International Journal of Engineering Innovation & Research
Volume 3, Issue 6, ISSN: 2277 – 5668

Composite Stabilization and Model Prediction of CBR and UCS Parameters of Unyeghe Residual Soils, AkwaIbom State, Nigeria

Essien Udo, Ndifreke Udoh, Charles Kennedy
Department of Civil Engineering, University of Uyo, Nigeria

Abstract **- Residual soils are heterogeneous due to variable weathering of the jointed rock mass. The heterogeneity of residual soils is due to the influence of relict joints, presence of boulders, and variability of the soil matrix. The repercussion of the heterogeneity is that properties of small samples of residual soil are unrepresentative of the mass. Most of Unyeghe areas are covered with granitic residual soil. Its deployment as flexible pavement material on Enwang-Unyeghe-Stubb Creek Access Road was a failure technically and economically because the predominant aluminiumsesquioxide and iron compound montmorillonite [which has the tendency to swell when their moisture content is allowed to increase] could not be curtailed by conventional plain compaction. The structural behaviour of Unyeghe residual soil from locations 1, 2, 3 and 4 when stabilized with cement-sand composite was adequate for both sub-base and base course applications. Results from composite stabilization of Unyeghe residual soil revealed soaked CBR values ranging from 91% - 168% with cement - sand content between 2% -8% and 10% - 50% respectively. The MDD of cement-sand stabilization increased from 2040kg/m^3–2140kg/m^3 with similar increase in cement-sand composite. Conversely the OMC decreased from 14.2% - 8.6% average with increase in cement-sand content. Results from UCS presents a linear relationship and the values ranged from 80% - 152% and 321% - 418% on 7/28 days curing durations. Finally multple nonlinear regressed models were developed for the purpose of prediction and optimization of CBR and UCS parameters.**

Keywords **- Cement, Composite-Stabilization, Residual Soil, River Sand.**

I. Introduction

1.1 Composite Soil Stabilization

Composite soil stabilization such as addition of river sand and inorganic chemical such as cement to residual soil has a dual effect on the behavior of the soil structure. While the river sand provides volume stability the cement addition accelerates chemical bonding and ensures reduction of permeability. In concert the soil structure increases in strength, durability as well as a reduction in deformability [1]. Composite soil stabilization therefore focuses on subjecting the natural soil to both physical and chemical treatments to improve its engineering properties. Generally stabilization of soft soil has a basic target, to find the most efficient and economical method so that the properties of a problematic soil become more like the properties of a soft rock. In most cases the goal of treating the soil is increasing shear strength and loading capacity, increasing stability and settlement control. In all practical cases, the primary ingredient necessary for stabilizing soils is calcium [% of cement]. In addition to plasticity reduction, Portland cement, by its inherent nature of producing strength – developing hydration products, provides improved strength and durability. Therefore the effectiveness of stabilization is based on the number of positions of exchangeable ions – mineralogical composition which is related to liquid limit and the amount of liberated calcium ions from cement [% of cement, % of compaction and curing time] which influences the durability [bonding effect] and unconfined compressive strength [bearing capacity].

II. Materials Selected

2.1 Unyenghe Residual Soil

Four soil samples selected for this research was dug with shovels from four borrow pits. The samples' locations are identified as detailed below:

Sample Identification	Location
1	Km1+000 Unyeghe-EsitEket road.
2	Km2+250 Unyeghe-EsitEket road.
3	Km2+500 Unyeghe-StubbCreek road.
4	Km7+800 Unyeghe-StubbCreek road.

The samples were excavated bearing in mind the variability of residual soil in its natural composition. The soil samples were excavated both vertically and horizontally and thoroughly blended. The samples wereconveyed in four, 50kg nylon bags, carefully tagged for identification purpose and transported to Mothercat Limited, Materials Testing Laboratory at Uyo.

2.2 Cement

The cement used in this research was the ordinary Portland cement (OPC). It was purchased from Ewet market in Uyo. This cement is the most widely used in the construction industry in Uyo, AkwaIbom State. Cement stabilization is mostly applicable to road stabilization and fills especially when the moisture content of the sub-grade is very high [2]. Ordinary Portland cement particle is a heterogeneous substance, containing minute tri-calcium silicate (C3S), di-calcium silicate (C2S), tri-calcium aluminate (C3A) and solid solution described as tetra calcium alumino-ferrite (C4A). When the pore water of the soil encounters with cement, hydration of the cement occurs rapidly and the major hydration (primary cementations) produces hydrated calcium silicate (C2SHx, C4AHx) and hydrated lime Ca(OH)2[3].

2.3 River Sand.

This is one of the most abundant stabilizing materials within the coastal plains and tributaries of the Atlantic. The material was obtained from a tributary of the Cross river in Itu. The deleterious and silty substances were thoroughly removed by washing. The material was then air-dried before particle size gradation through sieve analysis. The air-dried sample was separated through the riffle box and 1000g utilized for this experiment. The sample was sieved from 10mm through 0.075mm in a mechanical shaker. Sand plays a vital role in enhancing the bond in cementation reactions of soil mixing. It is found that grain size distribution provides a satisfactory skeleton, and the voids are filled with fine sand giving a compact and high load bearing capacity. From analysis the sand is observed to have a d50 equal to 0.620mm, d30 equal to 0.425mm and d10 of 0.300mm.

III. Preparation and Testing of Samples

3.1 Plain Mechanical Compaction tests

This test was conducted to determine the mass of dry soil per cubic meter and the soil was compacted in a specified manner over a range of moisture contents, including that giving the maximum mass of dry soil per cubic meter. For each of the samples, the Modified Proctor Compaction tests were conducted. The air-dried material was divided into five equal parts through a riffle box and weighed to 6000g each. Each sample was poured into the mixing plate. A particular percentage of distilled water was poured into each plate and thoroughly mixed with a trowel. An interval of about 1hour was allowed for the moisture to fully permeate the soil sample. The sample was thereafter divided into five equal parts, weighed and each was poured into the compaction mould, in five layers and compacted at 61 blows each using a 4.5kg rammer falling over a height of 450mm above the top of the mould. The blows were evenly distributed over the surface of each layer. The collar of the mould was then removed and the compacted sample weighed while the corresponding moisture content was noted. The procedure was repeated with different moisture contents until the weight of compacted sample was noted to be decreasing. With the optimum moisture content obtained from the Modified Proctor test, samples were prepared and inserted into the CBR mould and values for the plain mechanical compaction were read for both top and bottom at various depths of penetration.

3.2 Cement-River Sand Composite Stabilization Tests

Four residual soil samples were utilized in this experiment. The percentage of cement ranged from 2%, 4%, 6% to 8%. The percentage of river sand ranged from 10%, 20%, 30%, 40% to 50%. For each cement content the percentage or proportion of river sand was varied from 10% to 50%. It is an established fact that the measurement of the strength of soil-cement mixture in laboratory and the determination of the parameters which affect it, is very important for the estimation of the strength of mixture in-situ[4].The mixture was thoroughly blended and moisturized and modified proctor compaction test was conducted to establish the OMC and MDD. With the OMC and MDD results, three specimens each were prepared for the CBR test. One specimen was tested immediately while the remaining two were wax-cured for 6 days and thereafter soaked for 24 hours, and allowed to drain for 15 minutes. After testing in CBR machine, the average of the two readings was adopted. This procedure meets the provision of clause 6228 design criteria. FMW & H (1997).

3.3 California Bearing Ratio [CBR] Test.

The CBR test [as it is commonly known] involves the determination of the load-deformation curve of the soil in the laboratory using the standard CBR testing equipment. It was originally developed by the California Division of Highways prior to World War 11 and was used in the design of some highway pavements. This test has now been modified and is standardized under the AASHTO designation of T193 [5]. With the OMC and MDD results, three specimens each were prepared for the CBR test. One specimen was tested immediately while the remaining two were wax-cured for 6days and thereafter soaked for 24 hours, and allowed to drain for 15 minutes. After testing in CBR machine, the average of the two readings was adopted. This procedure meets the provision of clause 6228 design criteria. FMW & H (1997).

3.4 Unconfined Compressive Strength – Mbo Residual Soil and Cement – Sand Composite

In this test the curing durations (the time of development reactions by cat-ions exchange and flocculation processes) of 7 and 28 days of cement – sand – residual soil composite were observed. Only residual soil samples no.1 and no.4 were deployed for this experiment. The cement content ranged from 2%, 4%, 6%, to 8%.The river sand content ranged from 10%, 20%, 30%, 40%, 50% to 60%. For each cement content, river sand was varied from 10%-60%. The residual soil made up the 100% weight per specimen. The sample was moisturized to OMC derived from the compaction tests. Each specimen was put into a mould (35mm diameter and 71mm height) weighed and subjected to compaction test using BS 2.5kg standard rammer. The specimens were wax cured for 7 and 28 days. After the curing duration each specimen was inserted into the UCS machine to determine the crushing strength at peak deflection.

IV. Presentation of Test Results

Table1: Unyeghe Residual Soil at Plain Condition (Locations 1 – 4)

Sample No	MDD (Kg/m^3)	NMC %	unsoaked CBR (%)	Fines (%)
1	1950	11.4	66	29
2	1980	10.1	60	30
3	1940	9.5	64	35
4	1960	10.7	61	33

Table 2: Unyeghe Residual Soil and Cement-Sand Stabilization -Sample Location No. 1

Cement Content (%)	Sand Content (%)	MDD (kg/m3)	OMC (%)	Soaked CBR (%)
2	0	1810	8.4	82
	10	2040	14.2	94
	20	2030	12.4	108
	30	2040	11.4	117
	40	2050	12.5	122
	50	2060	12.4	130
4	0	2060	13.8	73
	10	2050	10.5	96
	20	2060	12.4	109
	30	2070	9.9	118
	40	2100	10.5	128
	50	2080	10.5	136
6	0	2050	10.3	77
	10	2030	8.6	110
	20	2050	7.7	117
	30	2090	11	129
	40	2080	8.2	140
	50	2100	8.7	148
8	0	2050	14.7	70
	10	2030	6.7	114
	20	2060	6.5	130
	30	2090	6.7	140
	40	2080	12.6	152
	50	2020	6.4	145

Table 3: Unyeghe Residual Soil and Cement-Sand Stabilization-Sample Location No. 2

Cement Content (%)	Sand Content (%)	MDD (kg/m3)	OMC (%)	Soaked CBR (%)
2	0	2080	13.4	73
	10	2040	12.4	91
	20	2040	11.5	106
	30	2050	9.9	117
	40	2060	11.3	118
	50	2070	12.1	128
4	0	2070	11.3	79
	10	2050	9.1	102
	20	2050	10.5	109
	30	2070	9.9	118
	40	2090	10.2	126
	50	2120	10.9	137
6	0	2040	12.8	83
	10	2060	10.8	112
	20	2080	8.2	119
	30	2090	10.8	129
	40	2100	7.9	139
	50	2100	8.1	148
8	0	2070	13.6	96
	10	2070	8.6	115
	20	2100	7.2	129
	30	2090	8.6	141
	40	2040	13.6	151
	50	2120	9.2	166

Table 4: Unyeghe Residual Soil and Cement-Sand Stabilization-Sample Location No. 3

Cement Content (%)	Sand Content (%)	MDD (kg/m^3)	OMC (%)	Soaked CBR (%)
2	0	2060	11.4	79
	10	2050	12.4	101
	20	2050	12.5	113
	30	2060	10.2	120
	40	2070	10.8	134
	50	2080	10.4	138
4	0	2130	13.1	82
	10	2030	10.2	118
	20	2070	12.4	126
	30	2050	9.8	131
	40	2080	10.6	148
	50	2100	9.9	150
6	0	2050	11.8	87
	10	2040	8.3	117
	20	2080	7.9	120
	30	2060	12.5	135
	40	2090	8.5	145
	50	2090	8.4	162
8	0	2070	13.2	94
	10	2070	8.5	125
	20	2080	8.9	131
	30	2110	8.8	135
	40	2050	12.7	153
	50	2120	8.6	168

Table 5: UnyegheResidual Soil and Cement-Sand Stabilization Sample Location No. 4

Cement Content (%)	Sand Content (%)	MDD (kg/m^3)	OMC (%)	Soaked CBR (%)
2	0	2100	11.2	70
	10	2040	12.4	110
	20	2030	9.1	119
	30	2040	9.5	128
	40	2050	10.4	140
	50	2070	10.8	149
4	0	1940	12.3	81
	10	2040	10.7	107
	20	2050	12.6	124
	30	2060	10.4	135
	40	2080	10.8	140
	50	2100	11	152

6	0	2040	12.9	87
	10	2060	7.4	114
	20	2080	11.8	128
	30	2060	12.5	138
	40	2110	10.8	155
	50	2130	10.4	164
8	0	2060	15.1	95
	10	2060	9.8	117
	20	2090	9.6	130
	30	2120	9.4	148
	40	2060	10.3	162
	50	2140	9.2	174

Table 6: Unconfined Compressive Strength -Unyeghe Residual Soil and Cement Sand Composite at 7- Days Curing

Cement Content(%)	Sand Content(%)	Age (days)	Compressive Strength(KPa)
Sample Location 1			
2	10	7	80
	20	7	86
	30	7	115
	40	7	120
	50	7	105
	60	7	58
4	10	7	111
	20	7	125
	30	7	152
	40	7	165
	50	7	175
	60	7	177
6	10	7	171
	20	7	200
	30	7	212
	40	7	220
	50	7	243
	60	7	255
8	10	7	267
	20	7	280
	30	7	291
	40	7	299
	50	7	310
	60	7	321

Table 7: Unconfined Compressive Strength -Unyeghe Residual Soil and Cement Sand Composite at 7-Days Curing.

Cement Content (%)	Sand Content (%)	Age (days)	Compressive Strength(KPa)
Sample Location 4			
2	10	7	80
	20	7	88
	30	7	117
	40	7	124
	50	7	110
	60	7	60
4	10	7	117
	20	7	137
	30	7	154
	40	7	165
	50	7	169
	60	7	179
6	10	7	127
	20	7	164
	30	7	169
	40	7	178
	50	7	209
	60	7	236
8	10	7	262
	20	7	283
	30	7	299
	40	7	319
	50	7	338
	60	7	355

Table 8: Unconfined Compressive Strength – Unyeghe Residual Soil and Cement Sand Composite at 28- Days Curing.

Cement Content (%)	Sand Content (%)	Age (days)	Compressive Strength(KPa)
Sample Location 1			
2	10	28	144
	20	28	158
	30	28	178
	40	28	186
	50	28	183
	60	28	163
4	10	28	180
	20	28	204
	30	28	209
	40	28	230
	50	28	261
	60	28	285
6	10	28	221
	20	28	238
	30	28	284
	40	28	302
	50	28	313
	60	28	339
8	10	28	360
	20	28	372
	30	28	386
	40	28	396
	50	28	404
	60	28	410

Table 9: Unconfined Compressive Strength – Unyeghe Residual Soil and Cement Sand Composite at 28- Days Curing

Cement Content (%)	Sand Content (%)	Age (days)	Compressive Strength (KPa)
Sample Location 4			
2	10	28	152
	20	28	163
	30	28	177
	40	28	170
	50	28	146
	60	28	195
4	10	28	201
	20	28	210
	30	28	222
	40	28	232
	50	28	244
	60	28	233
6	10	28	262
	20	28	270
	30	28	278
	40	28	291
	50	28	333
	60	28	350
8	10	28	359
	20	28	366
	30	28	378
	40	28	396
	50	28	407
	60	28	418

V. Discussion of Test Results

Table 1 presents Unyeghe residual soil at plain condition. Tables 2-5 present Unyeghe residual soil composite stabilization with river sand and ordinary Portland cement from locations one to four. With 2% cement, 10% sand and 88% residual soil, the MDD and CBR values are 2040kg/m^3, 2040kg/m^3, 2050kg/m^3, 2040kg/m^3 and 94%, 91%, 101%, 110% respectively. Conversely with increase in cement content to 6%, 10% sand and 84% residual soil the MDD and CBR values are 2030kg/m^3, 2030kg/m^3, 2040kg/m^3, 2060kg/m^3 and 110%, 112%, 117%, 114% respectively. A further increase in cement content to 8%, 10% sand and 82% residual soil revealed yet another MDD and CBR values of 2030kg/m^3, 2050kg/m^3, 2070kg/m^3, 2060kg/m^3 and 114%, 115%, 125%, 117% respectively. Tables 6 to 7 presentUnyeghe residual soil with cement-sand composite at 7 days curing duration, while Tables 8 – 9 present same at 28 days curing. Results show variations from 80 – 355KPa for 7 days and 144 – 418KPa for 28 days curing. The OMC values in nearly all the sample locations vary between 8.6% to 14.2%. It is therefore instructive that with 2% cement and 10% river sand, Unyeghe residual soil could be stabilized for use as base course material. CBR results from the four sample locations i.e. 94%, 91%, 101% and 110% are reasonably above the minimum specified by FMW & H (1997) which is 80% soaked CBR.

VI. Multiple Nonlinear Regressed Models

From analysis and utilizing multiple regressed programs, some models were developed for Unyeghe residual soils at various levels of composite stabilization. These models aid prediction and optimization to determine for what values of independent variables the dependent variable is a maximum or minimum.

$$CBR_1 = 6.157 + 0.298C + 0.407S - 0.208D - 0.283W + 0.235C^2 + 0.336S^2 + 0.112D^2 + 0.161W^2 + 0.288CS - 0.177CD + 0.385CW - 0.393SD - 0.255SW - 0.165DW \quad (1.1)$$

Where C = cement content [%], S = river sand [%], D = maximum dry density [Mg/m^3], W = optimum moisture content [%]

$$CBR_2 = 22.706 + 0.664C - 0.228S + 0.102D - 0.162W + 0.183C^2 + 0.172S^2 - 0.466D^2 + 0.137W^2 - 0.222CS - 0.325CD + 0.170CW + 0.114SD - 0.258SW + 0.649DW \quad (1.2)$$

Where C = cement content [%], S = river sand [%], D = maximum dry density [Mg/m^3], W = optimum moisture content [%]

$$CBR_3 = 71.336 – 3.764C + 0.706S + 0.508D - 0.512W - 0.129C^2 - 0.338S^2 + 0.261D^2 - 0.458W^2 + 0.849CS - 0.191CD - 0.214CW - 0.342SD - 0.104SW - 0.269DW \quad (1.3)$$

Where C = cement content [%], S = river sand [%], D = maximum dry density [Mg/m^3], W = optimum moisture content [%]

$$UCS_1 = 15.007 + 0.472C - 0.544S - 0.258T -0 .926C^2 + .O79S^2 - 0.368T^2 - 0.129CS - 0.676CT + 0.778ST \quad (1.4)$$

Where C = cement content [%], S = river sand [%], T = duration [days],

$$UCS_2 = 24.679 + 0.365C + 0.419S - 0.239T + 0.202C^2 + 0.361S^2 + 0.085T^2 + 0.105CS - 0.130CT - 0.150ST \quad (1.5)$$

Where C = cement content [%], S = river sand [%], T = duration [days],

$$UCS_3 = 26.105 + 0.386C + 0.442S - 0.253T + 0.213C^2 + 0.382S^2 + 0.090ST + 0.112CS - 0.137CT - .158ST \quad (1.6)$$

Where C = cement content [%], S = river sand [%], T = duration [days],

Table10: Multiple Regressed Variables for Measured and Computed CBR Values Residual Soil and Cement - Sand Composite Stabilization (Location 1)

Cement Content (%)	Sand Content (%)	MDD (kg/m^3)	OMC (%)	Measured CBR (%)	Computed CBR (%)
Sample Location 1					
2	10	2.04	14.2	94	40.815
2	20	2.03	12.4	108	108.519
2	30	2.04	11.4	117	250.279
2	40	2.05	12.5	122	451.221

2	50	2.06	12.4	130	724.161
4	10	2.05	10.5	96	51.458
4	20	2.06	12.4	109	131.973
4	30	2.07	9.9	118	283.565
4	40	2.1	10.5	128	496.838
4	50	2.08	10.5	136	780.236
6	10	2.03	8.6	110	65.790
6	20	2.05	7.7	117	158.538
6	30	2.09	11	129	309.883
6	40	2.08	8.2	140	545.543
6	50	2.1	8.7	148	835.598
8	10	2.03	6.7	114	80.116
8	20	2.06	6.5	130	182.763
8	30	2.09	6.7	140	352.167
8	40	2.08	12.6	152	561.988
8	50	2.02	6.4	145	897.377

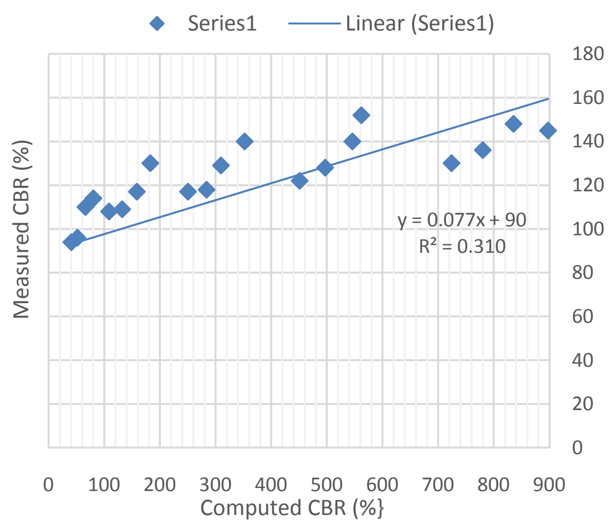

Fig.I. Cross Plot of Measured Vs Computed CBR Using Equation 1.1 (Location 1)

Table 11: Multiple Regressed Variables for Measured and Computed CBR Values Residual Soil and Cement - Sand Composite Stabilization (Location 2)

Sample Location 2					
Cement Content (%)	Sand Content (%)	MDD (kg/m^3)	OMC (%)	Measured CBR (%)	Computed CBR (%)
2	10	2.04	12.4	91	37.563
2	20	2.04	11.5	106	48.498
2	30	2.05	9.9	117	101.111
2	40	2.06	11.3	118	178.654
2	50	2.07	12.1	128	288.699
4	10	2.05	9.1	102	32.316
4	20	2.05	10.5	109	46.093
4	30	2.07	9.9	118	93.407
4	40	2.09	10.2	126	173.051
4	50	2.12	10.9	137	282.280
6	10	2.06	10.8	112	38.622
6	20	2.08	8.2	119	45.419
6	30	2.09	10.8	129	84.713
6	40	2.1	7.9	139	175.395
6	50	2.1	8.1	148	290.180
8	10	2.07	8.6	115	37.258
8	20	2.1	7.2	129	44.937
8	30	2.09	8.6	141	85.798
8	40	2.04	13.6	151	138.011
8	50	2.12	9.2	166	267.063

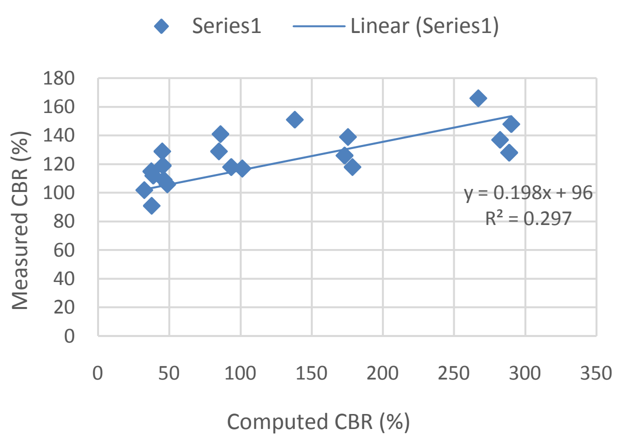

Fig.II: Cross Plot of Measured Vs Computed CBR Using Equation 1.2 (Location 2)

Table12: Multiple Regressed Variables for Measured and Computed CBR Values Residual Soil and Cement - Sand Composite Stabilization (location 3)

Sample Location 3					
Cement Content (%)	Sand Content (%)	MDD (kg/m^3)	OMC (%)	Measured CBR (%)	Computed CBR (%)
2	10	2.05	12.4	101	11.470
2	20	2.05	11.5	113	130.069
2	30	2.05	10.2	120	323.053
2	40	2.07	10.8	134	556.562
2	50	2.08	10.4	138	872.845
4	10	2.03	10.2	118	42.716
4	20	2.07	12.4	126	135.567
4	30	2.05	9.8	131	365.448
4	40	2.08	10.6	148	612.991
4	50	2.1	9.9	150	951.213
6	10	2.04	8.3	117	66.898
6	20	2.08	7.9	120	215.000
6	30	2.06	12.5	135	358.811
6	40	2.09	8.5	145	697.348
6	50	2.09	8.4	162	1045.090
8	10	2.07	8.5	125	65.871
8	20	2.08	8.9	131	221.087
8	30	2.11	8.8	135	449.656
8	40	2.05	12.7	153	680.505
8	50	2.12	8.6	168	1110.656

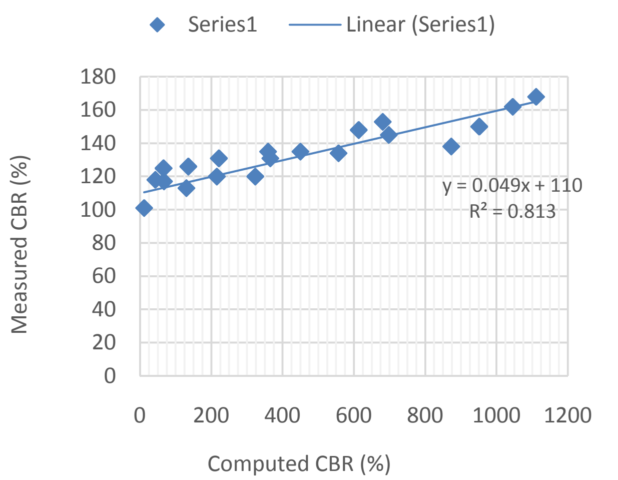

Fig.III.: Cross Plot of Measured Vs Computed CBR Using Equation 1.3 { Location3)

Table 13: Multiple Regressed Variables for Measured and Computed UCS Values Residual Soil and Cement - Sand Composite Stabilization at 7 Days Curing (location 1)

Sample Location 1				
Cement Content (%)	Sand Content (%)	Duration (days)	Measured UCS (KPa)	Computed UCS (KPa)
2	10	7	80	37.285
2	20	7	86	107.425
2	30	7	115	193.365
2	40	7	120	295.105
2	50	7	105	412.645
2	60	7	58	545.985
4	10	7	111	15.073
4	20	7	125	82.633
4	30	7	152	165.993
4	40	7	165	265.153
4	50	7	175	380.113
4	60	7	177	510.873
6	10	7	171	-14.547
6	20	7	200	50.433
6	30	7	212	131.213
6	40	7	220	227.793
6	50	7	243	340.173
6	60	7	255	468.353
8	10	7	267	-51.575
8	20	7	280	10.825
8	30	7	291	89.025
8	40	7	299	183.025
8	50	7	310	292.825
8	60	7	321	418.425

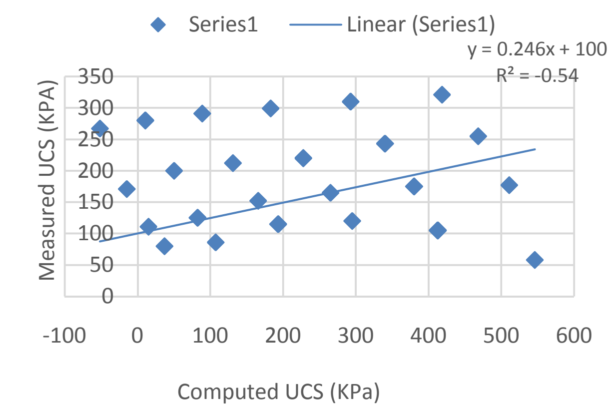

Fig.IV Cross Plot of Measured Vs Computed CBR Using Equation 1.4 (Location 1)

Table 14: Multiple Regressed Variables for Measured and Computed UCS Values - Residual Soil and Cement - Sand Composite Stabilization at 28 Days Curing (location 1)

Sample Location 1				
Cement Content (%)	Sand Content (%)	Duration (days)	Measured UCS (KPa)	Computed UCS (KPa)
2	10	28	144	79.745
2	20	28	158	152.335
2	30	28	178	297.125
2	40	28	186	514.115
2	50	28	183	803.305
2	60	28	163	1164.695
4	10	28	180	77.719
4	20	28	204	152.409
4	30	28	209	299.299
4	40	28	230	518.389
4	50	28	261	809.679
4	60	28	285	1173.169
6	10	28	221	77.309
6	20	28	238	154.099
6	30	28	284	303.089
6	40	28	302	524.279
6	50	28	313	817.669
6	60	28	339	1183.259
8	10	28	360	78.515
8	20	28	372	157.405
8	30	28	386	308.495
8	40	28	396	531.785
8	50	28	404	827.275
8	60	28	410	1194.965

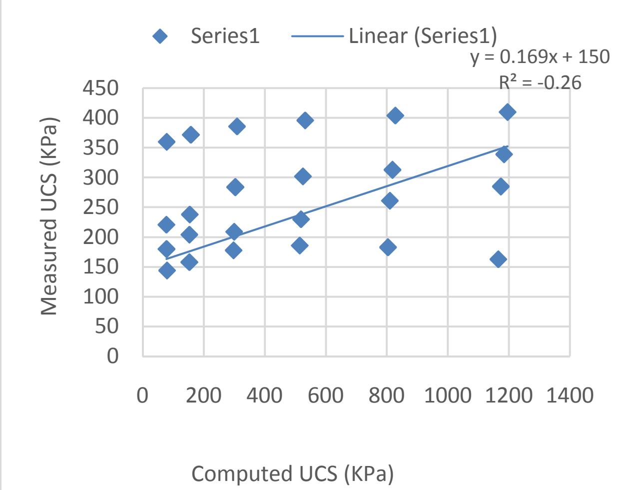

Fig.V. Cross Plot of Measured Vs Computed UCS Using Equation 1.5 (Location 1)

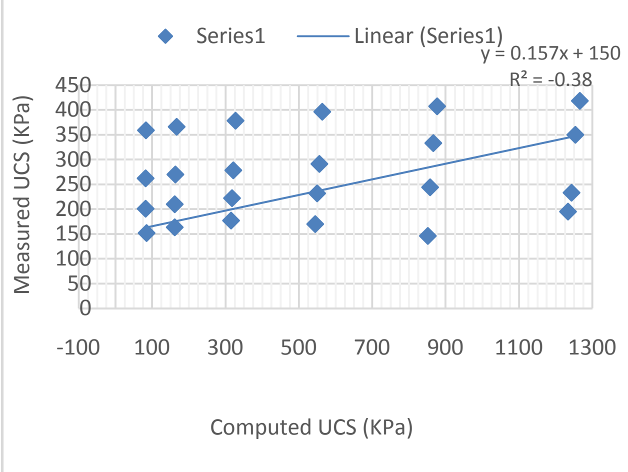

Fig.VI. cross Plot of Measured Vs Computed UCS Using Equation 1.6 (location 4)

Fig.15: Multiple Regressed Variables for Measured and Computed UCS Values - Residual Soil and Cement - Sand Composite Stabilization at 28 Days Curing (location 4)

Sample Location 4				
Cement Content (%)	Sand Content (%)	Duration (days)	Measured UCS (KPa)	Computed UCS (KPa)
2	10	28	152	84.545
2	20	28	163	161.565
2	30	28	177	314.985
2	40	28	170	544.805
2	50	28	146	851.025
2	60	28	195	1233.645
4	10	28	201	82.441
4	20	28	210	161.701
4	30	28	222	317.361
4	40	28	232	549.421
4	50	28	244	857.881
4	60	28	233	1242.741
6	10	28	262	82.041
6	20	28	270	163.541
6	30	28	278	321.441
6	40	28	291	555.741
6	50	28	333	866.441
6	60	28	350	1253.541
8	10	28	359	83.345
8	20	28	366	167.085
8	30	28	378	327.225
8	40	28	396	563.765
8	50	28	407	876.705
8	60	28	418	1266.045

VII. Conclusion

Tables 10 to 12 present multiple regressed variables for measured and computed values of CBR. Results vary from 94 - 168 KPa and 40 – 1110 KPa for measured and computed values respectively. Tables 13 presents the multiple regressed variables for measured and computed UCS values for 7 days curing. Results vary from 80 – 321 KPa and 37 – 418 KPa respectively while Tables 14 to 15 shows the UCS values for 28 days curing duration. Results vary from 144 – 418KPa and 79 – 1266KPa for measured and computed values.

The models 1.1 to 1.3 revealed that with 2% cement, 30% river sand and 68% residual soil the measured and computed CBR values are 117%/250% and 120%/323% at locations 1 and 3 respectively. These values are above recommended minimum specified by the FMW &H [1997] code.

Models 1.4 to 1.6 deal with the UCS parameter. The measured and computed compressive strength values show significant variations for all durations [7 and 28 days] of curing. For instance a 2%/30% cement/ sand content revealed a 7/28 days compressive strength as 115/178 kPa and 193/297 kPa for measured and computed values respectively. By implication the curing duration influences strength development.

The accuracy and reliability of the models 1.1 to 1.6 were checked by comparing the computed and measured values of the CBR and UCS and computing the correlation coefficients. Figures I to VI illustrate the computed and measured values based on non-linear regressed models. The models could further be optimized by subjecting the coefficients of the input variables to basic iteration. The straight line in the figure represents the line of perfect equality where the values being compared are exactly equal.

The correlation coefficients R^2 at 95% confidence interval are 0.310, 0.297,0.813 and -0.54, -0.26, -0.38 for CBR and UCS with cement content at 2% - 8% and river sand content at 10% - 60%. These values are statistically

International Journal of Engineering Innovation & Research
Volume 3, Issue 6, ISSN: 2277 – 5668

significant and therefore suggest that the measured and computed values of CBR and UCS are compatible.

ACKNOWLEDGMENT

The author would like to acknowledge the contribution of Esudo Engineering Ventures for support rendered in the course of this research.

REFERENCES

[1] Stavridakis, E.I. "Presentation and Assessment of Clay influence on Engineering Parameters of Cement Treated Clayey Mixtures" Electronic Journal of Geotechnical Engineering, 2005, Vol. 10.

[2] Thurairajah, A., Silver, S. and Loganathan, N. "Strength Correlation Factor for Residual Soil. J. GeotechniqueEngrg., 1992, Vol.118, issue 4, pp 593-610

[3] Muntohar, A. S.,and Hantoro, G. Influence of Rice Husk Ash and Lime on Engineering Properties of Clayey Subgrade. Electronic Journal of Geotechnical Engineering 2000, paper 094.

[4] Bergado, Soil Compaction and Soil Stabilization by Admixtures. Proc. of Seminar on Ground Improvement Application to Indonesian Soft Soil, Indonesia, Jakarta 1996, pp 23-26.

[5] Porbaha, A. "State-of-the art in Deep Mixing Technology, Design Considerations". Ground Improvement 2000, vol. 4, pp 111-125

AUTHOR'S PROFILE

Dr. Essien Udo

Dr. Udo holds a PhD in Geotechnical Engineering. He has industry experience in the analysis, design and supervision of Civil Engineering projects as a Consultant. He is currently a LECTURER 1 with the Department of Civil Engineering, University of Uyo, Nigeria.

Dr. Udo is a member of the Nigerian Society of Engineers, Member of Council for the Regulation of Engineering in Nigeria. He has been a researcher for the past five years and has published academic articles in International Journals such as NSE Technical Transactions, Electronic Journal of Geotechnical Engineering, Research Journal in Engineering and Applied Sciences, IOSR Journal of Mechanical and Civil Engineering.

Email: essienau2006@yahoo.com

Ndifreke Udoh

Mr. Udoh holds a MSc in Geotechnics (with Distinction) jointly from the Universities of Strathclyde and Glasgow, United Kingdom and a B.Eng in Civil Engineering from the University of Uyo, Nigeria.

He has industry experience spanning Oil and gas project management and Civil Engineering projects and is currently a LECTURER II in the Department of Civil Engineering, University of Uyo, Uyo in Nigeria, where he is involved in teaching and research. He teaches courses in Geotechnical Engineering and Computer applications in Civil Engineering.

Mr. Udoh is a member of the Nigerian Society of Engineers.

Email: ndiudoh@gmail.com

Engr. Charles Kennedy

(PG Student), Engr. Kennedy holds a Post Graduate Diploma in Civil Engineering from Rivers State University of Science and Technology, Port Harcourt and a HND in Civil Engineering Technology (With distinction) from the Rivers State Polytechnic, Bori, Nigeria. He is currently pursuing a Masters degree in Geotechnical Engineering in University of Uyo.

He is versatile and knowledgeable in the use of various Civil Engineering software and has a vast industry experience in Structural analysis and in design and management of Civil Engineering projects. He is currently a PRINCIPAL INSTRUCTOR with the Department of Civil Engineering, Rivers State polytechnic, Bori, Nigeria.

Engr. Kennedy is a member of the Nigerian Society of Engineers, Member of Council for the Regulation of Engineering in Nigeria, and an associate member of American Society of Engineers.

Email: ken_charl@yahoo.co.uk