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Effect of Mix Ratio and Curing on Compressive Strength of Sandcrete Hollow Blocks

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Research Article

Abstract

The standards of the materials used in a building's construction greatly influence its strength and durability. In Nigeria, hollow sandcrete block is the most common material used in buildings. This study evaluates the effect of the water-cement ratio and then the aggregate-cement ratio (mix ratio) on the compressive strength and density of hollow sandcrete blocks of size 9" (225 X 225 X 245mm). Six water–cement ratios (0.35, 0.40, 0.45, 0.50, 0.55 and 0.60) and five mix ratios (1:6, 1:7, 1:8, 1:9 and 1:10) were used and the compressive strength and density of the blocks were determined. The results were checked for compliance with the Nigerian Industrial Standard (NIS) (2004) and BS 2028 (1983). The results revealed that 0.45 is the optimum water-cement ratio with the highest compressive strength value of 3.34N/mm^2. Furthermore, the 28-days compressive strengths of the 1:6, 1:7, 1:8, 1:9 and 1:10 were found to be 2.88 N/mm^2, 2.85N/mm^2, 2.71N/mm^2, 2.49N/mm^2 and 2.46N/mm^2 respectively. The study samples have a density range of 1527kg/mm^3 to 1815kg/mm^3 meeting the minimum requirement of 1500kg/mm^3 by BS 2028 (1983). For commercial purposes mix ratios of 1:8 and below should be used because they meet the minimum requirement of 2.5N/mm^2 compressive strength specified by NIS (2004).

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Keywords
Compressive Strength, Density, Mix ratio, Sandcrete and Water-cement ratio

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1.0 Introduction

1.1 Preamble

Economic growth in Nigeria has brought about a spate of activities in the building sector (Abubakar and Omotoriogun, 2022). This means the need for hollow blocks is on the increase because in Nigeria about 90% of the walling units of houses are built using sandcrete hollow blocks (Baiden and Tuuli, 2004, Umasabor, 2023), Ewa and Ukpata, (2013) also share the same opinion. Ajoa*et al.,* (2018) mentioned that Sandcrete is made up of fine aggregate, cement and water mixed in the right proportions and later Awolusi et al (2021) added that any composite material made from a mixture of water, binder and fine aggregate is termed a Sandcrete block. Sandcrete Hollow Blocks (SHB) are the foremost unmistakable units within buildings nowadays, particularly within the development of private, industrial and commercial buildings (Ejeh and Ayinmode, 1982).

Ensuring the quality of the blocks cannot be over-emphasized, the major issue confronting the generation of SHB is that the strength delivered by most commercial square-making businesses did not meet the specified standard code of practice. SHB often exhibits low compressive strength, with common attributions pointing to factors such as inadequate cement-sand ratios and insufficient curing practices. Evaluation of the quality of the sandcrete hollow blocks produced by commercial block-making businesses uncovered that a larger part of the blocks had 28-day dry compressive strength within the range of 0.50N/mm^2 to 1.5N/mm^2. (Ejeh and Abubakar, 2008; Ewa and Ukpata, 2013; Onwuka *et al.,* 2013).

Odeyemi *et al.,* (2015) investigated the sandcrete blocks using a vibrating machine with a blend proportion of 1:6 and Dangote cement, the 28-day dry compressive strength of SHB was 1.78N/mm^2, this value failed to meet the BS EN 771-3 2006 and NIS 87: 2004 standard determinations of 2.9N/mm^2 and 2.5N/mm^2. This finding is in agreement with (Odeyemi *et al.,* 2015; Ewa and Ukpata, 2013 and Onwuka *et al.,* 2013). Orie and Ozegbo (2023) developed a model correlating the compressive strength of lightweight cement-Palm Kernel shell-Based Sandcrete Blocks with density using multiple regression and a mix ratio of 1:6. The authors found that after curing for 7, 14, 21, 28 and 56 days the compressive strengths of were 2.513 N/mm^2, 2.527 N/mm^2, 2.608 N/mm^2, 2.871 N/mm^2, 2.639 N/mm^2 and2.510 N/mm^2 respectively; this showed that a good sandcrete block can be produced even with lighter material because Orie and Ozegbo (2023) result passes the minimum of 2.5N/mm^2 for 28 days compressive strength as specify by NIS 87:2004. Mostly, block-making industries do produce not up-to-standard sandcrete hollow blocks and this has led to huge losses in the process of transportation and placement of the blocks. It should be emphasized that

increasing the cement content adds to the quality of the blocks in terms of strength and density, Okonko*et al* (2023) reported that both the wet and dry weight (density) of the sandcrete blocks increases with an increase in the cement content (Mix ratio).
This study aimed to assess the effect of the water-cement ratios and mix ratio on the strength and density of sandcrete hollow blocks.

2.0 Materials and Methods

2.1 Materials

2.1.1 Cement: The cement used for the study was Portland-Lime cement grade 42.5N produced by Dangote. It was sourced from the open market.

2.1.2 Fine Aggregate: The fine aggregate was sourced from Rafin-wawakarasain Kano.

2.1.3 Water: The water used for this research was water from the Civil Engineering Department laboratory at BayeroUniversity, Kano.

2.2 Methods

2.2.1 Sieve Analysis: This test was carried out according to BS EN 812-103(2000). The test results are presented in Figure 1

2.2.2 Determination of Cement Oxide Composition: The percentage of oxide in the Ordinary Portland cement according to BS EN 197-1:2011, and the cement compounds were computed using the Boque equation (Equation 1 to 4)

Tricalcium Silicate ($3CaO.SiO_2$):
$C_3S=4.07(CaO)-7.60(SiO_2)-6.72(Al_2O_3)-1.4(Fe_2O_3)-2.85(SO_3)$ (1)

Dicalcium silicate ($2CaO.SiO_2$):
$C_2S=2.8(SiO_2)-0.75(3CaO.SiO_2$ (2)

Tricalcium Aluminate ($3CaO.Al_2O_3$):
$C_3A=2.65(Al_2O_3)-1.69(Fe_2O_3$ (3)

Tetra calcium Alumino Ferrite ($4CaO.Al_2O_3$):
$C_4AF=3.04(Fe_2O_3$ (4)

2.2.3 Sandcrete Hollow Blocks (SHB) Production: The blocks were produced at the Department of Civil Engineering Laboratory of Bayero University, Kano, according to NIS 87:2004. Six water-cement ratios (0.35, 0.40, 0.45, 0.50, 0.55 and 0.6) and five mix ratios (1:6, 1:7, 1:8, 1:9 and 1:10) were employed for the production of the SHB specimens. The samples were cured by watering in the morning and evening and then covering them with cellophane paper.

2.2.4 Compressive Strength Test: The test on Sandcrete hollow blocks was performed at the Department of Civil Engineering Laboratory of Bayero University, Kano according to BS EN 12390-3 (2002).

2.2.5 Density Test: The density test was also performed at the Department of Civil Engineering Laboratory of Bayero University, Kano according to BS EN 772-13 (2000).

3.0 Results And Discussion

3.1 Sieve Analysis Result

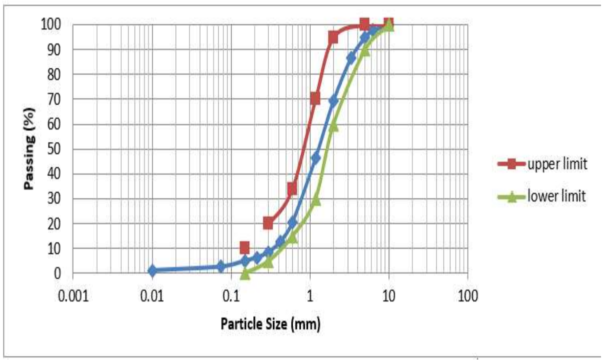

Figure 1: Particle Size Distribution of the fine aggregate

From Figure 1, the percentage of aggregates passing through various sieve sizes- 5mm: 93.67% (90-100%), 1.18mm: 43.04% (30-70%), 600µm: 20.51% (15-34%), 300µm: 7.34% (05-20%), 150µm: 3.24% (0-10%) are presented, the fine aggregate conforms to zone 1 in the Grading zone of BS 882: (1973) for fine aggregate grading requirements. According to NIS 87: 2004, the fine aggregate is a coarse fine aggregate which is highly suitable for block moulding.

3.2 Oxide Composition of the Cement

Table 1: Oxide Composition of the Cement

Ordinary Portland Cement	Chemical Oxides (%)
CaO	64.76
SiO_2	20.94
Al_2O_3	5.78
Fe_2O_3	3.95
SO_3	1.84
MgO	0.13
LOI	0.87
others	1.73
Total	100

Table 1 displays the percentage composition of the cement. Notably, the cement exhibits a substantial CaO content (64.7 %), consistent with the characteristics of Ordinary Portland cement. Other oxides include SiO_2 (20.94%), Al_2O_3 (5.78%), Fe_2O_3 (3.95%), SO_3 (1.84%), MgO (0.13%) and LOI (0.87%). The cementitious values, calculated using the Boque equations and derived from oxide composition for tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and tetra calcium alumina ferrite (C_4AF) are presented in Table 2.

Table 2: Cementitious Compound Percentages of the cement

OPC	Dangote Cement	BS EN 197-1:2000 Code range
C_3S (%)	52.74	42-67
C_2S (%)	22.06	08-31
C_3A (%)	7.31	05-14
C_4AF (%)	12.01	08-12

From Table 2, it can be seen that the cement used satisfies BS EN 197-1 (2000) requirements and is hence appropriate for the production of the SHB.

3.3 Effect of Water-Cement (W/C) Ratio on the Compressive Strength

The sandcrete hollow blocks were produced with a W/C ratio ranging from 0.3 to 0.6. The compressive strength results for each W/C are shown in Figure 2.

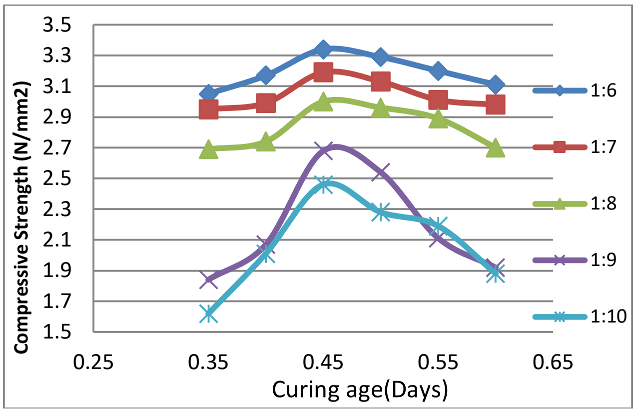

Figure 2: Variation of Compressive strength with W/C for each Mix ratio

From Figure 2, It is observed that the Mix ratio of 1:6 has the highest value of compressive strength values, followed by 1:7, 1:8, 1:9 and lastly 1:10. This is because 1:6 is the mix ratio with the highest cement content followed by 1:7 down to 1:10. With an increase in cement content, there is an increase in the production of Calcium-Silica-Hydrates (CSH) which is responsible for strength increase because as the hydration process advances, more CHS is produced because the cement reacts with water to form additional bonds leading to the development of more CHS gel. The increase in CHS contributes to the solidification and hardening of the sandcrete blocks, ultimately improving the strength of the block. This finding agrees with Okonko *et al.,* (2023). Furthermore, it is observed that increasing the water-to-cement ratio (W/C) from 0.3 to 0.45 improves the strength as sufficient water is provided for hydration product formation. However, surpassing 0.45 results in reduced strength, this is attributed to void formation due to excessive water in the mix. The optimal strength is observed at 0.45, beyond which there is a decline. This is because an excess of water makes the mix overly fluid, this compromises the cohesiveness of the mix and as the excess water evaporates, it leaves voids behind. This is in line with Panda *et al.,* (2020) findings.

3.4 Effect of Curing on the Strength of the SHB

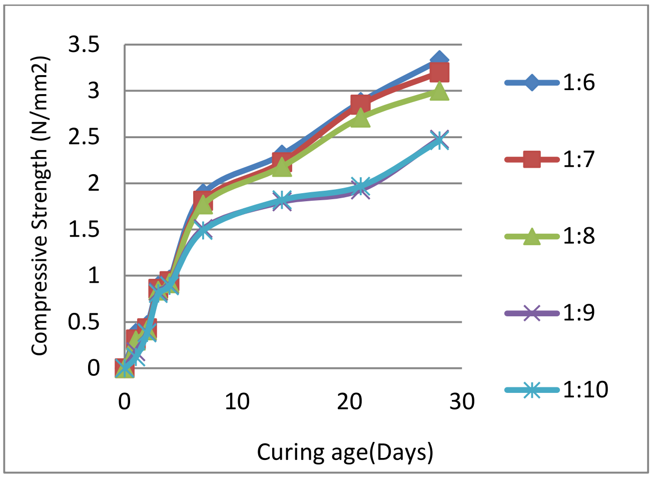

Figure 3: Compressive strength against curing age for different mix ratios

Figure 3 shows the variation of the compressive strength of the SHB against the curing age for each mix ratio (1:6 to 1:10) at the optimum W/C of 0.45. It can be observed that with an increase in the curing age, the compressive strength increases; this is because as the curing progresses, the water-filled spaces in the SHB matrix gradually get occupied by the hydration product in a gel form, this aligns with Sheikh *et al.,* (2017) findings. After a 28-day curing period, the results reveal that mix ratios of 1:8 (2.71N/mm^2), 1:7 (2.85N/mm^2), and 1:6 (2.88N/mm^2) meet the minimum strength requirement of 2.5N/mm^2 set by the NIS (2004) code of practice. Consequently, for commercial purposes, mix ratios of 1:8 and higher, with a water-to-cement ratio of 0.45 and 28-day curing, are recommended for the production of sandcrete hollow blocks. The recommendation and findings concur with Afolayan *et al.,* (2008) for mix ratios of 1:6 and 1:8.

3.5 Effect of the Mix Ratio on the Density of the Sandcrete Hollow Blocks

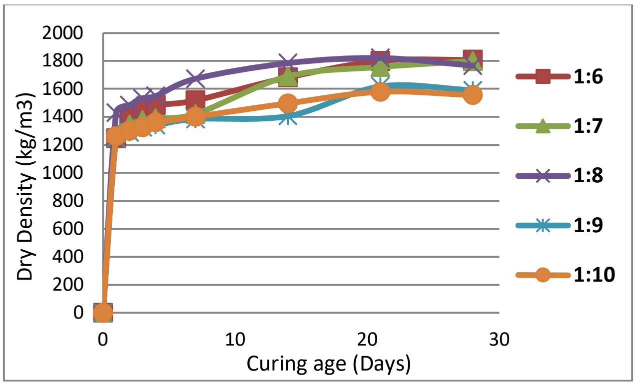

Figure 4: Density of the blocks against curing age for different mix ratios of the Sandcrete hollow blocks

Figure 4 presents the density results of SHBs across various mix ratios at different curing periods. Notably, mix ratios 1:6, 1:7 and 1:8 consistently exhibit the highest density values at all curing ages, reaching an approximate convergence at 1800 kg/m^3 after a 28-day curing period. In contrast, mix ratios 1:9 and 1:10 converged at 1600 kg/m^3 after the same curing period. This trend is attributed to the higher cement content in mix ratios 1:6, 1:7 and 1:8 which resulted in a denser matrix due to the presence of more hydration product (CSH). For the other mix ratios, the lower density values can be attributed to the reduction in cement and hence lower hydration products. According to Desmond *et al.,* (2013), the lower density values could also be because cement is a component of SHB with higher specific gravity when compared with the fine aggregate, therefore a reduction in the cement would lead to a reduced SHB weight and by extension the density.

4.0 Conclusion and Recommendation

4.1 Conclusions

From the results presented, the following conclusions were drawn:

1. The fine aggregate and cement used for the study satisfy the requirements for use as a sandcrete block production material.
2. The density of the sandcrete-hollow blocks falls within the range of densities for sandcrete blocks specified by BS 2028 (1983).
3. To enhance the strength and quality of Sandcrete blocks, it is essential to increase the cement content and extend the curing age.
4. The optimum ratio of water to cement for Sandcrete-hollow-blocks production was obtained as 0.45.

4.2 Recommendation

1:8 is recommended as the least mix ratio in terms of cement content to be used for the production of sandcrete blocks in compliance with BS 2028 (1983).

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