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

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Location of Test Site
Test Site Plan View

1:1 Test Slope
402+90 to 403+85

0.25:1 Test Slope
404+05 to 405+05

0.5:1 Test Slope
405+15 to 406+15

Field adjust ditch of each excavation lift to provide drainage out of test area

Test Sheeting
404+20 to 404+80

SPECIAL CUT DITCH
SEE DETAIL F

+00.00 -/+ 157.50' RT
+50.00 -/+ 150.00' RT
+14.36 -/+ 157.50' RT

FENCE
Test Site Cross-Section
Subsurface Conditions
Additional Subsurface Investigation
Additional Subsurface Investigations

Test Slope 1

Test Slope 2

Test Slope 3

CPT, DMT, SPT
Pressuremeter
Triaxial
Consolidation
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
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

- Started 1st excavation (7/17/13)
- Completed 1st excavation (9/5/13)
- Completed 2nd excavation (10/23/13)
- Completed 3rd excavation (12/20/13)
## Classification of test site soils

<table>
<thead>
<tr>
<th></th>
<th>Soil 1</th>
<th>Soil 2</th>
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<tbody>
<tr>
<td>Gs</td>
<td>2.75</td>
<td>2.74</td>
</tr>
<tr>
<td>LL</td>
<td>35</td>
<td>58</td>
</tr>
<tr>
<td>PI</td>
<td>7</td>
<td>21</td>
</tr>
<tr>
<td>% of fine content</td>
<td>58</td>
<td>88</td>
</tr>
<tr>
<td>AASHTO</td>
<td>A-4</td>
<td>A-7-5</td>
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<tr>
<td>USCS</td>
<td>ML</td>
<td>MH</td>
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</tbody>
</table>

By Wang (2014)

有效强度参数 (By Tang, 2014)
- A-7-5 soil : $\phi'= 27^\circ$ and $c'=10$ kPa
- A-4 soil : $\phi'= 30^\circ$ without effective cohesion

饱和渗透性 ($K_s$)
- A-7-5 soil : $3.15 \times 10^{-5}$ cm/s
- A-4 soil : $5.9 \times 10^{-5}$ cm/s
Location of instruments at sheet pile wall area
Soil characteristic profiles (BH 2)
Cross-section of test site

Distance from sheet pile wall (m)

Depth (m)

- Sheet pile
- Inclinometer casing
- Pressure cell
- FTC
- Moisture sensor

BH3  BH2
Initial suction profiles

Suction (kPa)

Depth (m)

BH 3

BH 2

BH 1
### Field SWCC for sheet pile wall area

![Graph showing Volumetric Water Content (\(\theta\)) vs. matric suction (kPa)].

\[\theta_s, \theta_r, a\] for different sample locations and soil types.

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>Depth (m)</th>
<th>Soil type</th>
<th>(\theta_s)</th>
<th>(\theta_r)</th>
<th>(a) (1/kPa)</th>
<th>n</th>
<th>m</th>
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<tbody>
<tr>
<td>BH2</td>
<td>4.5</td>
<td>A-4</td>
<td>0.435</td>
<td>0.038</td>
<td>0.034</td>
<td>1.771</td>
<td>0.435</td>
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<tr>
<td></td>
<td>10.4</td>
<td>A-4</td>
<td>0.509</td>
<td>0.038</td>
<td>0.050</td>
<td>1.589</td>
<td>0.371</td>
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<tr>
<td></td>
<td>13.5</td>
<td>A-4</td>
<td>0.490</td>
<td>0.038</td>
<td>0.065</td>
<td>1.511</td>
<td>0.338</td>
</tr>
<tr>
<td>BH3</td>
<td>1.6</td>
<td>A-7-5</td>
<td>0.533</td>
<td>0.17</td>
<td>0.078</td>
<td>1.328</td>
<td>0.247</td>
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<td></td>
<td>13.5</td>
<td>A-4</td>
<td>0.456</td>
<td>0.038</td>
<td>0.057</td>
<td>1.678</td>
<td>0.404</td>
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</table>
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

[Graph showing the movement of sheet pile wall with different stages of excavation marked.]

- Before excavation
- After 4.6m excavation
- After 6.1m excavation
- After 6.7m excavation

Dotted line: approximate initial line

Graph axes:
- X-axis: Lateral displacement (mm)
- Y-axis: Elevation (m)
- Z-axis: Depth (m)
Bending moments obtained from measured strain gauge

4.6 m excavation

6.1 m excavation

6.7 m excavation
Measured lateral stress change using pressure cell

![Graph showing lateral pressure change](image-url)
FEM Modeling of Wall
Field tests for the slopes
Geometry of model for 0.25:1 slope

![Diagram showing layers and depth for a 0.25:1 slope model. The diagram includes depth and distance measurements, with a total depth of 6.7 meters.]
Material properties for 0.25:1 slope

<table>
<thead>
<tr>
<th>Layer</th>
<th>Soil type</th>
<th>Layer thickness</th>
<th>$\gamma_{sat}$ (kN/m$^3$)</th>
<th>$\gamma_{dry}$ (kN/m$^3$)</th>
<th>Fines (%)</th>
<th>PI</th>
<th>$(u_a - u_w)$ (kPa)</th>
<th>$c'$ (kPa)</th>
<th>$\varphi'$ (deg.)</th>
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<tbody>
<tr>
<td>1</td>
<td>A-7-5 (1)</td>
<td>0.6</td>
<td>17.5</td>
<td>11.9</td>
<td>86</td>
<td>22</td>
<td>42</td>
<td>10</td>
<td>27</td>
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<tr>
<td>2</td>
<td>A-7-5 (1)</td>
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<td>22</td>
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<td>3</td>
<td>A-7-5 (2)</td>
<td>1.2</td>
<td>17.1</td>
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<td>22</td>
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<td>4</td>
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<td>86</td>
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<td>5</td>
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<td>11.3</td>
<td>86</td>
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<td>10</td>
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<td>A-7-5 (2)</td>
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<td>9.9</td>
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<td>A-7-5(2)</td>
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<td>9</td>
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<td>10</td>
<td>A-4 (1)</td>
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<td>15.7</td>
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<td>11</td>
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<tr>
<td>11</td>
<td>A-4 (1)</td>
<td>1.2</td>
<td>20.3</td>
<td>15.7</td>
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<td>11</td>
<td>22</td>
<td>0</td>
<td>30</td>
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<tr>
<td>12</td>
<td>A-4 (1)</td>
<td>3</td>
<td>21.1</td>
<td>17.1</td>
<td>42</td>
<td>5</td>
<td>10</td>
<td>0</td>
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</tr>
</tbody>
</table>
Initial suction profile

- Initial matric suction profile
- Measured initial matric suction
- Equilibrium profile from SEEP/W
FS for different initial matric suction profile

<table>
<thead>
<tr>
<th>Initial matric suction profile</th>
<th>FS</th>
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<tr>
<td></td>
<td>0.25:1 slope</td>
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<tr>
<td>Measured</td>
<td>1.55</td>
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<tr>
<td>No matric suction</td>
<td>0.80</td>
</tr>
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</table>
Lateral displacement from inclinometer

- **0.25 : 1 SLOPE**
  - Lateral movement (mm)
  - Depth (m)

- **0.5 : 1 SLOPE**
  - Lateral movement (mm)
  - Depth (m)

- **1 : 1 SLOPE**
  - Lateral movement (mm)
  - Depth (m)

Graphs showing lateral movement with depth for different slope angles, with data points indicating movement after 6.7 m excavation and after 1 month of infiltration.
Conclusion

• Measurement of Instrumentations help us understand the behavior of unsaturated Piedmont Residual soils

• NCDOT determining how to incorporate research results into construction practices


Questions ?