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Effect of Nano-additive on the Bonding Strength and Formaldehyde Emission of the Plywood Adhesive during Manufacturing of Wood Based Panel Products

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Abstract*: Nano science and nano technology provides numerous opportunities for enhancing the properties of wood based panel products. In this study an extender was made using nano silicon dioxide (Sio2), nano calcium carbonate(CaCo3) with some specialty chemicals at a certain reciprocal proportion. Efficacy study was carried out with both phenolic and amino resin in terms of rheological and formaldehyde emission test using reinforcement of nano additive as extender at different concentration level. The plywood panels has been tested as per IS: 1734-1983 for mechanical properties. The rheological and adhesive properties has been tested as per IS 848: 2006. The test data reveals that enhancement of rheological, bonding and mechanical properties have been achieved after reinforcement of synthetic resin. The increase in the percentage of nano-additive caused an increase of viscosity, glue shear strength and minimizing the formaldehyde emission than using individual nano silicon dioxide (Sio2), nano calcium carbonate(CaCO3) instead of the extender made by combination of above. Using nano additive extender at 5%, there is an increase in glue shear strength in the glue line and enhanced rheological properties in amino resin based adhesive was observed.

Keywords: Composite wood products, nanotechnology, nano additives, nano material-reinforced adhesives.

I. INTRODUCTION

Additives are basically made with special chemicals when added in small concentration, it enhances the adhesive properties and reduces the cost of the glue used in wood based panel industries to manufacture wood composites. Additives are inexpensive and therefore used to reduce the high cost of these synthetic resins. The focus is on green technology, sustain-ability, lower cost and safe products have led to the introduction of newer additives and chemistries. At the same time, it has been proven that nano-SiO_2 does not significantly affect the curing time of the resin and there is not necessary to change the press conditions (Lin et al. 2006).

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Addition of nano- SiO_2 does not have an effect in the thermal stability of the resin (Roumeli et al. 2012).
Considering this, the research was undertaken on the possibility of improving the properties of boards made of rape straw of nano-SiO2 to the Urea Formaldehyde resin. It was revealed in earlier numerous studies, that rape straw may constitute valuable substitute for wood chips in particle boards manufacturing on condition that relevant type or quantity of binder is applied (Dukarska et al. 2006, Keyhole et al. 2005, Paubicki et al. 2003. Some researchers have reported the good performance of nano clays when used as a reinforcing element in wood adhesives, obtaining significant gains in resistance, besides increasing the thermal stability (Moya et al. 2015).
Wood Adhesives are classified into two types (i) natural viz . starch, dextrin, protein glue, vegetable & animal glues (ii) Synthetic viz. thermosetting and thermoplastic resin. Due to high cost of these adhesives, certain materials are often added to reduce the cost of adhesive and to impart special effects on the mixture.
These materials are called additive and are classified as fortifier, extender and fillers.
These materials are inexpensive and therefore used to cut down the high cost of the synthetic resin. Depending on the nature of the resin, additive and wood species, the additive normally make up about 14% of the total cost of the adhesive mixture.

II. EXPERIMENTAL METHOD

Commercial grade formalin, caustic, urea etc. used for resin synthesis. Wood veneers used for manufacture of plywood were mainly Dipterocarpus spp. (Gurjan). The nano SiO_2 and nano $CaCO_3$ were procured from local market having properties (moisture content as to 9%, density as 2.4 g/cm3 to 2.93 g/cm3). respectively and dry particle size of (15 -40) nm Author (s) can send paper in the given email address of the journal. There are two email address. It is compulsory to send paper in both email address.

A. Urea Formaldehyde Resin

The urea formaldehyde plywood resin was manufactured as per the process given (Sahoo et al 2014) and taken for the study of extender quality. Properties of the resin has been studied.

B. Extender formulation

An extender was formulated by taking starch based material as a major percentage with some filler and nano particles like SiO_2 and $CaCO_3$ at certain proportion. The extender concentrations from (1-6) % on the basis of the weight of liquid resin was taken along with only urea formaldehyde resin as control to assess the quality of the extender as well as the ply board manufactured .

C. Glue formulation

Urea formaldehyde based glue was prepared by using extender starting from concentration 1.0% to 6% along with only urea formaldehyde resin without extender as a control. The glue was prepared by using laboratory stirrer for 30 – 45 minutes. The viscosity in terms of flow time was measured in B_6 cup (IS:3944-1982). Ref. Tab IV.

D. Properties of Extender

The different properties of the extender like ash content, PH, particle size etc was carried out as per IS:1508 .

E. Plywood Manufacturing

600 x 600 x 12mm ply board was manufactured by taking veneer of moisture content around 5 to 7% and glue applied at the rate of (280- 320) gm/m^2 on double glue line basis. The specific pressure was applied for 13 minutes at a temperature 115^0C. (Ref Tab III)

F. Assessment of adhesive bond

The bond quality of the plyboard was tested for water resistance test as per IS 848:2006 for MR grade. The other parameters relevant to bond quality were tested as per IS:1734-1983 for assessment of bond quality (Ref Tab III and Tab VII).

G. Formaldehyde emission assessment (Perforator value)

Formaldehyde emission value of the ply board made by using extender at various extension level with both UF and PF resin was determined by perforator method as per ENV-717.

III. RESULTS AND DISCUSSION

From the tests of particle size of the extender, it reveals that the particle size of the extender shows satisfactory results and meets as per the requirement of IS 1508 when tested as per sieve designation of 80 micron. The extender when mixed with urea formaldehyde resin shows a homogeneous mixture after mixing of 30 -45 minutes without showing any reaction or adverse effect with resin. The study of the extender shows that, the concentration level i.e. 3 percentage concentration of liquid resin in UF shows satisfactory concentration for glue spreader and adhesive mix viscosity after mixing properly in a glue spreader minimum 30 minutes. The viscosity of adhesive increased using higher percentage of extender made by additive from nano SiO_2 and $CaCO_3$.

From viscosity study (Ref Tab III), data shows that viscosity of the glue measured in terms of flow time in B_6 (IS : 3944-1982) showed satisfactory results at concentration 3%. Solid content of adhesive mix increases significantly as the concentration of the extender increases. From physico-mechanical property study of plywood, data shows there was a significant change in mechanical i.e at a higher side was achieved of plywood samples made by using extender during pilot scale study.

From the study for manufacture of plywood to assess the rheological properties of extender, the parameters for hot pressing and cold pressing (Ref Tab III), it shows satisfactory rheological properties of the resin and good bonding strength of the plywood. It also shows that the emission value (perforator value) of the plywood after at 3% concentration level was 12.6 mg/100gm compared to blank results 29.2 mg/100 gm of the board wherein it minimizes more than 50% in comparison to blank.

IV. CONCLUSION

The use of nano materials as extender leads to a change in mechanical properties for wood panels even with the addition of a relative lower percentage. Thus the results of this study are acceptable considering the lower quantity of nano SiO_2 and $CaCO_3$ mix to be an alternative to improve the bond quality of wood based panel. There is a significant reduction of formaldehyde emission by using the nano SiO_2 and CaCO3 based extender. The addition of up to 3% extender resulted in a relative improvement of glue shear strength. On addition of excess nano additive based extender leads to increase the viscosity of the adhesive system which give adverse effect on the bonding quality of the wood based panel. It can be concluded that there was a significant reduction in non volatile content with the addition of nano based extender. It has also shown that nano SiO_2 and CaCO3 mixed additive are promising for the improvement of amino base adhesive performance.

Table- I: Properties of resin

Gel Time at 100°C (seconds)	Flow Time (B4 cup) (seconds)	Solid content (%)	Water tolerance	pH	PH of Cured film	Free formaldehyde (%)
73	20	50.1	1:4	7.8	2.91	0.91

Table -II: Adhesive mix with different concentration

Component	Parts by weight (Pbw)						
	Level of concentration (%)						
	C_0	C_1	C_2	C_3	C_4	C_5	C_6
UF Resin Liquid 49% solid	200	200	200	200	200	200	200
Extender	0	2.0	4.0	6.0	8.0	10.0	12.0
NH_4Cl	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Liquid NH_4	1.6	1.6	1.6	1.6	1.6	1.6	1.6

Table -III: Board Pressing conditions

Parameters	Cold Pressing for UF Resin
Pressure	10.5 kg/cm^2
Temperature	110°C
Time	12 minutes

Table -IV: Properties of adhesive mix

Properties	Level of concentration (%)						
	C_0	C_1	C_2	C_3	C_4	C_5	C_6
Flow time	21/B_4	10	11.5	14	16	17.5	19
Solid content (%)	49.6	50.2	51.1	51.8	52.7	53.9	54.8
Adhesive pH	6-6.5	6-6.5	6-6.5	6-6.5	6-6.5	6-6.5	6-6.5
Pot life (hrs)	> 6	> 6	> 6	> 6	> 6	> 6	> 6

Table -V: Effect of coverage on Glue Shear Strength with respect to coverage spread = 350± 10 gms/m2 DGL

Type of Extender base on nano additive	Conc Level	Coverage / m^2 DGL/kg Liquid UF resin	Average Glue Shear Strength					
			Dry State		Cycling test as per MR Grade		Resistance to Mico-organism	
			Load (N)	Wood Failure (%)	Load (N)	Wood Failure (%)	Load (N)	Wood Failure (%)
UF Resin	C_0	5.68	788	65	720	55	652	50
	C_1	5.82	799	65	732	55	666	50
	C_2	5.90	808	65	748	55	698	50
	C_3	5.96	825	70	762	60	709	55
	C_4	5.98	887	70	775	60	716	55
	C_5	5.96	896	70	782	60	722	60
	C_6	5.98	1898	70	798	60	738	60

Table - VI: Composition of the adhesive mix used to prepare 7 ply of 1.2 mm thickness

Adhesive mix		Board parameters for 7 ply plywood	
Component	Parts by weight	Characters	Board Parameters (mm)
Resin UF Liquid	200	Number of plies	7
NH_4Cl	1.0	Face longitudinal	1.0
Liquid NH_4	1.6	Cross band	2.2
Extender	3.0	Panel core	2.2
Insecticide(GLP)	0.5	Cross band	2.2
		Panel core	2.2
		Cross band	2.2
		Back (Longitudinal grain)	1.0

Table -VII: Physico-Mechanical properties of the plywood

Sl. No.	Type of Extender used (%)	Average Glue Shear Strength						Static Bending				Tensile Strength (N/mm^2)	
		Dry State		Wet State		Resistance to Mico-organism		MoR (N/mm^2)		MoE (N/mm^2)			
		Load (N)	Wood Failure (%)	Load (N)	Wood Failure (%)	Load (N)	Wood Failure (%)	Along	Across	Along	Across	Along	Across
1	UF+Conv. Extender	776	70	722	60	696	55	38.26	39.64	3285	2842	26.52	29.53
2	UF+Nano. Extender	825	75	764	65	718	60	46.22	50.26	4655	4687	34.85	32.84

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