The Full Scale Mechanics of Surficial Slope Stabilization

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Overview of content

1. Slope stabilization options
2. The anchored mesh system
3. Full scale testing
4. Results of full scale testing
Slope Stabilization

Stability problems can occur as a result of

- Hillside water, saturation, water pressure in critical joints
- Stratification / joints unfavorably orientated
- Erosion
- Change of slope geometry
- Extraordinary effects (earthquake, etc.)
- External loads (traffic, etc.)
- Installed solutions, not properly designed for the conditions
Stability problems: Soil slope failure
Stability problems: Disadvantageous stratification
Stability problems: Stability problems downslope
Hard facing: Shotcrete
Hard facing: Shotcrete
- Facing has no static function
- No noteworthy force transmission possible
Flexible Facing - Mild steel mesh
The anchored mesh system

1. High-tensile steel wire mesh
2. System spike plates
3. Anchors
4. Dimensioning Concept
High tensile wire mesh

High-tensile steel wire: \( > 256 \text{ ksi} \)

- 2mm wire \( \rightarrow 1,200 \text{ lbs.} \)
- 3mm wire \( \rightarrow 2,800 \text{ lbs.} \)
- 4mm wire \( \rightarrow 4,900 \text{ lbs.} \)

\( DTWM \ (3mm) \rightarrow \sim 800 \text{ lbs.} \)
The dimensioning concept comprises two investigations

1. Investigation of local instabilities between single nails
2. Investigation of slope-parallel, superficial instabilities
Small scale tests
Anchored mesh system examples

Highway 101 – near Garberville, CA
Anchored mesh system examples

Hana Highway – Maui, HI
The anchored mesh system in comparison with shotcrete

West Virginia -- parking lot behind a Walmart
Advantages of the anchored mesh system

- cost effective solution
- natural appearance, allows revegetation
- a range of meshes and plates allow application to a wide variety of slope conditions
- provides effective static load transfer
- can be fully dimensioned with a design tool
Anchored mesh system achievements

- **Public clients:** DOTs, FHWA, and others
- **Private clients:** Railroads, hydro facilities, mines, commercial, residential
- **Applications:** Soil, rock, erosion, temporary shoring
- **> 6 million ft\(^2\)** installed in North America
- **The system has been very successful, but …**
Full scale testing

The Giant Sandbox!
Test Program Details:

• 40’ (12m) x 33’ (10m) x 4’ (1.2m)

• Instrumented anchor bars

• Load cells in boundary ropes

• Multiple soil types – rounded gravel (ϕ=33°), crushed gravel (ϕ=38°)

• Variable slope angle from 0° to 85°

• Multiple meshes and anchor plates

• Laser scanning to measure displacement
Strength properties of mesh

- Longitudinal
- Transverse
- Punching
- Mesh-plate interaction
Analysis of real sliding mechanisms

Standard duty mesh (3mm diameter wire)

\[ a = b = 11.5' \text{ (3.5m)} \]

Rounded gravel

Grain size 16 - 32 mm

\[ \alpha = 60^\circ \]
Analysis of real sliding mechanisms

Heavy duty mesh (4mm diameter wire)

\[ a = b = 11.5' \ (3.5m) \]

Rounded gravel

Grain size 16 - 32 mm

\[ \alpha = 60^\circ \]
Analysis of real sliding mechanisms

Heavy duty mesh
(4mm diameter wire)

\[ a = b = 11.5' \ (3.5 \text{ m}) \]

Crushed gravel

Grain size 0 - 63 mm

\[ \alpha = 60^\circ \]
What we learned from the Full-Scale Test

- Dimensioning concept validated
Proof of lateral influence of pressure cones
Analysis of load transfer within system

Punching Strength

Slope Parallel Strength
Analysis of load transfer within system
Analysis of load transfer within system
Analysis of load transfer within system
Analysis of load transfer within system
## Comparison of the different slope stabilization systems

### Comparison

<table>
<thead>
<tr>
<th></th>
<th>Light Duty Mesh (2mm)</th>
<th>Standard Duty Mesh (3mm)</th>
<th>Heavy Duty Mesh (4mm)</th>
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</thead>
<tbody>
<tr>
<td><strong>Small spike plate</strong></td>
<td></td>
<td></td>
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<tr>
<td>Friction angle [°]</td>
<td>33</td>
<td>33</td>
<td>33</td>
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<tr>
<td>Design level inclination [°]</td>
<td>42</td>
<td>51</td>
<td>55</td>
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<tr>
<td>Stabilized angle [°]</td>
<td>9</td>
<td>18</td>
<td>22</td>
</tr>
</tbody>
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**Load Transfer and Stabilized Angle**
Mesh options

- Severely Over-Steepened
  - Heavy Duty Mesh (4mm)

- Over-Steepened Slope
  - Standard Duty Mesh (3mm)

- Stable Slope
  - Light Duty Mesh (2mm)
Cost Optimization

Total Project Cost

- **Common Flexible Slope Stabilization Systems**
  - Standard Duty Mesh
  - Heavy Duty Mesh

- Anchor spacing

Mesh
Anchoring
The critical load transfer occurs at the *Wire-Plate Interface*
Strength properties of mesh

- Longitudinal
  - Evenly distributed loads do not occur on slopes

- Transverse
  - Gravity

Not relevant to system performance:

- Punching
- Mesh-plate interaction

The critical mesh characteristics for dimensioning and performance:
Results

What did we learn?

• Dimensioning concept validated
• Multiple meshes and plates
• Load transfer ability of mesh determines system performance

Why is it important to you?

• Design with confidence
• Stabilize more slopes, optimize costs
• Accurately predict performance of any facing type