Original Research Article

Influence of Burnt Sawdust Ash from Timber Species on the Chemical Strength Properties of Laterite-interlocking Blocks

Abstract

In the construction industry in Ghana and many other developing countries, blocks are predominantly used for the construction of walls in housing units. Their widespread application has led to the astronomical costs of producing the blocks units with significant environmental challenges as a results of materials like cement, fine aggregates and coarse aggregates. Therefore, an increasing quest globally to find low-cost and environmentally friendly alternative materials to replace cement with burnt sawdust ash (BSDA) from timber species in the manufacturing of compressed laterite interlocking blocks. This main aim of the study was to partially replace ordinary Portland cement (oPc) with burnt sawdust ash (BSDA) from timber species (Wawa-Triplochiton scleroxylon, Mansonia-Altissima, Teak-Tectona grandis, Odum-Milicia excels, Ceiba-Pentandra, Essah-Celtis mildbraedii and Mahogany-Swietenia macrophylla) in making interlocking laterite blocks by replacing 0-30 wt %. Mix proportion was 1:6 (cement + BSDA: laterite) with a 0.50 water-to-cement ratio. Two (2) tests were targeted for the research: Energy Dispersive X-Ray Spectroscopy (EDS) and Scanning Electron Microscopy (SEM) strength. It was observed that, the combined SiO_2, Fe_2O_3 and Al_2O_3 content satisfied the minimum requirement and the SiO_2 (29.5537.38%), Al_2O_3 (10.95-35%) contents were significantly great.

Keywords: ; Interlocking blocks; Burnt sawdust ash ; Scanning Electron Microscopy; Scanning Electron Microscopy.

1. Introduction

The most regularly used construction material in Africa and the developing countries is sandcrete block due to its durability, sustainability, versatility, malleability, energy efficiency and cost (Joshua, 2011). Utilization of this construction material in different structures has placed a high demand for its constituents materials, hence the need to research other eco-friendly materials to promote sustainability. Therefore, a plethora of research on substitute sandcrete blocks materials has been going on in several countries to find sustainable and more affordable substitutes for cement. In the construction industry, fine aggregates obtained from natural rock or gravel deposits have been used for sandcrete block works. The use of fine aggregate (sand, quarry dust, etc.) for blocks production in the construction industry has become very expensive. This is on account of excessive exploitation of limited sand and soil resources in the environment and the lack of new alternative materials for aggregate production (Freestone, 2011).

Moreover, other factors that have influenced the cost of blocks include the astronomical costs of producing the blocks units with significant environmental challenges as a results of materials like cement, fine aggregates and coarse aggregates (Assiamah et al., 2022). These factors among others have influenced manufacturers of blocks to the global market. (Andohful et al., 2021; Baiden & Tuuli, 2004).

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.

Sawdust or wood shaving is another waste material from the timber processing industry (Raheem & Ige, 2019). Where timber is sawn into planks. The wood process and timber industries' daily activities at saw mills cause heaps of wood waste to be generated after each day in nearly all major towns in Ghana. Various ways in which this stream of waste from wood-based industries can be used in the construction industry have been exploited in past studies (Adetoro & Oladapo, 2015; Assiamah et al., 2022; Awolusi et al., 2021; Sojobi, 2016). 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 this study.

2.0 Overview of walling systems

Common types of walls include compressed laterite interlocking blocks are different from conventional bricks since they do not need mortar after nthe foundation before laying, there is speed of canctruction, the blocks are laid dry and ineterlocked into place. There is also reduction of labour cost and materials. Once the base is properly laid, the blocks are stacked dry with the help of a wooden rubber hammer to knock the blocks gently in place (Nasly and Yasin, 2009).

The results of the study indicate that the pace of wall construction using the interlocking blocks is far more than using the sandcrete block. The elimination of non-value steps like spreading mortar, leveling, vertical mortar jointing and dressing of joints significantly reduces the cycle time of bonding blocks thus increasing the speed wall construction.

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)**	38	**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)**	25.06
	Clay (<0.002 mm)	26	Maximum dry density **(MDD k/m^3)**	14.70	**Plasticity index(Pl)**	36.34

Figure 1: Laterite set up

Figure 2: ordinary Potland cement

3.2 Cement

Ordinary Portland cement produced by GHACEM Cement Company in grade 42.5R will be used, which a fine mineral powder is made using extremely exact procedures. This powder, when combined with water, creates a paste that bonds and solidifies when placed in water. Due to the variable nature of the powder's composition and size, cement's qualities vary based on its makeup. The primary study's binding substance was GHA CEM's Ordinary Portland Cement (OPC).

3.3 Burnt Sawdust Ash

Sawdust was obtained from K. K Sawmills at Abesim in Sunyani, Ghana. Samples were taken to the Civil Department Workshop at production unit.

Sunyani Technical University, Ghana and dried at 30°C them very well in the sun before being burnt them in a very hot metal barrel into ash at a temperature of 300 °C for Five(5) hours. The fixing approach is shown in figure 5.

3.4 Chemical composition of burnt sawdust ash (BSDA)

Samples of the BSDA compressed laterite interlocking blocks after 28 days of curing were sent to the University of Ghana for laboratory tests to determine the chemical compounds/elements in the blocks and demonstrate how the interior of the compressed laterite interlocking blocks had been compacted to increase its strength. Energy Dispersive X-Ray Spectroscopy (EDS) and Scanning Electron Microscopy (SEM) were used to collect the data as illustrated in figure 3 & 4.

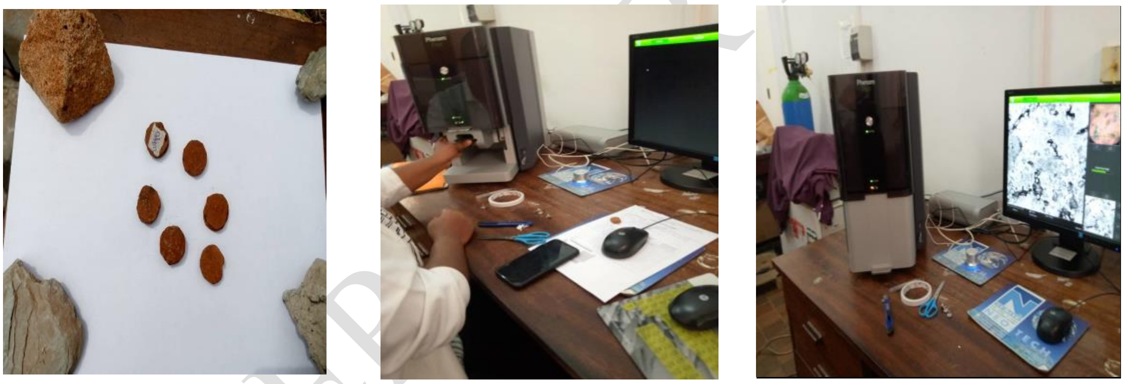


Figure 3 & 2: EDS and SEM analysis of compressed laterite interlocking blocks set up

Figure 5: Sawdust burning set up

Essah Ceiba Mansonia

Teak Odum Wawa Mahogani

Figure 6: Ashes from Timber species

3.5 Preparation of Bocks Materials

Figure 7: Batching of the various aggregates in percentages.

3.5.1 Mixing of raw materials

The work involved the use of cement and laterite in a mix ratio of 1:6 by weight and water-cement ratio of 0.6 to produce compressed laterite interlocking blocks. As shown in Figure 7 and 8, 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 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 odinary Portland cement (oPc) was applied as a control. The laterite and odinary 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.

Figure 8: Mixing set up

3.6 Production of SDBA landcrete interlocking blocks

A mix proportion of 1:6 parts of cement plus BSDA to laterite by weight (batching procedures in Fig. 3 and Table 2) was used in the work. The BSDA partial replacement of cement was in varying proportions of 0%, 10%, 20%, and 30 wt% since Class F fly ash is frequently used at dosages of 15–25 wt% of cementitious material (Kosmatka, 2002).

The mixing was performed by the use of a shovel to provide a more plastic paste. The cement samples were mixed with laterite us- ing a water-to-cement ratio of 0.6 For the experimental blocks, the laterite, cement, and BSDA replacement percentage ranging from 10% to 30% were blended to achieve a desirable consistency. The mixture was then loaded into the single block mold for the production of interlocking blocks of size 185 mm (Width) × 220 mm (Length) × 120 mm (Height) under hydraulically compressed and at a constant pressure of 10 N/mm^2. This procedure conforms to Hydraform concepts.

The blocks were cast, cured, weighed, and tested for SEM and EDS on day 7-28 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.

3.7 Curing of SDBA landcrete interlocking blocks

The de-moulded blocks were first allowed to dry under normal temperature and humidity in shady and sunny conditions (air-dried for 24 h). Thereafter, curing started by sprinkling water on the blocks in the morning and evening each day protected under plastic sheeting, and covered with a polythene sheet (shade) to prevent rapid drying (Figure 7).

Figure 9: and Curing set up

4.0 RESULTS AND DISCUSSION

The chemical tests conducted on the compressed laterite interlocking blocks include the following:

4. 3.1 Energy Dispersive X-Ray Spectroscopy (EDS) and Scanning Electrons Microscopy (SEM) Results

The EDS of the burnt-sawdust ash for all the seven BSDA compressed cement-laterite interlocking blocks for 28 days curing is shown in Figure 2.

Table 1: Chemical composition the species of BSDA

Timber Species Saw Dust Ash	**Chemical Properties / Composition in Percentage (%)**								
	SiO_2	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**SO_3**	**Na_2O**	**K_2O**	**$SiO_2 + Al_2O_3 + Fe_2O_3$**
Wawa	34.93	10.95	35.12	14.38	0.32	2.39	0.25	0.17	81
Mansonia	29.55	28.57	14.11	13.25	0.4	0.27	2.42	1.46	72.23
Odum	33.98	21.69	18	22.21	0.82	0.66	0.79	0.32	73.67
Ceiba	37.38	23.19	20.02	12.21	0.77	2.05	0.84	0.59	80.59
Teak	33.94	21.8	18.79	12.9	0.78	5.74	0.87	0.49	74.53
Essah	29.58	22.12	20.61	24.66	1.01	0.63	0.7	0.65	72.31
Mahogany	37.26	35	5.89	7.34	0.63	7.98	3.18	2.43	78.15

6.12

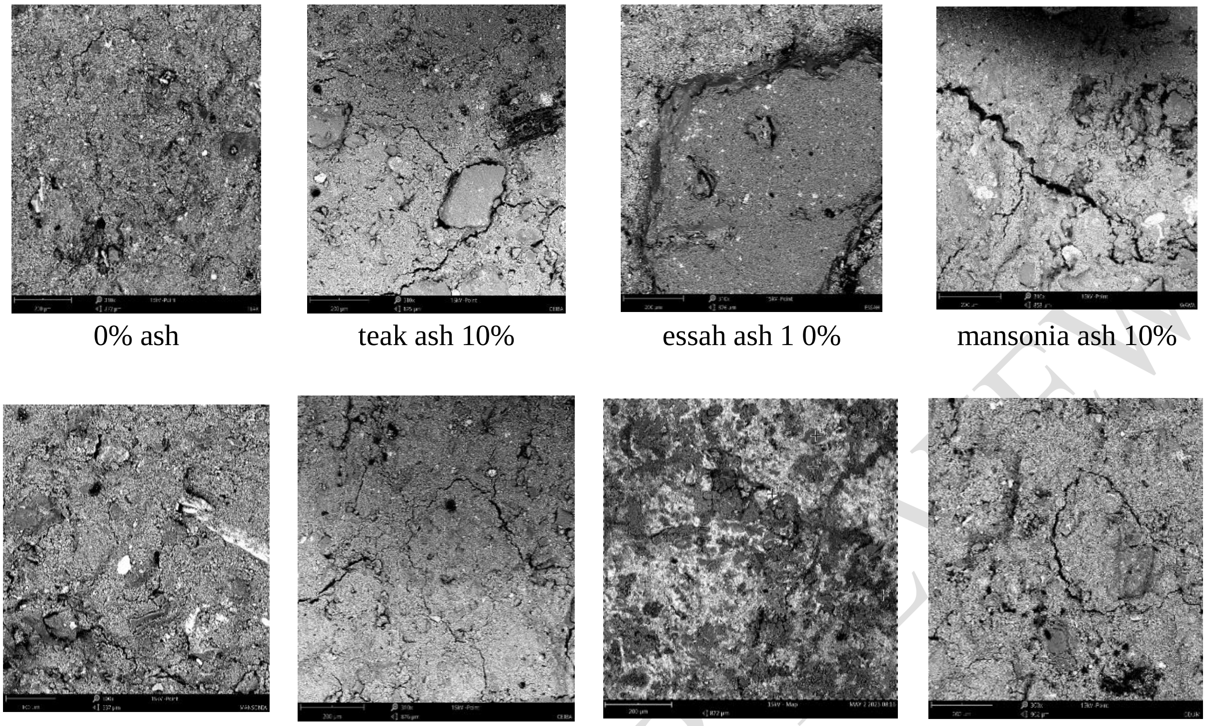
BSDA= burnt sawdust ash

The principal chemical components generated compared with the results of Assiamah et al., (2022), Raheem, and Ige, (2019). Thus from Table 2, the combined SiO_2, Fe_2O_3 and Al_2O_3 content satisfied the minimum requirement of 70.0% per American Society for Testing and Materials (ASTM C618-1991). Also, the SiO_2 (29.5537.38%), Al_2O_3 (10.95-35%) contents were significantly great. This proposes that the BSDA with a typical surface area of 300–500 m^2/kg and specific gravity of 1.9–2.8 is less likely to hydrate and harden under 45 min when exposed to water (Kosmatka, 2002). Thus, this characteristics support the decision to use BSDA as a pozzolanic admixture in manufacturing interlocking blocks capable of achieving the desired effects. Therefore, blocks become less workable as the BSDA percentage increases meaning, there is the need to add more water to make the mixes more workable. This means that BSDA laterite interlocking blocks have more water demand. This in line with the previous study of Raheen et al. (2012).

The BSDA found in literature, with total pozzolanic content range of 73.07–88.32 %, met the 70% minimum pozzolanic content (SiO_2 + Al_2O_3 + Fe_2O_3) required to be classified as supplementary cementitious material (SCM) and can be utilized as potential cement replacement (ASTM, 2016).

The BSDA from Wawa (Triplochiton scleroxylon) tree used in this research has a total pozzolanic content of 81%, Mansonia (Altissima) has 72.23%, Odum (Milicia excels) has 73.67%, Ceiba (Pentandra) has 80.59%, Teak (Tectona grandis) has 74.53%, essah has 72.31% and mahogany has 78.15 which met the minimum requirement of 70% to be utilized as BSDA to replace cement. However, Wawa (Triplochiton scleroxylon) BSDA achieved higher results among all the timber species selected which gained total pozzolanic content of 81%. Likewise, its SiO_2 content for Wawa (Triplochiton scleroxylon) is about 3.3–4.4 times that of Ordinary Portland Cement, mansonia is 2.94–3.92 times that of ordinary Portland cement, Odum (Milicia excels) is 3.0-4.0 times that of Ordinary Portland Cement, Wawa (Triplochiton scleroxylon) is 3.3-4.3 times that of Ordinary Portland Cement, Teak (Tectona grandis) is 3.0-4.1 times that of Ordinary Portland Cement, Esa (Celtis mildbraedii) 2.9-3.9 times that of Ordinary Portland Cement and Mahogany (Swietenia macrophylla) 3.2-4.2 times that of Ordinary Portland Cement which is similar to the ratio of 2.8–4.4 for SDA obtained in past researches in literature. Similar trend of pozzolanic content was also observed in wood waste ash and SDBA of Bediako (2018) and Assiamah et al, (2022) respectively.

In addition, according to Hannesson et al. (2012) and Oyebisi et al. (2018), the tardy gain in strength of BSDA when blended with water and cement is due to the small composition of calcium oxide (CaO) in it, which catalyzes the early strength development. At higher Class F ash as a replacement for cement, the gypsum concentration in the blend becomes high, which brings about increased the mixture’s re tarding characteristics (Hannesson et al 2012). Thus, at an early age, the BSDA contributes no strength but only acts as a filler, waiting for the hydration product of the cement.



0% ash teak ash 10% essah ash 1 0% mansonia ash 10%

wawa ash 10% ceiba ash 10% odum ash 10% mahogani ash %

Figure 10: SEM Images of all the seven BSDA compressed cement-laterite interlocking blocks

Figure 10 explains the Scanning Electronic Microscopy (SEM) images of all the seven (7) species of BSDA interlocking blocks. Since 10% achieved maximum compressive strength at the final day (day 28), it was selected to determine how these blocks were compacted: The rough surface blocks were good for bonding with cement matrix, smooth surface were also good for erosion and water absorption resistance relative good density which means there were no cracks within which can affect the strength.

Therefore, it is observed that, before ascertaining compatibility of BSDA as a suitable replacement for cement in producing compressed laterite interlocking block, an electron microscope (EM) image was taken. The SEM image revealed higher interspatial distances between SDA particles compared to cement particles, which look more compact. However, 10% for Wawa (Triplochiton scleroxylon) and Odum (Milicia excels) BSDA and 90% cement have smooth surface, which means inside compaction is very good and the rest like Ceiba (Pentandra), Esa (Celtis mildbraedii) , Teak (Tectona grandis) , Mahogany (Swietenia macrophylla) and Mansonia (Altissima) have rough surface as compare to others. There are also cracks and compaction is not very good. By so doing, the images with smooth surface (Wawa - Triplochiton scleroxylon and Odum-Milicia excels) have ability to resist erosion, water absorption and relatively good density. This is because pores in the blocks are sealed for strength improvement (Danso and Manu, 2019). While the images with rough surface like essah. Mahogany, mansonia and teak have ability to bond with the cement matrix or paste (Danso et al., 2015).

5.0 Summary and Conclusions

The research findings have some impacts on construction industry with regard to speed construction, environmental sustainability, lowered costs associated with the building, mortarless construction, and construction cost reduction. Initially, there is a great deal of potential for wall manufacturing and other economical and ecological uses in building units for interlocking goods made of 90% cement and 10% BSDA for Wawa (Triplochiton scleroxylon) and Odum (Milicia excels), respectively. Against this background, it is widely known that most interlocking block buildings use lean mortar or are mortarless. Moreover, the weight, time, and expense of building structures might all be reduced by using these interlocking masonry blocks. Furthermore, the creation of these interlocking, mortar-free, reasonably priced, and simple-to-assemble block units for housing could expressively lessen the risks connected to sawdust wastes, including air pollution, the unpleasant smell emanating from burning wood shavings outdoors, a number of aesthetic effects, and other hazardous contaminants. These pollutants jeopardize human life both locally and internationally, and they greatly rise greenhouse gas productions.

Lastly, the 10% BSDA of Wawa (Triplochiton scleroxylon) and Odum (Milicia excels) laterite interlocking blocks provide smooth surface for good compaction and improving strength properties of the specimen and others with the rough surface like Ceiba (Pentandra), Esa (Celtis mildbraedii), Teak (Tectona grandis), Mahogany (Swietenia macrophylla) and Mansonia (Altissima) for having ability to bond with the cement matrix. Therefore, it can be concluded that BSDA replacement interlocking laterite blocks have the potential of supporting the affordable housing concept in Ghana. Cement laterite interlocking blocks construction is likely to support sustainable construction concept since it uses materials that are abundant and possesses good strength, fair resistance to erosion and water absorption and relative good density properties.

To conclude, there are some notable limitations. Originally, shear strengths were not determined. Therefore, another research is needed to examine these properties using different magnitudes and dimensions of the newly presented blocks. Also, a study to establish more achievable or necessary methods to achieve sustainable building using this product is suggested. In addition, the structural behaviours such as load-deformation functionality, stress-strain relations and failure mechanisms should be studied through model walling systems since the current study did look into that. Also, the effect of gradation on the properties of the interlocking blocks may be investigated by interested researchers.

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