Paper Number: NSE-ABJ-23-006D

Manufacturing Processes and Statistical Analysis of Sandcrete Blocks Produced in Minna

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Abstract
The increasing incidence of building collapse in Nigeria has raised concerns about the quality of building materials, necessitating the review of the block manufacturing process for enhanced quality control. This study focused on assessing the quality of commercially produced Sandcrete blocks in Minna, Niger State. Statistical analysis, including sampling, and laboratory experiments, was employed to evaluate the blocks' compliance with the Nigeria Industrial Standard for Sandcrete block. Results revealed that the sampled blocks exhibited dimensions, compressive strength, and water absorption capacity below the specified standards. Regression analysis showed a significant negative relationship between block dimensions and compressive strength. The findings indicate a clear need for improved manufacturing processes, stricter quality control measures, and adherence to the recommended standards to ensure the production of sandcrete blocks with adequate compressive strength for safe and reliable construction.

Keywords. *Minna, Nigerian Industrial Standard, Sandcrete Blocks, Statistical Analysis, Quality Assessment*.

1. INTRODUCTION

The strong economic growth in West African countries, particularly Nigeria, has led to a surge in construction projects due to the increasing need for infrastructure development. As a result, there is a high demand for affordable housing since having a home is now seen as a necessity rather than a luxury. To address this, there is a growing focus on using low-cost building materials. In Nigeria, one popular and cost-effective material for building walls in homes, offices, and factories is the Sandcrete blocks. These blocks are widely used in the construction industry because they are affordable and practical. Sandcrete blocks are a mixture of cement, fine aggregates, and water, which are combined and shaped into different sizes (Barr, 1999). They are widely used in Nigeria and other African countries for constructing walling units and below-ground drainages. In Nigeria, these blocks are available in various sizes and can be either solid-filled or rectangular hollow pieces. The hollow blocks are commonly used and readily accessible (Ewa & Ukpata, 2013). They have multiple applications, including constructing load-bearing and non-load-bearing structures, partitions, construction site hoarding, fencing, and creating barriers. Sandcrete blocks offer benefits such as thermal, airborne, and sound insulation in buildings, making them a preferable choice over clay bricks. Their lightweight nature enables the production of larger units, resulting in faster construction and assembly of building structures. These blocks can be easily cut, shaped, and allow for the convenient installation of screws and nails (Oyekan & Kamiyo, 2011).

Blocks have been manufactured in various parts of Nigeria without proper consideration of local building requirements or ensuring good quality work (Oyekan & Kamiyo, 2008). However, in 2000, the Nigerian Industrial Standard for sandcrete blocks was introduced (NIS 87, 2000). The main objective of this standard was to regulate the quality of blocks by ensuring that all factories adhere to minimum requirements. It also serves as a reference document for producing Sandcrete blocks in Nigeria. In 2004, the document underwent a review, and the latest review took place in

2007, resulting in the current standard document for Sandcrete blocks in Nigeria (NIS 87, 2007). The increasing occurrence of building collapses in Nigeria has raised significant concerns regarding the quality of commonly used construction materials, including Sandcrete blocks. It is essential to continuously assess their suitability for construction purposes, considering that they contribute to over 90% of the physical infrastructure in Nigeria (Anthony *et al.*, 2015; Baiden & Tuuli, 2004). Of particular interest is the quality of Sandcrete blocks when used in the construction of load-bearing walls. According to NIS 87 (2000), it is recommended that individual non-load-bearing blocks should have a minimum compressive strength of 2.5N/mm^2, while load-bearing units should have a mean value of 3.45N/mm^2. This highlights the importance of ensuring adequate compressive strength in Sandcrete blocks to meet the required standards for different construction applications.

However, prior research conducted by Abubakar and Omotoriogun (2022); Abdullahi (2005); Tsado *et al.* (2015); and Yusuf *et al*. (2017) in Minna, Niger State, revealed that the quality of sandcrete blocks was consistently poor and did not meet the recommended standards set by the Nigerian Industrial Standard. The use of substandard blocks in construction can lead to the development of cracks in buildings, especially when they are used for load-bearing units. Additionally, in areas prone to high levels of moisture, the porosity of blocks increases, causing them to weaken and eventually fail. According to Omopariola (2014), the significant increase in the cost and demand for cement has had numerous effects on the cost of building blocks. As a result, many commercial block producers have compromised production standards in an attempt to maximize profits and produce affordable blocks. This compromises the overall quality and durability of the blocks. In the context of the Nigerian construction industry, there exists a research gap regarding the comprehensive assessment of the quality and performance of commercially produced sandcrete blocks. Previous studies; Abubakar and Omotoriogun, 2022; Abdullahi (2005); Tsado *et al.* (2015); and Yusuf *et al.* (2017) conducted in Minna, Niger State, have highlighted the poor quality of these blocks and their failure to meet the standard recommendations set by the Nigerian Industrial Standard. However, there is a lack of comprehensive investigations that specifically examine the strength, durability, and suitability of sandcrete blocks for various construction applications.

To bridge this research gap, this study aims to conduct a thorough quality assessment of commercially available sandcrete blocks in Minna. By employing statistical analysis, we can quantitatively evaluate the key characteristics, such as compressive strength, water absorption, and dimensional properties of the blocks. This will provide valuable insights into the quality of sandcrete blocks in the local market and enable a better understanding of their performance in construction applications.

2. MATERIALS AND METHOD

The method adopted for carrying out this study include laboratory experiments and statistical analysis. The analysis of the result obtained from the laboratory experiment was compared with the standard specifications of the Nigerian standard for Sandcrete blocks (NIS 87, 2007 and NBC, 2006). The correlations observed informed the conclusion of the study.

2.1 Laboratory Experiment

A total of eighty (80) nine inches hollow Sandcrete blocks five (5) each from sixteen (16) selected manufacturing factories in Minna metropolis was collected for the experiment. The laboratory experiment conducted on the block samples include block measurement, water absorption capacity and compressive strength tests. The procedures adopted in conducting these experiments are detailed as follows.

2.1.1 Block Measurement

The standard measuring procedure as specified in NIS 87 (2007) was followed. The samples were prepared by scraping off outcrops and redundant materials adhering to the surface before the length, width, and depth was measured using a measuring tape. The thickness of shells and web was measured by means of a Vernier calliper. The block dimensions obtained were compared with the standard specification for dimensions as provided by the NIS 87 (2007) and NBC (2006).

2.1.2 Water Absorption Capacity

The sandcrete block samples where sun dried until there was no further loss in their dry weight. The block samples were then weighed in their dry state to obtain dry mass (M_1). The blocks were then fully immersed completely in clean water under room temperature for 24hours after which the block samples were removed and reweighed to obtain the wet mass (M_2) as per ASTM C140 (2013). The procedure was repeated on all other samples and the water absorption capacity was computed from Equation 1.

$$W_c = \frac{M_2 - M_1}{M_1} \qquad (1)$$

Where: W_c = Water absorption capacity

M_1 = Mass of dry block before immersion

M_2 = Mass of wet block after immersion

The mean value of three (3) blocks obtained for each factory was regarded as the water absorption capacity and shall not exceed 12% (NIS 87, 2007).

2.1.3 Compressive Strength Test

The compressive strength of the block samples was determined by crushing as per BS 5628:1 (1992), this was carried out on all blocks obtained from the different factories. The blocks were weighed and a metal plate was placed underneath the block and gently placed between the plates of the crushing machine, another plate was also placed at the top of the block, thus to ensure uniform distribution of the load around the surface area of the block. The machine was switched on and load was applied at a constant rate until failure. The maximum load at which failure occurred was read and recorded, the load at failure was taken as the maximum load at which the specimen fails to produce any further increase in the indicator reading on the testing machine. The compressive strength of each block sample in N/mm^2 was calculated from Equation 2 as shown below

$$= \frac{Maximum\ load\ at\ failure\ (N)}{Cross\ sectional\ Area\ of\ block\ (mm^2)} \quad (2)$$

The mean value obtained was taken as the compressive strength of blocks from each factory and shall not be less than 3.45N/mm^2 for load bearing hollow Sandcrete blocks and 2.5N/mm^2 for non-load bearing hollow Sandcrete blocks produced mechanically (NIS 87, 2007).

2.2 Descriptive Statistics

Descriptive statistical analysis was performed to summarize the characteristics of the collected data. Measures such as mean, standard deviation, minimum, maximum, and other relevant statistics were calculated for the compressive strength.

2.2.1 Hypothesis Testing

i. Alternative Hypothesis for Mean Compressive Strength

The study aimed to investigate whether the mean compressive strength of sandcrete blocks in Minna differed significantly from the recommended mean compressive strength. The following null and alternative hypotheses were formulated:

Null hypothesis (H_0): The mean compressive strength of sandcrete blocks in Minna is not significantly different from the recommended mean compressive strength.

Alternative hypothesis (H_1): The mean compressive strength of sandcrete blocks in Minna differs significantly from the recommended mean compressive strength.

To test these hypotheses, a two-sample t-test was performed using the collected data. The significance level was set at $\alpha = 0.05$. The test statistic and p-value were calculated to determine whether there was sufficient evidence to reject the null hypothesis and support the alternative hypothesis.

ii. Alternative Hypothesis for the Effect of Block Dimensions

Another objective of the study was to examine the relationship between block water absorption, block dimensions (length, width, height, web thickness) and the compressive strength of sandcrete blocks produced in Minna. The following null and alternative hypotheses were formulated:

Null hypothesis (H_0): There is no significant association between the water absorption, block dimensions and the compressive strength of sandcrete blocks produced in Minna.

Alternative hypothesis (H_1): There is a significant association between the water absorption, block dimensions and the compressive strength of sandcrete blocks produced in Minna.

Multiple linear regression analysis was conducted to investigate this relationship. The regression coefficients, p-values, and the coefficient of determination (R-squared) were calculated. The significance of the regression model and the individual coefficients was assessed to determine the presence and strength of the relationship between block dimensions and compressive strength

3 RESULTS AND DISCUSSION

3.1 Block Dimensions

The result of this test as shown in Table 1 shows that the minimum dimensions in terms of length, width and depth of all block factories are within the specified dimensional tolerance by NIS 87 (2007) in terms of length, breadth and height. However, none of the factories met the minimum required web thickness of 50mm as specified except factory L and R recording a mean web thickness of 53.88 and 54.43mm respectively. Use of distorted moulds and improper tuning of the machine moulds are the primary causes of reduced web thickness. Reducing the web thickness may save material and cost but the volume and effective area available for resisting loads is essentially reduced consequently decreasing the density and compressive strength of the blocks.

Table 1: Mean dimension of sampled sandcrete blocks

Block Industry	Mean Length (mm)	Mean Width (mm)	Mean Height (mm)	Mean Web Thickness (mm)
A	458.0	231.2	230.6	38.60
B	456.2	228.2	230.6	40.68
C	459.4	229.6	230.0	36.25
D	458.6	228.8	230.0	39.46
E	457.0	230.8	228.6	41.27
F	453.8	228.6	228.2	40.01
G	453.8	225.2	226.0	40.02
H	455.0	225.2	230.0	40.27
I	457.2	229.4	230.6	36.81
J	459.6	229.6	229.6	37.62
K	456.0	227.0	226.8	36.97
L	460.6	231.5	230.5	52.01
Q	457.6	227.8	227.0	36.46
R	460.0	230.0	230.0	54.43
S	457.2	227.6	231.2	37.62
U	457.0	229.4	230.0	40.06

3.2 Manufacturing Processes

In the context of Sandcrete block manufacturing, this study explored the crucial elements of production processes. Across the 16 manufacturing industries examined and presented in Table 2, the use of the Rosacommetta-type electrical vibrating machine for moulding was standard practice, ensuring uniformity and efficiency. All industries consistently employed volume-based batching, utilizing wheelbarrows for precise sand measurements based on specific mix ratios.

However, a deviation from the NIS 87:2007-prescribed mix ratio of 1:8 was evident, with industries adopting mix ratios ranging from 1:14 to 1:18, potentially affecting block quality and structural stability. Manual mixing was universally practiced, leading to inconsistent mixing and cracks in fresh blocks. Therefore, the introduction of mechanical mixers for uniformity and homogeneity is recommended. Material choices included grade 42.5 Ordinary Portland Cement and variations in the source of fine aggregates, necessitating consideration for their compatibility with intended applications and structural integrity. These findings highlight the need for industry-wide assessment and adherence to recommended standards to ensure the production of high-quality Sandcrete blocks meeting construction criteria.

Table 2: Observed operations and response from block industries

Industry	Batching Method	Mix Proportion	Blocks Per Bag	Curing Period	Material Testing
A	Volume	1:19	46	3	No
B	Volume	1:18	42	3	No
C	Volume	1:16	42	3	No
D	Volume	1:16	40	3	No
E	Volume	1:18	45	2	No
F	Volume	1:16	42	2	No
G	Volume	1:16	40	3	No
H	Volume	1:14	36	3	No
I	Volume	1:18	45	3	No
J	Volume	1:18	45	3	No
K	Volume	1:16	42	3	No
L	Volume	1:18	45	2	No
Q	Volume	1:16	42	3	No
R	Volume	1:16	40	2	No
S	Volume	1:16	40	3	No
U	Volume	1:16	40	4	No

3.3 Water Absorption Capacity

The mean water absorption capacity of blocks from the selected factories is summarized in Figure 1. The mean water absorption capacities of all sampled blocks exceeded the standard value of 12% specified by NIS 87 (2007) except those from block-factories B, H, K and U.

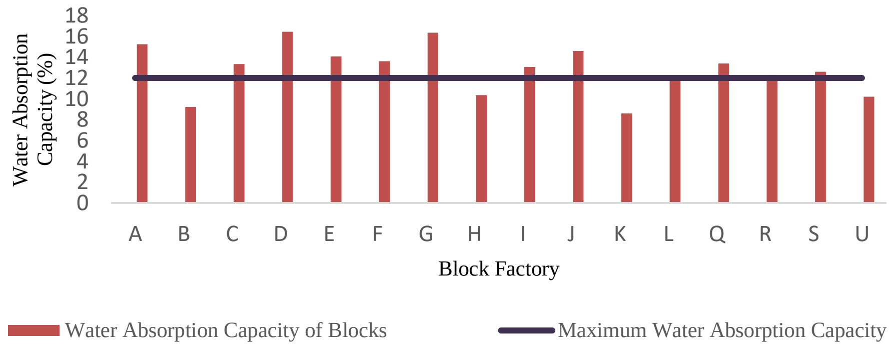

Figure 1: Mean Water Absorption Capacity

The mean water absorption capacity of the blocks ranged between 8.61-16.44%, blocks from D recording the highest water absorption capacity of 16.44% and K recording the least value of 8.61%. Poor mix ratio, inadequate curing, inadequate compaction and poor aggregate gradation are the causes of high-water absorption capacity of blocks.

3.4 Compressive Strength

The mean compressive strength of five (5) blocks from each factory is summarized in Figure 3

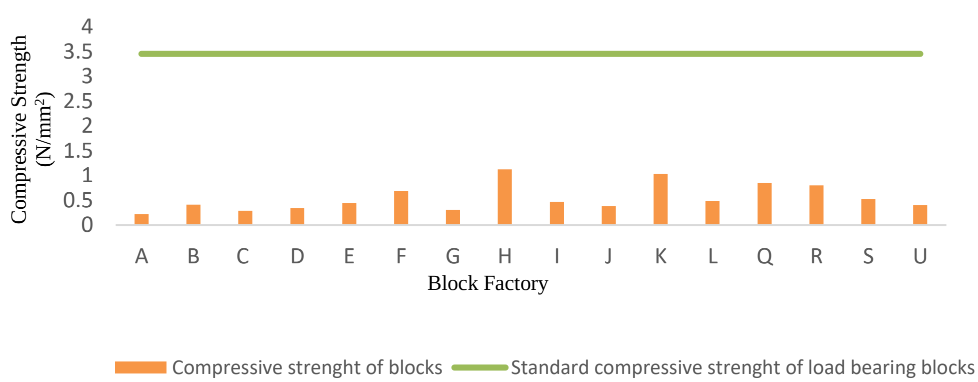

Figure 3: Mean Compressive Strength

The compressive strength of individual blocks ranged between 0.18- 1.26N/mm^2 and the mean compressive strength of five (5) blocks for each factory ranged between 0.27-1.12N/mm^2. Blocks from factory H recorded the highest mean compressive strength of 1.12N/mm^2 while those from factory A recorded the least value of 0.27N/mm^2. Granite fines was observed to be partly replaced for sharp sand in factory H, K, Q and R, hence blocks from these factories had better compressive strength than those produced from mixture of sharp sand and plaster sand only. This is due to the strong bonds that forms between granite and cement. However, these values are far below the standard specification of NIS 87 (2007) which stipulates that the lowest compressive strength of individual non-load bearing Sandcrete blocks shall not be less than 2.5N/mm^2 and average compressive strength of five (5) blocks shall not be less than 3.45N/mm^2. These values are also below the requirement of the Nigerian Building Code (2007) which recommends a minimum compressive strength of 2.0N/mm^2 for individual blocks. Similar trends were also observed in other parts of the country and reported (Ewa & Ukpata, 2013; Ambrose *et al.*, 2019; and (Odeyemi *et al.*, 2018)

Table 3: Descriptive Statistics of the Compressive strength

Mean	0.55
Standard Deviation	0.27
Kurtosis	0.04
Skewness	1.07
Range	0.85
Minimum	0.27
Maximum	1.12
Count	16

Based on these descriptive statistics as presented in Table 3, it can be concluded that the average compressive strength of sandcrete blocks in Minna is 0.55 MPa, with a moderate amount of variability around this mean value. The range of compressive strength values indicates differences in block quality among the 16 block industries.

A one-sample t-test was conducted to compare the mean compressive strength of sandcrete blocks in Minna (mean = 0.55 MPa) with the recommended mean compressive strength (mean = 3.45 MPa). The results revealed a highly significant difference between the two ($t(15) = 44.37$, $p = 2.54368E-17$). The observed mean compressive strength was significantly lower than the recommended value, indicating a potential quality concern.

Therefore, the null hypothesis (H_0) stating no significant difference between the mean compressive strength of sandcrete blocks in Minna and the recommended mean compressive strength is rejected. These findings support the alternative hypothesis (H_1) and suggest that the mean compressive strength of sandcrete blocks in Minna significantly differs from the recommended mean compressive strength.

These results underscore the need for further investigation and improvement in the manufacturing process of sandcrete blocks in Minna to ensure they meet the required strength specifications.

Table 4: Regression Analysis

Multiple R	0.75
R Square	0.59
Adjusted R Square	0.34
Standard Error	0.22
Observations	16

Table 5: Regression Model

	Coefficients	P-value
Intercept	16.04	0.28
Length (mm)	0.02	0.61
Width (mm)	-0.06	0.19
Height (mm)	-0.05	0.30
Web Thickness (mm)	0.01	0.38
water absorption	-0.06	0.04

From Tables 4&5, the regression model was not found to be statistically significant ($F(3, 12) = 0.099$, $p > 0.05$), indicating that the combined block dimensions did not significantly influence the compressive strength. The coefficient of determination (R^2) was 0.56, indicating that 56% of the variance in the compressive strength could be explained by the block dimensions.

Among the individual predictors, block length, block width, block height and the web thickness did not exhibit significant relationships with the compressive strength. However, the water absorption ($\beta = [0.044]$, $p < 0.05$) shows slightly significant relationship with the compressive strength. Thus, these results suggest that only water absorption had a significant impact on the compressive strength of sandcrete blocks produced in Minna. The block dimensions did not demonstrate significant associations with the compressive strength.

4 CONCLUSION AND RECOMMENDATION

Based on the statistical analysis performed on the data, several key conclusions can be drawn. Firstly, the mean compressive strength of the sandcrete blocks in Minna is significantly lower than the recommended mean compressive strength, indicating that the blocks do not meet the required standards set by the Nigerian Industrial Standard. The t-test results further support this finding, as they reveal a significant difference between the mean compressive strength of the blocks and the recommended value. However, the regression analysis does not indicate a significant relationship between block dimensions (length, width, and height) and compressive strength. This suggests that variations in block dimensions may not have a substantial impact on the compressive strength of the blocks. To address the quality deficiencies observed in the production of sandcrete blocks in Minna, several remedial measures should be considered. These measures include a focused effort on improving the manufacturing process, strict adherence to recommended standards, and the implementation of robust quality control practices throughout production. Continuous monitoring of the manufacturing process, including real-time testing and quality assurance checks, is crucial to ensure the consistency and reliability of sandcrete blocks. Furthermore, providing training and education to block manufacturers and workers, along with raising public awareness about the importance of using high-quality sandcrete blocks in construction, will collectively contribute to safer and more reliable structures in Minna

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