International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

Development of a Mathematical Model to Estimate Soaked California Bearing Ratio of a Lateritic Soil in Ekiti Northern Senatorial District, Nigeria

Oluwayinka Glory Akinwamide[1], Joseph Adebayo Ige[2], Joshua Tunbosun Akinwamide[3]

[1, 3]Department of Civil Engineering, School of Engineering, The Federal Polytechnic, Ado Ekiti, Ekiti State, Nigeria

[2]Department of Civil Engineering, Faculty of Engineering, LadokeAkintola University of Technology, Ogbomoso, Oyo State, Nigeria.

Corresponding author E- Mail address: [1]*akinwamideoluwayinka[at]gmail.com*
[2]*jaige[at]lautech. edu. ng*
[3]*akinwande_joshua[at]yahoo.com*

Abstracts: ***This paper investigates the Development of a mathematical model to estimate Soaked California Bearing Ratio of a lateritic soil. The study area was divided into Five Zones: A total of 40 samples were collected with Eight samples per zone. Laboratory tests such as: Particle size analysis, Consistency Limits tests, Compaction test, California Bearing Ratio (CBR), the data base was prepared in the laboratory by conducting tests on 40 soil samples obtained in borrowed pit found in Ekiti Northern Senatorial Districts, Ekiti State, South Western Nigeria e. The online available R software, R. studio and R. mark down was used to analyze Multiple Linear Regression (MLR) to develop a soaked CBR model the models input layer contain six nodes (soil index properties) and the output layer containing a single node (i. e. CBR) have been taken. The descriptive analysis for training and testing was performed, the predicting power of the developed models was examined in terms regression models, descriptive statistic, AIC and ANOVA. The visual soil profile description of all trial pits to a depth of 1.3m investigated, reveal little variation within the soil strata. The laboratory results on the index properties indicated that the soils of the study area is characterized as Clayey soils (A - 4, A - 6 and A - 7 - 5) and Silty or Clayey gravelling soils (A - 2 - 6, A - 2 - 7) according to AASHTO classification system The soil strength assessment indicates that the soils samples from all the Zones fell within the minimum dry density recommended for subgrade materials, stabilization is recommended for its suitability for either sub base or base course material for future contractor around this study area this will savage haulage expenses when material are move from far distance to the site of work The results of the mathematical model showed that Out of all the predictors for soaked CBR only MDD has a positive effect with the curve maintaining a symmetrical nature which indicates normality in residuals. The relationship between the actual values of soaked CBR and the predicted values is approximately 54 % strong. The deviations between the predicted and original CBR values are not significant This research work will serve as a data base for future planner and constructor within this Senatorial zone.***

Keywords: ANOVA, Multiple Linear Regression, Mathematical model, Soaked CBR, Senatorial zone

1. Introduction

The strength of a soil to be used as a sub - grade in pavement is assessed from its California bearing ratio (CBR) value. If the CBR value of soil is low, the thickness of pavement will be high, which will result in high cost of construction and vice - versa. Subgrade is the most important part of a pavement structure, which should have a reasonable stiffness modulus and shear strength Faisal Iqbal et al, (2018). CBR (California Bearing Ratio) test is performed to evaluate stiffness modulus and shear strength of subgrade soils. However, CBR test is laborious and time consuming, particularly when soil is discovered to be unsuitable. In order to overcome this limitation, it may be appropriate to correlate CBR value of soils with its index properties like grain size analysis, Consistency limits, and compaction characteristics such as MDD (Maximum Dry Density) and OMC (Optimum Moisture Content). Taşkıran (2010) had predicted CBR of soil using Artificial Neural Network (ANN). Different combinations of dry unit weight, optimum water content, liquid limit, plasticity index, sand content, No: 200 sieve passing percent (clay +silt) and gravel percent were taken as inputs. The best ANN model was the model which had all 7 inputs. Yıldırım and Günaydın (2011) had predicted CBR of soil using Statistical models (Simple Regression Analysis SRA and Multiple Regression Analysis MRA) and ANN model, the inputs taken were Sieve analysis data, Atterberg limits Maximum dry unit weight, and Optimum moisture content (OMC) and found that ANN model exhibits higher performance than statistical models. Kaur et al. (2011) had developed an efficient model for prediction of CBR of soil, taking percentage of gravel fraction, sand fraction, fine fraction, liquid limit, plasticity index and maximum dry density (MDD) as input variables.

Modeling means setting up mathematical models or formulations of physical or other systems. Such models are constructed for the assessment of the objective function after using the hindsight of observed operating variables. Hence or otherwise, model could be constructed for a proper observation of response from the interaction of the factors through controlled experimentation followed by schematic designed where such simplex lattice approach of the type of Scheffe (1958) optimization theory could be employed. Also entirely different physical systems may correspond to the same mathematical model so that they can be solved by the same methods. Erwin (2004) emphasizes that this is an impressive demonstration of the unifying power of mathematics.

No attempts have been made of recent to estimate any mathematical model to evaluate the correlations between CBR value and its index properties. Using MLRA (Multiple Linear Regression) based Models with Liquid limitLL %, Plastic limit PL %, Group index GI, Plastic index PI %, Optimum moisture content OMC (%) and Maximum dry density MDD (kN/m3) as input variables.

1.1 Research methodology

The method is as shown in the flow chart below

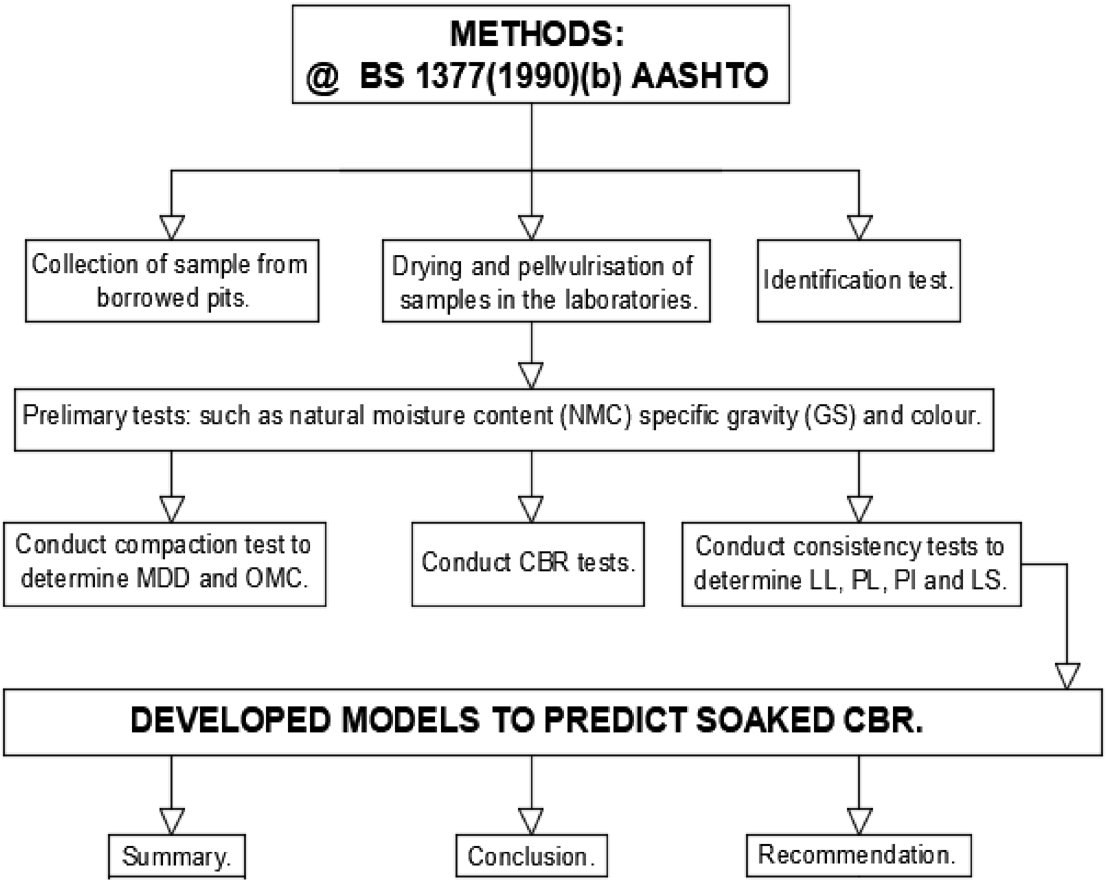

Figure 1.0: The flow chart for the research methodology

1.3 Experimental Program

Forty soils samples samples was obtained for this research work in Ekiti North Senatorial districts in Ekiti state, Nigeria and laboratory tests such as Liquid Limits (LL,) Plastic Limits (PL), Plasticity Index (PI), particle size distribution, Optimum Moisture Content (OMC), Maximum Dry Density (MDD) and California Bearing Ratio (CBR) values (both soaked and unsoaked) were carried out on samples at the Federal Polytechnic Ado Ekiti Soil Mechanic laboratory, Civil Engineering Department according to AASHTO and BS 1377 (1990) Specifications

2. Results and Discussions

The laboratory test results are presented here as tables and figures

2.1 The soils index properties

Soil index properties are the properties of soil that help in identification and classification of soil. These are properties of soil that indicate the type and conditions of the soil and provide a relationship to structural properties. Soil index properties are used extensively by engineers to discriminate between the different kinds of soil within a broad category (ELE, 2013). The results of the soil index properties are here by discourse below:

2.1.2. Soil Classification

Soil classification of the tests results and their classification based on AASTO soil Classification system. The soils of the study area is characterized as Clayey soils (A - 4, A - 6 and A - 7 - 5) and Silty or Clayey gravelling soils (A - 2 - 6, A - 2 - 7) according to AASHTO classification system (1986) respectively. Hence, the soils are describing as clay of high compressibility respectively. The engineering implication of soils with higher fines is that they are poor for road works and fill material and such soils may require stabilization if it will be useful for any serious Civil engineering project.

2.1.3. Grain Size Analysis

The grain size analysis is a curve which shows and classify soil according to their texture and grains sizes. The graph of grain size analysis performed on the soils samples are shown in table 2.1 representing zones A, B, C, D and E respectively within Northern Senatorial District of Ekiti

State Many of the zones had a very high percentage finer than 0.075 fractions that is > 35% varied between 15 and 75 % for (Zones A, B, C, D and E) respectively. The above results showed that there exists very fine material within the study area which can only be applicable for fill materials for subgrade which might require stabilization for its suitability for either sub base or base course material for future contractor around this study area.

2.1.4. Consistency Limits Tests

Consistency Limit Test results of Liquid Limit (LL %), (PL%) and plasticity index (PI %) experimented for all the trial pits within the five zones varied between 23 – 43 % and 20 – 50%, 27 - 45 %, 19 - 43 %, 19 - 47 % for LL% and Zones A, B, C, D and E respectively are shown in the Table 2.1 PL % results varied between 9 - 27, 8 - 27, 7 - 24, 13 - 26 and 8 - 21 % and for PI % the results varied between 8 and 37 % from the fore going according to (FMW, 1997) recommendation that, liquid limits not greater than 80% for sub - grade and not greater than 35 for sub base and base course materials. Also plasticity index not greater than 55% for sub - grade and not greater than 12% for both sub - base and base course. From the examined soil samples, the soils results fell within these specifications. The implication of this research shows that soils within this zones are only suitable for sub - grade, and earth fill materials.

Sample Zones. No	% Passing 200	LL	PL	PI	OMC	MDD	USK. CBR	SK. CBR	AASHO CLASSIFICATION
ZAS1	24.88	30	14.02	15	16.42	2227	20.67	2.88	A - 2 - 6
ZAS2	46.6	35.8	17.87	17.93	18.72	2026	17.37	2.83	A - 2 - 6
ZAS3	35.8	43.15	9	34.15	19.45	2173	21.92	2.63	A - 7 - 5
ZAS4	56.42	35.8	15.63	20.17	22.35	2242	21.54	2.38	A - 2 - 6
ZAS5	24.1	21.6	NP	NP	22.81	2170	18.79	3.02	A - 3
ZAS6	27.14	43.01	22.32	20.69	16.43	2267	22.55	1.38	A - 7 - 5
ZAS7	53.28	39.07	21.56	17.51	21.17	2234	20.67	1.75	A - 2 - 6
ZAS8	19.87	24.5	12.88	11.62	21.92	2160	18.16	1.89	A - 2 - 6
ZBS1	35.86	49.02	17.01	32.01	21.21	2242	22.55	4.15	A - 7 - 5
ZBS2	56.72	50.5	27.76	22.74	19.35	2089	18.16	3.4	A - 7 - 5
ZBS3	75.52	47.6	10.39	37.21	13.68	2118	16.28	1.75	A - 7 - 5
ZBS4	65.9	20.7	NP	NP	19.13	2168	17.79	3.26	A - 3
ZBS5	31.92	38.31	14.78	23.53	21.67	2197	32.82	1.89	A - 2 - 6
ZBS6	64.72	32.2	8.8	23.4	20.87	2113	36.45	2.63	A - 2 - 6
ZBS7	54.4	33.01	17.36	15.65	31.57	1854	17.75	3.4	A - 2 - 6
ZBS8	15.23	40.1	16.27	23.83	24.25	2093	30.59	2.51	A - 7 - 5
ZCS1	75.04	29	7.79	21.21	21.42	2180	24.05	3.26	A - 2 - 6
ZCS2	20.46	41	17.92	23.08	19.36	1936	19.21	2.51	A - 7 - 5
ZCS3	26.02	33.8	18.05	15.75	21.11	2215	21.92	3.63	A - 2 - 6
ZCS4	59.96	34.2	13.1	21.1	20.14	2249	16.28	1.88	A - 2 - 6
ZCS5	40.2	27.9	8.34	19.56	22.35	2258	22.55	2.38	A - 2 - 6
ZCS6	16.05	29.01	7.8	21.21	22.81	2207	16.03	4.13	A - 2 - 6
ZCS7	39.72	45	14.8	30.2	17.27	2236	22.55	2.83	A - 7 - 5
ZCS8	26.02	32.2	23.57	8.63	21.67	2266	16.03	2.13	A - 2 - 4
ZDS1	42.08	28.15	16.09	12.06	21.03	2054	22.55	3.4	A - 2 - 6
ZDS2	38.14	19.9	NP	NP	22.52	2060	16.03	3.26	A - 3
ZDS3	24.44	32.01	13.64	18	11.88	2377	23.55	9.39	A - 2 - 6
ZDS4	73.38	33.08	23.57	9.51	20.77	2295	16.53	3.4	A - 2 - 4
ZDS5	71.76	32.02	26.67	5.35	18.81	2318	18.16	3.13	A - 2 - 4
ZDS6	41.14	28.51	18.92	9.59	19.01	2123	16.66	3.51	A - 2 - 4
ZDS7	64.4	41.2	13.93	27.27	17.6	2035	18.16	3.51	A - 7 - 5
ZDS8	50.18	43.5	16.57	26.93	18.21	2091	16.53	2.63	A - 7 - 5
ZES1	56.42	35.8	15.63	20.17	22.35	2242	21.54	2.38	A - 2 - 6
ZES2	53.28	39.07	21.56	17.51	21.17	2234	20.67	1.75	A - 2 - 6
ZES3	75.52	47.6	10.39	37.21	13.68	2118	16.28	1.75	A - 7 - 5
ZES4	54.4	33.01	17.36	15.65	31.57	1854	17.75	3.4	A - 2 - 6
ZES5	26.02	33.8	18.05	15.75	21.11	2215	27.68	3.63	A - 2 - 6
ZES6	40.2	27.9	8.34	19.56	22.35	2258	21.92	2.38	A - 2 - 6
ZES7	38.14	19.9	NP	NP	22.52	2060	16.03	3.26	A - 3
ZES8	41.14	28.51	18.92	9.59	19.01	2123	16.66	3.51	A - 2 - 4

2.2 Soils Strength Properties

Soil strength properties are the geotechnical parameters that are capable of aiding the resistance of soil to shear stresses in terms of effective internal friction angle and effective cohesion.

2.2.1. Compaction characteristic

The results and graph of Maximum Dry Density (MDD kg/m3), and the Optimum Moisture Content (OMC %) performed on the trial pits within the zones on compaction test ranges from 1854 – 2277 Kg/m^3 and 13 – 31.3 % for all the zones investigated within the study area for OMC % and MDD Kg/m^3respectively are shown in the Table 2.1 for verification. The above analysis indicates that the soils samples from all the Zones fell within the minimum dry density recommended for subgrade materials. However, it can be recommended for sub grade and fill material, respectively since their MDD is within the minimum specification for sub grade and earth fill materials.

2.2.2. California Bearing Ratio

California Bearing Ratio is a measure of resistance of a material to penetration of standard plunger under controlled density and conditions, it compares the bearing capacity of a material with that of a well graded crushed stone. it is primarily intended for but not limited to evaluating the strengthof cohesive materials having maximum particles size less than 19 mm (AASHTO, 2000). The California bearing ratio parameter help in the design of sub grade in the flexible pavement design. Table 21 shows the results of the California bearing ratio performed on all the trial pits investigated, which varied between 16.03 – 30 % and 1 – 10 % for un soak (UN SK) and soaked (SK) CBR values for soils within the zones. Expectedly the influence of soaking is evident in the results obtained as the CBR values for the 24 hours soaked samples were much lower compared to the unsoaked sample. According to (Simon *et. al.*, 1973) in a high reduction in CBR values after soaking indicates that the soil is very sensitive to changes in the moisture content. Hence, adequate drainage facilities are to be provided if these soils are to be used for any construction purpose to prevent loss of strength. The above analysis shows that materials within this Zones are quite suitable materials for sub grade and earth fill during construction works.

2.3 Development of Mathematical Model for a Soaked California Bearing Ratio CBR

Mathematical model is a description of physical system using mathematical concept and language. Is a process of encoding and decoding of reality in which a natural phenomenon is reduced to a formal numerical expression by a casual structure. Tables1 and 2 below show some regression models and descriptive statistic of the developed soaked CBR model from the input variables adopted for this research work

Table 1: Model with five variables **summary** (soaked_model3)

```
## Call:
## lm (formula = soaked ~ gravel + sand + fine + ll + pl)
##
## Residuals:
## Min        1Q       Median     3Q       Max
## - 1.9511  -0.6795  -0.0911   0.3963   4.6641
##
##               Estimate    Std. Error   t value   Pr (>|t|)
## (Intercept)   9.902520    10.299907    0.961     0.343
## gravel        -0.008816   0.098416     -0.090    0.929
## sand          -0.077999   0.101692     -0.767    0.448
## fine          -0.063605   0.102111     -0.623    0.538
## LL            -0.011283   0.028042     -0.402    0.690
## PL            -0.005801   0.031875     -0.182    0.857
##
## Residual standard error: 1.151 on 34 degrees of freedom
## Multiple R - squared: 0.273, Adjusted R - squared:
0.1661
## F - statistic: 2.553 on 5 and 34 DF, p - value: 0.04579
```

Table 2.6: Model with seven variables **summary** (soaked_model4)

```
##
## Call:
## lm (formula = Soaked ~ Gravel + Sand + Fine + LL + PL
+ OMC + MDD)
##
## Residuals:
## Min 1Q Median 3Q Max
## - 1.9663 - 0.6506 - 0.1222 0.3360 4.3600
##
## Coefficients:
##               Estimate     Std. Error    t value   Pr (>|t|)
## (Intercept)   8.4583461    11.9830682    0.706     0.485
## gravel        -0.0044084   0.1007935     -0.044    0.965
## sand          -0.0697560   0.1044004     -0.668    0.509
## fine          -0.0565981   0.1046725     -0.541    0.592
## LL            -0.0168711   0.0334752     -0.504    0.618
## PL            -0.0037140   0.0347638     -0.107    0.916
## OMC           -0.0275779   0.0681703     -0.405    0.689
## MDD           0.0006677    0.0019685     0.339     0.737
##
## Residual standard error: 1.175 on 32 degrees of freedom
## Multiple R - squared: 0.2865, Adjusted R - squared:
0.1304
## F - statistic: 1.835 on 7 and 32 DF, p - value: 0.1144
```

2.3.1 Developed Model Interpretation

The equation derived from developed model 4 above is shown below:

Soaked CBR = 8.4583 - 0.0044 (Gravel) - 0.0697 (Sand) - 0.0565 (Fines) - 0.0168 (LL) - 0.0037 (PL) - 0.0275 (OMC) + 0.0006 (MDD) where, **Gravel** is the percentage of the gravel present in the soil sample, **Sand** is the percentage of sand content in the soil sample, **Fines** is the percentage of clay and silt content in the soil sample, **LL** is the Liquid Limits values in percentage of the soil sample, **OMC** is the maximum moisture content of the soil after compaction and **MDD** is maximum dry density of the soil sample after compaction test. Although the factors seem to be insignificant, but they have contributed to the response variables. of all the four models above, this model predicts best for the response variable ***Soaked CBR***. Out of all the predictors for *soaked CBR* only ***MDD* has a positive effect** though very low. This model is picked for prediction because it has the **highest value of R - square** (goodness of fit) as showed in table 2.7 below which indicates a good fit

Table 2.7: R - squares for the models

##model1_rsq	model2_rsq	Model3_rsq	Model4_rsq
1 0.2342697	0.265155	0.2729875	0.2864693

2.3.2 Picking the best Model using AIC and ANOVA

AIC is the Akaike Information Criterion. Is an estimator of prediction error and thereby relative quality of statistical models for a given set of data (Aho. K et al 2014) and (Akaike, H 1973) while ANOVA is a way to find out if survey or experiment results are significant. The best model test was evaluated using table 2.8, 2.9 below and figure 4.3,

International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2020): 7.803

the results showed that the curve is symmetrical nature which indicates normality in residuals (error values)

Table 2.8: AIC Description

	df	AIC
soaked_model1	3	126.3084
soaked_model2	5	128.6616
soaked_model3	7	132.2330
soaked_model4	9	135.4842

Table 2.9: Analysis of Variance Table (Using ANOVA)

	AIC
Model 1	soaked ~ gravel
Model 2	soaked ~ gravel + sand + fine
Model 3	soaked ~ gravel + sand + fine + ll + pl
Model 4	soaked ~ gravel + sand + fine+ ll + pl+ omc + mdd

Res.	Df	RSS	Df	Sum of Sq	F	Pr(>F)
1	38	47.404				
2	36	45.492	2	1.91203	0.6926	0.5076
3	34	45.007	2	0.48488	0.1756	0.8397
4	32	44.173	2	0.83462	0.3023	0.7412

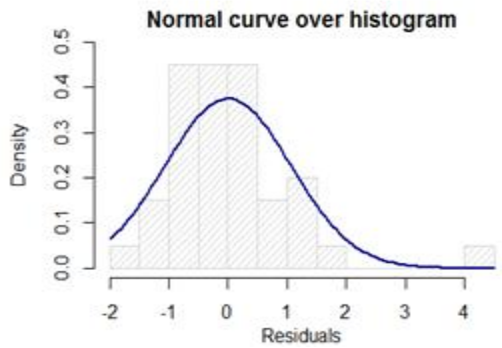

Figure 2.3: Normal curve over histogram (Normality curve)
The symmetrical nature of the curve indicates normality in residuals (error values)

Table 2.10: Prediction using model 4

1	2	3	4	5
2.680233	2.424837	2.724499	2.647890	2.502726
6	7	8		
2.665990	2.701835	2.358483		
9	10	11	12	13
2.566496	2.217425	2.440363	3.156209	2.398711
14	15	16		
3.229084	2.083082	2.338595		
17	18	19	20	21
2.947032	3.419624	3.682923	2.723585	2.595246
22	23	24		
2.803682	3.061198	4.096279		
25	26	27	28	29
4.121994	3.664358	5.030009	2.874832	2.950612
30	31	32		
3.357672	2.791391	2.513795		
33	34	35	36	37
2.595258	3.002257	2.743437	2.083082	4.267286
38	39	40		
2.529899	4.427265	3.370830		

Table 2.11: Summary of results for observed, predicted and residual values

	Observed	Predicted	Residuals
1	2.88	2.680233	0.19976749
2	2.83	2.424837	0.40516257
3	2.63	2.724499	-0.09449903
4	2.38	2.647890	-0.26788981
5	3.02	2.502726	0.51727396
6	1.38	2.665990	-1.28598958
7	1.75	2.701835	-0.95183489
8	1.89	2.358483	-0.46848274
9	4.15	2.566496	1.58350458
10	3.40	2.217425	1.18257470
11	1.75	2.440363	-0.69036331
12	3.26	3.156209	0.10379094
13	1.89	2.398711	-0.50871134
14	2.63	3.229084	-0.59908439
15	3.40	2.083082	1.31691813
16	2.51	2.338595	0.17140505
17	3.26	2.947032	0.31296822
18	2.51	3.419624	-0.90962374
19	3.63	3.682923	-0.05292255
20	1.88	2.723585	-0.84358549
21	2.38	2.595246	-0.21524603
22	4.13	2.803682	1.32631841
23	2.83	3.061198	-0.23119762
24	2.13	4.096279	-1.96627912
25	3.40	4.121994	-0.72199382
26	3.26	3.664358	-0.40435828
27	9.39	5.030009	4.35999153
28	3.40	2.874832	0.52516842
29	3.13	2.950612	0.17938803
30	3.51	3.357672	0.15232825
31	3.51	2.791391	0.71860938
32	2.63	2.513795	0.11620554
33	2.38	2.595258	-0.21525824
34	1.75	3.002257	-1.25225706
35	1.75	2.743437	-0.99343675
36	3.40	2.083082	1.31691813
37	3.63	4.267286	-0.63728601
38	2.38	2.529899	-0.14989844
39	3.26	4.427265	-1.16726546
40	3.51	3.370830	0.13917035

The correlation between the observed and the predicted values gave 53.52283 % This shows that the relationship between the observed or actual values of soaked CBR and the predicted values is approximately 54 % strong. This is a good model for prediction. This is justified in the overlay of soaked prediction on scatter plot in figure 2.4 below and table 2.10 and table 2.11 above, it can be observed that the predicted and the observed values of soaked *CBR* go in the same direction. The movement in the observed is maintained in the predicted. The only outlier is seen in location 27.

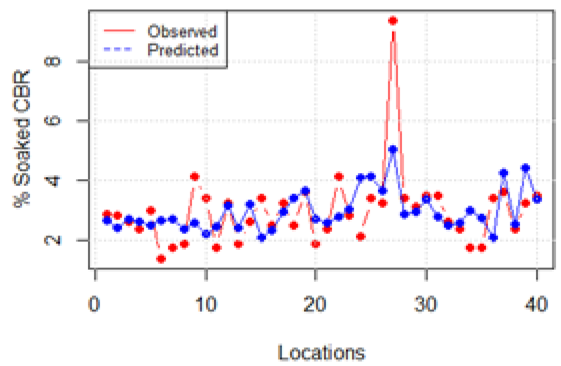

Figure 2.4: Overlay Soaked Predictions on Scatter Plot

3. Conclusions and Recommendations

3.1 Conclusions

Development of a mathematical model to estimate soaked California Bearing Ratio of a lateritic soil in Ekiti Northern Senatorial District of Ekiti State South Western Nigeria was carried out A trial pit 1 - 1m deep was excavated and 40 samples of disturbed soils was obtained for laboratory tests. From the results obtained, the following conclusions are drawn:

1) The soils of the study area is characterized as Clayey soils (A - 4, A - 6 and A - 7 - 5) and Silty or Clayey gravelling soils (A - 2 - 6, A - 2 - 7) according to AASHTO classification system respectively.). Hence, the soils are describing as clay of high compressibility respectively. The engineering implication of soils with higher fines is that they are poor for road works and fill material and such soils may require stabilization if it will be useful for any serious Civil engineering project.
2) Many of the zones had a very high percentage finer than 0.075 fractions that is > 35% vanried between 15 and 75 % for (Zones A, B, C, D and E) respectively. The above results showed that their exist very fine material within the study area which can only be applicable for fill materials for subgrade which might require stabilization for its suitability for either sub base or base course material for future contractor around this study area.
3) The consistency test varied between 23 – 43 % and 20 – 50%, 27 - 45 %, 19 - 43 %, 19 - 47 % for LL % and Zones A, B, C, D and E respectively are shown in the Table 4.1 and figure 4.6 – 4.10 respectively and for PL % the results varied between 9 - 27, 8 - 27, 7 - 24, 13 - 26 and 8 - 21 % and for PI % the results varied between 8 and 37 % from the fore going according to (FMW, 1997) recommendation that, liquid limits not greater than 80% for sub - grade and not greater than 35 for sub base and base course materials. Also plasticity index not greater than 55% for sub - grade and not greater than 12% for both sub - base and base course.
4) The compaction characteristic test (OMC and MDD) ranges from 1854 – 2277 Kg/m^3 and 13 – 31.3 % for all the zones investigated within the study area for OMC % and MDD Kg/m^3 respectively are shown in the Table 4.1 and Figure 4.11 – 4.15 respectively for verification. The analysis indicates that the soils samples from all the Zones fell within the minimum dry density recommended for subgrade materials
5) The results and graph of the California bearing ratio performed on all the trial pits investigated, which varied between 16.03 – 30 % and 1 – 10 % for un soak (UN SK) and soaked (SK) CBR values for soils within the zones. Expectedly the influence of soaking is evident in the results obtained as the CBR values for the 24 hours soaked samples were much lower compared to the unsoaked sample
6) The model 4 gave a perfect derived equation thus **Soaked CBR** = 8.4583 - 0.0044 (Gravel) - 0.0697 (Sand) - 0.0565 (Fines) - 0.0168 (LL) - 0.0037 (PL) - 0.0275 (OMC) + 0.0006 (MDD) where, **Gravel** is the percentage of the gravel present in the soil sample, **Sand** is the percentage of sand content in the soil sample, **Fines** is the percentage of clay and silt content in the soil sample, **LL** is the Liquid Limits values in percentage of the soil sample, **OMC** is the maximum moisture content of the soil after compaction and **MDD** is maximum dry density of the soil sample after compaction test.
7) Although the factors seem to be insignificant, but they have contributed to the response variables. of all the four models above, this model predicts best for the response variable *Soaked CBR*. Out of all the predictors for *soaked CBR* only *MDD* has a positive effect though very low. This model is picked for prediction because it has the highest value of R - square (goodness of fit)
8) The best model test was evaluated using AIC curve and ANOVA, the results showed that the curve is symmetrical in nature which indicates normality in residuals (error values
9) The correlation between the observed and the predicted values gave 53.52283 % This shows that the relationship between the observed or actual values of soaked CBR and the predicted values is approximately 54 % strong.
10) In the present study the soils selected for the study are largely belongs to clay family. Also only multiple linear regression models are developed with six soil physical property as independent variable and CBR as dependent variable. From the study it is established that a strong correlation exists between CBR and soil physical properties and the equations can be used for prediction of soaked CBR, where data availability is constrained by time and resources.

3.2 Recommendations

The results of this research work would be useful to engineers and construction managers in the construction industry. From this study, the following recommendations are made.

1) This research work will provide information for Engineers and Constructors to properly apply this data for planning particularly during the preliminary stage of their project work and will prevent possible delay and additional expenses during project execution.
2) **The simplified Soaked CBRmodel**= 8.4583 - 0.0044 (Gravel) - 0.0697 (Sand) - 0.0565 (Fines) - 0.0168 (LL) - 0.0037 (PL) - 0.0275 (OMC) + 0.0006 (MDD) is therefore recommended for use particularly for any contractor working within Ekiti North Senatorial Districts in Ekiti State Nigeria
3) As the soil samples used in the study largely belongs to Clay soils, there is a need to extend the studyfor other soil groups.

References

[1] 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.
[2] AASHTO.2000. Standard Specification for Transportation Materials and Methods of Sampling

and Testing, 20th Edition. American Association of State Highway and Transportation Officials: Washington, D. C.

[3] Adeyemi, O. A.2002. “Geotechnical Properties of Lateritic Soil Development over Quartz Schist in Ishara Area Southwestern Nigeria”. Journal of Mining and Geology.38 (1): 57 – 63.

[4] Arulkumaran, S. and Sukumar S. (2015) “Regression Model to Predict Subsurface Properties”, International Journal of Earth Sciences Engineering, Vol.8, Number 2, pp.233 - 239.

[5] Bayowa, O. G. Olorunfemi, O. M. Akinluyi, O. F. &Ademilua, O. L. (2014). A Preliminary Approach to Groundwater Potential Appraisal of Ekiti State, Southwestern Nigeria. Int. J of Sci. and Tech. Vol.4, No.3, pp.48 - 58.

[6] British Standard Institution. (1990.) “Methods of Test for Soils for Civil Engineering andTechnology. Engineering Properties (BS 1377) ”. British Standard Institution: London, UK.143.

[7] Erwin, K. (2004), Advanced Engineering Mathematics, 8 Edition, John Wiley and Sons, (Asia) Pte. Ltd, Singapore, pp.118 - 121 and 240 – 262.

[8] ELE International (2013) Chartmoor Road, Chartwell Business Park, Leighton Buzzard, Bedfordshire, LU7 4WG

[9] Faisal Iqbal, Aneel Kumar, Ali Murtaza. (2018) Co - Relationship between California Bearing Ratio and Index Properties of Jamshoro Soil. Mehran University Research Journal of Engineering and Technology, Mehran University of Engineering and Technology, Jamshoro, Pakistan, 37 (1), pp.177 - 190 http: //publications. muet. edu. pk/index. php/muetrj/article/view/121/62>. <hal - 01676724>

[10] Farzaneh, M., AlirezaJ. andGholamabbas. S (2013) “Estimation of Soil Compression Coefficient Using Artificial Neural Network and Multiple Regressions’’, International Research Journal of Applied and Basic Sciences, Vol.4, Number 10,, pp 3232 - 3236.

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

[12] Gunaydin, O., Gokoglu, A., Fener, M., 2010, “Prediction of artificial soil’s unconfined compression strength test using statistical analyses and artificial neural networks”, Advances in Engineering Software, vol.41, pp.1115–1123,

[13] Kaur, S., Ubboveja, V. S., and Agarwal, A. (2011) “Artificial Neural Network modeling for prediction of CBR, ” *Indian Highways*, Vol.39, No.1, pp.31 - 37.

[14] Ola, S. A.1983. “Geotechnical Properties of an Attapulgite Clay Shale in Northwestern Nigeria”. Engineering Geology.19: 1 - 13.

[15] Oladapo, M. I. and Ayeni, O. G. (2013). Hydro geophysical Investigation in Selected Parts of Irepodun LG. Area of Ekiti State, SW Nigeria. J. of Geol. and Ming Research. Vol.5, No 7, pp.200 - 2007

[16] Okunade, E. A. (2007). Eng. Properties of Lateritic Adobe Bricks for Local Bldg. Construction and Recommendations for Practice. J. of Eng. and Applied Sci. Vol.2 No 9. pp.1455 - 1459.

[17] Okunade, E. A. (2010). Design and Implementation of a Web - Based Geotech. Database Mgmt. System for Nigerian Soils. Modern Applied Sci. Vol.4. No.11. pp.36 - 42.

[18] Owolabi, T. A. and Aderinola, O. S. (2014). Geotech. Evaluation of Some Lateritic Soils in Akure South, Southwestern Nigeria. ElectronicJ. ofGeotech. *Eng.* Vol.19, pp.6675 - 6687

[19] Ramakrishna, A. N., Pradeep Kumar, A. V., Gowda, K. (2011) “Complex CBR (of BC Soil - RHA - Cement Mix) Estimation: Made Easy by ANN Approach [A Soft Computing Technique], ” *Advanced Materials Research*, Vols.261 - 263, pp 675 - 679.

[20] Schefe, H., (1958), Experiments with Mixtures, Royal Statistical Society journal. Ser B., Vol.20, 1958. pp 344

[21] Simon A. B, J. Geisecke. and G. Bidlo. (1973). Use of Lateritic soils for Road Construction in North Dahomey. Engineering Geology.7: pp 197 – 218.

[22] Talabi, A. O., Ademilua, O. L., Ajayi, O. Z. and Oguniyi, S. O. (2013). Preliminary Geophysical Evaluation ofOrin Bauxite Deposit, SW Nigeria. J. of Emerging Trends in Eng. and Applied Sci. Vol.4, No 3, pp.432437

[23] Taşkıran, T. (2010) “Prediction of California bearing ratio (CBR) of fine grained soils by AI methods, ” *Advances in Engineering Software*, Vol.41, pp.886 - 892.

[24] Yıldırım, B. and Gunaydın, O. (2011) “Estimation of California bearing ratio by using soft computing