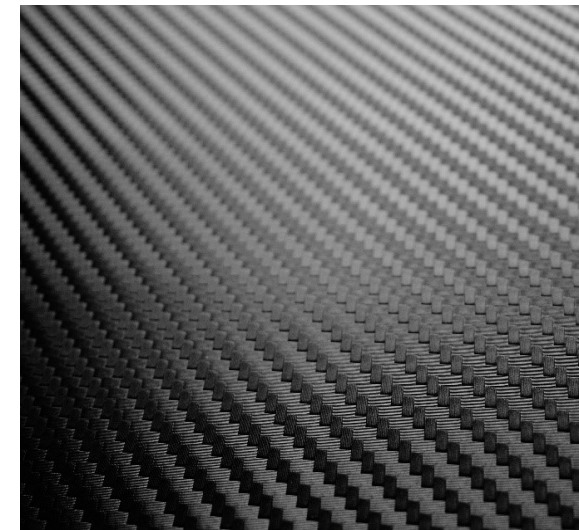
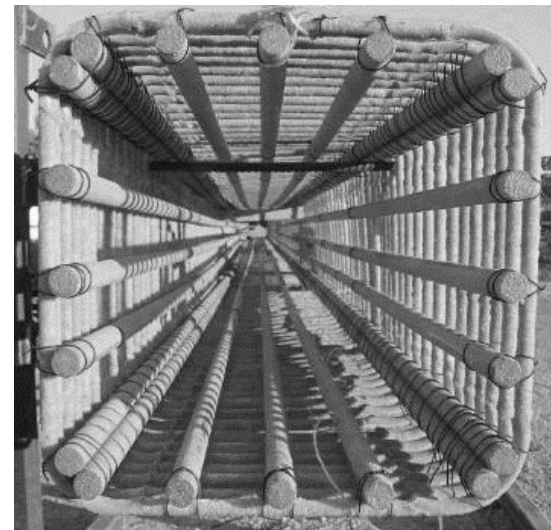




# Forecasting the FRP Future for FDOT Highway Bridges & Structures

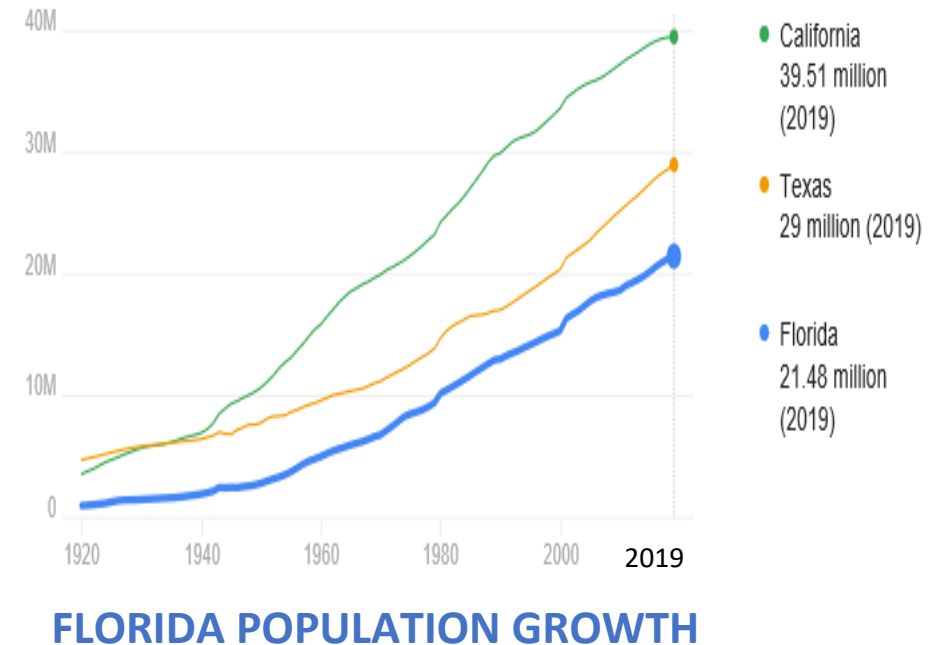
*Presenter: Steven Nolan, P.E. (FDOT State Structures Design Office)*

*Jan. 25<sup>th</sup> 10:00 AM - 11:30 AM EST*



# Forecasting the FRP Future for FDOT Highway Bridges & Structures

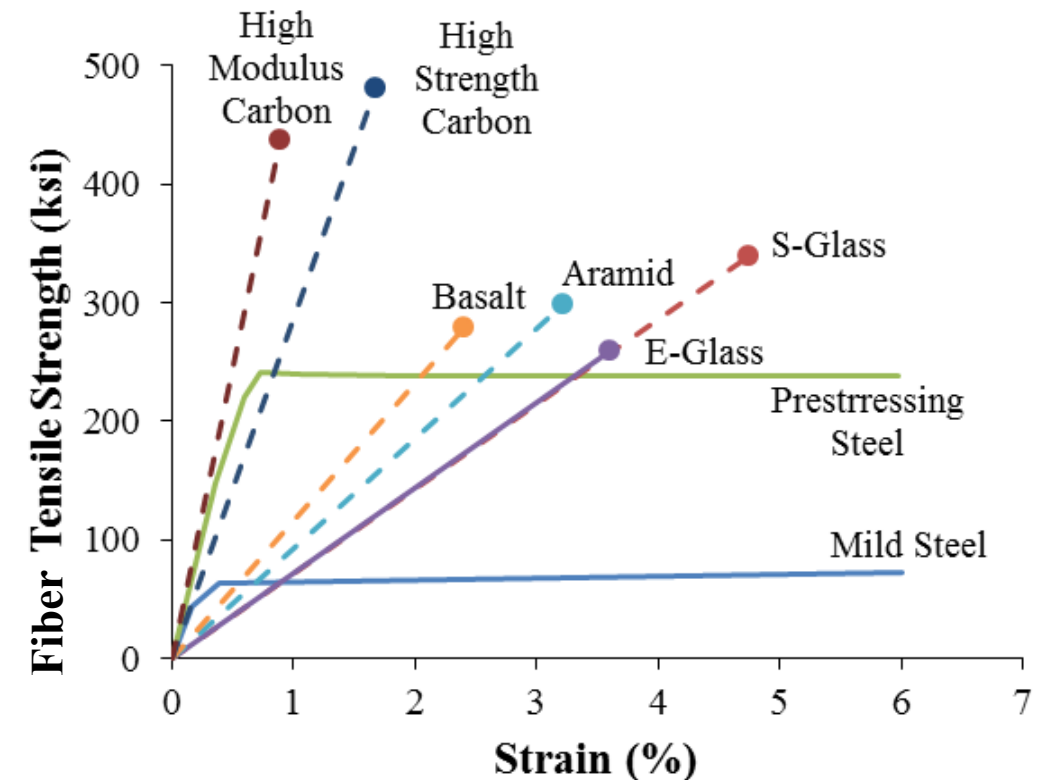
1. The Value Proposition
2. How does FRP align with Florida's Transportation Plan
3. FRP Material Systems used in Florida
4. FDOT Design Guidance, Specs, & Tools
5. Life-Cycle Cost analysis
6. Forecasting the Future
7. Technology Transfer & Future Development



Also see **IW-GFRPCS2** Case Study #4:  
[“FDOT GFRP-RC Market Size Estimate for Cast-In-Place Concrete by 2020”](#)

# The Value Proposition - structural advancement, durability & sustainability

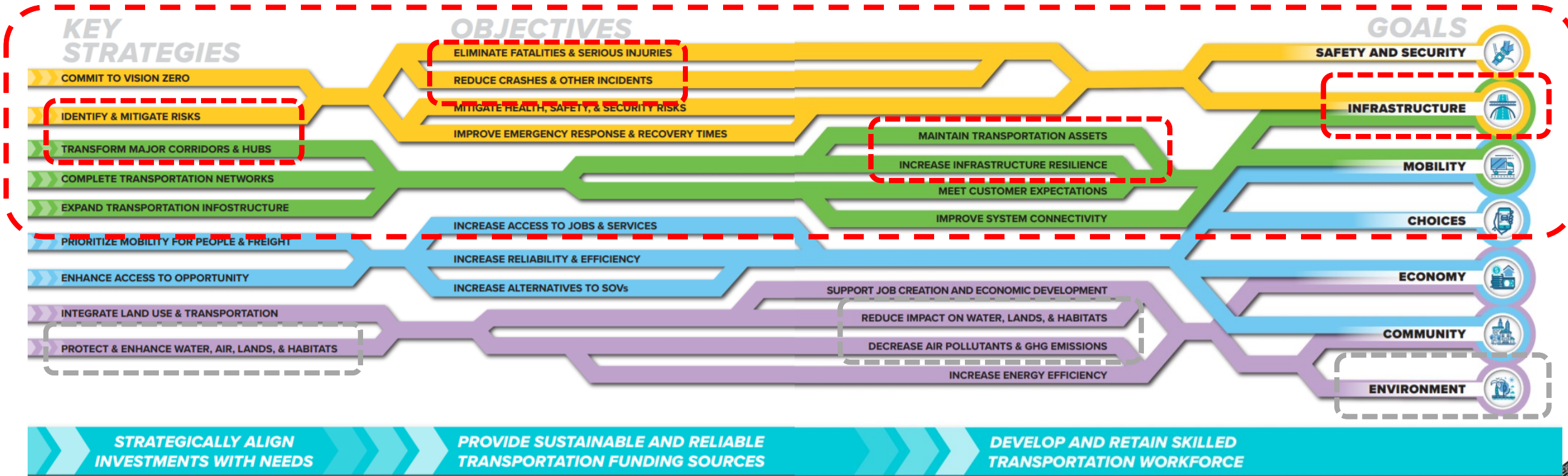
1. High Tensile Strength
2. Low Unit Weight
3. High Durability (corrosion-free)
4. Low Carbon Footprint
5. Innovative Technology Development
6. Local/Regional Manufacturing Opportunities



# The Value Proposition - structural advancement, durability & sustainability

How does FRP align or complement the (draft) 2045 Florida Transportation Plan ?

## FRAMEWORK > TODAY'S STRATEGIES / TOMORROW'S VISION



# The Value Proposition - structural advancement, durability & sustainability

## 2045 Florida Transportation Plan

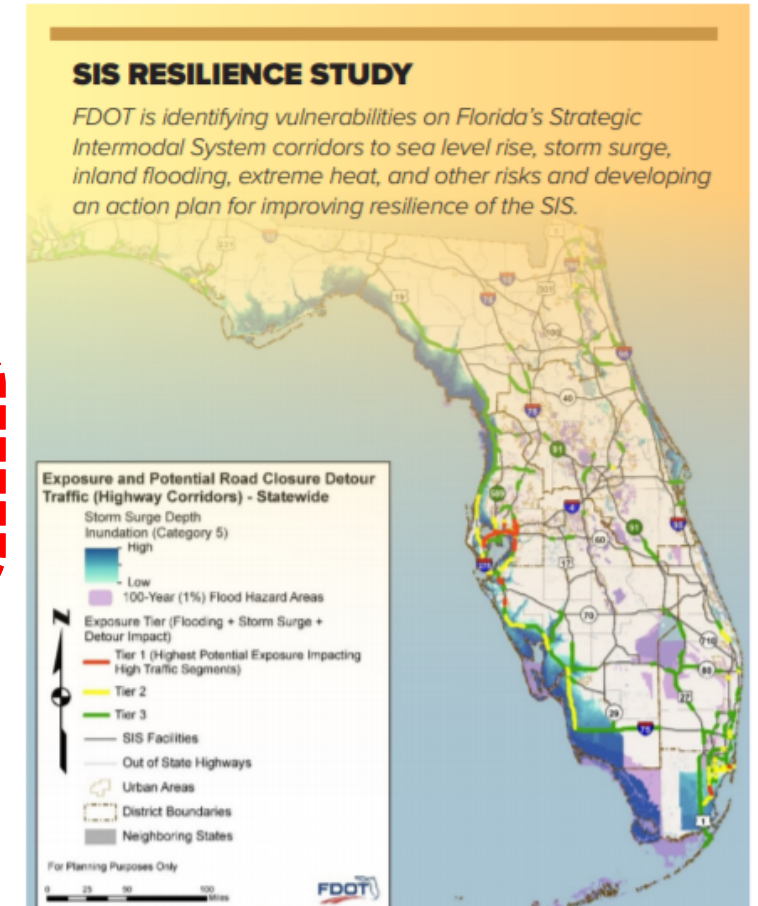
### A. relevant Key Strategies for Infrastructures:

- Address long-term costs
- Adaptability
- Advanced Materials
- ...

## KEY STRATEGIES > IDENTIFY & MITIGATE RISKS

Florida will place a high priority on identifying risks to its transportation system and the customers that use it. Florida will incorporate these risks into planning and management decisions for all modes. Florida will:

- > **Identify vulnerabilities** to hazards such as sea level rise, storm surge, coastal and inland flooding, and extreme heat and precipitation. Implement actions to avoid, reduce the likelihood of, or prepare the system to withstand these risks.
- > **Improve the agility of the transportation system** during emergencies and disruptions by expanding real-time information sharing, enhancing system management, providing more multimodal options, and supporting greater redundancy for critical infrastructure.
- > Expand asset management decisions to **address the long-term costs of known vulnerabilities**, such as the need for retrofitting existing facilities or repairing certain facilities multiple times.
- > **Adapt transportation design, construction, and maintenance techniques** to reduce vulnerability and improve resilience of existing and new transportation facilities, such as use of emerging technologies and advanced materials, stormwater management, and infrastructure modifications.
- > Identify and implement approaches for coordinating environmental management, land use, and urban design decisions to **improve overall infrastructure and community resilience**.
- > Establish a long-term approach to incentivize, where appropriate, the **transition of infrastructure and development** away from vulnerable areas.
- > **Update emergency management plans** covering preparedness, response, recovery, and mitigation to reflect the increasing intensity and severity of extreme weather events and other risks; shifts in Florida's population, development patterns, and travel choices; and increasing use of technologies such as automated and electric vehicles.



## KEY STRATEGIES

COMMIT TO VISION ZERO

IDENTIFY & MITIGATE RISKS

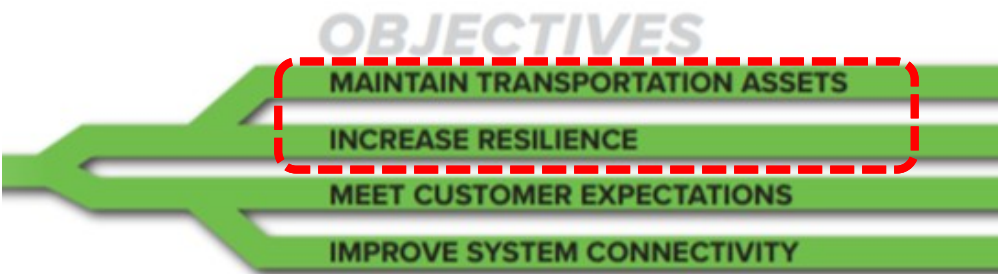
# The Value Proposition - structural advancement, durability & sustainability

## 2045 Florida Transportation Plan

### B. relevant **Key Objectives:**

- Maintain Assets in good repair
- Increase Resilience
- Quality Infrastructure
- ...

🎯 <b>OBJECTIVES</b>	📍 <b>PROGRESS INDICATORS</b>	
Maintain Florida's transportation assets in a state of good repair for all modes	<ul style="list-style-type: none"> <li>• Pavement condition</li> <li>• Bridge condition</li> </ul>	
Increase the resilience of infrastructure	<ul style="list-style-type: none"> <li>• Transit vehicle and facility condition</li> </ul>	
Meet customer expectations for infrastructure quality and service	<ul style="list-style-type: none"> <li>• Airport pavement condition</li> <li>• Seaport infrastructure condition</li> </ul>	
Improve transportation system connectivity	<ul style="list-style-type: none"> <li>• Spaceport infrastructure condition</li> <li>• Sidewalk and trail condition</li> <li>• Vulnerability to flooding or storm surge</li> <li>• Hours or days of transportation facility closure due to smoke, fire, flooding, wind, or extreme temperature</li> <li>• Frequency of repairs due to damage from extreme weather or other events</li> <li>• Customer satisfaction</li> <li>• Connections between modes/ systems and extent of system gaps</li> </ul>	

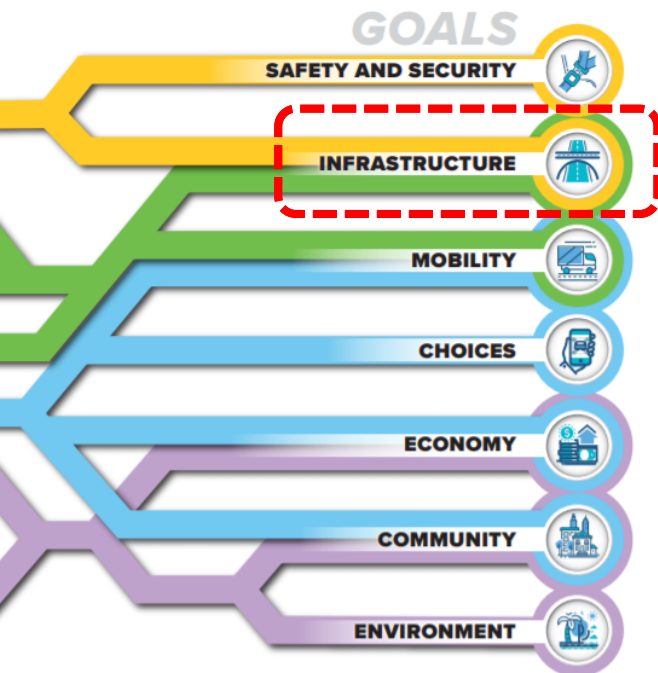


# The Value Proposition - structural advancement, durability & sustainability

## 2045 Florida Transportation Plan

### C. relevant **Goals:**

- Agile
- Resilient
- Quality infrastructure



**Infrastructure Station** Leave a Comment

**Goal: Agile, Resilient, and Quality Infrastructure.**

Florida's emphasis continues to expand from maintaining existing infrastructure to providing **agile, resilient, and quality infrastructure**. Our infrastructure will adapt to changing customer needs, business models, mobility options, technologies, and energy sources. Our infrastructure will be designed to withstand and recover from potential risks such as extreme weather events and climate trends. Our definition of infrastructure also is broader – it's not just concrete and steel, but also the communications backbone, sensors, and other technologies that enable the system to function.

Florida will place a high priority on identifying risks to its transportation system and the customers that use it. Florida will incorporate these risks into planning and management decisions.

To learn more about infrastructure in Florida, visit [The FDOT Source Book](#).

- [Pavement Condition](#)
- [Bridge Condition](#)
- [Maintenance Rating](#)

**\*\*Input needed: [Click here](#) to review draft strategies that help get us closer to this goal. Leave a Comment in the box above and let us know your thoughts.\*\***

# The Value Proposition - structural advancement, durability & sustainability

Cost : Benefit ???



Florida Department of Transportation

RON DESANTIS  
GOVERNOR

605 Suwannee Street  
Tallahassee, FL 32399-0450

KEVIN J. THIBAUT, P.E.  
SECRETARY

For Immediate Release  
January 7, 2021

Contact: Beth Frady  
[Beth.Frady@dot.state.fl.us](mailto:Beth.Frady@dot.state.fl.us)

## MACROECONOMIC ANALYSIS of Florida's TRANSPORTATION INVESTMENTS

### FDOT Macroeconomic Analysis Shows Transportation Projects Yield \$4 of Benefits for Every Dollar Invested

~ Investments provide short- and long-term benefits to transportation system users as well as the state's overall economy ~

**TALLAHASSEE, Fla.** – The Florida Department of Transportation (FDOT) recently completed a [macroeconomic analysis](#) and found that Florida's transportation projects are expected to yield an average \$4 of benefits for every dollar invested. In addition, the analysis found the benefits included investments across all transportation modes, including highway, transit, rail, airports, seaports and waterways, and spaceports. The investments will provide short- and long-term benefits for transportation system users as well as Florida's overall economy.

FISCAL YEAR  
**2019-2023**  
WORK PROGRAM

This study shows a lower overall benefit-cost ratio than the 2014 Macroeconomic Analysis. Indeed, the benefit-cost ratio has fallen with each iteration of the analysis since 2002. This trend reflects increasing construction costs and the advancing maturity of the system. Major highway expansion and construction that would reduce congestion on local roads has been accomplished over the past decades in many regions of Florida, and highway investments increasingly serve to meet FDOT's statutory commitment to maintaining pavement and bridges in good condition.



# FRP material systems used in FDOT's Highway Bridges & Structures

## 1. FRP-Prestressed Concrete (PC):

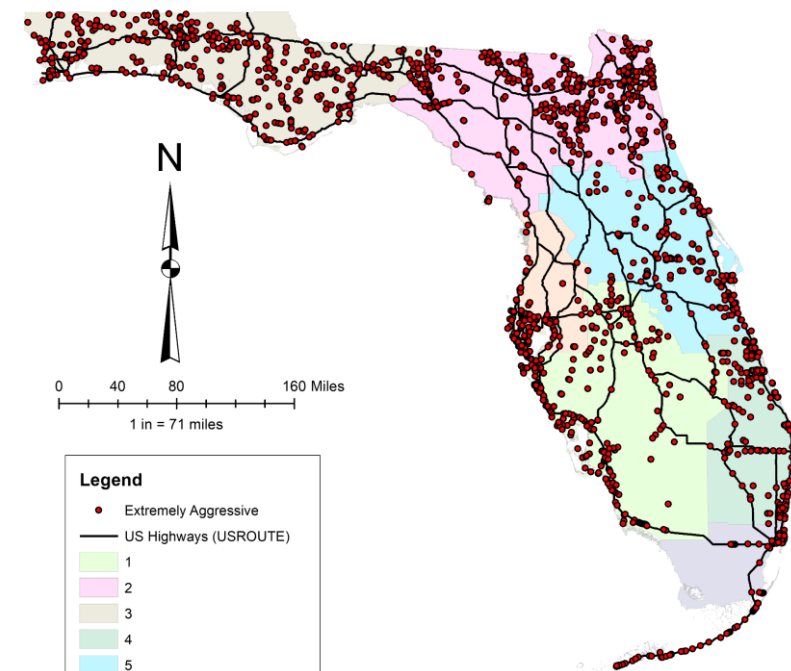
- Prestressed Beams - CFRP strands, GFRP/BFRP auxiliary
- Bearing Piles – CFRP strands, spirals, & splice dowels, (GFRP/BFRP auxiliary?? )
- Sheet Piles - CFRP strands, GFRP (BFRP ? submerged) stirrups

## 2. FRP-Reinforced Concrete (RC):

- CIP Decks & Flat-Slab Bridges - GFRP (BFRP now allowed)
- Seawalls – GFRP (submerged)
- Bulkhead Caps – GFRP/BFRP
- Retaining Walls - GFRP/BFRP
- Drainage Structures/Box Culverts – (no recent examples)

## 3. FRP Elements (MS):

- Fenders, Piles, HCBs, Pedestrian Structures



# FRP RC/PC material systems used in Florida's Highway Bridges & Structures

## Recent Completed Projects

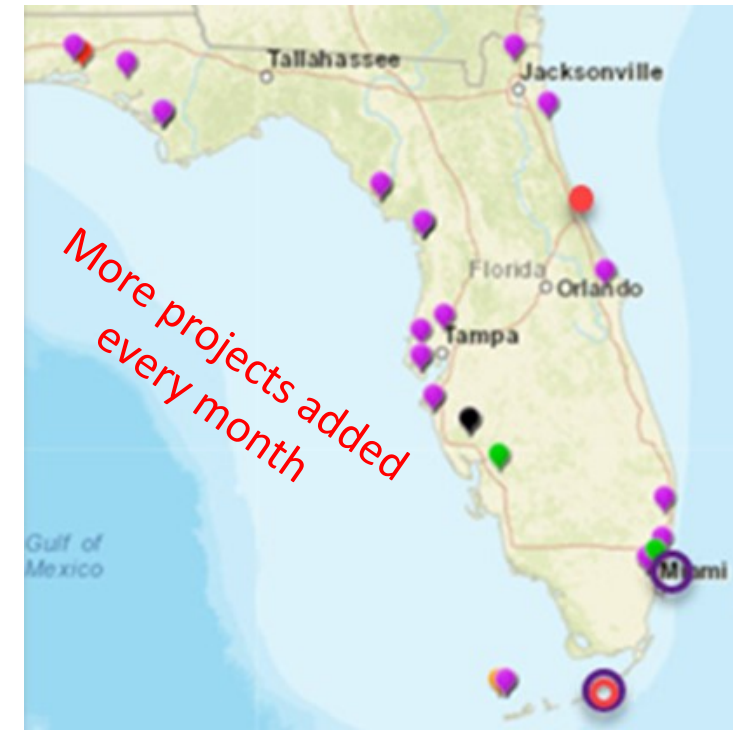
[Arthur Drive over Lynn Haven Bayou](#) \*\*  
[Bakers Haulover Cut Bulkhead Replacement](#) \*  
[Cedar Key Bulkhead Rehab](#) \*  
[Key West Bight Ferry Terminal Extension](#) \*\*  
[Halls River Bridge](#) \*\*\*  
[PortMiami Tunnel Retaining Walls](#)  
[South Maydell Dr over Palm River](#) \*  
[SR-A1A Flagler Beach Seawall \(Segment 3\)](#) \*  
[SR-5 \(US-17\) over Trout River Rehab](#) \*\*  
[SR-5 \(US 41\)/Morning Star and Sunset link-slabs](#)  
[SR-45 \(US 41\) over North Creek](#) \*\*\*  
[SR-312 over Matanzas River Rehab](#) \*\*  
[SR-520 over Indian River Bulkhead Rehab](#) \*  
[Sunshine Skyway Seawall Rehab & Extension](#) \*  
[UM Innovation Bridge](#) \*\*\*  
[UM Fate Bridge superstructure](#)  
[UM i-Dock](#) \*\*\*  
[US-1 over Cow Key Channel FSB's](#)

## Current Projects

4th St at Big Island Gap \*\*  
[40th Ave NE over Placido Bayou](#) \*\*\*  
Barracuda Blvd over Canal Bradano \*\*  
Bayway Structure-E Seawall Cap \*  
Bimini Dr over Duck Key Canal \*  
CR30A over Western Lake \*\*\*  
Jupiter Federal Observation Platform \*\*\*  
[NE 23<sup>rd</sup> Ave over Ibis Waterway](#) \*\*\*  
S. Maydell Dr/Palm River Bulkhead \*  
SR-A1A over [Myrtle Creek](#) and [Simpson Creek](#)  
SR-A1A N. Bridge Observation Platform \*\*\*  
SR 404 & 528 Indian & Banana Rivers Rehab \*  
SR5 over Oyster Creek \*  
SR 5/US 1 over Earman River Canal \*\*\*  
[SR-30 over St Joe Inlet](#) \*  
SR-112/I-195 Westshore waterway \*  
Village of North Bay Seawall \*  
West Wilson St over Turkey Creek \*\*

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

\* bulkhead/seawall only  
\*\* piling/substructure only  
\*\*\* complete bridge



# FRP structural member systems used in Florida's Highway Bridges & Structures

## Recent Completed Projects

- Acosta Bridge fender replacement \*
- Bayway Structure-E fender \*
- US-331/Choctawhatchee Bay fender wales
- [Halls-River Bridge - Hybrid Composite Beams](#)
- Howard Frankland Bridge NB fender \*
- [Ocala Water-Recharge Park Boardwalk](#) \*\*\*
- [Skyplex Blvd - Composite Arch Bridge](#) \*\*
- SR-A1A/Sisters Creek fender \*
- SR-A1A/Blue Heron fender replacement \*
- SR-3 over Barge Canal fender replacement \*
- SR-44 over Indian River fender replacement \*
- SR 714/South Fork St Lucie River \*



## Current & Future Projects

- Bimini Dr over Duck Key Canal ? \*\*
- CR510 3-Sided Culvert-Bridge ? \*\*
- [Marco Island Winter Berry Bridge](#)
- I-10/Apalachicola River Fender replace \*
- Jax. Main St Bridge Fender rehab \*
- SR-40 over Halifax River fender replacement \*
- SR-292 Perdido Key/ICWW fender replacement \*
- SR-520 over Indian River fender replacement \*
- US-192 over Indian River fender replacement \*
- SR-401 over Barge Canal fender replacement \*
- SR-518 over Indian River fender replacement \*



<https://www.fdot.gov/structures/innovation/frpms>

- \* complete fender system
- \*\* FRP concrete filled arch
- \*\*\* FRP pedestrian structure



# FRP Design Guidance, Specs, & Tools: Florida DOT



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

### Non-Corrosive

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

### Highly Corrosion-Resistant

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](#)

## “High-Performance Materials”

### 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**

# FRP Design Guidance, Specs, & Tools: Florida DOT

- **Mandatory Specifications**
- **Uniform Approval Processes**
  - Manufacturer Approval vs. Product Approval
- **Design Tools**



The screenshot shows the FDOT website's 'Structures Design' page. The main heading is 'Structures Design / Design Innovation' followed by 'Fiber Reinforced Polymer Reinforcing'. Below this, there is a sub-section for 'Fiber-Reinforced Polymer Members and Structures'. A navigation menu on the left includes 'Overview', 'Usage Restrictions / Parameters', 'Design Criteria', 'Specifications', 'Producer Quality Control Program', 'Projects', and 'Technology Transfer (T<sup>2</sup>)'. A search bar is visible at the top right of the page.

## FLORIDA DEPARTMENT OF TRANSPORTATION



## STRUCTURES MANUAL

- Volume 1 - Structures Design Guidelines
- Volume 2 - Structures Detailing Manual
- Volume 3 - FDOT Modifications to LRFDLTS-1
- Volume 4 - Fiber Reinforced Polymer Guidelines**

- Frequently Asked Questions
- 2018 Revision History
- Archived Structures Manuals
- Additional Links



## Materials Acceptance and Certification System

Select Report to View

Production Facility	
<a href="#">Aggregate Production Facility Listing</a>	Lists all Aggregate Production Facilities
<a href="#">All Producers (Excel)</a>	Lists all non-expired Production Facilities in an Excel file
<a href="#">Approved Aggregate Products For Friction Course</a>	Lists all Aggregate Friction Course Products by Geological
<a href="#">Approved Aggregate Products From Mines or Terminals Listing</a>	Lists Approved Aggregate Products for Mines or Terminals
<a href="#">Approved Products at Expired Mines or Terminals</a>	A summary report to identify Approved Products at Expired Terminals Expired at Mine
<a href="#">Asphalt Production Facility Listing</a>	Lists all Asphalt Production Facilities
<a href="#">Asphalt Recycled Products</a>	Approved Asphalt Recycled Products Report by Plant
<a href="#">Asphalt Targets</a>	A listing of the asphalt gradation and gravity (Gsb) data for /
<a href="#">Cementitious Materials Production Facility Listing</a>	Lists Cementitious Materials Production Facilities
<a href="#">Coatings Production Facility Listing</a>	Lists all Coatings Production Facilities
<a href="#">Fiber Reinforced Polymer Production Facility Listing</a>	Lists all Fiber Reinforced Polymer Production Facilities

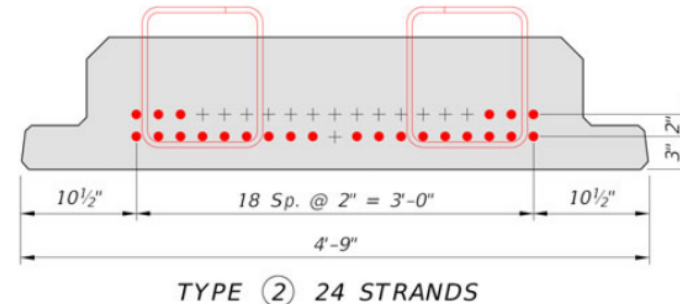
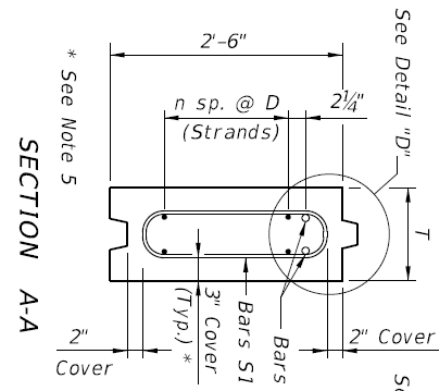
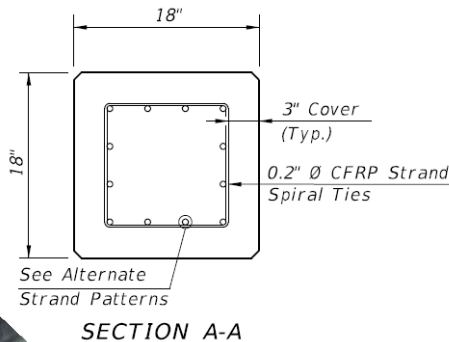
<https://www.fdot.gov/structures/innovation/>

# FRP Design Guidance, Specs, & Tools: Florida DOT

## Prestressed Concrete (CFRP-PC) Design & Construction Standards

Structures Foundations	
455-001	Square Prestressed Concrete Piles - Typical Details and Notes
455-101	Square CFRP and SS Prestressed Concrete Piles - Typical Details and Notes
455-102	Square CFRP and SS Prestressed Concrete Pile Splices
455-112	12" Square CFRP and SS Prestressed Concrete Pile
455-114	14" Square CFRP and SS Prestressed Concrete Pile
455-118	18" Square CFRP and SS Prestressed Concrete Pile
455-124	24" Square CFRP and SS Prestressed Concrete Pile
455-130	30" Square CFRP and SS Prestressed Concrete Pile
455-154	54" Precast/Post-Tensioned CFRP and SS Concrete Cylinder Pile
455-160	60" Prestressed CFRP and SS Concrete Cylinder Pile
455-400	Precast Concrete Sheet Pile (Conventional)
455-440	Precast Concrete Sheet Pile (CFRP/GFRP and HSSS/GFRP)

Florida Slab	
<b>D20450</b>	<b>Typical Florida Slab Beam Details and Notes</b>
Certification Statement	Permitted Projects FPID No(s):
<b>D20451</b>	<b>12" Florida Slab Beam</b>
Certification Statement	Permitted Projects FPID No(s):
<b>D20452</b>	<b>15" Florida Slab Beam</b>
Certification Statement	Permitted Projects FPID No(s):
<b>D20453</b>	<b>18" Florida Slab Beam</b>
Certification Statement	Permitted Projects FPID No(s):

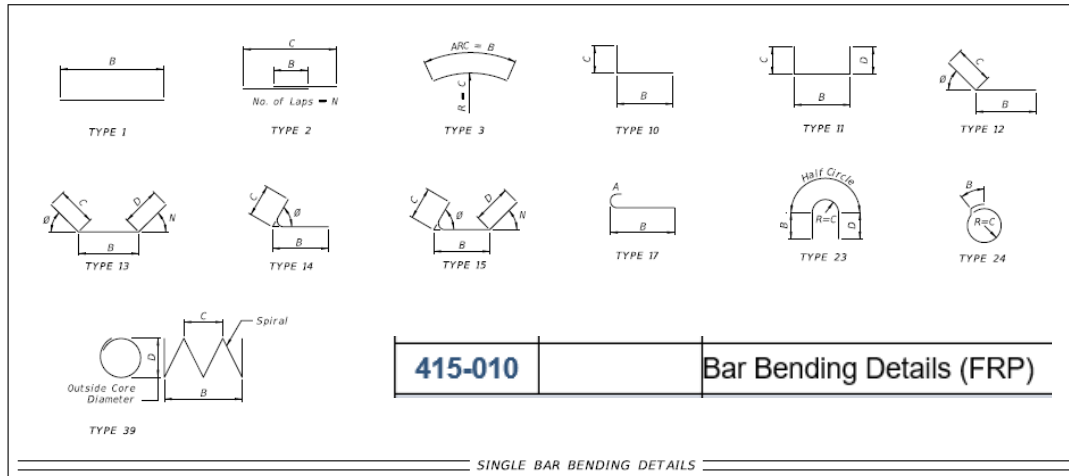


STRAND DESCRIPTION: USE 0.6" DIAMETER, CARBON FRP STRANDS, MEETING THE



# FRP Design Guidance, Specs, & Tools: Florida DOT

## Reinforced Concrete (RP-RC) Design & Construction Standards



### FRP REINFORCED TRAFFIC RAILINGS RAILINGS

**D22420** Traffic Railing (32" F Shape - GFRP Reinforced)

**Certification Statement**

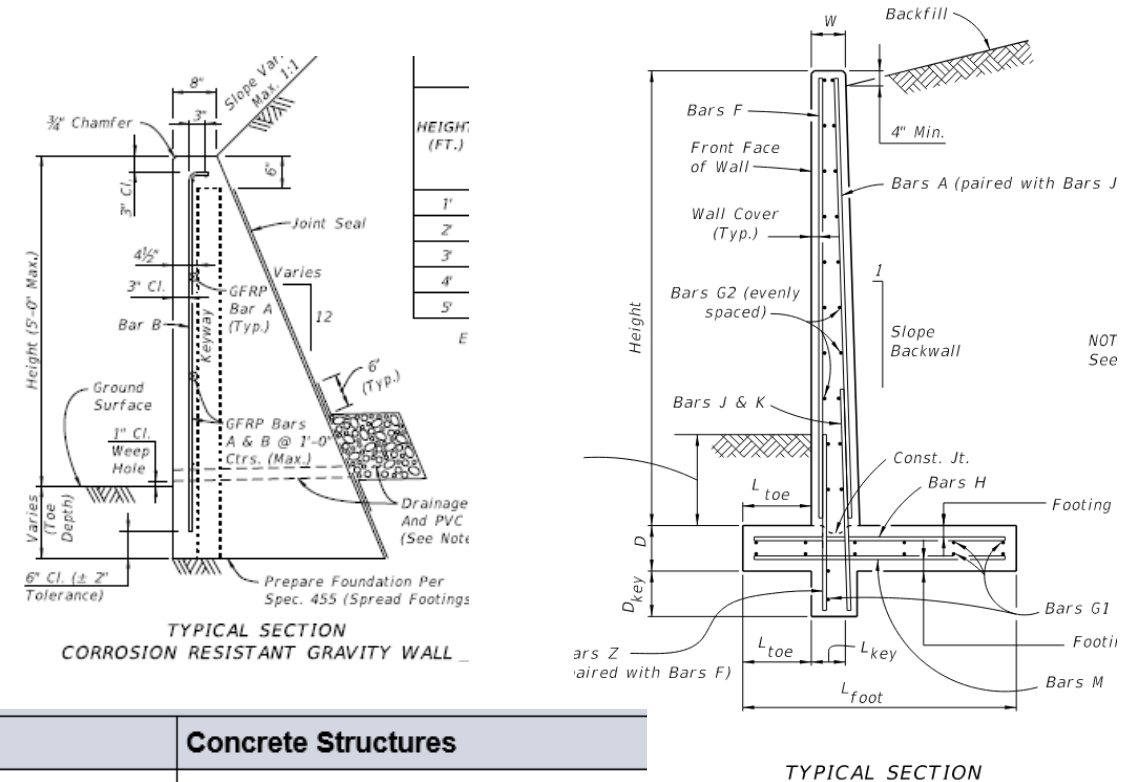
Permitted Projects FPID No(s):  
430021-1

### FRP REINFORCED APPROACH SLABS

**D22900** Approach Slab - GFRP Reinforced (Flexible Pavement Approach)

**Certification Statement**

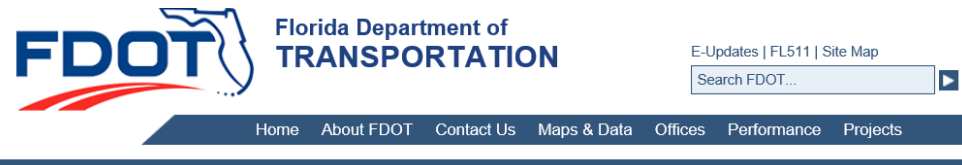
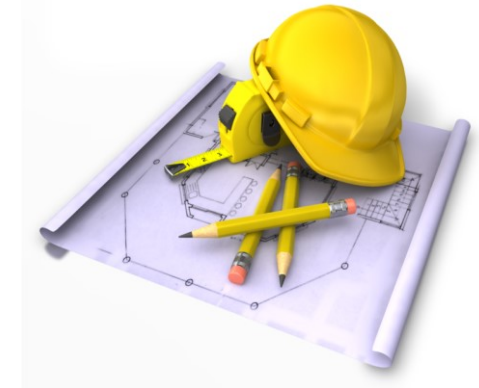
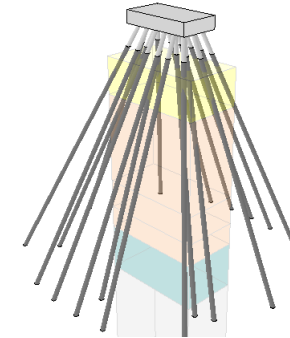
Permitted Projects FPID No(s):  
430021-1



Concrete Structures	
<b>400-010</b>	Cantilever Retaining Wall (C-I-P)
<b>D6011c</b>	Gravity Wall - Option C (GFRP Reinforced)
<b>Certification Statement</b>	Permitted Projects FPID No(s): 405600-2 430021-1

# FRP Design Guidance, Specs, & Tools: Florida DOT +

- Mandatory Specs
- Uniform Approval Processes
  - Manufacturer Approval vs. Product Approval
- Design Tools – Structural software

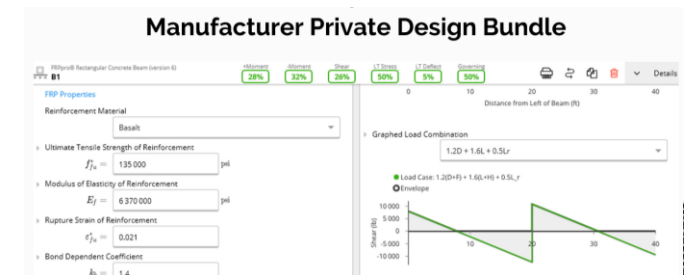


## Other's Design Software:

### 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*)
- **DeepEx** ([Deep Excavation, LLC](#)) *available*
- **FRPpro™** *pending*
- ...

Structures Design			
Structures Design Programs Library	<b>Box Culvert v4.0</b>	11/07/2018	Exe (Zip) (Mathcad 15)
	<i>(FRP-RC in development)</i>		
<i>V6.0 coming early 2021 →</i>	<b>Prestressed Beam v5.2</b>	11/07/2018	Exe (Zip) (Mathcad 15)
	<i>(beta version CFRP-PC)</i>		
<i>Includes FRP-RC →</i>	<b>Bent Cap v1.0</b>	11/07/2018	Exe (Zip) (Mathcad 15)
<i>Includes FRP-RC →</i>	<b>Retaining Wall v4.0</b>	06/01/2020	Zip (Exe) (Mathcad 15)





# LCC Design Guidance & Tools: AASHTO/NCHRP/ASCE

- Mandatory Specs
- Uniform Approval Proc  
- Manufacturer Approval v
- Design Tools –  
**SLD & LCC Guides**

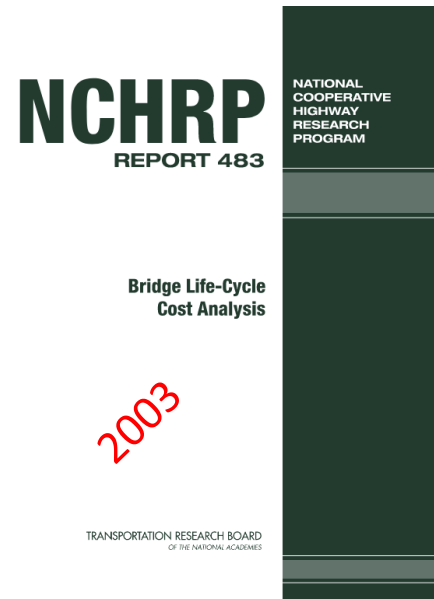
**GUIDE SPECIFICATION FOR SERVICE LIFE DESIGN OF HIGHWAY BRIDGES, 1<sup>ST</sup> EDITION**  
Item Code: HBSLD-1

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.

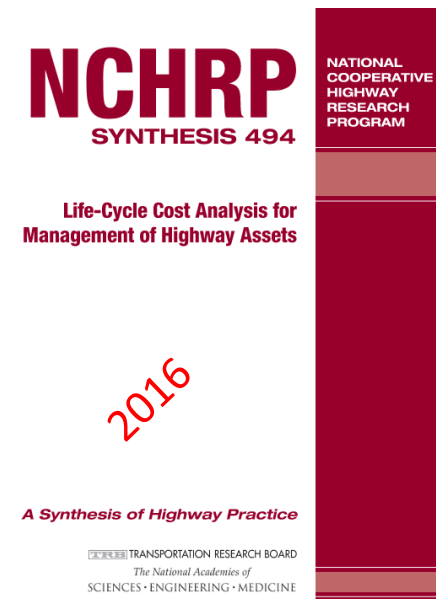


2020

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



2003



2016

**Life-Cycle Design, Assessment, and Maintenance of Structures and Infrastructure Systems**

Edited by  
Fabio Biondini  
Dan M. Frangopol

Dec. 2019



# LCC Design Guidance & Tools: USDOT/NIST

- Mandatory Specs
- Uniform Approval Processes
  - Manufacturer Approval vs. Product Approval
- Design Tools – LCC software



<https://www.nist.gov/services-resources/software/bridgelcc>

**BridgeLCC 2.0 Users Manual**  
Life-Cycle Costing Software for the Preliminary Design of Bridges

Inflation: 2.00% Real discount: 1.00%  
Nominal: 3.02%

Current mode: Basic

**Edit costs of alternatives**

	BC	Alt. 1	Alt. 2
<b>Total (\$)</b>	<b>\$125,214,074</b>	<b>\$110,317,457</b>	<b>\$115,307,746</b>

**Costs by bearer**

	BC	Alt. 1	Alt. 2
<input checked="" type="checkbox"/> Agency	\$125,214,074	\$110,317,457	\$115,307,746
<input checked="" type="checkbox"/> User	\$0	\$0	\$0
<input checked="" type="checkbox"/> Third Party	\$0	\$0	\$0

**Costs by timing**

	BC	Alt. 1	Alt. 2
<input checked="" type="checkbox"/> Initial Construction	\$113,379,257	\$124,717,182	\$130,386,145
<input checked="" type="checkbox"/> O, M, and R	\$3,993,395	\$531,129	
<input checked="" type="checkbox"/> Disposal	\$7,841,422	-\$14,930,854	

**Costs by component**

Elemental	BC	Alt. 1	Alt. 2
<input checked="" type="checkbox"/> Deck	\$0	\$0	\$0
<input checked="" type="checkbox"/> Superstructure	\$0	\$0	\$0
<input checked="" type="checkbox"/> Substructure	\$0	\$0	\$0
<input checked="" type="checkbox"/> Other	\$0	\$0	\$0

**Results**

	BC	Alt. 1	Alt. 2
<input checked="" type="checkbox"/> Non-elemental	\$125,214,074	\$110,317,457	
<input checked="" type="checkbox"/> New-technology introduction	\$0	\$0	

Overview | Run Simulation | View Results | Interpreting Monte Carlo results

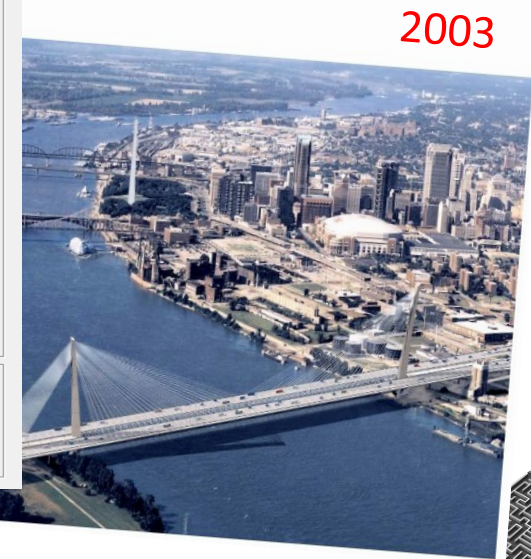
Graph of results

cycle costs, grouped in 20 bins (samples = 5000)

Bin	Alt1	Alt2	Alt3	Alt4	Alt5
1	\$132,912,421	\$134,704,342	\$136,496,264	\$138,288,185	\$140,080,106
2	\$141,872,028	\$143,663,949	\$145,455,871	\$147,247,792	\$149,039,713
3	\$150,831,636	\$152,623,556	\$154,415,477		

Replacement with FRP-RC/PC   
  Replacement with SS-RC/PC

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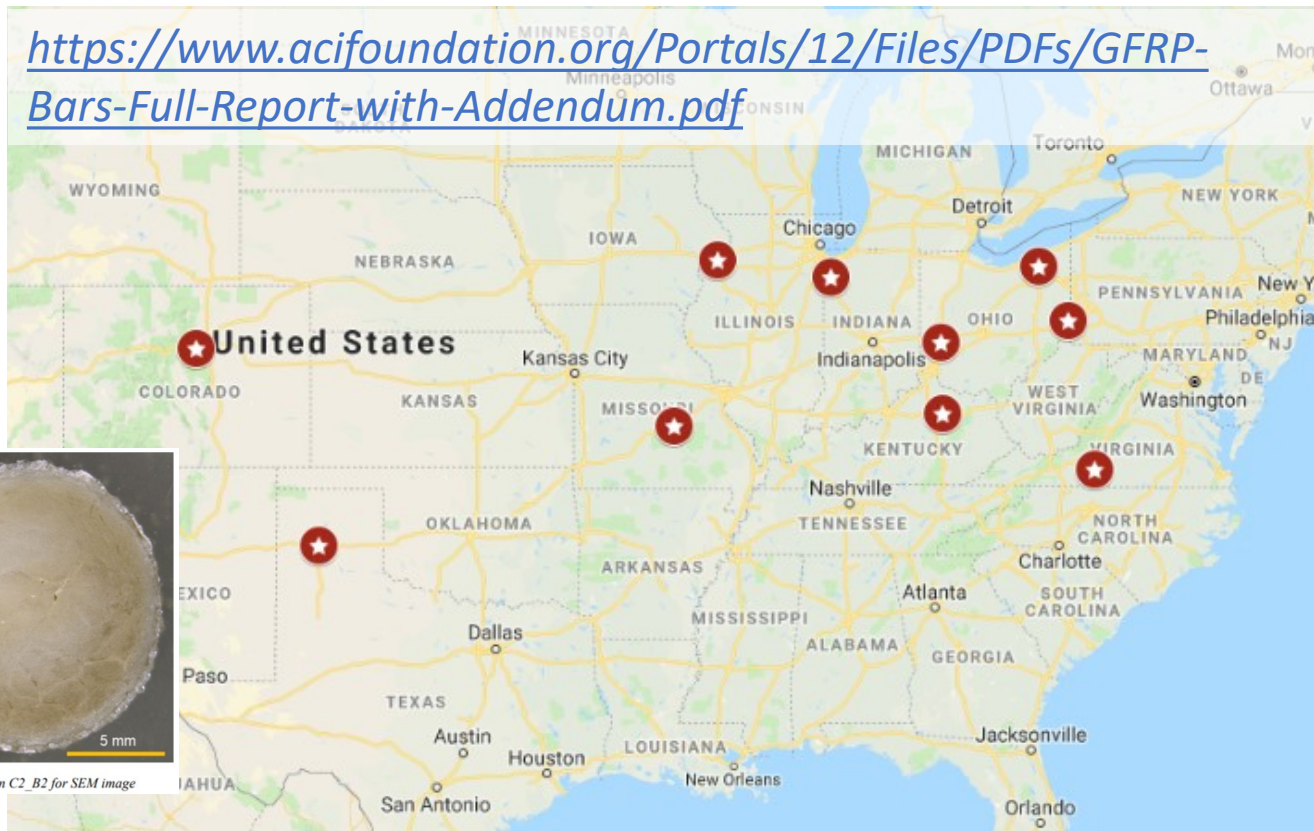


# FRP-RC Evaluation of Durability: **ACI selected Bridges**

- **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>



- 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)

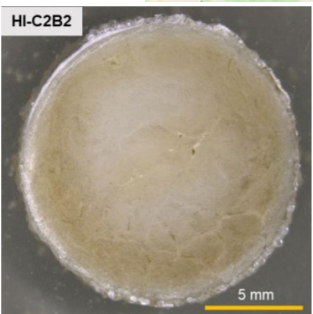


Fig. 34 -- Specimen C2\_B2 for SEM image

# FRP-RC Evolution from Durability Research

- **Environmental Reduction Factors** will be relaxed (~20-25%) for GFRP 100-year+
- **BFRP** rebar will be broadly adopted, sooner rather than later, if recent import tariffs are rescinded (~30%)
- **B&G-FRP** rebar design stiffness and strength will be significantly increase (~20-25%)
- **B&G-FRP** creep rupture limits will increase (20~30%), so partial/mild prestressing will become feasible.
- **Thermoplastic resin** FRP rebar will become predominant for bent bars
- **Sustainability** will become more important , so
- **FRP synergy** with recycled aggregates, seawater, & by-product SCM's will be advantageous.



**PROPOSED REVISIONS TO THE ACCEPTANCE CRITERIA FOR FIBER-REINFORCED POLYMER (FRP) BARS FOR INTERNAL REINFORCEMENT OF CONCRETE MEMBERS**

AC454

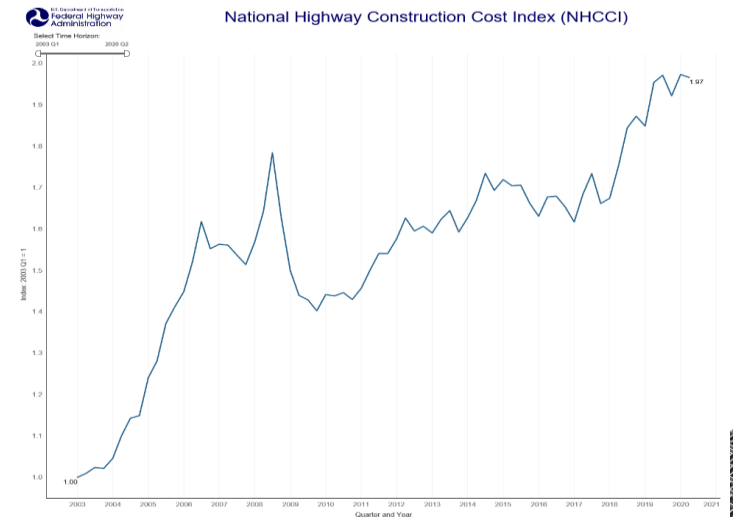
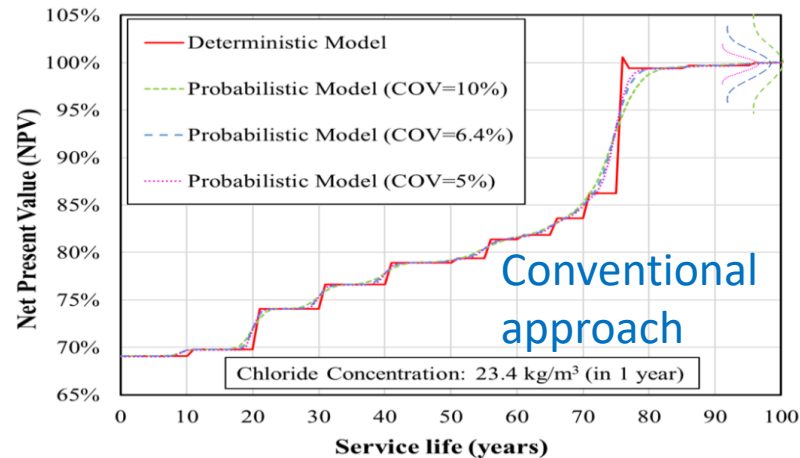
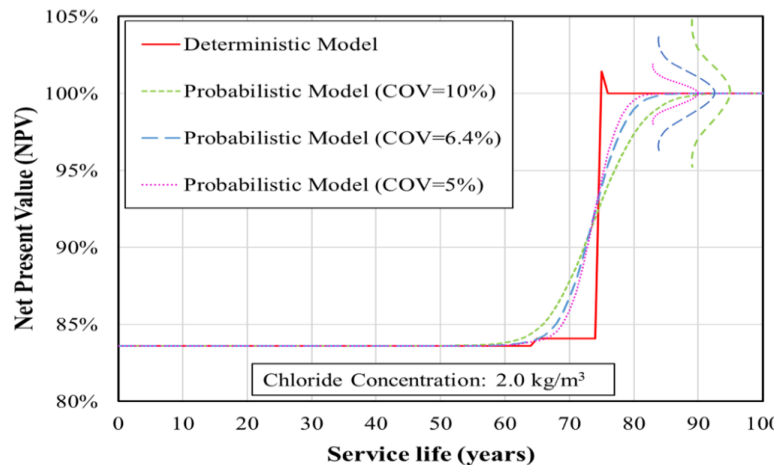
**Proposed December 2020/Approved June 2020**

Previously approved June 2020, February 2017, June 2016, May 2015 and June 2014

*Parallel progress for Building Codes*

# Life-Cycle Cost analysis

- Comparisons and synergies
  - Economics is in the eye of the beholder
  - Save now, \$\$\$ later or \$\$\$ now adaption 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”

# Life-Cycle Cost analysis

- Comparisons and synergies
  - Conventional-RC with periodic Repair & Rehabilitation

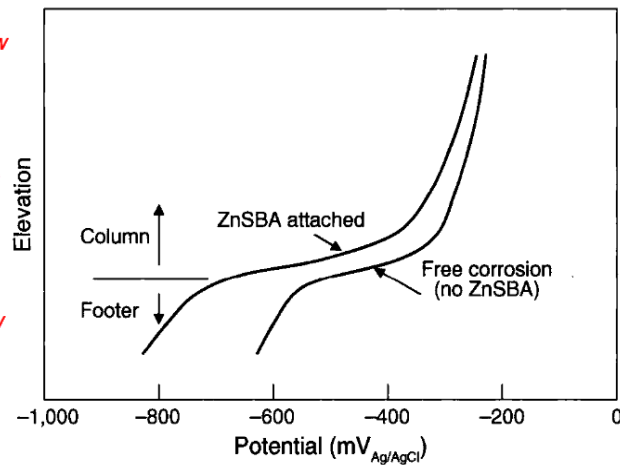
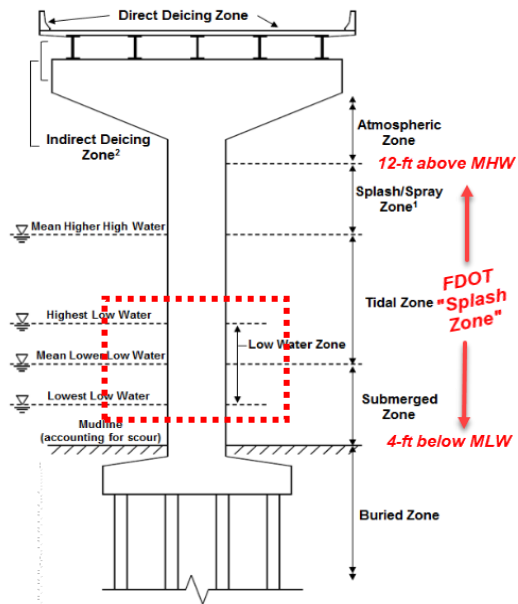
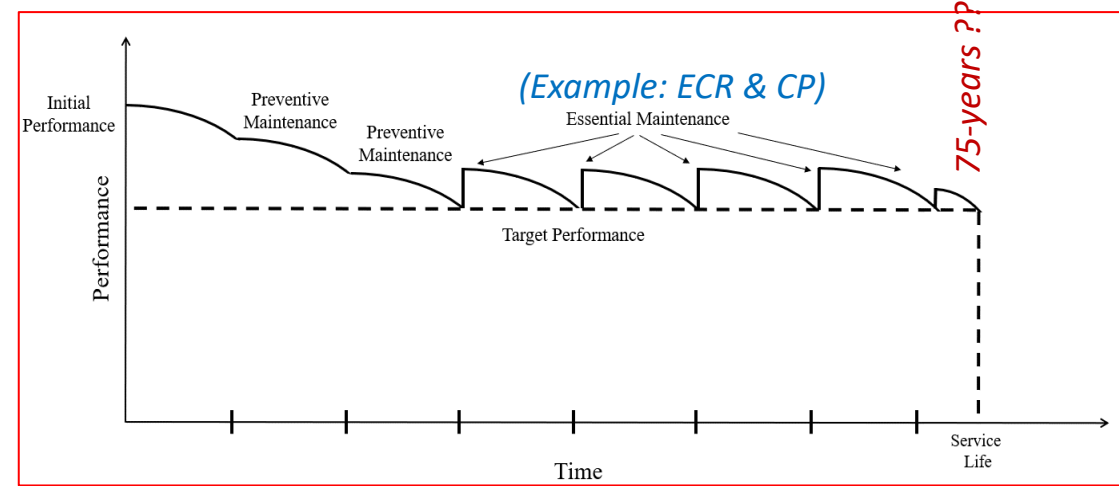


FIGURE 10. Schematic illustration of the potential shift of footer and column reinforcement that is expected to accompany ZnSBA activation.

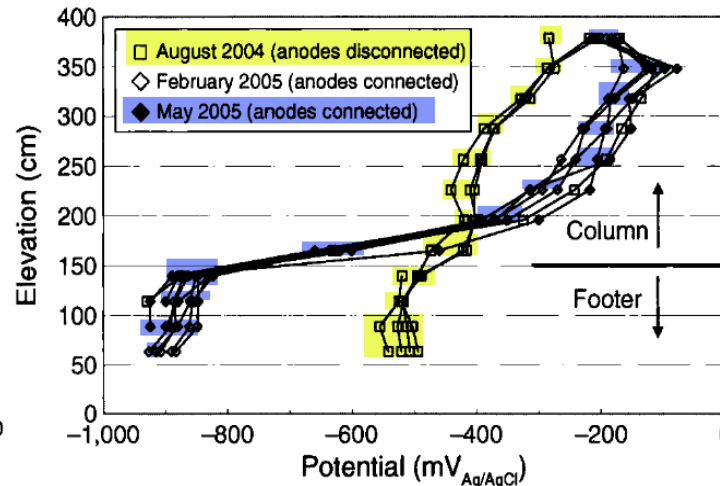


FIGURE 8. Free corrosion and polarized potentials as a function of elevation for the footer and column on Pier 40W-East. Elevation is referenced to the bottom of the footer.

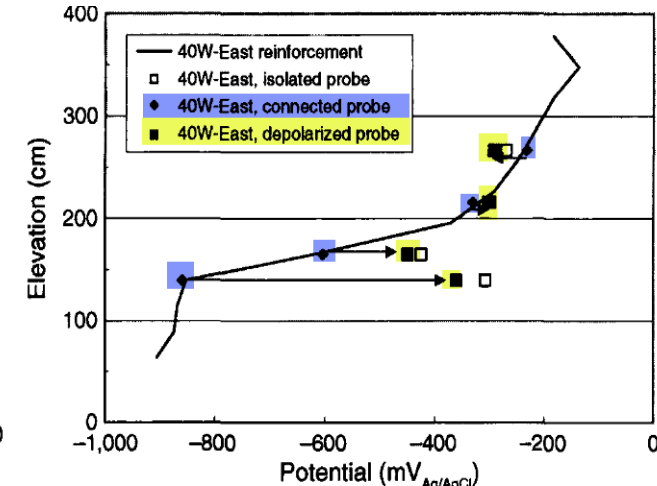
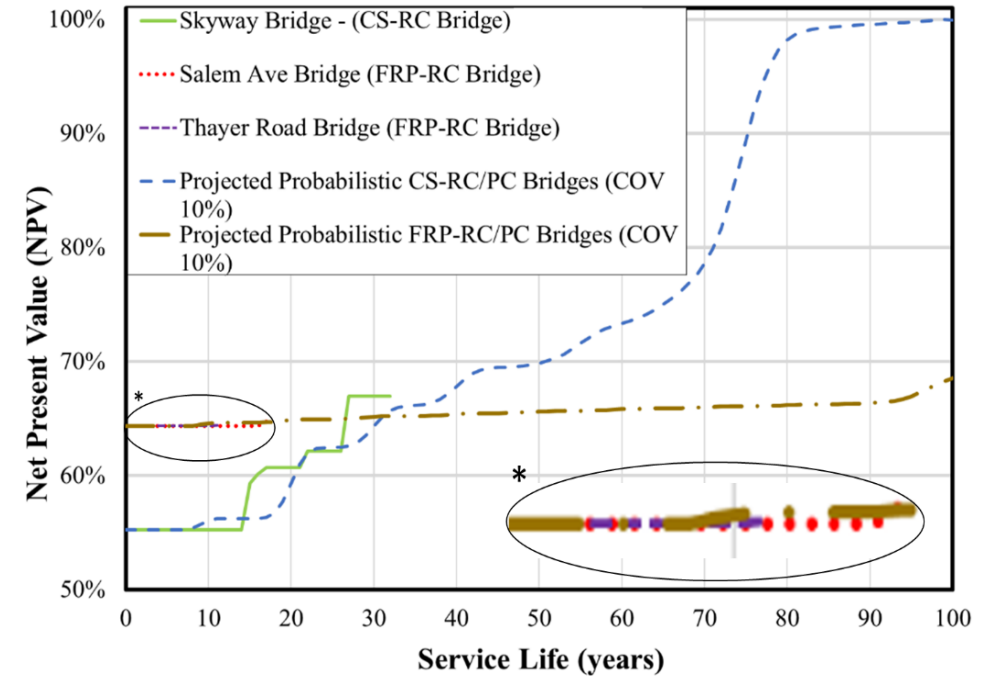
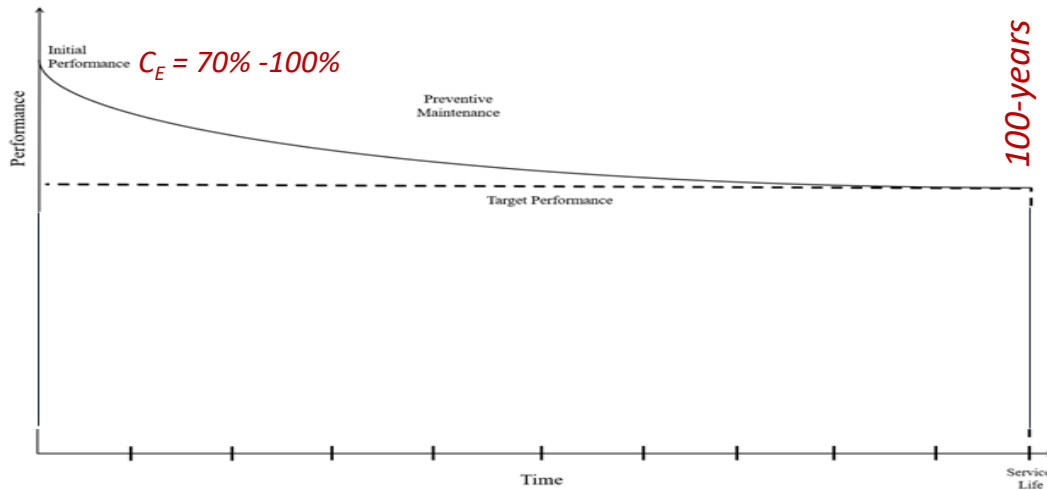
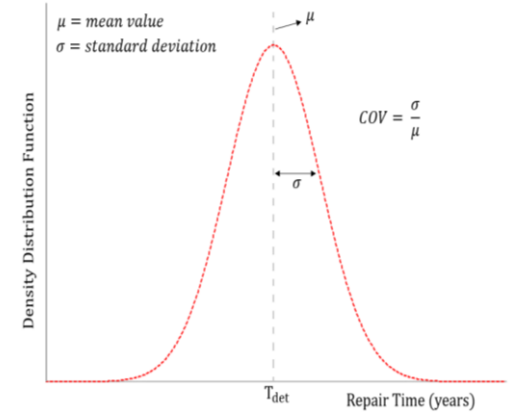


FIGURE 13. Polarized potential data for reinforcement and free corrosion, polarized, and depolarized potentials for probes on pier 40W-East.

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

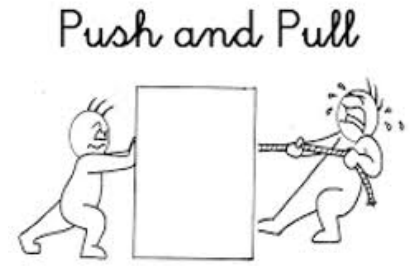
# Life-Cycle Cost analysis

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



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

# Forecasting the Future



BIDEN-HARRIS  
TRANSITION

President-Elect Vice President-Elect Nominees and Appointees

## • new Federal “Push Factor”



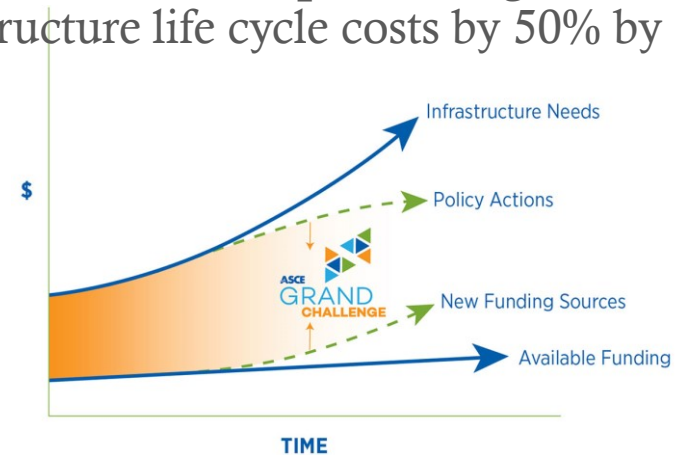
<https://buildbackbetter.gov/priorities/>

President-elect Biden is working to make far-reaching investments in:

- **Infrastructure:** Create millions of good, union jobs rebuilding America’s crumbling infrastructure – from roads and bridges to green spaces and water systems to electricity grids and universal broadband – to lay a new foundation for sustainable growth, compete in the global economy, withstand the impacts of climate change, and improve public health, including access to clean air and clean water.
- **Innovation:** Drive dramatic cost reductions in critical clean energy technologies, including battery storage, negative emissions technologies, the next generation of building materials, renewable hydrogen, and advanced nuclear – and rapidly commercialize them, ensuring that those new technologies are made in America.

## • Industry “Push Factors”

- **Closing the infrastructure Gap:** Shared goal of reducing infrastructure life cycle costs by 50% by 2025



## • State/Owner “Pull Factors”

- **Reducing Asset Management Risk:** limit need for corrosion related repairs, MOT, etc.
- **Benefits from Enlarging the Market:** increase supply chain security, regional manufacturing opportunity, etc.



# Technology Transfer & Future Development

- Strategies

- Seek to inform, not to persuade... *Inception!*
- Recognize that it is easier to do nothing than to change
- Encourage ownership of the challenges...



- Engagement and Education

- Need for mentorship of future designers
- Foster passion and curiosity
- Engineers can learn best, by doing



# Technology Transfer & Future Development

- **8th International Conference on Advanced Composite Materials in Bridges and Structures (ACMBS-VIII)**

August 5-7, 2021, **Online**, <https://acmbs2020.ca/>

**Person-contact :** Professor Brahim Benmokrane, University of Sherbrooke,  
E-mail :brahim.benmokrane@usherbrooke.ca



UNIVERSITÉ DE  
SHERBROOKE

- **Third International Workshop on GFRP Bars for Concrete Structures (IW-GFRP-3)**  
- **Workshop Theme : 'Advances in concrete reinforcement'**

August 3-4, 2021, **Online**, <https://acmbs2020.ca/iw-gfrpcs3/>

**Person-contact :** Professor Brahim Benmokrane, University of Sherbrooke,  
E-mail :brahim.benmokrane@usherbrooke.ca



# Conclusions

- Seek to inform, not to persuade
- Be good custodians for public infrastructure
- **Get familiar... FRP is here to stay as an essential tool for our future!**

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



# Questions ???



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