CHAPTER I

INTRODUCTION
Wood is an important naturally occurring renewable resource material, finding widespread use in industry. Its major uses are in the preparation of traditional structural materials, which are utilized for the construction of houses and furniture. In less advanced societies most of the wood is used as a fuel. For preparing low cost houses and furniture, wood is preferred over iron, cement and the like because of its certain valuable properties such as low thermal conductivity, high electrical resistivity, superior resistance to corrosion, high sound absorption, high strength to weight ratio, ease of procurement and workability to the desired shape and size, etc. Man, therefore, learnt to use wood and appreciated many of its virtues such as the warm friendly feel, the beauty of the natural colour and grain of different species. However, besides numerous properties available in the natural wood, some defects are also found in wood. The inclusion of these defects affects the properties and the value of the products. General defects in wood include reaction wood (compression wood and tension wood), knots inclusions, pitch pockets and decay. Wood and its major components are hygroscopic and normally retain several percent of water in equilibrium with ordinary atmospheric moisture. The problem of drying involves removal of free water (if present) and hygroscopically bound water without undesirable alteration of the substance under examination. In damp conditions, it swells while in dry conditions it may split. Observing all these characteristics by trial and error, methods of conversion of timber from the tree for use in construction were developed which overcome or minimized the above defects. However, because of the tremendous increase in the needs of the present day human civilization in diversified areas, the supply of the sawn timber could not keep the balance with the required
material. An alternative had to be looked upon which could fill the gap between the required product and the material to be used. This led to the development of wood based polymer composites.

The way in which narrow boards can be glued together to form a large panel and the method of framed construction-permitting swelling and shrinkage of the panel is well known. Ancient Egyptians were able to cut their veneer and glue them together in the form of plywood, the first attempt to improve on solid wood, and it was not until the late nineteenth century that plywood became available as a commercial product. Once it became readily available, the design of furniture changed to take advantage of these large flat panels, which were free from knots and shakes, and comparatively stable. Block board and laminated boards were also developed likewise and became established as material for furniture manufacture and similar purposes. This acceptance of panel material and the effect it had on design, ensured the acceptance of two other wood based panel materials i.e. hardboard and particle board. Both these materials resulted from an approach entirely different from that, which produced plywood. Thus, it was possible to breakdown wood substance into fiber form and reconstitutes it. A wet pulpwood mat compressed in a hot press produced a hard rigid sheet of considerable high-density hardboard as compared to the earlier fiberboard, suitable for many purposes including the making of furniture. This product quickly became accepted in many parts of the world. The production of hardboard was until very recently a ‘wet process’ with raw material in pulp form and did not require the addition of an adhesive. But the use of wood fiber in the dry state was difficult and a suitable method of forming a board material economically without the addition of an
adhesive was introduced. Also with the introduction of wood working machinery, the inevitable large quantities of wood residues produced in the form of off cuts, shavings and saw dust are available and the possibility of binding these particles together was recognized and this provided incentive to the manufacture of particle boards namely wood chipboards, flax boards, bagasse boards, etc. The term particle board appears to be the only English word available for use as generic description of various board products made from wood particles by dry process manufacturing technique. Despite the general acceptance of the term particle board there exists some confusion on the scope of the term and the precise definition of the material it describes. According to International conference under the auspices of the food and agricultural organization of the United Nations in 1957, the particle board was defined as, “A sheet material manufactured from small pieces of wood or other lignocellulosic materials (e.g. chips, flakes, splinters, strands, shives, etc.) agglomerated by use of an organic binder with one or more of the agents like heat, pressure, moisture, catalysts etc. The definition given in B.S. 1811, 1961 in substance is the same i.e. boards made from particle of wood and/or other lignocellulosic materials bounded with synthetic resin and/or other organic binder are termed as particle boards. For practical purposes, it can be defined as the generic term embracing wood chip boards and flax boards and might in future include such products as bagasse based boards, bamboo boards or similar boards made economically from lignocellulosic material indigenous to a particular area.
PREPARATION OF PARTICLE BOARDS

Cellulose is the principal component of the cell walls of wood. Cellulose from wood has found industrial uses as the source of paper making and dissolving pulps. The manufacture of particle boards from the wood waste with the help of adhesives involves the interaction of the cellulose content of the wood with the adhesive to give covalent linkages between the two, leading to the formation of a strong stable particle board/panel product. Many valuable cellulosic fibers and other cellulose derivatives are also obtained from other agricultural products such as seed hair (cotton), bark fibers (flax, jute and ramie), leaf fibers (hemp), stalks and straws, bagasse, etc. Based on the observation that particle boards are being manufactured from wood waste materials, a source of cellulose and adhesives, attempts have been made to utilize other agricultural products/waste, rich in cellulose content, for the preparation of particle boards all over the world.

The main constituent of particle board, thus, is fibrous lignocelluloses present in the form of discrete particles, which can be obtained from a variety of naturally occurring raw materials. These materials can properly be referred to as (1) forest residues, (2) industrial wood residues, (3) flax residues and (4) agricultural residues. The other constituents needed for the particle board, although less in bulk but are equal in importance are the resin/adhesives and additives. For the manufacture of the particle board from these raw materials, treatment of the material is possibly of greater significance even than the constituent materials themselves. The breaking down of the lignocellulosic material is carried out either by breaking or crushing and cutting. Generally cutting gives superior products for if long, smooth and slender chips are
produced, one can expect to have strong boards. The amount of adhesive has a direct influence on the strength of the board since the strength of the synthetic resin bond is higher than that of the lignocellulosic material itself. It is, however, unnecessary to cover the whole area to be bonded with resin but sufficient to bring the resin droplets close enough to each other to make them act on the whole surface of the material. Apart from the board strength, the amount of adhesive has a great influence on such properties such as resistance to water absorption, resistance to swelling in solvents, initial flatness and workability. These properties may suffer a setback at higher concentration of adhesive. With the correct amount of adhesive, uniform distribution within the material and hence in the particle board is also a very important factor. Any agglomeration of chips containing excess of resin is likely to affect not only uniformity of appearance of substance but also even the thickness of board. The well-known phenomenon is caused by the natural tendency of the urea-formaldehyde adhesive to shrink, this action being progressive for periods of two to three years. This means that a furniture component sanded, veneered and duly sanded again, during a period of years may develop an indentation on the surface corresponding to the agglomeration in the board. During the treatment of the lignocellulosic material with the adhesives, an additive has to be added to the mix in amounts large enough to be efficient with respect to water absorption and swelling resistance and small enough to adversely affect the bonds between the material and any subsequent gluing operation performed on the finished board.

An important factor to be aware of before the treatment of the mix i.e. lignocellulosic material and the adhesive, for the preparation of the particle boards under heat and
Excess of water may result in blistering unless the cycle is prolonged while lack of water results in poor bond, poor surface and poor strength. The distribution of the moisture content is independent of the particular constituent of the mix. The lack of moisture in the wood chips can be corrected by the excess of water in the adhesive and conversely dry urea-formaldehyde powder may be used directly as an adhesive instead of usual syrup, if the wood carried enough water.

The manner in which the mix is made ready for pressing determines the type of board obtained. Thickness of the mattress, speed of loading, speed of daylight, closing speed of applying full pressure, time and temperature of the press, unloading and stacking, cooling of hot pile, etc. are different factors that affect the quality of the particle board.

According to their structure and method of manufacture, boards are classified as:

(i) **Single-layer particle board**: It is a board made up of one uniform layer of particles and resin mix, predominantly of uniform texture and having uniform density across the board thickness.

(ii) **Three-layer particle board**: A board made of three layers of particles and resin mix, usually with finer and thinner particles for the top and bottom layers and coarser and bigger particles for core layer. Resin content in a three-layer board is usually higher in the face layers than in the core layer leading to a sandwich construction with stronger and denser skin.

(iii) **Graded density particle board**: It is a board formed by arranging the wood particles in a graded manner such that the smallest particles form the topmost
(iv) Layer and the largest particles form the middle layer. In graded particle boards there is gradual density gradient from top to the centre of board across its thickness.

(v) **Extruded particle board:** - It is resin bonded particle board manufactured by mixing wood particles of predetermined size and shapes with synthetic resin and curing and pressing while the mix is being forced through an extrusion hot platen press, pressure being applied in the direction of the length of extrusion which tends to orientate the wood particles considerably in a direction at right angle to the direction of extrusion.

(vi) **Flat pressed particle board:** - Resin bonded particle boards manufactured by mixing wood particles of predetermined size and shapes with synthetic resins and curing and pressing in a parallel platen hot press of the usual multi-day light type but may be pressed in a continuous hard type of pressure. The applied pressure is perpendicular to the plane of the board.

(vii) **Multi-layer particle board:** - It is a board made of more than three layers of like material in which particles of different shapes and sizes may be used in different layers.

**REVIEW OF LITERATURE**

The manufacture of particle boards, thus, utilizes the raw materials rich in cellulosic content along with the adhesives. Coniferous species of forest residue are used in virtually all those countries, which are foremost in the particle board development, primarily due to the fact that ample supplies of these species are available. Softwoods are also preferred as being easier to breakdown to particle size, less friable when broken down and more compatible chemically with another over the common range.
of species, than are hard woods. Apart from the very large quantities of forest products available in the round wood form, the normal conversion of timber to the sizes required by carpenter and joiner gives rise to slab wood and off cuts on initial conversion, and to shaving from planer, spindle and other wood working machinery at a later stage. The manufacture of plywood and block board provides a residue in the form of peeler cores, veneer trimmings and plywood off cuts. All these material, suitably processed can be utilized in the manufacture of wood chipboards. Other than this agricultural vegetation containing lignocellulosics are also available in large quantities. After proper treatment of these materials, cellulosic fibrous portion of the vegetation is separated out which is suitable for the production/manufacture of the particle board. The waste from the utilized agricultural material such as bagasse, jute fiber, and rice husks, etc. containing optimum cellulosic contents can also be used for the manufacture of particle boards. Development of particle boards using different lignocellulosic raw materials has been successfully attempted by different group of workers. Pine plywood was developed by Hse Chung Yun using phenolic resin and polymethylene polyphenylene isocyanate as adhesive, which can be adequately bonded better than conventional resins. Particle boards from wood chips were prepared from modified phenolic resins which imparted improved resistance to breakage. Specimens of 2-ply red canon plywoods were prepared by Japanese workers using soyabean based adhesives. The water proofing properties were improved with the addition of Millionate MR solution to the adhesive. Beams made from Siberian Larch bonded with phenol-formaldehyde based resins were prepared and examined for strength and deformability with regard to long term and short term
loading of the samples. Deodar plywood with warm water resistant specifications was prepared from hot setting urea-formaldehyde copolymer adhesive. Water repellency of Pinus nigra on treatment with alkyd, coumarone-indene and hydrocarbon resins was improved with the addition of paraffin wax. However, the same treatment did not improve the water repellency in beech as compared to the treatment with resins without paraffin wax. Treating wood fibers with acid and alkali catalyzed formaldehyde-phenol copolymer as adhesive, consolidating in a mat, followed by hot pressing gave fast and lignocellulosic particle board which exhibited no sticking. Particle boards from hardwood chips with increased internal bond strength were prepared by applying polymethylene polyphenylene isocyanate prior to addition of formaldehyde-phenol resin. A mixture of para-formaldehyde coconut shell and grits from phenolic or urea bonded board was used as hardner for formaldehyde-phenol copolymer adhesive for the manufacture of plywood from leech veneer with improved tearing resistance and puncture test. Thick plywood was prepared in a rapid process by pressing veneers coated with pressure sensitive 2-alkenoic acid copolymer adhesive by Ohinura. Takashi, Imada manufactured plywood from green and semidried panels using thermosetting aminoplast adhesive containing curing hardners and extenders. Particle board from Lanan chips with bending strength of 238 kg/cm² and peeling strength of 6.5 kg/cm² was prepared using phenol-formaldehyde resins containing poly (vinyl alcohol). The particle board showed improved properties over the boards prepared from a water soluble phenolic resin adhesive by using only sodium hydroxide. Japanese workers prepared wood boring beetle resistant 3-ply Lanin and Linden plywood using chlordane in the usual
phenolic-melamine or urea resin adhesives. Insect repellent Lanam plywood panels were prepared from vinyl acetate emulsion resins containing 0.001-100% chlordane. Bonding phenolic resin-impregnated kraft paper to plywood produced decorative board useful as a floor covering with a coating of a modified poly (vinyl acetate). Manufacture of wood veneers useful for plywood was undertaken by continuous process by partially coating two sides with an adhesive followed by reaction with water and a curing agent. Use of coffee husk in phenolic resin containing ground protein was made to produce an adhesive for hot water resistant plywood by a pharmaceutical company. Lanam veneers were coated with mixed composition of formaldehyde copolymer and pressed together for 10 min at 140°C to give antibacterial plywood with good cohesive strength. Adhesive strength data indicated that powdered Pinus roxburghii needles can be used as fillers and extender in formaldehyde-phenol copolymer binder for the production of plywood from Abies pindrow, Chloroxylon swictenia, Atrocarpus chal plasha, Dipterocarpus and Poplar wood. Lanam veneers prepared from emulsion type polyisocyanate modified adhesives produced a plywood with cohesive strength 11.9 kg/cm² after repeated immersion in boiling water whereas separation occurred on immersion of plywood manufactured with a similar composition without coronate 3053 i.e. polyisocyanate. Blending wood particles with < 6% adhesive consisting of propylmethyl diisocyanate urea or phenolic resin gave a rigid particle board with void volume ~ 10% . Resin coated wood chips were sandwiched between simple wood chips and were pressed to give particle boards without puncture. However, puncturing was observed in the particle boards obtained from coated chips sandwiched between wood chips also
coated with urea-formaldehyde resin having degree of condensation \( (d=3) \). Similarly three layered particle boards were prepared by coating wood chips with mixtures containing an amino resin and polyethylene glycol, sandwiching core chips between two layers of the first chips. These boards have increased surface density. Insect resistant plywood was manufactured with adhesives containing a microencapsulated formaldehyde resin or a vinyl resin insecticide. Southern pine veneer (moisture content 5\%), treated with formaldehyde-phenol copolymer and lignocellulosic material was added to Bentolite to give plywood with 90\% wood failure under 220 Psi vacuum pressure. Plywood made from veneer impregnated with the phenol-formaldehyde resin and \( \text{NH}_4 \text{H}_2\text{PO}_4 \) as fire retardant, and also melamine resin containing fire retardant met the requirement of standard JISA 1321 combustion tests. Modified adhesives were used in the manufacture of particle boards, plywood and bonded wood structures. Plywood with increased physico-mechanical properties was prepared using water resistant adhesive which retained its strength after exposure to \(-5.5^\circ\text{C}, 80\% \text{ humidity and 32 mm rainfall}\). Water containing (2.5\%) soft wood shaving were spray coated with an aqueous solution of formaldehyde-phenol copolymer containing a sacccharide, lignin sulphonate and \( \text{NH}_4\text{Cl} \) and were pressed to give particle board with cohesive strength of 112 Psi and water absorption (82.2\%). Adhesive containing 2,3-diiodoallyl alcohol as wood preservative was used for the manufacture of decay resistant wood boards. Plywood from Buna veneer with the modified adhesive has good decay resistant properties. Particle boards from Spruce-beech chip mix (60:40) were prepared on treatment with formaldehyde-melamine-phenol-urea resin containing aqueous mixture of ammonium.
salts of succinic acid, glutaric and adipic acid as hardners. The boards having bending strength of 31.5 N/mm² showed 1.9% swelling in water after 2 hours and have cross directional tensile strength of 1.10 N/mm². Fire retardant plywood with good adhesion is prepared by adhering fire retardant treated veneers (or untreated) with an adhesive containing 100 parts of aminoplasts and 1-50 parts of resorcinol resin with or without fire retardant and the boards have 10.1 kg/cm² sheer strength and 43% breakage. Wood chips coated with water borne adhesives containing 1 to 30 parts/100 parts of adhesive solids, elastomers containing units of a conjugated diene, a vinyl monomer and a cross linkable monomer are useful for manufacture of heat resistant particle boards. Strongly bonded plywood is prepared using water-thinned adhesives having thermally expandable microcapsule containing volatile solvents and cross linking agents. Cross-linking is done above the foaming temperature of the microcapsules under pressure. Particle boards with improved water resistance were prepared using excess of the adhesive so that the particle surface is completely covered after pressing. Particle boards with high transverse tensile strength of 0.58 N/mm², flexural strength of 30.5 N/mm² and formaldehyde evolution 8.0 mg/100gm were prepared using urea-formaldehyde resin having 0.20% melamine and 0.5% PhOH and NH₄ salts of inorganic acids. Plywood prepared by bonding Lanan veneers with urea resin containing NH₄H₂PO₄ and other additives showed adhesive strength of 12 kg/cm² and acceptable flame proof performance. Cellulosic particles of wood chips were pressed into boards using modified formaldehyde based amino and phenolic resin binders with internal bond strength of 7.2 kg/cm². Particle boards for use in furniture were prepared from wheat straw particles and polymeric
isocyanate resins. The boards revealed good physical and mechanical properties matching to standards required for the furniture particle boards. The use of fine particles (>40 mesh) of lignocellulosic materials typically wood, in combination with an extrudable plastic, allows an increased proportion of wood to be used (typically 750% wood to plastic) and still a particle board of good quality surface finish is obtained. Fire resistant particle boards were prepared from formaldehyde-urea copolymer and cotton stalks. Fire proofing agents used were oligomeric epichlorohydrin-phosphonic acid dimethylamide copolymer and monomeric product of phosphoric acid with cyanoguanidine and urea. Particle boards useful for furniture, fixture and building materials are manufactured by spraying wood chips of high water content (12-18%) with isocyanate adhesive and hot pressing. The foaming mats of the particle boards are thus hard to lose shape during conveying. The manufacture of high performance composite fiber boards and particle boards from bagasse, bamboo and jute was carried out by Zhang and Shiryo. They studied the mechanical properties and dimensional stability of the boards. Effect of adhesives and adhesive applying technique on the mechanical properties of the board was also investigated. Waste materials from flax proceeding are chip shaped with low moisture contents and are used for the manufacture of particle boards which satisfactorily meet the requirements set by the China standards (GB/T4897-92). Multi-layer particle boards with low density and good bending strength comprise surface layers prepared from wood chips containing 10% H2O and binder from formaldehyde-based resins and a core layer from chips containing 5-50% urethane polymer. The boards with ϕ=0.39, bending strength of 142 kg/cm², wet bending
strength (B Test) of 77 kg/cm², adhesive strength of 8.9 kg/cm² and good finish were obtained. Water proof particle boards were prepared by treating wood chips with nonflammable gases such as Ar, He, Kr, CO₂, NH₃ and SO₂ for approximately one hour at 100-200°C before bonding. Low density particle boards from Lanan wood chips which were prepared by treating with binders containing polymethylene polyphenylene isocyanates. The manufacture of multi-layer construction materials from wood particle mixtures and a thermosetting adhesive comprises a center layer of adhesive coated wood particles. The particle boards with bulk density of 620 kg/m³ and bending modulus of 2300 and bending strength of 17.5 units were obtained. Particle boards were made from coir pith using phenol-formaldehyde and urea-formaldehyde resins. The mechanical properties, modulus of rupture, tensile strength both parallel to surface and perpendicular to surface and other properties have been determined. An improved method of manufacturing particle boards has been used by Japanese co-workers. They used the granular solid materials coated with an aqueous dispersion of thermosetting resin with solid content of 10-65% and viscosity of 5-1000 cP. The particle boards were lightweight and have good mechanical strength, water resistance and machinability. Iwakoshi et.al have suggested methods to prepare amino resin adhesives with short time adhesion and particle boards. Wood particles metalized by electrolysis plating were found suitable as a raw materials for the manufacture of particle board materials having electromagnetic shielding effectiveness. The particle boards have greater electrical conductance and electromagnetic shielding. Water resistance and odorless boards showing storage stability are prepared by using amino resin adhesive with bending strength of 226
kg/cm², wet bending strength of 117 kg/cm². The sap and heartwood separated from middle and small diameter log of Japanese fir were used to prepare particle boards bonded with isocyanate glue. The modulus of rupture, internal bonding and screw bonding strength of the particle boards increased as the board density increased. Formamide, hexamethylene tetramine and K₂CO₃ were evaluated as catalysts for phenol-formaldehyde resins in the manufacture of particle boards from bagasse.
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