Microtensile Strength of Spruce Pine After Exposure to Acids and Bases

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ABSTRACT. Earlywood and latewood microtensile specimens from 12 trees of *Pinus glabra* Walt. were subjected to 10-percent solution of 5 acids and 3 bases at 90°C for up to 3 hours. Hydrochloric and sulfuric acids were the most damaging, lowering maximum tensile strength 27 and 17 percent in earlywood and 36 and 39 percent in latewood; they reduced work to maximum load 40 percent in earlywood and 65 percent in latewood. The bases increased maximum strength of earlywood 20 to 40 percent, increased modulus of elasticity 40 percent in earlywood and 18 percent in latewood, and raised work values for earlywood 40 to 50 percent.

WOOD IS WIDELY RECOGNIZED for its resistance to low concentrations of acids and alkalis, and conifers, especially the southern pines, are generally more resistant than hardwoods. Exposure has been shown by numerous researchers, however, to reduce strength significantly, alkalis generally being more detrimental than acids (Alliott 1926; Baechler 1954; Koch 1972, pp. 606-619; Ross 1956; Thompson 1969; Wangaard 1966; Welch 1936).

The cited works report effects of chemicals only on the bending strength of wood. In the study reported here, earlywood and latewood microspecimens were treated with five acids and three bases to determine effects on tensile strength. Wood from spruce pine (*Pinus glabra* Walt.), one of the minor species of southern pine, was used.

Procedure

A total of 12 spruce pines was felled at three locations in east-central Mississippi and three in southwest Alabama. One disk measurin 3 inches along the grain and showing 25 to 3 annual rings was removed from the lower portio of each stem. In each disk three rings wer selected: at 1/6, 3/6, and 5/6 of the ring coun from pith to bark. A microtome block was re moved at each radial position. After the block had been saturated in water, radial section

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Table 1. — MICROTENSILE STRENGTH PROPERTIES OF SPRUCE PINE EARLYWOOD AND LATEWOOD FOLLOWING CHEMICAL TREATMENT.

	Maximum tensile strength				Modulus of elasticity				Work to maximum load			
	Earlywood		Latewood		Earlywood		Latewood		Earlywood		Latewood	
Treatment	Psi	Percent of un-treated	Psi	Percent of un-treated	1000 Psi	Percent of un-treated	1000 Psi	Percent of un-treated	In-lb. per in.^{3}	Percent of un-treated	In.-lb. per in.^{3}	Percent of un-treated
Untreated	8,400	.....	21,500	.....	538	.....	1,174	.....	133	.....	398	.....
Acids												
Hydrochloric	6,100	73	13,700	64	503	94	1,119	95	78	58	141	36
Sulfuric	7,000	83	13,200	61	555	103	1,112	95	80	60	133	34
Acetic	8,400	100	20,600	96	557	103	1,124	96	136	102	308	77
Nitric	8,700	103	18,000	84	688	128	1,524	130	127	95	214	54
Phosphoric	8,700	103	18,600	86	544	101	1,130	96	126	94	257	64
Bases												
Potassium hydroxide	10,100	120	24,100	112	520	97	1,338	114	200	150	437	110
Calcium hydroxide	11,600	138	24,600	114	730	136	1,393	119	193	145	410	103
Sodium hydroxide	11,800	140	24,200	112	763	142	1,389	118	187	140	431	108

nominally 300 μm thick, were cut with a power microtome (this technique permitted later preparation of earlywood and latewood specimens). Wafers were either untreated or immersed in one of eight solutions (Table 1) for 1, 2, or 3 hours at 90°C — a total of 25 treatments including the check. Solution concentrations were 10 percent except for the calcium hydroxide, which was saturated at room temperature.

The wafers were cut 300 μm thick because Biblis (1970) found that strength of microtensile specimens is positively correlated with specimen thickness up to about 200 μm in latewood and 275 μm in earlywood, the thickest wafers he tested. Ifju *et al.* (1965) had observed that rectangular microspecimens yielded higher and more reproducible strength values than necked-down pieces. Earlywood and latewood specimens were therefore punched from each wafer with a pair of parallel-mounted microtome knives shim-spaced to yield rectangular specimens 100 to 500 μm in width, depending on tissue width in each wafer.

Prior to test, a pair of notecard tabs was glued with epoxy to both ends of each of the 1,800 specimens. Distance between tabs — the gage length — was 1/2-inch. Specimens were conditioned for at least 48 hours in air controlled to 73°F and 50-percent relative humidity, and then pulled to failure in tension. Crosshead speed on the universal testing machine was 0.006 inch per minute. Deflection and load data were plotted continuously to failure. Cross-sectional dimensions of each specimen were measured near the point of failure with a microscope fitted with a filar micrometer eyepiece.

Results

Microspecimens fail at considerably lower tensile stresses than ASTM Standard specimens (Salamon 1966; Biblis 1969). Data presented here, therefore, give relative rather than absolute values. There were no significant differences among the three exposure times, and the data were therefore combined. Statistical tests were at the 0.05 level.

Maximum Tensile Strength

Hydrochloric and sulfuric acids reduced maximum tensile strength of earlywood 27 percent and 17 percent respectively (Table 1). The other acids, acetic, nitric, and phosphoric, had no significant effect. Alkaline solutions increased maximum tensile strength of earlywood markedly. Earlywood tissue treated with potassium hydroxide averaged 20 percent stronger than the control, while earlywood subjected to sodium hydroxide and calcium hydroxide averaged approximately 40 percent stronger.

In latewood hydrochloric acid and sulfuric acid again reduced tensile strength, by 36 percent and 39 percent. Means for the other six chemical treatments did not differ significantly from that of the untreated latewood. However, samples subjected to the three alkaline solutions were significantly stronger than those treated with acetic, nitric, and phosphoric acid solutions.

Modulus of Elasticity (MOE)

Nitric acid increased MOE of earlywood by 28 percent, calcium hydroxide by 36 percent, and sodium hydroxide by 42 percent; the three treatments did not differ significantly. The other five solutions had no effect on earlywood MOE.

Of the acid treatments, only nitric affected latewood MOE, raising it by 30 percent. Latewood specimens exposed to sodium hydroxide and calcium hydroxide were 18 percent and 19 percent higher in MOE than untreated specimens; the 14-percent increase found with potassium hydroxide was not significant.

Work to Maximum Load

Hydrochloric acid and sulfuric acid reduced work to maximum load in earlywood by approximately 40 percent, while acetic, nitric, and phosphoric acids had no effect (Table 1). Potassium hydroxide, calcium hydroxide, and sodium hydroxide increased work by 40 to 50 percent above that of untreated specimens.

All acid treatments significantly reduced work in latewood. Work was reduced more by sulfuric acid (66 percent) and by hydrochloric acid (64 percent) than by nitric (46 percent), phosphoric (36 percent), and acetic (23 percent) acids. The three alkaline treatments had no effect.

Discussion

Hydrochloric and sulfuric acids reduced tensile strength and work to maximum load; acetic, nitric, and phosphoric acids diminished only work in latewood. This resistance to the effects of acids is in general agreement with results obtained by other researchers for bending properties. Acids attack the hemicelluloses of the cell wall, and Kass *et al.* (1970) have shown that species low in pentosan content (as the southern pines are) have relatively good resistance. The improvement in MOE by nitric acid treatment was unexpected, and the explanation is not known.

Alkalis are considered to be more destructiv to wood, at least in bending, and an improvemer in mechanical properties has not previously bee reported. In the present tests, the bases wer never detrimental. They increased tensile strengt of earlywood (by 20 to 40 percent), increase MOE (18 to 42 percent), and raised work valu for earlywood (40 to 50 percent). While th explanation of the improvement in properties wa not investigated, alkalis swell the wood and a tack the hemicellulose and lignin. It seems po sible that under the conditions tested the swellin process allowed relief of stresses within the ce walls and permitted more nearly parallel alignme of the cellulose chains. Tensile strength of cotto fiber is improved by the mercerization proces in which the material is subjected to a 12- to 1 percent solution of caustic soda (Immergut 196 p. 164). Perhaps the effect of alkalis on wood somewhat analogous.

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