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Performance evaluation of Commercial Sandcrete blocks produced in Idu District, Abuja

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Abstract: *This study evaluated the performance of commercially produced sandcrete hollow blocks in Kaura District, Nigeria. A total of one hundred and eighty (180), nine (9) inch sandcrete hollow blocks from ten randomly selected manufacturers were collected and subjected to compressive strength and Durability test, for compliance with existing standards: Nigerian Industrial Standard, Nigerian Building Code and British Standard. The blocks were cured using the sprinkling method at 7, 14, 21, and 28 days. The average dry density of hollow sandcrete blocks from the different factories after 28 days is 1837 Kg/m³, which were within the value specified by BS 2028 (1968) and NIS 87 :2000. The compressive strength of hollow sandcrete block samples ranges from 2.93 N/mm² to 0.61 N/mm². Results indicated that only 22.5% of commercially produced blocks in the Idu District of Abuja meet the minimum specification of 2.5 N/mm² for non-load bearing as specify in Nigeria Industrial Standard NIS 87 (2000) and 100% of the block produced by the factories do not meet the 3.45 N/mm² NIS requirement for load loading. According to test results, the total water absorption of all block samples that were collected was less than the BS 5628 maximum value of 7% and less than the NIS standard's 12% requirement. This study indicates that all of the hollow sandcrete blocks that were examined are considered to be of low porosity. This study recommended that manufac*

KEYWORDS: *Sandcrete Blocks, Compressive Strength, Durability, Quality*

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1. INTRODUCTION

The construction industry plays a pivotal role in economic growth and infrastructure development, making it an essential sector in any economy (Madandoust and Mousavi, 2012). In line with many developing nations, Nigeria's construction industry primarily relies on locally produced building materials to meet the increasing demand for housing and infrastructure. The selection of a building material by a structural engineer typically depends on factors such as availability, cost, durability, ease of maintenance, and the required structural performance of the building or structure (Akpokodje et al., 2021). A variety of materials are employed in constructing walls for buildings and other related structures. Commonly utilized building materials include precast concrete, sandcrete blocks, wood, metal sheets, gabions, bricks, insulated vinyl, and structural insulated panels. Among these materials, hollow sandcrete blocks are widely utilized due to their cost-effectiveness, availability of raw materials, simplicity of production, and adaptability to diverse environmental conditions. Composed of sand, cement, and water, these blocks serve as a fundamental building material, offering both structural stability and insulation in construction projects.

In recent years, sandcrete blocks have gained prominence in construction projects, particularly in African nations (Akpokodje et al., 2021). In Nigeria, sandcrete blocks are a fundamental building material, used in approximately 90% of residential constructions (Ewa and Ukpata, 2013). The tropical climate in the region necessitates the construction of structural walls that facilitate the flow of heat and air between the interior and exterior of buildings, making hollow sandcrete blocks a preferred choice in building construction (FAO, 1988).

The Nigerian Industrial Standard (NIS) identifies the 450 x 225 x 225 mm sandcrete block as the most commonly used size in the country (Nene, 2009). According to the NIS, sandcrete blocks are categorized into two types: Type A (load-bearing) and Type B (non-load-bearing). These blocks can either be solid or hollow. For non-load-bearing walls, the NIS specifies a minimum compressive strength of 2.5 N/mm², while load-bearing walls require a minimum of 3.45 N/mm² (NIS, 2000). The updated NIS standard (NIS 87:2004) further stipulates that machine-vibrated load-bearing blocks must achieve a minimum compressive strength of 2.5 N/mm² for individual blocks and an average compressive strength of at least 3.45 N/mm².

Research evidence highlights that commercially manufactured sandcrete blocks in Nigeria frequently fail to meet the minimum compressive strength requirements specified by the Nigerian Industrial Standard (NIS), raising significant concerns regarding their quality. Studies indicate that a majority of sandcrete blocks produced in Nigeria do not comply with NIS guidelines, posing potential safety risks in construction projects (Agbi et al., 2020). This issue is attributed to the widespread neglect of established standards by manufacturers, who often prioritize profit margins by utilizing substandard materials in the production process (Onwuka et al., 2013).

The performance of sandcrete blocks is primarily influenced by their durability and mechanical properties. Durability, a critical attribute of concrete, refers to its ability to maintain its intended functions, strength, and serviceability throughout its expected lifespan (Neville, 2011). Previous studies have identified key properties that are closely associated with the assessment of sandcrete block durability. These include block dry density (BDD), total water absorption (TWA), total volume porosity (TVP), wet compressive strength (WCS), and dry compressive strength (DCS) (Rigassi, 1995; Omopariola, 2014).

Hollow sandcrete blocks are extensively utilized in construction projects across Nigeria, including the Idu District of Abuja, the nation's capital. However, there is a lack of comprehensive studies specifically assessing the compressive strength of commercially produced sandcrete blocks in this region. This knowledge gap raises concerns about the quality, reliability, and structural integrity of these critical building materials. Therefore, the objective of this research is to evaluate the performance in terms compressive strength and durability test of hollow sandcrete blocks produced commercially within Idu District of Abuja, Nigeria. Findings from this study will help the appropriate authorities in monitoring the quality of the blocks produced in Abuja's Kaura District and its the surrounding areas.

II. MATERIALS AND METHODS

A. MATERIALS

The materials used for this study are commercial sandcrete hollow blocks produced in randomly selected factories of Idu District Abuja, Nigeria.

B. METHODS

This research was conducted using a combination of laboratory experiments and field surveys. Following analysis, the results from the field survey and laboratory experiment were compared with the British Standard, the Nigerian Building Code (NBC 2006), and the Nigerian Industrial Standard requirements for sandcrete blocks (NIS 87 2007).

Field Survey

This study involved the random selection and evaluation of 180 sandcrete block units sourced from ten different manufacturers within the Idu District of Abuja, Nigeria. A total of eighteen 9-inch blocks (450 x 225 x 225 mm) were procured from each manufacturer. To maintain confidentiality, the blocks from each manufacturer were labelled alphabetically, from A to J. These labels were assigned arbitrarily and do not correspond to the manufacturers' identities or indicate the quality of the blocks produced by the respective industries.

Industries Case Study

Detailed information regarding the production processes, types of materials used (such as granite fine and cement), and mix ratios (Cement: Sand and Water: Cement) was not consistently provided by all manufacturers. However, some manufacturers voluntarily disclosed certain data, while additional information was obtained through direct observation.

Laboratory Experiment

The laboratory tests conducted on the sandcrete hollow block samples include block measurement, bulk density assessment, compressive strength evaluation, and durability testing. The procedures used to carry out these tests are described as follows.

Sandcrete Blocks Acquisition

A total of one hundred and eighty (180) blocks of 450 mm x 230 mm x 230 mm sandcrete hollow blocks were randomly selected from ten (10) sandcrete blocks producing factories within Idu District of Abuja. All the blocks were collected after 3 days of production and curing. All the sampled blocks collected from the block factories were taken to the Concrete Laboratory of the Department of Civil Engineering, Baze University, Abuja, Nigeria continuous curing, compressive strength and durability test.

Mix Ratio

Fieldwork observations indicated that the volumetric batching method was utilized in all visited block industries which according to the block producer is faster and easier than batching by weight despite the fact that the weight batching method is more accurate. No recommended standard for the water-to-cement (w/c) ratio was adopted by any of the block producers. They all periodically add water to the cement and granite fine mixture, mostly according to their individual visual assessments of the mix's required consistency.

Mode of Block Production

According to field observations, most block producers used mechanical sandcrete mixers and vibrating block molds to produce blocks. Nevertheless, some producers mixed and molded their blocks by hand.

Density of Sandcrete Hollow Blocks

This test is carried out to evaluate the unit weight of the hollow sandcrete blocks. Each block was weighed and its dimensions measured in accordance with the procedures outlined in BS 2028 (1968). The density of the block is given by the following equation:

$$\text{Density } (\text{Kg}/m^3) = \frac{\textit{Weight of the Block}}{\textit{Block's Net Volume}} \quad (1)$$

Compressive Strength Test

The compressive strength test for the block samples was performed in accordance with BS 2028 and BS 1364 (1968) to evaluate the load-bearing capacity of the blocks. During the test, 9-inch (225 x 225 x 450 mm) sandcrete blocks were subjected to crushing using a universal compression testing machine, as illustrated in Fig. 1. Prior to testing, the weight of each block was recorded. To ensure uniform distribution of force and accurate crushing results, two steel plates measuring 230 x 460 x 20 mm were positioned at the top and bottom of each block sample. The prepared sample was then carefully aligned and secured within the marking pins of the compression testing apparatus. The maximum crushing load for each sample was determined by applying a continuous, shock-free load at a rate of 15 kN/min until failure occurred. The corresponding failure load was recorded when the blocks were crushed. The compressive strength of each block was then calculated using the following formula:

$$\text{Compressive strength } (N/mm^2) = \frac{\text{Crushing load}}{\text{Block's Net Area}} \quad (2)$$

Fig. 1: Crushing a block using the Universal Compression Machine

Durability Test Evaluation on Sandcrete Hollow Block

The bulk properties that were determined to be very relevant to the investigation into sandcrete's durability from randomly selected factories include the following

Block Dry Density

The density of a block is a critical parameter for assessing its quality. The Block Dry Density (BDD) was determined following the guidelines outlined in Part 2 of BS 6073 (1981). The block samples were oven-dried at a temperature of 105 ± 5°C for 24 hours and subsequently weighed using a precision scale. The BDD was then calculated using the following formula:

$$\text{BDD } (kg/m^3) \ell d = \frac{m}{V} \quad (3)$$

Where m = mass of oven dried block sample

V= volume of block sample

Total Water Absorption

Water absorption is defined as the ratio of the difference in mass between dry and wet samples to the mass of the dry sample. Prior to conducting the WCS tests, water absorption tests were carried out on the block samples. Following the procedures outlined in BS 3921 (1985), the TWA of the blocks was determined using the cold immersion method, as illustrated in Fig. 2. The block samples were oven-dried for 48 hours and then immersed in cold water. After 24 hours, the samples were removed from the water, and excess surface water was allowed to drain for approximately 30 minutes. The blocks were then weighed again. The percentage of water absorption was calculated using the formula provided below, with the results presented in Fig. 6.

$$TWA = \frac{W_w - W_d}{W_d} \times 100 \quad (4)$$

Where,

TWA = percentage water absorption (%)

W_w = mass of wet sample W_d =mass of dry sample

Fig. 2: Block samples submerged in water

Total Volume Fraction Porosity (TVP)

The TVP of sandcrete blocks can be directly determined by measuring the weight gain of an initially dry block after it has been fully saturated with water, with air removed from its pore network (Jackson and Dhir, 1996). As described earlier, the water absorption percentage by weight is calculated. This value can then be converted into volumetric porosity using the following relationship:

$$n = \frac{(TWA)\rho}{100\,\rho w} \quad (5)$$

Where n = volume fraction porosity

ρ = dry block density (kg/m3)

ρw = density of water kg/m3)

TWA = water absorption (%)

Wet and Dry Compressive Strength

To ascertain the hollow sandcrete block samples' load-bearing capacity, the wet and dry compressive strength test was conducted in compliance with BS 6073 Part 1 (1981). Compressive strength was obtained for each sample using the formula in Equation (6).

$$\text{Compressive strength } (N/mm^2) = \frac{\text{Crushing load}}{\text{Net area of block}} \quad (6)$$

Block samples were pre-soaked for 24 hours in order to test for wet compressive strength, then they were oven-dried to a constant mass in order to test for dry compressive strength.

III. RESULTS AND DISCUSSION

A. Field Investigation Report

Analysis of the results the field investigation carried out is presented in the table 1 below. 100% of the block factories visited produced Sandcrete blocks mechanically using the typical automatic block-making machine.

Table 1: Details of Sandcrete Block Production Procedure

S/N	Industry	Batching	Blocks Per Bag	Curing Period	Test on Materials	Curing Method	Mixing Method	Types Of Machine	Source Of Water
1	A	Volume	55	7	No	Sparkling	No specify	Automatic block-making machine	Borehole
2	B	Volume	60	3	No	Sparkling	No specify	Automatic block-making machine	Borehole
3	C	Volume	55	3	No	Sparkling	No specify	Automatic block-making machine	Borehole
4	D	Volume	60	3	No	Sparkling	No specify	Automatic block-making machine	Water works
5	E	Volume	Not specify	3 - 7	No	Sparkling	No specify	Automatic block-making machine	Borehole
6	F	Volume	Not specify	3	No	Sparkling	No specify	Automatic block-making machine	Water works/Boreholes
7	G	Volume	Not specify	3 - 7	No	Sparkling	No specify	Automatic block-making machine	Water works
8	H	Volume	60	3	No	Sparkling	No specify	Automatic block-making machine	water works
9	I	Volume	50	3 - 7	No	Sparkling	No specify	Automatic block-making machine	Borehole
10	J	Volume	65	3	No	Sparkling	No specify	Automatic block-making machine	Borehole

All the ten randomly selected factories visited used batching by volume. Batching was done using the wheel barrow to measure the required volume of sand used in each factory. It was noted that none of the factory adopted the recommended water – cement ratio and cement – sand mix ratio of 0.6 and 1:6 or 1:8 respectively as outlined by NIS. Hence, all the block factories failed to meet the NIS approved recommendations for sandcrete blocks. The number of blocks from one bag of cement ranges between fifty – five (55) to sixty-five (65). The curing days used before the blocks are sold ranges between three (3) to seven (7) days. There is inconsistence in the mixing process which is done manually in all the factories visited resulting in cracks in some of the blocks produced. Potable water from public water works constitute 30%, 70% drilled boreholes and 10% for both public water works and drilled boreholes was used to produce and cure the blocks.

Density of Hollow sandcrete Blocks

The calculated densities of the tested sandcrete hollow blocks obtained from the ten (10) randomly selected manufacturers within the Idu District of Abuja, Nigeria are shown in Table 2.

Table 2: Average Mean Density of Blocks from selected factories within Idu District, Abuja

S/N	Industry	7 Days	14 Days	21 Days	28 Days
1	A	1739.2	2043.9	1685.4	1876.1
2	B	1846.5	1679.6	1603.1	1700.8
3	C	1976.6	1808.0	1641.2	1744.7
4	D	1766.5	1736.5	1756.9	1760.6
5	E	2081.6	2111.3	1946.8	1865.9
6	F	1873.3	1743.7	1798.4	1773.8
7	G	1999.1	2075.3	2035.3	2011.6
8	H	1786.3	1736.2	1783.3	1799.9
9	I	1984.0	1987.1	2000.1	1977.6
10	J	1721.5	1646.7	1685.6	1711.3

From the 10 randomly selected factories, the mean density of blocks from the selected block producer ranges between 1603.1 Kg/m^3 and 2111.3 Kg/m^3 with an average of 1837.5 Kg/m^3 from all the samples collected from the ten (10) factories. The values of sandcrete block from the selected factories falls within the stipulated values of density for type "A" blocks according to BS 2028 (1970), and also falls within the minimum specification of 1500 Kg/m^3 recommended for first grade (type "A"- load bearing block) sandcrete blocks by Nigeria Industrial Standard NIS 87: 2000. These results are similar to one obtained by Musa and Ocholi 2020, where the density of blocks obtained are 1982 Kg/m^3.

Compressive Strength

The results of the average compressive strength test carried out on hollow sandcrete block samples from the ten (10) selected block factories within Idu District Abuja captured in this study at, 7, 14, 21, and 28 days of curing is shown in table 3 below. whereas the graph in Fig.3 shows the increase of the compressive strength of hollow sandcrete blocks with the age of curing for all the block factories.

Table 3: Average Compressive Strength of Hollow Sandcrete Blocks (N/mm²)

S/NO	Industry	7 Days	14 Days	21 Days	28 Days
1	A	0.61	1.00	1.35	1.86
2	B	1.46	1.47	1.5	1.61
3	C	1.51	1.53	1.55	1.69
4	D	1.61	2.07	2.25	2.35
5	E	2.46	2.76	2.78	2.93
6	F	0.95	1.04	1.12	1.20
7	G	2.43	2.64	2.71	2.79
8	H	1.75	2.17	2.41	2.51
9	I	2.03	2.32	2.70	2.93
10	J	0.68	0.90	1.11	1.27

The compressive strengths of all the selected block industry range from 0.6 N/mm² to 2.93 N/mm². This is similar with the findings of previous studies by Odeyemi *et al*. (2018) and Ewa and Ukpata (2013). According to studies by Ewa and Ukpata (2013), several block factories in Calabar produced sandcrete blocks of varying quality. They described the differences in compressive strength to the properties of the constituent materials used in the production of hollow sandcrete blocks. The findings show that, of the hollow sandcrete blocks produced commercially in the Idu District of Abuja, only 20% meet the Nigeria Industrial Standard NIS 87 (2000) minimum specification of 2.5 N/mm² for non-load bearing after 28 days of curing for industry E, G, H and I, with (2.76, 2.78 and 2.93) N/mm², (2.64, 2.71, and 2.79) N/mm², (2.51) N/mm², and (2.70, and 2.93) N/mm², respectively, and that 100% of the selected factories within Idu District of Abuja, Nigeria does not meet the required Nigeria Industrial Standard requirement for load loading sandcrete blocks of 3.45 N/mm². Similar findings were made by Onwuka *et al.* (2013), Yusuf *et al.* (2017), and Aiyewalehinmi and Tanimola (2013), and who found that the compressive strength of sandcrete blocks from different parts of Nigeria consistently falls short of the 2.5 N/mm² and 3.5 N/mm² requirement by the Nigeria Industrial Standard and Standards Organization of Nigeria for load-bearing walls and non-load-bearing walls, respectively. The low quality of the sandcrete blocks produced by factories F and J may be as a result of the poor fine aggregate (granite dust 1 and 2), mix ratios used by these block producers. Blocks from factory I recorded the highest mean compressive strength of 2.93 N/mm² while those from factory F recorded the least value of 1.20 N/mm²after 28 days of curing.

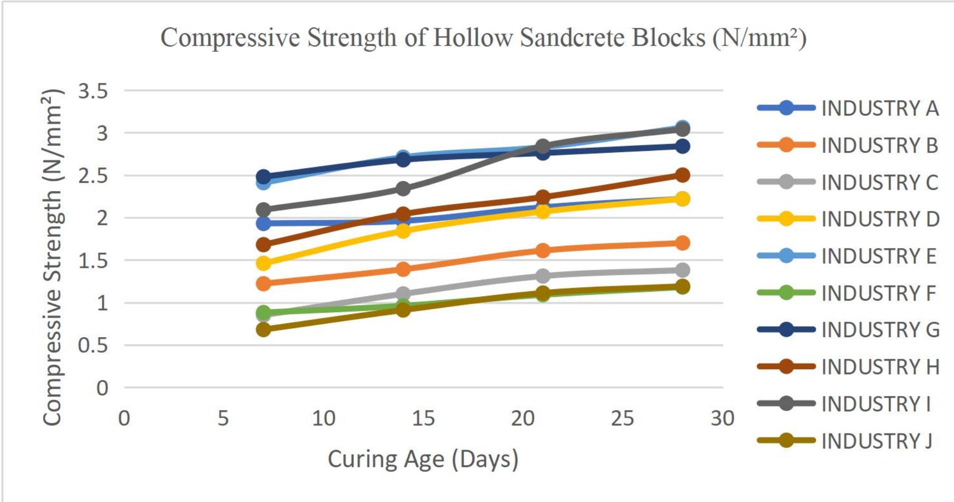

Fig. 3: Compressive strength of collected sandcrete block samples at different days of curing age

Dry Density of the Block Samples

Table 4 below shows the result of the block dry density, water absorption, and total volume porosity of hollow sandcrete block produced at randomly selected block factories within the Idu District of Abuja at 28 days of curing. The average dry density of a set of three hollow sandcrete blocks ranges between 1713.1 Kg/m^3 and 2047.4 Kg/m^3 with an average density of 1850.9 Kg/m^3. The values of hollow sandcrete block produced at the selected factories falls within the specify values of density for type "A" blocks according to BS 2028 (1970), and also falls within the minimum specification of 1500 Kg/m^3 recommended for first grade (type "A"-load bearing block) sandcrete blocks by Nigeria Industrial Standard NIS 87: 2000 and therefore comply with the requirements of the standards.

Table 4: Water absorption, block dry density and total volume porosity obtained from block factories

S/N	Industry	Dry weight (kg)	Weight after soaking for 24hrs (kg)	Water Absorption (%)	Block Dry Density (Kg/m³)	Total Volume Porosity (%)
1	A	19.67	20.13	2.29	1819.2	4.24
2	B	19.86	20.76	4.34	1722.7	7.61
3	C	19.54	20.43	4.36	1758.8	7.81
4	D	19.77	20.87	5.27	1793.3	9.64
5	E	19.00	19.75	3.80	1989.9	7.70
6	F	19.68	20.29	3.01	1844.8	5.65
7	G	18.81	19.55	3.79	2047.4	7.90
8	H	19.74	20.85	5.32	1845.4	10.01
9	I	19.97	20.49	2.54	1974.7	5.11
10	J	19.67	20.67	4.84	1713.1	8.45

Total Water Absorption (TWA)

The average total water absorption of a set of three hollow sandcrete blocks from the selected factories in Idu District of Abuja after 28 days of curing is summarized in table 4 which ranges between 2.29% and 5.32 with an average of 3.95% across the ten (10) selected factories. It was observed that all the selected block factories used quarry dust as fine aggregate making the average water absorption to drop. This may be due to the strong bond that is formed between the cement and the quarry dust (granite dust), which fills the voids space within the mixtures making the sandcrete hollow blocks to be more compact. Also, when compared with the standard specify by BS 2028 (1970) Part 1, all the block factories exhibited a low total water absorption, as their values fell below the specified maximum water absorption value of 7%. According to NIS 87: 2004, the average water absorption should be maximum of 12%. All values obtained fell below the maximum NIS specification. Thus, all the hollow sandcrete blocks produced by the selected factories passed the water absorption test.

Total Volume Porosity (TVP)

The result of the total volume porosity of all the hollow sandcrete blocks produced within Idu District of Abuja after 28 days of curing is shown in Table 4 which ranges between 4.24% to 10.1%. The Nigeria Industrial Standard and BS Code do not specify any particular standards for total volume porosity. However, according to Jackson and Dhir (1996), materials with a TVP exceeding 30% are classified as highly porous. Based on this specification, the hollow sandcrete blocks analyzed in this study can be considered to exhibit low porosity.

Dry and Wet Compressive Strength

The result of the average 28-day curing of the wet and dry compressive strength for all the selected factories with Idu District, Abuja is given in Table 5 below. The ratio of dry and wet compressive strength ranges between 1.16 and 2.44. The result show that the higher and broader the ratio between mean dry compressive strength and wet compressive strength, the lower can the degree of inter granular bonding be expected to be. The values obtained fall within the range of recommended values in literature that the ratio of the mean dry and wet compressive strength sandcrete hollow blocks should not be greater than 2, Keralli (2001).

Table 5: Ratio of Dry and Wet Compressive Strength of Hollow Sandcrete Blocks

S/N	Industry	Dry compressive strength	Wet compressive strength	Ratio
1	A	1.98	0.84	2.36
2	B	1.67	1.17	1.43
3	C	1.73	1.00	1.73
4	D	2.39	0.98	2.44
5	E	3.11	1.50	2.07
6	F	1.26	1.09	1.16
7	G	2.89	1.33	2.17
8	H	2.59	1.12	2.31
9	I	2.97	1.55	1.92
10	J	1.30	1.10	1.18

The values obtained fall within the range of recommended values in literature that the ratio of the mean dry and wet compressive strength sandcrete hollow blocks should not be greater than 2, Keralli (2001). Therefore, the experimental results obtained for 50% of the factories fall well within this limit while the remaining industries exhibited DCS to WCS ratios exceeding the recommended value.

V. CONCLUSION AND RECOMMENDATIONS

CONCLUSION

The following findings were reached after analyzing the results from the field survey and laboratory tests carried out on the selected block factories:

i. The findings indicate that a significant proportion of the blocks manufactured by industries in this district do not meet the requirements specified in NIS 87:2007.

ii. Preliminary observations prior to formal testing revealed that the selected industries fail to adhere to standard mix ratio guidelines essential for producing high-quality sandcrete blocks.

i. The 28-day compressive strength of commercially available sandcrete blocks obtained from the ten (10) selected block factories in Idu District, Abuja ranges between from 0.6 N/mm² to 2.93 N/mm². only 20% meet the Nigeria Industrial Standard NIS 87 (2000) minimum specification of 2.5 N/mm² for non-load bearing after 28 days of curing and 100% of the industry do not meet the required NIS standard for load loading sandcrete block of 3.45 N/mm².

ii. The density of hollow sandcrete blocks produced from the selected block factories have densities which were within the value required by BS 2028 (1968) and NIS 87 :2000

iii. The water absorption values of commercially available hollow sandcrete blocks obtained from ten block factories in Idu District, Abuja were lower than the maximum value of 7 % as stipulated in BS 5628 and also lower than 12% requirement of NIS standard.

iv. All the hollow sandcrete blocks examined during this research are considered to be of low porosity.

RECOMMENDATION

Based on these findings, the following recommendations are drawn

i. It is recommended that manufacturers prioritize the continuous education and training of their workforce to ensure adherence to best practices throughout the production process.

ii. Improved material management practices, particularly in the storage of fine aggregates should also be implemented. Moreover, strict compliance with established standards and specifications for sandcrete block production must be maintained.

iii. To reinforce compliance, regulatory agencies should conduct regular, unannounced inspections of sandcrete block manufacturing factories. Non-compliance should be met with appropriate penalties to uphold the integrity and safety of construction materials within the industry.

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