Corrosion Prevention and Mitigation

Highway Bridges

Virtual/In-Person Peer Exchange #2

Feb. 08, 2023 / Feb. 28 – Mar. 02, 2023

MS Teams / Orlando, FL

FDOT – Introductory Presentation

State Participant Introductions

Name (Rep. #1):	**Steven Nolan**
Position (Title):	Senior Structures Design Engineer
Years in Position:	8-years
Role / Responsibilities:	Structures Design coordination of corrosion-resistant materials
Relevant Experience:	26-years with FDOT, 4-years with Australian Contractor

Name (Rep. #2):	**Felix Padilla**
Position (Title):	State Structures Maintenance Engineer
Years in Position:	1
Role / Responsibilities:	Manage the following programs: Inspection, Repair and Maintenance, Load Rating, Evaluation and Permits of Bridges and Ancillary Structures.
Relevant Experience:	Inspection of steel railroad bridges with corrosion, Investigation of segmental bridges.

Presentation Outline

Part 1: Existing / In-service Bridges

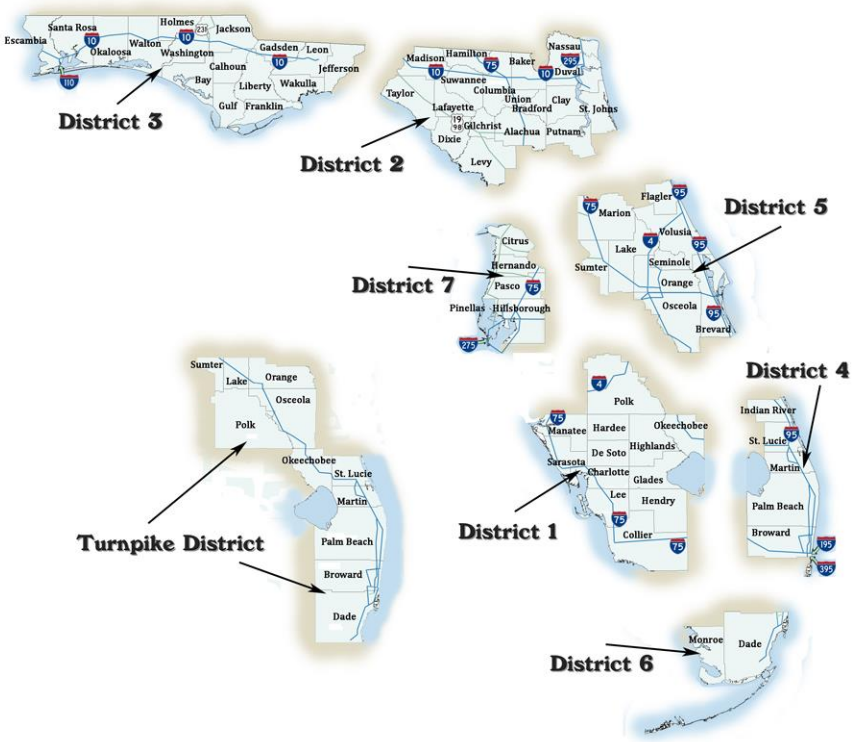
- **Agency Organizational Structure**
- **Bridge Assets Managed**
- **Bridge Corrosion Prevention and Mitigation**
  - My Agency's Greatest Challenges
  - My Agency's Greatest Successes
  - My Agency's Future Endeavors

Part 2: New Bridges / Bridge Design

- **Agency Organizational Structure**
- **Designing Bridges for Enhanced Durability and Resilience**
  - My Agency's Greatest Challenges
  - My Agency's Greatest Successes
  - My Agency's Future Endeavors

Part 1: Existing / In-service Bridges

Agency Organizational Structure

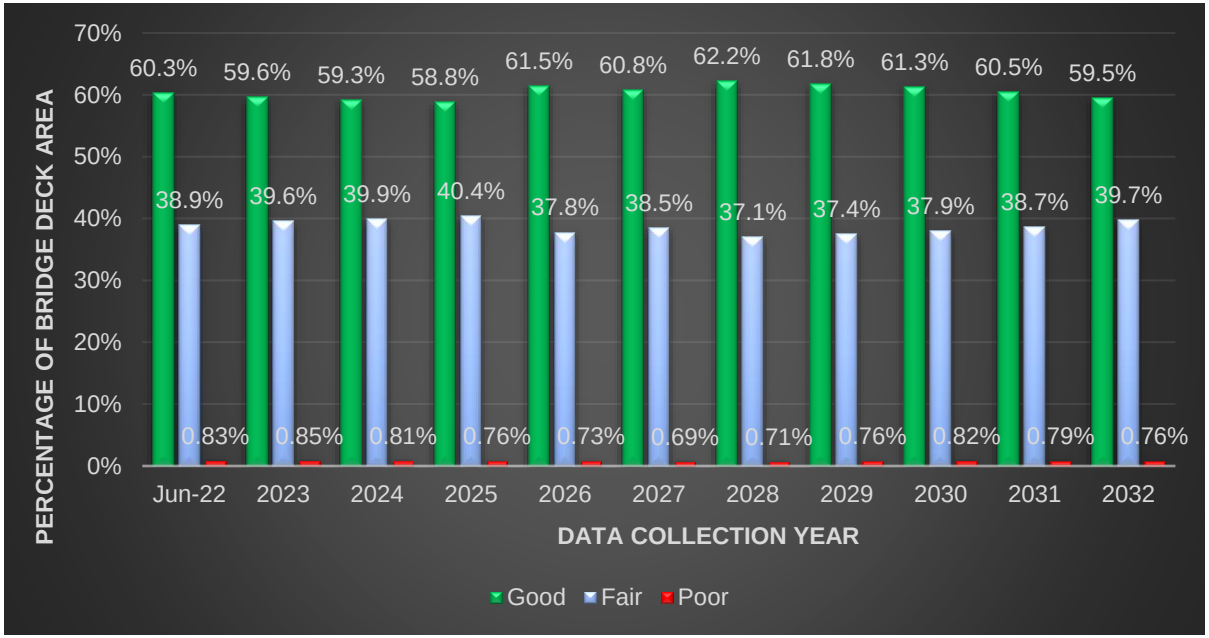


- Central Office: Policy, Procedures, Work Program
- Districts: Operations – Inspections, Repairs, Asset Management

Part 1: Existing / In-service Bridges

Agency Overview for Corrosion Prevention & Mitigation:

- Policies and Procedures
  - Florida Standards
    - F.S. 334.046 - Mission and Goals
- TAMP
  - Targets



Part 1: Existing / In-service Bridges

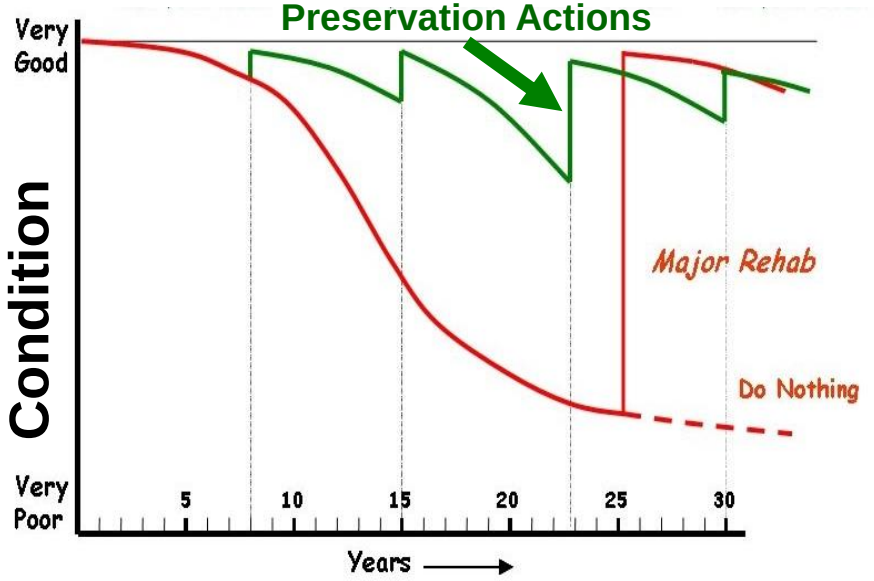
Agency Overview for Corrosion Prevention & Mitigation:

- In-Service Inspections
  - Bridge inspections
    - Recommendations
  - Work orders
    - FARC meetings
    - Classification/Priority
  - Follow-up actions
    - Work completion
    - QA/QC

Part 1: Existing / In-service Bridges

Agency Overview for Corrosion Prevention & Mitigation:

- Bridge Asset Management
  - Software
    - AASHTOWare BrM
    - In-house BMS
  - Research
    - Deterioration curves
    - Bridge Element Performance Measures

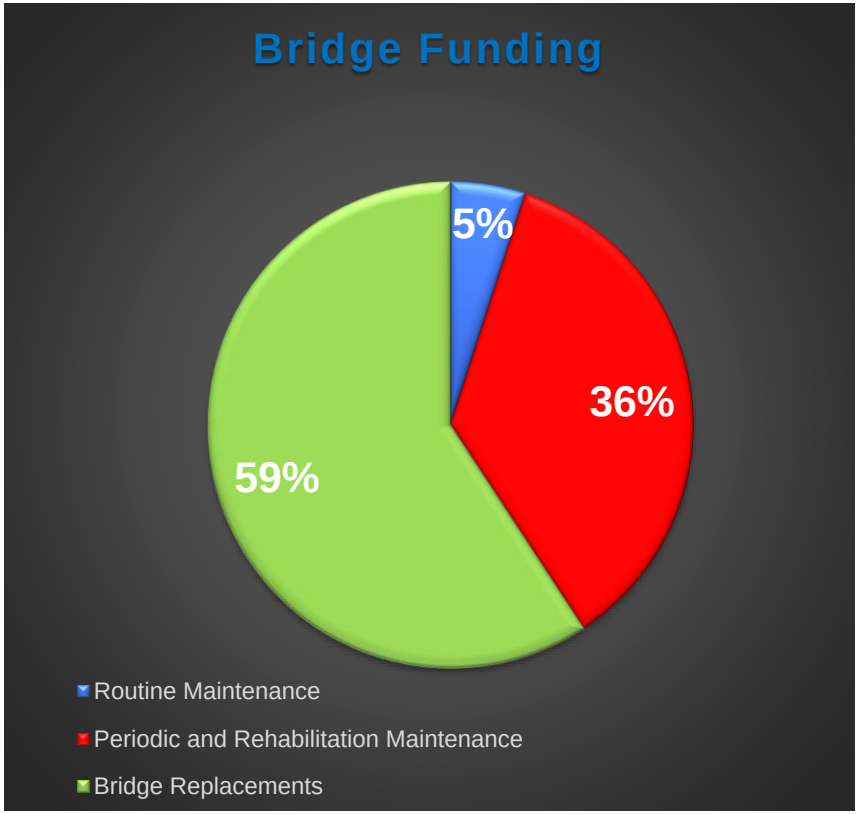


Steel Protective System: At least 95% of protective system area is in CS1 / CS2 with less than 1% of area including Peeling/Bubbling/Cracking (3420) and significant Effectiveness (3440) Defects.

Part 1: Existing / In-service Bridges

Agency Overview for Corrosion Prevention & Mitigation:

- Planning/Funding/Programming
  - Bridge Maintenance
    - Routine
    - Rehabilitation and Periodic Maintenance
  - Bridge Replacement
    - Strength Replacement
    - Economy Replacement



Part 1: Existing / In-service Bridges

Bridge Assets Managed (>20 ft. NBI)

❑ Steel

Steel Bridges - State Owned				
NBI Rating	Deck Area	%	Number Of Bridges	%
9	350,899	1%	12	1%
8	5,248,531	13%	218	21%
7	22,376,749	56%	536	53%
6	8,360,500	21%	158	16%
5	3,723,060	9%	66	7%
4	160,537	0%	24	2%
3	-	0%	0	0%
2	-	0%	0	0%
1	-	0%	0	0%
Total	40,220,276	100%	1014	100%

Steel Bridges - Locally Owned				
NBI Rating	Deck Area	%	Number Of Bridges	%
9	79,245	1%	8	2%
8	702,702	11%	41	10%
7	2,627,734	43%	127	30%
6	1,513,714	25%	108	25%
5	864,345	14%	83	19%
4	263,342	4%	43	10%
3	71,921	1%	11	3%
2	5,908	0%	6	1%
1	1,279	0%	1	0%
Total	6,130,192	100%	428	100%

Part 1: Existing / In-service Bridges

Bridge Assets Managed (>20 ft. NBI)

❑ Reinforced concrete

Reinforced Concrete Bridges - State Owned				
NBI Rating	Deck Area	%	Number Of Bridges	%
9	1,641	0%	2	0%
8	72,917	2%	38	3%
7	1,462,854	44%	522	43%
6	1,430,828	43%	586	48%
5	267,382	8%	65	5%
4	81,298	2%	7	1%
3	-	0%	0	0%
2	-	0%	0	0%
1	-	0%	0	0%
Total	3,316,920	100%	1220	100%

Reinforced Concrete Bridges - Locally Owned				
NBI Rating	Deck Area	%	Number Of Bridges	%
9	7,696	0%	4	0%
8	125,183	5%	109	7%
7	1,358,409	56%	793	52%
6	610,375	25%	416	27%
5	194,181	8%	151	10%
4	105,717	4%	45	3%
3	10,131	0%	4	0%
2	-	0%	0	0%
1	-	0%	0	0%
Total	2,411,691	100%	1522	100%

Part 1: Existing / In-service Bridges

Bridge Assets Managed (>20 ft. NBI)

❑ Prestressed Concrete

Prestressed Concrete Bridges - State Owned				
NBI Rating	Deck Area	%	Number Of Bridges	%
9	2,694,574	2%	106	3%
8	16,165,190	14%	958	23%
7	73,167,951	64%	2689	64%
6	14,520,615	13%	308	7%
5	7,300,263	6%	130	3%
4	1,057,317	1%	33	1%
3	-	0%	0	0%
2	-	0%	0	0%
1	-	0%	0	0%
Total	114,905,910	100%	4224	100%

Prestressed Concrete Bridges - Locally Owned				
NBI Rating	Deck Area	%	Number Of Bridges	%
9	569,009	3%	31	1%
8	3,867,800	17%	362	16%
7	12,172,421	54%	1262	56%
6	3,003,566	13%	222	10%
5	2,097,204	9%	277	12%
4	815,040	4%	105	5%
3	50,132	0%	10	0%
2	-	0%	0	0%
1	-	0%	0	0%
Total	22,575,172	100%	2269	100%

Part 1: Existing / In-service Bridges

Bridge Corrosion Prevention and Mitigation

- **My Agency's Greatest Challenges**
  - Saltwater environment
  - Durability of coating systems
- **My Agency's Greatest Successes**
  - State Materials Office
  - Economy replacements
  - Bridge element performance measures
- **My Agency's Future Endeavors**
  - Coatings warranty
  - Scour monitoring

Part 2: New Bridges / Bridge Design

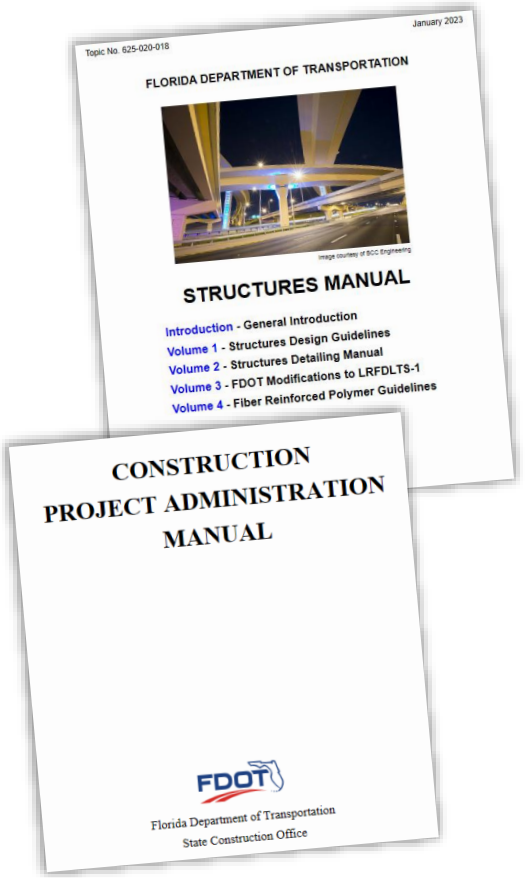
Agency Organizational Structure

- **Roles / Responsibilities for Enhancing Durability & Resilience of New Highway Bridges:**
  - Central Office Policy & Procedure.
  - ***Developmental Specifications*** and ***Developmental Standard Plans*** for tentative implementation.
  - ***Structures Advanced Material Technical Advisory Group (SAMTAG)*** meets quarterly on (FRP, SS, & UHPC).
- **Distinctions or Differences of Roles / Responsibilities among Central Office, Districts/Regions, Locals, Consultants**
  - 8 District Offices do very limited in-house design for bridges.
  - Most design is by Consultants for state and local bridges.
  - Large projects >$200M are most commonly **Design-Build.**

Part 2: New Bridges / Bridge Design

Agency Overview of Design for Durability & Resilience:

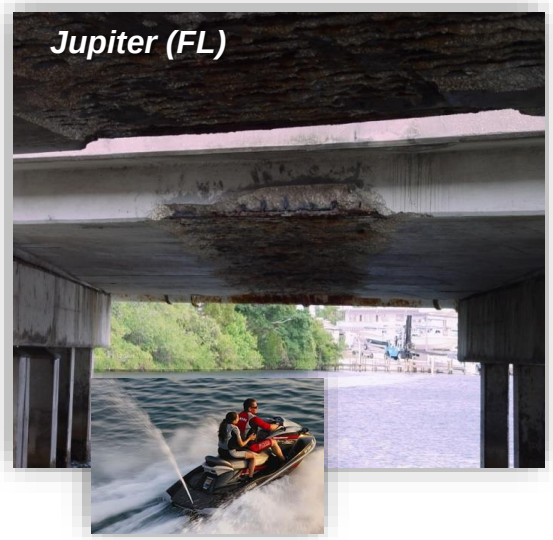
- **Policies and Procedures:** Structures Manual (***SM***)
  https://www.fdot.gov/structures/structuresmanual/currentrelease/structuresmanual.shtm
- **Innovative Materials:** *Webpages* & ***SM-Vol.4***
  - *Fiber Reinforced Polymer Reinforcing*
  - *FRP Members and Structures*
  - *Ultra-High Performance Concrete (UHPC)*
- **Design Methodology:** ***SM-Vol.1***
- **Construction Technology:**
  - *FTBA Construction Conference*
- **Construction QA/QC:**
  - *Construction Project Administration Manual*



Part 2: New Bridges / Bridge Design

Designing Bridges for Durability and Resilience

- **My Agency's Greatest Challenges**
  - Saltwater Corrosion
  - Jet Ski's Spray
  - Boat Trailers drip seawater on decks
- **My Agency's Greatest Successes**
  - FRP-Reinforced Concrete Design
  - FRP & HSSS Prestressed Concrete Design
- **My Agency's Future Endeavors**
  - UHPC Prestressed and CIP Connections
  - Reconsidering SS-Clad & UHPC
  - Expansion of FRP Applications,
  - New SCM's for concrete mix design and performance based concrete acceptance criteria



FDOT Innovations in Corrosion Prevention and Mitigation for Highway Bridges

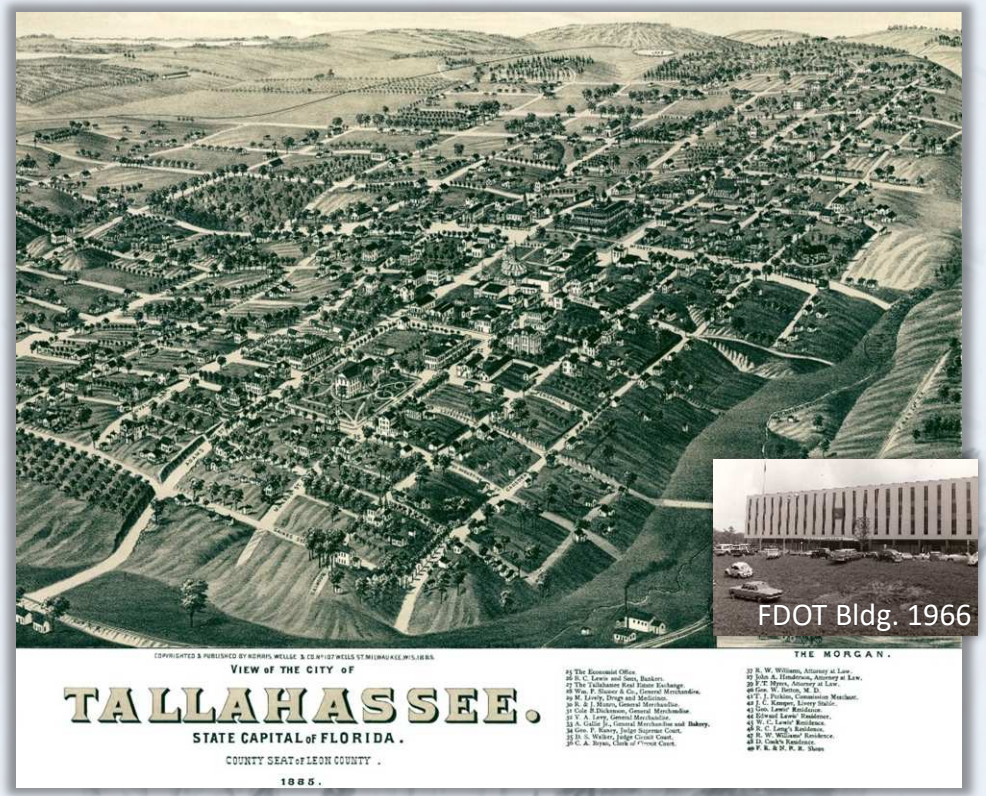
FHWA Virtual Peer Exchange #2

February 8th,2023.

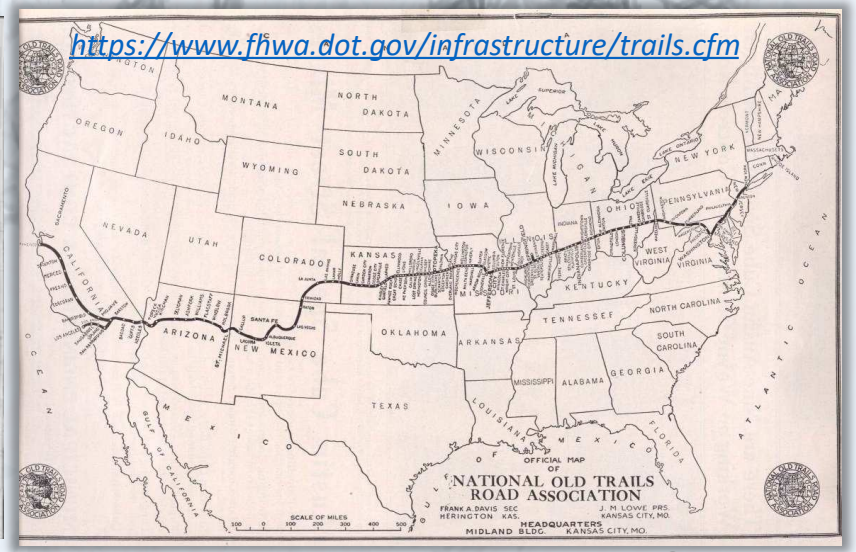
In the Beginning….

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

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

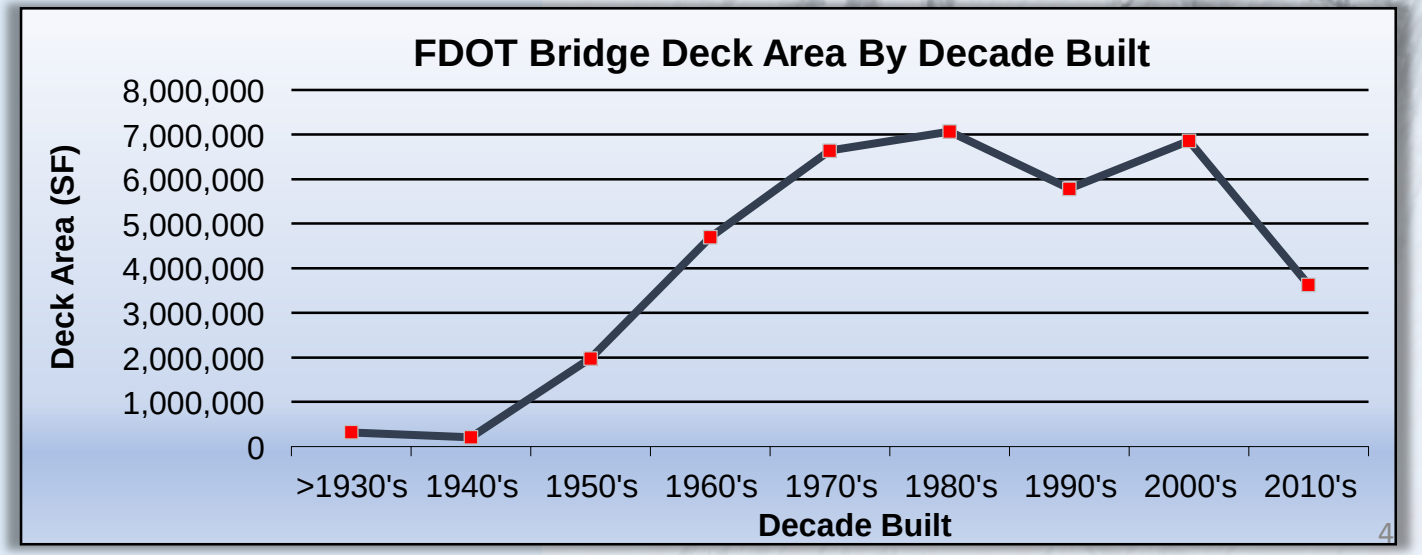


- **1914** Old Trails Road Assoc. plan
- **1915** FL State Road Dept. born.
- **1917** Florida roadmap network.
- **1956** National Interstate and Defense Highways Act signed.
- **1993** Last time the federal gasoline tax was raised *(18.4 cents/gal)*



… thru the Interstate Era …

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



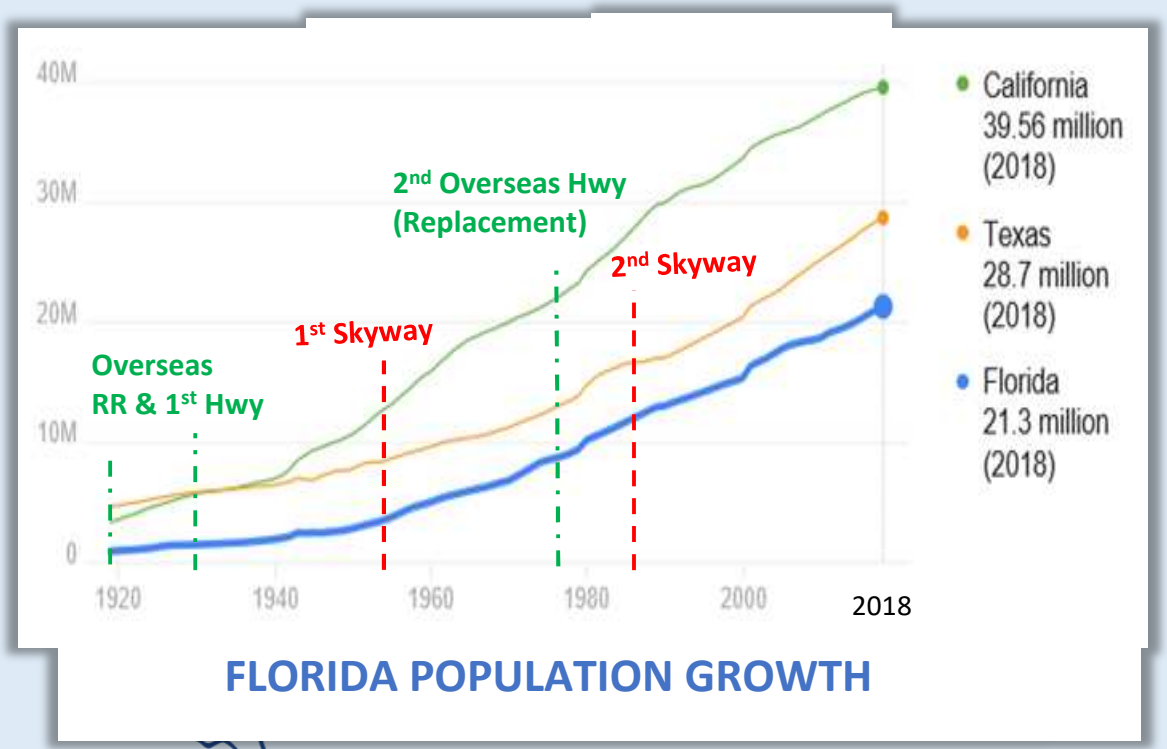
Innovations: Errors, Omissions, & Oversights Happen …

→ Lessons Learned

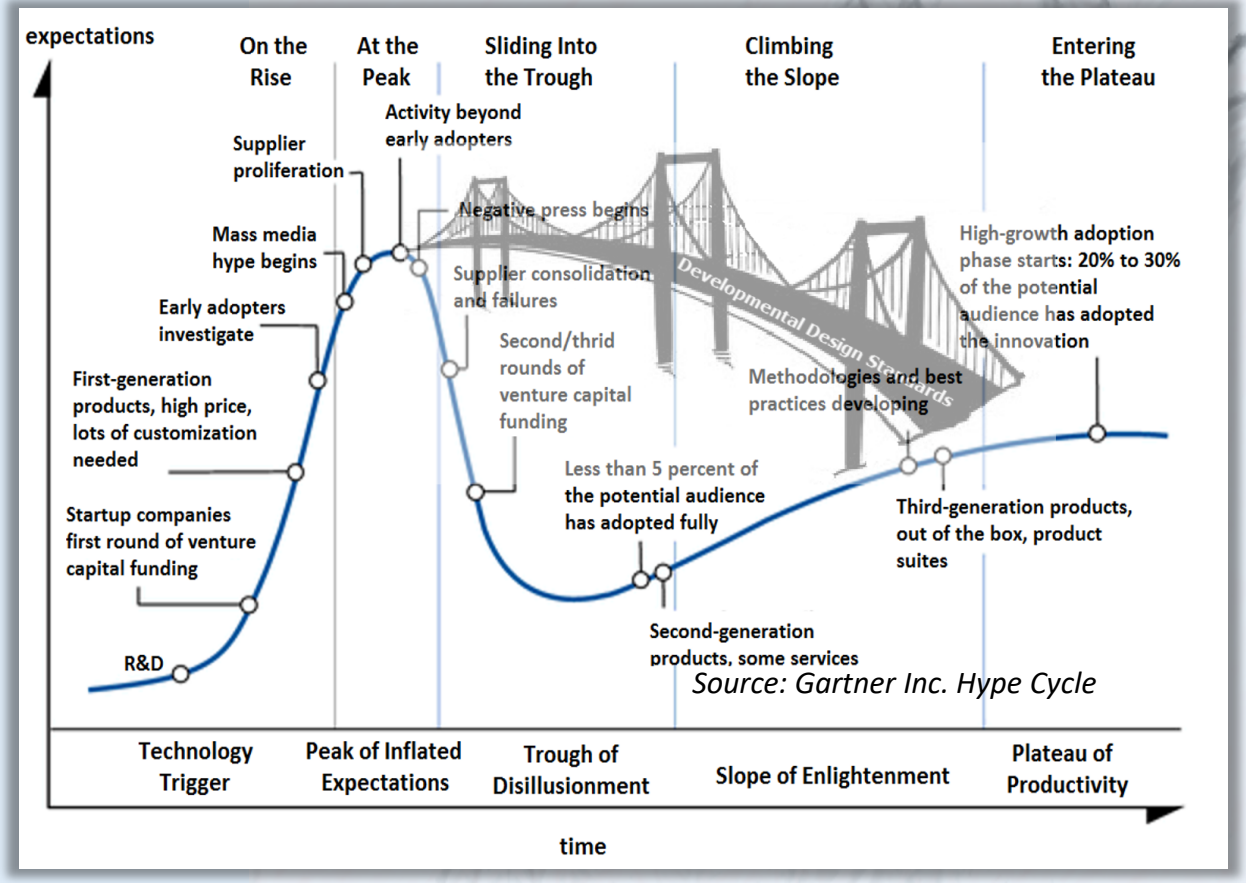
- **1940** Tacoma Narrows (WA) – *high strength/low stiffness*
- **1967** Silver Bridge (OH) – *high strength/fatigue/corrosion/low redundancy*
- **1983** I-95/Mianus River (CT) – *fatigue/corrosion/low redundancy*
- **2007** I35W Mississippi Rv (MN) – *buckling at high strength slender connection plate*
- **2000-2020** PT Corrosion…

…into the 21st Century ?

- Bridging the gap between ***innovation in corrosion prevention*** and ***institutional adoption***



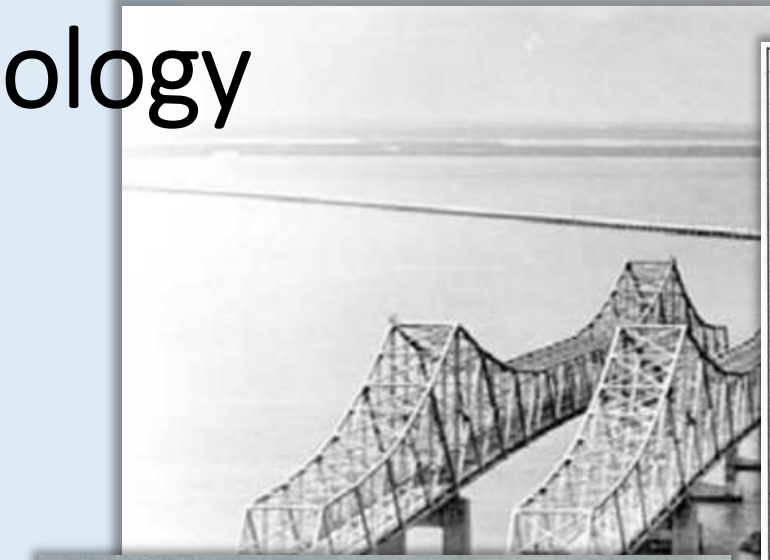
FLORIDA POPULATION GROWTH



Source: Gartner Inc. Hype Cycle

Historical Structural Technology Firsts in Florida Bridges...

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



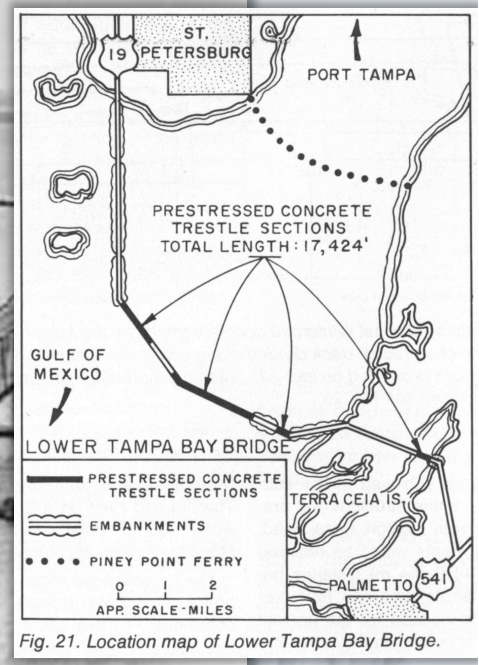


Fig. 21. Location map of Lower Tampa Bay Bridge.


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

Advancements in Corrosion Prevention and Mitigation in Florida…

- **1950's** Prestressed Concrete
- **1980's** FRP Research and Applications begin and Cathodic Protection
- **1990's** Improvements in Concrete Mix Designs (SCM's) and concrete cover thickness **2015** Adoption of HSSS & CFRP for Piles
- **2006** Adoption of FRP Fender Systems
- **2015** Adoption of HSSS & CFRP strands for Prestressed Piles
- **2016** Adoption of GFRP Reinforcing
- **2020** Adoption of HSSS & CFRP strands for Prestressed Girders and Slabs

FRP Structural Technology Firsts for Florida Bridges

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

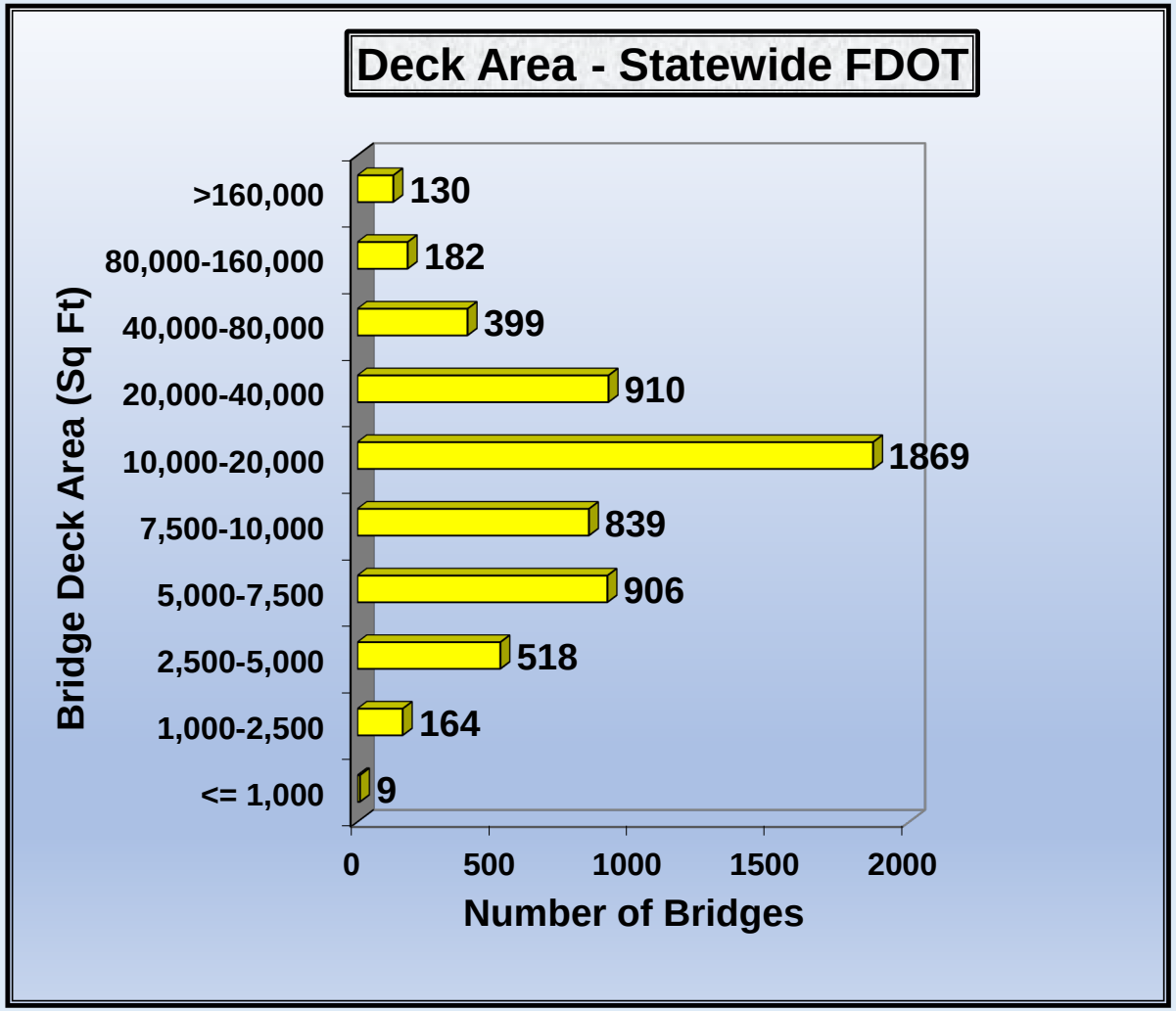
*** CAMX 2020 - Infrastructure Featured Speaker and Panel (September 23, 2020)*
Featured Speaker Presentation

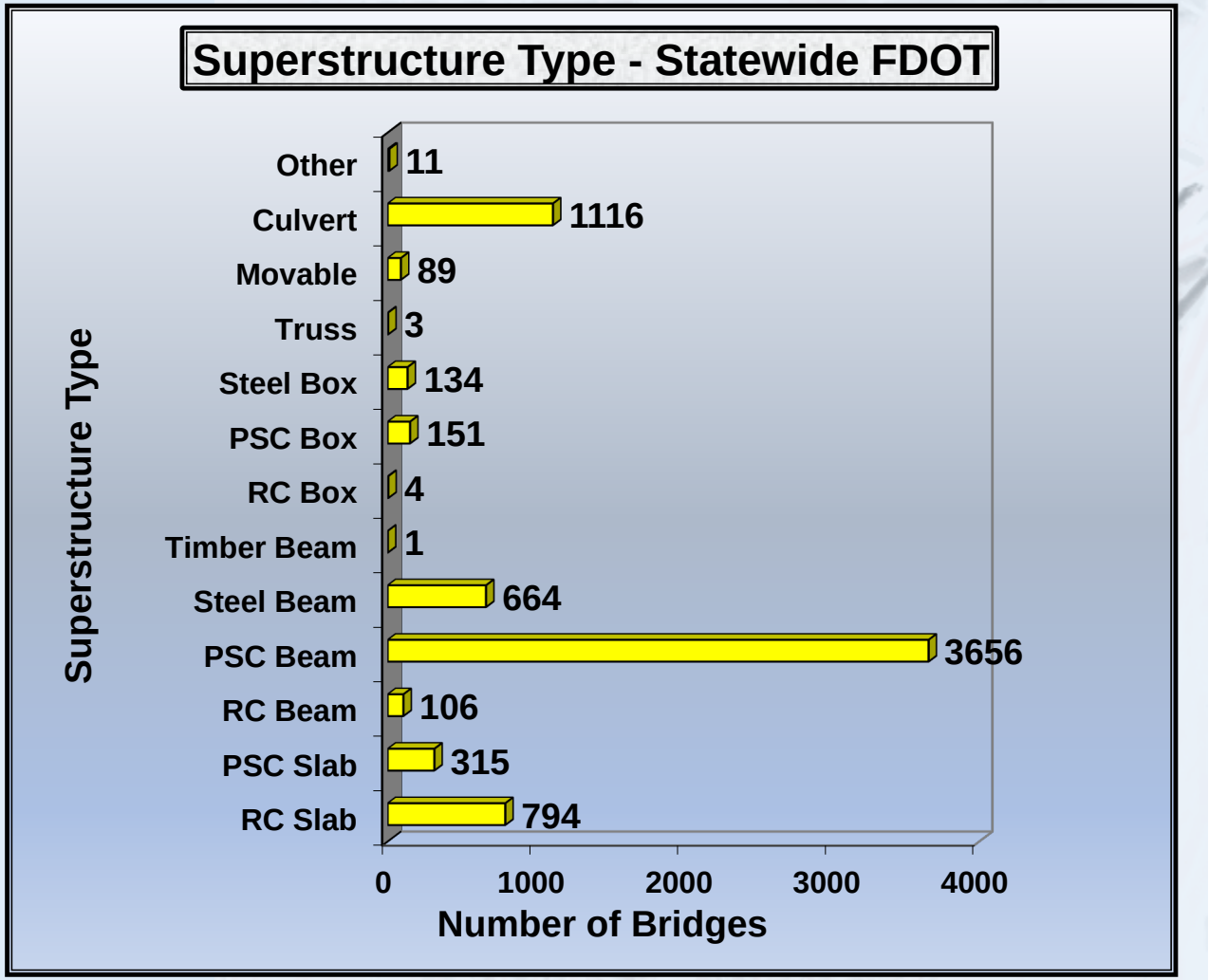
Taking stock of our Infrastructure…

FDOT's Structures Inventory:

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

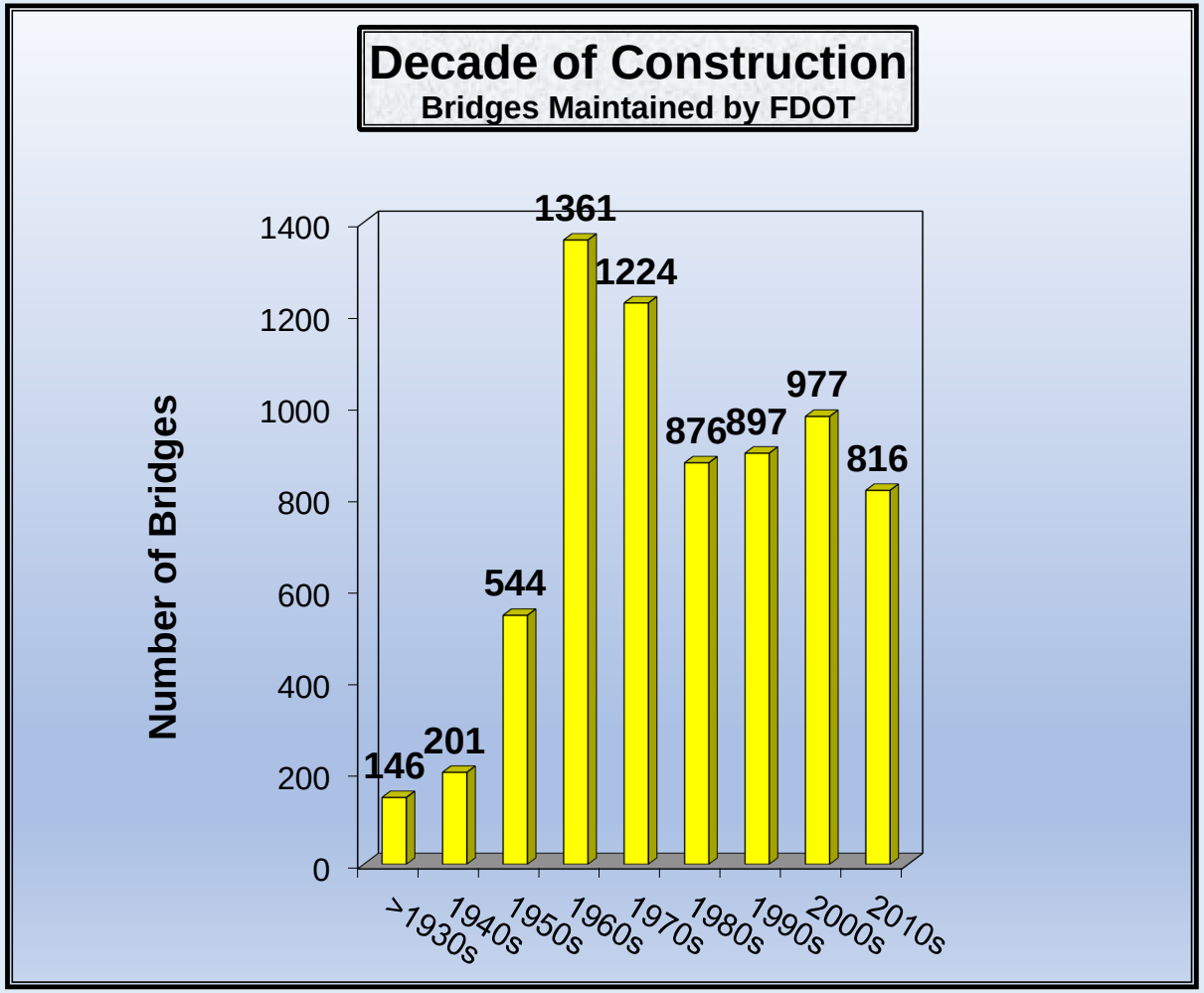
Florida's Bridges

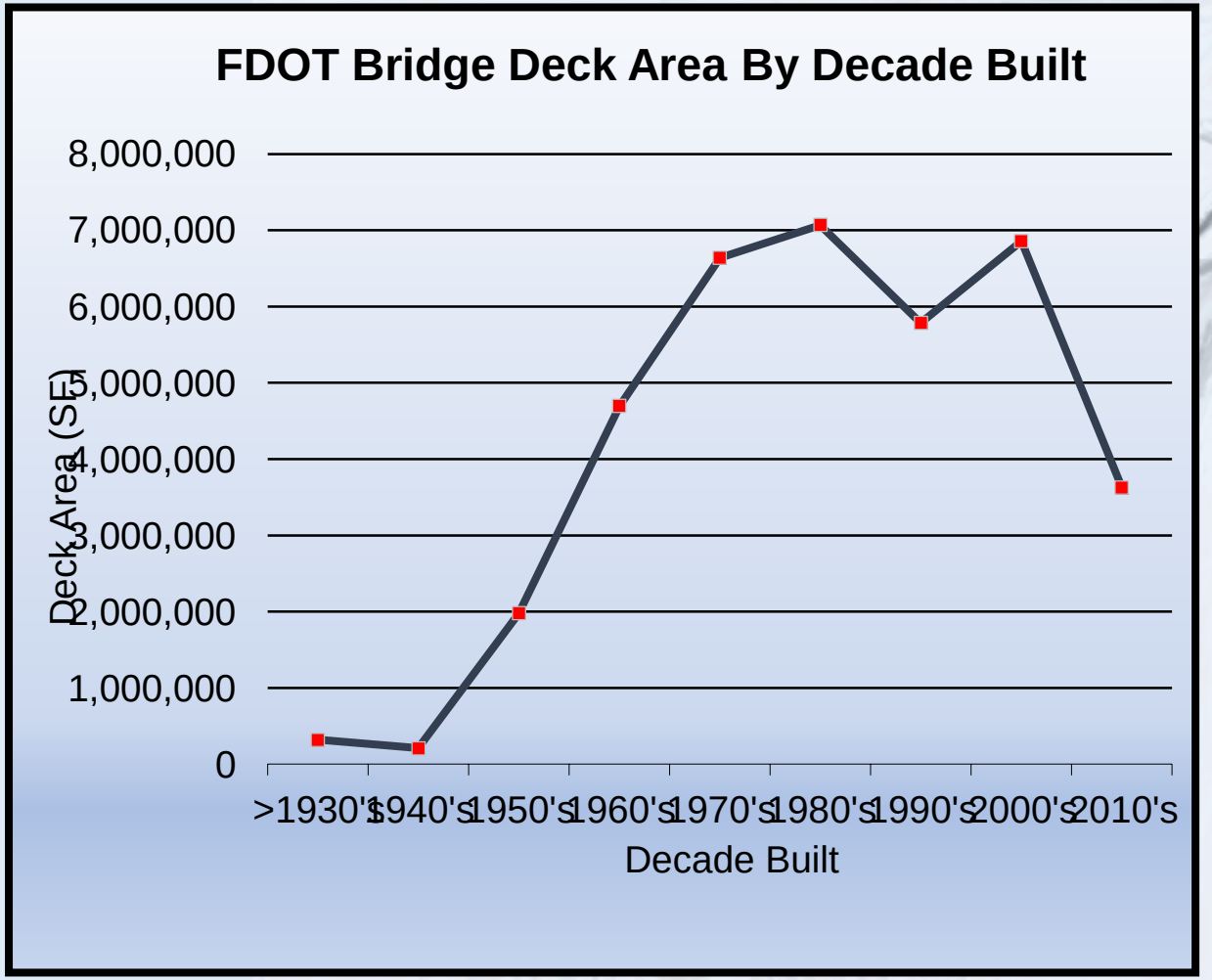




Source: 2020 FDOT Bridge Maintenance Annual Report

Florida's Bridges





Source: *2020 FDOT Bridge Maintenance Annual Report*

Florida's Bridges

Age of Bridges

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

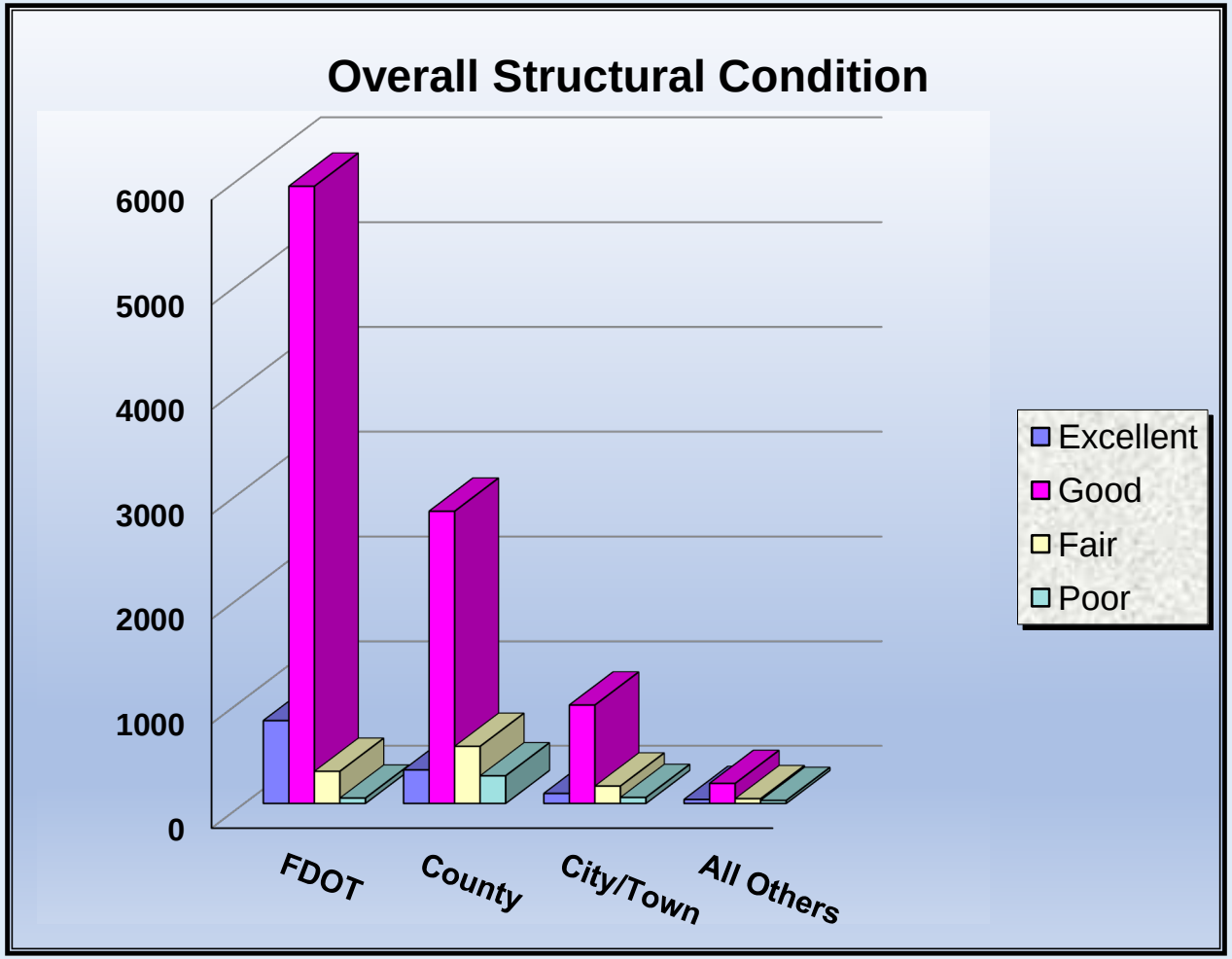
Source: 2020 FDOT Bridge Maintenance Annual Report

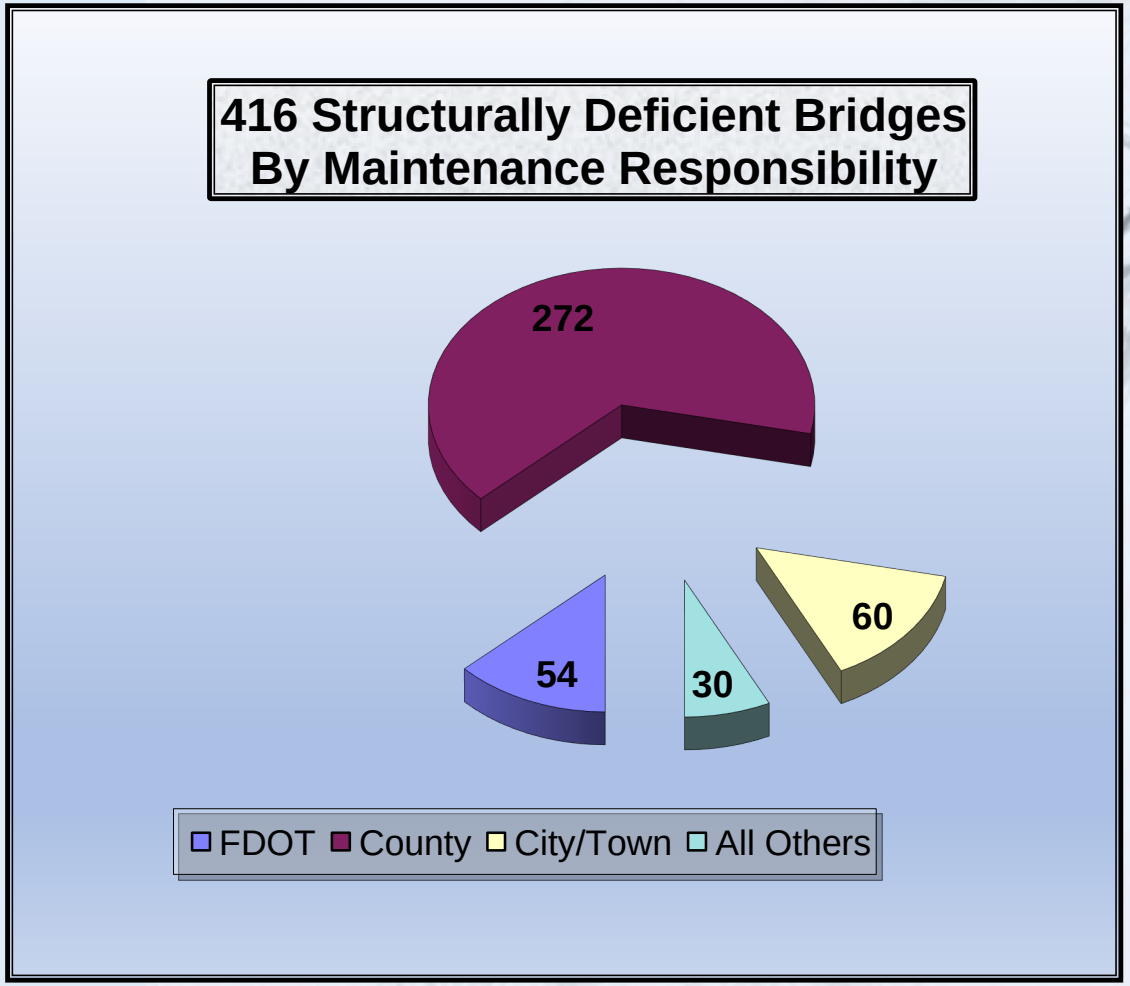
Florida's Bridge Program

FDOT bridge maintenance program

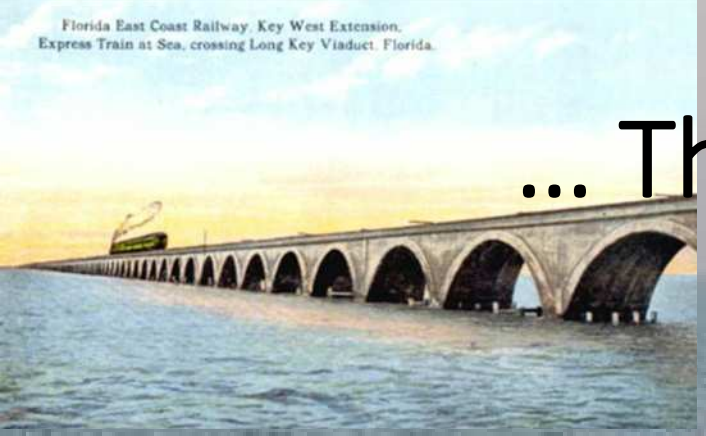
- $13 Million spent annually on routine bridge maintenance
- Programmed for bridge repair/replacement
  - FY 20/21 - $470.7M
  - FY 21/22 - $382.5M
  - FY 22/23 - $152.4M
  - FY 23/24 - $324.2M
  - FY 24/25 - $156.3M

Florida's Bridge Condition





… Then and Now …



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

"New" Seven-Mile Bridge, (Florida Keys)

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

Structures Design Office

Curved Precast Spliced U-Girder Bridges

Non-Corroding

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

Corrosion-Resistant

Ultra-High Performance Concrete (UHPC)

+ Stainless-Steel Prestressing Strand & Rebar

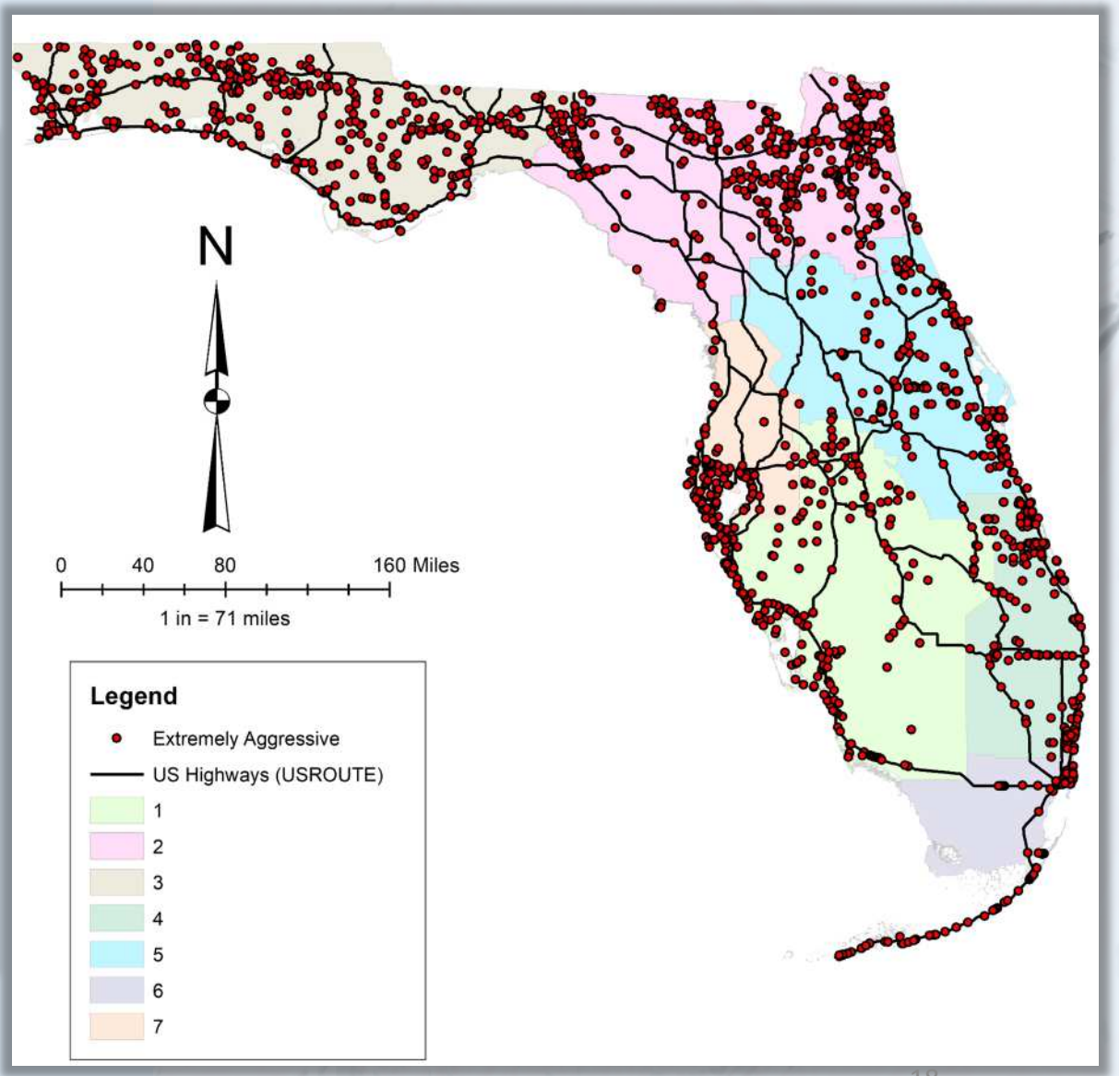
Florida's Bridge Condition

Table 1.3.2-1 Criteria for Substructure Environmental Classifications

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

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

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



Why use CR-HPM for Bridges

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

Figure 131—University Boulevard Bridge

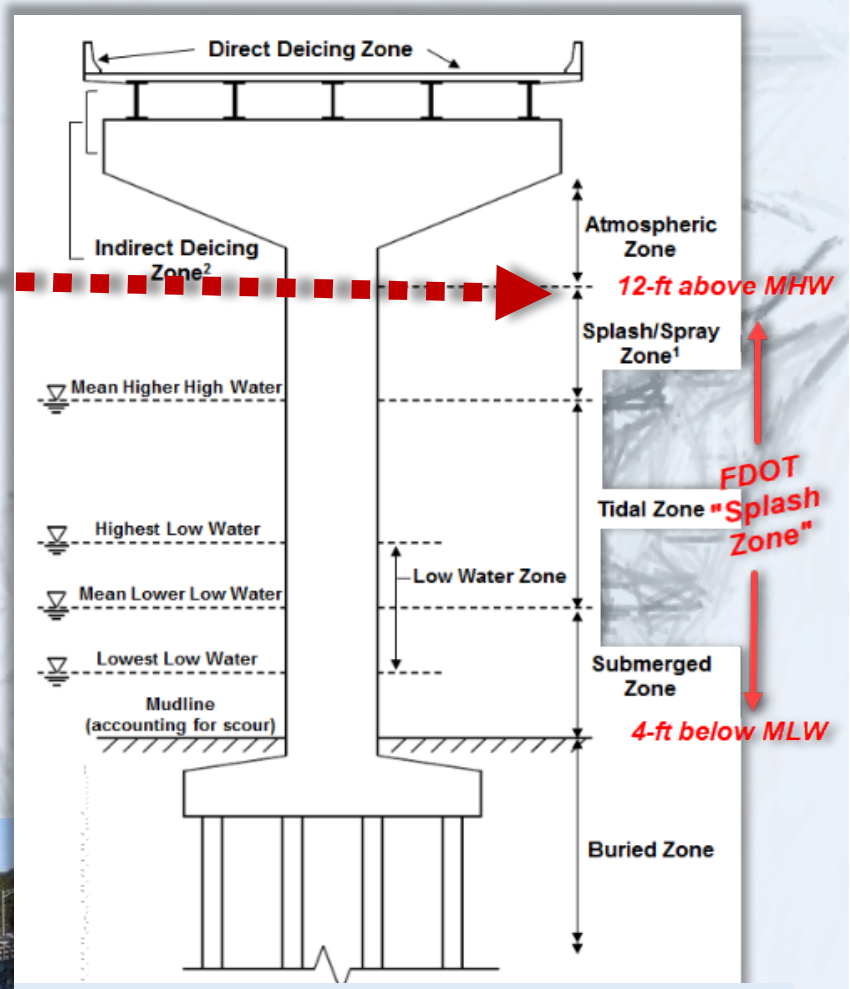


Figure 2.2.1.2-1—Micro Environment Exposure Zones

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

Why use CR-HPM for Bridges

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

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

Figure 136—High tide inundation of (a) spans

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

Why use CR-HPM for Bridges

- **Extremely Aggressive Environments** also include:
  - Areas subject to spray from jet skis.
  - In northern Florida there has been a move to place salt after winter storms. If this becomes a more common occurrence, consideration may be given to including these.
  - See **Cow Key Channel** 3-Span Replacement *[FRP-RC/PC Projects → **FAST-FACTS**]*

State Road 5 – Cow Key Channel Bridge Deck Pour

Why use CR-HPM for Bridges

But there are several other reasons FRP repairs and strengthening are necessary:

- Over-height truck impacts.
- In sufficient detailing past practice for shear strength.
- Segmental bridge joint repairs

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

FDOT 20-years+ Innovations in Concrete Bridge Decks Not The End…

Closing Thoughts:

- ✓ ***"If you're not at the table, you're on the menu!"*** *anom.* **(so Get Involved!).**
- ✓ **Implementing Change (innovation?) is often thankless but ultimately a worthwhile pursuit… you will *own the failures,* but ensure you *celebrate the successes* *(even when appropriated by others).***
- ✓ **Implement sustainable leaning practices now, rather than having them imposed on you later…**