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Preliminary Evaluation of Some Engineering Geological Properties of Soils in the New Yenagoa Town, Bayelsa State, Central Niger Delta

[1]YOUDEOWEI, P O; [2*]NWANKWOALA, H O

[1]*Institute of Geosciences and Space Technology, Rivers State University of Science and Technology, P.M.B 5080, Nkpolu, Port Harcourt, Nigeria*

[2]*Department of Geology, University of Port Harcourt, P.M.B 5323, Choba, Port Harcourt, Nigeria*

ABSTRACT: The subsurface investigation was undertaken by drilling of ten near the shore drill holes using rotary type drill machine. The boreholes were spaced 100m apart along the 1.2 km long river channel and drilled down to a maximum of 10m. The litho-log reveals light to dark brown, fine grained, cohesionless, loose, sands generally overlying dark grey, very fine grained, soft consistency, sticky, low plasticity, silty clays. Between the two major soil types is an intercalation of a 2.5m thick stratum of dark grey, fine grained, sticky, non-plastic silty sand in Borehole 1 (BH 1). BH 2 to BH 10 present single to two layered stratigraphy of the commonly occurring fine sand and silty clay in various thicknesses to the maximum drilled depth of 10m. Grain size analysis results show a range of poorly graded (well sorted) sands with uniform gradation curves and very little or no fines (0.08 to 6.56% passing of 0.075mm sieve). Specific gravity values ranged from 2.38 to 2.60 and generally low as a result of the fine grained nature of the sandy soils. Results also show a low plasticity range of 4.25 to 13.17% for the silty clay soils, with the sandy soils being non-plastic. Generally, apart from BH 2, BH 3, and BH 4, there is a non-uniform correlation of the boreholes, with the sands occurring as single layers in BH 5, BH 9 and BH 10. The homogeneous uniformity is an indication of deposition under similar energy conditions. Therefore, adequate attention should be given to the likely physical environmental degradation of river bank failure and liquefaction condition that may evolve as a result of dredging/reclamation work in the area. @JASEM

The generation of necessary baseline information useful for planning and for developing appropriate environmental management programme in order to reduce potential negative effects is crucial for sound environmental sustainability (Youdeowei & Nwankwoala, 2010a). Several environmental problems are expected to occur if no secure and environmental friendly measures associated with development are carried out (Bruno, 2007; Barends & Hagenaar, 2008; Depountis *et al*., 2009; Youdeowei & Nwankwoala, 2010b).

Yenagoa, the study area is characterized by the freshwater ecology of the upper reaches of the River Nun within the Niger Delta. It lies within the outcropping Benin Formation made up of continental deposits of Miocene to Recent sediments. The area is associated with freshwater swamps, backwamps and meander belts of flat to sub-horizontal elevation. There are severe drainage problems with seasonal and temporary flooding due to heavy rainfall and rise in groundwater table. This results in almost total submergence during the wet season with exception of the natural levees.

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). This study therefore aims to provide an integrated assessment of some geotechnical properties of soils in the New Yenagoa Town, Bayelsa State, Southern Nigeria. The geo-environmental assessment plan can help in preventing river bank failure and liquefaction condition.

Geomorphology and Geology: The study area is part of the Niger Delta. The geomorphology of the Niger Delta has been described by many researchers (NEDECO, 1954, 1959, 1961; Allen, 1965, Weber, 1971). The topography of the area is essentially flat, sloping very gently seawards. The area is low lying (usually does not exceed 20m above sea-level) and is drained and criss-crossed by network of distributaries. The Niger Delta 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 backswamps 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 lagoon beaches, sand bars, flood plains, seasonally flooded depressions, swamps, ancient creeks and river channels), the area can be sub-divided into five major geomorphological units namely:

(a) Active/abandoned coastal beaches
(b) Saltwater, mangrove swamps
(c) Freshwater swamps, back-swamps, deltaic plain alluvium and meander belt
(d) Dry deltaic plain with abundant freshwater swamps (Sombreiro-Warri deltaic plain) and
(e) Dry flat land and plain.

*Corresponding Author, **E-mail**: nwankwoala_ho@yahoo.com

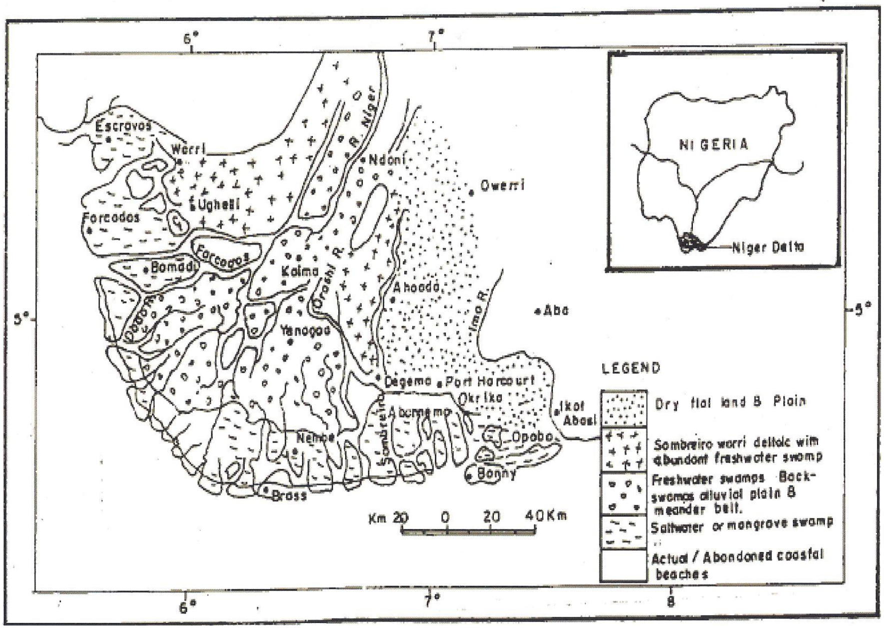

Fig.1: Major morphological Units of the Niger Delta (modified after Akpokodje, 1987)

Along the coastline lies a long coastal saline belt of active and abandoned beaches built by ocean currents and tides. This area is comparatively higher than the adjacent areas and its width varies from 1 to 10 km. Parallel to, and north of the coastal saline belt of the beaches, is a stretch of mangrove swamp with an approximate width of 10 – 25 km. North of the mangrove swamp is the freshwater swamp which is in turn succeeded inland by dry areas that are not prone to periodical flood inundation.

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

Consequently, the present knowledge of the geology of the Niger Delta was derived from the works of the following researchers (Reyment, 1965; Short and Stauble, 1967; Murat, 1970; Merki, 1970) as well as the exploration activities of the oil and gas companies in Nigeria.

The formation of the so called proto-Niger Delta occurred during the second depositional cycle (Campanian Maastrichtian) of the southern Nigerian basin. However, the modern Niger Delta was formed during the third and last depositional cycle of the southern Nigerian basin which started in the Paleocene.

The geologic sequence of the Niger Delta consists of three main Tertiary subsurface lithostratigraphic units (Short and Stauble, 1967) which are overlain by various types of Quaternary deposits. From bottom to top, the Tertiary units are the Akata, the Agbada and the Benin Formations (Table 1).

MATERIALS AND METHODS

Sub-soil Investigation: Subsoil investigations were undertaken by drilling ten boreholes near shore. Ten boreholes were drilled in the area using rotary-type drilling equipment. The boreholes were spaced 100m apart along the 1.2 km long river channel and sunk to maximum depths of 10m. The boreholes were logged on site and soil samples recovered at intervals where changes in soil type occur for laboratory analysis of grain size pattern, specific gravity, consistency (Atterberg) limits and classification purposes.

Laboratory Soil Testing: The soil samples recovered from the boreholes were subjected to both visual examinations and laboratory testing. Laboratory tests were carried out on representative samples in accordance with the British Standards (B.S) 1377, which are equivalent to the American Society for Testing and Materials (ASTM) Standards. These tests were carried out to provide detailed and quantitative information concerning the soils and hence extract the maximum amount of useful information about their nature.

RESULTS AND DISCUSSION

Grain Size Patterns: Grain size results show a range of poorly graded (well sorted) sands with uniform gradation curve and very little or no fines (0.08 to 6.56% passing 0.075mm sieve). Table 2 shows the general laboratory test result.

Specific Gravity: The specific gravity of the soil grains is the ratio of soil particle density to the density of water at 4^0C. Specific gravity values obtained from the test ranged from 2.38 to 2.60, which are considered generally low as a result of the fine grained nature of the sandy soils.

Soil Consistency: Atterberg limits (also known as consistency limits) expresses the water adsorbing and absorbing ability of fine-grained, cohesive soils, with the plasticity index indicating the range of water content through which the soil remains plastic. The result show a low plasticity range (4.25 to 13.17 %) for the silty clay soils, with the sandy soils being non-plastic. The soils fall within the soil classification groups of SP and CL under the Unified Soil Classification System (U.S.C) Scheme.

Sub-Soil Lithostratigraphy: The sub-soil stratigraphic sequence and correlation (Fig.1) reveals light to dark brown, fine grained, cohesionless, loose, plain sands generally overlying dark grey, very fine grained, soft consistency, sticky, low plasticity, silty clays. Between these two major soil types, there is an intercalation of a 2.5m thick stratum of dark grey, fine grained, sticky, non-plastic silty sand in borehole 1 (BH 1). Boreholes 2 (BH 2) to BH 10 present single to two layered stratigraphy of the commonly occurring fine sand and silty clay in various thicknesses to the maximum drilled depth of 10m. The fine grained nature of the soil represents low energy environmental condition of river (fluviatile) activities.

Table 2: Results of Laboratory Test for sand (S) and Silt Clay (SC) and compared with Unified Soil Classification Syst (U.S.C.S)

Sample No & Depth	Soil type	Grain Size Distribution				Consistency Limits			Specific Gravity	(U.S.C.S)
		No. 4 (4.75mm)	No. 10 (2.00mm)	No. 40 (0.42mm)	No 200 (0.075mm)	LL(%)	PL (%)	PI (%)		
BH1 (0-2.5m)	S	100	100	100	2.55	-	-	-	2.56	SP
BH1 (5-10m)	SC	-	-	-	-	26.30	20.5	5.85	-	CL
BH2 (0-2m)	Sand	100	100	100	2.82	-	-	-	2.56	SP
BH2 (2-10m)	SC	-	-	-	-	26.40	21.2	4.25	-	CL
BH3 (0-1.5m)	Sand	100	100	100	0.48	-	-	-	2.43	SP
BH3 (1.5-10m)	SC	-	-	-	-	26.00	20.5	5.45	-	CL
BH4 (0-1.5m)	Sand	100	100	99.74	0.46	-	-	-	2.46	SP
BH4 (2-10m)	SC	-	-	-	-	25.80	18.5	6.25	-	CL
BH5 (0-10m)	Sand	100	92.82	91.82	4.50	-	-	-	2.38	SP
BH6 (0-6m)	Sand	100	100	100	6.56	-	-	-	2.52	SP
BH6 (6-10m)	SC	-	-	-	-	26.00	20.5	5.45	-	CL
BH7 (0-1.5m)	SC	100	96.48	96.37	3.20	28.20	22.3	5.90	-	CL
BH7 (1.5-3m)	Sand	-	-	-	-	-	-	-	2.49	SP
BH7 (3-10m)	SC	-	-	-	-	33.00	19.8	13.1	-	CL
BH 8 (0-7.5m)	Sand	100	100	100	1.42	-	-	-	2.57	SP
BH8 (7.5-10m)	SC	-	-	-	-	26.0	19.7	6.30	-	CL
BH9 (0-10m)	Sand	100	100	100	0.08	-	-	-	2.50	SP
BH10 (0-10m)	Sand	100	100	100	0.88	-	-	-	2.60	SP

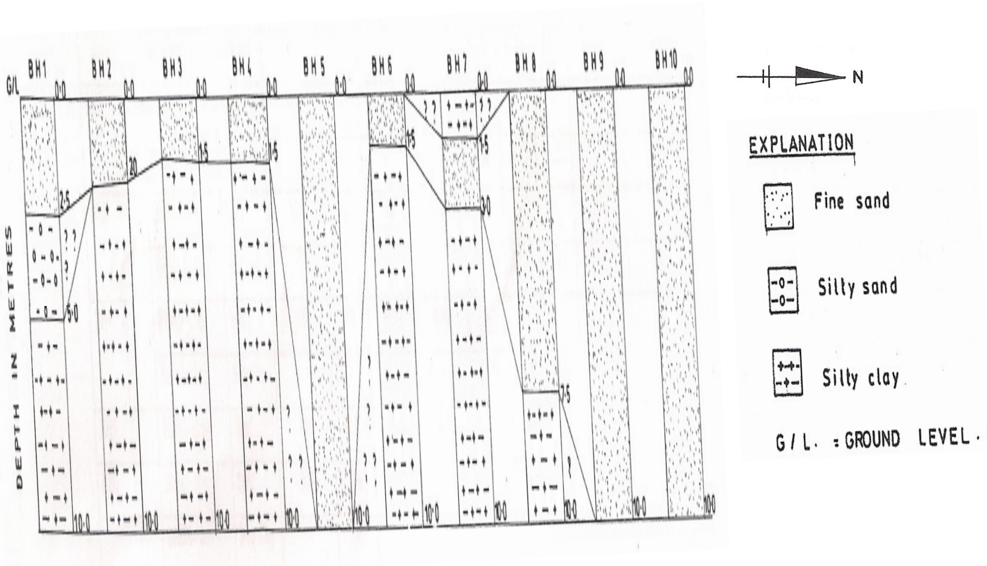

Fig. 1: Cross-Section and Stratigraphic Correlation of Boreholes along the Riverbank

Geo-Environmental Impact Assessment/Prediction: Some of the physical environmental problems that may arise as a result of on-going dredging/reclamation activities in the area may include:

(1) The dredging of the river channel during dredging exercises and the attendant undercutting of the toe of the banks by shoaling actions of river eddy currents. This could lead to bank slope instability and eventual collapse. (2) If dredging/reclamation activities take place during the flood recession period, rapid fall in river stage would result in water level in balance at the banks. This phenomenon coupled with sand pumping activities would aggravate river bank failure processes. (3) Liquefaction or quicksand condition is another consideration of impact prediction in the area. As a result of the fine grained, loose saturated state of the overburden sand, if during the dredging/reclamation phase, the sand deposit is subjected to sudden shock arising from cyclic or dynamic loading, the resultant pore-pressure build up would cause the soil to flow or behave as a viscous fluid or liquefy.

*Conclusion***:** The litholog of the sub-soil in the area reveal a general overburden of fine sand underlying fine grained, silty clay. Generally, apart from BH 2, BH 3 and BH 4, there is a non-uniform correlation of the boreholes, with the sands occurring as single layers in BH 5, BH 9 and BH 10. The homogenous uniformity is an indication of deposition under similar energy conditions. It is recommended that greater attention should be given to the likely physical environmental degradation of river bank failure and liquefaction condition that may evolve as a result of dredging/reclamation work in the area.

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