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Study of the Collapsible Potential of the Lateritic Soil of the City of Uberlândia (MG) – Brazil – Using Physical Characterization and Oedometer Tests

Étude du potentiel pliable du sol latéritique de la ville d'Uberlândia (MG) – Brésil – Utilisation de la caractérisation physique et des tests oedométriques

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ABSTRACT: This paper presents the collapsible potential of lateritic soil in Uberlândia (MG) – Brazil - from physical characterization and simple oedometer tests. For that, it was analysed a typical soil sample of the area, in this case, the east of the city, characterized as silty clay (ML unified classification). It was collected undisturbed and disturbed soil samples, for depths up to 3 meters. Physical characterization tests (grain size, grain density and Atterberg limits) and bulk density test were carried out. Simple oedometer tests were also conducted with flooding to a stress of 200 kPa. According to the qualitative criteria, the soil has a collapsible potential for all depths analyzed. The results also showed that the collapsible potential reduces with depth. The results of simple oedometer confirm the soil collapse when flooded and / or loaded.

RÉSUMÉ : Cet article présente le potentiel pliant du sol latéritique à Uberlândia (MG) - Brésil - à partir de la caractérisation physique et des tests oedométriques simples. Pour cela, il a été analysé un échantillon de sol typique de la zone, dans ce cas, l'est de la ville, caractérisée comme argile limoneuse (ML classification unifiée). On a recueilli des échantillons de sol non perturbés et perturbés, pour des profondeurs allant jusqu'à 3 mètres. Des essais de caractérisation physique (granulométrie, densité des grains et limites d'Atterberg) et des essais de densité apparente ont été effectués. Des essais oedométriques simples ont également été réalisés avec des inondations jusqu'à un stress de 200 kPa. Selon les critères qualitatifs, le sol présente un potentiel pliable pour toutes les profondeurs analysées. Les résultats ont également montré que le potentiel pliable diminue avec la profondeur. Les résultats de l'oedomètre simple confirment l'effondrement du sol lorsqu'il est inondé et / ou chargé.

KEYWORDS: Physical Characterization, Oedometer Tests, Collapsible Potential, Soil Lateritic.

1 INTRODUCTION

Some unsaturated soils are characterized by an abrupt variation in void ratio when subjected to an increase in degree of saturation and under constant vertical stresses, as a result of a collapse of the soil structure.

According to Lollo et al. (2010), the collapse of the soils can be understood as a deformation due to structural changes of the soil before variations in the stress state, electromagnetic equilibrium and attacks to the cement bonds.

The structure of these soils is maintained by the presence of a bond between the particles that causes an apparent increase of resistance. The insertion of some agent, usually water, reduces the action of these bonds and then provokes the displacement of the soil grains to the voids, causing the collapse (Vilar, 1979).

The main characteristic of collapsible soils is having a porous structure, where water infiltrates more easily, inducing to its instability. However, these soils can be developed in several geological conditions, presenting a diversity of fabrics.

The collapsibility is a geotechnical conditioning of great importance to studies in Geotechnical Engineering in order to prevent damages to constructions and financial losses.

Thus, the collapsible potential analysis of the soil is a very important factor to be verified and can be done by qualitative and quantitative methods. In qualitative analysis, physical characterization tests are performed for a preliminary knowledge of the collapsible potential of a soil. The second analysis is carried out by simple oedometer tests with flooding to a certain applied stress or by double oedometer tests.

Despite the methods used in qualitative analysis be considered as inconclusive, once they were developed for regional specific conditions, their results are useful for a preliminary analysis for the collapse study.

However, the verification and quantification of collapse are observed through oedometer tests.

This paper presents the characterization study of the soil from the east zone of Uberlândia as to collapsibility degree, by means of qualitative and quantitative criteria. For the qualitative criteria, tests of physical characterization and natural density of soil will be carried out. On the other hand, for quantitative criteria simple oedometer tests with specimen flooding will be performed. It is also object of this paper the comparison of these criteria for analysis of the collapsible potential of the soil of the region.

2 COLLAPSIBILITY DEGREE

The characterization of the collapsible behaviour can be done by means of laboratory and field tests. The criteria based on laboratory tests can still be divided in criteria based on characterization tests and criteria based on resistance tests (LOLLO ET AL., 2012).

In criteria based on characterization laboratory tests, the recognition of the collapsible behaviour is based on index properties, consistency limits, natural density and porosity of the soil. These consist of qualitative criteria.

On the other hand, the laboratory tests of resistance are based on compressibility tests (oedometer tests) and triaxial compression, consisting of quantitative criteria.

The laboratory tests are a very interesting alternative, since they provide an expeditious classification of collapsible materials, when characterization tests are used, and a reliable potential of behaviour prediction, when oedometer tests are used, both of them associated with low cost.

2.1 Oedometer Tests

The procedure of the conventional oedometer test consist of applying a load on the specimen and measure the displacements descendant from this load during a period of 24 hours. After this time, the load is doubled and the displacements on the specimen are measured again. The result of the test is presented on a semi logarithmic graph where the x-axis, in logarithmic scale, is the applied stresses and the y-axis is the volumetric variations, represented by the final void ratios at each loading stage.

In order to use the oedometer test for collapse quantification, the axial deformations caused by the flooding of the specimens under certain stress state are verified. This can be performed in two different ways: simple oedometer test (with flooding after the stress of interest) and double oedometer test (with samples of soil in natural condition and samples of saturated soil).

According to Cintra (1998), the collapse causes a discontinuity in the stress versus void ratio curve, as illustrated at Figure 1.

In the case of simple oedometer tests, the specimen with natural humidity is loaded to a stress of interest and then flushed with water (flooded). With the sample flooding, the confined compression curve (stress versus void ratio curve) can present a discontinuity due to the collapse.

In this case, it is habitual to use the proposal of Vargas (1978), in which the soil is considered collapsible when it presents a coefficient of collapsible (i) greater than 2%. This coefficient is calculated according to the Equation 1.

$$i = \frac{\Delta e}{1 + e_o} \cdot 100 \quad (1)$$

Where:

Δe - void ratio variation due to flooding

e_o - initial void ratio

2.2 Physical characterization and density tests: criteria of prediction

The prediction of the collapse in soil can be done with qualitative criteria based on physical characterization and density tests. The prediction methods used in this paper are described next.

2.2.1 Criterion of Gibbs & Bara (1962)

This criterion uses index properties and consistence limits for analysis of the potential of collapse of a soil, as expressed in Equation 2. According to these authors, if the degree of collapsibility (k_L) is less than 1 (one), there is collapse of the structure.

$$k_L = \frac{LL}{\left(\frac{\gamma_w}{\gamma_d} - \frac{1}{\gamma_s} \right)} \quad (2)$$

Where:

k_L → degree of collapsibility

LL → liquid limit

γ_w → unit weight of water

γ_d → dry unit weight of the soil

γ_s → unit weight of solids

2.2.2 Criterion of Feda (1964)

Feda (1964) determines that the soil porosity (n) must be greater than 40% to be susceptible to collapse.

2.2.3 Criterion of Feda (1966)

According to Feda (1966), the potential of collapse of a soil can be evaluated using the physical characterization and the consistency limits, as expressed in Equation 3.

$$k_L = \frac{w - IP}{S} \quad (3)$$

Onde:

k_L → degree of collapsibility

w → natural water content

S → natural saturation degree of the soil

IP → plasticity index

If the saturation degree is less than 60% and the collapse index is greater than 0.85, it means that the soil is susceptible to collapse.

2.2.4 Criterion of Clevenger (1985)

The criterion of Clevenger (1985) of collapse estimate is based on the dry density of soil. If it is less than 1.280 g/cm³, the soil will collapse after any change in water content. If the dry density is greater than 1.440 g/cm³, the soil will present small vertical displacements. For intermediary values, the displacements will be substantial.

3 METODOLOGY

The description of the materials and procedures used in this work execution will be presented in the next sections.

3.1 Sampling procedures

The samples were collected from the Glória Campus of Federal University of Uberlândia, which is located at the east side of the city. The collect spots were chosen according to geological maps of the area. Moreover, these are regions with collapse potential due to the laterization (tropical weathering) process of the soil and also a great potential of urban sprawl.

For the development of this collapse study, disturbed and undisturbed samples (ABNT NBR 9604/86) were obtained at a depth up to 3 meters.

The gathering of the samples were executed with undisturbed soil blocks cutting, properly waterproofed, and disturbed soil collection, at depths of 1m, 2m and 3 meters.

3.2 Characterization of the samples

The particle-size distribution test were performed according to the Brazilian standard ABNT NBR 7181: 1984 requirements.

The consistency limits allow the evaluation of the plastic properties of the soil and the prediction of the soil mineralogy. The tests for their determination were carried out in accordance with the Brazilian standards NBR 6459: 1984 and NBR 7180: 1984.

The particle-size distribution curves of the analysed samples. The results show the predominance of fine soils at the sample,

classified as silty clay according to its texture and as silt of low plasticity (ML), for the Unified Classification (SUCS).

For using the criteria of collapse prediction, the samples were also characterized regarding their structure, so tests of water content and natural density of the undisturbed soil samples were performed. From these tests and using physical characterization correlations, the other parameters, as dry density, void ratio, porosity and degree of saturation, were determined. These parameters reflect the structures of the in situ soil.

Table 2 presents the in situ conditions of the soil, which were determined for each depth studied. The points P1, P2 and P3 are referred to the depths of 1m, 2m, and 3m, respectively.

Table 2- Natural conditions of the soil (Author, 2014).

	P1	P2	P3
w average (%)	25,43	31,97	41,14
ρ_d (g/cm ³)	0,960	1,187	1,124
ρ_s (g/cm ³)	3,814	3,814	3,814
e	2,97	2,213	1,68
n %	75	69	63
Sr %	33	44	46
ρ natural (g/cm ³)	1,204	1,489	1,410

The works of identification and quantification of the collapsible potential of the studied soil were made by means of oedometer tests.

The oedometer test performed was of the simple type with flooding to a stress of 200 kPa. The used samples were cut in cylindrical specimens of diameter of 7.98mm and 3.2cm of height. For each depth analysed there were made duplicated tests.

4 PRESENTATION AND ANALYSIS OF THE RESULTS

The results of the collapse prediction, by means of physical characterization tests, and the results of the collapse quantification, using oedometer tests, are presented and discussed in the next sections.

4.1 Collapse evaluation using physical characterization test s: prediction criteria

With the natural conditions of the soil presented in Table 2, it was possible to have a preliminary knowledge of the behaviour of this soil for posterior comparison with the oedometer test results. The physical characterization results indicate soils of high void ratio, high porosity ($n > 40\%$) and unsaturated soils ($S < 60\%$), suggesting a behaviour typical of lateritic soils and a high collapse potential.

The Figures 4, 5, 6 e 7 illustrate the collapsible potential of the soil sample depending on the depth, according to the main criteria mentioned in this paper.

The results show that the presented criteria indicate the collapsible behaviour of the region soil for all the analysed depths. The criterion of Feda (1964), for instance, is based on the soil porosity. The tests results show that the region soil have around 70% of porosity, beyond the reference value, indicating a high potential of collapse.

Analysing the Feda (1996) criterion, it is also verified a potential of collapse of this soil, which, in this case, is due to the low plasticity values of the analysed sample. It is verified that the soil has a fraction of sand and silt, responsible for the characteristics of plasticity found and for the collapsible potential.

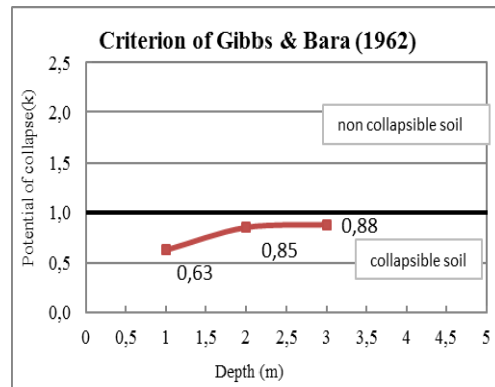


Figure 4-Analysis for the criterion of Gibbs & Bara (1962) (Author, 2014).

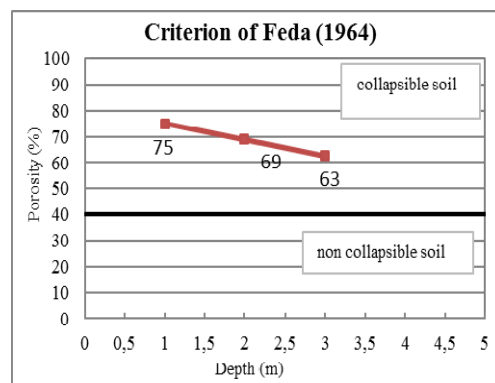


Figure 5- Analysis for the criterion of Feda (1964) (Author, 2014)

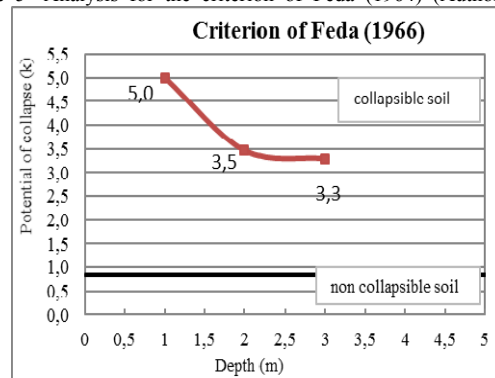


Figure 6-Analysis for the criterion of Feda (1966) (Author, 2014).

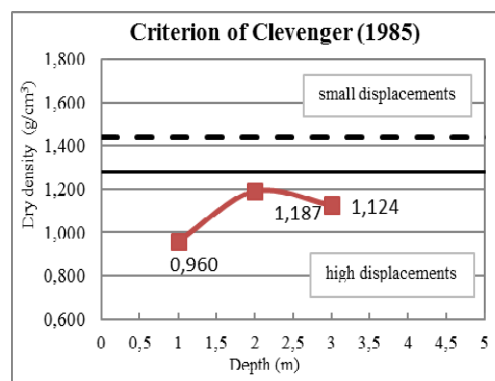


Figure 7-Depth analysis: criterion of Clevenger (1985) (Author, 2014).

Regarding the density of the in situ soil, low values of natural and dry density are verified, leading to an elevated potential of collapse according to the criterion of Clevenger (1985).

The analysis of the results also allowed to verify the influence of depth on the soils collapse. In accordance with what was expected, it was observed that the greatest collapsible potential occurs at the depth of 1 (one) meter. With the increase of depth, the potential of collapse decreased, although all the analysed depths had presented the potential.

It was possible to observe that the water content and the saturation degree raise as the depth increases. On the other hand, the void ratio and the porosity decrease with the depth due to the consolidation effect caused by the load of the overlying soil layer. Such aspects justify the decrease of the collapsible potential with the depth increase.

4.2 Evaluation of collapse using oedometer tests

The Figures 8 and 9 present the curves of void ratio variation (e) with respect to the logarithm of the effective stresses (σ') for the depths of 1,0m, 2,0m and 3,0m, respectively.

The tests results showed that the soil is collapsible when flooded and/or when loaded. For the depth of 1 meter, the average coefficient of collapsible (i) was 9,7%, which is greater than the value proposed by Vargas (1978) for the soil be considered collapsible.

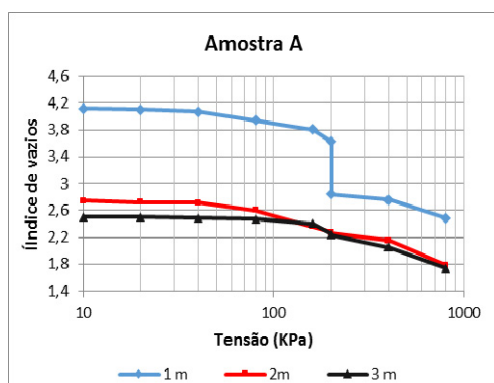


Figure 8- Consolidation curve of amostra A (Author, 2014).

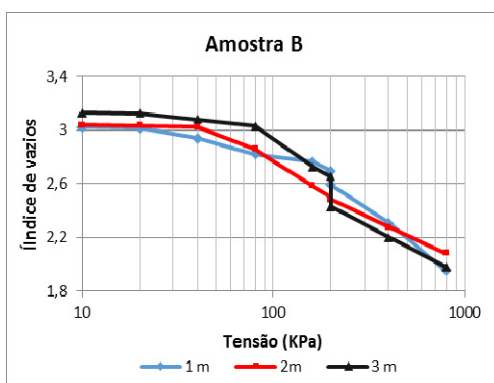


Figure 9- Consolidation curve of amostra B (Author, 2014).

In relation to the samples from 2 meters of depth, it was verified that the collapse occurred due to the load, not the flooding. It was also observed that the final deformations for this sample were of about 25%, same magnitude noticed in the case of collapse due to flooding at the depth of 1 meter. For the sample from a depth of 3 meters, it was observed collapse by both ways, flooding and loading.

The results also show that the collapse occurs up to the depth of 3 (three) meters, limit studied in this research.

Therefore, it can be concluded that the lateritic soil of the east region of Uberlândia presents collapse by loading and flooding for the stress considered in this study.

5 CONCLUSIONS

With this study, it was possible to see the collapsibility of the lateritic soil of east region of Uberlândia, by means of physical characterization tests and oedometer tests on undisturbed samples collected at different depths.

The characterization of the samples indicates a silt of low plasticity, with high porosity and void ratio and low saturation degree.

The results demonstrate that the soil of the region presents a collapsible potential for all depths analysed according to the prediction criteria found in the literature. It was also verified that the potential of collapse decreases with the depth.

Regarding the oedometer tests, it was also observed that the soil is collapsible for all depths studied. Moreover, it was verified that the collapse occurs for both flooding and loading.

Such results indicate that the criteria used here confirm the collapsible potential of the soil of the region. This way, this study enhances the necessity of proper studies and treatment for the urban planning, in special for designing and execution of civil works such as foundations and water and sewage systems.

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