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Guinea Corn Husk Ash As Partial Replacement Of Cement In Hollow Sandcrete Block Production

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Abstract
The quality of sandcrete blocks is a function of the method employed in the production and the properties of the constituent materials. The production of sandcrete blocks using guinea corn husk ash (GCHA) as cement replacement was investigated. 3 number sandcrete blocks were cast for each replacement levels (0, 5, 10, 15 and 20 percentage) with GCHA. The blocks were cured and crushed at 7, 14 and 28 days. The results show that the compressive strength ranges from 2.30N/mm^2 to 1.3N/mm^2. The strength at the optimum level was within the recommended limit of the National Building Code. The results also showed that the strength decreased with an increase in the content of GCHA. The density also decreased with an increase in GCHA which indicates that GCHA is a light material. It was also observed that the chemical composition of the GCHA qualifies the grading for pozzolana by BS but falls short of ASTM standards. A 5% replacement was recommended as the maximum replacement percentage, although 10% exhibited good strength. The research was aimed at the use of Guinea corn husk as partial replacement of cement in sandcrete block production to curtail pollution problems created by the husk and improve the strength properties of blocks in terms of production.

Keywords: Compressive strength, Density, GCHA, Sandcrete blocks.

INTRODUCTION

Over a long period of time in housing development, sandcrete blocks have been used in many developed and developing countries including Nigeria. According Ewa and Ukpata (2013),sandcrete blocks are the most widely used walling unit in Nigeria, accounting for 90% of houses. The quality of sandcrete blocks is a function of the method employed in the production and the properties of the constituent materials (Raheem and Sulaiman, 2013). The production of sandcrete blocks involves the use of sand, cement and water. It could be asserted that both the limited raw materials and the industrial processes undergone by cement during the manufacturing stages may have accounted for its high cost. This has necessitated producers of sandcrete blocks to produce blocks with low Ordinary Portland Cement content that will be affordable to people and with much gain (Adebakin, Adeyemi, Adu, Ajayi, Lawal and Ogunrinola, 2012).

The compressive strength of sandcrete blocks is affected by the mix proportion, quality of material used in making them, size, shape, and the mode of manufacture (i.e. hand or machine mould) (Yusuf and Hamza, 2011). Hollow sandcrete blocks (load and non-laod bearing) are produced commercially across the country. According Yusuf and Hamza (2011), walls built with poor quality blocks that falls short of the standard strength are likely to fail, thereby causing severe damage to the structure and sometimes even loss of lives and properties. Many studies have been carried out to identify highly available, low cost innovative material to use in construction industry as a solution to meet the ever increasing demand for raw materials (Prabagar, Kalya and Fonseka, 2015). Some quantities of wastes generated from agricultural sources are, rice husk, coconut husk, groundnut shell and acha husk. Reuse of such wastes as a sustainable construction material appears to be viable solution not only to pollution problem but also to the problem of the land-filling and high cost of building materials (Mangesh, Rahul and Sachin, 2012).

Guinea corn is a cereal crop commonly known as grain sorghum which belongs to the general class of sorghum; (Chukwu, Orhevba and Abubakar, 2011). It is the leading cereal grain produced in Africa. Guinea corn is mostly grown in the northern part of Nigeria in states like Bauchi, Plateau, Kaduna, and other northern states. When harvested, it is normally processed manually by threshing with sticks or mechanically by the use of combined harvesters leaving a large quantity of residue (husk) constituting waste annually. The advantages to be derived from the use of agro waste in the partial replacement of cement are low capital cost per tonne production compared to cement, promotion of waste management at little cost, reduced pollution by these wastes and increased economy base of famers when such waste are sold, thereby encouraging more production, conservation of limestone deposits and a reduction in CO_2 emission (Mahmoud et al., 2012). Guinea Corn husk ash is a residue of guinea corn husk after complete combustion and the analysis of the Guinea Corn Husk Ash (GCHA) showed that a combination of its chemical constituents qualified it as a pozzolana (Ndububa et al, 2015).The Guinea corn husk constitutes problems in terms of disposal annually though the burnt ash has the potential to be used in block production, it has not yet received necessary consideration in terms of research. This is also a problem the researcher will try to solve. The research is aimed at the investigation of the use of Guinea corn husk as a partial replacement to cement in the productionsandcrete blocks. This may bring about a reduction in cost, environmental pollution and an improvement in the desired properties of blocks.

LITERATURE REVIEW

Seeley (1993) also defines sandcrete blocks as walling material that is made of coarse natural sand or crushed rock dust mixed with cement in certain proportion and water, and moderately compacted into shapes. Concrete (Sandcrete) blocks were first produced in the early part of the last century by placing fresh concrete into moulds made of steel or wood. The moulds were stripped when the concrete had hardened. For the blocks to achieve its constructional purpose, it has to be made into a shape so as to support its imposed loads (live and dead loads). The early history of its manufacture is not known but by 1960 it had established an important place in building industry in Nigeria. In many parts of Nigeria, sandcrete block is the major cost component of the most common buildings (Oyekan&Kamiyo, 2008). It accounts for 90% of houses. Sandcrete blocks could be hollow or solid, British Standard (B.S) 2028 (1968) gives specification for precast concrete blocks which describes solid, hollow and cellular blocks with hollow blocks having a void percent of total volume of more than 25% but less than 50%. Sandcrete blocks are manufactured using a mix ratio of cement to sand of 1:4, 1:6, 1:8, 1:12 as used in previous research works with the common sizes obtainable in Nigeria commercially being 450x225x225 (9 inches block) and 450x225x150 (6 inches block). Tsado, Auta, James & Ahmed(2014) and Ewa&Ukpata (2013) reported that blocks produced by block industries do not meet up to NIS specified standards, strength required of 3.45N/mm^2 and 2.5N/mm^2 for load bearing and non-load bearing blocks respectively as specified by NIS 78:2007. The National Building Code section 10.3.14.4 also specifies a minimum of 2.00N/mm^2 for an average of 6 blocks and 1.75N/mm^2 as the lowest strength of an individual block.

They can be classified into these categories; classification by void percentage, by weight and aggregate used and also by its application or usage. Concrete (Sandcrete) blocks are manufactured to various workface dimensions in an extensive range of thicknesses, offering a wide choice of load-bearing capacity and level of insulation (Arthur, 2007). The properties of sandcrete blocks are; strength, thermal insulation, acoustic property, fire resistance, water absorption and durability. American society for testing and materials (ASTM) C618 (2001) defines pozzolana as a siliceous aluminum material which in itself possesses little or no cementitious value, but will when in firmly divided form and in the presence of water, chemically react with lime or calcium hydroxide at ordinary temperature to form compounds possessing cementing properties. Pozzolanas are grouped into two main classes;

i. **Natural Pozzolana**; some diatomaceous earths, opalinecherts and shales, tuffs and volcanic ashes or pumicites. Most natural pozzolansare volcanic in origin.
ii. **Artificial Pozzolana**; fly ash, blast furnace slag, siliceous and opalineshales, spent oil shale (used in Sweden to make "gas concrete"), rice husk ash, burnt banana leaves, burnt sugar cane stalks and bauxite waste.

METHODOLOGY

The materials for this study included Sand, Cement, Guinea Corn Husk Ash (GCHA) and water. Guinea Corn husk was obtained from Gindiri, Mangu Local Government Area of Plateau State, Nigeria. It was burnt at a kiln at a temperature of 700^{o}Cat the National Metallurgical Development Centre Jos, Plateau State. The chemical analysis was also carried out at same location. The specific gravity and sieve analysis were carried out in on the sand in accordance to BS 812: 1995 to ensure that it conforms to sand used for block making. Two mix ratio were adopted 1:6 and 1:8 (cement to sand) at 0%,5%,10%,15% and 20% replacement levels of cement with guinea corn husk ash (GCHA). The quantities of the materials were batched by weight. The mixing and tamping was done manually and about 50 blocks were cast altogether. The sand was obtained from a local supplier along Bauchi road in Jos town. The OPC was procured from local cement supplier in Jos Plateau State Nigeria. The study was limited to the use of GCHA (as obtained from local sources) as partial replacement of cement for the production of a 2 cell hollow sandcrete block (450x225x225mm). The study covers the determination of properties of GCHA, curing of the blocks for 7, 14 and 28 days and test for compressive strength.

Compressive Strength Test

The compressive strength test was conducted in accordance with relevant and International accepted standards. The mix ratio of 1:6 and 1:8 was adopted. The ratio was that of OPC (with levels of GCHA), fine aggregate and coarse aggregate. The hollow sandcrete blocks were moulded with replacement levels of 0%, 5%, 10%, 15% and 20% and cured for 7 days, 14 days and 28 days respectively. For each mix, 3 blocks were crushed to obtain the average strength.

The crushing strength will be obtained by dividing the crushing load by the solid area of the block (net area)

RESULTS AND DISCUSSION

Specific Gravity / Bulk Density

The specific gravity of GCHA was found to be 2.23 as shown in table 12. The value is close to 2.17 obtained by Oyekan and Kamiyo (2011) for Rice husk ash but its higher than the 1.76 obtained by Ndububa and Nurudeen (2015) for the same Guinea corn husk ash. These values indicate that the specific gravity of GCHA may be location and harvest-time dependent. The uncompacted bulk density of GCHA is 1212kg/m^3. The specific gravity and bulk density of GCHA were compared against that of OPC as shown in table 1 and it indicates that both values of OPC are higher than that of GCHA.

Table 1. Comparison BetweenPhyiscal Properties of OPC and GCHA

Item	Ordinary Portland Cement (OPC)	Guinea Corn Husk Ash (GCHA)
Bulk Density	*1320kg/m^3	1212kg/m^3
Specific Gravity	**3.15	2.23

Source: *Shaswata, Saroj and Adhikari (2012)
**MohdMajiduddin, Muzzaffar, Omer and Hashmath (2015)

Chemical Analysis

The result of the chemical analysis of GCHA is shown in table. The primary chemical requirement of a good pozzolan is SiO_2 + Al_2O_3 +Fe $_2O_3$ = 70% of the chemical composition where SiO_2 must be at least 25%. The total percentage composition of Iron oxide (Fe_2O_3= 7.30%), Aluminum oxide (Al_2O_3 = 0.03%) and Silicon dioxide (SiO_2 =52.10%) with a summation of 59.43% which is less than 70% as minimum required for pozzolanas according to ASTM C618 (2001). This reduces the pozzolanicity of the GCHA. The percentage composition of magnesium oxide (MgO=0.1%) and sodium oxide (Na_2O) was not detected were within the range specified by ASTM C618 requirement which have maximum range of 5% for Magnesium oxide and 1.5% for Sodium oxide. According to BS EN 197-1:2000 the reactive silicon dioxide content shall be not less than 25.0 % by mass, GCHA meets that requirements as a pozzolana as it has 51% by mass of SiO_2. The percentage composition of calcium oxide was 7.04% and this contributes in strength attainmentas shown in table 1.Phosphorus pentoxide (P_2O_5) has a percentage of 4.21% from table 15, which decreases early strength of cement with an increase in its percentage and if above 0.6% the setting time of cement will be delayed (Tae-Hyoung, Won-Seok, Chang-Bum, Byeong-Yong and Jong-Ryul 2007) as indicated in table 2.

Table 2: Chemical Composition of Guinea Corn Husk Ash

Elemental oxide	Percentage (%) of GCHA
SiO_2	52.1
Al_2O_3	0.03
Fe_2O_3	7.30
CaO	7.04
MgO	0.10
P_2O_5	4.21
K_2O	23.8
SO_3	0.50
PbO	0.26
Others	4.66

Density of Sandcrete blocks

The results for the density indicate that the densities of sandcrete block decreases with an increase in the amount of GCHA. This indicate that GCHA is a light material because an increase in its quantity decreases the density of sandcrete blocks. Although at 5% replacement at 28days curing the density was higher than that of plain (0%) sandcrete block. The rate of change or variations in the density of the hollow sandcrete block at the different curing ages can be seen in table 3

Table 3: Density of Sandcrete Block Type A

% Replacement	Average Weight of Blocks (kg)			Density of Blocks (kg/m^3) @7days	Density of Blocks (kg/m^3) @ 14 days	Density of Blocks (kg/m^3) @ 28 days
	7 days curing	14 days curing	28 days curing			
Mix Ratio 1:6						
0	27.7	27.4	27.8	1964.5	1943.3	1971.6
5	27.5	27.1	28.0	1950.4	1922	1985.9
10	27.01	26.6	27.7	1915.6	1886.5	1964.5
15	26.7	26.3	27.3	1893.6	1865.3	1936.2
20	26.3	26.0	27.2	1865.3	1844	1929.1
Mix Ratio 1:8						
0	28.2	28.1	28.1	2000	1993	1993
5	27.3	27.5	28.2	1936.2	1950.4	2000
10	26.9	27.1	27.8	1907.8	1922	1971.6
15	26.2	26.9	27.4	1858.2	1907.8	1943.3
20	26.0	26.4	27.1	1844	1872.3	1922

Compressive strength of the GCHA-cement Sandcrete Blocks

The results of the compressive strength test are shown on the tables below. The test results show that the compressive strength decreases with increase in the GCHA content, however the 5% GCHA replacement concrete presented an exception. The strength value increased over that of plain sandcrete before decreasing at higher replacement levels. This behaviour was significant for all mix ratios. Although 10% replacement for block also indicated significant compressive strength of 1.73N/mm^2.These strength however is higher than commercially produced blocks as reported by Ewa and Ukpata (2013) and Tsado et al, (2014) in some regions nationwide which ranges from 0.23N/mm^2 to 0.58N/mm^2**.** The rate of change or variations in the compressive strength of the hollow sandcrete blocks at the different curing ages can be seen in the figures 1 and 2, and table 2.

Relationship between Density and Compressive Strength

The compressive strength of both block type A and B decreased with a decrease in the density of the blocks as the percentage of GCHA increases as seen in table 24 below. The behaviour was observed for both mix ratios. The compressive strength decreased from 2.30 to 1.3N/mm^2 and the density decreased from 2000 to 1922kg/m^3. It can be concluded that a linear relationship exist between the compressive strength and the density of hollow sandcrete blocks, the compressive decreases as the density of the sandcrete blocks also decreases. The result indicated a percentage drop of about 43% in the compressive strength of hollow sandcrete blocks, from 0% replacement to 20% replacement level

Table 4 : Compressive Strength of Sandcrete Block

Percentage Replacement (%)	**Average Failure Load (KN)**			**Average Compressive Strength (N/mm^2)**		
	7 days Curing Period	**14 days Curing Period**	**28 days Curing Period**	**At 7 days**	**At 14 days**	**At 28 days**
Mix Ratio 1:6						
0	84	80	125	1.46	1.58	2.16
5	103.3	85	133.3	1.78	1.47	2.30
10	83	78.5	100.0	1.44	1.36	1.73
15	78.6	74	91.7	1.36	1.28	1.59
20	70.5	67	78.3	1.22	1.16	1.35
Mix Ratio 1:8						
0	65	70	88.3	1.12	1.21	1.53
5	71	68.3	95	1.22	1.18	1.64
10	65.7	61.7	87.3	1.13	1.05	1.51
15	64	60	82	1.10	1.01	1.42
20	56	53	75	0.97	0.92	1.30

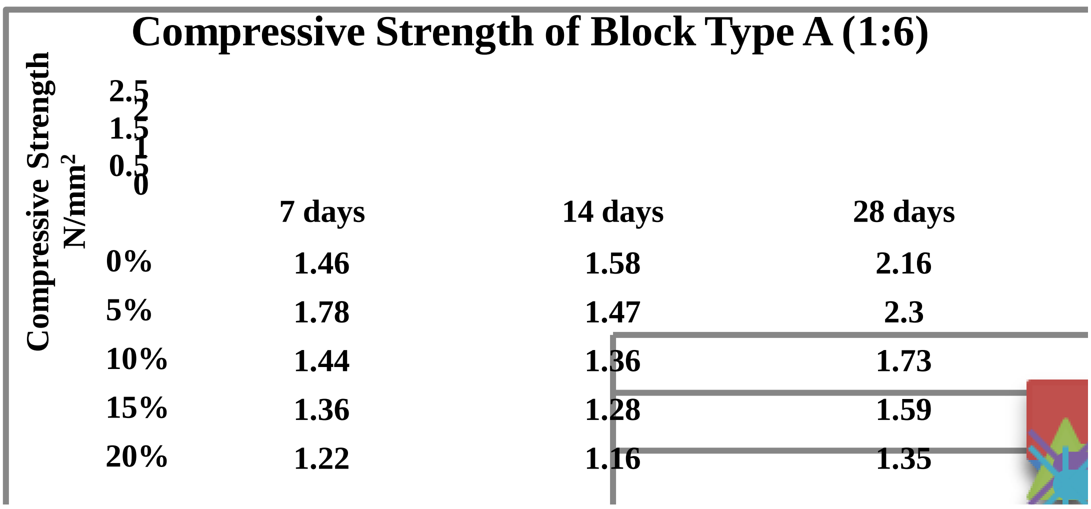
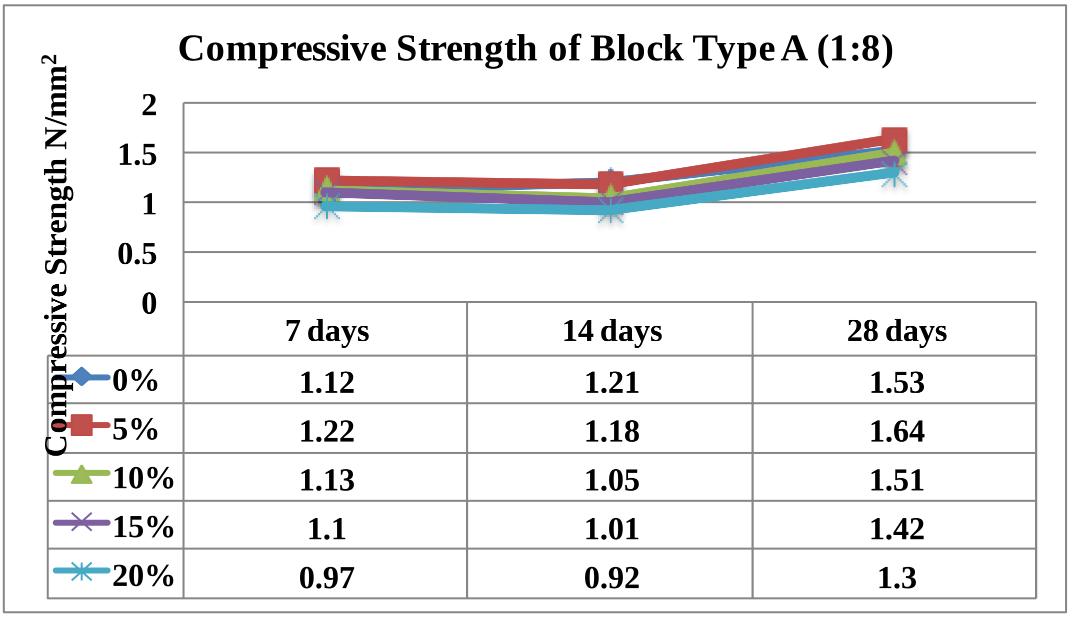


Figure 1 : Compressive Strength of Sandcrete Block (1:6)



	7 days	14 days	28 days
0%	1.12	1.21	1.53
5%	1.22	1.18	1.64
10%	1.13	1.05	1.51
15%	1.1	1.01	1.42
20%	0.97	0.92	1.3

Figure 2: Compressive Strength of Sandcrete Block (1:8)

CONCLUSION AND RECOMMENDATION

GCHA qualifies the grading for pozzolana by BS EN 197-1:2000 but falls short of ASTM standards. The guinea corn husk ash canbe used as a partial replacement of cement in sandcrete block to achieve a satisfactory compressive strength at about 10% percentage of the binder quantity but 5% replacement gives more desirable strength over 0% replacement. Optimum replacement however should be at 5% replacement for ultimate strength. The compressive strength of sandcrete block for a both mix ratio decreased as its GCHA content increases, although mix ratio of 1:6 had higher compressive strength than 1:8.Other measures should however be explored towards the improvement of the quality of GCHA to achieve adequate strength at higher replacement levels. Mechanical method of production can increase the strength of the blocks. Requisite test must be carried out on materials before use in the production of sandcrete blocks. There is need for sensitization in the production of commercial sandcrete block to manufacturers on the effect of the manufacture of substandard blocks and how GCHA can be used as a partial replacement of cement to achieve required profit within standards.

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