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Investigation and Survey on Quality of Sandcrete Hollow Blocks Production within Enugu Metropolis

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ABSTRACT
This research surveyed and investigated the quality of sandcrete hollow blocks produced for construction works within the Enugu metropolis. The study aimed to ascertain quality control, in terms of the compressive strength of sandcrete blocks, the grading of sands used, and the dimensions of blocks produced. The methodology used in this research involved a survey of nine block industries that were randomly sampled within the Enugu metropolis and practical moulding of blocks used as control. Three-block industries use the machine for mixing and moulding while the other six use manual hand moulding. Six samples of hollow sandcrete blocks were randomly selected from the nine-block industries (3 samples each from 6-inches and9-inches sizes) making it a total of 56 blocks. However, 6-block samples (3 samples each of 6 inches and 9 inches) were produced manually as control, using Nigeria Industrial Specificationwith cement/sand of 1:6, and water/cement of 0.8. The whole blocks were cured by sprinkling water on them for 14 days after which they were weighed and crushed to determine their compressive strengths. The results observed indicated that the quality of sandcrete hollow Blocksproduced within the Enugu metropolis was poor, with variations in dimensions, low compressive strength values ranging from 1.28 to $2.2N/mm^2$for 6 inches blocks, and $0.95$to $2.54N/mm^2$for 9 inches blocks. The values were below the specification of $3.45N/mm^2$load-bearing blocks are expected to have. The research concluded that the qualities of sandcrete hollow blocks produced within the Enugu metropolis were poor and that there was no quality control, inspection, and regulation of activities of block industries within the metropolis. The research recommended regulation and frequent inspection and monitoring of block industry activities within the state for certification of their products and ensuring conformation to specifications.

Keywords: sandcrete-block, quality-control, compressive-strength, Enugu-metropolis

I. INTRODUCTION

Sandcrete blocks, as definedby [1, 2, and 3], are composite materials formedby mixing cement, sand, and water in proportion, andmoulded into different sizes. However, the quality of blocks produced differs from each block-producing industry due to the differences in methods adopted in their production and the properties of the constituent materials mixed as emphasized by [4]. However,[5]noted that the differences experienced in the dimensions of sandcrete hollow blocks could be accredited to craftsmen that construct the moulds used by different block industries.[6]underlined that building collapse in Nigeria could beattributed to many factors of which human inaccuracy such as the use of low-grade building materials, is one of the causes. Nevertheless, [7] observed that blocks manufactured in many parts of Nigeria have been done just to certify local needs or just for good quality work. Likewise, [5] mentioned that during the use of those blocks for wallformation and construction of houses, masons/bricklayers do complain about their poor quality in strength which leads to damages and wastage of resources. A good number of researcheshave been reported on the use of sandcrete blocks as the major masonry units in Nigeria's construction industry, as pointed out by [8 and 9]. Nevertheless,the importance of sandcrete blocks in the construction industry cannot be overemphasized. Concerning that,[10] Emphasized that the use of blocks over bricks for construction works in Nigeria,and have increased rapidly and likewise encouraged the investigations into the

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quality of sandcrete blocks.Theminimum strength requirement of a Sandcrete hollow block as acknowledged by [1]is 2.5 N/mm^2 for non-load bearingand 3.45 N/mm^2 for load-bearing walls.Based on quality control,[11 and 10]enlightened that compressive strength is influenced by the level of quality control deployed on the production processes, as well as a good selection of materials and adequate curing method among other necessary practices that will enhance performance.

1.1 Statement of the Problem

The frequent observations and complaints from block layers/masons on how sandcretehollow blocks easily deteriorate and damage in the construction site on minimal pressure suggest that there are problems with quality control in sandcrete blocks produced within the Enugu metropolis. This poor quality of sandcrete blocks is evident on some buildings and formed walls (sandcrete block fences)as cracks and deformities can be visibly seen on some building structures within the metropolis. These cracks and deformities can compromise the stability, durability, aesthetics, and safety of buildings and their occupants. The quality of these sandcrete hollow blocks produced in the state commercially, however, needs to be checked and be sure that they meet the minimum specified national standards. This research work, therefore, investigated the quality of sandcretehollow blocks produced within the Enugu metropolis to determine their quality, compressive strength, dimensions, and suitability as a building unit to justify their conformity with Nigeria's Industrial Specification.

1.2 Aim and Objectives of the Study

The study aims to investigate the quality of sandcrete hollow blocks produced by various block manufacturing industries within the Enugu metropolis and to ascertain the level of compliance in ensuring quality control in their activities.

The objectives of the study include the following:

- To determine the mean compressive strength of six (6) inches of sandcrete hollow blocks produced by different block industries within the Enugu metropolis.
- To determine the mean compressive strength of nine (9) inches of sandcrete hollow blocks produced by different block industries within the Enugu metropolis.
- To determine the dimensions of hollow blocks produced by the various block industries within the Enugu metropolis
- To determine the grading of sand used by different block industries within the Enugu metropolis.
- To determine the design mix ratios of cement/sand and water/cement used by the various block industries within the Enugu metropolis

1.3 Research Questions

I. What are the mean compressive strengths of sandcrete hollow blocks (6-inches and 9-inches sizes) produced by the block manufacturing industries within the Enugu metropolis using: vibrating machines, manual hand molding for commercial purposes, and control groups?
II. What are the grading and particle size distributions of fine aggregates used in the production of sandcrete blocks by variousblock manufacturing industries and control groups?

1.5 Research hypothesis formulated to test the significance level of the study at 0.05 or 5%

I. There is no significant difference between the mean compressive strength of 6 inches of sandcrete hollow blocks produced by manufacturing industries in the Enugu metropolis.
II. There is no significant difference between the mean compressive strength of 9 inches of sandcrete hollow blocks produced by block-producing industries.

II. RESEARCHMETHODOLOGY

The methodology used in this research work involved a 'Random Survey of sandcrete hollow blocks collected from some block Industries within the Enugu Metropolis' and 'practically moulding of blocks according to Nigeria Industrial Specification that served as control'.

2.1 Random Survey of blocks collected fromsomesandcrete Block Industries in Enugu Metropolis

The methodology involves a random survey of block industries within the three local government areas (Enugu North, Enugu South, and Enugu East) that make up the Enugu metropolis to determine the quality of blocks produced with machine mould and hand mould for commercial purposes. There are so many block industries within the three local government areas under this study; however, nine (9) block industries were randomly selected, based on the method of production.From each of the three local government areas, machine moulds, and manual/hand moulds, wererandomly selected for

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the study. Three (3) samples each of 6-inches (450mm x 250mm x 250mm) and 9-inches (450mm x 250mm x 150mm)sandcretehollow block samples were purchased from each of the nine (9) block industries, making it a total number of fifty-four (54) block samples. The entire blocks were cured for 14 days by sprinkling water on them twice daily. The blocks collected from the block industries labeled samples A, B, and C were mixed and moulded by machine, while the rest of samples D, E,F, G, H, and I was mixed and moulded manually. Fine aggregate/sand used by the nine (9) randomly selected block industries was also collected for laboratory analysis and testing.

2.2 Practically Molding of Blocks According to NIS Specification

A total of six (6) units of hollow sandcrete blocks were hand moulded by NIS specification. Three (3) samples each of six (6) inches and nine (9) inches hollow sandcreteblocks were produced. The samples were labeled sample CT (control).

2.2.1 Procedures on How the Hollow Blocks Used as Control Were Moulded

a) **Source of Fine Aggregate/Sand:** The sand used for the hollow blockmoulding was obtained from Ekulu River in Enugu State.

b) **Batching, Mixing Materials, and Moulding of the Sandcrete Blocks:**

The materials for the hollow block production were batched by volume because that was what most of the visited block industries were using. After batching, the materials were manually mixed. A mix design of 1:6 was adopted for the cement-to-sand ratio, and the water/cement ratio of 0.8 was used. The mixture was blended sufficiently to get a uniform, even, and consistent color. A professional in block moulding helped in the production of the block samples as a Research assistant. Curing of the samples started the next day and the curing was done by sprinkling water on the block samples twice daily (morning and evening) for 14 days. After that, the samples were taken inside the lab a day before the crushing. Then the samples were weighed and crushed with a crushing machine to determine their compressive strength.

2.3 Other Tests Conducted on the Samples: A sieve analysis test was conducted to determine the particle size distribution, fineness modulus, and Zones of sand used in the production of the block samples.

2.4. Methods of Data Collection: The nine (9) randomly selected block industries within the three local government areas under this study were given questionnaires to determine the source of fine aggregate/sand, source of water, mix design ratio, method of batching, method of mixing materials, method of compaction, method of curing, and how they test their materials and blocks. However, the questionnaire was face-validated by professionals in measurement and evaluation, the construction industry, and by a Civil engineer. However,the compressive strengths of the blocks will be determined after crushing the blocks after 14 days of curing with water.

2.4.1 ANOVA Test (one-way ANOVA): The mean compressive strength results observed from the experiment were subjected to ANOVA F-Test to determine the level of significance at 5%.

III. ANALYSIS AND PRESENTATION OF RESULTS

To provide accuracy and efficiency of the experimental results, the results obtained will be compared with those reviewed in the literature (according to NIS and other specifications).

3.1.1 Cross-sections and Dimensionsof the Tested SandcreteHollow Block Samples

Table 3.1: Cross-sections and dimensionsof the six-inch (450*150*225 mm) hollow block samples from different block industries under the study.

Block Name	Block size(mm)	Center web thickness	edge web thickness	Side web thickness	Hollow Cell Cavity size (mm)		Areas of hollow cell Cavity (m^2)	Total Cross-sectional Area of block (m^2)	Net Area (m^2)
CT	450x225x150	50	40	35	160	80	25.60	67.50	41.90
A	450x220X153	35	35	35	172.5	80	27.6	68.85	41.25
B	450X230X150	35	35	35	172.5	80	27.6	67.50	39.90
C	450X220X150	35	40	30	172.5	90	31.02	67.50	36.45
D	450X220X150	30	35	35	175	80	28.00	67.50	39.50

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E	450X220X150	30	40	35	170	80	27.20	67.50	40.30
F	450X220X150	30	35	35	175	80	28.00	67.50	39.50
G	450x220x150	50	40	35	160	80	25.6	67.50	41.90
H	450x225x150	30	30	30	180	90	32.4	67.50	35.10
I	450x225x150	30	35	30	175	90	31.5	67.50	36.00

Table 3.2: Cross-sections and dimensions of the nine-inch (450*225*225 mm) hollow block samples obtained from different block industries.

Block Name	Block size (mm)	Center web thickness	edge web thickness	Side webthickness	Hollow Cell Cavity size (mm)		Areas of hollow cell Cavity (m^2)	Total Cross-sectional Area of block (m^2)	Net Area (m^2)
CT	450x225x225	60	40	40	155	145	44.96	101.25	56.30
A	450x225x228	40	40	40	165	148	48.84	102.60	53.76
B	450X225X225	40	35	40	170	145	49.30	101.25	51.95
C	450X225X220	30	30	35	180	150	54.00	99.00	45.00
D	460x220x225	40	35	40	170	145	49.30	101.25	54.20
E	450x220x225	40	40	35	165	155	51.16	101.25	50.10
F	450x230x225	40	35	35	170	155	52.70	101.25	48.55
G	458x225x230	40	40	35	169	160	54.08	105.34	51.26
H	450x225x225	40	35	35	180	160	57.6	101.25	43.65
I	450x220x225	40	40	35	165	160	52.8	101.25	48.45

3.1.2 Compressive Strength of the Hollow Block Samples

Table 3.3: Mean compressive strengths of the six (6) inches (450*150*225 mm)hollow block samples

Sample Name	Sample Number	Compressive strength (N/mm^2)	Mean Compressive strength (N/mm^2)
CT	CT1 CT2 CT3	3.58 4.58 4.06	4.07
A	A1 A2 A3	1.52 3.04 2.03	2.20
B	B1 B2 B3	2.03 2.03 2.33	2.13
C	C1 C2 C3	1.65 1.37 2.33	1.78
D	D1 D2 D3	1.54 1.47 1.52	1.51
E	E1 E2 E3	1.24 1.24 1.36	1.28
F	F1 F2	1.70 2.33	1.91

	F3	1.70	
G	G1 G2 G3	1.43 1.19 2.39	1.67
H	H1 H2 H3	1.42 1.71 1.42	1.52
I	I1 I2 I3	1.53 1.67 1.67	1.62

Table 3.4: Mean compressive strengths of the Nine (9) inches (450*225*225 mm) hollow block samples

Sample Name	Sample Number	Compressive strength (N/mm^2)	Mean Compressive strength (N/mm^2)
CT	CT1 CT2 CT3	4.12 3.82 5.68	4.54
A	A1 A2 A3	2.27 3.50 1.85	2.54
B	B1 B2 B3	2.06 2.29 3.10	2.48
C	C1 C2 C3	1.54 2.50 1.92	1.99
D	D1 D2 D3	0.83 0.74 1.29	0.95
E	E1 E2 E3	1.20 1.20 1.20	1.20
F	F1 F2 F3	1.53 1.12 0.99	1.21
G	G1 G2 G3	1.17 1.56 1.17	1.30
H	H1 H2 H3	1.33 1.33 1.78	1.48
I	I1 I2 I3	1.44 1.44 1.24	1.37

Table 3.5: The summary of reports on responses from the questionnaire submitted to the nine-block industries surveyedfor the research.

	Block Industry	
	Machine Mixed and Moulded	Hand Mixed and manual Moulded

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	A	B	C	D	E	F	G	H	I
SOURCE OF SAND	River	River	Borrow pit	River	River	Borrow pit	River	River	River
SOURCE OF WATER	River	River	Well water	Borehole	Borehole	Pump water	Stream water	Well water	Stream
DESIGN MIX RATIO (C:S)	1:10	1:10	1:10	1:10	Est.	Est.	Est.	Est.	Est.
METHOD OF BATCHING	Volume	Volume	Volume	Est.	Est.	Est.	Est.	Est.	Est.
MODE OF MIXTURE	Machine	Machine	Machine	By Hand	By Hand	By Hand	By Hand	By Hand	By Hand
WATER /CEMENT RATIO	Volume	Est.	volume	Est.	Est.	Est.	Est.	Est.	Est.
MODE OF COMPACTION	Machine	Machine	Machine	Manual	Manual	Manual	Manual	Manual	Manual
MODE OF CURING	Sprinkling of water twice daily	Sprinkling of water twice daily	Sprinkling of water twice daily	Sprinkling of water 3 times daily	Sprinkling of water twice daily	Sprinkling of water twice daily	Sprinkling of water twice daily	Sprinkling of water twice daily	Sprinkling of water twice daily
CURING DAYS BEFORE SUPPLY FOR USAGE	3 days	2 days	4 days	3 days	3 days	2 days	2 days	7 days	7 days
SIZE OF HOLLOW BLOCK PRODUCED (inches)	6" & 9"	6" & 9"	6" & 9"	6" & 9"	6" & 9"	6" & 9"	6" & 9"	6" & 9"	6" & 9"
COMPRESSIVE STRENGTH TEST OF BLOCK	Not Often	No	Not often	No	No	No	No	No	Not often
NO. OF HOLLOW BLOCKS PRODUCED PER BAG (9' and 6')	40, 45	40, 45	38, 50	40, 50	45, 50	45	40, 50	45, 55	38, 40
DAILY PRODUCTION	600	640	570	600	500	125	800	-	-
COST OF 6"	380	350	330	290	270	250	300	270	250

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BLOCK (₦)	9”	450	400	500	350	280	300	380	340	320

NB: Est ≡ Estimated

3.1.3 Particle Size Distribution: The sieve analysis results of the sand materials used for the production of the block samples are shown in Figure 3.1 below:

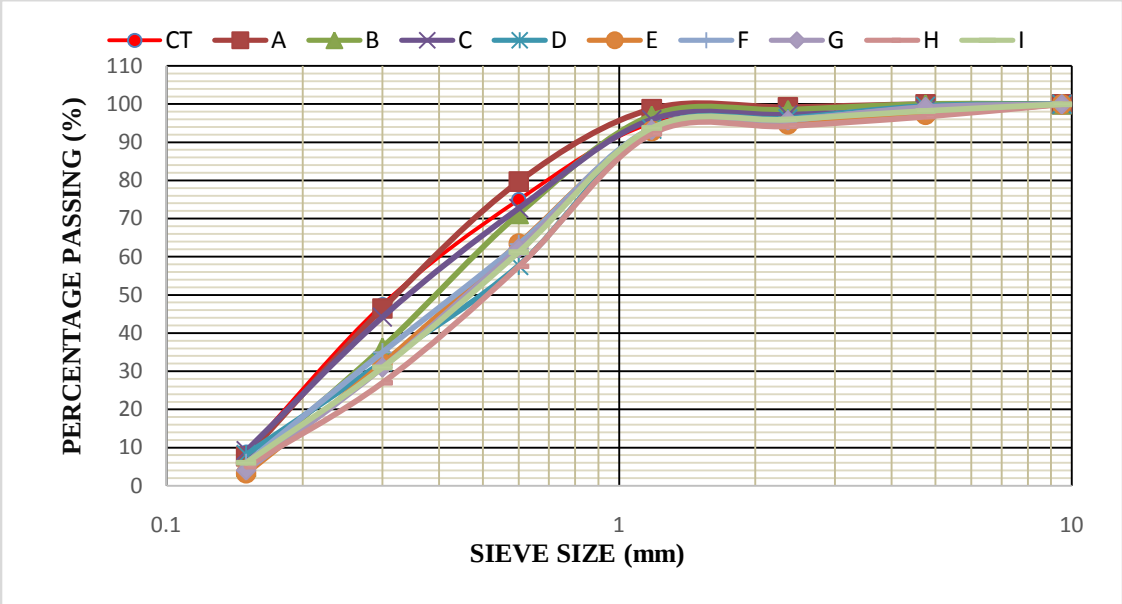

Fig 3.1: Particle size distribution of the sand samples

3.2 DISCUSSION OF RESULTS

Tables 3.1 and 3.2 above present the cross-sections and dimensions of the tested sandcrete hollow blocks from the various block industries within Enugu Metropolis together with the block samples moulded as a control for six (6) inches and nine (9) inches block samples. From the tables, it can be seen that there are variations in the dimensions of the hollow block samples obtained from different block industries. Samples CT, H, and I of table 3.1 and samples CT, B, and H of table 3.2 have dimensions that are in line with the approved dimensions of 450x225x150mm by Nigeria Industrial Specification while the other samples are off the approved standards by a little margin below or above as the case may be. However, there are variations also in the hollow cell cavity web thicknesses: only sample CT met the standard while other samples are below specification. These changes in dimensions may influence the compressive strength of the sandcrete hollow block samples. Nevertheless, these variations in dimensions of sandcrete hollow block could be attributed to craftsmen and welders that construct those moulds used by various block industries for block production as reviewed in the literature [5]. There is a need for those craftsmen and welders to stick to dimensions approved by quality control bodies like NIS for block production.

Table 3.3 above presents the experimental results obtained from the tested sandcrete hollow blocks samples; compressive strength, and mean compressive strength of the six (6) inches hollow blocks. From this table, the control group (CT) has the highest mean compressive strength of 4.07N/mm^2. Sample A has a mean compressive strength of 2.20N/mm^2 while other samples (B, C, D, E, F, G, H, and I) are within the range of 1.28 to 2.13N/mm^2. However, all the samples' values are below the minimum standard of 3.45N/mm^2 as reviewed in the literature according to [1]. The compressive strengths of these samples were subjected to the ANOVA test at 0.05 levels of significance, and there was evidence ($F_{crt}(2.51) > F_{cal}(1.67)$) that there was no difference in significance between the six-inch hollow block samples.Nevertheless, when the compressive strengths of the control group (CT) and other block samples were subjected to the same ANOVA test, the result shows that there was a significant difference as$F_{crt}(2.39) < F_{cal}(13.17)$.

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Table 3.4 above presents the experimental results obtained from the tested sandcrete hollow blocks samples; co compressive strength of the nine (9) inches hollow blocks and the mean compressive strength. From this table, the control group (CT) has the highest mean compressive strength of 4.54N/mm^2. Sample A has a mean compressive strength of 2.54N/mm^2 while other samples (B, C, D, E, F, G, H, I) are within the range of 0.95 to 2.48N/mm^2. However, all the samples' values are below the minimum standard of 3.45N/mm^2 as reviewed in the literature by [1]. The compressive strengths observed from block samples obtained from different block industries were subjected to Another ANOVA test at 0.05 levels of significance, and it was confirmed ($\text{as}F_{crt}(2.51) < F_{cal}(5.81)$) that there was a significant difference among the 9-inches hollow block samples obtained from different block industries within Enugu metropolis. On the other hand, when the compressive strengths of the control group (CT) and other block samples from different block industries were subjected to the same ANOVA test, the result shows that there was a significant difference $\text{as}F_{crt}(2.39) < F_{cal}(13.52)$.

Table 3.5above presents the summary of reports from responses to the questionnaire, and on-site surveyfrom the nine block industries. From the table, most of the block industries make use of estimation in the design mix ratio and batching except samples A, B, and C which make use of the machine in mixing and moulding their products. The design mix ratio is greater than the approved value given by the Nigeria Industrial Standard of 1:6 or 1:8 as reviewed in the literature. The number of days the block samples were cured by the various block industries, before supplying their products for construction work at sites is not enough. It does not give the blocks minimum time (7 days) to gain enough strength before use to avoid damage and waste of resources.

Figure 3.1illustrates a pictorial view of the scatter log graph of the particle size distribution of the sand samples obtained from the various block industries and the control group. From the graph, the finest modulus (FM) of all the samples was within the acceptable range of 2.25 – 3.25 as reviewed in the literature. The control group (CT) sand sample and all other sand samples fell within Zone 3 except sample G which fell within Zone 2. The sand samples are all good for construction work.

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

The following conclusions were therefore reached based on this research results:

i. The Nine (9) block industries surveyedwithin the Enugu metropolis (Enugu South, Enugu North, and Enugu East Local government areas) have reduced quality sandcrete hollow blocksin compressive strength.
ii. The mean compressive strength of all the block samples obtained from the various block industries (range from 0.95 to $2.54(\text{N/mm}^2)$) was below the specified standard value of (2.5 to $3.45(\text{N/mm}^2)$) except sample A (6 inches) and the control group (CT) with a value of $4.54(\text{N/mm}^2)$.
iii. There was a significant difference between the mean compressive strength of 9 inches of hollow blocks produced within the Enugu metropolis as reviewed in this research. However, the result of compressive strength for 6-inch hollow block samples indicated that there was no significant difference among the mean compressive strength produced in the three local governments considered in this research.
iv. The designmix ratio/proportion of cement to sand materials of the surveyed block industries wasmuch higher. Most of the block industries are using cement sand ratio between 1:10 to 1:12, while others are batching by estimations, instead of the recommended standard of 1:6 to 1:8 specified by Nigeria Industrial Specification.
v. Some of the block industries were batching their design mix by estimation which is inadequate and it negatively affects and reduces the compressive strength of the blocksamples.
vi. The method of production does not influence the compressive strength of the 6-inch block samples statistically. There was no significant difference between the same method of production and between different methods of production of six-inch block samples. The method of production does influence the compressive strength of the 9-inch block samples produced by the various block industries surveyed.
vii. The number of days the block samples were cured by the various block

industries, before supplying their products for construction work at sites is not enough. It does not give the blocks minimum time (7 days) to gain enough strength before use and will not be effective in developing the target mean compressive strength, to avoid damage, economic loss and waste of resources.

viii. The sand samples used for the production of the sandcrete hollow blocks, in all the industries surveyed, were generally sharp, clean, and good for construction work. They are mainly graded into zones 2 and 3 of the grading standard of BS 822.

ix. The finest moduli (FM) of all the sand samples used by various block industries were within the acceptable range of 2.25 – 3.25.

x. Quality control bodies like Nigerian Industrial Standard, do not inspect the activities of most of the block industries within the Enugu metropolis to ascertain their compliance to standardization.

xi. There was no price control in block industries within the Enugu metropolis. Each block industry determines the cost of their block samples concerning the expenses made on the cost of sand, cement, water, laborers, etc.

4.2 Recommendations

The following recommendations were made:

- The specifications ondesign mix ratio should be strictly adhered to by block-producing industries within the Enugu metropolis to produce durable sandcrete blocks with requisite compressive strength.
- Quality control bodies should have a routine inspection, regulation, and testing (of block samples) of block industry activities within the Enugu metropolis to ensure the quality of their products. The inspection and testing of block samples should be done at least twice yearly and those block industries with quality products certified while those with poor quality products should be penalized.
- There should be price regulation and control by the government so that the block production industries with substandard products will not sabotage the system.
- The cross-section and dimensions of the block mould should conform to the specified dimensions. This is to ensure that the dimensional variations do not affect the quality of the products.
- Producers of sandcrete hollow blocks should be enlightened through workshops and seminars to emphasize the need to produce blocks that meet the standard requirements, and the consequences of producing substandard blocks.

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