

Basic Engineering Geological Properties of Lateritic Soils from Western Niger Delta

F.C. Ugbe

Department of Geology, Delta State University, Abraka

Abstract: This study was carried out with aim of providing a valuable data base for emerging road construction engineers involved in opening up the rural areas for extensive petroleum exploration activities. A total of 152 samples were randomly collected with different geotechnical parameters tested according to the British Standards. The soils are generally fine to medium grained consisting mainly of clayey sand and sandy clays with low to medium plasticity. The mean value of the optimum moisture content of less than 12% suggests that during dry season, construction work in the field may not be a major problem. The soaked CBR values range from 3 to 43%. This falls below the stipulated 180% by Federal Ministry of Works for base course material. Consequently, this suggests that these soils should be subjected to some forms of stabilization to ensure the durability of roads in this region.

Key words: Base course, california bearing ratio, compaction

INTRODUCTION

Lateritic soils are the product of intensive weathering that occurs under tropical and subtropical climatic condition resulting in the accumulation of hydrated iron and aluminum oxides (Alexander and Cady, 1962; Gidigas, 1972). These soils are found in dry flat lands and plains in both eastern and western Niger Delta.

The general geology of the study area consists of relatively simple diverse types of Quaternary deposits overlying thick Tertiary sandy and clayey deltaic deposits. Three main subsurface lithostratigraphic units have been recognized (Short and Stauble, 1967). From the oldest to the youngest they are Akata, Agbada and Benin Formations. Detailed studies of the Quaternary deposits of the Niger Delta by Allen (1965) revealed that the sediments were deposited under the influence of fluctuating Pleistocene eustatic sea levels.

The geomorphology of the Niger Delta may be divided into three main environments namely the continental, transitional and marine environments. Five major geomorphological units have been recognized in the Niger Delta (Allen, 1965; Short and Stauble, 1967) (Fig. 1). These include:

- Active and abandoned coastal beaches
- Salt water mangrove swamps
- Freshwater swamps, backswamps deltaic plan, alluvium and meander belt
- Dry deltaic plan with abundant swamp zones, Sombreiro Warri plain
- Dry flat land and plain

In the Niger Delta, exploration and exploitation for oil and gas has been on for over five decades. This has

resulted in massive construction of roads in the region. Lateritic soils in the region have been the major construction material for these roads. These lateritic soils have generally been found to be unsuitable for construction of roads in their natural state. There is a general need to properly classify the soils to know which specific stabilization method that may be employed. This calls for detailed investigation of basic engineering geological properties of the soils. Considerable studies have been carried out on the engineering geological properties of the soil by various researchers (Akpokodje, 1986a, 1986b; Alabo and Pandey, 1987; Alabo *et al.*, 1983; Arumala and Akpokodje, 1987; Leton and Omotosho, 2004; Omotosho and Eze-Uzomaka, 2008).

All these studies have been however concentrated on the lateritic soils of the eastern Niger Delta. Very little work has been carried out on the lateritic soils of the western Niger Delta. The location of lateritic soils in the eastern and western Niger Delta is separated by a distance of over 150 km. A common error is to assume that because the soils are from the same region their engineering geological properties will be the same. However, Adeyemi and Wahab (2008) have established that there could be significant variability in geotechnical properties of lateritic soils within quite short distances. The objective of this study therefore is to classify the lateritic soils of the flat plains of the western Niger Delta. This classification will, however, aid road construction companies when sourcing for lateritic soils in the western Niger Delta.

MATERIALS AND METHODS

The soil samples were collected between 2nd October and 15th November 2010. The area covers parts of Edo

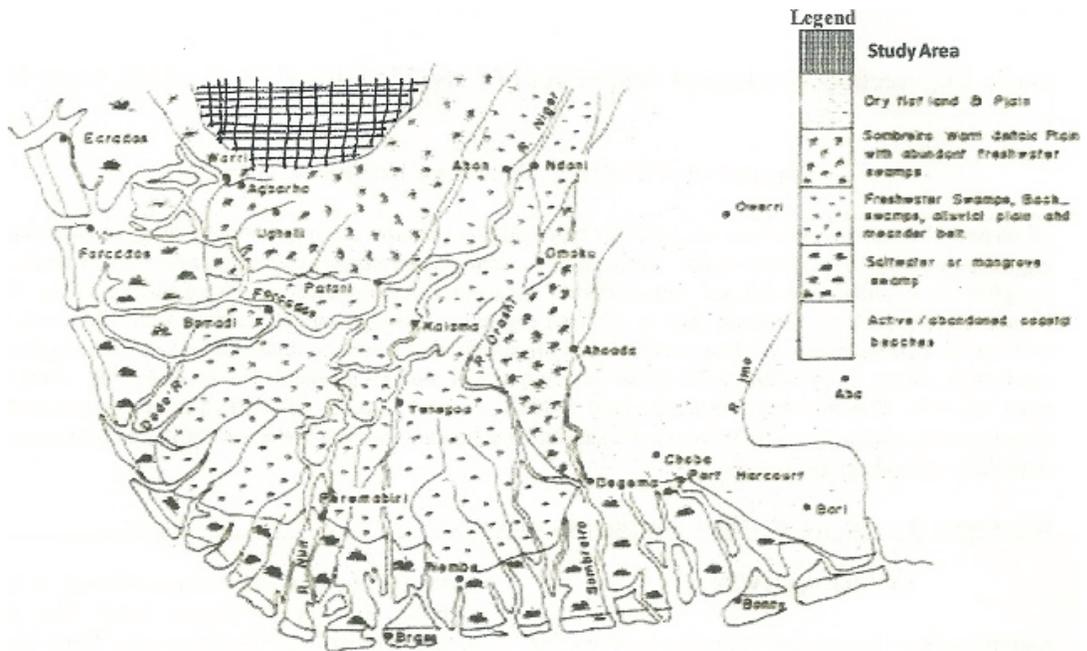


Fig. 1: The major geomorphic units of the Niger Delta (Allen, 1965)

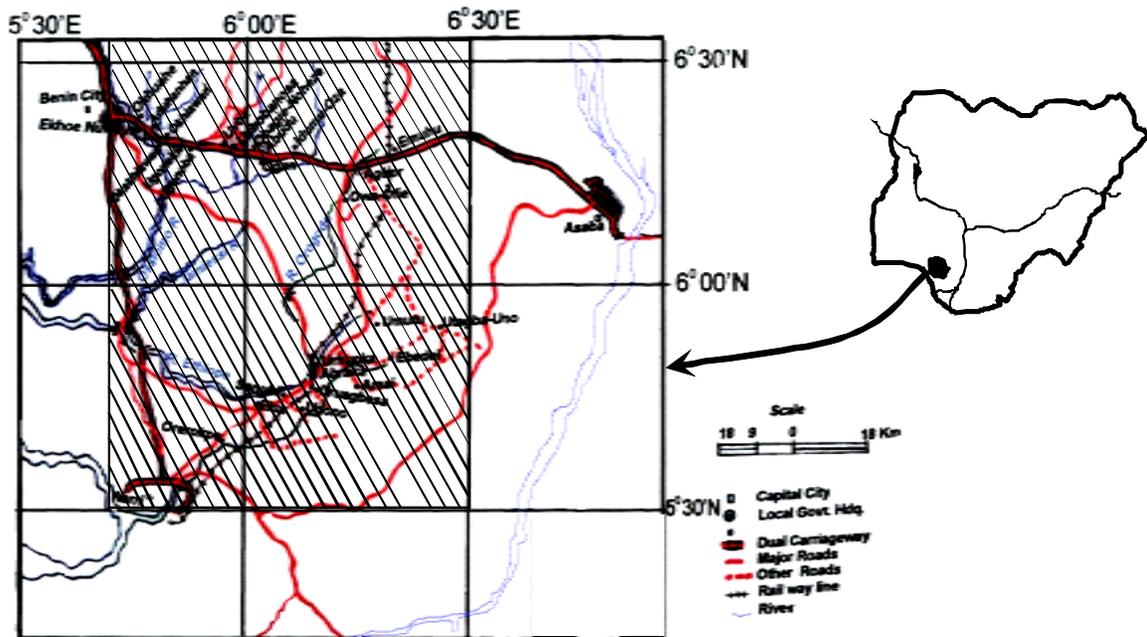


Fig. 2: Sample location map

Table 1: Coordinates of sample locations

Location	Longitude	Latitude
Owa Ofie	06°11'00"	06°14'00"
Agbor	06°11'55"	06°16'34"
Emuhu	06°14'21"	06°17'48"
Idumuoza	06°07'17"	06°16'05"
Abudu	06°03'21"	06°17'30"
Evbobanosa I	05°58'00"	06°17'00"
Evbobanosa II	05°58'02"	06°17'00"
Uvbe I	05°57'05"	06°17'56"
Uvbe II	05°57'33"	06°17'57"
Ugoneki	05°52'00"	06°18'00"
Ugonoba	05°51'00"	06°19'00"
Ekhoe	05°51'41"	06°19'17"
Okhiawan	05°47'05"	06°19'49"
Aduhanhan	05°48'07"	06°19'02"
Okhuahie I	05°46'00"	06°19'00"
Okhuahie II	06°45'00"	06°19'00"
Obagie Noheze	06°02'57"	06°17'31"
Ogan	06°03'00"	06°17'27"
Umutu	06°13'00"	05°54'00"
Amai	06°10'00"	05°47'00"
Urhoka	06°07'00"	05°49'00"
Abiraka	06°06'07"	06°47'06"
Urhugbesa	06°04'16"	05°45'06"
Ugono	06°04'00"	06°44'00"
Sanubi	06°02'00"	05°46'00"
Ebedei	05°53'00"	05°12'00"
Umukwata	05°50'00"	06°11'00"
Eku	05°45'00"	06°14'00"
Orookpe	05°39'00"	06°53'00"

Table 2: Frequency distribution of the percentage fines in the soil types in the study area

Soil type	No. of samples	Range of percentage of fines	Frequency (%)
A-2	100	15-20	14
		21-26	27
		27-33	58
A-6	20	36-39	24
		40-43	40
		44-47	34
A-7	32	37-41	27
		42-46	48
		47-51	10
		52-56	14

and Delta States of Nigeria. The area is accessible from Benin, Warri and Asaba (Fig. 2). A total of 152 bulk samples from different locations were randomly collected from burrow pits across the study area. The different locations were georeferenced (Table 1). The bulk samples were air-dried for a period of fifty days prior to being tested. The tests carried out were in accordance with BS 1377 (1990). The tests carried out included particle size distribution, specific gravity, liquid limit, plastic limit, compaction and C.B.R tests.

RESULTS AND DISCUSSION

Particle size distribution and plasticity: Table 2 summarizes the frequency distribution of percentage fines in the soil groups. Table 3 illustrates the various size ranges and the textural classification of the soils. The

dominant AASHO groups and the proportion of occurrence are A-2 (66%) and A-7 (21%) types with few occurrences of A-6 (13%) types. Only the A-2 soils contain some amount ($\leq 6\%$) of gravels. The percent fines for A-2 materials are between 15-33% which is consistent with the work of Akpokodje (1987). However, there are some differences between the results of Akpokodje's work as regards the dominant range of percentage fines in A-7 materials. While Akpokodje (1987) stated that the range of dominant percentage fines in A-7 materials is between 51-60%, this study revealed that 42-46% fines for the dominant A-7 materials. The reason may be due to the influence of seasonally and permanently flooded freshwater and saltwater mangrove swamps within the Eastern Niger Delta lateritic soils, which may have led to the increase in the percent of fines within the eastern part.

The particle size distribution envelopes in Fig. 3 to 4 indicate that the soils are clayey sands for A-2 and A-6 types. The percentage range of clay is 10-21% for A-2 soils, 28-34% for A-6 soils. Figure 5 indicates that the soils have percentage clays between 53-55% indicating sandy clays which is classified as A-7 type. Generally, the particle size distribution envelopes indicate fine to medium grained soils consisting mainly clayey sands and sandy clays. The high content of fines ($>30\%$) and extremely low percentage of gravels ($<7\%$ and absent in most samples) renders them unsuitable for the construction of granular roadbase and subbase courses. Some of the A-2 materials with less than 20% fines can however be used for subbase construction, general filling and embankment construction.

The soils are of low to medium plasticity ($LL < 50$) which indicate the probable absence of expandable clay materials. This corroborates the result in Table 2 where the dominant percentage of fines of the A-7 type ranges between 42-46%. This probably explains why the soils in the study area (western Niger Delta) exhibit lower plasticity than those from the eastern Niger Delta. The variations in the plasticity indices within each group increase as the soils becomes progressively more plastic. The values for the Skempton activity of the soils range from 0.50 to 1.24 which classifies the soils as inactive to moderately active clays. This plasticity index of the soil (P.I. 8 to 22%) (Table 4) classifies the soil as having low to medium swelling potential according to Ola (1982).

The majority of the soils plot above the A-line in the Casagrande Plasticity chart (Fig. 6) indicating that they are essentially clays and not silts which corroborates the results of the grading test. A-2 soils have liquid limits ranging from 22 to 44% and plasticity index between 8 to 22%. When compared with the FMW (1997) standard ($W_L \leq 30$; $P.I. \leq 12$), some of the A-2 soils can be used for general filling embankment, roadbase and subbase courses.

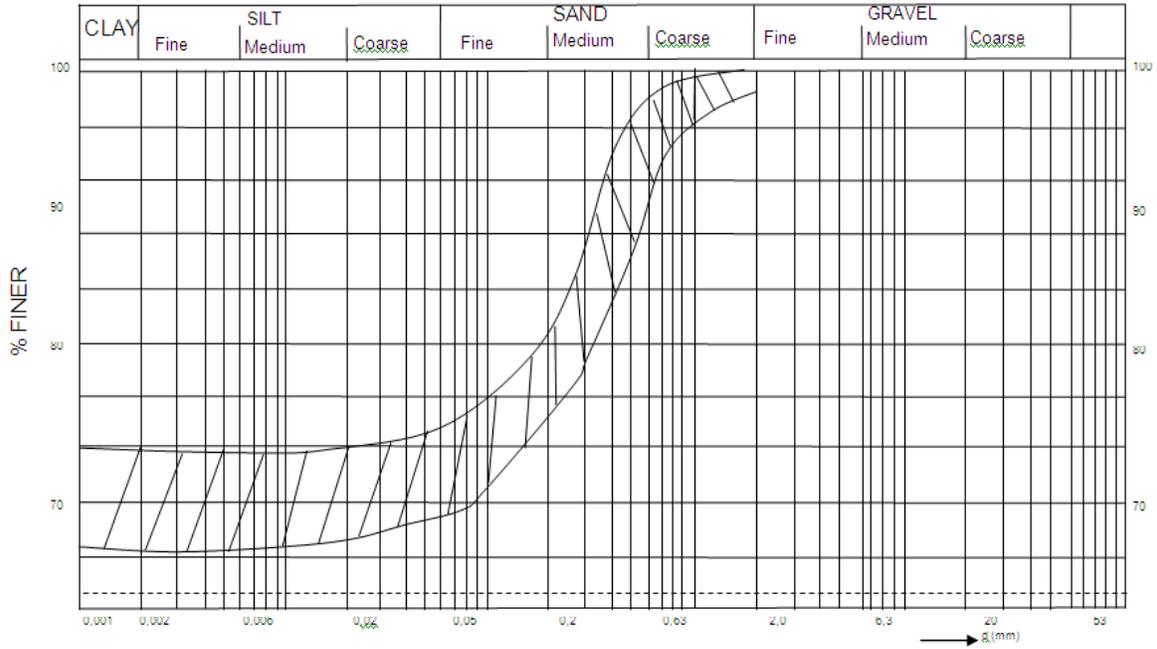


Fig. 3: Particle size distribution curve of soils of study area (A-2 type)

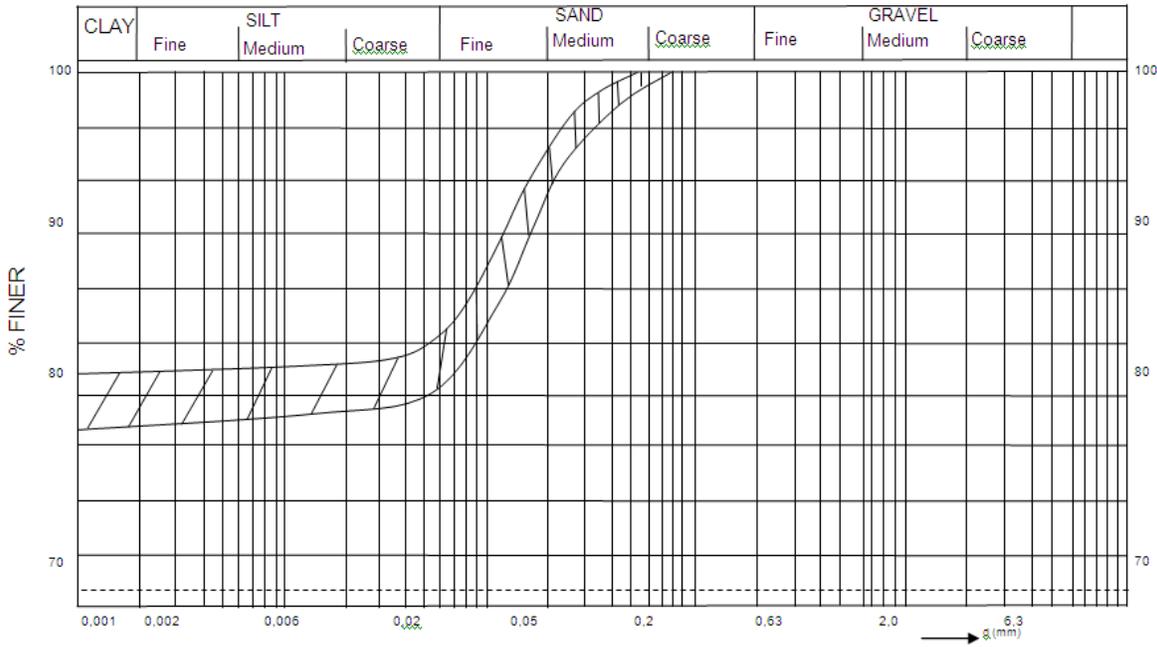


Fig. 4: Particle size distribution curve of soils of study area (A-6 type)

Table 3: Proportions of the various size ranges and textural classification of soils in the study area

No. of samples	% Passing 0.074 mm Sieve (Fines)	Gravel (2 mm)	Coarse to medium sand 2-0.2 mm	Fine sand 0.2-0.06	AASHO
100	15-33	0-6	40-75	16-35	A-2
20	36-47	0	32-46	13-25	A-6
32	37-56	0	30-51	12-21	A-7

Table 4: Range of plasticity values of the soil groups in the study area

No. of samples	Liquid limit (%)	Plastic limit (%)	Plasticity index	AASHO classification	Skempton activity	Category
100	22-44	15-30	8-22	A-2	0.50-0.70	Inactive
20	36-40	20-27	13-19	A-6	0.76-1.23	Moderately active
32	41-48	23-31	17-22	A-7	0.75-1.24	Moderately active

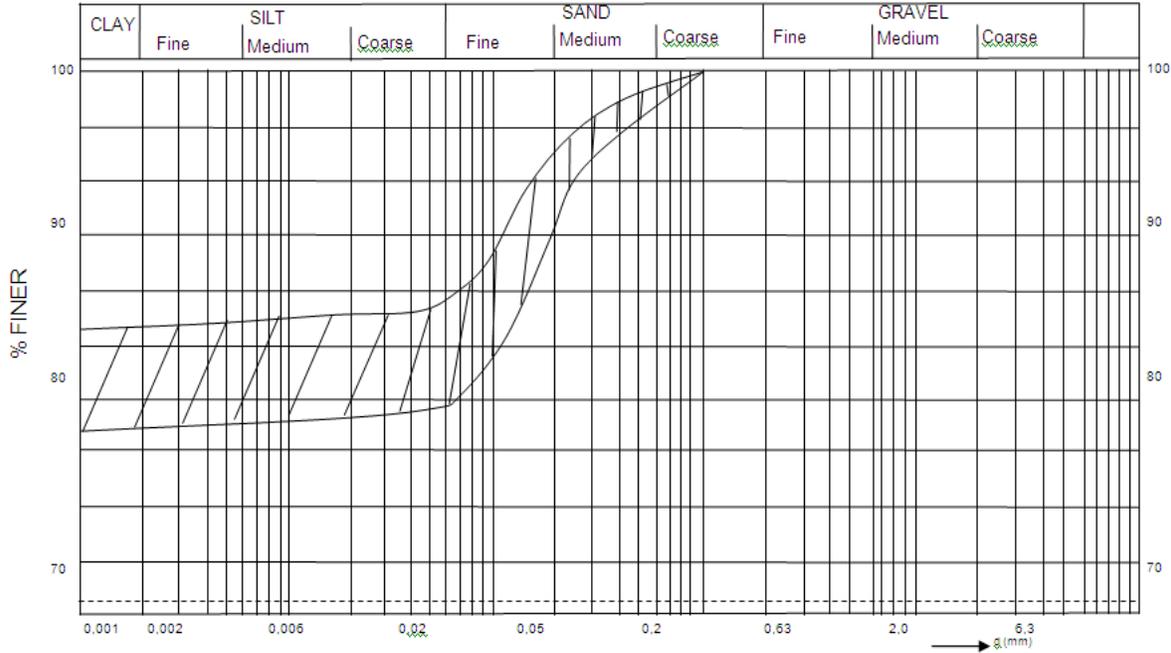


Fig. 5: Particle size distribution curve of soils of study area (A-7 type)

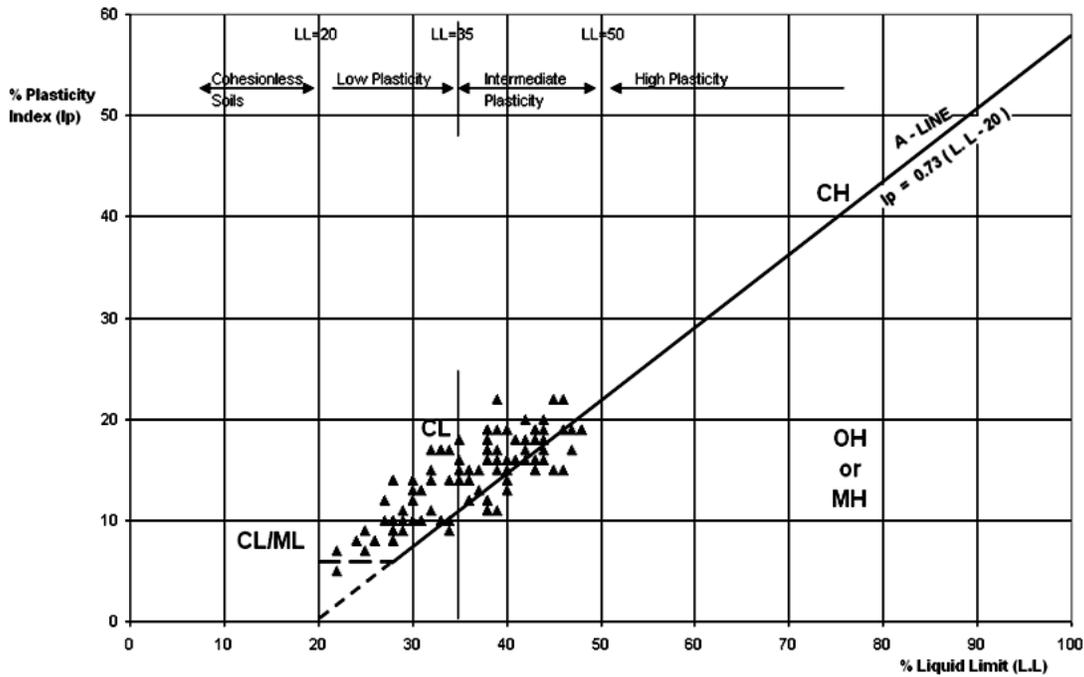


Fig. 6: Casagrande plot of soils from study area

Table 5: Range of maximum dry densities and optimum moisture

Soil type	No. of samples	Maximum dry density kg/m ³	Optimum moisture % content
A-2	100	1710-2140	8-15
A-6	20	1750-1980	10-14
A-7	32	1700-1950	14-18

Table 6: Statistical summary of test results

Variable	Range of values	Mean	SD
Fines (%)	14-56	33.54	9.70
Liquid limit (%)	22.2-48.30	36.39	6.35
Plastic limit (%)	14.4-31.20	21.83	4.08
Plasticity index (%)	4.60-25.80	14.50	4.24
Maximum dry density kg/m ³	1700-21.40	1961.81	95.08
Optimum moisture Content (%)	7.7-18.00	11.30	1.94
Specific gravity	2.50-2.83	2.62	0.08
Soaked CBR	3.00-43.00	19.42	8.38
Swelling (%)	0.03-0.18	0.09	0.02
Sand (%)	42.0-86.0	66.43	9.70

N = 152

As expected, the maximum dry density decreases with the increase in fines thereby making the A-2 material exhibit the highest maximum densities while the A-7 materials have relatively lower densities. Optimum moisture content and liquid limit increase with the increase in percentage of fines as expected. Generally as expected, maximum dry densities and optimum moisture contents of soils in study area are influenced by the grading and plasticity.

Maximum Dry Density and (MDD) and California Bearing Ratio (CBR): The maximum dry densities achieved in the laboratory exceed 1700kg/m³ in all the soil types as shown in Table 5. They are therefore suitable for general filling and construction of subgrade and subbase courses of some roads. The soaked CBR values (3-43%) of the soils indicate that none can be used for subbase and base course of roads because the values fall below the 180% stipulated by FMW (1997). Some A-2, A-7 and A-6 soils can however be used for general filling provided the fines are less than 35% and soaked CBR above 5%.

Statistical analysis of test results:

Mean values: The means and standard deviations of test results of the soils are presented in Table 6. The relatively wide range of values indicates the great diversity in the characteristics of the soils. This is mainly attributed to difference in mineralogy and texture of the soils. These lateritic soils with mean values of Fines (33.5%), Liquid Limit (36.4%), Plasticity Index I(14.5%) and Soaked CBR (19.4%) are unsuitable for road bases and subbase/subgrade courses when compared with the Nigerian General Standard Acceptable Limits (FMW, 1997; Fines ≤15%, Liquid Limit ≤30%, Plasticity Index ≤13%, Soaked CBR >30%). The soils fall short of the standard.

However, based on the general standard acceptable limits for construction of embankments and general filling, these lateritic soils are suitable because their mean fines and soaked CBR values were within the limits. The mean value of the optimum moisture content less than 12% may suggest that during the dry season, compaction work in the field may not be a major problem. The mean swelling percentage of the soils after 96 h of soaking suggests that expandable clay minerals may not be present in the soils.

CONCLUSION

This study reveals the basic geotechnical properties of lateritic soils from western Niger Delta. The soils have been found to be of A-2, A-6 and A-7 types with A-2 type soils being dominant. The soils have fines content ranging from 14 to 56% and extremely low gravels percentage of 0-6% which renders them unsuitable for granular road base and sub-base courses in their natural state. The Skempton activity of 0.50-1.24 classifies the soils as inactive to moderately active clays and plasticity index ranging from 8 to 22% which indicates that the soils are of low to medium swelling potential. The CBR value ranging from 3 to 43% indicate that these soils cannot be utilized to construct durable roads except they are stabilized with appropriate materials that are compatible with the soil properties.

ACKNOWLEDGMENT

The Project Manager, Julius Berger Nigeria PLC and the entire geotechnical laboratory staff of the Railway project, Delta State Nigeria, are highly acknowledged for the assistance in the geotechnical analysis during this study.

REFERENCES

Adeyemi, G.O. and K.A. Wahab, 2008. Variability in the Geotechnical Properties of a Lateritic Soil from South Western Nigeria. Bull. Eng. Geol. Environ., 67: 579-584.

Akpokodje, E.G., 1986a. The geotechnical properties of Lateritic and non-lateritic soils of South-Eastern Nigeria and other evaluation for road contribution. Bull. Int. Assoc. Eng. Geol. 33 pp. 115-121.

Akpokodje, E.G., 1986b. A method of reducing the cement content of two stabilized Niger Delta soils. Quar. J. Eng. Geol., 19: 359-363.

Akpokodje, E.G., 1987. The engineering geological characteristic and classification of the major superficial soils of the Niger Delta. Eng. Geol., 32: 255-261.

Alabo, E.H. and P. Pandey, 1987. Distribution of engineering properties of red soils in the central Lower Niger Delta, Nigeria. 9th African Reg. Conf. Soil Mechanics and Found. Engrg, Lagos, pp: 49-55.

- Alabo, E.H., W.H. Fitzjohn and F.A. Ogare, 1983. Geotechnical properties of tropical red soil from part of Eastern Niger Delta. *J. Min. Geol.*, 21(1-2): 35-39.
- Alexander, L.T. and J.G. Cady, 1962. Genesis and Hardening of Laterite in Soib. *Tech. Bull.* 1282 US Department of Agriculture.
- Allen, J.R., 1965. Late quaternary niger delta and adjacent areas. sedimentary environment and lithofacies. *Am. Assoc. Petrol. Geol. Bull.*, 49: 547-600.
- Arumala, J.O. and E.G. Akpokodje, 1987. Soil properties and pavement performance in the Niger Delta. *Q. J. Eng. Geol.*, 20: 287-296.
- British Standard Institute, 1990. *Methods of Tests for Soils for Civil Engineering Purposes*. B.S., pp: 1377-1557.
- Federal Ministry of Works, 1997. *General Specification (Roads and Bridges)*. Vol. 2, Federal Ministry of Works and Housing, Lagos, Nigeria.
- Gidigas, M.D., 1972. Mode of formation and geotechnical characteristics of Laterite materials in Ghana in Relation to soil forming factors. *Eng. Geol.*, 4: 79-91.
- Leton, T.G. and O. Omotosho, 2004. Landfill operations in the Niger Delta region of Nigeria. *Eng. Geol.*, 73: 171-177.
- Ola, S.A., 1982. Settlement of two oil tanks on Kaduna lateritic soils in Nigeria. *Q. J. Eng. Geol.*, 15: 317-324.
- Omotosho, O. and O.J. Eze-Uzomaka, 2008. Optimal stabilization of deltaic laterite. *J. S. Afr. Inst. Civil Eng.*, 50(2): 10-17.
- Short, K.C. and A.J. Stauble, 1967. Outline of the geology of Niger Delta. *Am. Assoc. Petrol. Geol. Bull.*, 51: 761-776.