BONDING OF RADIATA PINE VENEERS TREATED WITH CCA PRESERVATIVES BY THE MOMENTARY IMMERSION METHOD

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ABSTRACT

Radiata pine (**Pinus radiata** D. Don) veneers treated with copper-chrome-arsenate preservatives by the momentary immersion method had salt retention inversely proportional to veneer thickness. In plywood made from CCA-treated veneer glued with a phenol formaldehyde resin, shear failing loads decreased with increasing levels of preservative retention, but bond strengths were acceptable up to treatment levels of 10 kg/m^3. Urea-formaldehyde resin joints failed due to pre-cure.

INTRODUCTION

Radiata pine (*Pinus radiata* D. Don) is the New Zealand species most frequently used in the production of rotary-peeled veneer, accounting for more than 60% of plywood production (New Zealand Official Yearbook, 1974). Veneer is predominantly sapwood.

Sawn timber of radiata pine is usually treated with preservatives to protect the timber from insects and fungi. The processes, levels, and penetrations are laid down by the Timber Preservation Authority (1969). In recent years, there has been some interest in the treatment of veneers to extend the markets for plywood.

Preservative Treatment of Plywood and Effect on Bonding

The methods used to impart durability to plywood can be divided into three general categories (Sorsa, 1963):

(1) preservative treatment of finished plywood;
(2) addition of preservatives to the glue;
(3) immersion or pressure treatment of green veneer.

Current Timber Preservation Authority specifications permit only (2) and (3). In the past, pressure treatment of finished plywood with CCA preservatives has been used and satisfactory treatment obtained. However, re-drying of the pressure treated plywood causes buckling of the sheets and splitting of face and back veneers. New Zealand Standard Specifications call for the addition of 0.3-0.5% w/w insecticides to the glue

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for all categories of plywood, unless the veneers have been treated with an approved preservative. The level of preservative required varies with commodity, and for exterior use (out of ground contact) the required level is 5.0-5.4 kg/m^3.

Timber which has been treated and dried for laminated timber products is planed prior to glue-spreading to provide a fresh clean surface. Stanger (1960), in strength tests on treated timber planed immediately prior to glue application, found that joint strength of radiata pine was unimpaired at treatment levels of 30 kg/m^3. In bonding veneers to make plywood no alteration is made to the veneer surface. Thomson (1962), Sorsa (1963), Choong and Attarzadeh (1968) found that copper-chrome-arsenate preservatives in veneers reduced bond strength appreciably, particularly at preservative levels of 15 kg/m^3 and greater. On the other hand, in graveyard tests Gjovik and Davidson (1972) reported that Douglas fir veneers treated with 10-14 kg/m^3 of acid-copper-chromate and made into plywood were sound after 25 years' service. Bond strength was not tested.

This report covers initial studies of the treatment of radiata pine veneer with CCA preservatives using momentary immersion methods followed by diffusion and the effect of preservative levels on bond strength of plywood made from treated veneers.

PRESERVATIVE TREATMENTS

METHODS

Freshly-peeled 1.6-mm and 4.0-mm sapwood radiata pine veneer from a veneer mill was cut to 300-mm squares. These squares were randomly sorted into groups of 10 of each thickness and the moisture content of each group was determined.

The veneers were immersed momentarily in solutions of Tanalith NCA preservative at 20°C and at concentrations of 3, 5, 7 and 10% w/w. Veneer samples were weighed, immersed in solution for 5 s (seconds), drained for 15 s, and re-weighed. Also, groups of 8-10 samples of veneer were immersed in 5% solution for 1-, 5-, 10-, and 20-min. periods. One 100 × 50-mm piece was cut from the centre of each 300-mm square for preservative retention analysis.

To assess the effect of diffusion time on preservative penetration, groups of 1.6-mm and 4.0-mm veneer were immersed momentarily in 5% solution and block stacked. Pairs of 1.6-mm veneer samples were oven-dried (105°C) at 30-min. intervals up to a total diffusion period of 3½ h. The 4.0-mm veneers were dried at 2-h intervals up to 10 h diffusion and thereafter at 4- or 8-h intervals up to 30 h. Samples of flat-sawn radiata pine 500 × 25 × (75 or 100) mm were also immersed in 5% solution and the depth of preservative penetration was observed at various intervals during diffusion.

RESULTS

Momentary immersion

The absorption of preservative solution was 0.09 kg/m^2 for 1.6-mm veneers and 0.15 kg/m^2 for 4.0-mm veneers. The retention of preservative increased almost directly with increasing solution concentration (Table 1).

Effect of longer immersion times

There is some indication that immersion times longer than a few seconds lead to greater preservative retention (Table 2). However, the time intervals chosen appear to be too short, considering the relatively high initial uptake of preservative achieved by momentary immersion (Table 1). Twenty minutes in 5% w/w solution led to significant increases in preservative retention for both 1.6-mm and 4.0-mm veneers.

TABLE 1—Preservative retention following momentary immersion

Veneer thickness mm	Solution conc. %	Moisture content %	Salt retention kg/m^3	C. of V. %
1.6	10	90	9.65	5.19
1.6	7	75	6.23	10.75
1.6	5	128	4.39	7.29
1.6	3	105	3.64	4.95
4.0	10	108	3.92	8.16
4.0	7	117	2.91	6.87
4.0	5	112	1.84	9.24
4.0	3	112	1.35	15.56

TABLE 2—Preservative retentions (kg/m^3) with increasing immersion times in 5% w/w solution

Veneer	Immersion (min.)	Moisture content %	Salt retention	C. of V.	Significance
1.6 mm	1	92	3.66	8.47	***
1.6 mm	5	95	4.74	4.43	***
1.6 mm	10	105	4.79	3.55	***
1.6 mm	20	82	8.06	3.10	***
4.0 mm	1	106	2.22	11.26	***
4.0 mm	5	101	2.55	9.80	***
4.0 mm	10	100	2.25	8.89	***
4.0 mm	20	106	3.09	4.85	**

** Significant at 5% level
*** Significant at 1% level

Diffusion of preservative

Both veneers and flat-sawn timber were examined at intervals to gauge the amount of preservative penetration. The 1.6-mm veneers were fully penetrated after 1 h diffusion, whereas the 4.0-mm veneers were not uniformly penetrated after 30 h diffusion.

Lathe checks on the loose sides of the veneers add to the total surface area and therefore to the amount of solution absorbed in momentary immersion. Lathe checks, because of their diverse shapes, also make measurements of radial penetration difficult. Hence, a better estimate of radial preservative penetration may be obtained from solid timber. For the flat-sawn 25-mm radiata pine used here the depth of penetration of preservative with increasing time was as follows:

Diffusion Time (h):	1	3	5	7	11	16	21
Depth (mm):	0.77	1.07	1.20	1.52	1.55	1.57	1.65

Fixation time

The above results indicate that fixation of some preservative elements at 20°C was completed after about 10 h diffusion. For veneers also, using rubeanic acid spot test as an indicator of preservative penetration, no further significant diffusion took place 10 h after treatment (Fig. 1).

Treatment schedules

As a tentative guide for potential users, the relationship between salt retention, solution concentration, and veneer thickness is shown in Fig. 2. This refers to average retentions whereas Timber Preservation Authority Specifications refer to minimum levels of treatment.

DISCUSSION

Variation in solution uptake with veneer thickness is probably due to irregularities in veneer surfaces caused by lathe settings and peeling temperature. In this instance, logs were peeled cold and lathe check depths were 75% of veneer thickness. Peeling hot logs generally gives a smoother surface and reduces the depth of lathe checks (Koch, 1965). A probable compensating factor with hot-peeled veneer is greater moisture loss from the hot surfaces which would allow greater preservative solution absorption.

Preservative retention is directly proportional to solution concentration but there

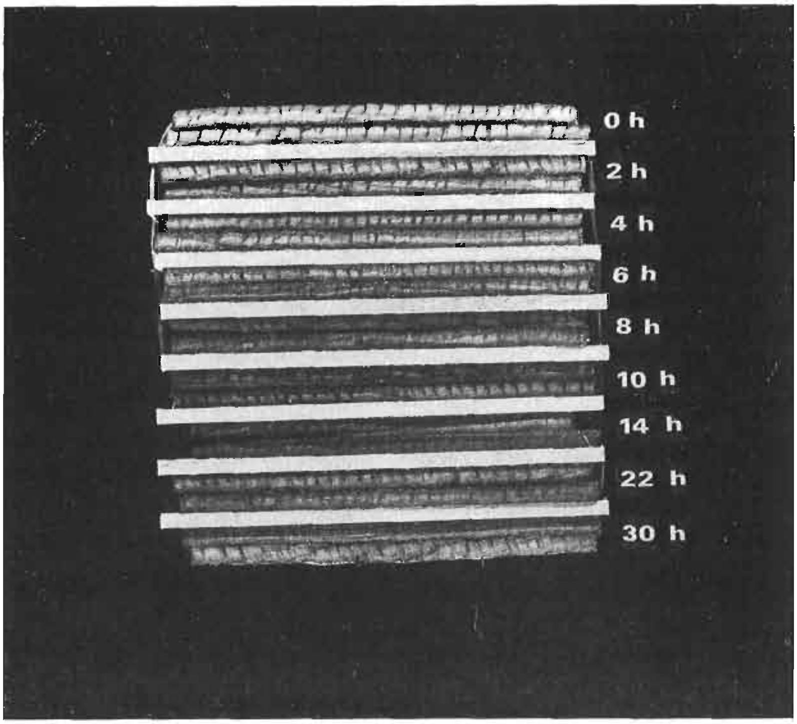

FIG. 1—Diffusion of CCA preservative (revealed by staining) into veneers with increasing time.

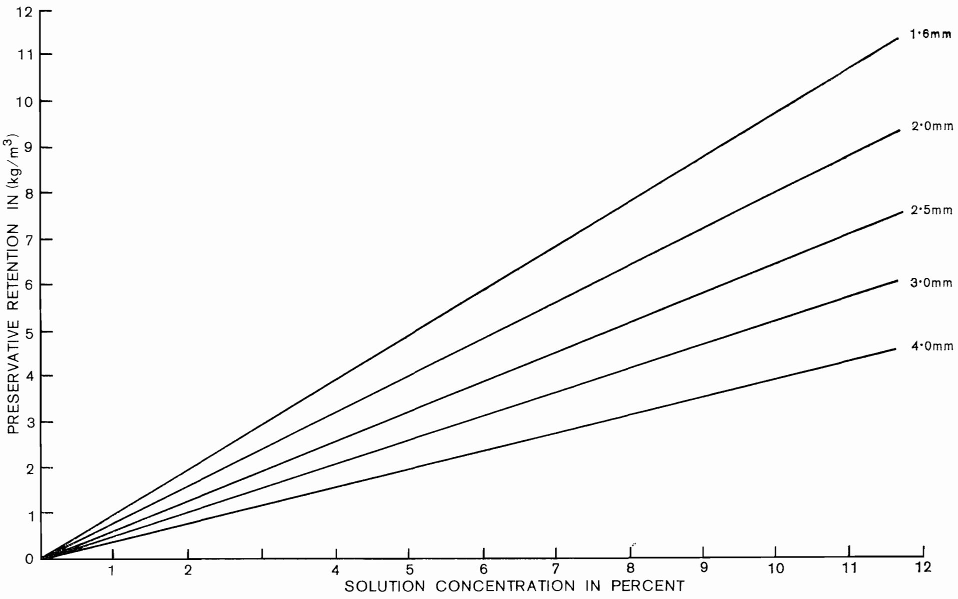

FIG. 2—Interrelationship between solution concentration, veneer thickness, and retention following momentary immersion.

were some discrepancies between expected and actual uptakes in relation to veneer thickness. Theoretically, the preservative retention for 1.6-mm veneers should be 2.5 times the retention for 4.0-mm veneers for the same solution strength. By weights after treatment the solution uptake for 1.6-mm veneers was 0.09 kg/m^2 (56.25 kg/m^3), while for 4.0-mm veneers the solution uptake was 0.15 kg/m^2 (37.5 kg/m^3) — a ratio of 1.5 : 1.0. However, the ratios from salt analysis were closer to the expected values, viz., 2.46, 2.14, 2.39 and 2.70 for the 10, 7, 5 and 3% solutions, respectively. Possibly, the evaporation rates were different for the two veneer thicknesses at the time of weighing.

For practical purposes the fixation of preservative was considered to coincide with cessation of diffusion after 10 h at 20°C. Wilson (1971) considers that Tanalith C is completely fixed after 42 h at 30°C. Fixation is temperature dependent and Dahlgren (1975) points out that, for Boliden K33 solutions, primary fixation is complete after 18 h at 45°C but may take 25 days at 5°C. The rapid fixation with higher temperature is useful for plywood manufacturers. Results for sawn timber at 20° imply minimum diffusion times for 1.6-, 2.0-, 2.5- and 3.0-mm veneers of 1, 3, 5 and 7 h, respectively. Veneer thicknesses greater than 3.0 mm would require a minimum of 20 h diffusion where maximum penetration is desirable. Veneers up to 3.0 mm thick could be treated and dried within a single shift as drying at around 150°C would ensure rapid fixation. Momentary immersion of veneer is a simple method for the treatment of radiata pine veneer and Fig 2 gives an approximation of solution concentrations required to achieve an average preservative loading for various veneer thicknesses.

BONDING OF TREATED VENEERS

Method

Consecutive 3.2-mm sheets from outer sapwood of radiata pine from a veneer mill were cut to 305-mm squares and randomised to provide three sheets of plywood for the following combinations.

Preservatives	(2)	Boliden K33, Tanalith NCA (20% solutions)
Treatment levels	(3)	10, 20, 30 kg/m^3
Resins	(2)	Phenol, urea-formaldehyde
Test methods	(2)	Open or close lathe checks.

To ensure discrete levels of treatment, all veneers were stored in water and dried in the laboratory for 45 min. prior to a 5-s immersion and a 15-s drainage period. After a 24-h diffusion period, veneers were again dried for 45 min. prior to re-immersion, to attain retention levels of 20 and 30 kg/m^3.

Veneers were dried to 5-6% m.c. and glued with a phenol formaldehyde resin plus 15% walnut shell flour at a spread of 344 g/m^2 per double glue line. Press temperature was 143°C and pressure 1240 kPa for 7.5 min. Shear tests were carried out according to ASTM D-906-64 to open or close lathe checks after samples were soaked in water at 20°C for 16-24 h. Chisel tests were carried out on three pieces of plywood for each preservative level and evaluated according to scales in BS 1455 (1963).

RESULTS

Solution retentions

The average solution retentions after immersion and drainage were 126 g/m^2 (76-175 g/m^2) for Boliden K33, and 135 g/m^2 (82-178 g/m^2) for Tanalith NCA.

Preservative retention in veneers

Twelve 75 × 75-mm sections of treated veneer analysed for each level of treatment gave the results (% w/w) shown in Table 3.

Distribution of preservatives was analysed within five pieces of veneer for each treatment level. Pieces 1 mm thick were removed by chisel from the tight and the loose sides to leave a core piece slightly thicker than 1 mm. Preservative retentions were lowest in the cores and highest on the loose sides of the veneers. For example,

TABLE 3—Active elements (% o.d. wood) and equivalents in terms of retentions of commercial salts (kg/m^3) for different treatment levels

Level (kg/m^3)	As	Boliden K33 Cu	Cr	Total	Equivalent
10	0.50	0.26	0.30	1.06	10
20	1.02	0.54	0.66	2.22	21
30	1.30	0.69	0.89	2.88	27
		Tanalith NCA			
10	0.46	0.24	0.28	0.98	10
20	0.94	0.48	0.61	2.03	20
30	1.46	0.75	0.91	3.12	31

preservative distribution within veneers for a retention of 10 kg/m^3 for Tanalith NCA (average of 5 samples), was:

	As	Cu	Cr	Total %
Tight side	0.49	0.23	0.32	1.04
Core	0.19	0.13	0.14	0.46
Loose side	0.68	0.30	0.40	1.38

For higher preservative retentions a similar pattern was apparent for both preservatives. The higher retentions on the loose side are attributable to the greater surface area provided by lathe checks.

Plywood Shear Tests

Twelve test pieces were pulled to close lathe checks and 12 were pulled to open lathe checks for each preservative level.

Analysis of variance for the shear tests showed (Table 4):

(1) no difference between preservatives at comparable levels of treatment;
(2) a difference between salt retentions (levels) significant at 0.1%;
(3) within treatment levels, a difference between test methods significant at 0.1%;
(4) that when closing lathe checks there was a difference between treatment levels significant at 0.1%;
(5) that when opening lathe checks there was no significant difference between treatment levels.

TABLE 4—Analysis of Variance

Source	DF	SS	MS	F	
Between preservatives	1	90	90	<1.00	NS
Between levels	2	3 869 951	1 934 975	41.10	***
Preservative × levels	2	8 002	4 001	<1.00	NS
Within sheets P × L	12	985 988	82 157	1.75	NS
Within sheets, test methods	18	33 694 356	1 871 908	39.80	***
Residual	108	5 082 968	47 064		
Total	143	43 641 257			

In Fig. 3 the line $Y = 2081 - 26.4X$ describes the decrease in shear failing loads with increasing preservative level when the two test methods are combined. Wettability tests were carried out on two replicates of Boliden K33 for each level, according to the method of Bodig (1962). The line $Y = 926 - 13.8X$ shows that wettability as measured by capillary rise of distilled water in tubes of wood flour, decreases with increasing preservative level.

Bond quality

Results of chisel tests were as follows:

Untreated veneers	bond quality	6.5
Veneers at 10 kg/m^3		5.8
Veneers at 20 kg/m^3		5.7
Veneers at 30 kg/m^3		5.2

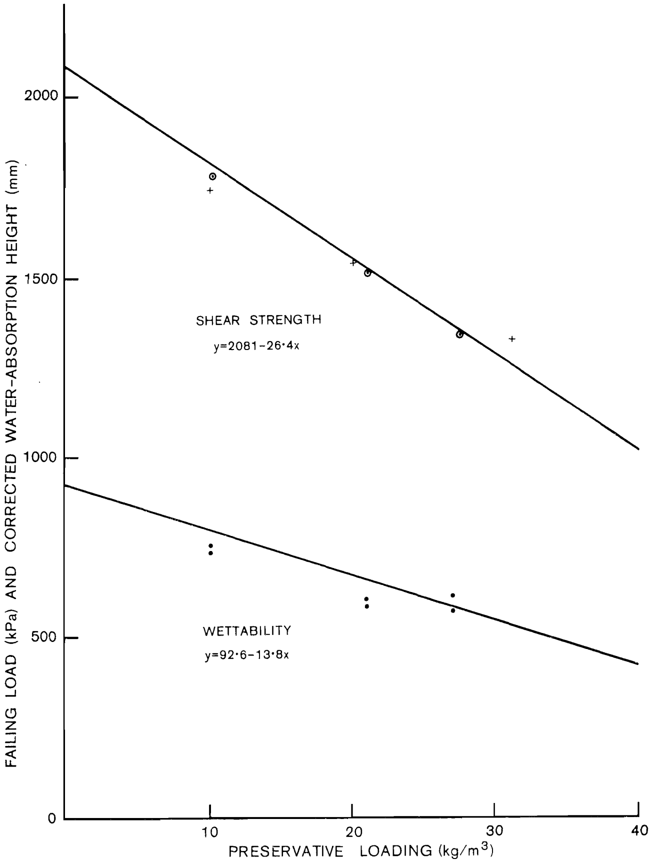

FIG. 3—Shear strength (circles, Tanalith NCA; crosses, Boliden K33) and wettability in relation to preservative loading.

According to BS 1455, "no glue-line shall have a bond quality of less than two and the average of all those tested shall be not less than five". All treatment levels thus pass the criterion for bond quality, though the sample size is small.

Shear block tests

One block of veneers was made up with veneer grain parallel, 38 mm thick, for both untreated veneer and veneer treated to a level of 20 kg/m^3. The two centre-line veneers were laid up tight side to tight side and 16 samples were cut from each block for shear tests according to ASTM D1037. Shear strengths were respectively 8940 and 9750 kPa for untreated and treated veneers. There was no significant difference between untreated and treated veneer shear strengths whereas the anticipated result was that the treated veneers would show reduced shear strength values.

DISCUSSION

The presence of copper-chrome-arsenate in veneers treated by the momentary immersion method to levels greater than 10 kg/m^3 has a marked effect on the shear strength of plywood joints. The cause of reduced shear strength is probably the changed veneer surface which affects the glue viscosity and reduces available hydroxyl groups for hydrogen bonds. The urea formaldehyde samples were discarded because of pre-cure and numerous test-pieces fell apart during the soak in cold water.

The distribution of preservative across the thickness of the veneer indicates the possibility that surface preservative loadings, which affect bond strength, are much higher than indicated by cutting 1-mm strips from treated veneers. Examination of core veneers from test pieces showed that untreated veneers had some lathe checks penetrated by glue whereas none of the treated veneer had any lathe checks penetrated. This factor could account for the uniformly low shear strengths of samples of treated plywood when lathe checks were pulled open, 1050 compared with 1900 kPa for untreated plywood.

The momentary immersion of green veneers is a simple method of treatment in the laboratory at least with small pieces of veneer. Larger sheets in factory production are more difficult to handle and veneer breakage may occur due to extra handling of individual sheets.

Timber Preservation Authority specifications on veneer treatment may require some revision as it is plain from Fig. 1 that adequate retention levels may be achieved by momentary immersion but there is little penetration without a diffusion period.

CONCLUSIONS

(1) Momentary immersion of green radiata pine veneers in copper-chrome-arsenate preservatives is simple and adjustment of solution concentration allows various preservative levels to be achieved.

(2) Some diffusion time is required for preservatives to penetrate veneers.

(3) Bond strength of veneers treated by the momentary immersion method is reduced with increasing preservative retentions. Although joints of satisfactory strength appear to be attainable at preservative levels of 10 kg/m^3, subsequent tests on larger sheets have shown greater variability, with some unacceptable bond quality, at this level.

REFERENCES

BS 1455, 1963: Specification for plywood manufactured from tropical hardwoods. **British Standards Institution.**

BODIG, J. 1962: Wettability related to gluabilities of five Philippine mahoganies. **For. Prod. J. 12(6):** 265-70.

CHOONG, E. T. and ATTARZADEH, A. 1968: Gluability of non-pressure treated southern pine veneer. **Louisiana State University, Agricultural Experimental Station Release, Note 18.**

DAHLGREN, S. E. 1975: Fixation of Cu-Cr-As based wood preservatives. **Swedish Wood Preservation Institute, Report 113.**

GJOVIK, L. and DAVIDSON, H. L. 1972: Comparison of wood preservatives in stake tests. **U.S. For. Serv. Res. Note FPL-02.**

KOCH, P. 1965: Maximising wet shear strength. **For. Prod. J. 15(11):** 463-5.

New Zealand Official Yearbook, 1974. Department of Statistics, Wellington.

SORSA, B. 1963: The preservation of plywood against decay and insect damage. **Pap. ja Puu 11:** 583-92.

STANGER, A. G. 1960: The influence of certain water-borne preservatives on the bond strengths of glued joints in tawa, the sapwoods of rimu and matai, and the heartwood of radiata pine. **N.Z. For. Serv., For. Res. Inst., For. Prod. Rep. No. 62** (unpubl.).

THOMSON, W. S. 1962: Gluing characteristics of treated sweet-gum veneer. **For. Prod. J. 12(9):** 431-6.

TIMBER PRESERVATION AUTHORITY (1969): "Timber Preservation in New Zealand: Specifications." New Zealand Timber Preservation Authority, Wellington.

WILSON, A. 1971: The effects of temperature, solution strength and timber species on the rate of fixation of a copper-chrome-arsenate wood preservative. **J. Inst. Wood Sci. 5:** 36-40.