QUALITY ASSESSMENT OF SUB-BASE HIGHWAY PAVEMENT MATERIALS IN LAGELU LOCAL GOVERNMENT AREA, IBADAN, OYO STATE, NIGERIA

ABSTRACT

Road development quality delivery in West Africa mostly depends on the quality of available sub-base pavement materials within economic distance. This paper thus aimed at assessing the quality of sub-base road pavement material in Lagelu Local Government Area of Ibadan, South-Western, Nigeria. Soil samples were collected from four different locations at depths ranging from 0.5m to 1.0m. Samples were subjected to Natural moisture content, Specific gravity, Grain size analysis, Atterberg limits, Compaction and California bearing ratio laboratory tests. The sieve analysis results indicate that the fine grain content varying from 16.80 % and 30.70 %. The soil samples are well graded ranging from coarse to clay particle sizes. The compaction test results revealed the maximum dry density range from 2.25 Mg/m^3 to 2.28 Mg/m^3 and optimum moisture content of between 7.1 % and 7.3 %. The materials were classified after AASHTO soil classification system as A-1-b with California Bearing Ratio (CBR) test results ranging from 74% to 76%. The variation in the values depends on the moisture content and the density of the materials. It was observed that the values were well within the permissible specification by the Federal Ministry of Works General Specifications of the country, rated as excellent to good sub-base materials.

Key words: Pavement, sub-base, classification, compaction and califonia bearing ratio (CBR)

INTRODUCTION

Early involvement in transportation was traced to movement from one place to another by foot on a path or track on which a foot-passenger could travel. In those days, men travelled by watching starts or own shadows, or noting the direction of wind. At those times, felled trees were used to cross narrow streams and rivers were crossed by swimming or by rafts. Animals were made to transport men and material.

Later on, man felt the necessity of easy transport. Wheel was invented and simple animal drawn wheeled vehicles were a common and popular mode of transportation for a long time. This gave birth to the necessity of a hard surface for the easy movement of these wheeled vehicles. The first hard surface roads were constructed in Mesopotamia about 4000 BC, https://www.aciindiana.com. Actually road construction work was taken in hand only during the period of Roman Empire. In that period roads were constructed on large scale and the earliest road construction techniques known are those of Roman roads, https://en.m.wikipedia.org

In Nigeria, the first road to be constructed for modern transport is traced to Ibadan- Oyo road, southwest of the country and was made in the year 1906, https://www.sciencedirect.com

The first professional road builder to emerge during the Industrial Revolution was John Metcalf, who constructed about 180 miles (290km) of turnpike road, in the north of England and later won a contract to build a three-mile (5km) section of road between Miiskip and Ferrensby. Metcalf acquired the mastery of his trade with his own method of calculation costs and materials, which he could never successfully explain to others (Whelan, 2015 and Kaplan, 2016).

Highway design in the United Kingdom based upon the recommendations of Road Research Laboratory (RRL) Road Note 29, A guide to the structural design of pavements. Methods of design are constantly being revised and evidence of this continual research can be seen by comparing the 1970 third edition of R.R.L. Road Note 29 with the original 1960 edition. Probably, the most comprehensive road research programme was the road tests conducted by the American Association of State Highway Officials (AASHO) in lllinois (Smith, 1972 & 1982).

In the case of soils formed by the tropical weathering of igneous and metamorphic rocks (e.g. the pre-cambrian basement complex of Nigeria) or where the climatic conditions favoured the formation of concretionary gravel (laterite) in fine grained materials, soils containing varying proportions of all the main size fractions are common and without more quantitave definition, Ackroyd (1965). Hence, it is important that soil material tests are carried out in the laboratory to determine geotechnical properties for appropriate engineering specification, see detail of the significance of each test as put together by Ackroyd (1965) in Table 1.

A roadway or runway consists of two parts (Smith, 1982): (a) Pavement and (b) The subgrade.

Pavement: Described as a hard crust constructed over the natural soil for the purpose of providing a stable and even surface for vehicles. Thus, pavement supports and distributes the wheel loads (Arora, 2009) as vehicle maneuver over it, so that the bearing capacity of the subgrade is not exceeded. It usually consists of two or more layers of material, a top layer or wearing surface which is durable and waterproof, and a base material. For economic reasons, the base material is sometimes split into two layers, a base and a sub-base. Three types of pavements generally identified (Arora, 2009), namely;

(i) Flexible pavement, (ii) Rigid pavement (iii) Composite or Semi-flexible pavements.

Table 1: Common road work laboratory tests and their importance.

TESTS	SIGNICANCE
MECHANICAL GRADING ANALYSIS	Classification, grading uniformity, effective sizes, clay fraction (≤ 75mic in size), chemical stabilization prospects.
SPECIFIC GRAVITY	Weight- volume relationship e.g for settlement and stability analysis or sample remoulding.
ATTERBURG/CONSISTENCY AND INDICES: **a) Liquid limit (LL)** **b) Plastic limit (PL)** **c) Shrinkage limit (SL)** **d) Plastic index, PI = LL - PL**	**Differentiation of different states of soil material based on the moisture content.** a) Moisture when soil changes from liquid to plastic state. b) Moisture when soil changes from plastic state to semi-solid. c) Moisture when soil changes from semi-solid to solid. d) Range of moisture when soil is in plastic state
COMPACTION: **a) Proctor Standard Laboratory** **b) Modified/WAS**	a) Moisture – density variation b) Control of field Compaction
CALIFORNIA BEARING RATIO (CBR): **Comparative shearing resistance test**	**Selection of road soils.** Sizing of structural component of a pavement e.t.c.
SHEAR STRENGTH PARAMETERS: **Cohesion and Frictional angles**	Bearing capacity, cutting and slope analysis
CONSOLIDATION	Settlement and consolidation analysis

Source: Ackroyd (1965)

However, in Nigeria, two general types of pavement are considered for use on highways according to the Federal Ministry of Works (2006);

(i) Flexible pavement (ii) Rigid pavement

The main difference between the types of pavement is the manner in which they distribute the load over their sub grade (Das, 1984). The factors that dictate the choice of pavement are;

(i) The strength of subgrade (ii) The class of vehicle

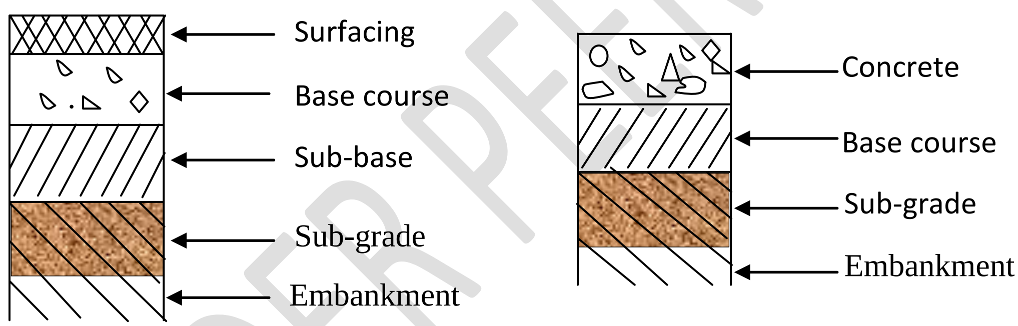
(iii) The traffic volume (iv) subgrade water table

Subgrade: Is the natural soil upon which the pavement is laid. The subgrade is seldom strong enough to carry a wheel load directly. There are two possibilities for making it adequate, Smith (1982):

(a) Improving the strength of the subgrade, thereby reduced the required pavement thickness.

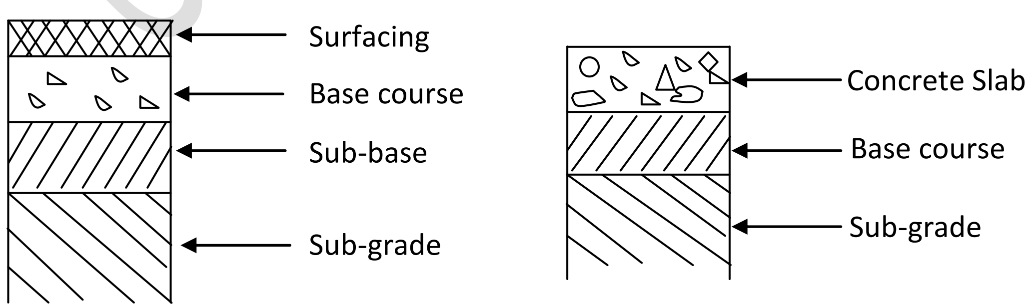
(b) Design and construct a sufficiently thick pavement to suit the subgrade

Road pavement materials are identified in pavement structures, Fig. 1.



(a) Flexible Pavement Structure (a) Flexible (b) Rigid Pavement Structure

Fig. 1: Highway pavement structures at fill section



(a) Flexible Pavement Structure (b) Rigid Pavement Structure

Fig. 2: Highway pavement structures at cut section

The Surfacing may asphaltic (consisting of binding and wearing courses), macadam of surface dressing by specification and construction. The base course could be made of lateritic or crushed stone materials, acting as the primary load bearing material. The subbase is the secondary load spreading layer in the profile and the preparatory platform for the placement of road base, Arshad, *et. al* (2018). Good efforts are being made in modern day technology to make base and subbase courses sustainable using reclaimed asphalt pavement and ground granulated blast furnace slag with a very less quantity of cement, Ram and Ramakrishna (2021)

The Study Area: The subject road project is located in the city of Ibadan, the largest city in West Africa. It is situated in Lagelu Local Government Area of Oyo State in the South-West geopolitical zone of Nigeria, Fig. 3. It lies between longitude 3°55’30’’ and 3°57’15’’E and latitude 7°28’30’’ and 7°23’15’’N on coordinates 101500 and 105250 Easting and 17500 and 25 750 Northing on 1:50,000 topographical map for Ibadan & Environs (1990).
The soil samples were collected from areas such as Olanla (Location 1), Alagbon (Location 2), Alagbon (Location 3), and Labua (Location 4) after Olorunda.

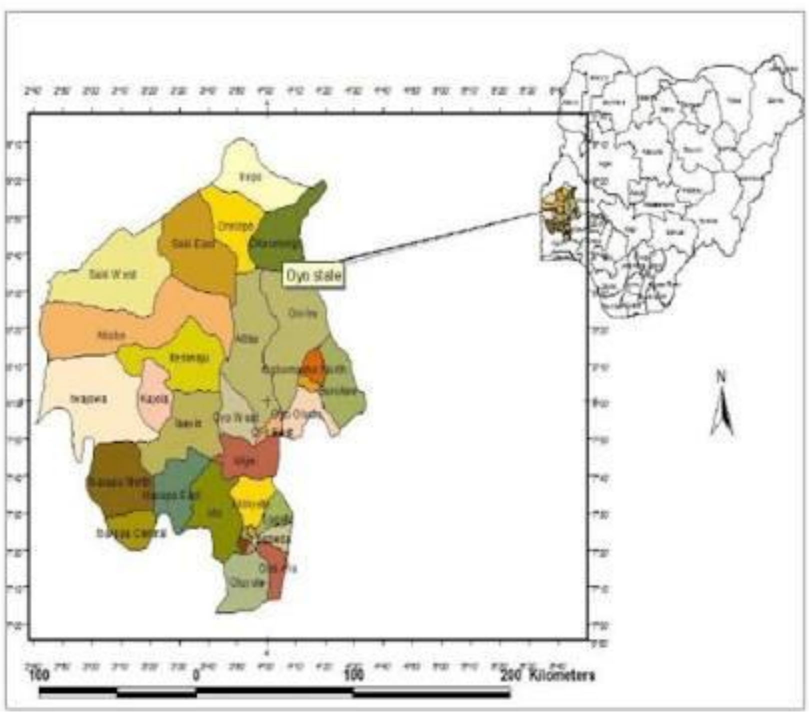


Fig. 3: Lagelu L.G.A. in Map of Oyo State, researchgate (2022)

MATERIALS AND METHODS

The samples were collected from four (4) different trial pits locations (2 from each of the two areas) at depth ranging from 0.5m to 1.0m of various locations in the month July, 2018. These samples were taken to the laboratory and subjected to Moisture Content test, Atterberg Limit test, Sieve Analysis test, Specific Gravity test, Compaction test and California Bearing Ratio (CBR) test, Plates 1 to 3.

Plate 1: Bored hole

Plate 2: Lab. Process

Plate 3: CBR Test set up

RESULTS AND DISCUSSION

Results: The results of laboratory tests on the four borrowed samples locations are detailed in Table 2 and scientifically analysed in Figures 4 to 8, for the following engineering discussion.

Table 2: Summary of the sub-base laboratory test results

Borrow Locations		1	2	3	4
Depth of sample (mm)		500	500	500	500
Liquid limit %		NP	NP	NP	NP
Plastic limit %		NP	NP	NP	NP
Plasticity Index %		NP	NP	NP	NP
Linear shrinkage		NP	NP	NP	NP
Grading: % Passing BS Sieve Apartures	25.4mm	100	100	100	100
	19.1mm	99.5	100	98.6	97.2
	12.7mm	98.7	97.5	91.6	93.2
	9.5 (10)mm	93.3	93	80.9	78.6
	6.3mm	91.8	92.5	-	0.5
	4.8mm	82.2	80.4	56.3	60.2
	2.36	-	-	51	47.8
	14No/1.18mm	63	64.5	44.3	43.5
	25No/600mic	45.2	43	35.1	38
	40/36No/425mic	37	39	31.6	32.2
	52No/300mic	27.4	25	22.8	22.2
	72No/212mic	24.4	21.6	17.0	16.0
	100No/150mic	11.0	9.5	10.1	10.5
	200No/75mic	0	3	0	2
Classification (AASHTO)		A-1-b	A-1-b	A-1-b	A-1-b
Type of Compaction			MOD AASHTO		
M.D.D. g/cm^3		2.28	2.25	2.25	2.25
O.M.C. %		7.3	7.1	7.1	7.1
CBR. %	Unsoaked	76	75	74	74

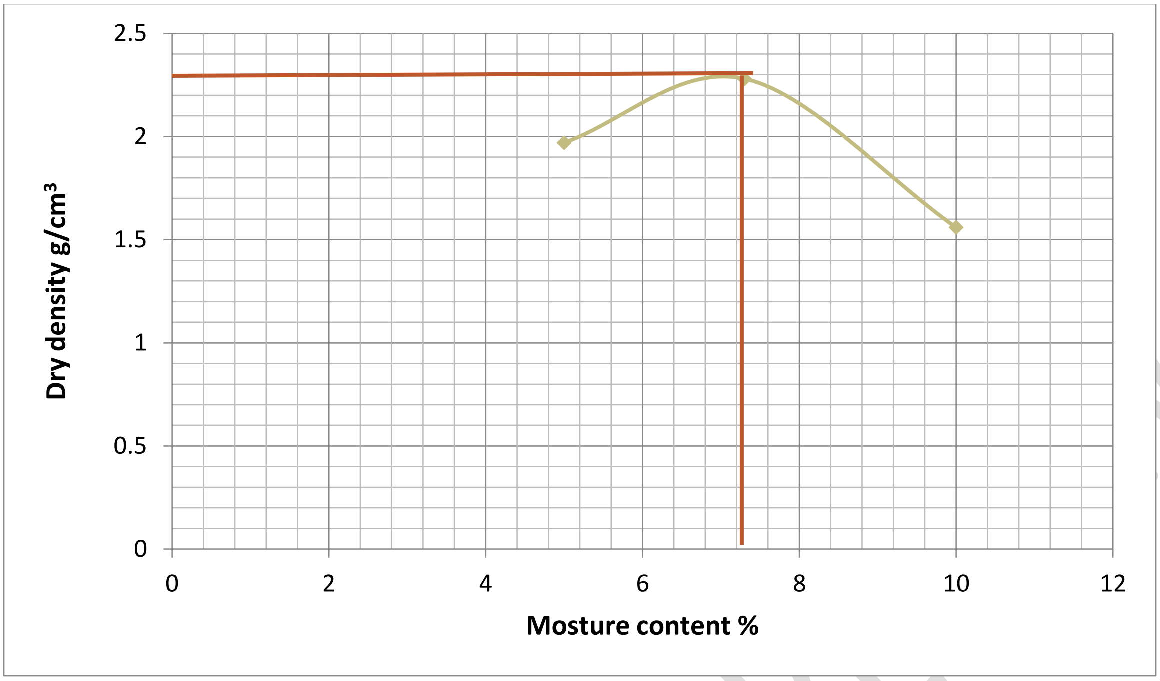


Figure 4: Compaction of sample at borrowed pit location 1

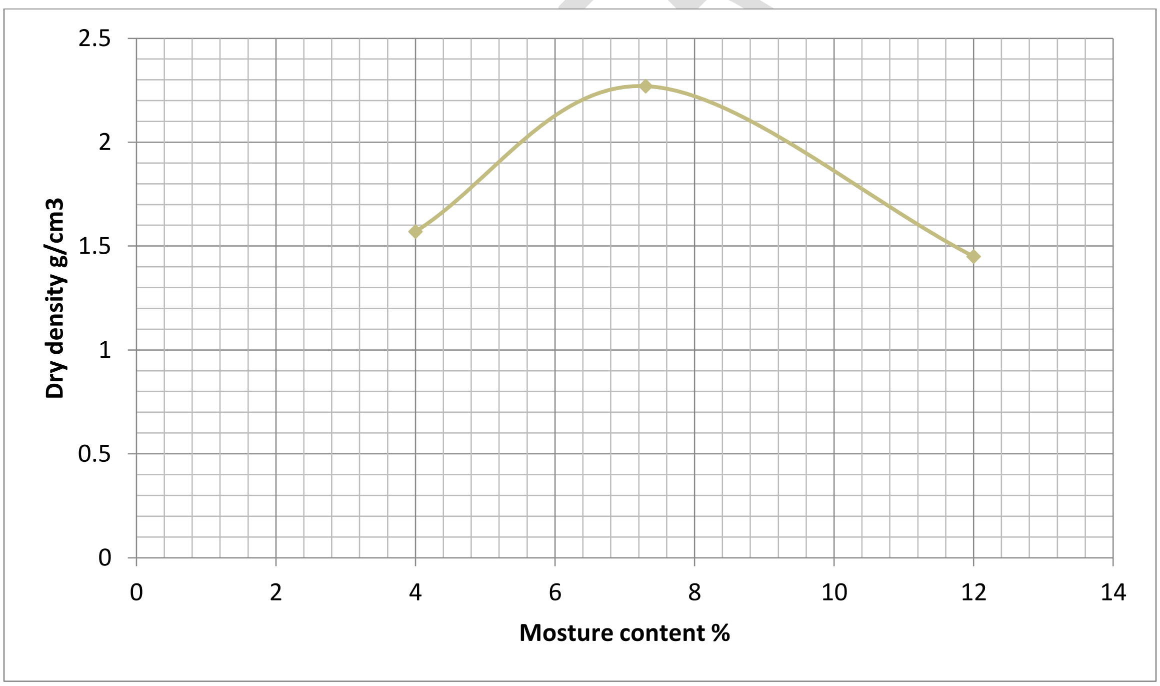


Figure 5: Compaction of sample at borrowed pit location 2

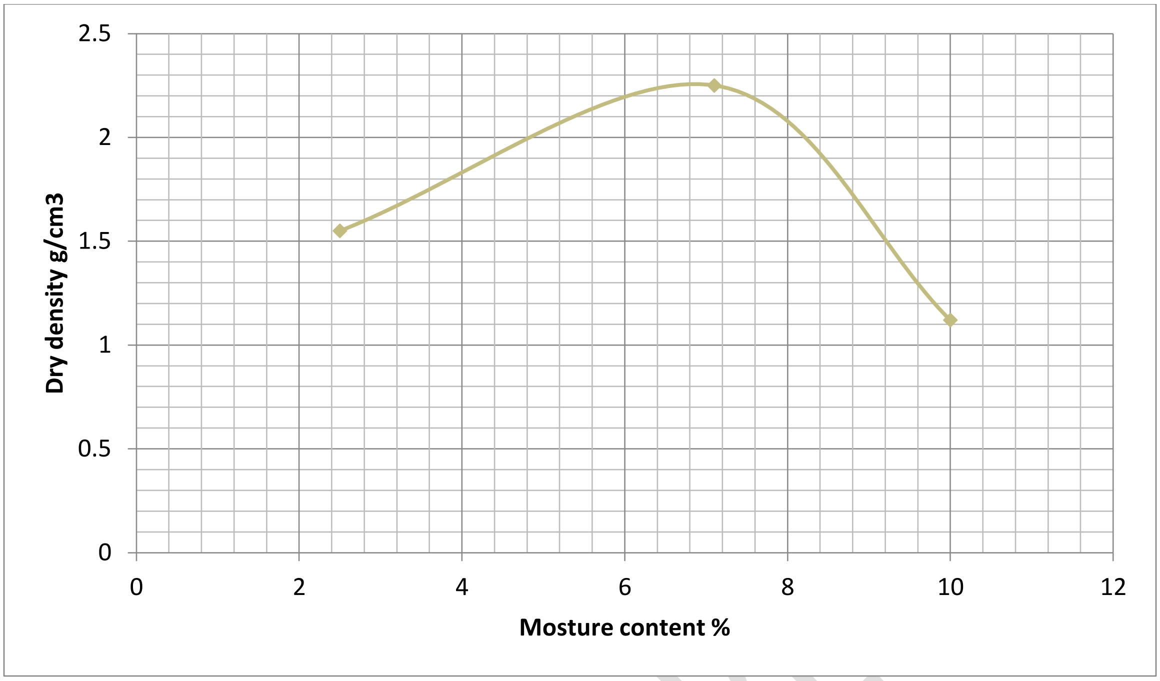


Figure 5: Compaction of sample at borrowed pit location 3

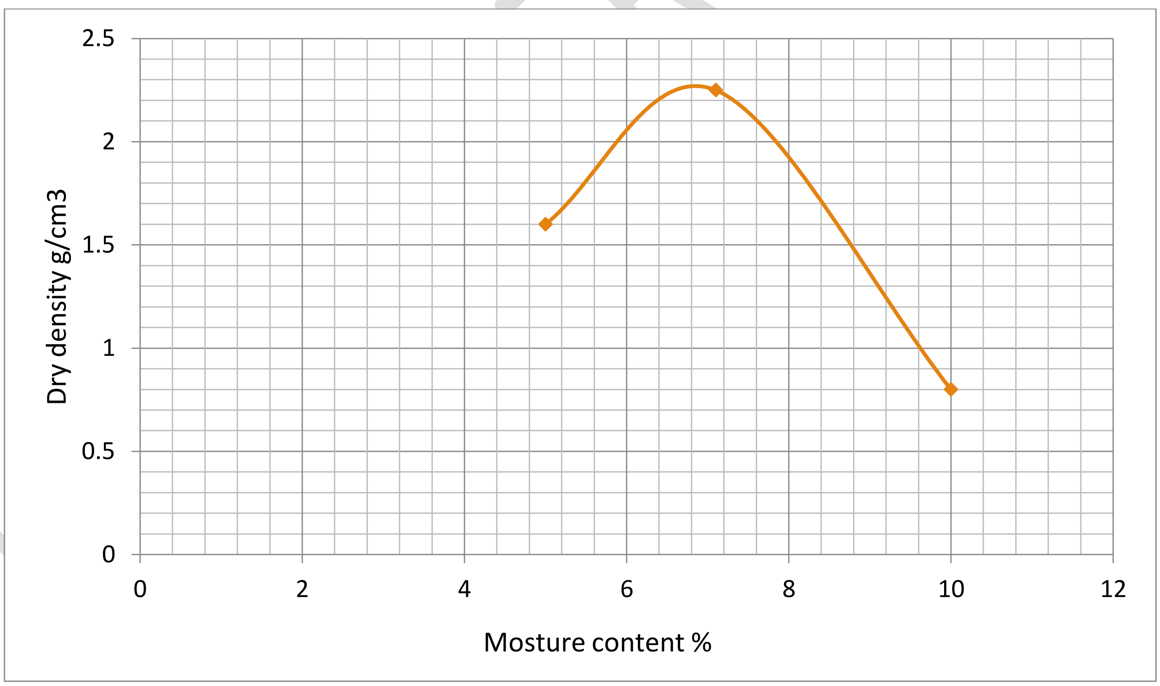


Figure 6: Compaction of sample at borrowed pit location 4

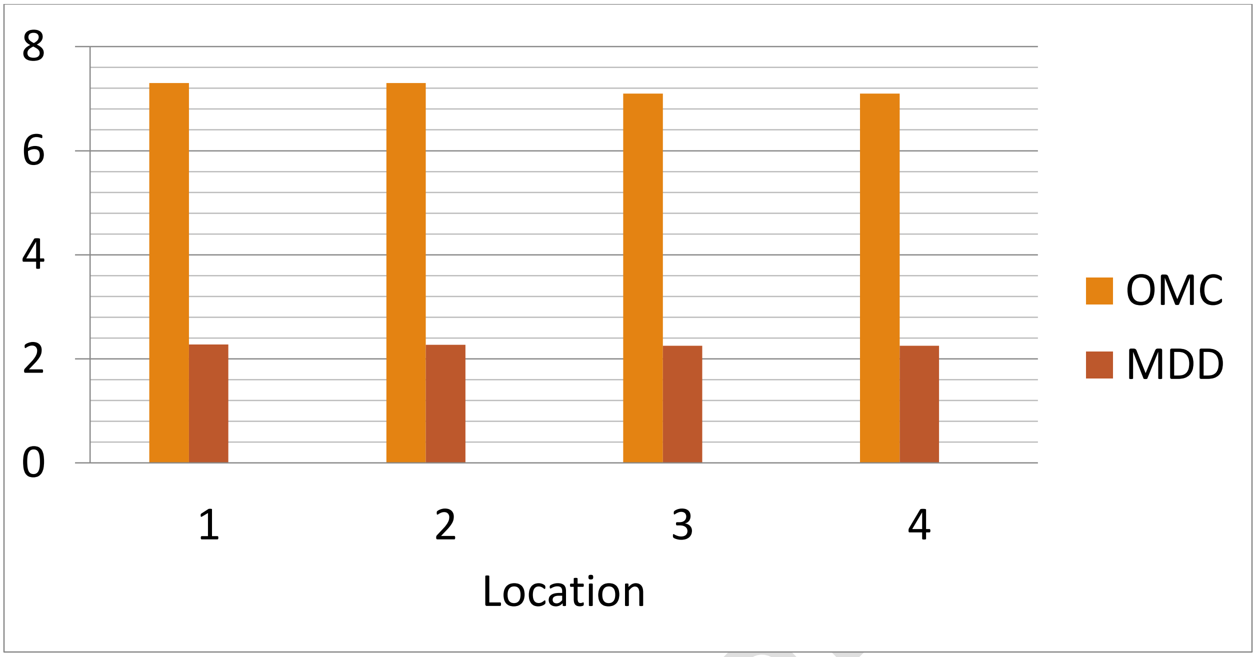


Figure 7: OMC @ MDD for effective compaction at various location

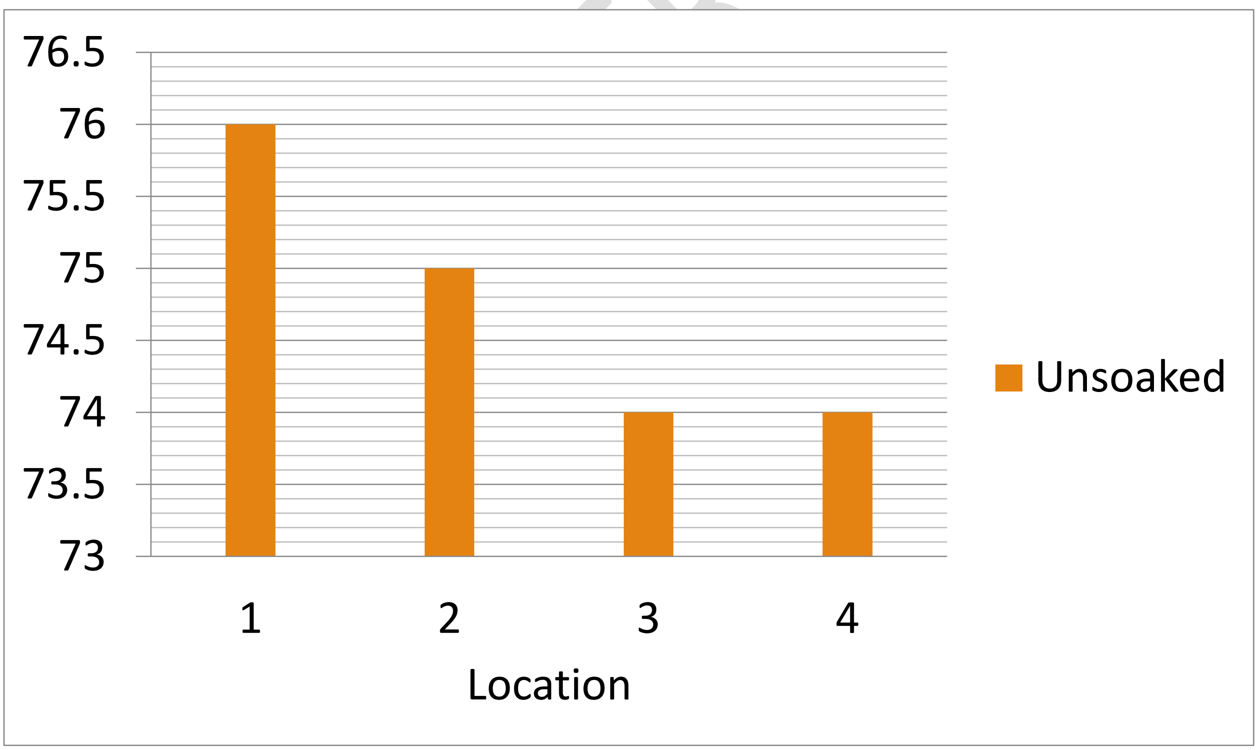


Figure 8: California Bearing Ratio (CBR) at various location

Discussion: Considering the results of the laboratory tests collated in Table 2. below compared with the standards for pragmatic decision as follows. Federal Ministry of Works General Specification requirements for roads and bridges (1994) recommend liquid limit not greater than 80 % for subgrade and not greater than 35 % for sub-base and base course. Also plasticity index not greater than 55 % for subgrade and not greater than 12 % for both sub-base and base courses. While the results reveals non plastic (NP) quality status with only presence of clay particles required for effective bonding. Comparing the results with the standards, it can be seen that all the sample fall within this specification for good sub-base. The expansive potential of the soils based on the plasticity index values of the soils is zero.

The results of sieve analysis (Table 2) show that less than 50% of the sample pass through sieve No 14 (1.18mm) indicate gravelly sandy nature of the materials.

For soil classification, Modified AASHTO classification system classified the four soil samples as A-1-b, less than 37% particles passing sieve No 40 while about 10% are retained on No 200 sieve (0.075mm). This indicate that AASHTO classification system confirm that all the soil sample formations are granular materials and since they have less than 35 % of silt and clay content, they are silty/clayed gravels and sands. The soil samples are rated excellent to good subgrade materials.

From the compaction test results in Figures 4 to 7, the maximum dry density range from 2.25 Mg/m^3 to 2.28 Mg/m^3 and optimum moisture content of between 7.1 % and 7.3 %.

The California Bearing ratio (CBR) is normally determined at unsoaked state. Figure 8, unsoaked test results indicate that the values vary between 74% and 76% which show that the sampled soil materials in the subject location are very suitable sub-base and even base course materials for highway construction and could attain maximum required strength at adequate compaction for durable road performance throughout its service life.

CONCLUSION

The results from this study showed that Lagelu L. G. A. of the state is blessed with excellent sub-base lateritic materials for durable road construction at appreciably cheaper cost. However, the required engineering procedures should be followed with sound grade of construction equipment to ensure adequate compaction. The soil samples should be compacted at optimum moisture content and reach their maximum dry densities when using them for that purpose.

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.

Ackroyd, L W. (1965), Road research overseas Bulletin No. 10 'The engineering classification of some Western Nigerian soils and their qualities in road building.

Arora, K.R. (2009), Soil Mechanics and Foundation Engineering. Reprinted Edition, Standard Publishers , Delhi. 773-785

Arshad, A. K., Shaffie, E., Ismail, F., Hashim, W. and Abd Rahaman, Z. (2018), Evaluation of Subbase materials for mechanistic pavement design. Internatonal journal of Civil Engineering and Technology (IJCIET), Vol.9, Issue 8, pp. 504-512.

British Standard Institution.1990. "Methods of Test for Soils for Civil Engineering Properties (BS 1377)". British Standard Institution: London, UK. 143.

Ram Kumar, B.A.V. and Ramakrishna, G. (2021), Sustainable materials in the production of pavement base and subbase. IOP Conference series: Materials Science and Engineering, Vol. 1025, 15th-16th November 2019, India.

Das, B. M. (2006). Principles of geotechnical engineering. Stamford,CT: Thomson Learning College.

Federal Ministry of Works and Housing. 1997. "General Specifications for Roads and Bridges"., Volume II.145-284. Federal Highway Department: Lagos, Nigeria.

https://www.researchgate.net/figure/Map of Oyo-State-showing-33-Local -Government-Areas_fig1_290625617 (02/11/2015)

https://www.aciindiana.com/blog/the-interesting-history-of-road-construction/, posted August 10, 2017 (02/11/2022)

https://en.m.wikipedia.org/wiki/Roman_roads (02/11/2022)

https://en.m.wikipedia.org/science/article/pii/S0386111214600327 (02/11/2022)

APPENDIX I

Table 3: Bearing capacity at varying breadth and depth

B (m) 1	D_f (m) 2	D_f^2 3	D_f^2/B 4	D_fB 5	$255.78D_f$ 6	$78.678 D_f^2/B$ 7	$3.8651D_fB$ 8	$19.188D_f^2$ 9	88.56B 10	Constant (k) 11	q_u (kN/m^2) 12	Diff. & Ave (kN/m^2) 13
1.00			0.16	0.40		12.588	1.5460		88.56		190.650	-
1.20			0.13	0.48		10.228	1.8552		106.27		206.309	15.66
1.40	0.40	0.16	0.11	0.56	102.31	8.654	2.1644	3.070	123.98	17.424	222.754	16.45
1.60			0.10	0.64		7.867	2.4737		141.69		239.986	17.23
1.80			0.08	0.72		6.294	2.7828		159.41		256.443	16.46 (16)
1.00			0.36	0.60		28.324	2.3190		88.56		262.156	-
1.20			0.30	0.72		23.603	2.7828		106.27		275.609	13.45
1.40	0.60	0.36	0.26	0.84	153.47	20.456	3.2466	6.907	123.98	17.424	290.636	15.03
1.60			0.23	0.96		18.096	3.7104		141.69		306.449	15.81
1.80			0.20	1.08		15.736	4.1743		159.41		322.273	15.82 (15)
1.00			0.64	0.80		50.353	3.0920		88.56		341.481	-
1.20			0.53	0.96		41.699	3.7104		106.27		351.155	9.67
1.40	0.80	0.64	0.46	1.12	204.62	36.192	4.3289	12.280	123.98	17.424	363.976	12.82
1.60			0.40	1.28		31.471	4.9473		141.69		377.584	13.61
1.80			0.36	1.44		28.324	5.5657		159.41		392.776	15.19 (13)
1.00			1.00	1.00		78.678	3.8651		88.56		428.647	-
1.20			0.83	1.20		65.303	4.6381		106.27		433.754	5.11
1.40	1.00	1.00	0.71	1.40	255.78	55.861	5.4110	19.188	123.98	17.424	442.796	9.04
1.60			0.63	1.60		49.567	6.1841		141.69		454.985	12.19
1.80			0.56	1.80		44.059	6.9571		159.41		467.970	12.99 (10)