Instrumentation of Steel Sheet Pile Wall and Steep Cut Slopes in Piedmont Residual Soils for Research

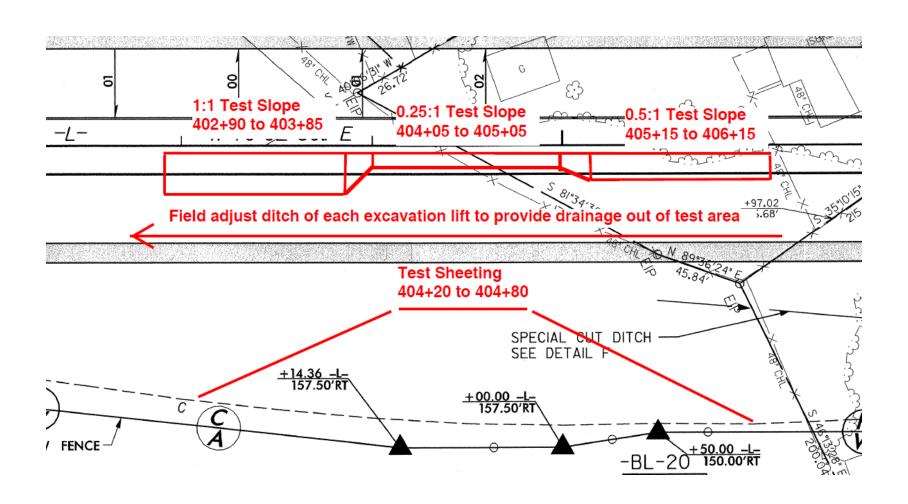
Michael Valiquette – ICE of Carolinas
Jungmok Lee – Subsurface Construction
Roy Borden – North Carolina State University
Mohammed Gabr – North Carolina State University

April 11, 2017

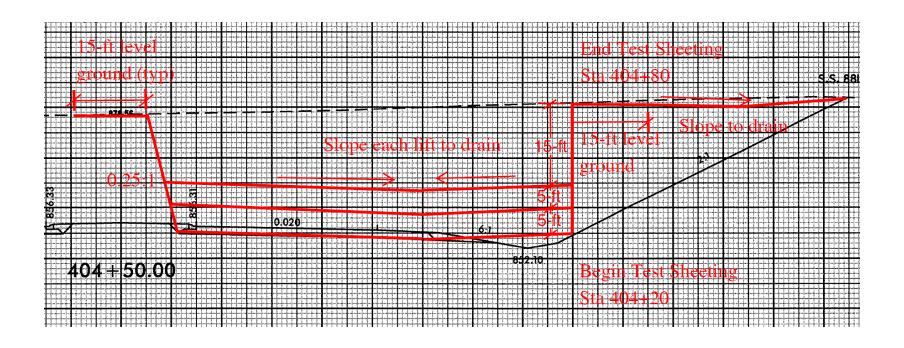
Location of Test Site



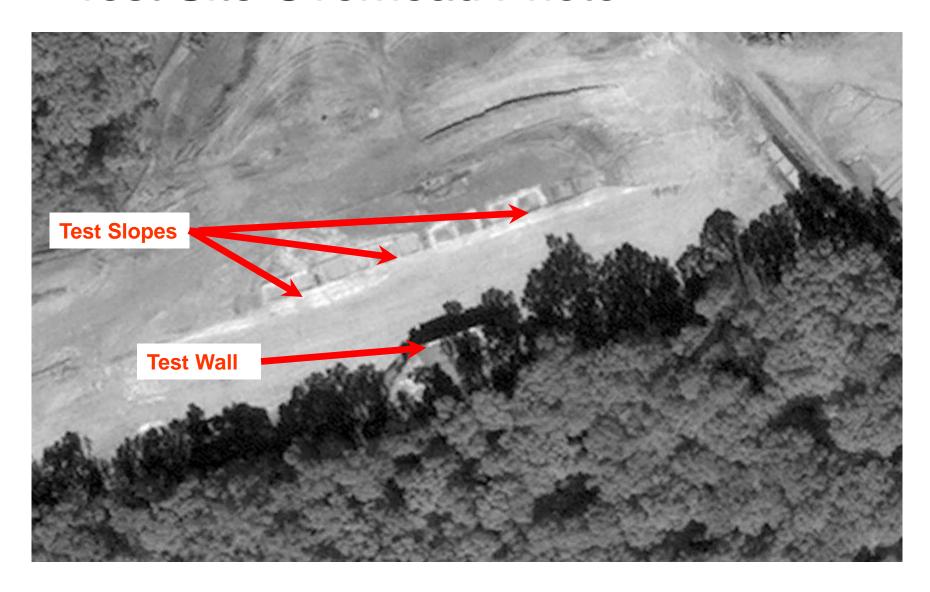
Test Site Plan View



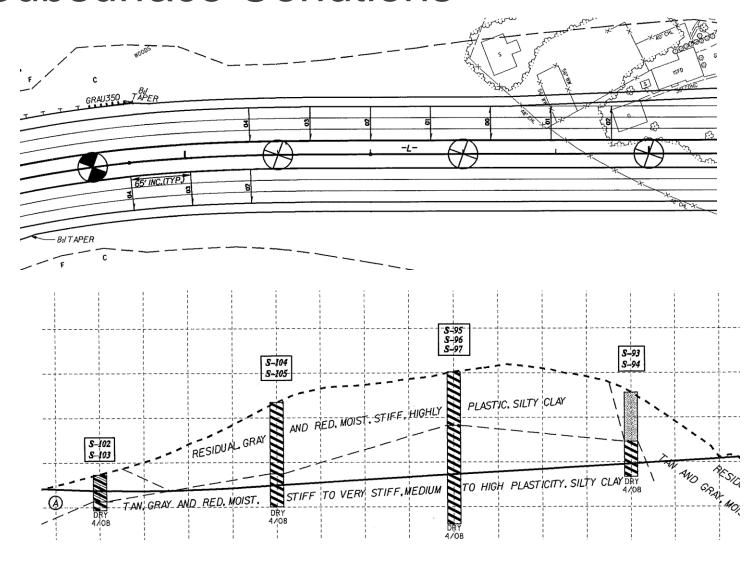
Test Site Cross-Section



Test Site Overhead Photo



Subsurface Condtions



Additional Subsurface Investigation



Additional Subsurface Investigations

Test Slope 1



Test Slope 2



Test Slope 3







CPT, DMT, SPT Pressuremeter Triaxial Consolidation

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## Additional Subsurface Investigations



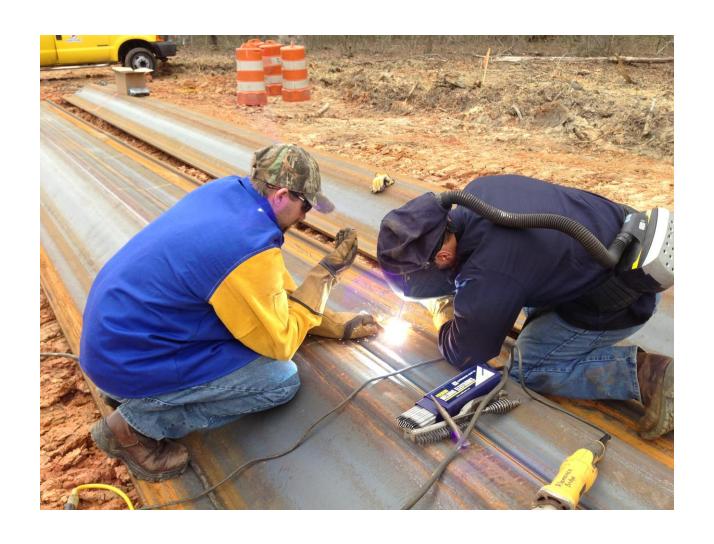
### Soil Suction Measurements



# Sheet Piling, PZC-13



## Strain Gauge Installation

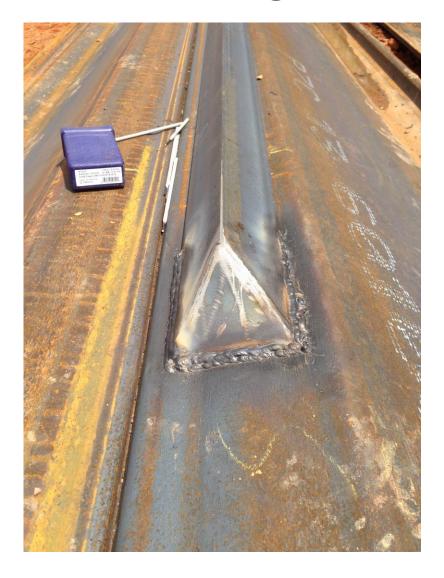


# Strain Gauge Installation





## Strain Gauge Cover Angles





## Strain Gauge Cover Angles





## Sheet Pile Vibratory Refusal, Advanced to tip with Diesel Hammer



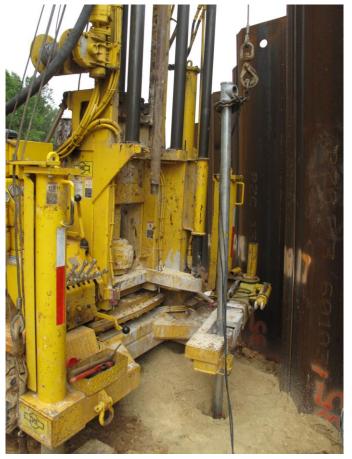
### Push in Pressure Cells





### Push in Pressure Cells





### In situ Instrumentation





### In situ Instrumentation



## In situ Instrumentation, Moisture Sensor



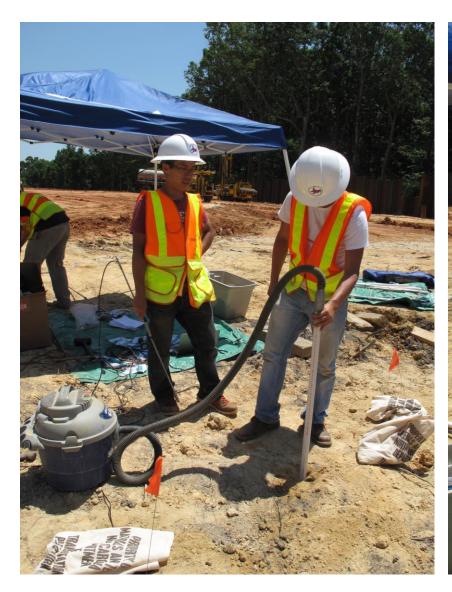


### In situ Instrumentation, Suction Sensors





### In situ Instrumentation, Suction Sensors





## In situ Instrumentation, Suction Sensors





## Initial Excavation Stage



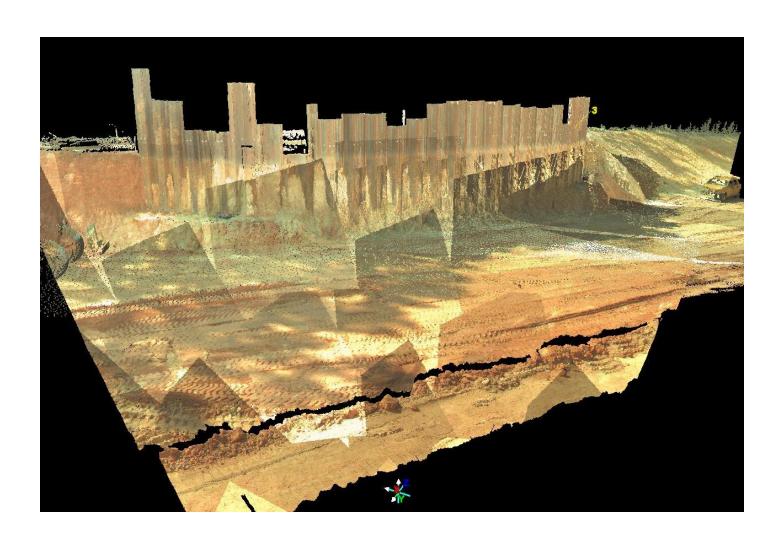
## Initial Excavation Stage



## LiDAR Scanning



## LiDAR Scanning



### **Infiltration Ponds**



# Full Height Excavation



## Full Height Excavation



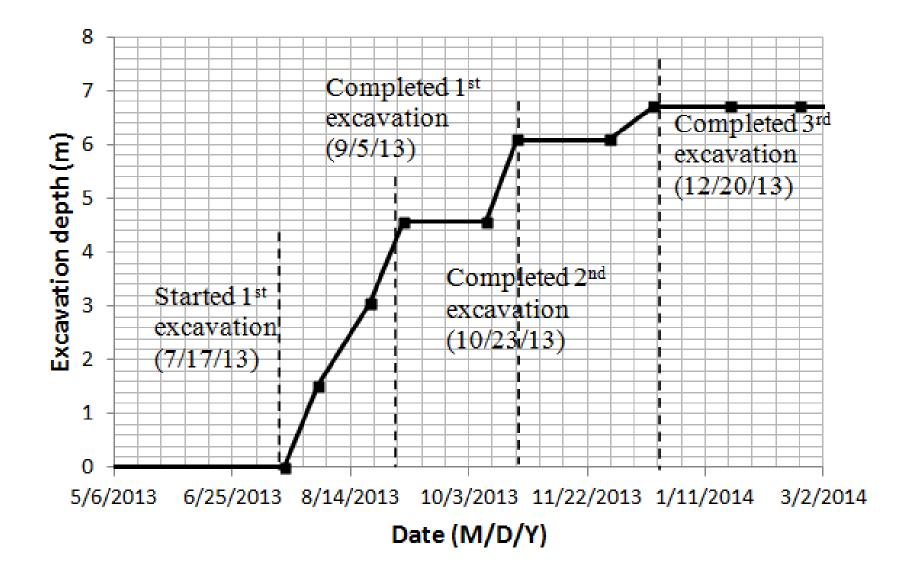
# Full Height Excavation



#### Picture of field site after 6.7 m excavation



### Excavation depths over time



#### Classification of test site soils

Soil 1	Soil 2		
2.75	2.74		
35	58		
7	21		
58	88		
A-4	A-7-5		
ML	MH		
	2.75 35 7 58 A-4		

By Wang (2014)

Effective strength parameter (By Tang, 2014)

• A-7-5 soil :  $\phi'$ = 27° and c'=10 kPa

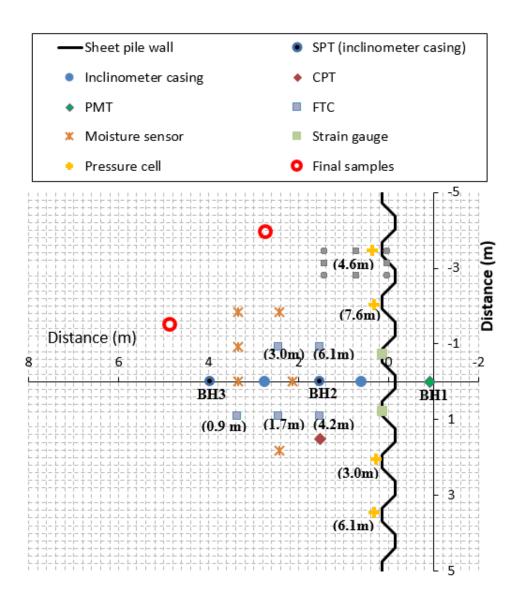
• A-4 soil :  $\phi'$ = 30° without effective cohesion

Saturated permeability (Ks)

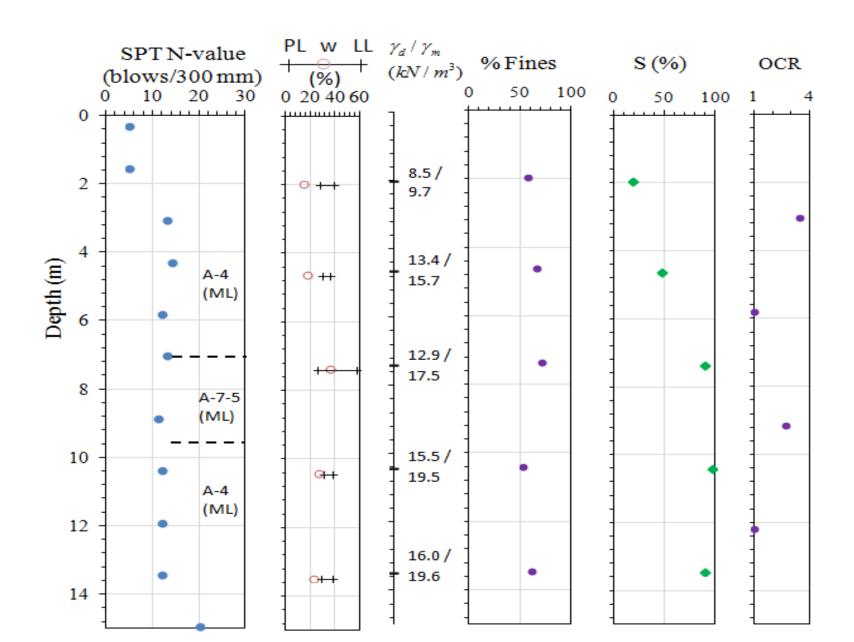
•A-7-5 soil : 3.15 x 10^-5 cm/s

•A-4 soil : 5.9 x 10^-5 cm/s

#### Location of instruments at sheet pile wall area

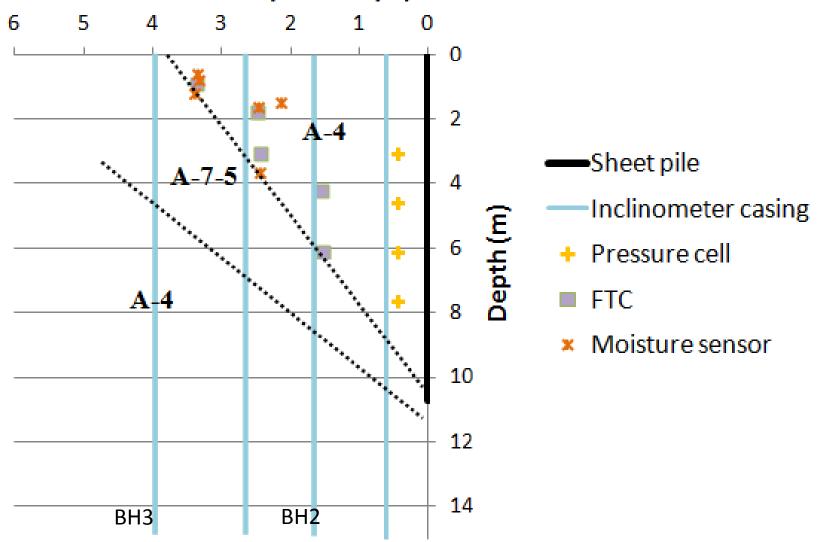


## Soil characteristic profiles (BH 2)

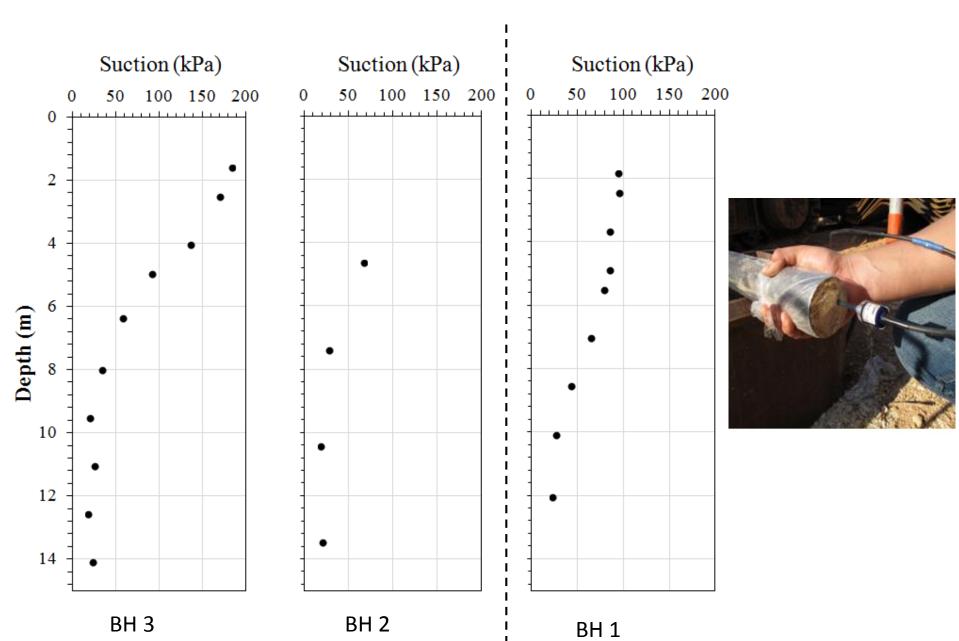


### Cross-section of test site

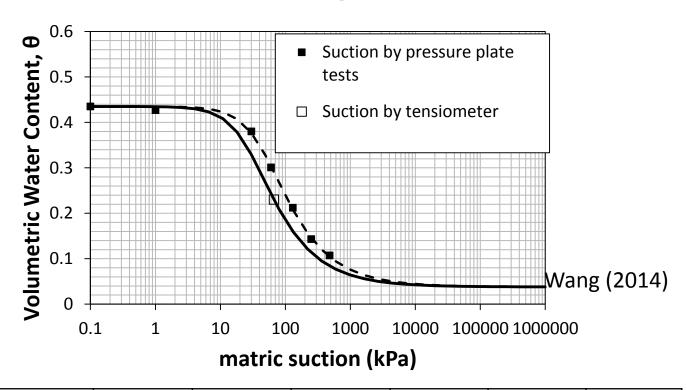




## Initial suction profiles

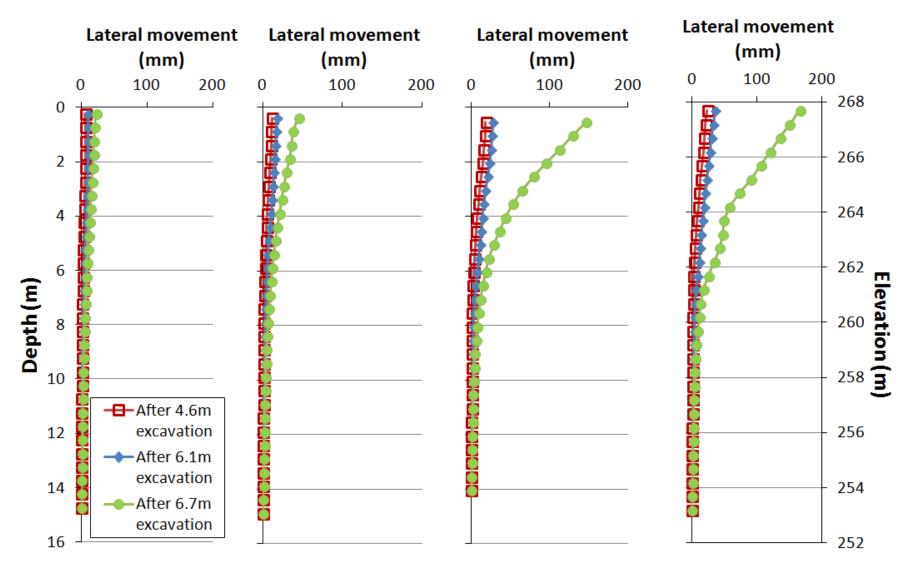


## Field SWCC for sheet pile wall area



Sample	Depth	Soil	Д	$\theta_r$	a	<b>n</b>	m
Location	(m)	type	$ heta_s$	$O_r$	(1/kPa)	n	
	4.5	A-4	0.435	0.038	0.034	1.771	0.435
BH2	10.4	A-4	0.509	0.038	0.050	1.589	0.371
	13.5	A-4	0.490	0.038	0.065	1.511	0.338
вн3	1.6	A-7-5	0.533	0.17	0.078	1.328	0.247
	13.5	A-4	0.456	0.038	0.057	1.678	0.404

## Measured displacement of soil



4 m from sheet pile wall

2.7 m from sheet pile wall 1.5 m from sheet pile wall

0.6 m from sheet pile wall

## Observed gap and cracks



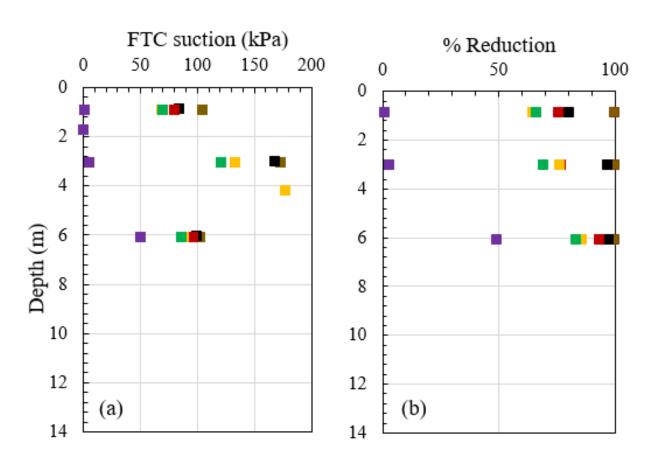
after 6.1 m excavation



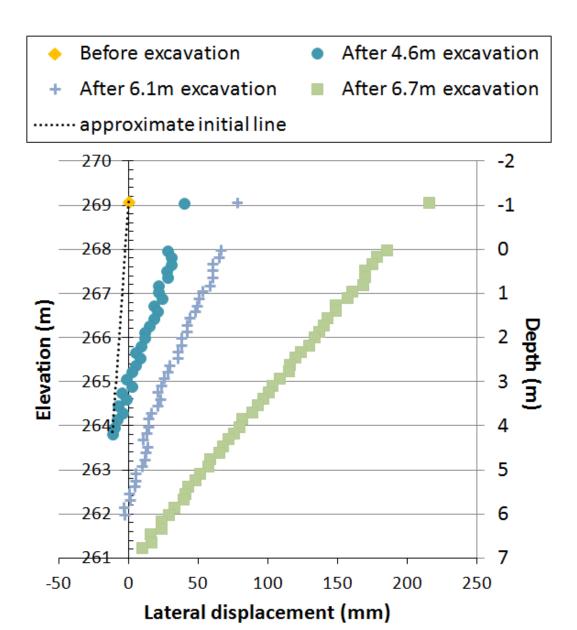
after 6.7 m excavation

## Suction profile (BH 2) from FTC

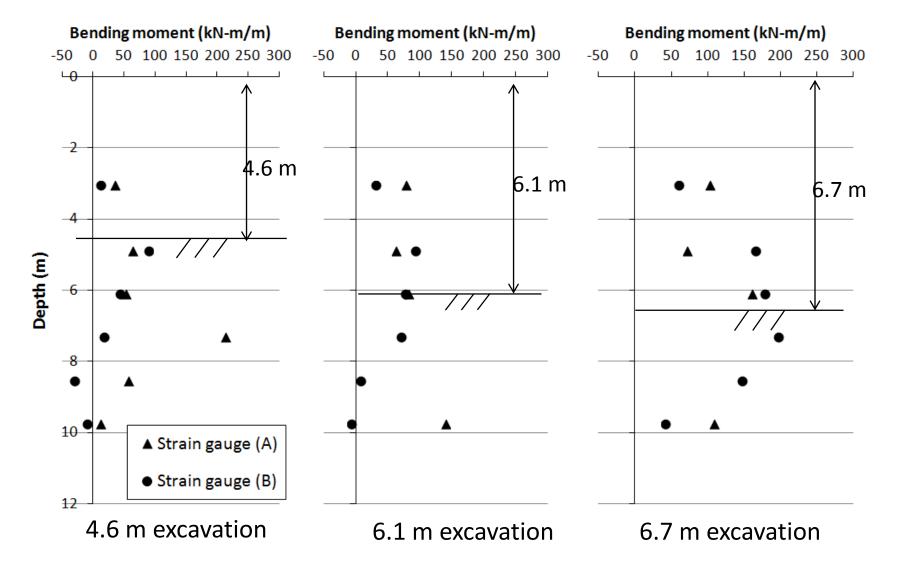




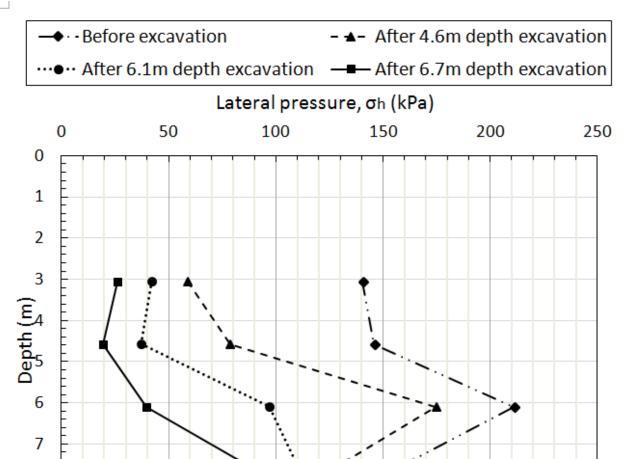
## Movement of sheet pile wall



# Bending moments obtained from measured strain gauge

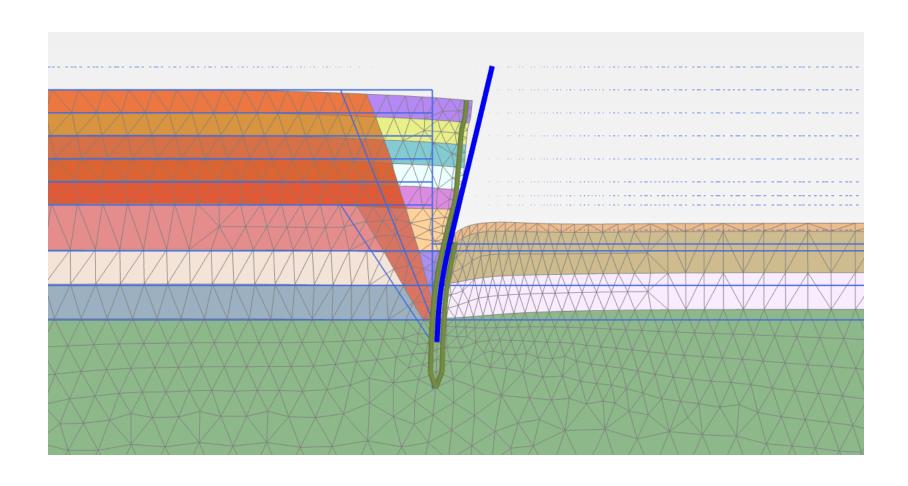


# Measured lateral stress change using pressure cell

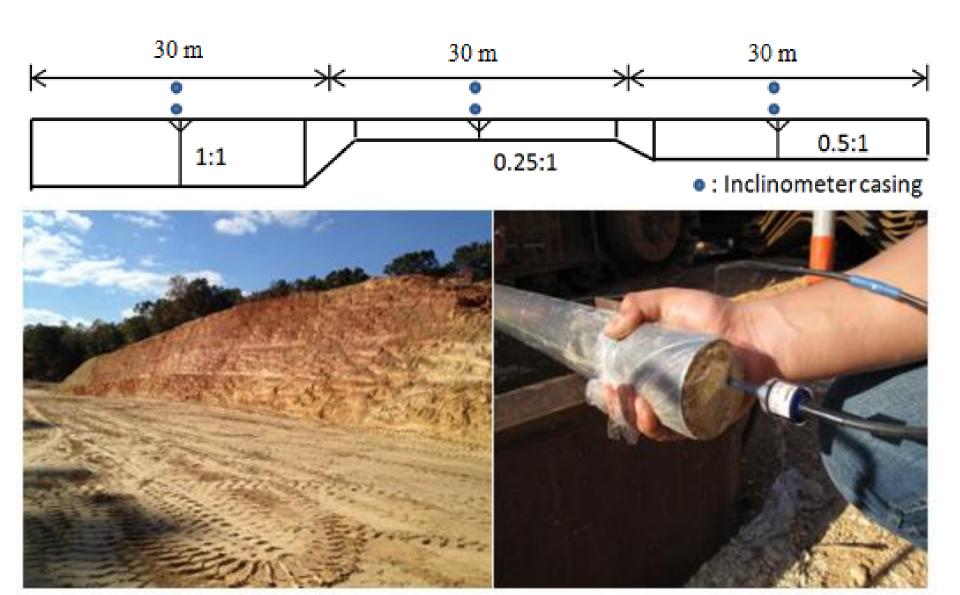


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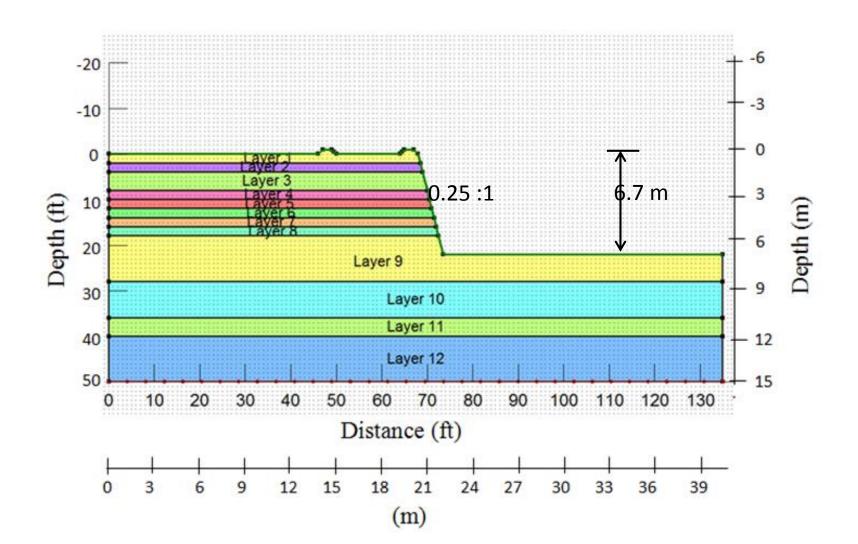
## FEM Modeling of Wall



## Field tests for the slopes



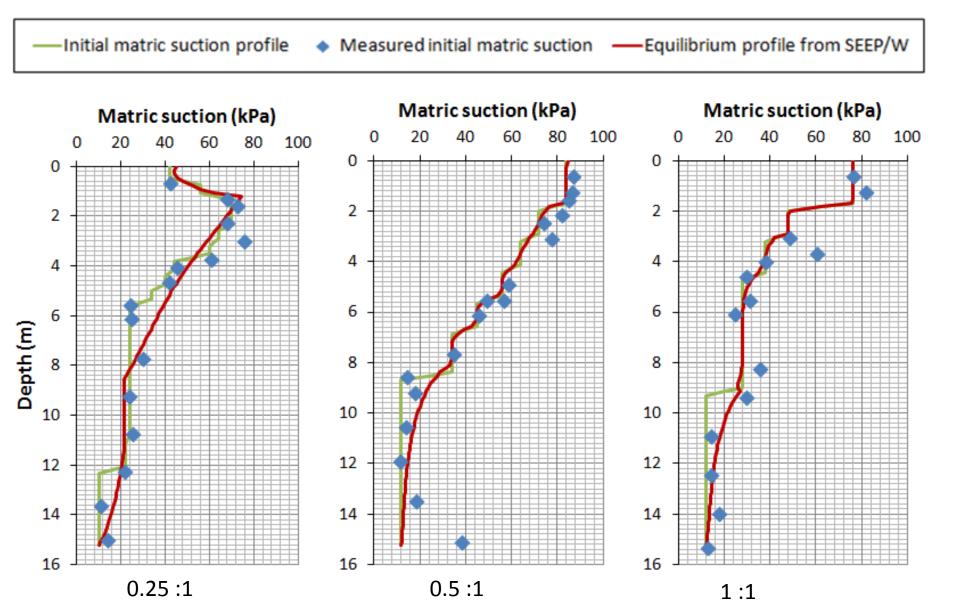
## Geometry of model for 0.25:1 slope



## Material properties for 0.25:1 slope

Layer	Soil type	Layer thickness	$\gamma_{sat}$	$\gamma_{dry}$	Fines	PI	$(u_a-u_w)$	c'	$\varphi$ '
		(m)	(kN/m ³ )	(kN/m ³ )	%		(kPa)	(kPa)	(deg.)
1	A-7-5 (1)	0.6	17.5	11.9	86	22	42	10	27
2	A-7-5 (1)	0.6	17.5	11.9	86	22	56	10	27
3	A-7-5 (2)	1.2	17.1	11.3	86	22	70	10	27
4	A-7-5 (2)	0.6	17.1	11.3	86	22	64	10	27
5	A-7-5 (2)	0.6	17.1	11.3	86	22	60	10	27
6	A-7-5 (2)	0.6	15.8	9.9	84	23	44	10	27
7	A-7-5 (2)	0.6	15.8	9.9	84	23	40	10	27
8	A-7-5(2)	0.6	17.6	11	84	17	34	10	27
9	A-7-5(2)	3	17.6	11	84	17	24	10	27
10	A-4 (1)	2.4	20.3	15.7	59	11	24	0	30
11	A-4 (1)	1.2	20.3	15.7	59	11	22	0	30
12	A-4 (1)	3	21.1	17.1	42	5	10	0	30

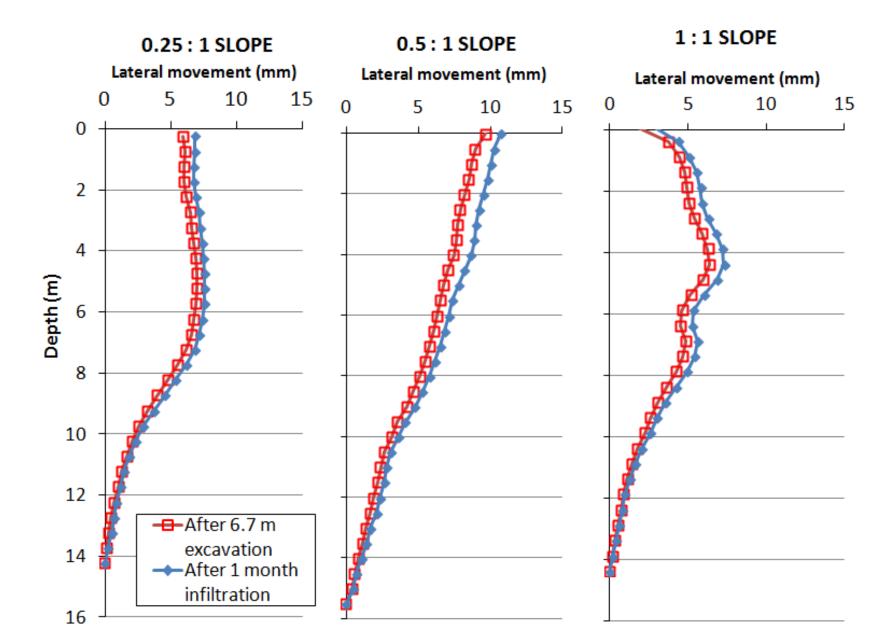
## Initial suction profile



# FS for different initial matric suction profile

Initial matric suction	FS					
profile	0.25:1 slope	0.5:1 slope	1:1 slope			
Measured	1.55	1.75	1.91			
No matric suction	0.80	1.02	0.86			

## Lateral displacement from inclinometer



#### Conclusion

- Measurement of Instrumentations help us understand the behavior of unsaturated Piedmont Residual soils
- NCDOT determining how to incorporate research results into construction practices

### REFERENCE

- Wang, Cheng. (2014). Soil Suction Characterization and New Model for Predicting Suction in Residual Soil. North Carolina State University, Raleigh, NC
- Tang, Chien-ting. (2016). Predication of Shear Strength as a Function of Matric Suction for North Carolina Residual Soils. North Carolina State University, Raleigh, NC
- Lee, Jungmok. (2016). Analysis and Design of Temporary Slopes and Excavation Support Systems in Unsaturated Piedmont Residual Soils. North Carolina State University, Raleigh, NC



**Questions?**