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QUALITY ASSESSMENT OF COMMERCIALLY PRODUCED SANDCRETE BLOCKS IN PART OF AKWA IBOM STATE, NIGERIA

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ABSTRACT
This study investigated the strength properties of commercially manufactured sandcrete blocks in four cities in Southern Nigeria. 12 sandcrete block firms were visited and ten sandcrete block samples were randomly selected from each of these firms and taken to the laboratory for testing. Two sets of control samples were produced in the laboratory using mix ratios of 1:8 and 1:6. Aggregates used for all the block molding were also collected and their particle size analysed. Compressive strength of blocks from the 12 firms visited ranged from 0.19 to 1.32N/mm^{2}and were far below the minimum specified values by NIS 87:2007.Authors ascribe this poor strength to non-compliance to standard. Compressive strength of the control samples revealed that complying with NIS 87: 2007 mix ratio and neglecting some other specified details is still not likely to produce standard products.

Keywords: *Compressive Strength, Sandcrete Blocks, Sieve Analysis.*

1. INTRODUCTION

Every man needs a roof over his head. As such, shelter is one of the basic necessity in life. As the population of any nation increases, so does the demand for housing and other infrastructures and the materials used in their construction. Sandcrete blocks have been the predominant walling material in both residential and commercial buildings in West Africa for over fifty years [1]. It has been reported that more than 90% of physical infrastructures in Nigeria are constructed with sandcrete blocks [2]. Therefore, they are very essential materials in the building industry in Nigeria and other West African countries, mostly as a result of their comparative advantages over other walling materials. For instance, they are cheaper and easier to produce. They possess high fire resistance and do not rust, decay or contain any material that is harmful to the environment.

According to Anosike and Onyebade [3] Nigerian Industrial Standard (NIS 87:2000) defines sandcrete blocks as composite masonry units comprising cement, sand and water molded into different sizes with dimensions exceeding that specified for bricks. In Nigeria, blocks are usually produced in either solid or hollow rectangular forms. Solid blocks have no opening but hollow blocks are produced with two cavities from top to bottom on each block and these voids occupy about one-third of the total volume of each block [4], hereby reducing its unit weight. Typically, in the production of sandcrete blocks, the materials are thoroughly mixed until a homogenous mix with uniform colour is obtained. The mixture is placed in a mold which is removed immediately after compaction and levelling of the top. The newly produced sandcrete blocks are self-supporting with zero slump, which is why they are often referred to as zero slump concrete [5]. Compaction is often achieved by manual compaction or machine vibration. The strength of the resulting hardened sandcrete blocks are to a great extend affected by mix composition, production method, method and duration of curing and properties of constituent materials.

There are many sandcrete blocks industries scattered all over Nigeria; of which most are operating at small

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scale level. In recent time, builders have resorted to purchasing ready-made sandcrete blocks instead of manufacturing on site. As such, the quality of sandcrete blocks produced by these industries plays a vital role in the strength, stability and durability of both residential and commercial buildings in our society. Cement is the most expensive constituent of sandcrete blocks. Hence, most blocks industries compromise the quantity of cement in their mix in order to reduce production cost and maximize profit. This and other factors like method of mixing and compaction result in production of poor quality sandcrete blocks by most of the block industries. Poor quality blocks have resulted in loss of lives and properties through building failures. Sometimes even when the building has not collapse, the aesthetics value is lost to cracks and other defects [4].

To solve this problem, Nigerian Industrial Standard (NIS 87:2007) which is a standard reference document for manufacturing of sandcrete blocks in Nigeria; specifies the minimum characteristics compressive strength of sandcrete blocks as 2.5N/mm^2 and 3.45N/mm^2 for non-load bearing and load bearing walls respectively [3, 4, 6, 7]. The document also specifies maximum water absorption as 12% [4]. However, cases of building failures are still rampant because as revealed by several researches, compliance to the NIS standard by sandcrete block industries is very poor in most cities in the country. Anosike and Oyebade [3] carried out a survey on 15 selected sandcrete blocks industries from Ota, Umuahia and Federal Capital Territory. From the report, mean compressive strength of blocks industries ranged from 0.75 to 2.19N/mm^2 while the mean water absorption ranged from 12.94 to 16.95%.In a study by Aiyewalehinmi and Tanimola [8] in Akure, the mean compressive strength was between 0.61 and 0.63N/mm^2. Similar surveys have also been carried out in Calabar [6], Adeta, Kwara state [4], Ibadan [7] and Owerri [1] with similar or even worse results. All these show the non-compliance of sandcrete block industries to the NIS standard in most cities in Nigeria.

This paper presents an experimental survey of the compressive strength of sandcrete blocks produced by commercial block industries in four cities (Abak, Eket, Onna and Ikot Abasi) in Akwa Ibom State, Nigeria and compares with the recommended strength by NIS 87:2007 standard.

2. METHODOLOGY

2.1 Field Investigation

Four cities in Akwa Ibom State (Nigeria) were selected for this survey. The cities were Abak, Eket, Onna and Ikot Abasi and three sandcrete blocks industries were visited from each of these cities, making a total of twelve blocks industries. Table 1 shows notations for blocks firms visited in each city. The aim of the visit was to find out the industries' mode of production, quality of sand used and other necessary information. For each industry visited, ten sandcrete blocks were purchased and taken to the labouratory for testing. Samples of sand used for casting were also collected from each industry and information on the date of casting were also received.

Table 1: Cities and Blocks Firms Visited

S/N	City	Block Firms
1.	Abak	A, B, C
2.	Eket	D, E, F
3.	Onna	G, H, I
4.	IkotAbasi	J, K, L

2.2 Materials

2.2.1 Binder

For the laboratory samples, Dangote brand of Portland Limestone cement (strength class 32.5R) conforming to NIS 444-1:2014 [9] was used. The cement was purchased at Abak Local Government Area of Akwa Ibom State in 50kg bags. Potable water was used, as supplied within the main campus of Akwa Ibom State University.

2.2.2 Fine Aggregate

The fine aggregate used for the laboratory samples was obtained from a river sand mining site at Ikot Ekong, Mkpat Enin Local Government Area of Akwa Ibom State.

2.3 Production of Control Samples

Two sets of sandcrete blocks were produced in the laboratory. The aim was to investigate if adopting a specified mix ratio and neglecting most other specifications can still yield acceptable results. A mix ratio of 1:6 (cement and sand) was used for one set while 1:8 was used for the other and ten blocks were produced for each set. Batching was carried out by volume. The constituent materials were mixed together manually using spade. The mixture was placed in a metal mold of 450 x 150 x 225mm, compacted manually and the mold removed immediately after levelling of the top. Manual compaction was achieved by dropping the mold together with the mixture against their weights from a height of about 0.6m. The newly produced sandcrete blocks were self-supporting with zero slump and were placed outside the laboratory to set and harden. Curing was done by sprinkling of water on the blocks on a daily bases starting from about 24 hours after molding.

2.4 Laboratory Tests

Two tests were carried out in the laboratory – sieve analysis on sand samples used and compressive strength test on sandcrete block samples. Sieve analysis was carried out on a total of 13 sand samples and the results are presented in Figures 1 to 13 and Table 3.The grading of soil is best determined by direct observation of its particle size distribution curve. Equations (1) and (2) were adopted in calculating the coefficient of uniformity and curvature, respectively. A total of 140 sandcrete block samples were tested for 28th day compressive strength. Each sample was loaded in compression until failure and the loads at failure were recorded. Compressive strengths were determined by dividing the loads at failure by their corresponding cross sectional area.

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

$$Cc = \frac{(D_{30})^2}{D_{60} \times D_{10}} \quad (2)$$

Where *Cu* is the uniformity coefficient, *Cc* is coefficient of curvature, D_{10}, D_{30} and D_{60} are the particle diameter corresponding to 10%, 30% and 60% finer on the cumulative particle size distribution curve, respectively. If *Cu* is less than 4.0 the soil is poorly graded; if *Cu* is greater than 4.0 the soil is well graded.

3. RESULTS AND DISCUSSIONS

3.1 Field Results

From the survey, the common size and types of sandcrete blocks produced in Nigeria are shown in Table 2. Information from the field were mainly gathered through interview of personnel met on the industries' production site and observations made during the visits. It was observed that workers on their production sites have no formal training in civil engineering, building technology or any allied discipline.

3.1.1 Materials used by blocks Industries

All the 12 industries visited used Portland limestone cement. They possess little or no technical know-how on type, specification and conformity of cements. Hence they use whichever cement is supplied closest to them. The brand supplied in these cities were Dangote Portland Limestone cement conforming to NIS 444-1:2014 [10] and Unicem Portland Limestone cement conforming to NIS 444-1:2003 [9], both of strength class 32.5R.

Most of the personnel in these industries have an understanding that the quality of sand affects the resulting strength of sandcrete blocks. However, their knowledge in aggregate gradation is limited. As such their choice of sand was usually by hand feel through experience. Fine aggregates used were sharp river sand. Findings show that some of these industries also use sand from borrow pits, either 100 percent or mixed it with river sand.

Table 2: Commonly Produced Sandcrete Blocks in Nigeria

S/N	Blocks Dimension (mm)	Type
1.	450 x 225 x 225	Solid
2.	450 x 225 x 225	Hollow
3.	450 x 150 x 225	Solid
4.	450 x 150 x 225	Hollow
5.	450 x 125 x 225	Solid

3.1.2 Mix Ratio

All the 12 blocks factories adopted batching by volume and most of the firms used wheel barrow and paint bucket to measure sand and water respectively. They do not adopt any standard mix ratio; rather, they aim to achieve a certain number of blocks per bag of cement. This they achieve based on trial and error. For instance, a particular factory uses about five wheel barrows of sand to a 50kg bag of cement. This according to them should produce about fifty 450 x 225 x 150 hollow blocks. On the average, these industries use between 4 to 6 wheel barrows of sand to a 50kg bag of cement. Surprisingly, some manufacturers do not use any form of measurement for the sand. The people mixing would just take a portion of sand based on past experience and mix it with a 50kg bag of cement. In all the factories, addition of water did not follow any technical basis. It was at the discretion of the mixer based on experience.

3.1.3 Method of Production

All the factories visited adopted manual mixing using spades or shovels and used vibrating machine to compact their blocks. One block is produced at a time. The produced blocks are exposed outside to set and harden. Most of the industries visited especially those operating on small scale do not cure their blocks. The few ones that do adopt the method of sprinkling of water on the exposed blocks from 24 hours after demolding, for the first few days.

3.1.4 Quality Control and Conformity to Standard

All the blocks industries sampled do not carry out any form of test on the sand and cement used. They equally do not carry out any test on the finished products. They do not conform to any standard or specification. In fact, most factory owners and operators are not aware of the existence of any standard for production of sandcrete blocks.

3.2 Laboratory Results

3.2.1 Sieve Analysis Results

It was observed from Figures 1 to 13 that the uniformity coefficient, C_u ranged from 2.59 to 4.01 while the coefficient of curvature, C_c ranged from 0.27 to 1.0 for the sand samples. The C_u values revealed that the fine aggregate used by firms D and J were well graded and met the requirement of NIS 87:2000[11] for use in sandcrete blocks. However, the rest of the sand were poorly graded.

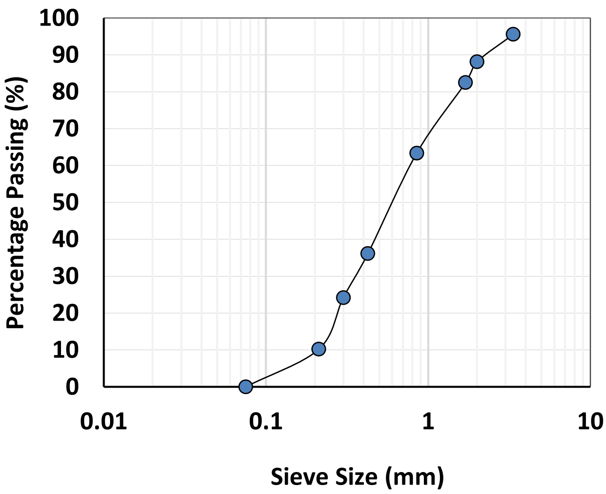

Figure 1: Particle Size Distribution Curve for Block Industry A

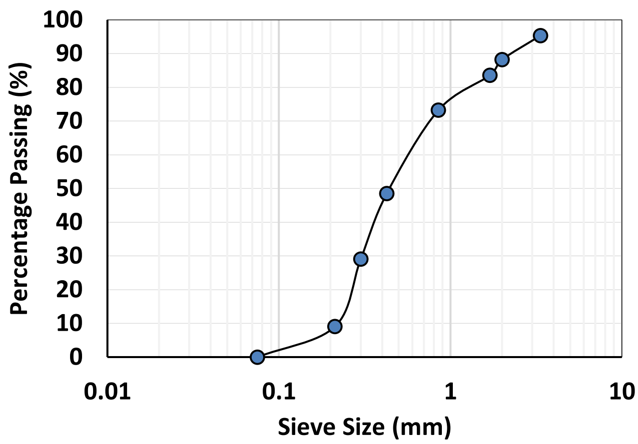

Figure 2: Particle Size Distribution Curve for Block Industry B

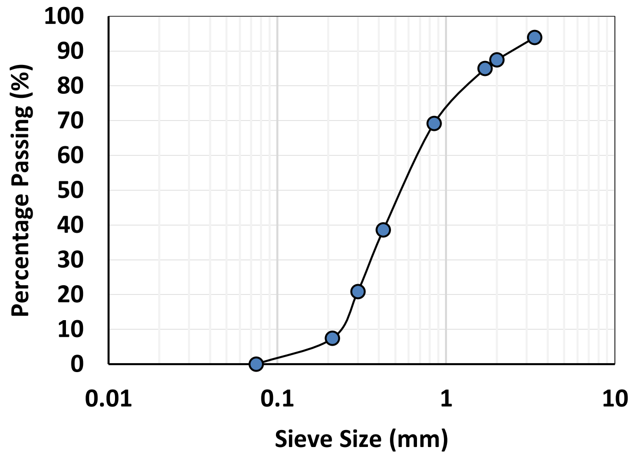

Figure 3: Particle Size Distribution Curve for Block Industry C

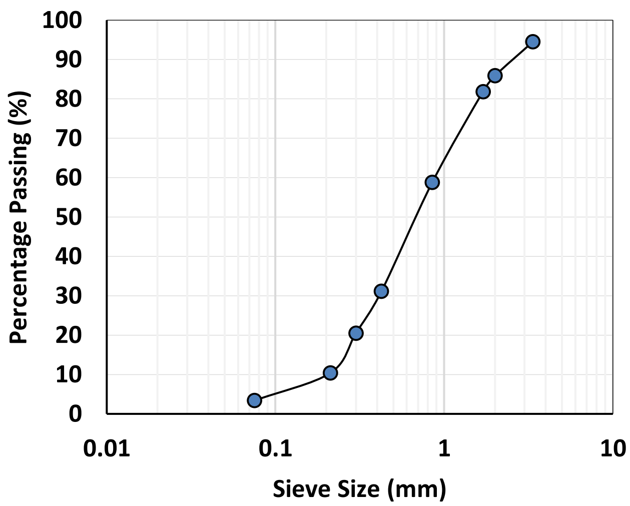

Figure 4: Particle Size Distribution Curve for Block Industry D

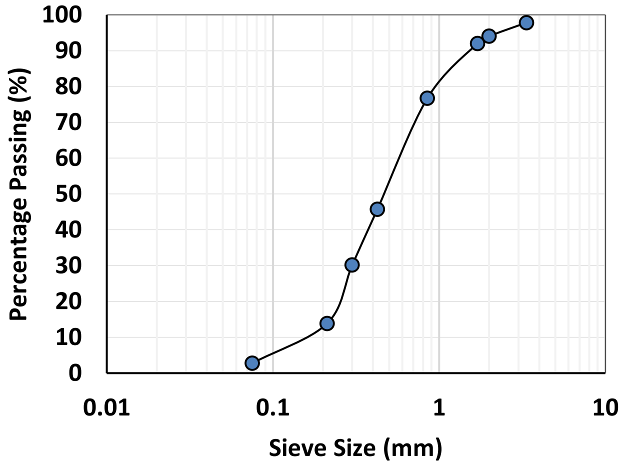

Figure 5: Particle Size Distribution Curve for Block Industry E

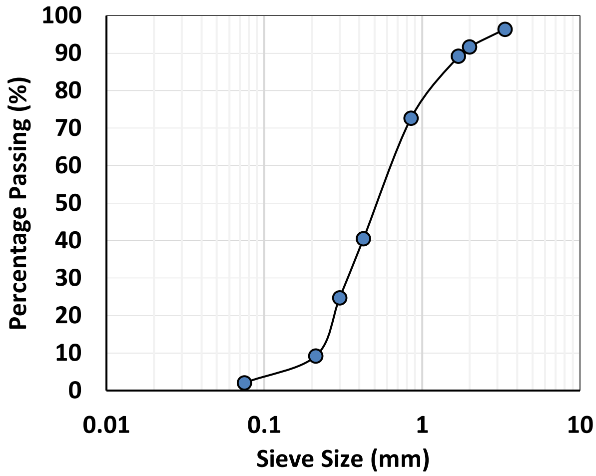

Figure 6: Particle Size Distribution Curve for Block Industry F

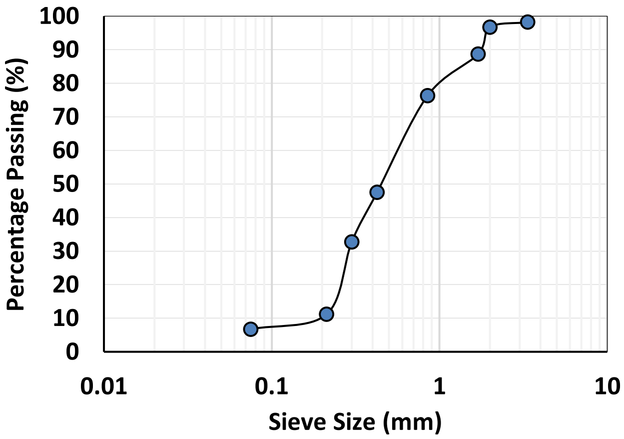

Figure 7: Particle Size Distribution Curve for Block Industry G

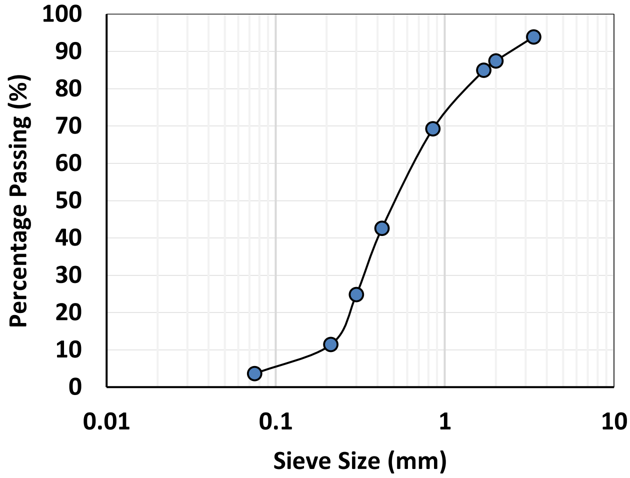

Figure 8: Particle Size Distribution Curve for Block Industry H

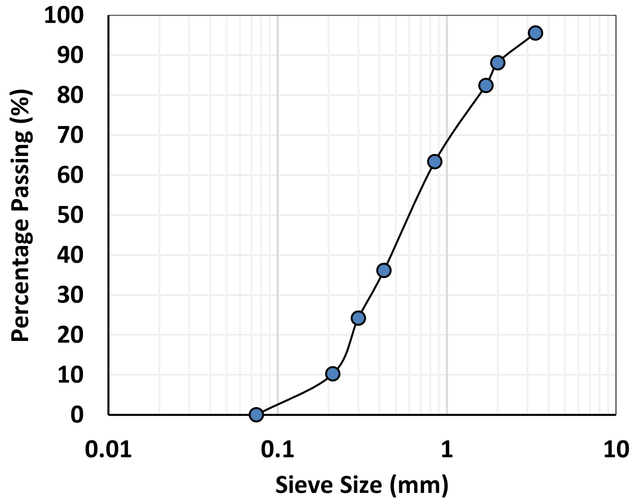

Figure 9: Particle Size Distribution Curve for Block Industry I

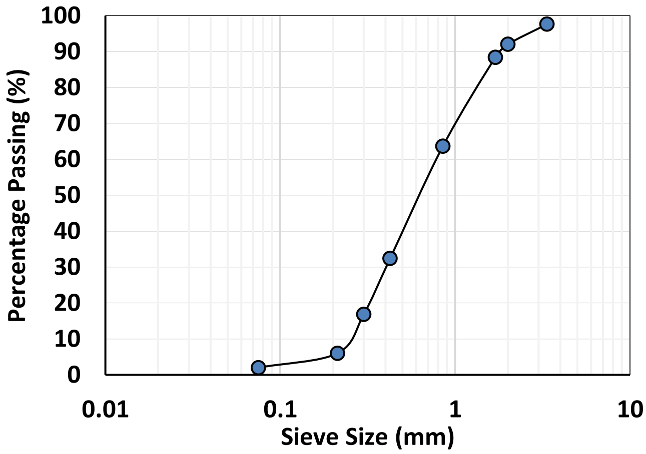

Figure 10: Particle Size Distribution Curve for Block Industry J

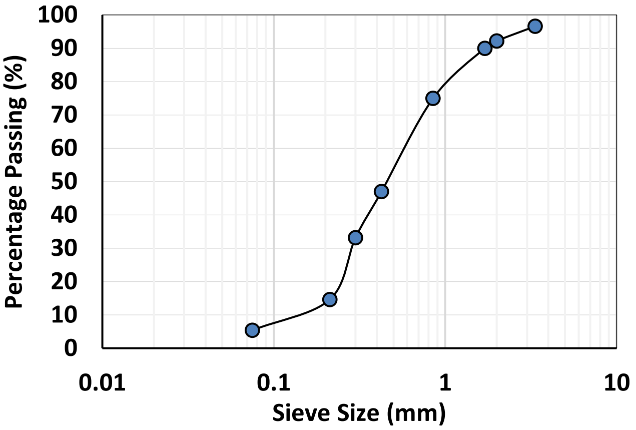

Figure 11: Particle Size Distribution Curve for Block Industry K

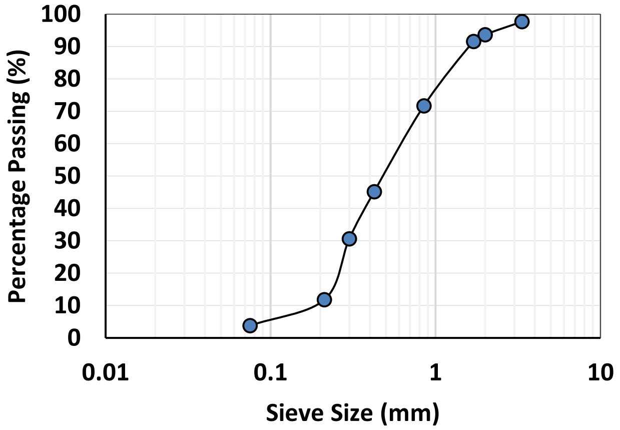

Figure 12: Particle Size Distribution Curve for Block Industry L

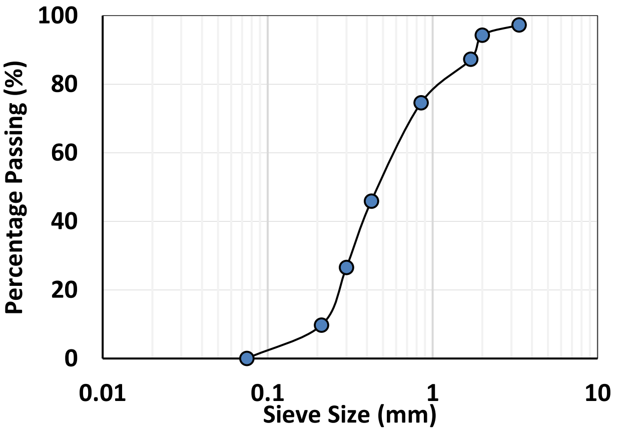

Figure 13: Particle Size Distribution Curve for control

3.3 Compressive Strength Results

3.3.1 Field Samples

Results of 28th day compressive strength of sandcrete blocks are presented in Tables 4, 5 and 6. Compressive strength of blocks from the 12 firms visited ranges from 0.19 to 1.32N/mm^2 while mean compressive strength per firm ranges from 0.21 to 0.89N/mm^2.

Table 3: Particle Size Distributions Parameters of Sand Used

	D_{60}	D_{10}	D_{30}	Cu	Cc
Control	0.6	0.212	0.32	2.83	0.81
A	0.79	0.2	0.38	3.95	0.91
B	0.59	0.212	0.3	2.78	0.72
C	0.69	0.216	0.37	3.19	0.92
D	0.85	0.212	0.42	4.01	0.98
E	0.58	0.18	0.3	3.22	0.86
F	0.65	0.212	0.35	3.07	0.89
G	0.55	0.212	0.29	2.59	0.72
H	0.65	0.18	0.32	3.61	0.88
I	0.8	0.212	0.36	3.77	0.76
J	0.8	0.2	0.4	4.00	1.00
K	0.59	0.15	0.29	3.93	0.95
L	0.62	0.18	0.3	3.44	0.81

Standard deviations for the data sets are low with an average value of 0.094. This shows that the data points for each firm do not deviate much from the mean values and as such are consistent. These compressive strength values all fall far below the minimum specified compressive strength by NIS 87: 2007 for load bearing and non-load bearing walls being 3.45N/mm^2 and 2.5N/mm^2 respectively. However, these results are not quite different from those obtained by several other researchers in different cities [1, 4, 6, 7, 8] and it confirms that sandcrete blocks produced by block manufacturers into our building industry are of consistently poor standard.

The reasons for this are not far-fetched. The practices employed by these firms in their production process as explained in Section 3.1 are very poor. They have no technical base, do not conform to any specified standard and as such cannot yield standard products. For instance, NIS 87: 2007 specifies a mix ratio (cement: sand) of 1:8 and a water-cement ratio of 0.45 [3, 7] for sandcrete blocks but none of the firms visited complied with this. In a bid to make much profit, their mix usually had very low cement content.

3.3.2 Laboratory Samples

Results of compressive strength test of samples produced in the laboratory are shown in Table 5. Samples with 1:8 mix ratio produced a mean compressive strength of 0.99 N/mm^2 while samples with 1:6 mix ratio produced a mean compressive strength of 2.07 N/mm^2. These strength values still do not measure up with the minimum requirements by NIS 87: 2007 although they are far better than those from field samples. It must be remembered that the aim of the laboratory samples was to find out if complying with NIS 87: 2007 mix ratio and neglecting some other specified details will still yield blocks with standard strength. As seen in the results, it does not. Author attribute the poor compressive strength of laboratory samples to the method of mixing and compaction adopted, use of poorly graded sand and non-compliance to specified water-cement ratio of 0.45. These factors affect compressive strength of sandcrete blocks [12, 13]. Ajagbe *et. al* [7] followed BS 6073 specification in producing sandcrete block samples using a mix ratio of 1:6and obtained an average compressive strength of 3.56N/mm^2. Anosike and Oyebade [3] likewise produced control samples with 1:8 mix ratio following NIS 87: 2007 specification and coincidentally obtained a mean compressive strength of 3.56N/mm^2. All these point to the fact that strict compliance to standard is the only guarantee of producing standard sandcrete blocks.

4. CONCLUSION

This study investigated the compressive strength of sandcrete blocks produced by commercial block industries in Abak, Eket, Onna and Ikot Abasi all in Akwa Ibom State, Nigeria and compares with the recommended strength by NIS 87:2007 standard. Compressive strength test results of all the 12 sandcrete blocks industries visited were far below the minimum specified values. This is because the practices employed by these firms in their production process are very poor.

Table 4: 28th Day Compressive Strength Test Results (f_c) for Blocks Firm A, B, C, D, E, F and G

Sample No	Compressive Strength (f_c) in N/mm^2						
	Firm A	Firm B	Firm C	Firm D	Firm E	Firm F	Firm G
1	0.58	0.37	0.47	0.22	0.28	0.35	0.37
2	0.73	0.49	0.58	0.27	0.44	0.32	0.47
3	0.53	0.53	0.48	0.30	0.53	0.40	0.33
4	0.41	0.67	0.51	0.25	0.33	0.35	0.34
5	0.42	0.80	0.37	0.23	0.37	0.37	0.48
6	0.38	0.74	0.35	0.24	0.47	0.41	0.36
7	0.57	0.59	0.43	0.21	0.26	0.45	0.30
8	0.35	0.62	0.39	0.19	0.36	0.45	0.40
9	0.50	0.67	0.54	0.32	0.35	0.59	0.38
10	0.40	0.67	0.34	0.34	0.35	0.29	0.36
Mean f_c	0.49	0.62	0.45	0.26	0.37	0.40	0.38
Variance (σ^2)	0.0125	0.0142	0.0062	0.0022	0.0063	0.0066	0.0030
Standard Deviation (σ)	0.112	0.119	0.079	0.047	0.079	0.081	0.055

Table 5: 28th Day Compressive Strength Test Results (f_c) for Blocks Firm H, I, J, K, L and Control

Sample No	Compressive Strength (f_c) in N/mm^2						
	Firm H	Firm I	Firm J	Firm K	Firm L	Control (1:8)	Control (1:6)
1	0.89	0.37	0.29	0.30	0.28	1.10	2.21
2	0.76	0.38	0.25	0.37	0.23	1.10	2.13
3	0.78	0.34	0.31	0.28	0.22	0.75	2.32
4	1.12	0.26	0.42	0.25	0.29	1.17	1.93
5	0.57	0.56	0.43	0.26	0.38	0.81	1.89
6	0.53	0.36	0.30	0.41	0.21	1.13	2.09
7	0.89	0.28	0.26	0.51	0.21	0.86	1.97
8	0.83	0.37	0.42	0.13	0.30	0.91	1.66
9	1.32	0.25	0.24	0.26	0.25	0.93	2.30
10	0.88	0.52	0.51	0.27	0.33	1.16	2.21
Mean f_c	0.86	0.37	0.34	0.30	0.27	0.99	2.07
Variance (σ^2)	0.0492	0.0094	0.0079	0.0097	0.0029	0.0222	0.0389
Standard Deviation (σ)	0.222	0.094	0.089	0.098	0.054	0.149	0.197

They have no technical base, do not conform to any specified standard and as such cannot yield standard products. It can therefore be concluded that sandcrete blocks produced by commercial firms in these cities are far below the specified standard by NIS 87: 2007 in terms of compressive strength. It has also been confirmed that complying only to specified mix ratio and neglecting other NIS 87 details is not likely to yield standard products. Author therefore suggest that government and engineering organizations should create a platform where sandcrete blocks manufacturers are enlightened on standard production processes and the need to conform to NIS 87 standard. Conformity to this standard should also be enforced. By so doing, our building industry will be safer.

Table 6: Mean 28th Day Compressive Strength and Standard Deviation Results of Firms

Block Firm	Mean f_c (N/mm^2)	Standard Deviation (σ)
A	0.49	0.112
B	0.62	0.119
C	0.45	0.079
D	0.26	0.047
E	0.37	0.079
F	0.40	0.081
G	0.38	0.055
H	0.89	0.222
I	0.28	0.094
J	0.26	0.089
K	0.51	0.098
L	0.21	0.054
Average	0.43	0.094

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