TOUGHNESS OF SAP-STAINED SOUTHERN PINE SALVAGED AFTER BEETLE ATTACK[1]

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ABSTRACT

Approximately 1,200 small clear specimens were machined from visually graded dimension lumber and tested for toughness. Dimension lumber was obtained from green healthy southern pine and beetle-killed southern pine at various times after foliage fade. The specimens machined from beetle-killed material were free of defects with the exception of sap stain, which is not currently considered in grading rules. Toughness generally decreased with increasing time between foliage fade and the harvesting of the beetle-killed sawtimber. Most of the loss in toughness occurred during the first year after foliage fade. For certain structural applications where toughness or shock resistance of wooden members may be of some importance, caution should be exercised in the utilization of beetle-killed southern pine.

Keywords: Southern pine beetle, toughness, blue stain, structural lumber, incipient decay.

INTRODUCTION

The southern pine forests produce over 25% of our nation's softwood lumber (Phelps 1977). However, southern pine as a host is susceptible to many forms of pathological and insect attacks, the most notable being *Dendroctonus frontalis* Zimm, the southern pine beetle. During 1973 alone, 170 million board feet of sawtimber were marketed from beetle devastated stands of southern pine (USDA 1975). Lumber grade recovery has been reported to be lower for this timber (Sinclair et al. 1977), and the occurrence of wood-destroying and staining fungi has been reported (Barron 1971).

Toughness, a measure of the energy required to cause rapid failure in a simply supported, centrally loaded beam, has been reported as the most sensitive standard test for the effects of stain and decay in wood (Cartwright and Findlay 1958; Chapman and Scheffer 1940; Findlay and Pettifor 1937). Thus, the toughness of wood infected with stain or decay fungi could be expected to be reduced faster than other mechanical properties. This can have serious consequences in impact loading situations such as wall systems or other structures subject to heavy gusts of wind, floor systems supporting moving machinery, or even a large group of dancers.

A preliminary study using matched specimens of beetle-killed shortleaf pine

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(*Pinus echinata* Mill.) with varying degrees of degrade associated with stain and due to incipient decay indicated that a drastic loss in toughness may occur within a relatively short time period following the death of the trees (Sinclair et al. 1978). Most studies of deterioration of toughness have been conducted on specimens infested with fungi under laboratory conditions. It is expected that decay rates and patterns in standing timber should produce larger variations in toughness. Consequently, the effects on laboratory-infected specimens may not be truly indicative of the effect on commercially acceptable lumber from trees where deterioration is controlled by natural factors.

Because of the potential for rapid loss of toughness in wood from beetle-killed pine and the subsequent hazards involved, the major objective of this study was to measure the toughness of small clear specimens machined from graded dimension lumber sawn from beetle-killed pine at various time periods after foliage fade. An additional purpose was to assess the effect of the time after foliage fade on deterioration. Consequently, this information in conjunction with strength and stiffness loss data (Sinclair et al. 1979) was to provide a basis upon which rational decisions concerning grading and potential salvage operations may be made.

MATERIALS AND METHODS

Representative bark beetle-infested plots of dead loblolly pine (*Pinus taeda* L.) and shortleaf pine (*Pinus echinata* Mill.) with known dates of foliage fade were located in the Piedmont and Coastal Plain of Virginia. Harvested sample trees were selected randomly from those dead trees that had reasonably straight boles, and logs were taken up to a 7-inch top diameter. Trees were harvested at periods of roughly 2 months, 12 months and 20 months following foliage fade. Healthy control trees were also harvested from the perimeter of the infested area. The logs were transported to a local sawmill for conversion to lumber. The resulting structural dimension lumber was visually graded by quality supervisors of the Southern Pine Inspection Bureau (SPIB). Sample pieces of the graded lumber, one from each log, were randomly selected on the green chain of the sawmill.

SPIB visual grading rules severely limit decay in dimension grades of lumber but allow sap-stain (SPIB 1970). Because actual decay is usually easy to detect and is a limiting factor in current grading practices, no sample boards in which decay was evident were selected. Incipient decay often associated with heavy sap-stain is not easily distinguishable even by expert graders. Therefore, no distinction between sap-stain and incipient decay was made in the selection process. Sap-stain is not considered a degrade.

It is well known that the juvenile wood near the pith of southern pine has different strength properties than the mature wood. Consequently, sample boards cut from near the pith of the trees were also avoided.

The lumber selected was air-dried, and standard toughness specimens were machined from each piece in accordance with American Society for Testing and Materials (ASTM) Standards (1970). Any previously undetected decay and juvenile wood were carefully avoided. All toughness specimens were then conditioned to a target moisture content of 12% before testing.

Four toughness test specimens, each 2 cm × 2 cm × 28 cm, were tested from each log using a Forest Products Laboratory pendulum-type toughness machine.

TABLE 1. *Grouping of plots of beetle-killed southern pine according to length of time between foliage fade and sample collection.*

Group	No. plots	Time between foliage fade and collection	Average tree characteristics		
			DBH (inches)	Age (years)	Height (feet)
Control	8	—	12.7	62	73
1	1	2 Mo. (Fall–Fall*)	10.8	63	65
2	3	12 Mo. (Smr.—Smr.)	12.2	71	70
3	3	12 Mo. (Wtr.—Wtr.)	13.9	53	74
4	1	~20 Mo. (~1⅓ W.S.**)	10.8	63	65
5	3	~20 Mo. (2 W.S.)	12.8	48	70

* Season of foliage fade–season of collection.
** W.S. = warm seasons (April–October).

Two specimens were loaded on the tangential face nearest the pith and two were loaded on the radial face with toughness determined according to the standard procedure (ASTM 1970).

Small blocks were cut from each specimen near the zone of failure to determine specific gravity and moisture content. Specific gravity was calculated on an oven-dry weight, green volume basis using a water displacement technique for measurement of green volume.

RESULTS AND DISCUSSION

There are no readily detectable anatomical differences in the structure of wood from shortleaf and loblolly pine or in their mechanical properties. Additionally, little difference in decay rates has been found (Lindgren 1953; Toole 1970). Both species are commonly marketed under a single name, southern yellow pine. Therefore, for the purposes of this study both species were considered as belonging to a single population.

It should be noted from the experimental design that the small clear specimens cannot be used to predict the extent of degradation of wood in the whole tree following a beetle attack. In an earlier paper it has been reported that significant lumber yield reductions occurred with time after death of the trees (Sinclair et al. 1977). These yield reductions were due to the normal grade-sawing practices in which sawyers remove from the logs all apparently decayed material leaving relatively sound lumber for grading. Thus, the lumber cut from severely decayed logs was intended to be theoretically of the same quality as that sawn from healthy trees because the heavily decayed portions had been removed at the headrig. In addition, each specimen was carefully screened to insure that apparent degrade was not present. The specimens did, however, contain sap stain, which was a result of beetle infestation. Thus, comparisons in this study are made between truly clear undamaged specimens, which should all belong to the same population.

Data collected were grouped on the basis of elapsed time between foliage fade and harvesting of the trees. Data from control specimens were combined to provide a base for comparisons with different time frames. The groupings and tree characteristics are summarized in Table 1.

No attempt was made to adjust the toughness values to a common specific

TABLE 2. *Summary of toughness data for tangentially loaded specimens of beetle-killed southern pine.*

	Butt logs							Upper logs						
				Toughness							Toughness			
Group	n	Moisture content (%)	Spec. grav.	Mean (in-lbs)	Std. dev.	Duncan's (1)	Scheffé (2)	n	Moisture content (%)	Spec. grav.	Mean (in-lbs)	Std. dev.	Duncan's (1)	Scheffé (2)
All control	88	12.6	.48	309	101	A	A	77	12.9	.42	219	79	A	A
1	32	10.9	.48	255	92	B	B	11	10.7	.42	207	63	A	A B
2	59	13.3	.45	175	72	C D	C	40	12.6	.42	154	48	B	B
3	62	11.8	.43	199	59	C	C	54	11.5	.39	168	61	B	B
4	28	14.6	.46	183	75	C D	C	22	14.4	.43	157	60	B	B
5	57	12.0	.44	160	61	D	C	47	12.2	.40	150	62	B	B

(1) Means with the same letter are not significantly different at the .05 level using a Duncan's multiple range test.
(2) Means with the same letter are not significantly different at the .05 level using a Scheffé multiple comparison procedure.

TABLE 3. *Summary of toughness data for radially loaded specimens of beetle-killed southern pine.*

	Butt logs							Upper logs						
				Toughness							Toughness			
Group	n	Moisture content (%)	Spec. grav.	Mean (in-lbs)	Std. dev.	Duncan's (1)	Scheffé (2)	n	Moisture content (%)	Spec. grav.	Mean (in-lbs)	Std. dev.	Duncan's (1)	Scheffé (2)
All control	90	12.6	.48	211	73.5	A	A	79	12.9	.42	152	35.2	A	A
1	31	10.8	.50	195	54.4	A	A	12	10.4	.42	144	25.4	A	A B
2	59	13.2	.45	130	46.7	B	B	42	12.7	.43	111	27.5	B C	B C
3	62	12.0	.43	141	34.7	B	B	55	11.3	.39	121	30.5	B	B C
4	29	14.5	.46	140	85.1	B	B	22	14.3	.43	110	37.7	B C	B C
5	58	12.0	.44	125	60.2	B	B	48	12.1	.39	102	32.2	C	C

(1) Means with the same letter are not significantly different at the .05 level using a Duncan's multiple range test.
(2) Means with the same letter are not significantly different at the .05 level using a Scheffé multiple comparison procedure.

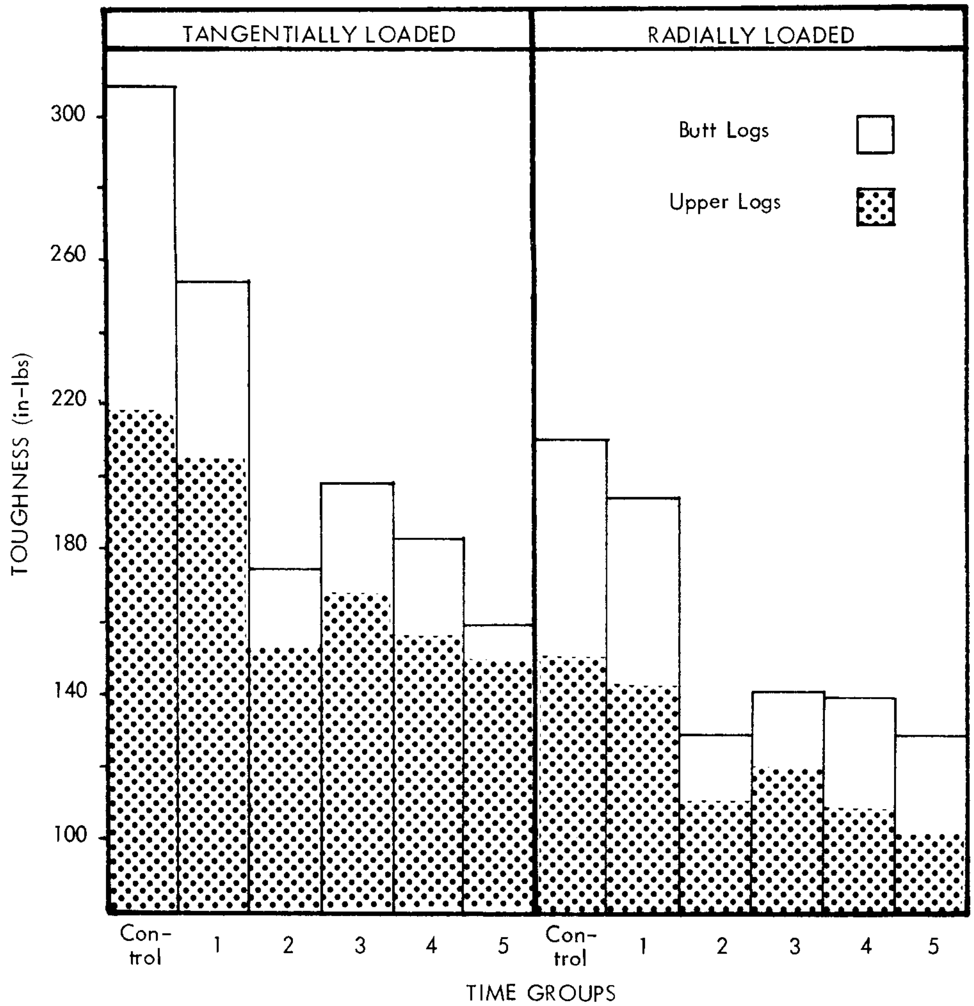

FIG. 1. Toughness of control and beetle-killed southern pine.

gravity because of a poor correlation between specific gravity and toughness in both the control specimens and those that exhibited stain and incipient decay. Average moisture content at the time of testing for the various groups varied somewhat more than was considered optimal. However, it has been shown that toughness is relatively insensitive to small changes in moisture content within the hygroscopic range (Kollmann and Côté 1968).

The toughness test results are shown graphically in Fig. 1 and are tabulated in Tables 2 and 3. The results indicate that the tangentially loaded specimens were tougher than the radially loaded specimens. Additionally, the butt log specimens were consistently tougher than those from the upper logs. This is likely due to the upper logs of southern pine having a generally lower specific gravity and to the observation that upper logs exhibit evidence of earlier decay than butt logs (Sinclair et al. 1977).

The majority of the strength loss compared to the control values occurred in the first 12 months. For example, the tangentially loaded specimens from butt logs showed a 40% loss in the first 12 months (Group 2) but only a 48% loss over a period of 20 months (Group 5). This may be explained by noting that generally after 12 months following foliage fade the main bole of the tree was sufficiently dried to partially inhibit decay (Ifju 1978).

The rate of strength loss or deterioration may also be affected by the period of warm seasons experienced by the tree after foliage fade. Even though there is approximately 8 months' time between the 12-month (2 and 3) groups and the 20-month (4 and 5) groups, there was no significant difference in the mean values for toughness between these two groups, regardless of the direction of loading or position in tree (see Tables 1 and 2). There is a slight but consistent reduction in the mean values between groups 2 and 3 and between groups 4 and 5 indicating some sensitivity to the period of the warm season experienced after foliage fade.

Tables 2 and 3 indicate the results of two statistical comparison procedures that were used to indicate significant difference between the means of the groups for each loading direction and log position. The two tests used were Duncan's multiple range test, which is commonly used but considered a weak test by some, and the Scheffé multiple comparison procedure, which is generally considered to be a very conservative test (Snedecor et al. 1971). Both tests were utilized with a 0.05 level of significance criterion.

The results of both of these tests, in general, indicate that there is no statistically significant difference between the means of groups 2, 3, 4 and 5. Although it is possible to make some distinctions between certain groups after 12 months of foliage fade, it appears that the majority of loss in toughness occurs during the first warm season after foliage fade regardless of the time of foliage fade. This may have significance in planning salvage operations of beetle-killed southern pine having recently experienced foliage fade.

Although the results showed little difference between the control and 2-month (1) groups, it should be noted that the 2-month group (1) was on the stump for the months of October and November. If this group had been left on the stump during a two-month period more suitable for rapid decay, these results might have been altered. Preliminary results using a small number of matched specimens of beetle-killed southern pine indicated that losses in toughness may begin very soon after the death of the tree (Sinclair et al. 1978).

CONCLUSIONS

From this study of approximately 1,200 small clear toughness specimens from green healthy and beetle-killed southern pine, the following conclusions may be drawn:

(1) Toughness of small clear specimens machined from visually graded dimension lumber generally tended to decrease with increasing time between foliage fade and harvesting of the sawtimber.

(2) The majority of the loss in toughness occurred with the first warm season following the death of the tree regardless of the time of foliage fade. Relatively little loss occurred in subsequent warm periods.

(3) Clear wood taken from top logs of dead trees showed a greater reduction of toughness than that from corresponding butt logs.
(4) The direct influence of the reduction of toughness of clear wood on the behavior of full-size structural lumber in dynamic stress conditions is not known. However, reductions noted in this study suggest that caution should be exercised when lumber sawn from trees dead for extended periods of time is used in such stress conditions. Further investigations of the effect on structural material are needed.

REFERENCES

American Society for Testing and Materials. 1970. Testing small clear specimens of timber. ASTM D 143–52.

Barron, E. H. 1971. Deterioration of southern pine beetle-killed trees. For. Prod. J. 21(3):57–59.

Cartwright, K. St. G., and W. P. K. Findlay. 1958. Decay of timber and its prevention. 2nd ed., Forest Products Research Laboratory. London.

Chapman, A. D., and T. C. Scheffer. 1940. Effect of blue stain on specific gravity and strength of southern pine. J. Agr. Res. 61:125–133.

Findlay, W. P. K., and C. B. Pettifor. 1937. The effect of sap-stain on the properties of timber. I. Effect of sap-stain on the strength of Scots pine sapwood. Forestry 11(1):40–52.

Ifju, G. 1978. Unpublished data on moisture content of beetle-killed southern pine. Department of Forest Products. Virginia Polytechnic Institute and State University. Blacksburg, Virginia.

Kollmann, F. F. P., and W. A. Côté. 1968. Principles of wood science and technology. Springer-Verlag, New York. P. 388.

Lindgren, R. M. 1953. Deterioration losses in stored southern pine pulpwood. Tappi 36(6):260–264.

Phelps, R. B. 1977. The demand and price situation for forest products. USDA For. Ser. Misc. No. 1357.

Sinclair, S. A., G. Ifju, and J. A. Johnson. 1978. Changes in toughness of wood from beetle-killed shortleaf pine. For. Prod. J. 28(7):44–47.

———, ———, and H. J. Heikkenen. 1977. Lumber yield and grade recovery from southern pine sawtimber after a beetle attack. So. J. Appl. For. 1(4):17–20.

———, T. E. McLain, and G. Ifju. 1979. Strength loss of small clear specimens of southern pine. For. Prod. J. (in press).

Snedecor, G. W., and W. G. Cochran. 1971. Statistical methods. 6th ed. Iowa State Univ. Press, Ames, Iowa.

Southern Pine Inspection Bureau. 1970. Standard grading rules for southern pine lumber. Southern Pine Inspection Bureau, Pensacola, Florida.

Toole, E. R. 1970. Variation in decay resistance of southern pine sapwood. For. Prod. J. 20(5):49–50.

United States Department of Agriculture. 1975. Southeast area southern pine beetle outbreak status. USDA For. Serv., Southeastern Area State and Private Forestry. Atlanta, GA.