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FIELD DRIVING TESTS OF PRECAST CONCRETE PILES REINFORCED WITH GFRP BARS AND SPIRALS

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Outline

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Introduction

Deterioration of concrete piles reinforcement with conventional steel bars or cables due to corrosion becomes a very serious and expensive problem specially for structures subjected to sever environmental and loading conditions.

Introduction

- In North America in particular, the corrosion of steel reinforcement in concrete bridges subjected to deicing salts and/or aggressive environments constitutes the major cause of structure deterioration, leading to costly repairs and rehabilitation as well as a significant reduction in service life.
- Estimates indicate that the United States spends billions of dollars annually to repair and replace bridge substructures such as piers ($2 billion), and marine piling systems ($1 billion) (NACE International).

Introduction

- In the last decade, there has been **a rapid increase** in using non-corrosive **FRP bars** for concrete structures due to enhanced properties and **cost-effectiveness**.
- The FRP bars have been used extensively in different applications such as **bridges, parking garages, tunnels and marine structures**.
- Many **significant developments** from the manufacturer, various researchers and Design Codes along with numerous successful installations have led to a much **higher comfort level and exponential use with designers and owners.**
- **After years of investigation and implementations,** public agencies and regulatory authorities in **North America** has now included FRP as a premium corrosion resistant reinforcing material in its **corrosion protection policy.**

Objectives

-Determine the structural performance (Axial, Flexural, and Shear capacity) of RC Piles reinforced with **GFRP bars, ties and Spirals.**

-Determine the bearing capacity and the technical viability of the use of precast GFRP RC piles in harsh environments and the possibility of installing them following the procedure normally employed for precast prestressed/noprestressed concrete piles.

-Recommendations for design, testing and installations of such these **piles for Bridge and Marine applications.**

Pile Driving Test - Design

Dynamic Load Testing on driven piles is a fast, reliable and cost effective method of evaluating foundation bearing capacity.

Three 24 x 24-in Precast Concrete Piles were tested

- Pile No. 1 Prestressed with CFRP cables
- Pile No. 2 and 3 Precast Concrete Reinforced with GFRP

Field Test Parameters:

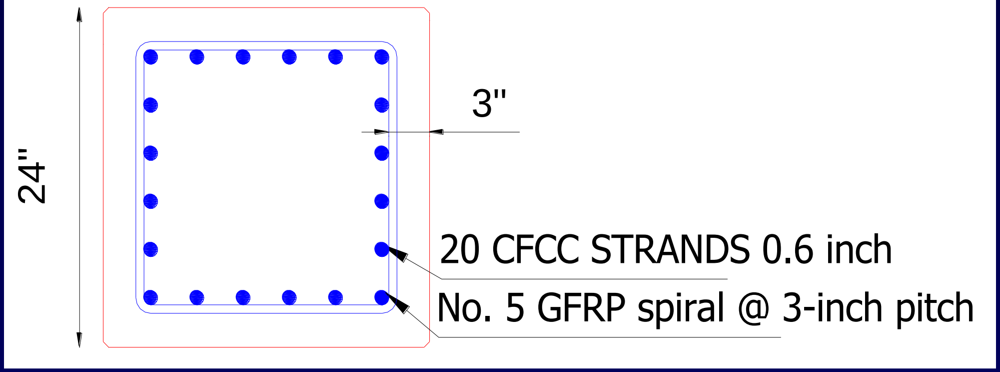
- CFRP prestressed vs. GFRP non-prestressed Piles
- 2 different GFRP Reinf. ratio of non-prestressed Piles

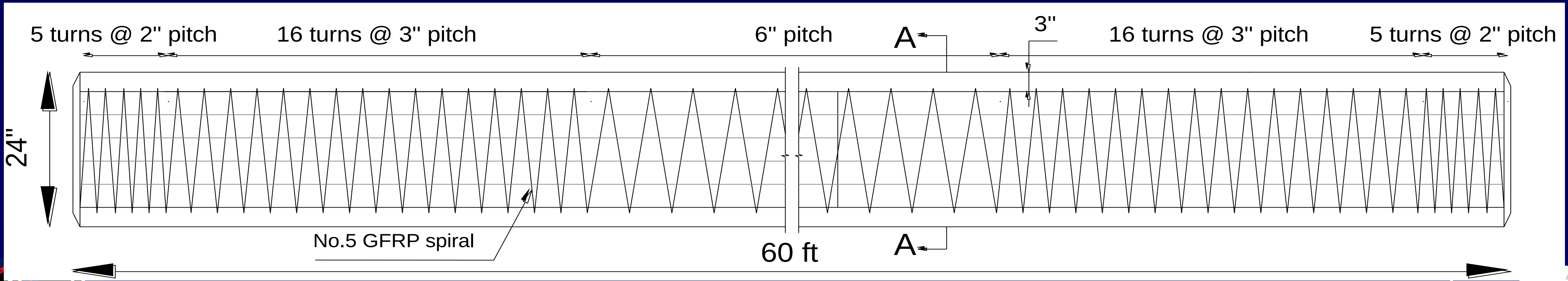
Pile Driving Test - Design

Pile No. 1 (CFRP-PC)

The prestressing strand pattern was based on FDOT's standard details for **a 24" square pile** with **20~0.6"** diameter (15.2mm) strands The 20~strand option was chosen because of GATE's casting bed strand template.

The number of turns and pitches for the **GFRP spirals** was designed to provide confinement to the concrete core and to avoid premature failure at the ends due to prestress release and impact load during driving.

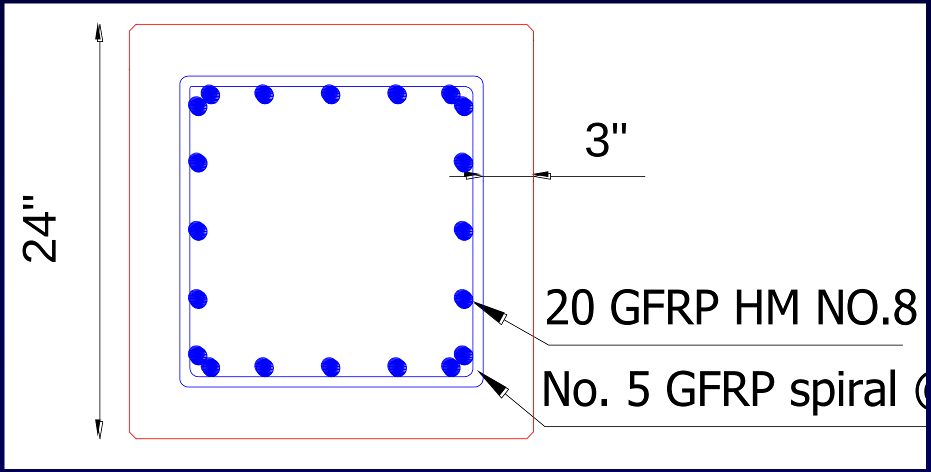


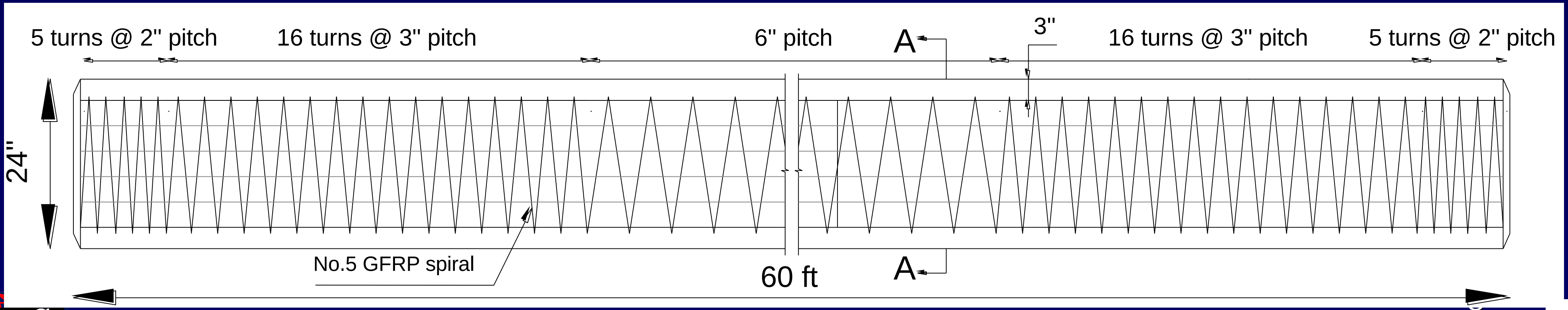


Pile Driving Test - Design

Pile No. 2 (GFRP-RC)

- 20 GFRP bars No. 8 (25 mm)
- GFRP Spirals No. 5 (16 mm)
- Reinforcement Ratio = 2.7%
- Spliced GFRP bars were used

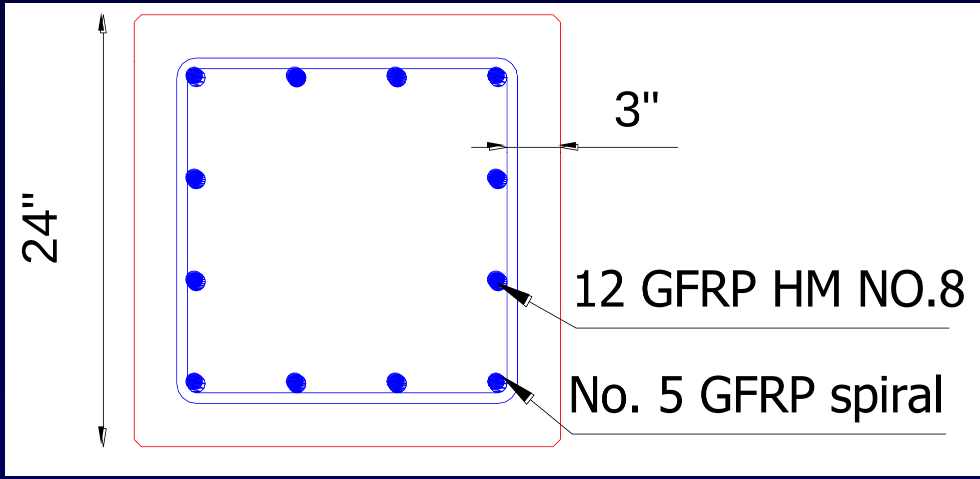


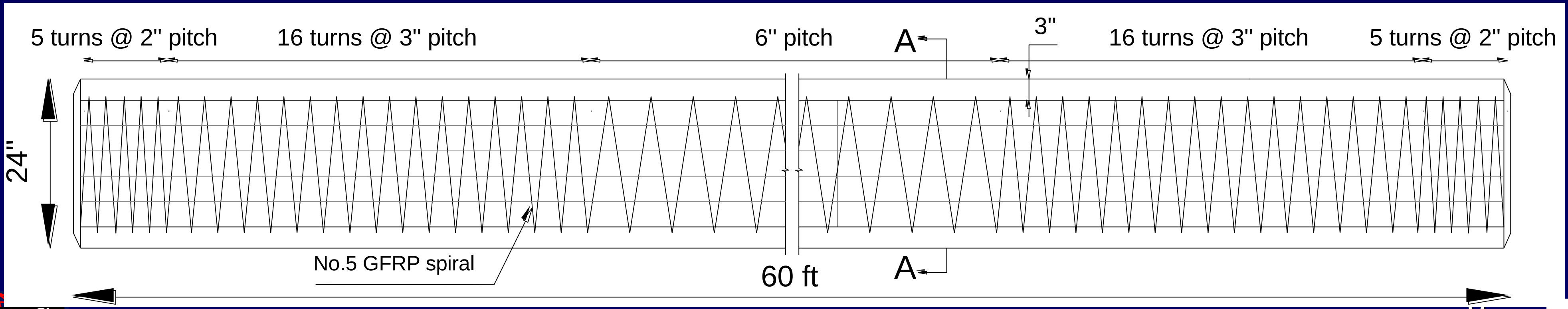


Pile Driving Test - Design

Pile No. 3 (GFRP-RC)

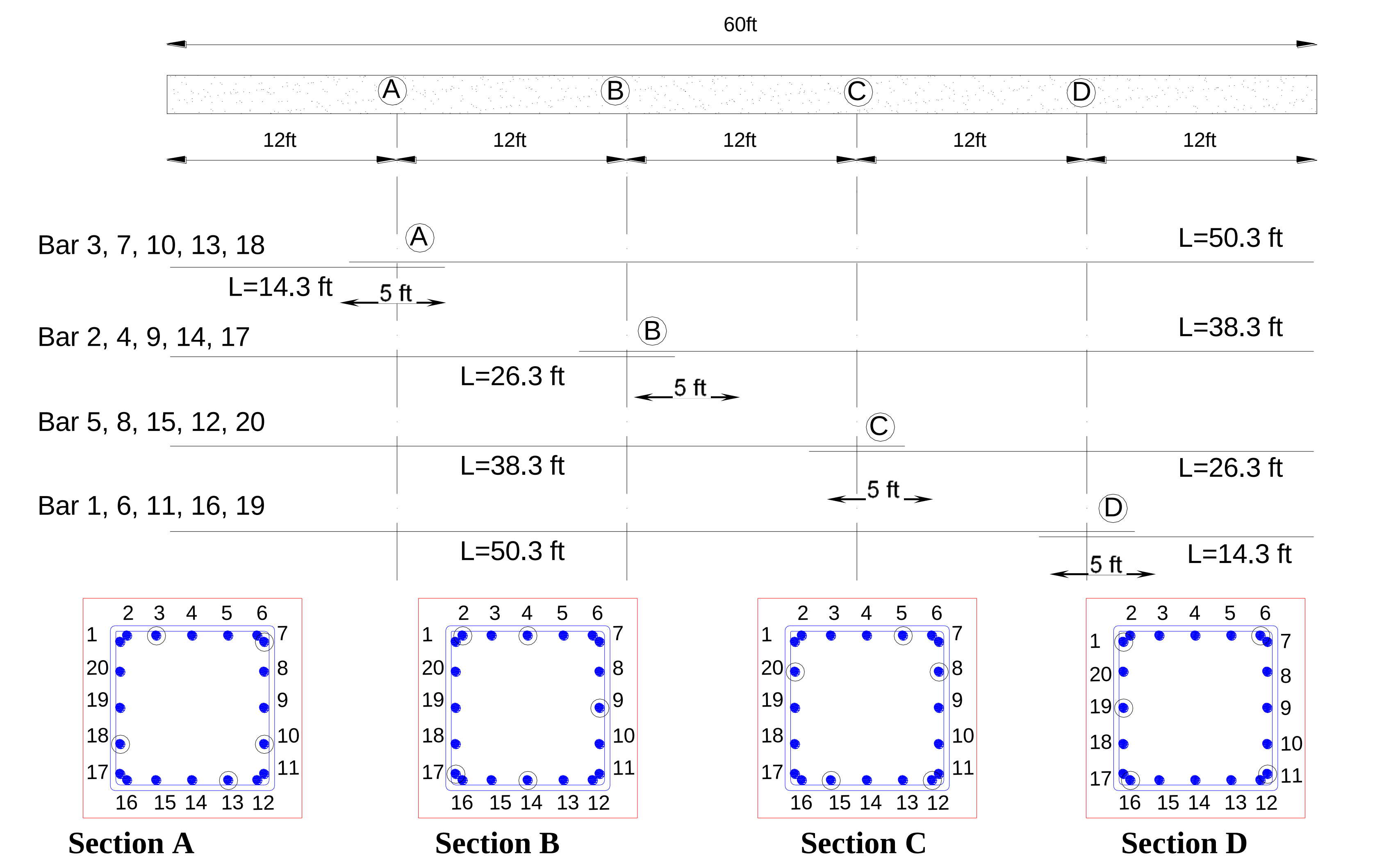
- 12 GFRP bars No. 8 (25 mm)
- GFRP Spirals No. 5 (16 mm)
- Reinforcement Ratio = 1.6%
- Spliced GFRP bars were used





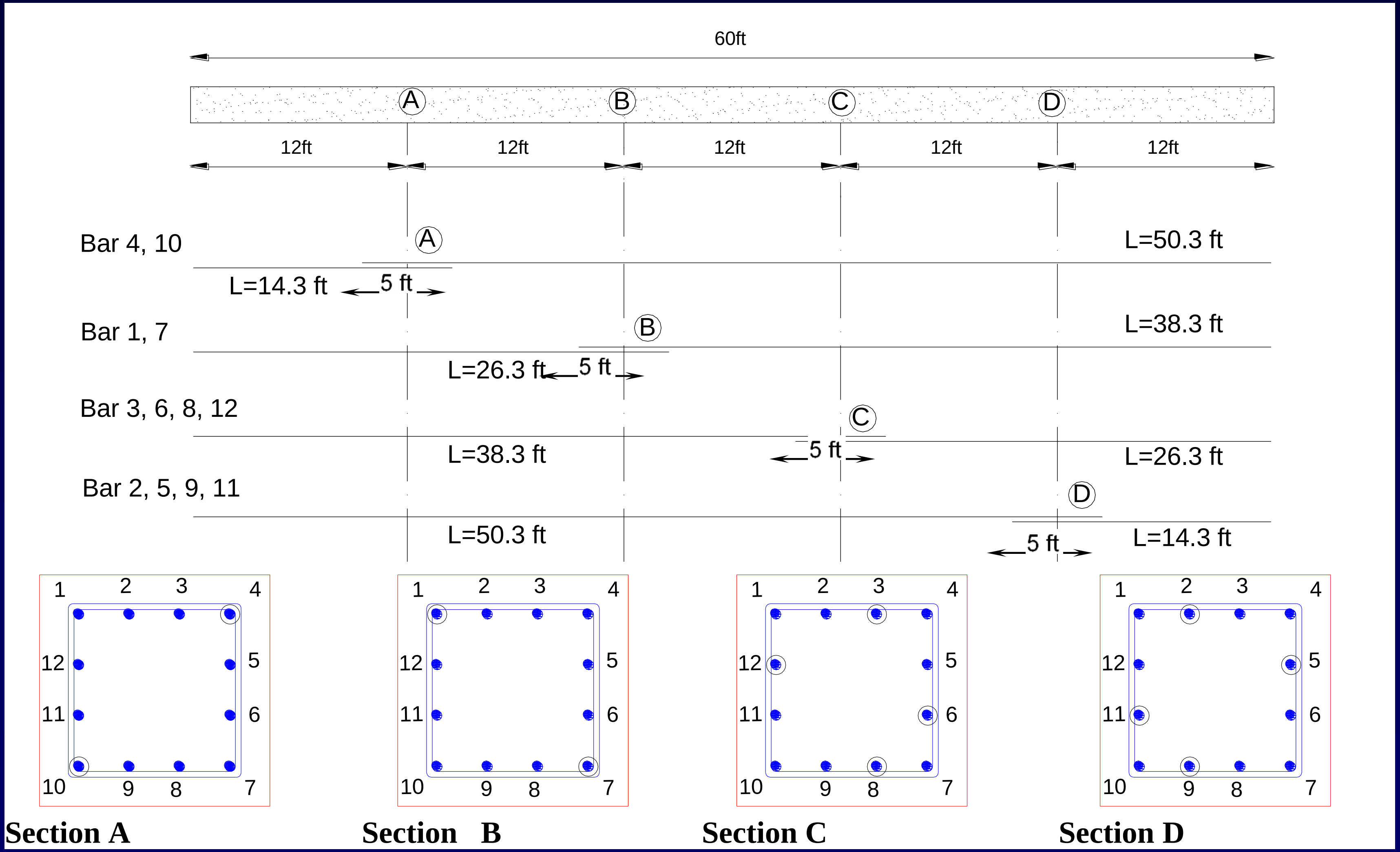
Pile Driving Test - Design

Pile No. 2 – GFRP Splice Length Details



Pile Driving Test - Design

Pile No. 2 – GFRP Splice Length Details



Pile Driving Test - Design

Wave Tensile Stress Analysis

FDOT maximum allowable pile stresses:

Pile compressive stresses (psi)

$$S_{apc} = 0.7 f_c' - 0.75 f_{pe}$$

$$S_{apc} = 0.7 \times 8500 - 0.75 \times 0.8 \times 1200 = 5230\,psi\ /1000 = 5.23\,ksi$$

$$S_{apc\ (non\text{-}prestressed)} = 0.7 \text{ x } 8500 = 5.95\,ksi$$

Pile tensile stresses (psi)

$$S_{apt} = 3.25\sqrt{f'_c} + 1.05 f_{pe}$$

$$S_{apc} = 3.25 \times \sqrt{8500} + 1.05 \times 0.8 \times 1200 / 1000 = 1.31\ ksi$$

$$S_{apt\ (non\text{-}prestressed)} = 3.25 \text{ x } \sqrt{8500} = 0.30\ ksi$$

…however, we suggested allowing 6.5√f'c = 0.60 ksi

Pile Driving Test - Fabrication

CFCC Cables for Pile No. 1

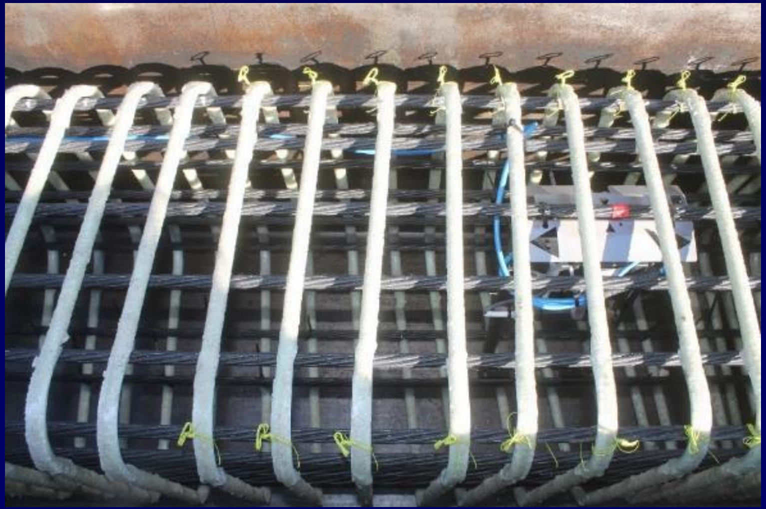
Pile Driving Test - Fabrication

Coupler and Prestressing - Pile No. 1

Pile Driving Test - Fabrication

EDC Instrumentation - Pile No. 1



Pile Driving Test - Fabrication

Casting - Pile No. 1

Pile Driving Test - Fabrication

GFRP Spirals & Long' Bars for Pile No. 2 and 3

Pile Driving Test - Fabrication

Cages fabrication for Pile No. 2 and 3

Pile No. 2

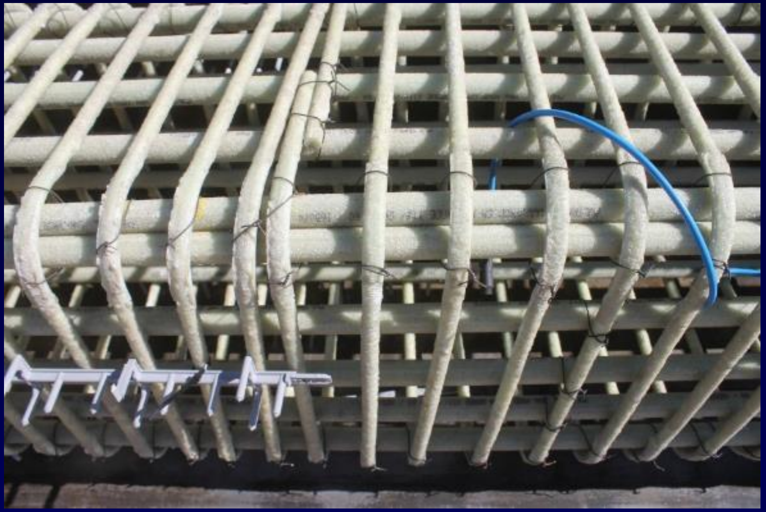
Pile No. 3

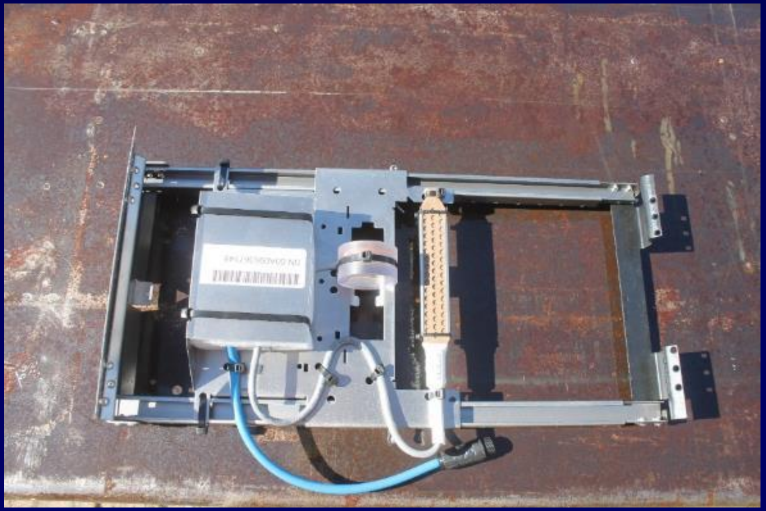
Pile Driving Test - Fabrication

Fabrication of Pile No. 2 and 3

Pile Driving Test - Fabrication

EDC Instrumentation - Pile No. 2 and 3

Pile Driving Test - Fabrication

Casting - Pile No. 2 and 3

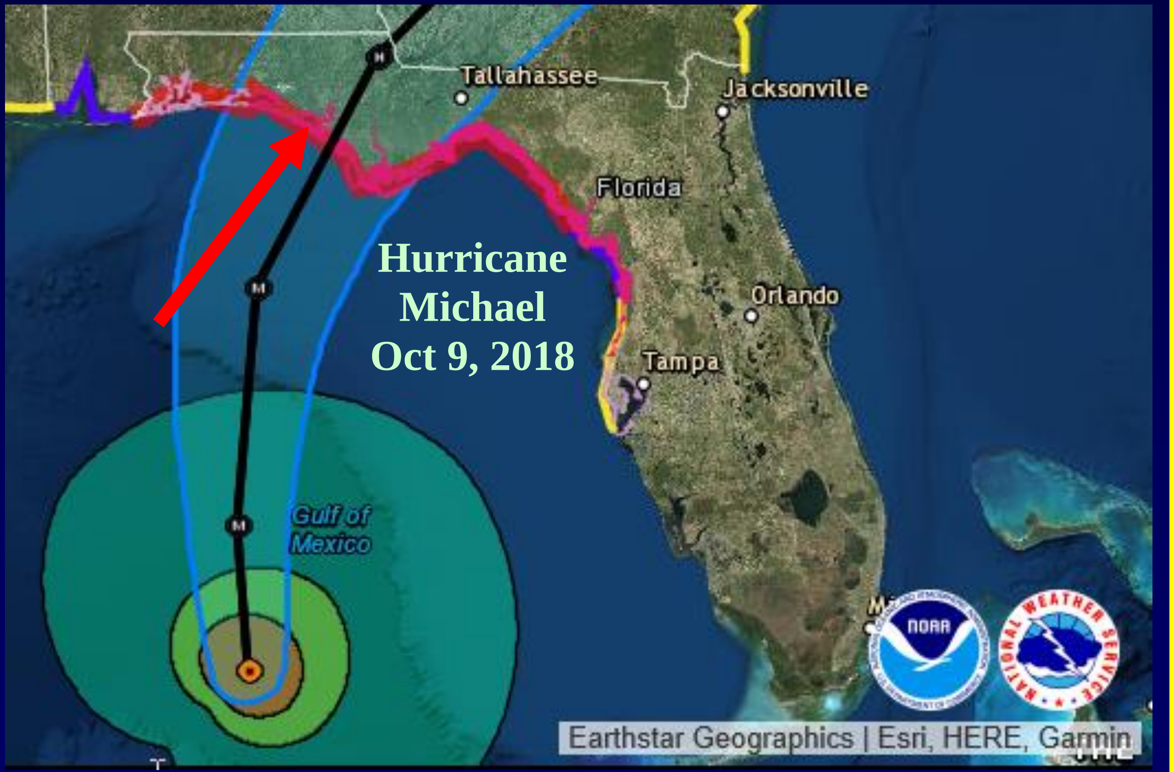
Pile Driving Test - Fabrication

Unmolding

Pile Driving Field Test Site

Dynamic Load Test

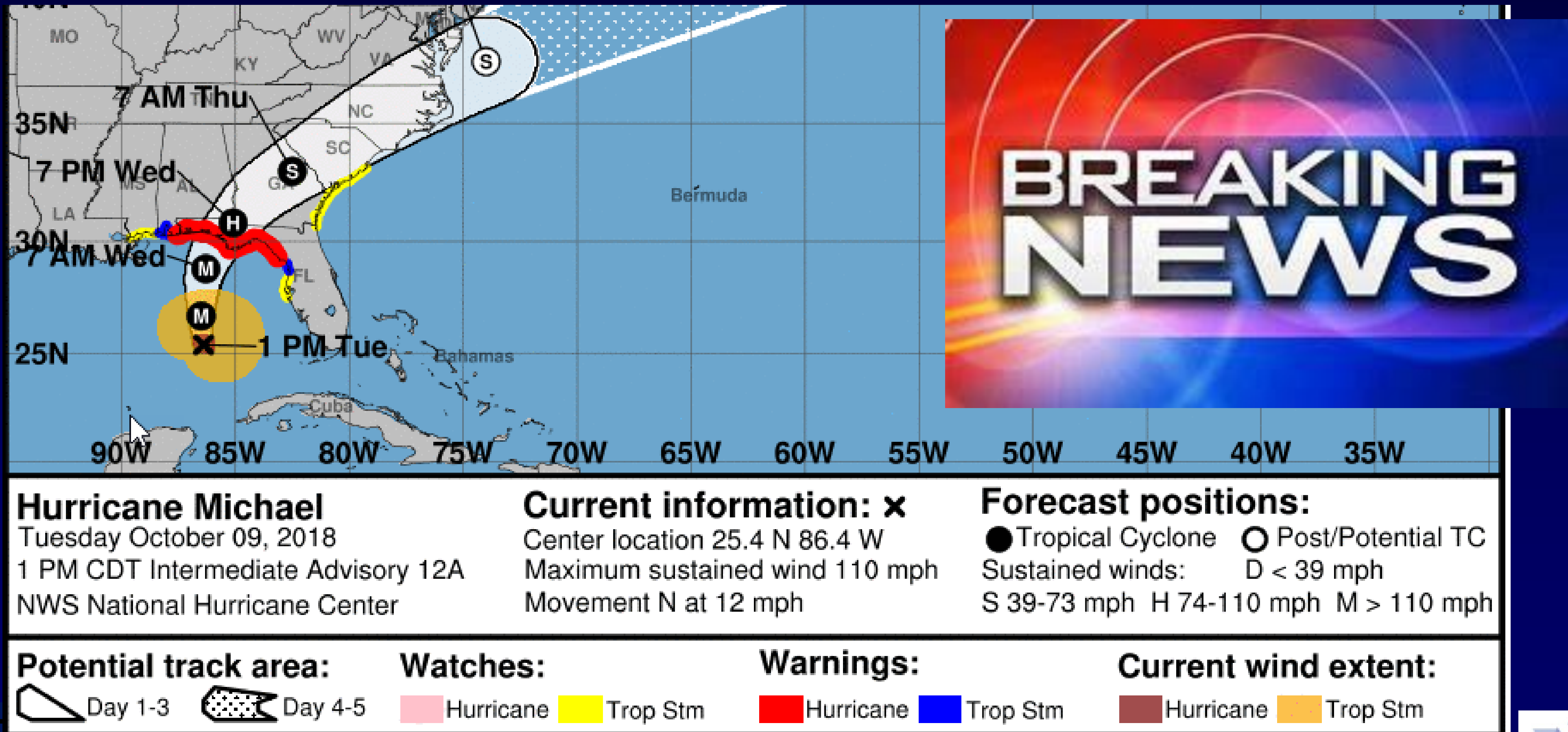
On March 2nd at the FDOT Arthur Drive project site in Lynn Haven, Florida, the three piles were tested



Pile Driving Field Test Site

Hurricane Michael

Lynn Haven in direct path of hurricane landfall in Florida on October 10th



Pile Driving Field Test

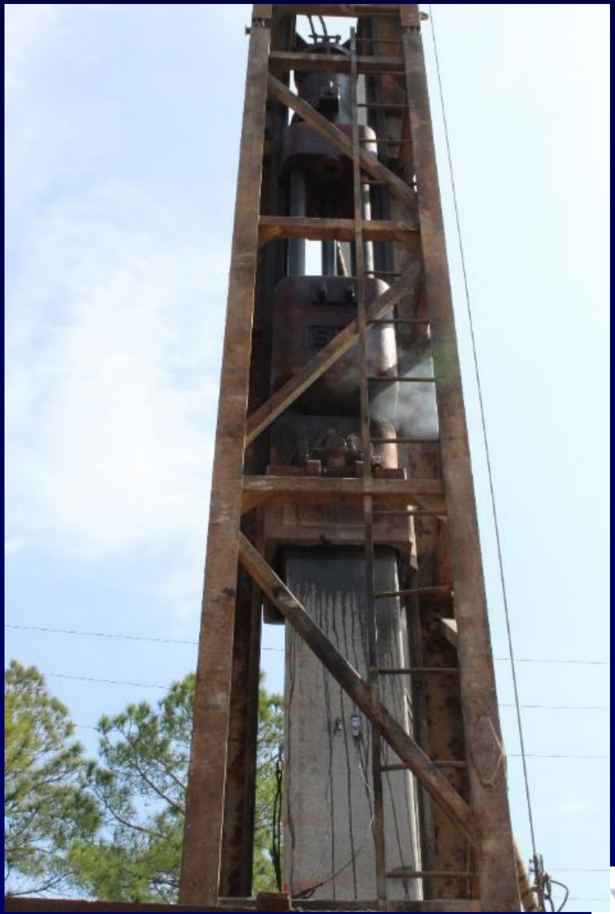
The three piles at the Bridge Site



Pile Driving Field Test

Hammer Type

Pile driving and testing were performed with a Vulcan 512 single-acting air hammer (12 kips ram weight, fitted with mechanism that allowed for reportedly 3 and 5 feet stroke heights).



Pile Driving Field Test

The three piles before driving test

Pile Driving Field Test

End of Driving and Dynamic Load Test

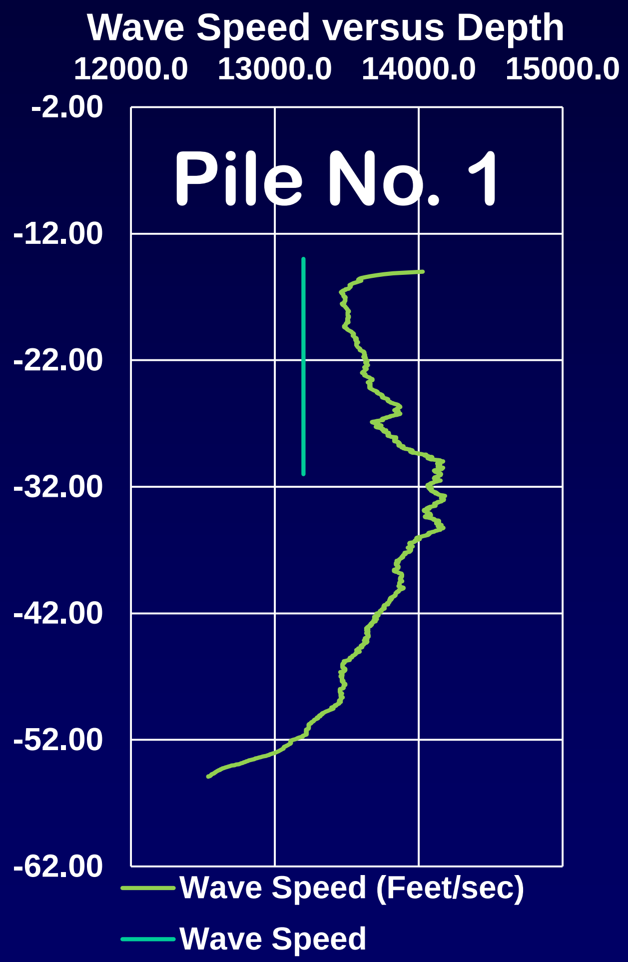
Pile Driving Field Test Results

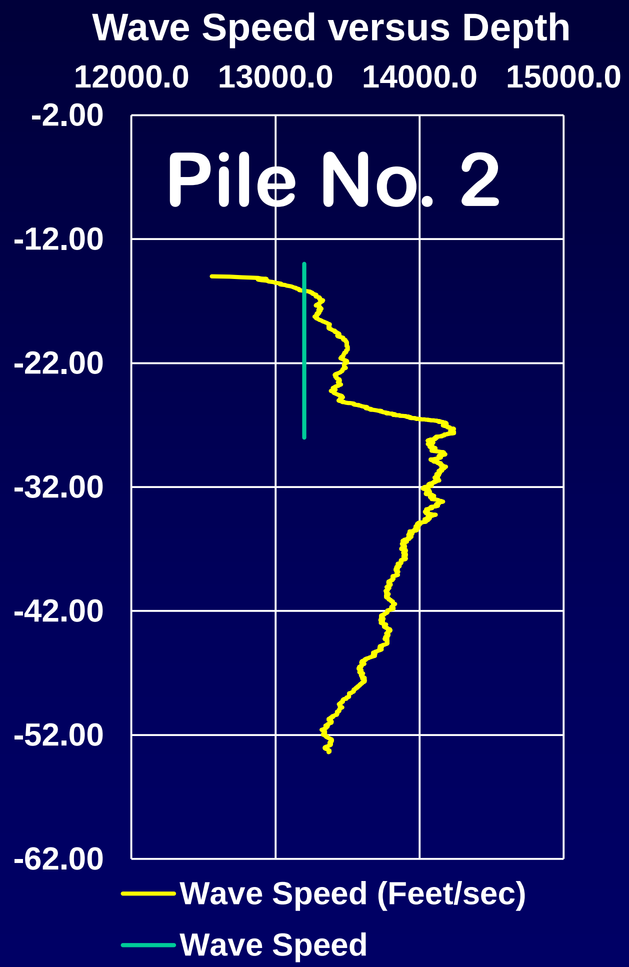
Visual observations

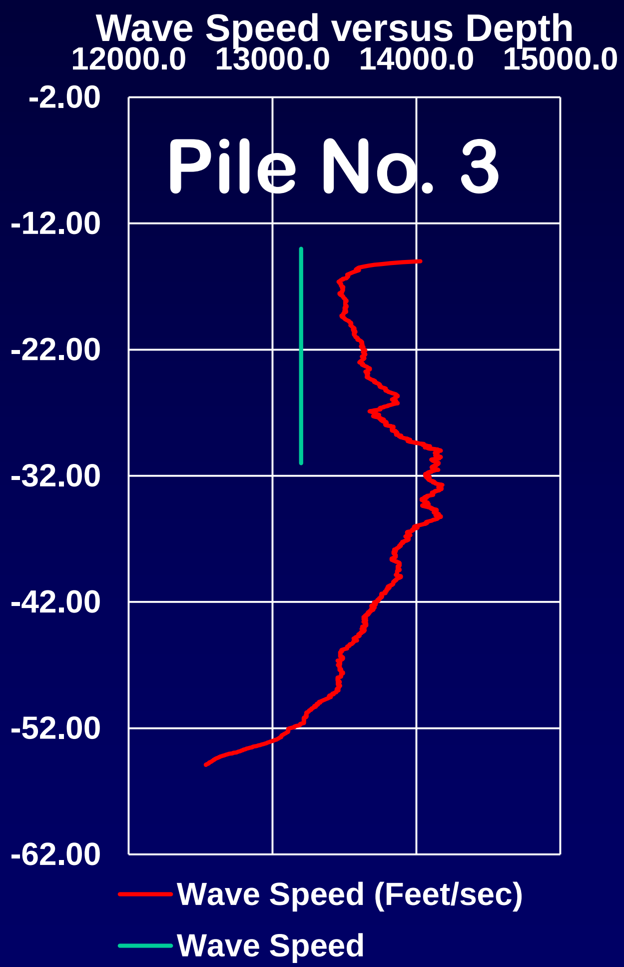
- Normal pile driving behavior
- No cover spalling
- No cracking
- No damage

Pile Driving Field Test Results

Measured Wave Speed versus Depth

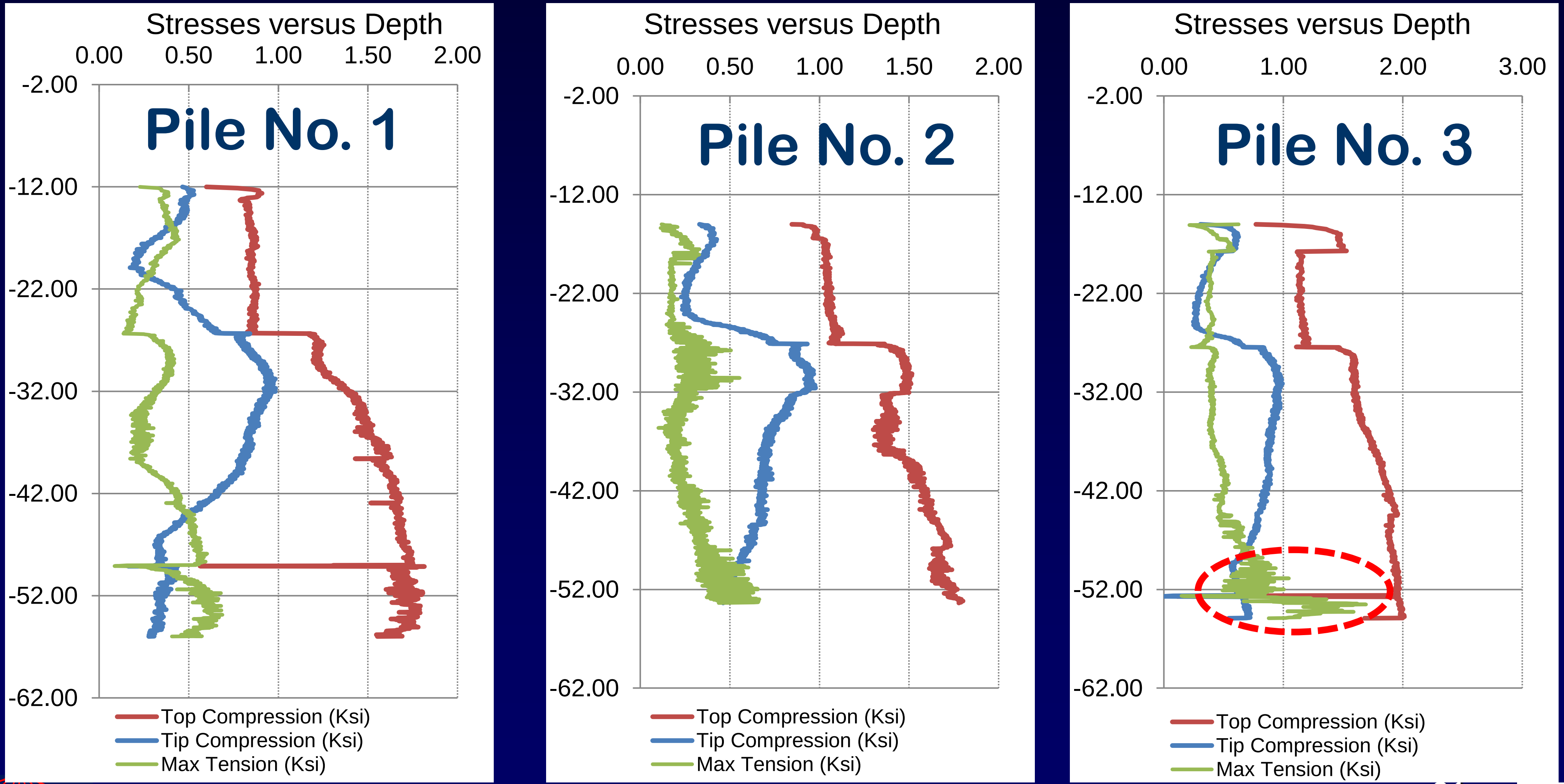






Pile Driving Field Test Results

Calculated Stress versus Depth



Conclusions

1. The VULCAN 512 Hammer has performed consistently in terms of the energy and stroke lengths during the installation of all 3 demonstration piles.

2. The CFRP prestressed concrete Pile 1 displayed **higher average calculated wave speed compared to the GFRP** non-prestressed Piles 2 and 3. The wave speeds are measured for each hammer blow by the EDC top and tip gages.

3. Pile 1 was driven with a similar stroke as used for Pile 2, therefore, both the piles followed identical compression and tensile stress patterns during installation.

4. **No pile damage occurred to Piles 1, 2 and 3** during installation.

Conclusions

5. GFRP spirals successfully confined the concrete core of the three piles and prevented the cover spalling during the driving.

6. The key conclusion is continuous stresswave path throughout pile lengths in compression loading; i.e., the piles do not have major damage (i.e., breakage in the common measure for an FDOT typical prestressed concrete pile) as far as strictly compression loading is concerned.

7. The positive results of the tests seem to suggest the technical viability of the use of precast GFRP reinforced concrete piles in harsh environments and the possibility of installing them following the procedures normally employed for prestressed concrete piles reinforced with steel bars.

Acknowledgment

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Économie, Science et Innovation Québec

NSERC CRSNG

GFRP Bars and Spirals

V-ROD PULTRALL

Carbon Fiber Composite (CFCC) Cables

TOKYO ROPE MFG. CO., LTD.

Gate Precast Company

GATE

Embedded Data Collectors (EDC)

SMARTSTRUCTURES

Pile-Driving Analyzer (PDA)

GRL engineers, inc.

Piles Driving

Contractor F&W CONSTRUCTION COMPANY, INC

UNF UNIVERSITY of NORTH FLORIDA

FDOT

Acknowledgment

Thank you very much for your attention

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