. solid UHPC piles (Freeman) – Flexure test 4/2/19 @ SRC 4-point bending on 30’ pile; driving demonstration of 100’ pile 4/4/19 @ Leware.
  - 30” x 30’ H-Pile COR-TUF UHPC: H-Pile tested at SRC 10/2/19
  - 30” x 140’ H-Pile COR-TUF UHPC: One pile driven at CR 339 on Feb 13, 2020 - PDA report available)
  - Providing COR-TUF for D1: US-41/Sunset Waterway Ped. Bridge link-slab, and D3 I-10 Precast App. Slab connections.
- **UHPC Material Producers: Lafarge, CorTuf USA, Argos USA: Developing proprietary mix**

UHPC Design guidance & standards documents

- Projects in Design:
  1. Precast Voided Slab - #-span continuous



  2. 250’ Single Span ?



HSSS-PC Design guidance & standards documents

3.

Interim Guidance webpage for Design Innovation *(pending)*


FDOT Florida Department of TRANSPORTATION

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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**

We also invite you to review our Design Office Innovations listed in the links below. Additional innovations will be added as they are identified and developed. If you have any questions, details and contact information are included within the information for each innovation web site.

Structures Design Office

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

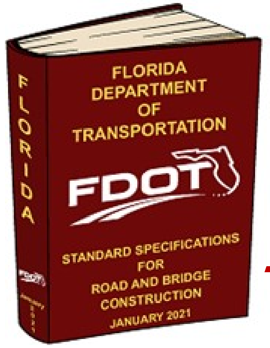
Ultra-High Performance Concrete (UHPC)

Stainless-Steel Pretensioned Concrete *(pending)*

3. HSSS-PC Design guidance & standards documents

Design Guidance, Specs, and Design tools:

- NCHRP Project → ***12-120*** (SS Strands for PC Beams) …
- FDOT Research Project ***BDK84 977-07*** (2014)
- FDOT Research Project ***BDV30 977-22*** (2020)



→ *Section 931*

USF UNIVERSITY OF SOUTH FLORIDA
Civil & Environmental Engineering

DESIGN AND CONSTRUCTION OF PRECAST PILES WITH STAINLESS REINFORCING STEEL
BDK84 977-07
FINAL REPORT

Principal Investigators:
Gray Mullins, Ph.D., P.E.
Rajan Sen, Ph.D., P.E.
Alberto Sagüés, Ph.D., P.E.

Researchers:
Danny Winters, Cara Morton, Joseph Fernandez, Kevin Johnson, Vincent DePianta, Jeff Vomacka, and Elizabeth Mitchell

Florida Department of Transportation

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Stainless Steel Strands and Lightweight Concrete for Pretensioned Concrete Girders

FDOT Contract No. BDV30-977-22
FSU Project No. 041063

Submitted to:
Florida Department of Transportation
Research Center
605 Suwannee Street
Tallahassee, Florida 32399-0450

Vickie Young, P.E.
Project Manager
FDOT Structures Design Office

FDOT

FAMU-FSU College of Engineering

Prepared by:
Michelle Rambo-Roddenberry, Ph.D., P.E.
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Graduate Research Assistant

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2525 Pottsdamer Street
Tallahassee, FL 32310-6046

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NCHRP 12-120 [Active]

Stainless Steel Strands for Prestressed Concrete Bridge Elements

Project Data	
Funds:	$600,000
Staff Responsibility:	Dr. Waseem Dekelbab
Research Agency:	University of Houston
Principal Investigator:	Dr. Abdeldjelil Belarbi
Effective Date:	7/1/2020
Completion Date:	3/1/2023

3. HSSS-PC Design guidance & standards documents

Design Guidance, Spec, and Design tools

- ***BDV30 977-22***

Mechanical properties

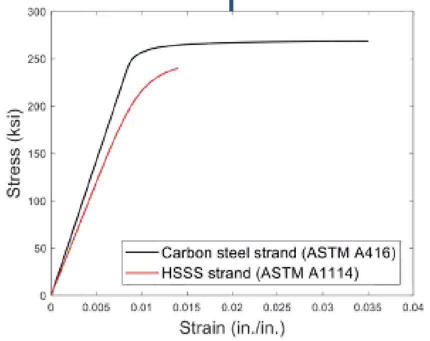
FAMU-FSU Engineering

HSSS strand Grade 240

- ASTM A1114
- Low-relaxation
- Ultimate stress = **240** ksi
- Ultimate strain = **1.4**%
- Elastic modulus = **24,000** ksi
- Keep increasing after yielding up to failure

Carbon steel strand Grade 270

- ASTM A416
- Low-relaxation
- Ultimate stress = 270 ksi
- Ultimate strain = 3.5%
- Elastic modulus = 28,500 ksi
- Reach plateau after yielding



Projects used HSSS strands in US

FAMU-FSU Engineering

- After successful research projects by Georgia, Florida, and Virginia DOTs, HSSS strands have been deployed in many projects

	Project Name - Owner Year (Application)
1	Nimmo Parkway - VDOT 2013 (piling)
2	Riceboro Creek - GDOT 2016 (piling)
3	Satilla River - GDOT 2016 (piling)
4	LA 1 Grand Isle - LADOT 2017 (piling)
5	Cedar Key Bridge - FDOT 2018 (piling)
6	High Rise Bridge - VDOT 2018/19 (piling)
7	Arlington Bridge - EFL 2018/19 (deck panels)
8	Wilmington River Bridge - GDOT 2018/19 (piling)
9	Jimmy Delouch Parkway - GDOT 2018/19 (piling)
10	Queens Creek - VDOT 2019 (piling)
11	Seneca 19 - ODOT 2019 (box beams)
12	Sterling Creek Bridge - GDOT 2019 (piling)
13	Pipe Makers Canal - GDOT 2019 (piling)
14	Skyway Bridge - FDOT 2019 (sheet pile)
15	Island Parkway - GDOT 2019 (piling)
16	Brick Kiln Creek Bridge - VDOT

HSSS-PC Design guidance & standards documents

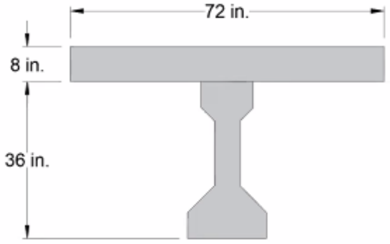
Design Guidance, Specs, and Design tools

- ***BDV30 977-22***

Girders design

FAMU-FSU Engineering

- Material properties
  - Concrete strength
    - Beam = 8.5 ksi
    - Deck slab = 4.5 ksi
  - Prestress reinforcement → HSSS strand (ASTM A1114)
    - Area = 0.231 in^2
    - Ultimate stress = 240 ksi
    - Ultimate strain = 0.014 in./in.
    - Elastic modulus = 24,000 ksi
- Initial jacking stress
  - 65% of ultimate stress
- Design method:
  - Force equilibrium and strain compatibility
- Design objective:
  - Determine optimum number of 0.6-in.-dia. HSSS strands

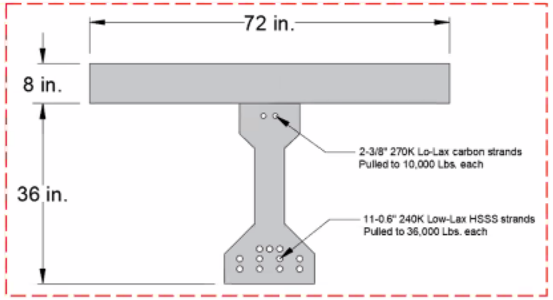


Interior beam

Girders design

FAMU-FSU Engineering

- Design limits:
  1. tensile stress at release (AASHTO 5.9.2.3.1);
  2. tensile stress at service (AASHTO 5.9.2.3.2);
  3. **minimum reinforcement (AASHTO 5.6.3.3);**
  4. strength (AASHTO 5.5.4).
- Failure mode
  - Rupture of strand
  - Resistance factor = 0.75 → brittle failure
- Results
  - 11 0.6-in. HSSS strands



3.

HSSS-PC Design guidance & standards documents

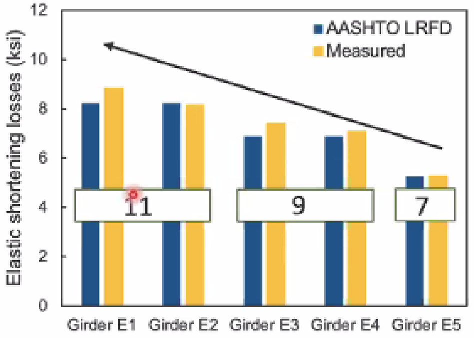
Design Guidance, Specs, and Design tools

- ***BDV30 977-22***

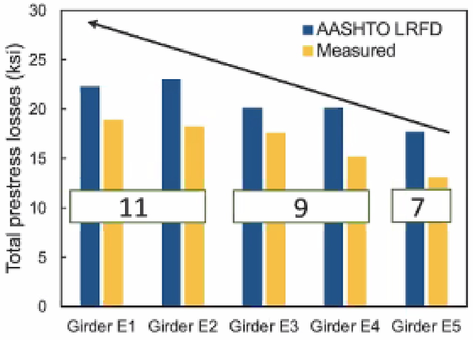
Prestress losses

FAMU-FSU Engineering

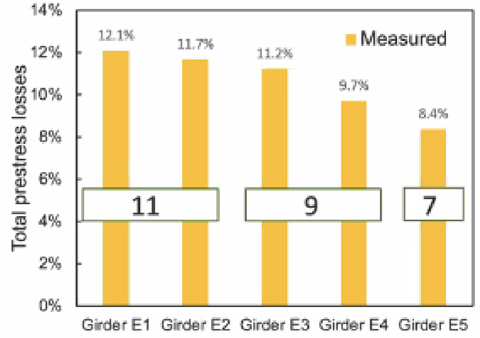
- Initial jacking stress → 156.5 ksi (65% of guaranteed ultimate stress)



Elastic shortening losses increased with increasing number of strand



AASHTO approximate method conservatively estimated the prestress losses of 0.6-in. HSSS strands



Maximum measured total prestress losses of 0.6-in. HSSS strand was 12.1%

3. HSSS-PC Design guidance & standards documents

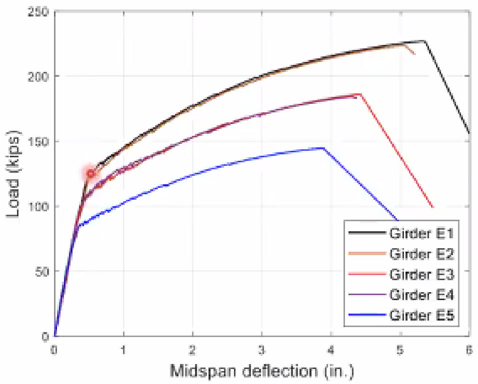
Design Guidance, Specs, Costs and Design tools

- ***BDV30 977-22***

Flexural test

FAMU-FSU Engineering

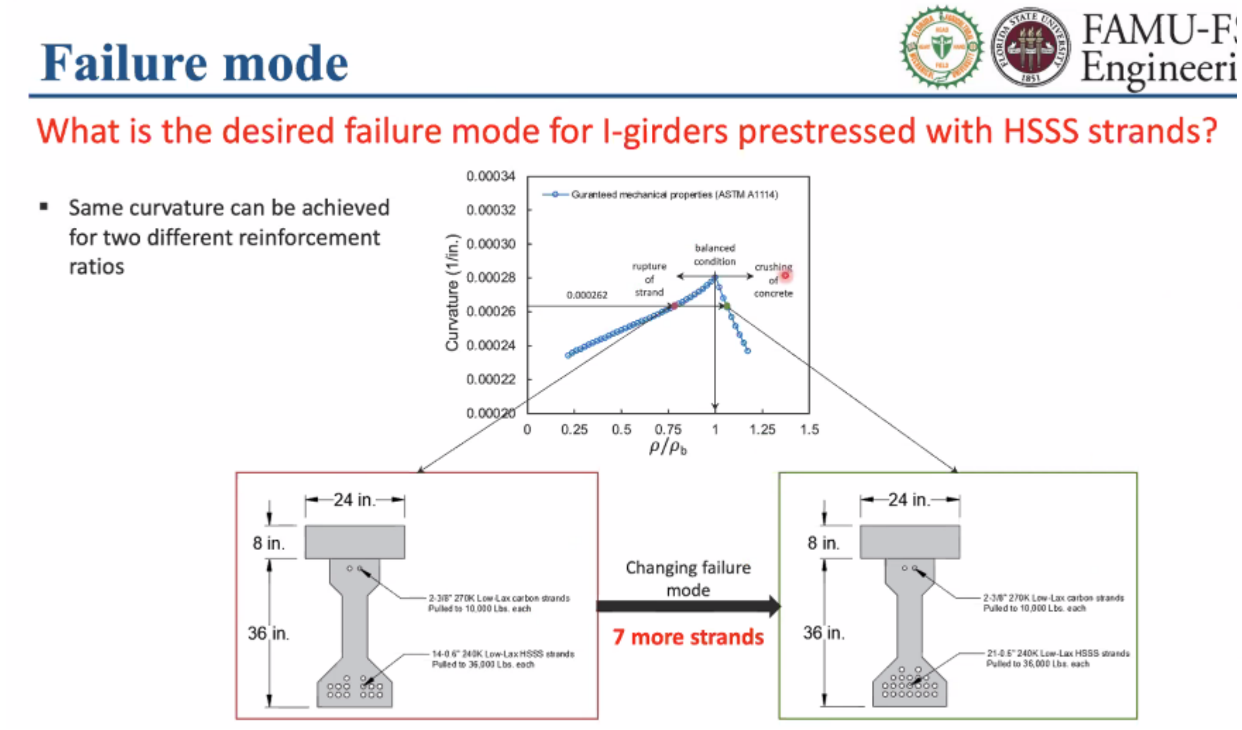
- Results
  - All girders satisfied AASHTO allowable deflection limit at service load
  - Post-cracking behavior continued to increase up to failure
  - Capacity and deformation increased linearly when increasing reinforcement ratio
  - All girders
    - Exhibited large reserve deflection beyond cracking load
    - Exhibited large reserve capacity beyond cracking load
    - Provided substantial warning through large deflection

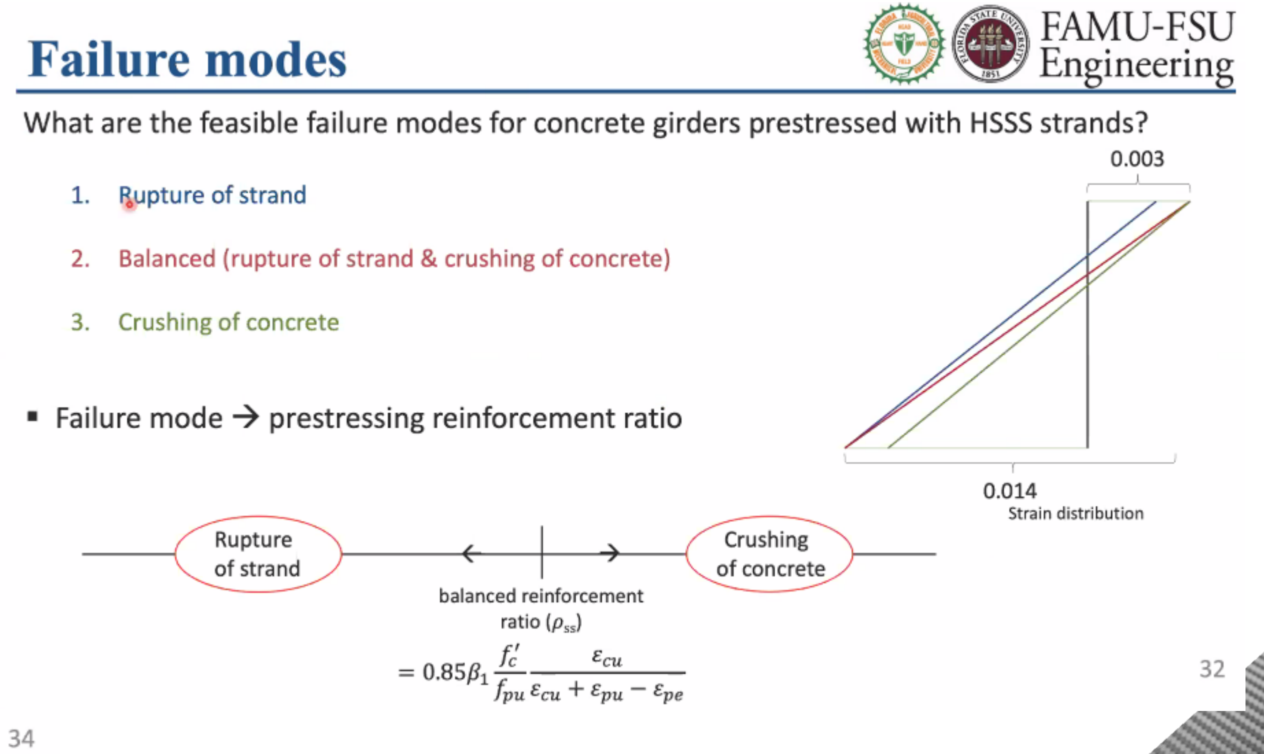


HSSS-PC Design guidance & standards documents

Design Guidance, Specs, and Design tools

- ***BDV30 977-22***

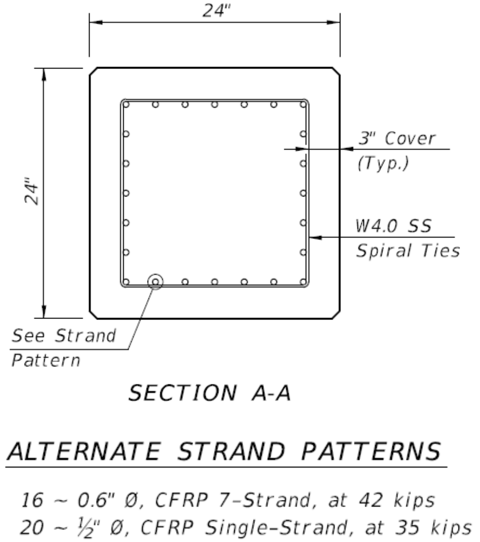


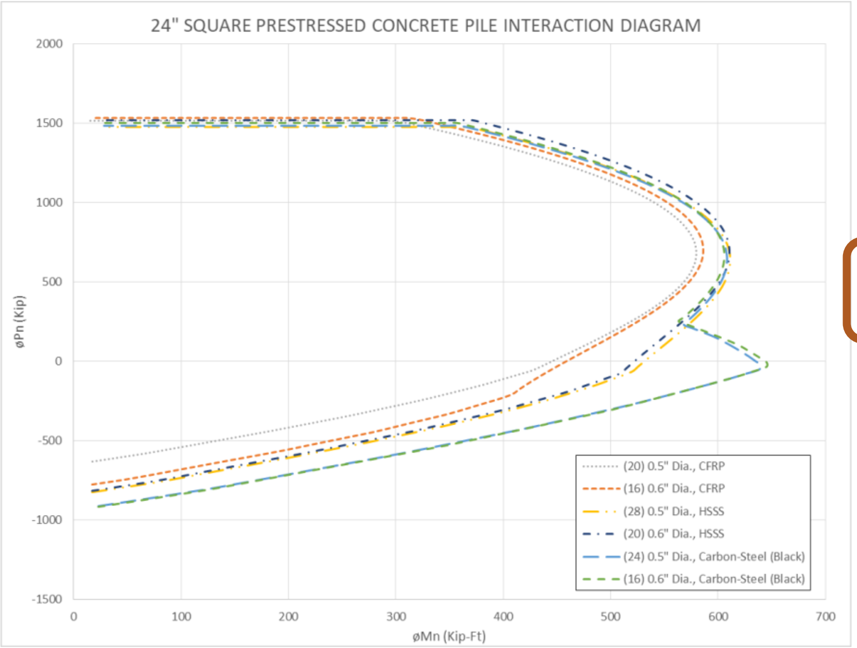


3. HSSS-PC Design guidance & standards documents

Design Guidance, Specs, and Design tools:

- Standard Drawings & Design Aids





455-101		Square CFRP and SS Prestressed Concrete Piles - Typical Details and Notes	22600	
455-102		Square CFRP and SS Prestressed Concrete Pile Splices	22601	
455-112		12" Square CFRP and SS Prestressed Concrete Pile	22612	
455-114		14" Square CFRP and SS Prestressed Concrete Pile	22614	SPI
455-118		18" Square CFRP and SS Prestressed Concrete Pile	22618	
455-124		24" Square CFRP and SS Prestressed Concrete Pile	22624	
455-130		30" Square CFRP and SS Prestressed Concrete Pile	22630	
455-154		54" Precast/Post-Tensioned CFRP and SS Concrete Cylinder Pile	22654	SPI
455-160		60" Prestressed CFRP and SS Concrete Cylinder Pile	22660	SPI
455-400		Precast Concrete Sheet Pile (Conventional)		SPI
455-440		Precast Concrete Sheet Pile (CFRP/GFRP and HSSS/GFRP)		SPI

https://www.fdot.gov/design/standardplans/current/default.shtm

3.

HSSS-PC Design guidance & standards documents

Design Guidance, Specs, and Design tools:

- Software:

V6.0 coming early 2021 → **Prestressed Beam v5.2** 11/07/2018 Exe (Zip) (Mathcad 15)

(beta version HSSS-PC)

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

4. CFRP-PC Design guidance & standards documents

Design Guidance, Specs, and Design tools:

- NCHRP Report 907 → 2018 *AASHTO Guide Spec – CFRP-1*
- NCHRP Project → 12-121 (FRP Auxiliary Reinforcing) …

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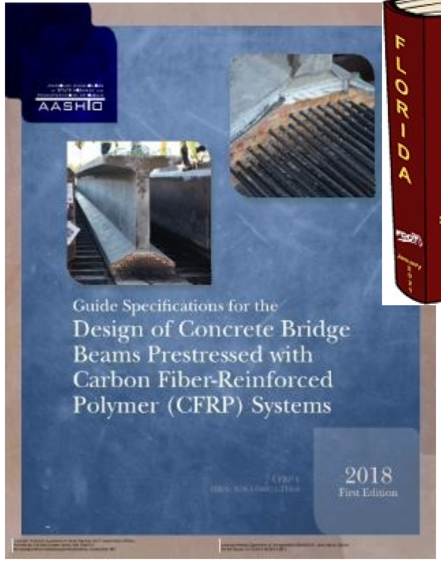

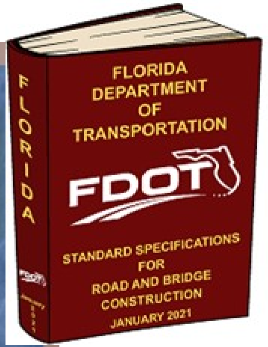

→ *Section 931*

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NCHRP 12-121 [RFP]

Guidelines for the Design of Prestressed Concrete Bridge Girders Using FRP Auxiliary Reinforcement

Posted Date: 11/5/2020

Project Data	
Funds:	$540,000
Contract Time:	36 months
(includes 1 month for NCHRP review and approval of each interim report and 3 months for NCHRP review and for contractor revision of the final report)	
Authorization to Begin Work:	6/1/2021 -- estimated
Staff Responsibility:	Dr. Waseem Dekelbab Phone: 202/334-1409 Email: wdekelbab@nas.edu
RFP Close Date:	1/11/2021
Fiscal Year:	2021

4. CFRP-PC Design guidance & standards documents

Design Guidance, Specs, and Design tools:

- Software:

V6.0 coming early 2021 → **Prestressed Beam v5.2** 11/07/2018 Exe (Zip) (Mathcad 15)

(beta version CFRP-PC)

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

Other's Design Software:

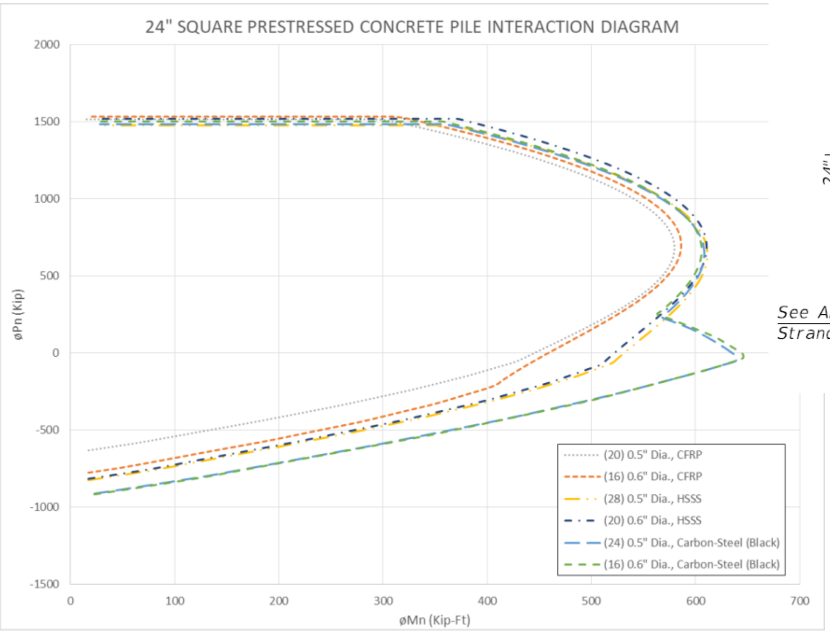
Adaption of FRP analysis or design enhancements:

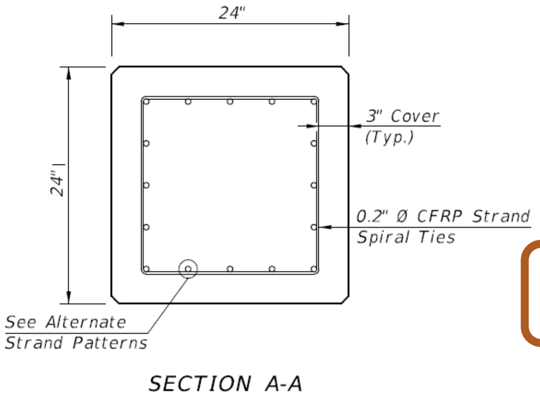
- **FB-MultiPier** *(BSI)* *CFRP-PC available in Jan. 2021*
- **Michigan DOT/LTU** CFRP-Beam Design Mathcad: *https://mdotjboss.state.mi.us/SpecProv/trainingmaterials.htm* *(also see TRB Webinar Dec 3, 2019)*

4. CFRP-PC Design guidance & standards documents

Design Guidance, Specs, and Design tools:

- **Standard Drawings & Design Aids:**





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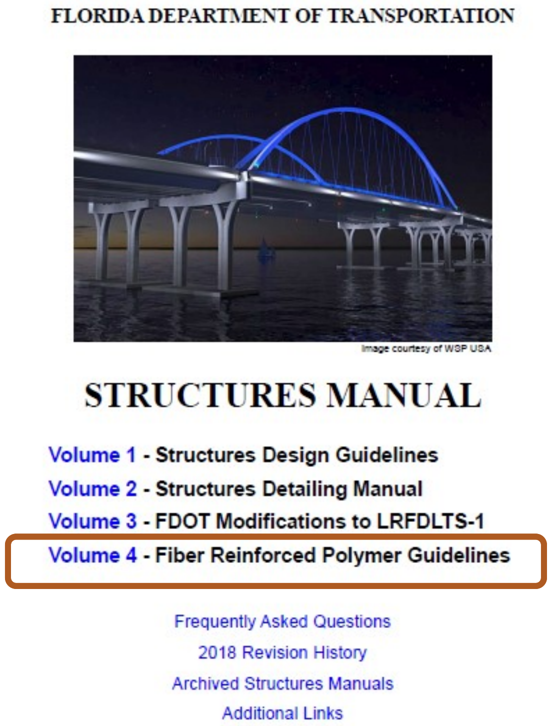
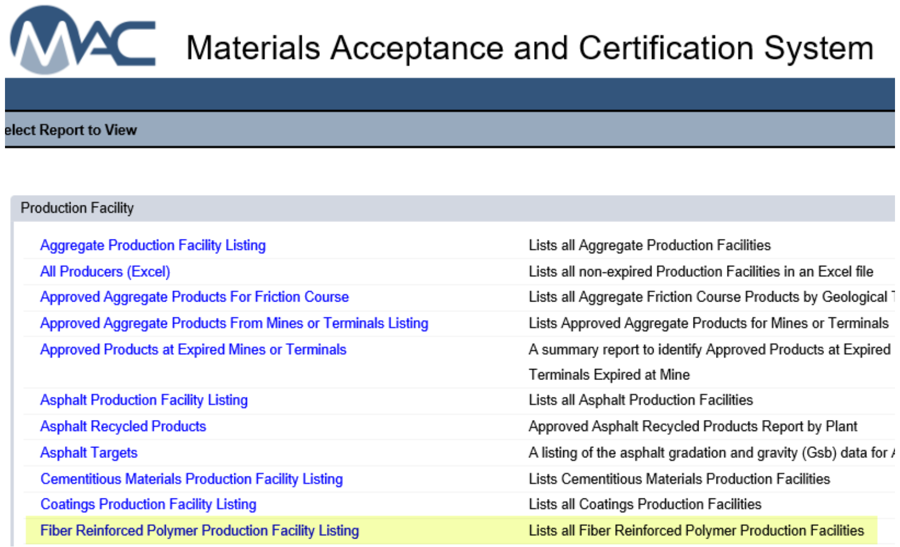
https://www.fdot.gov/design/standardplans/current/default.shtm

5.

FRP-RC Design guidance & standards documents

Design Guidance, Specs, and Design tools



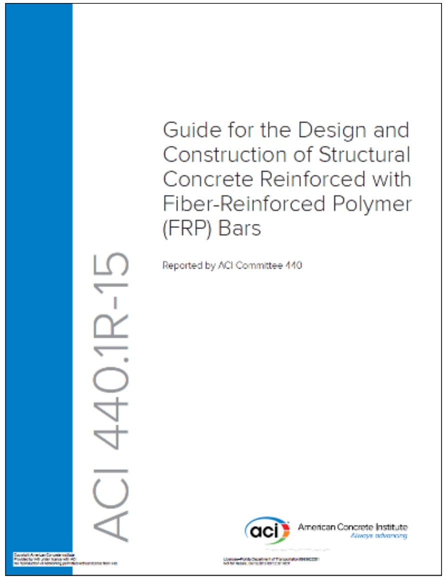


https://www.fdot.gov/structures/innovation/FRP.shtm

5.

FRP-RC Design guidance & standards documents

Design Guidance, Specs, and Design tools



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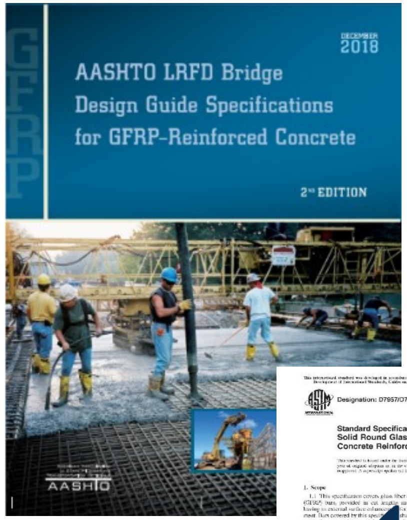

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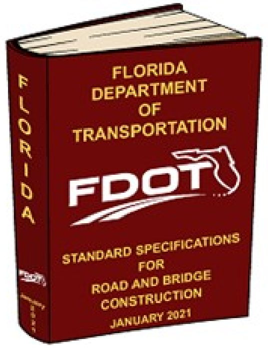


→ *Section 932-3*

- - ->

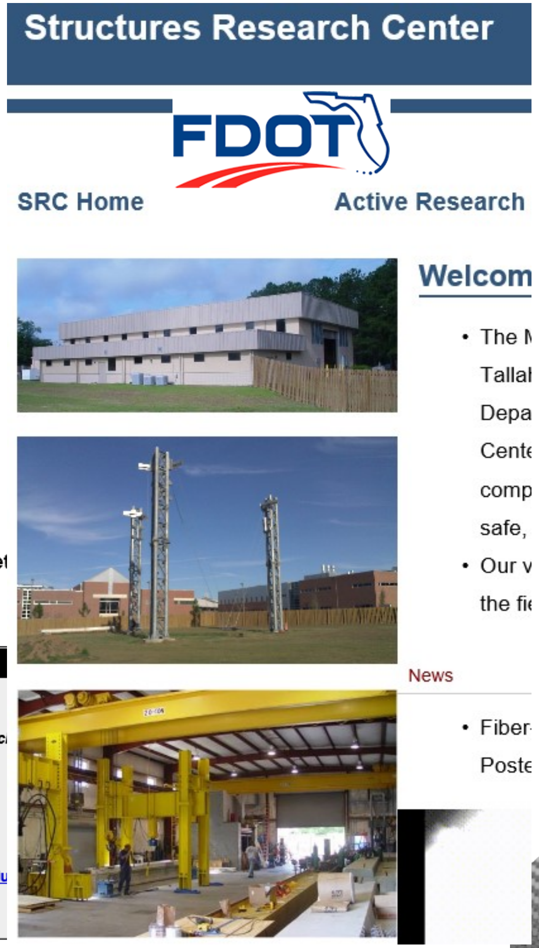
- - ->

NCHRP 12-121 [RFP]

Guidelines for the Design of Prestressed Concret

Posted Date: 11/5/2020

Project Data	
Funds:	$540,000
Contract Time:	36 months
(includes 1 month for NCHRP review and approval of eac and for contractor revision of the final report)	
Authorization to Begin Work:	6/1/2021 -- estimated
Staff Responsibility:	Dr. Waseem Dekelbab Phone: 202/334-1409 Email: wdekelbab@nas.edu
RFP Close Date:	1/11/2021
Fiscal Year:	2021

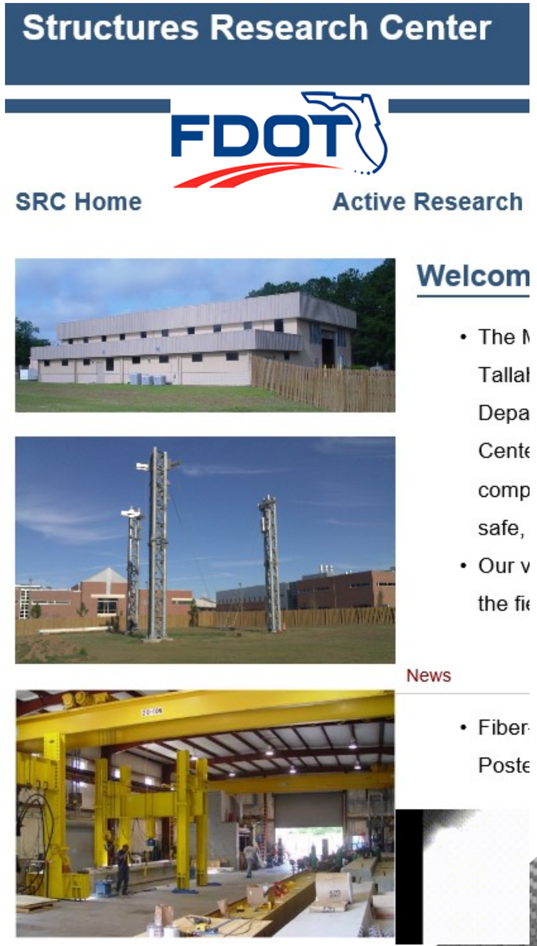


FRP-RC Design guidance & standards documents

Design Guidance, Specs, and Design tools

- Ongoing FDOT 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

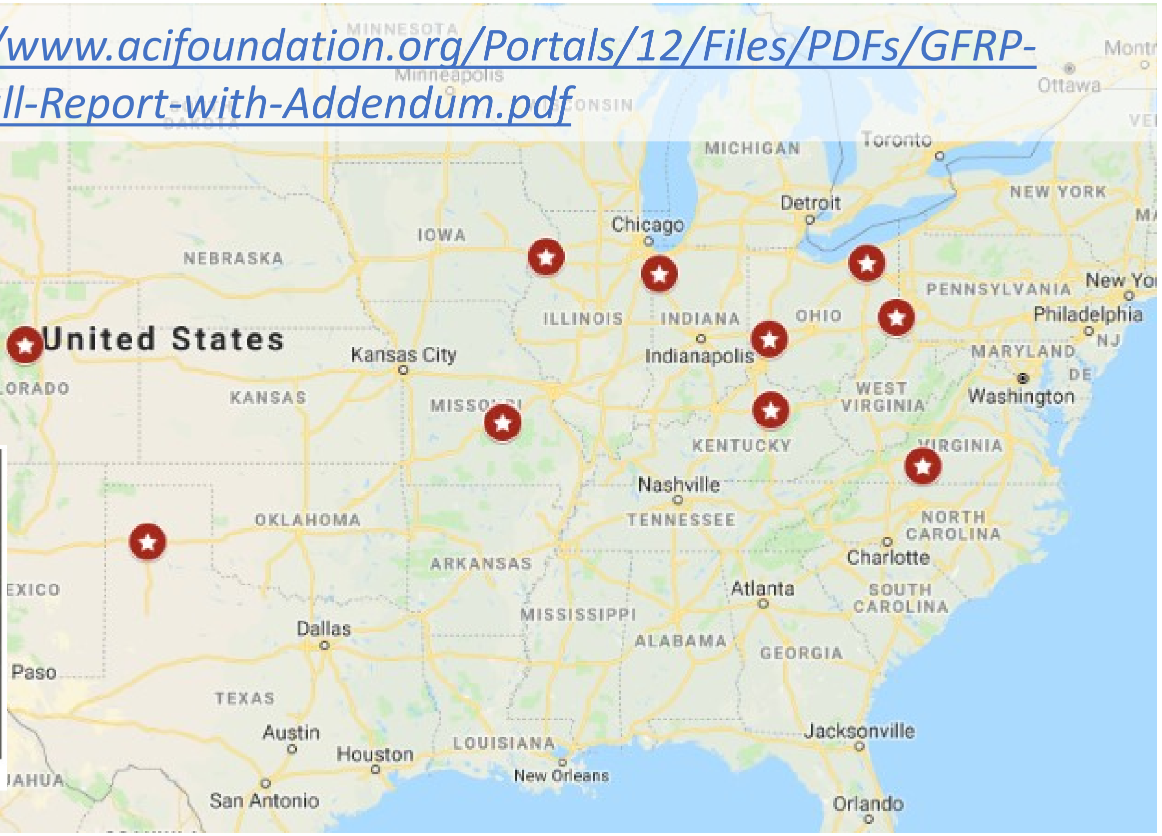


https://www.fdot.gov/structures/structuresresearchcenter/activeresearch.shtm

FRP-RC Evaluation of Durability: Selected Bridges

- **Eleven bridges** located across the United States in 2017-18
- Each bridge contains GFRP bars in deck or other location and has been in service for **at least 15 years**

https://www.acifoundation.org/Portals/12/Files/PDFs/GFRP-Bars-Full-Report-with-Addendum.pdf



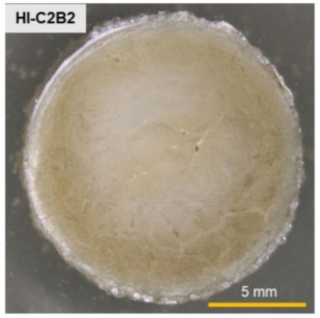


Fig. 34 –Specimen C2_B2 for SEM image

aci Foundation
Knowledge to Practice

- Gills Creek Bridge (VA)
- O'Fallon Park Bridge (CO)
- Salem Ave Bridge (OH)
- Bettendorf Bridge (IA)
- Cuyahoga County Bridge (OH)
- McKinleyville Bridge (WV)
- Thayer Road Bridge (IN)
- Roger's Creek Bridge (KY)
- Sierrita de la Cruz Creek Bridge (TX)
- Walker Box Culvert Bridge (MO)
- Southview Bridge (MO)

\+ Pearl Harbor Dry Dock #4 (HI)

5. FRP-RC Design guidance & standards documents

Design Guidance, Specs, and Design tools:

- Standard Drawings & Design Aids:

Office of Design

Office of Design / Standard Plans / Design Standards / Developmental Design Standards

Developmental Design Standards

Developmental Design Standards (DDS) are to be released by the appropriate section within the Office of Desi implement new technologies in a limited trial fashion on an as-needed or an as-available basis. As a ***DDS*** is relea ***Bulletin*** will be issued to announce its availability. Designers wishing to use a ***DDS*** must follow the *Developmenta Standards Usage Process* which is posted in the link provided below. Plans reviewers must verify each ***DDS***, incl set is permitted for the use by confirming the project's FPID number which is listed with the appropriate ***DDS*** belo

START HERE **Developmental Design Standards Usage Process for Design-Bid-Build Projects** START HERE

To skip directly to groups of Indexes, click on the index series: **200**, **400**, **500**, **800**, **6000**, **17700**, **20000**, **20350**, **20450**, **21300**, **22400**, **22600**, **22900**, **30000**
(*Site updated:* ***01/07/2021***)

Office of Design

Office of Design / Standard Plans / Developmental Standard Plans

Developmental Standard Plans

FDOT Standard Plans

Developmental Standard Plans are released by the appropriate section within the Office of Design to implement new technologies in a limited trial fashion on an as-needed or an as-available basis.

Use of Developmental Standard Plans requires approval by the FDOT Central Office monitor listed below.
See the **FDOT Design Manual (FDM), Chapter 115**, for additional information.

https://www.fdot.gov/design/standardplans/dev.shtm

5.

FRP-RC Design guidance & standards documents

Design Guidance, Specs, and Design tools: Software

FDOT Florida Department of TRANSPORTATION

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

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.
FB-MultiPier *CFRP-PC coming soon!*	**See UF-BSI Website**	Exe	FB-MultiPier is a nonlinear finite element analysis program for analyzing bridge pier structures and is supported and available from the University of Florida Bridge Software Institute.
Live Load Generator-LRFD v3.0	02/16/2011	Zip (Mathcad 15)	Calculates live loads for truck, truck train, lane, partial lane, and permit loads in accordance with the AASHTO LRFD Bridge Design Specification.
V6.0 coming early 2021 → **Prestressed Beam v5.2** *CFRP-PC (w/ GFRP-RC Shear) 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. *** Available on request*
Bent Cap v1.0 *GFRP-RC included*	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 v4.0 *GFRP-RC included*	06/01/2020	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.

6.

Managing SAM Implementation Challenges, LCC, and Technology Transfer

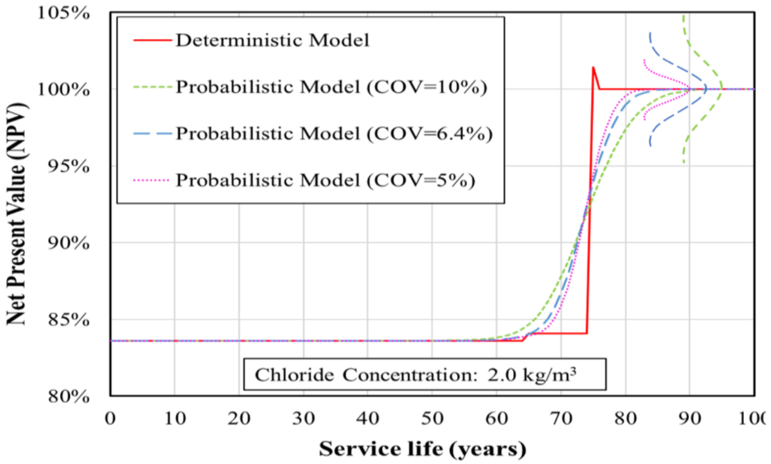
- Change is hard work and often thankless task…
- Provide early and accessible information…
- Economics is in the eye of the beholder!

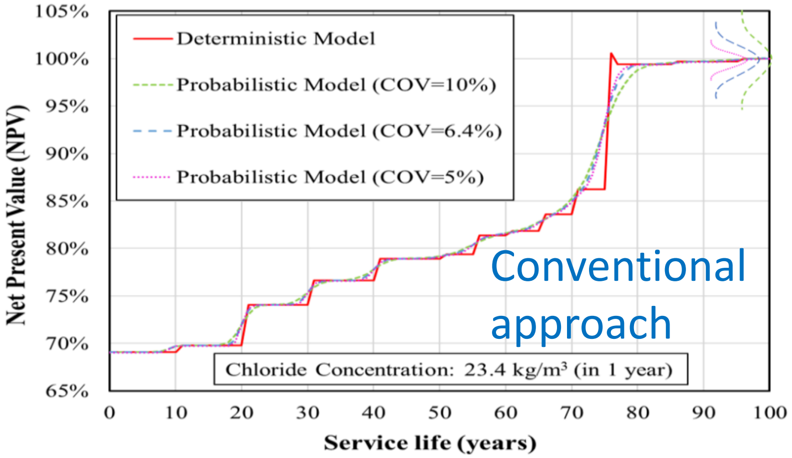
6.

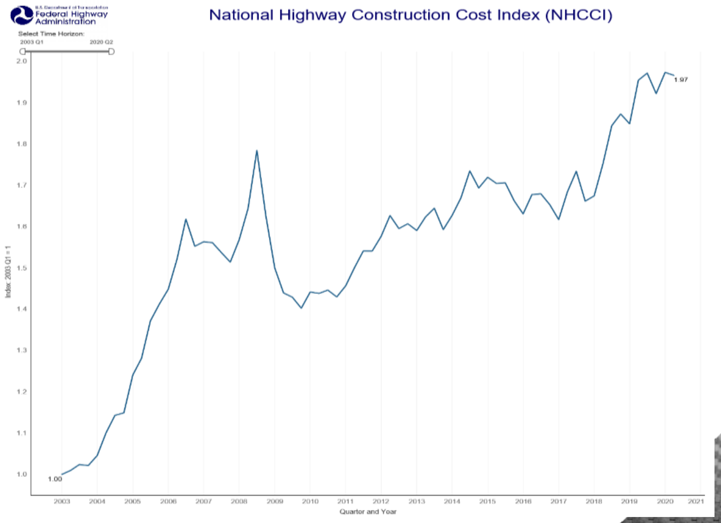
Life-Cycle Cost analysis strategies

- Comparisons and synergies
  - Economics is (sometimes) in the eye of the beholder
  - Save now, and $$$ later
  - Use realistic discount rates:

    (i) recognizing long-term investment using government bonding rates – highway/bridge construction inflation rates (NHCCI) = < 1%





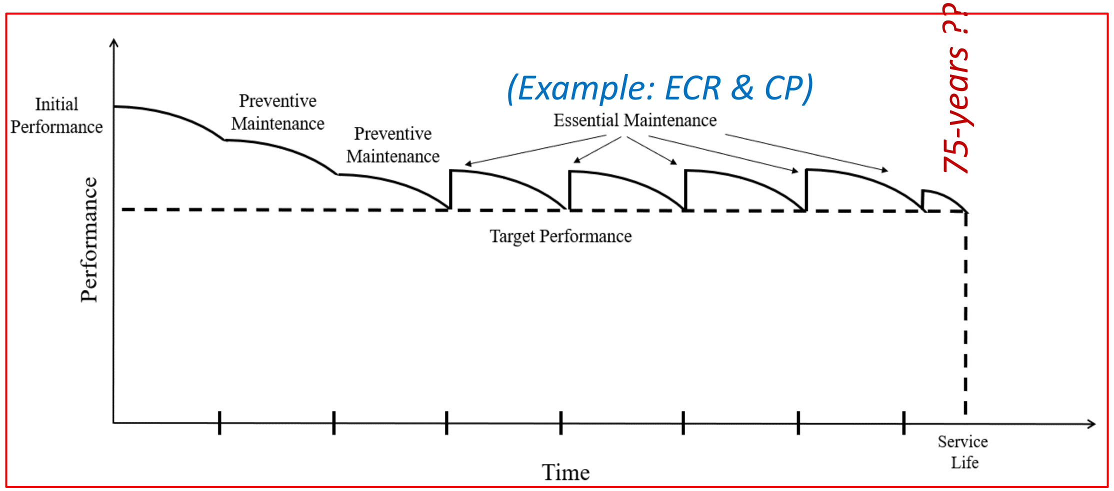


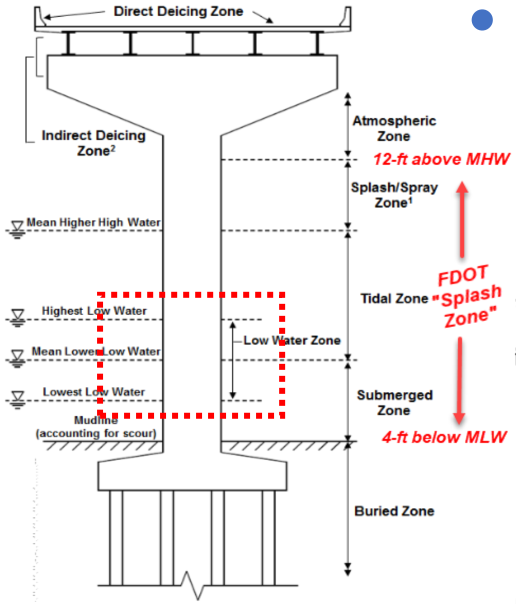
Idiom: "Penny wise and pound foolish"

6.

Life-Cycle Cost analysis strategies

- Comparisons and synergies
  - Conventional-RC with periodic Repair & Rehabilitation & CP
    - or Durable SAM's





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

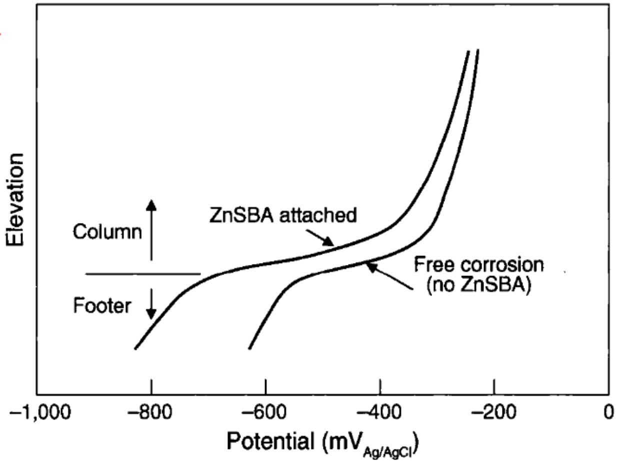


FIGURE 10. *Schematic illustration of the potential shift of footer and column reinforcement that is expected to accompany ZnSBA activation.*

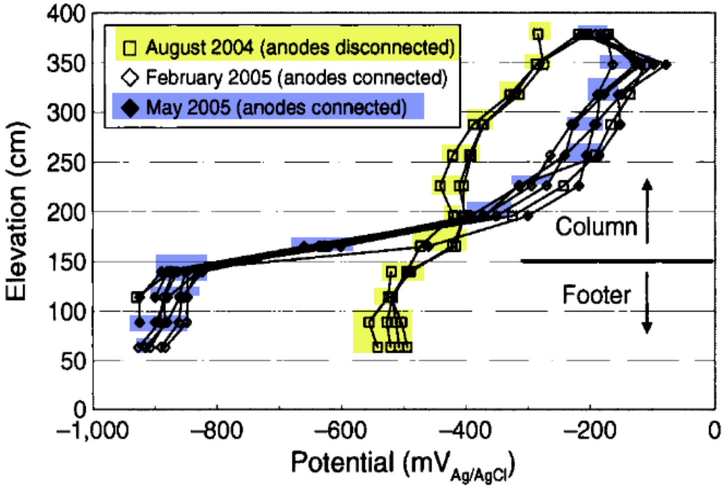


FIGURE 8. *Free corrosion and polarized potentials as a function of elevation for the footer and column on Pier 40W-East. Elevation is referenced to the bottom of the footer.*

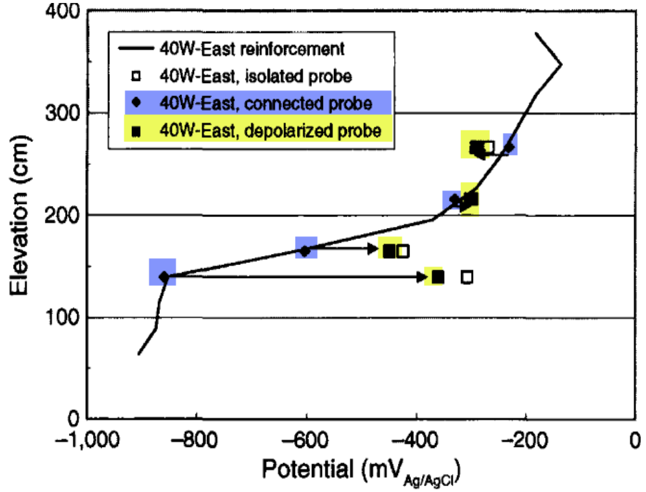
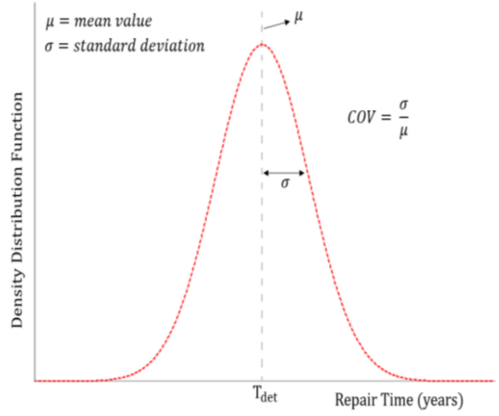


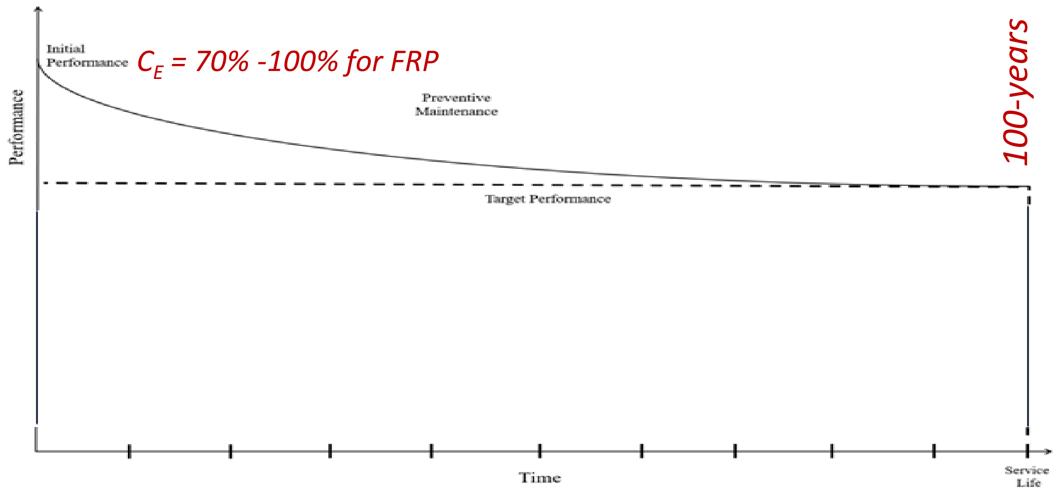
FIGURE 13. *Polarized potential data for reinforcement and free corrosion, polarized, and depolarized potentials for probes on pier 40W-East.*

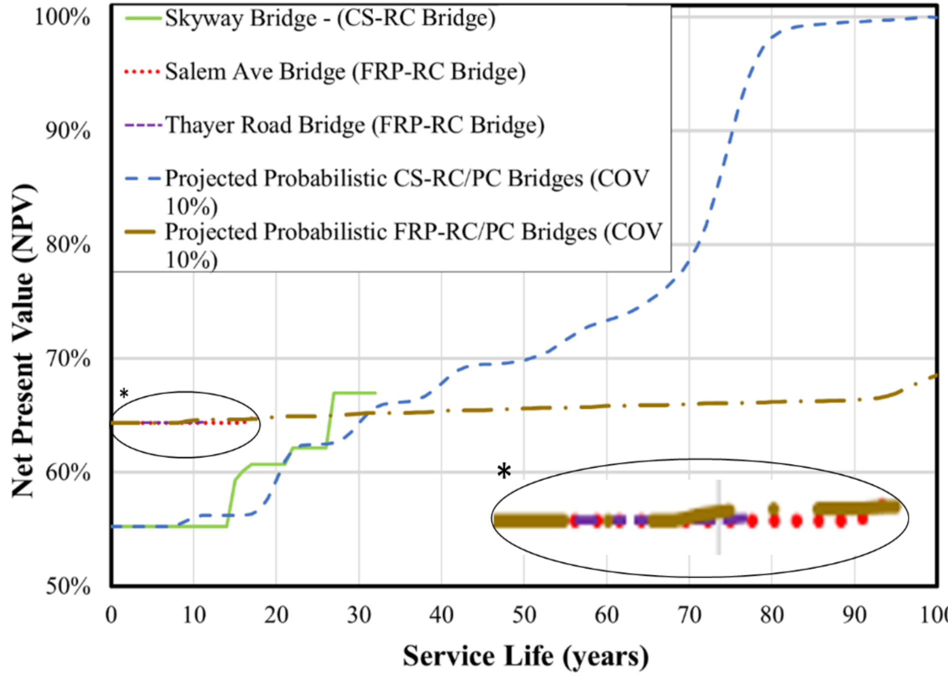
6.

Life-Cycle Cost analysis strategies



- Future enhancements or needs
  - Highly Corrosion-resistant solutions
  - Improvement of Probabilistic techniques





Cadenazzi at al. (2021), "Evaluation of Probabilistic and Deterministic Life-Cycle Cost Analyses for Concrete Bridges Exposed to Chlorides". *Journal of Cleaner Production (pending)*

Conclusions

- The is a definite place for **Structural Advance Materials**
- Balance **cost** and **needs => Value**
- Finding & showing the correct balance is **Our Challenge.**

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

Questions ???

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Florida Department of Transportation
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Website: *https://www.fdot.gov/design/Innovation/*