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Stability of Cover Systems for Landfills and Old Waste Dumps

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ABSTRACT

Old waste dumps often have steep slopes because waste has been tipped over from the top of the dump in a progressive manner. In new landfills, steep slopes are desirable to accommodate the maximum amount of waste possible. Cover systems provided on top of the waste dump to control leachate formation as well as to prevent emission of landfill gas consist of multiple layers of soils and geosynthetics. The stability of such cover systems is governed by the shearing resistance that develops between the various layers. This paper examines the influence of various parameters such as slope height, slope inclination, interfacial shearing resistance on the stability of the cover systems. It also describes the case study of a 18m high waste dump on which control measures are adopted in the form of a cover system along side slopes. The advantages and disadvantages of a various options are compared.

Keywords: *Landfills; Waste Dumps; Covers; Slope stability*

1.0 INTRODUCTION

The liner and cover configurations in landfills, as per the guidelines issued by the regulatory authorities (CPCB (2000), CPCB (2002) and MUA (2000)), are shown in Figures 1 and 2 for municipal solid waste (MSW) and hazardous waste (HW) for single liner system respectively.

The liner system for a MSW landfill comprises of a single composite barrier consisting of a geomembrane and 0.9m thick compacted clay. For a HW landfill, one can adopt a single composite barrier having a 1.5mm thick HDPE geomembrane over a 1.5m thick compacted clay layer or a double composite barrier depending on the site conditions. The cover system for a MSW landfill has five components as shown in Figure1 including a single barrier of 0.6m compacted clay. A HW landfill cover comprises of the same five components but includes a geomembrane as the sixth component which is a part of a composite barrier as shown in Figure 2.

The presence of multiple layers in the liner and cover system gives rise to the phenomenon of slippage at the interface of various layers along sloping sides. The interface between the geomembrane and the layer/component above it, as well as between geomembrane and the layer/component beneath it, are the two critical locations, which govern slope stability.

This case study discusses the need to take great care in arriving at safe slopes for covers of landfills.

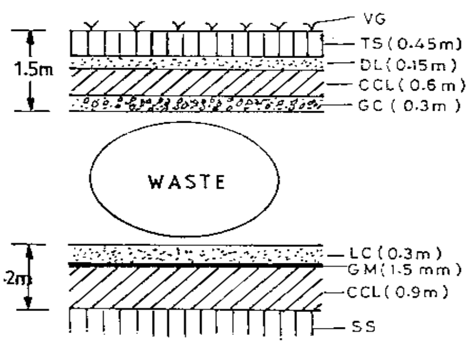


Figure 1 Components of MSW Landfill

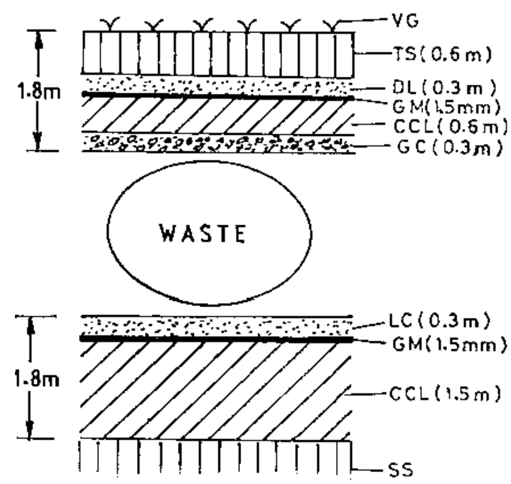


Figure 2 Components of HW Landfill

2.0 CONTROL MEASURES FOR AN OLD WASTE DUMP

2.1 Background

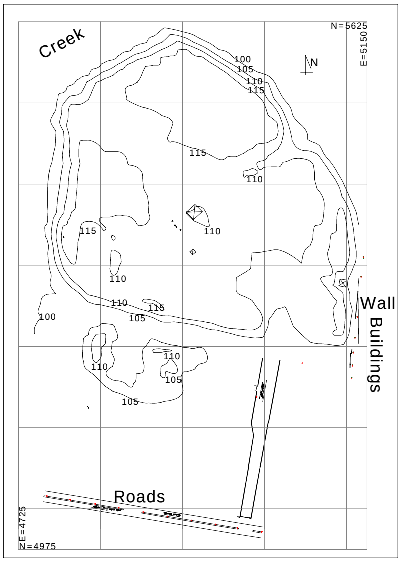
An old municipal solid waste dump occupies an area of 400m x 500m (approximately) in the suburb of a metropolitan city in western India (Figure 3). The waste height is 18m above the ground level (Fig. 4). On the northern side, the landfill protrudes into a creek and the waste has been dumped forward into the creek to a depth of a few meters below the water level. On the eastern side, a few buildings are close by and on the southern side, a road runs parallel to the boundary at some distance away from the perimeter.

Waste filling activities continue on top of the landfill by the 'tipping forward' method and at many locations the slope of the waste is in excess of 1:1 (horizontal:vertical). Uncontrolled gaseous emissions and foul odor emanate from the top of the waste dump. The base of the landfill slopes towards the creek and dark colored leachate flows along the base into the creek. Site investigations reveal the waste dump is underlain by clay followed by bedrock (Figure 4).

2.2 Control Measures

From a long-term perspective, the landfill must be stable, give an aesthetically pleasing appearance and have no harmful impact on the adjacent environment. This implies that the side slopes of the landfill must be made stable such that the factor of safety against slope instability is of the order of 1.5 as against 1.0 at present. It should be provided with a cover capable of supporting vegetative growth.

The nuisance of foul odor and the green house effect of the landfill gases is to be minimized by collecting and flaring or utilizing the gaseous emissions. The harmful impact of the leachate on the aquatic life in the creek has to be minimized by reducing the infiltration and by collecting and treating the leachate.



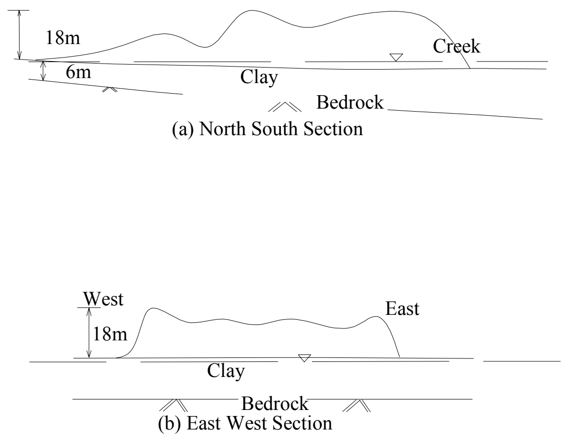


Figure 3 Plan View of Existing Landfill

Figure 4 Landfill Sections

Provision of an impermeable cover system along with a gas collection system is considered to be a suitable control measure to reduce the harmful impact on the environment. A cover system similar to that used for HW landfills is proposed as it facilitates efficient gas collection. Such a cover system is to be checked for stability along the side slopes.

2.3 Stabilization of Existing Side Slopes

The most attractive option of stabilizing the steep side slopes of the landfill was to strengthen them externally or internally without relocating the existing waste and without moving the toe of the slope. Three options were considered (Figure 5), namely a nailed slope, an anchored wall and a reinforced wall. These options are discussed hereafter.

Steep slopes in soils are often stabilized by the techniques of anchoring or nailing (Hausmann (1990)). Hence, an anchored or nailed slope with an impermeable cover and a vegetative mat was considered as an option (Figure 5(a)). The vegetative mat would initiate and sustain vegetation along the slope. However, three uncertainties were associated with this option: (a) the longevity of the anchors embedded in waste was suspect because the waste products could react with and weaken the anchors; (b) the settlements in the waste due to continuous biodegradation could change the alignment of the anchors and thus affect their functioning; and (c) the self-sustainability of the vegetation on such steep slopes could not be assured over the long–term. As a consequence, this option was ruled out.

An anchored wall (Figure 5(b)) was also considered as an alternative. It had the advantage of a concrete fascia on exterior which would require much lower maintenance in comparison to vegetation on a steep slope. However, this alternative also suffered from the disadvantage of uncertainty in the performance of the anchor buried in the waste. It was necessary to provide an anchor since a free standing wall would not be stable for a height in excess of 6 to 8m. A reinforced earth wall

(Figure 5(c)) too was considered and ruled out on account of complexities involved in placement and anchorage of the reinforcement. As a consequence, the focus shifted to stabilization of the slopes by re-grading and re-profiling of the waste.

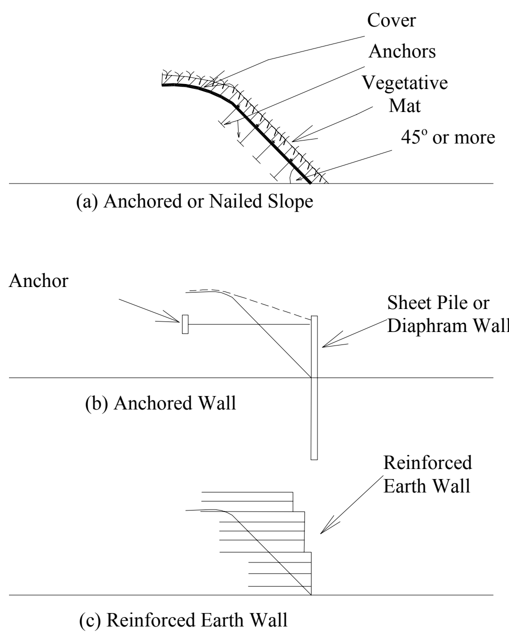


Figure 5 Possible Measures for Stabilization of Existing Slope

2.4 Re-Profiling of Side Slopes

A simple method for stabilization of the steep side slopes is to re-profile and re-grade them to a gentle slope of the order of 4 (horizontal) : 1(vertical). Such gentle slopes have adequate safety against sliding of components of the cover material over the waste. Re-profiling involves filling or excavating and re-locating the waste as shown in Figure 6, resulting in an increase in the height of waste to about 22m. Figure 7 shows how availability of space influences the adoption of this solution. Wherever space is available beyond the toe of the landfill, the slope can be re-graded to a gentler profile by filling waste or soil (Figure 7(a)). Such a situation is valid for the southern side of the landfill. At other locations, the toe would have to stay at its existing location or move inwards due to shortage of space as shown in Figures 7(b) and (c). The process of excavation and re-location of waste would produce additional foul odor. This would be acceptable on the side of the creek but would cause discomfort to the residents of the buildings on the eastern side. Hence on the eastern side, alternate measures would be required which would not involve excavation of waste.

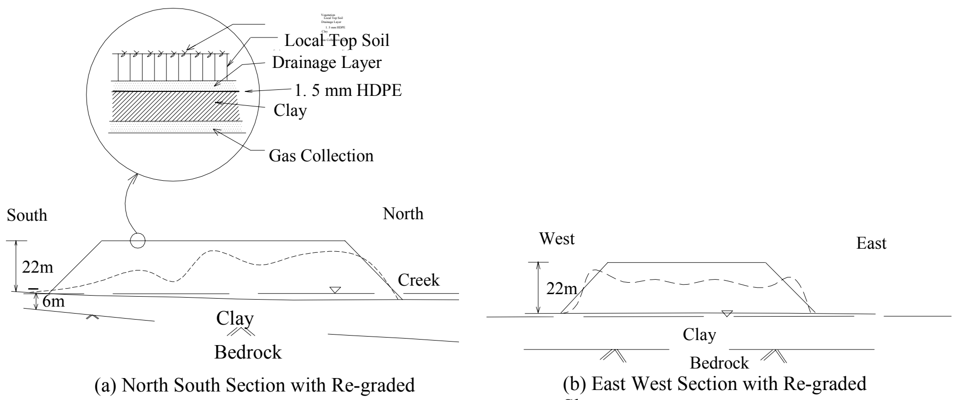


Figure 6 Landfill with Re-Graded Slope and Cover

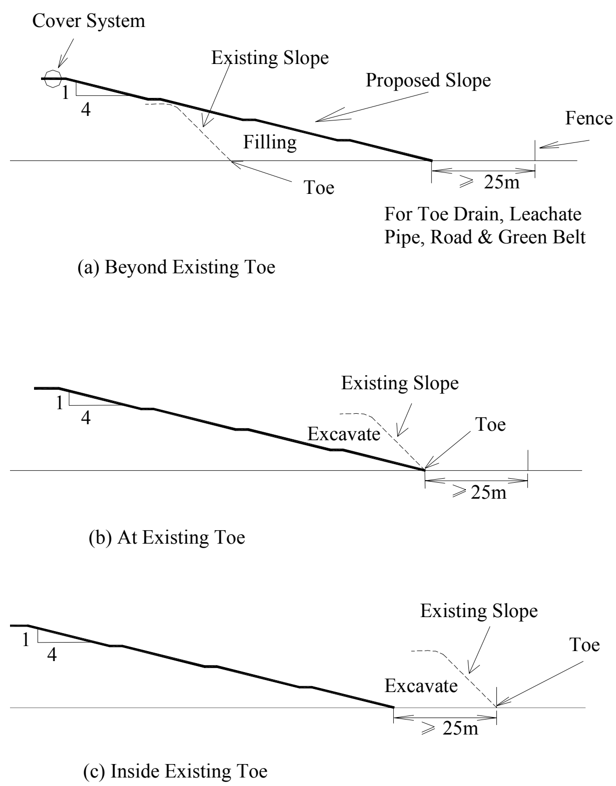


Figure 7 Position of Existing Toe and Re-Gradation of Slope

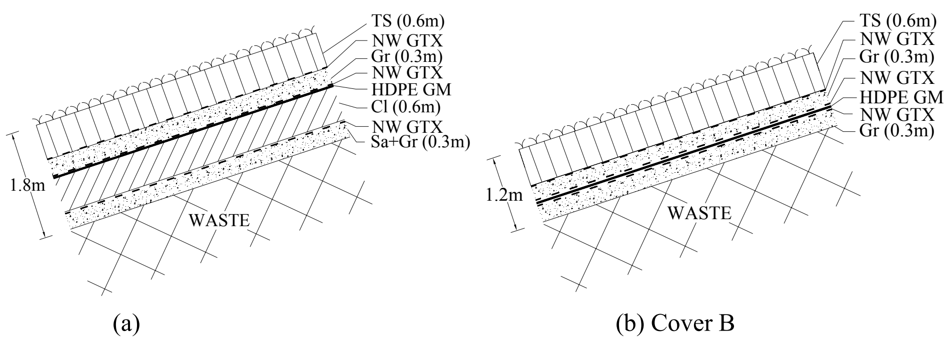
3.0 COVER STABILITY

Cover stability was examined for two cover systems as shown in Figure 8. The attempt was to arrive at the steepest slope with a factor of safety of 1.5. The results of the stability analysis are presented in Tables 1 and 2. It is evident from the figure and the tables that for Cover A, the weakest interface is the geomembrane – clay interface. Along this interface, the factor of safety is acceptable for textured geomembrabe when the slope inclination is 5 (hor.) :1 (ver.) and the slope height is 5.0m.

For cover B, the critical interface is the one between the geomembrane and the non-woven geotextile. An acceptable factor of safety is obtained for a slope inclination of 4.0 (hor.) :1 (ver.).

4.0 CONCLUDING REMARKS

This paper describes the factors which influence the stability of cover slopes of landfills and waste dumps. The interface between the geomembrane and soil / geotextile is the critical location at which slippage can occur. The shearing resistance along this interface as well as the slope height govern the choice of the stable slope angle. To improve the slope inclination, low thickness of soil layers and low height of slope (followed by berms) is considered important.



TS: Top Soil   NW GTX: Non-woven Geotextile
Gr: Gravel   HDPE GM: HDPE Geomembrane
Cl: Clay   Sa: Sand

Figure 8 Cover System

Table 1. Factors of Safety for GM (Textured)-Clay Interface ($\delta=14^0$) for Cover A

Slope (angle)	*Height* (m)*	*Length (m)*	*Driving force*	*Resisting force(without tension in GM)*	*Factor of safety*	*Resisting force(with tension in GM)*	*Factor of safety*
3:1 (18.43)	20	63.25	344.04	257.41	0.75	277.41	0.81
	10	31.62	172.00	128.69	0.75	148.69	0.86
	7.5	23.72	129.02	96.54	0.75	116.54	0.90
	5	15.81	86.00	64.35	0.75	84.35	0.98
	2.5	7.91	43.03	32.19	0.75	52.19	1.21
4:1 (14.04)	20	82.46	344.19	343.17	1.00	363.17	1.06
	10	41.23	172.09	171.58	1.00	191.58	1.11
	7.5	30.92	129.06	128.68	1.00	148.68	1.15
	5	20.62	86.07	85.81	1.00	105.81	1.23
	2.5	10.31	43.04	42.91	1.00	62.91	1.46
5:1 (11.31)	20	101.98	344.10	428.97	1.25	448.97	1.30
	10	50.99	172.09	214.53	1.25	234.53	1.36
	7.5	38.24	160.86	128.68	1.25	180.86	1.40
	5	25.50	86.05	107.27	1.25	127.27	1.48
	2.5	12.75	43.02	53.64	1.25	73.64	1.71

*Height less than 20m implies presence of berms at intermediate levels

Table 2. Factors of Safety for GM - Geotextile Interface for Covers a and B

Slope (angle)	*Height* (m)*	*Length (m)*	*Driving force*	*GM(Smooth) – GTX ($\delta=16^0$)*		*GM(Textured) – GTX ($\delta=24^0$)*	
				Resisting force	*Factor of safety*	*Resisting force*	*Factor of safety*
3:1 (18.43)	20	63.25	324.04	278.83	0.86	432.94	1.34
	10	31.62	161.99	139.39	0.86	216.44	1.34
	5	15.81	81.00	69.70	0.86	108.22	1.34
	2.5	7.91	40.52	34.87	0.86	54.14	1.34
4:1 (14.04)	20	82.46	324.18	371.72	1.15	577.17	1.78
	10	41.23	162.09	185.86	1.15	288.59	1.78
	5	20.62	81.06	92.95	1.15	144.33	1.78
	2.5	10.31	40.53	46.48	1.15	72.16	1.78
5:1 (11.31)	20	101.98	324.10	464.67	1.43	721.49	2.23
	10	50.99	162.08	232.38	1.43	360.82	2.23
	5	25.50	81.04	116.18	1.43	180.40	2.23
	2.5	12.75	40.52	58.09	1.43	90.20	2.23

***** Height less than 20m implies presence of berms at intermediate levels

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