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POTENTIALS OF SORGHUM STALK IN THE PRODUCTIONS OF CEILING BOARDS

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Abstract

This research work is centered at studying the potentialities of sorghum stalk in the production of ceiling boards. Other materials like saw dust, sugar cane bagasse, rice husk and waste paper were used by other researchers for the production of ceiling boards excepting sorghum stalk. Sorghum is one of the most widely agricultural crops cultivated in Nigeria but its residues (stalk) are mostly unused. In this research work, sorghum stalk is ground to particles and was mixed with adhesives (gum Arabic, kaolin and white cement) and water to form a paste that was cast in molds. The molds are of 2400 x 1200 x 20 mm, 2400 x 1200 x 10 mm, 2400 x 1200 x 5 mm. 1200 x 1200 x 20 mm, 1200 x 1200 x 10 mm, 1200 x 1200 x 5 mm, 600 x 600 x 20 mm, 600 x 600 x 10 mm, 600 x 600 x 5 mm. After allowing the cast paste to adequately dry for 7 days, the boards are tested for density, water absorption capacity and thermal conductivity. The tests are conducted using direct method, ASTM D570 and ASTM E1225 respectively. Two ceilings from the same mold 600 x 600 x 20 mm, using (gum Arabic) and (gum Arabic + kaolin + white cement) with density of 1.04 kg/m^3, thermal conductivity of 0.079 W/mK have firm physical condition.

Keywords: ceiling, Sorghum stalk, gum Arabic, kaolin, white cement, density, water absorption, thermal conductivity

1.0 Introduction

Nigeria is the second largest producer of Sorghum, with the majority of domestic production for household consumption/fodder. Sorghum is produced in virtually all the States in Nigeria, though some States produce more than others. Plateau, Kano, Kaduna, Sokoto, Gombe, Bauchi, Zamfara, Benue, Kogi, Nassarawa, Yobe and Taraba are major Sorghum producing States. It is grown on about 5.6 million hectares in Nigeria (INDORAMA FERTILIZERS, 2020). Ceiling is an overhead internal surface that covers the upper area in buildings. It is used in wall finishes of no concrete walls. Ceiling sheets are used as building materials in protecting the internal area of buildings from the effect of heat radiation generated from metallic roofs and walls (zinc and aluminum). Ceiling Sheets used in Nigeria are mostly imported either from Brazil, China or Holland. The availability of sorghum residues especially in the northern part of Nigeria is under utalised. Some of which normally perish on the farm land by termites or subsequent years rainfall destruction with the exception of those consumed by hungry ruminant animals. Farmers use, normally, to burn the sorghum residues at the beginning of every rain season so as to allow for ridging and planting of new crops.

This research covered the use of sorghum stalk with Gum Arabic, Kaolin and White Cement as additives in the production of ceiling boards. The process has not considered the use of saw dust, rice husk and waste paper as considered by other researchers.

The most available ceiling boards in the market are sized 2400 x 1200 mm. Different materials were used in different proportions to test their potentialities in the production of ceilings. Combination waste paper and rice husk was used in the production of ceiling boards. Tests of flexural strength, modulus of elasticity, water absorption and thermal conductivity were found to range between 0.03N/mm^2 to 0.1 N/mm2, 1250N/mm2 to 1320N/mm^2, 7.5% to 14.5% and 0.07kW/MK to 0.082kW/MK respectively (Ataguba, 2016).

Sugar cane bagasse being the largest residue from Brazilian agroindustry and bamboo stalk leaves obtained in most parts of Brazilian agriculture properties were found to have the potentials of being used in the production of ceiling board. The boards produced met esthetic expectations for use in housing as ceilings and walls without any need of paint. The combination of sugar cane bagasse and bamboo stalk leaves can also be used to produce homogeneous particle boards (HPB) with varying densities from 0.9 to 1.0 g/m^3 (Camila *et al*, 2009).

In another development, rice husk, in combination with sugar cane bagasse was used in the formation of ceiling boards by manual compression. It has been observed, after varying the mix ratio, that 100% sugar cane bagasse has more suitable properties (thermal conductivity 07 2.27W/mK, thermal resistivity of 0.441mK/W, water absorption capacity of 0.68% and density of 470Kg/m^3) to be considered as ceiling boards (Jesuloluwa and Bori, 2018).

Moreover, Waste paper and Sawdust material were separately used in the formation of ceiling boards. These were achieved using cement, calcium carbonate, kaolin, starch and water. Waste paper was found to be suitable if it is cast at 40% with 15%, cement, 10% kaolin, 10% calcium carbonate, 10% starch and 15% water. On the other hand, suitability was recorded when a mix of 40% saw dust, 10%, cement, 10% kaolin, 15% calcium carbonate, 10% starch and 15% water.

A three-layer experimental particleboard using a mixture of bagasse and industrial wood particles was also investigated and 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 (Ghalehno *et al*, 2013).

Some species of Malaysian fast grown timbers had their wood wool mixed with cement at a ratio of 2:1 in an attempt to produce composite ceilings. From the boards produced, it was observed that mechanical strength increase with increase in density while thickness is inversely related to modulus of elasticity and modulus of rupture (Ahmad et al, 2011). Water melon peels were also used to produce boards using Recycled Low-Density Polyethylene as a binder. It was realized that, the peels can replace wood based particle boards for general applications and of lesser cost (Idris et al, 2011). Particles of wood waste were also used in a trial to produce ceiling boards using Jatropha Seed Cake as an additive. That has reduced the environmental effect of wood waste

2.0 Materials and Methods

2.1 Materials

The materials to be used in this research work will includes
Sorghum stalk
Iron sheets
Adhesives (Gum Arabic, white cement and kaolin)
Water as mixing agent
Pressure weights for avoid pore spaces

Smooth Polythene

2.2 Methods

In this research work, sorghum stalk was to pass sieve size 10 mm of BS 882, 1992 to avoid larger particles in the paste.

Iron sheets of 1.5 mm thick were shaped to form molds of 2400 x 1200 x 20 mm, 2400 x 1200 x 10 mm, 2400 x 1200 x 5 mm. 1200 x 1200 x 20 mm, 1200 x 1200 x 10 mm, 1200 x 1200 x 5 mm, 600 x 600 x 20 mm, 600 x 600 x 10 mm, 600 x 600 x 5 mm. This was adopted for being full dimension, half bat dimension and quarter of the conventional ceiling boards in the society. After casting, the boards were allowed to adequately dry for seven days in an open space of less than 20% humidity. Thereafter, the boards were tested for density, water absorption and thermal conductivity.

2.2.1 Density Test

In this test, the dried ceiling panels are weighed; having known their dimensions, the volume of each was computed. After which the densities were computed. Results of which are as tablated in table 1

2.2.2 Water Absorption Capacity

Dried samples of the ceiling panels were weight before immersion in water. The wet samples were wiped using a cotton cloth to be free of running water. The samples are weighed after removal from water in accordance ASTM D570. Computation of the water absorption was done using average of the weights of three samples each, using the following formulae

$$WA = \frac{W_2 - W_1}{W_1} X100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where W1 = weight of the dry sample

W2 = weight of the wet sample

The variation of the thickness of the ceilings at 20 mm, 10 mm, and 5mm was for the purpose of selecting the best in terms of flexural strength, modulus of elasticity, water absorption and thermal conductivity.

2.2.3 Thermal Conductivity

This test was conducted using ASTM E1225 using the guarded-Comparative-Longitudinal Heat Flow Technique. Thermal conductivity is computed using the following equation

$$k = \frac{Qd}{A\Delta t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. 2$$

Where

Q = Amount of Heat Transferred (W/mk)

D = Distance between the Two Isothermal Planes (m)

A = Surface Area of the Sample (m^2)

Δt = Temperature Difference (k)

2.3 Sample Denotation

A: 2400 x 1200 x 20 mm

B: 2400 x 1200 x 10 mm

C: 2400 x 1200 x 5 mm

D: 1200 x 1200 x 20 mm
E: 1200 x 1200 x 10 mm
F: 1200 x 1200 x 5 mm
G: 600 x 600 x 20 mm,
H: 600 x 600 x 10 mm
I: 600 x 600 x 5 mm.

4.0 Results

4.1 Density

After testing for the weights of all the casted ceiling boards and having computed the volume of each mold using dimension of the molds, densities of the boards are computed and tabulated in table 1

Table 1: Density of the Ceiling Boards

Sorghum Stalk Powder with..	**Average Density (Kg/m^3)**
Gum Arabic	1.04
White Cement	5.72
Kaolin	6.16
Gum Arabic + Kaolin	4.00
Gum Arabic + White Cement	3.02
Kaolin + White Cement	5.82
Gum Arabic + Kaolin + White Cement	4.34

It can be observed from table 1, that kaolin contributes to denser ceiling board while gum Arabic contributes to lighter ceiling boards. Kaolin and white cement are denser in nature and are expected to produce denser ceiling products if compared to Gum Arabic that melt in water in preparation for use. Hence, the variation in density of up to 5.12 Kg/m^3 is observed. To encourage the importance of ligh weight construction material, ceilings with low densities may be preferred.

4.2 **WATER ABSORPTION**

Under normal circumstance, ceilings are not having any contact with water. However, when roofing sheets developed problems, water leaks to attack and destroy ceiling board before the occupants will observe.

Table 2: Water Absorption Capacity

Sorghum Stalk Powder with..	Average Water Absorption (%)
Gum Arabic	101
White Cement	72
Kaolin	104
Gum Arabic + Kaolin	102
Gum Arabic + White Cement	90
Kaolin + White Cement	53
Gum Arabic + Kaolin + White Cement	118

4.3 Thermal Conductivity

Ceilings are basically put in buildings to disallow solar heat radiation inside the buildings. Therefore ability to conduct heat by the produced ceiling was measured. Efficiency of ceilings is inversely measure by its ability to conduct heat. Results of the thermal conductivity is shown on table 3

Table 3: Thermal Conductivity

Sorghum Stalk Powder with..	Average Thermal Conductivity (W/mK)
Gum Arabic	0.079
White Cement	0.070
Kaolin	0.071
Gum Arabic + Kaolin	0.074
Gum Arabic + White Cement	0.076
Kaolin + White Cement	0.069
Gum Arabic + Kaolin + White Cement	0.077

From the results, it can be observed that, boards with gum Arabic have higher thermal conductivities. In terms of thermal conductivity, ceilings with lower thermal conductivity are better. All the samples are within a close range of 0.069-0.079W/mK.

4.5 Physical Condition after Drying

After de-molding and adequately drying the ceiling boards, condition of the their physical look are as tabulated below. Ceilings with thickness of 5mm appeared to break in all cases except those with gum Arabic.

Table 5: Physical Condition after Drying

Sorghum Stalk Powder with..	Physical Condition
Gum Arabic	Firm
White Cement	Loose
Kaolin	Loose
Gum Arabic + Kaolin	Fairly firm
Gum Arabic + White Cement	Fairly firm
Kaolin + White Cement	Very loose
Gum Arabic + Kaolin + White Cement	Very firm

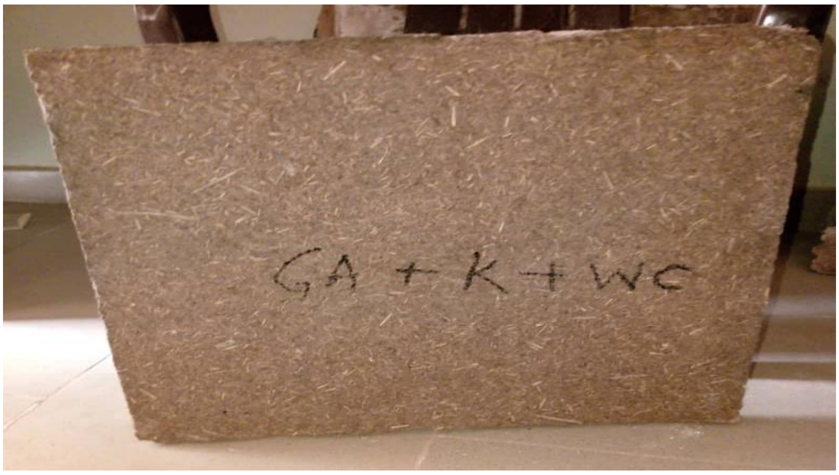

Plate 1: A sample of the produced ceiling board

Conclusion

The use of sorghum stalk in the production of ceiling was tested. Gum Arabic, Kaolin and White cement were used as binders. Water was used as in dissolving the binders to make them usable. Density water absorption capacity and thermal conductivity of all the samples were tested in the laboratory. Physical appearances of the produced ceilings were also observed. Those with gum Arabic only are found to have an average density of 1.04kg/m3 which is far below that with kaolin which has 6.16 kg/m^3. Ceilings boards with the gum Arabic as binders have higher water absorption capacity of 118%. This can be reasoned with low density which indicates higher porosity. Thermal conductivities of all the produced ceilings are within the range of 0.069 and 0.079 W/mK. In terms of physical condition, those produced with gum Arabic as binder and partial binder have better shape and flexibility.

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