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Fabrication of Hydrophobic Particle Board from Waste Coir Pith and Rice Husk Ash

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Abstract: In the present days research, maximum focus is being given in the generation of any valuable product from waste material. With special concern for environment and forest, in the present research an attempt is being made to provide an alternative material to serve the need for wood, timber or wood grade material. Along with fabrication of wood grade material here, an attempt has been made to prepare a hydrophobic particle board, which could resist the moisture and water attack. For developing the water resistivity, rice husk ash is used as the additive material. Rice husk ash is generated from raw rice husk, disposed as a waste material during rice cultivation.

Key words: Hydrophobicity, particle board, urea formaldehyde, coir pith, rice husk.

Introduction

Alao Kehinde Temitope et al. (2015) have explained that a large quantity of rice husk in Nigerian rice milling industries poses a serious environmental health hazard. Rice husk particle board is therefore one of such material which may be considered a potential substitute for woods-based board products. This study presents an experimental work which investigates the potentiality of rice husk in the production of particle boards using starch wood glue (Top bond) as an alternative source of adhesives. The weighing scale was used to weigh the rice husk, starch, wood glue (Top bond), the mixture ratio adopted being 0.75 kg, 0.15 kg, and 0.10 kg of the rice husk, starch, and wood glue respectively, thoroughly mixed manually by using the mixer. The mixture was then poured into a mould with a dimension 300 mm × 300 mm × 15 mm. The particle board was compacted using a hydraulic press in two compacts.

The particle board was tested for water absorption in both cold and hot media. The cold absorption test was performed by immersing the composite sample into the cold water for a period of 30 mins, 1 h, 2 h, 4 h, 6 h, 8 h at room temperature (25°C). The thickness of the board is measured before and after the test. In hot absorption test, the composite sample was immersed into the hot water with temperature ranging 45°C, 65°C, 85°C and 100°C at constant time period of one hour, the thickness of the board taken into consideration. The percentages of water absorption were then calculated for both the cold and hot media. The thickness of the particle board produced increases with an increasing temperature for both the cold and hot water, until a point is reached when a saturation point is attained and the board could no longer accommodate any more water. At this point, the density remains constant. This value indicates that the board should be reserved for indoor application since percentage of water absorbed increases with increasing time of immersion.

It is concluded that rice husk waste can be utilized in the manufacture of a water-resistant particle board, at tropical area like Nigeria with long rainy season. The

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use of starch, a biodegradable adhesive reduced the use of the more expensive synthetic adhesive based on petroleum resources. The test results showed that the rice husk, starch wood glue combination provides results which have high potential to be used in the production of particle board.

Stefan Veigel et al. (2012) have explained that adhesives on the basis of urea-formaldehyde (UF) and melamine-urea-formaldehyde (MUF) are extensively used in the production of wood-based panels. In the present study, the attempt was made to improve the mechanical properties of the particle board by reinforcing these adhesives with cellulose nanofibers (CNFs). The latter were produced from dissolving grade beech pulp by a mechanical homogenization process. Adhesive mixtures with a CNF content of 0, 1, and 3 wt% based on solid resin were prepared by mixing an aqueous CNF suspension with UF and MUF adhesives.

Laboratory-scale particle boards and oriented strand boards (OSBs) were produced, and the mechanical and fracture mechanical properties were investigated. Particle boards prepared with UF containing 1 wt% CNF showed a reduced thickness swelling and better internal bond and bending strength than boards produced with pure UF. The reinforcing effect of CNF was even more obvious for OSB where a significant improvement of strength properties of 16% was found. For both, particle board and OSB, mode I fracture energy and fracture toughness were the parameters with the greatest improvement indicating that the adhesive bonds were markedly toughened by the CNF addition.

Rui Liao et al. (2017) have explained that the development of natural adhesives derived from non-fossil resources is very important for the future. In this study, by taking sugarcane bagasse as the raw material, without using any synthetic resin but adding some eco-friendly additives (citric acid and sucrose), low density particle boards were successfully developed. The effects of board density and additive contents on the physical and mechanical properties of the boards were investigated. The bonding mechanism was observed by Fourier transform infrared spectroscopy (FTIR) and X-ray diffraction (XRD). The results showed that the low density bagasse particle board had good mechanical properties and dimensional stability relative to its low board density.

The modulus of rupture (MOR) and the thickness swelling (TS) values increased with increasing board density. The board with a density of higher than 0.40 g/cm^3 and manufactured at 15% additive content can meet the requirements of the Chinese national forestry industry standard LY/T 1718-2007 (2007). Based on the results of the FTIR spectra, the additive not only increased the hydrogen bond but also the molecular linkage force (C-O-C). X-ray diffraction showed the relationship between crystallinity of cellulose and the strength of particle board. Asha (2017) has explained that globally, the construction industry is growing at a rapid pace as a consequence of increasing population and standard of living. High performance synthetic materials for construction such as glass fibre and carbon fibre reinforced composites are available today. However, these materials are mainly used for high-tech applications in aerospace and motor sports due to their high costs.

In the present study, an attempt has been made to fabricate a low cost hydrophobic particle board from waste coir pith and rice husk (raw). In the process, rice husk contributes towards generating the hydrophobicity in the material. In order to utilize these two waste materials, the binder which is to be taken into consideration should not react with any of these base materials. During the study all five different resins are taken into consideration (i.e. UF, PF, MF, LF and MOF). These resins showed variable binding and adhesive properties. Different types of boards are obtained using these binders and their properties are well analyzed for their mechanical, chemical and physical parameters. By comparing the properties, the board which has showed higher durability, lower chemical reactivity and higher hydrophobicity is being identified.

Material and Methods

Materials Used for the Production of Particle Board

The materials required for this work are sourced locally. These are coir pith, rice husk, water, starch and wood glue along with different binders such as urea-formaldehyde, phenol-formaldehyde, melamine-formaldehyde, lignin-formaldehyde and molass-formaldehyde. These binders are used separately along with the above materials. The mix design is represented in Table 1.

Collection of Coir Pith and Rice Husk

Coir pith are collected from local coconut farm at Sakhigopal area, Puri. The reason for choosing this area is because the coir pith are readily available in large quantities and these are carelessly dumped around the coir factories on the road sides which eventually find their way into drainage system. Rice husk is also collected from the local rice mills.

Processing of the Coir Pith Mould Preparation

For this work, coir pith are collected separately. After the various types of coir pith are collected, the moisture is determined before they are placed separately directly under sun. This is to dehydrate the coir pith for 15 days. Being in particle form the drying is quite fast. The coir pith is sieved to two degrees of fineness. The finest particles are used for the surface. This is to ensure very fine surface finish as coir pith of larger particles will give a rough surface finish. Wood is used for the construction of the mould for the casting operation. The inner part of mould is covered with nylon sheet. This is for the particle board to have a fine surface finish. The mould is made having a rectangular cross-section measuring 300 mm × 300 mm × 15 mm.

Physical Tests of Particle Board

Tests are carried on the particle board samples to find out if they will efficiently serve the purpose of ceiling board in tropical environment characterized with long period of raining season. These are presented in the form of various tests as listed below.

Water Absorption Test (Cold Water)

The composite sample is immersed into the cold water for a period of 30 minutes, 1 h, 2 h, 4 h, 6 h and 8 h at room temperature (25°C) and the thickness of the board taken. The thickness of the particle board produced increases with an increasing time inside the cold water, until a point is reached when a saturation point is attained and the board could no longer accommodate any more water. At this point the density remains constant. The percentage of water absorbed is mathematically calculated as

$$\text{Cold water absorption} = \frac{(\text{Weight after immersion} - \text{Weight before immersion})}{\text{Weight before immersion}} \times 100$$

Weight of particle board before water immersion = 0.96 kg. The result is described in Table 2. This table shows that in terms of weight measurement, after immersion in water, particle board made up of urea formaldehyde (PB-1) shows a stability after 240 minutes (4 hrs) of retention time, with a weight variation of 16%. Similarly, when PF (phenol formaldehyde) is used, the particle board (PB-2) shows stability at 120 minutes (2 hrs) immersion time. During this period the percentage weight variation in the particle board is 10%. In case of particle board (PB-3) having melamine-formaldehyde (MF), the immersion stability is obtained at 60 minutes time (1 hr) and the percentage weight variation is 5.15%. In case of lignin formaldehyde resin, the immersion stability of particle board (PB-4) is obtained at 60 minutes time and the percentage weight variation is 3.06% and finally for molass formaldehyde resin, the immersion stability of particle board (PB-5) is not obtained perfectly, though in an average the percentage weight variation in the range between 14.1 and 14.7. Thus, weight variation in the water absorption (cold water absorption), particle board made up of lignin formaldehyde shows the best result along with a weight variation of 3.06%, followed by particle board with melamine-formaldehyde 5%, phenol-formaldehyde

Table 1: Materials for synthesis of different particle boards

PB	*Coir pith*	*Water*	*Starch*	*Wood glue*	*Resin*
PB-1	50%	10%	5%	5%	Urea formaldehyde (UF)
PB-2	50%	10%	5%	5%	Phenol formaldehyde (PF)
PB-3	50%	10%	5%	5%	Melamine formaldehyde (MF)
PB-4	50%	10%	5%	5%	Lignin formaldehyde (LF)
PB-5	50%	10%	5%	5%	Molass formaldehyde (MOF)

Table 2: Weight of the board after immersion (in kg) with different time

Sample	*0 mins*	*30 mins*	*60 mins*	*120 mins*	*240 mins*	*360 mins*
PB-1	0.96	0.97	0.99	1.10	1.12	1.12
PB-2	0.97	0.98	1.07	1.07	1.07	1.08
PB-3	0.97	0.99	1.02	1.02	1.02	1.03
PB-4	0.98	0.99	1.01	1.01	1.01	1.01
PB-5	0.99	1.00	1.08	1.12	1.14	1.13

10% and urea formaldehyde 16%, whereas particle board with molass formaldehyde shows an unstable weight variation with change in time. The results of the densities, the percentages of absorptions of cold water by the particle board are shown in Table 3.

Water Absorption Test (Hot Water)

The weight of the particle board to be tested is obtained with the aid of a weighing scale. The particle board is dipped into boiling water for 1 hour. The particle board is observed to float; thereafter a stone is placed on the particle board so that it will rest at the base of the boiling water container. After 1 hour, the particle board is reweighed and the quantity of water absorbed is obtained. The composite sample is immersed into the hot water with temperature ranging 45°C, 65°C, 85°C and 100°C at constant time period of 1 hour; the thickness of the board taken. The results are recompiled in Table 4.

Thickness of Swelling

The thickness of swelling of the Particle Board made up of different binders is represented in Table 5. The result showed that thickness of swelling is partially dependent on the type of resin used in the particle board. Using urea formaldehyde as the resin the thickness of swelling varied between 6.66% and 26.6%. In case of particle board made up of phenol formaldehyde resin, consistency is found just after 60 minutes immersion duration and there is approximately no change in the thickness. Similarly for melamine formaldehyde resin the thickness of swelling varies up to 13% from the actual size of the particle board and shows consistency at 120 minutes of immersion in cold water.

Interestingly, particle board with lignin formaldehyde as the reactant resin shows an encouraging result in which the percentage of thickness of swelling remains constant throughout, without any change whereas using

Table 3: Result of density variation of the particle board

Time of immersion (minutes)	*Weight of the board after immersion (kg)*	*Thickness of swelling (mm)*	*Volume of the particle board in water (m^3)*	*Density of the board in water (kg/m^3)*
0	0.960	15	0.001350	711.111
30	0.97	16	0.001351	717.987
60	0.99	17	0.001357	729.550
120	1.10	18	0.001359	809.419
240	1.12	19	0.001364	821.114
360	1.12	19	0.001364	821.114

Table 4: Weight of the particle board after immersion (in kg) with different temperature for constant time

Types of particle board	*0°C*	*45°C*	*65°C*	*85°C*	*100°C*
Particle Board I	0.990	0.993	0.994	0.996	0.996
Particle Board II	1.070	1.072	1.075	1.078	1.079
Particle Board III	1.020	1.023	1.023	1.023	1.024
Particle Board IV	1.010	1.011	1.012	1.012	1.012
Particle Board V	1.080	1.086	1.090	1.095	1.099

Table 5: Thickness of Swelling (in mm)

Type of Particle Board	*Thickness of Swelling (in mm)*					
	0 mins	*30 mins*	*60 mins*	*120 mins*	*240 mins*	*360 mins*
Particle Board - I	15	16	17	18	19	19
Particle Board -II	15	16	16	16	16	16
Particle Board-III	15	16	16	17	17	17
Particle Board-IV	15	15	15	15	15	15
Particle Board -V	15	17	18	18	19	20

molass formaldehyde as resin shows an unusual result of constant variation, in thickness of swelling. From the above data it is being concluded that using binders along with lignin formaldehyde resin, it is possible to obtain a high strength without any rise in thickness of swelling under cold water treatment.

From Table 6 the mechanical properties of the particle boards can be estimated. The data shows that in terms of tensile strength, Particle Board I (PB-I) prepared with urea formaldehyde resin, Particle Board II (PB-2) with phenol formaldehyde resin and Particle Board IV (PB-4) with lignin formaldehyde resin have an appreciable tensile strength of 2 as compared to 0.8 of Indian Standard – IS 3087. Similarly, for Particle Board III (PB-3) and Particle Board V (PB-5) the tensile strength is found to be 1, which is again more than the standard particle boards with an extra strength of 25%. In case of Compressive Strength, PB-1 shows an interesting result of compression with strength of 4.00 MPa, which is considered to be highest among all other particle boards under consideration. In case of particle board with phenol formaldehyde resin (PB-2), the compressive strength could be achieved up to 3.847 which is quite higher than the Indian Standard (IS – 3087) which is mentioned to be >2.5.

In case of Particle Board III (PB-3) prepared using melamine formaldehyde resin the Compressive Strength is found to be 2.889 MPa as against the standard Compressive Strength >2.5 (IS-3087), but for lignin formaldehyde based Particle Board (PB-4) the compressive strength is found to be 3.126 higher than 2.5 and can be considered further to have an in between range among very high and very low particle boards compressive strength. Particle board prepared with molass formaldehyde resin (MOF) shows a very low compressive strength below 15 (IS-3087) standard. Thus, PB-1, PB-2 and PB-4 show a better compressive strength as compared to PB-3 and PB-5. In terms of flexural strength, the IS-3087 standard the flexural strength should be within 9.11 MPa and in case of all the particle boards it remains within the range. For PB-1 the flexural strength is highest with 7.446 MPa, which is fabricated using urea formaldehyde resin. In case of phenol formaldehyde, the flexural strength is found to be 6.801, comparatively less than UF based particle board. Similarly using melamine formaldehyde resin, this parameter is obtained in the range of 3.923. When lignin formaldehyde is added as the binding factor, it is being found to have a flexural strength of 5.002 which is in a moderate value and stability. On the contrary, for Molass formaldehyde resin the flexural strength is 2.071.

This value indicates that the board should be reserved for indoor application since percentage of water absorption increases with increasing time of immersion. The scanning electron micrographs without and with silica embedment has been represented in Figures 1 and 2. Furthermore, there is no surface change, no cracks on the surfaces of the particle board which would result from the immersion of the particle board in cold water.

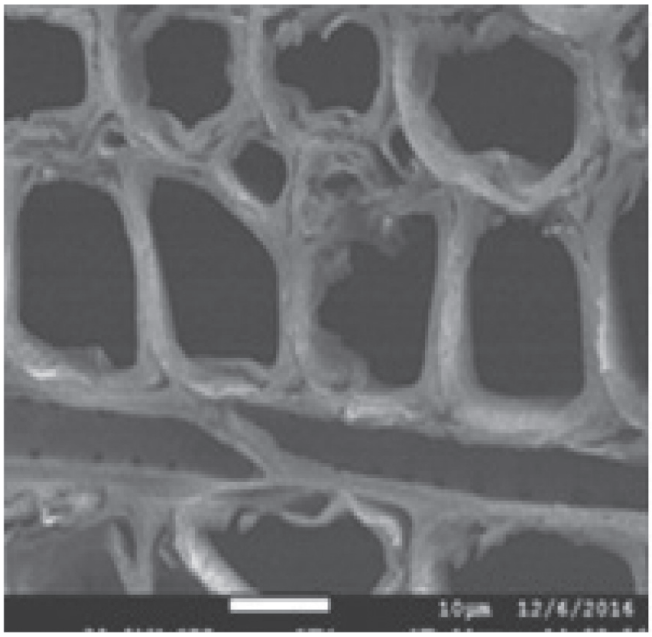

Figure 1: Honey comb structure of coir pith dust.

Table 6: Mechanical properties of the particle boards made with different resin

Type of particle board	*Tensile strength (MPa)*	*Compressive strength (MPa)*	*Flexural strength (MPa)*
Particle Board I	2	4.00	7.446
Particle Board II	2	3.847	6.801
Particle Board III	1	2.889	3.923
Particle Board IV	2	3.126	5.002
Particle Board V	1	1.632	2.071

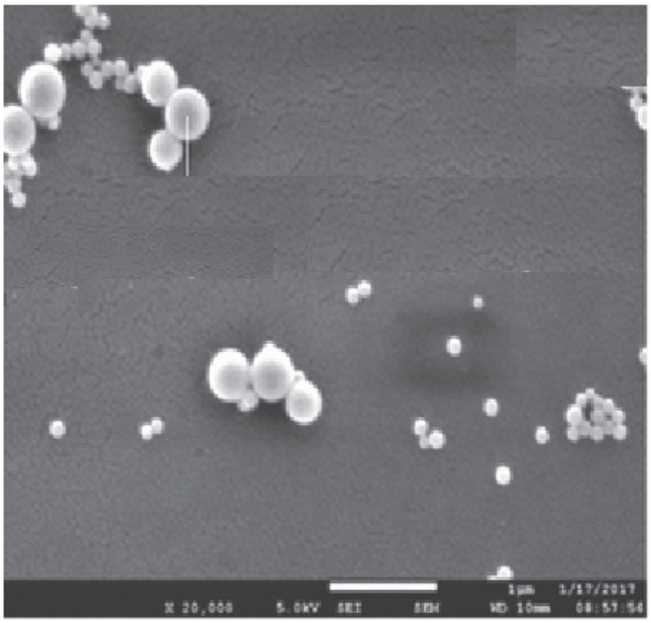

Figure 2: SEM of rice husk SiO_2 embedded CP.

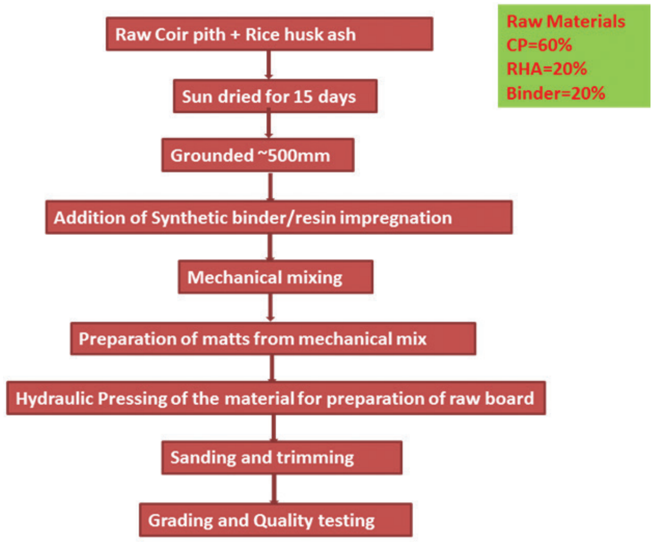

Figure 3: Process flow sheet for the Hydrophobic Particle Board prepared from coir pith.

Conclusions

- It is concluded that coir pith waste can be utilized in the manufacture of particle board and water resistant particle boards can be made adequately using rice husk as a hydrophobic medium.
- The resin, generally being used as the synthetic binder is chosen as a combination of urea formaldehyde/ phenol formaldehyde/lignin formaldehyde.
- The use of starch, a biodegradable adhesive reduced the use of the more expensive synthetic adhesive based on petroleum resources.
- The test results show that the coir pith, starch wood glue combination provides results which have high potential to be used in the production of particle board.
- The observations from the physical tests conducted show that the densities and percentage absorptions of the immersed particle board increases with increasing time of immersion.
- Since the construction industry is a growing industry, the use of renewable resources such as rice husk can reduce the strain on forest resource and form excellent replacement for wood based composite materials.
- Thus, using waste materials like coir pith, rice husk, starch, lignin, molass with variable combinations, it is possible to produce a high strength water resistant particle board, which is quite cost effective and environment friendly (Figure 3).

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