APPENDIX III-D.5-5

FINAL COVER STABILITY ANALYSIS

STATE OF TEXAS
JESSE PAUL VARSHO
114074
LICENSED
PROFESSIONAL ENGINEER

3-2-15

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CB&I Environmental & Infrastructure	**Client Name:** Rancho Viejo Waste Management, LLC		
	Project Name: Pescadito Environmental Resource Center	**Project No.:**	148866
	Prepared by: P. Thomas	**Date Prepared:**	2/24/2015
	Reviewed by: Jesse P. Varsho, PE	**Date Reviewed:**	3/2/2015

TITLE: FINAL COVER STABILITY ANALYSIS

Problem Statement

Determine the factor of safety of the landfill final cover system using infinite slope method of analysis. A factor of safety of 1.5 for static conditions is deemed appropriate (note the site is not located within a seismic hazard zone).

References

1. Abramson, L.W., Lee, T.S., Sharma, S., and Boyce, G.M., *Slope Stability and Stabilization Methods*, 2002 (refer to attached pages).
2. Landfill design specifications for layer types and thicknesses provided in the Summary of Geotechnical Design Parameters (contained in **Appendix III-D.5-1**).
3. Cross-sectional detail of final cover system provided in the Design Drawing set contained in this Application.

Assumptions

- Equation used in the analysis of forces for static conditions (**Reference No. 1**) and factor of safety (FS) against slope failure:

$$FS = \frac{c' + (h)(\gamma_{sat} - \gamma_w)(cos^2\beta)(tan\emptyset')}{(\gamma_{sat})(h)(sin\beta)(cos\beta)}$$

Where,

γ_{sat} = Saturated unit weight of soil
γ_w = Unit weight of water
β = Angle of slope
h = Thickness of cover soil
ϕ' = Effective shear strength friction angle of soil
c' = Effective shear strength cohesion of soil

- The final cover system design includes the following components from top to bottom:
  - 7" Vegetative Cover / Erosion Control Layer
  - 30" Infiltration Layer
- Maximum slope of final landform is 4H:1V, therefore β = 14.04 degrees.
- Various site soil materials are assumed to be used for the final cover system. The final cover is assumed saturated and the saturated unit weight is assumed equal to 132 pcf.
- Assumed more conservative shear strength parameters of final cover soils (i.e., long-term shear strength conditions): c' = 720 psf, ϕ' = 13.5

Calculation

Determine the factor of safety under static conditions:

$$FS = \frac{720psf + (3.083ft)(132pcf - 62.4pcf)(cos^2(14.04°))(tan13.5°)}{(132pcf)(3.083ft)(sin14.04°)(cos14.04°)} = 8.02$$

Conclusion

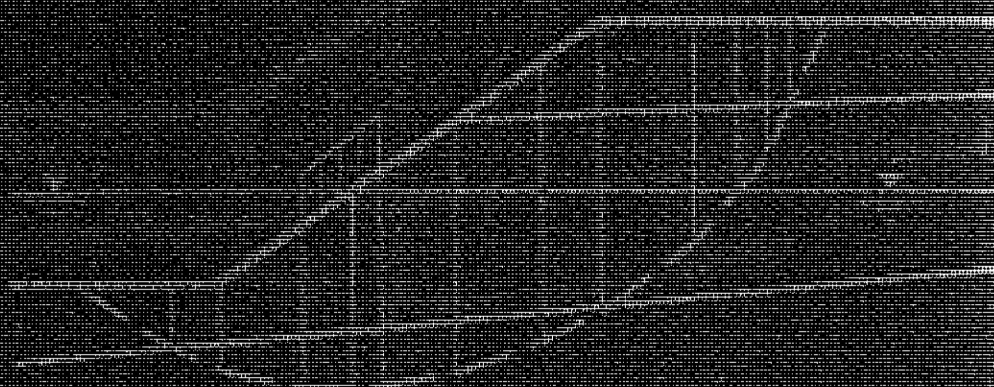
The final cover system will be stable on the final landform for the Pescadito Landfill Units based on the assumed conditions and shear strength values. The calculated FS of 8.02 exceeds the minimum recommended FS of 1.5.

Reference No. 1

Slope Stability Method
(Abramson, et al)

SLOPE STABILITY AND STABILIZATION METHODS

second edition



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Next the normal, N, and driving, T, forces are determined:

$$N = W\cos\beta \qquad \text{and} \qquad T = W\sin\beta \tag{Eq. 6-9}$$

The available frictional strength along the failure plane will depend on ϕ and is given by

$$S = N\tan\phi \tag{Eq. 6-10}$$

Then if we consider the FOS as the ratio of available strength to strength required to maintain stability (limit equilibrium), the FOS will be given by

$$F = \frac{N\tan\phi}{W\sin\beta} = \frac{\tan\phi}{\tan\beta} \tag{Eq. 6-11}$$

The FOS is independent of the slope height and depth, z, and depends only on the angle of internal friction, ϕ, and the angle of the slope, β. Also, at $F = 1$, the maximum slope angle will be limited to the angle of internal friction, ϕ.

6.6.2 Infinite Slope in c–ϕ Soil with Seepage

If a saturated slope, in cohesive c–ϕ soil, has seepage parallel to the slope surface as shown in Figure 6.14, the same limit equilibrium concepts may be applied to determine the FOS, which will now depend on the effective normal force, N'. From Figure 6.14, the pore water force acting on the base of the typical slice will be given by

$$U = (\gamma_w h\cos^2\beta)\frac{b}{\cos\beta} = \gamma_w bh\cos\beta. \tag{Eq. 6-12}$$

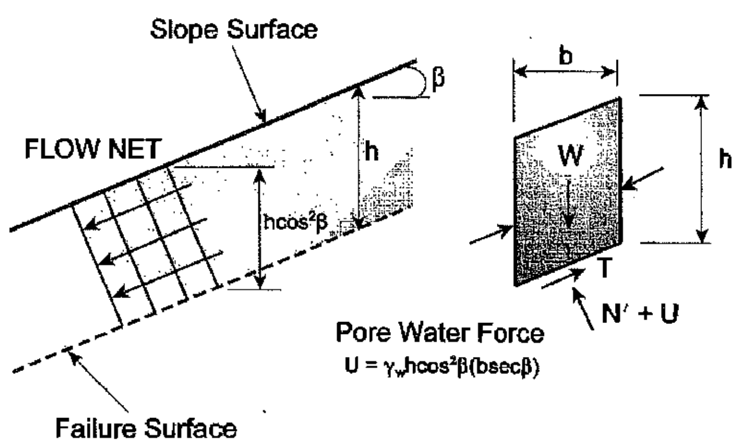

Figure 6.14 Infinite slope failure in c–ϕ soil with parallel seepage.

The available frictional strength along the failure plane will depend on ϕ' and the effective normal force and is given by

$$S = c'b \sec\beta + (N - U)\tan\phi' \qquad \text{(Eq. 6-13)}$$

So the FOS for this case will be

$$F = \frac{cb \sec\beta + (N - U)\tan\phi'}{W \sin\beta} \qquad \text{(Eq. 6-14)}$$

If we substitute $W = \gamma_{sat}bh$ into the above expression and rearrange, the FOS will be given by

$$\boxed{F = \frac{c' + h(\gamma_{sat} - \gamma_w)\cos^2(\beta)\tan\phi'}{\gamma_{sat}\, h \sin\beta\cos\beta}} \qquad \text{(Eq. 6-15)}$$

where $\gamma' = (\gamma_{sat} - \gamma_w)$. For a $c' = 0$ soil, the above expression may be simplified to give

$$F = \frac{\gamma'}{\gamma_{sat}} \times \frac{\tan\phi'}{\tan\beta} \qquad \text{(Eq. 6-16)}$$

From Equation 6.16 one can see that for a *granular* material, the FOS is still independent of the slope height and depth, h, but is reduced by the factor γ'/γ_{sat}. For typical soils, this reduction will be about 50 percent in comparison to dry slopes.

The above analysis can be generalized if the seepage line is assumed to be located at a height of $(m \times h)$ above the failure surface. In this case, the FOS will be given by

$$F = \frac{c' + h\cos^2\beta[(1-m)\gamma_m + m\gamma']\tan\phi'}{h\sin\beta\cos\beta[(1-m)\gamma_m + m\gamma_{sat}]} \qquad \text{(Eq. 6-17)}$$

and γ_{sat} and γ_m are the saturated and moist unit weights of the soil below and above the seepage line. The above equation may be readily reformulated to determine the critical depth of the failure surface for any seepage condition and a c'–ϕ' soil.

6.7 PLANAR SURFACE ANALYSIS

Planar failure surfaces usually occur in slopes with a thin layer of soil that has relatively low strength in comparison to the overlying materials. Also, this is the preferred mode of failure for jointed materials that may dip toward proposed excavations.

A planar failure surface can be readily analyzed with a closed-form solution that depends on the slope geometry and the shear strength parameters of the soil along the failure plane. For the slope shown in Figure 6.15, three forces—weight, W, mobilized shear strength, S_m, and the normal reaction, N—need to be determined in order to evaluate the stability.