



Modeling of California Bearing Ratio with Basic Engineering Properties along East-West Road – Section II (Port Harcourt to Kaiama)

John Engbonye SANI¹, George MOSES¹, Roland Kufre ETIM², Kabiru ADEBAYO¹ Omolara Kobdang KEVIN³ and Obinna Chukwudinma MBOGU⁴

¹Department of Civil Engineering, Nigeria Defense Academy, Kaduna

²Department of Civil Engineering, Akwa Ibom State University, Ikot Akpaden, Nigeria

³Department of Civil Engineering, Air Force Institute of Technology, Kaduna, Nigeria

⁴Postgraduate Student of Civil Engineering Department, Nigeria Defense Academy, Kaduna

ABSTRACT

In Highway design, California Bearing Ratio (CBR) is one of the most important methods to determine the strength of the subgrade material. To carry out CBR tests requires considerable time and effort, therefore it is vital to develop models for the prediction of CBR value. This research work aims to develop a statistical model to predict the CBR values of soil using their basic engineering properties which was achieved by collecting results from 46 disturb samples of trial pits and then developing a statistical regression model to predict the CBR. A prediction is a vital tool in Engineering that aid quick decision making. This study is an attempt to develop valid models to determine the CBR value from index properties of soil (such as LL, PL, PI, MDD and OMC) which are quicker to estimate from their standard method of testing. Various laboratory test results were collected from the ongoing Construction of East-West road, Section II (spanning from Port Harcourt to Kaiama). Various relationships between index properties and CBR of the collected samples were investigated using simple and multiple regression analysis and also predictive equations estimating CBR from the experimental index values were developed.

ARTICLE INFO

Article History

Received: September, 2021

Received in revised form: September, 2021

Accepted: November, 2021

Published online: December, 2021

KEYWORDS

California Bearing Ratio, Prediction, Regression

INTRODUCTION

Soil is usually evaluated to ascertain its suitability for the purpose it will be used for. Proper analysis is necessary to ensure that Civil Infrastructures such as roads, buildings, rails, dams, etc are safe and can withstand the load it is intended to carry. Geographical variance in soil conditions from one location to another makes it difficult to predict the behaviour of soil at every point. This has made it important for soil conditions at every site to be evaluated thoroughly for proper design and subsequent construction.

Most of our roads in Nigeria are constructed with flexible pavement which is made up of different layers such as subgrade, sub-base, base course and surface layer. The design and performance of this pavement type mainly depend on the strength of the sub-grade

material. The sub-grade is the bottom layer and serves as the foundation of road pavement and the load from the pavement is finally transferred to the sub-grade (Adeyemi, *et al.*, 2014)

The California Bearing Ratio (CBR) test is a measure of the resistance of a material to penetration of standard plunger under controlled density and moisture conditions. It is a laboratory (or in-situ) testing method to estimate the bearing value and the mechanical strength of highway subgrades in road construction. It was developed by the California Division of Highways as a method of classifying and evaluating soil-subgrade and base course materials for flexible pavements. It is the most widely used strength parameter for subgrade soils in flexible pavement design. CBR test may be conducted in the remoulded or undisturbed sample (Vishal and Yadav, 2016)



The laboratory CBR apparatus consists of a mould of 150 mm diameter with a base plate and a collar, a loading frame and dial gauges for measuring the penetration values and the expansion on soaking. The specimen in the mould is soaked in water for 4 days and the swelling and water absorption values are noted. The surcharge weight is placed on the top of the specimen in the mould and the assembly is placed under the plunger of the loading frame (ASTM, "D 1883-05).

In the Ministry of Niger Delta Affairs, road designs are usually contracted out to Consultants and it is always a difficult task confirming submitted values of CBR results used in the design of roads by the Consultants due to the following reasons; The process of laboratory testing of soil to get their CBR values consumes a lot of time and it involves a lot of labour, Insecurity in the Niger Delta Region, Funding constraints, Limited amount of confirmed CBR data in the Region.

Some of the Consultants exploit these limitations of the Ministry and this has led to designs conducted with poor CBR results to be used for road construction in the Niger Delta Region which has, in turn, led to road failures within the designed life of many projects in the Region.

CBR testing is time consuming, laborious and requires a high level of expertise for accurate results. The Ministry hardly verifies the CBR results used by Consultants for road designs due to the constraints mentioned above. This which led to failure within the designed life of many roads constructed within the Region. The application of prediction models might go a long way in validating the CBR values submitted by Consultants for road designs.

LITERATURE REVIEW

Different researchers have worked in this context. Various studies i.e. Black in 1962, Graft-Johns on & Bhatia in 1969, Agarwal and Ghanekar in 1970 and NCHRP in 2001 [i-iv] have focused the effect of geotechnical characteristics of soils and soil types on CBR values. Many researchers have made attempts to develop effective correlations

for prediction of California Bearing Ratio (CBR) from index properties of soils.

Black in 1962 aimed to develop an approximate method to quickly predict the CBR value. He established predictive models to predict CBR value based on Plasticity index [i].

Agarwal and Ghanekar in 1970 established a relation between CBR value and different index properties of soil [iii]. Following prediction model was proposed using liquid limit and optimum moisture content.

$$\text{CBR} = 2 - 16 \log(\text{OMC}) + 0.07\text{LL} \quad (1)$$

Yildirim&Gunaydin (2011) proposed following correlation for CBR soaked value with index properties of fine grained soils [iv].

$$\text{CBR} = 0.62\text{OMC} + 58.9\text{MDD} + 0.11\text{LL} + 0.53\text{PL} - 126.18 \quad (2)$$

Nugroho and Sri (2012) compared value of CBR given by un-soaked and soaked test and proposed following linear correlation of un-soaked and soaked CBR value with Index properties of soils

$$\Delta\text{CBR} = 25 + C_1 - C_2\text{LL} - C_3\text{PI} + 3.5\text{OMC} \quad (3)$$

Where C_1 , C_2 , C_3 , are coefficients depending upon the clay fraction.

Prediction models for CBR value documented in the National Cooperative Highway Research Program (2004) of the United States of America through the "Guide for Mechanical- Empirical Design of New and Rehabilitated Pavement Structures" developed some correlations that describe the relationship between soil index properties and CBR values based on a simple regression approach. Separate relationships were determined for coarse-grained soils that exhibit non-cohesive behaviour (GW, GP, SW, and SP) and for soils with more than 12 per cent fines that exhibit plastic behaviour (GM, GC, SM, SC, ML, MH, CL, and CH). A prediction model based on plasticity index is quoted for fine-grained soil and coarse-grained soil ($w_{PI} = 0$) D60, diameter at

60% passing from grain size distribution is used as a predictor.

$$CBR = \frac{75}{1+0.728wPI} \quad (4)$$

$$CBR = 28.09D60^{0.358} \quad (5)$$

Where: - D60 = Diameter on the cumulative size distribution curve where 60 percent of particles are finer (in millimeters)

wPI = Weighted Plasticity Index

Some other prediction models for CBR value from literature is presented in Table I. All these prediction models have their limitations. Hence, while adopting any prediction model, calibration of the models based on local materials situation is essential. Otherwise, a new model should be developed based on the actual data. No such attempt is made to develop prediction models for CBR value using locally available geo-materials in Port Harcourt and Kaiama axis. This study aims to develop valid prediction

models using locally available geo-materials in Port Harcourt through Kaiama using East-West Road Section II which runs through Port Harcourt and Kaiama.

MATERIALS

Sample Collection: To have sufficient and reliable data to achieve the objectives of the research study, laboratory tests were conducted on soil samples obtained randomly from the East-West Road (Section II – Port Harcourt to Kaiama). The samples were collected from the mentioned road construction project during the excavation stage. A total of 46 disturbed samples were gathered within the stretch of the road. The representative samples were selected based on visual identification of suitable subgrade soil. The location of the collected soil samples site is shown with the aid of a map in Figure 1.

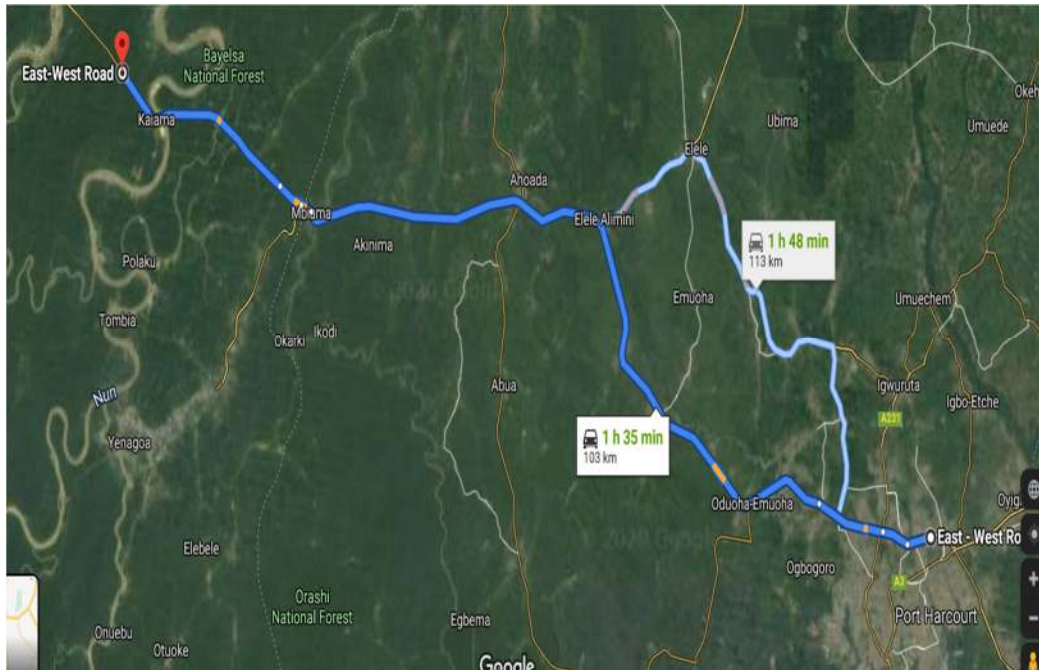


Figure 1: Map of East-West Road Section II (Port Harcourt to Kaiama)

Summary of Laboratory Test Results: To analyze the intended correlation, the test results were compiled and summarized in Table 1 and Table 2 shows the statistical data of the test

results showing the mean and standard deviation of the dependent variable (CBR) and the independent variables (P200, LL, PL, PI, MDD, OMC).



Table 1: Summary of Laboratory Test Results

S/No	Location	Grain Size Analysis % Passing	Atterberg Limits			Modified Proctor Test		California Bearing Ratio
			Liquid Limit	Plastic Limit	Plasticity Index	Maximum Dry Density	Optimum Moisture Content	
	CH.	P200 (%)	LL (%)	PL (%)	PI (%)	MDD (gm/cc)	OMC (%)	CBR (%)
1	1+460 - 2+460	39.3	42.4	20.5	21.9	1.79	16.3	12
2	2+460 - 3+460	40.1	43.3	19.4	23.9	1.82	14.5	13
3	3+460 - 4+460	35.1	39.8	18	21.8	1.8	14.7	14
4	4+460 - 5+460	39.6	35.6	18.1	17.5	1.81	15	12
5	6+000 - 7+000	36	35.3	15.3	20	1.76	16	13
6	7+000 - 8+000	35.5	34.2	16.4	17.8	1.75	15.4	14
7	9+800 - 10+300	41.6	42	18.5	23.5	1.78	14.5	12
8	10+300 - 10+800	42.4	44.2	18.4	25.8	1.73	18.2	5
9	10+800 - 11+300	44.4	40.2	22.3	17.9	1.69	18.4	11
10	13+450-13+850	40.3	44.2	22.3	21.9	1.67	18.2	12
11	13+850-14+175	37.7	43.2	23.5	19.7	1.68	18.5	15
12	14+175-15+000	36.3	35	18.5	16.5	1.75	16.3	14.5
13	15+000 - 16+000	33.5	33.2	14.9	18.3	1.76	14.6	15
14	16+000 - 17+000	51.7	50.2	18.2	32	1.74	17.1	6
15	17+000 - 18+000	38.1	41.3	22	19.3	1.72	16.4	15
16	18+000 - 19+000	38.6	34.5	16.1	18.4	1.79	15.2	16
17	20+000 - 21+000	23.7	19.3	14.4	4.9	1.86	11.2	16
18	24+500 - 24+750	44.5	39.4	21.4	18	1.76	16.8	8
19	24+750 - 25+000	42.2	35.6	17.7	17.9	1.81	16	6
20	25+000 - 25+275	36.2	33.2	18.6	14.6	1.78	16.4	11
21	47+500	32	27.5	15.6	11.9	1.86	14.4	17
22	47+750	32.8	29.5	17.5	12	1.82	17	12
23	48+000	35.9	41	25.4	15.6	1.87	15	16
24	48+250	31.9	32.2	15.1	17.1	1.86	13.9	14
25	48+500	34.4	40.7	23.9	16.8	1.87	15.9	16
26	48+750	35.8	44.5	24.9	19.6	1.8	15.8	13
27	49+000	33.5	37.3	18.7	18.6	1.85	15.9	13



S/No	Location	Grain Size Analysis % Passing	Atterberg Limits			Modified Proctor Test		California Bearing Ratio
			Liquid Limit	Plastic Limit	Plasticity Index	Maximum Dry Density	Optimum Moisture Content	
	CH.	P200 (%)	LL (%)	PL (%)	PI (%)	MDD (gm/cc)	OMC (%)	CBR (%)
28	49+250	35	42	22.9	19.1	1.81	16.8	15
29	49+500	29.7	36	19	17	1.86	15.2	16
30	49+750	33.5	42.5	21.8	20.7	1.8	14.4	11
31	50+000	35.3	42.5	21	21.5	1.8	17.4	16
32	50+250	41.6	46.5	22.2	24.3	1.81	15.6	8
33	50+500	32.4	39.4	19.3	20.1	1.83	15	18
34	50+750	35	41.3	22.1	19.2	1.85	16.7	15
35	51+000	35.3	43.4	21.7	21.7	1.79	17.3	11
36	51+250	31.4	38.2	19.7	18.5	1.82	16.4	15
37	51+500	36.6	43	21.3	21.7	1.76	16.5	15
38	51+750	34.9	44.9	24.4	20.5	1.72	17.1	13
39	52+000	29.6	35	23.8	11.2	1.83	15.7	15
40	52+250	35.4	44.2	25.1	19.1	1.7	18.2	10
41	52+500	33.5	40.2	21.4	18.8	1.78	16.9	16
42	52+750	38.1	41.7	21.9	19.8	1.69	17.3	12
43	67+000-67+500	53.7	62.9	30.9	32	1.76	17.8	8.3
44	76+000	57.3	67.2	29.6	37.6	1.82	15.7	9
45	91+500-92+000	78	56.8	30	26.8	1.79	17	6.6
46	96+000-96+500	89.8	60.8	37.9	22.9	1.77	16.6	9

Table 2: Statistical Data of Test Results

Variable Type	Variable Name	Unit of Measurement	No. of Samples	Ranges		Mean	Standard Deviation
				Min.	Max.		
Dependent	CBR	%	46	5	18	12.61739	3.20517953
Independent	P200	%	46	23.7	89.8	39.33043	11.2935701
	LL	%	46	19.3	67.2	41.02826	8.46996389
	PL	%	46	14.4	37.9	21.12174	4.5416389
	PI	%	46	4.9	37.6	19.90652	5.34132381
	MDD	gm/cc	46	1.67	1.87	1.786304	0.05247603
	OMC	%	46	11.2	18.5	16.11304	1.38746072

METHODS OF TESTING

Single Linear Regression Analysis (SLRA): To establish a relation between soaked CBR and different soil properties, graphs are plotted with CBR against different soil parameters and the suitable trend line is drawn with a higher correlation coefficient. Correlation quantifies the degree to which dependent and independent variables are related. Linear regression quantifies goodness of fit with the R^2 value. R^2 value provides a measure of how well future outcomes are likely to be predicted by the model. Any correlation with an R^2 value of more than 0.80 will be viewed as the best fit.

Multiple Linear Regression Analysis (MLRA): Multiple linear regression (MLRA) also known as multiple regression is used to determine a mathematical relationship among several random variables.

In other terms, MLRA examines how multiple independent variables are related to one dependent variable. Once each of the independent factors has been determined to predict the dependent variable, the information on the multiple variables can be used to create an accurate prediction on the level of effect they have on the outcome variable. The model creates a relationship in the form of a straight line (linear) that best approximates all the individual data points.

In principle, multiple linear regression is a simple extension of linear regression, but instead of relating one dependent outcome variable y to one independent variable x , one tries to explain the outcome value y as the weighted sum of influences from multiple independent variables x_1, x_2, x_3, \dots

In equation form,

$$y = k + ax_1 + bx_2 + cx_3 + \dots + R^2$$

where k is the intercept of the line on the y -axis; a , b , and c are the slopes of the relations between y and x_1 , x_2 , and x_3 , respectively; and R^2 is again the random error term. This is just plotting the best-fit line, but instead of doing it on a two-dimensional graph, it is plotted through $n + 1$ -dimensional space (n independent variables plus one dependent variable). For regression analysis in this research study, the use of Microsoft Excel was deployed.

RESULTS AND DISCUSSION

Correlation

Scatter Plot

To study the relationship between the independent variable and the dependent variable, a scatter plot is generated using Microsoft Excel software. This is done to determine the strength of the relationship between the independent and dependent variables. Considering the data in Table 1, the scatter plot showing the different relationships are presented in Figure 2 – 7.

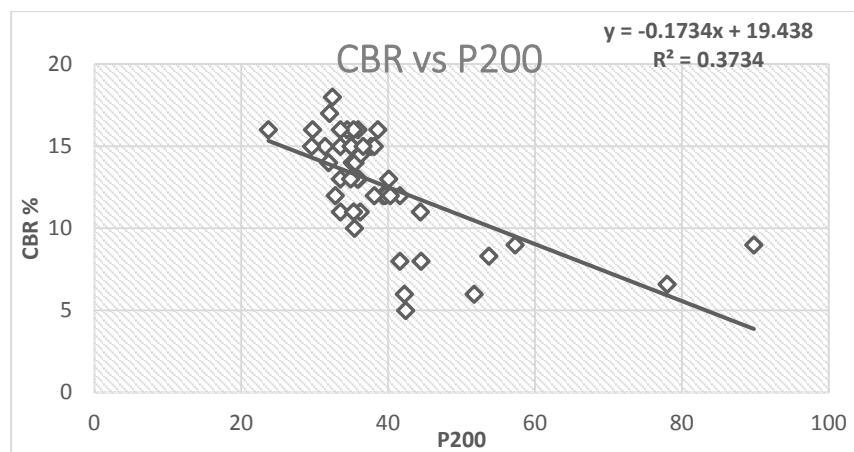


Figure 2: Scatter plot of CBR vs Percentage Passing Sieve No. 200

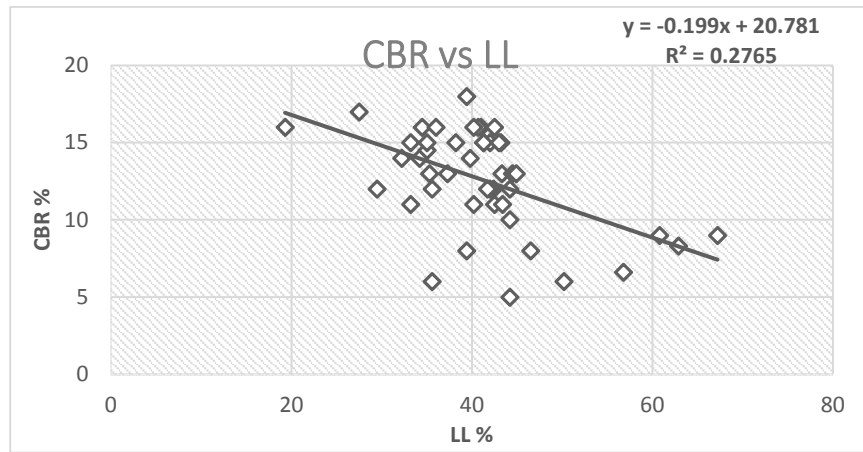


Figure 3: Scatter plot of CBR vs Liquid Limit

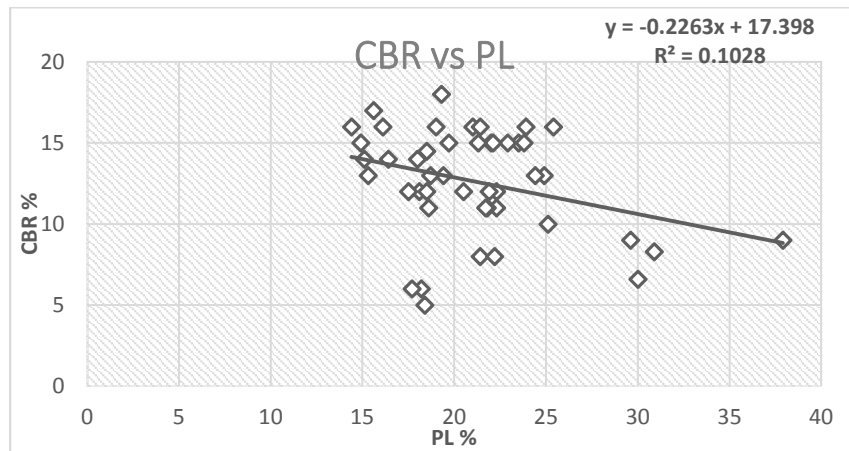


Figure 4: Scatter plot of CBR vs Plastic Limit

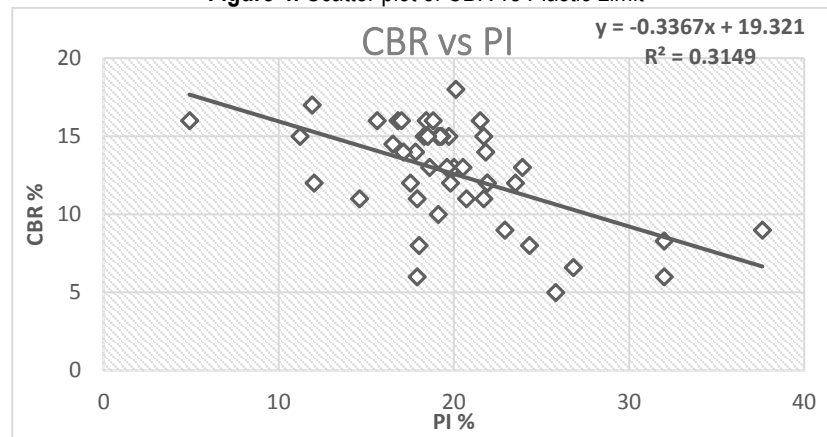


Figure 5: Scatter plot of CBR vs Plasticity Index

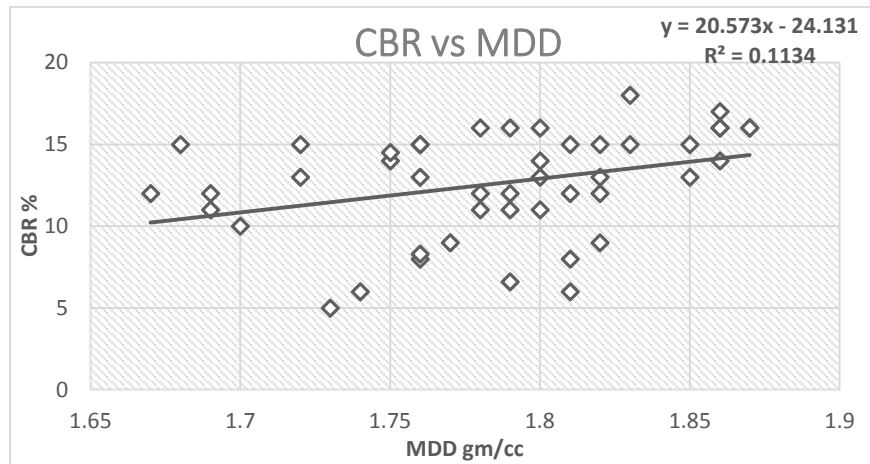


Figure 4-6: Scatter plot of CBR vs MDD

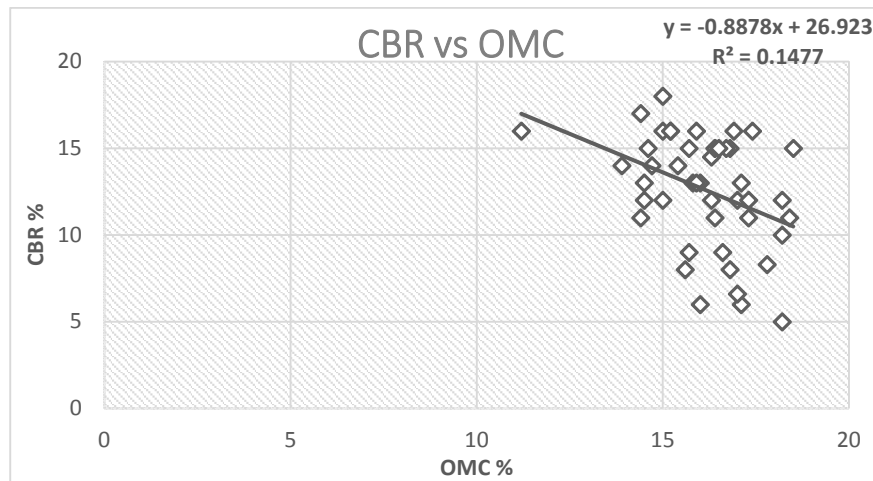


Figure 7: Scatter plot of CBR vs OMC

From the above scatter diagrams, it is obvious that no simple line or curve can pass through all the points but the points lie scattered randomly around a straight line, particularly for the Percentage Passing Sieve No.200, Liquid Limit and Plasticity Index.

While the plots of other independent variables such as Plastic Limit, Maximum Dry Density, Optimum Moisture Content fall a bit farther away from the possible straight line. Relatively the scatter plots indicate a linear

response and hence, a linear regression model expresses the association between the subject parameters.

Pearson's Correlation Coefficient

To further determine the degree of association between the variables, a linear regression analysis has been done and the respective Correlation Coefficients established. The Pearson's Correlation Coefficient matrix is shown below in Table 3



Table 3: Pearson's correlation coefficient

Pearson's Correlation (R)	P200 (%)	LL (%)	PL (%)	PI (%)	MDD (gm/cc)	OMC (%)	CBR (%)
P200 (%)	1.00						
LL (%)	0.75	1.00					
PL (%)	0.71	0.83	1.00				
PI (%)	0.59	0.88	0.47	1.00			
MDD (gm/cc)	-0.22	-0.27	-0.16	-0.29	1.00		
OMC (%)	0.30	0.47	0.43	0.38	-0.66	1.00	
CBR (%)	-0.61	-0.53	-0.32	-0.56	0.34	-0.38	1.00

The higher the R-value, the better the correlation between the variable, a range of R-value between ± 40 - ± 69 shows a strong relationship between the variables. From the above linear relationship, it shows that the Passing Sieve No.200, Liquid Limit and Plasticity Index posts the highest Correlation Coefficient (R) value against the CBR. Therefore, the variables Passing Sieve No.200, Liquid Limit and Plasticity Index have a higher degree of association with the CBR than the other variables. In addition to the correlation analysis, some other alternative linear regression analysis that best fits the obtained results have been carried out. The detailed results of the single and multiple linear regression analysis using Microsoft Excel Software are summarized subsequently.

Single Linear Regression Analysis

Model 1: Correlation Between CBR and Passing Sieve No.200 (P200)

The resulting regression analysis after correlating CBR with P200 is expressed by the following single linear equation with its corresponding correlation coefficients:
 $CBR = 19.438 - 0.173(P200)$ (6)
 $R = 0.61$ and $R^2 = 0.37$ $n = 46$

The details of the statistical output indicate that the relationship developed between P200 and CBR is significant ($\alpha < 0.05$)

Model 2: Correlation Between CBR and Liquid Limit (LL)

The resulting regression analysis after correlating CBR with LL is expressed by the

following single linear equation with its corresponding correlation coefficients:

$CBR = 20.781 - 0.199(LL)$ (7)
 $R = 0.53$ and $R^2 = 0.28$ $n = 46$

The details of the statistical output indicate that the relationship developed between LL and CBR is significant ($\alpha < 0.05$)

Model 3: Correlation Between CBR and Plastic Limit (PL)

The resulting regression analysis after correlating CBR with PL is expressed by the following single linear equation with its corresponding correlation coefficients:
 $CBR = 17.398 - 0.226(PL)$ (8)
 $R = 0.32$ and $R^2 = 0.10$ $n = 46$

The details of the statistical output indicate that the relationship developed between PL and CBR is significant ($\alpha < 0.05$)

Model 4: Correlation Between CBR and Plasticity Index (PI)

The resulting regression analysis after correlating CBR with PI is expressed by the following single linear equation with its corresponding correlation coefficients:
 $CBR = 19.321 - 0.337(PI)$ (9)
 $R = 0.56$ and $R^2 = 0.31$ $n = 46$

The details of the statistical output indicate that the relationship developed between PI and CBR is significant ($\alpha < 0.05$)

Model 5: Correlation Between CBR and Maximum Dry Density (MDD)

The resulting regression analysis after correlating CBR with MDD is expressed by the

Corresponding author: Sani, J. E. ✉ jesani@nda.edu.ng ✉ Department of Civill Engineering, Nigerian Defence Academy, Kaduna, Kaduna State. © 2021. Faculty of Tech. Education, ATBU Bauchi. All rights reserved



following single linear equation with its corresponding correlation coefficients:

$$\text{CBR} = -24.131 + 20.573(\text{MDD}) \quad (10)$$

$$R = 0.34 \text{ and } R^2 = 0.11 \quad n = 46$$

The details of the statistical output indicate that the relationship developed between MDD and CBR is significant ($\alpha < 0.05$) as shown in Model-5 of Appendix A.

Model 6: Correlation Between CBR and Optimum Moisture Content (OMC)

The resulting regression analysis after correlating CBR with OMC is expressed by the following single linear equation with its corresponding correlation coefficients:

$$\text{CBR} = 26.923 - 0.888(\text{OMC}) \quad (11)$$

$$R = 0.38 \text{ and } R^2 = 0.15 \quad n = 46$$

The details of the statistical output indicate that the relationship developed between OMC and CBR is significant ($\alpha < 0.05$)

The above developed single linear regression models, based on the significant standard error (α) and coefficient of determination (R^2), indicates that the CBR value correlates relatively better with Passing Sieve No.200, Liquid Limit and Plasticity Index which suggests that these variables can be used to form the multiple regression models that could yield a better correlation result. While the remaining parameters showed a weak relationship with CBR.

Multiple Linear Regression Analysis (MLRA)

The following suggested variables Passing Sieve No.200, Liquid Limit and Plasticity Index were used against the CBR to run MLRA and the following results were obtained:

Model 7: Correlation Between CBR with P200 and LL

The resulting regression analysis after correlating CBR with P200 and LL is expressed by the following multiple linear equation with its corresponding correlation coefficients:

$$\text{CBR} = 20.513 - 0.141(\text{P200}) - 0.057(\text{LL}) \quad (12)$$

$$R = 0.62 \text{ and } R^2 = 0.38 \quad n = 46$$

The details of the statistical output indicate that the relationship developed between CBR with P200 and LL is significant ($\alpha < 0.05$)

Model 8: Correlation Between CBR with P200 and PI

The resulting regression analysis after correlating CBR with P200 and PI is expressed by the following multiple linear equation with its corresponding correlation coefficients:

$$\text{CBR} = 21.103 - 0.122(\text{P200}) - 0.185(\text{PI}) \quad (13)$$

$$R = 0.66 \text{ and } R^2 = 0.44 \quad n = 46$$

The details of the statistical output indicate that the relationship developed between CBR with P200 and PI is significant ($\alpha < 0.05$)

Model 9: Correlation Between CBR with LL and PI

The resulting regression analysis after correlating CBR with LL and PI is expressed by the following multiple linear equation with its corresponding correlation coefficients:

$$\text{CBR} = 20.030 - 0.054(\text{LL}) - 0.262(\text{PI}) \quad (14)$$

$$R = 0.57 \text{ and } R^2 = 0.32 \quad n = 46$$

The details of the statistical output indicate that the relationship developed between CBR with LL and PI is significant ($\alpha < 0.05$)

Model 10: Correlation Between CBR with P200, LL and PI

The resulting regression analysis after correlating CBR with P200, LL and PI is expressed by the following multiple linear equations with its corresponding correlation coefficients:

$$\text{CBR} = 19.346 - 0.173(\text{P200}) - 0.189(\text{LL}) - 0.386(\text{PI}) \quad (15)$$

$$R = 0.69 \text{ and } R^2 = 0.47 \quad n = 46$$

The details of the statistical output indicate that the relationship developed between CBR with P200, LL and PI is significant ($\alpha < 0.05$)

Model 11: Correlation Between CBR with P200, LL, PL, PI, MDD and OMC

The resulting regression analysis after correlating CBR with P200, LL, PI, MDD and OMC is expressed by the following multiple linear equation with its corresponding correlation coefficients:

$$\text{CBR} = 23.325 - 0.183(\text{P200}) - 0.153(\text{LL}) + 0.412(\text{PL}) + 1.562(\text{MDD}) - 0.539(\text{OMC}) \quad (16)$$



R = 0.72 and R² = 0.52 n= 46
 The details of the statistical output indicate that the relationship developed between CBR with P200, LL, PI, MDD and OMC is significant ($\alpha < 0.05$)

From the above, it can be deduced that the MLRA yielded higher R² values than the SLRA. The Model-V from the MLRA yielded the highest R² value amongst the above-stated Models. Furthermore, the correlation results are summarized in Table 4.

Table 4: Summary of regression analysis with an order of significance

Regression Type	Model Name	Equation	R	R ²	Order of Significance in terms of R ²
Single Linear Regression Models	Model 1	CBR = 19.438 – 0.173(P200)	0.61	0.37	1
	Model 2	CBR = 20.781 – 0.199(LL)	0.53	0.28	3
	Model 3	CBR = 17.398 – 0.226(PL)	0.32	0.10	6
	Model 4	CBR = 19.321 – 0.337(PI)	0.56	0.31	2
	Model 5	CBR = - 24.131 + 20.573(MDD)	0.34	0.11	5
	Model 6	CBR = 26.923 - 0.888(OMC)	0.38	0.15	4
Multiple Linear Regression Models	Model 7	CBR = 20.513 – 0.141(P200) – 0.057(LL)	0.62	0.38	4
	Model 8	CBR = 21.103 – 0.122(P200) – 0.185(PI)	0.66	0.44	3
	Model 9	CBR = 20.030 – 0.054(LL) – 0.262(PI)	0.57	0.32	5
	Model 10	CBR = 19.346 – 0.173(P200) – 0.189(LL) – 0.386(PI)	0.69	0.47	2
	Model 11	CBR = 23.325 – 0.183(P200) – 0.153(LL) + 0.412(PL) + 1.562(MDD) – 0.539(OMC)	0.72	0.52	1

Validation of Developed Correlation

To validate the results of the correlations conducted, the Model-11 [CBR = 23.325 – 0.183(P200) – 0.153(LL) + 0.412(PL) + 1.562(MDD) – 0.539(OMC)] is selected based on the order of significance in terms of R². Using the results of the CBR tests and the selected correlation equation, the predicted CBR values are determined and compared with the actual CBR values. Table 5 shows the compared results below;

Table 5: Validation of the developed correlation

CH.	P200 (%)	LL (%)	PL (%)	PI (%)	MDD (gm/cc)	OMC (%)	Actual CBR (%)	Predicted CBR (%)	Difference
1+460 - 2+460	39.3	42.4	20.5	21.9	1.79	16.3	12	12.1	-0.1
2+460 - 3+460	40.1	43.3	19.4	23.9	1.82	14.5	13	12.4	0.6
3+460 - 4+460	35.1	39.8	18	21.8	1.8	14.7	14	13.1	0.9
4+460 - 5+460	39.6	35.6	18.1	17.5	1.81	15	12	12.8	-0.8
6+000 - 7+000	36	35.3	15.3	20	1.76	16	13	11.8	1.2

Corresponding author: Sani, J. E. jesani@nda.edu.ng Department of Civill Engineering, Nigerian Defence Academu, Kaduna, Kaduna State. © 2021. Faculty of Tech. Education, ATBU Bauchi. All rights reserved



CH.	P200 (%)	LL (%)	PL (%)	PI (%)	MDD (gm/cc)	OMC (%)	Actual CBR (%)	Predicted CBR (%)	Difference
7+000 - 8+000	35.5	34.2	16.4	17.8	1.75	15.4	14	12.8	1.2
9+800 - 10+300	41.6	42	18.5	23.5	1.78	14.5	12	11.9	0.1
10+300 - 10+800	42.4	44.2	18.4	25.8	1.73	18.2	5	9.3	-4.3
10+800 - 11+300	44.4	40.2	22.3	17.9	1.69	18.4	11	11.0	0.0
13+450-13+850	40.3	44.2	22.3	21.9	1.67	18.2	12	11.2	0.8
13+850-14+175	37.7	43.2	23.5	19.7	1.68	18.5	15	12.2	2.8
14+175-15+000	36.3	35	18.5	16.5	1.75	16.3	14.5	12.9	1.6
15+000 - 16+000	33.5	33.2	14.9	18.3	1.76	14.6	15	13.1	1.9
16+000 - 17+000	51.7	50.2	18.2	32	1.74	17.1	6	7.2	-1.2
17+000 - 18+000	38.1	41.3	22	19.3	1.72	16.4	15	12.9	2.1
18+000 - 19+000	38.6	34.5	16.1	18.4	1.79	15.2	16	12.2	3.8
20+000 - 21+000	23.7	19.3	14.4	4.9	1.86	11.2	16	18.8	-2.8
24+500 - 24+750	44.5	39.4	21.4	18	1.76	16.8	8	11.7	-3.7
24+750 - 25+000	42.2	35.6	17.7	17.9	1.81	16	6	11.7	-5.7
25+000 - 25+275	36.2	33.2	18.6	14.6	1.78	16.4	11	13.2	-2.2
47+500	32	27.5	15.6	11.9	1.86	14.4	17	14.8	2.2
47+750	32.8	29.5	17.5	12	1.82	17	12	13.7	-1.7
48+000	35.9	41	25.4	15.6	1.87	15	16	15.8	0.2
48+250	31.9	32.2	15.1	17.1	1.86	13.9	14	14.2	-0.2
48+500	34.4	40.7	23.9	16.8	1.87	15.9	16	15.0	1.0
48+750	35.8	44.5	24.9	19.6	1.8	15.8	13	14.5	-1.5
49+000	33.5	37.3	18.7	18.6	1.85	15.9	13	13.5	-0.5
49+250	35	42	22.9	19.1	1.81	16.8	15	13.7	1.3
49+500	29.7	36	19	17	1.86	15.2	16	14.9	1.1
49+750	33.5	42.5	21.8	20.7	1.8	14.4	11	14.7	-3.7
50+000	35.3	42.5	21	21.5	1.8	17.4	16	12.4	3.6
50+250	41.6	46.5	22.2	24.3	1.81	15.6	8	12.2	-4.2
50+500	32.4	39.4	19.3	20.1	1.83	15	18	14.1	3.9
50+750	35	41.3	22.1	19.2	1.85	16.7	15	13.6	1.4
51+000	35.3	43.4	21.7	21.7	1.79	17.3	11	12.6	-1.6
51+250	31.4	38.2	19.7	18.5	1.82	16.4	15	13.9	1.1
51+500	36.6	43	21.3	21.7	1.76	16.5	15	12.7	2.3
51+750	34.9	44.9	24.4	20.5	1.72	17.1	13	13.6	-0.6
52+000	29.6	35	23.8	11.2	1.83	15.7	15	16.8	-1.8
52+250	35.4	44.2	25.1	19.1	1.7	18.2	10	13.3	-3.3



CH.	P200 (%)	LL (%)	PL (%)	PI (%)	MDD (gm/cc)	OMC (%)	Actual CBR (%)	Predicted CBR (%)	Difference
52+500	33.5	40.2	21.4	18.8	1.78	16.9	16	13.5	2.5
52+750	38.1	41.7	21.9	19.8	1.69	17.3	12	12.3	-0.3
67+000-67+500	53.7	62.9	30.9	32	1.76	17.8	8.3	9.8	-1.5
76+000	57.3	67.2	29.6	37.6	1.82	15.7	9	9.1	-0.1
91+500-92+000	78	56.8	30	26.8	1.79	17	6.6	6.4	0.2
96+000-96+500	89.8	60.8	37.9	22.9	1.77	16.6	9	7.0	2.0
AVERAGE							12.6	12.7	0.0

In order to further verify the suitability of the developed correlation, a comparison graph of Actual CBR values is plotted against the Predicted CBR values as shown in Figure 8.

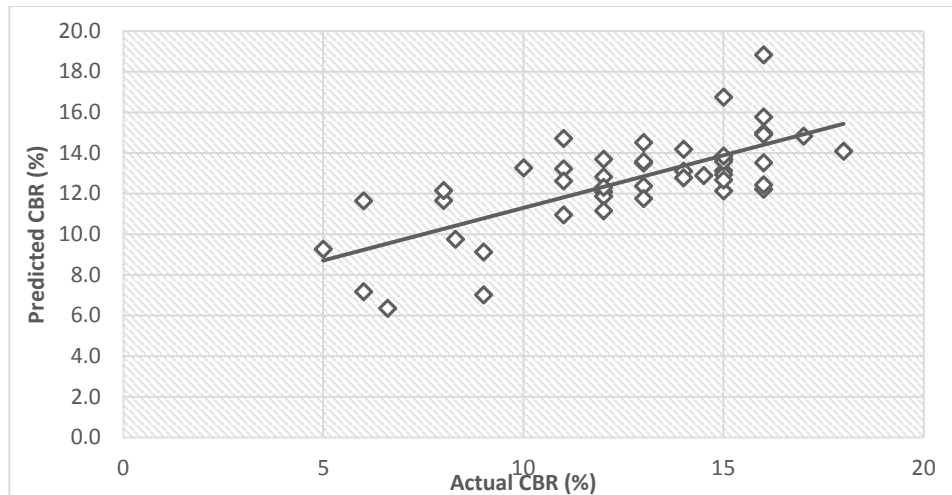


Figure 8: Graph of Actual CBR against Predicted CBR

The line of best fit is the point where Actual CBR equals Predicted CBR and the graph shows that most of the values scatter near the line of best fit. Whereas relatively fewer values deviated far away from the line of best fit.

CONCLUSION

The research subject was conducted on samples recovered at random along the East-West Road, Section II (Port Harcourt to Kaiama) to find a correlation between CBR value and soil index properties within the scope of the study. Forty-Six (46) test results were used to run single and multiple linear regression analysis, relationships were established and equations that

predict CBR value in terms of index properties of the results.

The satisfactoriness of the developed models was evaluated and arrived at the following conclusions;

1. The results of the Single Linear Regression Analysis indicate that the correlation between CBR and P200 which produced Model-I yielded the best correlation coefficient and gave the closest prediction. The relationship can be expressed in the model below;

$$\text{CBR} = 19.438 - 0.173(\text{P200})$$
 With resultant $R = 0.61$ and $R^2 = 0.37$
 $n = 46$.



2. To get an improved correlation, the Multiple Linear Regression Analysis yielded 5 models and from the correlation coefficient and other parameters, the correlation between CBR with P200, LL, PL, PI, MDD and OMC (which produced Model-V) indicated the highest correlation coefficient and gave the closest prediction. The relationship can be expressed in the model below;
$$\text{CBR} = 23.325 - 0.183(\text{P200}) - 0.153(\text{LL}) + 0.412(\text{PL}) + 1.562(\text{MDD}) - 0.539(\text{OMC})$$

With $R = 0.72$ and $R^2 = 0.52$ $n = 46$
3. From the above, it is safe to conclude that the combination of soil index properties (P200, LL, PL, PI, MDD and OMC) correlates better with CBR (strength parameter) than individual soil properties. Therefore, Model-V is the recommended model within the scope of the study.
4. To confirm the accuracy of the strength parameter (CBR) of soil used in the design of roads by Consultants within the East-West Road Section II (Port Harcourt to Kaiama), the above Model-V might be used.

RECOMMENDATIONS

The following recommendations are made based on the exposure encountered during the period of study;

1. To predict and confirm CBR values within the study area (East-West Road Section II – Port Harcourt to Kaima), the use of Model-V is recommended.
2. It is recommended that the same test be carried out with larger sample size, as this particular study is limited to 46 sample sizes because of the cost. The more the sample size, the better the accuracy of prediction.
3. It is also recommended that further localized studies like this be conducted in other parts of the Niger Delta Region where the Ministry has interests.

REFERENCES

- Adeyemi, G. O., Oloruntola, M.O and Adeleye, A.O (2014). Geotechnical Properties of Subgrade Soils along Sections of the Ibadan–Ife Expressway, South-Western Nigeria. *Journal of Natural Sciences Research*, 4 (23): 67 - 75.
- Agarwal K. B., Ghanekar K. D. (1970). Prediction of CBR values from plasticity characteristics of the soil. *In Processing of 2nd South East Asian Conference on Soil Engineering*, Singapore, 11- 15.
- American Society for Testing and Materials, "D 1883-05, Standard test method for CBR (California bearing ratio) of laboratory-compacted soils" *Annual Book of ASTM Standards*, Vol. 04.08. West Conshohocken, PA: ASTM, 2005.
- Black, W. P. M. (1962). *A method of Estimating the California Bearing Ratio of Cohesive Soils from Plasticity Data*, Geotechnique, 12, pp. 271-282.
- National Cooperative Highway Research Program (2004). *Guide for Mechanistic-Empirical Design of New and Rehabilitated Pavement Structures, Correlation of CBR Values with Soil Index Properties*. NCHRP, Transportation Research Board, National Research Council, Washington DC.
- Nugroho S. A., and Sri R. N. (2012). Correlation Between Index Properties and California Bearing Ratio Test of Pekanbaru Soils with and Without Soaked. *Canadian Journal on Environmental, Construction and Civil Engineering* Vol. 3, No. 1.
- Vishal, C. and Yadav, R K (2016). Prediction of CBR from Physical Properties of Coarse-Grained Soils. *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*. Jabalpur, India. Vol. 4 Issue XI Pp 589 – 593.
- Yildirim B, O. Gunaydin (2011). Estimation of CBR by soft computing systems. *Expert Systems with Applications*, Elsevier, 38, 6381-6391, 2011.