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Effect of nanoclay on water absorption and thickness swelling of wood based composite

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ABSTRACT

The demand for wood composite products such as particle board has increased distinguishingly. Future of particle board is dependent on the cost reduction of the resin and effort to improve its performance under service condition. The amount of water absorbed influences the swelling of the composite in thickness which affects the mechanical properties of the composite. Nano technology plays a vital role in significantly improving physical and mechanical properties of composites due to their nanoscale size. In this study, Nanomer PGV and Nanomer1.44p nanoclays were used to produce particle board of Poplar species. Nano clays were used as reinforcement filler for urea formaldehyde resin by mechanical mixing. Scanning electron microscope images (SEM) and X-ray diffraction (XRD) confirmed the dispersion and exfoliation of nanoclays in the adhesive. Prolonged gelation time was observed for Nanomer PGV reinforced resin. Particle board of 12mm thickness with 700 kg/m3 were manufactured using nanoclay reinforced resin. Water absorption and thickness swelling were evaluated as per Indian standard, for the laboratory scale made particle board. Water absorption and thickness swelling of wood composite was significantly reduced by adding Nanomer1.44 p to the resin. However Nanomer PGV did not show suitable effect on the stability of water absorption and Thickness swelling of the particle board.

Introduction:

Particleboard (PB) is a commonly used panel product made from hammer-milled wood particles that has a relatively low cost of production compared with Medium fiber board (MDF). It has a smooth surface that can be easily laminated or painted. As a result it is widely used in furniture applications such as desks, shelves and cabinets [1]. Particle board has some drawbacks similar to the other wood-based panels such as instability in the dimension and swelling in thickness properties. Therefore, it is important to control such disadvantages to improve efficient use of panels. At the present time, an increasing attraction is observed in the investigation of nanocomposite materials, comprising layered silicate clay. The important characteristics pertinent to application of clay minerals in polymer nanocomposites are their richest intercalation chemistry, high strength and stiffness and high aspect ratio of individual platelets, abundance in nature, low cost and high gas barrier quality [2].

Lei found that slight percentages of sodium montmorillonite nanoclay could improve the performance of thermosetting UF resin and it had an accelerating effect on the curing of UF that could result in the improvement of physical and mechanical properties of wood based composites [3]. The effect of nanoclay as reinforcement filler on the properties of MDF investigated by Ashori and Nourbaksh showed that the increase in the addition of nanoclay, the thickness swelling was reduced [4]. The UF-nanoclay gelling property results suggest that the nanoclay modified with methyl dihydrogenated tallow significantly enhances UF gel times. It is assumed that the nanoclay with functional groups influences the formation of bonding in the composite wood product. This effect beneficially improves dimensional stability compared to the control boards [5].

Since the addition of small amount of nanoclay could substantially enhance the Physical and mechanical properties of composites. Employing nanotechnology on wood composite products would have high performance and desirable serviceability. Hence the objective of the study is to evaluate the effect of Nanomer PGV and Nanomer 1.44P Nano clay as filler to reinforce the Ureaformaldehyde resin on the water absorption and thickness swelling properties of wood composite(Particle board).

Materials and methods:

Wood species poplar (Poplus deltoids) was used in the study for the manufacture of wood composite. Particle board measuring 0.3×0.3×0.012 m3 with density of 750-800 kg m-3 were manufactured. Urea formaldehyde resin having a flow time of 22 sec with a solid content of 50 % was synthesised for the manufacture of the three layered particle board. Two Montmorillonite nanoclays used in the study were procured from M/S Sigma Aldrich chemicals pvt ltd, Bangalore. Properties of the Nanoclays used are given in Table-1. Nano clay (0, 1, 2, 4, % wt) on the dry weight of the resin, was added to the liquid resin at room temperature. Nano clay was added to the resin and the mixture was stirred using a mechanical stirrer at a rotation speed of 1000rpm for thorough dispersion. Hardener was then added into the resin for further 5 min mixing time.

Table: 1. Properties of Nano clay

Nanoclay	Modifier	Colour	Bulk density (kg/m^3)	Average particlesize (micron)	Loss on drying
Nanomer PGV	None	Light tan – brown	600-1100	< 25	<_ 18.0%
Nanomer 1.44p	35-40 % Dimethyl-dialkyl amine	Beige	200-300	< 20	<_ 3.0%

Characterisation:

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 103^0 c for 24 hrs, 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 Diffract meter and scanned from 3 -150 with a step size of 0.04 and o.8s /step. X ray radiation was generated by using a 35KV, 40mA cobalt radiation source. EDAX of the Nanoclay were analysed to know the chemical composition of the materials. A SEM TQQ/P.CIF.LE.101.1 with EDM, JEOL JSM-6380LA scanning electron microscope was used to study the dispersion of NanomerPGV (B) and Nanomer 1.44p (M) in the resin .Samples were gold coated subjecting it to SEM analysis. The samples (consisting of resin, clay and hardener) of 5-10 g was taken in an test tube and kept in water at 100^0C to find the gelation time of the adhesive.

Manufacturing of Particle board:

Particles of poplar species having slenderness ratio of 160-180 for face and 50-80 for core particles were dried to a moisture content of 2-3% before blending with the resin. The particles were blended with 12% resin on dry solid basis for face particles and 8% resin for core particles. Nano clay and hardener were added to the resin as described previously. Manually glue blended particles were placed into a mat forming box with base dimensions of 330mm x 330mm.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 to12mm were placed on either ends of the assembly. The assembly was then loaded into a hot press of size 350mm x 350mm wherein the temperature of the platens was maintained at 155 - 160 °c for the manufacture of three layered particle board. Pressure of 24kgs/sq cm (compression cycle) for 7 minutes and 12kgs/sq cm (curing cycle) for 5 minutes were employed. The boards were kept for stabilization for about 24 -48 hours to attain equilibrium moisture content and then trimmed. The trimmed boards were further dimensioned to required sizes and subjected after conditioning for testing as per IS: 3087(Specifications for medium density particle board).Total of about 7 boards with replica of 3 sets in each formulation namely B1, B2, B4 containing 1%, 2% and 4% Nanomer PGV respectively and M1, M2, M4 containing 1%, 2% and 4% Nanomer 1.44p respectively.

Water absorption and thickness swelling test:

Water absorption and thickness swelling was carried out using 100×100mm samples according to IS: 2380(1985). The composite samples were immersed in cold water at room temperature. The water absorption was determined from equation (1) for 2 hrs & 24 hrs and thickness swelling was determined from equation (2) for 2 hrs. Samples were weighed before and after the samples were removed they were gently blotted with filter paper to remove excess water from the surface and the weight and dimensions of the samples were recorded.

Water absorption (%) = [wf-wi] / wi (1)

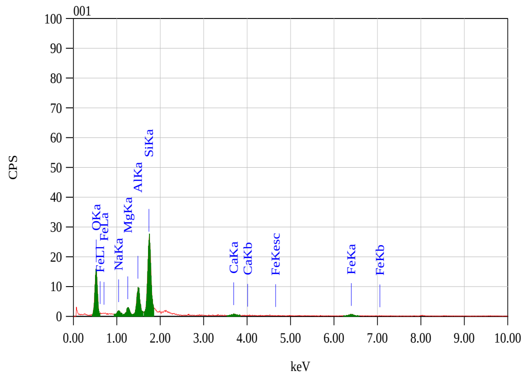
Wi-initial weight of the sample before immersion, Wf-final weight of the sample after immersion

Thickness swelling (%) = [Tf -Ti] / Ti (2)

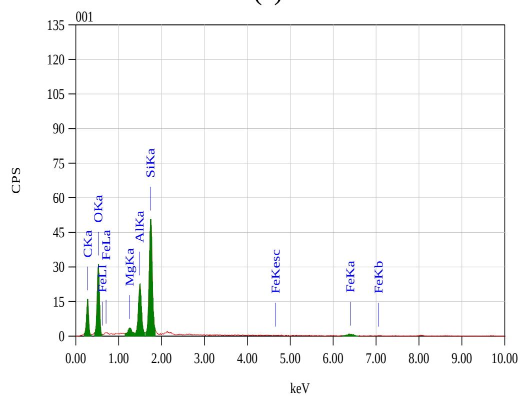
Ti-initial thickness of the sample before immersion, Tf-final thickness of the sample after immersion.

Results and discussions:

Analysis of chemical composition by EDAX reveals that Nanomer PGV (B) contains 32.34 mass percentage of silicon, 10 .11 of Aluminium and 2-3 % of sodium & magnesium. Whereas chemical composition of Nanomer 1.44 P (M) indicates the mass percentage rich in carbon with 37.71 and 11.56 of silicon as shown in Fig-1a-b.



(a)

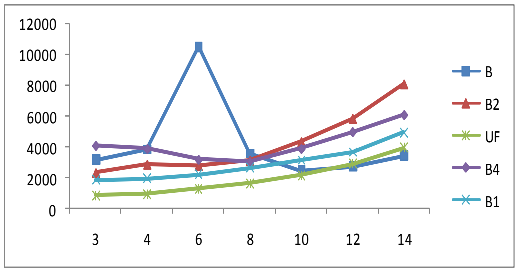


(b)

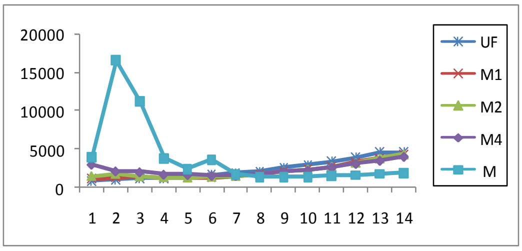
Fig: 1a-b EDAX analysis graph of (a) NanomerPGV , and (b)chemical composition of Nanomer 1.44p

XRD analysis of the Nano clay incorporated resin:

X-Ray diffraction is useful for evaluating the degree of clay dispersion in polymer matrices. The result of an XRD test is a pattern of X-ray intensity vs. the diffraction angle. The peak appearing at 6.478 corresponds to Nanomer PGV to a d spacing of 1.363 nm according to bragg equation in Fig-3. For the UF/B system the (001) peak disappeared both at 1% and 2% B. This indicates that the periodic atomic structure of ordered zones of the nanoclay does not exist anymore. That means nanoclay is completely exfoliated when mixed with UF resin. But at 4% Nanoclay (B) peak has been shifted to 4.679 with a d spacing of 1.889nm. As the intensity of peak shifting to a lower 2theta, indicating that Uf resin with 4 % nanoclay was all intercalated. Higher the addition of nanoclay higher is the intensity peak.



(a)



(b)

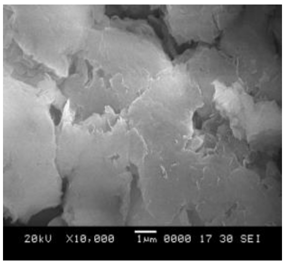
Figure: 4 a-b XRD graph of (a) Nanomer PGV & Nanomer PGV with UF resin , and (b) Nanomer 1.44P & with Nanomer 1.44P UF resin

Two peaks at 3.41 and 6.99 have been observed in XRD of UF/M system in fig -4. The peak appearing at 3.41corresponds to Nanomer 1.44P to a d spacing of 2.588nm according to bragg equation. For the UF-M system the (001) peak disappeared at 1%, 2% and 4 % .This indicates that the nanomer 1.44P was completely exfoliated. The intensity peak of Nanomer PGV (1%, 2%) And Nanomer 1.44P (1-4 %) disappeared after being dispersed into the UF resin by mechanical mixing.

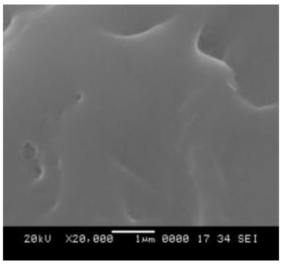
SEM analysis of the Nanoclay incorporated resin:

The scanning electron microscopic images of Urea formaldehyde resin with nanoclays are shown in Figure 5, 6. As it can clearly be seen, for the samples(c, d of fig-6) containing 2 and 4 % of

Nanomer 1.44P no agglomeration is observed and the nanoparticles were evenly dispersed in the UF matrix. The rough surface of sample (c, d of fig-6) compared to matrix (b of fig-6) is representative of good interaction between matrix and filler particles, implying the effective reinforcement of fillers. While the SEM of sample containing 4 % of Nanomer PGV (d, Fig-5) show agglomeration formed between the nanoparticles.



(a)



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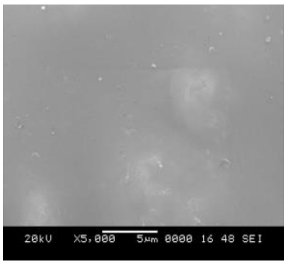
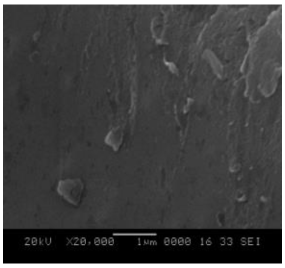
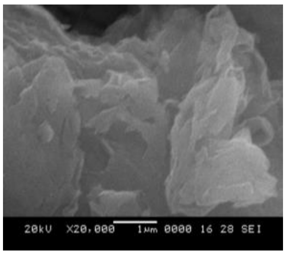


(c)

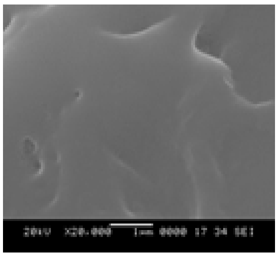


(d)

Figure: 5a-d. SEM photographs of (a)Nanomer PGV, (b)Urea formaldehyde resin, c)Uf + 2% B, and d)Uf + 4% M



(a)



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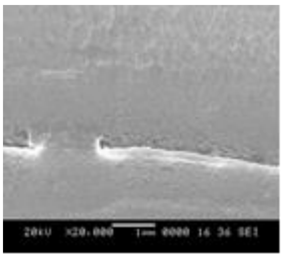
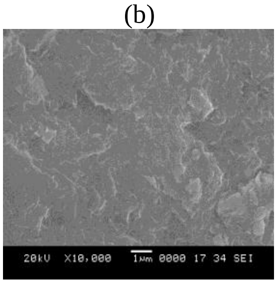


(c)



(d)

Fig: 6a-d SEM Photographs of (a)Nanomer 1.44P,(b)Urea formaldehyde resin,(c)Uf + 2% M, and (d)Uf + 4% M.

Gelation time of resin:

The curing of a UF is an irreversible exothermic reaction. Table -3, indicates that adding Nano clay PGV to the Urea formaldehyde resin show the delayed gelation time of the resin compared to UF resin. This higher time indicates a delay in the curing reaction .Gelation time has been increased in case of Nanomer PGV whereas no increase in gelation time being observed with the addition of Nanomer 1.44P.

Table: 3. Gelation time of the resin

Particulars	Gelation time (sec)
UF(0)	64
UF +M	64
UF +B	74

Water absorption and thickness swelling properties:

Water absorption and thickness swelling properties of all the samples were within the value as prescribed in IS: 3087 -2005. Wood composite show a rapid intake of water due to the hydrophilic nature of cellulosic materials. This water molecules remain in the intermolecular fibrilar space in cellulosic structure which causes cracks and voids at the surface of composite[6,7]. This water filled voids at the interface result in debonding[6]. Fig 7-9 shows that board M2 has shown significant effect on the reduction of water absorption and thickness swelling of particle board to about 21 % and 22 % respectively.

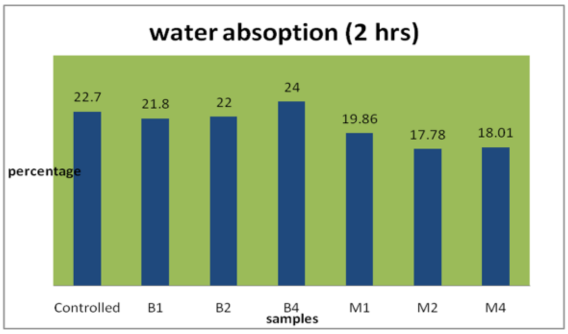


Fig: 7. Water absorption properties of samples (2 hr)

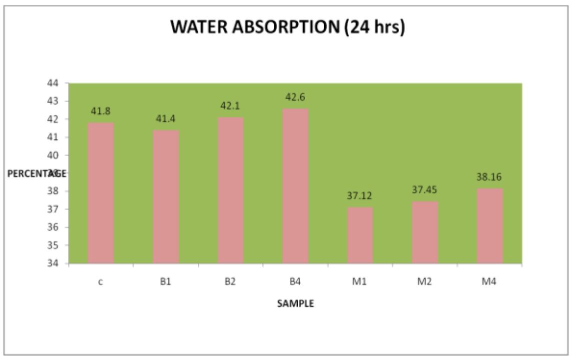


Fig: 8. Water absorption properties of samples (24 hr)

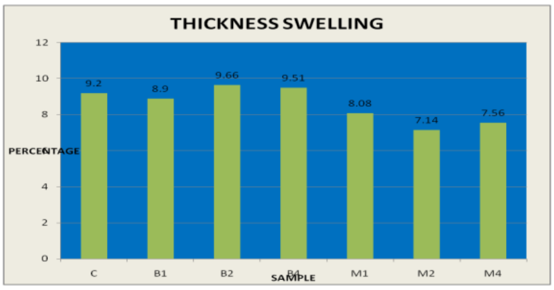


Fig: 9. Thickness swelling properties of samples (2 hr)

Hydrophobic property of Nanomer 1.44p particles has made moisture transmission in particle board difficult. On the other hand, usage of Nanomer1.44p has improved adhesion property of the resin with wood fibers. But Board M4 did not show significant effect on the reduction of water absorption and thickness swelling of particle board. This could be due to the increase of viscosity of the resin as the percentage of nanoclay increases which has diminished the interaction of the resin with wood particle. Whereas no significant effect was observed in the boards B1, B2, B4. There are three interactions in the structure the particle board produced using Nanomer PGV that is the interaction of water molecules (moisture) with the hydrophilic nanoclay, the interaction of water molecules with UF resin and the interaction of water molecules with the hydroxyl groups of the wood fibers. The interaction of water with the hydrophilic nanoclay has resulted in the increase of thickness swelling and waterabsorption of the Nanomer PGV added Particle board.

Conclusion:

Particle board of dimensions 0.3 x 0.3 x 0.012 m 3 using Poplar species of density 750-800 kg/m3 were manufactured. Two types of nanoclays, Nanomer PGV and Nanomer 1.44p were used as filler to reinforce the urea formaldehyde resin .Mechanical mixing method used to disperse the nanoclays in the resin has proved to be efficient by XRD and SEM analysis. Water absorption and thickness swelling was evaluated as per Indian standard-IS: 3087-2005 (Specification for medium density particle board).

Water absorption and Thickness swelling of wood composite was significantly reduced by adding Nanomer1.44 p to the resin. However Nanomer PGV did not show suitable effect on the stability of water absorption and Thickness swelling of the particle board. Further experiments are in progress.

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