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Assessment of the Quality of Sandcrete Blocks In Use in Owerri Imo State, South-East Nigeria

Joan I. Arimanwa, Michael C, Arimanwa, Chinenye E, Okere, Chioma T. G. Awodiji

Abstract;- This paper investigates the strength properties of sandcrete blocks obtained from ten different commercial sandcrete block-manufacturing industries in Owerri, Imo State, South Eastern part of Nigeria and its environs. Ten sandcrete block samples with nominal dimensions 450 x 225 x 225mm were randomly obtained from each of the manufacturers for a period of four consecutive weeks. Sand samples used in producing the blocks were also collected for laboratory analysis while the source of water for each industry was noted. Compressive strength and density tests were conducted on the blocks while grain size distribution analysis was conducted on the sand samples. The test results revealed that the sand aggregates used are substantially suitable for block making. The average compressive strengths of the sandcrete blocks for all ten block manufacturing industries investigated fell below the standards recommended by the Nigerian Industrial Standard (NIS) 87: 2000 and BS 6073 - 1:1981 which are 2.76 N/mm^2, and 2.8 N/mm^2 respectively. Only two out of the ten industries satisfied the requirements of the National Building Code (2006) of Nigeria, which requires the average strength of six blocks to be not less than 2.0 N/mm^2 and the lowest strength of individual blocks should be not less than 1.75 N/mm^2. The compressive strength of individual blocks was between 0.55 N/mm^2 and 2.43 N/mm^2 and the average compressive strength of the blocks was between 0.62 N/mm^2 and 2.35 N/mm^2. Standardization of block manufacturing processes and strict supervision of the manufacturers by the Council for the Regulation of Engineering Practice in Nigeria were recommended as measures to improve the quality of sandcrete blocks.

Index Terms: **Sandcrete blocks, Compressive Strength, Quality, Standardization**

I. INTRODUCTION

Sandcrete blocks are building units usually made up of ordinary Portland cement, sharp sand obtained from rivers or streams and water from streams, rivers or water boreholes, mixed in appropriate proportions and moulded into different desired sizes. Sandcrete blocks also have been defined as composite material made up of cement, sand and water, moulded into different sizes [1]. Sandcrete block units are commonly used in Nigeria for the construction of load bearing and non-load bearing walls. They are also useful for creating partitions in buildings, hoarding of construction sites, fencing, creating barriers and other protective purposes. They are rectangular and have various sizes, the commonest among them being 450mm x 225mm x 225mm, 450mm x 150mm x 225mm, 450mm x 125mm x 225mm, and 450mm x 100mm x 225mm. The first two referred to as hollow sandcrete blocks appear with holes, which run from top to bottom and occupy about one-third of the volume of the block while the last two are manufactured without holes and are called solid sandcrete blocks. Sandcrete blocks are usually bedded or joined together in Nigeria using cement mortar in stretcher bond. The spate of the collapse of buildings in Nigeria has put in the front burner the need to investigate the quality of building materials available to and commonly used by builders and developers. One important area of concern is the quality of sandcrete blocks especially when they are used in the construction of load bearing walls. Available evidence shows that the quality of sandcrete blocks produced differs from one block manufacturing industry to the other. Reference [2] agrees that quality and standardization of sandcrete blocks are of paramount importance in the study of building components since these will serve as yardsticks for measurement, reflecting the level of development attained by a nation. Reference [3] suggests improvement in the selection of materials and curing techniques as remedy for enhancement of the quality of sandcrete blocks. This paper focuses on the compressive strength of 450mm x 225mm x 225mm hollow sandcrete blocks obtained from the selected manufacturing industries. It is intended to draw the attention of government and the engineering profession to the possible danger of allowing block-manufacturing industries to continue to operate without any mechanism to ensure quality by monitoring their compliance to available standards.

II. MATERIALS AND METHODS

The selected sandcrete block manufacturing industries in Owerri, Imo State of Nigeria were visited and their manufacturing processes were carefully observed without any interference. Ten hollow sandcrete block samples with nominal overall dimensions 450 x 225 x 225 were randomly obtained from the ten different industries every week for a period of four weeks in accordance with [4]. Samples of river sand used for block production by each industry were also collected. The individual blocks were checked for compliance for length, height and thickness as specified by [5]. The blocks were weighed and tested for compressive strength using the compression-testing machine in accordance with [6] after 28 days of curing. The densities of the blocks were also determined. Grain size distribution analysis was carried out on the river sand samples in accordance with [7] to ascertain their suitability for block making. The water source for each block industry was noted. The physical properties of the ordinary Portland cement brands used were determined. The compressive strength results obtained were compared

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with three available standards namely the National Building Code of Nigeria as well as the Nigerian Industrial and British Standards. The block industries have been identified as Industry "A", "B", "C", "D", "E", "F", "G", "H", "J", and "K". The block and sand samples obtained from the industries are also identified in like manner. For instance, block and sand samples "A" were obtained from Block Industry "A" etc. All the laboratory tests were carried out in the Concrete Workshop of the Civil Engineering Department, Federal Polytechnic, Nekede, Owerri.

A. *General Observations*

The ratio of cement to sand used by the block manufacturing industries investigated varied from 1:8 to 1:12 by volume in some and unknown in others. Those whose cement/sand ratios were unknown did not use standard measures in batching sand. Instead of wheelbarrows or head pans, they shoveled the sand and depended on visual inspection or "experience" to know when an adequate quantity of sand had been measured. Water was arbitrarily added to the cement and sand mixes in all the industries. The concept of water-cement ratio was unknown to all of them. Curing was performed by sprinkling water on the blocks every morning and evening for two to five days depending on demand. Water for the mixes were obtained either from boreholes developed by the industries within their premises or from water vendors who supply water obtained from streams in tankers. The number of 450mm x 225mm x 225mm-hollow sandcrete blocks produced per 50kg bag of ordinary Portland cement varied from 24 to 28 for those industries that used cement/sand ratios of 1:8 to 1:12 and 26 to 31 for those that used "experience" to batch sand. The sand suppliers did not give any information about the sources of the sand they supplied.

III. RESULTS AND DISCUSSION

A. *Quality of Cement*

All the industries investigated used one of the following three ordinary Portland cement brands: Eagle, Dangote and Elephant. All the cement brands satisfied the requirements of [8] as shown in Table I. The initial setting times were determined in accordance with [9].

Table I: Physical properties of ordinary Portland cement brands used

Property	Dangote	Eagle	Elephant	[8] Requirement
Initial Setting Time (Minutes)	50	46	53	$\geq$ 60 (-15)
Final Setting Time (Minutes)	415	410	399	$\leq$ 10 Hours*
Soundness (mm)	2.0	2.1	2.0	$\leq$ 10 (+1)

***** This is a requirement of [10]

B. *Grain Size Distribution Analysis of Sand Samples*

Table II shows the requirements for sand used for concrete or sandcrete unit construction as specified by [7]. In addition to the above, the code also specifies that not more than one (1) in ten consecutive samples shall have a grading outside the limits for any of the grading Coarse (C), Medium (M) or Fine (F) as given in Table II. The results for the grain size distribution analysis performed on individual sand samples collected from the various block-manufacturing industries once a week for the period of the investigation (that is, four weeks) are shown in Table III.

Table II: Sand-grading meeting the requirements of [7]

Sieve Size	Percentage by mass passing BS sieve			
	Overall Limits	Additional limits for grading		
		Coarse C	Medium M	Fine F
5.00mm	89 to 100	-	-	-
2.36mm	60 to 100	60 to 100	65 to 100	80 to 100
1.18mm	30 to 100	30 to 90	45 to 100	70 – 100
600µm	15 to 100	15 to 54	25 to 80	55 – 100
300µm	5 to 70	5 to 40	5 to 48	5 to 70
150µm	0 to 15	-	-	-

Table III: Grain size distribution analyses of sand (percentage) samples from different industries

Sieve Size (mm) ⇒	5.00	2.36	0.60	0.15	Sieve Size (mm) ⇒	5.00	2.36	0.60	0.15
Sample A	(%)				**Sample F**	(%)			
Week 1	100	96.4	45.8	0.5	Week 1	98.5	90.5	60.8	11.2
Week 2	98.5	94.5	44.9	0.55	Week 2	95.6	88.1	60.2	10.1
Week 3	100	95.2	43.5	0.67	Week 3	97.8	89.1	62.2	8.4
Week 4	95.4	90.6	45.2	0.72	Week 4	99.4	91.2	60.1	9.9
Sample B	(%)				**Sample G**	(%)			
Week 1	97.4	95.1	64.4	10.2	Week 1	100	98.1	66.3	13.2
Week 2	98.2	96.1	67.5	8.5	Week 2	99.2	96.4	66.8	14.4
Week 3	100	98.5	65.2	6.4	Week 3	99.5	94.3	67.4	15.1
Week 4	99.4	97.4	66.1	5.8	Week 4	99.7	95.1	70.0	13.5

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Sample C	(%)					**Sample H**	(%)			
Week 1	99.8	96.8	65.6	17.8		Week 1	100	97.6	68.1	15.9
Week 2	100	98.3	68.4	12.5		Week 2	99.4	94.2	65.7	14.4
Week 3	99.2	95.9	67.1	9.3		Week 3	100	97.1	66.3	13.8
Week 4	99.7	97.2	65.3	10.4		Week 4	99.6	95.7	67.5	12.2
Sample D	(%)					**Sample J**	(%)			
Week 1	98.1	90.3	63.1	13.2		Week 1	99.3	95.5	61.2	17.1
Week 2	96.2	91.4	65.6	10.5		Week 2	98.5	93.8	59.7	15.5
Week 3	95.4	90.1	66.6	9.5		Week 3	99.5	96.2	58.8	16.3
Week 4	98.2	91.1	68.1	8.4		Week 4	99.2	95.7	57.3	13.5
Sample E	(%)					**Sample K**	(%)			
Week 1	99.6	95.5	64.2	8.1		Week 1	100	96.6	44.0	9.8
Week 2	95.9	89.9	60.1	18.3		Week 2	99.6	96.2	52.6	10.2
Week 3	98.0	90.4	63.9	14.8		Week 3	98.4	93.1	48.2	8.8
Week 4	94.5	88.8	61.4	10.3		Week 4	99.2	94.4	46.6	12.3

From Table III, sand samples from industries A, B, D, F and K satisfied the overall grading limits according with [7] for the four weeks under consideration. Sand samples from industries C and H contained excess of fines in the first week only. Sand samples from industries E and G contained excess of fines in the second and third weeks respectively while the samples from Industry J contained excess of fines in the first three weeks. Overall grading limit requires percentage by mass finer than 150µm to be between 0% and 15% as indicated in Table II.

C. *Physical properties of selected sandcrete blocks*

Table IV shows the physical properties of the selected sandcrete blocks from the different manufacturing industries namely actual average overall dimensions of the blocks, the sizes of holes/voids, net material volume per block, average mass of block per industry and the net area of material available for resisting compressive force/load. These properties are related to the dimensions length (l), width (w) and height (h) of the blocks as shown in Fig. 1. The dimensions were measured in accordance with the provisions of [11].

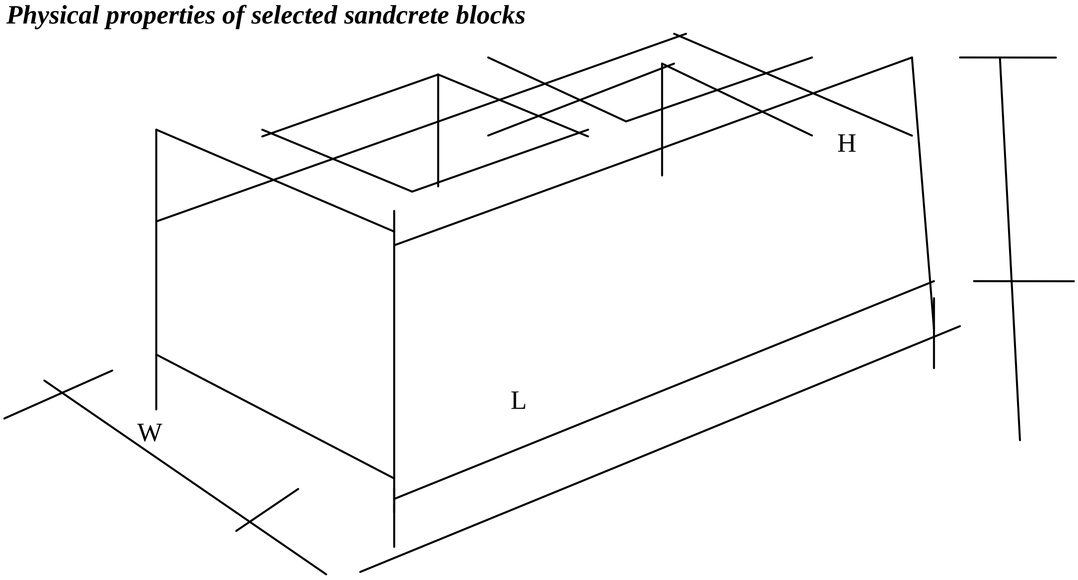

Fig 1: Dimensions of selected blocks

Table IV: Physical properties of selected blocks

Block Industry ID	Average Actual Block Dimensions l x w x h (mm x mm x mm)	Size of Holes (mm x mm x mm)	Net Volume (mm^3)	Net Area (mm^2)	Average Mass (kg)
A (WBHENO)	450 x 230 x 225	155 x 142 x 225 x 2	13,383,000	59,480	22.88
B(PHRO 1)	460 x 232 x 226	169 x 145 x 226 x 2	13,042,460	57,710	21.11
C(PHRO 2)	460 x 230 x 225	170 x 145 x 225 x 2	12,712,500	56,500	21.43
D(MRO 1)	463 x 230 x 229	163 x 145 x 229 x 2	13,561,380	59,220	22.57
E(ORO 1)	465 x 228 x 223	170 x 140 x 223 x 2	13,027,660	58,420	21.50
F(ORO 2)	455 x 228 x 225	160 x 140 x 225 x 2	13,261,500	58,940	21.12
G(MRO 2)	460 x 230 x 228	170 x 140 x 228 x 2	13,269,600	58,200	23.10

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H(NIRO)	455 x 230 x 228	165 x 145 x 228 x 2	12,950,400	56,800	20.78
J(ARO 1)	456 x 228 x 226	163 x 140 x 226 x 2	13,182,128	58,328	21.15
K(ARO 2)	455 x 230 x 224	165 x 140 x 224 x 2	13,092,800	58,450	20.93

KEY: WBHENO – Industry at World Bank Housing Estate, New Owerri,
PHRO 1 and PHRO 2 - First and second industry respectively on Port Harcourt Road, Owerri
MRO 1 and MRO 2 – First and second industry respectively on Mbaise Road, Owerri
ORO 1 and ORO 2 – First and second industry respectively on Onitsha Road, Owerri
NIRO – Industry on Nekede/Ihiagwa Road, Owerri
ARO 1 and ARO 2 – First and second industry respectively on Aba Road, Owerri

Allowable dimensional deviations in accordance with [11] are as follows:

Length: Nominal value – 5 to Nominal value + 3 (mm)

Width: Nominal value ± 2 (mm)

Height: Nominal value – 5 to Nominal value + 3 (mm)

Comparing the dimensions of Table IV with the nominal dimensions 450mm x 225mm x 225mm shows that all the industries produced sandcrete blocks with dimensional variations outside the allowable range.

D. Strength properties of selected sandcrete blocks

The crushing loads of selected sandcrete blocks tested in accordance with [6] are shown in Tables V to XIV.

Test Time → Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	130.9kN 2.20 N/mm^2	124.4kN 2.09 N/mm^2	126.3kN 2.12 N/mm^2	118.8kN 2.0 N/mm^2	1710 kg/m^3
Block 2	119.0kN 2.0 N/mm^2	121.6kN 2.04 N/mm^2	126.8kN 2.13 N/mm^2	122.5kN 2.06 N/mm^2	
Block 3	122.3kN 2.06 N/m^2	120.0kN 2.02 N/mm^2	122.4kN 2.06 N/mm^2	128.2kN 2.16 N/mm^2	
Block 4	121.5kN 2.04 N/mm^2	125.5kN 2.11 N/mm^2	124.5kN 2.09 N/mm^2	119.6kN 2.01N/mm^2	
Block 5	125.4kN 2.11 N/mm^2	128.2kN 2.16 N/mm^2	119.5kN 2.01 N/mm^2	125.3kN 2.11 N/mm^2	
Block 6	120.0kN 2.02 N/mm^2	118.2kN 1.99 N/mm^2	120kN 2.02 N/mm^2	128.8kN 2.17 N/mm^2	
Block 7	128.6kN 2.16 N/mm^2	126.3kN 2.12 N/mm^2	128.2kN 2.16 N/mm^2	120.5kN 2.03 N/mm^2	
Block 8	124.4kN 2.09 N/mm^2	122.1kN 2.05 N/mm^2	130.4kN 2.19 N/mm^2	117.8kN 1.98/mm^2	
Block 9	127.2kN 2.14 N/mm^2	127.6kN 2.15 N/mm^2	122.2kN 2.05 N/mm^2	123.6kN 2.08 N/mm^2	
Block 10	124.0kN 2.08 N/mm^2	125.0kN 2.10 N/mm^2	127.5kN 2.14 N/mm^2	121.5kN 2.04 N/mm^2	
Average	124.3kN 2.09 N/mm^2	123.89kN 2.08 N/mm^2	124.78kN 2.10 N/mm^2	122.66kN 2.06 N/mm^2	

Table V: Crushing load and compressive strength of sandcrete blocks from Industry A (Net Area 59,480 mm^2)

Table VI: Crushing load and compressive strength of sandcrete blocks from Industry B (Net Area 57,710 mm^2)

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Test Time → / Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	88.2kN 1.53 N/mm^2	89.0kN 1.54 N/mm^2	80.3kN 1.39 N/mm^2	90.0kN 1.56 N/mm^2	1619 kg/m^3
Block 2	81.5kN 1.41 N/mm^2	97.9kN 1.70 N/mm^2	84.3kN 1.46 N/mm^2	82.4kN 1.43 N/mm^2	
Block 3	85.1kN 1.47N/mm^2	82.4kN 1.43 N/mm^2	88.0kN 1.52 N/mm^2	80.8kN 1.40 N/mm^2	
Block 4	80.7kN 1.40 N/mm^2	80.8kN 1.40 N/mm^2	82.2kN 1.42 N/mm^2	78.8kN 1.37 N/mm^2	
Block 5	78.3kN 1.36 N/mm^2	92.9kN 1.61 N/mm^2	78.6kN 1.36 N/mm^2	87.0kN 1.51 N/mm^2	
Block 6	82.5kN 1.43 N/mm^2	85.2kN 1.48 N/mm^2	86.5kN 1.50 N/mm^2	88.5kN 1.53 N/mm^2	
Block 7	82.8kN 1.43 N/mm^2	83.6kN 1.45 N/mm^2	83.3kN 1.44 N/mm^2	80.0kN 1.39 N/mm^2	
Block 8	88.0kN 1.53 N/mm^2	93.4kN 1.62 N/mm^2	90.1kN 1.56 N/mm^2	85.2kN 1.48 N/mm^2	
Block 9	80.2kN 1.39 N/mm^2	84.2kN 1.46 N/mm^2	82.8kN 1.43 N/mm^2	84.4kN 1.46 N/mm^2	
Block 10	79.4kN 1.38 N/mm^2	87.5kN 1.52 N/mm^2	84.7kN 1.47 N/mm^2	80.0kN 1.39 N/mm^2	
Average	82.67kN 1.43 N/mm^2	87.69kN 1.52 N/mm^2	84.08kN 1.46 N/mm^2	83.71kN 1.45 N/mm^2	

Table VII: Crushing load and compressive strength of sandcrete blocks from Industry C (Net Area 56,500 mm^2)

Test Time → / Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	91.4kN 1.62 N/mm^2	95.2kN 1.61 N/mm^2	99.8kN 1.77 N/mm^2	88.5kN 1.57 N/mm^2	1686 kg/m^3
Block 2	90.6kN 1.60 N/mm^2	104.0kN 1.84 N/mm^2	91.4kN 1.62 N/mm^2	95.2kN 1.68 N/mm^2	
Block 3	85.8kN 1.52 N/mm^2	96.7kN 1.71 N/mm^2	92.2kN 1.63 N/mm^2	102.3kN 1.81 N/mm^2	
Block 4	95.6kN 1.69 N/mm^2	89.8kN 1.59 N/mm^2	90.0kN 1.59 N/mm^2	94.7kN 1.68 N/mm^2	
Block 5	106.3kN 1.88 N/mm^2	91.2kN 1.61 N/mm^2	89.4kN 1.58 N/mm^2	97.3kN 1.72N/mm^2	
Block 6	88.7kN 1.57 N/mm^2	93.8kN 1.66 N/mm^2	95.3kN 1.69 N/mm^2	90.8kN 1.61 N/mm^2	
Block 7	92.3kN 1.63 N/mm^2	90.4kN 1.60 N/mm^2	100.5kN 1.78 N/mm^2	94.6kN 1.67 N/mm^2	
Block 8	96.6kN 1.71 N/mm^2	106.4kN 1.88 N/mm^2	90.6kN 1.60 N/mm^2	104.7kN 1.85N/mm^2	

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Block 9	86.2kN 1.53 N/mm^2	95.1kN 1.68 N/mm2	93.0kN 1.65 N/mm^2	90.2kN 1.60N/mm^2	
Block 10	91.0kN 1.61 N/mm^2	88.6kN 1.57 N/mm^2	96.4kN 1.71 N/mm^2	98.8kN 1.75 N/mm^2	
Average	90.91kN 1.61 N/mm^2	95.12kN 1.68 N/mm^2	93.86kN 1.66 N/mm^2	95.71kN 1.69 N/mm^2	

Table VIII: Crushing load and compressive strength of sandcrete blocks from Industry D (Net Area 59,220 mm^2)

Test Time → Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	105.0kN 1.77 N/mm^2	91.8kN 1.55 N/mm^2	88.5kN 1.49 N/mm^2	95.4kN 1.61 N/mm^2	
Block 2	90.0kN 1.52 N/mm^2	88.8kN 1.50 N/mm^2	94.3kN 1.59 N/mm^2	91.8kN 1.55 N/mm^2	
Block 3	97.6kN 1.65 N/mm^2	95.6kN 1.61 N/mm^2	103.8kN 1.75 N/mm^2	98.5kN 1.66 N/mm^2	
Block 4	92.4kN 1.56 N/mm^2	103.4kN 1.75 N/mm^2	98.8kN 1.67 N/mm^2	95.7kN 1.62 N/mm^2	
Block 5	87.1kN 1.47 N/mm^2	98.2kN 1.66 N/mm^2	90.2kN 1.52 N/mm^2	98.8kN 1.67 N/mm^2	1664 kg/m^3
Block 6	94.2kN 1.59 N/mm^2	100.1kN 1.69 N/mm^2	97.5kN 1.65 N/mm^2	89.8kN 1.52 N/mm^2	
Block 7	86.8kN 1.47N/mm^2	92.3kN 1.56 N/mm^2	95.3kN 1.61 N/mm^2	104.3kN 1.76 N/mm^2	
Block 8	90.3kN 1.52 N/mm^2	86.8kN 1.47 N/mm^2	88.8kN 1.50 N/mm^2	92.6kN 1.56 N/mm^2	
Block 9	99.5kN 1.68 N/mm^2	95.6kN 1.61 N/mm^2	98.3kN 1.66 N/mm^2	99.8kN 1.69 N/mm^2	
Block 10	93.2kN 1.57 N/mm^2	90.4kN 1.53 N/mm^2	94.4kN 1.59 N/mm^2	100kN 1.69 N/mm@	
Average	93.8kN 1.58 N/mm^2	94.3kN 1.59 N/mm^2	94.99kN 1.60 N/mm^2	96.67kN 1.63 N/mm^2	

Table IX: Crushing load and compressive strength of sandcrete blocks from Industry E (Net Area 58,420 mm^2)

Test Time → Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	90.0kN 1.54 N/mm^2	95.2kN 1.63 N/mm^2	87.7kN 1.50 N/mm^2	95.8kN 1.64 N/mm^2	
Block 2	85.4kN 1.46 N/mm^2	88.8kN 1.52 N/mm^2	90.4kN 1.55 N/mm^2	83.9kN 1.44 N/mm^2	
Block 3	92.7kN 1.59 N/mm^2	90.5kN 1.55 N/mm^2	83.6kN 1.43 N/mm^2	90.8kN 1.55 N/mm^2	
Block 4	88.3kN 1.51 N/mm^2	90.5kN 1.55 N/mm^2	83.9kN 1.44 N/mm^2	94.1kN 1.61 N/mm^2	

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Block 5	82.7kN 1.42 N/mm^2	87.7kN 1.50 N/mm^2	86.2kN 1.48 N/mm^2	90.0kN 1.54 N/mm^2	1650 kg/m^3
Block 6	94.2kN 1.61 N/mm^2	84.9kN 1.45 N/mm^2	90.4kN 1.55 N/mm^2	88.2kN 1.51 N/mm^2	
Block 7	93.0kN 1.59 N/mm^2	90.0kN 1.54 N/mm^2	94.8kN 1.62 N/mm^2	85.5kN 1.46 N/mm^2	
Block 8	91.9kN 1.57 N/mm^2	96.2kN 1.65 N/mm^2	96.0kN 1.64 N/mm^2	88.8kN 1.52 N/mm^2	
Block 9	86.6kN 1.48 N/mm^2	94.0kN 1.61 N/mm^2	89.9kN 1.54 N/mm^2	92.2kN 1.58 N/mm^2	
Block 10	82.9kN 1.42 N/mm^2	87.6kN 1.50 N/mm^2	92.0kN 1.57 N/mm^2	94.0kN 1.61 N/mm^2	
Average	88.77kN 1.52 N/mm^2	90.54kN 1.55 N/mm^2	89.49kN 1.53 N/mm^2	90.33kN 1.55 N/mm^2	

Table X: Crushing load and compressive strength of sandcrete blocks from Industry F (Net Area 58,940 mm^2)

Test Time → Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	33.8kN 0.57 N/mm^2	38.2kN 0.65 N/mm^2	35.5kN 0.60 N/mm^2	36.8kN 0.62 N/mm^2	1593 kg/m^3
Block 2	35.5kN 0.60 N/mm^2	42.5kN 0.72 N/mm^2	43.0kN 0.73 N/mm^2	37.8kN 0.64 N/mm^2	
Block 3	40.4kN 0.69 N/mm^2	36.2kN 0.61 N/mm^2	32.9kN 0.56 N/mm^2	38.3kN 0.65 N/mm^2	
Block 4	38.2kN 0.65 N/mm^2	38.3kN 0.65 N/mm^2	35.3kN 0.60 N/mm^2	42.6kN 0.72 N/mm^2	
Block 5	32.8kN 0.56 N/mm^2	40.4kN 0.69 N/mm^2	38.2kN 0.65 N/mm^2	33.5kN 0.57 N/mm^2	
Block 6	35.0kN 0.59 N/mm^2	36.6kN 0.62 N/mm^2	32.7kN 0.55 N/mm^2	34.2kN 0.58 N/mm^2	
Block 7	42.3kN 0.72 N/mm^2	34.7kN 0.59 N/mm^2	38.1kN 0.65 N/mm^2	37.4kN 0.63 N/mm^2	
Block 8	32.9kN 0.56 N/mm^2	36.5kN 0.62 N/mm^2	40.3kN 0.68 N/mm^2	38.1kN 0.65 N/mm^2	
Block 9	35.8kN 0.61 N/mm^2	37.2kN 0.63 N/mm^2	40.2kN 0.68 N/mm^2	38.8kN 0.66 N/mm^2	
Block 10	36.6kN 0.62 N/mm^2	33.7kN 0.57 N/mm^2	35.5kN 0.60 N/mm^2	33.3kN 0.56 N/mm^2	
Average	36.33kN 0.62 N/mm^2	37.43kN 0.64 N/mm^2	37.17kN 0.63 N/mm^2	37.08kN 0.63 N/mm^2	

Table XI: Crushing load and compressive strength of sandcrete blocks from Industry G (Net Area 58,200 mm^2)

Test Time → Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	130.4kN 2.24 N/mm^2	135.3kN 2.32 N/mm^2	136.3kN 2.34 N/mm^2	136.2kN 2.34 N/mm^2	

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Block 2	124.8kN 2.14 N/mm^2	128.0kN 2.20 N/mm^2	135.5kN 2.29 N/mm^2	140.3kN 2.41 N/mm^2	
Block 3	132.0kN 2.27 N/mm^2	125.6kN 2.16 N/mm^2	141.2kN 2.43 N/mm^2	135 .7kN 2.33 N/mm^2	
Block 4	128.7kN 2.21 N/mm^2	125.2kN 2.15 N/mm^2	130.8kN 2.25 N/mm^2	137.4kN 2.36 N/mm^2	
Block 5	135.6kN 2.33 N/mm^2	130.1kN 2.24 N/mm^2	133.7kN 2.30 N/mm^2	141.5kN 2.43 N/mm^2	1741 kg/m^3
Block 6	138.3kN 2.38 N/mm^2	129.8kN 2.23 N/mm^2	131.8kN 2.26 N/mm^2	138.2kN 2.37 N/mm^2	
Block 7	129.8kN 2.23 N/mm^2	125.7kN 2.16 N/mm^2	130.4kN 2.24 N/mm^2	135.8kN 2.33 N/mm^2	
Block 8	135.5kN 2.33 N/mm^2	129.8kN 2.23 N/mm^2	130.5kN 2.24 N/mm^2	133.5kN 2.29 N/mm^2	
Block 9	130.7kN 2.25 N/mm^2	124.9kNs 2.15 N/mm^2	135.4kN 2.33 N/mm^2	131.6kN 2.26 N/mm^2	
Block 10	135.3kN 2.32 N/mm^2	130.2kN 2.24 N/mm^2	140.6kN 2.42 N/mm^2	139.2kN 2.39 N/mm^2	
Average	132.11kN 2.27 N/mm^2	128.46kN 2.21 N/mm^2	134.62kN 2.31 N/mm^2	136.94kN 2.35 N/mm^2	

Table XII: Crushing load and compressive strength of sandcrete blocks from Industry H (Net Area 56,800 mm^2)

Test Time → Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	77.5kN 1.36 N/mm^2	80.4kN 1.42 N/mm^2	83.0kN 1.46 N/mm^2	77.3kN 1.36 N/mm^2	
Block 2	76.3kN 1.34 N/mm^2	74.5kN 1.31 N/mm^2	80.2kN 1.41 N/mm^2	79.8kN 1.40 N/mm^2	
Block 3	81.2kN 1.43 N/mm^2	74.4kN 1.31 N/mm^2	78.6kN 1.38 N/mm^2	82.5kN 1.45 N/mm^2	
Block 4	80.4kN 1.42 N/mm^2	78.2kN 1.38 N/mm^2	82.8kN 1.46 N/mm^2	82.0kN 1.44 N/mm^2	
Block 5	75.5kN 1.33 N/mm^2	80.6kN 1.42 N/mm^2	84.8kN 1.49 N/mm^2	79.7kN 1.40 N/mm^2	1605 kg/m^3
Block 6	82.4kN 1.45 N/mm^2	80.4kN 1.42 N/mm^2	84.2kN 1.48 N/mm^2	83.5kN 1.47 N/mm^2	
Block 7	74.8kN 1.32 N/mm^2	85.3kN 1.50 N/mm^2	80.6kN 1.42 N/mm^2	83.7kN 1.47 N/mm^2	
Block 8	78.5kN 1.38 N/mm^2	79.8kN 1.40 N/mm^2	80.3kN 1.41 N/mm^2	81.2kN 1.43 N/mm2	
Block 9	80.8kN 1.42 N/mm^2	83.3kN 1.47 N/mm^2	79.8kN 1.40 N/mm^2	80.1kN 1.41 N/mm^2	
Block 10	75.5kN 1.33 N/mm^2	80.8kN 1.42 N/mm^2	81.6kN 1.44 N/mm^2	80.6kN 1.55 N/mm^2	
Average	78.29kN 1.38 N/mm^2	79.77kN 1.40 N/mm^2	81.59kN 1.44 N/mm^2	81.04kN 1.43 N/mm^2	

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Table XIII: Crushing load and compressive strength of sandcrete blocks from Industry J (Net Area 58,328 mm²)

Test Time → Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	75.8kN 1.30 N/mm²	79.9kN 1.37 N/mm²	82.8kN 1.42 N/mm²	77.6kN 1.33 N/mm²	1604 kg/m³
Block 2	82.2kN 1.41 N/mm²	81.1kN 1.39 N/mm²	84.6kN 1.45 N/mm²	79.5kN 1.36 N/mm²	
Block 3	80.5kN 1.38 N/mm²	84.0kN 1.44 N/mm²	81.7kN 1.40 N/mm²	78.3kN 1.34 N/mm²	
Block 4	78.7kN 1.35 N/mm²	82.8kN 1.42 N/mm²	79.3kN 1.36 N/mm²	78.3kN 1.34 N/mm²	
Block 5	77.0kN 1.32 N/mm²	79.3kN 1.36 N/mm²	78.2kN 1.34 N/mm²	77.1kN 1.32 N/mm²	
Block 6	78.7kN 1.35 N/mm²	79.9kN 1.37 N/mm²	80.5kN 1.38 N/mm²	77.8kN 1.33 N/mm²	
Block 7	78.2kN 1.34 N/mm²	80.5kN 1.38 N/mm²	79.3kN 1.36 N/mm²	78.8kN 1.35 N/mm²	
Block 8	76.4kN 1.31 N/mm²	82.2kN 1.41 N/mm²	78.7kN 1.35 N/mm²	78.8kN 1.35 N/mm²	
Block 9	80.6kN 1.38 N/mm²	83.5kN 1.43 N/mm²	80.6kN 1.38 N/mm²	78.0kN 1.34 N/mm²	
Block 10	78.2kN 1.34 N/mm²	81.7kN 1.40 N/mm²	80.5kN 1.38 N/mm²	77.0kN 1.32 N/mm²	
Average	78.63kN 1.35 N/mm²	81.49kN 1.40 N/mm²	80.62kN 1.38 N/mm²	78.12kN 1.34 N/mm²	

Table XIV: Crushing load and compressive strength of sandcrete blocks from Industry K (Net Area 58,450 mm²)

Test Time → Block No ↓	Week 1	Week 2	Week 3	Week 4	Average Density
Block 1	55.5kN 0.95 N/mm²	51.5kN 0.88 N/mm²	60.3kN 1.03 N/mm²	58.3kN 1.00 N/mm²	1599 kg/m³
Block 2	52.6kN 0.90 N/mm²	49.2kN 0.84 N/mm²	58.8kN 1.01 N/mm²	60.2kN 1.03 N/mm²	
Block 3	46.8kN 0.80 N/mm²	47.2kN 0.81 N/mm²	64.3kN 1.10 N/mm²	55.2kN 0.94 N/mm²	
Block 4	58.5kN 1.0 N/mm²	52.7kN 0.90 N/mm²	68.2kN 1.17 N/mm²	60.2kN 1.03 N/mm²	
Block 5	60.0kN 1.03 N/mm²	59.8kN 1.02 N/mm²	72.6kN 1.24 N/mm²	65.0kN 1.11 N/mm²	
Block 6	56.7kN 0.97 N/mm²	65.1kN 1.11 N/mm²	76.0kN 1.30 N/mm²	71.4kN 1.22 N/mm²	
Block 7	72.3kN 1.24 N/mm²	64.8kN 1.11 N/mm²	65.8kN 1.13 N/mm²	62.1kN 1.06 N/mm²	
Block 8	65.2kN 1.12 N/mm²	60.2kN 1.03 N/mm²	70.2kN 1.20 N/mm²	63.5kN 1.09 N/mm²	

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Block 9	63.6kN 1.09 N/mm^2	58.0kN 0.99 N/mm^2	65.5kN 1.12 N/mm^2	60.2kN 1.03 N/mm^2	
Block 10	59.4kN 1.02 N/mm^2	54.5kN 0.93 N/mm^2	60.2kN 1.03 N/mm^2	58.8kN 1.03 N/mm^2	
Average	59.06kN 1.01 N/mm^2	56.3kN 0.96 N/mm^2	66.19kN 1.13 N/mm^2	61.49kN 1.05 N/mm^2	

Table XV: Summary of Strength Characteristics of Blocks from the industries

Industry	Range of Compressive Strength of Individual Blocks for Four Weeks	Range of Average Compressive Strength for Each Industry for Four Weeks	Average Density of Blocks for Each Industry
Industry A	1.98 – 2.20 N/mm^2	2.06 – 2.10 N/mm^2	1710 kg/m^3
Industry B	1.36 – 1.70 N/mm^2	1.43 – 1.52 N/mm^2	1619 kg/m^3
Industry C	1.53 – 1.88 N/mm^2	1.61 – 1.69 N/mm^2	1686 kg/m^3
Industry D	1.47 – 1.77 N/mm^2	1.58 – 1.63 N/mm^2	1664 kg/m^3
Industry E	1.42 – 1.65 N/mm^2	1.52 – 1.55 N/mm^2	1650 kg/m^3
Industry F	0.55 – 0.73 N/mm^2	0.62 – 0.64 N/mm^2	1593 kg/m^3
Industry G	2.14 – 2.43 N/mm^2	2.21 – 2.35 N/mm^2	1741 kg/m^3
Industry H	1.31 – 1.55 N/mm^2	1.38 – 1.44 N/mm^2	1605 kg/m^3
Industry J	1.30 – 1.45 N/mm^2	1.34 – 1.40 N/mm^2	1604 kg/m^3
Industry K	0.80 – 1.42 N/mm^2	0.92 – 1.22 N/mm^2	1599 kg/m^3

Table XV which is the summary of Tables V – XIV shows that the compressive strengths `of individual sandcete blocks from all the manufacturing industries range from 0.80 to 2.43 N/mm^2 while their average compressive strengths range from 0.92 to 2.35 N/mm^2. Reference [6] provides that the average crushing strength of ten blocks tested in accordance with Appendix B shall not be less than

(i) G
(ii) 0.9G + 0.62S

Where G is 2.8 N/mm^2 and S is standard deviation.

These values of compressive strength for all the industries investigated, therefore, fall below 2.8 N/mm2 and 2.76 N/mm2 which are the requirements of [6] and [12] respectively for sandcrete blocks for use in load bearing walls. Only two out of the ten industries satisfied the lower provisions of [13], which require that the average strength of six blocks should not less than 2.0 N/mm2 and that the lowest strength of individual blocks should not be less than 1.75 N/mm2.

IV. CONCLUSION

All the ten block-manufacturing industries investigated produced blocks with compressive strengths lower than those specified by [6] and [12], which are 2.8 N/mm^2, and 2.76 N/mm^2 respectively for sandcrete blocks manufactured for use in load bearing walls. Only two out of the ten industries satisfied the lower provisions of [13], which require that the average strength of six blocks should not be less than 2.0 N/mm^2 and that the lowest strength of individual blocks should not be less than 1.75 N/mm^2. In addition, all the industries produced sandcrete blocks with dimensional variations outside the range allowed by [5]. The sand used by all the industries generally satisfied the requirements of [7]. The water used by the industries was from reliable sources. The compressive strength of sandcrete blocks is proportional to the density. The results showed some increase in compressive strength every time the density increased and vice versa.

V. RECOMMENDATIONS

Sandcrete blocks from Industries A and G alone are recommended for use in the construction of load bearing walls since they satisfied the strength requirements of [13]. The blocks from the remaining eight industries can only be used in the construction of non-load bearing partitions, site hoarding and similar jobs. In view of the results of this investigation, it is further recommended that the government of Nigeria takes immediate steps to standardize the processes of block manufacturing and work through the Council for the Regulation of Engineering Practice in Nigeria (COREN) to ensure

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proper registration and strict supervision of block manufacturers as a means to improve the quality of commercially available sandcrete blocks for construction works.

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AUTHOR BIOGRAPHY

Joan I. Arimanwa holds the Bachelor of Engineering (B.Eng) in Civil Engineering and the Master of Engineering (M.Eng) in Structural Engineering both from Federal University of Technology, Owerri, Nigeria. She is a Lecturer 1 in the Civil Engineering Department of the same university and a member of the Nigeria Society of Engineers, Nigerian Institution of Civil Engineers and Association of Professional Women Engineers of Nigeria. She is registered by the Council for the Regulation of Engineering Practice in Nigeria (COREN) as a Civil Engineer.

Michael C. Arimanwa holds the Bachelor of Engineering (B.Eng) in Civil Engineering and the Master of Engineering (M.Eng) in Structural Engineering both from Federal University of Technology, Owerri, Nigeria. He is a Chief Lecturer in the Civil Engineering Department, Federal Polytechnic, Nekede, Owerri, Nigeria. He is a member of the Nigeria Society of Engineers, Nigerian Institution of Civil Engineers and registered by the Council for the Regulation of Engineering Practice in Nigeria (COREN) as a Civil Engineer.

Chinenye E. Okere holds the Bachelor of Engineering (B.Eng) in Civil Engineering, the Master of Engineering (M.Eng) in Structural Engineering, and the Doctor of Philosophy (PhD) in Structural Engineering all from Federal University of Technology, Owerri, Nigeria. She is a Lecturer 1 in the Civil Engineering Department of the same university and a member of the Nigeria Society of Engineers and Association of Professional Women Engineers of Nigeria. She is registered by the Council for the Regulation of Engineering Practice in Nigeria (COREN) as a Civil Engineer.

Chioma T. G. Awodiji holds the Bachelor of Engineering (B.Eng) in Civil Engineering and the Master of Engineering (M.Eng) in Structural Engineering both from Federal University of Technology, Owerri, Nigeria. She is an Assistant Lecturer in the Civil Engineering Department of the same university.