Geosynthetics: Applications, Design and Construction, De Groot, Den Hoedt & Termaat (eds)
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Evaluation of soil-PVC geomembrane interface friction for landfill design

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ABSTRACT: Landfill waste containment systems often are composed of several layers of geosynthetics and natural soils. In most systems, a clay layer and a geomembrane are placed in direct contact in order to increase the total effectiveness of the hydraulic barrier to contaminant migration out of the landfill. In less developed countries, the landfill design is still in its infancy due mainly to the lack of regulations and liner material. The present paper concerns a preliminary study of the clay-PVC geomembrane interface. This investigation is related to a study of lining systems and possible use of a locally (Algerian) made PVC geomembrane as liner for some landfills situated in Algiers (Algeria). It was found that the textured locally made PVC, in terms of efficiency, can contribute to a "safe " disposal of domestic waste.

1 INTRODUCTION

It is known that landfill is the most widely used method of municipal solid waste (MSW) disposal. Currently in Australia and in the United States, 80 % of wastes are landfilled, 10 % incinerated and 10 % recycled. In the European Community, 70 % of the municipal solid waste and 35 % of the industrial wastes are disposed in a landfill. Although strict new government policies, in certain countries, will significantly reduce the proportion of waste being deposited in a landfill (for example, the Australian government has stipulated that the amount of solid waste deposited as landfill within Australia must be reduced by 50% by the year 2000), its overall volume will still be extremely high. The overall world wide demand for landfills will therefore, continue to be very high. Landfills have traditionally been designed on the basis that the surrounding soil and groundwater have the ability to dilute, disperse or attenuate any leachate formed. For example, in the U.K, landfills were often deliberately sited in high permeability strata since mixing the leachate with a large volume of ground water was thought to be sufficient to reduce the concentration of any pollutant to a safe level (Potter & Yong, 1993). In less developed countries, the situation is worse. Most of the landfills have no underliner or leachate collection system. In some areas of Bolivia, for example, the groundwater seems to be contaminated up to 70 m depth. In Algeria, soil and water pollution has reached a very high level of pollution around a number of landfills (Bouazza, 1993a, 1993b).

Until 1982, most of the landfill liners constructed were single clay liners. Generally, over the clay liner, there is a layer of gravel with perforated pipes for leachate collection and removal, The filter is employed to protect the holes in the perforated pipes against the movement of fine soil particles. Nowadays, most of the modern waste containment facilities are constructed according to the principle of having liner barriers composed of a composite system (geotextile and/or geomembrane in combination with clayey soils). Typically, the soil layers are fine grained and consist of large amounts of clay. Soils and geosynthetics are used in a liner system to serve as drainage and collection layers as well as hydraulic barriers. In most systems, the clay layer and a geomembrane are placed in direct contact in order to increase the total effectiveness of the hydraulic barrier to contaminant migration out of the landfills. Multiple barrier and collection layers are often combined to provide redundancy to the design. Collectively, the geosynthetic and soil comprise a landfill liner system.

In this paper, a preliminary study on the clay/PVC geomembrane interface friction is presented. This was part of a study of lining systems for some landfills situated in Algiers (Algeria). This study has been carried out in the prospect of a possible use of locally (Algerian) made PVC geomembranes as liner.

2 MATERIALS

The geomembranes used in the present study are of a PVC types. Two types have been used: a) textured (PVC1); b) smooth (PVC2). No information on the geomembrane properties were provided. The soil used was a clay from the El-Harrach area where the main Algiers landfill is sited. All samples were taken at a depth of about 4-5 m. The physical properties from laboratory tests are: unit weight = 17.10 kN/m^3, natural moisture content = 12%, optimum moisture content (omc) =14.5%, liquid limit = 38%, plasticity index = 17%, internal friction angle ϕ=29°. The mineralogical analysis of the sample showed that the soil was of a kaolin type.

3 TESTING PROCEDURE

A 100 mm x 100 mm shear box was used to determine the interface friction of the PVC geomembranes in a non saturated state (dry condition). Conventional shear box tests were initially conducted to ascertain the internal angle of friction of the clay. Further shear box tests were then conducted but with clay in the upper half of the box only, with the liner element material in the lower half. The lower half of the box was occupied by a hardwood block and the liner material was glued firmly to the surface of the block. The geomembrane was aligned so that shearing occured in a direction parallel to the longitudinal axis, along shearing direction. The block was adjusted so that the surface of the reinforcement was flush with the top edge of the bottom half of the box, in order to ensure shearing could only occur at the interface. Clay at omc + 2% and 96% maximum dry density was placed in the top half of the box, and a normal load varying from 100 to 400 kPa was applied. The shearing rate was 0.1 mm/min.

4 DISCUSSION

Figure 1 shows typical direct shear data for the interface between the El-Harrach clay and the different types of PVC. The shear stress is plotted as a function of the horizontal displacement for a constant normal stress, σ_n = 200 kPa. The measurements indicate that the roughness of PVC1

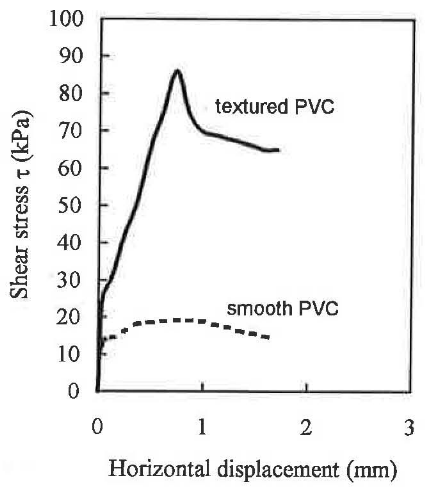

Figure 1: Shear displacement relationship for smooth and textured PVC at σn= 200 kPa.

contributes to the increase in the amount of the shear resistance at the clay/PVC interface. Apparently the rough surface of the PVC1 creates a better interlocking with the clay material than the smooth surface of PVC2. One can also notice that the sample with a textured surface (PVC1) shows a peaking of shear strength at small displacements of less than 0.8 mm. Whereas the sample with smooth surface (PVC2) shows a flatter shear displacement curve. Another feature is also depicted in Fig.1. Indeed, one can also notice that the residual stregth of the soil/PVC2 system is almost identical to its peak value. Whereas in the soil/PVC1 system the drop from peak to residual strength value is visible.

Figure 2 indicates that the interface friction angle δ is sensitive to normal stresses, especially for the case of textured geomembrane (PVC1) where the values of δ varied from 25° to 20° over the range of stresses available in the test. For the smooth geomembrane (PVC2), the value of δ is very low (in the order of 5°) and the range of variation is almost negligible. The contact efficiencies are generally expressed as the ratio of interface to internal friction angles. In the present case, the textured PVC interface efficiency ranged from 69% to 86% for the range of stress available in the tests. The smooth PVC geomembrane was found to have an efficiency of approximately 17%. The low interface friction angle value and efficiency attained in the present case with the smooth PVC represent a high risk potential of failure due to slippage. Therefore, the use of such type of material should be avoided.

Table 1: Some interface shear angle values between geomembrane & compacted clay or silt.

Sources	Interface Components	Peak interface angle δ (°)	Residual interface angle δ_r (°)
Mitchell et al. (1990)	HDPE/c.clay	13.6	12.4
Pasqualini et al.(1993)	LDPE^2/c.clay	-	14°
	LDPE^2/c.clay	-	11.5
Orman (1994)	HDPE^1/c.silt	29	29
	HDPE^1/c.silt	31	31
	HDPE^1/c.silt	32	32
	HDPE^2/c.silt	12	12
	HDPE^2/c.silt	12	12
	HDPE^2/c.silt	10	10
present study	PVC^1/c.clay	22*	20*
	PVC^2/c.clay	5*	5*

(1) textured (2) smooth, * average value

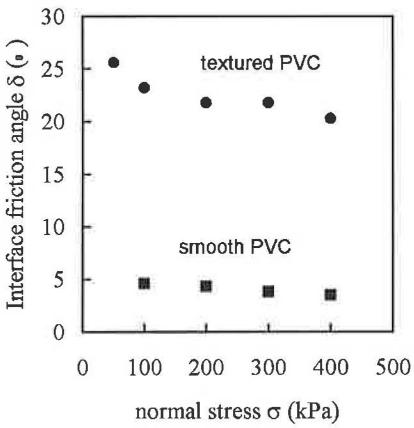

Figure 2: Variation of internal friction angle with normal stress.

The results of the geosynthetics interface shear test reported by Mitchell et al. (1990) in connection with the initial Kettleman Hills failure investigation as well as the results reported by Martin et al (1984), Williams & Houlihan (1986), Negussey et al. (1989), Pasqualini et al. (1993) and Stark et al. (1996) are particularly instructive examples of the values and variabilities of interface shear resistances. Clay/geomembrane interfaces exhibited sometimes a comparable range of shear strengths; exceptionally however interface friction values as low as 4.5° as in the present case are reported (see Table 1).

5 CONCLUSIONS

In the present specific case, it appears that the use of textured locally (Algerian) made PVC can alleviate certain environmental issues and contribute to the "safe" disposal of domestic waste. Economically, this is also a viable alternative for local authorities since the cost of having a composite liner is reduced. However, one should stress that this is not the panacea to all waste disposal problems in Algeria. Proper regulation should be put forward. More testing encompassing all aspects linked to landfill design are needed in order to optimise the locally made PVC

ACKNOWLEDGMENTS

The help provided by the ENTP (Algiers) and the LTPC (Algiers) is gratefully acknowldged.

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