Treatment of Shale-Sand Mixture with Cement for Use as Pavement Material.

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ABSTRACT

This paper reports the outcome of an investigation into the use of 2-14% cement to stabilize Igumale shale, mixed with 10-50 % sand, for use as road building material. Atterberg's limits test, California Bearing Ratio (CBR) and unconfined compressive strength (UCS) tests were conducted on the natural shale and the treated soil, specimens. The plasticity index of the natural shale reduced from 45 % to a minimum value of 10 % when treated with a mixture of 50 % sand plus 14 % cement, while strength indices of the natural shale was greatly improved as the 7 day UCS and CBR values of the natural shale increased from 350 kN/m^2 and 0.65% respectively, to 2200 kN/m^2 and 193% respectively, when treated with a combination of 50 % sand plus 14 % cement. Based on results obtained from the study, the use of a mixture of 50 % sand plus 12 % cement and 50 % sand plus 14 % cement is recommended for the treatment of shale for use as base material.

(Keywords: cement, stabilization, Igumale shale, sand, construction, pavement material)

INTRODUCTION

Road building in areas characterized with the presence of troublesome soil, has been a big challenge to road construction as the cost of running such unsuitable material to spoil and importing good materials from borrow pit as a replacement is always enormous, especially when such materials are not readily available within free haul distance. However, where economic analysis of alternative on site is in favor of the stabilization of such unsuitable material, the treated material may be used as pavement material.

At Igumale town the headquarters of Ado Local Government area of Benue state, Nigeria, a troublesome soil called shale has been identified, and scarcity of good borrow material is a big challenge, thereby necessitating the option of stabilization. Cracks ranging in size from fractions of a few millimetres to about 10 millimetres are observed on buildings and access roads within the town in addition to different types of defects such as ruts, potholes, etc. (Agbede, 2004) are attributed to the underlying shale, which extends to a depth of more than 5 meters below ground level, and contains a high percentage of illite/smectite clay mineral, that swells and shrink with variation in moisture, resulting in low strength indices.

Shale as described by De-Graft Johnson et al. (1973) is the product of highly consolidated clay silt and sand or a mixture of all the three fractions of soil derived from the weathering of rocks. These fractions of soil are deposited in sea or riverbed in layers and subjected to high overburden pressure, which lead to consolidation and diagenesis.

General geology carried out by Ezepue (1993) showed that the Okpokwu-Igumale district is underlain by two sedimentary rock formations. The older Ezeaku shale formation of Turonian age, and the younger Awgu shale of Conacian-Santonian age. Based on the findings of Agbede (2004) and Ezepue (1993) Igumale town is underlain by a troublesome soil, which swells and shrinks with variation of moisture, a phenomena that affects the soil strength indices. To overcome the problem associated with shale and make it fit for road building, stabilization is the option chosen for the study. The use of cement for soil stabilization is a well-known technique of improving soil properties.

The use of cement in soil stabilization normally leads to the production of hydrated calcium silicate and hydrated calcium aluminates, which are cementitious products, in addition to pozzolanic reaction of free lime liberated during cement hydration with the silicious components of clay fraction of soils.

The use of cement for soil stabilization is very effective when the plasticity index is less than 10%. According to Garba and Hoel (2010) where plasticity index value is greater than 10% more cement will be required for effective stabilization.

An alternative to the use of high percentage of cement is the use of lime as a modifier to reduce the plasticity index of the soil before the use of cement for stabilization, in Nigeria the cost of hydrated lime is twice the cost of ordinary Portland cement, hence the need for an alternative. Balogun (1991) reported improvement in the strength indices of black cotton soil, when sand was used to modify black cotton soil for lime stabilization. Sand, an inert material was to alter the grading of the original soil when the sandy portion in a clay-sand mixture was increased with the use of cement as the stabilizing agent.

When sand-cement mixture is applied to shale, the expected reaction is the hydration of cement in the presence of moisture to produce hydrated calcium silicates and hydrated calcium aluminates, which are cementitious products. While the free lime product of hydration of cement reacts with the silica and alumina of the clay fraction of the soil as well as the unused components of cement in a reaction which is pozzolanic in nature, responsible for the time-dependent gain in strength of the stabilized soil.

The suitability of cement sand combination in the stabilization of Igumale shale will be evaluated using the requirement specified in The Nigerian general specification for road and bridges (1997), The aim of this study is to treat Igumale shale with a combination of cement and sand in order to improve its properties and ascertain its suitability for use as pavement material.

MATERIALS AND METHODS

Sample was collected from a trial pit located north of River Okpokwu at a distance of 600m from the gate of the local government secretariat located along Igumale-Otukpo road. The pit was dug beside a double celled box culvert, close to a gully erosion site where shale outcropped.

Laboratory tests were performed on the sample obtained from Igumale in accordance with BS1377 (1990) for the natural shale and BS1924 (1990) for the stabilized shale. California bearing ratio (CBR) tests were conducted in accordance with the Nigeria code which stipulated that specimens be cured in the dry for six days then soaked for 24 hours before testing. Tests performed on shale sample mixed with cement and sand include, Atterberg's limits tests, compaction tests, Unconfined Compressive strength (UCS) tests and California bearing ratio tests.

Compaction was carried out at the energy level of the standard proctor only because this was easily achieved in the field. The resistance to loss in strength was determined as a ratio of the unconfined compressive strength (UCS) of specimens cured for 7 days under controlled conditions, which were subsequently immersed in water for another 7 days to the UCS of specimens cured for 14 days. X-ray diffraction analysis was carried out on the shale samples to aid in the identification of clay minerals, using a diffractometer. The river sand used for the study was obtained from river Okpokwu at Igumale, and its particle size distribution was determined.

RESULTS AND DISCUSSION

The grain size distribution curve of the river sand and Igumale shale is as presented in Figure 1, while the output of X-ray diffraction analysis is as summarized in Table 1. Summary of the result of test on natural Igumale shale is as presented in Table 2. Igumale shale was found to be an A-7-6 and CH soil by the AASHTO and unified soil classification systems respectively. The use of different models to predict swelling potential, confirmed the status of Igumale shale as a troublesome soil (Chen, 1988) thus requiring stabilization. The concentration of soluble sulphate in Igumale shale and its organic content values allow for use of ordinary Portland cement, without any negative effect (BRE, 1993). X-ray diffraction analysis confirmed the presence of mixed layer of illite/smectite. More details on Igumale shale minearology can be obtained from Agbede (2004, 1998).

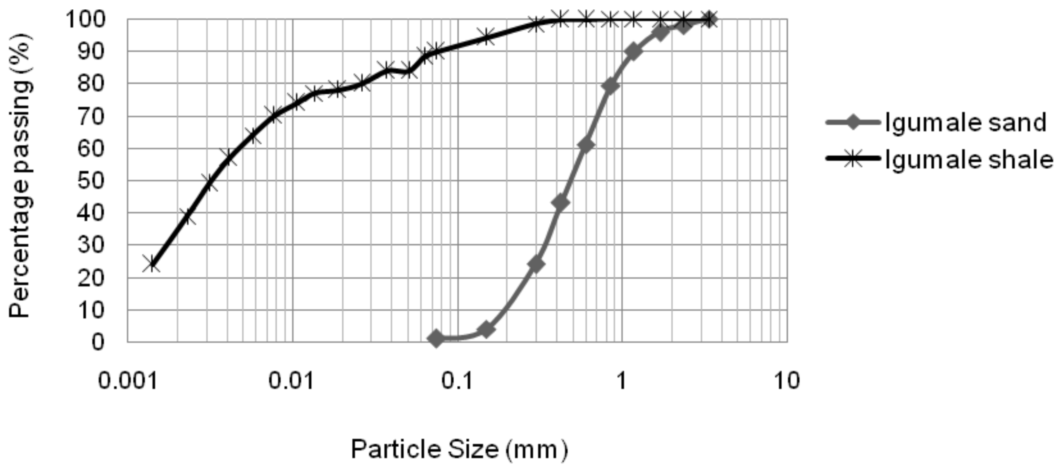

Figure1: Particle Size Distribution of Igumale Shale and Sand.

Table 1: Summary of X-ray Diffraction Analysis Result of Igumale Shale.

Angle [2Ɵ]	d-value α L[Å]	Peak Intensity [counts]	Minerals Identified
6.345	13.9185	185	Illite/Smectite
12.895	6.8596	376	Microcline
18.230	4.8624	64	-
21.395	4.1497	219	Microcline and Goethite
25.440	3.4983	231	Illite/smectite
27.190	3.2770	762	Quartz
28.540	3.1250	119	Pyrite
35.495	2.5270	48	Gbonate
37.080	2.4225	85	Pyrite
40.025	2.2508	48	Goethite
43.015	2.1010	56	Goethite
46.375	1.9563	37	Muscovite
50.670	1.8001	100	Orthoclase/ Dolomite
55.555	1.6528	16	Quartz
60.435	1.5305	69	Kaolinite
62.525	1.4843	18	-
66.100	1.4124	12	-
68.240	1.3732	45	Flourite
68.720	1.3648	48	-

Table 2: Some Properties of Natural Igumale Shale.

PROPERTY	QUANTITY
Percentage Passing BS Sieve NO200 (%)	90
Liquid Limit, (%)	72
Plastic Limit (%)	27
Plasticity Index (%)	45
Linear Shrinkage,(%)	21
AASHTO Classification	A-7-6
USCS Classification	CH
Maximum Dry Density, Mg/m^3	1.51
Optimum Moisture Content (%)	22
Unconfined Compressive Strength KN/m^2	360
California Bearing Ratio,% (after 24hrs soaking)	0.68
pH	6.83
Free Swell,%	50
Specific Gravity	2.55
Concentration of Water –soluble Sulphate (Mg/L)	1.5
Organic Content (%)	0.10
Color	Grey
Natural Moisture Content (%)	25

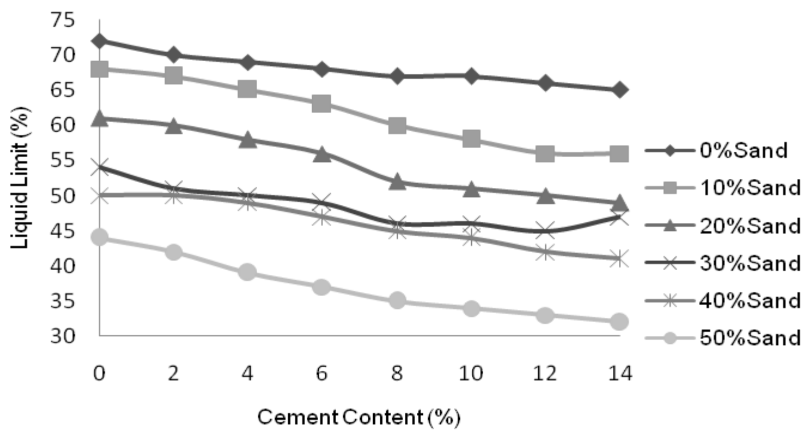

Figure 2: Variation of Liquid Limit with Cement and Sand Content.

The addition of both cement and sand to Igumale shale improves its consistency indices, as the plasticity index reduced from 45% to 10% when treated with a combination of 50% sand and 14% cement. Variation of liquid limit and plastic limit of Igumale shale with sand and cement content is as reflected in Figures 2 and 3, respectively.

The variation of maximum dry density and optimum moisture content with sand and cement content is as presented in Figures 5 and 6 respectively. The addition of either sand or cement and their combinations to Igumale shale resulted in increased maximum dry density, due to a decrease in the surface area of the clay fraction in Igumale shale arising from the substitution of shale with sand. In addition to the high specific gravity of cement (3.15) and sand (2.65) used in the stabilization of shale which had a specific gravity of 2.55. The maximum dry density of shale increased from $1.51Mg/m^3$ for the natural shale to $1.74Mg/m^3$ when treated with a mixture of 50% sand plus 14% cement, while the optimum moisture content decreased with sand and cement content.

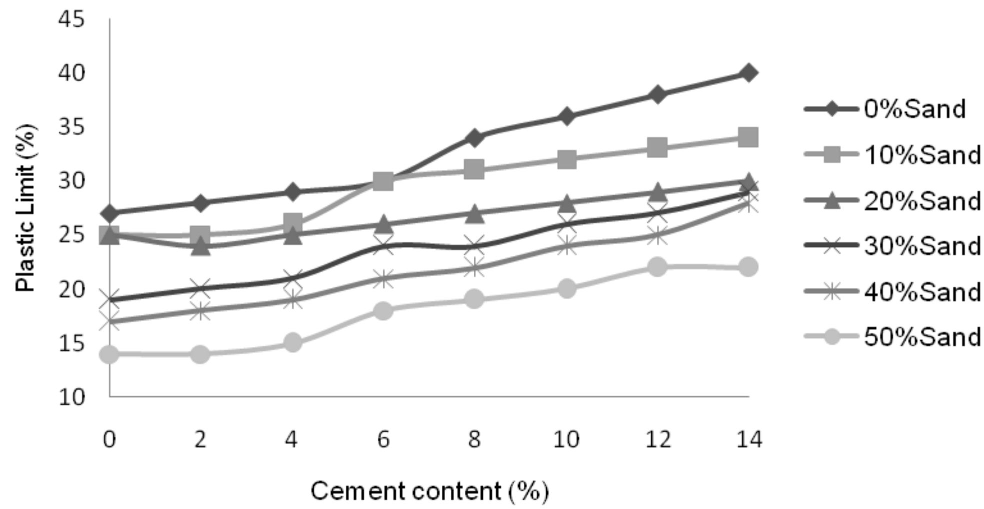

Figure 3: Variation of Plastic Limit with Cement and Sand Content.

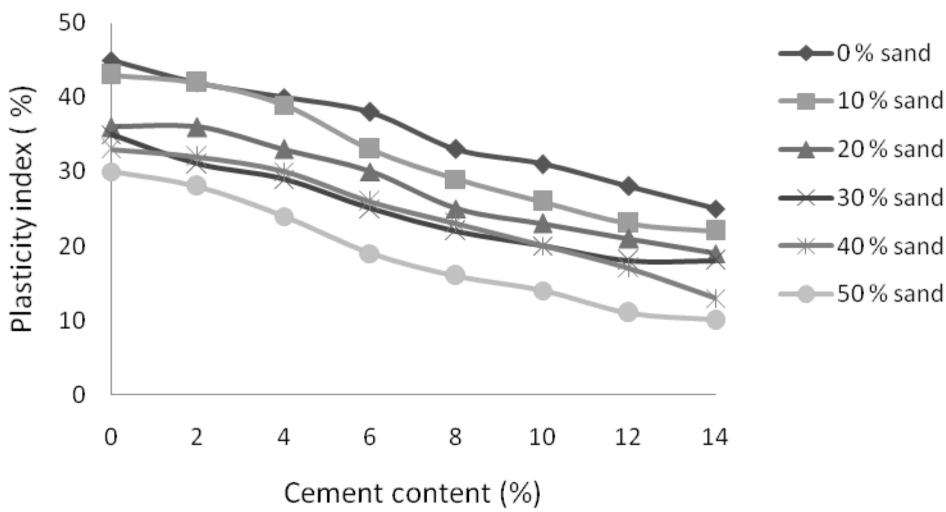

Figure 4: Variation of Plasticity Index with Cement and Sand Content.

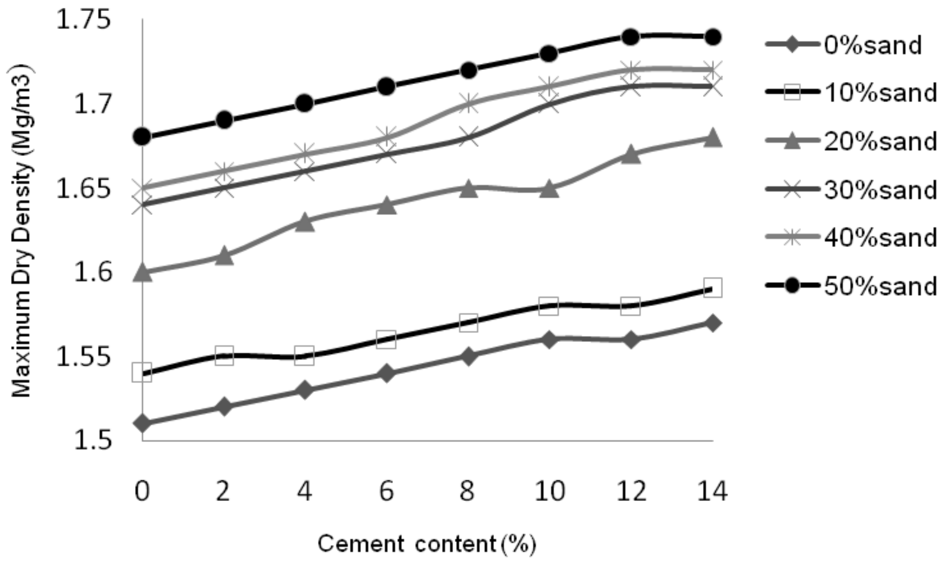

Figure 5: Variation of Maxiumum Dry Density with Cement and Sand Content.

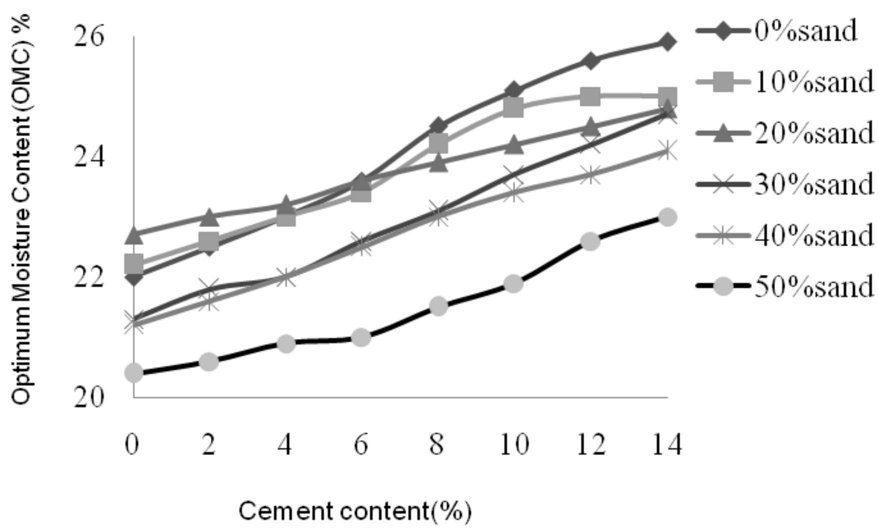

Figure 6: Variation of Optimum Moisture Content (OMC) with Cement and Sand Content.

Table 3: Durability and Strength Indices Result of Igumale Shale Sand-Cement Combination.

Cement Content (%)		**0**	**2**	**4**	**6**	**8**	**10**	**12**	**14**
0% sand	CBR(%)	0.68	3.40	12.0	18.0	49	61	78	82
	7dUCS	360	684	780	1034	1292	1403	1505	1682
	14dUCS	360	863	1155	1286	1323	1574	1694	1811
	28dUCS	360	914	1254	1309	1500	1678	1712	1901
	R (%)	0	21	31.2	50.5	58.4	66.2	70.3	75
10% Sand	CBR(%)	1.15	6.0	15.0	27	52	62	84	89
	7dUCS	390	729	939	1143	1328	1461	1564	1833
	14dUCS	390	910	1180	1304	1389	1600	1730	1897
	28dUCS	390	1112	1310	1407	1704	1909	2067	2184
	R (%)	0	24.3	29.8	48.7	57.3	67.4	71.4	76.2
20 % Sand	CBR(%)	7.2	12	19.0	39	58	69	88	100
	7dUCS	440	753	1030	1170	1382	1501	1610	1932
	14dUCS	440	1022	1215	1365	1426	1641	1841	1966
	28dUCS	440	1190	1270	1480	1780	1932	2138	2213
	R (%)	0	27.7	33.5	51.7	59.5	68.4	73.7	79.4
30 % Sand	CBR(%)	5.2	14.0	29	54	70	94	112	127
	7dUCS	360	634	858	1140	1300	1472	1791	2031
	14dUCS	360	862	1060	1306	1513	1753	1903	2005
	28dUCS	360	1050	1206	1672	1805	1985	2181	2315
	R (%)	0	35.4	38.4	56.9	63.4	71.4	76.5	83.2
40 % Sand	CBR(%)	3.10	23.0	48	75	83	110	137	158
	7dUCS	251	563	702	1154	1214	1531	1948	2269
	14dUCS	251	623	914	1055	1286	1580	1989	2368
	28dUCS	251	970	1187	1306	1686	1914	2261	2479
	R (%)	0	42.4	47.3	59.4	65.6	75.4	77.8	78.3
50 % Sand	CBR(%)	1.13	25	64	89	116	139	168	187
	7dUCS	178	302	657	1074	1206	1405	1906	2285
	14dUCS	178	569	850	1122	1308	1641	1891	2300
	28dUCS	178	805	1060	1283	1490	1736	1951	2351
	R (%)	0	50.3	55.1	63.5	70.4	78.6	82.3	83.1

CBR = California Bearing Ratio (%) , R = Resistance to loss in Strength, (%).
7 dUCS= Seven day Unconfined Compressive Strength, kN/m^2
14 dUCS= Fourteen day Unconfined Compressive strength, kN/m^2
28 dUCS = Twenty eight day Unconfined Compressive strength, kN/m^2

The results of strength indices and durability tests carried out on Igumale shale sand cement mixture is as presented in Table 3. 7 day UCS value of shale increased from 360 kN/m^2 to 1682 kN/m^2 when treated with 14 % cement, while it increased to a peak value of 440 kN/m^2 at 20 % sand after which a decline in value was observed, when it was mixed with only sand. Treatment with sand cement mixtures exhibited increase in strength with cement content at the different percentages of sand used, with the attainment of maximum 7 day UCS value of 2285 kN/m^2, when the shale was treated with a combination of 14 % cement plus 50 % sand.

The use of only cement or sand did not satisfy the minimum resistance to loss of strength value of 20 %, specified by Ola (1974). The use of sand-cement mixture improved the resistance to loss of strength of shale with the attainment of maximum resistance to loss of strength value of 83.1 % at a combination of 50 % sand plus 14 % cement. CBR value of Igumale shale treated with only sand, exhibited a peak value of 7.2 % at 20 % sand, after which a decline was observed. The use of only cement exhibited continues increase in CBR value with cement content.

The use of a combination of cement and sand exhibited a maximum CBR value of 187 % when the shale was treated with a combination of 50 % sand plus 14 % cement. The satisfaction of minimum 7day UCS value of 1720 kN/m^2 specified by Millard (1993),CBR value of 160 % specified by the Nigerian code and durability requirement specified by Ola (1974), when the shale was treated with some of the combinations is an indication that treated shale can be used for road work. Igumale shale treated with a combination of 50 % sand plus 12 % cement using the plant-mix method and 50 % sand plus 14 % cement using the mixing in place method are recommended for use as base material. The high cement content recommended is justified as the Nigerian code specified a treatment range of 10 – 14 % cement content for an A-7 soil like shale.

CONCLUSIONS

The use of sand as a modifier greatly enhanced the stabilization of Igumale shale with cement as the suitability requirements which could not be attained with the singular use of cement was achieved with the addition of sand.

Addition of sand to Igumale shale have effect on the plasticity of shale as plasticity index decreased from 45% for the natural shale to 10 % when treated with 14 % cement plus 50 % sand.

Igumale shale treated with a combination of 50 % sand plus 6 % cement is recommended for use as sub-base material in pavement work, with the adoption of appropriate water-table lowering measures such as the use of river sand blanket.

Igumale shale treated with a combination of 50 % sand plus 12 % cement and 50 % sand plus 14 % cement is recommended for use as base course material in the construction of pavement.

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