

Mechanical Properties of Millet Husk Ash Bitumen Stabilized Soil Block

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ABSTRACT: This study presents an investigation into the improvement of strength and durability properties of lateritic soil blocks using Millet Husk Ash (MHA) and Bitumen as additives so as to reduce its high cost and find alternative disposal method for agricultural waste. The lateritic soil samples were selected and treated with 0%, 10%, 15%, 20%, 30%, 40% and 50% of MHA by weight of laterite. The lateritic soil-MHA mixture was later admixed with 0%, 2%, 4%, 6%, 8%, 10%, 12% and 14% cut-back bitumen solution by weight of laterite. Both the natural lateritic soil, lateritic and MHA, and the blend of Soil, MHA and Bitumen were first subjected to physical and chemical analysis using X-Ray Fluorescence (XRF) and Scanning Electromagnetic Machine (SEM) to determine their engineering properties followed by the performance test on bricks cast with varying quantities of the additives. A total of one hundred and ninety two (192) cubes were tested for moisture absorption, erodability and compressive strength tests. The result of the test showed that MHA and Bitumen acted as pozzolana in performance test on the soil blocks. Up to 30% MHA – laterite and 20% MHA admixed with 8% laterite were found to give optimum compressive strength of 10.8N/mm² and 10.9N/mm² for the bricks produced. The result also showed that about 50% MHA blended with 14% Bitumen solution ensured water tight bricks. Thus the use of MHA as partial replacement of cement will provide an economic use of by-product and consequently produce a cheaper soil block construction without comprising its strength.

KEYWORDS: Millet husk, ash, bitumen, soil block, mechanical properties, compressive strength.

[Received February 18 2017; Revised June 15 2017; Accepted June 17 2017]

I. INTRODUCTION

Most people in rural areas of Nigeria dwell in mud houses made from lateritic-soil block. Mud houses have proven useful for generation that they are ideal for tropic, they tend to be cooler during hot season as a natural ventilation system draws fresh air into the building eliminating the need for air-conditioning and are warm during the cold harmattan season, (Dahiru, 1998). Lateritic block are produced cheaply from lateritic soil which are abundantly available in most areas of the country.

Millet is a group of highly variable small-seeded grasses, widely grown around the World as cereal crops or grains for fodder and human food. Millets are important crops in the semiarid tropics of Asia and Africa (especially in India, Mali, Nigeria, and Niger), with 97% of millet production in developing countries McDonough *et al.* (2000). The husk ash, referred to as Millet Husk Ash (MHA) can be obtained from burning the millet husk produced after processing using a control burning method.

According to FAO (2007), about nine species of millet are available with a total product of 28.38 million tons, out of which 11.36 million tons (40%) are produced in Africa. Nigeria produces about 40% of the millet produced in Africa (Obilana 2002) and was rated as the second largest producer of millet in the World as reported by FAO (2007).

Akande, (2002) reported that 40% of the weight of the harvested millet is removed as husk from the stroke. The husk is of no known economic value and sometimes been used as filling materials.

Recent research (Uche *et al.*, 2012) shows that the MHA can be used as a pozzolana in cement-based material. They reported that MHA has cementitious compound which contribute in the strength improvement of concrete. This study tends to investigate the effect of MHA admixed with bitumen on the physical properties of soil blocks with a view to improving the engineering properties of the lateritic soil-blocks.

II. METHODOLOGY

A. Materials

A single borrow pit was carefully selected in Mashi town (Lat. 12°59'00" N Long 7°57'00"E) in Mashi Local Government Area of Katsina State, Nigeria. Lateritic soil samples were obtained from a depth below 1.2m with simple manual digging using digger, hoe and shovel. Samples were collected in polythene bags and plastic bucket for easy transportation to laboratory in its in-situ state. The lateritic soil was observed to be reddish brown in colour.

Millet Husk was obtained from local farmers in Mashi town after harvesting and threshing the millet. The ash was

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then obtained by burning the Millet Husk in a control temperature of not below 600^oc in a furnace for 2 hours. The sample specimens were cooled and sieved through 425µm BS-sieve. The ash passing through the BS-sieve size was used for this study. Cut-back bitumen of MC125 grade obtained from local dealer in Kano, Nigeria was used in this study.

The water used for mixing and curing purposes was fresh pipe borne water obtained from the taps in the Laboratory of Civil Engineering Department, Bayero University, Kano and satisfied ASTM C1602-12 specification of water for use in concrete mixtures.

B. Methods

i. Batching/Production of Lateritic Soil Blocks

The material samples of lateritic soil, MHA and Bitumen were thoroughly mixed with water at the design ratio shown in Table 1. The mix properties were used in producing soil bricks of 150m x 150m x 150mm. About 192 cubes were produced and cured with jut bags covers and sprayed with water in the morning and evening hours.

Table 1: Mix Proportion of the Sample Specimen.

% Replacement	Lateritic soil (g)	MHA (g)	Bitumen (g)	H ₂ O (g)	
				MHA	Bitumen
0	100	0	0	0	0
5	93	5	2	0.5	0.5
10	86	10	4	0.5	0.5
15	79	15	6	0.5	0.5
20	72	20	8	0.5	0.5
30	60	30	10	0.6	0.4
40	48	40	12	0.65	0.35
50	36	50	14		0.30

ii. Experimental Procedure

Laboratory tests were carried out on the lateritic soil to provide a basis for classification, comparison and accessing the suitability of the soil for engineering purposes using their physical characteristics and appearance as well as the chemical analysis of the elemental oxides. The soil was influenced mainly by the particle size distribution and plasticity properties associated with the mineralogical composition and water content. Also chemical and elemental oxide compositions were also carried out on the MHA and bitumen in order to establish its mineralogical composition.

The natural moisture content, bulk density, specific gravity, compaction and Atterberg’s limits tests were conducted on the natural lateritic soil samples and samples admixed with MHA and bitumen in accordance with provision of BS 1377 (1990).

iii. Chemical Composition of Materials

The chemical composition analysis of the lateritic soil, Millet Husk Ash (MHA) and Cut-back Bitumen (BIT) were conducted using the X-Ray Fluorescence (XRF) and Scanning Electron Microscope (SEM) methods. The XRF was conducted at Defence Industries Corporation of Nigeria (DICON) whereas the SEM was conducted at Chemical

Engineering Laboratory of Ahmadu Bello University, Zaria, both in Kaduna State Nigeria.

iv. Compressive Strength Test

The compressive strength of the lateritic soils blocks with varying quantities of additives was determined in accordance with NIS 87 (2004) using Avery Denison compressive machine at low load application rate of 0.05 N/s. The compressive strength was taken as the maximum compressive load the cube can carry per unit areas. The test was carried out after 3, 7, 28 and 56 days of curing ages.

III. RESULTS AND DISCUSSIONS

A. Properties of Un-stabilized Lateritic Soil

The properties of un-stabilized lateritic soil as shown in Table 2 showed that the natural moisture content was 15.45% indicating that the soil was visibly wet when collected while the Specific Gravity (GS) of 2.44 indicated that the soil need improvement for it to meet the range of value stipulated for clay minerals.

Also the MDD/OMC relationship of the compacted sample which are 1.77g/cm³/16.22% indicates that when the soil was compacted slightly above 16.22%, the compressibility would be better at relative low stress level.

Comparing the liquid limit, plastic limit and plasticity index which are 28.8%, 25.0% and 3.8% respectively, the natural lateritic soil has low to medium plasticity (Raw, 2000). The percentage fraction of gravel, sand and fines of 59.0% 10.80% and 29.30% indicate gravely sandy soil which is good in making lateritic bricks.

Table 2: Properties of Un-stabilized Lateritic Soil.

S/N	Characteristics	Average Values
1	Natural moisture Content	15.45%
2	Percentage sand	10.80%
3	Percentage gravel	59.00%
4	Percentage fines	29.30%
5	Liquid limit (LL)	28.8%
6	Plastic limit (PL)	25.0%
7	Plastic Index (PI)	3.8%
8	Linear Shrinkage	2.2%
9	Maximum Dry Density	1.77gkm3
10	Optimum Moisture Content	16.22%
11	Specific gravity (GS) colour	2.44

B. Chemical Composition Result Analysis

The oxide composition tests for Laterite, MHA and Bitumen presented in Tables 3, 4 and 5 respectively showed that the materials contain varying percentage of oxides as compared with cement. The combined composition of SiO₂ + Al₂O₃ + Fe₂O₃ in MHA is about 80% which is greater than the ASTM C618 minimum limit of 70% for a good pozzolana. This suggests that the MHA is very reactive and have the possibility of pozzolanic reactions when blended as reported by Elinwa et.al (2008); Uche et al., (2012) and Ogork et al., (2014).

Table 3: Oxide Composition of Laterite.

Oxide	% Concentration
Al ₂ O ₃	25.8%
SiO ₂	50.8%
K ₂ O	1.09%
CaO	0.621%
TiO ₂	1.26%
V ₂ O ₅	0.078%
Cr ₂ O ₃	0.022%
MnO	0.035%
Fe ₂ O ₃	18.44%
NiO	0.002%
CuO	0.021%
ZnO	0.003%
Ag ₂ O	1.58%
Eu ₂ O ₃	0.15%
Re ₂ O ₇	0.061%

Table 4: Oxide Composition of the Millet Husk Ash.

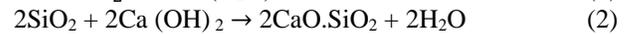
Oxide	% Concentration
SiO ₂	65.94%
P ₂ O ₅	4.81%
SO ₃	2.61%
K ₂ O	9.800%
CaO	10.59%
TiO ₂	0.725%
V ₂ O ₅	0.018%
MnO	0.0884%
Fe ₂ O ₃	3.307%
CuO	0.024%
ZnO	0.0774%
Ag ₂ O	1.84%
BaO	0.16%

Table 5: Oxide Composition of Bitumen.

Oxide	% Concentration
SiO ₂	0.39%
Al ₂ O ₃	0.95%
Fe ₂ O ₃	0.357%
CaO	0.776%
Sc ₂ O ₃	0.031%
TiO ₂	0.059%
V ₂ O ₅	1.09%
Cr ₂ O ₃	0.067%
NiO	0.201%
MoO ₃	19.2%
Ag ₂ O	9.21%
Eu ₂ O ₃	0.34%
HfO ₂	0.40%
Re ₂ O ₇	0.64%

The element composition of laterite, MHA and Bitumen using the Scanning Electron Microscope (SEM) showed the formation of Ca, Si, O elements which indicated possibility of formation of C-S-H and Ca(OH)₂ compounds during pozzolanic chemical reactions, while the composition of the

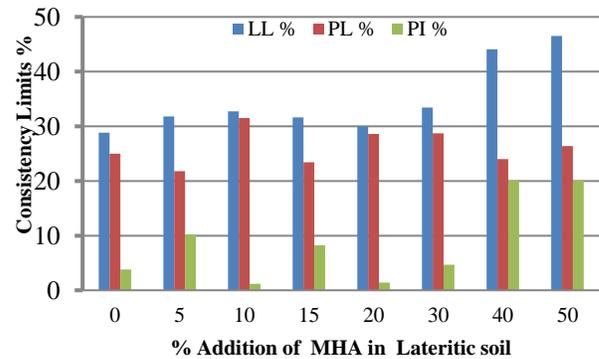
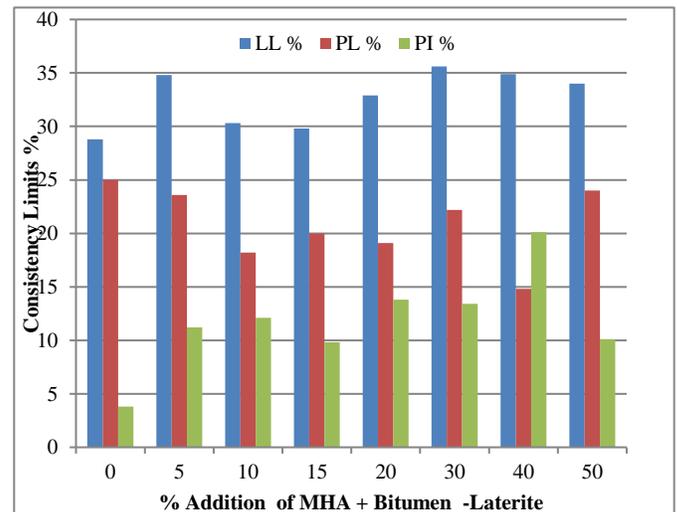
Bitumen showed possibility of water proofing effect of the blended lateritic soil. There is possibility of chemical reaction between water and oxides in the admixture leading to production of Calcium Hydroxide Ca(OH)₂ as shown in equation 1 which in turn reacts with Silicon Dioxide SiO₂ to produce Di-Calcium Silicate as represented in equation 2.



Where 2CaO.SiO₂ is the di-calcium silicate.

C. Effect of MHA and MHA Admixed with Bitumen on Atterberg Limit of Lateritic Soil

Figures 1 and 2 show the inconsistencies in the variations of the Liquid Limit, Plastic Limit and Plastic Index as increase in MHA, and MHA + Bitumen additives. The addition of Bitumen in the lateritic soil – MHA showed decrease in the Atterberg's Limits and this led to decrease in workability as the flocculation and agglomeration of the clay particles caused by ion exchange is not as desired. The MHA and Bitumen ion exchange might have cause cementation effect and hence reduced water absorption of the blended lateritic soil.

**Figure 1: Variations of Atterberg Limit with MHA - Laterite.****Figure 2: Variations of Atterberg Limit with MHA +BITUMEN - Laterite.**

D. Effect of MHA and MHA Admixed with Bitumen on Compressive Strength of Lateritic Soil.

It was observed from Figure 3 that the compressive strength of bricks with MHA alone increases with increase in the MHA content to a maximum of 30%. This increase may not be unconnected with the pozzolanic activities of the MHA which have been shown through XRF analysis to have contained a combined SiO_2 , Fe_2O_3 and Al_2O_3 of about 80%, thus making it a very good reactive pozzolana when blended.

Figure 3 also showed that there is an optimum amount of MHA above which the compressive strength starts reducing. This optimum MHA content of 30% corresponds to the maximum compressive strength of 10.8 N/mm^2 at 28 day curing which is greater than control. The reduction of strength after 30% MHA addition may be due to dilution effect of excess MHA leading to low pozzolanic reaction. Figure 4 on other hand showed the same trend of variation of compressive strength with MHA admixed with Bitumen

emulsion. The blend of 20% MHA and 8% Bitumen emulsion result in maximum strength of 10.9 N/mm^2 at 28 day strength, thus signifying that the Bitumen emulsion helped in the strength gain. The reason may not be unconnected with earlier reasons.

Generally, it was recorded from Figures 3 and 4 that the compressive strength of lateritic soil and soil blends increases with curing age which was as a result of improvement in the hydrating oxides composition of the materials with time.

IV. CONCLUSIONS

The study has assessed the improvement of strength and durability properties of lateritic soil blocks in Mashi Area of Katsina State Nigeria using Millet Husk Ash (MHA) and Bitumen as additives. The following conclusions were drawn from the study:

1. The lateritic soil found in Mashi area of Katsina State Nigeria is of sandy-gravelly soil with moisture content of 16.22%, specific gravity of 2.44, linear shrinkage limit of 2.2%, atterberg limits of 28.8%, 25.0 and 3.8 for liquid limit, plastic limit and plastic index respectively.
2. The physico – chemical properties of MHA showed that it contains cement oxides with combined sum of SiO_2 , Al_2O_3 and Fe_2O_3 equal to about 80% which is greater than the 70% sum of ASTM C 618 for good pozzolana.
3. Increase in MHA additives on the lateritic soil improves the strength of MHA-lateritic soil with maximum strength attained at 30% MHA at 28 day curing age.
4. The use of MHA-Bitumen also improves the compressive strength with maximum strength recorded at 20% MHA blended with 8% bitumen emulsion.
5. The optimum MHA-Bitumen content was established as 20:8 percentage as this gave the highest compressive strength of 10.9 N/mm^2 at 28 day strength.

It is therefore recommended that MHA Bitumen be used in lateritic soil brick production in Mashi Area of Katsina State and other areas with similar soil properties.

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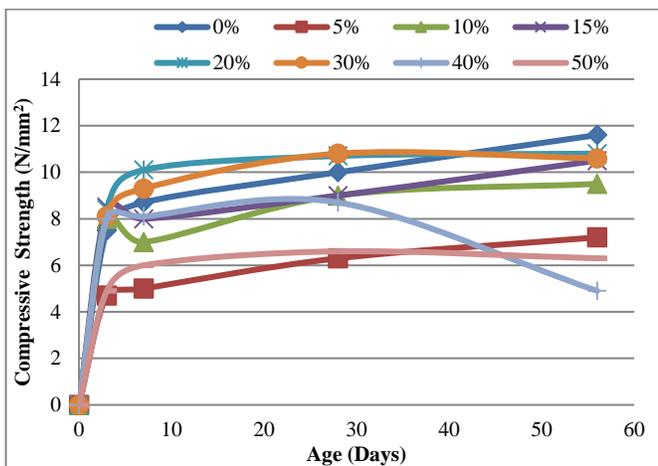


Figure 3: Compressive Strength of MHA Stabilized Lateritic Soil.

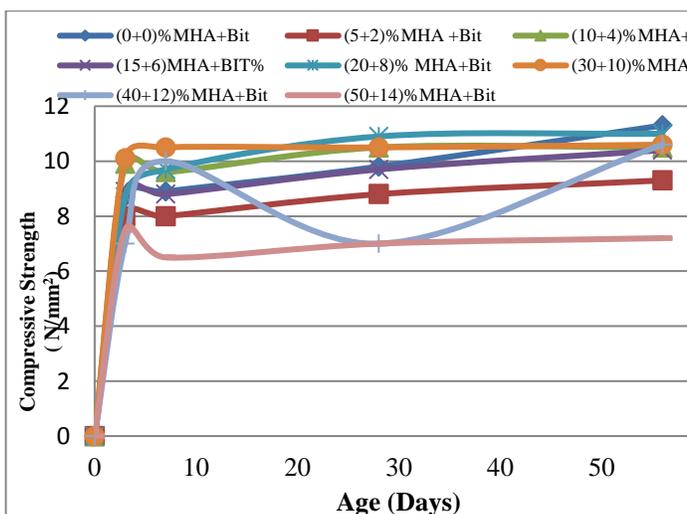


Figure 4: Compressive Strength of MHA Admixed with Bitumen on Lateritic Soil.

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