Correlation Between the California Bearing Ratio (CBR) and Unconfined Compressive Strength (UCS) of Stabilized Sand-Cement of the Niger Delta

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Abstract

The California bearing ratio and the unconfined compressive strengths of sand- cement were measured in ten (10) different prepared CBR and UCS specimens. The sand-cement mix was prepared by mixing 10.5kg of sand with 5.5% by weight of cement and moisture content of 12%. The CBR specimens were cured for 6 days followed by 24 hours soaking while the UCS specimens were cured for 7 days. The CBR and UCS specimens were tested after their curing and soaking periods and gave values greater than 200% and 2500kpa respectively. The data obtained were subjected to regression analysis to check their correlation. The R^2 obtained showed that there is a little correlation between CBR and UCS.

Keywords: *California bearing ratio, unconfined compressive strengths, regression analysis, soaking, sand-cement mix, moisture content, correlation.*

I. INTRODUCTION

Geotechnical engineering has been critical to highway construction since engineers realized that successful civil works depended on the strength and integrity of the foundation material [3-6]. Road design and construction over soft ground especially over very soft and soft marine deposits are interesting engineering challenges to engineers especially at the approaches to bridges and culverts. Many geotechnical options are available for engineer's consideration. Very soft and soft deposits of river alluvium and marine deposits are common in the South-south area of Nigeria. The river alluvium and marine deposits normally consist of clay, silty clay and occasionally, with intermittent of sand lenses especially near a major river mouth and delta. The marine deposits in Nigeria are encountered within the Niger delta region.

Embankment design of roads needs to satisfy two important requirements among others; stability and settlement [7]. The short term stability for embankment over soft clay is always more critical than long term simply because the subsoil consolidates with time under loading and the strength increases. In design, it is very important to check for the stability of the embankment with consideration for different potential failure surfaces namely circular and noncircular. It is also necessary to evaluate both the magnitude and rate of settlement of the subsoil supporting the embankment when designing the embankment so that the settlement in the long term will not influence the serviceability and safety of the embankment [8-11].

Very often, the non-circular failure is more critical than circular slip failure for layered soil especially with very soft subsoil at top few meters. Long term stability of embankment is usually not an issue for embankment over soft marine deposits because the subsoil would gain strength with time after the excess pore water pressure in the subsoil dissipates during consolidation. When the analyses based on subsoil and thickness of embankment indicating multistage construction is required, the construction of embankment usually take substantially longer time especially when the cohesive subsoil does not have sand lenses. However, geometric change requires wide road reserve due to flatter slope and stabilizing berms. It has been shown that geotechnical design can be innovative solutions for highway construction problems [12-16].

Nowadays, in Nigeria, there are so many constructions of highways. Since highways also involve foundation, these means geotechnical aspects are also important in the highway construction. Shear strength parameters are always associated with the bearing capacity of the soil. However, highway engineers always prefer using CBR test to determine the suitable strength for designing road pavement. This paper therefore, aims at finding the correlation between CBR and unconfined compressive strength of cement-stabilized sand. It can provide better understanding between highway and geotechnical engineering.

II. EXPERIMENTAL PROGRAMME

The sand sample used in this study was collected from a sand dump belonging to Setraco Nigeria Limited at Mbiama Community in Ahoada West Local Government area of Rivers state. The cement used in this research is ordinary portland cement (OPC). The fresh water was collected from a tap at the site yard of Setraco Nigeria Limited. The tap water was used for both mixing, soaking and curing of the moulded samples. Sieve analysis was carried out to determine the particle size distribution of sand. 10kg of oven-dried sand was weighed and poured into a mixing tray. 5.5% by weight of sand was also weighed and poured into the mixing tray. The mixture was turned over and over manually using a shovel until a homogeneous mix was obtained. Water (14% by weight of cement) was weighed and poured into the mixture and mixed properly. The moisture content of the sand-cement mixture then determined. Thereafter, the samples for CBR and UCS tests were prepared using the sand-cement mixture.

III. RESULTS AND ANALYSIS

Table 1: Result of Sieve Analysis

Material description: Sand

Source of material: Setraco sand dump at Mbiama Comm.

Sieve size (mm)	Weight retained(gm)	(%) Retained	(%) Passing
10.0	Nil	Nil	100
5.0	5	0.6	99.4
2.0	18	2.3	97.7
0.600	140	18.2	81.8
0.425	168	21.8	78.2
0.300	566	73.5	26.5
0.150	731	94.9	5.1
0.075	748	97.1	2.9

Weight of dry sample before wash (gm) = 770

Weight of dry sample after wash (gm) = 752

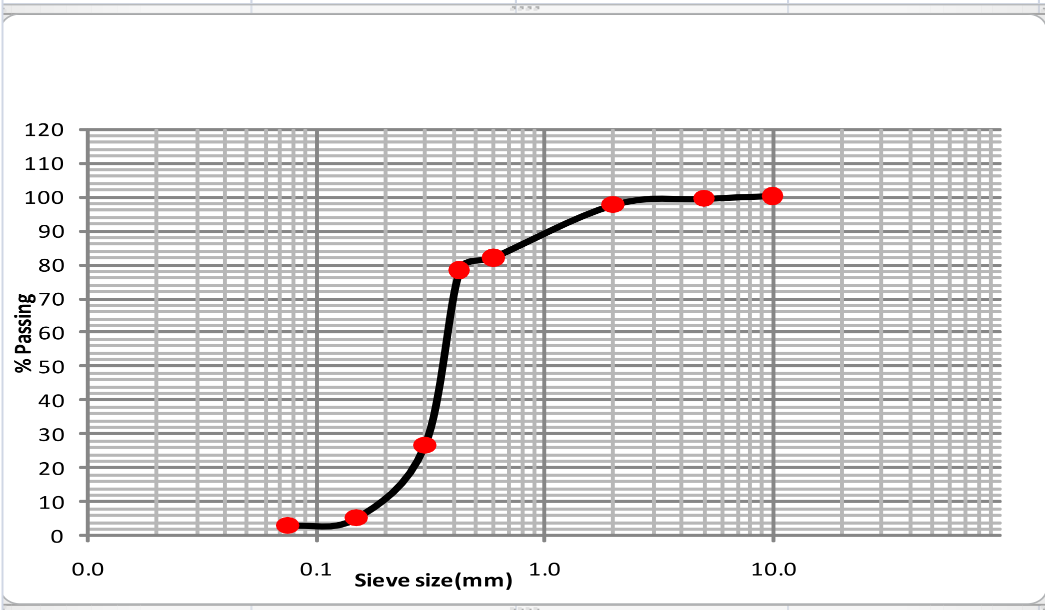
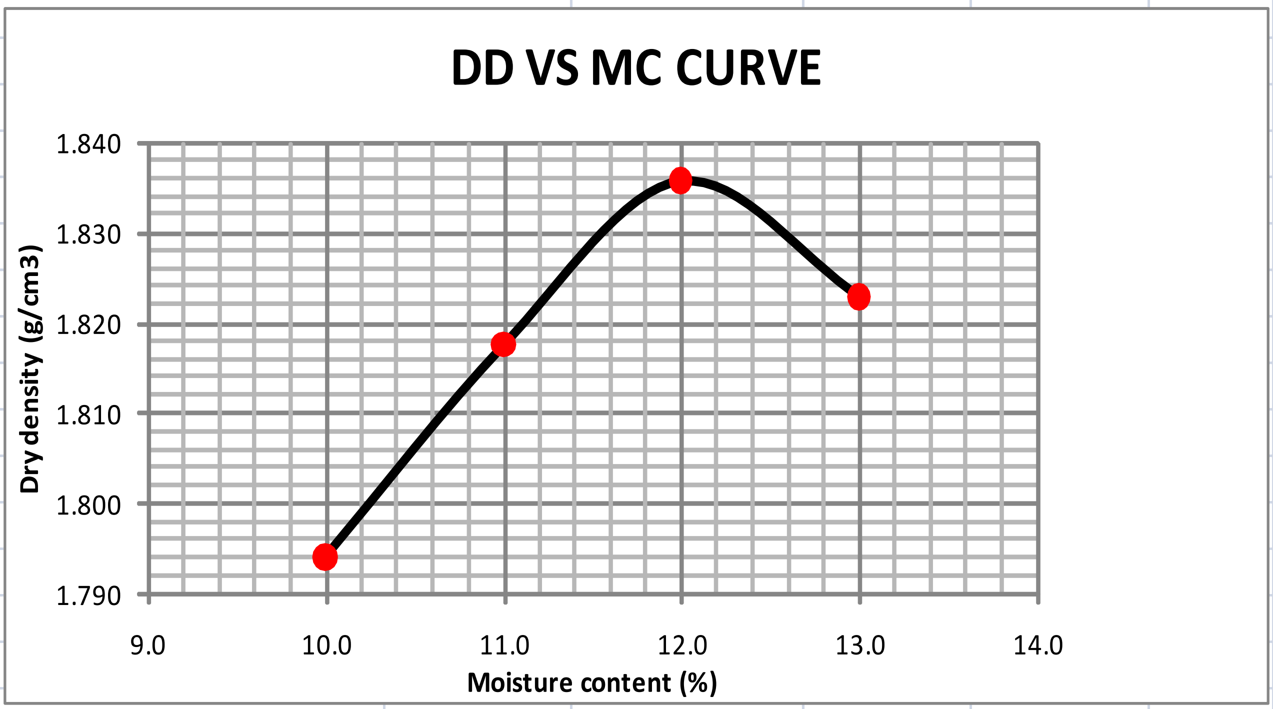


Figure 1: The Graph of Percentage Passing Against Sieve Sizes

Table 2: Dry Density and Moisture Content Relationship

Material description: Sand mixed with cement				
Source of material:Sand cement mix				
Weight of mould (g) = 6016	Volume of mould (cm3) = 2106	Weight of rammer (kg) = 4.5		
Mould No	1	2	3	4
Weight of mould +wet sand cement (gm)	10172	10265	10346	10354
Weight of sand cement (gm)	4156	4249	4330	4338
Wet density (g/cm3)	1.973	2.018	2.056	2.060
Container No	i	ii	iii	iv
Weight of container +wet sand cement (gm	610.4	436.9	540.8	637.2
Weight of container + dry sand cement (gm)	563.8	401.3	495.4	573.9
Weight of moisture (gm)	46.6	35.6	45.4	63.3
Weight of container (gm)	97.9	77.9	117.1	86.7
Weight of dry sand cement (gm)	465.9	323.4	378.3	487.2
Moisture content (%)	10.0	11.0	12.0	13.0
Dry Density (g/cm3)	1.794	1.818	1.836	1.823



Maximum dry density	**1.836 g/cm3**	**Optimum moisture cont.**	**12.0%**

Figure 2: Relationship Between Axial Stress and Unconfined Compressive Strength

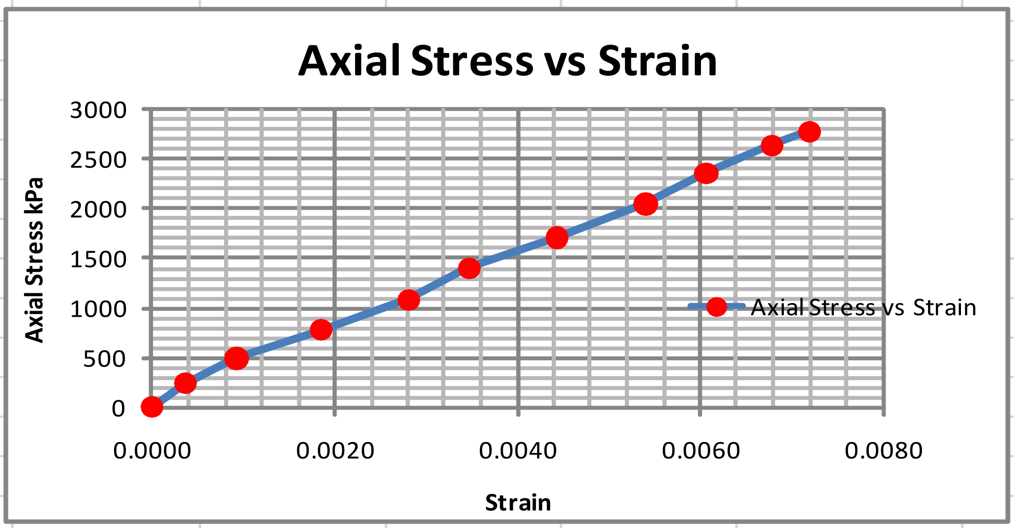
Analysis of the Results using Regression equations

Table 3: CBR and Moisture Content of Sand-Cement Mixture

Sample Source: Sand cement mix

Specimen Details		Specimen Details	
Diameter d (mm)	58	Type of Specimen	Compacted
Length L_o (mm)	116	Specimen Condition	24 hrs soaked
Mass (gm)	627.6	Date of Sampling	2/3/2015
Area A_o (mm^2)	2642	Date of Testing	2/10/2015
Volume (cm^3)	306	Moisture Content (%)	9.8
Density (g/cm^3)	2.05	Deformation rate (mm/min)	0.58

Compression Test				
Compression of Specimen ΔL (mm)	**Strain ϵ = ΔL/Lo**	**Axial Force p (N)**	**Corrected Area (mm^2) A = Ao/1-ϵ**	**Axial stress (kPa) σ = 1000p/A**
0.000	0.0000	0	2642	0
0.042	0.0004	635	2643	240
0.107	0.0009	1284	2644	486
0.215	0.0019	2037	2647	770
0.325	0.0028	2863	2649	1081
0.403	0.0035	3712	2651	1400
0.513	0.0044	4531	2654	1707
0.626	0.0054	5424	2656	2042
0.703	0.0061	6243	2658	2349
0.787	0.0068	6988	2660	2627
0.834	0.0072	7372	2661	2770



Unconfined Compressive Strength q_u = 2770 kPa

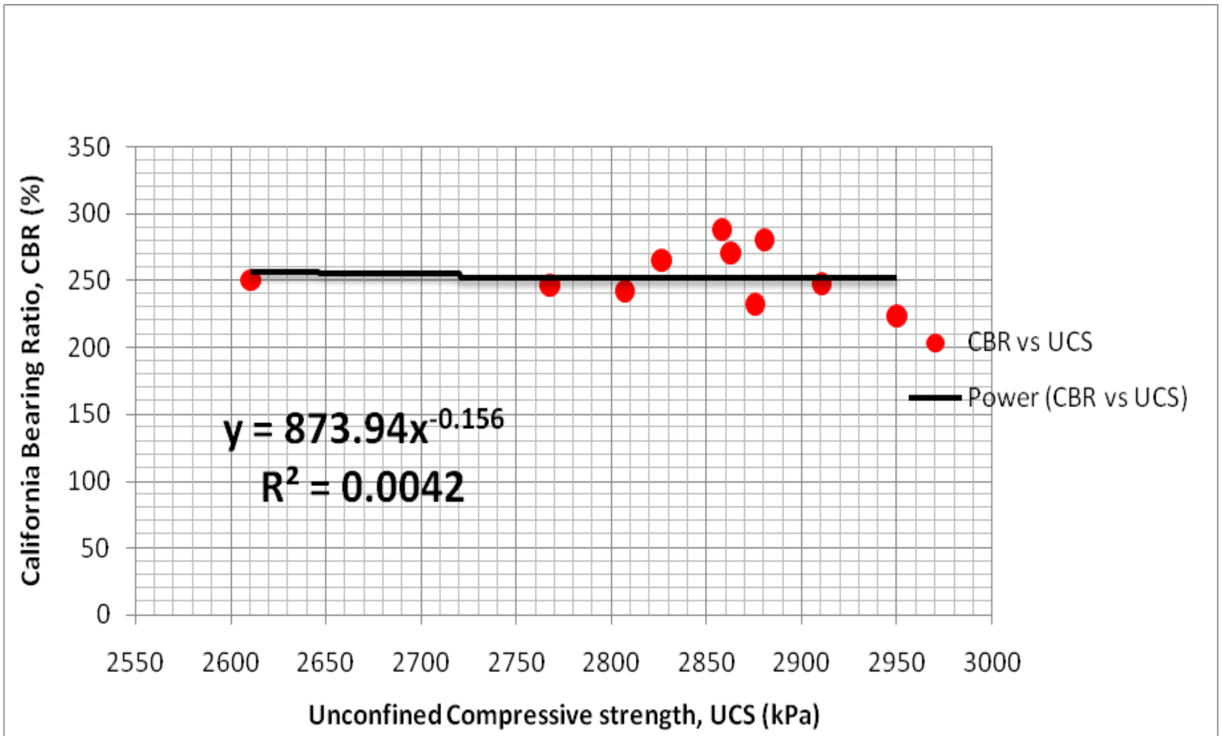


Figure 4: Logarithmic Relationship Between CBR And UCS

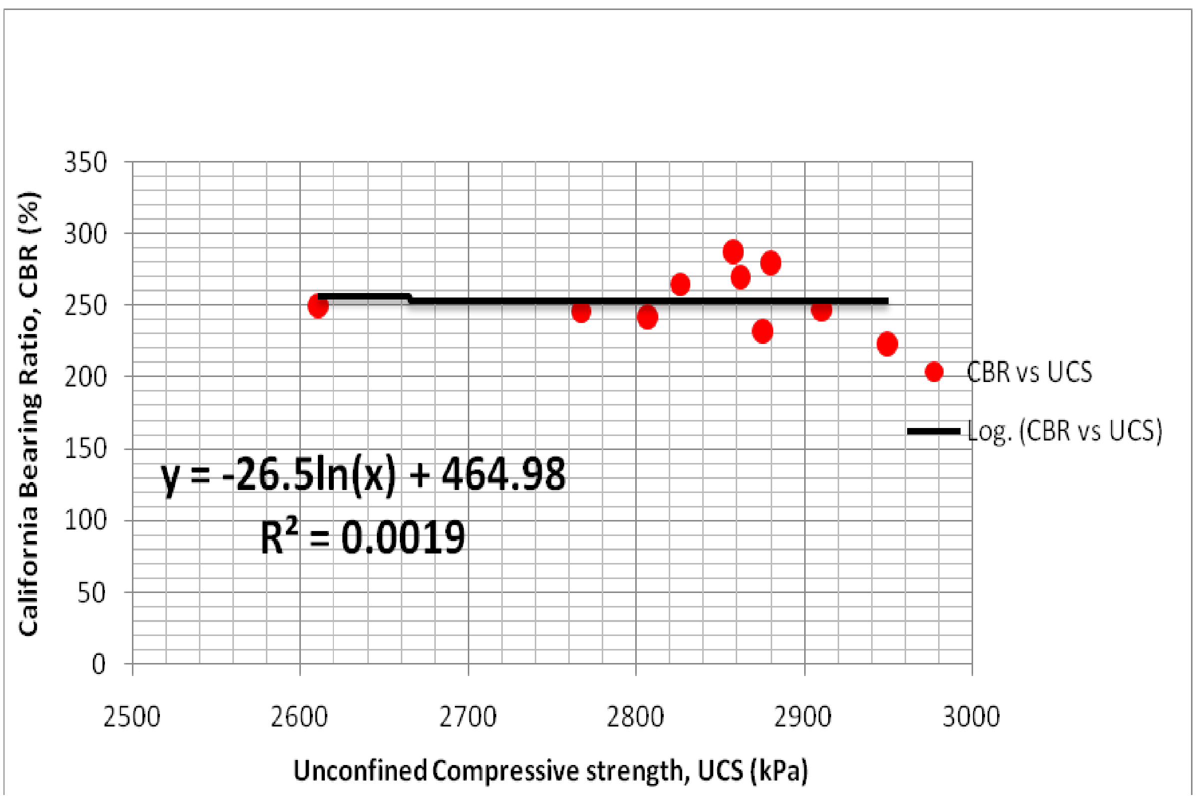


Figure 5: Power Relationship Between CBR and UCS

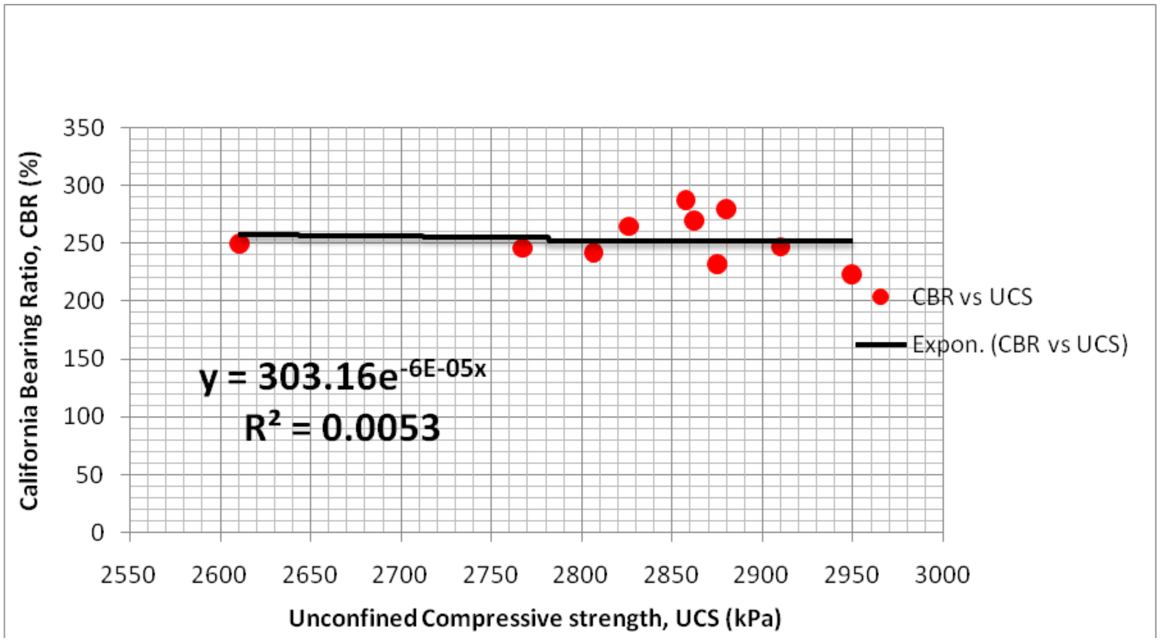


Figure 6: Power Relationship Between CBR and UCS

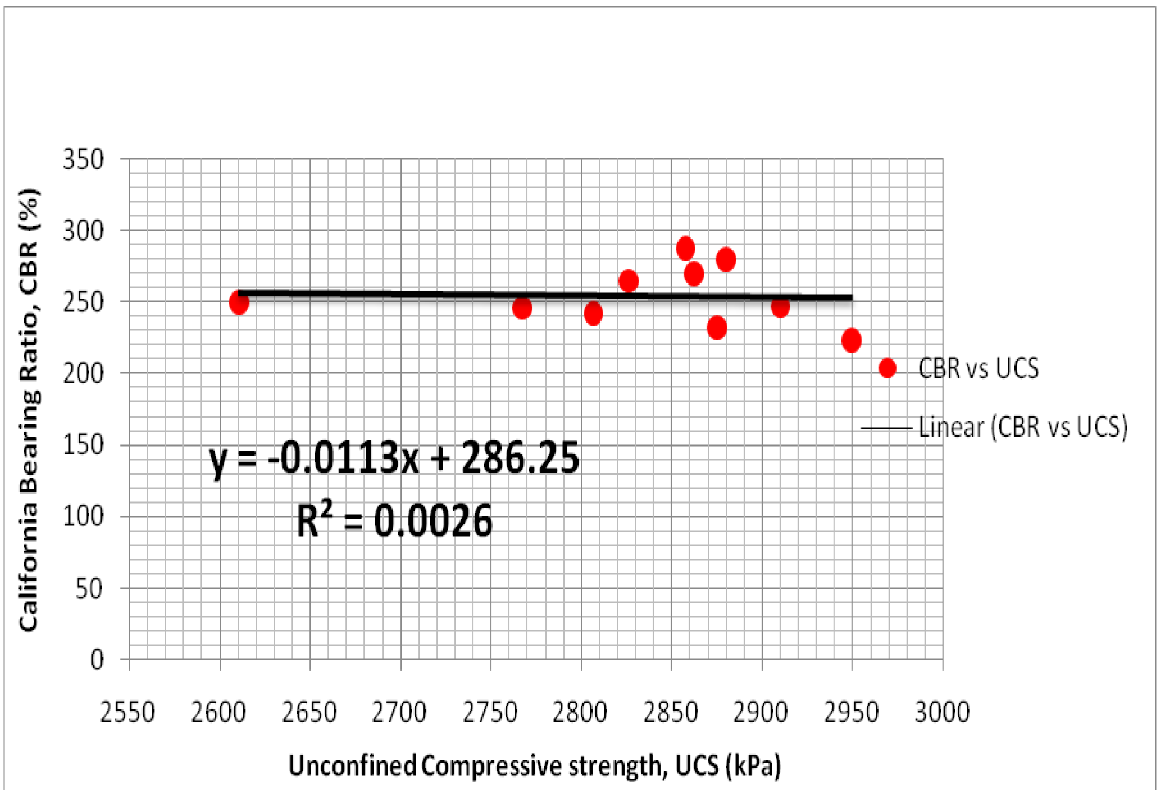


Figure 7: Power Relationship Between CBR and UCS

Table 4: Summary of Regression Models and their Corresponding R^2 Values

Type of regression	Equation Generated	R^2-Value
Linear	$Y = -0.0113X + 286.25$	0.0026
Exponential	$Y = 303.16e^{-6E-05X}$	0.0053
Logarithmic	$Y = -26.5In(X) + 464.98$	0.0019
Power	$Y = 873.94X^{-0.156}$	0.0042

Discussion and Analysis of Results of Regression Models

Sand- cement data had been obtained and analysed accordingly. All the results were obtained from laboratory tests accordance to British Standard. Data acquired for analyses are from CBR values for sand- cement specimen, moisture content and unconfined compressive strength from the compression test. Total sand- cement data obtained were ten (10) in number and eight (8) graphs have been produced.

The generated regression models and their corresponding R^2 values are presented in Table 4. The models are linear, exponential, logarithmic and power models. From Table 6, it can be seen that the exponential model gave the highest value of R^2 (0.0053), followed by power model (0.0042), followed by linear model (0.0026) and then the logarithmic model (0.0019). The R^2 value for each generated regression model is indicative of the degree of accuracy of each model. This implies that the exponential model gave a better correlation between CBR and UCS compared to other regression models generated. However, the R^2 value is poor for all the regression models.

IV. CONCLUSION

The following conclusions can be drawn from the study.

1. With the addition of 5.5% by weight of Cement and moisture of about 12% to stabilize sand graded zone 4, the expected CBR and UCS values will be greater than 200% and 2500kPa respectively.
2. The correlation between CBR value and UCS from compression test has been established. From the correlation, CBR value can be predicted using either one of these four regression equations given in Table 4.
3. The established correlation can close the gap between geotechnical and highway engineer in unconfined compressive strength aspect for road pavement design in Nigeria.

Recommendations

1. The sample of soil used in this study is a cohesionless soil (sand). Using laterite in place of sand for further study is recommended.
2. More data for sand-cement samples should be obtained to obtain a better correlation.
3. Establishment of the correlations using soil samples from other regions in Nigeria rather than Niger Delta areas is recommended.
4. Correlation of CBR with other variables such as percentage of cement, Moisture content and unconfined compressive strength using multiple regression analysis is recommended.

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