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CHEMICAL SEASONING AND DIMENSIONAL STABILIZATION OF WOOD

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Formulations of hygroscopic salts, formalin and molten wax have been applied to four woods viz. Babul, Siris, *Eucalyptus* and Pakar, available in Pakistan and alteration, if any, in their dimensional stability have been recorded. Simple soaking in solutions (Non-Pressure Treatment) has been found to improve the quality of some of these inferior woods. Studies with regard to moisture absorption, shrinkage and swelling, chemical retention and leaching carried out on untreated and treated specimens of different woods indicate that thiourea and formalin which are effective in cross-link formation create the desired hydrophobic micro-environment and hence are appropriate for their dimensional stabilization. Hygroscopic salts on the other hand comprise the hydrogen-bondable materials and on interaction with the polysaccharides and lignins of the woods provide the desired hydrated environment for chemical seasoning. The results have been found to be in accord with the theory which holds dehydration as the main mechanism for aging of plants.

Key words: Hygroscopic salts, Formalin, Molten wax, *Eucalyptus*

INTRODUCTION

Wood or timber constitutes an important component of the building material and accounts for at least 12-15% of the total cost of construction of a dwelling unit in Pakistan. Unfortunately the forest covered area of the country is hardly 3% and that too includes inferior wood e.g. Babul (*Acacia arabica*), Siris (*Albizzis* spp.), Pakar (*Ficus lacon* Buch), *Eucalyptus* etc. which undergo high shrinkage and swelling, giving rise ultimately to bending, checking, honeycombing, distortion, decay, splitting and internal collapose of their structures [1]. On account of their low grade they are burnt as fuel in the rural and suburban area. It is known that by chemical modification even inferior woods can be upgraded for use as building material [1-9]. The present investigation aims at improving the quality of the said woods, in the light of the theory developed earlier [14-15]. Simple soaking with hydrogen bondable materials is effective in chemical seasoning while chemicals like formalin, are effective in cross-link formation. Both the processes introduce a hydrophobic micro-environment so that further interaction with water is retarded and shrinkage is reduced substantially.

No shrinkage occurs on drying green wood until the moisture content is reduced below the fibre saturation point viz. 27-32% [2]. However, when timber dries, its cell walls shrink in cross section. Since the wood cells in the same timber vary in thickness, unequal shrinkage often takes place resulting in stresses which tend to split and wrap the timber [1]. Dehydration of the hydrogen bondables like the polysaccharides and lignins is perhaps the main reason for unequal shrinkage and hence a moisture content above the fibre saturation point stabilizes the dimension of the woods. The addition of water above this level neither affects the size of the cells nor the hydrogen bondables in the inter-cellular space. Warping, splitting or the stress problems, attributed to the effects of the shrinkage process [3] are overcome if the optimum moisture content can be maintained in the micro-environment. It has been found that collapse and volumetric shrinkage are related positively to moisture content and polysaccharides, and negatively to basic density, lignins and extractive contents [10, 11, 12]. It has also been noted that late wood tends to be more highly water saturated than early wood and that the collapse susceptibility is higher in late wood than in early wood [13]. This is most likely because of dehydration as a result of the aging process. The early wood being elder to late wood is expected to contain a lower moisture and fibre content due to cross-linkages formed during plant processes [14]. The higher collapse subsceptibility is thus in line with the theory on aging [15]. It may also be mentioned that plant processes leading to heartwood formation constitute the aging process which calls for progressive reduction of moisture content of the inner sapwood.

Stabilization of wood is important in such applications where it has to maintain its dimensions. For example, in the case of panels enclosed in a frame, their swelling may push the corners of the latter apart; their shrinkage, on the other hand may withdraw them from the grooves. Lumber warps seriously when the surfaces are exposed to differentials in moisture in their macro-environment [4].

Dimensional stabilization of wood can be effected by chemical seasoning which comprises the initial step of immersing the green form in a chemical solution. The wood undergoes physical changes through the exchange of moisture with the chemical solution. This is possible because the differences in vapour pressure between green wood and the chemical solution create the necessary gradient for moisture movement. The diffusion of chemicals into the wood through the water contained therein is governed by the driving force for moisture movement or the gradient of spreading pressure which is itself a surface phenomenon. The extent of diffusion depends on the nature of the chemical, the duration of soaking, the moisture already available in wood and its morphological characteristics [5]. Chemical reaction between the wood and hygroscopic salts does not seem to be involved.

The initial step in chemical seasoning involves soaking the wood with a solution of urea or hydrogen bondable materials like molasses and easily hydrated chemical salts such as nitrates of sodium, calcium or ammonium. In the subsequent step air saturated with moisture is used for heating it to about 38° in a kiln [1]. Heating urea treated wood for 12 to 14 hours causes decomposition and loss of urea. However, there is some fixation of the latter in the wood since it is difficult to remove the same by leaching. With the exception of urea, all other nitrogen compounds are easily leached out from the wood [6]. Despite the loss of urea during heating, the blocks heated to 100° still contain about three times as much of this chemical after leaching as do blocks heated to 70° [6]. The presence of hydrogen bondables in the micro-environment provides the optimum moisture necessary for anti-shrink efficiency.

The other process which has been adopted for dimensional stabilization comprises treatment with formaldehyde. The process could provide strong support to the theory [14, 15], if the chemical reaction between the hydroxyl groups of the various constituents of wood e.g. celluloses, lignins and tannins, on the one hand and formaldehyde on the other hand introduces cross linkages so as to impart stability to its dimensions.

EXPERIMENTAL

Two block sizes, one for swelling/shrinkage and the other for moisture absorption were used in accord with standard specifications [16]. Three small clear specimens of timber measuring 7.5 cm (parallel to the grain direction) x 2.5 cm (perpendicular to the grain direction) x 0.9 cm and six measuring 5 cm (parallel to the grain direction) x 1.6 cm (perpendicular to the grain direction) x 0.9 cm, containing about 8-12% moisture, each from Babul, Siris, *Eucalyptus* and Pakar woods were immersed in the solutions of hygroscopic salts, formalin, thiourea followed by formalin, for three days at about 40° and with molten wax, hot (110°) and warm (70°), both systems having been adopted for 4 hours.

For each determination, a set of six test specimens 5 cm x 1.6 cm x 0.9 cm was used for evaluating shrinkage and swelling while another set of three test specimens 7.5 cm x 2.5 cm x 0.9 cm used for determining the percent moisture absorption, weight percent gain (WPG) and leaching etc. (Tables 1-4).

Treatment of the wood samples was carried out using the following sequence of steps [17]. Having recorded the weight (w_u) and the dimensions of the samples before treatment, the samples were immersed in either hygroscopic salts or formalin or molten wax. They were removed from the treatment medium, air dried and cured by oven drying at 50° for 24 hours. The treated samples were weighed (w_t) and their dimensions were again recorded. Comparative studies with regard to swelling, recovery and moisture absorption were carried out by standard methods [16] whereby;

$$\text{\% Moisture absorption of that of control sample} = \frac{A_t}{A_u} \times 100 \quad \ldots\ldots\ldots (1)$$

where:

A_t = % moisture absorption of treated sample,

A_u = % moisture absorption of untreated (control),

% Shrinkage (Sh) was obtained from the formula [3],

$$\text{\% Sh} = \frac{\Delta SW}{SW} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where:

ΔSW = Change in dimension from swollen to oven dried condition,

SW = Swollen wood size,

$$\text{\% Shrinkage of that of control sample} = \frac{Sh_t}{Sh_u} \times 100 \quad \ldots\ldots\ldots\ldots (3)$$

where:

Sh_t = % shrinkage of treated samples,

Sh_u = % shrinkage of untreated (control) samples,

The anti-shrink efficiency is given by

$$(\text{ASE}) = \frac{S_u - S_t}{S_u} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where S_u is the volumetric swelling of the untreated (control) samples and S_t is the volumetric swelling of treated samples [17].

The weight percent gain (WPG) or chemical retention was calculated from:

$$\text{WPG} = \frac{W_t - W_u}{W_u} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

W_t is the weight after treatment and W_u is the dry untreated weight based on the control sample [18].

Treated and weight (W_t) samples were immersed in water for 24 hours, oven dried at 103° for 24 hours and again weighed (W_L).

The weight percent leaching (%L) was calculated as follows;

$$\%L = \frac{(W_t - W_L)}{W_L} \text{ x } 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

where W_t is the weight of the dry treated samples and W_L that of the sample after its leaching.

RESULTS

Tables 1-4 summarise results concerning the non-pressure treatments of test pieces of inferior wood viz. Babul, Siris, *Eucalyptus* and Pakar with different chemicals e.g. formalin, saturated solutions of inorganic hygroscopic

Table 1. Dimensional stabilization of Babul.

	% Moisture absorption			% Shrinkage			% Swelling		%	%	%	%
	Untreated control	Treated	of that of control	Untreated	Treated	of that of control	Untreated	Treated	Antishrink efficiency (A.S.E.)	Chemical retention (W.P.G.)	Leaching (L)	Recovery
Formalin 5 %	43.00	15.00	34.88	12.97	5.54	42.71	14.92	6.44	56.83	4.51	6.67	9.66
Formalin 0.5% Zinc chloride 0.1%	34.89	18.82	53.94	12.40	10.12	81.61	14.92	12.05	19.23	3.54	6.09	1.896
Molasses 25 %	34.89	19.30	55.31	12.40	8.92	71.93	14.92	9.88	33.74	7.33	8.61	1.12
Urea + Sodium chloride saturated (1:1)	34.89	15.30	43.85	12.40	9.92	80.00	14.92	7.89	47.08	20.76	16.72	0.97
Ammonium nitrate (Saturated soln:)	58.36	24.40	41.80	14.39	9.67	67.19	–	–	–	33.1	19.95	–
Ammnium nitrate Urea saturated soln. (1:1)	58.36	29.80	51.06	14.39	10.62	73.80	13.55	10.89	19.63	27.04	20.5	8.41
Calcium nitrate Saturated soln.	40.00	30.20	75.50	14.39	10.39	72.20	13.55	11.87	12.39	22.30	17.1	5.63
Molasses + urea Saturated soln. (1:1)	40.00	26.86	67.15	14.39	10.40	72.27	14.92	8.57	39.84	11.49	11.81	0.50
Molten wax	40.00	6.63	16.57	14.39	7.18	45.90	13.55	6.78	45.88	24.92	10.92	0.40
Thio-urea and formalin	40.00	12.79	31.97	14.39	10.16	70.60	13.55	10.67	21.18	15.75	4.15	5.61

Table 2. Dimensional stabilization of siris.

	% Moisture absorption			% Shrinkage			% Swelling		%	%	%	%
	Untreated control	Treated	of that of control	Untreated	Treated	of that of control	Untreated	Treated	Antishrink efficiency (A.S.E.)	Chemical retention (W.P.G.)	Leaching (L)	Recovery
Formalin 0.5% + Zinc chloride 0.1%	37.90	15.40	40.63	10.09	9.29	92.07	10.65	10.84	–	2.27	5.609	-1.849
Molasses 25%	40.01	42.50	106.22	10.09	8.095	80.22	10.65	8.704	18.21	22.25	6.95	-1.179
Ammonium nitrate saturated soln.	40.01	18.93	47.31	10.09	8.62	85.43	–	–	–	35.1	23.6	–
Ammonium nitrate + urea saturated soln: (1:1)	40.01	26.38	65.53	10.09	9.89	58.01	10.65	8.552	15.54	26.16	20.57	-4.467
Calcium nitrate saturated soln.	40.01	30.68	76.68	10.09	6.55	64.91	10.65	5.85	45.07	19.00	15.70	-9.943
Molasses + urea saturated soln.	40.01	33.81	84.50	10.09	6.767	67.06	10.65	6.99	34.36	19.35	17.6	-3.653
Molten wax	40.01	7.3	18.20	10.09	4.25	42.12	10.65	4.43	58.40	22.79	8.95	-0.136

Table 3. Dimensional stabilization of *Eucalyptus*.

	% Moisture absorption			% Shrinkage			% Swelling		%	%	%	%
	Untreated control	Treated	of that of control	Untreated	Treated	of that of control	Untreated	Treated	Antishrink efficiency (A.S.E.)	Chemical retention (W.P.G.)	Leaching (L)	Recovery
Formalin 0.5% + Zinc chloride 0.1%	63.50	25.70	40.47	14.88	11.63	78.15	17.87	8.36	53.18	5.35	5.91	3.77
Molasses 25%	85.85	78.20	91.08	14.88	7.35	49.39	17.87	7.74	56.68	11.22	11.5	-2.46
Urea + sodium chloride saturated soln (1:1)	63.50	29.30	46.14	14.88	13.78	92.60	17.87	7.52	57.91	44.47	28.22	-1.93
Ammonium nitrate saturated soln:	84.65	33.25	39.27	14.88	11.06	74.31	17.87	9.70	45.71	68.9	34.2	-9.7
Ammonium Nitrate + urea saturated soln (1:1)	84.65	39.5	46.66	14.88	8.09	54.36	17.87	8.24	53.88	62.15	25.65	-6.385
Calcium nitrate saturated soln:	63.00	38.69	61.41	14.88	7.736	51.98	17.87	7.76	56.57	50.20	25.70	-7.38
Molasses + urea saturated soln: (1:1)	63.00	43.10	68.41	14.88	10.34	69.48	17.87	10.63	40.51	25.10	20.80	-7.801
Molten wax	86.00	13.50	15.65	14.88	7.015	47.14	17.87	7.72	56.79	49.95	10.57	2.453
Thiaurea formalin	86.00	35.06	40.76	14.88	6.83	45.90	17.87	7.38	58.70	30.51	7.54	0.763

Table 4. Dimensional stabilization of Pakar.

	% Moisture absorption			% Shrinkage			% Swelling		%	%	%	%
	Untreated control	Treated	of that of control	Untreated	Treated	of that of control	Untreated	Treated	Antishrink efficiency (A.S.E.)	Chemical retention (W.P.G.)	Leaching (L)	Recovery
Molasses + urea saturated soln: (1:1)	56.40	50.59	89.69	8.98	5.92	65.92	10.01	6.02	39.86	28.62	13.80	-4.30
Molten wax	56.40	9.76	17.30	8.98	3.83	42.65	10.01	4.01	59.94	52.6	12.40	0.816
Thiourea + formalin	56.40	33.55	59.48	8.98	6.88	76.61	10.01	7.41	25.97	20.00	5.29	0.260

salts and their mixtures and molten wax. These treatments lead to partial hydration followed by distribution of salts in the cellular structure of wood.

Table 1 records the treatment of Babul wood with molten wax and suggests a remarkable decrease in moisture absorption and shrinkage to the extent of 17% and 50% of that of control samples respectively. The decrease in moisture absorption with the treatment of thiourea followed by formalin and with 5% formalin alone is 32% and 35% respectively of that of control samples. The behaviour of saturated solutions of ammonium nitrate and mixture of urea and sodium chloride in reducing the moisture absorption is effective to the extent of 42% and 44% of that of control samples respectively. The shrinkage and anti-shrink efficiency with 5% formalin treatment is noted as 43% and 57% respectively which appears from Table 1 to be quite satisfactory. The effectiveness of different chemicals in reducing moisture absorption of Babul wood decreases in the following order:

Molten wax > Thiourea followed by formalin > 5% Formalin > Ammonium nitrate > Urea + Sodium chloride > Urea + Ammonium Nitrate > 0.5% Formalin > Molasses > Urea + Molasses > Calcium nitrate.

Table 2 summarises the effects of different chemicals on Siris wood. It suggests that on treatment with molten wax there is a reduction in moisture absorption and shrinkage to the extent of 18% and 42% respectively of that of control samples of Siris. The anti-shrink efficiency with molten wax and calcium nitrate treatments has been noted as 58% and 45% respectively which appears to be relatively higher among the various treatments listed in Table 2. Calcium nitrate and molasses + urea have also been found effective in reducing shrinkage to the extent of 65% and 67% of that of control samples respectively. In the case of Siris, treatment with 0.5% formalin catalyzed with 0.1% zinc chloride and saturated solutions of ammonium nitrate have been found moderately effective in reducing the moisture absorption by 41% and 47% of that of control samples respectively. The order of effectiveness of different chemicals for Siris wood is almost the same as that obtained for Babul wood.

Table 3 summarises the effect of different treatments on *Eucalyptus* wood. Molten wax has proved superior in reducing the moisture absorption by 16% of that of control. The reduction in moisture absorption by the treatment with aqueous solutions of ammonium nitrate, 0.5% formalin, thiourea-followed by formalin, urea + sodium chloride and urea + ammonium nitrate has been found satisfactory to the extent of 39, 40, 41, 46 and 47% respectively of that of control samples. The shrinkage of control samples with the treatment of thiourea followed by formalin, molten wax and molasses have been recorded as 46, 47 and 49% respectively. Calcium nitrate, ammonium nitrate and urea even though less efficient in lowering the shrinkage have nevertheless the values of 56 and 54% antishrink efficiency of that of control respectively. The effectiveness of different chemicals on Eucalyptus in reducing moisture absorption may be summarized in the following order:

Molten wax > Ammonium nitrate > 0.5% Formalin + 0.1% Zinc chloride > Thiourea followed by Formalin > Urea + Sodium chloride > Urea + Ammonium Nitrate > Calcium nitrate > Urea + Molasses > Molasses.

Table 4 shows that Pakar wood when treated with molten wax develops a remarkable decrease in moisture absorption and shrinkage compared with treatment with molasses + saturated solution of urea and with thiourea followed by formalin.

DISCUSSION

Results listed in Tables 1-4 for laboratory scale trials support the theory on aging since treatment with hydrophobic substances molten wax, or chemicals which are effective in introducing cross-linkages such as formalin catalyzed with zinc chloride and thiourea followed by formalin, are useful in reducing the moisture absorption, shrinkage and swelling of most of the native inferior woods. It is indeed found from the results reported in Tables 1-4 of the present study and supported by literature data [7] that the treatments listed there are effective in reducing the swelling or in improving the anti-shrink efficiency and moisture absorption properties. Use of high concentration of formalin farmulation causes embrittlement of the wood which is a postulate of the theory on aging. The reduced mechanical strength of formaldehyde-treated wood is partially due to excessive dehydration owing to cross linkages and partially to the hydrolysis of the carbohydrate backbone of the cell wall [14, 15]. This treatment, at the same time, improves wood resistance against micro-organisms [18].

The use of formalin has further disadvantages in that it is harmful to health, corrosive to metals and is particularly not suitable in the case of wood with compact structures as it makes it hard and brittle. Handling timber by the hot and cold processes with molten wax treatment also seems technically quite difficult in handling. On the other hand, treatment of oven dried wood with hygroscopic salts is sufficiently effective in controlling shrinkage. This is perhaps due to the fixation of some of the salts into the internal structure of wood. The latter process also provides the hydrogen bondables so that the conditions for obtaining the optimum moisture content in the micro-environment are maintained.

The suggestion just made is borne out from Tables 1 and 3. The anti-shrink efficiency of wood has been substantially increased on treatment with saturated solution of urea and sodium chloride i.e. 58% for *Eucalyptus* and 47% for Babul or in other words swelling of the samples immersed in water was greatly reduced by the treatment. It may be seen from the said Tables that chemical retention using ammonium nitrate, calcium nitrate, urea + sodium chloride, particularly in the case of *Eucalyptus*, is sufficient but unfortunately about 50% of these salts are leached out from the wood when immersed in water. Further investigations regarding the use of low cost hygroscopic salts and fungicides in salt seasoning and quick drying of fresh cut green wood is obviously indicated by this study.

The hygroscopic salts have been found to be comparatively more effective in the case of Siris and *Eucalyptus* than with Babul in controlling the shrinkage and swelling. This is most likely because the salts are able to introduce appropriate amount of hydration of the dry cells thereby introducing absorption of salts by the structure of wood within which swelling takes place. This is greater in the case of less dense woods like Siris and *Eucalyptus* than in Babul. The treatment of inferior wood with molasses has shown a fair increase in the anti-shrink efficiency in the case of Babul and *Eucalyptus* which is 33 and 50% respectively.

The anti-shrink efficiency, using the in situ synthetic resin forming chemicals is perhaps not so much due to a decrease in the rate of absorption of moisture, as would be obtained by coating with waxes, but to a shift in the equilibrium processes relating to absorption [8]. The synthetic resin formed in the body of the wood increases the hardness and the compressive strength but the static bending properties and toughness are hardly affected [3]. Impregnating the wood with phenolic bodies imparts better properties than urea resin treatment [9]. Fairly good efficiencies are obtained, however, by the simple diffusion process using bees wax or a combination of bees wax with other materials [19].

The resin forming chemicals and admixtures of thiourea and formalin have been found satisfactory in reducing the moisture absorption in the case of Babul but they were found ineffective in controlling the shrinkage and swelling. The anti-shrink efficiency of *Eucalyptus* increased substantially *viz.* by 58%, suggesting that swelling was greatly reduced by the treatment. It may, however, be seen from Table 1-4 that chemical retention is higher with molten wax and calcium nitrate in all the species of wood.

It may be concluded from the results on laboratory scale trials that treatment with molten wax, formalin and a mixture of formalin and thiourea are useful in reducing the moisture absorption, shrinkage and swelling of most of the native inferior wood. However, a mixture of urea and sodium chloride imparts higher anti-shrink efficiency to Babul and *Eucalyptus* through a less rigorous dehydration mechanism and introduction of not so extensive cross-linkages.

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