Reflections about interface strength between soils and textured geomembranes

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ABSTRACT: Geomembranes are very important components in impermeable barrier systems used in landfills and effluent ponds. The lining system stability depends on interface strength between geomembrane and other materials, such as soil and geotextile. This interface strength can be relatively low, and the lining system stability can be affected. Within this context, this paper presents interface shear test results between textured HDPE geomembrane 1.0mm thick and two different soils: dry sand and silty clay. Literature results were showed in order to propose some reflections about this theme

1 INTRODUCTION

Geomembranes are used as barriers in control systems in geotechnical and environmental applications. Among its various applications, is important to highlight its use in impermeable barrier systems of landfills and effluent ponds. These systems can combine, in addition to geomembranes different materials with functions of protection, reinforcement and drainage, such as compacted soils, granular soils and other synthetic materials like geotextiles and geosynthetic clay liner, forming the composed barriers, as illustrated in Figure 1.

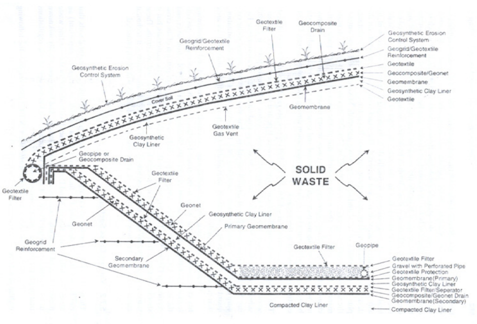

Figure 1 – Typical applications of geosynthetics (Koerner, 1998).

The use of these barriers on slopes requires great attention to the stability analysis due to the presence of interfaces that may exhibit low shear strength and act as a potential slide surface. This aspect becomes even more relevant when considers the modern tendency to optimize the landfill storage capacity by constructing embankments increasingly steep and deep.

The importance of the matter may be revealed by several cases of waste landfills rupture reported in the literature since the 80's, when the beginning of the intensive use of geosynthetics in such applications. Among these cases, can be cited the Kettleman Hills Landfill. After the landfill rupture, studies were conducted to try understanding the behavior of interface strength and to quantify it properly (e.g. Mitchell et al., 1990).

To contribute to better performance of barrier systems on slopes, several manufacturers have developed a geomembrane with a textured surface to increase the frictional characteristics at the interface with the soil, concrete and other materials. The most common type of texturing is manufactured by the blown-film coextrusion process.

In this context, this paper presents interface shear test results between textured HDPE geomembrane 1.0mm thick and two different soils: a dry sand and a silty clay. Literature results were showed in order to propose some reflections about this theme.

2 TESTS

A tests program was conducted to evaluate the interface strength between a HDPE textured geomembrane of 1.0mm thick (manufactured by Neoplastic) and two different types of soil: dry sand and compacted silty clay. Tables 1 and 2 show the main characteristics of the used soils, while Figures 2 and 3 show the particles size distribution of the soils used, obtained according to the Brazilian Standard NBR-7181 (ABNT, 1984).

Table 1 – Dry sand characteristics.

Property	e_{max}	e_{min}	e	ρ (kN/m³)	ρ_s (kN/m³)
Value	0,75	0,5	0,62	16,5	26,7

Table 2 – Silty clay characteristics.

Property	LL (%)	LP (%)	w_{ot} (%)	ρ_{dmax} (kN/m³)	ρ_s (kN/m³)
Value	45	31	25,5	16,2	31,5

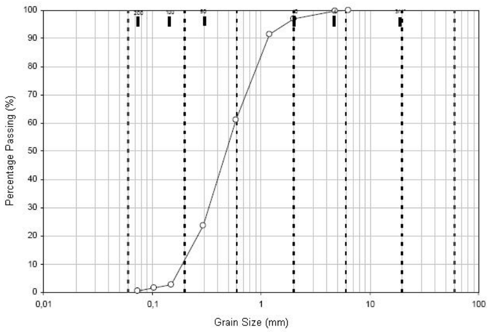

Figure 2 – Particle size distribution for dry sand.

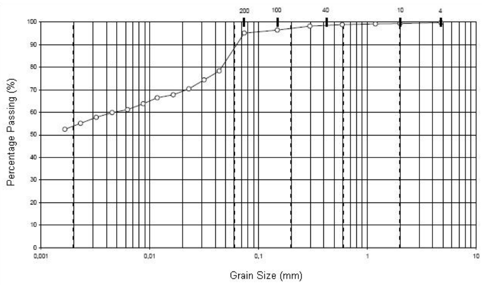

Figure 3 – Particle size distribution for silty clay.

Direct shear tests were carried out using a square box of 100mm side, conform Koerner (1998) suggests. The test speed was 0.5mm/min. The normal stresses used in the tests were 25, 75 and 150kPa, simulating a fill ranging between 1m to 8m, approximately. From these tests the shear stress by horizontal displacement curves of the interface between the geosynthetic and the different soils can be obtained. To characterize the post-peak strength of the tested interfaces, displacements up to 20mm were performed.

3 RESULTS

Figure 4 presents the tests results of the shear interface between HDPE textured geomembrane and sand.

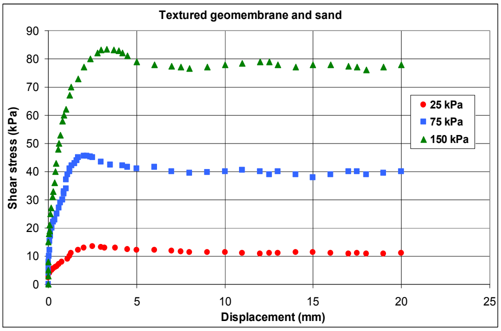

Figure 4 – Results of the shear interface textured geomembrane x sand.

Considering the peak and the residual stresses, shown in the Figure 4, is possible to obtain the Mohr-Coulomb failure envelope, as shown in Figure 5.

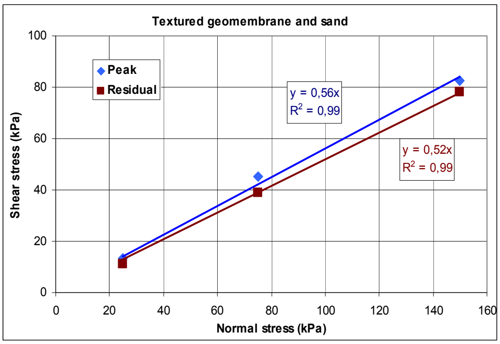

Figure 5 – Peak and residual failure envelopes of geomembrane and sand interfaces.

Figure 6 presents the tests results of the shear interface between HDPE textured geomembrane and silty clay.

Considering the peak and the residual stresses, shown in the Figure 6, is possible to obtain the Mohr-Coulomb failure envelope, as shown in Figure 7.

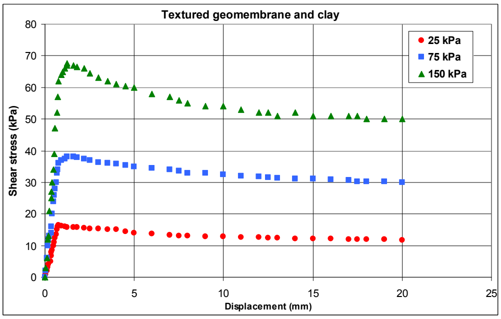

Figure 6 – Results of the shear interface textured geomembrane x silty clay.

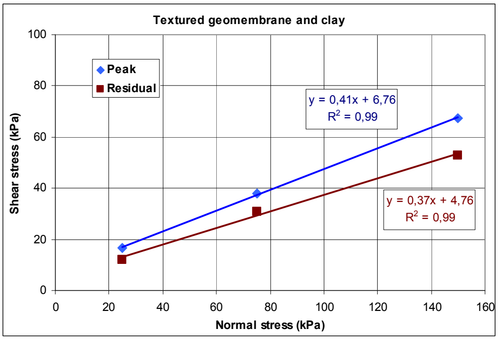

Figure 7 – Peak and residual failure envelopes of geomembrane and clay interfaces.

Table 3 shows the peak friction angle, the peak adhesion, the residual friction angle and the residual adhesion values obtained from interface shear tests.

Table 3 – Summary of parameters obtained from interface shear testing.

Soil	Peak friction angle (º)	Peak adhesion (kPa)	Residual friction angle (º)	Residual adhesion (kPa)
Sand	29,0	---	27,4	---
Silty clay	22,3	6,8	20,0	4,8

The friction angles obtained are consistent with the values reported in the literature. Izgin & Waste (1998) suggest values between 24° and 44.5º for interfaces between HDPE textured geomembrane and sand. For interfaces between geomembrane and clay, Sharma & Lewis (1994) indicate friction angles between 7° and 35°.

Table 4 presents a comparison of the interface shear strength obtained in this paper with HDPE textured geomembranes, manufactured in Brazil, tested by Rebelo (2003) and Vidal (2007).

Table 4 – Summary of parameters obtained for Brazilian HDPE textured geomembranes.

Author	Texture	Soil	δ Peak (°)	δ Resid. (°)	Peak adhesion (kPa)	Resid. adhesion (kPa)
Present research	Blown-Film	Sand	29	27,4	-	-
		Clay	22,3	20	6,8	4,8
Rebelo (2003)	Blown-Film	Sand	31	27	-	-
	Flat die	Sand	31	26	-	-
Vidal (2007)	Blown-Film	Clay	26	18	-	-
	Flat die (*)		27,5	23,8	6,3	-

(*) Average values

As can be seen in Table 4, the results presented in this paper and the results presented by Rebelo (2003) are similar, so the evaluated geomembranes have equivalent performance. For the present study, the peak interface friction angle was 29° and the residual interface friction angle was 27.4°. Rebelo (2003) obtained peak values of 31° and residual values of 27°.

For clayey soils the geomembrane tested presented peak interface friction angle of 22.3° and peak adhesion of 6.8kPa. In the residual condition, the values were 20° and 4.8kPa, respectively for friction angle and adhesion. Vidal (2007) obtained average values of interface friction angle of 27.1° and adhesion of 6.3kPa for peak condition. For residual condition, the average value of interface friction angle was 22.4° and no adhesion was achieved. For both conditions, the adhesion presented by the geomembrane tested in this research was higher than the tested by Vidal (2007), especially in the residual condition.

Table 5 shows the peak friction angle, the peak adhesion and the residual friction angle values obtained from HDPE smooth geomembranes, manufactured in Brazil, tested by Rebelo (2003) and Vidal (2007).

Table 5 – Summary of parameters obtained for Brazilian HDPE smooth geomembranes.

Author	Soil	δ Peak (°)	δ Resid. (°)	Peak adhesion (kPa)
Rebelo (2003)	Sand	18	16	-
	Clay	19	11	2,4
Vidal (2007)	Clay	19	11,3	2,4
	Silt	19,3	13,2	-

Comparing the interface shear strength obtained in this paper with the results showed in Table 5, it can be seen that the increase in peak interface friction angle of textured geomembrane is about 60% for sandy soils. For clayey soils, the increase is almost 20%. For residual friction interface, the increase is approximately 70% and 80% for sandy and clayey soils, respectively. Finally, the peak adhesion of textured geomembrane is about 3 times higher than the smooth geomembrane.

4 CONCLUSIONS

Direct shear tests were carried out to evaluate the interface shear strength between textured geomembranes 1mm thick and two different soils: sand and silty clay. The main conclusions of this work are as follow:

- The evaluated geomembranes presented interface friction angle values substantially higher than those of smooth geomembranes reported in national and international literature;
- There is an equivalent performance between the textured geomembranes manufactured in Brazil and those used in this work, both in sandy and clayey soils;
- The geomembranes tested in this work have perfect conditions for use in slope, considering the local stability, since properly designed and analyzed.

It is important to emphasize that these tests were conducted in a particular group of sands and clays. Thus, the values obtained are specific to the soils used in this analysis. For purposes of design, a proper characterization of soil-geomembrane interface parameters is recommended.

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