Covenant Journal of Research in the Built Environment (CJRBE) Vol. 5, No. 1, June 2017

An Open Access Journal available online

Influence of Variation in the Composition of Fine Aggregate on the Properties of Sandcrete Blocks

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***Abstract*:** Sandcrete block is predominantly used for the construction of walls. Sandcrete block is made from a mixture of cement and fine aggregate (sharp sand). This study investigates the influence of variation in the composition of fine aggegate on the properties of sandcrete block. Laboratory experiments were conducted on the materials used as well as on the hollow sandcrete block samples. A total of 120 sandcrete block samples were produced using cement and sharp sand at different mix ratios of 1:6 or 1:8 mixes, as well as mixes containing partial replacement of sharp sand with fine sand or granite dust at 1:6:2, 1:5:3 and 1:4:4 by volume. Result revealed that the compressive strength at 21 and 28 days curing age for 1:6 mixes are 3.87 N/mm^2 and 4.17 N/mm^2 respectively and for the 1:8 mixes are 2.81 N/mm^2 and 2.95 N/mm^2 respectively. For cement, sharp sand and fine sand constituents of 1:6:2, 1:5:3 and 1:4:4; the compressive strength at 28 days curing is 2.24 N/mm^2, 1.72 N/mm^2 and 2.5 N/mm^2 respectively. Similarly, for cement, sharp sand and granite dust constituents, 28 days compressive strength are 2.13 N/mm^2, 1.61 N/mm^2 and 1.42 N/mm^2 respectively. The study recommends appropriate mix proportion for sandcrete block constituents to avoid huge lifecycle maintenance cost.

Keywords: Granite dust, masonry units, material properties, sandcrete blocks

1.0 Introduction

Sandcrete block is a masonry unit which is predominantly used as walling materials in the construction of shelters and other infrastructures (Abdullahi, 2005; Onwuka, Osadebe and Okere, 2013; Adeyeye, 2013). Sandcrete block is made from a mixture of cement and sharp sand in the ratio of usually 1:6 with minimum amount of water. In some cases, admixtures are added. Sandcrete block could be made hollow or solid and are available in sizes of 450x225x225mm, 450x150x225mm, or 450x100x150mm. In Nigeria, sandcrete blocks are used both as external and partition walls in over 90% of buildings (Hijab, Halilu and Hadi, 2010; Anosike and Oyebade, 2012; Alohan, 2012; Oladeji and Awos, 2013). Sandcrete blocks have also been used for the construction of load bearing and non load bearing structures such as roof gutters, drainage ditches and strip foundations among others.

The quality of sandcrete blocks produced in Nigeria differs from one manufacturer to the other due to the different methods employed in their production and the properties of the constituent materials (Adeyeye, 2013; Awolusi, Soyingbe and Oyeyipo, 2015). Ewa & Ukpata (2013) reported that aesthetic value of a building is lost to cracks and other defects partly due to poor quality of sandcrete block as a walling units. The poor quality of sandcrete blocks affects their compressive strength, making them susceptible to any tragedy such as seismic activity (Abdullahi, 2005). Previous researches on the quality of sandcrete blocks sold by commercial bock manufacturers show that they exhibited compressive strength far below the standard requirement for the construction of buildings (Awolusi et al., 2015; Aladeloba *et al*., 2015; Omopariola, 2014; Hamisu and Mohammed, 2014; Akeem and Umar, 2013; Onwuka *et al.*, 2013; and Anosike and Oyebade, 2012). NIS recommends that the lowest crushing strength of individual load bearing blocks shall not be less than 2.5N/mm^2 for machine compacted and 2.0N/mm^2 for hand compacted sandcrete blocks.

The quality of sandcrete blocks is also partly influenced by the quality of constituent materials (Awolusi *et al*., 2015) as well as the mix proportion (Akeem and umar, 2013). Omopariola (2014) averred that lack of uniformity in the production of sandcrete blocks by commercial block producers stem from ignorance of the existence of any relevant code or specifications relating to block production. He further stated that standard process of sandcrete block production and quality control are not ensured leading to low quality sandcrete blocks. According to Alohan (2012), the majority of sandcrete blocks used in the Nigerian building industry fall short of minimum specification. Akeem and Umar, (2013) and Alohan (2012) confirmed it by stating that the production of low quality blocks may have led to the increase in collapsed buildings in recent times.

NIS 84:2000 specifies the use of cement-sharp sand of 1:6 mix ratio for sandcrete block production. Oyekan & Kamiyo (2008) observed that instead of the standard mix proportion of one part of cement to six parts coarse sand (1:6) by volume, many local sandcrete block manufacturers use a mix proportion of 1:8. In another study by Omopariola (2014), the mix proportion being used by commercial block producers in all the sites visited varied from 1:10 to 1:12 of cement and sharp sand constituents by volume. Another common practice among sandcrete block producers is combining sharp sand with fine sand, clay or granite dust in a bid to improve its plasticity. However, as observed by Anosike and Oyebade (2012), this practice will not only weaken the bond between cement and the constituents in the green state, it could have a deleterious effect on the compressive strength of the blocks. The effect of partially replacing sharp sand in the production of sandcrete blocks with either fine sand or granite dust is a gap in existing literature. Furthermore, there are no specifications for the use of fine sand and granite dust in the manufacture of sandcrete blocks. This scenario has therefore prompted the need for this research since it is a common practice among sandcrete block manufacturers in Lagos, Nigeria.

The aim of this study was to investigate the influence of partial replacement of sharp sand on the properties of sandcrete blocks. The specific objectives of the study are to: investigate the physical and chemical property of sand and granite dust used in the production of hollow sandcrete block and determine the effect of partial replacement of sharp sand on the compressive strength of sandcrete block samples.

2.0 Materials and Methods

2.1 Materials

The materials used for this research work include cement, fine aggregate (sharp sand, fine sand and granite dust) and water. Ordinary Portland Cement (grade 32.5) with the trade mark "Dangote Cement" which complied with BS EN 197-1 and fully certified by Standard Organisation of Nigeria (SON, 2003) was used as the binder. The sand used for this study was sharp river sand dredged from the Lagos Lagoon in Ibeshe-Ikorodu. Physical inspection on the sand indicates that it was free from deleterious materials such as dirt and sea shells. The fine aggregate used were those that passed through 5mm British Standard sieve and had a specific gravity of 2.63 and an average moisture content of 9.07 %. Clean Tap water, free from particles and good for drinking as specified in BS EN 1008 (2002) was used for mixing.

2.2 Apparatus

The apparatus used for the laboratory experiment comprises the following: Weighing balance, Set of sieves, Electrically controlled sieve shaker, Cleaning brush, Measuring cylinder (250ml capacity); Block molding machine; Curing tank; Muffle furnace; Oven; Compression testing machine; Spectroscope

2.3 Experimental Procedure

The procedure for carrying out the laboratory experiment as described in the relevant sections of the British Standard is presented below:

(i) Particles size distribution/Sieve analysis. The dry sieve analysis method was adopted in determining the proportion of various sizes of particles in the aggregate so as to ascertain whether the particle distribution is in compliance with recognized standards. The test was carried out for all the aggregates according to standard procedures (BS EN 933-1, 1997).

(ii) Specific gravity of aggregates. Specific Gravity (G_S) is the ratio of the density of a substance to the density (mass of the same unit of volume) of a reference substance. The specific gravity of a soil is often used to describe the relationship between the weight of soil and its volume. The test method adopted for the test is in accordance with BS 812-2: 1995.

(iii) Silt/Clay content test. The silt/clay content test is carried out to determine the quantity of silt and clay present in the fine aggregates. The presence of silt and clay in fine aggregate prevents a good bond between it and cement. If the silt and clay present in the sand is in large quantities (above 35%), it results in increased water absorption which will have significant influence on the strength of the sand Crete blocks. The test method is in accordance with British standards BS 812-103: Part 2 1989.

(iv) Organic matter content test. Organic matter influences many of the physical, chemical and biological properties of soil. Some of the properties influenced by organic matter include soil structure, soil compressibility and shear strength. Loss on ignition test was performed to determine the amount of organic matter present in the fine aggregate. The organic matter content is the ratio, expressed as a percentage, of the mass of organic matter in a given mass of soil to the mass of the dry soil solids. The method adopted for this test is in accordance with British standards BS 1377-3:1990 (Standard Test Methods for Moisture, Ash, and Organic matter of peat and Organic soils).

(v) Moisture content. Moisture content is the quantity of water contained in a material. It is the ratio of the water present in the soil mass to the weight of the soil solids. The moisture content of the fine aggregate was determined by means of the oven-dried method according to BS EN 1097-5(2008). Known weight of aggregate was oven-dried for 24 hours at a temperature above 100°C, the weight was then taken after drying to determine the weight of water evaporated and that of the dry soil.

(vi) Chemical analysis test. The chemical analysis of the sharp sand was carried out to determine the percentage composition of the compounds present in the sand. The test was determined using Atomic Absorption Spectrophotometry (AAS). This is a technique in which the absorption of light by fine gaseous atoms in a flame or furnace is used to measure the concentration of atom in a given sample. The radiation produced corresponds to the emission spectrum of that element and so the required line may be readily isolated by the monochromator. Individual hollow cathode lamps are available for large number of elements.

(vii) Compressive strength test of blocks. The compressive strength is a measure of the strength of blocks. The test was performed in accordance with BS EN 12390-3 (2002) specifications. The compressive strength test was carried out on the blocks after they were cured for 7, 14, 21 and 28 days.

3.0 Results and Discussions

3.1 Preliminaries Investigation

The results of investigation conducted to determine some characteristics of the aggregate as previously described are presented in Table 1. There is no much difference between the specific gravity of sharp sand and soft sand as indicated in Table 1. However, the specific gravity of sand is a little higher than that of granite fines. They all fall within the range of specific gravity of the solid substance of most inorganic soils which varies between 2.60 and 2.80. The specific gravity of granite fines indicates the presence of organic or porous rock particles. The high moisture content of the aggregate as indicated in Table 1 may not be unconnected with the rainy season. In addition, the silt content of the sharp sand is within the acceptable limit of 8%, which makes it suitable for sand Crete block production.

From the result obtained from the organic matter content test of the sharp sand, it was observed that the percentage composition of the organic matter such as decayed vegetation humps, coal dust etc present in the sharp sand is 0.48%, soft sand is 0.36%
and granite dust is 0.48% respectively. The organic matter in the aggregate is quite negligible as it is far below 1.5 %

limit defined by **BS** EN 13039:2011 granite fines are relatively free from organic matter. Sand containing more than 30 percent organic matter is not suitable for construction purpose. hence, the sharp sand, soft sand and

Table 1: Aggregate Characterization

Property	Sharp Sand	Soft Sand	Granite Fines
Specific gravity	2.63	2.64	2.54
Moisture content (%)	9.07	3.93	7.33
Silt content (% by volume)	2.51	16.6	-
Loss on Ignition (LOI) at	0.48	0.36	0.48

3.2 Particle Size Distribution of Aggregates

The results for the particle size distribution of the sharp sand, soft sand and granite fine is presented in figure 1. The percentage by mass of soft sand finer than BS sieve 150μm (No. 100) was 22.52%, which exceeds the allowable grading limit of 0-15% for sieve size 150μm . This indicates an excess of fines. The particle size distribution curve of sharp sand shows that the sharp sand used falls between the medium sand to coarse sand region (BS 882:1992) and is uniformly graded. While the particle size distribution of Granite fines shows that the granite fines used falls in the coarse sand region (BS 882:1992). The sharp sand and granite fines are both suitable construction material especially for the production of sand Crete blocks.

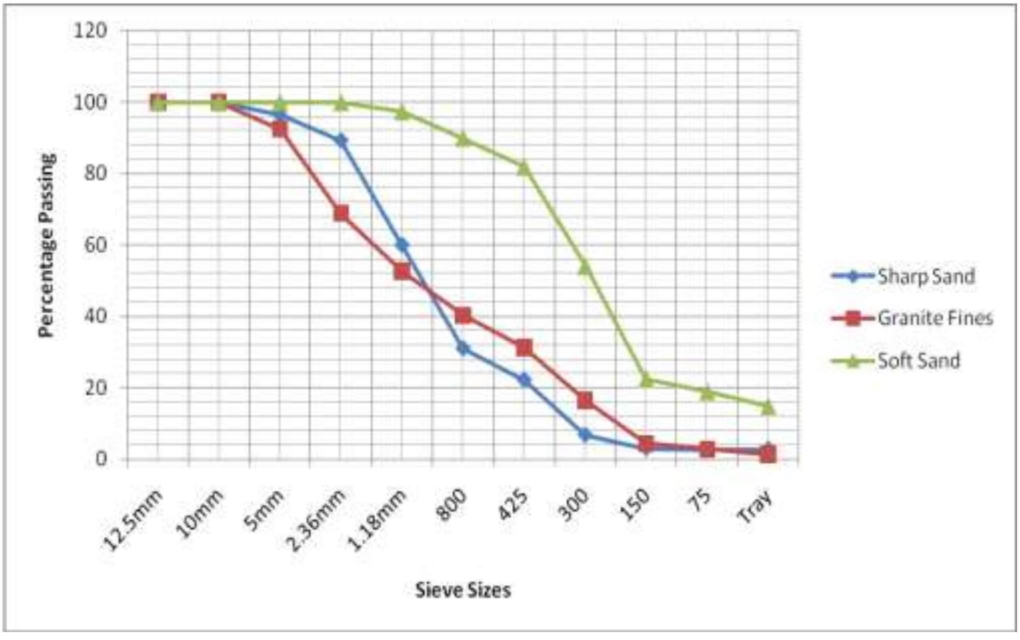

Figure 1: Particle size distribution of the aggregates (sharp sand, soft sand and Granite fines)

3.3 Chemical composition of aggregate (sharp sand, soft sand and granite fines) sample.

The result of the chemical analysis of sharp sand, soft sand and granite fines is shown in Table 2.

The amount of chloride ions (Cl^-) = 165mg/kg and sulphate ions (SO_4^-) = 24mg/kg present in the sharp sand used are within the acceptable limit according to NIS 87:2000, which makes is suitable for sand Crete block production.

Table 2: Chemical analysis result of sharp sand, soft sand and granite fines

Chemical Components	Percentage composition		
	Sharp Sand	**fine Sand**	**Granite dust**
Silica Oxide (SiO_2)	97.22	98.50	62.48
Sodium Oxide (NaO_2)	0.003	0.0025	Nil
Potassium Oxide (K_2O)	0.002	0.01	3.18
Calcium Oxide (CaO)	0.008	0.001	4.83
Magnesium Oxide (MgO)	0.005	0.0025	2.56
Aluminium Oxide (Al_2O_3)	0.026	0.43	18.72
Iron Oxide (Fe_2O_3)	0.002	0.22	6.54
Sulphur Oxide (SO_3)	0.000	0.001	0.000
Cl^- (mg/Kg)	165.0	Nil	Nil
SO_4^- (mg/Kg)	24.0	Nil	Nil
pH	5.70	5.70	5.70

3.4 Water Absorption Capacity of Sandcrete Blocks

The results of percentage water absorption of the standard mixes 1:6 and 1:8 are 4.0% and 5.16% respectively. Also, the percentage water absorption of the sandcrete block containing cement, sharp sand and soft sand composition for 1:6:2, 1:5:3 and 1:4:4 mixes are 5.94%, 5.14% and 4.81% respectively. These indicate a decrease in the water absorption capacity of sandcrete block samples as the percentage replacement of soft sand increases. This could be because of its fine content, which reduced the void between the particles making the sandcrete block samples more compact. Similarly, the percentage water absorption of the mix proportion containing granite fine increased significantly as the percentage replacement of the sharp sand by granite fines increases from 3.84% for the 1:6:2 mix to 7.0% for the 1:5:3 mix and 7.81% for the 1:4:4 mix. This could be because of more pores created by the granite fines. This result is in tandem with that of Oyekan & Kamiyo, (2008).

Water absorption capacity values shown in Fig. 2 satisfy the permissible values.

According to BS 5628 part 1, water absorption value below 7% is regarded as low, while those above 12% as high As shown in Fig. 2 below, the water absorption for all the sandcrete block specimens fall below the upper limit of

12% (BS 5628 part 1), hence the blocks can be used in moist environment.

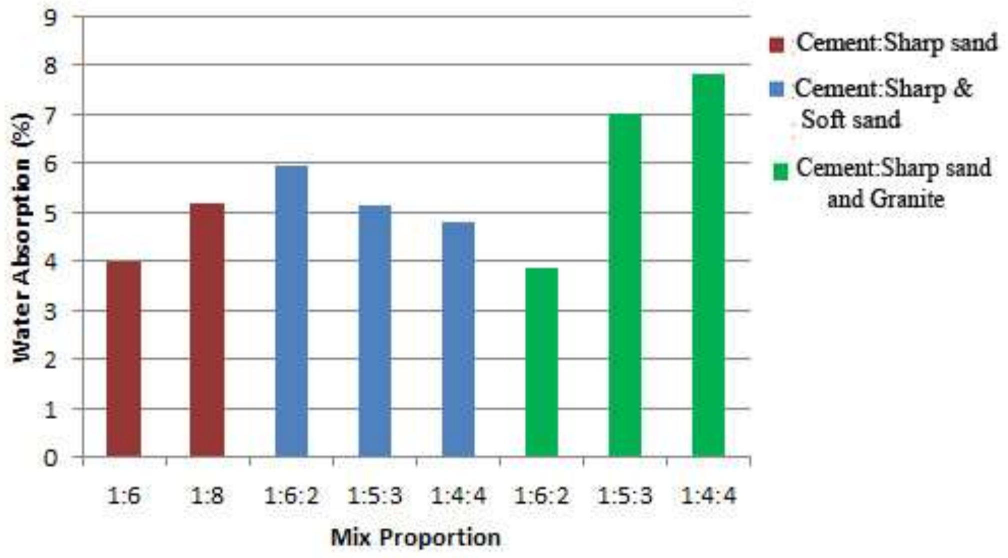

Figure 2: Water absorption capacity of various sand compositions and mixes of the sandcrete blocks

3.5 Compressive strength test of hollow sandcrete blocks

The results of the 7, 14, 21 and 28 days compressive strength test carried out on three hollow sandcrete block samples each of size 450 x 225 x 225mm made from different mix compositions is presented in Figure 3 and 4. The results show that the compressive strength of the block for the standard mixes of 1:6 and 1:8 (with sharp sand composition) increased significantly from 2.30N/mm^2 at 7 days to 4.17N/mm^2 at 28 days and from 2.08 N/mm^2 at 7 days to 2.95 N/mm^2 at 28 days respectively. Similarly, the compressive strength of the block with soft sand composition of 1:6:2 (cement, sharp sand and soft sand) mix increased from 1.72 N/mm^2 at 7 days to 2.24 N/mm^2 at 28 days as sown in Figure 3. These satisfy the minimum requirement of 1.60N/mm^2 specified by the National Building code (2006), for non load bearing wall.

For the 1:5:3 (cement, sharp sand and soft sand) mix, compressive strength raise steadily from 1.55 N/mm^2 at 7days to a peak of 1.81 N/mm^2 at day 21 and then dropped to 1.72N/mm^2 at 28 days. Compressive strength of 1:4:4 (cement, sharp sand and soft sand) compositions increased from 1.40 N/mm^2 at 7 days to 2.50 N/mm^2 at 28 days which meets the required NIS standard of 2.50N/mm^2 for non load bearing walls.

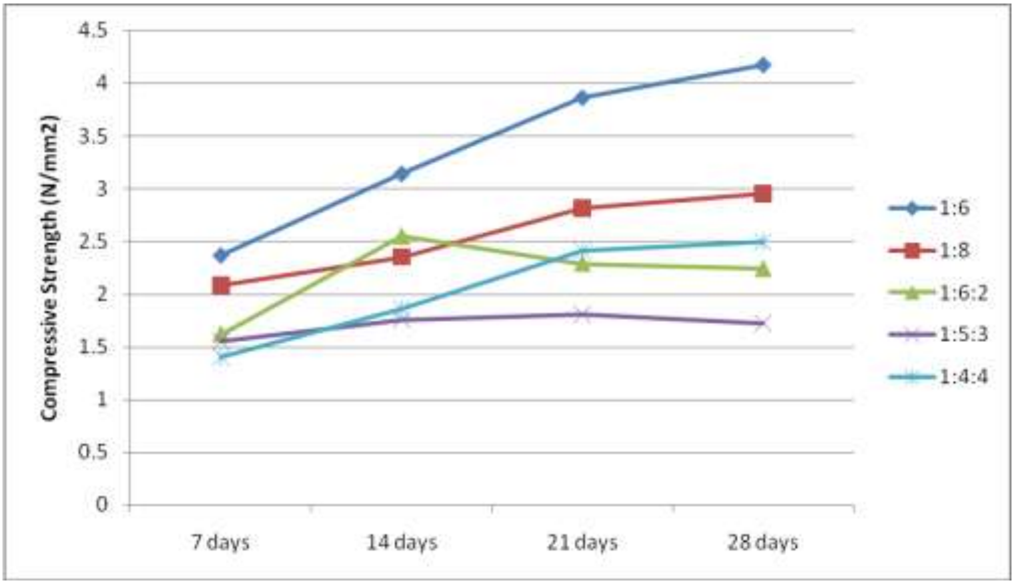

Figure 3: Compressive strength of block (cement, sharp sand and soft sand mix) at different curing days

For the mix composition using granite fines in Fig 4 below, the 1:6:2 (cement, sharp sand and granite fine) mix recorded a compressive strength of 1.90N/mm^2 at 7 days and increased steadily with age of curing up to 2.13 N/mm^2 at 28 days. Similarly, the 1:5:3 and 1:4:4 mixes recorded a compressive strength of 1.85N/mm^2, 1.61N/mm^2 and 0.84N/mm^2, 1.42N/mm^2 for 7 days and 28 days respectively.

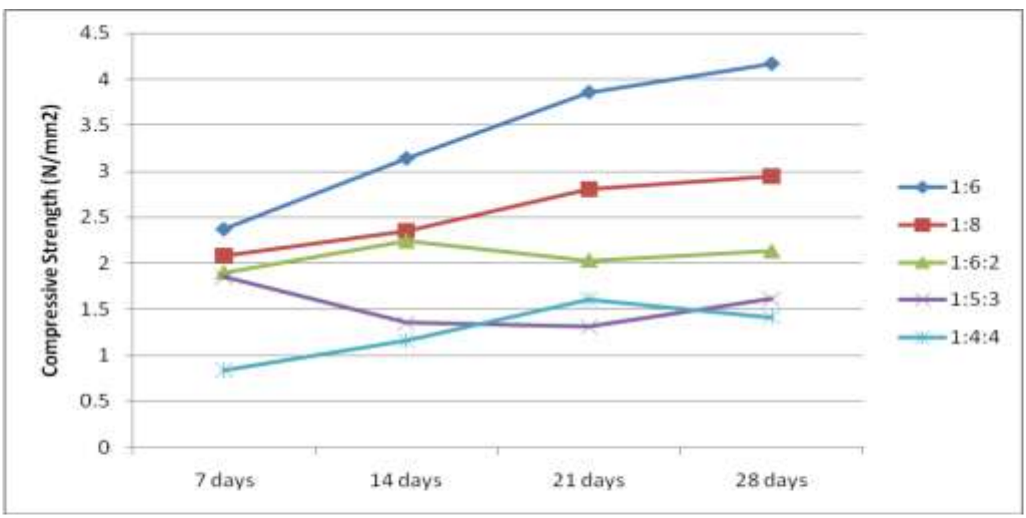

Figure 4: Compressive strength of sandcrete block (cement, sharp sand and granite fines

4.0 Conclusion

The result of variation in the fine aggregate component of sandcrete blocks reveals that the compressive strength of the block with cement, sharp sand and soft sand composition of 1:6:2 and 1:4:4 by volume increased progressively to a peak of 2.24 N/mm^2 and 2.5N/mm^2 respectively at 28 days. These meets the required NIS and National Building code standards for non load bearing walls. The compressive strength of 1:5:3 cement, sharp sand and soft sand compositions is within the permissible strength recommended by the National Building code but the strength reduces with age.

The compressive strength of cement, sharp sand and granite fine composition of 1:6:2 by volume satisfied permissible values recommended by NIS and National Building code. However, 1:5:3 and 1:4:4 cement, sharp sand and granite fine composition recorded steady decline as the block sample age, hence, not suitable for block production. The water absorption capacity of sample with granite fine is the highest in comparison to others It is therefore recommended that the practice of using granite fines as partial substitute for sand in sandcrete block production should be discouraged. However, for soft (plaster) sand, the mix proportion of 1:4:4 by volume is recommended.

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