# GEOTECHNICAL INDEX PROPERTIES OF SOIL FROM CHOBA AND ITS ENVIRONS, NIGER DELTA NIGERIA.

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**ABSTRACT**

A geotechnical evaluation of some soils in Choba, Port Harcourt, South-South, Nigeria has been carried out. This was done to determine the suitability of the soils for use as subgrade/filling, sub-base and base course materials for road construction. The samples were collected from ten different areas, at surface and sub-surface levels. The areas are along Rumuokoro – Choba within the East – West Road. The soil samples were subjected to laboratory investigations in conformity with the American Association of State Highway and Transportation (AASHTO) specifications. Results of the geotechnical tests indicate that the proportion passing the AASHTO sieve N0. 10 - 60 range from Cc: 1.59% to $D_{60}$: 0.450% whereas plasticity index ranges from 4.4.0 to 26.1 respectively. The compaction test result revealed an optimum Moisture Content (O.M.C) value of 18.70% and a maximum Dry Density (M.D.D) value is 1983kg/m3. The plastic limit values ranges from 25.8% to 65.0%. Soils at Choba and its environs are thus considered suitable for use as sub-grade/filling materials, while the soil at some sites are unsuitable for use as subgrade/filling and sub-base material. This is probably why the road at these areas failed after construction.

**KEYWORDS:** Geotechnical evaluation, sub-grade/filling, sub-base, base course, laboratory.

## INTRODUCTION

In highway design and construction, careful attention is not only given to sampling and testing of the aggregates which are required to provide a pavement that will be sound and durable; but also to the subsoil materials which will provide support for the pavement (Okagbue and Uma, 1988).
In selecting the route for the highway, one of the important factors considered is the geotechnics of the subsoil. At least a casual study of the subsoil through which the highway must pass is exceedingly helpful. From it the general stability of the area can be determined.
Furthermore experience has shown that sub-soil conditions along a highway route can be a crucial factor in the serviceability and good performance of the highway (Weinert,1968; Earquhar, 1980). It is therefore very crucial to determine the geotechnical properties of soils in order to establish whether a particular soil is suitable for use as fill, grade or sub-base materials. Some of the roads in Choba area have failed and hence constitute potential hazard to pedestrian and motorists alike because of lack of informed geotechnical data on the sub soil conditions.
Most of the previous work done in the study area are mainly regional (Akpokodje, 1979) and have described the geology of the Niger Delta in terms of sedimentary and stratigraphic aspects. Subsequently, (Doust and Omatsola, 1990) gave some details on the geology, geological

structure, hydrology and water quality of the old Southern Nigeria in which the study area is included. Offodile (1976) wrote on the origin of the Benue Trough and Geology of the Cretaceous of the valley. Doust and Omatsola (1990) studied the sedimentation and tectonics of the Niger Delta with emphasis on facies architecture and their provenance significance. Offodile (1976) also gave some details on the sedimentation, tectonics and hydrolithological characteristics of part of the Benue Trough. Head (1988) indicated the various methods to be employed in the treatment of expansive soils and gave out the procedure to be adopted in the laboratory. Obiefuna et al., (1999), gave detailed account of the geological and geotechnical evaluation of selected gully sites in Yola area of Adamawa, north–east, Nigeria and recommended on how to tackle the environmental hazards.

The objective of this study is to determine the geotechnical factors responsible for the suitability of some soils in Choba and its environs. To achieve the objective of this research, the result of the various tests have been analysed and used to proffer ways geared towards constructing durable roads.

**STUDY AREA**

The study area is located along East-West road between Rumuokoro and Choba in Obio/Akpor Local Government Area of Rivers State as shown in Fig. 1. The samples were obtained from borrow-pit used for the construction of a section of the East-West road. Also, Global Positioning System (GPS) was used, which determined the elevation above sea level of 16m (52ft), latitude 04º46ˈ38″N and longitude 07º00ˈ48″E.

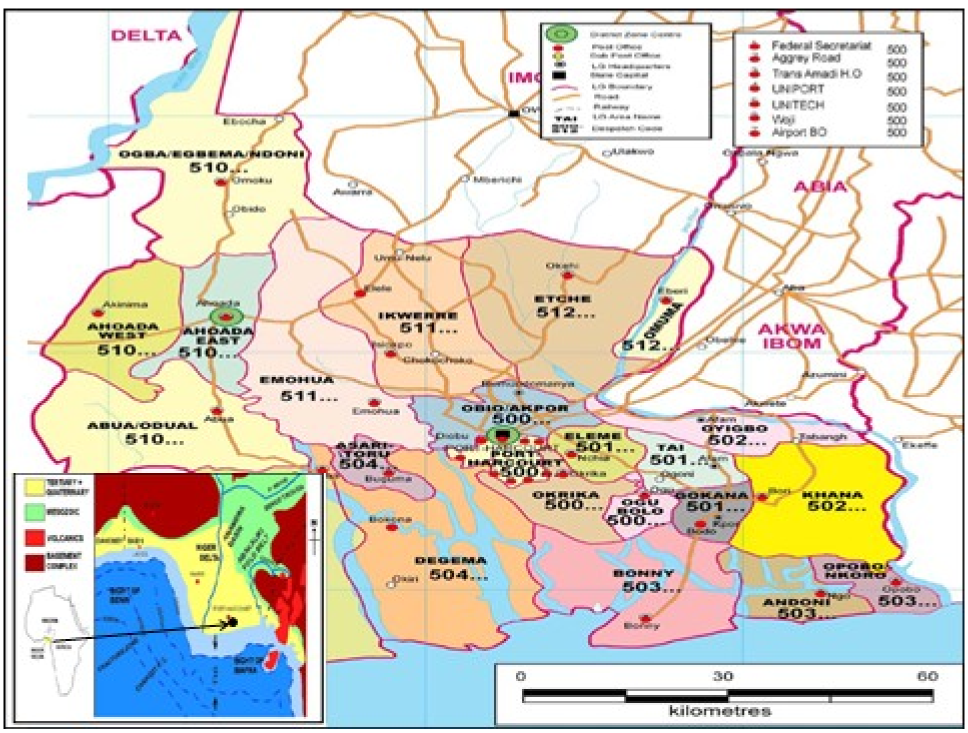


Fig. 1: Map of the study area (in set; map of Africa and Nigeria showing Port Harcourt in the Niger Delta).

The land surface of the study area can be grouped into three main divisions; the fresh water, the mangrove swamps of Akuku Toru, Abualdual, Asari Toru, Degema, Okrika, Ogubolo, Bony, Andoni and Opobo Local Government Areas (LGAs); and the coastal sand ridges zone. The fresh water zone is the plain that extends northwards from the mangrove swamps. This land surface is generally less than 20m above sea level.

This lower Niger floodplain has a greater silt and clay foundation and is more susceptible to perennial inundation by river floods. The value of the mean thickness appreciates upward to about 45m in the northeast and over 9m in the beach ridge barrier zones to the southwest. The flood plain is a homoclinal geomorphic structure whose trends westwards and southwards are broken in many places by small hogback ridges and shallow swamp basins (Avbovbo and Ogbe, 1978). The southern part is affected by great tidal influence.

Most water channels in the fresh water zone are bounded by natural levees, which are of great topographical interest and of great economic importance to the local people for settlements and crop cultivation. The upland is undulating to the hinterland and sandwiched with NW-SE and E-W direction ridges and attains a maximum height of 30m above sea level at Okubie to the Southwest. The narrow strip of sandy ridges and beach ridges lie very close to the open sea. The soils of the sandy ridges are mostly sandy or sandy loams and supports crops like coconuts, oil palm, raffia palm and cocoyam. Fourteen of the 23 LGAs of the state are located on the upland with varying heights between 13 to 45m above sea level. These include Ogoni, Ikwerre LGAs Ahoada, Abual/Odual, Ogba/Egbema/Ndoni LGAs and Port Harcourt LGAs. The drier upland area of Rivers state covers about 61% while riverine area, with relief range of 2m to 5m, covers about 39% of the state. The entire topography of the state is also characterized by a maze of affluent rivers, lakes, creeks, lagoons and swamps creeks crossing the low lying plains in varying dimensions.

Drainage is poor, being low-lying, with much surface water and a high rainfall of between 3,420mm and 7,300mm. Thus, almost all riverine LGAs are under water at one time or another. Again, some areas of the state are tidally flooded, while others are seasonally, thus limiting agricultural practices and nucleated/urban settlement development that would have enhanced social welfare facility provision. The state is drained by two main river systems, i.e. fresh water systems whose waters originate either outside or wholly within the coastal lowlands, and tidal systems confined largely to the lower half of the state.

Drainage densities of rivers within the states have typical value of 1.5km and sinuosity ratios are in excess of 1.9, indicating that the meandering channels are tortuous. These systems have a general downstream increase in width and velocity, especially in the fresh water zone. The state is drained by the Bonny New Calabar river systems and by a maze of effluent creeks and streams. River bank levees are prominent and valley side slopes are very gentle and experience a great deal of erosion and accretion. All the rivers enter into the sea through wide estuaries.

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Rainfall in Rivers state is seasonal, variable, and heavy. Generally, south of latitude 05ºN, rain occurs, on the average, every month of the year, but with varying duration. The state is characterized by high rainfall, which decreases from about 4,700mm on the coast to about 1,700mm in extreme north of the state. It is 4,698mm at Bonny along the coast and 1,862mm at Degema.

Rainfall is adequate for all year round crop production in the state. The duration of the wet season is not less than 330 days, of which a great number is rainy days (days with 250mm or more of rain). For Port Harcourt, the rainy days are about 182. Mean maximum monthly temperatures range from 28ºC to 33ºC, while the mean minimum monthly temperatures are in the range of 17ºC to 24ºC.

The mean monthly temperature is in the range of 25ºC to 28ºC. The mean annual temperature for the state is 26ºC. The hottest months are February to May. The difference between the dry and wet season temperatures is only about 2ºC. Relative humidity is high in the state throughout the year and decreases slightly in the dry season (Akpokodje, 2001).

The "upland" area was originally occupied by rainforest which has been drastically modified by human activities. In most places, economic trees, particularly oil palm, have been preserved and thus the sobriquet for this vegetation as "oil palm bush". The riverine area is divisible into three man hydro vegetation zones namely, the beach ridge zone, the salt water zone and the fresh water zone.

The beach ridge zone is vegetated mainly by fresh water swamp trees, palms and shrubs on the sandy ridges and mangroves in the intervening valleys or tidal flats. The salt water zone is the tidal flat or swamps vegetated by the red stilts rooted mangrove and two other species of mangrove. The outliers of raised alluvial ground or coastal plan terrace within the swamps are vegetated by tall forest tree species and oil palm. The freshwater zone is mainly the upper and lower Delta floodplains of the Niger, having fresh water forest trees which are the edaphic variants of the rainforest. The Abura tree, oil palm, raffia palm, shrubs, lianas, ferns and floating grasses and reeds are the typical vegetation.

## GEOLOGY OF THE STUDY AREA

The Choba, in Port Harcourt metropolis is mainly found within the Eastern Niger Delta Basin of Nigeria. The studies of the Niger Delta have widely been done mostly by oil companies and academician because of its petroliferous province which is of economic importance. Many authors have investigated and summarized the basic geology, structural setting, depositional environments, production characteristics, and field development strategies among others. Short and Stauble (1967), outlined the regional geology of the Niger Delta. The origin of the Niger Delta were attempted and they established that the Tertiary deltaic fill is represented by a strong diachronous sequence (Eocene- recent), which is divided into three lithofacies units namely; the Akata, Agbada and Benin Formations.

Doust and Omatsola (1990), observed that sands of the Niger Delta are poorly consolidated with porosity as high as 40% in oil bearing reservoir, reservoir sands of more than 15m thick in most places consists of two or more stacked channel. They also observed gradual reduction of porosity with depth and permeability in hydrocarbon bearing reservoirs are commonly in the range of 1-2

Darcy and sands shallower than 3000m have porosity of more than 15%, but below 3000m only a few sands have more than 15% porosity. Bustin (1988) established that the Niger Delta basin is divided into continental, marginal marine and marine facies. He also observed that sediments of the onshore are separately mapped as alluvium in contrast with the offshore sediments, in which the youngest sediments were not investigated because cutting samples could not be collected from the upper hundred feet below sea level.

Akaegbobi and Schmitt (1998), established that heterogeneity of reservoir, and formation evaluation problems can make it difficult to characterize fluid distribution, determine permeability and estimate hydrocarbon in place. They suggested that the approach used in characterizing a reservoir involves a combination of analysis of geological framework of the reservoir, hydrocarbon trapping components (stratigraphic and structural), formation evaluation and calculation of volumetric hydrocarbon in place. Haack et al. (2000) discussed the tertiary petroleum systems of the Niger Delta. He observed the lower cretaceous petroleum system is characterized by lacustrine source rocks which occurs in the north-western part of the delta and might be present in the Benin trough and the upper cretaceous lower Paleocene petroleum system, which is characterized by marine source rocks, is defined for the north-western part of the delta.

Various depositional processes gave rise to the Niger Delta Cenozoic stratigraphy. The studies of Short and Stauble (1967), Frankyl and Cordey (1967) and Avbovbo and Ogbe (1978) provided the initial information on the stratigraphic units distribution of the Niger Delta subsurface. Also, the works of Evamy et al. (1978), Ejedawe et al. (1984), Nwachukwu and Chukwura (1986), Haack et al. (2000), Reijer (1996) among others provided useful information on the stratigraphic units of the region. The Niger Delta subsurface is divided into three major lithostratigraphic units such as the Akata, Agbada and Benin Formations (Reijers, 1996) (Fig. 2). Basin-ward, there is a decrease in age, which reflects the overall regression of the Niger Delta clastic wedge depositional environments. In the south southern Niger Delta, stratigraphic units equivalent to these three formations are exposed, and it reflect a gross coarsening upward progradational clastic wedge (Short and Stauble, 1967), deposited in marine, deltaic and fluvial environments (Weber and Daukoru, 1975; Weber, 1987).

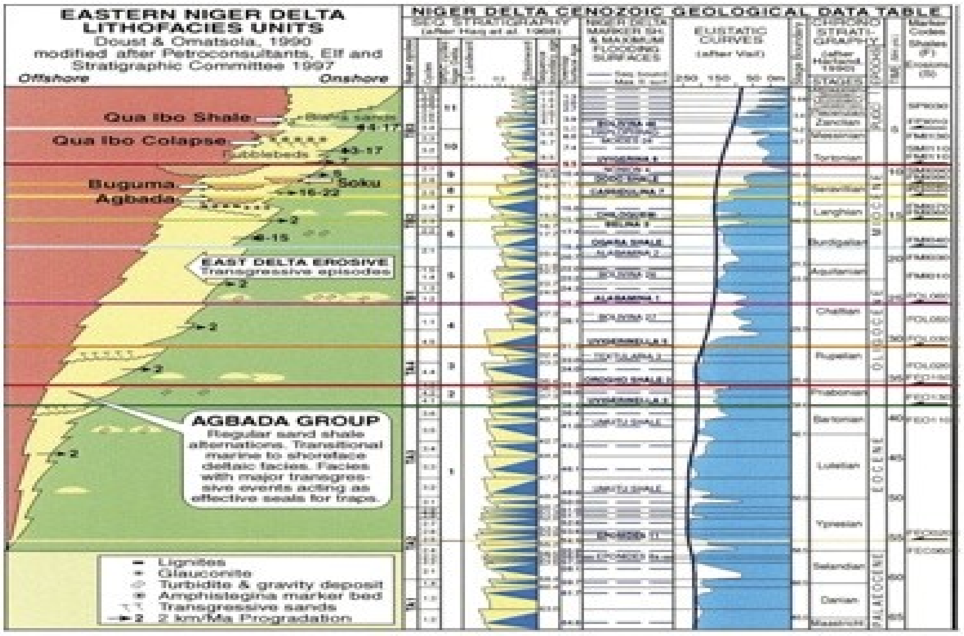


Fig. 2: Stratigraphic Column showing Eastern Niger Delta lithofacies units and Cenozoic Geological Data (Reijers, 1996).

## MATERIALS AND METHODS

This research work started with a field reconnaissance survey at point where road failures were noticed. This was achieved with the aid of a topographic map of the area. Pictures of the failure portion or point were taken. Soil samples were collected at grade, sub base and base levels, with the use of geologic equipments such as geologic hammer, measuring tape, chisel and sample bags for carrying the samples. Ten samples were collected at ten different pits at sub-surface levels. Before taking the samples, the faces of the soil were scrapped to remove long exposed Oxidized materials to enable the collection of fairly fresh samples.
Soil samples were collected at base, sub base and grade levels, which were taken to the laboratory for geotechnical analysis. These include the Atterberg limit test, California Bearing Ratio test, compaction test and particle size distribution test. All samples were air dried and lumps broken using a rubbered pistle. This was done to stimulate as much as possible the field condition especially as it affects the use of soil in road construction.

## RESULTS AND DISCUSSION

The result indicates (a) Sieve analysis test result for Choba and its environs (b) Atterberg limit test result and (c) Compaction test, for the various places in Choba area where the samples were collected.

Table 1: Summary of the natural moisture content and sample description

| Distance (m) | Sample/test | Moisture content % | Soil description |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 500 | 1 | 113.3 | Brownish clayey sand |
| 1000 = 1km | 2 | 105.3 | Brownish clayey sand |
| 1500 | 3 | 114.8 | Dark brown clayey sand |
| 2000 = 2km | 4 | 110.4 | Dark brown clayey sand |
| 2500 | 5 | 114.7 | Blackish sandy clay |
| 3000 = 3km | 6 | 113.9 | Blackish sandy clay |
| 3500 | 7 | 111.0 | Brownish clayey sand |
| 4000 = 4km | 8 | 112.2 | Brownish clayey sand |
| 4500 | 9 | 118.4 | Brownish, clayey sand |
| 5000 = 5km | 10 | 120.7 | Dark brown sandy clay |

Natural water content ranges from 105% to 120.7% with average value of 113% (Table 1). This is because samples were taken during the wet season and it is expected that the values will be lesser in the dry season. The values of the moisture content may partly reflect the sandy texture of the soils. The moisture content does not show a definite trend with the variations in samples. Soil description also matches with that of Akpokodje (1979). Specific gravity of some minerals includes; Quartz – 2.65, Calcite – 2.72, Kaolinite – 2.61, Montmorrilorite – 2.74, and muscovite – 2.7 to 3.1 (Table 2). The different values of specific gravity are due to the present of different textures, i.e. it is far from homogenous.

Table 2: Summary of bulk density and specific gravity.

| Distance (m) | Sample/test | Volume of mould ($cm^3$) | Bulk density ($g/cm^3$) | Specific gravity (Gs) |
|---|---|---|---|---|
| 500 | 1 | 105.2 | 1.727 | 2.53 |
| 1000 = 1km | 2 | 105.2 | 1.550 | 2.57 |
| 1500 | 3 | 105.2 | 1.721 | 2.52 |
| 2000 = 2km | 4 | 105.2 | 1.402 | 2.58 |
| 2500 | 5 | 105.2 | 1.738 | 2.60 |
| 3000 = 3km | 6 | 105.2 | 1.472 | 2.59 |
| 3500 | 7 | 105.2 | 1.569 | 2.38 |
| 4000 = 4km | 8 | 105.2 | 1.513 | 2.61 |
| 4500 | 9 | 105.2 | 1.700 | 2.62 |
| 5000 = 5km | 10 | 105.2 | 1.530 | 2.48 |

This result shows that the soil has high organic matter and contains mineral feldspar ranges from 2.54 to 2.57 with average of 2.55.

The results reveal that the plasticity of the soil (with liquid limit ranging from 34% to 65%) is of high plasticity or compressibility since plasticity is less than 50% and the swelling potential is low to medium (Table 3).

The federal Government on Nigeria standard design specification values for both base and sub-base course materials recommends that the liquid limit and plasticity index should not be greater than 30% and 12% respectively and with the results shown in Table 3, the soil is not recommendable for sub- material. There is a direct relationship between the percentage of fines and the plasticity index as shown in Fig. 3 below. The higher the percentage of fine grains, the higher the plasticity index.

Table 3: Summary of Atterberg Limit results.

| Sample | Liquid Limit (%) | Plastic Limit (%) | Plasticity index (%) |
|---|---|---|---|
| 1 | 40.6 | 36.1 | 4.4 |
| 2 | 34.0 | 26.9 | 7.1 |
| 3 | 40.0 | 30.8 | 9.2 |
| 4 | 60.0 | 44.5 | 15.5 |
| 5 | 55.0 | 39.1 | 15.9 |
| 6 | 34.0 | 49.9 | 15.9 |
| 7 | 53.0 | 34.5 | 18.5 |
| 8 | 52.4 | 31.1 | 21.3 |
| 9 | 25.8 | 51.0 | 25.2 |
| 10 | 65.0 | 38.9 | 26.1 |

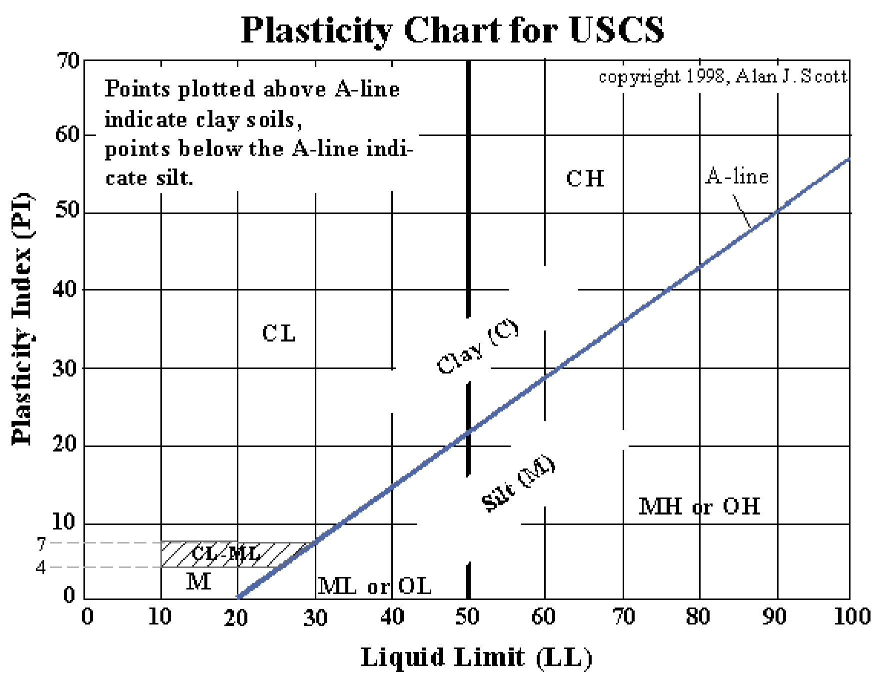


Fig. 3: Showing plasticity chart.

The summary of the sieve analysis results are presented in Table 4 and their various deductions from the PSD curve.

Table 4: summary table of sieve analysis

| Sample | $D_{60}$(mm) | $D_{50}$(mm) | $D_{30}$(mm) | $D_{10}$(mm) | CU | Cc |
|---|---|---|---|---|---|---|
| 1 | 0.500 | 0.450 | 0.254 | 0.125 | 4.000 | 1.032 |
| 2 | 0.600 | 0.450 | 0.250 | 0.126 | 4.762 | 0.827 |
| 3 | 0.650 | 0.600 | 0.500 | 0.250 | 2.600 | 1.538 |
| 4 | 0.650 | 0.550 | 0.498 | 0.230 | 2.826 | 2.659 |
| 5 | 0.550 | 0.500 | 0.340 | 0.153 | 3.595 | 1.374 |
| 6 | 0.650 | 0.550 | 0.499 | 0.250 | 2.600 | 1.532 |
| 7 | 0.550 | 0.450 | 0.200 | 0.126 | 4.365 | 0.577 |
| 8 | 0.550 | 0.450 | 0.250 | 0.100 | 5.500 | 1.136 |
| 9 | 0.250 | 0.200 | 0.155 | 0.090 | 2.778 | 1.068 |
| 10 | 0.550 | 0.455 | 0.450 | 0.250 | 2.200 | 1.472 |
| Range | 0.25-0.65 | 0.20-0.60 | 0.16-0.50 | 0.09-0.25 | 2.20-5.50 | 0.53-2.65 |
| Mean | 0.450 | 0.400 | 0.330 | 0.170 | 3.85 | 1.59 |

The result shows PSD extending over a very limited range i.e. all particles in the soil are more or less of the same size. The PSD curve is almost vertical and this is seen as a well sorted soil to a sedimentologist which also means that the pore spaces are small and can retain water for a long time.

The maximum dry density (MDD) and the optimum moisture content were recorded as 1983kg/m$^3$ and 18.7% respectively. The result shows that, the higher the optimum moisture content, the higher the maximum dry density which is in line with established trend. There is a definite relationship between the texture and maximum dry density. According to Emesiobi, 2001, the soil is fair enough for sub-grade material.

Table 5: showing compaction classification (Emesiobi, 2000)

| Maximum Dry Density | General value as sub-grade foundation material |
|---|---|
| Over 21.21 | Excellent |
| 19.98-21.21 | Good |
| 17.95-19.98 | Fair |
| 16.32-17.95 | Poor |
| 11.42-16.32 | Very poor |

For Choba, the results indicate the proportion passing AASHTO Sieve N0 10 - 60 of the sieve analysis to be between Cc: 1.59 to $D_{60}$: 0.450%. The same area indicates plastic limit value of 38.28%, liquid limit value of 45.98% and plasticity index of 15.91 respectively. An optimum moisture content of 18.7%, the Maximum dry density of1983kg/m3 was recorded (Table 5). Therefore based on the recommendation of American Association of State Highways and Transportation (AASHTO), the soil in Choba site is suitable for use as sub-grade/filling material. However some parts of the roads sites failed probably because of poor work done during construction. The road at some sites failed probably because the values of result exceed the AASHTO recommended limits.

**CONCLUSION**

Geotechnical analyses of some soils in Choba area were carried out. The soils were sampled at grade, subbased and base levels at 500m intervals along Rumuokoro-Choba axis. The study area is underlain by river course alluvial deposits, the Benin Formation, and the Agbada Formation. Geotechnical test such as Atterberg limits tests, grain-size distribution and compaction test were carried out and used to analyse the soil in the study area. This was done to determine their suitability for use as sub-grade/filling material and sub-base material for road construction. The results of the analysis indicate that soil of Choba are suitable for use as Sub-grade/filling materials, while that of some sites are not suitable for use as sub-grade/filling and sub-base material. This is probably the cause of the failed road at those sites.

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