Alligator River Bridge Update

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Geotechnical Group

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
GeoTechnical Engineering Unit

Overview

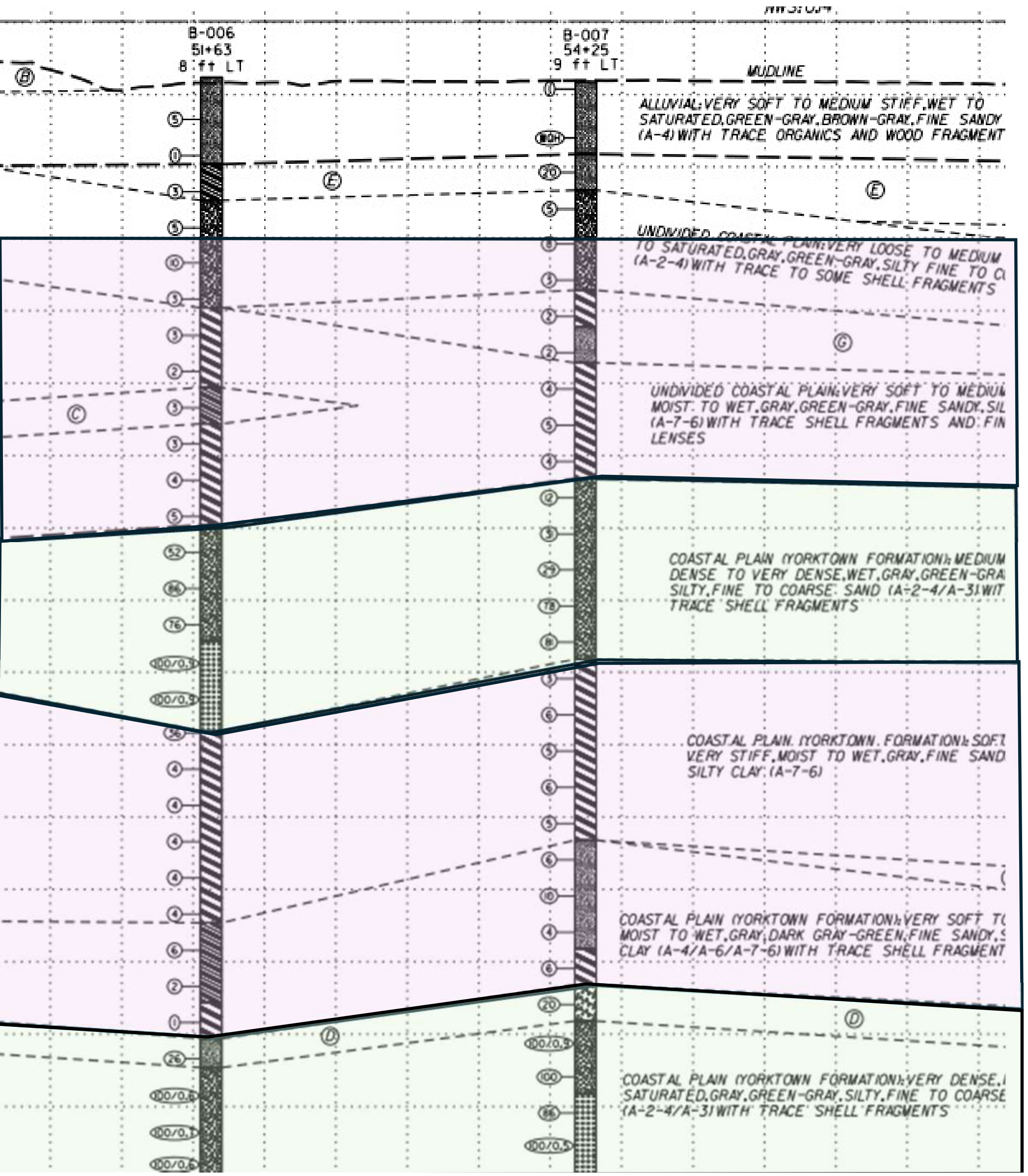
- Recap on test pile program and additional subsurface exploration
- Final foundation design
- Production pile driving
- Embankment monitoring instrumentation
- Next Steps


US 64 – Eastern NC
~ 3.3 Miles Long
Norfolk
Chesapeake
South Boston
Emporia
Roanoke
Rapids
Moyock
Corolla
Henderson
Ahoskie
Elizabeth City
Duck
Kitty Hawk
Edenton
Nags Head
Manteo
Wanchese
Alligator River
Durham
Wake Forest
Raleigh
Cary
Apex
Garner
Clayton
Wilson
Plymouth
Greenville
Washington
Pamlico River
Goldsboro
Kinston
Avon
Buxton
Frisco

New Alignment ~ 1,000 ft North of Existing Bridge

Challenges

- River moratorium
  - River- July 15 to Sept 30
  - Channel- Feb 15 to June 30
- Difficult subsurface conditions for pile driving
  - Very dense sand underlain by “soft” silt/clay
  - Concerns driving into or through very dense sand
  - Differential settlement concern



-10 ft +- Mudline
N values 0-5

-30 ft +- Scour
N values 0-10

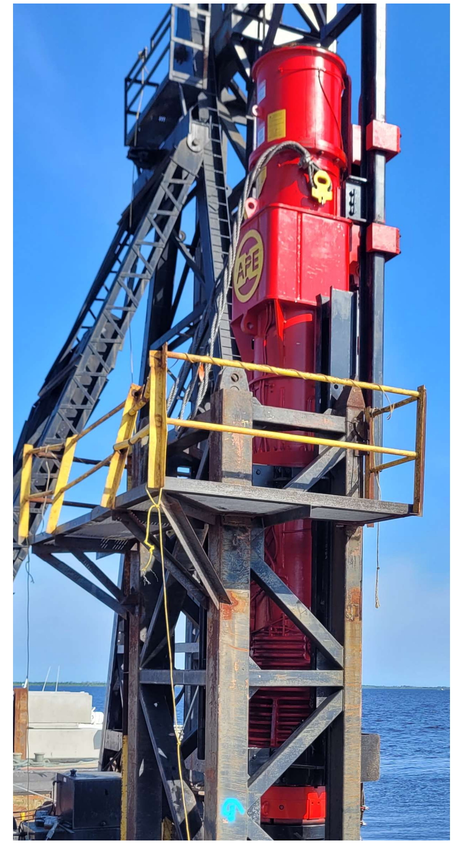
-70 ft +- Top of VD Sand
N values 20-100

-100 ft +- Top of Soft Clay
N values 0-10

-140 ft +- Deeper Bearing
N values 20-100

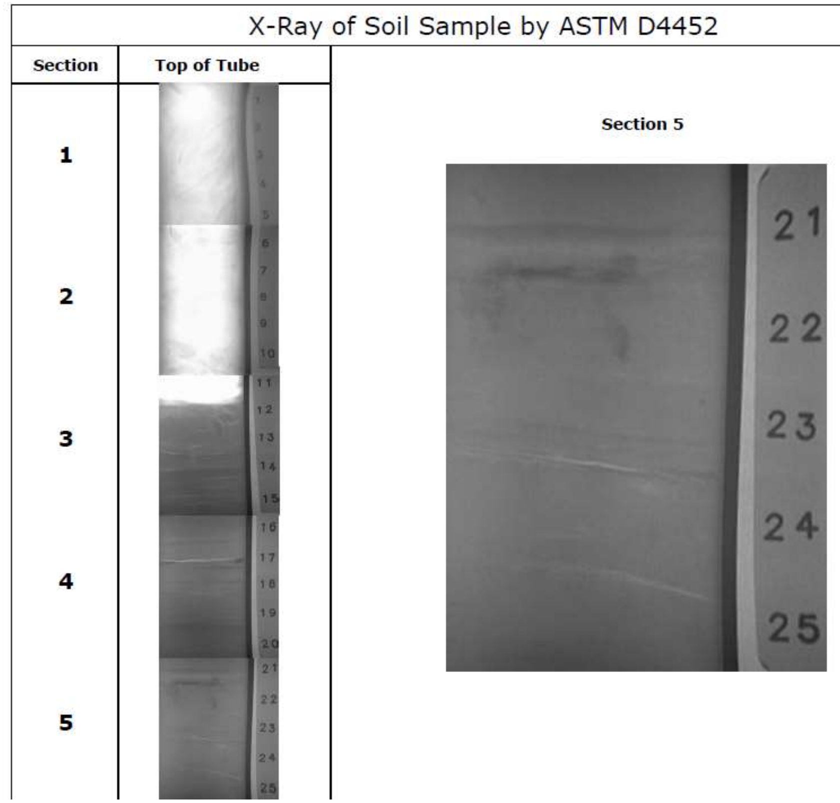
Test Pile Program

- Eleven 36” Square PCP driven (165’ to 185’)
- Spread out along bridge alignment
- One pile driven to lower very dense sand layer
- Casing/pile excavation attempted
- APE D180, APE D220, APE 40-5 hammers used



Additional Subsurface Exploration

- 10 additional borings/sounding completed
- CPT sounding cased through very dense sand
- Up to 180’ deep
- 8-10 Shelby tubes per boring in “soft” clay
- Lab testing
  - All tubes X-rayed
  - Consolidation
  - CU triaxial- estimate OCR via SHANSEP method

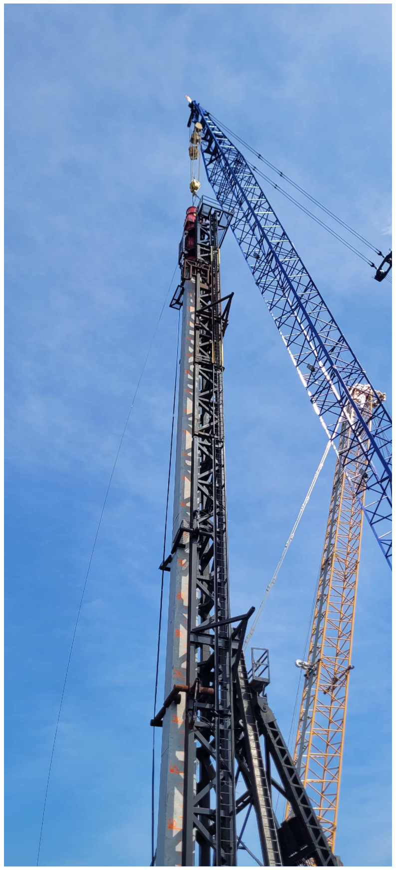


Conclusions from Test Piles/Lab Testing

- Pile excavation would cause delays/cost too much
- Driving through very dense sand not feasible
- Ample capacity in upper very dense sand
- No pile relaxation at site seen from restrikes
- Oedometer, CPT, and CU Triaxial tests show OCR > 1.5
  - Differential settlement concern eliminated

Conclusions from Test Piles/Lab Testing

- Lateral stability is ok with short piles
  - FB Multipier analysis
- Tip piles in upper very dense sand
- Estimated savings – $80 million + shortened schedule



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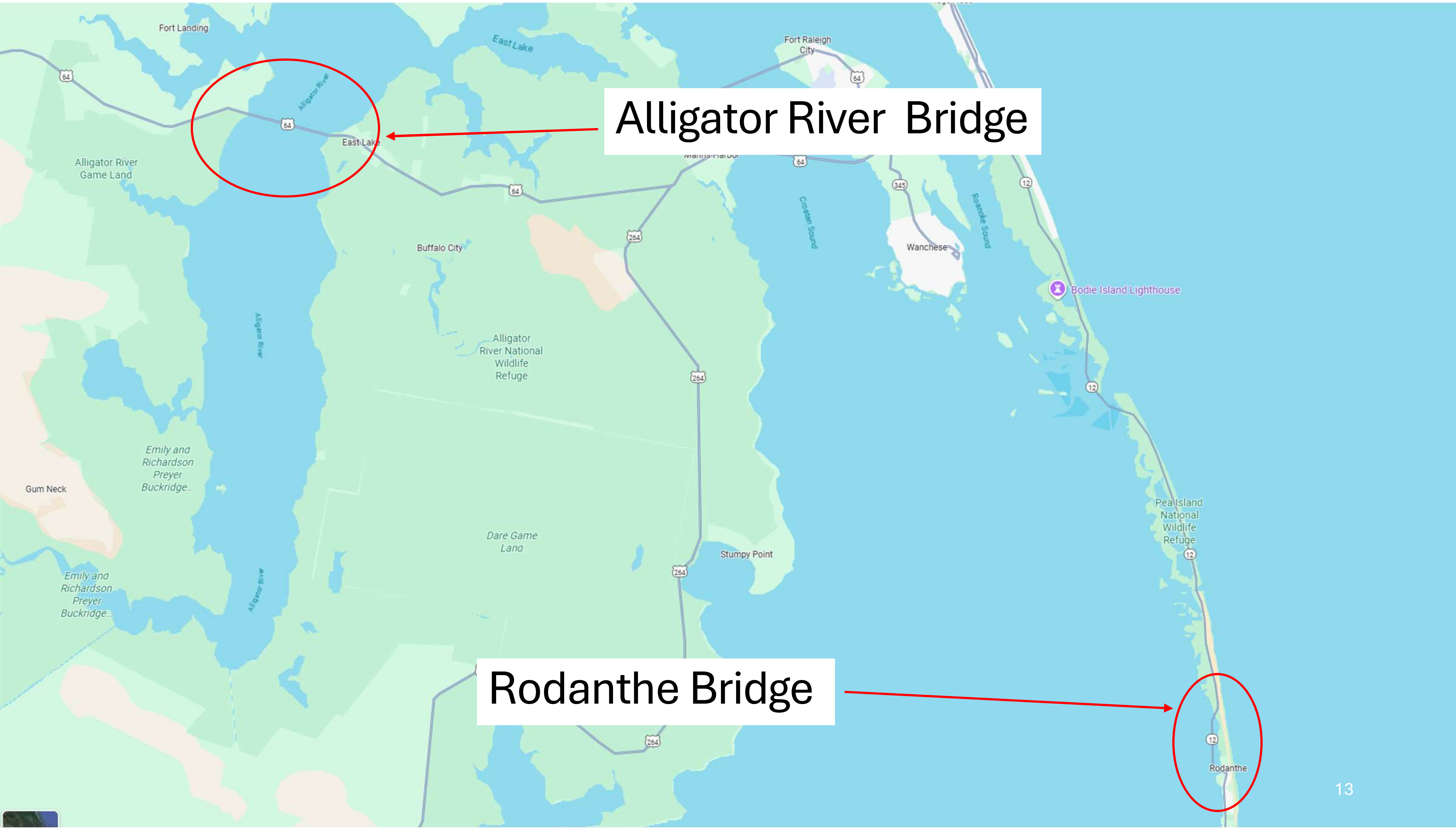
Foundation Design

- 136 bents
  - 36” squares at low level interior bents and transition bents
    - Voided piles at Bents 1-7 and 121-134 (21” void)
  - 54” Dia. w/ 6.75” wall thickness cylinders at high rise portion
    - Bents 47 to 54
  - 105’ avg length
- Minimum tips
  - set 7’ into very dense sand for squares
  - set 10’ into very dense sand for cylinders

Cylinder Piles

- High rise portion changed to cylinder piles after test pile program
  - More capacity than expected
  - Reduced number of piles to drive
- Concerns based on Rodanthe bridge construction
  - Similar driving through a very dense sand layer
  - Broke 10 cylinder piles
  - Pre-drilling through pile


Alligator River Bridge
Rodanthe Bridge
Fort Landing
East Lake
Fort Raleigh City
Alligator River Game Land
East Lake
Buffalo City
Wanchese
Croatan Sound
Roanoke Sound
Bodie Island Lighthouse
Alligator River National Wildlife Refuge
Alligator River
Emily and Richardson Preyer Buckridge...
Gum Neck
Dare Game Land
Stumpy Point
Pea Island National Wildlife Refuge
Rodanthe
64
264
345
12

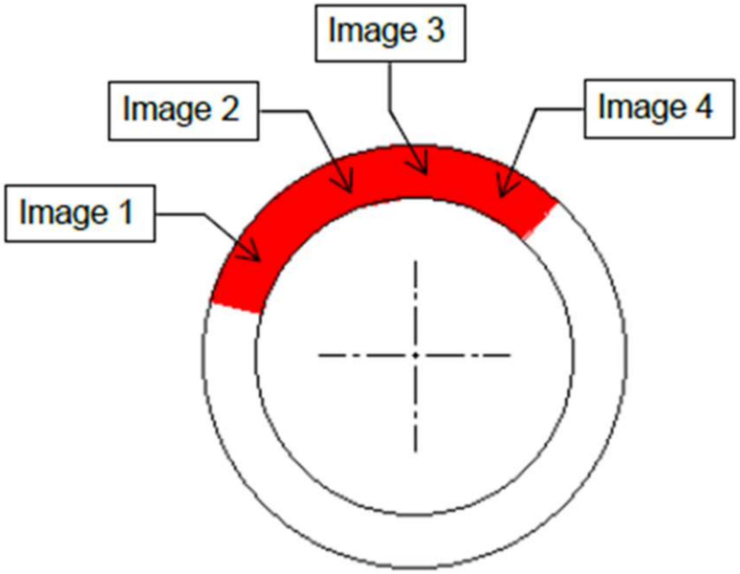


Image 1 taken at approximate elevation -14ft. Vertical and horizontal cracking with . Water intrusion is evident.

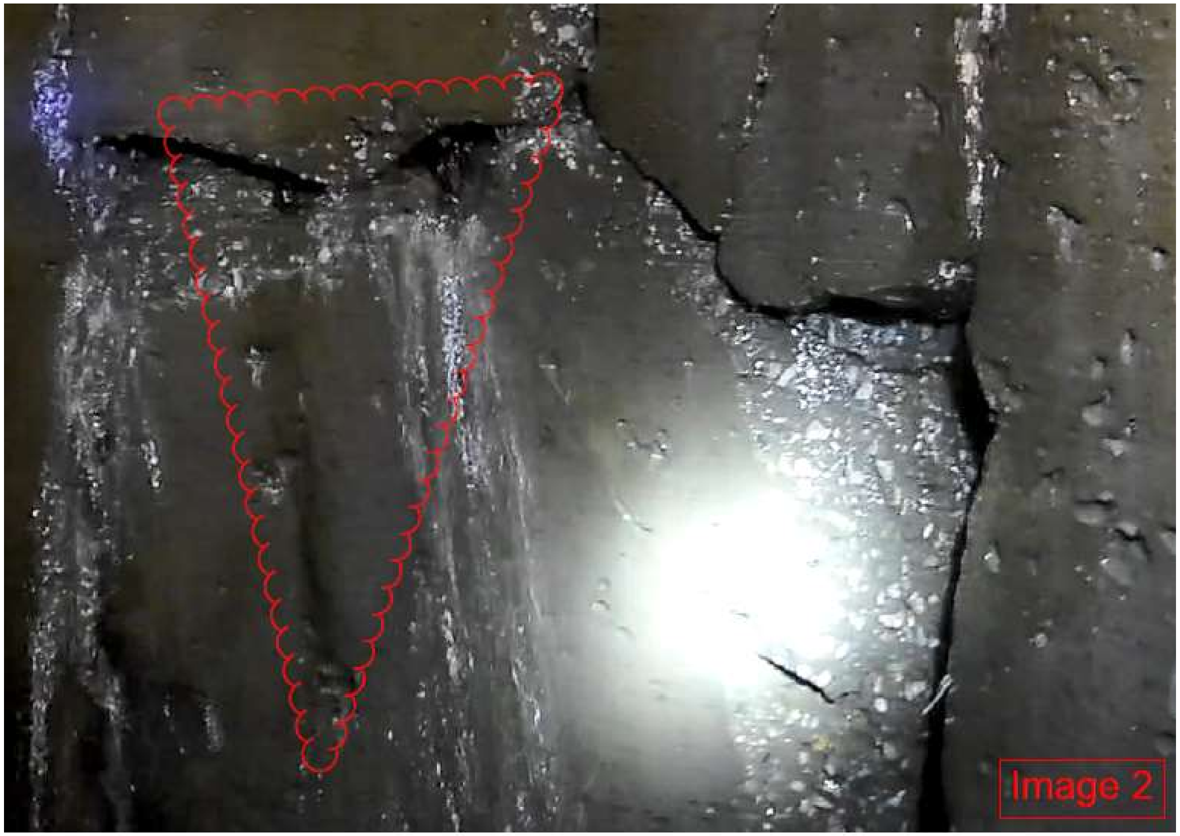


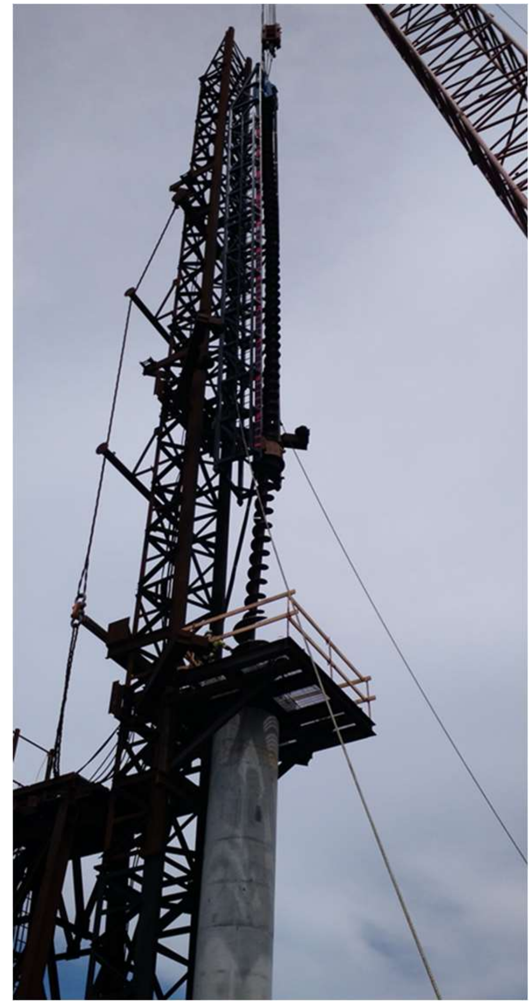
Image 2 taken at approximate elevation -15ft to -16ft. Multiple reinforcing strands are exposed. Strands appear to have shallow cover. Water intrusion evident.

Image 3 taken at approximate elevation -17ft.

Image 4 taken at approximate elevation -18ft to -19ft.

Multiple reinforcing strands and spirals exposed.

Unable to excavate lower than this elevation with current equipment setup.



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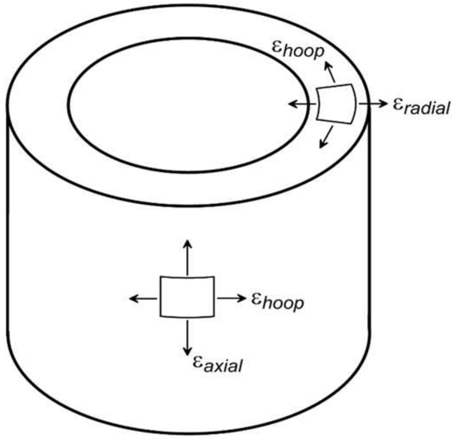
Hoop Stress

- Poisson effect, axial compression causes lateral expansion
- Limit to strain where tensile splitting occurs
- Hooke's law, $\varepsilon_{ts} = f_t / E_c$

  Where f_t = limiting concrete tension E_c = Elastic modulus of concrete
- Estimate Hoop Strain, $\varepsilon_{hoop} = -\nu \cdot \varepsilon_{axial}$

  Poisson's ratio for concrete ≈ 0.2
- See Dan Brown's 2016 STGEC presentation



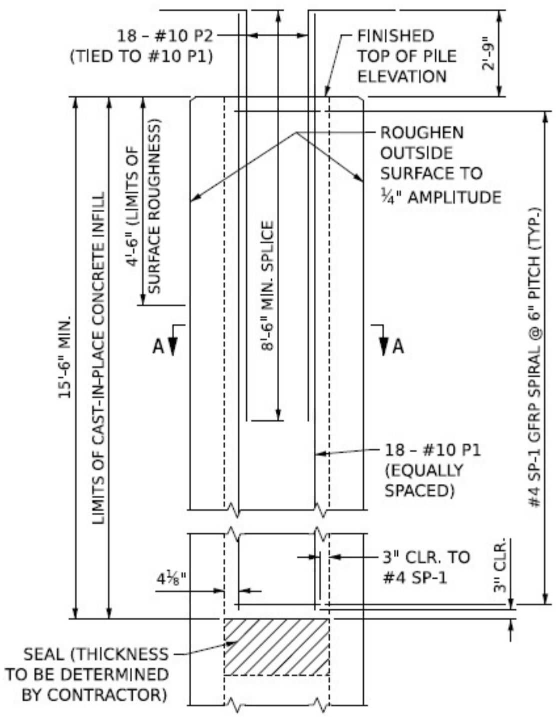
Hoop Stress

- NCDOT formula, **Compression Limit= 0.85*f'c – fpe**

  Where f'c = compressive strength of concrete, fpe = effective prestress

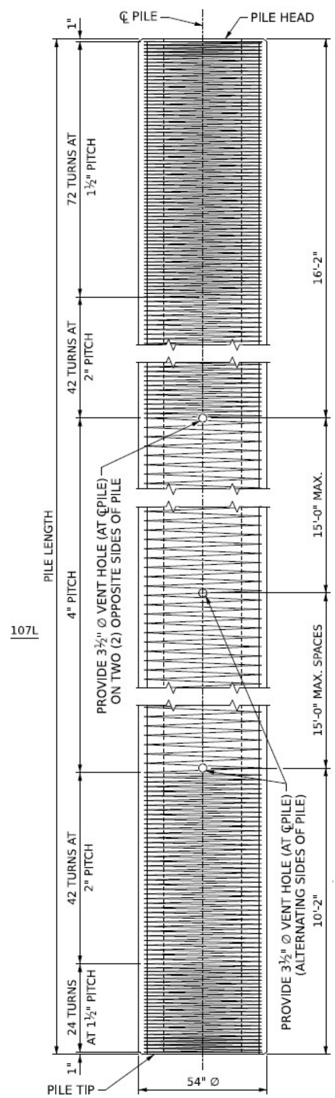
- To mitigate hoop stress cracking we needed to reduce our limit

  Compression Limit*(3/8)

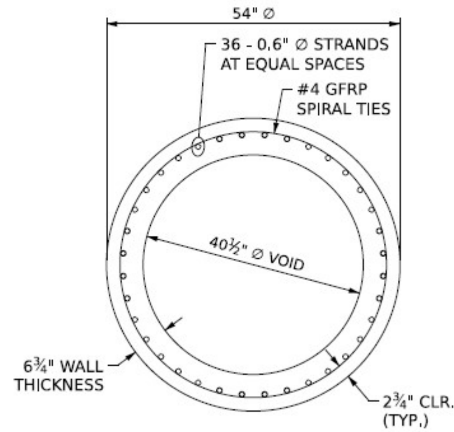


CAST-IN-PLACE CONCRETE PLUG

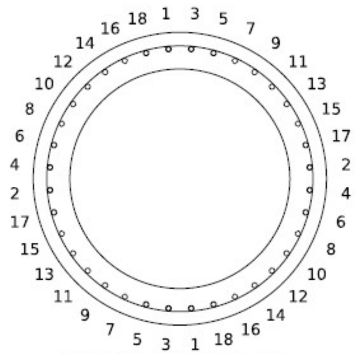
(TYP. AT THE TOP OF ALL 54" ∅ CYLINDER PILES)



ELEVATION

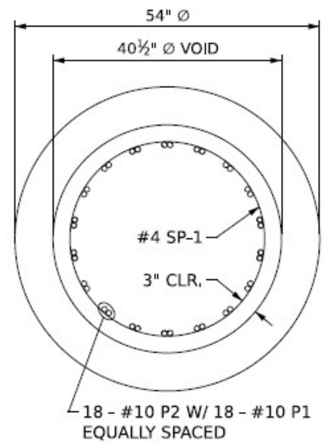


TYPICAL SECTION



TYPICAL PATTERN FOR CUTTING STRANDS

36 - 0.6" ∅ CFRP STRANDS



SECTION A-A

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
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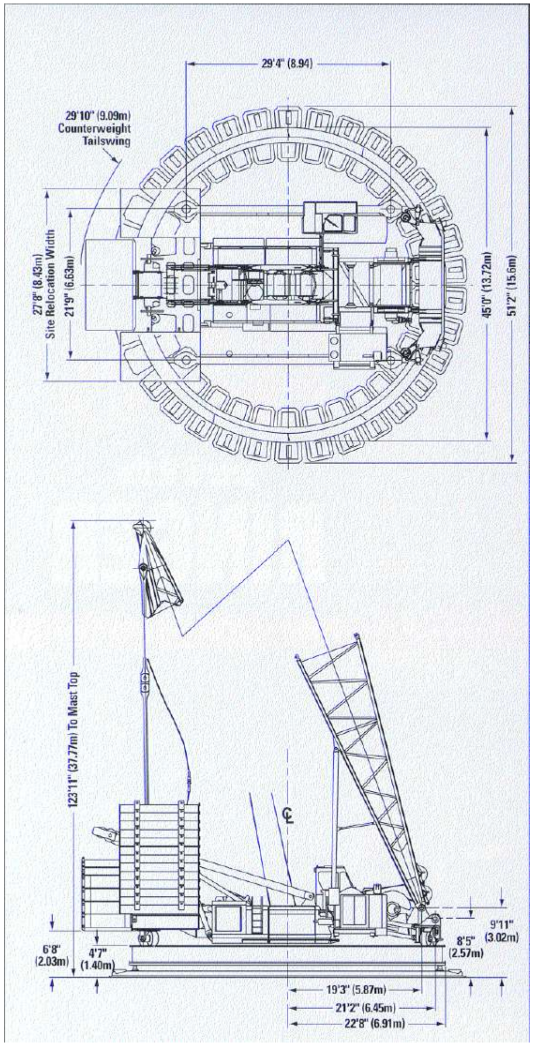
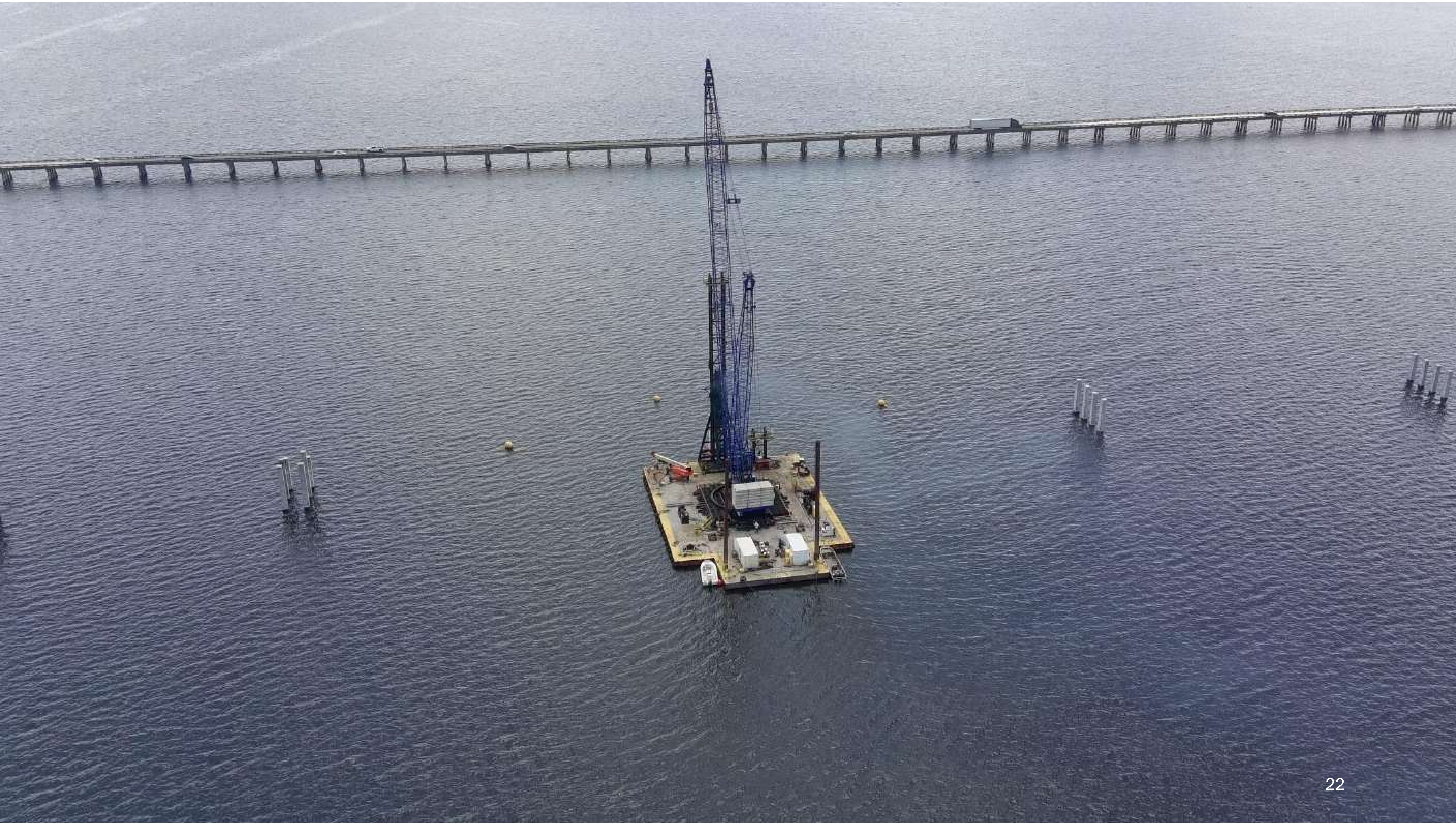
Foundation Design

- Pile design
  - 10,000 psi concrete used
  - 36-0.6" dia. CFRP Strands, 41kip pull
  - Maximized pull and concrete strength for stress limits
- Stress limits
  - Squares-solid
    - 7.6 ksi compression
    - 1.2 ksi tension
  - Cylinders
    - 2.7 ksi compression
    - 1.5 ksi tension

Production Piles

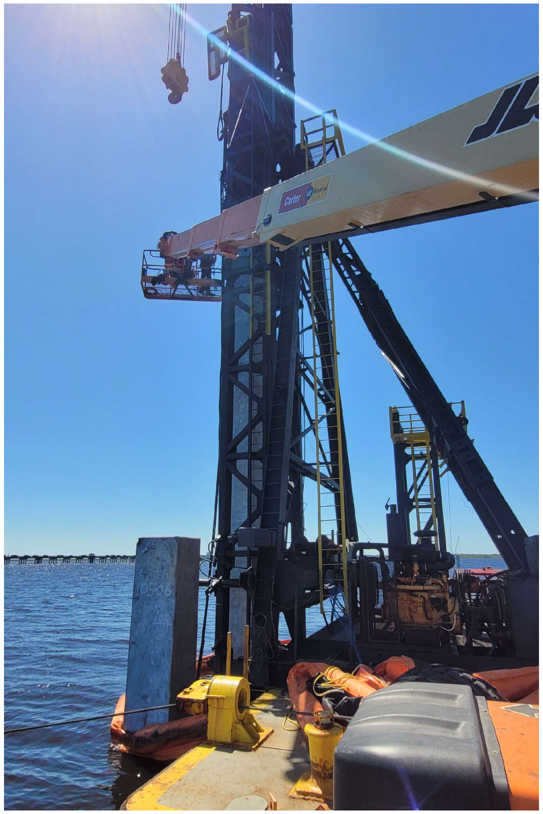
- Ringer crane barge
- 75” fixed leads- “A frame”
- Separate barge for piles





Square Production Piles

- APE D180
- Driving 1-3 piles per day per crew
- Dynamic pile testing every 3rd bent



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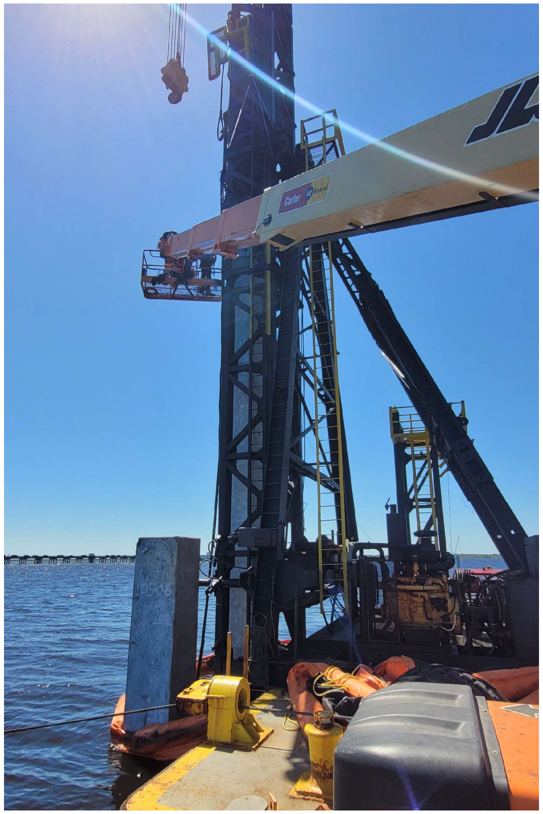
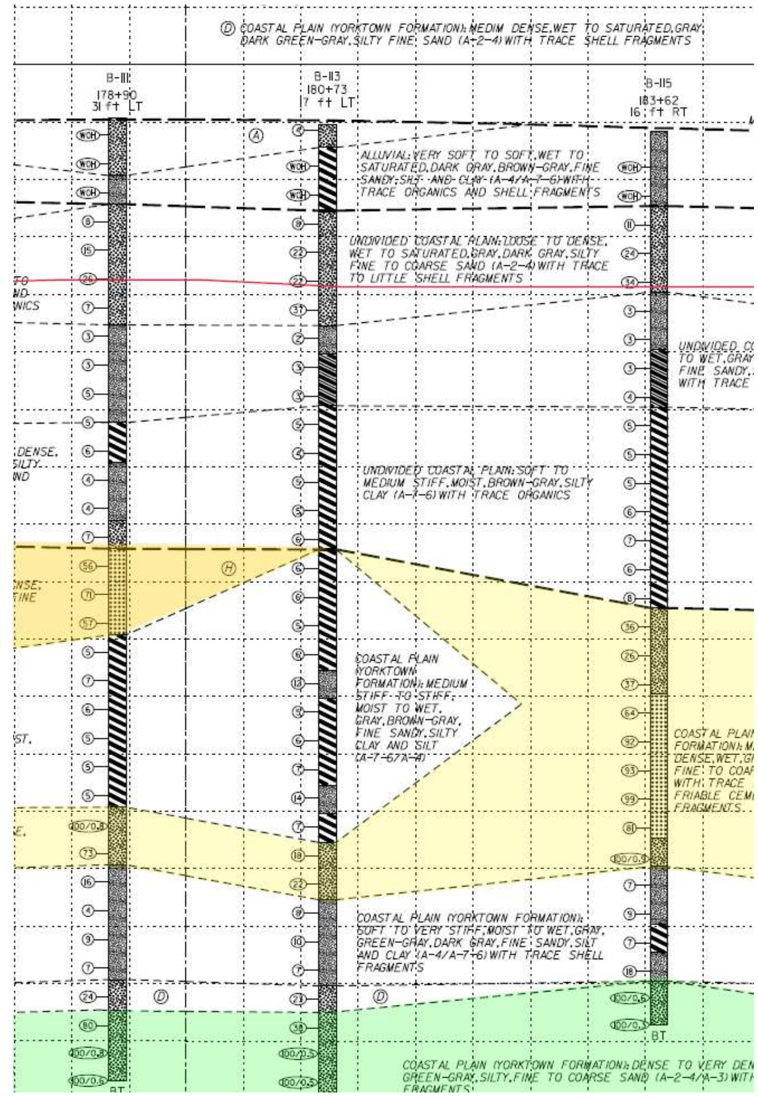
Square Production Piles

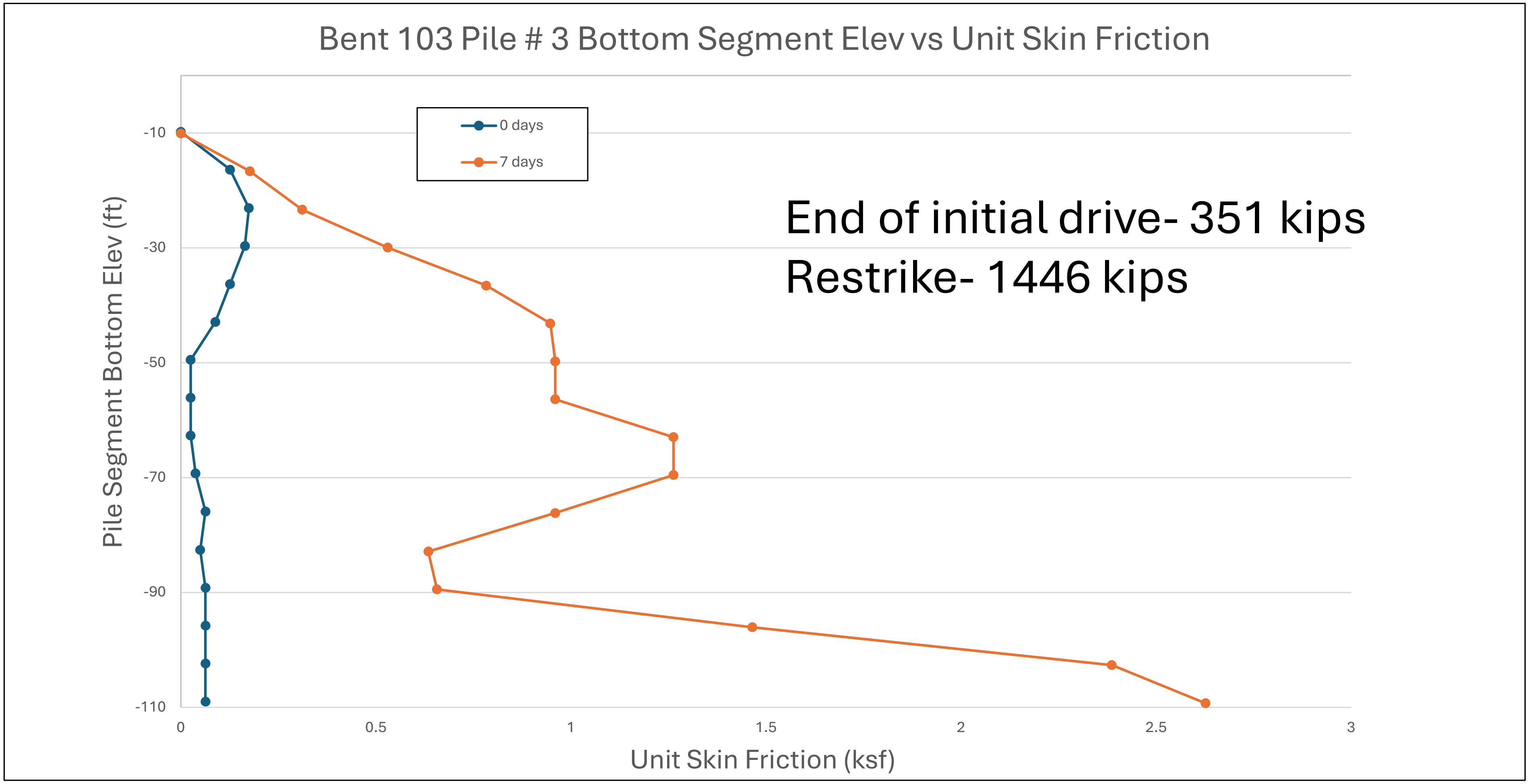
- Piles sinking under own weight first ~20’
- High tension stress in soft alluvial layers
- High compression stress in very dense sand
  - Mitigated with 18” plywood pile cushion
- AVG resistance ~2300 kips
  - RDR 1520 kips at most



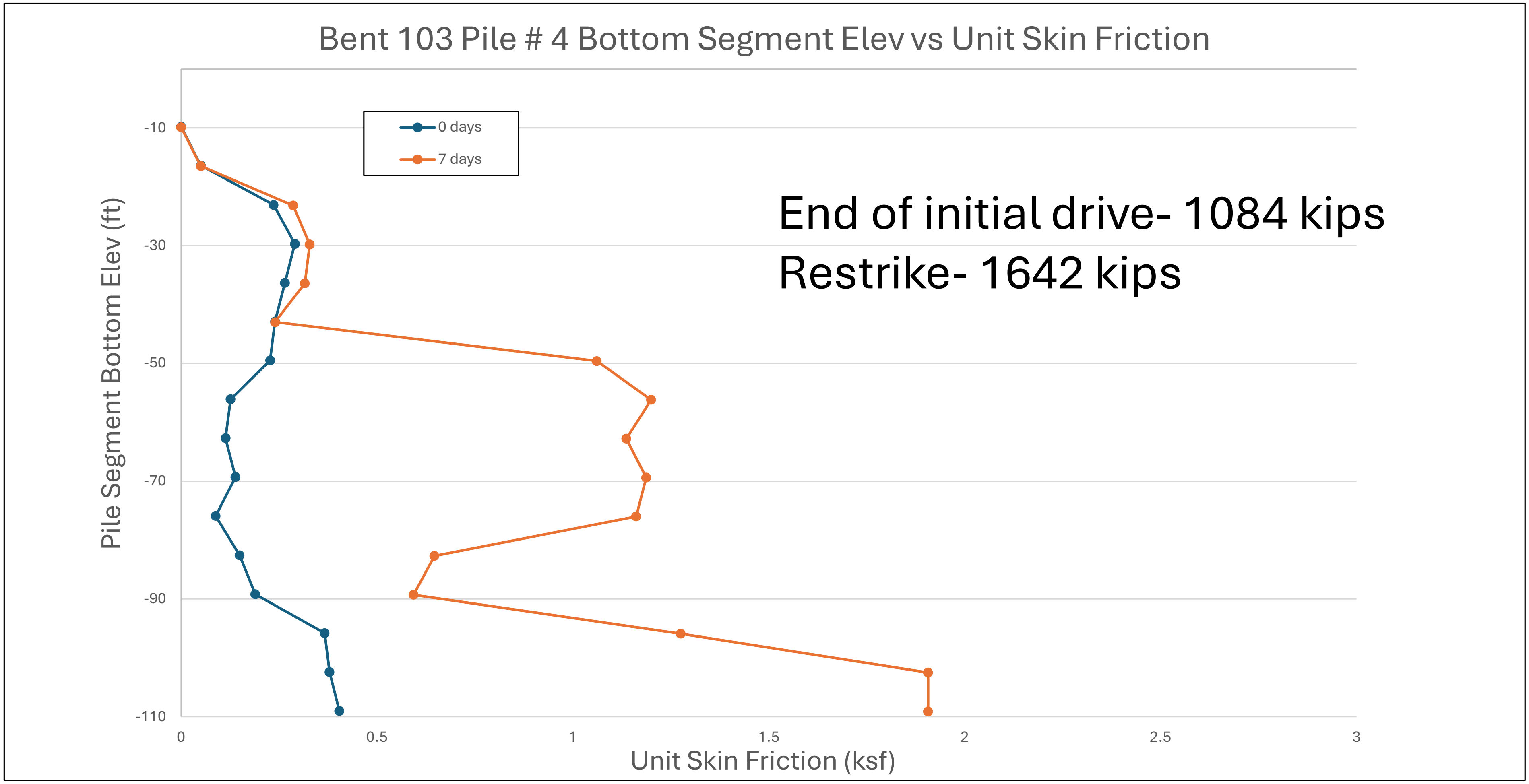
Square Production Piles

- Bent 101-103
- “Hole” in very dense sand layer
- Cast extra long piles to count on setup/restrikes, 125’
- Piles did not get RDR (1395 kips) on initial drive
- Restrike performed





Bent 103 Pile # 3 Bottom Segment Elev vs Unit Skin Friction
0 days
7 days
End of initial drive- 351 kips
Restrike- 1446 kips
Pile Segment Bottom Elev (ft)
-10
-30
-50
-70
-90
-110
0
0.5
1
1.5
2
2.5
3
Unit Skin Friction (ksf)



Bent 103 Pile # 4 Bottom Segment Elev vs Unit Skin Friction
0 days
7 days
End of initial drive- 1084 kips
Restrike- 1642 kips
Pile Segment Bottom Elev (ft)
-10
-30
-50
-70
-90
-110
0
0.5
1
1.5
2
2.5
3
Unit Skin Friction (ksf)

Cylinder Production Piles

- Stand and drive
- APE D180
- 3 or 4 DPTs per pile footing
- Compression stress restriction
- If BPF reached 120 remove soil plug

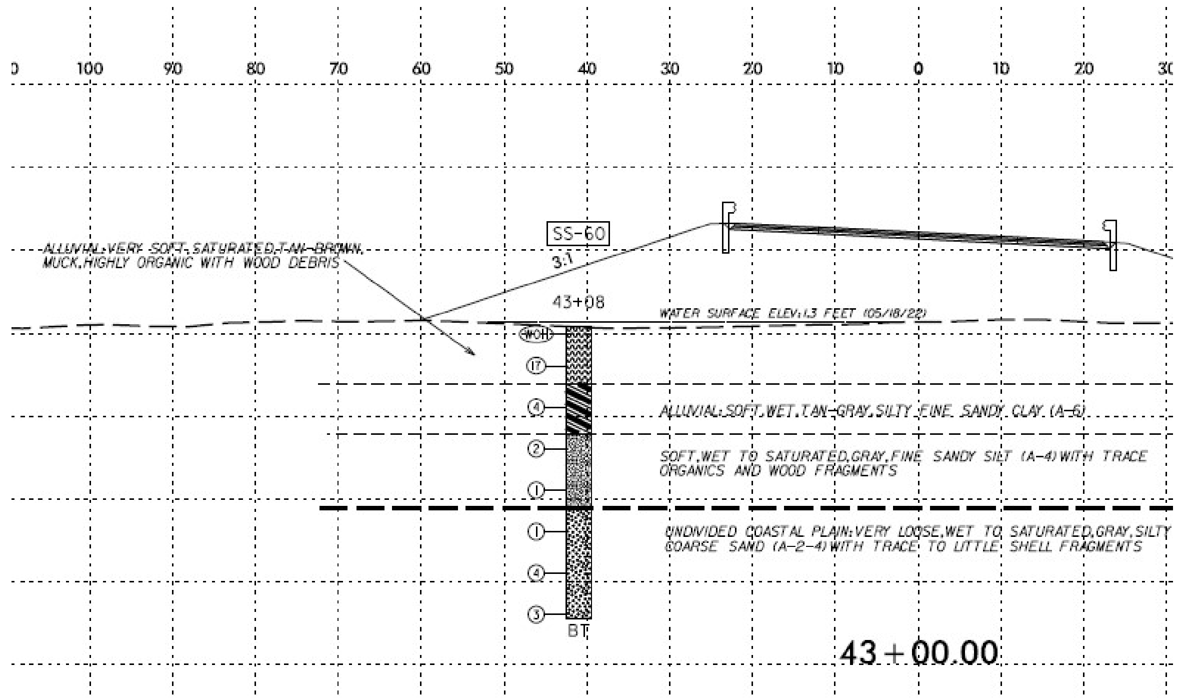
Cylinder Production Piles

- 2.25” thick plywood pile cap used
  - Typically broke once hammer placed
- Compression limit reached during hammer startup
  - Mitigated by lowering fuel pressure
- RDR reached on all cylinder test piles

Embankment Monitoring

- EB1- 35”   EB2- 12”

- Undercut in-situ soils 5’
- Build embankment
- Surcharge 5’
- Wait period
  - 4 months EB1
  - 2 months EB2



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Embankment Monitoring

- Magnet extensometers
- Settlement gauges
- VW piezometers
- Vertical Inclinometers

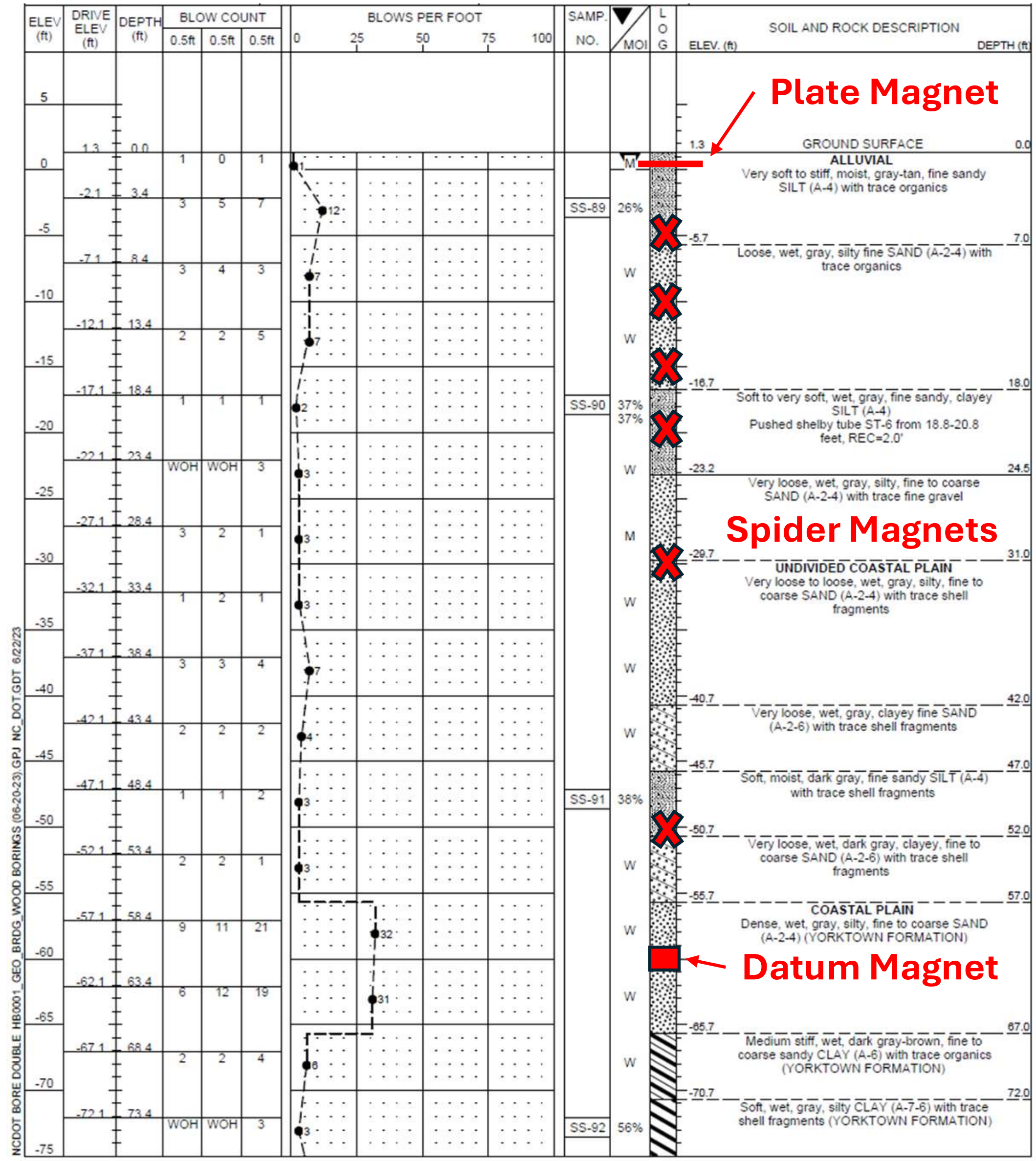
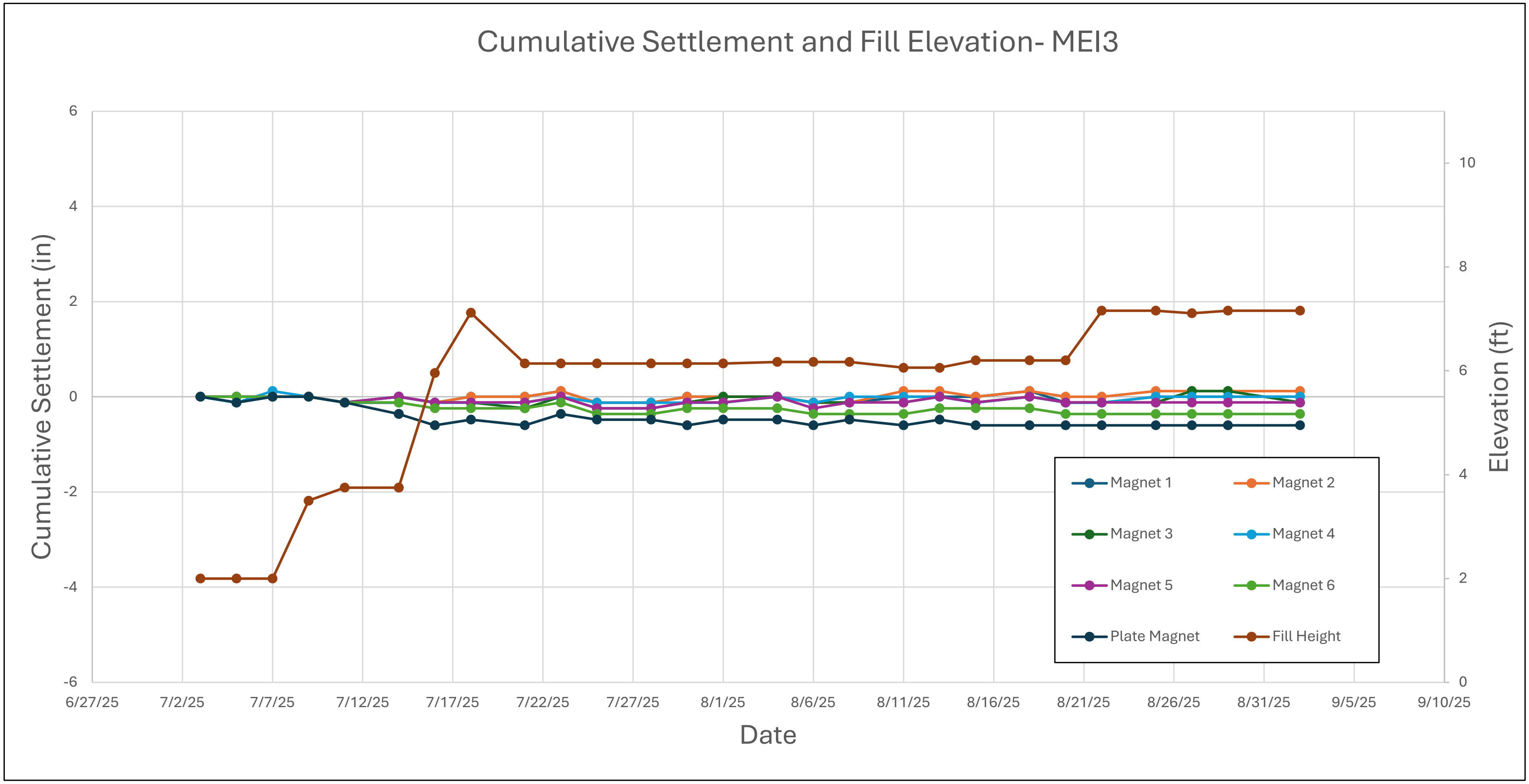
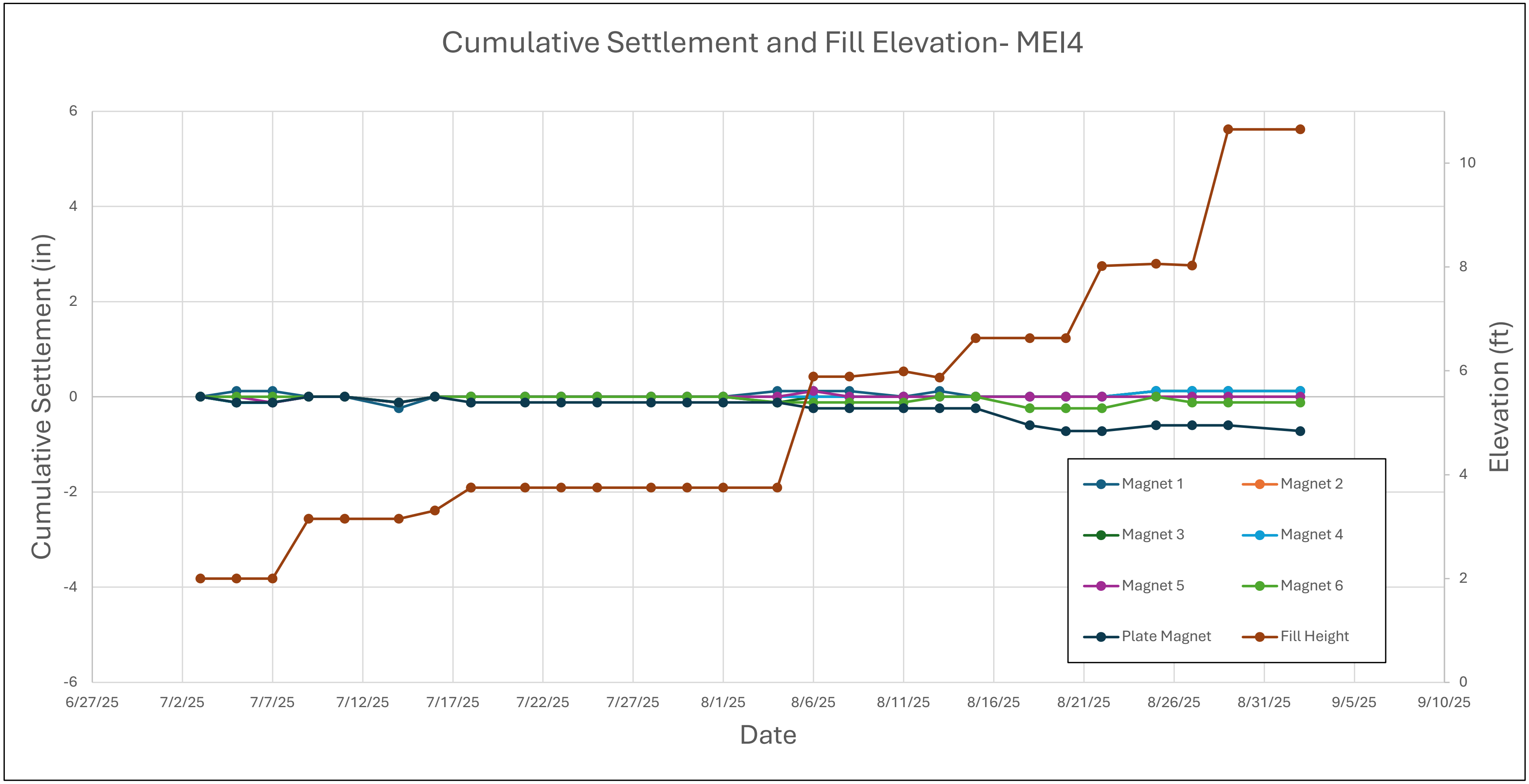


Plate Magnet
Spider Magnets
Datum Magnet
ELEV (ft)
DRIVE ELEV (ft)
DEPTH (ft)
BLOW COUNT
0.5ft 0.5ft 0.5ft
BLOWS PER FOOT
0 25 50 75 100
SAMP. NO.
MOI
LOG
SOIL AND ROCK DESCRIPTION
ELEV. (ft)
DEPTH (ft)
GROUND SURFACE
ALLUVIAL
Very soft to stiff, moist, gray-tan, fine sandy SILT (A-4) with trace organics
Loose, wet, gray, silty fine SAND (A-2-4) with trace organics
Soft to very soft, wet, gray, fine sandy, clayey SILT (A-4)
Pushed shelby tube ST-6 from 18.8-20.8 feet, REC=2.0'
Very loose, wet, gray, silty, fine to coarse SAND (A-2-4) with trace fine gravel
UNDIVIDED COASTAL PLAIN
Very loose to loose, wet, gray, silty, fine to coarse SAND (A-2-4) with trace shell fragments
Very loose, wet, gray, clayey fine SAND (A-2-6) with trace shell fragments
Soft, moist, dark gray, fine sandy SILT (A-4) with trace shell fragments
Very loose, wet, dark gray, clayey, fine to coarse SAND (A-2-6) with trace shell fragments
COASTAL PLAIN
Dense, wet, gray, silty, fine to coarse SAND (A-2-4) (YORKTOWN FORMATION)
Medium stiff, wet, dark gray-brown, fine to coarse sandy CLAY (A-6) with trace organics (YORKTOWN FORMATION)
Soft, wet, gray, silty CLAY (A-7-6) with trace shell fragments (YORKTOWN FORMATION)
SS-89
SS-90
SS-91
SS-92
NCDOT BORE DOUBLE HB0001_GEO_BRDG_WOOD BORINGS (06-20-23).GPJ NC_DOT.GDT 6/22/23



Cumulative Settlement and Fill Elevation- MEI3
Cumulative Settlement (in)
6
4
2
0
-2
-4
-6
Elevation (ft)
10
8
6
4
2
0
6/27/25
7/2/25
7/7/25
7/12/25
7/17/25
7/22/25
7/27/25
8/1/25
8/6/25
8/11/25
8/16/25
8/21/25
8/26/25
8/31/25
9/5/25
9/10/25
Date
Magnet 1
Magnet 2
Magnet 3
Magnet 4
Magnet 5
Magnet 6
Plate Magnet
Fill Height


Cumulative Settlement and Fill Elevation- MEI4
Cumulative Settlement (in)
6
4
2
0
-2
-4
-6
Elevation (ft)
10
8
6
4
2
0
6/27/25
7/2/25
7/7/25
7/12/25
7/17/25
7/22/25
7/27/25
8/1/25
8/6/25
8/11/25
8/16/25
8/21/25
8/26/25
8/31/25
9/5/25
9/10/25
Date
Magnet 1
Magnet 2
Magnet 3
Magnet 4
Magnet 5
Magnet 6
Plate Magnet
Fill Height

Next Steps

- Continue pile driving in October
  - 384 of 710 piles driven(54%)
- Monitor pile footing settlement
  - Confirm no differential settlement issue
- Install remaining embankment monitoring instrumentation
- Build up embankments and wait


Thank You!