Friction Angle of Textured HDPE Geomembranes

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ABSTRACT: In many applications, such as in landfills and in mining stockpiles, it becomes economical to increase the steepness of side slopes in order to increase storage of wastes in a minimum area. Smooth surface geomembranes have friction angles with soils approximately three quarter of those of the soils themselves. Recently many textured geomembranes have been developed to improve the geomembrane/soil friction.

Recent published results indicate that friction angles between textured geomembranes and different types of soils are similar to those of the soils themselves. It constitute a great improvement when compared to friction angles of smooth HDPE geomembranes.

The geomembrane/soil friction of commercial textured geomembranes produced by different processes have been investigated to compare their friction behaviour. Results obtained are presented and compared to the published data. The difficulties encountered in comparing results are also discussed: the influence of molding water content, time between sample preparation and condusting the test, shear box scale effects, liner stiffness and confining pressure.

1. MANUFACTURING OF TEXTURED GEOMEMBRANES

Basically, four types of HDPE textured geomembranes are produced: a) a textured sheet manufactured by attaching an HDPE friction surface to an HDPE geomembrane. This friction surface can be attached on one or on both sides of the geomembrane; b) a textured a HDPE sheet (at extruder die exit) using Nitrogen bubbles; c) a textured geomembrane manufactured by spraying fine HDPE bits on an extruded sheet; d) a structured sheet in the form of surface spikes manufactured by using a profiled calender roll immediatly after flat cast extrusion (with or without studs on the other side.

Because of the large differences of the surface characteristics of produced textured geomembranes, their characteristics such as shear strength, adhesion to soils and friction angles with different soils varied significantly.

2. PRINCIPLES OF DIRECT SHEAR TEST

Direct shear test is used to measure a frictional behaviour of soils. Recently, the test was modified to be used to evaluate frictional behaviour when shearing geosynthetics against soils. During test with geomembranes, a portion of soil is made to slide along a geomembrane, or vise versa, under a constant rate of displacement, while a constant load is applied normal to the plane of relative movement. The maximum shear stress is obtained and the test is conducted at different normal confining pressures. As a result, shear stress/displacement curves for specimens tested under different normal pressure as well as the Mohr-Coulomb envelope are plotted as shown in Fig. 1a, Fig. 1b.

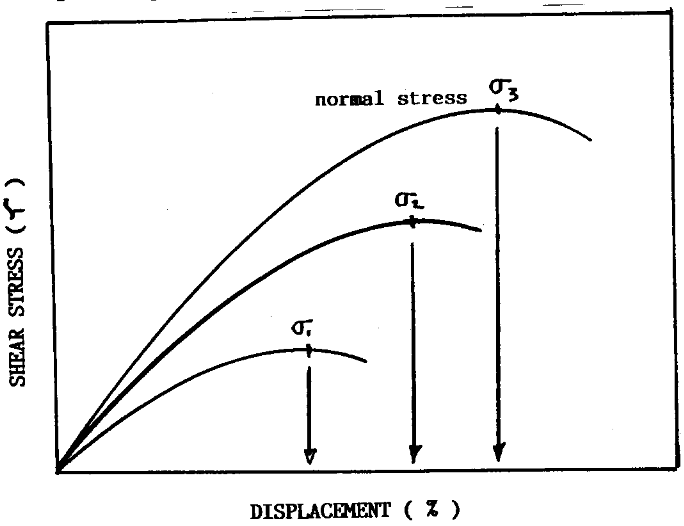

Fig. 1a Shear stress/displacement curves

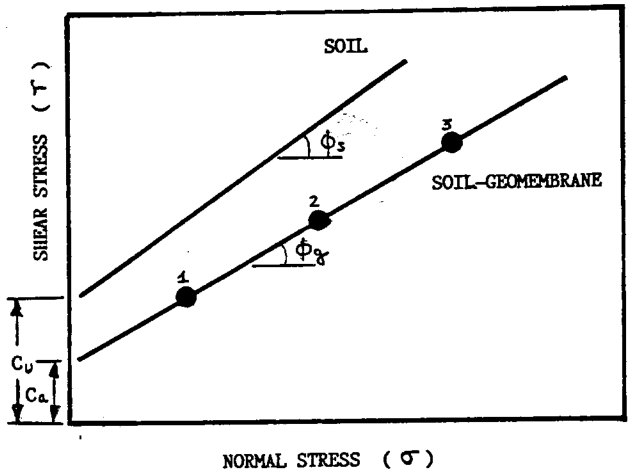

Fig. 1b Mohr-Coulomb envelopes

It is well known from Coulomb's equation that the shearing resistance of soils is generally made up of two components:

a) friction (expressed by the friction angle of the soils Φ_s), which is due to the interlocking of particles and the friction between them when subjected to normal stress, and

b) cohesion (expressed by the cohesion of the soil C_U), which is due to internal forces holding soil particles together in a solid mass.

Similarly, the shearing resistance of a geomembrane against soils is expressed by two parameters:

a) friction (expressed by the friction angle of the geomembrane against a chosen soil Φ_g), which is due to the friction between the soil particles and the geomembrane surface, the interlocking of particles between surface wrinkles or studs of textures geomembrane when subjected to normal stress, and

b) adhesion (expressed by the adhesion of the chosen soil to the geomembrane C_a), which is due to the interface force holding soil particles at the geomembrane surface.

Using the obtained data, the efficiency on friction ($E\,\Phi$) and the efficiency of cohesion (E_C) can be calculated using the following equations:

$$E\,\Phi = (\tan \Phi_s)/(\tan \Phi_g) \quad [1]$$

$$E_C = C_U/C_a \quad [2]$$

The results of direct shear test are very sensitive to a number of factors thus very difficult to interpret, such factors as: for soils - water content, time between sample preparation and conducting the test, preconsolidation pressure, strain rate, shear box dimensions, and for geomembranes - stiffness and thickness have to be always taken into consideration.

3. RESULTS

Data on friction angles of textured HDPE geomembranes against different soils have been gathered from publications (Martin et al, 1987; Koerner et al, 1986; Peggs et al, 1983), manufacturers (SLT (1990)) and shear tests performed at Ecole Polytechnique (Lafleur and Rollin, 1992; Mlynarek and Marcotte, 1993). The results are presented in Table 1 and in Fig. 2 and Fig. 3.

The major problem encountered in gathering published results was related to the lack of data on the detailed procedure and conditions applied during testing as well as the friction angle of the soil itself. It was supposed that all tests were carried out according to the ASTM-D-5321-92 procedure. This procedure, however, does not specify precisely all parameters of the test leaving to the authors to report all details of the procedure applied. For example, the rate of displacement at wich the specimen was sheared has to be reported to inform about drainage conditions which is of particular importance when a geomembrane is tested against clay. The water content, the degree of saturation and the presonsolidation pressure should also be reported when geomembranes are tested against clays. In case of sandy soils, it was supposed that in all tests the soil was in dense state. The thickness of the geomembrane should also be reported.

Table 1 Friction angle of HDPE textures geomembrane/soil systems

GEOMEMBRANE FRICTION ANGLE (°)

	SAND			TILL			CLAY		
	system	soil	E_ϕ	system	soil	E_ϕ	system	soil	E_ϕ
Type A	37	28	1.42	-	-	-	29	30	0.96
	34	33	1.04	-	-	-	-	-	-
Type B	34	33	1.04	31	36	0.83	25	22	1.15
	34	33	1.04	-	-	-	26	24	1.10
	31	28	1.13	-	-	-	27	30	0.88
	-	-	-	36	38	0.9	29	36	0.82
Type C	30	28	1.09	36	36	1.00	32	30	1.08
	-	-	-	35	36	0.96	-	-	-
Type D	26	28	0.92	-	-	-	28	32	0.85
	35	28	1.32	38	36	1.07	-	-	-

The data reported in this paper were obtained for confining pressures ranging from 25 to 100 kPa for three categories of soils: medium clean sand; tills and clays. The results obtained with sandy soils are presented in Fig. 2 while the results obtained with tills and clays are presented in Fig. 3. In both Figures the linear correlation representing smooth geomembrane/soil friction angles is shown for comparison (Koerner et al, 1986; Lafleur et al, 1992; Peggs et al, 1993).

The friction angle of textured geomembrane in contact with sandy soils is ranging from 26 to 38° mobilizing from 92% to 142% of soils' friction angle itself. This is an indication that the friction angles of textured geomembranes are similar and higher to those of the sands themselves. The analysis of the results obtained with the sand having a friction angle of 28° clearly indicates that the friction mobilization is a function of the surface characteristics of the products used as shown in Fig.2.

The friction angle of textured geomembranes against glacial tills and clays is ranging from 25 to 38° which is from 82% to 115% of the soil itself. The similar trend can be observed as for sandy soils-geomembranes friction angles are almost equal to the soils themselves as shown in Fig. 3.

This constitutes a great improvement when compared to friction angles of smooth HDPE geomembranes.

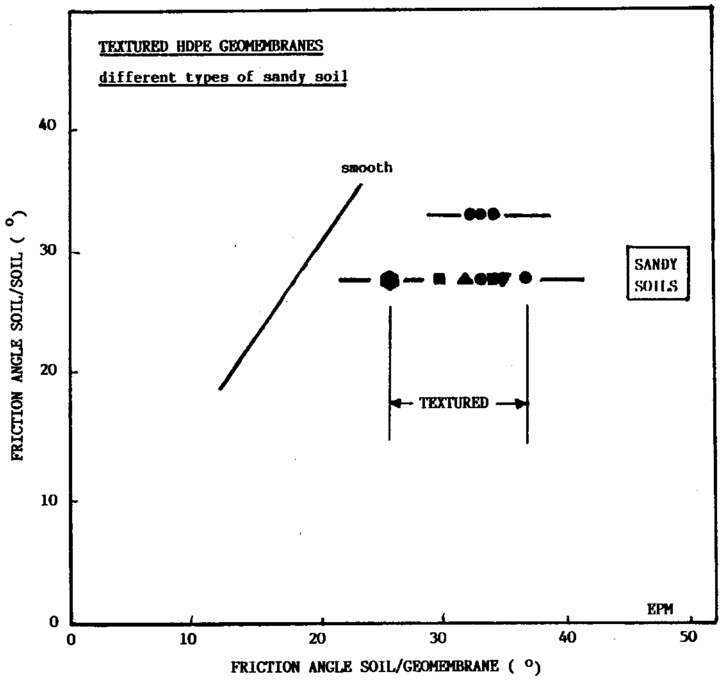

Fig. 2 Friction angles of HDPE textured geomembranes against sandy soils

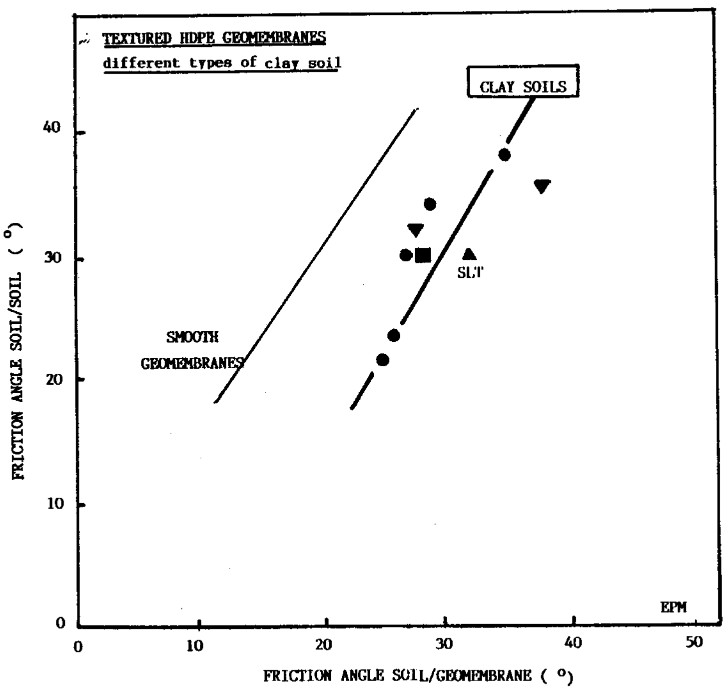

Fig.3 Friction angles of textured HDPE geomembranes against tills and clays

4. CONCLUSION

For sandy soils, no correlation could be established since the friction angle of the systems soil/geomembrane is very sensitive to the surface characteristics of the products. The friction angles are similar and greater than those of the sands themselves upon the geomembrane surface roughness. In the futur, roughness of textured geomembranes should be characterized. Until then, for design purpose it is recommended that laboratory testing be conducted for each application to determine the friction angle needed by designers.

The friction angles of textured geomembranes against tills and clays varied considerably with values lower or greater than the soils themselves. This behaviour is unexplained.

5. ACKNOWLEDGEMENTS

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