

# DECAY RESISTANCE OF SALTWATER-EXPOSED DOUGLAS-FIR PILES<sup>1</sup>

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## ABSTRACT

Wood that is submerged in fresh water for long periods has increased permeability and other changed properties. Wood that is submerged in salt water may absorb considerable quantities of salts, which may render the wood resistant to microbial colonization. In this report, we describe decay tests on Douglas-fir sapwood and heartwood after long-term exposure in the Great Salt Lake of Utah. This wood was generally resistant to fungal attack, but was susceptible to leaching. Scanning electron microscopic examination revealed that salt crystals in the wood were primarily sodium chloride, which was readily removed in a leaching procedure. Decay resistance attributed to saltwater exposure declined with prolonged leaching.

*Keywords:* Decay, Douglas-fir, heartwood, sapwood, piles, salt water.

## INTRODUCTION

Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) heartwood is moderately resistant to attack by decay fungi and is often used without supplemental treatment in non-soil contact exposures (Scheffer and Cowling 1966). An excellent example of such an application was a nearly 20-km-long Southern Pacific trestle that crossed a portion of the Great Salt Lake in Utah. The trestle consisted of untreated Douglas-fir piling supporting a redwood superstructure. The first piles were driven in 1902, and support pilings were added in 1930. The trestle was supplemented and eventually replaced by a concrete causeway built adjacent

to it, but the original structure was used until 1978. In the late 1980s, wood in the trestle was salvaged. Most of the redwood was re-manufactured into lumber, but reuse of the Douglas-fir was limited by concerns about its durability and strength, especially because it had absorbed up to 11% salt by weight during exposure to the lake water. Preliminary trials indicated that the piles had lost some strength (Engineering Data Management 1983; Hoyle 1995). The effect of saltwater immersion on durability of wood has not been supported by substantial experimental data.

Submerging wood in fresh water for prolonged periods can lead to extensive bacterial attack and marked increases in permeability (Ellwood and Ecklund 1959). Repeated saltwater immersion followed by drying can re-

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sult in tracheid separation and bursting in the wood surface (Johnson et al. 1992), but the effects of this damage on durability are less clear. There is relatively little information on prolonged exposure in salt waters, primarily because marine borers rapidly destroy such materials (Zabel and Morrell 1992). Those organisms are absent from the Great Salt Lake, making a study of the effects of prolonged salt exposure on durability possible. We tested Douglas-fir from the Southern Pacific trestle for resistance to fungal decay and for the distribution and composition of absorbed salts.

#### MATERIALS AND METHODS

One cross section (50 to 100 mm thick) was cut from the formerly submerged zone of each of 10 Douglas-fir piles from the trestle. Series of 19-mm blocks were cut from each cross section in zones corresponding to sapwood, the outer heartwood nearest the sapwood, and the inner heartwood near the pith. For each cross section, 18 blocks were cut, 2 from the inner heartwood and 2 from each of the 4 cardinal points in the outer heartwood and sapwood. The blocks were oven-dried (54°C) to a stable weight and weighed (nearest 0.001 g). For each cross section, 9 blocks (1 from each position) were leached by impregnating them with distilled water, followed by soaking in a stirred-water bath for 6 h, then another stirred bath for 24 h (American Wood-Preservers' Association (AWPA) 1995). The leached blocks were then oven-dried and weighed again.

The leached and nonleached blocks were then placed in plastic bags that were exposed to 2.5 mrads of ionizing radiation from a Cobalt 60 source. The sterile blocks were then exposed in an AWPA soil block test using *Postia placenta* (Fr.) M. Larsen et Lombard (Isolate ATCC 11538) as the test fungus.

The identification, distribution, and relative quantification of salts in the wood were studied by removing 2 additional blocks from sites in 2 pile cross sections adjacent to where the decay test blocks had been removed. One set

of these blocks was subjected to the previously described leaching procedure; then all the blocks were oven-dried, placed on aluminum specimen holders, and carbon-coated.

Coated samples were then examined under an AMR 1000A scanning electron microscope (SEM); the accelerating voltage was 20 kv, the tilt was 30°, and the working distance was 12 mm. Samples were evaluated for the presence of various elements with a KEVEX System 7000 energy dispersive X-ray analyzer (EXDA). Samples were subjected to a full-field scan as well as to spot scans for specific elements; X-ray results from the leached and non-leached samples were then compared. To subtract background X-rays from those of sodium, chlorine, potassium, and sulfur in saltwater-exposed wood, we first determined the quantities of these elements in wood from the same zones of freshly cut Douglas-fir poles that had never been exposed to the Great Salt Lake.

#### RESULTS AND DISCUSSION

Weight losses from leaching alone ranged from 5.6% to 31.0%, reflecting both the high initial salt content of the wood and the ease with which such material can be removed by water (Table 1). Those salts would probably be lost rapidly in soil exposure, a use that was proposed for this wood.

We chose *P. placenta* for the soil block test because this fungus is a common inhabitant of decaying Douglas-fir piling above the water line and can cause substantial degradation of the heartwood (Graham and Corden 1980). Average weight losses from leached samples after exposure to *P. placenta* ranged from 3.3% to 16.7% (Table 1). The weight losses were relatively low, particularly for the sapwood, which has little or no natural durability (Scheffer and Cowling 1966). The exposure to salt and other materials clearly appears to have enhanced the durability of sapwood in a manner that resisted leaching. Heartwood durability did not differ markedly from that of the sapwood, however; this suggests that the salts

TABLE 1. Weight losses of Douglas-fir blocks associated with leaching and/or exposure to *Postia placenta* in an AWPA soil block test.

Pile cross-section	Wood weight loss (% <sup>a</sup> )												
	Sapwood				Outer heartwood				Inner heartwood				
	Leached		Non-leached		Leached		Non-leached		Leached		Non-leached		
	Non-fungal	Fungal	Total	Fungal	Total	Non-fungal	Fungal	Total	Non-fungal	Fungal	Total	Non-fungal	Fungal
A	17.1 (3.7)	6.7 (0.8)	23.8	21.9 (4.2)	23.3 (1.5)	9.6 (1.8)	32.9	25.9 (2.7)	21.4	9.7	31.1	23.5	23.5
B	24.3 (3.5)	12.5 (3.0)	36.8	24.6 (1.8)	24.1 (3.6)	7.2 (2.1)	31.3	26.1 (3.9)	26.0	7.9	33.9	27.8	27.8
C	21.7 (4.5)	8.6 (1.0)	30.3	22.5 (4.3)	24.1 (0.8)	11.0 (0.8)	35.1	26.0 (2.1)	24.2	10.8	35.0	23.1	23.1
D	29.3 (5.1)	5.9 (0.8)	35.2	27.7 (3.3)	22.3 (5.3)	5.7 (1.1)	28.0	22.8 (3.3)	8.9	3.3	12.2	8.1	8.1
E	21.7 (1.0)	7.7 (0.7)	29.4	23.8 (1.6)	17.1 (1.1)	10.4 (1.1)	27.5	18.0 (11.0)	5.6	7.2	12.8	7.3	7.3
F	8.9 (2.4)	9.3 (1.7)	18.2	10.5 (2.2)	14.1 (5.6)	5.5 (1.2)	19.6	14.2 (4.6)	11.8	4.2	16.0	13.0	13.0
G	15.8 (6.9)	16.7 (5.0)	32.5	27.0 (9.4)	13.1 (1.4)	12.7 (4.0)	25.8	22.5 (3.7)	8.8	11.8	20.6	15.6	15.6
H	23.5 (6.2)	7.9 (1.7)	31.4	26.7 (4.5)	26.2 (1.4)	7.8 (2.4)	34.0	28.4 (1.9)	31.0	8.7	39.7	33.6	33.6
I	25.6 (8.0)	11.0 (1.1)	36.6	27.7 (8.0)	18.4 (9.4)	7.6 (4.6)	26.0	22.9 (8.5)	15.7	5.7	21.4	22.5	22.5
J	19.6 (5.1)	10.4 (4.5)	30.0	18.9 (8.1)	11.7 (3.1)	5.5 (1.8)	17.2	12.7 (2.6)	14.2	9.0	23.2	15.0	15.0
Avg	20.8 (4.6)	9.7 (2.0)	30.3 (6.0)	23.1 (4.7)	19.4 (4.5)	8.3 (2.1)	27.7 (5.9)	22.0 (4.4)	16.8 (8.5)	7.8 (2.8)	24.6 (9.8)	19.0 (8.6)	19.0 (8.6)

<sup>a</sup> Values represent means of 4 blocks per section for the sapwood and outer heartwood; for the inner heartwood, values represent 1 block per section. Values in parentheses represent one standard deviation.



FIG. 1. Scanning electron micrograph of salt crystals within a bordered pit from sapwood of Douglas-fir (4000 $\times$ ) exposed to salt water.

did not confer additional protection to the already moderately durable heartwood. Therefore, prolonged immersion in salt water slightly improved the durability of sapwood and had little or no effect on the decay resistance of heartwood. This added durability might be useful for preventing the development of decay in service, although it is difficult to assess the benefits of such salt loadings when the risk of leaching is high. Applying an oil-based treatment to the sapwood might retard leaching loss and maintain the protection.

Weight losses for non-leached blocks ranged from 7.3% to 33.6% after exposure to *P. placenta* (Table 1). Non-leached blocks had markedly higher weight losses than did the leached blocks, although visual examination showed that fungal growth and damage were considerably greater on the leached blocks. This anomaly probably reflects the loss of salts from the non-leached blocks during the decay test. We sometimes noted that salt leaching from the non-leached blocks during the test killed fungi on the feeder strips.

Scanning electron microscope examination indicated the presence of salt deposits throughout the wood (Fig. 1). We detected elements including aluminum, calcium, chlorine, magnesium, silica, sulfur, and sodium. Element concentrations tended to drop slightly

TABLE 2. Relative abundance of sodium, chlorine, potassium, and sulfur in samples from Douglas-fir blocks cut from piling exposed in the Great Salt Lake, Utah.

Cross section zone	Concentration ratio <sup>a</sup>											
	Na			Cl			K			S		
	Unleached	Leached	%	Unleached	Leached	%	Unleached	Leached	%	Unleached	Leached	%
Sapwood	3.11	0.08	97.4	9.32	0.09	99.0	0.30	0.02	93.3	2.88	2.58	10.4
Outer heartwood	3.18	0.05	98.4	9.73	0.03	99.7	0.30	0.00	100.0	2.19	2.27	+3.7
Inner heartwood	2.82	0.21	92.6	8.35	0.02	99.8	0.27	0.00	100.0	2.09	2.26	+8.1

<sup>a</sup> Values represent an average of 3 replicates per position. Values were adjusted by removal of background levels and normalized to a non-exposed Douglas-fir sample. Percent (%) is the element loss attributed to leaching.

from the sapwood to the heartwood (Table 2). Levels were generally higher than those found previously (Hoyle 1995), but these differences may reflect the methodologies employed. The values should thus be used only for comparative purposes within this test. Salt crystals were virtually absent in leached wood. EDXA analysis of selected wood samples (Fig. 2) indicated that most of the crystals present con-

tained chlorine, sodium, potassium, and sulfur. Wood exposed to salt water appeared to contain high levels of sodium chloride and lesser amounts of potassium chloride. Leaching resulted in nearly complete losses of chlorine, potassium, and sodium (Table 2). Although EDXA examination showed elevated levels of sulfur and a strong odor of sulfur was emitted from fresh samples, the source of this element could not be determined. Sulfur appeared to be resistant to leaching (Table 2).

#### CONCLUSIONS

High loadings of salt resulting from exposure to the waters of the Great Salt Lake appeared to produce a slight, leach-resistant improvement in durability of Douglas-fir. Numerous crystalline deposits were found in nonleached blocks, but were nearly absent in leached wood. This suggests that the protective effect of these salts might be lost in wood exposed to prolonged leaching.

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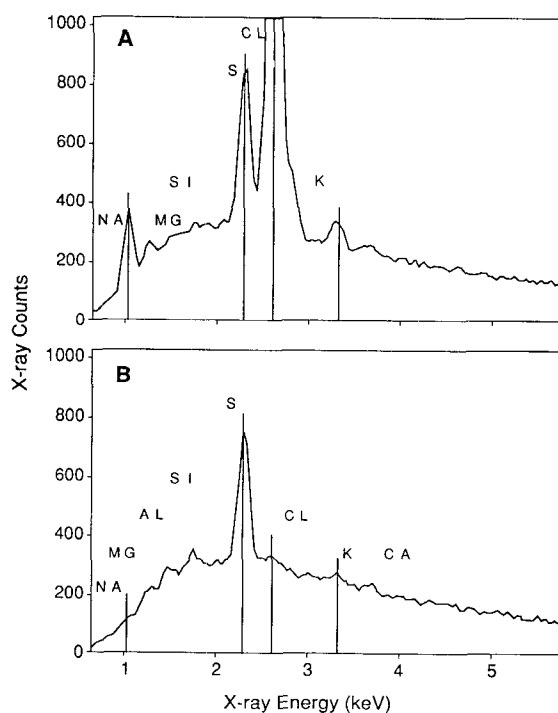


FIG. 2. Energy dispersive X-ray analysis of (A) non-leached and (B) leached Douglas-fir sapwood blocks showing qualitative changes in various elements (full-field scans at 20 $\times$  for 120 sec using 20 kV excitation and a 12-mm working distance).

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