International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

# Performance Effectiveness of the Amino Resin Based Laminating Adhesive to Laminate on Wood Composites

**Sadhu charan Sahoo[1], Amitava Sil[2]**

[1, 2]Indian Plywood Industries Research and Training Institute, Field Station Kolkata, An Autonomous Body under Ministry of Environment, Forests and Climate Change, India

**Abstract:** ***The objective of this study was to formulate a new low temperature thermosetting adhesive for plywood lamination and to evaluate the potential of the laminating adhesive on wood composite material. A fast setting powder based laminating adhesive was developed to paste the laminates on the wood composite materials so as to increase the productivity efficiency. The adhesive was formulated by taking powder amino resin (MR-202) as a base material with some tackifier and viscosity enhancer as special chemicals. Dispersion of adhesive was carried with ratio 1:1 (adhesive : water) and the resultant adhesive was taken for laminate pasting on wood composite material. The chemical and mechanical properties of the laminated wood were carried out. The resultant dispersion adhesive which contain 50% solid content approx. demonstrated the setting of laminates on wood composite material both at room temperature and at the temperature 60-70$^0$C with a shorter time than the conventional laminating adhesive used at present. The experimental data reveals that the resultant adhesive confirms the requirements when tested as per IS 4835:(1976) for the parameters like pH, solid content, moisture content, ash content, glue joint strength, early strength development and stability etc. The significant bonding of laminate at a shorter time without warpage and cracking shows encouraging results for the potential of this technology.***

**Keywords:** Plywood lamination, powder amino resin (MR-202), glue joint strength, early strength development and stability

## 1. Introduction

When dispersion adhesives are based on polyvinyl acetate (PVAc), they are often used for gluing of wood due to easy preparation and application. These adhesives are healthy safety in point of view and also their quality of the bond and their use is growing day by day. PVAc adhesives provides very strong bonds having good affinity to wood and flexibility. Curing of PVAc dispersions is essentially a physical process in which wood gradually takes water from the glue, while the glue line creates a continuous polymer film.

Adhesive penetration into the wood structure was evaluated by (Hass et al. 2012). PVAc are resistant to micro-organisms and fungi, nonflammable with partial resistance to increased temperature, humidity and water (Proszyket al. 1997). Due to their favourable non-toxic properties, they replace formaldehyde adhesives during production of plywood, veneering of furniture parts or surface finishing e.g. laminating. These adhesives are most often used for assembly bonding joints of furniture parts, finger jointing, production of solid wood panels (SWP), or for the production of glued laminated timber (Glue lam) for non-bearing construction purposes (Sedliačik 2005). In recent years, there has been a significant increase of productivity by improving technology through the shortening of the curing time as described in (Avramidis et al. 2011). This also includes new requirements for dispersion adhesives by reducing the amount of water in dispersion adhesive causes deterioration of the coating quality. These coloured laminates are based on solvent-borne adhesives tinted with solvent-based dye or solvent-based concentrates of mixtures of dyes and pigments, as commercially available as, e.g., Color Stick ® (Comp. Hartmann, now Sun Chemical).

There are many ways to modify PVA dispersions which have already being described. They reduce the solubility of poly (vinyl alcohol) to change OH groups by hydro- phobic ones, to induce the netting of molecules. For example, as modifying the dispersion additive monoaldehide – formaldehyde is suggested [Ivanov. N.A, 1982]. Other substances to modify PVA dispersion are known as well, such as isoprophylene alcohol, iron trichloride, potassium bichromate, butyl acrylate, methyl methacrylate [Qiao.Let.al, 2000], alkoxysilane [Witucki.G.L- 1992], polyisocyanate [Qiao.L, etal, 2001]. Good results were obtained by modifying PVA dispersion with the resin of carbamide, melamine, furol, formaldehyde [Gos.B.Kuchnki etal, 1995] with the resin of epoxy “УП-160” [Trizno V.L -1976]. Additional modifications are needed in order to produce water resistance glue described in EN204 standard.

This study relates to develop an improved adhesive composition alternative to PVAc based and its performance, effectiveness particularly applicable to laminated cellulosic structures such as plywood in which the improved adhesive compositions will be used as bonding medium.

## 2. Materials and methods

### 2.1 Materials

In order to simulate industrial production, commercial grade raw materials without further purification were used for formulation of adhesive. i. e. amino resin

MR -202, Melamine Urea Formaldehyde based (Supplied by M/s ARCL, Kolkata), starch powder (Merck), dextrin (Merck), Poly Vinyl Alcohol (Merck), Resole (Merck), Soya flour (46% protein) from local market were chosen for formulation of laminating adhesive. Rotary cut dipterocarpus spp. (Gurjan) and eucalyptus veneers having thickness 1.8 mm and density around (0.8-0.9) gm/cm$^3$ were taken for testing purpose. Laminates having thickness 0.6 mm were procured from local market for this study.

### 2.2 Adhesive formulation

Five different composition was experimented to formulate laminating adhesive formulation. The details are given in Table1.

**Table 1:** Adhesive composition

| Components | Comp-1 (C2) % by wt | Comp-1 (C3) % by wt | Comp-1 (C4) % by wt | Comp-1 (C5) % by wt | Comp-1 (C6) % by wt |
|---|---|---|---|---|---|
| Amino resin (MR -202) | 10 | 20 | 30 | 40 | 50 |
| Starch | 20 | 20 | 15 | 15 | 10 |
| Dextrin | 35 | 30 | 30 | 20 | 15 |
| PVA(Cold) | 30 | 25 | 20 | 20 | 20 |
| CMC(Carboxy Methyl Cellulose) | 01 | 02 | 02 | 02 | 02 |
| Soya powder | 4.0 | 3.0 | 3.0 | 3.0 | 3.0 |

**Table 2:** Analysis concerning the properties of the formulated laminating adhesive

| Test | Test Method | Criteria for conformity | Results | | | | |
|---|---|---|---|---|---|---|---|
| | | | Comp-1 | Comp-2 | Comp-3 | Comp-4 | Comp-5 |
| Solid Content(%) | Clause 6.1 of IS :4835 - 1976 | Not less than 40% | 49.92 | 49.7 | 50.6 | 49.8 | 50.4 |
| Ash Content(%) | Clause 6.2 of IS :4835 - 1976 | Not more than 2% | 1.08 | 1.17 | 1.09 | 1.28 | 1.05 |
| $P^H$ Value | Clause 6.3 of IS :4835 - 1976 | Not less than 5, Not more than 7 | 5.2 | 5.2 | 5.7 | 5.8 | 5.7 |
| Glue joint Strength Dry strength (Kg) | Clause 6.5.1 of IS :4835 - 1976 | Min 300 kgs Wood failureNot less than 85% | 300.6 Wood failure 75% | 307.4 Wood failure 80% | 342.8 Wood failure 85% | 355.0 Wood failure 85% | 356.8 Wood failure 90% |
| Early strength development(%) | Clause 6.6 o1976 | More than 60% of the dry strength.180 kg | 60.2% 182.4 | 62.5 192.1 | 65 222.8 | 68.4 242.8 | 70 249.7 |
| Stability | Clause 6.7 of IS :4835 - 1976 | Meets the requirement of stability | Meets the requirement of stability | | | | |
| Working consistency | Clause 6.8 of IS :4835 - 1976 | Satisfactory | Satisfactory | | | | |

### 2.3 Blending of adhesive

Each composition starting from C1 to C5 was blended with water in the ratio 1:1 (adhesive : water ) in a high speed stirrer with high rpm for 45 to 60 minutes until the required viscosity achieved to formulate a water based adhesive with excellent bond strength and rheology.

**Figure 2:** Laminating dispersive adhesive

### 2.4 Pasting of laminates on plywood

0.6 mm thick laminate was pasted on the substrate like plywood in both room temperature and at 60-70$^0$C under specific pressure of 6 – 7 Kg/cm$^2$. At room temperature, water based laminating adhesive was applied on the both the substrate and laminate at a spread rate of adhesive (150-200gm (approx.). Across the substrate and kept under specific pressure of 6 – 7 Kg/cm$^2$ for 3 to 4 hrs.The adhesive was spread on the plywood surface and kept in the hot press at 60-700C using BOPP paper for 20 minutes under specific pressure of 6 – 7 Kg/cm$^2$ (Ref Table 3)

**Table 3:** Parameters used for pasting the laminates outlines

| Component | Values |
|---|---|
| Surface | Should be properly level |
| Coating | Should be on both the surface |
| Humidity | Should be used @ humidity 40-50% |
| Humidity more than 80% | Should not be used |
| Pressure used | Under pressure @6 kg/cm$^2$ |
| Spread of the adhesive (gm/m$^2$) | 150-200 |
| Open assembly time | 1-20minutes |
| Hot pressing time @60$^0$C | 10-20minutes |

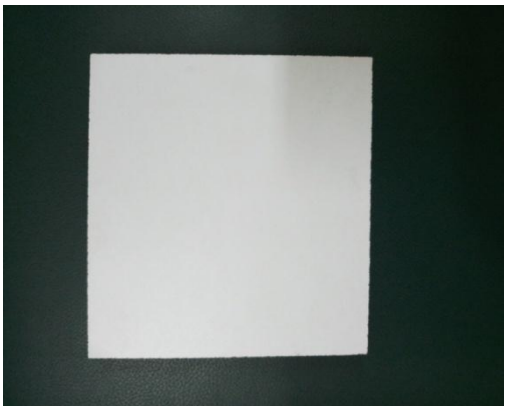

**Figure 1:** Laminate pasted plywood

### 2.5 Sample preparation for Glue joint strength

Ten pieces sample was prepared from dipterocarpus spp.(Gurjan) having density of (0.8 - 0.9) gm/cm$^3$ and the sample was prepared as per IS 4835 - 1975. Each test pieces were made from two slip of dipterocarpus spp.(Gurjan) veneer having 115 mm in length, 25mm in width and 3.2mm in thickness which were joined together with the adhesive under test so as to produce 25mm overlap joint.

### 2.6. Total solids

Two grams of sample were taken and weighed accurately in an open petri dish and kept for drying in oven at a temperature of 105°C for approximately 3 hours up to a constant mass. The sample was then cooled in a desiccator and weighed. Total solid content was calculated as follows:

$$Percentage\ of\ solid = \frac{Final\ mass\ of\ dried\ sample\ X\ 100}{\text{Initial mass of sample}}$$

### 2.7 Ash content

About 3 gms of adhesive was accurately weighed in a platinum crucible and incinerated. The percentage of ash content was calculated.

### 2.8 pH value

The pH value of the dispersive adhesive was carried in pH meter as per test method given in IS : 4835 - 1976.

### 2.9 Glue Joint Strength

The average failing load of a set of ten test pieces prepared by the method specified in Appendix F of IS 851 - 1978 conditioned approximately as specified in Appendix D of IS 851 - 1978 and glue joint strength and percentage of wood failure was carried out as per method mentioned in IS 8435 - 1976.

### 2.10 Early Strength Development

Six test pieces of samples were prepared as per the test method mentioned in IS 851 - 1978 and the test was carried as per IS 8435 – 1976.

### 2.11 Adhesive performance study (Treatment)

The treatment determined by standard EN-13353- 2008 for evaluation of bonding quality wood panels and adopted in this study were:
Dry conditions : 24 hours in water
Humid conditions : 6 hours in boiling water, 1 hours cooling in water.
External conditions : 4 hours in boiling water, 16 to 20 hours drying (60 ± 3°C), 4 hours in boiling water, 1 hours cooling in water (Ref Table 4)

**Table 4:** Adhesive performance study of laminated wood panel

| Treatment | Pressing time @temp 60°C in minutes | Comp-1 | Comp-2 | Comp-3 | Comp-4 | Comp-5 |
|---|---|---|---|---|---|---|
| Dry condition | 20 | No delamination | No delamination | No delamination | No delamination | No delamination |
| Humidity condition | 20 | No delamination | No delamination | No delamination | No delamination | No delamination |
| External condition | 20 | Delaminated | Delaminated | Delaminated | Delaminated | Delaminated |

## 3. Results and Discussion

### 3.1 Properties of laminating adhesive

The result of analysis concerning the properties of the formulated laminating adhesive are presented in Table 2. From the result, data reveals that the homogeneous adhesive composition prepared after dispersion with water and white milky colored i.e. white glue forms with equivalent colour with D3 adhesive convention material available in local market. All the test parameter meets as per the requirement of IS 4835 -1976. Comparing the properties of the laminating adhesive starting from comp-1 to comp-5 with the conventional, it has been observed that comp-3 is showing better rheological properties. The results clearly demonstrate a substantial increase in glue joint strength by increasing the concentration of powder amino resin.

From the analysis for the setting time of laminates on plywood panel both in cold and hot condition, the results obtained were satisfactory. The best results of pasting of laminates were achieved when adhesive was spread on to the substrate in one direction and onto the back of the laminates in other direction i.e. along the length of the substrate and across the width of the laminates which gives a cross linking effect when the two surfaces are joined together. Increasing the amount of powder resin concentration also leads to increase the glue joint strength and percentage of wood failure in dry state. The solid content, concentration of hydrogen ion (pH) remains practically unchanged.

### 3.2 Adhesive performance

One objective of this research was to develop a new low temperature thermosetting adhesive to laminate the wood composite materials and its performance study. To properly asses the adhesive, their properties and performance was evaluated in both adhesive and composite panel by pasting laminates. The parameters used for pasting the laminates are outlined in Table 3 and considered to be the reasonable cost simulations for commercial operation.

From the adhesive performance study i.e. after laminated wood panel sample treated is dried in humidity and external condition, the data of the panels depicted in Table 4 shows that the laminates were not delaminated from the panel. The significantly bonding of laminate at a shorter time without warpage and cracking gave highly encouraging results which validates the potential of this technology. From the stability study, data reveals that sample after storage as per suitable environmental conditions, the properties does not changes to maintain the consistency.

## 4. Conclusion

Based on the experimental data and observations it can be concluded that the adhesive can be used at lower temperature with a shorter time to enhance the production efficiency for lamination on composite panels instead of using long curing conventional adhesive which takes long time . The amino powder based laminating adhesive is much more efficient

than the conventional laminating adhesive in which glue joint strength gave satisfactory results. Since laminating adhesive is based on mixing of powder based solid material, hence it can be used at any quantities as required by making dispersion with water at ratio (1:1).

## 5. Acknowledgement

The authors express their gratitude to Director, IPIRTI Bangalore for his timely encouragement, guidance and advices rendered during the course of the study.

## References

[1] Avramidis G., NothnickE., Militz H., Viol W., Wolkenhauer A., "Accelerated curing of PVAc adhesive on plasma-treated wood veneers", European J. Wood Prod., Vol69, pp. 329–332, 2011.
[2] ProszykS., Krystofiak. T., "Activation energy of the solidification processes and thermal decomposition of PVAC adhesives", Chemickélisty, Vol 91 (9), pp. 759-761, 1997.
[3] Sedliacik. J., "Procesylepeniadreva, plastov a kovov.Zvolen: TechnickáuniverzitavoZvolene", pp. 220, ISBN 80-228-1500-4, 2005.
[4] EN 204-2005, Classification of Thermoplastic Wood Adhesives for Non-structural Applications.
[5] IS 4835-1979, Specification for polyvinyl acetate dispersion based adhesives for wood.
[6] Ivanov, N. A, "Polymeric Dispersion Adhesives and their ApplicationFurniture Review information", Vol 8, pp. 2 – 11 (in Russian), 1982.
[7] Qiao, L. ,Easteal, A., et al., "Improvement of the Water Resistance of Poly(vinyl acetate) Emulsion Wood Adhesive Pigment & Resin Technology", Vol29 (3), pp. 152 – 158, 2000.
[8] Witucki, G. L., "Poly(vinyl acetate) Emulsion Adhesive Containing an Alkoxysilane. European Patent Office, Bulletin No 11, 1992.
[9] Qiao, L., Easteal, A., et al., "Thermomechanical Analysis and Performance Tests of Some EPI Wood Adhesives Pigment & Resin Technology", Vol 29 (4), pp.229 – 237, 2000.
[10] Gos, B., Kucinski, S., "Modification of PolyvinylacetateGlues Wood industry", Vol 1, pp. 25 – 27 (in Polish), 1985.
[11] Trizno, V. L., Rozentuler, C. M., Mnacakanov, S. S. Plastics. Moscow, Chimija, 394 (in Russian), 1976.
[12] IS 851- 1978, Specification for synthetic resin adhesives for construction (non structural) in wood.
[13] BS EN 13353:2008, A1:2011 Solid wood panels.

## Author Profile

**Mr. S.C.Sahoo,** M.Sc (Chem.), Scientist in Indian Plywood Industries Research & Training Institute, MoEF , GoI, 2/2, Biren Roy Road (west), Sarsuna, kolkata -700061 is the **first author**. His research interests include in wood based panel products, wood adhesive, polymers and composite products from lignocellulosic materials. Total no of publications international, and national, workshop, articles is apprx.60nos.

**Mr. Amitava Sil,** M.Tech (Structures), NIT, Scientist, IPIRTI Field Station Kolkata as the **corresponding author.** His research interests include design of bamboo houses for seismic prone areas, eco-friendly composite materials, testing and evaluation wood and wood based panel products. He is also a life time member of IAWS, Institute of Engineers. He is also a principal member of council CED 13 of Bureau of Indian Standards also a member of IPPS, SEA, ISE and GPVI. He has published more than 30 research papers in national and international journals and conferences proceedings.