Presentation #39

Thursday, February 8, at 1:40 pm (Session B3)

Low Impact Secant-Pile Seawall for protecting SR-A1A along Lower Flagler & Upper Volusia Co.

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- **Steven Nolan, P.E.** *(FDOT State Structures Design Office)*
- **Antonio Nanni, PhD, P.E.** *(University of Miami)*
- **Landolf Barbarigos, PhD, P.E.** *(University of Miami)*

** Presenter*

National Conference on Beach Preservation Technology

Abstract

Low Impact Secant-Pile Seawall for protecting SR-A1A along Lower Flagler & Upper Volusia Co.: **Presentation #39** ***(Thursday, February 8, at 1:40 pm in Session B3)***

Extensive hurricane related erosion of sand dune systems along the Gulf Coast necessitated intervention to avoid future collapse of SR-A1A and beach contamination along Flagler Beach, especially considering increasingly extreme weather and sea level change. Extensive damage from Hurricane Matthew in 2016, resulted in undermining of several miles of the state highway northbound lane (see Figure 1). A secant-pile system and dune restoration was proposed in 2017 and constructed in 2019 for a highly vulnerable one-mile section in north Flagler Beach. Additional hurricanes in 2020 (Dorian) and 2022 (Ian and Nicole) scoured the replenished sand-dunes exposing the new seawall but without distress to SR-A1A along the protected length. Beyond the limits of the seawall north and south, A1A was severely damaged encouraging the consideration by the local community and FDOT for extending the secant-pile seawall system. The goal of two current projects is to protect more of SR-A1A against hurricane erosion while minimizing impacts to the remaining sand dunes and adjacent properties during construction. The seawall secant-piles are designed with Glass Fiber-Reinforced Polymer rebar which provides extended maintenance-free service life for 100-years+ and therefore minimizes any future repair or reconstruction of protective structures along the coastal dune system. This strategy was determined as the preferred solution for the foreseeable future until other options become available, such as highway realignment as part of any future adaptation or managed retreat strategies.

Outline

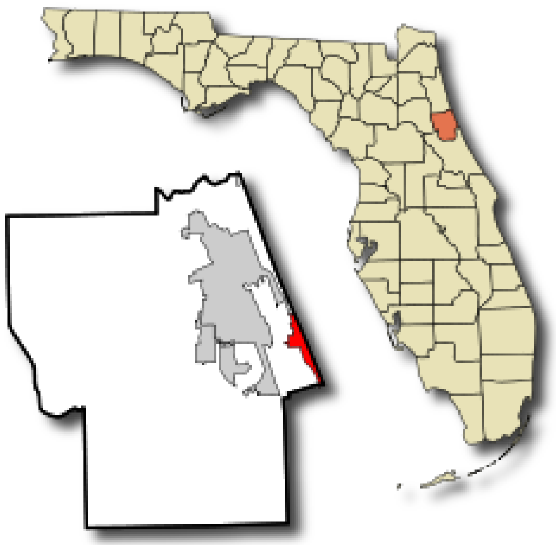
- Project Background
- History of Storm Damage
- Previous Wall Feasibility Studies and Projects
- Secant-Pile Wall Overview & Segment 3 (Project #1 – 2019)
- Revised Wall Design - Segment 1 (Project #3 - 2024)
- Future Innovations for Low-Maintenance Coastal Structures (Project #4 and beyond)
- Evaluation of prototype SEAHIVE systems

Collaboration Teams

Project #1 (2019)		Project #3 & 4 (2024)
FDOT-District 5	OWNER	FDOT-District 5
RS&H	ROADWAY & DRAINAGE	KCA
Mott Macdonald	STRUCTURES DESIGN	KCA
GEC	GEOTECH	Universal
INTERA	HYDRAULICS	INTERA
HNTB	PROJECT MANAGEMENT	HNTB
Superior Const.	CONTRACTOR	Superior
Malcom Drilling Co.	PILING SUBCON.	XXXX Co.

Background

FLAGLER BEACH – A1A SEAWALL



LOCATION:

- South Flagler County & North Volusia County, FL -
  -- Hurricane affected beach areas

2018-19 PROJECT PURPOSE (Project #1 - Segment 3):

- **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 after Hurricane Matthew (2016), *[a similar commitment made after Hurricane Nicole, 2022 for Segments 1 & 2].*
- **Keeping Flagler Beach, Flagler Beach** – sand, turtles, A1A alignment.

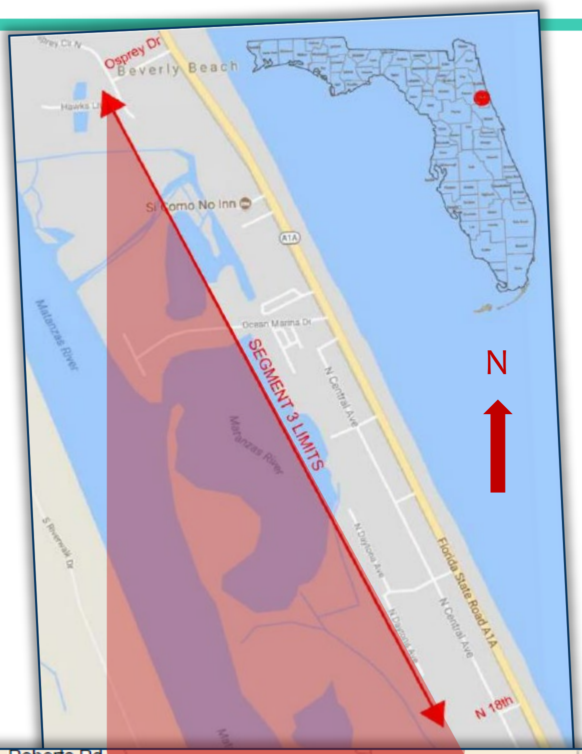
Background – Project #1

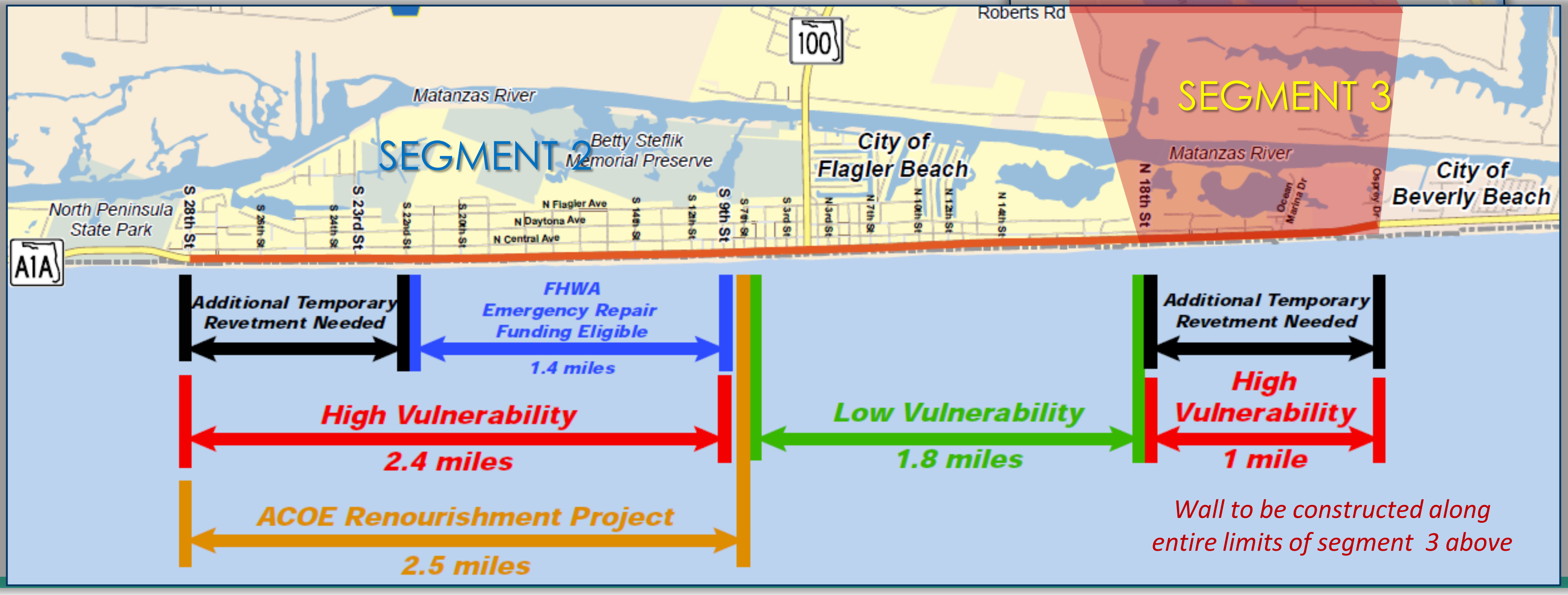
NORTH FLAGLER BEACH – A1A SEAWALL

2019-SEAWALL LOCATION *(Segment 3)*:

FPID 452444-1:

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





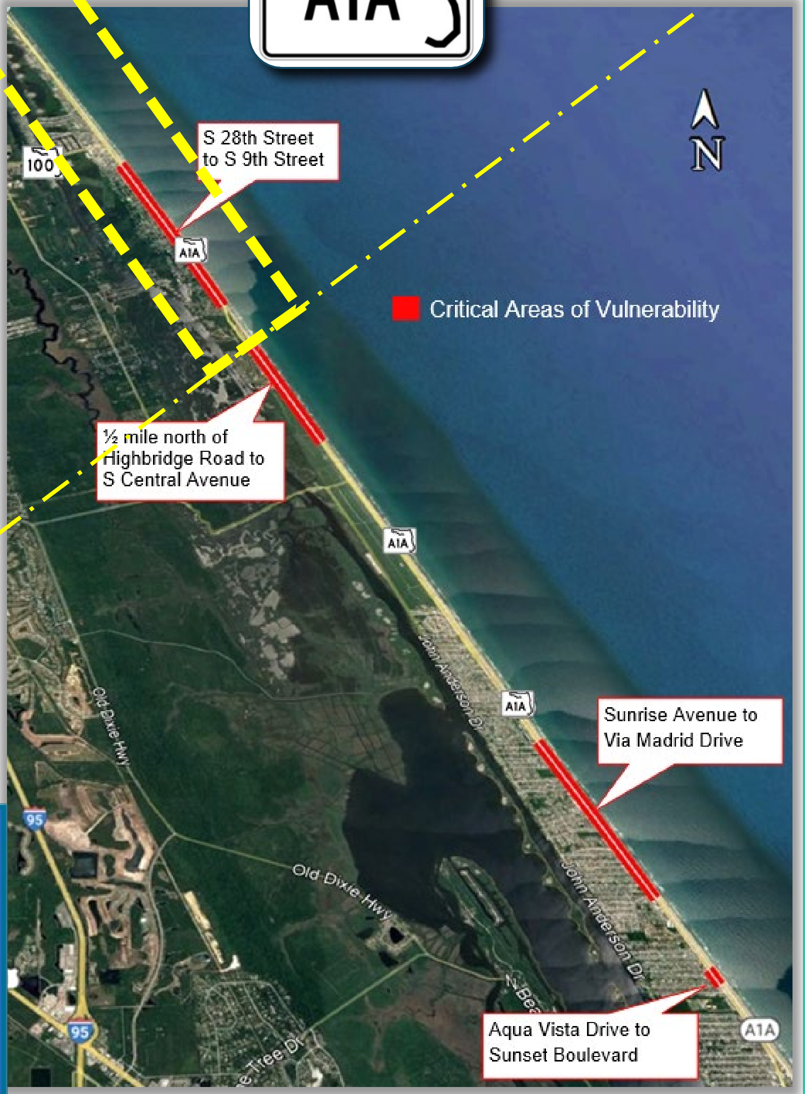
Current Project #3

SOUTH FLAGLER BEACH – A1A SEAWALL

2023-24 PROJECT LOCATION *(Segment 2 & 3)*:

FPID 452444-1:

- Studied 6.1 miles of beach along East Flagler Beach – from Volusia County Line north (includes previous secant-pile section in Segment 3)
- See redline “Critical Areas of Vulnerability” for secant-pile seawall (South 9th Street to South 28th Street ~ 1 mile)



Tentative Schedule

Start November 2022 → Coastal Engineering Review December 2022 → Community Listening Sessions January 2023 → Select Preferred Options February 2023 → Plan Complete March 2023

Contact Information:

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FDOT Strategic Initiatives Manager
386-943-5039

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Ty Garner

FDOT Project Manager

Future Project #4

NORTH VOLUSIA COUNTY – A1A SEAWALL

2024-25 PROJECT LOCATION (*Segment 1*):

FPID 452443-1:

- Studied 7 miles of beach along Ormond-by-The-Sea (Volusia County) - Roberta Rd to Flagler County Line
- See redline "Critical Areas of Vulnerability" for secant-pile seawall (~2 x 1 mile)

Tentative Schedule

Contact Information:

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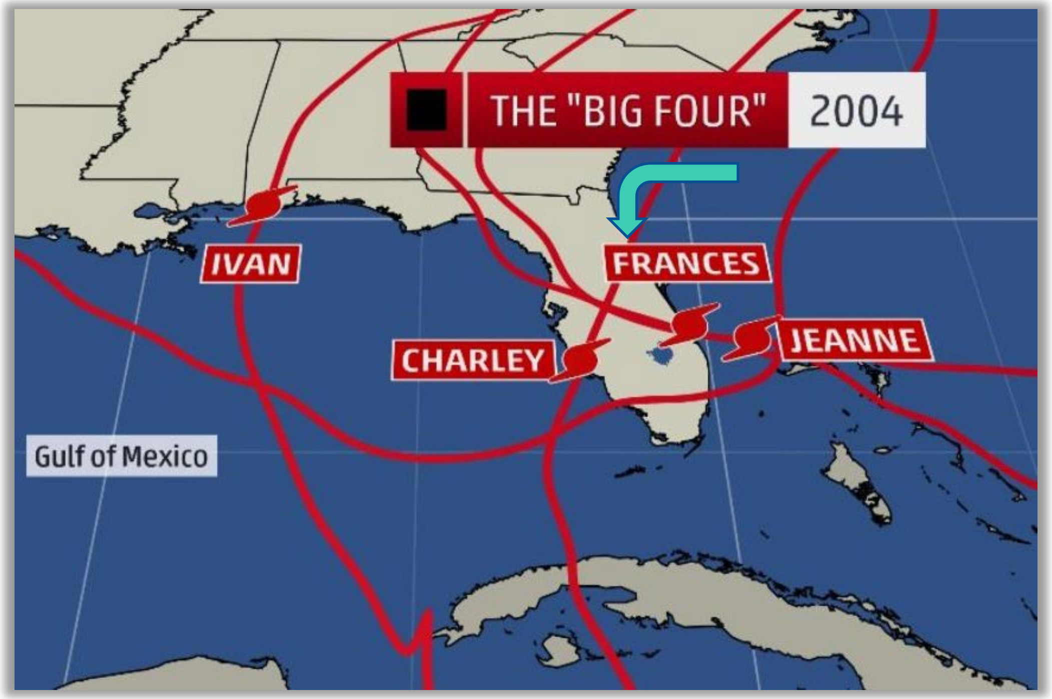
Ty Garner

FDOT Project Manager

Background – Past Storms & Responses

FLAGLER BEACH – A1A SEAWALLS

- **A HISTORY OF STORM DAMAGE IN THIS AREA**
- **2004 – 2005 HURRICANES**
  - *Charlie … Frances … Ivan … Jeanne … Dennis … Katrina … Rita … Wilma*



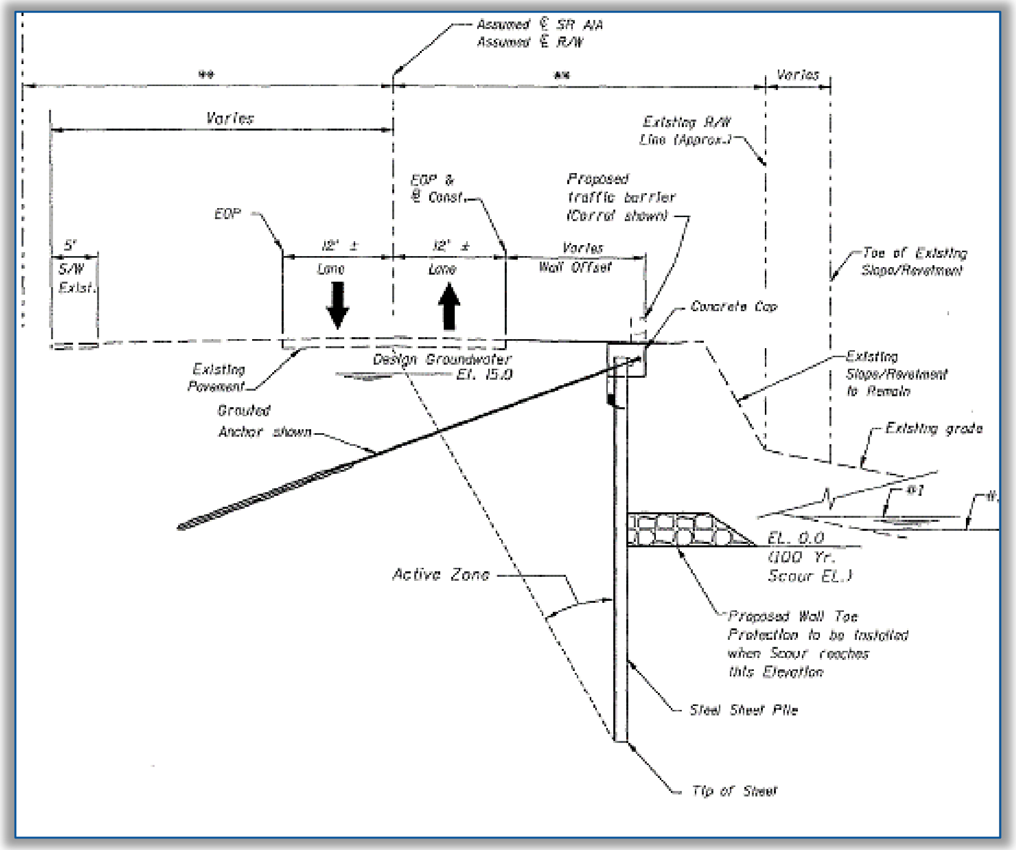
Background - Coastal Defense Concepts

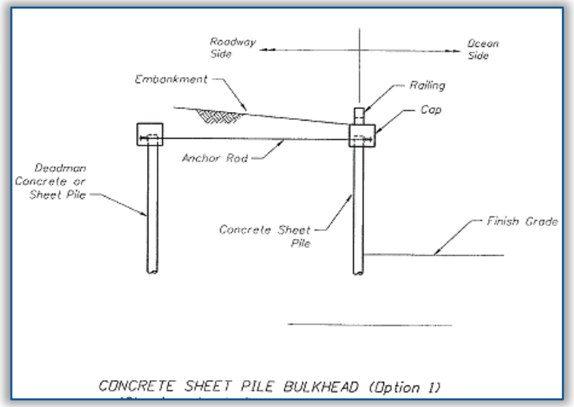
N O R T H   F L A G L E R   B E A C H   –   A 1 A   S E A W A L L

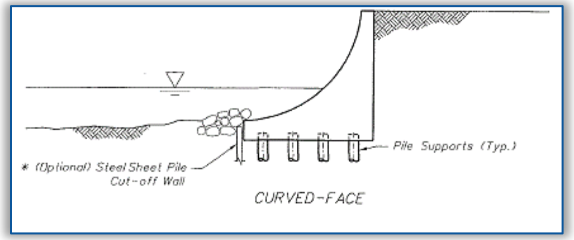
2005 WALL FEASIBILITY STUDY

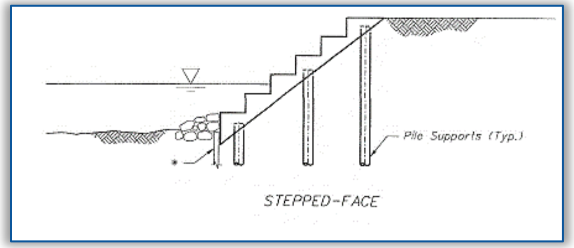
- Initial Wall Feasibility study prepare looked at 5 options

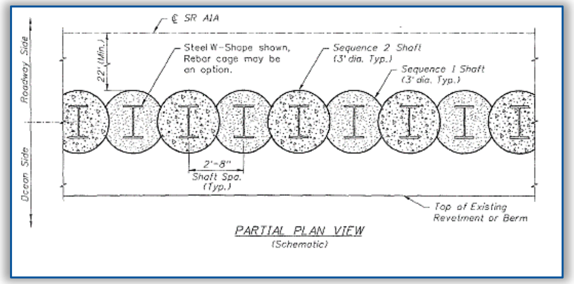
1. Grouted Anchor Tie-Back
2. Concrete Sheet Pile Bulkhead with Deadman Anchors
3. Curved Face
4. Stepped-Face
5. Combination Stepped and Curved Face *(not shown)*
6. Secant Pile Wall









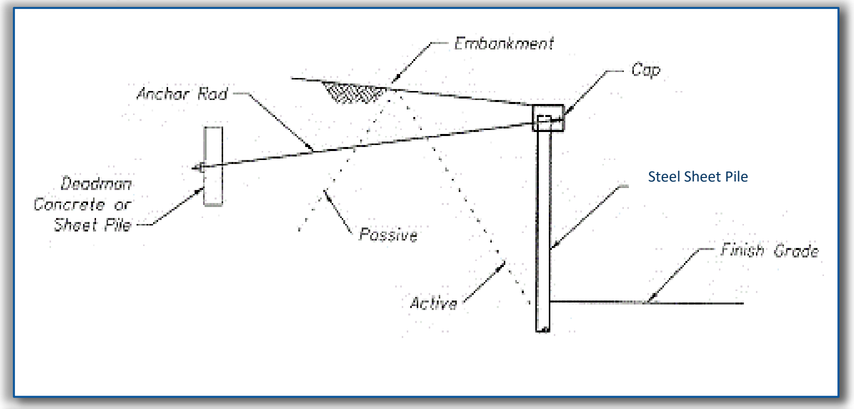


Background - 2006

NORTH FLAGLER BEACH – A1A SEAWALL

2006 EMERGENCY CONTRACT WALL *(Partial Segment 2):*

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



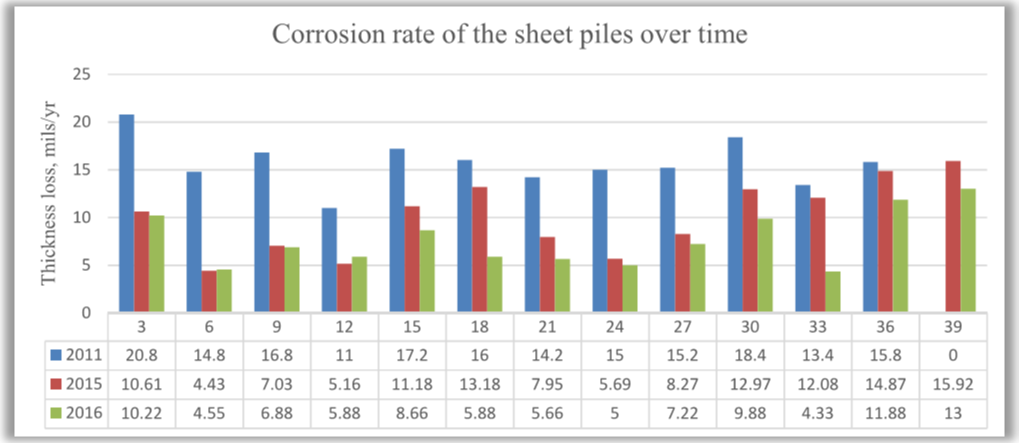
Background – 2011 & 2015

NORTH 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*** *rate.*



	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

FDOT

Background – 2016

SOUTH FLAGLER BEACH – A1A

OCT. 2016 – HURRICANE MATTHEW:

- CATEGORY 4 : > 130 mph winds, storm surge, flooding
- **Segment 2 -** Storm Damage

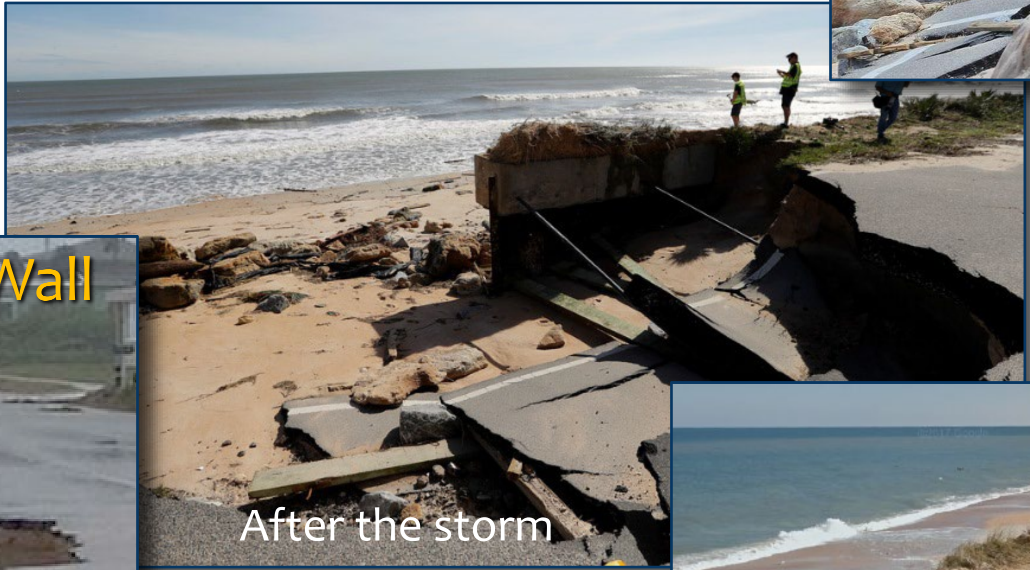
Background – 2016 (cont.)

NORTH FLAGLER BEACH – A1A SEAWALL

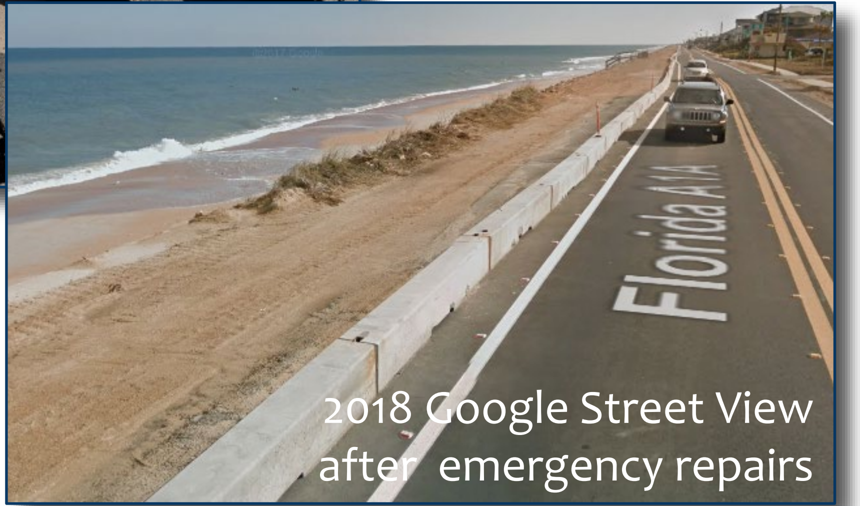
OCT. 2016 – HURRICANE MATTHEW:

- **Segment 3 –** Storm Damage


After the storm showing exposed steel tie-back rods


After the storm

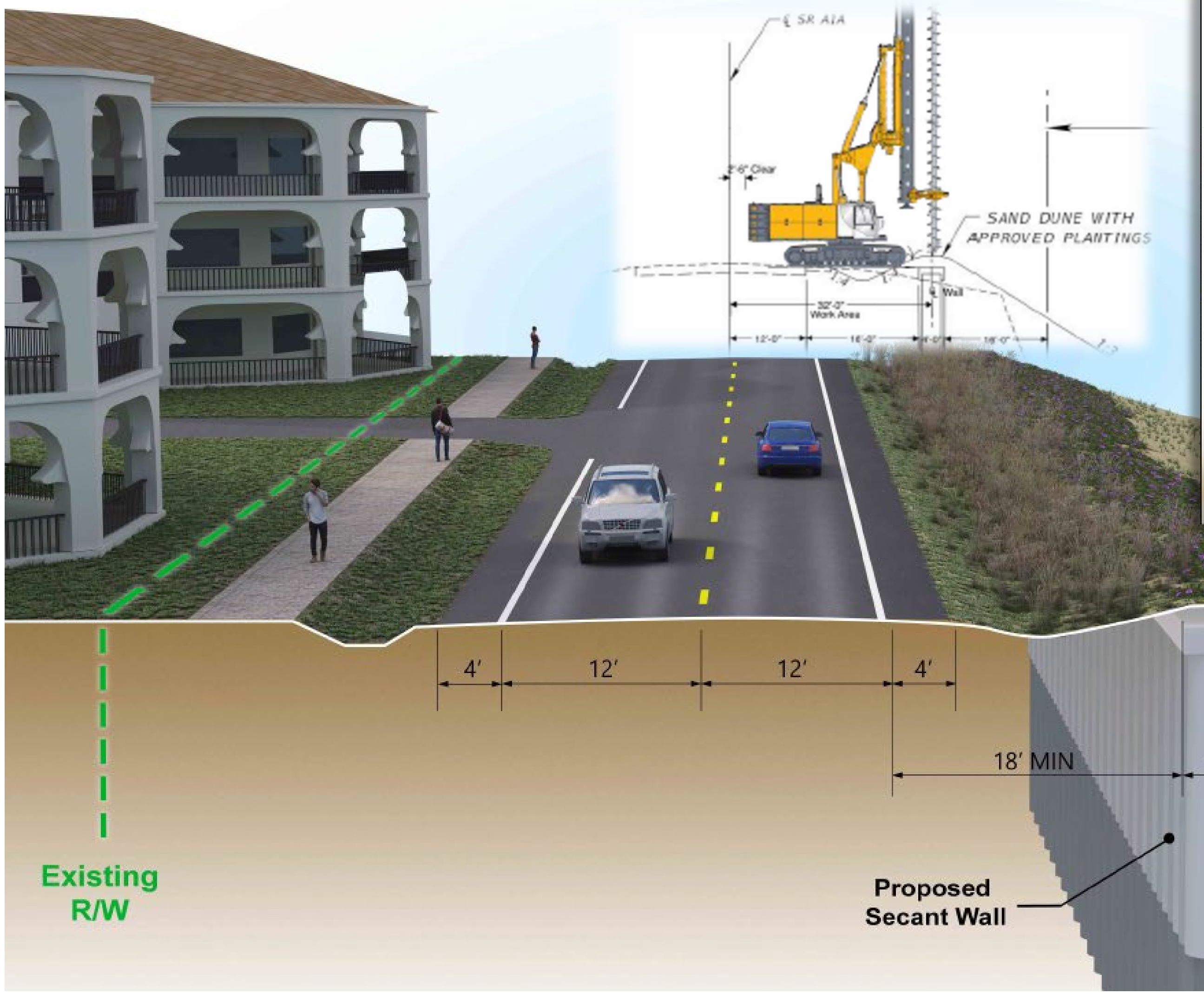
During the storm

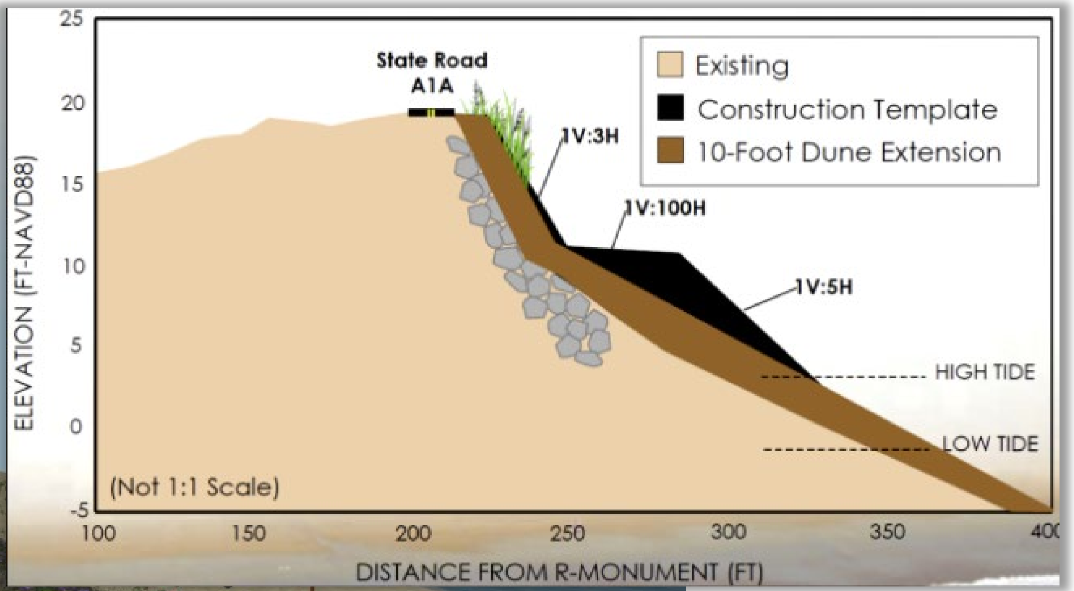


2018 Google Street View after emergency repairs

Background - 2019: Project #1 (Buried Secant-Pile Wall)

GLASS FIBER-REINFORCED POLYMER REBAR





See the February 2019 FSBPA Tech Conference Presentation for more details

Background – 2019: Post-Construction

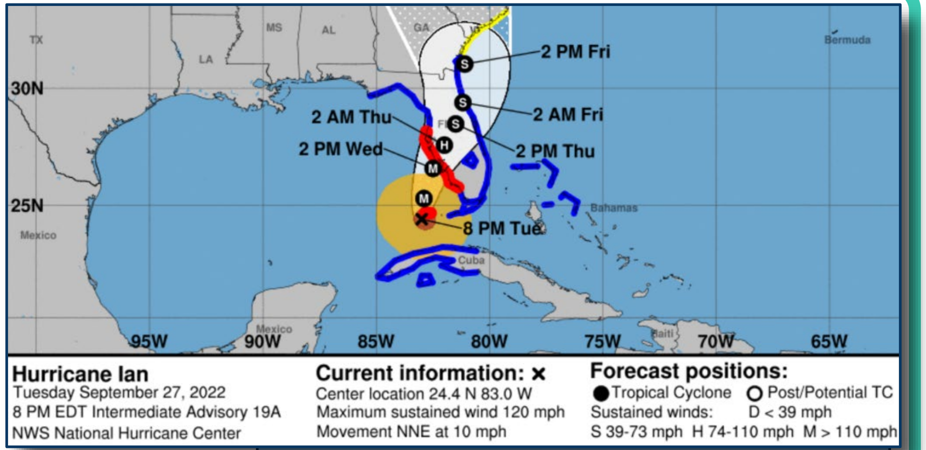
NORTH FLAGLER BEACH – A1A SEAWALL

SEPT. 2019 – HURRICANE DORIAN:

- **Segment 3** - Significant Beach Erosion, but no highway damage or wall exposure)

Background - 2022

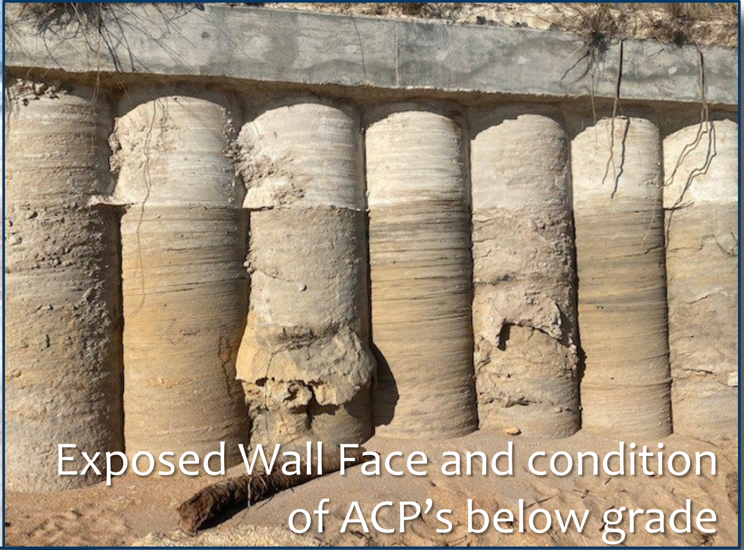
NORTH FLAGLER BEACH – A1A SEAWALL



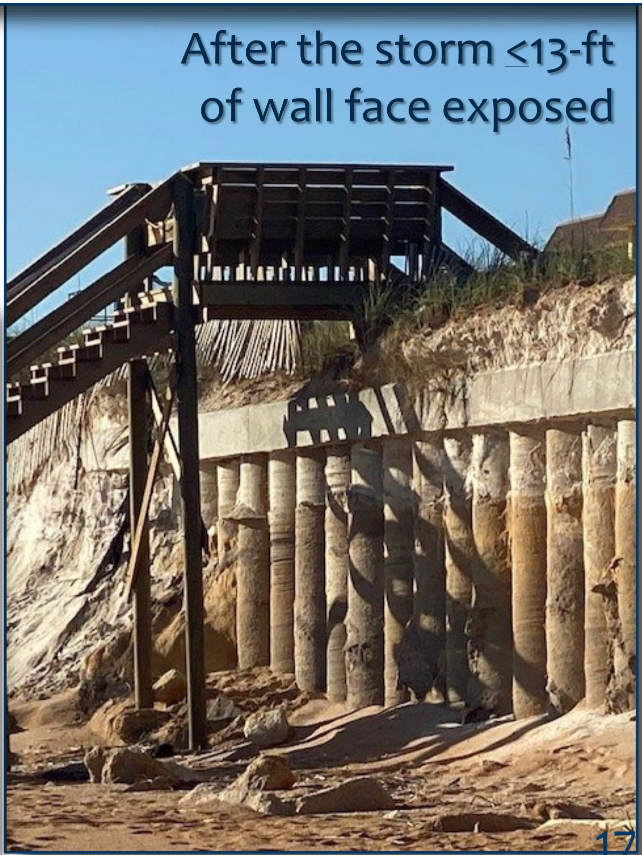
SEPT. 2022 – HURRICANE IAN:

- **Segment 3 -** Significant Beach Erosion, seawall exposure up to 13-foot at face, but <u>no damage</u> to SR-A1A.

After the storm ≤ 13-ft of wall face exposed



Exposed Wall Face and condition of ACP's below grade



After the storm ≤13-ft of wall face exposed

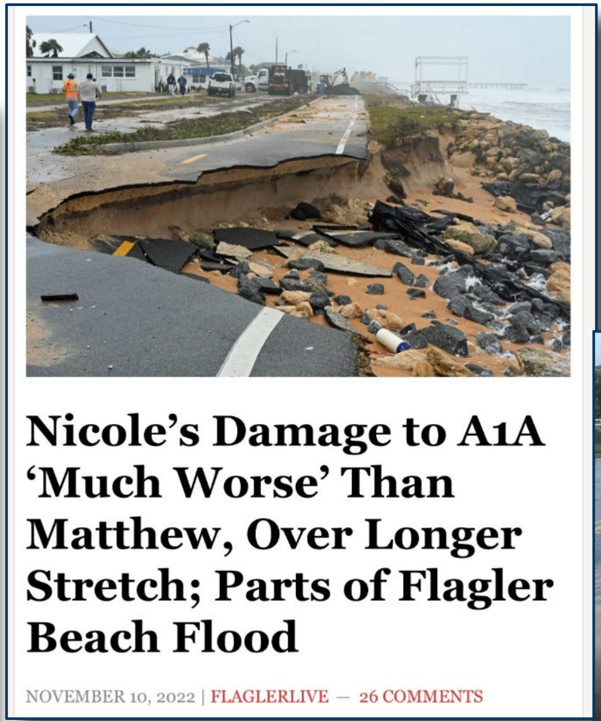
Background – 2022 (cont.)

SOUTH FLAGLER BEACH – A1A SEAWALL

OCT. 2022 – HURRICANE NICOLE:

- **Segment 1 & 2 -** Significant highway damage north and south of seawall.


Governor DeSantis surveys damage along A1A with Speaker of the House Paul Renner, and Florida Emergency Management Director Kevin Guthrie (*source: Flagler County Emergency Management Office*).


Nicole's Damage to A1A 'Much Worse' Than Matthew, Over Longer Stretch; Parts of Flagler Beach Flood

NOVEMBER 10, 2022 | FLAGLERLIVE — 26 COMMENTS

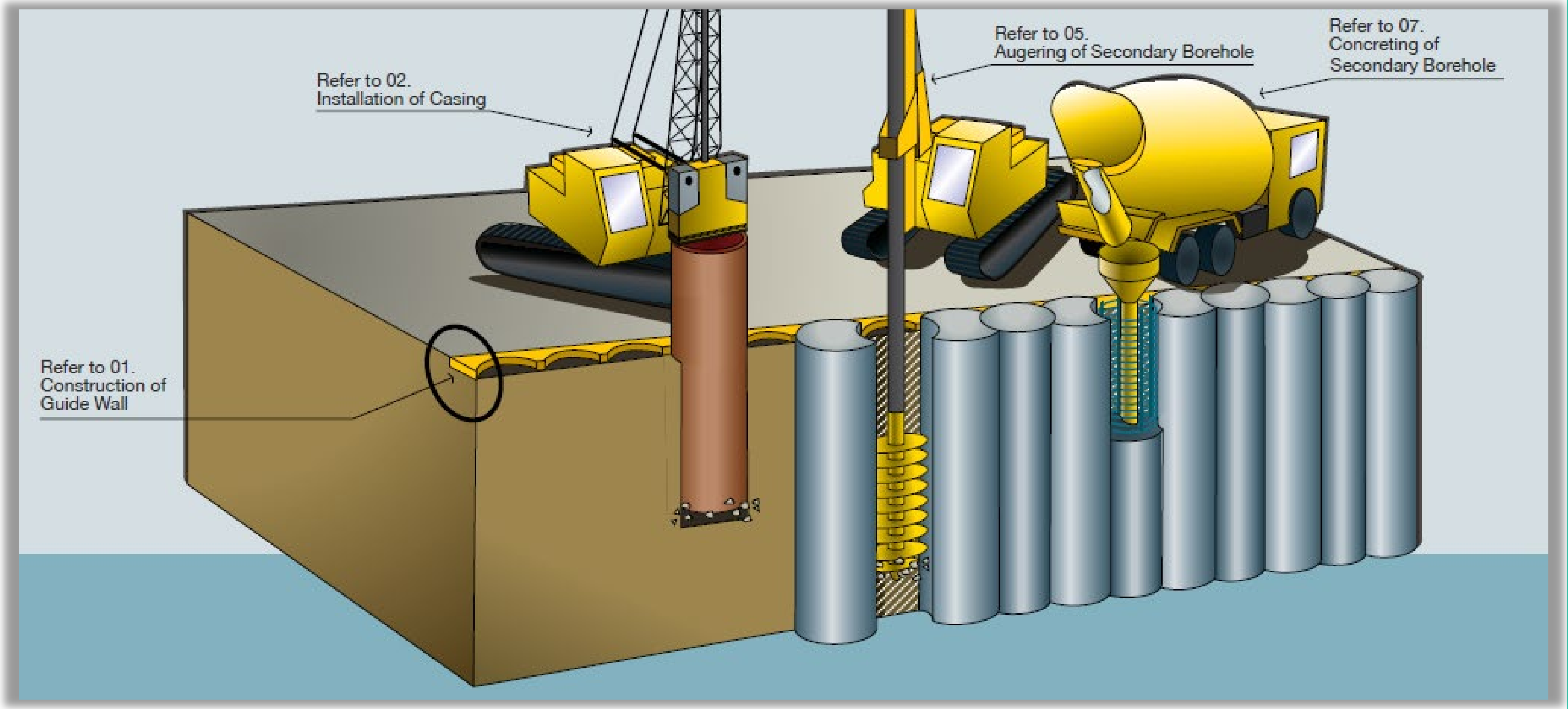
Background – 2022 (cont.)

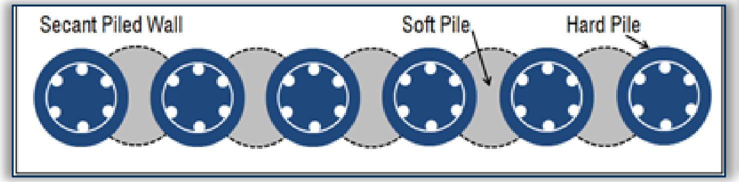
NORTH FLAGLER BEACH – A1A SEAWALL

OCT. 2022 – HURRICANE NICOLE:

- **Segment 3 -** Additional sections of wall exposed but some accretion from littoral drift, but <u>no damage</u> to SR-A1A behind the seawall.

Secant Pile Wall Technology





FRP Reinforcing Deployment – 2015 (FDOT Adoption)

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 REBAR vs Glass FRP REBAR

- *Advantages*

STEEL REBAR

- Bonds very well to concrete.
- Post-yielding ductility → Significant concrete cracking and deflection warning before ultimate failure.
- Can be used in prestressed applications.

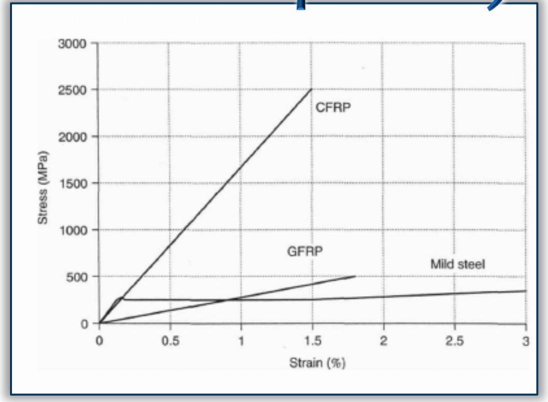
GFRP REBAR

- Corrosion resistant (so less concrete cover required).
- Higher tensile strength compared to traditional steel yield point (110-170 ksi fracture vs. 60-100 ksi yield).
- Lightweight (¼) and easy handle and cut on-site.
- Moderate fatigue endurance.

FDOT

FRP Reinforcing Deployment – 2015 (FDOT Adoption)

GLASS FIBER-REINFORCED POLYMER REBAR



STEEL REBAR vs Glass FRP REBAR

- *Limitations*

STEEL REBAR

- Corrodes very rapidly in extremely aggressive environments (thicker concrete cover required).
- Heavy and difficult to handle and cut on-site.
- Relatively large CO2 footprint.

GFRP REBAR

- Largest ASTM D7957-17 bar size #10 Bar. *(FDOT added #11's in 2024)*
- Variable surface to concrete bond capacity.
- Bends only ~60% strength of straight bar.
- No yield (warning) before failure but extensive concrete cracking visible.

Tension rupture of GFRP bar at failure

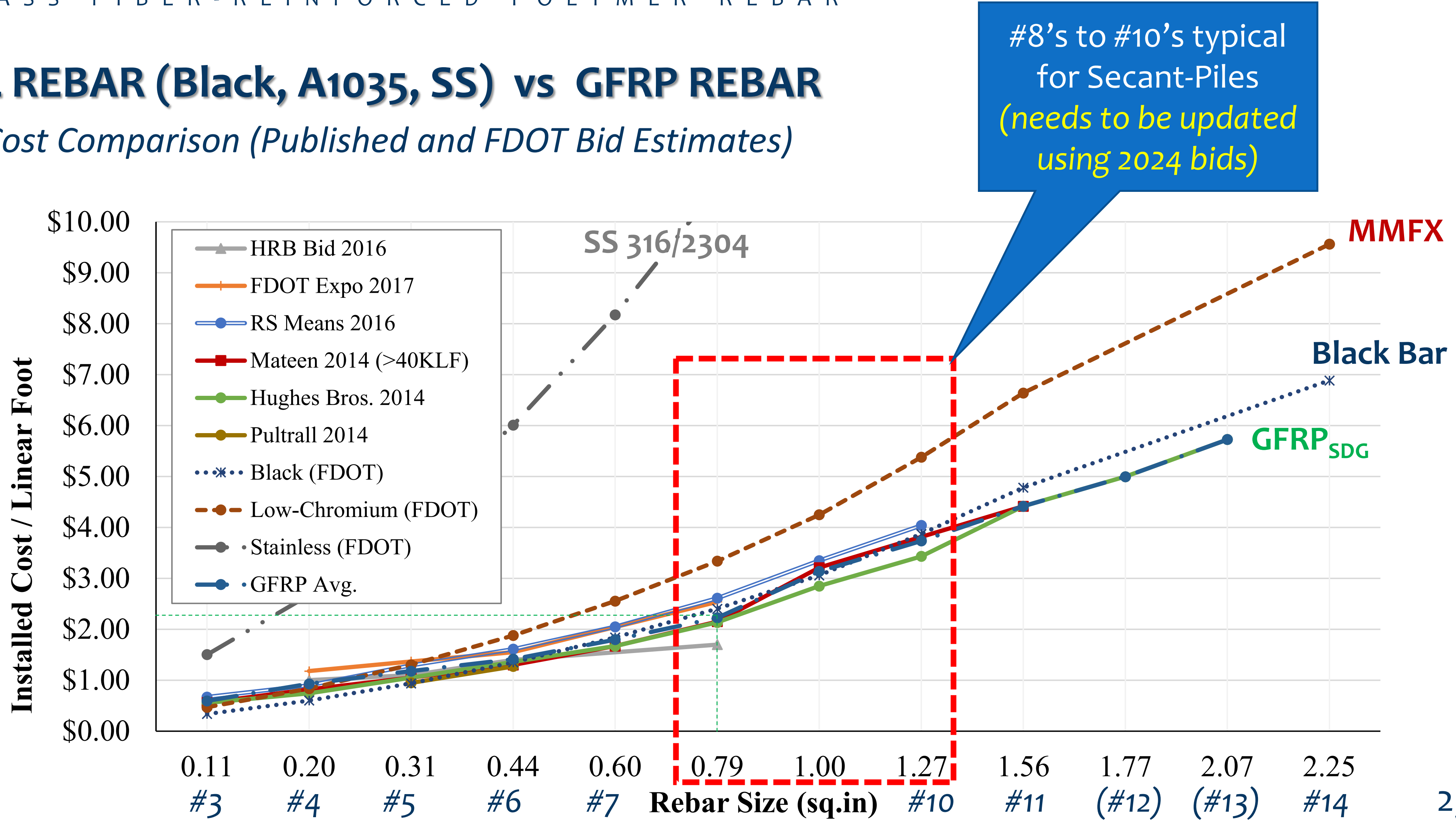
FDOT

FRP Reinforcing Deployment – 2015 to 2024 (FDOT)

GLASS FIBER-REINFORCED POLYMER REBAR

STEEL REBAR (Black, A1035, SS) vs GFRP REBAR

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



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FRP Rebar Innovation – 2024 (FDOT advancement)

GLASS & BASALT FIBER-REINFORCED POLYMER REBAR

STEEL REBAR vs GFRP & BFRP REBAR

- Cost Comparison *(2024 **Structures Design Manual** – Volume 1)*
- Added *Grade III* (***ASTM D8505-22***) Hi-Modulus/Hi-Strength Glass & Basalt FRP straight bars to ***Specification 932-4***)

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

#8 Steel Rebar (@$1.05/lb) = $2.80/ft

Steel Bars

#8 GFRP Rebar: $2.25/ft + testing

GFRP Bars

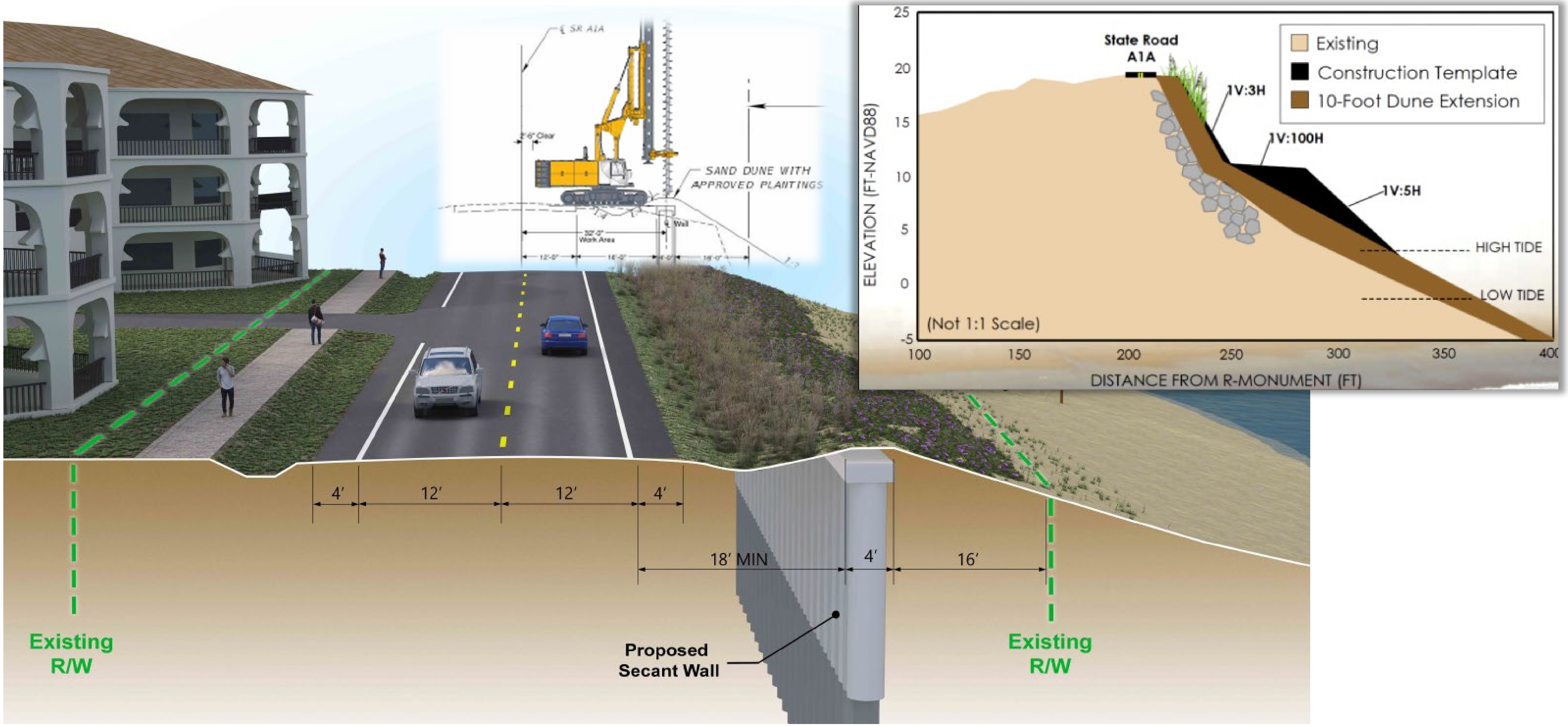
6,500 ksi *(Grade O)*
vs.
8,700 ksi *(Grade III)*

→ 33% increase in stiffness

FDOT

Flagler Beach #1, 3 & 4: SR-A1A Wall Design (2019 & 2024)

GLASS FIBER-REINFORCED POLYMER REBAR



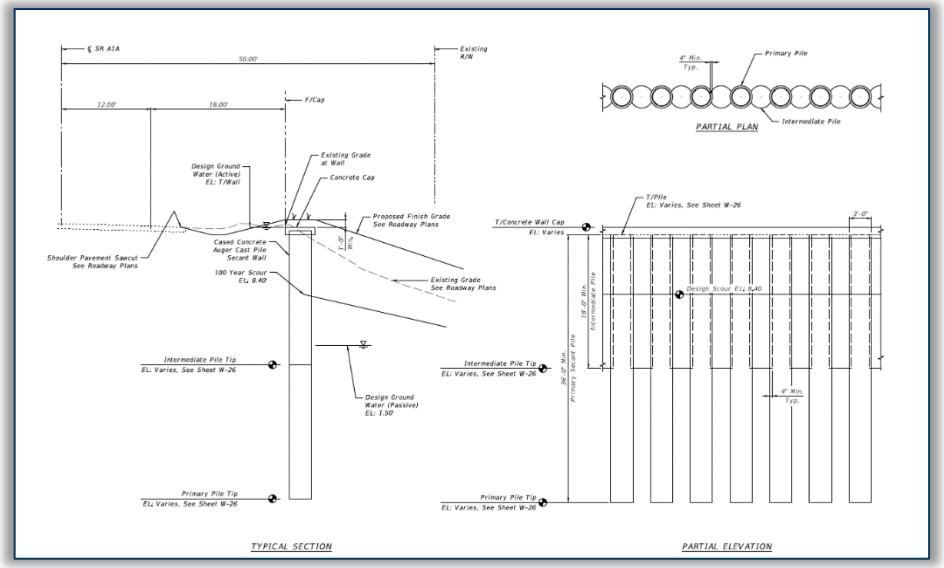
Flagler Beach #1: SR-A1A Wall Design (2019)

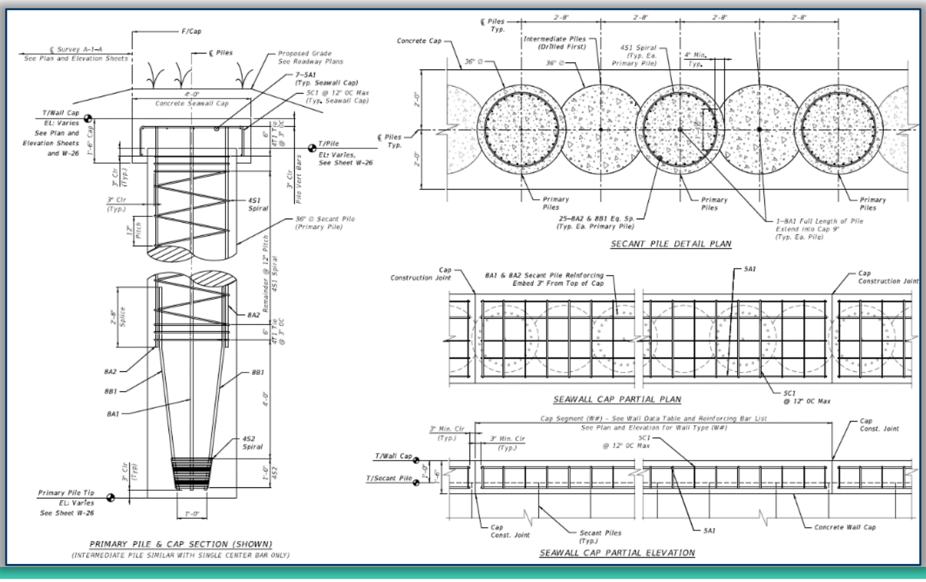
GLASS FIBER-REINFORCED POLYMER REBAR

DESIGN SUMMARY *(Segment 3)*

- 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 (*Grade II*): **25 ~ #8 bars *(A_f = 19.75 in^2)*** *deflection governs.*
- **#4's spirals @ 12" pitch** with tapered pile tip.
- 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





Flagler Beach #3: SR-A1A Wall Design (2024)

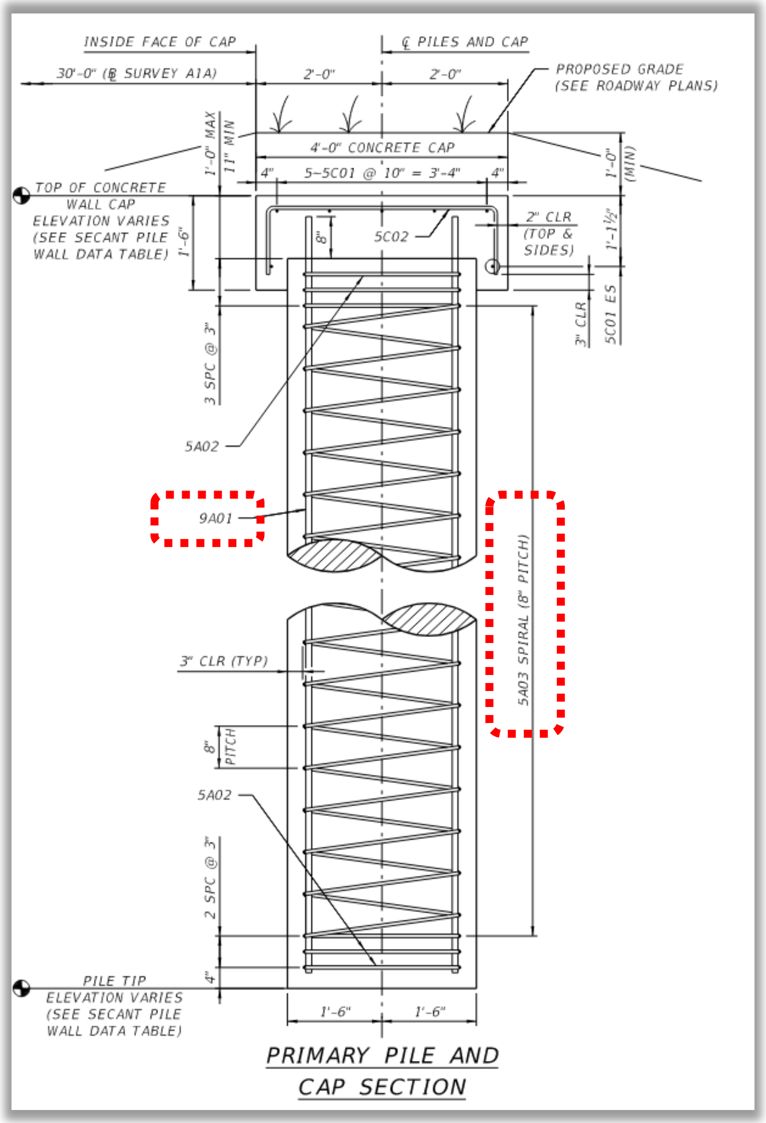
GLASS FIBER-REINFORCED POLYMER REBAR

DESIGN SUMMARY *(Segment 2)*

- Designed to 100-year scour depth to eliminate need for toe protection.
- With conventional steel: **9 ~ #11 bars?** required ***(A_s = 14.0 in^2).***
- With *Grade I*-GFRP rebar: **28 ~ #9 bars** ***(A_f = 28.0 in^2) deflection governs.***
- **#5's spirals @ 8" pitch** with <u>no</u> tapered pile tip.
- 36" dia. x (36-ft. to 38-ft.) long **Reinforced Auger Cast Piles**.
- 36" dia. x 18-ft. long **<u>Non</u>-Reinforced Auger Cast Piles**.

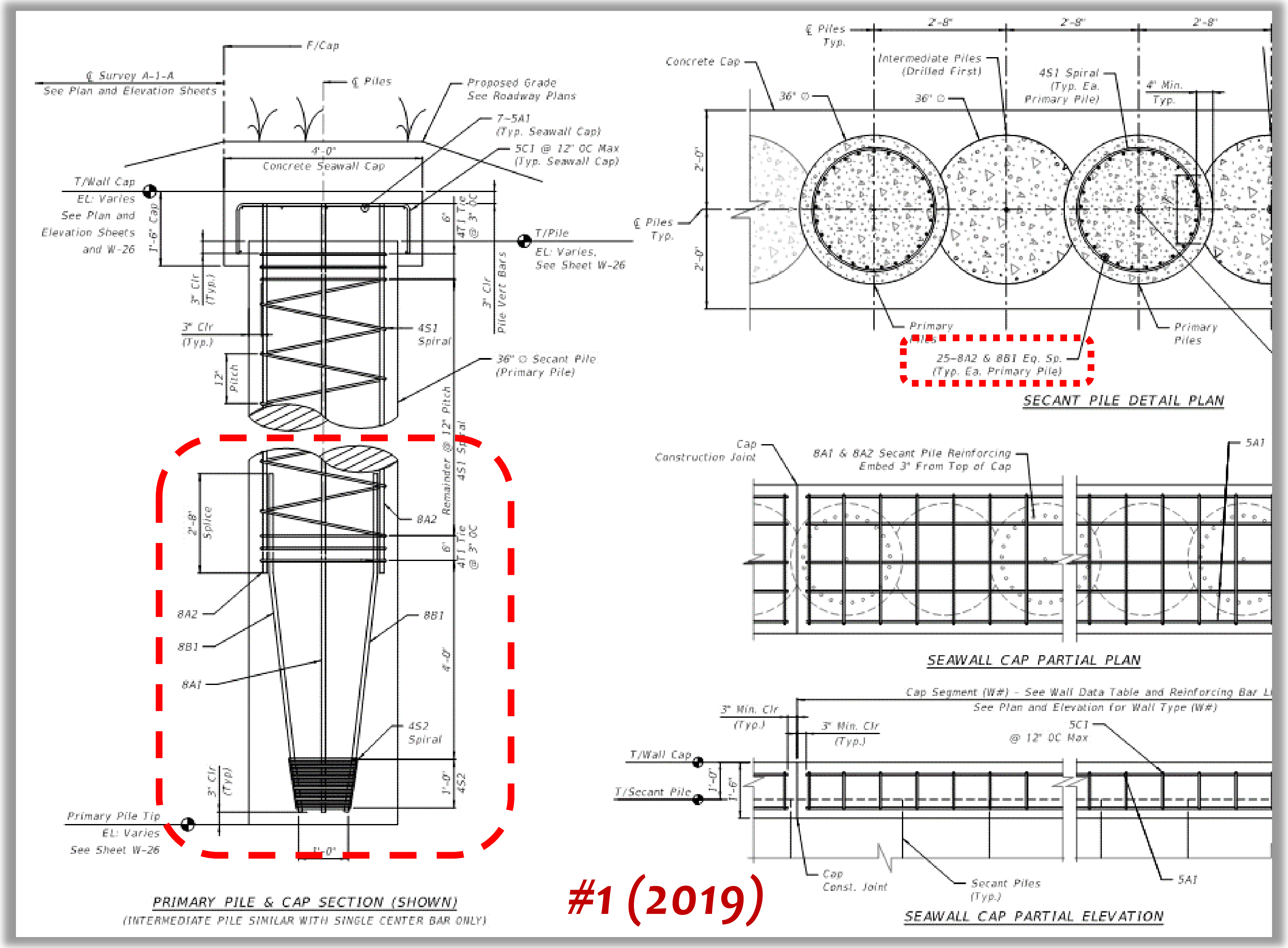
POSSIBLE DESIGN INNOVATIONS *(Segment 1)*

- ***Grade III-***GFRP rebar: **26 ~ #8 bars** ***(A_f = 20.5 in^2)***
- ***Grade III #4's*** spirals **@ 8" pitch**
- ***24" dia***. x (36-ft. to 38-ft.) long **Reinforced Auger Cast Piles inside** 36" dia. x 18-ft. long ***FRP-PPC Hex-Pile casing***.

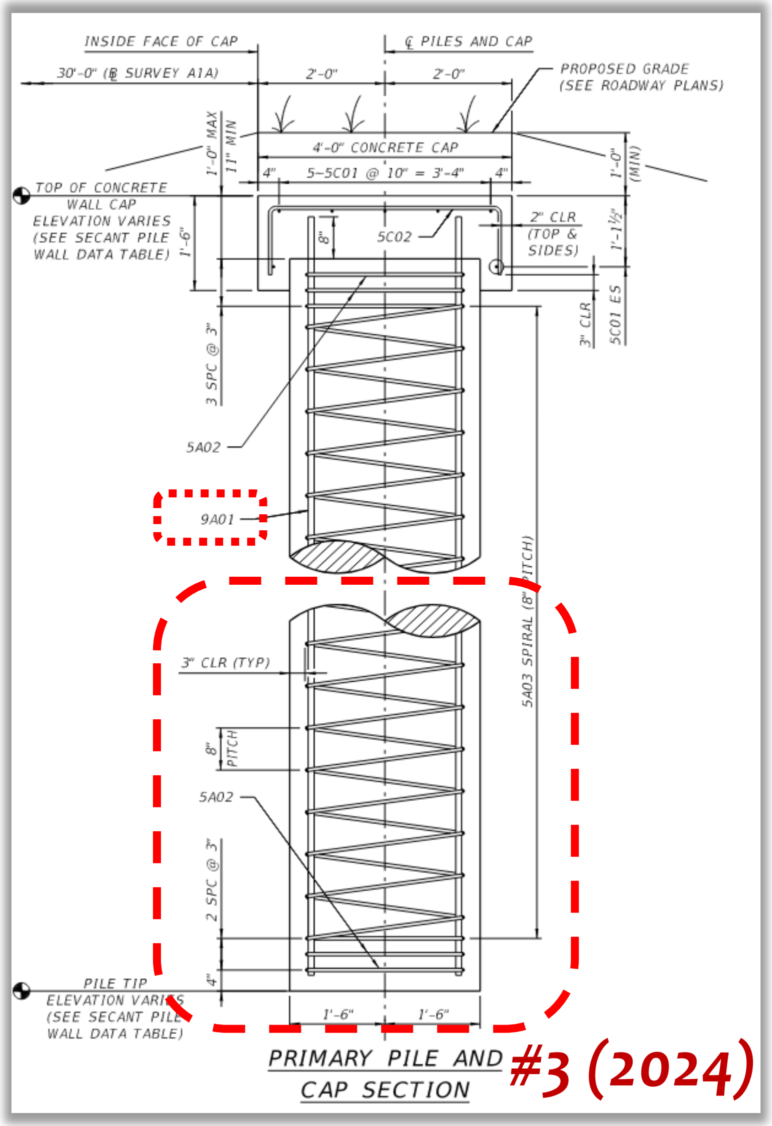


Flagler Beach: SR-A1A Wall Design (2019 versus 2024)

GLASS FIBER-REINFORCED POLYMER REBAR



#1 (2019)



#3 (2024)

Possibilities for Future Protection (2025+)

FLAGLER BEACH – A1A SEAWALL

SUSTAINABLE & RESILIENT POSSIBILITIES for CRITICAL AREAS:

- Seawater/Marine concrete using Hex-Tube/SEAHIVE.
- Open capped topping possibilities.

Hex-Tube and/or SEAHIVE facing

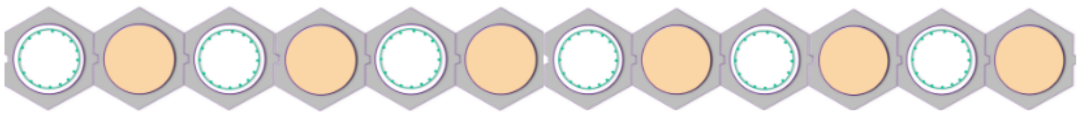
Possibilities for Future Protection (2025+)

FLAGLER BEACH – A1A SEAWALL

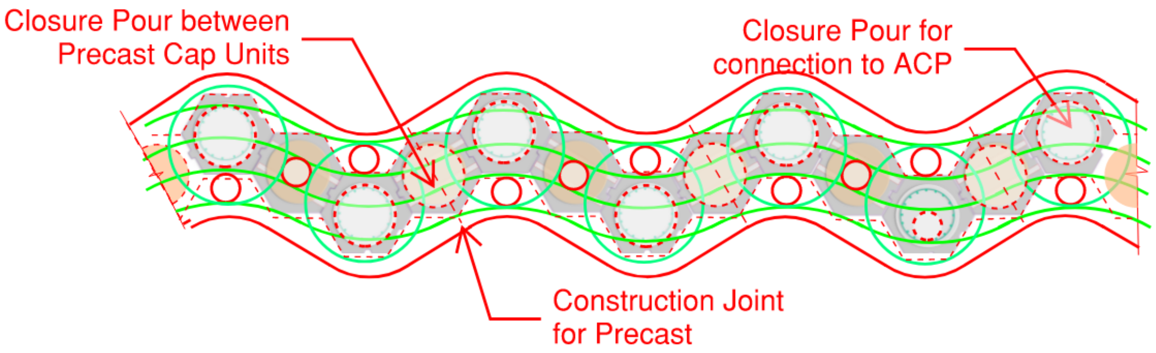
SEAHIVE using LC3 or seawater concrete

SUSTAINABLE & RESILIENT POSSIBILITIES for CRITICAL AREAS:

- Hex-Tube/SEAHIVE & Voided Cap possibilities

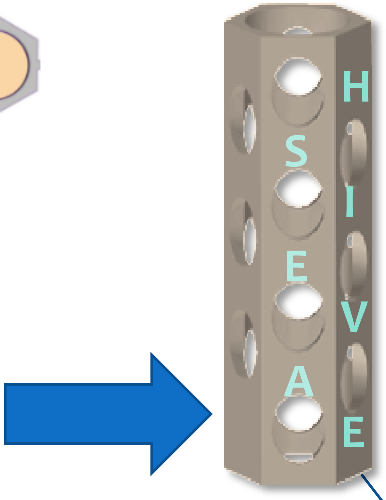


Option 1: 6-ACPx6-SFH Straight Wall Configuration

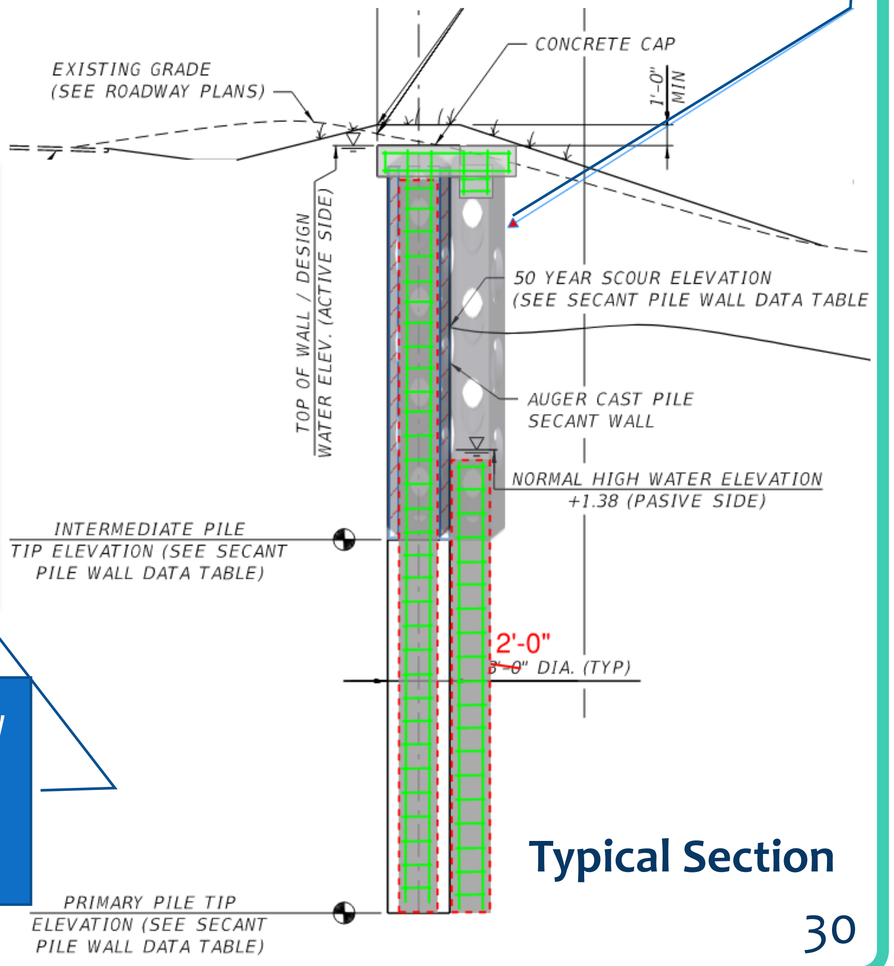


Option 2: 6-ACPx6-SFH Sine-Wall Configuration

Plan Views



Hex-Tube Casing/ SEAHIVE™ Revetment



Typical Section

Possibilities for Future Protection (2025+)

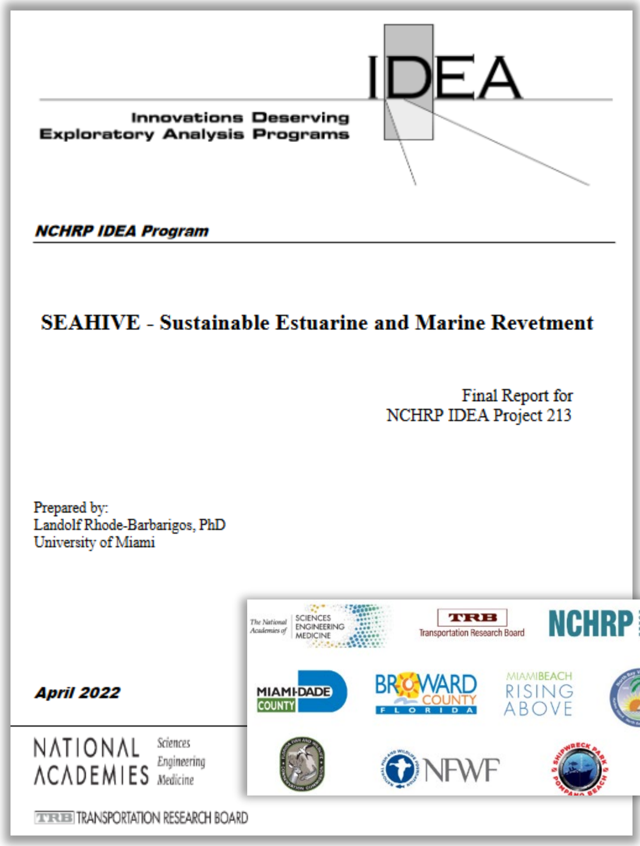
FLAGLER BEACH – A1A SEAWALL

SUSTAINABLE & RESILIENT POSSIBILITIES:

EWN Engineering With Nature®

https://ewn.erdc.dren.mil/

- SEAHIVE developed under **NCHRP IDEA-213** (2022)


IDEA

Innovations Deserving Exploratory Analysis Programs

NCHRP IDEA Program

SEAHIVE - Sustainable Estuarine and Marine Revetment

Final Report for
NCHRP IDEA Project 213

Prepared by:
Landolf Rhode-Barbarigos, PhD
University of Miami

April 2022

NATIONAL ACADEMIES Sciences Engineering Medicine

TRB TRANSPORTATION RESEARCH BOARD

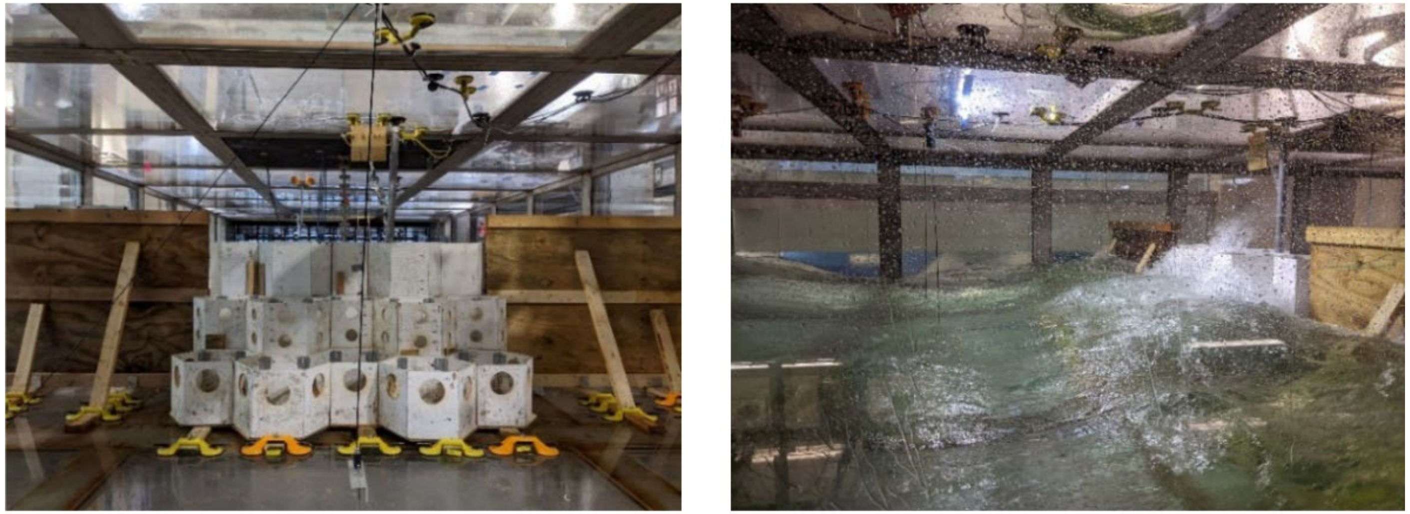
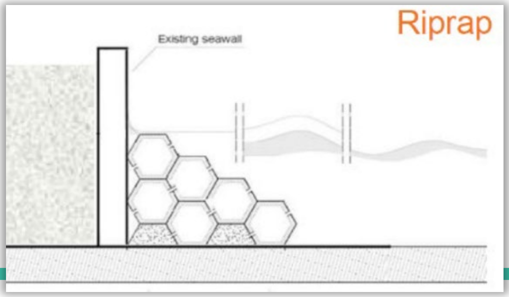
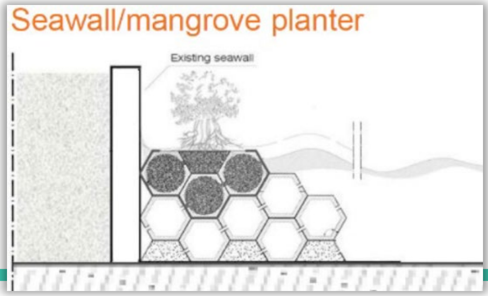
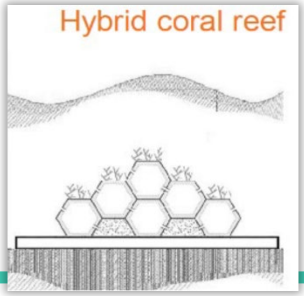
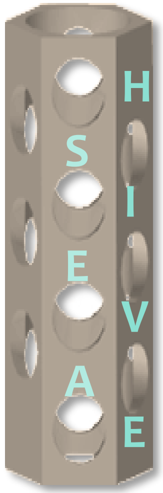


FIGURE 11 Semi-perforated SEAHIVE system model configuration in SUSTAIN.









Current Status of Repair & Protection Projects

FDOT

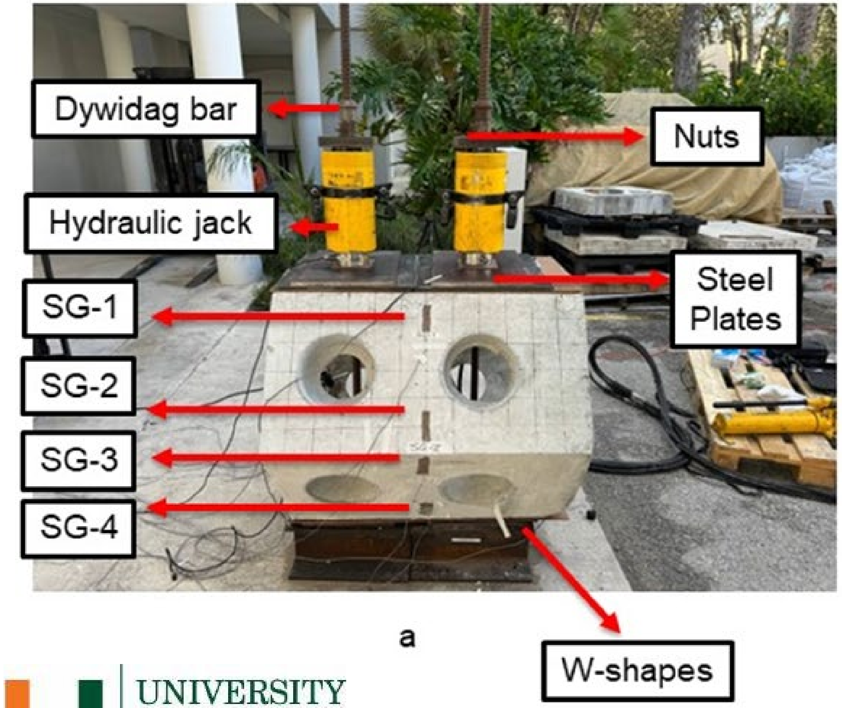
PROJECT DELIVERY EXCELLENCE

- **AFTER STORM EMERGENCY REPAIRS INSTALLED:**
  - ✓ *Project let and completed shortly after Hurricane Nicole.*
  - ✓ *Repaired dunes, Placed revetment/rip rap, rebuilt/repaved damaged highway sections.*

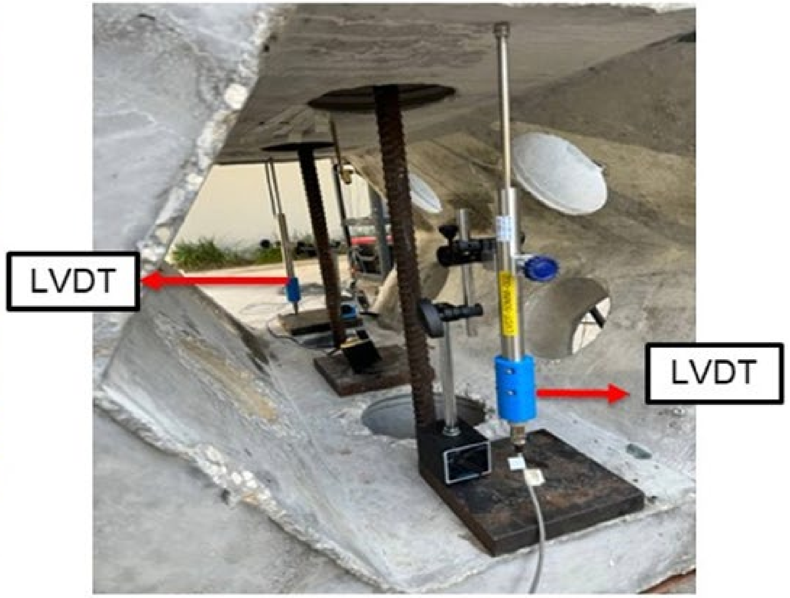
- **SR-A1A ADDITIONAL PROTECTION under Projects #3 & #4 (Flager/Volusia Counties):**
  - ✓ *Design started (FPID 452443-1 & 452444-1).*
  - ✓ *Projects are funded for construction.*
  - ✓ *Preliminary Engineering began December 28, 2022.*
  - ✓ *Community Listening Session held January 2023.*
  - ✓ *Design-Build Contract Awarded April 2024.*
  - *Estimated Construction to begin Feb. 2024.*
  - *Estimated Completion 2025.*

Structural performance of prototype SEAHIVE

- **Evaluating SEAHIVE performance under Compressive (2023) and Flexural (2024) loading:**

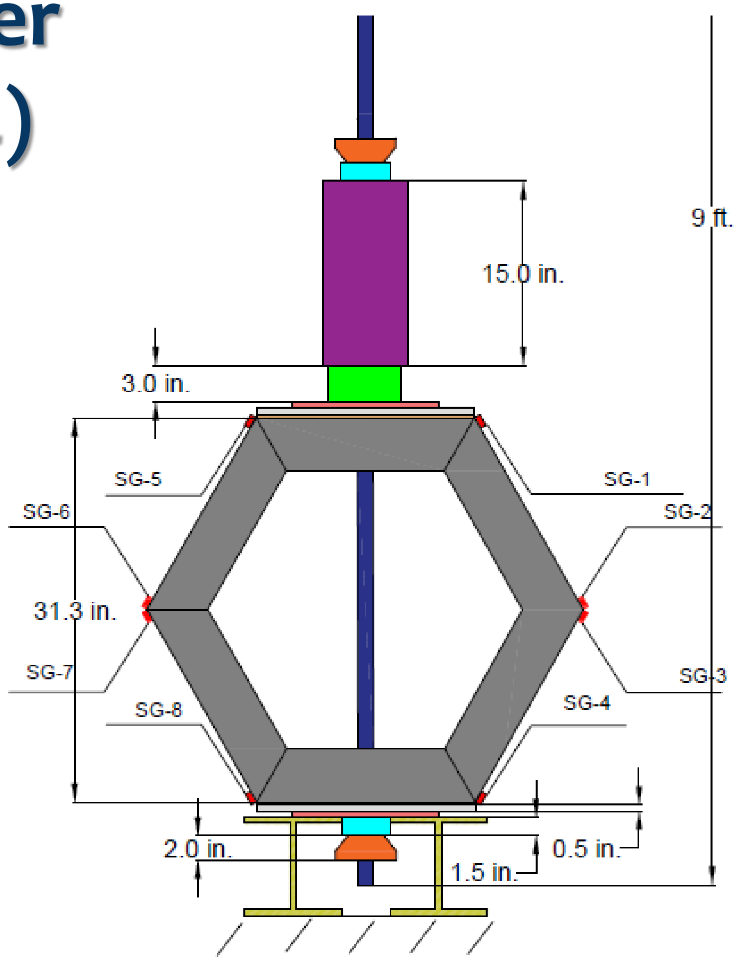


a



b

Inside Section



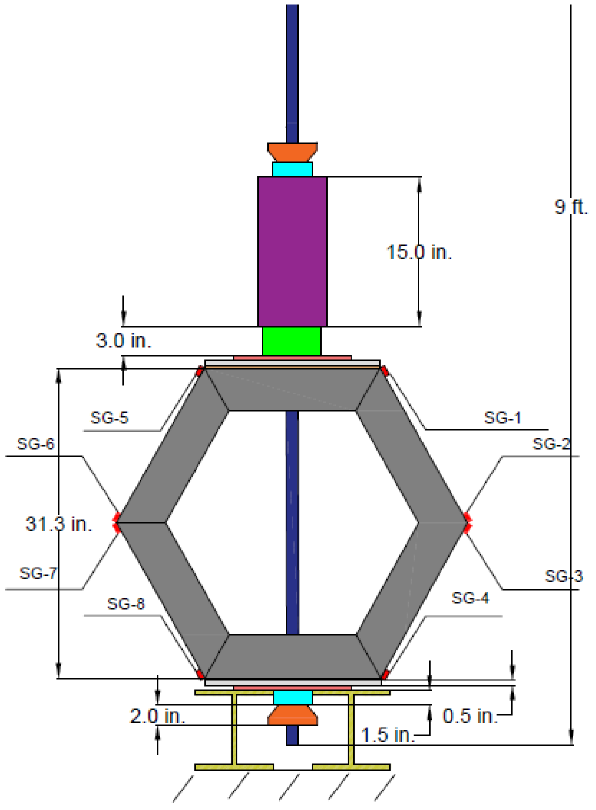
Typical Section

Structural Performance of prototype SEAHIVE

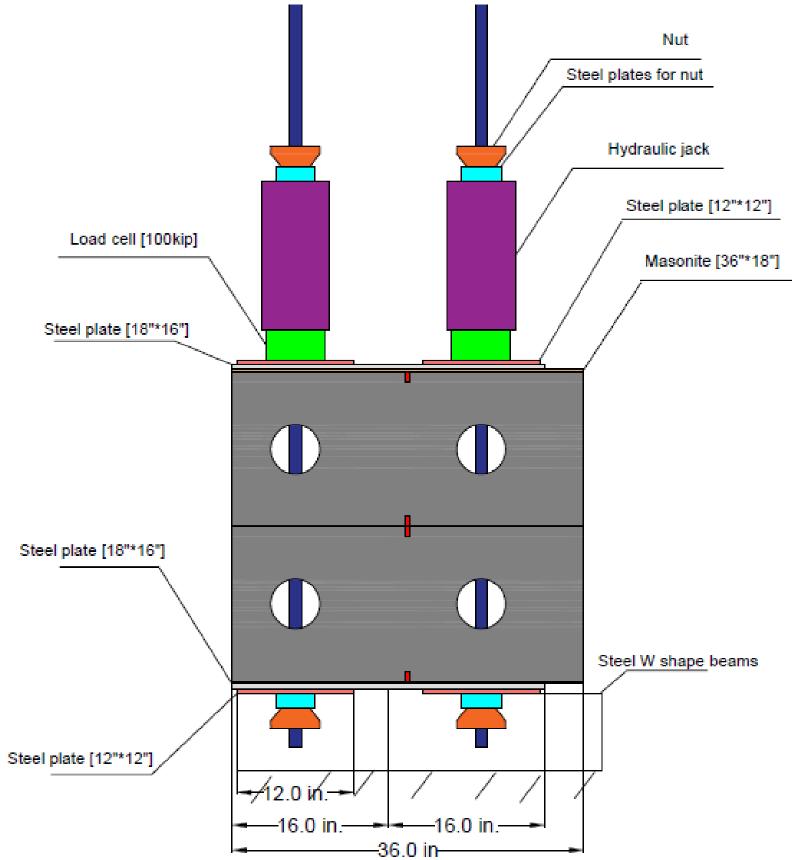
Compression Testing:

Applying uniform compressive load by:

- Two steel plates on the top and bottom of the element.
- Two hydraulic jacks



Typical Section



Side View

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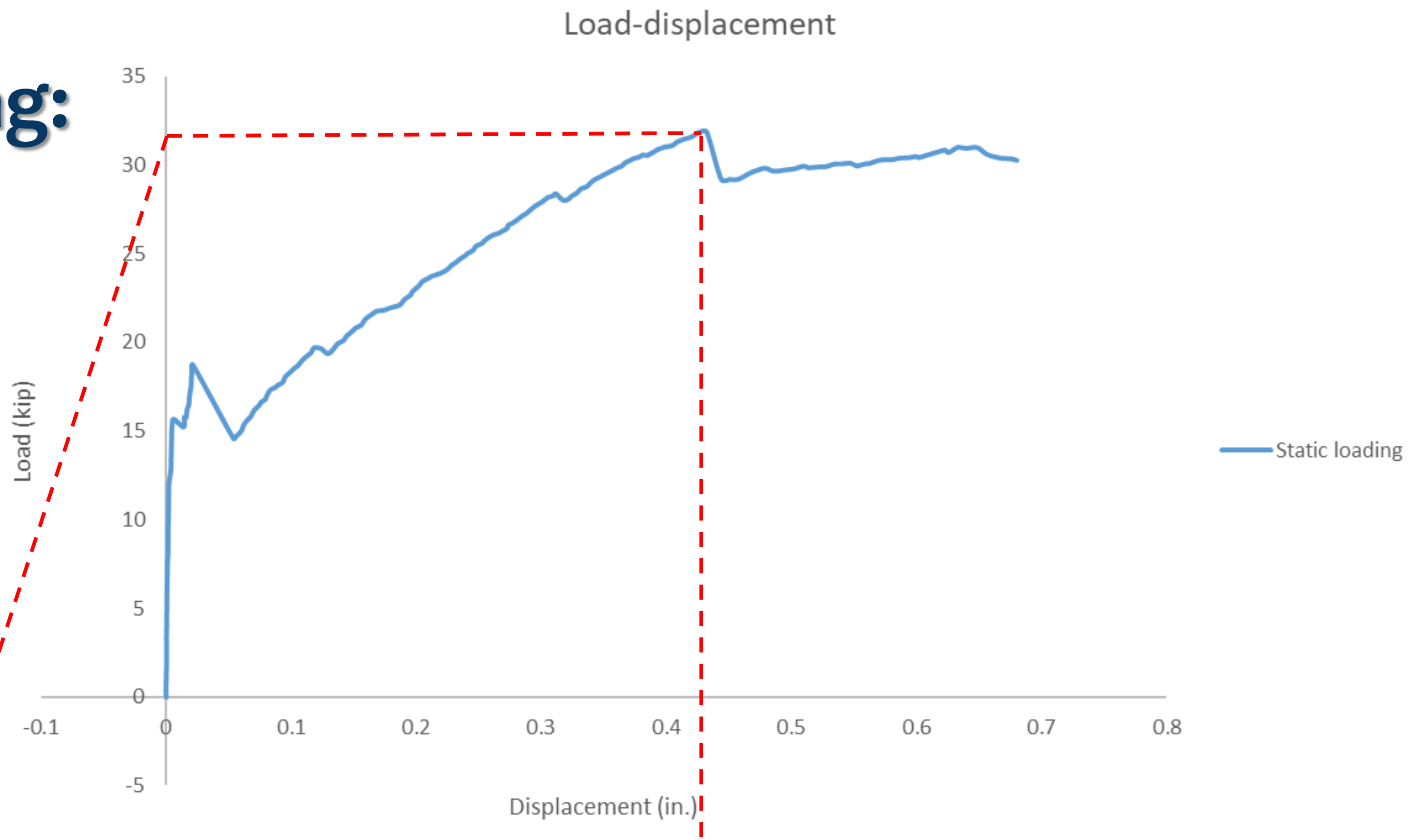
Results of the statical compressive load on SEAHIVE element

Compression Testing:



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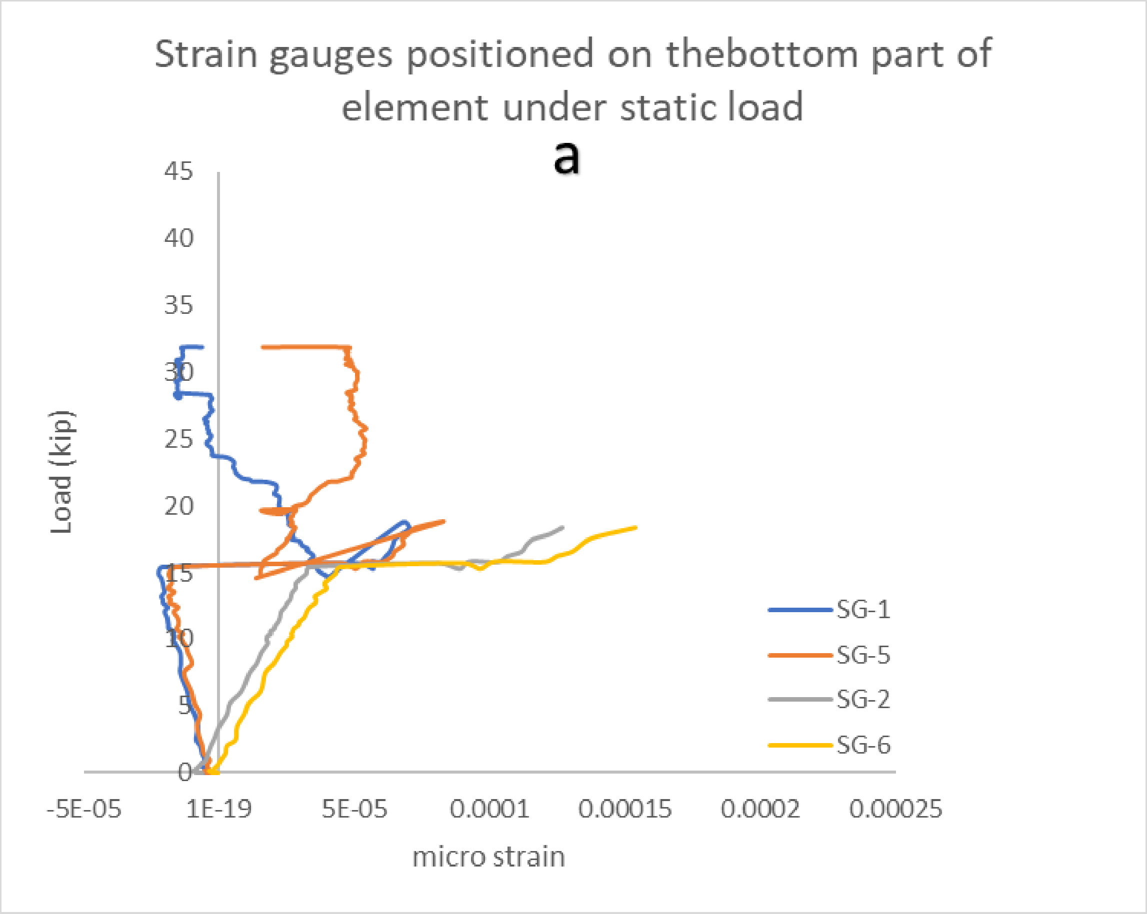
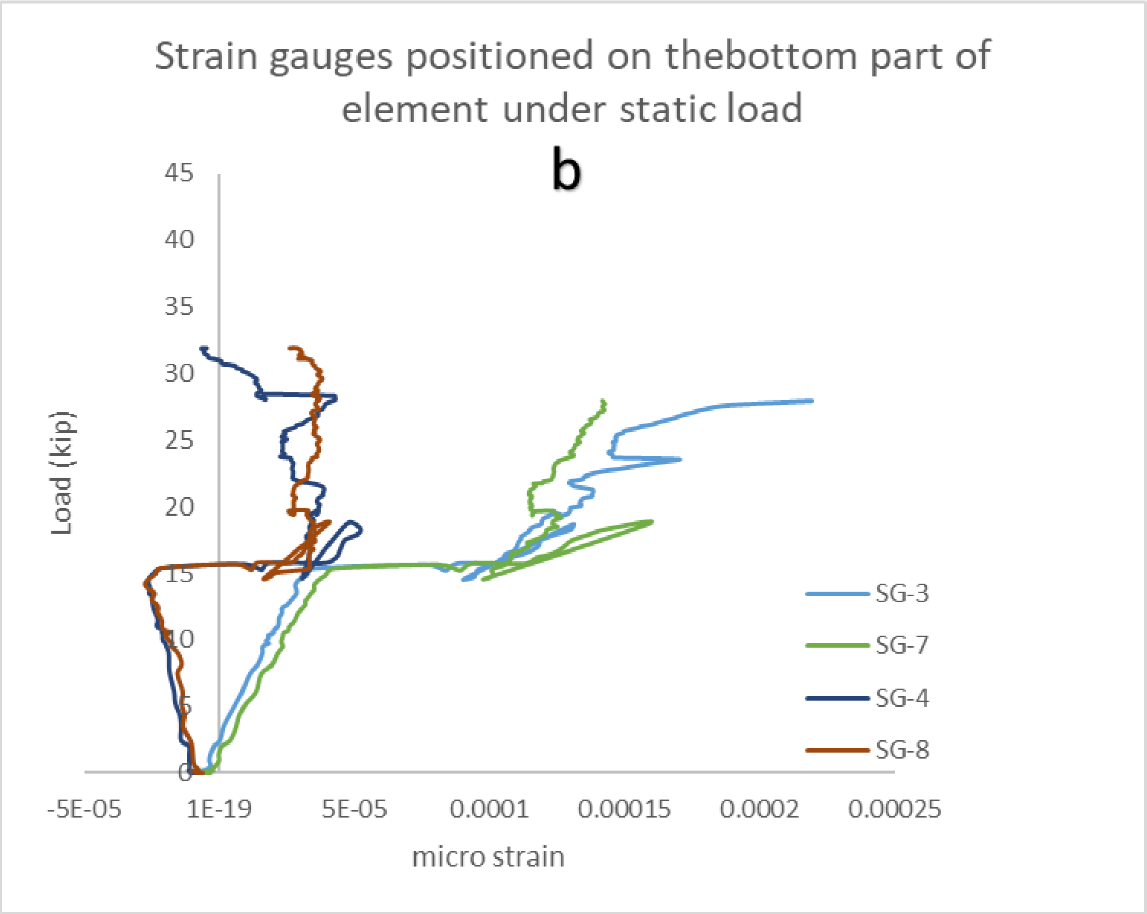
Loading condition	Maximum Load (kips)	Displacement at maximum load (in.)	Load at first drop (kips)
Static	**31.86**	**0.43**	**16.07**

Results of the statical compressive load on SEAHIVE element





- Results from the strain gauges show that the method of applying load to the element is uniform and acceptable because every two parallel strain gauges exhibit almost identical patterns.

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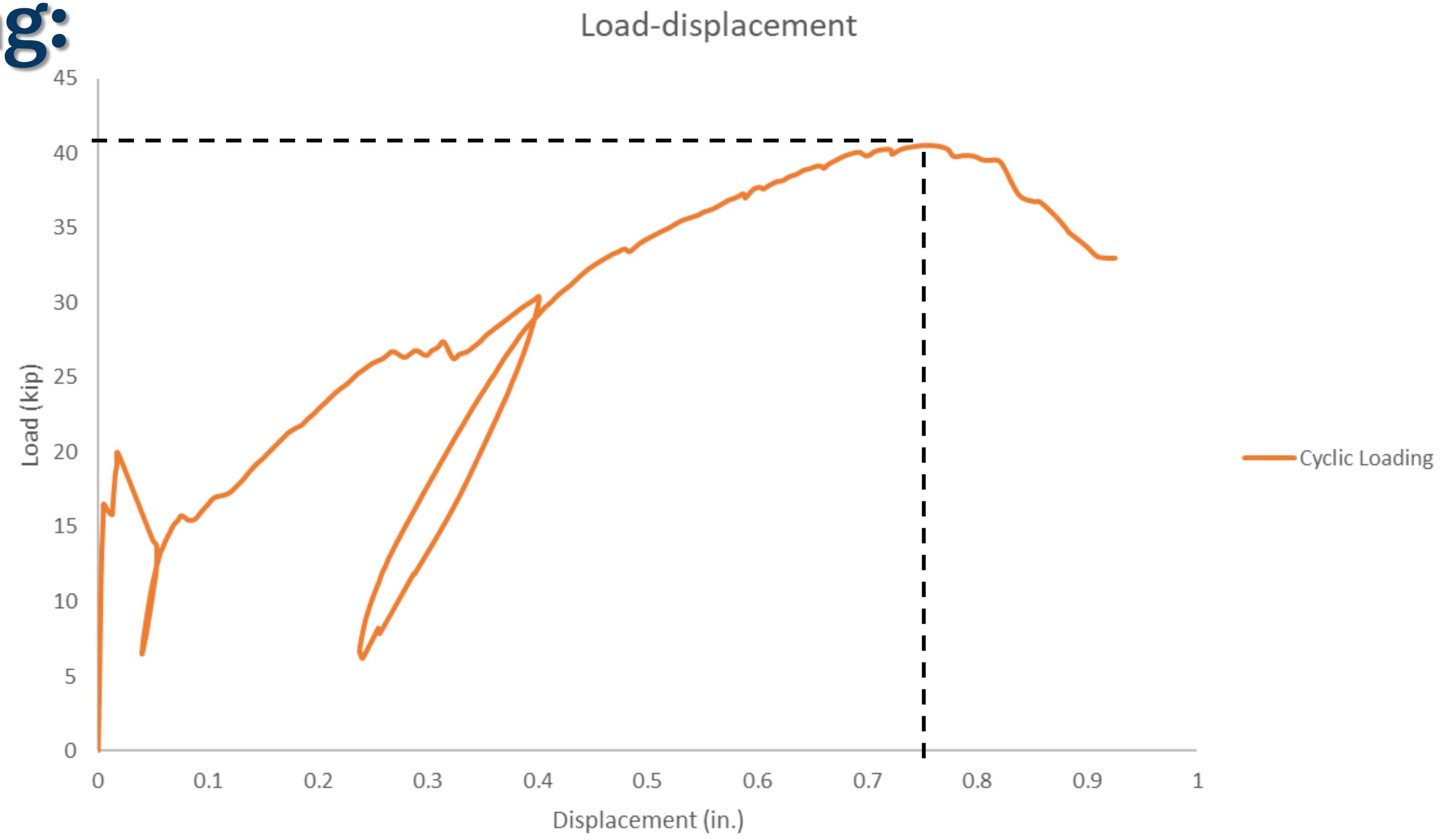
Results of the cyclic compressive load on SEAHIVE element

Compression Testing:

- Load applied in three consecutive cycles as follows:

The first two load cycles were at **20 kips** and **30 kips**, and at the end of each load cycle, the specimen was unloaded to about **5 kips**.



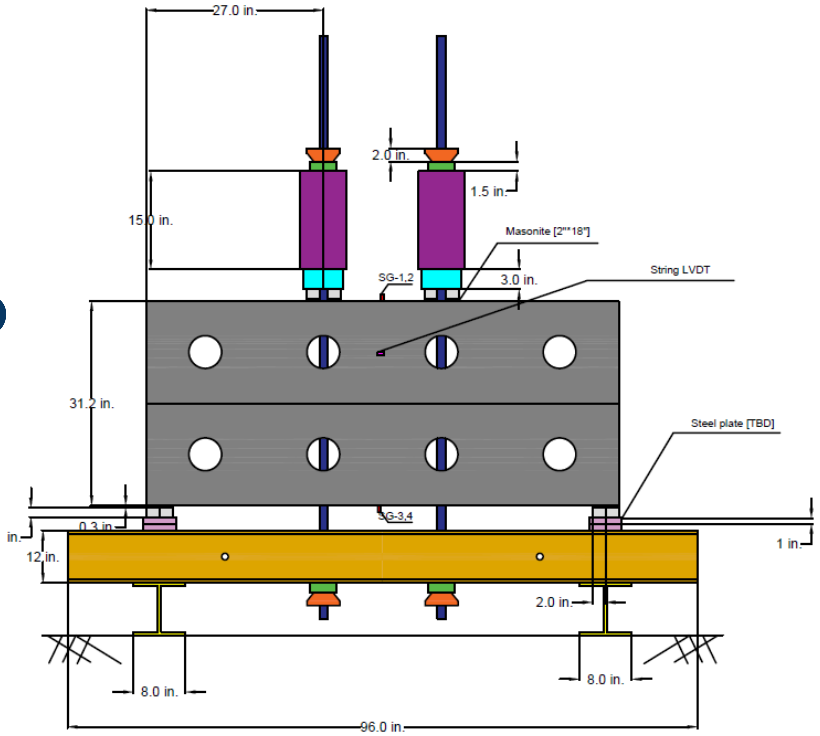
Loading condition	Maximum Load (kips)	Displacement at maximum load (in.)	Load at first drop (kips)
Cyclic	**40.53**	**0.75**	**15.56**

Structural Performance of prototype SEAHIVE (cont.)

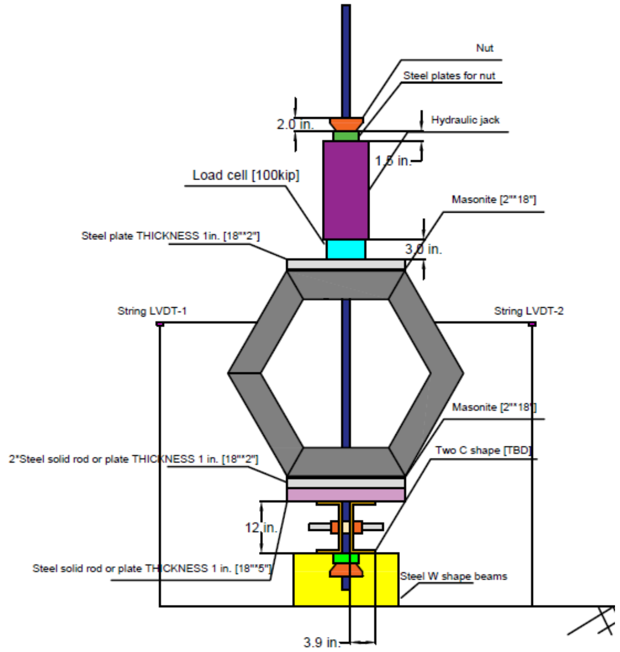
Flexural Testing:

Applying four-point flexural load by:

- steel knives on the top and bottom of the element.
- Two hydraulic jacks



Side View



Typical Section

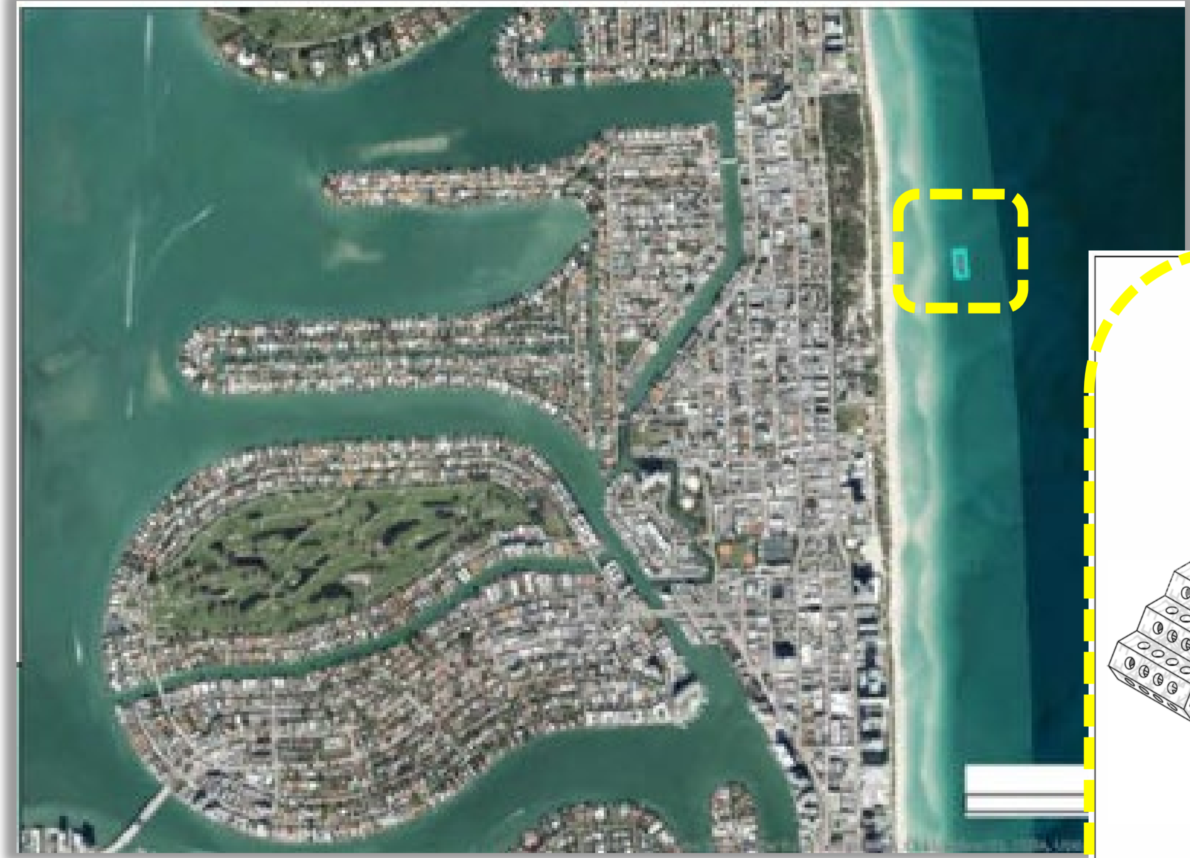
Results of the Flexural loading on SEAHIVE element

Cross-section View

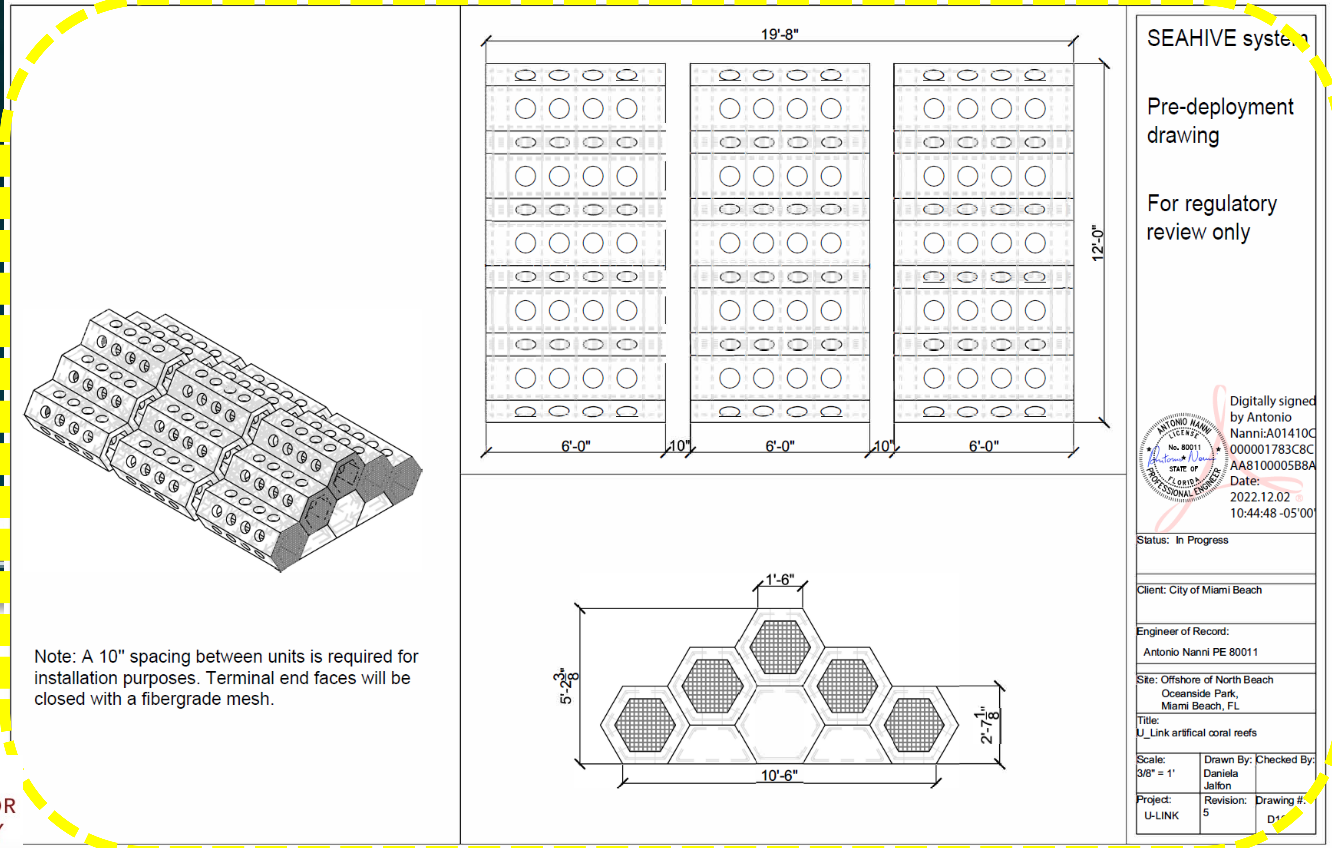
Side View

Cracks started to initiate at **17 kips**. Moreover, the ultimate load is **60 kips**. It should be noted that both loads represent the total load of two jacks.

Demonstration Installation for SEAHIVE



Miami Beach: Nearshore location & Stacked configuration.



EcoReef with **SeaHive**©

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Center for Integration of Composites into Infrastructure

SLAC NATIONAL ACCELERATOR LABORATORY

Results of Demonstration Installations for SEAHIVE

Miami Beach: March 2023

EcoReef with **SeaHive**©

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Center for Integration of Composites into Infrastructure

SLAC NATIONAL ACCELERATOR LABORATORY

Results of Demonstration Installations for SEAHIVE

March 2023:
Miami Beach installation

EcoReef with **SeaHive**©

October 2023:
Marinelife "oasis" in a sandy desert!

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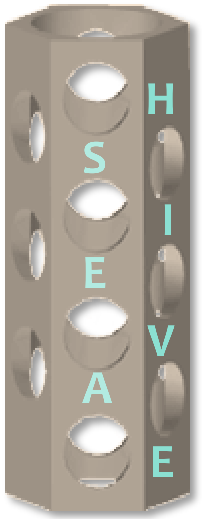
Future work on SEAHIVE Project

- Conducting quality control (QC) and quality assurance (QA) on SEAHIVE modules to ensure the quality of the concrete used for fabricating SEAHIVE units involves the following procedures:
    1. Extracting concrete cores from SEAHIVE modules.
    2. Determining the compressive strength of the concrete used in fabricating SEAHIVE units.
    3. Performing ultrasonic pulse velocity (UPV) tests on the extracted cores.
    4. Measuring the density of the concrete cores.
    5. Evaluating the bulk resistivity of the cores.



Additionally:

- Conducting additional flexural tests on SEAHIVE units to assess their performance under optimized reinforcing configurations.
- Attempting to simulate the response of compressive and flexural loading and failure modes, using finite element modelling (FEM).

Questions & Contacts

National Conference on
Beach Preservation Technology

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