



Comparative Durability of Untreated Wood in Use Above Ground

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ABSTRACT

Cross-brace units constructed of 10 different softwoods and nine different hardwoods were exposed on a test fence in Wisconsin for up to 22 years. Sapwood was included for all species and heartwood for some. The objective of this study was to determine the above-ground longevity of these woods against decay. The wood was classified into above-ground decay resistance groups. The longevity spans apply only to structural components similar in cross-sectional size to the test units used in this study. Millwork and fencing components may fit into this category. Woods estimated to last more than 20 years above ground, and thus classified as most resistant, included the heartwood of Douglas-fir, western white pine, redwood, Eucalyptus sp., red and white oak, lodgepole pine, ponderosa pine, western red cedar, and the sapwood of redwood, white oak, and red oak. No woods fell into the nonresistant class (≤ 7 years expected average life). The remaining woods were classified moderately resistant or resistant based upon service lives of 8 to 13 and 14 to 19 years, respectively.

INTRODUCTION

We initiated a study in 1972 to determine the relative durability of American woods in above-ground exterior use. Both sapwood and heartwood were exposed above ground in the form of cross-brace units in high- and

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moderate-decay hazard locales (Scheffer, 1971). The longevity of the various wood species and the basidiomycetes associated with decay through 12 years exposure has been published (Eslyn *et al.*, 1985). In addition, all woods tests in the high decay hazard climate of Mississippi were removed at 12 years and classified into decay resistance groups (Eslyn *et al.*, 1985).

In the moderate decay hazard climate of Wisconsin, most woods decayed too slowly for estimates to be made of their longevity, and those test units remained in the test. Thus, this paper reports the estimates of longevity of woods exposed in Wisconsin.

MATERIALS AND METHODS

Test units were constructed of 1.9 by 7.62 by 15.24 cm (3/4 by 3 by 6 in) long boards, nailed together at their centers to form a cross (Fig. 1). The intersection of the boards provided a water catchment area similar to joints where decay often originates in wood structures. Ten units were constructed of wood from each tree species. When both sapwood and heartwood were available from a given species, 10 units were constructed of each wood type. Each series of units was then installed on test fences (Fig. 1) located near Madison, Wisconsin. The Madison climate is moderately favorable for promotion of decay (Scheffer, 1971).

The test units (crosses) were constructed from sapwood (unless otherwise noted) of the following tree species:

Coniferous woods

- (1) Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco
- (2) Douglas-fir heartwood
- (3) Western hemlock, *Tsuga heterophylla* (Raf.) Sarg.
- (4) Lodgepole pine, *Pinus contorta* Dougl. ex Loud.
- (5) Lodgepole pine heartwood
- (6) Ponderosa pine heartwood, *Pinus ponderosa* Dougl. ex Laws.
- (7) Red pine, *Pinus resinosa* Ait.
- (8) Southern yellow pine, *Pinus* sp.
- (9) Western white pine heartwood, *Pinus monticola* Dougl. ex D. Don.
- (10) Redwood, *Sequoia sempervirens* (D. Don) Endl.
- (11) Redwood heartwood
- (12) Engelmann spruce, *Picea engelmannii* Parry
- (13) Engelmann spruce heartwood
- (14) Western red cedar, *Thuja plicata* Donn.
- (15) Western red cedar heartwood.

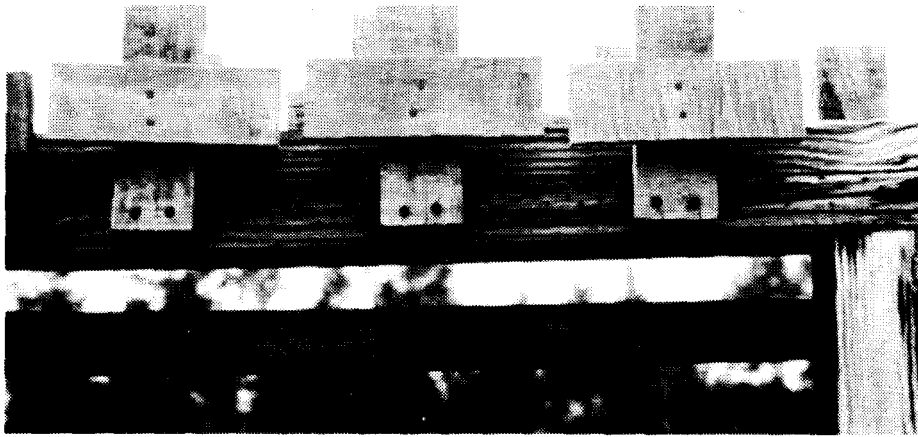


Fig. 1. Test crosses installed on fence.

Hardwoods

- (1) Red alder, *Alnus rubra* Bong.
- (2) Basswood, *Tilia americana* L.
- (3) Basswood heartwood
- (4) Yellow birch interior wood, *Betula alleghaniensis* Britton
- (5) Eucalyptus, *Eucalyptus* sp.
- (6) Eucalyptus heartwood
- (7) Sugar maple interior wood, *Acer saccharum* Marsh — true heartwood is not formed in this species, hence the term 'interior' wood is used
- (8) Red oak, *Quercus* sp.
- (9) Red oak heartwood
- (10) White oak, *Quercus* sp.
- (11) White oak heartwood
- (12) Balsam poplar, *Populus balsamifera* L.
- (13) Sweetgum, *Liquidambar styraciflua* L.

Each summer test units were examined for decay and fungal fruiting structures, and isolations were attempted, usually from two units within each group of tree species. In addition, units that had failed were brought back to the laboratory for dissection and intensive isolation work. Malt agar and Taylor's (1971) agar were used for all isolations. Basidiomycetes isolated from the test units were reported in a previous paper (Esllyn *et al.*, 1985). We considered breakage of the unit by hand force to be failure of the unit.

The following decay ratings were used:

- 1 = sound
- 2 = sound appearing but infected with Basidiomycetes or a *Xylaria* spp.

3 = up to 25% decayed

4 = 26–50% decayed

5 = >50% decayed.

RESULTS AND DISCUSSION

Natural durability, as used in this study, is the resistance of untreated wood to fungal decay in service above ground. The time for more than half the test units of a given wood species to fail was termed the 'average service life' (Table 1). When failure of six or more units of one species occurred prior to final inspection, the average service life was readily discernible. However, determination of the service life of those wood species in which less than half the test units had failed required extrapolation from data on related wood in the test and from the condition of the surviving units.

Based upon determined or estimated service life, the Wisconsin-exposed woods were rated on above-ground decay resistance (Table 2). Classified as 'most resistant' with an expected average service life of at least 20 years were heartwood of Douglas-fir, western white pine, redwood, *Eucalyptus* sp., red and white oak, lodgepole pine, ponderosa pine, western red cedar and sapwood of redwood, white oak and red oak. No woods fell into the 'nonresistant' class (≤ 7 years expected average life). The remaining woods were 'moderately resistant' or 'resistant' based upon expected service lives of 8–13 and 14–19 years, respectively.

Climatic conditions affect expected average life. A comparison of the average expected life of test units in Wisconsin and southern Mississippi is given in Table 3. According to the climate decay hazard map developed by Scheffer (1971), Wisconsin is a moderate decay hazard climate and southern Mississippi a severe decay hazard climate with high rainfall and warm and humid weather. As expected, test units in Wisconsin usually had a greater average life than test units in Mississippi, but in several instances the average life expectancies were very close.

The expected average life of the species is also affected by board size and kind of structural joint. For example, 10.2 cm (4 in) thick planks of untreated Douglas-fir heartwood were estimated to have a service life of only 12 years in southern Mississippi (Highley & Scheffer, 1986), considerably less than the 20+ years life determined for the test crosses of the same species used in the present test. The shorter longevity of the larger units may be due to lengthy periods of moisture retention, particularly if checking is involved. Thus, lengthy periods of moisture retention would increase the time that invading fungi can grow and deteriorate the wood.

TABLE 1
Decay Evaluation and Longevity of Test Units Composed of Different Woods and Exposed Above Ground in Wisconsin

<i>Species</i>	<i>Wood type</i>	<i>Failed units</i>		<i>Remaining units</i>			<i>Average service life^b (year)</i>
		<i>Number</i>	<i>Years</i>	<i>Number</i>	<i>Years</i>	<i>Rating^a</i>	
Douglas-fir	Sapwood	1	11	0	—	—	16
		3	15				
		6	16				
Hemlock, western	Heartwood	0	22	10	22	1	>30E
	Sapwood	2	9	0	—	—	13
		1	10				
		2	12				
Pine, lodgepole	Sapwood	1	13	0	—	—	9
		4	15				
		6	9				
Pine, ponderosa	Heartwood	4	10	9	22	1	>30E
	Heartwood	1	14	7	21	5	23E
Pine, red	Sapwood	2	15	0	—	—	10
		6	10				
		2	11				
Pine, southern yellow	Sapwood	2	12	0	—	—	13
		2	9				
		2	11				
		1	12				
		2	13				
Pine, western white	Heartwood	3	14	5	22	3	25E
		0	22				
		5	22				

Comparative durability of untreated wood

Continued overleaf

TABLE 1 — contd.

Species	Wood type	Failed units		Remaining units			Average service life ^b (year)	
		Number	Years	Number	Years	Rating ^a		
Redwood	Sapwood	4	17	6	22	5	23E	
	Heartwood	0	22	10	22	1	>30E	
Spruce, Engelmann	Sapwood	1	11	0	—	—	16	
		2	12					
		1	13					
		4	16					
		2	18					
	Heartwood	6	14	0	—	—	14	
		2	16					
		2	17					
		1	8	0	—	—	11	
		2	9					
Western redcedar	Sapwood	2	10					
		3	11					
		2	12					
		0	22	0	—	—	>30E	
		1	9	0	—	—	12	
	Alder, red	Sapwood	1	10				
			3	11				
			1	12				
			1	15				
			2	16				
Basswood	Sapwood	1	17					
		5	9	0	—	—	10	
		5	10					

Basswood — <i>contd.</i>	Heartwood	6	8	0	—	—	8
		3	9				
		1	10				
Birch, yellow	Interior	3	14	0	—	—	15
		3	15			4	17
<i>Eucalyptus</i> sp.	Sapwood	10	18	0	—	—	18
	Heartwood	0	21	5	21	2	25E
Maple, sugar	Interior	5		5	21	3	
		2	10	0	—	—	14
		2	12				
Oak, red	Sapwood	6	14				
		0	21	10	21	3	25E
		0	19	10	19	2	25E
Oak, white	Sapwood	0	21	10	21	1	30E
	Heartwood	0	21	10	19	1	30E
Poplar, balsam	Sapwood	1	9	0	—	—	16
		3	14				
Sweetgum	Sapwood	6	16				
		1	8	0	—	—	9
		6	9				
		1	10				
		2	11				

^aDecay rating: 1 = sound; 2 = appearing sound but infected with a Basidiomycete or *Xylaria* spp.; 3 = up to 25% decayed; 4 = 26–50% decayed; 5 = +50% decayed.

^bTime required for failure of six or more test units to occur. An E following figure indicates that time is estimated.

Comparative durability of untreated wood

TABLE 2
Grouping of Test Woods for Above Ground Decay Resistance and Service Life in a Climate such as that of Wisconsin^a

<i>Most resistant (≥ 20 years)</i>	<i>Resistant (14–19 years)</i>	<i>Moderately resistant (8–13 years)</i>	<i>Nonresistant (≤ 7 years)</i>
Douglas-fir, heartwood	Douglas-fir, sapwood	Western hemlock, sapwood	None
Western white pine, heartwood	Englemann spruce, sapwood	Lodgepole pine, sapwood	
Redwood, heartwood	Englemann spruce, heartwood	Southern yellow pine, sapwood	
Redwood, sapwood	Eucalyptus sp., sapwood	Red pine, sapwood	
<i>Eucalyptus</i> sp., heartwood	Sugar maple, interior	Western red cedar, sapwood	
Red oak, sapwood	Yellow birch, interior	Red alder, sapwood	
Red oak, heartwood	Balsam poplar, sapwood	Basswood, sapwood	
White oak, heartwood		Basswood, heartwood	
White oak, sapwood			
Lodgepole pine, heartwood		Sweetgum, sapwood	
Ponderosa pine, heartwood			
Western red cedar, heartwood			

^aBased on years to failure of cross-brace joints in Madison, Wisconsin.

TABLE 3
Comparison of Longevity of Test Units Exposed in Wisconsin and Mississippi

Species	Wood type	Estimated life ^a (year)	
		Wisconsin	Mississippi ^b
Douglas-fir	Sapwood	16	16E
	Heartwood	>30E	>20E
Hemlock, western	Sapwood	13	11
Pine, lodgepole	Sapwood	9	7
	Heartwood	>30E	16E
Pine, ponderosa	Heartwood	23E	14E
Pine, red	Sapwood	10	8
Pine, southern yellow	Sapwood	13	10
Pine, western white	Heartwood	25E	>20E
Redwood	Sapwood	25E	15E
	Heartwood	30E	>20E
Spruce, Engelmann	Sapwood	16	14E
	Heartwood	14	14E
Western redcedar	Sapwood	11	9
Alder, red	Sapwood	12	5
	Heartwood	>35E	—
Basswood	Sapwood	10	4
	Heartwood	8	4
Birch, yellow	Interior	15	7
<i>Eucalyptus</i> sp.	Sapwood	18	10
	Heartwood	25E	16E
Maple, sugar	Interior	14	6
Oak, red	Sapwood	25E	>20E
	Heartwood	25E	>20E
Oak, white	Sapwood	>30E	>20E
	Heartwood	>30E	—
Poplar, balsam	Sapwood	16	7
Sweetgum	Sapwood	9	4

^aTime for failure for more than 50% of test units to occur; an E following figure indicates that time is estimated.

^bData reported by Eslyn *et al.* (1985).

The influence of joint type on rate of decay is illustrated in Table 4. For example, red oak L-joint units had an average life of 6 years compared to the 20+ life of cross-brace units. The L-joints provided much greater end-grain absorption of water than did the cross-brace units and L-joints do not dry as quickly. Therefore, average service life reported here should be extrapolated only to structural components similar in cross-sectional size and construction to the test units used in this study. Millwork and fencing components may fit into this size category.

The heartwood of a species is usually much more resistant to fungal

TABLE 4
Effect of Structural Joint and Board Size on Estimated Service Life of Woods Exposed Above Ground in Southern Mississippi

Type of unit	Estimated years to failure ^a			
	Pine	Douglas-fir	Red oak	Maple
Cross-brace (2 by 7.5 by 15 cm)	10	>20	>20	6
L-joint (3.8 by 3.8 by 20.3 cm)	6	9	6	5
Plank (10.2 by 25.4 cm)	5	12	—	—
Post-rail (3.8 by 8.9 by 30.5 cm)	7	20	—	—

^aSource: Highley (1993); Highley and Scheffer (1986, 1993).

attack in service than the sapwood. Decay resistance is often correlated with the content of fungicidal compounds (inhibitory phenols and terpenes that accumulate during the transition of sapwood into heartwood). When both heartwood and sapwood of a species were tested in this study, greater heartwood durability was generally the case, but Englemann spruce and basswood were the exceptions. Sapwood of all timbers is considered to be very susceptible to fungal attack. Surprisingly, there was considerable variation in the average life of the sapwood among the different species. Estimated average life of sapwood varied from 9 years in sweetgum and lodgepole pine to 25 years in red oak, white oak and redwood. Although toxic extratives play a dominant role in the natural durability of heartwood, Scheffer and Cowling (1966) discussed other mechanisms of natural resistance to microbial deterioration, such as structural and nutritional differences, that may contribute to the variable decay resistance of the sapwood observed here. The variance encountered in sapwood decay susceptibility supports previous laboratory findings (Eslyn & Highley, 1976).

Durability is also affected by variation within species. For example, Scheffer *et al.* (1949) concluded that use of white oak will provide superior decay resistance in general, but some individual trees of this species may have only moderate resistance. Furthermore, they reported variability in decay resistance with locality, tree size, and position of the wood in the tree. Variation in durability within a species or individual tree can also be due to different stages of the decay process, prior to visible changes in the wood (Smith & Shortle, 1988).

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