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Effect of Wood Ash and Sawdust Ash Admixtures on the Engineering Properties of Burnt Laterite-Clay Brick from Igboora

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ABSTRACT

An attempt to reduce environmental waste and the high cost of conventional stabilizers has led to ongoing studies on the economic utilization of ash from agro-residues to improve the engineering properties of burnt brick. This paper investigated the effect of the addition of sawdust ash and wood ash admixtures to a 70:30 parts by weight of laterite-clay soil. The admixtures were added in various combinations of proportions by weight (from 0 to 10%) and the proportions of laterite-clay soil mixed with SDA and wood ash admixtures were labelled as sample X, A, B, C, D, and E, respectively. The natural soil was subjected to index properties tests for classification according to AASHTO and USCS, while the oxide composition of the ashes was determined by XRF test. The natural soil used was classified according to AASHTO and USCS as A-7-5 and MH-OH, respectively, and there was a general increase in compressive strength of the brick with an increase in admixture and sample D (SDA:7.5% and WA:2.5%) has the highest value of 11.45 MN m-2. Samples D, B and E were categorized as first-class bricks with compressive strength higher than 10.3 MN/m2; therefore, adequate for structural building bricks in Grade NW condition. While samples A and C are also categorized as second-class bricks with compressive strength higher than 7.0 MN/m2. The control sample X is categorized as a third-class brick with compressive strength between 3.5 and 7.0 MN/m2 (ASTM C62 99, 2000). The 24-hour water absorption capacity generally increased from 15.65% for control sample X to the highest value of 24.35% for sample D; this was due to a change in internal structure during firing.

INTRODUCTION

The need to reduce the quantity of waste to keep the environment safe and the high cost of soil stabilizers have led to continuous studies on the economic utilization of ash from waste for improving the engineering properties of soil. In addition to high cost, the production of some industrial-based stabilizers, such as cement, constitutes a greater threat to the ozone layer. Cement, which is the principal hydraulic binder and stabilizer used in many modern-day constructions, is the product of an industry that is not only energy–intensive but also responsible for the large emission of carbon dioxide into the atmosphere (Mehta and Monterio, 2006; Oluremi *et al.,* 2014; 2016). The production of one tonne of Portland cement clinker emits nearly one tonne of CO_2 into the atmosphere (Mehta and Monterio, 2006). Badur and Chaudhary (2008) reported that Portland cement manufacturing accounts for 7 percent of the total global emission of CO_2. Hence, an attempt to manage the increasing waste materials in the surroundings and to find alternative stabilizers has given rise to the use of waste material in modifying the engineering properties of some problematic soils. Lateritic soils are commonly found in the leached soils of the humid tropics and are formed as products of tropical weathering processes. The soils may be problematic and non-problematic types depending on field performance (Eberemu, 2015). The problematic ones are composed of high moisture contents, high liquid limits and low natural densities (Osinubi *et al.,* 2009).

When possible, they are used in many construction projects such as roads, earth dams, embankments and bridges. The properties of non-problematic lateritic soils in the vicinity of the construction project may not meet the required specifications. Such soils need to be stabilized to meet the required geotechnical specification for the desired engineering application. Recently, the focus of several studies (Osinubi *et al*., 2019; Oluremi *et al*., 2012; Eberemu, 2015; Adedokun *et al*., 2016) in the field of engineering has been on the effective utilization of agricultural and industrial residues. Because the most common, cheap and readily available alternative materials to replace the expensive chemical stabilizers in developing countries are ashes developed from agro-based wastes.

Notable among these wastes are Saw Dust Ash (SDA), Coconut Husk Ash (CHA), Millet Husk Ash (MHA), Corn Cob Ash (CCA), Rice Husk Ash (RHA), Bagasse Ash (BA) and Locust Bean Ash (LBA) (Amu and Adetuberu, 2010). These waste ashes are pozzolanic in nature and their utilization in soil stabilization can lead to promotion of waste management at little or no cost, reduction in environmental pollution, low stabilization cost and improved geotechnical properties of soil. This would thereby minimize the consumption of industrial-based stabilizers like cement, which will eventually lead to conservation of limestone deposits and reduction of CO_2 emissions to the atmosphere. This study therefore researched the impacts and effectiveness of these agricultural and industrial waste products on the geotechnical properties of lateritic soils.

MATERIALS AND METHODS

Preparation of Sample Mixes

The research was conducted at Igboora in Ibarapa Central Local Government Area of Oyo State in southwestern Nigeria. The location of Igboora lies between coordinate of lat. 7.4368^0 N and long. 3.2885^0 E, respectively. It has been shown by Okunade (2007) that the conditions enhancing the formation of laterites and lateritic soil are prevalent in the region and in fact, there is a preponderance of such soils there, making them readily available and a useful source of building material.

The laterite soil samples were collected from three different locations within the study area at depth of about 1.0 m below the ground surface of plate 1 and were labelled as Samples L1, L2 and L3 respectively, the soil samples were spread out in the laboratory for a few days for air-drying, after which the clods were broken down and the samples well pulverized, the particle size distribution of samples L1, L2 and L3 as presented in Table 1. The clay soils were also collected at two different locations, both at a depth of 1.5 m below ground level and labelled as samples C1 and C2. Sample C1 was collected at Igboole, while Sample C2 was collected around Idofin along Ideere Road, both at Igboora, Oyo State and the particle size distribution of samples C1 and C2 is presented in Table 2.

Plate 1: Sawdust sun drying

Table 1: Grain-size distribution and physical properties of lateritic soil samples

Physical properties		Sample L1 dark brown Well graded Sand	Sample L2 light brown clayey sand	Sample L3 light brown well graded sand
Grain size distribution (Percentage passing sieve sizes)	9.50mm	100	100	99.4
	4.750mm	98.9	99.9	96.1
	2.360mm	96.7	97.1	91.1
	1.180mm	88.7	89.4	82.3
	0.850mm	84.4	84.8	78.3
	0.425mm	74.5	74.6	70.8
	0.300mm	60.3	60.6	60.6
	0.075mm	27.4	26.6	27.0
Specific gravity		2.62	2.64	2.58
Liquid limit (%)		35.8	36.0	36.0
Plastic limit (%)		16.2	17.5	16.0
Plasticity index (%)		19.6	18.5	0.0
Optimum moisture Content (BS proctor) (%)		16.5	16.0	15.0
Maximum dry density (standard proctor) (kg m^{-3})		1.7	1.6	1.7
AASHTO classification.		A-2-6	A-2-6	A-2-6
Group index		1	1	2
Universal soil classification		SC	SC	SC

Table 2: Grain-size distribution and physical properties of clay soil samples

Physical properties Description		Sample C1 highly plastic, Yellowish clay	Sample C1 highly plastic Brownish clay
Grain size Distribution (Percentage passing sieve sizes)	9.50mm	92.2	93.5
	4.750mm	88.62	90.2
	2.360mm	77.73	80.5
	1.180mm	66.23	72.60
	0.850mm	63.05	70.50
	0.425mm	59.60	60.35
	0.300mm	56.60	58.0
	0.150mm	50.82	52.35
	0.075mm	44.87	46.50
Specific gravity		2.55	2.50
Liquid limit (%)		52.0	53.0
Plastic limit (%)		33.0	33.5
Plasticity index (%)		19.0	19.5
Optimum moisture Content (BS proctor) (%)		18.4	19.0
Maximum dry density (standard proctor) (kg m^{-3})		1.68	1.7
AASHTO classification.		A-7-5	A-7-5
Group index		0	0
Universal soil classification		MH-OH	MH-OH

The laterite-clay soil (sample x) used for the research was derived by employing methods outlined in O'Flaherty (1974) for blending two or more different aggregates to get desired final gradations that fall within given grain-size specifications, 70% by weight of lateritic soil from Sample Llin Table 1were thoroughly mixed with 30% by weight of clay soil from Sample Cl in Table 2 to obtain the laterite-clay blend with the gradation shown as sample x in Table 3.

Table 3: Final grain-size distribution (percentage passing BS sieve sizes) of combined lateritic and clay soil samples

BS sieve sizes (mm)	Laterite, sample L1 = 70%	clay sample C1 = 30%	laterite-clay sample X
9.5	100 x 0.7=70	92.2x0.3=27.66	97.66
4.75	98.9x0.7=69.23	88.62x0.3=26.59	95.82
2.36	96.7x0.7=67.69	77.73x0.3=23.33	91.02
1.18	88.9x0.7=62.23	66.23x0.3=19.87	82.10
0.850	84.4x0.7=59.08	63.05x0.3=18.92	77.97
0.425	74.5x0.7=52.15	59.60x0.3=17.88	70.03
0.300	60.3x0.7=42.21	56.60x0.3=16.98	59.19
0.075	27.4x0.7=19.18	44.87x0.3=13.46	32.64

The sawdust was sourced at the central sawmill in Igboole, Igboora, and transported to the foundry section of the research laboratory at Oyo State College of Agriculture and Technology, Igboora, for further processing. The sawdust was sun-dried for 24 hours, as shown in Plate 1, to reduce the moisture content for easy combustion to Sawdust ash (SDA) in a metal container/iron drum incinerator in Plate 2 at a temperature of 600˚C for 18 hours and sieved through sieve No 200 (0.075mm) to remove impurities and achieve a fineness material similar to cement in accordance with ASTM. The sawdust ash was added because of its pozzolanic properties to improve bonding between particles. Malik *et al* (2015) found the major chemical composition of SDA to be SiO_2, Al_2O_3, and Fe2O3, which indicated the properties of a pozzolanic material.

Plate 2: Drum incinerator with infrared thermometer

The wood ash used in this study was obtained from a bakery in the Idofin area of Igboora. It was collected in a polythene bag and transported to the research laboratory for further processing. It was sundried and sieved through sieve No 200 (0.075mm) to remove impurities and achieve a material similar to cement in accordance with ASTM. Naik *et al.* (2003) also found the major elements in wood ash to be carbon, calcium, potassium, magnesium, phosphorus and sodium, all in various proportions. In its chemical composition, they foundSiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, K_2O, SO_3, organic matter, moisture and available alkali, all with significant variations. Abdullahi (2006) found the specific gravity of wood ash obtained from a bakery in Minna, Niger State, Nigeria to be 2.13 and the bulk density 760 kg/m^3 and his analysis showed the chemical constituents as SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, TiO_2, K_2O, SO_3 and organic matter (loss on ignition LOI = 27%).

The wood ash, being usually rich in calcium carbonate, which is a good binding agent and its other chemical components, acts as a pozzolana with good stabilizing properties. Naik (2000) performed some Investigations into the properties of wood ash from different sources and established their potential for being used in cement-based construction materials. Naik *et al.* (2003), in an Investigation into the use of wood ash in cement-based materials, found that wood ash could be utilized in making self-compacting Controlled Low-Strength Materials (CLSM), air-entrained and non-air-entrained concretes and bricks/blocks/paving stones.

Different sample mixes were obtained by mixing the 70:30 (O'Flaherty 1974) parts by weight laterite-clay blend with varying proportions (by weight) of SDA and wood ash admixtures, as shown in Table 4. Sample x, the control mix, was pure laterite-clay, with 0% additions of SDA and wood ash.

Table 4: Proportions of laterite clay mix with SDA and wood ash admixtures

Sample	Laterite clay mix (%)	Saw dust ash mix (%)	Wood ash mix (%)	Total
X	100	0	0	100
A	90	0	10	100
B	90	2.5	7.5	100
C	90	.5.0	5.0	100
D	90	7.5	2.5	100
E	90	10	0	100

Preparation and Testing of Brick Specimens

The dimensions of the brick size commonly employed in the local building industry, in the standard order specified by the BIA (1993) for listing brick dimensions in specifications (of width first, followed by height, then length), are 225x150x300 mm. This, incidentally, is equal in length and approximate in height to one of the modular brick sizes given by them (BIA, 1993). ASTM C 67: Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile (ASTM) also requires that the brick specimen for the compressive strength test be full height and width and approximately one-half of a brick in length, plus or minus 25 mm (i.e., an approximate half-brick). Thus, the moulds used were of dimensions 225x150x100 mm. The laterite-clay blend was thereafter mixed thoroughly with an adequate amount of water with reference to the optimum moisture content, to cast five bricks for each mixing ratio. To form a uniform consistency and a workable state. The moulding was done using the sand-moulding method to ensure easy release of the brick from the mould without the deformation of the brick as obtained with the slop moulding method. The plastic soil was pressed into individual moulds and given light compaction through repeated ramming with prismatic wooden blocks.

After moulding, the bricks were first air-dried in the laboratory for a total of 48 h, with the bricks turned on edge after 24 h. Afterwards, they were placed outside in the open for sun-drying for a further period of 14 days. This is to permit development in the bricks of some strength before the firing is done and to avoid the development of cracks that might result from a fast and high rate of dehydration. It is desirable that the drying should be relatively slow. The rate at which moisture evaporates from the surface should not be faster than the rate at which it can diffuse through the fine pores of the green brick. During the period of sun-drying, the bricks were given protective mulch covering (with leaves and grass placed on them) to avoid rapid drying out. And though the study was carried out during the dry season period when rainfall was nil, adequate care was taken to protect the samples from precipitation from dew or occasional rainfall by covering them up with waterproof material during the nights, as shown in Plate 3.

Plate 3: Bricks during sun drying and curing

The bricks were fired in a furnace where the heat application was gradual to avoid the formation of cracks. The temperature was measured by means of a pyrometer, whose operation is based on the principle of the thermocouple (CaO *et al*, 1992). The desired temperature for the project was a minimum of 900^0 C.

This temperature was attained after about 8 h of firing and then maintained for a further 24 h. The bricks were allowed to cool at room temperature for another 24 h before being taken to the laboratory for engineering properties tests. The brick samples were thereafter tested. Tests required, according to BIA (1988), are the compressive strength and the 24 h cold water absorption as shown in Plates 4 and 5. Also tested are the dry density, durability and abrasion resistance of the finished brick product. The testing, as far as was relevantly applicable in the circumstances, was done in accordance with ASTM C 67: Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile (ASTM 2001). The compressive strength test was conducted with each sample being loaded along its shortest axis. This is because the bricks are usually placed in walls in the stretcher position.

Plate 4: Bricks being crushed with compressive strength machine

Plate 5: Bricks soaked in water

RESULTS AND DISCUSSION

From the five bricks cast for each mix ratio, the average of five results for each engineering property for bricks made from the different sample mixes is shown in Table 5. The effects of the different proportions of the admixtures on each of the engineering properties of the bricks produced from the different mixes are discussed.

Density: The density of a material normally influences other properties such as compressive strength, durability, thermal conductivity, porosity, etc. and depends on the mineral composition. Average density of the burnt bricks made from the control mix was 1.67 gcm^{-3}. Shestoperov (1983) specifies the density of special masonry as ranging between 1.2 and 2.4 gcm^{-3}. The value of the densities showed a decline with the addition of the admixture, with the highest content of (sawdust 2.5% and wood ash 7.5%) producing the lowest dry density of 1.45 gcm^{-3}.

Table 5: Engineering properties of bricks made from blended soil

Properties	Sample X	Sample A	Sample B	Sample C	Sample D	Sample E
Laterite-Clay mix (70:30 weight)	100	90	90	90	90	90
Sawdust ash, weight ($^{\%}$)	0	0	2.5	5.0	7.5	10
Wood ash, weight ($^{\%}$)	0	10	7.5	5.0	2.5	0
Dry density (kg m^{-3})	1.67	1.53	1.45	1.55	1.46	1.56
Dry compressive strength (MN m^{-2})	6.65	8.56	10.65	8.65	11.45	10.98
(psi)	964.5	1237.2	1544.6	1254.6	1660.7	1592.5
Wet compressive strength (MN m^{-2})	3.15	5.17	6.23	5.17	7.37	7.56
24 h cold water absorption (%)	15.65	22.67	24.18	22.32	24.35	22.71
Durability (Softening coefficient ks)	0.47	0.66	0.58	0.59	0.64	0.68
Abrasion index	1.62	1.69	1.57	1.78	1.47	1.42

Compressive strength: The compressive strength is a mechanical property used in brick specifications, which has assumed great importance for two reasons. Firstly, with a higher compressive strength, other properties like flexure, resistance to abrasion, etc., also improve. Secondly, while other properties are relatively difficult to evaluate, the compressive strength is easy to determine (Adeola, 2007). From a quality control point of view, the compressive strength of bricks is the accepted measure of the quality of most brickwork. Generally, compressive strength decreases with increasing porosity, but strength is also influenced by clay composition and firing.

The dry and wet compressive strengths of bricks made from the control mix were 6.65 and 3.15 MN $m^{-2,}$, respectively. There was a marked increase in the compressive strengths of the brick with the

addition of sawdust ash and wood ash. This increase is even sharper for the wet compressive strengths. However, the trend is that compressive strengths increased with the increase in the SDA and WA. This is due to the pozzolanic action of both ashes. The bricks made from mix Sample D (with 7.5% SDA and 2.5% WA) have the highest dry compressive strength of 11.45 MN m^{-2}; this is classified as a first-class brick, with bricks from samples B and E, as their compressive strengths are greater than 10.5 MN m^{-2}. While bricks of sample A and B are classified as second-class bricks with compressive strength ranges between 7-10.5 MN m^{-2} and bricks from sample X are classified as third-class bricks with compressive strength within the range 3.5-7.5 MN m^{-2} (I.S 1077 (2002)).

Water absorption (porosity): Water absorption is the property of a material to be saturated with water. The average 24 h cold water absorption of bricks made from the control mix is 15.65 %. The influence of the SDA and WA showed that there is an increase in the water absorption due to the filling of the void in the soil with the admixtures.

Durability: The durability of a material is its ability to withstand a particular recurrent weathering effect without failure. It is often measured by the softening coefficient, ks, which is the ratio of the wet compressive strength to the dry compressive strength. The durability of a masonry structure under severe weather conditions (wind, rain, heat, etc.) is dependent upon the quality of the unit materials. The values of durability are relatively close to samples E and X, having the highest and lowest values, respectively. Durability is determined by the value of both wet and dry compressive strength. Bricks were classified by compressive strength and water absorption capacity.

Abrasion resistance: The resistance of a masonry unit to abrasion is often measured by the abrasion index. This is obtained by dividing the 24 h cold water absorption by the dry compressive strength (expressed in psi) and then multiplying by 100. The values of Abrasion resistance are relatively close to samples A and E has the highest and lowest values, respectively, as shown in Table 5.

CONCLUSION

From this study on the effect of wood ash and sawdust ash admixture on the engineering properties of Igboora burnt laterite-clay brick, the following conclusions were drawn:

1. The Igboora laterite-clay soil used for this research is classified as A-7-5 and MH-OH, based on AASHTO and USCS classification, respectively.
2. The additions of the two admixtures have a positive impact on the compressive strength of the laterite-clay brick and sample D (7.5% SDA and 2.5% WA) has the highest strength of 11.45 MN m^{-2}.
3. The samples B, D and E are categorized as first-class bricks with compressive strength higher than 10.3 MN/m^2. Based on strength requirements (ASTM C62 99, 2000), therefore adequate for structural building bricks in Grade NW condition.
4. The samples A and C are also categorized as second-class bricks with compressive strength higher than 7.0 MN/m^2. Based on strength requirements (ASTM C62 99, 2000), they are therefore adequate for general construction brickwork in Grade NW condition.
5. The control sample X is categorized as a third-class brick with compressive strength between

3.5 and 7.0 MN/m^2. Based on strength requirements (ASTM C62 99, 2000), therefore adequate for a temporary brick structure in Grade NW condition.

6. The 24-hour water absorption capacity generally increased with the addition of the two admixtures due to changes in internal structure during firing and filling of voids with the admixtures.

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