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Research Article

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Composite Stabilization and Model Prediction of Geotechnical Parameters of Ekpuk Residual Soils, Akwa Ibom State, Nigeria

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Abstract Lime and quarry dust were utilized for this laboratory stabilization experiments. The primary purpose was to evaluate the behaviour of Ekpuk residual soil on application of various percentages of lime and quarry dust and compactive effort on maximum dry densities and corresponding optimum moisture contents.When lime is added to fine-grained soil, cat-ion exchange takes place, with the calcium and magnesium in the lime replacing the sodium and potassium in the soil. The tendency to swell as a result of increase in moisture content is therefore immediately reduced. The plasticity index value of the soil is also reduced. Pozzolanic reaction may also occur in some resulting in the formation of cementing agents that increase the strength of the soil. When silica or alumina is present in the soil, a significant increase in strength may be observed over a long period of time. An additional effect is that lime causes flocculation of the fine particles, thereby increasing the effective grain size of the soil. The percentage of lime used for any project depends on the type of soil being stabilized. Four different residual soil samples from four distinct borrow pits were utilized for this investigation. Lime content varied from 2% to 8% while quarry dust content varied from 10% to 60%. The CBR values obtained at 6%/30%, lime/quarry dust stabilization ranged from 81% - 97% and 84% - 210% for measured and computed values respectively. For the UCS model formulation the lime content varied from 2% - 6% and quarry dust contents from 10% - 40%.Results obtained for measured and computed values ranged from 75KPa – 135KPa and 74 kg/m^3- 139 kg/m^3 for 7 days and88KPa – 132KPa and102KPa – 152KPa for 28 days curing duration. Finally multiple non-linear regressed models were developed to aid prediction and optimization of CBR and UCS parameters of Ekpuk residual soi at various levels of composite stabilization.

Keywords composite stabilization; lime; quarry dust; residual soil.

1.0 Introduction

1.1 Lime - Quarry Dust Stabilization

One of the oldest processes of improving the engineering properties of soils is by lime stabilization. Addition of lime helps to arrest the shrinkage and swelling behaviour of soil [1].This is due to the creation of chemical bonds and aggregation [2]. The use of lime to improve the engineering properties of soil had been in practice for long in many parts of the World. The lime used in this work was purchased from Ewet market in Uyo. Lime stabilized soil is an engineered product that must be properly evaluated, proportioned and constructed in order to obtain the good and long-term performance[3]. Generally lime reduces the plasticity of a highly expansive soil, as well as improving the stress-strain behaviour [4]. The determination of the quantity of lime is usually based on an analysis of the effect that different lime percentages have on the reduction of plasticity and the increase in strength of the soil. Generally stabilization is designed to improve the physical properties of residual soils utilized for engineering applications. Several methods are used to stabilize soils such as: compaction, consolidation, grouting, admixtures, reinforcement and stone column. The ability of any of these methods to improve soil properties depends on several factors, including soil type, degree of saturation, initial relative density, initial in-situ stresses, initial soil structure and special characteristics of the method used. In most cases the goal of treating the soil is increasing shear strength and loading capacity, increasing stability and settlement control. Quarry dust contains substantial amount of fines. In addition to plasticity reduction, quarry dust, provides improved strength and durability. The effectiveness of quarry dust stabilization is predicated on the structural composition of the residual soil and the plastic limit which influences durability on compaction.

2.0 Materials Selected

2.1 Ekpuk Residual Soils

Four soils samples selected for this research were dug with shovels from four distinct borrow-pits alongUsop – Ekpuk access road and. The soil samples were disturbed and at depths varying from 3.0 meters to 5.0 meters of the profile. The samples were excavated bearing in mind the variability of residual soils in its natural composition. Hence the soil samples were excavated both vertically and laterally and thoroughly blended. The samples were conveyed in two, 50kg nylon bags, carefully tagged for identification purpose and transported to the Mothercat Limited, Materials Testing Laboratory at Uyo. The sample locations are identified as shown:

Sample Identification	Location
1	Km 2+175Usop – Edeghe road
2	Km 5+250Usop – Edeghe road
3	Km 8+375 Edeghe – Ekpuk road
4	Km12+250Edeghe – Ekpukroad

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

2.2 Lime

Lime helps to arrest the shrinkage and swelling behaviour of soil. This is due to the creation of chemical bonds and aggregation [5]. The use of lime to improve the engineering properties of soil had been in practice for long in many parts of the World. The lime used in this work was purchased from Ewet market in Uyo. The primary purpose was to evaluate the behaviour of Ekpuk residual soil on application of various percentages of lime and compactive effort on the maximum dry densities and corresponding optimum moisture contents. Lime stabilized soil is an engineered product that must be properly evaluated, proportioned and constructed in order to obtain the good and long-term performance. Generally lime reduces the plasticity of a highly expansive soil, as well as improving the stress-strain behaviour.

2.3 Quarry Dust

The quarry dust used in this experiment came from the limestone quarry factory in Akamkpa, Cross River State. This is the by-product or sediments derived from the crushing of limestone. This soil modifying agent has a high percentage of fines, and as expected, the CBR value of quarry dust was the minimum value of all, in that it in fact increases the overall fines content of Ekpuk residual soil. The material was purchased from a local supplier at Aka-Itiam street depot in Uyo.

3.0 Preparation and Testing of Samples

3.1 Plain Mechanical Compaction

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 mold, 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 mold. The blows were evenly distributed over the surface of each layer. The collar of the mold 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 in the CBR mold and values for the plain mechanical compaction were read for both top and bottom at various depths of penetration.

3.2 Quarry Dust - Lime Composite Stabilization Tests

The percentage of lime ranged from 2%, 4%, 6% to 8% . The percentage of quarry dust ranged from 10%, 20%, 30%, 40%, 50% to 60%. For each lime content the percentage or proportion of quarry dust was varied from 10%-60%. It is an established fact that the measurement of the strength of soil-lime 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. 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 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).

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

3.4 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.

4.0 Presentation of Test Results

Table 1: Ekpuk Residual Soil Compaction at Plain Condition

Sample No	MDD Kg/m^3	NMC %	unsoaked CBR %	Fines %
1	1940	9.5	32	29
2	1950	10.7	26	30
3	1940	10.2	32	33
4	1830	10.5	30	33

Table 2: Lime - Quarry Dust Stabilization Results -Sample Location 1

Lime content (%)	Quarry dust content (%)	MDD (kg/m^3)	OMC (%)	Soaked CBR (%)
2	10	1990	8.5	56
	20	2010	8’3	71
	30	2040	8.3	104
	40	1910	8.2	124
	50	1960	6.3	99
	60	1820	7.6	64

4	10	2000	6.2	54
	20	1910	8.5	68
	30	1930	6.1	86
	40	1950	6.7	108
	50	1980	6’7	89
	60	1780	8.5	50
6	10	1920	11.5	52
	20	2010	11.5	83
	30	2020	8.3	81
	40	2070	9.2	117
	50	2030	10.1	83
	60	2030	8.6	56
8	10	1890	6.2	63
	20	2010	9.8	98
	30	2060	7.8	101
	40	2050	8.4	111
	50	2030	11.5	88
	60	1990	8.2	65

Table 3: Lime - Quarry Dust Stabilization Results -Sample Location 2

Lime content (%)	Quarry dust content (%)	MDD (kg/m^3)	OMC (%)	Soaked CBR (%)
	10	1990	6.2	60
	20	2000	8.5	64
	30	1910	6.1	86
2	40	1930	6.7	88
	50	1950	8.5	89
	60	1980	8.5	50
	10	1940	9.5	72
	20	2030	10.2	78
	30	2070	12.4	86
4	40	2050	9.8	94
	50	2080	10.6	98
	60	2100	9.9	68
	10	2050	11.8	74
	20	2040	8.3	87
	30	2080	7.9	90
6	40	2060	12.5	103
	50	2090	8.5	115
	60	2090	8.4	67
	10	2070	13.2	96
	20	2070	8.5	105
	30	2080	8.9	114
8	40	2110	8.8	116
	50	2050	12.7	123
	60	2120	8.6	78

Table 4: Lime -Quarry Dust Stabilization Results -Sample Location 3

Lime content (%)	Quarry dust content (%)	MDD (kg/m^3)	OMC (%)	Soaked CBR (%)
2	10	2080	8.4	65
	20	2040	9.4	71
	30	2040	10.5	76
	40	2050	9.9	87
	50	2060	10.3	128
	60	2070	8.1	68
4	10	2070	9.3	59
	20	2050	9.1	72
	30	2050	10.5	89
	40	2070	9.9	123
	50	2090	10.2	131
	60	2120	10.9	67
6	10	2040	9.8	53
	20	2060	10.8	62
	30	2080	8.2	89
	40	2090	10.8	119
	50	2100	7.9	129
	60	2100	8.1	68
8	10	2070	13.6	56
	20	2070	8.6	65
	30	2100	7.2	118
	40	2090	8.6	119
	50	2040	13.6	128
	60	2120	9.2	66

Table 5: Lime - Quarry DustStabilization Results - Sample Location 4

Lime Content (%)	Quarry dustcontent (%)	MDD (kg/m^3)	OMC (%)	Soaked CBR (%)
	10	1810	8.4	56
	20	2040	14.2	64
2	30	2030	12.4	78
	40	2040	11.4	97
	50	2050	12.5	132
	60	2060	12.4	61
	10	2060	13.8	53
	20	2050	10.5	66
	30	2060	12.4	79
4	40	2070	9.9	98
	50	2100	10.5	122
	60	2080	10.5	62
	10	2050	10.3	57
	20	2030	8.6	67
	30	2050	7.7	97
6	40	2090	11	109
	50	2080	8.2	130
	60	2100	8.7	68
	10	2050	14.7	55

	20	2030	6.7	84
	30	2060	6.5	115
8	40	2090	6.7	118
	50	2080	12.6	132
	60	2020	6.4	65

Table 6: Lime - Quarry Dust Stabilization UCS Results at 7 days Curing Duration

Lime content (%)	Quarry dust content (%)	Duration (days)	Compressive Strength (KPa)
Sample Location 2			
2	10	7	69
	20	7	75
	30	7	104
	40	7	111
	50	7	119
	60	7	125
4	10	7	81
	20	7	105
	30	7	112
	40	7	144
	50	7	158
	60	7	162
6	10	7	81
	20	7	119
	30	7	122
	40	7	130
	50	7	142
	60	7	153
8	10	7	85
	20	7	97
	30	7	121
	40	7	139
	50	7	151
	60	7	158

Table 7: Lime - Quarry Dust Stabilization UCS Results at 7 days Curing Duration

Lime content (%)	Quarry Dust content (%)	Duration (days)	Compressive Strength (KPa)
Sample Location 4			
	10	7	61
	20	7	68
	30	7	82
2	40	7	84
	50	7	91
	60	7	98
	10	7	101
	20	7	116
	30	7	124
4	40	7	135
	50	7	141

	60	7	151
	10	7	107
	20	7	133
	30	7	149
6	40	7	157
	50	7	167
	60	7	176
	10	7	113
	20	7	124
	30	7	139
8	40	7	150
	50	7	177
	60	7	184

Table 8: Lime - Quarry Dust Stabilization UCS Results at 28 days Curing Duration

Lime content (%)	**Quarry dustcontent (%)**	**Duration (days)**	**Compressive Strength (KPa)**
Sample Location 2			
2	10	28	81
	20	28	88
	30	28	97
	40	28	116
	50	28	123
	60	28	133
4	10	28	80
	20	28	85
	30	28	93
	40	28	113
	50	28	134
	60	28	147
6	10	28	72
	20	28	88
	30	28	94
	40	28	106
	50	28	131
	60	28	172
8	10	28	78
	20	28	85
	30	28	126
	40	28	145
	50	28	173
	60	28	196

Table 9: Lime - Quarry Dust Stabilization UCS Results at 28 days Curing Duration

Lime content (%)	**Quarry dustcontent (%)**	**Duration (days)**	**Compressive Strength(KPa)**
Sample Location 4			
	10	28	80
	20	28	83
	30	28	116

2	40	28	130
	50	28	146
	60	28	155
	10	28	87
	20	28	88
	30	28	112
4	40	28	132
	50	28	144
	60	28	163
	10	28	82
	20	28	110
	30	28	126
6	40	28	131
	50	28	153
	60	28	187
	10	28	98
	20	28	136
	30	28	146
8	40	28	165
	50	28	193
	60	28	208

5.0 Discussion of Test Results

Table1presents the results of Ekpuk residual soil at unstabilized or plain condition. The values of MDD and CBR range from 1830 kg/m^3 - 1950 kg/m^3 and 26% - 32% respectively. Tables 2 to 5 present the results of composite stabilization of Ekpuk residual soil with lime and quarry dust from the four distinct borrow pits. In all the samples and utilizing 2% lime, 20% quarry dust and 88% residual soil the resulting MDD and CBR are 1910 kg/m^3, 2000kg/m^3, 2040 kg/m^3, 2040kg/m^3 and 71%, 64%, 71%, 64%, respectively. With an increase in lime content to 6% and quarry dust content maintained at 30% the resulting MDD and CBR values are 2020kg/m^3, 2980kg/m^3, 2080kg/m^3, 2050kg/m^3 and 81%, 90%, 89%, 97%respectively. If the lime content is further increased to 8%, quarry dust 30% and residual soil 62%, the resulting MDD and CBR values are; 2060 kg/m^3, 2080 kg/m^3, 2100 kg/m^3, 2060 kg/m^3, and 101%, 114%, 118%, 115%respectively. Tables 6 and 7 present results of UCS experiments from locations 2 and 4 for 7 days curing duration while Tables 8 and 9 present results from 28 days curing duration. The UCS values obtained with 6% - 8% lime content vary from 57KPa – 184KPa for 7 days curing and 72KPa – 208KPa for 28 days curing duration respectively.From the four locations and with 6% lime, 30% quarry dust and64% residual soil, the CBR values of 81%, 90%, 89% and 97% are reasonably above recommended minimum of 80% by the code of practice [6].

6.0 Multiple Non-linear Regressed Models

Based on analysis and utilizing multiple non-linear regressed programs, some models were developed for Ekpuk 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.

$CBR_{(1)} = 9.087 + 6.956L + 1.175Q + 3.751D - 1.187M - 1.234L^2 - .073Q^2 - 1.787D^2 + .283M^2 + .242LQ + 1.641LD - .451LM - .568QD + .342QM + .428DM$ ……………………………………1.1

Where L = Lime Content (%), Q = Quarry Dust content (%), D = Maximum Dry Density (kg/m^3), M = Optimum Moisture Content (%)

$CBR_{(2)} = 4.551 + 9.833L + 4.033Q - 8.614D - 2.157M + 6.719L^2 - .279Q^2 + 5.092D^2 + .833M^2 + .262LQ - 4.767LD - .892LM + 1.315QD - .597QM - .559DM$ ……………………………………1.2

Where L = Lime Content (%), Q = Quarry Dust Content (%), D = Maximum Dry Density (kg/m^3), M = Optimum Moisture Content (%)

$CBR_{(3)}$ = 8.271 - 1.361L + .655Q – 2.539D + .581M – 3.542L^2 + .387Q^2 + 1.268D^2 - .299M^2 + .373LQ + .616LD + .751LM + .328QD +.198QM + .262DM ………………………………………………..1.3

Where L = Lime Content (%), Q = Quarry Dust Content (%), D = Maximum Dry Density (kg/m^3), M = Optimum Moisture Content (%)

$CBR_{(4)}$ = 4.711 + 1.426L – 1.506Q + .805D - .101M - .934L^2 - .375Q^2 - .429D^2 + .163M^2 - .407LQ + .839LD - .953LM + .942QD - .609QM - .521 DM……………………………………………...1.4

Where L = Lime Content (%), Q = Quarry Dust Content (%), D = Maximum Dry Density (kg/m^3), M = Optimum Moisture Content (%)

$UCS_{(7a)}$ = 33.283 + 6.182L + .752Q - .292T - .121L^2 -.131Q^2 + .417T^2 - .176LQ + .883LT + .107QT…………………………………………1.5

Where L = Lime Content (%), Q = Quarry Dust Content (%), T= Duration (days).

$UCS_{(7b)}$ = 36.332 + 6.748L + .821Q - .318T- .132L^2 - .143Q^2 + .455T^2 - .192LQ - .964LT + .117QT…………………………………………1.6

Where L = Lime Content (%), Q = Quarry Dust Content (%), T= Duration (days).

$UCS_{(28a)}$ = 7.924 + 6.699L + .276Q + .352T - .119L^2 - .076Q^2 - .013T^2 + .224LQ - .239LT + .198QT…………………………………………..1.7

Where L = Lime Content (%), Q = Quarry Dust Content (%), T= Duration (days).

$UCS_{(28b)}$ = 9.081 + 7.676L + .316Q + .403T - .137L^2 - .087Q^2 - .014T^2 + .256LQ - .274LT + .113QT………………………………..1.8

Where L = Lime Content (%), Q = Quarry Dust Content (%), T= Duration (days).

Table 10: Multiple Regressed Variables for Measured and Computed CBR Values Lime - Quarry Dust Stabilization– Sample Location1

Sample Location 1					
Lime Content (%)	**Quarry Dust Content (%)**	**MDD (kg/m^3)**	**OMC (%)**	**Measured CBR (%)**	**Computed CBR (%)**
2	10	1.99	8.5	56	61.969
2	20	2.01	8.3	71	72.196
2	30	2.04	8.3	104	68.844
2	40	1.91	8.2	124	51.920
2	50	1.96	6.3	99	-19.145
2	60	1.82	7.6	64	-38.000
4	10	2	6.2	54	52.265
4	20	1.91	8.5	68	82.424
4	30	1.93	6.1	86	56.032
4	40	1.95	6.7	108	45.014
4	50	1.98	6.7	89	11.915
4	60	1.78	8.5	50	10.902
6	10	1.92	11.5	52	75.420
6	20	2.01	11.5	83	90.226
6	30	2.02	8.3	81	99.780
6	40	2.07	9.2	97	108.282
6	50	2.03	10.1	83	88.870
6	60	2.03	8.6	56	23.669
8	10	1.89	6.2	63	31.721

8	20	2.01	9.8	98	78.304
8	30	2.06	7.8	101	72.196
8	40	2.05	8.4	111	75.888
8	50	2.03	11.5	88	116.983
8	60	1.99	8.2	65	23.270

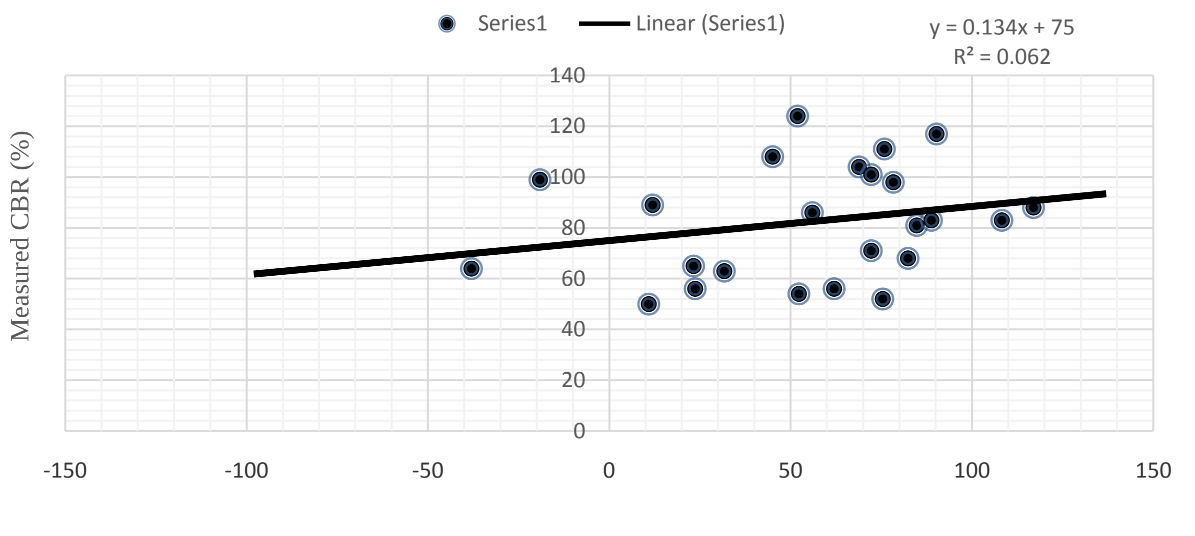

Fig 1: Plot of Measured Vs Computed CBR Values Using Equation 1.1

Table 11: Multiple Regressed Variables for Measured and Computed CBR Values Lime - Quarry Dust Stabilization – Sample Location 2

Sample Location 2					
Lime Content (%)	**Quarry Dust Content (%)**	**MDD (kg/m^3)**	**OMC (%)**	**Measured CBR (%)**	**Computed CBR (%)**
2	10	1.99	6.2	60	42.657
2	20	2	8.5	64	-17.002
2	30	1.91	6.1	86	-112.842
2	40	1.93	6.7	88	-283.803
2	50	1.95	8.5	89	-542.675
2	60	1.98	8.5	50	-826.828
4	10	1.94	9.5	72	119.043
4	20	2.03	10.2	78	54.493
4	30	2.07	12.4	86	-80.445
4	40	2.05	9.8	94	-240.650
4	50	2.08	10.6	98	-486.675
4	60	2.1	9.9	68	-759.414
6	10	2.05	11.8	74	249.059
6	20	2.04	8.3	87	191.349
6	30	2.08	7.9	90	91.152
6	40	2.06	12.5	103	-140.068
6	50	2.09	8.5	115	-297.236

6	60	2.09	8.4	67	-568.306
8	10	2.07	13.2	96	427.284
8	20	2.07	8.5	105	373.566
8	30	2.08	8.9	114	266.374
8	40	2.11	8.8	116	109.210
8	50	2.05	12.7	123	-194.785
8	60	2.12	8.6	78	-368.940

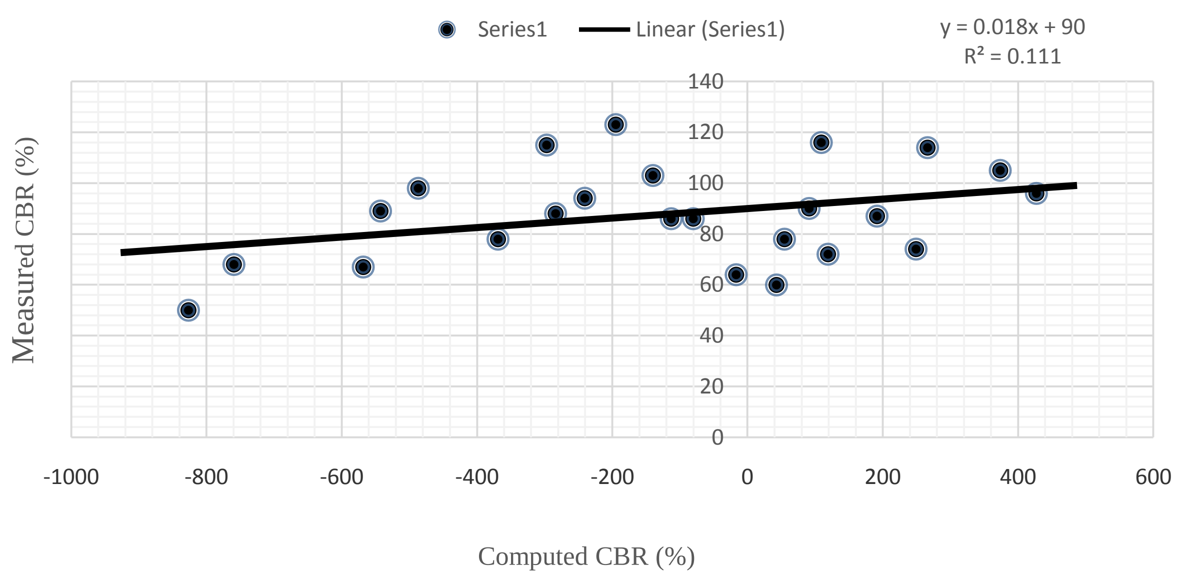

Fig.2: Plot of Measured Vs Computed CBR Values Using Equation 1.2

Table 12: Multiple Regressed Variables for Measured and Computed CBR Values Lime - Quarry Dust Stabilization – Sample Location 3

Sample location 3					
Lime Content (%)	**Quarry Dust Content (%)**	**MDD (kg/m^3)**	**OMC (%)**	**Measured CBR (%)**	**Computed CBR (%)**
2	10	2.08	8.4	65	71.290
2	20	2.04	9.4	71	225.603
2	30	2.04	10.5	76	461.284
2	40	2.05	9.9	87	771.208
2	50	2.06	10.3	128	1162.667
2	60	2.07	8.1	68	1609.982
4	10	2.07	9.3	59	49.330
4	20	2.05	9.1	72	211.305
4	30	2.05	10.5	89	456.899
4	40	2.07	9.9	123	773.635
4	50	2.09	10.2	131	1172.687
4	60	2.12	10.9	67	1654.535
6	10	2.04	9.8	53	0.330
6	20	2.06	10.8	62	175.192
6	30	2.08	8.2	79	210.828

6	40	2.09	10.8	119	754.405
6	50	2.1	7.9	129	1131.288
6	60	2.1	8.1	68	1610.995
8	10	2.07	13.6	56	-68.436
8	20	2.07	8.6	65	95.504
8	30	2.1	7.2	80	338.108
8	40	2.09	8.6	91	680.780
8	50	2.04	13.6	128	1139.968
8	60	2.12	9.2	66	1584.438

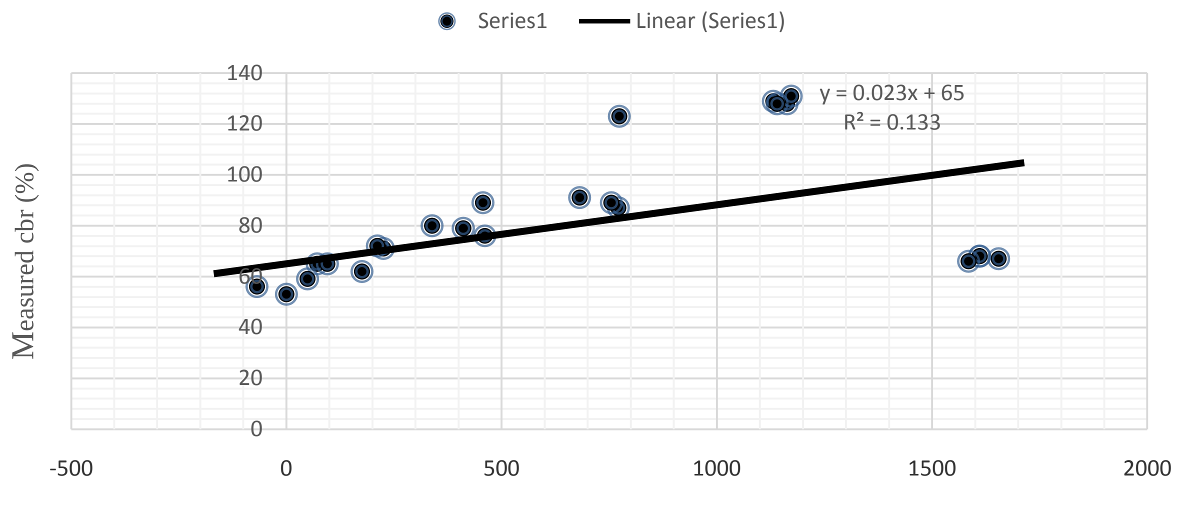

Fig 3: Plot of Measured Vs Computed CBR Values Using Equation 1.3

Table 13: Multiple Regressed Variables for Measured and Computed CBR Values Lime - Quarry Dust Stabilization – Sample Location 4

Sample Location 4					
Lime Content (%)	**Quarry Dust Content (%)**	**MDD (kg/m^3)**	**OMC (%)**	**Measured CBR (%)**	**Computed CBR (%)**
2	10	1.81	8.4	56	-101.169
2	20	2.04	14.2	64	-334.540
2	30	2.03	12.4	78	-582.119
2	40	2.04	11.4	97	-900.343
2	50	2.05	12.5	132	-1343.425
2	60	2.06	12.4	61	-1831.876
4	10	2.06	13.8	53	-169.023
4	20	2.05	10.5	66	-334.080
4	30	2.06	12.4	79	-634.397
4	40	2.07	9.9	98	-919.720
4	50	2.1	10.5	122	-1347.302
4	60	2.08	10.5	62	-1836.373
6	10	2.05	10.3	57	-184.230

6	20	2.03	8.6	67	-352.818
6	30	2.05	7.7	77	-592.242
6	40	2.09	11	109	-1013.420
6	50	2.08	8.2	130	-1342.332
6	60	2.1	8.7	68	-1843.879
8	10	2.05	14.7	55	-279.417
8	20	2.03	6.7	64	-370.293
8	30	2.06	6.5	85	-621.194
8	40	2.09	6.7	98	-956.497
8	50	2.08	12.6	132	-1576.291
8	60	2.02	6.4	65	-1835.128

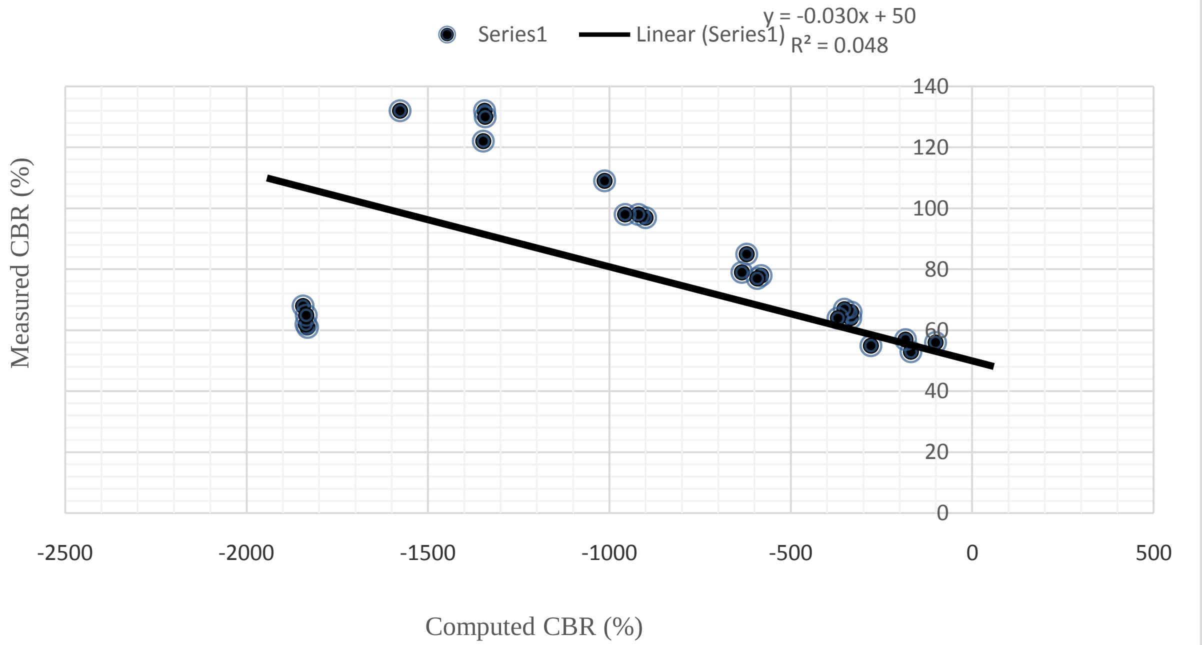

Fig.4: Plot of Measured Vs Computed CBR Values Using Equation 1.4.

Table 14: Multiple Regressed Variables for Measured and Computed UCS Values Lime - Quarry Dust Stabilization – Sample Location 2

Sample Location 2				
Lime Content (%)	**Quarry Dust Content (%)**	**Duration (days)**	**Measured UCS (KPa)**	**Computed UCS (KPa)**
2	10	7	69	74.304
2	20	7	75	46.494
2	30	7	104	-7.516
2	40	7	111	-87.726
2	10	7	81	74.304
4	20	7	105	62.728
4	30	7	112	5.198

4	40	7	144	-78.532
6	10	7	85	97.844
6	20	7	97	112.994

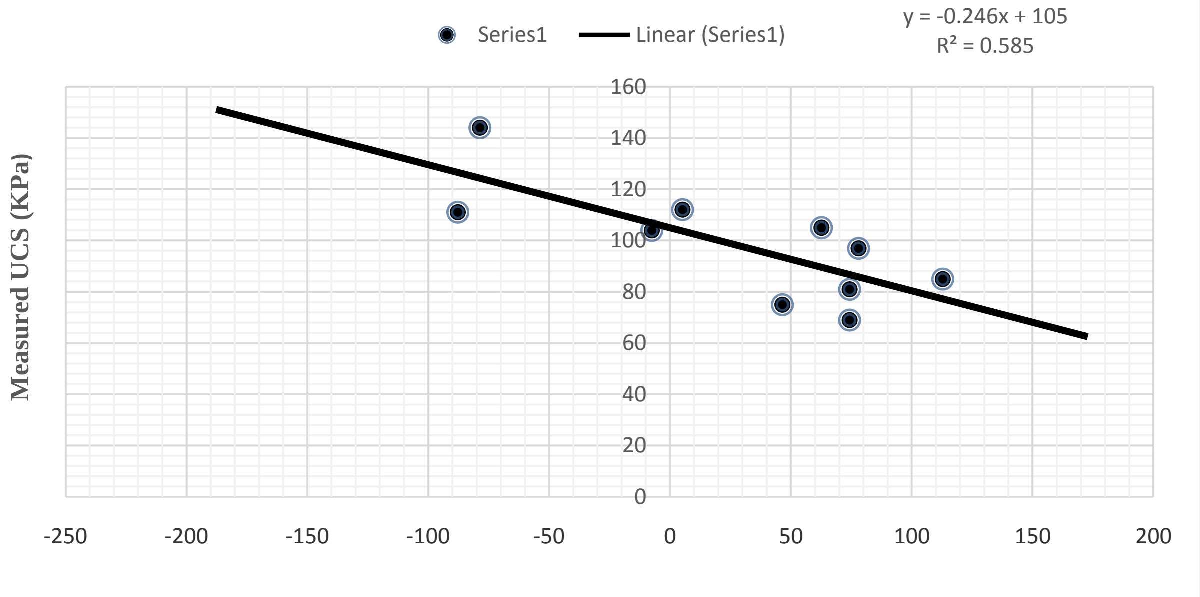

Fig. 5. : Plot of Measured Vs Computed UCS Values Using Equation 1.5

Table 15: Multiple Regressed Variables for Measured and Computed UCS Values Lime - Quarry Dust Stabilization - Sample Location 4

Sample Location 4				
Lime Content (%)	**Quarry Dust Content (%)**	**Duration (days)**	**Measured UCS (KPa)**	**Computed UCS (KPa)**
2	10	7	61	54.123
2	20	7	68	23.783
2	30	7	82	-35.157
2	40	7	84	-122.697
4	10	7	101	48.689
4	20	7	116	14.509
4	30	7	124	-48.271
4	40	7	135	139.651
6	10	7	107	42.199
6	20	7	133	4.179

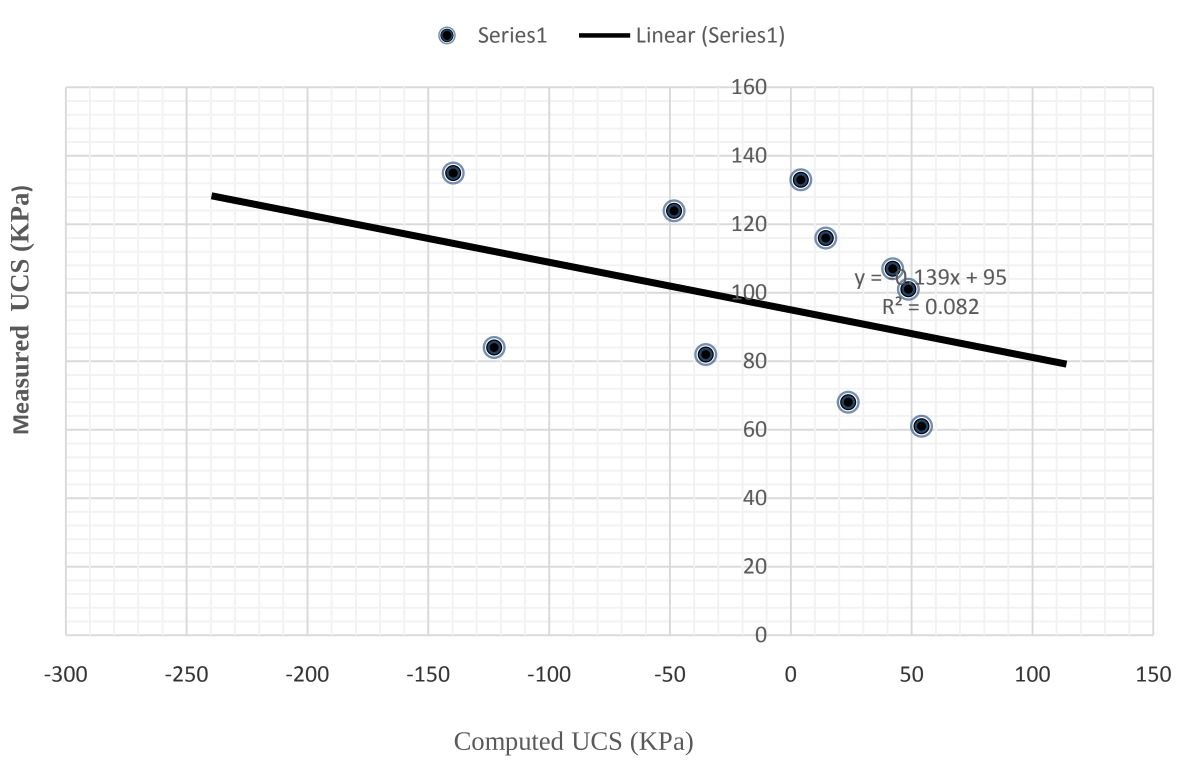

Fig. 6.0:Cross Plot of Measured Vs Computed UCS Values Using Equation 1.6

Table 16: Multiple Regressed Variables for Measured and Computed UCS Values Lime - Quarry Dust Stabilization - Sample Location 2

Sample Location 2				
Lime Content (%)	**Quarry Dust Content (%)**	**Duration (days)**	**Measured UCS (KPa)**	**Computed UCS (KPa)**
2	10	28	81	62.206
2	20	28	88	102.086
2	30	28	97	126.766
2	40	28	116	136.246
4	10	28	80	65.272
4	20	28	85	109.632
4	30	28	93	138.792
4	40	28	113	152.752
6	10	28	72	107.386
6	20	28	88	116.226

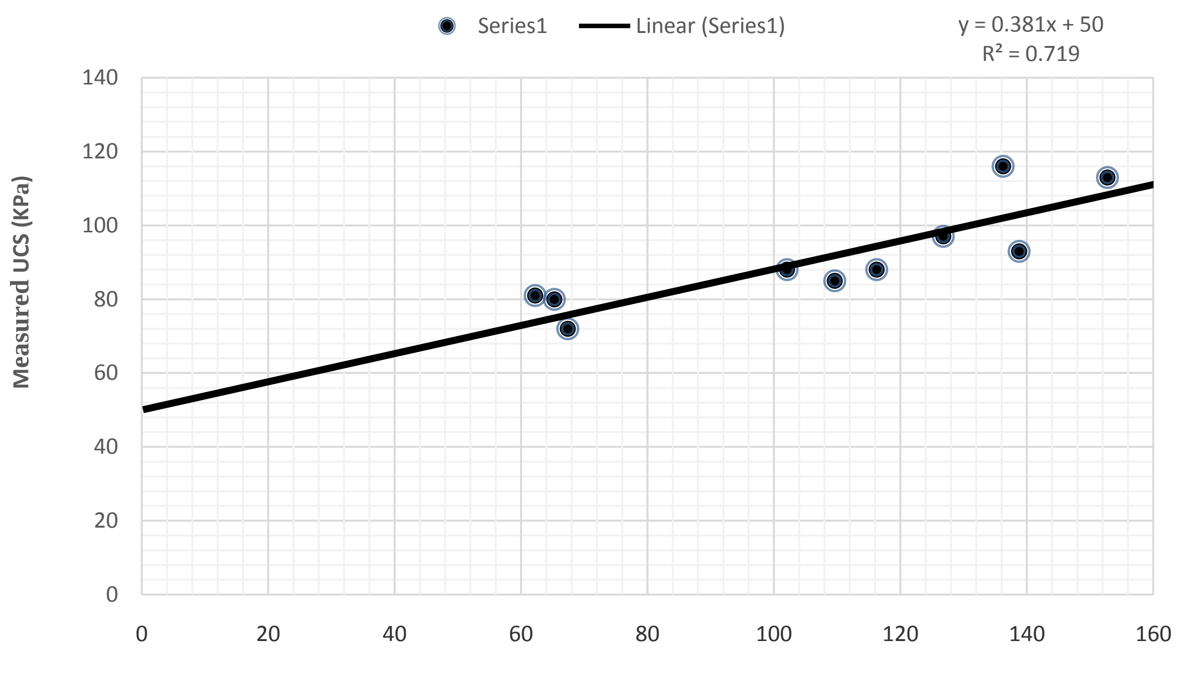

Fig. 7.0: LIme - Quarry Dust Stabilization UCS Results at 28 days Curing Duration Using Equation 1.7

Table 17: Multiple Regressed Variables for Measured and Computed UCS Values Lime - Quarry Dust Stabilization - Sample Location 4

Sample Location 4				
Lime Content (%)	**Quarry Dust Content (%)**	**Duration (days)**	**Measured UCS (KPa)**	**Computed UCS (KPa)**
2	10	28	80	40.069
2	20	28	83	53.889
2	30	28	116	50.309
2	40	28	130	29.329
4	10	28	87	43.553
4	20	28	88	62.493
4	30	28	112	84.033
4	40	28	132	88.173
6	10	28	82	45.941
6	20	28	110	70.001

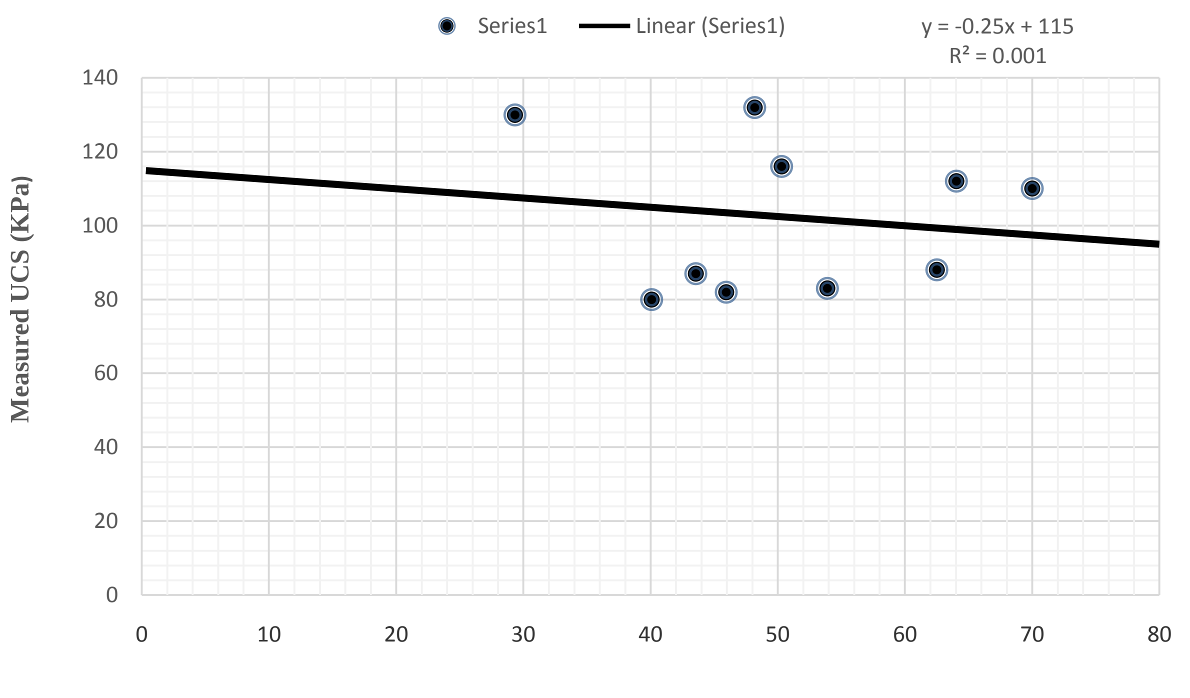

Fig. 8: Lime - Quarry Dust Stabilization UCS Results at 28 Days Curing Duration using equation 1.8

7.0 Conclusion

Tables 10 – 13 present the multiple regressed variables for measured and computed CBR values derived from lime–quarry dust composite stabilization. The data obtained varied from 56%-114% and 61%-266% for measured and computed values respectively. The negative values generated could be ignored. Tables14 and 15 present the result of UCS for 7 days curing duration. The values obtained varied from 69KPa-135KPa and 74KPa-139KPa for measured and computed values. Tables 16 and 17 show the results of UCS data for 28 days curing duration. The values varied from 88KPa-113KPa and 102KPa-152KPa for measured and computed UCS values respectively.

The models 1.1, 1.3, 1.5 and 1.7 appear appropriate for this research. Model 1.1 revealed that with 6% lime content and quarry dust ranging from 20%-40%, the measured and computed CBR values varied from 83%-97% and 90%-108% respectively. Model 1.3 at similar composite revealed variations ranging from 62%-119% and 175%-754% for measured and computed CBR values.

Model 1.5 revealed that at 6% lime content and 10%-20% quarry dust UCS values for 7 days curing duration ranged from 97KPa-133KPa and 112KPa-139KPa for measured and computed values. Model 1.7 revealed UCS values at 6% lime content and 10%-20% quarry dust content at 28 days curing duration as 72KPa-110KPa and 107KPa-116KPa for measured and computed values respectively.These values are adequate for both sub base and base course applications because they are above acceptable minimum.

The accuracy and reliability of the models were checked by computing the measured and computed values of CBR and UCS and computing the correlation coefficients. Figures 1 to 8 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 coefficient R^2 at 95% confidence interval for the selected models are 0.1113, 0.1338 for CBR with lime content from 2%-8% and quarry dust from 10%-60%. The UCS R^2 values are 0.5855, 0.7197 for lime content from 2%-6% and quarry dust content from 10%-40%. These values are significant statistically and suggest that the measured and computed values are compatible.

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