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5/30/19
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TEXAS REGISTRATION F-2578

# FINAL COVER STABILITY

Made By: VK
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## 1.0 OBJECTIVE

To investigate the stability of the final cover lining system.

## 2.0 GIVEN

Maximum slope of the geomembrane within the final cover is approximately 25%.

A geotextile drainage layer will be installed in areas with final cover slope ≤ 5% , while a geocomposite drainage layer will be install in areas with slope > 5%.

## 3.0 ASSUMPTIONS

Proposed final cover liner system consists of (from top to bottom):

- 36-inch Soil Cover
- Drainage Layer:
  - Case 1: 200-mil double-sided geocomposite layer for areas with slope > 5%
  - Case 2: 8-oz non-woven goetextile layer for areas with slope ≤ 5%
- 40-mil LLDPE textured geomembrane
- GCL

For **Case 1**, The soil cover is assumed to be dry since the head is maintained within the thickness of the geocomposite layer as shown in the attached Geocomposite Analysis for Final Cover calculations.
For **Case 2**, the soil cover is assumed to be fully saturated.

Based on a review of available data, the following parameters were assigned to the materials.

| Material | Strength Parameters | | Unit Weight (pcf) | | Reference |
|---|---|---|---|---|---|
| | $\phi$ | c | Moist | Saturated | |
| Soil cover | 28 | 0 | 115 | 132 | Estimate-conservative |
| Soil cover/Geocomposite | 28 | 0 | N/A | N/A | Golder(1) |
| Soil cover/Nonwoven Geotextile | 29 | 0 | N/A | N/A | Golder(1) |
| Geocomposite/Textured Geomembrane(2) | 21 | 0 | N/A | N/A | Golder(1) |
| Nonwoven Geotextile/Textured Geomembrane(3) | 21 | 0 | N/A | N/A | Koerner and Narejo, 2005 (Ref. 1) |
| Textured Geomembrane/GCL | 24 | 0 | N/A | N/A | Golder(1) |

(1) Based on unpublished testing data for similar materials presented in Figures 1, 2, 3, and 5.

(2)The data indicates a lower-bound angle of 24°, but since the final cover pertains to a long-term condition a conservative angle of 21° is assumed for the calculation.

(3) The data indicates an average peak friction angle of 26 degrees - See Figure 4, but since the final cover pertains to a long-term condition a conservative angle of 21° is assumed for the calculation.

Based on the shear strength parameters, the critical interface occurs along the geocomposite/ textured geomembrane interface for Case 1; this interface was assigned a conservative friction angle of 21 degrees. For Case 2, the critical interface occurs along the nonwoven geotextile/textured geomembrane interface; this interface was assigned a conservative friction angle of 21 degrees.

## 4.0 METHOD

A model was created representing the final cover slopes. A limit equilibrium analysis was performed to determine the minimum factor of safety against a sliding block failure along the critical interface.

Infinite Slope Analysis

$$FS = \frac{c + (\gamma b \cos\beta - \gamma_w d \cos\beta)\tan\phi}{\gamma b \sin\beta}$$

based on Soong and Koerner 1996 (Ref. 2).

Case 1 Sliding at Geocomposite/Textured Geomembrane Interface

| | | | |
|---|---|---|---|
| $\phi$ = | 21 | interface friction angle | |
| $\beta$ = | 25% | slope angle - max | |
| | 14.0 | slope angle - max (degrees) | 0.24497866 |
| c = | 0 | cohesion of soil (psf) | |
| $\gamma$ = | 125 | saturated unit weight of soil (pcf) | |
| b = | 3.0 | soil thickness (ft) | |
| d = | 0 | water depth in cover (ft) | |
| $\gamma_w$ = | 62.4 | unit weight of water (pcf) | |

**FS = 1.54**

Case 2 Sliding at Nonwoven Geotextile/Textured Geomembrane Interface

| | | | |
|---|---|---|---|
| $\phi$ = | 21 | interface friction angle | |
| $\beta$ = | 5% | slope angle - max | |
| | 2.9 | slope angle - max (degrees) | 0.0499584 |
| c = | 0 | cohesion of soil (psf) | |
| $\gamma$ = | 125 | saturated unit weight of soil (pcf) | |
| b = | 3.0 | soil thickness (ft) | |
| d = | 3 | water depth in cover (ft) | |
| $\gamma_w$ = | 62.4 | unit weight of water (pcf) | |

**FS = 3.85**

## 5.0 RESULTS

Using the Golder Associates interface friction angle data, the critical angle of internal friction was conservatively assumed to be 21 degrees for the geocomposite/textured geomembrane interface. The resulting minimum factor of safety was calculated to be 1.54. Using data from the literature, the critical angle of internal friction was conservatively assumed to be 21 degrees for the nonwoven geotextile/textured geomembrane interface. The resulting minimum factor of safety was calculated to be 3.85

## 6.0 CONCLUSION

Through analysis of the lining system, the final cover slope is found to be stable.

## 7.0 REFERENCE

(1) Robert M. Koerner and Dhani Narejo, "Direct Shear Database of Geosynthetic-to-Geosynthetic and Geosynthetic-to-Soil Interfaces," GRI Report #30, Geosynthetic Research Institute, Drexel University, Philadelphia, PA, June 2005.

(2) Te-Yang Soong and Robert M. Koerner, "Cover Soil Slope Stability Involving Geosynthetic Interfaces," GRI Report #18, Geosynthetic Research Institute, Drexel University, Philadelphia, PA, December 1996.

**Figure 1**

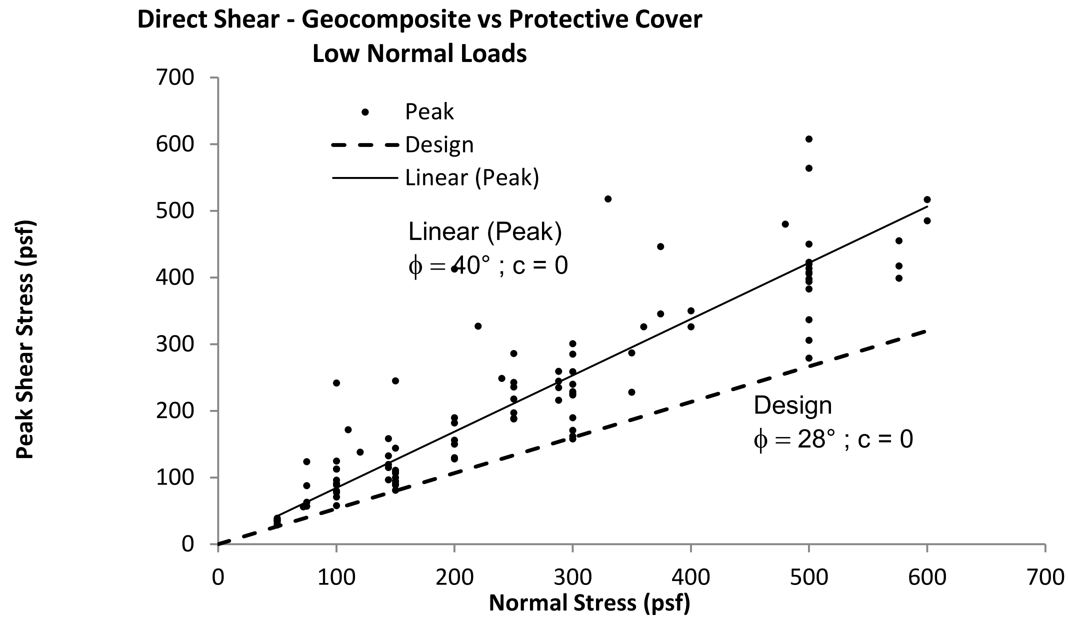



**FIGURE 2**

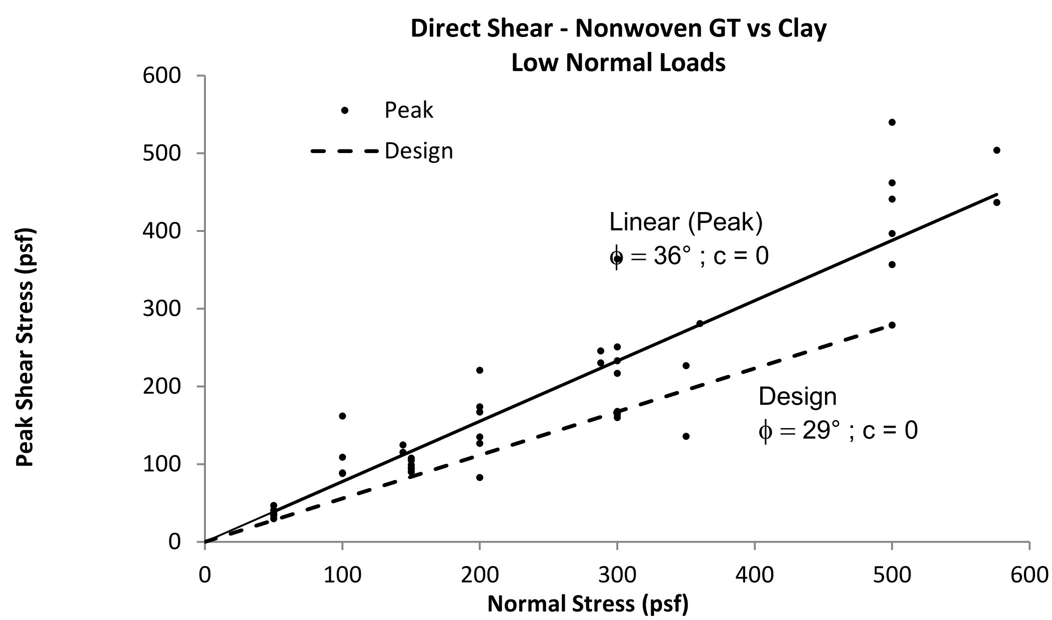


**FIGURE 3**

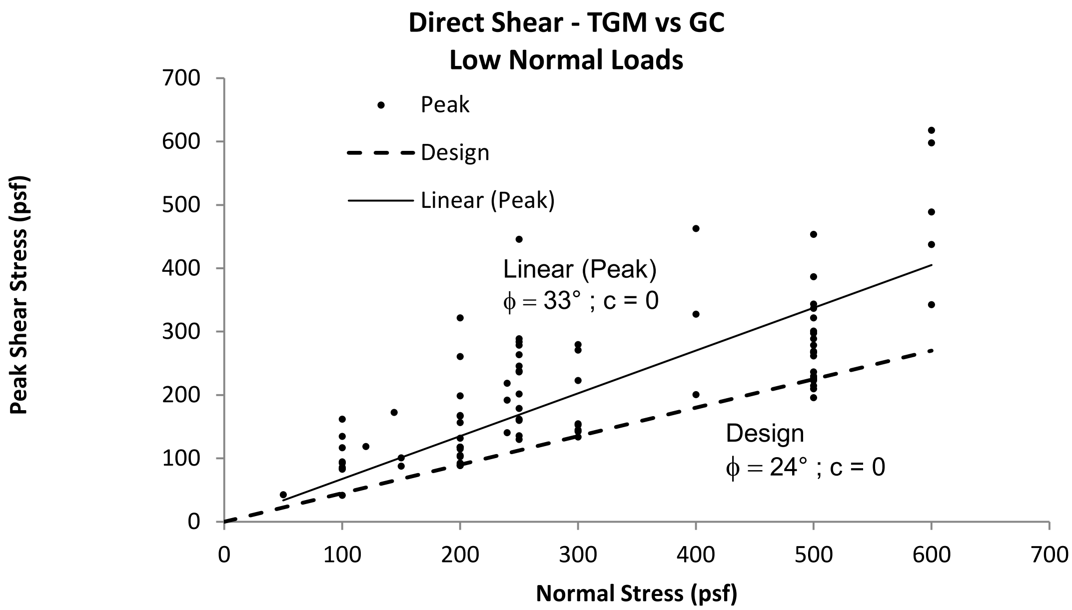



**FIGURE 4** Peak Shear Strength; Textured HDPE against NW-NP Geotextile (Figure from Koerner and Narejo 2005)

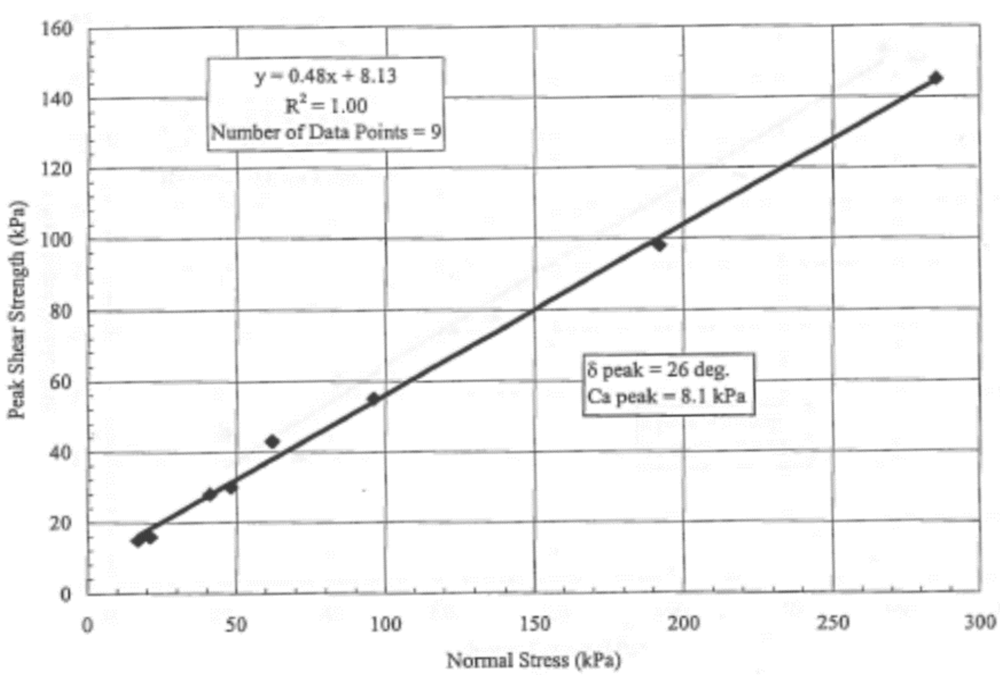
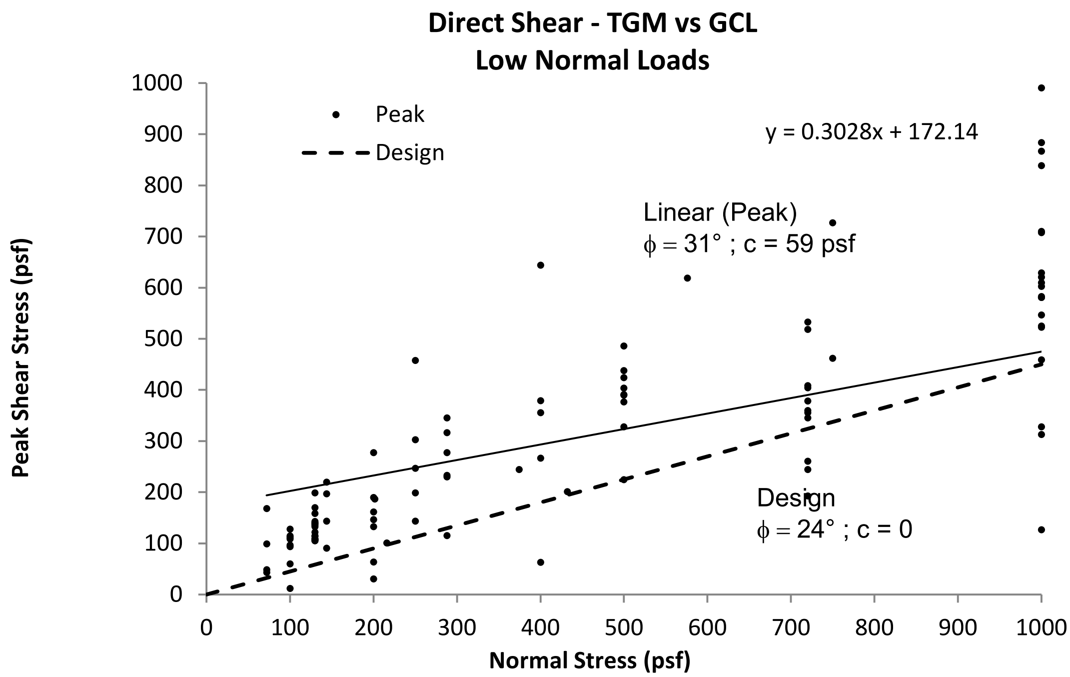


**FIGURE 5**


Direct Shear - TGM vs GCL
Low Normal Loads
Peak
Design
y = 0.3028x + 172.14
Linear (Peak)
ϕ = 31° ; c = 59 psf
Design
ϕ = 24° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
100
200
300
400
500
600
700
800
900
1000

## GEOCOMPOSITE ANALYSIS FOR FINAL COVER

Made By: VK
Checked by: JBF
Reviewed by: AMF

### 1.0 OBJECTIVE

I) Determine the required transmissivity of the final cover geocomposite drainage layer on the maximum final cover slope length.

### 2.0 GIVEN

Maximum length of the 4H:1V slope is approximately (L) = 60 ft.

### 3.0 ASSUMPTIONS

The permeability of the vegetative cover, $K_{veg}$ = 1.0E-05 cm/s (typical value)

### 4.0 METHOD

Determine the required transmissivity of the final cover geocomposite after applying reduction factors and a factor of safety.

$$\boldsymbol{\Theta_{measured\text{ -}req} = FS\Pi(RF)q_h L/(\sin\beta)}$$ (Ref. 1)

$\Theta_{measured\text{ -}req}$ = required transmissivity of geocomposite measured in laboratory test

Test Conditions: i = 0.1 (min)

Normal Stress = 1,000 psf (min)

Boundary Cond'ns = steel plates

Test Time = 1 hour

FS = factor of safety = 2.0

RF = reduction factors (see below)

$\Pi$(RF) = product of all reduction factors

$q_h$ = rate of liquid supply expressed per unit surface area measured horizontally.

Worst case condition consists of a saturated vegetative cover over geocomposite. Under this condition, the gradient = 1.0 and $q_h$ is equal to the hydraulic conductivity of the soil.

L = length of geocomposite in direction of flow

$\beta$ = slope angle

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| Reduction Factor | Description | Value (Ref. 1) |
|---|---|---|
| $RF_{in}$ = | Reduction Factor for intrusion of geotextile into geonet | 1.2 |
| $RF_{cr}$ = | Reduction Factor for geonet creep | 1.1 |
| $RF_{cc}$ = | Reduction Factor for chemical clogging of geotextile and/or geonet | 1.2 |
| $RF_{bc}$ = | Reduction Factor for biological clogging of geotextile and/or geonet | 3 |
| | $\Pi$(RF) = | 4.8 |

## 5.0 CALCULATIONS

I) Transmissivity for maximum flow length

$\Theta_{measured\ -req}$ = **7.7E-04 ft$^3$/s-ft** = **7.2E-05 m$^3$/s-m**

## 6.0 CONCLUSIONS

The required measured transmissivity of a geocomposite drainage layer to adequately convey surface water infiltration on the maximum slope length on the final cover system is 7.2 x $10^{-5}$ m$^3$/s/m. The typical transmissivity values for double-sided geocomposites are in the $10^{-4}$ m$^3$/s/m range. Hence, the required transmissivity is less than typically achievable values and the geocomposite drainage layer will have adequate capacity.

## 7.0 REFERENCES

1. Giroud, J.P, Zornberg, J.G., and Zhao, A., "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers", Geosynthetics International, Vol. 7, Nos. 4-6, 2000.