

Rubber Solution Adhesives for Wood-to-Wood Bonding

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ABSTRACT: Rubber solutions were prepared and used for bonding wood pieces. The effect of the variation of chlorinated natural rubber (CNR) and phenolformaldehyde (PF) resin in the adhesive solutions on lap shear strength was determined. Natural rubber and neoprene-based adhesive solutions were compared for their lap shear strength. The storage stability of the adhesive prepared was determined. The change in lap shear strength before and after being placed in cold water, hot water, acid, and alkali was tested. The bonding character of these adhesives was compared with different commercially available solution adhesives. The room-temperature aging resistance of wood joints was also determined. In all the studies, the adhesive prepared in the laboratory was found to be superior compared to the commercial adhesives. © 1998 John Wiley & Sons, Inc. *J Appl Polym Sci* 68: 1185–1189, 1998

Key words: wood-to-wood bonding; lap shear strength; water resistance; solution adhesives

INTRODUCTION

The performance or behavior of a wood-adhesive system is dependent on a wide range of variables, such as surface smoothness of the wood substrate, pH, presence of extractives, and amount of debris present, which are related to the environment such as to the level and rate of change in both temperature and relative humidity.¹ The bonding mechanism of wood adhesives is due to the complex chemistry of the substrates.² In some cases, strong forces of covalent bonding and other weaker forces such as van der Waals forces and hydrogen bonding will operate or mechanical interlocking may occur.^{3,4}

Adhesives based on urea formaldehyde (UF) and phenolformaldehyde (PF) are the major adhesives used for bonding wood.^{5–7} But these adhesives are very sensitive to hydrolysis^{8,9} and stress scission.¹⁰ The UF and PF adhesives produce

health hazards due to formaldehyde release.¹¹ Iso-cyanate-type adhesives have disadvantages such as shorter pot life, higher cost, limited durability, and lack of tack.¹² In this article, we report the preparation and evaluation of the properties of solution-based wood adhesives based on chloroprene rubber and natural rubber.

EXPERIMENTAL

Materials

Neoprene (CR) AD Type ML(1 + 4) 100°C 45 was supplied by E. I. DuPont, Akron, OH. Neoprene (CR) W Type ML(1 + 4) 100°C 45 was also supplied by E. I. DuPont. Natural rubber (NR) ISNR 5 ML(1 + 4) 100°C 82 was supplied by RRII Kottayam India. MgO, Accinox TQ, Wood rosin, etc., were commercial grade. PF resin was supplied by Bakelite Hylam, and the toluene used was commercial grade. Chlorinated natural rubber (CNR) was prepared in our laboratory by passing chlorine gas into an NR solution (3%) for 8 h. The chlorine content of the sample was estimated vol-

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Table I Formulations of Rubber Compounds

Ingredients	Formulations		
Neoprene AD	100	0	0
Neoprene W	0	100	0
NR	0	0	100
MgO	5	5	2
Wood rosin	10	10	20
PF resin	20	20	20
Accinox TQ	1	1	1

umetrically and found to be 65%. Wood pieces were a type of soft wood (Accesia) of carpentry grade.

Adhesives

The following were used: A, adhesive prepared in the laboratory; B, Dunlop adhesive supplied by Dunlop India Ltd, Calcutta; C, superbond adhesive supplied by Superchem MIDC, Thane; D, dentrite adhesive supplied by Chandra's Chemicals Enterprises, Calcutta; and E, Fevibond adhesive supplied by Pidilite Industries Ltd., Bombay.

Adhesive Preparation

Rubber compounds were prepared on a laboratory two-roll mill (6 × 12 in.) as per the formulations in Table I. The compound was sheeted out from the mill and cut into small pieces and dissolved in toluene to make a 40% solution. The solution was kept for 2 days and then stirred vigorously using a high-speed mechanical stirrer. The solution become uniform and was then kept in airtight bottles.

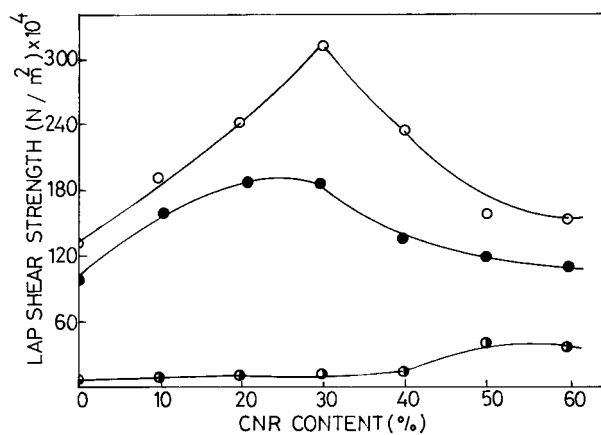


Figure 1 Variation of lap shear strength with CNR content: (○) neoprene AD; (●) neoprene W; (●) NR.

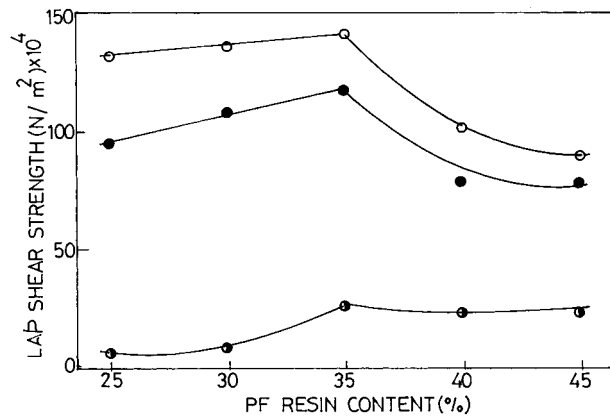


Figure 2 Variations of lap shear strength with PF resin content: (○) neoprene AD; (●) neoprene W; (●) NR.

Wood Preparation

Wood pieces were cut into 25 × 300 × 3-mm strips and polished using sandpaper grit no. 60 (250 μm).

Wood Bonding and Testing

Using a brush, the adhesive solution was applied on both pieces for a thickness of 0.1 mm and a lap joined for a 25 × 30-mm area of overlap. A load of about 1 kg was placed over the joint and kept for 24 h. After that, the wood joints were kept at room temperature (30°C) and at a relative humidity (RH) of 50 ± 5 for 7 days. These wood joints were tested for lap shear strength on a Zwick UTM Model 1445 as per ASTM D 906-49 (72).

Effect of CNR and PF Resin

The effect of CNR on lap joint strength was measured by varying its amount from 10 to 60 phr in

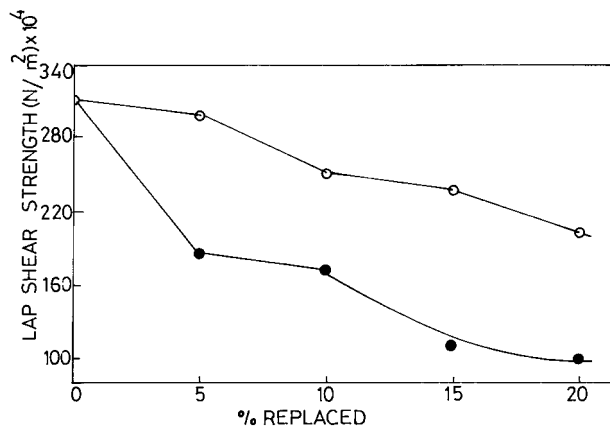


Figure 3 Variation of lap shear strength when the amount of neoprene AD is replaced by neoprene W and NR: (○) neoprene W; (●) NR.

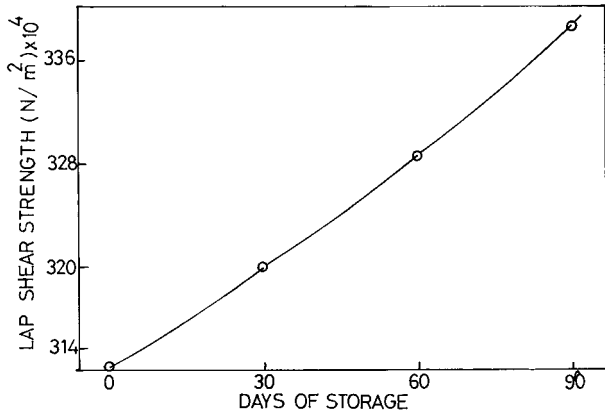


Figure 4 Effect of shelf life of adhesive on lap shear strength.

the formulations in Table I. Similarly, the amount of PF resin was varied from 20 to 45 parts and the change in lap shear strength was determined.

Replacing CR AD Type with W-Type CR and NR

Adhesive-grade neoprene was partially replaced by W-type neoprene and lap shear strength was determined. Similarly, neoprene AD was replaced by NR and its effect on lap shear strength was studied.

Shelf Life of the Adhesive

The neoprene-based adhesive was kept for 2 months and lap shear strength was determined at equal intervals of time to determine the shelf life of the adhesive.

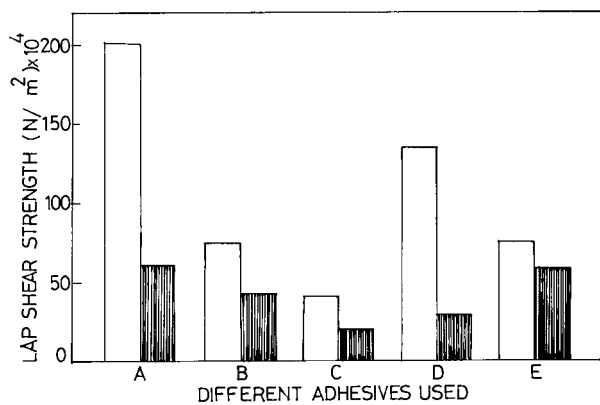


Figure 5 Lap shear strength of different adhesives: (empty column) before soaking; (lined column) after soaking in cold water.

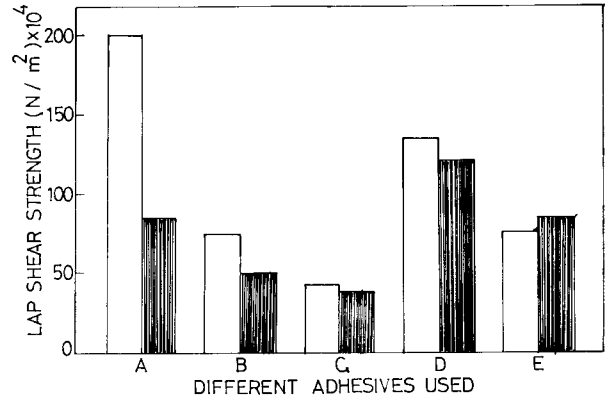


Figure 6 Lap shear strength of different adhesives: (empty column) before soaking; (lined column) after soaking in hot water.

Comparison with Commercial Adhesives

The properties of the adhesive having the maximum bond strength were compared with some commercial adhesives. The solid content of the adhesive prepared in the laboratory was reduced from 40 to 25% by adding more solvent to the solution and stirring in order to compare with the commercial adhesives.

Resistance of the Wood Joints

Wood pieces bonded with the adhesive prepared in our laboratory and some of the commercial adhesives were kept in cold water (30°C) for 1 day. Then, they were taken out, dried at room temperature (30°C and RH 50 ± 5) for 1 day and lap shear strength was determined. Similarly, bonded pieces were immersed in hot water at 100°C and in acid (pH 2) and alkali (pH 10), both at 80°C

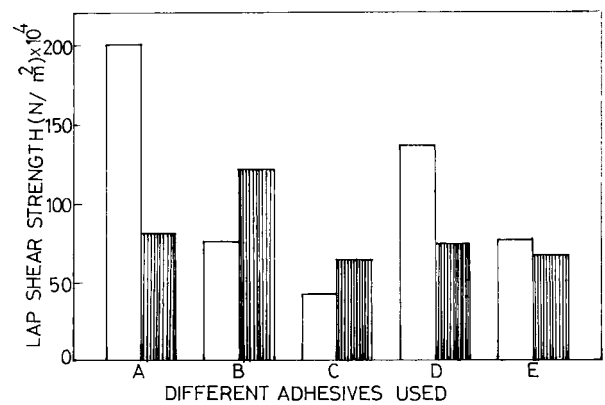


Figure 7 Lap shear strength of different adhesives: (empty column) before soaking; (lined column) after soaking in acid.

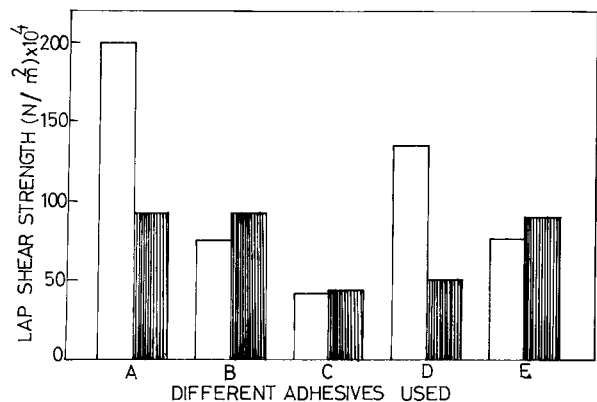


Figure 8 Lap shear strength of different adhesives: (empty column) before soaking; (lined column) after soaking in alkali.

for 1 h. After that, lap shear strength was determined as described earlier. The bonded wood pieces were kept for 1 month at room temperature and lap shear strength was measured; thus, the aging resistance of the wood bonds was determined.

Direct Shear Method

Wood pieces were cut into a $60 \times 60 \times 20$ -mm size, dried, and polished using emery paper no. 60 ($250 \mu\text{m}$). Adhesives were applied on both pieces to the full area to a thickness 0.1 mm. A load of 1 kg was placed over it for 1 day and then it was kept for 7 days at room temperature. These wood joints were tested on a direct shear machine and the load required for shearing one piece over the other was obtained and this result was expressed as N/m^2 by considering the area of the wood pieces. The test was conducted as per IS 2720 (1972) part XIII.

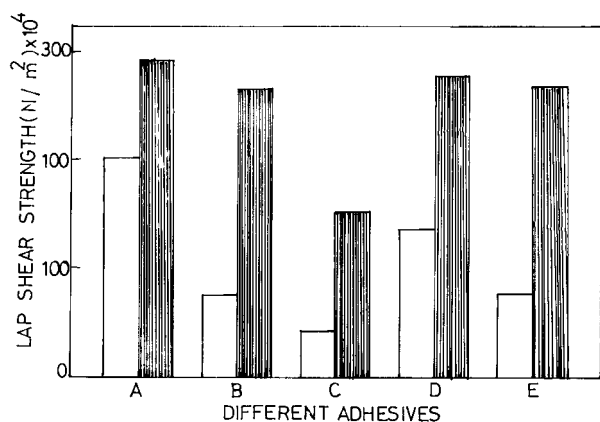


Figure 9 Lap shear strength of different adhesives: (empty column) before soaking; (lined column) after room-temperature aging.

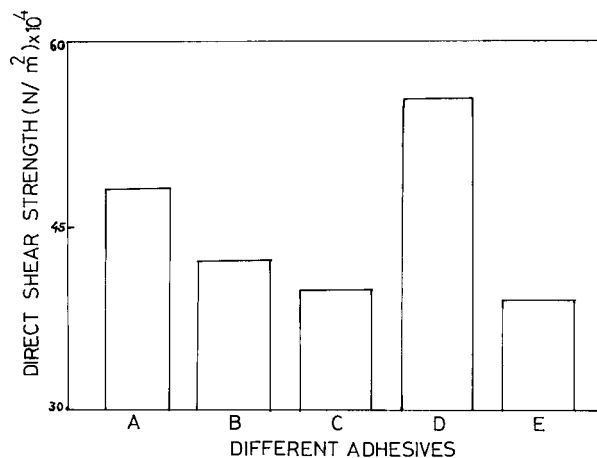


Figure 10 Direct shear strength of different adhesives.

RESULTS AND DISCUSSION

Figure 1 shows the effect of the variation of CNR in the adhesive solutions on the lap shear strength. Lap shear strength increases as the amount of CNR increases, reaches a maximum, and then decreases. In the case of the NR solution, the highest strength obtained was at 50 phr CNR. There is an optimum concentration of CNR which can give maximum bond strength. At higher concentrations, CNR may form the continuous phase and the bond joint loses its elastomeric nature. There is no visible phase separation. The solution is homogeneous in nature.

In the case of the W-type CR-based adhesive, the increase in lap shear strength reached a maximum and then decreased, similar to that of the neoprene AD-type adhesive. But the W-type neoprene-based adhesive shows lower lap shear strength relative to neoprene AD, which may be due to the slower crystallizing nature of neoprene W.¹³ The NR-based adhesive shows only a marginal increase in lap shear strength even at 50 phr CNR, which may be due to the low compatibility of polar CNR and nonpolar NR.

In Figure 2, the effect of variation of the PF resin in the adhesive solutions on lap shear strength is shown. Lap shear strength increases initially and then decreases, which may be due to the phase change¹⁴ in the solutions when the PF resin becomes the continuous phase and the lap shear strength decreases. CR AD type, CR W type, and NR show the same trend when the amount of PF resin was varied.

The decrease in lap shear strength when part of the adhesive-grade CR was replaced by W-type CR is shown in Figure 3. The CR AD type crystal-

lizes much faster than does the CR W type¹⁴ and, so, the W-type CR has lower strength compared to the CR AD type. This figure also shows that the decrease in lap shear strength was more pronounced when adhesive-grade CR was replaced by NR. This may be due to the nonpolar nature of NR. Polar adhesives make the bond strength higher on polar adherends like wood.

Figure 4 shows the variation of lap shear strength of the adhesive with days of storage. The joint strength was found to increase with the length of storage of the adhesive solution, which may be due to the increase in solid content due to the slight evaporation of the solvent and partial precuring of the solution during storage.

The water resistance of the joints prepared with the commercial adhesives and the adhesive prepared in the laboratory is shown in Figure 5. Compared to commercial adhesives, the water resistance is found to be superior for the adhesive prepared in the laboratory.

Figure 6 shows the hot water resistance of the adhesives. There is a slight increase in bond strength for some of the joints, which may be due to the slight crosslinking of the adhesive film in boiling water. The adhesive prepared in the laboratory was found to be comparable to that of commercial adhesives.

The acid and alkali resistance of the adhesives are shown in Figures 7 and 8, respectively. The adhesive prepared in the laboratory gave better resistance compared to the other adhesives.

Figure 9 shows the results of room-temperature aging of the wood joints for 1 month. The results show an increase in joint strength, which may be due to the crosslinking of the adhesive film during storage.

The direct shear strength of different adhesives is shown in Figure 10. The adhesive prepared in the laboratory shows better direct shear strength compared to the other commercial adhesives.

CONCLUSIONS

1. The adhesive solution prepared with the neoprene AD type was found to give superior

bonding to that of commercial wood adhesives.

2. The optimum amount of CNR (30%) and PF resin (35%) improves the adhesive strength of neoprene-based adhesives.
3. The neoprene AD-based adhesive solution was found to have better resistance to cold water, hot water, acids, and alkalis compared to some of the commercial adhesives.
4. The shelf life of the adhesive was found to be comparable to that of the commercial adhesives.

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REFERENCES

1. A. Pizzi, *Wood Adhesives Chemistry and Technology*, 1st ed., Marcel Dekker, New York, 1983, p. 12.
2. V. C. Charles, *Hand Book of Adhesive Bonding*, 1st ed., McGraw-Hill, New York, 1973, p. 17.5.
3. I. Skeist, *Hand Book of Adhesives*, 1st ed., Van Nostrand, New York, 1962, p. 669.
4. D. E. Packham, *Hand Book of Adhesions*, 1st ed., Longmann, London, 1992, p. 407.
5. J. T. White, *Adhes. Age*, **July**, 19 (1981).
6. G. E. Myres, *Adhes. Age*, **Oct.**, 31 (1988).
7. R. O. Ebewe, B. H. River, and G. E. Myers, *Adhes. Age*, **Dec.**, 23 (1993).
8. G. G. Freeman and S. Kreibich, *Forest Prod. J.*, **18**, 39 (1968).
9. G. E. Tronghton and S. Chow, *J. Inst. Wood. Sci.*, **21**, 29 (1968).
10. J. M. Dinwoodie, *J. Inst. Wood Sci.*, **8**(2): 59 (1978).
11. J. B. Wilson, *Adhes. Age*, **May**, 41 (1981).
12. H. Pagel and E. R. Luckman, *Adhes. Age*, **Oct.**, 34 (1981).
13. *The Vanderbilt Rubber Hand Book*, 13th ed, R. T. Vanderbilt, Norwalk, 1993, p. 160.
14. L. H. Lee, Ed., *Adhesive Chemistry: Development and Trends*, Plenum Press, New York, 1984, p. 693.