Large-scale Physical Model Tests of Micropile Stabilized Slopes

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Stabilization Technique

- Reinforced Concrete Cap
- Road Surface
- Soil
- Micropiles (Typ.)
- Top of Rock
Motivation

- How is force developed within reinforcing members?
- What is the interaction between the soil and the reinforcing members?
- How does geometric arrangement affect load transfer and limit loads?
- What group or network effects exist?
Research Methods

Geometric Scale Factor, $\lambda$

1:1 1:~8 1:~100

Field Testing
- Actual performance, but
- no control of environmental conditions
- remote test sites
- failure data rare

Large-scale Physical Modeling

Centrifuge Testing
- Reproduce stresses, but
- cannot model construction techniques
- member/soil interaction questionable
Modeling Device
Model Container

7.4 ft.

5.0 ft.

0.10-in. sheeting

Sand-filled grating

Toe
## Model Soil

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Limit</td>
<td>23</td>
</tr>
<tr>
<td>Plastic Limit</td>
<td>14</td>
</tr>
<tr>
<td>Plasticity Index</td>
<td>9</td>
</tr>
<tr>
<td>Organic Content</td>
<td>1%</td>
</tr>
<tr>
<td>Fines Content</td>
<td>19%</td>
</tr>
<tr>
<td>$\gamma_{\text{d-max}}$</td>
<td>115 pcf</td>
</tr>
<tr>
<td>$W_{\text{opt}}$</td>
<td>13%</td>
</tr>
<tr>
<td>$\phi'$</td>
<td>33°</td>
</tr>
</tbody>
</table>

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### Grain Size Distribution

- **Percent Finer by Dry Weight**
- **Grain Size (inch)**

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### Densities

- **$\gamma_d$ (lb/ft$^3$)**
  - Zero Air Voids
  - Reduced Proctor

- **Grain Size (mm)**

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### Graphical Representation

- **Graph** showing the relationship between moisture content and density.
Pore Pressure Control System

Sprinkler System
Instrumentation: Pore Pressure
Instrumentation: Displacement
Reinforcement & Similitude

- Can’t scale stresses, but can scale reinforcement stiffness appropriately:

\[
\lambda = 8 \\
\lambda_{EI} = 1,448 \\
El = 2,200 \text{ lb-ft}^2
\]

\[
El = 3.65 \times 10^6 \text{ lb-ft}^2
\]
Instrumentation: Strain Gages
Construction
Construction: Model Micropiles
Construction: Model Micropiles
As-constructed
Testing
Failure!
Time Lapse
Movie Clip
Model Performance – pore pressures

Elapsed Time (Hours)

Pore Pressure (psf)
Model Behavior - deformations

Elapsed Time (hours)

Displacement (inches)
Forensics
Interpretation of Results

![Graph 1: Slope Face Angle vs Factor of Safety](image1)

- U2
- U3
- U4

![Graph 2: Slope Displacement vs Factor of Safety](image2)

- U2
- U3
- U4
Moment Distribution

Distance from Micropile Bottom (in)

Moment (lb-in)

- 30
- 38
- 45

Moment Distribution Graph
Load Transfer

Maximum Induced Bending Moment (lb-in)

Inclination (Degrees)

- R1, S/D = 29.3
- R2, S/D = 14.7
- R3, S/D = 9.8
Completed Testing

- Unreinforced models

- Single Line, Perpendicular to Slope
  - s/d from 8 to 30
  - “rigid” and scaled members

- Single Line, A-Frame
  - s/d from 4 to 8
  - No cap beam
Future Testing

- A-frame arrangement with capping beam
- Reticulated micropile
- Larger scale device
Observations

- Tests performed for unreinforced slopes indicate modeling errors are small

- Model micropiles reasonably representative of field scale micropiles

- Mobilization of resistance is roughly linear

- Capping beam necessary for conditions tested to date
Acknowledgements

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