Journal of Soil Science and Environmental Management Vol. 2(2), pp. 34-38, February 2011
Available online at http://www.academicjournals.org/JSSEM
ISSN 2141-2391 ©2011 Academic Journals

Full Length Research Paper

Studies on sub-soil characteristics of sand deposits in some parts of Bayelsa State, Eastern Niger Delta, Nigeria

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Accepted 11 January, 2011

Sub-surface investigation was undertaken by drilling boreholes within and along the Nun River Channel covering three communities of Kaiama, Opokuma and Sabagreia, Bayelsa State, Nigeria. The route extent was over 5 km long and the study was necessitated to provide materials as structural fills for road construction purposes. Eight boreholes were drilled in the three locations to a maximum depth of 14 m from the river bed. Results reveal an overlying ligh grey to dark brown, very fine grained (anhedral), soft to stiff consistency, highly plastic silty clay soil in all the boreholes. This unit varies in depth vary in depth of 1.0 to 7.0 m and is proceeding thinner towards the Sabagreia axis from Kaiama. Beneath this overburden lie light grey, medium grained sands, in BH 2 to BH 6 covering the Kaiama and Opokuma axis. The sands are about 7 to 12 m in thickness to the maximum drilled depth of 14 m. In BH 7 and BH 8 in the Sabagreia axis, the underlying sands are coarse grained in texture and about 13 in thickness to the borehole depth. It is recommended that the sand may be derived at minimum depths of about 1.0 m below the river bed in the Sabagreia area, about 2.0 m in the Opokuma region and about 4.5 to 7.0 at the Kaiama axis. Medium to coarse grained; poorly graded (well sorted) sands which display uniform size gradation in the sand range were encountered below the river bed in the area.

Key words: Soils, grain size, engineering properties, stratigraphy, Niger Delta.

INTRODUCTION

The need for accurate information and adequate understanding of the geotechnical properties of the foundation of subsoil cannot be over emphasized. Geotechnical information are useful in ensuring that the effects of projects on the environment and natural resources are properly evaluated and mitigated where necessary (Nwankwoala et al., 2009).

Several environmental problems are expected to occur if no secure and environmental friendly measures associated with development are carried out, as this can prevent severe contamination in soil and groundwater (Bruno, 2007; Barends and Hagenaar, 2008; Depountis et al., 2009; Youdeowei and Nwankwoala, 2010a; Youdeowei and Nwankwoala, 2010b).

Bayelsa State is a fast growing state in the Southern Nigeria with associated environmental problems, which have been a subject of primary concern. There are severe drainage problems with seasonal and temporary flooding due to heavy rainfall and rise in groundwater table, resulting in almost total submergence during the wet season with exception of the natural levees (Allen, 1965).

In the study area, only little effort have been made in understanding the engineering and environmental properties of the shallow subsurface soils which are the foundation of civil engineering structures such as housing

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units, oil production facilities, waste management facileties etc that are directly or indirectly related to the oil and gas industry. This study therefore, provides geotechnical data on subsoil characteristics to guide future development in the area.

DESCRIPTION OF THE STUDY AREA

The study sites are characterized by a typical freshwater ecology of the upper reaches of the River Nun within the Niger Delta area. The area lies within the outcropping Benin Formation made up of continental deposits of Miocene to recent sediments. The areas are associated with freshwater swamps, backswamps and meander belts of flat to sub-horizontal elevation (Etu-Efeotor and Akpokodje, 1990; Allen, 1965). The river banks vary in heights of 4 to 6 m above the low water stage with gradients ranging from gentle to very steep (30 to 70°). The major soil types are light to dark grey, fine sand to silty clay. The mean annual rainfall exceed 2000 mm and rain falls all year round with over 85% during the wet season (Iloeje, 1972).

Geomorphologically, the Niger Delta has been described by a number of writers (NEDECO, 1961; Allen, 1965; Weber, 1971). The topography of the area is essentially flat, sloping very slightly seawards. The area is low lying and is drained and criss-crossed by an anastomosing network of distributaries. The area constitutes an extensive plain exposed to periodical inundation by flooding when the rivers and creeks overflow their banks. A prominent feature of the rivers and creeks is the occurrence of natural levees on both banks, behind which occur vast areas of back-swamps and lagoons/lakes where surface flow is negligible.

Although various types of morphological units and depositional environments have been recognized in the area (coastal flats, ancient/modern sea, river and lagoonal beaches, sand bars/flats, flood plains, seasonally flooded depressions, swamps, ancient creeks and river channels), the area can be sub-divided into five major geomorphological units, namely: (1) Active/ abandoned coastal beaches; (2) Saltwater, mangrove swamps; (3) Freshwater swamps, backswamps, deltaic plain alluvium and meander belt, (4) Dry deltaic plain with abundant freshwater swamps (Sombreiro- Warri deltaic plain), and (5) Dry flat land and plain. Table 1 shows the geologic units of the Niger Delta.

Our present knowledge of the geology of the Niger Delta was derived from the works of Reyment (1965), Short and Stauble (1967), Murat (1970), Merki (1970), and the exploration activities of oil and gas companies. The formation of the so-called proto-Niger Delta occurred during the second depositional cycle (Campanian-Maastrichtian) of the southern Nigerian basin. However, modern Niger Delta was formed during the third and last depositional cycle of the southern Nigerian basin which started in the Paleocene. Generally, the Niger Delta was formed during the Tertiary period as a result of the interplay between subsidence and deposition arising from a succession of transgressions and regressions of the area. These phenomena evolved the three main lithostratigraphic units of Akata, Agbada and Benin Formations, with an overall approximate thickness of over 5,000 m of sediment body (Short and Stauble, 1967).

The Akata Formation (outcropping as the Imo Shale Group) is made up of marine clay, shale and limestone and is estimated to be about 1,000 m in thickness. The Agbada (Eocene) which outcrops as the Ameki Formation overlies the Akata Formation (Paleocene) and comprises various alaternations of marine shales and sandstones. It has an estimated thickness of 1,700 m. The youngest of these formations, the Benin Formation (Miocene – Recent) basically consists of coarse sand with occasional clay and shales with a total thickness of over 2000 m. Quaternary deposits of about 100 m in thickness comprising recent deltaic sediments made up of sand, silt and clay beds, overlie the Benin Formation in the swampy areas of the delta and comprises rapidly alternating sequences of sand and silt/clay with the latter becoming increasingly more prominent seawards (Etu-Efeotor and Akpokodje, 1990).

STUDY TECHNIQUES

Field investigation

Subsurface investigation was undertaken by drilling boreholes within and along the Nun River Channel covering the three communities. The bathymetric sounding data of the river profile provided the necessary preliminary information for the borehole drilling programme. A 12' × 14' floating raft (pontoon) with a drilling spot (moon) at the centre was constructed and the drilling rig mounted on it for the drilling exercise. Soil boring was done with the use of a hand-operated light cable percussion rig of the pilcon way farrer type to maintain minimal disturbance of soil samples retrieved for logging and analysis.

Eight boreholes were drilled at the sites to a maximum depth of 14 m from the river bed. The boreholes were logged on site and soil samples recovered at intervals of 1 m for field and laboratory examination. Grain size distribution analysis was carried out on the sandy soils in accordance with British Standards (B.S, 1377, 1975) to delineate the textural characteristics.

RESULTS AND DISCUSSION

Grain size distribution of soil samples

Grain size analysis results show a range of poorly graded (well-sorted) sands with uniform gradation curve displaying very little or no fines (0.1 to 0.4% passing 0.075 mm sieves). The results are presented in Table 2 and the gradation pattern shown in the particle-size distribution curve (Figure 1). The sands are classified as SP (pooly graded) under the unified soil classification system

Table 1. Geologic units of the Niger Delta (after Akpokodje, 1989).

Geologic unit	Lithology	Age
Alluvium (General)	Gravel, sand, clay, silt	
Freshwater backswamp, meander belt	Sand, clay, some silt, gravel	
Saltwater mangrove swamp and backswamp	Medium-fine sands, clay and some silt	Quaternary
Active/abandoned beach ridges	Sand, clay, and some silt	
Sombreiro-warri deltaic plain	Sand, clay, and some silt	
Benin formation (Coastal Plain Sand)	Coastal to medium sand; subordinate silt and clay lenses	Miocene-Recent
Agbada formation	Mixture of sand, clay and silt	Eocene-Recent
Akata formation	Clay	Paleocene

Table 2. Grain size distribution of soil samples.

Sample no and depth (m)	Particle size distribution (percent passing sieves)				Unified soil classification system (U.S.C.S.)
	No. 4 (4.75 mm)	No. 10 (2.00 mm)	No. 40 (0.42 mm)	No. 200 (0.075 mm)	
BH1 (13)	100	100	90.8	0.2	SP
BH 2 (10)	100	100	92.4	0.2	SP
BH3 (8)	100	100	88.5	0.1	SP
BH 4 (6)	100	100	96.7	0.4	SP
BH 5 (2)	100	100	95.0	0.3	SP
BH 6 (12)	100	100	95.4	0.4	SP
BH 7 (12)	100	97.8	76.8	0.3	SP
BH 8 (9)	100	97.5	79.7	0.3	SP

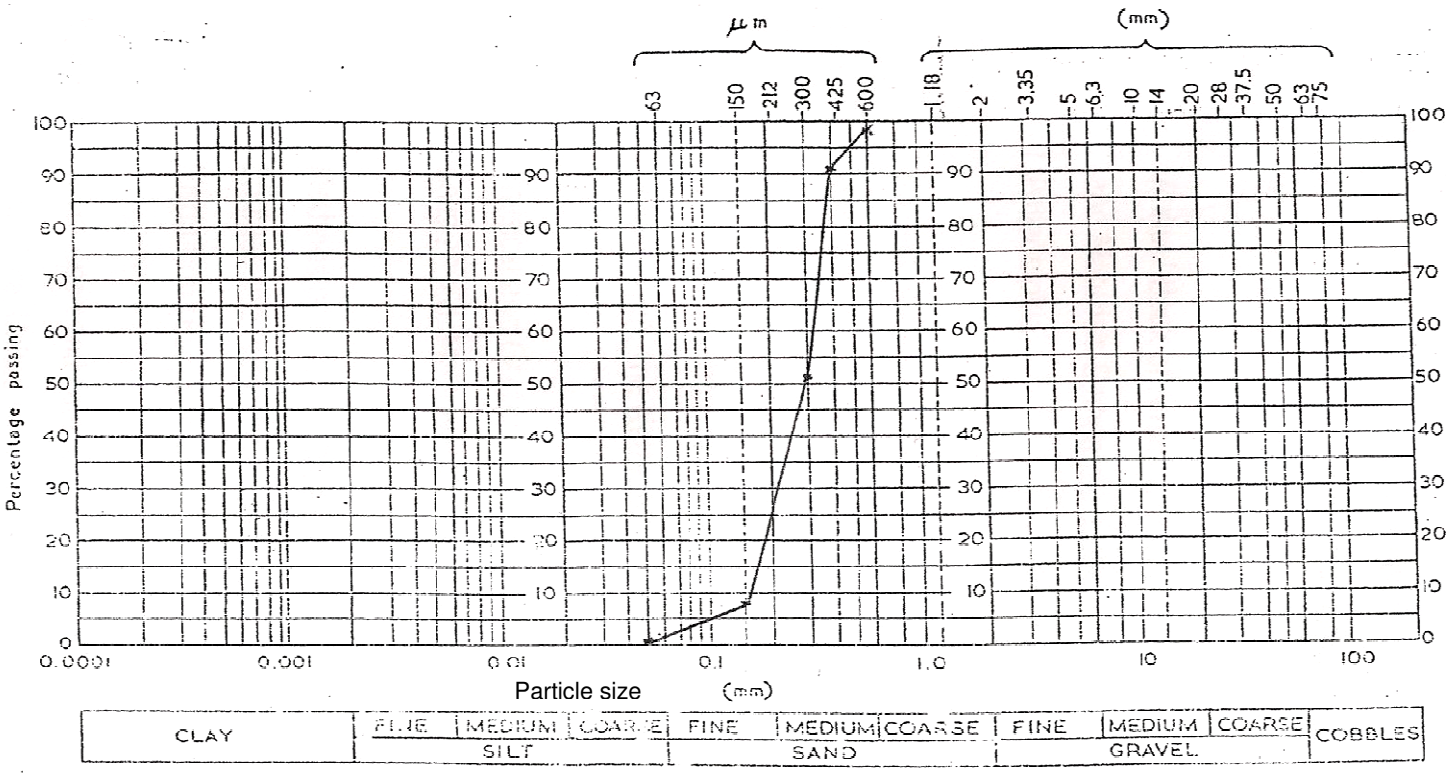

Figure 1. Particle size distribution curve.

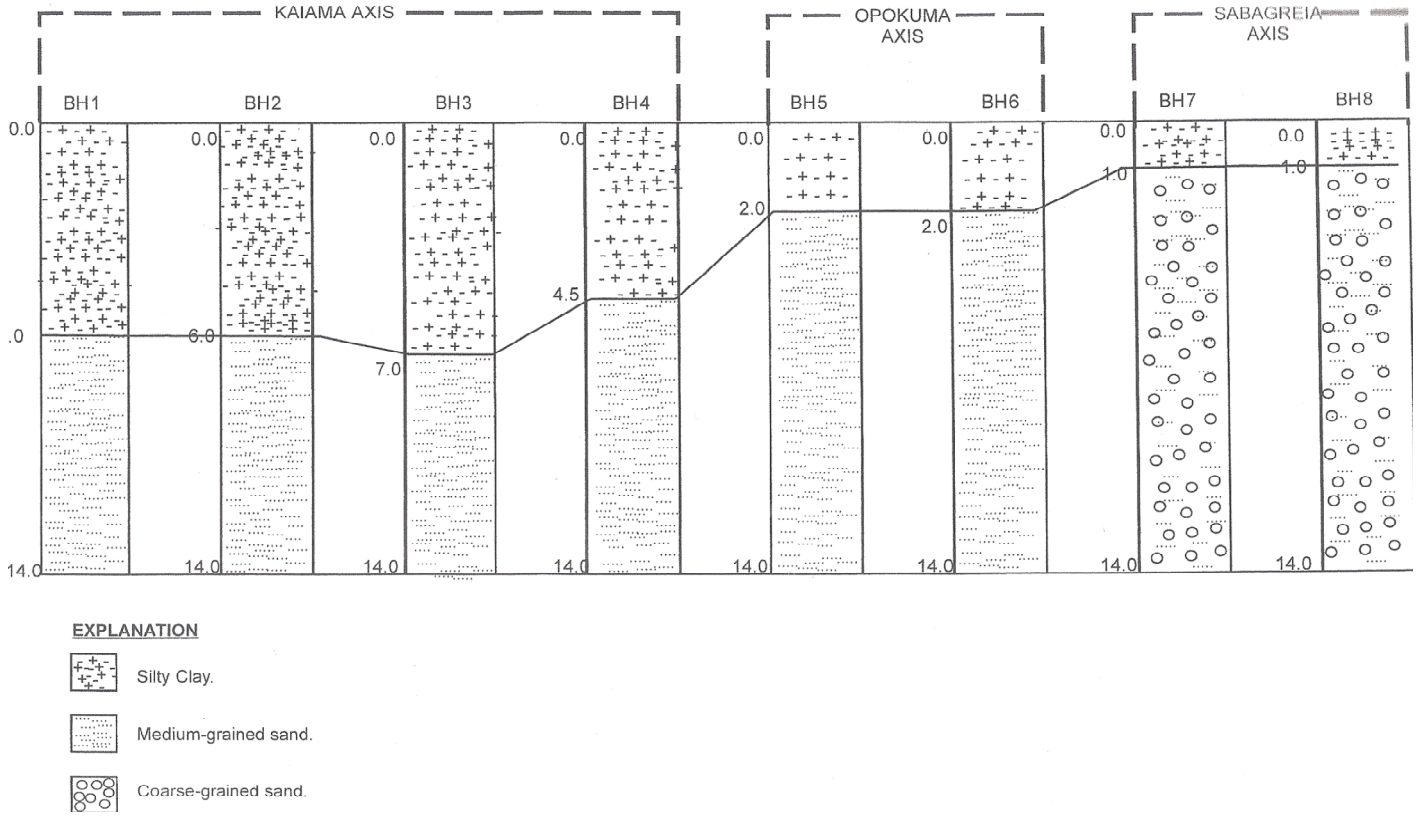

Figure 2. Cross-section and stratigraphic correlation of boreholes along the river channel.

(U.S.C.S).

Soil stratigraphy and physical properties

The sub-soil stratigraphic profile and correlation of the eight (8) boreholes drilled at the three (3) sites is shown in Figure 2. There is an overlying light grey to dark brown, very fine grained (anhedral), soft to stiff consistency, highly plastic silty clay soil in all the boreholes. The unit varies in depth of 1.0 to 7.0 m and proceeding thinner towards the Sabagreia axis from Kaiama. Beneath this overburden lies light grey, medium grained sand in BH 1 to BH 6 covering the Kaiama and Opukuma areas. The sands are about 7 to 12 m in thickness to the maximum drilled depth of 14 m. In BH 7 and BH 8 in the Sabagreia axis, the underlying sands are coarse grained in texture and about 13 m in thickness to the borehole depth.

GEOTECHNICAL IMPLICATIONS

The fine grained nature of the soils in the area implies a low permeability potential and the proportion of silty clay size fractions in the soils will have significant influence on the behaviour of the soils, whereby it may display a considerable amount of compressibility.

The strength properties of the soil should be evaluated for proper design of shallow foundation system that would bear the weight of structures. The foundation system may derive their bearing strength from the silty clay soil which has a stiff consistency, with attention given to the water table condition in the area.

Generally, considering the fact that the study area is within the Eastern Niger Delta (coastal zone), geo-technical considerations are very desirable. The coastal zone which comprises the beach ridges and mangrove swamps is underlain by alternating sequence of sand and clay with a high frequency of occurrence of clay within 10 m below the ground surface (Youdeowei and Nwankwoala, 2010c). Because of the nearness of the compressible clays to the surface, the influence of imposed loads results to consolidation settlement. The impact of the imposed loads is exacerbated by the thickness and consistency of the compressible layer. This in addition to other intrinsic factors contributes to the failure of civil engineering structures.

More importantly, it is not anticipated that the soil conditions as revealed in this study will vary significantly. However, the soil conditions may vary during con-struction, hence, it would be necessary to evaluate the engineering significance of such variations which could

result in further investigations.

Conclusion

The lithostratigraphic profile along the river channel of the three (3) study sites reveal an overburden of very fine grained, soft to stiff consistency, silty clay overlying medium to coarse grained, plain sands. The thickness of the underlying coarse sand to the maximum drilled depth is greater at the Sabagreia area. The medium grained sands which cover the Opukuma and Kaiama axis preponderates over the coarse sand in areal extent. It is recommended that sand may be derived at minimum depths of about 1.0 m below the river bed in the Sabgreia are, about 2.0 m in the Opokuma region and about 4.5 to 7.0 m at the Kaiama axis. Medium to coarse grained, poorly graded (well sorted) sands which display uniform size gradation in the sand range were encountered below the river bed in all the locations.

ACKNOWLEDGEMENTS

The authors thank and appreciate the input of two anonymous reviewers for providing helpful and unbiased comments that improved the technical quality of this paper.

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