EFFECTS OF LIQUID LEVELS TO INTERIM SLOPE STABILITY DURING SUSTAINABLE LANDFILL PRACTICE

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ABSTRACT: The concept of designing a sustainable sanitary landfill that reuses the existing landfill footprint has gained much attention in recent years. The sustainable sanitary landfill consists of multiple cell phasing and development, partial cell closure, operating a bioreactor, landfill gas recovery, landfill mining, waste material sieving and sorting, and reusing of the landfill footprint in various phases of developement. This paper focuses on landfill mining, and more specifically on how the liquid levels within a sanitary landfill effect the interim slope stability during a specific phase of waste excavation during landfill mining. Landfill mining is a way to reclaim a contaminated old landfill or to empty a partially closed lined cell in a sanitary landfill. During the mining process, steep slopes may be created by waste excavation and relocation which can create instability of the waste mass.

As the waste mass is exposed during mining operations, surface infiltration to the waste mass will likely increase, especially during seasonal heavy rainfall event(s) where there is no cap system to control excessive infiltration into the waste mass. The liquid level within the waste mass may rise to a level that may contribute to a unstable condition. Because of this concern, a parametric slope stability analysis was conducted for this paper to evaluate the effect of liquid levels within the waste mass on any operational landfill slope.

A model was developed for this parametric case study: the landfill mining operational interim slope ranges between 1(V):2.5(H) and 1(V):3.5(H); the landfill height varies at 6, 15, 24 and 37 m; and the liquid head varies between 0, 0.7 and 1.5 m, measured above the bottom liner system. The goal of this parametric analysis is to identify any potential instability issues during operations. A widely accepted minimum factor of safety for a static condition for a long term condition is 1.5. Although a factor of safety of 1.3 is accepted for a temporary slope condition, the minimum factor of safety considered in this study is 1.5. Graphical charts presented in the paper aim to identify various slope angles, waste heights and leachate head levels that could fall below the required minimum factors of safety.

The results of this landfill mining operational slope stability analysis are summarized in tables and plotted in a graph. This graph can be used to estimate the factor of safety (FS) against slope stability for conditions depicted and within the slope configuration and liquid level limits assumed in the paper. Waste and interface shear strength properties used in the analysis are shown in Table 1.

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The factors of safety for waste excavation interim slope stability analyses (under static loading conditions) for the above-mentioned slope section configurations are listed in Table 2; these results are depicted graphically in Figure 1, which represents all slope conditions on a single chart.

Table 1. Shear Strength Parameters

Layer	In-Situ Density (KN/m^3)	Shear Strength Parameters	
		Friction Angle (deg.)	Cohesion (KN/m^2)
Waste	8.64	33	0
Bottom Liner System	18.85	21*	0
Soil Foundation	18.85	0	96

* Use of textured geomembrane interace

Table 2. Summary of Waste Interim Slope Stability Analysis

Liquid Head on Liner (m)	Waste Height (m)	Factor of Safety (FS)		
		1:3.5 Slope	1:3.0 Slope	1:2.5 Slope
0	6	1.99	1.77	1.56
	15	2.09	1.85	1.60
	24	2.13	1.89	1.64
	37	2.22	1.94	1.66
0.7	6	1.70	1.52	**1.31**
	15	1.99	1.74	1.51
	24	2.04	1.83	1.59
	37	2.17	1.91	1.63
1.5	6	**1.27**	**1.15**	**1.03**
	15	1.78	1.52	**1.36**
	24	1.90	1.73	1.52
	37	2.09	1.83	1.58

The analytical results presented in Table 2 indicate that FS above 1.5 will be achieved for the all slopes modeled, provided that leachate head levels are less than 0.7 m above the liner. For the 1:2.5 slope, the FS values drop below 1.5 if the liquid level above the liner is greater than 0.7 m and when the waste height is less than 24 m. For the 1:3.5 and 1:3 slopes, the FS values is less than 1.5 when the liquid level above the liner is greater than 0.7 m and the waste height is less than 15 m.

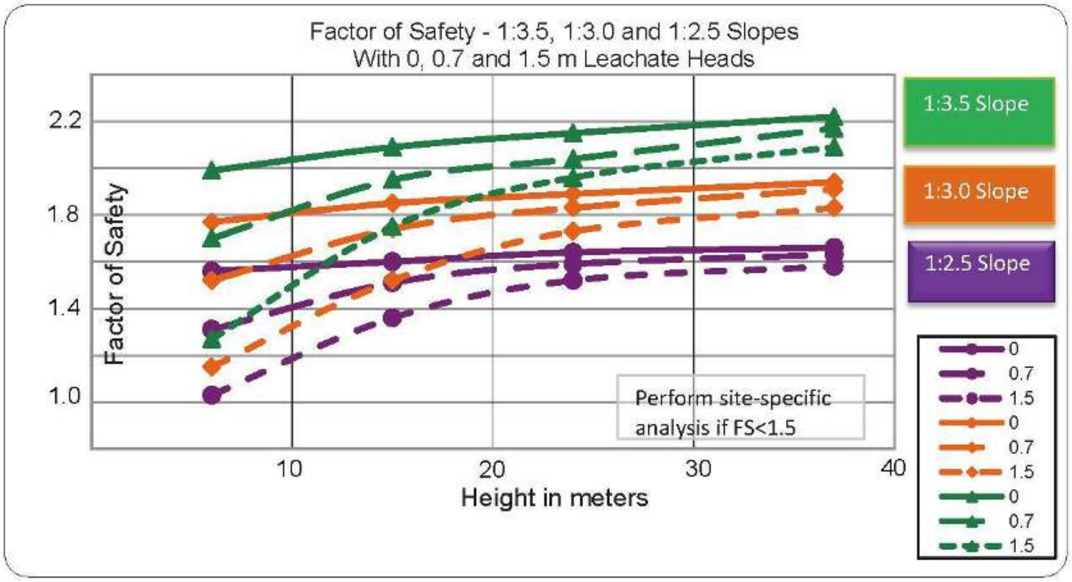

Figure 1. Waste Excavation Interim Slope Stability Chart

Figure 1 indicates that FS values decrease more significantly when leachate heads increase, compared with the scenario of a greater waste height. It is an indication that the leachate head has more of an influence of the critical surface than for the increased waste heights. For the situation where the leachate head on liner is zero, the relationship is reversed, as would be expected.

This study concludes that a circular failure mode is more critical than the block-type failure mode when the interface shear strength of a txtured geomembrane is used. However, when the analysis involves a liquid level above a smooth liner system, the interface shear strengths of the smooth liner system may control the factor of safety calculated. The graphical presentation in Figure 1 can be utilized as an important guide for a landfill site manager who may be excavating through waste mass for whatever reasons, and has a resulting steep and exposed waste slope. He can use the graph to assess whether the operating slopes and waste heights can maintain an acceptable minimum factor of safety, at liquid levels that are either measured in the field or observed at the sideslope seep locations.

The results discussed herein **does not** represent an actual site or specific site conditions. More refined, site-specific modeling, taking into account actual slopes, material properties, liquid levels and other factors should be performed. Factor of Safety values will be lower than indicated in Figure 1 chart if the assumed shear strength properties of the materials are less than indicated in Table 1 **or** if leachate levels are higher than the 1.5 m level modeled.