PalArch's Journal of Archaeology of Egypt / Egyptology

GEOTECHNICAL CHARACTERIZATION OF TWO SOILS IN A SUBTROPICAL REGION

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Jair Arrieta, Carlos Millan, Fernando Jove. Geotechnical Characterization Of Two Soils In A Subtropical Region-- Palarch's Journal Of Archaeology Of Egypt/Egyptology 19(3), 482-488. ISSN 1567-214x

Keywords: Guabirotuba Formation, Geotechnical Characterization, Laboratory Tests

ABSTRACT

The present work aims to geotechnically characterize two soils of the Guabirotuba Formation in Curitiba/PR and compare them with reference to characterization. For this, two silty soils were collected in different places in the city and in different colors: yellow and purple. The three soils were submitted to tests of real specific gravity of the grains, granulometry by sieving and sedimentation, limit of liquidity, limit of plasticity and compaction in normal, intermediate and modified energy. According to the Unified Soil Classification System (SUCS) yellow soil and purple soil are classified as sandy elastic silts (MH). The largest granulometric fraction in the two soils corresponds to silt (0.002 mm < diameter < 0.075 mm) varying in percentages of 57.6% and 53% for the yellow and purple soils, respectively. As for the clay fraction (diameter < 0.002 mm), it is smaller in purple soil (9%). The normal compaction results show the soil with maximum density of γ_{dmax}=13.80 kN/m^3 and the yellow soil with γ_{dmax}=13.75 kN/m^3. In the modified compaction, the yellow soil had the highest γ_{dmax} with 16.75 kN/m^3. On the other hand, it was found that the plasticity index (PI) is higher in purple soil (21.3%) and lower in yellow soil. Although the soils were collected in different locations in the city and in different colors, they present similar geotechnical characteristics due to their same sedimentary origin and geological formation.

INTRODUCTION

The Guabirotuba Formation is a geological formation of the Curitiba Sedimentary Base, of which it is the main stratigraphic unit. The sediments of this Formation are found in the municipality of Curitiba and Metropolitan Region, extending from the municipalities of Campo Largo to Quatro Barras, also covering the municipalities of Curitiba, Campo Largo, Colombo, Almirante

Tamandaré, Pinhais, Piraquara, Campina Grande do Sul , Quatro Barras, Araucária, Fazenda Rio Grande, São José dos Pinhais and Tijucas do Sul, with an area of approximately 900 km², while the Curitiba Sedimentary Basin has an area of 300 km² (Kormann, 2002; Felipe, 2011).

Salamuni and Salamuni (1999) divide the lithologies of the Guabirotuba Formation into 4 groups, which are: clays, arkoses and archesian sands, conglomeratic deposits and carbonate deposits, where the group of clays constitutes the main lithofaciological group of the Formation. The group of clays or claystones as they are known in geological terms are, for the most part, gray in color and of bluish-greenish and brownish tones, but in the more superficial layers the colorations can change color to red or yellow, and almost all clays have smectite as their main clay mineral. In reference to the group of arches and archesian sands, they appear in the middle of clay deposits where the sediment matrix is formed by sandy grains of smaller dimensions where the presence of clay and silt can still be seen. The colorations of this second group range from gray to red to whitish; and the layers of the arkose have thicknesses that can reach 3 meters.

Lithotype conglomeratic deposits are formed by granular materials embedded in a clayey matrix and can be found at the edges of the basin (Kormann, 2002). Finally, the group of carbonate deposits is made up of caliches (hardened calcium carbonate deposits) and appear in more superficial layers of smaller thickness, with caliches coming from rare earth minerals such as neodymium, lanthanite and praseodymium. Caliches are deposits found in greater quantities in desert areas.

In hydrogeological terms, the Guabirotuba Formation behaves as an aquiclude and only locally in sandy and/or arcosian lenses there is an aquifer behavior. In general, tubular wells in this Formation have very low productivity or, at most, temporarily medium productivity. The basement of the aforementioned Formation, however, has medium to high productivity where structural discontinuities occur, regardless of depth, behaving, as a whole, as a fractured aquifer (Salamuni and Stellfeld, 2001).

Figure 1 shows the profile of the Guabirotuba Formation, composed mainly of transported soils, arkoses and clays.

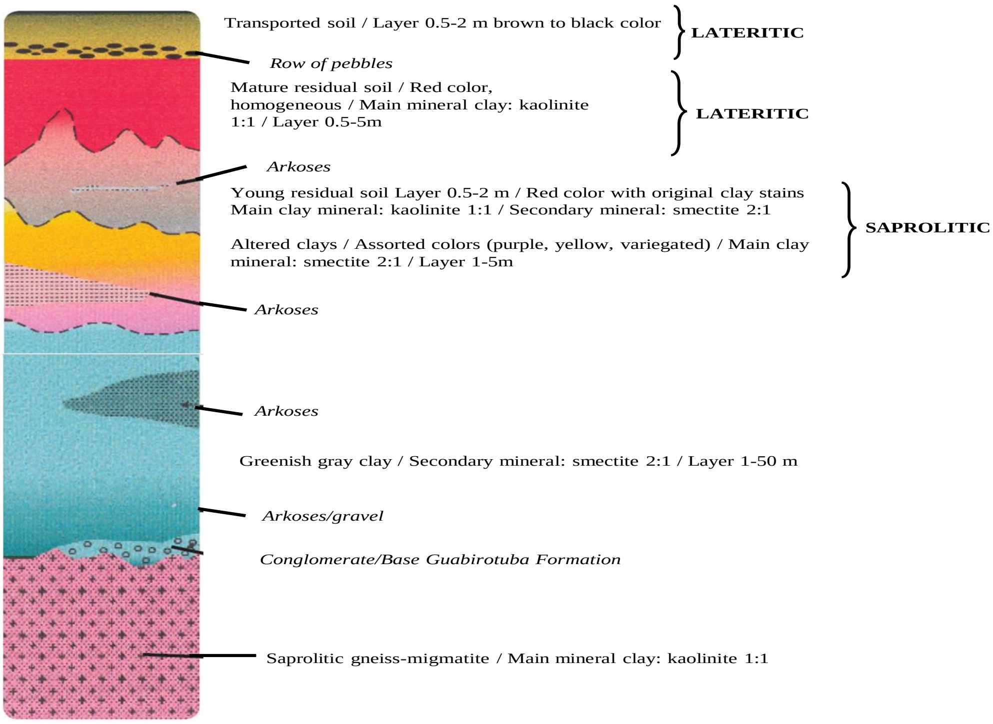

Figure 1. Profile of the Guabirotuba Formation. Source: Felipe (1999).

The natural moisture content of the hard clays of the Guabirotuba Formation is normally high, with an average value of approximately 32% and, consequently, the degree of saturation is high, with an average value close to 94%. This characteristic can be associated with the phenomenon of capillary rise, as well as regional climatic conditions, with annual rainfall in the order of 1200 to 2100 mm. Hard clay can present high levels of matrix suction, which directly interferes in the effective tensions and in the behavior of the soil with regard to erosion. Kormann (2002) presents a program to determine characteristic curves and suction values of samples in natural humidity for the hard clays of the Guabirotuba Formation. For natural humidity ranging from 21.4% to 25.7%, with a degree of saturation from 84% to 98%, it obtained suctions ranging between 1600 and 2500 kPa

The predominance of clay minerals from the smectite group, with a high probability of the presence of montmorillonite, gives these soils their characteristic of expansiveness. This characteristic, associated with constant variations in surface humidity, constitutes the factor that controls and triggers intense erosive processes in these soils, when exposed to the action of surface water. With drying, the soil surface is caked and, when it comes into contact with water again, it disaggregates, initiating an erosive process (Kormann, 2002).

Chamecki (2002) recommends avoiding the exposure of hard clays from the Guabirotuba Formation in slopes, excavations and landfills due to their high erodibility. Its surface must be kept protected by vegetation or other materials to preserve its moisture. Based on the information provided above, this work aims to study the geotechnical characteristics of two soils in the Formation.

MATERIALS AND METHODS

The experimental program was divided into two stages: the first was the carrying out of soil characterization tests: soil granulometry according to the NBR standard (ABNT, 2016), soil Atterberg limits according to the NBR 7180 standards (ABNT, 1984) and NBR 6459-84 (ABNT, 1984), the actual specific mass of soil grains according to standard 6458 (ABNT, 2016); and the second stage consisted of testing the soil compaction properties in the three energies (normal-EN, intermediate-EI and modified-EM) according to the Brazilian standard NBR 7182 (ABNT, 2016).

Two types of soils were used to study their geotechnical characteristics in different locations of the Guabirotuba Formation. Soil 1 (purple soil) was collected in Fazenda Rio Grande/PR, and soil 2 (yellow soil) was collected in São José dos Pinhais/PR. All soils are part of the same Guabirotuba Geological Formation. The water used for the soil characterization tests was distilled according to the specifications of the standards, while being free of impurities and avoiding unwanted reactions.

RESULTS

Soil classification

The two soils were collected manually and in sufficient quantity to carry out all the planned tests. The soils were collected and transported in drums to the Geotechnics Laboratory of the UTFPR Campus Curitiba.

Figure 2 shows the coloraturas of the soils: purple and yellow. Theoretically, according to Figure 1, these coloraturas are between 1 and 5 m for the yellow and purple soil. The yellow soil was collected on a slope at 3 m from the ground level, the purple soil was collected in a construction of popular houses at 2 m. Thus, it can be established that there is a theoretical-experimental correlation between the coloraturas in Figure 1 vs the depth at which the 2 soils were collected. Soil color is determined by the existence and proportion of organic and mineral compounds. The yellowish color is given by the low oxidation of metals as well as the purple soil.

Figure 2. Soil coloraturas.

The results of Atterberg limits, granulometry and actual grain density are presented in Table 1. Note that the purple soil has no coarse sand fraction while the yellow soil has a small fraction of 6%.

Table 1. Physical properties of soils

Property	**Soil 1**	**Soil**
Liquid limit	53.1%	50.4%
Plastic index	21.3%	14.41%
Specific gravity	2.71	2.63
Coarse sand (2.0 mm < ϕ< 4.75 mm)	0%	6.0%
Medium sand (0.42 mm< ϕ <2.0 mm)	7.5%	12.0%
Fine sand (0.075 mm < ϕ < 0.42 mm)	25.9%	15.0%
Silt (0.002 mm < ϕ < 0.075 mm)	57.6%	53.0%
Clay (ϕ < 0.002 mm)	9.0%	14.0%
Mean particle diameter (D_{50})	0.025 mm	0.030 mm
SUCS classification	MH	MH

The largest granulometric range of the two soils corresponds to silt, which is greater than 50%. The real density of the grains is higher in the purple soil (2.71), being the soil heavier. The results of the Atterberg limits indicate that the purple soil has the highest plasticity and the others of the rest have an average plasticity index of 14%. Thus, taking into account the values presented in Table 1 and according to the Unified Soil Classification System (SUCS), the purple and yellow soil can be classified as an elastic sandy silt (MH).

Compaction properties

Figure 3 shows the soil compaction curves 1 in the three compaction energies: normal, intermediate and modified, in addition to the zero air curve (100% saturation). The Figure 4 shows the same compaction properties for yellow soil.

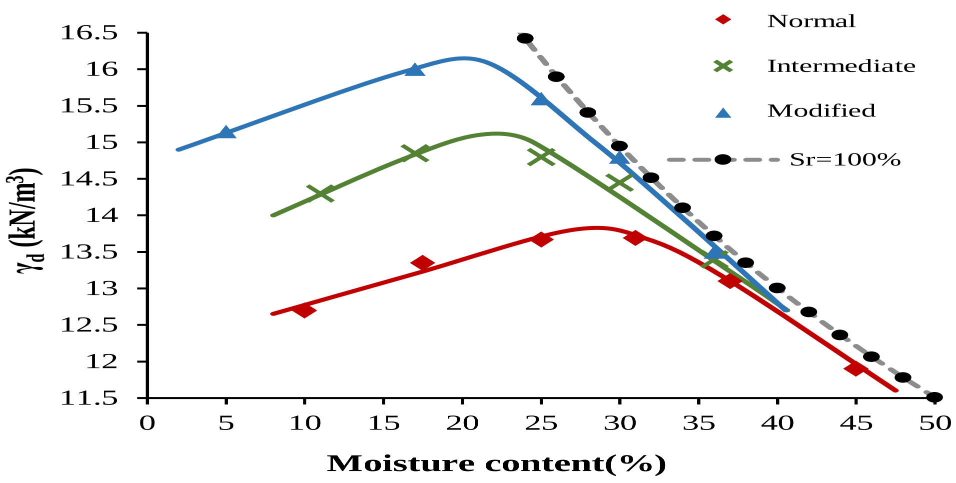

Figure 3. Soil compaction curves – Soil 1 (purple).

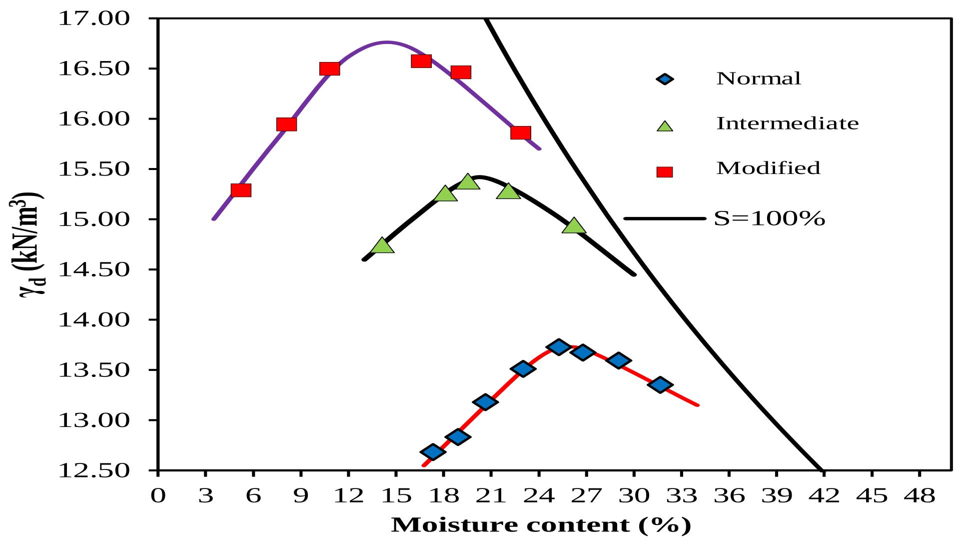

Figure 4. Soil compaction curves – Soil 2 (yellow)

Comparing the compaction properties of the two soils, it can be mentioned that the highest density found is in the yellow soil in the modified energy with γ_{dmax}=16.75 kN/m^3, followed by the purple soil with 16.15 kN/m^3. In normal energy, the highest density found was in the purple soil with 13.80 kN/m^3 and then in the yellow soil with 13.75 kN/m^3. Finally, at the intermediate energy, the order from highest to lowest at maximum density was yellow and purple.

As for the optimal moisture content, it was lower in the yellow soil with 15% (Modified energy). The highest optimal moisture content in normal energy was found in purple soil (28.5%) and the lowest in yellow soil (26.5%).

Although the soils present some differences in their geotechnical characteristics, they also present other very similar ones, such as the granulometry in the silt range, plasticity index and real specific mass of the grains. The similarities are due to the fact that the soils belong to the same geological formation.

CONCLUSION

The work presented the geotechnical characterization of two soils of the Guabirotuba Formation in Curitiba. The three soils were classified as silts according to SUCS. The compaction properties, granulometric distribution and consistency limits show that the soils present similarities in these properties due to their same sedimentary origin. It is recommended to deepen the characterization with X-Ray and XRD fluorescence assays

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