DOI: 10.36108/laujoces/8102/10(0150)

Geotechnical Characterization of Sub-Soil within Ladoke Akintola University of Technology, Ogbomoso-Nigeria

Ige J. A.

Department of Civil Engineering, Ladoke Akintola University of Technology, Ogbomoso-Nigeria

Correspondence: jaige@lautech.edu.ng, ***Phone: 07038065010***

Abstract

This study investigates geotechnical characterizations of sub-soil within LAUTECH community as well as the relevant engineering characteristics were evaluated to enable appropriate foundation design. Nine (9) soil samples were obtained at 1.0, 2.0 and 3.0m using boring methods from three locations: LAUTECH Security Unit,(LSU:N8^{0}5.977; E4^0 10.112), LAUTECH Chapel, (LC:N8^0 07.756; E004^0 12.981), and LAUTECH Software Building, (LSB: N8^0 09.986; E4^{0}15.781^1). The samples were subjected to visual examination and subsequently geotechnical tests in accordance to British Standards BS 1377, (2000). The tests were Specific Gravity (SG), Particle Size Distribution Analyses (PSDA), Liquid Limit (LL), Plastic Limit (PL), and Compaction test using British Standard Light (BSL) compactive effort, California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS). The samples from all the locations varied from light brown sand to reddish gravel. The SG values for LSU, LSB and LC were (2.66, 2.63, 2.37); (2.68, 2.59, 2.60); (2.48, 2.67, 2.43), respectively, while the grain size varied from fine to coarse. The LL values obtained for LSU, LSB and LC were 38.0, 37.0, 44.0% and 34.0, 32.0, 35.0%, while the corresponding PL values were 21.0, 26.0, 28.0%, and 24.0, 20.0, 21.0%, respectively. The maximum dry density values were (1.94, 1.66, 1.38; 2.38, 2.23, 1.93; 2.02, 2.12, 1.77) g/cm^3 and OMC values were (13.5, 17.2, 19.2; 11.6, 16.4, 13.8; 12.1, 9.4, 14.0)%, respectively. The ranges of CBR values for the soaked and un-soaked samples for LSU, LSB and LC were 26.0 - 38.0; 36 – 52; 26.0 - 59.0%, and 61 – 74; 71 – 85; 56 - 70%, respectively. The UCS values for the disturbed and undisturbed samples were (363 – 865; 497 – 694; 202 – 596) kN/m^2 and (396 – 831; 427 – 726; 236 – 732) kN/m^2. The samples obtained from LSU and LC were classified as A-2, while LSB sample was classified as A-4 and A-6. The samples obtained at (1m) depths within LAUTECH Community are suitable as sub-grade materials. Hence, stabilization is recommended at further depths prior to their applications for engineering purposes.

Keywords: Characterization, Sub-soil, Geotechnical properties, Specific gravity, California bearing ratio and Unconfined compressive strength

Introduction

The investigation of geotechnical properties of soil/ sub soil materials is very vital in having a better understanding and knowledge of the nature, behavior and response of soils to various geological and engineering works. Soil which is a universally available natural material is derived from rocks and rocky minerals by means of weathering, as soil is a product of nature it possesses an inherently variable and complex character.

For engineering purposes, soil can be defined as any loose sedimentary deposits, i.e. sand, clay or a mixture of fine and coarse materials. Parent rock, vegetation, climate, topography, age and human activities are the factors that influence soil formation. The properties of soil are also affected by pre-treatment and testing procedures.

During the weathering process, four different components (minerals in solution, iron and aluminum oxides, silicon oxide compounds and stable wastes mostly quartz) are released. The economic potential of soils for engineering construction works depend on their chemistry and mineralogy. The parent rock also play a significant role when classifying soil in terms of their uses, although Ogunsanwo (1989) stated that the chemistry and mineralogy are the major factor when classifying soil samples in terms of the application in engineering construction works. Lateritic soils generally have a high tendency of undergoing degradation when subjected to high level of compaction which varies from one geological environment to another, thus it is very important and essential to study lateritic soil properties and characteristics in order to determine the geotechnical properties of the soil and the extent to which it could be used in engineering construction works.

In recent times in Nigeria and in particular, Lagos state, there are several cases of building collapse; the collapse of building in most cases could not be investigated. Recently the Synagogue for All Nations Church collapsed in Lagos and the investigations are still on to ascertain the cause of the collapse, there are loss of lives and properties as a result of poor construction, inappropriate choice of foundation and foundation failure conditions in our society. The situations in the urban areas are more pathetic, most of the inhabitants lives in an environment that can be described dash slum.

In Lagos for example, the hectares of land available for construction is far short of the population requirement. It is obvious that the percentage of swampy land is high, thus restricting people to build on the little available land with little or no convenience for the construction of structures with suitable foundation. Also, the recently constructed dual carriage high way at Ogbomoso, along Ogbomoso Grammar School – Ikoyi Road Ogbomoso, Oyo State Nigeria has sown deformations at some intervals/sections of the highway pavement.

It is therefore expected that this research work will assist to know the geotechnical characteristic of soil at different location with varying depth and be able to recommend appropriate foundation and foundation condition for civil constructions.

Materials and Methods

Sub – soil investigation and collection of samples for laboratory tests

Sample of eighteen, (9) disturbed and (9) Undisturbed sub-soil samples were collected from three different locations within LAUTECH community namely; location A –Lautech Security Unit (LSU); location B – Lautech Chapel area (LC); Location C – Newly constructed Software laboratory (LSB), along Lautech farm area. The trial pits considered for this study at 3GPS position and at a depth ranging from 0 – 3.0 meters vis-à-vis LSU (08^0 05.977N, $004^0$10.112E),LC($08^0$07.756^{1}N, $004^0$12.981^{1}E) and LSB($08^0$09.986^{1}N, $004^0$15.781^1 E)

Quantitative geotechnical properties laboratory test

For the purpose of determining the engineering properties of sub-soil samples within Lautech community, the following tests were carried out.

Particle-size distribution

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 I accordance with Bs1377

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 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 from the equation:

$$Moisture\ Content = \frac{m2 - m1}{(m3 - m1)x100}\% \qquad 1$$

where:

m1 = mass of container (g)

m2 = mass of container and wet soil (g)

m3 = mass of container and dry soil (g)

Liquid limit

The liquid limit is the empirically established moisture content at which a soil passes from the liquid state to the plastic state. The Casagrande method was used for the determination of the liquid limit of a sample of natural soil

Plastic limit

The plastic limit is the lowest moisture content at which the soil is plastic. It is used together with the liquid limit to determine the plasticity index. .

Compaction

The internal volume *(V)* of the mould was calculated in cm^3. The bulk density p (in Mg/m^3) of each compacted specimen was calculated from the equation.

$$Bulk\ density, p = (m2 - m1)/V \qquad 2$$

where:

m2 = mass of mould and base plate (g)

m2 = mass of mould, base plate and compacted soil (g)

V = Volume

The dry density Pd (in Mg/m^3) of each compacted specimen was calculated from the equation:

$$p_d = \frac{p}{1+w} \qquad 3$$

where p = bulk density

w = moisture content of the soil (in %)

Specific gravity

It is also known as the particle density test. The small pycnometer method was used for this study; small pycnometer is a definitive method (in the UK) for soils composed of sand, silt and clay-sized particles. Method requires the soil particles to be oven-dried at 105°C and then placed in a container for weighing with and without being topped up with water. The particle density was determined from the equation:

$$ps = \frac{m2 - m1}{(m4 - m1) - (m3 - m2)} \qquad 4$$

where,

m1 = mass of container (g)

m2 = mass of container and soil (g)

m3 = mass of container, soil and water (g)

m4 = mass of container and water (g)

California bearing ratio (CBR)

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 compressive strength

In the UCS test, a cylindrical specimen of cohesive soil was subjected to a steadily increasing axial compression until failure occurs. The axial force is the only force applied to the specimen.

Results and Discussion

Index properties of natural soil

The particle size distribution curve shows that the soil samples at LSU has approximate proportion of 35% silty clay, 32% sand and 33% gravel at 1.0m and 35% silty clay, 35% sand and 30% gravel at the depth of 2.0m . The result satisfies the specification limit of 35% or less for roads according to Roads and Bridges Specification Revised Edition of Federal Ministry of Works (1997). At 3.0m depth it contains 41%silty clay, 28% sand and 31% gravel respectively whereby the soil sample at this depth does not satisfy the specification for highway sub-grade due to its high clayey content, from this result the sample at 1.0 and 2.0m are good sub-grade material while soil sample at 3.0m is good for base course.

The LC, soil samples at 1.0, 2.0 and 3.0m has 30%silty clay, 52% sand, 18% gravel; 25%silty clay, 66% sand, 9% gravel and 17%silty clay, 72% sand and 11% gravel respectively. This result satisfies the specification limit for Federal Ministry of Works for Highway sub-grade, sub-base, and base course material. The soil samples obtained at LSB has 39%silty clay, 35% sand and 26% gravel at 1.0m depth, 39%silty clay, 29% sand and 32% gravel at 2.0m depth and 36%silty clay, 31% sand and 33% gravel. Thus sample at 1.0m is relatively fair for sub-grade while soil sample at 2.0 and 3.0m can be use as fills and sub-base course material.

The index properties of the lateritic soil collected at LSU, LC and LSB at the depth of 1m, 2m and 3m are presented in Table 1. The Liquid limit, plastic limit and plasticity index values for samples from LSU at various depths are 38, 37, 44%; 21, 26, 28%; 17, 11, 16 and LSB soil sample had 34, 32, 35% as Liquid limit, 24, 20, 21% as plastic limit and 10, 12 14 plasticity index values. Sample from LC is a non-plastic soil. According Whitlow (1995), liquid limit less than 35% indicates low plasticity, between 35 and 50% indicates intermediate plasticity, between 50% and 70% high plasticity and greater than 90% are extremely high plasticity. This indicates soil samples from LSU had intermediate plasticity at all depth and soil sample from LSB are of low Plasticity (Figure 1). The classification of the soil samples is in accordance with American Association for state Highway and Transportation Officers (AASHTO) (1986). Soil samples from LSU are classified as A-2-6 at 1.0 and 2.0m depth while it is A-6 at 3m depth. Soil sample from LC are classified as A-2-4 at all depth. Sample from LSB are classified as A-4 at 1m depth and A-6 at 2.0 and 3.0m depth respectively. Also, the soil samples from all the three locations are classified as CL according to the Unified Soil Classification System (USCS)(ASTM, 2004)

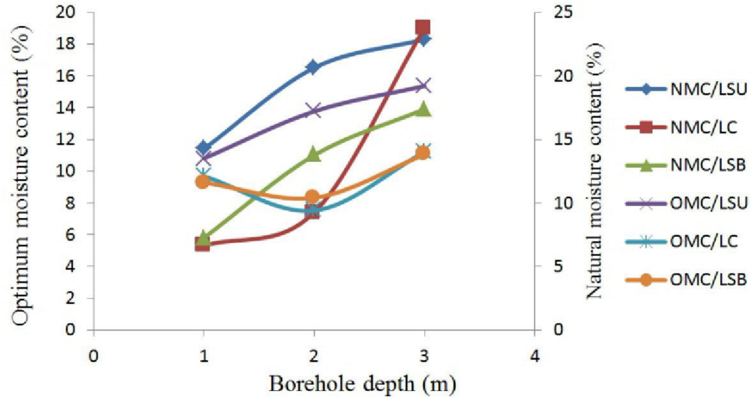

Fig. 1: Relationship between Natural and Optimum Moisture content and Borehole depth for soil sample at each location

The maximum dry density (MDD) ranges from 1.38 to 2.88 g/cm^3, the field density(DD) ranges from 1.79 to 2.16 g/cm^3 and the optimum moisture content ranges from 9.4 to 19.2%, natural moisture content (NMC) ranges from 5.3 to 19%. The increase in the compaction rate was due to the rammer blows applied and the more closely packed the soil becomes the lesser the voids present in the soil.(Figures 2-4)

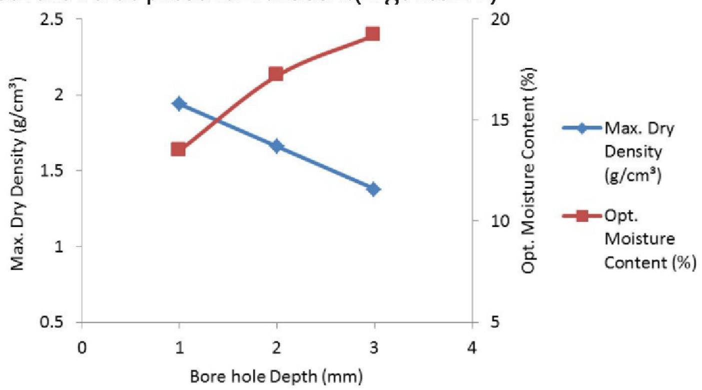

Fig. 2: Variation of maximum dry density and optimum moisture content at BSL for LSU soil sample.

Table 1: Properties of the natural laterite soil samples

Properties	LSU			LC			LSB		
	1m	2m	3m	1m	2m	3m	1m	2m	3m
Liquid limit (%)	38	37	44	0	0	0	34	32	35
Plastic limit (%)	21	26	28	0	0	0	24	20	21
Plastic index (%)	17	11	16	0	0	0	10	12	14
Percent passing BS No. 200 sieve	34.6	34.5	41.3	30.1	25.3	17.0	38.5	38.9	35.9
Group index	1	0	6	0	0	0	1	1	1
AASHTO classification	A-2-6	A-2-6	A-7	A-2-4	A-2-4	A-2-4	A-4	A-6	A-6
Maximum dry density (g/cm³) at BS compaction	1.94	1.66	1.38	2.02	2.12	1.77	2.38	2.23	1.93
Optimum moisture content (%) at BS compaction	13.5	17.2	19.2	12.1	9.4	14.0	11.6	10.4	13.8
C.B.R (%) (24hrs soaked)	33	38	26	59	54	26	37	52	36
C.B.R (%) (un-soaked)	74	61	72	70	60	56	85	81	71
Specific gravity	2.66	2.63	2.37	2.48	2.67	2.43	2.68	2.59	2.60
Natural moisture content	11.4	16.5	18.3	5.3	7.4	19.0	5.8	11.0	13.9
Colour	Dark brown	Reddish brown	Reddish clayey	Light brown	Reddish sandy	Reddish grey	Brown clayey	Brown clayey	Reddish gravel

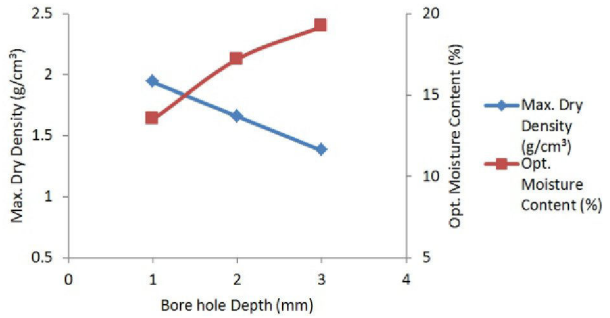

Fig. 3: Variation of maximum dry density and optimum moisture content at BSL for LC soil sample

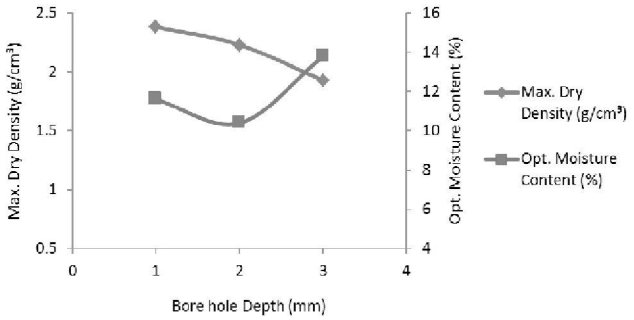

Fig. 4: Variation of maximum dry density and optimum moisture content at BSL for LSB soil sample

California Bearing Ratio (CBR) Results

The results of CBR (Soaked and Unsoaked) for LSU, LC and LSB soil samples were presented in Figures 5 and 6. The results show the strength of the sub-grade in terms of the load bearing capability of all the locations per depths, the values of unsoaked and soaked CBR for LSU at 1, 2 and 3m depth are 74.2, 60.8, 71.6 % and 32.9, 38.1 and 26.3% respectively. The values of unsoaked and soaked CBR for LC at 1, 2 and 3m depth are 69.5, 59.8, 55.7% and 58.9, 53.6 and 25.8% respectively. The values of unsoaked and soaked CBR for LSB at 1, 2 and 3m depth are 84.5, 80.9, 71.1 % and 37.1, 51.3 and 36.1% respectively. When comparing the CBR values with federal ministry of works specification, the soaked CBR for all sample obtained at all points were greater than 3 and 30% except the sample obtained at 3.0m from LSU which is below 30% soaked CBR specified for sub-base material. So therefore all the samples from all locations per depth fall within the guideline of federal ministry of works specification which makes it suitable for sub-grade. It was observed that the values of unsoaked CBR are greater than that of soaked CBR values.

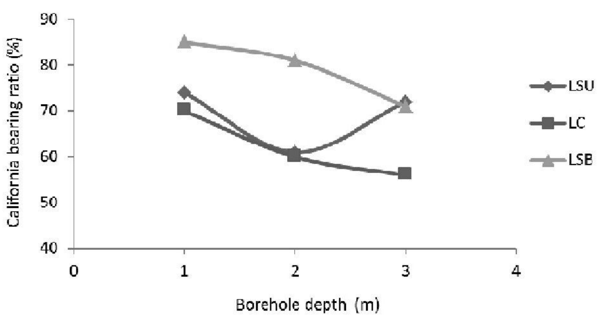

Fig. 5: Variation of California Bearing Ratio (Un-soaked) at BSL with Borehole Depth for LSU, LC and LSB Soil Samples

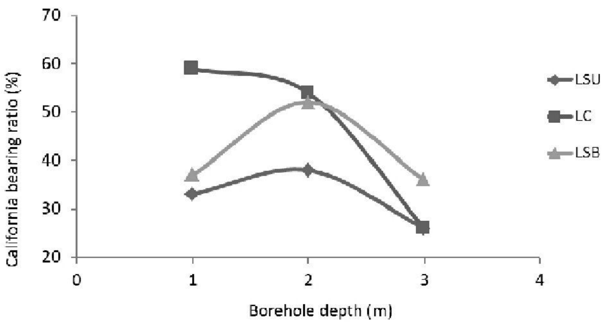

Fig. 6: Variation of California Bearing Ratio (Soaked) at BSL with Borehole Depth for LSU, LC and LSB Soil Samples

Unconfined Compressive Strength Test

The results of the unconfined compressive strength for the disturbed and undisturbed LSU, LC and LSB soil samples were presented in Figures 7and 8. The values of the unconfined compressive strength for the disturbed and undisturbed LSU at 1, 2 and 3m depth are 363, 698, 865 kN/m^2 and 396, 624 and 831 kN/m^2 respectively. The values of the unconfined compressive strength for the disturbed and undisturbed LC at 1, 2 and 3m depth are 202, 596 and 375 kN/m^2 and 236, 566 and 732 kN/m^2 respectively. The values of the unconfined compressive strength for the disturbed and undisturbed LSB at 1, 2 and 3m depth are 497, 660 and 694 kN/m^2 and 427, 726 and 630 kN/m^2 respectively.

According to Das (2000) unconfined compressive strength is the fundamental determinant of consistency of clayey soil; between 0-25kN/m^2 indicates very soft, between 25-50kN/m^2 indicates soft, between 50-100kN/m^2 indicates medium, between 100-200kN/m^2 indicates stiff, between 200-400kN/m^2 indicates very stiff and greater than 400kN/m^2 indicates hard clay. Hence, the results of unconfined compressive strength for the disturbed and undisturbed LSU, LC and LSB soil samples at 1, 2 and 3m could be described as very stiff and hard clay.

Generally, the UCS value revealed that the cohesion of the lateritic soil decreased. The unconfined compressive strength test (UCS) results for the natural soil [undisturbed sample] ranges from 236 to 831 kN/m^2 and disturbed UCS values ranges from 202 to 865 kN/m^2. The shear strength values for the undisturbed samples ranges from 118 to 416kN/m^2 and shear strength for the disturbed soil samples ranges from 101 to 433kN/m^2. The sensitivity [expansions'] between the natural state of all samples and the human effort applied ranges from 0.86 to 1.95.

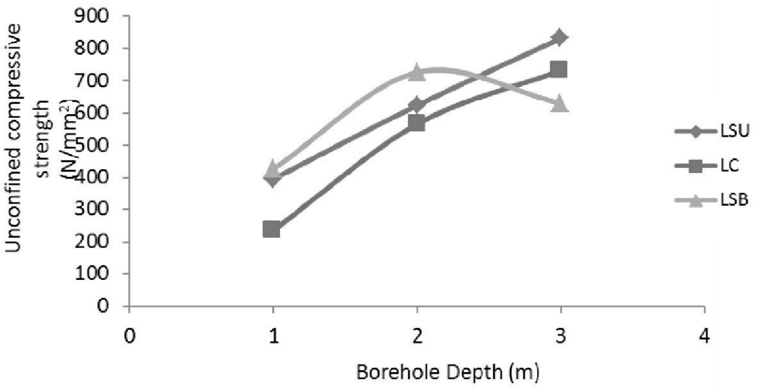

Figure 7 Variation of Unconfined Compressive Strength with Borehole Depth for Undisturbed LSU, LC and LSB Soil samples

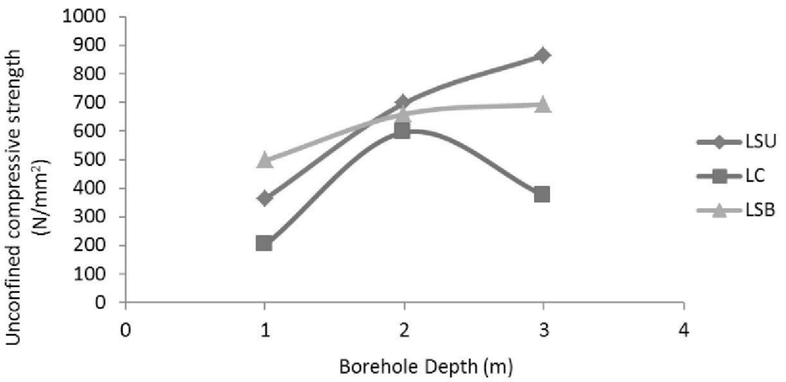

Figure 8 Variation of Unconfined Compressive Strength with Borehole Depth for Disturbed LSU, LC and LSB Soil samples

Conclusion

Based on the result of field and laboratory tests, the following conclusions are drawn;

1. The sub- soil terrain of LAUTECH community exhibit wide variation in formation
2. Giving a general rating of all samples according to the Association of America State Highway Transport officer [AASHTO] classification. Sample from LSU at depth of 1m and 2m are classified as A-2-6 respectively and at depth of 3.0m is classified as A-6, which shows the high level of clayed soils than the depth of 1m to 2m. The samples from LC at depths of 1, 2 and 3m are classified as A-2-4 respectively. The samples from LSB at depth of 1m is classified as A-4, and 2m and 3m are classified A-6 respectively – all the samples points investigated within LAUTECH campus has a good sub-grade materials, sub-base and also can be use as fill materials in a constructions having satisfied the guild line of federal ministry of works specifications.
3. Location at LC in case of building project the foundation around the area should be between 1m to 2m because it contains dominate of fine-sand which can retained load when encounter with load without any swelling potentials, the soil material around the area can also be useful in block molding industry, in dam construction materials and it can also be use as fill material which required high void and porosity like a swampy area because of its non cohesive nature.
4. The sample obtained from LSU can be use as a borrow pot for fill, sub-grade and base course materials but the depth of excavation should not exceed 2.0m if need to extend to the depth of 2m further investigation need to be carried out . It is cohesive soil material
5. The samples obtained from LSB if to be use for borrow pit the depth should not exceed 2.0m, if not further investigation need to be carried out, in term of building project deep foundation need to be considered because the soil in the area are highly compressible and more compaction effort is required from the site to

have 100 % compaction to disallow void and porosity that can be lead to differential settlement of a structure. It is cohesive material.

6. With regards to CBR, it shows that the strength of the sub-grade and sub-base material in term of load bearing capability and suitability of all locations conforms with the Federal ministry of works specification except sample obtained at 3.0m from LSU which is below 30% soaked CBR specified for sub-base material.

References

AASHTO, (1986), Standard Specification for Transportation Materials and Methods of Sampling and Testing 14th Edition. American Association of State Highway and Transportation Officials: Washington, D. C.

ASTM (2004) Standard Test method for Liquid, Plastic Limit and Plasticity Index soils. D4318 – 00. Annual book of ASTM standards. Volume 04. 08.

Das, B. M. (2002), Soil Mechanics Lab. Manual, Oxford University Press. New York

Manjriker Ganaratne, (2007). The Foundation Engineering Handbook, Taylor & Francis

Ogunsanwo, O. (1989), CRB and Shear Strengths of Compacted Laterites Soils from Southwestern Nigeria" Quarterly Journal Engineering Geology, London, 22:317 – 328.

Ola, S. A. (1983), "Geotechnical Properties of an Attapulgite Clay Shale in Northwestern Nigeria". Engineering Geology, 19:1 – 13.

Osinubi, K. J (2000), "Influence of compaction energy levels and delays on cement treated soil, "Nigerian society of Engineers Technical transaction, Vol. BC, NO. 4, pp. 1 – 3.

Venkatramaiah, C. (2005). Geotechnical Engineering Revised 3rd Edition, New Age International Publishers, New Delhi.