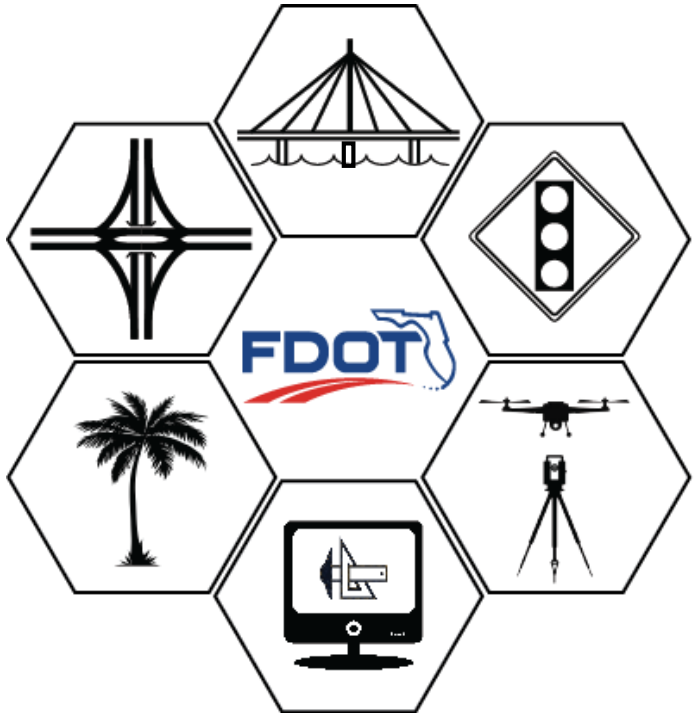


FDOT TRANSPORTATION SYMPOSIUM

June 19th, 2018

Structural Advanced Materials for Florida's Transportation Infrastructure

Steve Nolan, Mohit Soni, and Felix Padilla

Outline

What, Who, When, & How:

- Overview SAM-TAG;
- Discuss Innovative Structural Materials for Transportation Infrastructure;
- Provide Example Projects;
- Technical Panel Q & A.

What, Why, Who, When & How

?

Structural Advanced Materials = SAM

+

Technical Advisory Group = TAG

What, Why, Who, When & How

SAM-TAG Mission:

- Advance the safe implementation and broad deployment of innovative structural materials through advisement to the **Structures TAG** and coordination with national and international specification development organization representatives…

What, Why, Who, When & How

- **SAM Technologies being "nurtured":**
  1. Glass FRP rebar (GFRP-RC);
  2. Stainless-Steel rebar (SS-RC);
  3. Carbon FRP prestressing (CFRP-PC);
  4. High-Strength Stainless-Steel prestressing (HSSS-PC);
  5. FRP Fender Systems;
  6. Ultra-High Performance Concrete (UHPC);
  7. Basalt FRP rebar (BFRP-RC).

What, Why, Who, When & How

- **Potential Technologies to be considered:**
  8. GFRP pre-tensioning (GFRP-PC) – This has received a ***NCHRP Highway IDEA*** Grant;
  9. Fiber-Reinforced Concrete (FRC) – Being investigated under ***FDOT Research Projects*** BDV31 977-41 & BDV31 977-72;
  10. HSCS Prestressing – 300/340 ksi pre-tensioning strand. Current ***ASTM Work Item***.

What, **Why**, Who, When & How

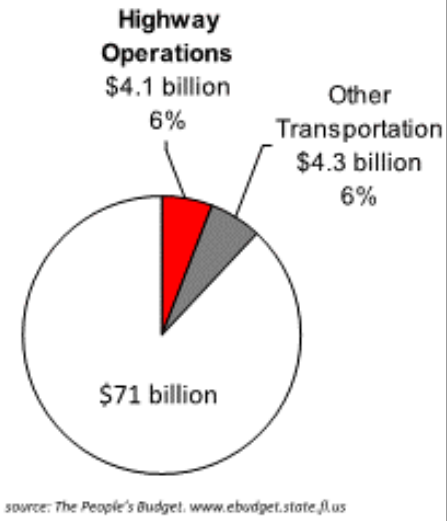
- Mostly motivated by durability concerns…

EXAMPLE:
Transportation- 12% of Florida's Budget

- Large integrated investment in state bridges. ~6,000 bridges.

  1/2 in aggressive marine service.

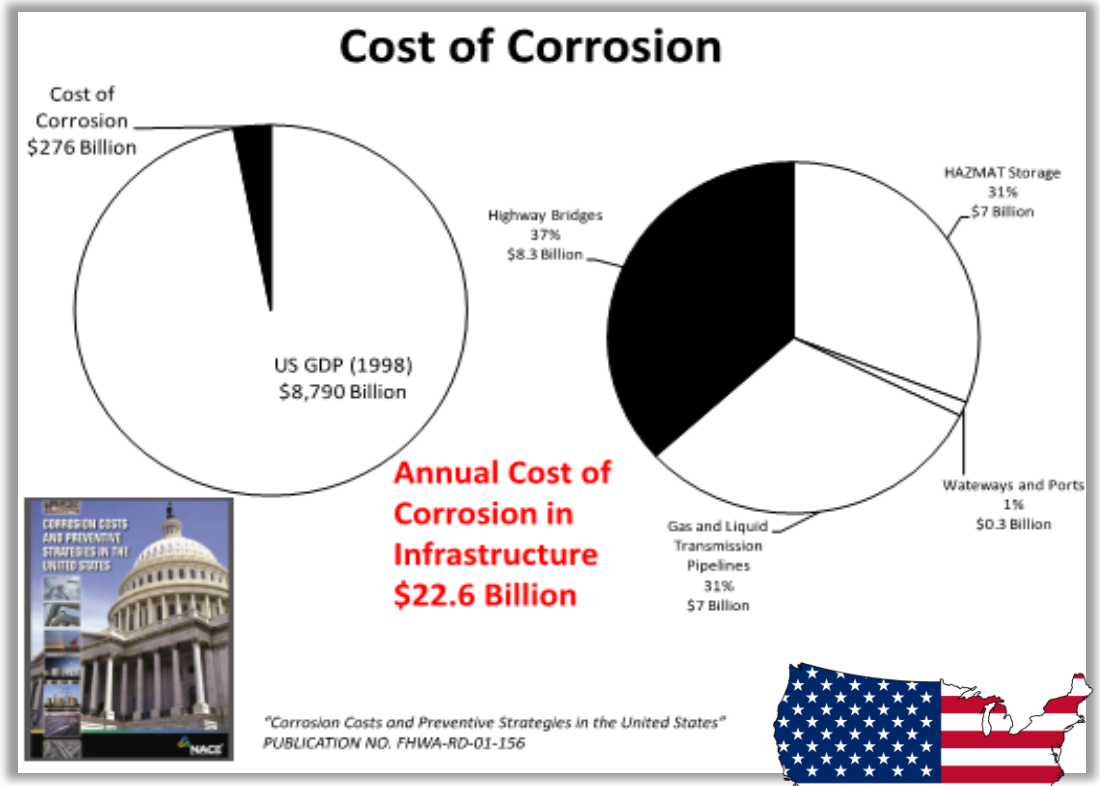
- ~ $300 million per year spent on bridge construction. Additional yearly costs for maintenance.
- 75-year design life - potential huge cost in life reduction due to corrosion.
- *Need to improve design to control corrosion, develop tools to assess future performance to decide on best design and rehab alternatives, and assess need for future maintenance.*



source: The People's Budget. www.ebudget.state.fl.us

FDOT

Chart: FY 2012-2013 http://www.floridafirstbudget.com/
(FY 2015-16: Total = $78B, Hwy.Op. = $5.6B, Other = $4.4)
from TRB webinar "Controlling Corrosion of Infrastructure Systems" – K. Lau & M. O'Reilly, August 2016.



https://www.nace.org/uploadedFiles/Publications/ccsupp.pdf

What, **Why**, Who, When & How

- Florida is Ranked ***2nd*** behind Alaska in the longest US coastline.

RESEARCH COMMUNICATIONS RESEARCH COMMUNICATIONS

Engineering away our natural defenses: an analysis of shoreline hardening in the US

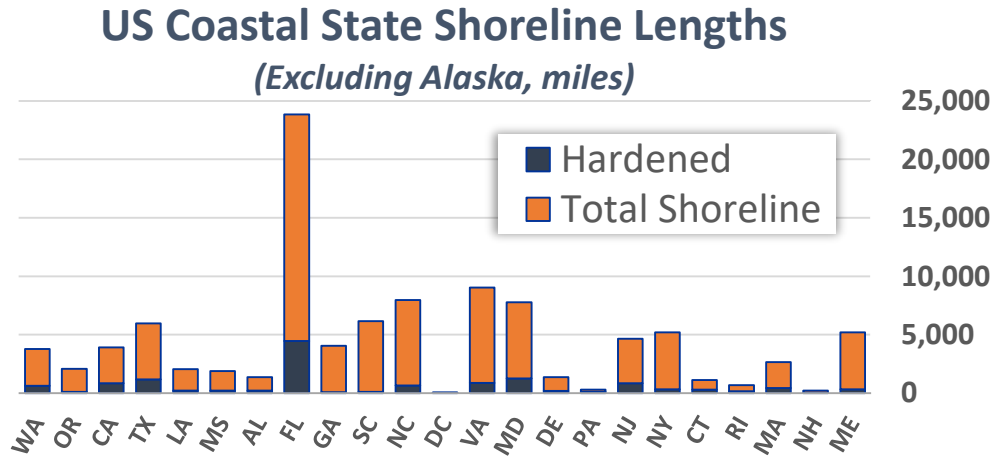
Rachel K Gittman[1*†], F Joel Fodrie[1], Alyssa M Popowich[1], Danielle A Keller[1], John F Bruno[1], Carolyn A Currin[2], Charles H Peterson[1], and Michael F Piehler[1]

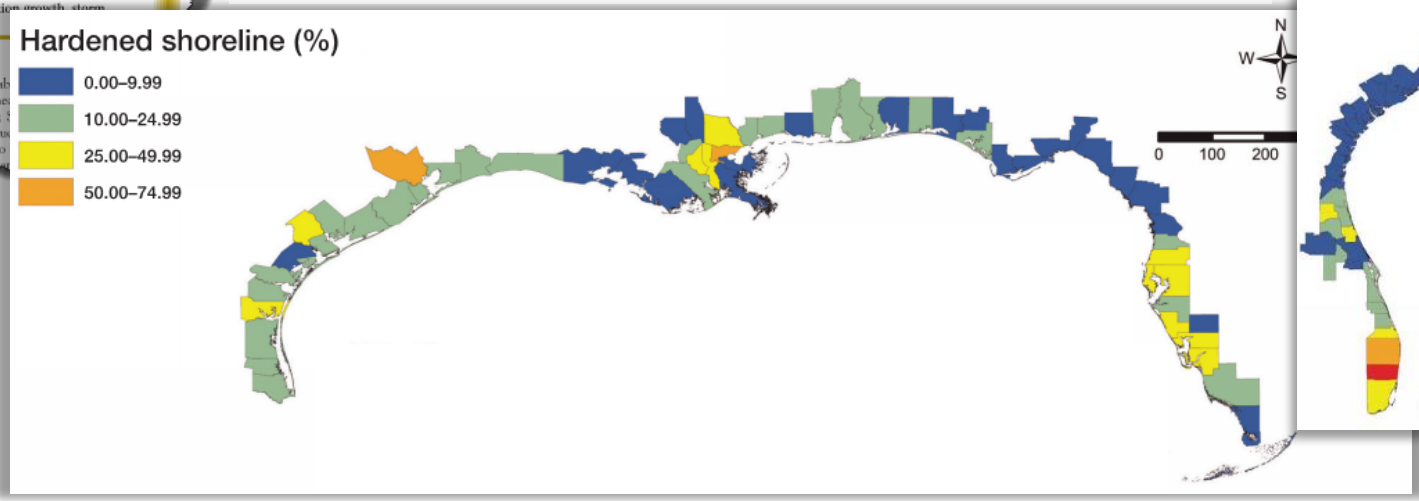
Rapid population growth and coastal development are primary drivers of marine habitat degradation. Although shoreline hardening or armoring (the addition of concrete structures such as seawalls, jetties, and groins), a byproduct of development, can accelerate erosion and loss of beaches and tidal wetlands, it is a common practice globally. Here, we provide the first estimate of shoreline hardening along US Pacific, Atlantic, and Gulf of Mexico coasts and predict where future armoring may result in tidal wetland loss if coastal management practices remain unchanged. Our analysis indicates that 22 842 km of continental US shoreline – approximately 14% of the total US coastline – has been armored. We also consider how socioeconomic and physical factors relate to the pervasiveness of shoreline armoring and show that housing density, gross domestic product, storms, and wave height are positively correlated with hardening. Over 50% of South Atlantic and Gulf of Mexico coasts are fringed with tidal wetlands that could be threatened by future hardening, based on projected population growth, storm frequency, and an absence of coastal development restrictions.

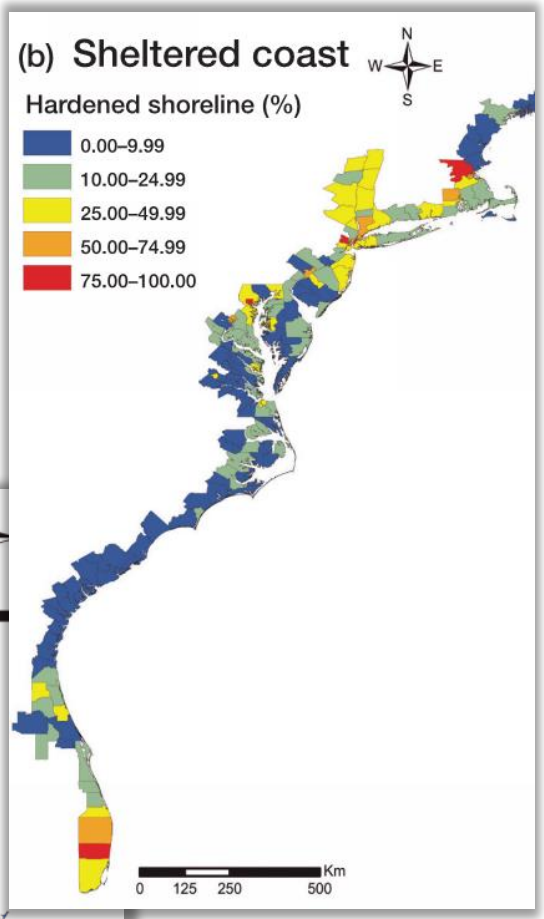
Front Ecol Environ 2015; 13(6): 301–307, doi:10.1890/150065

Although coastal regions constitute less than 4% of the Earth's land area, coastal habitats (eg beaches and tidal wetlands; Figure 1) rank among the most valuable natural resources globally (MA 2005). Over one-third of the human population lives within 100 k

also provide less physically complex hab with natural shorelines, so that hardene erally support fewer species (Figure 1; Gittman *et al.* in press). When constru structures may also



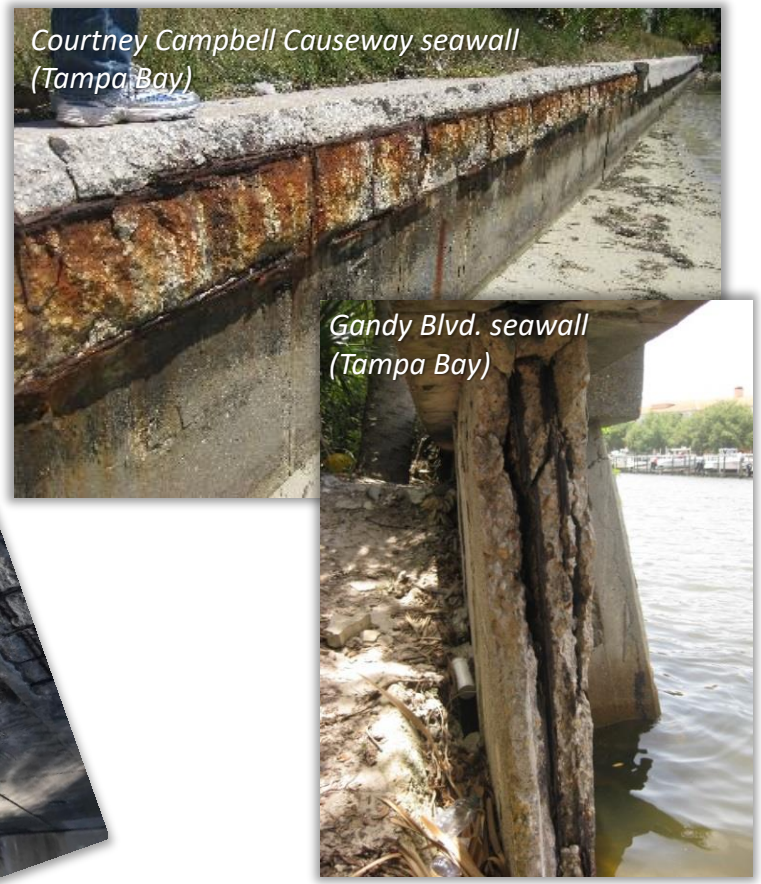




FDOT TRANSPORTATION SYMPOSIUM

What, **Why**, Who, When & How

- Florida Maintains ***185,708,400*** *sq.ft.* of bridge area.



What, **Why**, Who, When & How

- Need for cost effective solutions to corrosion and durability challenges;
- Potentially longer service-life for bridges;
- Rapidly advancing materials technologies;
- Push for ABC (= more connections…)

What, Why, **Who**, When & How

These volunteers support DSDE's to make informed choices:

- 1 ~ ***Champion*** & 1 ~ ***Backup*** from each ***DSDO***;
- 2 ~ ***Consultants*** - structures design community;
- 2 ~ ***State Materials Office*** materials experts;
- 2 ~ ***SSDO*** facilitators & coordinators;
- 1 ~ ***Structures Research Center*** representative;
- ***Friends*** of the TAG (***Collaborators***);
- … future ***Construction*** and ***Maintenance*** representatives?

What, Why, Who, **When** & How

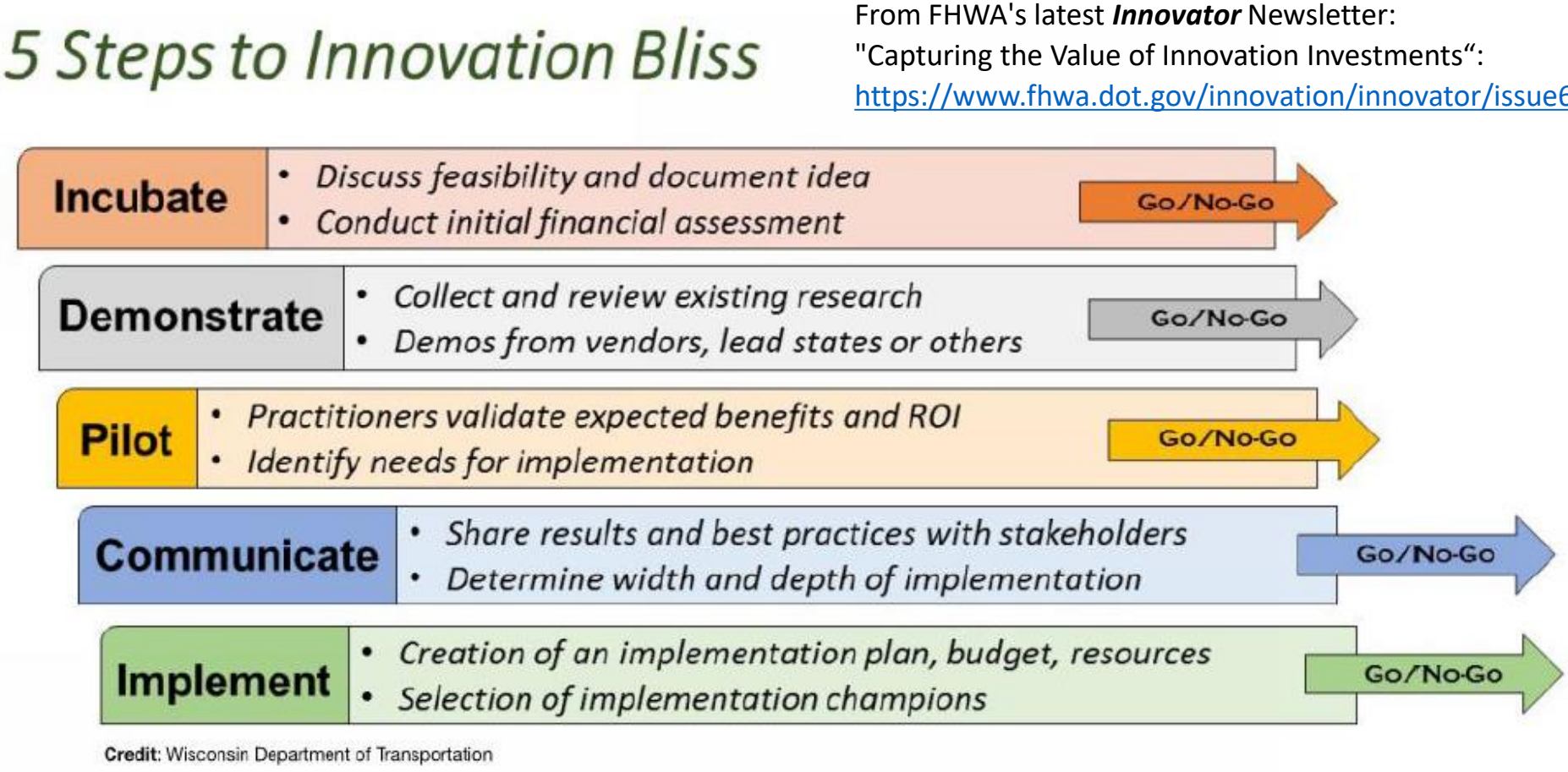
This is all happening currently…

- ***Monthly Meetings*** to advance the technology transfer;
- ***Structures Research Center*** coordination;
- ***State Materials Office*** Research co-ord.;
- Implementation of the technology on ***Pilot Projects***.

What, Why, Who, When & How

Example of How other states might be do it…

From FHWA's latest ***Innovator*** Newsletter:
"Capturing the Value of Innovation Investments“:
https://www.fhwa.dot.gov/innovation/innovator/issue66/3dIssue/



What, Why, Who, When & **How**

Tools:

- **NCHRP Report 768**: …Technology Transfer;
- Technical State-of-the-Art Reports…
  - ***NCHRP Synthesis 512***: Use of Fiber-Reinforced Polymers in Highway Infrastructure (2017);
  - ***NCHRP Project 20-68A***, Scan 13-03: Advances in FRP Composites in Transportation Infrastructure (2013);
  - ***NCHRP Report 503***: Application of FRP Composites to Highway Infrastructure (2003);
  - ***FHWA*** EDC, UHPC TechNotes and Guidelines.
- Project **GIS-Mapping** Application;
- FDOT **Design Innovation** website

How = Technology Transfer (T^2)

NCHRP Report 768 (2014):

- 10 key components provide practitioners with a ***"roadmap"*** through a guided ***T^2*** process:

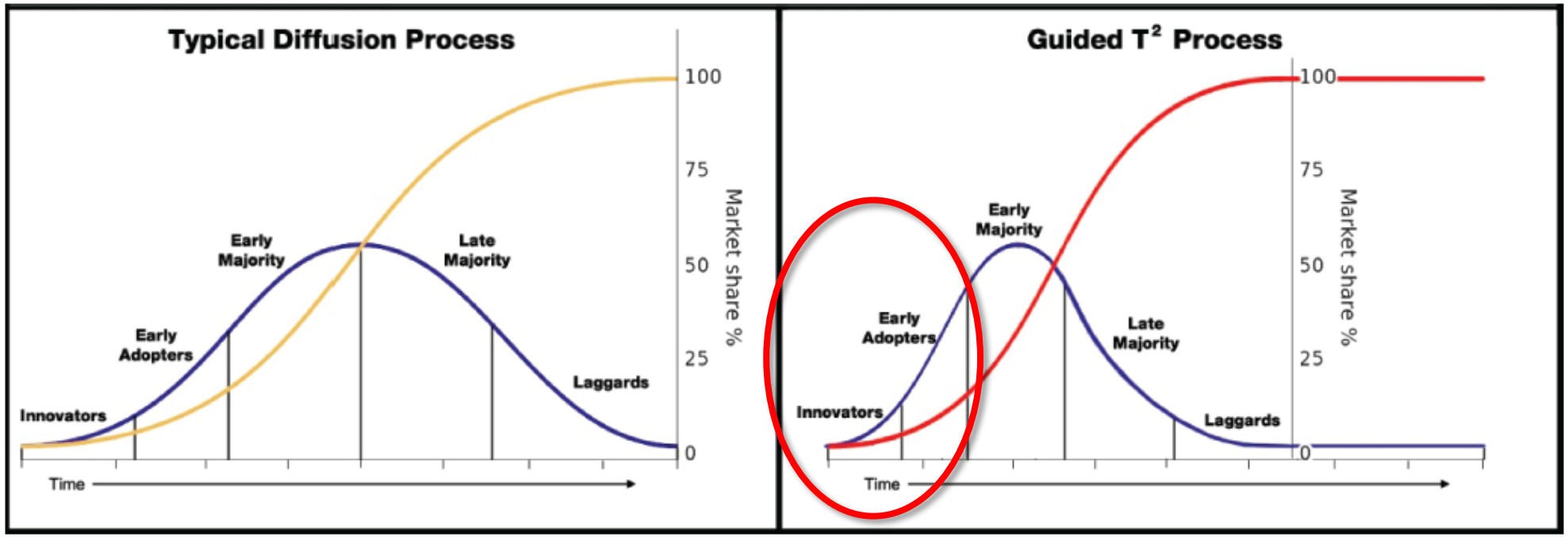


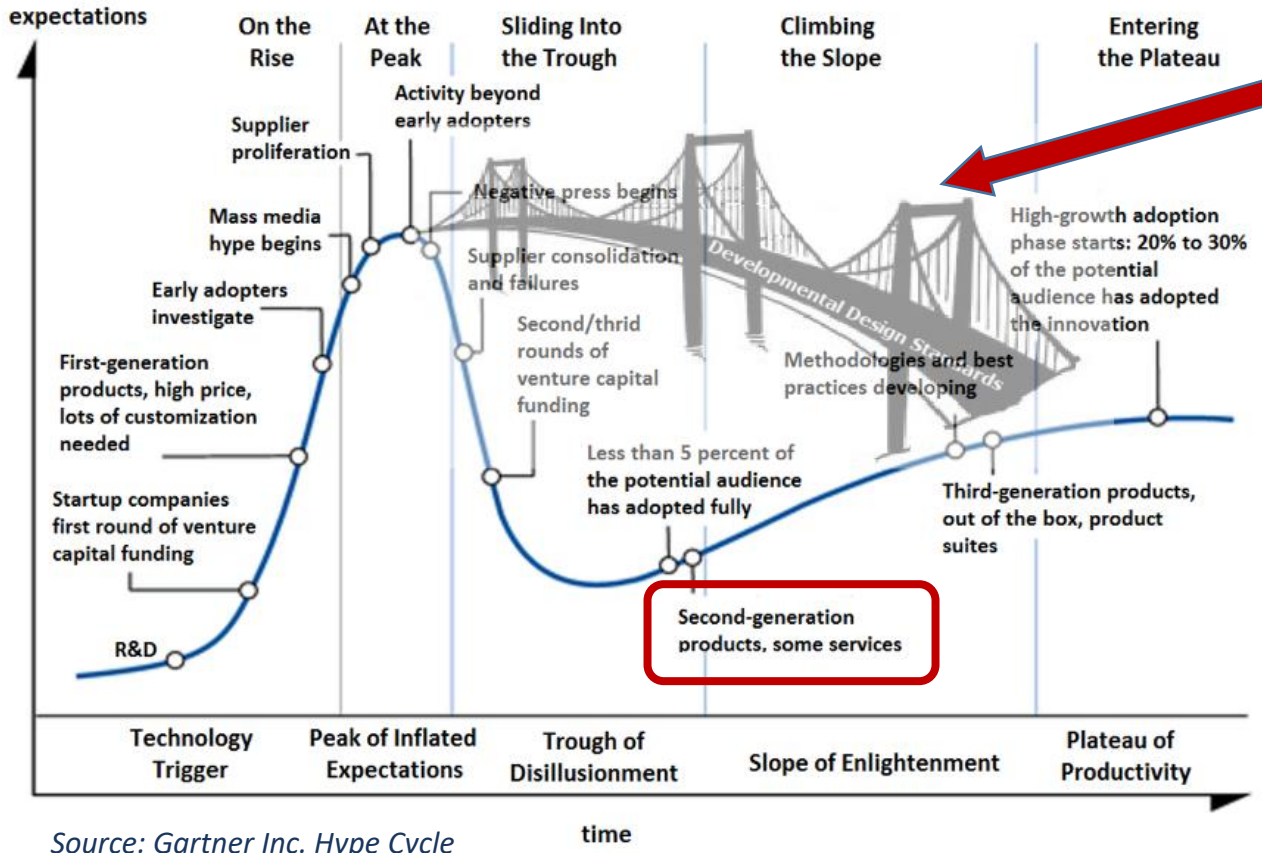
Figure 1-2. Conceptual representation of the intent of guided T^2.

How = Technology Transfer (T^2)

NCHRP Report 768 (2014):

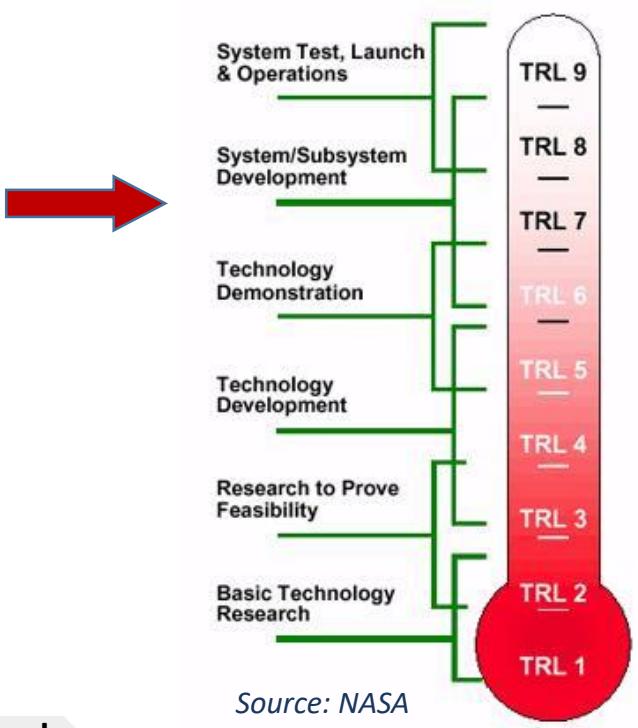
- 10 key components provide practitioners with a ***"roadmap"*** through a guided ***T^2*** process:
  1. Address societal and legal issues; *??*
  2. Have an effective champion; ✓
  3. Engage decision makers; ✓
  4. Develop a T^2 plan; ✓
  5. Identify, inform, and engage stakeholders; ✓
  6. Identify and secure resources; ✓
  7. Conduct demonstrations/showcases; ✓
  8. Educate, inform, and provide technical assistance; ✓
  9. Evaluate progress; ✓
  10. Reach [wider] deployment decision. ✓

How = Technology Transfer (T^2)



Source: Gartner Inc. Hype Cycle

Developmental Standards
can bridge the *"Trough of Disillusionment"*
for effective implementation!



Source: NASA

Research (TRL 1-3)	Demonstration Project (TRL 4-5)	Developmental (*DDS*) Index (TRL 6-8)	Design-Standard Plans Index (TRL 9)

How = Technology Transfer (T^2)

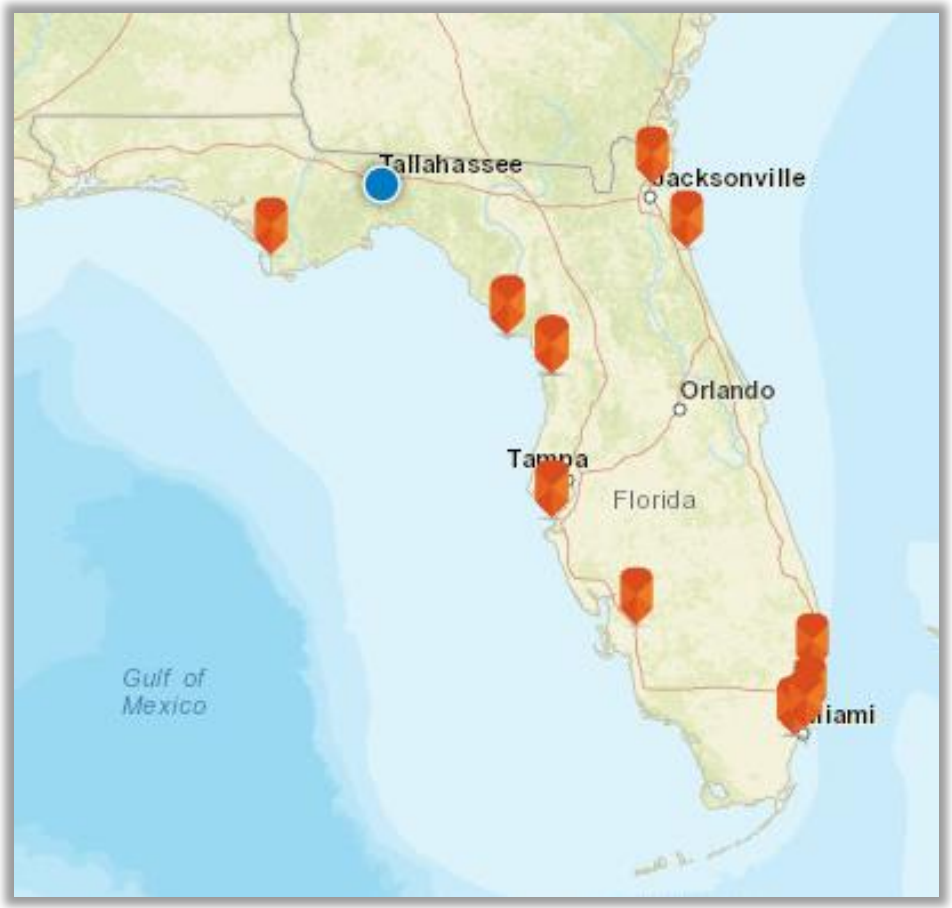
- Project example **GIS-Mapping** Application demonstration…

Currently includes:

- Active and Completed FRP-RC/PC projects;

Plan to add:

- Bridge beam repair/strengthening projects in future (25+ year history of wet-layup repairs)
- FRP-Fender Systems
- HSSS projects
- UHPC projects



https://fldot.sharepoint.com/sites/FDOT-Design/Structures/SpecialProjects/Lists/FRP%20Rebar%20Project/AllItems.aspx

What, Why, Who, When & **How**

- Project example **Fast-Facts**… (similar to ***A.I.I.***)
  - EOR's requested to complete for each new project


FDOT Transportation Innovation Initiative:

FRP – Design Innovation

Fast Facts:

Glass Fiber Reinforced Polymer

Project Location: FDOT District Two, Levy County, Cedar Key, Florida

Agency: Florida Department of Transportation

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

Project Name: SR 24 over Number Three Channel Bridge No. 340003 FPID: 426169-1

Project Description: Rehabilitation of three bridges in Cedar Key

Project Purpose & Need: Bridge Inspection Reports identified deterioration, including evidence of corroded steel reinforcement in the bulkhead cap on bridge 340003. Work activities included removal of the existing bulkhead cap and installation of a new bulkhead cap with GFRP reinforcement.

$741,630.00 (Construction Contract)

GFRP reinforcement is used in the bulkhead cap, which is within the splash zone, to reduce future maintenance requirements. Removable blocks, reinforced with varying types of FRP, were cast with the bulkhead cap for monitoring long-term durability.

Describe Traditional Approach: Traditional approach includes installation of grade 60 steel rebar in a cast-in-place bulkhead cap.

Describe New Approach: Utilization of GFRP bars in lieu of traditional grade 60 steel rebar in the bulkhead cap, located in the splash zone.

Top Innovations Employed: Utilization of GFRP bars within the splash zone/marine environment.

Primary Benefits Realized/Expected: Longer service life of the bulkhead cap.

Project Start Date/Substantial Completion Date: 11/30/2015 – 8/3/2016

Kisinger Campo & Associates Corp.
Pneumatic Concrete Co, Inc.
JEA Construction Engineering Services
Patrick Mulhearn, P.E.
Kisinger Campo & Associates Corp.
Jeff Bailey
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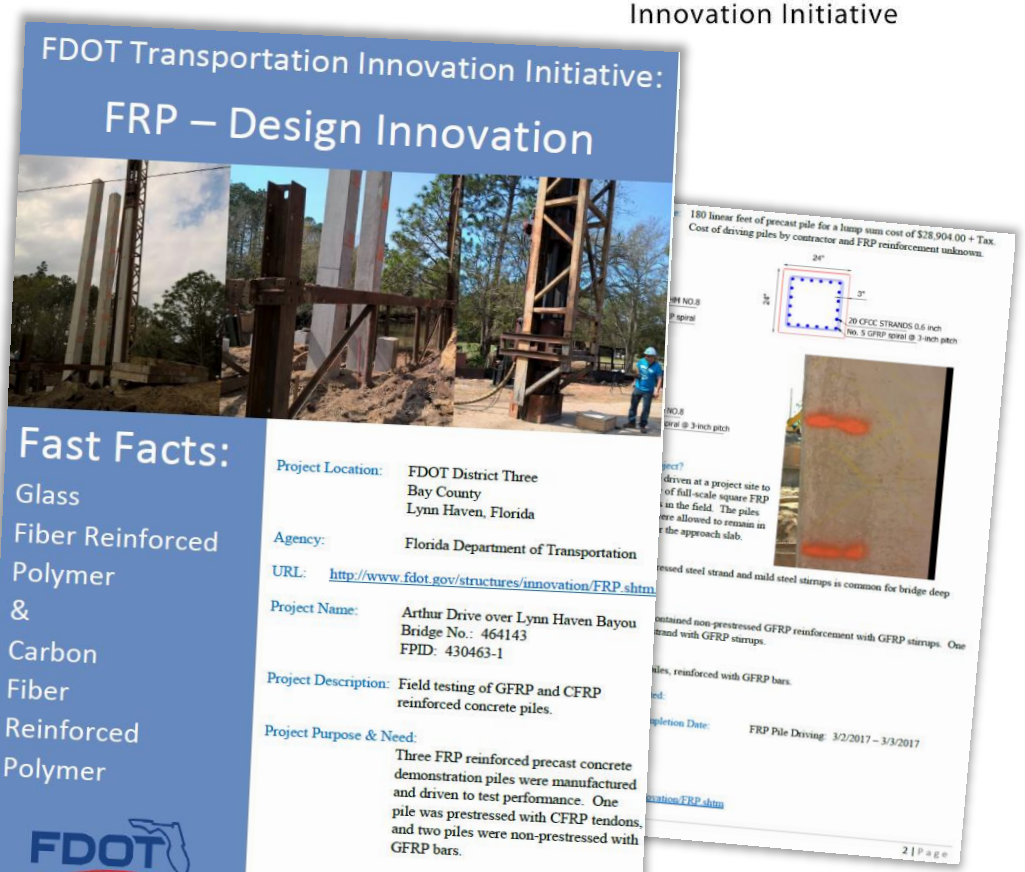

FDOT Transportation Innovation Initiative:

FRP – Design Innovation

Fast Facts:

Glass Fiber Reinforced Polymer & Carbon Fiber Reinforced Polymer

Project Location: FDOT District Three, Bay County, Lynn Haven, Florida

Agency: Florida Department of Transportation

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

Project Name: Arthur Drive over Lynn Haven Bayou Bridge No.: 464143 FPID: 430463-1

Project Description: Field testing of GFRP and CFRP reinforced concrete piles.

Project Purpose & Need: Three FRP reinforced precast concrete demonstration piles were manufactured and driven to test performance. One pile was prestressed with CFRP tendons, and two piles were non-prestressed with GFRP bars.

180 linear feet of precast pile for a lump sum cost of $28,904.00 + Tax. Cost of driving piles by contractor and FRP reinforcement unknown.

20 CFCC STRANDS 0.6 inch

FRP Pile Driving: 3/2/2017 – 3/3/2017

2 | Page

What, Why, Who, When & **How**

We always Champions for each technology!

- Discuss with your **DSDE**'s
- Presentations at Technical Events
- Liaison with **Technical Committees**
- Develop ***SAM-TAG*** Technology **Fast-Facts** sheets
- Identifying and promoting **Demonstration Projects** or Supporting **Needed Research** for improvement

What, Why, Who, When & How

For Local Projects

- Identify potential project:
  - Marine environment; Bridge in its ultimate configuration; New or Replacement ?
- Discuss with local District Structures Design Engineer (DSDE):
  - http://www.fdot.gov/structures/General/contacts.shtm
- DSDE will notify ***SAM-TAG:***
  - Lessons learn → Latest Development → Best Practices

Example Projects

- **US17 Trout River (GFRP-RC *Tech#1*)**
  - Utilization of GFRP bars in conjunction with Shotcrete; traditional cast-in-place; and removal of concrete from GFRP bars in the splash zone (2014-2016).

Example Projects

- **Bakers Haulover Cut Rehab (GFRP-RC *Tech#1*)**

(Jan 2017 – Nov 2018)


North Wall


South Wall


Bulkhead wall cap GFRP reinforcement in place

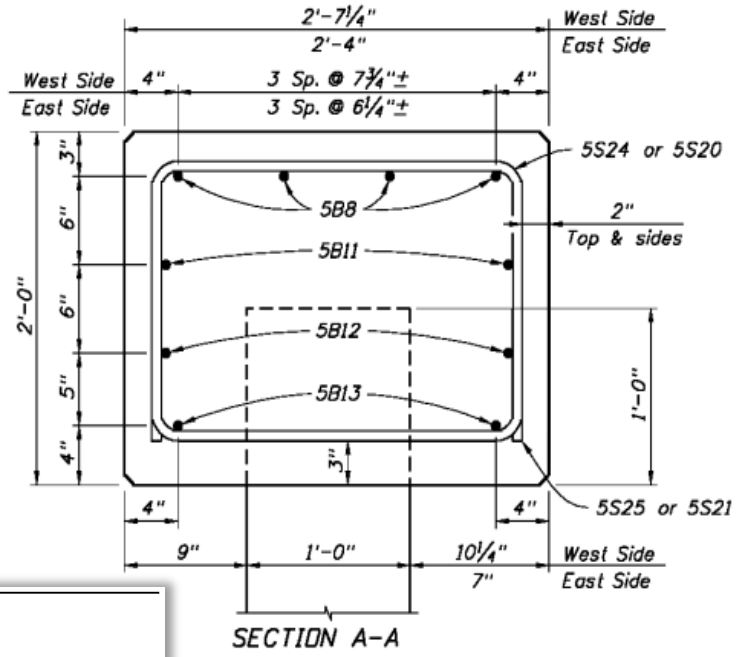

Hoisting GFRP rebar mat for placement in form


Bulkhead wall cap GFRP reinforcement in place

Example Projects

- **Jensen Beach & SR 30A (SS-RC *Tech#2*)** (2002 - 2004) & (2013)

Figure 3: View of Pier 12 showing footer and two octagonal columns of Bridge 890145. Stainless steel 2101LDX used on footer and column.



Standard Specification for

Uncoated, Corrosion-Resistant, Deformed and Plain Chromium Alloyed, Billet-Steel Bars for Concrete Reinforcement and Dowels

AASHTO Designation: M 334M/M 334-17[1]

AASHTO

Technical Section: 4f, Metals

Release: Group 2 (June 2017)

New Updated Specification

Example Projects

- **Halls River Bridge (CFRP-PC *Tech#3,* & GFRP-RC *Tech#1*)**

(Jan 2017 – Dec 2018)


Aerial view 2017 – Bent Cap forming and Pile installation


HCB's set on GFRP-RC Pile Caps


GFRP reinforcing for Pile Caps


CFRP-PC sheet pile installation

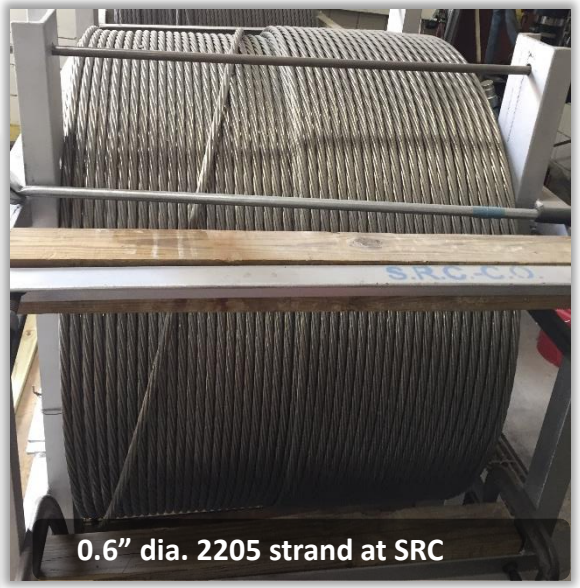

CFRP-PC bearing pile and splice setting

Example Projects

- **Cedar Key: Daughtry Bayou & Lewis Pass (HSSS-PC *Tech#4*)**

  Pile driven (April-May 2018)

Prestressed Concrete Piles driven at Lewis Pass



0.6” dia. 2205 strand at SRC

Example Projects

- **I-95 over CR 5A (UHPC *Tech#6*)**

  Precast Deck Panel Replacement (April 2018)


Removal of existing deck


Placement of Precast Deck Panels


Pour UHPC joint

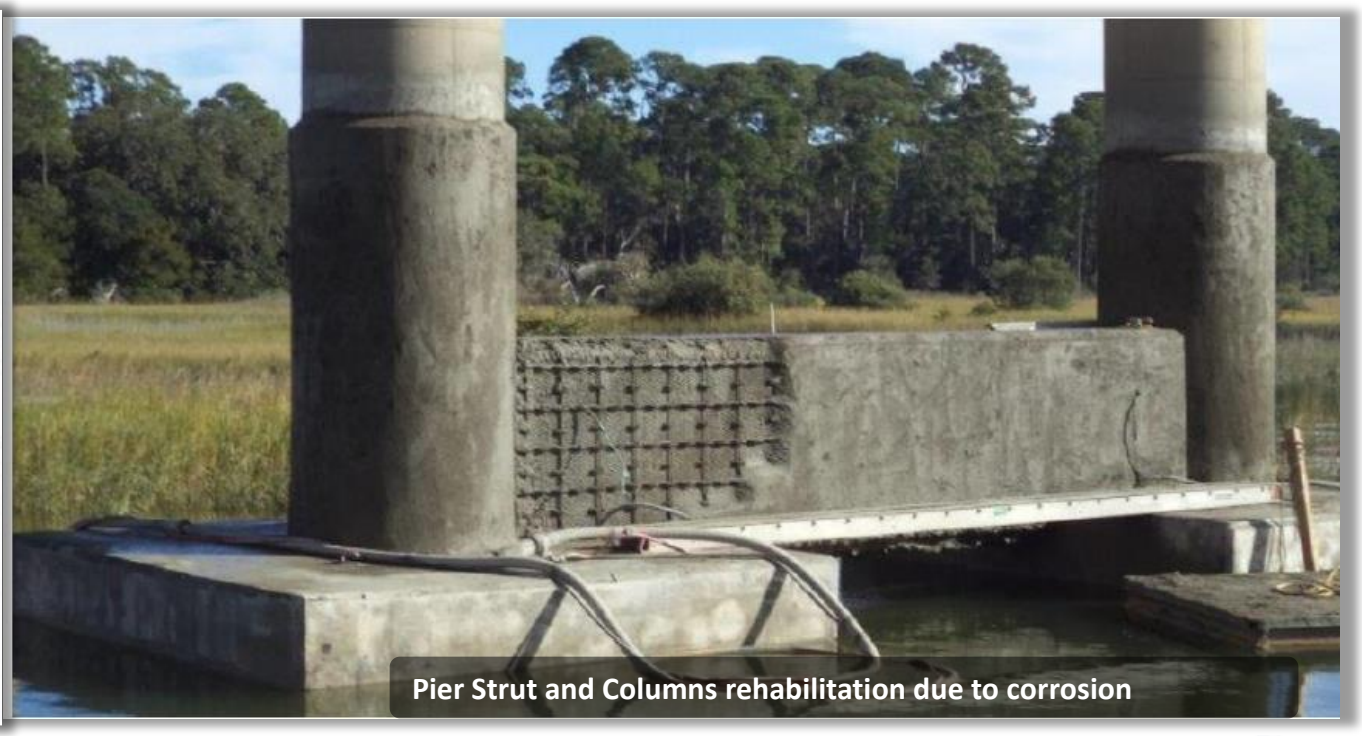

Early age grinding required for UHPC

Example Projects

- **SR 312 Over Matanzas River (BFRP-RC *Tech#7*)**

Use of GFRP dowel bars in conjunction with BFRP mesh in the marine environment (2014-2015)

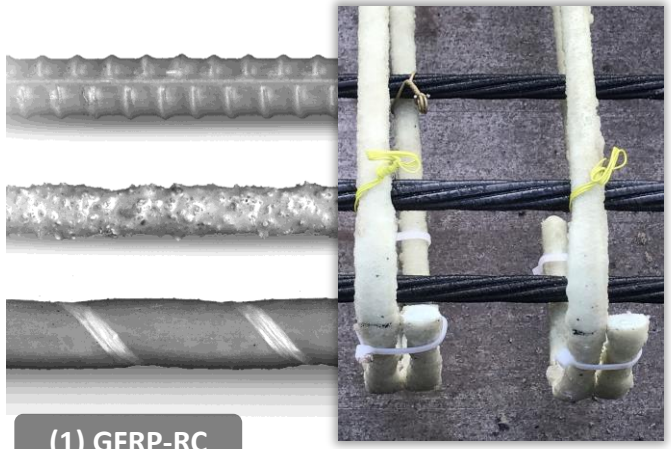
Shotcreting Pier Columns thru BFRP mesh



Pier Strut and Columns rehabilitation due to corrosion

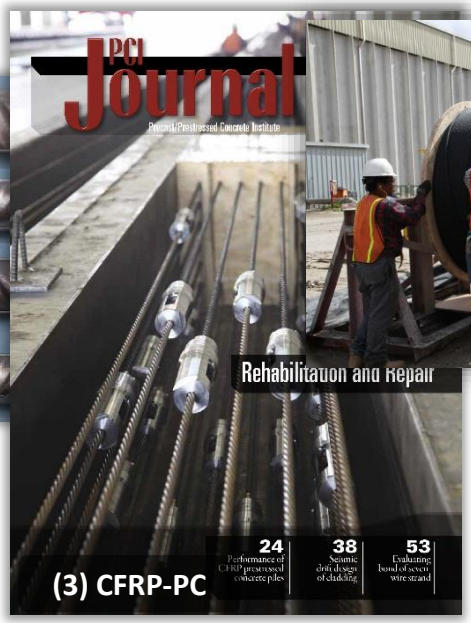
Technical Panel - Questions

a)
b)
c)



(1) GFRP-RC

(2) SS-RC



(3) CFRP-PC

(4) HSSS-PC

(5) FRP-Fender Systems

(6) UHPC

(7) BFRP-RC

Technical Panel Questions – T^2 1 of 2

1	Q. Does Nos. 1 thru 7 technologies reflects priorities of the FDOT or they are just randomly numbered? *A. They are not in any order of priority*
2	Q. How will the SAM-TAG communicate their progress (website, newsletter, emails etc…)? *A. This is through a monthly online meeting. Periodic updates to the relevant Innovation webpages, Developmental Specification or Standards will be also made.*
3	Q. Is the location of the pilot projects available for general public (website etc…)? *A. Work is underway to make a GIS application public*
4	Q. Has the Department considered using this technology within small test areas on rehab or even proposed structures? An example may be a single bent on a multi-span structure located in an aggressive environment. This may provide an opportunity for a side-by-side comparison. *A. Yes*
5	Q. Is there any funding program for the local municipalities implementation of these technologies into their projects? *A. Not from FDOT, but FHWA does have the AID program which supports implementation of new technologies which is available to local agencies.*
6	Q. Who should local municipalities contact if they want to implement some of these technologies into this project? *A. The District Structures Design Engineer in the area of the project.*
7	Q. How can other consultants get involved or be in the loop if they wish to do so? *A. Send an email to the SAMTAG chair, currently Steve.Nolan@dot.state.fl.us*
8	Q. Can you give an update of how far each technology is from full implementation? *A. Some of the technologies are more advanced than the other, there is currently no timeline established for the adoption and implementation.*

Technical Panel Questions – T^2 2 of 2

9	Q. How does the Selection of implementation champions work? *A. Champions have been selected based willingness to participate and experience in the particular SAM-TAG technology.*
10	Q. Are there any ongoing pilot projects? (Besides HRB) *A. There are several projects currently in planning, design, and construction phase. Please contact DSDE in the area you are interested to know more about these projects.*
11	Q. Can you give examples of the type of coordination efforts currently ongoing with the different organizations mentioned in the presentation? *A. SAMTAG members and friends are on TRB AFF80, AASHTO CBS T-6 & T-10, ACI 440 committees. Presentations by members are being made at TRB, ACI, ASCE, AASHTO, and fib events, to exchange information and gather feedback.*
12	Q. What are biggest challenges in implementing these technologies? *A. Acquistion cost, and adoption into mandatory codes such as the AASHTO BDS.*
13	Q. Is any of the 7 technologies more advanced as compared to one another? *A. Tech #1, #3, & #5 have more established design and construction criteria for FDOT.*
14	Q. How is Florida in implementing/researching these technologies as compared to the rest of the country? *A. Several states are interested in Implementing corrosion resistant solutions such as CFRP, GFRP and SS technologies. FDOT has arguably the most robust FRP Fender System design and specification requirements. UHPC use is more extensively in other states, but additional research for FDOT focus initiatives is ongoing. FDOT is currently leading the efforts to implement BFRP-RC though a STIC Incentive project.*

Technical Panel Questions – Design 1 of 4

1	Q. How does one get approval to use any of these innovative materials for a project that has corrosion concerns? OR I want to propose one of the SAM technologies for a project I am designing. What process should I follow to propose the technology and how can the SAM-TAG committee assist me in any way? *A. Contact the District Structures Design Engineer (DSDE) to discuss. If the DSDE has no objections. Contact the lead coordinator for the technology on the Innovation website or one of the SAM-TAG champions to get the pertinent information.*
2	Q. What is the status of development of the AASHTO Codes for incorporation of these technologies? *A. Various technologies are in different stages of early bridge code adoption. Some have AASHTO Guide Specifications (GFRP, CFRP) and/or ACI Guidelines, others only have NCHRP reports and/or FHWA or FDOT Guideline requirements. The goals is to absorb successful technologies into the AASHTO Bridge Design Specification, but this often takes many years and multiple state DOT support.*
3	Q. What is the approach for the incorporation of these technologies into Structures Manual as well as in specs book? *A. Currently the Structures Manual Vol.4 - FRPG address Tech #1 and #3 (Glass and Carbon FRP), and Specification Section 932 & 933 address material requirements respectively.* *Specification 931 addresses Tech #2 (SS Rebar), Design is the same as carbon-steel rebar.* *Specification 933 addresses Tech #4 (HSSS Strand), and design guidance is being developed for non-standardized applications.* *Specification 471 & SDG 3.14 addresses Tech #5 (Fender Systems)* *Developmental Specifications are being prepared for Tech #6 (UHPC), based on FHWA guidelines.* *Specification 931 & FRPG Chapter 2 will be revised in 2019 to include Tech#7 (Basalt FRP rebar)* *These will be updated periodically and similarly other technologies will be added once they are mature and adopted*

Technical Panel Questions – Design 2 of 4

4	Q. Is there a research/general data available for comparing the additional cost associated with these technologies vs increase in service life of the structure/reducing the maintenance cost of the structure? *A. Unit cost data will be added to SDG Chapter 9 as it becomes available. Life Cycle Cost guidelines are being developed based on both NCHRP Project 12-108 and supplemental FDOT criteria. Anticipated to be published by late 2019.*
5	Q. Currently, the FRP bar bending details on Index D21310 are all dimensioned to the center radius of the bend in bent bars which is different from dimensioning the bars out-to-out like we do with black steel. Why was the method of dimensioning RFP changed and does Central Office plan on releasing a revised version Microstation Rebar program to use this new method of dimensioning? *A. The first release for Index D21310 dimensioned bars to the center of the radius based on FRP industry request. This pratice was subsequently revised in the 12/01/17 version to match the traditional convention of out-to-out dimensioning used for steel rebar. The Rebar Application is in redevelopment for 2019 to include FRP rebar.*
6	Q. What is the expected service life of a concrete bridge constructed with FRP reinforcement compared to steel? *A. Recommended service life with minimal maintenance, based on current environmental reduction factors, is 100 years. ACI's FRP Committee 440 is reevaluating these factors and FDOT is conducting further research for future refinement.*
7	Q. How are concerns with fire/high temperatures for GFRP being mitigated? *A. No additional criteria for fire mitigation is currently specified for highway structures. This is considerr more of a concern in occupied/building structures. Research is ongoing, but initial findings indicated that if the anchorage zones are protected, sufficient residual strength remains to avoid sudden collapse, albeit with extensive deflection. Research is ongoing.*

Technical Panel Questions – Design 3 of 4

8	Q. Based on past designs, it appears that the area of GFRP bars required to resist a load is greater than the area needed for black steel: a. Is this true and if so, how does the initial cost for GFRP reinforcing compare to the black steel? How long of a design life is needed to offset the higher initial cost for GFRP? b. The ultimate strength of GFRP greater than black steel so I suspect that the need for additional area is to be account for the brittle nature of GFRP as well as to be somewhat more conservative with this relatively new material. Do you foresee the design codes getting less conservative as our experience grows with time? *A. This depends on the structural element and the critical load application. Currently the conservative design limits are being revaluated. The 2nd Edition Guide Specification will raise some of the allowable design limits. Tyically service limit states will control the design due to the the lower elastic modulus of GFRP, and can be based on either: minimum reinforcement; crack width control; sustained load; or fatigue. Typical service life expectation is 100 years with minimal maintenance.*
9	Q. With the price of steel fluctuating as a result of the market and recent tariff talks, is the Department providing any incentive to designers or contractors to explore non-metallic reinforcing on upcoming projects? *A. No incentives at this time. Unlike steel, FRP is not traded as a commodity, so the pricing historically has been much more consistent than steel products.*
10	Q. Are there any concerns in using FRP to resist impact loads, such as connecting barriers to deck slabs, do to their inherent brittle nature? What has been done in the past and can be done in the future to overcome this possible problem? *A. Crash test sponsored by Canadian manufacturers indicate good performance with reduced areas of FRP reinforcing for standard barrier shapes. Ductility in flexural elements is addressed by over-strength design procedures similar to compression-controlled failure in steel reinforced structures.*

Technical Panel Questions – Design 4 of 4

11	Q. What are good candidate projects for Ultra-High Performance Concrete (UHPC)? *A. Precast connections for rapid construction. Narrower joints with simplified (short straight) rebar connections. Thin precast elements where weight reduction is important for either handling or sustained loads.*
12	Q. What is the status with mechanical splices for GFRP? *A. This is under investigation, but fundamentally challenging due to the lower shear strength of the composite material in friction or threaded connections*.
13	Q. How do lap splices for GFRP compare to steel? *A. Similar but not the same.*
14	***Q. SDG 4.2*** indicates, *"…, traffic railing/noise wall combinations, etc., may be considered only if applicable crashworthiness evaluations have been completed and proof of FHWA acceptance is provided..."* - Is there any plan for CO to do crash testing and create some "standards" for FRP in traffic railings with limitations for allowing their use rather than engineers and DB teams needing to deal with crash testing and case by case approval? (example use for traffic railings, is Toll Gantry areas where reinforcing can be troublesome with loops & detectors). *A. Standards are being developed for traffic railings and barriers. Index 410 has been updated for some toll gantry applications. Developmental Index D420 will be updated to the Single-Slope geometry for GFRP reinforcing in 2019 under the Index D521-400 series.*
15	Q. What is the effect of ultra-violet light on GFRP? *A. There is some loss of strength in the outer fibers over time and a loss of toughness in the surface resin. Specification 415 requires covering of GFRP reinforcing in storage. When long-term exposed to sunlight is anticipated filed covering is recommend. Specific time limits have no been established, but will likely be measured in months, not days.*
16	Q. What is the schedule for implementing the full depth precast deck panel with UHPC in FL? *A. There is no schedule.*

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SAM-Tech Deployment Train

BFRP-RC → UHPC → FRP-Fenders → HSSS-PC → CFRP-PC → SS-RC → GFRP-RC

FDOT TRANSPORTATION SYMPOSIUM