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WEATHERING EFFECTS ON THE DECAY RESISTANCE OF CREOSOTE-TREATED OAK

Poo Chow and Dilpreet S Bajwa
Professor of Wood Science and Graduate Research Assistant
Department of Natural Resources and Environmental Sciences
University of Illinois, Urbana, Illinois

Abstract: The resistance to decay of wood represents an important aspect of the functional durability of wood products. A standard soil block culture method ASTM [D 2017-81] was used to test the decay resistance of creosote-treated Oak crossties. Two types of crossties , naturally aged and accelerating (artificially) aged were used in the experiment. Creosote treated oak crosstie samples from service ages of 0, 5, 15, 20, 25, 30 and 40 years was infected by brown and white-rot fungi. Changes in some physical properties provided decay resistance bench mark for materials. Results show that brown-rot caused greater change in weight-loss and some physical properties in naturally aged samples than white-rot. Weight-loss of 43 to 47 percent, thickness-change from 2.35 to 17.83 percent, volume change from 6.89 to 28.51 percent and density change from 3.26 to 26.40 percent were observed. Naturally aged samples were found to be more susceptible to fungal attack as compared to artificially aged ones. Creosote content ranged from 3.41 pcf to 8.55 pcf. Type of fungus and number of cycles contributed significantly in the deterioration of the physical properties of wood. Relationship between the weight-loss and the creosote retention exists. On the basis of decay resistance, six cycles of this laboratory accelerated weathering or aging technique may be equivalent to more than 20 years of natural weathering on railroad track. This cyclic aging technique can be used as a quality control method in the development of oak crosstie products.
Keywords: Accelerated aging, Biodegradation; Brown-rot, Creosote Content; Decay White-rot; Red oak.

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Introduction

Wooden crossties occupy a significant place in timber usage throughout the world. They have been in service since 1831 (Bescher, 1977). Primarily they have been used in US either in the rail road industry or in the bridge construction. The chemically treated crossties account for more than 30 percent by volume of treated wood products which measures to 500 million cubic feet (14.16m3). It accounts for 1.46 billion dollars of merchandise annually. The major factors contributing to its degradation of treated oak rail road crossties are splitting, decay and other mechanical factors. Decay accounts for almost 12.2 percent of total ties removed every year. It is shown that the biological factors primarily fungi cause a significant effect on the service life of crossties (Bescher, 1977; Hope, 1983; Masters, 1982; USDA, 1973). Previous studies show that 43.6 percent of wood crossties were removed from track due to decay (Russel, 1986). Most of the fungi penetrate the material through a check associated with incision in the wood. Brown-rot and white-rot fungi are mainly associated with crossties decay.

Creosote constitutes as major preservative in treating rail road crossties and has been in use since 1838. Wide range of weight-loss among the samples infected by brown-rot fungi has been observed . It has been observed that brown-rot fungi like Lentinus lepidus and *Poria vaporaria* and *Coniophora cerebella* can grow in the presence of creosote (CartWright et al., 1958). Wood having creosote less than 2 lbs per

cubic foot is easily decayed by brown-rot (Hartley, 1958). Creosote content vaporizes with time in the natural environmental conditions (Reginald, 1972). Its content ranges from 4.4-13.6 Pcf for 15-20 years sample (Schmitz et al., 1937 and 1941). Creosote is also found to be biodegradable thereby making wood more susceptible to attack by fungi.

The objectives of this study were to compare the rate of decay of naturally-aged and artificially aged red oak (Quercus rubra) crossties against the brown and white-rot decay fungi. Secondly to estimate the amount of creosote present in these crossties.

Methodology

1. Materials and Methods

Red Oak (*Quercus Spp.*) railroad crossties were selected from Norfolk Southern Railroad track at Sadorus, Illinois and used for the experiment. These crossties represented service ages of 0, 5, 15, 20, 25, 30 and 40 years. The artificially accelerating-aged samples were taken from new red oak crossties which were pressure treated using creosote coal tar (60/40). The test samples were taken from each cycle of accelerated aging process. The artificial aging test consisted of six cycles, each cycle consisting of the following procedure (Chow et al., 1986 and 1987):

1. 30 minutes under water and 25 inch (63.5 cm) vacuum.
2. 30 minutes under water and 170 psi (1.75 kg/cm²) pressure.
3. 3 hours in a 0/F (-17.8/C) freezer.
4. 10 hours of steaming at 250/F (121/C) and 15 psi (103.4 kPa).
5. 9.5 hours of oven drying at 220/F (104/C), and
6. 22 hours of conditioning at 70/F or 21/C and relative humidity of 90 percent.

Test samples from each age group and cycle were taken from the top 50 mm section of these crossties. Samples with dimension 25x25x9 mm were taken from the clear, and defect free two locations, top (surface 0-25mm) and bottom (surface 25-50mm). The samples were air dried and after conditioning them to constant weight they were weighed accurately in the laboratory and then transferred into the test bottles maintained at 26.1±1°C and relative humidity of 70±4%. Two type of fungus, white-rot (*Polyporous versicolor* L.ex.Fr.) ATCC No. 12679 and brown-rot (*Postia placenta* (Fr). Cke. ATCC No. 11538 were used to study the efficacy of creosote against the decay. Standard method of accelerated laboratory test of natural decay resistance of wood (ASTM D2017-96) was used in the study (ASTM, 1996). Reference blocks were made of sweetgum. There were eight replications for each sample. The decay test was terminated after 14 weeks when the reference blocks obtained a weight-loss of 60 percent. Mycelium was brushed off and test samples were air dried and again conditioned to constant weight. The weight was recorded for each sample. The difference in weights of samples before and after the decay test gave the rate of decay in test samples.

2. Creosote Concentration

The creosote content in the test block was analyzed by using AWPA (American Wood Preserver's Association) standard A6-96, a method for the determination of oil type preservative and water in wood (AWPA, 1996). Test blocks weighing more than 5 grams were reduced to shaving chips or shivers and weighed accurately to 0.001gm. Xylene solvent was used to extract creosote. The samples were refluxed in a special apparatus for about 6 hours. The water present in the chips was collected in the water trap. Chips were dried for 90 minutes in oven at 125°C and weighed accurately. The difference in the weight of the test samples before and after refluxing and volume of water gave the amount of creosote present in the samples.

Results and Discussions

1. Weight-loss

Tables 1 and 2. show the weight-loss of naturally-aged and artificially accelerating-aged samples infected by both brown and white-rot fungi. It is clearly evident from the results that brown-rot attacks the creosote treated wood more vigorously than white-rot. The weight-loss was found to be higher for older aged samples. In Table 1, the average weight-loss for artificially accelerating-aged samples varied from 3.67 percent for cycle one samples to

11.48 percent for cycle six samples infected by white-rot. The brown-rot fungus caused an average weight-loss from 5.13 percent to 14.97 percent for the artificially aged samples. It was observed that the average weight-loss was slightly more for samples taken from bottom location of crosstie in white-rot test. However, Table 5 shows that the location did not significantly affect the weight-loss of samples according to the statistical analysis.

As shown in Table 2, the naturally-aged samples exhibited an average weight-loss from 6.83 to 47.38 percent. White-rot fungus caused weight-loss from 6.83 percent for 5 years old oak crosstie sample to 24.95 percent for 40 years old samples. In case of brown-rot, the average weight-loss ranged from 11.26 percent (5 year old) to 47.38 percent for 40 year old samples. However it was observed that the brown-rot infected 30 and 40 years old samples from bottom location showed greater weight-loss. It was noted that there was drastic change in weight-loss between 25 and 30 years old age samples. In the artificially-aged sample, the effect of both aging cycle and fungus type on weight-loss was significant as shown in Table 5. Table 6. shows that the crosstie age, fungus type, sample location and age x fungus interaction were found to be significant factors in influencing the weight-loss of naturally aged oak crosstie samples.

2. Thickness Change

Decayed wood exhibited a various degree in thickness change. The decay resistant wood generally shows a minimal thickness change. Fungus *Poria placenta* caused more change in thickness than *Polyporous versicolor*. Tables 3 and 4. show the mean change in the thickness of samples infected by fungus *Poria placenta* and *Polyporous versicolor*.

The naturally-aged samples showed more change in thickness as compared to the artificially-aged sample. For naturally-aged oak crossties, *Poria placenta* infected samples exhibited thickness reduction from 2.35% to 17.83% and *Polyporous versicolor* showed thickness change from 2.42% to 10.07%. The maximum change in thickness (17.80%) was observed in 40 years samples infected by *Poria placenta*.

Table 3. shows thickness reduction in artificially-aged sample. It varied from 0.38% to 8.06%. The maximum change in thickness was observed for sample representing cycle two (8.06%) infected by fungus *Polyporous versicolor*.

Brown-rot infected samples created more change in thickness than white-rot which was further supported by the other studies on the nature of decay by *Poria placenta* (Schmitz, 1945 and Schulze, 1948). In case of naturally-aged oak crossties thickness change was significant for Age, Fungus, Age x Fungus. Only Fungus and Fungus x Location were significant for artificially-aged crossties (see Table 5 and 6).

3. Volume Change

Decayed wood shows volume change or shrinkage in drying. The dimension changes were more pronounced for *Poria placenta* as compared to *Polyporous versicolor*. As wood is hygroscopic and sensitive to moisture. It was hard to get accurate measurement, as some of samples were found to be deformed, brittle and collapsed.

Tables 3 and 4. show the mean volume change in the samples attacked by fungi. The volume change for naturally-aged samples was considerably more than the artificially-aged sample. The *Poria placenta* infected samples exhibited more change in volume than the samples infected by *Polyporous versicolor.*

The naturally-aged samples, as shown in Table 4, had the average change ranging from 1.48% for 5 year to 28.51% for 40 year old samples. A drastic volume change from 25 year to 30 and 40 year old samples was observed. The *Poria placenta* was capable of reducing the volume of oak crosstie samples up to 28.51 percent whereas the *Polyporous versicolor* accounted for a maximum volume reduction of 16.08 percent for the naturally-aged oak crosstie samples.

In Table 3, the artificially accelerated-aged samples showed the volume change ranging from 1.00% to 10.18%. Samples subjected to 5 cycles of artificially aging and tested using *Poria placenta* showed a maximum change of 10.18%.

Table 5. indicates that the artificial aging cycle and fungus type were significant factors in affecting volume change for accelerated-aged samples whereas for the naturally-aged service age, fungus type, Age

xFungus and sample location were significant factors.

4. Density Reduction

Density changes were also recorded for all samples. Wood decay generally leads to the destruction of this woody mass and making it less dense. The destruction of this woody mass, leads to change in density. As density is a function of mass and volume hence the density change for samples infected by brown and white-rot varied. Tables 3 and 4, show the mean change in density of the samples. Naturally-aged samples showed density reduction in the range from 3.26% to 26.40% infected by fungus *Poria placenta* whereas in artificially-aged samples, the density was reduced from 2.48% to 7.26% by the same fungus. The density reduction for control samples was less than one percent.

It was observed that fungus *Poria placenta* reduced density of oak samples more than the *Poly-porous versicolor*. Artificially-aged samples exhibited lower density change than the naturally-aged samples. Density was reduced drastically in naturally-aged from 25 years old sample onwards. Density change for artificially-aged samples didn't show much fluctuation. Only the aging-cycle number was found to be significant for accelerated-aged crossties whereas for naturally-aged crossties variables of Age, Fungus, and Age x Fungus were significant (Table 5 and 6).

5. Creosote Retention

Table 7. shows the amount of creosote present in the test samples. It ranged from 5.31 Pcf to 8.55 Pcf in the artificially accelerated-aged samples. There was a gradual decrease in the average creosote content from cycle one to cycle six. Cycle one samples from bottom location had an average of 8.12 Pcf of creosote content where as the bottom location of cycle five samples showed a 5.31 Pcf of creosote content. In case of naturally-aged samples, the average creosote content ranged from 3.41 Pcf to 8.60 Pcf. The 40 year old samples from the bottom location were found to have a 3.41 Pcf of creosote retention and 5 year samples from the top location had a 4.39 Pcf of creosote retention. It is clearly evident from Table 7. that creosote amount decreases with age and this can be attributed to the environmental and natural weather degradation of creosote with time. Moreover it was discovered that creosote content vaporizes with time (Reginald, 1972). From Tables 1, 2 and 7, a clear relationship can be established that the weight-loss is a function of the amount of creosote present in the oak crossties samples.

Conclusions

This study clearly demonstrates that naturally-aged samples are more susceptible to decay than artificially-aged samples. Brown-rot can cause considerable damage to creosote treated wood in the natural weathering with age on track service condition (47.38%). White-rot is observed to be less aggressive on the creosote treated oak crosstie. Weight-loss sharply increased after 25 years of on track service in naturally-aged samples. Similarly brown-rot fungus caused considerable thickness, volume and density reduction in naturally-aged samples as compared to artificially accelerating-aged samples. The process of laboratory artificial-aging did not significantly change the amount of creosote content present in the samples as much as that in naturally-aged samples in which the creosote decreased with time. There is a clear relationship between the weight-loss and the amount of creosote present in the samples. Furthermore, higher creosote content generally prevents samples from weight-loss in wood infected by wood deteriorating fungi.

Based on the data collected on the biode-gradation or decay resistance (weight-loss), and the creosote retention in this study, six cycles of this laboratory accelerated aging technique may be equivalent to more than 20 years of natural weathering on rail road tracks. The results of this study agree to that of a previous study using mechanical properties to relate artificial accelerated and natural aging of oak crossties (Chow et. al., 1987). It can be concluded that this laboratory cyclic accelerated weathering technique can be adopted as a routine quality control method to predict the long term in service decay resistance performance of creosote treated oak crossties as well.

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Table. 1

Mean Values of Percent Weight-loss of Artificially-aged samples by *Poria placenta* and *Polyporous versicolor*

	Poria placenta		*Polyporous versicolor*	
Artificial Aging Cycles	Bottom	Top	Bottom	Top
Control (0)	1.14	3.91	4.17	2.72
Cycle 1	5.13	6.41	4.51	3.67
Cycle 2	8.70	8.82	6.50	6.38
Cycle 3	9.43	12.28	7.70	6.77
Cycle 4	14.29	11.20	10.95	9.94
Cycle 5	14.97	12.82	11.48	10.65
Cycle 6	13.86	12.79	11.17	10.69

Note: Each value is an average for seven samples.

Table. 2

Mean Values of Percent Weight-loss of Naturally-aged samples by *Poria placenta* and *Polyporous versicolor*

	Poria placenta		*Polyporous versicolor*	
Natural Age	Bottom	Top	Bottom	Top
Control (0)	4.14	3.91	4.18	2.73
5 Year	11.26	14.32	6.83	8.12
15 Year	11.74	12.73	10.62	11.60
20 Year	14.57	14.89	11.93	12.79
25 Year	19.43	22.09	13.43	14.65
30 Year	40.21	30.83	10.97	14.64
40 Year	47.38	43.05	24.81	24.95

Note: Each value is an average for seven samples.

Table. 3

Mean Values of Percent Thickness Change of Artificially-aged samples by *Poria placenta* and *Polyporous versicolor*

	Poria placenta		*Polyporous versicolor*	
Artificial Aging Cycles	Bottom	Top	Bottom	Top
Control (0)	-1.31	-1.80	-7.69	-1.46
Cycle 1	-2.12	-1.60	-0.38	-2.02
Cycle 2	-2.19	-3.80	-8.06	-1.61
Cycle 3	-3.22	-1.18	-6.40	-3.15
Cycle 4	-1.01	-3.69	-3.99	-4.72
Cycle 5	-3.00	-3.33	-3.09	-3.57
Cycle 6	-1.98	-2.82	-2.80	-4.51

Note: Each value is an average for seven samples.

Table. 4

Mean Values of Percentage Thickness Change of Naturally-aged samples by *Poria placenta* and *Polyporous versicolor*

	Poria placenta		*Polyporous versicolor*	
Natural Age	Bottom	Top	Bottom	Top
Control (0)	-1.31	-1.80	-7.69	-1.47
5 Year	-3.84	-2.35	-2.95	-2.85
15 Year	-5.84	-4.83	-3.89	-2.78
20 Year	-5.14	-4.45	-5.55	-7.45
25 Year	-3.83	-7.14	-8.56	-10.07
30 Year	-11.90	-6.30	-3.45	-2.42
40 Year	-17.28	-17.83	-6.75	-5.91

Note: Each value is an average for seven samples.

Table. 5

Factorial Analysis for Artificially-aged Oak Crossties

Independent Variables	Dependent Variables			
	Weight-loss	Thickness Change	Volume Change	Density Change
Cycle No.(7)a	S [b]	NS[c]	S	S
Fungus(2)d	S	S	S	NS
Cycle No.x Fungus	NS	NS	NS	NS
Loc(2)e	NS	NS	NS	NS
Fungus x Loc	NS	S	NS	NS

a.- Aging cycle number was seven including control condition.
b-S- Significant at a five percent level.
c- Not significant at a five percent level.
d- Fungus- Two levels of fungus (*P.placenta* and *P.versicolor*).
e- Location- Two levels of location.

Table. 6

Factorial Analysis for Naturally-aged Oak cross-ties

Independent Variables	Dependent Variables			
	Weight-loss	Thickness Change	Volume Change	Density Change
Age(7)a	Sb	S	S	S
Fungus(2)c	S	S	S	S
Age x Fungus	S	S	S	S
Loc(2)d	S	NSe	S	NS
Fungus x Loc	NS	NS	NS	NS

a.- Actual crossties age level.
b-S- Significant at a five percent level.
c- Fungus- Two levels of fungus(P.placenta and P.versicolor).
d- Location- Two levels of location.
Not significant at a five percent level.

Table. 7

Estimation of Creosote for Naturally-aged and Artificially-aged Oak Crossties

Natural Service Age on track	Sample Location	Creosote Content Pcf a	Artificial Aging-Cycle	Sample Location	Creosote Content Pcf
Control	Top b	7.20	Control	Top	7.20
Control	Bottom	8.55	Control	Bottom c	8.55
5 Year	Top	4.39	Cycle 1	Top	7.00
5 Year	Bottom	6.13	Cycle 1	Bottom	8.12
15 Year	Top	8.60	Cycle 2	Top	7.25
15 Year	Bottom	6.34	Cycle 2	Bottom	6.59
20 Year	Top	6.84	Cycle 3	Top	7.91
20 Year	Bottom	4.52	Cycle 3	Bottom	7.21
25 Year	Top	5.13	Cycle 4	Top	6.01
25 Year	Bottom	5.03	Cycle 4	Bottom	6.56
30 Year	Top	5.00	Cycle 5	Top	6.38
30 Year	Bottom	4.02	Cycle 5	Bottom	5.31
40 Year	Top	3.82	Cycle 6	Top	5.53
40 Year	Bottom	3.41	Cycle 6	Bottom	6.59

Note:

a - Pounds per cubic foot (Each value is an average of seven tests).

b - 0-25 millimeter from surface.

c - 25-50 millimeter from surface.