Synthetic Water Repellent Soils and Slope Engineering

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What is water repellent soil?

- Wettable soil
- Water repellent soil
Contact angle

• Young's equation (Shaw, 1992)

\[ \cos \theta = \frac{\gamma_{sg} - \gamma_{sl}}{\gamma_{lg}} \]

• where \( \theta \) denotes contact angle, \( \gamma \) denotes interfacial surface tensions
Origins of soil water repellency

- Natural water repellent soils (DeBano, 2000)
  - Plant oil & wax
  - Fungi species
  - Decomposed organic matter
  - Wildfire heating
- Influenced by environment
  - Temperature & Relative humidity
- Losses in agriculture

(www.permacultured.us)
Origins of soil water repellency

- Synthetic water repellent soils
  - Hydrophobizing agents (e.g. Silane compounds)
  - Simple sample preparation
  - Persistent water repellency

\[
\text{Surface of wettable soil} + \text{DMDCS} \rightarrow \text{Surface of water repellent soil}
\]

(Ng and Lourenço, 2016)
Quantification of water repellency

- Water drop penetration time (WDPT)
  - Index test
  - Simple operation

<table>
<thead>
<tr>
<th>Water repellency level</th>
<th>WDPT (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wettable</td>
<td>≤5 s</td>
</tr>
<tr>
<td>Slightly repellent</td>
<td>5-60 s</td>
</tr>
<tr>
<td>Strongly repellent</td>
<td>60-600 s</td>
</tr>
<tr>
<td>Severely repellent</td>
<td>600-3600 s</td>
</tr>
<tr>
<td>Extremely repellent</td>
<td>≥3600 s</td>
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</tbody>
</table>

(Doerr, 1998)
Quantification of water repellency

- Sessile drop method (SDM)
  - Direct measurement
  - Reproducible result

(Bachmann et al., 2000)

Soil sample for SDM

CA=70°
CA=90°, threshold
CA=120°
Rainfall-induced landslides

• “The slope failure was the result of infiltration during intense rainfall, in end-tipped, loose fill, followed by loss of strength…”

-Sau Mau Ping Landslide, 1972
-Po Shan Road Landslide, 1972

-GEO Report No. 86
Rainfall-induced landslides

- Failure mechanism (Eckersley, 1986)
  - Wettable soils
  - Infiltration
  - Excess pore pressure
  - Decreased strength

- Stabilizing method
  - Reinforcement element
  - Prevention of infiltration
Potential applications

• Slope engineering

Slope stabilization

• Natural and man-made slopes
  • Water repellent soils as impermeable barrier
  • Infiltration is delayed and reduced

• Advantages
  • Infiltration rate can be controlled
  • Can be integrated with vegetation
Aim & Objectives

• To model slopes under rainfall condition, and identify the optimum condition for water repellent soils in sloping ground

• Objectives
  • To establish the relation between infiltration/surface runoff discharge and soil water repellency
  • To investigate how the effectiveness of water repellent soil is influenced by various factors (e.g. slope angle, relative compaction and rainfall intensity)
Set-up of flume

An ongoing flume test

Rainfall simulator calibration

Nozzle: to obtain uniform rainfall

Flowmeter: to control rainfall discharge rate
Effect of soil water repellency

- Contact angle

$55^\circ, 120^\circ$

Water content vs. Time (CA=55°)

Water content vs. Time (CA=120°)
• Effect on infiltration pattern
  • Advancing of wetting front
Conclusions

• Increase in soil water repellency leads to a reduction of infiltration rate, which can be further controlled by manipulating the level of water repellency (contact angle).

• Increase in soil water repellency leads to a reduction of amount of water retained in the slope.

• Water repellent soils are promising materials for slope stabilization, improve slope safety by reducing both the infiltration and generation rate of surface runoff.
THANK YOU!

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