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SOME ASPECTS OF PHYSICAL AND MECHANICAL PROPERTIES OF HOLLOW BLOCKS PRODUCED FROM HOT WATER TREATED SAWDUST.

ALGUNOS ASPECTOS DE LAS PROPIEDADES FÍSICAS Y MECANICAS DE LOS BLOQUES HUECOS PRODUCIDOS A PARTIR DE AGUA CALIENTE Y ASERRÍN.

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ABSTRACT

The study investigated sawdust as a partial replacement for sand in production of hollow blocks with a view to reducing cost and converting waste to resource use. Sawdust of *Daniella oliveri* was collected from Timber Shed along New Bridge Wurukum, Makurdi. It was boiled and spread to dry. Standard ratio of 1:8 (cement and sand) was used in the study. Replacement levels of 0%, 2%, 4%, 6% and 8% of sawdust were used for sand, while cement was kept constant throughout the mixture. Density, percentage water absorption (PWA), and compressive strength (CS) of the blocks produced were tested after 28 days of curing. PWA results showed that blocks produced from 0% sawdust replacement level had least mean of 10.06%, while 8% sawdust replacement had the highest mean of 11.40%. Mean density values showed that 8% sawdust replacement had the least value of 1090.40Kg/m^3 and while the highest value (1346.60Kg) was observed for 0%. The mean CS for 0% sawdust replacement was highest (3.20N/mm^2) and falls within the Nigeria Building Codes of 2.5N/mm^2 - 3.45N/mm^2 and Ghana Building Code of 2.75 N/mm^2. Mean CS value of

2.0N/mm^2 was obtained for 2% and 4% sawdust replacement levels respectively. The CS value of 2% and 4% sawdust replacement levels meets the minimum standard of 2.0N/mm^2 according to National Building Code for non-load bearing walls and 1.7 N/mm^2 according to Ghana Building Code. However, 6% and 8% sawdust replacement levels showed the least CS of 1.00N/mm^2 which is below standards. In conclusion, blocks produced with 2% and 4% sawdust replacement levels as obtained in this study are recommended for building and construction of non-load bearing walls purposes.
Keywords: Blocks, Building code, cement, sand, sawdust, standard.

RESUMEN

El estudio investigó el aserrín como un reemplazo parcial de la arena en la producción de bloques huecos con el objetivo de reducir los costos y convertir los desechos en uso de los recursos. El aserrín de Daniella oliveri se recolectó en Timber Shed a lo largo de New Bridge Wurukum, Makurdi. Fue hervido y extendido a secar. Se usó una proporción estándar de 1: 8 (cemento y arena) en el estudio. Se usaron niveles de reemplazo de 0%, 2%, 4%, 6% y 8% de aserrín para arena, mientras que el cemento se mantuvo constante durante toda la mezcla. La densidad, el porcentaje de absorción de agua (PWA) y la resistencia a la compresión (CS) de los bloques se probaron después de 28 días de curado. Los resultados de PWA mostraron que los bloques producidos a partir del 0% de nivel de reemplazo de aserrín tuvieron una media mínima de 10.06%, mientras que el reemplazo de aserrín al 8% tuvo la media más alta de 11.40%. Los valores de densidad media mostraron que el reemplazo del aserrín al 8% tuvo el valor mínimo de 1090.40 Kg / m3 y mientras que el valor más alto (1346.60 Kg) se observó para el 0%. El CS medio para el reemplazo de aserrín al 0% fue el más alto (3.20 N / mm2) y está dentro de los Códigos de Construcción de Nigeria de 2.5N / mm2 - 3.45N / mm2 y el Código de Construcción de Ghana de 2.75 N / mm2. Se obtuvo un valor medio de CS de 2,0 N / mm2 para niveles de reemplazo de aserrín del 2% y 4%, respectivamente. El valor cumple con el estándar mínimo de 2.0N / mm2 de acuerdo con el Código Nacional de Construcción para paredes sin carga y 1.7 N / mm2 de acuerdo con el Código de Construcción de Ghana. Sin embargo, los niveles de reemplazo de aserrín del 6% y 8% mostraron la menor CS de 1.00 N / mm2 que está por debajo de los estándares. En conclusión, los bloques producidos con niveles de reemplazo de aserrín del 2% y 4% como se obtuvieron en este estudio se recomiendan para fines de construcción.

Palabras clave: Bloques, Código de construcción, cemento, arena, serrín, estándar.

INTRODUCTION

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); 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.

Sawdust is a loose particles or wood chippings obtained as by-products from sawing of timber into standard useable sizes. Sawdust as an industrial waste in the wood industry constitutes a harmful impacts to both the human health and environment when not properly managed as reported by Elinwa and Abdulkadir (2011). Sawdust is one of the major underutilized by products from sawmilling and Timber Shed operations. The generation of wood wastes in form of sawdust in sawmill industries is an unavoidable or cannot be totally eliminated, hence a great efforts are made in the utilization of such waste (Zziwa *et al,* 2006).

Sawdust wastes are accumulated from different sawmills and Timber Sheds cause serious environmental problems and health hazards to man-kind. In most places were forest industry are clustered, the volume of wood waste generated is always very high and constitute 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. Wood waste that entering into water ways like the one in New timber Shed located at bank of River Benue, Makurdi, leach their extractives in the water, thereby, polluting the water; all these necessitated need for integrated and economic management of wood waste in Nigeria (Ogunwusi, 2014).

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 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. 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 affirmed in the standards Olugbenga *et al.,* (2014).

Sawdust as an industrial waste in the wood industry constitutes a harmful impacts to both the human health and environment when not properly managed as reported by Elinwa and Abdulkadir, (2011). In Nigeria, proper utilization of sawdust has not been given proper attention. The use of sawdust from *Daniella oliveri* in Benue State have not been used in Block making elsewhere, therefore, if this study is successful it would reduce our environmental sawdust pollution. The heaps of the waste are burnt for days, disturbing visibility and causing pollution, thereby endangering health of residents, motorists and passersby. Wood waste that entered into water ways leached their extractives in the water, thereby, polluting the water; all these necessitated need for integrated and economic management of wood waste in Nigeria (Ogunwusi, 2014). *Daniellia oliveri* is the commonest wood species sawn in Makurdi and the waste is always high.

Plate1: Heap of sawdust at Timber Shed along New Bridge Road Wurukum, Makurdi.

The objectives of the present study were: first, to produce hollow block from sawdust of *Daniella oliveri* as a partial replacement for sand and the use of Portland cement as a binder with a view to recycling the waste for profitable resource which is currently causing environmental problem in Makurdi metropolis. And the second objective was to determine percentage of water absorption and compressive strength of the blocks produced to ascertain it suitability in building walls. Finally, the third objective was to determine bulk density of the produced blocks.

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), Benue State which lies between Latitude 7º and 44´ North and 8º and 33´ East in the middle belt region of Nigeria. The area is characterized by two distinct seasons dry and wet in the Southern Guinea Savannah. The climate of the place is tropical sub-humid climate with high temperatures; high humidity; average maximum and minimum daily temperature of 35° and 21°C in wet season and 37°C and 16°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 (Tyowua, *et al*., 2013).

Collection of Materials: Materials that were used in this study include: Ordinary Portland Cement commonly used in the construction works in the study area and was obtained from the cement shop. Sawdust generated from *Daniella oliveri* from Timber Sheds along New Bridge Wurukum, Makurdi was collected, sieved and treated by boiling at 100^{0}C to eliminate or reduce the retarding effect of the extractable substances in sawdust on setting and hardening of bricks. The sawdust was dried under room temperature to improve the sawdust quality. River sand was collected from River Benue in Makurdi. The sand was clean to ensure it was free from dirt and other particles. Portable water from FUAM water works was used.

Experiment Procedure: Mortal was prepared according to ASTM C652-13 (2013), using mix ratio of 1:8 (cement to sand), river sand was replaced with sawdust at various replacement levels of 0%, 2%, 4%, 6% and 8% respectively as shown in table1 below.

Production of sawdust Sandcrete Block: Cement, sand and sawdust at various levels of replacement were mixed with required quantity of water. Mix method was used for brick constituent i.e (cement, sand and sawdust) before the addition of water randomly as deemed fit by the researcher. The constituents were mixed together thoroughly to obtain a homogeneous mixture, with water added randomly as deem fit during the mixture process. No definite water-cement ratio was used in the mixture as stated by Samuel, (2014).

The composite was introduced into mould in block moulding machine. The blocks were produced by vibrating its freshly mixed content in the moulding machine with single 6” (450mm x225mm x 150mm) mould and vibrated with 5.0 KVA power machine for adequate compaction according to Raheem (2006). The blocks on wooden pallets were removed from the block moulding 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.

Table1: Weight and percentage replacement level of sand and sawdust

Replacement Level		Cement to sand ratio	Sand (Kg)	Sawdust (Kg)	Water/Binder
Sand	Sawdust				
100%	0%	1:8	160	0	0.64
98%	2%	1:8	158	2	0.86
96%	4%	1:8	156	4	1.01
94%	6%	1:8	154	6	1.23
92%	8%	1:8	152	8	1.42

Compressive Strength, Bulk Density and Water Absorption properties were determined from each sawdust bricks after 28 days of curing according to Adebakin *et al.,* 2012; Thanikasalapradeep *et al.,* 2014.

Laboratory Test: five samples of brick from each mixture were used for laboratory test (compressive strength, density and water absorption) respectively.

Percentage of Water Absorption test: The absorption capacity was determined by using the water absorption test as per IS 3495 (part2):1992 (Thanikasalapradeep *et al.,* 2014). Five (5) block samples each of the replacement level were weighed and their individual weighed noted as (M_1). These sample bricks were immersed in water for 24 hours. After 24 hours the specimens were removed from water and weighed to be determined their weight (M_2). The water absorption of blocks immersed in water after 24 hours were given by the formula below:

$$\text{Water Absorption } (^{O}/_{O}) = \frac{M_2 - M_1}{M_1} \times 100 \text{ ……………………….Eqn. 1}$$

Where M_1 = Dried weight of bricks before soaking; M_2 = weight of bricks after soaking.

Compressive Strength Test: Compressive strength test on sample bricks were determined as the maximum load that the block could withstand. Compressive strength of block depends upon the composition of clay, method of brick manufacturing and degree of firing (Thanikasalapradeep *et al.,* 2004). The test was carried out using the compression testing machine of maximum 300 tones capacity. The test was progressed with a constant rate of loading 50 N/s. The surface (frog) of the block was filled with mortar and the level of bed surface was also ensured before testing. The load at which the block failed in (N) was noted and the maximum compressive strength of individual brick was evaluated by the equation (ii) below.

$$\text{Compressive Strength} = \frac{\text{Maximum load at failure}}{\text{Contact Area}} \quad (\text{in N}/mm^2) \text{ ……………….Eqn. 2}$$

Bulk Density test: The Bulk Density of the hollow blocks was calculated by weight of the block unit divided by the dimensional volume according to BSI 2028(1975). Mathematically expressed as:

$$\text{Bulk Density} = \frac{mass\ of\ block\ (kg)}{dimensional\ volume\ of\ block (m^3)} \text{ ....Eqn.3}$$

Data Analysis: Data collected for this study was analyzed using a simple descriptive analysis while One-way Analysis of Variance (ANOVA) was used to analyze the differences in means between treatments. Follow up test was carried out using Duncan Multiple Range Test (DMRT) where significant differences exist.

RESULTS

The result of the percentage rate of water absorption of sandcrete hollow blocks of this work is shown in table 2. Mean of water absorption of 100% sand and 0% sawdust replacement was the highest (10.06%). This was followed by 98% and 2% sawdust replacement (10.22%), 96% sand and 4% sawdust replacement (11.25%), 94% and 6% sawdust replacement (11.33%), 92% sand and 8% sawdust replacement (11,40%) respectively.

The result of compressive strength of the hollow blocks of this work is presented in table 3. The highest mean compressive strength (3.20N/mm^2) of the produced block was recorded for 100% sand and 0% sawdust replacement level. This was followed by mean compressive strength of 98% sand and 2% with 96% sand and 4% sawdust replacement having 2.00N/mm^2 respectively. However, 94% sand and 6% sawdust with 92% sand and 8% replacement levels both had 1.00 N/mm^2 mean compressive strength.

Result on density the hollow blocks is presented in table 4. The result reveals that 100% sand and 0% sawdust replacement level had the highest mean density of 1346.60Kg/m^3, followed by 98% sand and 2% sawdust replacement with mean density of 1257,20Kg/m^3, 96% sand and 4% sawdust replacement with mean density of (1234.80/m^3), 94% sand and 6% sawdust replacement having mean density of (1176Kg/m^3), and 92% sand and 8% sawdust replacement with mean density of (1090Kg/m^3).

Table 2: Percentage water absorption of hollow blocks produced from sawdust as partial replacement for sand.

Replacement Level (%)	Block No.	Dry Weight of Block (Kg)	Wet Weight of Block (Kg)	Mean Water Absorption
0%	1	17.60	19.60	10.06 ± 0.72^{a}
	2	17.20	19.20	
	3	16.99	18.74	
	4	16.99	18.74	
	5	17.00	19.10	
2%	1	15.90	17.92	10.22 ± 0.34^{b}
	2	16.20	18.31	
	3	16.00	18.10	
	4	15.99	17.92	
	5	15.99	17.98	
4%	1	15.60	17.58	11.25 ± 0.34^{c}
	2	15.40	17.60	
	3	15.70	17.46	
	4	15.60	17.90	
	5	15.70	17.50	
6%	1	14.90	16.70	11.34 ± 1.26^{d}
	2	14.94	16.56	
	3	15.00	17.10	
	4	15.15	17.00	
	5	14.90	16.11	
8%	1	13.80	15.60	11.40 ± 1.26^{e}
	2	13.76	15.24	
	3	13.80	15.34	
	4	14.00	15.99	
	5	14.10	16.20	

Table 3: Results of compressive strength of hollow blocks produced from sawdust
as partial replacement for sand.

Replacement Level (%)	Block No	Net Area the Block (mm^2)	Crushing Load(KN)	Mean Compressive Strength of the Block(N/mm^2)
0%	1	36900	117	
	2	36900	116	
	3	36900	118	3.20 ± 0.447^{a}
	4	36900	118	
	5	36900	114	
2%				
	1	36900	87	
	2	36900	89	2.00 ± 0.00^{b}
	3	36900	92	
	4	36900	84	
	5	36900	88	
4%	1	36900	69	2.00 ± 0.00^{b}
	2	36900	67	
	3	36900	69	
	4	36900	69	
	5	36900	68	
6%	1	36900	49	
	2	36900	49	1.00 ± 0.00^{c}
	3	36900	45	
	4	36900	46	
	5	36900	49	
8%	1	36900	30	1.00 ± 0.00^{c}
	2	36900	28	
	3	36900	28	
	4	36900	31	
	5	36900	26	

Table 4: Bulk Density of hollow blocks produced from sawdust of as partial replacement for sand.

Replacement Level (%)	Block Number	Dry Weight(Kg)	Volume (m3)	Mean Bulk Density (Kg/m^3)
0%	1	17.60	0.01274	
	2	17.20	0.01274	
	3	16.99	0.01274	1346.60±22.440^a
	4	16.99	0.01274	
	5	17.00	0.01274	
2%	1	15.90	0.01274	
	2	16.20	0.01274	1257.20±8.871^b
	3	16.00	0.01274	
	4	15.99	0.01274	
	5	15.99	0.01274	
4%	1	15.60	0.01274	1234.80±12.377^c
	2	15.40	0.01274	
	3	15.70	0.01274	
	4	15.60	0.01274	
	5	15.70	0.01274	
	1	14.90	0.01274	
	2	14.96	0.01274	
6%	3	15.00	0.01274	1176.00±7.842^d
	4	15.15	0.01274	
	5	14.90	0.01274	
	1	13.80	0.01274	1090.40±11.908^e
8%	2	13.76	0.01274	
	3	13.80	0.01274	
	4	14.00	0.01274	
	5	14.10	0.01274	

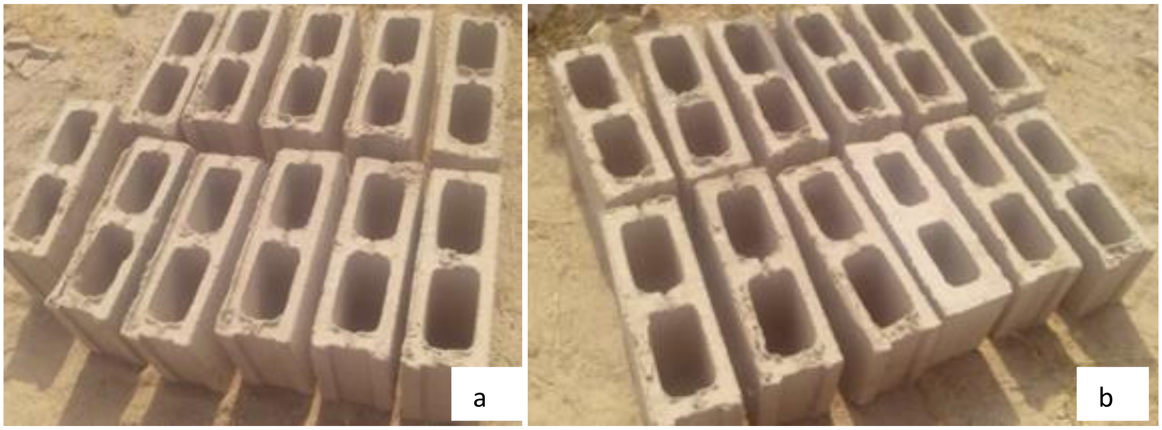

Fig. 2. a. Blocks produced from 0% sawdust replacement for sand. b. Blolocks produced from 2% sawdust replacement for sand

Fig. 2. Blolocks produced from 4% sawdust replacement for sand

DISCUSSION

Water absorption: the water absorption of hollow blocks of this study increased as the percentage replacement of sawdust for sand increases. This may be due to the fact that wood is a hygroscopic material. Hollow blocks with 8% sawdust replacement was the most porous. This absorption rate is less than 16.95% obtained by Anosike *et* *al.,* (2011). And the acceptable value of 12% according to BS 5628: Part 1: 2005. The absorption rate is also less than 18.2% obtained by Ekhuemelo *et al.,* (2016). The reason for increase in absorption may be as a result of trapped air bubbles due to porosity of the sawdust. From the water absorption test result obtained above shows that, there are significant differences among the means of all the replacement levels.

Compressive strength: the mean compressive strength value of 3.20N/mm^2 of sandcrete blocks produced with 100% sand and 0% sawdust from the result obtain is above the minimum standard for load bearing walls of 2.0N/mm^2 according to the National Building Code (2006), and 2.75N/mm^2 according to Ghana Building code (1989). However the mean compressive strength value of 2.0N/mm^2 of 2% and 4% sawdust replacement levels obtained meet the minimum standard for non load bearing walls of 2.0N/mm^2 according to National Building Code (2006) for non-load bearing walls, and N/mm^2 according to Ghana Building Code (1989).

Both compressive strength values failed to meet the 3.5N/mm^2 according to British Standard. Mean compressive strength of hollow blocks produced with 4% and 2% sawdust content were above the minimum requirement of 1.4N/mm^2 according to Ghana Building Code (1989) for non-load bearing walls. The results do not meet the minimum strength of 2.1N/mm^2 and but meet the lowest strength of 1.7N/mm^2 specified by the Federal Ministry of Works (1979) as reported by Tyagher, *et al.,* (2011). The results meet Nigeria National Building Code recommendation of average strength of 6" sandcrete block of 2.00N/mm^2 and lowest strength for individual block of 1.75N/mm^2 sandcrete block (NIS 2000. NIS 87: (2000). Mean compressive strength of hollow blocks produced with 4% and 2% sawdust content were also above 1.5N/mm^2 obtained by Ekhuemelo *et al.,* (2016).

Test result indicates that the compressive strength decreases with increase in sawdust content. This conforms to Adebakin *et al.,* (2012) on their work on the uses of sawdust as admixture in production of low cost and light-weight hollow blocks. From the compressive strength result, there is no significant difference between 2% and 4% sawdust replacement because their mean values are the same. There is also no significant difference between 6% and 8% sawdust replacement level because their mean values are also the same.

Density: bulk density of hollow blocks from sawdust replacement decreased with increase in percentage of sawdust substitution. For all cases considered, the minimum density obtained was 1090Kg/m3 at 28days. This is less than the minimum value of 1500Kg/m3 recommended for first grade sandcrete blocks by NIS 087, (2000) for load bearing walls. The minimum value of density obtained in the study met the requirement of New Technology for Rural Development (2009) which ranges from 1000Kg/m3 to 1100Kg/m3 for non-load bearing walls.

The mean density values of hollow blocks obtained at 0%, 2%, 4%, 6% and 8% replacement levels of sand with sawdust are respectively, 1346Kg/m^3, 1257Kgm^3,1234Kg/m^3, 1176Kg/m^3, and 1090Kg/m^3. The density ranges from 1090Kg/m3 to1346Kg/m^3. These values are lower than those of Raheem (2006) which range from 2073.5 Kg/m3 to 2166.3 Kg/m^3. This may be due to differences in the physical properties of the sand used and the substitution levels of saw dust in the production control. However, this value are also less than the above minimum value of 1500Kg/m^3 recommended for first grade hollow blocks by NIS 087, (2000). From the bulk density test result obtained in table4 above showed that, there are significant differences among the means of all the replacement levels.

As conclusion, it increase in the percentage replacement level of sawdust increases the rate of water absorption or water ratio used. It was also observed that the density of hollow blocks decreases as the percentage replacement levels of sand with sawdust increases. The compressive strength of hollow blocks also decreases as the percentage replacement levels of sawdust increases. To achieve a better result in the use of sawdust in block production, the percentage replacement of sand by weight of sawdust should not be more than 4%. The best sawdust replacement level as obtained in this study were 2% and 4%. Therefore, up to 4% sawdust replacement level of sawdust in hollow blocks production as found in this study is recommended for non-load bearing walls.

It suggests for owners of block industries should adopt up to 4% replacement level of sawdust in block production to reduce cost and minimize the use of sawdust. As second suggestion, the further research should be carried out to evaluate sawdust of different species for sandcrete blocks production.

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