A NOTE ON ASSESSING THE DETERIORATION OF THIN WOOD VENEERS DURING WEATHERING

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ABSTRACT

Weight loss was used to assess the deterioration of thin wood veneers during weathering. Significant weight losses resulting from degradation of the lignocellulosic matrix rather than from losses of water-soluble extractives occurred during exposure.

Keywords: Radiata pine, weathering, weight loss, lignin, polysaccharides, solubility.

INTRODUCTION

Wood exposed to the weather undergoes physical and chemical degradation due to the combined effects of light, water, heat, environmental pollutants, and certain microorganisms (Feist and Hon 1984). Such changes are confined to superficial layers of wood and are distinct from decay in which, in the presence of moisture and ligno-cellulolytic micro-organisms, wood can deteriorate rapidly (Kirk and Cowling 1984). Quantification of the physical deterioration occurring during natural weathering has been achieved using a reflecting light microscope to measure depth of erosion of exposed early and latewood compared to similar adjacent surfaces protected from weathering by a covering of aluminium foil (Feist and Mraz 1978). Using this technique, significant erosion can be detected over prolonged periods of time (1–8 years). Artificial weathering may accelerate rates of erosion approximately tenfold, giving significant deterioration within 24 weeks (Feist and Mraz 1978; Sell and Feist 1986). Alternatively, loss in mean tensile strength during weathering of batches of thin wood veneers (100–150 microns thick) expressed as a percentage of serially cut unexposed controls has recently been used to reduce exposure times and assess deterioration (Raczkowski 1980; Derbyshire and Miller 1981). Losses in tensile strength appear to result from light-induced depolymerization of cellulose, and this may occur because of a reduction in specimen thickness since ultraviolet and visible light penetrate wood to depths of 75 and 200 microns, respectively (Hon and Ifju 1978).

Weight loss that can detect small but significant differences in the deterioration of materials is employed widely in preference to tensile strength in the assessment of the weathering of polymeric materials (Davis 1981; Qayyum and Davis 1984), yet it has not been used extensively to assess the weathering of wood. Previous studies of weight losses occurring in large dimension specimens during natural weathering over prolonged exposure periods (Jemison 1937; Arndt and Willeitner 1969), and in chemically modified wood subjected to accelerated weathering in the laboratory (Rowell et al. 1981; Feist and Rowell 1982) have revealed small losses.

This note reports an experiment undertaken to assess the use of the weight loss

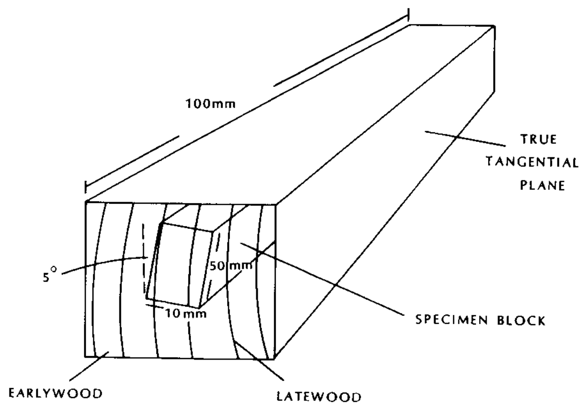

FIG. 1. Dimensions and orientation of growth rings in specimen blocks.

criterion as a means of assessing the deterioration of thin wood veneers during natural weathering.

EXPERIMENTAL

Disks, measuring 450 mm in diameter × 200 mm longitudinally, were cut from four, 53-year-old radiata pine (*Pinus radiata* D. Don) trees at a height 150 mm from the groundline. Straight-grained material free of all visible defects was selected from the outer sapwood (4–5 growth rings/cm) of each disk and converted into 4 blocks 100 mm (longitudinal) × 50 mm (tangential) × 10 mm (radial); growth rings were generally inclined about 5° to the tangential surface (Fig. 1). A total of 125 veneers, about 85 microns thick, were microtomed from the radial face of each block and batched into 4 × 5 groups of 25 strips (500 strips in toto). These groups were then oven-dried to a constant weight at 105 C ± 1 C.

Veneers were laid across glass backing plates (600 mm in length × 120 mm in width) and clamped lightly at their ends. These were exposed outdoors in a randomized complete block design facing equatorially with an inclination of 45° at Canberra, Australia, for 10, 20, 40, 60, 80, and 100 days from the 20th of August 1986 to the 28th of November 1986. After exposure, batches of veneers were examined visually for microbial colonization and then oven-dried to a constant weight, and weight losses were calculated. Solubility in diethyl ether (Browning 1967), ethanol (7) : toluene (3) (Garves 1981; Goetzler 1982), cold water (23 ± 2 C) (TAPPI T1m, Browning 1967), hot water (boiling) (TAPPI T1m,

TABLE 1. *Weather conditions in Canberra during the exposure trial.*

Year	Month	Temperature[1] (°C) Max	Temperature[1] (°C) Min	Rainfall[2] (mm)	Relative humidity[1] (%) 9 am	Relative humidity[1] (%) 3 pm	Sunshine[1] (hours)
1986	August	13.5 (2.3)*	2.0 (3.7)	58.0	80 (10)	51 (14)	6.5 (3.0)
1986	September	16.2 (2.7)	4.0 (3.6)	39.8	70 (12)	51 (12)	7.1 (3.8)
1986	October	17.2 (3.5)	5.3 (3.2)	82.6	68 (12)	50 (17)	7.8 (3.8)
1986	November	21.4 (4.5)	8.8 (3.5)	105.6	69 (11)	49 (17)	7.4 (4.8)

[1] Measurements based on daily readings totalled and averaged for the monthly period.
[2] Rainfall total for the month.
* Standard deviation in parentheses.

TABLE 2. *ANOVA on weight loss with linear and quadratic regression.*

Source	[1] df	S.S.	M.S.	F	Significance
Between trees	3	9.6	3.2	2.1	NS
Time	5	6,150	1,230	828	***
Linear	1	6,046	6,046	4,071	***
Quadratic	1	72.8	72.8	49.0	***
Departure	3	31.4	10.4	7.0	**
Residual	15	22.3	1.485		
Total	20	6,172	308.6		
Grand total	23	6,182			

*** $P < 0.001$.
** $P < 0.01$.
NS = Non significant.
[1] df = Degrees of freedom; S.S. = Sum of squares; M.S. = Mean squares; F = F ratio.

Browning 1967) and lignin content (72% sulphuric acid method, Mahood and Cable 1922; modified by Ritter et al. 1932) were then determined sequentially. The percentage of hexoses in the cold and hot water extracts was determined colorimetrically (Dubois et al. 1956).

Information regarding the meteorological conditions encountered during the experiment was obtained from measurements made in Canberra by the Australian Department of Science and Technology, Bureau of Meteorology (Table 1).

Weight loss results were subjected to a two-way analysis of variance (ANOVA); tree sample × time with linear and quadratic regression.

RESULTS AND DISCUSSION

Significant ($P < 0.001$, Table 2) weight losses occurred during exposure with little inter-sample variability (Fig. 2).

The high weight losses here, relative to those of earlier studies, appear to result from extensive breakdown of the ligno cellulosic matrix. The increasing isolation of hexose sugars following aqueous extraction (Table 3) may result from depolymerization of cellulose or hemicellulose in accord with the findings of Derbyshire and Miller (1981). Lignin in accord with previous observations of the chemical changes in wood during natural weathering (Richter 1935; Kalnins 1966; Feist and Hon 1984) appeared to be rapidly degraded during exterior exposure (Table 3), although its loss here may be due in part to its increasing solubility in the extraction procedure used prior to its determination.

During exterior exposure, absorption of ultraviolet light by wood leads to the generation of radical cations and results in oxidative degradation of lignin (Feist and Hon 1984). Lignin and hemicelluloses may also be degraded through the hydrolytic effects of water (Banks and Evans 1985). Wetting of weathered wood surfaces frequently leads to colonization by blue stain fungi (Duncan 1963), which utilize wood storage products (starches, pectins) and lower molecular weight polysaccharides (Seifert 1964). These organisms were not detected by visual examination of weathered strips here possibly due to the relatively dry and sunny weather conditions prevailing over the exposure period (Table 1), and the reduction in lignin content noted here (Table 3) is probably the result of physico-chemical rather than microbial degradation.

Weight losses in large-dimension specimens during natural (Arndt and Wil-

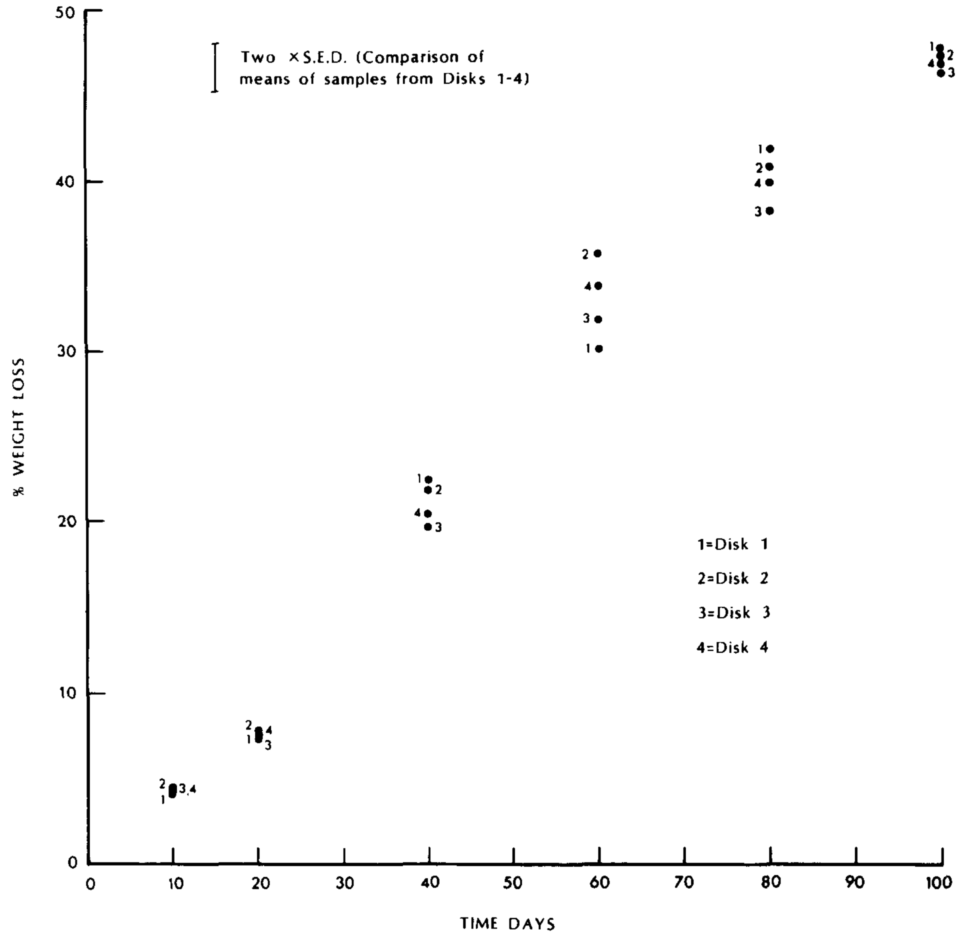

FIG. 2. Loss in weight of thin wood strips during weathering.

leitner 1969) and artificial weathering (Banana 1984) have been greater in wood species with high extractive contents, e.g., weight losses in alpine ash (*Eucalyptus delegatensis* T.T. Bak), brush box (*Lophostemon confertus* R. Br), and tallow wood (*Eucalyptus microcorys* F.V.M.), subjected to 1,800 hours of accelerated artificial weathering were two to three times greater than in *P. radiata,* a species with a relatively low extractive content (Banana 1984). After natural weathering, western red cedar (*Thuja plicata,* D. Don) and redwood (*Sequoia sempervirens* D. Don, End) specimens of large dimensions showed marked reduction in natural durability when subsequently exposed in the laboratory to fungi and termites (Arndt and Willeitner 1969). Thus, in large-dimension specimens, weight losses during weathering appear to result primarily from losses of water-soluble extractives with superficial degradation of structural polymers of lesser importance. This occurs because weathering is largely confined to the surface layers of wood. With reduction in specimen size, degradation of the lignocellulosic matrix assumes greater relative importance.

The strong linear trend evident from Fig. 2 is confirmed (significant, $P < 0.001$,

TABLE 3. *% Changes in solubility, lignin content and hexose sugars in water extracts:* P. radiata *strips exposed to the weather over 100 days (expressed as a % of the initial unexposed dry weight).*

Exposure time (days)	Solubility %*					Lignin %*
	Diethyl ether	Ethanol: toluene	Cold water	Hot water	Total	
0	1.9	0.51	0.65 (26.7)†	0.89 (21.4)†	3.9	24.5
10	0.29	1.1	2.8 (77.4)	3.5 (40.1)	7.8	18.5
20	0.48	1.9	5.5 (50.5)	4.7 (41.9)	12.6	17.4
40	0.4	1.2	5.4 (59.6)	4.9 (41.7)	11.9	12.3
60	0.11	0.52	3.7 (48.2)	4.6 (56.2)	8.9	9.5
80	0.39	0.23	4.5 (41.4)	5.6 (53.5)	10.7	7.9
100	0.37	0.97	4.4 (40.2)	4.6 (51.3)	10.3	3.4

* Mean value for 4 analyses.
† % Hexose sugars in cold and hot water extracts.

Table 2), although there is also a significant quadratic effect ($P < 0.001$) and a significant departure ($P < 0.01$) from the linear and quadratic models (Table 2). Deviations from linearity over the exposure period may result from variation of the climatic components of the weathering process and/or to increasing resistance of the specimen to degradation with time after solubilization of the more easily degraded hemicellulose and lignin fractions.

CONCLUSION

While loss in tensile strength of thin wood veneers has been used as a parameter to assess more quickly the weathering process (Raczkowski 1980; Derbyshire and Miller 1981), weight loss is easier to measure, results in lower between sample variation, and its use is in accord with tests for other polymeric materials (Davis 1981). Further, the use of weight loss as a criterion for assessing deterioration during weathering allows greater flexibility in choice of test material since tensile tests require careful selection of wood species and quality to ensure minimum variability in strength.

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