

Research Article

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Geotechnical Index Properties of Soil in Main Campus, University of Port Harcourt, Port Harcourt, Nigeria

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Abstract

Geotechnical index properties of soil were carried out on samples obtained from the study area in Abuja campus, University of Port Harcourt, Rivers State, Nigeria, to study, identify, classify and determine suitability of the soil through detailed field and laboratory investigation, soil profiling and classification. Four soil samples were collected in all. Soil samples were obtained within Faculty of Management Science (location one), Arena (location two), Faculty of Science (location three) and Faculty of Engineering (location four). The samples obtained were evaluated through their bulk density, natural moisture content, particle size distribution and the Atterberg's limit (Liquid and Plastic limit). The natural moisture content ranges from 12.65% - 23.89% in location one, 10.54% - 23.81% in location two, 8.63% - 21.62% in location three and 16.38% - 27.26% in location four, Atterberg limit test which shows that the soil is an inorganic clay of low-intermediate plasticity index of 20.82% - 27.68% in location one, 12.88% - 18.52% in location two, 4.06% - 13.04% in location three and 16.38% - 26.10% in location four. With liquid limit of 43% - 53% in location one, 35% - 38% in location two, 28% - 39% in location three and 35% - 42% in location four and plastic limit of 20.88% - 27.68% in location one, 19.48% - 22.12% in location two, 23.94% - 25.96% in location three and 16.38% - 27.26% in location four. From the analysis, the particle size distribution shows the presence of silt, sand and other clay minerals. The soil is moderately graded with high proportion of medium to fine grain. The result reveals that the soil from the study area is generally good foundation materials for any proposed construction. This study has shown the knowledge of the geotechnical

Keywords

Campus,
Geotechnical index,
properties,
soil

characteristics of the area and provided valuable data for foundation design and other forms of construction for civil structures in order to minimize adverse effects and prevention of post construction problems. All fill materials should be inorganic soils, free of vegetation, debris and fragments larger than 3 inches in size. Pea gravel or other similar non-cementitious, poorly-graded materials should not be used as fill or backfill without the prior approval of the geotechnical engineer.

Introduction

Geotechnical index properties of geo-materials are very vital in construction and buildings purposes as it enables us to determine the stability of soils as construction and foundation materials. Some studies have been carried out on geotechnical properties of the subsoil in parts of Nigeria (Oke & Amadi, 2008; Oke et al., 2009). The University of Port Harcourt Area has witnessed mirage of creeks in buildings and collapse of structures. In recent times this has been attributed to incompetent strata. Therefore, the need for adequate and reliable geotechnical Investigation of sub-soil is very important. The investigation and determination of subsurface engineering foundation structures in Nigeria is not usually fully explored. This has gone a long way in contributing to failures and high cost of operations in such projects (Amadi et al., 2012). The compact of the composed load is exacerbated by the thickness and consistency of the compressible layer. These in additions to other intrinsic factors contribute to the failure of civil engineering structures. Consequently, it becomes imperative to carry out through site investigation and laboratory analysis to obtain geotechnical information on the sub-soil of the area at different depths. It is this information that engineers and geologist sought for in the construction of engineering works. The success of a construction depends on the geotechnical index properties of the subsoils, the more resistance a subsoil has to deformation the more loads it can bear. Geotechnical information is useful in ensuring that the effects of projects on the environment and natural resources are properly evaluated and mitigated where necessary. Soils have been found to develop in different sub climates and drainage environments with each often-exhibiting unique set of physical, chemical and geotechnical

properties of soils which are closely related to the physical conditions of the materials, that include particles size distribution (PSD), Atterberg's Limits, Plasticity Limits and liquidity Limits, bulk density, specific gravity, moisture content these properties determine the instability of material for construction purposes. The importance of geological structures in foundation investigation for engineering structures like roads, bridges, dams and buildings cannot be underestimated (Annor et al., 1987). The objectives of this study are first and foremost to determine the geotechnical properties of the soils in the study area, secondly, classify them based on some of the widely used soil classification schemes and lastly establish possible interrelationships between the various classification schemes. The sampled area of this investigation covers selected locations within the university vicinity. The geology, hydrogeology and geotechnical characteristics of the area have been described by Doust, and Omatsola (1990), Etu-Efeotor and Akpokodje (1990) and Nwankwoala and Oborie (2014) respectively.

Materials and Methods

Description of studied area

The study area is situated within the Niger Delta that is located in the latest Africa continental Margin. It is located along East-West road, Choba, Rivers State, Nigeria. On the map of Rivers State, it lies between latitude 4°53'27.5" N of the equator, and between longitudes 6°55'8.375" Greenwich meridian.

The site is easily accessible through the east west road in Rivers State

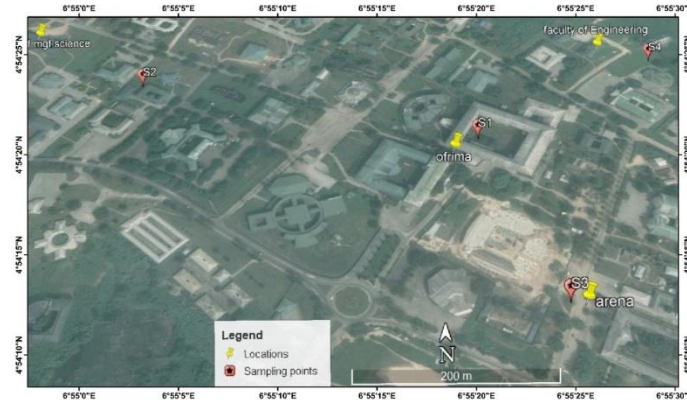


Fig 4: Satellite Map showing the studied Area

Geology of the studied area

The area of study lies within the Niger Delta and results shows that the geotechnical properties are a reflection of the geomorphic sub environment the area generally has a dry flatland surface and high-water table. The Niger Delta is situated in the Gulf of Guinea and extends throughout the Niger Delta Province as defined by Klett and others (1997). From the Eocene to the present, the delta has prograded southwestward, forming depobelts that represent the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world with an area of some 300,000 km² (Kulke, 1995), a sediment volume of 500,000 km³ (Hospers, 1965), and a sediment thickness of over 10 km in the basin depo center (Kaplan and others, 1994). The depositions of the Niger Delta resulted from the Paleocene-Eocene transgressive and regressive sequence .it is a body of transitional, continental and marine deposits formed by sediments supplied mainly by the Benue and Niger rivers in the tertiary and customary times.

The evolution of the Niger Delta is controlled by pre-and syn-sedimentary tectonics as described by Short & Stauble (1967); Frankl and Cordry (1967); Weber and Daukoru (1975); Evamy et al. (1978); Ejedawe (1981); Knox & Omatsola (1987); Doust and Omatsola (1990); Stacher (1995); Corredor et al (2005), among others. The water table depths in the area increase seawards,

varying from about 5m (inland) to 0.5m at the coast, the high-water table in the Delta resulting from the high rainfall, general swampiest and flat topography of the area these feature of the Niger Delta also account for the high-water content of soil in the region, affecting the geotechnical properties of its soils negatively and causing serious drainage problem in the Niger Delta. The Tertiary Niger Delta is a sedimentary structure, of classic sediments, ranging in thickness from 9,000 to 12000 meters.

The three main depositional environments typical of most deltaic environment (marine, mixed and continental) are observable in the Niger Delta and are represented by the three major lithostratigraphic units in the Niger delta underlying the superficial soils from bottom to top the Akaka, Agbada and Benin Formations respectively they have been described in detailed by Nedaco 1954, 1959 and 1961; Allen 1964 and 1965; Reyment 1965; short and Stauble, 1967; Maron, 1969; Weber 1971; Burke, 1972; Kogbe, 1989 and Etu-Efeotor 1997.

Soil Sampling

Soil samples (disturbed) were collected at regular interval of 0.5 meter. The sample collected were then examined, identified and thoroughly classified on the field with respect to soil type, color, texture, before being packaged and transported to the laboratory for further analyses.

Soil samples were obtained within Faculty of Management Science (location one), Arena (location two), Faculty of Science (location three) and Faculty of Engineering (location four).

In the field 12 geotechnical boreholes was drilled to a depth of 1.5metres, using a hand auger the holes were drilled by pushing and rotating the hand auger into the ground to the desired depth after which it is withdrawn to collect the fresh soil samples. The soil samples were secured in water proof bags and brought to the laboratory for sample preparation and testing. Atterberg limits and grain size distribution laboratory tests were carried out on the samples to determine their geotechnical index properties in accordance with ASTM (2010) D 4318 and ASTM (2007) D 422-63 standards respectively.

Grain size distribution test

The grain size distribution test of the soil samples was conducted using a set of sieves and hydrometer. Samples collected into the pan placed at the bottom of the set of sieves was used for the hydrometer test after mechanically shaking the assembly for the duration of about 10mins. Particle distribution curve was produced for each sample by plotting the percentage mass passing a particular sieve against the sieve mesh diameter.

Liquid limit and plastic limit tests

The moisture content at the Liquid limit boundary is arbitrarily defined as the water content at which two halves of a soil cake will flow together for a distance of 12.7 mm along the bottom of a groove of standard dimensions separating the two halves when the cup of a standard liquid limit apparatus is dropped 25 times from a height of 10 mm at the rate of two drops/second. The moisture content at the plastic limit boundary is arbitrarily defined as the water content at which a soil will just begin to crumble when rolled into a thread 3 mm in diameter using a ground glass plate or other acceptable surfaces. The numerical difference between the liquid limit and plastic limit of a soil is referred to as plasticity index.

Soil Classification schemes

Four soil classification schemes were used in this study and the results were compared to evaluate interrelationships between the classification systems. The schemes include (1) Unified Soil Classification System (USCS) based on ASTM D2487-11, (2) British Soil Classification System (BSCS) following guidelines stipulated in BS 5930:1981 (3) American Association of State Highway and Transportation Officials (AASHTO) in line with AASHTO (2013) and modified by Das and Soban (2014), and (4) United State Department of Agriculture (USDA) based on USDA (1987).

Results and Discussion

Table 1 Lithologic Profile of the soil

Borehole no	Depth	Soil type	Color	Texture
BH 1	Top soil	Clayey silty sand	Dark brown	Coarse-medium
BH 1	0.5m	Sandy clay	Brown	Coarse-fine
BH 1	1.0m	Sandy clay	Brown	Coarse-fine
BH 1	1.5m	Sandy clay	Brown	Coarse-fine
BH 2	Top soil	Clayey silty sand	Brown	medium-fine
BH 2	0.5m	Silty clayey sand	Dark brown	Coarse-fine
BH 2	1.0m	Sandy clay	Brown	Coarse-fine
BH 2	1.5m	Sandy clay	Reddish brown	Coarse-fine
BH 3	Top soil	Clayey sand	Dark brown	medium-fine
BH 3	0.5m	Clayey silty sand	Brown	medium-fine
BH 3	1.0m	Clayey sand	Brown	medium-fine
BH 3	1.5m	Silty clayey sand	Brown	medium-fine
BH 4	Top soil	Clayey silty sand	Dark brown	medium-fine
BH 4	0.5m	Clayey sand	Brown	medium-fine
BH 4	1.0m	Sandy clay	Brown	medium-fine
BH 4	1.5m	Sandy clay	Brown	medium-fine

Table 2 results of the laboratory tests carried out

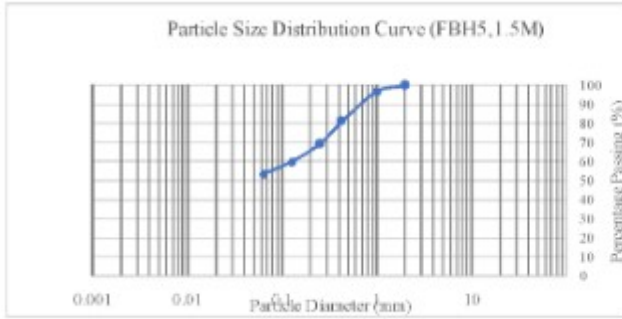
Borehole No	Depth	Moisture content	Liquid limit	Plastic limit	Plasticity index	Bulk density	Unit weight	Dry density
1	Top soil	12.65	-	-	-	1.35	11.76	1.20
1	0.5m	21.60	50	20.88	29.12	1.58	12.74	1.30
1	1.0m	23.89	43	22.18	20.82	1.62	12.84	1.31
1	1.5m	22.93	53	27.68	25.32	1.59	12.64	1.29
2	Top soil	10.54	-	-	-	1.45	12.84	1.31
2	0.5m	12.50	-	-	-	1.54	13.42	1.37
2	1.0m	23.81	35	22.12	12.88	1.64	12.94	1.32
2	1.5m	19.13	38	19.48	18.52	1.70	14.01	1.43
3	Top soil	8.63	-	-	-	1.37	12.45	1.27
3	0.5m	11.11	-	-	-	1.33	11.76	1.20
3	1.0m	16.55	28	23.94	4.06	1.27	10.68	1.09
3	1.5m	21.62	39	25.96	13.04	1.34	10.78	1.10
4	Top soil	9.63	-	-	-	1.36	12.15	1.24
4	0.5m	17.39	35	16.38	18.62	1.31	10.98	1.12
4	1.0m	25.6	41	27.26	13.74	1.46	11.37	1.16
4	1.5m	27.57	42	26.10	15.90	1.52	11.76	1.20

Table 3 results of particle size distribution

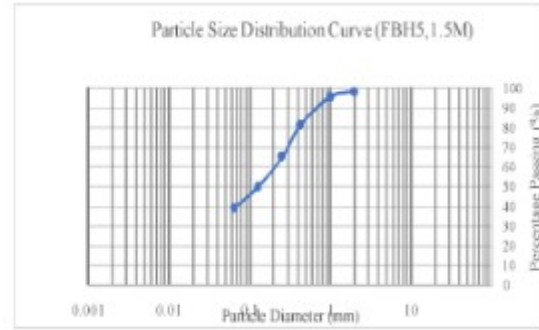
location	Depth	Sieve diameter	% passing
1	Top soil	2.0mm	99.3
		1.0mm	96.5
		0.425mm	79.2
		0.25mm	60.5
		0.015mm	46.9
		0.063mm	38.0
		Pan	36.3
1	0.5m	2.0mm	99.8
		1.0mm	96.7
		0.425mm	81.0
		0.25mm	69.3
		0.015mm	59.7
		0.063mm	53.5
		Pan	52.1
1	1.0m	2.0mm	99.8
		1.0mm	96.3
		0.425mm	81.1
		0.25mm	65.9
		0.015mm	53.6
		0.063mm	47.7
		Pan	47.5
1	1.5m	2.0mm	99.7
		1.0mm	95.3
		0.425mm	80.0
		0.25mm	65.8
		0.015mm	54.5
		0.063mm	48.9
		Pan	48.6
2	Top soil	2.0mm	98.4
		1.0mm	95.5
		0.425mm	81.2
		0.25mm	65.2
		0.015mm	49.8
		0.063mm	39.0
		Pan	38.2

Representative results of grain size distribution and liquid limit laboratory tests of some selected soil samples are presented in Figures 5 and 6 respectively. The particle size distribution curve

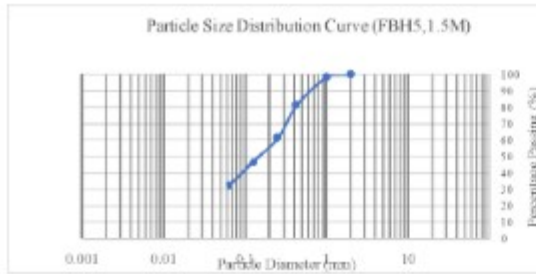
shows that the soil samples were predominantly composed of fine soils, fine-medium sands, with a lesser proportion of coarse sand and gravel fractions.



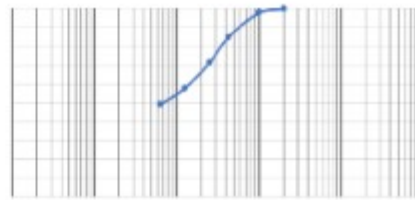
Location 1 Depth 0.5m



Location 2 Depth 1.5m



Location 2 Depth 1.0m



Location 2 Depth 1.5m

Casagrande chart (Figure 4) which essentially shows the relationship between plasticity index and liquid limit, also display domains into which the fine-grained soils and fine-grained fractions of coarse-grained soils are plotted or located in the classification. From the chart, it can be seen that most of the samples are sandwiched between the A-LINE and U-LINE and fall within the CL section.

It is noteworthy that, the USCS, BSCS and AASHTO schemes rely upon both particle size gradation and Atterberg limits for their classification, while USDA is based only on grain size analysis of the soil samples. A comprehensive summary of the laboratory analytical results which include grain type (size), liquid limit (LL), plasticity index (PI) and the four classification scheme results is presented in Table 1. Liquid limit values determined from the analysis ranged between 22%-73%, the plastic limit (PL) was 16%-36%, and plasticity index ranged between 6%-41%.


USCS

The basic criteria for determination of the USCS classification for soil samples include: (a) % passing through 0.075mm sieve, (b) % retained in 0.075mm sieve (c) the value of LL (d) the section in which PI against LL of sample plots with respect to the A-line on the Casagrande plasticity chart, and (e) gradation of the sample. From the results, classification of the thirty soil samples was such that, 6 samples each were of Fat Clay (CH) and Lean Clay categories respectively, 10 samples were classified as Clayey Sand (SC) or Silty Sand (SM), while 4 samples each were Poorly Graded Sand with Silt (SP-SM) and Poorly Graded Sand (SP) respectively. Generally, the upper sections (< 10m depth) were dominated by fine (clay and silt) sediments, while the proportion of coarse (sand and gravel) increased with depth.

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