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QUALITY EVALUATION OF SANDCRETE BLOCKS PRODUCED IN SELECTED LOCAL GOVERNMENT AREAS OF KADUNA STATE, NIGERIA

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Abstract

Nigeria has witnessed problems in the construction industry such as the collapse of buildings which is a consequence of the use of substandard materials in building construction, poor supervision, negligence to standard code of practice, poor maintenance culture, and faulty design amongst others. Quality assurance and quality control are highly imperative to take cognisance of while examining building companies. This research examined the quality of nine-inch hollow concrete blocks produced using machine moulding in Kaduna Metropolis, which includes Kaduna North, Kaduna South, parts of Igabi, and parts of Chikun Local Government Areas in Kaduna State. The study employed a mixed research design method comprising experimental design and interviews. The result of the laboratory test carried out on the blocks showed the mean compressive strength of the blocks ranges from 0.21N/mm^2 to 0.62N/mm^2 which does not meet the minimum of 1.6N/mm^2 compressive strength provided by the Nigerian Industrial Standard (NIS) 87:2000. The bulk densities of the samples tested range from 1286kg/m^3 to 1537kg/m^3 and are below the minimum of 1,800kg/m^3 provided by NIS 87:2000. The result of the interview conducted across 32 block industries showed a complete ignorance of standards as block industries determine their standard based on market forces. Only 3% of the block industries complied with the mix ratio of 20-25 blocks per one bag of cement, and less than 10% carried out quality assurance checks such as weekly inspection of mould for wear and tear and taking measurements of the dimensions to ensure that it meets the standard. In all, only one of the block industries provided evidence of certification from the Standard Organisation of Nigeria (SON). The study further underscored the urgent need for enforcing industry standards in the production of hollow sandcrete blocks in the Kaduna metropolis.

1.0 INTRODUCTION

A house is a building usually made of wood, masonry concrete or other form of materials which served as a dwelling for man from time immemorial [1]. In Africa, houses were built with mud and thatch roofing to serve as shelter and protect man from weather such as rainfall and heat from the sunshine. Over time, with the incursion of people, especially Europeans, the materials for the construction of houses gradually change from mud and thatch roofing to block and corrugated roofing [2]. Sandcrete blocks are extensively utilized in Nigeria's construction sector, constituting over 90% of physical infrastructure. This material plays a pivotal role in building construction due to its widespread adoption [3]. The hollow blocks, known for their lightweight nature, offer significant

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cost savings in both foundation and superstructure design, as highlighted by [4]. In addition to Nigeria, sandcrete blocks are commonly employed as load-bearing and non-load-bearing walling units in neighbouring countries such as Ghana and other parts of Africa. Sandcrete blocks, made from sand, cement, and water, are commonly used in the construction of walls and structures [5].

They adhere to size and composition standards set by [6,7], with dimensions like 450 mm X 225 mm X 225 mm (Hollow) for load-bearing walls and 450 mm X 150 mm X 225 mm (Hollow) for non-load-bearing walls. They're defined as larger than bricks but not exceeding specific dimensions. Hollow and solid types are available, with the former having a void. Sandcrete block is strong when hardened, with a range of 2.5 N/mm2 to 3.45 N/mm2. Strength varies based on production methods, curing, size, and materials. They're cost-effective, durable, and environmentally safe, making them a preferred choice in construction [8]. Quality, often defined as "fitness for purpose" or meeting specifications, refers to the set of features needed by a product or service to fulfill stated or implied requirements [9]. [10] defines it as the characteristics that enable a product or service to satisfy needs. In manufacturing, it signifies excellence and freedom from defects, achieved through adherence to standards. Quality is a crucial factor in construction projects and plays a vital role in risk assessment [11].

Various research has been conducted on the quality of sandcrete blocks across different states in Nigeria and the majority of them were below standards. [12] assessed the quality of sandcrete hollow blocks in specific Local Government Areas within Kaduna Metropolis. Twelve industries were chosen through purposive sampling. The findings revealed that the average strength ranged from 1.84 N/mm² to 1.95 N/mm², with eleven out of twelve industries producing blocks with less than 2.0 N/mm² strength. The observed low-quality blocks were attributed to the mix ratio used, emphasizing the necessity for enhanced production techniques. [9] checked the blocks manufactured in many parts of Nigeria and found out that manufacturers struggled to achieve the intended outcome because of subpar quality control, inadequate material selection, and insufficient curing periods. The research conducted by [13], focusing on sandcrete blocks in the Calabar metropolis, uncovered that the compressive strengths at the 28-day mark fell within the range of 0.23N/mm² to 0.58N/mm². These values were lower than the minimum requirements specified in the Nigerian National Building Code, which are 1.75N/mm² for non-load-bearing walls and 2.0N/mm². [14] assessed block quality in Adeta, Ilorin West, Kwara State, Nigeria, comparing eight block factories to Nigerian Industrial Standards.

The findings revealed elevated absorption rates and compressive strengths below the minimum standards, suggesting that an insufficient mix ratio was a factor contributing to subpar quality. [15] investigated the compressive strength and statistical attributes of sandcrete blocks sourced from 25 block industries in Ondo State, Nigeria. Findings reveal subpar strength and compressive performance, suggesting deficiencies in quality control during production. [16] examined the compressive strength of sandcrete blocks in Delta. The study found that all the blocks failed to meet the Nigerian Industrial Standard's requirement of 2.5 MPa for non-load-bearing walls, mainly due to inadequate mix ratios. [17] examined sandcrete blocks from Enugu East, Nigeria. Samples from five block industries included sand, water, and 9" hollow sandcrete blocks. Testing at Enugu State University of Science and Technology covered sand and water quality. The water absorption exceeded limits and compressive strength tests after 14 and 28 days of curing fell below standards. [18] evaluated the quality control practices of commercial block manufacturers in the Yewa South Area of Nigeria.

The study employed visual inspection and laboratory testing to assess block quality. The research revealed that contractors lacked formal training in quality control, and factors such as mix ratio, quality, and curing method had an impact on the quality of sandcrete blocks. [19] conducted pilot experiments on sandcrete blocks in Owerri Municipal, Imo State, Nigeria. Compressive strength and water absorption were tested, using 35 hollow sandcrete blocks as control samples. Results didn't meet Nigerian Standards Institute (NIS) standards, indicating issues with production quality control and regulatory efficiency. [20] collected 18,000 Sandcrete masonry blocks (6 inches and 9 inches thick) from 300 block-making factories in Lagos, Ibadan, and Abeokuta, Nigeria. Results were compared to [7] standards. In Lagos and Ibadan, all blocks were substandard. However, in Abeokuta, 30% of 6-inch blocks and 50% of 9-inch blocks met the standard, making them ideal for construction. [21] conducted a study in Ifo, Ogun State, Nigeria, where they analyzed 18 sandcrete blocks from three production sites. Their findings indicated that while the aggregate material used was of good quality, the average compressive strength of 1.16 N/mm² fell short of the minimum standards. [22] experimented in three Nigerian states, an examination

of 54 sandcrete blocks revealed that a majority of them did not meet acceptable standards.

The findings in Lagos metropolis indicated that the compressive strength of blocks produced by manufacturers varied between 0.21N/mm^2 and 1.26N/mm^2 for 225mm thick blocks, and between 0.28N/mm^2 and 0.95N/mm^2 for 150mm thick blocks [23]. These values fall significantly below the minimum standard requirements of 3.45N/mm^2 and 2.5N/mm^2 for the respective block thicknesses. This was attributed to issues such as inadequate mix-design, subpar production methods, insufficient curing durations, and a lack of oversight from governmental agencies and professionals, which have been recurring themes in block production in Nigeria. Thus, it can be inferred that in the North-East, North Central, South-South, and South-Western regions of Nigeria, the production of sandcrete blocks does not meet the minimum requirements set by the Nigerian National Building Code (NNBC) and the Nigerian Industrial Standard (NIS) due to inadequate quality control measures [24].

Over half of the building collapses in both urban and rural areas in Nigeria are attributed to the use of manually crafted blocks [25]. Another 30% can be traced back to the use of substandard iron and steel, with the remaining cases being the outcome of unethical practices by certain contractors. To address the issue of poor-quality block production and reduce building collapses in Nigeria, the Standard Organisation of Nigeria (SON) in Ogun State is collaborating with the National Association of Block Moulders of Nigeria (NABMON) to improve block quality. However, it's worth noting that some block moulders evade SON officials, posing challenges to enforcing standards. This collaboration with the association is seen as a strategic approach to reach a wider range of block moulders and promote compliance with quality standards [26, 27].

[28] investigated the quality of commercial sandcrete blocks produced in Minna, Niger State, due to concerns over building collapses across Nigeria. The study involved field surveys, sampling, and laboratory tests on blocks from sixteen factories, assessing dimensional accuracy, water absorption, and compressive strength. Results indicated that the blocks fell short of standard specifications, with poor mix proportions, curing practices, and blockage observed in the factories. As a result, it was recommended that blocks produced in Minna should not be used for load-bearing walls. Similar results were also reported from the findings of [29, 30]. Thus, this research aims to determine the quality of sandcrete blocks produced in the Kaduna metropolis. The study tested the compressive strength of hollow sandcrete blocks and conducted interviews to gather information about block production standards, including mix ratio, water-cement ratio, compaction, production type (manual or machine), and knowledge of Nigerian Industry Standards.

2.0 METHODOLOGY

A mixed research design method was adopted for the study. The methods are experimental research design and interviews. Whereas the experimental research design was adopted ìn determining the compressive strength and density of the hollow sandcrete blocks to evaluate their structural integrity, interviews were conducted to ascertain basic knowledge of block production standards by the manufacturers such as standard mix ratio, water cement ratio, compaction, type of production that is manual or machine production and knowledge of Nigerian Industry Standards. Experimental research design helps in testing hypotheses by reaching valid conclusions about the relationship between dependent and independent variables [31, 32]. With the ever-growing population of the Kaduna metropolis and the continued expansion of the city, the two designs are adequate for the study.

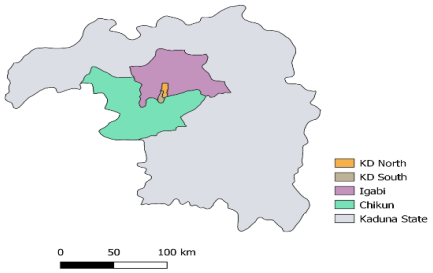

Figure 1: Map of Kaduna State showing Kaduna North, Kaduna South, Igabi and Chikun Local Government Areas

2.1 The Study Area

The study involved the collection of samples from sixteen (16) block industries located in the local government areas that constitute the Kaduna metropolis namely: Kaduna North, Kaduna South, parts of Igabi and Chikun Local Government Areas (Figure 1 to Figure 5) for laboratory experiment which was carried out at the Structural Engineering Laboratory located in the Department of Civil Engineering, Faculty of Engineering, Nigerian Defence Academy (NDA), Permanent Site, Afaka, Igabi Local Government Area of Kaduna State. Also, oral interviews were conducted by administering an online questionnaire via Google Forms to thirty two

(32) block industries within the aforementioned local government areas and the results were documented using Google Sheets.

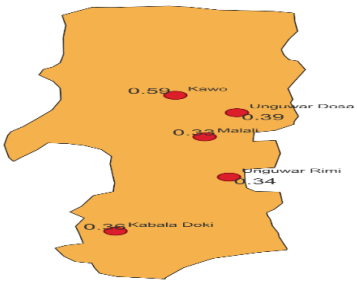

Figure 2: Map of Kaduna South Local Government Showing location of samples and corresponding Compressive Strength

Figure 3: Map of Kaduna North Local Government Showing location of samples and corresponding Compressive Strength

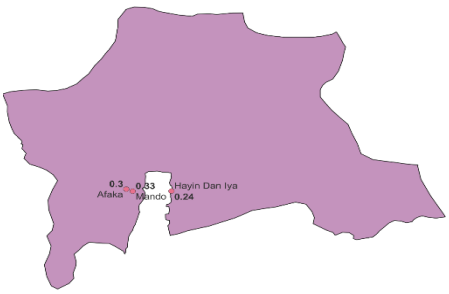

Figure 4: Map of Chikun Local Government with parts of Kaduna metropolis showing location of samples and corresponding Compressive Strength

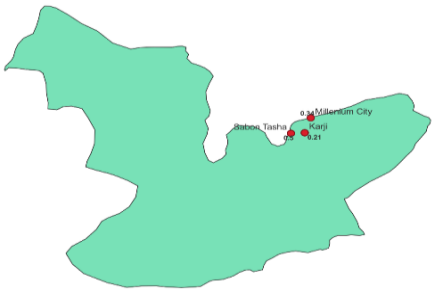

Figure 5: Map of Chikun Local Government (parts of Kaduna metropolis showing location of samples and corresponding Compressive Strength

2.2 Field Work and Laboratory Test

Out of the total sixteen (16) block industries visited for the collection of sample for laboratory analysis it comprise the following: five (5) from Kaduna North Local Government, five (5) from Kaduna South Local Government, three (3) from Chikun Local Government Area and three (3) from Igabi Local Government Area were visited for the collection of a total of eighty (80) units of 450mm x 225mm x 225mm (9") hollow sandcrete blocks for laboratory experiments. Pictures of some of the samples used for testing are shown in Figure 6.

Figure 6: Showing the block sample in form and inside the structural laboratory in the Department of Civil Engineering, NDA Afaka

It was observed that all the block industries use wheelbarrows to measure the amount of sand required to mix one bag of cement which varied from one block industry to another. No standard mix ratio was observed. The general is either $5^1/_2$ wheelbarrow to a bag of cement or 4, $4^1/_2$ or 5 as the case may be. The mixing is manual using a shovel. During sample collection and interviews, no industry was found to use a mixer. The hired labourers mix the cement and sand. The amount of water used is determined by the labourers carrying out the mix under the supervision of the person in charge of the industry. They use their initiative to ensure that it is not excessively watery. The amount of water is usually less during the wet season compared to during the dry season.

The mortar is poured into the mould and the machine compacts it to ensure the removal of air voids. Almost all the block industries cure their blocks using a hose connected to either a borehole, a reservoir or a well connected to a pumping machine. Some cure three times a day while others cure twice daily for a maximum of 3days as against a minimum of between seven (7) days specified by the National Building Code of the Federal Republic of Nigeria (2006) and the British Standard [33]. For some block industries that have less capacity, they fetch water in a bucket and use it to cure by pouring on the blocks.

2.3 Density Determination

The Density of the blocks was calculated as the weight of the block unit divided by the dimensional volume according to [34]. The process is shown in Figure 7. The density of the blocks is determined using Equation 1.

$$\text{Density} = \frac{\text{Mass of the block (Kg)}}{\text{Dimensional volume of block (m}^3\text{)}} \quad (1)$$

Figure 7: Density testing

2.4 Compressive Strength

The procedure involves placing the hollow sandcrete block in the testing machine and subjecting it to a compressive force until it fails, as shown in Figure 8. The maximum load sustained by the block during the test is recorded, and the compressive strength is calculated based on the cross-sectional area of the block, according to [35]. The strength is determined using Equation 2.

$$\text{Compressive strength} = \frac{\text{Maximum load (kN)} \times 1000}{\text{Cross- sectional Area (mm}^2\text{)}} \quad (2)$$

Figure 8: Compressive strength test

2.5 Test Procedure and Results Computation

Results of the experiment were obtained in accordance with standard computations [29,7]. The procedure involves placing the hollow sandcrete block in the testing machine and subjecting it to a compressive force until it fails. The maximum load sustained by the block during the test is recorded, and the compressive strength is calculated based on the cross-sectional area of the block.

2.6 Oral Interview

The oral interviews were conducted using Google forms and the questions in Table 1 were asked.

Table 1: Sample questions asked during the oral interview

S/N	Questions
1	Type the Location
2	What type of Cement do you use for your production
3	What is the typical mix ratio you use for producing 9" hollow sandcrete blocks?
4	How many blocks do you produce from 1bag
5	How many days do you allow the blocks to cure before they are considered ready for use?
6	Are there any specific curing methods or techniques you employ to ensure proper curing of the blocks? If yes, please describe them.
7	Are you familiar with the relevant standards and codes for manufacturing hollow sandcrete blocks? (e.g., ASTM C55, BS 6073, NIS 87)
8	What quality assurance body certify your blocks
9	What quality assurance measures do you have in place to maintain the consistency and quality of your hollow sandcrete blocks?
10	Do you have any certifications or accreditations related to the production of hollow sandcrete blocks? If yes, please provide details.

3.0 RESULTS AND DISCUSSIONS

3.1 Compressive Strength Result

The results of the laboratory test carried out on the samples collected from the block industries located in the research area are shown in Table 2.

Table 2: Compressive Strength of Blocks from Block Industries in Kaduna Metropolis

S/N	LGA	Block Industry	Location	Compressive Strength (N/mm^2)	Mean Comp Strength (N/mm^2)
1	Kaduna North	B1	Kawo	0.48	0.59
		B2		0.46	
		B3		0.53	
		B4		0.77	
		B5		0.71	
2		F1	Unguwar Dosa	0.31	0.39
		F2		0.40	
		F3		0.46	
		F4		0.42	
		F5		0.37	
3		N1	Malali	0.39	0.33
		N2		0.33	
		N3		0.37	
		N4		0.23	
4		G1	Unguwar Rimi	0.35	0.34
		G2		0.27	
		G3		0.31	
		G4		0.42	
		G5		0.36	
5		O1	Kabala	0.29	0.36
		O2		0.36	
		O3		0.40	
		O4		0.38	
6	Kaduna South	H1	Television	0.36	0.29
		H2		0.29	
		H3		0.31	
		H4		0.23	
7		I1	Barnawa	0.25	0.26
		I2		0.25	
		I3		0.28	
		I4		0.26	
8		L1	Kinkinau GRA	0.21	0.29
		L2		0.27	
		L3		0.33	
		L4		0.34	
9		K1	Badiko	0.35	0.36
		K2		0.44	
		K3		0.19	
		K4		0.45	

10		M1	Gwamna Road	0.79	0.62
		M2		0.73	
		M3		0.57	
		M4		0.39	
11	Igabi	A1	Hayin Dan Iya	0.26	0.24
		A2		0.24	
		A3		0.21	
		A4		0.22	
		A5		0.28	
12		C1	Mando	0.48	0.33
		C2		0.19	
		C3		0.36	
		C4		0.29	
		C5		0.31	
13		P1	Afaka	0.27	0.30
		P2		0.31	
		P3		0.38	
		P4		0.23	
14	Chikun	E1	Millenium City	0.41	0.34
		E2		0.29	
		E3		0.28	
		E4		0.20	
		E5		0.49	
15		D1	Karji	0.21	0.21
		D2		0.19	
		D3		0.22	
		D4		0.24	
		D5		0.19	
16		J1	Sabon Tasha	0.75	0.50
		J2		0.30	
		J3		0.42	
		J4		0.51	

From the results of the laboratory test conducted the mean compressive strength ranges from 0.21N/mm^2 to 0.62N/mm^2. This is below the minimum compressive strength of 1.8N/mm^2 specified by the SON for load bearing walls. This is obviously due to the average curing age of 3 days adopted by the block industries as well as the lack of a standardized mixed ratio.

3.2 Bulk Density

The mean Density of blocks within Kaduna Metropolis compared with the minimum density of 1,800kg/m^3 specified by the [7] is shown in Figure 9. The result computed showed that only one (1) block industry has a bulk density of 2240kg/m^3 which satisfied the provision of the [7] for the minimum bulk density of block to be 1,800kg/m^3 while the rest range from 1286kg/m^3 to 1537kg/m^3 which is below the minimum.

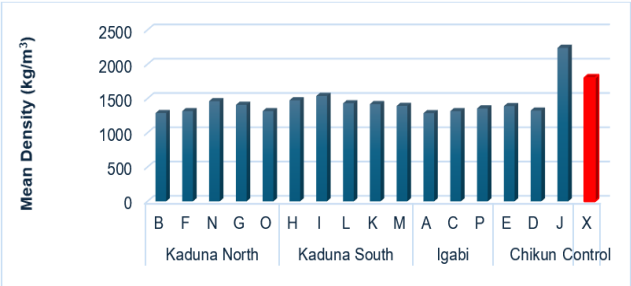

Figure 9: A bar chart of the mean density of blocks within Kaduna Metropolis compared with the minimum density of 1,800kg/m3 specified by the NIS 87 2000

3.3 Discussion on Responses Received Via the Online Interview

From interviews in Kaduna South Local Government Area, it appears that “The Hose Spray" curing technique is commonly used in 9 out of 12 industries. Among these, only one industry explicitly references compliance with a specific standard, the SON standard, and holds SON Certification. This implies that most industries may not have established internal quality assurance procedures, indicating a potential absence of internal quality control systems. The block production methods in Kaduna North exhibit diversity, primarily employing the "Spray with Hose" curing approach, although one producer opts for the "Pour with Bucket" technique. Nevertheless, there is a notable absence of knowledge regarding industry norms, the absence of a dedicated quality control entity, and no certification from the Local Government Authority. Dangote cement is frequently utilized, with mixing ratios spanning from 5 to 6 wheelbarrows per bag and curing durations varying between 3 to 7 days. The methods employed in parts of the Igabi Government Area for curing include both techniques mentioned. However, there is a lack of compliance with standards, an absence of an external organization for block quality assurance, and no certification for quality assurance. In parts of the Chikun Government Area, the curing process involves "Spray with Hose," but there is an absence of awareness regarding industry standards, a block quality assurance entity, internal quality assurance protocols, and any form of quality assurance certification. Additionally, the data demonstrates uniformity in terms of cement type, mix ratio, block production quantity, and curing duration.

In summary, within the Kaduna metropolis, just 31% of block industries are acquainted with the quality assurance agency responsible for ensuring block quality.

3.4 Other Notable Points

3.4.1 Block size

The blocks generally vary in dimension which indicates that most of the industries do not regularly inspect their mould. This results in the production of blocks that are usually slightly more than the standard size. Only five of the thirty-two (32) block industries visited carry out routine inspections of mould. One of the manufacturers claimed they can 'gauge' whether the size has changed by mere visual inspection while another claimed unless there is a complaint from the customers especially when there is an increase in the number of courses required to reach the roof level which shows a decrease in the height of their block,

only then will they inspect and possibly replace the mould.

3.4.2 Test on the finished product

None of the block industries visited carry out any test on the finished product.

3.4.3 Mandatory conformity assessment program certification (MANCAP)

Only one of the block industries provided a certification from the Standard Organisation of Nigeria (SON), the agency responsible for setting standards for block manufacturing in Nigeria. Three (3) others confirm that SON usually comes around for certification but no evidence of certification was seen.

4.0 CONCLUSION

The findings revealed that the block industries employed a manual mixing method using a shovel, and there was no standard mix ratio observed among them. The amount of water used in the mix was determined by the labourers, and it varied based on their discretion. The moulding process involved pouring the mortar into moulds and using a compaction machine to remove air voids. The curing of the blocks was predominantly done using a hose connected to a water source, such as a borehole, reservoir, or well. The results of the laboratory experiments tests carried out, showed variations in the compressive strength of the blocks across different block industries and locations. The average compressive strength ranged from 0.19N/mm² to 0.79N/mm². Density calculations were also conducted, providing insights into the weight and volume of the blocks. From the result of the interview conducted, out of the 32 block industries visited, only 3% complied with the mix ratio of 20-25 blocks per bag of cement. 34% of the block industries are familiar with the quality assurance agency responsible for assuring the quality of blocks produced within the Kaduna metropolis. 15% of the block industries carry out quality assurance checks that is weekly inspection of the mould for wear and tear and taking measurements of the dimensions to ensure that it meets the standard. In addition, only one of the block industries showed evidence of certification from the SON, while three others confirmed that SON usually comes around for certification but no evidence of certification was seen.

This research shows the importance of establishing uniform procedures for manufacturing hollow sandcrete blocks within the Kaduna metropolis. These measures encompass adopting a standardized mix ratio, enforcing a minimum curing period of 7 days, providing education to block producers about mould inspections, certifying manufacturers, and implementing annual quality assurance assessments for all block businesses. These steps are essential for ensuring consistent quality, reliability, safety, and structural soundness. They, in turn, contribute significantly to sustainable development and enhance the overall quality of infrastructure in the Kaduna region.

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