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Properties of plywood of *Melia composita* at three different pressures with five nano-filler loadings

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Abstract
In the proposed study the effect of pressure and nano clay loading on the properties of plywood were investigated. Samples for control and nano clay loadings (1%, 2%, 3%, 4%, 5%) were tested for glue shear strength, modulus of rupture (MOR), modulus of elasticity (MOE) and Tensile strength test (along and perpendicular to grain). The highest values for GSSD (158 Kg) and GSSW (115 kg) were observed for boards with 1% Nano clay loading and 17.5 Kg/cm^{2}specific pressures. Similar results have been observed with tensile strength. Though increase in loading levels of Nano clay has shown detrimental effects of the properties of plywood.

Keywords: Phenol formaldehyde (PF), nanoclay, glue shear strength dry (GSSD), glue shear strength wet (GSSW), MOR, MOE, tensile strength

Introduction
Phenol formaldehyde resins are extensively used for exterior grade wood composites. The improved properties affect the performance of the wood panels. Over past few decades use of nanotechnology, nano sized particles with at least one dimension in the range of 1 to 100nm has grown tremendously. One of the first application of nanotechnology was the production of nano-fillers for the improvement of the mechanical properties of composites (Alireza and Noutbaksh 2009) [1]. Micron particles size fillers have a little modifying effect, but decreasing particle size to nano scale, because of high chemical activity of nano particles, can improve modifying effect of filler (Doosthoseini and Hosseinabadi 2010) [4]. The effects of the nano-filler on the composite materials depend on its size, aspect ratio, and hybrid morphology. Lei *et al* (2008) [8] found that slight percentages of sodium montmorillonite nanoclay could improve the performance of thermosetting Urea Formaldehyde (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. Reinforcement with aluminium oxide nano-particles in various resins have been investigated for the development of value added products (Kumar *et al* 2013) [7]. Nanoclay offer high interest from an industrial point of view since the use of small quantities of them is enough to improve the overall properties of a composite material at a relatively low cost (Ashori and Nourbakhsh 2009) [1-2]. Further wood based industries are looking for cost effective and new techniques to produce composite wood. The main objective of this study is to evaluate the effects of nanoclay/nano-fillers on Phenol Formaldehyde (PF) resin and properties of plywood.

Materials and Methods
Fresh logs of *Melia composita* were procured by Forest Range Office, Forest Research Institute. These logs were peeled into veneers of 2mm thickness and peeled veneers were cut into 21x21 inches squares. The veneers were dried to 8-10% moisture content. The nano-filler used in this study was procured from Connell Bros. Company (India) Private Limited (Table 1).Nano clay was added into PF at loadings levels of 1%, 2%, 3%, 4% and 5% weight percent of total dry weight of the resin. Mixture of PF resin and nanoclay was mechanically stirred for homogenous distribution of nano-particles into the resin. The amount of glue applied was about 110 gm/m^2 in single glue spread on solid basis. The modified resin was applied on both the surfaces of core ply using a brush. Then plies were air dried for one day. Three ply combinations were prepared for control (N_0) and each level (N_1, N_2, N_3, N_4, and N_5) of nanoclay. These plies were loaded in an electrically operated hot press and pressed at specific pressure14Kg/cm^2, 17.5Kg/cm^2, 21.0Kg/cm^2, For 11 minutes at 150 ^{0}C. Prepared plies were conditioned at room temperature.

Results and Discussion

Testing was carried out as per IS: 1728 (1983). In Table2 are given the mean values of physical and mechanical properties of plywood with different pressure levels and nanoclay loading. Permissible limit for glue shear strength dry and wet, modulus of rupture (MOR), modulus of elasticity (MOE) and tensile strength (TS), along and across the grain were taken as per IS 10701 (1983) [5].

To study statistically the effect of nanoclay loadings and pressures on glue bond strength of PF-bonded 3 ply plywood prepared from Melia composita technique of analysis of variance was applied to glue shear strength. Glue shear data in dry state and wet state was analyzed for each pressure and five nanoclay loadings.

Glue Shear Strength for dry (GSSD) and wet samples (GSSW) at three pressure levels for each nanoclay loadings

From figure1 and table 2 it can be observed that for control (N0) glue shear strength for dry and wet samples meet the standard at all three pressure levels. Maximum values were observed at pressure level 21.0kg/cm2. It can be observed from figure 1&2 that when 1% nanoclay has been added into PF resin, GSSD (158Kg) and GSSW (115Kg) were highest for pressure level 17.5Kg/cm2. In case of 2% nanoclay loading (N2), glue shear strength for dry samples (152kg) is highest at 21.0kg/cm2 and glue shear strength for wet samples (100Kg) is highest at 14.0kg/cm2. When 3%, 4% and 5% nanoclay loadings were added to the resin glue shear strength dry ad wet has shown decline. In case of 5% nanoclay, glue shear strength for dry and wet samples did not meet the standard IS 10701 (1983) [5].This can be due to higher loading levels of nanoclay. Candan *et al*., 2015 observed in their work that bonding strength values of the composites reinforced with nanoSiO2, nanoAl2O2 and nanoZnO2decreased with increasing the nonmaterial loading levels from 1% to 3%.

Modulus of Rupture (along and perpendicular to grains) at three pressures for each nanoclay loadings: Results of table 2 and figure 3 shows that MOR (along the grain) for control test samples and test samples with different nanoclay loadings meets the Indian standard: 10701 (1983) [5], at all three pressure levels. It can be observed that MOR values are lowest for 5% nanoclay loading at 17.5kg/cm2 specific pressure. At 21.0kg/cm2 and 5% nanoclay loading MOR has shown better results. This indicated to point that pressure plays a significant role with respect to strength properties. MOR (perpendicular to the grain) with different nanoclay loadings fails to meet the standard (Figure 4). Lie *et al* (2010) has concluded on the basis of his study that it is difficult for Na-Montmorillonite to effectively mix with resin at molecular level. Whereas Nabil *et al*. (2015) [10] has indicated in the study that using ultra-sonication technique can successfully disperse the nanoclay in Phenol formaldehyde.

Modulus of Elasticity (along and perpendicular to grain) at all three pressure levels for each nanoclay loadings: It can be observed from table 2 that MOE (along and perpendicular to the grain) for control and all nanoclay loadings at all specific pressure meet IS: 10701(1983) [5]. But noticeable difference is not observed in MOE values between control samples and nanoclay loaded samples at all specific pressure. It can be inferred that though nanoclay loading is not increasing MOE values but it has no detrimental effect on the MOE strength.

Tensile strength (along and perpendicular to grains) at three pressures for each nanoclay loadings: It can be observed from table 2 that tensile strength (along and perpendicular to grains) at all three pressures for control samples meets IS: 10701(1983) [5]. Maximum value for tensile strength for control samples (along and perpendicular to grains), are observed at 21kg/cm2 specific pressure. This again indicates that pressure plays a role in strength properties of the plywood. It can be observed from figure 6&7 that tensile strength (along and perpendicular to grains) at all three pressures for 1% & 2% nanoclay loading meets IS: 10701(1983) [5] whereas tensile strength (along and perpendicular to grains) at all three pressures for 3%, 4% and 5% nanoclay loading does not meet the standard except at 21kg/cm2 for 5% nanoclay loading. With higher values of nanoclay tensile strength has shown decline. Lie *et al* (2010) observed for tensile strength that lower loading levels of nanoclay gave higher tensile strengths. Similar results have been observed in our study that tensile strength is performing better for lower loading levels. Saraeian *et al* (2012) [12] also observed that in polystyrene nano-composite too increase in strength by adding the proportion of nanoclay up from 4 to 5%. However, when nanoclay reaches 6%, the strength decreases. Samariha *et al* (2015) [11] results indicated that tensile and flexural modulus increased with an increase in nanoclay content. However, the addition of 4% nanoclay resulted in reductions of these properties.

Conclusion

The above study indicates that pressure plays an important role in strength properties of plywood. Control samples have shown increase in all properties with increasing pressure. Nanoclay introduced into PF resin could not give explicit results. This could be due to insufficient exfoliation of nanoclay into resins. High loading levels of nanoclay into resin has reflected detrimental effect on strength properties of the plywood. It is noticeable that highest value of GSSD and GSSW was seen in plywood samples having 1% nanoclay loading level. The role of nanoclay in PF resins needs further investigations.

Table 1: Specifications of nanoclay

Composition	Moisture (%)	Dry particle size µm (d50)	Packed bulk density(g/l)	Density(g/cm^3)	x-rayresultsd001(nm)	colour
Cloisite Na$^+$	4 - 9	<25	568	2.86	1.17	Off white

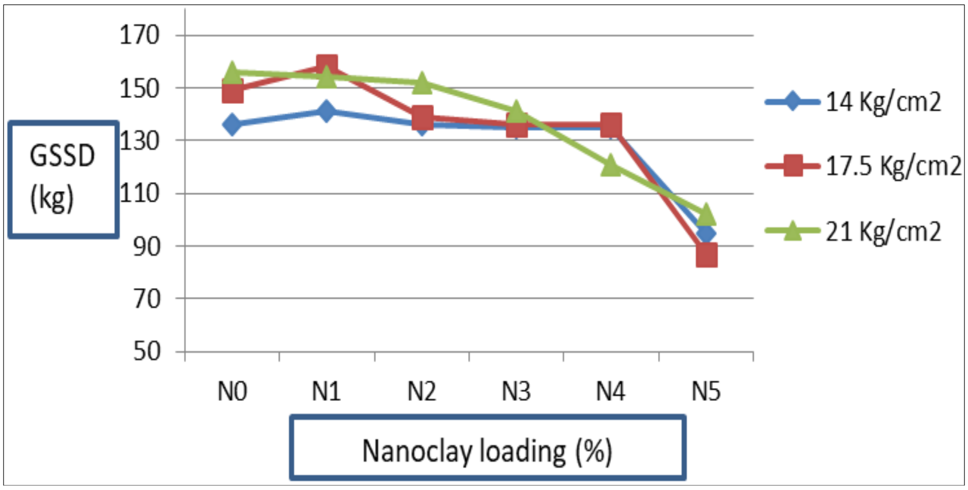

Fig1: Glue shear strength dry test

Table 2:- Effect of three pressures on Physical and Mechanical properties of Plywood at different nanoclay loadings

Plywood	Nanoclay	Pressure	GSSDRY	GSSWET	MOR (along the grain)	MOR (∟ the grain)	MOE (along the grain)	MOE (∟ to grain)	TS (along the grain)	TS (∟ the grain)
	(%)	(kg/cm^2)	(Kg)	(Kg)	(Kg/cm^2)	(Kg/cm^2)	(x 10^{3}Kg/cm^2)	(x10^3 Kg/cm^2)	(Kg/cm^2)	Kg/cm^2)
A1	0	14.0	136	102	767	298	107	8	556	369
B1	1	14.0	141	110	761	211	125	8	553	376
C1	2	14.0	136	100	710	232	122	9	669	386
D1	3	14.0	135	102	729	216	137	9	383	284
E1	4	14.0	135	100	762	191	114	7	467	234
F1	5	14.0	95	59	683	177	121	6	504	231
A2	0	17.5	149	106	722	257	121	8	583	371
B2	1	17.5	158	115	770	232	122	8	567	354
C2	2	17.5	139	95	733	176	116	8	557	365
D2	3	17.5	136	106	690	158	142	7	419	316
E2	4	17.5	136	92	750	172	128	6	496	308
F2	5	17.5	87	73	579	191	119	8	540	426
A3	0	21.0	156	115	726	248	122	9	617	399
B3	1	21.0	154	101	796	212	124	7	550	420
C3	2	21.0	152	95	792	238	140	8	553	342
D3	3	21.0	141	104	651	217	134	8	464	312
E3	4	21.0	121	93	674	202	113	7	524	417
F3	5	21.0	102	82	784	171	127	7	560	333

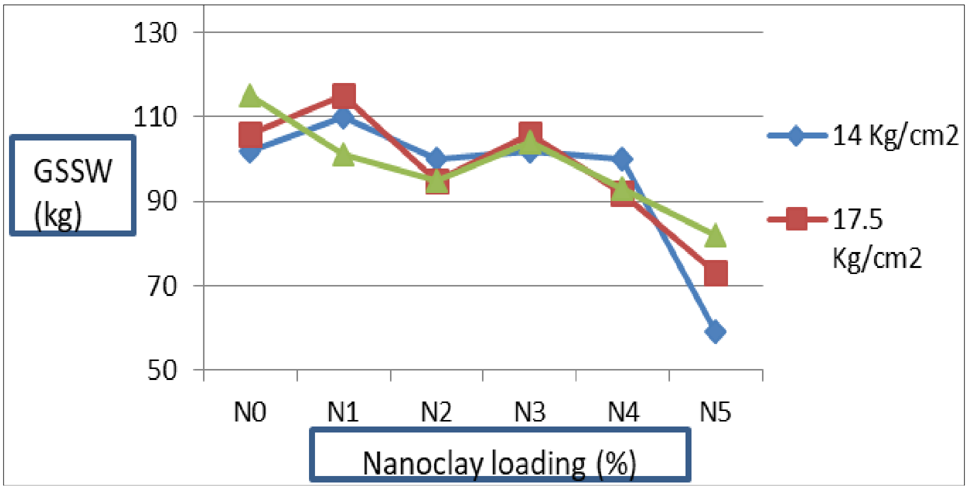

Fig 2: Glue shear strength wet test

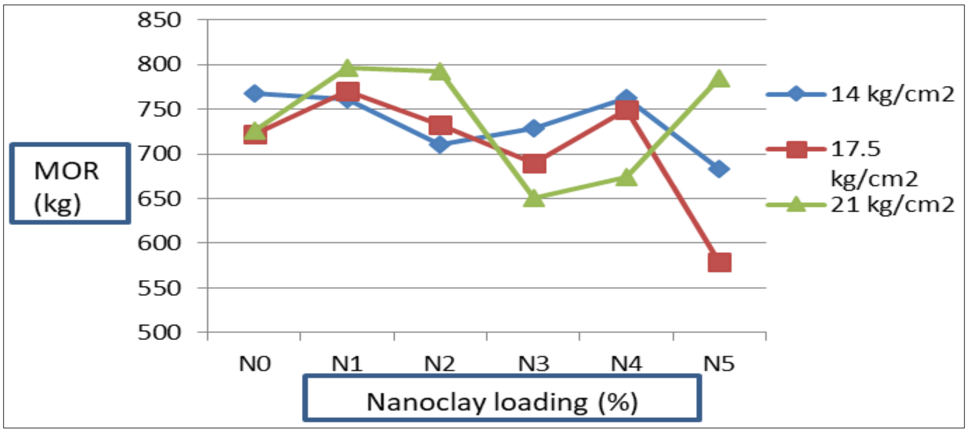

Fig 3: MOR along the grain

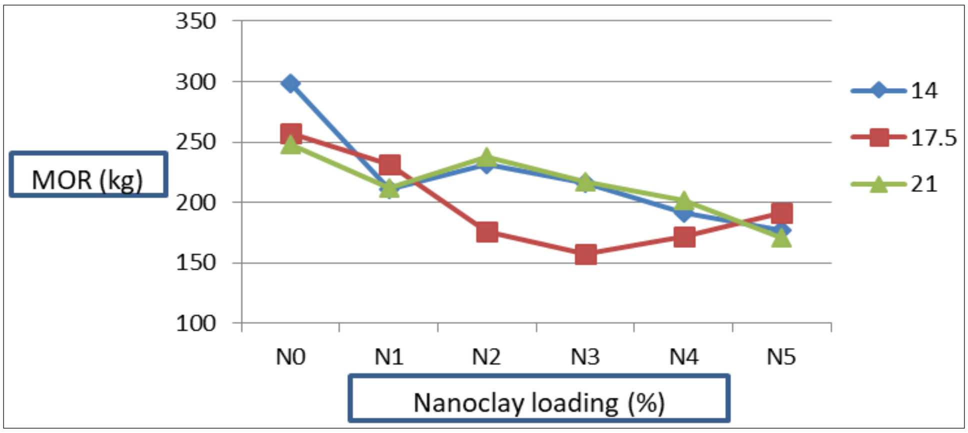

Fig 4: MOR perpendicular to grain

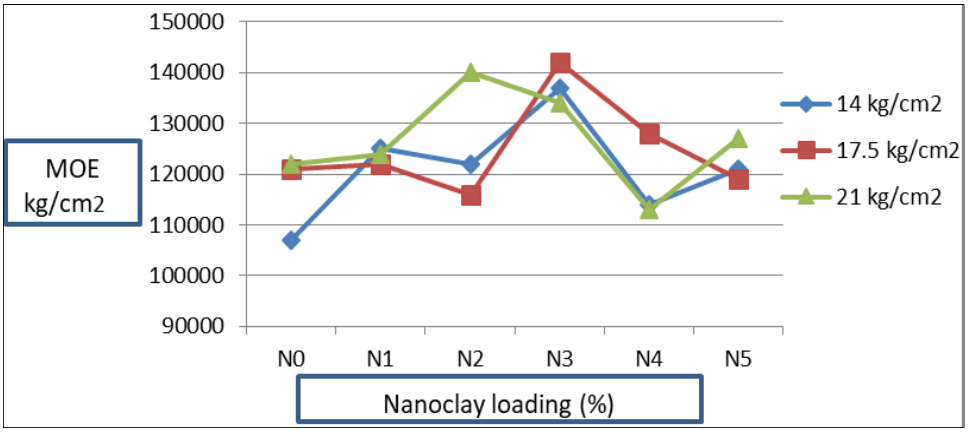

Fig 5: MOE along the grain

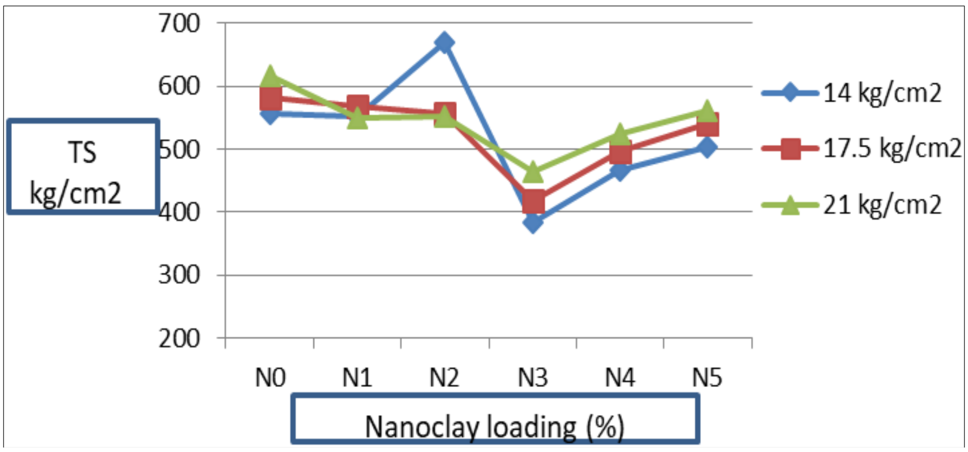

Fig 6: Tensile strength along the grain

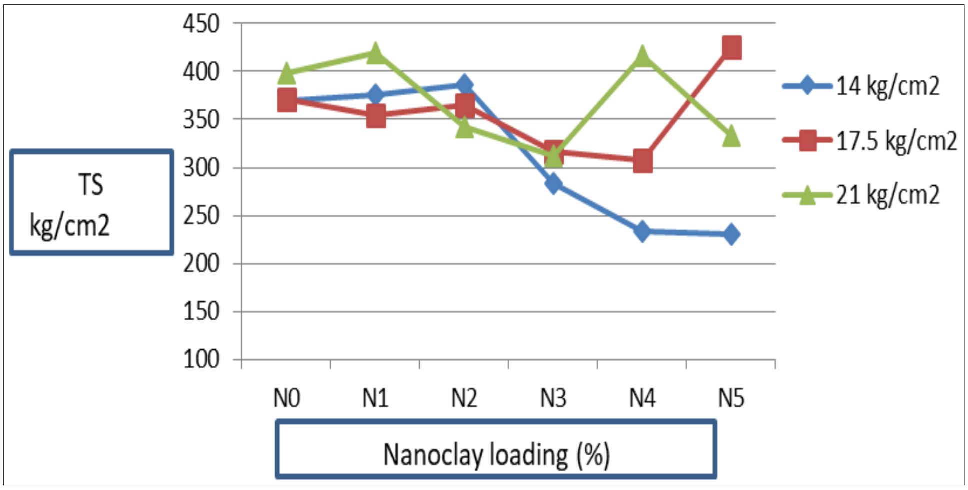

Fig 7: Tensile strength perpendicular to grain

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