EXPERIMENTAL ANALYSIS OF THE PERFORMANCE OF CHIPPINGS, STONEDUST, AND SAND IN THE PRODUCTION OF DURABLE SANDCRETE HOLLOW BLOCKS

[1*]Ajayi J. A., [2]Adanikin A., [3]Aiyewalehinmi E. O., [4]Adeyemi F. O., [5]Gana A. J. and [6]Oshin A. O.

[1]Department of Civil and Environmental Engineering, Elizade University, Ilara-Mokin, Nigeria.
[2]Department of Engineering and mathematics, Sheffield Hallam University, United Kingdom
[3]Department of Civil Engineering, Federal University of Technology, Akure, Nigeria.
[4]Department of Civil Engineering, Ajayi Crowder University, Oyo, Nigeria.
[5]Department of Civil Engineering, Landmark University, Omu-Aran, Kwara State, Nigeria
[6]Department of Electrical and Electronics Engineering, Elizade University, Ilara-Mokin, Nigeria.

[*]Corresponding Author E-mail: Jsosfeb01@gmail.com

ABSTRACT

Sand, a crucial component in sandcrete block production, is becoming increasingly scarce due to over-exploitation of riverbeds. This scarcity has spurred concerns, as the mechanical properties of sandcrete blocks significantly impact the longevity of structures. Therefore, this study investigates the potential of using alternative materials to improve the strength of hollow sandcrete blocks. The study employed a conventional block molding machine to fabricate sandcrete hollow blocks (450 x 225 x 150 mm) in three categories: Category A: 100% stonedust replacing sand entirely, Category B: 50% stonedust and 50% chippings, and Category C: 40% stonedust, 40% chippings, and 20% sand. All block categories were produced with a 1:6 cement ratio. Ninety blocks were cast in total, and compressive strength alongside other tests were conducted at 7, 14, 21, and 28 days. Statistical analysis was performed using SigmaPlot 14.0 software. The study found that hollow sandcrete block samples made with a combination of stonedust and chippings exhibited the highest compressive strength, reaching 6.67 N/mm^2, which surpassed the strength of blocks in other categories. Furthermore, all tested samples exceeded the Nigerian Industrial Standard (NIS) for compressive strength. These findings suggest that partially or entirely replacing sand with stonedust and chippings in sandcrete block production can be a viable approach to improve block strength.

Keywords: *Chippings, compressive strength, sandcrete hollow block, statistical analysis, stonedust*.

INTRODUCTION

Sandcrete blocks are constructed from a mixture of sand, cement, and water, (Abdullahi, 2005). The expansion of most developing countries' economies has resulted in a rise in construction activity. Housing as a basic requirement, as well as the construction of extremely sophisticated commercial structures, are now a reality in various countries. Fine aggregates have historically been used to manufacture concrete, mortar, precast buildings, and building blocks in the construction sector. Sand has indeed been used as one of the crucial ingredients of building materials due to its widely available nature and well-graded nature with grains of sand of all sizes, (Dongapure & Shivaraj, 2014). Sandcrete blocks have been used all throughout the world, including Africa, (Oyetola & Abdullahi, 2006). Every country's infrastructural development is growing increasingly reliant on block molding or sandcrete technology (Onwuka *et al.*, 2013). A sandcrete block is typically composed of a 1:6 cement-to-sand ratio mixed with an appropriate amount of water and allowed to dry gradually, (Anosike & Oyebande, 2012). The quality of the component materials, the production method, the curing time, and the shapes and sizes of the fine aggregate are all factors that influence the performance of sandcrete blocks, Adewuyi *et al.* (2013).

Walls are built using sandcrete hollow blocks as either load-bearing or non-load-bearing to give shelter and safety for man and his property, according to a study by Agbi *et al.(* 2020). Sandcrete blocks are commonly utilized as walling components in buildings, drainage systems, and other masonry projects. There are two types of walling components: load-bearing and non-load-bearing. The most popular sandcrete blocks are hollow sandcrete blocks. For load and non-load-bearing walls, they are normally 450 x 225 x 225 mm or 450 x 225 x150 mm in size. The void is about a third of the size of the blocks. A void does not exist in a solid sandcrete blocks. Hollow sandcrete blocks are an excellent building material. In nations like Ghana and Nigeria, it is the main structural component of single-story structures such as residences and education institutions, Adewuyi *et al.* (2013).

Sand is a significant part of the sandcrete block manufacturing process. Sand has long been the most common source of natural fine aggregate. However, continuing exploitation of river sand has wreaked havoc on the ecology [6; 8; 9]. The loss of water-retaining soil strata, deepening of river beds and resulting bank slides, loss of vegetation along riverbanks, and disturbance of aquatic life as well as agriculture are all examples of these issues. As a result, in addition to the requirement to provide affordable housing for everybody, various alternatives to fine aggregates must be investigated. Alternative fine aggregate sources, including laterites, have been examined in sandcrete blocks across Africa (Adewuyi *et al.*, 2013; Agbede & Manasseh, 2008; Ibearugbulem *et al.*, 2015). Laterites, on the other hand, have not been utilized in the development of medium to large-scale building structures, owing to a lack of data in the study and design of structures made of lateritic soils (Ukpata *et al.*, 2012).

Natural fine aggregate resources are also depleting, (Palaniraj, 2003). Natural fine aggregate may or may not be of high quality in various circumstances. As a result, the natural fine aggregate used in sandcrete blocks needs to be replaced or supplemented (Palaniraj, 2003). In Nigeria, Sandcrete blocks are still an important part of construction (Aiyewalehinmi & Tanimola, 2013). Nearly 90% of Nigeria's physical infrastructure is made of sandcrete blocks (Baiden & Tuuli, 2004). Sandcrete blocks have been manufactured in Nigeria for a long period in a variety of places without consideration for construction regulations or high-quality workmanship (Oyekan, & Kamiyo, 2008). According to the study of Akpokodje *et al.* (2021), the mechanical qualities of sandcrete blocks have a considerable impact on the durability of structures formed of them, hence there is a need for research into ways to increase the strength of sandcrete blocks used in building construction. As a result, the focus of this research was on how to enhance the performance of load-bearing sandcrete hollow blocks by using alternate materials instead of the conventional fine aggregate (river sand) in the manufacturing process.

MATERIALS AND METHOD

Materials Used

The following materials were utilized to produce the sandcrete blocks that were used in this study. Sharp sand, stonedust and chippings were procured from a quarry in Akure, Ondo State, Nigeria. The fine aggregates were also subjected to a sieve analysis test following British standards (British Standard

882, 1992). The cement for this study was Portland Limestone Cement (PLC) from a local distributor at Ewekoro in Ogun State, which complied with (BS EN, *1995).* Table 1 shows the experimental design used for the research. Potable water that was devoid of suspended particles, salts, and oil pollution was used.

Table 1: Experimental Design

CODE	SAND (%)	STONEDUST (%)	CHIPPING (%)	REPLICATE (%)
CAT A	0	50	50	30
CAT B	20	40	40	30
CAT C	0	0	100	30

Mixing

The manual mixing approach was employed in this investigation for machine-compacted block samples. The cement and sand were mixed dry, then water was poured in modest proportions to allow the cement to hydrate. Excess water was avoided, which would have resulted in block shrinkage and distortion after drying. In this study, the water-cement ratio was 0.45. The mix ratio was 1:6 (one part cement to six parts fine aggregate) following (BS 6073, 1981) standard.

Production of Sandcrete Blocks Samples

Sandcrete hollow block samples were produced following the experimental design depicted in Table 1. The batching was done by weight. Each category had 30 samples, bringing the total number of blocks manufactured to 90, which were examined for water absorption, bulk density and compressive strength at ages 7, 14, 21, and 28. The blocks had dimensions of 450 mm x 150 mm x 225 mm and were made using Elephant Cement.

Compaction and Curing

The blocks were compacted using a-standard vibrating compacting equipment and were cured in water for 28 days while compression test was conducted at 7, 14, 21 and 28 days. The block samples were fully cured in curing tanks to keep the moisture content of the sandcrete blocks at a safe level and allow for proper hydration and hardening.

Determination of Water Absorption Test

The water absorption test was carried out following British Standards (BS 1881-122, 2011). The specimens were removed after 7, 14, 21 and 28 days of curing inside water. They were shaken to remove the excess water as quickly as possible with a cloth and the weight of the sample was recorded as wet weight (W_2). The concrete specimens were heated for 72 hours at a temperature of 105^0 in an oven, the weight was recorded as dry weight (W_1). The percentage (%) of water absorption for each specimen was computed using Equation 1.

Percentage water absorption

$$= \frac{wet\ weigth\ (W2) - dry\ weight\ (W3)}{dry\ weight\ (W1)} X\ 100 \qquad (1)$$

Determination of Bulk Density and Compressive Strength

The bulk density was determined in line with ASTM standards while the 2000kN compressive testing machine was used for the compression test of the sandcrete blocks at 7, 14, 21, and 28 days following a relevant standard. The tests were conducted at the

Concrete Laboratory of the Department of Civil Engineering, Elizade University, Ondo State. Equation 2 was used to calculate the compressive strength (BS EN 12390-4, 2019).

$$\text{Compressive strength} = \frac{Crushing\ load}{Effective\ surface\ area\ of\ the\ block} \quad (2)$$

Effective surface area of block = Total Area of block – Area of hollow

Effective surface area of the sandcrete block = (455 x 150) mm^2 – 2(160x85) mm^2= 41,050 mm

Statistical Analysis

To analyze the data, statistical software (SigmaPlot 14.0) was employed. The Friedman Repeated Measures Analysis of Variance on Ranks was used to assess differences among the three groups: 100% stonedust (coded as St), 50% stonedust + 50% chippings (coded as C), and 40% stonedust + 40% chippings + 20% sand (coded as Sa). Additionally, normality testing (Shapiro-Wilk) and a test for equal variances (Brown-Forsythe) were conducted to ensure the data met the assumptions of the chosen statistical test.

RESULTS AND DISCUSSION

Results of Material Properties

The Ordinary Portland cement used for the study has a consistency of 34mm and contains 96g of water, which accounts for 32 percent of the 300g of cement sample tested. The tested cement exhibited satisfactory setting times. The initial set occurred within 55 minutes, and the complete set was achieved within 540 minutes. These results comply with ASTM C191, (2014) specifications, which mandate an initial setting time of less than 1 hour and a final setting time within 10 hours. The silt content of 6% falls within the standard requirement of less than 10%. The analysis of particle size distribution revealed that both the stonedust and the sand samples are well-graded according to the Unified Classification System (UCSC). The stonedust had coefficients of uniformity (CU) and curvature (CC) of 1.3 and 6.5, respectively, while the sand exhibited CU and CC values of 1 and 6.1. Following the American Association of State Highway and Transportation Officials classification system (AASHTO, 1993), these results indicate that the fine aggregates can be categorized as A-1-a. Table 2 summarizes the results of the various tests conducted on the materials used in this study.

Water Absorption Test Result

The water absorption capacity of the sandcrete block samples is presented in Figure 1.

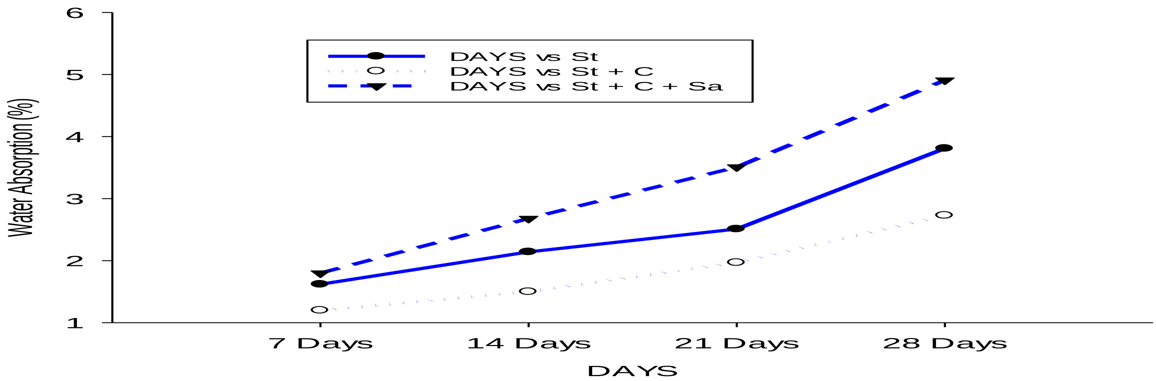

Figure 1: Graph of water absorption against the age of the block

Table 2: Tests on the Materials Used

Material	Test	Results	Specification
Cement	• Fineness test	4.5%	It must be less than 10%
	• Soundness test	3.5mm	It must be less than 10mm
	• Initial setting time	65minutes	Min 30min and max 1hr
	• Final setting time	540minutes	Min. 5hrs and max. 10hrs
Stonedust	➢ Moisture content	4.16%	Not specified
	➢ Silt content	3.1%	<10%
	➢ Specific gravity	2.80	2.60-2.80 (ASTM D854-02 (2002)
	➢ Bulk density	1680kg/m^3	1600-1920 (ASTM C29/C29M, (2017)
Stonedust + chippings	• Bulk density	1915 kg/m^3	1600-1920 (ASTM C29/C29M, (2017)
	• specific gravity	2.92	
	• Moisture content	3.65	2.5 – 3.0 (ASTM D854-02 (2002)
	• Silt content	2.2%	Not specified <10%
Stonedust + chippings + sand	➢ Specific gravity	2.75	2.5 – 3.0 (ASTM D854-02 (2002)
	➢ Bulk density	2050 kg/m^3	1600-1920 (ASTM C29/C29M, (2017)
	➢ Moisture content	5.05	
	➢ Silt content	3.0%	Not specified <10%

Table 3 further details the statistical analysis of these test results. Interestingly, samples produced with a 50% stonedust and chipping mix exhibited the lowest water absorption rate, while those containing stonedust, chipping, and sand had the highest value of 4.91%.

The Friedman Repeated Measures Analysis of Variance on Ranks shows that the test results passed the Normality Test (Shapiro-Wilk) at P = 0.620 and the Equal variance test (Brown-Forsythe) at P = 0.203. The analysis of variance result is shown in Table 3.

BULK DENSITY

The bulk density determination of the sandcrete blocks is shown in figure 2, while the ANOVA Result for Bulk Density Test is shown in Table 4. According to the results, the bulk density of the blocks exceeds the minimum limit of 1920kg/m^3 for individual blocks and 2020kg/m^3 for an average of three (3) blocks (ASTM C29/C29M, 2017). Stonedust + chippings + sand (S+C+SD) had the lowest bulk density after 28 days of curing at 2180kg/m^3, whereas Stonedust + Chippings (S+C) had the highest at 2211kg/m^3. This shows that the compaction is within permissible limits.

The Friedman Repeated Measures Analysis of Variance on Ranks shows that the test results passed the Normality Test (Shapiro-Wilk) at P = 0.945 and the Equal variance test (Brown-Forsythe) at P = 0.431. The analysis of variance result is as shown in Table 4.

Table 3: ANOVA Result for Water Absorption Test

Treatment Name	N	Missing	Mean	Std Dev	SEM
St	4	0	2.520	0.934	0.467
St + C	4	0	1.850	0.667	0.333
St + C + Sa	4	0	3.225	1.323	0.661

Source of Variation	DF	SS	MS	F
Between Subjects	3	8.498	2.833	
Between Treatments	2	3.782	1.891	16.146
0.004				
Residual	6	0.703	0.117	
Total	11	12.983	1.180	

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.004<0.050)".

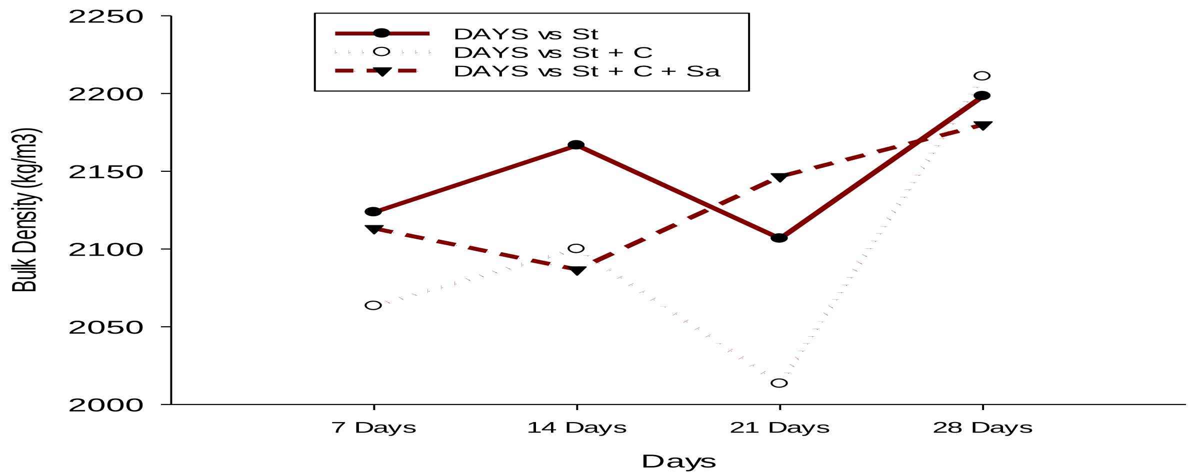

Figure 2: Graph of bulk density against the age of the block

Table 4: ANOVA Result for Bulk Density Test

Treatment Name	N	Missing	Mean	Std Dev	SEM
St	4	0	2148.835	41.549	20.775
St + C	4	0	2096.915	83.943	41.972
St + C + Sa	4	0	2131.668	40.506	20.253

Source of Variation	DF	SS	MS	F	P
Between Subjects	3	21231.375	7077.125		
Between Treatments	2	5597.528	2798.764	1.678	0.264
Residual	6	10009.085	1668.181		
Total	11	36837.988	3348.908		

"The differences in the mean values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.264)".

The Friedman Repeated Measures Analysis of Variance on Ranks shows that the test results passed the Normality Test (Shapiro-Wilk) at P = 0.945 and the Equal variance test (Brown-Forsythe) at P = 0.431. The analysis of the variance result is shown in Table 4.

Compressive Strength

Figure 3 illustrates the compressive strength achieved by the sandcrete hollow block samples. The result followed similar trend as reported in the study (Alejo, 2020; Raheem *et al.*, 2012). Table 5 provides a detailed analysis of these results using ANOVA. A key finding from this analysis is that, throughout the study, sandcrete blocks made with a combination of stonedust and chipping consistently exhibited higher compressive strength compared to those produced with other material combinations. It is also noteworthy that all samples surpassed the compressive strength standards specified by NIS (2000).

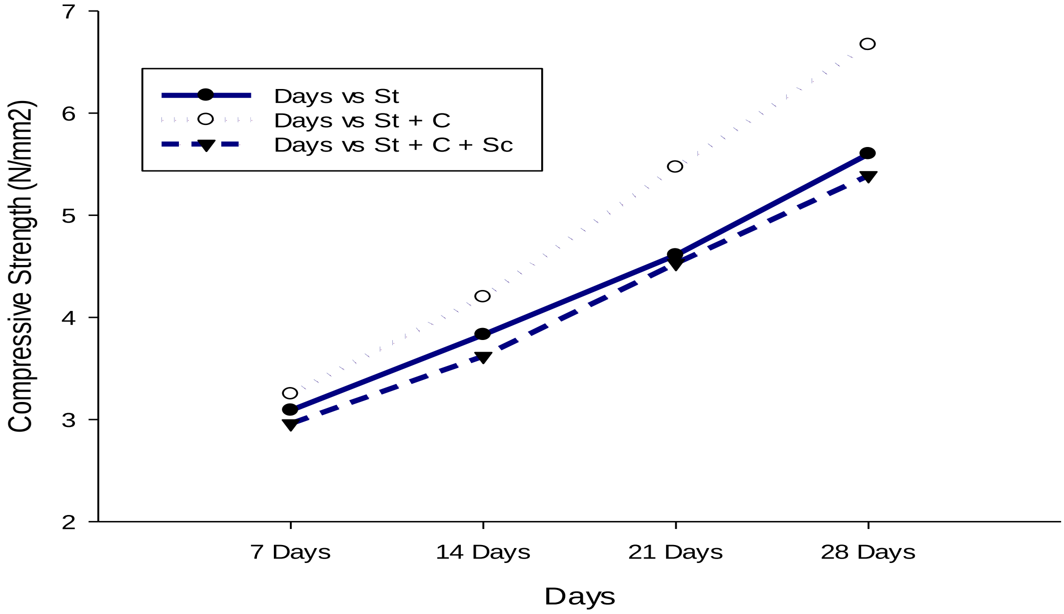

Figure 3: Graph of Compressive strength plotted against the block's age.

Table 5: ANOVA Result for Compressive Strength Test

Treatment Name	**N**	**Missing**	**Mean**	**Std Dev**	**SEM**
St	4	0	4.282	1.075	0.538
St + C	4	0	4.898	1.491	0.746
St + C + Sc	4	0	4.125	1.061	0.530

Source of Variation	**DF**	**SS**	**MS**	**F**	**P**
Between Subjects	3	13.149	4.383		
Between Treatments	2	1.333	0.667	10.888	0.010
Residual	6	0.367	0.0612		
Total	11	14.850	1.350		

"The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.010)".

The Friedman Repeated Measures Analysis of Variance on Ranks shows that the test results passed the Normality Test (Shapiro-Wilk) at P = 0.932 and the Equal variance test (Brown-Forsythe) at P = 0.098. The ANOVA result is shown in Table 5.

CONCLUSION

This study investigated the use of alternative materials like stonedust and chippings to partially replace sand in sandcrete hollow blocks. The results demonstrate that these alternative materials can indeed enhance the compressive strength of the blocks. At 28 days, all sandcrete block samples met the minimum compressive strength requirement of 2.5 N/mm^2 stipulated by the Nigerian Industrial Standard (NIS) for various construction materials. Notably, blocks fabricated with a combination of stonedust and chippings (CAT A) exhibited the highest strength, making them suitable for load-bearing walls according to NIS guidelines. Furthermore, the observed increase in compressive strength and decrease in water absorption over the curing period aligns with previous research findings. These results suggest that using alternative materials in sandcrete block production has the potential to improve block performance while adhering to established quality standards.

REFERENCES

AASHTO 145-91, (1993). American association of state and highway transportation officials, recommended practice for the classification of soils and soil-aggregate mixtures for highway construction purposes, Standard Specifications for Transportation Materials and Methods of Sampling and Testing.

Abdullahi M. (2005). Compressive Strength of Sandcrete Blocks in Bosso and Shiroro Areas of Minna, Nigeria. *AU Journal of Technology*, *9*(2): 126-131.

Adewuyi T. O., Olusola K.O., & Oladokun M.G., (2013). Engineering properties of Sandcrete blocks made with blended bamboo leaf ash (BLA) and Ordinary Portland cement. *A Multidisciplinary Journal of Graduate School*, *1*(3): 48-59.

Agbede I.O. & Manasseh J., (2008). Use of cement: Sand admixture in laterite brick production for low-cost housing. *Leonardo Electronic Journal of Practices and Technologies*, 163-174.

Agbi G.G., Akpokodje O.I., & Uguru H., (2020). Compressive strength of commercially produced sandcrete blocks within Isoko Metropolis of Delta State. *Nigeria Turkish Journal of Agricultural Engineering Research, 1(1): 91-103*

Aiyewalehinmi E.O., and Tanimola M.O., (2013). Strength properties of commercially produced sandcrete block in Akure: Ondo State. *International Journal of Engineering Science Invention*, 2(5): 22-33.

Akpokodje O.I., Agbi G.G., Uguru H., & Nyorere O., (2021). Evaluation of the compressive strength of commercial sandcrete blocks produced in two metropolises of Delta State, Nigeria. *Applied Journal of Physical Science*, 3(2): 61-71.

Alejo A. O., (2020). Comparison of strength of Sandcrete blocks produce with fine aggregate from different sources. *Nigerian Journal of Technology (NIJOTECH)*, 39: 332 – 337

Anosike M. & Oyebande A., (2012). Sandcrete blocks and quality management in Nigeria building industry. *Journal of Engineering Project and Production Management*, *2*(1): 37-46.

ASTM C191-13, (2014). *Time of setting of hydraulic cement by Vicat needle, American society for testing and materials. "Available: www.astm.org*

ASTM C29/C29M, (2017). Standard test method for bulk density ("Unit Weight") and Voids in Aggregate.

ASTM D854-02 (2002). Standard test methods for specific gravity of soil solids by water pycnometer. ASTM International, West Conshohocken, PA

Baiden B. K. and Tuuli M. (2004). Impact of quality control practices in sandcrete blocks production, *Journal of Architectural Engineering*, 10(2): 55-60

British Standard 882, (1992). *Specification for aggregate from natural sources for concrete*.

BS 1881-122, (2011). *Testing of concrete, method for determination of water absorption. British* Standard Institution.

BS 6073 – 1, (1981). Precast concrete masonry units. Specification for precast concrete masonry units.

BS EN 12390-4, (2019). Testing hardened concrete. Compressive strength. Specification for testing machines. British Standard Institution

BS EN 196-3, (1995). Methods of testing cement. Determination of setting time and soundness. British Standard Institution.

Dongapure A. R. & Shivaraj S. M. (2014). Study on Strength of Concrete using Lateritic Sand and Quarry Dust as Fine Aggregates. *International Journal of Engineering Research & Technology*, *3*(12): 126-130.

Ibearugbulem O., Okonkwo E., Nwachukwu A.N., & Obi L.O., (2015). Determination of compressive strength of lateritic sandcrete cubes. *International Journal of Scientific & Engineering Research*, *6*(5): 1190-1194.

NIS 87, (2000). Nigerian Industrial Standard: Standard for Sandcrete blocks. *Standard Organization of Nigeria, Lagos, Nigeria.*

Onwuka D., Osadebe N. & Okere C. (2013). Structural characteristics of sandcrete blocks produced in southeast Nigeria. *Journal of Innovation Research in Engineering Science*. *4*(3): 483-490.

Oyekan G. L, &. Kamiyo O.M, (2008). A study on the Engineering Properties of sandcrete blocks. *Journal of Engineering and Technology Research, 3(3): 88-98.*

Oyetola E. B. & Abdullahi M. (2006). The Use of Rice Husk Ash in Low-Cost Sandcrete Block Production. *Leonardo Electronic Journal of Practices and Technologies*, 8, 58- 70.

Palaniraj S., (2003). Manufactured sand. *Intl. Conf. on Recent Trends in Concrete Technology*. Pp 1-8.

Raheem A. A., Momoh A.K., and Soyingbe A.A., (2012). Comparative Analysis of Sandcrete Hollow Blocks and laterite interlocking blocks as walling elements. *International Journal of Sustainable Construction Engineering & Technology*, 3(1): 1-9.

Ukpata J.O., Ephraim M.E, & Akeke G.A., (2012). Compressive Strength of Concrete Using Lateritic Sand and Quarry Dust as Fine Aggregate. *Asian Research Publishing Network (ARPN)*, 7(1): 72-81.