POLYMERIC PARTICLE BOARD:A SUSTAINABLE SUBSTITUTE TO WOODEN BOARDS

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Abstract
The aim of this paper is to give overview about polymeric particleboards and its development. Particle boards are wood composite prepared from wood waste, stalks, wood shaving, etc and polymeric resin. Urea-Formaldehyde (UF) and Phenol Formaldehyde (PF) being widely used resin for preparation of particle board. Here we discuss about different types wood and resin used for manufacture of particleboard. The effect of different woods and resin on properties like internal bond strength, thickness swelling, modulus of rupture, modulus of elasticity and water absorption. Various chemical additives used to modify the properties of particle board and also fire retardant property of particle board. World is leading towards sustainable development thus use of particle board can help us in achieving a small part of it.

Keywords: particle board, polymeric resins, wood particles, chemical modification, fire retardant

1. Introduction
Wood has been essential component of our life. It has been fulfilling the basic needs of fuels and construction from ages. The basic composition of wood is cellulose (40-50%), hemicelluloses (15-25%) & lignin (15-30%). Large amounts of wood waste in form of sawdust, wood shaving, barks, etc. are generated in large amount. The increasing population has put added pressure on the natural resources so it is important to use those resources efficiently and to the optimum level. Wood being one of the most important natural resource, it is necessary to use the waste generated due to processing of wood. Particle board is best way to make use the waste generated from wood processing. Particle board is a composite of wood particles bound by epoxy, amine, phenol resins and formaldehyde derivatives being common [1]. Particle board is composite engineered wood made up of
wood chips, sawmill shaving and sawdust. Particleboard is cheaper, denser and more uniform than conventional wood and plywood and is substituted for them when appearance and strength are less important than cost. However, particleboard can be made more attractive by painting or the use of wood veneers that are glued onto surfaces that will be visible.

2. Highlights

2.1. History

Modern Plywood, as an alternative for conventional wood was invented used in 19th century. But in 1940’s, there was a shortage of timber that lead to search of another alternative for wood. The inventor of particleboard is Max Himmelheber of Germany. The first commercial piece was produced during World War II at Bremen, Germany. It was produced by smashing wood shaving, off cut or sawdust-hammer milled into chips and bound by phenolic resins. It was found that use of uniform chips can lead to better strength, appearance and also efficient use of resins. Producers than began to use fine layers of solid birch, pine, alder and spruce directly on the outer covering of the board with the core containing cheaper chips. These boards were known as “Three layered Particle Boards” [2] [3].

2.2. Wood

The woods generally used are hardwoods, softwoods and tropical hardwoods. Hardwoods are deciduous trees that thrive in temperate climate like oak, ash, cherry, maple and poplar species. Each of the species can be crafted for furniture, flooring, with variation grain pattern [4]. Softwood are made from conifers have needle like leaves. Softwood trees include cedar, fir, hemlock, pine, redwood and spruce. Tropical hardwoods include mahogany, rosewood, teak and wenge. Softwood are most commonly used for production of particle board [4]. Hardwood residues are not used in particle board industry because of its high density and high contain of extractives [5]. Softwood are easier to break down to any particle size and are chemically more compatible with one another over any other common species of hardwoods [6]. Sugarcane bagasse is also a potential product for particle board. Sugarcane stalk are crushed to obtain sucrose. Large quantity of bagasse is left after crushing. This bagasse contains both fibers as well as pith [7]. The Athel Tree (Tamarixaphylla) is a potential biomass used to manage saline subsurface water in arid agriculture land. Particle Board from Athel tree had a very good performance n humid condition due to their low equilibrium moisture content [8]. Kenaf bast is another bioresource that could be used to produce a medium density particle board. They showed excellent mechanical as well as dimensional properties[9]. Particle boards can also be prepared from rubber seed pod and cashew nut shell. The properties satisfied the ASTM for construction building boards[10]. Trials were made to use Sunflower stalk from Sudan to make particle boards with phenol formaldehyde resin. But the results stated that addition of other wood by products like saw dust was required to make it usable [11]. Experiments were carried on eggplant (Solanummelongena) stalk in production of particle board. The experiments proved viable and the eggplant could be used as a raw material to fulfill needs of particle board industry [12]. Rice husk can also be used as a raw material for particle board. The RH-SPC (soy protein concentrate) particle board have minimum required properties. It could be used in were water resistance is not required [13].
2.3 Resins as Adhesives

Wood and other similar material form the bulk of particle board. An adhesive is required to bind all these particles into one piece. Here resins are used for generation of homogenous mass. For this purpose, the only resins that can be used are Synthetic resins. Generally a relatively small quantity of resin about 4% - 12% resin solids are used. The commonly used resins are Urea-Formaldehyde and Formaldehyde.

a. Urea Formaldehyde

It is commonly used as they have low cost with a flexible formulation and reasonable tolerant of variations in processing. The U-F resin is colourless and gives attractive colour to the resultant particle board. U-F is mixed with catalyst which gives them a predetermined pot life. The main disadvantage of U-F resin based particle board is low tolerance towards humid conditions due to water solubility of UF resin.

b. Phenol Formaldehyde

It is more expensive than U-F and coloured. They give particle boards an unattractive brown colour. Phenolic resins are used without catalyst and have indefinite pot life. Phenolic resins are also said to have good tolerance towards water.[6][14].

c. U-F with Scavengers

They are nowadays used instead of only U-F. Urea Formaldehyde has high formaldehyde émission rate as compared to phenolic resin. To reduce emission, we add scavengers like melamine or hexamine. But they cannot eliminate it completely. They can reduce emission by 2-10 times. Phenolic resins have nearly 90% less emission as compared to urea formaldehyde [15].

d. Soy Flour

Biomass based adhesives have been of used in past. Vegetable proteins were widely used as they have large number of functional groups like carboxyl group, amine group and hydroxyl group. Soy flour is preferred not only because of its high soy protein content but also it is cheap and readily available. The biomass adhesive gave very poor mechanical properties as compared to phenolic or formaldehyde resins. Soy flour is now chemically modified to obtain better mechanical strength. Plywood bonded with soy protein based adhesives such as soy flour treated with polyethylenimine epichlorohydrin resin, melamine urea formaldehyde resin, polyacrylic acid solution and sodium dodecyl sulphate has improved wet strength as well as warm water resistance [16].

e. pMDI(methylenebis (diphenylissocyanate))

pMDI and Phenol formaldehyde resins are some major adhesives used in particle board. The use of pMDI has increased nowadays due to its advantages in production and performance. Some of the advantages are short press time, lower resin loading, higher moisture tolerance, no formaldehyde emission, better strength and durability [17].
2.4 Properties

The mechanical properties are determined by a variety of tests. Modulus of rupture reflects the maximum load carrying capacity of a member in bending and is proportional to maximum moment borne by the specimen. Tension strength parallel to surface is the maximum from stress sustained by a specimen from a test with tension forces applied parallel to the surface. Tension strength perpendicular to surface (internal bond strength or IB) is maximum stress sustained by a specimen for a test with tension forces applied perpendicular to the surface. Compression strength parallel to surface is the maximum stress sustained by a specimen from a test with compression forces applied parallel to the surface. Interlaminar shear (planar shear) indicates the ability to resist internal slipping of one layer upon another within the panel. Hardness is measured as resistance to indentation. Fastener holding strength is maximum resistance to separate or withdraw a fastener in plane normal to the testing face [18].

The mechanical properties of low density straw particle board were determined. The particle board with 5% MDI has better mechanical properties because MDi molecules were small and had both mechanical and chemical bonding abilities [19]. Particle board made from tobacco stalk and wood particle showed a significant increase in thickness swelling and water absorption by increasing the proportion of tobacco stalk compared to wood particles. Particle boards from 100% tobacco stalk show relatively high TS and WA of about 112% and 80% respectively [20]. The mechanical and water absorption properties of wheat straw fibers and soybean straw fibers are comparable. The modulus of elasticity is higher in wheat straw fiber particle as compared to soybean straw fibers. Wheat straw fibers and soy straw fibers are inferior in MDF production as compared to softwood. But as they are renewable and environmental friendly could be alternative to declining wood supply [21]. Particle board made from wood particles impregnated on bark of Pinus brutia showed decrease in mechanical properties but better dimensional stability and decay resistance. Particleboard with unimpregnated bark of Pinus brutia had excellent mechanical properties but highest thickness swelling and weight loss [22]. Kenaf stem was found to be a suitable partial replacement for Rubber Wood (RW). Particle board made from 50-60% kenaf stem and resin content of 8-10% was optimum to give a MOE, MOR and IB equivalent to RW boards [23].

2.5 Chemical Modification

The properties of particle board vary according to wood or raw material used as well as resin used. Each of these combinations has certain advantages and disadvantages. The particle board manufactured must satisfy a certain level of of properties to be made useful. Chemical modifications are done on these particle boards to fulfill these requirements or to enhance properties. The various chemical reactions and compound that react with wood are Acetylation, Acid chloride, anhydride, carboxylic acids, Isocyanate, Epoxides, Formaldehyde, Methylation, Alkyl chloride, β-Propiolactone and Acrylonitrile [24]. Particle boards made from wood chips modified from propionic anhydride. The dimension stability of boards was greatly improved by propionylating chips with propionic anhydride. But particle boards show decrease in internal bond strength (IB) [25]. Spruce and alder based particleboards were treated with acetic anhydride, succinic anhydride, maleic anhydride & phthalic anhydride. On treatment, low density particle board were formed using maleic anhydride. Acetic anhydride and succinic anhydride led to formation of high density
particle board. Alder chips treated with maleic anhydride showed high EMC (equilibrium moisture content). For both alder and spruce particle boards, acetic anhydride and succinic anhydride show low EMC values. Also, the modified boards have decreased thickness swelling and water absorption. Alder based particle boards show better absorption values. Phthalic anhydride based particle boards gave very good MOE and MOR [26]. When softwood is treated with 30% concentration of thermosetting resins like Phenol-Formaldehyde (PF), Melamine Formaldehyde (MF) and Urea Formaldehyde (UF), dimensional stability became efficient by 70.59%, 68.23% & 48.5% respectively at 90-100°C & 75 psi pressure. Modulus of rupture and Modulus of Elasticity increased by 12-20% & 5-12% [27]. Direct Fluorination of wood flour used as reinforcement in Polymer composites lead to decrease in hygroscopic nature of the polymers [28]. Coir fibers treated with chlorine dioxide followed reaction with furfuryl alcohol. A thin coat of FA was applied on polymer composites. This thin coating of FA leads to decrease in intrinsic hygroscopic nature [29].

2.6 Fire Retardant

Fire retardant are chemicals that are either applied externally or react with wood to protect particle board from fire. Fire retardant treated low formaldehyde particle board were made from Recycling wood waste using polymeric 4, 4’-methyleneiphenyl isocyanate (PMDI) & phenol formaldehyde resin. Fire retardant is a mixture of ammonium phosphate, diammmonium phosphate, ammonium sulphate, borax, boric acid, and ammonium bromide, in the ratio of 20:23:40:1:1:15, and with a specific gravity of 1.1.

The particle board showed increase in bending strength, internal bond strength and screw holding strength increased as we increased the PMDI: PF ratio. Fire retardant could pass third grade fire resistant performance as specified by CNS 6532 [30] [31]. Kenaf core particles were treated with 10% concentration of three types of flame retardants: Diammonium phosphate ((NH₄)₂HPO₄), monoammonium phosphate ((NH₄) HPO₄) & BP® (mixture of 27-33% boric acid, 67-73% guanylurea phosphate and 0.0-4.2% phosphoric acid). BP® treated particle board performed the best in mechanical tests even though IB value for particle board was slightly 1.31% lower than DAP. MOE performance of BP® particle boards was better than untreated kenaf particle board. DAP treated kenaf particle board have lowest thickness swelling. DAP has water absorption lower than untreated kenaf particle board [32].

Fire retardancy can be imparted in particle board using intumescing concept. An intumescent is a substance that swells as a result of heat exposure, thus increasing in volume & decreasing in density.

Ordinary wood particleboard were treated with two flame retardants: Phosphate based flame retardant – ammonium polyphosphate(PB) and expanding char layer forming flame retardant (IFR)-expandable graphite. PB, a standard flame retardant gives efficient flame retarding properties. The latter was chosen since it has char layer forming abilities at elevated temperatures. IFR showed better fire retardant performance than PB [33]. Aluminum trihydroxide (ATH) was used as a fire retardant additive and mixed with medium density fiberwood(MDF) made from rubberwood fibers & recycled old corrugated containers. Phenol formaldehyde resin content was 2%. As ATH loading was increased limiting oxygen index of MDF also increased. This indicates that fire retardancy increases. The internal bond strength increased, thickness swelling and water absorption was reduced [34].
2.7 Pre-treatment on Particle Board

Particle board require certain treatments to make its performance durable for a long time. Particle board is a wood product, thus could be subjected to discoloration, crap and wrap when exposed to temperature and moisture. Particle boards need to be treated for water resistance as presence of water can lead to generation of mold (fungi) [35]. UF- rice straw particle boards when treated with steam and short durations of oxalic acid, it improved mechanical properties, internal bond strength and dimensional stability. Steam treated particle board showed better performance as compared to Oxalic Acid treated particle board [36]. Metallic based additives were used to impart decay resistance in particle boards. But the problem of biodegradation of these additives has led to development of natural additives. Methanol obtained from wood extracts provides excellent antifungal properties against T. versicolor, P. sanguineus, and S. commune, while methanol obtained from flower extracts had excellent performance against C. gestroi. Thickness swelling, internal bond strength and formaldehyde was not negatively affecteded [37]. Steam treated particle board along with polyhydroxyalkanoates as additive at various loading helped to increase the mechanical properties. The MOR and MOE also enhanced with addition of polyhydroxyalkanoates.

3. Conclusion

The particle boards have proved to great product out of reusable waste. Although, its properties may not be equivalent to that of wood, it certainly can act as substitute for wood in certain application like furniture. The properties can be enhanced using various resins, chemical additives as well as by choosing write wood waste. Moreover, its properties have been found to be suitable for application construction industry but further research must be focused on this aspect. Wood being a natural resource which has been exploitated by the mankind to extreme levels; it has now become important to use its alternatives to safeguard it for future generation. Particle Board although are a fitting alternative to this very natural resource.

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