REDUCTION OF GCL-L INTERFACE STRENGTH UNDER THAWING FROZEN SUBGRADE CONDITIONS

By: Thomas Steiner P.E. (ARCADIS)

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Introduction

- Farley Mine Site, Lynn Lake, Manitoba
- Consolidate and cap reactive mine tailings and waste rock (ARD)
- GCL-L cover system
- Concerns regarding potential reduction of GCL-L interface strength during thawing frozen subgrade conditions
Area of “Sporadic Discontinuous Permafrost”

CONTINUOUS (90-100%)

EXTENSIVE DISCONTINUOUS (50-90%)

SPORADIC DISCONTINUOUS (10-50%)

Farley TMA
Farley TMA Remedy

- **FUGITIVE TAILINGS**
- **AREA 40 WASTE ROCK PILE**
- **COARSE TAILS PRIMARY CONSOLIDATION AREA (FML COVER)**
- **INTERMEDIATE TAILS (STONE COVER)**
Area 40 Waste Rock Pile

- ~16 acres
- Originally planned to consolidate
- Frozen material encountered approx. 1-2 m below grade (unable to excavate)
Area 40 Solution

- Regrade and cap frozen material in place
- Laminated GCL (GCL-L) based cover system
Cover System Design

• **OBJECTIVE:**
  • Separate waste rock material from water and oxygen ingress to inhibit ARD generation

• **COVER SYSTEM:**
  • Rock-and-Soil Cover Systems with GCL-L Barrier Layer
  • 20% Max Slopes
Why a GCL-L?

- Cost
- Ease of Construction
- Manufacturer recommended a laminated GCL (GCL-L) to address potential concerns associated with cation exchange... current state of practice
Cover System Design

☆ No drainage layer
• 20% maximum slopes
• CRITICAL DESIGN CONSIDERATION:
  • VENEER STABILITY at laminate interface
Veneer Stability Evaluation

- CRITICAL INTERFACE: Smooth LLDPE/HDPE vs. Soil

<table>
<thead>
<tr>
<th>Table 5.7 PEAK FRICTION VALUES AND EFFICIENCIES OF VARIOUS GEOSYNTHETIC INTERFACES*</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) Soil-to-Geomembrane Friction Angles</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geomembrane</th>
<th>Concrete Sand (φ = 30°)</th>
<th>Ottawa Sand (φ = 28°)</th>
<th>Mica Schist Sand (φ = 26°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Textured</td>
<td>30° (100%)</td>
<td>26° (92%)</td>
<td>22° (83%)</td>
</tr>
<tr>
<td>Smooth</td>
<td>18° (56%)</td>
<td>18° (61%)</td>
<td>17° (63%)</td>
</tr>
<tr>
<td>PVC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rough</td>
<td>27° (88%)</td>
<td>—</td>
<td>25° (96%)</td>
</tr>
<tr>
<td>Smooth</td>
<td>25° (81%)</td>
<td>—</td>
<td>21° (79%)</td>
</tr>
<tr>
<td>CSPE-R</td>
<td>25° (81%)</td>
<td>21° (72%)</td>
<td>23° (87%)</td>
</tr>
</tbody>
</table>

Interface Testing

- Laboratory testing of proposed GCL-L product with site-specific materials...
  - GCL-L (laminate side) vs. Site Borrow Soil
- Peak Interface Shear Angle = 21° (assume 20° for conservatism)

*Testing provided by SGI Testing Services, LLC, Norcross, GA
Why put the laminate on the bottom?

• Cover Soil With Seepage Forces
  • $FS = 0.5 \times \tan \beta / \tan \delta$
  • $FS = 0.5 \times \tan (20 \text{ deg}) / 0.20$
  • $FS = 0.91 < 1.5 \therefore \text{No Good}$

• Cover Soil Without Seepage Forces
  • $FS = \tan \beta / \tan \delta$
  • $FS = \tan (20 \text{ deg}) / 0.20$
  • $FS = 1.82 > 1.5 \therefore \text{OK}$

• Laminate needs to go on the bottom...

Justifications for Laminate on Bottom...

• GCL-L anticipated to remain hydrated
  • Cation exchange not as significant an issue if bentonite remains hydrated
• If it doesn’t...
  • Laminate still serves as a secondary barrier should GCL-L dry out and experience desiccation cracking
• GCL on top also provided greater protection to laminate during construction
Concerns

• Cover system constructed in late fall
• Experienced wet fall weather
• What if subgrade is saturated/wet at time of placement and freezes shortly after construction...
  • Planning for the unexpected
  • Potential for thin layer of water developing between subgrade and laminate when subgrade thaws
Additional Testing...

• Developed custom “Constant-Load” shear test with help of testing lab

![Setup of Constant-Load Shear Test under Frozen/Thawing Conditions.](image)

**Test Procedures:**

1. Prepare the test specimen;
2. Place the test specimen in a freezer for 24 hours;
3. Take the frozen specimen out of freezer and setup the test (surrounding temperature 20+/−2 degree C);
4. Apply normal stress (500 psf);
5. Apply a target shear stress in approximately 10 seconds; and
6. Measure and record shear displacements throughout thawing by using SGI’s data acquisition system.
Test Conditions

- Tested various percentages of maximum peak
- 10% increments, then 5% increments

90% Max. Peak **FAILED**

80% Max. Peak **PASSED**

85% Max. Peak **FAILED**
Results of 90% Testing (Failed)

Figure 2. The soil specimen was partially frozen at the completion of Test #1 (90% of peak shear load).

*Photo courtesy of SGI Testing Services, LLC, Norcross, GA
Results of 80% Testing (Passed)

Figure 3. The soil specimen was completely thawed at the completion of Test #2 (80% of peak shear load).

*Photo courtesy of SGI Testing Services, LLC, Norcross, GA
Results of 85% Testing (Failed)

Figure 4. The soil specimen was partially frozen at the completion of Test #3 (85% of peak shear load).

*Photo courtesy of SGI Testing Services, LLC, Norcross, GA
Conclusions

• Up to 15 to 20% reduction in peak shear under thawing subgrade conditions!
• What does this mean for the design?...
All good...

- Assume worst case 20% reduction in Peak Shear
- $0.80 \times \tan(20 \text{ deg}) = 0.29$
- Veneer Stability Calculations
  - $FS = \tan \beta / \tan \delta$
  - $FS = 0.29 / 0.20$
  - $FS = 1.45 \approx 1.5 \Rightarrow \text{OK!...}$
    [sigh of relief]
Lessons Learned

• Ask the hard questions
• Perform interface testing on site-specific materials
• Account for potential variability in products
• Look to manufacturer’s technical experts for assistance but be cautious of manufacturer’s claims
• What are the two basic variables used to estimate veneer stability factor of safety?
What are the two basic variables used to estimate veneer stability factor of safety?

- Interface angle ($\beta$), Slope angle ($\delta$)
PDH Questions for Group...

• What are the two basic variables used to estimate veneer stability factor of safety?
  • Interface angle ($\beta$), Slope angle ($\delta$)

• What would be the minimum required interface angle for a 3H:1V slope with and without seepage forces?
PDH Questions for Group...

• What are the two basic variables used to estimate veneer stability factor of safety?
  • Interface angle ($\beta$), Slope angle ($\delta$)

• What would be the minimum required interface angle for a 3H:1V slope with and without seepage forces?
  • With seepage forces: $1.5 = 0.5 \times \tan(\beta) / 0.33$
    • $\beta = 44.7$ deg!
  • Without seepage forces: $1.5 = \tan(\beta) / 0.33$
    • $\beta = 26.3$ deg
What are some common interface angles for the following interfaces?

• Smooth HDPE to Sand ($\phi = 28-30$ deg)

• Textured HDPE to Sand ($\phi = 28-30$ deg)

• Non-Woven Geotextile to Sand ($\phi = 28-30$ deg)
What are some common interface angles for the following interfaces?

- Smooth HDPE to Sand ($\phi = 28-30$ deg)
  - 18 to 20 deg (or less)
- Textured HDPE to Sand ($\phi = 28-30$ deg)
  - 26 to 30 deg (or less)
- Non-Woven Geotextile to Sand ($\phi = 28-30$ deg)
  - 26 to 30 deg (or less)
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THANK YOU