Research Article

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Properties of particleboard produced from discarded sawdust and cassava waste blends

Abstract

The felling of wood has resulted in environmental problems such as deforestation and climatic change. One way of solving this problem of high demand is by sourcing alternative raw materials for the production of particleboards. In the prevailing literature, there is a lack of methodical studies including variation water adsorption of particleboards developed from sawdust and cassava waste (starch) in the tropics and exposure period, and trends of compaction and bulk density of the particleboard and cement fraction. In this research, for (i) enhancing the particleboard produced from sawdust waste and cassava starch, (ii) increasing use of cement fraction was employed, (1) key properties particleboard produced were determined according to ASTM standards, and (2) finally, regression models as a function of cement content were postulated for the water adsorption. The water-absorbent of the particleboard increased with the increase in the exposure period and cement content. Water adsorption (W_a) is correlated with cement fraction through the least square regression method. The quadratic equation is appropriate for W_a at the different exposure periods. The R^2 values range from 0.9984 to 0.9996, expressing these equations marginally reflect the discrepancy of W_a. The higher changes in the compressive strength and bulk density of the particleboards at the higher cement blend compared to those lower and no cement blends, implying better compaction between the mixture of sawdust-starch. The results of the study can help physical property collection for the particleboard industry and guide for improving the properties of particleboards in the tropics.

Keywords: natural adhesive, cement-bonded particleboard, water absorption, compressive strength, sawdust

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Olusegun D. Samuel,[1] Ajayi R. Oyelayo,[2] Peter A. Oghenekowho,[1] Idubor I. Fabian,[3] B.H. Akpeji,[4] Ikuobase Emovon[1]

[1]Department of Mechanical Engineering, Federal University of Petroleum Resources, Nigeria
[2]Department of Mechanical Engineering, Osun State University, Nigeria
[3]Department of Marine Engineering, Federal University of Petroleum Resources, Nigeria
[4]Department of Chemistry, Federal University of Petroleum Resources, Nigeria

Correspondence: Olusegun D Samuel, Department of Mechanical Engineering, Federal University of Petroleum Resources, Effurun, Delta State P.M.B 1221, Nigeria, Email samuel.david@fupre.edu.ng

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Introduction

The increase in the demand for wood and wood-based products is the main cause of deforestation and this has serious environmental effects, such as loss of biodiversity and climate change, on our society. Particleboard, which is the chief of all wood-based composites consumes 57% of all wood panels and its use is increasing 2-5% annually.[1] The problem of the wood industry is that the waste product poses land and air pollution as they are allowed to lie waste until they decompose. An increase in the demand for wood and wood-based products is the main cause of deforestation and this has serious environmental effects, such as loss of biodiversity and climate change, on our society. One way of solving this problem of high demand is by sourcing alternative raw materials for the production of particleboards. Much has been done in this regard to reduce the pressure on the forest by replacing wood, either partially or completely, with sycamore leaves,[2] agricultural waste,[3] maize stalk,[4] waste paper,[5] Kenaf,[6,7] wheat straw,[7,8] rice straw,[9] corn pith,[8] paper sludge,[10] waste tire rubber,[11] cotton carpel chips,[12] almond shell,[13] oil palm, and trunk biomass waste[14,15] and palm kernel shell[16] in the manufacture of particleboards of different densities. The combined issue of scarcity of raw material and pollution can be tackled by recycling and reusing wood products and wastes. Several wastes have been explored for the production of particleboards. For example, Sawdust[16,17] and wood particle char[18] with the combinations of other materials have been successfully exploited to make particleboards.

Methods in the production of the particleboards vary. Marashdeh et al[7] & Xu et al.[19] hinted that particleboards can be developed without a binder. However, other researchers[20,21] highlighted the feasibility of producing novel particles with either binders or adhesives. As expected, Moubarik, et al.[22] stated that particleboard formulated with binder/adhesives have enhanced mechanical and thermophysical properties compared to that of the board without adhesives/binders. A major drawback to the use of adhesive is the emission of harmful substances from synthetic adhesive-based particleboards that may result in adverse environmental and health issues.[23] Refs,[23, 24] posited that owing to the eco-friendliness nature of natural binder adhesive, they are is capable of curtailing the harmful emissions. Cement-bonded particleboards are becoming common due to improved properties such as modulus of rupture, modulus of elasticity, thickness swelling, and water absorption.[3,4,25] The compatibility of cement and wood/wood particles can be improved either by pre-treating the wood with hot water[26] or CO_2 curing.[27] The effect of particle size and geometry on the properties of particleboard has been investigated by some researchers. Miyamoto et al.[28] reported that linear expansion and internal bond strength of particleboards increased with decreasing particle size while thickness swelling decreased. Also, effects of particle size on the mechanical properties of particleboard have been reported. For instance, Marashdeh et al.[29] stated that the particle size influences the internal bond strength and dimensional stability of the properties of particleboard while Yang et al.[9] concluded that the particle size does not influence the properties of particleboard. Sotannde et al.[24] stressed that the heterogeneous particle sizes tend to enhance bending strength properties. However, to the best of the authors' knowledge, there is the absence of preliminary investigation on the effect of blending of additives on the properties of particleboards produced from cement and sawdust and starch extracted from cassava and explored as a natural adhesive. The study will go a long way in providing a platform to adequately convert and prevent environmental nuisance which might emanate from the dropping of sawdust in the environment.

Methodology

Materials

The materials used for this study are ordinary Portland cement, sawdust from a local wood sawmill and starch extracted from a cassava fermentation process.

Method

The sawdust was sieved to obtain an average particle size of 710 µm, washed with hot water of about 80 °C for one hour, and then rinsed in cold water. A known quantity of hot water was then added to the weighed amount of starch to make a gel. The starch gel was then added to the weighed amount of sawdust and mixed thoroughly. The cement of varying percent (0-10%) was added to a constant mass (25 g) of the sawdust mixture. After stirring to obtain a homogenous mix, it was then pressed with a uniform force of 30 kN and allowed to dry in the air for three months for proper curing.

Experimental investigations

Water absorption test

The test is carried out to find out the amount of water that will be absorbed by the manufactured particleboard within a stipulated period of time. Ten specimens of approximately equal weights were used. Time of immersion, weight before and after immersion was recorded. This procedure was repeated for each mix for specimens with 0%, 2%, 5%, 8% and 10% cement. The percentage of water absorbed was computed with the aid of equation (1)

$$W_A = \frac{(W_2 - W_1)}{W_2} x100 \qquad (1)$$

where W_1, W_2 are the mass of specimen before immersion (g), the mass of specimen after immersion (g) and W_A is the percentage of water absorbed (g)

Compression test

The test was done to determine the crushing or maximum compressive strength of the produced particleboard. Three samples were used for each mix and the average computed. The average area of the prepared surfaces was determined by using a Vernier caliper to measure the lengths and breadths. Each of the specimens was then fixed on the horizontal compression apparatus already mounted on the Tensometer testing machine and the maximum crushing load was recorded. The maximum compressive strengths of the particleboards were calculated using equation (2):

$$C = \frac{W}{A} \qquad (2)$$

where W and A are maximum compressive load (N), average area (length x breadth) of the bearing faces in (mm^2) while C is the maximum compressive strength of particleboard (N/mm^2)

Thickness

Vernier caliper was used to measure the thickness of the particleboard at both edges and at the middle. The average reading was found to be the same for the whole board irrespective of the mix.

Density measurement

The dry masses of the samples were measured using an electronic weighing machine of sensitivity of the order of 0.01g. The volume of the weighed specimen was obtained by measuring its length, breadth, and thickness using a Vernier caliper. The average density for two specimens for each mix was then calculated the density was then calculated by using equation (3)

$$\rho = \frac{M}{V} \qquad (3)$$

Results and discussion

Water absorption

Water absorbent (W_a) of particleboards developed from varying cement content and sawdust (0-10 %C) is presented in Figure 1 where points and lines represent the measured data at the various exposure periods (60, 90, 120, 150, 180, 210, 240, 270, 300, and 480 s) and the values computed from the curve fit equation. The water-absorbent of the particleboard increased with the increase in the exposure period and cement content. The rate of absorption of water was rapid at lower times (between 60-300 seconds) of immersion and it was observed that the rate decreased between 300-480 seconds. The decrease in the rate of water absorption was a result of water saturation. Table 1 summarizes the water-absorbent correlations reliant on the cement content, and their regression coefficients (R^2). The W_a of particleboards at the different exposure periods are detected to be appropriately tailored by the quadratic equations as portrayed in Figure 1 & Table 1. The R^2 values are estimated between 0.9984 and 0.9996 for the various exposure durations, as presented in Table 1. A comparable finding was also found in the prevailing literature.[30]

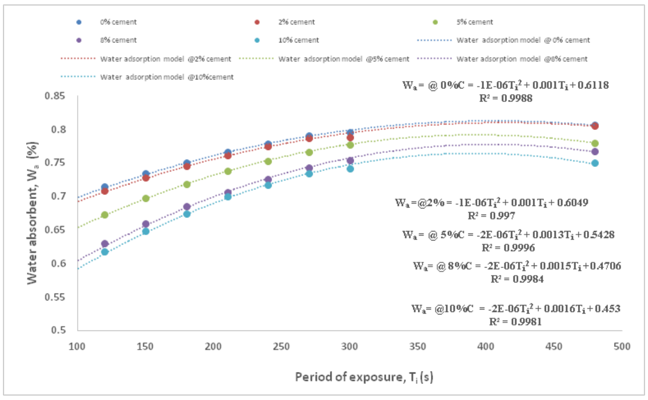

Figure 1 Variations in water absorptions of particleboard versus period of exposure.

Compression test result

Figure 2 depicts the variation of compressive strength of the particleboard and cement content. As observed, there was a uniform increase in the compressive strength of the particleboard as the percentage content of the cement increase.

Bulk density

Figure 3 portrays the variation of bulk density of the particleboard and cement content. As detected, there was an increase in the bulk density of the particleboard as the percentage content of the cement increase.

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Table 1 Regression models for water adsorption of particleboard

Cement content	Regression models	R^2
0	$W_a = -1X10^{-6}T_i + 0.001T_i + 0.6118$	0.9988
2	$W_a = -1X10^{-6}T_i + 0.001T_i + 0.6049$	0.9970
5	$W_a = -2X10^{-6}T_i + 0.0013T_i + 0.5428$	0.9996
8	$W_a = -2X10^{-6}T_i + 0.0015T_i + 0.4706$	0.9984
10	$W_a = -2X10^{-6}T_i + 0.0016T_i + 0.453$	0.9981

W_a = Water adsorbent (%); T_i = exposure period (sec)

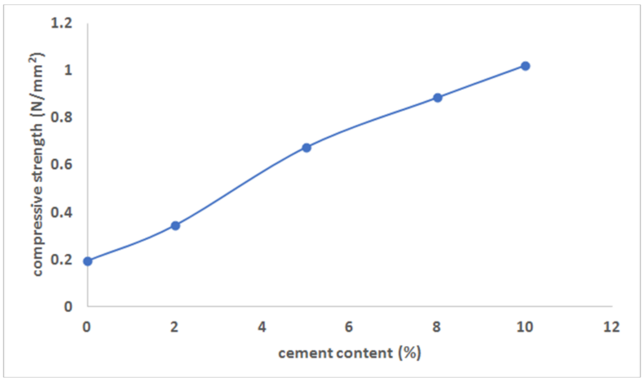

Figure 2 Variations in compressive strength of particleboard and cement content.

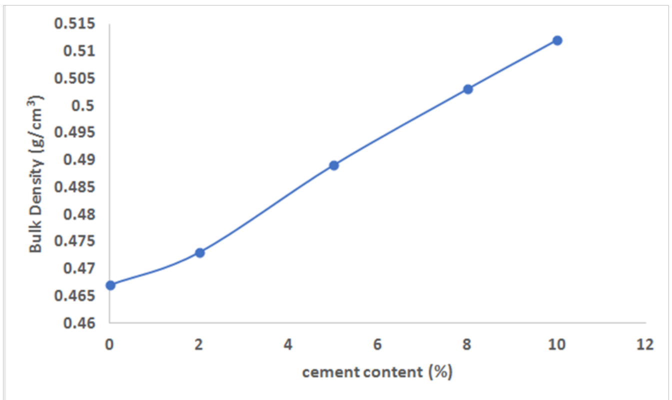

Figure 3 Variations in bulk density of particleboard and cement content.

Conclusion

In this research, for (i) enhancing the properties of particleboard produced from sawdust waste and cassava starch, (ii) increasing use of cement fraction was employed, (1) key properties particleboard produced were determined according to ASTM standards, and finally regression models as a function of cement content were postulated for the water adsorption and in the scope of this study, physical (density, water absorption, and thickness swelling) and mechanical (modulus of elasticity, bending strength, internal bond strength) investigations on the particleboards formulated will be investigated. The following conclusions can be established from this study:

I. The water-absorbent of the particleboard increased with the increase in the exposure period and cement content.

II. Water adsorption (W_a) is correlated with cement fraction through the least square regression method.

III. The quadratic equation is appropriate for W_a at the different exposure periods. The R^2 values range from 0.9984 to 0.9996, expressing these equations marginally reflect the discrepancy of W_a.

IV. The higher changes in the compressive strength and bulk density of the particleboards at the higher cement blend compared to those lower and no cement blends, implying better compaction between the mixture of sawdust-starch.

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None.

Conflicts of interest

The authors declare that there is no conflict of interest.

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