Evaluation of The Non-Confined Axial Compression of Soils With Geosynthetics Incorporation

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ABSTRACT
This research has the aim to evaluate the mechanic behaviour of Guabirotuba formation soil, with tactile and visual description of a grey silty clay, reinforced with geosynthetics. The soil was reinforced with a woven geotextile with mass 180g/cm2 and tensile strength of 35kN/m in both directions. The experimental program involved non-confined axial compression tests with natural and reinforced soil. The conclusions show: I) the undrained shear strength doubled; II) the specific axial deformation increased from 0,52% to 1,10%; III) the compression strength raised 100%.

1. INTRODUCTION

The geotechnical study of soils from Guabirotuba Formation has a big regional importance, because this material serves as base for most part of engineering construction in Curitiba and region. However, this soil presents some unfavourable geotechnical conditions for civil constructions like expansibility and heterogeneously.

It's engineer's responsibility to promote the convenient modifications to adequate the soil behaviour to the project's demand, choosing the most economic option. Because of this, the soil reinforcement is an important alternative that most of times is cheaper than a laboured structure.

In this research a study about the incorporation of geosynthetics in compressed soil was done. It was used samples of woven geotextile, one of the most used types.

The knowledge about the characteristics of geosynthetics mechanical behaviour and their maintenance in time are very important to the designer. The determination of the geosynthetics' influence in the soil reinforcement can be done through compression tests, which take into account the geosynthetics interaction with the adjacent material. This property is fundamental to soil reinforcement's projects, in any application.

The diffusion of the triaxial test decreased the use of non-confined tests. However, in this work, the non-confined compression test was chosen because it is cheaper, simple and provides good results.

The strength x deformation curve that is obtained with the test allows an evaluation of the resistance variation with the strength's increase and it allows quantifying this variation with the geosynthetics' introduction.

It was obtained, experimentally, the attestation that the use of geosynthetics increases significantly the shear resistance through the fracture surface of the compressed soil sample tested by the non-confined compression test.

2. GUABIROTUBA FORMATION

For this research, the reinforced soil identification is very important. The soil sample used in the laboratory tests is from Guabirotuba formation, withdraw from REPAR (Getúlio Vargas refinery), in Araucária city, Paraná state, Brazil. This kind of soil has occurrence in Curitiba city and region, Brazil.

Guabirotuba formation, according to Prates (1999), has its origin as a transported soil. The author complements that the name of this formation was given because of the neighbourhood where were done the first descriptions of this formation formed by the Curitiba catchments area deposits. There are theories about the Curitiba catchments area geological formation. Prates (1999) mentions the theories of Carvalho e Siemiradzki. The first says that the formation occurred because of an association of rigorous climate conditions and north hemisphere glaciations, but the second theory says that the fractures angle is responsible for the formation of the Curitiba catchments area.

According to Salamuni (1999), Guabirotuba formation is the principal transported soil unit of Curitiba catchments area. The thickness is irregular, ranging since 1,0 m to a maximum of 80,0 m. The biggest thicknesses are located in central and central-southeast portion, where are located the depressions that formed the principal valley of the Curitiba catchments area. On average, the thickness is 40,0 m.

The soils of Guabirotuba formation are basically composed by over consolidated silty clays and clayey silts, with high plasticity and frequently high expansion. Until some years ago there were few studies about its mechanical behavior (DYMINSKI, RIBEIRO e ROMANEL, 1999).

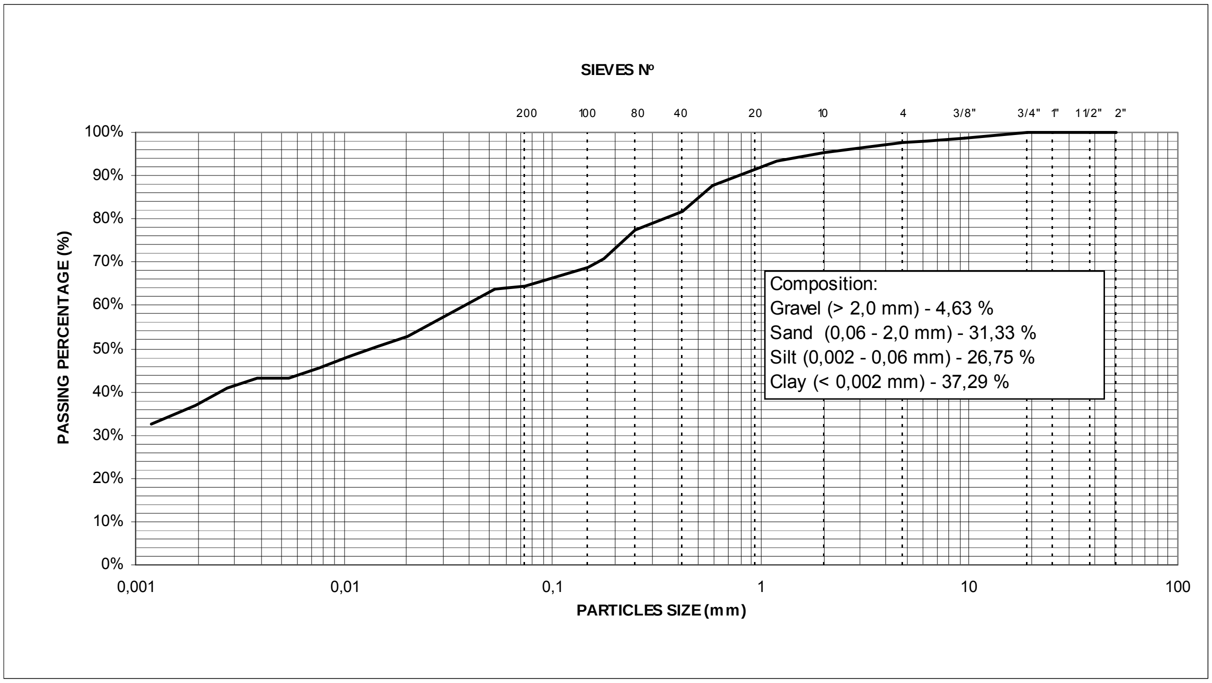
According to Kormann (1999), Guabitotuba formation soils have high consistency, from stiff to hard, as main characteristic. Frequently the SPT resistance ranges from 15 to 30. The author mentions that the sediments are mostly composed by gray, greeny gray and brow silty clays. These stiffs' clays are hard in its natural state and become slippery when wet, which gives its popular name of "cabloco soap". Kormann (1999) concludes that the soil is stable when confined, but when excavated, the soil suffers a relief of horizontal pressure in the ground, determining the appearance of negatives pore pressures. Because of the polish surfaces and fractures that Guabirotuba formation presents, the soil doesn't have the capacity to support the suction caused by the stress decrease.

The physical and mechanical characteristics of Guabirotuba formation present certain uniformity; therefore this study's conclusions are based in a little sample to provide preliminaries information, having its purpose with relatively degree of effectiveness.

3. SAMPLES CHARACTERIZATION

3.1 SOIL

The soil sample used can be described tactile and visual as gray silty clay. The particle size distribution is presented on graph 1.



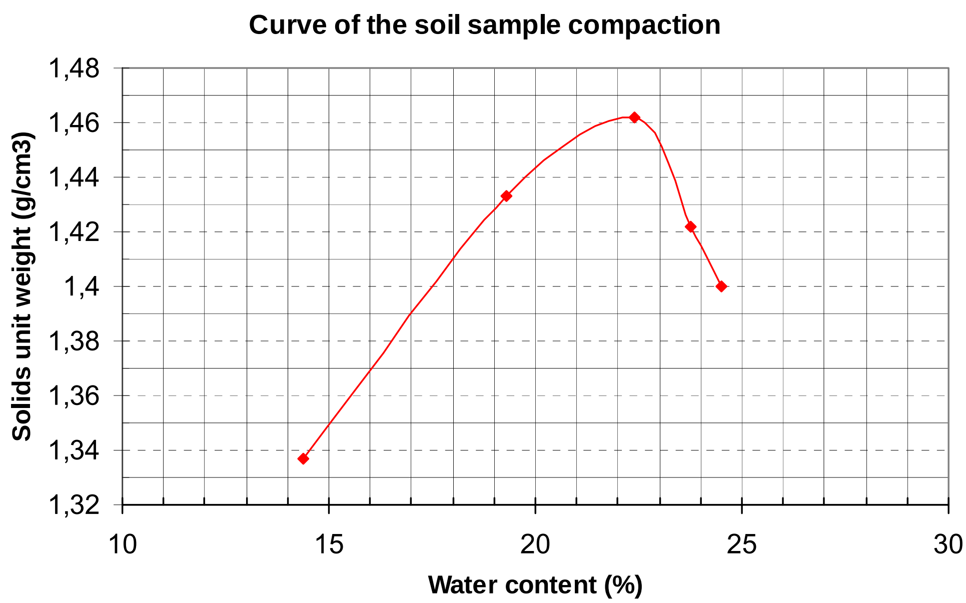
Graph 1: Curve of the sample's particle size distribution.

The sample's complete characterization is presented on table 1.

Table 1. Characteristics of soil sample

Soil Sample – Guabirotuba Formation	
Water Content	7,76%
Liquid Limit	56,30%
Plasticity Limit	22,48%
Plasticity Index	33,82%
Solids Unit Weight	2,656 g/cm3

The Normal Proctor compaction test was done for the soil sample, for the purpose of having the maximum dry unit weight and the optimum water content. The compaction curve is presented by the graph 2.



Graph 2: Curve of the soil sample compaction

The result's summary is showed on table 2.

Table 2. Summary of the compaction test

γd_{max}	1,465 g/cm^3
w_{opt}	22,0 %

3.2 GEOSYNTHETIC

The geosynthetic used in the test was a woven geotextile provided by Huesker Ltda. Its commercial name is HaTe® 35/35 and dimensions are (5,00 x 1,00) m². The synthetics fibers are tread by needles and the woven geotextile has mass 180g/m².

The nominal strengths of this geotextile are:

- Punching resistance CBR (ABNT 13359): > 4,5 kN;
- Traction resistance (ABNT 12824): > 35 kN/m in both directions.

4. PRESENTATION AND DISCUSSION OF THE RESULTS

4.1 TESTS RESULTS

4.1.1 Compacted soil

The non-confined axial compression tests were done with Guabirotuba formation soil, using the procedures from NBR 12770 (ABNT, 1992). The samples were dynamically compacted by Normal

Proctor Test, according to NBR 7182 (ABNT, 1986), in its great water content w_{opt} = 22%, using a bi-slice mold created exclusively for this work to facilitate the soil extraction, how the picture 1 shows.

Picture 1. Bi-slice Mold

During the soil and water moisture to get the great water content, it was seen the formation of lumps, what difficult the homogenization. With that, it was realized that the sample behaved as a granular material, forming micro-clefts inside facilitating the sample collapse.

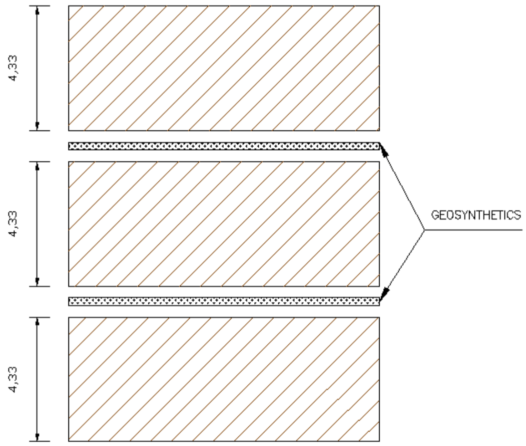
It was prepared seven samples to fulfill the non-confined compression test of the natural soil. The medium axial deformation obtained on failure was ε = 0,52% and the undrained shear strength, which is defined by $\frac{q_m}{2}$, in these samples had a approximate value of Su = 60 kPa. The simple compression strength found in the test was qm = 122,02 kN/m2.

During the tests, the Guabirotuba formation soils samples without geosynthetics collapsed with an approximate inclination of 67º.

4.1.2 Soil reinforced with geosynthetics

The non-confined axial compression tests were done with Guabirotuba formation soil with incorporation of woven geotextile Hate® 35/35. The samples were dynamic compacted by Normal Proctor test, in the optimum water content w_{opt} = 22%, using the same bi-slice mold for the test without geosynthetics.

The woven geotextile was included in the sample twice, in each compacted layer, according to picture 2. It was molded seven samples with this configuration, to execute the non-confined compression test of the reinforced soil with geosynthetics.



Picture 2. Samples configuration with geosynthetics incorporation.

The bi-sliced mold was not capable to avoid sample's segmentation during the extraction. It was necessary to use oil in small quantities in the internal mold walls to avoid the soil joining. Since the oil doesn't mix with water, its use don't cause any change in soil water content.

The average compression strength found was q = 244,04 kN/m2 and the average axial deformation on failure obtained was ε = 1,10%. Comparing to the result without geosynthetics, the values almost doubled. The undrained shear strength in these samples was almost Su = 120 kPa, being exactly the double of the value found in the samples without geosynthetic.

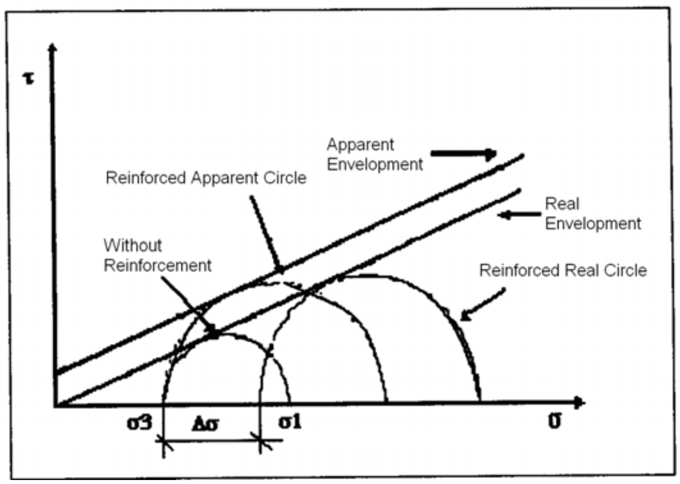
The soil from Guabirotuba formation has a singular behavior when in contact with water. The soil is basically formed by small particles, but they have a big cohesion. When mixed with water, to increase the water content of the soil, the particles get together in lumps. This is one of the biggest difficulties with this kind of soil, it doesn't homogenize well. During the tests, the samples of Guabirotuba formation with woven geotextile collapsed because of this behavior of the soil that doesn't allow the creation of the apparent cohesion with geosynthetic and the manner as the geosynthetics was applied in the sample (horizontal). The internal micro-clefts were more visible near the interaction soil-geosynthetic zone, according to picture 3.

Picture 3. Collapsed sample with woven geotextile incorporation.

4.2 RESULTS DISCUSSION

Geotextiles are continuous planar blankets that separate the soil mass in horizontal layers and work exclusively by frictional mechanisms (SIEIRA, 2003). For these materials, sliding tests basically indicate friction coefficients (or any parameters of interface strength) for the interface between soil and geosynthetic.

A mass of soil collapses when, in a determined plan, the shear stress reaches the soil shear resistance. When the mass of soil is reinforced, the increase in the shear strength is verified because of the introduction of the reinforcement. According to Teixeira (2006), this increase can be seen as an apparent cohesion assigned to the set soil-reinforcement. So, the inclusion of elements in the soil can be considered to have a similar effect to an increase in the confinement, because the shear strength has an increase. The reinforcement's effect in the strength can be seen at graph 3.

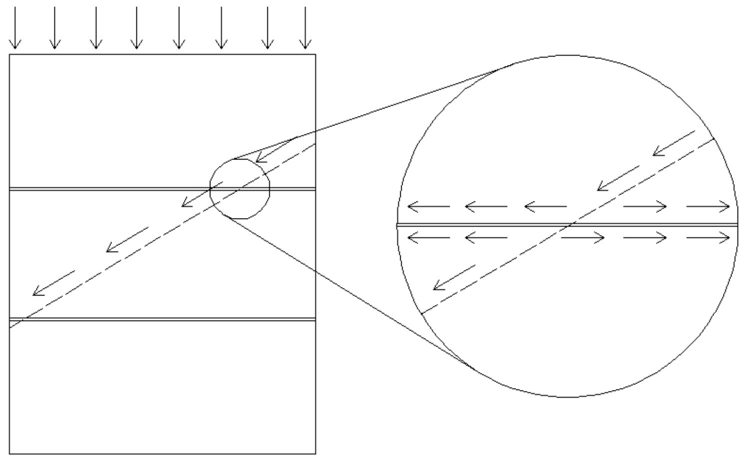


Graph 3. Reinforcement's effect in the soil strength (TEIXEIRA, 2006, p. 32).

There are two kinds of collapse in the soil-geotextile interface: one for lack of tensile strength and other for lack of adhesion between soil and geosynthetic.

According to Mendonça (2004), the stability of a reinforced soil is deeply related with the efficiency of the load transfer from soil to reinforcement.

The non-confined axial compression test applies a vertical stress in the sample. This stress is transferred to the soil-geosynthetic interface, in which the shear strength is mobilized as the sample's compression continues. The result of the soil-geosynthetic interaction is translated by the availability of tensile strength, which is mobilized as the fracture surface tends to develop in the sample (picture 4).



Picture 4. Strengths mobilized in the non-confined axial compression test

The traction strength which is mobilized in the soil-geosynthetic interface is different of the nominal strength. It depends of the friction angle ($\delta_{soil\text{-}geosynthetic}$) and the apparent cohesion ($c_{soil\text{-}geosynthetic}$) called interaction coefficient by Teixeira (1999).

In this research can be understood that the geosynthetic traction strength was mobilized even without the sample's confinement and it increased the compression strength in 100% of the natural soil's value. Besides of the geotextile's extensibility, the apparent cohesion that was created in the soil-geosynthetic interface could have contributed to the increase of the strength. In clayey soils, this apparent cohesion can be noticed with more facility than in granular soils.

5. CONCLUSIONS

In the compaction test, the maximum dry unit weight of the Guabirotuba formation's soil was 1,465g/cm3 and the optimum water contend was 22,0%.

The natural soil axial deformation on failure was almost half of the reinforced soil, having values of 0,52% e 1,10%, respectively. The natural soil undrained shear strength was Su= 60 kPa, while in the samples with geosynthetics, the value had an increase of 100%, Su = 120 kPa.

The non-confined axial compression test applies a vertical stress in the sample. With this, shear strength is mobilized in the soil-geosynthetic interface and it mobilizes the geotextile's tension strength.

The woven geotextile used as soil reinforcement supports high deformability, what decreases its efficiency for mobilization of the strength in its interface with soil. It presents its interaction mechanism basically on lateral friction and adhesion soil-geosynthetic, being the last mobilized in case of cohesive soils.

With the friction and the cohesion soil-geosynthetic that were created in the non-confined axial compression test, it was obtained results of q_m = 122,02 kN/m2 for natural soil and q_m = 244,04 kN/m2 for soil with geosynthetics. It can be realized that was a increase of 100% in the strength of samples with geosynthetics incorporation.

The authors recommend, for futures researches, others kinds of geosynthetics to be tested, as nonwoven geotextiles and geogrids, for the purpose of having a bigger sampling universe which allows the different performance comparison.

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