The National Conference On
Beach Preservation Technology

February 6-8, 2019 (St Augustine, FL)

Low Impact Secant-Pile Seawall for protecting SR-A1A along Flagler Beach

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***** Presenter**

Abstract

Severe corrosion damage of existing steel sheet pile bulkheads and extensive erosion damage of adjacent sand dune systems necessitated intervention to avoid future collapse of SR A1A along Flagler Beach, especially considering increasingly extreme weather and sea level change. The most recent damage from Hurricane Matthew in 2016, resulted in severe damage and undermining of almost one mile of the state highway (see Figure 1). Several mitigation solutions have been under investigation since 2005, with the final alternative utilizing a secant-pile system scheduled for construction in 2019 (see Figure 2). The secant-pile system will minimize impact on the existing sand dunes and adjacent properties during construction. Additionally, the piles are designed with glass fiber-reinforced polymer rebar which will provide extended maintenance-free service life to minimize future construction activities along the coastal dune system. This presentation will describe the challenges and rationale for selection of the preferred alternative, including LCC analysis and potential improvements for similar future applications.

Outline

- Project Background
- History of Storm Damage
- Wall Feasibility Studies (2005 & 2017 update)
- Secant Pile Walls
- Innovations
- A1A Final Wall Design
- LCC Evaluation
- Future Innovations for Low-Maintenance Coastal Structures

Collaboration Team

FDOT (D5 STRUCTURES)

RS&H (ROADWAY – DRAINAGE)

MOTT MACDONALD (STRUCTURES)

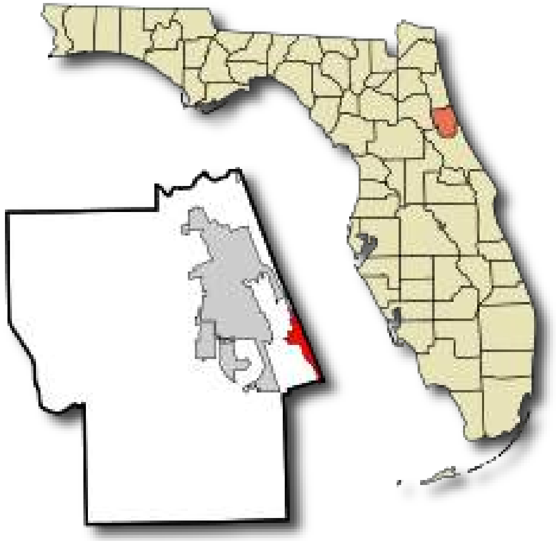
GEC (GEOTECH)

INTERA (HYDRAULICS)

HNTB (PROJECT MANAGEMENT)

Project Background

FLAGLER BEACH – A1A SEAWALL



LOCATION:

- Flagler Beach, FL --- Hurricane affected beach area

PROJECT PURPOSE:

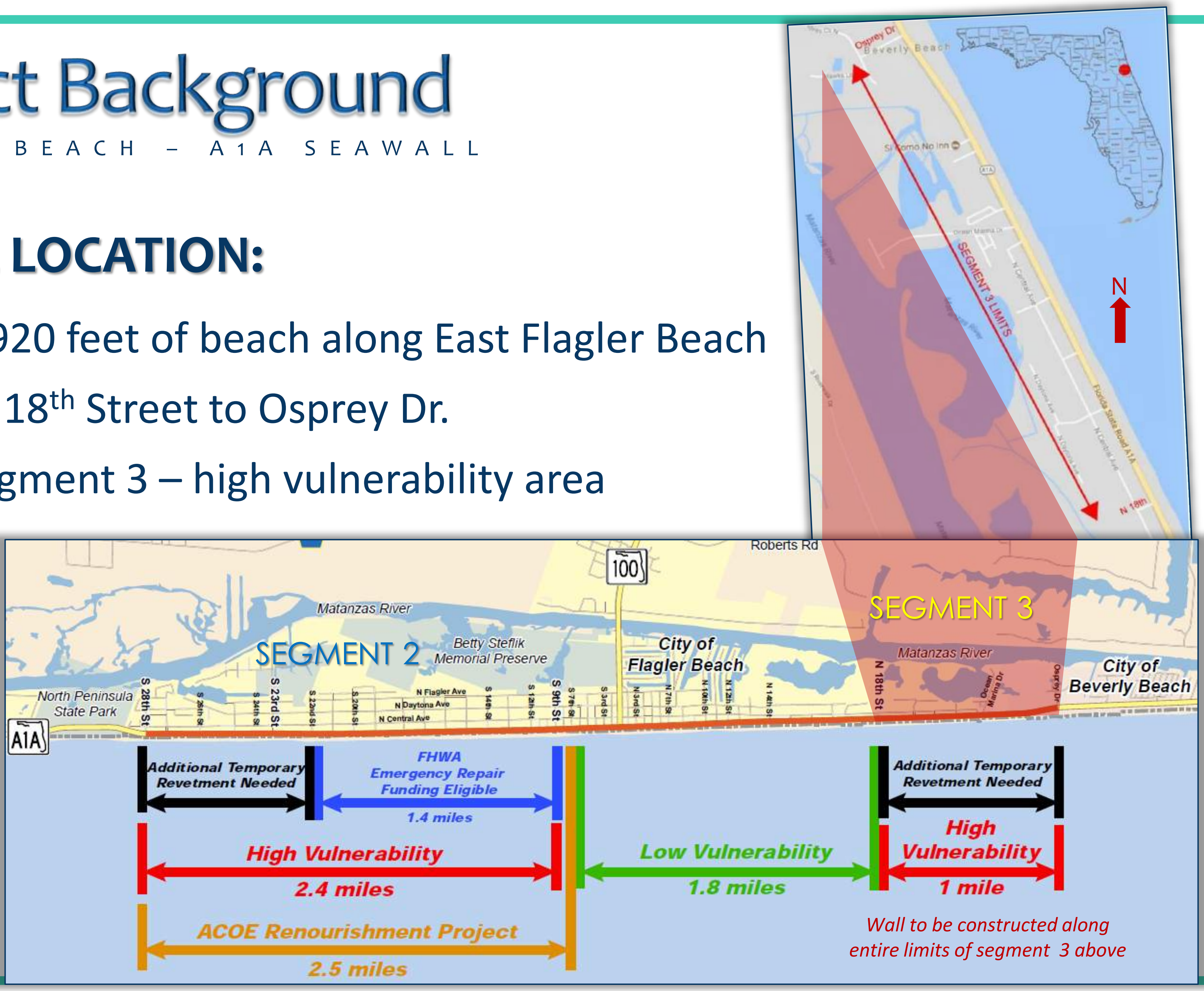
- **Historical erosion issues** due to hurricane impacts
- Provide a **long term, permanent solution** to protect A1A roadway
  - A wall design was needed to protect roadway in the most vulnerable areas
- **Governor's commitment** – accelerated acquisition, design, & construction schedule
- **Keeping Flagler Beach, Flagler Beach** – sand, turtles, A1A alignment

Project Background

FLAGLER BEACH – A1A SEAWALL

WALL LOCATION:

- 4,920 feet of beach along East Flagler Beach
- N. 18th Street to Osprey Dr.
- Segment 3 – high vulnerability area



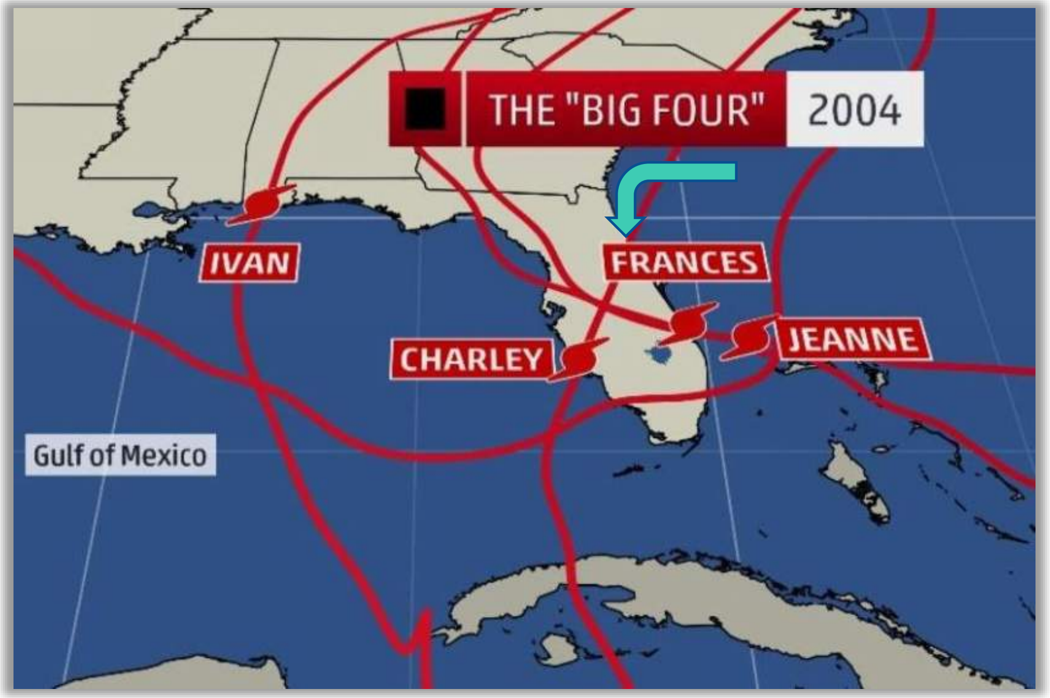
Project Background

FLAGLER BEACH – A1A SEAWALL

A HISTORY OF STORM DAMAGE IN THIS AREA

2004 – 2005 HURRICANES

- *Charlie … Frances … Ivan … Jeanne … Dennis … Katrina … Rita … Wilma*



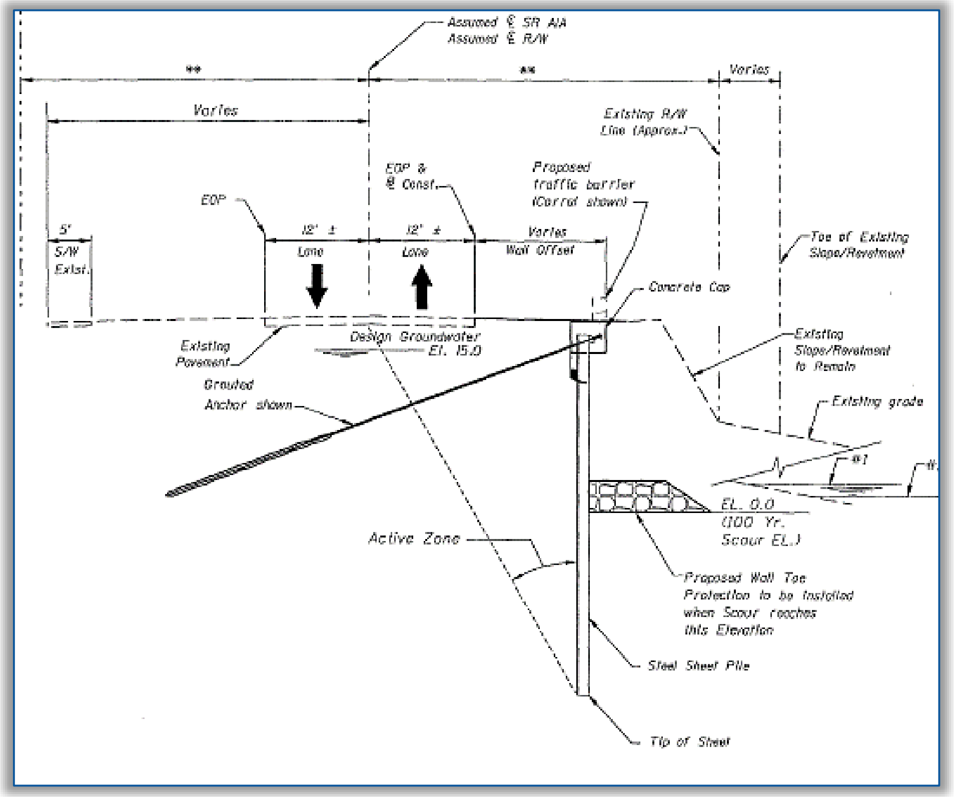
Project Background

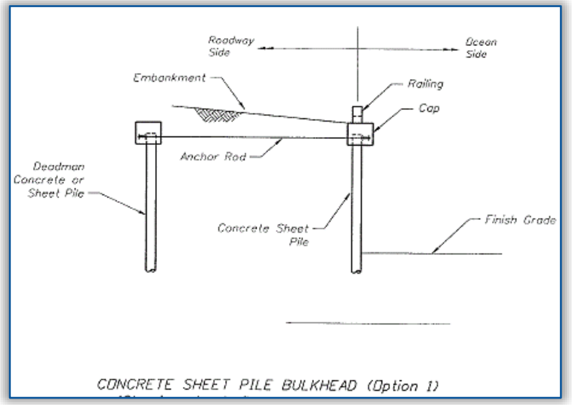
FLAGLER BEACH – A1A SEAWALL

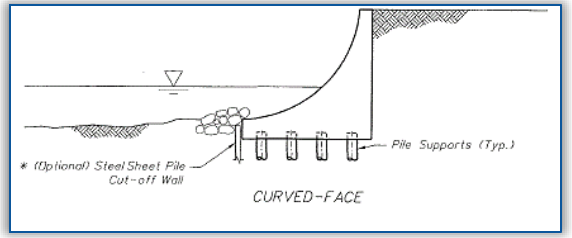
2005 WALL FEASIBILITY STUDY

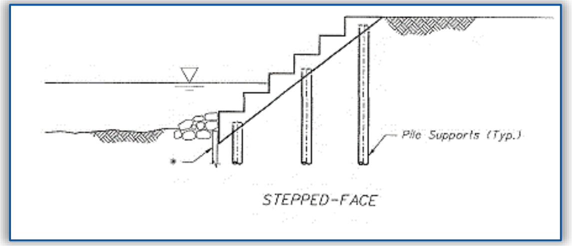
- Initial Wall Feasibility study prepare looked at 5 options

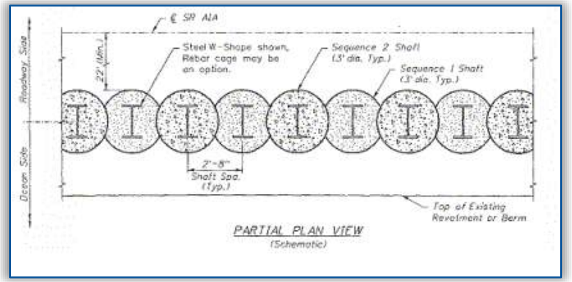
1. Grouted Anchor Tie-Back
2. Concrete Sheet Pile Bulkhead with Deadman Anchors
3. Curved Face
4. Stepped-Face
5. Combination Stepped and Curved Face
6. Secant Pile Wall









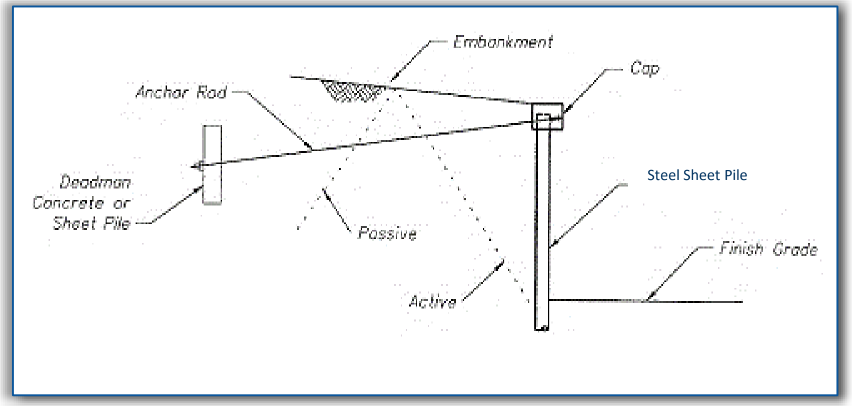


Project Background

FLAGLER BEACH – A1A SEAWALL

2006 EMERGENCY CONTRACT WALL (Segment 2)

- In response to storm damage and roadway undermining
- Steel Sheet Pile Wall with deadman tie-backs



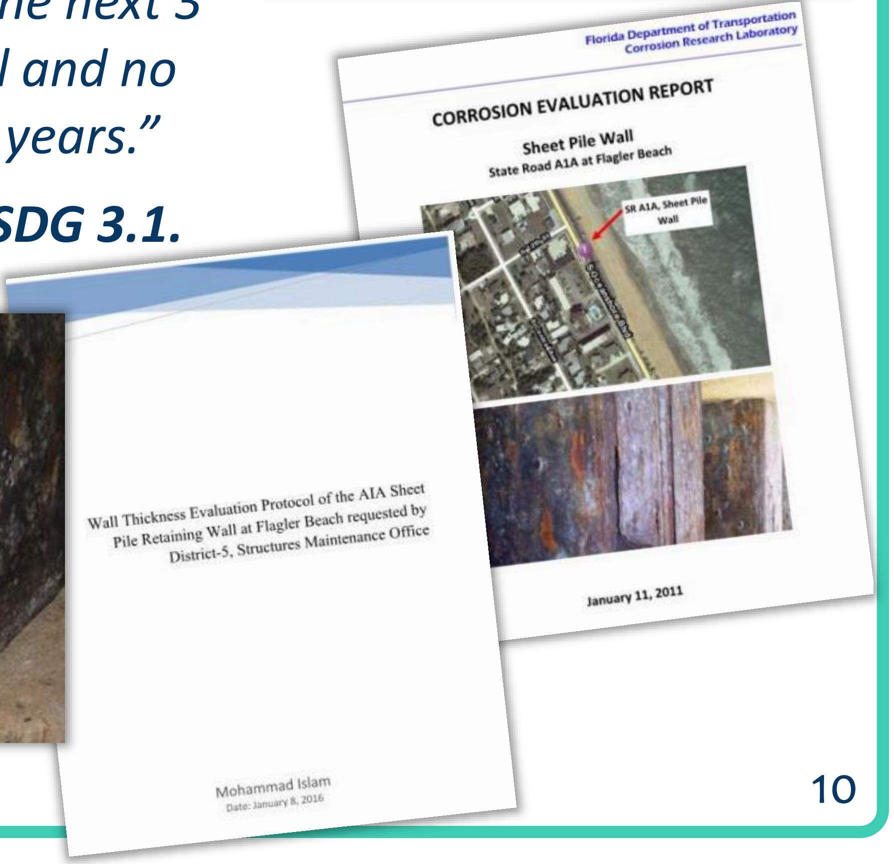
Project Background

FLAGLER BEACH – A1A SEAWALL

Figure 3 - Corrosion at the joint between two sheet piles showing complete section loss.

2011 & 2015 STEEL SHEET PILE EVALUATIONS

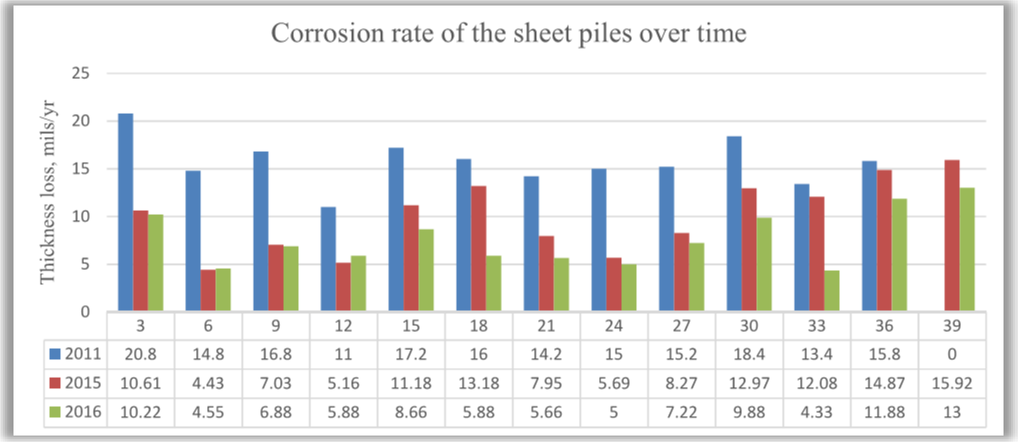
- Wall Thickness Evaluation Protocol of A1A Sheet Pile Retaining Wall at Flagler Beach *(Report Date: Jan 8, 2016)*
- *"…If the corrosion progress at the current rate, by the next 3 years many piles will start losing the sacrificial steel and no piles will have any sacrificial steel left by the next 7 years."*
- *Average Section loss up to 13 mils/year > 2 times **SDG 3.1.***



Florida Department of Transportation
Corrosion Research Laboratory
CORROSION EVALUATION REPORT
Sheet Pile Wall
State Road A1A at Flagler Beach
SR A1A, Sheet Pile Wall
January 11, 2011

Wall Thickness Evaluation Protocol of the AIA Sheet Pile Retaining Wall at Flagler Beach requested by District-5, Structures Maintenance Office

Mohammad Islam
Date: January 8, 2016



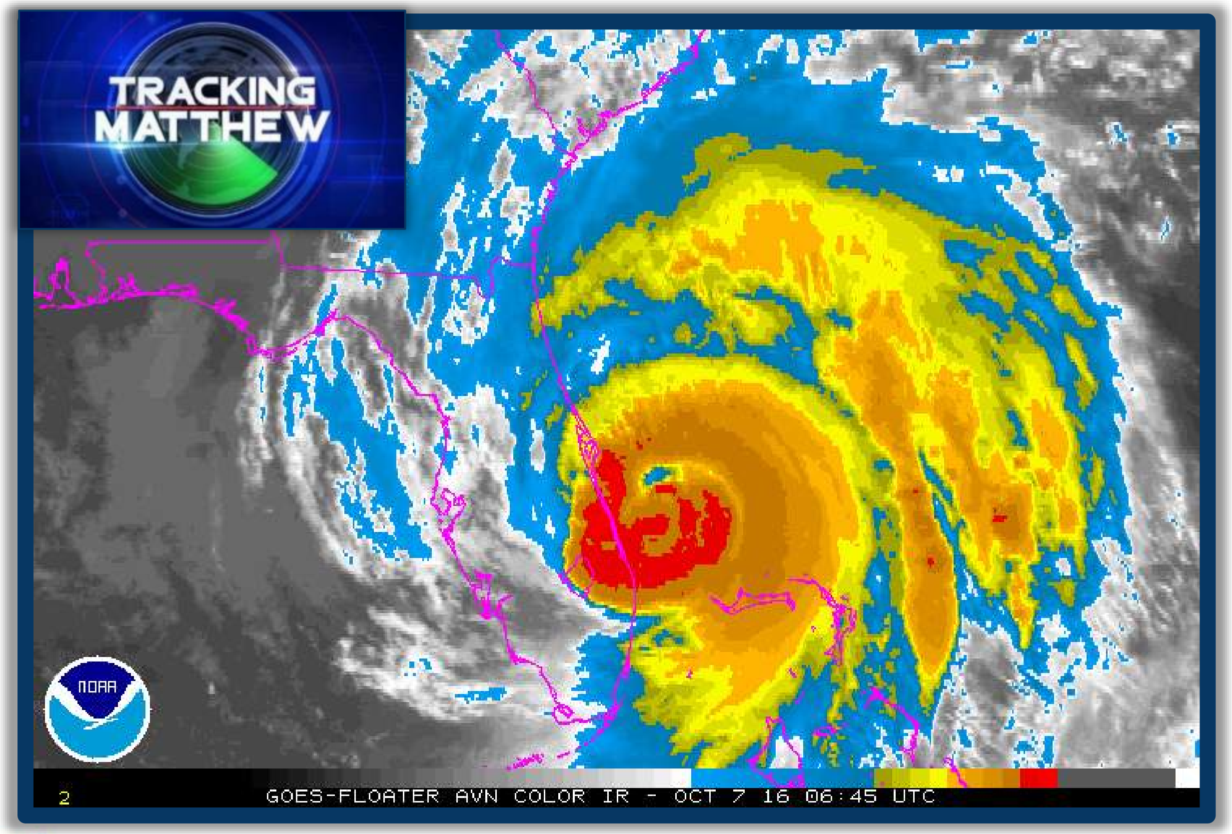
	3	6	9	12	15	18	21	24	27	30	33	36	39
2011	20.8	14.8	16.8	11	17.2	16	14.2	15	15.2	18.4	13.4	15.8	0
2015	10.61	4.43	7.03	5.16	11.18	13.18	7.95	5.69	8.27	12.97	12.08	14.87	15.92
2016	10.22	4.55	6.88	5.88	8.66	5.88	5.66	5	7.22	9.88	4.33	11.88	13

Project Background

FLAGLER BEACH – A1A SEAWALL

OCT 2016 – HURRICANE MATTHEW

- *CATEGORY 4 :* >130 mph winds, storm surge, flooding



Project Background

FLAGLER BEACH – A1A SEAWALL

OCT 2016 – HURRICANE MATTHEW

- Storm Damage

Project Background

FLAGLER BEACH – A1A SEAWALL

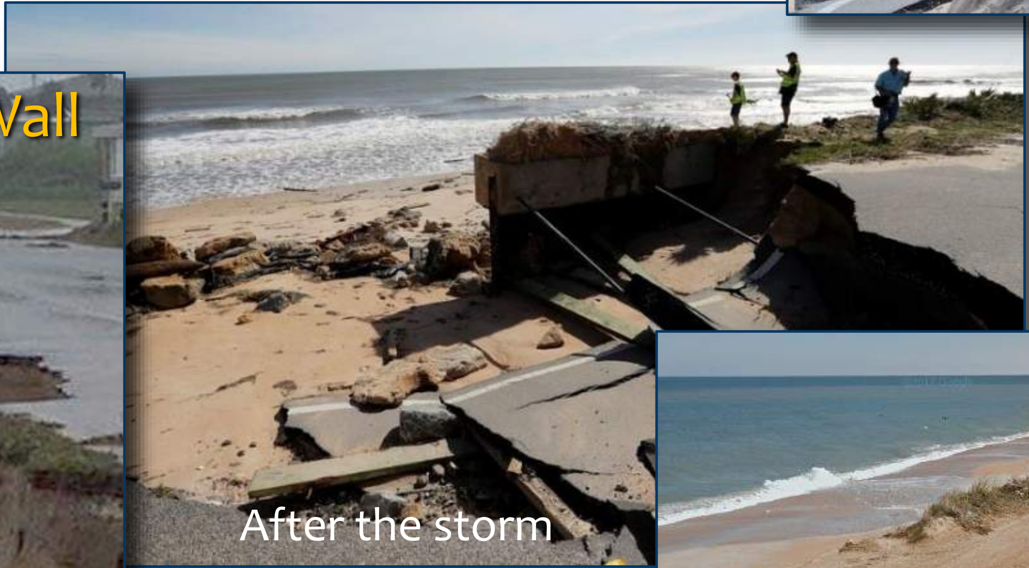
OCT 2016 – HURRICANE MATTHEW

- Storm Damage (Segment 2)


After the storm


2006 Emergency Contract Wall

During the storm


After the storm

Google Street View after emergency repairs

Wall Feasibility Study

FLAGLER BEACH – A1A SEAWALL

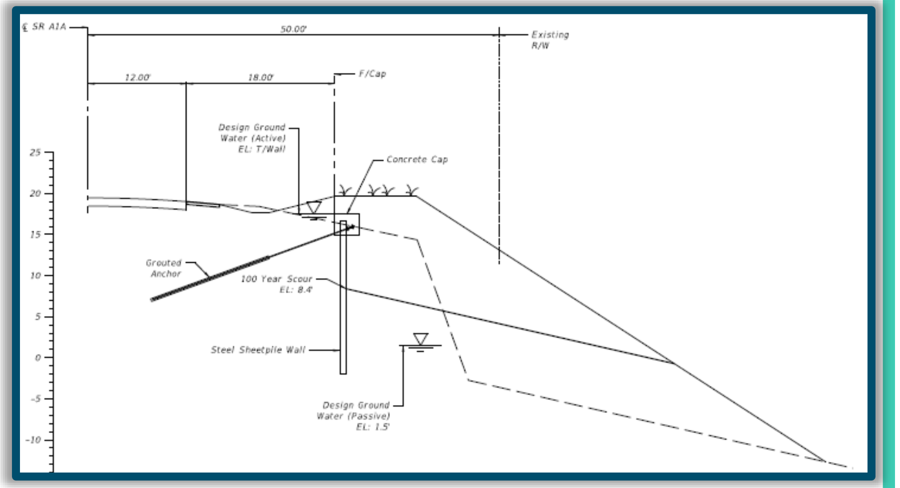
2017 – WALL FEASIBILITY REPORT UPDATE

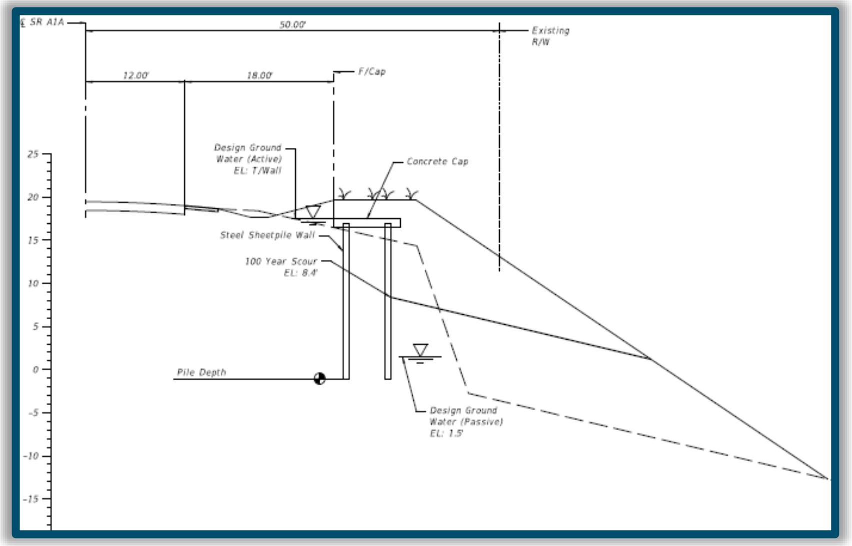
- *To Determine a wall design in most vulnerable areas of Flagler Beach to prevent future damage*
- *<u>Alternatives Evaluated:</u>*

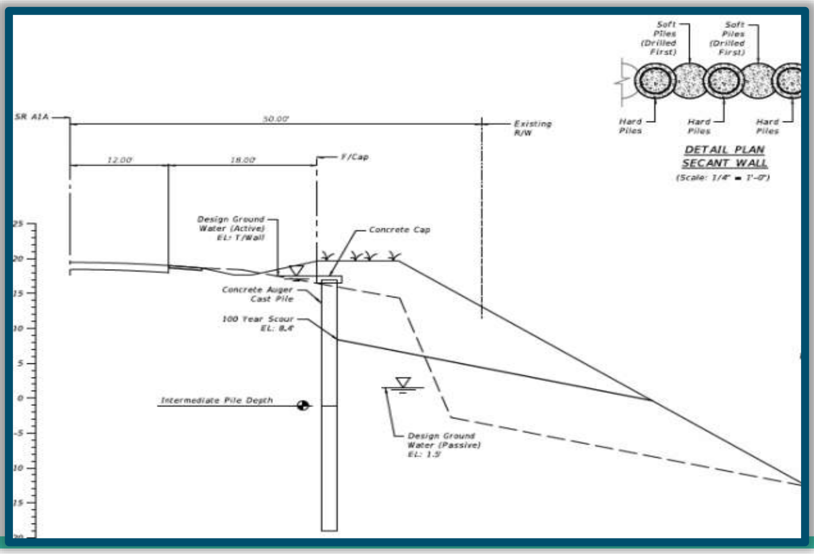
  A – ANCHORED SHEET PILE WALL

  B – DOUBLE CANTILEVER SHEET PILE WALL

  C – SECANT PILE WALL



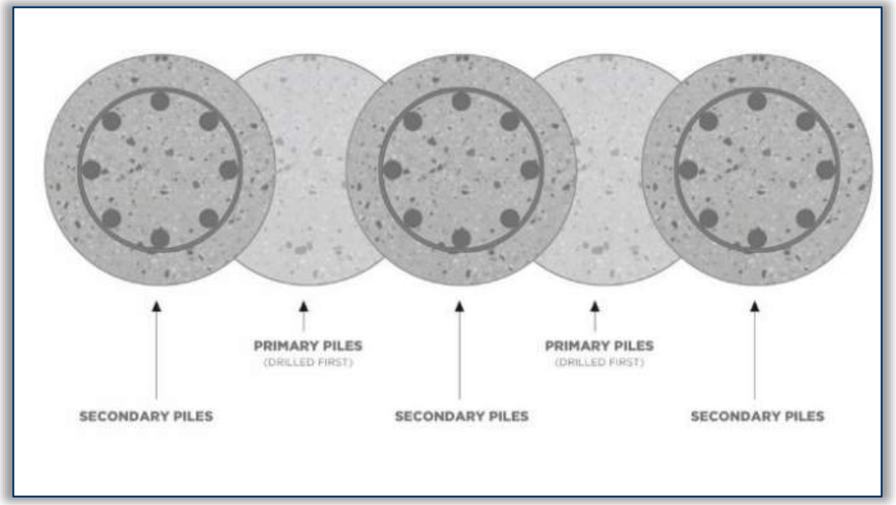




Update Wall Feasibility Study

2017 – WALL FEASIBILITY REPORT UPDATE (Segment 3)

- *ALTERNATIVE SELECTED:* ***SECANT PILE WALL***
  - ***Corrosion-resistant reinforcing*** *– Glass Fiber-Reinforced Polymer (GFRP) rebar;*
  - ***Ease of Construction*** *-- shallow dense coquina rock difficult to drive sheeting; less equipment;*
  - ***Speed of Construction*** *– no predrilling required;*
  - ***Less Impacts to Community*** *– less vibration, only one lane closure required to install (no tie backs)*



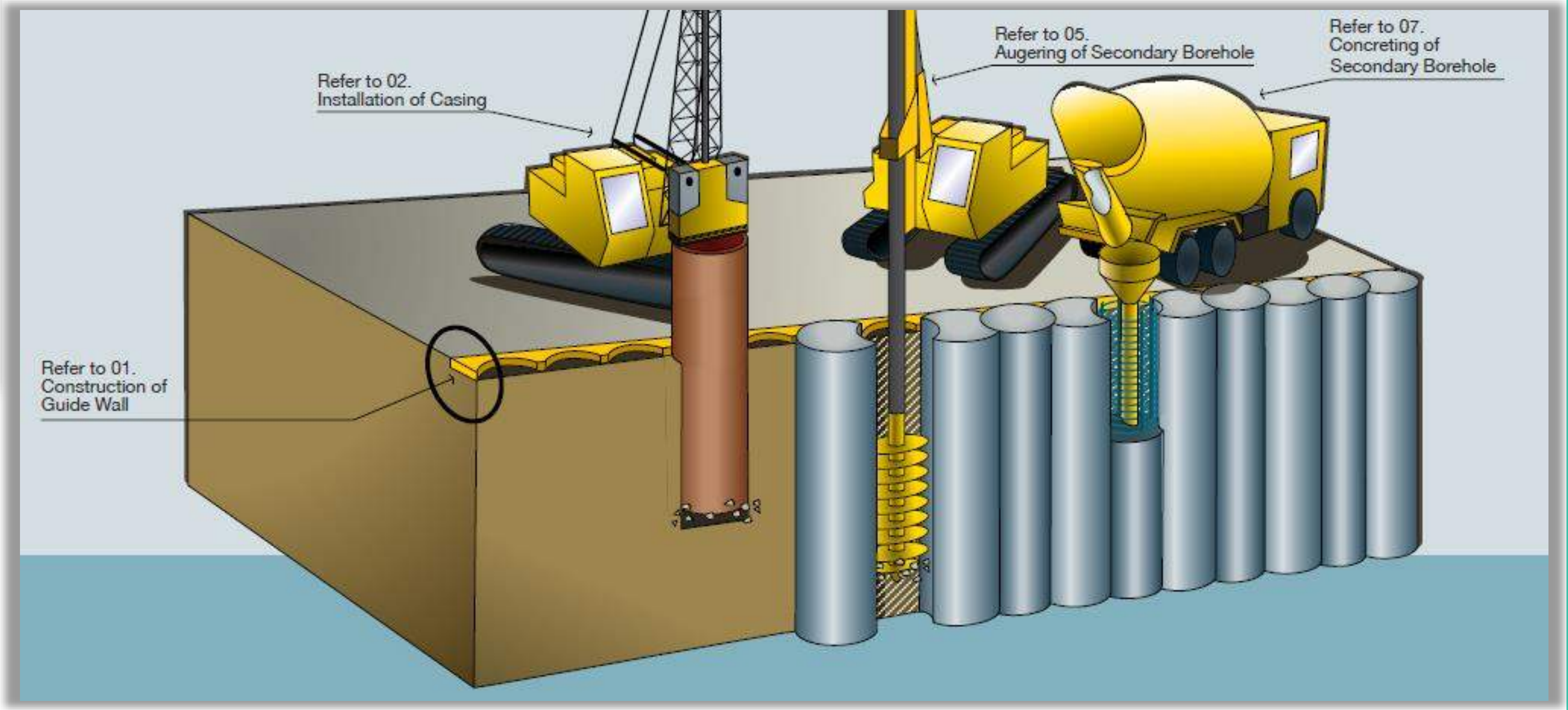
Update Wall Feasibility Study

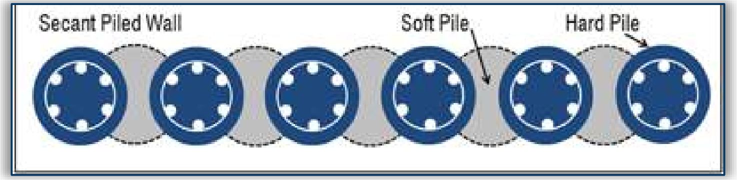
2017 – WALL FEASIBILITY REPORT UPDATE (Segment 3)

Cost Comparison:

Alt No.	Description	Wall Cost / FT*	Weighted Scores: Cost 50%	Weighted Scores: RUI 25%	Weighted Scores: Const. 5%	Weighted Scores: Maint. 20%	Total Score	Final Rank
1	36" Diameter Secant Pile (steel bars)	$ 2123.16	250	86	25	50	411	2
2	36" Diameter Secant Pile (FRP bars)	$ 2308.00	230	86	25	100	441	1
3	Anchored Steel Sheet Pile	$ 2,146.63	247	125	8	25	406	3
4	Double Cantilever Sheet Pile	$ 2,790.81	190	94	13	33	330	4

Secant Pile Walls

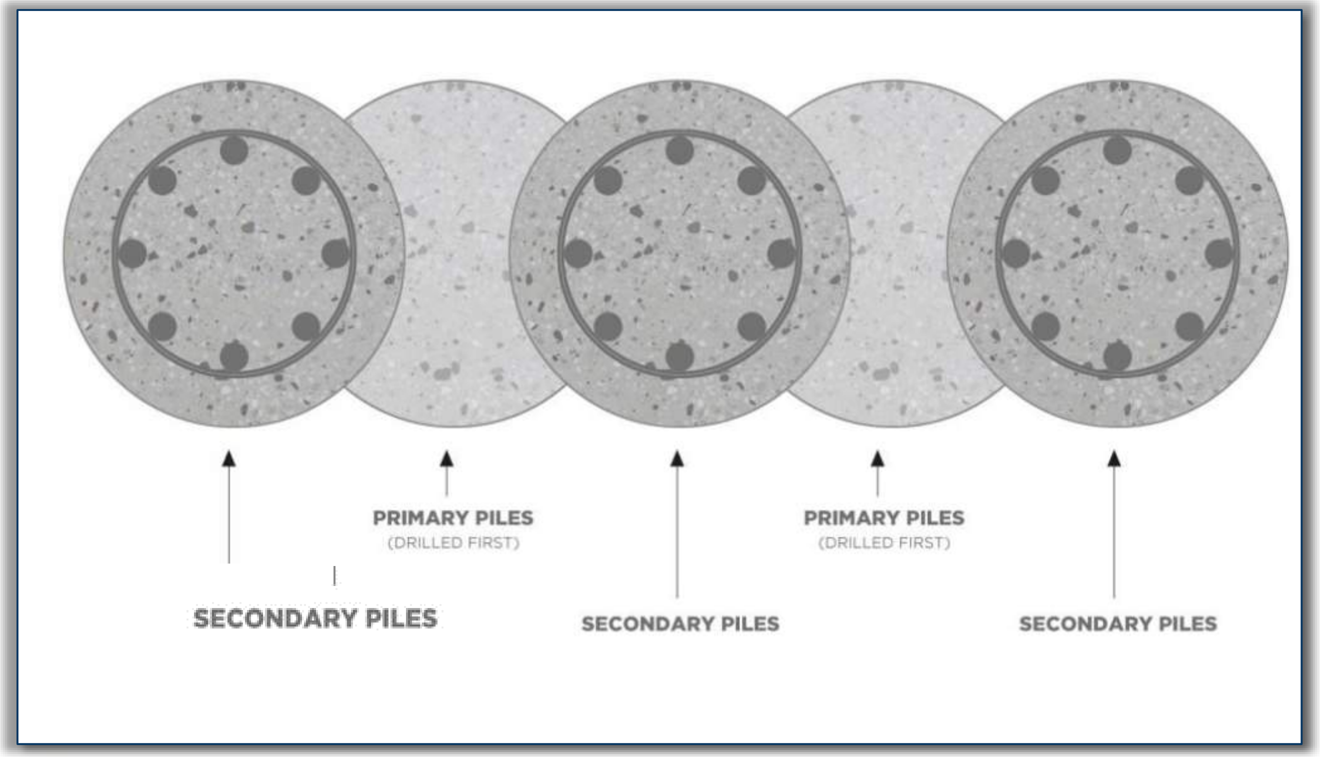




Definition

SECANT WALL CONSTRUCTION

- A bored pile retaining wall consisting of interlocking reinforced concrete piles



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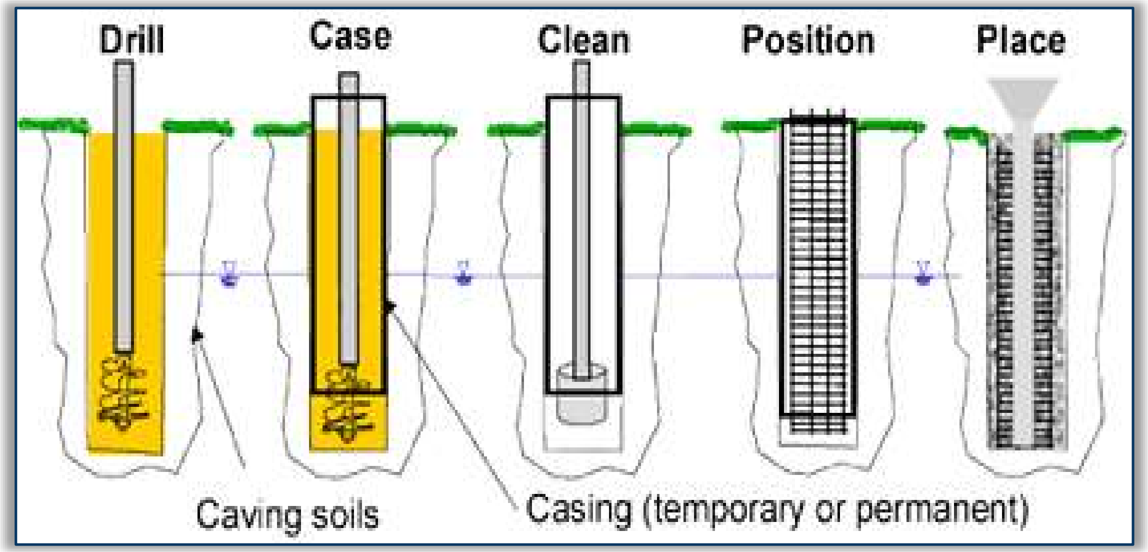
SECANT WALL CONSTRUCTION

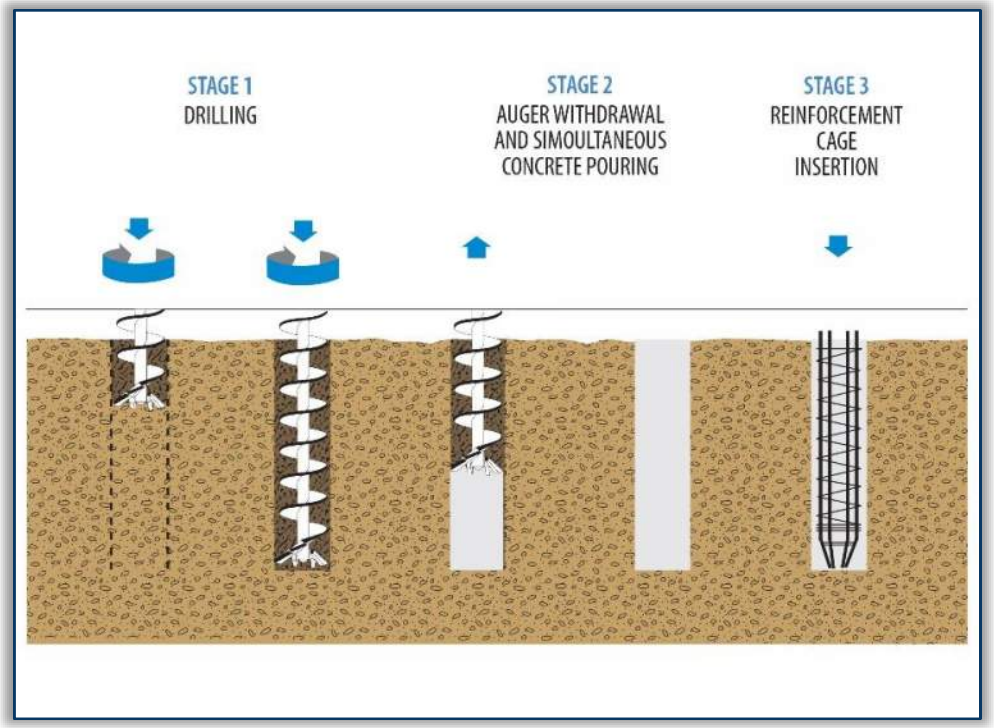
DRILLED SHAFTS vs AUGER CAST PILES

- *What's the difference?*

DRILLED SHAFTS



AUGER CAST PILES



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SECANT WALL CONSTRUCTION

DRILLED SHAFTS vs AUGER CAST PILES

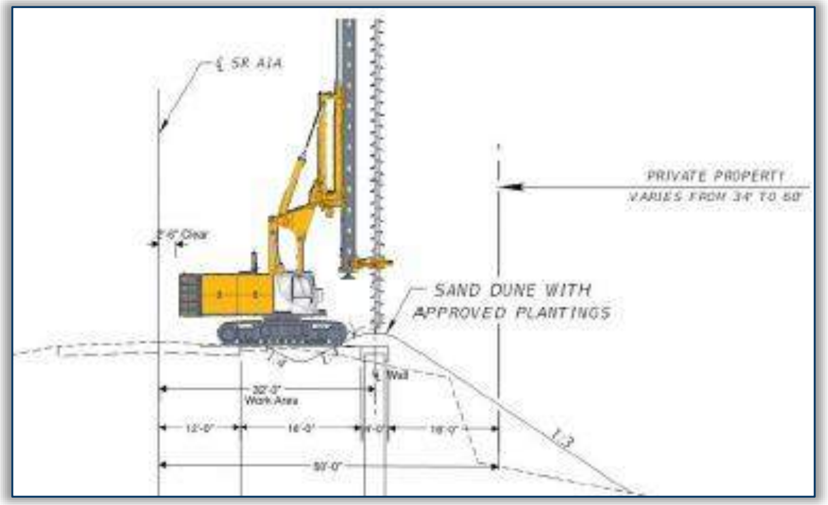
- *Advantages and Disadvantages*

DRILLED SHAFTS

- Easier to ensure quality of shaft
- Relatively expensive
- Common FDOT method
- Slow install time

AUGER CAST PILES

- Harder to ensure quality of shaft
- Less expensive than Drilled Shafts
- FDOT typically only uses for Noise Walls
- Fast installation time

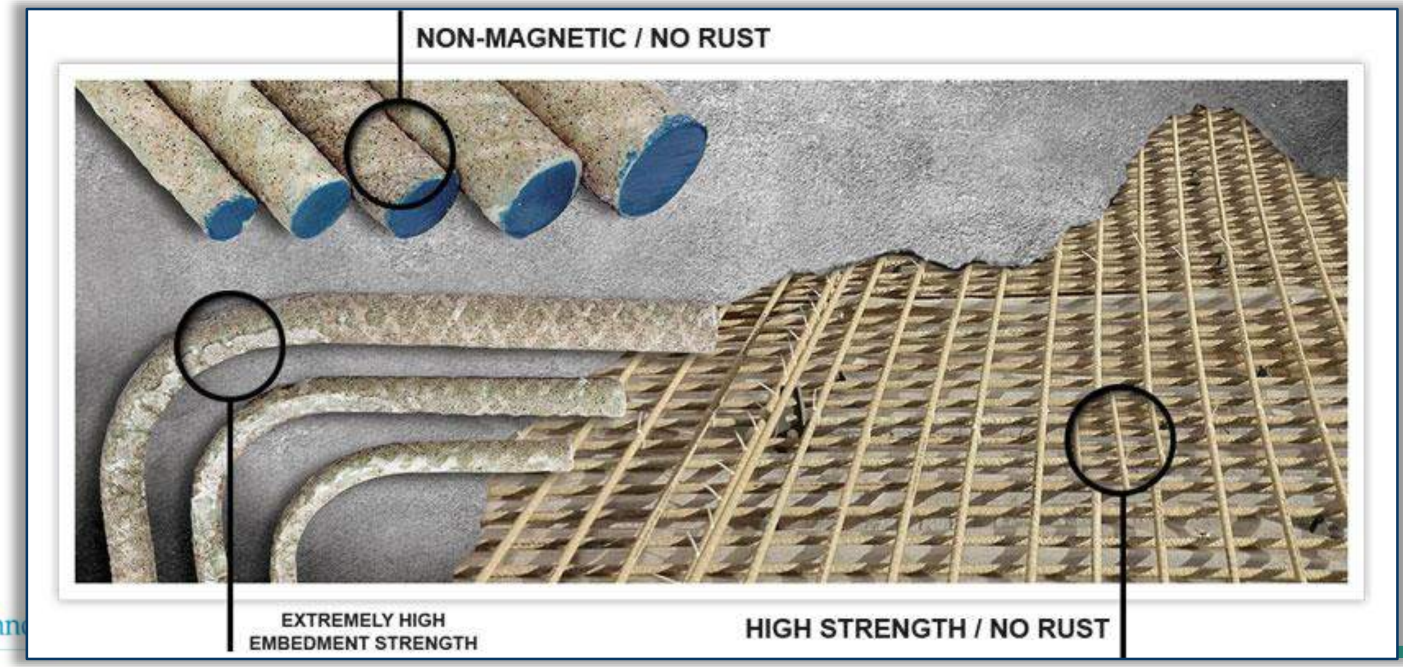


Glass Fiber-Reinforced Polymer (GFRP) Reinforcing Bars

Definition

GLASS FIBER-REINFORCED POLYMER REBAR

- **Glass fiber reinforced polymer (GFRP)** is an alternative material to the steel rebar.
- Lightweight, **no corrosion**, superior tensile strength, and high mechanical performance.
- Installation of the GFRP rebar is similar to steel rebar, but with **less handling and transporting** effort.



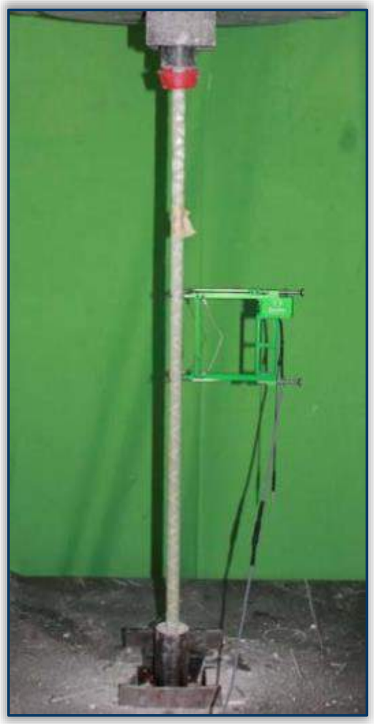
Definition

GLASS FIBER-REINFORCED POLYMER REBAR

Glass fiber reinforced polymer (GFRP)

SO HOW DOES IT WORK???

- FRP Rebar are made of **fibers** embedded in **Polymeric Resin**
  - ✓ Fibers provide strength and durability
  - ✓ Resin holds fibers together, transfers load between fibers, and protects from abrasion/environment



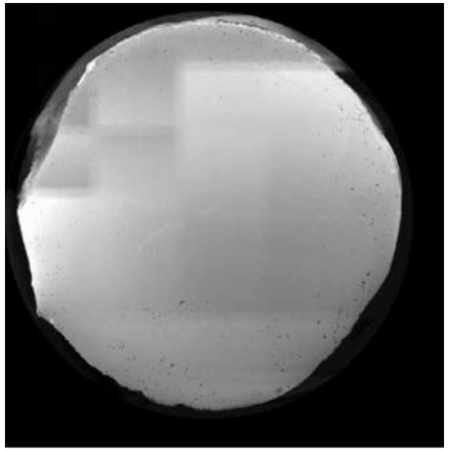


Figure 25. #3

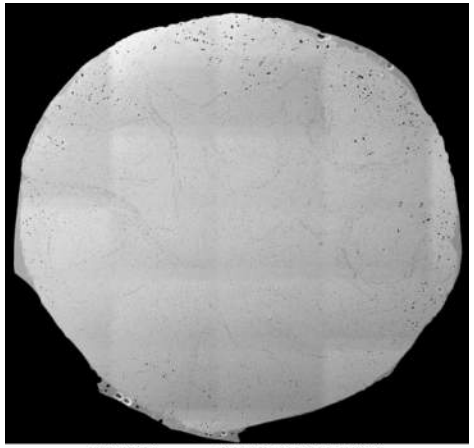


Figure 31. aged for 60 days at 60C

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GLASS FIBER-REINFORCED POLYMER REBAR

STEEL REINFORCING vs GFRP REBAR

- *Advantages*

STEEL REINFORCING

- Bonds very well to concrete
- Warning before failure
- Can be used in prestressed applications

GFRP REBAR

- Corrosion resistant (less concrete cover required)
- Higher tensile strength compared to traditional steel yield point
- Lightweight and easy to work with
- Moderate fatigue endurance

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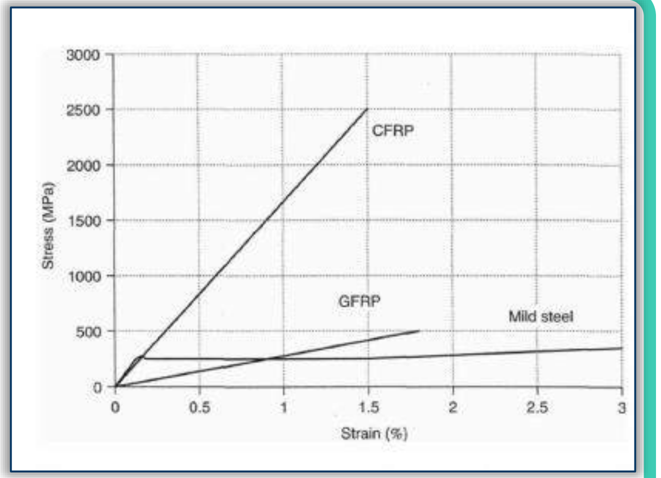
G L A S S   F I B E R - R E I N F O R C E D   P O L Y M E R   R E B A R



STEEL REINFORCING vs GFRP REBAR

- *Limitations*

STEEL REINFORCING

- Corrodes very rapidly in extremely aggressive environments (thicker concrete cover required)
- Heavy and difficult to work with in the field

GFRP REBAR

- Largest ASTM D7957 bar size (for now): #10 Bar. *(Now looking at need for #11+)*
- Variable surface to concrete bond capacity
- Bends only 60% of straight bar strength
- No yield (warning) before failure

Tension rupture of GFRP bar at failure

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GLASS FIBER-REINFORCED POLYMER REBAR

STEEL REINFORCING vs GFRP REBAR

- *Cost Comparison (2019 **Structures Design Manual** – Volume 1)*

  https://www.fdot.gov/structures/StructuresManual/CurrentRelease/StructuresManual.shtm

#8 Steel Rebar: \$2.67/ft	#8 GFRP Rebar: \$2.25/ft

Steel Bars

GFRP Bars

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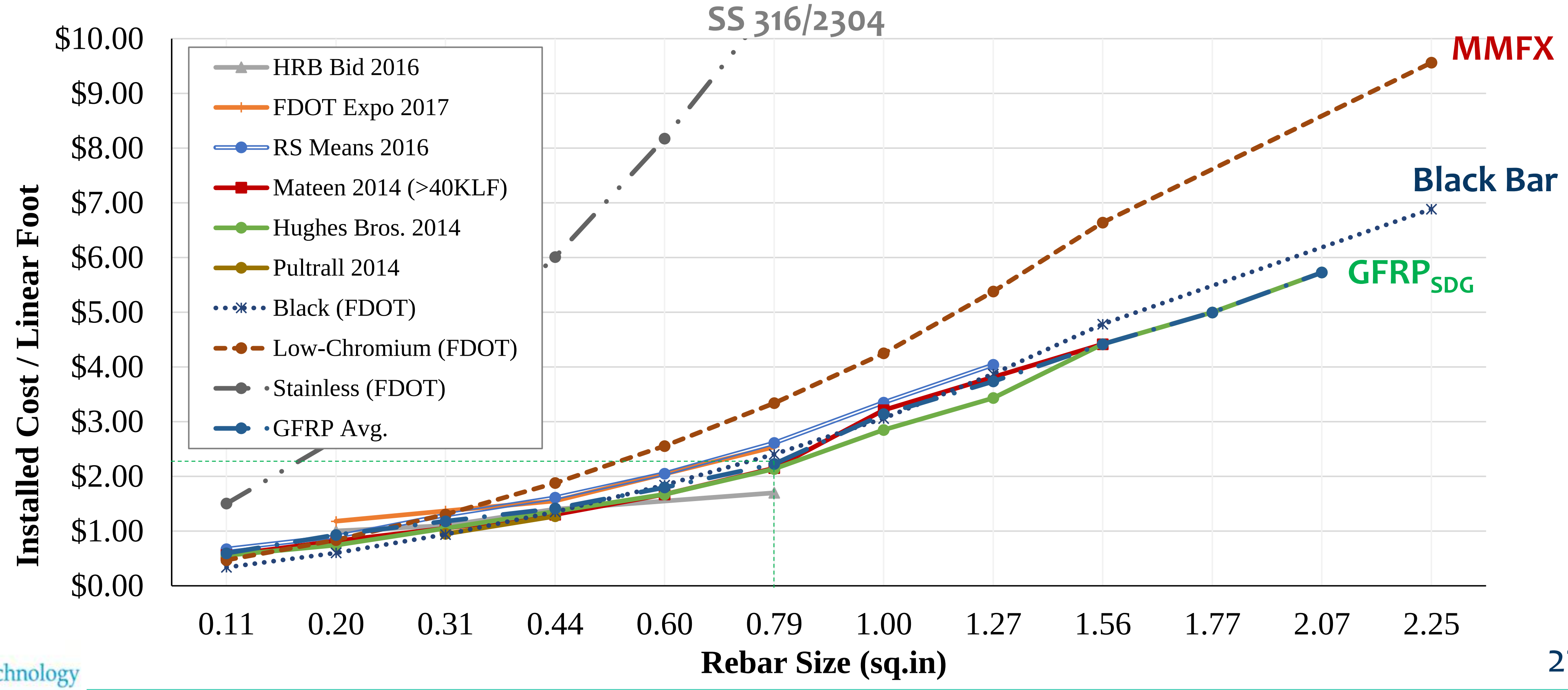
GLASS FIBER-REINFORCED POLYMER REBAR

STEEL REINFORCING vs GFRP REBAR

- *Cost Comparison (Published and FDOT Bid Estimates)*



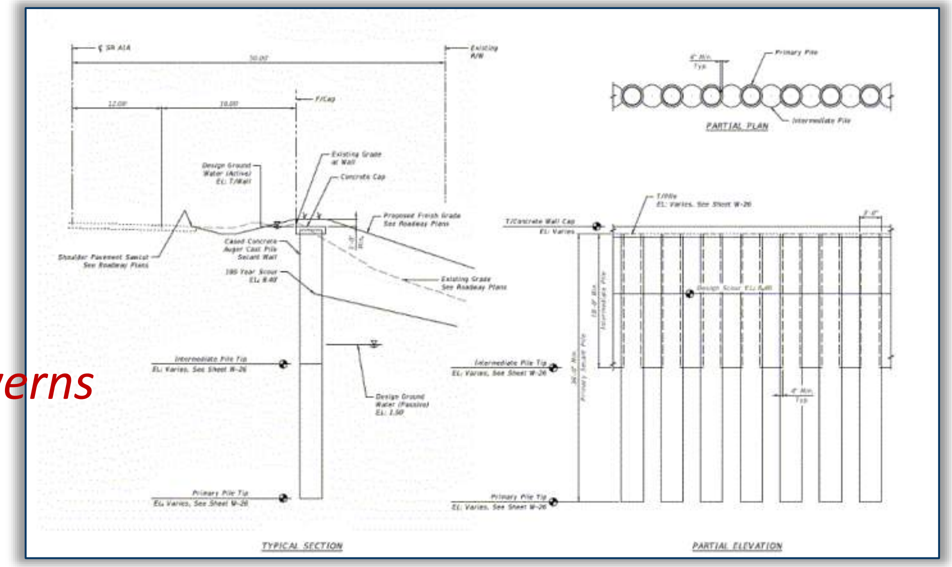
A1A Wall Design

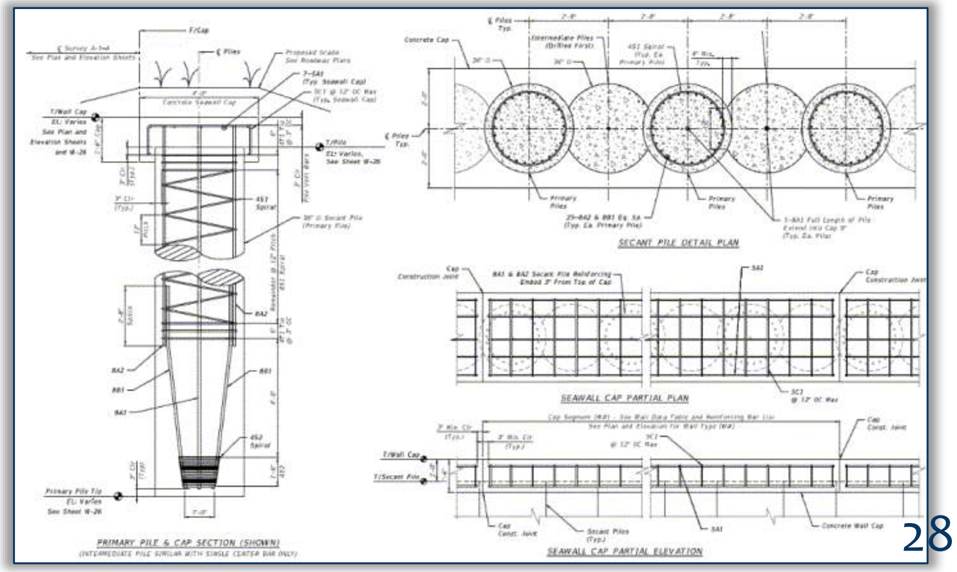
GLASS FIBER-REINFORCED POLYMER REBAR

SOME FACTS ABOUT DESIGN

- Designed to 100 year scour depth to eliminate need for toe protection
- With traditional steel: **9 ~ #11 bars** required ***($A_s = 14.0\ in^2$)***
- With GFRP rebar: **25 ~ #8 bars** ***($A_f = 19.75\ in^2$)*** *deflection governs*
- 36” dia. x 36-ft. long Reinforced Auger Cast Piles
- 36” dia. x 18-ft. long Non-Reinforced Auger Cast Piles

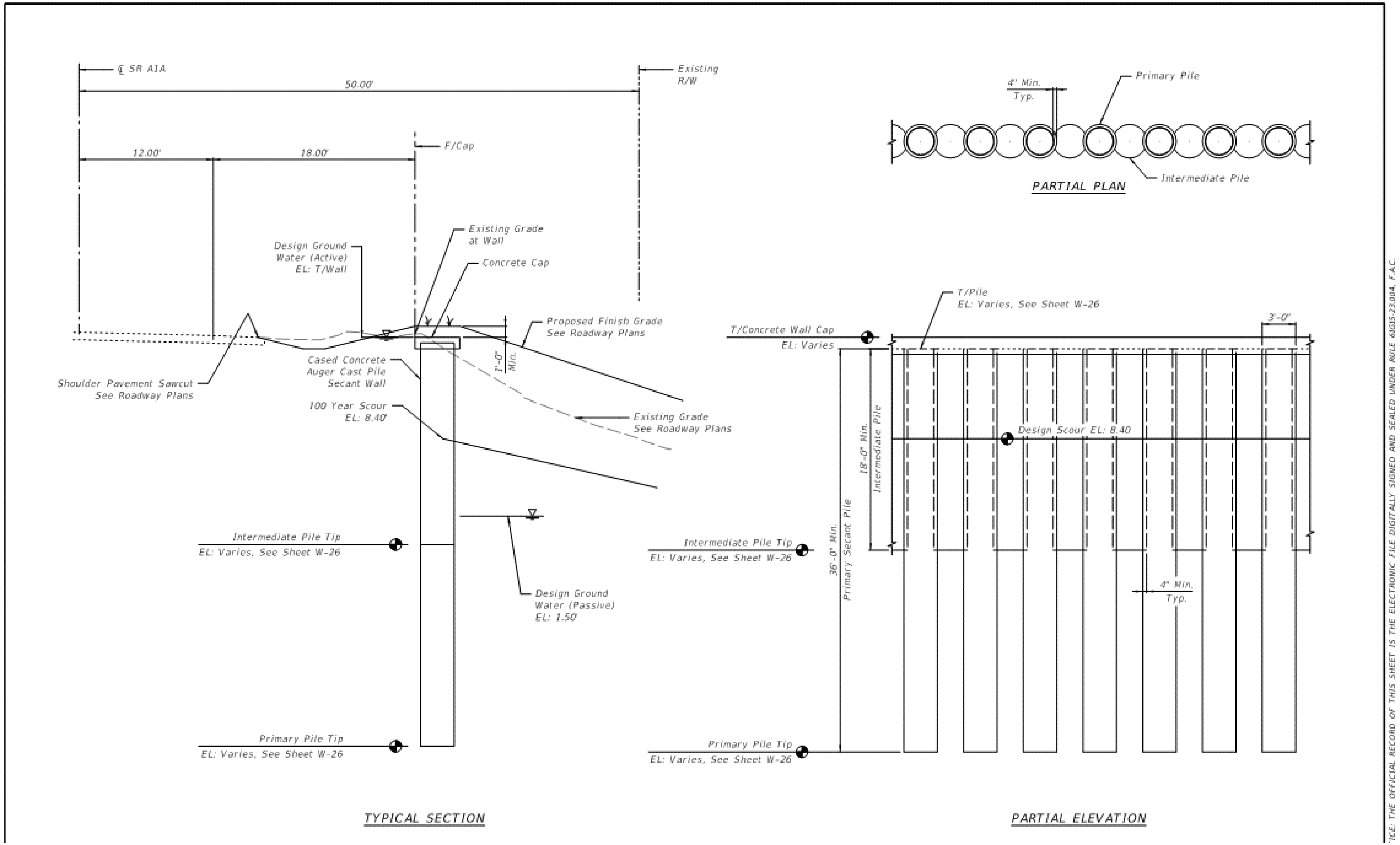
Full Length Wall Cost =	$11,355,377
8% Mobilization =	$908,430
5% Contingency=	$567,769
Total Wall Cost =	$12,831,576
Full length wall construction Time =	119 days
Mobilization Time =	15 days
Lag Time =	30 days
Work to Calendar Day Factor =	1.4
Total Wall Construction Time =	229 Calendar Days





A1A Wall Design

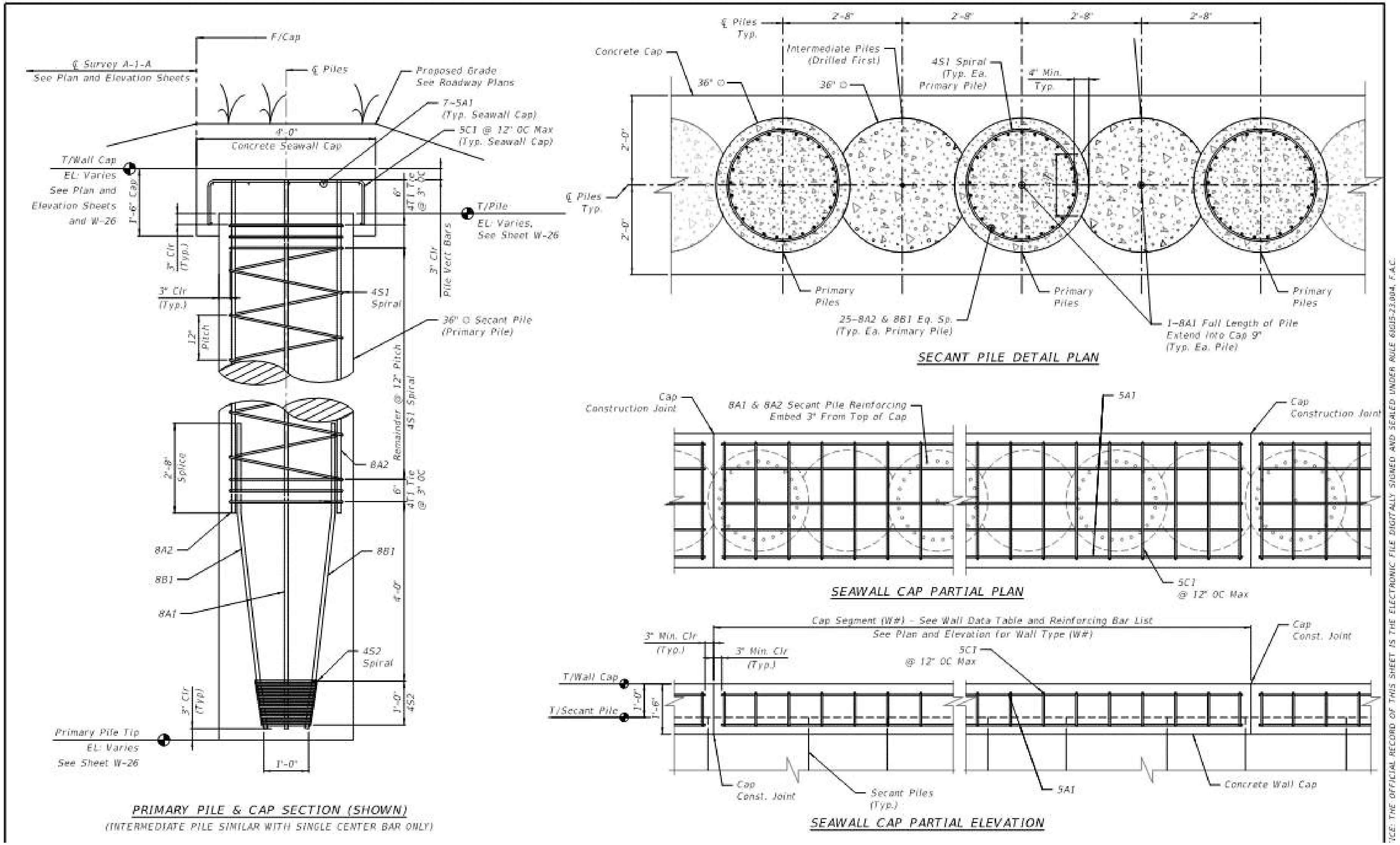
GLASS FIBER-REINFORCED POLYMER REBAR



The National Conference On Beach Preservation Technology

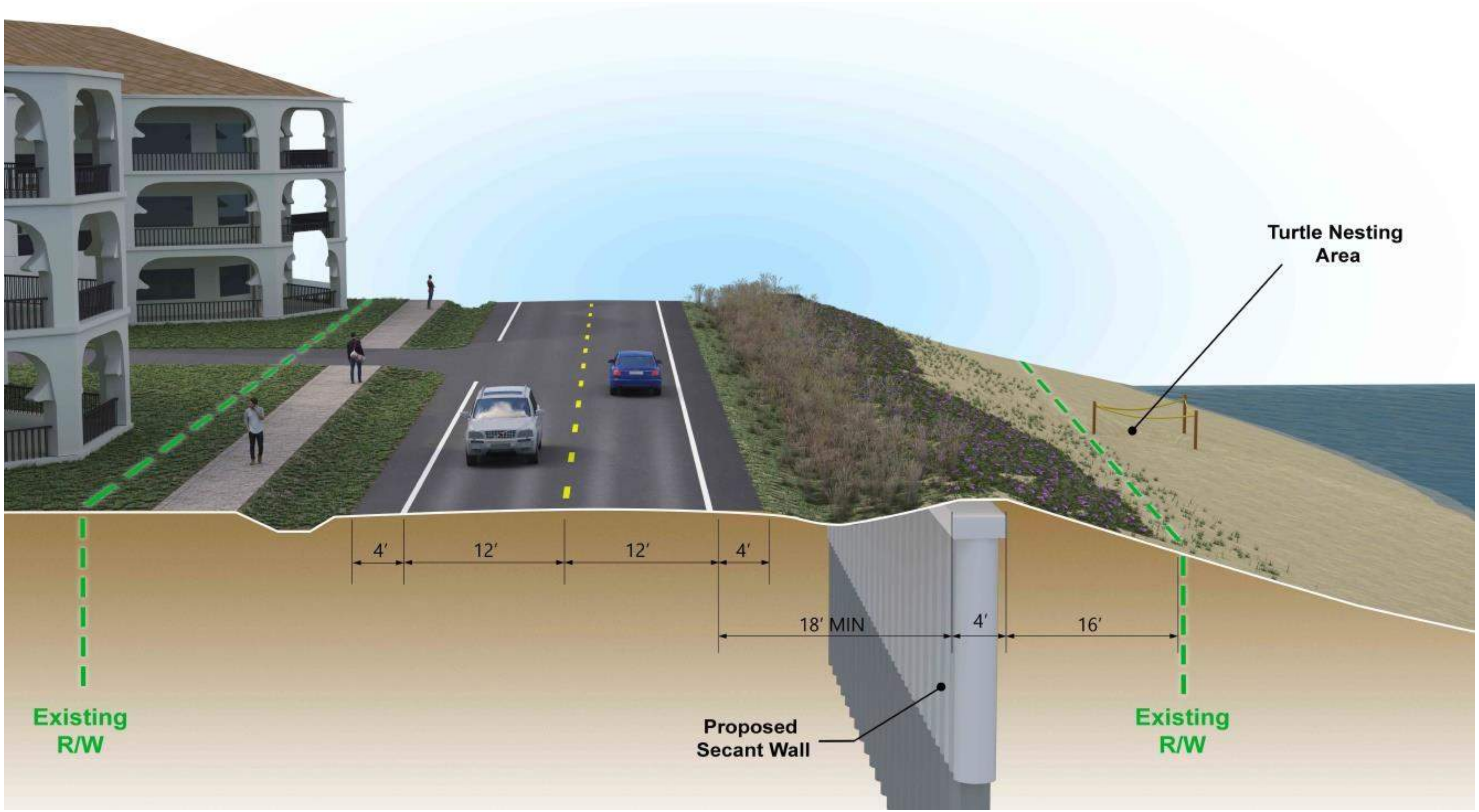
A1A Wall Design

GLASS FIBER-REINFORCED POLYMER REBAR



A1A Wall Design

GLASS FIBER-REINFORCED POLYMER REBAR



Life Cycle Cost Evaluation

GLASS FIBER-REINFORCED POLYMER REBAR

Engineer's Estimate:

Traditional steel reinforced auger-cast pile = $191.50 / ft. length pile installed
GFRP-reinforced concrete auger-cast piles = $209.25 / ft. length pile installed

Assuming 75-year life for traditional RC = $2.55 /year/ft.
Assuming 100-year (min.) for GFRP-RC = $2.09 /year/ft. *(not considering reduced maintenance costs and environmental benefits) > 18% savings!*

Bid Quantities & Unit Cost:

400-4-11	Class IV Concrete (Wall Cap) = (864 CY)($775/CY)	= $669,600	Low Bid $415.00/CY = $358,560
415-10-5	GFRP Reinforcing, #5 = (61892 LF)($1.37/LF)	= $84,792	Low Bid $1.45/LF = $89,743
455-112-6	Pile Auger Grouted, 36" Dia. = (51724 LF)($209.25)	= $10,823,247	Low Bid $156.50/LF = $8,094,806

Total Proposal Budget Estimate = $27,276,946 **Low Bid = $22,429,705**

Other Project Challenges

- **GOVERNOR SCOTT'S COMMITMENT**
  - *Condensed Schedule – wall to be under construction within 2 years*

- **COORDINATION WITH ARMY CORPS**
  - *Future beach renourishment project to the south*

- **KEEPING FLAGLER BEACH, FLAGLAR BEACH**
  - *SR A1A Alignment – move inland or keep along the beach*
  - *Minimize Sea Turtle Impacts – start construction outside turtle nesting season*
  - *Soil Replacement – specific criteria similar to native soil*

Project Delivery

- **GOVERNOR SCOTT'S CONSTRUCTION COMMITMENT**

- **CONDENSED PRODUCTION SCHEDULE:**

  - *Production/Permitting – normally takes 3 years, completed in 11 months;*
  - *Consultant Acquisition – condensed into 5 weeks with ELOI's;*
  - *Extensive Coordination – weekly planning & design meetings;*
  - *Accelerated Plans Development – submit wall feasibility study then 90% Plans;*
  - *Accelerated Plans/Calcs Review – interactive reviews.*

- **CONDENSED CONSTRUCTION SCHEDULE:**

  - *300 Day Construction Schedule – so construction only occurs in one hurricane season!*
  - *Contract Incentives & Disincentives to finish on time;*
  - *Start construction outside of sea turtle nesting season.*

Project Status

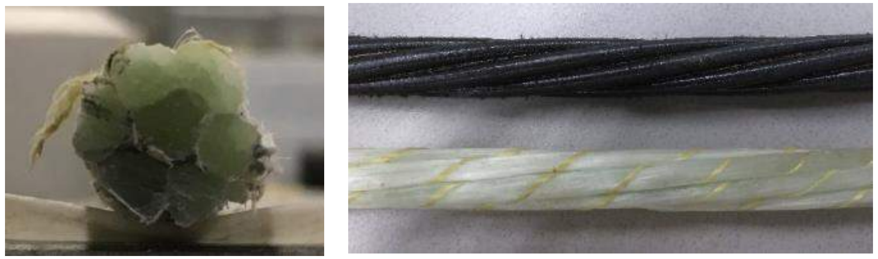
- **AFTER STORM EMERGENCY REPAIRS INSTALLED:**
  - ✓ *Project let and completed shortly after Hurricane Matthew*
  - ✓ *Repaired Dune, Placed Revetment / Rip Rap back, Road Pavement*

- **A1A SEAWALL:**
  - ✓ *Design completed (FPID 440557-7)*
  - ✓ *Project has been Let (T5641)*
  - ✓ *Contractor Selected*
    - ✓ *Superior Construction Co.*
  - ✓ *Notice to Proceed January 4, 2019*
  - ✓ *Construction began February 4, 2019*
  - *Estimated Completion October, 2019*

Future Innovations for Low-Maintenance Coastal Structures…

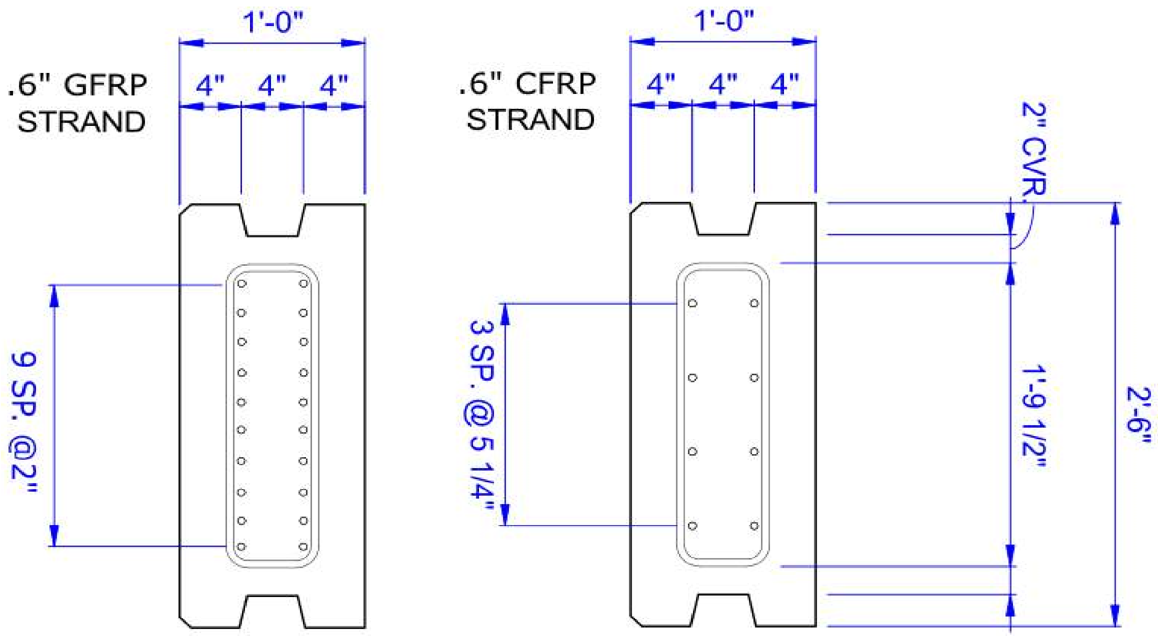
FIBER-REINFORCED POLYMER PRESTRESSING

(a) & (b) CFRP strand failure during tensioning;
(c) cracking following strands release.



(a) GFRP strand prototype cross section;
(b) compared to a CFRP alternative.

NCHRP IDEA Project #207 - *MILDGLASS*



(a) GFRP-PC sheet pile concept
(b) CFRP-PC sheet pile design for Halls River Bridge

http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4654

… Future Innovations for Low-Maintenance Coastal Structures…

FIBER-REINFORCED POLYMER REBAR & PRESTRESSING

- STIC 2018 Incentive Project:
  - *Basalt-FRP Rebar Standardization*
- Adhoc continuous stirrups
- High Modulus FRP rebar

FDOT

STIC State Transportation Innovation Councils

"Develop standard (guide) design specification, and standard material and construction specifications for basalt fiber-reinforced polymer (BFRP) bars for the internal reinforcement of structural concrete"

Photo courtesy of Don Smith, RAW Energy Materials (2019)

https://www.fhwa.dot.gov/innovation/stic/incentive_project/

…Future Innovations for Low-Maintenance Coastal Structures…

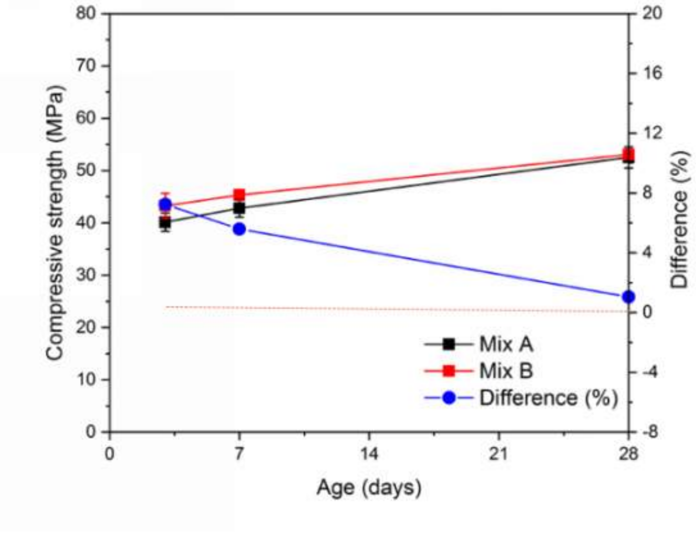
SUSTAINABLE CONCRETE

SEACON

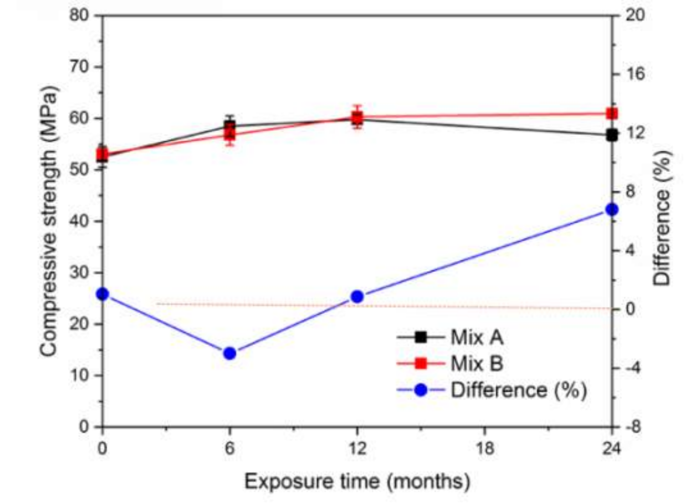
Sustainable concrete using seawater, salt-contaminated aggregates, and non-corrosive reinforcement

Infravation
An Infrastructure Innovation Programme

U.S.Department of Transportation
Federal Highway Administration



Early-age compressive strength and percentage difference.



Compressive strength and percentage difference in subtropical environment Coral Gables, FL for 24 months (1 MPa = 145.038 psi).

Source: Khatibmasjedi, M. "Sustainable Concrete Using Seawater and Glass Fiber Reinforced Polymer Bars" (2018)

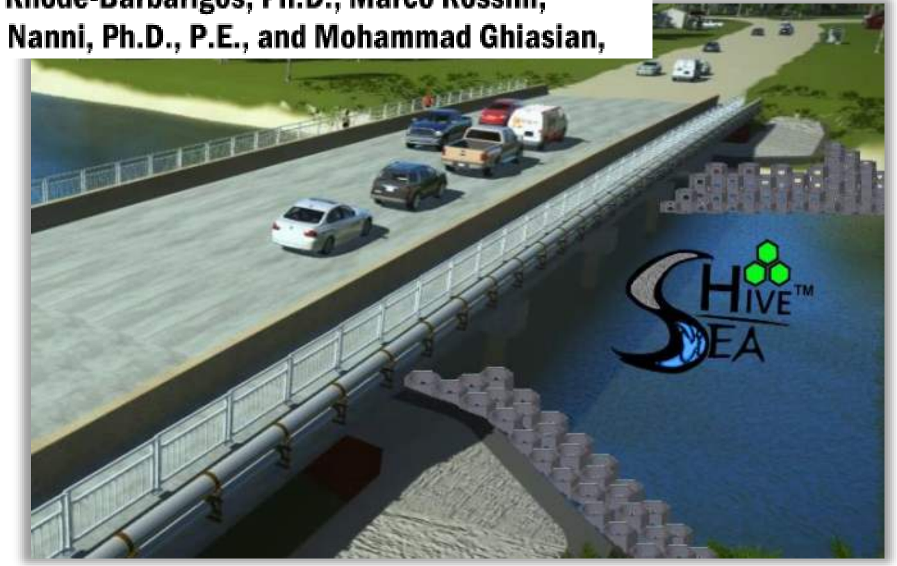
http://seacon.um-sml.com/

… Future Innovations for Low-Maintenance Coastal Structures

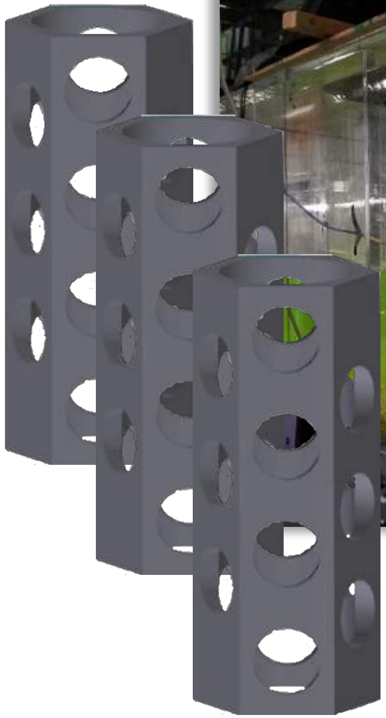
FIBER-REINFORCED POLYMER REBAR & PRESTRESSING

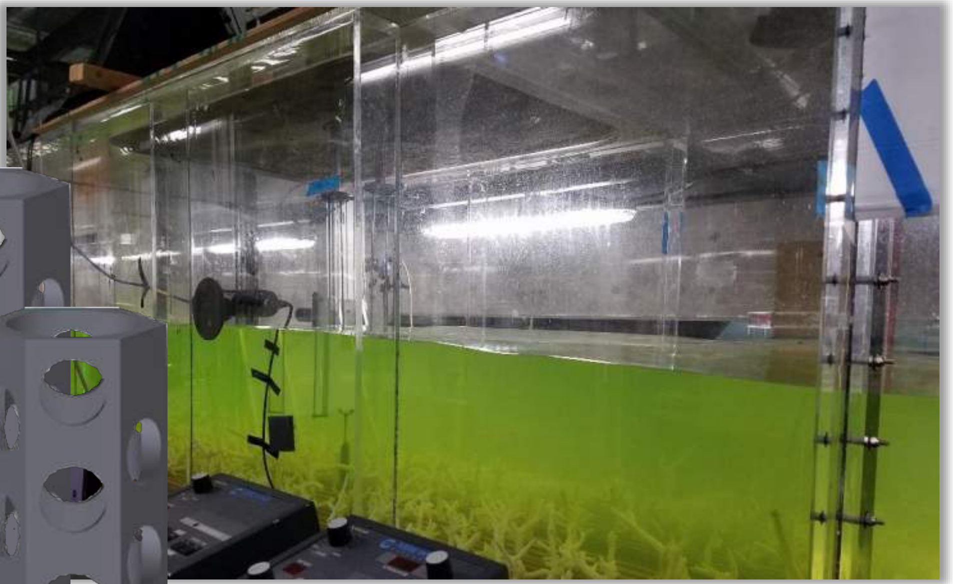
9:00 a.m.
Towards the Experimentally Based Design of an Effective and Eco-friendly Modular Shoreline Protection System for High Energy Tidal Flow
Landolf Rhode-Barbarigos, Ph.D., Marco Rossini, Antonio Nanni, Ph.D., P.E., and Mohammad Ghiasian,

NCHRP IDEA Project #213 - SEAHIVE



(a) Seahive units for use as scour protection





(b) SUSTAIN wind-wave tank at UM

Questions ???

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