Redline / Strikeout Version

Part III, Appendix III-D.5-3

Foundation Bearing Capacity Analyses

APPENDIX III-D.5-3

FOUNDATION BEARING CAPACITY ANALYSES

STATE OF TEXAS
JESSE PAUL VARSHO
114074
LICENSED
PROFESSIONAL ENGINEER

3-2-15

This document is released for the purpose of permitting only under the authority of Jesse P. Varsho, P.E. #114074. It is not to be used for bidding or construction. Texas Registered Engineering Firm F-5650

This document is released for the purpose of permitting only under the authority of Michael W. Oden, P.E. #67165. It has been Updated in August 2017 to match the current landfill configuration. It is not to be used for bidding or construction. Texas Registered Engineering Firm F-5650.

Appendix III-D.5-3, Foundation Bearing Capacity Analyses

- Updated calculations to match new landfill geometry

APTIM	Client Name:	Rancho Viejo Waste Management, LLC		
	Project Name:	Pescadito Environmental Resource Center	Project No.:	~~148866~~155145
	~~Prepared~~ Modified by:	~~P.Thomas~~O. Covert	Date ~~Prepared~~Modified:	~~2/24/2015~~8/1/17
	Reviewed by:	~~Jesse P. Varsho, PE~~ P. Thomas	Date Reviewed:	~~3/2/2015~~8/7/17

TITLE: FOUNDATION BEARING CAPACITY ANALYSES

Problem Statement

Determine the factor of safety against bearing capacity failure of the landfill foundation.

References

1. Summary of Geotechnical Parameters contained in **Appendix III.D.5-1** of this Report.
2. Coduto, D.P., "Foundation Design Principles and Practices," 2nd Edition (attached pages).
3. Caterpillar Product Information, 836H, Landfill Compactor (attached pages).
4. Landfill design specifications for layer types and thicknesses presented on design details in Design Drawing Set contained in this Application.
5. Landfill design grades for the mass excavation, liners, and final landform presented on design plan drawings in Design Drawing Set contained in this Application.

Assumptions

The following conservative assumptions were utilized in the analysis:

Scenarios Analyzed

1. Compacted soil liner bearing capacity under vehicle loading (short-term shear strength / loading conditions).
2. Compacted soil liner bearing capacity for the final landform at the point of maximum waste height (long-term shear strength / loading conditions).

Foundation Material Properties

- Stratum IV Foundation Soils. The lithologic unit occuring immediately beneath the base liner of the ~~North Unit and South Unit L~~landfill~~s~~ is Stratum IV (**Reference No. 1**). The unit weights and shear strength parameters assumed for this foundation unit are as follow (**Reference No. 1**):

  Unit Weights
  - Moist unit weight = 129 pcf
  - Saturated unit weight = 132 pcf

  Shear Strength - Short-Term Conditions
  - cohesion c = 2,500 psf
  - friction angle, Φ = 5 degrees

  Shear Strength - Long Term Conditions
  - cohesion c' = 720 psf
  - friction angle, Φ' = 13.5 degrees

Landfill Material Properties

- The following saturated unit weights were conservatively assumed in the bearing capacity calculations for the final cover soil, protective cover soil, compacted low permeable soil liner, and waste fill (**Reference No. 1**):

  Unit Weights
  - final cover soil moist and saturated unit weights = 129 pcf / 132 pcf
  - protective cover soil moist and saturated unit weights = 129 pcf / 132 pcf
  - compacted low permeable soil liner moist and saturated unit weights = 129 pcf / 132 pcf
  - waste fill moist and saturated unit weight = 65 pcf.

- The length and width of the smallest landfill cell occurs in Cell N4 of the North Unit Landfill and is approximately 1,872 feet long by 765 feet wide. The shorter dimension of **765 feet** was analyzed as "B."

- The maximum final elevation in Cell N4 Cell NE-2 occurs on the northern cell edge at elevation 726 704 ft. MSL. However, to be conservative the maximum final waste column thickness of approximately **380 241 feet** (which occurs at the center of both the North and South Unit LandfillsCell NE-2) was conservatively assumed in the long-term (final landform loading) bearing capacity calculation.

- The smallest landfill cell is Cell NE-1 with a length of 839 feet and a width of 1,165 feet. The length of Cell NE-2 is approximately 1,000 feet. To be conservative, half of the length of Cell NE-2 (approximately **500 feet**) was analyzed as "B."

- The corresponding elevation and thickness of each landfill and foundation layer used in these calculations are summarized in **Table 1** below. The location of this point is shown in **Figure 1**.

Table 1
Summary of Average Thickness of Landfill Layers

Layer	Top Elevation (ft. MSL)	Thickness (ft.)
Final Cover System (not located at maximum elevation)	858703	3
Waste (including intermediate cover)	855700	380241
Protective Cover Soil	475459	2
Compacted Low Permeable Soil Liner	473457	3
Foundation Materials	470454	-
	Total Height of Landfill, H =	**388 249 ft**

Bearing Capacity Equation for Static Conditions

The factor of safety for bearing capacity is as follows:

$$FS = \frac{q_{ult}}{\sigma'_v}$$

Where,

q_{ult} = ultimate bearing capcity (psf)
σ'_v = effective vertical stress (psf)

- Karl Terzaghi's bearing capacity equation for continuous footings is used to calculate bearing capacity of landfill foundation for static conditions. Due to the size and depth of the landfill, the equation is overly conservative for landfills.

$$q_{ult} = c'N_c + \sigma'_{zD}N_q + 0.5\gamma'BN_\gamma$$

Where,

q_{ult} = ultimate bearing capcity, psf
c, c' = soil cohesion, psf
σ'_{zD} = vertical effective stress, psf
γ' = effective unit weight of soil, pcf
B = width of foundation, feet
N_c, N_q, N_γ = non-dimensional bearing capacity factors, functions of Φ
Φ, Φ' = soil friction angle, degrees

- Using Terzaghi's bearing capacity factors the of N_q, N_c, and N_γ were determined (**Reference No. 2**):

For Short-Term Loading Conditions:

$\Phi = 5° \rightarrow N_c = 7.3, N_q = 1.6, N_\gamma = 0.4$

For Long-Term Loading Conditions:

$\Phi' = 13.5° \rightarrow N_c = 11.75, N_q = 3.8, N_\gamma = 1.75$

Calculations

Calculate ultimate bearing capacity, q_{ult} on the Foundation Materials. The vertical effective stress (σ'_{zD}) is conservatively assumed equal to zero for short term loading conditions. The Stratum IV foundation soils beneath the landfill base liners are characterized as slightly moist to dry, however to be conservative the saturated moist unit weights are assumed (instead of the moist unit weights) in the calculations below.

Short-Term Loading Conditions:

$$q_{ult} = c'N_c + \sigma'_{zD}N_q + 0.5\gamma'BN_\gamma$$

$$q_{ult} = (\sout{720}2{,}500psf)(7.3) + (0psf)(1.6) + ((0.5)(132 - 62.4)\,pcf(\sout{765ft}500ft)(0.4))$$

$$q_{ult} = \sout{15{,}904}25{,}210\ psf$$

Long-Term Loading Conditions:

$$q_{ult} = c'N_c + \sigma'_{zD}N_q + 0.5\gamma' BN_\gamma$$

$$q_{ult} = (720psf)(11.75) + (((3')(129pcf) + (241')(65pcf)\sout{383')(132-62.4)pcf})(3.8))) + ((0.5)(132-62.4)\,pcf\,(\sout{765}500ft)(1.75))$$

$$q_{ult} = \sout{156{,}344}99{,}908\ psf$$

Compacted Soil Liner Bearing Capacity under Vehicle Loading

Calculate the effective overburden stress (σ'ᵥ) due to the placement of the leachate collection system, clay liner and loading by a vehicle (compactor). Conservatively assume that the vehicle load does not attenuate with depth (refer to **Table 2** below).

Assume loading by CAT 836H compactor (**Reference No. 3**, attached pages)

Vehicle Weight (W_{veh}) = 122,586 lbs

Contact Pressure (P)

$$P = \frac{122{,}586\ \text{lbs}}{4\ \text{drums} \times \text{Area}_{\text{contact}}}$$

$$P = \frac{122{,}586\ \text{lbs}}{4\ \text{drums} \times (4.58\ \text{ft} \times \frac{1}{3} \times 5.67\ \text{ft})} = 3{,}540\ \text{psf}$$

Table 2 Effective Overburden Stress σᵥ, on Foundation Materials from Vehicle Load			
Layer	**Thickness, t (ft)**	**Unit Weight, γ' (pcf)**	**σ'ᵥ = (t) x (γ) (psf)**
Vehicle Load	-	3,540	3,540
Protective Soil	1	129	129
Protective Soil (saturated)	1	(132-62.4) = 69.6	69.6
Clay Liner	3	(132-62.4) = 69.6	208.8
Total Thickness =	**5**	**Σ(σ'ᵥ) =**	**3,947.4 psf**

Factor of Safety against bearing capacity failure due to vehicle loading and short-term static conditions, FS:

$$FS_{short-term} = \frac{q_{ult}}{\sigma'_v} = \frac{\sout{15{,}904}25{,}210\ psf}{3{,}947.4\ psf} = \sout{4.0}6.39$$

Compacted Soil Liner Bearing Capacity under Final Landform Loading

Calculate the effective overburden stress (σ'_v) due to waste and soil load for the worst case final conditions (**Table 3** below):

Table 3
Effective Overburden Stress, σ'_v, on the Foundation Materials From Final Landform

Layer	Thickness, t (ft)	Unit Weight, γ (pcf)	σ'_v = (t) x (γ) (psf)
Final Cover	3	129	387
Waste	~~380~~241	65	~~24,700~~15,665
Protective Soil Layer	1	129	129
Protective Soil Layer (saturated)	1	(132-62.4) = 69.6	69.6
Compacted Clay Liner	3	(132-62.4) = 69.6	208.8
Total Thickness =	~~388~~ 249 ft	**Σ(σ'_v) =**	~~25,494.4~~16,459.4 psf
	Weighted Average γ'_v =	~~65.7~~66.1 pcf	

Factor of Safety (FS) against bearing capacity failure at final landform height under long-term static conditions:

$$FS_{long-term} = \frac{q_{ult}}{\sigma'_v} = \frac{\sout{156{,}344}99{,}908\ psf}{\sout{25{,}494}16{,}459\ psf} = \sout{6.1}6.07$$

Results

The Pescadito Landfill has been designed to achieve a minimum factor of safety against bearing capacity failure of 2.0 under static conditions. A summary of the determined factors of safety against bearing capacity failure of the landfill foundation is presented in **Table 4** below.

Table 4
Factors of Safety Against Bearing Capacity Failure

Loading Conditions	Calculated Factor of Safety	Minimum Recommended Factor of Safety
Short-Term / Static Conditions: Vehicle Loading	~~4.0~~6.4	2.0
Long-Term / Static Conditions: Final Landform Loading	~~6.1~~6.1	2.0