Revista
GEOCIÊNCIAS

unesp

ISSN: 1980-900X (online)

GEOTECHNICAL CHARACTERIZATION AND GEOREFERENCING OF SOME SOFT SOIL DEPOSITS OF THE METROPOLITAN REGION OF ARACAJU

CARACTERIZAÇÃO GEOTÉCNICA E GEORREFERENCIAMENTO DE ALGUNS DEPÓSITOS DE SOLOS MOLES DA REGIÃO METROPOLITANA DE ARACAJU

Letícia Menezes Santos SÁ, Erinaldo Hilário CAVALCANTE, Guilherme Bravo de Oliveira ALMEIDA

Universidade Federal de Sergipe. Cidade Universitária Prof. José Aloisio de Campos. Avenida Marechal Rondon, S/N, Jardim Rosa Elze, São Cristóvão – SE. E-mails: leticiamenezes0512@gmail.com; erinaldohc@gmail.com; gbravo1982@gmail.com

RESUMO - Investigações geotécnicas preliminares e complementares permitem obter informações importantes sobre as camadas que compõem o subsolo. Porém, na prática diária, essa etapa é normalmente negligenciada. Esse problema se torna mais grave quando há no subsolo camadas de solo mole, devido às particularidades desse tipo de solo. A Região Metropolitana de Aracaju (RMA) possui poucos dados registrados acerca dos seus depósitos de solo mole, o que dificulta o dimensionamento geotécnico. Por isso, esse estudo tem por objetivo realizar a caracterização geotécnica de alguns depósitos de solo mole da RMA e georreferenciá-los usando um Sistema de Informação Geográfica (SIG). Os resultados obtidos mostraram que os solos analisados possuem um comportamento medianamente plástico a muito plástico (IP entre 8.00 e 33.00). Valores de teor de umidade natural foram consideravelmente mais baixos que aqueles obtidos em outros estados brasileiros (entre 29% e 84%), possivelmente devido à influência das lentes de areia. Quanto à atividade, as argilas da RMA são predominantemente inativas. Além disso, a análise de qualidade das amostras deixou clara a dificuldade de coletar amostras de solo indeformadas nesses depósitos. Pesquisas futuras devem ser realizadas para aumentar o banco de dados sobre os solos moles da RMA.
Palavras-chave: Solos moles. Investigações geotécnicas. Ensaios de campo. Ensaios de laboratório. Amostras indeformadas.

ABSTRACT - Preliminary and complementary geotechnical investigations allow to obtain important information about the subsoil layers. However, in daily practice, this step is usually neglected. This problem becomes harder when there are layers of soft soils in the subsoil, due to the particularities of this kind of soil. Metropolitan Region of Aracaju (MRA) have few recorded data about their soft soil deposits, which difficult geotechnical design. Hence, this study aims to perform the geotechnical characterization of some soft soil deposits existent in the MRA and georeferencing these deposits, using a Geographic Information System (GIS). The results obtained show that the studied deposits have a medium plastic to very plastic behavior (PI ranging from 8.00 to 33.00). Values of natural moisture content were considerably lower than those obtained in other Brazilian states (between 29% and 84%), possibly due to the influence of the sand lenses. As for the activity, the MRA clays are predominantly inactive. Furthermore, the analysis of the quality of samples made it clear that is difficulty to collect undisturbed soil samples in these deposits. Future research should be carried out to increase the database about the soft soils of the RMA.
Keywords: Soft soils. Geotechnical investigations. In situ tests. Laboratory tests. Undisturbed samples.

INTRODUCTION

Soft soils are sedimentary soils that have low penetration resistance and predominance of silty and clayey particles. These particles give the soil cohesion and compressibility properties. Along the entire Brazilian coast, it is possible to find soft soil layers. In some places, these layers have small thickness and are intercalated or underlain by bigger sandy layers. In others, thicker deposits of soft soil are found (Costa Filho et al., 1985; Massad, 2010).

The Baixada Santista and the Metropolitan Regions of Rio de Janeiro, Porto Alegre and Recife have important deposits of soft clays that have been studied by many authors throughout the past few years (Costa Filho et al., 1985; Coutinho 1986, 1988a; Coutinho & Ferreira, 1988; Coutinho et al., 1993; Coutinho & Lacerda, 1994; Dias et al., 1993; Massad, 1985). These deposits have as main features high compressibility, low penetration resistance and high organic matter content. Therefore, it is crucial to perform preliminary and complementary geotechnical investigations that make it possible to identify and to characterize the soft soil layers (Costa Filho et al., 1985).

However, it is not rare to find cases in which the geotechnical investigations were despised or insufficient. Consequently, projects are elaborated without a rational analysis, which results in problems. Trying to avoid these kinds of problems, some authors have studied the deposits of compressible soils in Brazil (Costa Filho et al., 1985; Massad, 1985; Ribeiro, 1992; Coutinho et al., 1993; Hallal, 2003; Futai et al., 2004; Almeida et al., 2008; Andrade, 2009; Coutinho & Bello, 2014; Baroni, 2016; Cadete, 2016; Póvoa, 2016) and around the world (Bjerrum, 1973; Hanzawa, 1979; Ohtsubo et al., 1982; Graham et al., 1983; Touiti et al., 2009; Hore et al., 2018; Touiti &Impe, 2018).

Nowadays, there are few records about the location and geotechnical features of the soft soils deposits from the Metropolitan Region of Aracaju (MRA). The most important record was from the early 90’s, by Ribeiro (1992). From then on, about thirty years later, almost nothing has been published about the subject.

Thus, it is fundamental to recover these data and to register new occurrences of areas that have deposits of soft soil in the MRA. This kind of information is crucial to guide geotechnical engineers and researchers in future projects and/or studies. Therefore, the present research has as its main purpose to perform the geotechnical characterization of some soft soil deposits existent in the Metropolitan Region of Aracaju and the georeferencing of these deposits, using a Geographic Information System (GIS).

AREA OF STUDY, MATERIALS AND METHODS

Area of Study

The area of study comprises the Metropolitan Region of Aracaju, located in the state of Sergipe, covering the municipalities of Aracaju, Barra dos Coqueiros, Nossa Senhora do Socorro and São Cristóvão.

Information about the studied soft soil deposits of these areas arises from three main sources: site and laboratory investigations previously performed by regional companies to elaborate projects; geotechnical research about compressible soils deposits from this region and site and laboratory tests performed during this research, with samples collected by local companies.

Eight different natural clay deposits were studied in Aracaju, Barra dos Coqueiros and Nossa Senhora do Socorro. Figure 1 shows the distribution of the studied deposits in the MRA. Each deposit was identified with a letter, to facilitate their presentation on the maps created using the software QGIS 2.18.7. These maps were extracted from the Digital Atlas about Water Resources of Sergipe (Sergipe, 2016) and adapted according to the research necessities.

Materials

In general, the soil samples collected from the deposits of the MRA were composed by dark gray organic clays, proper of marine environments and with peculiar odor. In some samples, it was possible to identify sand lenses intercalated to the clay sediments: a typical behavior of materials found in the coast of Sergipe.

Methods

This research was developed according to the following sequence:

a) Laboratory tests were conducted with the undisturbed samples of soft soil collected in the sites A and B, and some field tests were also performed.

b) Information present in technical reports and drilling bulletins, referring to the sites C, D, E and F, was organized and parameters that are not in these reports were calculated.

c) The results previously found by Ribeiro (1992) and Santana Júnior (2017) were incorporated to the present work (sites G and H).

d) Details about identification of each place and tests results were saved in a database and maps were created using QGIS 2.18.7.

Laboratory tests were performed in the Laboratory of Geotechnics and Paving (GEOPAV), at the Federal University of Sergipe (UFS).

In addition, Standard Penetration Tests (SPT) were conducted by a specialized local company in all studied sites and the inspection Vane shear tests were performed by the authors of this paper, in Site A.

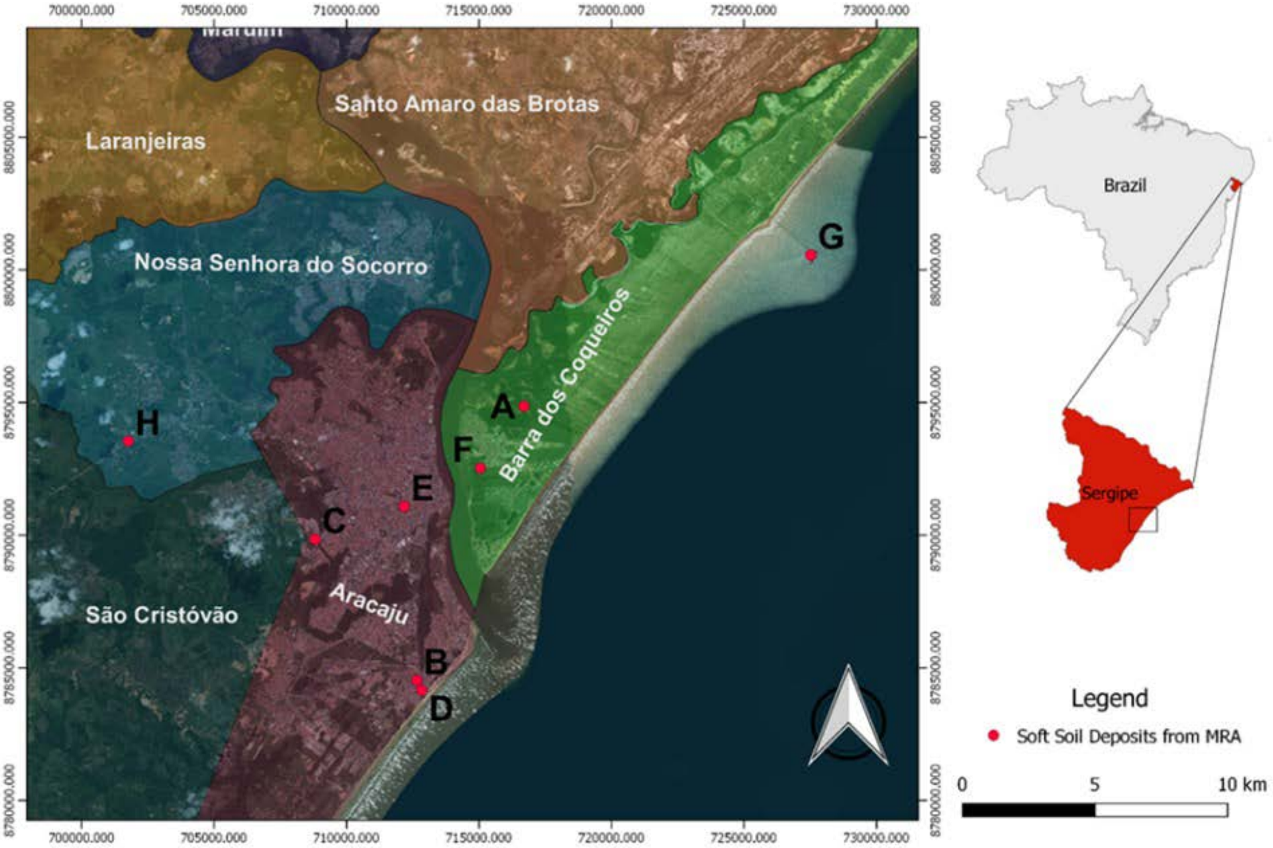

Figure 1 - Soft soil deposits studied in this research.

Sampling

Three undisturbed samples of compressible soil were collected during the development of this research. Two of them correspond to the place A and the other, to the place B. For the other places, samples were collected in the past by local companies. All these collections followed the procedure established by NBR 9820 (ABNT, 1997) and used sampler Shelby.

Tests

Field and laboratory tests were performed to obtain geotechnical parameters for the studied deposits. Geotechnical characterization was accomplished for sites A, C, D, E, F, G e H and involved five different tests, performed in the majority of the sites: granulometric analysis, determination of moisture content, specific gravity and Atterberg limits (WL and WP). Consolidation parameters were obtained by conventional consolidation tests, for all sites studied, and consolidation with controlled strain rate tests, only for site G (Ribeiro, 1992).

Results of UU (for deposits A, B and G) and CIU (only for deposit G) triaxial compression tests and special triaxial compression tests (with isotropic consolidation and sheared under undrained conditions, only performed for site G) were registered in the database. About field tests, inspection Vane shear tests (site A) and conventional Vane shear tests (site G) were performed. Results of SPT tests for all sites are also available.

Analyzing the accomplished tests, a trend of local companies can be identified: they did not give great attention to the tests that allow obtaining parameters of soil strength and strain.

Georeferencing Database

A database was created, with the geotechnical information about the studied deposits. Furthermore, the georeferencing of these deposits was made using QGIS 2.18.7. The Geographical Coordinate System and the Datum SIRGAS 2000 (the official geodesic system of Brazil) were adopted (IBGE, 2005). Maps from the Digital Atlas about Sergipe Water Resources (Sergipe, 2016) were accessed using QGIS 2.18.7 and the georeferenced deposits were placed into these maps. Five maps were created, referring to satellite images, geology, geomorphology and pedology of the eight sites.

RESULTS AND DISCUSSIONS

Georeferencing of the studied places using QGIS 2.18.7

Firstly, it was created a map with the location of each point in a satellite image overlapped to the map of Sergipe (Figure 1). It is important to notice that site G is an offshore deposit. Because of it, there is no available information about this place on the maps that will be presented bellow. After, it was created a second map, containing information about the geology of the deposits (Figure 2). Geological Brazilian Service – CPRM (Mineral Resources Research Company) provides the information about the geology of Sergipe, accessed using QGIS 2.18.7.

Sites A, B, D, E and F can be classified as Coastal Deposits. They belong to the geological class of Unconsolidated Sediments, formed in the Quaternary Period, in the Holocene Age. These deposits are eolian, composed by well selected sands. On the other hand, site C belongs to the Fluvial-Lagoon Deposits, of the geological class Sedimentary, formed also in the Quaternary Period. These deposits are composed of sand and clayey-silts, rich in organic matter. Finally, site H belongs to the Calumbi Formation. This formation is composed by argillites and shales, shading from gray to greenish, and it was formed in the Cretaceous Period, in the Superior Age (CPRM, 1993).

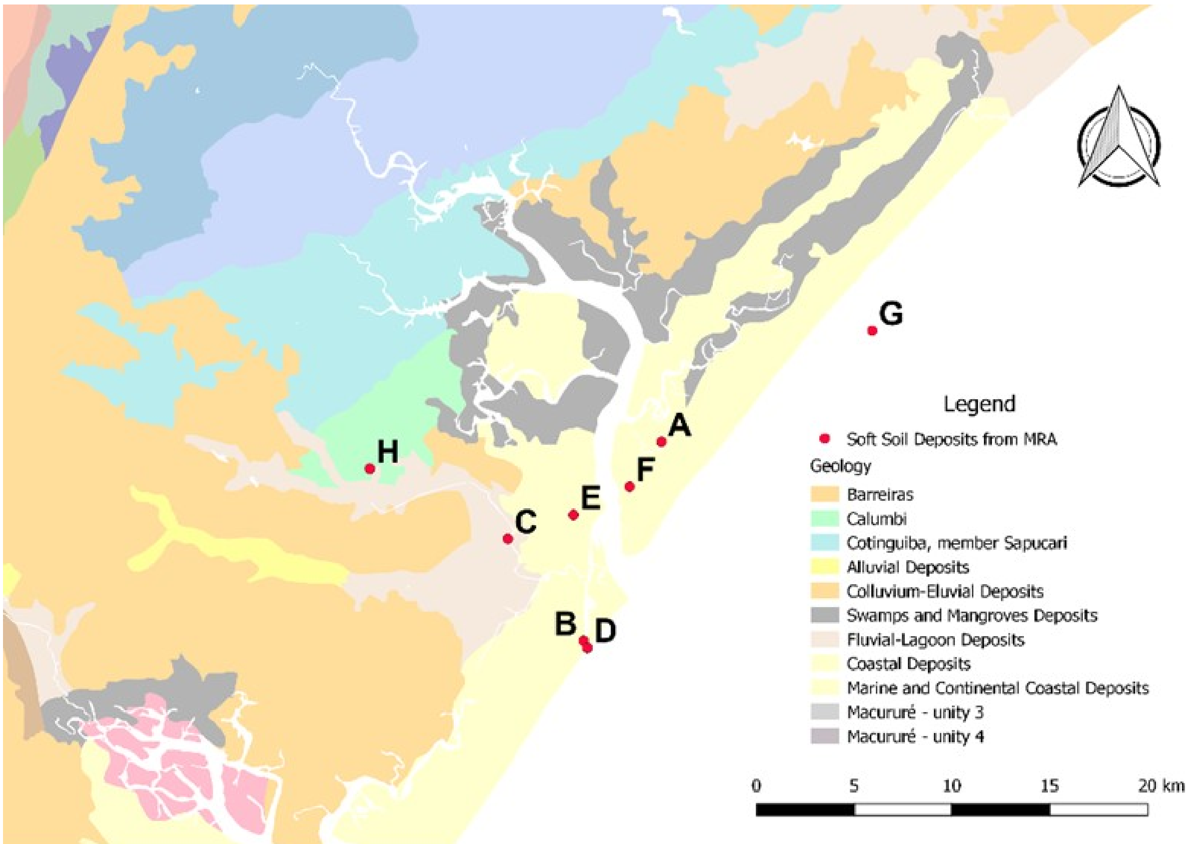

Figure 2 - Geology of the studied soft soils deposits of MRA.

In sequence, a third map was created, referring to the geomorphology of the studied deposits (Figure 3). This information was supplied by JICA (Japan International Corporation Agency), in the year of 2000. Sites A, E and F belong to the class of Coastal Plains and to the subclass of Marine Terraces. Sites B, C and D are also fit in the class of Coastal Plains, but in the subclass of Fluvio-Marine Plains and site H belongs to the class of River Surfaces, and to the subclass of Dissected Plateaus in Hills and Tabular Interfluves.

At long last, the map showed in figure 4 refers to the pedology of Sergipe. This information was supplied by EMBRAPA & SUDENE (1975) and was accessed using QGIS 2.18.7. Soils of the sites B, D, E and F were classified as Espodosoils. Site A, in its turn, is an area of Gleisoils. Meanwhile, point C belongs to an area of Vertisoils and site H, Clayey Soils.

In addition, QGIS 2.18.7 allows to associate with each point a set of information. Then, there were recorded mean values of WL, WP, PI, and Specific Gravity of the studied deposits, when available.

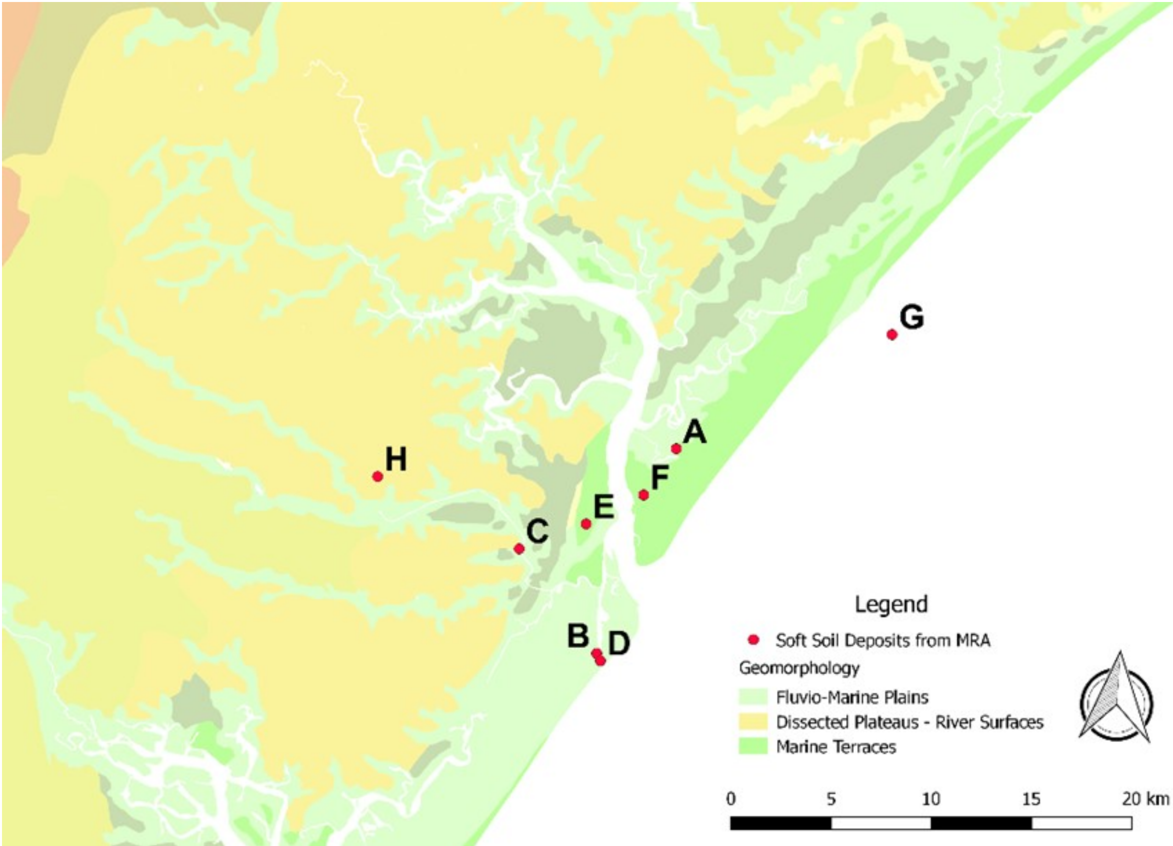

Figure 3 - Geomorphology of the studied soft soils deposits of MRA.

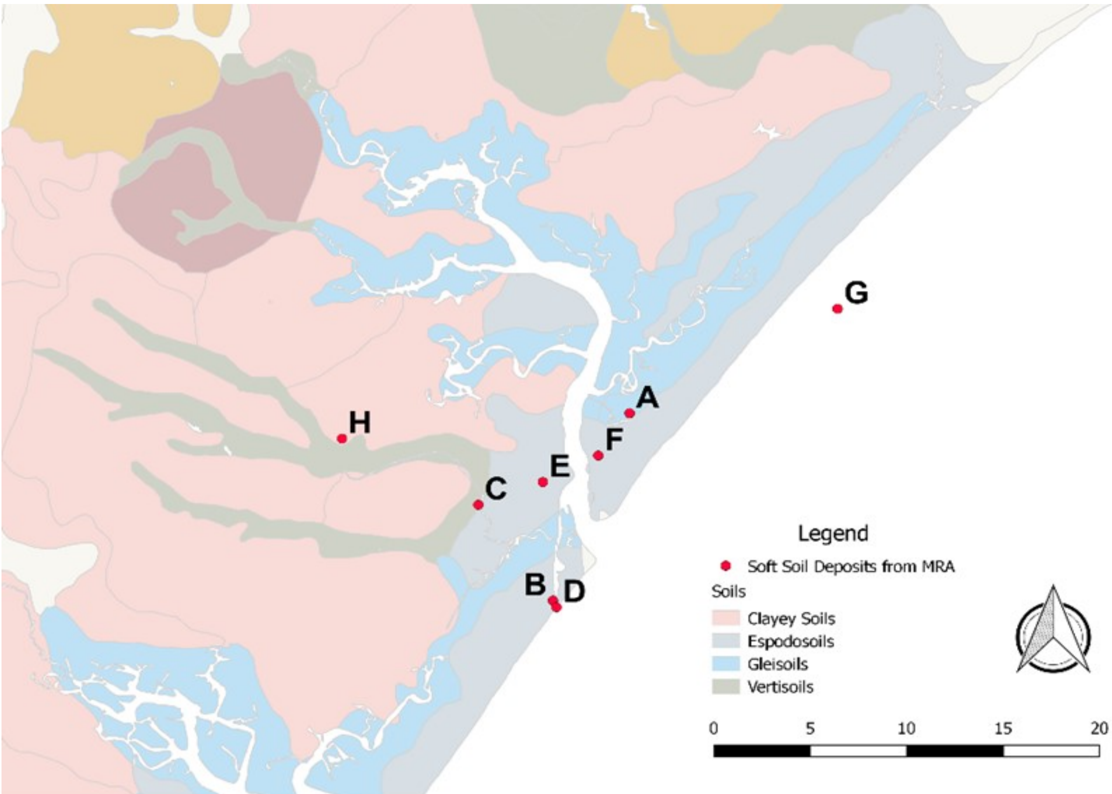

Figure 4 - Pedology of the studied soft soils deposits of MRA.

Site A: Sítio Pomonga

Sítio Pomonga is in Barra dos Coqueiros municipality, near the coast and Sergipe River. In this place, two undisturbed samples were collected: SP 01-B (1.00 m deep) and E-45 (1.50 m deep). SPT tests reveals layers of organic clay, with consistence varying from soft to very soft, of dark gray color, overlain or interlayed with sandy layers. The penetration strength obtained was very low, as expected for soft soils, between

0 and 5. Similar values were found in another researches (Ribeiro, 1992; Hallal, 2003; Lemos & Pires, 2017; Hore et al., 2018).

Geotechnical characterization tests showed differences between the two samples. SP 01-B has a sandy percentage higher than silt and clay percentages added. On the other hand, E-45 is predominantly composed of silt and clay. These differences can be justified by the shallow depth of the SP 01-B and by a sandy landfill that had been placed in that site to improve traffic circulation on the road, which may have contaminated this sample. Table 1 shows some geotechnical parameters obtained for each sample.

Table 1 - Geotechnical characterization results for site A.

Samples	δ (g/cm³)	w_0 (%)	WL (%)	WP (%)	PI (%)	AI
SP 01-B	2.56	29.41	27.41	18.81	9.00	0.44
E-45	2.61	28.65	43.45	25.19	19.00	0.63

δ: Specific Gravity; **w_0:** Natural Moisture Content; **WL:** liquidity limit; **WP:** plasticity limit; **PI:** Plasticity Index; **AI:** Activity Index.

Based on reference values suggested by Jenkins (Caputo & Caputo, 2016), soil of the sample SP 01-B can be classified as moderately plastic and soil of the sample E-45, as very plastic. Comparing these plasticity indexes with the results found by Ribeiro (1992), clays studied in this research have a lower PI.

The natural moisture content values are also low, probably because of the presence of sand lenses, that facilitate water drainage. Despite of it, in the sample SP 01-B, the values of water content are higher than the liquidity limit. Regarding the activity index, soils of both samples can be identified as inactive, based on the classification of Skempton (1984).

Conventional consolidation tests were performed too. By these tests, it was not possible to estimate the σ'_a because of the disturbance of the samples.

Thus, the values of OCR for this place were not found. On the other hand, C_c and C_r were determined, as shown in table 2.

Finally, three different tests were used to obtain the Undrained Shear Strength (S_u) for this site: unconfined compression test, UU triaxial compression test and Vane shear test. A comparison between the results of these tests can be seen in table 3.

Table 2 - Values of Cc and Cr obtained by consolidation tests.

Sample	C_c	C_r
CP-111	0.260	0.035
CP-113	0.234	0.019

Cc: Compression Index; **Cr:** Recompression index.

Comparing the results for site E-45 using different tests (Table 3), it can be noticed that the sampling process may have reduced the soil resistance. Field values were higher than laboratory results. For easy comparison, the results of Vane shear tests displayed in this table correspond to the depth of sample collection. It was not possible to perform UU triaxial compression tests for the sample extracted from SP 01-B because there was not enough material available. In the same way, as the water content for this sample was higher than the liquidity limit, unconfined compression tests would not present reasonable values.

Table 3 - Comparison between the values of Su obtained through different methods.

Site (average values)	Unconfined Compression Test (UCT)	UU Triaxial (UUT)	Vane Shear Test (VST)	UCT/VST	UUT/VST
E-45	5.10 kPa	10.00 kPa	18.5 kPa (1.50 m)	0.27	0.54
SP 01-B	-	-	12.00 kPa (1.00 m)	-	-

UU: Unconsolidated Undrained.

The ratio between results of UU triaxial compression tests and Vane shear tests for the site E-45 allows to infer that the sampling process reduced the soil resistance by almost half. The reduction was even more drastic with the unconfined compression tests: has been found a reduction of almost 80% of the S_u value. The disturbance of the collected samples possibly interfered in the results, causing these significant reductions.

Site B: Condominium 1

Site B is a residential condominium, in Atalaia neighborhood. One undisturbed sample was collected in this site, between the depths of 14.50 and 15.50 m. SPT results revealed a layer of organic clay, at great depths, with consistence varying from soft to very soft, interspersed with sand lenses. During the sample collection, it was necessary to interrupt the process due to the presence of a sandy layer, to avoid soil disturbance. Thereat, the sample obtained was smaller than the usual.

Since the collected sample was small, there was not enough material to perform the ge-technical characterization tests. However, conventional consolidation tests were conducted, and the values of C_c, C_r and w_0 were obtained, as table 4 shows. Due to soil disturbance, it was not possible to estimate σ'_a, thus the values of OCR for this place were not found.

Table 4 - Values of w_0, C_c and C_r obtained through consolidation tests.

Sample	w_0 (%)	C_c	C_r
CP-113	40.95	0.260	0.035
CP-114	43.46	0.234	0.019

w_0: Natural Moisture Content;
Cc: Compression Index; **Cr:** Recompression index.

Undrained shear strength was determined by UU triaxial compression tests, due to the small size of the available sample. The failure line obtained based on UU triaxial compression tests can be seen in figure 5.

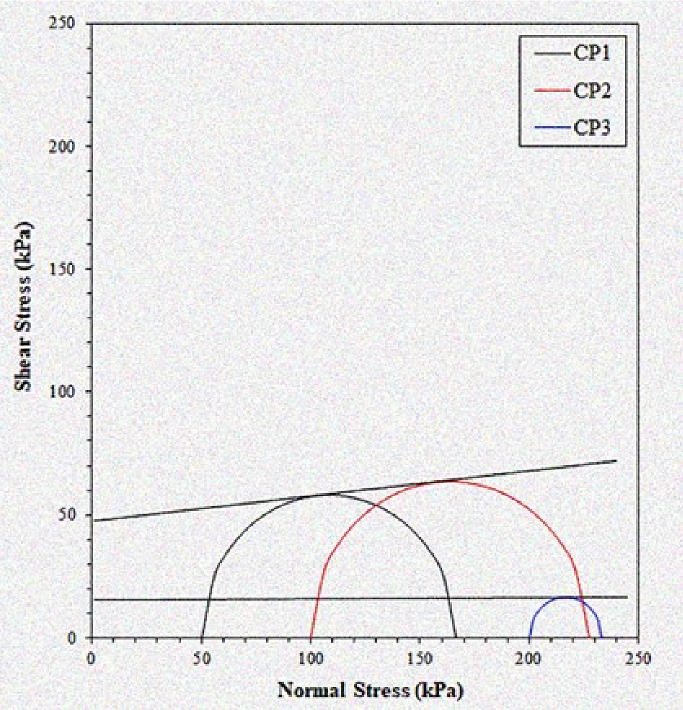

Figure 5 - Failure line obtained by the results of UU triaxial compression tests.

Three specimens were tested: CP-1; CP-2 and CP-3. CP-1 and CP-2 have a different behavior than that expected for soft soils, due to the high values of stresses found. The failure line, obtained for these two specimens is inclined, contradicting the characteristic behavior of the UU triaxial compression tests. This may be justified by the presence of sand lenses in the soil used to mold the specimens, which difficulted the molding and may have interfered in the results obtained. Meanwhile, the circle of CP-3 behaves like the clays of the site A.

It was necessary at least two specimens to obtain the failure line. In this case, a rough estimate was made and was obtained an approximated value of S_u for CP-3 (16.00 kPa). This value is coherent when compared with the results of site A.

Site C: Condominium 2

Site C is a residential condominium, situated in Jabutiana neighborhood, in Aracaju. Two samples were collected there, using Shelby sampler: Hole 02 - Sample 02 (depth varying from 6.80 to 7.50 m) and Hole 02 A - Sample 02 (depth from 6.00 to 6.70 m). SPT tests revealed layers of organic clay, whose consistence varies from soft to very soft, thicker than sites A and B (13.20 m thick). Geotechnical characterization and conventional consolidation tests provided the results displayed on table 5.

Soils from local C are classified as moderately plastic and, regarding the activity, as inactive clays. Specific gravity values shown in table 5 are consistent when compared to those found in another Brazilian regions (Soares, 1997; Costa Filho et al., 1985; Duarte, 1977; Sayão, 1980; Cavalcante, 2002).

Table 5 - Geotechnical characterization and conventional consolidation tests results for site C.

Physical Indices and Consolidations Parameters	δ (g/cm³)	w_0 (%)	WL (%)	WP (%)	PI (%)	AI	C_c	C_r	σ'$_a$	OCR
HOLE 02 -SAMPLE 02	2.59	53.66	39.00	24.00	15.00	0.56	0.69	0.11	54.00	1.11
HOLE 02 A - SAMPLE 02	2.59	48.80	36.00	23.00	13.00	0.55	0.50	0.05	49.00	1.00

δ: Specific Gravity; **w_0:** Natural Moisture Content; **WL:** liquidity limit; **WP**: plasticity limit; **PI:** Plasticity Index; **AI:** Activity Index; **Cc:** Compression Index; **Cr:** Recompression index; **σ$_a$':** Pre-consolidation Stress; **OCR:** Over Consolidation Ratio.

Therefore, some places did not have SPT results referring to the exact local of collection of the samples. Then, it was calculated a mean geostatic stress, using data from nearby drill holes. Based on OCR results, the soil from site C can be classified as slightly overconsolidated for Hole 02 - Sample 02 and as normally consolidated for Hole 02 A - Sample 02.

Site D: Condominium 3

Site D is also a residential condominium, situated in Atalaia neighborhood. There were collected two undisturbed samples: Hole AI-01 (14.90 to 15.60 m depth) and Hole AI-01 (14.40 to 15.10 m depth). In SPT tests, it was verified the presence of layers of very soft organic clay, with dark gray color, intercalated with sandy layers. The results of geotechnical characterization and conventional consolidation tests are in table 6.

According to table 6, soil from both samples can be considered very plastic and, regarding to activity, as inactive clays. Conventional consolidation tests were also performed, and it was possible to obtain values of Cc, Cr, σ'$_a$ and OCR, presented in table 6. Based on OCR values, it is possible to infer that this soil behavior is different from what is expected for the depth in which the sample was collected. For this depth, it was expected an over-consolidated or normally consolidated clay. So, the results obtained can be explained by the disturbance of the samples, which could have reduced σ'$_a$.

Table 6 - Geotechnical characterization and conventional consolidation tests results for site D.

Physical Indices and Consolidations Parameters	δ (g/cm³)	w_0 (%)	WL (%)	WP (%)	PI (%)	AI	C_c	C_r	σ'$_a$	OCR
HOLE AI-01	2.66	41.40	48.00	27.00	21.00	0.56	0.59	0.11	127.00	0.83
HOLE AI-02	2.66	39.08	37.00	21.00	16.00	0.59	0.41	0.09	125.00	0.81

δ: Specific Gravity; **w_0:** Natural Moisture Content; **WL:** liquidity limit; **WP:** plasticity limit; **PI:** Plasticity Index; **AI:** Activity Index; **Cc:** Compression Index; **Cr:** Recompression index; **σ$_a$':** Pre-consolidation Stress; **OCR:** Over Consolidation Ratio.

Site E: Pumping Station EE-14

During the building of the Pumping Station EE-14, in Salgado Filho neighborhood (Aracaju/SE), there were collected four undisturbed samples (Sample 01, Sample 02, Sample 03 and Sample 04) at 2.30 to 2.60 m depth. Analyzing SPT tests, it was identified a layer of organic matter in decomposition, whose consistence varies from soft to very soft, 6.30 m thick and with presence of thin sand.

The report containing data about this site did not presented results of Atterberg Limits tests. There is only the information that none of the samples presented plastic behavior in the consistence limit tests. Results of geotechnical characterization and conventional consolidation tests presented in the report, can be seen in table 7.

Table 7 - Geotechnical characterization and conventional consolidation tests results for site E.

Physical Indices and Consolidations Parameters	δ (g/cm³)	w_0 (%)	C_c	C_r	σ'$_a$	OCR
SAMPLE 01	2.55	39.79	0.41	0.09	60.00	1.96
SAMPLE 02	2.54	50.23	0.58	0.07	68.00	2.22
SAMPLE 03	2.43	83.97	0.93	0.11	65.00	2.12
SAMPLE 04	2.59	-	-	-	-	-

δ: Specific Gravity; **w_0:** Natural Moisture Content; **C_c:** Compression Index; **C_r:** Recompression index; **σ'$_a$:** Pre-consolidation Stress; **OCR:** Over Consolidation Ratio.

Granulometric analysis showed a great amount of sand in the soil. This can be explained by a superficial layer of a sandy fill existing in the soil profile and by the presence of sand in the organic matter. Values of specific gravity, shown in table 7, are coherent when compared to those of other studied places. Regarding natural moisture content, Samples 02 and 03 have higher values than Sample 01. The organic matter content of the soil was obtained by laboratory tests and the ratio between weight of organic matter and weight of solids varied from 8.51% to 23.64%.

Finally, results of conventional consolidation tests are presented in table 7. This soil had high values of OCR, indicating a strong over-consolidation of the organic matter layer. It could be caused by the sandy landfill, identified in the SPT tests, that was disposed above the organic matter layer

Site F: Maturation Lagoon of the Sewage System of Barra dos Coqueiros

Site F is in the Barra dos Coqueiros municipality, on the left margin of Sergipe River. Two undisturbed samples were collected (Hole SP-01 and Hole SP-04, 0.80 to 1.60 m depth). SPT tests reveals the presence of clayey layers, with consistence between soft and very soft, containing organic matter and, in some cases, intercalated with sandy layers. Records about granulometric analysis of this soil were not found. However, some geotechnical characterization and consolidation parameters were presented in table 8. Based on this data, soil of Site F can be considered very plastic. Conventional consolidation tests were performed allowing to obtain values of C_c and C_r. There was no information about σ'$_a$ and OCR values.

Table 8 - Geotechnical characterization and conventional consolidation tests results for site F.

Physical Indices and Consolidations Parameters	δ (g/cm³)	w_0 (%)	WL (%)	WP (%)	PI (%)	C_c	C_r
HOLE SP-04	2.61	46.01	43.60	22.68	21.00	0.37	0.18
HOLE SP-01	-	-	-	-	-	0.57	0.25

δ: Specific Gravity; **w_0:** Natural Moisture Content; **WL:** liquidity limit; **WP:** plasticity limit; **PI:** Plasticity Index; **C_c:** Compression Index; **C_r:** Recompression index.

Site G: Port Terminal of Sergipe

Site G are largely discussed in the research developed by Ribeiro (1992). It is an offshore soft soil deposit, on which the Port Terminal of Sergipe was built. Ribeiro (1992) presented these results with details in his work, so, in this paper, they will be only briefly listed for comparison purposes. Nine undisturbed samples were collected, in depths varying from 4.50 to 10.06 m. SPT tests reveals a clayey layer, with shell fragments, 8.00 m thick and with consistence varying from soft to very soft. A summary of the results obtained by Ribeiro (1992) for this place is presented in table 9.

Table 9 - Parameters obtained by Ribeiro (1992) for Site G.

Physical Indices (mean values)	PI (%)	AI	Organic Matter Content (Chemical Attack Test - %)	Organic Matter Content (Heating Loss Test - %)	S_u (kPa)
	23.5	1.04	1.50 to 2.50	2.50 to 6.50	8.00 to 20. 00

PI: Plasticity Index; **AI:** Activity Index; **Su:** Undrained Shear Strength.

Site H: BR-101 South, KM 94

Site H is a highway, in Nossa Senhora do Socorro municipality, in which occurred a landfill rupture. Based on this accident, Santana Júnior (2017) developed his research, in partnership with DNIT (National Department of Transport Infrastructure).

Two samples were collected in this site: AMI SP-07 and AMI SP-08, with depths varying approximately from 5.00 to 6.00 m. SPT tests exhibit layers of organic sandy clay, with soft consistence. It is possible to see the results of geotechnical characterization tests in table 10.

Geotechnical characterization tests evidenced differences between the soils of the two samples. It is important to highlight that the drill bulletin provided by the company responsible for the SPT tests contains the information that, due to the large heterogeneity of the materials after the landfill rupture, it was not possible to clearly define the layers. Because of this, the thicknesses indicated in the drill profiles could be vary.

Table 10 - Geotechnical characterization and conventional consolidation tests results for site H.

Physical Indices and Consolidations Parameters	w_0 (%)	WL (%)	WP (%)	PI (%)	AI	C_c	C_r	σ'$_a$	OCR
AMI SP-07	18.30	26.00	16.00	10.00	1.06	0.14	0.01	25.00	0.59
AMI SP-08	37.74	60.00	21.00	39.00	1.35	0.24	0.03	23.00	0.54

w_0: Natural Moisture Content; **WL:** liquidity limit; **WP:** plasticity limit; **PI:** Plasticity Index; **AI:** Activity Index; **C_c:** Compression Index; **C_r:** Recompression index; **σ'_a**: Preconsolidation Stress; **OCR:** Over Consolidation Ratio.

Analysis of particle size distributions results evidenced the possible contamination of the soil from AMI SP-07. This behavior also reflects on the results of other tests, for example, the natural moisture content values, higher for sample AMI SP-08. According to table 10, soil from AMI SP-07 can be considered moderately plastic and soil from AMI SP-08, very plastic. Regarding the activity index, clays corresponding to AMI SP-07 can be classified as moderately active and those corresponding to AMI SP-08, as active. This activity can be justified by the location of this deposit: Nossa Senhora do Socorro usually presents deposits of soil that contains montmorillonite, an active clay mineral (Leite, 2015).

Conventional consolidation tests were performed, and the results obtained by Santana Júnior (2017) are presented in table 10. The value of C_c found by this author for AMI SP-07 was very low. After recalculating it, a new more coherent result was obtained and adopted. The OCR values found by Santana Júnior (2017) were less than 1.0. But, comparing these results with that showed in Table 10, they seem incompatible, because the natural water content and the results of Atterberg limit tests indicate a slightly over consolidated soil.

S_u values, estimated using Skempton (1957) method (7.8 kPa) and calculated based on direct shear tests (9.7 kPa), are like the others obtained in this research. Only the results obtained with AMI SP-8 were incorporated into the final database, due to the geotechnical characteristics presented by AMI SP-07, which differ from the behavior of soft soils. These divergences can be explained by the possible contamination of the clay layer, caused by the material from landfill rupture.

Quality of the samples

The proposal of Coutinho (2007) was used to classify the samples studied in this research. Thus, it is possible to evaluate the sample quality of the studied deposits. It is clear the difficulty in collecting undisturbed samples with good quality (Table 11). Three of the samples were classified as very bad and six as bad, according to the method of Coutinho (2007). The sample AMI SP-07 was discarded from the results due to the contamination with the landfill material.

For sites A and B, it was possible to evidence the bad quality of samples just by observing the compression curves. Due to the absence of transition between the recompression and the virgin sections, it was not possible to estimate the σ'_a for the soils of these deposits (Martins & Lacerda 1994).

Table 11 - Method of Coutinho (2007) to evaluate quality of the samples.

Parameters	HOLE 02 (SAMPLE 02)	HOLE 02 A (SAMPLE 02)	HOLE AI-01	HOLE AI-02	SAMPLE 01	SAMPLE 02	SAMPLE 03	AMI SP-07	AMI SP-08
$\Delta e / e_0$	0.142	0.142	0.145	0.121	0.133	0.097	0.090	0.083	0.136
Quality	Very bad	Very bad	Very bad	Bad	Bad	Bad	Bad	Bad	Bad

$\Delta e/e_0$: relative variation in void index.

According to Skempton (1984), it is difficult to collect undisturbed samples of good quality in layers of sensitive clay, located at great depths, when these clays have activity below 0.75, that is, they are inactive. In the studied sites, it is verified that the clays are classified as inactive, in its great majority. Although it was not possible to obtain the soil sensitivity, there may be a correlation between the clay inactivity and the complete disturbance of the samples. Touiti et al. (2009) studied the soft clays of Tunis and observed that some factors contribute to the clay sensitivity. One of them was the water content: when the water content is higher than the liquidity limit, the soil, in general, is more sensitivity. It happened in most of the MRA studied sites.

In accordance with Hight (1983), the worse the quality of sampling, the lower the values of resistance, deformation modulus and preconsolidation stress (S_u, E_u and σ'_a, respectively). Thus, it is not recommended to use the estimated parameters found in this research for settlement calculations, for example, since the expected periods for stabilization based on disturbed samples may be higher (Almeida & Marques, 2011).

It is important to remember that the great majority of the results of this work were obtained in the past, by local companies, and the intention here is to join these data in a database. Other research should be developed in the future with the purpose of collect samples in a more careful way than that used by the local companies, to compare with the results already obtained.

Comparison between the obtained results

A summary of Brazilian soft clays characteristics, extracted from researches developed by several authors, is showed in table 12 (Schnaid & Odebrecht, 2012). Data obtained in this research were added to this table, to complement and expand national database. Furthermore, it is possible compare the found parameters with others existing in literature.

Values of S_u were not included in this table because the analysis of quality of the samples revealed that there was a disturbance on the specimens, generating bad and very bad quality samples. In this way, as in laboratory tests S_u values were obtained from not good quality samples, it is coherent not including them in the database. Organic matter results were not included too, because there are values only from site E, that could be not sufficient to represent the whole MRA.

Analyzing table 12, it is possible to notice that water content of the studied soils is lower than other sites, resembling that of Rio Grande (RS). This behavior can be explained by the presence of sand lenses, which reduces the water retention capacity granted by the thinner particles. On the other hand, the water content, on average, is higher than the liquidity limit.

Soils studied in this research vary from medium plastic to very plastic, different from what can be observed for the other sites of table 12, which have mostly very plastic soils. Based on the average values, the plasticity index (PI) for RMA varies from 8% to 33%. These results are like that obtained by Wroth & Houslby (1985), in the United States (PI = 12% - 41%), and for Tavenas et al. (1975) apud Ching & Phoon (2014), in Canada (PI = 10% - 37%).

Table 12 - Geotechnical physical indices of Brazilian soft clay deposits.

Local \ Physical Index	W (%)	WL (%)	WP (%)	Clay (%)	Activity	G_z	Organic Matter	S_u (kPa)	References
Porto Alegre, RS	47-140	80-130	30-57	37-70	0.9-1.7	2.54-2.59	0.4-6.3	10-32	Soares (1997)
Sarapuí, RJ	110-160	110-140	75-110	55-80	1.4-2.0	2.60-2.67	4.0-6.5	5-15	Costa Filho et al. (1985) Duarte (1977) Sayão (1980)
Santos, SP	100-140	80-150	30-90	30-80	1.0-2.2	2.60-2.69	4.0-6.0	10-60	Árabe (1995) Massad (1985) Samara et al. (1982)
Recife, PE	50-150	30-110	15-75	50-80	Inactive	2.50-2.70	4.0-8.0	2-40	Gusmão Filho et al. (1986) Coutinho & Ferreira (1988) Ferreira et al. (1986)
João Pessoa, PB	35-150	30-60	15-30	30-80	-	2.50-2.65	-	13-40	Cavalcante (2002)
Jurturnaíba, RJ	40-400	50-390	30-280	-	-	2.10-2.60	7.0-70.0	5-37	Coutinho (1988b)
Sergipe	57-72	58-85	24-35	-	1.0-1.4	2.69	2.5-6.5	8-20	Ribeiro (1992)
Metropolitan Region of Aracaju, SE[1]	29-84	27-60	19-27	13-48	0.44-1.35	2.43-2.69	-	-	Sá (2022), present work
Rio Grande, RS	38-64	41-90	20-38	34-96	0.4-1.1	2.48-2.66	-	-	Dias & Bastos (1994)
Vitória, ES	-	30-130	20-57	26-81	-	-	-	-	Castilho & Polido (1986)
Barra da Tijuca, RJ	190-670	67-610	20-113	-	-	1.78-2.54	6-51	4-6	Baroni (2010)
Barra da Tijuca, RJ	100-400	100-200	35-70	10-60	1.81-46.9	2.36-2.58	3.9-45	5-45	Teixeira (2012)

[1] Except data from Ribeiro (1992), that already had represented in another line of this table.
W: water content; **WL:** liquidity limit; **WP:** plasticity limit; **G:** grains bulk density; **S_u:** undrained shear strength.

Clay percentage also fits within a range with lower limits than those presented for the other sites, due to the presence of sand intercalating the layers of soft clay soil. The local values are comparable to those found by Teixeira (2012), for Barra da Tijuca (RJ). Regarding activity, the clays analyzed in this research are predominantly inactive (only sites H and G had active and moderately active behavior) and the range of values found resembles Rio Grande's (RS).

The values of grains bulk density are consistent when compared to the other sites, and the organic matter content surpasses some other sites. The dark gray color of some soil samples collected illustrates the abundance of organic matter in pore water, similar on which was found by Touite et al. (2009).

CONCLUSIONS

Geotechnical characterization tests revealed that the presence of sand lenses interspersed with clay layers occurred with considerable frequency in some deposits of MRA, especially in that near the coastal zone.

Furthermore, it was verified that the studied deposits of soft clays have a medium plastic to very plastic behavior (PI ranging from 8.00 to 33.00). Values of natural moisture content were considerably lower than those obtained in other Brazilian states (between 29% and 84%), possibly due to the influence of the sand lenses. As for the activity, the MRA clays are predominantly inactive, except for sites H and G.

Values of undrained shear strength are low, varying between 2.5 and 19.0 kPa, typical for soft soil deposits. It was verified that sampling process can have reduced this parameter, thus, the undrained shear strength determined in laboratory was lower than the value found in field tests. Furthermore, the presence of deposits of inactive clays may have made the collect of the samples more difficult.

Therefore, according to what has been presented, it is possible to conclude that the present study reached its main purpose of georeferencing soft soils deposits of MRA using a GIS and obtaining their geotechnical properties. Thus, the formation of a database containing relevant information about the MRA soft soils was started.

Some suggestions for further research are to perform the tests that are not available in the developed database and repeat that were executed with bad quality undisturbed samples; to investigate the existence of other deposits of soft soils in MRA and to study their properties; to perform detailed chemical and mineralogical analysis of the deposits studied and of new layers that may arise; to evaluate the existence of a relationship between the activity index of the clays and the disturbance of the samples collected and to determine the sensitivity of local clays.

ACKNOWLEDGEMENTS

The authors would like to thank the companies that contributed to the execution of some of the field tests and that provided data that made this research possible, as well as the team from the Geotechnics and Paving Laboratory (GEOPAV) at Federal University of Sergipe (UFS), which collaborated in the execution of the laboratory tests.

REFERÊNCIAS

ALMEIDA, M. S.S.; FUTAI, M.M.; LACERDA, W.A. Laboratory Behaviour of Rio de Janeiro Soft Clays. Part 1: Index and Compression Properties. **Soil and Rocks**, v. 31, n. 2, p. 69-75, 2008.

ALMEIDA, M.S.S. & Marques, M.E.S. **Aterros sobre Solos Moles: Projeto e Desempenho**. São Paulo: Oficina de Textos, 254 p., 2011.

ANDRADE, M.E.S**. Contribuição ao Estudo das Argilas Moles da Cidade de Santos**. Rio de Janeiro, 2009, 397 p. Dissertação (Mestrado em Engenharia Civil), Universidade Federal do Rio de Janeiro.

ÁRABE, L.C.G. **Aplicabilidade de Ensaios In-Situ para a Determinação de Propriedades Geotécnicas de Depósitos Argilosos e de Solos Residuais**. Rio de Janeiro, 1995, 330 p. Tese (Doutorado em Geotecnia) - Pontíficia Universidade Católica do Rio de Janeiro.

BARONI, M. **Comportamento Geotécnico de Argilas Extremamente Moles da Baixada de Jacarepaguá, RJ.** Rio de Janeiro, 2016, 292 p. Tese (Doutorado em Engenharia Civil) - Universidade Federal do Rio de Janeiro.

BARONI, M. **Investigação Geotécnica em Argilas Orgânicas muito Compressíveis em Depósitos da Barra da Tijuca**. Rio de Janeiro, 2010, 249 p. Dissertação (Mestrado em Engenharia Civil) - Universidade Federal do Rio de Janeiro.

BJERRUM, L. Problems of Soil Mechanics and Construction on Soft Clays and Structurally Unstable Soils (Collapsible, Expansive and Others). In: INTERNACIONAL CONFERENCE ON SOIL MECHANICS AND FOUNDATION ENGI-NEERING, 8, 1973, Moscow. **Anais**… Moscow, 1973, p. 111-159.

CADETE, A.N.M. **Avaliação da Resistência Não-Drenada de uma Argila Orgânica Mole no Bairro Chão de Estrelas em Recife-PE**. Recife, 2016, 161 p. Dissertação (Mestrado em Engenharia Civil), Universidade Federal de Pernambuco.

CAPUTO, H.P. & CAPUTO, A.N. **Mecânica dos Solos e suas Aplicações: Fundamentos**. Rio de Janeiro: LTC, 272 p.,2016.

CASTILHO, R.R. & POLIDO, U.F. Algumas Características de Adensamento das Argilas Marinhas de Vitória-ES. In: CONGRESSO BRASILEIRO DE MECÂNICA DOS SOLOS E ENGENHARIA DE FUNDAÇÕES, 8, 1986, Porto Alegre. **Anais**...Porto Alegre: Associação Brasileira de Mecânica dos Solos e Engenharia Geotécnica, 1986, p. 149-159.

CAVALCANTE, E.H. **Investigação Teórico-Experimental sobre o SPT**. Rio de Janeiro, 2002, 410 p., Tese (Doutorado em Engenharia Civil) - Universidade Federal do Rio de Janeiro.

CHING, J. & PHOON, K.K. Transformations and correlations among some clay parameters - the Global Database. **Canadian Geotechnical Journal**, v. 51, p. 663-685, 2014

CINTRA, J.C.A.; AOKI, N.; ALBIERO, J.H. **Fundações Diretas: Projeto Geotécnico**. São Paulo: Oficina de Textos, 140 p., 2011.

COSTA FILHO, L.M.; ARAGÃO, C.J.G.; VELLOSO, P.P.C. Características Geotécnicas de Alguns Depósitos de Argilas Moles na Área do Grande Rio de Janeiro. **Solos e Rochas**, v. 8, n. 1, p. 3-13, 1985.

COUTINHO, R.Q. & BELLO, M.I.M.C.V. Geotechnical Characterization of Suape Soft Clays, Brazil. **Solos e Rochas**, v. 37, n. 3, p. 257-276, 2014.

COUTINHO, R.Q. & FERREIRA, S.R.M. Argilas Orgânicas do

Recife – Estudos de Caracterização em Seis Depósitos. In: SIMPÓSIO SOBRE DEPÓSITOS QUATERNÁRIOS DAS BAIXADAS BRASILEIRAS, 1988, Rio de Janeiro. **Anais**... Rio de Janeiro: Sociedade Brasileira de Geologia, 1988.

COUTINHO, R.Q. & LACERDA, W.A. Caracterização/ Consolidação da Argila Orgânica de Juturnaíba. **Solos e Rochas**, v. 17, n.2, p. 145-154, 1994.

COUTINHO, R.Q. Aterro Experimental Instrumentado Levado à Ruptura sobre Solos Orgânicos – Argilas Moles de Juturnaíba – RJ. **Solos e Rochas**, 1986.

COUTINHO, R.Q. Characterization and Engineering Properties of Recife Soft Clays. In: INTERNATIONAL WORKSHOP ON CHARACTERIZATION E ENGINEERING PROPERTIES OF NATURAL SOILS, 2, 2007, Singapore. **Anais**…Singapore, 2007, p. 2049-2099.

COUTINHO, R.Q. Parâmetros Tensão-Deformação-Resistência no Estado Natural das Argilas - Solos Orgânicos de Juturnaíba. In: SIMPÓSIO NOVOS CONCEITOS DE ENSAIOS DE CAMPO E LABORATÓRIO EM GEOTECNIA, 1988b, Rio de Janeiro. **Anais**...Rio de janeiro: 1988b, v. p. 709-726.

COUTINHO, R.Q. Propriedades Geotécnicas dos Depósitos de Argilas Orgânicas Moles de Recife. In: SIMPÓSIO SOBRE DEPÓSITOS QUATERNÁRIOS DAS BAIXADAS BRASILEIRAS, 1988a, Rio de Janeiro. **Anais**... Rio de Janeiro: Sociedade Brasileira de Geologia, 1988a.

COUTINHO, R.Q., OLIVEIRA, J.T.R. DE & DANZIGER, F.A.B. Caracterização Geotécnica de uma Argila Mole de Recife. **Solos e Rochas**, v. 16, n. 4, p. 255-266, 1993.

DIAS, C.R. & BASTOS, C.A.B. Propriedades Geotécnicas da Argila Siltosa Marinha de Rio Grande, RS: Uma Interpretação à Luz da História Geológica Recente da Região. In: CONGRESSO BRASILEIRO DE MECÂNICA DOS SOLOS E ENGENHARIA GEOTÉCNICA, 10, 1994, Foz do Iguaçu. **Anais**...Foz do Iguaçu: Associação Brasileira de Mecânica dos Solos e Engenharia Geotécnica, 1994, p. 555-562.

DIAS, R.D., BASTOS, C. & PINHEIRO, R. Perfis de Solos Residuais da Região Metropolitana de Porto Alegre. **Solos e Rochas**, Publicação especial comemorativa do aniversário da COPPE/UFRG, 1993.

DUARTE, A.E.R. **Características de Compressão Confinada da Argila Mole do Rio Sarapuí, no km 7,5 da Rodovia Rio-Petrópolis**. Rio de Janeiro, 1977, 210 p., Dissertação (Mestrado em Engenharia Civil), Pontifícia Universidade Católica do Rio de Janeiro.

EMBRAPA & SUDENE. **Levantamento Exploratório: Reconhecimento de Solos do Estado de Sergipe. Recife: Convênio de Mapeamento de Solos** EMPRAPA/CPP-SUDENE/DRN Convênio MA/CONTAP/USAID/ETA, 506 p.,1975.

FERREIRA, S.R.M.; AMORIM, W.; COUTINHO, R.Q. Argila Orgânica do Recife - Contribuição ao Banco de Dados. In: CONGRESSO BRASILEIRO DE MECÂNICA DOS SOLOS E ENGENHARIA DE FUNDAÇÕES, 8, 1986, Porto Alegre. **Anais**... Porto Alegre: Associação Brasileira de Mecânica dos Solos e Engenharia Geotécnica, 1986.

FUTAI, M.M.; ALMEIDA, M.S.S.; COSTA, A.M.; AMARAL, C.S. Investigação Geotécnica em um Depósito de Argila Muito Mole da Baixada Fluminense. In: SEMINÁRIO DE ENGENHARIA DE FUNDAÇÕES ESPECIAIS E GEOTECNIA, 5, 2004, São Paulo. **Anais**... São Paulo: Associação Brasileira de Mecânica dos Solos e Engenharia Geotécnica 2004.

GODOY, N.S**. Fundações: Notas de Aula**, Curso de Graduação. São Carlos: Escola de Engenharia de São Carlos – USP, 1972.

GRAHAM, J.; CROOKS, J.H.A.; BELL, A.L. Time Effects on Stress-Strain Behavior of Natural Soft Clays. **Géotechnique**, v. 33, n. 3, p. 327-340, 1983.

GUSMÃO FILHO, J.A., SILVA, J.M.J. DA, JUCÁ, J.F.T. & FERREIRA, S.R.M. (1986). Parâmetros Geomecânicos dos Solos dos Morros de Olinda. In: CONGRESSO BRASILEIRO DE MECÂNICA DOS SOLOS E ENGENHARIA DE FUNDAÇÕES, 8, 1986, Porto Alegre. **Anais**... Porto Alegre: Associação Brasileira de Mecânica dos Solos e Engenharia Geotécnica, 1986, p. 199-210.

HALLAL, R.R. (2003). **Características de Depósitos de Argilas Moles no Estado do Rio Grande do Sul.** Porto Alegre, 2003, 132 p. Dissertação (Mestrado em Engenharia), Universidade Federal do Rio Grande do Sul.

HANZAWA, H. Undrained Strength Characteristics of an Alluvial Marine Clay in the Tokyo Bay. **Soils and Foundations**, v. 19, p. 69-84, 1979.

HIGHT, D.W. **Laboratory Investigations of sea-bed clays**. Londres, 1983, 408 p. Tese (Doctor of Philosofy in the Faculty of Engineering), University of London.

HORE, R.; AREFIN, M.R.; ANSARY, M. (2018). Development of Zonation for Bangladesh Based on Soft Clay Using. In: INTERNATIONAL CONFERENCE ON ADVANCES IN CIVIL ENGINEERING, 4, 2018, Bangladesh. **Anais**… Bangladesh, 2018.

IBGE. Resolução 01/2005 (2005) Altera a caracterização do Sistema Geodésico Brasileiro. IBGE. Disp. em: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwixncyqxe71AhVjr5UCHU7bCiQQFnoECAQQAQ&url=https%3A%2F%2Fgeoftp.ibge.gov.br%2Fmetodos_e_outros_documentos_de_referencia%2Fnormas%2Frpr_01_25fev2005.pdf&usg=AOvVaw19H0FfdQYEbSne4UhImleM. Acessado em: 05/03/2017.

LEITE, R.P. **Estabilização de Solo Expansivo através da Adição de Cal Estabilização de Solo Expansivo através da Adição de Cal**. São Cristóvão, 2015, 69 p. Trabalho (Conclusão de Curso Bacharel em Engenharia Civil), Universidade Federal de Sergipe.

LEMOS, S.G.F.P. & PIRES, P.M.J. The Undrained Strenght of Soft Clays Determined from Unconventional and Conventional Tests. **Soils & Rocks**, v. 40, n. 3, p. 291-301, 2017.

MARTINS, I.S.M. & LACERDA, W.A. Sobre a Relação Índice de Vazios-Tensão Vertical Efetiva na Compressão Unidimensional. **Solos e Rochas**, v. 17, n. 3, p. 157-166, 1994.

MASSAD, F. As Argilas Quaternárias da Baixada Santista: Características e Propriedades Geotécnicas. **Solos e Rochas**, 1985.

MASSAD, F. **Obras de Terra: Curso Básico de Geotecnia**. São Paulo: Oficina de Textos, 216 p., 2010.

NBR 9820. Coleta de **Amostras Indeformadas de Solos de Baixa Consistência em Furos de Sondagem.** Rio de Janeiro: ABNT, 5 p., 1997.

OHTSUBO, M., TAKAYAMA, M. & EGASHIRA, K. Marine Quick Clays from Ariake Bay Area, Japan. **Soils and Foundations**, v. 22, p. 71-80, 1982.

PÓVOA, L.M. DE M. **Caracterização geotécnica de um depósito de solo mole em área de baixada localizada em Macaé-RJ.** Campo dos Goytacases, 2016, 156 p. Dissertação (Mestrado em Engenharia Civil), Universidade Estadual do Norte Fluminense Darcy Ribeiro.

RIBEIRO, L.F.M. **Ensaios de Laboratório para Determinação das Características Geotécnicas da Argila Mole de Sergipe**. Rio de Janeiro, 1992, 201 p. Dissertação (Mestrado em Engenharia Civil), Pontifícia Universidade Católica do Rio de Janeiro.

SÁ, L.M.S. Caracterização Geotécnica e Georreferenciamento de Alguns Depósitos de Solos Moles da Região Metropolitana de Aracaju. São Cristóvão, 2019, 197 p. Dissertação (Mestrado em Engenharia Civil), Universidade Federal de Sergipe.

SAMARA, V., BARROS, J.M.C., MARCO, L.A., BELICANTA, A. & WOLLE, C.M. (1982). Some Properties of Marine Clays from Santos Plains. In: CONGRESSO BRASILEIRO DE MECÂNICA DOS SOLOS E ENGENHARIA GEOTÉCNICA, 7, 1982, Recife. **Anais**... Recife: Associação Brasileira de Mecânica dos Solos e Engenharia Geotécnica, 1982, p. 301-318.

SANTANA JÚNIOR, Z.A. **Condicionantes Geotécnicos que Levaram à Ruptura um Aterro Rodoviário sobre Solo Mole no Estado de Sergipe**. São Cristóvão, 2017, 99 p. Dissertação (Mestrado em Engenharia Civil), Universidade Federal de Sergipe.

SAYÃO, A.S.F.J. **Ensaios de Laboratório na Argila Mole da Escavação Experimental de Sarapuí**. Rio de Janeiro, 1980. Dissertação (Mestrado em Engenharia Civil), Pontífica Universidade Católica do Rio de Janeiro.

SCHNAID, F. & ODEBRECHT, E. **Ensaios de Campo e Suas Aplicações à Engenharia de Fundações.** São Paulo: Oficina de Textos, 224 p., 2012.

SERGIPE. **Atlas Digital sobre Recursos Hídricos de Sergipe. Secretaria de Estado do Meio Ambiente e dos Recursos Hídricos**, Aracaju: SEMARH – Secretaria do Meio Ambiente e dos Recursos Hídricos, 2016.

SKEMPTON, A.W. Discussion of the Planning and Design of the New Hong Kong Airport. Institution of Civil Engineers. In: PROC. INST. CIV. ENGRG., 1957. **Anais**… Hong Kong: 1957, v. 7, p. 305-307.

SKEMPTON, A.W. **The Colloidal "Activity" of Clays**. Selected Papers on Soil Mechanics, p. 57-61, 1984.

SOARES, J.M.D. **Caracterização do depósito de argilas moles da região metropolitana de Porto Alegre.** Porto Alegre, 1997, 330 p. Tese (Doutorado em Engenharia Civil), Universidade Federal do Rio Grande do Sul.

TAVENAS, F.A., BLANCHETTE, G., LEROUEIL, S., ROY, M. & ROCHELLE, P.L. Difficulties in the In-Situ Determination of K_0 in Soft Sensitive Clays. In: CONFERENCE ON IN SITU MEASUREMENT OF SOIL PROPERTIES, 1975, North Carolina. **Anais**… North Carolina, 1975, p. 450.

TEIXEIRA, C.F. **Análise dos recalques de um aterro sobre solos moles da Barra da Tijuca-RJ.** Rio de Janeiro, 2012, 322 p. Tese (Doutorado em Engenharia Civil), Pontíficia Universidade Católica do Rio de Janeiro.

TOUITI, L. & IMPE, W.V. Considerations on the Stiffness of Sensitive Soft Soils. In: INTERNATIONAL CONGRESS AND EXHIBITION "SUSTAINABLE CIVIL INFRASTRUCTURES: INNOVATIVE INFRASTRUCTURE GEOTECHNOLOGY", 2018, Cham. **Anais**... Cham: Springer, 2018, p. 20-37.

TOUITI, L.; BOUASSIDA, M.; IMPE, W.V. Discussion on Tunis Soft Soil Sensitivity. **Geotechnical and Geological Engineering,** v. 27, n. 5, p. 631-643, 2009.

WROTH, C.P. & HOULSBY, G.T. Soil Mechanics-Property Characterization and Analysis Procedures. In: INTERNATIONAL CONFERENCE ON SOIL MECHANICS AND FOUNDATION ENGINEERING, 11, 1985, San Francisco. **Anais**... San Francisco, 1985, p. 1-55.

Submetido em 8 de fevereiro de 2022
Aceito para publicação em 2 de junho de 2022