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Exploratory assessment of strength characteristics of millet husk ash (MHA) blended cement laterized concrete

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ABSTRACT

The exploratory assessment of the strength characteristics of MHA blended cement laterized concrete was investigated with a view to determining its suitability as an alternative building material. It involved casting of 54 laterized concrete cubes and 27 laterized concrete beams with different percentage replacement of sand with laterite and cement with MHA in 0%, 10% and 20% replacement and cured for 7, 21 and 28 days respectively with the views of establishing the ash and laterite that will be used in cement and sand matrix. The results obtained showed that the best strength performance was obtained at 10% MHA and 0% LAT and 10% LAT and 10% MHA with strength of 19.04N/mm^2 and 20.01N/mm^2 which when compared with the control result (normal concrete) which is 32.98N/mm^2 at 28 days for compressive strength. The flexural strength development at 28 days is 5.03 for 0% LAT and 10% MHA, 5.21N/mm^2 for 10% LAT and 0% MHA and 5.10N/mm^2 for 20% LAT and 0% MHA respectively. From the foregoing, MHA laterized concrete holds promise in the quest for alternative building material, and as such can be used in light weight structures such as masonry walls, walk ways.

Keywords: MHA, Laterite, Laterized concrete, Compressive strength, Flexural strength

INTRODUCTION

The provision of building materials that are affordable to the generality of people in urban and rural areas has been recognised as one the impediments to improved housing situations in developing countries. It is also a fact that establishment of state-of-the-art building materials industries based on the model of the developed countries can make minimal contribution in meeting the immediate needs of the developing world. In a related development, some of the conventional materials are imported and their prices are beyond what the average Nigerian can afford. As a result of this, to stem the tide of over dependence on these materials, efforts have been directed by various researchers towards the local sourcing of alternative building materials that are not only affordable but are durable [1-3]. Efforts have also been channelled towards changing the properties of materials such as concrete by wholly or partially adding additives.

Concrete, is one of the most important materials in modern construction today involving Building and Civil Engineering projects, its versatility in terms of its workability i.e. its ability to be moulded into various shapes required makes it unique. Conventional concrete is a composite material containing fine aggregate, coarse aggregate and cement in predefined mix proportion. The combination gives concrete its characteristics density, which is high (2200kg/m^3-2400kg/m^3) and this limits its use in some structural works [4]. One of the ways by which concrete could be improved upon according to Ademiluyi cited by [5-6] is by modifying it constituents by including chemical admixtures in its matrix. As a result of this, research efforts over the years, have been focused on the possibility of knowing the properties of abundantly available local materials; particularly agricultural waste ash and improve on it, in order to meet both service and engineering requirements.

Low cost binders are materials that are not Portland cement but have cementitious properties and in which in certain situations could be produced and made available to people at a cheaper rate. These materials have in common the use of simple processing technology when compared with Portland cement production and in most cases the potential for lower energy consumption [1,7]. One of these binders is called pozzolana.

Pozzolanas as stated by [1] are siliceous materials which on their own have little or no binding characteristics but when mixed with materials such as lime in the presence of water, will set and harden like cement. Neville [8] stated that it is essential that pozzolana be in a finely divided state as it is only then that the silica can combine with calcium hydroxide (produced by the hydration of cement) in the presence of water to form stable calcium silicates which have cementitious properties. Neville [8] further stated that the silicon has to be amorphous i.e. glossy because crystalline silica has very low reactivity. These pozzolanic materials can improve the durability of the concrete as well as the strength thus reducing the rate of liberation of heat which is beneficial for mass concrete.

There are two types of pozzolanas according to [1,9-10]; the naturally occurring pozzolana such as volcanic ash, silica fume, pumicite, tuffs, trass, opaline shale and the artificially occurring pozzolana such as fly ash (FA), rice husk ash (RHA), groundnut husk ash (GHA), baggase ash (BA) and millet husk ash (MHA). The pozzolanas can be put to use in two ways:

- In lime-pozzolana mixtures, substituting for cement in a wide range of building applications that is not limited to block-making and low strength concrete.
- To make blended cement by inter-grinding it with Portland cement clinker in suitable proportions.

There has been a growing interest in the use of agricultural wastes as pozzolanas while in search of environmentally friendly and sustainable materials [9]. There are many benefits of using pozzolana material in cement and concrete as stated by [10]:

- Their ability to convert calcium hydroxide to calcium silicate hydrate, therefore, the capillary voids are either eliminated or reduced in size. This in turn improves cement-concrete material such as strength and durability of the hydrated paste.
- Pozzolanas can also be used as cement replacement material (it is also economical since most pozzolanas are cheaper than cement). This promotes the use of waste products and thus conserves energy and resource.

Laterite refers to as a porous soil ranging from soft earthly material to hard rock which ranges in colour from white to dark red depending on the amount of iron in the soil. It is found below the earth surface and chemically made of silica and alumina, which is formed by the weathering of rocks hence given rise to many variation of laterite in composition and properties. It is common in Nigeria and areas of high temperatures with high rainfall and well defined rainy seasons [3, 11-14]. Lateritic soil has been used especially in the rural areas in Nigeria for many years to construct houses. In order to modify the properties, according to [3], Adepegba work was the first published research effort when normal concrete and concrete that the fine aggregate was partially replaced with laterite were compared. The findings were encouraging and hold better prospects for the modification of concrete in Nigeria. Laterized concrete was defined by Adepegba according to [15] as concrete in which part or all the aggregate has been replaced by soil of lateritic origin.

Millet husk ash (MHA) is a byproduct from the burning of millet husk in a large open drum. Millets are a group of small seeded species of cereal crops or grains widely grown around the world for food and fodder. They are prevalent in semi-arid tropics of Asia and Africa. Millet husk is gotten from the harvest of millet before it is been sold in the market [16].

Over the years, researchers such as [2,3,6-7,9-10,14-16,18-24] carried out extensive work in the modification of normal concrete. Some of them used different types of pozzolanas as a partial replacement of cement to make concrete, while others, in addition to the partial replacement of cement, the fine aggregate was also partially or wholly replaced to form laterized concrete. However, none of the researchers has carried out work on the partial replacement of cement with millet husk ash (MHA) and the fine aggregate with laterite and subsequently determining the compressive and flexural strengths. It is on the basis of this that the exploratory strength characteristics of MHA blended cement laterized concrete is being investigated with a view to determining its suitability.

MATERIALS AND METHODS

The materials used for this research includes; fine aggregate, coarse aggregate, laterite, which serve as the composite materials, MHA which is the pozzolana and cement which serve as the binder. Dangote ordinary Portland cement was source from a local seller Kpakungu, Minna, Niger State. Fine aggregate are those materials that pass through the 4.75 BS sieve size and they include sharp sand and laterite; these were also sourced from Minna. The crushed granite with sizes of 19-20mm was obtained from Takum Fada (nearby village to Minna), while the millet husk was gotten from Dama village along Bida Road, Minna. The husk was dried and burnt in open air to get the ash which act as the pozzolanic material. All the materials were transported to Building Department laboratory, Federal University of Technology, Minna where the following tests were conducted: chemical analysis of millet husk ash (MHA), sieve analysis, moisture content, specific gravity, bulk density, slump, compressive and flexural strengths. A total number of 54 concrete cubes with size (100×100×100) mm and 27 beams with size (500×100×100) mm were cast with varying percentages as shown (0%, 10% and 20%) and cured for 7, 21 and 28 days respectively before crushing to obtain their compressive and flexural strengths. All the tests were carried out in accordance with the following standards: BS EN 197: 2000, BS EN 933: 1997, BS EN 1097: 1997, BS EN 1097: 1997, BS EN 12390 parts 1-3: 2000 and BS 1881-118: 1983. The concrete was designed with target strength of 25N/mm^2 and water-cement ratio of 0.65.

Table 1: Chemical Composition of MHA

Constituent	Percentage by weight
SiO_2	73.1
Al_2O_3	0.025
Fe_2O_3	4.2
CaO	10.5
MgO	0.04
K_2O	7.5
P_2O_5	1.61
MnO	0.44
SO_3	1.4
L.O.I	11.04
P^H	8.1

Source: Lab work at Institute of Agriculture Research and Training, Ibadan.

The result of the chemical properties of millet husk ash (MHA) as shown in Table 1 indicates that the proportion of silicon dioxide (SiO_2), Aluminum oxide (Al_2O_3) and Iron oxide (Fe_2O_3) present in the ash was 77.352% and it satisfies [32] requirement for chemical constitution of a pozzolana which stipulates a minimum combined proportion of 70%. It also satisfies the ASTM requirement for the loss on ignition which puts it at a maximum of 12%.

Table 2: Summary of the Physical Properties of the Aggregates and MHA

Property	Sand	Laterite	Coarse aggregate	MHA
Fineness modulus	3.00	3.37	2.90	
Specific Gravity	2.60	2.60	2.69	2.50
Bulk Density(Ratio)	0.84	0.73	0.85	
Moisture Content	6.90	13.8		

The majority of natural aggregates have an apparent specific gravity of between 2.6 and 2.7 [33]. From the table, the aggregates have a specific gravity ranging from 2.60 to 2.69 which means it satisfies the standard requirement. The Ratio of loose bulk density to compacted bulk density lies usually between 0.87 and 0.96 or 0.61 and 0.87 [34]. From Table 2 above, the aggregates bulk density lies between 0.73 and 0.85 which means it is satisfactory as stated in [34]. The typical values of fineness modulus range from 2.3 and 3.0 [34]. The fineness modulus of sand and granite lies between 2.90 and 3.0 which indicates it is finer in nature while that of laterite is 3.37 which indicates it is a coarser soil.

Table 3: Slump Test of Fresh Concrete

LAT%	MHA%	SLUMP (MM)
0	0	12
	10	23
	20	15
10	0	13
	10	15
	20	14
20	0	16
	10	15
	20	10

Table 3 shows the workability of the concrete and it shows that the higher the percentage replacement, the lower the workability and the workability for this research lies between 0 – 30mm from the mix design and the result gotten all fall within this range.

Table 4: Summary of Compressive Strength Test

LAT (%)	MHA (%)	7 DAYS	21 DAYS	28 DAYS
0	0	21.57	30.43	32.98
	10	14.48	16.63	19.04
	20	13.48	12.48	14.34
10	0	7.66	18.61	20.57
	10	15.51	14.01	20.01
	20	12.61	13.87	15.05
20	0	13.36	16.77	16.80
	10	12.42	16.14	17.84
	20	10.97	11.07	13.53

Table 4 shows the summary of the development of compressive strength of MHA laterized concrete at various percentage replacements. The result shows that the compressive strength decreases as the percentage of MHA and laterite increases. However, the optimum result is obtained between 0% LAT and 10% MHA and 10%LAT and 10% MHA replacement with strength of 19.04N/mm^2 and 20.01N/mm^2 respectively in 28 days hydration period which can be used for structural light weight concreting such as small foundations and concrete walls. The graphical representations of the compressive strengths at various days of hydration are presented below.

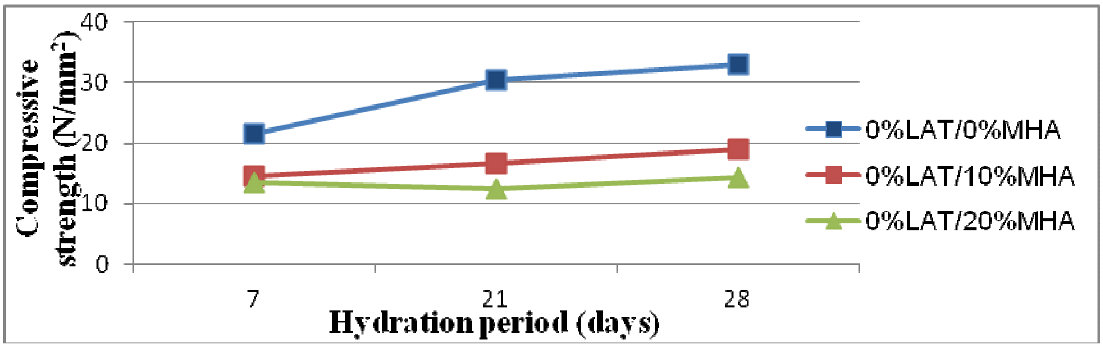

Fig 1: Average compressive strength of 0% LAT and 0%, 10% and 20% MHA

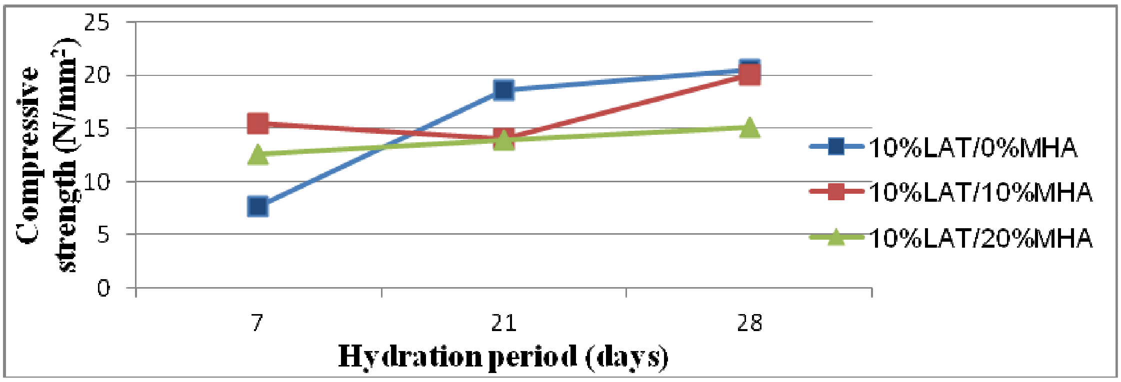

Fig 2: Average compressive strength of 10% LAT and 0%, 10% and 20% MHA

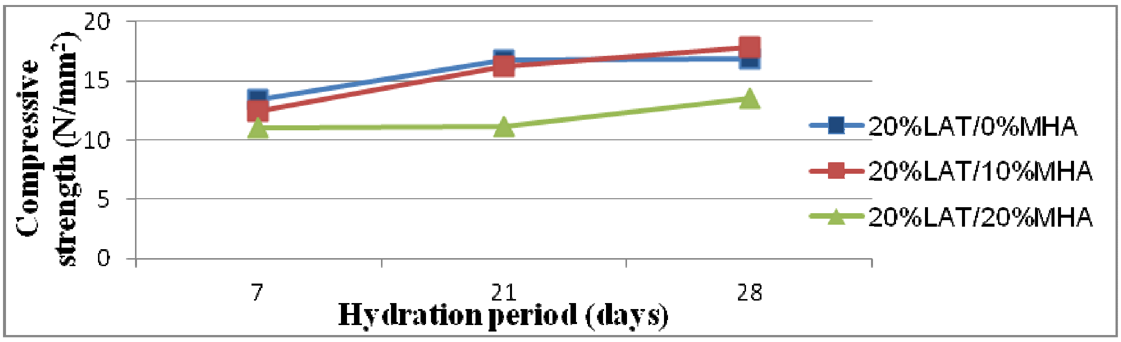

Fig 3: Average compressive strength of 20% LAT and 0%, 10% and 20% MHA

Table 5: Flexural strength test at 28 days hydration period

LAT (%)	MHA (%)	WEIGHT (Kg)	LOAD (KN)	DENSITY (Kg/mm^3)	FLEXURAL STRENGTH	AVERAGE (N/mm^2)
		12.466	14.0	2493.2	4.76	
	0	11.979	13.0	2395.8	4.42	4.87
		13.018	16.0	2603.6	5.44	
		13.102	16.0	2620.4	5.44	
0	10	12.526	14.0	2595.2	4.76	5.04
		12.020	14.5	2404.0	4.93	
		12.199	12.0	2439.8	4.08	
	20	12.879	16.0	2575.8	5.44	5.04
		13.012	16.5	2602.4	5.61	
		12.875	17.0	2575.0	5.78	
	0	12.898	15.0	2579.6	5.10	5.21
		12.699	14.0	2539.8	4.76	
		13.753	13.0	2750.6	4.42	
10	10	12,224	11.0	2444.6	3.74	4.08
		12.221	12.0	2444.2	4.08	
		12.040	13.0	2408.0	4.42	
	20	12.093	14.0	2418.6	4.76	4.78
		12.150	15.0	2430.0	5.10	
		12.785	15.0	2557.0	5.10	
	0	12.728	15.0	2545.6	5.10	5.10
		12.597	15.0	2519.4	5.10	
		11.654	11.0	2330.8	3.74	
20	10	13.143	11.0	2628.6	3.74	3.85
		12.651	12.0	2530.2	4.08	
		12.925	15.0	2585.0	5.10	
	20	12.319	12.0	2463.8	4.08	4.53
		13.041	13.0	2608.2	4.42	

Table 5 shows the development of flexural strength of MHA laterized concrete at various percentage of replacement. The result shows that the flexural strength at 0% LAT, 10% MHA increased compared to the other replacements with strength of 5.03N/mm^2. But when laterite was 10% and 20% with 0% MHA, the strength was increased compared to other replacements with strength of 5.21N/mm^2 and 5.10N/mm^2 respectively in 28days hydration period. The flexural strength is expressed as modulus of rupture and is usually about 10-20% of compressive strength depending on the type, size and volume of aggregate used [35].

CONCLUSION

From the results of the tests carried out, the following conclusions can be drawn:

- With the physical and chemical properties of MHA and aggregates (laterite), they can be used as alternative material along with the conventional materials (cement and sand). MHA blended cement laterized concrete holds promise in the quest for alternative building materials.
- MHA and latreite can be blended in small amount between 0 and 10% replacement by welght or volume of cement and sand in concrete making for light weight structures such as in masonry walls, simple foundations, low cost constructions, pavements and walk ways.
- Optimum value was reached when 10% MHA and 10% laterite were used to replace cement and coarse aggregate respectively.

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