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Friction measurement by direct shearing or tilting process – Development of a European standard

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ABSTRACT: Two different procedures has been proposed by the Technical Committee 189 "Geotextiles" of CEN, to measure the friction characteristics of all the geosynthetics in interaction with soil, using a common european standard. In the framework of the Measurement and Testing Programme, a research was carried out at IRIGM (Direct Shear test) and tBU (Tilting test) to improve the draft document. This paper describes the features of the standard test, the research work performed, and the revised proposal of standard.

1 INTRODUCTION

1.1 *Objectives*

As far as the design of reinforced and waste disposal applications is concerned, it is necessary to have a good knowledge of the interaction geosynthetic - soil interface. Two test methods have been put forward by the CEN-TC 189 - WG3 :
- the direct shear test (Shear Box apparatus : SB)
- the tilting test (Inclined Plane apparatus : IP)

The objective of the research carried out in the framework of the EC Measurement and Test Programme is to investigate how these two candidates methods are suitable for the determination of friction. The main problems to study are :
- the experimental conditions of test
- the possibility of testing for every type of geosynthetic
- the selection of the direct shear or tilting test in function of the application
- the classification of these tests as index or performance tests

Two european laboratories carried out the research, IRIGM for the direct shear tests and tBU for the inclined plane tests.

The documents of reference are draft European Standard : Direct Shear test : CEN-TC 189-WG3-N21-Rev.2 (June 94) and Inclined Plane test : CEN-TC 189-WG3-N23. Rev.C (June 94).

1.2 *General programme of tests :*

The programme of research includes more than 100 tests in the shear box (SB) and 75 tests on the inclined plane (IB).

Several types of geomaterials (soils and geosynthetics) were necessary to test in order to validate the process.

1.2.1 Soils

To standardize a test at CEN level, we proposed a standard soil, representative of the conditions of application in the field, even if the test has to be considered as an index test : the sand EN 196, widely used in Geotechnics was chosen as the soil of reference to characterize the friction properties. The sand was compacted at a specific weight γ_d = 16,45 kN/m^3. However it is important to propose an experimental procedure adapted to derived tests (performance tests) on different soils : a coarse soil (crushed stone or gravel) was chosen to examine firstly the possible scale effect correlated to the particles size, and secondly to consider the adaptability of the test to evaluate the damage effect of sharp soil particles in friction. The specific weight of the crushed stone in the test is γ_d = 17,10 kN/m^3.

The figure 1 presents the soil grading for sand and crushed stoned.

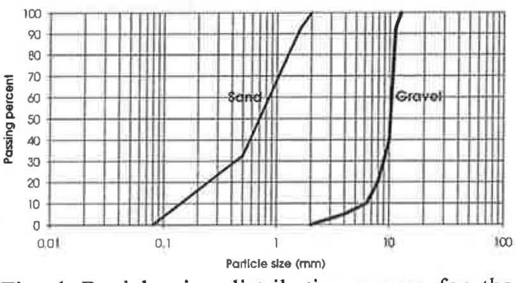

Fig. 1 Particle size distribution curves for the cohesionless soils

Complementary tests on cohesive soils were performed because the adhesion between a geosynthetic and this kind of soil mobilizes mechanical phenomena at the interface different of the ones with cohesionless soils. Artifical clay "'Glyben" mixing bentonite with glycerine (in place of water) was selected, in comparison with a natural clay. The main experimental problem with cohesive soils is the influence of the displacement rate on the results of friction because of the viscosity and the possible drainage. The results on this kind of soil are not included in this paper.

1.2.2 Geosynthetics

The family of geosynthetics is very wide. We decide to select two geotextiles, a non-woven needlepunched polyester (nw TGV) and a wowen (w TGA), two geogrids, one with thick ribs (G_g TGR) and one very flat (G_g TGP) and two geomembranes, one PVC (Gm THK) and one HDPE (Gm THL). All the tests are performed in the machine direction.


Fig. 2. Inclined plane apparatus with the small box.

2 INCLINED PLANE

2.1 Test apparatus

The tBU-inclined plane apparatus (figure 2) consists of a 1.5 m x 1.5 m frame with plywood surface and two alternative upper boxes, 1 m x 1 m box with vertical wooden closures, the other .5 x .5 m2 box with the possibility to fix the upper and lower wall in different angles to apply the dead load vertical onto the inclined plane at estimated slipping angles. The inclination is measured by a wire displacement transducer and the inclination-speed may be varied by a thyristor controller and fix gearbox variation of the hoist.

Depending on the test, wooden frames for clamping the geosynthetic can be fixed in slope and crosswise. For the determination of the small box-wall inclination preliminary tests are necessary. According to the resulting angle of these tests the walls were fixed. For the tests with resulting angles between 20° and 35° the walls were fixed to 27°. Smaller angles than 20° were not measured. At higher values than 35°, the walls were fixed to 40°. To avoid motion of the deadloads (steel blocks) during the test, two section walls were implemented. The friction between the box´s walls and sand or gravel is not sufficient. To maintain the gap of ca. 1 mm between box and subbase during the test and to get an uniform pressure across the whole area of the box, load distributing bars were fixed across the width of the box.

In the big box (1 m x 1 m), 9 load distributing bars of a diameter of 20 mm are fixed at 40 mm distance between center of bar and bottom of box.

The displacement of the box is measured by potentiometric transducers. Inclination- and displacement-transducers are connected to a Multiplex-Analog-Digital-Converter (ADC), to transmit the information to a PC.

2.2 Fixation of specimen

The specimen were fixed to the plywood base in different ways, to confine the relative movement between geosynthetic and support.
PET / PE woven multifilament fabric and PET-non-woven were glued on to the smooth side of a 3 mm hardboard. The hardboard was clamped at front and rear crosswise to the inclination by wood (40 mm x 60 mm) and screws.

PET-geogrid (woven) and HDPE-geogrid (extruded + stretched) were clamped on 4 sides.
PVC-geomembrane was fixed at front and rear end of the plywood plate.

2.3 Placing and compaction of soil

With a small shovel sand EN 206/196 or crushed stone was placed in both boxes. The tool was moved slowly in contact with the support, to prevent a segregation of soil particles. After a test the soil was taken back to stock and mixed up.

Table 1. The soil thickness.

Soil	Unit	.25 m2 box	1 m2 box
Sand (EN 196)	mm	50	50
Gravel	mm	50	40

To avoid friction between box and specimen, it was not acceptable that the box gets in contact to the specimen. The boxes were kept ca. 1 mm above the geosynthetic.

During the installation, wedges were used to set a gap of 1 mm between the box and the specimen. For the tests with sand, flat platens were necessary under the load distributing bars to prevent the box from coming into contact with the specimen. For gravel, the platens were not necessary.

2.4 *Normal pressures*

The tests were performed at normal stresses of 2.5 kPa and 5.0 kPa. One part of the stress resulted from the mass of box and soil. The missing part was realized by steel blocks and stones.

$$\sigma_{n,0} = \frac{W \ 9{,}81}{A \ 1000}; \quad \sigma_{n,\beta} = \frac{W \cos\beta \ 9{,}81}{A \ 1000}$$

where:
σ_{no} and $\sigma_{n\beta}$ = normal stress in kiloPascals; W = mass of soil surcharge, weight in kilograms; β = slipping angle; A = contact area in m^2

2.5 *Data logging and accuracy*

The data logging software was DIA / DAGO from the Gesellschaft für Strukturanalyse (GfS). 10 sets of data per second were stored for angle β and displacement s. Displacement s was measured with an accuracy of 1 mm. Angle β was measured with an accuracy of 1°

2.6 *Definition of $\beta = \phi_{gp}$ (scientific approach)*

The tests were evaluated analytically and graphically. The plotted graphs show displacement s versus angle β. For the evaluation of results two limit values $\beta = \phi_{gp}$ are to be seen: ϕ_o = angle of first movement; ϕf = angle of failure.

ϕo is defined by the following conditions : The differential ratio $ds/d\beta$ is greater than 2 for more than 3 datasets. This was to eliminate vibration and noise caused by the wire of the hoist.
ϕf is the angle of the slippage without interruption up to the end of allowed displacement.
ϕf is defined by the conditions: $ds/d\beta$ greater than 2; number of data sets trends to infinite.
$\Delta\phi = \phi f - \phi_o$

A graphical example is shown in figure 3. The upper part of figure 3 shows s versus β. The lower part shows the ratio of the differential ds and $d\beta$. Gaps in the lower graph are „no value" location, mathematically undefined because of identical values $d\beta$.

Tests for commercial customers performed after the CEN-Interlab tests showed, that a determination of $\beta = \phi f$ from the displacement vs inclination-curve at the inclination for 50 mm displacement, gives satisfying results.

2.7 *Results inclined plane tests*

The graphs may be categorized in 3 categories:
Category 1 : *„Sudden death"*. A long period of s = 0 is followed by a nearly linear increase of s versus β, a relative movement of the boxes of 1 mm to 2 mm are registered. Then there is a sudden and steep increase of the differential ratio. This is the place, where conditions for ϕ_o and ϕ_f are fulfilled. The difference is zero. An example is showed on fig. 4.

Category 2 : *slow motion before sudden death.*
The difference to tests of the 1st category is a bigger displacement of the box (up to 7 mm) before sudden failure, again $\phi_o = \phi_f$; $\Delta\phi = 0$. An example is showed on fig.5.

Category 3 : *In this category ϕ_o and ϕ_f do not coincide*. There are steps in the graph, with constant values following. This is repeated up to twice. The residual slippage displacement after ϕ_f is greater than 80 mm, excluding the tests sand EN 206/196 on TGV

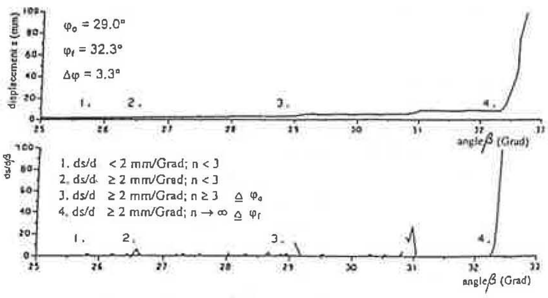

Fig. 3. Definition of ϕ_{gp}

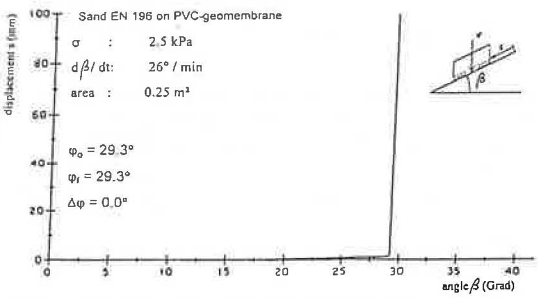

Fig. 4. Sand EN 196 on PVC-geomembrane, THL.

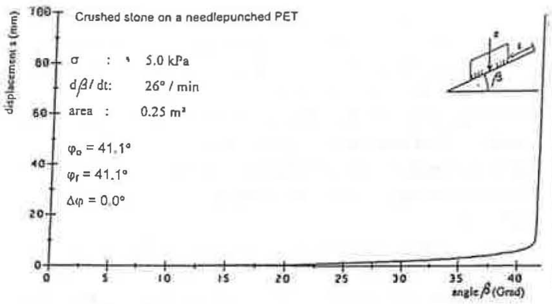

Fig. 5. Crushed stone on a needlepunched PET, TGV.

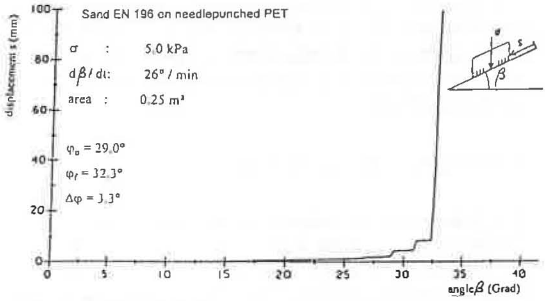

Fig. 6. Sand EN 196 on needlepunched PET,TGV.

at a normal pressure of 5 kPa, dβ/dt with 20° / min and an area of 1.00 m2, as there were no final slippage. An example is showed on fig. 6, sand on needlepunched PET.

Some tests of the 3rd category with sand at 5 kPa normal pressure lead to contact box / geosynthetic after the o-point. There was increased friction as the box end acted as runners of a sledge.

Three other observations were made:

1. Testing sand EN 206/196 lead to small losses of soil at the front wall of box.
2. After the test, there was some sand or coarse crushed stone behind the rear wall.
3. On the geosynthetic's surface, fine particles of sand accumulated.

2.8 *Repeatibility of tests*

These tests were performed with crushed stone on PVC-geomembrane, THL. Test parameters: σ_{no} = 2.5 kPa; dβ/dt = 20°/min; area = 0.25 m^2.

The repeatibility may depend on other test parameter but is satisfying. The steps in the 3rd category graphs followed by no motion without contact of box/geosynthetic (sand EN 206/196, σ_{no} = 2.5 kPa and tests with crushed stone) may be caused by

-change in density of the soils by the motion resulting in different (elevated) shear strength,

Table 2. Repeatibility of tests.

Test No.	Unit	φo	
1	degree [°]	31.9	0.0
2	degree [°]	32.4	0.0
3	degree [°]	32.0	0.0
4	degree [°]	32.2	0.0
5	degree [°]	32.0	0.0
$\overline{x}$	degree [°]	32.1	0.0
s	degree [°]	0.2	0.0
v	%	0.6	0.0

-gripping of coarse grains behind the ribs of grids for crushed stone and geogrid, which may stop an initial movement of the box.

2.9 *Conclusions*

The tests with the inclined plane method leads to the desired knowledge set by the objectives and can be concluded as follows:

The inclined plane test is a simple and fast test for the determination of friction behaviour in construction phases, characterised by low normal pressures.

Normal pressures σ_{no} higher than 5 kPa are only applicable with enhanced effort and inconvenience for the operators.

The box size of .5 m x .5 m is easy to handle, it is to be prefered to 1 m x 1 m

Speed of inclination is not critical for index tests with sand, values of ca. 20 °/min give satisfying results. For geotextiles on geomembranes 2 °/min are recommended.

For geogrids a hard subbase does not characterise the behaviour in soil, as a different partition of the area, covered by the box is tested as sand/subbase friction. The subbase for grids should be soil.

Measurement of displacement : Tests after those on soil/geosynthetics showed motion between box and geosynthetic before slippage of geosynthetic on geomembrane. Therefore the displacement should be measured at the geotextile, not on the box; slippage is tested on geomembrane.

3 - SHEAR BOX

3.1 *Test apparatus*

The shear box apparatus of IRIGM is a Wykeham Farrance (100 kN). The size of the box is 300 mm x 300 mm. On the lower part of the box, a rigid plane support is fixed. The lower box is the sliding part.

The geosynthetics are fixed to the rigid plane support (figure 7) to prevent relative movements and wrinkles of the geosynthetic : geotextiles (TGV and TGA) and geomembranes (THL and THK) are sticked to a plywood base. Geogrids (TGP and THK) present large apertures and the direct contact between

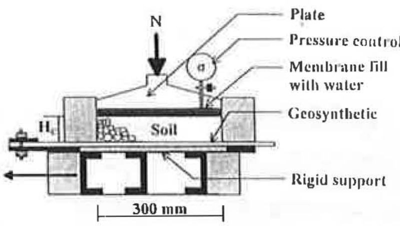

Fig. 7 Shear box apparatus

the support and the soil influences the friction results. So in this case, geogrids are directly attached to the metallic support (calibrated roughness) to avoid an influence of damaging of the plywood by soil particles.

The constant rate of displacement is 1mm/min.

3.2 *Definition and obtention of c_{gs} and ϕ_{gs} (figure 8)*

Generally, we don't observe peak shear stresses τ for the friction tests, on account of the low dilatancy of the soil in the conditions of test. So cohesion and friction angle are defined without ambiguity from the maximum values of τ, at every constant value of the normal stress σ_n. We have distinguished three different modes of obtention of ϕ_{sg} and c_{sg}. The angle of friction is defined as the slope of the best fit straight line through the plot of maximal shear stress against normal stress. The first mode corresponds to the 3 experimental values τmax (for the 3 normal pressures), the second mode includes the point 0, considering a cohesionless soil behaviour at low normal pressures (for sand and gravel only) and the third mode corresponds to the line obliged to pass through the point 0. The mode 1 which minimizes the ϕ_{sg} value, was selected (table 3).

The shear tests on sand and gravel alone (without geosynthetics and with soil in the lower box) give for the mode 1, respectively ($\phi^1{}_s$ = 39,3° and $c^1{}_s$ = 2,45 kPa) for the sand and ($\phi^1{}_s$ = 54,3° and $c^1{}_s$ = 4,1 kPa) for the gravel. The results for some cases of interaction soil - geosynthetic are exhibited on the table 3.

The research has also demonstrated the interest to introduce a new coefficient, the *coefficient of friction efficiency*

$$f_\phi = \frac{tg\ \phi_{sg}}{tg\ \phi_s} \qquad \text{(cohesion less soil)}$$

with ϕ_s friction angle of the soil, and ϕ_{sg}, friction angle of the interface soil-geosynthetic.

For the particular case of cohesive soil, it will be necessary to use :

$$f_\tau = \frac{c_{sg} + \sigma_n.\ tg\ \phi_{sg}}{c_s + \sigma_n.\ tg\ \phi_s}$$

Table 3. Mode of obtention of ϕ_{sg} and c_{sg}

Geosynthetic	Cover Soil	1 ϕ_{sg} (o)	1 c_{sg} (kPa)	2 ϕ_{sg}	2 c_{sg}	3 ϕ_{sg}	3 c_{sg}
nw TGV	sand	30,4	1,25	30,7	1,00	30,8	0
nw TGV	gravel	41,2	1,45	41,5	0,9	41,6	0
gm THK	sand	23,6	1,8	24,2	0,5	24,4	0
Gg TGR/sand	sand	33,8	1	34,1	0,3	34,2	0

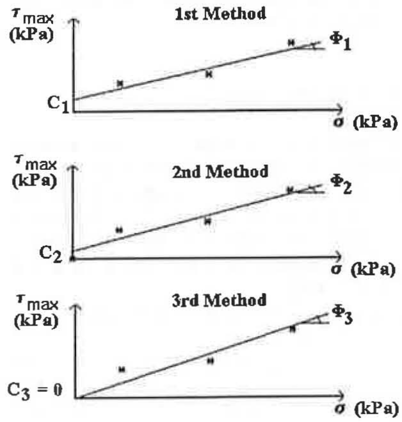

Fig. 8 Three modes of obtention of the best fit straight line

Table 4. f_ϕ for sand/nw TGV interaction

γ_d (kN/m^3)	Dr. (%)	ϕ_s	ϕ_{sg}	f_ϕ
15,45	46	32,9	23,7	0,68
15,95	63	35,7	26,8	0,70
16,45	80	39,3	30,4	0,72

Table 5. f_ϕ for gravel/nw TGV interaction

γ_d (kN/m^3)	Dr. (%)	ϕ_s	ϕ_{sg}	f_ϕ
15,65	30	45,9	33,3	0,64
16,45	55	49,2	36,3	0,63
17,10	82	54,3	41,2	0,63

We observed the relative independance of this coefficient, in function of different experiemental parameters like the soil specific weight.

For example, for the EN196 sand in interaction with the geotextile nw TGV, a variation of the initial specific weight of the sand leads to a significative variation of ϕ_{sg} but clearly to a lower variation of f_{ϕ} (table 4).

Dr is the relative density.

The same phenomenon is observed for the gravel, for instance in interaction with the nw TGV (Table 5).

Therefore, the use of f_{ϕ} in place of ϕ_{sg} could allow some deviation in the conditions of compaction, if the same procedure is used for shear tests on soil alone and on soil with geosynthetic. However this conclusion has to be confirmed.

3.3 *Normal pressure σn (figure 9)*

The tests were performed at normal stresses 50 kPa, 100 kPa and 150 kPa. In the draft EC standard, 25 kPa, 100 kPa and 200 kPa are proposed, but we selected this set of pressures to avoid the influence of additional parameters, damage of the geosynthetic for heavy pressures and higher intrinsec value of ϕ and low accuracy for 25 kPa.

Generally the vertical load N is applicated by the way of a simple rigid plate, in a direct shear test. We proposed to use a flat bag filled with water ("membrane") to distribute the vertical load (figure 7). Like this, it is possible to obtain an homogenous value of the normal pressure σ_n on the soil. It was demonstrated that, without the "membrane", the stresses σ_n are significantly higher in the front area than in the rear area of the box. In addition, the "membrane" allows a control of the vertical load by the way of the hydraulic pressure in the bag.

In all the cases, maximal shear stresses are higher in a friction test performed with the "membrane" (figure 9).

3.4 *Thickness of soil H_c* (figure 10)

The initial EC standard proposed a compacted thickness of soil of 75 mm in the upper box, but in a standard box, the height is often too small to include also the hydraulic bag (minimum 25 mm, to compensate the rotational movement of soil into the

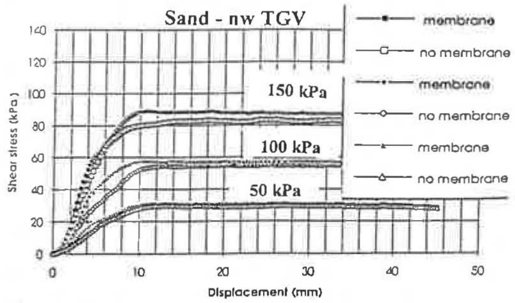

Fig.9 Influence of the mode of application of the vertical load (Shear Box) - Sand/nw TGV

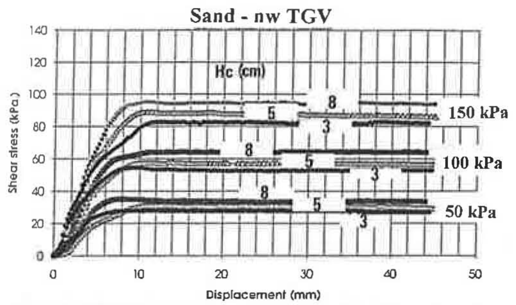

Fig. 10 Influence of the thickness of soil in the upper box (Shear Box) - Sand/nw TGV

shear box during the friction test). Moreover, the lateral friction on the sides of the box is increasing with H_c. So it was unexpected the increase of friction values with H_c (figure 10). For the following tests, we selected $H_c = 50$ mm.

3.5 *Support of the geosynthetic*

It is possible to remove the rigid plate and to spread the geosynthetic on the soil filling the lower box. Some tests performed on a gravel support in place of the rigid support demonstrate the influence of the flexibility of the geosynthetic : the friction is higher for a corrugated support (Delmas et al, 1979).

As far as geogrids with large apertures are concerned, the results are expected to be strongly depending of the support. On figure 11, we compare the results obtained with a smooth rigid support and with a layer of sand as an alternative support. It is not surprising to obtain a higher friction with the sand support because the mechanism of mobilisation of the geogrid to the relative displacement is different.

If we consider for geogrids the direct shear test as an index test, the major problem is not the unrealistic condition of the rigid plate support but the difficulty to reproduce in another laboratory the roughness condition of the metallic support. So we proposed to calibrate a support roughness, for instance by sticking a rough glass paper on the rigid support.

Considering an academic point of view, we can demonstrate the three-dimensional effect due to the structure of the geogrid (here the TGR of the figure 11) :

The opening ration (surface of interaction sand/sand or sand/rigid support through the apertures) is $\alpha o = 0{,}605$.

The friction between upper sand and sand in the lower box is known ($\phi_s = 39{,}3°$ $c_s = 2{,}45$ kPa) and between upper sand and smooth rigid support (without geogrid) is illustrated on the figure 11 ($\phi_s = 18{,}8°$ $c_s = 0{,}6$ kPa).

The friction between HDPE geogrid core and sand was estimated from tests on geomembrane ($\phi_{sc} = 23{,}6°$ $c_{sc} = 0$).

If friction sand/geogrid THK would be a mere two-dimensionnal phenomena, the shear strength could be theoritically expressed by the addition of friction with geogrid material and friction through the apertures :

$$\tau^{th.}_{max} = \alpha_o \left(c_s + \sigma n.tg\ \phi_s\right) + (1-\alpha_o)\left(c_{sc} + \sigma_n.tg\ \phi_{sc}\right)$$

This value can be compared to the experimental value $\tau^{exp.}{}_{max}$, for the two support smooth rigid support and sand :

(σn = 150 kPa)	τ^{th}_{max} (kPa)	$\tau^{exp.}_{max}$ (kPa)
smoot rigid support	57,2	84,3
sand support	101,6	103,8

The discrepancy between the experimental and theoritical values can be explained partially by the three-dimensional effect.

3.6 *Repeatability of tests*

In the table 6 below, we present the results obtained for the same type of test reproduced 3 times at 3 levels of vertical loading. To avoid an influence of the heterogeneity of the materials, we selected the more "simple" geomaterials, a sand and a geomembrane HDPE on a rigid support. The repeatability can be considered as satisfying. Considering the extreme values of shear stress, we obtain for the best fit straight lines, (Max : ϕ_{sg} = 23,7°, c_{sg} = 1,9 kPa) and (Min : ϕ_{sg} = 22,1° and c_{sg} = 1,4 kPa).

4 COMPARISON BETWEEN TILTING TEST AND DIRECT SHEAR TEST

In the table 7 below, we compare typical results obtained on the same geomaterials (soil and geosynthetic) with the two apparatus. The conditions of tests are the ones proposed for standardization

Table 6. Repeatability (Sand/Gm THK)

Normal stress (kPa)		50	100	150
Shear stress	Test n°1	24,2	44,99	68,1
(kPa)	Test n°2	21,9	43,96	64,7
	Test n°3	21,75	41,96	62,45
mean τ_{max} (kPa)		22,6	43,65	65,05
Std Dev		1,4	1,55	2,85
Variance		1,9	2,35	8,1

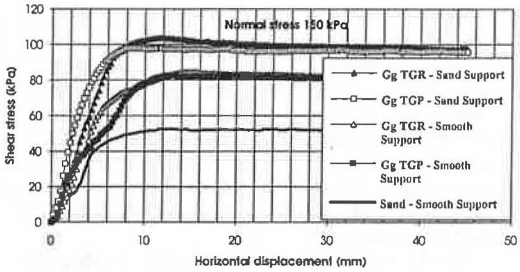

Fig. 11 Influence of the support on the friction between geogrid and sand

Table 7. Comparaison between Tilting and Direct Shear tests

Geosynthetic	Soil Cover	Shear Box ϕ_{sg}	Inclined Plane ϕo	ϕf
w TGA	Sand	27,9	33,1	33,1
nw TGV	Sand	30,4	32,8	33,7
Gm THL	Sand	20,8	29,3	29,3
Gg TGR/(rigid Support)	Sand	28,7	33,7	33,7

(displacement ratio : 1mm/min for the shear box, $d\beta/dt$ = 20°/min and σno = 2,5 kPa and S = 0,25 m^2 for the inclined plane.

Generally ϕf (inclined plane test) is higher than ϕ_{sg} (direct shear test) but the difference is lower than 10% (except for the case of sand with geomembrane THL-see table 7), and ϕ_o is closer to ϕ_{sg}. This result could be expected because it is well know that the "secant" ϕ_{sg} value is decreasing with and increasing normal stress (so between σn = 25 kPa and over 50 kPa).

5 GENERAL CONCLUSION

It is important to keep in mind that Direct Shear test is a test more difficult than it looks.

Shear box is a facility very common in the laboratoires of soil mechanics. The adaptation to specific tests of friction with geosynthetic is not technically difficult. Basically the direct shear test has to be considered as an index test, the tests performed with standard sand giving a significative information on the interface behaviour.

It is also possible to modify slightly the experimental conditions to simulate field conditions. However it is questionable to use the shear box for low normal stresses.

The inclined plane was just planed to be used in this case. Initialy, this test was imagined to modelise stability problems of veneers on geosynthetics for steep slopes. The inclined plane can be considered as a performance test with which it is possible to reproduce for example the stability of a multi-layers system, or friction creep tests, for low normal stresses. It is worth noting a restriction of the inclined plane test : the normal stress at the interface is decreasing during the test.

Finally the question of relevance of a friction test to characterize the geogrid behaviour in interaction with soil leaves under discussion.

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REFERENCES

Delmas, P., Gourc, J.P., Giroud, J.P. - "Experimental analysis of soil-geotextile interaction", proceedings of the International Conference on Soil Reinforcement, Vol. 1, Paris, France (Mar 1979), pp 29-34.

Friction - Task 3-a, final report - (IRIGM-tBU) - EC Measurement and Testing Programme - Project 0169 - (Dec. 1995)

Purwanto, E. - Etude des interfaces geosynthétiques en géotechnique - Thèse Irigm Université Joseph Fourier, Grenoble , France - (Feb. 1996).