Research and Industry
Vol. 25, December 1980, pp. 191-197

1980 0941 105

Wood Particle Board: Its Applications and Performance in Buildings

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Received 17 *June* 1980; *accepted* 14 *October* 1980

Wood particle board is a reconstituted wood-based panel product, now made in large quantities in India. Its preparation, properties and in-service performance in building have been discussed in the paper. Experimental constructions with wood particle boards were put up to evaluate their in-service performance. The boards were greatly damaged by water. Excessive thickness swelling, delamination and disintegration of wood particles at the edges and joints were the most conspicuous failures. Volume increase as a result of weathering lowered the strength of the board as well as its grip on screws. Popping of wood particles damaged the coating on them. Application of paint and water proofing coatings improved the performance. However, soaking water proofing agents or cashewnut shell liquid resin into the board appeared to be more effective compared to a surface coating on the board. A constructional design that allowed free flow of rain water extended the life of the board.

Particle board is a wood-based panel product which provides a smooth surface of greater length and cross-section compared to wood. It maintains the appearance and warmth of wood. The anisotropic behaviour of wood is absent in its swelling and shrinkage with changes in moisture content. The dimensional stability is, therefore, greatly improved. Like wood it can be cut, screwed and nailed. All these characteristics make it a potential material for many applications in building.

The production of particle board in India started almost after 1960. There are about nine units in production, located in UP, Karnataka, MP, Kerala, Tamil Nadu and AP. However, the growth of consumption has been rather disappointing. From 700 tonnes in 1962, the production had gone up only to slightly above 25000 tonnes by 1978[1]. It mostly finds use in construction and furniture.

Particle boards may be classified according to:

(A) Density

(1) Low density board $\leq$ 400 Kg/m^3.
(2) Medium density board 500 Kg/m^3 to 900 Kg/m^3.
(3) High density board $>$ 900 Kg/m^3.

(B) Type of resin binder used

(1) Cold and warm water resistant (CWR and WR).
(2) Boiling water resistant (BWR).

(C) Arrangement and distribution of wood chips

(1) Three-layered board.
(2) Non-layered board.
(3) Graded board.

(D) Method of manufacture

(1) Extruded board.
(2) Flat pressed board.
(3) Tubular board.

Most of the units in India employ the flat platen pre-press process of manufacture. There is, however, one unit which is based on extrusion process. Three-layered boards were very common in the seventies. Now mostly non-layered boards with fine or thin particles on the surface are manufactured. Such boards give smooth surface which presents a favourable appearance when painted or veneered.

Raw materials

A particle board consists essentially of wood chips of suitable size, resin binder and a small quantity of paraffin wax. There is no major restriction on the type of wood used. Normally, soft woods of low density are preferred. Residues of low grade woods, including mixtures of soft wood and hard wood species, forest thinnings, planer shavings, and even sawdust can be used for its manufacture. It is sometimes desirable to mix species of a wide range of densities and produce acceptable particle boards of different densities. Apart from wood and wood waste, large quantities of farm waste, such as bagasse and jute sticks are important raw materials for the production of particle board.

Phenol formaldehyde and urea formaldehyde resins are the most widely used adhesives in the manufacture of particle boards. Compared to phenol formaldehyde resins, urea formaldehyde resins and melamine modified urea resins give a better looking product because of their light colour. These resins can be produced and used at higher concentration (~60%) than the phenol formaldehyde resins (40%). The use of urea formaldehyde resins, therefore, extends the usable moisture range of wood chips. However, particle boards made using urea formaldehyde are not truly water proof and, therefore, can be used only for interior applications. For exterior use, particle boards bonded with phenol formaldehyde resins are suitable. Liquid PF resins are not able to withstand tropical conditions and so almost all major factories in India manufacture their own ready-for-use resin.

The absolute quantity of adhesive used in the production of particle boards is very large, although it constitutes a small proportion when calculated on the total surface area of the particles to be bonded. On cost basis, it accounts up to 50-60% of the total cost of the board. Both phenol formaldehyde and urea formaldehyde resin adhesives are petrochemical based adhesives and, therefore, it is unlikely that their prices may fall. Natural adhesives have not succeeded in supplanting synthetics in India. However, there exists wide scope for fortifying synthetics with tannins and lignosulphonates.

Wax in the form of water emulsion is also added to the bonding composition used in the manufacture of particle boards. Its addition improves the resistance of the board to water. However, addition of more than 1% wax by weight affects the strength of the board adversely.

Methods of manufacture

Preparation of wood chips—The wood chips are produced by cutting and breaking wood through hammer mills and attrition mills. In general, wood chips are of two broad types: (i) those produced by the action of a cutting knife to form flakes with predetermined geometry, and (ii) those formed primarily through a breaking or tearing action. The particles thus obtained are passed through special screens until all the undesirable particle fractions are screened out. The wood dust is also eliminated. The wood particles are next dried in driers to control their moisture content to less than 15% before the application of glue.

Blending wood particles with glues—The majority of the new installations use short retention time rotary drum blenders. These blenders allow the consumption of less resin than the older types. Resin and wax are blended with dried particles. These are introduced through air atomizing spray nozzles, or through the shaft of a rotor and dispersed into wood particles by centrifugal force. The post-drying of the adhesive coated particles is accomplished by pulling warm air (50°C) through it.

Mat forming and pressing—New types of mat forming machines have been developed recently to suit thick flakes and low cost wood residues. Normally, a mat is formed by gravity deposition of the adhesive coated particles on a flat support. With this method, a random deposition of particles with certain discontinuity of the particle layer is obtained. Fine particles settle at the bottom of the support, while large particles form the top side of the board.

For mat transport, both caul system and caulless system are used. The caul system is predominantly adopted. However, the caulless system, generally using prepressed mats, has gained importance during the last ten years.

The mat is next cut to a uniform thickness and then hot pressed to a predetermined thickness and density in an electrically heated hydraulic press. The pressure is normally maintained at 18-22 kg/cm^2. It is higher (25-30 kg/cm^2) for multiplaten presses. Depending upon the thickness of the board and the type of adhesive used, the press is kept closed (12-15 min) at a temperature of 115-150 C. Great care is exercised to obtain uniform thickness to avoid precuring glue line near the press platen before the densification is completed and maximum contact between particles and glue is developed.

The particle boards thus made are next cooled to room temperature and their surfaces are finished with belt sanders. These are then cut to standard sizes. Laminated particle board with thin thermosetting plastic impregnated papers are not made in India. Wood veneered particle boards are made in large quantities.

Properties of wood particle boards

The individual wood pieces in a platen formed particle board are randomly oriented. Therefore, the net change in a given dimension of the board is the sum of the changes in the dimensions of individual particles in the direction of measurement. However, the overall properties of particle boards are the result of a combination of component variables, such as board density, species of wood, size and shape of particles, type of resin, its quantity and distribution, press cycles and other production variables. Board density is the most important parameter, as virtually all strength and acoustical properties of particle board are strongly correlated to density. Maximum strength for a given wood and particle size can perhaps be obtained if the binder and the particle geometry are such that 100% resin efficiency is obtained and the axes of the wood fibres within the board are in the plane of the board. However, in three-layer board of a given species of wood, the maximum strength properties of the surface layers can differ from those of the core only through differences in density and particle orientation or both. In non-layer board, the composition throughout its thickness is the same. Like all wood and wood-based products, particle board expands and contracts with change in moisture content brought about by changes in humidity. Thinner panels are greatly affected by these changes.

The main properties of a few Indian particle board samples were determined and are given in Table 1. It is obvious that there is wide variation in properties from board to board which suggests the need for improvement of the method of their manufacture. Values for water absorption are quite high and those for vertical absorption are

Table 1—Characteristics of Particle Boards

Characteristic	PF 3-layered board (A)	PF 3-layered board (B)	PF single-layered board (A)	PF single-layered board (B)
Bulk density, kg/m³	735	765	750	800
Moisture content, %	7.1	7.3	8.7	7.1
Modulus of rupture, kg/cm²	221	173	122	189
Modulus of elasticity, kg/cm² (× 10)	49.3	27.3	20.1	28.3
Tensile strength perpendicular to surface, kg/cm²	9.4	6.0	11.0	11.6
Water soaking behaviour				
vertical soaking				
Water absorption, % (24 hr)	34.7	35.9	36.0	15.4
Thickness swelling, % (24 hr)	4.0	12.4	10.2	5.1
Horizontal soaking				
Water absorption, % (24 hr)	10.9	9.4	23.9	6.2
Thickness swelling, % (24 hr)	2.6	5.2	4.8	2.8
Nail holding strength normal to the surface				
Nail holding, kg	75	37	6.0	110
Screw holding, kg	250	148	175	362

Table 2—Strength Properties of Particle Boards after Outdoor Weathering

Type of board	Bending strength after 8 months			Tensile strength perpendicular to the surface				Nail and screw holding strength (normal to the surface) 24 months		
				12 months		24 months				
	Moisture content at test %	Modulus of rupture kg/cm²	Modulus of elasticity kg/cm²	Moisture content at test %	Tensile strength kg/cm²	Moisture content at test %	Tensile strength kg/cm²	Moisture content at test %	Nail holding kg	Screw holding kg
P.F. Three-layered board (A)	7.6	133	28.4	6.0	4.8	5.3	4.6	10.8	42	205
P.F. Single-layered board (A)	9.7	53	—	7.2	3.0	6.1	3.0	—	45	165

higher than those for horizontal absorption. These are harmful for the particle to particle bonds and particle to glue bonds. The use of particle boards in exterior applications has, therefore, been very limited. Considering these factors, a systematic investigation on the use of particle boards as cladding and roofing units was undertaken at this institute. The first part of the investigation involved outdoor exposure of untreated particle boards, while the second part involved its application as a cladding and roofing material in construction.

Test panels were exposed vertically facing south in two ways: free and fixed on wooden frames[2]. It was observed that the boards suffered in general from mould growth, loss of colour, surface erosion and thickness swelling. Particle popping was also most conspicuous. As a result of surface erosion and particle popping, the surface had become very rough. Edge cracking and delamination were other important failures of the boards. The bending strength, however, dropped down to 30-50% (Table 2). Boards exposed on wooden frames fixed with nails and

Table 3—Characteristics of Particle Boards taken from the Wall and Roof of Standing Structures

Characteristic	Walling panel (12 mm)		Roof panel (19 mm)	
	Before exposure	After 4 years' exposure	Before exposure	After 10 years' exposure
Bulk density, kg/m³	765	630	800	680
Water absorption, %	52.1	79	6.2	22
Modulus of rupture, kg/cm²	172	98	189	150
Modulus of rupture (wet), kg/cm²	—	—	—	105
Tensile strength (perpendicular), kg/cm²	6.0	—	11.6	—
Tensile strength at max. load (M/C=12.6), kg/cm²	—	—	—	52.5
Thickness swelling, % of standing structure	8.7	12	2.6	10
after 24 hr water soakings	—	12+12=24	—	10+5.8=15.8
Screw holding strength, normal to the surface, kg	275	60	362	144
Nail holding strength normal to the surface, kg	70	66	110	96.5

screws performed better than the free panels. Boards having low initial water absorption and high internal bond strength and tensile strength performed better.

The performance of non-layered particle board under used condition was studied by putting up a number of small structures giving due consideration to spacing of the support, size and spacing of screws/nails, etc.[3]. Particle boards for a walling were 12 mm thick, whereas 19 mm thick boards were used for roofing. The structure had a 30° pitched roof on timber ridge and rafters. The exterior surface of the walling board was given a three-coat paint system, viz. pink primer, synthetic enamel undercoating and finishing. Cashewnut shell liquid (CNSL) resin coating extended with iron oxide red was also applied over a few panels. For roofing, special grade particle boards heavily coated with paraffin wax were used. A section of the roof was given a three-coat paint system after sealing it with a coat of CNSL resin.

The paint system consisting of pink primer and synthetic enamel applied to side walls failed in two years. The south-east wall showed excessive cracking and peeling of the paint film. The exposed edges of the boards failed due to thickness swelling and cracking in less than two years. A coat of synthetic enamel was applied at this stage and the observations were then recorded again after a period of two years. The south-east facing boards lost strength considerably. Values of change in density, water absorption thickness swelling and modulus of rupture before and after weathering are given in Table 3. The ground joints failed on account of excessive thickness swelling and disintegration of the wood particles. At many places, the board opened up at its lower end. The horizontal joints and wood beadings did more harm than good to control thickness swelling of the edges. They obstructed the free flow of rain water and caused thickness swelling, softening and disintegration of the board. The walling boards which were given a thick water proof coating based on CNSL resin and protected by roof projection performed better than those finished with synthetic enamel based on alkyd. The structures which received maintenance coating are still in good condition.

Roofing boards remained in good condition even after 10 years. Only the ends were affected by thickness swelling, delamination and crumbling. Boards which were partly under a tree and received a lot of dripping water during rains got damaged after 8 years. The underside of the board suffered from mould growth and water stains. One of the board was removed and subsequently examined in the laboratory. The results are given in Table 3.

The structures remained in good condition where the boards were treated with CNSL resin or regularly received a coat of synthetic enamel every twelve months.

Discussion

The single most important factor that contributes to outdoor weathering of particle boards is the change in its moisture content. UV radiations and chemical changes do not appear to have significant effects on its weathering. Constant changes in moisture content create shrinkage and swelling stresses on the glue line in between the adjacent particles as well as in the particles themselves. In the initial stages, resin accommodates stresses through its plastic flow; increase in resin content improves the resistance against these stresses for a long period[4]. However, much of the advantage is lost on ageing[5]. The extent of water vapour permeance is of minor importance below a certain maximum value (1.2 G/M^3 24 hr mm Hg)[5]. It is the absorption and desorption of liquid water that lead to excessive thickness swelling, surface roughening and distortion of the board. Thickness swelling is caused by normal swelling of wood particles and swelling due to release of compressible set.

From the observations given in Table 3 it is seen that the boards have swelled by 10-12% of their original thickness while standing and this process is irreversible. This increase in bulk volume is clearly reflected in the strength properties of the boards. The modulus of rupture has dropped down by 35-43%. These boards had an initial protective coating on them. Compared to this, the unprotected board showed a drop of more than 40% strength in only 18 months' exposure[2]. In fact, a paint film can at best delay and prevent excessive moisture penetration in the board temporarily, but cannot stop it. The effectiveness of paints increases if the gaps between the particles are sealed and the surface is smoothened before painting[6]. A normal alkyd paint has a limited exterior life of about two years on particle boards[7]. A regular maintenance painting is, therefore, necessary for extending the useful life of such structures.

The satisfactory solution has not been found for the water proofing of particle boards. The addition of 1-1.5% paraffin as emulsion during its preparation appears inadequate. The swelling of wood particles on the surface layer of the board forces out any finish on it[8].

Cashewnut shell liquid resin (CNSL) protects the board by virtue of its being resistant to water and its excellent outdoor durability. Soaking the resin into the board appears more effective than the coating. Even roof panels with CNSL treatment perform better. CNSL resin forms essentially a phenolformaldehyde type of condensate and so its extensive use on particle boards for exterior applications in building is quite effective. The impregnation of PF resin has been reported to reduce irreversible thickness swelling significantly and to confer greater stability than the same percentage of resin applied entirely as a binding resin[9]. Oil tempering and post-heat treatment of the board have also been found to influence the dimensional stability and strength of the board[10,11].

Surface roughening and popping of wood particles have also been serious problems associated with the weathering of particle boards. Normal oil-based paints fail to check them. They allow rain water to remain on the surface of the board for a long period and thereby increase the risk of more water soaking into the board. These defects can be remedied only with the use of micro-chips on the surface and water-proofing the surface of the board. Although particle boards are available in large size, their application in buildings necessitates many joints. These joints are very often covered with wood beadings, which obstruct the free shedding of rain water. This not only allows water to get into the board through the open ends by capillary action but also delays its subsequent evaporation, resulting in decay of the board around the beadings. The best solution is again water-proofing and adequate sealing of the open ends before nailing and covering them with wood beadings. The use of tapered beadings is likely to help smooth flow of the rain water.

Acknowledgement

The paper is a contribution of the Central Building Research Institute and is published with the permission of the Director.

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