Effect of Proximity of Sheet Pile Walls on the Apparent Capacity of Driven Displacement Piles (BDV31 TWO 977-26)

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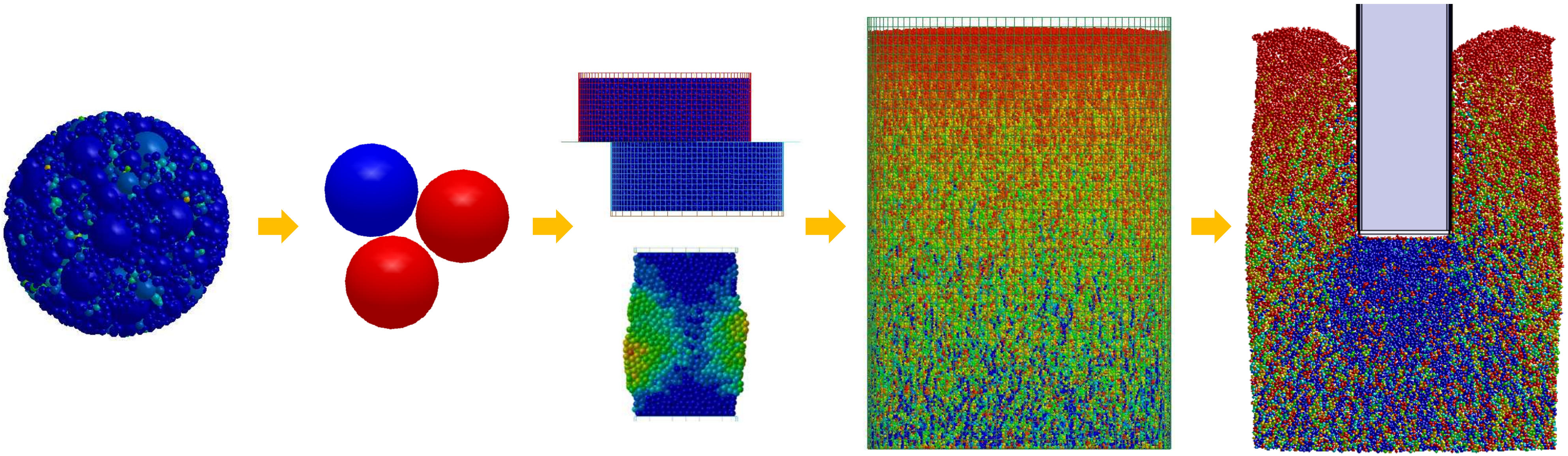

2017 GRIP Meeting

Gainesville, Florida

August 18, 2017

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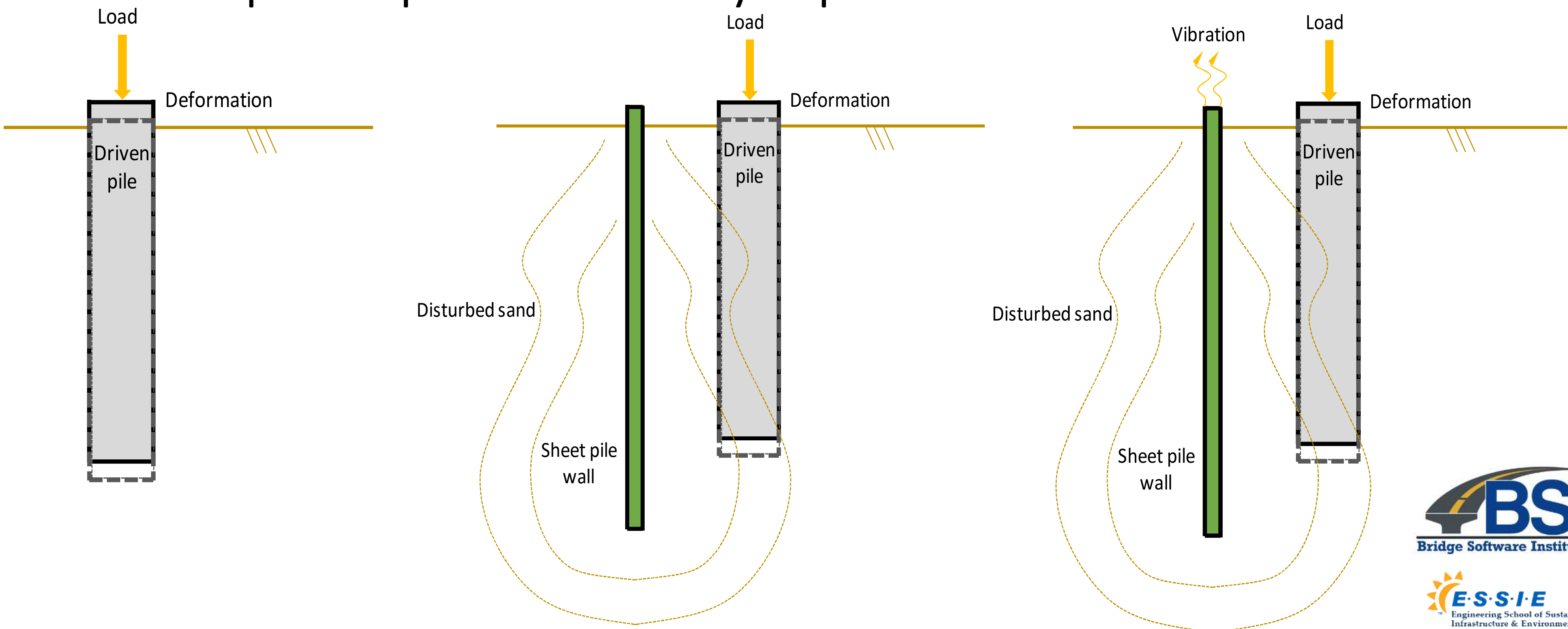
Modeling of Driven Pile and SPW in Granular Materials

- **Deliverables**
  - Development of a driven pile model
  - Development of a pile and pre-driven SPW model (no removal)
  - Development of a pile and pre-driven SPW model (w/ removal)
  - Report of parametric study of pile-soil-SPW simulations



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Agenda

- Progress in Geotechnical Centrifuge Modeling
- Progress in Numerical Modeling (in association with centrifuge modeling)

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Geotechnical Centrifuge Modeling

Shear strength and deformation behaviors of granular soils depend on loading history and corresponding granular structure; the main benefit of centrifuge modeling is to simulate repeatable geostatic stress states similar to in-situ conditions.

Quantity	Symbol	Scale Factor
Gravity	g	N
Length	l	N^{-1}
Force	F	N^{-2}
Stress	σ	1
Acceleration	a	N
Time (Dynamic)	t_{dyn}	N^{-1}
Time (Diffusion)	t_{diff}	N^{-2}
Frequency	f	N

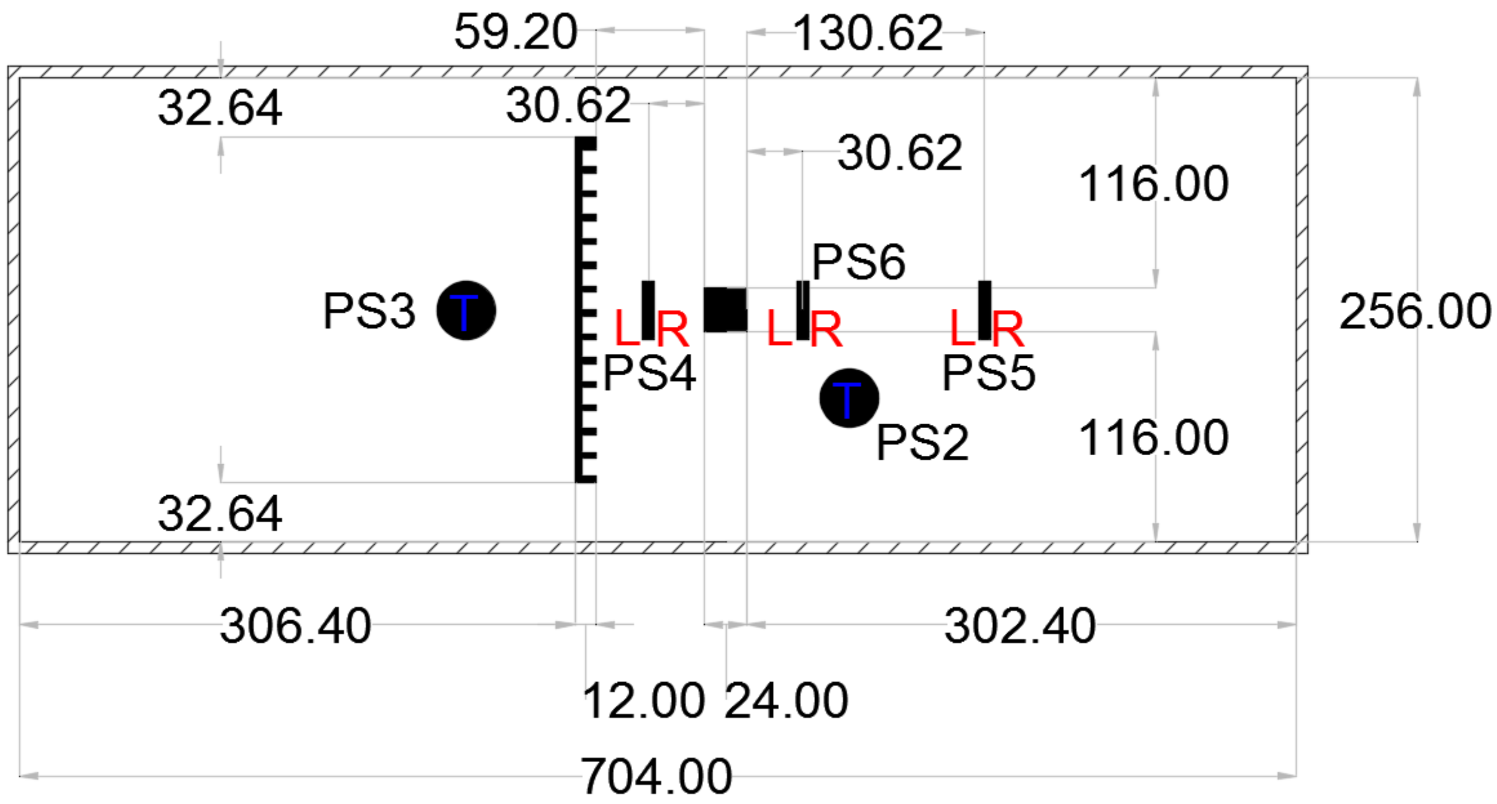
UF Centrifuge Equipment

UF Centrifuge

Radius = 1.5 m
Max. Payload = 12.5 g-ton
Max. Acceleration = 80 g

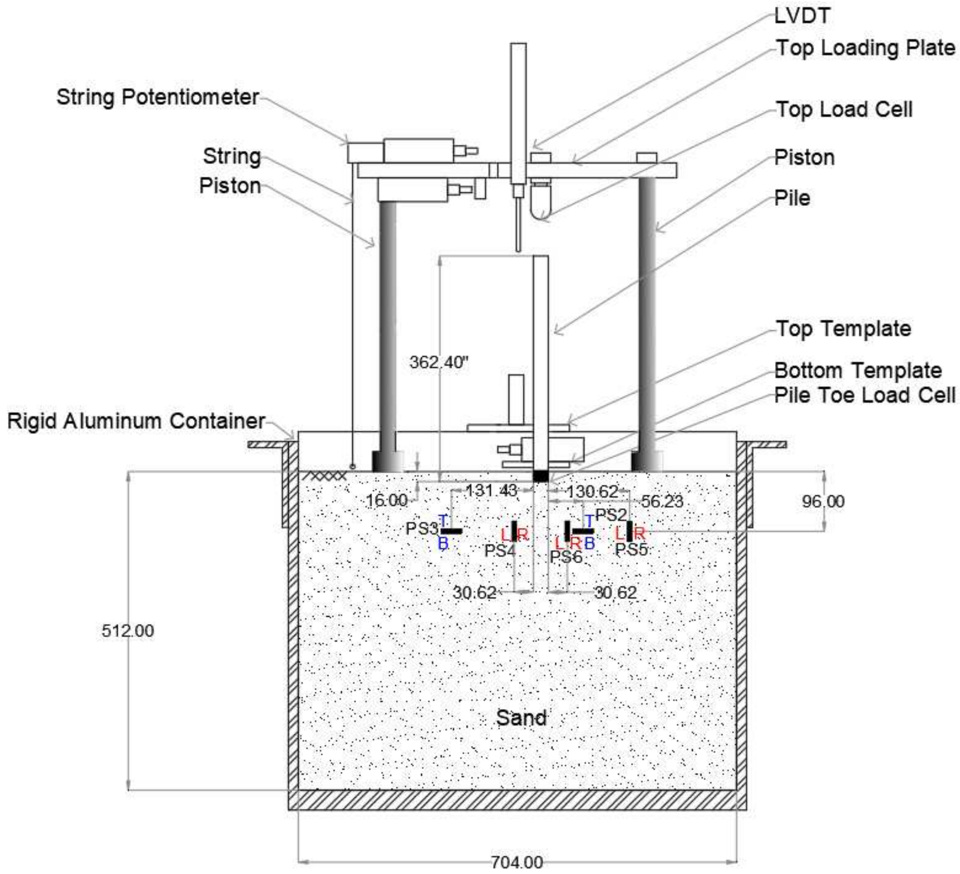
Centrifugal Acceleration = 32 g

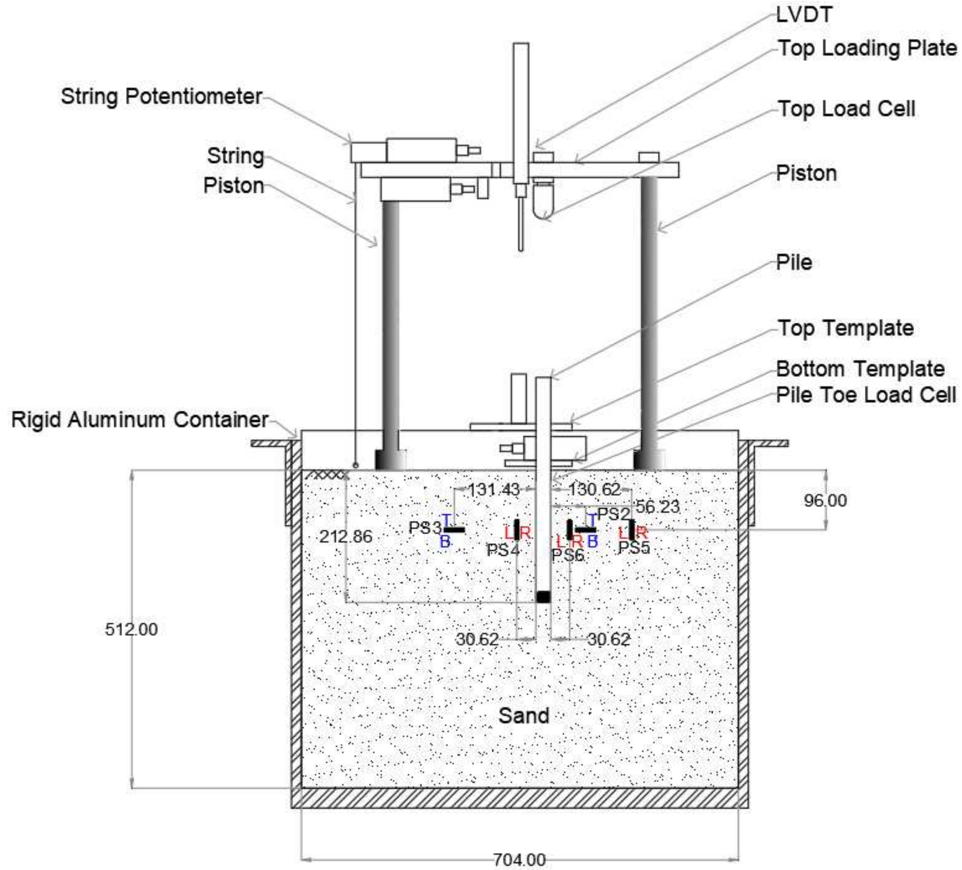
Task 4. Centrifuge Test Set-up: Plan View



Prototype scale dimensions (inches)

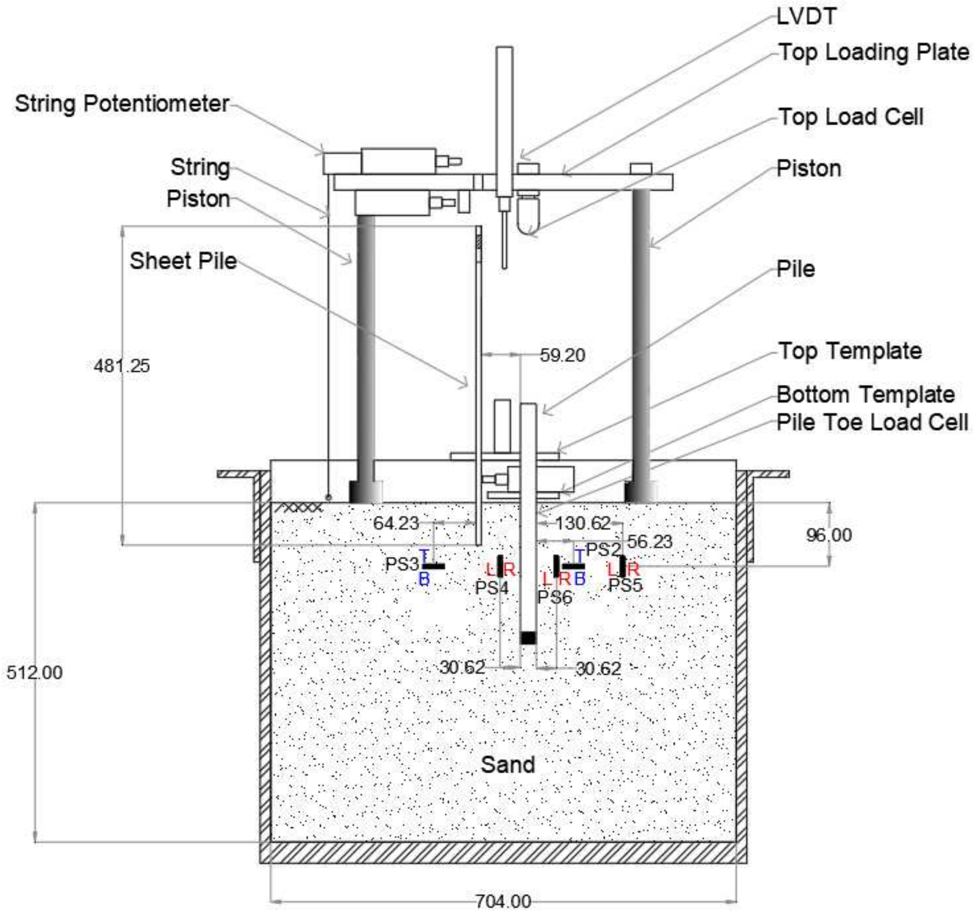
Centrifuge Test Set-up: Loading Scenario 1

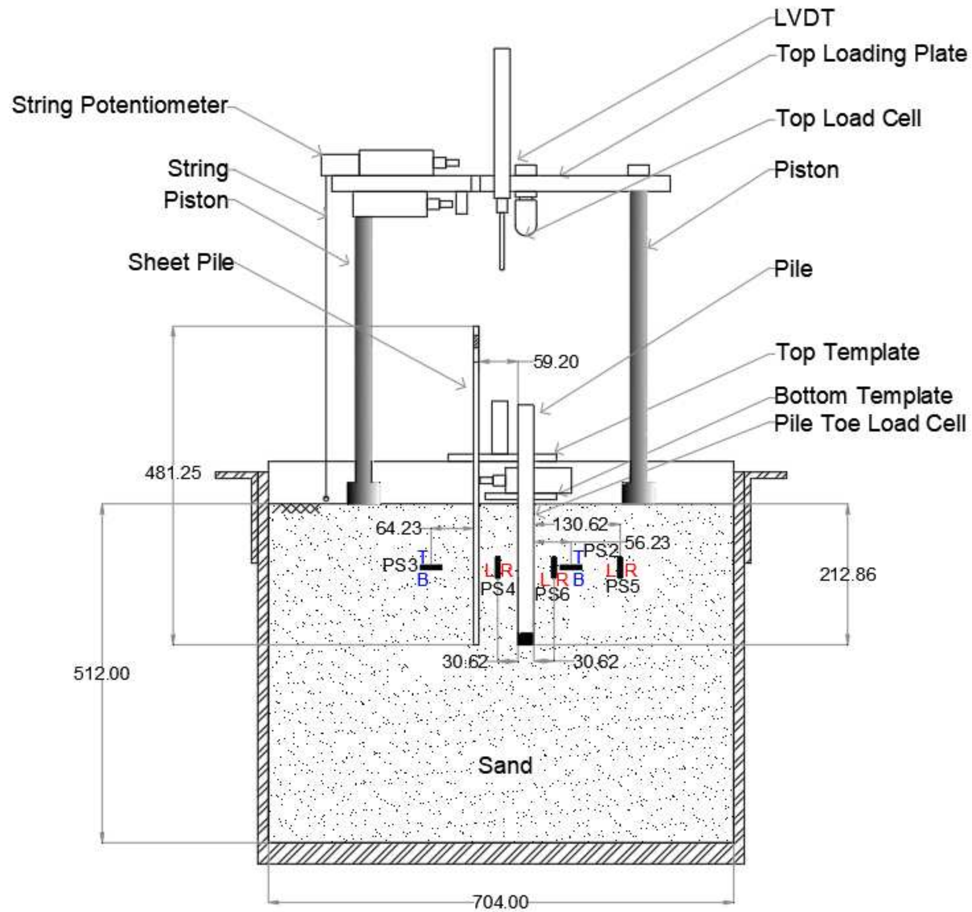




Prototype scale dimensions (inches)

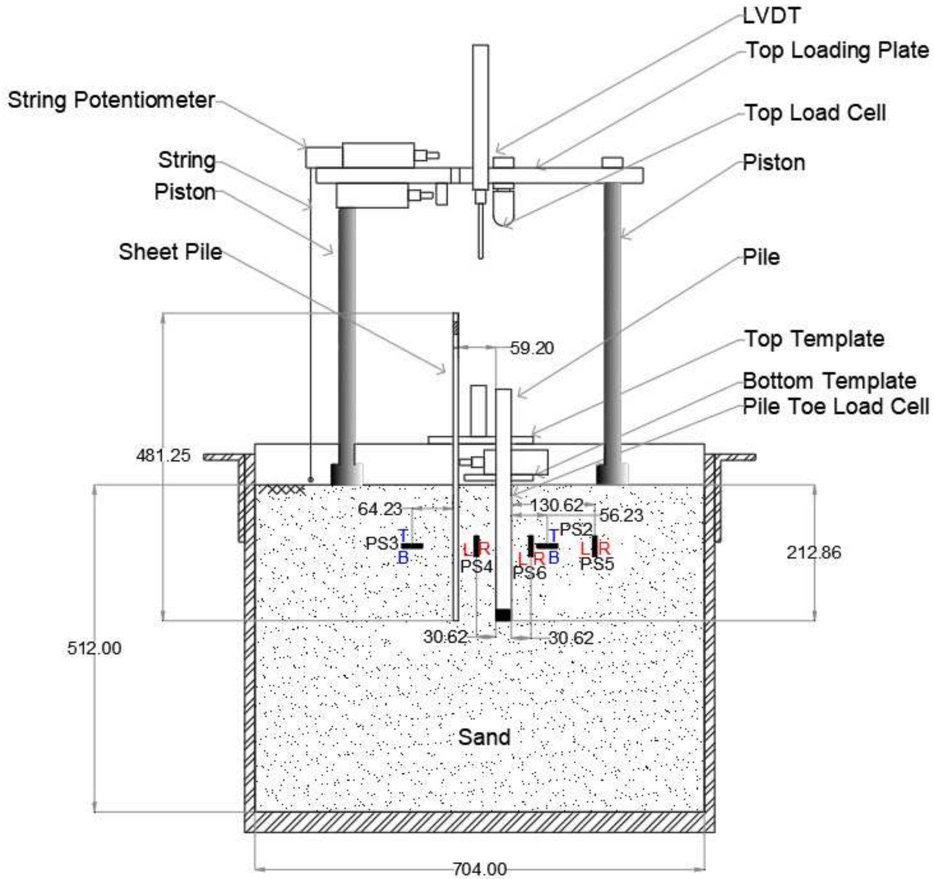
Centrifuge Test Set-up: Loading Scenario 2

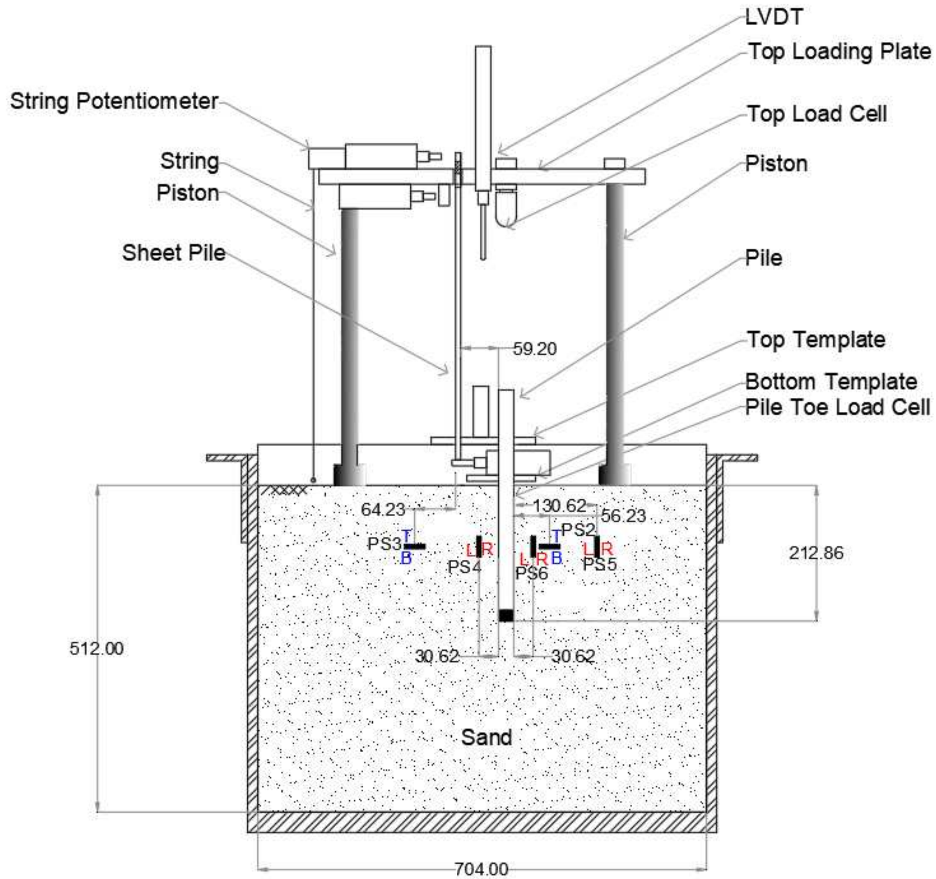




Prototype scale dimensions (inches)

Centrifuge Test Set-up: Loading Scenario 3





Prototype scale dimensions (inches)

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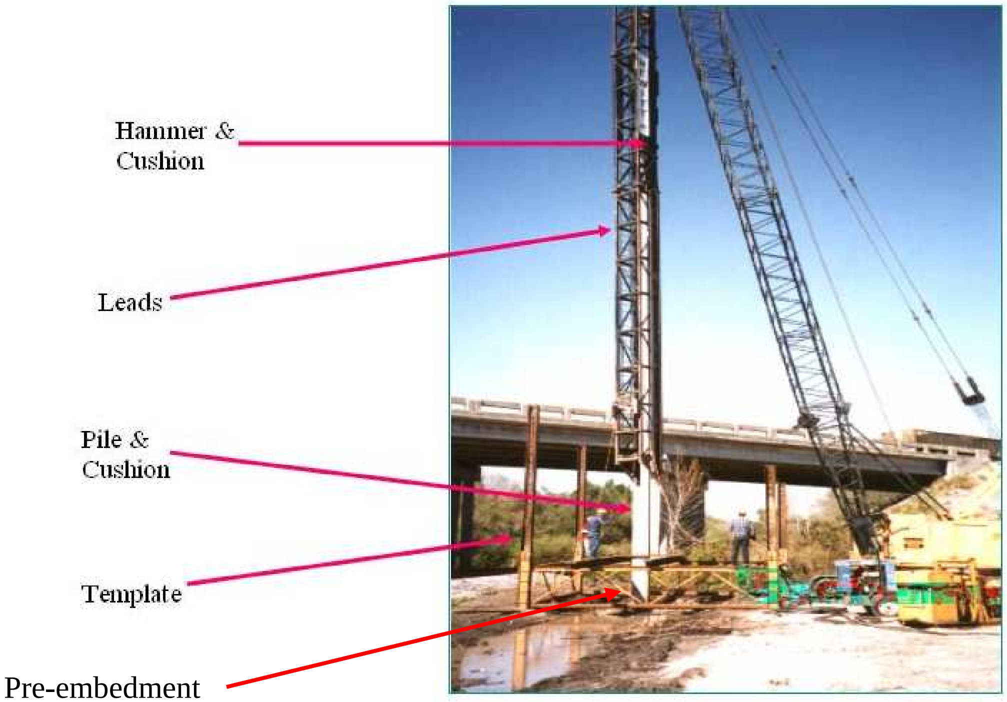
Dimensions of Prototype Pile

Scale	Scale factor	Length (in)	Outside width (in)	Area (in²)	Modulus of Elasticity (ksi)	E.A (kips)	Pre-embedment depth (in)	Total embedment depth (in)
Model	1.0	11.33	0.75	0.31	1.0×10^4	3125	0.5	6.65
Prototype	32.0	362.4	24	320	1.0×10^4	3.2×10^6	16	212.86



Pile Driving

Source for deliverable items: http://osp.mans.edu.eg

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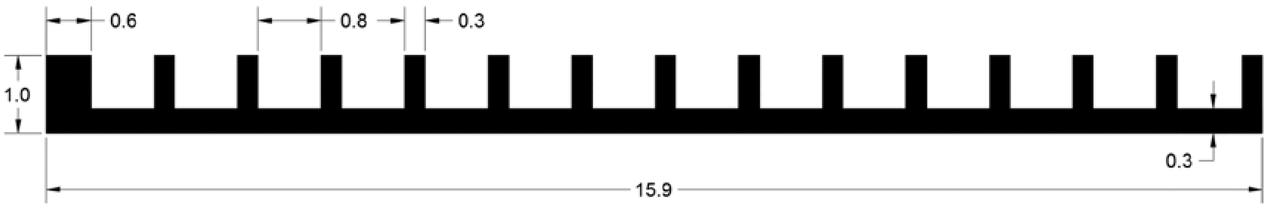
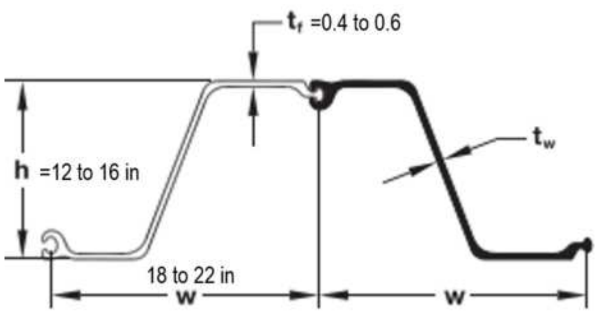
Dimensions of Sheet Pile Wall (SPW)

Scale	Scale factor	Length (in)	Width (in)	Wall thickness (in)	Area (in^2)	Modulus of Elasticity (ksi)	E.A (kips)	Pre-embedment depth (in)	Total embedment depth (in)
Model	1.0	15.04	5.96	0.375	1.14	2.9×10^4	33147	2	6.65
Prototype	32.0	481.25	190.72	12	27796	2.9×10^4	8.1×10^8	64	212.86

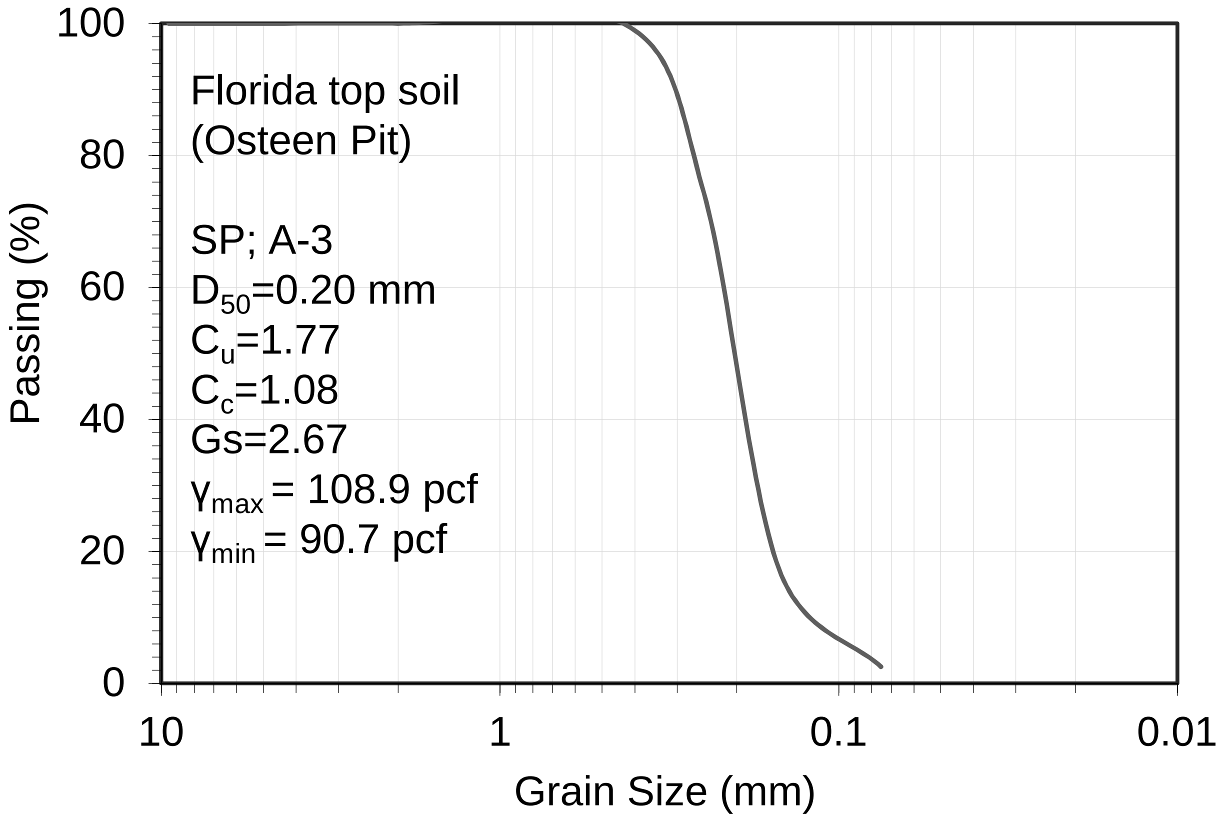


Plan view of the sheet pile wall with tongue-groove pattern in centrifuge tests



Plan view of a typical steel sheet pile wall

Granular Soil for Centrifuge Model



Laboratory test results provided by SMO

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Preparation of Centrifuge Models

Target relative density of FL sand (by pluviation) = 60%, K_0=0.5, ϕ=30°

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Instrumentation in Centrifuge Models

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Centrifuge Apparatus and Load Mechanism

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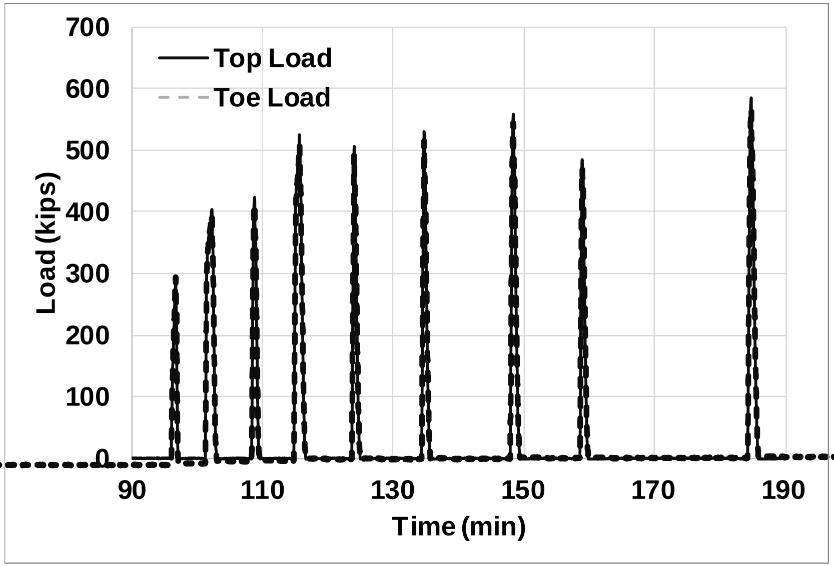
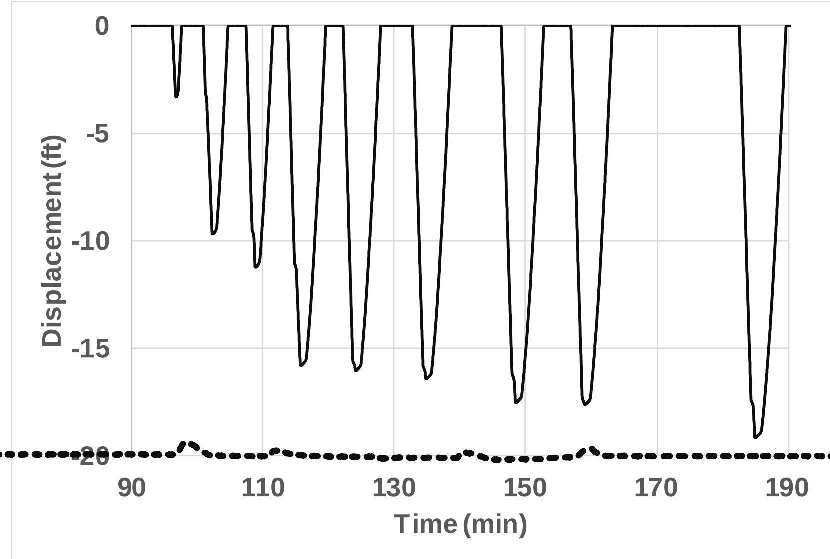
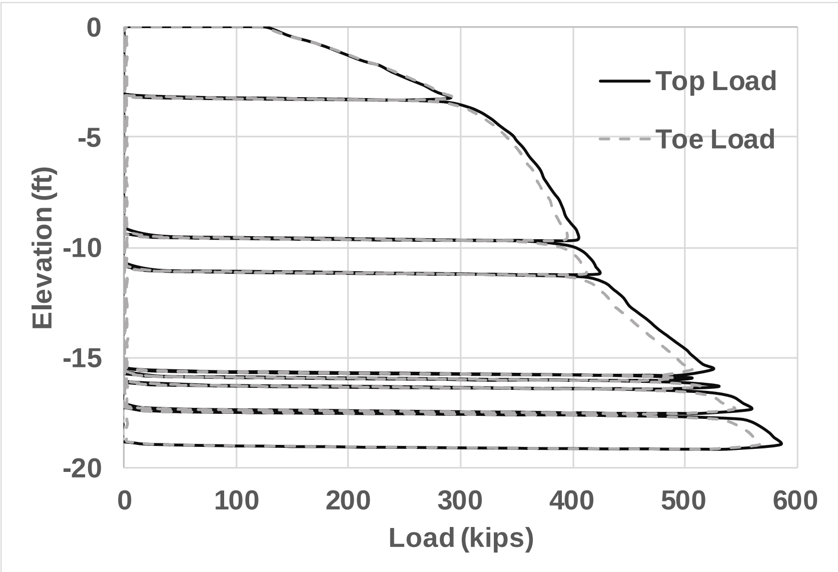
Displacement and Load-Time Histories during Pile Driving

All values are in prototype scale.

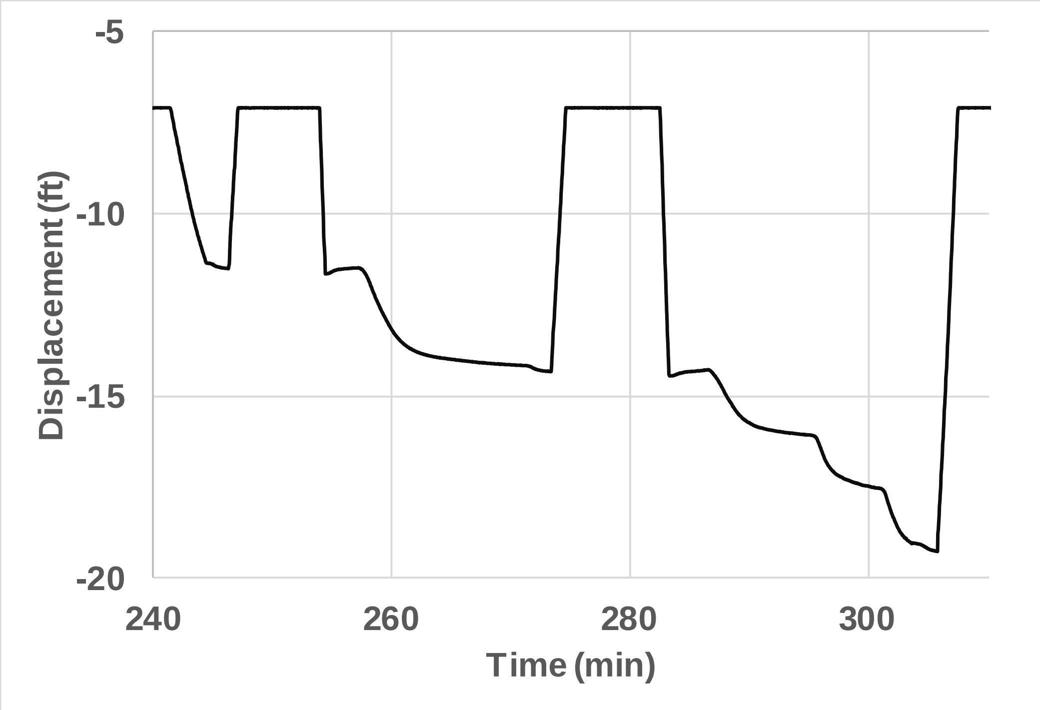






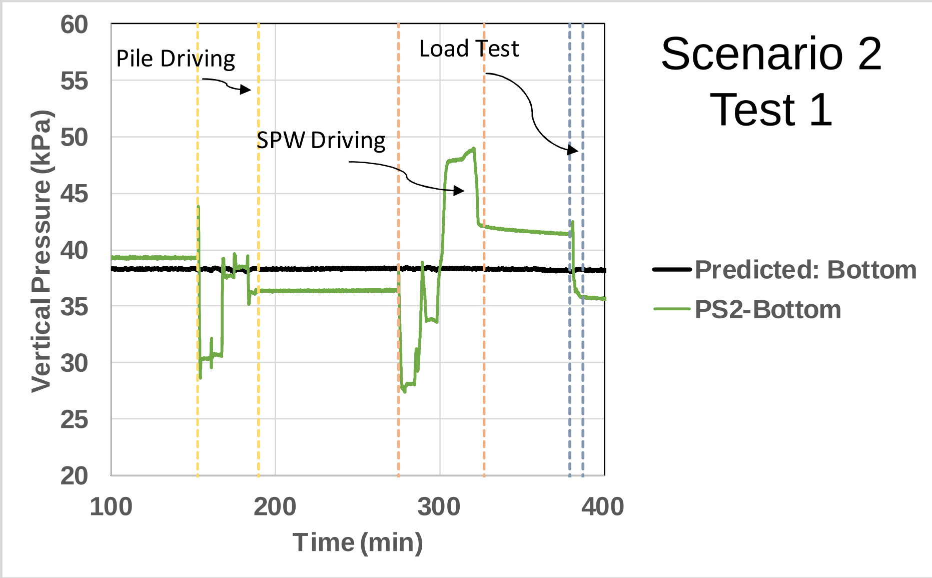
Displacement-Time History during SPW Driving

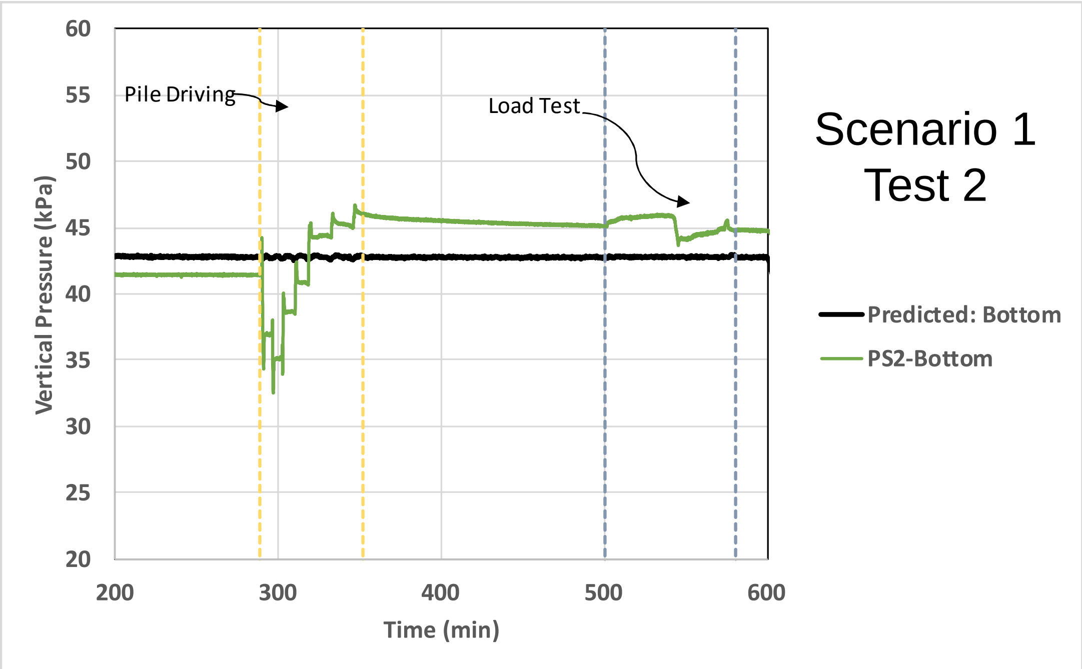
All values are in prototype scale.



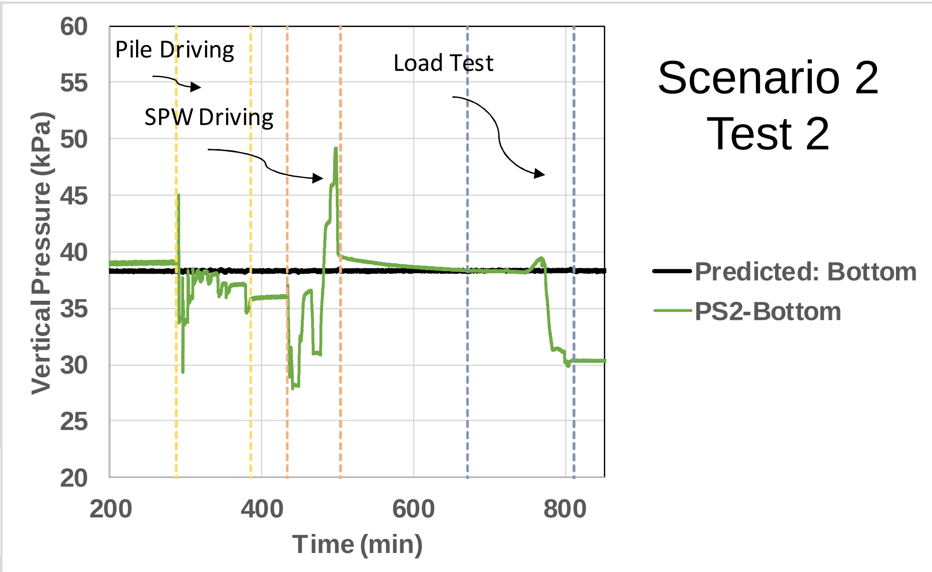
Vertical Pressure – Time History
(at 2.8D Right Side of the Pile)

Pressure sensor depth = 8 ft
Pile Driving in 5 increment: -6.2 → -8.4 → -12.7 →… →-17.8 ft





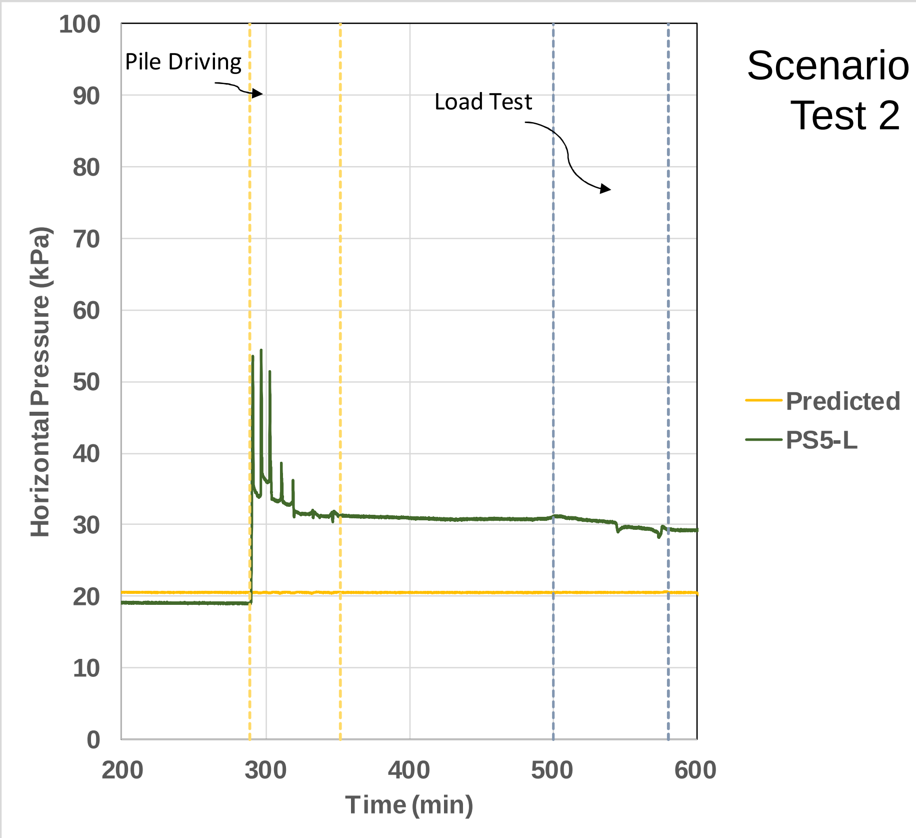
Pressure sensor depth = 8 ft
Pile Driving in 7 increment: -6.7 → -8.2 → -12.4 →… →-17.8 ft

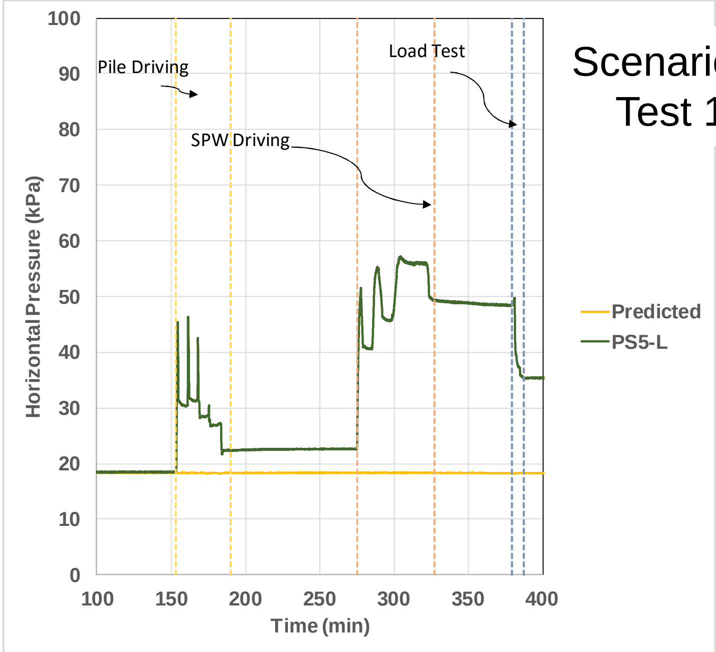


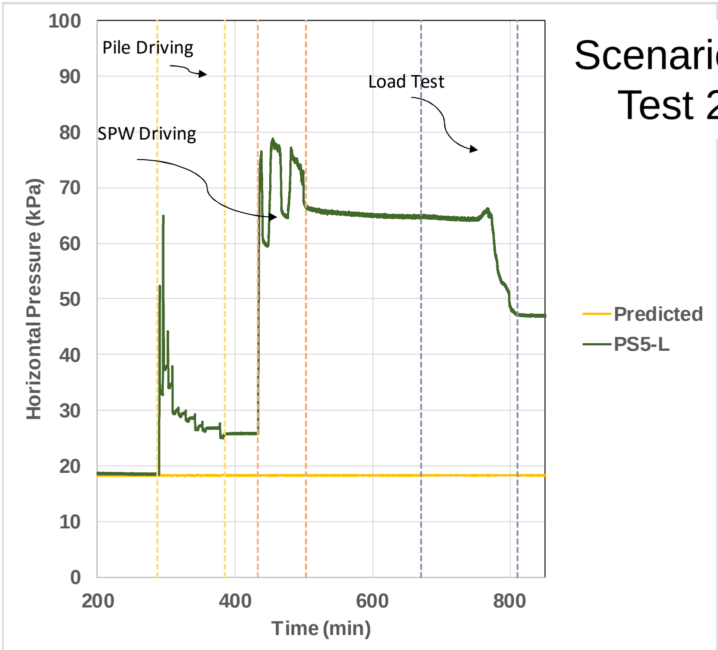
Pressure sensor depth = 8 ft
Pile Driving in 9 increments: -3.3 → -9.7 → -11.2 →… →-17.8 ft

Far-Field Horizontal Pressure – Time History

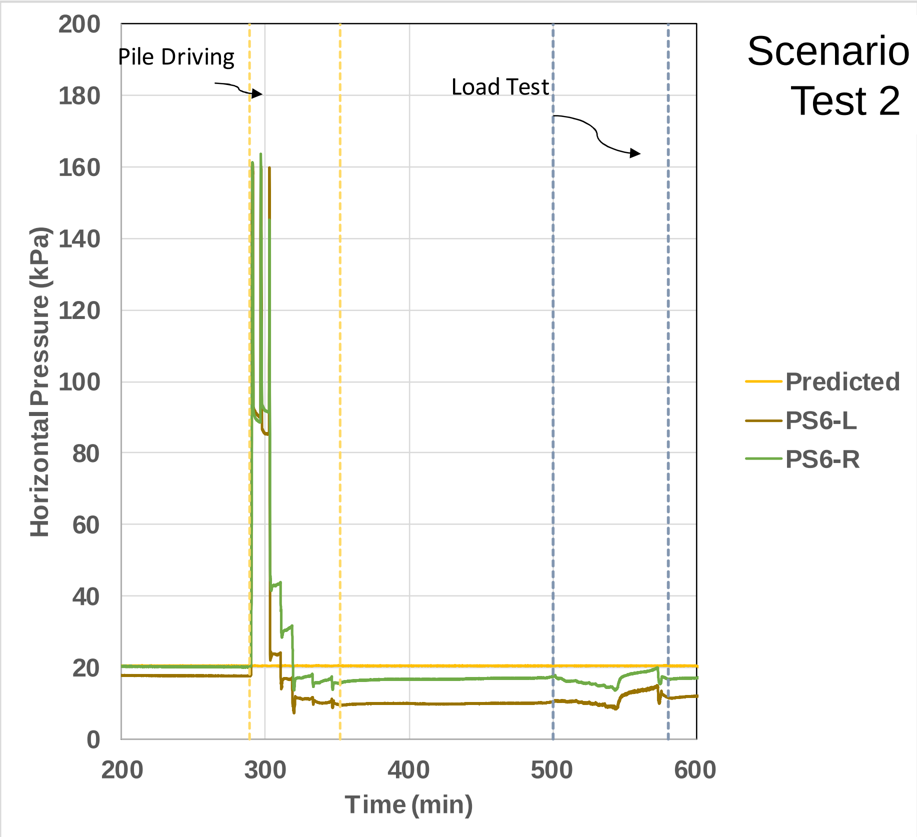
(at 5.9D Right Side of the Pile)

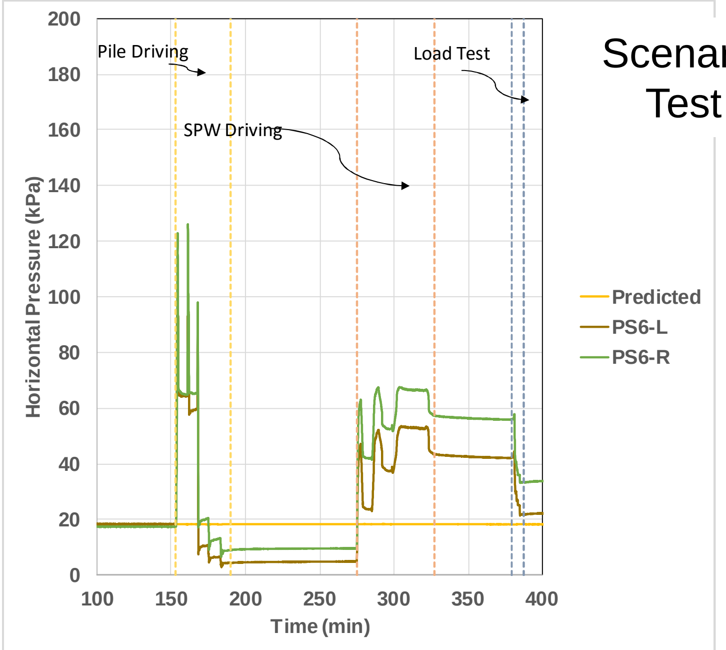


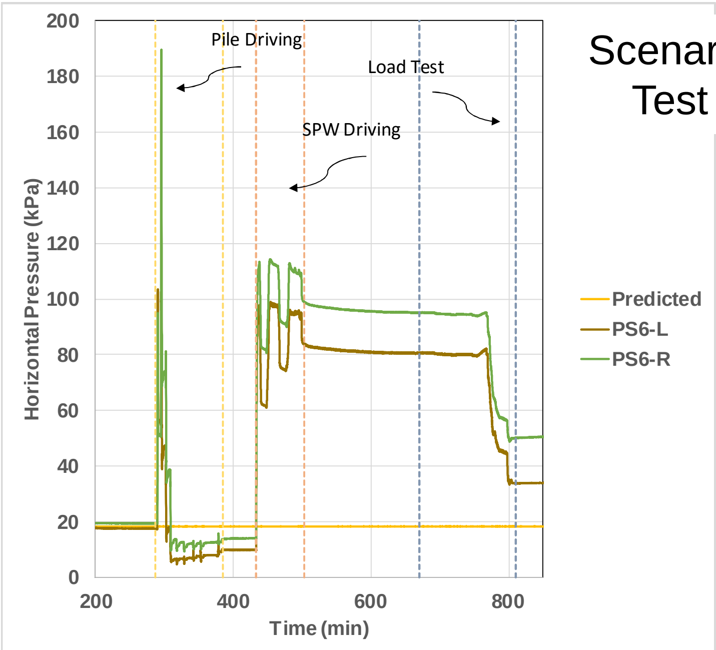




Near-Field Horizontal Pressure – Time History
(at 1.8D Right Side of the Pile)







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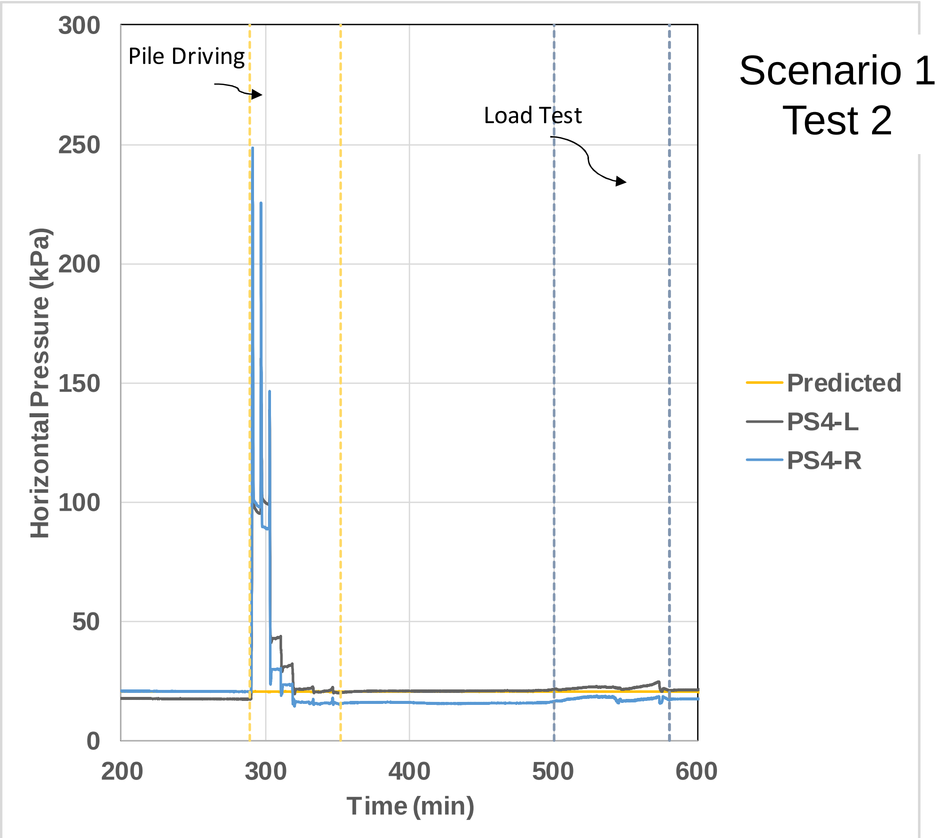
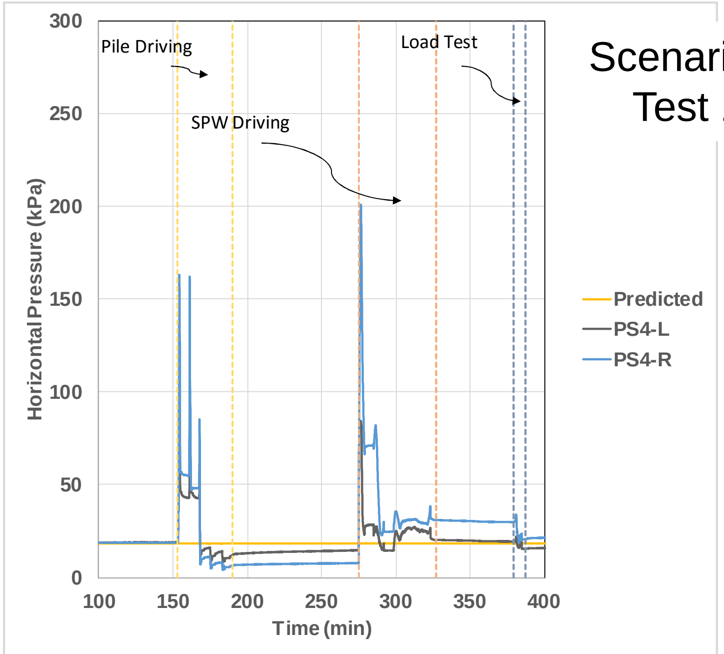
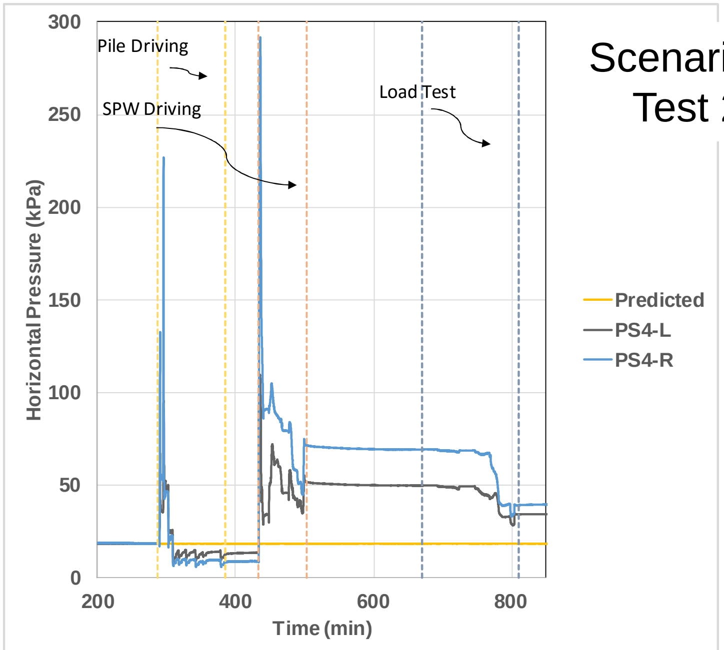
Horizontal Pressure between Pile and SPW

(at 1.8D Left Side of the Pile)







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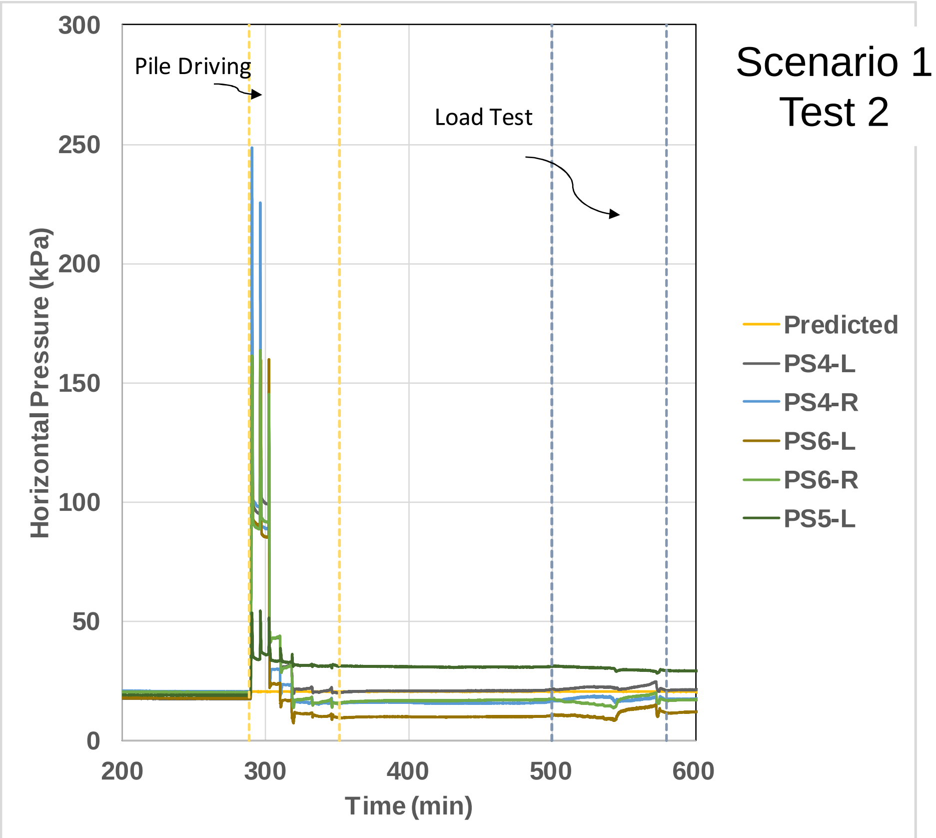
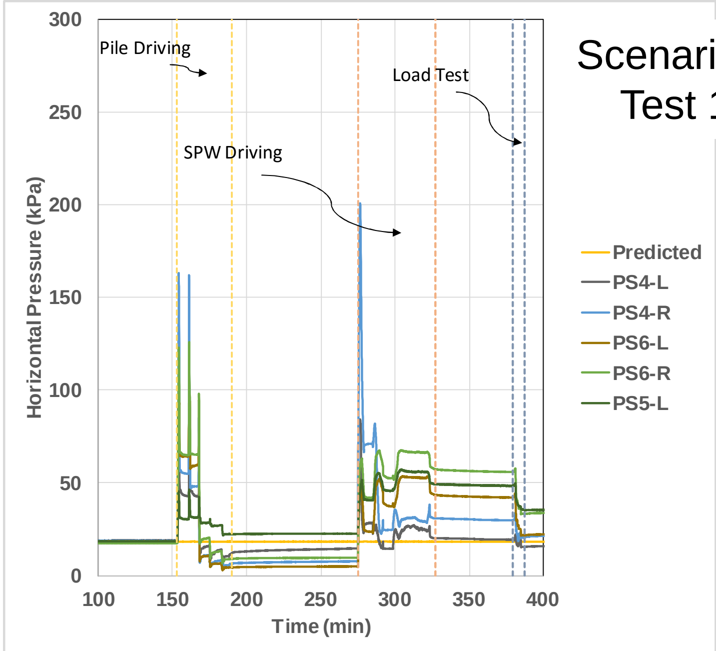
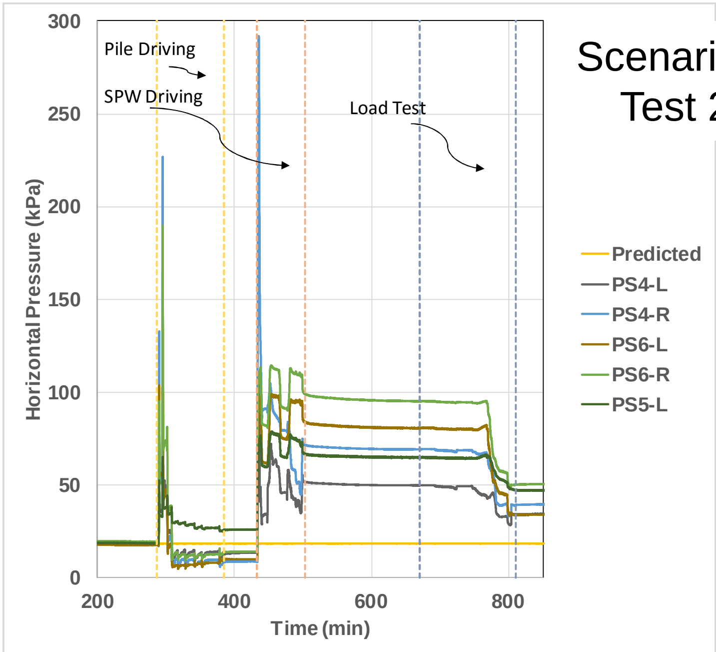
Comparative Horizontal Pressure – Time History







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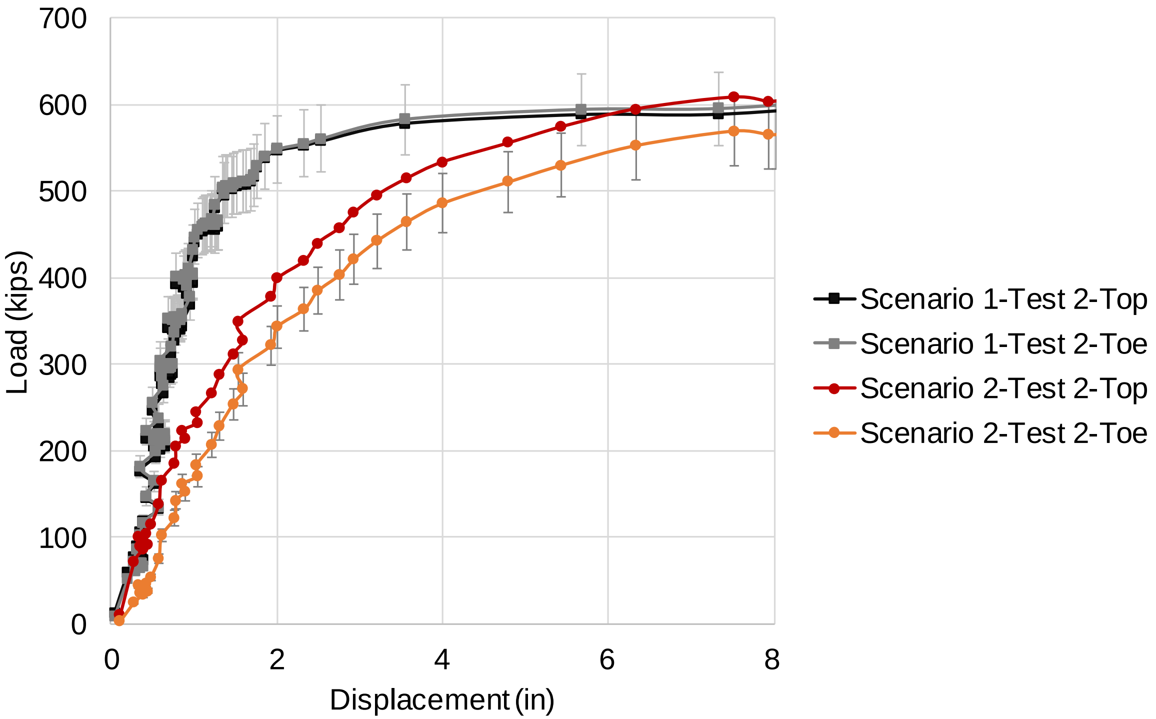
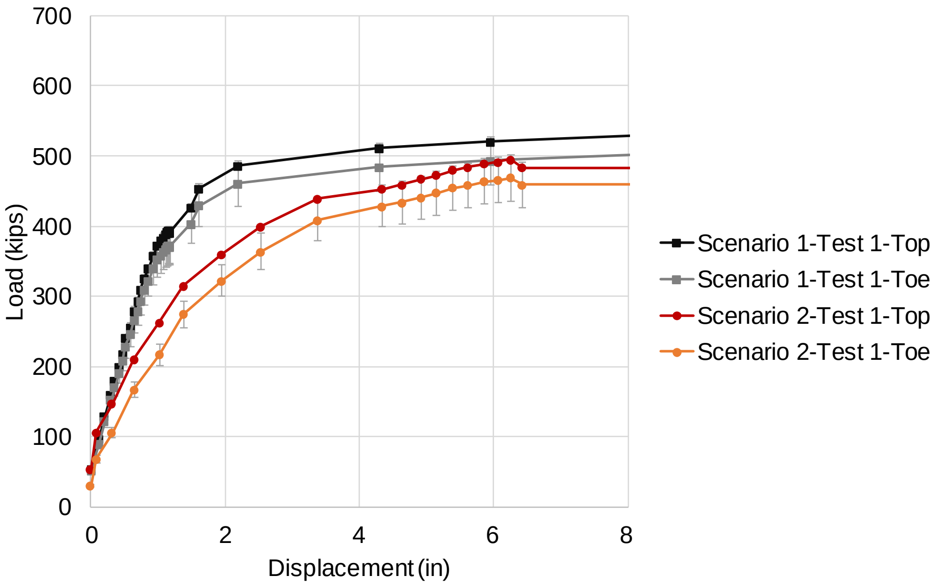
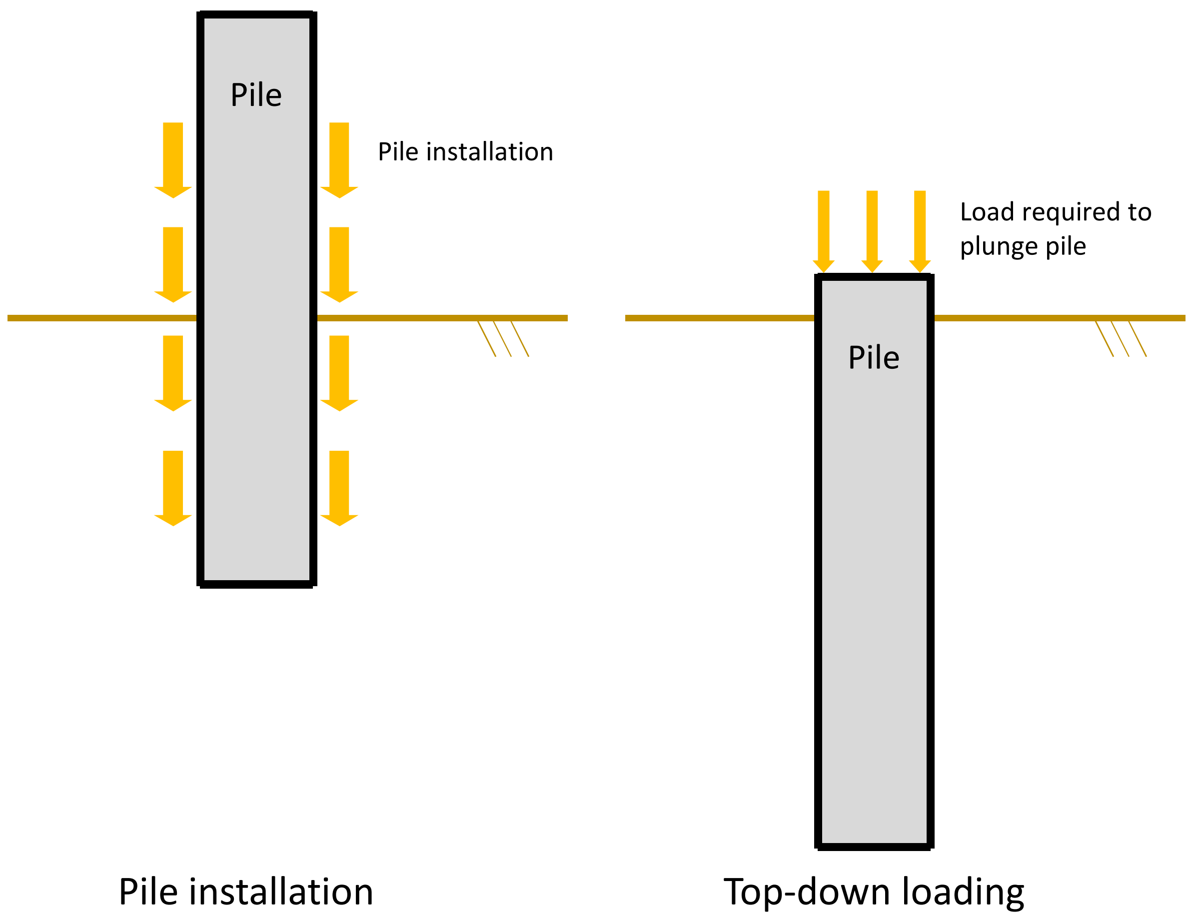
Centrifuge top-down load tests results





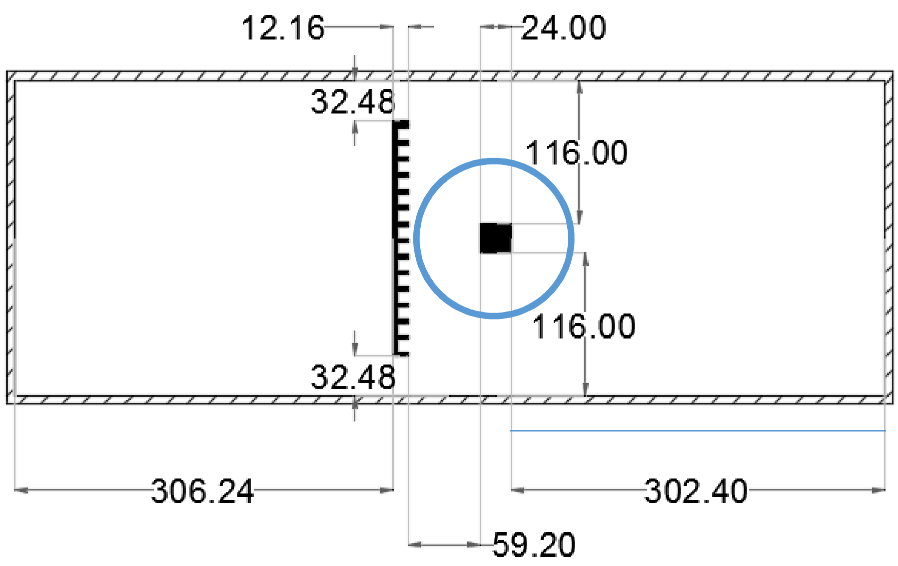
Task 3. Numerical Modeling of Driven Pile and SPW in Granular Soil

- Scenario 1: Driven pile

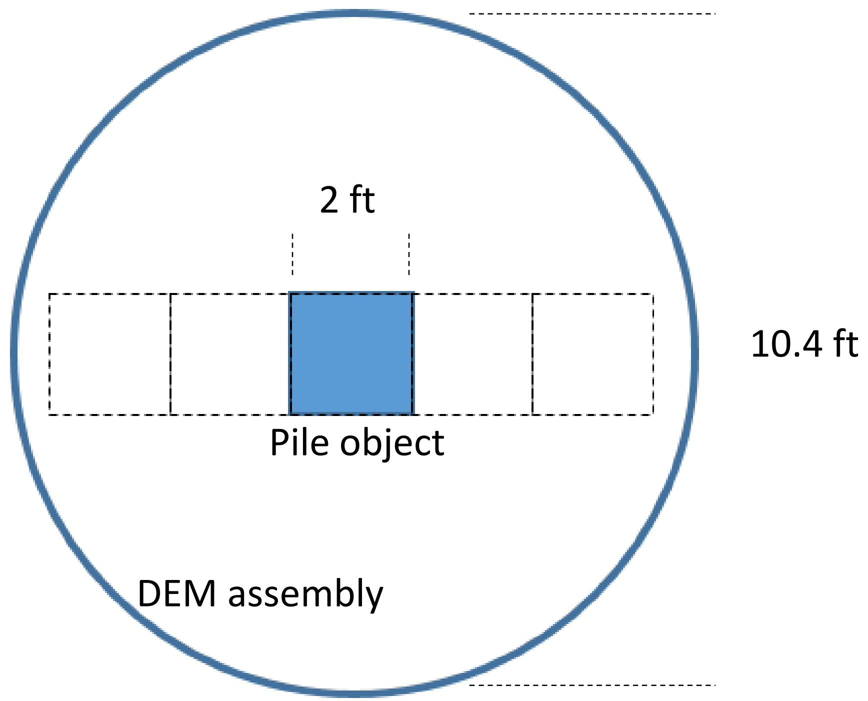


DEM-FEM Modeling of Scenario 1

- Model overview:
  - Soft-particle dynamics
  - Prototype scale (32g)



Plan view of centrifuge test setup

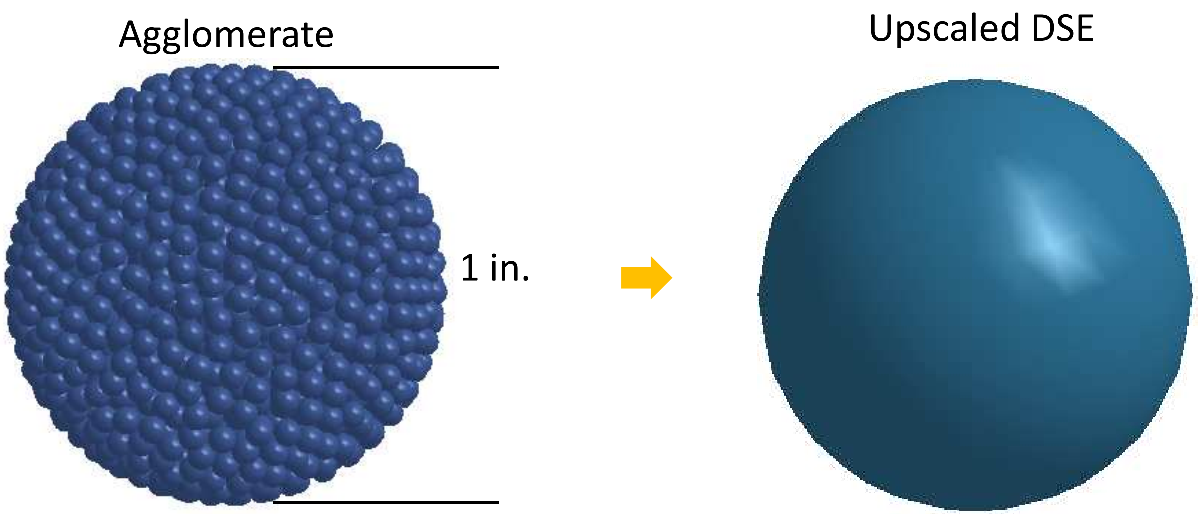


Plan view schematic of numerical model

Source for pile and sheet pile wall prototype object dimensions: Preliminary Task 3/Task 4 report, submitted Dec. 2016

Task 3. Numerical Modeling

- Mesoscale Discrete Spherical Element (MDSE)
  - Modeling DSE at grain scales is not feasible for prototype-scale domain
    - Requires 1E+09~ 1E+10 elements
    - Current limits are ~1E+07 elements
  - Averaged values of contact stiffness and friction coeff. are mapped onto the representation of upscaled DSE
  - Partitioning of continuum-scale volume (e.g., a 4x8 in. cylinder) requires mass-averaging to ensure conservation of mass as per weight and void ratio of a sample.



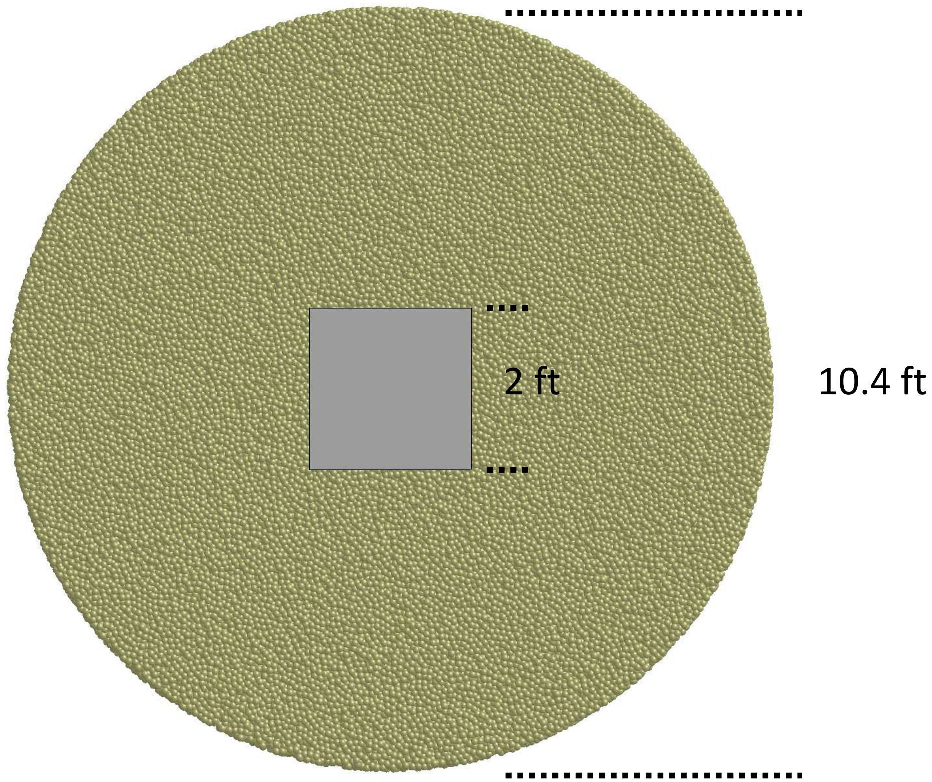
Parameters of Upscaled DSE

- Parameters of mesoscale DSE for use in pile-driving and top down load test simulations:
  - Mass density of upscaled DSE based on void ratios of medium dense sand (Dr = 58%; D_{50} = 0.32 mm; γ = 102 pcf; Yamamuro et al. 2011)
  - Model prediction indicates that the extended DEM is applicable to simulation of coarse-grained soil with phi = 30˚ - 32˚
  - Inter-granular sliding and rolling friction coefficients are parameters to simulate various shear strengths of macro-volumes.
  - Low restitution: constituent particle coulombic damping is prevalent.

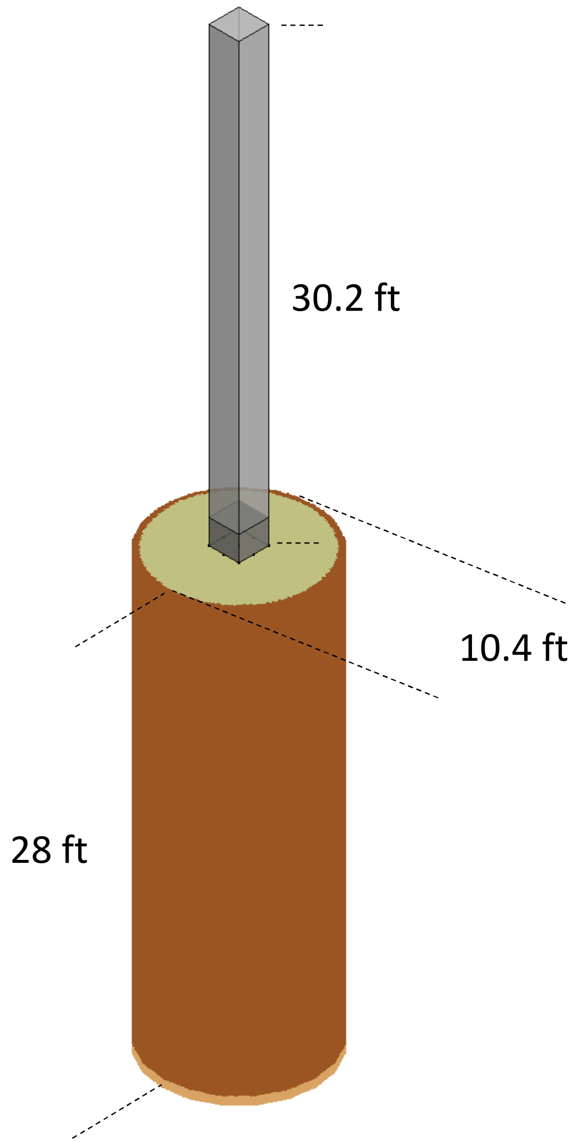
Property	Value	Unit
Diameter	1.0	in
Density (by weight)	101	lb/ft^3
Bulk modulus	24	ksi
Inter-granular friction coefficient	0.47	- -
Coefficient of restitution	0.001	- -

DEM-FEM Modeling of Scenario 1

- Model overview:
  - Soft-particle dynamics
  - Bulk unit weight: 101 pcf



Plan view of aluminum pile

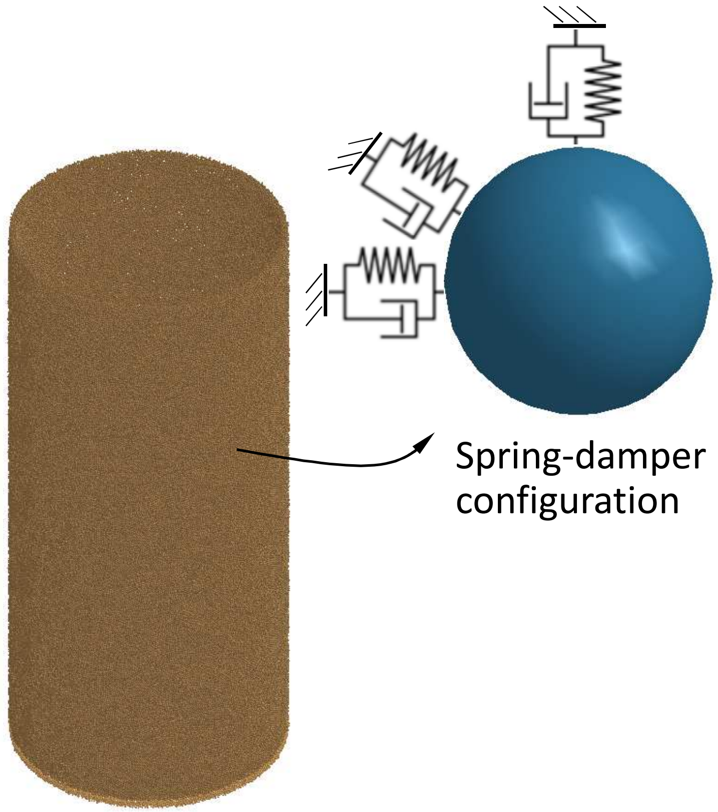


DEM-FEM model

Source for pile and sheet pile wall prototype object dimensions: Preliminary Task 3/Task 4 report, submitted Dec. 2016

DEM-FEM Modeling of Scenario 1

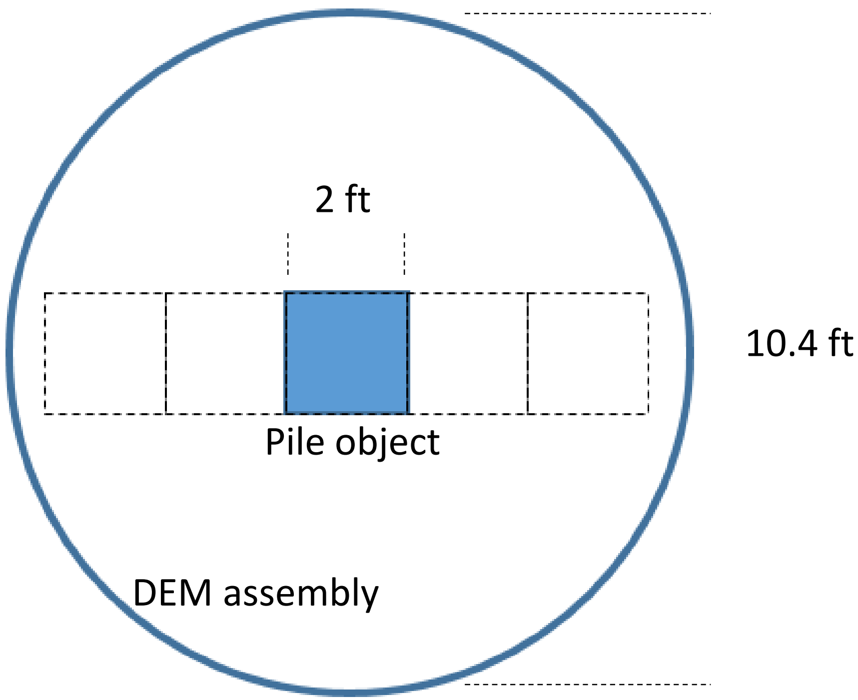
- Boundary conditions:
  - Network of boundary spheres
    - Sides
    - Bottom
  - Confining Pressure
    - Maintains horizontal/vertical stresses
    - Incorporated as spring initial offsets
  - Spring-damper
    - Each translation DOF
    - Spring stiffness tributary to confinement
    - Dampers match sphere-sphere contact



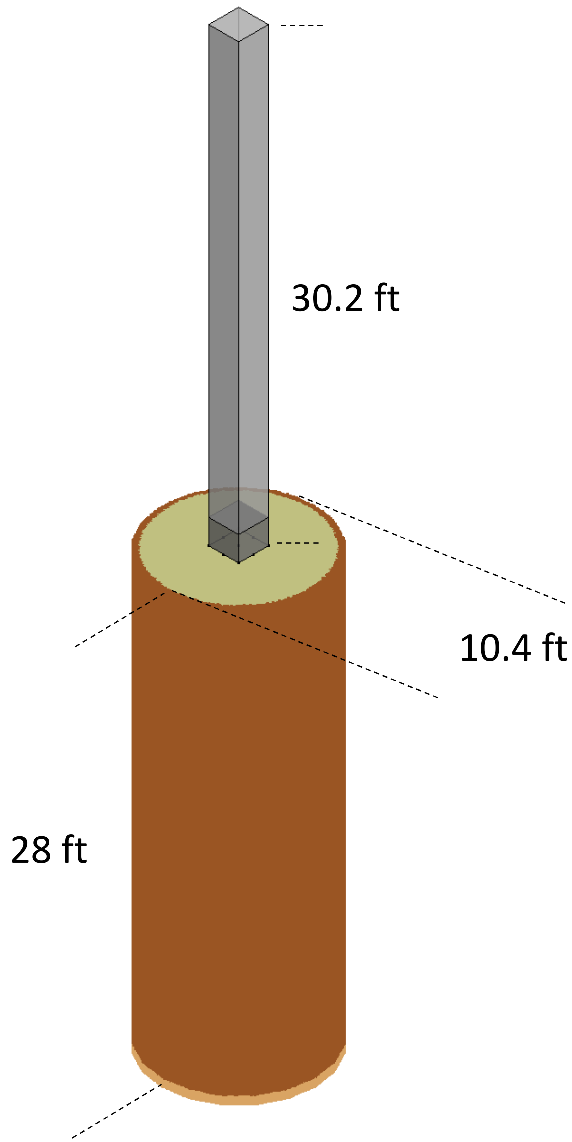
Boundary condition modeling

DEM-FEM Modeling of Scenario 1

- Model overview:
  - Soft-particle dynamics
  - Cylindrical configuration
    - ~4.8 million spheres (1 in. diameter)
    - Est. 7 days simulation



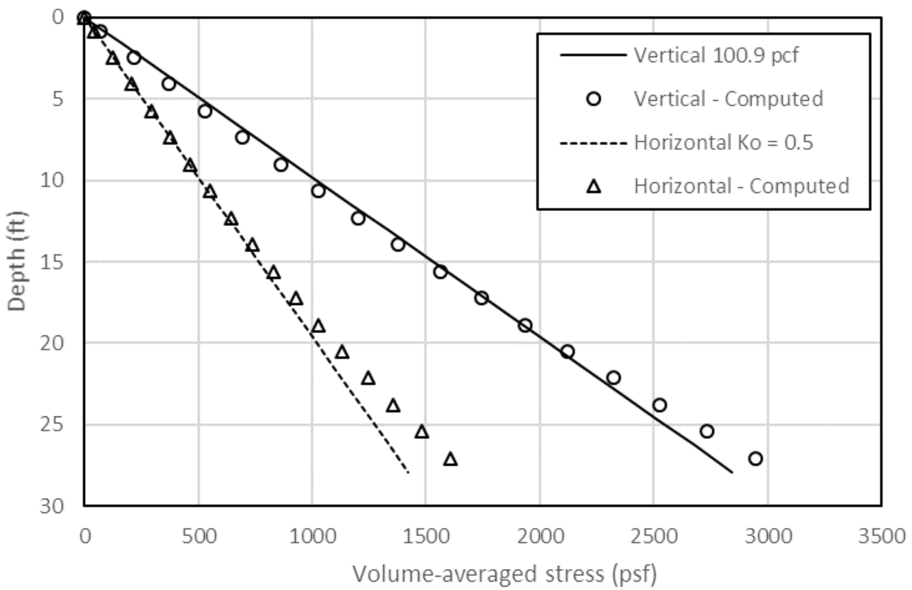
Plan view schematic of numerical model



DEM-FEM model

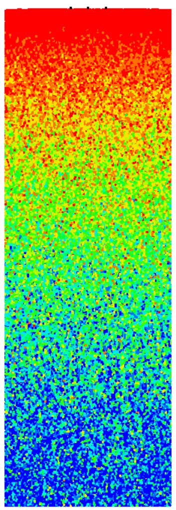
DEM-FEM Modeling of Scenario 1

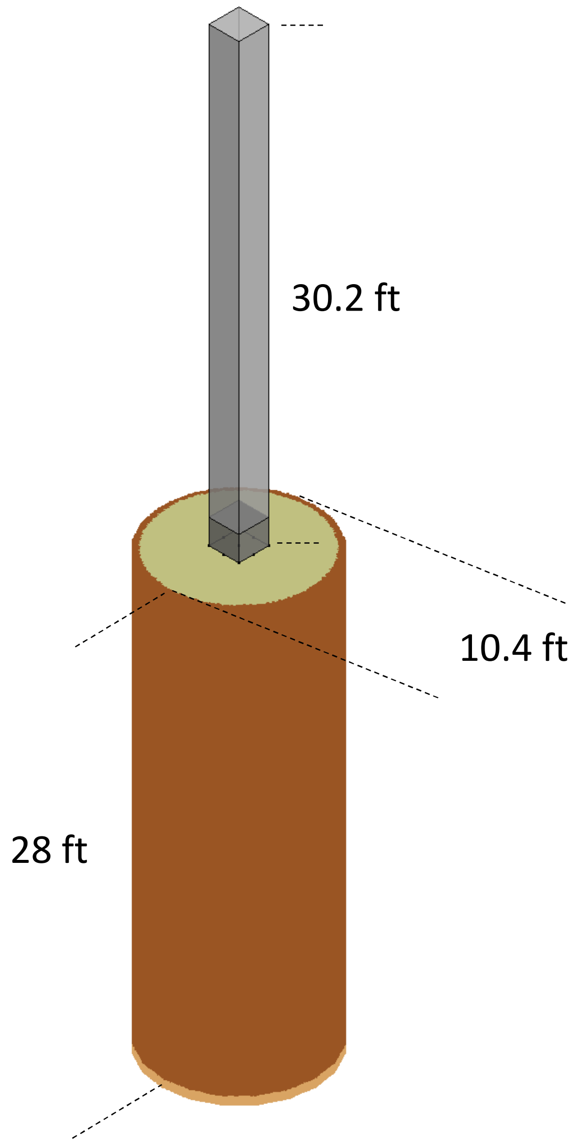
- Simulation stage 1:
  - Gravity acting on DEM assembly
  - Geostatic stresses consistent with physical tests
  - K_o = 0.5 -> Phi ~ 30˚



Geostatic stresses for DEM assembly under gravity

Z stress
RED -> 0 psf
BLUE -> 4200 psf

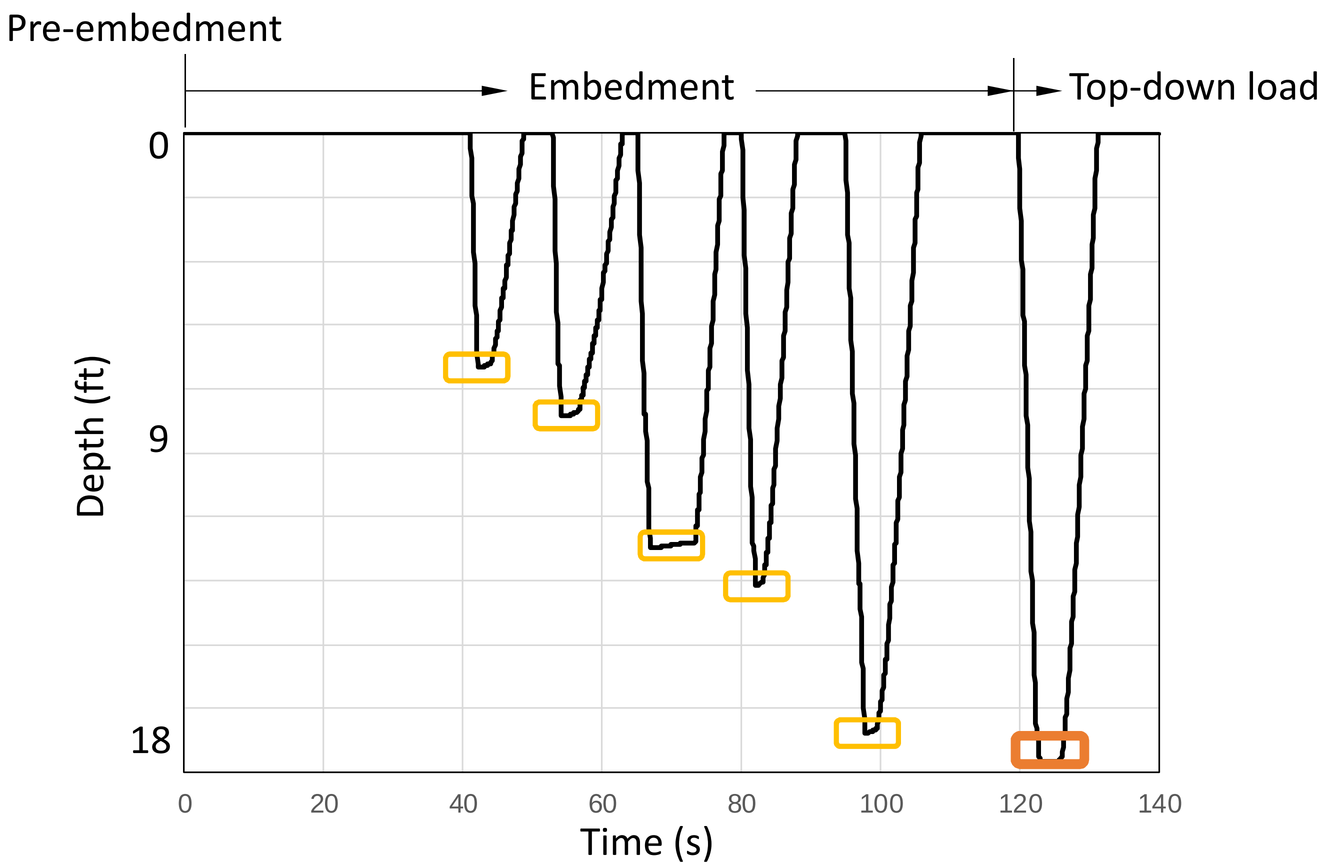




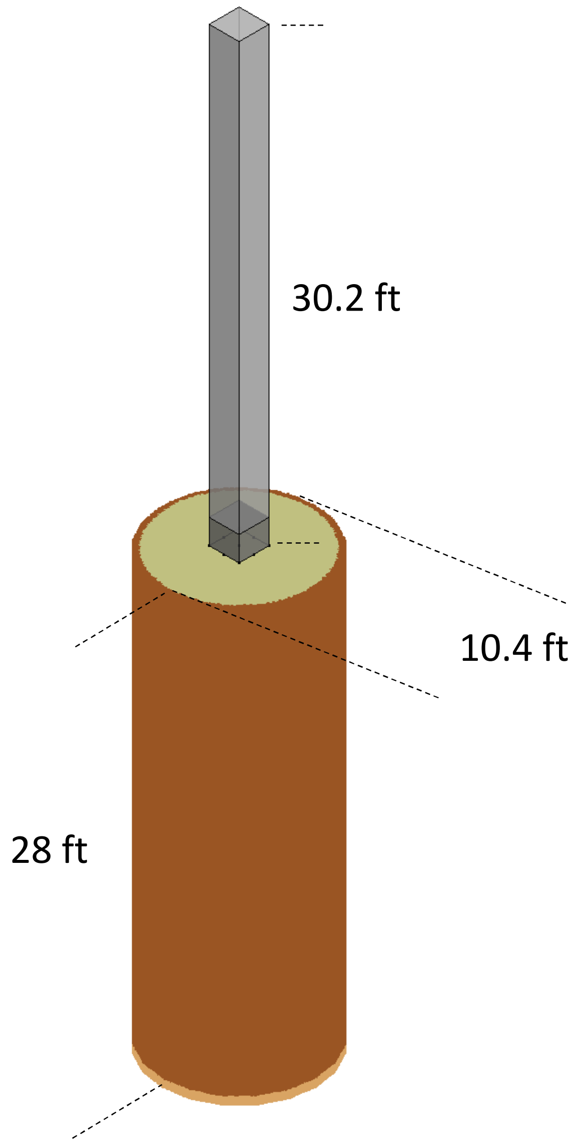
DEM-FEM model

DEM-FEM Modeling of Scenario 1

- Simulation stage 2:
  - Driving sequence based on physical test



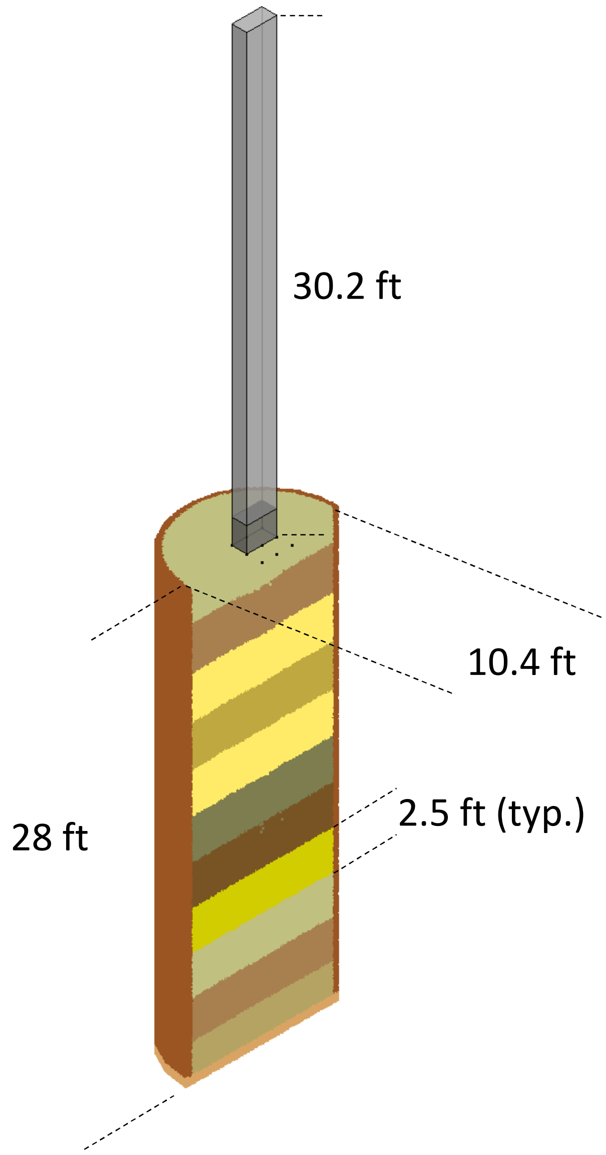
Physical centrifuge test (6 step sequence)



DEM-FEM model

DEM-FEM Modeling of Scenario 1

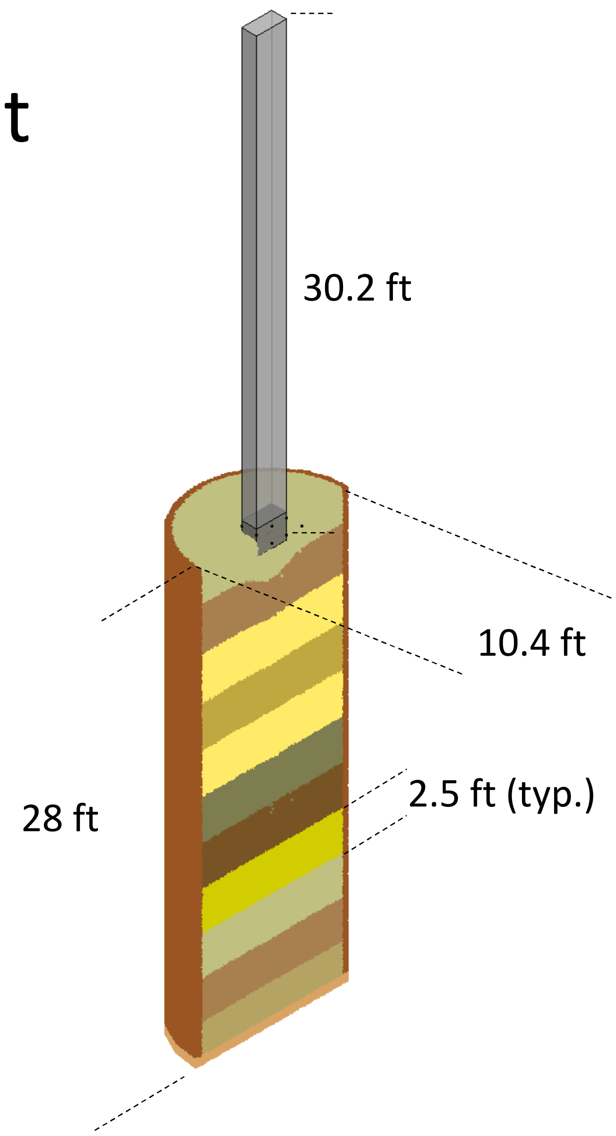
- Start of Stage 2
  - Pile tip depth:
    - 0 ft



Interior DEM assembly (elevation cutaway)

DEM-FEM Modeling of Scenario 1

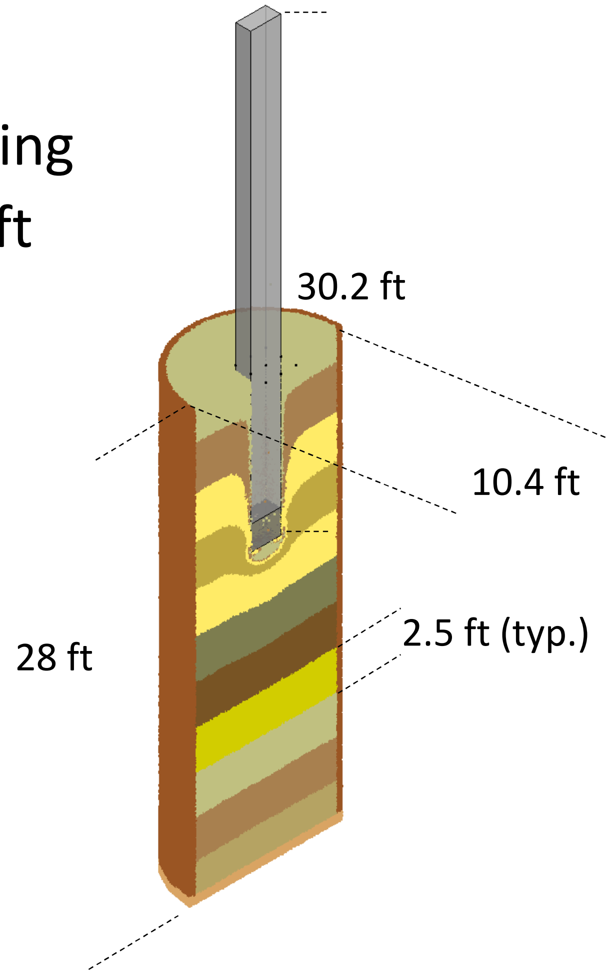
- Pre-embedment
  - Pile tip depth:
    - 1.3 ft



Interior DEM assembly (elevation cutaway)

DEM-FEM Modeling of Scenario 1

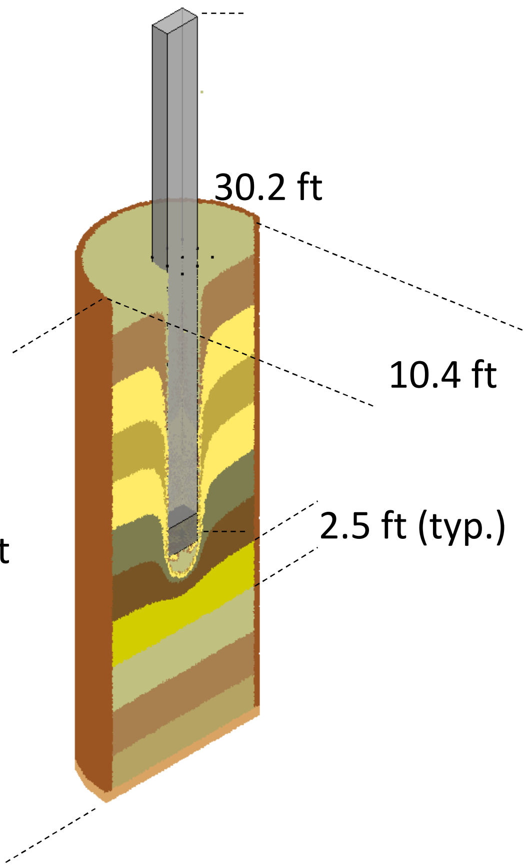
- Driving
  - Pile tip depth:
    - Matched staging
    - 1.3 ft to 17.8 ft



Interior DEM assembly (elevation cutaway)

DEM-FEM Modeling of Scenario 1

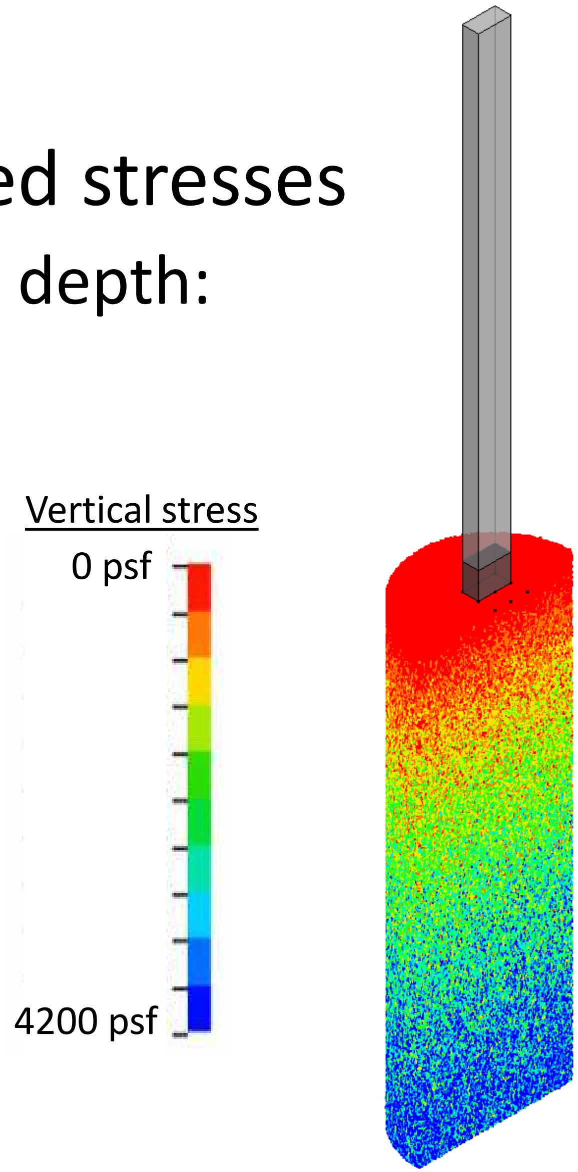
- Driving
  - Pile tip depth:
    - Matched staging
    - 1.3 ft to 17.8 ft

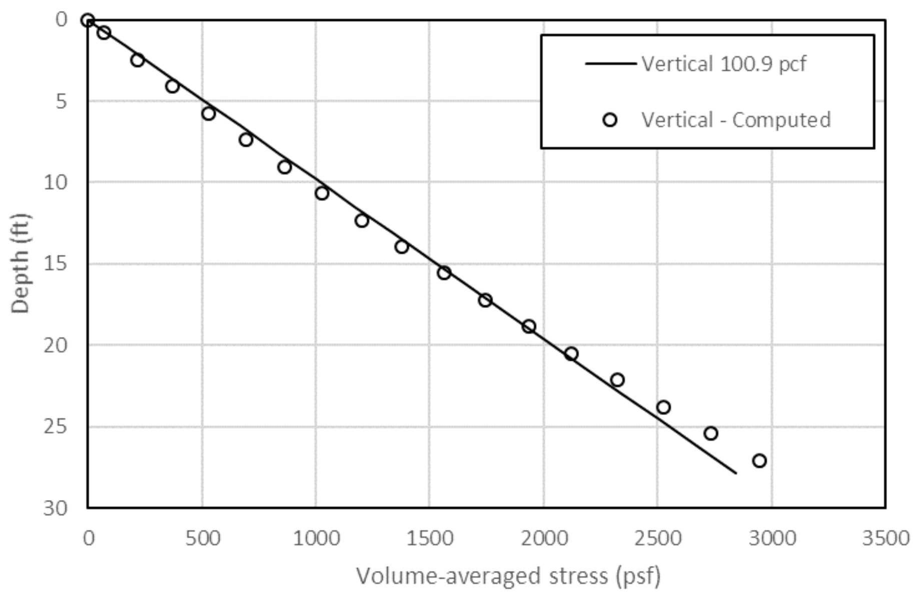


Interior DEM assembly (elevation cutaway)

DEM-FEM Modeling of Scenario 1

- Computed stresses
  - Pile tip depth:
    - 0 ft



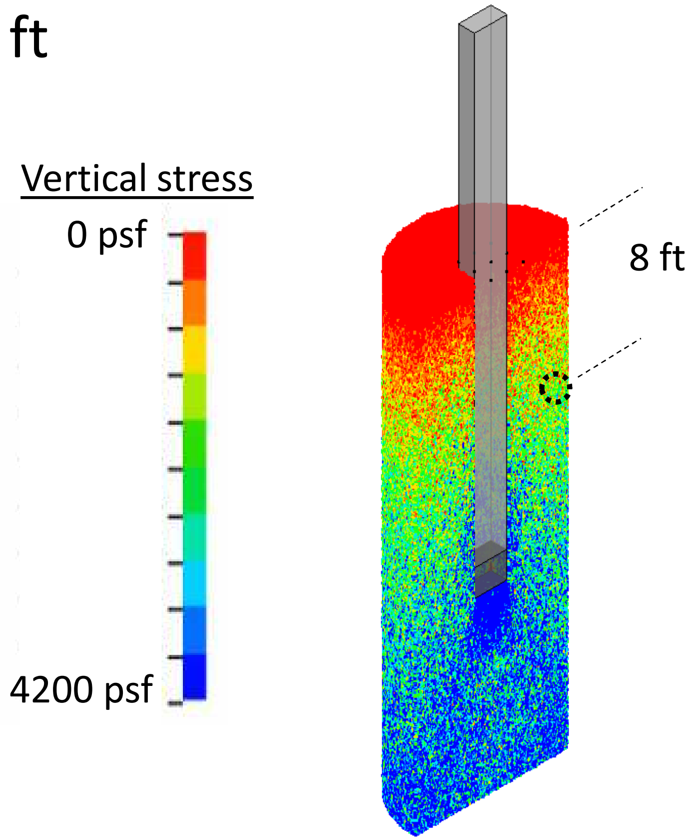


Interior DEM assembly (elevation cutaway)

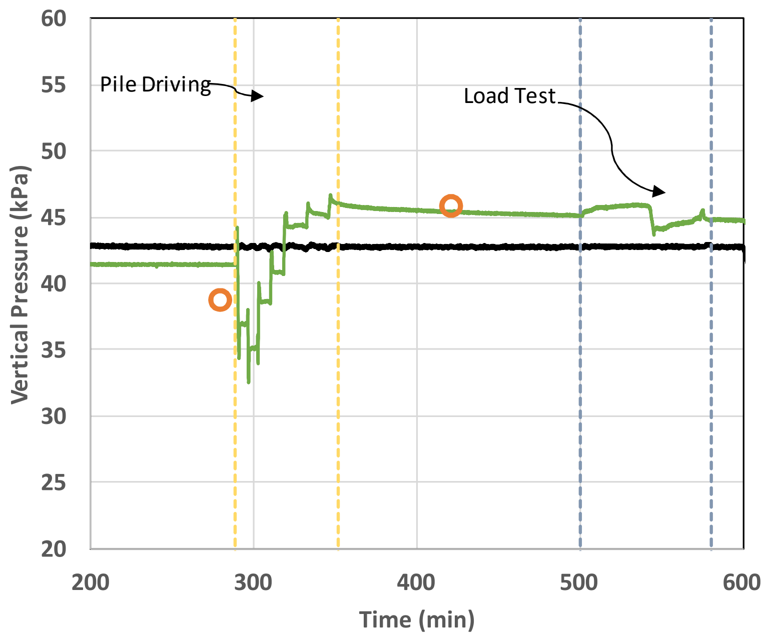
DEM-FEM Modeling of Scenario 1

- Computed stresses
  - Pile tip depth:
    - 17.8 ft

Computed vertical stress 800 psf to 960 psf
Measured vertical stress 877 psf to 940 psf

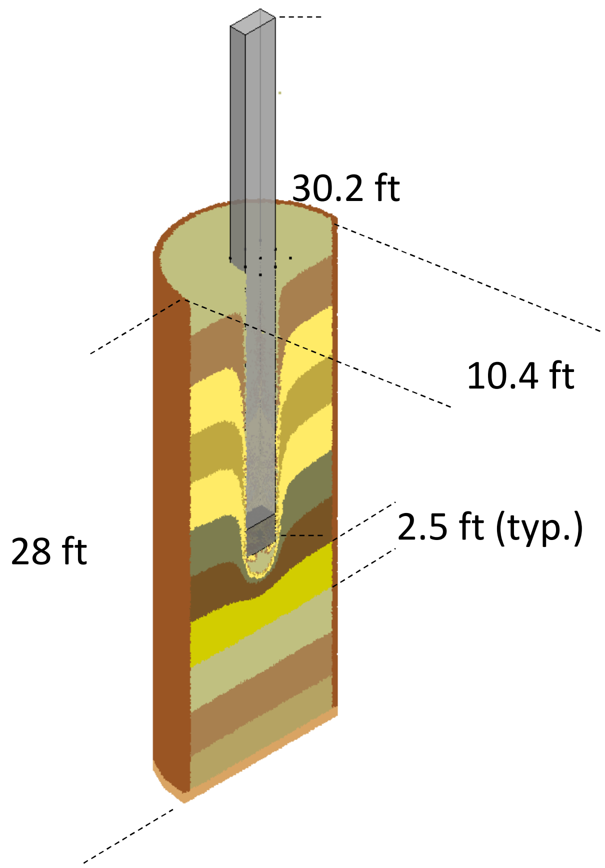


Interior DEM assembly (elevation cutaway)

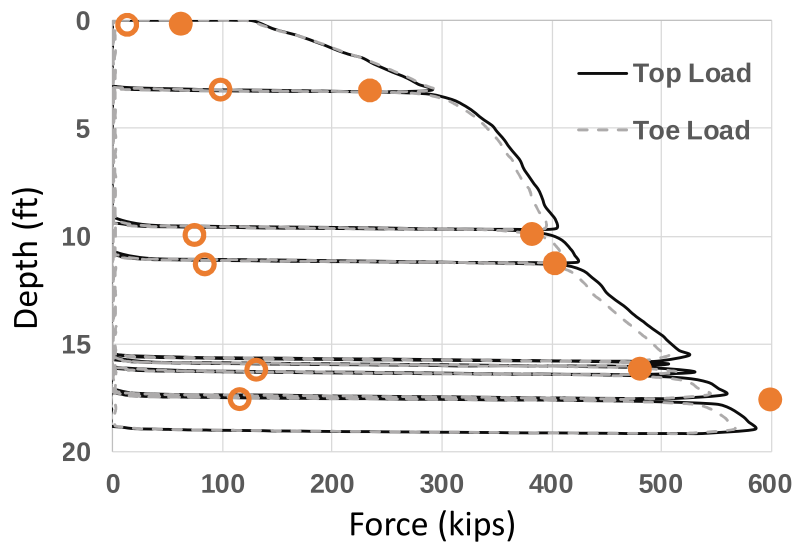


DEM-FEM Modeling of Scenario 1

- Preliminary load results during driving



Interior DEM assembly (elevation cutaway)



Measured vs computed envelopes

Task 3. Numerical Modeling

- Next steps
  - Scenario 1: Perform top-down load test simulations and compare to physical test results
    (August - September 2017)
  - Scenarios 2-3: Incorporate SPW installation and removal into simulations
    (October - December 2017)

Thank you.

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