HIGH CAPACITY LATERAL LOAD TESTING FOR AUGER CAST IN PLACE PILES

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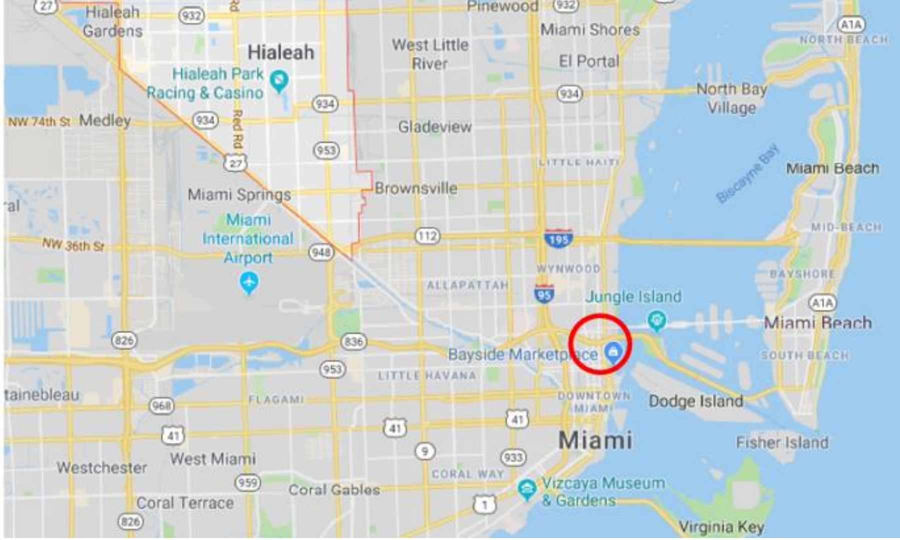
HDR

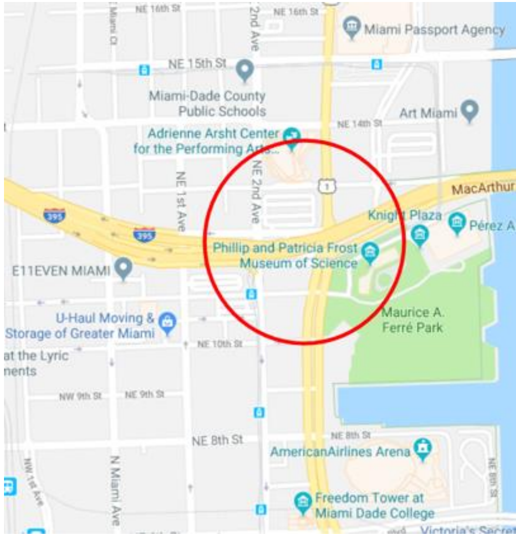
UNIVERSAL ENGINEERING SCIENCES

Project Overview

Highlights

- $802M Design Build
- Archer-Western/deMoya Construction, a JV
- HDR Prime Designer for Signature Bridge
- Universal Engineering Services (UES) Geotechnical Engineer of Record
- Load Test Consulting (LTC) performed lateral load test

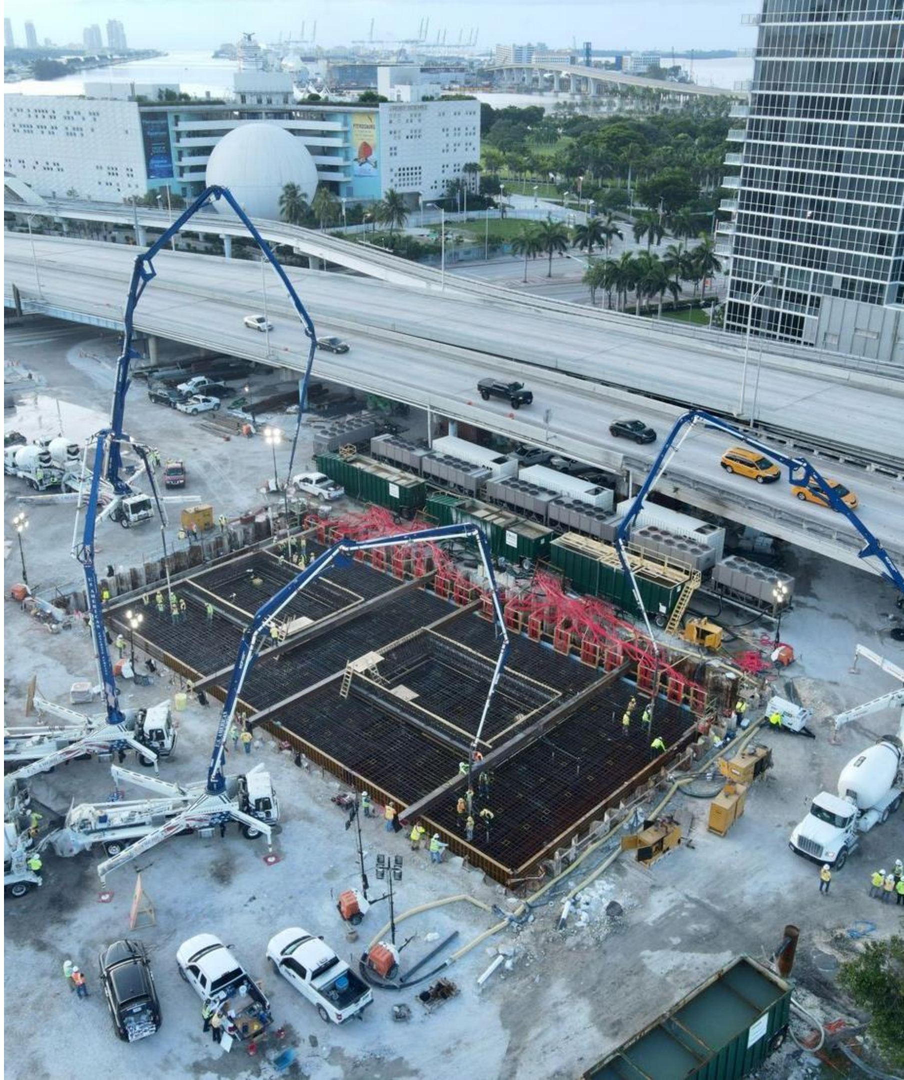




Project Overview

Key Features

- 1200’ span joint-to-joint
- Auger cast piles
- 6 Arches (longest is 330’ crest elev., 650’ span) – true arch structure
    - CIP starter segment at each support
- CIP cable supported superstructure - Hybrid (P/T, Reinforced)
- Arches monolithic with footings on piles.
- Center Pier



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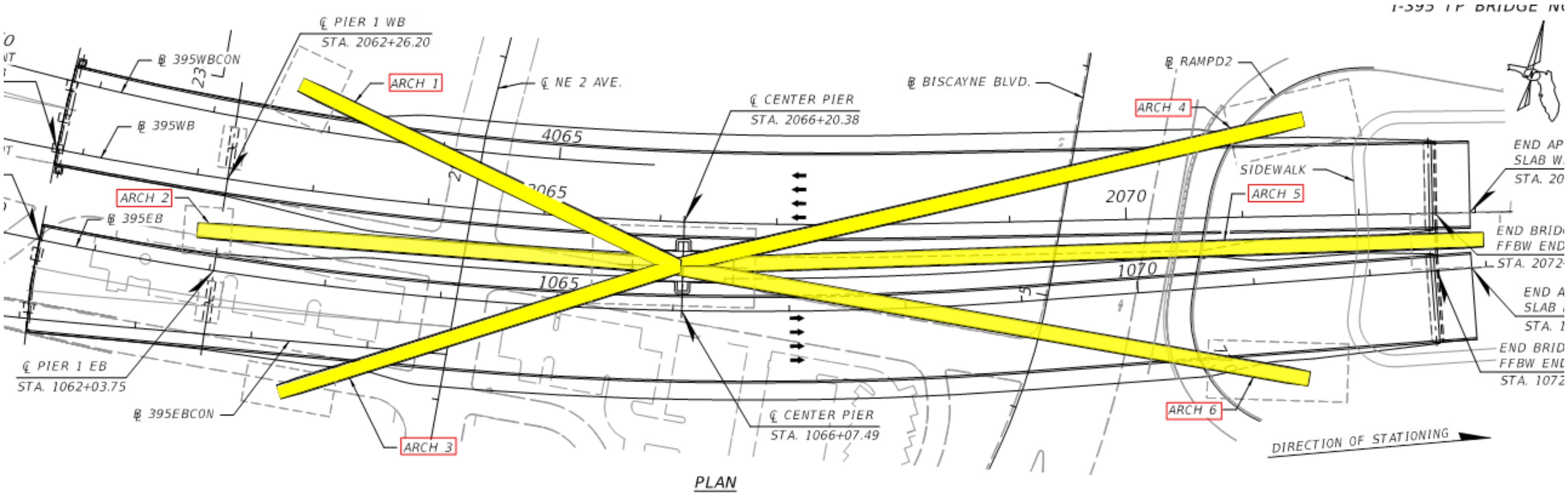

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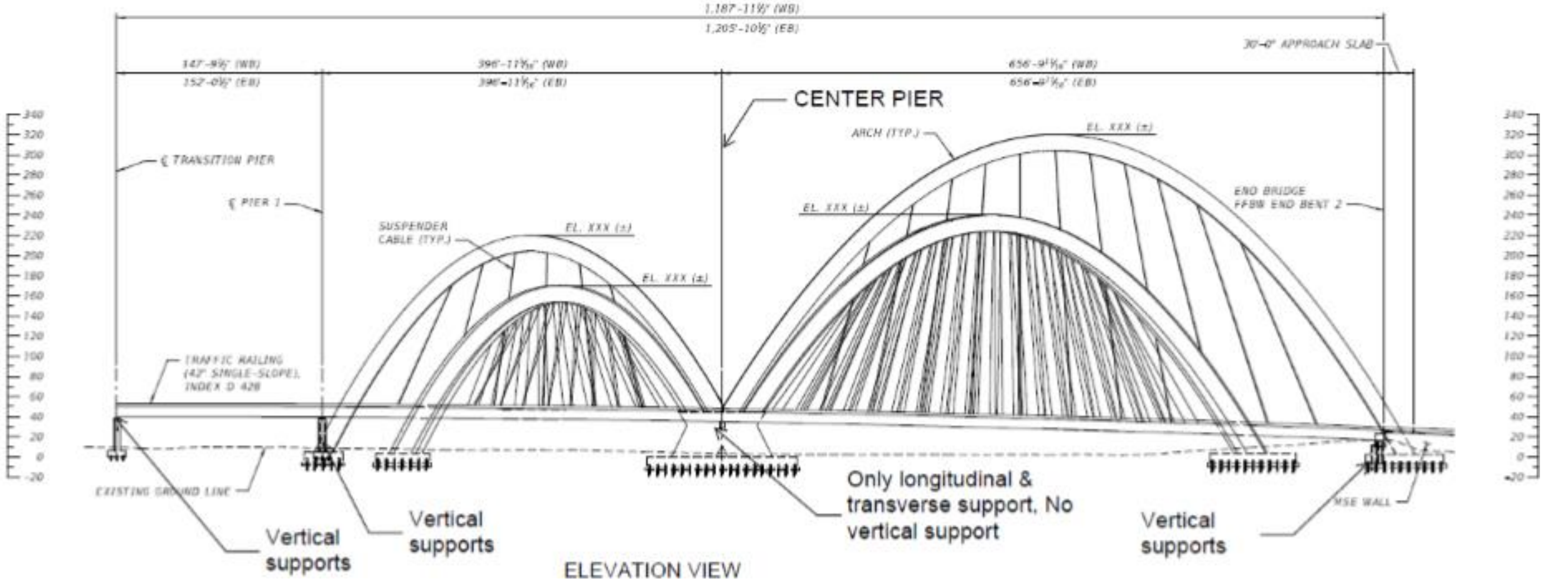
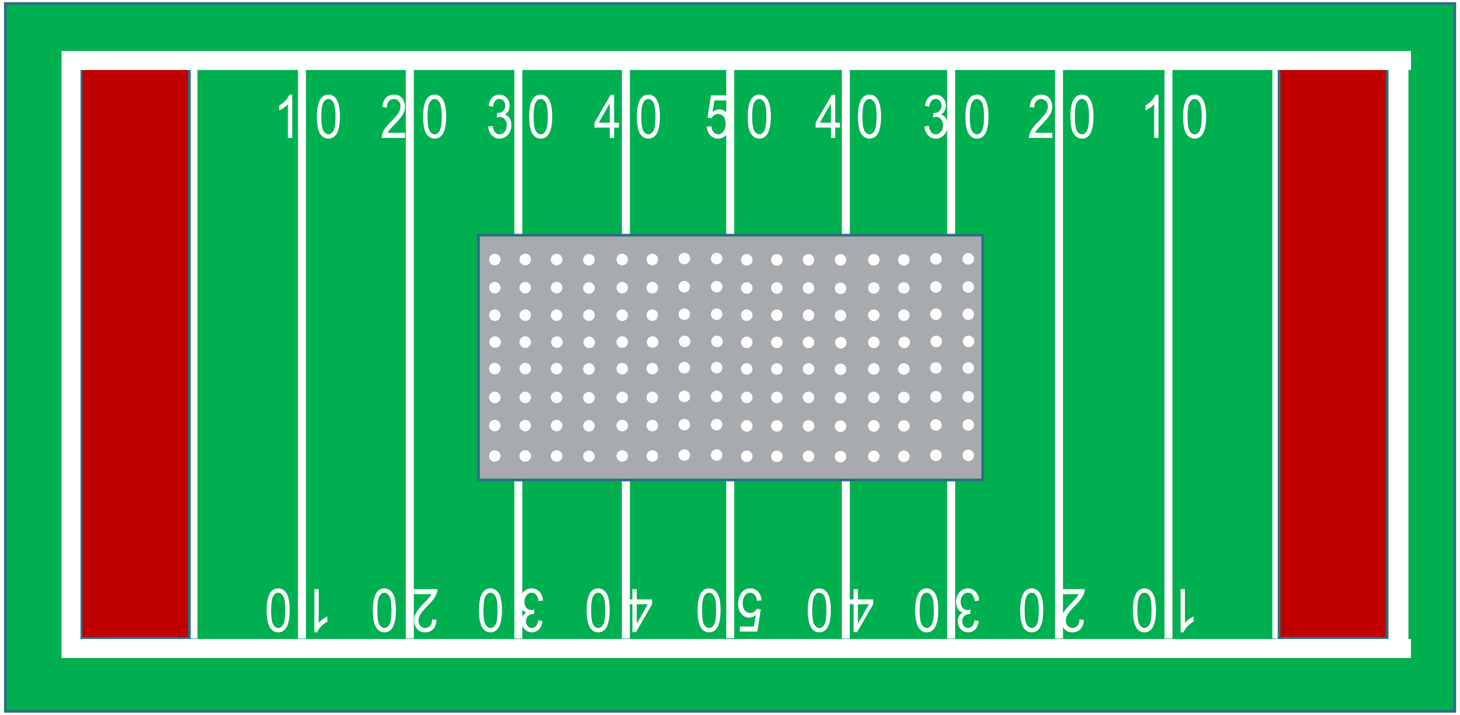


Project Overview

Center Pier Footing vs American Football Field

- 128 auger cast piles at 36-inch diameter



Project Overview

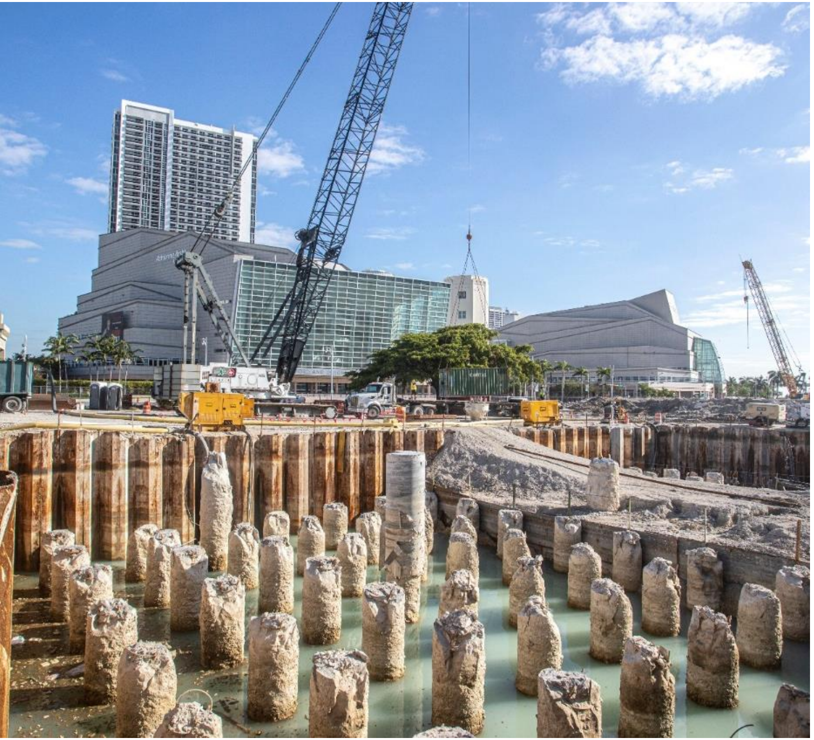
Hoover Dam Bypass

- True arch – outward lateral load from arch carried by the ground

Project Overview

I-79 Neville Island Bridge Pittsburgh

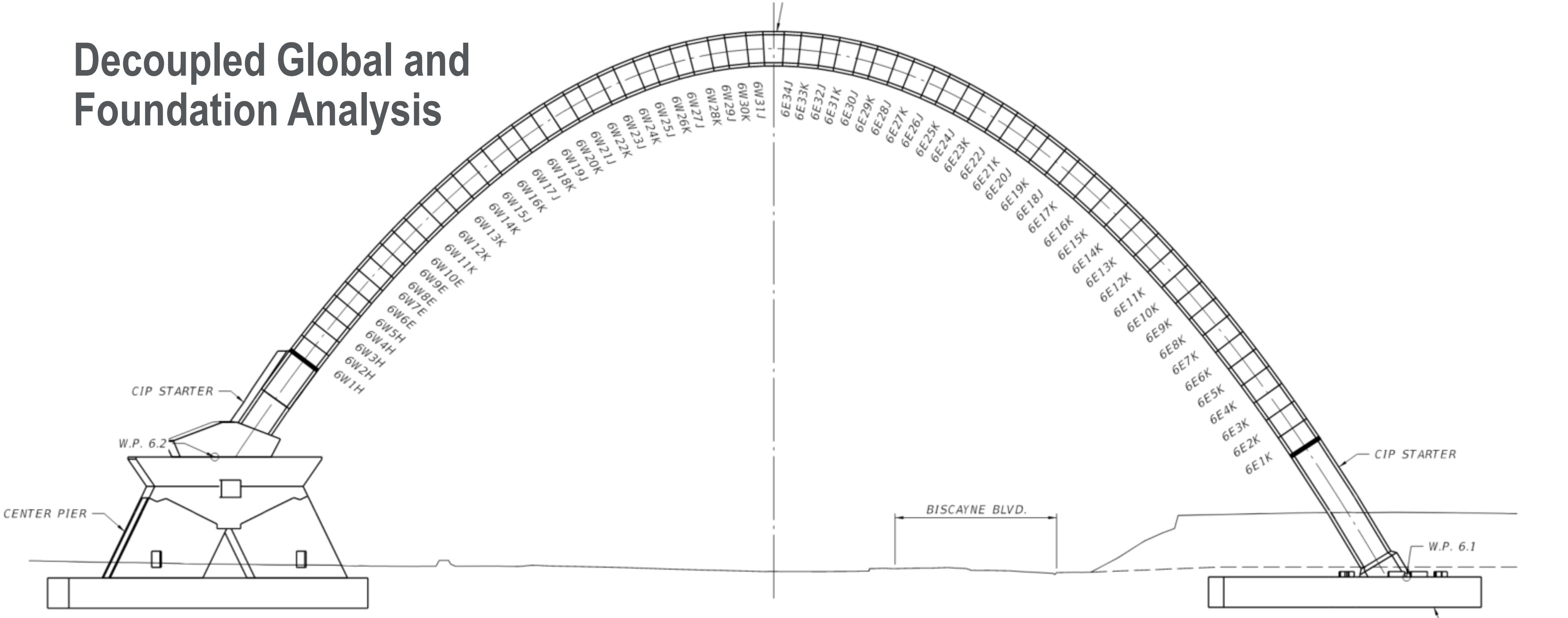
- Tied arch – outward lateral load from arch carried by tension ties within bridge



02 Design Approach

Design Approach

Decoupled Global and Foundation Analysis

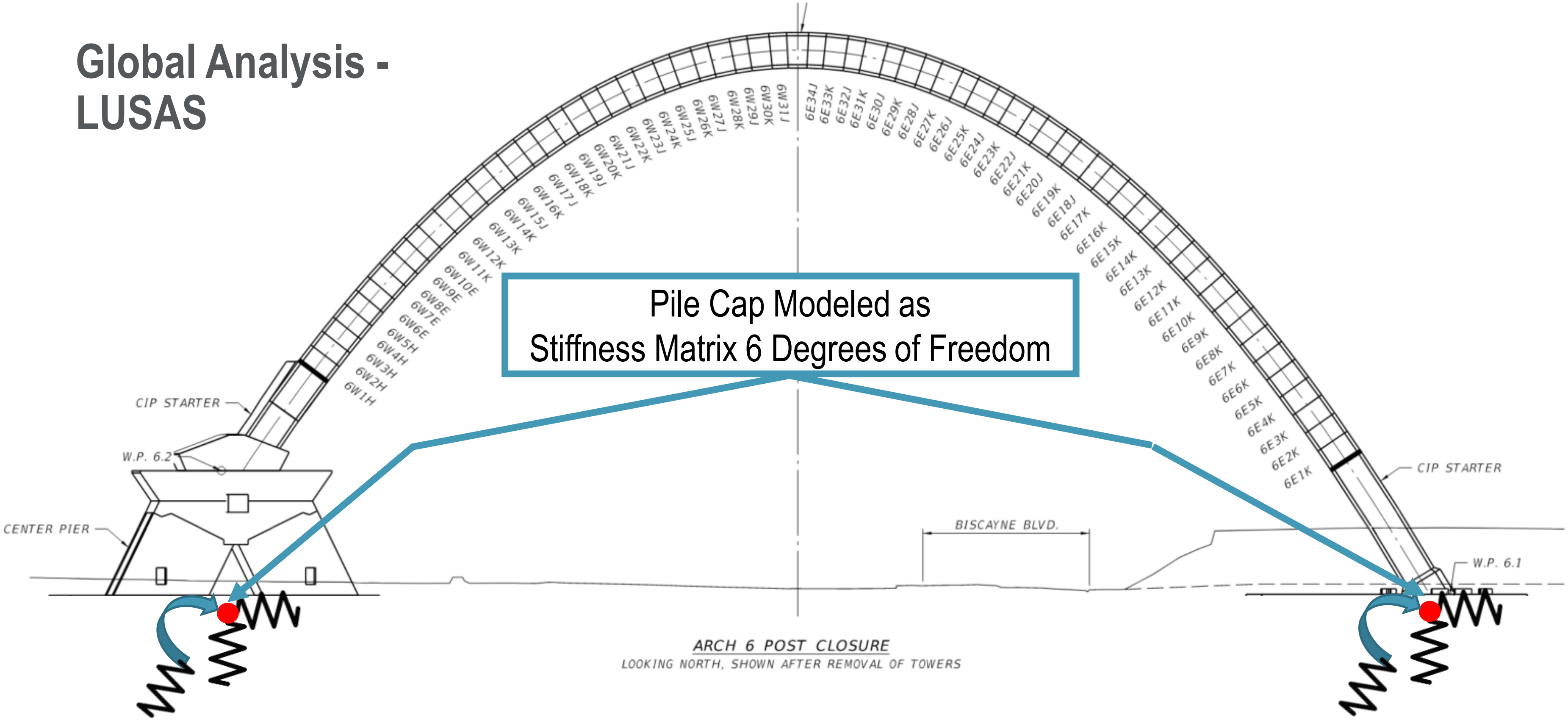


ARCH 6 POST CLOSURE

LOOKING NORTH, SHOWN AFTER REMOVAL OF TOWERS

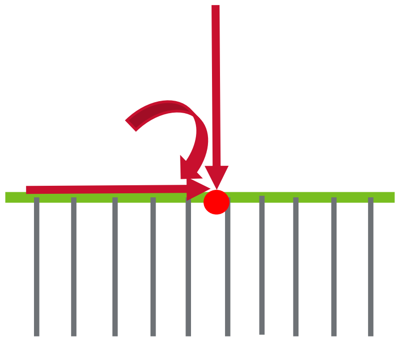
Design Approach

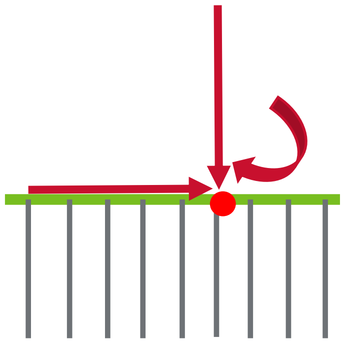
Global Analysis - LUSAS



Design Approach

Foundation Analysis –
FB MultiPier





Design Approach

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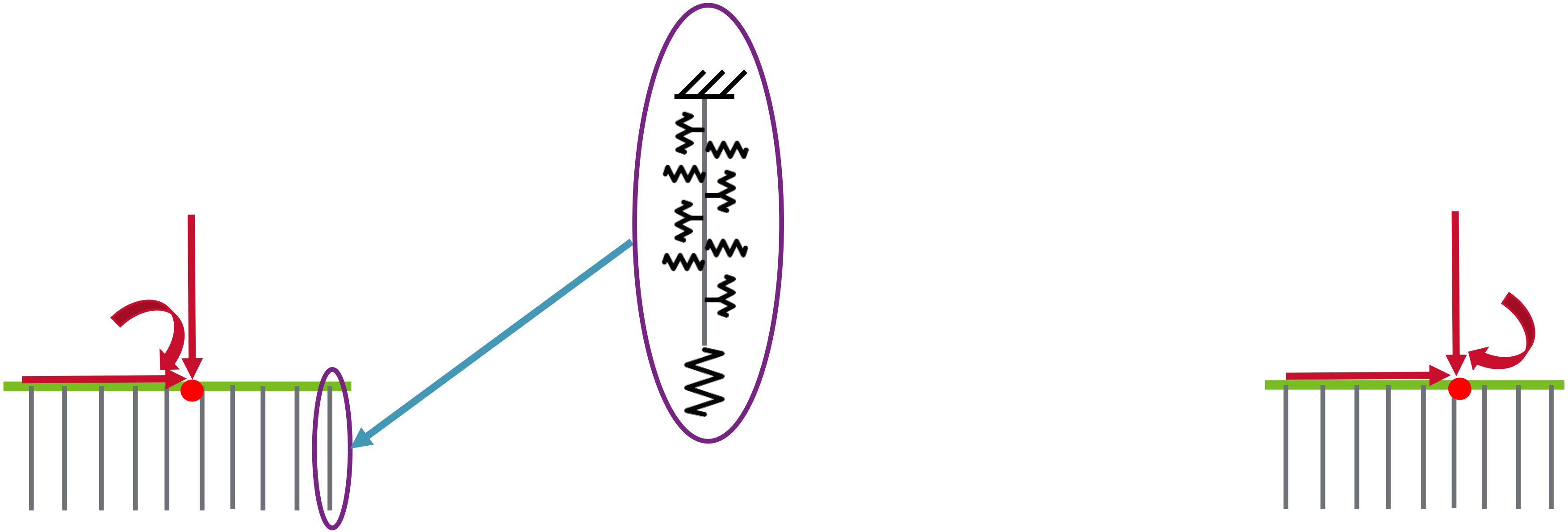

Design Approach

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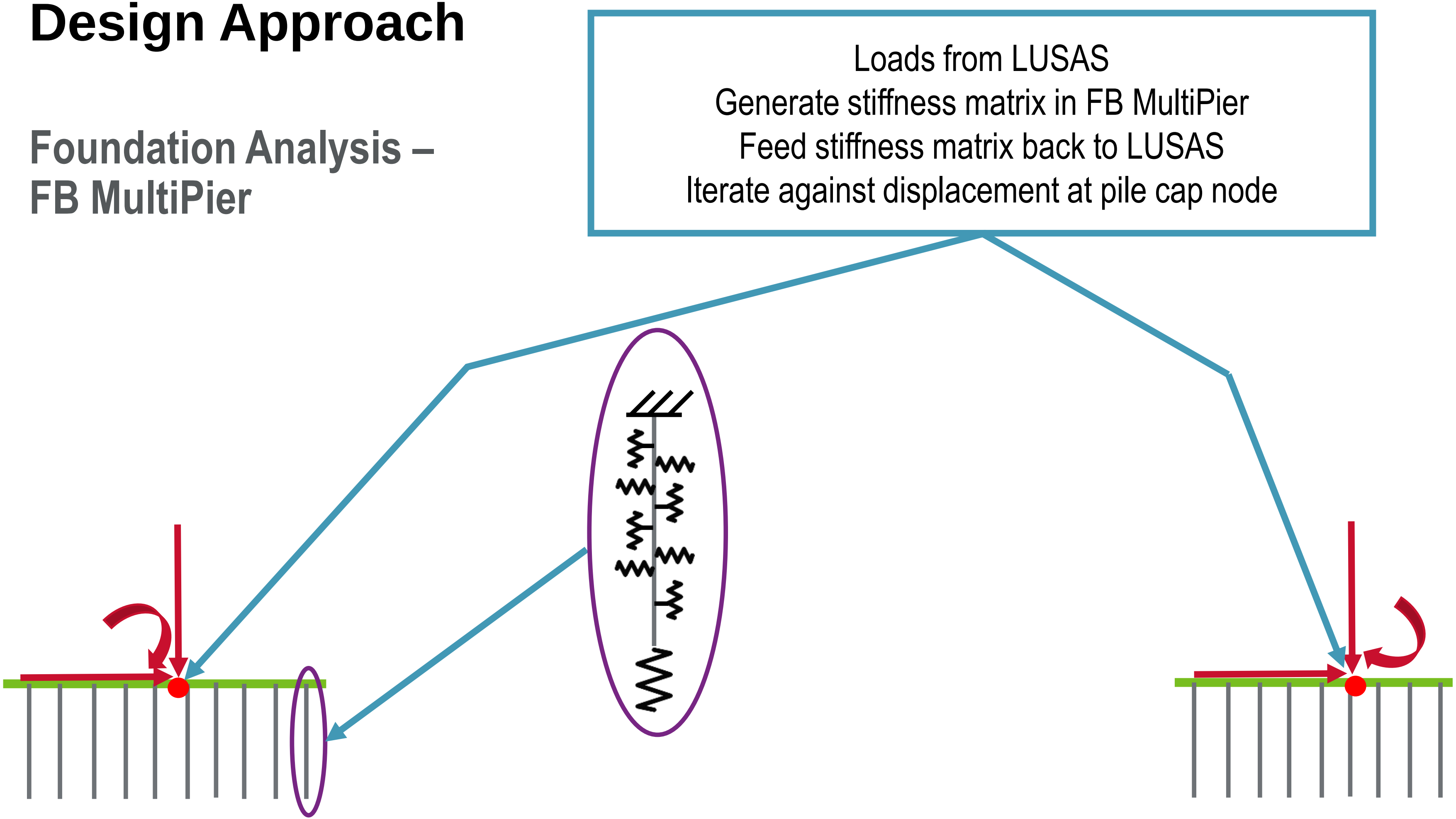
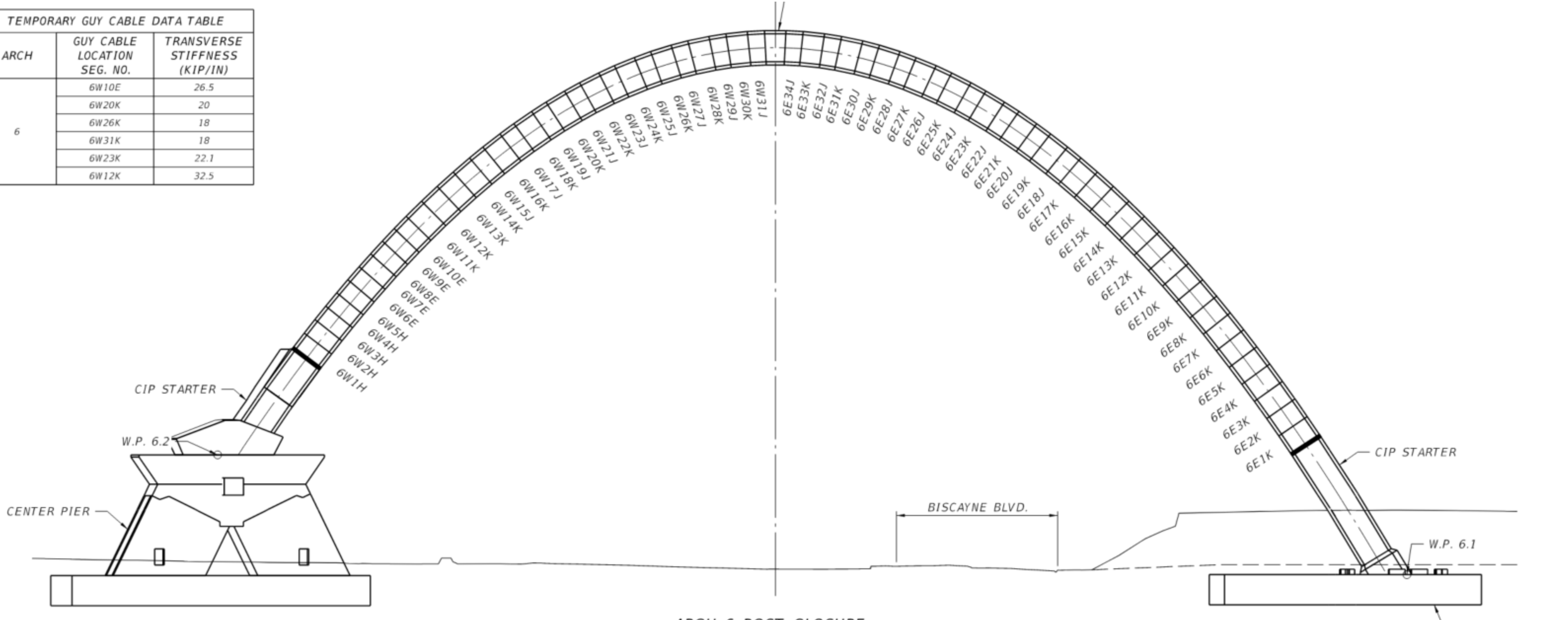


AUGER CAST PILES

Large Sustained Lateral Pile Loads

TEMPORARY GUY CABLE DATA TABLE		
ARCH	GUY CABLE LOCATION SEG. NO.	TRANSVERSE STIFFNESS (KIP/IN)
6	6W10E	26.5
	6W20K	20
	6W26K	18
	6W31K	18
	6W23K	22.1
	6W12K	32.5



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AUGER CAST PILES

Large Sustained Lateral Pile Loads

Permanent thrust due to arch dead load

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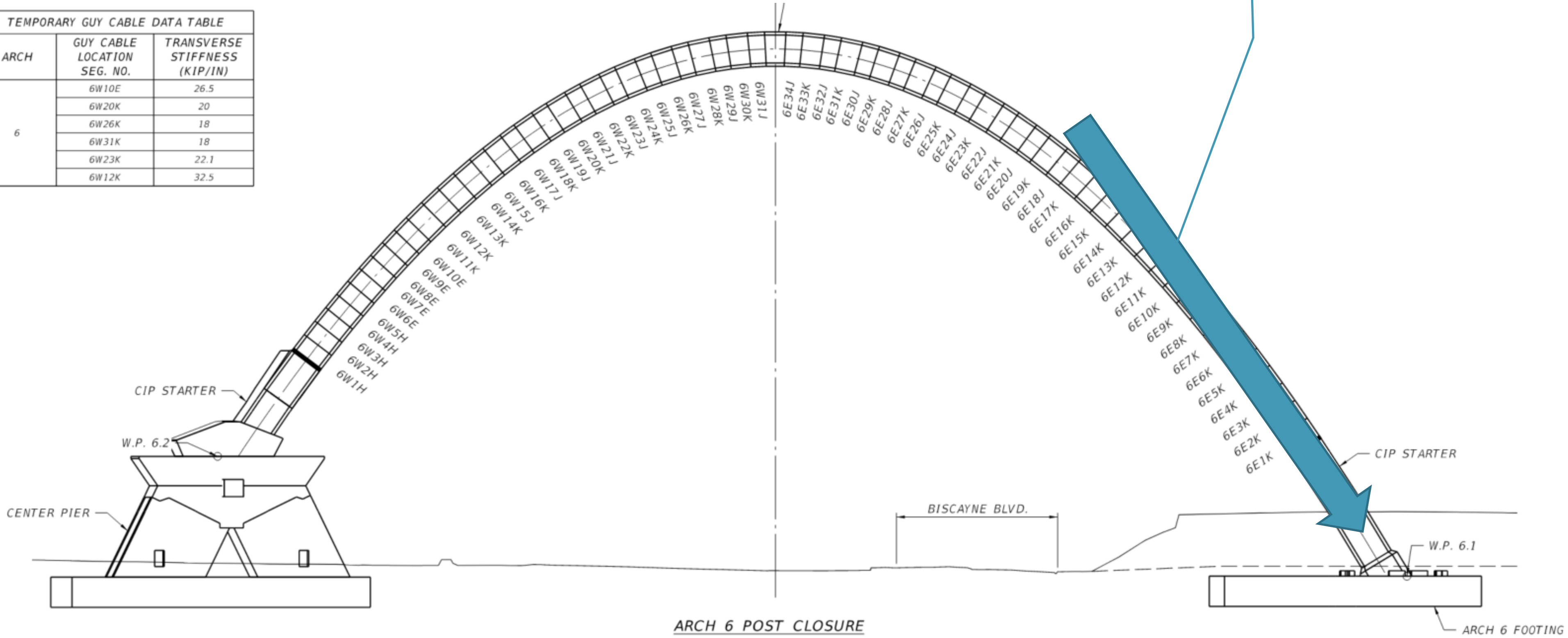

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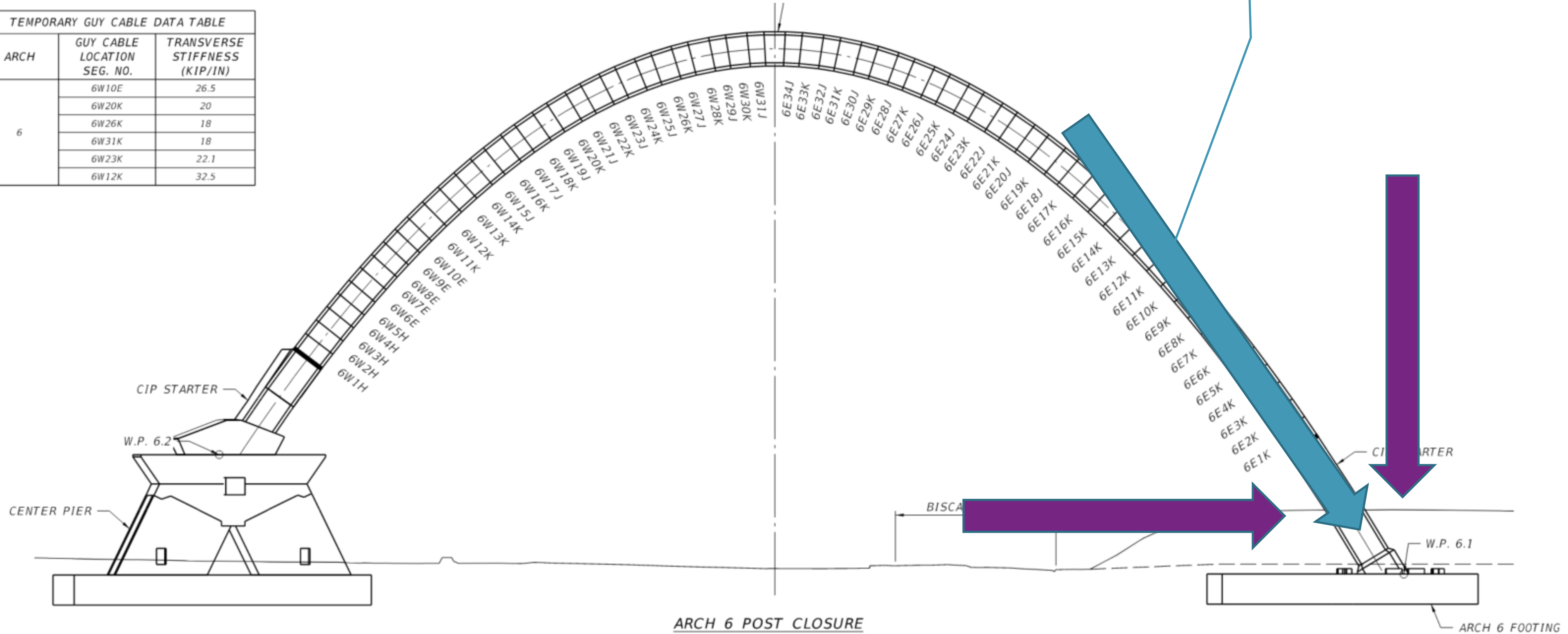


ARCH 6 POST CLOSURE
LOOKING NORTH, SHOWN AFTER REMOVAL OF TOWERS

03 Load Testing Setup

Load Testing Setup

Value of Verification of Parameters

- Magnitude of lateral loads (**> 500 kip** max pile shear strength load)
- Pile response under permanent lateral loading
- Signature structure

Load Testing Setup

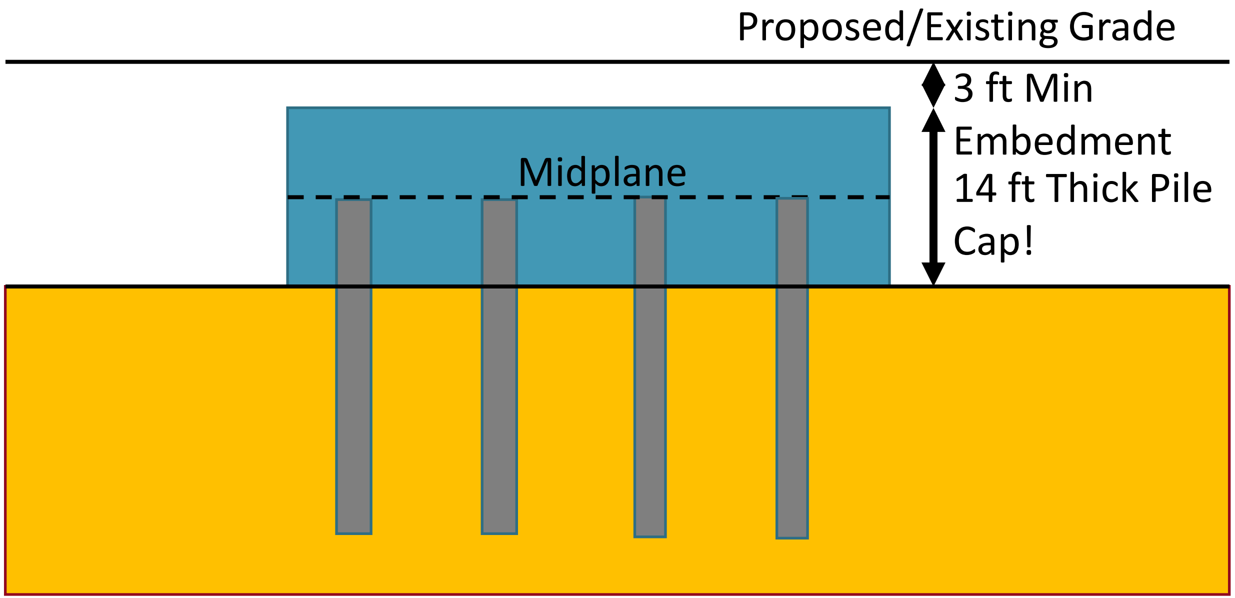
Foundation Stiffness Validation

- Initial validation of p-y curve stiffness with pressuremeter testing to build confidence in soil parameters
- HDR and UES worked together to establish load test criteria
- Lateral load testing intended to validate foundation soil stiffness in FB MultiPier

Load Testing Setup

Point of Load Application

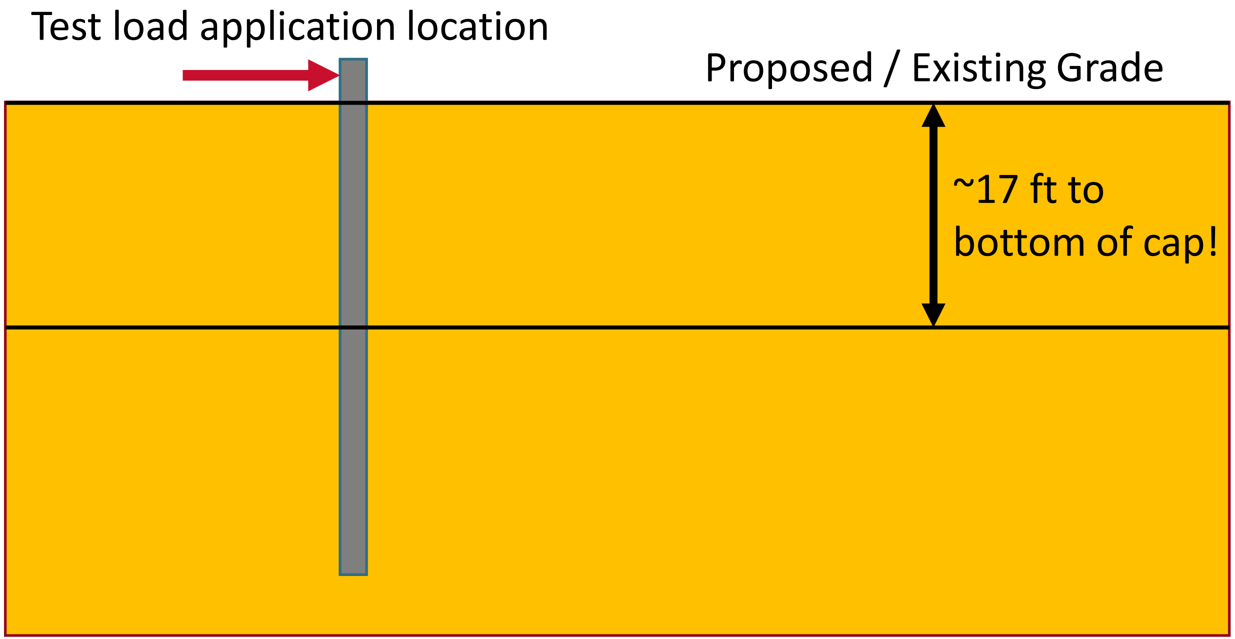
Production pile heads **fixed** against rotation



Load Testing Setup

Point of Load Application

Test pile head **free** to rotate



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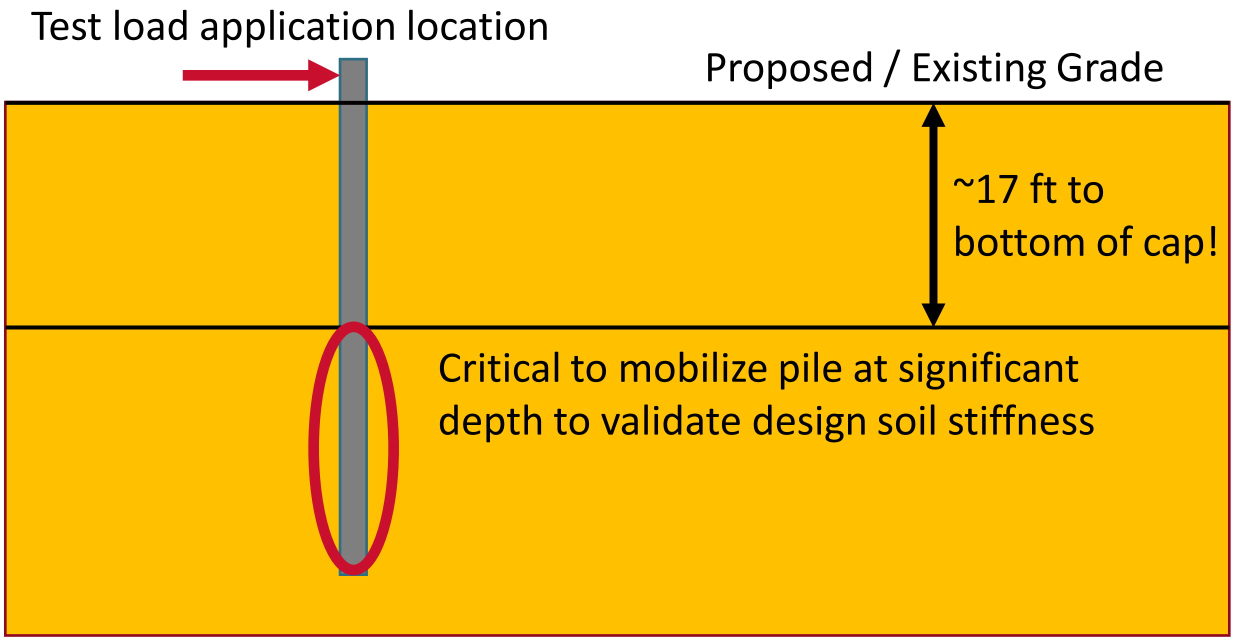

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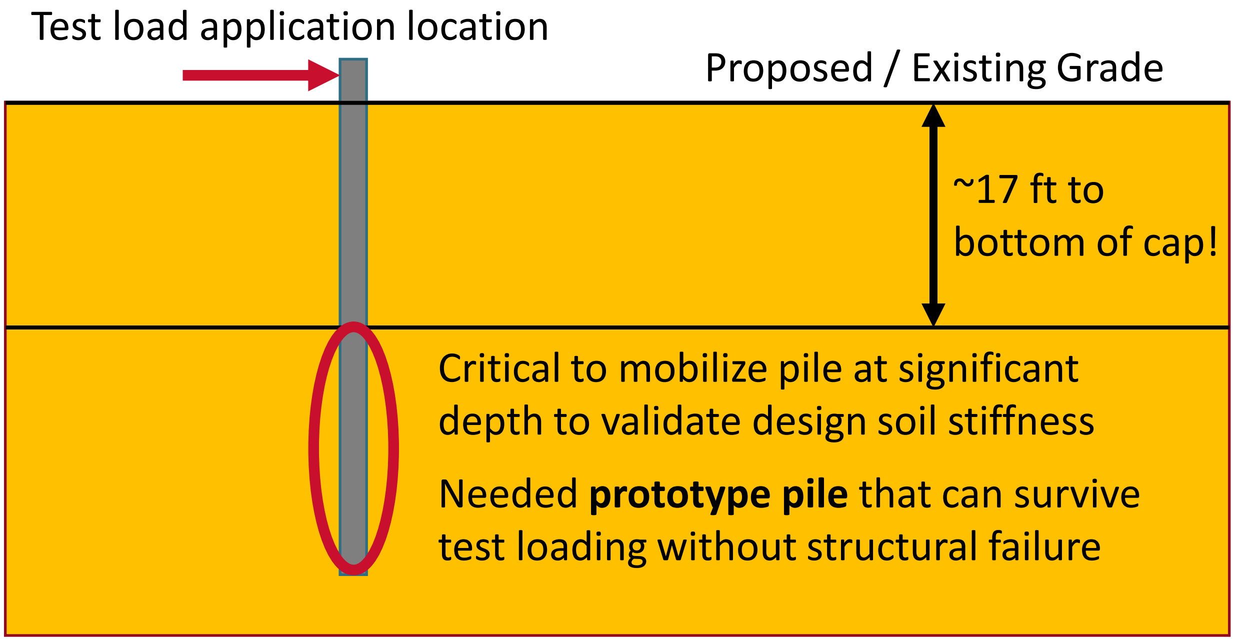
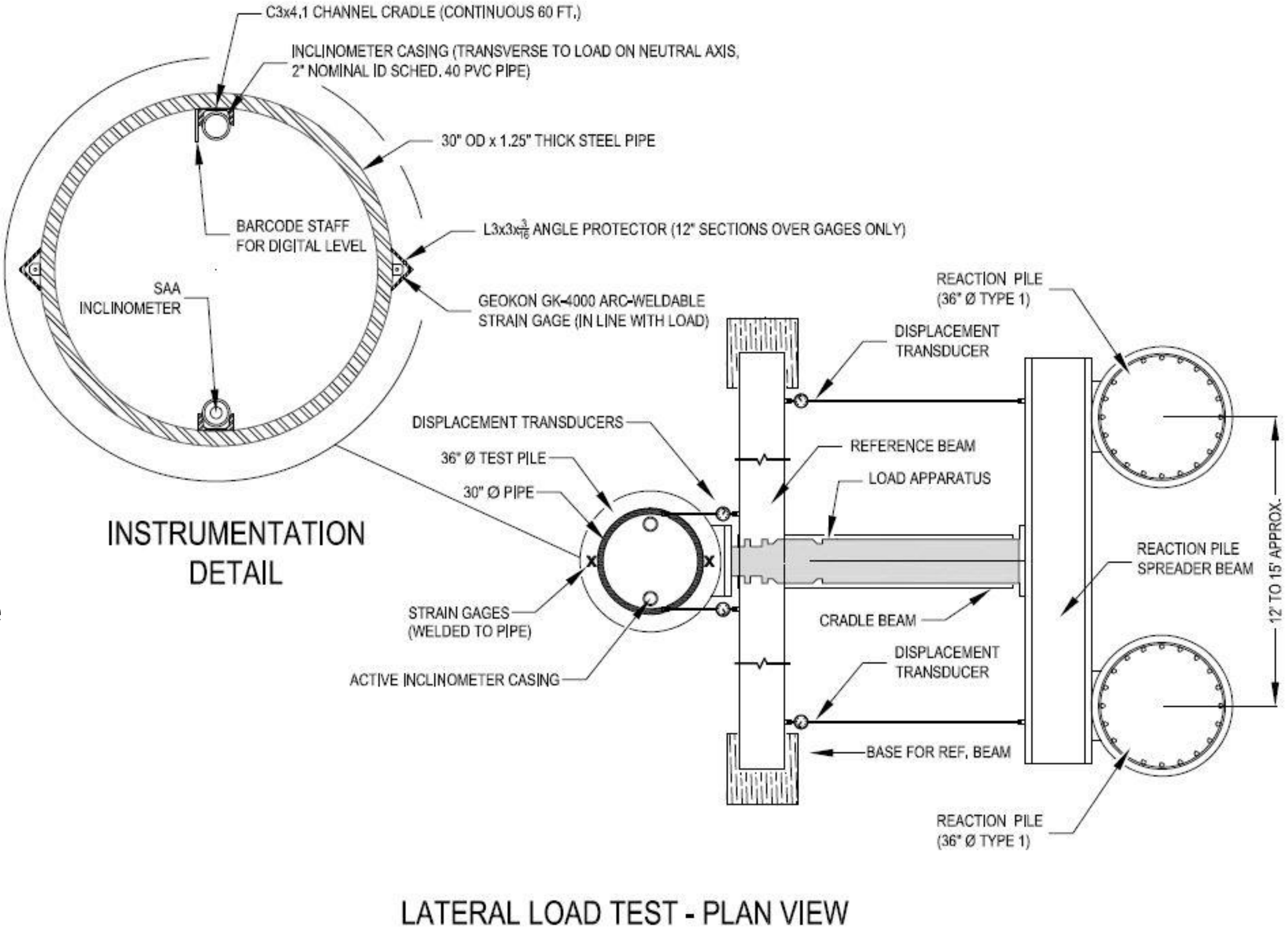


Load Testing Setup

Prototype Pile

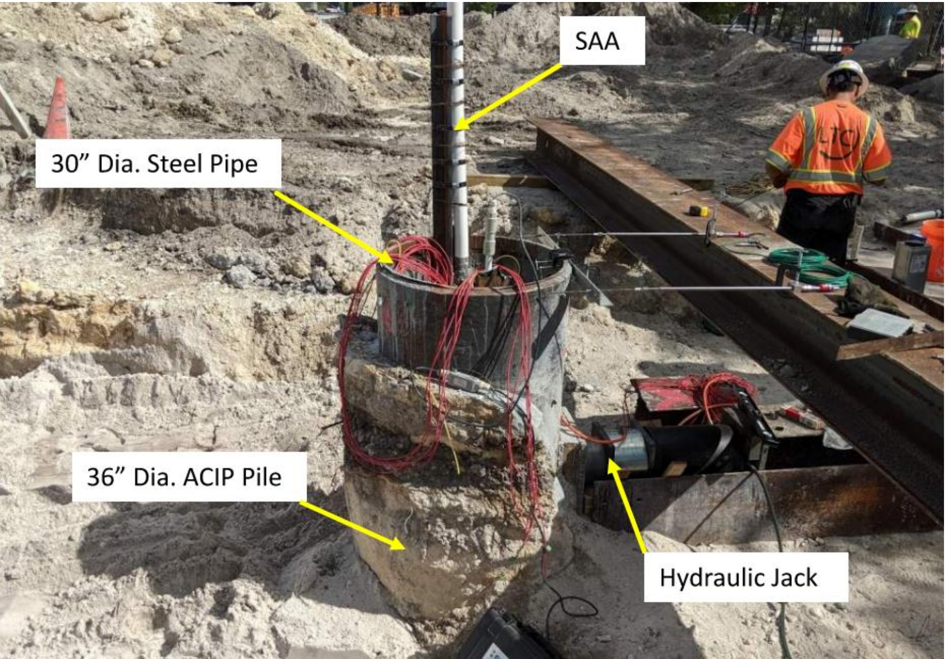
- Three lateral load test piles
- 1 production pile with 17 #18 bars
- 2 prototype piles with 30” OD x 1.25” steel pipe pile placed inside auger cast pile
- 24 hour hold

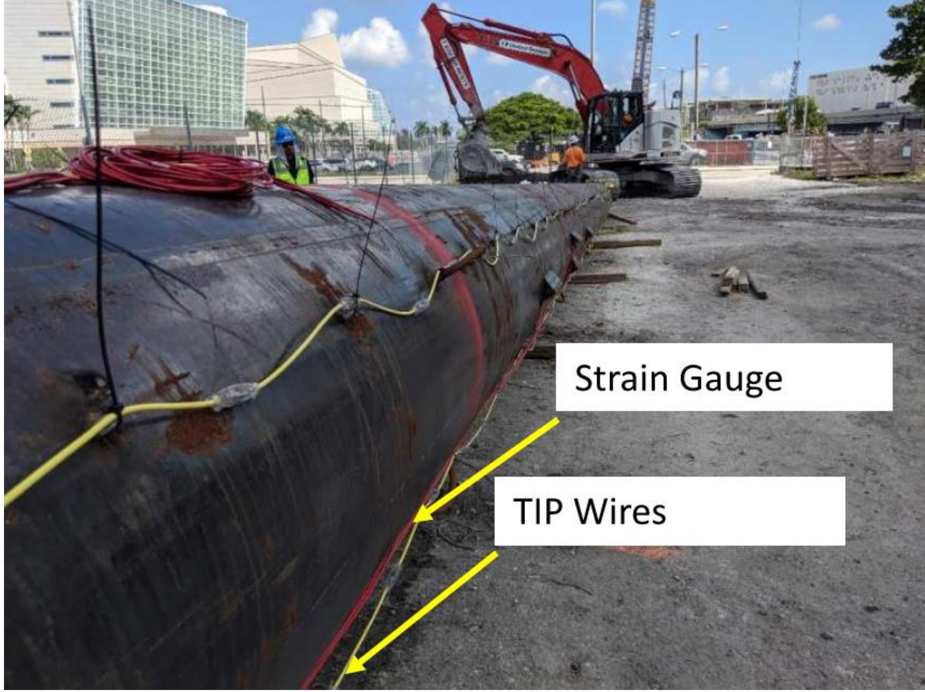


Load Testing Setup

Lateral Load Test

- Shape arrays measure deflected pile shape along entire pile depth





- Strain gages embedded in pile relate to stress along pile

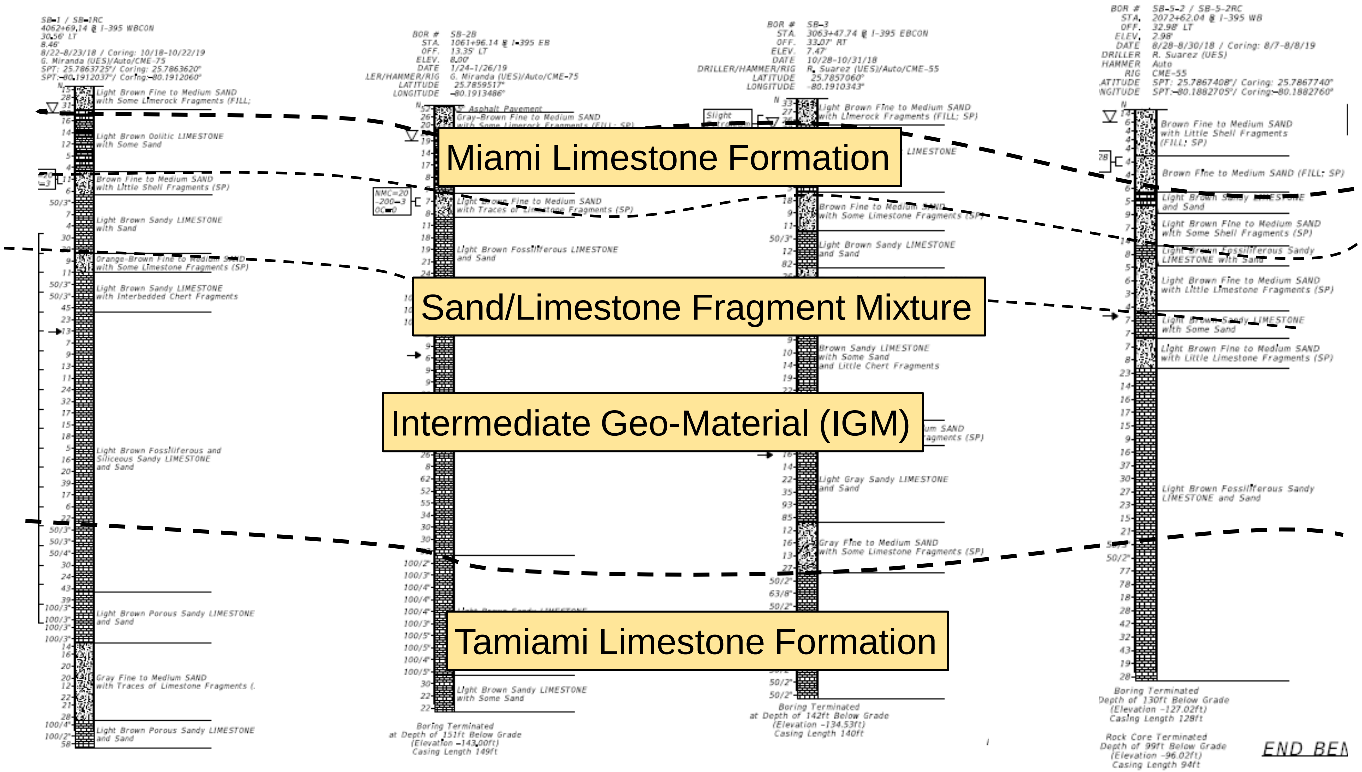
Location: SB-C4 **Elevation:** -39.56' to -44.56' **REC:** 87% **RQD:** 69%

Location: SB-C4 **Elevation:** -44.56' to -49.56' **REC:** 64% **RQD:** 63%

Location: SB-C4 **Elevation:** -49.56' to -54.56' **REC:** 16% **RQD:** 0%

04 Subsurface Conditions

Subsurface Conditions



Subsurface Conditions

Soft Limestone Geology

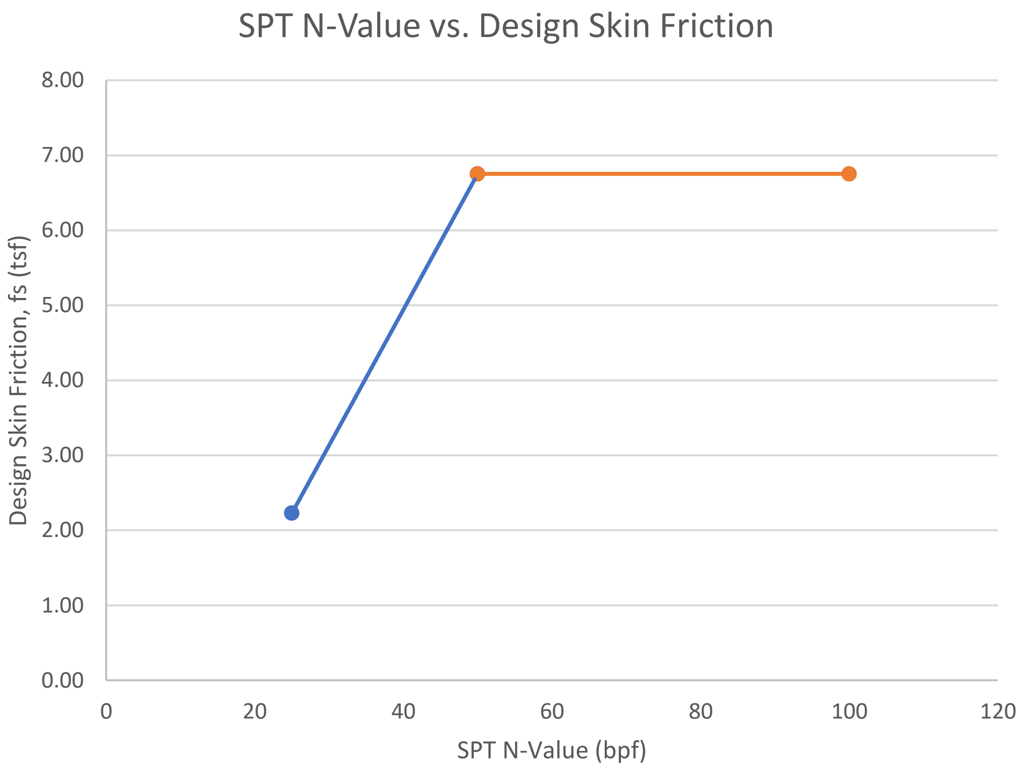
- Limestone could be less than 50 blows per foot from SPT with isolated zones of refusal

- Not stratified in horizontal layers, highly variable with depth, no “basement rock” formation

- Very brittle and very low skin friction for driven piles, local practice is to assume end bearing only for driven piles

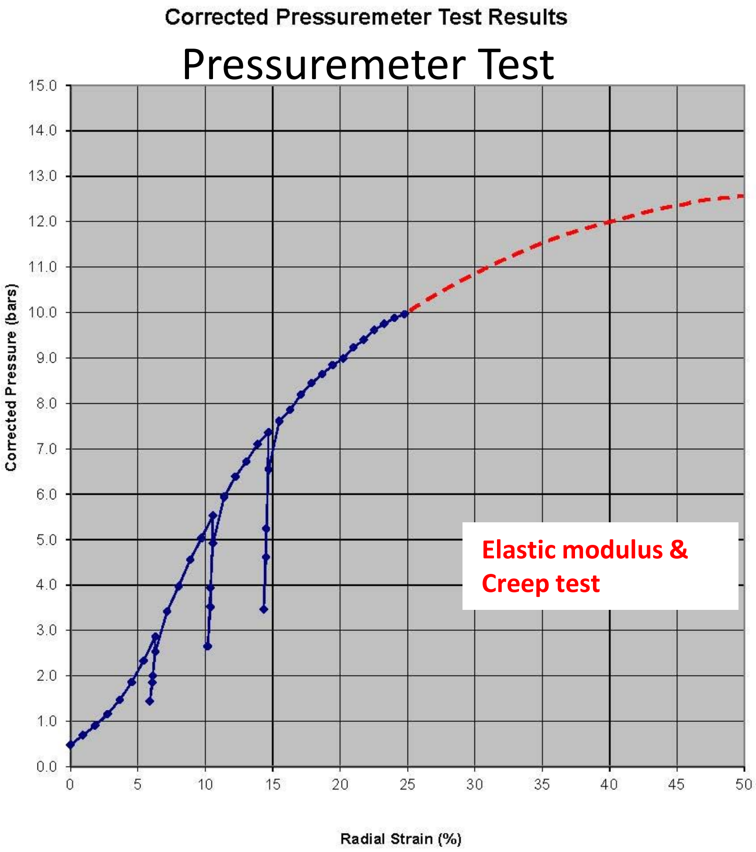
Subsurface Conditions

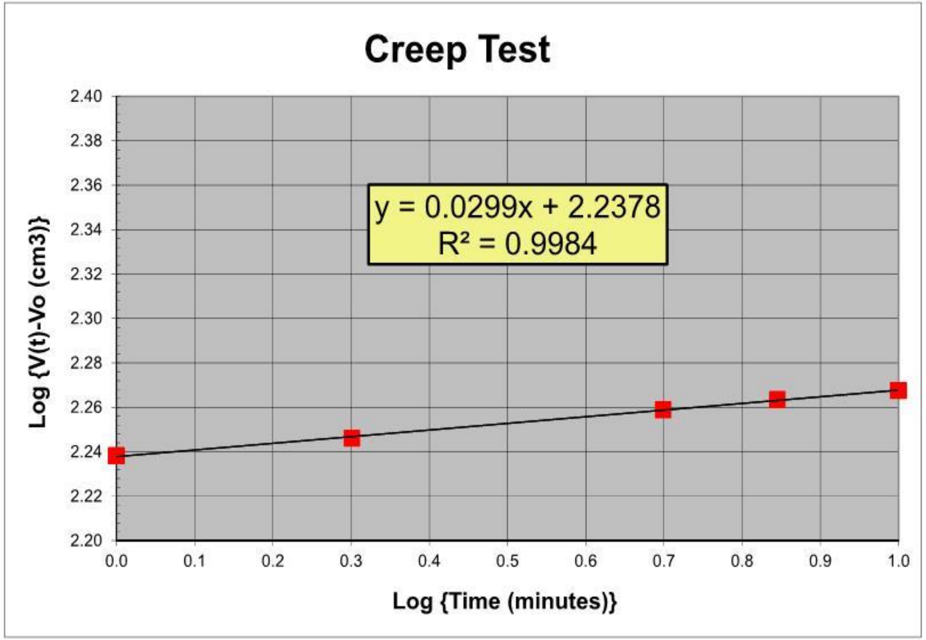
- Standard Penetration Test (SPT) borings as deep as 260 feet.
- Rock coring with 4-inch diameter custom wireline (maximize recovery)
- Pressuremeter testing by open-borehole (Menard)



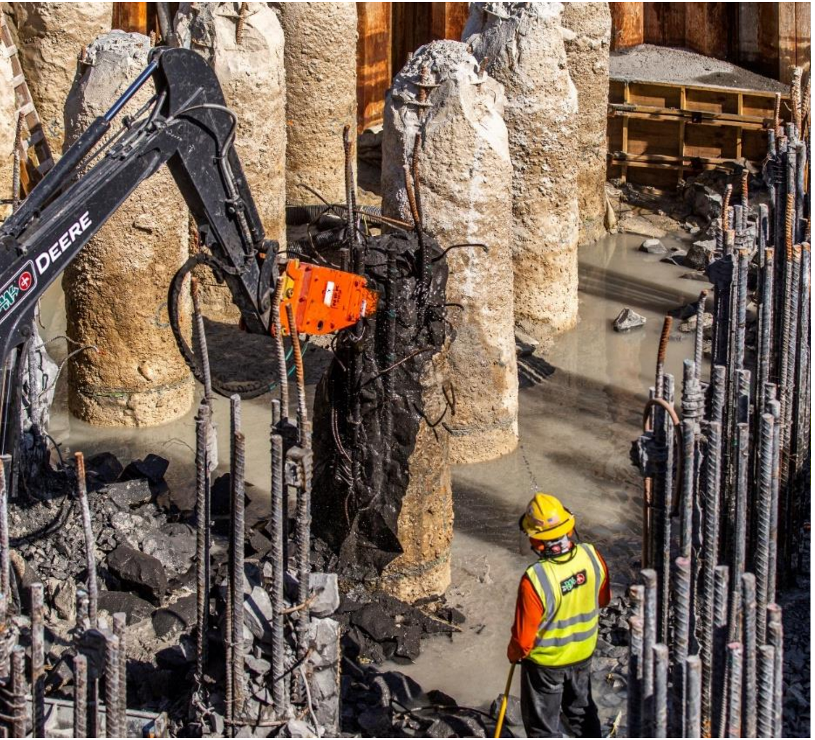
Subsurface Conditions

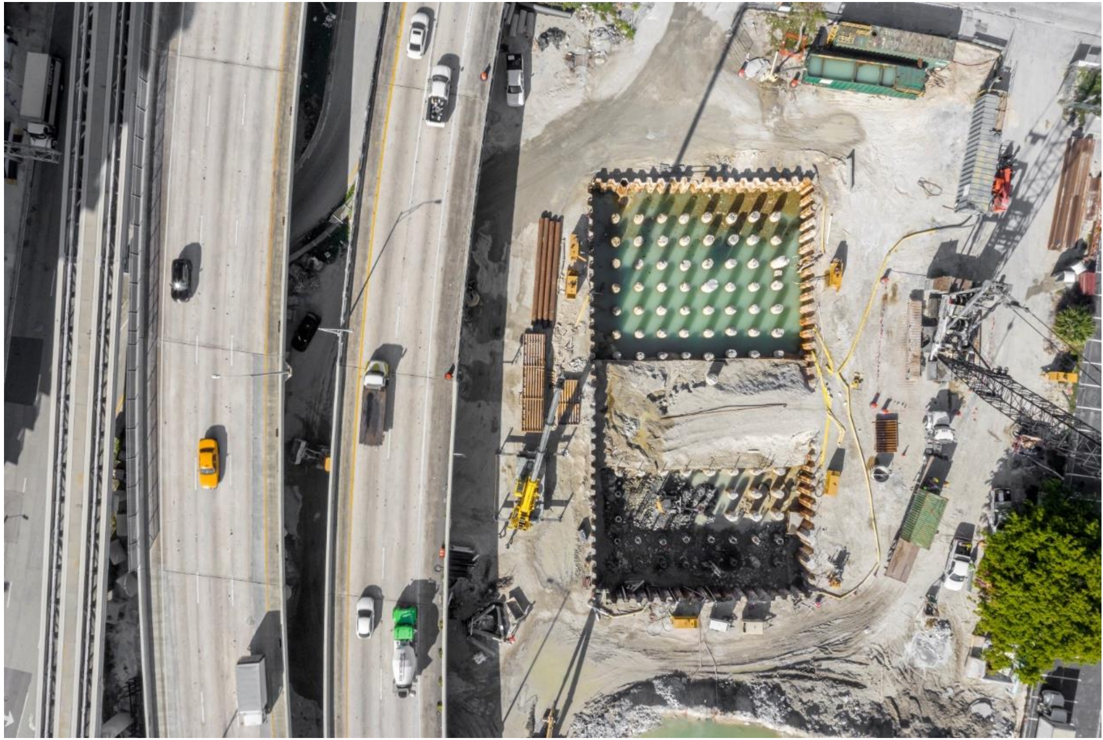
$$E_0(t)/E_0(t=1\text{ min}) = \{t/1\}^{-n}$$
$$n = \quad 0.0299$$





1) Modulus values
2) Estimate subgrade modulus, k
3) Estimate creep





05 Auger Cast Piles

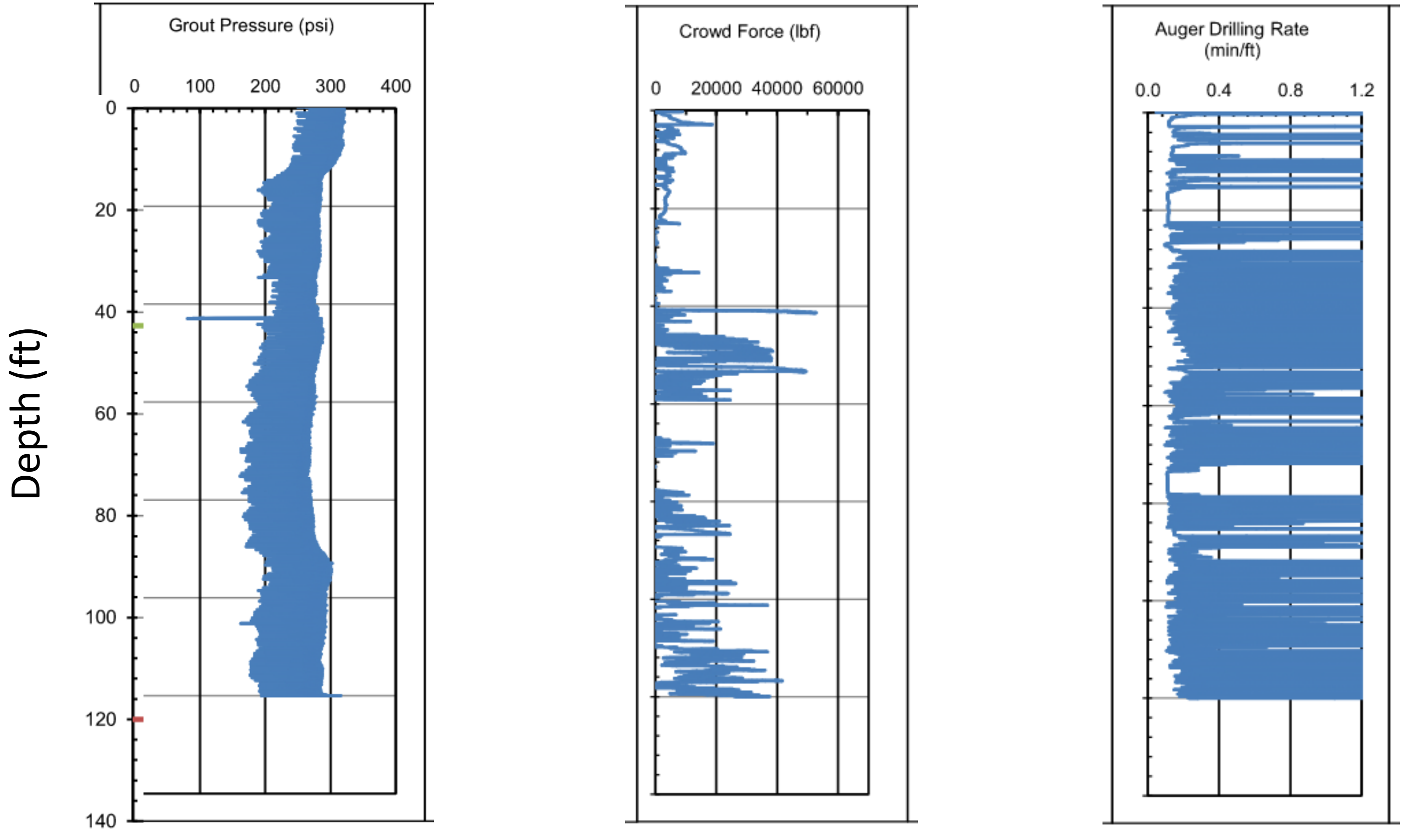
Auger Cast Piles

Overview

- FDOT historically used for noise walls
- Quality control historically questionable
- Long reinforcing cages difficult to insert due to wet placement in grout
- Very efficient in limestone geology
  - No drilling slurry used
  - No drill casing used
  - Pressurized grout fills limestone voids
  - Very high skin friction compared to all other foundation types

Auger Cast Piles

AME Data

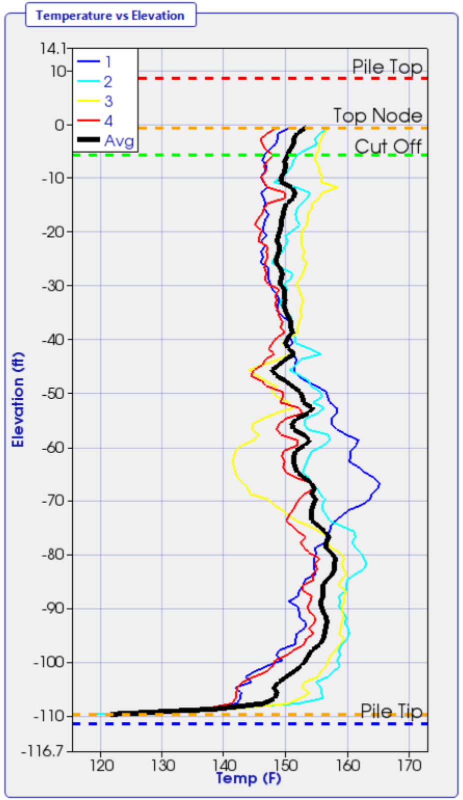


Grout Pressure (psi) Downward Drill Force (lb) Drilling Rate (min/ft)

Auger Cast Piles

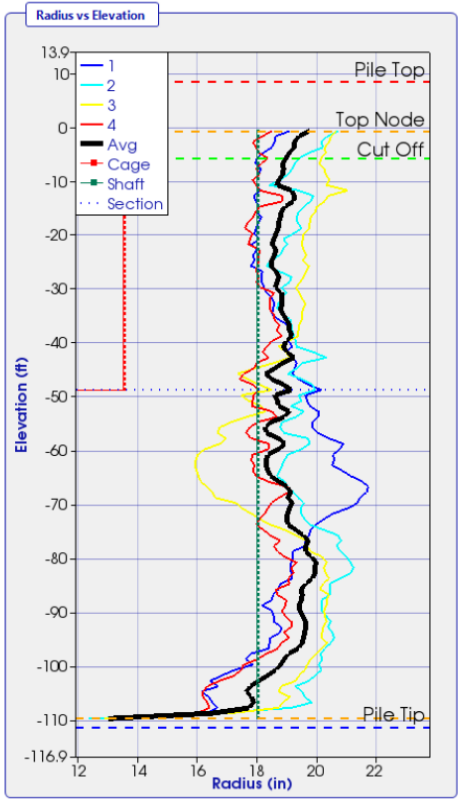
Thermal Integrity Profiling (TIP)

Elevation (ft)



Temperature (ºF)

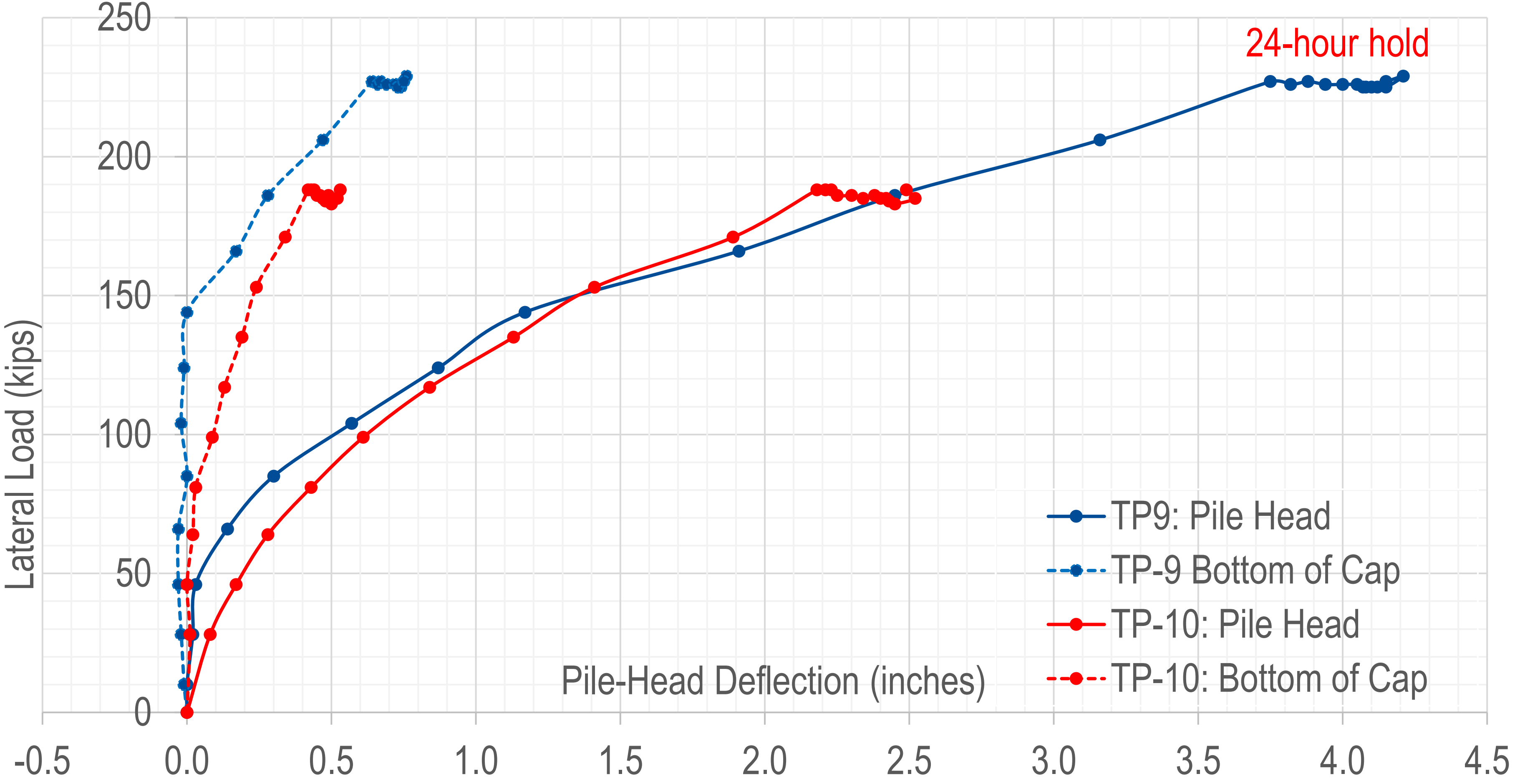
Elevation (ft)



Pile Radius (in)

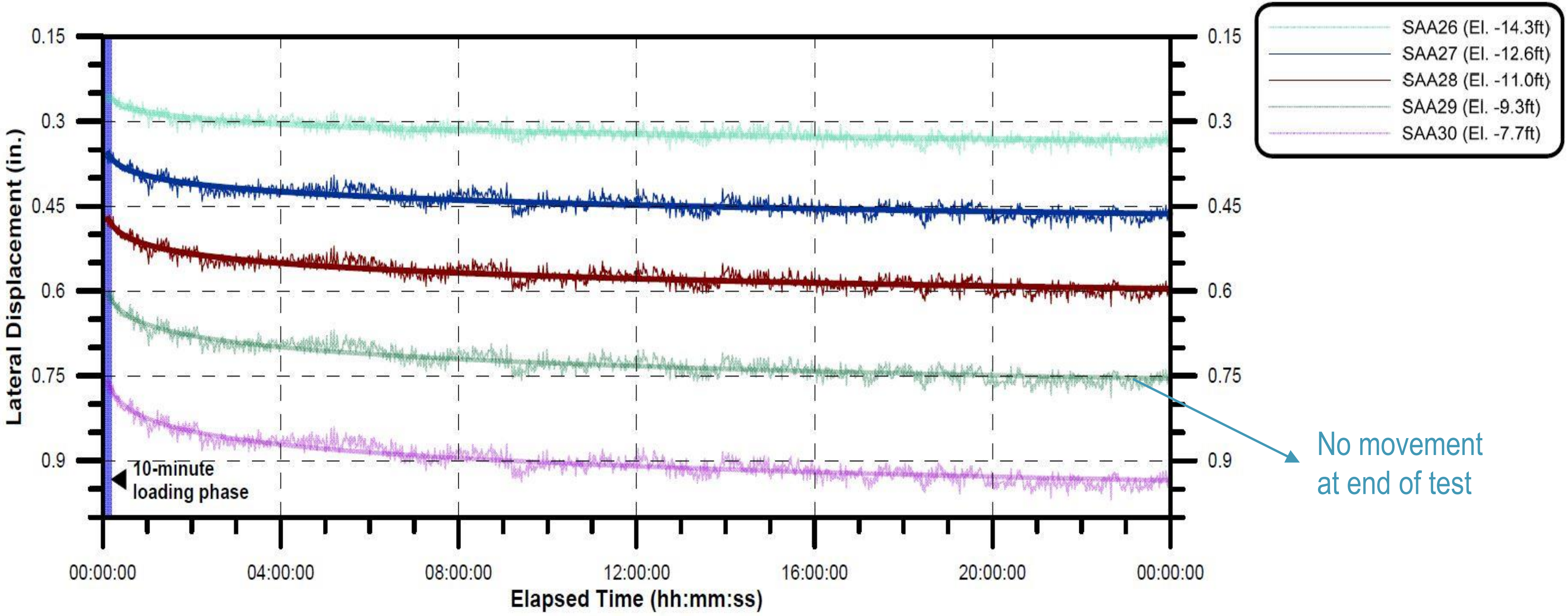
06 Load Testing Results

Load Testing Results

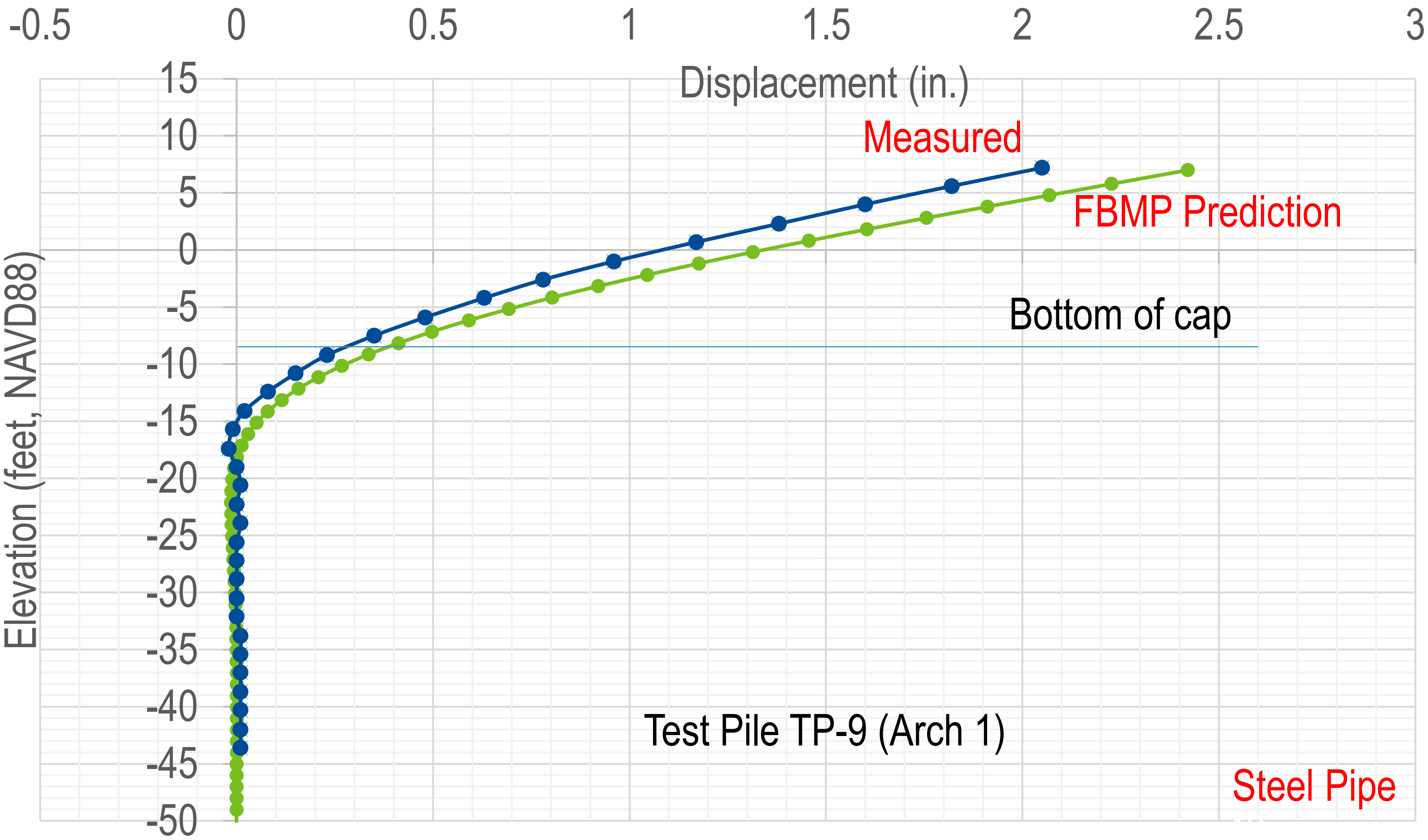


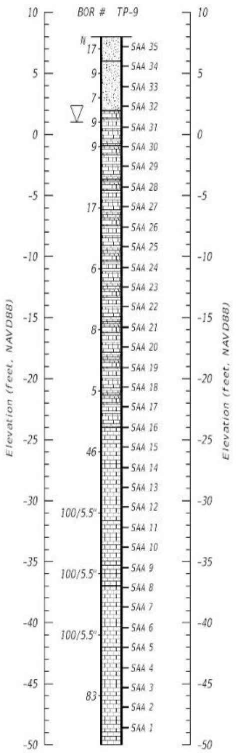
Load Testing Results

Did creep end during 24-hour hold period?



Load Testing Results – Method 1





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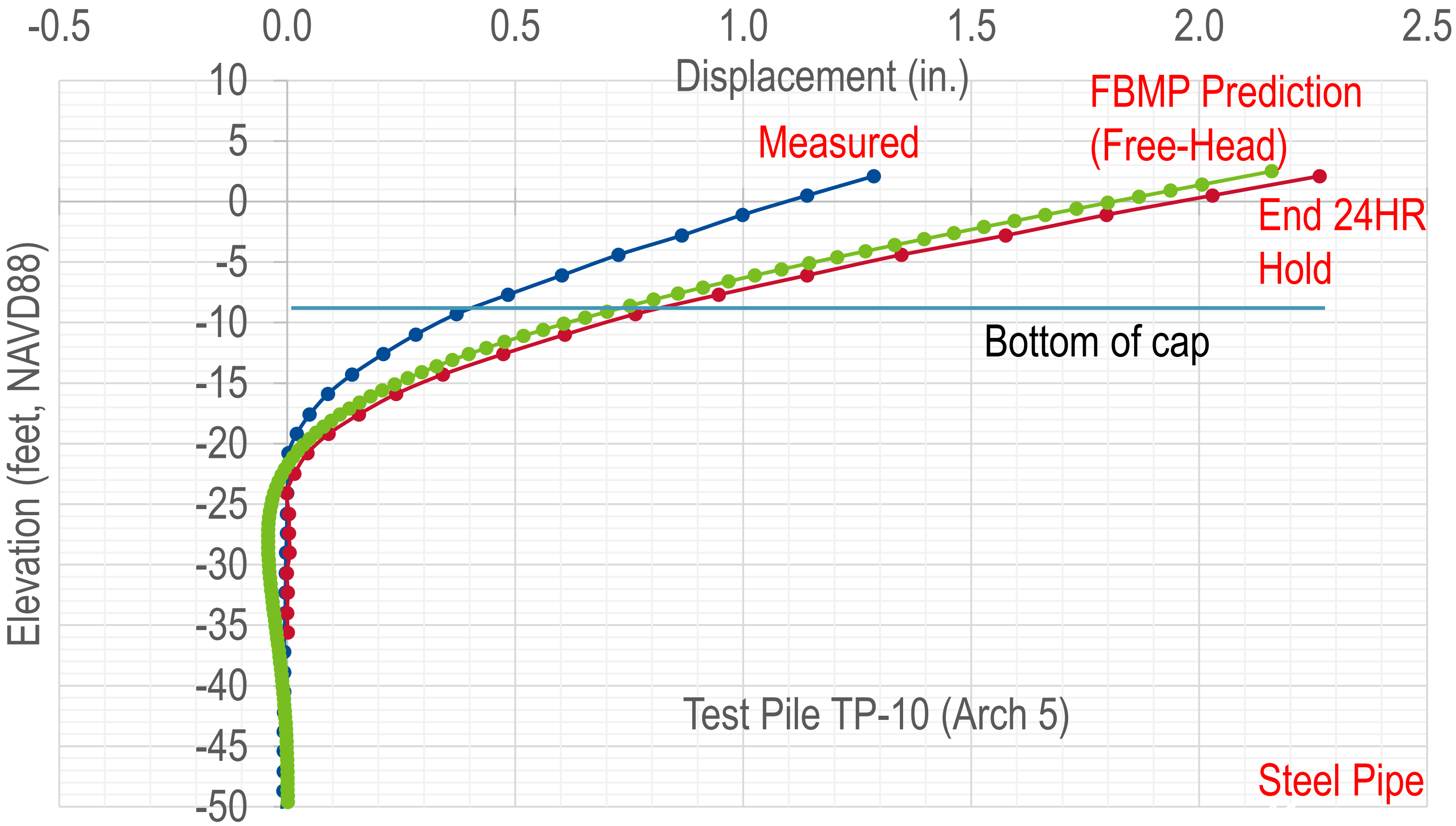
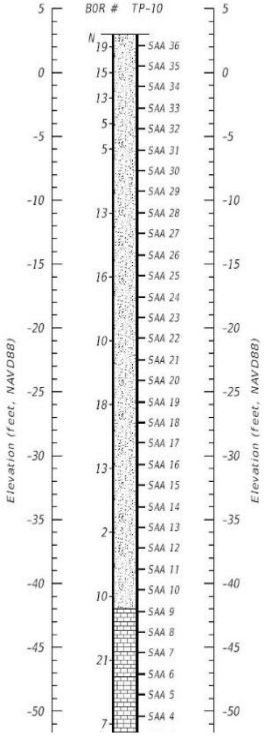
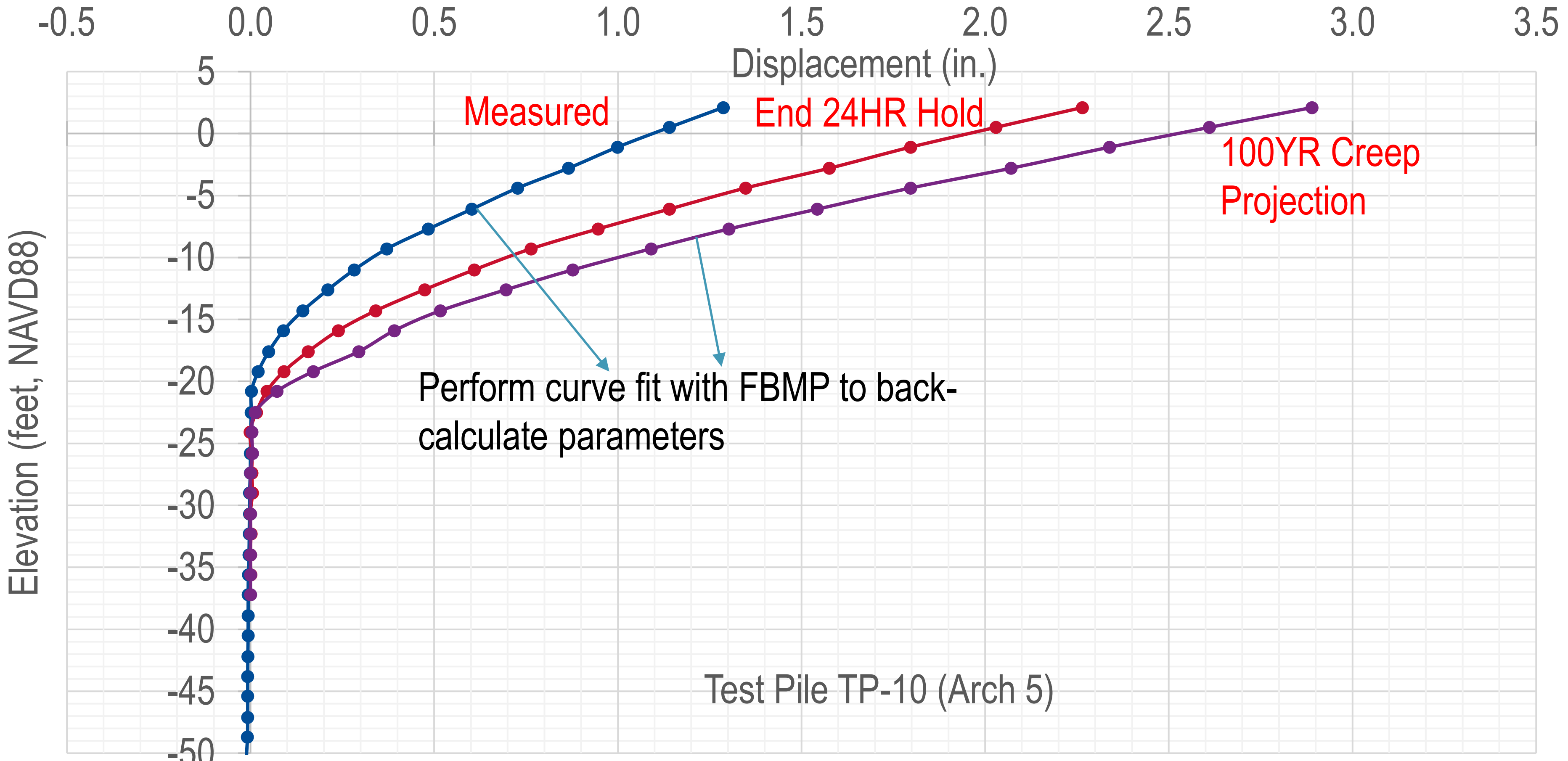




Load Testing Results – Method 2

TP-10: Step #1 – Curve fitting



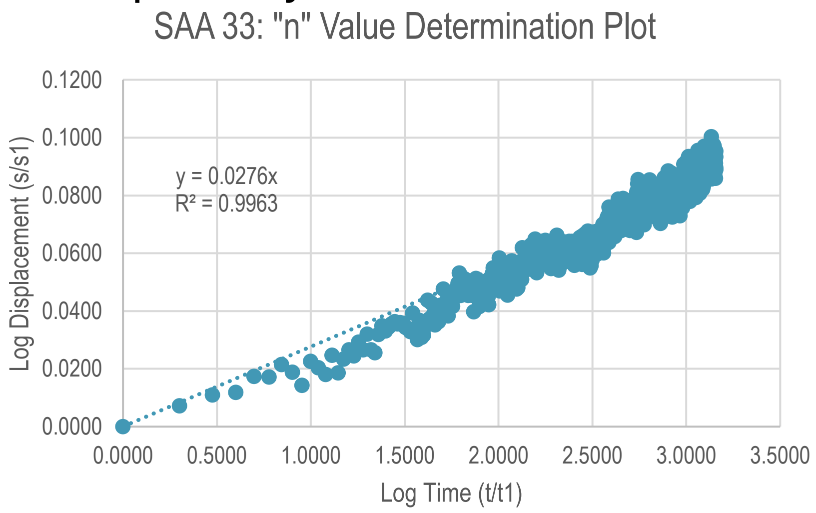
Load Testing Results – Method 2

TP-10: Step #1 – Creep

- Power Law Model to Predict Creep Movement at 100 Year Time[1].
- Analyses performed at each shape array accel. to estimated pile deflected shape.

$$\frac{s_f}{s_1} = \left(\frac{t_f}{t_1}\right)^n$$

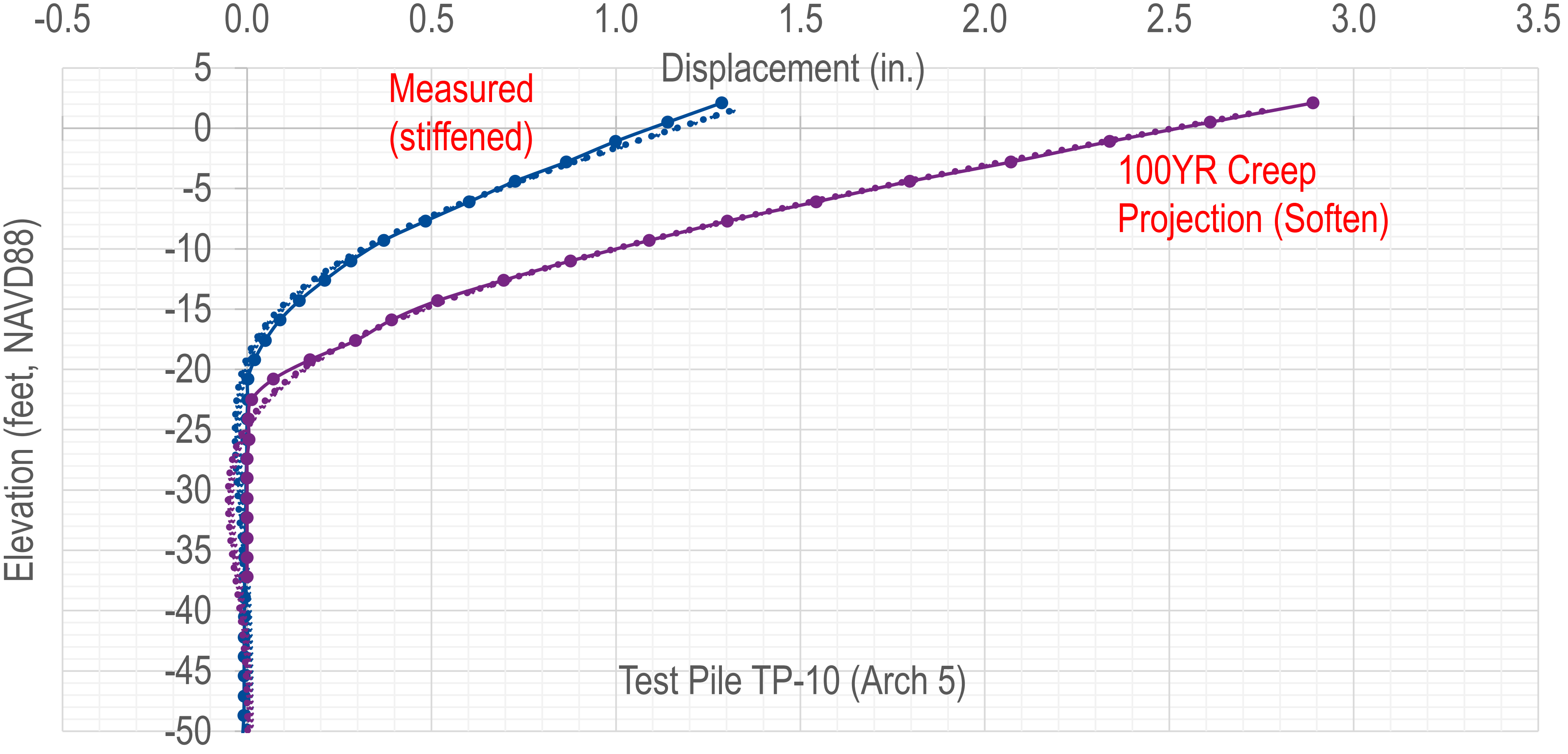
- Sample Creep Plot from shape array accel. #33



[1]*Power Law Model to Predict Creep Movement and Creep Failure* (Bi, Briaud, Sanchez, and Kharanaghi, 2019)

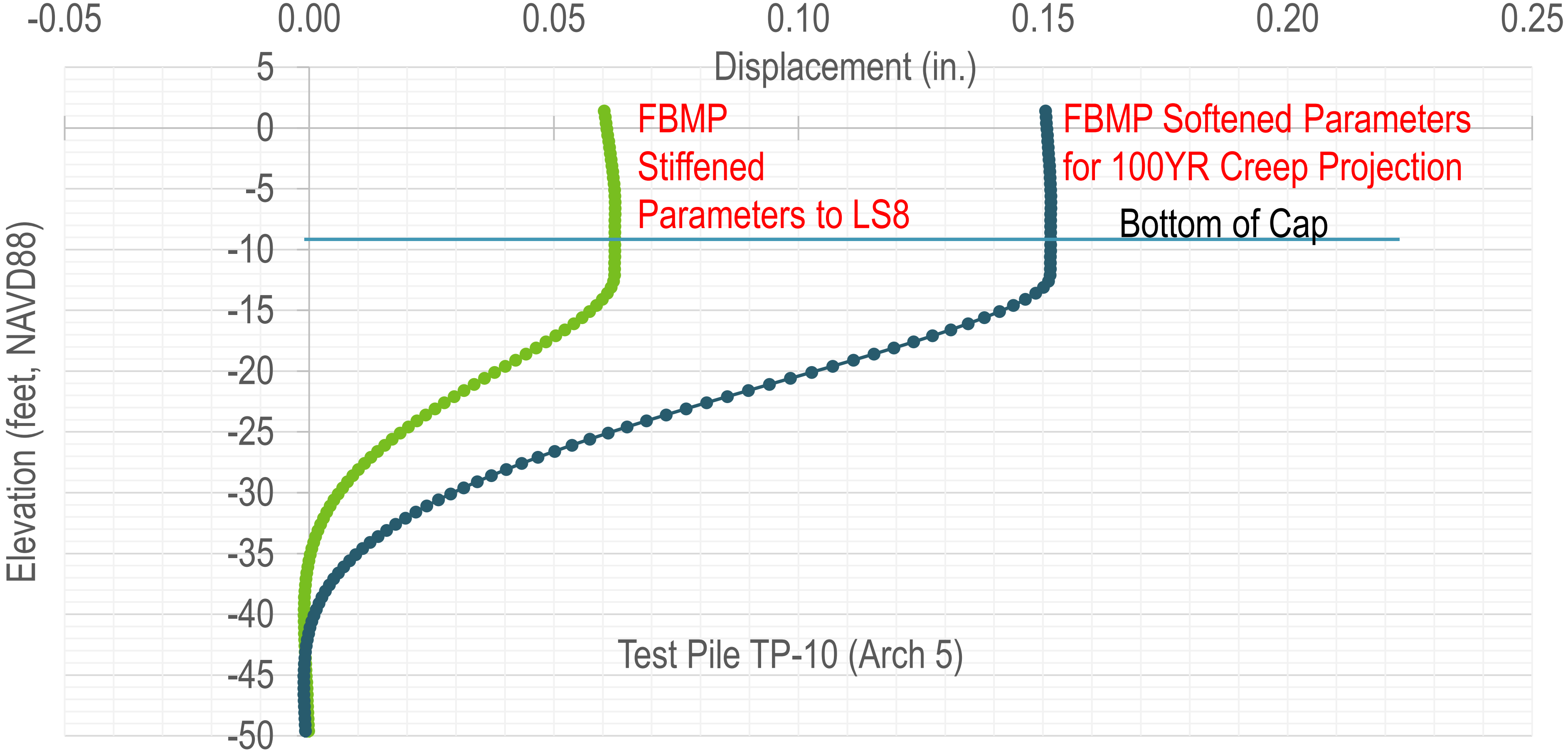
Load Testing Results – Method 2

TP-10: Step #2 – Curve Fit



Load Testing Results – Method 2

TP-10: Step #3 – Curve Fit



Load Testing Results – Method 2

TP-10: Step #4 – Creep Estimate Under Fixed-Head

Displacements (in.) at Bottom of Cap -12'			
	LS8	100YR Creep	Delta
Fixed (FBMP)	0.06	0.152	0.092

TP-10: Step #5 – Production FBMP + “Creep”

- Inputting stiffened parameters curve-fitting to LS8 in production model, bottom of cap displacement is 0.18 inches.
- Projected bottom of cap displacement = 0.18” + 0.092” = 0.27”
- Maximum bottom of cap displacement is 0.25” in FBMP production model at Arch 5

Questions?

Thanks to FDOT, Archer Western / De Moya CJV, and Load Test Consultants for the opportunity and data that allowed us to share this information with the industry!

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