

An Alternative Preservative Treatment Procedure for Marine- and Shuttering-Grade Plywood in India

Aparna Kalawate

Abstract

The present research was performed with an aim to develop an alternative preservative treatment method for marine- and shuttering-grade plywood. Per Indian Standards, 12 kg/m³ of retention is required in marine- and shuttering-grade plywood, which is very difficult to achieve. The higher loadings of wood preservative chemical are being achieved only by the pressure impregnation method. The pressure impregnation method requires energy to run the equipment, skilled manpower, and sophisticated instruments; a large amount of damage takes place to the plywood during the process. Hence, an alternative to this glue-line poisoning followed by hot and cold dipping of plywood has been found suitable to achieve the 12 kg/m³ of retention without affecting the glue and plywood properties.

In the past, people had the privilege of having abundant quantities of high-quality wood from natural forests. In India, however, because of stringent standards, the supply of these wooden raw materials has become scarce. The dependence of wood industries on fast-grown plantation wood as the main source of raw materials is predicted to significantly increase in the coming years (Carle and Holmgren 2008, Food and Agriculture Organization of the United Nations 2009). Under proper conditions, wood can give centuries of service. Proper treatment of wooden material with preservative chemicals must be provided during processing and use. While applying preservative treatment it is important to select a preservative that is compatible with the adhesive. The changes of physical properties caused by the preservative treatment of wood and the chemical and physical mechanisms of these changes have been studied by numerous researchers for a long time. The effects of boron treatments on mechanical, biological, and dimensional properties of wood and wood-based materials have been widely investigated (Laks et al. 1988, Dimri and Shukla 1991, Hashim et al. 1992).

Vick (1990) investigated preservative compatibility with phenol-formaldehyde (PF) resin for 13 nonacidic water-borne preservatives using pretreated aspen veneers. Results indicated that the borate-containing preservatives tested caused poor bonds. The author found promising results for several didecylmethyl ammonium chloride formulations, sodium fluoride, and ammonium hydrogen fluoride. Prasad et al. (1994) evaluated bond strength development of chromated copper arsenate (CCA)– or ammoniacal copper zinc arsenate (ACZA)–pretreated lap shear specimens bonded with PF resin. The authors concluded that neither

CCA nor ACZA pretreatment produced negative effects on tensile strengths of plywood tested. In Japan and India, insect-resistant plywood is commercially produced incorporating chlorpyrifos in the glue line (Laks 1999). Beal (1975) reported promising results in adding insecticides to plywood to prevent termite attack.

Different types of plywood are available in India, viz., commercial-, marine-, and structural-grade plywood, etc. Among these marine and shuttering grades are specialized plywood. Marine plywood is frequently used in the construction of docks and boats, in ships, in high-humidity areas, etc., whereas structural-grade plywoods are being used in the construction of bridges, cooling towers, etc. As per Indian Standard 710 (Bureau of Indian Standards [BIS] 2010), marine- and shuttering-grade plywood shall be given treatment by pressure impregnation with a fixed type, either water-soluble or oil-based preservatives, and with a minimum retention of 12 kg/m³ in the case of CCA, copper chrome boron (CCB), or acid copper chromate (ACC) compositions. These types of plywood are required to withstand rigorous conditions like fluctuating temperature and humidity.

The author is Ex-Scientist, Indian Plywood Industries Research & Training Institute, Bangalore. The author is currently Scientist at the Zoological Survey of India, Western Regional Centre, Pune, Maharashtra (aparna_ent@yahoo.co.in). This paper was received for publication in May 2015. Article no. 15-00029.

©Forest Products Society 2016.

Forest Prod. J. 66(5/6):284–289.

doi:10.13073/FPJ-D-15-00029

The BIS has brought out specifications on preservative treatment of plywood for various conditions. However, preservative treatment is mandatory in the case of marine- and shuttering-grade plywood (Kamal et al. 2003). According to the latest estimates, there are about 5,547 wooden fishing craft in service in India. In recent reports by Kumar (2005), the current use of wood in India is estimated at 39.5 million m³, of which nearly 22.5 million m³ is being used in adverse conditions requiring protection against biodegradation. Special-grade plywood requires specialized preservative chemical and treatment methods to resist rotting in a high-moisture environment and also insect attack. In the case of commercial-grade plywood, the most common method of treating with chemicals is glue-line poisoning (GLP) to enhance its service life. The GLP process is a simple, economical, and less cumbersome process of treating plywood to make it resistant against insect attack. In this process, a small quantity (from 0.5% to 2.5%) of biocidal chemicals are incorporated into the glue mix when applying the glue to the veneers. The toxic ingredient gets diffused into the veneers from the glue line during hot pressing, making the plywood resistant to insect attack. This method does not require additional equipment. The GLP-treated plywood neither gets discolored nor hazardous to handle. Moreover, the glue line is a relatively safe location for biocidal chemicals.

The problem with the GLP method is that only the inner part of plywood is treated and the exposed surface remains untreated and obviously prone to attack by fungus in severe conditions, viz., marine and shuttering applications. Also, there are no established data on the performance of glue-line-treated plywood under actual marine condition. Despite excellent performance of glue-line-treated plywood against borers under interior and exposed terrestrial conditions, the same treatment has not been recommended to treat shuttering and marine plywood in India. It has been observed that loading 12 kg/m³ of CCA or CCB or ACC by the recommended process, i.e., pressure impregnation, is very difficult, and if this is done by the pressure impregnation process, a large amount of damage takes place to the plywood. The solution to the aforesaid problem in an environmentally benign way is one of the biggest challenges but also an opportunity for wood technologists. Penetration of preservatives can also be achieved by diffusion, a process that involves less expensive equipment but requires much more time and higher levels of stock holding, but 12 kg/m³ is difficult to achieve.

Keeping the above-mentioned facts in mind, an experiment was conducted to develop a simple and economical treatment schedule to protect the marine- and shuttering-grade plywood against wood-destroying organisms. The present study dealt with development of an alternative treatment procedure for marine- and shuttering-grade plywood.

Materials and Methods

Plywood specimens

Marine plywood has been extensively used for marine construction purposes. Because of its commercial feasibility, high economic viability, and relatively low damage in aquatic conditions, marine-grade plywood has been well established as a boat-building material. It comprises as much as 80 percent of the material of any plywood vessel.

To improve the quality of the plywood, chemical treatment is usually used.

The plywood was made in two different patterns, Patterns I and II, as listed below. The thickness of the face veneer, panel core, and glue core was 0.5, 1.6, and 1.6 mm, respectively, in both patterns. For testing mechanical properties of Pattern I, the thickness of the face veneer was kept at 1.6 mm, and the glue and panel core veneers were also 1.6 mm.

Pattern I:

Face veneer	Gurjan (<i>Dipterocarpus</i> spp.)
Glue core	Poplar (<i>Populus deltoides</i>)
Panel core	Eucalyptus (<i>Eucalyptus</i> spp.)
Glue core	Poplar (<i>P. deltoides</i>)
Panel core	Eucalyptus
Glue core	Poplar
Panel core	Eucalyptus
Glue core	Poplar
Face veneer	Gurjan

Pattern II:

Face veneer	Gurjan
Glue core	Rubber wood (<i>Hevea brasiliensis</i>)
Panel core	Rubber wood
Glue core	Rubber wood
Panel core	Rubber wood
Glue core	Rubber wood
Panel core	Rubber wood
Glue core	Rubber wood
Face veneer	Gurjan

The above-mentioned wood species were utilized for making the marine- and shuttering-grade plywood.

Conventional PF resin

Conventional PF resin was used for making the marine- and shuttering-grade plywood. The resin had the following properties: flow time, 24 ± 2 seconds at 25°C, when measured in a B-4 flow cup according to IS 3944 (BIS 2005); water tolerance, 1:12; solid content, 48 percent. PF resin was stored in an airtight container at room temperature. The pH of the resin was 9 and was not changed even after adding the copper-ethanolamine-boron (CEB) chemical to it.

Test pesticide and preservative chemical

The CEB (10%, wt/vol) chemical combination was used to treat the plywood and consisted of copper sulfate, mononethanolamine, boric acid, octanoic acid and caprylic acid, and propiconazole-based aqueous solution (Kalawate 2013).

Pot life

The effect of the addition of the chemical CEB on the pot life of the adhesive was assessed by checking the flow time of the adhesive through a flow period after 8 hours of mixing the chemical preservative in the resin. An 8-hour period was chosen with the assumption that resin should remain usable for the entire duration of normal production in the plywood manufacturing industry.

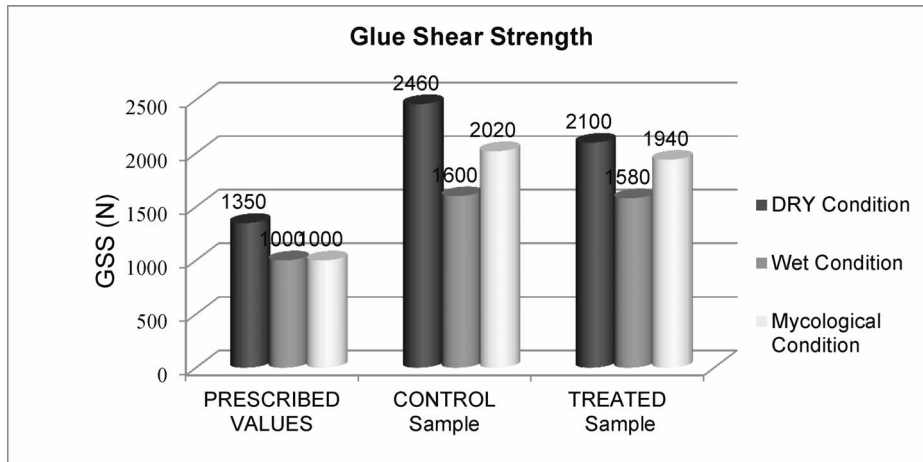


Figure 1.—Glue shear strength of copper-ethanolamine-boron-treated marine plywood.

Chemical treatment

Two types of treatment methods were adopted to treat the plywood for achieving 12 kg/m³ of retention of preservative chemical as per IS 710 (BIS 2010): surface treatment followed by glue-line treatment, and glue-line treatment followed by hot and cold dipping.

Surface treatment followed by glue-line treatment.—For the surface treatment, the face veneer was dipped in a preservative solution of CEB (10%, wt/vol) at 1 percent concentration for half an hour. The dipped veneers were then removed from the CEB solution and stacked to dry. These veneers were used as face veneer to make the plywood. For the glue-line treatment (GLP), 2 percent CEB (10%, wt/vol) was mixed with liquid PF resin (48% solid content) as glue additive on the weight of liquid PF resin. Untreated control samples were also prepared in which the preservative chemical was not added in the glue. Laboratory-scale plywood of 12-mm thickness was made using the wood species, viz., poplar, rubber wood, and the combination as described earlier. The face veneer treated by the dipping process was used in the combination. The veneers were dried to a moisture content of 6 to 8 percent and then

coated with the above adhesive mix. The glue-coated veneers were given an open assembly time of 1½ to 2 hours to attain a moisture content of 12 to 14 percent.

The veneers were then assembled and loaded into the hot press. The assembly was hot pressed at a temperature of 145°C ± 5°C with a specific pressure of 14 to 16 kg/cm². Curing time of thickness + 3 minutes was used. The hot-pressed panel was downloaded and stacked for about 24 to 48 hours for stabilization. The panels were then dimensioned to the required size for further evaluation.

Glue-line treatment followed by hot and cold dipping.—CEB (2%; 10%, wt/vol) was mixed with liquid PF resin (48% solid content) as glue additive on the weight of liquid PF resin. The glue core veneers were brush coated with the above-mentioned adhesive. Open assembly time of 1½ to 2 hours to attain a moisture content of 12 to 14 percent was given. Then the veneers were assembled and loaded into the hot press. The pressing parameters applied for pressing were as mentioned above. After hot pressing, the plywood was immediately dipped into the cold preservative solution of CEB (10%, wt/vol). The strength of the solution was 2 percent. The plywood was dipped for half an hour and then

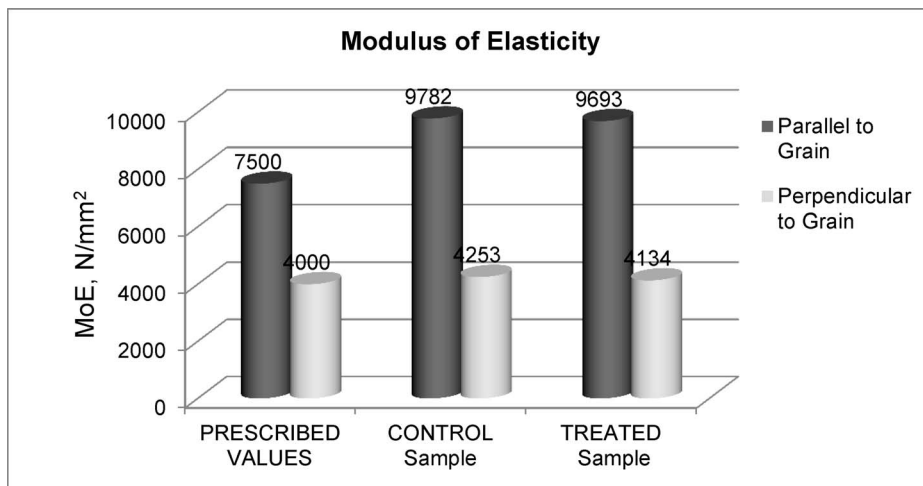


Figure 2.—Modulus of elasticity of copper-ethanolamine-boron-treated marine plywood.

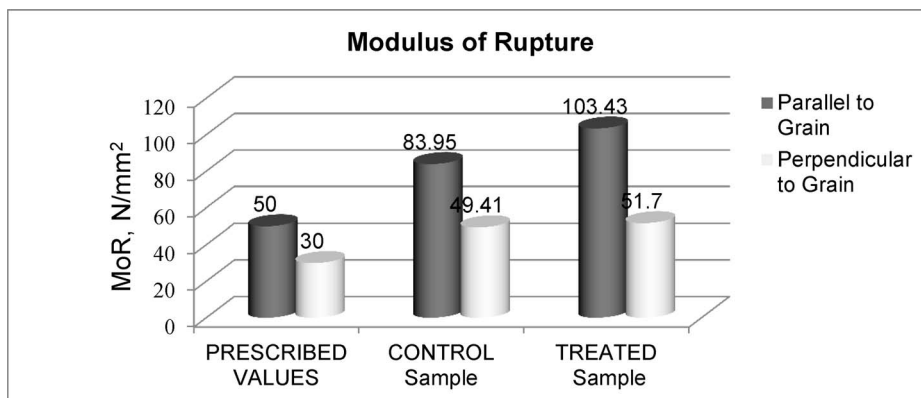


Figure 3.—Modulus of rupture of copper-ethanolamine-boron-treated marine plywood.

removed and stacked to attain the requisite moisture content. The plywood was then subjected for preservative retention analysis by the analytical method.

Bond quality

A cyclic test was carried out for the 12.5 by 12.5-cm samples as per IS:848 (BIS 2006) for boiling water proof (BWP)-grade plywood. The samples were immersed in boiling water for 8 hours and then allowed to dry at $65^{\circ}\text{C} \pm 2^{\circ}\text{C}$ for 16 hours. This process was repeated for six cycles as per IS 848 (BIS 2006). Thereafter, a knife test was done by forcibly separating the plies and the observations were recorded.

Determination of mechanical properties

The treated and untreated control plywood samples were subjected for evaluation of mechanical properties as per IS 1734 parts 4, 11, and 9 (BIS 1983). The results obtained were compared with IS:710 (BIS 2010).

Estimation of copper and boron by analytical method

The analysis of copper and boron content and retention was carried out. The method adopted for analysis was as per IS 2753 (BIS 1991). The retention was calculated for both

treatment methods (surface treatment followed by GLP and GLP followed by hot and cold dipping).

Results and Discussion

The studies on pot life of liquid PF resin after adding the CEB chemical showed that the addition of preservative chemical did not change the viscosity after 8 hours. The flow rate recorded after mixing the chemical in glue was 26 seconds in a B-6 cup. From the results it can be concluded that incorporation of preservative chemical into the glue did not affect the pot life of PF resin.

The boiling water test was carried out for surface treatment followed by glue-line-treated samples and glue-line treatment followed by hot- and cold-dipped samples to determine the effect of the chemical on bond quality of plywood. The test was performed as per IS 848 (BIS 2006). After carrying out the cyclic test for BWP plywood, the separation of plies at the edges or surface at the end of six cycles was observed. The separation of plies was nil. Plies were forcibly separated with a knife after the cyclic boiling test. On forcible separation of plies, 80 to 90 percent of wood failure was observed in the case of glue-line treatment followed by hot- and cold-dipped samples, indicating excellent bond quality. The inclusion of chemical in the glue has not affected the bond quality of the resin.

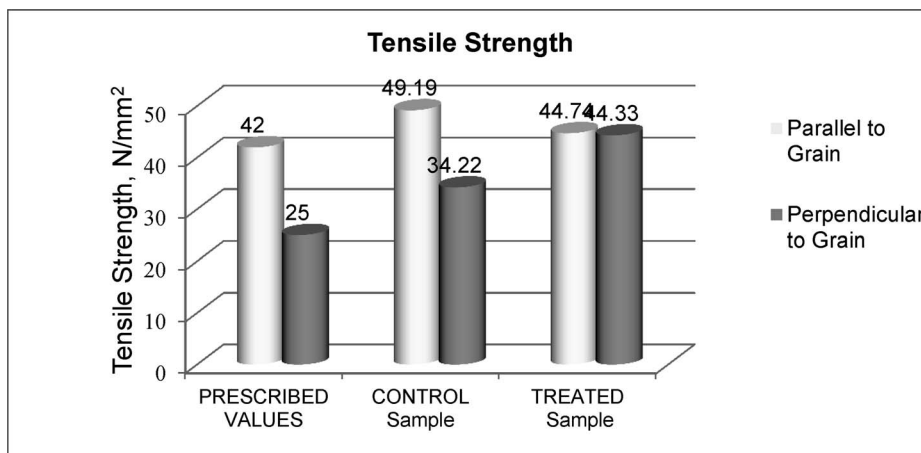


Figure 4.—Tensile strength of copper-ethanolamine-boron-treated marine plywood.

Table 1.—Analysis of variance results.

Source of variation	SS	df	MS	F	P value ^a	F crit
A. Modulus of elasticity along the grain						
Between groups	10,302.25	1	10,302.25	0.082808	0.800606	18.51282
Within groups	248,822.5	2	124,411.3			
Total	259,124.8	3				
B. Modulus of elasticity across the grain						
Between groups	15,500.25	1	15,500.25	1.1861	0.389858	18.51282
Within groups	26,136.5	2	13,068.25			
Total	41,636.75	3				
C. Modulus of rupture along the grain						
Between groups	543.123	1	543.123	10.97158	0.080317	18.51282
Within groups	99.00545	2	49.50273			
Total	642.1285	3				
D. Modulus of rupture across the grain						
Between groups	50.76563	1	50.76563	1.810631	0.310687	18.51282
Within groups	56.07505	2	28.03753			
Total	106.8407	3				
E. Tensile strength along the grain						
Between groups	4	1	4	0.587574	0.523476	18.51282
Within groups	13.6153	2	6.80765			
Total	17.6153	3				
F. Tensile strength across the grain						
Between groups	173.8442	1	173.8442	66.21061	0.0147	18.51282
Within groups	5.25125	2	2.625625			
Total	179.0955	3				

^a Significant at the 5 percent level of probability.

The glue shear strength (GSS) in dry, wet, and mycological conditions was tested as per IS 1734 (BIS 1983) and the results were compared with IS 710 (BIS 2010). The results are depicted in Figure 1. The GSS remained unaffected or negligibly affected by the loadings of CEB chemical. The mean glue adhesion strength or GSS in the dry state of CEB-treated samples was 2,100 N against 2,460 N obtained in an untreated sample. Similarly, the mean GSS of 1,580 N in the wet state was recorded in CEB-treated samples, which is on par with untreated samples (1,600 N). The mean glue shear adhesion strength in a mycological state (resistance to microorganisms) for CEB-treated samples was 1,940 N. The results conformed to IS 710 (BIS 2010). Per Indian standards, it is mandatory to perform a mycological test on plywood samples. A mycological test was performed as per IS 1734 (BIS 1983).

The effect of incorporating preservative in the glue on mechanical properties of plywood was also studied. The mean values of mechanical properties are summarized in Figures 2 through 4. The modulus of elasticity (MOE) for CEB-treated samples was recorded as 9,693 N/mm² for parallel-to-face grain and 4,134 N/mm² for perpendicular-

to-face grain (Fig. 2; Tables 1A and 1B). From Figure 3 (Tables 1C and 1D) it can be seen that the mean strength values for treated samples obtained from the static bending test (modulus of rupture [MOR]) for parallel-to-face grain was 103.43 N/mm² and for perpendicular-to-face grain was 51.7 N/mm². The untreated samples have recorded 83.95 and 49.41 N/mm² of MOR at parallel- and perpendicular-to-face grains, respectively. Similarly, the tensile strength values for untreated samples were found as 49.19 and 34.22 at parallel- and perpendicular-to-face grains respectively (Fig 4; Tables 1E and 1F). All of the above-mentioned tests conformed to IS 710 (BIS 2010). There is no statistical difference in MOR, MOE, and tensile values of treated samples when compared with untreated control samples.

The retention of copper and boron in the treated plywood was calculated as per the analytical method described in IS 2753 (BIS 1991). The total retention of copper and boron was found to be 5.12 kg/m³ in surface treatment followed by glue-line-treated samples (Table 2). This retention was achieved by surface veneer dipping in CEB chemical followed by GLP (1% CEB). In the case of GLP (2%

Table 2.—Retention of copper and boron.

Treatment method	Retention (kg/m ³)		Total retention (kg/m ³)
	Copper	Boron	
Surface treatment followed by glue-line treatment	4.58	0.54	5.12
Glue-line poisoning followed by hot and cold dipping	13.32	0.79	14.11

CEB) followed by hot and cold dipping (2% CEB) of the plywood, the retention achieved was 14.11 kg/m³ (Table 2).

Conclusions

In the present study, 12 kg/m³ of retention was achieved by treating the plywood by GLP and then following with hot and cold dipping in the solution of preservative chemical. This treatment method is simple and conforms to the requirements of strength properties as per relevant Indian specifications without increasing the capital cost as is required for pressure impregnation.

Literature Cited

- Beal, R. H. 1975. Fighting termites chemically. *Build. Off. Code Adm.* 9(9):14–17
- Bureau of Indian Standards (BIS). 1983. Indian Standard. Methods of testing for plywood. IS: 1734. BIS, New Delhi.
- Bureau of Indian Standards (BIS). 1991. Indian Standard. Methods for estimation of preservatives in treated timber and in treating solution. IS: 2753 (Part-1). BIS, New Delhi.
- Bureau of Indian Standards (BIS). 2005. Indian Standard. Method for determination of flow time by use of flow cups. IS: 3944. BIS, New Delhi.
- Bureau of Indian Standards (BIS). 2006. Indian Standard. Specification for synthetic resin adhesives for making plywood (phenolic and amino plastics). IS: 848. BIS, New Delhi.
- Bureau of Indian Standards (BIS). 2010. Indian Standard. Specification for marine-grade plywood. IS: 710. BIS, New Delhi.
- Carle, J. and P. Holmgren. 2008. Wood from planted forests: A global outlook 2005–2030. *Forest Prod. J.* 58(12):6–18.
- Dimri, M. P. and K. S. Shukla. 1991. Study on the effect of wood preservatives on the glue bond strength of plywood. *Van Vigyan* 29(1):35–39.
- Food and Agriculture Organization of the United Nations (FAO). 2009. Status of the world's forests report 2009. FAO, Rome. <ftp://ftp.fao.org/docrep/fao/011/i0350e/i0350e02a.pdf>. Accessed November 5, 2014.
- Hashim, R., D. Dickinson, R. Murphy, and J. Dinwoodie. 1992. Effect of vapour boron treatment on mechanical properties of wood based board materials. Document No. IRG/WP/3727-92. International Research Group on Wood Protection, Stockholm.
- Kalawate, A. 2013. Evaluation of copper ethanolamine boron based wood preservative to control wood destroying insects. *Mol. Entomol.* 4(2):6–12. DOI:10.5376/me.2013.04.0002
- Kamal, S. Z. M., S. Padmanabhan, and K. Mohandas. 2003. Dursban 50 WT as a glueline additive for protection of plywood against borers. IPIRTI Research Report No. 129. Indian Plywood Industries Research & Training Institute, Bangalore.
- Kumar, S. 2005. Status of wood preservation industry in India. Document No. IRG/WP 05-30388. International Research Group on Wood Protection, Stockholm.
- Laks, P. E. 1999. The past, present, and future of preservative-containing composites. In: 33rd International Particleboard/Composite Materials Symposium Proceedings, M. P. Wolcott, R. Tichy, and D. F. Bender (Eds.), Washington State University, Pullman. pp. 151–158.
- Laks, P. E., B. A. Haataja, R. D. Palardy, and R. J. Bianchini. 1988. Evaluation of adhesives for bonding borate-treated flake boards. *Forest Prod. J.* 38(11/12):23–24.
- Prasad, T. R. N., P. E. Humphrey, and J. J. Morrell. 1994. The effects of chromated copper arsenate and ammoniacal copper zinc arsenate on shear strength development of phenolic resin to Sitka spruce bonds. *Wood Fiber Sci.* 26(2):223–228.
- Vick, C. B. 1990. Adhesion of phenol-formaldehyde resin to waterborne emulsion preservatives in aspen veneer. *Forest Prod. J.* 40(11/12):25–30.