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Geosynthetic pullout in fine-grained soil: Analysis of soil/geosynthetic interface behaviour

Pinho-Lopes, M.
University of Aveiro, Portugal

Silvano, R. & Lopes, M.L.
University of Porto, Portugal

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ABSTRACT: The aim of this paper is to study the soil-geosynthetic interface resistance in a fine-grained soil using pullout tests. The type of geosynthetic is one of the parameters of high importance on the pullout behaviour of geosynthetics. To evaluate the influence of the structure of geosynthetics in their pullout behaviour a series of pullout tests was carried out. Five different geosynthetics, within a range of tensile strengths, embedded in a fine soil, were tested according to the procedures described on EN 13738. The results obtained are presented and discussed. The main conclusions from this study are also presented.

1 INTRODUCTION

The aim of this paper is to study the soil-geosynthetic interface resistance in a fine-grained soil using pullout tests.

The type of geosynthetic is one of the parameters of high importance on the pullout behaviour of geosynthetics. To evaluate the influence of the structure of geosynthetics in their pullout behaviour in a fine-grained soil a series of pullout tests was carried out.

The geosynthetics considered are of different types and have a relative large range values for their nominal tensile strength.

Five different geosynthetics, embedded in a fine-grained soil, were tested according to the procedures described on EN 13738.

2 GEOSYNTHETICS

The criterion to choose the geosynthetics was their structure, which should be representative of different types of materials.

Therefore five geosynthetics were studied: GTXw, GGRw, GGRc, GGRe, GTXc (Table 1).

While GTXw and GGRw are biaxial, the other materials studied are uniaxial. As the pullout mechanism is relevant mainly for reinforcement applications, the behaviour of the soil-geosynthetic interface was studied only for the machine direction of the materials.

Table 1. Geosynthetics tested.

	Geosynthetic	Nominal strength MD (kN/m)
GTXw	Woven PP-tape (320g/m^2)	65
GGRw	Woven PET geogrid	55
GGRc	Composite geogrid – PET filament coated in PP	50
GGRe	Extruded HDPE geogrid	80
GTXc	Composite geotextile	100

3 SOIL

In this study a fine-grained soil was used (Figure 1). In fact, 93% of the soil particles are less than 2 mm wide and 20% of the particles are smaller than 0.074 mm.

In Table 2 the main characteristics of the soil are presented and in Table 3 the strength parameters of the soil are included.

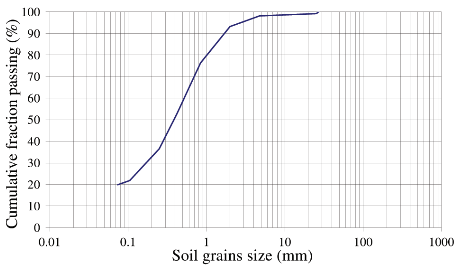

Figure 1. Grain size distribution of the soil.

Table 2. 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

Table 3. Main characteristics of the soil.

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

In the pullout tests the soil was compacted to a relative density of 50%, therefore the value of the corresponding soil unit weight value is presented.

4 PULLOUT TESTS

4.1 *Test equipment*

The pullout tests were carried out using the test equipment in Figure 2.

The interior dimensions of the box are: 1.5 m length, 0.90 m width and 0.60 m height. To reduce the influence of the upper boundary, a 0.025 m thick smooth neoprene slab was placed on the top of the box immediately over the soil, and, regarding the front boundary, a steel sleeve 0.20 m long was used inside the box, near the front wall.

To have a reduced unconfined length of geosynthetic during the pullout test the clamp is placed inside the metal sleeve with almost zero length of material outside the box (Figure 3). During pullout the unconfined length increases at the displacement rate imposed during the test.

Two different types of clamps were used, depending on the structure of the geosynthetic in question: wedge clamps, for GGRe and capstan clamps, with 47 mm diameter, for all the other materials.

The displacements along the geosynthetic are measured using inextensible wires connected (in one end) to the geosynthetic and (in the other) to linear

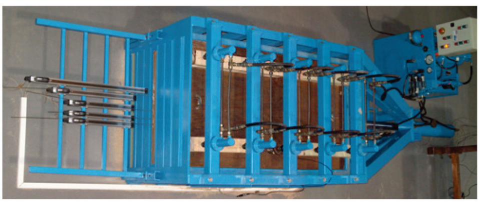

Figure 2. Equipment used for the pullout tests – large box.

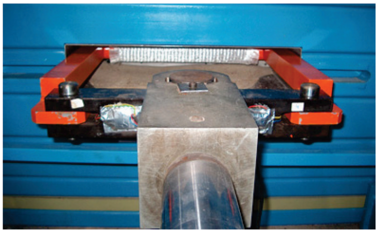

Figure 3. Clamp inside the metal sleeve.

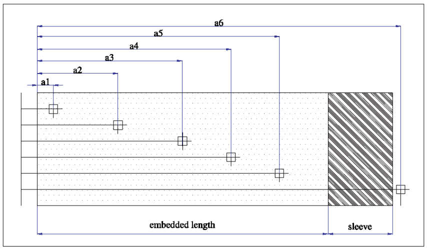

Figure 4. Clamp inside the metal sleeve.

potentiometers placed outside the box (see Figure 4).

The tests were carried out at a constant displacement rate of 2 mm/min. The pullout force is applied by a hydraulic system and measured by a load cell placed in the clamping system which transmits the force to the reinforcement.

The confining stress is applied by ten small jacks acting on a wood plate on top of the soil and is measured by a load cell.

The results are recorded during the test by an automatic data acquisition system.

A more detailed description of the equipment can be found in Lopes and Ladeira (1996) and Lopes and Lopes (1999).

4.2 *Test procedure*

To fill the box, the soil was poured from a constant height of 0.50 m and placed in 0.15 m thick layers. Each layer was levelled and compacted to the required unit weight using an electric vibratory hammer. When the soil reached the metal sleeve at the front of the box (0.30 m height), the reinforcement was laid on the surface of the compacted soil and fixed to the clamp outside the box.

The inextensible wires, used to measure the displacement along the reinforcement, were then placed and connected to the linear potentiometers at the back of the box. Five potentiometers were used in the tests. A sixth potentiometer is used to measure the displacement of the clamp.

Finally, two 0.15 m thick soil layers were placed, levelled and compacted, resulting in a total soil thickness of 0.60 m with the geosynthetic reinforcement at the middle. The geosynthetic specimens were 0.30 m wide and 1.00 m long (embedded length). The normal stress applied at the reinforcement level (i.e. at 0.30 m) was 50 kPa and a displacement rate of 2 mm/min was used.

For each geosynthetic three specimens were tested, giving a total of 15 pullout tests (all performed in the machine direction of the geosynthetic).

During the pullout tests the pullout force, the normal stress applied, the front displacement and the displacements along the geosynthetic were recorded every 4s.

5 TEST RESULTS

The results obtained are summarised in Table 4, and include the pullout resistance, i.e., the maximum pullout force per unit width, and the front displacement, as well as the corresponding values for the coefficient of variation. For all the materials tested the failure occurred by pullout of the geosynthetic from the soil.

Figure 5 shows the pullout plots for the specimens of the three specimens for each of the five geosynthetics tested.

All the pullout curves (with the exception of GGRe,) present an initial part with almost zero pullout force for increasing front displacement. This is due to the adjustment of the specimens in the clamps and to the structure of these materials. In fact, this behaviour is also clear in the wide-width tensile tests and reflects the lower initial stiffness of these geosynthetics.

The highest values for the average pullout resistance were obtained for GTXw (47 kN/m), and GTXc (34 kN/m), followed by GGRw (31 kN/m), GGRe (29 kN/m) and GGRc (28 kN/m).

It is important to note that the materials with openings (GGRw, GGRe and GGRc) and the geosynthetics with higher nominal tensile strength (GGRe and GGRc) are the ones with lower pullout resistance.

As far as the front displacement registered for the pullout resistance, the higher values were obtained for GGRc (150.50 mm), GTXw (125.28 mm), followed by GGRw (109.42 mm) and GTXc (105.80 mm) and GGRe (73.06 mm).

The results exhibit some scatter, illustrated by the coefficient of variation of the pullout resistance (ranging from 7% to 3%) and corresponding front displacement (between 9% and 4%).

During pullout, there are three mechanisms that can be mobilized in soil-geosynthetic interfaces: (a) skin friction over the planar geosynthetic interface; (b) soil-soil friction through the geogrid apertures; and (c) passive resistance of the geogrid bearing members. Therefore, it was expectable that materials with openings, able to mobilize the soil-soil friction through the apertures and the passive resistance of their bearing members would have higher pullout resistances.

Nevertheless, the values obtained indicate the opposite trend. In fact, the geosynthetic presenting higher pullout resistance is GTXw, planar and continuous material.

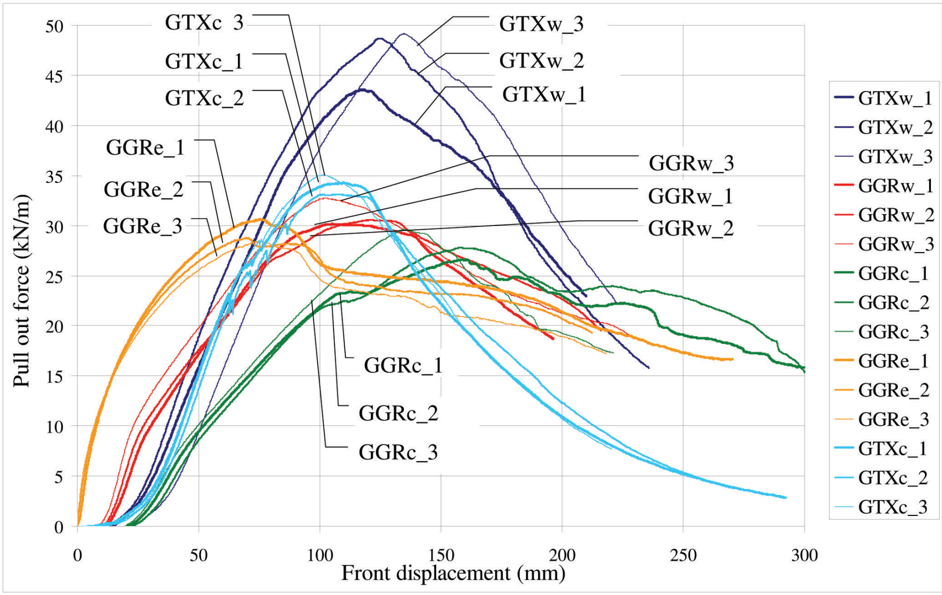

Figure 5. Pullout plots of the specimens tested.

Table 4. Summary of the pullout test results.

Material	Specimen	Pullout resistance (kN/m)	Front displacement (mm)
GTXw	1	43.56	117.18
	2	48.68	124.13
	3	49.14	134.53
	Average	47.13	125.28
	C.V. (%)	6.57	6.97
GGRw	1	30.17	105.09
	2	30.55	120.85
	3	32.73	102.33
	Average	31.15	109.42
	C.V. (%)	4.43	9.13
GGRc	1	26.61	158.38
	2	27.81	158.00
	3	29.62	135.12
	Average	28.02	150.50
	C.V. (%)	5.41	8.85
GGRe	1	30.61	75.04
	2	28.77	70.00
	3	28.40	74.14
	Average	29.26	73.06
	C.V. (%)	4.05	3.68
GTXc	1	34.28	109.85
	2	33.14	106.81
	3	35.06	100.74
	Average	34.16	105.80
	C.V. (%)	2.83	4.38

Previous results, presented by Lopes and Ladeira (1996), Lopes and Lopes (1999) and Silvano et al. (2004), show the expected trend. However, these results refer to sands, both coarse and fine.

The results of the pullout tests now presented refer to a different type of soil – a fine-grained soil.

The test plan implemented and the results obtained indicate that for this fine-grained soil the skin friction over the planar geosynthetic interface is more important for the pullout resistance than the other mechanisms referred. In fact, the planar and continuous materials, with higher surface area, exhibit higher values for the pullout resistance.

Apparently, the front displacement necessary to mobilize the pullout resistance of GGRe is smaller, however if the initial part of the pullout plot of the other geosynthetics is not considered, the magnitude of the displacements referred is similar.

One possible explanation for the smaller importance of the passive resistance of the geogrid bearing members is the relationship between the size of those bearing members and the soil gains.

To confirm this hypothesis, additional tests, suppressing the bearing members of the grids should be carried out.

6 CONCLUSIONS

To study the behaviour of the soil-geosynthetic interface, five geosynthetics were subjected to pullout test from a fine-grained soil.

The main conclusions that can be stated from this study are:

- the highest values for the average pullout resistance were obtained with GTXw (47 kN/m) and GTXc (34 kN/m);
- followed by GGRw (31 kN/m), GGRe (29 kN/m) and GGRc (28 kN/m);
- the higher values for the pullout resistance are likely to be due to higher contact area between the soil and the geosynthetic, as these are planar and continuous materials;
- the lower pullout resistance of the grid type geosynthetics indicates that for the fine-grained soil considered the passive resistance mobilized in their bearing members is not as significant as in sands.

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