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# Physicomechanical Characterization of Ceiling Board Produced from Waste Biomass Materials and Gum Arabic Adhesive

Alexander Asanja JOCK

Department of Chemical and Petroleum Engineering, University of Uyo, PMB 1017, Uyo, Nigeria

jockalexander@uniuyo.edu.ng

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**Abstract:** *Ceiling board is a composite product manufactured from particles of wood or other cellulosic fibre materials using adhesive as a binder. The need for shelter and structural accessories such as ceiling sheets is in high demand. In this study, the physicomechanical properties of ceiling boards produced with different blending proportions by weight of saw-dust and waste carton paper using gum Arabic were determined. Physical and mechanical tests such as water absorption, bulk density, tensile strength, modulus of elasticity, compressive strength, friction test and impact resistance were carried out on the produced ceiling boards. The findings revealed that the board C2 has the highest density (882kg/m$^3$) and lowest values of water absorption (10.23 %) at 24 h soaking, tensile strength (26.4 kpa), Young's modulus of elasticity (0.31 Mpa) and coefficient of friction (0.65). These properties are within the America Society for Testing and Materials (ASTM) standard for medium density fibre-cement ceiling board. Thus the potential of sawdust and waste carton materials in the formulation of ceiling board is feasible.*

**Keywords:** *Ceiling board, characterization, physicomechanical properties, sawdust, waste carton.*

## 1. INTRODUCTION

The use of wood waste can generate environmental issue because of the various treatments of the wood which leads to numerous contaminants that can be leached out, disturbing the wood cement compatibility and also limiting the potential range of application due to the toxicity of the waste [1].

Huge quantities of post-consumer waste timber are generated worldwide especially in developing countries at a significant rate and the level of its recycling is small when compared with other construction and demolition wastes [2]. Nigeria is endowed with abundant natural resources from forest reserves majorly found in the southern part, with sawmills accounting for over 93% of the entire wood processing industries, leading to generation of huge amount of wood waste [3].

The major marketable product of most forest is wood (timber), fuel-wood, pulp and paper, providing an estimated timber equivalent of 3.4 billion cubic meters a year globally [4]. The wood when converted for use in industries, it produces waste in form of chippings, slabs, off cuts, sawdust and shavings, which are generally discarded as waste. Sawdust is a by-product of wood, which is produced from sawing of wood [5].

Different agricultural products and wastes such as corn cob, corn stalk, coconut fibres, rice husks, rice, bagasse, cereal, palm leaves oil, bamboo, straw, palm kernel, cotton stalks, kenaf, sunflower hulls and stalks, banana stalks, durian peel among others have been investigated for the production of particleboards, hardboards and fibre boards, with emphasis on their thermal insulation capabilities [6, 7].

Amongst many methods of waste management, collection and recycling is one of the best methods of waste wood management. Waste paper are generated daily in tons, which can be recycled and converted into useful products, otherwise used as a secondary fibre which can also serve as a filler material in fibre reinforced composite production. More frequent use of waste paper in fibre reinforced composite production may likely prevent the present and future menace that the enormous waste paper generated would have caused [8].

These wood wastes as well as waste paper could be reused by sorting, processing and utilized as raw materials for the development of particle boards and fibre boards. It could be used as ceiling boards, flooring, wall and office dividers, furniture, cabinet, bulletin boards and desktops [9]. Ceilings are panel sheets covering the upper layer of an internal section of a building which improves its aesthetics and reduces sound and heat transmission in the house; it is an essential part in the building process which plays a key role in the thermal comfort of a building [10].

Ceiling board is composite products manufactured from particles of wood or other cellulosic fibre materials using adhesive as a binder. The use of waste wood and waste paper in the production of ceiling board is of good economics for building purposes. The quality of ceiling board depends on the properties of the materials used. The aim of this study is to characterize ceiling board produced from saw-dust and waste carton paper using gum Arabic for physicomechanical properties.

## 2. MATERIALS AND METHOD

### 2.1 Samples Collection and Preparation

Sawdust was collected from Band saw mills at Itam Timber market, while the waste carton materials were obtained from refuse dump site both in Uyo, Akwa Ibom State, Nigeria. The sawdust was washed with water to remove dust, fungus and other foreign materials. The sample was sun dried for 48 h and further dried in an oven at 110 °C for 4 h. The dried sample was pulverized and sieved through 75 µm, 250 µm and 500 µm particle sizes for fine, medium and coarse fractions respectively.

The waste cartoon materials were cleaned dried in the sun for 12 h and also oven dried at 110 °C for 4 h. The dried carton waste was shredded into smaller sizes of about 1 cm and soaked in distill water for 48 h and stirred vigorously for homogeneity. The gum Arabic was pulverized, dissolved in 50ml of boiled water and was stirred gently until a uniform sticky mass was obtained.

### 2.2 Production of Ceiling Board

The procedure used for production of the ceiling board was adopted from [11] using the following steps; sorting, beating, mixing, moulding, drying and trimming as shown in Figure 1.

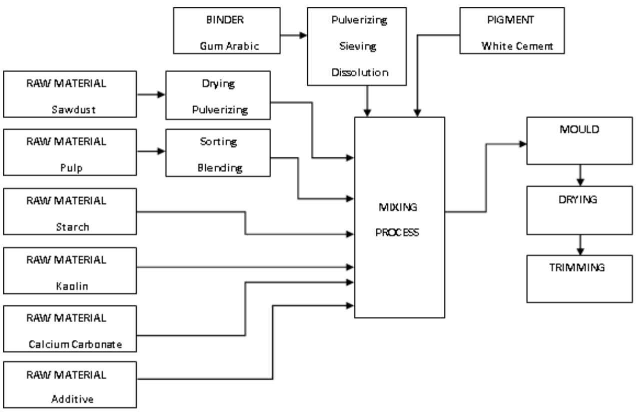
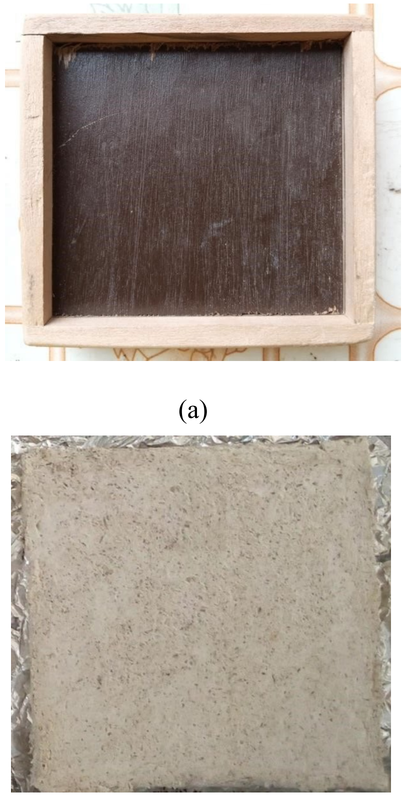



Figure 1: Schematic representation of the production process of composite ceiling board

For the production of batch A1, 60g saw-dust and 60g soaked carton waste (pulp) were stirred gently, then continuously until properly mixed. 30g each of kaolin, calcium carbonate and starch with 35g of white cement were added to the mixture and stirred. Dissolved gum Arabic sieved with a nylon cloth was also added and stirred with a stirring rod gently and continuously until it was well mixed and form a mat of homogenous slurry phase. The formed material was then poured into a wooden mould of dimensions 10cm by 10cm by 1.5cm and compressed using a pressure of $1.37Nm^{2.}$ It was allowed to set for 24 h, thereafter, the produced ceiling board was carefully removed from the mould. It was dried at room temperature for 24 h and then in an oven at 7°C for 48 h. The procedure was repeated by varying the proportions of the ingredients to obtain other batches, A2, B1, B2, C1 and C2 as presented in Table 1. The fabricated wooden mould and the produced ceiling board sample is shown in Figure 2.

Table 1: Composition of blending materials for the production of ceiling board

| Materials | Sample composition (100%) | | | | | |
|---|---|---|---|---|---|---|
| | A1 | A2 | B1 | B2 | C1 | C2 |
| Sawdust | 21.82 | 24.50 | 30.19 | 32.00 | 15.38 | 8.00 |
| Pulp | 21.82 | 24.50 | 15.09 | 8.00 | 30.77 | 32.00 |
| Gum Arabic | 10.91 | 6.67 | 11.32 | 3.33 | 11.54 | 3.33 |
| Kaolin | 10.91 | 5.00 | 11.32 | 12.67 | 11.54 | 12.67 |
| $CaCO_3$ | 10.91 | 15.33 | 13.21 | 20.00 | 15.38 | 20.00 |
| Starch | 10.91 | 3.33 | 7.55 | 3.33 | 3.85 | 3.33 |
| White cement | 12.73 | 20.00 | 11.32 | 20.00 | 11.54 | 30.00 |
| $CaCl_2$ | - | 0.67 | - | 0.67 | - | 0.67 |



(a)

(b)

Figure 2: (a) Wooden mould and (b) Ceiling board sample

### 2.3 Physicomechanical properties of ceiling board

The following physicomechanical properties: density, water absorption, modulus of elasticity, tensile and compressive strength, impact resistance and frictional test of the produced ceiling board were conducted based on the established standard prescribed by ASTM.

#### 2.3.1 Water absorption

The type of materials and additives are some of the factors that affect water absorption. The water absorption capacity of the ceiling boards was done based on ASTM D1037 (1999) standard [12]. The water absorption was determined at 24 h was calculated using Eq. 1.

$$water\ Absorption = \frac{W_2 - W_1}{W_1}\ X\ 100\% \quad (1)$$

Where $W_1$ is the weight of dried sample and $W_2$ is the weight of sample after immersion in water.

#### 2.3.2 Density

Density of the ceiling board was evaluated according to ASTM D1037 (2012) standard [13] and was calculated using Eq.2

$$Densty = \frac{Mass}{Volume} \quad (2)$$

#### 2.3.3 Tensile Strength

This was carried out using the Mohan Brothers Tensile testing machine CAP, 500KG$^F$ ISO9001 model. The samples were prepared for this test according to ASTM D1037 (2012) standard [13]. Each sample was carefully placed in the tensile testing machine and clamped at both ends. The machine was turned on and the load at which each sample fractured was recorded. The tensile strength was calculated using Eq.3.

$$Tensile\ strength = \frac{Maximum\ load}{Original\ cross\ section\ area} \quad (3)$$

#### 2.3.4 Compressive Strength

Compressive test was carried out using the AMBROS universal testing machine and performed as highlighted by ASTM D1037 (2012) standard [13]. The specimens were prepared according to this standard with dimension 20mm by 20mm and were tested on a support span of 130mm as per the standard. The load at which each sample was compressed as a result of the force applied on it by the machine was recorded. The compressive strength was calculated using Eq. 4.

$$Compressive\ Strength = \frac{Maximum\ load}{Original\ cross\ section\ area} \quad (4)$$

#### 2.3.5 Impact Resistance

This was carried out using a pendulum impact testing machine JBS-300N model. Standard sample was prepared of dimensions 1cm by 8cm size maintaining the original of 0.5 cm. It was then placed on the plate of the impact test machine wherein the handle jack was carefully released for the load to strike the ceiling board sample. After which the energy of impact was recorded. The impact resistance strength was determined using Eq. 5.

$$Impact\ Resistance = \frac{Absorbed\ energy}{Cross\ section\ area} \quad (5)$$

#### 2.3.6 Friction Test

Friction test was conducted using the Cusson's friction test device graduated from $0^o$ - $90^o$ and was performed based on ASTM D1037 (1999) standard [12]. The sample was placed on an inclined surface of the equipment and the angle at which the specimen slides down the surface freely was recorded. The coefficient of friction was calculated using Eq. 6.

$$Coefficient\ of\ Friction = tan\theta \quad (6)$$

where $\boldsymbol{\theta}$ is the angle of repose

#### 2.3.7 Modulus of Elasticity

Young's Modulus of Elasticity $(Y)$ is stress per unit strain and was calculated using Eq. 7

$$Y = \frac{Stress}{Strain} \quad (7)$$

## 3. RESULTS AND DISCUSSION

**Physicomechanical Properties of Produced Ceiling Board**

The physicomechanical properties of the produced ceiling board samples are summarized in Table 2. The density for the various combinations of sawdust, waste carton and other additives ranged from 882kg/m$^3$to 510 kg/m$^3$. It is observed that the board C2 has the highest density. The high density in C2 could be due to high amount of calcium carbonate and white cement with low sawdust content in formulation. The density of the board is a function of fibre to cement ratio and increases from A1 to C2. This trend is in agreement with an increase in calcium carbonate and cement content. The density of board has effect on the mechanical properties as increasing density can cause higher compaction ratio in the board. The densities of the produced ceiling board are comparable to those of wood production industries which range between 590 and 800kg/m$^3$ [14].

Figure 3 presents the water absorption of the ceiling board samples for 24 h. The highest water absorption was obtained in A1 as presented in Table 1. The variation in water absorption could be due to the different particle sizes of sawdust and the mixed proportions the ceiling board ingredients used in the formulation as well as the hygroscopic nature of lingocellulose fibres which allow for moisture intake. Decrease in sawdust and increase in cement content reduce the rate of water absorption. This could be attributed to hydrophilic nature of sawdust and hydrophobic nature of cement. The water absorption values confirmed that lingocelluloses generally tend to rise the hydrophilic nature of cement-bonded wood composite due to large number of porous structures which accelerates water penetration through capillary [15].

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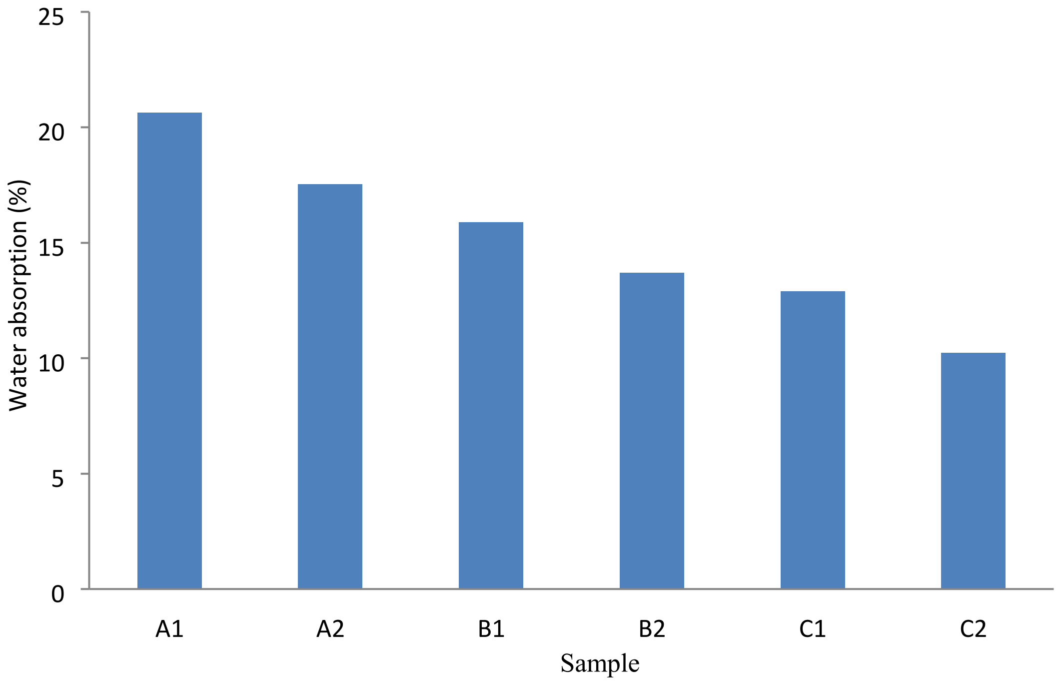


Figure 3: Water absorption of formulated ceiling boards at 24 h and 25 °C

Table 2: Physicomechanical characterization of formulated ceiling board

| Sample | Properties | | | | | | |
|---|---|---|---|---|---|---|---|
| | Density ($kg/m^3$) | Water absorption (%) | Compressive Strength (MPa) | Tensile Strength (KPa) | Impact Strength ($KJ/m^2$) | Coefficient of Friction | Modulus of Elasticity (MPa) |
| A1 | 510.20 | 20.62 | 106.00 | 75.00 | 1720.00 | 0.70 | 1.23 |
| A2 | 585.71 | 17.53 | 133.00 | 81.00 | 1789.50 | 0.67 | 1.94 |
| B1 | 724.34 | 15.90 | 98.20 | 61.00 | 1660.70 | 0.73 | 1.69 |
| B2 | 807.29 | 13.71 | 82.70 | 264.30 | 1338.35 | 0.70 | 2.23 |
| C1 | 542.77 | 12.90 | 66.50 | 46.00 | 828.57 | 0.67 | 0.82 |
| C2 | 881.92 | 10.23 | 65.30 | 26.40 | 819.05 | 0.65 | 0.31 |

The tensile strength of a material is a measure of the force required to pull a material to the point where it breaks. Table 2 revealed that the tensile strength of C2 is the lowest compared to other samples. This could be due to the low amount of sawdust and high cement content used in the formulation of the sample.

The compressive strength which is the capacity of a material to withstand axially directed pushing forces was higher in A2 with highest fibre content. This implies that A2 will have a greater resistance to compressive loading than C2 with lower compressive strength as presented in Table 2.

Impact strength is the resistance of a material to fracture by a blow, expressed in terms of the amount of energy absorbed before fracture. This implies that the ability of each board to absorb energy when fractured at high velocity decreases. The impact strength of the samples presented in Table 2 is between 819.05 and 1720 $KJ/m^2$. Sample A2 (1:1 sawdust to pulp ratio) exhibited the highest impact strength and C2 (ratio 1:4 sawdust to pulp) the lowest. The low value obtained in batch C2 could be due to high in the amount of pulp used in the formation. However, the impact strength of the samples agreed with the result obtained by [16].

The coefficient of friction of batch B1 has the highest value (0.73) and C2 the lowest (0.65). These values are however similar indicating that all the boards showed close response to free falls over the same surface.

The modulus of elasticity (MOE) is a measure of the stiffness of an elastic material. It depends on the stress and strain or elongation of the material. Samples C1 and C2 with the lowest modulus of elasticity may have lower stiffness as compared with A1 and B2 having the highest. The MOE values of the boards are close and within the minimum acceptable value of 0.55Mpa specified by the American National Standard [14].

## 4. CONCLUSION

Ceiling board was produced from sawdust and waste carton materials using gum Arabic as binder. The density is of the ceiling board was between 510 and 882kg/m$^3$. The physical and mechanical properties of samples are close with the America Society for Testing and Materials standard for medium density fibre-cement ceiling board. Therefore, ceiling board with better physicmechanical properties can be produced technologically from saw-dust and waste carton using gum Arabic as binder. Hence, the production of the ceiling board from waste materials will help in cleaning up the environment and creating wealth from waste.

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