Table of contents Search Author index

Geosynthetics - 7th ICG - Delmas, Gourc & Girard (eds) © 2002 Swets & Zeitlinger, Lisse ISBN 90 5809 523 1

Influence of the friction test conditions on the characterization of the geosynthetics interfaces

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ABSTRACT: Assessment of the behavior of an interface geosynthetic-soil and geosynthetic-geosynthetic is important for any study dealing with the stability such as works of watertighness on slope. In this work it is highlighted that the shear box and inclined plane tests are complementary, despite of their different kinetics. One of the aims of this article is to present an inclined plane test following a special procedure that enables the detection of a creeping behavior at a polypropylene-geospacer interface.

1 INTRODUCTION

Composite liner systems (CLS) are widely used for river banks, dams, reservoirs, landfill liners cap and bottom (Gourc et al. 2001). But in the past several failures of this system were observed, due to the uncontrolled sliding of one of the components. It was demonstrated (Villard et al. 1999, Gourc et al. 2001) that the modelisation of the mechanical behavior of the CLS by an analytical or finite element method is not completely satisfactory. Actually the results are conditioned by the different interface relationships which are not easy to determine experimentally.

In a companion paper of this conference (Feki et al. 2002), a field experimentation is presented. This is an application for a real landfill cap cover with a monitoring of the relative displacements between the different synthetic and mineral layers. This paper, dedicated to the experimental assessment of the interface properties, is illustrated by examples of combination of geosynthetics taken from this case history.

2 INCLINED PLANE DEVICE

The Lirigm laboratory has participated in the development of the European Standard “pr EN ISO 12957-2” which is concerned with the measurement of the soil-geosynthetic friction using an inclined plane device. The advantage of this device it is that one can work using different configurations in addition to the standard test conditions (Lalarakotoson et al. 1998). This paper proposes an evolution on the test conditions, this as a result of the reflection done after the application into a real case.

The soil-geosynthetic tests have been carried out with the machine shown in the Figure 1: The upper box containing the soil has a width B = 0.70 m and the length (in the direction of the slip) L = 0.18 m (not L = 0.30 m as recommended by European Standard). The height of sand is H = 0.30 m and the transversal walls of the box are tilted at 30°. The unit weight of sand is $\gamma = 17.6$ kN / m^3 so the initial normal stress is $\sigma'_o = 5.28$ kPa .

The geosynthetic layer below the box is extended over the plane, that is 0.70 m wide (B) and 1.1 m long (L), besides it is fixed on the top.

The advantage of the inclined plane compared to the shear box it is that it allows testing under very low normal stress.

For a weight of soil $W = \gamma . L . B . H$, the initial normal stress on the soil-geosynthetic interface is $\sigma'_o = \gamma . H$.

The disavantage however, is that the normal stress reduces during the test, as a function of the inclination β: $\sigma' = \sigma'_o \cos \beta$.

In addition, to calculate the soil-geosynthetic angle friction, one must take account of the parasite friction from the rails on which the upper box runs. One can calculate, for a given limit inclination β_s, the corresponding friction angle value ϕ_g:

$$\tan \phi_g = \tan \beta_s + (W_b \sin \beta_s - F_o) / W \cos \beta_s \qquad (1)$$

Where F_o the force required to overcome the friction between the box (not containing soil) and the slope, and W_b being the weight of the empty box (whose the normal component $W_b \cos \beta$ is taken by the guides).

The rate of increase of the tilt (except in some special cases) is $d\beta/dt = 3°/$ min.

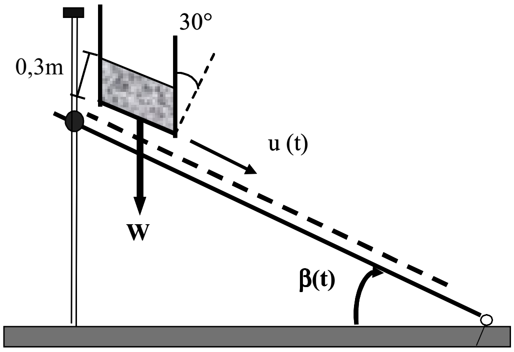
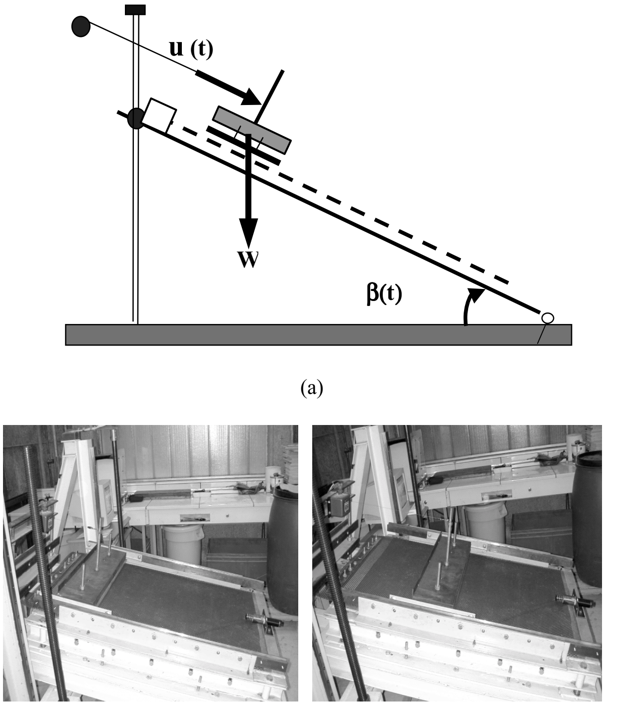


Figure 1. Schema of Inclined Plane device (IP) for soil-geosynthetic interface

The device allows us to record the displacement u of the upper box, not only as a function of the inclination, u(β), as stated in the European Standard, but also as a function of the time, u(t). In this way it allows us to carry out creep tests (see below) and also dynamic tests (with measured acceleration).

In addition, to allow doing friction tests with a geosynthetic-geosynthetic interface (Fig. 2), the upper box has been replaced by a plate which is B = 0.70 m et L = 0.18 m, the upper geosynthetic has been sticked on it. The normal stress is given by metal masses fixed on the plate. In every test the initial normal stress is $\sigma'_o = 5.7$ kPa. For the geosynthetic-geosynthetic test, the upper box is not used so $W_b = 0$ and one can consider that the guidance system does not produce any parasite friction during the sliding. In this way the limit inclination angles can be considered as the "real" friction angles:

$$\tan \phi_g = \tan \beta_s \qquad (2)$$



(a)

(b)

Figure 2. Schema (a) and photographs (b) of Inclined Plane device (IP) with metal plates for geosynthetic-geosynthetic interfaces

3 FULL-SCALE EXPERIMENTATION

The interfaces studied in this work refer to real case concerning the cap liner of a landfill on slope which is composed of 4 different soil-geosynthetics systems (Fig.3). The relative displacements between the different mineral and synthetic layers have been monitored during construction (Villard and al, 2000). Measurements for two years following construction are shown in another paper written for this conference (Feki et al. 2002). A detailed study into the behavior of each interface as proposed here will allow a simulation by a finite element model.

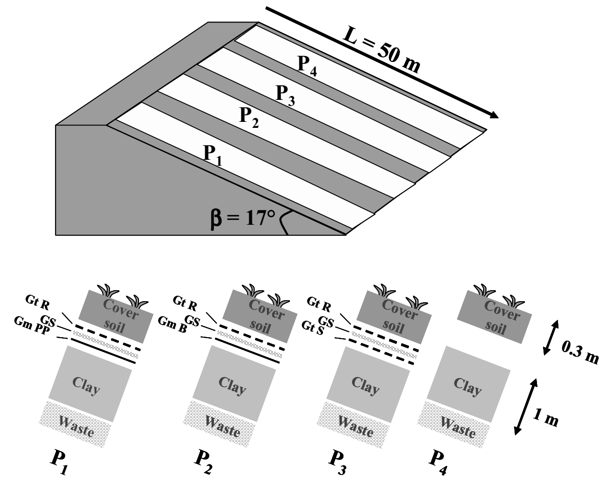


Figure 3. Inclined cap liner systems real scale experimentation (Torcy landfill).

The characteristics of the geosynthetic materials used on the slope are reported in Table 1 and those for clay in Table 2. The "GTr" is a non-woven geotextile, reinforced by knitted threads. The aim of this geotextile is to support the overlying soil layer. The "GS" is a grill used for draining. The"GMb" is a bituminous geomembrane and the "GMpp" is a polypropylene geomembrane whose function is the watertighness. High friction between the soil cover layer and the support geotextile is essential inorder to prevent the soil cover layer from sliding. Low friction between the geomembrane and the geospacer is also very important in order to avoid a tension of the geomembrane.

Table 1. Characteristics of the geosynthetics.

Geosynthetic	Thickness	Tension at failure	Secant tensile stiffness
	mm	T_f (kN/m)	J (kN/m)
GTr	2.5	95	580
GTs	1.6	12	27(ε = 10%)
GMb	4.0	25	80(ε = 15%)
GMpp	1.0	13.9 – (threshold 6.5)	51(ε = 7.5%)
GS	4.4	7.5	25

Table 2. Characteristics of the Clay.

	$w_{opt.}$(%)	$\gamma_{opt.}$ (kN/m^3)	w_{field} (%)	w_{SB}(%)*
Clay	8.9	19.5	13-23	13

* w_{SB} = for Shear Box test.

4 SOIL-GEOSYNTHETIC STANDARD FRICTION TESTS

A previous study undertaken at the Lirigm laboratory which compared shear box to inclined plane interface tests results (Lalarakotoson et al 1999), have demostrated that the values found for friction angles ϕ_g are compatible when the difference in the normal stress is taken into account: ϕ_g decreases as the normal stress increases.

This is found in friction tests carried out under standard conditions (prEN ISO 12957-1) with the support geotextile "GTr" (Tab.1) and a sand that simulates the soil cover layer: The results of tests carried out in a 0.30 m x 0.30 m shear box, under a normal stress σ' = 20 kPa, for a sand-sand shear test and a sand-GTr friction test are shown in Figure 4. The limit inclination angle β_s = 32° is obtained for the corresponding inclined plane test (Fig.1), under a normal stress σ'_o = 5.7 kPa as shown in Figure 5. Using formula (1) we obtain ϕ_g = 38.6° compared with ϕ_g = 34° (under a normal stress σ' = 20 kPa) for the shear box test.

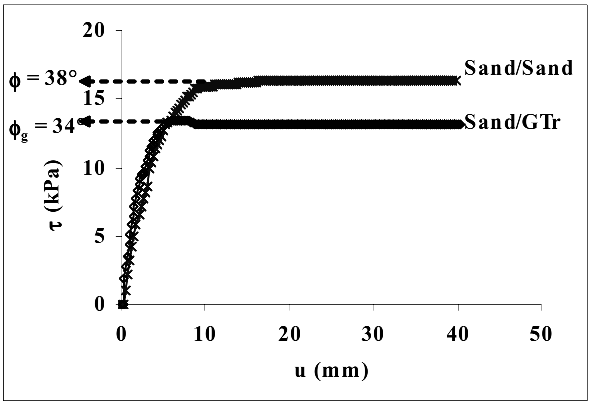


Figure 4. Shear Box test results for the interfaces sand-sand and sand-GTr (30 cm x 30 cm area and σ' = 20 kPa).

The same procedure has been adopted for the study of geosynthetic-geosynthetic interfaces. The standards have been adapted for this purpose: Both geosynthetics are glued on to wooden boards for the shear box test. The Inclined Plane test is carried out as shown in Figure 2. The tests for the GTr-GS interface, which is shown in Figure 3, are as following:

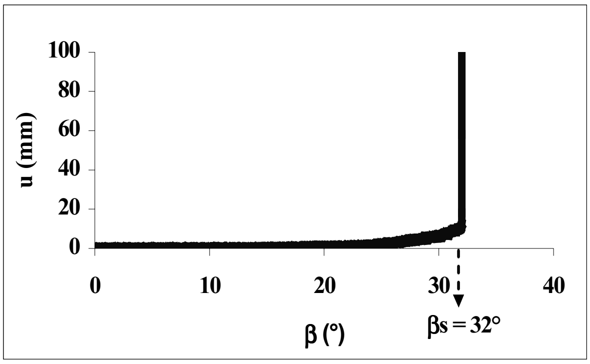


Figure 5. Inclined Plane test result for the interface Sand-GTr ($\sigma' = 5.7$ kPa).

The shear box tests (Fig.6) under three different normal stresses $\sigma' = 25$, 50 and 75 kPa result in $\phi_g = 16.8°$ for the peak. The corresponding inclined plane test (Fig.7) produce $\beta_s = \phi_g = 18.4°$. Once again, it is observed that the friction angle decreases as the normal stress increases.

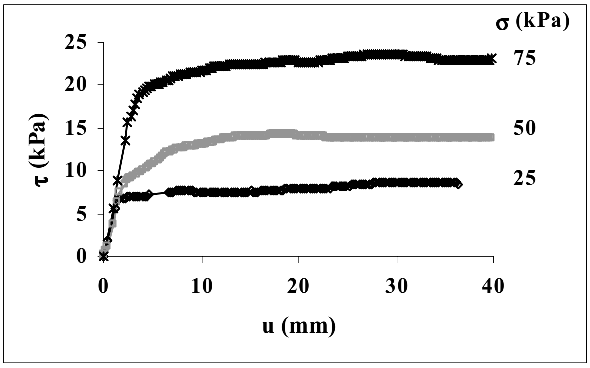


Figure 6. Shear Box test results for the interface GTr-GS (30 cm x 30 cm area).

Thus, it can be considered that under rigorous test conditions, the limit friction angle values obtained from both tests are compatible. Nevertheless, kinematics is very different for each kind of test and this has led us to try to do a comparison between them concerning the behavior in the phase of small displacements that precedes the phase of limit displacement which is characterized by the ϕ_g angle.

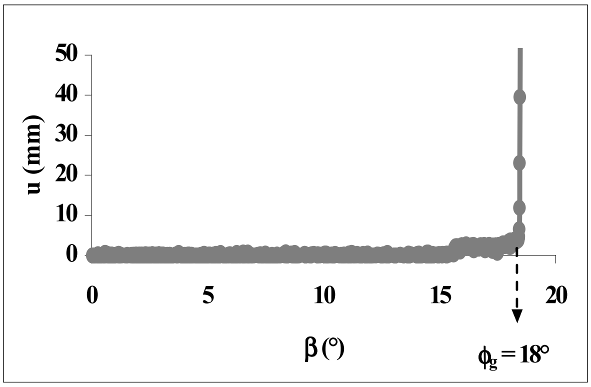


Figure 7. Inclined Plane test result for the interface GTr-GS.

In the inclined plane test, σ' decreases as the test proceeds ($\sigma' = \sigma_o' \cos \beta$), whereas it remains constant throughout the shear box test. Figure 8 gives the results of the tests corresponding to Figures 6 and 7: It is observed that the displacements of the displacement limit are clearly smaller in the inclined plane tests. Considering the existing knowledge, this difference cannot be attributed to the fact that the normal stress is lower in the inclined plane test. Further researches aiming a precise definition of the interface law would be merited.

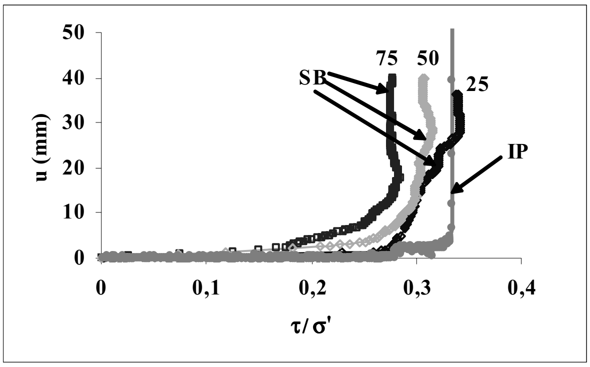


Figure 8. Comparison of the results in the Shear Box test and Inclined Plane test for the inteface GTr-GS.

5 CREEPING BEHAVIOR AT THE INTERFACE

Friction test at the interface GMpp-GS of the real case shown in Figure 3, have revealed a creeping behavior at the interface. This phenomenon needs to be taken into account in design since it corresponds to actual conditions of performance (normal and tangential stresses constants and constant inclination) and conveys a decrease of the limit effective friction angle.

The first observation is that influence of time is not noticeable in the test for different inclination rates of the plane. Approximately the same diagram as on Figure 9 is obtained for the tilted rates in the range: 0.5° / min < $d\beta / dt$ < 3° / min with a limit friction angle $\beta_s = \phi_g = 14.2°$.

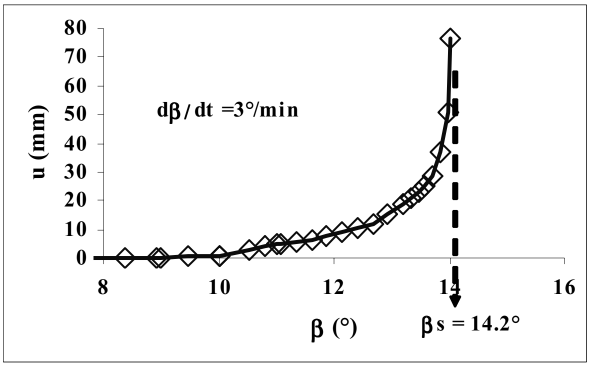


Figure 9. Inclined Plane test results for the interface GMpp-GS (test static).

Taking into account the constant inclination rates it is possible to plot the diagram shown in Figure 9 not as a function of inclination, but of time (Fig. 10) with $\beta = 0$ for $t = 0$. The values of inclination corresponding to the time t have been included on the graph.

The "creep test" is carried out under the same initial conditions of a standard test but in this case the inclination of the plane is stopped when the angle is β_c at a time t_c, before the limit inclination β_s is reached. The sliding displacements are then recorded as a function of time with a constant angle of inclination.

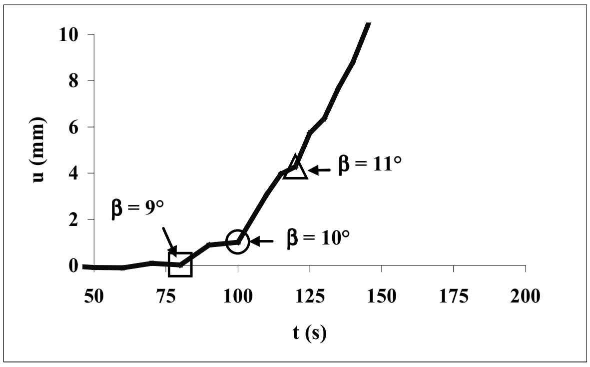


Figure 10. Identification of the points for β = 9°, 10° and 11°. Interface GMpp-GS (static test).

The results (Fig. 11) demonstrate very clearly that for values of β far smaller than the limit inclination βs obtained from a "quick test", that the displacements are not yet stabilised. The velocity of the creeping displacement du/dt is larger the nearer the inclination is to the limit β_s.

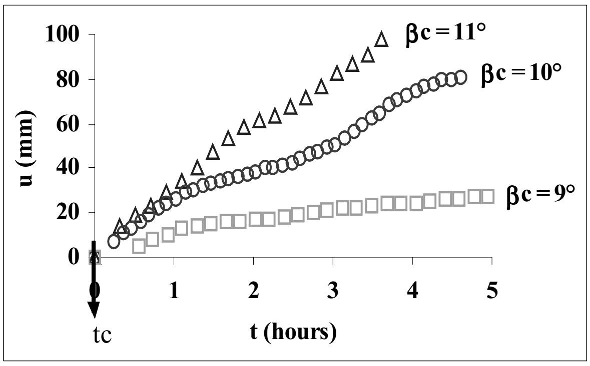


Figure 11. Three creep tests on the Inclined Plane device for the GMpp-GS

Results from both standard and creeping test (Fig. 10 and 11) have been merged in Figure 12.

However, it has to be underlined that the creeping behavior is not significant for all geosynthetic interfaces.

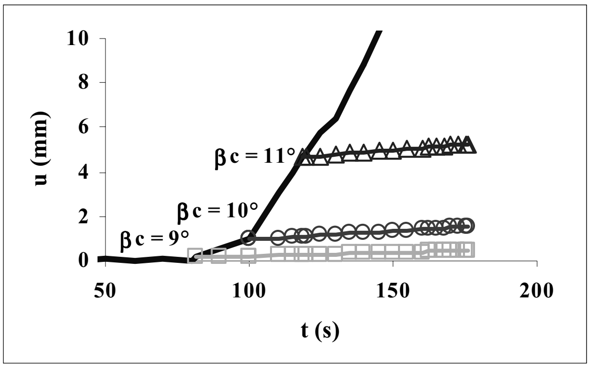


Figure 12. Merger of results of the figures 10 and 11

6 CONCLUSIONS

The Inclined Plane experimental device is currently employed to study the friction phenomena of geosynthetics under conditions of low normal stress. The Shear Box test is usually employed by modellers because a stress-displacement relationship is obtained, which is not the case for the standard inclined plane test.

However, the present study demonstrates that the inclined plane test can be valuable for the following reasons:

- The "standard" value of limit friction angle found in both test is comparable under the condition of taking into account the difference of value of normal stresses.
- The behavior before the limit sliding remains poorly understood then rendering very difficul its comparison in the two type of tests.
- The use of the inclined plane device has permitted the detection of a creeping behavior, at least in one case of geosynthetic-geosynthetic interface. This could lead to a reconsideration of the meaning of the limit friction angle ϕ_g determined from a standard "quick test" on the shear box or on the inclined plane device.

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