APPENDIX L

FINAL COVER VENEER STABILITY ANALYSES FOR SCA DESIGN

GEOSYNTEC CONSULTANTS

COMPUTATION COVER SHEET

Client: Honeywell **Project:** Onondaga Lake SCA Design **Project/Proposal #:** GJ4299 **Task #:** 18

TITLE OF COMPUTATIONS **FINAL COVER VENEER STABILITY ANALYSES FOR SCA DESIGN**

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FINAL COVER VENEER STABILITY ANALYSES FOR SCA DESIGN

INTRODUCTION

This package was prepared in support of the design of the Sediment Consolidation Area (SCA) for the Onondaga Lake Bottom Site, which will be constructed on Wastebed 13 (WB-13). The SCA will contain geotextile tubes (geo-tubes) surrounded by a perimeter dike. This package presents analysis of the static slope stability, in a veneer slip mode, of the final cover system that will be placed over the geo-tubes.

Seismic stability was not evaluated because the site is not located in a seismic impact zone as defined by New York State Department of Environmental Conservation (NYSDEC) Regulations Section 360-2.7(b)(7). A detailed explanation regarding the seismic impact zone assessment has been presented in “Slope Stability Analyses for SCA design” (Appendix G of the SCA Final Design and referred to herein as the “Slope Stability Package”).

METHODOLOGY

Static Slope Stability

Slope stability of a final cover system can be analyzed by assuming infinite slope conditions or finite slope conditions. The infinite slope method considers a slope of infinite length whereby driving and resisting forces occur only along or parallel to an interface (i.e., slip plane). The finite slope method considers a slope of finite length and additionally takes into account soil strength above a slip plane, primarily as a toe-buttressing effect. The evaluations in this package have been performed using a finite slope method, following the equations of Giroud, et al [1995].

$$
\begin{aligned}
FS = {} & \left[\frac{\gamma_t(t-t_w)+\gamma_b t_w}{\gamma_t(t-t_w)+\gamma_{sat} t_w}\right]\frac{\tan\delta}{\tan\beta} + \frac{a/\sin\beta}{\gamma_t(t-t_w)+\gamma_{sat} t_w} \\
& + \left[\frac{\gamma_t(t-t^*_w)+\gamma_b t^*_w}{\gamma_t(t-t_w)+\gamma_{sat} t_w}\right]\left[\frac{\tan\phi/(2\sin\beta\cos^2\beta)}{1-\tan\beta\tan\phi}\right]\frac{t}{h} \\
& + \left[\frac{1}{\gamma_t(t-t_w)+\gamma_{sat} t_w}\right]\left[\frac{1/(\sin\beta\cos\beta)}{1-\tan\beta\tan\phi}\right]\frac{ct}{h} \qquad (1)
\end{aligned}
$$

where: FS = factor of safety;
δ = interface friction angle;
a = interface adhesion intercept;
ϕ = soil internal friction angle;
c = soil cohesion intercept;
γ_t = moist soil unit weight;
γ_{sat} = saturated soil unit weight;
γ_b = buoyant soil unit weight = $\gamma_t - \gamma_w$;
γ_w = unit weight of water;
t = depth of cover soil above critical interface;
t_w = water depth above critical interface;
t^*_w = water depth at slope toe;
β = slope inclination; and
h = vertical height of slope.

It should be noted that while the above equation is specifically for an interface above a geomembrane or similar layers, it can also be applied to interfaces below the geomembrane by changing the coefficient of the first term, (i.e., the coefficient of $\tan\delta / \tan\beta$) to 1.0. The slope geometry, which is used to derive the above equation, is shown in Figure 1. It is noted that tension in the geosynthetics (T) has conservatively not been included in the above equation or analyses presented herein.

Target Factor of Safety

Two target factors of safety (FSs) were considered for stability of the proposed SCA. The target FS values using peak and residual shear strength values were considered to be 1.5 and 1.2, respectively. The analyses were performed by solving the finite slope stability equation, (i.e., Equation 1) for various combinations of internal/interface shear strength parameters (i.e., "δ" and "*a*" for above and below a geomembrane) corresponding to the target FS. By using this method, minimum acceptable internal/interface shear strength parameters for the cover system components could be established.

MATERIAL PROPERTIES

Cover System Along SCA Side Slopes

The proposed final cover system above the geo-tubes consists of a leveling layer, a low density polyethylene (LDPE) geomembrane (GM), a geocomposite drainage layer along the side slopes, 24 inches of protective soil and 6 inches of topsoil. It is further noted that the type of GM is not expected to impact the results because required shear strength properties are back-calculated to be compared with actual properties. The protective soil and the topsoil are modeled as a single 30 inch thick soil layer above the GM. This soil layer was modeled with a unit weight of 120 pcf, as discussed in the Slope Stability Package. The shear strength parameters of the final cover soils were modeled with a friction angle of 30 degrees and a cohesion intercept of zero, as discussed in the Slope Stability Package.

SCA Slope Geometry

The current design of the side slopes of the final cover assumes a minimum thickness of 30 inches of cover soil material on top of five stacks of geo-tubes, the leveling layer, and the geosynthetics (i.e., geomembrane and geocomposite drainage layer). Each geo-tube stack is offset 20 ft from the layer below and is assumed to be approximately 6 ft thick. This results in side slopes of 20 horizontal:6 vertical (20H:6V), a total slope height of 30 ft, and a slope angle β=16.7 degrees.

Depth of Water t_W

The water depth in the drainage layer (t_W) was computed using the "Hydraulic Evaluation of Landfill Performance" (HELP) software, Version 3.07, developed by the U.S. Environmental Protection Agency. The HELP model is a quasi two-dimensional hydrologic model of water movement across, into, through and out of landfills. The HELP model accepts weather, soil, and design data and uses solution techniques to account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, lateral drainage, and leakage through liners [Schroeder, 1994]. More detailed information on the use of HELP is presented in Appendix I of the SCA Final Design, "Evaluation of Hydraulic Performance for SCA Design" (hereafter referred to as the "HELP package"). The highest daily value for the average water depth (i.e., average peak daily water depth) on the SCA side slopes was calculated by HELP to be 0.02 inches (0.002 ft). This value is less than the thickness of a typical geocomposite.

RESULTS OF ANALYSES

The interface friction angle and adhesion combinations for the final cover system that meet the target FS were calculated using a computer spreadsheet (see Tables 1 and 2). Results of final cover system veneer stability analyses are presented in Figures 2 and 3. These figures represent various combinations of peak and residual internal/interface shear strength parameters (i.e., δ and a) required for a calculated static FS of 1.5, and 1.2, respectively. It is noted that the required parameters to achieve the target FS for components above the GM were found to be more critical than required parameters for components below the GM. Therefore, only the required shear strength parameters to achieve stability above the GM are shown on these figures. These required parameters can be achieved with commercially available products.

SUMMARY AND CONCLUSIONS

Results of the final cover system veneer slope stability indicated that a peak internal/interface shear strength of δ = 22.7 degrees and a = 0 psf (or equivalent δ–a combinations as shown in Figure 2), and a residual internal/interface shear strength of δ = 18.1 degrees and a = 0 psf (or equivalent δ–a combinations as shown in Figure 3) were the minimum requirements for a calculated FS of 1.5 and 1.2, respectively. These required properties correspond to a confining stress of approximately 300 psf due to the weight of the protective soil and topsoil layers.

It is noted that the minimum requirements for internal/interface shear strength parameters for the final cover are typical of many commercially available geosynthetic materials. Prior to construction of the final cover system, the internal/interface shear strength properties of the soil and geosynthetic materials selected for use should be verified by performing site-specific interface shear strength testing.

REFERENCES

Giroud, J.P., Bachus, R.C., and Bonaparte, R., "Influence of Water Flow on the Stability of Geosynthetic-Soil Layered Systems on Slopes," Geosynthetics International, Vol. 2, No. 6, 1995, pp. 1149-1180.

Schroeder, P.R., et al. *"The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3"*, EPA/600/9-94/xxx, U.S. EPA Risk Reduction Engineering Laboratory, Cincinnati, OH, 1994.

Written by: **Joseph Sura** Date: **11/23/2009** Reviewed by: **R. Kulasingam/Jay Beech** Date: **12/2/2009**

Client: **Honeywell** Project: **Onondaga Lake SCA Final Design** Project/ Proposal No.: **GJ4299** Task No.: **18**

Tables

Onondaga Lake SCA Final Design
Finite Slope Equation [Giroud et. al., 1995]

FS Above GEOMEMBRANE

Input Parameters:		
γ_t (Moist soil unit weight):	120	pcf
γ_{sat} (Saturated soil unit weight):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water depth above critical interface):	0.002	ft
t^* (water depth at slope toe):	0.002	ft
δ (interface friction angle):	***22.7***	deg
ϕ (soil internal friction angle):	30	deg
a (interface adhesion intercept):	***0.0***	psf
c (soil cohesion intercept):	0	psf
h (vertical height of slope):	30	ft
t (depth of cover soil above critical interface):	2.5	ft
β (slope inclination):	16.7	deg
FS:	**1.50**	

FS Below GEOMEMBRANE

Input Parameters:		
γ_t (Moist soil unit weight):	120	pcf
γ_{sat} (Saturated soil unit weight):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water depth above critical interface):	0.002	ft
t^* (water depth at slope toe):	0.002	ft
δ (interface friction angle):	***22.7***	deg
ϕ (soil internal friction angle):	30	deg
a (interface adhesion intercept):	***0.0***	psf
c (soil cohesion intercept):	0	psf
h (vertical height of slope):	30	ft
t (depth of cover soil above critical interface):	2.5	ft
β (slope inclination):	16.7	deg
FS:	**1.50**	

Table 1. Peak Stability Calculation Spreadsheet

Written by:	**Joseph Sura**	Date:	**11/23/2009**	Reviewed by:	**R. Kulasingam/Jay Beech**	Date:	**12/2/2009**
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Onondaga Lake SCA Final Design
Finite Slope Equation [Giroud et. al., 1995]

FS Above GEOMEMBRANE *Input Parameters:*		
γ_t (Moist soil unit weight):	120	pcf
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γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water depth above critical interface):	0.002	ft
t* (water depth at slope toe):	0.002	ft
δ (interface friction angle):	***18.1***	deg
ϕ (soil internal friction angle):	30	deg
a (interface adhesion intercept):	***0.0***	psf
c (soil cohesion intercept):	0	psf
h (vertical height of slope):	30	ft
t (depth of cover soil above critical interface):	2.5	ft
β (slope inclination):	16.7	deg
FS:	**1.20**	

FS Below GEOMEMBRANE *Input Parameters:*		
γ_t (Moist soil unit weight):	120	pcf
γ_{sat} (Saturated soil unit weight):	120	pcf
γ_w (Unit wt of water):	62.4	pcf
γ_b (Buoyant unit wt of soil):	57.6	pcf
t_w (water depth above critical interface):	0.002	ft
t* (water depth at slope toe):	0.002	ft
δ (interface friction angle):	***18.1***	deg
ϕ (soil internal friction angle):	30	deg
a (interface adhesion intercept):	***0.0***	psf
c (soil cohesion intercept):	0	psf
h (vertical height of slope):	30	ft
t (depth of cover soil above critical interface):	2.5	ft
β (slope inclination):	16.7	deg
FS:	**1.20**	

Table 2. Residual Stability Calculation Spreadsheet

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Figures

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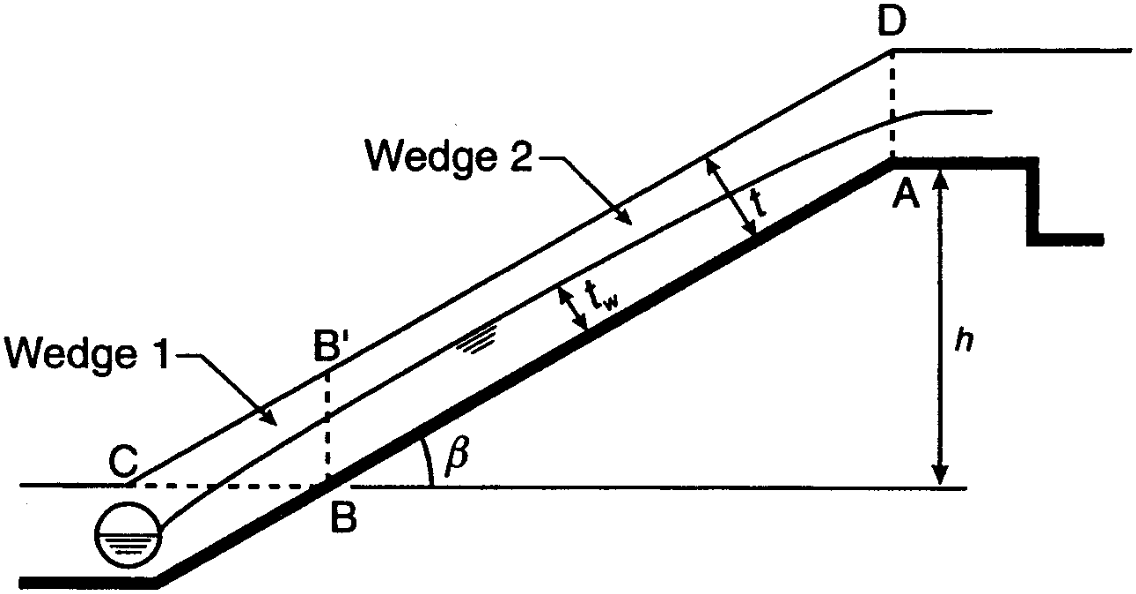

Figure 1. Slope Geometry used to derive Slope Stability Equation
[Giroud et al, 1995]

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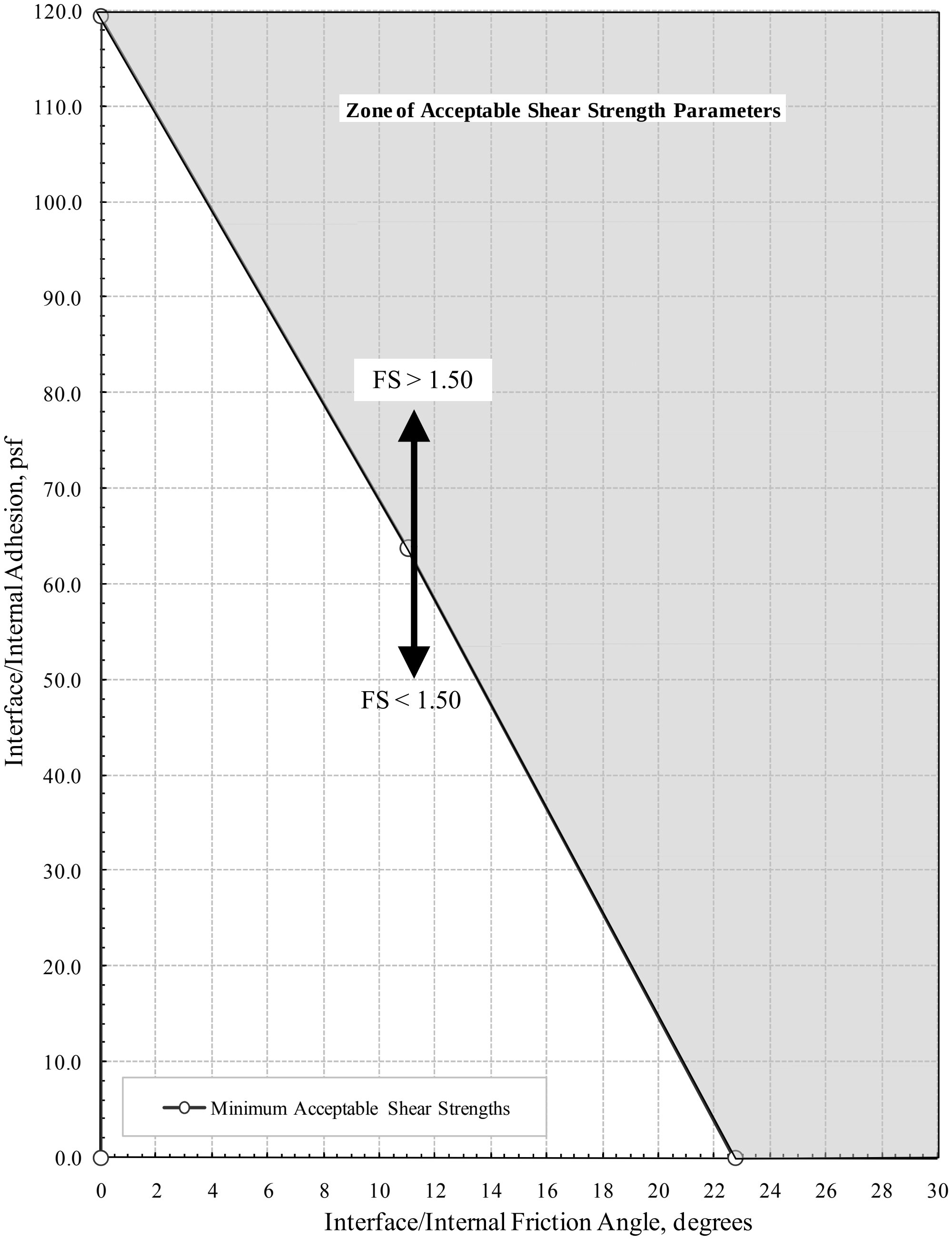

Figure 2. Minimum Required Peak Interface/Internal Shear Strength Parameters for Cover System Geosynthetic Components

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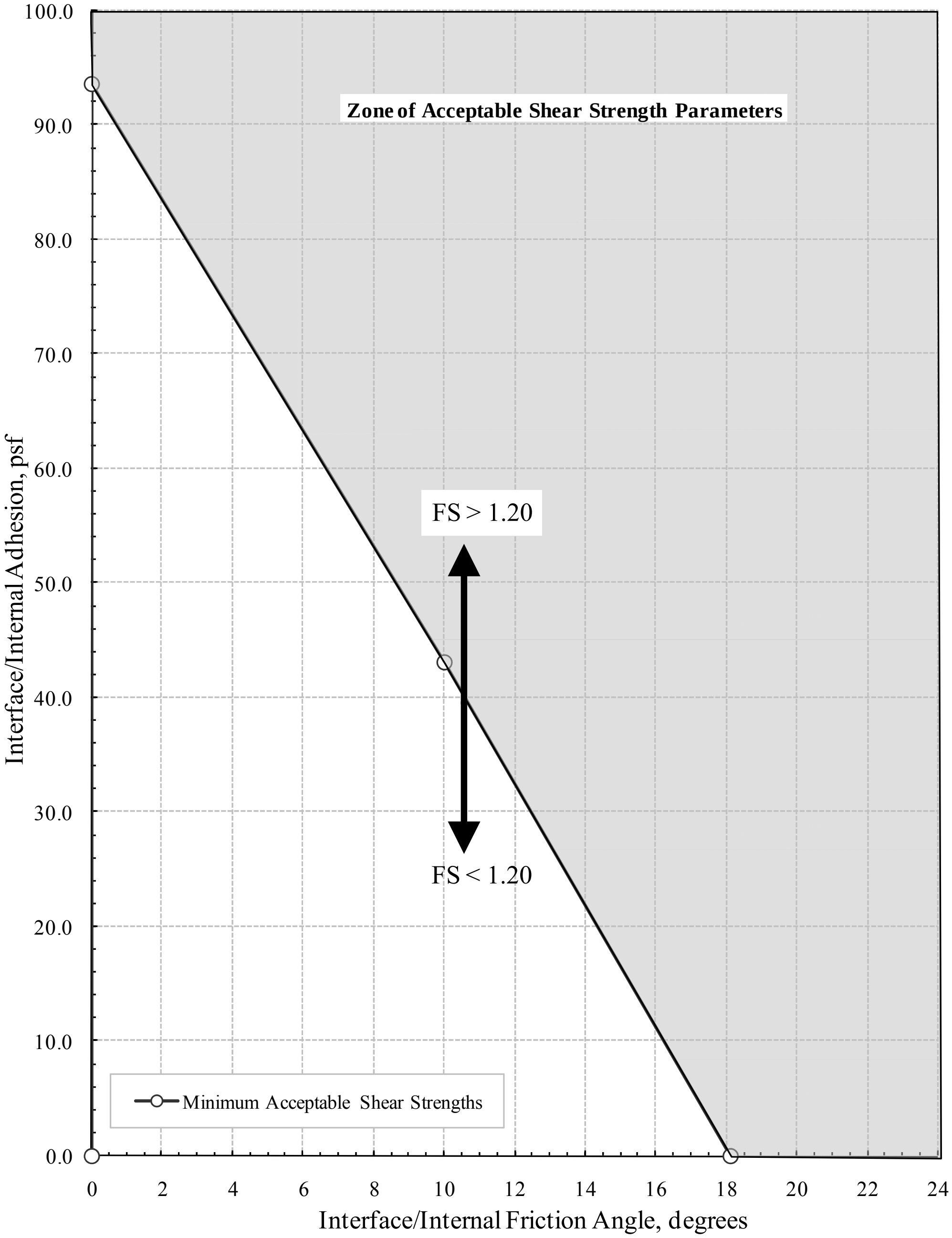

Figure 3. Minimum Required Residual Interface/Internal Shear Strength Parameters for Cover System Geosynthetic Components