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Soil/Geosynthetic interface characterization - The influence of some aspects of the test procedure

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ABSTRACT: This paper deals with the variability of results associated with aspects of the test procedure when characterizing soil/ geosynthetic interface through direct shear tests. Strange scatter of results has been observed when carrying out several direct shear tests with the large size apparatus developed in the Laboratory of Geosynthetics of the Faculty of Engineering of Porto (LGS). This variability of results is thought to be related to some aspects of the test procedure. In order to confirm this hypothesis some modifications were introduced in the test procedure and a new series of tests was performed to evaluate the corresponding improvements. It was found that vertical stress applying time before horizontal displacement starting has an important role in soil/geosynthetic interface's behaviour.

1 INTRODUCTION

Plenty of papers have been published in the last years about the discrepancy of results associated with soil/ geosynthetic interface characterization by direct shear tests. This paper deals with the variability of results which can be associated with aspects of the test procedure.

Strange scatter of results has been observed when carrying out several direct shear tests with the large size apparatus developed in the Laboratory of Geosynthetics of the Faculty of Engineering in Porto (LGS). This variability of results is supposed to be related to some aspects of the test procedure, namely vertical stress applying time before horizontal displacement starting and an inadequate gap definition. In order to confirm these hypotheses and evaluate the corresponding improvements some modifications were introduced in the test procedure and a new set of tests was performed with a reinforcing geocomposite and a fine grained soil. The number of tests performed (four tests for each of the three vertical stresses defined in EN ISO 12957-1) allowed the determination of the characteristic values for the interface shear strength parameters according to Dixon et al. (2002).

2 DIRECT SHEAR TEST

2.1 *Equipment*

A large size direct shear apparatus was used to carry out this set of tests. Figure 1 shows a cross section view of the equipment.

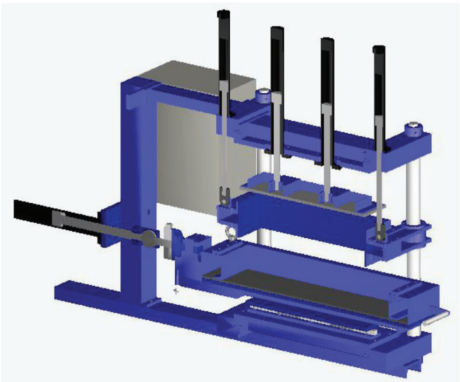

Figure 1. Cross section view of the direct shear apparatus.

Five hydraulic actuators, controlled by computer, assure equipment movements. The horizontal actuator has a maximum load capacity of 50 kN and is connected to a 50 kN tension/compression load cell. Horizontal displacement is controlled by an internal displacement transducer. Vertical pressure is applied by two vertical actuators which are connected to a rigid plate with 600 * 300 (mm * mm) of loading area. A rigid loading solution was chosen at this stage, considering Hsieh and Hsieh (2003) findings.

Shear tests with the geosynthetic placed over a rigid base, as referred on EN ISO 12957-1, can be performed by placing a rigid box, which consists on an association of steel beams and a steel plate, inside the lower part of the shear box. To grant a rough surface to the top of the metallic smooth plate, an aluminium oxide abrasive sheet (P80) was glued over it in order to avoid any slippage between the geosynthetic to be tested and the support. Additionally to the rough support along the specimen the equipment has clamps on both edges. A detailed description of the equipment and verifications made before starting test performance can be found in Silvano and Lopes (2005).

2.2 *Problem identification*

A presentation of the characterization of the interface between a non woven geotextile and a coarse sand with the direct shear apparatus of LGS was made by Silvano and Lopes (2005). Following that study more tests were then performed intending to simulate the same conditions (displacement rate, soil height over geotextile, vertical stress) but changes in the interface behaviour were observed. Despite maximum shear stress acceptable variation (maximum coefficient of variation around 5%) significant differences were found in horizontal displacement vs interface shear stress curves shape.

There were pointed out two main reasons to cause the observed differences:

- inclusion of a vertical displacement measuring system (as the vertical displacement measuring system can only be placed after the vertical load is applied, it is thought that the time between these two instants may influence soil/ geotextile interface behaviour);
- inadequate definition of the gap in the tests (the gap between the upper half of the direct shear box and the geotextile was established without any vertical pressure applied, which means that the resultant gap at the beginning of the shear depends on the value of the vertical pressure).

Figure 2 shows the results of tests performed at 50 kPa and 150 kPa before (old) and after (new) the inclusion of the vertical displacement measurement system. It is possible to see that there exists an increase in maximum shear stress value as a consequence of the larger vertical stress applying time before horizontal displacement starting.

2.3 *Modifications of the test procedure*

In order to overcome the problems caused by the two identified perturbing aspects and consequently improve

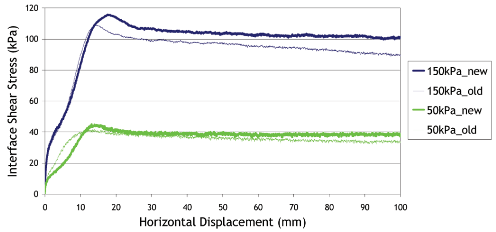

Figure 2. Vertical displacement measurement system influence.

test results consistency some modifications were introduced in the test procedures. The changes consisted in:

- establishing a fixed period of time of the vertical pressure application before starting the shear (chosen in such a way that allows the vertical displacement measurement system placement with no problem before the start of the horizontal displacement);
- gap definition with vertical pressure applied over the geotextile (placing a thick geotextile between the loading plate and the geotextile to be tested, in order to avoid any damage).

3 EXPERIMENTAL PROGRAM

3.1 *Materials*

To confirm the improvements introduced with the modified test procedures, a new set of shear tests was carried out enabling the characterization of the interface between a reinforcing geocomposite and a fine grained soil. The geosynthetic used is a nonwoven PP geotextile reinforced with high strength PET yarns and has an ultimate tensile strength of 115 kN/m for an elongation of 13%.

The main characteristics of the soil are presented in Table 1 and the strength parameters of the soil are included in Table 2. The grain size distribution of the soil used in the tests is shown in Fig. 3 (93% of the soil particles are less than 2 mm wide and 20% of the particles are smaller than 0.074 mm. All the tests were carried out using the soil in a dry state and

Table 1. Main characteristics of the soil.

Characteristic		Value
% < 0.074 mm	(%)	19.87
D_{30}	(mm)	0.19
D_{50}	(mm)	0.39
D_{60}	(mm)	0.55
D_{max}	(mm)	38.10
γ_{min}	(kN/m^3)	17.20
γ_{max}	(kN/m^3)	13.59
$\gamma_{ID=50\%}$	(kN/m^3)	15.18

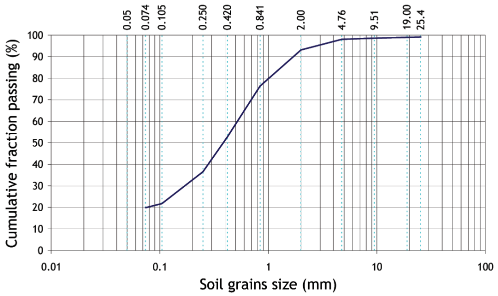

Figure 3. Grain size distribution of the soil.

Table 2. Main characteristics of the soil.

	c′ (kPa)	ϕ′ (°)
Peak	0	41.1
Residual	0.5	36.6

compacted to a relative density of 50%, similarly to Silvano and Lopes (2005).

3.2 *Test procedure*

The test sequence adopted in this experimental program can be, in resume, described as follows:

- geosynthetic sample placed over the rigid base (flat, free from folds and wrinkles) and then clamped;
- vertical stress applying over the geosynthetic in order to position upper part of shear box in relation to the geosynthetic (thick geotextile placed between the loading plate and the geosynthetic in order to avoid any damage);
- vertical stress release;
- soil pouring and compaction (a pre-weighed mass of soil is poured so that, when compacted, the material has the required density and occupies the required volume);
- vertical stress establishing;
- vertical displacement measurement system placement;
- horizontal displacement starting 20 minutes after vertical stress applying over soil;
- end of the test when horizontal displacement achieves 100 mm (≈16.5% × 600 mm).

The experimental study consisted in testing four samples for each of the three vertical stresses defined on EN ISO 12957-1 (50 kPa, 100 kPa and 150 kPa). Besides allowing a more accurate variability evaluation, the number of tests performed was chosen in order to enable the determination of soil/geocomposite interface characteristics as introduced in Dixon et al. (2002).

The tests were carried out at a 1 mm/min constant rate horizontal displacement and a 50 mm soil height over geosynthetic was adopted. Table 3 summarizes the characteristics of the several shear tests which were performed.

Table 3. Test Program.

	Vertical stress (kPa)	Soil height (mm)	Relative density (%)	Displacement rate (mm/min)
1 2 3 4	50	50	50	1
5 6 7 8	100			
9 10 11 12	150			

3.3 *Results*

Horizontal displacement vs interface shear stress curves exhibit excellent repeatability (Fig. 4).

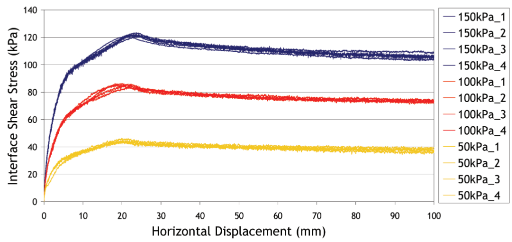

Figure 4. Horizontal displacement vs interface shear stress.

In fact, comparing the values for the coefficient of variation obtained in this series of tests with the ones before the changes in the test procedure there can be observed a quite significant reducing of the variability (Fig. 5). This means that the changes introduced in the test procedure resulted in an improvement of test results quality. The values for the interface maximum shear stress, the corresponding

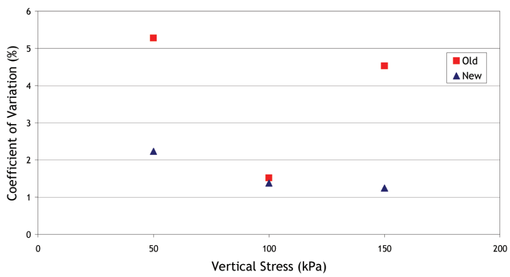

Figure 5. Comparison between coefficient of variation values obtained before (old) and after (new) the changes in test procedure.

horizontal displacement and the ratio of interface maximum shear stress to vertical stress for the several tests are shown in Table 4.

Table 4. Test results.

	Peak					
σ (kPa)	τ (kPa)		δ (mm)		(τ/σ)	
50	41.61		19.23		0.83	
	42.26		20.35		0.85	
	41.61		20.19		0.83	
	43.61		19.98		0.87	
M CV	42.27	2.24	19.94	2.48	0.85	2.24
100	79.93		21.98		0.80	
	81.47		18.14		0.81	
	82.09		21.80		0.82	
	82.50		18.27		0.83	
M CV	81.50	1.38	20.05	10.62	0.81	1.38
150	114.48		20.66		0.76	
	116.73		23.80		0.78	
	114.84		24.71		0.77	
	117.47		23.71		0.78	
M CV	115.88	1.25	23.22	7.60	0.77	1.25

It can be seen in Table 4 and Fig. 4 that with the increase of vertical stress value interface shear stress gets larger as well as the horizontal displacement for the maximum interface shear stress while the ratio of shear strength to vertical stress is reduced.

Dixon et al. (2002) presented guidance on selection of characteristic values for interface shear strength parameters. In this paper it was chosen to apply the methodology that consists on carrying out a minimum of four tests for each of three vertical stresses, enabling the mean (X_m) and standard deviation (σ_m) of measured shear strengths to be calculated for each vertical stress level. According to the referred authors, the characteristic values of shear strengths can then be calculated by:

$$X_k = X_m - 0.5\,\sigma_m \qquad (1)$$

The characteristic values for interface shear strength parameters can be obtained by drawing the best-fit straight line through the characteristic values of shear strengths for each of the vertical stresses (Fig. 6).

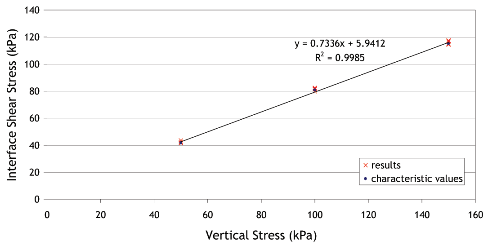

Figure 6. Best-fit straight line through characteristic values of interface shear strength.

Table 5. shows the characteristic values obtained for apparent adhesion ($[c'_{slg}]_k$) and friction angle ($[\phi'_{slg}]_k$). Besides allowing interface property determination in a more precise way the methodology presented by Dixon et al. (2002) approximates interface shear strength parameters to EC7 philosophy.

Table 5. Interface shear strength parameters.

$(c'_{slg})_k$	$(\phi'_{slg})_k$
(kPa)	(°)
5.94	36.26

4 CONCLUSIONS

It was observed that vertical stress applying time before horizontal displacement starting influences soil/geosynthetic interface behaviour. It was also found the need to define the gap between the upper part of the shear box and the geosynthetic with test vertical stress already applied.

Changes were introduced in the test procedure consisting in:

- establishing a fixed period of time of the vertical pressure application before starting the shear;
- gap definition with vertical pressure applied over the geotextile.

Several shear tests were then performed with the modified test procedure and excellent results were found.

The number of tests carried out for each vertical stress (four) enabled the determination of interface shear strength parameters characteristic values according to Dixon et al. (2002).

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