COMPARISON OF LABORATORY AND FIELD METHODS TO EVALUATE DURABILITY OF PRESERVATIVE-TREATED SHAKES

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(Received November 1993)

ABSTRACT

Environmental concerns and life-cycle requirements of treated wood products require methods that define the minimum amount of preservative that will be needed to protect products in use. This study illustrates the relative merits of three methods that are used to evaluate the durability of treated wood shakes. Severity of challenge from decay fungi is greatest in laboratory soil jar methodology, next greatest is in field modules composed of stacked shakes, and least is in shakes exposed on small sections of roof decks in the field. Small sections of roof decks allow assessment of stability, color, and other weathering characteristics. Modules of stacked shakes allow opportunities to design field experiments to evaluate effectiveness of preservatives with a test unit that is conducive to decay.

Keywords: Preservative, shakes, wood decay.

INTRODUCTION

Treated wood products are expected to remain durable (in-service) for lengthy periods. Increased environmental concerns and life-cycle requirements of treated wood products, from manufacture through disposal or reuse, require methods and protocols that define the minimum amount of preservative that is needed to ensure a prescribed performance.

The objective of this study was to illustrate the relative merits of three different methods to evaluate the durability of treated wood shakes. This study was part of a larger investigation on treated wood shakes that were manufactured from several species of trees in the western United States.

MATERIALS AND METHODS

Results from the laboratory soil jar method and two field methods were compared using waterborne and oilborne preservatives (Table 1). The same range of preservative retentions could not be used with all methods, but comparable retentions were used in different assays. The total array of results provided an opportunity to evaluate the attributes of different methods.

When possible, comparisons of results from different methods were made with one species, either western hemlock (*Tsuga heterophylla* (Raf.) Sarg) or Pacific silver fir (*Abies amabilis* Dougl. ex Forbes). Tapersawn shakes, 11/16 to 13/16 in. (1.7 to 2.1 cm) thick and either 18 or 24 in. (45.7 or 61.0 cm) long, were cut from butt logs of old growth trees that were harvested from the Puget Sound Peninsula in Washington.

Throughout this study, preservative treatment of shakes was accomplished by the full-cell process with an initial vacuum for 30 or 60 min, followed by 125 lb/in.^{2} (851 kPa) of pressure for 120 min. Prior to treatment, shakes were dried to 12% or less moisture content. With copper octoate (CuOct), a petroleum solution containing 1% metal was diluted in toluene to achieve desired concentration of the

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Wood and Fiber Science, 26(3), 1994, pp. 306–314

TABLE 1. *Preservatives used in decay tests of treated wood shakes.*

Preservative	Code[a]	Description
An ammoniacal copper/quaternary ammonium compound (CuO/DAC)	2	An ammoniacal, waterborne preservative. The quaternary ammonium component is octydecyldimethyl ammoniumchloride. The CuO:Quat ratio is 1:1.
Didecyl dimethyl ammonium chloride plus 3-Iodo-2-propynyl butyl carbamate (DDAC/IPBC)	3	A patented aqueous mixture of DDAC and IPBC in a ratio of 8.5 to 1.[b]
Copper octoate (CuOct)	13	Solution in petroleum carrier A (paraffinic oil)
Copper octoate (CuOct)	25	Solution in petroleum carrier D (naphthenic oil)
Control	16	Untreated

[a] The same code number was used for each preservative in a series of experiments. Code numbers are included, out of sequence, to aid the reader in cross referencing with Tables 4 to 7 of this report and to compare results from this investigation with that from other studies.
[b] Ward 1990.

treating solutions. The petroleum carriers were hydrotreated paraffinic and naphthenic distillates (Table 2).

At time of treating, several species may have been included in one charge. Furthermore, shakes destined for different evaluations may have been treated in the same charge. Thus, charge numbers are listed throughout this paper.

Following treatment, 10 or 20 shakes of each species per charge were randomly selected for decay studies or chemical analyses. Decay studies were conducted using only 10 shakes per species per charge. For analyses intended to provide a technical reference of actual retentions, all slices from each of the 10 shakes per treatment/retention/species were combined and processed for chemical analysis.

When the shakes had dried, samples from the entire cross section of the shake were removed, 5.5 to 6.0 in. (14.0 to 15.2 cm) from the butt end, and were ground in a Wiley mill to pass a 30-mesh screen. In doing this, three ⅛-in.- (3.1-mm-) thick slices were cut from the entire cross section of each shake. Slices were cut in consecutive order, starting 6 in. (15.2 cm) beneath the butt and moving towards the butt end. The ground wood was analyzed using either atomic absorption spectroscopy (AWPA 1991) for metals or high pressure liquid chromatography (HPLC) for organics (AWPA [in press]).

Retentions determined by chemical analysis were reported on a weight/volume basis, that is, pounds per cubic foot (pcf). Wood densities were accepted as published in AWPA Standard A12 (AWPA 1992a) or computed using specific gravities as published for green material in Table 4-2 of the Wood Handbook (Forest Products Laboratory 1987). Retentions for an ammoniacal copper/quaternary ammonium compound (CuO/DAC) and didecyl dimethyl ammonium chloride plus 3-Iodo-2-propynyl butyl carbamate (DDAC/IPBC) were reported for total active ingredient. Retentions for CuOct were reported on the basis of metal per unit of wood.

In the laboratory experiments, cross sections of entire shakes were subjected to attack by a wood decay fungus in a soil jar method similar to that previously used by Wilcox (Wilcox 1980). In the first experiment, the entire cross section, 6.0 to 6.5 in. (15.2 to 16.5 cm) from the butt end, was cut from each of 10 randomly selected shakes per species and treatment combination. These cross sections were exposed to attack by *Gloeophyllum trabeum* (Pers. ex. Fr.) Murr. [Madison 617, /ATCC No. 11539], following the procedures of ASTM, Testing Wood Preservatives by Laboratory Soil Block Cultures (ASTM 1986). However, 1-qt (0.95-liter) jars were used, not 8-oz (225-cm^3) jars as noted in the ASTM method. The jars were laid horizontally, and 150 g of soil was loaded into each jar. This amount of soil was sufficient to cover the bottom of each jar. Elongated feeder

TABLE 2. *Physical properties of petroleum carriers used in pressure treatment of shakes with CuOct.*

	ASTM method	Petroleum[a]	
		Paraffinic oil	Naphthenic oil
Viscosity index	D2270	73	
Viscosity CST at 40 C	D445	4.02	
Viscosity SUS at 100 F	D2161	40.0	108
Viscosity CST at 100 C	D445	1.41	
Viscosity SUS at 210 F	D2161	30.8	38.2
Flash Point, COC, F/C	D92	260/126	340/171
Color	D1500	<0.5	0.5
Gravity, deg API	D287	32.5	25.0
Density at 15 C, kg/dm^3	D1298	0.8625	
Pound/gallon	D1250	7.18	7.53
Aniline Point, F/C	D611	156/69	160/171
Viscosity—Grav const	D2501	0.856	0.866
Molecular weight	D2502	204	300
Refractive index	D1747	1.4728	1.4950
Aromatics (%)	D2007	23.0	36.6
Saturates (%)	D2007	76.9	61.4

strips were placed on top of the soil, and water was added to bring the moisture content of the soil to 130% of the water-holding capacity. Processing of the decay chambers (jars) was in accordance with ASTM D 1412 (ASTM 1986). Entire cross sections from one or two shakes, treated with the same preservative and retention, were incubated in each jar. Cross sections were not leached prior to incubation. If the cross section was too long to fit inside the jar, the cross section was broken in half and then inserted into the jar. Cross sections in the jars were exposed to decay fungi for 16 weeks.

In the second experiment, shakes were cut to a constant width prior to treatment. Following treatment, similar cross sections were removed from shakes, then decayed for 12 weeks in 8-oz (225-cm^3) soil block jars (De Groot [in preparation]). With both experiments, amount of wood lost to decay during this time was expressed as a percentage of the initial weight.

Two methods of exposure were used in the field. In the first method, treated shakes were exposed in 10 replicate modules, each composed of 4 shakes stacked upon each other in alternating directions (Fig. 1). This assembly provided an internal, horizontal interface and two interfaces on a slight incline. Modules of shakes treated with CuO/DAC and DDAC/IPBC were installed in the field February 1988; modules of shakes treated with CuOct were installed in the field June 1988.

In the second field method of exposure, treated shakes were placed on small decks that simulated exposure on a roof (Fig. 2). Roof decks were 3⅓ ft wide by 4½ ft long (1.0 by 1.3 m). Construction details were those described in paragraph 5 of ASTM E 108, Fire Tests of Roof Coverings (ASTM 1989), with the following exceptions or options:

TABLE 3. *Decay rating criteria.*

Decay rating	Condition
0	Wood bright, no discoloration or suspicion of decay
1	No decay suspected, wood discolored
2	Decay suspected
3	Evidence of decay present; decay evidenced by fruiting bodies or small spots of decayed wood
4	At least 10% but less than 50% of wood decayed
5	At least 50% but less than 75% of wood decayed
6	At least 75% of wood decayed
7	Destroyed by decay, item can be easily broken

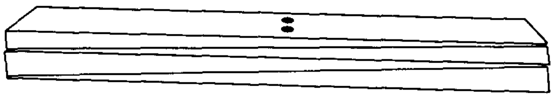

FIG. 1. Side view of experimental module composed of four shakes, bolted together. Modules rested upon horizontal support in an open field.

Southern pine lumber, pressure treated with chromated copper arsenate (CCA), was substituted for No. 1 white pine lumber as framing material.

Decks were constructed of nominal 1- by 4-in. (25- by 100-mm) lumber, spaced a minimum of $1\frac{5}{8}$ in. (4 cm) apart and securely nailed to two nominal 2- by 4-in. (50- by 100-mm) wood battens.

Shakes were fastened to the decks with stainless steel, power-driven staples. Shakes and shingles were applied from left to right within each row.

Test roof decks were positioned with a 4-in-12 slope, facing south, exposed to full sunlight in an open field in the Harrison Experimental Forest near Saucier, Mississippi. Shakes treated with CuO/DAC and DDAC/IPBC were 18 in. (45.7 cm) long, installed with a $5\frac{1}{2}$-in. (13.9-cm) weather exposure, and had no felt interlayment. Decks with these shakes were placed in the field February 1988. Shakes treated with CuOct were 24 in. (60.9 cm) long and installed with a 7.5-in. (19.0-cm) weather exposure; these treated shakes were installed in the field June 1988. All field evaluations reported in this paper were made January 1993.

Evaluation of decay in the experimental field modules was based on the most severely decayed shake within each replicate module. Decay evaluation represented an overall assessment of shakes in the deck. The same measurement criteria for decay were used for the modules and roof decks (Table 3).

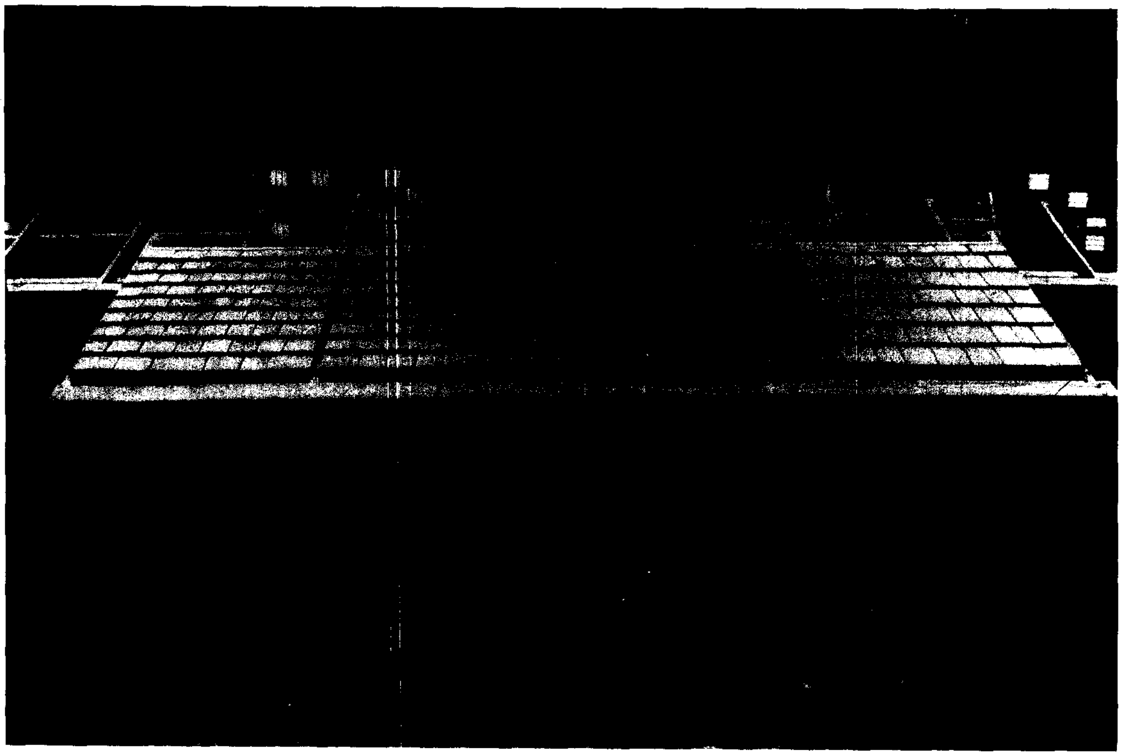

FIG. 2. Test decks of treated shakes on support rack in an open field.

TABLE 4. *Performance of western hemlock shakes treated with a waterborne formulation containing DDAC/IPBC.*

Test	Preservative[a]	Code[b]	Charge	Retention (pcf)[c] Target	Retention (pcf)[c] Analyzed	Weight loss[d] (%)	Decay rating[e]
16-week laboratory soil jar	DDAC/IPBC	3	359	0.33	0.24	1.71	
	DDAC/IPBC	3	461	0.33	0.26	2.65	
	DDAC/IPBC	3	361	0.49	0.25	1.33	
	Control	—	—	—	—	44.29	
59-month open field module	DDAC/IPBC	3	345	0.03	0.03		1.2[f]
	DDAC/IPBC	3	347	0.09	0.08		1.0[f]
	DDAC/IPBC	3	355	0.16	0.13		1.0[f]
	DDAC/IPBC	3	359	0.33	0.24		1.0[f]
	DDAC/IPBC	3	361	0.49	0.25		1.0[f]
	DDAC/IPBC	3	349	0.66	0.36		1.0[f]
	Control	16	—	—	—		6.0[f]
59-month open field simulated roof deck number:							
4007	DDAC/IPBC						
4008		3	355	0.16	0.13		1
4010	DDAC/IPBC	3	359	0.33	0.24		1
4000	DDAC/IPBC	3	361	0.49	0.25		1
	Control	16	—	—	—		3

[a] See Table 1.
[b] See Table 1.
[c] 1 pcf = 16 kg/m^3.
[d] Average of 10 observations.
[e] See Table 3 for decay rating.
[f] Average of 10 observations; each observation represents the most advanced decay observed in any 1 of 4 shakes in each replicate stack.

RESULTS

No evidence of decay was observed on western hemlock shakes treated with DDAC/IPBC and exposed on roof decks. Retentions in shakes installed on the roof decks ranged from 0.13 to 0.25 pcf (2.1 to 4.0 kg/m^3) of active ingredient (Table 4). Retentions of DDAC/IPBC in shakes exposed in modules ranged from 0.03 to 0.36 pcf (0.5 to 5.8 kg/m^3). In field modules, decay was slightly indicated only in western hemlock shakes treated to 0.03 pcf DDAC/IPBC.

In soil jar tests with cross sections of treated shakes, the least decay occurred in shakes treated with DDAC/IPBC. Shakes from treating charges 359 and 361 were used for roof decks, field modules, and soil jar studies. No evidence of decay was seen on these shakes when exposed in the field. Less than 2% weight loss was observed in soil jar studies with shakes from these charges. This was regarded as operational error and not evidence of serious decay. Response to chemical indicators indicated that uniform, thorough penetration of the entire cross section of the western hemlock shakes was achieved in charge 361. Pockets of decay were not observed in cross sections of these shakes after incubation in soil jars. Another charge (461) was treated to a similar retention, but results with chemical indicators suggested that the preservative was not uniformly distributed through the cross sections of these shakes. Small pockets of decay developed in cross sections of these shakes during the soil jar decay tests. Nevertheless, the percentage weight loss due to decay was less than 3% (Table 4).

Substantial suppression of decay in cross sections of treated shakes was also achieved with the formulation of CuO/DAC (Table 5). Thorough penetration of preservative was achieved in treating charges 470 (0.25 pcf) and 477 (0.35 pcf). No evidence of decay was seen in shakes from these charges when installed on

TABLE 5. *Performance of western hemlock shakes treated with CuO/DAC.*

Test	Preservative[a]	Code[b]	Charge	Retention (pcf)[c] Target	Retention (pcf)[c] Analyzed	Weight loss[d] (%)	Decay rating[e]
12-week laboratory soil jar	CuO/DAC	2	424	0.60	0.53	2.74	
	CuO/DAC	2	477	0.45	0.35	7.84	
16-week laboratory soil jar	CuO/DAC	2	470	0.30	0.25	14.56	
	CuO/DAC	2	477	0.45	0.35	6.2	
	Control	16	—	—	—	44.29	
59-month open field module	CuO/DAC	2	421	0.03	0.01		2.0[f]
	CuO/DAC	2	422	0.07	0.06		1.0[f]
	CuO/DAC	2	434	0.15	0.10		1.0[f]
	CuO/DAC	2	470	0.30	0.25		1.0[f]
	CuO/DAC	2	477	0.45	0.35		1.0[f]
	CuO/DAC	2	424	0.60	0.53		1.0[f]
	Control	16	—	—	—		6.0[f]
59-month open field simulated roof deck number:							
4004	CuO/DAC	2	470	0.30	0.25		1
4006	CuO/DAC	2	477	0.45	0.35		1
4000	Control	16	—	—	—		3

[a] See Table 1.
[b] See Table 1.
[c] 1 pcf = 16 kg/m^3.
[d] Average of 10 observations.
[e] See Table 3 for decay rating.
[f] Average of 10 observations; each observation represents the most advanced decay observed in any 1 of 4 shakes in each replicate stack.

roof decks or exposed in field modules, but some weight loss did occur in soil jar tests with cross sections of treated shakes for these charges. In the modules of stacked shakes, decay occurred only in shakes treated to a retention of 0.01 pcf CuO/DAC, which was less than 0.10 the retention used in the soil jars.

In soil jar studies, substantial weight loss caused by decay fungi occurred in cross sections of shakes treated with CuOct to retentions of 0.03 and 0.05 pcf. Nevertheless, after almost 5 years of field exposure, western hemlock shakes treated to comparable retentions that had substantial weight loss in the laboratory test had no evidence of decay in the field. Indeed, results from modules of stacked shakes indicated that even modest retentions of CuOct had some beneficial effect in protecting those shakes during exposure (Tables 6, 7).

DISCUSSION

It is recognized that a full complement of wood-destroying fungi are required in standard tests (AWPA 1992b). Nevertheless, the magnitude of differences between laboratory and field tests described herein was not minimized by use of only one standard decay fungus in the laboratory tests. The methods being compared did not present the same challenge to comparably treated products, nor was the effectiveness of the treatments evaluated by similar criteria in each method. The laboratory test exposed cut surfaces of treated shakes to a pure culture of *G. trabeum* under conditions that were nearly ideal for brown-rot fungi. However, field exposure permitted colonization of the test material by a natural population of fungi, although it was anticipated that brown-rot fungi would be the predominant decay fungi in softwoods exposed above ground. Field conditions also exposed the treated materials to both seasonal and cyclical changes in temperature as well as fluctuations in moisture. Shakes installed on small sections of roof decks would seemingly be subjected to the greatest wetting/drying stress. The modules composed of stacked shakes were designed to address the

TABLE 6. *Performance of Pacific silver fir shakes treated with CuOct in a hydrotreated light paraffinic distillate.*

Test	Preservative[a]	Code[b]	Charge	Retention (pcf)[c] Target	Retention (pcf)[c] Analyzed	Weight loss[d] (%)	Decay rating[e]
16-week laboratory soil jar	CuOct	13	585	0.04	0.05	34.34	
	Control	16	—	—	—	50.67	
54-month open field module	CuOct	13	588	0.004	0.003		1.6[f]
	CuOct	13	587	0.010	0.007		1.0[f]
	CuOct	13	584	0.02	0.02		1.0[f]
	CuOct	13	585	0.04	0.05		1.0[f]
	CuOct	13	586	0.06	0.06		1.1[f]
	CuOct	13	583	0.08	0.08		1.0[f]
	Control	—	—	—	—		4.2[f]
54-month open field simulated roof deck number:							
4078	CuOct	13	585	0.04	0.05		1
4089	Control	—	—	—	—		2

[a] See Table 1.
[b] See Table 1.
[c] 1 pcf = 16 kg/m^3; retention is computed on the basis of metal ion (Cu) in the treated product.
[d] Average of 10 observations.
[e] See Table 3 for decay rating.
[f] Average of 10 observations; each observation represents the most advanced decay observed in any 1 of 4 shakes in each replicate stack.

potential hazard of long-term wetting that may buffer the effects of intermittent wetting and solar drying. Shakes within the module were subjected to wetting by capillary action from the side and from water moving around the bolts that held the module together. The most severe decay would usually occur in the third shake from the top or in the bottom shake, the fourth from the top.

Criteria for monitoring decay also varied. Percentage weight loss as a result of decay was determined in laboratory tests, whereas field assessments were visual. Therefore, comparisons between methods in relative performance of treatments must account for different evaluation criteria.

Visual assessment of preservative distribution, that is, the index of penetration, was not a good indicator of field durability during the course of this observation. Given this pattern of restricted decay within the severely challenged cross sections of some treatments, there seemed to be a need to question whether uniform, thorough penetration of preservatives is needed for adequate performance.

It may be that protection of shakes in the field resulted from two significant components: prevention of decay establishment and suppression of progress, once established. The weight losses observed in cross sections of shakes treated with CuOct did not indicate that good performance would be achieved in the field during this exposure. However, that test would not be sensitive to the phenomenon of establishment. Thus far, marked benefits of treatments with low retentions of CuOct suggest that some benefit must be derived through the delay in establishment of decay. In untreated wood, decay, once started, progresses rather extensively through the members (De Groot 1992) in this type of experimental unit. In the future, it will be interesting to determine whether decay, once established, moves as extensively through these shakes or will be somewhat restricted in development.

The challenge still remains, therefore, to extrapolate from results with individual test protocols to estimate long-term durability in specific use environments. Test methodology should reflect the prevailing microbial ecosystems at respective use sites. Brown-rot fungi predominate in softwood construction used above ground in the United States. In prior laboratory studies (Preston 1983; Preston and

TABLE 7. *Performance of western hemlock and Pacific silver fir shakes treated with CuOct in a light naphthenic distillate.*

Test	Preservative[a]	Code[b]	Charge	Retention (pcf)[c] Target	Retention (pcf)[c] Analyzed	Weight loss[d] (%)	Decay rating[e]
16-week laboratory soil jar							
Western hemlock	CuOct	25	634	0.04	0.03	53.24	
	Control	16	—	—	—	44.29	
54-month open field module							
Pacific silver fir	CuOct	25	630	0.004	0.003		1.4[f]
	CuOct	25	632	0.01	0.007		1.4[f]
	CuOct	25	643	0.02	0.02		1.0[f]
	CuOct	25	634	0.04	0.03		1.0[f]
	CuOct	25	635	0.06	0.04		1.0[f]
	Control	16	—	—	—		4.2[f]
Western hemlock	Control	16	—	—	—		4.7[e]
54-month open field simluated roof deck							
Western hemlock deck number:							
4083	CuOct	25	634	0.04	0.02		1
4088	Control	16	—	—	—		4
Pacific silver fir deck number:							
4084	CuOct	25	634	0.04	0.03		1
4089	Control	16	—	—	—		2

[a] See Table 1.
[b] See Table 1.
[c] 1 pcf = 16 kg/m^3; retention is computed on the basis of metal ion (Cu) in the treated product.
[d] Average of 10 observations.
[e] See Table 3 for decay rating.
[f] Average of 10 observations; each observation represents the most advanced decay observed in any 1 of 4 shakes in each replicate stack.

Nicholas 1982; Tsunoda and Nishimoto 1987), alkylammonium compounds generally were somewhat more effective against brown-rot fungi than against white-rot fungi. Some evidence already exists that shows promising results of wood roofing materials treated with DDAC, alone, and exposed for 28 months in Mississippi (Barnes et al. 1985). Microbial tests must also consider organisms other than decay fungi. Ruddick (1986) concluded that the performance of alkylammonium compounds could be significantly reduced as a result of the action of staining fungi that colonize wood used in contact with the soil.

Scheffer (1971) emphasized that the potential for decay in wood used above ground is influenced by climate. Demonstration of resistance to decay fungi in soil jar methods would suggest potential for good performance of treated shakes in severe environments, but provides little information on potential for performance in less than severe environments. Results with CuOct illustrated the differences between laboratory and field evaluations. Acceptable, short-term performance of shakes treated with CuOct and exposed on small roof decks in Mississippi indicated that these treatments may have potential for use in environments with low or moderate decay hazard, the results from soil jar tests notwithstanding. The challenge is to define the limits of those potentials.

CONCLUSIONS

The potential for attack by decay fungi is greatest in soil jar methodology, next greatest is in field modules composed of stacked shakes, and least is in shakes exposed on small sections of roof decks. This conclusion is based upon the pattern of results with untreated controls and treated shakes.

The merits of the soil jar methodology rest in the severity of challenge by the test organism presented. With adequate representation of challenging organisms, you would anticipate that treatments that withstand this challenge would withstand severe challenge in the field. The soil jar method does not address questions of physical appearance and stability.

Small sections of roof decks present an excellent demonstration of physical performance characteristics, weathering characteristics, color, and appearance. The strength of this method is in its power as a demonstration tool; however, questions remain about various options of roof deck construction, exposure, and slope.

Field modules composed of stacked shakes present a greater potential for decay in the field than do shakes exposed on small sections of roof decks. However, this challenge is still substantially less than that presented by the soil jar methodolgy. The small size of each module permits design of experiments with sufficient replicates to adequately test hypotheses under field conditions. It permits design of field experiments with minimal material requirements for evaluation of candidate treatments in different environments. The uppermost shake was fully exposed to the weather, but the method of fastening does not simulate a roof; hence its performance does not provide an indication of potential stability profiles.

ACKNOWLEDGMENT

This research was part of a cooperative program (FP-86-0885) between the Northwest Independent Forest Manufacturers and the USDA Forest Service. The assistance of the following is gratefully acknowledged: Dan Foster and Roger Pettersen and staff for analyses of wood preservatives; Bessie Woodward for laboratory decay studies; and David Gutzmer for construction and evaluation of field units.

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