ISSN No:-2456-2165

Geotechnical Characterization of Lateritic Soils in Some Selected Parts of Lagos State

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Abstract:- In Nigeria, the non-availability of generalized relevant data on materials used for road construction particularly for initial preliminary engineering planning and designs, has been the bane and cause of failure of most of our highway construction projects, such that, failure occurs almost immediately after the project is commissioned or even before. Hence, the needs to characterize the engineering properties of lateritic soils in various borrow pits in Lagos state.

Disturbed soil sample were collected at three different points from three different borrow pits namely Nisha at Eleranigbe, Okeosho and Ibeshe Ikorodu, all in Lagos state, South-western Nigeria for relevant geotechnical analysis at Civil Engineering laboratory, University of Lagos, Nigeria . The samples were subjected to laboratory tests to determine their index properties, shear strength, compaction and soil bearing capacity in accordance to British Standard Specification: BS: 1377 of 1990.

From the result,the natural water content and specific gravity for Nisha, Oke osho and Ibeshe were 4.83, 13.7& 8.87% and 2.69, 2.66 & 2.66 respectively while the average percentage by weight passing the No. 200 sieve (0.075mm) are 7.3, 45 and 43.7%. The average liquid limit, plastic limit, shrinkage limit and plasticity index for Oke osho and Ibeshe were (46.5, 16.4, 7.3& 30.2%), and (45.1, 15.0, 6.3& 30.1%) respectively while samples from Nisha borrow pit was non-plastic. From the analysis, theMaximum Dry Density (MDD) values and the Optimum Moisture Content (OMC) are 1.817, 1.857&1.788 mg/m3 and 10.3, 15.1 &16.3% respectively. The soaked and unsoaked CBR values were 48, 25.3 & 16.3% and 54.3, 43 & 35.3% for Nisha, Oke-osho and Ibeshe respectively. The unconfined compressive strengths were 5.3, 123.3 and 74kN/m2 while the cohesion were 2.7, 61.7 and 37kN/m2for Nisha, Oke osho and Ibeshe respectively.

According to AASHTO Classification System, samples from Nisha are grouped as A-1 (1) while samples from Oke Osho and Ibeshe can be group as A-5(8). Laterite soil from Nisha met the requirement to be used as sub base for road construction while laterite soil from Oke osho and Ibeshe are poor material for road construction according to Nigerian Standard of soil classification for roads and bridges and therefore require stabilization.

Keywords:- *Concrete and gravel.*

I. INTRODUCTION

Geotechnical characterization is the evaluation of the properties of soil to ascertain its suitability for the project under consideration, through scientific means. It is a fundamental step towards the proper design, construction and long term performance of all types of geotechnical projects. For a Highway Engineer, knowledge of the characterization of soil is extremely important, since the pavement structure and foundation of structures rests on soils. The engineering properties of soils are investigated, because the stability of the pavement and the structures is governed by the strength of soils on which they rest. Soils are seldom uniform in character due to its parent material, hence the need for geotechnical characterization to increase the productivity of soil and to improve the workability of the soil mass. The understanding of soil behavior in solving engineering and environmental issues as swelling soil especially expansive lateritic soils that can cause significant damage to road construction and other Engineering application is the sole aim of geotechnical engineering. (Adeyemi, 2014).

The design life of a road project is the guaranteed life span it is designed to last, while the useful life is the period of commencing from the date of commissioning to the last day it ceases to be useful. The design life of a good or well-constructed road varies from 10 to 50 years depecnding on the type of highway condition. The various conditions are high volume (Trunk A: 30 to 50 years), high volume (Trunk B: 20 to 50 years), low volume (paved: 15 to 25 years) and low volume (aggregate surface: 10 to 20 years) (Kadyali and Lal, 2013). One of the major causes of road accident is bad road which is usually caused by wrong application of constructional materials especially laterite as base and sub-base material by construction companies (Ogunribido *et al*., 2014).

The subgrade is the compacted natural earth immediately below the pavement layers. It is the foundation for road works. Its functions are to receive the stress generated from the above layers, to receive materials from the above layers and act as bedding layers. The sub base is the layer of aggregate material laid on the subgrade, on which the base course layer is located. Sub base is often the main load-bearing layer of the pavement. Its role is to spread the load evenly over the subgrade, improve drainage condition, and minimize frost action damage and to remove heave. The quality of sub base is very important for the useful life of the road and can outlive the life of the surface, which can be scrapped off and after checking that the sub base is still in good condition, a new layer can be applied.

ISSN No:-2456-2165

The base course layer is a structural element of the pavement, located directly under the surface layer. If there is a sub base course, it is constructed directly above this layer. Otherwise, it is built directly on top of the sub grade. Its purpose is to distribute traffic wheel loads over the whole foundation and contributes to drainage and frost resistance. A pavement is said to be defective, when it can no longer perform these functions during its design life. Kadyali and Lal (2013,). Hence, the durability of a highway pavement is a function of the ease and rigidity of the pavement soil to transmit the stress induced in it to the sub-soil such that unnecessary deformation is avoided. Sunil and Shrinhari (2006).

In many countries in Africa there is a growing realization of the cost-effectiveness of upgrading gravel roads to a sealed standard even at relatively low traffic levels, often less than 200 vehicles per day. This has challenged road authorities to make optimum use of naturally occurring materials which are often rejected by traditional specifications for use in the upper layers of road pavements. One such naturally occurring material is Laterite.

Lateritic soils are very important in the construction industries and activities as construction material and foundation support for engineering structures. It forms in tropical and subtropical regions where the climate is humid. Laterites are reddish brown, well graded and sometimes extend to depth of several tens of meters. The significant features of the lateritic soils are their unique colour, poor fertility, and high clay content and lower cation exchange capacity. Abundance of these soils and their favourable engineering properties make them useful as a construction or foundation material for roads construction. However, if successful use is to be made of this material, the conditions under which it can be successfully used must be carefully specified. Generally, previous researches show that roads failed due to negligence of road maintenance, inadequacies in design and poor workmanship, poor soil properties like low CBR and high liquid limits etc. among others (Adeleke and Adetoro, 2014; Jegede, 2004).

II. MATERIALS AND METHODS

A. Location and Description of the Study Area

Lagos is a state located in the South-Western geopolitical zone of Nigeria. It is divided into 5 divisions namely; Ikeja, Badagry, Ikorodu, Lagos Island and Epe. Lagos is a part which originated on Islands separated by creeks, such as Lagos Island, Badagry and Epe, fringing the South West mouth of Lagos Lagoon while protected from the Atlantic Ocean by islands. It is the nation's largest urban area. The study areas are to be considered are borrow pits of laterite at, Nisha, Eleran igbe (Epe Local Government)**,** Ibeshe (Ikorodu Local Government) and Oke Osho, Temu village (Epe Local Government)

B. Data Acquisition

Disturbed soil samples weighing at least 50kg, were collected at three different points from each of the study areas, for relevant geotechnical analysis at Civil Engineering laboratory, University of Lagos, Nigeria . All the tests were performed according to British Standard Specification: BS: 1377 of 1990.

C. Tests to determine Geotechnical Properties of Lateritic Soils

For the purpose of this study the tests required are specific gravity, sieve analysis, moisture content, Atterberg's limits, compaction, California Bearing Ratio (CBR) and Unconfined Compression(UC).

➢ *Specific gravity*

It is also known as the particle density test. The two methods that are mostly used to determine soil particle density are the gas jar and small pycnometer methods. The gas jar method is suitable for all soil, including gravel, provided that not more than 10 percent material is retained on a 37.5mm test sieve. The small pycnometer method is the definitive method (in the UK) for soils composed of sand, silt and clay-sized particles. Both methods require the soil particles to be oven-dried at 105^0C and then placed in a container for weighing with and without being topped up with water. The particle density was determined from the equation:

$$\mathbf{G_S = (m_2 - m_1) / [(m_4 - m_1) - (m_3 - M_2)]} \quad \text{(equ 4)}$$

where,

m_1 = mass of container (g)
m_2 = mass of container and soil (g)
m_3 = mass of container, soil and water (g)
m_4 = mass of container and water (g)

➢ *Sieve analysis*

Particle size distribution was used to determine the percentages of various grain sizes present in the soil samples. The wet and the dry sieving method were used for the grain size analysis.

➢ *Determination of Moisture Content*

The amount of water present in a soil has a profound effect on soil behavior. Moisture content is the amount of water expressed as a proportion by mass of the dry solid particles. The moisture content is required as a guide to classification of the lateritic soil and as a control criterion in re-compacted soils. The oven-drying method was used to determine the moisture content in this work. The moisture content of the soil was calculated as a percentage of the dry soil.

➢ *Index Properties Determination (Atterberg Limits)*

Knowing these properties helps in calculating shear stress actions on soil mass and the behavior of the soil in changing moisture conditions.

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- *Liquid limit*

The liquid limit is the empirically established moisture content at which a soil passes from the liquid state to the plastic state. Two methods can be used to determine the liquid limit. They are the cone-penetrometer and the Casagrande method. The Casagrande is used for the determination of the liquid limit of a sample of natural soil, the Casagrande method was used in this work.

- *Plastic limit*

The plastic limit is the empirically established moisture content at which a soil becomes too dry to be plastic. It is used together with the liquid limit to determine the plasticity index. The plastic limit is the lowest moisture content at which the soil is plastic.

➢ *Compaction*

This test was performed to determine Maximum Dry Density (MDD) Optimum and corresponding Moisture Contents (OMC) in accordance with BS 1377 procedure and liquid limit (LL) and plastic limit (PL) were determined along with.

➢ *California bearing ratio*

The laboratory CBR test measures the shearing resistance of a soil under controlled moisture and density conditions. The test yields a bearing-ratio number that is applicable for the state of the soil as tested.

➢ *Unconfined Compression Test*

Air dried soil were compacted at the optimum moisture content (OMC) and maximum dry density (MDD) respectively. After compaction, the compacted soils were extruded from the mould (split mould). The samples were placed in a load frame machine driven strain controlled at 0.10%/min until failure occurred. Three specimens were prepared for each test and the average result taken.

III. RESULTS AND DISCUSSION

➢ *Specific Gravity Test*

Results of specific gravity tests in Table 1 reveal that samples from Nisha has specific gravity of an average value of 2.69, Oke Osho has specific gravity that ranges from 2.65 to 2.66 having an average value of 2.66 while samples from Ibeshe ranges from 2.66 to 2.69 (appendix iv) with an average value of 2.66. In like manner, laterite samples from Ogbagi and Akoko (table 2.14) and Ibadan-Ife expressway (table 2.17) also ranged between 2.60 and 2.76.

Test No	**Nisha**	**Oke Osho**	**Ibeshe**
Wt. of bottle filled with water, m_4 (gm).	77.7	77.7	77.7
Wt. of bottle +soil +water, m_3 (gm).	93.6	93.5	93.5
Wt. of bottle +soil , m_2 (gm)	52.9	52.9	52.9
Wt of bottle, m_1(gm)	27.6	27.6	27.6
Wt of water used,(m_3-m_2)gm	40.7	40.6	40.6
Wt of soil used, (m_2-m_1) gm	25.3	25.3	25.3
Volume of soil, (m_4-m_1)-(m_3-m_2)	9.4	9.5	9.5
$Gs = \frac{m2 - m1}{(m4 - m1) - (m3 - m2)}$	2.69	2.66	2.66

Table 1:- Summary of Specific Gravity Test Results

➢ *Particle Size Distribution by Wet Sieving Analysis*

The summary of the sieve analysis result are presented in Figures 1,2and 3. It shows the percentages by mass of the soil passing in the individual test sieves of varying sizes. The average percentage by weight passing the No. 200 sieve (0.075mm) from Nisha is 7.3; Oke osho recorded an average value of 45 while Ibeshe recorded an average value of 43.7. The grain size distribution shows that the soil sample from Nisha borrow pit can be described as Reddish brown silty medium fine grained soil with occasionally fine grained gravels, soil sample from Oke osho can be described as Reddish brown silty sandy clay with occasional fine grained gravels while the soil sample from Ibeshe borrow pit can be described as Brown silty sandy clay with occasional fine grained gravels. According to AASHTO Classification System (Table 2.2), samples from Nisha are grouped as A-1 and rated excellent to good as a subgrade while samples from Oke Osho and Ibeshe can be group as A-5 and rated fair to poor. The lateritic soils from Minna were classified as A-3, A-2-4 and A-2-6, sample from Neni in Anambra sample was classified as A-2-4 with the AASHTO classification while the other soils were classified as A-2-6 soils but were all classified as SC (Clayey sands) according to USCS classification system. The grain size analysis for laterite samples from Quarry, Ilorin shows that soil sample ADET 1 is silt-clayey, very gravelly sand while sample ADET 2 is gravelly, silt-clayey sand. The samples from Ibadan-Ife expressway are generally well graded with average amount of coarse particles between 73.39% & 59.71%.

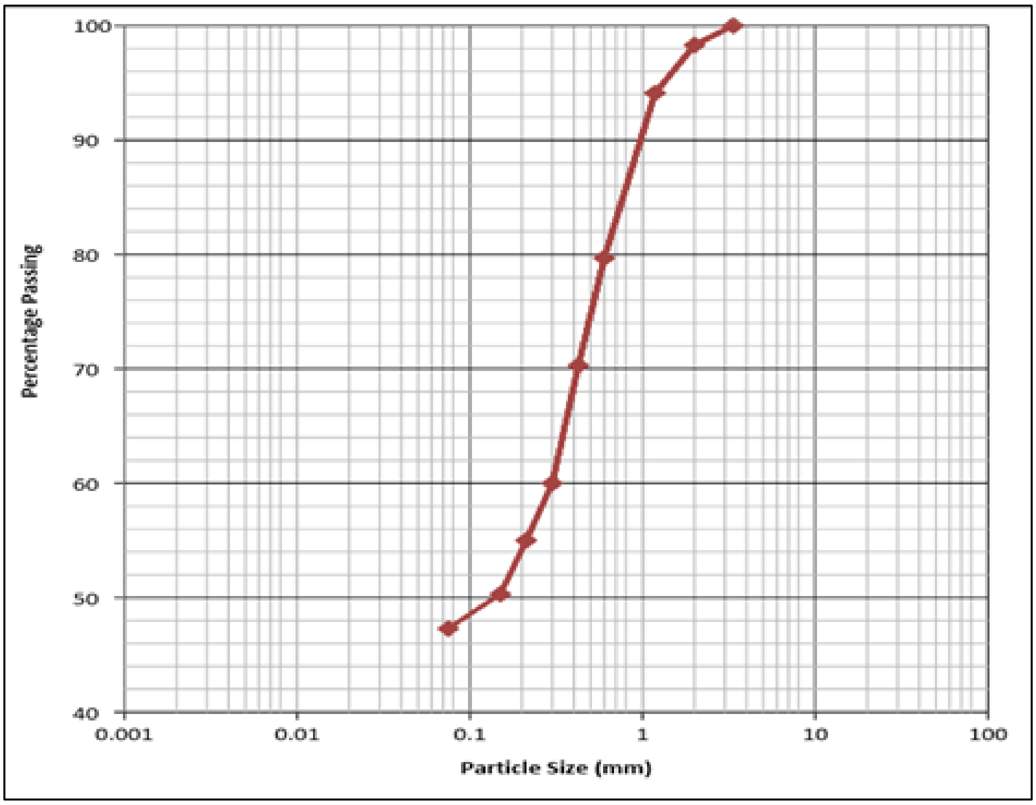

Fig 1:- Particle Size Distribution Curve for Nisha

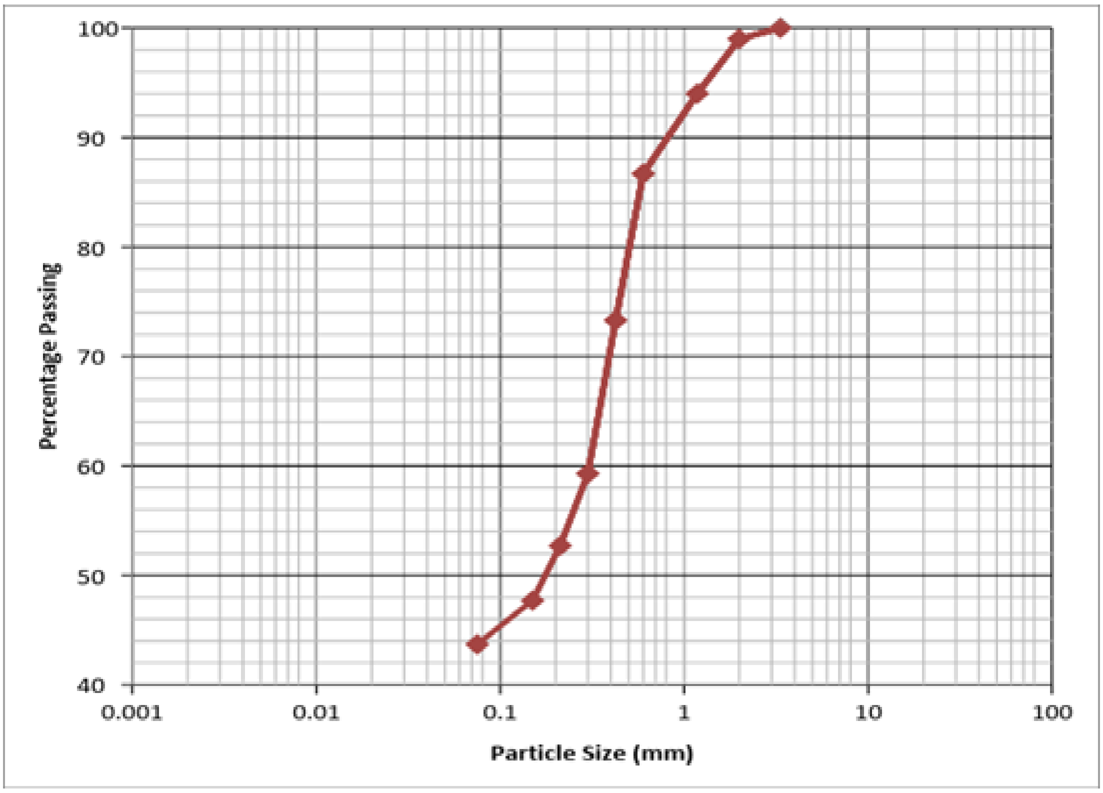

Fig 2:- Particle Size Distribution Curve for Oke Osho

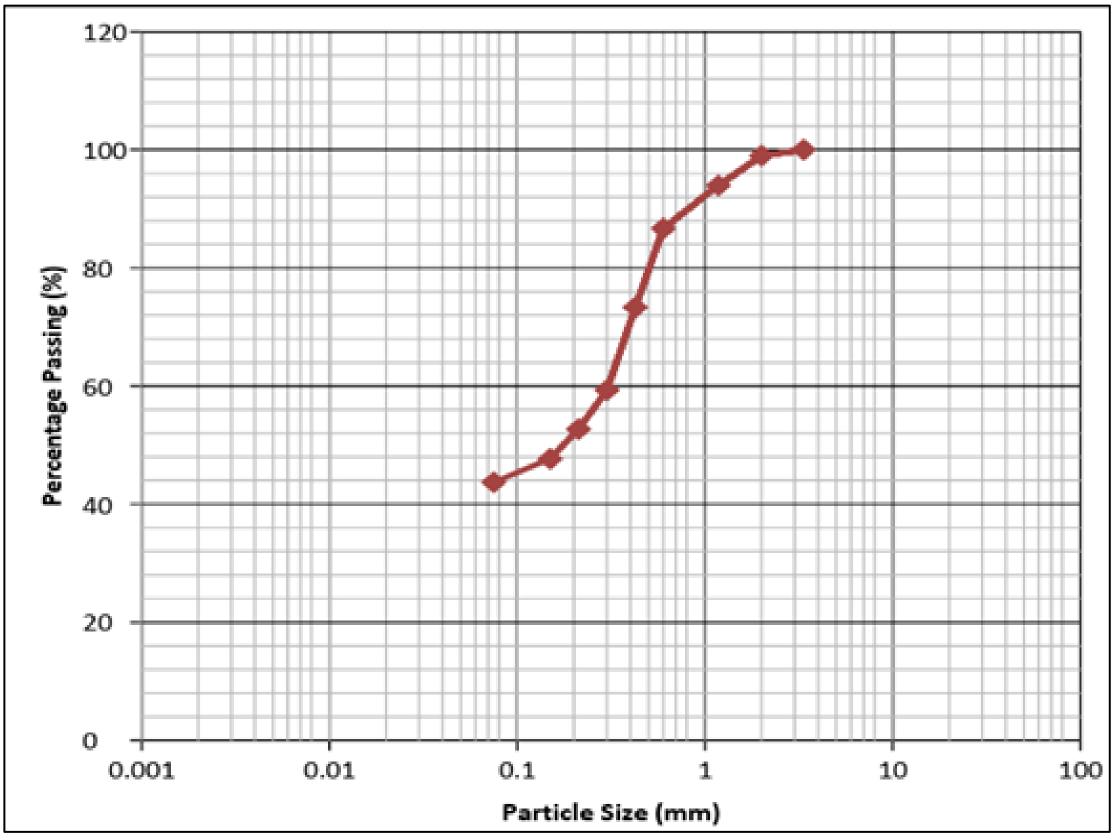

Fig 3:- Particle Size Distribution Curve for Ibeshe

- *Moisture Content Determination*

The natural water content of soil samples from Nisha borrow pit ranges from 4.5% to 5.3% with an average value of 4.83, Oke osho ranges from 13.3% to 14.1% with an average of 13.7 while Ibeshe ranges from 8.5% to 9.4% with an average of 8.87% (table 4.2). The average natural water content for all the samples are lower than the optimum moisture content (table 4.6) which shows that they are not prone to failure. The natural moisture content for lateritic soils at Ogbagi and Akoko are also lower than the optimum moisture content (table 2.14).

	Nisha	**Oke Osho**	**Ibeshe**
1	4.5	13.3	8.5
2	4.7	13.7	8.7
3	5.3	14.1	9.4
Aver. (%)	4.8	13.7	8.9

Table 2:- Summary of water content

- *Atterberg Limit*

Soil samples from Nisha borrow pit can be described as non-plastic, the liquid limit for Oke Osho has an average value of 46.5%, plastic limit of an average of 16.4% while the plasticity index is of average value of 30.2%. The liquid limit for Ibeshe has an average of 45.1%, plastic limit of an average value of 15.0% while the plasticity index has an average value of 30.1% (table 4.3). The liquid limit values for samples from Minna, Ogbagi and Anambra ranged from 28.85% to 34.9% while liquid limit values for Agidi- Akoko, Quarry- Ilorin and Ibadan-Ife expressway ranged from 34.2% to 53.5%.

The plastic limit and plasticity index values for samples from Minna, Agidi-Akoko ranged from 18.2 to 28.92 and 9.11 to 29.5 respectively while samples from Ogbagi has zero for both plastic limit and plasticity index value.

ISSN No:-2456-2165

location /sample number	Natural water content wc (%)	Liquid limit, LL (%)	Plastic limit, PL (%)	Plasticity Index, PI (%)
Nisha 1,2 & 3	4.8	Non Plastic		
Oke osho 1	13.3	46.7	16.6	30.1
Oke osho 2	13.7	46.5	16.3	30.2
Oke osho 3	14.1	46.4	16.2	30.2
Average	13.7	46.5	16.4	30.2
Ibeshe 1	8.5	45.3	15.1	30.2
Ibeshe 2	8.7	45.1	15.1	30.0
Ibeshe 3	9.4	45.0	14.9	30.1
Average	8.9	45.1	15.0	30.1

Table 3:- Summary of Atterberg Limit

- *Compaction Test (WAS)*

From table 4.4, samples from Nisha gave optimum moisture content (OMC) of an average value of 10.3% and maximum dry density (MDD) of an average value of 1.817**(**mg/m^3**).** Samples from Oke osho have the OMC of an average value of 15.1% with the MDD of an average value of 1.857(mg/m^3). The OMC for Ibeshe borrow pit as an average value of 16.3% with the MDD of an average value of 1.788(mg/m^3). Samples from Anambra has OMC and MDD of 9.5% to 14.6% & 1.77g/cm^3 to 1.98g/cm^3 respectively while samples from Ogbagi and Akoko are 13.5% & 26.0% and 1483kg/m^3 & 1780kg/m^3. However, samples from Minna and Ibadan- Ife expressway are 9.74% & 1.858g/cm^3 and 9.6% to 15.4% & 1810 to 2076kg/m^3 respectively

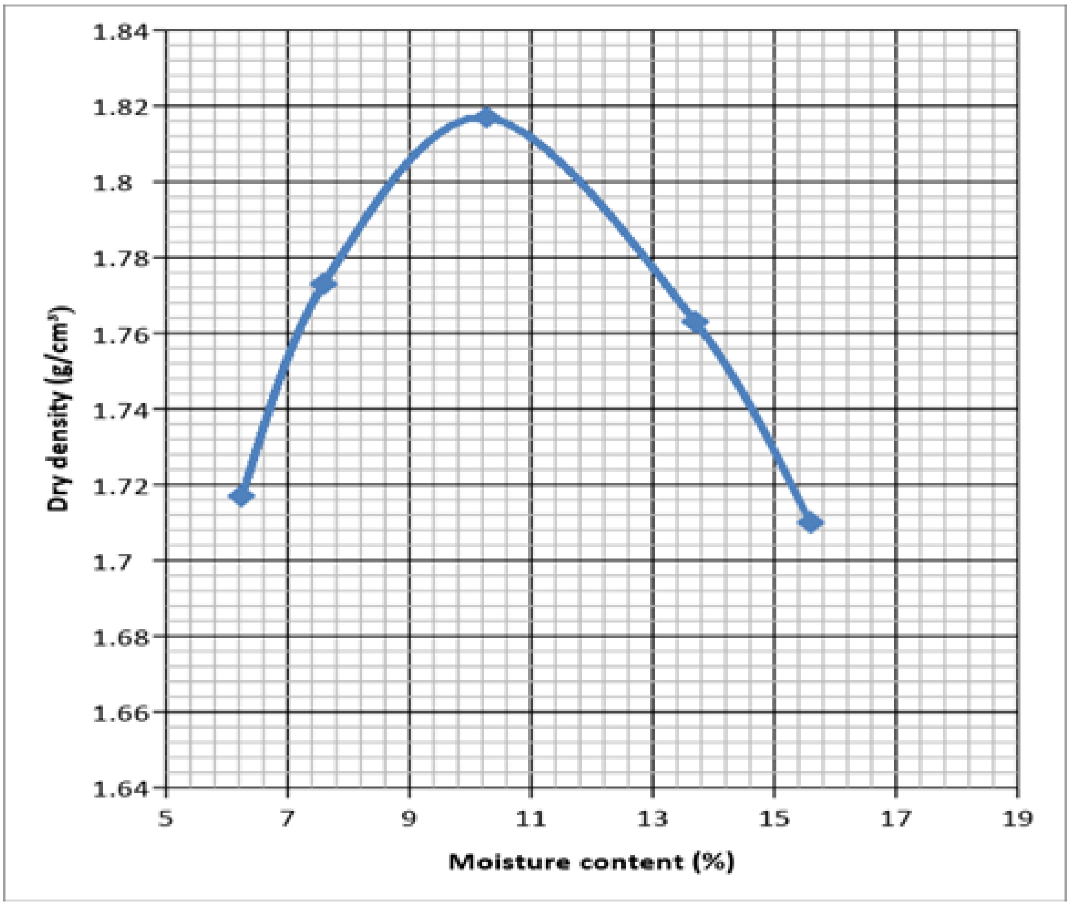

Fig 4:- Moisture content versus Dry density Curve of Nisha

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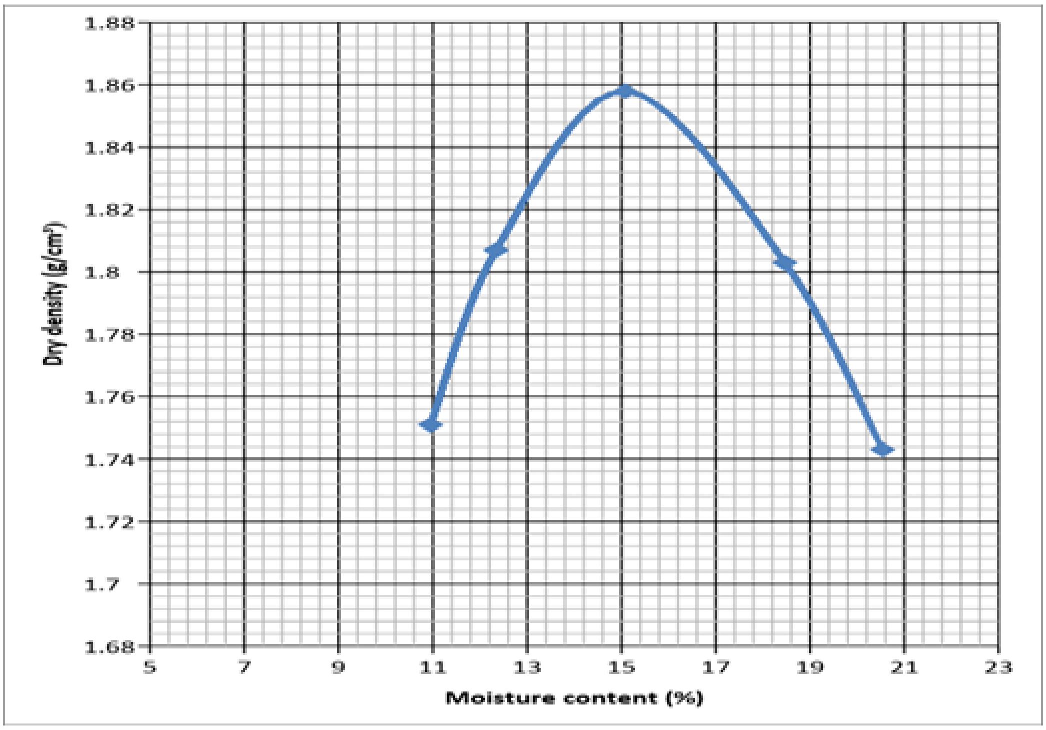

Fig 5:- Moisture content versus Dry density Curve of Oke osho

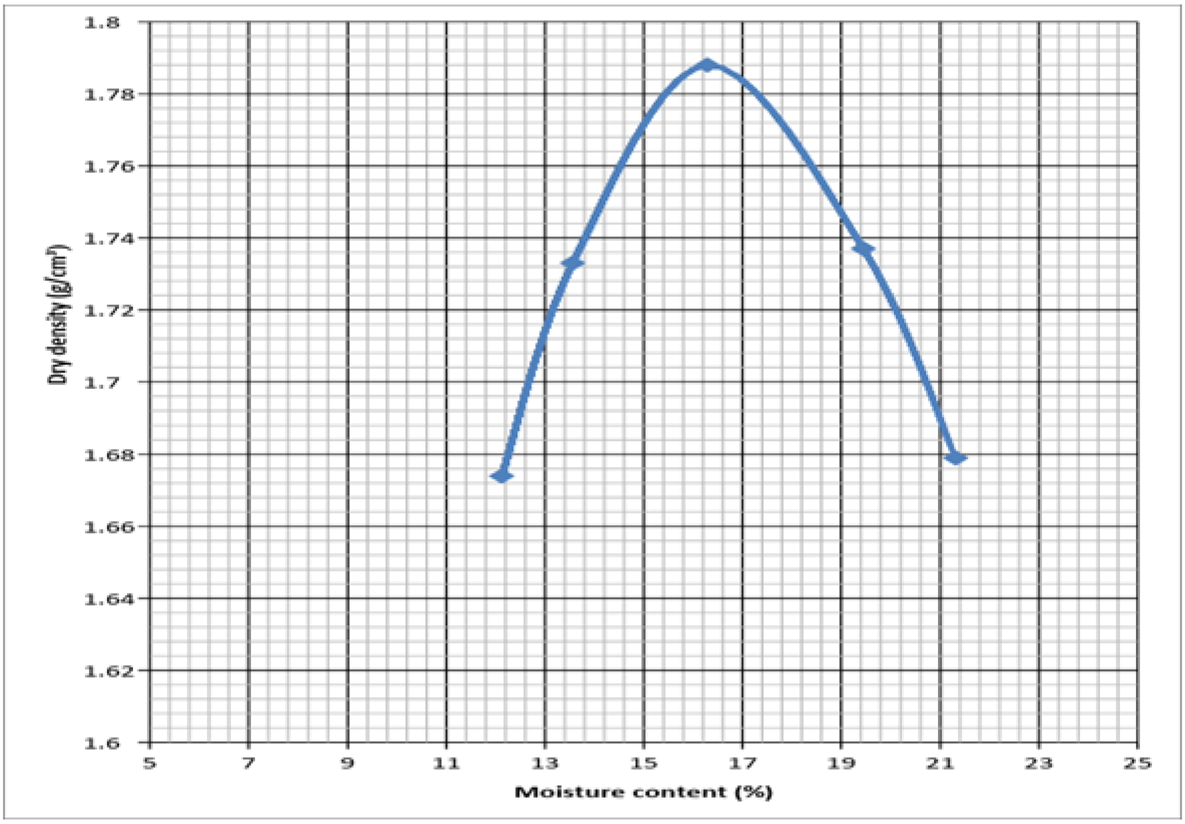

Fig 6:- Moisture content versus Dry density Curve of Ibeshe

➢ *California Bearing Ratio*

From the result in Table 4 the samples from Nisha, Oke Osho and Ibeshe borrow pits have soaked CBR values of an average of 48%,25.3% and 16.3% respectively while the unsoaked values are an average value of 54.3%,43% and 35.3% respectively.

However, samples from Ogbagi and Akoko have CBR values of 14% and 31% respectively while the CBR values for samples from Ibadan-Ife are below recommended values.

location/ sample number	Moisture content before soaking MC (%)	Moisture content after soaking MC (%)	unit weight before soaking γ_b (Mg/m^3)	unit weight after soaking γ_b(Mg/m^3)	% swelling potential	CBR Value (%)	
						unsoaked	soaked
Nisha 1	10.5	10.8	1.993	2.071	0.000083	52.0	46.0
Nisha 2	10.3	10.7	2.005	2.109	0.000079	54.0	47.0
Nisha 3	10.1	10.5	2.013	2.103	0.000077	57.0	51.0
Average	10.3	10.7	2.004	2.094	0.000077	54.3	48
Okeosho1	15.3	17.8	2.128	2.218	0.288	40.0	23.0
Okeosho2	15.1	17.4	2.137	2.219	0.279	43.0	25.0
Okeosho3	14.9	17.2	2.148	2.227	0.275	46.0	28.0
Average	15.1	17.5	2.138	2.221	0.281	43	25.3
Ibeshe 1	16.5	18.8	2.076	2.159	0.379	32.0	14.0
Ibeshe 2	16.3	18.5	2.078	2.146	0.368	35.0	17.0
Ibeshe 3	16.1	18.3	2.083	2.167	0.347	39.0	18.0
Average	16.3	18.5	2.079	2.157	0.365	35.3	16.3

Table 4:- Summary of California Bearing Ratio Results

➢ *Unconfined Compressive Strength*

The unconfined compressive strength for the soil samples from Nisha, Oke Osho and Ibeshe borrow pits are an average value of 5.3 kN/m2,123.33kN/m2 and 74kN/m2 respectively while cohesion values are 2.7kN/m2 , 61.7kN/m2 &37.0kN/m2 respectively.

However, soil samples from Ibadan-Ife expressway have unconfined compressive strength that ranged from 105.62 to 123.65kN/m2 for stable location and 50.92 to 135.8kN/m2 for unstable location.

Unit Strain (Σ) $\Delta L/L_0$	% Strain	Average Sample stress kN/m^2 (Nisha)	Average Sample stress kN/m^2 (Okeosho)	Average Sample stress kN/m^2 (Ibeshe)
0	0	0	0	0
0.20	20	1.19	16.94	8.81
0.40	40	2.2	28.73	16.23
0.60	60	3.21	40.48	22.60
0.80	80	4.04	50.50	30.30
1.00	100	4.70	62.16	34.44

ISSN No:-2456-2165

1.20	120	5.03	71.43	40.24
1.40	140	5.28	78.98	46.37
1.60	160	7.01	87.51	50.43
1.80	180	7.00	95.33	54.67
2.00	200	5.99	102.86	62.37
2.20	220		111.55	67.23
2.40	240		120.44	70.57
2.60	260		121.86	73.08
2.80	280		119.47	75.25
3.00	300		116.60	71.15

Table 5:- Summary of Percentage strain and Average sample stress

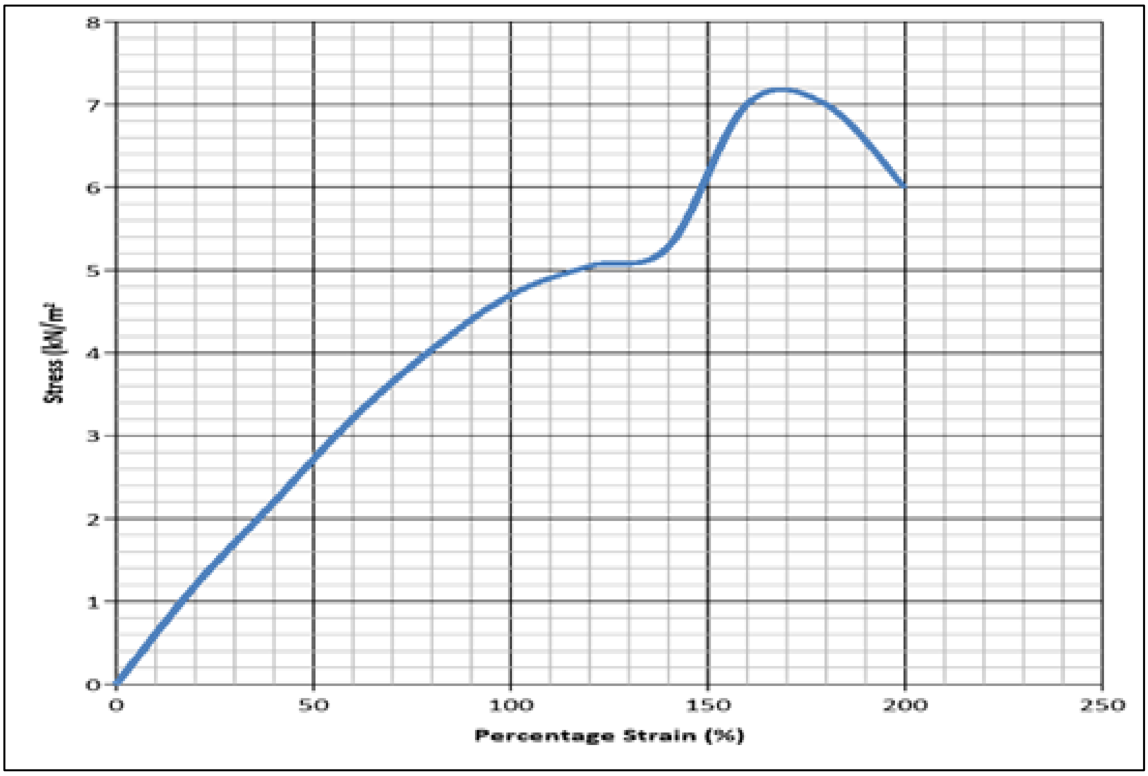

Fig 7:- Unconfined Compressive Strength Curve for Nisha

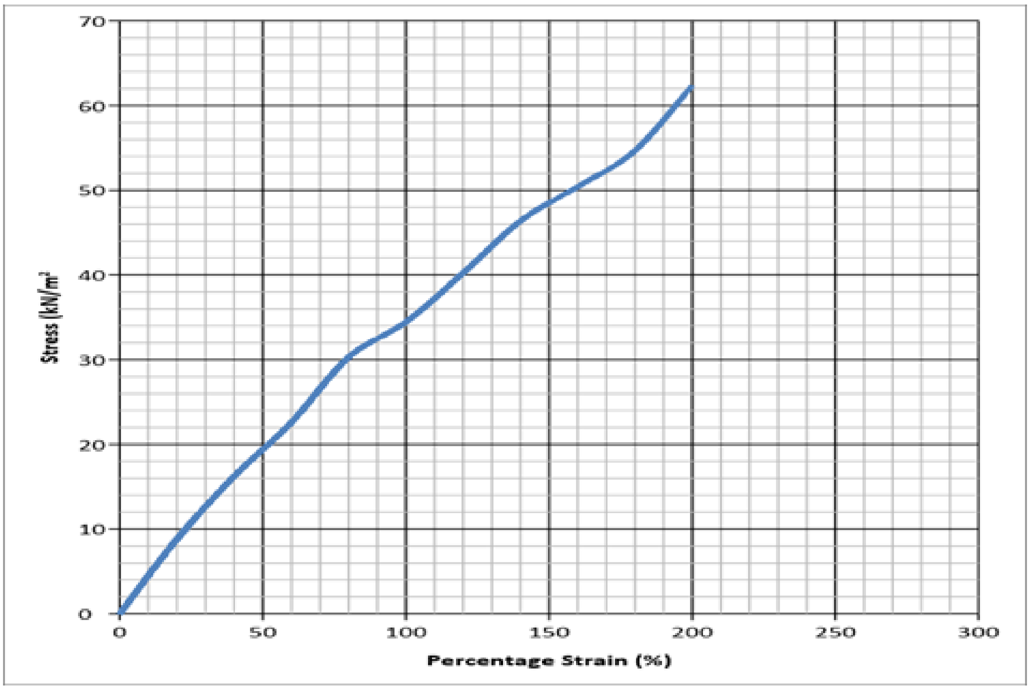

Fig 8:- Unconfined Compressive Strength Curve for Oke osho

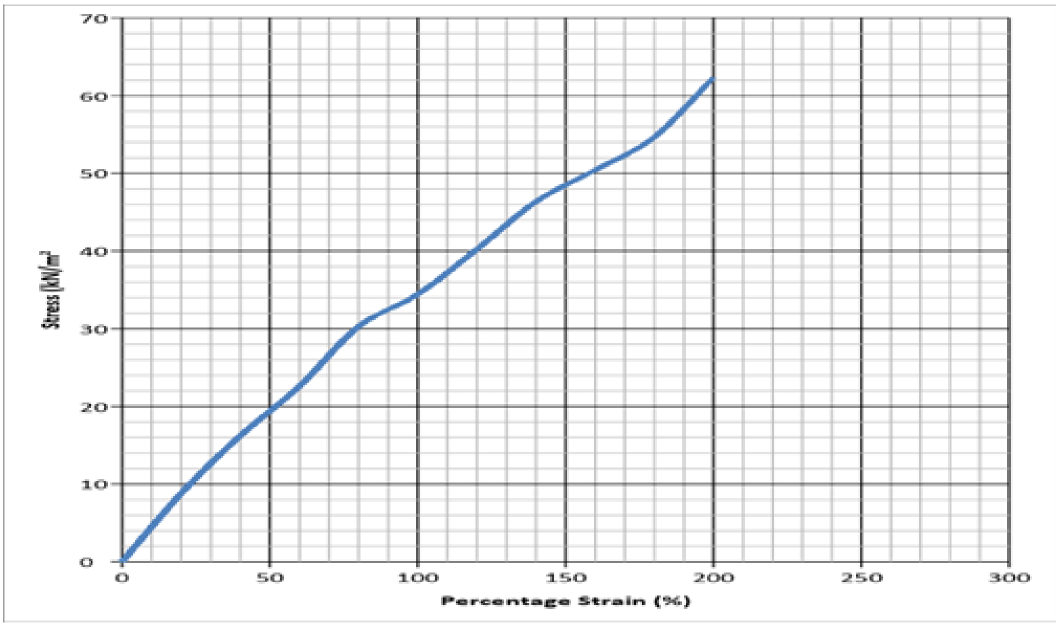

Fig 9:- Unconfined Compressive Strength curve for Ibeshe

IV. CONCLUSION

Based on the result of laboratory tests, the following conclusions are drawn:

- The average natural water content for all the samples are lower than the optimum moisture content which shows that they are not prone to failure hence good as a pavement material.
- The average percentage by weight passing the No. 200 sieve (0.075mm) from Nisha is 7.3; Oke osho recorded an average value of 45 while Ibeshe recorded an average value of 43.7 , indicating that samples from Oke osho and Ibeshe were more plastic compared to sample from Nisha,
- Soil samples from Nisha satisfy the recommended values for both the MDD (1.672 -2.12) and OMC (9.6 – 19.2) to be classified as Silty clays (CL) and samples from Oke osho and Ibeshe also meets the requirements to be classified as Clayey Silts (ML).
- Samples from Nisha meets the requirement for the sub base only and does not meet the requirement for the base course while samples from Oke osho and Ibeshe does not meet any of the requirements.
- Giving a general rating of all samples according to the AASHTO system of soil classification laterite soil from Nisha are grouped as A-1 and rated excellent to good while laterite soil from Oke osho and Ibeshe are grouped as A-5 and rated fair to poor.

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