Investigation And Model Prediction Of Cbr And Ucs Parameters Of Composite Stabilized Orukim Residual Soils, Akwa Ibom State, Nigeria.

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***Abstract*—Cement and river sand were deployed for this laboratory stabilization experiments. The objective was to ascertain the response of Orukim residual soils to various levels of composite stabilization and the structural behaviour in engineering applications. The major goal of treating residual soil is to increase the shear strength and load bearing capacity. Four different residual soil samples from four distinct borrow pits were utilized for this investigation. The cement content varied from 2% to 8% while river sand content varied from 10% to 60%. For the purpose of model formulations the cement content was restricted to 6% and river sand content to 40% for CBR and 4% cement content to 40% river sand content for UCS. The CBR obtained ranged from 85%-145% and 71%-178% for measured and computed values respectively. The UCS values varied from 69kPa-189kPa and 122kPa-260kPa for 7 and 28 days curing durations respectively. It must be noted that the contribution of hydrated calcium silicate [$C_2S_xH_X.C_3S_2H_X$] and calcium aluminate [$C_2AH_X.C_4AH_X$] in cement tend to increase the bonding between particulate structures and in concert with fines from river sand contribute to plasticity reduction in residual soil hence gaining in strength propagation. Finally multiple nonlinear regressed models were developed to aid prediction and optimization of CBR and UCS parameters of Orukim residual soils at various levels of composite stabilization.**

***Keywords* - residual soil; cement; composite stabilization; river sand;**

I. INTRODUCTION

A. Cement–River Sand Stabilization

This is a composite process. In this process, the amount of cement to be added to the river sand and residual soil is determined by conducting laboratory experiments. The objective is to achieve comparatively higher CBR values on sub base and base course materials applications. Having determined the quantity of cement and river sand required the mixing can be carried out either on the site (site -mixing) or in a central plant (plant mixing). In site mixing, the cement is usually delivered in bulk in dump or hopper trucks and spread by a spreader box or some other type of equipment that will provide a uniform amount over the pulverized soil. Enough water is then added to achieve a moisture content that is one per cent or two per cent higher than the optimum required for compaction, and the soil, river sand-cement and water are properly blended to obtain uniform moisture of soil, river-sand, and cement. Blending at moisture content slightly higher than the compaction optimum moisture content allows for loss of water by evaporation during the mixing and compaction processes. Soil, cement-river sand mixing is used in several applications as a more economical or improved performance alternative to some other geosystem methods. The improvement of the properties of cement treated soil has been attributed to the soil-cement reaction[2] which produces primary and secondary cementitious materials in the soil-cement matrix.[3]

II. MATERIALS SELECTED

A. 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[4]. The sand is observed to have a D60 grain diameter at 60% passing equal to 1.00mm, D30 grain diameter at 30% passing equal to 0.525mm and D10 grain at 10% passing equal to 0.250mm.

B. Orukim Residual Soil

Four soil samples from four distinct borrow pits were selected for this research. The samples were dug with shovels bearing in mind the variability of residual soils in its natural composition. The samples were excavated both vertically and horizontally and thoroughly blended. The sample locations are identified as shown:

Sample Identification	***Location***
1	Km 1+075 Orukim Bridge
2	Km 3+025 Orukim – Unyeghe road
3	Km 6+175 Orukim – Eto Essek road
4	Km11+150 Orukim – Okposi road

The samples were conveyed in four, 50kg nylon bags, carefully tagged for identification purpose and transported to Mothercat Ltd, Materials Testing Laboratory at Uyo.

C. 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, Akwa Ibom State. Cement stabilization is mostly applicable to road stabilization and fills especially when the moisture content of the sub-grade is very high[5].Ordinary Portland Cement particle is a heterogeneous substance, containing minute tri-calcium silicate (C_3S), di-calcium silicate (C_2S), tri-calcium aluminate (C_3A) and solid solution described as tetra calcium alumino-ferrite (C_4A). When the pore water of the soil encounters with cement, hydration of the cement occurs rapidly and the major hydration (primary cementitions) produces hydrated calcium silicate (C_2SHx, C_4AHx) and hydrated lime Ca $(OH)_2$.[6]. In the case of residual soils addition of inorganic chemical such as cement has a two-fold effect on the soil which is acceleration and promotion of chemical bonding.

III. PREPARATION AND TESTING OF SAMPLES

A. Plain Mechanical Compaction Tests

This test Plain Mechanical Compaction Tests 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.

B. Cement-River Sand Stabilization Tests.

The four residual soil samples were utilised in this experiment. The percentage of cement ranged from 2%, 4%, 6% and 8%. The percentage of river sand ranged from 10%, 20%, 30%, 40%, 50% to 60%. For each cement content the percentage or proportion of residual soil complemented the 100% level. 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[7]. The mixture was thoroughly blended and moisturised 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 6days and thereafter soaked for 24 hours, and allowed to drain for 15minutes. 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)[8].

C. 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 II 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. 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 15minutes. After testing in CBR machine, the average of the two readings was adopted. CBR gives the relative strength of a soil with respect to crushed rock, which is considered an excellent coarse base material. The main criticism of the CBR test is that it does not correctly simulate the shearing

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forces imposed on sub-base and sub-grade materials as they support highway pavement.

D. Unconfined Compression Test

Unconfined Compression Test is a triaxial test in which the axial load is applied to a specimen under zero all round pressure. This test is applicable only for testing intact fully saturated soils i.e. only on saturated samples which can stand without any lateral support. By implication the test is applicable to cohesive soils only. The test is an undrained test and is based on the assumption that there is no moisture loss during the test. The unconfined compression test is one of the tests used for the determination of the undrained shear strength of cohesive soils. In this test no radial stress is applied to the sample and the plunger load is increased rapidly until the soil sample fails. The loading is applied quickly so that pore water cannot drain from the soil; the sample is sheared at constant volume.

IV. PRESENTATION OF TEST RESULTS

Table I: Orukim Residual Soil Compaction at Plain Condition

Sample No.	***MDD (Kg/m^3)***	***NMC (%)***	***unsoaked CBR (%)***	***Fines (%)***
1	1940	9.5	64	35
2	1960	10.7	61	33
3	2020	10.2	60	37
4	1980	10.5	61	31

Table II: Cement- Sand Stabilization CBR Results - Sample Location 1

Cement Content (%)	***Sand Content (%)***	***MDD (kg/m^3)***	***OMC (%)***	***Soaked CBR (%)***
2	10	2100	11.2	83
	20	2040	12.4	120
	30	2030	9.1	129
	40	2040	9.5	138
	50	2050	10.4	150
	60	2070	10.8	159
4	10	1940	12.3	91
	20	2040	10.7	117
	30	2050	12.6	134
	40	2060	10.4	145
	50	2080	10.8	150
	60	2100	11	162
6	10	2040	12.9	97
	20	2060	7.4	124
	30	2080	11.8	138
	40	2060	12.5	148
	50	2110	10.8	165
	60	2130	10.4	174
	10	2060	15.1	105
	20	2060	9.8	127
	30	2090	9.6	140
8	40	2120	9.4	158
	50	2060	10.3	172
	60	2140	9.2	184

Table III: Cement- Sand Stabilization CBR Results - Sample Location 2

Cement Content (%)	***Sand Content (%)***	***MDD (kg/m^3)***	***OMC (%)***	***Soaked CBR (%)***
2	10	2060	11.4	88
	20	2050	12.4	111
	30	2050	12.5	123
	40	2060	10.2	130
	50	2070	10.8	144
	60	2080	10.4	148
4	10	2130	13.1	92
	20	2030	10.2	128
	30	2070	12.4	136
	40	2050	9.8	141
	50	2080	10.6	158
	60	2100	9.9	160
6	10	2050	11.8	97
	20	2040	8.3	127
	30	2080	7.9	130
	40	2060	12.5	145
	50	2090	8.5	155
	60	2090	8.4	172
8	10	2070	13.2	104
	20	2070	8.5	135
	30	2080	8.9	141
	40	2110	8.8	145
	50	2050	12.7	163
	60	2120	8.6	178

Table IV: Cement- Sand Stabilization CBR Results - Sample Location 3

Cement Content (%)	Sand Content (%)	MDD (kg/m3)	OMC (%)	Soaked CBR (%)
2	10	2080	13.4	85
	20	2040	12.4	101
	30	2040	11.5	116
	40	2050	9.9	127
	50	2060	11.3	128
	60	2070	12.1	138
4	10	2070	11.3	89
	20	2050	9.1	112
	30	2050	10.5	119
	40	2070	9.9	128
	50	2090	10.2	136
	60	2120	10.9	147
6	10	2040	12.8	93
	20	2060	10.8	122
	30	2080	8.2	129
	40	2090	10.8	139
	50	2100	7.9	149
	60	2100	8.1	158
8	10	2070	13.6	106
	20	2070	8.6	125
	30	2100	7.2	139
	40	2090	8.6	151
	50	2040	13.6	161
	60	2120	9.2	176

Table V: Cement- Sand Stabilization CBR Results - Sample Location 4

Cement Content (%)	Sand Content (%)	MDD (kg/m3)	OMC (%)	Soaked CBR (%)
2	10	1810	8.4	90
	20	2040	14.2	104
	30	2030	12.4	118
	40	2040	11.4	127
	50	2050	12.5	132
	60	2060	12.4	140
4	10	2060	13.8	83
	20	2050	10.5	106
	30	2060	12.4	119
	40	2070	9.9	128
	50	2100	10.5	138
	60	2080	10.5	146
6	10	2050	10.3	87
	20	2030	8.6	120
	30	2050	7.7	127
	40	2090	11	139
	50	2080	8.2	150
	60	2100	8.7	158
8	10	2050	14.7	80
	20	2030	6.7	124
	30	2060	6.5	140
	40	2090	6.7	148
	50	2080	12.6	162
	60	2020	6.4	175

Table VI: Cement-Sand Stabilization UCS Results at 7 Days Curing Duration

Cement Content (%)	Sand Content (%)	Duration (days)	Compressive Strength (KPa)
Sample Location 2			
2	10	7	69
	20	7	75
	30	7	104
	40	7	111
	50	7	95
	60	7	55
4	10	7	101
	20	7	115
	30	7	142
	40	7	154
	50	7	164
	60	7	172
6	10	7	160
	20	7	189
	30	7	202
	40	7	210
	50	7	232
	60	7	243
8	10	7	255
	20	7	270
	30	7	281
	40	7	289
	50	7	311
	60	7	318

Table VII: Cement-Sand Stabilization UCS Results at 7 Days Curing Duration

Cement Content (%)	Sand Content (%)	Duration (days)	Compressive Strength (KPa)
Sample Location 4			
2	10	7	71
	20	7	78
	30	7	92
	40	7	94
	50	7	101
	60	7	108
4	10	7	111
	20	7	126
	30	7	144
	40	7	155
	50	7	161
	60	7	169
6	10	7	117
	20	7	153
	30	7	159
	40	7	167
	50	7	200

	60	7	226
8	10	7	253
	20	7	274
	30	7	289
	40	7	310
	50	7	327
	60	7	344

Table VIII: Cement-Sand Stabilization UCS Results at 28 Days Curing Duration

Cement Content (%)	***Sand Content (%)***	***Duration (days)***	***Compressive Strength KPa)***
Sample Location 2			
2	10	28	122
	20	28	138
	30	28	157
	40	28	166
	50	28	163
	60	28	143
4	10	28	162
	20	28	185
	30	28	193
	40	28	213
	50	28	241
	60	28	267
6	10	28	202
	20	28	218
	30	28	264
	40	28	286
	50	28	301
	60	28	320
8	10	28	340
	20	28	352
	30	28	366
	40	28	375
	50	28	383
	60	28	394

Table IX: Cement-Sand Stabilization UCS Results at 28 Days Curing Duration

Cement Content (%)	***Sand Content (%)***	***Duration (days)***	***Compressive Strength (KPa)***
Sample Location 4			
2	10	28	132
	20	28	143
	30	28	156
	40	28	170
	50	28	146
	60	28	195
4	10	28	200
	20	28	210
	30	28	221
	40	28	232
	50	28	244
	60	28	233
6	10	28	252
	20	28	260
	30	28	268
	40	28	281
	50	28	303
	60	28	310
8	10	28	328
	20	28	336
	30	28	346
	40	28	355
	50	28	373
	60	28	388

V. DISCUSSION OF TEST RESULTS

Table 1 presents Orukim residual soil compaction at unstabilized or plain condition. The MDD and NMC varies from 1940kg/m^3 – 1980kg/m^3 and 9.5% - 10.7% respectively. The CBR values vary from 64% - 61% within the four locations. Tables 2 to 6 present the residual soil with cement-sand composite stabilization from the four distinct borrow pits. From all the samples and deploying 2% cement content, 20% river sand and 78% residual soil the MDD and CBR values are 2040kg/m^3, 2050kg/m^3, 2040kg/m^3, 2040kg/m^3 and 120%, 111%, 101%, 104% respectively. With increase in cement content to 6% and reduced river sand content to10% and residual soil at 84% the resulting MDD and CBR values are 2040kg/m^3, 2050kg/m^3, 2040kg/m^3, 2050kg/m^3 and 97%, 97%, 93%, 87% respectively. A further increase in cement content to 8%, river sand 10% and residual soil 82% yields the following MDD and CBR values; 2060kg/m^3. 2070kg/m^3. 2070kg/m^3, 2050kg/m^3 and 105%, 104%, 106%, 80% respectively. Tables 6 and 7 present the UCS values of samples from locations 2 and 4 at curing duration of 7 days while Tables 8 and 9 show the values resulting from 28 days curing duration. The UCS results indicate variations from 69kPa – 344kPa for 7 days curing and 122kPa – 394kPa for 28 days curing. In all the samples the OMC values vary from 7.9% to 14.7%. It is therefore pertinent to note that with 2% cement, 20% river sand, Orukim residual soil could be stabilized for use as base course material in engineering applications. The CBR values from the four locations; 120%, 111%, 101% and 104% are reasonably above recommended minimum of 80% by the FMW&H (1997) specification.

VI. MULTIPLE NONLINEAR REGRESSED MODELS

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

CBR_2 = 21.217 - 1.016C - .073S +.723D - .807M - .881C^2 + .047S^2 - .342D^2 + .278M^2 + .362CS +

.494CD +.649CM +.339SD + .081SM + .361DM….1.1

Where C = cement content [%], S = River sand content [%], D =Maximum dry density [kg/m^3], M = Optimum moisture content [%]

CBR_3 =10.861 - 0.138C - .359S + 0.114D - 0.149M - 0.694C^2 - 0.016S^2 + 0.577D^2 + 0.196M^2 + 0.942CS - 0.754CD + 0.712CM + 0.251SD + 0.102SM - 0.753DM……………………………………………1.2

Where C = cement content [%], S = River sand content [%], D =Maximum dry density [kg/m^3], M = Optimum moisture content [%]

$UCS_{7(2)}$ = 25.831 + 0.479C +0.583S - 0.226T - 0.943C^2 - 0.102S^2 + 0.323T^2 - 0.137CS - 0.685CT + 0.834ST…………………..………..……………....1.3

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

$UCS_{7(4)}$ = 24.157 +0.448C + 0.545S - 0.212T - 0.882C^2 - 0.095S^2 + 0.302T^2 - 0.128CS - 0.641CT + 0.779ST………………….…..……………………..1.4

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

$UCS_{28(2)}$ = 9.271 +0.783C + 0.323S + 0.412T - 0.139C^2 + 0.089S^2 + 0.147T^2 + 0.262CS +0.279CT - 0.115ST…………..…………………………………1.5

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

$UCS_{28(4)}$ = 10.431 + 0.881C + 0.363S + 0.463T - 0.157C^2 + 0.101S^2 + 0.165T^2 +0.295CS + 0.314CT - 0.129ST……...…………………………………….1.6

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

Table X: Multiple Regressed Variables for Measured and Computed CBR Values- Residual Soil, Cement-Sand Stabilization – Sample Location 2

Cement Content (%)	River Sand Content (%)	MDD (kg/m^3)	OMC (%)	Soaked CBR (%)	Computed CBR (%)
2	10	2.06	11.4	88	88.796
	20	2.05	12.4	111	101.364
	30	2.05	12.5	123	135.486
	40	2.06	10.2	130	156.514
4	10	2.13	13.1	92	118.182
	20	2.03	10.2	128	83.929
	30	2.07	12.4	136	134.837
	40	2.05	9.8	141	152.855
6	10	2.05	11.8	97	109.022
	20	2.04	8.3	127	71.312
	30	2.08	7.9	130	98.898
	40	2.06	12.5	145	178.334
8	10	2.07	13.2	104	125.171
	20	2.07	8.5	135	72.831
	30	2.08	8.9	141	105.943

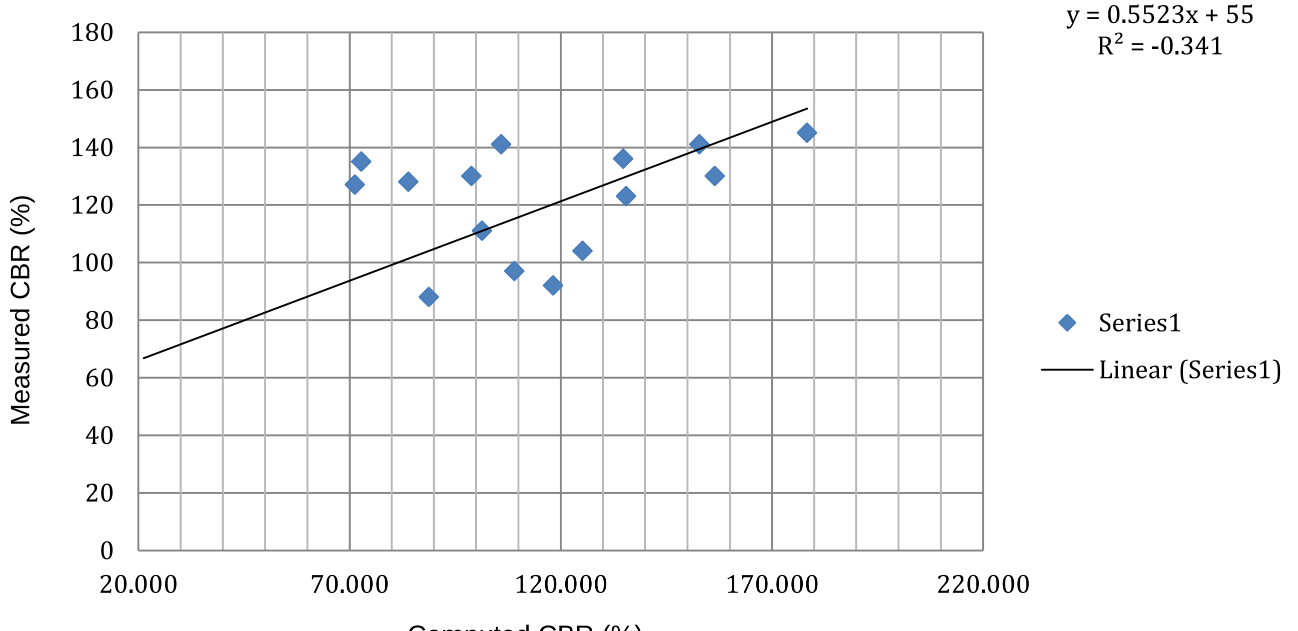

Fig.I : Cross Plot of Measued Vs Computed CBR Values Using Equation 1.1

Table XI: Multiple Regressed Variables for Measured and Computed CBR Values – Residual Soil, Cement-Sand Stabilization – Sample Location 3

Cement Content (%)	*River Sand Content (%)*	*MDD (kg/m^3)*	*OMC (%)*	*Soaked CBR (%)*	*Computed CBR (%)*
2	10	2.08	13.4	85	71.236
	20	2.04	12.4	101	44.693
	30	2.04	11.5	116	45.418
	40	2.05	9.9	127	36.986
4	10	2.07	11.3	89	82.794
	20	2.05	9.1	112	29.622
	30	2.05	10.5	119	39.752
	40	2.07	9.9	128	37.088
6	10	2.04	12.8	93	113.185
	20	2.06	10.8	122	36.837
	30	2.08	8.2	129	28.293
	40	2.09	10.8	139	42.963
8	10	2.07	13.6	106	135.294
	20	2.07	8.6	125	27.735
	30	2.1	7.2	139	24.022

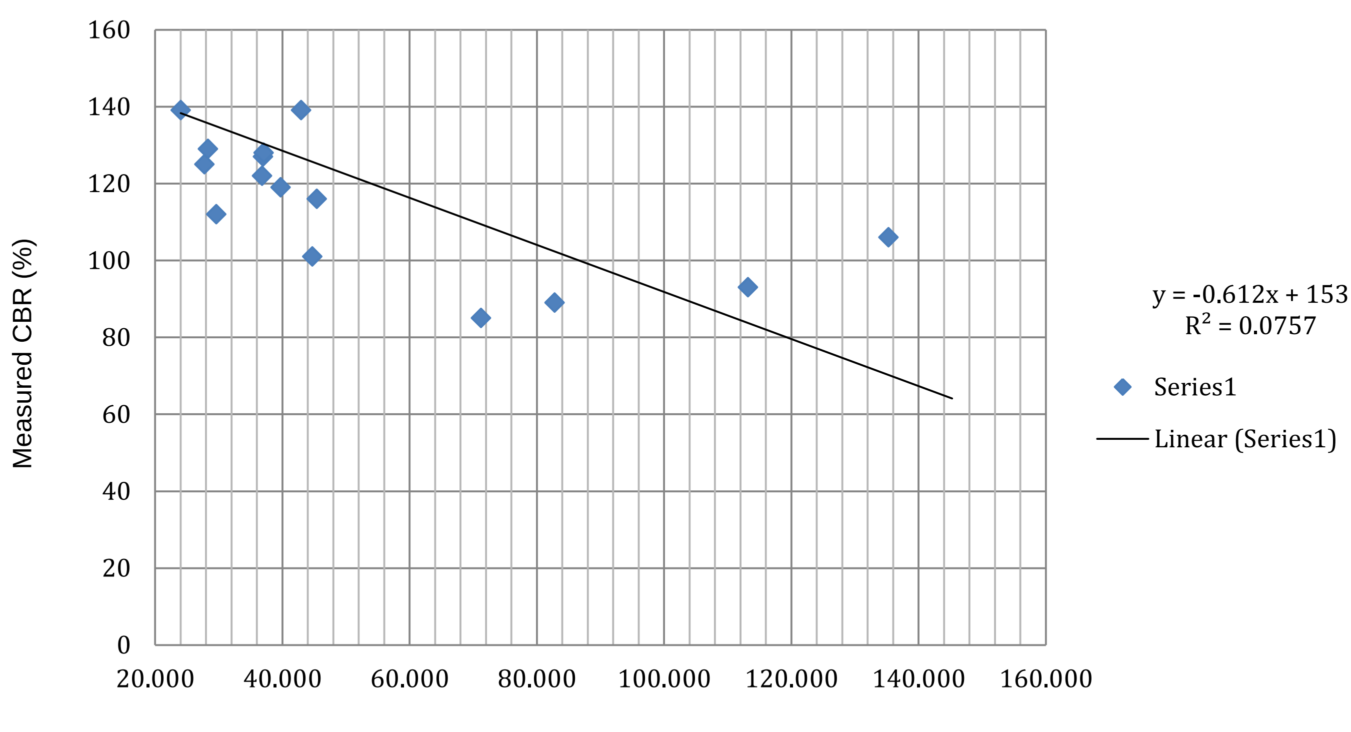

Fig.II: Cross Plot of Measured Vs Computed CBR Values Using Equation 1.2

Table XII: Multiple Regressed Variables for Measured and Computed UCS Values – Residual Soil, Cement-Sand Stabilization – Sample Location 2

Cement Content (%)	*Sand Content (%)*	*Duration (days)*	*Measured UCS (KPa)*	*Computed UCS (KPa)*
2	10	7	69	78.942
2	20	7	75	109.812
2	30	7	104	120.282
2	40	7	111	110.352
2	10	7	101	78.942
2	20	7	115	109.812
4	30	7	142	92.114
4	40	7	154	79.444
4	10	7	160	56.254
4	20	7	189	84.384

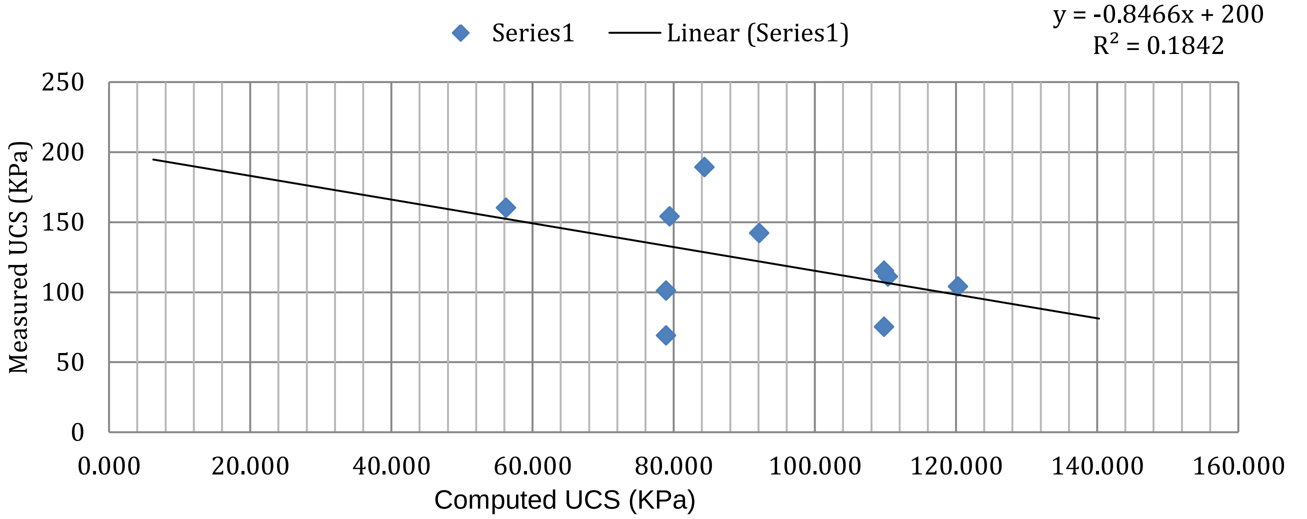

Fig. III: Cross Plot of Measured Vs Computed UCS Values Using Equation 1.3

Table XIII: Multiple Regressed Variables for Measured and Computed UCS Values – Residual Soil, Cement-Sand Stabilization – Sample Location 4

Cement Content (%)	***Sand Content (%)***	***Duration (days)***	***Measured UCS (KPa)***	***Computed UCS (KPa)***
2	10	7	71	73.785
2	20	7	78	102.705
2	30	7	92	112.625
2	40	7	94	103.545
2	10	7	111	73.785
2	20	7	126	102.705
4	30	7	144	86.283
4	40	7	155	74.643
4	10	7	117	52.563
4	20	7	153	78.923

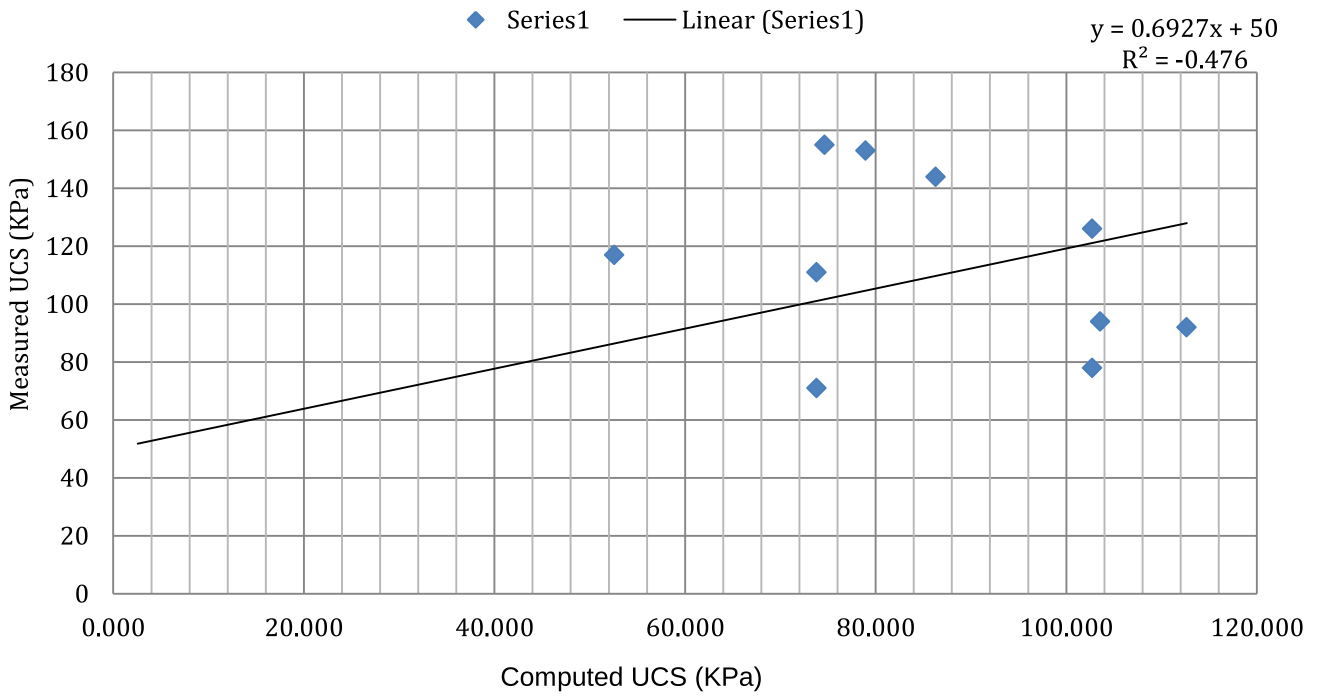

Fig. IV: Cross plot of measured Vs Computed UCS Values using Equation 1.4

Table XIV: Multiple Regressed Variables for Measured and Computed UCS Values – Residual Soil, Cement-Sand Stabilization – Sample Location 2

Cement Content (%)	*Sand Content (%)*	*Duration (days)*	*Measured UCS (KPa)*	*Computed UCS (KPa)*
2	10	28	122	127.379
2	20	28	138	119.869
2	30	28	157	130.159
2	40	28	166	158.249
2	10	28	162	127.379
2	20	28	185	119.869
4	30	28	193	129.961
4	40	28	213	152.811
4	10	28	202	137.661
4	20	28	218	124.911

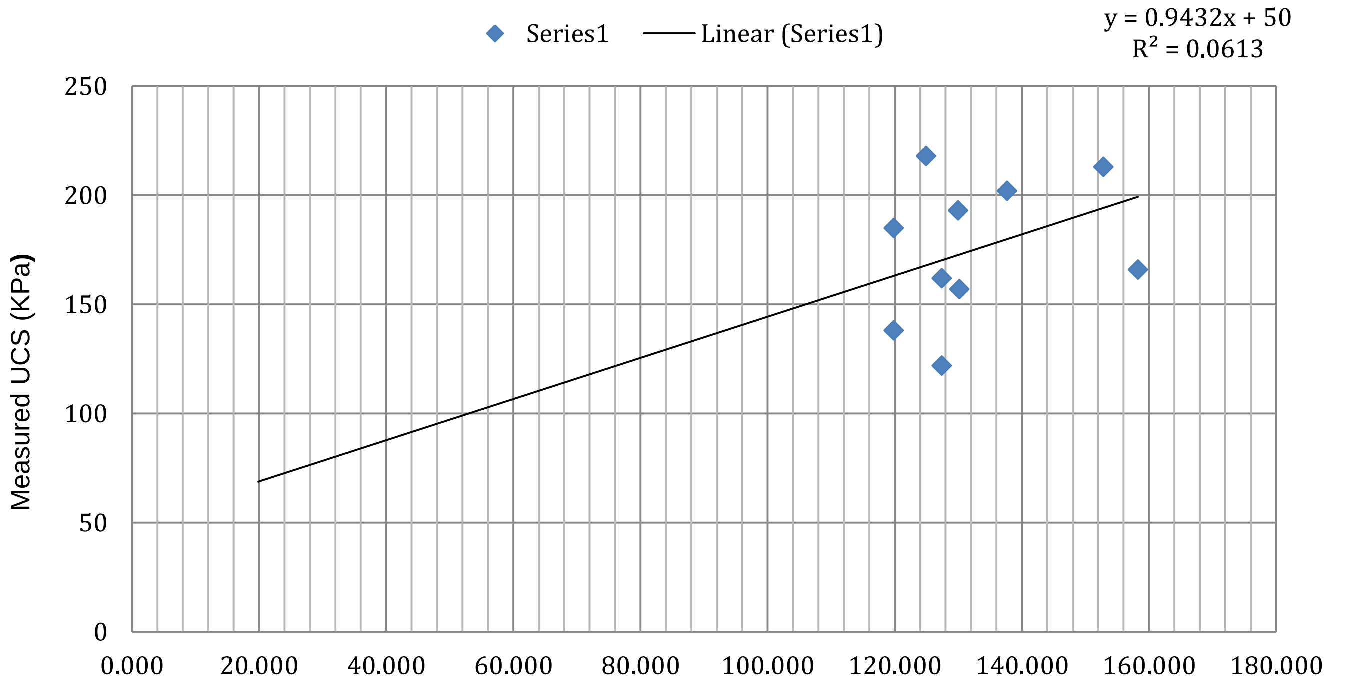

Fig V: Cross Plot of Measured Vs Computed UCS Values Using Equation 1.5

Table XV: Multiple Regressed Variables for Measured and Computed UCS Values – Residual Soil, Cement-Sand Stabilization – Sample Location 4

Cement Content (%)	*Sand Content (%)*	*Duration (days)*	*Measured UCS (KPa)*	*Computed UCS (KPa)*
2	10	28	132	143.183
2	20	28	143	135.093
2	30	28	156	147.203
2	40	28	170	179.513
2	10	28	200	143.183
2	20	28	210	135.093
4	30	28	221	146.965
4	40	28	232	173.375
4	10	28	252	154.745
4	20	28	260	140.755

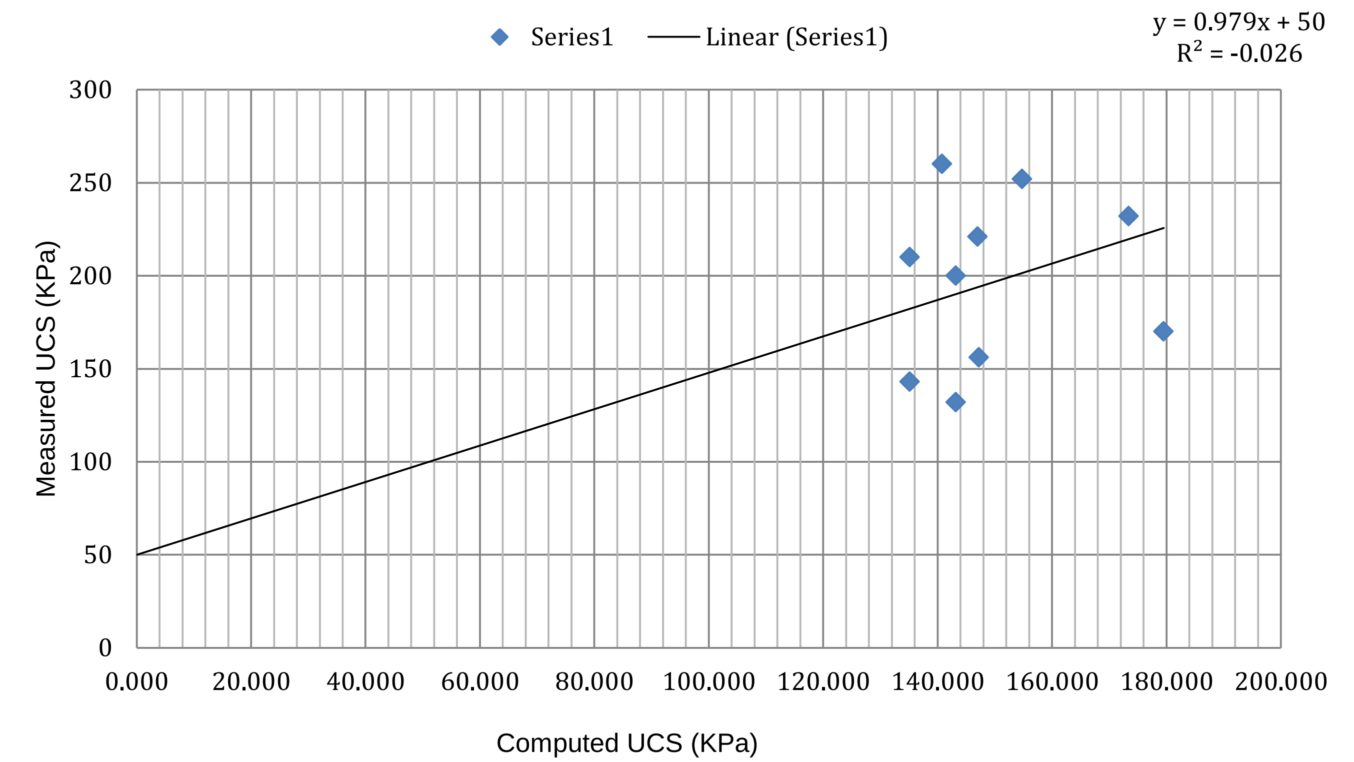

Fig. VI: Cross Plot of Measured Vs Computed UCS Vlues Using Equation 1.6

VII. CONCLUSION

Tables 10 and 11 present the multiple regressed variables for computed CBR values derived from cement-sand composite stabilization. The values vary from 85% – 145% and 71% – 178% for measured and computed values respectively. Tables 12 and 13 show the results of UCS values for 7 days curing duration. Tables 14 and 15 show the UCS values for 28 days curing duration for sample locations 2 and 4 respectively. The UCS values vary from 69kPa – 189kPa and 122kPa – 260kPa for both durations.

The models 1.2 and 1.3 do not seem to generate higher correlations between the measured and computed values hence could further be optimized by subjecting the coefficients of the input variables to further basic iterations.

The models 1.1, 1.4, 1.5 and 1.6 are adequate for this research. Model 1.1 revealed that with 2% cement content and sand content from 10% - 40% the measured and computed CBR values vary from 88%-130% and 88%-156% respectively. With models 1.4 and 1.6 similar input variables revealed measured and computed UCS values ranging from 71kPa – 94kPa and 73kPa - 103kPa for 7 days curing duration and 132kPa – 170kPa and 143kPa – 179kPa for 28 days curing duration. These values are adequate for both sub base and base course applications because they are above recommended minimum by the FMW&H Specifications.

The accuracy and reliability of the models were checked by comparing the measured and computed values of CBR and UCS and computing the correlation coefficients. The figures I to VI illustrate the measured and computed values based on non-linear regressed models. The straight line in the figure represents the line of perfect equality where the measured and computed values are exactly equal.

The correlation coefficients R^2 at 95% confidence interval are 0.341, 0.0757, for CBR with cement content from 2% to 6% and sand content from 10% to 40%. The UCS R^2 are 0.1842, 0.476, 0.0613 and 0.026 for cement content from 2% to 4% and sand content from 10% to 40%. These values are statistically significant and suggest that the measured and computed values are compatible.

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