ENGINEERING GEOLOGICAL PROPERTIES OF SUBSOILS OF YENAGOA IN NIGER DELTA, NIGERIA.

[1]ONYEBUOLISE, B. C. & [2]AKPOKODJE, Enuvie G.
[1]Civil-Marine Department-Deep Water Projects, (SNEPCo), Lagos.
[2] Department of Geology, Faculty of Science, University of Port Harcourt, Nigeria.

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ABSTRACT
The major aim of this research work is to determine the stratigraphy and engineering geological properties of foundation subsoils of Yenagoa, the fast growing capital city of Bayelsa state in the Niger Delta, which can be used as reference database for future infrastructure and environmental development of the area. A total of six (6) boreholes were drilled to depths of about 20m and soil samples were subjected to several geotechnical tests (including natural moisture content, particle size distribution, plasticity, bulk density, specific gravity, organic content, shear box test, consolidation, etc). The study revealed that the subsoil profile from 0 - 20m, essentially consists of an organic clayey-silt top layer, a middle sand stratum and a gravelly-sand at the bottom. There are great variations in the values of the geotechnical index properties of the soils hence the geotechnical data of one location cannot be used as a basis for design of foundation in other locations. The top organic silty clay horizon can only be considered as foundation substratum for very small/light civil engineering structures whilst the sand and gravelly- sand horizons constitute the best foundation substratum for medium and large civil engineering structures.

INTRODUCTION

Since the discovery of oil in the Niger Delta in the 1950's, considerable research efforts and publications have been directed towards understanding and quantifying the geology and properties of reservoir and source rocks. By contrast, little effort has been made in understanding the engineering geological properties of shallow sub-surface soils which constitute the foundations of many civil engineering structures such as housing units, oil production facilities, pipelines, etc which are directly or indirectly related to the oil and gas industry. Akpokodje (1986, 1987), Abam and Okogbue (1997) and Teme (2002) observed that the shallow subsurface zone of interest in foundation engineering has remained poorly studied. They also noted the low foundation quality of the subsoils because of the frequent and erratic occurrences of highly compressible organic and peaty clays. The properties of these soils and their variations have not been clearly understood.

The overall objective is to determine the stratification and geotechnical properties of subsoils of Yenagoa, the capital of Bayelsa State, in the Niger Delta.

The study location, Yenagoa, capital of Bayelsa state of Nigeria lies between latitudes 6° 15′ 51″ in the East and longitude 4° 55′ 29″ in the North. In the East, it is bounded by the Rivers state, in the West and North by Delta state, in the south and west by the Atlantic Ocean (Fig. 1.1). Bayelsa State was created in 1996 from the former Rivers state. The geomorphology of this region is characterized by lowlands and plains with small rivers and creeks all discharging into the Atlantic Ocean. The main vegetation is mangrove/fresh water swamp. Yenagoa has a riverine and estuarine setting like other deltas and most low lying land in other parts of the world (Mississippi, Mekong deltas,etc).

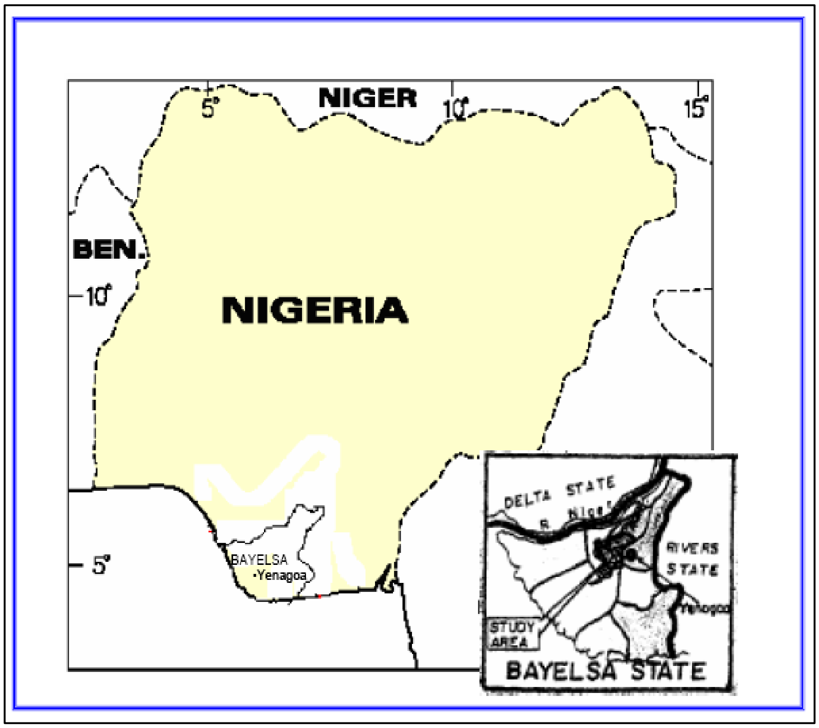

Fig 1 Location Map of Study Area (Yenagoa, Bayelsa of Nigeria)

METHOD OF STUDY

Soil Boring, Sampling and In-Situ Testing

The field investigation involved soil boring, in-situ testing and sampling performed according to procedures specified in methods of site investigation (BS 1377, 1990). A total of six boreholes were drilled to maximum depth of 65ft (20m). The detailed geo-references of the six boreholes arte presented in Table 1 whilst the borehole locations are shown in Figure 2. The drilling equipment comprises of a monopole airframe with a horizontal turntable clamp. A flexible horse was also attached to the open end to inject water into the drilled hole during stuck pipe to release the drilling pipe. The drilling technique is purely manual drilling. SPT was the only in-situ carried out in the field. In this test, a 50mm diameter spoon sampler was driven 450mm into the cohensionless strata using a 63.5kg hammer free-falling through a height of 760mm; the number of blows required to effect the last 300mm penetration is termed the penetration resistance, or N-value.

Laboratory Testing

The basic engineering index property tests, as well as shear and compressibility tests, were carried out in the laboratory according to procedures specified by various sections of British Standards as contained in BS 1377 (1990). The index property and classification tests carried out included: (I) Natural moisture content (II) Atterberg limits (III) Particle size distribution (Dry and Wet sieve), (IV) Specific gravity (V) Bulk density. The strength and compressibility tests included are (i) Shear box test and (ii) Oedeometer consolidation test

Table 1. Location Data of the 6Nos Boreholes

Borehole No	GPS Location	Description
1	04 57 55N, 006 24 42E	(Along NDU road to Amassoma)
2	05 00 87N, 006 23 66E	(at Okaki Junction)
3	04 56 35N, 006 20 24E	(OPOLO-ELEBELE roundabout)
4	04 50 46N, 006 17 82E	International conference center)
5	Location: 04 54 41N, 006 16 87E	(Swali-Oxbow Lake roundabout)
6	04 56 42N, 006 16 27E	(Surveyor General office compound)

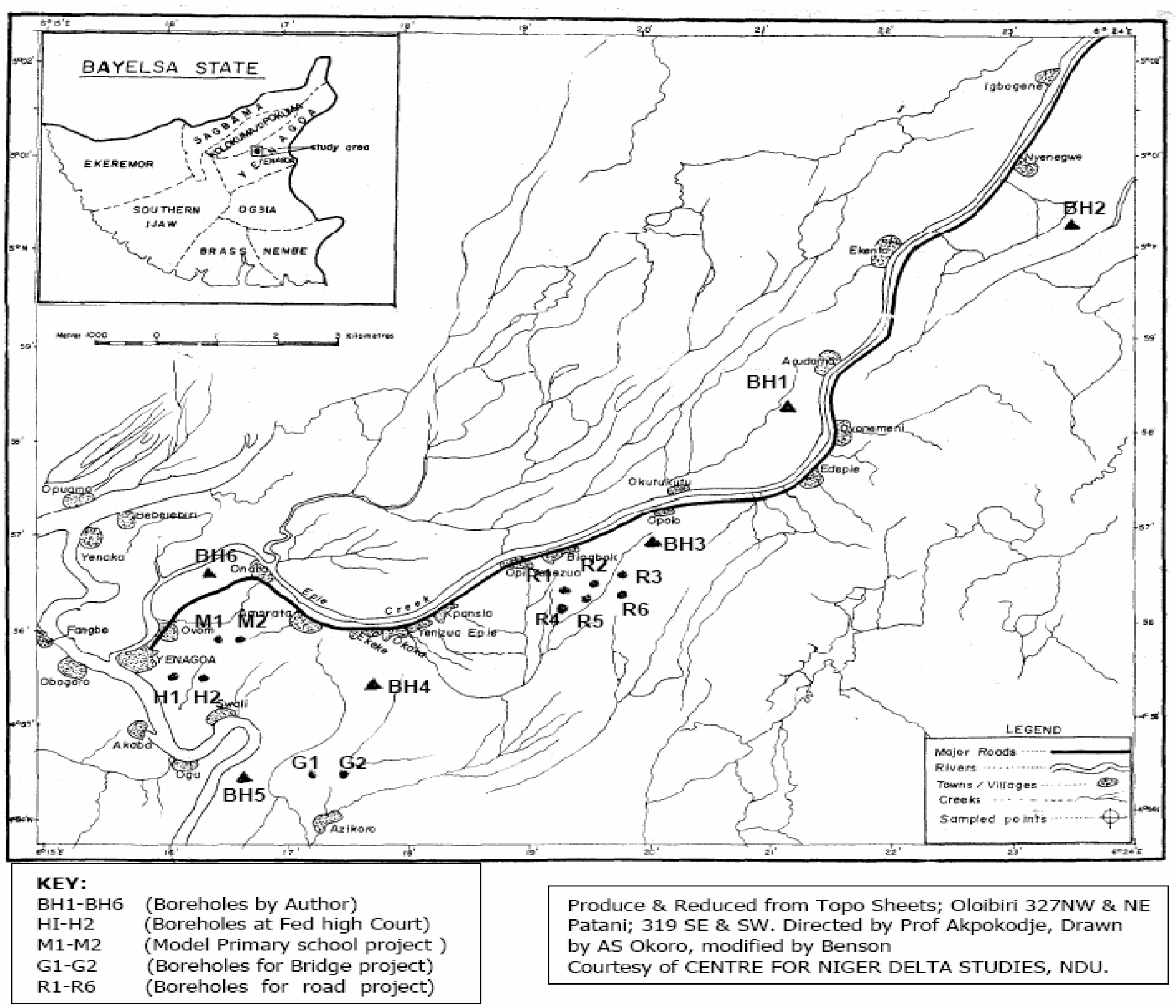

Fig. 2 Map of the Area showing locations of boreholes

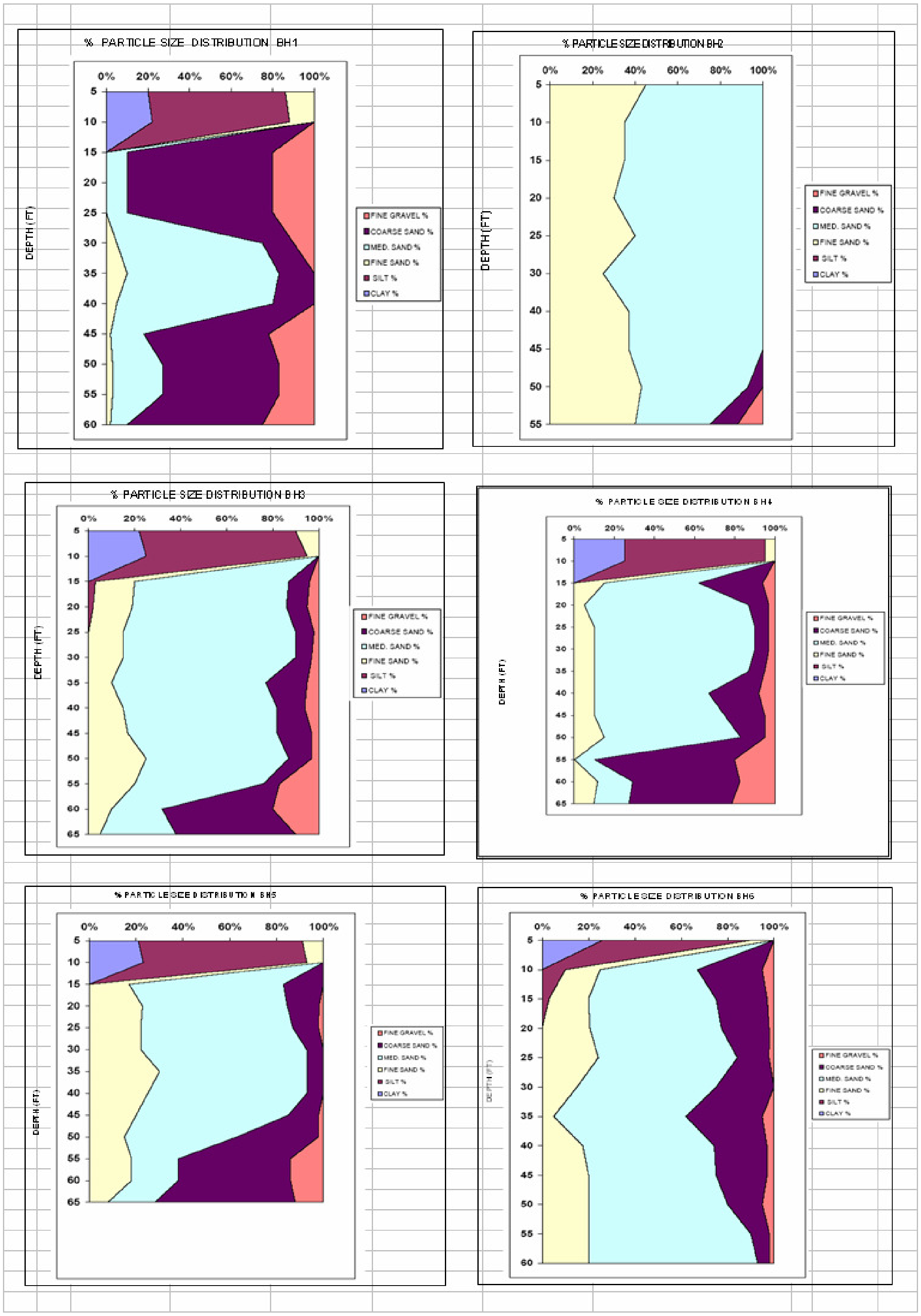

Fig. 3 Textural histograms of the boreholes

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RESULTS OF ANALYSIS AND DISCUSSIONS.

The textural variations in the six boreholes are presented in the form of textural histograms in Figure 3. A close study of the figures shows the dominance of medium to coarse sand throughout the profiles with the silty clay mostly confined to the top horizon.

Generally the profiles have similar textural patterns with the exception of borehole BH1 where the top organic silty clay is absent. A plot of the top silty clay on the Casangrande plasticity chart (Fig. 4) reveals that the clays vary from medium to high plasticity.

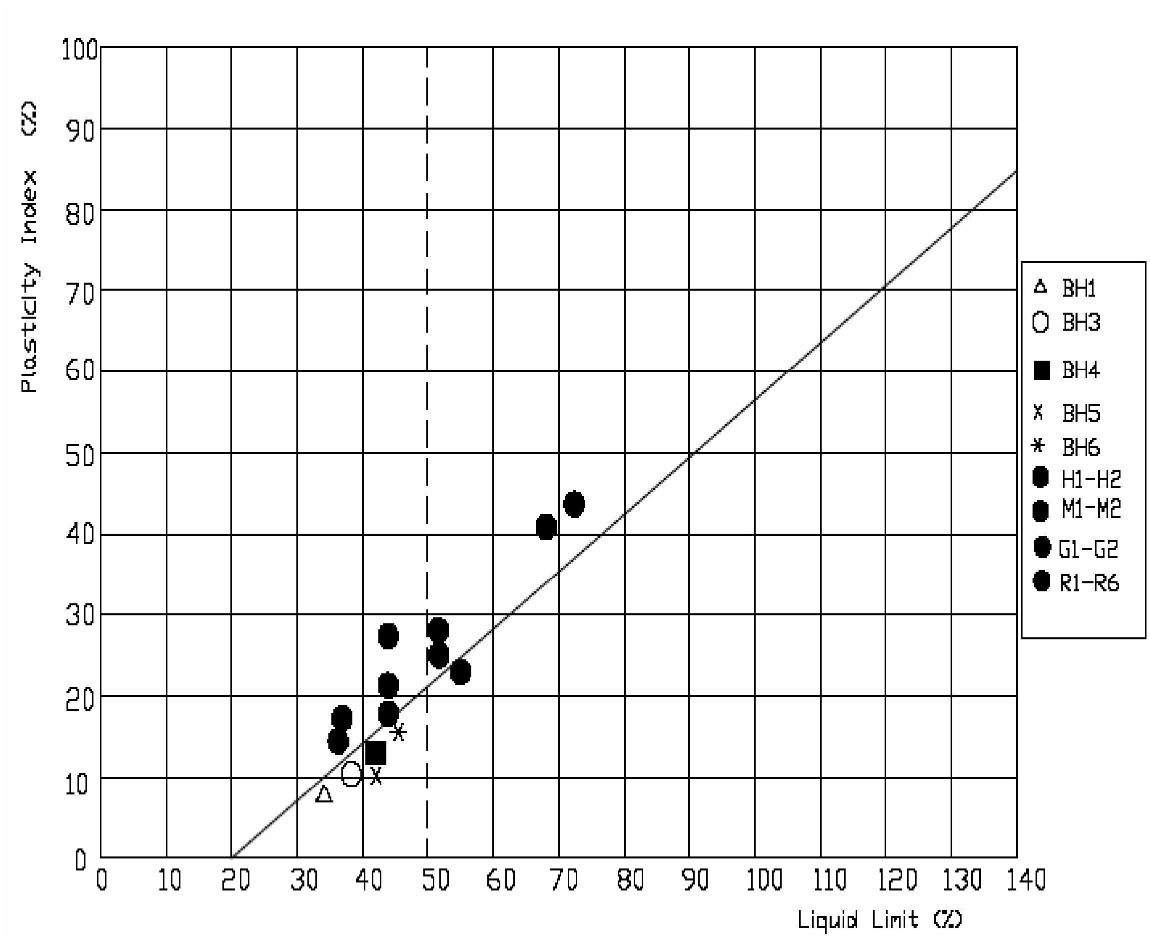

Fig. 4 Plasticity of the top silty clays

Types of subsoil profiles

Four types of subsoil profiles (Fig. 5) were identified in the study area. The major characteristics of these subsoil profile types are outlined below.

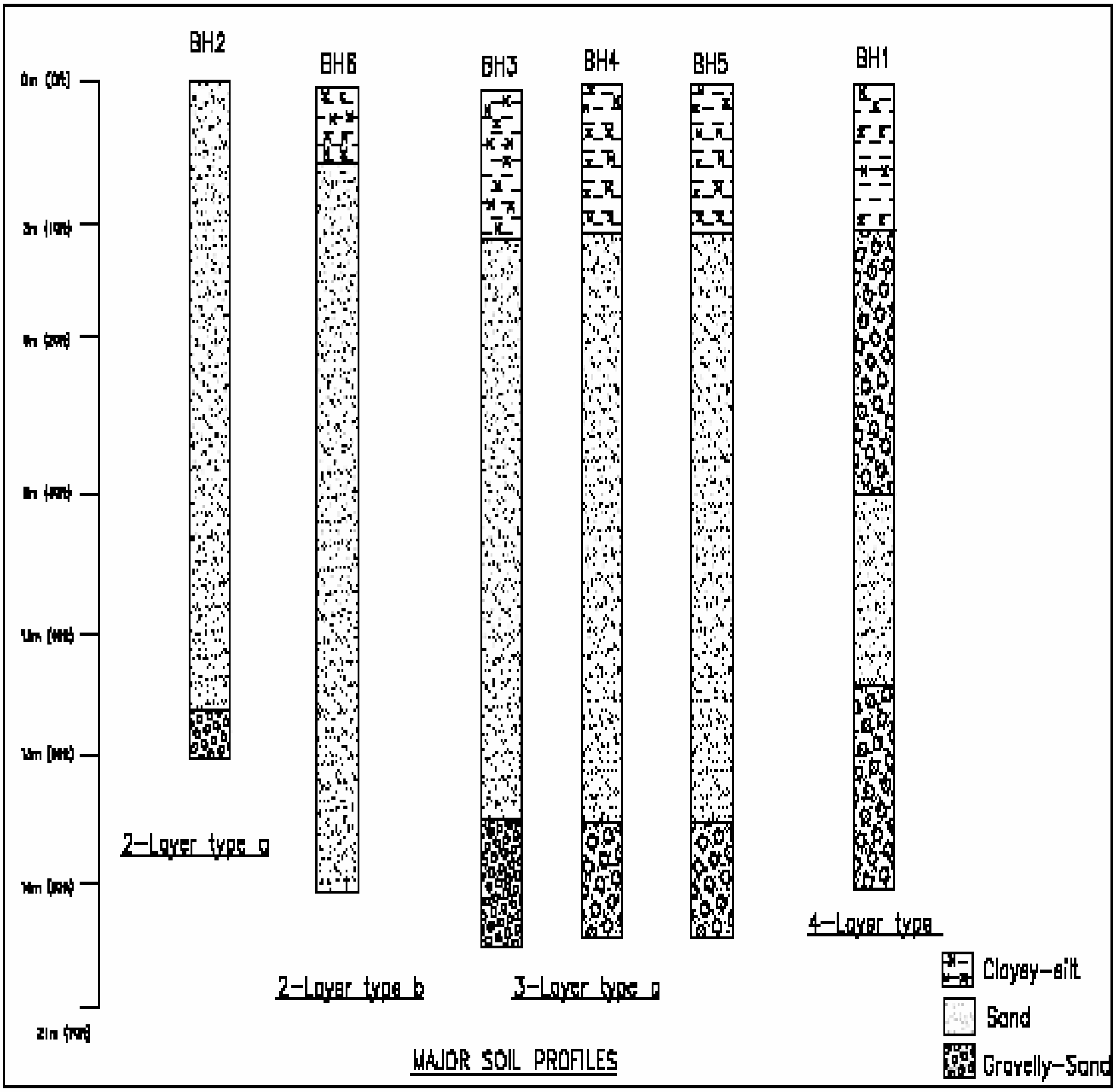

Fig 5 Four types of subsoil profiles

Two-layer type "a" subsoils profile.

The two-layer subsoil profile occurs only in Borehole location BH2 (around Okaki junction) area. The highly rich organic topsoil layer is absent. The profile is characterized by: (i) Sandy soil of about of 10.0m thick at the top and underlain by a 3m thick gravelly-sand layer and (ii) The absence of the clayey-silt layer may be due to erosional washout or human interferences after deposition.

Two-layer type "b" subsoil profile.

This type of subsoil profile consists of: (i) a thin layer of brown to dark, clayey or clayey-silt soil. It is very soft, fibrous and highly compressible with SPT values of less than 10 blows. The layer extends from the ground surface to a depth of about 3m, (ii) Underlying the organic rich clayey-silt is a layer of loose to medium dense fine to medium grained sand. It occurs between 3 and 18 meters below the ground surface. The SPT ranges between 12-20. This subsoil profile type is one of the dominant profiles and was encountered in central Yenagoa occurring within the Surveyor general office complex and also around Akaka and central Yenagoa.

Three-layer type "a" subsoil profile

This is the most dominant subsoil profile type in Yenagoa. It occurs around the locations of Opolo-Elebele roundabout, International conference center, within Swali Oxbow lake roundabout and also on boreholes R3-R6 (along Aziko-Agbura-Otiokpoti road). This profile consists of:

(i) Top, soft, highly compressible and fibrous clayey-silt (3m thick),
(ii) (ii) Middle layer of dense gravelly-sand (about 6m thick), with occasional medium sand. The range of STP value is 18-26 and
(iii) The third layer consists of dense gravelly-sand (3-8m thick).

Four-Layer type subsoil profile

The profile consists of the following:

(i) Top, soft, dark brown clayey-silt occurring from surface to 3m depth,
(ii) thick gravelly-sand underlying the clayey-silt (an unusual occurrence within the location)
(iii) Fine to medium sand
(iv) Dense gravelly-sand (3-8m thick). This subsoil profile occurs mainly around the road to Amassoma (North East Yenagoa city).

SETTLEMENT ANALYSIS

The settlement evaluation is based on Terzaghi equation and Hough method (see below) using the Chart method of vertical stress distribution. The summary of settlement in all the boreholes (BH1-BH6) is presented in fig 6.

The definitions of the variables used in the model on fig 1.8 are:

r= radius of foundation, **D**= diameter , **Z**= Depth, $\mathbf{q_o}$= initial pressure

$\mathbf{a_i}$= 1-1/(1+(R/Z)2)3/2 (correction coefficient), $\mathbf{q_v}$ = qo*ai (kpa), final pressure

Cc= consolidation index, $\mathbf{q_v}$'= qo-qv, (incremental pressure)

Se= (qv*hi)/Ei (settlement)………………. Terzaghi settlement equation

Se= h*1/Cc*lin(qo+qv')/qv'………… …………Hough settlement equation

$\mathbf{C_c}$= e'/log P2/P1 = e'/log 10 from e – log P graph

E= 2900N for Sands (Table 5.6- Foundation Analysis & design)

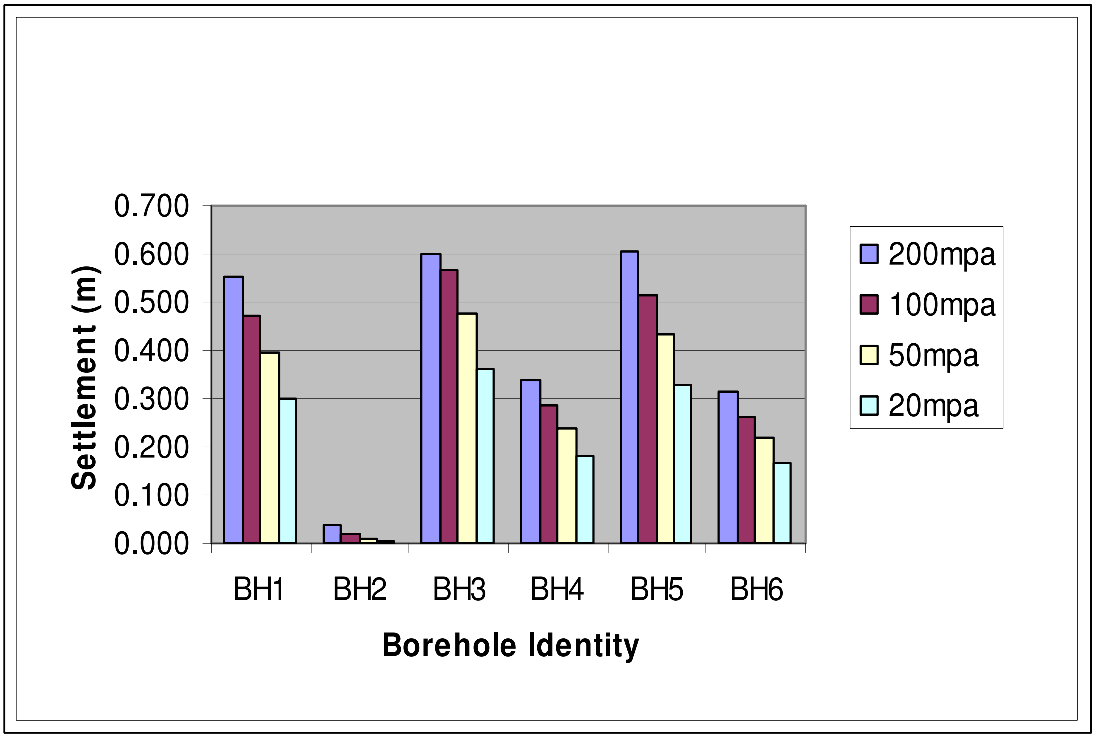

Fig 6 Settlement Model Results for Various Loadings

The foundation loading concept considered a point load, and the radius of influence is 10m from the centre of foundation. From the results, it can be stated that any foundation within the top 3m in the entire area of Yenegoa will experience significant settlement because of the weak clayey-silt spread over the terrain. The engineering geological implication is that the clayey-silt must be handled adequately. The following two major solutions could be considered. Firstly, the foundation area can be subjected to surcharge loading, thereby reducing the pore spaces within the clayey-silt layer. The time required for this pre-consolidation exercise can also be enhanced by providing horizontal and vertical drain conditions. This method was used in the ExxonMobil Qua-Iboe terminal crude storage tank foundations analysis, (Sage Engineering 1997 and Onyebuolise B.C. 1999 unpublished M.Sc thesis). Secondly, the compressible clayey-silt soil can be removed and replaced with a load material such as sand. Overall, considering the results of the settlement loading scenarios obtained in this research, and then settlement is real parameter to be taken into account in foundation engineering within Yenagoa.

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Bearing capacities of foundations

The standard penetration test (SPT) values were used to determine the bearing capacities of mat and raft foundations on the various soil layers. This makes it possible to estimate the bearing capacities without rigorous analysis. Figure 7 (a & b) shows the summary charts of mat and raft foundations respectively.

On the mat foundation, the major engineering geological implication of this bearing capacity analysis is that it is not advisable for structures to be founded at a depth less than 3m.

The bearing capacities ranges from 19-26kPa. It is advisable to remove the organic peaty topsoil and replace it with sand or any other load bearing material such as sand cement. Alternatively, pile can be used to carry load to deeper and more competent strata. It will be paramount to stress here that the foundation width of this case study is 6m. Below this layer, the mat foundation can be used since the bearing pressures in these layers are reasonably safer. In the case of the raft foundation, the chart clearly shows that is it not advisable to found any structure within the top compressible clayey-silt layer (depth 0-3m).

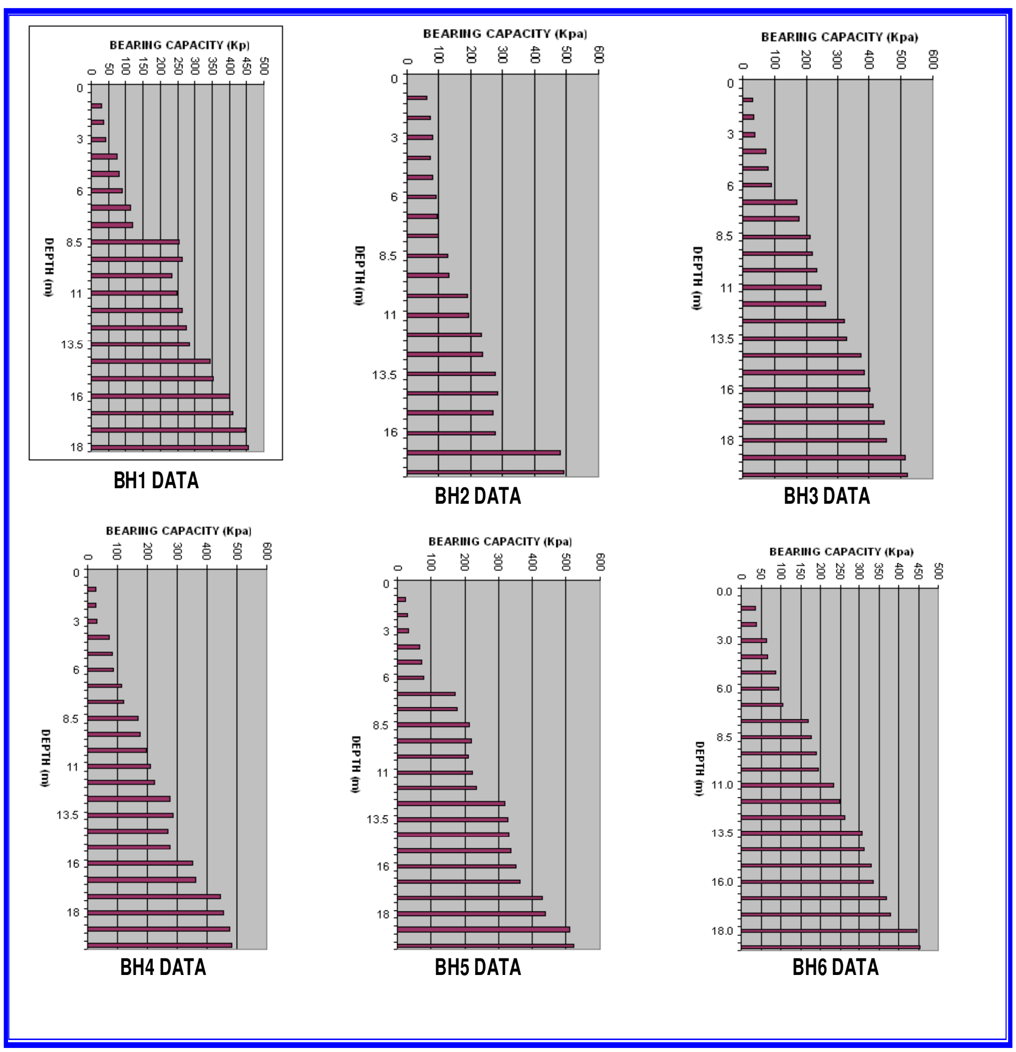

Fig 7a Charts of Bearing Capacity (Kpa) of mat foundation (Bh1- 6, B=6m)

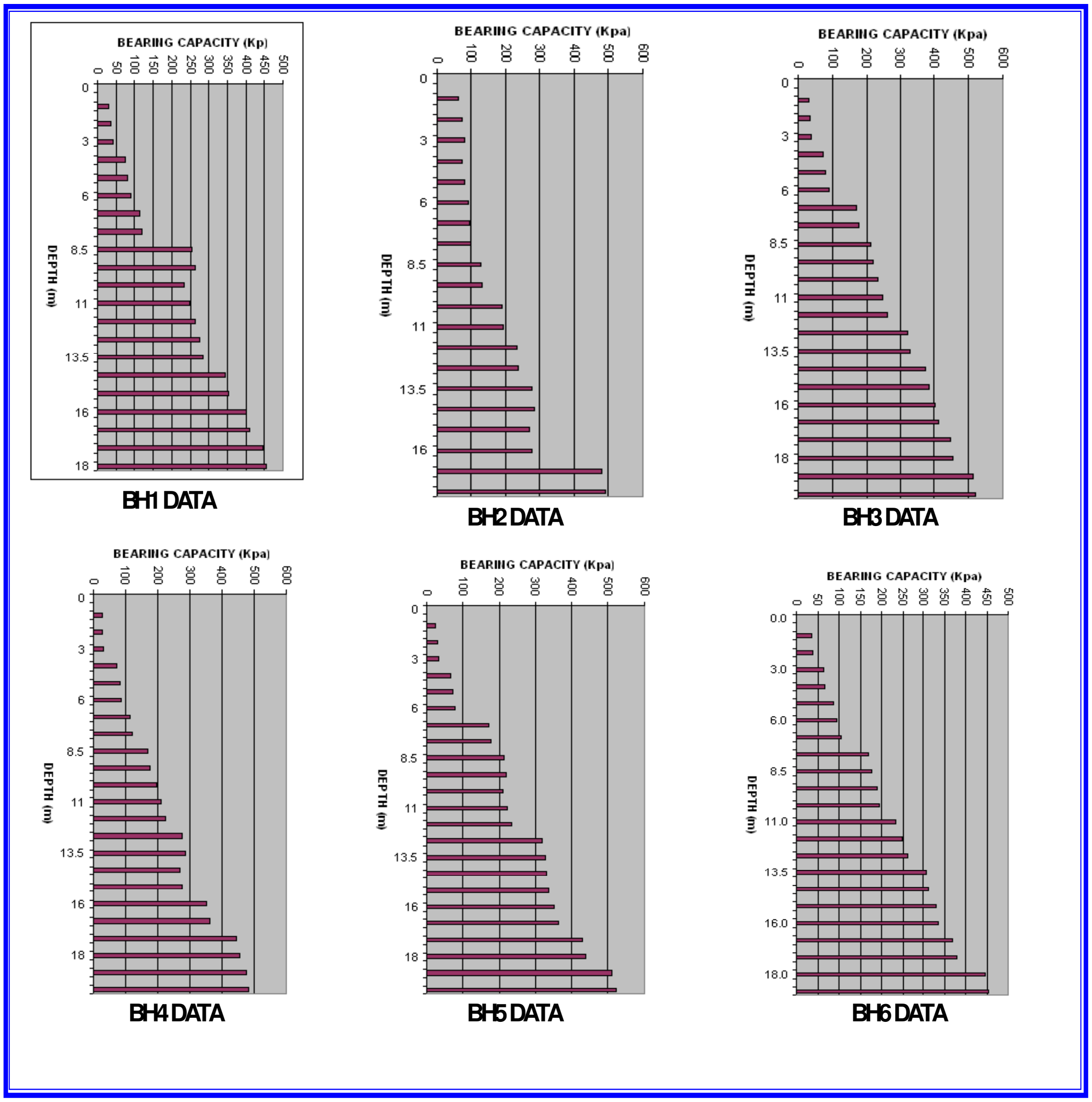

Fig 7b Charts of Bearing Capacity (Kpa) of Raft Foundation BH1-BH6, (B=6M)

Conclusion

The major goal of this study is to understanding the stratification and geotechnical properties of subsurface soils between 0-20m in Yenagoa and its environs. Soils within this depth interval constitute the foundation substratum of most civil engineering structures in the developing city of Yenagoa and its environs.

Soil profiles across the study area consist of three main horizons, from top to bottom, namely, peaty clayey-silt, sand and gravelly-sand. Generally the horizons are not purely non-homogenous, because pockets of horizons or soil types are usually found within the major unit in the form of lenses or intercalations. The 3-layer

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subsoil profile type is dominant in almost all the boreholes.

The geotechnical properties reveal that the top peaty silty clay horizon (0-3m depth) is not recommended as a foundation stratum because of its extremely low bearing capacity. SPT values are usually negligible (less than 6) within the compressible clayey-silt layers. For other layers, sand and gravelly–sand indicates an increasing bearing capacity with depth. Arising from the above, on significant variations in the stratification and the engineering geological properties of the subsoils, then the geotechnical data of one location should not be used for foundation design of nearby/adjacent locations. The sand and gravelly-sand horizons constitute good foundation substratum for medium and large civil engineering structures.

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