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Chemical Stabilization Of A Quartz Schist Derived Lateritic Soil From Erijiyan-Ekiti, Southwestern Nigeria

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Abstract: This work was meant to find out if 5% or 10% by volume of cement can be appropriate for effective stabilization of lateritic soils from Erijiyan- Ekitisouthwestern, Nigeria for production of durable bricks and to determine the ideal energy level that can be used to produce fairly strong brick.Rock samples and four bulk samples of the lateritic soil were collected.Petrographic analysis of the representative rock samples were carried out.Laboratory tests include specific gravity, grain size distribution; consistency limits, compaction and unconfined compression test on the compacted samples werecarried out in accordance with the specification of British Standard 1337. Samples of the lateritic soils were stabilized with 5% and 10% by volume of Portland cement before they are subjected to 10, 20, 30, 40, 50, 60 blows using the modified American Association of States Highway and Transportation Officials (AASTHO) compaction level. The dominant minerals in the rocks are quartz with subordinate amounts of muscovite and feldspar. The soils are well graded and belong to group A-7-5 of the AASTHO classification system.The soils are of medium to high plasticity. Specific gravity reveals the soils are inorganic lateritic soil.Samples stabilized with 10% by volume of cement possessed high cured unconfined compressive strength (UCS) and dry density than samples stabilized with 5% by volume of cement. At higher mechanical energy, UCS of samples stabilized with 5% by volume of cement compared well with UCS of samples stabilized with 10% by volume of cement at lower energy.Samples mixed with 5% by volume of cement possessed adequate strength requiredto support bungalows if subjected to fairly high energy level.

Key words: Lateritic, Compressive strength, Bricks, Compaction, Stabilization

INTRODUCTION

The rapidpopulation growth, low Gross National Product and low purchasing power are factors that contribute to the progressive deterioration of the housing situation in developing economies. Provision of housing is a challenge in most of developing countries around the world. An obstacle to the solution of the problem is the scarcity and/or the high-cost of building materials as most of these countries rely on imported materials which required foreign exchange.The problems affecting construction industry observed by Hashim (1992) includes scarcity and cost of construction materials, high demand for housing, lack of promotion of use of locally sourced materials.The use of cheap and high quality local natural resources for this purpose is therefore very vital in order to meet housing demands in cities of the developing countries.

To minimize over reliance on conventional building materials, especially cement and also addressing the problem of 7% CO_2 emission to atmosphere (Rashid *et al* 2010), researches have been intensified on alternative materials that can be used to replace cement partially or wholly for construction purposes (Okoli and Zubairu, 2002; Adam and Agib 2003).However, recent awarenessregarding sustainable living, better understanding of the thermal benefits, safety and durability of earth, and the lower energy inputs of construction using earth (e.g., Heathcote 1995; Ren and Kagi 1995; Walker 1999) have initiated renewed interest in earth as an alternative building material.

Among the alternative raw materials available for low cost housing production are the compressed laterite soil blocks or bricks (Onaolapo 2010). Laterites has been the oldest and most widely known used building material.Most structures constructed with only basic earth materials undergo rapid deterioration due to low dry strengths which decreases to zero in wet conditions and also have high porosities and water absorption capacities. Likewise, they also show shrinkage cracks under dry conditions, swelling under wet conditions, and high susceptibility to damage due to periodic wetting and drying. However, Mbumbia *et al* (2000)and Heathcote(1991) have shown that blocks and bricks made from lateritic local soil can be improved upon to produce masonry units/bricksstrong enough to meet building standards. Soil stabilizationhas over the year gained popularity among soils users. Soil stabilization implies the modification of properties of a soil to obtain lasting quality which are compatible with a particular application (UNCHS 1986).

Various materials have been used to stabilize laterite for bricks making. Prominent among these are cement, lime, bitumen, burnt brick, corn-cob ash and clay. Portland cement is the most widely used earth stabilizer.Stabilizing a soil by adding a chemical stabilizer (usually cement and/or lime) and compacting it increases the material's compressive strength and durability, reduces shrink and swell, and provides

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waterproofing qualities (Winterkorn 1975; Akpokodje 1985; UN 1992; Heathcote1995; Symons 1999; Walker 2004).Akinmusuru(1994) has shown that the inclusion of grids of wood or bamboo cores significantly improves the bending strength of earth walls built for appropriate use by rural dwellers. This study shows that the compressive strength can be further increased by the addition of ordinary Portland cement to the lateritic soil mix.

In-spite of the elaborate work that has being done on laterite bricks, little has been done or documented on laterite bricks produced by cement stabilization using percentage volume. This work assesses the strength characteristics of laterites soil samples stabilized with 5% and 10% by volume of cement under different level of energy for the production of bricks.

The study area is locatedin Erijiyan –Ekiti, southwestern Nigeria.The lateritic soil developed over a quartzite (Figure 1). This rock is part of the Precambrian basement complex of southwestern Nigeria. The weathering profile (top-down) of the study area shows an overburden thickness of about 0.3 meter and a dark-grey horizon enriched in organic matter. The second horizon varies in thickness from 0.5 to 3 meters. It is reddish brown in color and made up of sandy clay materials. The third layer marks the bottom of the profile; it consists of grey highly weathered friable materials.

MATERIALS AND METHODS

Four bulk disturbed samples of the lateritic soils were collected within the lateritic horizon at interval of 10m from each other laterally within the depth of 1.0m and air dried for two weeks. Petrographic analysis of the representative rock samples were carried out in order to determine their texture and mineralogical composition. Laboratory tests were carried out in accordance with the specification of British Standard 1337. The tests include specific gravity, grain size distribution, consistency limits, compaction and unconfined compression tests. Samples of the lateritic soils were mixed with 5% and 10% by volume of Portland cement before subjected to 10, 20, 30, 40, 50, 60 blows using the energy level of modified American Association of States Highway and Transportation Officials (AASTHO) compactions. The compacted samples were then subjected to unconfined compression test.

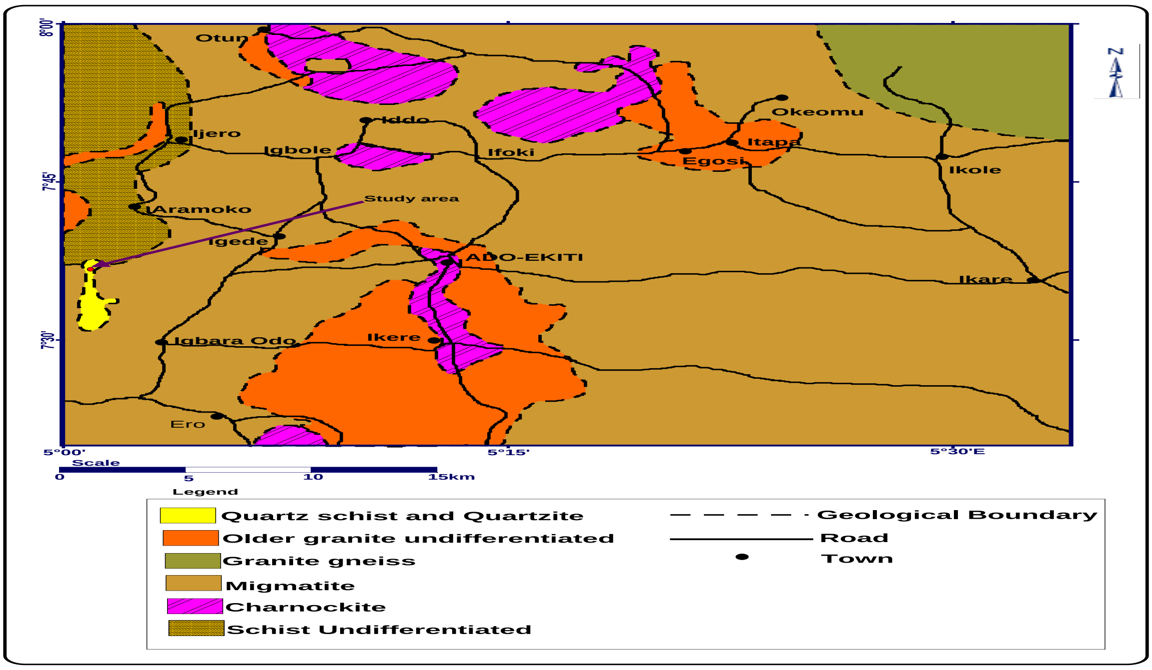

Fig. 1: Geological map of the study area.

RESULTS AND DISSCUSIONS

Petrography of Parent Rocks:

The texture and mineralogy of the parent rocks are likely to influence the engineering properties of the derived soil such as texture and plasticity. The major minerals are quartz with subordinate amounts of muscovite and feldspar. Quartz present in the parent rock will be retained as sand grains in the derived soil, both the feldspar and muscovite decompose into secondary minerals (clay minerals) which are lighter than their primary minerals. This makes the derived soil have fairly high dry density, low to medium plasticityand low amount of fines. The soil is also expected to exhibit fairly high cohesion, hence high shear strength.

Specific Gravity:

Specific gravity is closely linked with the mineralogical/chemical composition and degree of weathering of a soil. De Graft Johnson (1969) noted that the higher the degree of laterization, the higher the specific gravity. Table 1 shows the result of the specific gravity test. The specific gravity ranges between 2.60 - 2.70. Lateritic soils are classified as soils with specific gravity between 2.60 and 3.40 (De Graft Johnson, 1969). All the soil samples have their specific gravity fall within this range.According to Ramamurthy and Sitharam (2005) the studied soils can be classified as inorganic soils base on their values of specific gravity.

Table 1: Result of Specific Gravity Test

LOCATION	SPECIFIC GRAVITY VALUE			
	A	B	C	D
E1	2.63	2.62	2.60	2.65
E2	2.65	2.60	2.65	2.70
E3	2.62	2.65	2.60	2.60
E4	2.66	2.60	2.70	2.65

Grain Size Distribution Characteristics:

Grain size distribution is important in the estimation of relative proportion of various size grades in the samples. The engineering properties of lateritic soils have been found to depend on their grain size characteristics. The results of the grain size distribution areshown (Table 2) and further illustrated in Figures 3-6.From the grain size distribution test, it was found that the lateritic soil contained (average) gravel (5.96%), sand (55.07%), silt (22.89%), and clay (16.16%) which indicates the soil is very clayey silty sand.Based on the grading curves, the soil samples are well graded. Lee (1961) stated that the sand size particles contribute to the mechanical strength while the colloidal content of clay provides the plasticity. Adeyemiet. al. (1991) noted that an inverse relationship exists between the percentage clay size fraction and crushing strength of bricks. The soil is expected to display fairly high strength. Graham and Burt (2001) proposed that the ideal soil should compose soil with a combined clay (15-20 percent) and silt content of approximately 25-40 percent (by volume), and a sharp sand content of approximately 40-70 percent (by volume). Using the AASTHO method of classification the samples all fall into group A-7-5.

Table 2: Grain Size Analysis Results.

LOCATION	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	AMOUNT OF FINES (%)
E1a	4.02	54.20	24.79	13.21	38.00
E1b	8.01	55.09	22.00	15.00	37.00
E1c	6.60	50.41	26.00	17.00	43.00
E1d	5.00	62.02	20.00	12.20	32.20
E2a	9.09	58.23	18.50	14.50	33.00
E2b	7.10	61.60	19.00	12.30	31.30
E2c	8.00	57.50	14.50	20.00	34.50
E2d	6.00	70.00	14.00	10.00	24.00
E3a	3.40	56.00	20.60	20.00	40.60
E3b	4.00	43.00	37.70	18.30	56.00
E3c	3.60	56.40	20.00	20.00	40.00
E3d	4.90	54.50	25.60	15.00	40.60
E4a	8.00	47.00	25.00	20.00	45.00
E4b	2.50	59.00	23.20	15.30	38.50
E4c	7.09	45.00	30.72	18.00	48.72
E4d	8.02	51.30	24.60	17.80	42.40

Consistency Limits:

The plasticity of a lateritic soil is a vital consideration in the determination of geotechnical properties of such soil. Lateritic soil should be plastic in order to be easily manipulated. However, excessive plasticity can cause deleterious effect on bricks during firing such as development of cracks. Table 3 below shows the consistency limits obtained for the lateritic soil samples. Casagrande classification (Figure 7) shows that the lateritic soils are inorganic clays of medium plasticity. The lateritic soils are likely to be easily worked for brick making and are not likely to exhibit high volumetric shrinkage on firing since their plasticity index are less than 25% (Ola, 1982). This may be attributed to high amount of kaolinite and sand fractionsin the lateritic soil.The average plasticity index of laterite was found to be17%, indicating that the lateritic soil samples can be described as having low plasticity (<35%) according to BS: 1377 (1975). This indicates that the lateritic soil samples have good cohesion and hence can receive proper compaction to enhance strength and durability characteristics. Furthermore, Houben and Guillard (1994) found that soil with plasticity index below 20% is suitable for cement stabilization while Burroughs (2008) states that soil with linear shrinkage of 6.0–11.0%, plasticity index 15–30% and sand content less than 64%, respond favorably well when stabilized with quantities of cement and lime that averaged 4% and 2%, respectively. The plasticity index of the lateritic soil samples satisfies the above specifications.

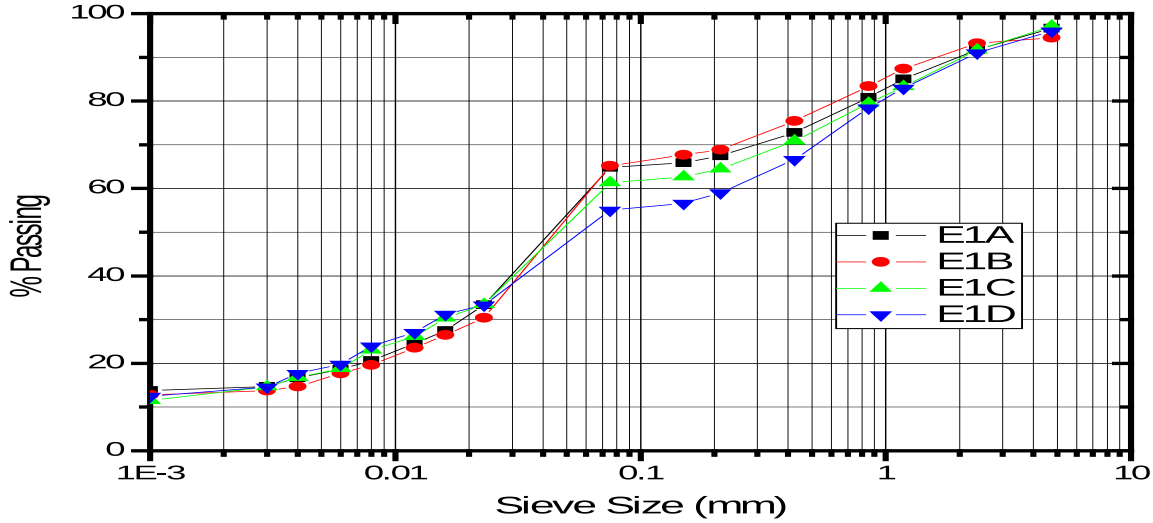

Fig. 3: Particle Size Distribution curves (Sample E1)

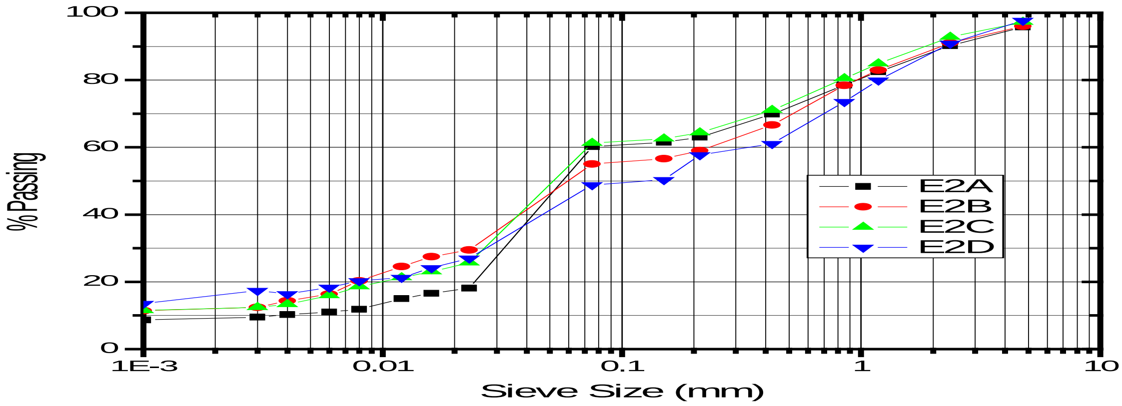

Fig. 4: Particle Size Distribution curves (Sample E2)

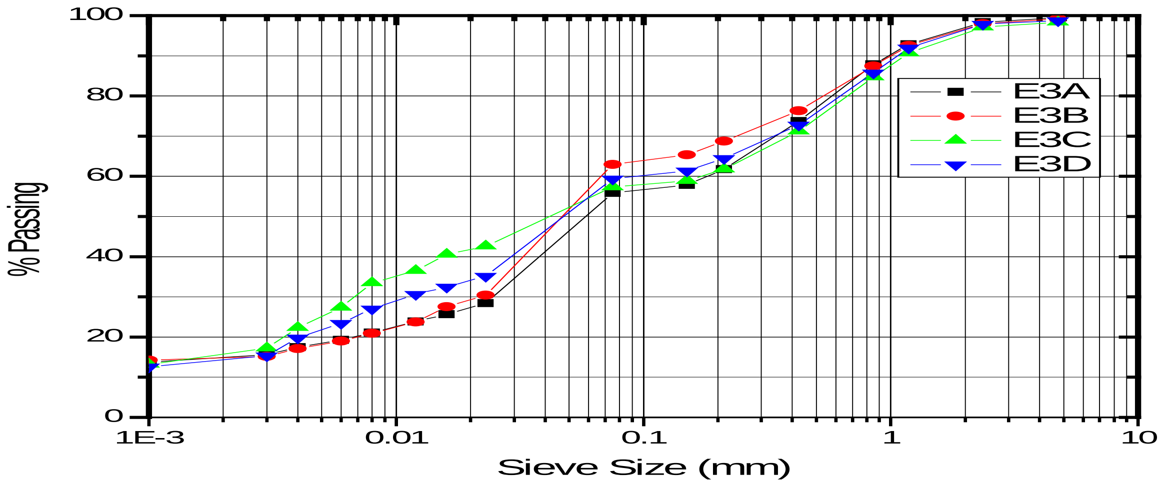

Fig. 5: Particle Size Distribution curves (Sample E3)

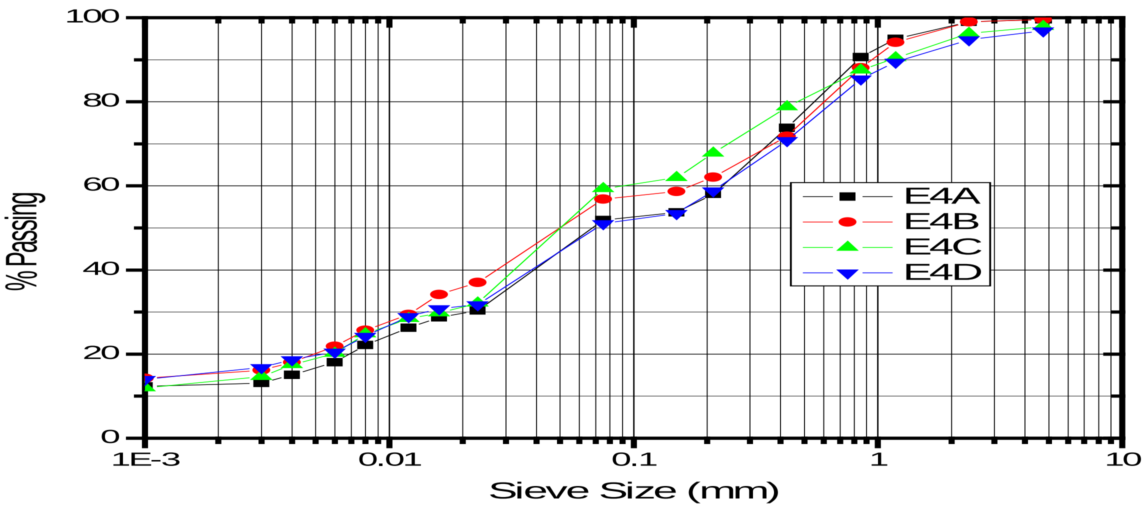

Fig. 6: Particle Size Distribution curves (Sample E4)

Table 3: Plasticity Test Results

Location	Liquid Limit (%)				Plastic Limit (%)				Plasticity Index (%)			
	A	B	C	D	A	B	C	D	A	B	C	D
E1	47.14	45.00	54.80	57.01	26.63	25.73	34.69	38.76	20.51	19.27	20.11	18.24
E2	40.50	40.20	44.00	56.01	22.88	23.11	25.51	37.35	18.22	17.09	18.49	18.66
E3	41.12	42.20	43.02	52.00	24.59	25.27	26.41	35.14	16.53	16.90	16.61	16.86
E4	45.46	43.25	42.18	45.40	27.73	25.24	22.75	27.04	17.00	18.00	19.00	18.36

Compaction Parameters:

The compaction characteristics in relation to dry density is largely a function of the constituent material's characteristics, moisture content during pressing and the degree of compactive energy applied. Table 4 show the maximum dry density (MDD), optimum moisture content (OMC)of the lateritic soil samples compacted at modified AASTHO level without the addition of cement. The values of MDD obtained are lower than the recommended value of 1810kg/m^3 specified by Nigeria Building and Road Research Institute (NBRRI) for bungalow bricks (Agbede and Manasseh, 2008).`

Table 4: Compaction Characteristics of Unstabilized Soil samples

LOCATION	MDD (kg/m^3)	OMC(%)
E1	1705.35	21.12
E2	1728.10	19.01
E3	1712.23	19.74
E4	1758.50	18.96

Table 5 shows the values of MDD and OMC of the lateritic soil after stabilizing with 5% and 10% by volume of cement with the number of applied blows. From the table, both the MDD and OMC increases and decreases respectively with the addition of cement and increase in mechanical energy. These can be attributed to micro fabric changes and formation of various compounds such as calcium silicate hydrates and calcium aluminates hydrates in the soil. It may also be due to promotion of cementation and semi-rigid soil frame work. Furthermore, increase in mechanical energy will lead to decrease in the frequency of pores and elimination of larger pores resulting from the structural rearrangement of soil particle in the soil mass. Also lateritic soil samples stabilized with 10% volume of cement have higher MDD and lower OMC compared with samples stabilized with 5% by volume of cement.Although, this shows an improvement in the compaction characteristics of the soil but the percentage increase in MDD and decrease in OMC is minimal. This implies that an increase in amount of cement when stabilizing a soil does not necessarily yield proportional increase in compaction characteristics.The recommended value of 1820kg/m^3 specified by Nigeria Building and Road Research Institute (NBRRI) for bungalow bricks is attained in lateritic soils stabilized with 5% by volume of lateritic soil at higher mechanical energy (40% blows) compared to 20 blows when stabilized with 10% by volume of cement. The may be attributed to the difference in the amount of cement used.

Unconfined Compressive Strength (UCS):

Apparently, compressive strength is the most generally accepted value for determining the quality of bricks. Nevertheless, it is related with the soil types, stabilizer content, compaction pressure and types of compaction. Table 6 shows the value of cured unconfined compressive strength (UCS) of the soil samples after stabilizing with 5% and 10% by volume of cement. It is observed that the cure UCS increases with addition of cement. The increase in strength on addition of cement is as a result of moisture affinity of grains of soil attributable to surface chemical reaction and also due to the promotion of cementation and semi rigid soil framework. Also at both 5% and 10% stabilization, the compressive strength of the soil samples increases as the mechanical energy increases. This is attributed to the fact that strength increases with increase in compactive energy. The strength of lateritic soil samples stabilized with 10% volume of cement is higher compared with samples stabilized with 5% by volume of cement. The percentage increase in some of the samples are more than 100% while it is less in some but generally the percentage decreases with increase in compactive energy.

UCS of 1650KN/m^3 is the minimum recommended value given by NBBRI for a bungalow brick (Agbede and Manasseh 2008). Values above this recommendation are obtained when samples were mixed with 5% by volume of cement at higher compactive energy (50 blows and above) while these values are obtained at low compactive energy (10 blows) when the samples were mixed with 10% by volume of cement. However considering cost implication, 5% by volume of cement stabilization under a high compactive energy will be effective as using 10% by volume of cement could lead to higher cost implication.

Table 5: Variation of Maximum Dry Density and Optimum Moisture Content with Cement Content

LOCATION	NO OF BLOWS		10	20	30	40	50	60
E1	MDD(kg/m^3)	5% Cement	1760.23	1799.56	1823.28	1848.56	1865.23	1889.30
		10% Cement	1790.40	1822.18	1852.12	1892.38	1932.1	1951.98
		% Increase	1.71	1.26	1.58	2.37	3.59	3.32
	OMC (%)	5% Cement	21.60	20.9	19.20	18.25	17.7	16.8
		10% Cement	20.46	20	18.42	17.21	16.71	16.1
		% Decrease	5.28	4.31	4.06	5.70	5.59	4.17
E2	MDD(kg/m^3)	5% Cement	1758.39	1790.3	1825.05	1852.39	1871.35	1896.51
		10% Cement	1790.15	1817.48	1860.34	1895.66	1905.95	1950.43
		% Increase	1.81	1.52	1.93	2.34	1.85	2.84
	OMC (%)	5% Cement	19.89	18.8	18.05	17.92	17.24	17.05
		10% Cement	18.4	18.04	17.5	17	16.7	16.2
		% Increase	7.49	4.04	3.05	5.13	3.13	4.99
E3	MDD(kg/m^3)	5% Cement	1770.10	1801.25	1815.22	1837.22	1856.22	1870.00
		10% Cement	1792.74	1821.00	1850.56	1883.04	1912.26	1970.55
		% Increase	1.28	1.10	1.95	2.49	3.02	5.38
	OMC (%)	5% Cement	21.01	20.8	19.89	18.5	17.01	16.9
		10% Cement	19.6	19.19	18.42	17	16.5	16.2
		% Increase	6.71	7.74	7.39	8.11	3.00	4.14
E4	MDD(kg/m^3)	5% Cement	1788.15	1809.00	1820.10	1840.10	1861.30	1895.10
		10% Cement	1808.02	1830.00	1870.25	1910.05	1950.1	1980.00
		% Increase	1.11	1.16	2.76	3.80	4.77	4.48
	OMC (%)	5% Cement	21.2	19.6	19.09	18.8	18.09	17.2
		10% Cement	19.5	18.7	18	17.7	16.56	15.9
		% Increase	8.02	4.59	5.71	5.85	8.46	7.56

Table 6: Unconfined Compressive Strength of the Stabilized Soil

LOCATION	NO OF BLOWS		10	20	30	40	50	60
E1	Cured UCS (KN/m^3)	5% Cement	820.00	1100.00	1210.10	1420.23	1876.25	1980.04
		10% Cement	1849.59	1998.36	2061.78	2310.05	2582.54	2647.11
		% Increase	125.56	81.67	70.38	62.65	37.64	33.69
E2	Cured UCS (KN/m^3)	5% Cement	824.4	1050.94	1344.00	1540.14	1780.59	1940.04
		10% Cement	1904.57	2058.92	2149.43	2350.58	2573.69	2690.91
		% Increase	131.02	95.91	59.93	52.62	44.54	38.70
E3	Cured UCS (KN/m^3)	5% Cement	750.16	983.71	1226.33	1437.46	1650.8	1990.10
		10% Cement	1903.29	2111.20	2178.51	2259.51	2536.39	2798
		% Increase	153.72	114.62	77.64	57.19	53.65	40.60
E4	Cured UCS (KN/m^3)	5% Cement	1310.65	1602.19	1660.00	1960.14	2050.00	2308.00
		10% Cement	1821.58	1934.43	2173.44	2396.34	2561.98	2709.91
		% Increase	38.98	20.74	30.93	22.25	24.97	17.41

Conclusions:

Lateritic soil developed over quartzite in southwestern Nigeria was tested for its suitability for the production of bricks when stabilized with 5% and 10% by volume of cement. The petrography of the rock reveals that the major minerals are quartz with subordinate amounts of muscovite and feldspar. The rock is also expected to disintegrate to coarse to medium grained soil. The soil is well graded and contain high amount of coarse particles. Specific gravity reveals the soils are inorganic lateritic soil. The soils are of medium to high plasticity making it to respond well to cement stabilization.Samples mixed with 5% and 10% by volume of cement and subjected to different blow showed increase in maximum dry density and cured unconfined compressive strength. Samples stabilized with 10% by volume of cement possessed high cured unconfined compressive strength and dry density than samples stabilized with 5% by volume of cement.At higher mechanical energy, unconfined compressive strength of samples stabilized with 5% by volume of cement compared well with unconfined compressive strength of samples stabilized with 10% by volume of cement at lower energy. Therefore, considering cost implication, 5% by volume of cement stabilization under a high compactive energy will be effective as using 10% by volume of cement could lead to higher cost implication.

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