Evaluation of unconfined axial compression of Guabirotuba formation soils with woven geotextile incorporation

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ABSTRACT:

This research aims to evaluate the effect of geosynthetic reinforcement on mechanic behavior of a Guabirotuba formation soil, classified as a gray silty clay, a CH soil according to the unified soil classification system. The soil was reinforced with a woven geotextile, with mass per unit area equal to 180g/cm² and tensile strength equal to 35kN/m, in both directions. The experimental program involved performing unconfined axial compression tests with unreinforced and reinforced samples of soil. The main obtained conclusions were: i) the undrained shear strength of reinforced soil is about 100% higher than strength of unreinforced soil and ii) the axial strain at strength peak increased from 0,52%, for unreinforced soil, to 1,10%, for reinforced soil.

1 INTRODUCTION

The geotechnical understanding of soils from Guabirotuba formation has a great regional importance, since these soils are used as foundation material in several engineering construction in Curitiba city and metropolitan region. However, such soils present some unfavorable geotechnical characteristics for civil constructions like expansibility and heterogeneity.

In this research a study about the influence of geosynthetics reinforcement on this soil behavior was done by means of unconfined compression tests. In this study, samples of woven geotextile, one of the most common and used types, were used.

The knowledge about the geosynthetics properties, the mechanical behavior of reinforced soil and geosynthetic performance along the time are very important to designers. The determination of the geosynthetics' influence on the reinforced soil can be evaluated through compression tests, which take into account the geosynthetic interaction with adjacent material. This property is fundamental for designing reinforced soil, in any application.

The diffusion of using triaxial test tends to decrease the use of unconfined tests. However, in this work, unconfined compression test was chosen because it is cheap, simple to be done and provides a good basis for comparison.

In this work, it was obtained, experimentally, the attestation that the use of geosynthetics increases significantly the shear resistance of the compressed soil sample, by means the unconfined compression tests.

2 RESEARCH DEVELOPMENT

2.1 *Guabirotuba formation*

For this research, the unique geotechnical characteristics of reinforced soil are very important to be considered. The soil sample used in the laboratory tests is typical of Guabirotuba formation, and was collected in REPAR (Getúlio Vargas Petroleum Refinery), in Araucária city, Paraná state, Brazil. This kind of soil has occurrence in Curitiba city and region, in Brazil.

Guabirotuba formation, according to Prates (1999), has its origin as a transported sedimentary soil. The author complements that the formation name relates to the neighborhood where the first descriptions of this material was made, and it is largely found in Curitiba sedimentary catchments area.

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

The soils of Guabirotuba formation are basically composed by over consolidated silty clays and clayey silts, with high plasticity and frequently highly expansive. Up to 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, greenly gray and brow silty clays. These stiffs' clays are hard in field condition and become slippery when wet, which gives its popular name of "cabloco's 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, generating 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 in deposition basin; therefore this study is based in a small sample to provide preliminaries information, having its purpose with relatively degree of effectiveness.

2.2 *Samples Characterization*

2.2.1 *Soil*

The used soil sample can be described as a gray silty clay. The grain size distribution curve is presented on Figure 1.

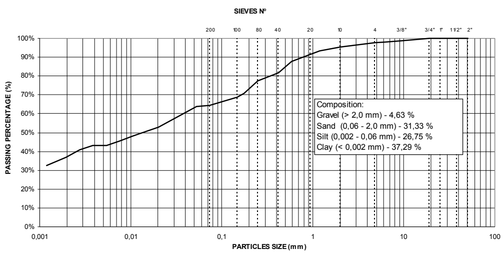

Figure 1: Curve of the sample's grain size distribution curve.

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 %
Unified Soil Classification System (USCS)	CH
Solids Unit Weight	2,656 g/cm^3

The compaction test for normal compaction energy was done for the soil sample, aiming to determine the maximum dry unit weight and the optimum water content. The compaction curve is presented in Figure 2.

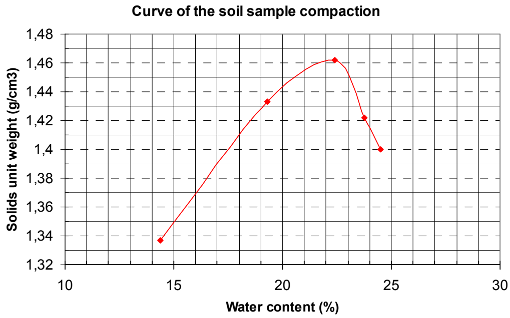

Figure 2: Compaction curve of the soil.

The results of compaction test are summarized in Table 2.

Table 2: Summary of the compaction test results

γd_{max}	1,465 g/cm^3
W_{opt}	22,0 %

2.2.2 *Geosynthetic*

The geosynthetic used in the tests was a woven geotextile manufactured by Huesker Ltda, with commercial name HaTe® 35/35. The geotextile's fibers are tread by needles and the woven geotextile has mass per unit area equal to 180g/m².

The nominal strenght of this geotextile are:

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

2.3 *Presentation and Discussion of the Results*

2.3.1 *Compacted soil*

The unconfined axial compression tests were done with Guabirotuba formation soil, using the procedures from NBR 12770 (ABNT, 1992). The samples were dynamically compacted in a Proctor compaction cylinder, according to NBR 7182 (ABNT, 1986), in its optimum water content w_{opt} = 22%, using a bi-sliced mold created exclusively for this work to facilitate the soil extraction, as shown in Figure 3.

Figure 3: Bi-slice Mold

During the soil moistening, to achieve the higher water content values, it was observed the formation of lumps, making difficult the soil homogenization. Because of that, it was realized that the sample behaved as a granular material, forming micro-voids inside facilitating the sample collapse.

It was prepared seven samples to be used on unconfined compression test of the unreinforced soil. The average axial strain obtained at failure was ε = 0,52% and the undrained shear strength, which is defined by as $q_m/2$, in these samples had a approximate value of Su = 60 kPa. The average unconfined compression strength found in the tests was q_m=122,02 kN/m2.

2.3.2 *Soil reinforced with geosynthetics*

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

The woven geotextile was placed in the samples in two positions along the specimen length, between the three compacted layers, according to Figure 4. It was molded seven samples with this configuration, to execute the unconfined compression test of the reinforced soil with geosynthetics.

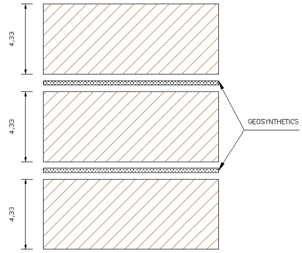

Figure 4: Samples configuration with geosynthetics incorporation.

The bi-sliced mold was not capable to avoid sample's segmentation during the extraction. It was necessary to use a mineral 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 fine particles (clay and silt), presenting high cohesion. When mixed with water, to increase the water content of the soil, the particles get together in lumps, becoming difficult to be homogenized. During the tests, the soil samples, from Guabirotuba formation, with woven geotextile collapsed since it doesn't allow the creation of the apparent cohesion with geosynthetic and also due the manner as the geosynthetics was inserted in the sample (horizontal). The soil collapse (Figure 5) means that the soil lost its support capacity, having a deformation larger than acceptable.

Figure 5: Collapsed sample with woven geotextile incorporation.

2.3.3 *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, direct shear 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. The inclusion of reinforcement elements in the soil can provide an effect similar to an increasing in the confinement, causing an increasing in the shear strength.

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 mass is deeply related with the efficiency of the load transfer from soil to reinforcement.

The unconfined axial compression test applies a vertical stress to 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 depends on the availability of tensile strength, which is mobilized as shear develops in the sample (Figure 6).

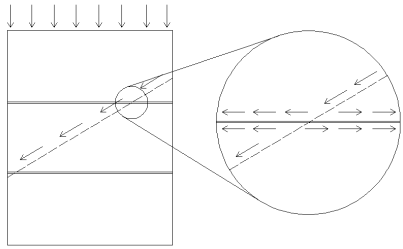

Figure 6: Strengths mobilized in the non-confined axial compression test.

The shear strength mobilized in the soil-geosynthetic interface depends on the friction angle ($\delta_{soil\text{-}geosynthetic}$) and the apparent cohesion ($c_{soil\text{-}geosynthetic}$), summarized in the parameter called interaction coefficient (Teixeira, 1999).

From this research, it can be inferred that the geosynthetic tensile force was mobilized even without the sample's confinement, increasing the unconfined compression strength in 100%, in comparison with unreinforced soil. Besides of the geotextile's low extensibility, the apparent cohesion that was created in the soil-geosynthetic interface and the friction developed at interface could have contributed to the increasing in strength. In clayey soils, the apparent cohesion is more evident than in granular soils.

3 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 unreinforced soil axial stress at failure was almost half of the value for reinforced soil, whose values are 0,52% e 1,10%, respectively. The unreinforced soil undrained shear strength was Su= 60 kPa, while in the samples reinforced with geosynthetic, 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 is very stiff, and this can have some influence on mobilization of the strength in its interface with soil. The interaction mechanism is based on lateral friction and adhesion at soil-geosynthetic interface. The adhesion can be an important mobilized parcel in case of cohesive soils.

In unconfined compression tests it was obtained: q_m = 122,02 kN/m² for unreinforced soil and q_m = 244,04 kN/m² for soil reinforced with geosynthetic. It can be realized that there was an increasing of 100% due the geosynthetics incorporation in soil.

The authors recommend, for futures researches, others kinds of geosynthetics to be tested, as nonwoven geotextiles and geogrids, with the purpose of evaluating a larger sampling universe, allowing different performance comparison.

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