Formation of Ceiling Boards by the Combination of Sugarcane Bagasse and Rice Husk

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Abstract— *Constructing housing components from agricultural wastes have become a special area of research in engineering. Hence a lot of resources is pushed into this to obtain sustainable, eco-friendly and low-cost houses. This work studies some properties of ceiling boards produced from sugarcane bagasse and rice husk. The ceiling boards were produced using water, cement as binder with binder composite ratio of 3:2 by weight, sugarcane bagasse and rice husk of varying ratios by weight from 100% of bagasse to 0% of it with a 25% decrease. The compression of the boards was done manually using moulded block as weight. From the results, it was observed that the ceiling board produced with 100% sugarcane bagasse has better properties to be considered for ceiling board as compared with the most commonly used ceiling boards like Plaster of Paris(POP), asbestos and Poly Vinyl Chloride(PVC). The properties examined are thermal conductivity, thermal resistivity, water absorption and density. The better ceiling board has thermal conductivity to be 2.27W/mK, thermal resistivity of 0.441 mK/W, water absorption of 16.89 and density of 470.3 kg/m^3.*

Keywords— ceiling board; rice husk; sugarcane bagasse; thermal conductivity; thermal resistivity.

1 INTRODUCTION

Ceiling boards are slabs usually horizontal that covers the upper part of a room or internal space. It is not generally considered a structural element, but a finished surface concealing the underside of the roof structure or the floor of a storey above.

It is a shell concealing a roof structure above it. Roof structures could be plain, carry pipes or carry acoustic and thermal insulation. In modern buildings, ceilings carry electric light, security cameras, smoke detectors and more. There are several ceiling materials used in Nigerian homes such as asbestos, Plaster of Paris (P.O.P), Poly Vinc Chloride (PVC) and some use wood each having its own advantages and disadvantages. Some of these have been found to be hazardous to health especially the asbestos which is the most common in the average Nigerian home. Agriculture is native to Nigeria, hence a lot of waste is generated in the farm, during processing and during consumption. Hence a lot of research has been going on to check how agricultural wastes can be used as ceiling boards among other applications which will also compete favorably with the characteristics of the existing ones.

2 LITERATURE REVIEW

2.1 Wood wool composite board

A research on the mechanical properties of wood wool cement composite board using some selected Malaysian timber species was carried out [1]. The work involved using a cement to wood wool ratio of 2 to 1 by weight to make the composite board. From the result obtained, it was found out that the mechanical properties of the board were influenced by the density such that as the mechanical strength decreased as the density decreased. Also, the compressive strength increased with the thicker boards (50mm and 75mm) while as the thickness increased, the modulus of elasticity and modulus of rupture decreased.

2.2 Water melon peels

The suitability of using water melon peels as alternatives to wood-based particleboard composites was studied [4]. Water melon peels composite boards by compressive moulding using recycled low-density polyethylene (RLDPE) as a binder was produced. The RLDPE was varied from 30 to 70% by weight at intervals of 10%. The microstructure, water absorption (WA), thickness swelling index (TS), modulus of rupture (MOR), modulus of elasticity (MOE), internal bonding strength (IB), impact strength and wear properties of the boards were determined. The results showed that high modulus of rupture of 11.45 MPa, MOE of 1678 MPa, IB of 0.58 MPa, wear rate of 0.31 g was obtained from particleboard produced at 60% RLDPE. From the investigation, it was concluded that water melon particles can be used as a substitute to wood-based particleboards for general purpose applications. Aside from being environmental friendly, using watermelon and RLDPE in production of particleboard, it was also found to be very cost-effective.

2.3 Jatropha seed cake

Similarly, a study on the estimation of the properties of composite ceiling boards that employ the use of wood waste particles and jatropha seed cake was carried out [6]. In this work, Predictive models for the simulating physical and mechanical properties of the composite products was done; and used to study the characteristics of bulk density (BD), thickness swelling index (TS), modulus of rupture (MOR), modulus of elasticity (MOE) and internal bonding strength (IB) of the composite ceiling boards analyzed.

Using Equal amounts of jatropha and sawmill dust in the theoretical composite particle/ceiling board, it resulted in values of properties, bulk density 0.8975 g/cm3, thickness swelling index 9.83%, modulus of rupture 25.05 MPa, modulus of elasticity 2.42 GPa and internal bonding strength 13.86 MPa respectively. It was found out that

Improved mechanical properties and denser composite particle/ceiling board can be produced with addition of jatropha to sawmill dust under specified control conditions of fiber-matrix mixture aggregates.

2.4 Rice husk and waste paper

Likewise, the properties of ceiling boards produced from a composite of waste paper(WP) and rice husk(RH) was researched [2]. The composite was prepared using hot water starch as binder. The number of composites prepared were six varying from 100% of rice husk (RH) reducing downward to 0% while the waste paper started from 0% to 100% in a range of 20% each. Samples were prepared to suit the tests to be carried out. They were then oven dried under the temperature of 80^{o}C for 24 hours. Then the samples were tested for water absorption, density, thermal conductivity modulus of elasticity and flexural strength properties. It was observed that the water absorption capacity of the composite material varies between 7.5% and 14.5% and this increases with an increase in waste paper(WP) content. Furthermore, it was found out that the composite exhibited a decreasing thermal conductivity with increasing WO content varying between 0.082- 0.07kW/MK for 0%:100% WP/RH mix to 100%:0% WP/RH mix respectively. Also, the density test showed that the density exhibited a decreasing trend with increase in WP content.

2.5 Sugarcane Bagasse and wood particles

A three-layer experimental particleboard using a mixture of bagasse and industrial wood particles was also investigated [3]. The boards produced were with ratio of the mixture of bagasse and wood particles, in the surface and middle layers given as 20:80, 30:70 and 40:60, respectively using the press times at two levels of 5 and 7 minutes. Two levels of urea formaldehyde resin were selected for the surface layers, namely: 9 and 11 percent. The Modulus of elasticity (MOE), modulus of rupture (MOR), internal bonding (IB) and thickness swelling (TS) of the panels were determined. The results indicated that all mechanical and physical properties of particleboards improved with an upper percentage of bagasse particles added. It was also observed that the treatment with 40% bagasse, 11% resin in the surface layers and with a 7 min press time resulted in an optimum particleboard product.

Haven reviewed literature, it was noted that investigation on the combination of sugarcane bagasse and rice husk has not been done. Therefore, the aim of this study is to investigate some mechanical properties such as thermal conductivity, water absorption, density of locally produced ceiling boards from a combination of sugarcane bagasse and rice husk using cement as its binder.

3 METHODS

The Rice husk used in this study were obtained from a rice mill in Bida, Niger state and the sugarcane bagasse were gotten on the streets of Minna as they were freshly chewed. The Sugarcane bagasse was sun dried for seven days until there was no significant water content. This was ensured by weighing and reweighing after drying using a weighing scale. After the sugarcane was dried, they were sent to the grinding mill to reduce its size. Then, a sieving mesh was used to sieve and get an average size after grinding. The Rice husk was of an appropriate size because they were obtained from the mill.

Ordinary Portland cement was used as binder and was obtained from the building material market in Minna. Hand trowel for mixing was also gotten from the same market. Metallic mould of size 500mm by 300mm by 30mm was manufactured at a welding workshop for the purpose of the study. Furthermore, polyvinyl chloride (PVC), Plaster of Paris (POP) and asbestos ceilings were obtained also so as to compare its property also while testing the manufactured board.

3.1 Preparation of the cement bonded board

Composite, cement in the ratio of 3:2 (respectively by weight) and water, were mixed thoroughly until all the mixture was coated with cement paste. A layer of polyethene was laid in the mould to enhance easy demoulding. Then the cement composite mix is then carefully spread out into the metallic mould. After pouring the mix into the mould, another layer of polythene was place on the mix to prevent the board from sticking to the mould cover during compression. The board was then pressed with the use of blocks for 2-3 days and the demoulded. After demoulding, the boards were cured by wetting and air drying for up to 21days. A total of 10 boards were produced consisting of 2 samples each for the following sugarcane bagasse to rice husk content ratio, 100:0, 75:25, 50:50, 25:75, 0:100 by weight.

3.2 Test Method

The following are the tests carried out and how they were done.

3.2.1 Thermal Conductivity λ:

The thermal conductivity test was conducted by steady plate method according to American society for testing and materials (ASTM) E1225 using a thermal conductivity meter (as shown in appendix A).

The probe consists of a single heater wire and thermocouple. When constant electric power (energy) is given to the heater, the temperature of the wire will rise in exponential progression. Temperature rising curve is plotted in linear line with time axis scaled in logarithm. The angle of this line increases if the sample has less thermal conductivity, and decreases if it has higher Thermal conductivity. Therefore, the thermal conductivity of a sample can be determined from the angle of the rising temperature graphic line. The formula used to calculate the thermal conductivity is as shown.

$$\lambda = \frac{[illegible]}{[illegible]} \quad (1)$$

λ ; thermal conductivity of sample [W/mK]

q ; generated heat per unit length of sample/time [W/m] = 500 for all, but 50 for PVC.

$t_1.t_2$; measured time length [min]

$T_1.T_2$: Temperature at $t_1.t_2$ [K]

3.2.2 Thermal resistivity

Thermal resistance is the ability of a material to resist flow of heat. Thermal resistivity is the reciprocal of thermal conductivity and can be expressed as

$$r = {}^{1}/_{\lambda} \quad (2)$$

Where r=thermal resistivity(mK/W)

3.2.3 Density:

This test was carried out according to the ASTM D1475 method. Sample was poured into the pycnometer and weighed. The weight was recorded as *W,* and the weight of the empty pycnometer as, *w,* in grams. The density was calculated in grams per milliliter as follows:

$$D = \frac{W - w}{V} \quad (3)$$

Where:

D = density g/ml. (1g/ml=1000kg/m^3)

V = volume of pycnometer ml

3.2.4 Water Absorption Test

The samples were air dried at 323 K up to a constant weight and then immersed in a static deionized water bath. The specimens were taken out of the water at certain periods of time, wiped with tissue paper to remove surface water, reweighed and immediately put back into the water. The water absorption test was conducted according to ASTM D570 method. At least three specimens for each sample were used and the average values were reported. The percentage of water absorption (WA) was calculated by the weight difference between the samples exposed to water and the dried samples according to the following equation:

$$WA(\%) = \frac{m_f - m_i}{m_i} * 100 \quad (4)$$

where: M_f is the mass of the sample after immersion (g)

and M_i is the mass of the sample before immersion (g).

The water absorption was determined by weighing on a balance with precision of 0.001 g.

4 RESULTS AND DISCUSSIONS

The thermal conductivities and resistivities of the composite as compared to the available ceiling boards are summarized in figure 1

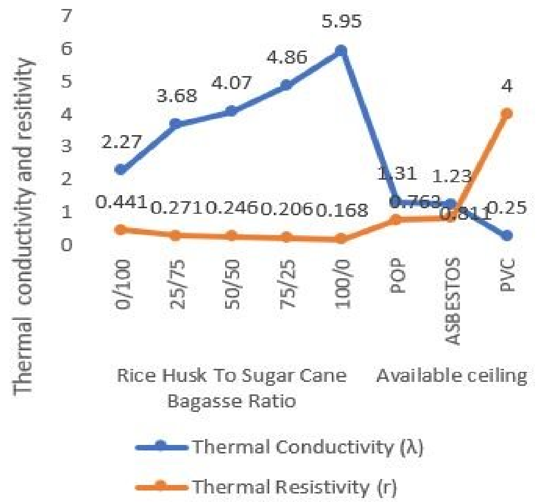

Figure 1: Thermal conductivity and resistivity test result from the composite and available ceiling

The results showed that the thermal conductivity of the composite increased as the amount of the rice husk increased. This is to say that sugar cane bagasse has a higher thermal resistance than rice husk. Among the available ceiling boards currently in used, the widely used POP has a lower thermal resistivity than the rest of its counterparts while PVC has the highest resistivity.

The above results show that using sugarcane bagasse alone to make a ceiling board will suffice for thermal applications. It will be more efficient if used with another binder that can withstand hot compress. Also, there is a possibility that it will compete with POP for thermal applications if some additives are added to it.

The water absorption of the composite as compared to the available ceiling boards are as shown in figure 2

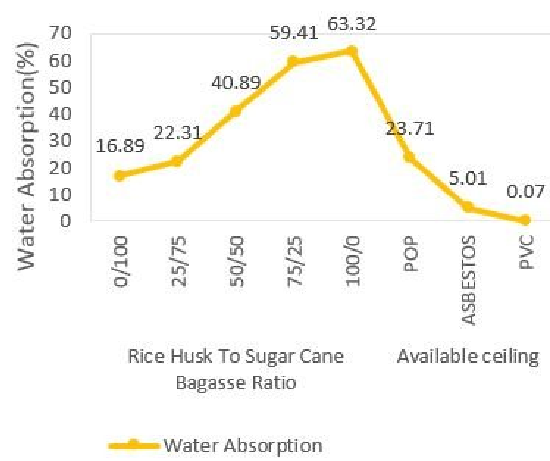

Figure 2: Water absorption test result from the composite and available ceiling

The results show that the water absorption also increase as the percentage of the rice husk increased. This trend is similar to what was observed by that the water absorption capacity is more in composites having more rice husk [5]. The ratios with the lowest absorption are rice husk to bagasse ratios 0:100 and 25:75. And these ratios are higher than Plaster of Paris. Asbestos and PVC are far away from it and are better for water absorption.

The result for density of each composite is as shown in figure 3

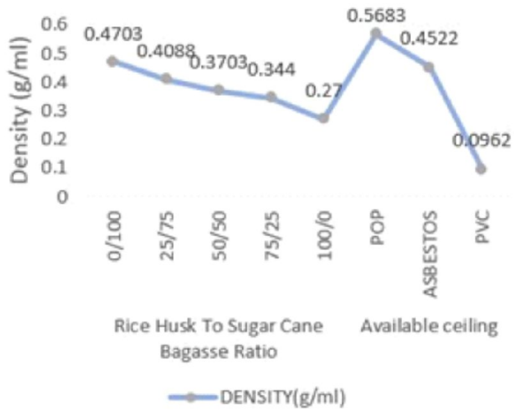

Figure 3. Density test result from the composite and available ceiling

The density of the composites decreased with an increase in the percentage of rice husk. The densest has been the one with lower thermal conductivity and water absorption.

5 CONCLUSIONS

In conclusion, the result of this experimental study showed that the most applicable composite as compared with the available ceiling materials for use for thermal applications is the ratio 0:100 (Rice husk: Sugarcane bagasse). Also, the higher the density the better for use as ceiling board.

After this study it can be recommended that the following are done for further improve on the quality and usability of this kind of ceiling board

i. A water-resistant binder be used to improve the water absorption rate of the materials.

ii. Ceiling boards be produced with a hot press as this might impact the thermal conductivity.

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8 APPENDIX A