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PHYSICAL AND STRENGTH PROPERTIES OF BRICKS PRODUCED FROM PORTLAND CEMENT AND SAW DUST OF DANIELIA OLIVERII WOOD

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Abstract:
This study investigated the use of sawdust as partial replacement for sand in wood-concrete hollow blocks. Sharp sand, ordinary Portland cement (binder) and sawdust were used as raw materials. Sawdust was treated by boiling then sieved after drying using British Standard sieve of 3.35mm to remove sticky wood capable of causing pores. The quantities of sawdust used were 0%, 5%, 10%, 15% and 20%. A mixing proportion of 1:8 cement sand ratio, moulding machine with single 6" (450mm x 225mm x 150mm) mould and vibrated with 5.0KW power machine for adequate compaction were used. Wood-concrete block was cured for 28 days. The blocks produced were tested for compressive strength and water absorption. The results showed that mean compressive strength of 100% sand was 2.81N/mm^2 followed by 95% sand and 5% sawdust replacement with 1.58N/mm^2; 90% Sand and 10% sawdust replacement with 0.55N/mm^2); 85% sand and 15% sawdust replacement with 0.43 N/mm^2 and 80% sand 20% sawdust replacement with 0.24N/mm^2. The result further showed that as the percentage of sawdust increased, the compressive strength decreased. At 28 days, the compressive strength of blocks with 5% SD replacement satisfied meets Ghana Building Code for non- load bearing walls. The results also reveals that blocks with 80% sand 20% sawdust replacement level has the highest water absorption (23.72%) followed by 85% Sand and 15% sawdust replacement (20.40%); 90% sand and 10% sawdust replacement (18.0%); 95% sand and 5% sawdust replacement (12.12%) and 100% sand and 0% sawdust replacement (11.43%). It was concluded that 5% sawdust (8kg) replacement and cured 28 days could be used for non-load bearing walls. It was recommended that further research should be carried out to evaluate sawdust replacement level within the range of 1-4% to ascertain results that could be used for various other purposes.

Key words: *compressive strength; sawdust; wood-concrete block; water absorption.*

INTRODUCTION

Construction industry is a very significant sector of the economy. It plays vital position in a nation's economy such as Nigeria because of the transient trend in national growth (Anosike and Oyebade 2012). The rapid growth in the country's economy and population requires additional physical infrastructures to accommodate additional various component of the Gross National Product (GDP). Over 90% of physical infrastructures in Nigeria are being constructed using cement blocks making it a very important material in building construction (Baiden and Tuuli 2004).

Concrete is a combination of cement, fine and coarse aggregates and water, which are mixed in a particular proportion to get a particular strength. The cement and water react together chemically to form a paste, which binds the aggregate particles together. The mixture sets into a rock-like solid mass, which has considerable compressive strength but little resistance in tension (Agbede and Menessh 2009). Cement block is a composition of usually (1:6) mix of cement and sharp sand with the barest minimum of water mixture, and in some cases admixture, molded and dried naturally. NIS 87:2000 defines cement block as a composite material made up of cement, sand and water, molded

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into different sizes. According to them, they are masonry units which when used in its normal aspect exceeds the length or width or heights specified for bricks. The block can consequently be made either in solid and hollow rectangular types (for normal wall) or decorative and perforated in different designs, patterns, shapes, sizes and types (for screen wall or sun-breakers). Cement blocks are widely used as walling units and over 90% of houses in Nigeria are being constructed of cement blocks (Baiden and Tuuli 2004).

The most widely used fine aggregate for the making of concrete in Makurdi is the natural sand mined from the riverbeds. The availability of river sand for the preparation of concrete is becoming scarce due to the excessive non-scientific methods of mining from the riverbeds, lowering of water table and sinking of the bridge piers among others, are becoming common treats (Mageswari and Vidivelli 2010). The worldwide consumption of sand as fine aggregate in concrete production is very high, and several developing countries have encountered some strain in the supply of natural sand in order to meet the increasing needs of infrastructural development in recent years (Divakar *et al*. 2012). Accumulation of unmanaged wastes especially in developing countries has resulted in an increasing environmental concern (Olugbenga *et al.* 2014). However, the increase in the recognition of using environmental friendly, lightweight construction materials in building industry has brought about the need to investigate how this can be achieved by benefiting environment as well as maintaining the material requirements affirmed in the standards. Since a large demand has been placed on building material industry especially in the last decade owing to the increasing population that causes a chronic shortage of building materials, there is the challenged to convert the industrial wastes to useful building and construction materials (Turgut 2007).

Sawdust as an industrial waste in the wood industry constitutes a harmful impacts to both the human health and environment when it is not properly managed as reported by Elinwa and Abdulkadir (2011). Wood sawdust wastes are accumulated from different sawmills and would cause certain serious environmental problems and health hazards to man-kind if it remains in nature and would decompose. In most forest industry clusters, the volume of wood waste generated is very enormous and constitute a nuisance to the environment. In most cases, the wood waste piles up to form big heaps which disturb activities within the mills. The heaps of the waste are burnt for days, disturbing visibility and causing pollution, thereby endangering health of residents, motorists and passersby. Since wood is used in large quantities in many different sectors and is a part of our everyday lives, the volumes of sawdust and other recovered wood available are also large (Eboziegbe and Mizi 2013). Wood waste that enters into water ways bleached their extractives in the water, thereby, polluting the water; all these necessitated need for integrated and economic management of wood waste in Nigeria as Ogunwusi (2014) stated.

The generation of wood wastes in form of sawdust in sawmill industries is an unavoidable and cannot be totally eliminated, hence a great efforts are made in the utilization of such waste (Zziwa *et al.* 2006). Discovery the appropriate uses of sawdust would help to counterbalance production costs and increase the profitability of sawmilling operations in developing countries' plantation forests. Several researches carried out in the past used wood ash wastes as a replacement for cement in concrete mixes (Elinwa and Mahmood 2002, Udoeyo and Dashibil 2002). Wood-concrete is a new material made from sawdust or other wood wastes.

Cement blocks according to Ewa and Ukpata (2013), are the commonest and most popular masonry walling units in Nigeria. Cement most important and expensive constituent of the block is cement; to minimise cost and maximise profit, commercial producers of these blocks reduce the quantity of cement needed to give acceptable quality required by various standards (Okafor and Ewa 2012), cement blocks are the most widely used walling unit in Nigeria and accounts for about 90% of houses (Baiden and Tuili 2004). Concrete is a mixture of cement, fine aggregate, coarse aggregate and water. It plays a vital role in the development of infrastructure like buildings, industrial structures, bridges and highways etc. leading to utilization of large quantity of concrete. It is difficult to point out another material of construction which is as variable as concrete. Concrete is the best material of choice where strength, durability, impermeability, fire resistance and absorption resistance are required (Sri Chandana and Shaik 2015).

High demand is placed on building material industry especially in the last decade owing to the increasing population that causes a serious shortage of building materials such as river sand, cement and so on. The Civil Engineers have been challenged to convert the industrial wastes to useful building and construction materials as reported by Turgut (2007) and Olugbenga *et al.,* (2014). The use of a mixture of sawdust, sand and cement for making bricks, blocks or wall panels has been fairly common in parts of African countries for many years. The history of this technology goes back to at least the 1930's, and it has been researched and applied in parts of the USA, UK and Germany. In some instances, the materials (with various adaptations) have been used for flooring as well as walling. The possibilities for this medium are probably endless.

Wood-concrete is a new building material has previously been developed from sawdust, inorganic binder and addition of waste paper, finding its use mainly for wall panelling or other non- and semi-structural applications with good thermal insulating properties (Eboziegbe and Mizi 2013). Recycling of sawdust wastes as building materials appears to be one of the viable solutions not only to such pollution problem but also to the problem of economic design of buildings. The increase in the popularity of using environmentally friendly, low-cost and lightweight construction materials in building industry has brought about the need to investigate how the used of hard-wood sawdust from some forest trees species can be achieved by benefiting to the environment as well as maintaining the material requirements, as was affirmed in the standards by Olugbenga *et al.,* (2014).

OBJECTIVES

This study therefore aimed to:

i. produce wood-concrete blocks from sawdust of *Daniellia Oliveri* wood, commonly used in Makurdi with a view to recycling the waste which is currently causing environmental problem in the metropolis.
ii. determine compressive strength and water absorption of wood-concrete produced in partial replacement for sand to ascertain; their suitability in building.

MATERIALS AND METHODS

Study Area

The experiment was carried out in the Multipurpose Laboratory of the Department of Civil Engineering, Federal University of Agriculture Makurdi (FUAM). FUAM is located on Longitude 8° 33N and Latitude 7° 44E in Benue State which lies in the middle belt of Nigeria. The area is characterized by two distinct seasons- dry and wet in the Southern guinea savannah. The climate of the area is tropical sub-humid climate with high temperatures, high humidity, the average maximum and minimum daily temperature of 35^{o}C and 21^{o}C in wet season, 37^{o}C and 16^{o}C in dry season respectively. The mean annual rainfall value is 1200mm to 1500mm. The vegetation of the area has been described as Northern Guinea savannah (Gyang 1997).

Collection and Treatment of Sawdust

Sawdust was collected from timber shed located at old bridge, north bank, Makurdi. The collected sawdust was boiled in a drum in order to dissolve all soluble organic components (carbohydrate, tannins, waxes and resins) according to Vaickelionis and Vaickelioniene, (2006). The boiled sawdust was washed in cold water and spread on a sack mat to dry. Treated sawdust was sieved, using British standard sieve of 3.35mm to remove sticky wood capable of causing pores inside of wood-concrete blocks.

Preparation of mortar

Percentage of 5%, 10%, 15%, and 20% by weight of sand was used sawdust for replacement. A mix proportion of 1:8 cement and sand ratio was used as showed on table 1. Water was added in sufficient quantity to ensure workability of the mixture. Mixture of the samples was done manually. The mixture was turned over a number of times until a homogeneous mix with uniform color was attained.

Table 1

Weight of sand and sawdust replacement

Replacement level		Cement to sand ratio	**Add mix of sand and sawdust ratio**		**Water/Binder Ratio**
			Sand (Kg)	Sawdust (kg)	
100% Sand	0% sawdust	1:8	160	0	0.52
95% Sand	5% sawdust	1:8	152	8	1.04
90% Sand	10% sawdust	1:8	144	16	1.56
85% Sand	15% sawdust	1:8	136	24	2.6
80% Sand	20% sawdust	1:8	128	32	2.6

Production of hollow blocks from sawdust wood-concrete

Cement, sawdust and sand were mixed together to obtain a uniform mixture. The measured quantity of water was then sprayed on to the mixture by means of bucket. The mixture was further turned using shovels till a mix of the desired workability was achieved.

The composite mixture was introduced into mould in block molding machine. The blocks were then manufactured by vibrating its freshly mixed content in the molding machine with single 6" (450mm x 225mm x 150mm) mould and vibrated with 5.0KW power machine for adequate compaction according to Raheem (2006). The blocks formed on a wooden pallet was removed from molding machine and placed on the ground for curing. Water was sprinkled on the blocks, at least twice a day for proper curing for 28 days thereafter, the wooden pallets separated from the blocks. The molded blocks were later sent for compressive tests.

Compressive Strength

The compression machine is connected to the main and the pointer on the reading calibration scale is adjusted to the zero mark. The metal sheet placed on top of the block (to spread the load) is weighed so as to add it to the compressive strength value read from the machine and this sum is taken as the compressive strength value of the block sample. The block was weighed and recorded and then placed between the metal plates that completely cover the area of the block and fed into the compression zone and locked with the block centralized within the compression zone.

The start button is depressed to initiate the electronic compression and as the compressive force is applied to the block, the pointer reading the compressive strength value in kilo-Newton (KN) gradually rises till it reached its peak and then begins to drop back. The maximum value just before the pointer begins to drop or the pointer reading when visible cracks is evident on the block is taken as the compressive strength of the block which is indicated by another pointer in the former case. The compression was then powered off by depressing the red button and the block released and the crushed blocks poured out for disposal. This was calculated using the next relationship (Eq.1):

$$CS = \frac{F}{A}\ [\frac{N}{mm^2}] \quad (1)$$

where:

F - force at failure, in N;

A - Net area of crashing, in mm^2.

Six samples per mixture (0%, 5%, 10%, 15% and 20% replacement level) content were removed from the curing area and sun-tried until there was no further loss in dry weight. The samples were then immersed in water for 24hours and allowed to drain for 1 minute before taking the weight (wet weight). The difference in weight is used to calculate the percentage water absorbed. This was calculated using the formula.

$$\%\ \text{Water absorption} = \frac{Ws - Wd \times 100}{wd} \ldots\ldots 2$$

where:

Wa - Water absorption ratio expressed in %;

Ws - Weight of wet block in kg;

Wd - Weight of dried block (initial, before immersion), in kg.

Fig.1 shows block sample being weighed.

Fig. 1.
Weighing of block sample.

RESULTS

The result of the compressive strength of wood-concrete of this work is shown in Table 2. Mean compressive strength of 100% sand and 0% sawdust replacement was (2.81N/mm^2). This was followed by 95% sand and 5% sawdust replacement (1.58N/mm^2); 90% sand and 10% sawdust replacement (0.55N/mm^2); 85% Sand and 15% sawdust replacement (0.43N/mm^2) and 80% sand 20% sawdust replacement (0.24N/mm^2).

Result on percentage water absorption is presented in Table 3. The result reveals that 80% Sand 20% sawdust replacement level has the highest water absorption (23.72%) followed by 85% sand and 15% sawdust replacement (20.40 %); 90% sand and 10% sawdust replacement (18.0%); 95% sand and 5% sawdust replacement (12.12%) and 100% sand and 0% sawdust replacement (11.43%).

Fig. 2 shows blocks made from 100% sand and 0% sawdust replacement while Fig. 3 blocks made from 95% sand and 5% sawdust replacement.

Table 2

Compressive strength test results

Replacement level (%)	Block No	Net area of block mm^2	Crushing load (KN)	Compressive strength of block (N/mm^2)	Mean compressive strength (N/mm^2)
0	1	36900	114	3.09	2.81± 0.20
	2	36900	112	3.04	
	3	36900	108	2.93	
	4	36900	108	2.93	
	5	36900	104	2.82	
	6	36900	100	2.71	
5	1	36900	62	1.68	1.58± 0.08
	2	36900	60	1.63	
	3	36900	58	1.57	
	4	36900	58	1.57	
	5	36900	56	1.51	
	6	36900	56	1.51	
10	1	36900	18	0.49	0.55± 0.02
	2	36900	18	0.49	
	3	36900	16	0.43	
	4	36900	16	0.43	
	5	36900	15	0.41	
	6	36900	12	0.33	
15	1	36900	16	0.43	0.43± 0.06
	2	36900	15	0.41	
	3	36900	14	0.38	
	4	36900	14	0.38	
	5	36900	8	0.22	
	6	36900	8	0.22	
20	1	36900	16	0.43	0.24± 0.09
	2	36900	15	0.41	
	3	36900	14	0.38	
	4	36900	14	0.38	
	5	36900	8	0.22	
	6	36900	8	0.22	

Table 3

Result of percentage Water Absorption test

Replacement level (0%)	Block No	Dry Weight (kg)	Wet Weight (kg)	Weight of water absorbed (kg)	Water absorption %
0	6	17.5	19.5	2.00	11.43± 2.76
5	6	15.42	17.33	1.91	12.38±1.40
10	6	12.5	14.75	2.25	18.0± 2.19
15	6	11.42	13.05	2.08	18.21± 0.32
20	6	10.58	13.08	2.50	23.62± 3.29

Fig. 2.
Blocks made from100% Sand and 0% sawdust replacement.

Fig. 3.
Blocks made from 95% sand and 5% sawdust replacement.

DISCUSSION

Compressive Strength

At the 28 days hydration period, compressive strength of blocks produced with 100% sand and 0% sawdust from the result obtain met the minimum standard for load bearing walls of $2.0N/mm^2$ according to National Building Code (2006) and $2.75N/mm^2$ according to Ghana Building code (1989). However, the result failed to meet the $3.5N/mm^2$ according to British standard. The higher compressive strength recorded in 100% sand and 0% sawdust replacement is due to the stronger mix ratio of 1:8 (cement:sand) employed without sawdust.

At the 28 days hydration period, mean compressive strength of block produced with 95% sand and 5% sawdust content ($1.58N/mm^2$) met the minimum requirement of $1.4N/mm^2$ according to Ghana Building code (1989). Block produced with 90% sand and 10% sawdust, 85% sand and 15% sawdust and 80% sand with 20% sawdust all failed to meet local and international standard for both load bearing and non-load bearing walls. Test result indicates that the compressive strength decreases with increase in sawdust content. This confirm that Adebakin *et al.* (2012) stated on their work on uses of sawdust as admixture in production of lowcost and light-weight hollow blocks.

Water absorption percentage

Percentage of water absorption is according to Baiden and Tuuli (2004) as the water weight of a block unit absorbs when immersed in water at a normal day temperature for a stated length of time. Sawdust is more susceptible to moisture and hence water absorption test on each blocks was carried at 28 days (Boob 2014).It is also expressed as a percentage of the weight of the dry unit of block. Blocks with 0% and 5% sawdust replacement assumption rate were not higher than the one obtain by Anosike and Oyebade (2011) and the acceptable value of 12% according to BS 5628: part 1. Blocks with 10%, 15% and 25% sawdust replacement were porous. The water assumption rate was higher than 16.95% obtain by Anosike and Oyebade (2011) and the acceptable value of 12% according to BS 5628: Part 1: 2005. It was observed that the water absorption increases as the percentage replacement of sawdust increases. Boob 2014) reported that absorption of water to some extent was appreciable and advisable, but excessive of it would cause various defects in the block.

CONCLUSION

Increase in the replacement level of sawdust increased the water ratio. It was observed that the percentage water absorption increases as the percentage replacement of sawdust for sand increases. At 5% sawdust replacement, there was 2% reduction in production cost and also increase in production by 2 blocks. To achieve a better result in the use of sawdust in block production, percentage replacement of sand by weigh should not be more than 5%. The best sawdust replacement level was 5%. Therefore, 5% sawdust replacement blocks as obtained in this study is recommended for non-load bearing walls according to literature and own experiments.

RECOMMENDATION

Owners of block industries should adopt 5% replacement of sawdust in block production as obtained in this study. Further research should be carried out to evaluate sawdust replacement level within the range of 1-4% to ascertain results that could be used for various purposes.

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