Improving Tensile Strength Characteristics and Water absorptionof Laterite Interlocking Blocks Enhanced with Different Burnt Sawdust Ash from Timber Species

Abstract

Laterite interlocking blocks are usually compressed with cementing materials, Burnt Sawdust Ash (BSDA) to improve their performanceproperties for construction purpose.The study aimed topartiallyreplaceordinaryPortlandcement(oPc)withburnt sawdustash(BSDA) from timber species (Wawa, Mansonia, Teak, Odum, Ceiba, Essah and Mahogany) in making interlocking laterite blocks by replacing 0-30 wt %. Mixproportionwas1:6(cement+ BSDA:laterite)witha0.60water-to-cementratio. 330 specimens of size 185 mm × 220 mm × 120 mm were produced and cured at normaltemperatureandhumidityundershadyandsunnyconditionsfor7,14,21and28days. Three (3) tests were research targeted: density,tensile strength and water absorption. However, it was observed 10% Wawa and ceibahave relative good density properties and mansonia and ceiba have better water absorption properties. It was observed that, up to 10% of Mansonia, Wawa(Triplochiton scleroxylon) and Odum(Milicia excels) BSDA have the potential to perfectly substitute cement in the production of interlocking blocks in terms of tensile strength.

Keywords:;Interlocking blocks;Burnt sawdust ash ; Tensile strength; Bulk density; Water absoprtion

1. Introduction

The ever-increasing population increase in developing nations has created an extremely high demand for new building structures. Due to the unaffordable construction costs brought on by the rising prices of building supplies, this need cannot be satisfied. the claim is (Wi-Afedzi et al., 2019). As a result of the high cost of construction supplies, particularly cement, homes are becoming so expensive that the average worker cannot afford to build one for themselves. The exorbitant cost of construction materials, which many people cannot afford, has resulted in a 1.7 million housing shortage in Ghana.
The study by Adebakin et al. (2012) explains that cement is widely noted to be one of the most expensive materials in construction. It could be asserted that both the limited raw materials and the industrial processes that are undergone by cement during the manufacturing stages may have accounted for its high cost. Thus, a reduction in the cost of cement will reduce the cost of production of blocks and ultimately that of the building. To reduce the price of cement to be consumed in mortar, blocks and concrete production, the search for an alternative binder or partial cement replacement has led to the use of industrial and agricultural waste materials believed to have the potential of exhibiting cementitious properties (Assiamah et al., 2022). These secondary cementitious materials have very high pozzolanic contents.

Today, there are numerous research areas focused on energy conservation, ecologically friendly material recycling, and sustainable practices. Numerous earlier studies have produced insightful findings about the use of industrial wastes in the development of different types of building materials. Wood ash wastes were substituted for cement in concrete mixtures in certain earlier studies (Elinwa and Mahmood,2002).

Additional attempts have been made to use waste materials in the brick-making process; they include rubber (Turgut and Yesilata, 2008),wood and limestone sawdust (Turgut and Algin 2005), processed waste tea (Demir, 2005), fly ash (Lin, 2006), and sludge (Dondi et al., 1997). The pollution issue can be effectively solved by recycling these wastes and using them to make building materials.Sawdust, as used in this study, is defined as loose particles or wood chips that are left over after cutting wood into regular, usable sizes. Reusing wood chips, like sawdust, appears to be the greatest insulator that provides the necessary ceramic product qualities.

Sawdust's primary chemical constituents are nitrogen (0.90%), oxygen (33.83%), hydrogen (5.19%), and carbon (60.8%) (Horisawa et al.,1999). Cellulose, lignin, hemicelluloses, and trace amounts (5–10%) of other substances make up dry wood.

Sawdust is a leftover or by-product from several different steps in the production of wood.

These comprise joinery, furniture manufacturing, drilling, sawing, planning, routing, and sanding processes. This waste stream consists of fine wood particles or tiny, irregular chips (Kumar et al., 2014).

Sawdust is often disposed of via open burning, dumping, or dumping in landfills (Adu et al., 2014).The disposal of sawdust in landfills causes additional strain on the sites, and burning it releases greenhouse gases into the atmosphere (Clarke, 2018). Although open burning presents health risks and air pollution, saw millers frequently utilize it as the most convenient method of disposing of sawdust (Schmidt, 2014). Sawdust can negatively impact aquatic life when it is deposited on the banks of streams and rivers. Rainwater and wind can carry the dust into surface water. Furthermore, when sawdust is carelessly discarded on land, it kills vegetation and produces wood dust when it is released into the sky (Claudiu, 2014). Reducing disposal costs and creating jobs would result from adding value to this waste stream (Clarke, 2018). Furthermore, utilizing wood-based goods in construction, such as sawdust composites, helps mitigate the effects of climate change (Hurmekoski, 2017). Two kinds of sawdust were taken into consideration: eucalyptus (a broad family of hardwoods) and Alep pine (a family of coniferous woods). The two types of wood wastes differ in terms of their structure, origin, physical characteristics, chemical makeup, etc. The properties of clays, tuff, and sawdust mixtures with 3, 6, and 9% weighted sawdust particles with diameters of 0.5, 1, and 1.6 mm with shaping moisture ranging from 22, 24 to 26% weighted have been studied (Guettala et al. (2002).

Laterite interlocking blocks (LIBs) have been the subject of extensive research, however their use as a typical building material is not what was anticipated. Compressive strength and Water absorptionofLIBs are the two primary problems. According to Guettala et al. (2002), moisture weakens LIBs, which lowers block strength. Walker (1995) stated that when LIBs becomes saturated, up to half of its dry strength can be lost because of the higher levels of silt and clay as well as the reduced cement content compared to regular concrete masonry units.

Although it is still an environmentally benign material, many countries find that it is not cost-effective for commercial use. The amount of clay and silt in LIBs was the primary variable for both of these important criteria. The development of affordable, ecologically friendly alternative building materials is desperately needed, according to Jayasinghe and Perera (Jayasinghe and Perera, 1999). LIBs is one such alternative material. The majority of earlier studies (Guettala et al., 2002 concentrated on modifying the clay and silt content by adding various soils, sand, fly ash, quarry dust, and other such materials. Although the compressive strength was increased by adding materials to change the clay and silt composition, the durability was not much increased. Previous studies have determined that the ideal range for clay and silt in relation to compressive strength is between 5 and 20% (Walker, 1995). However, there is no concrete data about the range for LIBs durability. In lateritic soils, silt typically ranges from 20 to 35 percent. This study looked at the relationship between compressive strength and durability and the reduction of clay and silt content in LIBs manufacture.

Recently there has been a worldwide resurgence of interest in earth building like laterite bricks or blocks, especially in developing countries where local earth is the most accessible source of building material. However, most soils do not contain the mix of clay, silt and sand required for good brick making. Modern stabilization technology (such as Anyway Soil Brick - a non-toxic chemical stabilizer) has broadened the range of natural soils suitable for making LIBs, and increased their strength and durability. Landcrete bricks materials may be as simple as mud, or mud mixed with straw to make cob. Sturdy dwellings may be also built from sod or turf. Soil may be stabilized by the addition of lime or cement, and may be compacted into rammed earth. Construction is faster with pre-formed adobe or mud bricks, compressed earth bricks, earth bags or fired clay bricks. Building blocks can be used as a foundation, claim Akinyemi et al. (2020). claims that earth or laterite may be used to create building blocks. The material employed determines the type of block that is generated. To lower the cost of walling in the construction of homes in Ghana, it is crucial to discover substitute local resources for block manufacture that are equal in performance but less expensive than sand. In order to create new composite materials, ways of combining different existing ones, such as sand, may be necessary in the hunt for these substitute materials (Nturanabo et al., 2019). The most effective technique to reduce costs for the production of blocks might be to combine laterite and cement. In all regions of Ghana, laterite can be found It is an extraordinary substance. According to laterite, around 70% of Ghana's land surface is covered (Asiedu, 2017). In the tropical region, laterite is a cheap, environmentally benign, and widely accessible building material (Agyekum et al., 2020). The general economy of the regions where laterite is found benefits. Their degree is incredibly broad and includes mining research (iron, aluminum, and manganese), agronomy, and civil building. Making compacted earth squares is one of laterites' primary development design actions (Vetturayasudharsanan et al., 2020).

Continuous generation of wastes arising from industrial by-products and agricultural residue, create acute environmental problems both in terms of their treatment and disposal. The construction industry has been identified as the one that absorbs the majority of such materials as filler in concrete (Teo et al., 2007). If these fillers have pozzolanic properties, they impart technical advantages to the resulting concrete and also enable larger quantities of cement replacement to be achieved (Hossain, 2003). Appropriate utilisation of these materials brings ecological and techno-economic benefits.

However, how burnt sawdust ash obtained from different timber species affects the properties of compressed laterite interlocking blocks is understudied. Therefore, eco-friendly ways to convert different species of timber wastes into useful by-product is the focus of the study. Thus, there is a need to search for local materials as alternatives for the construction of functional but low-cost buildings in both rural and urban areas. Some of the local materials that have been used are earth-gypsum and outdoor plasters (Fabbri & Morel, 2016; Mattone et al., 2017; Svoboda & Procházka, 2012) and lateritic interlocking blocks (Raheem et al., 2010, 2012).

3. Materials and methods

3.1 Laterite

The source of the laterite shown in Figure 1 was in Abesim in Sunyani, Ghana. Large lumps of material were broken up and passed through ASTM sieve No. 8 (aperture 2.36mm). Several laboratory studies were conducted to evaluate the laterite's general qualities. According to British Standard requirements (BS1377:1990), these tests were carried out. The Sunyani Highways Authority Workshop was used to carry out wet sieving and sedimentation to analyze the laterite's grain-size distribution.

Some physical tests conducted to determine the geo-technical properties of the laterite included Sedimentation test, Linear Shrinkage test and Atterberg limits test and the results are presensed in Table 1.

Table 1: Results of Geo-technical Properties of the soil samples

Laterite Type	**Grain Sizes (%)**		**Compaction**		**Atterberg Limits (%)**	
Red	**Gravel (>2 mm)**	35	**Optimum moisture content OMC (%)**	18.34	**Liquid limit(wL)**	51.34
	Sand (2 - 0.063 mm)	30				
	Silt (0.063 - 0.002 mm)	14			**Plastic limit(wP)**	12.00
	Clay (<0.002 mm)	21	Maximum dry density **(MDD k/m^3)**	14.70	**Plasticity index(Pl)**	31.34

Figure 1: Laterite used

3.2 Cement

Ordinary Portland cement produced of grade 42.5R was used,as the main binder for the control lateritic blocks as well as partially replaced binder in the BSDA blocks.

Figure 2: DANGOTE's **ordinary Portland cement**.

3.3 Burnt Sawdust Ash

Samples of sawdust obtained locally were taken to the laboratory and first air-dried at approximately 30^{o}C ambient temperature before being burnt in a very hot metal barrel into ash at a temperature of 250-300 ^{o}C for six hours. The sawdust burning set-up and burnt sawdust ash are depicted in figures 3 and 4, respectively.

Figure 3: Sawdust from Timber species burning set up

Essah Ceiba Mansonia

Teak Odum Wawa Mahogani

Figure 4: Ashes from Timber species

3.4 Batching of the Materials

Batching was the process of measuring components or materials by weight to produce laterite interlocking blocks mix to get quality concrete or blocks mix. Before materials were utilized, all materials were inspected upon arrival at the job site. The sawdust ashes, cement, water, fine aggregate were all batched by weight. The process was done by weighing using electronic scale before which a regular monitoring, correction and collaboration of the equipment was done in order to provide a consistent batch of material between the mix with a ratio of 1:6 (binder : laterite) respectively as shown in Figure 5. The quantities of materials required for the study are presented in Table 2.

Figure 5: Batching of the various aggregates in percentages.

3.5 Mixing of raw materials

The work included the utilization of cement and laterite in a mix ratio of 1:6 by weight and water-cement ratio of 0.6 to produce the laterite interlocking blocks As indicated in Figure 5, each type of sawdust ash was combined in amounts of 0%, 10%, 20%, and 30% of the cement and laterite weight in the mixture.BS EN 2002 was followed in the preparation of the block specimen. By mixing the ingredients by hand and with a shovel, an extremely plastic and usable paste was produced.To attain the appropriate consistency, the laterite samples were combined with sawdust ash species, cement, and a water-cement ratio of 0.6 were added, and regular Portland cement (oPc) was applied as a control.The laterite and regular Portland cement (oPc) samples were blended to the desired consistency for the experiment, and BSDA was included in varying amounts, from 10% to 30%. For uniform circulation and homogeneity, the laterite samples were then extensively mixed with the sawdust ash species and cement as shown in Figure 6.

Table 2: Quantities of constituent needed for BSDA interlocking block specimen.

MaterialControlandexperimentalspecimens(Quantitying)

NO. Material	**Quantity(grams)**			
	Control Specimen	**Experimental Specimen**		
	100%Cement:0%BSDA	70%Cement:30%BSDA	80%Cement:20%BSDA	90%Cement:10%BSDA
Laterite	8082	8082	8082	8082
Blend	2694	1886Cement: 808BSDA	2155.2 Cement: 538.8BSDA	2424.6Cement: 269.4 BSDA
Water	1664	1664	1664	1664
Total	**12,440**	**12,440**	**12,440**	**12,440**

Figure 6: Mixing and moulding with hydraform machine set up

3.6 ProductionofBSDAlandcreteinterlockingblocks

A mix proportion of 1:6 parts of cement plus BSDA to laterite by weight (batching procedures in Figure 5and 2) was used inthe work. The BSDA partial replacement of cement was in varying proportions of 0%, 10%, 20%, and 30 wt% since Class F fly ash is frequentlyusedatdosagesof10–30wt%ofcementitiousmaterial (Kosmatka, 2002).

Themixingwasperformedbytheuseofashoveltoprovideamoreplasticpaste.Thecementsampleswere mixedwithlateriteus-ing a water-to-cement ratio of 0.6 For the experimental blocks, the laterite, cement, and BSDA replacement percentage rangingfrom 10% to 30% were blended to achieve a desirable consistency. The mixture was then loaded into the single block mold for theproduction of interlocking blocks of size 185 mm (Width) × 220 mm (Length) × 120 mm (Height) under hydraulically compressedand at a constant pressure of 10 N/mm^2 as shown in 6. This procedure conforms to Hydraform concepts when using Hydraformblockmakingmachine.

Three Hundred and Fifteen (315) blocks were cast, cured, weighed, and tested for density,tensile strength and water absorptionon days 7, 14, 21, and 28 to satisfy the 14–21 days period for each percentage (10%, 20%, and 30%) substitution of the typical fine aggregate with the burnt-saw dust ash content as actual parameters, as shown in Table 3 at each percentage substitution (10%, 20%, and 30%) of the conventional fine aggregate with the burnt-saw dust ash content.

To serve as a control, Fifteen (15) interlocking blocks were moulded in 100% cement and the total number of blocks produced there were Three Hundred and Thirty pieces for the test (330).

Table 3: Details of test specimens of the compressed laterite interlocking blocks

	Interlocking Blocks Moulded (%)					
Test	Experiment	7-Days Curing	14-Days Curing	21-Days Curing	28-Days Curing	**Total**
Tensile strength and densityTest from 7-28 curing days	0%	-	-	-	3	**12**
	10%	-	-	-	21	**84**
	20%	-	-	-	21	**84**
	30%	-	-		21	**84**
Erosion Test for 28 curing days	0%	-	-	-	3	**3**
	10%	-	-	-	21	**21**
	20%	-	-	-	21	**21**

	30%	-	-	-	21	**21**
TOTAL NO. OF BLOCKS		**66**	**66**	**66**	**132**	**330**

3.7 Curing of Compressed Laterite Interlocking Blocks

The blocks were first allowed to air dry under a shade made with polythene sheet for 24 hours. Thereafter, curing was continued by sprinkling water morning and evening and covering the blocks with polythene sheet to prevent rapid drying out of the blocks which could lead to shrinkage cracking. The blocks were afterward stacked in rows and columns with maximum of five blocks in a column as shown in Figure 7 until; they were ready for strength and durability tests.

Figure 7: Curing and storage of compressed laterite ineterlocking blocks.

3.7.1 Density: The density of the specimens was ascertained in compliance with British Standards BS EN 771-1(2003). The dimensions of the compressed laterite interlocking blocks were measured. The blocks were oven dried at 35°C after each curing age until a consistent mass was measured, signifying a normal dry block. The density was computed following the weighing of the dry compressed laterite interlocking blocks, as shown in Figure 8. Equation 2 was used to compute the density of the dry blocks.

Bulk density (kg/m^3) = M/V……..………………………. Eq. 2
where M = mass of block (kg)
V = volume of block (m^3)

Figure 8: Weighing of compressed laterite interlocking blocks

3.7.2 Tensile strength Test: The splitting tensile strength test was conducted on the blocks in accordance with the British Standards BS EN 12390-6 (2009) using a universal testing machine. The blocks was centrally placed under splitting jigs above and below it.The loading was applied continuously on the blocks at a constant rate of 0.2 N/mm^2 per second until the compressed laterite interlocking block failed as shown in Figure 9. The maximum load at which each of the interlocking blocks failed was recorded and its failure mode was documented. The split tensile strength of the blocks was computed using equation 3:

Split tensile strength = $2P/\pi DL$……………………………………………………………………………….Eq. 3
where P = maximum applied load (N)
D = depth of block (mm)
L= length of block (mm)

Figure 9:Tensile test of compressed laterite interlocking blocks.

3.7.3 Water absorption test

The water absorption capacity of the BSDA blocks was measured in accordance with the British Standard (BS EN 771-1:2011+A1, 2015) for building units. Three LIBs of the desired age were randomly selected from each test group and weighed using an electronic scale. The cured LIB pieces were placed inside a metal tray filled with 20 mm of water and rested on a one-inch-thick plywood base (as shown in Figure 10). Cured LIBs were allowed to float freely in the water for 10 mm before water absorption began through capillary action. After 20 minutes, the interlocking block pieces were removed from the water and weighed again to determine the amount of water absorbed. The percentage water absorption of the test block specimen was computed using Equation 1.

(a). Water absorption set-up **(b)**. Partial immersion of blocks **(c)**. Surface dry weighing of blocks

Figure 10. Water absorption test of block samples

4. RESULTS AND DISCUSSIONS

4.1 BulkdensityofBSDA-lateriteblocks(kg/m^3)

The results of BulkdensitiesofBSDA-lateriteblocks(kg/m^3)are shown in Table 4.

Table 4: Bulk densities of BSDA-Compressed-laterite interlocking blocks (kg/m3)

Bulk density = M/V, where M = mass of the block (kg).

BSDA	CURING AGE			
	DAY 7	DAY 14	DAY 21	DAY 28

Control (0%)	1963.739	1872.4406	1860.5651	1815.2123
Wawa-10%	1958.596	1865.2743	1853.3308	1801.5405
20%	1915.504	1853.3308	1844.6928	1768.19
30%	1910.729	1840.2031	1835.2416	1742.072
Mansonia 10%	1950.041	1821.7854	1815.8886	1773.5135
20%	1931.613	1811.3104	1771.253	1752.285
30%	1914.005	1801.0073	1733.7755	1700.3439
Teak 10%	1847.9524	1772.0802	1744.4635	1721.9082
20%	1830.088	1756.7403	1720.3087	1717.5184
30%	1813.219	1739.8443	1703.8599	1702.0802
Odum 10%	1847.9524	1832.0802	1821.9082	1804.4635
20%	1832.088	1826.7403	1812.0802	1783.3087
30%	1752.219	1739.8443	1717.5184	1710.8599
Ceiba 10%	1958.5012	1856.0114	1835.2088	1786.5601
20%	1943.522	1841.8509	1825.2416	1747.461
30%	1927.584	1832.8419	1823.8083	1723.8083
Essah10%	1887.7968	1860.9746	1845.4463	1801.1466
20%	1861.007	1848.9271	1834.185	1763.5135
30%	1855.856	1838.8943	1824.5618	1753.5135
Mahogany 10%	1881.9001	1836.9205	1829.7215	1778.4602
20%	1855.111	1815.1105	1815.1515	1742.4242
30%	1823.407	1781.5315	1761.0565	1729.9344

BSDA=Burnt sawdustAsh.

Table 4 shows the summary of the average density of BSDA laterite interlocking blocks which explains as the curing days increases the density decreases alongside for each percentage of BSDA content. This is because as the blocks are drying their moisture contents were gradually reducing at each curing age, in order to gain their strength. Therefore, as curing days increased, the bulk densitiesdecreasedalongsideeachpercentageofBSDAcontentadded. However, the control specimen (0%) ash recorded highest from day 7-day 28 over the 10%, 20% and 30% specimen as shown in Table 4. It was also observed that,Wawa (Triplochiton scleroxylon) and Ceiba (Pentandra),satisfyingtheallowableminimumdensityofaprecastconcreteblockof 1500 kg/m^3 or as specified by British Standard (BS) 2002, standard. This means that the mortar-free interlocking blocks were gradually losing theirmoisturecontentsandweightatthedryingstage (Danso, 2017).However, results also indicate that the densities of the burnt sawdust ash (BSDA)-laterite-interlocking blocks of wawa (1958.596) slightly declined from 10% to 30% ash replacement of the cement respectfully. The slight differences in the densities of the blocks can be attributed to the difference in the specific weight of the cement. However,resultssuggest that up to 10% of Wawa-Triplochiton scleroxylon and Ceiba-Pentandra BSDA have the potential to perfectly substitute cement in the production of interlocking blocks for load-bearingwalls in Ghana.

The research findings are also consistent with previous studies on ash-based interlocking blocks suggesting that up to 10%sawdust (Adebakin, 2012) and 15% corncob ash (Oyebisi et al., 2018) could feasibly replace cement to produce that category of blocks. Such types of blocks arerenowned for not only being eco-friendly but less expensive earthen construction materials to bridge the increasing housing gap inrural-urbanareas. Similar results were obtained in the study of Assiamah et al. (2022) which used sawdust ash with low specific weight as a partial replacement of cement in landcrete interlocking blocks production.

4.1.1 Experimental value and theoretical relationship between Bulk density and percentage BSDA-laterite blocks (kg/m3)

The experimental test results and theoretical (regression) analysis of densitiesof BSDA-Compressed-lateriteinterlockingblocks(kg/m^3) for the different curing ages are presented in Table 5.

Table 5: Experimental value and theoretical relationship between Bulk density and percentage BSDA-laterite blocks (kg/m3)

BSDA From Timber	DAY 7	DAY 14	DAY 21	DAY 28
Wawa	y = -176x + 1963.74	y = -107.47x + 1872.44	y = -84.43x + 1860.57	y = -243.8x + 1815.21
Mansonia	y = -165.77x + 1963.74	y = -238.1x + 1872.44	y = -422.63x + 1860.57	y = -382.9x + 1815.21
Teak	y = -501.73x + 1963.74	y = -442x + 1872.44	y = -522.37x + 1860.57	y = -377.1x + 1815.21
Odum	y = -705.07x + 1963.74	y = -442x + 1872.44	y = -476.83x + 1860.57	y = -347.83x + 1815.21
Ceiba	y = -120.53x + 1963.74	y = -132x + 1872.44	y = -122.53x + 1860.57	y = -304.67x + 1815.21
Essah	y = -359.6x + 1963.7	y = -111.83x + 1872.44	y = -120.03x + 1860.57	y = -205.67x + 1815.21
Mahogany	y = -467.77x + 1963.74	y = -303.03x + 1872.44	y = -331.7x + 1860.57	y = -284.27x + 1815.21

The theoretical regression analysis of experimental results of bulk density and percentage ash content resulted in a linear relationship. There was very close mapping of the experimental and theoretical results of relationship between bulk density and percentage ash replacement of all BSDA species at all curing ages. In all cases the bulk density of the interlocking block of each BSDA species decreased consistently with increasing ash contents. The results indicated that the greatest rate of reduction (gradient of -705.07) in bulk density was in Odum BSDA block on the 7th day of curing as shown in Table 4. On the other hand, the least rate of decrease in bulk density with increasing ash content was exhibited by wawa BSDA block on 21 day of curing (as revealed in Table 4 with a gradient of -84.4). However, the average rate of reduction of bulk density as the ash content replacement increased in their theoretical relationship was 303.51.

4.2 Tensile strength characteristics

The results of the tensile tests of all the seven BSDA interlocking blocks from 7- 28days are shown in Figure 11 to 14.

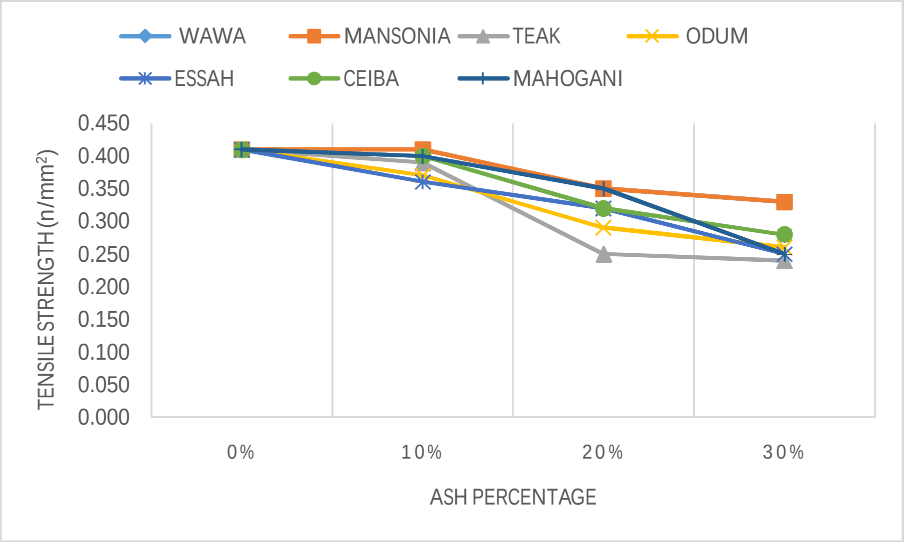

Figure 11: Tensile tests results of all the 7 BSDA interlocking blocks at 7days

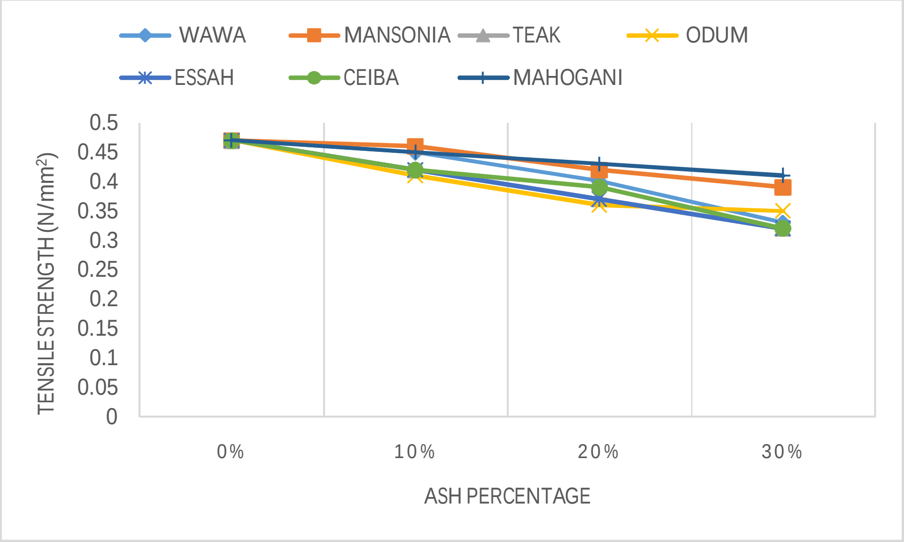

Figure 12: Tensile tests results of all the seven BSDA interlocking blocks at 14days

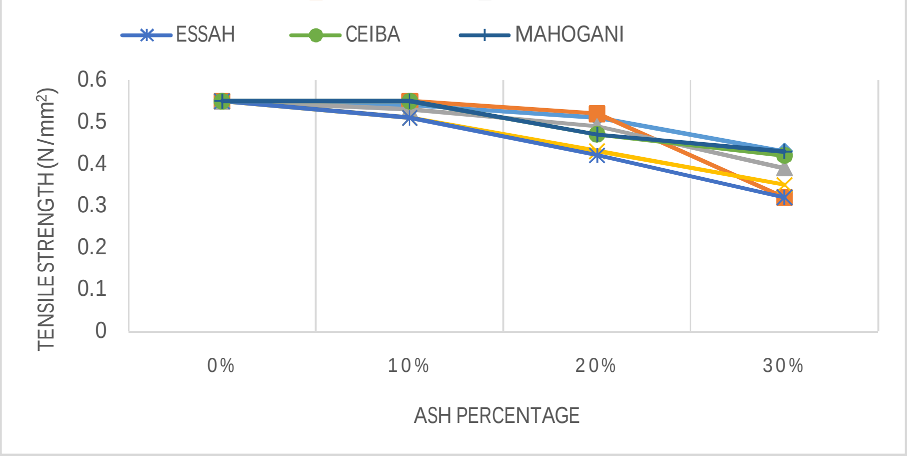

Figure 13: Tensile tests results of all the 7 BSDA interlocking blocks at 21days

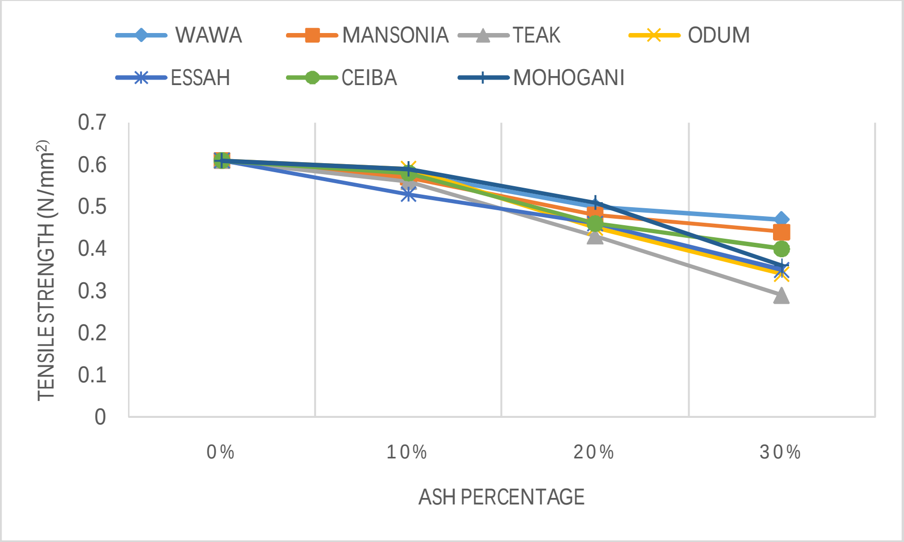

Figure 14: Tensile tests results of all the 7 BSDA interlocking blocks at 28days

Observations from the results of BSDA species revealed that the tensile strength of Wawa BSDA replacements is generally lower than the control (0% replacement) at all curing times except for 28 days (0.47 N/mm2), where there is no significant difference. Unlike 10% replacement at 7 days, Mansonia BSDA replacements have a tensile strength comparable to the control at all curing times. In some cases, such as 20% replacement at 7 days, the tensile strength of Mansonia BSDA replacements is even higher than the control. Teak BSDA replacements show a mixed trend. At 7- and 14-day curing time, the tensile strength is lower than the control for all replacement levels. At 21 and 28 days, the tensile strength is similar to or higher than the control for all replacement levels. Odum BSDA replacements show a similar trend to Teak. At 7 days of curing time, the tensile strength is lower than the control for all replacement levels. At 14 and 21 days, the tensile strength is similar to the control for all replacement levels. At 28 days, the tensile strength is higher than the control for all replacement levels. Essah BSDA replacements show a mixed trend. At 7 days of curing time, the tensile strength is lower than the control for all replacement levels. At 14 days, the tensile strength is similar to the control for all replacement levels. At 21 and 28 days, the tensile strength is higher than the control for 10% and 20% replacement levels and lower than the control for 30%. Ceiba BSDA replacements mostly have a tensile strength lower than the control at all curing times and replacement levels. Similarly, Mahogany BSDA replacements show a mixed trend. At 7 days of curing time, the tensile strength is lower than the control for all replacement levels. At 14 and 21 days, the tensile strength is similar to the control for all replacement levels. At 28 days, the tensile strength is higher than the control for all replacement levels. The effect of utilizing BSDA materials to partially replace cement in interlocking blocks on tensilestrength is mixed and depends on the specific BSDA species and curing time. Some species, such as Mansonia, showed comparable or even slightly higher tensile strength than the control for some replacement levels and curing times. Odum is a possible contender, mainly if the application allowslonger curing before full strength is required. Other species, such as Ceiba, consistently decreased the tensile strength with increasing BSDA replacement. For most species, tensile strength increased with curing time. While some species, like Mansonia, showed good promise based on tensile strength, a definitive decision would require considering other factors and properties. Besides, selecting the best timber species for tensile strength may rely on the specific conditions of the interlocking block application. Here, the environmental impact of sourcing wastes, the minimum tensile strength required, the importance of early strength, and cost and availability remain critical factors to consider.

Nevertheless, according to the Ghana Building Code (1989), the tensile strengths of Mansonia (Altissima), Wawa (Triplochiton scleroxylon) and Odum (Milicia excels) satisfied the minimum permitted strength of sandcrete blocks for load-bearing masonry constructions. This seems to suggest that replacing cement with Mansonia (Altissima), Wawa (Triplochiton scleroxylon) and Odum (Milicia excels)species of BSDA has no significant effect on the tensile strengthof the blocks, especially beyond 10% of Wawa (Triplochiton scleroxylon) and Odum (Milicia excels) BSDA addition. The research findings are also consistent with previous studies on ash-based interlocking blocks that suggested up to 10%sawdust replacement to achieve good tensile strength of BSDA blocks (Odera et al., (2011), Assiamah et al., (2022) and Adebakin, (2012).

4.2.1 Experimental value and theoretical relationship between Tensile strengthand percentageBSDA-lateriteblocks

The experimental test results and theoretical (regression) analysis of Tensile strengthof BSDA-Compressed-lateriteinterlockingblocks(kg/m^3)for the different curing ages are presented in Table 6.

Table 6. Experimental value and theoretical relationship between Tensile strengthand percentageBSDA-lateriteblocks

BSDA From Timber Species	DAY 7	DAY 14	DAY 21	DAY 28
Wawa	y = -0.27x + 0.41	y = -0.47x + 0.47	y = -0.4x + 0.55	y = -0.4x + 0.61
Mansonia	y = -0.27x + 0.41	y = -0.27x + 0.47	y = -0.77x + 0.55	y = -0.57x + 0.61
Teak	y = -0.57x + 0.41	y = -0.5x + 0.47	y = -0.53x + 0.55	y = -1.07x + 0.61
Odum	y = -0.5x + 0.41	y = -0.4x + 0.47	y = -0.33x + 0.55	y = -0.87x + 0.61
Ceiba	y = -0.43x + 0.41	y = -0.5x + 0.47	y = -0.43x + 0.55	y = -0.7x + 0.61
Essah	y = -0.53x + 0.41	y = -0.5x + 0.47	y = -0.77x + 0.55	y = -0.97x + 0.61
Mahogani	y = -0.53x + 0.41	y = -0.2x + 0.47	y = -0.4x + 0.55	y = -0.83x + 0.61

The theoretical regression analysis of the experimental results of tensile strength and percentage ash content resulted in a linear relationship between the variables. There was very good similarities of trends and theoretical relationship between tensile strength and percentage ash replacement of all BSDA species at all curing ages. In all cases the tensile strength of the interlocking block of each BSDA species decreased consistently with increasing ash contents. The results indicated that the greatest rate of reduction (gradient of -1.07) in tensile strength was found in Teak BSDA block on the 28th day of curing as shown in Table 6. On the other hand, the least rate of decrease in water absorption with increasing ash content was exhibited by Mahogany BSDA block on 14 day of curing (as revealed in Table 6 with a gradient of -0.2). However, the average rate of reduction of tensile strength with increasing percentage ash content in all BSDA blocks at all ages was 0.54.

4.2 Water absorption results

A species-by-species breakdown of water absorption for BSDA-compressed laterite interlocking blocks after a 28-day curing period (based on Figure 10). It can be observed that water absorption rates increased as the percentage of BSDA replacement increased for all species. This aligns with existing research findings (6-17% range). Wawa, Odum, and Mahogany species showed minimal differences in sensitivity to water compared to the control (0% BSDA) at 10% replacement. Their absorption values ranged from 5.2% to 5.4%. With increasing BSDA replacement, absorption rose gradually (Wawa: 5.2% - 7.7%, Odum: 5.2% - 7.1%, Mahogany: 5.3% - 7.5%). Blocks made with Mansonia, Teak, and Ceiba ashes, similar to the previous group, exhibited a gradual increase in water absorption with higher BSDA content. Their absorption values ranged from 5.2% to 6.6% at 10% replacement and reached 6.3% - 7.8% at 30% replacement. Essah species displayed a slightly higher sensitivity to water compared to others. Even at 10% replacement, the susceptibility to water was 5.6%, increasing to 7.7% at 30% replacement. As expected, the control specimens (0% BSDA) had the lowest water absorption value (5.2%) for all species.

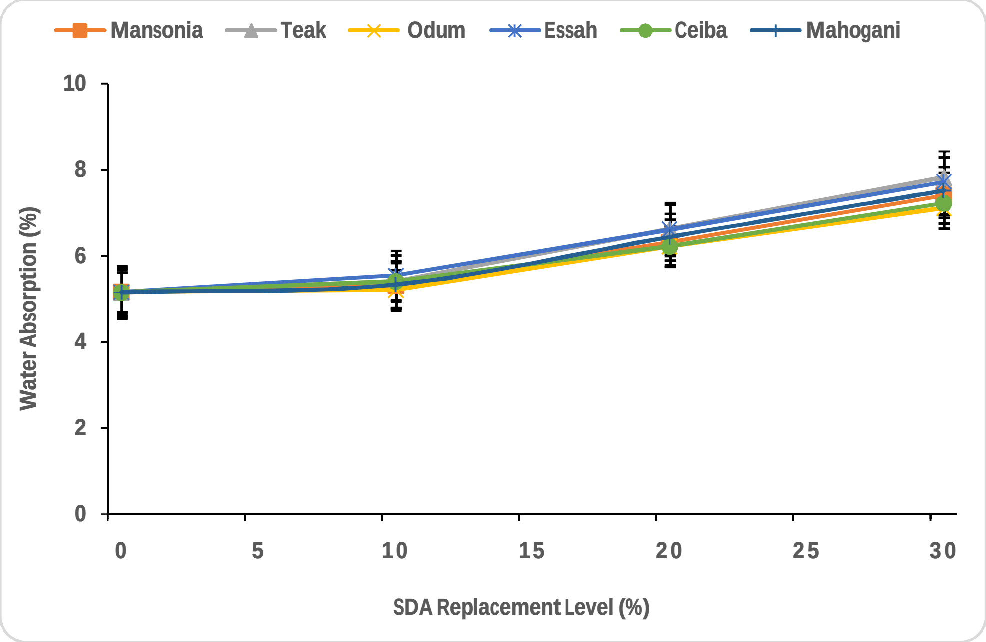

Figure 15. Water absorption test results of block samples on day 28.

While there were some variations between species, all the BSDA replacements resulted in higher water absorption compared to the control. Odum, Mansonia and Ceibashowed the least increase initially, but all species followed a similar trend of increasing absorption with higher BSDA content. On water absorption capacity or moisture absorption, a similar concerning trend observed was the increase in water absorption with increasing BSDA content as found in other studies (Assiamah et al., 2022; 2021; Fadele & Ata, 2018). This suggests higher porosity within the blocks, potentially leading to faster moisture ingress and compromising their structural integrity over time, especially in humid environments. The choice of wood type can also influence the water absorption properties of the blocks areOdum, Mansonia and Ceiba.

5. Summary and Conclusion

In order to produce interlocking blocks, the current study examined the feasibility of using burnt sawdust ash (BSDA) from timber species (wawa, mansonia, odum, ceiba, essah, teak, and mahogany) to partially replace cement. The geotechnical characterization of the lateritic soil, water absorption and tensile strength were determined at 7, 14, 21, and 28-day periods after each species of sawdust ash (BSDA) replaced cement at 10% incremental levels. The usually preferred batching method by weight was used with a cement-to-laterite mix ratio of 1:6 to each species of timber. The results show that at 28 days, the maximum density of 1801.54 kg/m3 was achieved with a 10% addition of wawa BSDA, while the minimum density was 1958.59 kg/m3 with a 10% quantity of BSDA. The Ghana Building Code (1989) and the European Standard (2015), Specification for Masonry Units. According to the ASTM and Ghana Standards Authority, the maximum allowable water absorption capacity of 12.61% for sandcrete blocks used in masonry walls was satisfied by the water absorption rates, which varied between 5.15% and 7.71%. The experimental interlocking blocks might be referred to as lightweight bricks or blocks because they were made lighter by the use of BSDA, which is a typical practice in Ghana for load-bearing walls. For every interlocking block specimen, the contents of all seven (7) BSDA replacements grew at a linear rate in water absorption rates.The research findings have some impacts on environmental sustainability, speed construction, and construction cost reduction. Firstly, there is a great deal of potential for wall manufacturing and other economic and ecological uses in building units for interlocking goods made of 90% cement and 10% BSDA for Wawa and Odum in terms of tensile strength.

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1.

2.

3.

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