integrity Research Journals

Global Journal of Earth and Environmental Science
Volume 7(2), pages 42-49, April 2022
Article Number: 1E7130073
ISSN: 2636-6002
https://doi.org/10.31248/GJEES2022.123
https://integrityresjournals.org/journal/GJEES

Full Length Research

Comparative analysis of the compressive strength of commercially produced sandcrete blocks in Asaba region of Nigeria

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Received 26th February, 2022; Accepted 15th April, 2022

ABSTRACT: The upsurge in the rate of buildings collapse in Nigeria had become a major concern to the government and populace. This research was done to determine the suitability of sandcrete blocks used for buildings construction in Asaba metropolis. 100 blocks were sampled from sandcrete blocks producing factories within the Asaba region, and their compressive strength determined according to ASTM International procedure. Field observations made revealed that blocks factories managers had failed to compile with Nigeria Industrial Standard (NIS) or any other international approved guidelines for sandcrete blocks production. Results obtained from the compressive test indicated that the compressive strength of the 6-inch blocks ranged between 0.87 MPa and 2.53 MPa; while the compressive strength of the 9-inch blocks varied from 1.03 MPa to 2.93 MPa. The study findings further revealed that only 20% of the blocks met NIS requirement; while the remaining 80% of the blocks failed to meet the NIS requirement. The study affirmed that blocks incorporated with granite fines developed higher strength, when compared to the blocks produced without granite fines. Findings of this study is an indication for the Nigeria government to closely commercially produced blocks in Delta State, to ensure that they conformed with the NIS recommendation for wall building materials.

Keywords: Building failure, compressive strength, granite fines, Nigeria Industrial Standard, sandcrete blocks.

INTRODUCTION

Several conventional materials are used in the construction of modern day civil engineering structures; and sandcrete and concrete blocks formed a bulk of the building materials. Sandcrete and concrete blocks are composite material; consisting of cement, water, coarse aggregate, fine aggregate and other admixtures. The engineering properties of sandcrete/concrete blocks are highly dependent on the cement or fine aggregate volume in the composite, curing method adopted, cement to water ratio, etc. (Akpokodje and Uguru, 2019; Akpokodje *et al*., 2020; Akpokodje *et al*., 2021; Erakpoweri and Onah, 2022). Majority of residential and commercial buildings in Nigeria are being constructed with sandcrete blocks of different sizes and shapes (Baiden and Tuuli, 2004). Sandcrete block typically takes two major forms, solid and hollow forms (Odeyemi *et al*., 2018); and they are mainly utilized for the construction of building walls. Therefore, sandcrete blocks must have adequate strength and stability to withstand the prevailing atmospheric conditions, and their intended use of building construction (Esegbuyota *et al*., 2019; Agbi *et al*, 2020). It had been observed that incorporation of special treatments (e.g. admixtures) and granite fines into concrete and sandcrete blocks, help to enhance their structural qualities (Oyekan, 2001; Siddique, 2003; Odeyemi *et al*, 2019; Ihemegbulem *et al*., 2022), and widen their industrial applications.

Utilization of substandard building materials is on the rise in Nigeria, due to sharp practices of the manufacturers, properties developers, etc.; thereby exposing the buildings and its occupants to great hazards. High price and non-availability of standard materials are another major factors contributing to use of counterfeit materials for buildings construction in Nigeria (Uguru and Obukoeroro, 2020; Nair *et al*, 2006). Poor quality building materials have low resistance, compression and tensile behaviours; which can results in mechanical/electrical failure of any structure built from them (Omoregie and Alutu, 2006; Uguru and Obukoeroro, 2020). Several researchers (Akpokodje *et al*., 2021; Obukoeroro and Uguru, 2021a; Obukoeroro and Uguru, 2021b), had reported that substandard building materials is one of the leading causes, causing the upsurge in building failures and electrical fires recently witnessed in Nigeria. This rising incidences of building failures and electrical fires in Nigeria had become a major threat nationwide; as it affects both the governments, properties developers, landlords and occupants of those structures, among others (Chendo and Obi, 2015).

Although some Nigeria regulatory agencies such as: Standard Organization of Nigeria (SON) and Nigeria Industrial Standard (NIS), recommended that load bearing and non-load bearing walls should have a minimum compressive strength of 3.45 MPa and 2.5 MPa, respectively (NIS, 2000; NIS, 2007). Several researches conducted within the last two decades revealed that majority of sandcrete blocks produced in Nigeria, fell greatly short of these regulatory guidelines. Ambrose *et al*. (2019) reported that the compressive strength of sandcrete blocks produced within some metropolitan areas of Akwa Ibom State, ranged between 0.19 MPa and 1.32 MPa; thereby, making them unsuitable for the construction of non-load bearing walls. Likewise, an investigation into the mechanical properties of sandcrete blocks, produced within Isoko region of Delta state, revealed that the blocks' compressive strength varied between 0.65 MPa and 1.20 MPa (Agbi *et al*, 2020). Furthermore, it was observed that the strength developed commercially produced sandcrete's blocks within Calabar metropolis, southern Nigeria, was below the NIS/SON recommended standard for sandcrete blocks (Ewa and Ukpata, 2013). Additionally, Akpokodje *et al*. (2021) in their studies reported that some commercially produced sandcrete blocks in Kwale and Ughelli metropolises of Delta State were able to meet NIS recommended; although most of the mass produced blocks sampled during the research failed to meet the NIS/SON standard.

Even though several appraisals had been done on the quality of sandcrete block produced in different parts of Nigeria, there is no much literature on the compressive strength of commercially manufactured sandcrete blocks in Asaba, Delta State, Nigeria. Consequently, the purpose of this research is to carry out a comprehensive appraisal, on the quality status of massed produced sandcrete blocks in Asaba metropolitan area, Delta State, Nigeria.

MATERIALS AND METHODS

Study area description

Asaba the capital city of Delta State is located in southern Nigeria, with a landmass of approximately 268 km^2, and population of approximately 500,000 people (DSG, 2015). Asaba had two main climatic seasons, the rainy season that comes with flood (rainfall above 1800 mm per annual) and erosion; and the dry season which comes with dry wind and high temperature and low relative humidity (Agbi *et al*., 2021). Asaba is an administrative/commercial town. It has one university campus, one polytechnic, one domestic airport, tourist attraction centers, and several small and medium scales enterprises. Resulting from commercial growth of the city, a lot of civil engineering structural constructions are taking place within the metropolitan area. This has increased the demand and utilization of building materials within the area, including sandcrete blocks. Resulting from the high demand of sandcrete blocks for buildings construction, there are numerous sandcrete blocks producing factories within the Asaba municipal area, which are managed by individuals with little or no formal knowledge of civil/structural engineering. Therefore, these blocks are being produced without proper adhesion to NIS/SON guidelines for sandcrete blocks production.

Sandcrete blocks procurement

Ten sandcrete blocks producing factories were randomly selected for this research work. At each sandcrete blocks producing factory, five 9-inches and five 6-inches hollow sandcrete blocks were sampled arbitrarily; but considering their date of production. All the blocks sampled were approximately 28 days old. The blocks were taken to the Laboratory of the Department of Civil and Water Resources, Delta State University of Science and Technology, Ozoro, Nigeria, for compressive strength determination.

Field observations

The following observations were made during the procurement of the sandcrete blocks.

Cement used

Dangote and BUA Portland limestone cement brands were the commonly cement brands used by the sandcrete blocks producers. All the cement brands met the NIS grade of 42.5, approved cement to be used in buildings construction.

Fine aggregate (sand)

All the blocks' producers use river bed (sharp) sand for the blocks production. This can be attributed to the proximity of Asaba region to the River Niger. Sharp sand is usually free from organic matters, very fine grain particles, chemical materials, etc. (Ihemegbulem *et al*., 2022).

Granite fines

Few blocks producers utilized granite fines as partial replacement of fine aggregate. Sandcrete blocks quality is usually increased with the introduction of granite fines (Prokopski *et al*., 2020).

Curing

Appropriate curing methods were not adopted by the sandcrete block producers. Although, the irrigation methods was partial adopted.

Compressive strength test

The sandcrete blocks compressive strength was determined according to ASTM International (ASTM C109/C109M-02) procedures. The block was placed into the crushing chamber of the machine, supported with platens at the top and bottom surfaces, and compressed axially, until the block experienced microstructural failure. Then the block's compressive strength can be calculated by using the expression shown in Equation 1.

$$\text{Compress strength} = \frac{\text{crushing force (N)}}{\text{Net area of block } (mm^2)} \qquad 1$$

Net area of 9 inch hollow sandcrete block = 67500 mm^2
Net area of 6 inch hollow sandcrete block = 33750 mm^2

Particles grain size grading (sieve analysis)

The sieve analysis of the fine aggregates used for the blocks production was carried out in accordance to IS-2720 (Part 4):1985 recommended procedure (IS-2720, 2015).

Statistical analysis

Results obtained from the compression tests were subjected to Analysis of Variance (ANOVA), using statistical analysis software (SPSS) version 20.0 to determine the effect of block size and production method on the compressive strength of the blocks. Furthermore, the means were separated using the Duncan's Multiple Range Test (DMRT) at 5% significance level.

RESULTS AND DISCUSSION

Table 1 presents the summary of the procedures adopted for the sandcrete block production. The cement-sand ratio adopted for the block's production by the various factories varied from 1:10 and 1:18 (by volume). Factories 1, 2, 4, 5 and 8 used the higher cement to sand mix ratio; while factories 3, 6, 7, 9 and 10 used the lower cement to sand mix ratio. This depicted that the sandcrete block produced by factories 3, 6, 7, 9 and 10 had higher sand volume, when compared to sandcrete block produced by factories 1, 2, 4, 5 and 8. Additionally, volumetric batching method was used during the blocks production, as it was faster and easier compared to the weighing batching method. Although volumetric batching method was wholesomely adopted in all the block production sites, there were cases of mistakes in proportion exactness during the batching. This might led production of sandcrete block with variations in the mechanical properties; probably blocks with lower compressive strength (Esegbuyota *et al*., 2019; Ajao *et al*, 2018). It was also observed from the field work that 40% of the block's producers partially replaced the sharp sand with granite fines; while the remaining 60% neither uses granite fines nor any other forms of treatment.

Furthermore, Table 1 revealed that most (70%) of the factories used mechanical methods (mixers and vibrating moulding machine) to produce their block; while the remaining 30% utilized manual methods to produce the block. This was contrary to the observations made by (Akpokodje *et al*., 2021; Agbi *et al*, 2020), where most of the sandcrete block produced within their areas of study was done by using the manual method. Furthermore, Table 1 depicted that none of the block's factories within the Asaba region adhered to NIS (2007) guidelines of water volume to be used for sandcrete/concrete production. This observation was not strange, as previous researchers (Akpokodje *et al*., 2021; Agbi *et al*., 2020; Ajao *et al*., 2018), where the block's producers uses his own discretion to regulate the volume of water to be used for the block's production. Among the factory managers, none of them was qualified civil/structural engineers; as the field study revealed that all the managers were Mason.

Sieve analysis

Figures 1, 2 and 3 present the sieve analysis results of the fine aggregate used for the blocks production. As revealed in the plots in Figures 1, 2 and 3, all the aggregate used for the blocks production was not well graded, according

Table 1. Sandcrete block production procedures adopted.

Factory	Manager	Mix ratio	w/c (%)	Treatment	Mixing method	Production method	Batching method
1	Mason	1:10	ND	Granite fines	Mechanical	Mechanical	Volumetric
2	Mason	1:12	ND	Granite fines	Mechanical	Mechanical	Volumetric
3	Mason	1:16	ND	None	Manual	Manual	Volumetric
4	Mason	1:12	ND	Granite fines	Mechanical	Mechanical	Volumetric
5	Mason	1:12	ND	Granite fines	Mechanical	Mechanical	Volumetric
6	Mason	1:14	ND	None	Mechanical	Mechanical	Volumetric
7	Mason	1:14	ND	None	Manual	Manual	Volumetric
8	Mason	1:10	ND	None	Mechanical	Mechanical	Volumetric
9	Mason	1:14	ND	None	Mechanical	Mechanical	Volumetric
10	Mason	1:18	ND	None	Manual	Manual	Volumetric

ND = not determined.

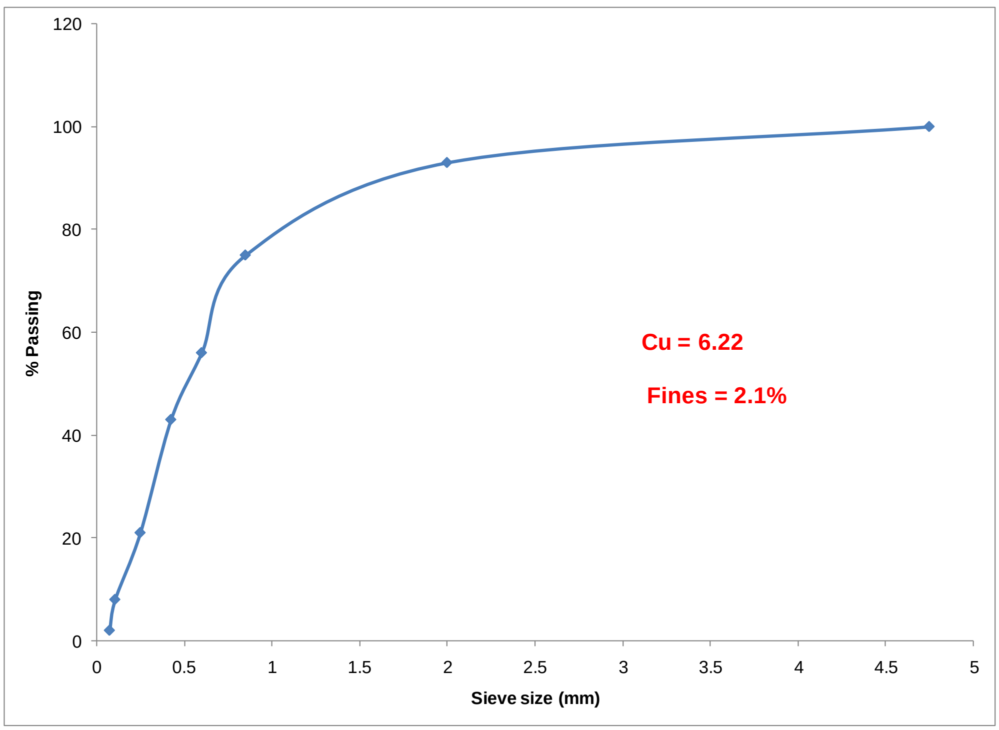

Figure 1. Sieve analysis of fine aggregate from blocks factories 1, 2 and 4.

to the Unified Soil Classification System (USCS) guidelines. The USCS stated that fine aggregate having coefficient of uniformity (Cu) greater than 6 and the fines less than 5% is considered Well Graded, and it is suitable for sandcrete blocks production (Agbi *et al*, 2020; USCS, 2015). As depicted by the results, Figures 1 and 2 contained little amount of fines (<3%). This showed that this aggregate will produced sandcrete blocks with better quality, since fine aggregate with high amount of fines produces blocks with lower quality (Agbi *et al*, 2020).

Sandcrete block compressive strength

The one-way ANOVA results resented in Table 2 revealed that the block size and production point (factory) had significant ($p \leq 0.05$) effect on the compressive strength of the sandcrete block. This finding portrayed that mode of block production and volume of materials used by various blocks producers, significantly influenced the block's compressive properties. Similar observations were made by Ewa and Ukpata (2013), where compressive strength

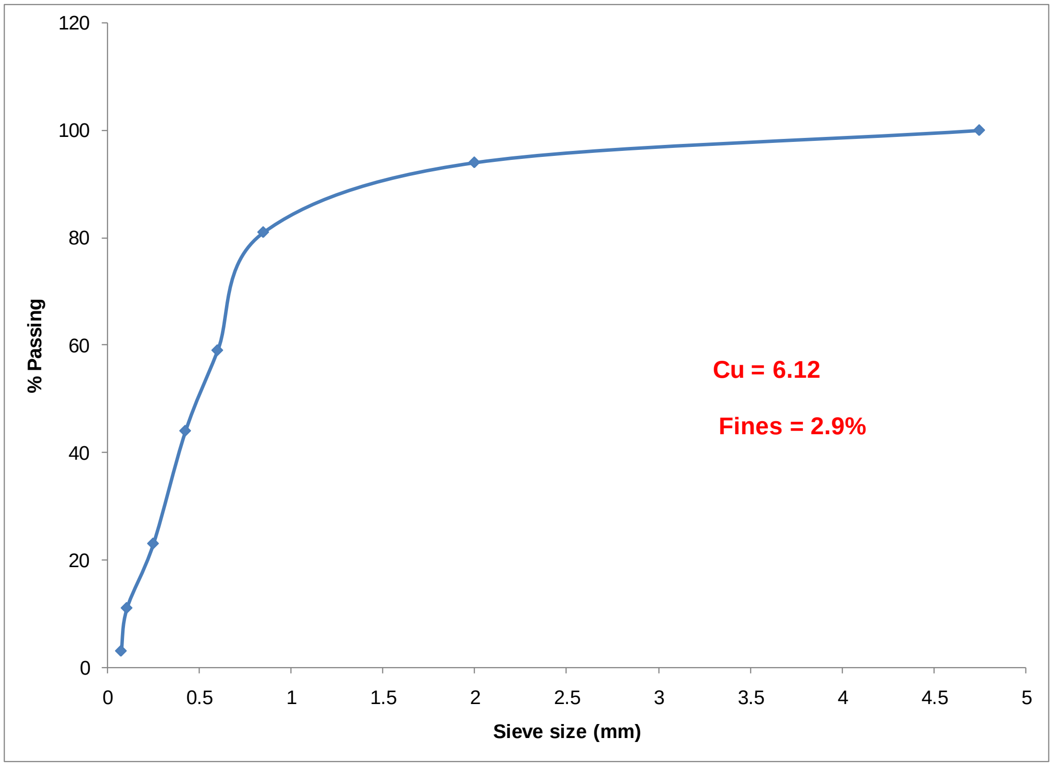

Figure 2. Sieve analysis of fine aggregate from blocks factories 3, 5 and 8.

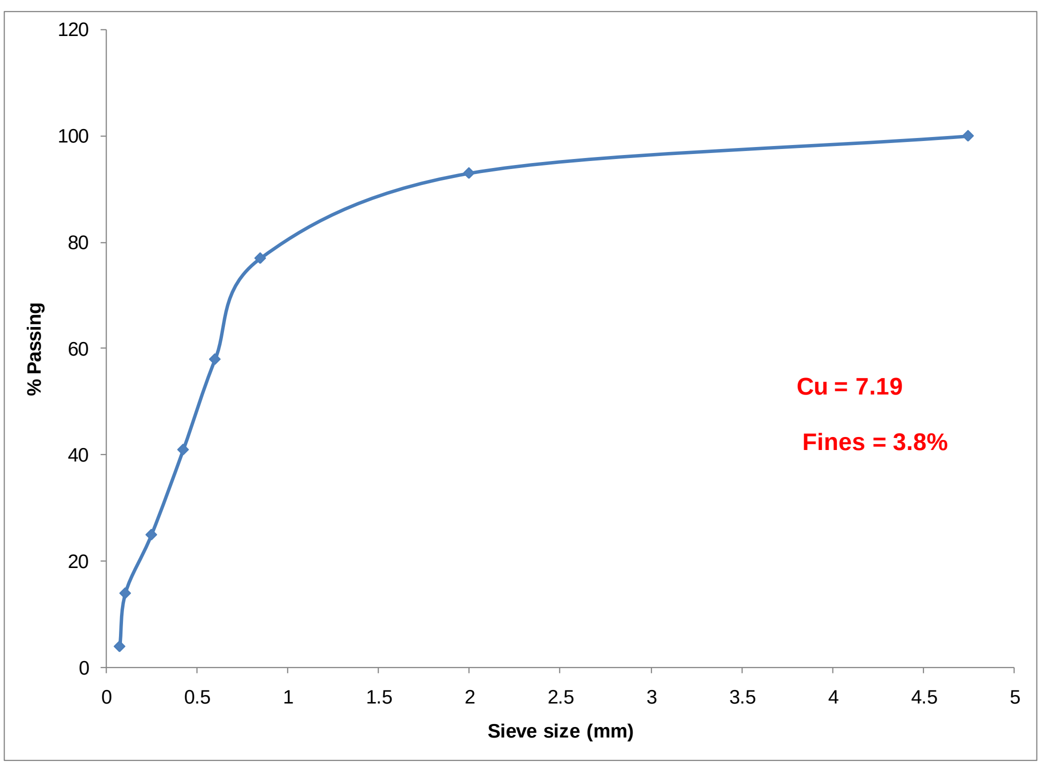

Figure 3. Sieve analysis of fine aggregate from blocks factories 6, 7, 9 and 10.

Table 2. Effect of block size and producers on sandcrete block's compressive strength.

Size	Between/ within groups	Sum of squares	df	Mean square	F	p-value
Six	Between groups	9.56	9	1.062	99.55	1.25E-14*
	Within groups	0.21	20	0.011		
	Total	9.77	29			
Nine	Between groups	11.18	9	1.242	128.46	1.05E-15*
	Within groups	0.193	20	0.010		
	Total	11.37	29			

*Significant at p ≤0.05, according to DMRT.

of sandcrete block varied widely along the different manufacturers.

Table 3 presents the separated means of the sandcrete blocks' compressive strength. Generally, the compressive strength of the 6-inch blocks ranged from 0.87 to 2.53 MPa; while the compressive strength of the 9-inch blocks varied between 1.03 and 2.93 MPa. This further revealed that the 9-inch blocks were stronger in terms of compressive strength, compared to the 6-inch blocks. It can be seen that only 20% of the factories sampled, produced block with compressive strength relatively above than the minimum standard (2.5 MPa) recommended by NIS for non-loadbearing walls. The findings (Table 3) further revealed that none of the factory was able to produce block that met NIS recommendation (3.5 MPa) for the construction of load bearing walls. It was observed that factories 3, 6, 9 and 10 produced block with very poor quality. This can be caused by the mode of production and filler volume (sand) in the block. Filers' volume had significant effect on the compressive strength and other engineering properties of sandcrete blocks and other composites (Ajao *et al*., 2018; Ambarish *et al*., 2011; Oghenerukewve and Uguru, 2018; Edafiadhe *et al*., 2019). Regardless of the mix ratio adopted, it was observed that the strength of factories 1, 4 and 5 blocks, was generally higher (2.53, 2.33 and 2.67 MPa respectively for the 6-inch blocks, and 2.93, 2.20 and 2.83 Mpa respectively for the 9-inch blocks), compared to the other factories blocks. This can be attributed to the granite fines used for the blocks' production. Previous studies (Akpokodje and Uguru, 2019; Akpokodje *et al*., 2020; Akpokodje *et al*., 2021; Ambarish *et al*., 2011; Oyekan and Kamiyo, 2008; Agbi and Uguru, 2021) confirmed that treatments and granite fines greatly improved the strength of sandcrete/concrete blocks. Also, it was observed in this research that, despite the granite fines used by factory 2 for their blocks production, the blocks developed very poor strength at day 28. This might likely be caused by the volume of granite fines used as partial replacement for the sand. According to Olaniyan *et al*. (2012), at lower proportion (≤10% of the fine aggregate volume), granite fines helps to improve the strength of sandcrete blocks; but at higher proportion, granite fines hinders strength development in standcrete blocks.

Table 3. Summary table of the sandcrete block compressive strength at day 28.

Factory code	Compressive strength (MPa)	
	6-inch	9-inch
1	2.53^{g}±0.06*	2.93^{g}±0.15*
2	1.93^{e}±0.15	2.30^{e}±0.10
3	1.47^{c}±0.06	1.83^{c}±0.06
4	2.33^{f}±0.06	2.20^{f}±0.10
5	2.67^{g}±0.15*	2.83^{g}±0.06*
6	1.43^{c}±0.06	1.57^{d}±0.12
7	1.70^{d}±0.10	1.53^{d}±0.12
8	2.20^{f}±0.10	2.47^{f}±0.06
9	1.23^{b}±0.15	1.33^{b}±0.06
10	0.87^{a}±0.06	1.03^{a}±0.12

±Standard deviation; means followed by the same common letter (superscript) in the sample column are not significantly (p ≤0.05) different according to DMRT; * compressive strength that met NIS requirement for non-load bearing walls.

The information presented in Table 3 revealed that the compressive strength of the sandcrete block produced within Asaba metropolis varied extensively from one producer to another. The findings depicted that block's strength is dependent on the skill of factory supervisor, and his ability to monitor the batching, mixing, moulding and curing of the blocks. This is because, despite the similar production and mix methods adopted by the various factories' managers, the block produced significantly (p≤0.05) exhibited different compressive strength. This is in conformity to pervious researches (NIS, 2007; Ewa and Ukpata, 2013; Oyekan and Kamiyo, 2008; Aiyewalehinmi and Tanimola, 2013) which observed that commercial block's quality differ from one producer to another, irrespective of the mix ratio, materials and methods adopted.

The poor blocks' quality (lower compressive strength) observed in some of the factories block, despite the rich mix ratio used, could also be attributed to the amount of water used for the production, and the curing method adopted by the producers. Even if cement needs water for complete reaction (formation of tobermorite gel), excess water (high water-cement ratio) can caused serious alteration in the chemical reaction, and separation of the aggregates from the mixture; thus, leading to formation of sandcrete blocks with poor compressive strength (Akpokodje *et al*., 2021; Mahmoud *et al*., 2010). Moreover, the poor curing method adopted by the producers, will results in rapid evaporation of water from the block; consequently leaving little water available for the chemical reaction, resulting in incomplete reaction. Although, the block's strength recorded in this research was generally higher than those recorded by some previous researchers (Akpokodje *et al*., 2021; Agbi *et al*., 2020; Ewa and Ukpata, 2013), the results generally reflected that commercially produced block is of poor quality. This persistent problem is mainly caused by the corrupt nature of the blocks' producers in other to maximize profit. Therefore, standard regulatory and monitoring should closely monitor the quality of commercially produced sandcrete block in Nigeria and Delta State in particular, to make sure that the block met international and local standards.

Conclusion

This appraisal was done to ascertain the standard of sandcrete blocks produced within Asaba, the Delta State capital, and determine their suitability for residential/ commercial buildings construction. The field observations made during this study depicted that none of the factory strictly followed the standards recommended by NIS for sandcrete blocks production. The compression test results indicated that, most of the sandcrete blocks produced within the study area do not conform to the NIS standard (3.5 MPa) for the erection of load bearing wall. Nevertheless, few blocks factories were able to produce sandcrete blocks that meet the NIS standard (2.5 MPa), for sandcrete blocks suitable for the erection of non-load bearing wall. Arising from the findings of this research, the authors strongly recommended that Nigeria standard monitoring agencies should organized seminars for the sandcrete blocks producers in the region, in order to improve the quality of blocks produced.

CONFLICT OF INTEREST

The authors have that they have no conflict of interest.

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