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MECHANICAL STABILIZATION OF LATERITIC CLAY FROM ARA-IJERO, SOUTHWESTERN NIGERIA.

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Three bulk samples of Ara-Ijero clay were mixed with varying percentages of nearby lateritic soil and compacted at the West African and Modified American Association of States Highways and Transportation Officials (AASHTO) energy levels respectively. This was with a view to determining the influence of mechanical stabilization on the Unconfined (uniaxial) Compressive Strength (UCS) of the fired samples. Petrographic study of the parent rock was done while samples of the clay and lateritic soils were subjected to x-ray diffraction. Classification tests were carried on both the clay and lateritic soil samples prior to mechanical stabilization using 10%, 20%, 30%, 40% and 50% respectively by volume of lateritic soil as stabilizer. The stabilized samples were subjected to unconfined compression test at air-dried, sun-dried and fired states. Results of modal analysis showed that the parent rock is migmatite-gneiss with quartz as the most abundant mineral followed by alkali feldspar, plagioclase feldspar, biotite and muscovite with minor amounts of other minerals. The average amount of Kaolinite in the clay samples (35.4%) is typical of Kaolinitic clays. The clay and lateritic soil had average fine fractions of 62.7% and 53.0% respectively, an indication that the lateritic soil had better geotechnical property than the clay. The fired strengths were found to increase both with the amounts of stabilizer and the energy of compaction. However, the increases in strength as a result of increase in energy of compaction from the West African to the modified AASHTO level were found to be marginal. The increases in strengths noticed beyond 40% by volume of the stabilizer were also found to be insignificant. Fired bricks of adequate strength for construction of bungalow buildings can thus be produced by mixing 40% by volume of lateritic soil with clay with compaction at the West African level. This study has showcased the effectiveness of mechanical stabilization of clay with lateritic soil in the study area.

***Keywords**: Unconfined Compressive Strength (UCS), Mechanical stabilization, Migmatite-gneiss, Fired state, West African level.*

***Wordcount**: 294*

INTRODUCTION

The bulk of the soils in the tropics are reddish brown soils called lateritic soils. Gidigasu (1976) defined laterite as a hardened material formed by primary weathering of residual soil or the secondary enrichment and cementation of transported or residual soil.

Lateritic clay originated from weathering of rocks by weathering agents such as rain, ice, and wind. Tropical clays are usually reddish brown in colour and they are termed lateritic clays. Clay can also be defined as a soil composed of hydrous aluminium phyllosilicate minerals and has a particle size that is typically less than 2μm in diameter. Chen (1977) defined clay as a kind of natural earth which becomes plastic and mouldable when mixed with water and becomes hard on drying and firing. It can also be whitish or greyish depending on the extent to which there is replacement of silicon, aluminium and magnesium by cations like iron or potassium.

Adeyemi *et al.* (1990), determined the index properties and crushing strengths of lateritic clay deposits from southwestern Nigeria. It was established that sesquioxide coatings decreased the clay size content, the plasticity character of clay and increase its crushing strength. Ibrahim (2007) executed mechanical stabilization of lateritic clay from Ajebo-Abeokuta road in southwestern Nigeria. He noticed that doubling the amount of the stabilizer did not affect any appreciable increase in the strength of the stabilized samples. However, 50% of the stabilizer gave optimum strength. The objective of this work was to establish the basis for using lateritic soil as stabilizer for Ara-Ijero clay, in order to ascertain the suitability or otherwise of the stabilized samples for bricks construction, and to determine the influence of the percentage of stabilizer on the strength of bricks produced from the stabilization.

STUDY AREA

The area under study is “Ara” popularly named after a nearby community called Ijero, hence the name “Ara-Ijero”, it is located in Ekiti-State, South Western, Nigeria. Ara-Ijero is located some 8km South East of Ijero Ekiti, about 30km Northwest of Ado-Ekiti, (Figure 1). It lies within Latitudes 07° 46" N to 07° 49" N and Longitudes 05° 06" E to 05° 12" E. Samples of lateritic clay were collected from three locations while samples of lateritic soils were collected from three borrow pits at the outskirt of Ara-Ijero village, which is about 3km from Ara village. The area is underlain by Precambrian Basement Complex rocks of Nigeria as classified by several authors like Jones and Hockey (1964), Oyawoye (1964) and Rahaman (1976). Locally the area is underlain by migmatite with banded biotite gneiss as the major component and the presence of structures such as pegmatitic intrusions and quartz veins.

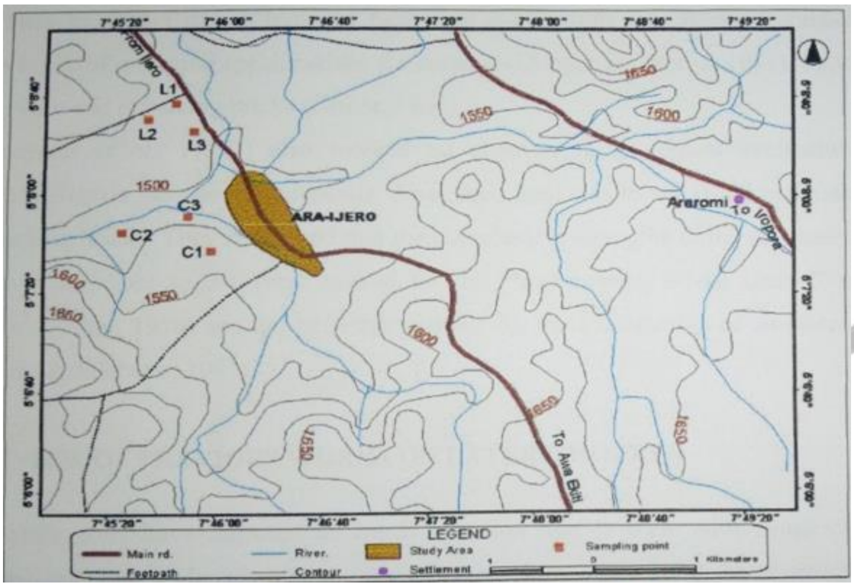

Figure 1: Topographic map of Ara-Ijero showing sampling points and road networks.

METHODOLOGY

Six bulk samples each of lateritic soil and lateritic clay were collected from sampling locations. Petrographic analyses of the representative rock samples were carried out in order to determine their texture and mineralogical composition. The clay and lateritic soil samples were subjected to x-ray diffraction analysis to determine their mineralogy. Laboratory tests such as grain size distribution, consistency limits, specific gravity of grains, mechanical stabilization and unconfined compression tests were carried out in accordance with the specifications of the British Standard 1337 of 1975. It was confirmed that the amount of fine fraction and plasticity index of the lateritic soil samples were lower than those of the clay. The clay samples were then mixed with 0% to 50% by volume of the lateritic soil (the stabilizer) and compacted at both the West African and Modified AASHTO energy levels.

RESULTS AND DISCUSSIONS

PETROGRAPHY OF PARENT ROCKS

Locally, the area is underlain by a highly complex rock; migmatite, that is an intimate mixture of granitic composition and high-grade metamorphic rock. The major rock present in the study area is banded biotite gneiss (Elueze and Bolarinwa, 1995). Petrographic study of the banded biotite gneiss indicates the dominance of quartz, microcline, plagioclase, biotite, muscovite and opaque minerals in subordinate amounts. (Table 1), the rock is expected to weather to a well graded plastic soil.

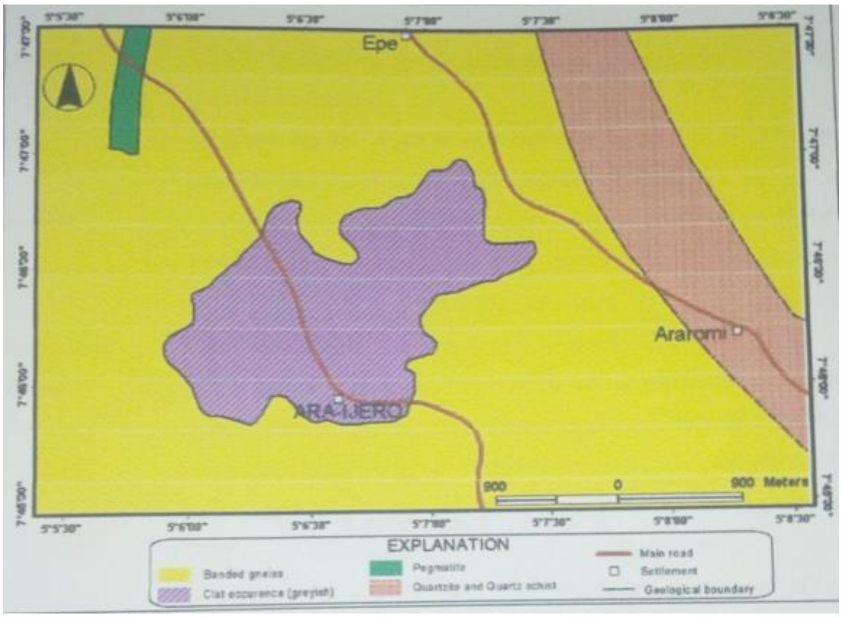

Figure 2: Modified geological map of Ara-Ijero area and clay site (After Elueze and Bolarinwa, 1995).

Table 1: Modal composition of the rock in the area of study

Granitic component of the Migmatite		Biotite Banded Gneiss (major rock)	
Mineral	% Composition	Mineral	% Composition
Quartz	35	Quartz	37
Alkali Feldspar	21	Alkali Feldspar	20
Plagioclase	15	Plagioclase	13
Biotite	15	Biotite	18
Muscovite	10	Muscovite	10
Pyroxene	5	Garnet	2
Opaque minerals	2		

INDEX PROPERTIES

SPECIFIC GRAVITY OF GRAINS

The physical and engineering properties of lateritic soils have been found to depend on their textural characteristics. Of particular relevance to this study is the amount of clay-sized particles which has been found (Gidigasu, 1976) to have some relationship with plasticity (and hence workability) of lateritic soils. The values of the specific gravity of grains of the samples falls within the range 2.60 and 2.70 (table 2) for lateritic soils in line with ranges given by De Graft Johnson (1969) while those of the lateritic clay range between 2.50 and 2.55.

GRAIN SIZE DISTRIBUTION

The higher percentages of gravel size fraction and lower percentages of fines in the lateritic soil are due to a higher degree of laterization that the lateritic soil have been subjected to, which explains the higher specific gravity of the grains of lateritic soil samples. The results obtained from grain size distribution analysis are displayed in Table 2. The samples contain an average of 31.20% and 37.50% sand fraction, 6.20% and 9.5% gravel fraction and 62.7% and 53% of fines present in Ara-Ijero clay and the lateritic soil respectively, the higher amount of the coarse fraction in the lateritic soil indicates higher strength than the lateritic clay which suggests that it will be a good stabilizer for the clay. The lateritic soil and clay are well graded as shown in figures 4a and b.

Table 2: Summary of the index properties of the samples studies

	SAMPLE	SPECIFIC GRAVITY OF GRAINS	CONSISTENCY LIMITS (%)			GRAIN SIZE DISTRIBUTION (%)				
			LIQUID LIMIT (%)	PLASTIC LIMIT (%)	PLASTICITY INDEX (%)	GRAVEL (%)	SAND (%)	SILT (%)	CLAY (%)	AMOUNTS OF FINES (%)
Lateritic soil	FL.1	2.6	45.01	26.97	18.04	5	35	33	27	60
	FL.2	2.65	40.80	24.51	16.29	12	40	27	21	48
	FL.3	2.62	53.80	29.53	24.27	10	37	35	18	53
	FL.A	2.66	43.01	25.97	17.04	14	39	29.5	17.5	47
	FL.B	2.60	41.00	25.48	15.52	11	39	27.5	22.5	50
	FL.C	2.68	52.00	26.70	25.3	5	35	31.5	28.5	60
Average		2.63	45.94	26.53	19.41	9.15	37.50	30.58	22.42	53
Ara-Ijero clay	FC.1	2.53	55.20	27.61	27.59	3	20	40	37	77
	FC.2	2.56	39.10	25.48	13.62	14	34	22.5	29.5	52
	FC.3	2.55	48.75	25.65	23.10	6	39	19	36	55
	FC.A	2.52	53.26	26.44	26.82	2.5	25.5	35.5	36.5	72
	FC.B	2.58	37.15	24.36	12.79	8	38	21.5	32.5	54
	FC.C	2.55	50.20	26.59	23.61	3.5	30.5	28	38	66
Average		2.54	47.28	26.01	21.27	6.16	31.16	27.75	34.91	62.67

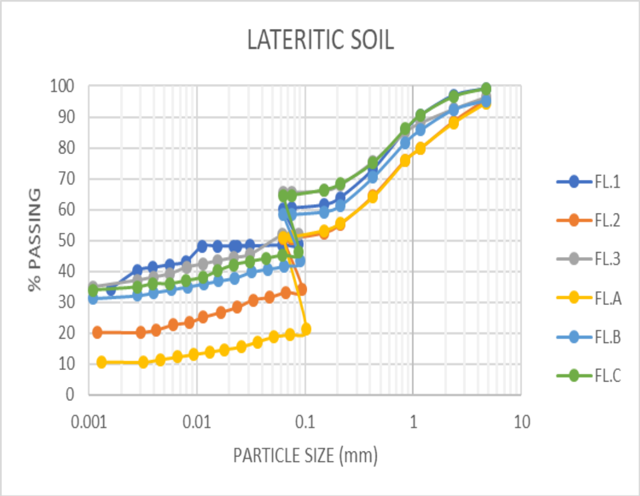

Figure 3a): Grading curves of nearby lateritic soil samples.

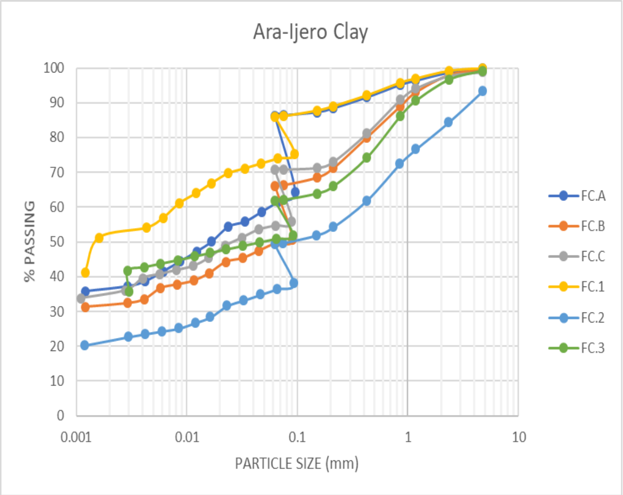

Figure 3b): Grading curves of Ara-Ijero clay samples.

CONSISTENCY LIMITS

A clay should be plastic enough to enable easy manipulation, however excessive plasticity causes negative effects on bricks during firing and can lead to development of cracks. Plasticity is an important factor employed in the selection of lateritic soil both as sub-base and sub-grade materials. The Ara-Ijero clays are likely to be easily worked for brick making, they plot mainly within the field of inorganic clay of high plasticity. Bell (1993) reports that plasticity of lateritic soils tend to straddle the A-line as it is shown in Figure 4a, the average value of the plasticity index of the lateritic soil samples are generally less than 25%, thus the samples would undergo low to medium swelling potential (Ola, 1983 cited in Adeyemi, 2000). The specifications of the Federal Ministry of Works (1997), on laterite highway sub-base soils for roads and bridges, are maximum values of 30% and 12% respectivley for liquid limit and plasticity index. However, the values obtained for the liquid limit of the lateritic soil ranged between about 40% and 53% with plasticity index that ranged between 15 and 25. This makes the soil unsuitable as sub-base/sub-grade material but based on Simon et al, (1973) that recommended an upper limit of 25% value of plasticity index for sub-base/sub-grade materials for road construction in tropical Africa, the soil can be fairly good sub-base and sub-grade material.

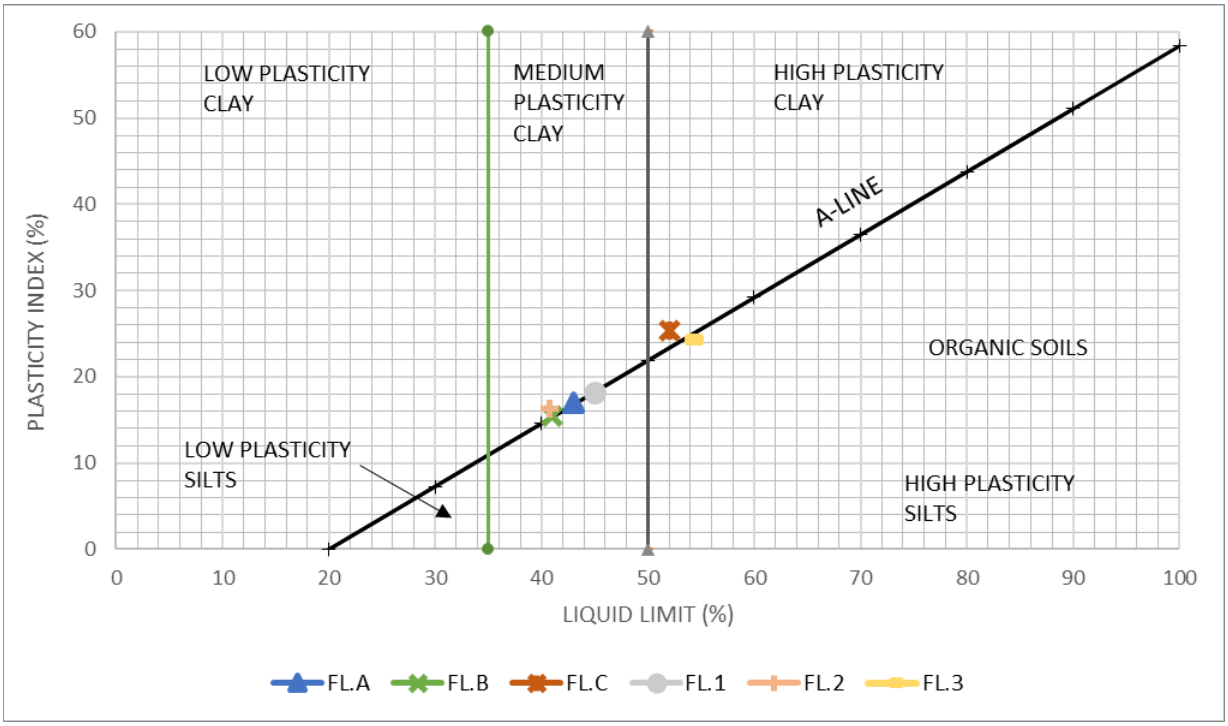

Figure 4a): Casagrande chart classification of lateritic soil samples.

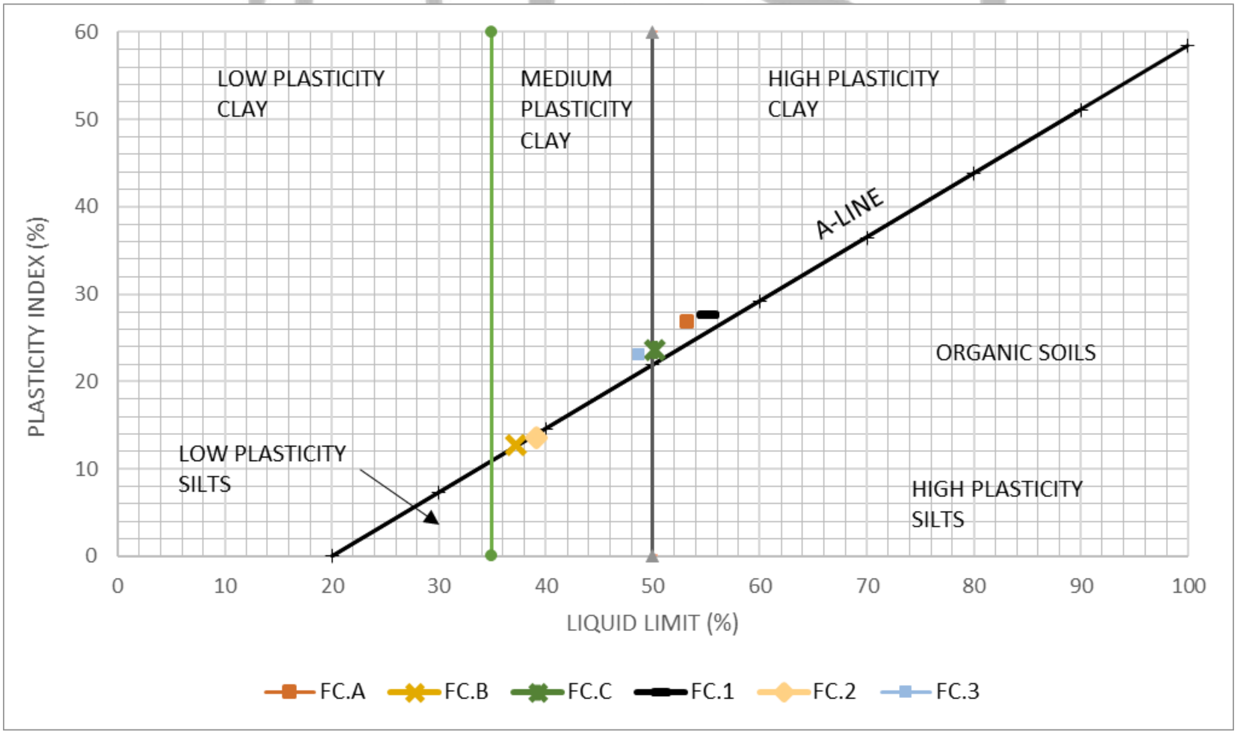

Figure 4b): Casagrande chart classification of Ara-Ijero clay samples.

Figures 4a and 4b show that samples of the lateritic soil have lower plasticity than those of the clay and they can thus be used as stabiliser for the clay.

MINERALOGY

Results of the mineralogical analyses presented in Tables 3 and 4 show that Kaolinite is the major clay mineral with subordinate amounts of illite. Quartz is the major non-clay mineral reflected in the diffractogram while feldspar occurs in subordinate amount. The low plasticity is attributable to the higher amount of Kaoloinite in the lateritic soil samples.

Table 3: Average mineralogical composition (%) of the clay samples

kaolinite	35.4
Illite	11.3
Halloysite	6.9
Quartz	26.2
Vermiculite	6.5
Feldspar	8.8
Others	4.9

Table 4: Average mineralogical composition (%) of the lateritic soil samples

kaolinite	36.8
Illite	10.2
Vermicullite	7.4
Quartz	25.2
Feldspar	7.2
Haematite	11.8
Others	1.4

MECHANICAL STABILIZATION AND UNCONFINED COMPRESSIVE STRENGTH

The results of the classification tests as shown in Table 2 confirm that the lateritic soil had better engineering properties than the Ara-ijero clay, hence, it was used to stabilize the clay. The clay samples were subjected to mechanical stabilization using 10%, 20%, 30%, 40% and 50% respectively by volume of lateritic soil as stabilizer at West African and Modified AASHTO energy levels of compaction. The unconfined compressive strength is an important test often used to estimate the shear strength of engineering soils. For clayey soils, the shear strength is about half of the unconfined compressive strength (Krynine and Judd, 1957).

Table 4: Unconfined Compressive Strength (UCS) of the lateritic soil-stabilized Ara-Ijero clay sample (FC1).

Stabilizer (%)	FC1				
	West African Level (W.A)		Modified AASHTO level (M.A)		
	Fired UCS (KN/m^2)	% increase in UCS	Fired UCS (KN/m^2)	% increase in UCS	% increase in UCS from W.A to M.A levels
0	-	-	2185.06	-	-
10	2053.94	-	2192.53	0.34	6.32
20	2252.77	8.82	2240.70	2.15	-
30	2256.39	0.16	2409.73	7.01	6.36
40	2269.58	0.58	2607.55	7.55	12.96
50	2227.54	-	2659.28	1.98	16.24

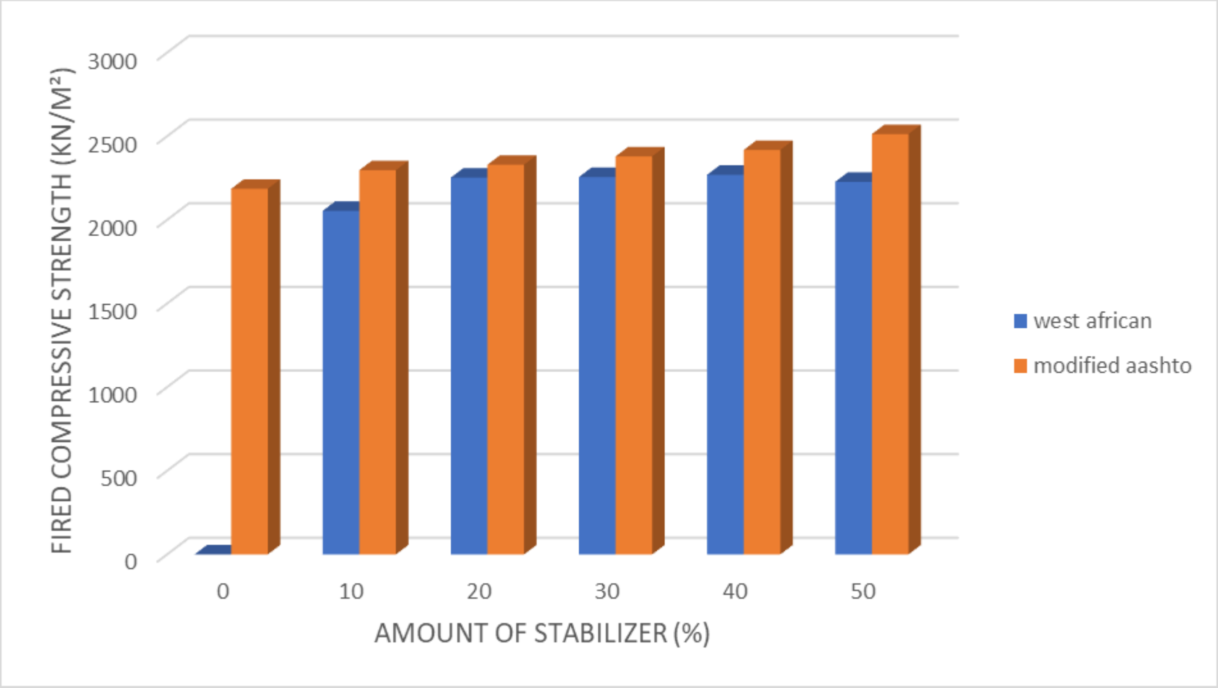

Figure 5: Bar chart showing the fired strength of stabilized sample FC1 compacted at the West African and Modified AASHTO levels.

Table 5: Unconfined Compressive Strength (UCS) of the lateritic soil-stabilized Ara-Ijero clay samples (FC2).

Stabilizer (%)	FC2				
	West African Level (W.A)		Modified AASHTO level (M.A)		
	Fired UCS (KN/m^2)	% increase in UCS	Fired UCS (KN/m^2)	% increase in UCS	% increase in UCS from W.A to M.A levels
0	-	-	2238.29	-	-
10	2056.94	-	2239.00	0.03	8.13
20	2102.23	2.15	2267.16	1.24	7.27
30	2278.10	7.72	2293.63	1.15	0.68
40	2358.97	3.43	2468.16	6.96	4.42
50	2416.87	2.40	2465.67	-	1.98

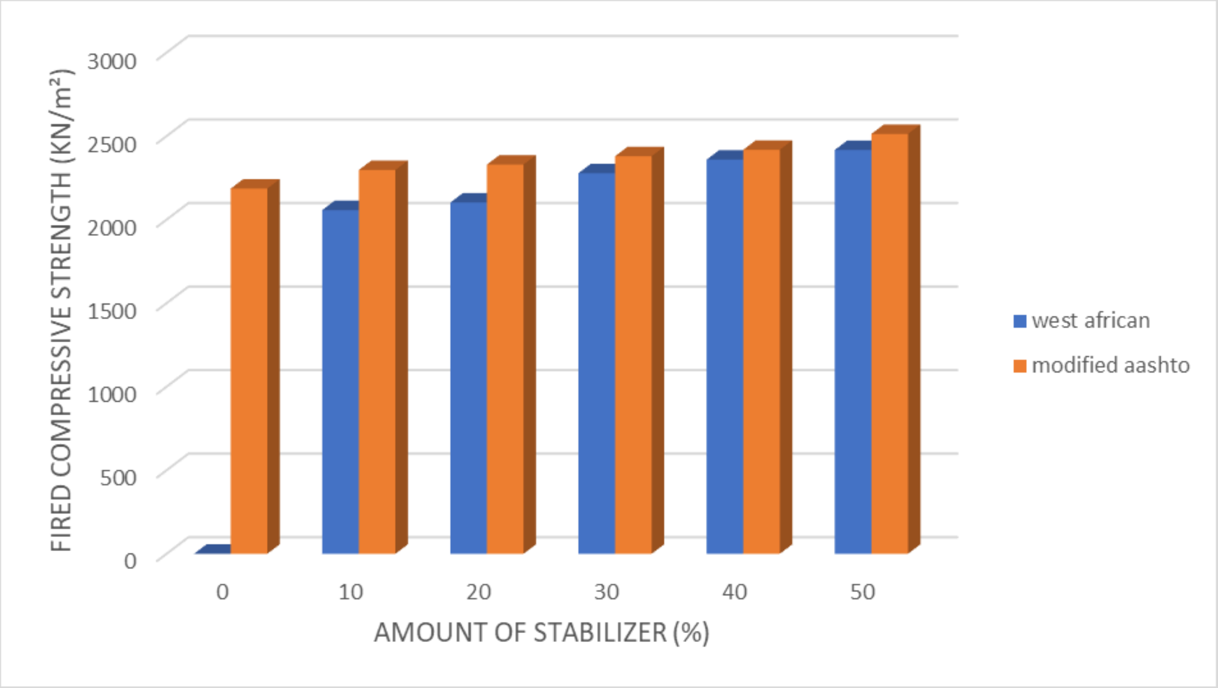

Figure 6: Bar chart showing the fired strength of stabilized sample FC2 compacted at the West African and Modified AASHTO levels.

Table 6: Unconfined Compressive Strength (UCS) of the lateritic soil-stabilized Ara-Ijero clay samples (FC3).

Stabilizer (%)	FC3				
	West African Level (W.A)		Modified AASHTO level (M.A)		
	Fired UCS (KN/m²)	% increase in UCS	Fired UCS (KN/m²)	% increase in UCS	% increase in UCS from W.A to M.A levels
0	-	-	2185.62	-	-
10	2181.44	-	2296.98	4.85	5.03
20	2265.89	3.72	2329.70	1.40	2.74
30	2293.09	1.21	2379.68	2.10	3.64
40	2388.80	4.01	2417.99	1.71	1.21
50	2459.62	2.88	2512.91	3.78	2.12

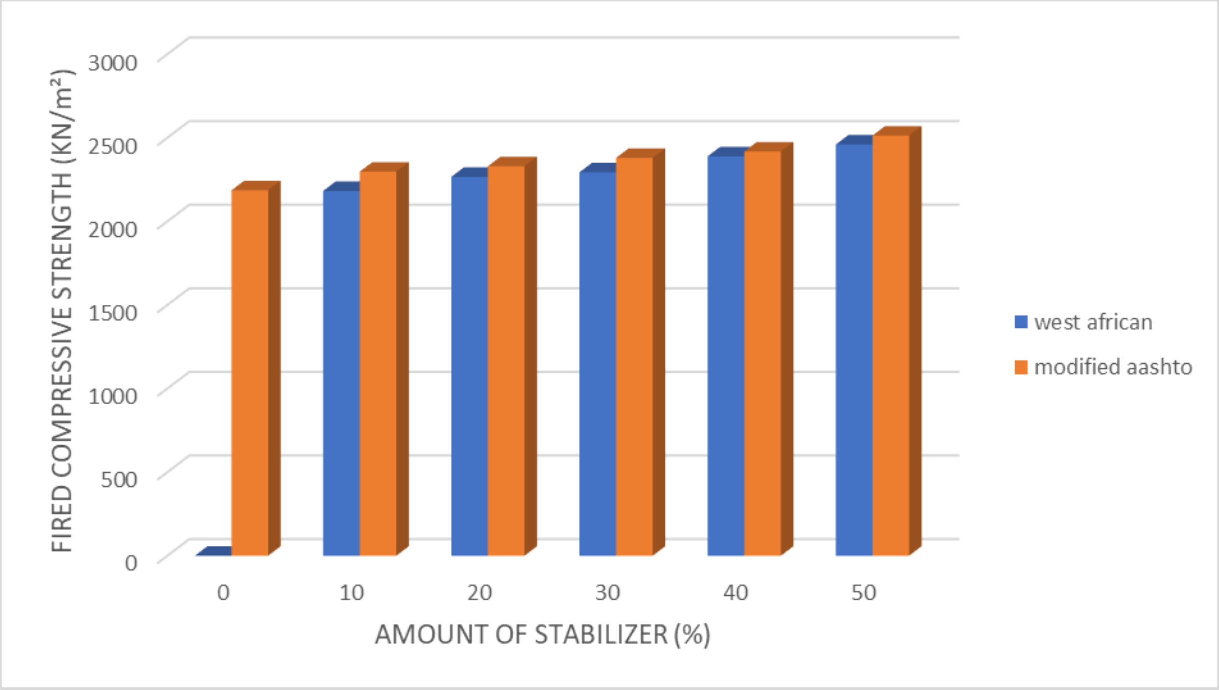

Figure 7: Bar chart showing the fired strength of stabilized sample FC3 compacted at the West African and Modified AASHTO levels.

As shown in the Tables 3,4 and 5 above, the fired strengths were found to increase both with the amounts of stabilizer and the energy of compaction for all the samples except at West African level (50 blows) of sample FC1 which decreased from 2269.58 KN/m^2 to 2227.54 KN/m^2 and Modified AASHTO level of FC2 which also decreased from 2468.16 KN/m^2 to 2465.67 KN/m^2.

In sample FC1, the difference between the fired compressive strength of samples compacted at West African and Modified AASHTO levels increased continually and significantly from 10% to 50% of the stabilizer. At the West African and Modified AASHTO levels (10 blows) the strength was 2053.94 KN/m^2 and 2192.53 KN/m^2 respectively, while at West African and Modified AASHTO levels (50 blows) the strength was 2227.54 KN/m^2 and 2659.28 KN/m^2 respectively. The percentage increase from the West African and Modified ASSHTO reached 16.24% at 50 blows. While for samples FC2 and FC3, the increase in the fired compressive strength from the West African level to the Modified AASHTO level were marginal, with the percentage increase reaching 4.42% at 40 blows then dropping to 1.98% at 50 blows in sample FC2 and percentage increase of 1.21% at 40% and 2.12% at 50 blows in sample FC3. The Nigerian Building and Road Research Institute recommends a minimum strength of 1650KPa for bungalow bricks (Agbede and Manasseh, 2008). Therefore, fired bricks of adequate strength for building construction can be produced by using 40% by volume of lateritic soil as stabilizer at the West African level of compaction, this could be an alternative to cement which is more expensive than either lateritic soil or clay

CONCLUSIONS

Samples of Ara-Ijero clay were stabilized with 10%, 20%, 30%, 40% and 50% respectively, by volume of lateritic soil, after it was confirmed through classification tests that the lateritic soil was better. Petrographic study of the rock samples was carried out, Unconfined compression test and mineralogical analysis using x-ray diffraction method was conducted.

The underlisted conclusions can be drawn from the study:

i. Petrographic analysis reflected quartz and feldspars as the dominant minerals followed by biotite and muscovite.

ii. The values of the specific gravity of the grains of the Ara-Ijero clay ranged from 2.52 - 2.58, while those of the lateritic soil had a range of 2.60 – 2.68. This difference in specific gravity implies that the lateritic soil is more laterized than the clay since both soils were derived from the same parent rock.

iii. Grain size distribution analysis and consistency limits test confirmed that the lateritic soil was better than the clay and on the basis of that it was used as a stabilizer for the clay.

iv. X-RD analysis revealed that the dominant clay mineral in both soil samples is Kaolinite. Hence, the studied soils will exhibit moderate shrinkage on exposure to dryness and moderate expansion in the presence of water.

v. Although there is progressive increase in the unconfined compressive strength with the amounts of stabilizer, the percentage increase in the strength of the samples were found to be marginal after 40% by volume of stabilizer was used.

vi. The percentages increase in strength as a result of increase in energy of compaction from the West African to the Modified AASHTO level were found to be marginal. Therefore, compacting at the Modified AASHTO level is not necessary.

vii. The stabilised bricks have adequate strength for construction of bungalows at appropriate amount of stabiliser and energy of compaction.

RECOMMENDATIONS

Similar study should be carried out on clay deposits in sedimentary terrain in order to determine the possible influence of parent rock and mechanical stabilization on strength of clays.

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