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Geogrid pullout tests using small scale equipment

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ABSTRACT: This work presents results of geogrid pullout tests carried out using small scale equipment. To investigate the feasibility of the small scale test facility, comparisons were made between the coefficient of interaction obtained from small and large dimension tests. The small scale equipment is 250 mm long, 300 mm wide and 150 mm high. The main advantage of this equipment is the small volume of soil used in test preparation, resulting in reduced testing time, greater control of the water content and degree of compaction, and significant reduction in overall testing costs. The pullout load was applied using a universal loading frame capable of recording the pullout load and the frontal displacement of geogrid. In addition, the tests were instrumented with an earth pressure transducer installed at the level of geogrid inclusion. The geogrid used in the tests was Fortrac110/30-20. The soil used in the tests presented unit weight of soil particles equal to 2.67, liquid limit equal to 18%, plastic index equal to 4%, and (D_{50}) equal to 0.17mm. The soil was classified as silt sand by SUCS. The water content and compaction degree used in the tests were equal to 10.7% and 93%, respectively. Small scale tests were carried out using three different confining pressures (25, 50 and 100 kPa). The results show that there were no differences between pull out parameters obtained from both equipments for the tested materials. The larger difference in the results using both equipments was smaller than 6%. This differences is within the error range of both equipments.

1 INTRODUCTION

The use of reinforced soils in Brazil has been steadily growing since the early nineties. This can be attributed to the good technical performance and the reduced cost of reinforced structures compared to classical geotechnical solutions.

The most relevant parameters in the design of reinforced soil structures are the soil-inclusion interface friction and passive resistances, which are eminently experimental parameters.

Due to the great number of variables that influence the pull-out resistance of geogrids, the interaction coefficient (*f*) is frequently used in design due its simplicity. This parameter does not split the pull-out resistance into interface friction and passive resistance, but it considers the pull-out resistance, T, as a whole. It is calculated as a ratio between shear and normal stresses acting on the inclusion level and it depends on the embedded area, on the interaction between the soil and the geogrid, and on the shear resistance parameters of the soil (Teixeira, 2003).

The coefficient of interaction, *f*, is a site specific parameter obtained from field or laboratory pull-out tests. Field tests can represent local soil peculiarities and stress states, but can be expensive and time consuming. Besides that, their boundary conditions are difficult to be evaluated. Laboratory tests, on the other hand, are cheaper than field tests and if properly carried out can adequately represent field conditions. Therefore because of cost and time consumed, laboratory tests have been preferred to field tests.

Large-scale laboratory tests are appropriate to study the interaction between soil and geogrid, since they allow parametric studies about the most important factors that affect the soil-inclusion behavior. The main advantages of this type of test are the capability to reproduce the physical structure of reinforced soil and the capacity of applying stress and strain levels similar to those observed at the field. They may however be expensive, time consuming, use large amount of soil, and present the relative difficulty in controlling moisture content and degree of compaction during test preparation.

In view of these facts, the use of small-scale equipments may be advantageous in certain circumstances because of easiness of test preparation and because they can reproduce very well the result of large scale pull-but tests.

The present work evaluates the viability of using small scale pull-out apparatus to quantify the pull-out resistance of dense mesh geogrids, as defined by Teixeira et al. (2004), embedded into fine grained soils.

Test data obtained using this small-scale test devices were compared with results obtained from large-scale pullout tests by Teixeira, (2003).

2 MATERIAL AND PROCEDURES

The small scale test equipment was designed and built by Teixeira (2003). The internal dimensions of test box is 250 mm in length, 300 mm in width and 150mm in height, resulting in a volume of approximately 0,01125 m^3. The application of the pull-out force is made through a universal machine. The external instrumentation of the system consisted of load cell to register the pullout force and a LVDT to measure the axial displacement of the geogrid.

An inflatable PVC air-bag, coupled to the box cover, allowed the application of normal stress through the compressed air.

The internal instrumentation consisted of an earth pressure transducer to monitor the total stress on soil and is installed immediately below the inclusion. The system allows the use of an electric piezometer to measure the pore pressure generated during test preparation and during the pull-out. Fig. 1 presents a general view of the test equipment.

Two cohesive soils (A and B) were used in experimental program. The most important geotechnical characteristics of soils A and B are presented in Table 1.

Two flexible polymeric geogrids used in this work were Fortrac 55/30-20 and Fortrac 110/30-20.

3 ANALYSES OF RESULTS

Two series of tests were performed. The first series were carried out in order to calibrate the test equipment, defining repeatability of the test results. The second series was performed to allow comparisons with large scale results obtained by Teixeira (2003).

Figure 1. Device for small-scale tests.

Table 1. Soil properties.

Properties	Soil A	Soil B
γ_s (kN/m^3)	29.8	26.7
W_L (%)	46	18
W_P (%)	28	14
γ_d (kN/m^3)	16.5	19.50
$W_{compaction}$ (%)	23.5	10.7
ϕ (º)	34.8	33.5
c (kPa)	27.5	23.8
Fine soil fraction (%)	58	20

3.1 *Calibration of equipment*

To calibrate the test equipment and to verify the variability of the obtained results, a series of eight tests with the same characteristics were performed. Table 2 presents the test parameters used in this series.

Table 2. Configuration of tests used to verify the equipment repeatability.

	Geogrid (Fortrac)	Soil	Vertical stress (kPa)	Displacement rate (mm/min)
Test 1 to 8	55/30-20	A	40	4.6

Figure 2 presents the curves displacement vs. pull-out force for this series of test.

As can be seen, there were a great similarity in displacement and maximum pull-out force as well in the shape of the resulted curves for the eight test shown in Fig. 2. Table 3 presents the results of the maximum pull-out force and respective displacements.

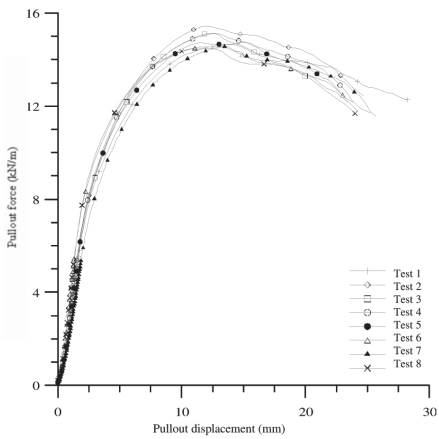

Figure 2. Displacement versus pullout force curves.

Table 3. Pullout test responses.

Test	Pullout force (kN/m)	Displacement (mm)
1	14.66	13.49
2	15.44	11.82
3	15.15	12.27
4	15.13	12.63
5	14.72	11.55
6	14.54	11.79
7	14.56	13.47
8	14.47	12.27
Mean	14.83	12.41
Std deviation	0.36	0.74
variance	2.4 (%)	6.0 (%)

From these data, the average, the standard deviation and the coefficient of variation for both parameters were obtained.

Through this series of tests, it was verified that the equipment generated results with variation coefficient equal to 2.4 and 6,0%, for pull-out force and of displacements, respectively. It shows that the equipment is perfectly trustful.

3.2 *Comparison among obtained results of equipment of great and small dimensions*

To evaluate the viability of using small-scale tests to reproduce results obtained from large-scale equipments, three tests were carried out keeping the same test conditions used by Teixeira (2003). His tests were performed in large scale pull-out equipment 700 mm wide, 1500 mm long and 480 mm in height. The comparison results of large and small tests are presented in Table 4.

Tests T1, T2 and T3 identify the are Teixeira (2003), data obtained in the large-scale pullout box, and K9, K10 and K11 are tests carried out in the small-scale equipment. These tests were performed using the same type of soil which was prepared at the same test conditions regarding soil compaction and geogrid properties. The tested geogrid was the Fortrac110/30-20.

Table 4. Comparison of the rehearsal results.

Equipment	test	σ (kPa)	Pullout stress (kPa)	*f*
small	K1	25	28.33	0.70
small	K2	50	38.57	0.68
small	K3	100	61.29	0.68
large	T1	25	29.75	0.74
large	T2	50	36.67	0.64
large	T3	100	61.58	0.68

Comparing the pull-out strengths, using the small device to those obtained by Teixeira (2003), it can be observed that the values are very close. The higher differences, 6%, observed between tests performed with normal stress of 25 and 50 kPa, are within test variability. The good agreement between these set of data, and considering that these differences can be credited to test variability, it is possible to say that for the tested material the small scale apparatus was able to reproduce results of large scale pull-out devices. Comparing the pullout stresses obtained from tests K1, K2 e K3 with that results obtained from large-scale equipment, the largest found difference was equal to 5.2% for a surcharge of 50 kPa. For a surcharge of 25 kPa, the difference was equal to 4.7% and for a surcharge of 100 kPa, the values were practically the same.

The soil-geogrid interface envelopes obtained from both equipments were practically coincident. Besides that, the tests performed with small-scale equipment presented the smallest interaction coefficient dispersion, for the three tested surcharges.

The obtained results of this analysis suggest that the small-scale equipment is appropriate to reproduce the results obtained from large-scale tests and, therefore, the measured interaction coefficients. Besides that, the additional advantages of small pullout tests are its simplicity, low execution cost, easiness of assembling, and utilization of a computerized data storage system. Another important advantage of that equipment is the exceptional economy of time, when compared with time spent to execute conventional pullout tests.

Figure 3 presents the displacement vs. pullout stress curves for the normal stresses of 25, 50 and 100 kPa, obtained with the small-scale test device. As can be seen these curves are very similar those of large scale apparatus in which the pull-out force reaches a maximum with horizontal displacements increasing with the normal stresses.

Figure 4 presents the oscillations of normal stresses registered in the total stress cell during the execution of the tests K1, K2 e K3.

Figure 4 shows pull-out horizontal geogrid displacement versus the readings of the earth cell. As can be seen the curves chow oscillation of the registed

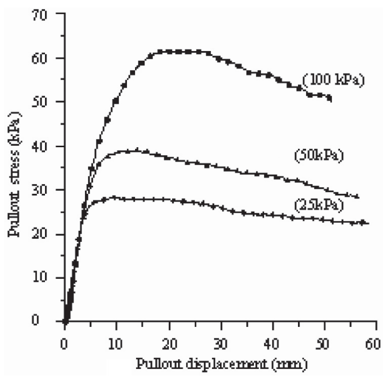

Figure 3. Pullout tension verse pullout displacement.

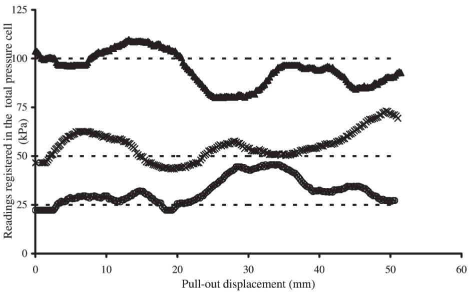

Figure 4. Displacement verse readings earth pressure transducer.

stress in a similar partern as shown by Teixeira et al. (2004).

In conducting the small scale pull-out tests, it was noticed that the average time spent on each pullout test was one hour and thirty minutes, not considering the time for soil preparation (collecting, correction water content, etc.).

4 CONCLUSIONS

The small scale pull-out equipment can be used to obtain the pullout resistant force for dense mesh geogrids embedded in fine grained soils, since their results were in good agreement with large-scale test results obtained by Teixeira (2003), which were performed in the same test conditions. The comparison shows that the obtained large and small scale test results were identical. The small observed variation reached 6% and were scattered, suggesting these differences can be credited to test errors ad discrepancies in test preparation.

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