GEOTECHNICAL ANALYSIS OF LATERITIC SOIL FROM SELECTED BORROW PITS IN MINNA METROPOLIS

Tsado, R. I., Adejumo, T. W. E., Aguwa, J. I. and David, B. T.

Tsado, R. I.
Department of Civil Engineering, Federal University of Technology, Minna
Email: rtsado20@yahoo.com
+234-706-831-2854

Adejumo, T. W. E.*
Department of Civil Engineering, Federal University of Technology, Minna
Email: adejumo.taiye@futminna.edu.ng
+234-903-379-5541

Aguwa, J. I.
Department of Civil Engineering, Federal University of Technology, Minna
Email: james.aguwa@futminna.edu.ng
+234-803-316-3634

David, B. T.
Federal Road Maintenance Agency, Jos
Email: boaztdo@yahoo.com
+234-803-715-4335

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ABSTRACT

Laterite is a construction material widely used in roads, embankments, fill materials, building constructions and many more; its basic engineering properties especially geotechnical characteristic is still being explored. Eighteen soil samples were collected from three locations and subjected to geotechnical tests; Specific gravity, Sieve analysis, Consistency tests, *Compaction and California Bearing Ratio (CBR) Tests. The results show that specific gravity ranges from 2.57 – 2.71 for Maikunkele, 2.52 – 2.62 for Maitumbi and 2.62 – 2.69 for Birgi. According to AASHTO classification, the soil samples are classified as Maikunkele: A – 2 group (granular materials), Maitumbi: A – 4, A – 6 group (Silty – clay materials) and Birgi: A – 4, A – 6, A – 2 – 5 group (Silty – clay materials) and USCS classification as mostly CL-ML, ML and CL. CBR values at 2.5mm and 5.0mm for Maikunkele sample ranges from 6.21 to 21.65% and 19.32 to 40.58%. Maitumbi sample ranges from 14.25 to 18.93% and 20.66 to 26.79%, while Birgi sample ranges from 10.27 to 23.36% and 24.61 to 30.64% respectively, indicating that most of the soils are suitable for sub-grade materials. Compaction results using different energy level for these areas varied with depth: MDD of 1.96 to 2.92 g/cm3, OMC of 7.20 to 14.60% for Maikunkele laterite, MDD of 1.85 to 2.19 g/cm3, OMC of 10.9 to 16.00% for Maitumbi laterite and MDD of 1.95 to 2.11 g/cm3, OMC of 8.40 to 14.70% for Birgi laterite. At 5mm penetration, Maikunkele laterite has the highest CBR value of 40.58, while Maitumbi and Talba Farm are 26.79 and 30.64% respectively. Based on these results, all the laterite samples obtained around Minna can be used as sub-base, sub-grade and fill materials in road constructions.*

Keywords: California Bearing Ratio, Compaction, Lateritic soil, Maximum Dry Density, Optimum Moisture Content, Soil Strength

INTRODUCTION

Laterite consists of hard granules formed by cementing action which range from sandy clays to gravels, and are used for road (sub-bases or bases) foundations. Laterite is a set of soil formed as a result of weathering and is completely without gravel sized component under tropical climatic condition resulting in the accumulation of hydrated oxides of Iron and Aluminum (Gidigasu, 1972; Apkokogje, 2001). The usage of lateritic soil, as reported by Abubakar (2006) has led to development of its potentials as reliable and durable construction material that is readily available. Laterite is mostly abundant in local environment with their usage basically constrained to construction of engineering infrastructures such as roads, embankment and landfill works which are mostly used in filling works (Akintorinwa *et. al*., 2012).

Understanding of soil behaviour will go a long way in solving engineering and environmental issues especially expansive and swelling or other lateritic soils. The impropriety in the property of laterite can cause significant damage to roads and other engineering infrastructure. This is of great concern to geotechnical engineers (Abubakar, 2006); Oke and Amadi, (2008). 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 materials among other factors (Oke *et al*., 2009a; Nwankwoala *et al*., 2014). The characteristics and durability of any constructional material is a function of its efficiency in response to the load applied on it (Oke *et al*., 2009b; Nwankwoala and Amadi, 2013). CBR value less than 30 – 80 %, is recommended for soils to be used as sub-base and base materials respectively (FMWH, 1997). Asphalt Institute (1962) stipulated CBR value of between 0 to 3% for sub-grade and 3 to 7% for sub-base. Soil with MDD greater than 1600 kg/m3 has been suggested by Kabir and Taha (2006) for use as landfill barriers.

Gidigasu, (1976) revealed that sample re-used for compaction test gives rise to high dry unit weights than fresh sample. This attributed to the fact that the soil sample break down progressively under the impact of the rammer. This study is aim at producing a compendium containing relevant engineering analysis of selected geotechnical properties of lateritic collected from selected borrow pits in Minna metropolies. The findings will be useful for foundation design, roads and other construction purposes in Minna metropolis and by extension other places with similar soil conditions.

METHODOLOGY

The soil sample used for this study was collected from Maikunkele, Maitumbi and Birgi village. The three communities are located in Minna metropolis, Niger State. Minna, the capital city of Niger State, Nigeria is at 9°37'N, 6°32'E, 256 m (841 ft) above sea level. Geological study of these areas revealed that the area were underlaid by ferruginous tropical soils derived from acid igneous and metamorphic rocks (Akintola, 1982 and Areola 1982), which belongs to basement complex according to Obaje (2009).

The soil used in this study is a naturally occurring laterite which is reddish brown in colour. Total of eighteen (18) samples were collected by disturbed sampling, three samples from each burrow pit at depth of 0.5m, 1.5m and 2.5m below the ground level. The soil samples were obtained from burrow pits in Maikunkele, Maitumbi and Birgi along Talba farm, Minna. Investigation conducted on disturbed soil samples includes sieve analyses, consistency tests, Atterberg limits test. Besides the index property tests, major test were compaction and un-soaked California Bearing Ratio tests. The tests were conducted according to the guidelines in BS 1377 (1990). Four method of compaction tests (Reduced British Standard Light (RBSL), British Standard Light (BSL), West Africa Standard (WAS) and British Standard Heavy (BSH) were carried out in accordance with the BS 1377 (1990). The OMC and MDD of each sample was used to prepare a specimen for CBR test after 24 hours of soaking. After which the CBR specimen was weighed and placed under the CBR machine and seating load of approximately 4.5 kg was applied. Load was recorded at penetration of 2.5 and 5.0 mm. The average CBR for both ends of the moulded specimen was calculated.

RESULTS AND DISCUSSION

The physical properties of the samples are summarized in Tables 1 – 3. The natural moisture content from all the sites increase with depths the trend probably resulted from surface water infiltration. The sieve analysis show that MKA_1 and MKA_2 has irregular curve compare to the other samples and does not follow the grading curve. (This indicated a non-uniform distribution of grain sizes which implies poor grading (Figure 1.0). MKA_1 (0.5m) and MKA_2 (1.5m) soils samples. The non-plasticity of MKA_1 (0.5m) shows that there is little aggregate obtained which confirmed the irregularities recorded in Figure 1.0. According to FMWH, (1997) subgrade or fill material should have liquid limit $\leq$ 50% and plasticity index $\leq$ 30% while for sub-base, liquid limit should be $\leq$ 30% and plasticity index $\leq$ 12%.

Also, according to Wright (1986), the liquid limit and plasticity index values of 40% and 10% above are considered high in pavement design and construction. All the soil samples are suitable for subgrade or fill materials and samples from Birgi Table 3 are suitable for sub-base within the recommendation standard. Although the other soils of MKA_2 (1.5m), MKB_1 (0.5m), BRA_1 (0.5m), MTA_1 (0.5m) and MTB_1 (0.5m) have plasticity index lower than the recommended value for sub-base, subgrade or fill material, their liquid limits are within the recommendation standard. The compaction test is to determine the optimum moisture content (OMC) and maximum dry density. Compaction Results of the samples are summarized in Tables 4 – 6.

Table 1.0: Index Properties of Test Samples from Maikunkele area of Minna

Sample location:	MKA_1 (0.5m)	MKA_2 (1.5m)	MKA_3 (2.5m)	MKB_1 (0.5m)	MKB_2 (1.5m)	MKB_3 (2.5m)
Percentage Passing B.S Sieve No. 200	50.5	55.0	95.3	49.6	54.5	89.6
Natural Moisture Content, (%)	5.2	8.4	22.5	5.6	8.8	23.1
Liquid Limit, (%)	20.4	22.2	28.7	21.2	23.4	30.8
Plastic Limit, (%)	Non-plastic	12.6	17.0	12.7	13.2	18.2
Plasticity Index, (%)	20.4	9.6	11.8	8.5	10.2	12.6
Specific gravity	2.71	2.67	2.57	2.69	2.62	2.65
Colour	Reddish-with black patches	Brown with white patches	Brown with white patches	Reddish with white patches	Brown with white patches	Reddish with grey patches
AASHTO Classification	A-2-6	A-2-4	A-4	A-2-4	A-3	A-2-5
USCS	CL	CL-ML	ML	CL	ML	CL-ML

Table 2.0: Index Properties of Test Samples from Maitumbi area of Minna

Sample location:	MTA_1 (0.5m)	MTA_2 (1.5m)	MTA_3 (2.5m)	MTB_1 (0.5m)	MTB_2 (1.5m)	MTB_3 (2.5m)
Percentage Passing B.S Sieve No. 200	99.0	99.6	99.9	99.3	99.6	99.8
Natural Moisture Content, (%)	14.2	16.4	16.6	15.5	16.6	17.1
Liquid Limit, (%)	33.4	29.0	29.4	29.8	32.4	30.2
Plastic Limit, (%)	30.3	17.0	18.2	21.3	20.7	17.7
Plasticity Index, (%)	3.1	12.0	11.2	8.5	11.7	12.5
Specific gravity	2.52	2.58	2.62	2.56	2.58	2.63
Colour	Reddish	Reddish with brown patches	Reddish with brown patches	Reddish with grey patches	Reddish with white patches	Reddish brown
AASHTO Classification	A-4	A-6	A-6	A-4	A-6	A-6
USCS	ML	CL-ML	CL-ML	ML	CL-ML	CL-ML

Table 3.0: Index Properties of Test samples from Birgi area of Minna

Sample location:	BRA_1 (0.5m)	BRA_2 (1.5m)	BRA_3 (2.5m)	BRB_1 (0.5m)	BRB_2 (1.5m)	BRB_3 (2.5m)
Percentage Passing B.S Sieve No. 200	99.9	99.7	99.8	99.6	99.8	99.9
Natural Moisture Content, (%)	18.8	17.3	17.8	14.8	16.2	16.5
Liquid Limit, (%)	32.6	30.4	31.2	31.6	30.6	29.7
Plastic Limit, (%)	24.2	20.4	15.9	18.3	Non-plastic	15.2
Plasticity Index, (%)	8.4	14.0	15.3	13.3	30.6	14.5
Specific gravity	2.61	2.59	2.63	2.57	2.61	2.64
Colour	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown	Reddish brown
AASHTO Classification	A-4	A-4	A-6	A-6	A-2-5	A-4
USCS	ML	ML	CL-ML	CL-ML	CL	ML

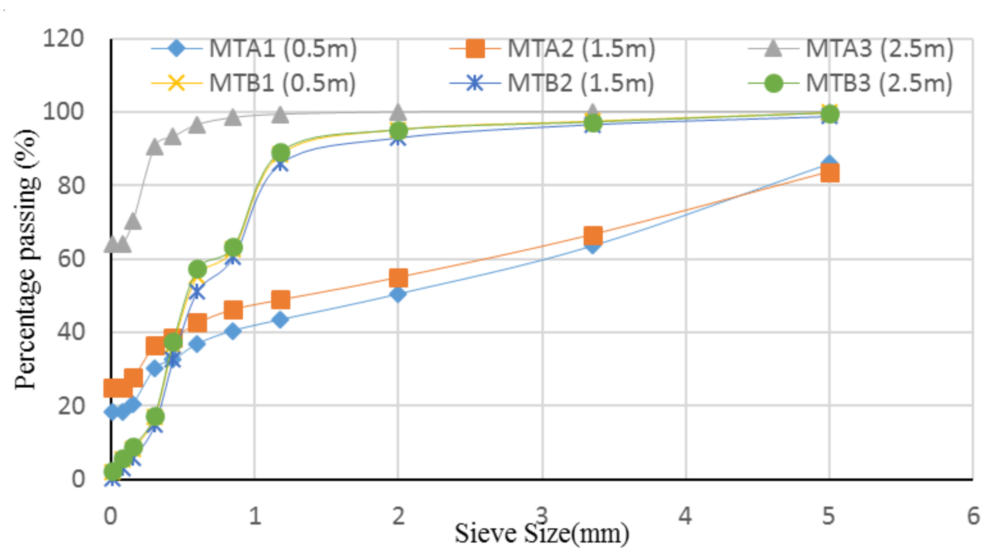


Figure 1.0: Particles size distribution of samples from Maikunkele at selected depths

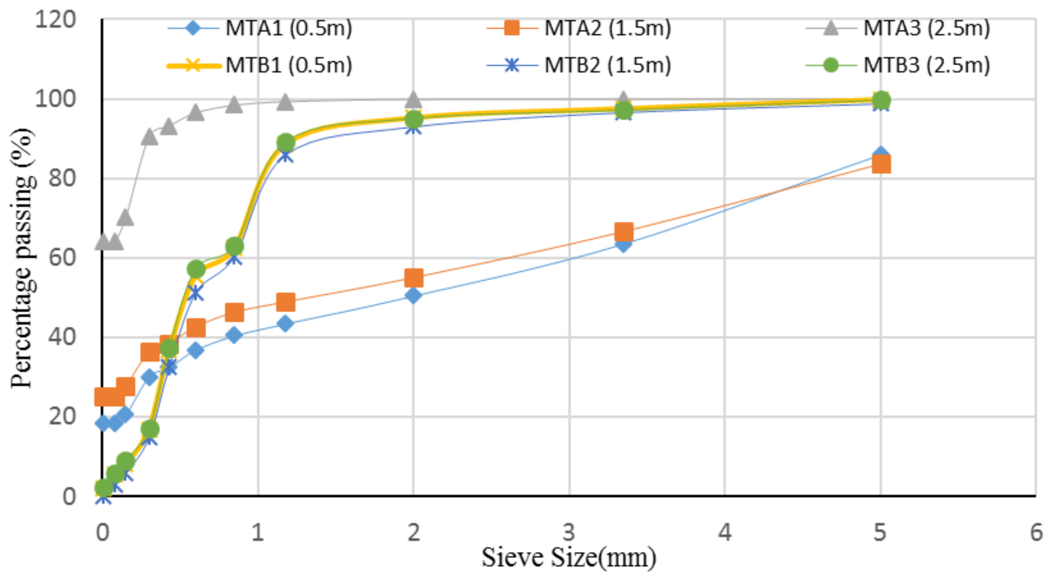


Figure 2.0: Particles size distribution of sample from Maitumbi at selected depths

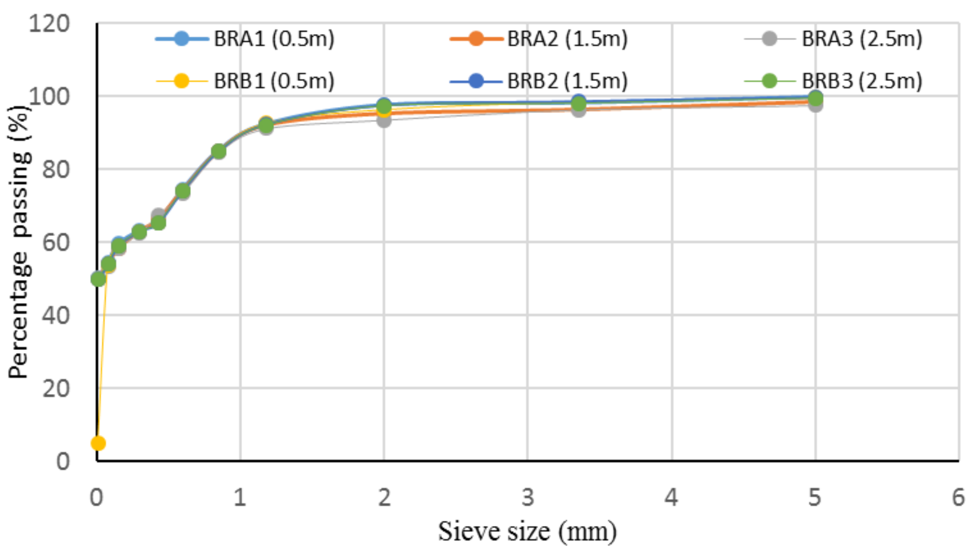


Figure 3.0: Particles size distribution of sample from Birgi at selected depths

Table 4.0: Summary of Compaction Results for Test samples

Depth	MKA$_1$ (0.5m)		MKA$_2$ -1.5m		MKA$_3$ (3.0m)		MKB$_1$ (0.5m)		MKB$_2$ (1.5m)		MKB$_3$(3.0m)	
	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD g/cm^3	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)
BSH	8.80	2.45	7.20	2.52	13.20	2.14	11.2	2.14	9.97	2.02	9.46	2.14
RBSL	10.0	2.36	8.93	2.38	14.00	1.98	11.1	2.01	10.8	1.89	11.03	1.96
WAS	11.2	2.44	9.60	2.50	14.00	1.98	10.2	2.12	9.42	2.02	10.41	1.97
BSL	12.4	2.32	10.28	2.46	14.60	2.92	11.5	2.10	12.5	2.50	11.08	2.32

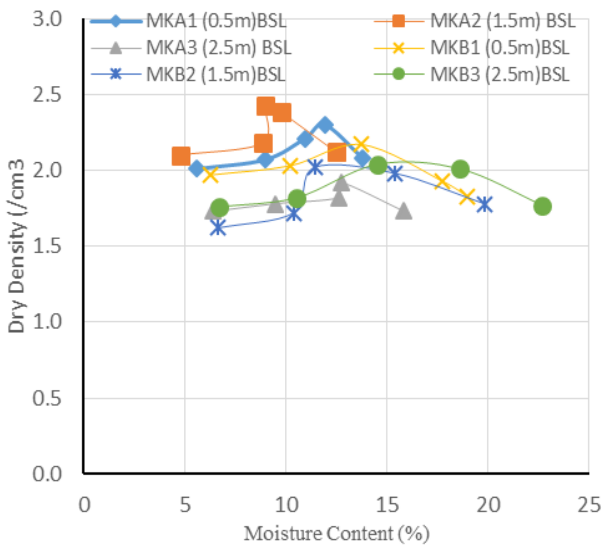
Table 5.0: Summary of Compaction Results for Test samples

Depth	MTA$_1$ (0.5m)		MTA$_2$ (1.5m)		MTA$_3$ (1.5m)		MTB$_1$ (0.5m)		MTB$_2$ (1.5m)		MTB$_3$ (2.5m)	
	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD (g/cm^3)	OMC (%)	MDD kg/cm^3	OMC (%)	MDD kg/cm^3
BSH	13.50	2.11	11.50	2.14	11.20	2.19	12.6	2.01	10.9	2.02	11.40	1.98
RBSL	15.50	1.85	13.50	2.03	13.2	2.10	14.3	1.99	12.8	1.95	12.7	1.95
WAS	16.00	1.97	15.00	2.06	14.00	2.10	14.8	1.98	13.7	2.01	15.61	2.02
BSL	14.00	2.02	16.00	1.96	15.00	2.00	12.8	1.89	14.6	1.96	16.42	1.96

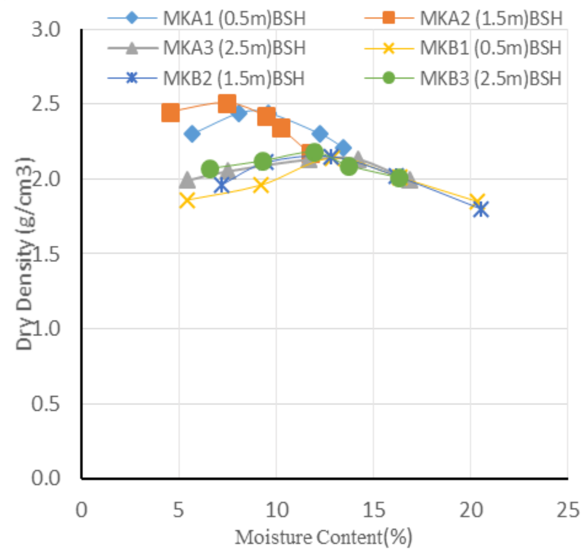
Table 6.0: Summary of Compaction Results for Test samples

Depth	BRA$_1$ (0.5m)		BRA$_2$ (1.5m)		BRA$_3$ (2.5m)		BRB$_1$ (0.5m)		BRB$_2$(1.5m)		BRB$_3$(0.5m)	
	OMC (%)	MDD (kg/cm^3)	OMC (%)	MDD (kg/cm^3)	OMC (%)	MDD kg/cm^3	OMC (%)	MDD kg/cm^3	OMC (%)	MDD kg/cm^3	OMC (%)	MDD kg/cm^3
BSH	9.90	2.01	11.8	2.11	8.80	1.98	8.40	2.01	10.4	2.10	10.4	1.97
RBSL	10.6	1.97	12.6	1.98	9.90	2.01	9.7	1.96	11.2	2.01	11.3	1.95
WAS	12.6	1.98	13.5	1.96	10.5	2.02	10.8	1.95	12.6	1.96	12.1	2.01
BSL	12.8	2.04	14.7	2.06	11.7	1.97	11.5	1.97	13.4	2.02	14.2	1.98

From the result obtained from Table 4-6 for: OMC-BSH lowest and highest values of 7.20 % and 13.50 %, OMC-RBSL lowest and highest values of 8.93% and 15.50 %, OMC-WAS lowest and highest values of 9.42 % and 16.00 % and OMC-BSL lowest and highest values of 9.28 % and 16.42 % respectively. Generally, OMC decrease with increase in compaction energy level which is not in agreement with Osinubi (1998), Osinubi (2000) and Nigerian General Specification (1997). Maximum Dry Densities (MDD) for different energy level (BSH, RBSL, WAS and BSL) are shown in Figure 4–6. The MDD-BSH lowest and highest values of 1.97 and 2.52 g/cm^3, MDD-RBSL lowest and highest values of 1.85 and 2.3.8 g/cm^3, MDD-WAS lowest and highest values of 1.95 and 2.50 g/cm^3 and MDD-BSL lowest and highest values of 1.89 and 2.92 g/cm^3.



a) British Standard light Method



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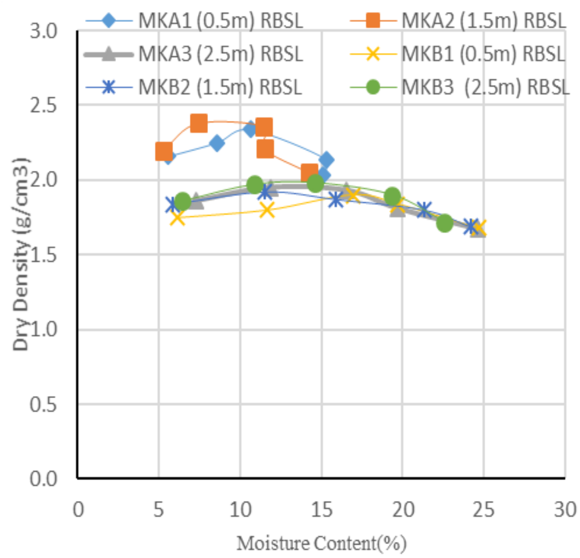
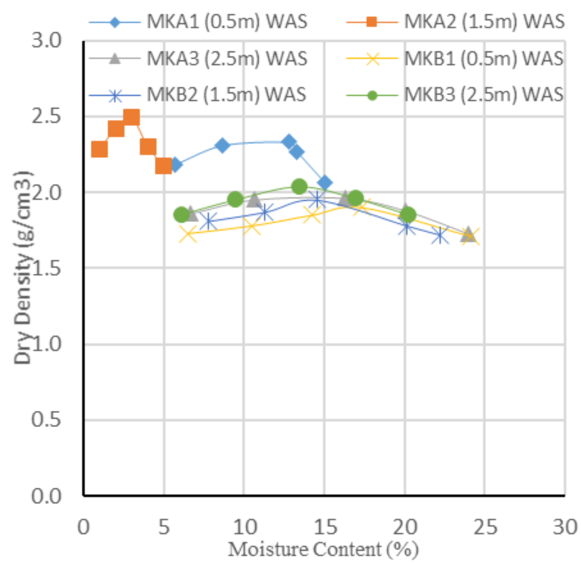
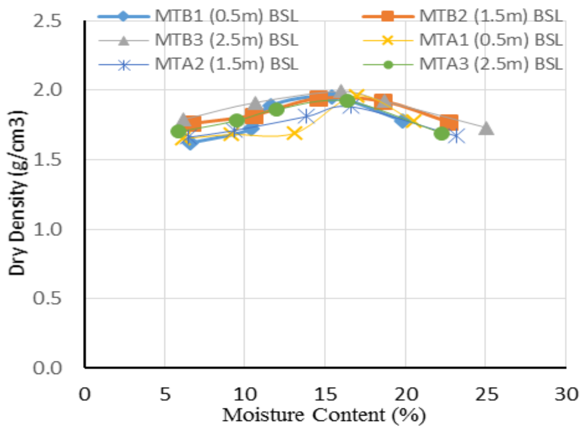


(c) Reduced British Standard Light Method

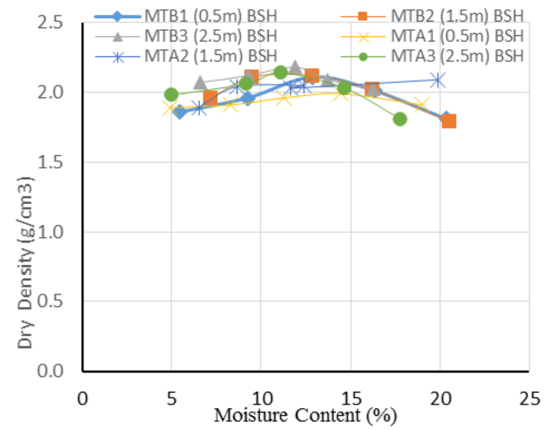


(d) West Africa Standard Method

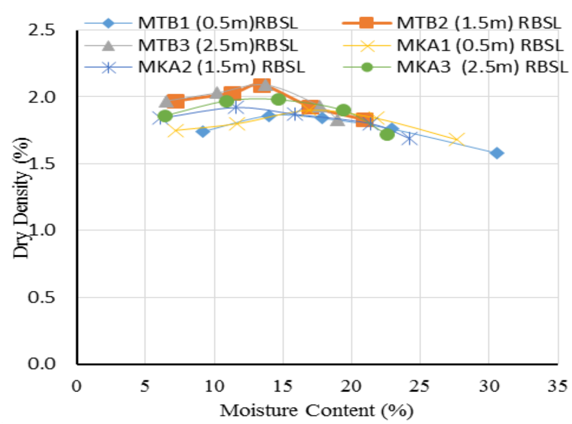
Figure 4.0: Compaction Results of samples from Maikunkele at selected depths



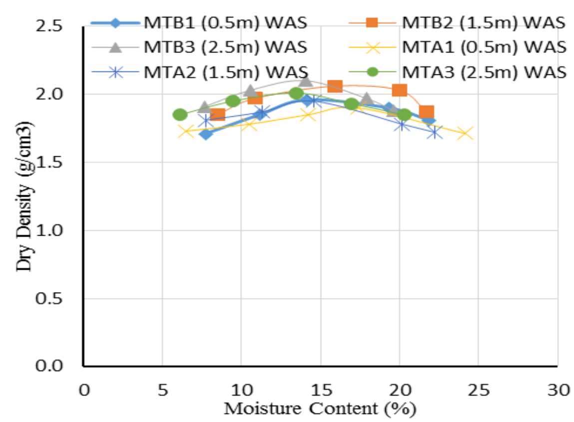
(a) British Standard light Method



(b) British Standard Heavy Method

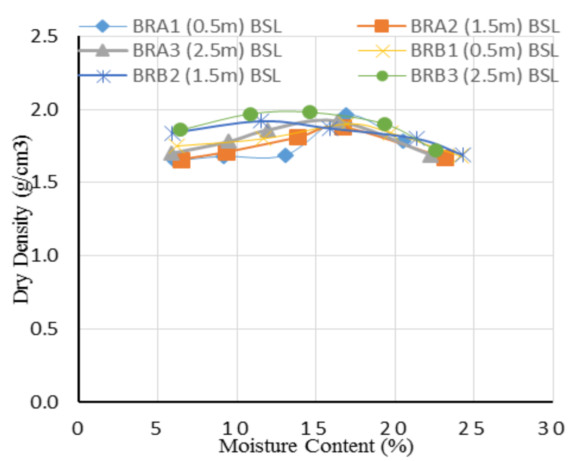


(c) Reduced British Standard Light Method

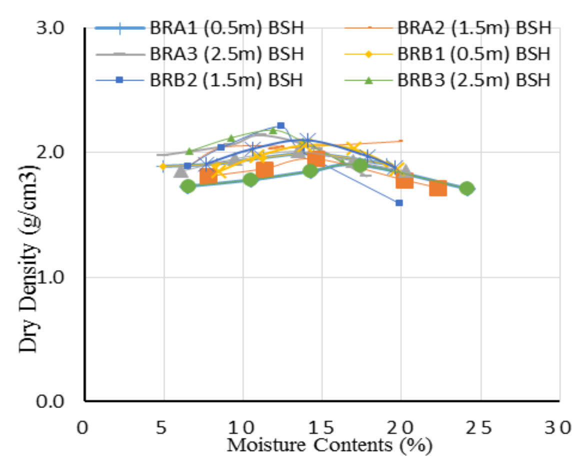


(d) West Africa Standard Method

Figure 5.0: Compaction Results of samples from Maitumbi at selected depths



a) British Standard light Method



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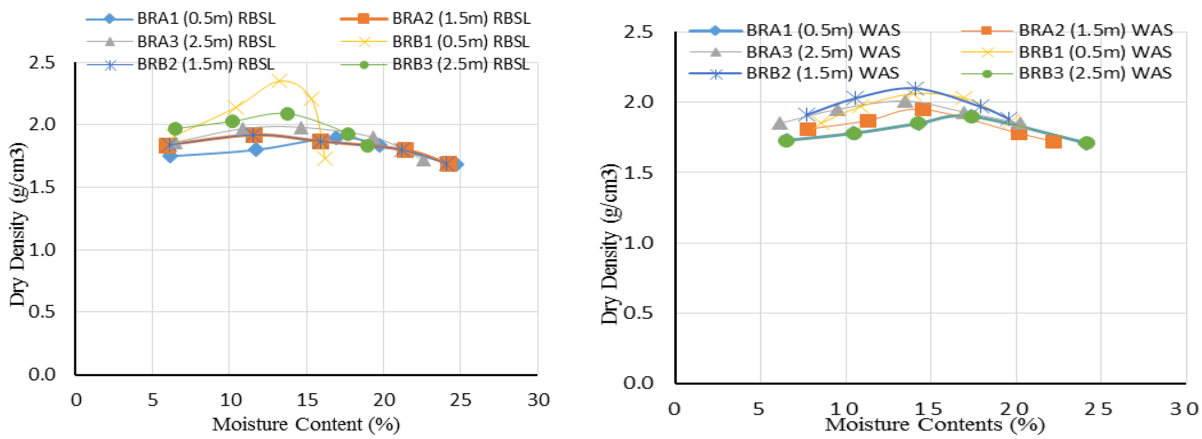

(c) Reduced British Standard Light Method (d) West Africa Standard Method

Figure 6.0: Compaction Results of samples from Birgi at selected depths

Table 7.0: Summary of California Bearing Ratio for Test Samples from Maikunkele

Penetration (mm)	MKA_1(0.5m) (%)	MKA_2(1.5m) (%)	MKA_3(2.5m) (%)	MKB_1(0.5m) (%)	MKB_2 (1.5m) (%)	MKB_3(2.5m) (%)
At 2.5	8.17	6.21	19.17	9.25	10.55	21.65
At 5.0	27.89	19.32	28.04	29.92	32.75	40.58
OMC (%)	8.80	7.20	13.2	10.56	12.78	14.67
MDD (g/cm^3)	2.45	2.52	2.14	2.51	2.43	2.15

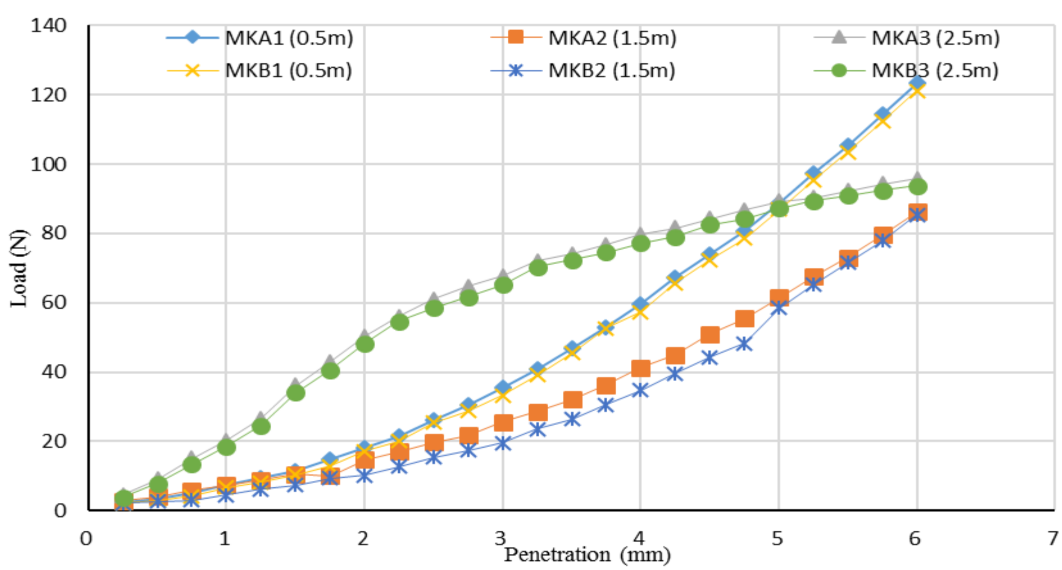

Figure 7.0: CBR Values of Lateritic Samples from Maikunkele borrow pits

Table 8.0: Summary of California Bearing Ratio for Test Samples from Maitumbi

Penetration (mm)	MTA_1(0.5m) (%)	MTA_2(1.5m) (%)	MTA_3(2.5m) (%)	MTB_1(0.5m) (%)	MTB_2(1.5m) (%)	MTB_3(2.5m) (%)
At 2.5 mm	15.24	18.93	13.67	14.25	16.46	15.26
At 5.0 mm	23.64	26.79	20.66	21.66	24.54	20.37
OMC (%)	13.5	11.5	11.2	12.4	11.8	11.2
MDD (g/cm^3)	2.11	2.14	2.19	2.31	2.24	2.10

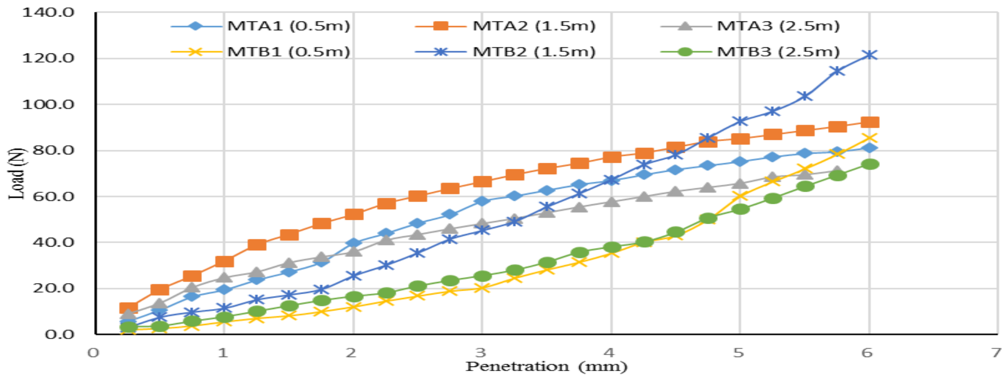

Figure 8.0: CBR Values of Lateritic Samples from Maitumbi borrow pits

Table 9.0: Summary of California Bearing Ratio for Test Samples from Birgi

Penetration (mm)	BRA_1(0.5m) (%)	BRA_2(1.5m) (%)	BRA_3(2.5m) (%)	BRB_1(0.5m) (%)	BRB_2(1.5m) (%)	BRA_3(2.5m) (%)
At 2.5mm	13.14	11.32	25.15	12.24	10.27	23.36
At 5.0mm	29.26	24.61	30.64	27.13	25.17	29.22
(OMC)	8.90	8.70	14.26	8.06	8.01	12.15
(MDD)g/cm^3	2.25	2.51	2.12	2.15	2.57	2.06

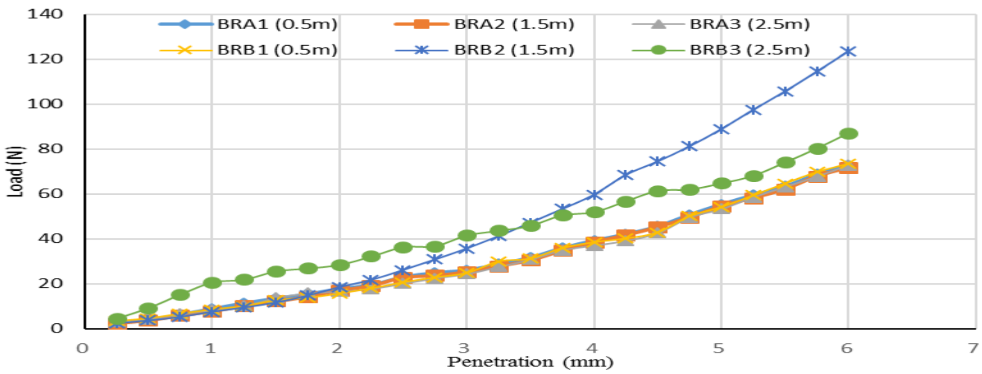

Figure 9.0: CBR Values of Lateritic Samples from Birgi borrow pits

Federal Ministry of Works and Housing recommendation for soils uses as fill or subgrade, sub-base and base materials are: ≤ 10%, ≤ 30% and ≤ 80% respectively for un-soaked soil. This show that all values less than 30% are good materials for subgrade and sub-base materials at both 2.5 and 5.0mm penetration. With the exception of MKB_2 (1.5m) and MKB_3, (2.5m) all the samples from the three locations have their unsoaked CBR value less than 30% which is the maximum value recommended for soils to be used for sub-base (FMWH, 1997). Asphalt Institute (1962) stipulated CBR value of between minimum of 0 to 3% for sub-grade and 3 to 7% for sub-base. Based on this, the lateritic soils studied having such CBR values can be used as sub-base, sub-grade and fill materials in road constructions.

CONCLUSION

The result of Sieve analysis shows that all the samples are not well graded. According to AASHTO classification, Birgi samples belong to A – 4, A – 6, A – 2 – 5 group which is majorly Silty-clay materials. Maitumbi samples belong to A – 4, A – 6 group which is majorly Silty-clay materials. Maikunkele samples belong A – 2 group which is majorly granular materials. According to USCS the samples majorly ranged from CL-ML, ML and CL. The soil from most of the locations have the CBR value less than 30 – 80 %, which is recommended for soils to be used as sub-base and base materials respectively. The lateritic soils from most locations are suitable materials for fill and sub-grade materials. Also the lateritic soils studied can be used as sub-base, sub-grade and fill materials. Liquid limits for samples are less than 30 percent. This value is also an indication of a good sub grade or fill material rating, hence the suitability of the soil for road construction. The dry density of samples generally decrease with increase in moisture content, at the energy of the modified proctor. With the MDD of some samples greater than 1600 kg/m^3, they are suitable for use as landfill barriers.

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