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Physical and Mechanical Properties of Low Density Sandcrete Blocks and Cubes with Sawdust Inclusion

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Abstract
Large volumes of sawdust are usually generated through sawmilling activities causing environmental pollution. Finding appropriate use has been a major concern among environmentalists. The use of sawdust inclusion in producing low-density sandcrete blocks was investigated with sand and sawdust mixture varied in volume to volume proportion of 80:20 %, 60:40 % and 40:60 % respectively, while cement was kept constant at a mixing ratio of 1:6, 1:8 and 1:10 respectively. Properties tested include density, water absorption, and volumetric shrinkage, while the compressive strength of the block was carried out using the compression testing machine after a curing period of 28 days. The density values obtained showed that 40:60 % sand to sawdust proportion had the least density of 60 kg/m^3 and the highest value was observed for the control level at 210 kg/m^3. The compressive strengths for the control are 2.8 and 3.5 N/mm^2, which are within the standard values of 2.5 N/mm^2 and 3.45 N/mm^2 in the Nigeria Industrial Standard (NIS 87, 2000), while 40 to 60 % sand to sawdust mixture showed 0.8 and 1.1 N/mm^{2,} respectively, which is far below the specified standard, making it suitable for construction only where lightweight is of utmost importance. A water absorption test carried out after 24 hours of soaking showed that sandcrete cubes produced without sawdust inclusion had the least absorption of 18.78 %, while 60 % sawdust inclusion had the highest absorption of 39.0 %. Volumetric swelling indicated that 40:60 % had the highest value of 11.15 % while the control mix had the least value of 0.12 %. However, based on the study, 80 % to 20 % and 60 % to 40 % sand and sawdust inclusion met the required standard. Incorporating sawdust into sandcrete block production in a specified proportion could help to produce light-weight and sound-insulating blocks required for internal partitions in buildings.

Keywords: *Sandcrete, building; sawdust; density; Mixing ratio*

Introduction

In recent times, the high cost of building materials and the need to drastically reduce housing shortages, especially in urban areas, have been a concern, which has necessitated the need to search for alternative, innovative and cost-effective building materials. Apparently, utilizing sawdust in an economical way to produce materials that could be used for construction will go a long way to solving disposal and wood conservation challenges (Olaoye, 2013). In the process of exploitation or utilization, wastes are generated from the wood, which constantly constitute an environmental nuisance. The most common wood waste is sawdust, which is a by-product of wood generated or produced from sawn wood (Badejo and Giwa, 1985). Sawdust is produced from the sawmilling activities and the activities of wood-based industries. As wood is converted and used for various purposes, heaps of sawdust are produced, which come in various sizes and shapes. According to Ogunsawo (2001), the non-utilization of sawdust creates disposal problems that are burdensome. Therefore, it is important to find ways of recycling wood waste to produce other forms of material. The wood converted for use in wood industries produces residue in the form of chippings, slabs, off-cuts, sawdust, and shavings, which are generally discarded as waste. This by-product of the sawmill can be reprocessed or converted to value-added products, for example, cement-bonded particleboard, wood plastic composite, or briquette (Stark *et al.,* 2010).

In order to reduce pressure on the forest and ensure sustainable utilization of harvested wood, it is imperative to find alternative use for the waste generated in the form of sawdust during conversion. The inclusion of these wastes in sandcrete block production will decrease environmental damage caused by burning and produce value-added building materials. Earlier work done by the Raw Materials Research Development Council (2002) showed that sawdust was in commercial quantity and could be used for the production of building materials. It has many advantages over traditional concrete, such as low bulk density, better heat preservation and heat insulation properties, and less pollution to the environment.

In order to balance the weight of material in construction, particularly when low density is required at the upper levels of high-rise buildings, there is a need to investigate the inclusion of alternate building materials which are commonly available (Ucol-Ganiron and Alaboodi, 2013). To produce low-density sandcrete blocks, the inclusion of sawdust or other light-weight material would be needed. This study therefore explores the possibility of reducing the weight of sandcerete block production at varying percentages of inclusion.

Materials and Method

The materials used for this study were cement (Portland), sawdust, sand, metal mould, wooden cube mould, sieve, hand trowel, shovel, plastic bowl, bucket, water and weighing balance. Twenty-seven 150mm hollow sandcrete blocks and 150 x 150 mm cubes were produced from the mixture of sand, sawdust, and cement in three replicates per unit. Another set of nine sandcrete blocks and cubes containing only pure sand and cement were produced to serve as the control. Sawdust was sourced from Oyo Sawmill Industries along Ilesha Road, Akure, Ondo State. The sawdust was pre-treated by boiling in hot water to remove extractives, which can inhibit the binding of cement with sawdust.

During production, sawdust and sand measured on volume-to-volume ratio were manually mixed together with shovel at the various proportions (Table 1) to obtain a uniform blend, after which a small proportion of water was added until it attained a moist state. The resulting mixture was transferred to the metal mould and the wooden cube mould, and adequately pressed and compacted using a vibratory machine before it was removed. The block samples were left to cure for 28 days before the test was carried out.

Experimental Design

The experimental design used for this research was estimated using 3 x 4 factorial experiments in a Complete Randomized Design. The data collected was analyzed using Analysis of Variance (ANOVA). The significance of the different treatment variables was estimated by the Duncan Multiple Range Test (DMRT).

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Plate 1: The block and cube at the early stage of production

Plate 2: Sandcrete block and cube during the curing process

Table 1: The mixing and Blending Proportion

	BLENDING PROPORTION			
	A	B	C	D
	Sand + Sawdust	Sand + Sawdust	Sand + Sawdust	Sand
MIXNG RATIO 1 : 6	80 % + 20 %	60 % + 40 %	40 % + 60 %	100 %
1 : 8	80 % + 20 %	60 % + 40 %	40 % + 60 %	100 %
1 : 10	80 % + 20 %	60 % + 40 %	40 % + 60 %	100 %

Parameters Tested

Determination of Cube Density

Cubes produced from sand to sawdust mixture with constant cement ratio were dried and cured for 28days in the Composite wood Laboratory. Density was determined using:

$D = \frac{M}{V}$……………………………………. (1)

Where;

D = Density (kg/m^3)
M = Mass of the cube (kg)
V = Volume of the cube (m^3)

Determination of Water Absorption

The cubes were completely immersed in water at room temperature for 24 hours. The initial weights (dry) of the cubes were taken before soaking in water and later removed from the water, weighed immediately using weighing balance and the weight recorded. Water absorption was calculated using:

WA = $\frac{W_{wet} - W_{dry}}{W_{dry}} \times 100$……………………..………….. (2)

Where,

WA= Water Absorption (%)
W_{wet} = wet Weight of unit in (kg)
Wet_{dry} = dry Weight of unit in (kg)

Volumetric Swelling

The initial volume (V_1) and final volume (V_2). was determined after 24 hours soaking The volumetric swelling was estimated using the formula:

$V_s = \frac{V_1 - V_2}{V_2} \times 100$……………………………………. (3)

Where;

V_s = Volumetric Swelling (%)
V_1 = Initial volume (mm)
V_2 = Final volume (mm)

Compressive Strength

The test was conducted using the compression testing machine (Plate 3) and was calculated from failure-load divided by cross-sectional area resisting the loading in accordance with American Society for Testing and Materials (ASTM D570, 2005).

Values obtained after crushing were used to calculate the compressive strength using:

CS = $\frac{L_c}{A_c}$…(N/mm^2) ……………… (4)

Where:

CS= Comprehensive Strength
*$L_{c=}$ Crushing Load (KN)*1000 (N)*
$A_{s=}$Surface Area of the Block (mm^2)

3

Plate 3: Compressive testing of the developed Sandcrete

Results

Physical Properties of Sandcrete cubes with sawdust inclusion

The results of the effect of production variables on the density of the sandcrete cubes shown in Figure 1 revealed variation in the density distributions of the samples produced with different mixing ratios. The minimum density obtained was 60 kg/m^3 at 40:60 % sand/sawdust material aggregate, while the maximum value was obtained at 80:20 % with 115 kg/m^3 after 28 days of curing. The results of the analysis of variance (ANOVA) on Table 2, showed that there was a significant difference in the density obtained and mean separation showed that the control had a higher mean value and was closely followed by 80:20 at 1:6 cement sand ratio at 5 % probability level (Table 3 and 4). **The** effect of production variables on water absorption (WA) of sandcrete cubes illustrated on Figure 2 showed that WA ranged from 18 % to 39 %, the highest value was recorded for the samples produced from the 40-60 % and control has the least. However, the ANOVA result presented on Table 5, showed that there was a significant difference in the WA obtained and the Duncan Multiple Range Test showed that 20 % sand replacement at 1:6 cement sand ratio could be the best choice among the sandcrete cubes tested at a 5 % probability level (Table 3 and 4).

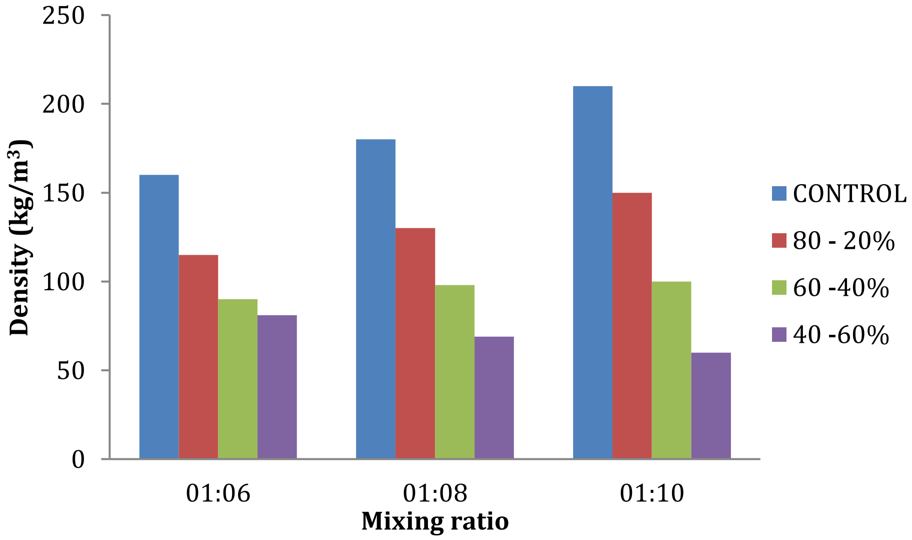

Figure 1: Density variation among the Cube

Table 2: Analysis of Variance for density of the sandcrete hollow blocks

Source of Variation	Sum of Square	df	Mean Square	F-cal
Material aggregate	0.033	3	0.011	393.33*
Mixing ratio	0.002	2	0.001	32.700*
M.A * M.R	0.003	6	0.000	15.233*
Error	0.001	24	2.778E-005	
Total	0.038	35		

*The degree of significance are represented by letters in superscript *=significant;*

Table 3: Duncan Multiple Range Test for Material Aggregate

Material aggregate (%)	Density	Water Absorption	Volumetric swelling
Control	0.186^{a}	9.250^{a}	1.088^{a}
80:20	0.158^{b}	25.201^{b}	6.309^{b}
60:40	0.141^{c}	27.778^{ab}	6.422^{a}
40:60	0.102^{d}	30.556^{a}	7.031^{a}

Means in the same column having the same superscripts are not significantly different at 5 % probability level

Table 4: Duncan Multiple Range Test for Mixing Ratio

Mixing ratio	Density	Water absorption	Volumetric swelling
1:6	0.157^{b}	17.778^{c}	4.250^{a}
1:8	0.143^{b}	22.948^{b}	4.751^{a}
1:10	0.141^{a}	28.863^{a}	6.634^{a}

Means in the same column having the same superscripts are not significantly different at 5 % probability level

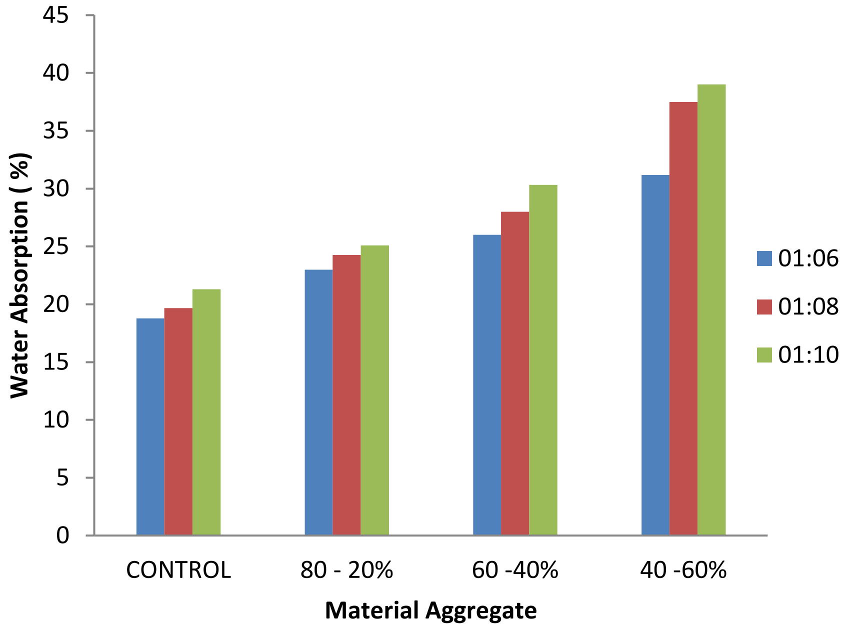

Figure 2: Effect of Production Variables on Water Absorption for Cube Test

Table 5: Analysis of Variance for water absorption of the sandcrete hollow blocks

Source of Variation	Sum of Square	Df	Mean Square	F-cal
Material aggregate	2463.004	3	821.001	36.657*
Mixing ratio	738.487	2	369.243	16.487*
M.A * M.R	424.966	6	70.828	3.162*
Error	537.520	24	22.397	
Total	4163.976	35		

*The degree of significance are represented by letters in superscript; *=Significant difference*

The result of the volumetric swelling (VS) of sandcrete cubes as influenced by the production variables shown in Figure 3 revealed that 40-60 % sand to sawdust had the highest value while the control sample without sawdust had the least value. Volumetric swelling values ranged from 0.12 % to 11.15 %. The sandcrete cubes differs in swelling property as revealed by the Analysis of Variance tested at 5 % probability level presented on Table 6, while the least VS recorded was observed for the 20 % sand replacement and 1:6 cement sand ratio as shown by Duncan Multiple Range Test (Table 3 and 4).

Strength Property

The effect of the production variables on compressive strength of the sandcrete blocks shown in Figure 4 revealed that the control with 3.1668N/mm^2 has the highest mean value of compressive strength, followed by the 80-20 % with 2.2667N/mm^2, higher than 60-40 % with 1.4667N/mm^2, and while the 40-60 % material aggregate has the lowest value of 0.9233N/mm^2. The compressive strength values reported for this study ranged from 0.8 N/mm^2 to 1.1 N/mm^2. The Duncan Multiple Range Test was used to separate the mean at a 5 % probability level (Table 7) which revealed that sandcrete blocks produced from 20 % sand replacement with a 1:6 cement sand ratio were found to have the highest mean.

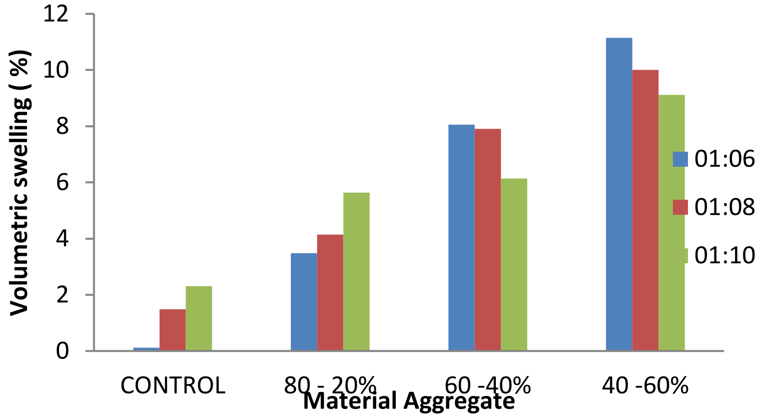

Figure 3: Effect of production variables on volumetric swelling

Table 6: Analysis of Variance for volumetric swelling of the sandcrete hollow blocks

Source of Variation	Sum of Square	df	Mean Square	F-cal
Material aggregate	206.876	3	68.959	3.162*
Mixing ratio	19.490	2	9.745	0.447 ns
M.A * M.R	39.986	6	6.664	0.306 ns
Error	523.333	24	21.806	
Total	789.685	35		

*The degree of significance are represented by letters in superscript; *=Significant difference; ns=no significant difference*

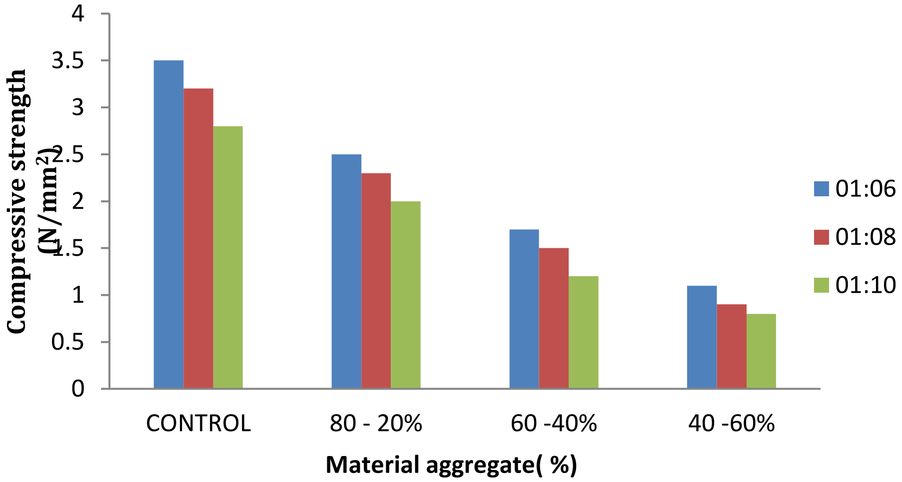

Figure 4: Effect of the production variables on compressive strength

Table 7: Duncan Multiple Range Test for Material Aggregate of Sandcrete Block

Material aggregate (%)	Compressive Strength
Control	3.1668[a]
80-20	2.2667[ab]
60-40	1.4667[bc]
40-60	0.9233 [c]

Discussion

Physical Properties

The variation in the density distribution across the different mixing ration depends on the volume of sand and sawdust ratio incorporated into the blending proportion during the production process of the sandcrete cubes. Likewise, the minimum and maximum density value recorded for the different material aggregate was as a result of the lowest quantity of sawdust inclusion. Density decreases with an increase in sawdust inclusion. The density values obtained in this study were lower than those observed by Raheem (2006) for commercially produced sandcrete, which ranged from 2073.5 kg/m^3 to 2166.3 kg/m^3. Material density is a major determinant of strength and material usage in construction. Both high and low density materials have their special applications. While high density blocks are used for external and load-bearing members, low density blocks are used for interior and non-load-bearing members, particularly for partition walls.

The changes in the values recorded for the WA for the produced samples showed that WA increased as sand replacement with sawdust increased. Sandcrete cubes produced from 60 % sand replacement showed the highest affinity for water, with an absorption rate of 35 % to 39 %. This is higher than the 16.95 % obtained by Anosike and Oyebade (2011). The reason for the increase in absorption rate may be the porosity of sandcrete and the hygroscopic nature of wood. According to Oyekan and Kamiyo (2011), sandcrete blocks exposed to persistent floods absorb much water due to their high level of porosity and, consequently, become weakened and eventually fail. The least WA rate of the control samples satisfied the minimum requirement for sandcrete block production. While the values recorded for VS of the tested materials was similar to the observation of Oyekan and Kamiyo (2011) which stated that gradual increase in the volume of the sandcrete cubes was observed with 5 % lignocellulosic materials added. The swelling ability of the sandcrete cubes due to sawdust inclusion may limit its use to internal wall partitioning or areas less prone to floods. The results recommended 20 % sand replacement at 1:6 cement sand ratio as the best among the sandcrete cubes produced due to its low VS rate.

Compressive Strength

The values recoded for the compressive strength of the sandcrete blocks correspond with the work of Abdulahi (2005) on compressive strength of commercial sandcrete blocks produced in Minna, Nigeria which were found to vary between 0.11 N/mm^2 to 0.75N/mm^2, this is below the minimum prescribed value for load bearing sandcrete block specified by NIS (Nigeria Industrial Standard). However, 80-20 % showed that the compressive strength is between 2.0N/mm^2 to 2.5N/mm^2 both of which conformed with the required standard of 2.00N/mm^2 as the minimum specified by the National Building Code (2006) for non-load bearing walls. These types of sandcrete blocks are type C which is lightweight concrete blocks for non-load bearing walls (partitions). The control mix value ratio 1:6 has 3.5N/mm^2 which is the highest value, can be compared to 3.45N/mm^2 which is the minimum strength specified in Nigeria Industrial Standard, (2000) for a load bearing sandcrete block classified as Type B which is lightweight concrete block for load bearing walls

Compressive strength has been influenced by the level of quality control employed in the selection of materials and adequate curing is a factor to be considered when producing sandcrete blocks (Afolayan *et al.*, 2008), while Abdulahi (2005) also stated that the quality of sandcrete blocks is inconsistent due to the different production methods employed and the properties of constituent materials.

Conclusion

The inclusion of sawdust in the production of low-density sandcrete blocks influenced both its physical and mechanical properties. The value observed for the sandcrete cubes gives an indication that variation in density depends on sand and sawdust ratios used for the mixing proportion. The values recorded for water absorption and volumetric swelling revealed water interaction with sawdust due to the hygroscopicity behaviour of wood, suggesting pretreatment of the sawdust with water repellants chemicals before production. The comprehensive strength values obtained for the sandcrete block meet the minimum specification for non-load-bearing walls. However, the inclusion of sawdust into sandcrete block production in a specified proportion will produce lightweight blocks required for internal partitions in buildings and open avenues for using sawdust wastes as value-added product while reducing environmental pollution.

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