

## ADMIXTURE STABILIZATION OF LATERITE BLOCK USING HYDRATED LIME AND MAKUBA

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### ABSTRACT

*This study is an investigation into the effect of lime as an admixture to soil-makuba stabilization. The laterite was modified with 1 and 2% of hydrated lime and then consequently stabilized with 10, 15, and 20% of makuba. Preliminary results presented shows that the soil is classified as an A-6(8), based on AASHTO classification. Detail result presented shows that the OMC increases while the MDD decreases with increasing makuba and admixed lime contents. Also, with increase in makuba content, the plasticity increases while it decreases with increase in admixed lime. The UCS generally increases with Makuba content for each lime content until a maximum is reached after which there is a fall. For % lime content, the initial increase may be due to increase in cohesion as a result of Soil- Makuba interaction, while the decrease in strength beyond 15% Makuba content may be due to gradual eating up of the soil as a result of excess Makuba. With increase in lime content, the strength decreases, the reason may be due to the fact that the Makuba and Lime have different chemical, mineralogical and physio-chemical characteristics and using them together will result in different expansion and contraction and hence a weak adhesion. Based on the Portland Cement Association (PCA) strength and durability criteria and Osula strength criteria for stabilized block production, the soil-lime-makuba mixture did not meet any of the specification. But it should be noted that the maximum value of 1.13N/mm<sup>2</sup> obtained at 15% makuba content for soil-makuba (0% lime) is higher than the stabilization.*

**KEYWORDS:** *Stabilization, makuba, crushing strength, unconfined compressive strength.*

### INTRODUCTION

The present economic situation in Nigeria has given rise to astronomical increase in the price of construction materials, beyond the reach of common-man. This has impelled research into the quality of the locally available construction materials such as laterite, makuba, katsi, Gabaruwa, Dafara etc.

Laterite has been used extensively in Nigeria for building roads and residential houses. It can be defined as a "highly weathered tropical soil rich in secondary oxides of any or a combination of iron, aluminium and manganese (Olusola, 1984).

In Nigeria, especially in the Northern part, to enhance the usefulness of laterite, local stabilizers such as Makuba, Katsi, Gabaruwa, Dafara, etc, has been in-use as admixture to laterite for some time now. The use of Makuba as an admixture to soil for rendering purposes has been reported by Abubakar (1992).

This study is actually an extension of Abubakar's (1992) work, but with primary emphasis on admixture stabilization. By this, two stabilizers, in this case Lime and Makuba are used together to enhance the quality of the laterite. Lime is used as the modifier while makuba is the stabilizer. Modification is the change in the physical properties of the soil while stabilization is the change in the strength properties of the soil. The objective is to study the effect of compaction characteristics, plasticity characteristics on soil-lime-makuba and find out if the soil-lime-makuba mixture meets the conventional strength and

durability characteristics requirement for stabilized blocks.

### LATERITE

Laterite has been given many definitions and description by many researchers. Laterite as defined by Alexander and Cady (1962) is a highly weathered material rich in secondary oxides of iron, aluminum, or both. In the developing countries of tropical regions, laterite soils are the most encountered soil in various engineering and road projects (Osinibi 2001), while laterite is defined as the product of a physicochemical weathering of parent rocks that are rich in oxides of iron aluminum and in some cases silica in the tropic and subtropic regions (IFG 2007)

Researchers like Bunchan (1807), Alexander and Cady (1962), Little (1969) and Osula (1984) define laterite in terms of material content. Joachin and Kandiah (1941) and Madu (1977) use silica-sesquioxide ratios to categorise laterite. Gidigas (1976) group soils according to soils hardening properties, chemistry and morphology. While Ola (1978) adopted a local terminology in his definition.

### ENGINEERING CHARACTERISTICS OF LATERITE

The chemical and mineralogical characteristics of all laterite soils exhibits some similarities Clare and O'Reilly (1960), Terzaghi (1958). The physico-chemical characteristics of lateritic soil is confined to the PH, organic content and calcium carbonate content (Clare and O'Reilly, 1960).

Laterites contain all size fractions from clay, silt to gravel and some times contained some large materials. Particle size distribution in stable temperate and tropical zones has revealed that particle size distribution exerts great influence on the engineering properties of soils.

The bonding factors of the finer particles to form larger aggregate is the cementing agents in lateritic soils. However during leaching these aggregate are broken down. This is reflected by the increase in liquid limit after leaching Ola (1978). Where laterite soils are matured, they form a good bearing stratum. The hard pan or harden crust may not be easily compressible. This means that settlement within hardened crust is likely to be negligible, hence the strength of the laterite may decrease with increase depth.

#### **ADMIXTURE STABILIZATION**

Admixture stabilization has yielded appreciable improvement in soil properties Thompson (1966) Ola (1977), Lees et al (1982) and Osula (1984). A research study of the properties of the incinerator fly ash derived from municipal solid waste (MSW) incineration indicated that fly ash is a potential source of jet-grouting admixture for soil improvement. Kuan et al, (2003). Admixture stabilization is a process that involves soil modification and soil stabilization.

#### **SOIL MODIFICATION**

Soil modification essentially involves the improvement of the soil's frictional characteristics and the reduction of its plasticity characteristics (Obeahon S.O 1993). This is distinct from soil stabilization which is the improvement of the strength (usually measured as unconfined compressive strength) of the soil. The main difference is the inclusion of compaction in the process of stabilization.

As with stabilization, many kinds of agents are used in modification. They include lime, cement, etc. The purpose of modifiers is to modify the soil properties and render it workable for use as modifiers or in some cases for subsequent stabilization with cement or bitumen.

Work on soil modification by Lees et al (1982) used particle size distribution, plasticity and shear strength characteristics ( $c-\Phi$ ) as evaluation criteria. Osula (1991) used the evaluation criteria mentioned in Lees et al, together with the Nigeria general specification for Bridge and Road work, and the Highway Research Board and Millard and O' Reilly free-flow criterion.

Proportion of hydrated lime in the order of 2-3% have been recommended for soil modification (Ingles and Metcalf, (1972), Kedzi, (1979), Yoder and Witczak (1975) recommended proportion of ½-4% for hydrated lime and cement. Appreciable improvements in soil properties, such as decreased

plasticity and increased shear strength had earlier been attributed to lime in American soils (Thompson, (1966) and confirmed later on Nigeria laterites (Ola, 1977, Osula, 1991). Ola went further and recommended it for improvement of soils worse than those in the A-2 sub-groups. Similar results were recently obtained from tests performed on synthesized kaolinite and montmorillonite soils for which 2% lime modification optimum was obtained for the kaolinite soils using the C-O criterion alone (Lees et al, 1982). Osula (1991) reported modifying a problem laterite with 3% lime using the grain size and plasticity criteria of the Highway Research Board limits for soils that can be stabilized with Portland cement.

He also reported that using only the plasticity criterion, the soils can be modified with 2% lime. Successes in field trails have also been made with use of lime to aid pulverization and reclaim unstable sub-grade (Berman, 1963, Sheaham and Siembieda, 1972). Decrease in plasticity has also been mentioned for cement (Yoder and Witczak, 1975).

#### **STABILIZATION OF LATERITE**

Stabilization of laterite is the improvement of the strength and durability of the soil, thus providing satisfactory construction materials. Different types of stabilizers are in-use in different parts of the world. Some stabilizers being peculiar to a particular locality relative to their abundances (Rahman, 1986).

Stabilizers in-use locally and internationally includes, cement, lime, bitumen, makuba, pozollanas, strain, katsi, gabaruwa, and dafara, etc.

Satisfactory results with cement have been obtained by a lot of researchers (Ola, 1974, Mesida, 1978, Holmes 1981, and Rahman 1986).

Lime has not been used as extensively as cement for stabilizing laterite, but its use as stabilizer has also been reported (Ola, 1978, Rahman 1986, Lasisi, 1977).

Bituminous stabilization has also been recommended for use for sub-base course or lightly traffic roads (Ola, 1978).

Other reports on stabilizers include, rice-husk ash (Rahman, 1986) and makuba (Abubakar, 1992).

In the case of makuba, Abubakar (1992) found out that 20% of makuba content can be used as stabilizer for rendering walls.

#### **MAKUBA**

'Makuba' in Hausa refers to the brownish fruit pods of the locust bean tree (*Parkia filicoidea*) known as 'dorawa' in Hausa. The origin of makuba and the circumstances leading to the discovery of makuba is not known as describe by all the builders interviewed by Abubakar (1992).

### **Improvement in soil properties**

Some of the ways in which makuba is processed for use according to the builders that Abubakar (1992) interviewed are ; the powdered makuba is spread over a heap of soil (usually Jarkasa-fine red soil) and covered with lots of dry grass. Water is poured over this arrangement about twice a day continuously for 8-14 days at the end of which the grass is removed and the mass is mixed thoroughly by trampling over it with feet. It is then ready to be used in covering walls. Other builders mixed makuba powder with the soil and enough water to make it plastic is added to it and mixed thoroughly and then covered with grass. The wetting and mixing is repeated daily for about 1-2 weeks, each time removing and replacing the grass. The final wetting and mixing is done on the day it is to be used. The grass prevents the top of the mixture from drying up. Another variation in processing is that the builders soaked the makuba powder in water and after some days, 5-10 days the mixture, which by now would be in form of a viscous and gelatinous liquid is poured into the soil and trampled on by foot until a homogenous mixture was obtained.

For mix proportion of makuba-soil, a few builders interviewed by Abubakar (1992), claimed that there was no such a thing as a standard mix ratio-that it depends solely on the judgement of the individual. Base on the data of Abubakar (1992) the ratios of 1:4, 1:5, and 1:6 by volume batching are used.

The method of applying makuba plaster is simple and straight forward. The mason first wets a portion of the wall to be rendered; this reduces heat and sunction and hence enhances proper bonding. The mason throws the ball of the mixture with force onto the wet surface and smoothen it on using his palm and during the process make indentations on the wall. The mason gauges the thickness with his eyes.

Shrinkage and cracking are two phenomena that go hand in hand. Rendering with makuba is only carried out during the dry season and preferably during the harmattan, so that problem of ulternate wetting and drying prevalent during the other seasons does not arise, and day time temperature are invariably low. Since these factors do not exist, cracking will be rare. According to the builders interviewed by abubakar (1992), rendering with makuba does not cause crack.

The surface of makuba-rendered walls, are not smooth but rough, therefore little chance for water to have any abrasive effect on the rendering, however there is no likelihood of the rendering absorbing any water, because the rendering is done during the dry season (making it to have had ample time to dry and harden before rains set in).

Makuba has high fire resistance (Abubakar, 1992). When makuba plaster is freshly made and spread

on the wall it appear bright reddish-brown (Sienna) colour. After some few hours, it begin to becomes a moderate brown colour or Vandyke brown when completely dry and hard.

In conclusion, Abubakar (1992) reported that makuba increases the plasticity and resistance to water erosion (nearly to the same degree as cement/sand of soil renders. She also found out that makuba decreases the moisture absorption (far less than the value of cement/sand) and drying shrinkage (close to that of cement/sand) of soil renders.

### **Mechanism of Reaction (Obeahon S.O 1993)**

"In soil-lime, the general consensus is that the lime is added to a soil, it dissociates in the presence of water into calcium and hydroxyl ions there by increasing soil PH. Following this dissociation, one of the two things happens, either the excess calcium ions supplied replace cations or other elements present in the soil, or the calcium ions are absorbed by the soil if there are other unattached anaions (a part from hydroxyl ions) on the soil particle surface. Either of these cation exchange reaction. Following cation reaction are flocculation and agglomeration. Flocculation may be due to the overcrowding of the excess calcium ions on the absorbed surface of the clay particles there by causing the lowering of the zeta potentials or the repelling power of like ions in the medium (O' Flaherty, 1974). Agglomeration is caused by the attraction of the remaining soil particles still carrying negative charges to the positive charge of the flocculated particles. Osula (1991) reported that above explanation in which cation exchange is seen as the major process does not include the cation of the cementing gel material product of pozzolanic reactions which are responsible for strength gain in lime stabilization may only be any benefit after compaction and after a much longer period than is considered for modification.

Comparing lime with cement, it is expected that lime will be the better modifier. This is because the type of reaction produce is a fuction of the lime-clay ratio (Dewet and Skinner, 1967)"

### **METHODOLOGY OF RESEARCH**

This research was carried out by means of laboratory investigations. The engineering properties was determined in the lab in order to establish the properties and behavior of the soil-lime-makuba mixtures with varying percentages of makuba mixtures and hydrated lime as stated in the scope. 0 - 2% of hydrated lime was chosen based on the order of 2-3% been recommended for soil modification of (Ingles and Metcalf, (1972), The laterite soil sample used was collected at Rijiyar Zaki in Ungogo L.G.A. of Kano state.

The sample was collected at a depth of between 1.4m to 2.0m corresponding to the B-horizon usually characterized by accumulation of materials leached from the overlying A-horizon.

In carrying out the strength test three (3) 100x100 mm cubes were produced for each of the percentage of soil-lime- makuba used. The cubes were cured for seven day and then crushed in a universal testing machine. The respective results were then compared with standard.

For the durability test two cubes were casted for each percentage of soil-lime-makuba mixture. The cubes were initially cured for seven days and then soaked in water for four days. The result obtained was then compared with standard.

**EVALUATION CRITERIA**

For this study, the following were adopted as evaluation criteria.

1 For the strength properties, the Portland cement Association (PCA) and Osula's (1991) specification for stabilized block were used. The minimum crushing strength values are 1.73 N/mm<sup>2</sup> and 1.38 N/mm<sup>2</sup>, respectively.

2 To test for durability, the Portland cement Association (PCA) specification of 20% lost in strength as the maximum allowable for UCS specimens soaked for 4 days after curing for seven days was adopted.

**TEST AND RESULTS**

**Classification and preliminary tests**

Preliminary classification tests as well as tests to determine compaction characteristics were performed on the soil in accordance with B.S. 1377:1990.

The results obtained are summarized in table 1

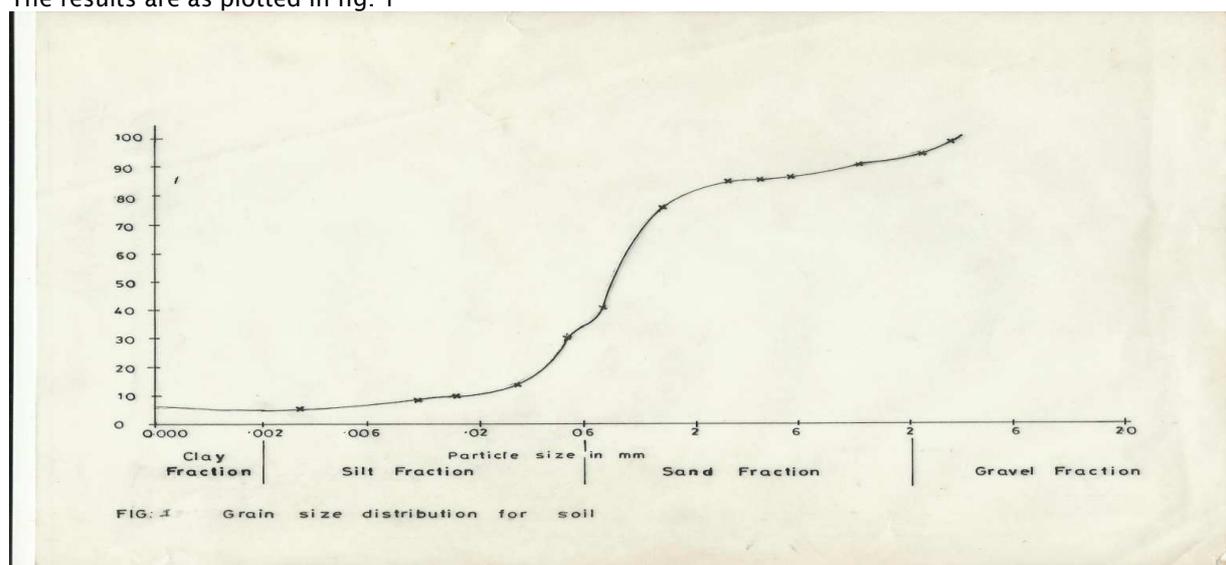
**Table.1 Properties of the soil**

Characteristics	Description
Passing No.200 B.S Sieve	41.0%
Liquid limit	24.5%
Plastic limit	12.7%
Plasticity index	11.8%
Linear shrinkage	2.86%
Unconfined coefficient (Uc)	62
Group index	8
AASHTO Classification	A-6 (8)
MDD (Mg/m <sup>3</sup> )	1.83
OMC	12.0%
Unconfine compressive strength (UCS)	0.35
Colour	Reddish-brown

**Grain size Analysis**

The grain size analysis was based on wet sieving and sedimentation tests. The tests were performed in accordance with B.S 1377:1990.

The results are as plotted in fig. 1



**STABILIZATION TESTS**

performed in accordance with B.S 1377; 1990. The results are shown in table 2

**Compaction characteristics**

Compaction tests were carried out using the standard proctor compaction. The tests were

**Table 2 The effect of Maximum dry density (MDD) and optimum moisture content OMC on soil-lime makuba.**

Lime content (%)	0		1		2	
Makuba content (%)	MDD (%)	OMC (%)			MDD Mg/m <sup>3</sup>	OMC (%)
0.0	1.83	12.0	-	-	-	-
10.0	1.60	12.4	1.45	26.0	1.55	20.5
15.0	1.55	16.0	1.40	26.5	1.44	21.5
20.0	1.50	20.0	1.35	28.0	1.48	27.5

The variation curves are as shown in figure 2 and 3

**Plasticity characteristics**

The liquid limit, plastic and shrinkage limits tests were performed in accordance with B.S 1377:1990. The results are as shown in tables 3 and 4

**Table3. The effect of liquid limit (LL), plastic limit (PL) and plasticity index (PI) on Soil-lime-makuba**

Lime content (%)	0			1			2		
Makuba content (%)	LL (%)	PL (%)	PI (%)	LL (%)	PL (%)	PI (%)	LL (%)	PL (%)	PI (%)
0.0	24.5	12.70	11.80	-	-	-	-	-	-
10.0	34.0	19.47	14.53	31.75	21.35	10.40	29.83	20.27	9.56
15.0	39.0	23.71	15.29	35.17	25.48	9.69	33.00	24.29	8.71
20.0	42.0	24.50	17.62	41.92	32.08	9.84	40.00	32.18	7.82

**Table4. The effect of shrinkage limit (SL) on soil-lime-makuba**

Lime content (%)	0	1	2
Makuba content (%)	Linear shrinkage (SL)	Linear shrinkage (SL)	Linear shrinkage (SL)
0.0	4.43	-	-
10.0	5.54	0.68	0.0
15.0	6.07	1.32	0.0
20.0	6.68	2.68	0.89

The variation cases are as shown in figure.3, 4 and 5

**Strength characteristics**

The unconfined compressive strength (UCS) tests were performed in accordance with B.S.1377:1990. The results are as shown in table 5

**Table 5. Effect of makuba content on UCS (N/mm<sup>2</sup>) for soil-lime-makuba.**

Lime content (%)	Makuba content 0% 7 days	Makuba content 10% 7 days	Makuba content 15% 7 days	Makuba content 20% 7 days
0	0.35	0.950	1.133	0.980
1	-	0.760	0.913	0.867
2	-	0.640	0.597	0.567

The variation curves are as shown in figure 7

**Durability characteristics**

The durability tests were carried out in accordance with Portland cement Association (PCA) wetting and drying tests. The results are as shown in table 6

Table .6 Effect of immersion in water on UCS (N/mm<sup>2</sup>) for soil-lime-makuba

Lime content (%)	Makuba content 0 (%)			Makuba content 10 (%)			Makuba content 15 (%)			Makuba content 20 (%)		
	Pc	pi	R(%)	Pc	pi	R(%)	Pc	pi	R(%)	Pc	pi	R(%)
0	0.35	0	0	0.95	0.42	44.2	1.133	0.503	44.6	0.980	0.35	35.7
1	-	-	-	0.75	0	0	0.913	0.265	29.0	0.867	0.20	23.1
2	-	-	-	0.64	0	0	0.597	0	0	0.567	0	0

Note: Resistance to loss in strength,  $R = (P_i \times 100 / P_c)\%$

Where  $P_i$  is soaked UCS (specimens cured for seven days) and  $p_c$  is UCS (specimens cured dry for seven days).

## ANALYSIS AND DISCUSSION

### Preliminary tests

The results of tests for identification of the soil and the determination of its properties before stabilization are presented in table 1. The grain size distribution of the soil is shown in figure 1. The soil is classified as A-6 (8) based on AASHTO classification system. It is reddish brown well graded fined-grain soil with inorganic clay of low plasticity. The clay content is about 5%. The

percentages of gravel, sand, and silt are 7, 58 and 30 % respectively.

### Compaction characteristics

The results of the compaction carried out are as shown in table 2. The variation of the optimum moisture content (OMC) and the maximum dry density (MDD) with makuba content are shown in figures 2 and 3 respectively.

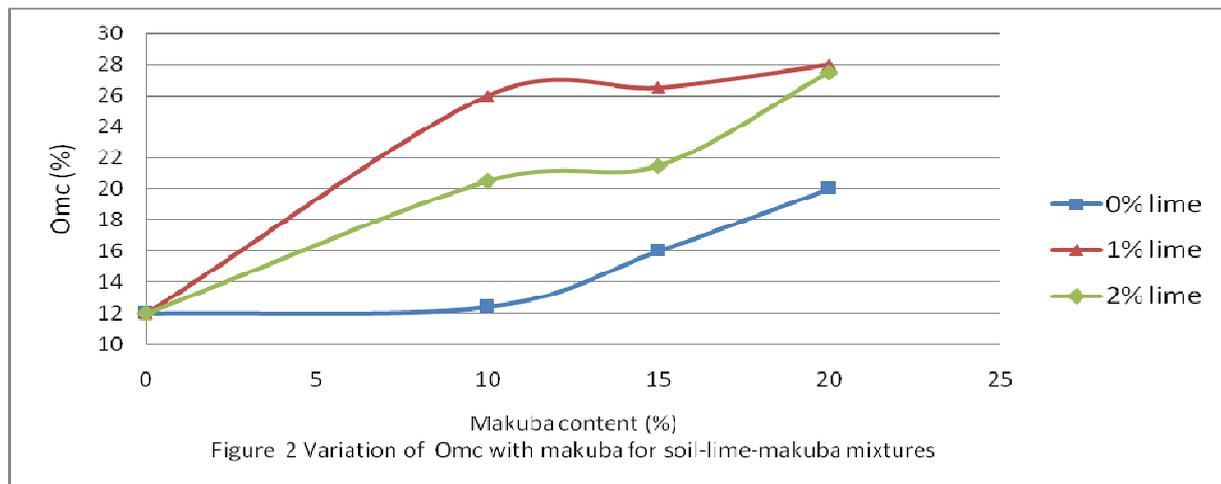


Figure 2 Variation of Omc with makuba for soil-lime-makuba mixtures

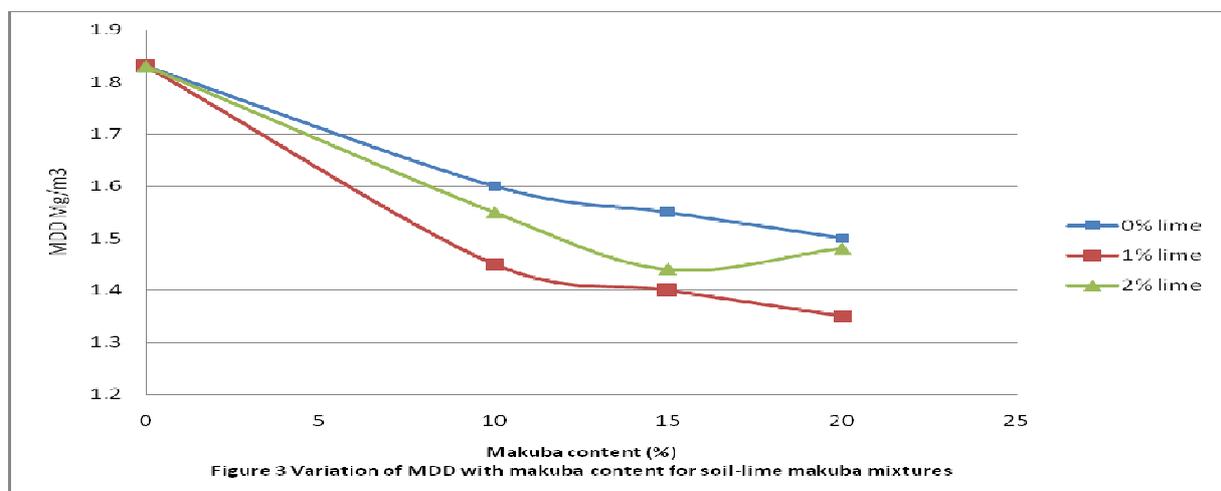
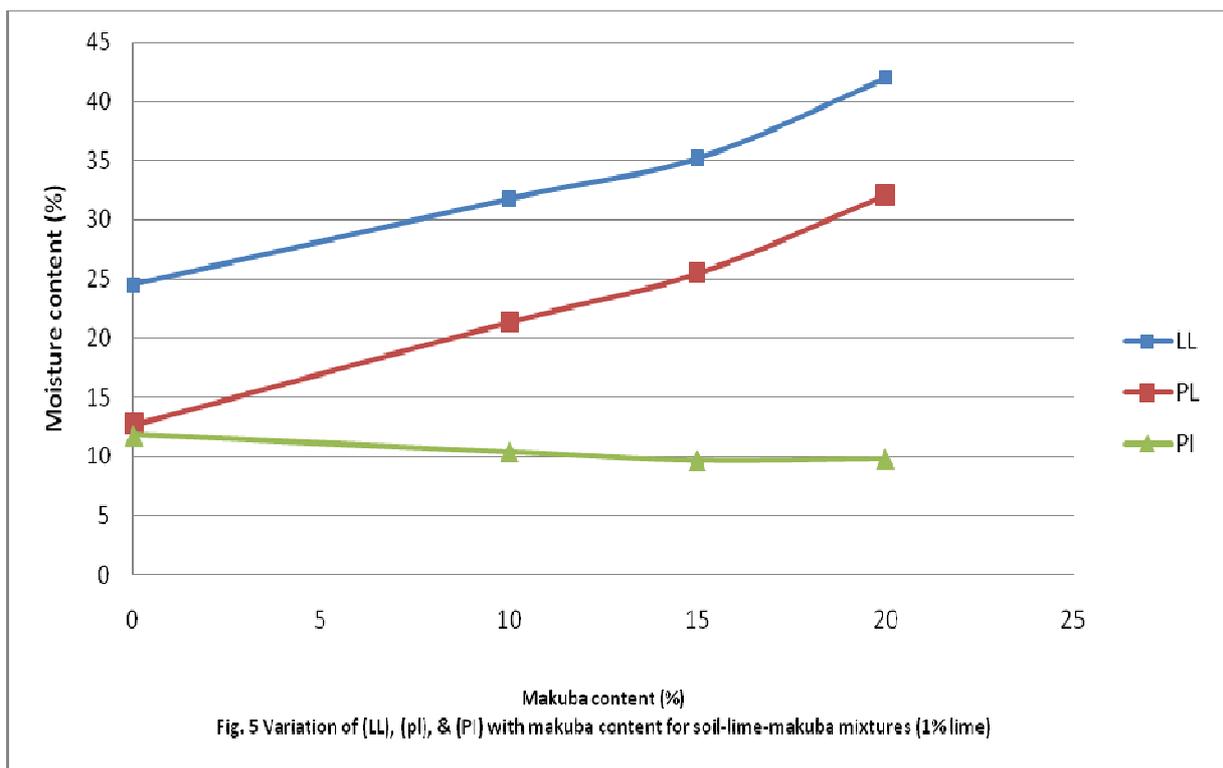
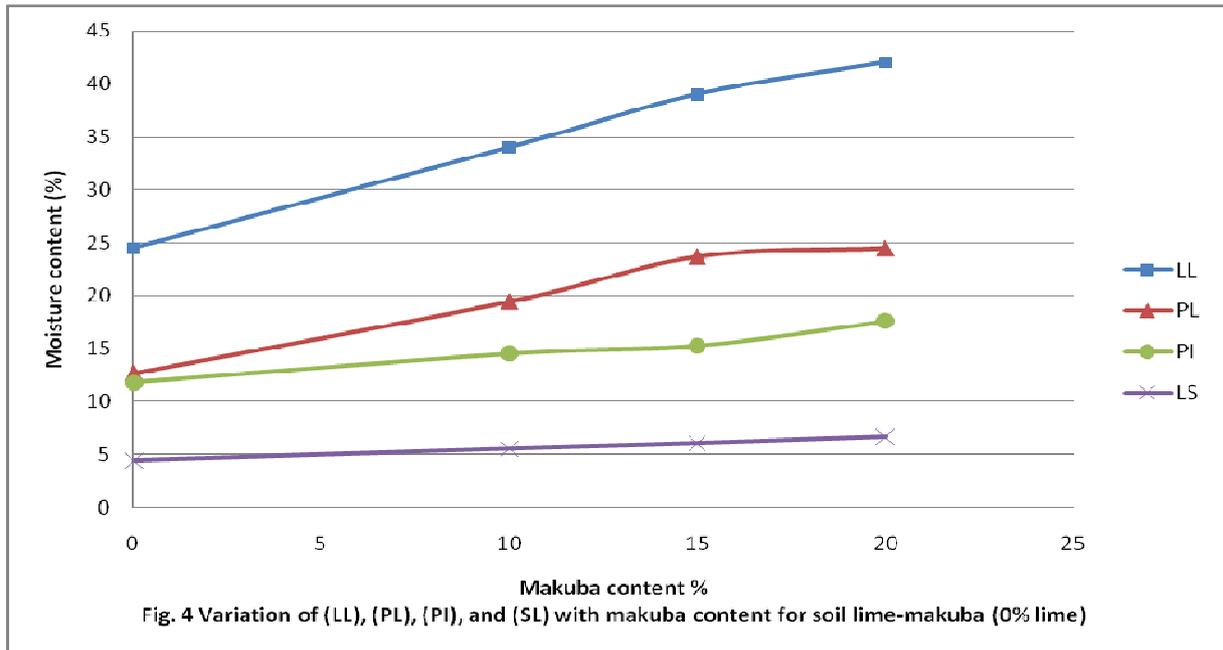


Figure 3 Variation of MDD with makuba content for soil-lime makuba mixtures



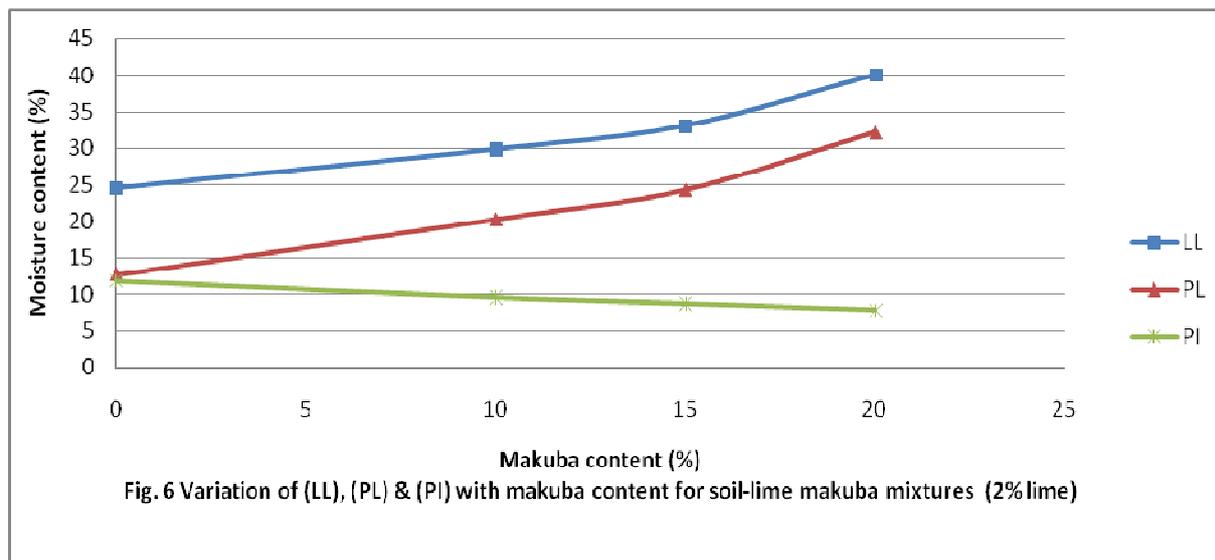


Fig. 6 Variation of (LL), (PL) & (PI) with makuba content for soil-lime makuba mixtures (2% lime)

Generally, the OMC increases with makuba content for each lime content. The increase may be due to increase in surface area of the particles caused by makuba addition. More water is then needed to lubricate the entire matrix of the soil, lime and makuba to enhance compaction. Also the presence of lime increases the desire for water as more water is required for the dissociation of lime into calcium and hydroxyl ions to supply more calcium ions for cation exchange reaction.

A comparison of the three curves in figure 2 shows that the OMC for 1% lime is higher than 0% and 2% lime addition for all makuba content. The reason may be that the surface area of the soil-lime - makuba decreases with beyond 1% lime as the lime content increases.

The MDD-makuba content curves are virtually a mirror image (inverted) of the OMC-makuba content-curves. Generally, for each lime content there is a decrease in density to the OMC-makuba content curves, this trend is in order and agrees with the usual increasing-OMC/decreasing-MDD and decreasing -omc/increasing MDD pattern. The decrease in density may be due to the excess free lime from admixed lime. As the makuba is increased, the lighter makuba content particles fill the voids in the soil matrix to give a lighter matrix.

#### Plasticity characteristics

The plasticity results are as shown in tables 3 and 4. The variation for liquid limit (LL), plastic limit (PL) and plasticity index (PI) are as shown in figures 4, 5 and 6, for 0,1 and 2% admixed lime respectively.

The liquid limit (LL), plastic limit (PL) and plasticity index (PI) increases with increase in makuba content (figure 4). This is due to the fact that makuba increase the plasticity of soil (Abubakar 1992).

The effects of the admixed lime on soil-makuba are as shown in figures 5 and 6. The liquid limit (LL) and plasticity index (PI) decreases with increasing lime contents while the plastic limit (PL) increases. The decrease in liquid limit (LL) and plasticity index (PI) with lime content may be as a result of the exchange reaction which flocculates the soil particles and reduces the clay size fraction and hence the soil surface area. Table 3 shows that the liquid limit (LL) and plasticity index for 0% lime is higher than that of 1% and 2% admixed lime for all makuba content. The increase in plastic limit (PL) may be due to the contribution of the highly plastic nature of lime, the net result being an immediate increase in the plastic limit that may be unconnected with any soil-lime-makuba reactions.

The linear shrinkage increases with increase in makuba content (figure 4). The reason may be due to the increase in plasticity with increase in makuba content. The linear shrinkage reduces with increase in lime content (table 4). This may be as a result of reducing effect of lime on plasticity.

#### THE STRENGTH CHARACTERISTICS

##### UCS characteristics

The unconfined compressive strength (UCS) test results are presented in table 5. The variation of unconfined compressive strength (UCS) with makuba content for soil-lime -makuba mixtures are shown in figure 7.

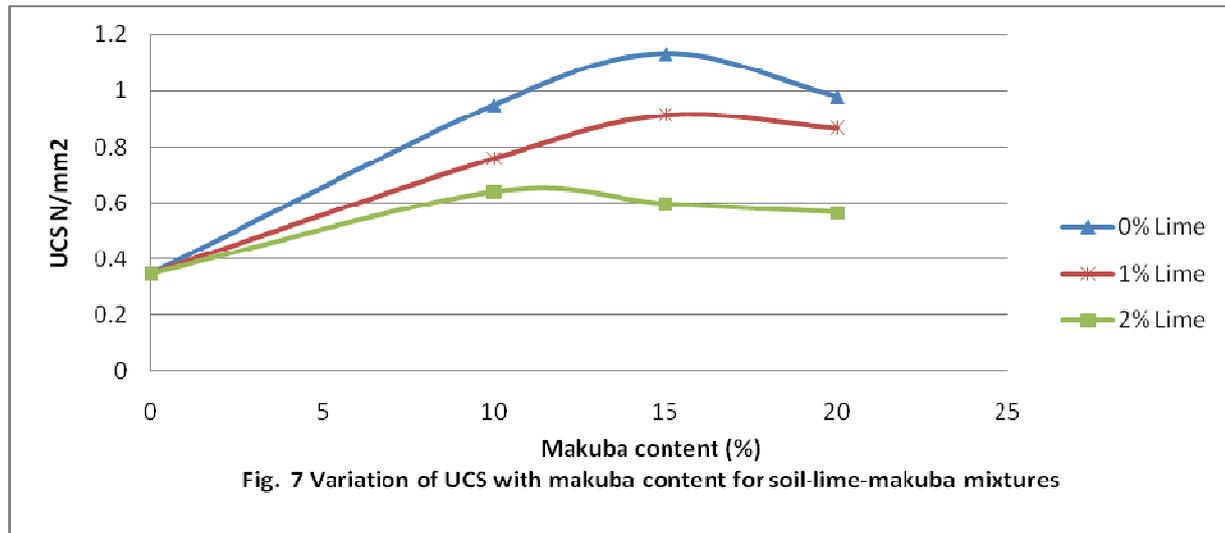


Fig. 7 Variation of UCS with makuba content for soil-lime-makuba mixtures

The UCS generally increases with makuba content for each lime content until a maximum is reached after which there is a fall.

For 0% lime content, the initial increase may be due to increase in cohesion as a result of soil-makuba interaction, while the decrease in strength beyond 15% makuba content may be due to gradual eating up of the soil as a result of excess makuba. Too high makuba is known to "eat up" soil (Abubakar, 1992).

With increase in lime content, the strength decreases.. the reason may be due to the fact that the makuba and lime have different chemical, mineralogical and physio-chemical characteristics and using them together will result in differential expansion and contraction and hence a weak adhesion. Makuba is also known to "eat up" cement (Abubakar,1992). Hence, since lime is a by-product of soil-cement interaction, it can be deduced that makuba also "eats up" lime.

The loss in strength of about 20 and 33% was obtained for 10% makuba content, 19 and 47% for 15% makuba content and 12 and 42% for 20% makuba content, for 1 and 2% admixed lime respectively.

The strength of the soil-lime-makuba did not meet with the minimum specified value of 1.73 N/mm<sup>2</sup> as specified by PCA, nor the value of 1.38 N/mm<sup>2</sup> as specified by Osula (1991) for stabilized block production.

#### Durability characteristics

Table 6 shows that the resistance to loss in strength is generally too low for all the mixtures tested. The highest value obtained for the soil-lime-makuba is 44.6% for mixtures with 0% lime. Also 0% was recorded for mixtures with 2% lime.

Judging, therefore, from the low durability indicated by the resistance to loss in strength (R<sub>i</sub> of the order of 0% i.e, 100% in strength) recorded for specimen after soaking for four days (table 6) and

taking into account the usual 20% maximum allowable loss in strength, all the admixtures are not suitable.

#### CONCLUSIONS

Within the scope of this work the following conclusions were drawn.

1. The laterite is identified to be A-6 (8) soil based on AASHTO classification system. It contains 7, 58, 30 and 5% of gravel sand, silt and clay respectively.
2. The optimum moisture content (OMC) increases while the maximum dry density (MDD) decreases with increase in makuba and lime contents.
3. With increase in makuba content, the plasticity increases (these agrees with Abubakar,1992). While it decrease with increase in admixed lime.
4. The UCS generally increases with makuba content for each lime content until a maximum is reached after which there is a fall. For 0% lime, the maximum strength of 1.13N/mm<sup>2</sup> occurs at 15% makuba content. For 1% admixed lime, the maximum strength of 0.91N/mm<sup>2</sup> occurs at 15% makuba content. For 2% admixed lime, the maximum strength of 0.64N/mm<sup>2</sup> occurs at 10% makuba content. This shows that with increase in admixed lime content, the strength decreases.
5. Based on PCA specification of 1.73N/mm<sup>2</sup> and 1.38N/mm<sup>2</sup> of Osula's (1991) specifications for stabilized block, all the UCS values obtained did not satisfy the two criteria. Though it should be noted that the value of 1.13N/mm<sup>2</sup> at 15% makuba content for soil-makuba is higher than the conventional value of 1.08N/mm<sup>2</sup> for lime.

6. The durability for soil-lime-makuba mixtures are far below the standard value of 20% as specified by PCA.
7. Finally it can be deduced that soil-lime-makuba is not suitable for stabilized block production.

### Recommendation

Based on the strength and durability criteria lime is not recommended as an admixture to makuba.

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