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MECHANICAL STABILIZATION OF A PEGMATITE DERIVED LATERITIC SOIL FROM IKIRE, SOUTHWESTERN NIGERIA

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ABSTRACT

Stabilization of lateritic soil developed over pegmatite by compacting it with soil developed over granite around Ikire and its environs was executed with the aim of determining the optimum combination of percentage by volume of the soil and the energy of compaction that will give adequate strength for construction purpose.

Preliminary tests were carried out to determine the better set of soil prior to stabilization. Laboratory tests included petrographic study, grain size distribution analyses, consistency limits tests and specific gravity determination, prior to stabilization with 15% and 30% respectively by volume of stabilizer and varying compactive energy before being subjected to unconfined compression test.

The major minerals in the pegmatite were quartz and feldspars with 25% and 51% respectively while the amounts in granite were 46% and 25% respectively. The pegmatite-derived soil possessed higher amount of fines than the soil developed over granite with average values of 42% and 25% respectively, due to the amounts of feldspars. This showed that the granite-derived soil is better than the soil developed over pegmatite. The values of the plasticity index ranged from 19.1% to 22.4% for pegmatite-derived samples and 10.0% to 15.2% for granite-derived samples. High energy of compaction gave values of Maximum Dry Density (MDD) higher than the recommended value of 1810Kg/m^3 for bungalow bricks. The peak values of suncured unconfined compressive strength (UCS) obtained were higher than the minimum acceptable figure of 1034KPa for bungalow bricks. Strong positive correlations (0.95, 0.96 and 0.82) were established between UCS and compactive energy. Stabilization of pegmatite-derived soil with granite-derived soil using 30% by volume of stabilizer at higher compactive energy was quite effective and it generated MDD and UCS which make it suitable for use as bungalow bricks and good sub-base material for building and road construction respectively.

INRTODUCTION

Lateritic soils occupy are important in regard to both their extensive occurrence and peculiar properties. They are formed under intense weathering system and they are composed of clayey soils that are rich in Aluminum and Iron compounds which are formed on the parent tock or transported to another location. The grain size can vary from fine grains to gravel according to its origin, thus influencing the geotechnical properties such as plasticity and compressive strength. The soils are weathered under conditions of high temperatures and humidity with well-defined alternating wet and dry seasons resulting in soils which may need improvements in engineering properties due to high plasticity, poor workability, low strength, high permeability, tendency to retain moisture and high natural moisture content (Gidigasu 1976). Lateritic soils that present such problems during construction processes are termed problematic laterites (Oyediran 2001). The modification/stabilization of engineering properties of soils is recognized by engineers as an important process of improving the performance of problematic soils and makes marginal soils perform better as construction material. In geotechnical engineering, soil improvement could be achieved by stabilization or modification or both. Several researches have focused on the stabilization of lateritic soils using chemical, physical and biological stabilizers especially to determine the effects of such stabilizers on the engineering properties of soils. Mechanical stabilization of soils with those of better geotechnical properties have not gained wide popularity. However, Adeyemi et al(2013) noticed appreciable improvement of some geotechnical properties of migmatite-gneiss derived soil after stabilizing with Schistose-quarzite derived soil from Ido-Ile, Ekiti, Southwestern Nigeria, This study was therefore carried out with the aim of stabilizing a lateritic soil with another lateritic soil of different origin and better engineering properties and to determine the most appropriate combination of energy level and percentage by volume of soil that will give optimum strength. Lateritic soil developed over pegmatite and the one developed over granite were considered for this study.

STUDY AREA

Two locations were chosen for this study, The pegmatite derived soil and granite derived soil were picked at ikire and ikoyi respectively. The study area lies between longitude 7°21’12.5’’ to 7°22’18.24’’ and latitude 4°10’15.2’’ to 4°11’50.64’’ on the topographical map of Ikire, Southwestern Nigeria (Fig 1). The topography is drained (dendritic) mainly by Osun River. The geology of the study area is a subset of the Precambrian basement complex of Nigeria has described by Jones and Hockey (1964) (Fig 2). The rocks in the study area comprises of gneiss, schist, charnockite, granite, granodiorite and pegmatite (oladeni and oziegbe, 2019). Granite in the study area are fine to coarse grain and porphyritic in some areas while the pegmatite show variation in grain sizes, though very coarse grain. Some of the pegmatite bodies are highly weathered.

METHODOLOGY

Three bulk samples of lateritic soil were collected from the vicinity of the two outcrops each at sampling points of 5meters apart. Petrographical analyses of the representative rock samples were carried out in order to determine their texture and mineralogical composition. Laboratory test such as grain size analyses, hydrometer test, consistency limits test, compaction and unconfined compression test were carried out in accordance with the specification of british standard 1337 of 1975. The prelimenary classification tests were carried out on the two lateritic soils of different origin to determine the soil sample with better engineering properties. The pegmatite derived soil was then mixed with 15% and 30% by volume of granite derived soil prior to being compacted together at 15, 25, 35, 45 and 55 blows of energy. The sample was then subjected to unconfined compression test. Correlation analyses were used to determine the effectiveness of the stabilizer on engineering properties of stabilized soils.

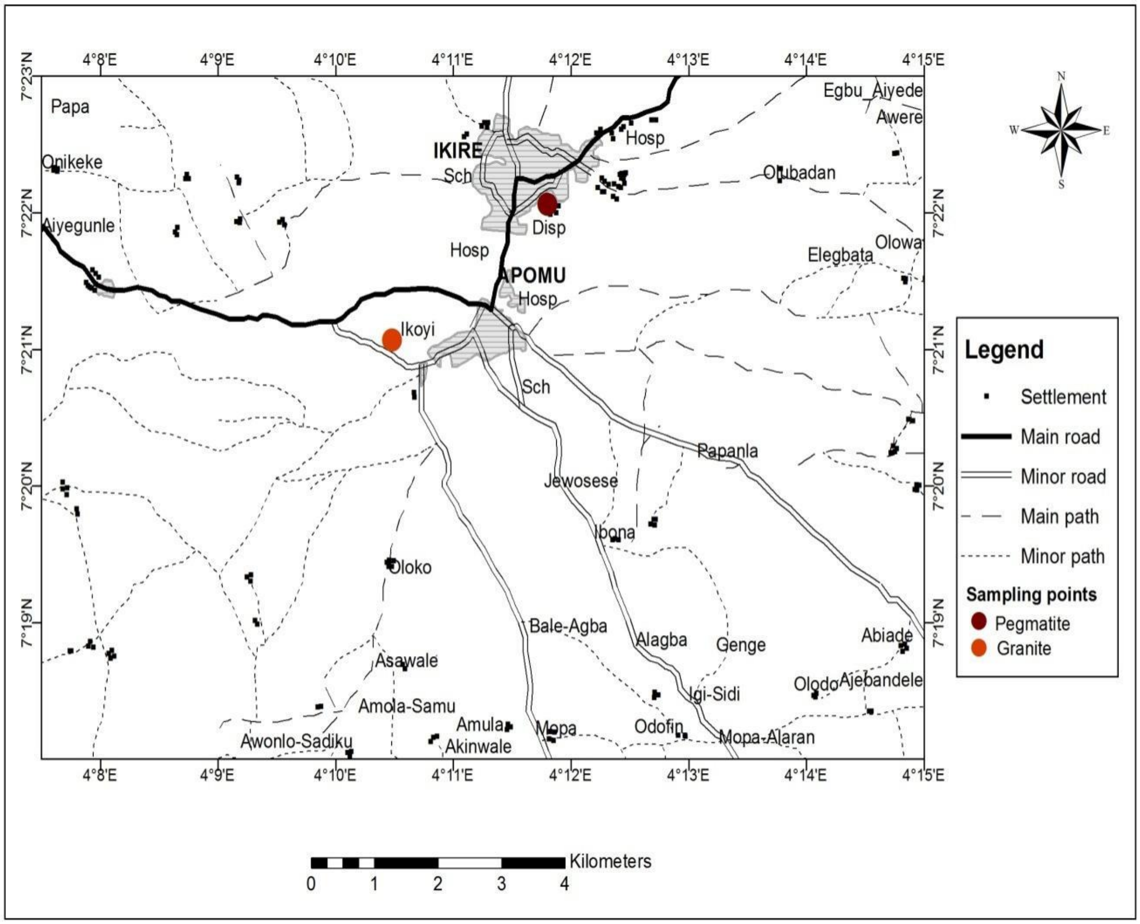


Figure 1: Map of the study area showing sampling location and accessibility

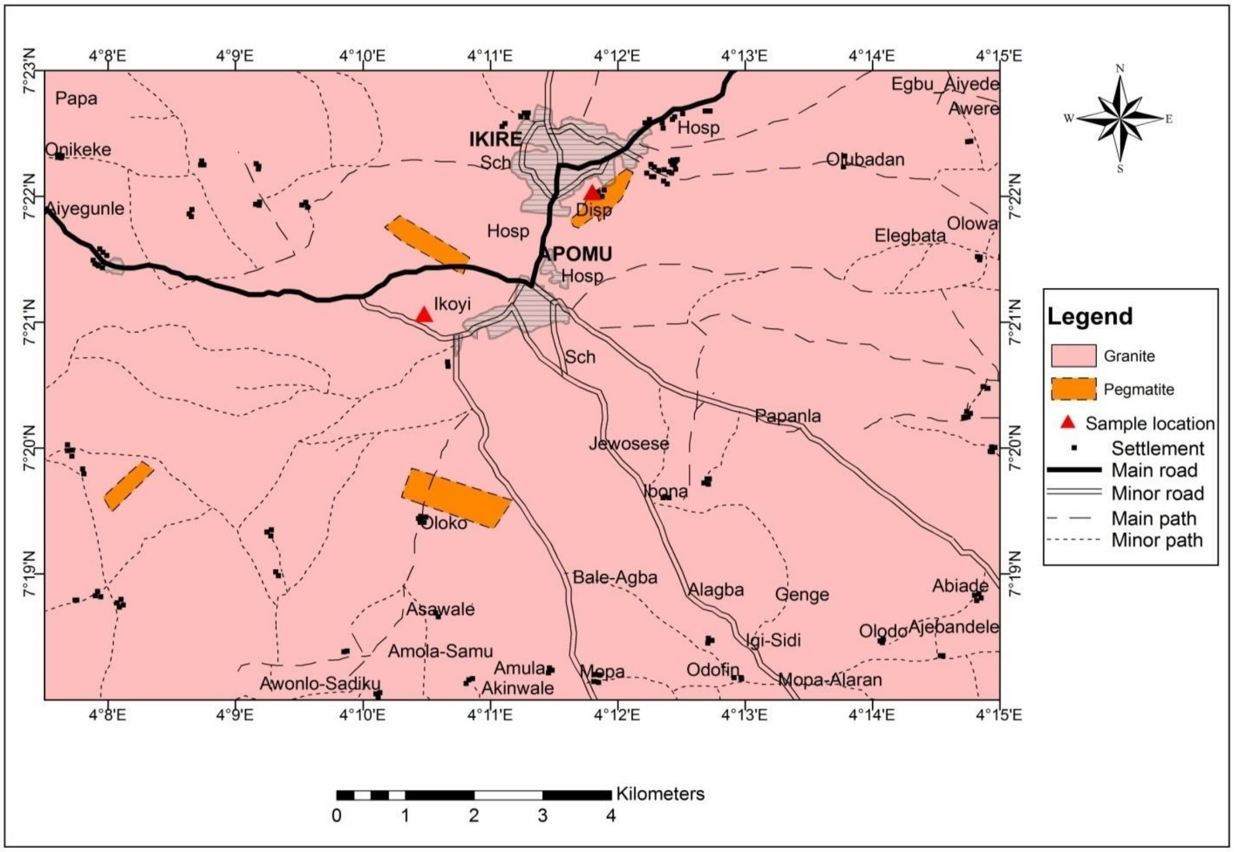


Figure 2: Geological map of the study area.

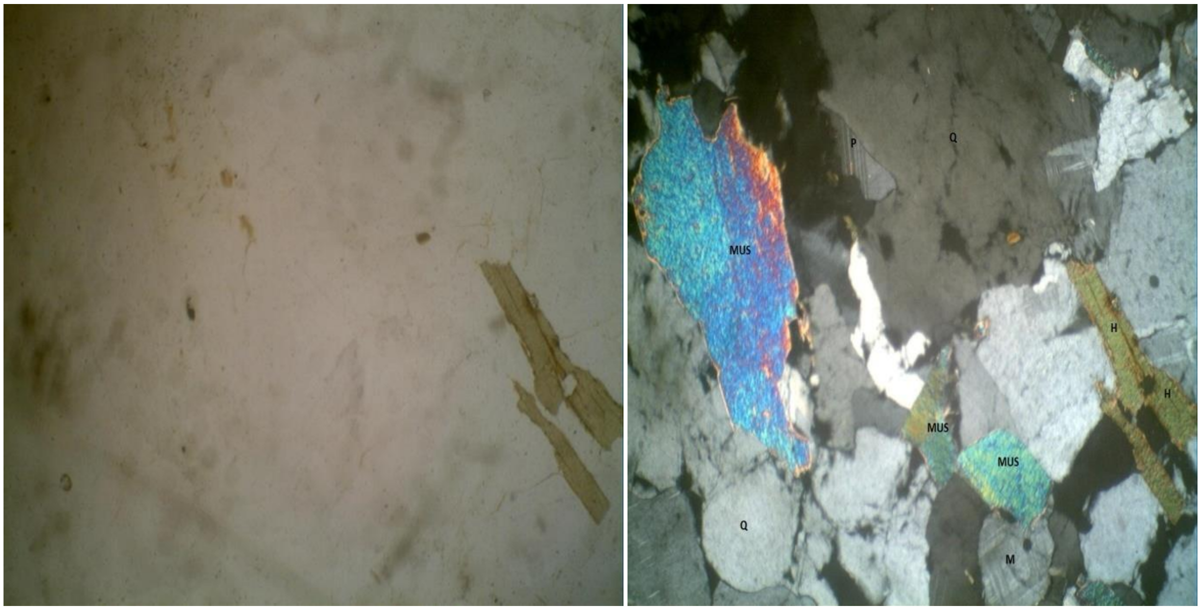
RESULTS AND DISCUSSIONS

PETROGRAPHY OF PARENTS ROCKS

Minerals and texture are identified on the basis of their optical properties in both plane polarized and cross polarized lights. The mineralogy of the pegmatite rock included the following: quartz, plagioclase, microcline and muscovite (plate 2.0). This rock is expected to disintegrate into fine grain soils with some coarse grain due to the abundant of feldspar and large crystals of dominant quartz that are resistance to weathering (Oloruntola et al., 2008). The granite on the other hand, contains quartz, feldspar, biotite and other accessory mineral (plate 1.0), and is thus expected to weather into fine to medium grained soil. Quartz in the studied rock will be retained as gravel and sand grains in the derived soil due to it resistance to weathering while the feldspars and muscovite decompose into secondary minerals (clay minerals). This implies low to medium plasticity and low amount of fines for granite-derived soil samples and high amount of fines and plasticity for pegmatite-derived soil. The results of petrographic analysis of the thin section of the rock samples are presented in table 1.

Table 1: Modal composition of rock samples.

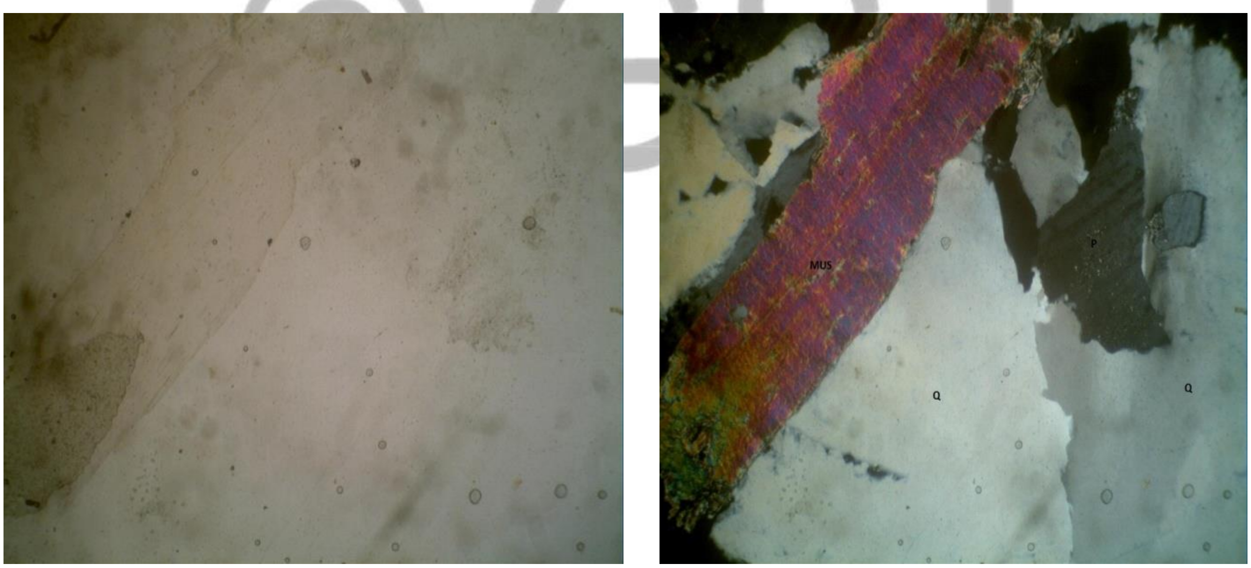
	RELATIVE ABUNDANCE OF MINERALS IN %						
	QUARTZ	MICROCLINE	MUSCOVITE	PLAGIOCLASE	BIOTITE	HORNBLENDE	OPAQUE
PEGMATITE	**25**	**37**	**23**	**14**	**-**	**-**	**1**
GRANITE	**46**	**17**	**8**	**9**	**13**	**6**	**1**



(a) (b)

Plate 1.0: Photomicrograph of Granite under (a) plane-polarized light (b) cross-polarized light

[Bar scale = 2mm, Mag = x40]



(a) (b)

Plate 2.0: Photomicrograph of pegmatite under (a) plane-polarized light (b) cross-polarized light

Q= QUARTZ, B=BIOTITE, P=PLAGIOCLASE, H=HORNBLENDE, MUS=MUSCOVITE, M=MICROCLINE. [Bar scale = 2mm, Mag = x40]

CLASSIFICATION TESTS

The index test results were use to determine the engineering properties of the soils and determine the better sample. The index tests results were shown in table 2. The specific gravity ranges between 2.60 - 2.65 for the pegmatite derived lateritic soil samples while the granite has a uniform specific gravity of 2.60. De Graft Johnson, (1969) gave a range of specific gravity between 2.60 and 3.40 for lateritic soils. All the soil samples have their specific gravity fall within this range. Since this value falls within the lower range, the lateritic soils can be said to have undergone a low degree of laterization which translates to low degree of weathering and the slight difference in specific gravity can be linked to variation in texture of the parent rocks.

The result obtained from the grain size analysis (Table 2) showed that the amount of fines present in the pegmatite derived soil ranges between 40% and 44%, while the fines in the granite derived soil range between 23% and 38%, thus showing that the fine fraction of the pegmatite soil is more than that of the granite derived soil. Oloruntola et al., (2008) reported similar case for pegmatite-derived lateritic soil. The physical and engineering properties of soils have been found to depend on their textural characteristics. This variation can be attributed to the difference in the mineralogical characteristics of the parent materials as pegmatite contains in addition to quartz minerals such as feldspar and micas which often decompose into clay particles unlike the granite which contain less feldspar compare to pegmatite. The two genetically different soils are well graded as shown on the grading curve (Fig 1 and 2).

The plasticity index and liquid limit of granite derived lateritic soil samples are lower than those of pegmatite derived lateritic soil samples. This variation in plasticity between the two derived soils can be credited to difference in basic mineralogy of the parent rocks. However, the plasticity index and liquid limit of the two derived soils indicate 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.

Table 2: Summary of index properties of the studied soil samples

			CONSISTENCY LIMIT (%)			GRAIN SIZE CLASSIFICATION (%)				
ROCK TYPES	SAMPLE	SPECIFIC GRAVITY	LIQUID LIMIT LL (%)	PLASTIC LIMIT PL (%)	PLASTICITY INDEX PI (%)	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	AMOUNT OF FINES (%)
PEGMATITE	**P1**	**2.65**	**57.02**	**38.18**	**19.84**	**23**	**34**	**27**	**16**	**43**
	P2	**2.60**	**46.21**	**23.54**	**22.67**	**21**	**35**	**28**	**16**	**44**
	P3	**2.60**	**49.44**	**26.52**	**22.92**	**21**	**36**	**28**	**15**	**43**
GRANITE	**G1**	**2.60**	**37.42**	**21.89**	**15.53**	**2**	**60**	**27**	**11**	**38**
	G2	**2.60**	**38.36**	**27.51**	**10.85**	**4**	**70**	**18**	**8**	**26**
	G3	**2.60**	**37.02**	**27.02**	**10.00**	**3**	**74**	**15**	**8**	**23**

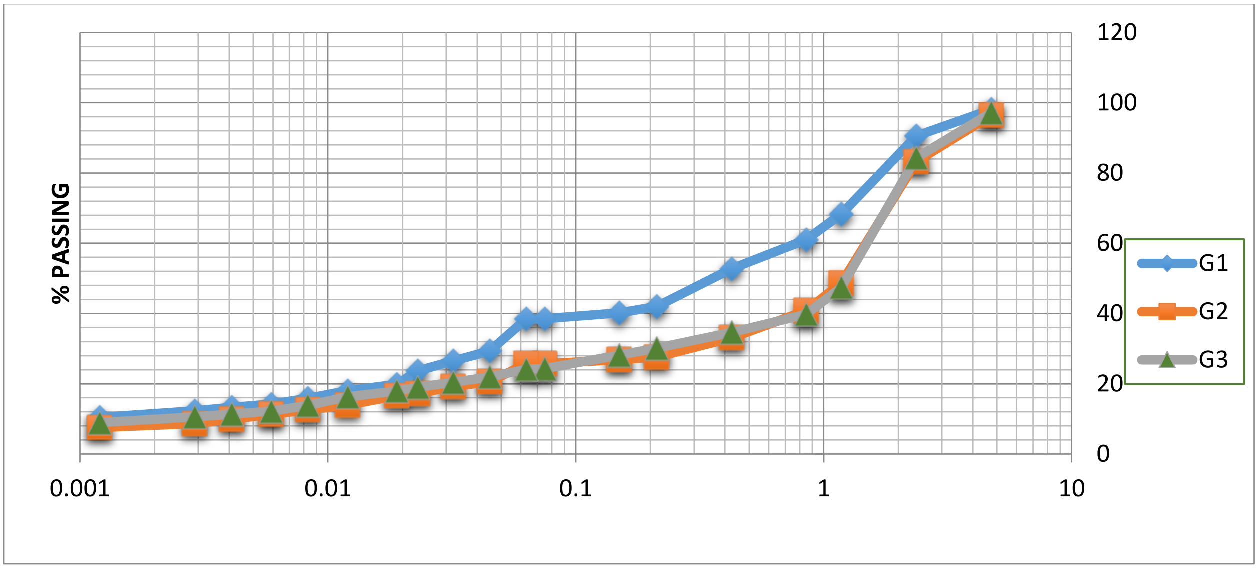


Figure 3: Grading curves of granite derived soil samples

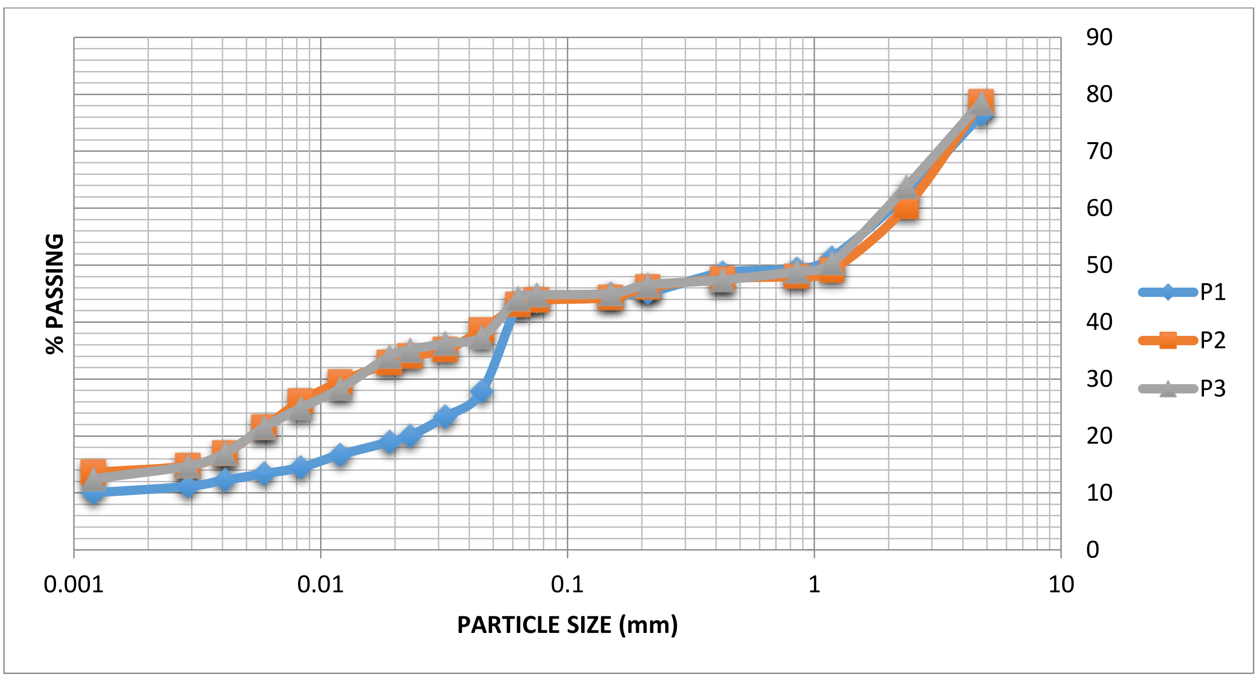


Figure 4: Grading curves of pegmatite derived soil samples

From the results of the preliminary classification test shown in Table 2, lateritic soil samples derived from granite have better engineering properties than those developed over pegmatite. Therefore, 15% and 30% by volume of granite derived soil was mixed with pegmatite derived soil before compacting at 15, 25, 35, 45 and 55 blows.

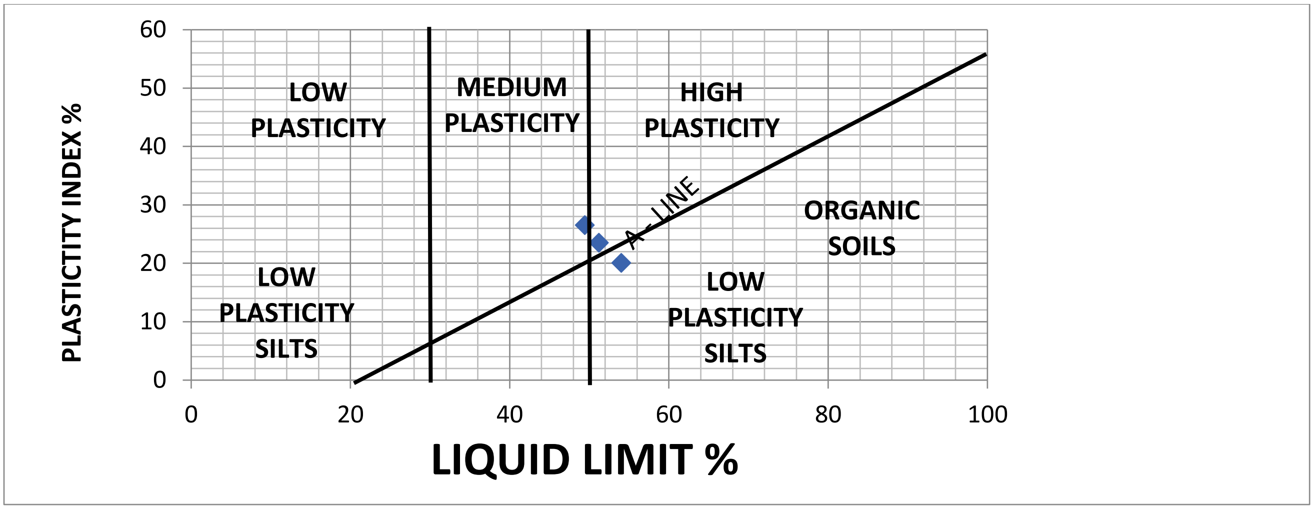


Figure 5. Casangrande chart of Pegmatite-derived soil samples

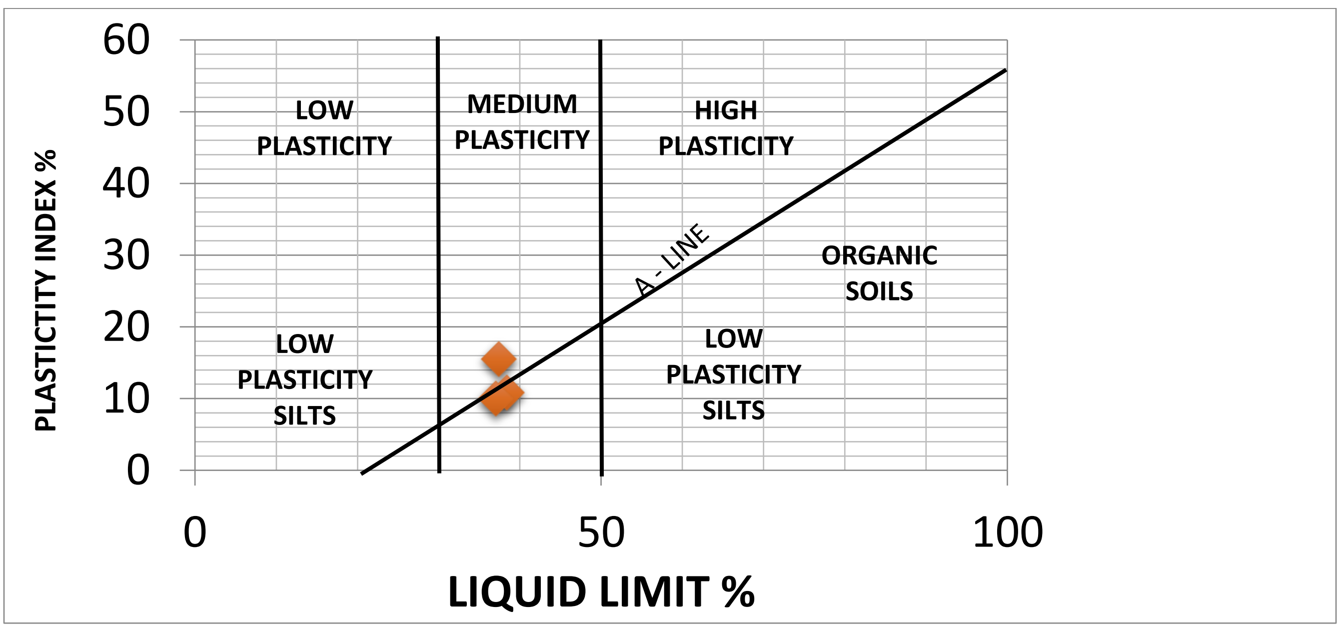


Figure 6. Casangrande chart of Granite-derived soil samples

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INFLUENCE OF STABILIZATION

Maximum Dry Density (MDD)

The pegmatite derived lateritic soils were mixed with 15% and 30% by volume of granite derived lateritic soil prior to compacting at 15, 25, 35, 45 and 55 blows. The effect of varying compactive effort on the maximum dry density (MDD) of the lateritic soil samples (P1, P2, P3) with 15% and 30% by volume of stabilizer is presented in table 3. It was observed that values increased with increase in stabilizer content for all five compactive efforts considered. This increase is however minimal ranging from 5.85% to 0.62%. There is a strong positive correlation between the MDD and Number of blows (Compactive Energy) as shown in figure 7 below. The peak values of 1910Kg/m^3 and 1990Kg/m^3 were recorded at 15% and 30% by volume of stabilizer respectively. From the values of MDD obtained, only samples at higher energy level of compaction (from 25 blows and above), gave values of MDD higher than the recommended value of 1810kg/m^3 specified by Nigeria Building and Road Research Institute (NBRRI) for bungalow bricks (Agbede and Manasseh, 2008). The increase in MDD could also be as a result of stabilizer which has higher sand particle that fills up the void space of the fines in the pegmatite-derived soil samples thus resulting in mixture with higher specific gravity and higher MDD. Similar cases were reported by Ishola (2014) and Osinubi et al.,(2015)

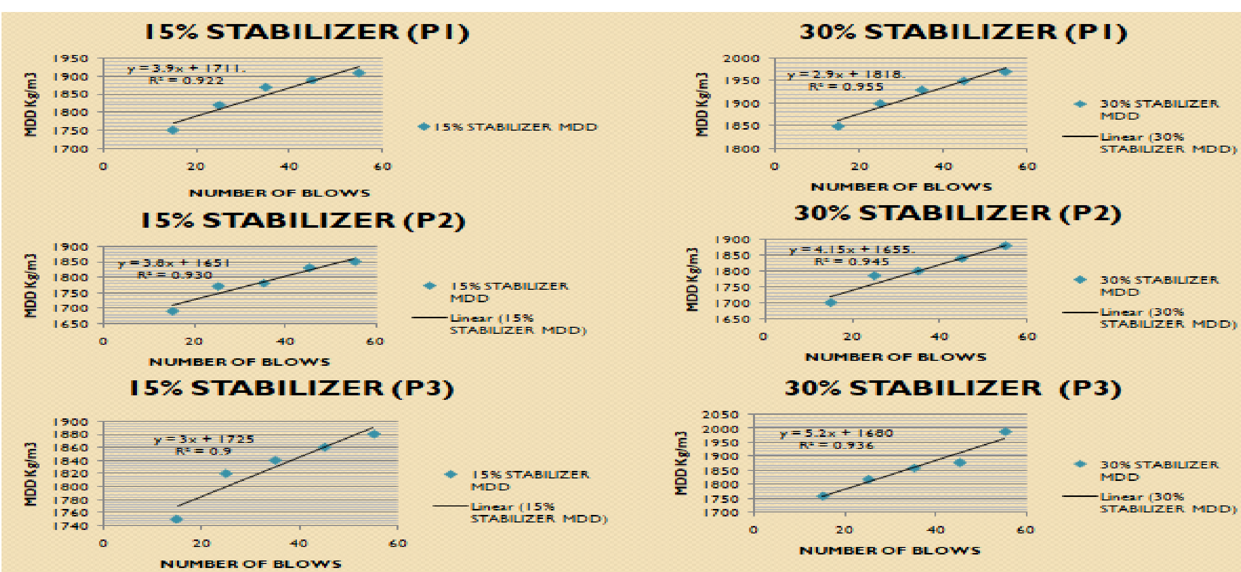

Figure 7: Cross Plots of MDD against Various Compactive Energy

Table 3: summarizing the effect of stabilizer on MDD at various compactive effort

MAXIMUM DRY DENSITY (MDD Kg/m^3)									
NUMBER OF BLOWS	**P1**			**P2**			**P3**		
	AMOUNT OF STABLIZER		**% INCREASE IN MDD**	**AMOUNT OF STABILIZER**		**% INCREASE IN MDD**	**AMOUNT OF STABILIZER**		**% INCREASE IN MDD**
	15%	**30%**		**15%**	**30%**		**15%**	**30%**	
15	**1620**	**1630**	**0.62**	**1610**	**1640**	**1.86**	**1630**	**1650**	**1.23**
25	**1820**	**1900**	**4.40**	**1770**	**1785**	**0.85**	**1820**	**1810**	**-**
35	**1870**	**1930**	**3.21**	**1780**	**1800**	**1.12**	**1840**	**1860**	**1.09**
45	**1890**	**1950**	**3.18**	**1830**	**1840**	**0.55**	**1860**	**1880**	**1.08**
55	**1910**	**1970**	**2.14**	**1850**	**1880**	**1.62**	**1880**	**1990**	**5.85**

Optimum Moisture Content (OMC)

The effect of varying stabilizer content on the optimum moisture content (OMC) of the lateritic soils stabilized with 15% and 30% of stabilizer at 15, 25, 35, 45 and 55 blows of compactive effort. Generally, it was observed that as the compactive effort increases there was a decrease in the OMC across all energy levels except in a few cases where the OMC either remained constant or increased slightly. The OMC increased when the percentage by volume of stabilizer was increased from 15% to 30% except in few cases. The variation in OMC with percentage stabilizer is however more pronounce in lower blows than higher blows. Despite this, peak OMC values of 18.4% were recorded for the derived soil samples. The most significant decrease in OMC was seen in sample P2 where the values decreased at 15blows and 25 blows when the stabilizer was increased from 15% to 30%. The decrease in values observed were 18.4% to 18% at 15 blows and 17.2% to 16.8% at 25 blows in sample P2. A similar trend were noticed in the decrease in OMC at 35 blows for sample P1 and at 55 blows for sample P3 when the stabilizer was increased from 15% to 30% of stabilizer. This may be due to the fact that when there was no water movement as the fine sands fill the void space and the available moisture was used up in the hydration reaction.

Unconfined Compressive Strength (UCS)

For this study, the suncured Unconfined Compressive Strength (UCS) of the samples was employed having cured the samples for 48hours before testing. The effect of granite-derived soil on UCS at varying quantity of stabilizer (15% and 30% by volume) for compactive efforts 15, 25,35, 45 and 55blows for all the samples are shown in Tables 5. Generally, the UCS of lateritic soil increased with increasing stabilizer content for all the soil samples. Comparing the variation in UCS values with stabilizer content at west African level (25 blows) and modified AASHTO level (55 blows), it was observed that the values increased from 678kN/m^2 to 1181kN/m^2, 644kN/m^2 to 1290kN/m^2, 682kN/m^2 to 946kN/m^2 with 15% volume of stabilizer for sample P1, P2 and P3 respectively while an increase from 1059kN/m^2 to 1277kN/m^2, 761kN/m^2 to 1300kN/m^2, 1227KN/m^2 and 1307KN/m^2 with 30% volume of stabilizer for sample P1, P2 and P3. This observed trend at 25 blows compaction energy is similar to those for other compaction energy levels. Though the value of UCS increases with increase in stabilizer, this increase was minimal with higher compactive effort of 55 blows. Percentage increase in UCS values from 15% to 30% by volume of stabilizer ranged from 79.92% to 0.78% for the studied soil samples. The UCS shows average positive correlation or 0.95, 0.96 and 0.82 for sample P1, P2 and P3 respectively (fig. 5). The UCS produced at 25blows with 30% volume of stabilizer can also be achieved by using 55 blows with 15% volume of stabilizer. This indicates the cost can be reduced by stabilizing at lower volume with higher energy of compaction. The trend in percentage increase observed with the MDD for samples P1, P2 and P3 15% and 30% volume of stabilizer is replicated with the UCS for the soil samples. Also at both 15% and 30% 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. However UCS value of 1650KN/m^2 and 1750KN/m^2 recommended by NBBRI and Nigerian Association of Engineers respectively for a bungalow brick (Agbede and Manasseh 2008; Ministry of works, Oyo state) were not met by the samples. Despite the constraint in utilization as bungalow bricks, the obtained cured strength of the stabilized soil samples is higher than the minimum acceptable value of 1034KN/m^2 (Ola, 1977).

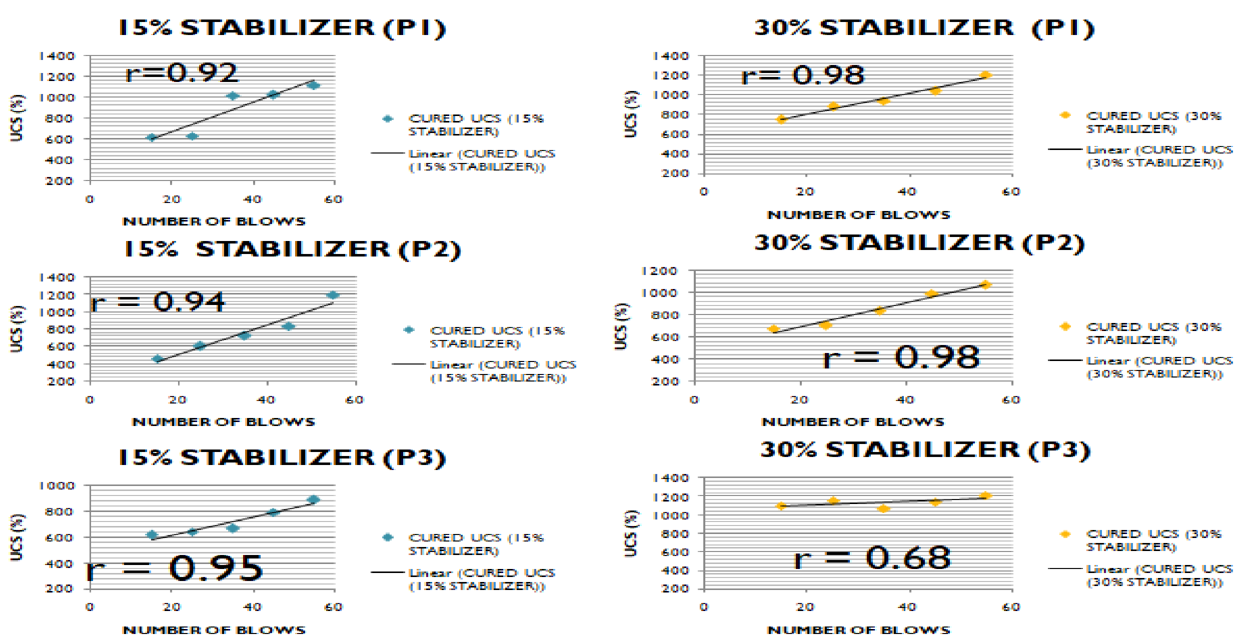

Figure 8: Cross plots of Cured UCS against Number of Blows (Compactive Energy)

Table 4: variation of cured UCS with number of blows (energy of compaction) with 15% and 30% volume of stabilizer.

CURED UCS (KN/m^2)									
NUMBER OF BLOWS	P1			P2			P3		
	AMOUNT OF STABLIZER		% INCREASE IN UCS	AMOUNT OF STABLIZER		% INCREASE IN UCS	AMOUNT OF STABLIZER		% INCREASE IN UCS
	15%	30%		15%	30%		15%	30%	
15	667	900	34.93	500	725	45.00	672	1203	79.01
25	678	1095	56.19	644	761	18.17	682	1227	79.91
35	1101	1144	3.90	767	866	12.90	711	1140	60.33
45	1120	1266	12.92	923	1121	21.45	864	1229	42.24
55	1118	1277	8.12	1290	1300	0.78	946	1307	38.16

CONCLUSIONS

The study was able to establish that Granite-derived soil has better engineering characteristics than Pegmatite derived soil and 30% of Granite-derived soil at 55 blows is quite appropriate for the stabilization of Pegmatite-derived lateritic soil since significant increase in strength were recorded at 30% stabilization and 55 blows. The mechanical stabilization of pegmatite derived soil was found to produce UCS values typical of sub grade and sub base materials and can also be use as Bungalow bricks for construction. Similar studies should be extended to other tropical soils developed over rocks of different mineralogy. This will give more information and importance of geology on engineering properties of soil as well as influence of mechanical stabilization on the soil.

REFRENCES

Agbede, I.O, and J. Manasseh, 2008. Use of cements and admixture in laterite bricks production for low cost housing, Leonardo electronic journal of practices and technologies, pp: 163174.

Adeyemi, G.O., Afolagboye, L.O. and Bolaji, C.A. 2013. Chemical stabilization of Quartz schist derived from soil Erijiyan Ekiti, Southwestern Nigeria. Australian Journal of Basic and Applied Sciences Vol. 7 (2), pp. 63 – 69.

De Graft-Johnson, J.W.S., 1969. Engineering properties of lateritic soil proceedings of the special session in laterite soils., 4: 1050-1066.

FMW (Federal Ministry of Works) 1997. General specifications (roads and bridges), Vol II, Federal Ministry of Works and Housing, Lagos, Nigeria.

Gidigasu, M.D. 1972: Mode of formation and Geotechnical Characteristics of laterite materials of Ghana in relations to soil forming factors: Eng. Geol., 6: 79 – 150.Ireland (1972).

Ishola, K., 2014: Modification of Lateritic Soil With Iron Ore Tailing. Unpublished M.Sc. Thesis Civil Engineering Department, Ahmadu Bello University, Zaria.

Ola, S.A. 1977: potential of lime stabilization of lateritic soils. Engineering Geology vol. II, pp 305-317.

Oloruntola M.O., Adeyemi G.O., Adebisi N.O., Oduneye O.C., 2005: Geotechnical properties of cement stabilized soils developed over pegmatite and banded gneiss from Ago-lwoye, Southwestern Nigeria. Quarterly publication of the scientific society of the mineral wealth technologists. 2005; 135:25–36.

Osinubi, K. J. Yohanna P. and Eberemu A. O. 2015. Cement Modification of Tropical Black Clay Using Iron Ore Tailings as Admixture. Transportation Geotechnics 5(2015):35-49.

Oyediran A.I.,(2001) Primary cause of highway failure insouth-western Nigeria and lasting solution, Technical Transactions of the NigerianSociety of Engineers, 2001, 36(3), p. 54 60.

Simon, A.B., Geisecke, J. and Bidlo, G., 1973, Use of Lateritic soils for Road Construction in North Dahomey. *Engineering Geology*. 7: pp 197 – 218