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GEOTECHNICAL ASSESSMENT OF SUBSOILS IN PARTS OF AKWA IBOM STATE UNIVERSITY, IKOT AKPADEN, AKWA IBOM STATE, NIGERIA.

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ABSTRACT

A pre-construction assessment of the geotechnical properties of subsoils in parts of the main campus of Akwa Ibom State University was carried out to determine the stratigraphy, identify and classify the soils between 0 to 7m. Six boreholes were drilled to 7m each using a hand Auger, while soil samples were extracted for different laboratory classification tests including moisture content, atterberg limit, particle size distribution, compaction and california bearing ratio. The subsurface stratigraphic profile consists of a clayey silty sand topsoil in all the boreholes excluding BH5 where it did not occur throughout the drilled depth and BH6, where it was found from 0-7m. Underlying the topsoil is a sandy silty clay layer at different depths in BH1, BH2, BH3, BH4 and in BH5, where it was found from 0-7m. The clayey silty sands were of low to intermediate plasticity (9% to 17%) with liquid limit and moisture content values of 23% to 40 % and 15% to 41.1% respectively. The sandy silty clays had a higher plasticity index (11% to 32%) and liquid limit (27% to 92%) than the topsoil. Particle size distribution curves of the sands showed poorly graded fine to medium to coarse-grained sands with minimal gravel fractions. The maximum dry densities (1700kg/m^3 to 1770kg/m^3) fell within the acceptable range for good backfill materials although the optimum moisture content percentages (14.3% to 16.5%) were slightly higher than the acceptable range. Therefore, the soils should be improved and a bearing capacity analysis carried out before construction for an adequate foundation design.

Keywords: Geotechnical properties, Subsurface stratigraphy, Classification tests, Soil improvement, Bearing capacity analysis

INTRODUCTION

A geotechnical investigation of the subsoil is very important before any structure is built; whether it is a road, residential building or an industrial complex. This pre-construction investigation is carried out to obtain information on the physical and mechanical properties of soils and rocks underlying a construction site, for the design of an appropriate foundation for a proposed structure and for the repair of distress, caused by subsurface conditions. The physical (textural) properties of the soil such as the particle size distribution and the plasticity, which are used in the identification and classification of the soil, are obtained from laboratory tests on disturbed soil samples (Akpokodje, 2001). The need for adequate and reliable geotechnical characterization of subsoils is fundamental because the negative impacts of imposed loads are exacerbated by the thickness and consistency of the compressible soil layers (Oke and Amadi, 2008). Subsurface stratigraphic investigations in the Niger Delta have shown that the presence of compressible clay soil layers are very common in the Niger region, where they may occur at shallow depths close to the ground surface or at greater depths as intercalations within sands. This, in addition to other intrinsic factors, contribute to the failure of civil engineering structures (Youdeowei and Nwankwoala, 2013). Consequently, experts in the field of geology and geophysics have often emphasized a lack of adequate information on the nature of subsurface conditions before construction as a major contributor to this phenomenon (Adebiyi et al., 2019). This is why a clear understanding of the occurrence, composition, distribution, geologic history as well as the geotechnical properties of subsurface soils in an area is necessary (Ngah and Nwakwoala, 2014). To improve the standard of working and learning in a more conducive environment, the main campus of Akwa Ibom State University Ikot Akpaden is undergoing an expansion of its internal roads, hotels and office complexes. An assessment of the geotechnical properties of subsoils is carried out as a pre-construction investigation to determine the stratigraphy, identify and classify the subsoils between 0-7m for the proposed structures within the campus.

Description of study location

Akwa Ibom State University located in Ikot Akpaden, Mkpat Enin local government area of AkwaIbom State, Nigeria lies between longitude 7˚46ˈ0" E and 7˚46ˈ45" and latitude 4˚37ˈ0" N and 4˚37ˈ45" N. This study area is located in the Tertiary Niger Delta sedimentary basin which consists of a regressive clastic succession, which attains a maximum thickness of 12,000m (Orife and Avbovbo, 1982). The lithostratigraphy of the Tertiary Niger Delta can be divided into three major units: Akata, Agbada and Benin formations, in order of decreasing age with depositional environments ranging from marine, transitional and continental settings respectively (Short and Stauble, 1967). The study area falls within the Benin Formation which consists predominantly of fresh water continental friable sands and gravel that are of excellent aquifer properties with occasional intercalation of shales. The Benin Formation is overlain by various types of quaternary alluvial deposits comprising mainly of recent deltaic sand, silt and clay of varying thickness. These alluvial deposits occur in five major geomorphic units namely; Active and abandoned coastal beaches, Saltwater/Mangrove swamps, Freshwater swamps, Sombreiro-Warri deltaic plain with abundant freshwater swamps and the Dry flat land and plain (Akpokodje,2001). The Benin Formation constitutes the regional aquifer in the Niger Delta, knowledge of the groundwater conditions in the Niger Delta area can be obtained from various studies including Etu-Efeotor and Akpokodje (1990), Nwankwoala and Udom (2011) etc. Geomorphologically, Akwa Ibom State is generally a flat, low-lying terrain and riverine environment (Usoro, 2010). The land rises steadily northward from the sea level at Eket in the south to 150m at Obotme in the north (Beka and Udom, 2014).

MATERIALS AND METHODS

Soil samples (disturbed) were collected at regular intervals of 1m each, from six boreholes drilled in different locations (Fig. 1) and (Table 1) across the main campus to a maximum depth of 7m each using a hand Auger. The soil samples were described on the field and bagged for different classification (index) tests in the laboratory such as moisture content, atterberg limits, particle size distribution, compaction and california bearing ratio test (CBR) according to the American society for testing and materials, ASTM (1975), British standard BS 1377 (1990) and BS 5930 (1999).

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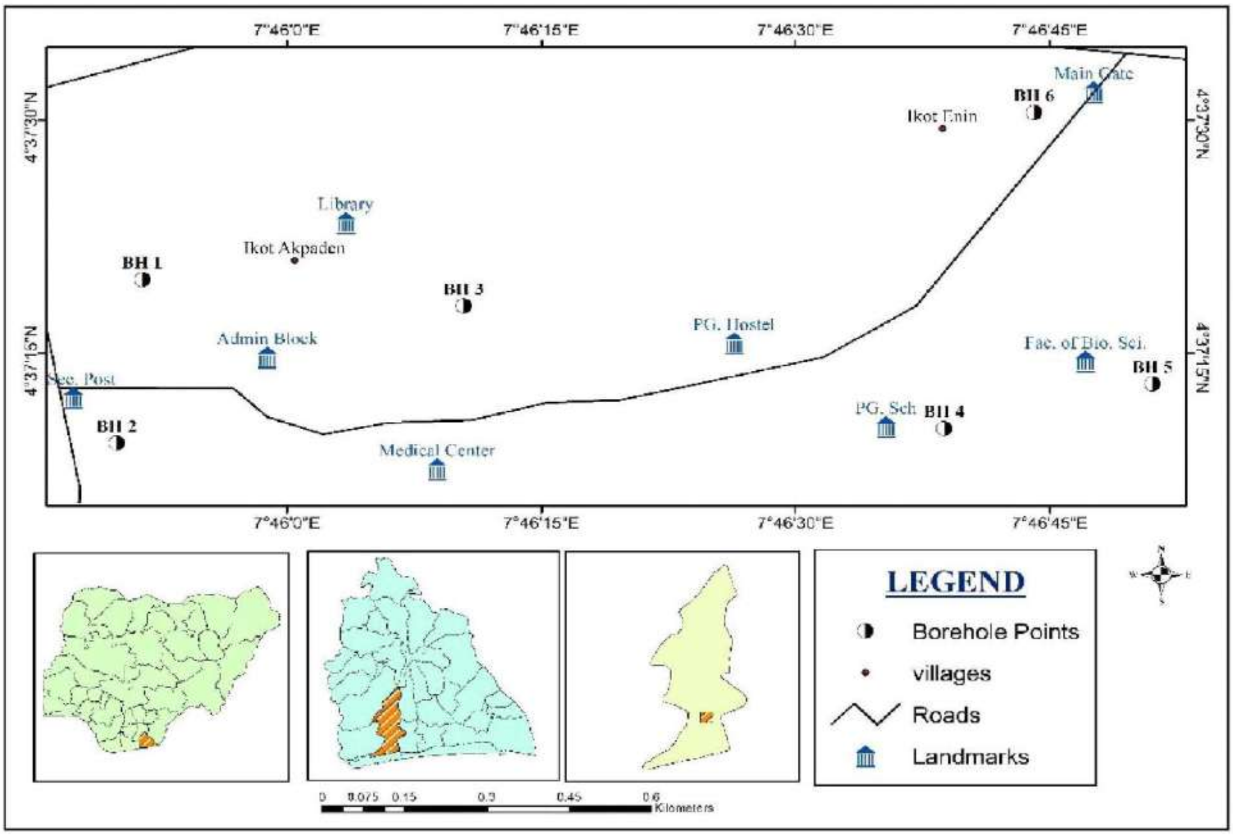

Fig 1: Map of Mkpat Enin Local Government Area showing the borehole locations in Akwa Ibom State University

Table 1: Borehole locations and their co-ordinates

Sample location	Longitude	Latitude
BH1	E007˚45’47.2”	N04˚37’23.1”
BH2	E007˚45’44.9”	N04˚37’14.4”
BH3	E007˚45’11.8”	N04˚37’17.8”
BH4	E007˚46’34.4”	N04˚37’11.2”
BH5	E007˚46’44.4”	N04˚37’14.9”
BH6	E007˚46’40.1”	N04˚37’31.8”

RESULTS

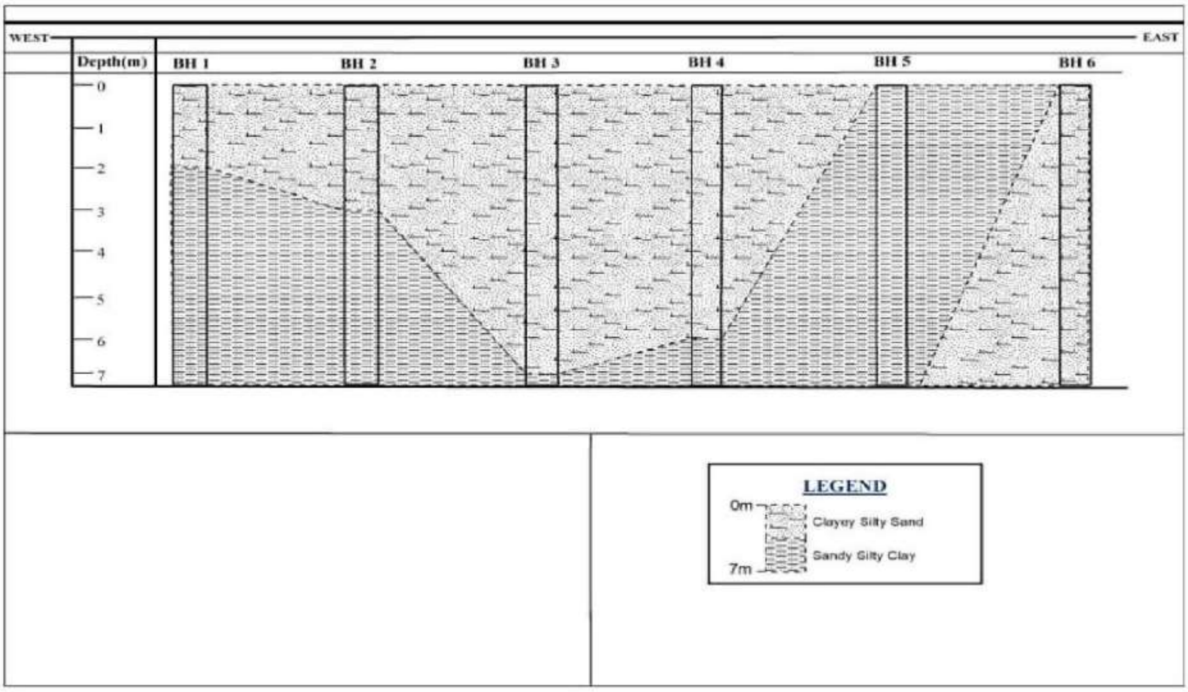

Fig. 2: Stratigraphic profile of subsoils in the main campus of Akwa Ibom State University, showing the different lithologies between 0-7m depth

Table 2: Average values of the geotechnical index properties of the clayey silty sand

Sample location	BH1	BH2	BH3	BH4	BH6
Moisture content (%)	17	41.1	20.2	21.3	15
% Fines (clay & silt)	33.13	48.07	38.93	49.0	36.73
% Sand	66.87	51.80	59.27	51.0	63.13
D_{50}	0.39	0.50	0.11	0.08	0.30
LL (%)	40	23	35	36	37
PL (%)	23	14	23	22	20
PI (%)	17	9	12	14	17
LS (%)	7.14	21.43	11.43	24.29	10.0
USCS	CI	CL	CL	CI	CI
Omc (%)	16.5	14.3	15.0	14.3	15.0
MDD (kg/m3)	1700	1770	1740	1740	1740
CBR (%) soaked	12	3	7	4	7
AASTHO CLASSIFICATION	A-2-6	A-4	A-6	A-6	A-6

LL- liquid limit (%) PL-plastic limit (%) PI-plasticity index (%) LS-linear shrinkage (%) USCS-Unified Soil Classification System, OMC-Optimum Moisture Content, MDD-Maximum Dry Density, CL-Clays of Low Plasticity, CI-Clays of Intermediate plasticity CBR-California Bearing Ratio

Table 3: Average values of the geotechnical index properties of the sandy silty clay

Sample location	BH1	BH2	BH5
Moisture content (%)	79.6	73.9	27.6
% Fines (clay & silt)	86.0	85.6	29.0
% Sand	14.0	14.4	71.0

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D_{50}	0.50	0.32	0.14
LL (%)	92	56	27
PL(%)	60	33	16
PI(%)	32	23	11
LS (%)			7.86
USCS	MV	MH	CL
Omc (%)	-	-	16.5
MDD (kg/m3)	-	-	1700
CBR (%) soaked	-	-	12
AASTHO CLASSIFICATION	-	-	A-2-6

CL- Clays of low plasticity MH- High plasticity of Silts MV- Very high plasticity of silts

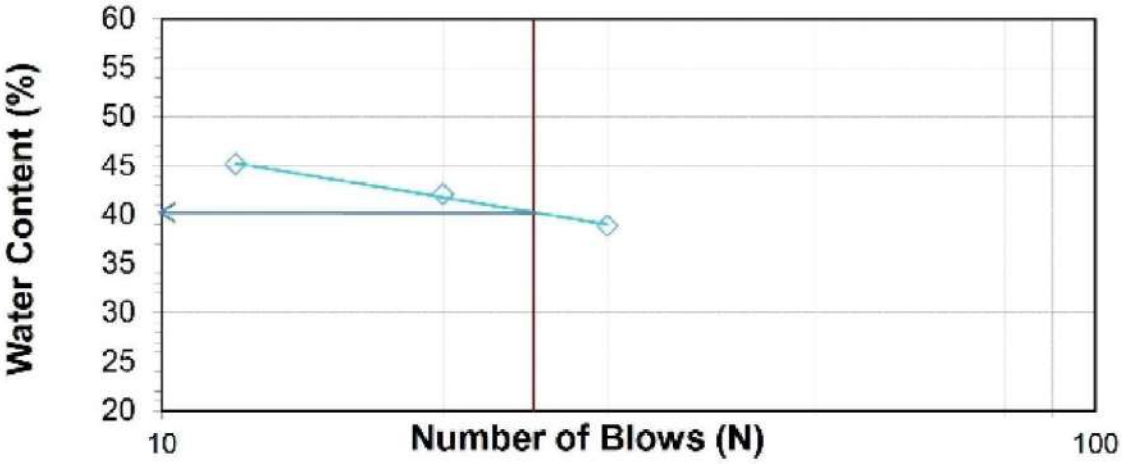

Fig. 3: A plot of the moisture content against the number of blows showing the Liquid limit percentage (40%)of the clay in BH1 at a depth of 2m

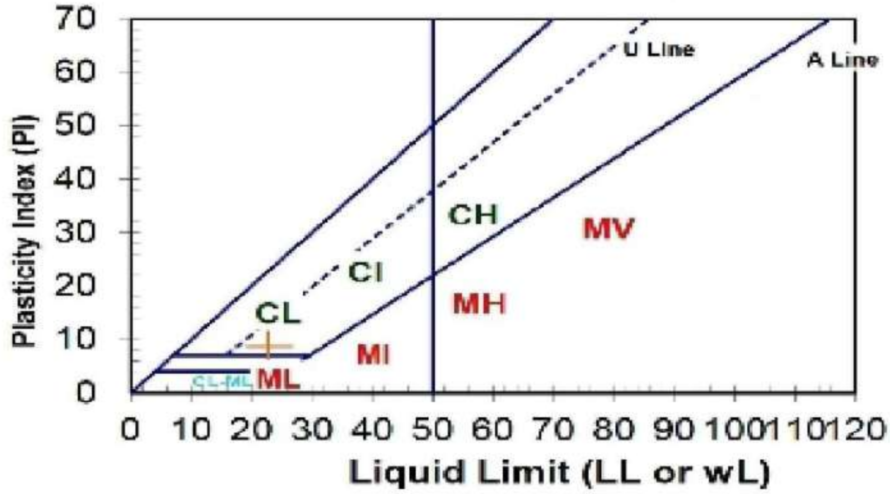

Fig.4: Plot of the Plasticity Index versus Liquid Limit showing the low plasticity of clay in BH2 at a depth of 1.0m in the clayey silty sand layer.

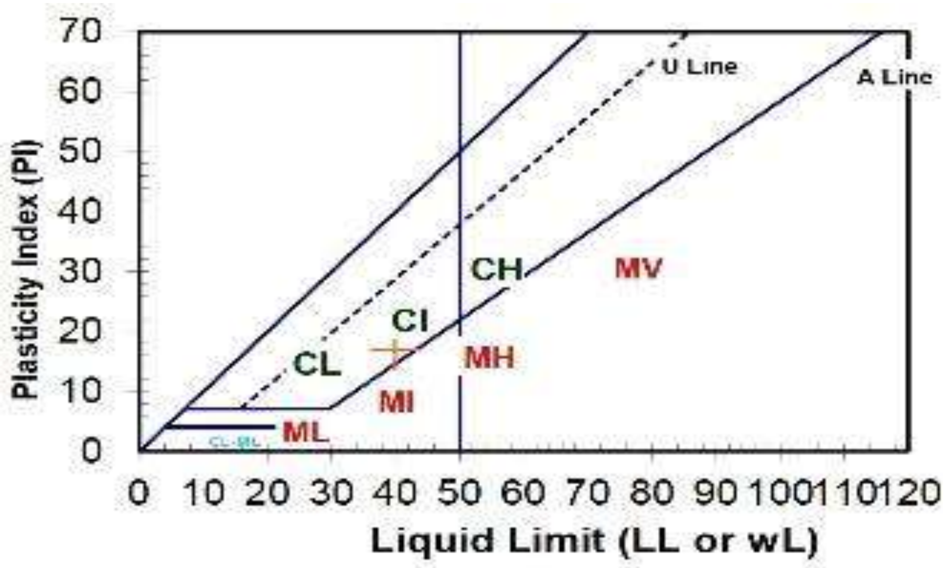

Fig.5: Plot of the Plasticity Index versus Liquid Limit showing the intermediate plasticity of clay in BH1 at a depth of 2m in the clayey silty sand layer.

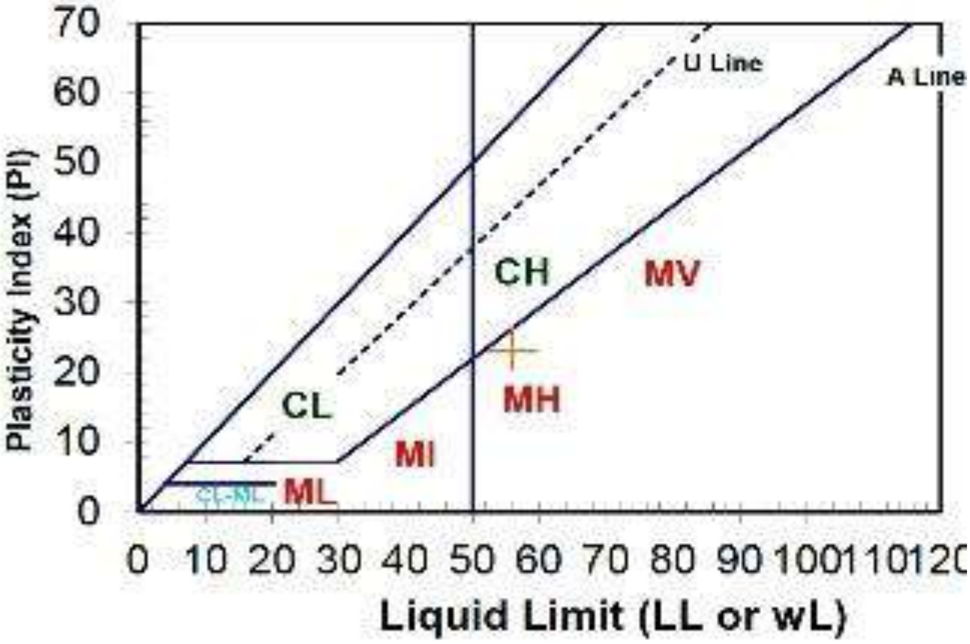

Fig. 6: Plot of the Plasticity Index versus Liquid Limit showing the high plasticity of silts in BH2 at a depth of 6m in the sandy silty clay layer.

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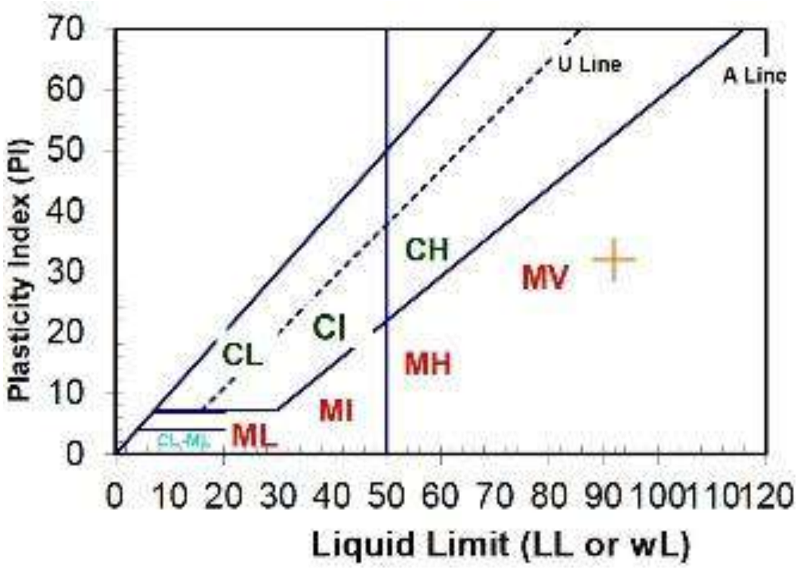

Fig. 7: Plot of Plasticity Index versus Liquid Limit showing the very high plasticity of silts in BH1 at a depth of 7.0m in the sandy silty clay layer.

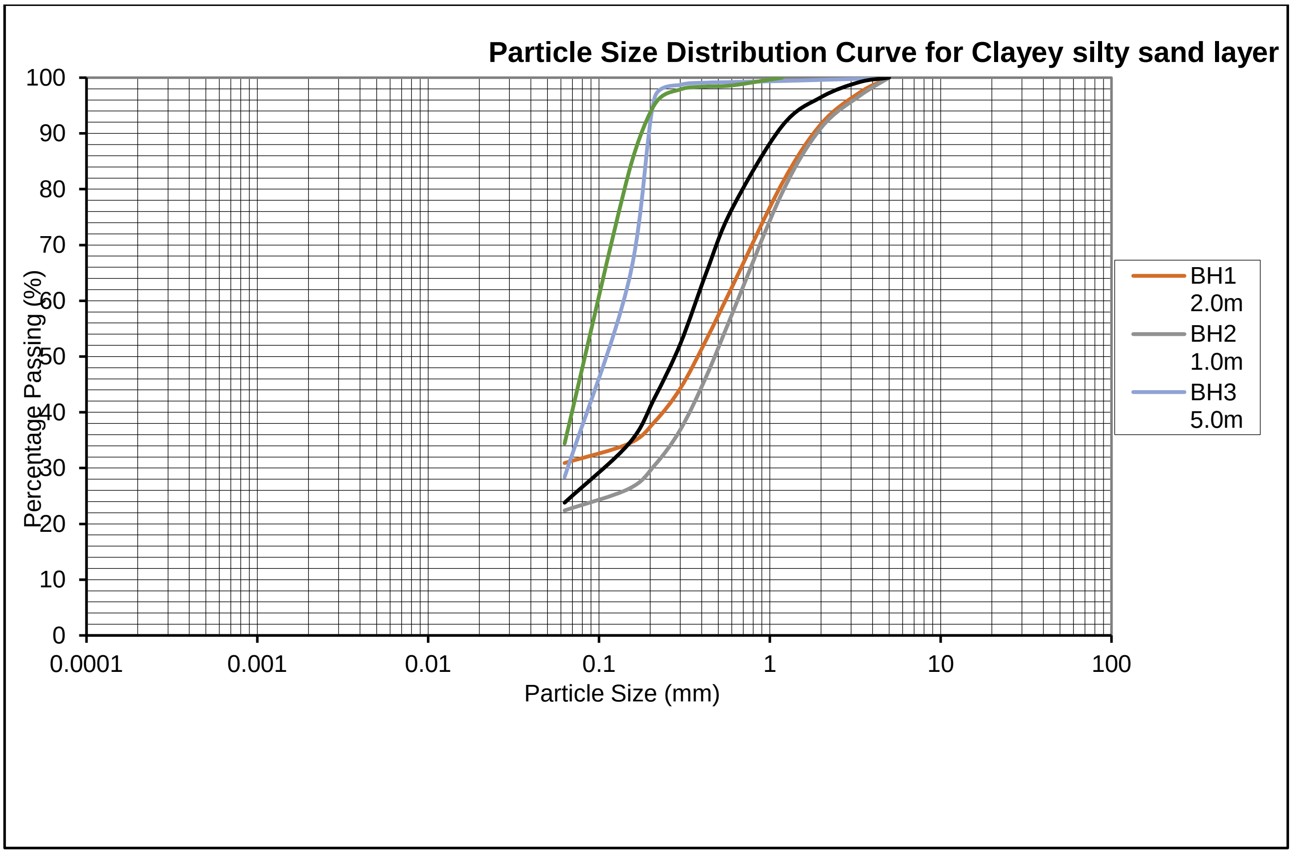

Fig. 8: Representative curves of the particle size distribution showing the soil fractions in different boreholes for the clayey silty sands

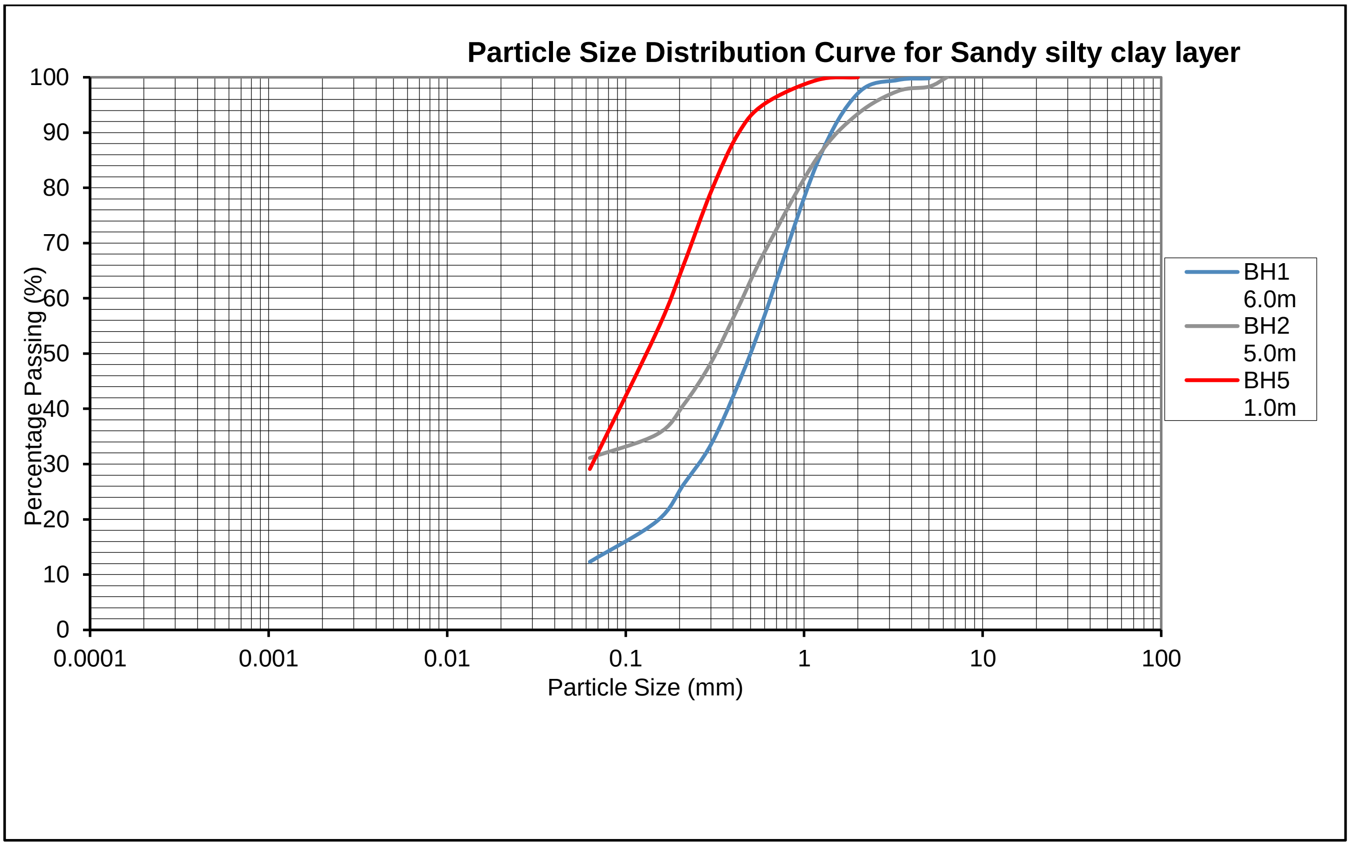

Fig. 9: Representative curves of the particle size distribution showing the soil fractions in different boreholes for the sandy silty clays

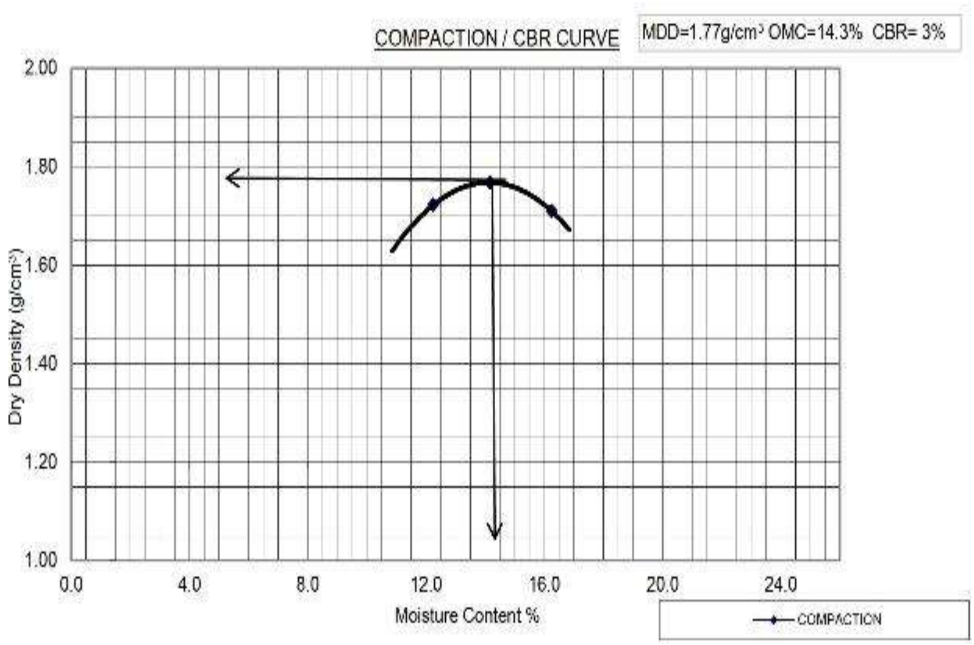

Fig. 10: The maximum dry density versus optimum moisture content plot of soils in BH2

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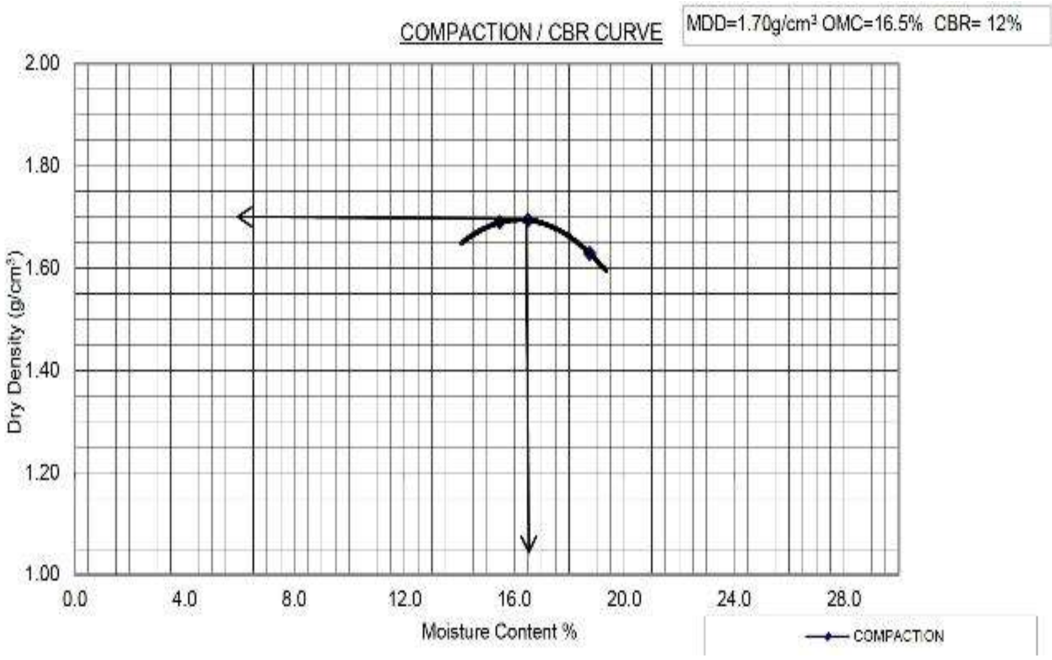

Fig. 11: The maximum dry density versus optimum moisture content plot of soils in BH5

DISCUSSION

Stratigraphy

The subsurface stratigraphic profile (Fig. 2) consists of two different lithologies a light to dark brown, clayey silty sand topsoil between 0 to 2m in BH1, 0 to 3m in BH2, 0 to 6.5m in BH3, 0 to 6m in BH4 and 0 to 7m in BH6. The clayey silty sand was not present in BH5. Underlying the upper layer of soil to the termination depth of 7m , is a sandy silty clay soil between 2m to 7m in BH1, 3m to 7m in BH2, 6.5m to 7m in BH3, 6m to 7m in BH4 and 0 to 7m in BH5. The geotechnical index properties of the clayey silty sand and sandy silty clay are discussed below.

Clayey silty sand

The average values of the geotechnical index properties of the clayey silty sand presented in Table 2 showed the moisture content of the soil ranged from 15% in BH6 to 41.1% in BH 2, while the percentage of fines (clay & silt) ranged between 33.13% in BH1 to 49% in BH4. The moisture content of a soil varies greatly with season, clay and organic content (Akpokodje, 1986) as shown by the range in the percentages of fines and moisture contents in this layer. The soils were of low plasticity in BH2 and BH3 with liquid limit values of 23% and 35%, plastic limit values of 14% and 23% and plasticity index values of 9% and 12% respectively. An intermediate plasticity clay was found in BH1, BH4 and BH6 with average liquid limit values of 40%, (Fig. 3) 36% and 37% respectively and plasticity index values of 17% in (BH1, BH6) and 14% in BH4. The low plasticity values of the clayey silty sands in BH2 and BH3 may be attributed to the percentages of fines 48.07% and 38.93% respectively present in these boreholes. Generally, the liquid limit values of the clayey silty sands fell below 50% indicative of the low to medium compressibility of this soil according to British standard 5930 (1999) and the low to medium swelling potential as presented by the plot of the soil above the A-line in the region of low to intermediate plasticity (CL - CI) on the plasticity chart in figures 4 and 5. Similar plasticity values have been obtained by Ehibor *et al*., (2019) for soils in Uyo town, Akwa Ibom state.

The particle size distribution graph of the clayey silty sand in Figure 8 displayed a poorly graded, fine to medium to coarse grained sand, with minimal gravel fractions in BH1, BH2 and BH6. These results along with the mean diameter (D_{50}) of the sand which ranged from 0.08mm to 0.50mm are indicative of the low water retention capacity of the sands. Optimum moisture content percentages (OMC) of the clayey silty sands vary between 14.3% and 16.5%, while the maximum dry densities (MDD) were between 1700kg/m^3 to 1770kg/m^3. BH1 had the highest OMC of 16.5% and the lowest MDD of 1700kg/m^3, while BH2 with an OMC of 14.3%, had the highest MDD of 1770kg/m^3 as shown on the compaction plot in Figure 10. Although the optimum moisture content and maximum dry densities of the soil demonstrate that the clayey silty sands can be used as backfill materials, their low CBR values which ranged from 3% in BH2 to 12% in BH1 points out that the soils cannot be used as a sub base in pavement construction. These results are similar to the outcomes of Ehibor and William (2023) on the textural characteristics of subsoils in Ikot Akpaden, Eastern Niger Delta, but differ from the findings by Avwenagha *et al.,* (2014) on geotechnical properties of subsoils in Warri, Western Niger Delta. The soils are classified as A-2-6, A-4 and A-6 soils according to AASHTO (1975) which implies that they are fair to poor subgrade materials. Some A-2, A-4 and A-6 soils can however be used for general filling provided the percentage of fines are less than 35% and soaked CBR above 5% (Ugbe, 2011).

Sandy Silty clay

The average values of the geotechnical properties of the sandy silty clays as presented in Table 3, showed that the sandy silty clays, which generally had a higher percentage of fines than the topsoil were of a low plasticity (CL) in BH5 with a liquid limit average of 27%, moisture content average of 27.6% and plasticity index average of 11%. A high plasticity silt (MH) exists in BH2 with a plasticity index value of 23%, liquid limit of 56% and moisture content value of 73.9%. A very high plasticity silt (MV) was found in BH1 with a plasticity index value of 32%, moisture content of 79.6% and liquid limit of 92%. Similar moisture content and plasticity index values in the Niger Delta have been obtained by Ezenwanka *et al.,* (2014), Ehibor and Akpokodje (2019) and Ashioba and Udom (2023). The soils in BH2 and BH1 plotted below the A-line in the region of high plasticity silts (MH) and very high plasticity silts (MV) on the plasticity plots in figures 6 and 7 respectively. These results implied a low to high compressibility of the soils according to BS 5930 (1999) and a low to high swelling potential of the soil. The particle size distribution graphs of the sandy silty clay in Figure 9 displayed a poorly graded fine to medium to coarse grained sand with minimal gravel fractions in BH1 and BH2. It had a mean diameter ($D_{50)}$ ranging from 0.14mm to 0.50mm. The results of the particle size distribution infer the free draining ability of the sand while their compaction results have shown that the soils with an OMC of 16.5% and MDD of 1700kg/m^3 (fig.11) are suitable backfill materials but cannot be used as a sub base because of their low CBR value of 12%. The soils were also classified as A-2-6 soil according to AASHTO (1975) which indicates that the soils are fair to poor subgrade materials.

CONCLUSION

The pre-construction investigation of the geotechnical properties of subsoils between the depth of 0-7m in parts of the main campus of Akwa Ibom State University revealed two different stratigraphic profiles from soil samples obtained during drilling namely; a clayey silty sand and a sandy silty clay. The clayey silty sands which formed the topsoil in all the boreholes excluding BH5 where it did not occur throughout the drilled depth and BH6 where it was present from 0-7m the depth of termination, had liquid limit values generally below 50% and a low to intermediate plasticity indicating the low to medium compressibility of the soil. The sandy silty clay was found beneath the topsoil in all the boreholes at different depths excluding BH5 where it was present from 0-7m and BH6 where it did not occur all through the drilled

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depth. This layer of soil which had a higher percentage of fines and liquid limit than the topsoil also had the presence of a high plasticity silt (MH) in BH2 and a very high plasticity silt (MV) in BH1.Generally, the particle size distribution curves of the clayey silty sand and sandy silty clay showed poorly graded fine to medium to coarse grained sands with minimal gravel fractions. Although the maximum dry densities of the soils in all the locations fell within the recommended range for good backfill materials, the optimum moisture content of the soils were slightly higher than the acceptable range. Thus, the soils were classified as A-2-6, A-4 and A-6 soil types which depicts fair to poor subgrade materials. The low CBR values also showed that the soils were unsuitable as sub base materials. From the results of the liquid limit, plasticity index, particle size distribution, maximum dry density and optimum moisture content, it can be concluded that the soils are appropriate as backfill materials however, due to their classification as A-2-6, A-4 and A-6 soils, the soils should be improved to be utilized as subgrade materials and the bearing capacity of the soils should be determined before the commencement of construction for an appropriate foundation design of the proposed structures.

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