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Physico-Mechanical Properties of Particle Board made from Coconut Shell, Coconut Husk and Palm Kernel Shell

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Abstract: This research involves the production of particle boards made from coconut shell, palm kernel shell and coconut husk in different ratios varying from 25%, 30%, 35%, 40% and 50%. These materials were homogeneously mixed with Urea Formaldehyde resin which was the adhesive used commonly known as Top Bond. The physical and mechanical characteristics of produced particle boards which were density, water absorption, thickness swelling, modulus of rupture and modulus of elasticity were analysed. The densities ranged between 995kg/m^3 and 600kg/m^3. The particle board which had 50% coconut shell, 25% palm kernel shell and 25% coconut husk (E1) had the least value for water absorption after 2hours and 24 hours which was 17.26 and 26.19 respectively. The mean values for Modulus of Rupture and Modulus of Elasticity varied from 0.650N/mm^2 to 3.149N/mm^2 and 11.659N/mm^2 to 146.850N/mm^2. It was observed that the particle board which had the most preferable properties both physical and mechanical properties was E1 which was composed of 50% coconut shell, 25% palm kernel shell and 25% coconut husk.

1. Introduction

Boards are flat pieces of materials used for special purposes and are made mostly from wood. According to [1,2], developing countries have increasing quantities of agricultural waste due to increase in agricultural activities. Due to lack of technology for effectively utilization of agricultural residues and PET bottles, they have remained unused causing pollution. In recent times, agricultural residues have been used alternatively for the production of boards which includes sawdust[3–5], sugarcane bagasse [6,7], corncob [8], bamboo [9,10], rice husk [11], sunflower stalk [12], cashew shells [1], banana leaves [13] and so on . It can also be said that agricultural waste materials can be used in the production of particleboards used only for interior purposes such as shelves or tables which is simply because it has good physical properties.

Coconut (C. nucifera) belongs to the family of the Arecaceae (Palmae), the subfamily Cocoideae. The coconut fruit is used for a number of functions, both for food and non-food products. Coconuts are cheap and readily available. There are different parts of a coconut which are the core, husk, shell, coconut meat and the coconut water. A well growned coconut consists of 28 wt.% of coconut meat, 12 wt % of coconut shell and 35 wt % of coconut husk. that the coconut husk comprises of 30 wt% of coir fibre and 70 wt% of pith which are both extremely high in lignin and phenolic contents used in board production [14,15]. Particle boards are materials made by flattening wood chips under pressure with urea formaldehyde used as glue. Boards produced from lignocelluloses materials are non- scientifically termed Particle Board.

These materials are primarily separate or different particles consolidated with engineering resins or adhesives, compacted together under specific temperature and pressure in hot press by a process in which the entire particle board is made by additional cover and to which other materials are added during manufacturing process to enhance its properties [3,4]. Glue is the most important material needed for panel production asides lignocelluloses and the ones that are commonly used are urea formaldehyde (UF), phenol formaldehyde (PF), melamine formaldehyde (MF) resins, etc., which are expensive. Coconuts grow abundantly in tropical regions, and the husk is usually seen as waste. Tropical countries like Malaysia, Indonesia, Thailand, Sri Lanka and India are known as the home of natural fillers like Coconut shell. Natural fillers has been used by different researchers in composites and attention is drew majorly to coconut shell filler because of its high strength and modulus properties [16–18].

2. Materials and Methods

The materials that were used for this project are coconut husk, coconut shell, Palm kernel shell and urea formaldehyde resin popularly known as top bond. The coconut shell which was collected from Badagry was oven dried for an hour at a temperature of 80^0C. The coconut shells were then crushed into smaller sizes and then sieved using sieve number 4 of size. The moisture content of the processed coconut shell was about 2% to 3%. The coconut husk which was also gotten from Badagry separated from the coconut shell. The husk was cut in smaller size of about 30mm using a scissors and then separated. The palm kernel shell was oven dried for an hour at a temperature of 80^0 for easy grinding. The palm kernel shell was then crushed into smaller sizes and then sieved using sieve number 4.

All the materials used in the production of the particle boards which includes coconut shell, coconut husk, palm kernel shell and urea formaldehyde were all measured in volume using a measuring cylinder. The urea formaldehyde used was 20% of the entire composition (693cm^3). The calculated quantity (Table 1) of each of the particles that was clearly stated was poured into a head pan and then the measured urea formaldehyde was emptied into the pan and they were all thoroughly mixed together until the glue was evenly mixed and a good mixture was acquired.

Table 1. Experimental Design

Board Sample	% Composition of Coconut Shell	% Composition of Palm Kernel Shell	% Composition of Coconut Husk	% Composition for Batching Format CS:PS:CH
A1	25	25	50	25:25:50
A2	25	50	25	25:50:25
B1	30	30	40	30:30:40
B2	30	35	35	30:35:35
B3	30	40	30	30:40:30
C1	35	30	35	35:30:35
C2	35	35	30	35:35:30
D1	40	30	30	40:30:30
E1	50	25	25	50:25:25

Cellophane was used to line the interior layer of the mold and cover the mixture after filling the mold for easy removal of the particle board. The homogeneous mixture was transferred into the lined mold and then tamped properly with iron rod to reduce air voids. The cover was then placed on it and then transferred for compression using an hydraulic jack. A metal plate was placed on the mold for uniform compression to a thickness of 15mm at room temperature. The pressure was applied for 30 mins and then transferred into the oven to dry for 1 hour at a temperature of 80^0C. The mold was then removed from the oven and allowed to cool for 10mins before removing the panel from the mold and left for 24 hours after which it was kept in the oven for 3 hours and then removed again and placed on a flat surface for cooling.

Figure 1. Particleboards Sample.

The samples of the particle boards used for carrying out the water absorption and the thickness swelling tests were cut into 50mm × 50mm × 15mm sizes while the samples for Modulus of elasticity (MOE) and modulus of rupture (MOR) were cut into 350mm × 50mm × 15mm sizes.

2.1 Physical and Mechanical Tests

2.1.1 Density Test: Density is the ratio of weight to the volume of the particle boards at a particular moisture content. This test was carried out based on the British Code of Standards [19] as shown in eqn 1.

$$\boldsymbol{\delta = \frac{m}{v}} \quad (1)$$

Where δ = density, m = mass if each board, measured (kg), ν = volume of board (m^3)

2.1.2 Water Absorption Test: Water absorption test was carried out to determine the quantity and amount of water that the particle board can absorb within a particular time frame and also to determine dimensional stability of the board. The samples that were cut to previously stated size were measured as initial weight (Wi) and then soaked in water at room temperature for 2 hours and 24 hours for final weight (Wf) as specified by [20] . The percentage water absorption was then calculated as presented in eqn 2:

$$WA = \frac{W_f - W_i}{W_i} \times 100 \quad (2)$$

Where WA = water absorption, W_f = final weight, W_i = initial weight

2.1.3 Thickness Swelling Test: This is a dimensional test which was used to determine the change in thickness of the samples of particle board after immersion in water for a particular period of time. The initial thickness of the samples were measured using a digital Vernier caliper before immersing them in water at room temperature. After 2 hours and 24 hours alternatively the samples were then removed, measured and recorded as directed by [21]. The percentage thickness swelling was then calculated as:

$$TS = \frac{T_2 - T_1}{T_1} \times 100 \quad (3)$$

Where TS = thickness swelling, T_2 = final thickness, T_1 = initial thickness

2.1.4 Static Bending Test: This test was carried out using the Universal Testing Machine (UTM) following the central loading system. The board had two supports at each end and then a point load was applied gradually until the beam failed. MOE was given by the machine and MOR was calculated from the given parameters.

$$MOE = \frac{pL^3}{4bd^3H} \quad (4)$$

$$MOR = \frac{3pL}{2bd^2} \quad (5)$$

Where MOE = modulus of elasticity, MOR = modulus of rupture, p = breaking load, L = distance between the knife edge and sample support, b = width of test specimen, d = mean thickness of the specimen, H = increment in deflection.

Figure 2. Universal Testing Machine

3. Results and Discussion

3.1 Physical Properties

Table 2. Mean Values of Board Density, Water Absorption and Thickness Swelling

Board Sample	Mean Density (kg/m^3)	Water Absorption		Thickness Swelling	
		WA% After 2 Hours	WA% After 24 Hours	TS% After 2 Hours	TS% After 24 Hours
A1	740	37.04	43.52	5	11.67
A2	890	22.56	31.71	7.25	13.04
B1	600	32.82	36.64	18.84	21.74
B2	707	28.36	35.07	8.82	13.24
B3	742	23.3	32.95	12.5	22.5
C1	646	40.71	45.13	3.39	13.56
C2	631	27.21	35.37	8.97	17.95
D1	932	20.62	29.38	4.11	6.85
E1	995	17.26	26.19	5.11	7.15

3.1.1 Density: The density for the various combinations of Coconut Shell (CS), Palm Kernel Shell (PS) and Coconut Husk (CH) ranged from 932kg/m^3 and 600kg/m^3 as shown in table 2. It was observed that the panel E1 has the highest density. The density increased with increase in the percentage of CS. According to [22] board density and particle size has effect on the physical and mechanical properties. Density also has effect on flexural strength, increasing density can cause the higher compaction ratio in the board. The densities of the produced particle boards are comparable to those of wood production industries which ranges between 590 and 800 kgm^3.

3.1.2 Water Absorption Test: This helps to determine the amount of water or moisture that the particle board can absorb for a particular period of time. After 2 hours of immersion in water, E1 was observed to have the least value for water absorption(WA) which was made of 50% coconut shell(CS), 25% palm kernel shell(PS) and 25% coconut husk(CH) while C1 had the highest value for water absorption(WA). Also after 24 hours immersion in water E1 had the least value for water absorption followed by D1, A2, B3, B2, C2, B1 and A1 respectively while C1 had the highest value of water absorption (WA) as shown in Table 2.

It was observed that the water absorption decreased with increase in coconut shell and increased with increase in coconut husk. The increase in water absorption as a result of the increase in coconut husk is attributed to the fact that the adhesive's ability to bind with the particles reduces as it increases. Low water absorption was also observed in A2 which was made of 25% coconut shell(CS), 50% palm kernel shell(PS) and 25% coconut husk(CH).

3.1.3 Thickness Swelling Test: The samples were immersed in water for 2 hours and 24 hours respectively. After 2 hours immersion in water A2 was observed to have the least thickness swelling value and B1 had the highest thickness swelling value. After 24 hours D1 had the least thickness swelling value followed by E1, A1, A2, B2, C1, C2 and B1 respectively and B3 had the highest thickness swelling value.

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3.2 Mechanical Properties

The values of Modulus of Rupture varied from 3.149N/mm^2 to 0.564N/mm^2 as seen in Table 3. It was observed that E1 had the highest value for Modulus of Rupture (MOR) and C2 has the least value for MOR. Modulus of Elasticity (MOE) also follows the same pattern as Modulus of Rupture (MOR) as in Figure 3 and Figure 4, C2 has the lowest value for Modulus of Elasticity which is 11.659N/mm^2 and E1 has the highest value which is 146.850N/mm^2.

Table 3. Modulus of Rupture and Modulus of Elasticity

Board Type	MOR (N/mm^2)	MOE (N/mm^2)
A1	0.65	21.76
A2	1.714	107.961
B1	0.789	29.879
B2	0.75	28.315
B3	0.849	20.754
C1	0.87	35.06
C2	0.564	11.659
D1	2.784	91.829
E1	3.149	146.85

Panels intended for structural purposes that have their densities greater than 420kg/mm^2 are required to have their minimum values for Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) to be 5N/mm^2 and 400N/mm^2 respectively, this is according to British Standard. This implies that from the data gotten from the above table, none of the particle boards can be used for structural purposes.

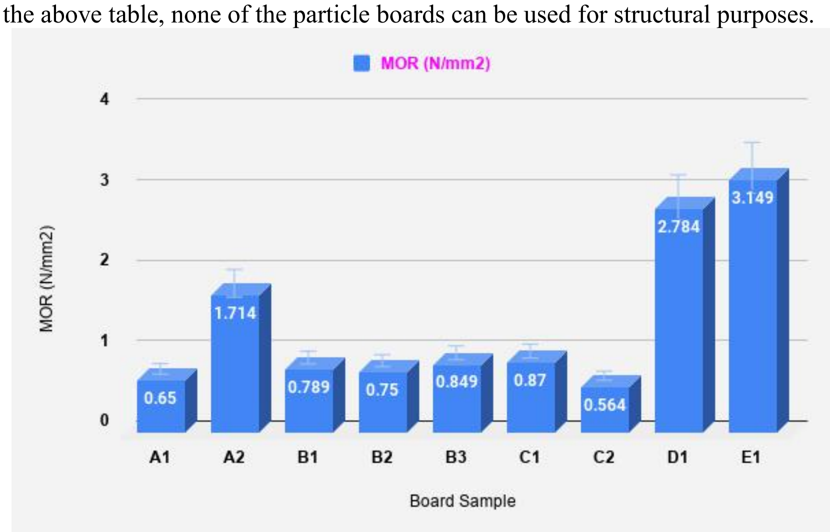

Figure 3. Graph showing Modulus of Rupture values

Figure 4. Graph showing Modulus of Elasticity values

4. Conclusion

It was also discovered that the particleboards produced cannot be used for structural purposes or in load bearing which is as a result of their poor mechanical properties. From the Modulus of Rupture (MOR) and Modulus of Elasticity (MOE) results gotten from the project work, the mechanical properties of the particleboards increased as coconut shell composition increased. In conclusion, board type E1 with 50% coconut shell, 25% palm kernel shell and 25% coconut husk has the most preferred physical and mechanical properties.

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