TURKISH JOURNAL OF AGRICULTURAL ENGINEERING RESEARCH (TURKAGER)
(Türk Ziraat Mühendisliği Araştırmaları Dergisi)
ISSN:
Research Article (Araştırma Makalesi)
Volume/ Cilt: 1 (2020) Issue/ Sayı :1 (91-103)
https://dergipark.org.tr/tr/pub/turkager

Compressive Strength of Commercially Produced Sandcrete Blocks within Isoko Metropolis of Delta State, Nigeria

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ABSTRACT

The study was carried to evaluate the level of compliance of commercially manufactured sandcrete blocks in Isoko metropolis of Delta State, Nigeria, to International standards. One hundred and fifty (150), twentyeight (28) days old, six (6) inch solid sandcrete blocks were collected from fifteen (15) major sandcrete blocks mouding industries within the Isoko metropolis. Ten block samples were randomly selected from each block industry. The compressive strength of selected blocks was tested in accordance with ASTM recommended procedures. In Addition, the physical characteristics (specific gravity and sieve analysis) of the fine aggregate used for the sandcrete blocks production were equally analyzed. Results from the compressive strength tests showed that all the sandcrete blocks were substandard, as they fall below the minimum permissible compressive strength valve recommended by Nigeria Industrial Standard (NIS-87). From the results, the mean compressive strength ranged from 0.653 Nmm^{-2} to 1.203 Nmm^{-2}. In addition, the results of the sieve analysis showed that most of the fine aggregate used for the sandcrete blocks blocks production was poorly graded and did not meet NIS standard standard for fine aggregate required for sandcrete blocks production. Data obtained from this study will help the government in setting up a quality control unit within the metropolis, so that sandcrete blocks produced and sold to the public are able to meet international (NIS and BS) standards.

RESEARCH ARTICLE

Received: 21.03.2020
Accepted: 30.04.2020
Available online: 06.05.2020

Keywords :

- Compressive strength,
- Delta state,
- Sandcrete block,
- Sieve analysis,
- Block industry

To cite: Agbi GG, Akpokodje OI, Uguru H (2020). Compressive Strength of Commercially Produced Sandcrete Blocks within Isoko Metropolis of Delta State, Nigeria Turkish Journal of Agricultural Engineering Research (TURKAGER), 1(1): 91-103.

INTRODUCTION

Sandcrete block is a cementitious composite material consisting of cement, fine aggregate (usually sand), water, and at times special additives, moulded into various shapes and sizes (Akpokodje and Uguru, 2019). According to the British standards (BS 2028, BS 1364), sandcrete block is any walling unit with dimensions greater than that of a brick as specified in BS 3921 (Hamisu and Mohammad, 2014). Sandcrete blocks are the most prominent building units in Nigeria, and likewise in other West Africa countries. The most common sandcrete block size in Nigeria which is in accordance with the BS and Nigeria Industrial Standard (N1S) recommendations is the 450 mm x 225 mm sandcrete block (Nene, 2009). About 75% of building structures in Nigeria are being constructed with sandcrete blocks, making it a vital component of the buildings (Baiden and Tuuli, 2004). Apart from residential and commercial structures which are constructed with sandcrete blocks, also many farm structures are being constructed with concrete blocks. Sandcrete blocks used in agricultural structures come in number of different shapes and sizes. Rural buildings have become a vital part of integrated rural development programs globally (FAO, 2011). Likewise, it is an important task for structural engineers to interpret the drawings and technical documentation to the farmers; as well as supervising that the right materials are used during the construction work (FAO, 2011). Sandcrete blocks which met international (NIS and BS) standards, can be used for the construction of both load bearing and non-load bearing walls. Cracks (failure) observed in a buildings wall is a major sign that substandard blocks may have been used during the construction. This can eventually leads to total collapse of the structure, if not amended on time. According to Akeem and Umar (2013), building wall failures and crack development result from poor quality of blocks used during the construction, which can be attributed to ignorance on the part of the block producers and the site engineer.

The compressive strength of sandcrete blocks is highly dependent on the cement-sand mix ratio, physical characteristics (specific gravity, moisture content, etc.) of the sand used, size and shape of the block, curing method, mode of production (hand or machine vibrated mould), and the water quality (Yusuf and Hamza, 2011; Akpokodje and Uguru, 2019). Water is an essential constituent of a sandcrete block, because it is needed for the hydration reaction of the cement used for the sandcrete block production. Too little or too much water has the ability of reducing the strength properties of the block, because the hydration reaction and product quality will not take their fill course. Therefore, the water-cement ratio and water quality are important factors to be considered, since they strongly influence the final strength properties of the sandcrete block (Palmquist, 2003; Adewumi *et al.*, 2016; Akpokodje and Uguru, 2019). Despite their comparative lower strength properties, when compared to steel and synthetic fibres, sandcrete blocks are gaining popularity in building and construction companies due to their higher resistance to rusting and crumbling, cheapness, and non-hazardous nature (Odeyemi *et al.*, 2015; Esegbuyota *et al.*, 2019).

For the past decade, many builders preferred buying already moulded and cured sandcrete blocks from blocks industries, to producing the blocks themselves, probably due to lack of skilled labour. Results from previous studies have shown that the compressive strength of sandcrete blocks differs from manufacturer to manufacturer, and most of them are consistently of poor standard, failing to meet NIS and BS standards. This can be attributed to the different production methods (mixing ratio, curing, vibration, etc.) adopted by the blocks producers as well as the physical characteristics of the fine aggregate, and the quality of the water used. Baiden and Tuuli (2004) noted that the compressive strength of sandcrete block is highly dependent on several factors, namely; quality of constituent materials, batching of aggregate, mixing method, mode of production, curing method, storage and transportation method, mix ratio and water quality/content. Afolayan *et al.* (2008) reported that the mean compressive strength of seventyfive blocks (size: 450 mm x 225 mm x 150 mm) sampled from the twenty-five block industries in Akure, Ondo State, was 0.549 N mm^{-2}, which is far below the recommended NIS standard. Onwuka *et al.* (2013) in their study observed that sandcrete blocks produced in the South-Eastern part of Nigeria failed to meet international standards. In a study conducted within Minna metropolis, Niger State, Nigeria, Tsado and Yewa (2013) reported that hollow sandcrete blocks produced within the area within review were substandard and were not produced in accordance to NIS-87 recommendations. According to NIS recommendation, a minimum permissible compressive strength of 2.5 Nmm^{-2} is required for non-load bearing walls, and 3.45 Nmm^{-2} for load bearing walls.

The increasing rate of building failures recorded in Nigeria lately has necessitated the need to determine the compressive strength and other physical qualities of the sandcrete blocks in circulation in Delta States. Despite much literature recorded on the strength quality of commercial sandcrete blocks produced in various parts of the country, there is no recorded literature on the strength quality of commercial blocks produced within Isoko metropolis of Delta State, Nigeria. Therefore, the aim of this research is to evaluate the compressive strength of sandcrete blocks produced within Isoko region of Delta State. The specific objectives of this research are to:

i. determine the compressive strength of sandcrete blocks produced in the Isoko region of Delta State, and assess their conformity with relevant international standards;
ii. establish the factors responsible for compressive strength results obtained from the study;
iii. evaluate the processes of the sandcrete blocks production with the aim of improving their strength properties.

The data obtained will be compared with set standards, to determine if the sandcrete blocks produced within the Isoko metropolis and sold to customers within and outside the metropolis meet international (NIS and BS) standards.

MATERIAL and METHODS

Study area

Isoko metropolis is home to one of the major tribes in Nigeria. It has a population of about 340,994 and occupies an area of about 1,181 km² as extrapolated from the Delta State government portal (DSG, 2015). The metropolis can be fairly classified as an educational and industrial centre, because it houses a university campus, a polytechnic, one technical college and several oil exploring companies and facilities. Due to the above-mentioned facts, a lot of buildings constructions (mostly students' hostels and hotels) are on-going in the region, while many others have been completed.

Acquisition of Materials

Fifteen major sandcrete producing industries were visited in the metropolis under review, for an on the spot assessment. Ten sandcrete blocks (6 inch) were randomly collected (purchased) from each block industry visited, in order to evaluate their compressive strength. For the purpose of this research, only 28 days old sandcrete blocks were purchased from each block industry. The blocks sampled were coded in accordance with the fine aggregate used in the blocks production. Sandcrete blocks that were produced from white sand obtained from local sand dredgers, were coded S; blocks that were produced from river bed (sharp) sand were coded K; while those that were produced from a mixture of white sand and river bed sand were coded N.

In addition, fine aggregate was collected from each corresponding block industry in order to determine their physical characteristics (specific gravity and sieve analysis). Questionnaires were further administered to the directors of the block industries, in other to obtain vital information (fine aggregate type and cement type used, curing methods, mixing ratio, block moulding method used and sales) from them. From the answers provided by the directors of the sandcrete blocks industries, the following materials were used in the production of the sandcrete blocks:

Cement

Ordinary Portland cement (Dangote and BUA brands) was the binder used in all the block industries visited during this research. The cement was of grade 42.5, which was in compliance with Nigeria Industrial Standard (NIS-444, 2003). Portland cement has the capacity of hardening faster and has higher compressive strength, when compared to hydraulic lime (FAO, 2011). Cement is the most expensive constituent of a sandcrete block, it gives acceptable quality required by various international standards to the blocks (Okafor and Ewa, 2012).

Fine aggregate (sand)

There were variations in the quality of the fine aggregates used by the blocks producers. Some of the block producers used river bed (sharp) sand; while others used ordinary white sand obtained from local sand dredgers in Delta State, Nigeria. The choice of the sand used by each sandcrete block producer for the sandcrete production was highly dependent on the nearness of the sand source to the producers. The quantity of fine aggregate employed was a major component of the sandcrete blocks, that is, with respect to the cement-sand mixing ratios adopted by the various sandcrete block producers. It had been experimentally proven that the volume of fine aggregate used in sandcrete block production, is directly proportional to the compressive strength of a sandcrete block.

Methods

Mix ratio

The answers provided by the block industries directors showed that a cement-sand mixing ratio ranging between 1:12 and 1:16 was adopted. According to the directors, they choose these mix ratios because they provide the best possibility to recoup the money spent on the block production, and still make little profit due to the low price of the sandcrete blocks and high cost of materials. All the blocks industries visited adopted batching by volume method, while the addition of water to the mix did not follow any recommended approved standard. The addition of water was done arbitrary, and it was based mainly on the discretion of the block producer (moulder) and based on the perception of a suitable consistency of the mix.

Sieve analysis

Sieve analysis was carried on the fine aggregate (sand) used for the production of all the sandcrete blocks, to determine if they are in accordance with NIS-87 standard recommendation. Before the test, the fine aggregate was air-dried in the laboratory under ambient temperature (30±5^{0}C) for two weeks. During the test, a British standard (BS 882) sieves set was arranged in descending order; the largest aperture sieve was placed at the top, followed by the immediate smaller one, until the smallest aperture sieve was placed at the bottom. Then 1 kg of the fine aggregate was weighed with the aid of an electronic weighing balance and poured into the uppermost sieve of the pre-arranged sieve set. The set was carefully inserted into a mechanical sieve shaker, and ran for twenty minutes. After that, each sieve was carefully removed from the set, and the fine aggregates retained in each sieve was weighed and recorded (Esegbuyota *et al.*, 2019). The cumulative weight of fine aggregate that passed through each sieve was calculated as a percentage of the total sample weight (Odeyemi *et al.*, 2018). From the particle size distribution curve obtained through the sieve analysis, the coefficient of uniformity (C_u) of the fine aggregate was calculated with equation 1, as approved by Unified Soil Classification System (USCS, 2015).

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

Where:

C_u = uniformity coefficient (ASTM D2487),

D_{60} = Diameter corresponding to 60% finer in the grain size distribution.

D_{10} = Diameter corresponding to 10% finer in the grain size distribution. Also known as the Effective Size (USCS, 2015).

According to USCS (ASTM D2487-11), a sand (fine aggregate) is Poorly Graded (P) if C_u is less than 6 (C_u<6) and fines particles are less than 5% (fines< 5%). While a sand is Well Graded (W) if C_u is greater than 6 ($C_u \geq 6$) and the fines particles are less than 5% (fines< 5%).

Specific gravity determination

The specific gravity of the fine aggregate was determined using the standard recommended methods of the Association of Analytical Communities (AOAC, 1990). Specific gravity of the fine aggregate was calculated using equation 2.

$$S_g = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad (2)$$

Where:

W_1 = Weight of the empty bottle

W_2 = Weight of the bottle filled fine aggregates.

W_3 = Weight of the bottle and its content filled with distilled water up to the meniscus.

W_4 = Weight of the bottle filled with distilled water to the meniscus.

Mode of block production

From the answers provided by the directors, some used manual moudling method, while others used concrete mixers and vibrating moulding machine.

Curing

From the questionnaires retrieved from the block industries directors, curing was done once daily by sprinkling the blocks with water for a period of seven days. After the first seven days, the blocks were cured once weekly by sprinkling the blocks, until they find a buyer.

Mechanical test

The compressive strength of the sandcrete block was carried out in full compliance with NIS-87 recommendations. An electronic Concrete Compression Testing Machine (STYE 2000), manufactured in China, was employed to carry out the compression test. During the crushing, each sandcrete block was clamped between the two flat plates (placed above and below the bed surfaces of the block) in the compression chamber of the machine, and loaded axially at constant speed until failure occurred. The compressive force of the block at failure point was displayed on the screen of the machine, from where it was read from. In order to obtain the compressive strength of the sandcrete block, the failure force of the block was divided by the effective surface area of the sandcrete block, as shown in Equation 3. All the compression tests were done under ambient laboratory temperature of 30±5^{0}C.

Computing the compressive strength of 6 Inches solid sandcrete block

$$\text{Compress strength} = \frac{\text{crushing force (N)}}{\text{Net area of block } (mm^2)} \quad (2)$$

Effective area of 6 inch solid sandcrete block = 450 mm x 150 mm = 67 500 mm^2

Statistical Analysis

The data obtained from this research were statistically analyzed using the MS Excel 2015 (Microsoft Corporation Redmond, WA 98052). The summary of the readings was plotted in Microsoft Excel 2015.

RESULTS and DISCUSSION

The answers provided by the blocks industries directors and observations made during the field work, showed that none of them followed NIS recommendations during the process of their sandcrete blocks production. Fine aggregate laboratory analyses were not done, and at times fresh fine aggregate just obtained from the dredging sites (with high moisture content) were used for the blocks production. It was also observed that none of the workers in all the industries visited had any formal education in civil engineering or any allied discipline. Most of the workers resulted to informal means (through hand feeling), in determining the quality of the fine aggregate; since they were aware from experience that the fine aggregate quality affects the compressive strength of the sandcrete blocks produced from them.

Sieve Analysis Results

The results of the sieve analysis of the fine aggregate, as presented in Figures 1 to 15 showed that most of the aggregate were not well graded. The uniformity coefficient (Cu) of the fine aggregate used by the various blocks industries ranged from 4.91 to 7.21. From the fine aggregate analyzed, the fine aggregate used by firms N2, S1, S4, K1 and K5 were Well Graded and met NIS and USCS standards; while fine aggregate used by firms N1, N4, S2, S3, K2 and K6 for the sandcrete blocks production were Poorly Graded sand with significant amount of silt content. In addition, from the sieve analysis results, it can be seen that even though some fine aggregate were "Well Graded", they still contained significant amount of silt (fines). This could be attributed to the indiscriminate mixture of fine aggregate by the sandcrete blocks producers. From the on the spot assessment carried out, it was observed that most of the block industries mixed River bed sand and ordinary dredge white sand together to maximize profit. Within Delta state, where this study was carried out, a 30 ton payload of River bed sand cost 38 000 Nigeria naira (about 123 USD), while the same 30 ton payload of ordinary white sand cost 15 000 Nigeria naira (about 48 USD).

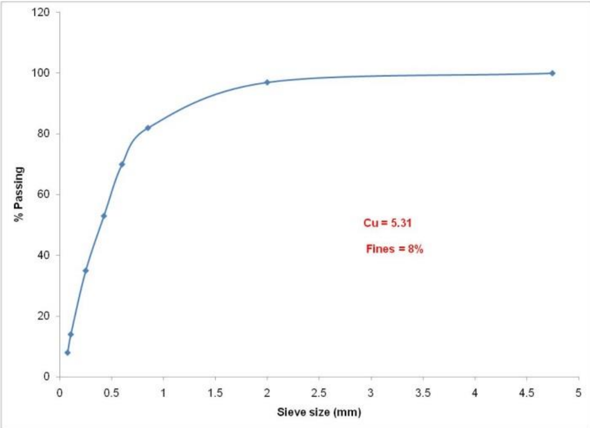

Figure 1. Particle size distribution curve for block industry N1

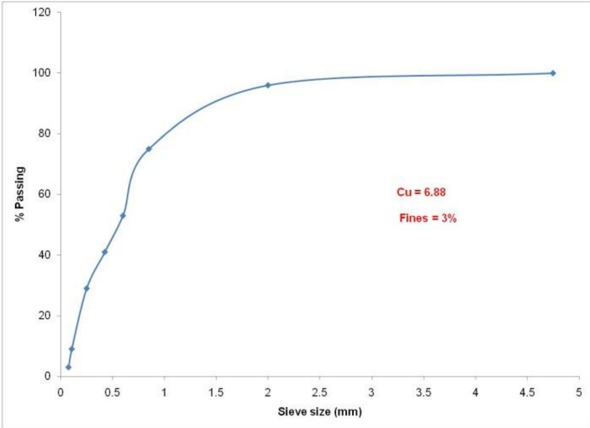

Figure 2. Particle size distribution curve for block industry N2

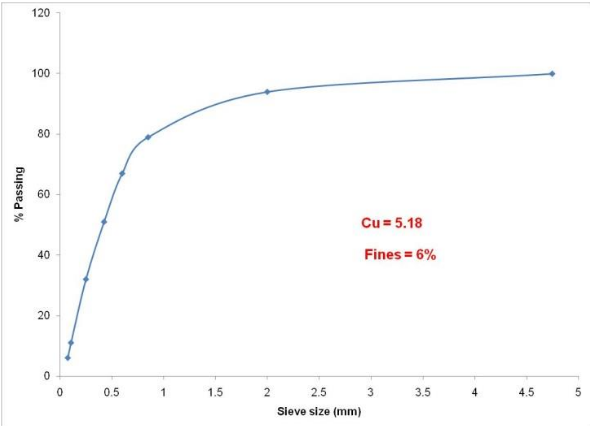

Figure 3. Particle size distribution curve for block industry N3

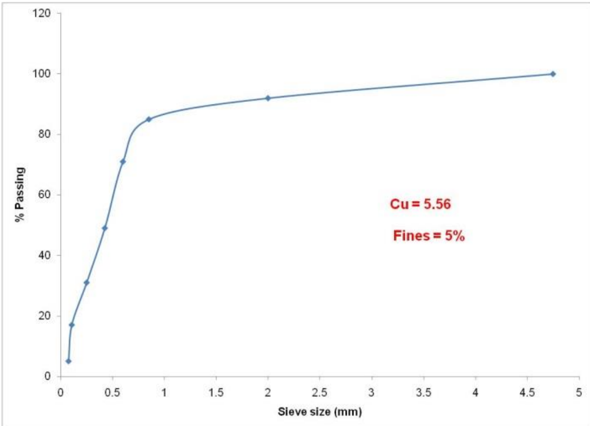

Figure 4. Particle size distribution curve for block industry N4

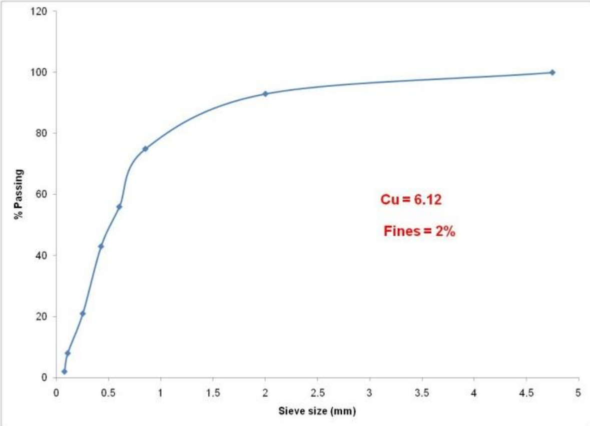

Figure 5. Particle size distribution curve for block industry S1

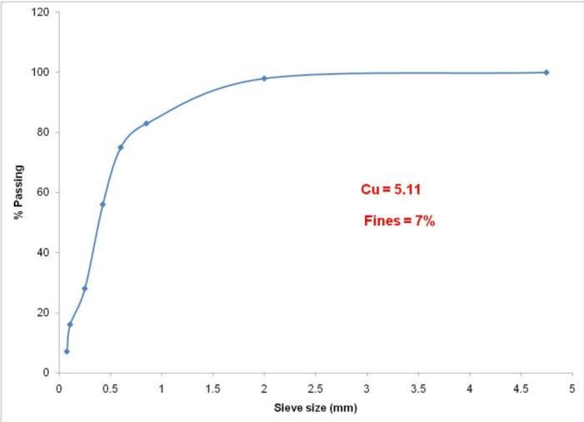

Figure 6. Particle size distribution curve for block industry S3

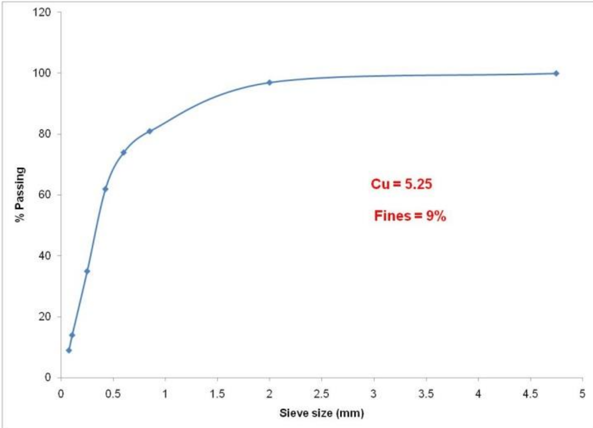

Figure 7. Particle size distribution curve for block industry S4

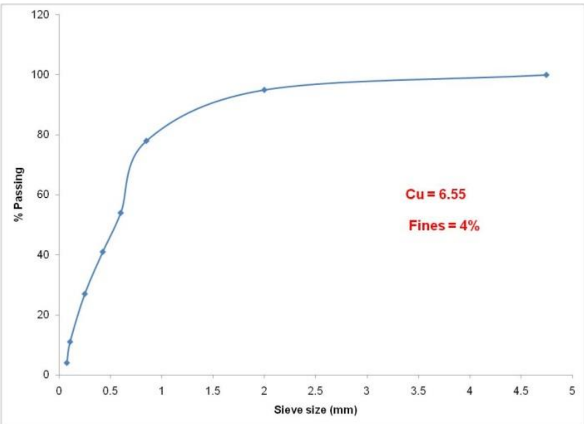

Figure 8. Particle size distribution curve for block industry S4

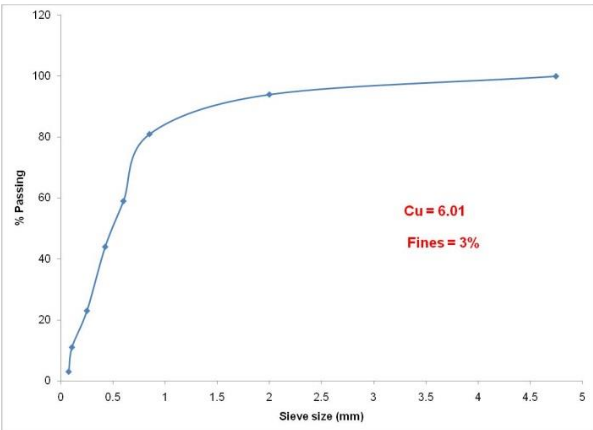

Figure 9. Particle size distribution curve for block industry K1

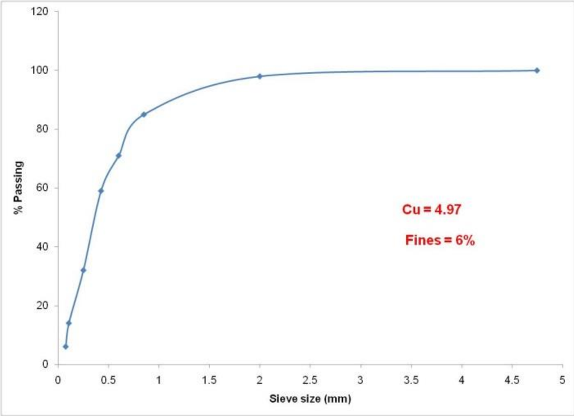

Figure 10. Particle size distribution curve for block industry K2

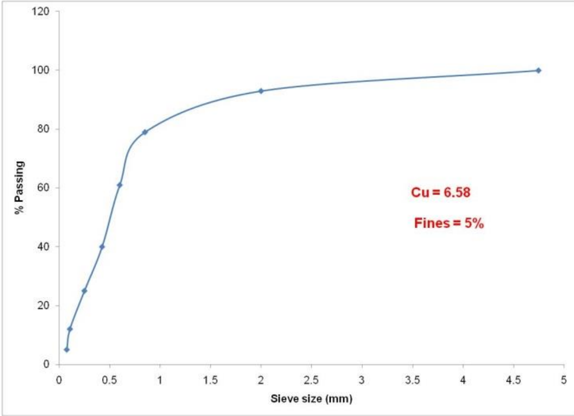

Figure 11. Particle size distribution curve for block industry K3

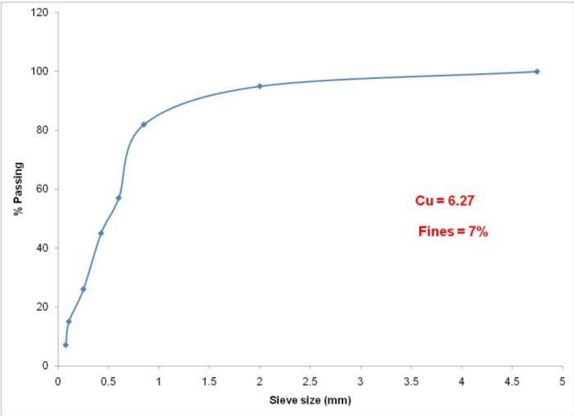

Figure 12. Particle size distribution curve for block industry K4

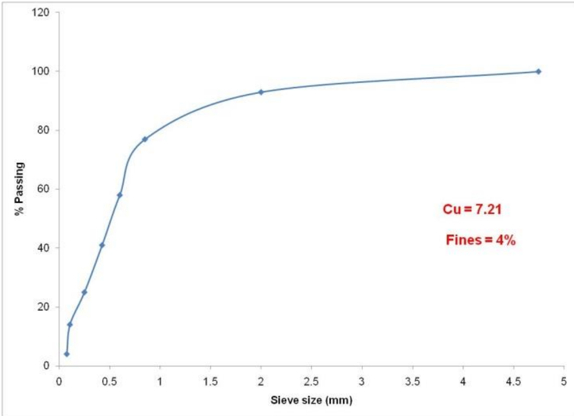

Figure 13. Particle size distribution curve for block industry K5

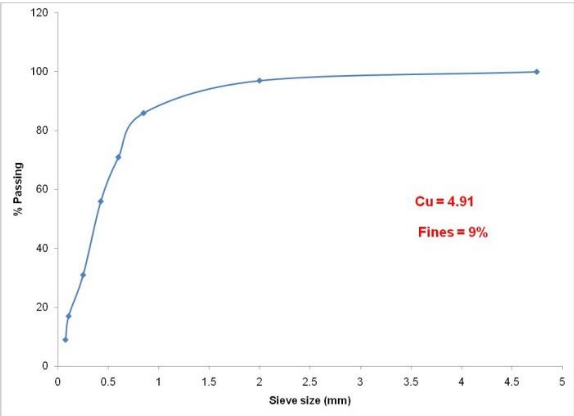

Figure 14. Particle size distribution curve for block industry K6

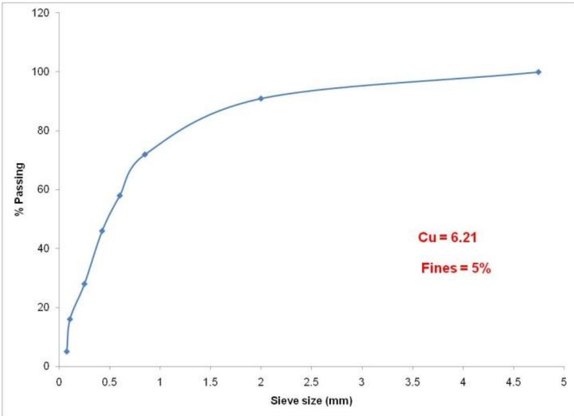

Figure 15. Particle size distribution curve for block industry K7

Fine aggregate specific gravity

The result of the specific gravity of the fine aggregate is shown in Table 1. As shown in Table 1, the specific gravity of the fine aggregate used by some of the sandcrete block producers were a little bit lower than the recommended NIS value for fine aggregate.

Table 1. Fine aggregate specific gravity

Block Industry Code	Specific gravity
N1	2.45
N2	2.56
N3	2.51
N4	2.68
S1	2.72
S2	2.65
S3	2.64
S4	2.61
K1	2.82
K2	2.56
K3	2.72
K4	2.71
K5	2.63
K6	2.65
K7	2.61

Compressive strength

The results of the compressive strength and the mixing ratio of the blocks randomly sampled from the study area are presented in Figure 15 and Table 2. For all cases, the compressive strength of the sandcrete blocks sampled range between 0.653 Nmm^{-2} and 1.203Nmm^{-2}. These results all fall below the minimum permissible compressive strength recommended by the Nigerian industrial Standard (NIS 87:2000) and British Standard (BS 2028) for individual sancdcrete blocks. The minimum permissible compressive strength of 3.25 Nmm^{-2} was recommended by BS 2028 for individual sandcrete block, used for load bearing walls. As seen in the results the mean compressive strength of sandcrete blocks with the code K was comparatively higher (0.961 Nmm^{-2}), when compared to the results obtained from the blocks coded "S" and "N" (0.858 and 0.772 Nmm^{-2}). This could be attributed to the differences in the mode of the blocks production, and the specific gravity of the fine aggregate used. From the results, the fine aggregate used to produce "K" blocks had a higher specific gravity when compared to the specific gravity of the fine aggregate used to produce "S" and "N" blocks (Table 1). According to Akpokodje and Uguru (2019), if International standard recommendations are strictly adhered to, fine aggregate having higher specific gravity tends to producer stronger and denser sandcrete blocks, when compared to their counterparts produced with fine aggregate having lower specific gravity value.

The results further showed that most of block industry owners compromise on the cement-sand mix ratio in order to maximize profit. The methods employed by all the block industries, do not conform to any international standard recommendations. All the mix ratios (cement: sand) adopted by the block industries falls below the NIS-87 recommendation of maximum of 1:8, while the water cement ratio was 0.5 (or 0.45) for sandcrete block as specified by BS-6073 and NIS-87, was not strictly adhered to a compressive strength of sandcrete block higher than 2.7 Nmm^{-2} is attainable if there is full compliance to NIS recommendations. Adebakin *et al.* (2012) reported that after 28 curing days, sandcrete blocks produced in compliance with NIS recommendations had a compressive strength of 4.26 Nmm^{-2}. In the study of Esegbuyota *et al* (2019), they reported that compressive strength of 3.24 Nmm^{-2} was recorded for sandcrete block produced with a mix ratio of 1:7, with water cement ratio of 0.5. In addition, *Ajagbe et* *al.* (2013) adopted BS-6073 recommendations using a mix ratio of 1:6, and produced sandcrete blocks with mean compressive strength of 3.56 N mm^{-2}. However, based on previous researchers' results, the compressive strength of commercially produced sandcrete blocks in Nigeria, all fall below the specified standard recommendation by NIS-87. Our results are similar to the previous researchers' results, were the compressive strength of commercially produced sandcrete blocks in Nigeria fall far below the specified standard recommendation by NIS-87. Yusuf *et al.* (2017) and Onwuka *et al.* (2013) all reported that the average compressive strength of the blocks within their area of study falls below the NIS recommended value of 3.5 Nmm^{-2}, and encouraged the government to set up a quality monitoring agency. Aiyewalehinmi and Tanimola (2013) observed that sandcrete blocks produced by block industries and sold to the public are of consistently substandard. Yusuf *et al.* (2017) stated that the Council for the Regulation of Engineering in Nigeria (COREN) should liaise with the government and sandcrete block producers to help in the regulation some of the sharp practices in the industry.

Table 2. Compressive strength test results of the sandcrete blocks (28th day)

Block Industry Code	Cement-sand mix ratio	Mixing and mode of production
N1	1:16	Manual
N2	1:12	Mechanical
N3	1:12	Manual
N4	1:12	Mechanical
S1	1:10	Mechanical
S2	1:14	Mechanical
S3	1:12	Manual
S4	1:14	Manual
K1	1:12	Mechanical
K2	1:16	Mechanical
K3	1:12	Mechanical
K4	1:12	Mechanical
K5	1:14	Manual
K6	1:10	Manual
K7	1:12	Manual

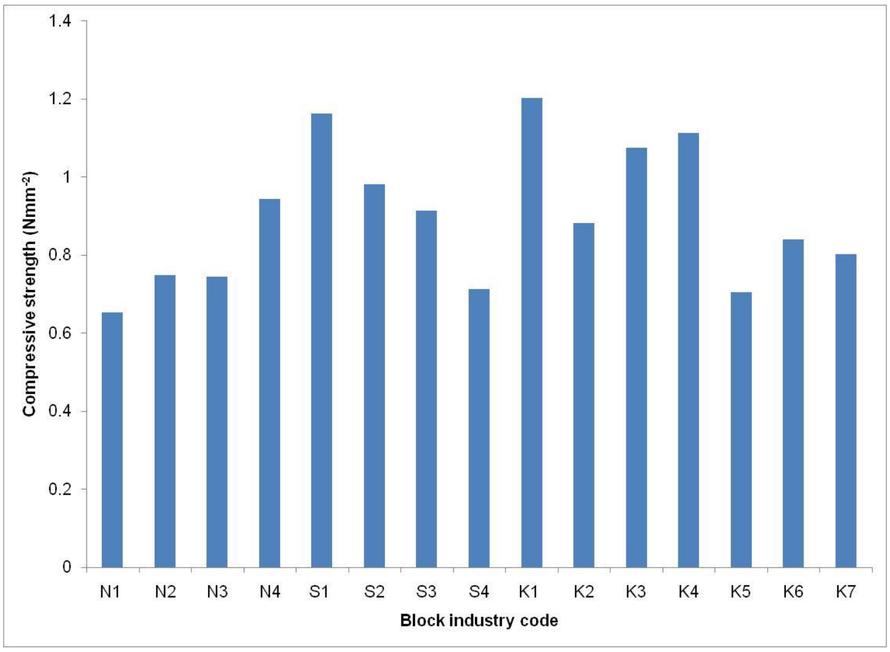

Figure 16. Compressive strength of the blocks sampled from the block industries

CONCLUSIONS

This study was carried to determine the compressive strength of commercially produced sandcrete blocks within Isoko metropolis. Observations made during the field work showed that none of the block industries adhered to NIS-87 recommendations from sandcrete blocks production. The mean compressive strength of all the blocks randomly sampled from the 15 sandcrete blocks industries falls below the minimum permissible compressive strength recommended by NIS. From the results the mean compressive strength ranged from 0.653 Nmm^{-2} to 1.203 Nmm^{-2}. This is because the sandcrete blocks producers tried to maximize profit, by using higher volume of fine aggregate in the block production, leading to a poor quality of sandcrete blocks produced. From the results of this study, it will be appropriate for the government to set to up a quality control agency, to closely monitor the quality of sandcrete blocks produced in the state. In addition to this, constant training should be provided by the Government in collaboration with Structural engineers (COREN) to educate the sandcrete blocks producers on how to improve the quality of sandcrete blocks produced in the country. This is necessary as Nigeria has started to experience earth tremors due likely to seismic activities.

DECLARATION OF COMPETING INTEREST

The authors declared that they have no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

The authors declared that the following contributions are correct.

Goodnews Goodman Agbi: Literature review and methodology.
Ovie Isaac Akpokodje: Data analysis and review of the original draft.
Hilary Uguru: Design the research and writing the original draft.

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