CORRELATION OF CALIFORNIA BEARING RATIO WITH GEOTECHNICAL PROPERTIES OF SELECTED LATERITIC SOILS

Adejumo, T. W. E. *& Tsado, R. I.*

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

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

ABSTRACT

This work presents the correlation of CBR with index and compaction properties of selected lateritic soil in Minna, Niger State. Twenty-seven (27) samples were collected from 3 locations in Minna metropolis. Classification tests, British Standard Heavy and Light compaction tests, Consistency limit test as well as CBR test were carried out on the samples. Microsoft Excel tool was used to analyze the results. From the tests results, the samples are classified in AASHTO and USCS system as A–2, A–4, CL–ML, CL and ML respectively. Samples from Maikunkele are majorly granular, while those from Maitumbi and LapaiGwari are mainly Silty-clay materials with reddish, grey or brown patches. The Average Liquid Limit (LL), Plastic Limit (PL), Plastic Index (PI) and specific Gravity (Gs) of test samples are 20. 40 – 33.40%, 12.6 – 30.0%, 8.4 – 30.6% and 2.52 – 2.71 respectively. The British Standard Heavy compaction test result produced average MDD and OMC values 1.97– 2.52 g/cm^3 and 7.20 – 13.5%, while the British Standard Light compaction test result produced average 1.89 – 2.92 g/cm^3 and 10.28 – 16.00 % as MDD and OMC values respectively. The average CBR values range from 11.90 – 109.9 %. Using the Microsoft Excel tool, the study further established a regression equation for the CBR value of lateritic soils. The performance of the regression model was assessed in terms of correlation coefficients, F-statistics and residuals pattern. Using the developed model, the regression equations developed indicated strong correlation of CBR and PL, LL, PI, and Gs (with R^2 = 0.89 – 0.99). However, the work revealed a poor and moderate correlation of CBR with MDD and OMC with R^2 = 0.45 and R^2= 0.73 respectively at BSL compaction energy level.

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

1.0 INTRODUCTION

Engineering projects such as road embankments, earthen dams, river dykes, railway formations require borrow materials to be compacted for the formation of earth embankment. To avoid failure of these earthen structures, field compaction control of the borrow materials after placement is a must. Maximum dry unit weight *(*MDD) and

Optimum Moisture Content (OMC) are the two parameters which are determined in the laboratory by performing standard Proctor compaction, modified Proctor compaction or West African compaction test. These parameters are used to check the relative compaction requirements in the project specifications. The MDD and the OMC of coarse-grained soils are influences by grain size distribution, index properties and the mineralogical composition of the soil samples (Korfiatis & Manikopoulos, 1982). The dry density of lateritic soil generally decreases with increase in moisture content, at the energy of the modified proctor. With high MDD, lateritic soils are suitable for use as road base and landfill barriers (Tsado *et al*., 2018).

However, for fine-grained soils, consistency limits have considerable effects on the compaction characteristics. Index properties have wide applications in geotechnical engineering practice and a number of index properties which are easily recognized in soil mechanics have been outlined by many researchers, namely Frempong & Yanful, (2008); Osinubi & Bello, (2011); Bello, (2011a, b, c). It is a usual practice to attempt to predict the engineering behaviour of soils from their index properties. Osinubi & Bello (2011) and Bello (2011) opined that the micro structure, composition, homogeneity and other features of soil make the use of index properties to predict soil behaviour appropriate. Many works have proposed models to predict the compaction characteristics of both coarse-grained and fine-grained soils using gradational parameters and index properties of the soils without conducting extensive laboratory compaction tests. Some of these works include Korfiatis & Manikopoulos (1982), Mujtaba *et al.*, (2013), Omar *et al.*, (2003) for coarse-grained soils, and Blotz *et al*. (1998), Gurtug & Sridharan (2002) for fine-grained soils. This study therefore, correlates the CBR values with index and compaction properties of selected lateritic soil in Minna, Niger State from extensive laboratory investigation and analysis. The findings is useful for foundation design, roads and other construction purposes in Minna area of Niger State and by extension other places with similar soil conditions.

2.0 MATERIALS AND METHODS

Disturbed sampling method was used for sample collection, where sample were collected directly from existing active and functioning (still in use) borrow pits sites. The selected borrow pits are located in Maikunkele, Maitumbi and LapaiGwari, all in Minna metropolis, Niger State. These sites and their locations are shown in Figure 2.1

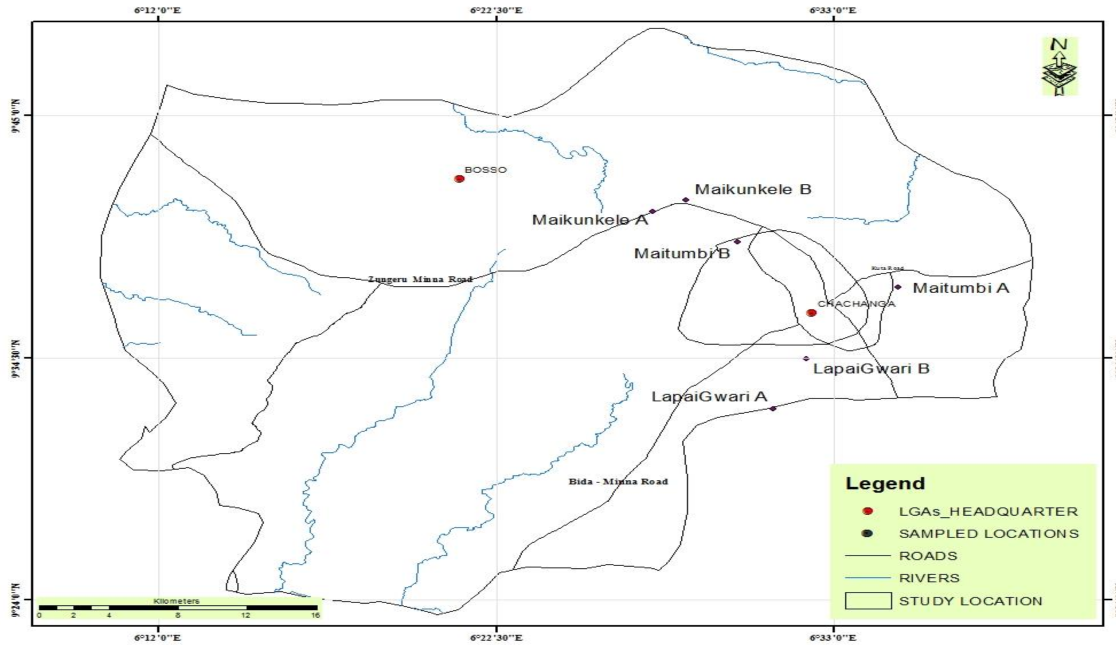


Figure 2.1: Sample collection point in Minna, Niger State

Three borrow pits indicated as A, B and C from the three cluster sites, totaling 9 pits were explored manually as shown in Table 2.1. A total of twenty-seven (27) samples, three (3) from each borrow pits, were collected at 0.5m, 1.5m and 2.5m depths below the ground from Maikunkele, Maitumbi and LapaiGwari, the selected cluster areas of Minna, Niger State. Thereafter, the samples were transported, air dried, sorted to remove impurities and pulverized. The basic and detailed tests conducted on the samples according to BS 1377 (1990) include; Moisture content, Grain size distribution, Specific gravity, British Standard Light and British Standard Heavy compaction tests and California Bearing Ratio (CBR) test.

To establish a relationship between CBR and soil index properties, i.e. correlating the properties, multiple line regression analysis was developed using Microsoft Excel for correlating the CBR values.

3.0 DISCUSSION OF RESULTS

The summary of the geotechnical properties of the twenty-seven (27) soil samples collected from the 9 borrow pits is shown in Tables 3.1 – 3.3. The samples are mostly plastic with the exception of sample A and Q. Samples A – I are from Maikunkele sites with A – C, and D – F obtained from borrow pits 1 – 3 respectively. Samples J – R are from borrow pits 4 – 6 respectively. Samples S – Z1 are from LapaiGwari sites borrow pits 7 – 9 respectively. Physical examination of samples collected at designated depths for identification is shown in Table 3.4. The grading curves from sieve analysis for the samples is shown in Figures 3.1 – 3.3.

Table 3.1: Summary of geotechnical properties of test samples from site A

Sample	Depth (m)	LL(%)	PL(%)	PI(%)	G_S	NMC (%)	BSH		BSL		Bulk Density (kg/m^3)	AVG CBR Value (%)
							MDD(g/cm^3)	OMC(%)	MDD(g/cm^3)	OMC(%)		
A	0.5	20.40	NP	20.4	2.71	5.2	2.45	8.80	2.32	12.4	2.06	57.40
B	1.5	22.20	12.60	9.60	2.67	8.4	2.52	7.20	2.46	10.3	2.00	40.65
C	2.5	28.70	17.00	11.7	2.57	22.5	2.14	13.2	2.92	14.6	1.94	75.15
D	0.5	21.20	12.70	8.50	2.69	5.6	2.14	11.2	2.10	11.5	1.99	56.10
E	1.5	23.40	13.20	10.2	2.55	8.8	2.02	9.97	2.50	12.5	1.75	36.95
F	2.5	30.8	18.20	12.6	2.65	23.1	2.13	9.46	2.32	11.1	2.15	46.72
G	0.5	22.3	13.4	8.9	2.67	7.9	2.02	9.82	2.26	10.4	1.89	72.91
H	1.5	20.6	14.2	6.4	2.60	12.2	2.05	8.88	2.19	11..6	2.04	52.82
I	2.5	25.4	11.6	13.8	2.61	10.3	2.18	11.4	2.27	12.8	1.99	59.21

Table 3.2: Summary of geotechnical properties of test samples from site B

Sample	Depth (m)	LL(%)	PL(%)	PI(%)	Gs	NMC (%)	BSH		BSL		Bulk Density (kg/m^3)	AVG CBR Value (%)
							MDD(g/cm^3)	OMC(%)	MDD(g/cm^3)	OMC(%)		
J	0.5	33.40	20.10	13.3	2.52	14.2	2.11	13.50	2.02	14.00	1.64	61.90
K	1.5	29.00	17.00	12.0	2.58	16.4	2.14	11.50	1.96	16.00	1.92	72.80
L	2.5	29.40	18.20	11.2	2.62	16.6	2.19	11.20	2.00	15.00	1.93	54.65
M	0.5	29.80	21.30	8.50	2.56	15.5	2.01	12.61	1.89	12.81	1.72	38.50
N	1.5	32.40	20.70	11.7	2.58	16.6	2.02	10.91	1.96	14.61	1.90	64.15
O	2.5	30.20	17.70	12.5	2.63	17.1	1.98	11.40	1.96	16.42	1.93	37.90
P	0.5	31.3	16.2	15.1	2.62	12.9	2.11	12.82	2.26	13.44	1.69	42.17
Q	1.5	28.9	13.1	15.8	2.58	14.2	2.15	10.91	2.09	13.62	1.14	59.23
R	2.5	31.5	17.3	14.3	2.63	13.3	2.08	11.44	2.11	12.82	1.69	62.18

Table 3.3: Summary of geotechnical properties of test samples from site C

Sample	Depth (m)	LL(%)	PL(%)	PI(%)	Gs	NMC (%)	BSH		BSL		Bulk Density (kg/m^3)	AVG CBR Value (%)
							MDD(g/cm^3)	OMC(%)	MDD(g/cm^3)	OMC(%)		
S	0.5	32.60	24.20	8.40	2.61	18.8	2.01	9.90	2.04	12.18	2.07	109.90
T	1.5	30.40	20.40	14.00	2.59	17.3	2.11	11.8	2.06	14.27	2.12	11.90
U	2.5	31.20	15.90	15.30	2.63	17.8	1.98	8.80	1.97	11.17	2.07	47.50
V	0.5	31.60	18.30	13.30	2.57	14.8	2.01	8.40	1.97	11.51	2.02	37.40
W	1.5	30.60	NP	30.60	2.61	16.2	2.10	10.4	2.02	13.24	2.04	57.50
X	2.5	29.70	15.20	14.50	2.64	16.5	1.97	10.4	1.98	14.42	2.01	50.60
Y	0.5	29.31	10.12	19.19	2.56	17.5	2.13	9.72	2.16	11.22	2.12	32.64
Z	1.5	28.94	10.21	18.73	2.58	14.5	2.05	11.29	2.03	12.21	2.14	69.63
Zz	2.5	30.52	11.33	19.19	2.59	17.7	2.09	10.64	2.14	12.82	2.10	82.26

NP: None Plastic

Table 3.4: Summary of AASHTO and USCS classification for the lateritic soils

Samples	Depths (m)	Descriptions	
A	0.5	Granular materials:	Reddish-with black patches, A-2-6, CL
B	1.5		Brown with white patches, A-2-4, CL-ML
C	2.5		Brown with white patches, A-4, ML
D	0.5		Reddish with white patches, A-2-4, CL
E	1.5		Brown with white patches, A-3, ML
F	2.5		Reddish with grey patches, A-2-5, CL-ML
G	0.5	Silty – clay materials:	Reddish, A-4, ML
H	1.5		Reddish with brown patches, A-6, CL-ML
I	2.5		Reddish with brown patches, A-6, CL-ML
J	0.5		Reddish with grey patches, A-4, ML
K	1.5		Reddish with white patches, A-6, CL-ML
L	2.5		Reddish brown, A-6, CL-ML
M	0.5	Silty – clay materials:	Reddish brown, A-4, ML
N	1.5		Reddish brown, A-4, ML
O	2.5		Reddish brown, A-6, CL-ML
P	0.5		Reddish brown, A-6, CL-ML
Q	1.5		Reddish brown, A-2-5, CL
R	2.5		Reddish brown, A-4, ML
S	0.5	Silty – clay materials:	Reddish brown, A-4, ML
T	1.5		Reddish brown, A-4, ML
U	2.5		Reddish brown, A-6, CL-ML
V	0.5		Reddish brown, A-6, CL-ML
W	1.5		Reddish brown, A-2-5, CL
X	2.5		Reddish brown, A-4, ML
Y	0.5	Granular materials:	Reddish-with black patches, A-2-6, CL
Z	1.5		Brown with white patches, A-2-4, CL-ML
Zz	2.5		Brown with white patches, A-4, ML

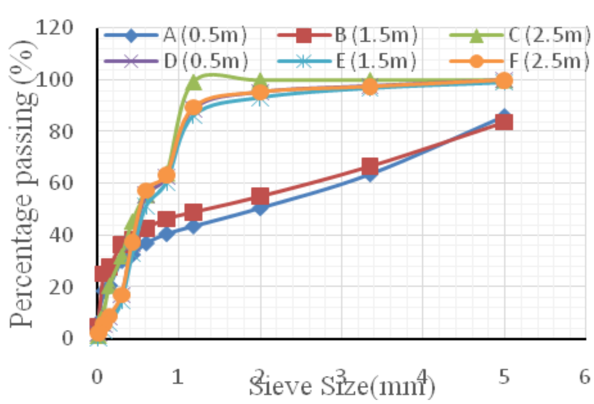


Figure 3.1: Grading curve for Maikunkele samples

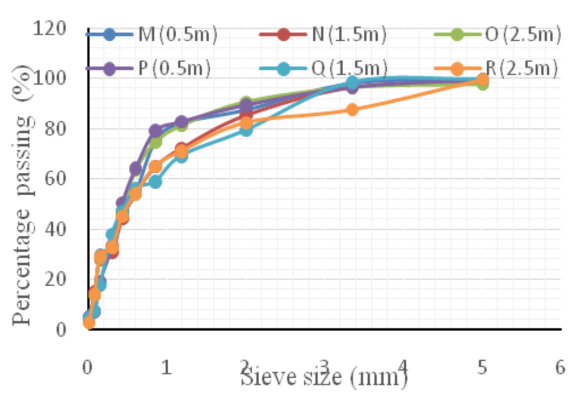


Figure 3.2: Grading Curve for Maitumbi samples

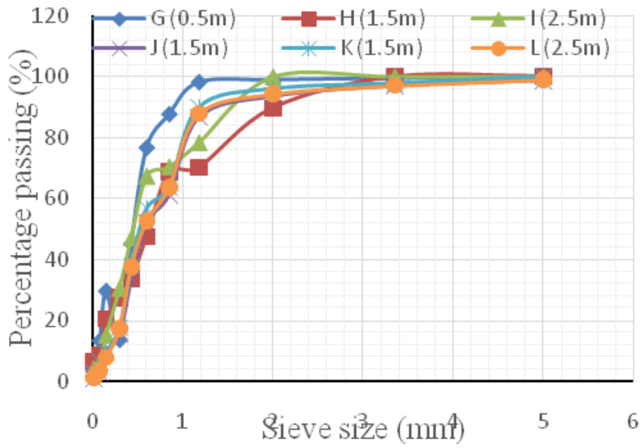


Figure 3.3: Grading Curve for LapaiGwari samples

3.1 Compaction Characteristics of Test Lateritic soil Sample

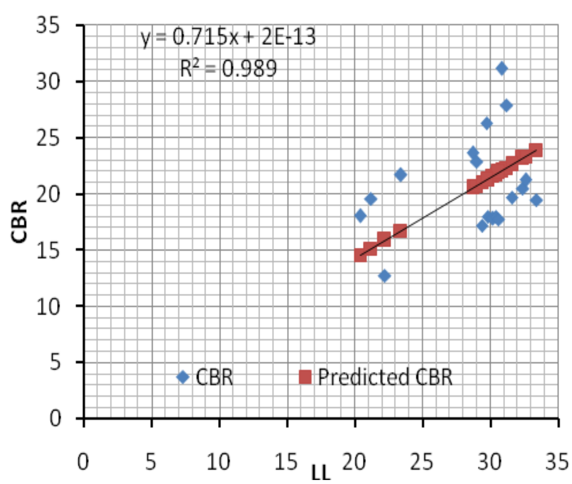
The results obtained from the laboratory, soil samples were collected in two borrow pits from each locations, for Maikunkele: BSL has the highest values of MDD = 2.92 g/cm^{3}at 13.09 %, for Maitumbi: BSH has the highest values of MDD 2.18 g/cm^3 at 11.92 %, for LapaiGwari: BSH has the highest values of MDD = 2.14 g/cm^3 at 14.46 %. The Maikunkele borrow pits required less water and light energy to attained its MDD and an increase in average MDD values and a decrease in average OMC values down the soil profile according to laboratory results obtained, this could be due to the filling of available voids in the soil with silica grains down the horizons (Udeoyo and Abubakar, 2001).Furthermore, there is a variation in compaction properties along the profile. Samples collected from Maikunkele borrow pits have higher MDD values and lower OMC values compared with samples collected from Maitumbi and LapaiGwari Pits. Usually, the higher the MDD, the more well graded, coarse and granular the soils and this enhances their subsequent performance. The downward increase in MDD is also in agreement with the results of Adeyemi (2002), who examined some lateritic soils developed over quartz schist in South-western Nigeria. Also, the MDD obtained for these lateritic soils falls within the observed range of 1.3 – 2.4 g/cm^{3}obtained by (Ogunsanwo, 1990, Madu, 1975 and Gidigasu, 1972).

3.2 **Correlation of Samples' CBR with Index properties**

The summary of regression analysis on the correlation of CBR with index properties of the lateritic soil samples investigated is shown in Table 3.5. The key component output are Correlation equations, Regression (R), Regression square (R^2), Adjusted Regression (R), t – statistics and F. The correlation graphs are in Figures 3.4 – 3.11. With the exception of MDD and OMC which poorly and moderately correlated with CBR with R^2= 0.45 and R^2= 0.73 respectively under BSL compaction energy level, other index properties correlated well in both BSL and BSH compaction energy levels. Properties such Liquid Limit, Plastic Limit, Plasticity Index and Specific gravity have similar correlation results pattern with strong correlation coefficient R^2 range between 0.89 and 0.99.

Table 3.5: Summary of Regression Analysis Output for selected samples

Model No	Correlation of CBR with:	Equation of Correlation	R	(R^2)	Adjusted R	t-stat	F
1	LL	y = 0.715x + 2E-13 R² = 0.99	0.98	0.989	0.99	19.94	397.63
2	PL	y = 1.0887x - 3E-14 R² = 0.89	0.91	0.899	0.89	9.13	83.36
3	PI	y = 1.3711x - 5E-14 R² = 0.89	0.90	0.898	0.89	8.36	69.97
4	Gs	y = 7.9302x R² = 0.97	0.98	0.969	0.97	20.05	402
5	MDD (BSL)	y = -0.3214x + 23.527 R² = 0.45	0.97	0.448	0.45	17.89	320
6	OMC (BSL)	y = 1.5307x + 5E-13 R² = 0.73	0.97	0.728	0.73	16.43	270
7	MDD (BSH)	y = 9.7013x - 1E-12 R² = 0.97	0.97	0.968	0.97	16.74	280.51
8	OMC (BSH)	y = 1.9123x - 3E-13 R² = 0.96	0.96	0.961	0.96	15.94	254.14



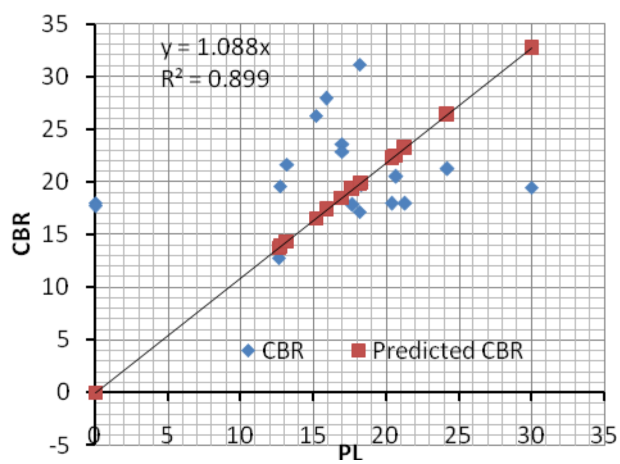
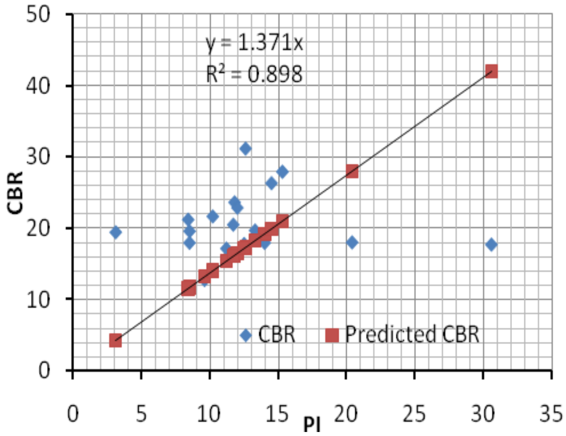


Figure 3.4: Linear Correlation between CBR and LL **Figure 3.5: Linear Correlation between CBR and PL**



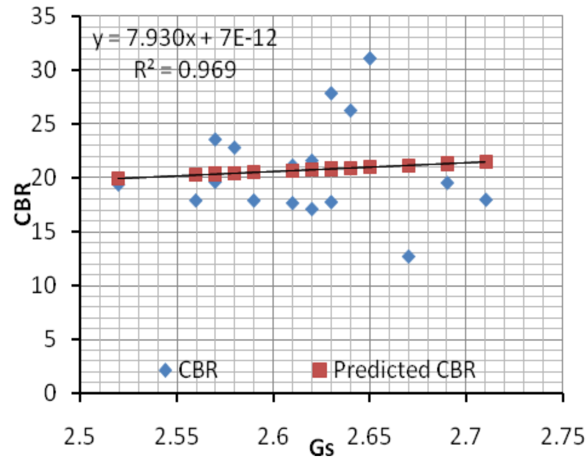
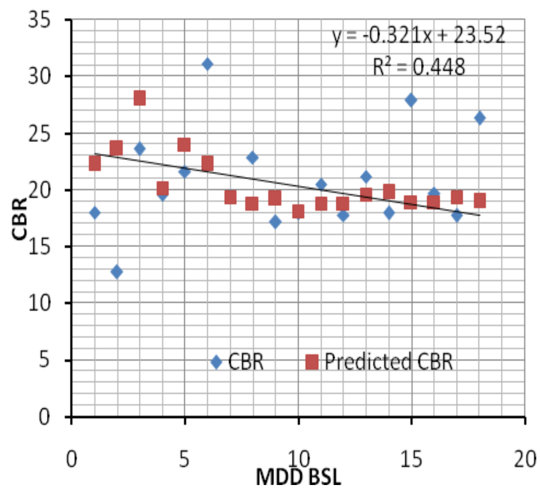


Figure 3.6: Linear Correlation between CBR and PI **Figure 3.7: Linear Correlation between CBR and Gs**



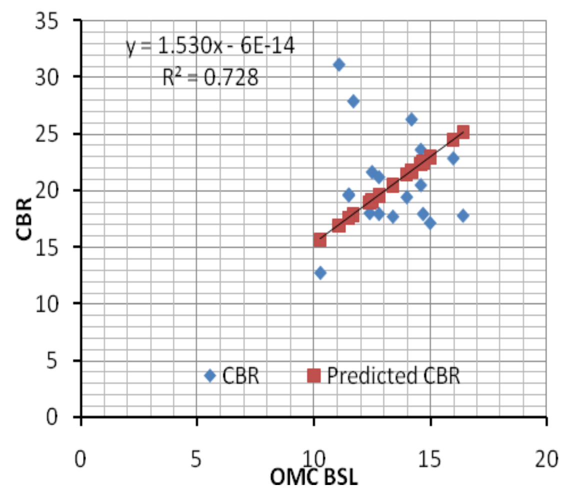


Figure 3.8: Linear Correlation between CBR and MDD (BSL) **Figure 3.9: Linear Correlation between CBR and OMC (BSL)**

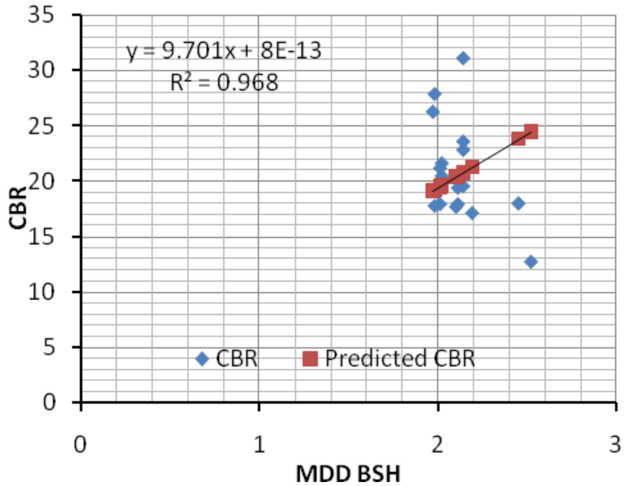


Figure 3.10: Linear Correlation between CBR and MDD (BSH)

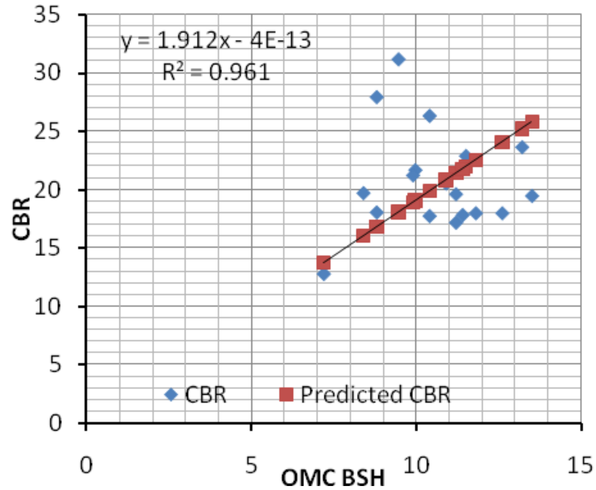


Figure 3.11: Linear Correlation between CBR and OMC (BSH)

CONCLUSION

From the laboratory investigation and analysis presented on the correlation of CBR with index properties of selected lateritic soils in Minna, the following conclusions were drawn. The lateritic soil samples from the selected borrow pits; have been classified as CL–ML, CL and ML corresponding to A–2, A– 4, A– 3, A– 6 based on USCS and AASHTO system respectively. With the exception of MDD and OMC which poorly and moderately correlated with CBR with R^2= 0.45 and R^2= 0.73 respectively under BSL compaction energy level, other index properties correlated well in both BSL and BSH compaction energy levels. Properties such as Liquid Limit, Plastic Limit, Plasticity Index and Specific gravity have similar correlation results pattern with strong correlation coefficient R^2 range between 0.89 and 0.99. These derived relations and the equations can be used for predicting the CBR values of similar lateritic soils with regards to the index properties.

In addition, practicing road and geotechnical engineers would find this model useful in estimation or prediction of compaction characteristic with California Bearing Ratio values of lateritic soils with similar properties as that of Minna metropolis.

REFERENCES

Adeyemi, G. O. (2002). Geotechnical properties of lateritic soil developed over Quartz schist in Ishara Area, Southwestern Nigeria. *Journal of Min. and Geol.* 38, 65-69.

Bello, A. A. (2011a). The use of Standard Proctor for the determination of Shrinkage Properties of Reddish Brown Tropical soil, *Leonardo Journal of Science*, 19(2), 51-62.

Bello, A. A. (2011b). Analysis of Shear Strength of Compacted Lateritic Soils, *Pacific Journal of Science and Technology,* 12(1), p. 425-433.

Bello, A. A. (2011c). Influence of Compaction Delay on CBR and UCS of Cement Stabilized Lateritic Soil, *Pacific Journal of Science and Technology*, 12(2), 87-98.

Blotz, L. R., Benson, C. H., & Boutwell, G.P. (1998). Estimating the optimum water content and maximum dry unit weight for compacted clays. *J. Geotech. Geoenviron. Eng*. 124(9), 907–912.

BS 1377 (1990). Method of tests for soils for civil engineering purposes. British Standards Institution. London.

Frempong E. M. & Yanful E. K. (2008). Interactions between three tropical soils and municipal solid waste landfill leachate, *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, 134(3), p. 379-396.

Gidigasu, M. D. (1972)**.** Mode of formation and geotechnical characteristics of laterite materials of Ghana in relation to soil forming factors. *Engineering Geology, (6*) 79-150.

Gurtug, Y., & Sridharan, A. (2002). Prediction of compaction characteristics of fine grained soil. *Geotechnique* 52(10), 761–763.

Korfiatis, G. P., & Manikopoulos, C. N. (1982), Correlation of maximum dry density and grain size. *Journal of Geotech. Eng*. Div. ASCE 108 (GT9), 1171–1176.

Madu R. M. (1975). Sand-laterite mixture for road construction (A laboratory investigation). *Nigerian Journal of Technology*, Vol. 1(1), 28-37.

Madu, R. M. (1975)**.** Some Nigerian residual lateritic soil, their characteristics and relative road building properties on Group Basis. *Proceedings of 6th Regional Conference for Africa Soil Mechanics and Foundation Engineering. Durban, South Africa*. *International Society for Soil Mechanics and Foundation Engineering,* 1, 121-129.

Mujtaba, H., Farooq, K., Sivakugan, N. & Das, B.M. (2013). Correlation between gradational parameters and compaction characteristics of sandy soils. *Int. J. Geotech. Eng.* 07(4), 395–401.

Ogunsanwo, O. (1990). Geotechnical properties of undisturbed and compacted amphibolite derived laterite soil. *International Engineering Geology,* volume 31(2), 183 – 188.

Omar, M. Shanableh, A., Basma, A., & Barakat, S. (2003). Compaction characteristics of granular soils in United Arab Emirates. *Geotech. Geol. Eng.* 21, 283–295.

Osinubi K. J.,& Bello, A. A. (2011). Soil water characteristics curves for Reddish brown tropical soil, *Electronic Journal of Geotech. Engineering,* 16, 1-25.

Tsado, R. I., Adejumo T. W. E., Aguwa, J. I. & David, B. T. (2018). Geotechnical Analysis of Lateritic Soil from Selected Borrow Pits in Minna Metropolis, *Proceedings of the 16th International Conference & AGM*, 23-26 October 2018, A Publication of Nigerian Institution of Civil Engineers: Paper 17:130 – 141.

Udoeyo F. F. & Abubakar M. A. (2001). Influence of Compaction delay on some characteristics of lateritic soil stabilized with cement kiln dust. *Glo. Jour. Pure. Appl. Sci*., 7, 727-731.