Effect of Nitrogen and Vitamins on the Decay Rate of Pine Sapwood Exposed above Ground

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Abstract

A need exists to develop improved test methods for evaluating potential wood preservatives in aboveground outdoor exposure. Our studies have shown that the three-component lap joint specified in AWPA Standard E27-15 represents an improved design for aboveground testing. One option for evaluating the extent of decay with this method relies on visual assessment. However, based on my observations in field tests, this assessment method does not provide an accurate measurement of the extent of wood biodeterioration in the early stages of decay. A second method of evaluation provided in this standard (in figure 4 of the standard) uses bending stiffness and dynamic modulus of elasticity (MOE) as alternate methods for determining the extent of decay, and this option was chosen to follow the progress of biodeterioration in this study. It was found that both of these methods provided an accurate assessment of decay in the early stages of biodeterioration that was superior to visual assessment.

In an attempt to accelerate the rate of wood decay, some of the test units were treated with nitrogen-rich casein, and this resulted in a greater than twofold increase in the decay rate compared with the untreated controls. Another group of samples were treated with thiamin, but this resulted in only a slight increase in decay rate, whereas a combined treatment with both casein and vitamins resulted in a further increase in the decay rate beyond that of casein treated samples. Based on the results from this study, it is concluded that pretreatment of wood samples with thiamin has the potential for accelerating wood decay in aboveground test samples. Furthermore, the use of bending stiffness and dynamic MOE to measure the extent of wood decay was found to be superior to mass loss. Additional studies are needed to determine whether this concept could be useful in accelerating development of new wood preservatives.

The development of new or modified wood preservative systems is severely hampered because of inadequate test methods. Although current methods for evaluating the efficacy of wood preservatives provide valid data, the time required to obtain definitive results is extensive because reliable decisions on efficacy against wood decay organisms must rely on long-term field test data. To reduce the test time, it is necessary to develop field tests that optimize the wood decay process. In addition, improved quantitative and definitive methods are needed for detecting and measuring the extent of wood decay, as compared with the subjective visual rating system traditionally employed.

To biodegrade wood, fungi require nutrients and vitamins (Cochrane 1958). Thiamine and biotin are the critical vitamins required by many fungi (Zabel and Morrell 1992). With regard to nutrients, nitrogen is unquestionably the most important compound because substantial quantities are needed for synthesis of fungal proteins and other fungal cell constituents. Phosphorus is also important because a deficiency of this element limits the uptake of nitrogen by fungi (Rayner and Boddy 1987). Other major mineral elements required by fungi are potassium, magnesium, and sulfur. Trace amounts of iron, zinc, copper, manganese, and molybdenum are also required by fungi. Wood contains several mineral elements along with low levels of nitrogen (Zabel and Morrell 1992). Nitrogen is located primarily in living parenchyma cells (Cowling and Merrill 1966). The total amount of nitrogen present in wood is quite variable within as well as among wood species, ranging from 0.038 to 0.227 percent weight/weight (w/w) in softwoods and 0.051 to 0.106 percent w/w in hardwoods (Cowling and Merrill 1966).

Studies have shown that nitrogen levels influence the rate of wood decay. Cowling and Merrill (1966) demonstrated in lab tests that the rate of decay by *Gloeophyllum trabeum* and *Trametes versicolor* was twofold greater in wood rings that

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contained 0.149 percent nitrogen as compared with that from inner rings that contained only 0.044 percent nitrogen. Furthermore, Levi and Cowling (1969) showed that the decay rate of aspen by soft rot fungi could be accelerated fivefold to tenfold by pretreating wood with 2 percent casein hydrolysate.

Based on the above studies, it is apparent that wood decay rates in laboratory experiments can be accelerated by increasing nitrogen levels. However, it is not known whether increasing the wood nitrogen levels will increase the natural decay rate for larger test samples exposed in an aboveground outdoor environment. Consequently, the major objective of this study was to determine whether the pretreatment of test samples with a nitrogen-rich compound (casein hydrolysate) would accelerate the outdoor decay rate. Secondary objectives were to determine whether pretreatment of the wood with vitamins required by fungi would accelerate the decay rate and to determine whether definitive quantitative methods based on bending stiffness and dynamic modulus of elasticity (MOE) to determine the extent of wood decay are comparable to traditional visual subjective methods.

Experimental Methods

Twenty lap joints were manufactured from three defect-free, flat sawn spruce pine (*Pinus glabra* Walt) sapwood boards in accordance with figure 4 in AWPA Standard E27-15 (AWPA 2015). These are five component lap joints held together with two polyvinyl chloride pipe clamps. Each lap joint contained two sticks measuring 3 by 13 by 150 mm long, which were used for bending stiffness measurement. Each lap joint also contained two sticks measuring 12 by 26 by 150 mm long, which were used for the dynamic MOE measurements. The lap joints were randomly divided into four groups, providing five lap joints for each of the three treatments and the untreated controls. This provided 10 replicate sticks each for bending test and an additional 10 for the dynamic MOE evaluation for each of the three different treatments and the untreated controls. Details for the various treatments are shown in Table 1. Deionized water was used as a diluent for all three treatments. The test samples were treated by a full-cell process, using 15 minutes vacuum at –95 kPa followed by 30 minutes pressure at 1050 kPa. All chemicals were 99 percent pure and were obtained from Sigma Aldrich. Following treatment, the samples were air-dried prior to installation.

Prior to evaluating the first set of test samples designated for bending stiffness MOE before exposure, the samples were soaked in deionized water overnight to bring the moisture content up to approximately 50 to 60 percent, with separate containers used for each treatment to avoid cross contamination. They were then sealed in plastic bags and allowed to equilibrate for a minimum of 72 hours before further processing. These samples were evaluated for bending stiffness MOE on a small laboratory test apparatus capable of continuously recording stress/strain relationships. The samples were loaded to a deflection of 1.75 mm at a speed of 10 mm/min using a load span of 120 mm.

Table 1.—Treatment formulations and lap joint retentions achieved by pressure treatment.

Chemical concentration	Mean retention (% w/w)
Casein hydrolysate (0.002%)	0.280
Thiamin hydrochloride (0.0001%)	0.016
Biotin (N-Z Amine B) (0.0001%)	0.0014

The second set of samples designated for dynamic MOE testing were soaked overnight in deionized water to bring the moisture content up to around 50 to 60 percent, then they were placed in sealed plastic bags and allowed to equilibrate for a minimum of 72 hours before further processing. The samples were then tested for dynamic MOE with a Grindo-sonic MK 4-1 (Limmens-Elektronika N.V., Belgium). The sample supports were placed 33.6 mm (0.224 times length of sample) from each end of the sample. Immediately prior to testing, each sample was weighed on a balance. Several frequency measurements were made for each sample, with data from only those producing uniform values being recorded. Three of the untreated control samples produced erratic frequency values and were deleted from the experiment. The weight and frequency data were used to calculate the dynamic MOE of each component using the equation developed by Machek et al. (2001).

The lap joints were assembled with the plastic sleeves on each edge and exposed on a concrete pad at the Mississippi State University Forest Products Laboratory that had an overhead watering system. The watering system applied a fine mist of deionized water spray periodically to the test samples in order to maintain the moisture contents above fiber saturation, with a target moisture content in the range of 40 to 60 percent. The water spray was applied twice weekly during dry weather, with the sample moisture contents monitored by weighing selected samples.

The lap joints were removed from the test pad about every 3 months for evaluation. Prior to removal, water spray was applied to the samples to bring the moisture content up above fiber saturation. After removal, the lap joints were disassembled, and the test components were stored in plastic bags for a minimum of 24 hours to allow moisture equilibration. Following this, the two sticks in the upper part of the lap joints designated for dynamic MOE were weighed and then evaluated. The small sticks in the lower part of lap joint designated for bending stiffness were weighed and evaluated for bending stiffness. After completion of these tests, the lap joints were reassembled and returned to the pads for additional exposure. The experiment was run for approximately 18 months. After 532 days exposure, the lap joints were rated visually for decay in accordance with AWPA Standard E27-15 (AWPA 2015).

Results and Discussion

The data in Tables 2 and 3 clearly show that treatment of the wood with vitamins and casein enhance the wood decay rate in lap joints exposed above ground. Pretreatment of the wood with nitrogen-rich casein alone resulted in a greater than twofold increase in the decay rate compared with the untreated controls. In contrast, the addition of the vitamin thiamin resulted in only a slight increase in decay rate, whereas a combined treatment with both casein and the two vitamins resulted in a further increase in the extent of decay beyond that of the casein treatment. Visual observation of the decayed wood indicated that the wood biodegradation was mainly due to brown rot fungi.

Previous studies (Machek et al. 2001, Li et al. 2006) showed that the MOE of wood decreases rapidly as wood

Table 2.—Average percentage decrease in bending stiffness MOE for sticks in lap joints after progressive exterior exposure periods.[a]

Treatment	Exposure time (d)					
	85	174	298	386	459	532
Untreated	0.3	3.1	3.9	7.4	8.5	8.0
Thiamin	3.0	4.2	5.0	9.0	10.3	12.4
Casein	5.5	7.9	10.9	16.7	19.4	23.3
Thiamin + casein + biotin	3.1	7.5	9.3	15.5	18.9	26.4

[a] Mean values for 10 lap joint sticks.

Table 3.—Average percentage decrease in dynamic MOE for lap joint sticks after progressive exterior exposure periods.[a]

Treatment	Exposure time (d)					
	85	174	298	386	459	532
Untreated	4.0	3.5	4.3	5.9	8.7	9.2
Thiamin	4.8	3.9	6.8	8.0	9.6	9.8
Casein	7.0	7.7	10.3	17.3	23.2	23.7
Thiamin + casein + biotin	9.1	9.7	11.5	19.2	26.3	28.8

[a] Mean values for 10 lap joint sticks.

decay progresses. The results of this study provide further verification that both bending stiffness (Table 2) and dynamic MOE (Table 3) are good methods to assess the extent of wood decay. It is apparent from these data that the decreases in both MOEs are similar, but slightly greater MOE loss values were obtained from the dynamic MOE measurements. In addition to these two definitive methods of assessing the extent of decay, all the lap joints were subjectively evaluated visually for decay in accordance with AWPA Standard E27-10 (AWPA 2015) after the last exposure period (Table 4). From these data it is apparent that the mean visual ratings for each treatment group correlate reasonably well with the final mean MOE loss values. Furthermore, the data also suggests that a visual decay rating of 7—which is generally considered to represent the degree of decay to render a product non-serviceable—occurs when the MOE loss is approximately 30 percent.

A major problem with evaluating wood preservatives in aboveground applications is the lengthy exposure time it takes to obtain definitive results. Based on the data from this study, it appears that the addition of nitrogen to the test samples results in an acceleration of the decay process and may have potential for reducing the time required to evaluate wood preservatives for aboveground applications. However, the effect of added nitrogen on the efficacy of wood preservatives needs to be evaluated before this concept can be considered as a viable approach for accelerating the evaluation of wood preservative systems.

Table 4.—Mean visual decay ratings of all lap joints components after 532 days exposure.

Treatment	Visual rating[a]
Untreated	9.4
Thiamin	9.2
Casein	8.7
Thiamin + casein + biotin	7.6

[a] Rating in accordance with AWPA Standard E27-15 (AWPA 2015). With this system a "10″ represents no decay, with increasing degrees of decay down to a rating of 0, representing failure.

Conclusions

This study demonstrated that increasing the nitrogen level in wood enhances the rate of decay for test samples in aboveground exposure. Pretreatment of pine sapwood lap joints with casein increased the nitrogen level and resulted in a twofold to threefold increase in the rate of biodeterioration compared with the untreated controls. In contrast, pretreatment of the samples with the essential vitamin thiamin resulted in only a slight increase in the rate of decay. The assessment of decay by both bending stiffness and dynamic MOE provided comparable results and were more accurate than visual ratings.

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