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(Research Article)

Investigation of the suitability of the borrow pit materials utilized for the construction of 9.5 km ring road three in Uyo local government area

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Abstract

This research is an investigation of the geotechnical engineering properties of the Laterite soils employed for the construction of the 9.5km Ring Road Three in Ukyo Local Government, Akwa Ibom State, Nigeria. Two samples were collected from the borrow-pit at Mokoro Nist, nit Ibim Local Government Area, Akwa Ibom State at depths ranging from 0.5m to 1.5m. The samples were subjected to the following laboratory tests: Particle (grain) size analysis, Atterberg limit test, Compaction test and California bearing ratio (CBR) test. From the above-mentioned laboratory tests, the percentage passing sieve no. 200 (75µm) ranges between 1.4501% and 4.1476%, liquid limits (LL) ranges between 27% and 29%, Plasticity index (PI) ranges between 4.13% and 6.05%, Optimum moisture content (OMC) ranges between 9.82% and 10.42%, Maximum dry density (MDD) ranges between 19.21kN/m3 and 19.33kN/m3 and the CBR (unsoaked) ranges between 61.21% and 61.46%. In accordance with clause 6201 and 6252 of the Federal Ministry of Works and Housing (1997) Specification Requirement, the lateritic soil is considered suitable for sub-base and base course since their percentage passing sieve No. 200, liquid limits, plasticity index are not greater than 35%, 50% and 12% respectively and also MDD is not greater than 20.0kN/m3 recommended. It could also be deduced that the borrow –pit material is suitable for sub-base only since the CBR (unsoaked) is not less than 30% recommended. However, the Lateritic soils have been found to be of A-2-4 based on the AASHTO classification Scheme and hence, they have significant constituent materials of mainly silty or clayey gravel and sand classified as sandy clay according to O'Flaherty. In conclusion, the borrow-pit material deployed will only be adequate and suitable for sub-base and will not be suitable for base course.

Keywords: Compaction Test; Lateritic Soil; Plastic Limit; California Bearing Ratio Test; Atterberg Limit Test

1. Introduction

Lateritic soils have wider applications in the Nigerian construction industry, especially in road-construction projects where they are utilized as fill materials and flexible pavement foundations. Their usage as sub-base and base construction materials is mainly because they are easy to manipulate on the road surface and have natural stable grading with a suitable proportion to act as binders. One of the major causes of a road accident is a bad road which is usually caused by wrong application of constructional materials, especially laterite as base and sub-base material by construction companies.

For a material to be used as either a base course or sub base or sub-base course depends on its strength in transmitting the axle-load to the sub-soil and or subgrade (the mechanical interlock). The degree of success in each case depends on the genetic characteristic of the soils and the specific purpose for which they have been used. The performance of lateritic soils as foundations for structure is varied and appears to depend on the nature of the soil, the degree of

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weathering, topography, the drainage condition and more importantly on the type of foundation, and the number of loads imposed.

The area of study is at Mbiokporo Nsit, Nsit Ibium Local Government area of Akwa Ibom State. The area lies approximately between latitude 4.84'' North and Longitude 7.85'' East and Elevation of 154m. The area shares boundaries with Ibesikpo/Asutan (East), Etinan (West), Nsit Ubium (South) and Uyo (North) Local Government Areas. Ring Road Three is about 9.5 kilometers (9.5KM) stretch from Nnung Ndung Aka – Road intersection through Oron-Road to Nwaniba Road all in Uyo L.G.A. The road is currently undergoing construction.

Hence, the durability of a highway pavement depends on the quality of its sub-base and base course layers. The sub-base and base course layers play key roles in militating against the detrimental effect of climate and the static and dynamic stresses generated by traffic. Therefore, building a stable sub-base and a properly drained and compacted standard base course is vital for construction an effective and long-lasting pavement system. Hence this study will ensure that the right materials and method with the right criteria are deployed as sub-base material for road construction in Akwa-Ibom state and environs, thereby ensuring their durability

For any highway to perform its traditional function of carrying vehicles and passengers safely from one location to another it must be properly designed, properly constructed, regularly maintained and at a later age, properly rehabilitated to improve on its residual life. However, no matter how beautifully the highway is designed; no matter how accurately the component is set out and no matter how efficiently the operator manipulates the machines, if the construction materials are of poor quality, the highway will not outlive its useful life. The objective of this study is to assess and investigate and analyse the geotechnical properties of the lateritic soil sample used as sub-base, the method and the external factor used for constructing of Ring Road Three, thereby verifying its adequacy.

1.1. Specific Objectives

- Obtaining representatives sample of the soil at five (5) different locations within depths of 1.5m for identification.
- Classification of these samples for use in laboratory test to investigate the relevant geotechnical properties of the soil.
- Determine whether these geotechnical properties meet the required standard and specification recommended for each purpose (sub-bases and base course).
- To assess the strength of the sub-base and base course (this would entail whether or not the road would be able to carry the vehicular load that would be subjected to it).
- To determine whether these samples deployed were adequate or not and to suggest possible solutions, should the subgrade properties not be good enough for the road construction.

The outcome of this study will help in selection and evaluation of suitable construction materials which will aid to reduce road deterioration such as cracks of different kinds, depressions ruts and potholes and thereby provide comfort, reduce traffic congestion and also contribute to the health being of the occupants that were living near the area and carrying out their business. Additionally, it will provide technical information on the geotechnical properties of soil materials used in the construction of 9.5KM Ring Road Three (3) and thereby provides safety and comfort for road users. Researchers, individuals, students, government and non-governmental organizations would be aware of the quality of soils to be used for road construction and will serve as guidelines for civil engineers and builders in selection of materials and the types of equipment to be deployed for the construction of roads.

This study was limited to the assessment and investigation of the geotechnical properties of lateritic soils deployed for the construction of 9.5KM Ring Road Three (3) and to verify whether the material deployed were adequate for the desired purpose or not with a view of avoiding any failure (cracks and potholes) in the future.

2. Material and methods

Before embarking on this research study, several findings were made from libraries, the internet and academic journals to obtain related literatures which help in confirming the actual existence of the problems intended to be solved.

2.1. Description of the Study Area

Mokoro I is a village in Nist-Ibom Local Government Area and is the primary area of focus. It is situated in the North-East region of Akwa-Ibom State and has Tropical climate conditions which are governed by the movement of the Inter-

Tropical Conveyance Zone (ITCZ). Nsit Ibom Local Government Area lies between Latitude 4o53’0’’ North and Longitude 7o54’0’’ East and is 154 meters above the sea level. Flood plains, sandy ridge complexes separated by muddy swamp define the project area. Also, as in all Nigeria coastal states bordering the Atlantic Ocean, coastal erosion affects the vicinity of the project area because, the low-lying terrain consists of unconsolidated mud and sandy particles, which present no serious resistance to the impact of breaking waves and the flood currents associated with the shorelines.

Five lateritic soil sample designated as point-1, point-2, point-4 and point-5 respectively were obtained by manual effort using shovel, auger, sack bags and measuring tape. To prevent loss of moisture in the samples, the samples were put and tied in waterproof in each location. Labelling followed for easy identification and were taken to the laboratory for subsequent tests and evaluation.

2.2. Laboratory Tests

Testing soil samples in the laboratory plays an important role in civil engineering practice. Laboratory tests are carried out for description and classification of soils, to investigate their basic mechanical properties and to determine value for the stiffness and strength parameters. The soil samples that are to collected were subjected to the following laboratory tests.

- Natural Moisture Content.
- Sieve Analysis (particle size distribution or Gradation test).
- Atterberg Limit (Liquid Limit and Plastic Limit).
- Compaction test (Bulk density and Dry density).
- California Bearing Ratio (CBR).

The tests were analyzed using British Standard (BS) 1377 (12) and results were compared with the standard specified value and group in accordance with general specification for roads and bridges Federal Ministry of Work Handbook (18), and American Association of State Highway and Transportation Officials (8) respectively.

2.3. Natural Moisture Content Determination Test

The aim of the moisture content test is to determine the water content in a soil sample. The apparatus used for the test include

- Drying oven with temperature of 105oC to 110oC
- Weighing balance readable and accurate to 0.001g.
- Metal container (Tin) and Hand scoop.

The metal containers (tins) were cleaned thoroughly and weighed to the nearest 0.01g as M1. A soil sample of at least 30g were loosely placed in the metal container, covered with a lid, weighed and recorded as M2. The lid was removed and placed on the metal container with the sample in the oven for 24 hours. The samples were removed from the oven and allow cooling for some minutes and covered with the lid and then weighed and recorded as M3.

2.3.1. Calculation

$$\text{Moisture Content} = \frac{M3-M2}{M3-M1}(100)\% \text{ ....Equation (1.1)}$$

2.4. Particle Size Analysis Test (Gradation Test)

The aim of particle size analysis test is to obtain a quantitative particle size distribution of soil sample in order to classify it. The aim is also to determine the relative proportion of the different granular sizes as they are passing through certain sieve sizes. The following apparatus were used for the test: BS sieve 4.75mm, 3.35mm, 2.36mm, 1.70mm, 1.18mm, 850µm, 600µm, 400µm, 250µm, 150µm, and 75µm. weighing balance, Oven of temperature of (105oC to 110oC), sieve brush, tray, electric, Hand scoop etc.

2.4.1. Test Procedure

The Air-dried soil sample were weighed and at least 1000g poured into a tray filled with water and then stirred, washed, sieved with sieve No.200 (75µm) under tap until the water becomes clean. This were done to remove clay/silt particles finer than sieve No. 200. The particles retained in the sieve shall be collected into the crucible and oven dried at a temperature of 105oC for 24 hours to expel moisture content preparatory for dry sieving. Dry sieving was accomplished by passing/pouring the particle through assemblage of sieves of various sizes. These sieves were shaken for 2 minutes so that each sieve could retain particles not finer than the sieve and weight of particles retained in each determined, from where percentage retained and percentage passing was deduced. The following were the formula used:

Actual weight = Total weight – Weight retained………………………………………………………………. Equation 1.2

Percentage retained = $\frac{Weight\ retained}{Total\ Weight}\ x\ 100\%$……………………………………………Equation 1.3

Percentage passing = 100 – Percentage retained ……………………………………………Equation 1.4

2.5. Atterberg Limit Test (Consistency Test)

The main objective of the Atterberg limit test is to determine the liquid limit, plastic limit and plasticity index of the soil.

2.6. Liquid Limit Test

The aim of this test is to determine the water absorbing property of the soil and its swelling potential. The following apparatus were used: Flat glass plate (500mmx500mm size and 10mm thick), Casagrande cup (liquid limit device), Spatulas (200mm long and 30mm wide), Grooving tool and gauge, Electric Oven, weighing balance, BS sieve (0.425mm), moisture content tins, Wash bottle (plastic) and mortar.

2.7. Test procedure

A dried sample (dried laterite) was selected for pounding using a mortar and pestle in order to breakdown the slump particles present in the sample. Sieve 425 mm micron were used to sieve the sample after which about 200g of the sieved sample was weighed out and placed on the glass plate which was then mixed thoroughly with distilled water to form a uniform paste. A portion of the soil sample (well mixed) was placed in a brass cup half-filled (that is, liquid limit device) and the top bucked up parallel to the base. The cup was lifted by 10mm and the device turned in a clockwise direction to cause blows and the value at which the groove closed over a length of 10mm was recorded. These procedures were repeated four times. For each close of groove, samples were collected for moisture content determination. A graph of moisture content against the number of blows was deduced and the liquid limit value was obtained from the graph. Thus, the liquid limit is the moisture content that corresponds to 25 blows.

2.8. Plastic Limit Test

The aim is to determine the minimum moisture content at which a soil is plastic. The following were the apparatus used; Flat glass plate, Spatula, moisture content apparatus, weighing balance, wash bottle, a length of metal rod 3mm in diameter and about 100mm long.

2.8.1. Test Procedure

When the liquid limit test is completed, the remaining homogenous paste was used for the plastic limit test. A dried portion of the sample was added to a homogeneous paste to enable it to be roll and mound into a ball. The ball shape was rolled between the palm and the glass plate with sufficient pressure; the ball was rolled freely to and from without sucking to the surface of the glass plate or the palm. The balls were then rolled into a thread of uniform diameter of about 3mm throughout its length. As the diameter of the thread reaches 3mm, the soil begins to crumble and it will no longer be rolled into a thread. The crumbling indicated the satisfactory end point. Portions of the crumbled soils were gathered and place into moisture content tins and place in an electric oven at a temperature of 105-110oC for moisture content determination. However, the value of the average moisture content after oven-drying the sample gives the plastic limit.

Weight of dry soil = (weight of dry soil + tin) – weight of tin…………………………………………………. Equation 1.5

Weight of water = (weight of wet soil + tin) - (weight of dry soil + tin) ……………………………………Equation 1.6

Moisture content (%) = $\frac{weight\ of\ water}{weight\ of\ dry\ soil} X100\%$ ………………………………………………………….. Equation 1.7

Plasticity index = liquid limit-plastic limit. ……………………………………………………….. Equation 1.8

2.9. Compaction Test

The objective of compaction test is to determine the relationship between optimum moisture content (OMC) and maximum dry density (MDD) of the soil. It is also to reduce or eliminated the volume of air or void space in a soil mass in order to attain more closely packed soil particles. The apparatus used for this test include the following; standard compaction mould, metal rammer weighing 4.5kg dropping at 450mm height, large mixing tray, scrapper, hand scoop, straight of edge knife, measuring cylinder, moisture contend tins, weighing balance, electric oven, wash bottle etc.

2.9.1. Test Procedure

An air-dried soil sample of 6000g was weighed and placed on a large tray passing the 20mm BS sieve. An empty mould with the base plate fitted with paper to the nearest 1g were weighed and recorded. The mould was fitted with the detachable collar placed on a solid base. The sample were mix with the require amount of water and ensured the soil samples thoroughly mix in the tray and were then shear into five (5) layers and each layer were giving 27 blows of 4.5kg rammer dropping from 450mm height above the soil. The blows were distributed uniformly over the surface of each layer and leaving not more than about 6mm soil sample were struck off when the collar is removed from the mould a carefully levelled off to top of the mould with a steel straight edge. The mould with soil sample were weighed and recorded. The representative samples from the remains of the soil sample were taken for moisture content determination. Other separate soil samples left in the tray were compacted following the above procedure. The above procedures were repeated for each increment of required water added (2%). The total numbers of determinations made were at least four (4), and the ranges of moisture content were such that the optimum moisture content, at which the maximum dry density occurs, was within that range. A graph of dry density versus moisture content was deduced and the maximum dry density (MDD) along with the optimum moisture content (OMC) was then obtained from the graph.

Weight of wet soil = (weight of soil + mound) – weight of mound……………………………………………….Equation 1.9

$$\text{Wet density} = \frac{weight\ of\ wet\ soil}{Mould\ volume}$$ ……………………………………………Equation 2.0

Weight of dry soil = (weight of dry soil + tin) – weight of tin……………………………………Equation 2.1

Weight of water = (weight of wet soil) – (weight of soil) ……………………………………Equation 2.2

$$\text{Moisture content (\%)} = \frac{weight\ of\ water}{weight\ of\ dry\ soil}\ x100\%$$ ……………………………………Equation 2.3

$$\text{Dry density} = \frac{Wet\ density}{(100+moisture\ content)}\ x100\%$$ ……………………………………Equation 2.4

2.10. California Bearing Ratio (CBR) Test

The aim and objective of CBR test is to measure the penetration or depression of an applied load on a soil sample. It is also to determine and evaluate the mechanical strength of road sub grade and base materials. The following are the apparatus used for the test; a 5mm and 19.05mm BS sieve, Standard CBR mould, cylindrical metal plunger of 1935mm2, CBR machine for applying the test force through the plunger, Dial gauge for measuring penetration into the soil sample, Annular surcharge discs of 2kg, A metal rammer of 50mm diameter circular surface., Weighing balance readable and accurate of 1g, Measuring cylinder of 100ml capacity., A wash bottle, Hand scoop.

2.10.1. Test Procedure

A compacted wet soil was placed on the California Bearing Ration (CBR) Machine. The proving ring gauge and plunger penetration gauge were set at zero. Immediately the plunger penetration made a contact with the soil, the gauges started working simultaneously and, the readings were taken on the proving ring gauge at every 0.25mm division on the plunger penetration gauge. The first 10 readings were referred to as first pointer and the 10th reading being the correct reading were adopted and multiply with a multiplication factor 0.01 while the last 10 readings were referred to as second pointer, and so also, the 20th reading were adopted and multiplied with a multiplication factor of 0.01. The test was done on both top and bottom of the compacted wet soil. The higher of the two values were chosen as the actual CBR. The average of the top and bottom were however the final actual CBR. The same were done for the remaining three compacted wet samples.

2.10.2. Sample Classification

The soil was classified according to the American Association of State Highway and Transportation Officials (AASHTO) system. The particle size analysis and the Atterberg limit (liquid limit and plasticity index) are employed in this system. Generally, a table is used as a guide.

3. Results and Discussion

3.1. Natural Moisture Content

The natural moisture content results conducted on all the five samples collected from site are ass shown in Table 4.1 below, the result of the laboratory analysis are summarized in Figure 1.1. The American association of state highway and transportation officials (AASHTO) system is shown in Figure 1.2.

Date: 25 - 09 - 2019											
	NATURAL MOISTURE CONTENT										
MATERIAL	LATERITE SOIL										
SOURCE	BORROW PIT,MKBIOKPORO 1										
		SAMPLE 1		SAMPLE 2		SAMPLE 3		SAMPLE 4		SAMPLE 5	
Tin No.		TD	SP	UW	BY	585	SPN	UTD	LJ	ST	BY
Wt of Tin (g)	M1	18.3	18.3	18.5	22.5	18.2	18.5	22.4	22.1	21.9	18.2
Weight of wet soil + tin (g)	M2	38.8	33.6	36.6	45.9	40.1	36.5	42.5	38.5	41.6	37.5
Wt of dry soil + Tin (g)	M3	35.8	32.1	34.7	43.3	37.8	34.2	40.1	36.7	39.8	35.4
Wt of moisture (g)	M4 = M2 -M3	3	1.5	1.9	2.6	2.3	2.3	2.4	1.8	1.8	2.1
Wt of dried soil (g)	M5 = M3 - M1	17.5	13.8	16.2	20.8	19.6	15.7	17.7	14.6	17.9	17.2
Moisture content (%)	(M4*100)/M5	17.14	10.87	11.73	12.50	11.73	14.65	13.56	12.33	10.06	12.21
Average moisture content (%)		14.01		12.11		13.19		12.94		11.13	

Figure 1 Natural Moisture Content Results

SAMPLES	PASSING 75mm SIEVES	LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICIDY INDEX	AASHTO	MDD (Kg/m^3)	OMC (%)	CBR (%) KN/mm	REMARK
1	11.71	32	22.48	9.52	**A-2-4**	2.07	11.7	40.4	Very Good
2	10.71	29.6	21.43	8.17	**A-2-4**	2.07	9.9	36.8	Very Good
3	10.35	30.5	21.69	8.81	**A-2-4**	2.09	11.3	32	Good
4	8.13	23	20.46	2.53	**A-2-6**	2.11	10.1	34	Good
5	8.36	32	24.22	7.78	**A-2-4**	2.15	9.3	22.3	Fair

Figure 2 Summary of Laboratory Results

3.2. Particle Size Analysis

According to American Association of State Highway and Transportation Officials (AASTHO) system for a sample to be used as sub-base, the percentage by weight passing the No. 200 sieve (75umm) shall be equal to or less than 35%. (i.e. <= 35%). And if the percentage passing sieve No. 200 for a laterite sub base is greater than 35% (I.e. >35), no need for further test. The material should be rejected. In the above sample under review ranged from 11.71% to 8.13% which were good samples because percentage by weight passing sieve NO. 200 do not exceed the required 35%.

3.3. Atterberg Limit Test

The American Association of state highway and transportation officials (AASHTO) recommends liquid limit of 40% maximum and a plastic index (PI) of not more than 10% for sub-base material. In the view of the above result, the liquid limit (LL) 0f the sample range for 23% to 32% and the plasticity index (PI) range from 2.53% to 9.52% (see Figure 2) which are fit to be used in road construction. Since both their Liquid Limits and Plastic Index values do not exceed the stipulated values of 40% and 10% respectively.

3.4. Compaction Test

The Maximum Dry Density (MDD) for the soil samples varied between 2.07Kg/m3 to 2.15Kg/m3 while that of Optimum Moisture Content (OMC) ranged between 9.3% to 11.7%. according to O'Flaherty (1988) the range of value that may be anticipated when using the standard proctor test method are for clay, maximum dry density (MDD) may fall before 1.44g/cm3 to 1.685g/cm3 and the optimum moisture content (OMC) may fall between 20% to 30%. For silty clay MDD is usually between 1.6g/cm3 to 1.845g/cm3 and OMC ranged between 15% to 25%. For sandy clay, MDD usually ranged between 1.76g/cm3 to 2.165%/cm3 and OMC between 8% to 15%. Thus, looking at the results of the soil samples. It could be noticed that the samples are sandy clay soil. However, the MDD values met the required values for sub-base materials (i.e. MDD> 2.0 Kg/m3) and can be considered suitable for the purpose.

3.5. California Bearing Ratio (CBR) Test

The Unsoaked California Bearing Ratio (CBR) test results for the sample are 40.4%, 36.8%, 32%, 34% and 22.37% (see Table 4.2) for sample 1 to sample 5 respectively. According to clause 6201 of Federal Ministry of Works Housing (!997) Specification requirement, the minimum strength for sub-base shall not be less than 30% CBR (unsoaked). In view of the above study, the sample under review ranges from 40.4% and 32% with the exception of sample 5.

4. Conclusion

Based on the investigations of the study on the materials deployed as sub-base for the construction of Ring Road 3, the results obtained from laboratory analysis have shown that

- In accordance with clause 6201 of Federal Ministry of WORK AND housing (1997), Specification Requirement, the laterite soil sample were suitable of sub-base and since their percentage passing sieve No. 200. Liquid limit and plasticity index clause are not greater than 35%, 35% and 12% respectively.
- In accordance with O'Flaherty (1988), the laterite soil is classified as sandy clay and the maximum dry density (MDD) values met the required specified values for sub-base (i.e., MDD >2.0g/cm3) and its considered suitable for the construction purpose.
- In accordance with clause 6201 of federal ministry of works and housing (1997) Specification Requirement, the laterite soil samples are considered fit for sub-base since the CBR (unsoaked) values ranges from 35% to 37% which are not less than the stipulated value of 30% recommended for sub-base except for sample 5.
- Based on the investigation of the study and the results, I recommend that civil engineers, builders and contractor should always work in accordance with code of practice of engineering and building profession so as to maintain standards and avoid failures in our country.

Compliance with ethical standards

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Disclosure of conflict of interest

The author declares that there are no conflicts of interest regarding the publication of this manuscript. There are no financial, personal, or other relationships that could have influenced the work reported in this project.

Statement of ethical approval

The study did not involve the use of human participants or animal. Therefore, the ethical approval was not required for the conduct of this research.

Statement of informed consent

Informal consent was not applicable to this study, as no human participants.

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