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Research Article

Investigation into the Mechanical Properties of Commercial Sandcrete Blocks Produced in Nigeria: A Case Study of Warri Metropolis

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ABSTRACT

This study investigated the extent to which the mechanical strength of commercially produced sandcrete blocks in Delta State, Nigeria, conforms to recognized international standards. Fifty sandcrete blocks (28 curing days) were sampled from ten known sandcrete block manufacturers in Warri municipal area, five blocks from each manufacturer. The compressive strength of the blocks was determined in accordance with the American Society for Testing and Materials (ASTM) International guidelines. The results showed that the compressive strength of all the blocks failed to meet the Nigeria Industrial Standard (NIS) benchmark for load loading sandcrete block, while only 20% of the blocks attained NIS requirement for non-load bearing walls. Field observation revealed that poor mixing ratio of the sandcrete; inconsistencies in the batching method and sand used in the production of the sandcrete blocks were responsible for the poor quality (low compressive strength) of the sandcrete blocks manufactured in the region. The findings of this study underscore the importance for the Nigerian Institution of Structural Engineers, to rigorously monitor the strength of sandcrete blocks made in Nigeria to ensure that their quality meets internationally recognized standards. This will reduce the occurrence of structural damage in Nigeria, due to the use of low quality blocks for wall construction.

Keywords: *Agricultural structure, Housing shortage, Quackery, Quality control, Sandcrete blocks*

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INTRODUCTION

Nigeria is currently facing a significant housing deficit. The housing shortage problem is mostly caused by the poor economic situation, urbanization/industrialization, increased in population growth, and inadequate investments in the real estate sector. The Federal Mortgage Bank of Nigeria (FMBN), an institution responsible for the provision of affordable housing in Nigeria, stated that Nigeria currently lacks about 21 million housing units, which may increase to 28 million by 2050 if appropriate actions are not taken (Adenikinju, 2019). Adequate safe, conducive, accessible and affordable housing is a fundamental human right as stated laws of the United Nations. Additionally, Article 11(1) of the International Covenant on Economic, Social and Cultural Rights (ICESCR), enshrines the Right of every person (individual) to an adequate standard of living without unsafe housing (ICESCR, 1996; UN Habitat, 2001). Similarly, Goal 11 of the Sustainable Development Goals encourages sustainable accommodation for people without discrimination.

Affordable but standard building materials will play an indispensable role in overcoming the accommodation problem in Nigeria. It is necessary to recognize that using counterfeit/fake composite parts during civil engineering structures construction tends only not to compromise their integrity and the safety of their occupants, but also has long-term economic and societal consequences. It is therefore imperative for the sustainability of infrastructural development in Nigeria to address this important issue (Uguru and Obukoeroro, 2020; Ihemegbulem *et al.*, 2022). Materials selection is one of the critical aspects in the construction industry, and this process requires serious attention to achieve the specific project requirements. Therefore, engineers need to consider this factor seriously, to ensure that sandcrete blocks and other concrete materials used for the construction of buildings comply with international and local building codes/standards (Erakpoweri and Onah, 2022). Sandcrete block which is a masonry unit is made from sand, cement and water; the cement acting as the binder from the composite material, while the water hydrates the cement which lead to chemical reaction that binds the sand and cement together (Sholanke *et al.*, 2015; Awolusi *et al.*, 2021). The percentage of the sand, cement and water used to produce the block can vary, and this variation is dependent on the specific requirements for the desired mechanical properties of the blocks (Akpokodje *et al.*, 2021). Sandcrete blocks have become popular building material in most African countries, due to their cost-effectiveness, availability, ease of production, and relatively good structural properties (Baidenand and Tuuli, 2004). Farm structures faced severe environmental conditions-moisture content, chemical reactions from agricultural chemicals, wide temperature fluctuations, and physical stress-in most cases. Most farm structures are built with various forms of the sandcrete blocks, making the quality of sandcrete blocks an issue of paramount interest, since building structures with poor quality materials have serious negative long-term effects (Agbi *et al.*, 2020). Since most farm structures are unframed structures built with poor quality wall materials (low load-bearing elements), the walls lack the required compressive strength and structural integrity, leading to cracks in the walls and eventually failure of the structure (Kashani *et al.*, 2023).

The preference for commercially (mass) produced sandcrete blocks in building works in Nigeria is really overwhelming, as developers seek to the bridge housing deficit in the country (Agbi *et al.*, 2020). Numerous scientific investigations have been conducted to appraise the engineering properties of sandcrete block that are mass-produced in the African continent (Ajao *et al.*, 2018; Akpokodje *et al.*, 2021; Ogunbayo and Aigbavboa, 2021). They noted that the engineering behaviors of these composite blocks were strongly influenced by the type and quantity of aggregates and cement used in the sandcrete blocks production. According to Esegbuyota *et al.* (2019), the sandcrete block mix ratio, curing methods and the presence of admixture significantly affect the mechanical properties and durability of the products produced.

Proper quality control and testing procedures are critical to achieving the desired performance and durability of these materials in construction (Rubaratuka, 2008; Schabowicz, 2021). Despite numerous investigation into the quality (in terms of mechanical strength) of blocks produced in Nigeria (Onwuka *et al.*, 2013; Odeyemi *et al.*, 2018; Ambrose *et al.*, 2019), literature search revealed no results on recent appraisal of the compressive strength of commercially produced sandcrete blocks within Warri metropolis. Therefore, this research was conducted to access the compressive strength of commercially manufactured sandcrete blocks in Warri metropolis of Delta State, Nigeria. Warri is one of major commercial cities in Nigeria with a lot of residential, industrial and farm structures. Hence, the information provided by this research will help to monitor the quality of building materials used in Nigeria.

MATERIALS and METHODS

Study area

This research was conducted with Warri metropolis of Delta State, Nigeria, as shown in Figure 1. Warri is the largest city in Delta state and also a major oil hub of Nigeria, with a population of approximately 400,000 people (DSG, 2015). Geographically, the study area is located between latitudes 5˚30′ and 5˚35′ North and longitudes 5˚29′ and 5˚48′ East. The area is located in the tropical region of Nigeria with moderate temperature and high annual rainfall (about 1800 mm per annual) that is widely distributed across the year (Efe and Ojoh, 2013; Uguru *et al.*, 2023). The Warri metropolitan area can be confidently classified as a commercial, industrial and educational center. The city has several tertiary institutions, medium and large-scale businesses, and urban markets; hence, there are lots of buildings constructions in new residential and industrial layouts.

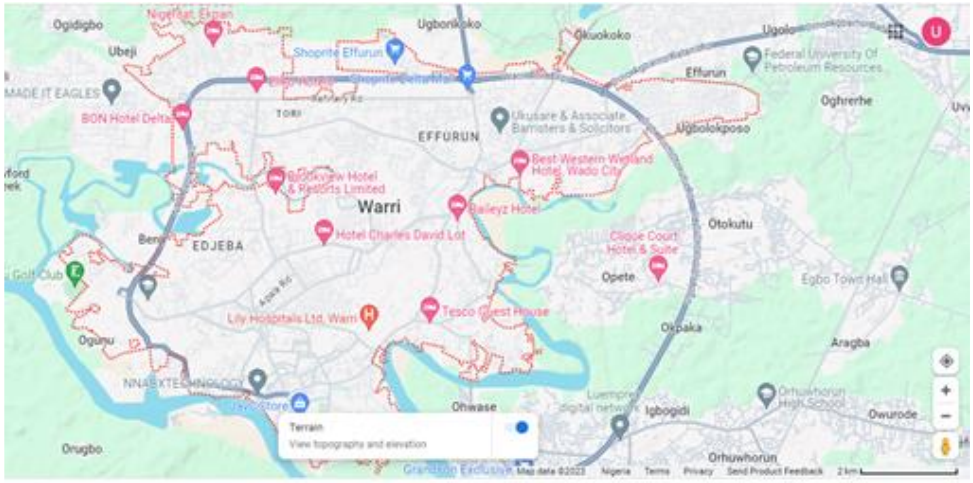

Figure 1. *Warri and its environs map (Goggle Map, 2023).*

Samples collection

A total of fifty books were sampled from 10 block producing industries (Figure 2) within the metropolis, 5 blocks per industry. Additionally at each block moulding industry, 2 kg of sand was taken for sieve analysis, to determine the suitability of the sand for sandcrete blocks production. The blocks were cured by watering twice a day.

Figure 2. *A sandcrete blocks producing industry.*

Block production and field observations

The observations made during the field survey are presented in Table 1. It was noted from the field observations that seven out of the ten industries visited used mechanical sandcrete mixers and vibrating block moulding machines for their sandcrete block production. This method increases the mechanical strength of the blocks, since vibrated blocks tend to have higher compressive strength than non-vibrated blocks (Akpokodje *et al.*, 2021).

In all the blocks industries visited within the study area, batching was done by volumetric methods with a lot of inconsistencies in dosing. An inconsistent mix ratio can lead to variations in the rate at which these blocks absorbed compression force, resulting in a reduction of the effective life span of the sandcrete blocks (Akpokodje *et al.*, 2021). Furthermore, it was noted during the on-the-spot assessment that all the blocks industry supervisors did not adhere to any water-cement ratio, as water was added to the mix arbitrarily based on the discretion of the sandcrete blocks moulders. This singular act will affect the quality of the blocks produced since water-cement ratio is an essential factor in sandcrete technology. It plays a vital part in determining the mechanical properties of blocks produced, irrespective of the batching or mixing method adopted.

Table 1. *Sandcrete blocks production method.*

Block industry	Cement-sand mix ratio	Water-cement mix ratio	Site manger	Mixing method	Batching method
1	1:10	N	Engineer	Mechanical	Volumetric
2	1:12	N	Mason	Manual	Volumetric
3	1:14	N	Mason	Mechanical	Volumetric
4	1:12	N	Mason	Mechanical	Volumetric
5	1:10	N	Mason	Mechanical	Volumetric
6	1:12	N	Mason	Manual	Volumetric
7	1:14	N	Mason	Manual	Volumetric
8	1:10	N	Mason	Mechanical	Volumetric
9	1:12	N	Mason	Mechanical	Volumetric
10	1:14	N	Mason	Mechanical	Volumetric

N = not determined

Laboratory analysis

Sieve analysis

The sieve analysis of the 10 soil samples collected from the various sandcrete blocks moulding centers, was carried out in harmony with the procedures recommended by ASTM C136 (2006) . Then the major coefficients-uniformity (C_U) and curvature (C_C) values of the sand based on USCS guidelines, were calculated through Equations 1 and 2 respectively. These two coefficients provide meaningful information about the particle size distribution pattern of the soil (Eboibi *et al.*, 2022).

$$Cu = \frac{D_{60}}{D_{10}} \quad (1)$$

$$Cc = \frac{(D_{30})^2}{D_{60} \times D_{30}} \quad (2)$$

Where: D_{60} is the volume of 60% finer soil particles, and D_{10} is the volume of 10% finer soil particles (USCS, 2015).

Compressive test

The compressive strength of the blocks on 28th day of curing was determined in agreement with techniques approved by ASTM C39 / C39M (2014), by using a digital concrete strength testing machine (manufactured in China, model: STYE 2000).

During the test, each block was clamped in the crushing chamber of the machine (Figure 3), and the blocks were compressed at a rate of 10 mm min^{-1} until failure of the block occurred. Thereafter, the sandcrete block compressive strength value was calculated through the formula presented in Equation 3 (Akpokodje and Uguru, 2019).

$$\text{Compressive strength (MPa)} = \frac{Force\ (N)}{Area\ (mm^2)} \quad (3)$$

Figure 3. *Sandcrete block undergoing compressive strength testing.*

Statistical analysis

The results were statistically analysis-using the mean as a statistical tool-with the aid of Microsoft for Excel-2019 version. Thereafter, mean compressive strength values were plotted using the appropriate bar chart.

RESULTS AND DISCUSSION

Soil particle size grading (PSD)

The PSD curves from the sieve analysis of the various sand samples collected from the blocks industry are displayed in Figure 4, and their coefficients of uniformity and curvature are presented in Table 2. Sieve analysis of one of the geotechnical tests carried out on sand to determine its suitability for various construction applications, including concrete and sandcrete blocks production. Table 2 shows that 70% of the fine aggregates used to make the blocks were poorly graded sand "PGS", while only 30% of the fine aggregates were well graded sand "WGS", using the Unified Soil Classification System (USCS) guidelines. Well-graded soils have a wide range of particle sizes and are considered more stable and less susceptible to settling or segregation (USCS, 2015). The Nigeria Industrial Standard (NIS) recommends WGS for concrete and sandcrete blocks production, as sandcrete blocks made from WGS

tend to have better (higher) compressive strength, compaction and resistance to settlement (NIS-87, 2005).

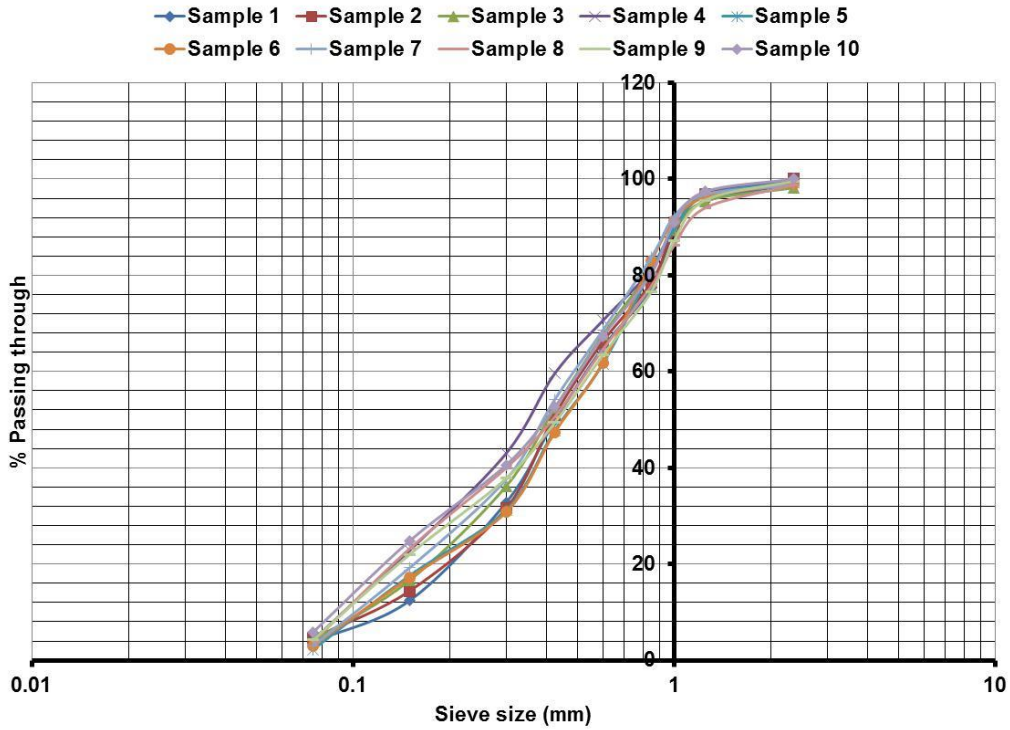

Figure 4. *Soil particle size distribution curves.*

Table 2. *Grading of the soil samples according to USCS.*

Soil sample	Cc	Cu	Fines	USCS grading
Sample 1	1.33	4.58	3.8	PGS
Sample 2	3.55	4.72	4.6	PGS
Sample 3	2.45	5.00	4	PGS
Sample 4	1	4.00	4.2	PGS
Sample 5	1.55	6.00	2.2	WGS
Sample 6	1.81	5.27	3	PGS
Sample 7	1.23	5.1	3	PGS
Sample 8	0.77	6.3	3.8	WGS
Sample 9	0.81	6.5	4.2	WGS
Sample 10	0.54	6.67	5.8	PGS

PGS = poorly graded soil, WGS = well graded soil

Compressive strength

Figure 5 shows the plot of the mean values of the sandcrete blocks' compressive strength at curing day 28. It was noted from Figure 5 that the blocks' compressive strength ranged from 0.76 to 3.42 N mm^{-2} across the 10 major sampling points. It was detected from the results that 100% of the blocks commercially produced within the Warri municipal area failed to meet the required NIS standard for load loading sandcrete block, while 80% of the sampled sandcrete blocks tested could not meet the international (NIS) condition for non-load bearing walls. The NIS and SON

recommendations for building materials state that, the lowest permissible compressive strength of sandcrete blocks for non-loading wall construction is 2.5 N mm^{-2}, while blocks for load bearing walls should have a minimum compressive strength of 3.5 N mm^{-2} (NIS-87, 2005). These results are similar to those obtained by Aiyewalehinmi and Tanimola (2013), Onwuka *et al.* (2013) and Yusuf *et al.* (2017), where the compressive strength of sandcrete blocks from other regions of Nigeria are consistently below the NIS/SON recommended values of 2.5 and 3.5 N mm^{-2} for load and non-load bearing walls respectively.

The poor quality of the blocks produced by these sandcrete blocks producers could be linked to the poor formation of these blocks manufacturers, the quality of the fine aggregates used, and blocks production method adopted. The poor quality of the blocks produced by most of the block's industry sampled could be partially attributed to the poorly graded soils that were used as a primary material during the sandcrete blocks production (Omoregie, 2013). The geotechnical properties of the sand used in the production of sandcrete blocks usually have a significant impact on the quality (mechanical properties) of the final product (blocks) produced. According to Akpokodje *et al.* (2021) reports, cement-composites (concrete or sandcrete) produced from poor quality fine aggregate tend to develop lower compressive strength, when compared to their counterpart produced with high quality fine aggregates.

Furthermore, the quantity of cement used in sandcrete block production plays a critical role in the final strength developed by block (Ewa and Ukpata, 2013; Alejo, 2020). Consequently, the poor compressive strength generally recorded in all the block moulding sites could be linked to the poor cement-sand mix ratio (1:10 and above) used by all those responsible for making their blocks. Sholanke *et al.* (2015) in their reports stated that, the mechanical behaviors of sandcrete block are inversely proportional to its cement content. It is very unfortunate that majority of the sandcrete block industry producer in Nigeria internationally altered the standard (NIS approved mix ratios of 1:6, 1:8 and 1:10) sandcrete block mix design ratios to maximize their profit, thereby exploiting their customers and lowering the integrity of the blocks produced. Therefore, the sand-cement and water-cement ratios should be strictly controlled to ensure that the blocks have the desired strength and durability.

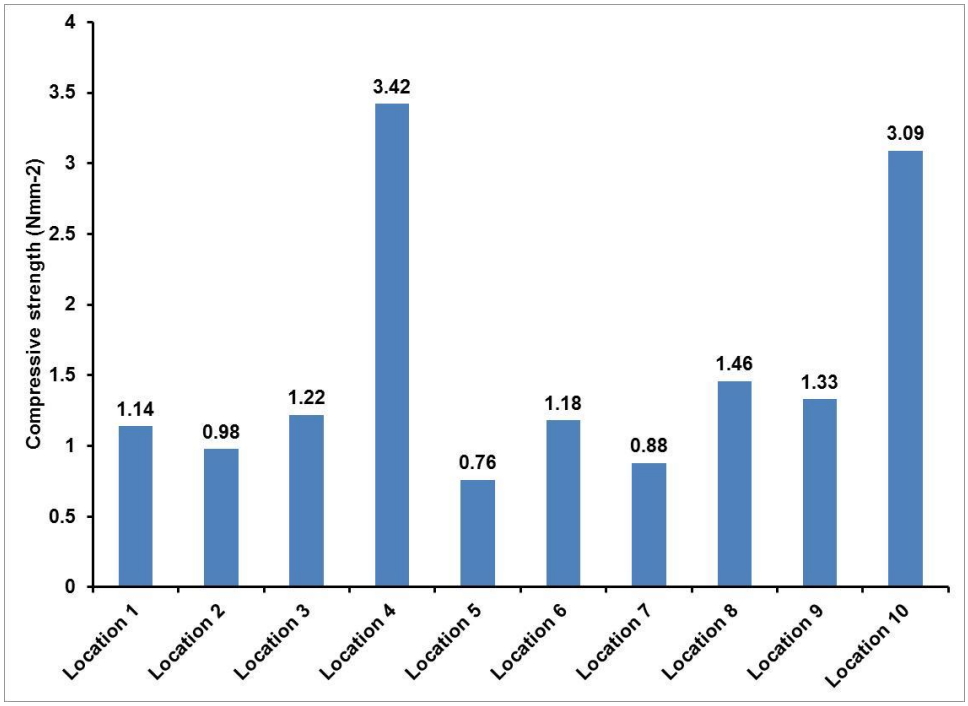

Figure 5. *The sandcrete blocks compressive strength results.*

The identification of poor sandcrete mix ratio, inconsistencies in the batching method, and the use of poorly graded sand as contributing factors to the low quality (low ability to absorb compression loading) of the sandcrete blocks is a very significant finding. These factors can have a substantial impact on the overall performance and structural integrity of the blocks. This study's findings emphasize the significance of consistence monitoring of the sandcrete blocks produced in the region, to check their compliance to international/local approved standards. Load-bearing blocks are vital components of an unframed structure, as they provide the structural support for the building. Therefore, the use of substandard blocks in the construction of unframed building raises potential issues regarding the integrity and reliability of the building.

CONCLUSION

This work was conducted to evaluate the compressive strength of sandcrete blocks manufactured in Warri metropolis of Delta State, Nigeria; and evaluate their compliance with international building materials standards. 50 sandcrete blocks were randomly sampled from the study area, and their compressive strength was determined in harmony with ASTM International approved methods. The findings obtained through the laboratory test indicated that 100% of the sandcrete blocks sampled failed to meet Nigeria Industrial Standard (NIS) requirement - compressive strength of 3.5 N mm^{-2} for load bearing walls, while only 20% of the sandcrete blocks complied with NIS recommendation -compressive strength of 2.5 N mm^{-2} for non-load bearing walls. Compressive strength is an essential material when selecting building wall materials, as it specifies the capacity of the wall building material to withstand axial loads.

The results of this study have highlighted the necessity of regular monitoring of sandcrete blocks produced in the region, to ensure that block producers prioritize quality over short-term profit maximization. Furthermore, more research should be conducted to explore sustainable alternative materials, which can produce sandcrete blocks with better compressive strength without compromising their standards and cost-efficiency.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no conflict of interest

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.
Oderhowho Nyorere: Designed the research and writing the original draft.
Moses Akwenuke: Edited the manuscript.
Otaghogho Zion Tachere: Designed the research Methodology and writing of the original draft.

ETHICS COMMITTEE DECISION

This article does not require any ethical committee decision.

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