

Strength and Absorption of Sorghum Husk Ash Sandcrete Blocks

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ARTICLE INFO

Received: October, 2019

Accepted: December, 2019

Published: January, 2020

Keywords:

Density

Compressive strength

Fine aggregate

Sorghum husk ash

Sandcrete block

ABSTRACT

Sorghum husk is one of the main agricultural wastes in milling processes that is available in large quantity in Nigeria. The available methods of handling sorghum husk have serious health and environmental implications. Hence, there is need for proper disposal of this agricultural waste. The chemical compositions of Sorghum Husk Ash (SHA) were determined using X-ray fluorescence analyzer. Production of sandcrete blocks by incorporating SHA as partial replacement for cement was investigated. SHA replacement levels of 1, 2, 3, 4 and 5% were used. A total of 54 hollow block specimens of dimension 450 × 225 × 225 mm were cast to undergo density, water absorption and compressive strength tests at 7, 14, and 28 days of curing respectively. Results revealed that percentage sum of silica, alumina and ferric oxide contents was 77.3% which exceeds 70% specified limit by ASTM C 618 for pozzolanic material categorization. The results also indicate that increase in SHA replacement (0 - 5%) led to decrease in density (2273.8 - 2185.4 kg/m³) and increase in water absorption (6.1 – 9.2%). The 28 day compressive strength increased by 1.5, 7.3, 20.8, 5.2 and 6.7% for 1, 2, 3, 4 and 5% SHA replacement respectively. It is concluded that SHA is a good pozzolan and can be used to improve the compressive strength of sandcrete blocks at satisfactory density and water absorption.

1. INTRODUCTION

Sorghum husk is one of the main agricultural wastes in milling processes that is available in large quantity in Nigeria. Husks of the large quantity of sorghum produced in Nigeria is about 6.55 million metric tons per year according to USDA (2017) and are mostly disposed-off by open air burning.

Sandcrete blocks are products of fine aggregate, cement and water in a prescribed mix ratio proportions (Ajagbe *et al.*, 2013). However, mineral admixtures are sometimes incorporated to produce special properties sandcrete blocks (Raheem and Sulaiman, 2013). The power of sandcrete blocks is governed by two major factors, namely; material compositions and method of curing (Aiyewalehimi and Tanimola, 2013). Nevertheless, blocks quality varies from one industry to another owing to the diverse methods

employed in the manufacture and the properties of the component materials (Raheem *et al.*, 2012; Ajagbe *et al.*, 2013).

Pozzolanic cements are produced by mixing pozzolan material with Portland cement in order to obtain special cement with fewer heat of hydration development, good resistance to chemical attack and low cost of production (Tijani *et al.*, 2018; Dashan and Kamang, 1999). Readily available material being used in Nigeria to partially replace cement without economic implications are agricultural wastes such as sorghum husk, rice husk ash, guinea corn husk ash, palm oil fuel ash, groundnut shell ash and sawdust ash (Tijani *et al.*, 2018).

Several authors have worked on partial replacement of cement with agricultural wastes in sandcrete blocks production. Mahmoud *et al.*, (2012) investigated the effect of replacing cement with groundnut shell ash in sandcrete blocks production. Cement was replaced by 10, 20, 30, 40, and 50% groundnut shell ash in sandcrete blocks production. Compressive strength was found to decrease with increase in percentage replacement of groundnut shell ash above 20% replacement. Effect of rice husk ash as partial replacement for cement in sandcrete blocks was investigated by Oyekan and Kamiyo (2011). Results showed that the addition of rice husk ash produces blocks of lower density. The compressive strength of the block was not enhanced while the thermal properties of the blocks were significantly affected. Raheem and Sulaiman (2013) investigated the use of sawdust ash (5, 10, 15, 20 and 25%) as partial replacement for cement in sandcrete blocks. It was observed that sandcrete blocks with up to 10% sawdust ash replacement can be used for non-load bearing walls.

This study presented the properties of sandcrete blocks produced by partial replacement of cement with SHA at 0, 1, 2, 3, 4, and 5% in order to improve the strength of sandcrete blocks and reduce the environmental effect associated with the disposal of sorghum husk.

2. MATERIALS AND METHODS

Cement and sharp sand used for this study were obtained from an ongoing construction site within the campus of Osun State University, Osogbo and were subjected to specific gravity test in accordance with BS EN 1097-6 (2013). Sieve analysis was carried out on sharp sand to determine its particle size distribution. Portable water from the Department of Civil Engineering Laboratory, Osun State University, Osogbo was used both for the production and curing of the sandcrete blocks.

Sorghum husk was obtained from Kuje Market, Kano State. The husk was burnt to ashes at a temperature of 700°C using in muffle furnace at the Civil Engineering Laboratory, Osun State University, Osogbo. The ash was allowed to cool before grinding to a very fine texture and then allowed to pass through 212 microns sieve. The chemical analysis of SHA was conducted at Federal University of Technology, Akure using X-ray fluorescence spectrometer (Model: X'Pert Powder X-ray Diffractometer) as specified in BS EN 196-2, (1995).

The mix proportion of 1:6 cement-sand ratio was adopted at 1, 2, 3, 4 and 5% replacement level of cement (by weight) with SHA to produce blocks of sizes 225 x 225 x 450 mm. The mixing and tamping were done by hand and 54 blocks were moulded altogether. The blocks were kept wet in an open space by watering daily for 28 days. The density, water absorption and compressive strength were determine at 7, 14 and 28 days.

Density test was carried out before crushing of the sandcrete blocks. At the end of each curing period, the sandcrete blocks were weighed using an electric weighing balance. Density was calculated as mass of sandcrete blocks (kg) divided by net volume (m^3). Water absorption was performed by removing blocks from curing area and sun dried until no further loss in dry weights. Samples were then immersed in water for 24 hours and allow to drain for 10 minutes before taking the wet weight. The difference in weight was recorded as percentage water absorption. Compressive strength test was determined using universal testing machine by recording the crushing/failure loads of the blocks from the machine. The compressive strength was recorded as the ratio of the maximum load at failure and the cross sectional area of the block. The strength value was taken as the average of three specimens.

3. RESULTS AND DISCUSSION

Specific Gravity

Table 1 shows the specific gravity of the cement, SHA and sand used for the production of sandcrete blocks in this study. The specific gravity of SHA was obtained to be approximately 28% lesser than that of cement. However, it fell within the range of 1.9 to 2.4 specified for pulverized ash by Oyetola and Abdullahi (2006). Furthermore, the specific gravity of sand fell within the range of 2.5 – 3.0 specified for natural aggregates by Neville (2011).

Table 1. Specific Gravity of Materials

Materials	Specific Gravity
Cement	3.14
SHA	2.27
Sand	2.57

Particle Size Distribution of Sand

The particle size distribution curve for the sand used for the production of the sandcrete blocks is shown in Figure 1. The effective diameter corresponding to 60 percentage Passing (D_{60}) was 2 mm from the curve and that of D_{10} was 0.27mm. Coefficient of uniformity (C_u) was obtained to be 7.41. Since C_u is greater than 4.0 and the coefficient of gradation (C_c) is 0.58. The sand is said to be well graded. The sharp sand met the British Standard requirements for fine grading zone as specified in BS 882: 1992 and therefore suitable for use in the production of sandcrete block.

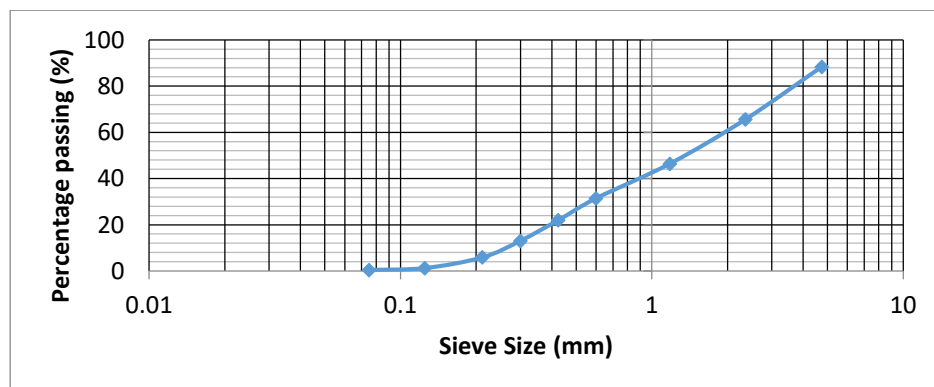


Figure 1: Particle Size Distribution Curve of Sand

Chemical Analysis of SHA

Table 2 shows the result of chemical analysis of SHA. The major chemical composition of SHA was silica content (SiO_2) having the percentage composition of 55.30%. According to BS EN 197-1:2000 the reactive silicon dioxide content in a good pozzolan should not be less than 25.0% by mass. The results indicated that the sum of percentages of SiO_2 , Al_2O_3 and Fe_2O_3 obtained for SHA was 77.3% which is greater than 70% specified by ASTM C 618 (2001).

Table 2. SHA Chemical composition

Chemical components	% composition
SiO_2	55.30
Al_2O_3	10.10
Fe_2O_3	11.90
SO_3	0.50
MgO	1.20
K_2O	4.50
Na_2O	0.70
CaO	10.40
$\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$	77.30
LOI	6.10

Density of the SHA Sandcrete Blocks

The results of the density test is presented in Figure 2. The densities slightly decreased as the curing age increased from 7 to 28 days. This is because water initially available in the mix is continuously been used for hydration making the density to be reduced with age. Furthermore, the voids created after evaporation of capillary water could also be responsible for the decrease in density. In addition, it could be observed that densities slightly decreased as the amount of SHA addition increased from 0 to 5%. The decrease in densities with increase in the amount of SHA could be attributed to the low specific gravity of SHA (2.27) as compared to that of cement (3.14). However, the values of density obtained for all sandcrete block mixtures examined were above the minimum value of 1500 kg/m^3 recommended for first grade sandcrete blocks by NIS 087 (2000).

Water Absorption of the SHA Sandcrete Blocks

The results of the water absorption test are shown in Figure 3. It was observed that the rate of water absorption increased as the percentage replacement of SHA increased. The 5% SHA substitution was seen to have highest water content. Increase in water absorption might be as a result of trapped bubbles due to porosity of SHA. The water absorption rate of all the replacement level was within the acceptable value of 12% maximum water absorption rate stipulated by BS5628: part 1: 2005.

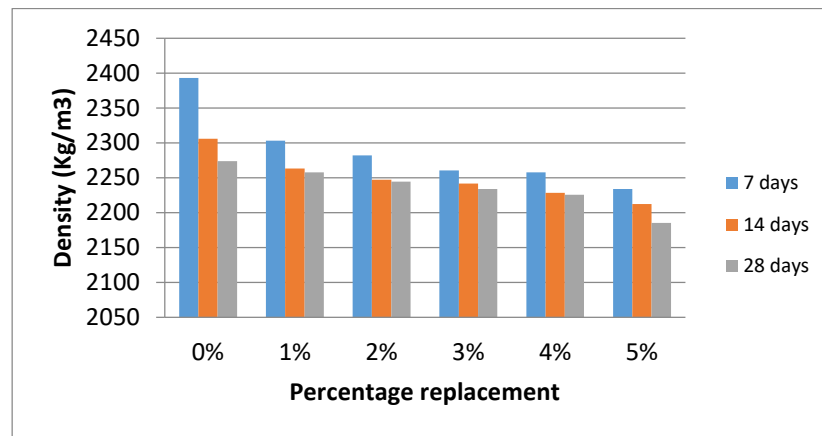


Figure 2: Density of SHA Sandcrete blocks at 7, 14 and 28 days

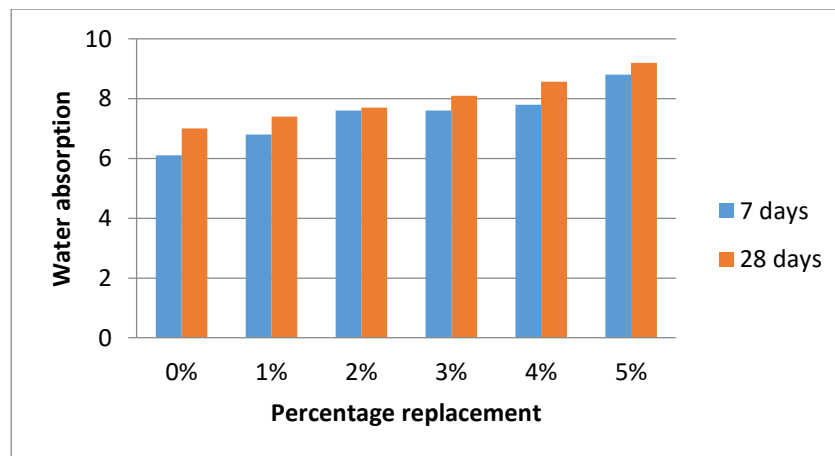


Figure 3: Water absorption of SHA Sandcrete blocks

Compressive Strength of the SHA Sandcrete Blocks

The results of the compressive strength test at 7, 14 and 28 days are shown in Figure 4. As anticipated, an increase in compressive strength with increase in curing age from 7 to 28 days was observed. However, there is an observed steady increase in compressive strength from 0 to 3% SHA replacement before a slight decrease in strength at 4%, and a further increase at 5% replacement level at all days. The highest strength of 4.18 N/mm² was obtained at 28 day at 3% SHA replacement. The compressive strength of the control (0% SHA) at 28 day was obtained to be 3.46 N/mm² and increased by 1.5, 7.3, 20.8, 5.2 and 6.7% for 1, 2, 3, 4 and 5% SHA replacement respectively. The growth in compressive strength may be due to increased pozzolanic reaction and the packing ability of the fine particles of SHA as similarly reported by Tijani *et al.* (2019). The reason for the reduction in strength after the optimum value obtained at 3% could be due to mixing effect of cement and formation of weaker C-S-H gel as a result of pozzolanic reaction of SHA. The result showed that the values obtained for partially replacing cement with SHA were above the required minimum standard of 3.45N/mm² stipulated by the Nigeria Industrial Standards (NIS) for load bearing walls.

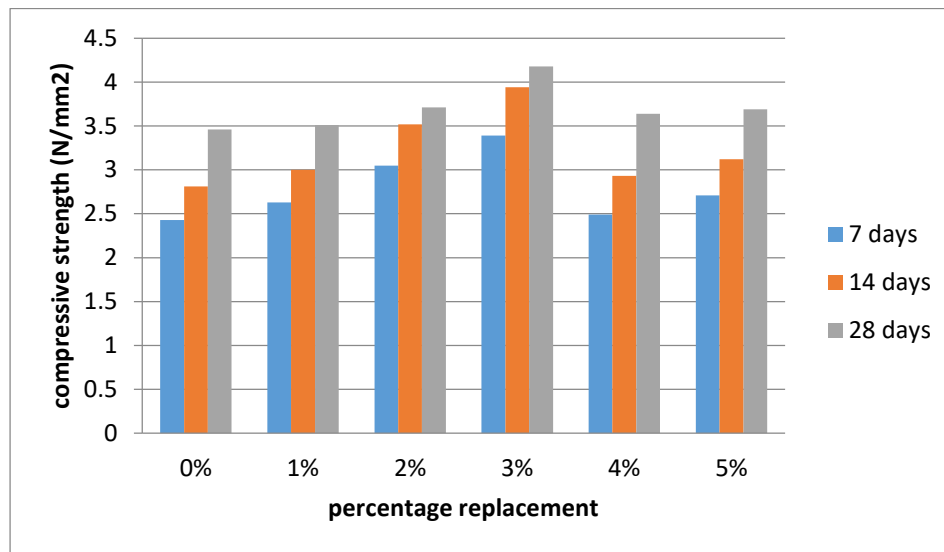


Figure 4: Compressive strength of SHA Sandcrete blocks

4. CONCLUSION

The following conclusions were drawn from the study;

- Sorghum husk ash (SHA) is a suitable material for use as a pozzolan, since it satisfied the requirement for such a material by having the sum of SiO_2 , Al_2O_3 and Fe_2O_3 of more than 70%.
- Density of sandcrete blocks slightly decreases as the amount of sorghum husk ash increases. However, the values of density obtained for all sandcrete block mixtures examined were above the minimum value of 1500 kg/m^3 recommended for first grade sandcrete blocks by NIS 087 (2000).
- Water absorption rate of sandcrete blocks increases as the amount of sorghum husk ash increases. The water absorption rate of all the replacement levels were within the acceptable value of 12% stipulated by BS5628: part 1: 2005.
- Compressive strength was improved due to pozzolanic reaction by partially replacing cement with sorghum husk ash. The values obtained were above the required minimum standard of 3.45 N/mm^2 stipulated by the Nigeria Industrial Standards (NIS) for load bearing walls.

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