PRESSURE IMPREGNATION OF HARDWOODS: TREATMENT SCHEDULES FOR EASY-TO-TREAT INDIAN HARDWOODS

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ABSTRACT

On the basis of penetration pattern of inorganic chemicals in the wood microstructure, penetration indices for different wood species were developed. Pressure treatment schedules have been suggested on the basis of penetration index and gross absorptions obtained with CCA salts in treatability class 'a' and 'b' hardwoods. Mango and kadam earlier placed under the 'a' treatability class have been transferred to the 'b' treatability class because of poor penetration of the fibers in these species. Similarly, white bombwe earlier classified under class 'b' has been shifted to class 'a' because of its high penetration index.

Keywords: Hardwoods, CCA, penetration indices, treatability, pressure treatment schedules.

INTRODUCTION

Increasing industrial demand for timber and the depletion of durable wood species in India have encouraged utilization of many nondurable species which require protection against biodegradation. Such protection is usually carried out by pressure-impregnating toxic chemicals. Although most commercially available indigenous wood species have been tested for treatability, specific pressure treatment schedules have not been developed to achieve the retentions and penetration required by the Indian Standards (Anon. 1982). The various wood species have been broadly grouped into five treatability classes, a to e, according to ease of preservative impregnation. An earlier paper reported the pressure treatment schedules for five easy-to-treat hardwoods listed under the 'a' treatability class (Kumar and Sharma 1982). Those recommendations were based on the gross absorption of preservatives obtained in end-sealed specimens measuring 305 × 38 × 38 mm.

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It has been observed that many hardwoods and bamboos, although treated to the required preservative retentions and penetration, fail prematurely. Early failure of hardwoods has been attributed to soft rot attack (Aston and Watson 1976; Greaves 1977). This failure probably results from poor preservative penetration of the various cells, especially the fibers that constitute a major volume of hardwoods (Dickinson and Sorkhoh 1976). Retention recommendations generally ignore this microdistribution aspect. This paper reports on treatment schedules developed for seven wood species listed under class 'a' and 'b' treatability, including reanalysis of the previously reported data for four class 'a' treatability wood species (Kumar and Sharma 1982). A primary consideration in undertaking this study was to improve the treatment schedules in the light of suggestions that penetration of different cell types plays an important role in the performance of treated timbers (Dickinson and Sorkhoh 1976).

MATERIALS AND METHODS

The wood species used for the present study were bahera (*Terminalia bellerica* Roxb.), gurjan (*Dipterocarpus indicus* Bedd.), haldu (*Adina cordifolia* Hook F.), kadam (*Anthocephalus chinesis* Mig.), kusum (*Schleichera oleosa* Willd.), mango (*Mangifera indica* Linn.) and white bombwe (*Terminalia procera* Roxb.). Defect-free dowel specimens, 20 mm in diameter and 25 mm long used earlier for gas permeability measurements (Kumar and Chaubey 1987), and sticks (305 × 38 × 38 mm) obtained from the heartwood of each species were tested for this study. The ends of the sticks were coated with a synthetic resin to prevent end penetration.

The dowel specimens were conditioned to 9% moisture content, while the sticks were conditioned to 12% moisture content prior to treatment. All specimens were accurately weighed (0.1 g) prior to treatment. Treatments were carried out by submerging the specimens in water/preservative solution in small plastic trays in a pressure treatment cylinder. Dowel specimens were treated with water under pressure varying from 100 kpa (1 kg/cm^2) to 690 kpa (7 kg/cm^2) for 20 minutes. This was done to get some idea about water retention and to correlate these data to solution retentions in larger specimens. Fifty dowel specimens were used for each treatment condition. A four percent CCA solution, salt formulation containing arsenic pentoxide, copper sulphate, and sodium dichromate at a ratio of 1:3:4 conforming to Indian Standard 10013 (Anon. 1981) was used for treating the sticks. Stick specimens were treated using pressures varying from 345 kpa (3.5 kg/cm^2) to 1,205 kpa (12.25 kg/cm^2) for periods of 30 minutes to 2 hours. Ten stick specimens were used for each treatment. After treatment, the specimens were wiped to remove any excess liquid adhering to the surface and were then weighed to determine preservative absorptions. Swollen dimensions of each specimen were measured with a vernier caliper to obtain wood volume. Specific gravity (Sg, oven-dry weight/green volume basis) was used to compute the air voids (V_{air}) using the following formula (Stamm 1964).

$$V_{air} = [1 - Sg/1.53]100$$

Preservative retention was calculated in terms of percentage of void volume occupied by water/chemical solution as well as dry salt weight per unit volume basis.

Since all the species treat well, complete penetration was obtained with all the

TABLE 1. *Comparison of available voids and absorptions in permeability and treatability specimens.*

	Permeability specimens				Treatability specimens			
Wood species	Sg	Pressure (kpa)	Voids (%)	Voids filled (%)	Sg	Pressure (kpa)	Voids (%)	Voids filled (%)
Bahera	0.67	690	35	42	0.65	690	58	39
Gurjan	0.60	690	61	25	0.62	690	60	22
Haldu	0.54	345	65	35	0.55	345	64	31
Kadam	0.53	345	66	48	0.43	345	72	30
Kusum	0.76	345	50	29	0.74	345	52	29
Mango	0.53	345	66	29	0.64	345	58	16
Mango	0.53	690	66	38	0.64	690	58	24
White bombwe	0.53	690	65	42	0.47	690	69	59

specimens as indicated by Chrome Azurol indicator (AWPA 1987). The degree of preservative penetration at the microscopic level was, therefore, estimated from the percentage of cells penetrated with silver nitrate stain (Chaubey et al. 1986). This information was used to compute the penetration index of each species as follows.

Different weight factors were assigned for various cell types, depending upon their importance.

These factors were:

a. Vessels constitute the main flow paths in hardwoods and fibers constitute a major part of the wood volume and their deterioration will cause strength failure. Each was assigned a weight factor of three.
b. Rays play a significant role in lateral transport of the preservative solution and were therefore assigned a weight factor of two.
c. Parenchyma were assigned a weight factor of one.

The composite penetration index was calculated as below:

$$\text{Penetration index} = \sum_{i=1}^{4} W_i P_i / 27$$

where W is the weight factor assigned as above and P is the degree of penetration of each cell type assigned as 'zero' (less than 10% penetration), 'one' (between 10–30% penetration, 'two' (30–60% penetration) and 'three' (more than 60% penetration). A higher penetration index (Max. 1.00) indicated a more uniform preservative distribution in all the structural elements.

RESULTS AND DISCUSSION

It is generally believed that lumber treatability may have no relation to permeability or treatability data obtained on small samples, since flow rates decrease nonlinearly with increased specimen length (Hudson and Shelton 1969). An earlier study revealed that within the same wood species, treatability data for small dowel samples correlated well with gas permeability (Chaubey et al. 1987). Although the treating periods for the small dowel specimens differed from the large stick specimens treated after end-sealing, the percentage of voids filled was similar. Only kadam and mango absorptions in larger specimens were lower than those obtained in dowel specimens using similar pressure conditions. The similarity in

TABLE 2. *Penetration index for various hardwoods studied.*

Wood species	Treatability class*	Tissue penetrated	Degree of penetration**	Penetration factor	Penetration index
Bahera	b	Vessels	+	1 × 3 = 3	
		Fibers	+	1 × 3 = 3	
		Rays	+	1 × 2 = 2	
		Parenchyma	+	1 × 1 = 1	0.33
Gurjan	b	Vessels	–	–	
		Fibers	–	–	
		Rays	–	–	
		Parenchyma	–	–	–
Haldu	a	Vessels	+++	3 × 3 = 9	
		Fibers	+++	3 × 3 = 9	
		Rays	+++	3 × 2 = 6	
		Parenchyma	+++	3 × 1 = 3	1.00
Kadam	a (b)	Vessels	++	2 × 3 = 6	
		Fibers	++	2 × 3 = 6	
		Rays	++	2 × 2 = 4	
		Parenchyma	++	2 × 1 = 2	0.66
Kusum	a	Vessels	+++	3 × 3 = 9	
		Fibers	+++	3 × 3 = 9	
		Rays	+++	3 × 2 = 6	
		Parenchyma	+++	3 × 1 = 3	1.00
Mango	a (b)	Vessels	+++	3 × 3 = 9	
		Fibers	–	0 × 3 = 0	
		Rays	++	2 × 2 = 4	
		Parenchyma	+++	3 × 1 = 3	0.59
White bombwe	b (a)	Vessels	+++	3 × 3 = 9	
		Fibers	+++	3 × 3 = 9	
		Rays	++	2 × 2 = 4	
		Parenchyma	++	2 × 1 = 2	0.89

* IS-401: 1982 (revised class shown in parenthesis).
** Chaubey et al. 1986; – no penetration (less than 10% of the cells were penetrated).
+ Partial penetration (between 10 to 30% of the cells penetrated).
++ Moderate penetration (30 to 66% of the cells penetrated).
+++ Complete penetration (more than 66% of the cells were penetrated).

results is significant since the treatability specimens and dowel specimens were not end-matched. In fact, there was considerable variation in the specific gravity between the two materials in some species (Table 1). Gross retention in wood is thus dependent on void structure, i.e., permeability and density of wood.

The penetration indices of the various wood species, computed from silver nitrate penetration, indicate that there was a wide variation in the penetration even within the 'a' treatability class (Table 2). This variation was also noticeable in gross retentions, particularly in mango (Table 3). Thus the existing treatability classification is absolutely arbitrary and has no relation to either cell penetration or gross absorptions obtainable using different treating conditions as indicated in Table 1. This classification can be misleading and may overstate the performance of treated wood in certain wood species, if treatment does not ensure uniform penetration of the various cell types, despite adequate gross absorptions and visual penetration. Microscopic distribution of the preservative should therefore be an important consideration when classifying timber for treatability.

TABLE 3. *Percent voids filled and absorptions obtained in hardwoods of 'a' treatability under different pressure treatment schedules with 4% CCA (Kumar and Sharma 1982).*

	Treatment pressure and pressure period					
Wood species kpa min:	345 30	345 60	515 30	515 60	690 30	690 60
			Loading in kg/m³ (percent voids filled)			
Haldu	10.34 (31)	—	9.68 (29)	11.67 (36)	—	—
Kadam	11.42 (30)	—	13.96 (39)	16.32 (46)	—	—
Kusum	9.65 (29)	—	9.56 (29)	9.80 (30)	—	—
Mango	5.96 (16)	8.24 (22)	7.94 (24)	8.20 (28)	8.04 (24)	7.85 (24)

CCA retention data obtained in the stick specimens of four treatability class 'a' species indicate that increased pressure and time did not result in increased retention in haldu, kusum and mango, although the percent voids filled ranged between 25 to 36% (Table 3). In haldu and kusum, all the cell types penetrated well (penetration index 1). Retention may, therefore, be controlled by changing the solution concentration. On the basis of these observations, revised treatment schedules for haldu and kusum were developed (Table 4).

In mango, the penetration of fibers is limited to those contiguous to vessels (Kumar and Dobriyal 1983). Higher pressures or prolonged pressure periods or both may be necessary to obtain higher degree of penetration in the fibers and increased retention. In kadam, cell penetration was not uniform (penetration index 0.66), but the use of higher pressure increased retention (Table 3). The use of higher pressures or prolonged pressure periods may be necessary to improve the performance of this wood species. The preservative distribution pattern at the microscopic level does not justify placement of mango and kadam under treat-

TABLE 4. *Revised treatment schedules for 'a' treatability class wood species.*

Aimed absorption (kg/m³)	Wood species	Solution concentration (%)	Pressure (kpa)	Pressure period (min)
12	Haldu	4.5/3.0	515	30/60
	Kusum	4.5/3.0	515	30/60
	White bombwe	4.0	515	45
8	Haldu	2.5	515	30
	Kusum	2.5	515	30
	White bombwe	3.0	515	45
6.5	Haldu	2.0	515	30
	Kusum	2.0	515	30
	White bombwe	2.5	515	45
3.2	Haldu	2.0	345	20
	Kusum	2.0	345	20
	White bombwe	1.0	315	45

TABLE 5. *Percent voids filled and absorptions in hardwoods of 'b' class treatability under different pressure schedules with 4% CCA.*

Wood species	Treatment pressure and treatment period					
	515 kpa	690 kpa			1,205 kpa	
	1 h	1 h	1.5 h	2 h	1 h	2 h
		Loading in kg/m³ (Percent voids filled)				
Bahera	—	12.42 (39)	11.99 (37)	15.39 (52)	14.27 (47)	14.60 (48)
Gurjan	—	10.21 (22)	10.14 (20)	8.20 (18)	5.88 (10)	7.0 (15)
White bombwe	11.93 (33)	12.96 (37)	12.90 (38)	15.36 (45)	16.30 (48)	15.16 (45)

ability class 'a' although adequate preservative absorptions suggest that this is the correct classification. Both mango and kadam should be classified under treatability class 'b.'

Retention data of the class 'b' treatability species also indicated the shortcomings in the present classification system (Table 5). The behavior of gurjan was erratic, showing a decrease in gross retentions with increasing pressure and longer pressure periods. It failed to respond to silver nitrate stain, and did not give any penetration data. In white bombwe, over 45% of voids were filled using different combinations of pressures and pressure periods. White bombwe exhibited good penetration (penetration index 0.89) and retention, even under the lowest pressure tested. This species should therefore be classified in the class 'a' treatability group. The suggested treatment schedule for this species is included in Table 4. In bahera, the degree of penetration in different cell tissues was low (penetration index 0.33), although all the cell types were penetrable. This species may be tentatively placed in the 'b' category. Suggested treatment schedules for wood species under treat-

TABLE 6. *Pressure treatment schedules for 'b' treatability wood species with CCA type wood preservatives.*

Aimed absorption (kg/m³)	Wood species	Solution concentration (%)	Pressure (kpa)	Pressure period (min)
12	Bahera	4.0	690/1,205	120/60
	Kadam	3.0	690	60
	Mango	6.0	690	30
8	Bahera	3.0	690	90
	Kadam	2.5	690	60
	Mango	4.0	690	30
6.5	Bahera	2.5	650	90
	Kadam	2.0	515	30
	Mango	2.0	690	30
3.2	Bahera	1.0	690/1,205	120/60
	Kadam	2.0	345	20
	Mango	3.0	345	20

ability class 'b' (bahera, mango and kadam) are given in Table 6. Further studies are needed to determine the actual distribution of the preservatives in the cell structure of bahera and gurjan using different treatment parameters.

CONCLUSIONS

The study, although limited in scope, suggests that the arbitrary system of assigning treatability class based on gross preservative absorptions and penetration depths may not serve the purpose of preserving wood, since the preservative may be concentrated in easily permeable structural zones in the wood. The wood is likely to fail, therefore, due to presence of untreated pockets. Treatment schedules based on penetration index will ensure a uniform distribution and adequate levels of absorption, for better performance of treated wood. The tests need to be replicated on commercial-sized lumber to modify current treatment practices. The optimized schedules are likely to affect economy in preservative use as well as treating costs.

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