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A Review Report on Physical and Mechanical Properties of Particle Boards from organic Waste

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Abstract: Environmental friendly or green building materials are becoming more widely used as our society becomes aware of harmful consequences associated with the use of standard practises in industrial production. This leads to growing tendency of recycling of waste materials and using them production of particle boards. Particle Boards are produced from Municipal solid waste, agro-waste materials such as rice husk, jute sticks, waste wood, sugarcane waste, kitchen waste etc. The physical and mechanical properties such as high board density, high surface hardness, abrasion resistance, tensile strength play a vital role in the efficient usage of them for domestic and industrial purposes. All these properties majorly depend on the kind of raw material used and these properties may be improved for the quality betterment of the products and also their applications can be extended. The present study reviews about the different raw materials used for particle board production and their varied properties for improving their quality and wide applications.
Keywords: Particle Boards, Drying, Hydraulic Press, Environmental Friendly.

1. Introduction

In recent years, there is a growing tendency towards recycling of the waste and using it for producing the composite wooden products like Particle Board. On the other side depletion of forest resources has increased demand for these kinds of products. Use of renewable materials for manufacturing particleboards could contribute the solution of raw material shortage for the particleboard industry [1]. Environmentally friendly or green building materials are becoming more widely used as our society becomes aware of harmful consequences associated with the use of standard practices in industrial production. These materials are nontoxic and are made from renewable or recyclable resources[2]. Nowadays, many manufacturing units all over the country are in the production of particle board in small scale sector.

Particle Boards are produced from Municipal solid waste, agro-waste materials such as rice husk, jute sticks, waste wood, sugarcane wastes and kitchen waste etc. It is recommended that Particle Board can also be produced from watermelon peels as an alternative to wood based Boards [3]. Particleboard produced from Fonio husk, and bonded with gum Arabic as the resin adhesive [4] and Chilli Pepper stalks were used as raw material for the manufacture of particle Board [5]. Many materials are also used for the preparation of Particle Board. These materials include bark, sawdust and shavings [6], Wheat straw [7], Waste wood chips [8], Eastern Redcedar trees [9], Leucaena Leucocephala tree [10], Rice straw [11], Maritime pine [12], Waste paper [13], Bamboo waste [14], Kenaf particles [15], Mixture of baggase and industrial wood particles [16], Roselle stalks [1], Watermelon peels [3]. Afzelia Africana wood residues [17], Radiata pine wood [18], Baggase and industrial wood particles [19], Kelempayan [20], Jatropha curcas [21], Sago particles [22], Fonio husk [4] and Kitchen waste [23].

Particle boards have many desirable properties such as high density, high surface hardness, abrasion resistance, high durability etc. Influence of Board density and particle sizes can obtain better Physical and mechanical properties. Physical and mechanical properties differed significantly according to the board types. Increasing the Press time also improves the Physical and mechanical properties of the board [19]. The relationships between board properties and manufacturing variables were complicated by various board densities and various kinds and combinations of wood species, raw material forms and processing methods [24]. The uniform distribution of the particles and the binders in the microstructure of the board composites is the major factor responsible for the improvement in the properties [25]. Particle Board can be manufactured in different sizes, shapes, thickness and densities. Some of the applications of the particle board are shelves, furniture, laminating doors and cupboards [23]. Particleboard is commonly used for cabinetry, tabletops, shelving, wall and floor panels, doors, furniture, and other non-structural architectural applications.

In this present review paper, the physical and mechanical properties of the Particle Board manufactured with different raw materials in different combinations are assessed. It has been observed that the both physical and mechanical properties of particle boards depend on the raw material used for the manufacturing process. However, properties of the Particle Board play a major role after the manufacturing process when compared with the standards.

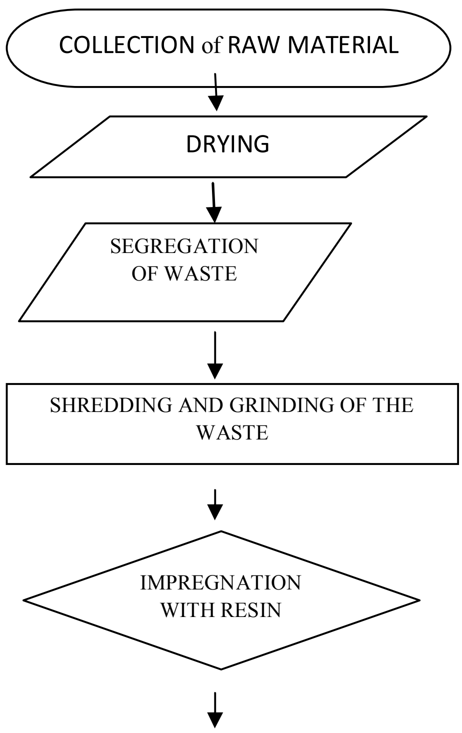
2. Particle Board

Particle Board has been manufactured from different varieties of raw materials in the form of small particles impregnated with resins or other appropriate binders reinforced together with heat and pressure. The main difference between Particle Board and other conventional wooden boards is its material and the manufacturing process. Particle Boards can be utilised for housing, industries and in commercial buildings as partition walls, window entryway boards, table tops, board sheets and so on.

2.1 Process Description

Particle Boards can be manufactured in desired shapes and sizes with suitable binders or fibres impregnating with resins such as Polyester, Urea Formaldehyde, Melamine Formaldehyde, Phenol Formaldehyde, Epoxy resins etc. The important equipment required for the production process are dryer, shredder, material handling equipment, grinder, sieve shaker, resin impregnation unit, hydraulic presser with heating arrangement etc.

The general steps used to produce Particle Board is shown in Figure 1.



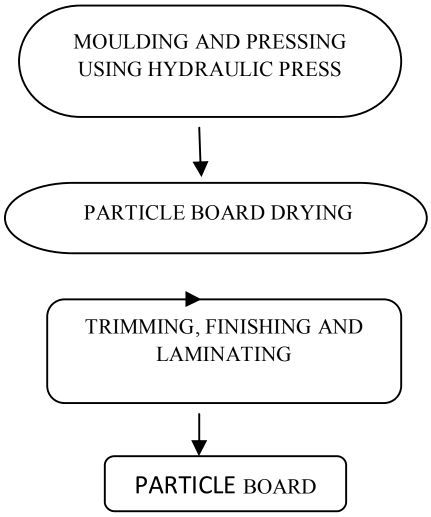


Figure 1. Steps Involved in the Particle Board Production

2.1.1 Drying

a) Sun Drying

Sun drying is very simple and ancient skill used for drying of different waste. It is only possible in areas where in an average year the weather allows the waste to be dried immediately. The main advantage of sun drying is low capital and operating cost and also the fact that little expertise is required. Hence, it is primarily preferred for drying of raw materials for particle board making [26].

b) Solar Dryers

Solar dryers have some advantage over sun drying when it is correctly designed. They give faster drying rates by heating the air to 10^0c to 30^oc above ambient which causes the air to move faster through the dryer and reduces its humidity. The faster drying rate reduces the risk of spoilage of raw materials and gives a high throughput so reducing the drying area required for drying. Different Types of solar dryers are

a) Absorption or hot box type dryer in which the product is directly heated by sun.
b) Indirect or convective dryer in which the product is exposed to warm air which is heated by means of solar absorber or heat exchanger
c) Combination of both hot box dryer (direct) and convection dryer (Indirect) [26].

c) Oven Drying

One of the most common methods used for drying the capacity of air in removal of moisture depends on temperature and moisture amount of air. Hot air ovens can be operated from 50 to 300^oc to control the temperature. When waste being placed in the dryer heat reaches to humid temperature in short. The drying process continues with uniform rate which means equivalence in removing and absorbing of moisture from waste [27].

2.1.2 Segregation

Segregation of waste from its source is the primary step involved during the collection of raw materials for Particle Board making. The different agro waste were sorted and segregated at the source of generation itself. For example rice husk, saw dust, wood chips were segregated where it is generated from its source. In case of Municipal solid waste the segregation can be done as bio-degradable (Vegetables, fruits, kitchen waste, flowers, leaves etc) and Non-biodegradable waste (plastics, metal, glass, paper etc). Most of the bio degradable wastes segregated such as fruit peels, kitchen waste and leaves are being used for Particle Board production.

2.1.3 Shredding and Grinding

Shredders vary in many ways according to the function they perform. Shredding also employs grinder, chipper, granulators, hammer mills, shear shredder, speciality shredder and all purpose shredders for size reduction, pulverization of materials to produce granulated products or powdered products of different waste like municipal solid waste, rice straw, wheat straw, wood chips. This shredding process makes the handling of waste ease for the Particle Board making [28].

2.1.4 Hydraulic Pressing

Hydraulic press is the most efficient form of presses. It applies hydraulic mechanism for applying large lifting or compressive force. Once the mats of waste are cut in to desired lengths, they are conveyed to the press. Where the press applies heat and pressure to activate the resin and bond the fibre in to a solid panel. Both single opening presses and multi opening batch presses are used in most of the domestic particle board plants. Continuous presses may also useful to produce Particle Boards. Presses are generally heated using steam generated by an onsite boiler that burns wood residue. However, hot oil and hot water are used to heat the press. Mostly the operating temperature for Particle Board press generally range from 149^o c to 182^o c. Press temperature and time vary according to the products that are being produced [29].

2.2 Physical and Mechanical Properties

The statistics relating to physical and mechanical properties of the particle board are major concern to guarantee the right application where the product or material is being utilized and to give important data for the use in new applications. Data on the effects of moisture content, water absorption, thickness swelling, internal bonding strength, tensile strength, compressive strength, Flexural strength, hardness, rate of loading, press temperature and pressing time are very much essential for the analysis of physical and mechanical properties of the particle board made from any kind of the material. Table 1 summarises some of the physical and mechanical properties of different raw materials involved in particle board making.

The data on these properties will mainly depend on the type of material and resin used for the process. It is both possible and practical to use engineering methods with almost any material if sufficient information is available on the strength and the elastic properties of that material as well as its behaviour under load. This also applies to particle board [24]. There are many properties to consider but some of the important properties to be considered for a particle board are:

a) Density

It is noted that difference in raw material and impregnation ratio is making some effect on the board density. All Particle Boards should be medium density boards (37-50 lb/cubic ft) that are commercial standard. Board density is having lot of impact on properties like MOR, MOE, IB, TS and WA etc.

Density (g/cm^3) = W_a/V_a (1)
W_a- air dried weight
V_a – air dried volume

b) Moisture Content

Equilibrium moisture content for the Particle board is 8% and average moisture content of all boards was 9%. Equilibrium moisture content is mainly depends on relative humidity. Particle Boards should be conditioned to reach equilibrium with the humidity level in which it is to be used. Measurement of moisture content can be achieved by weighing or by using electric moisture meter. Linear dimensions and thickness will change if there is change in moisture content.

Moisture content (%) = (W_a - W_o/W_o)*100 (2)
W_a- air dried weight
W_o- Oven dried weight of the particle board

c) Water Absorption Test

For water absorption, the test piece was cut and immersed in distilled water in a glass vessel at room temperature 20-30◦C for every 2 hours duration till constant weight was obtained. The effect of water on the properties like bending strength and bending stiffness is very severe. There is a chance of strength reduction of boards because of the water. So, water absorption is an most important property for any type of Particle Boards.

Water absorption (%) = $(W_f - W_i/W_i)*100$ (3)
W_f – final weight
W_i – initial weight

d) Thickness Swelling

The effect of thickness swelling in the Particle boards is because of the moisture and absorption properties. Thickness swelling should not be more than 2-3%. Thickness swelling is very much lower after drying. For Thickness swelling, the specimen is immersed in distilled water at room temperature.

Thickness swelling (%) = $(T_f - T_i/T_i)*100$ (4)
T_i = initial thickness
T_f = final thickness

e) Tensile Strength or Internal Bond Strngth

Internal bond strength is commonly examined property for any type of Particle Boards. In terms of strength properties, this is one of the properties which have lot of significance. Tensile strength test is a mechanical test performed on packaging materials to determine the maximum load that can be applied to a material before it ruptures or tears. Tensile testing machine is used to calculate the tensile strength. The sample was placed on the machine and anchored at both ends. As the machine was pumped manually, both tensioned ends were stretched till it failed. Failure occurred by splitting. The tensile strength was calculated using the formulae $\delta t = Wt\ b \times t$ Where, δt = Tensile stress (N/mm^2), Wt = Failure tensile load (N) b = Breadth of the specimen (mm) and t = Thickness of the specimen (mm)

f) Bending Stiffness (MOE)

Modulus of elasticity is an important property because of its measure of stiffness or resistance to bending when stress is applied.

MOE = $P_{bp}L^3/4bh^3Y_p$ (5)
Where P_{bp} – load at the proportionality limit
L – Span length in mm
b – Width of the specimen in mm
h – Thickness of the specimen in mm
Y_p – deflection corresponding to P_{bp} (mm)

g) Bending Strength (MOR)

Modulus of rupture is an important property determining the application of the product for structural components. This property results will depend according to the board density. A concentrated bending load was applied at the center with a span of 15 times the thickness of the Specimen. MOR can be calculated by load deflection curves using the formula

MOR= $3P_bL/2bh^2$ (6)
Where P_b – Maximum load
L – Span length in mm
b – Width of the specimen in mm
h – Thickness of the specimen in mm

Both Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) shows the effect based on the moisture content, particle size and type of raw material used.

h) Press Temperature and Time

The pressing operation is extremely important step in Particle Board. Press Temperature and time will depend on the type of raw material is used and type of product being produced. During Pressing operation both press temperature and time are very important parameters because they can affect all the properties of the Particle Board. Both press temperature and time should be carefully monitored and controlled. Press pressure is of minor importance when compared with Press time and temperature. Therefore, Press temperature and Press time are needed to be closely monitored and controlled to maintain adequate temperature levels [30].

Table: 1 Physical and mechanical properties of Particle Board with different wastes

SNO	RAW MATERIAL	RESIN USED	PROPERTIES						REFERENCE
			MC (%)	WA (%)	TS (%)	IB (MPa)	MOE (MPa)	MOR (MPa)	
1	Wood waste chips	Phenol Formaldehyde	2-4	-	7-18	0.56-0.73	20.8-34.5	11.4-27.1	[8]
2	Afzelia Africana wood residues	Chemical additives ($CaCl_2$,$MgCl_2$ and $AlCl_3$)	12	8.52-44.07	0.97-4.66	0.19-0.59	-	5.38-15.45	[17]
3	Bagasse and industrial wood particles	Urea Formaldehyde	12 & 8	-	14.45-19.14	0.33-0.78	1706-2384	10.03-16.59	[19]
4	Chilli pepper stalks	Urea Formaldehyde	4-5	64.1-82	31.8-43.9	0.61-0.88	1856-2532	12.2-16.3	[5]
5	Jatropha carcus	No binder	5-20	7.5-9.5	7.6-21	-	-	-	[21]
6	Kelempayan tree	Urea Formaldehyde	<5	112-131.1	30.68-53.6	0.55-0.813	5309.22-10967.9	17.503-35.84	[20]
7	Kenaf particles	Urea Formaldehyde	9.3-10.3	65-70	26-34	0.51-1.52	1559-2712	15.1-19.6	[15]
8	Leucaena Leucocephala	Urea Formaldehyde and Melamine Urea Formaldehyde	5	-	-	0.37-1.29	1373-3384	12.31-22.23	[10]
9	Maritime pine	Corn starch Tannin adhesive and Urea Formaldehyde	8-10	-	-	0.45-0.48	2307-2481	15-17	[12]
10	Waste paper	Maleic Anhydride	5	-	-	0.35-1.09	1541-2683	14.0-24.4	[13]
11	Mixture of bagasse and industrial wood particles	Urea Formaldehyde and Ammonium chloride	4	-	12.4-21.2	0.39-0.81	1020-2550	9-16	[16]
12	Bamboo waste	Urea Formaldehyde	4	-	6-7.1	0.08-0.29	749-2166	6.5-21.5	[14]
13	Roselle (Hibiscus Sabdariffa)	Urea Formaldehyde	3	-	14.12-20.36	0.36-0.72	-	-	[1]
14	Sago particles	Urea Formaldehyde	5	40-85	8-17	-	-	-	[22]
15	Water melon peels	RLDPE(Recycled low density polyetylene)	-	-	10.5	0.65	1650	12	[3]
16	Wheat straw	Urea and urease inhibitor N-(n-butyl) thiophosphoric triamide (n BTPT)	8	-	101-140.6	3.7-5.6	2601.6-3343.2	8.9-14	[7]

MC-Moisture content, WA-Water absorption, TS-Thickness swelling,

IB-Internal bonding, MOE-Modulus of elasticity, MOR- Modulus of rupture

Conclusion:

There are lot of advantages using sustainable alternatives to wood based Particle Board. There are numerous similarities between composition, application and creation process. These similarities make it hard to recognise the differences in quality concerned. The uniform distribution of particles of the particles and binders in the microstructure of board composites is the major factor responsible for the improvement in the properties. Different fibres can improve the strength of the Particle Board. For any type of Particle Board the most important property to study is water absorption and thickness swelling to compare with conventional Particle Boards but only few has done water absorption study. Almost all the researchers are using Urea Formaldehyde for manufacturing the Particle Board but it gives lot of emissions. So, the test of Urea Formaldehyde emission is important but only very few are considering this property. Particle to resin ratio is also an important consideration because both physical and mechanical properties mostly depend on this ratio. Press time and resin ratio has significant effect on physical and mechanical properties of the Particle Board. In conclusion, advancement of standard quality control tests for Particle Board allows manufacturers to examine and reducing the manufacturing problems.

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