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Durability and Performance of Particle Board made Using Nanoclay Reinforced Resin

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ABSTRACT
For the present study, particle board made using (0.25% wt and 0.5% wt) nanoclay were compared with (0% and 0.5%) boric acid. Boards were made using synthetic amino resin viz.: Urea formaldehyde resin urea-formaldehyde (UF) and melamine UF resin (MUF). Dispersion of nanoclay in the UF and MUF resin was done by mechanical mixing, and it was characterized using X-ray diffraction. Efficacy of nanoclay against white rot fungus (polyporousversicolour) was studied using agar block method as per IS:4873. Physical and mechanical properties of the board were evaluated as per IS:3087-2005. Nanoclay reinforcement in the resin did not affect the physical and mechanical properties of the boards. Nano clay has shown useful effect on controlling the average weight loss due to white rot fungus in particle board. Nanomer PGV (0.25% and 0.5%) has performed better than boric acid (0% and 0.5%). The durability against white rot fungus suggests that the presence of nanoclay significantly increased the durability of the board without affecting the physical and mechanical properties.

Key words: *Nanoclay, Particle board, White rot fungi, Amino resin.*

1. INTRODUCTION

Non-structural engineered wood composites such as particle board, medium density fiberboard, etc., are now used in both interior and exterior applications [1]. The increasing use of low formaldehyde emission resin such as E1 grade urea formaldehyde (UF) resin and melamine UF (MUF) resin for the manufacture of particle board has led researchers to find ways to improve the durability of the products against bio-deterioration agents [2]. Particle board is susceptible to wood decay fungi, which can severely affects its economic value and usefulness.

White-rot causing fungi degrade all cell wall components including lignin. It is important to develop long protection methods during manufacturing process [3]. It has been reported that the strength in particle board is considerably reduced due to the weakening of glue line by the fungi. Improving the durability of the board by preservative treatment is one way of extending its end uses [4].

Using nanoclay to reinforce polymer-based composite have raised great attention in the academic and industrial sectors. Because, these materials have strong absorbability as well as high-barrier property. The effect of organo-modified montmorillonite (OMMT) loading on the natural durability properties of polypropylene/wood flour composites exposed to brown-rot fungi (coniophora puteana) was studied. The results indicated that OMMT had significant effects on the natural durability of the studied composite formulations [5]. Effects of addition of different percentages of nanoclay on the decay resistance and physical-mechanical properties of natural fiber-reinforced plastic composites against white-rot fungi (trametes versicolor) suggest that the lowest weight loss and the highest hardness were observed in the composite containing 5 phcnanoclay [6]. Many preservative chemicals studied, showed a significant increase in the durability with the increase in the percentage by affecting the physical and mechanical properties of the composite. Hence, the objective of this study was to investigate if the incorporation of nanoclay in the amino resin system would have an improvement in the durability of particle board without affecting the physical and mechanical properties.

2. EXPERIMENTAL

UF and MUF resin was synthesized for the manufacture of the single layered particle board. Properties of the

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resin used are as shown in Table 1. Nanoclay used in the study was procured from M/S Sigma-Aldrich chemicals private limited, Bangalore. Nanomer PGV is unmodified nanoclay with a bulk density of 600 kg/m^3-1100 kg/m^3, having a micron size <25 and loss on drying <18%. Nano clay (0% wt, 0.25% wt, 0.5% wt) on the weight of the resin was added at room temperature. Nanoclay was added to the resin and the mixture was stirred using a mechanical stirrer at a rotation speed of 1000 rpm for thorough dispersion. Hardener was then added into the resin for further 5 min mixing time. Wood species poplar (populus deltoids) was used in the study for the manufacture of particle board measuring 0.3 m × 0.3 m ×12 mm with density of 750 kg/m^3-800 kg/m^3.

2.1. Characterization

To evaluate the degree of clay dispersion in polymer matrices, X-ray diffraction was used. After mixing the nanoclay to the resin, the mixture was cured in a drying oven at 103°C for 24 h, then removed from the oven and cooled. The samples were ground down to powder and mounted in the sample holders of D8 focus (Bruker) X-ray diffractometer and scanned from 3-15°with a step size of 0.04 s/step and 0.8 s/step. X-ray radiation was generated by using a 35 KV, 40 mA cobalt radiation source. Energy dispersive X-ray analyses (EDAX) of the Nanoclay were analyzed to know the chemical composition of the materials.

2.2. Manufacturing of Particle Board

Particles of poplar species were dried to a moisture content of 2-3% before blending with the resin. The particles were blended with 10% resin on dry solid basis of particles. Nanoclay, and hardener were added to the resin as described previously for the boards P1, P3, P5, and P6. Formulations of the boards made are as shown in the Table 2. Manually glue blended particles were placed into a mat-forming box with base dimensions of 330 mm × 330 mm. Prepressing and compression of the particles were done by pressing a matching wooden plate on the mat in the forming box by applying manual pressure. Supporting rods to control the thickness to 12 mm were placed on either ends of the assembly. The assembly was then loaded into a hot press of size 350 mm × 350 mm wherein the temperature of the platens was maintained at 160-165°C for the manufacture of single layered particle board. Pressure of 24 kg/cm^2 (compression cycle) for 7 min and 10 kg/cm^2-12 kg/cm^2 (curing cycle) for 5 min were employed for UF resin and MUF resin, respectively.

Table 1: Properties of the resin.

Resin	UF	MUF
Flow time (sec)	21	19
Solids (%)	50	51
PH	8.0	8.5-9.0

MUF: Melamine urea formaldehyde, UF: Urea-formaldehyde

Table 2: Formulation of the boards.

Particulars	P1	P2	P3	P4	P5	P6	P7	P8
Resin	MUF	MUF	MUF	UF	UF	UF	MUF	UF
Nanoclay (%)	0.25	-	0.5	-	0.25	0.5	-	-
Boric acid	-	-	-	-	-	-	0.5	0.5

MUF: Melamine urea formaldehyde, UF: Urea-formaldehyde

2.3. Physical and Mechanical Properties of the Boards

The boards were kept for stabilization for about 24-48 h to attain equilibrium moisture content and then trimmed. The trimmed boards were further dimensioned to required sizes and subjected after conditioning for testing. The board properties were tested as per the requirement of IS:3087 (specification for medium density particle board) [7] are as shown in Table 3. Physical properties of the boards', i.e., water absorption, thickness swelling, and mechanical properties of the board, i.e., Modulus of rupture and modulus of elasticity were tested as per the specifications.

2.4. Method of Test against White Rot (Agar block)

A nutrient medium containing agar (20 g) and malt (20 g) extract in a liter of distilled water, autoclaved at 120°C for 20 min was taken in Kolle flask. The test blocks (P1-P8) were made of the size 50 mm × 25 mm × 15 mm. The whole set of flask were then incubated for 12 weeks at 27°C. The test was carried as per IS:4873 (anonymous 2008) [8]. The oven dry weight of the samples after sterilizing was incubated for 12 weeks. After the completion of 12 weeks, the samples were removed from the Kolle flask and the mycelium adhering to it was cleaned by taking care not to remove the splinters of the particle board. The blocks were dried to constant weight to get a constant weight. The mean percentage weight loss was calculated as per IS:4873 (anonymous 2008). The result of the toxicity study has been tabulated in Table 4.

3. RESULTS AND DISCUSSIONS

Analysis of chemical composition by EDAX reveals that nanomer PGV (B) contains 32.34 mass percentage of silicon, 10.11 of aluminum and 2%-3 % of sodium and magnesium as shown in Figure 1.

3.1. X-ray Diffraction (XRD) Analysis of the Samples

The interlayer space between clay layers can be detected by XRD by a peak in the X-ray intensity at a characteristic angle and the inter-platelet distance calculated. According to Bragg's law, the interlayer spacing (d) in nanoclays and the relative intercalation of the polymer in nanoclays can be determined using the following equations, $n\lambda = 2d\sin\theta$. Where n is the integer number of wavelength (n = 1); λ is the wavelength of

Table 3: Physical and mechanical properties of particle board.

Properties	Prescribed value as per IS 3087-(2005) grade-2	P1	P2	P3	P4	P5	P6	P7	P8
Density kg/m^3	500-900	789	761	776	774	783	752	766	779
Moisture content, %	5-15	5.82	5.13	5.04	5.11	5.01	6.00	5.32	5.18
Water Absorption,%									
a) After 2 h of soaking,	Maximum 40,	17.64,	17.12,	18.22,	26,	25.78,	27.12,	18.93,	27.98,
b) After 24 h of soaking	Maximum 80	28.49	29.34	31.54	39	38.81	39.28	31.06	40.86
Thickness swelling due to general absorption, % (after 2 h soaking)	Maximum 12	9.01	9.14	9.18	10.89	10.45	10.96	10.14	11.23
Modulus of rupture, N/mm^2	Minimum 11	20.12	20	21.34	18.92	18.01	18.25	20.47	18.12
Modulus of elasticity, N/mm^2	Minimum 2000	3486	3496	3554	2986	2945	2992	3124	2886
Internal bond strength, N/mm^2	Minimum 0.8	1.0	0.98	1.07	0.86	0.86	0.87	0.91	0.85

Table 4: Average weight loss of the samples.

Samples	Average weight loss	
	UF	MUF
Nanoclay	(P5) 9.32 (P6) 7.68	(P1) 9.34 (P3) 8.07
Boric acid	(P8) 15.39	(P7) 10.95
Control	(P4) 15.15	(P2) 10.53

MUF: Melamine urea formaldehyde, UF: Urea-formaldehyde

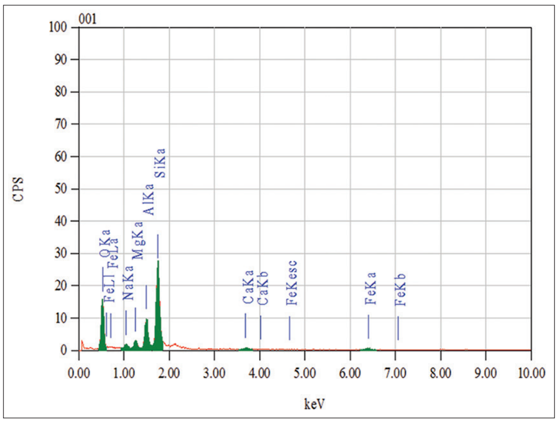

Figure 1: Chemical composition of Nanomer PGV.

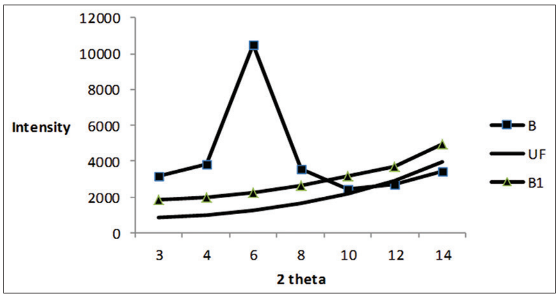

Figure 2: X-ray diffraction spectra of nanomer PGV, nanomer PGV (0.5%) with uf resin.

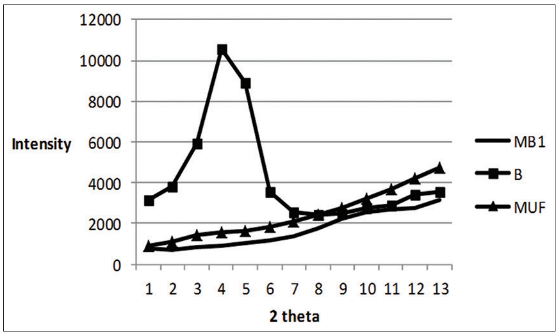

Figure 3: X-ray diffraction spectra of Nanomer PGV (0.5%) with melamine urea formaldehyde resin.

X-ray; d is the actual interlayer or d-spacing of the clay in the matrix; θ is the diffraction angle corresponding to a specific intensity peak. From the Bragg Law, the lower peak diffraction angles indicate larger distances between the interlayers of nanoclay [9].

The peak appearing at 6.478 corresponds to Nanomer PGV to a d spacing of 1.363 nm according to Bragg equation. From the Figures 2 and 3, for the UF/B and MUF/B system the (001) peak disappeared. This indicates that the periodic atomic structure of ordered zones of the nanoclay does not exist anymore. It states that nanoclay is completely exfoliated when mixed with UF resin or with MUF resin. The intensity peak of bentonite disappeared after being dispersed into the UF resin and MUF resin by mechanical mixing. This indicates that the UF resin or MUF resin was able to enter the interlayer space of Nanomer PGV (Figure 4).

3.2. Physical and Mechanical Properties of the Particle Boards

The test results in Table 3 indicate that the physical and mechanical properties of all the boards were within the prescribed limit as per the standards. Incorporation of (0%, 0.25%, and 0.5%) nanoclay or 0.5% boric acid in the UF or MUF resin has not affected the physical and mechanical properties of the boards. Whereas increased

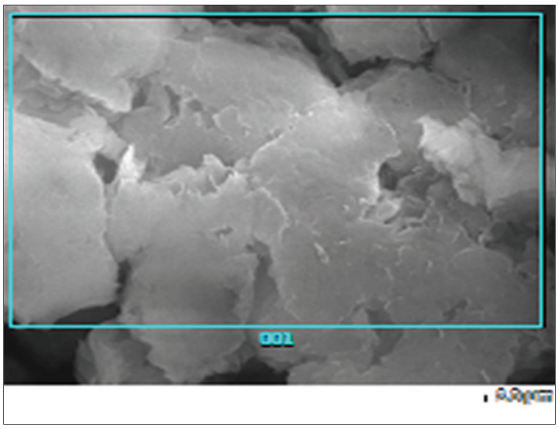

Figure 4: Energy dispersive X-ray analysis photograph of Nanomer PGV.

mechanical properties were observed in the nanoclay incorporated MUF resin. As the percentage of nanoclay increased, samples showed increased properties. This indicates that the nanoclay shows better mechanical properties in MUF resin than in UF resin.

3.3. Test Against White Rot

To compare the efficacy of particle board made using nanoclay incorporated UF resin and MUF resin, along with the control board and also boric acid incorporated particle board were manufactured. The efficacy of Nanoclay was evaluated against white rot fungus (polyporous versicolour), and the results are as tabulated in Table 4.

The results revealed that control boards had an average percentage weight loss of 15.15 and 10.13 in samples UF and MUF resin, respectively. The lowest weight loss observed among the boards was of nanoclay (0.5%) with a reduction of 49% from the control sample (Table 3). The average weight loss observed for 0.25% nanoclay incorporated UF resin was reduced by 38%. As the percentage of nanoclay increased to 0.5% in the UF resin, the average weight loss decreased was 7.86 with a reduction of 48% from the control board was observed. The samples 0.25% and 0.5%, nanoclay reinforced MUF resin bonded particle board showed a reduction of 23% and followed the same trend as with UF resin.

According to Hamid *et al*. [10] an increase in the percentage of silica reduces the deterioration. As bentonite nanoclay contains silica, which has reduced the average percent weight loss against white rot fungus. Generally Boric acid is being used to treat the panel products in India. Hence in the present study boric acid has been taken as a check to compare the efficacy of nanoclay against white rot fungus along with the control board. Average weight loss 15.39, and 10.95 was recorded in boric acid (0.5%) in UF and MUF resin particle board, respectively. These results were same as the control boards.

4. CONCLUSION

From the study, it can be concluded that Nanoclay Nanomer PGV was shown through XRD analysis to exfoliate into UF and MUF resin. Physical and mechanical properties of the board were within the limits as prescribed by the IS standards. The results of the test against white rot fungus indicates that 0.5% nanoclay has reduced the average weight loss to about 50% in the UF resin and to about 23% in the MUF resin. Nanomer PGV (0.5%) has performed better than boric acid (0.5%). However, further study on its efficacy against termite and borer is needed.

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***Bibliographical Sketch**

B.S. Mamatha, Scientist, IPIRTI, working on development of wood adhesives using cardanol.lignin, soya, tannin, fire retardant flush door, particle board, composites from agro residues viz., Rice straw, rice husk, wheat straw, jute, dyeing of veneers, compregs