SANDCRETE BLOCKS MADE WITH RICE HUSK AS PARTIAL REPLACEMENT OF AGGREGATE

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ABSTRACT

This study investigated the suitability of using rice husk (RH) as partial replacement of fine aggregate in sandcrete blocks. River sand was partially replaced with RH (by volume) at 0%, 10%, and 20%, with the 0% replacement serving as a control specimen. Twenty solid blocks of 450 × 225 × 125 mm dimensions were molded manually for each percentage replacement, giving a total of 60 blocks. Bulk density and compressive strength tests of the blocks were carried out at 7, 14, 21, and 28 days of curing, respectively. It was observed that both bulk density and compressive strength increased as curing age increased, but reduced as the percentage replacement level increased. The values of the bulk density at 28 days of curing for the 0%, 10% and 20% substitution levels were 2074 kg/m^3, 1509 kg/m^3 and 1470 kg/m^3, respectively, while values of compressive strength for the same curing age and percentage replacement levels were 3.42 N/mm^2, 1.83 N/mm^2, and 1.40 N/mm^2, respectively. The compressive strength results for the 10% and 20% RH replacement levels satisfied the requirements for insulating, lightweight concrete but failed to meet up with the specifications for both load bearing and unload bearing sandcrete blocks. Therefore, RH sandcrete is not suitable for load bearing and unload bearing partitioning in buildings, but shows potential as a non-structural insulating material. It is recommended, amongst others, that other properties of sandcrete containing RH such as splitting tensile strength, flexural strength, and thermal conductivity should be studied.

Keywords: Bulk density; compressive strength; fine aggregate; rice husk; sandcrete

INTRODUCTION

Sandcrete blocks are commonly used as walling units in buildings. Sandcrete is produced by mixing cement, fine aggregate and water in a specified proportion. Fine aggregate forms the largest volume of sandcrete. In Nigeria, river sand is conventionally used as fine aggregate in both sandcrete and concrete. However, factors such as rising prices of building materials and environmental impact associated with excavation of aggregate have raised concerns about the sustainability of the built environment. There is a developing urge to use alternative sustainable materials as a partial or total substitute for aggregates in sandcrete and concrete. A significant increase in research on eco-friendly materials in construction using vegetable resources has been reported recently (Chabannes et al., 2014).

Some agricultural by-products possess the properties of lightweight aggregates. Advantages of using lightweight aggregates in concrete are well-known, which include lighter dead loads, improved thermal insulation, and considerable savings in construction costs (Neville & Brooks, 2010; Shetty, 2012; Mo et al., 2016).

Rice husks (RHs) are the outer protective shells of rice grains and are separated from the grains during the milling process. RH represents about 20% weight of rice (Siddique, 2008). Rice is a staple food in Nigeria and is cultivated in several parts of the country such as the middle belt and northern states of Benue, Kaduna, Niger, and Taraba, as well as the southern states of Enugu, Ebonyi, and Cross River (Cadoni and Angelucci, 2013). Nigeria is the largest producer of rice in West Africa (Cadoni and Angelucci, 2013), and Nigeria produced 6,734,000 tons of rice in 2014 (Food and Agriculture Organization of the United Nations, n.d.). This means that over one million tons of Nigerian RH were produced in 2014. RHs are primarily used as fuel for cooking and heating. Heaps of unused RHs are usually dumped or burnt as waste in open fields, thereby causing environmental problems such as contamination and pollution. A possible way of utilizing RH waste is to use RH as an alternative construction material.

The literature on utilization of RH in sandcrete and concrete focused on the performance of RH ash as a pozzolanic material. Few researchers have used RH as partial replacement of fine aggregate in concrete. Sisman et al. (2011, 2014) concluded that insulating and structural concrete containing RH as partial replacement of sand could be used in constructing agricultural buildings subjected to small loads. Obilade (2014) reported that 1:2:4 concrete mix containing up to 15% RH aggregate as volume replacement of sand achieved the British Standard compressive strength requirement for Grade 15 lightweight concrete, and recommended that concrete containing RH as partial replacement of fine aggregate should be volume-batched. Chabannes et al. (2014) worked on lightweight insulating concrete using RH and lime, and the results of RH concrete were compared with concrete produced from commercial hemp hurd using different mix ratios. The apparent density and compressive strength of RH concrete at 60 days ranged from 503-746 kg/m^3 and 0.33 ± 0.03 MPa, respectively. Son et al. (2017) investigated agro-concrete using a lime binder and RH aggregate and reported compressive strength value of 0.48 ± 0.02 MPa for one-month curing.

To the best of the authors' knowledge, no experimental study has been reported on the influence of RH aggregate on the physicomechanical properties of sandcrete blocks. This study aims to investigate the suitability of RH as partial replacement of sand in sandcrete blocks. Compressive strength and bulk density properties of sandcrete blocks containing RH were compared with control sample.

EXPERIMENTAL INVESTIGATION

Materials

Ordinary Portland cement, water, rice husk (RH), and river sand were the materials used in the experimental study. Ordinary Portland cement manufactured in accordance with NIS 444-1 (2003) requirements was bought from a cement depot in Owerri, Imo State. Water from a borehole in Owerri, Imo State was used for mixing and curing. RH was obtained from a rice milling factory in Afikpo, Ebonyi State. The husks were stored in sacks. River sand collected from Otammiri River in Imo State was used as fine aggregate. The loose bulk density, compacted bulk density, specific gravity and fineness modulus of the sand were 1560 kg/m^3, 1590 kg/m^3, 2.64 and 2.89, respectively. The particle size distribution of the sand is shown in Fig. 1.

Fig. 1. Particle size distribution curve for river sand

Specimens

Sandcrete mix was batched by volume using cement/sand mix proportion of 1:6. RH served as a partial replacement of river sand (by volume) at 0%, 10%, and 20%, with the 0% replacement serving as the control sample. Mixing was done manually on a concrete pavement using a spade. Sand and RH were first mixed in a dry state to a constant color. Cement was later added, and the whole process of mixing continued until a uniform color was observed. Water was added finally to the cement paste to workable sandcrete mixes of uniform color were obtained. Twenty solid blocks of 450 × 225 × 125 mm dimensions were molded manually for each percentage replacement, giving a total of 60 blocks. The blocks were cured for 7, 14, 21, and 28 days, respectively. Curing was achieved by water sprinkling, twice daily.

Testing

The bulk density and compressive strength of the blocks were tested for each percentage replacement and curing age. For each percentage replacement and curing period, the mass of five blocks was obtained separately, before crushing. The density of each block was calculated by dividing the mass by its volume, and the mean density was calculated.

For the compressive strength test, each block was subjected to crushing in a universal testing machine (Fig. 2). Loading was applied gradually without shock until failure occurred. The machine automatically stops when a failure occurs, and the compressive load is displayed on the device. The compressive load of each block divided by the cross-sectional area of the block gives the numerical value of the compressive strength.

Fig 2. A sandcrete block subjected to compressive loading in a universal testing machine

RESULTS AND DISCUSSION

Bulk density

The results of the bulk density are shown in Fig. 3. The bulk density of the blocks increased with curing age but decreased with increase in percentage replacement by RH. The maximum density is observed at 28 days caring for the control samples (0% replacement level). The density of blocks mainly depends on the degree of compaction, block form, and density, size, and grading of aggregate (Dhir et al., 1996). The typical range for bulk density of blocks is 500-2100 kg/m^3, with solid blocks being on the heavier end of the scale (Dhir et al., 1996). The values of the bulk density at 28 days of curing for the 0%, 10%, and 20% replacement levels were 2074 kg/m^3, 1509 kg/m^3, and 1470 kg/m^3, respectively. It can be observed that the bulk density of the samples obtained in the present study falls within the range for bulk density of sandcrete blocks. The reduction in bulk density for the 10% and 20% replacement levels is attributed to the low bulk density of rice husk aggregate. The dry mass of rice husk is around 96-160 kg/m^3 (Kumar et al., 2012) which is very low when compared with the bulk density of river sand.

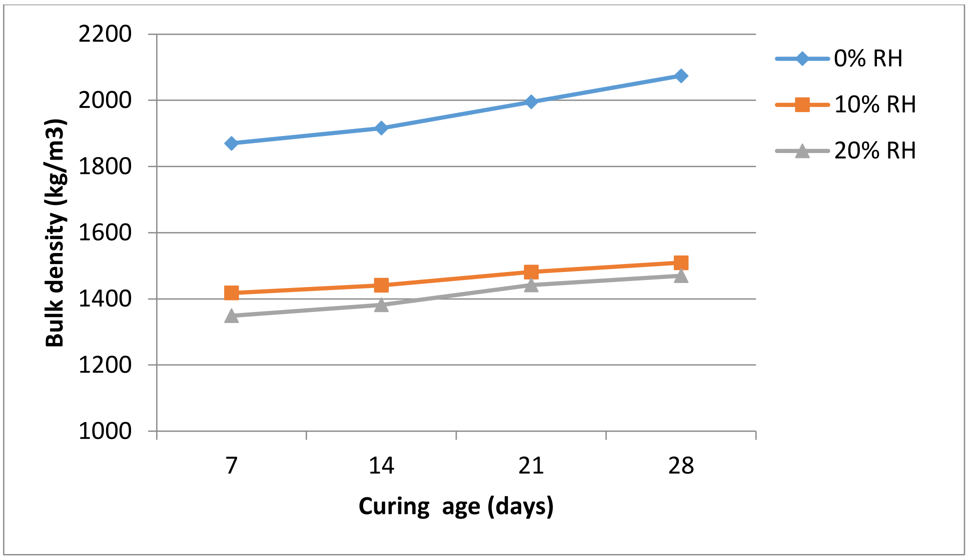

Fig. 3. Bulk density of sandcrete blocks containing RH aggregate

Compressive strength

The compressive strength values at various percentage replacement levels and curing ages are given in Fig. 4. Compressive strength increased as curing age increased, but reduced as the percentage replacement level increased. Partial substitution of sand with RH decreased the compressive strength of sandcrete blocks. NIS 87 (2004) specifies that the average compressive strength of sandcrete blocks for load bearing walls and unload bearing walls should not be less than 3.45 N/mm^2 and 2.5 N/mm^2, respectively. Only blocks made with sand at 0% replacement (3.42 N/mm^2) met the minimum required standard for unloading bearing sandcrete blocks as recommended in NIS 87 (2004), while the other percentage replacement levels were below the required compressive strength for unload bearing walls.

Nevertheless, the values of the compressive strength for 10% and 20% RH sandcrete blocks at 28 days of curing were 1.83 N/mm^2 and 1.40 N/mm^2, respectively, which fall within the category for compressive strength of lightweight insulating concrete (0.49-6.96 MPa) (De Gennaro et al., 2008, cited in Sisman et al., 2014).

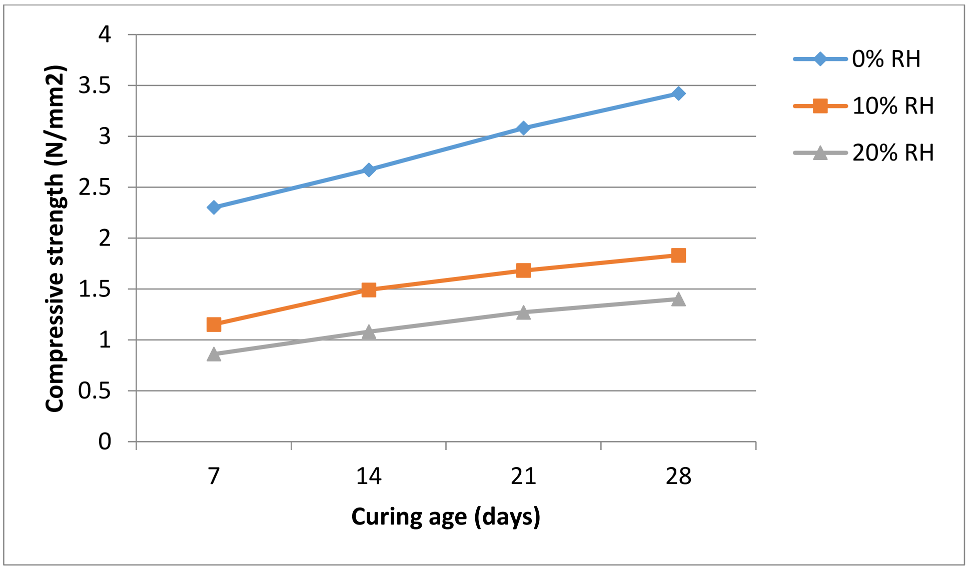

Fig. 4. Compressive strength of sandcrete blocks containing RH aggregate

It was also observed that the cement paste bonded rather poorly with the RH grains. The particles of the control specimen sandcrete bonded better than particles of sandcrete containing RH aggregate. RH – Portland cement compatibility in sandcrete mixes is a technical aspect that should be further studied.

CONCLUSION AND RECOMMENDATION

The partial replacement of sand with RH in sandcrete blocks reduced both the bulk density and compressive strength. Partial replacement of sand with RH in sandcrete block production is shown to improve the bulk density since it reduced the self-weight of sandcrete. For the compressive strength, only blocks made with sand at 0% replacement satisfied the minimum compressive strength standard for nonload bearing sandcrete blocks. The compressive strength for all the percentage replacement levels, however, met the strength requirement for lightweight insulating concrete. Therefore, RH sandcrete is not suitable for load bearing and unload bearing partitioning in buildings but shows potential as a non-structural insulating material. It is recommended that other tests such as splitting tensile strength, flexural strength and thermal conductivity should be carried out on sandcrete containing various percentages of RH as partial replacement aggregate. It is also recommended that further investigations should be carried out to check the effects of superplasticisers and bonding admixtures on sandcrete blocks containing RH aggregate. Also, lime binders should experiment on RH aggregate blocks. Durability properties of RH – sandcrete should also be studied.

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