International Journal of Polymer Science
Vol. 1: Issue 1
www.journalspub.com

Enhancement of Fire Retardancy Properties of Plywood by Incorporating Silicate, Phosphate and Boron Compounds as Additives in PMUF Resin

S. C. Sahoo[1]*, Amitava Sil[1], A. Solanki[1], P. K. Khatua[2]
[1]Indian Plywood Industries Research and Training Institute, Field Station Kolkata, Kolkata (West Bengal) India
[2]Haldia institute of Technology, Haldia, (West Bengal) India

Abstract
Wood is one of the supreme sustainable, naturally growing materials that consist principally of combustible organic carbon compounds. Since plywood are widely used now a day especially in buildings, furniture and cabinets. Since the demand of plywood with fire retardancy properties has been increasing over last years, the objective of this study is to improve the fire retardancy of Wood Panel Products by adding Tricresyl phosphate, Di-Sodiumocta Borate and Sodium Silicate compounds as an additive in PMUF resin and used as glue for manufacture of plywood. In order to produce Fire proof board with good properties such as; fire-resistance, environmental protection and good bonding, PMUF resin has synthesized. Tricresyl phosphate (TCP), Disodiumocta-borate tetra hydrate (DOT) and Sodium Silicate was added as additive with various concentrations to prepare adhesive-mix. 12 mm plywood was manufactured and for resistance properties was studied as per IS:5509:2000. Date revels that the treated plywood shows better fire resistance properties than the untreated plywood. It has been observed that satisfactory fire retardancy properties like flame penetration and flammability was achieved when tested as per IS:5509:2000. The use of TCP and silicate not only increased the fire retardancy but also improved the bonding quality.

Keyword: *Phosphate and boron compounds, PMUF resin, fire retardancy, flammability, flame fenetration, IS: 5509:2000*

****Author for Correspondence*** *E-mail ID: mantas3in@yahoo.co.in*

INTRODUCTION

Wood is one of the most sustainable, aesthetically pleasing and environmentally benign materials. The demand to use wood and wood-based products for applications in both residential and non-residential building construction has been increasing over recent years. However, due to the inherent flammability of such products, they often contribute to unwanted fires, resulting in numerous injuries and fatalities. The use of wood is, therefore, limited by various safety requirements and regulations pertaining to its flammability and spread of fire characteristics. In order to improve the reaction to fire performance, timber products are commonly treated with fire retardants. At present, the level of development of such products with improved fire performance does not match the increasing use. Some of the fire retardant timber treatments are almost two millennia old, where alum and vinegar were first used. Little improvement has been observed since, with treatments exploiting the synergism between boron, phosphorus and nitrogen to promote char formation still prominent. Fire-retardant treatment of plywood and other wood panel products is therefore a crucial part of public and commercial building design for decades. However, only limited fire resistance can be achieved in wood, because no wood material is completely fire proof[1]. Wood is one of the most sustainable, aesthetically pleasing and environmentally benign materials. The demand to use wood and wood-based products for applications in both residential and non-residential building construction has been increasing over recent years. However, due to the inherent flammability of such products, they often contribute to unwanted fires, resulting in numerous injuries and fatalities. The use of wood is, therefore, limited by various safety requirements and regulations pertaining to its flammability and spread of fire characteristics[2]. Many studies have investigated the effectiveness of various fire retardant treatments on wood and wood particleboards. For example, the use of a solution containing urea, phosphoric acid, and ethanol as a fire retardant for wood resulted in excellent fire retardation. Pereyra and Giudice[3] used flame-retardant impregnants based on alkaline silicates to treat wood and obtained high fire-retardant efficiency as well as high water insolubility. A mixture of ammonium sulphate, diammonium phosphate, borax, boric acid, and ammonium bromide was used as fire-retardant agent to treat recycled wood-waste particles prior to use in particleboards manufacture. Terzi *et al.*[4] evaluated the fire performance and decay resistance of solid wood and plywood treated with quaternary ammonia compounds and common fire retardants. Heat release rates were lower for treated than untreated specimens. The most important properties of flammable material are time to ignition, heat release rate, extinction flammability index and thermal stability index, mass loss, smoke toxicity, limiting oxygen index, surface spread of flame and fire resistance (Mouritz and Gibson)[5]. Among the many polymeric materials used, epoxy resins are one of the most problematic: they are used in sectors such as; electronics or public transportation, where standards are particularly restrictive. Unfortunately, they tend to burn easily while releasing high quantities of smoke and gases[6]. There are three methods by which fire-retardant plywood can be made:

1. Coating the plywood with fire-retardant paint.
2. Impregnating the plywood with fire-retardant chemicals.
3. Impregnating the veneer with fire-retardant chemicals before gluing.

The first method would be the simplest however, a paint that is as effective as impregnation with chemicals has not yet been made. The disadvantage of the second alternative is good water-resistant glue must be used to withstand the impregnation treatment. The impregnation of the veneer with fireproofing chemicals would be a very satisfactory and simple method if a successful glue bond could be obtained. This procedure raises a very definite problem, that of the effect of fire-retardant chemicals on the uncured glue. In this study second method used i.e., fire retardant chemicals are used in adhesive by incorporating fire retardants like TCP, DOT and Silicate compounds.

MATERIALS AND METHODS

Materials

Veneers of guarjan (*Diptocarpus sp.*) of thickness 1.8 mm as core and having thickness 0.3–0.5 mm as face veneers were cutting into 30×30 cm size, the average moisture content after drying and before manufacturing of plywood was maintained to 6 to 8 percentage. Adhesive was used as for manufacturing of plywood with suitable extender and fire retardants as an additive. 250 to 300 g glue was applied on the core veneer on D.G.L

PMUF Resin Preparation

400 parts by weight of formalin (Formaldehyde content 37%) was charged into resin kettle and made alkaline with 50% sodium hydroxide solution to pH

8.0–8.5. 100 parts by weight of urea and 60 parts of melamine was gradually added to the kettle and stirring started. Stirring continued till the end of the reaction. Temperature was raised by passing steam and then set at 92º±2ºC and kept at this temperature under agitation for 1½ –2 h. In the second stage, the pH of the solution was lowered to 7.0–7.5 by adding 50% solution of acetic acid and reaction was continued under agitation at the same temperature. The progress of the reaction was followed by measurement of viscosity and water tolerance. Six parts by weight of sodium hydroxide dissolved in 15 parts of water was added. Exothermicity was carefully controlled at this stage. Reaction is further continued at 85ºC. When viscosity of the resin is 80–100 cp or flow time 20–30 sec in B_4 flow cup of IS: 3944-1982, and water tolerance 1:5 or 6 the resin was cooled and discharged from the kettle (Table 1).

Table 1: *Properties of Synthesized PMUF Resin.*

Gel Time (min)	Flow Time (B4 cup) (sec)	Solid Content (%)	Water Tolerance	pH	Free Phenol (%)
17	28	51	1:4	10.26	0.48

Adhesive Formulation
100 parts PMUF resin, 5–10 parts Triciryl phosphate, 5–10 parts sodium silicate and borax was mixed uniformly for 30 min by taking wheat flour as an additive.

Preparation of Specimen
12 mm plywood was manufactured by using Gurjan Sp. as core and face veneer in 75 Ton Hydraulic hot press. The plywood specimen were conditioned for 07 days to achieve equilibrium mixture at 23ºC and 50% RH before cutting samples for testing as per IS:5509:2000.

Incombustibility Test
The untreated and fire retardant coating treated plywood were tested according to IS:5509:2000. To assess the fire retardancy properties of the plywood after coating, flammability, Flame Penetration, and Rate of Burning was carried. All the test has been carried as per IS:1734 (Part 3).

Mechanical Properties Study
Physico mechanical properties of the fire retardant ply wood has been carried as per IS:1734.

EQUIPMENT

RESULT AND DISCUSSION

Effect of Fire Retardant Chemicals on Incombustible Properties
It has been observed that in the presence of heat or flame the substrate reducing the penetration of heat, thus retarding the flame spread and delaying structural failure. The results of fire retardancy complies with the requirement of IS:5509 (Table 2). Under the heating action phosphorous compounds decomposes at lower temperature to give phosphoric acid then creates an intumescent protection layer which prevents further oxidation and improves the char formation. Boron compounds decompose under heat to form a glossy protection layer which act as a barrier for polymer chain oxidation. Both

phosphorous and boron compounds also act as smoke suppressant. Silicate compounds act as high thermal stability from the fire retardancy test (Table 2).

Table 2: *Results of Fire Retardancy.*

Samples	Flame penetration (min)	Flammability (min)	Burning (min)
A (untreated)	32	22	14
B (treated with TCP+Silicate)	45	34	18
C (treated with boron+Silicate)	48	37	16
D (t treated with TCP+Silicate+Boron)	62	49	21

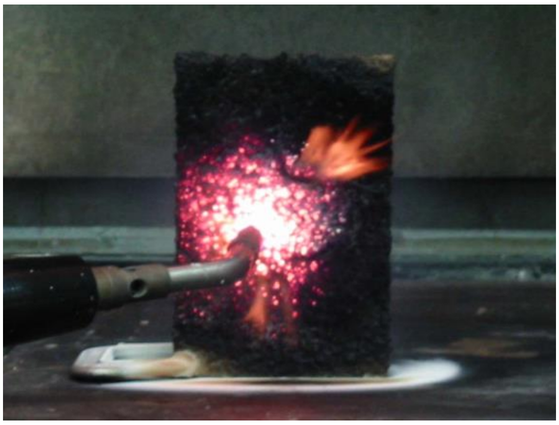
Treated plywood which shows a marked improvement compared to untreated plywood. The improvement in tire resistance depended upon the type and concentration of treated chemical and the thickness of the plywood. The results from mechanical test indicate that new fire retardant combination exhibit superior mechanical strength in comparison to commercial treated plywood (Table 3).

Table 3: *Physico-Mechanical Properties of the Plywood after Coated.*

S. No.	Sample Type	Average Glue Shear Strength						Static Bending				Tensile Strength, N/mm2	
		Dry State		Wet State		Resistance to Mico-organism		MoR, n/mm2		MoE, N/mm2			
		Load, (N)	Wood Failure, (%)	Load, (N)	Wood Failure, (%)	Load, (N)	Wood Failure, (%)	Along	Across	Along	Across	Along	Across
1	PMUF	1084	70	800	60	730	60	37.8	30.65	4052	2896	28.36	30.16
2	PMUF+FR chemicals	988	65	820	60	850	60	38.2	32.82	5512	3012	30.15	35.64

CONCLUSION

In conclusion since a wide range of fire retardant treatment and coating systems for wood have been studied throughout recent years and many others are currently under development and combinations of phosphorus and nitrogen continue to prove themselves as very powerful solutions for wood-based applications. It has been suggested that Triceryl phosphate can be effectively used as a retardant for wood and cellulosic materials especially combination with boron compounds. In addition to the fire retardancy properties boron compounds act as anti insect, fungus and less toxic material to human beings. The greater fire retardancy and bonding properties can be achieved by adding silicate compounds with the combination of phosphorous and boron compounds due to its high thermal stability properties.



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