A Case Study On Slope Failure in A Sanitary Landfill

H. Turan Durgunoglu
Professor of Civil Engineering, Bogaziçi University, Istanbul, Turkey

Turhan Karadayilar
CE, M.Sc.,Geotechnical Engineer, Zetas Zemin Teknolojisi AS, Istanbul, Turkey

C. Güney Olgun
CE, Ph.D. Research Scientist, Virginia Tech. Department of Civil and Environmental Engineering Blacksburg VA 24061 USA

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ABSTRACT: The increasing concern on the environmental effects of solid wastes, has made the implementation of sanitary landfills the only proper solution for the isolation of contaminants. Siting, design and construction of a sanitary landfill requires the consideration and fulfilment of serious environmental and engineering criteria. A case study of a landslide in the municipal sanitary landfill in Istanbul is presented as an example of problems concerned with initial stage engineering and environmental judgments. The sliding mechanism of the failure has been investigated and the resultant effects of the landslide on the safety of the landfill has been evaluated. The site is situated very close to one of the main drainage basins of the city. The continuity of the clay liner and geomembrane has been examined and major cracks have been observed to develop due to sliding. The presence of sand lenses in the clay formation in the subsoil accelerates the transportation of the contaminants. It has been concluded with the performed evaluations that any further disposal would result in a severe contamination of the groundwater unless additional appropriate measures are implemented.

1 Introduction

Göktürk sanitary landfill is located 8 km northwest of Istanbul Kemerburgaz, situated very close to one of the main drainage basins of the city and is surrounded by the main forestry area of Istanbul. The location of the disposal site is shown in Figure 1, along with the geological map of Istanbul. The complete disposal site encompasses an area of 500 acres and is planned to be the solid waste disposal facility for the European section of Istanbul with an estimated storage capacity of 5000 ton/day. The first stage is composed of four cells totalling an area of 60 acres.

Construction of this area was started in 1992 and all operational units were planned to be completed by the end of 1995. However, although the hospital waste burning unit was incomplete, commencement of storage at the site containing hazardous waste was begun in early 1995. Moreover 30 cm thick clay liner covered with gravel and geomembrane was constructed as the impermeable base of the first stage disposal cell instead of the 60 cm clay liner specified by the Turkish Standards. Finally, it was rather surprising that the site was under operation by Municipality without construction of leachate treatment facilities. Obviously this led to serious legal dispute between Municipality of Greater Istanbul Metropolitan Area and local municipality and people of Göktürk town.

The excavation of the 60 acre first stage disposal site was completed by 1993. No stability problems have been encountered in these slopes since the start of disposal in this area in January 1995 until April 1995. Following the heavy rains of the preceding spring and winter a slope failure has occurred in the western section of the landfill where waste has been stored. Investigations have been performed to identify the slope failure in the landfill and determine the extent of damage on the operational systems, such as clay liner, leachate collection and removal system.

Figure 1. Geologic map and location of investigation area.

2 Subsoil conditions

It has been observed that the local geological formation consists of alternating silt and sand lenses erratically distributed in the clayey subsoil. Fill and vegetative soil is present at the surface with thicknesses varying between 0.5-3.0m at maximum reaching to 9.0m. Silty sand is present at the upper portions of the side slopes of the storage area. The surface of the waste storage area is covered with a silty clay, which has silt and sand lenses within its formation. Below these alluvial deposits, at a depth of ~30.0m, greywacke is present. No groundwater is detected within the subsoil during the investigations. The clayey subsoil located at the surface prevents the intrusion of surface water into the subsoil. The schematic cross section of the soil profile is given in Figure 2. Since a closed coal mining site partly occupies the disposal site, the natural topography has been altered to great extent.

3 Slope stability problems and investigations

No natural stability problems have been encountered in the location of the solid waste disposal site covering an area of 500 acres. The vicinity consists of natural slopes with 10 - 30 degrees. The first stage of the solid waste disposal site has been completed in 1993 with side slopes of percent. It is reported that no stability and ground water problems were encountered during the excavations performed during construction. The base of cell BA-1 which is planned to be the initial storage unit of the first stage has been covered with a 30 cm clay liner and 2mm HDPE geomembrane. It has been opened to waste storage by January 1995 and a sliding movement was initiated by April 1995. The movement has continued for nearly two months resulting in ~300mm vertical and horizontal displacement and then it has accelerated for a period of one month totalling a displacement of ~1700mm and finally diminished and stayed constant by the end of four months. The schematic cross section of the sliding is shown in Figure 3.

The effect of sliding on the operational system of the landfill has been investigated. It has been observed that extensive displacements due to sliding have resulted in the breakage of the leachate collection and removal system. The resulting movement (1000mm vertical and 1500mm horizontal displacement) of a sliding block of 320 m width has caused the leachate collection and removal pipes to break. Several investigations have been performed for the evaluation of the sliding movements and its resulting effects. The monitoring data of vertical and horizontal movements during the period of sliding movements are given in Figure 4 (Özaydın et. al., 1995).

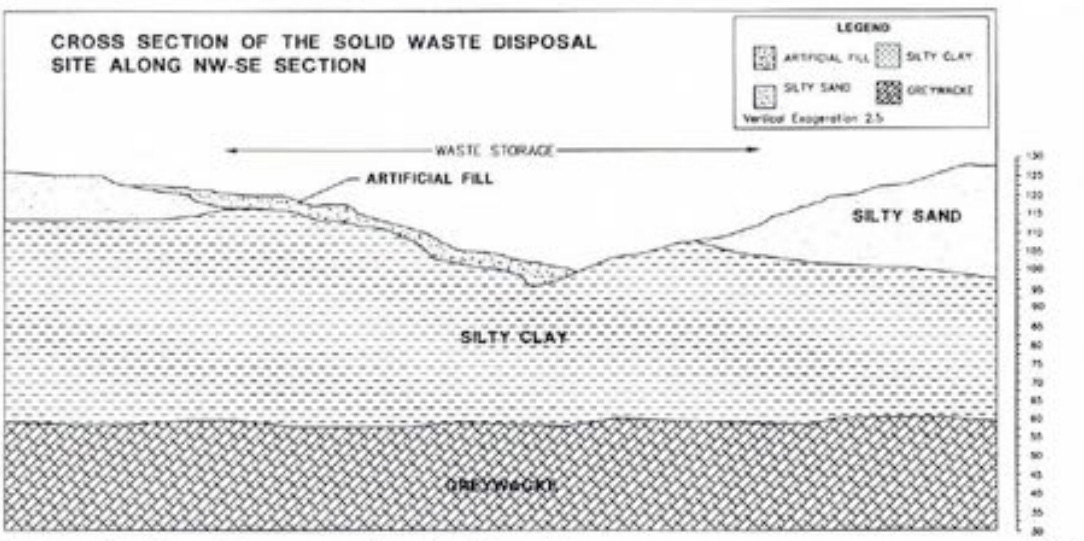

Figure 2. Schematic cross section of soil profile.

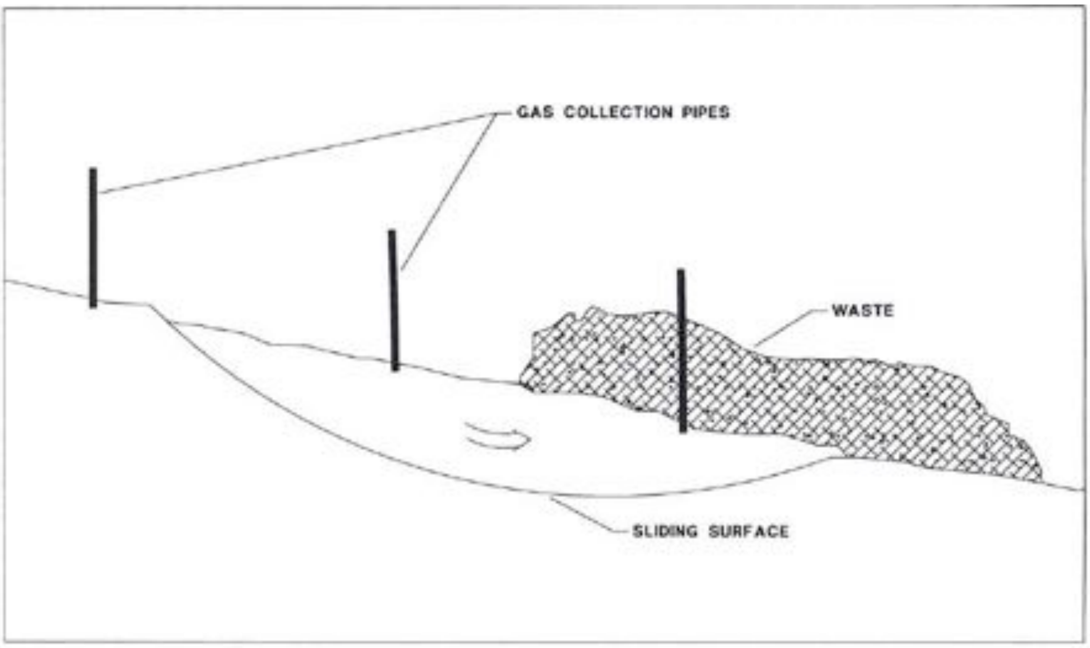

Figure 3. Typical geometry of sliding.

Although not much concerned with the slope failure, it has been determined that the design specifications are not met during construction (Durgunoglu et. al. 1995). The spacing of the vertical gas collection pipes are different from the spacing specified in the design documents. The clay liner under construction in the new cells does not have a protective cover and have been completely eroded in some sections due to heavy rainfall. Moreover observations along the section exposed at the crown of sliding indicate the absence of the geomembrane layer specified to be continuously laid between the clay liner and covering gravel. Such poor implementations in such an important project indicate that the problem is not confined with a slope stability failure. Therefore, it is essential that series of rehabilitation measures must be taken before further waste is accumulated in the site.

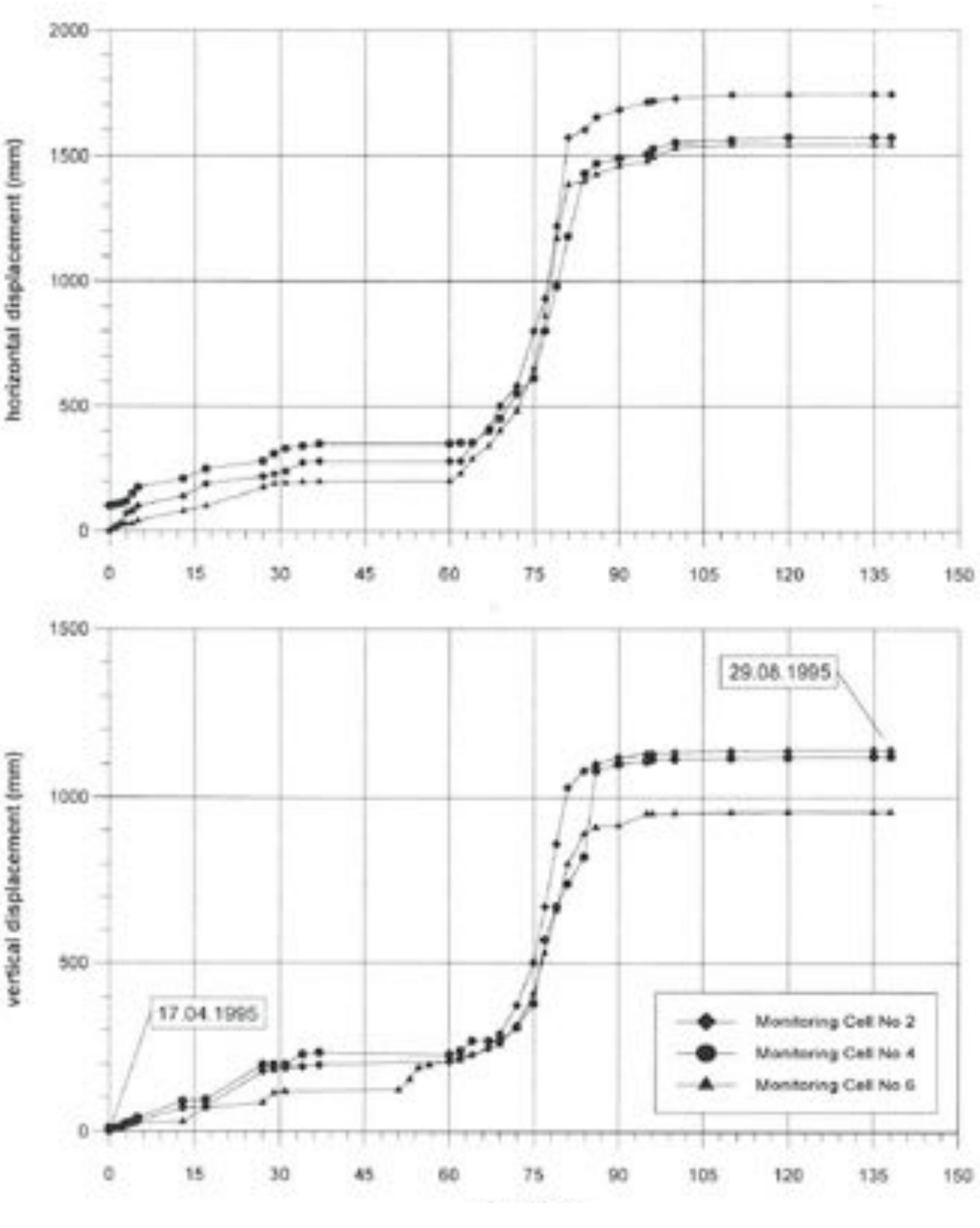

Figure 4. Monitoring data of horizontal and vertical movements.

Several analyses have been performed by various investigators to determine the reasons of sliding. Performed analyses indicate that the given geometry with the present subsoil conditions is safe in terms of stability unless the pore water pressure rises to excessive values. It has been reported (Özaydın et. al, 1995) that the factor of safety drops from 1.34 to 1.00 when the pore water pressure coefficient rises from 0.25 to 0.50. Similar results are presented in other investigations, which demonstrate that the excessive rise of porewater pressure is the main reason leading to sliding (Ülker and Saðlamer, 1995). Stability analyses are additionally performed for this study using conventional method of slices. These analyses indicate that previous analyses present the case and demonstrate the reason of sliding clearly. Under very low shear strength parameters the factor of safety is between 1.47-1.57 when pore water pressure coefficient, ru : 0.15. The rise of this value to 0.45 results in the factor of safety to drop to unity. The summary of the stability analyses are presented in Table 1.

Table 1. Summary of stability analysis.

Analysis	**Strength**	**Pore Water Pressure**	**Factor of Safety**
Özaydın et. al. (1995)	c′ 1 kPa ϕ' 17° γ 19 kN/m3	ru : 0.25 ru : 0.50	1.34 1.00
	c′ 0 kPa ϕ'12° γ 19 kN/m3	ru : 0.35 ru : 0.50	1.30 1.00
Ülker and Sağlamer (1995)	c′ 0 kPa ϕ'10° γ 19 kN/m3	ru : 0.50 ru : 0.60	1.04 1.01
This study	c′ 0 kPa ϕ'13° γ 20 kN/m3	ru : 0.15 ru : 0.25 ru : 0.45	1.47 1.28 1.00
	c′ 0 kPa ϕ'18° γ 20 kN/m3	ru : 0.15 ru : 0.25 ru : 0.45	1.57 1.36 1.10

c′ : effective cohesion
ϕ' : drained friction angle
γ : unit weight
r_u : pore water pressure coefficient

It is seen from the summary of analyses that the factor of safety is not very much sensitive to shear strength parameters. On the other hand the pore water pressure coefficient drastically affects the factor of safety. Even though very low shear strength is mobilized within the subsoil, sliding is not critical unless the pore water pressure rises excessively. Such an effect is primarily due to the flatness of the slope.
It has been observed from field investigations that the sandy clay layer overlying the clayey subsoil is exposed to the ground surface at the upper portions of the slope due to excavations performed during construction. Precipitation permeated this formation and caused a rise in pore water pressure in vertically and horizontally connected silt and sand lenses within the clayey subsoil finally resulting in sliding. Such a saturation process in the sand layer which contributed to formation of a potential sliding surface within the clayey subsoil is mainly due to extensive rainfall during the period of Winter-Spring 1995, preceding the failure. Therefore the main reason of sliding is determined to be the rise pore water pressure in the subsoil.

4 Conclusion

The reasons of the slope failure in Göktürk sanitary landfill located in Istanbul are investigated. Field investigations have been performed to determine the mechanism of sliding and the effects of sliding on the operational units. Several analyses performed previously have also been evaluated in determining the reasons of sliding. The performed investigations indicate that unless pore water pressure rises to excessive values, no stability problem is possible to occur in the slopes.
Former investigations show that the landfill was, at the start of operation, safe in terms of slope stability. The failure that occurred subsequently is determined to take place with the intrusion of surface water into the silty and sandy lenses within the clayey subsoil forming a weak surface leading to sliding, which was not considered in the

design. Such a case is supported with several investigations performed after failure. It is observed the operational units of the sanitary landfill including the clay liner, leachate collection and removal system have been damaged to great extent. It has also been determined that the gas collection pipes have not been constructed as specified in the design project and minimum requirements specified in Turkish Standards for clay liner are not met in the resulting application. Therefore, it is essential that series of rehabilitation measures must be taken before further waste is accumulated at the site.

5 References

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