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Preliminary study on a hybrid board of poplar fibers and particles mixture

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Abstract
The concept of mixing particles and fibres of same species in lieu to achieve a board having strength of both particle and fibres was the idea of great interest of the present study. In the present study a hybrid board was prepared by mixing fibres and particles of poplar in equal ratio with urea formaldehyde at 8, 10 and 12% resin content and tested for physical and mechanical properties. The results showed that both physical and mechanical properties of hybrid board exhibited satisfactory results better than particle board based on Indian Standards and gave a possibility to replace particle to some extend by fibres in particle board.

Keywords: Hybrid board, urea formaldehyde, ammonium chloride, physical and mechanical properties

Introduction
Particle board is one of the most important panel products in India which is attracting industries since it works on the concept of zero wastage and a leading way to conserve limited forest resources (Maloney, 1989) [10]. A wide variety of species, low grade or wood waste, logs, branches, roots etc can be used for manufacturing of particle board. It is made from low grade wood or wood wastes. It makes its cost very low as compared to other boards such as plywood (Anonymous, 2017) [3]. However the products made by particle board are not as strong when compared to other engineered woods like plywood. The most important reason is lower density of panel which is liable to be easily getting damaged during handling. Apart from being low on strength, it is also sensitive to moisture and humid condition (Anonymous, 2018[a]) [1]. Instead of wood particles, fibers play major role in internal bonding and smoothening of the surface. The fiber board is denser in nature than particle board. Medium density fiber board (MDF) is most popular composite board in recent years. It is more uniform, dense, smooth, and free of knots and grain patterns which make an excellent substitute for solid wood in many applications. Its smooth surface also used as excellent base for veneers and laminates (Anonymous, 2018[b]) [2].
The fiber and particle have distinct physio mechanic characteristics. So it was assumed if a hybrid board could be prepared which had the combined strength of particle as well as fibres and better than the particle board. Therefore in this study a preliminary experiment was conducted to know the feasibility of a hybrid board. The board was manufactured by particles and fibers of *Populus deltoids* in 50: 50 ratios and urea formaldehyde was used as resin at 8, 10 and 12% resin content. The effect of resin content on physical and mechanical properties of hybrid board was also studied.

Materials and Methods: Lops and tops of Poplar (*Populus deltoids*) were collected from Forest Research Institute Campus, Dehradun. Hybrid boards were prepared by mixing of particles and fibres (50:50 ratio) of Poplar species. Synthetic resin urea formaldehyde (35% solid content) were used as a binder in this study.

Particle and Fibre preparation: Poplar lops and tops were converted into small pieces, dried and processed in condux mill. The particles were sieved (20 Mess) through to get uniform size particles. For fibre preparation, the small chips of poplar were treated with 4% NaOH solution for 72hrs. After soaking, the chips were processed through condux mill and washed thoroughly. Then the fibres were dried, and reduced up to 8% moisture level.

Preparation of Board: For the preparation of 10mm thick and 21sq inch hybrid board, the dried particles and fibres were mixed together in 50:50 ratios (1400g fibres and 1400g particles). Urea Formaldehyde resin having 35% solid content at three different concentration (8%, 10% and 12%) were mixed with water as a binder. 2% (by weight of UF) Ammonium chloride were also mixed with UF resin and applied through spray gun. After this, the mat formation of material was done in 21" x 21" wooden frame followed by hot pressing in hydraulic press at 21kg/cm^2 pressure and 150 °C temperature for 30 minutes. The board was removed from press and further conditioned for 2-3 days at room temperature. The edges were trimmed to avoid edge effect on the boards during testing.

Testing: The boards were further cut into various test samples in circular saw for evaluation of physical and mechanical properties of boards as per IS: 2380 (1998) [8].

Table 1: Different sample size for physical and mechanical properties testing

Sl. No.	Physical and Mechanical properties	Size of test Sample
1	Density	150mm X 75 mm
2	Moisture Content	150mm X 75 mm
3	Water Absorption	300 mm X 300 mm
4	Thickness Swelling	125 mm X 100 mm
5	Modulus of Rupture	24 X t* + 50 mm
6	Tensile Strength	50 mm X 50 mm
7	Screw Withdrawal (Face and Edge)	150mm X 75mm

*t- Thickness of board

Statistical analysis: The data recorded was analysed statistically at 5% significance level to find out the variation between adhesive percent and the relationship between the observed physical and mechanical parameters. The data was analysed using "SPSS" package (16.0). Different parameters taken into account during the course of study were subjected to ANOVA.

Results and Discussion: The mean values obtained for physical and mechanical properties such as Density, Moisture Content, Water Absorption, Thickness Swelling, Tensile Strength, Modulus of Rupture (MOR), and Screw Withdrawal of Hybrid Boards are presented in Table 2 and 4. Whereas Table 3 and 5 exhibits the One-way Analysis of Variance (ANOVA) for the data obtained for all the properties at significance level 0.05. Duncan's subset was formed using SPSS to determine the variation of effect of specific adhesive percent on board properties.

Physical Properties: The mean density of 0.87, 0.89 and 1.04 g/cm^3 was recorded at 8, 10 and 12% resin content respectively. It was noted that density of the board at 8 and 10% resin content was statistically not significantly different, however the density obtained at 12% resin was found significantly different from the other test concentrations (p<0.05).

Board prepared at 8, 10 and 12% showed 8.87, 6.19 and 5.44% mean moisture content respectively and met the minimum criteria of particle and MDF board as per Indian standards (Table 2). The moisture content of board statistically decreased on increasing the resin content in board. The results of water absorption showed 5.24-13.88% and 34.04-53.70% mean water absorption by board after 2 and 24 hours of soaking respectively. However the board having maximum 9 and 30% water absorption after 2 and 24 hr respectively can be accepted as per IS: 12406 and IS:3087. So board prepared at 12% resin content seems most suitable for applications. The results showed that addition of resin reduced the water absorption capacity significantly at 5% significance level which further reduced the moisture content as well as thickness swelling of board.

The maximum thickness swelling permissible in particle and MDF board is 10 and 8% (IS: 3087, 12406). Board prepared at 12% resin content matched with the minimum criteria as laid by Indian standard and board at 8 and 10% resin content showed more than 10% mean thickness swelling. Even thickness swelling was found twice at 8 and 10% resin of that noticed at 10% resin content. The probable reason may be the high concentration of resin content that restrict the uptake of water inside the board. Similar kind of results also found in case of particle board (Childs, M. R. 1956 and D.P. Khali and Hemant Kumar, 2008) [4]. The one way ANOVA of these physical parameters behave significantly at p<0.05 (Table 3).

Table 2: Mean Physical Properties of Hybrid Boards

Resin Content	Density (g/cm^3)	Moisture Content (%)	Water absorption in 2hr water soaking (%)	Water absorption in 24hrs water soaking (%)	Thickness Swelling in 2hrs Water soaking (%)
8% (R_1)	0.87^a	8.87^a	13.88^a	53.70^a	10.51^a
10% (R_2)	0.89^a	6.19^b	11.41^b	44.76^b	10.33^a
12% (R_3)	1.04^b	5.44^c	5.24^c	34.04^c	5.15^b
IS:3087 Particle Board	-	-	25 (max)	50 (max)	10 (max)
IS:12406 MDF	0.6 - 0.9	10 (max)	9 (max)	30 (max)	8 (max)

$^{a, b, c, d}$ = Significant (p<0.05)

Table 3: ANOVA for Physical Properties of Hybrid Boards

Source of Variation	Sum of Square	Df	Mean Square	F	Sig.
Density (g/cm^3)	0.105	2	0.052	49.879	0.000
Errors	0.016	15	0.001		
Moisture Content (%)	39.047	2	19.524	69.655	0.000
Errors	4.204	15	0.280		
Water absorption in 2hr water soaking (%)	237.911	2	118.955	206.918	0.000
Errors	8.623	15	0.575		
Water absorption in 24hrs water soaking (%)	1162.167	2	581.084	106.892	0.000
Errors	81.543	15	5.436		
Thickness Swelling in 2hr Water soaking (%)	111.189	2	55.594	251.195	0.000
Errors	3.320	15	0.221		

Mechanical Properties: Table 4 presented the mean values of mechanical properties of hybrid board prepared at different resin content. Mean tensile strength of board was found minimum 0.73 N/mm^2 and maximum 0.83 N/mm^2 at 8 and 12% resin content. The effect of resin content on tensile strength was found statistically similar at 10 and 12% (p<0.05) (Table 4). Mean MOR of 18.99, 23.09 and 20.42 N/mm^2 was noticed in board prepared at 8, 10 and 12% resin content respectively, which were statistically significant. However the values obtained were more than the required for particle board but less than the required for MDF as per IS: 3087 and 12406 respectively (Table 4). The hybrid board exhibited the outstanding strength in screw withdrawal test in face as well in edge as compared to IS: 3087 and IS: 12406 (Table 4). Mean screw withdrawal strength was observed 2836-3056 N and 1577-2108 N at face and edge respectively. The effect of resin content on screw withdrawal was found significant in face, however in edge it was found significant at 12% resin content only as compared to 8 and 10% resin content.

The stiffness and screw holding capacity decreasing, while increasing resin percent (more than 10%) in hybrid board. Similar kind of results also observed in screw withdrawal face and edge surface (Table 4). In case of particle board when the urea formaldehyde content is increasing, mechanical property also increases (Hse, C.Y. 1974) [6].

Table 4: Mechanical Properties of Hybrid Boards

Resin Content	Tensile Strength (N/mm^2)	Modulus of Rupture (N/mm^2)	Screw withdrawal Face (N)	Screw withdrawal Edge (N)
8% (R_1)	0.73^a	18.99^a	3056^b	2108^b
10% (R_2)	0.79^b	23.09^c	3263^c	2137^b
12% (R_3)	0.83^b	20.42^b	2836^a	1577^a
IS: 3087 Particle Board	0.80 (min)	11 (min)	1250 (min)	850 (min)
IS: 12406 MDF	0.80 (min)	28 (min)	1500 (min)	1250 (min)

$^{a, b, c, d}$ = Significant (p<0.05)

Table 5: ANOVA for Mechanical Properties of Hybrid Boards

Source of Variation	Sum of Square	df	Mean Square	F	Sig.
Tensile Strength (N/mm^2)	0.033	2	0.016	9.526	0.002
Errors	0.026	15	0.002		
Modulus of Rupture (N/mm^2)	51.976	2	25.988	35.059	0.000
Errors	11.119	15	0.741		
Screw withdrawal Face (N)	545045.4	2	272522.7	13.957	0.000
Errors	292873.7	15	19524.91		
Screw withdrawal Edge (N)	1192804	2	596402	46.902	0.000
Errors	190738	15	12715.87		

Conclusion: The objective of the present study was to amalgamate the properties of particles and fibres of poplar in achieving a board better than the particle board. The prepared hybrid board showed better physical and mechanical properties as compared to IS: 3087 standandr for particle board. Even the properties were improved on increasing the resin content. The best results in terms of physical as well as mechanical properties were recorded at 10% urea formaldehyde adhesive. The results suggest that fibre and particle can be mixed in 50:50 ratios to get a better board than particle board by using 10% urea formaldehyde resin.

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