Properties of Mud Brick Stabilized with Sugarcane Peel Ash

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Abstract: **This paper aimed at determining the properties of mud brick stabilized with sugarcane peel ash. This is done with the opinion of finding beneficial use of the peels in the production of sustainable cheap and environmental-friendly brick. The lateritic soil used in this study was obtained at Ajegunle (6°53'20.44"N, 3°10'55"E), Ogun State, Nigeria while the sugarcane peel (SCP) was obtained from a waste dump at Papalanto (6°53'20.44"N, 3°13'50.98"E),Ogun State, Nigeria. The SCP was dried, calcined and used as a partial replacement to lateritic soil in the production of mud brick at 0, 2, 4, 6% by mass in this research and the compressive strength, water absorption, capillarity and erosion resistance tests were performed in accordance with ASTM C67 and New Zealand Standard NZS 4298 (1998) on the bricks to determine its suitability as building unit. The compressive strength increased considerably from 3.05to 3.72 MPa at 28 days between 0% and 6%, the erosion resistance also improved from a penetration of 1.75 to 0.95mm/min at 28 days, water absorption reduced from 38.8% at 0% addition of SCPA to 27.8% at 6% at 28 days while water capillarity also reduced from 76mm to 63mm from 0% and 6% respectively at the 28 day. Therefore, SCPA possesses the ability to enhance the quality of lateritic mud brick.**

Keywords: **Mud bricks, sugarcane peel ash, compressive strength, erosion resistance, water absorption and capillarity**

I. INTRODUCTION

The human population is growing and so is the housing deficit because an average citizen in developing countries cannot afford the construction cost of a moderate accommodation. It is then imperative to employ innovative and sustainable technologies in making available low-cost and effective building materials. Mud brick, an affordable low-cost building material made from lateritic soil, has associated problems with some of its properties hence must be modified to ensure its suitability. The identified issues with mud brick include the mechanical and durability problems such as perforation of the walls and gradual erosion of the brick building as an effect of water which limit its usage and acceptability. Mud bricks are made from the abundantly available and low-cost lateritic soil. Laterite is a residual of rock decay that is red, reddish brown and yellowish in color and has a high content of oxides of iron and hydroxides of aluminum and low proportion of silica [9]. According to Alhassan (2008), lateritic soil in its natural state generally has low bearing capacity and strength due to high content of clay [1]. When lateritic soil contains a large amount of clay materials its strength and stability cannot be guaranteed under load especially in the presence of moisture.

II. BACKGROUND STUDY

The improvement in the strength and durability of lateritic soil in the construction of mud brick in recent time has become imperative; this has interested researchers toward using stabilizing materials that can be source locally at a very low cost [2],[3],[4].These local materials can be classified as either agricultural or industrial wastes [4]. The ability to blend the naturally occurring lateritic soil with some chemical additives to give it better engineering properties in both strength and water proofing is very essential [7]. According to Bello (2013), cement and lime have been the two main materials used for stabilizing soils over the years [8]. These materials have rapidly increased in price due to the sharp increase in the cost of energy and high demand for them thereby preventing developing countries like Nigeria in meeting up with provision of low-cost housing scheme. Lear (2005) showed that Portland cement, by the nature of its chemistry, produces large quantities of CO_2 for every ton of its final product which contributes to the melting of the ozone layer covering the earth surface [13]. Therefore, replacing proportions of the Portland cement in soil stabilization with agricultural waste material such as sugarcane peel ash will reduce the overall environmental impact of the stabilization process. The global production of sugarcane was reported to be 1900 million in 2009 [11]. Sugarcane Peels (SCP) is a by-product of sugarcane utilization either for domestic consumption or industrial uses. SCP constitutes between 30-45% of the weight of the cane. It has also been found to possess 0.95 (w/w) waxes of dried sugarcane peels [14]. The wax serves as a good waterproofing material.

The indiscriminate disposal of sugarcane peels due to gross under-utilization is also an environmental challenge hence the need for appropriate means of recycling them. Therefore, this study looked into the properties of Sugarcane Peels Ash modified brick.

III. METHODOLOGY

The materials used in this study were lateritic soil, sugarcane peel and water. The lateritic soil was collected at a depth not less than 1.2m from a borrow pit at Ajegunle (6°53'20.44"N, 3°10'55"E) along Ilaro - Papalanto road, Ogun State, Southwestern Nigeria.

Fig. 1: Excavation of soil sample.

The soil was air-dried for two weeks to allow partial elimination of natural water which may affect analysis, then sieved through 4.75mm opening to obtain the final soil samples for the tests. After the drying period, lumps in the sample were slightly pulverized with minimal pressure. The preliminary classification of the lateritic soil was conducted in accordance with [10]**.** Sugarcane peel (see fig. 2) used for this study was collected at a waste dump at Papalanto *($6^{o}53'20.44''N$, $3^{o}13'50.98''E$)*, Ogun State Southwestern Nigeria.

Fig. 2: Sugarcane Peel

It was sundried for seven days, pulverized, calcined in a muffle furnace at a temperature of 1000°C for 45 minutes to derive the ash at the concrete laboratory of the Department of Civil Engineering in The Federal Polytechnic Ilaro. After cooling, the resultant sugarcane peel ash (SCPA) was grinded into finer particles (almost at cement fineness, 225sq.m/kg) at Dangote Cement Factory mill. The ash was analyzed at the Department of Science Laboratory Technology of the University of Ibadan using the fusion method. An integrated X-ray analyzer was used to obtain the general oxides.

Bricks of 285mm x 135mm x 85mm dimension were moulded with SCPA replacing lateritic soil at 0%, 2%, 4% and 6% content. The bricks were made with locally fabricated mould attached to a hydraulic press which moulds the bricks by compression. The bricks were sundried for 7, 14, 21 and 28 days before subjected to compressive strength test, total water absorption (by immersion) test, capillary rise (penetrability) test in conformation with [5] and erosion resistance test in accordance with Section D of New Zealand Standard NZS 4298 (1998) .

IV. RESULTS AND DISCUSSION

The results from the soil classification tests (natural moisture content, specific gravity, particle size analysis, and Atterberg's limits) of the lateritic soil sample, SCPA oxides analysis, as well as the engineering properties (compressive strength, total absorption, capillarity and erosion resistance tests) of the mud bricks are discussed below.

A. Classification Test: From Table 1, the sample was reddish brown, with a natural moisture content of 18.4% which is a function of its void ratios. This showed that the soil sample contained an appreciable amount of moisture which is largely affected by the climatic condition [3]. The specific gravity of the soil which is 2.61 falls within the range for clay minerals considered as sodium and calcium feldspar (2.62-2.76). Lambe (1979) and Ola (1978) aver that the higher the specific gravity, the higher the degree of laterization [12], [16]. This indicates that soil sample exhibits a good degree of laterization.

Soils suitable for production of mud brick must contain between 25 - 50% clay and silt and 50 -75% coarser particles [19]. The result from the particle size analysis (Fig.1) shows that the clayey/silty constituent (passing 75µm) of the lateritic soil is about 31% which indicates that the soil is adequate for producing mud bricks as it was found to be without organic matter which would have obstructed the binding of the brick material. The result of the Atterberg Limits test shows that the Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) of the soil sample is 30.50%, 20.53% and 9.97% respectively. According to Whitlow (1995), liquid limit less than 35% indicates low plasticity, between 35% and 50% indicates intermediate plasticity, between 50% and 70% high plasticity and between 70% and 90% very high plasticity and greater than 90% extremely high plasticity [18]. This shows that soil sample has a low plasticity. Based on the (LL) and (PI), the sample was further classified as A-4(0) which indicates the sample is fairly good for most geotechnical construction works. It was found that the soil contains an appreciable amount of clay although the tendency for swelling has been greatly reduced since the laterite is not in the high plasticity class and shrinkage is expected to be minimal since the clay content is not at a high level. The soil would also have good binding properties due to the presence of clay in the soil.

Table 1: Summary of properties of soil sample

Properties	Values
Colour	Reddish brown
Natural moisture content	18.4%
Percentage passing BS 200	85%
Liquid limit	30.5%
Plastic limit	20.53%
Plasticity index	9.97%
Specific gravity	2.61
AASHTO classification	A-2-4
Group Index	0

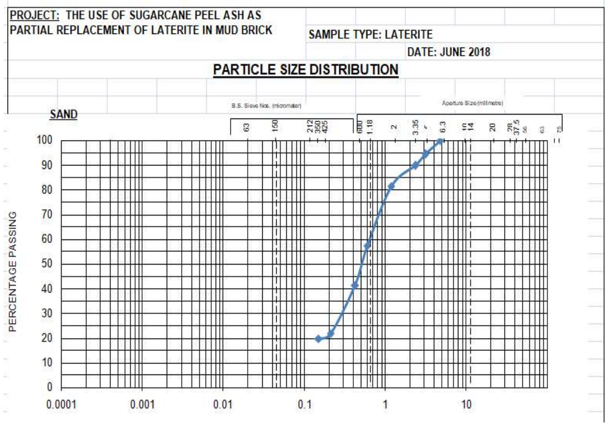

Fig.3: Particle size distribution curve of lateritic sample.

Table 2: Summary of oxides of SCPA @ $1000^{O}C$

Chemical composition	%
SiO_2	70. 24
Al_2O_3	2.05
Fe_2O_3	2.21
CaO	11.56
MgO	2.03
K_2O	3.08
Na_2O	3.08
TiO_2	0.03
P_2O_5	1.27
SO_3	4.32
Li_2O	0.65
LOI	2.00

At the calcining temperature of $1000^{o}C$, the SCPA is found to be pozzolanic in accordance with recommendations of [6]; hence it can be a substantial binder.

B. Engineering Tests: The summary of the results of the engineering tests are as shown in Table 3 below.

The compressive strength of the unmodified soil sample ranged between 1.21 to 3.05 MPa from 7days to 28 days. The replacement of the soil sample with sugarcane peel ash in 2, 4, and 6% by mass of sample generally increased the compressive strength. The compressive strength increased from 1.43 to 3.26 MPa at 2%, 1.65 to 3.53 MPa at 4% and 1.82 to 3.72 at 6% (Fig.4). It was observed that there was gain in the compressive strength of the mud brick as the age increases and also with the increase in SCPA addition. This increase in compressive strength with age may be due to the fact that the water in the brick matrix gives way and allow for the bonding of the clay material with the sand constituent as the age increases while the increase in compressive strength with the additional SCPA may be attributed to the additional binding effect of the pozzolanic SCPA. The additional binding effect ensures that the voids in the brick are reduced hence ensure the particles of the brick are closely packed with resultant high load-carrying capacity. The results from the water absorption test (Fig. 5) showed a decrease in the water absorption of the mud blocks as the percentage of the sugarcane peel ash was increased depicting a reduction in the porosity of the mud block. This shows that the sugarcane peel ash improved the property of the mud block in this respect. The improvement can be attributed to the presence of wax in the sugarcane peel serving as a sheath which prevents the ingress of water into the mud brick. It was also observed that the water absorption continued decreasing even until the 6% sugarcane peel ash addition which was an indication that the water repelling quality of the mud brick may be further improved by increasing the quantity of sugarcane peel ash added to the mud brick. Fig. 5 (see also table 3) presents the summary of the capillary rise test results of the modified brick. In general the results show that sugar cane peel ash modified bricks perform much better in resisting water penetration, compared with non-modified brick. It can be seen that the capillary rise of water of the bricks decreased with the increase in sugarcane peel ash content (Fig.6). The low moisture penetrability in the mud bricks with increased sugarcane peel ash content may be attributed to the sheath provided by the wax of the sugarcane peel ash as well as the reduced porosity. The erosion test result presented in Fig. 7 shows a reduction in erosion with increase in sugarcane peel ash content up to 6%. According to Walker (2004), erosion resistance for cement stabilized soil blocks used for external walls must be less than 1 mm/min [17]. With the exception of the blocks containing 6% of sugarcane peel ash at 28 days, all the other bricks failed this test.

Table 3: Summary of the Engineering Properties of Mud brick

% SCPA replacement		Compressive Strength (MPa)				Total Water Absorption (%)				Capillary Rise mm/mm				Erosion Resistance (mm/min)	
	Days	7	14	21	28	7	14	21	28	7	14	21	28	21	28
0		1.21	2.51	2.83	3.05	14.5	19.2	27.8	38.8	0.41	0.50	.70	.76	1.75	1.74
2		1.43	2.77	2.98	3.26	14.4	18.1	23.5	35.8	0.39	0.44	.52	.64	1.50	1.48
4		1.65	2.97	3.11	3.53	14.1	15.4	23.3	30.5	0.31	0.36	.42	.43	1.27	1.23
6		1.82	3.03	3.24	3.72	13.9	14.3	22.6	27.8	0.30	0.32	.35	.40	1.03	0.96

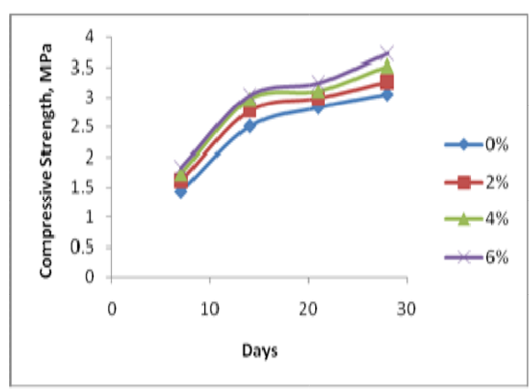

Fig. 4: Variation of Compressive Strength of Different Samples with Age

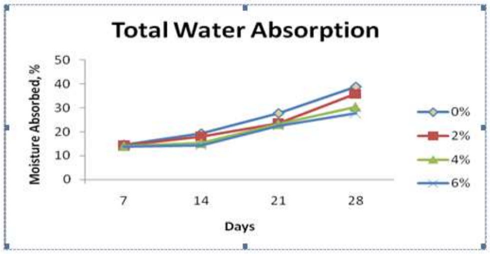

Fig.5: Results of the Water Absorbed by Mud Brick at Varying % SCPA Addition with Age

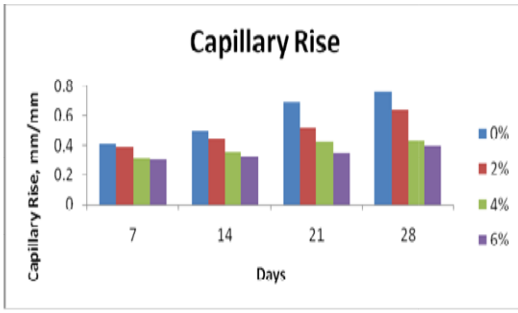

Fig.6: Results of the Capillary Rise in Mud Brick at Varying % SCPA Addition with Age

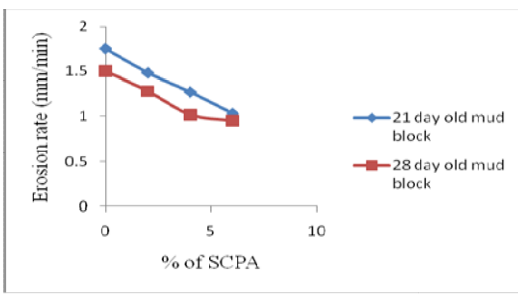

Fig. 7: Erosion resistance results at age 21 and 28 days

V. CONCLUSION

Based on the summary of results discussed above, it could be concluded that sugarcane peel ash is effective in improving the engineering properties of lateritic soil bricks. The modified bricks are stronger and more durable than non-modified ones making it more viable for housing construction. Hence it can be clearly recommended for cost effective construction for low cost housing in developing countries where housing deficit is a growing concern. However, the optimum quantity of sugarcane peel ash that would produce most favorable mud bricks for construction could not be established by the research, it is therefore recommended that further tests are carried out at the addition of higher percentages of sugarcane peel ash to get the optimum quantity of SCPA addition that gives optimum brick quality.

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REFERENCES

[1]. Alhassan M (2008). Potential of rice husk ash for soil stabilization .AUJT, 71(4) 246- 250.
[2]. Amu O.O & Adetuberu A.A.(2010).Characteristics of bamboo leaf ash stabilization on lateritic soil in highway construction . International Journal of Engineering and Technology, 2(4):212-219.
[3]. Amu O.O, Bamisaye O.F & Komolafe I.A (2011b). The Suitability and Lime Stabilization requirement of Some Lateritic Soil Samples as Pavement. International Journal of Pure Applied Science and Technology, 2 (1):29–46.
[4]. Amu O.O, Ogunniyi S.A & Oladeji O.O. (2011). Geotechnical properties of lateritic soil stabilized with sugarcane straw ash. American Journal of Scientific and industrial Research, 2(2):323-331.
[5]. ASTM C67 –18 :Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile. America.
[6]. ASTM C618 – 00: Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete. America.
[7]. Bello A.A & Awogboro O.S, Oriaje A.T. (2014). Influence of Compactive Efforts on Lateritic soil stabilized with Rice Hush Ash. International Journal of Applied Engineering, ;9(21):9639-9653.
[8]. Bello A.A, Ige J. (2014). Geotechnical properties of lateritic soil stabilized with cement-bamboo leaf ash admixtures. International Journal of Applied Engineering Research, 9(21):9639-9653.
[9]. Bello A.A, & Adegoke C.W. (2013). Geotechnical characterization of abandoned dumpsite soil. ARPN Journal of Earth Sciences, ISSN 2505-403,; Available: http://www.arpnjournals.com, 2(3):90-100.
[10]. BS 1377 (1990): Methods of Testing Soil for Civil Engineering Purposes. London: British Standards Institute.
[11]. FAOSTAT,2010, http://www.fao.org/economic/ess/ess-publications/ess-yearbook/ess-yearbook 2010/production/en/.
[12]. Lambe W.T & Whiteman V.R (1979.).Soil Mechanics, SI Version. New York: John Wiley and Sons, Inc.
[13]. Lear L.K.A.(2005). Should you be using more PFA. Proc. Int. Conf. Cement Combination for Durable Concrete. University of Dundee Scotland.
[14]. Mangesh, B.I., Lele S. S. 2012. Extraction and characterization of sugarcane peel wax. International Scholarly Research Network, ISRN Agronomy, doi:10.5402/2012/340158.
[15]. NZS 4298 (1998). Materials and workmanship for earth building, New Zealand.
[16]. Ola S.A. (1978). Stabilization of Nigeria Lateritic Soils with Cement, Bitumen and Lime.Proceedings 6th Reg. Conf. Africa on Soil Mechanics and Foundation Engineering. Durban, South Africa.
[17]. Walker. (2004). Strength and Erosion Characteristics of Earth Blocks and Earth. Journal of Materials in Civil Engineering, doi:10.1061/(ASCE)0899-1561(2004)16:5(497).
[18]. Whitlow, R. (1995). Basic Soil Mechanics. 3rd ed. Edinburgh Gate: Addison Wesley Longman Limited.
[19]. www.fao.org./3/s1250e/S1250E07.htm