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Effect of Chemical Stabilization on the Strength Characteristics of Lateritic Soils Derived from Quartz Schist in OJOO, IBADAN, Southwestern Nigeria

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ABSTRACT: In a bid to investigate the possibility of improving the physical and strength properties of reddish-brown lateritic soils developed over quartz schist within Ibadan, stabilization and compaction were executed on samples of the residual soils. Geological mapping and petrography confirmed the rock type. Classification, compaction, and unconfined compressive strength (UCS) tests were carried out on the specimens following standard procedures which were modified to take care of peculiar characteristics of lateritic soils. Samples of the lateritic soils were stabilized with 5% and 10% by volume of Portland cement before being subjected to 10, 20, 30, 40, 50 blows using the modified American Association of States Highway and Transportation Officials (AASTHO) compaction level. The quartz- schist-derived samples had medium plasticity and classify in both A-6 and A-7-6 groups of the AASHTO classification system. Properties of the natural and treated soil samples showed that stabilization is slightly more effective at 10% cement by volume compared to at 5%by volume of cement; with higher Maximum Dry density (MDD), lower Optimum Moisture Content (OMC) and higher cured Unconfined Compressive Strength (UCS). UCS value of 1650KN/m^3 and 1750 KN/m^3 recommended by NBBRI and Nigerian Association of Engineers respectively for a bungalow brick were met by samples of the quartz schist-derived lateritic soils when mixed with 5% by volume of cement at higher compactive energy of 55 blows while these values are obtained at a relatively lower compactive effort (35 and45 blows) when the samples were mixed with 10% by volume of cement.

I. INTRODUCTION

In geotechnical engineering, soil stabilization is the treatment of soils to improve their strength and durability such that they become totally suitable for construction beyond their original classification. Lambe (1958) defined it as the alteration of any property of a soil to create an improved soil possessing the desired engineering properties or performance. Soil modification and stabilization increases the strength, bearing capacity and durability of the soil (Gidigasu, 1976). Several workers including Ola (1974), Adeyemi et al. (2003), Amu et. al. (2011), and Adeyemi and Afolagboye (2013), have stabilized lateritic soils using various methods, they have shown that geotechnical properties such as linear shrinkage, plasticity index, maximum dry density (MDD), optimum moisture content (OMC), California bearing ratio (CBR) and unconfined compressive strength (UCS) are improved with the addition of the stabilizing agent. However, little has been done on the stabilization of lateritic soils derived over quartz schist within the area under study so as to recommend to the engineers a specific combination of appropriate energy level and percentage volume of cement that is well suited for soil-cement stabilization in the area. Hence this study focuses on the behavior of lateritic soils developed over quartz schist rocks within Ibadan area.

II. RELATED WORK

Upon comprehensive review, it was observed that on the local and global scale, quite a number of researches has been carried out principally on the application of different stabilizers including cement, lime, Rice Husk Ash (RHA), Banana Ash, Asphalt as well as waste materials. These researches include Remus and Davidson (1961) which reported an increase in strength of lime-established lateritic soil with increasing compactive efforts.
De Graft – Johnson et al., (1969) reported that due to the high sesquioxide in laterites, they can be stabilized with small amount of lime and cement because of the reaction of lime with iron and aluminum oxides. The work of Ola (1977) also

showed that with increasing the quantity of cement led to a corresponding increase in the compressive strength of lateritic soils.

Balogun (1982) having stabilized some amphibolit-derived and mica-schist-derived lateritic soils as well as coastal plain sands from similar climatic environment in southwestern Nigeria, observed that the coastal plains sands was the most sensitive to lime stabilization followed by the amphibolites-derived lateritic soils. The mica-schist-derived lateritic soil was the least sensitive. This is as a result of mineralogical contrasts..

Adeyemi and Abodurin (2000) stabilized lateritic soil from Ife/Sekona road, southwestern Nigeria. It was established from this research that the samples stabilized with cement exhibited higher strength than those stabilized with a mixture of cement and lime, while lime-stabilized samples were observed to possess the least strength.

A study of the characteristics of lime- stabilized lateritic soil from Ile-Ife, southwestern Nigeria, established that addition n of lime led to a decrease in the plasticity index and linear shrinkage of the studied samples.

The effect of Lime on the engineering properties of soil was studied by Mohammed et al (2001), it showed that there was a reduction the consistency limit of the studied soil.

Adeyemi and Salami (2004) studied the geotechnical properties of termite-reworked soils from Ago-Iwoye . it was established that the geotechnical properties of the reworked soils were better than that of nearby soils even though no there was no clear cut influence of the reworking on the grain size distribution and moisture-density characteristics of the studied soils.. From a comparative study of the termite-reworked soils and neighboring lateritic soils, it was also established that the specific gravity of grains and the California Bearing Ratio of the termite-reworked soils were higher than those of nearby soils. They found out that the plasticity indices and linear shrinkage of the termite –reworked soil were significantly lower than those of nearby soils while the Unconfined Compressive Strengths were significantly higher. A fairly positive correlation was established between the strength parameters (CBR and UCS) and energies of compaction of the residual lateritic soil.

Study of the geotechnical properties of cement-stabilized soils developed over different parent rocks (i.e Pegmatite, Banded Gneiss and porphyroblastic Gneiss) from Ago-Iwoye by Oloruntola et al (2005), showed that chemical stabilization has varying influence on geotechnical properties such as California Bearing Ratio, Plasticity, Moisture-Density relationship and Unconfined Compressive strength of genetically different soils.

Owolabi et al (2014) evaluated the geotechnical properties of termite-reworked lateritic soil from selected sites in southwestern Nigeria and their suitability for road construction. Form their evaluation, it was revealed that the termite-reworked soils exhibited higher plastic limits, specific gravities, maximum dry densities (MDD) and California bearing Ratios (CBR) that non-reworked soils while their plasticity indices, liquid limits and Optimum moisute contents(OMC) were lower. In conclusion, the termite-reworked lateritic soils were adjudged suitable as sub-grade and sub-base materials for road construction.

Adeyemi and Afolagboye (2013) while investigating the possibility of improving the geotechnical properties of lateritic soils developed over migmatite gneiss by compacting it with lateritic soils developed over quartz schist of a Migmatite Gneiss-derived lateritic Soil from Southwestern Nigeria, made the following conclusions;

i. Quartz schist derived soil has better engineering characteristics than migmatite gneiss derived soil.
ii. 40 percent of the stabilizer is quite appropriate for the stabilization of the studied soil since marginal increase in strengths (CBR and UCS) were recorded beyond 40% stabilization.
iii. Mechanical stabilization of migmatite gneiss derived lateritic soil was found to produce CBR values typical of sub grade materials. The uncured and cured strength of the stabilized soil is lower than the minimum acceptable values of 103KN/M2 and 1034KN/M2.

Singh et al (1961) used lime for the stabilization of soil and concluded that it is an excellent stabilizer for highly active soils which undergo frequent expansion and shrinkage, and that Lime acts immediately and improves various property of soil such as carrying capacity of soil, resistance to shrinkage during moist conditions, reduction in plasticity index, increase in CBR value and subsequent increase in the compression resistance with the increase in time.

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III. STUDY AREA

The study area is located within faulty of technology, University of Ibadan, between longitude 7°26'212.5'' and latitude 3°53'31.2'' in Ibadan, Southwestern Nigeria. The area falls within the Precambrian basement complex of southwestern Nigeria.

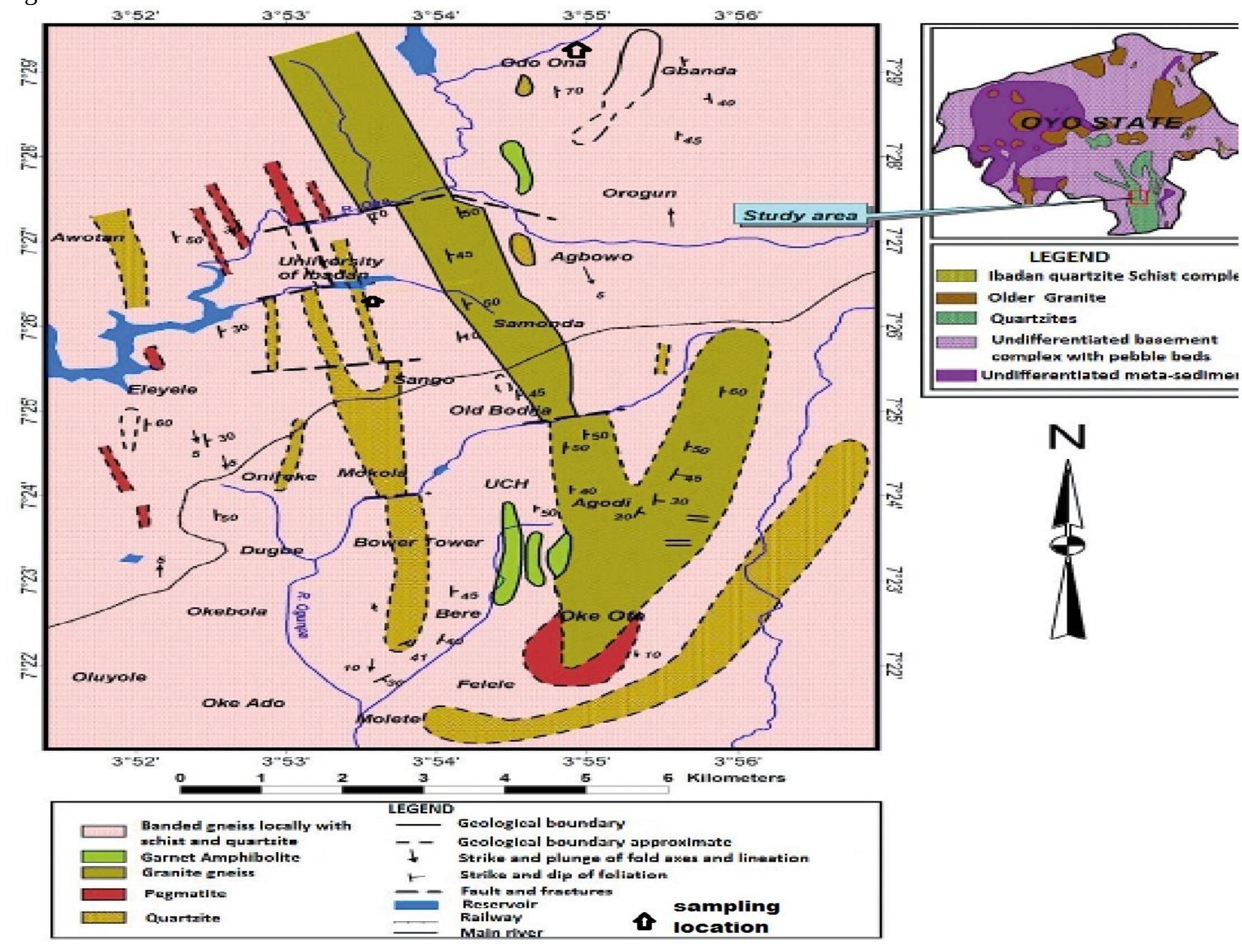

Figure 1.0: Geological map of Ibadan showing the sampling location (modified from Amobichukwu, 2015).

IV. MATERIALS AND METHODS

The disturbed lateritic soil samples used for this study were collected from a lateritic soil formation behind the Department of Agricultural Engineering, Faculty of technology, University of Ibadan. Three bulk disturbed samples of lateritic soils were obtained from test pits at sampling intervals of 5meters and air dried for two weeks. Petrographic analysis of the representative rock samples were carried out in order to determine the mineralogical composition of the parent rocks and texture. Laboratory tests were carried out in accordance with the specification of British Standard 1337 of 1975 with some minor modifications where necessary. Tests including; grain size analysis, consistency limits, specific gravity, compaction and unconfined compressive strength tests were performed. Samples of the lateritic soils were mixed with 5% and 10% by volume of Portland cement and subjected to 10, 20, 30, 40 and 50 blows using the energy level of modified AASTHO compaction. Unconfined compression test was employed in determining the strength of the stabilized soils.

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V. RESULTS AND DISCUSSION

Table 2.0: Summary of Index Properties of the studied soils.

Rock type	Sample	Specific gravity	Consistency limits (%)			Grain size Distribution (%)				
			Liquid limit	Plastic limit	Plasticity index	Gravel sized	Sand sized	Clay	Silt	Fine
Quartz schist	A 1	2.60	47.48	28.9	18.58	1.02	35.58	11.8	51.6	63.4
	A 2	2.60	51.33	31.24	20.09	6.96	23.24	13.5	56.3	69.8
	A 3	2.65	38.21	20.80	17.41	5.55	23.24	9.5	37.24	46.74

A. CONSISTENCY LIMITS

The physical and engineering properties of soils have been found to depend on their textural characteristics. The result obtained from the grain size analysis (Table 2.0) show that the amount of fines present in the quartz schist-derived soil ranges between 45% and 65%. The amount of fines in the soil is due to the dominance of quartz. The soil is well graded. Figure 4.0 shows the grading envelope of a quartz schist-derived soil sample . According to the specification of the Federal Ministry of Works and Housing an amount of fines not more than 15% is required for a sub base material (FMWH, 1997). Based on this, the soil does not meet the required standard for road construction.
Using the grainsize distribution and the consistency limits, the soil samples of the quartz schist sample classify between A-6 to A-7-6 based on the AASHTO classification system. Consistency limits characteristic is an important factor employed in the selection of lateritic soils both as sub-grade and base materials. The plasticity index between 17.14 and 20.09, and liquid limit between 38.21 and 51.33 indicates that the soils are not suitable as base/sub-base materials in road construction because they are above the maximum figure of 12% and 30% respectively recommended for sub-base/base soils by FMWH specification (1997). However, based on the recommendation of upper limit of 25% for plasticity index of sub base materials for road construction in tropical Africa by the French (Simon et al, 1973), the soils could be used as a highway sub base materials. Figures 3 shows the plasticity charts of the schistose quartzite derived soils. The Casagrande chart classification indicates medium plasticity and hence medium compressibility for schistose quartzite-derived soils hence these soils are not expected to suffer any significant deformation when loaded.

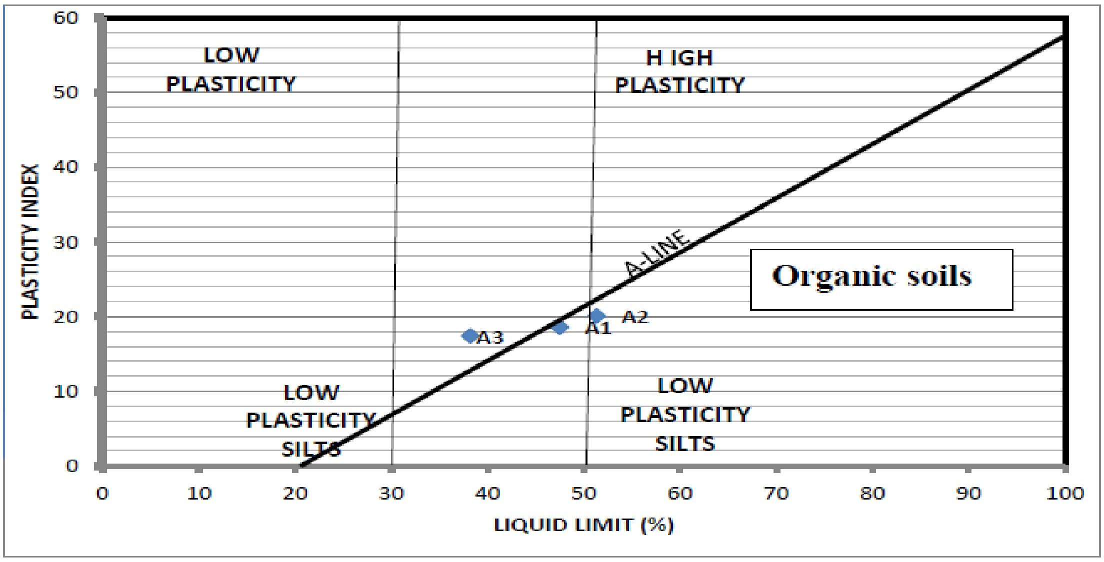

Figure 3.0: Cassagrande plasticity chart for Quartz schist-derived soil samples

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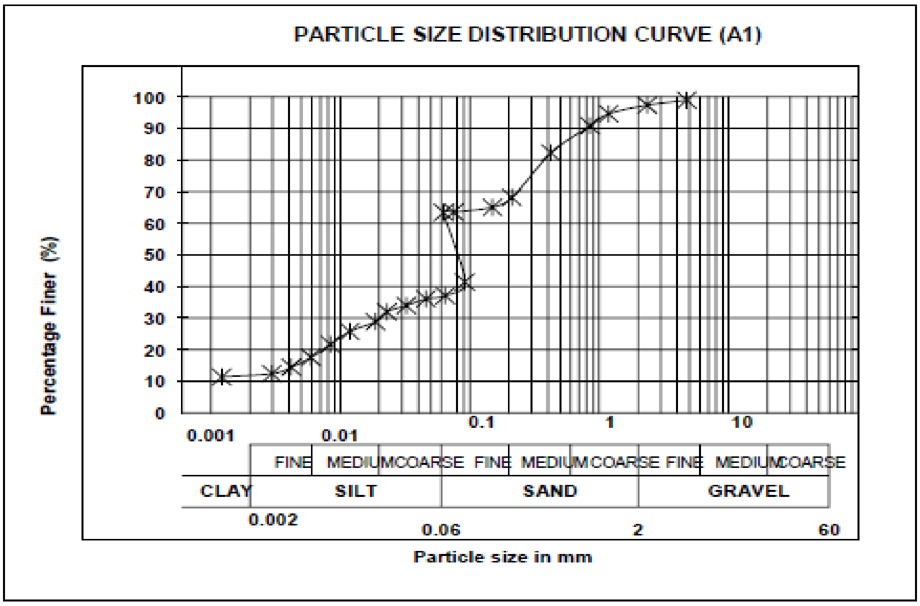

Figure 4.0: Particle size distribution curve of a Quartz-schist derive lateritic soil

B. INFLUENCE OF STABILIZATION ON COMPACTION PARAMETERS

The residual soils were subjected to compaction first at West African level prior to the addition of the stabilizing agent (cement), and then mixed with 5% and 10% by volume of cement and compacted at 15, 25, 35, 45 and 55 blows. Table 3.0 shows the values of compaction parameters obtained at West African energy level, prior to stabilization with cement. The values of MDD obtained are lower than the recommended value of 1810kg/m3 specified by Nigeria Building and Road Research Institute (NBRRI) for bungalow bricks (Agbede and Manasseh, 2008).Table 4.0 show the influence of compactive efforts on the MDD and OMC of the quartz schist-derived soil samples (A1, A2 and A3) after stabilization with 5 and 10% by volume of cement at respective energy levels. It was observed that values of MDD increased while OMC decrease with increase in cement content and compactive efforts. According to Adeyemi *et al*, (2013) this can be attributed to micro fabric changes and formation of various compounds such as calcium silicate hydrates and calcium aluminates hydrate in the soil. The increase in MDD could also be as a result of cement which has a higher specific gravity replacing the soil particles which has a lower specific gravity of 2.65 -2.60 resulting in the formation of a mixture with higher specific gravity and higher MDD as reported by Ishola, (2014). The observed decrease in OMC with higher compactive effort according to Osinubi, (1999) is not unconnected to the ease with which flocculated aggregates are broken down, shear planes destroyed and large poles eliminated at higher compaction energies

Amu *et al.*, (2011) stated that an increase in MDD values with increase in percentage of cement being added to lateritic soil indicates improvement in soil properties. This increase is however minimal; for the MDD, it ranges from 0.5% to 6% increase despite a 100% increase in cement content while the percentage decrease in OMC ranges from 5.05% to 0%. Peak MDD values of 1830.2Kg/m^3 and 1870Kg/m^3 were recorded at 5% and 10% by volume of cement respectively for the soil samples, while the least OMC values of 17.0 and 17.2 were recorded at 10% and 5% by volume of cement respectively. Apparently, soil samples stabilized with 10% by volume of cement have higher Maximum Dry Density and lower Optimum Moisture Content than those stabilized with 5% by volume of cement. Thisvariation is fairly significant. Thus an increase in the volume of stabilizer does not necessarily give a corresponding effect on the compaction parameters.

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Table 3.0 Result of compaction test

West African Level of Comapction		
Sample designation	OMC (%)	MDD (Kg/m^3)
A1	17.6	1725
A2	17.2	1750.11
A3	17.4	1770.15

Table 4.0 Influence of stabilization on compaction parameters

			SAMPLE A1					
NO OF BLOWS	5% CEMENT MDD	10% CEMENT MDD	% INCREASE IN MDD	NO OF BLOWS	5% OMC	10 % OMC	% INCREASE IN OMC	CUMMULATIVE%
15	1740	1750.15	0.58	15	18	17.8	-1.11	-1.11
25	1758.5	1780	1.22	25	17.8	17.6	-1.12	-2.23
35	1780.05	1820	2.24	35	17.4	17.4	0.00	-2.23
45	1810	1850.1	2.22	45	17.6	17.6	0.00	-2.23
55	1830.2	1870	2.18	55	17.2	17	-1.16	-3.40
			SAMPLE A2					
NO OF BLOWS	5% CEMENT MDD	10% CEMENT MDD	% INCREASE IN MDD	NO OF BLOWS	5% OMC	10 % OMC	% INCREASE IN OMC	CUMMULATIVE
15	1610.02	1710	6.21	15	18.15	17.6	-3.03	-3.03
25	1640.05	1730	5.49	25	18.8	19.2	2.13	-0.90
35	1720.07	1740.05	1.16	35	20.8	20.4	-1.92	-2.83
45	1760.14	1780.04	1.13	45	20	20.8	4.00	1.17
55	1780	1810	1.69	55	19.8	18.8	-5.05	-3.88
			SAMPLE A3					
NO OF BLOWS	5% CEMENT MDD	10% CEMENT MDD	% INCREASE IN MDD	NO OF BLOWS	5% OMC	10 % OMC	% INCREASE IN OMC	CUMMULATIVE
15	1630	1660.08	1.85	15	18.2	18.1	-0.55	-0.55
25	1690.1	1720.13	1.78	25	18	17.68	-1.78	-2.33
35	1725	1735.2	0.59	35	18.2	18.6	2.20	-0.13
45	1780.25	1795	0.83	45	18	18.8	4.44	4.32
55	1802	1830.1	1.56	55	19.2	19	-1.04	3.27

C. EFFECT OF STABILIZATION ON THE UNCONFINED COMPRESSIVE STRENGTH OF THE SOILS

The effect of varying quantity of cement (5% and 10% by volume) on the Unconfined Compressive Strength (UCS) for compactive efforts 15, 25,35, 45 and 55blows for all the samples is shown in Table 5.0. Generally, the UCS of the residual soil increased with increasing cement content for all the studied samples. Though the values of the Unconfined Compressive Strength increases with cement content, these increments were minimal; percentage increase in UCS values from 5% to 10% by volume of cement ranges from 0.61 to 24.02%. 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 (Adeyemi *et al.,*, 2013). Also, there was an increase in UCS with compactive effort at both levels of stabilization. This results from increase in strength with compactive energy.

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Table 5.0 Summary of suncured Unconfined compressive strengths (UCS) of all soil samples at various energy levels and percentage cement.

% stabilizer	Energy level of compaction (blows)	UCS of SAMPLES (kN/m²)					
		A1	Percentage increase	A2	Percentage increase	A3	Percentage increase
	West African	760.2	-	665.8	-	600.15	-
5%	15	1104.85	45.34	978.55	-	398.5	- -
	25	1159.8	4.97	1169.95	19.56	1164.8	192.30
	35	1281.85	10.52	1291.85	10.42	1205.15	3.46
	45	1417.3	10.57	1427.05	10.47	1224.2	1.58
	55	2178.7	53.72	2188.65	53.37	2194.5	79.26
10%	15	1113.15	-	1125.35	-	539.95	-
	25	1438.5	29.23	1448.5	28.72	1157.75	114.42
	35	1321.7	-8.12	1334.4	-7.88	1223.4	5.67
	45	1701.45	28.73	1711.35	28.25	1242.55	1.57
	55	2259.95	32.82	2269.95	32.64	2212.65	78.07

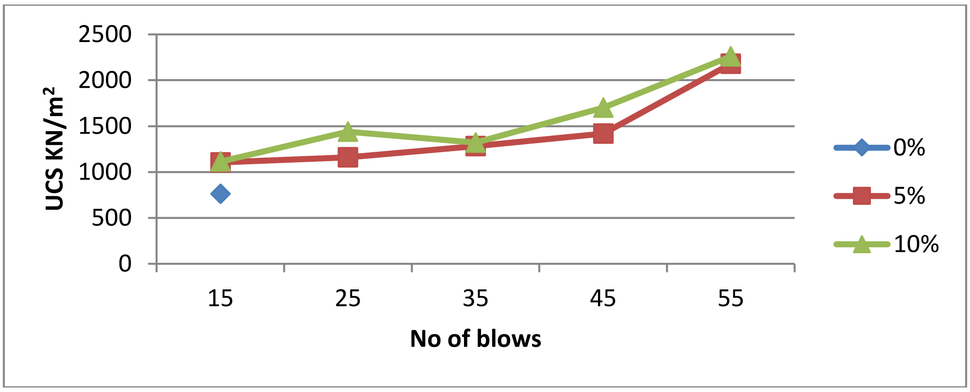

Figure 5.0 Relationship between the number of blows and cured strength using 5% and 10% by volume of stabilizer for sample A1

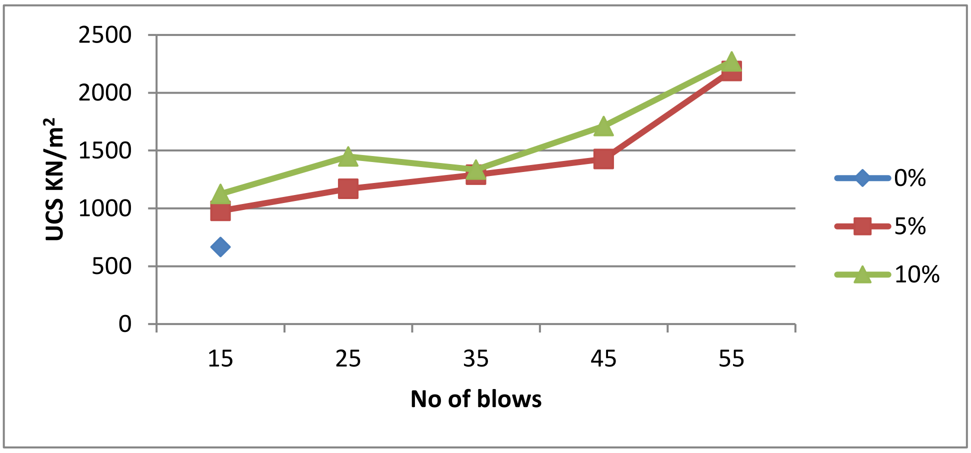

Figure 6.0 Relationship between the no of blows and cured strength using 5% and 10% by volume of stabilizer for sample A2

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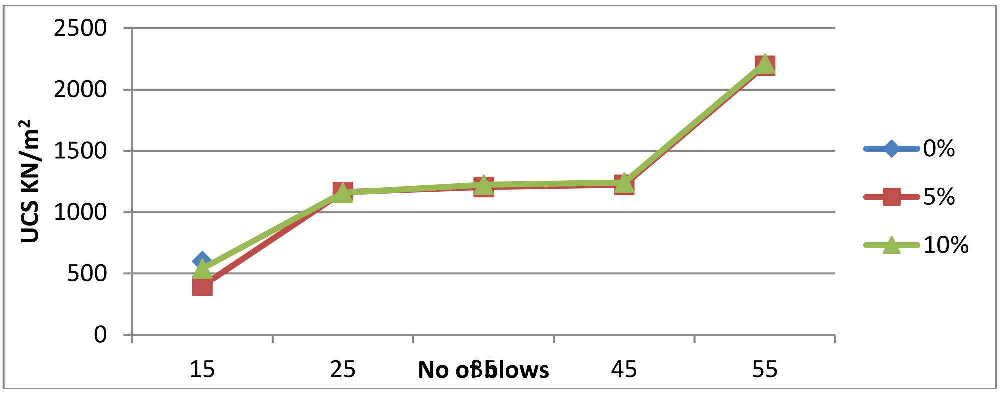

Figure 7.0 Relationship between the number of blows and cured strength using 5% and 10% by volume of stabilizer for sample A3

VI. CONCLUSION

The grain size distribution analysis showed that both the quartz schist-derived soils are well graded and have medium plasticity. From AASTHO classification, the soils classify as A-6 and A-7-6. The specific gravity values obtained fall within the 2.60-3.40 range specified by De-Graft Johnson for lateritic soils. However, based on results of consistency limits tests, the soils in their natural state do not meet the required standard of a maximum value of 12% and 30% for base/sub-base materials in road construction.

The residual soils possess Maximum Dry Densities (MDD) between 1725Kg/m^3 and 1750.08Kg/m3, and Optimum Moisture Content (OMC) between 17.6% and 18.4%.. Generally, lateritic soil samples stabilized with 10% volume of cement have higher MDD and lower OMC compared to samples stabilized with 5% by volume of cement. Although, this shows an improvement in the compaction characteristics of the soil, 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. Values of MDD obtained at higher energy level of compaction (from 35 blows and above), were higher than the recommended value of 1810kg/m3 specified by Nigeria Building and Road Research Institute (NBRRI) for bungalow bricks (Agbede and Manasseh, 2008). Peak values of Unconfined Compressive Strength (UCS) were obtained at the highest level of compaction for any amount of stabilizer. Increase in values of UCS was minimal. For the studied soils however, a similar effect was obtained at lower cement content of 5% by volume as 10% by volume of cement at 35 and 55 blows compactive effort for all stabilized soil samples of the schistose derived soils and across all energy levels for the migmatite.

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Babatunde, Adekunle Adeyeri is particularly interested in the field of Engineering and Hydrogeology geology. He graduated from the prestigious University of Ibadan with a Bachelor's degree in Geology and proceeded to with a Master's degree in Engineering and Hydrogeology in the same institution, graduating top of his class with a distinction. His Master's thesis focused on the stabilization of lateritic soils from different locations within Ibadan, southwestern Nigeria. He is currently working on the effect of mechanical stabilization of lateritic soils.