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Performance of Two Solid Fumigants in Covered Bridges

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Abstract

The potential for two solid wood fumigants, dazomet and methylisothiocyanate (MITC), to move through wood at levels sufficient to arrest decay in covered bridges was assessed. Dazomet alone failed to decompose to MITC and move into the wood at effective levels, probably because too little moisture was available for breakdown. Adding a copper accelerant improved dazomet decomposition to the point at which it produced an effective level of chemical up to 600 mm from the point of application. The MITC levels in bridges receiving the active chemical in an aluminum tube were 15 to 20 times the protective levels within 2 years of treatment. Although both chemicals eventually provided protective levels, MITC in aluminum tubes produced the most consistent chemical distribution in the shortest time.

Keywords: covered bridge, wood decay, fumigant, dazomet, methyisothiocyanate

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Performance of Two Solid Fumigants in Covered Bridges

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Introduction

Covered bridges have a long history of successful use in North America as a means of protecting the bridge deck from wetting and decay (Pierce and others 2005). The roof decreases but does not completely prevent wetting, which can still occur particularly near the bridge approaches and through any windows or other penetrations in the roof or siding. Water ingress can also occur through leaks or from underneath during flooding. The resulting moisture can create conditions conducive to decay development, which shortens bridge service life.

Establishing a routine bridge inspection program can help detect decay before it decreases bridge capacity, but it is equally important to arrest and remediate any decay as it is discovered (Morrell and Lebow 2005). For many years, the options for arresting decay in service were limited. Surface treatments lacked the ability to penetrate deeply into the wood of most species to the point where fungi were actively growing. In addition, the complex designs of many covered bridges creates obstacles that making it difficult to effectively treat some members. During the past 20 years, a number of diffusible treatments have emerged that can address some of these challenges. Water-diffusible boron compounds can be applied as either solid rods to holes drilled in timbers or as liquids. Boron diffuses with moisture and is effective against fungi and insects. Boron also has exceptionally low toxicity to birds and mammals. One drawback of boron in covered bridge applications is that it needs water to diffuse and wood in a properly maintained covered bridge should not be wet enough for diffusion to occur. As a result, boron is not useful in covered bridge applications except as a preventative treatment in locations where the wood is destined to become wet. Fumigants, which are solid or liquid compounds with high vapor pressures, are another common type of diffusible preservative system. These systems volatilize and can move through wood as gases to control fungi as far as 900 to 1,200 mm away from the point of application, depending on the dosage and wood species. More importantly, these treatments interact and remain in the wood for several years after treatment, providing long-term protection against renewed fungal attack.

Originally, fumigants used for bridge applications were liquids that were either caustic or had strong odors that made them difficult to work with, especially over water (Morrell and Corden 1986, Morrell and others 2013). More recently, two solid fumigants have emerged as safer alternatives. Methylisothiocyanate (MITC) is a solid at room temperature but sublimes directly to a gas. It is applied in aluminum tubes and volatilizes through the tube top into the wood. This system has provided 7 to 12 years of protection against fungal attack in utility poles (Morrell and others 1992, 1998; Ziobro and others 2004). The other fumigant is dazomet (tetrahydro-3,5-dimethyl-2-H-1,3,5, thiodiazine-6-thione), which is a solid crystalline material at room temperature. Unlike MITC, dazomet is not volatile or highly fungitoxic. Instead, it decomposes to produce MITC which then diffuses through the wood (Forsyth and Morrell 1993, 1995). Dazomet decomposition is highly dependent on the presence of free water, although it can be accelerated by the co-application of copper compounds such as copper naphthenate (Love and others 2010). The fact that dazomet and MITC are easy to handle makes them appear to be ideal treatments for bridges, but little information exists on the ability of these compounds to perform in these applications. In this report, we examine the ability of dazomet and MITC to diffuse through covered bridges in various parts of the United States.

Materials and Methods

Bridge Selection

Six bridges located in five states were selected for treatment. The bridges contained four different wood species and were made using four different construction types (Table 1).

Table 1. Characteristics of covered bridges used to assess dazomet and MITC movement

Bridge	Year built	Type	Wood species	MC (%)	Treatment(s)	Treatment pattern
Honey Run Bridge, Butte County, CA	1896	Pratt and king-post truss	Douglas-fir	11.3	Dazomet, MITC	Downward holes at 1.2-m intervals in 288- by 375-mm- or 300- by 450-mm-deep beams
Oregon Creek Covered Bridge, Yuba County, CA	1860–1862	Howe pony truss	Douglas-fir	13.0	Dazomet, MITC	Sloping holes in 238-mm square or 238- by 300-mm columns
Cooley Covered Bridge, Pittsford, VT	1849	Town lattice truss	Eastern spruce	12.9	Dazomet, MITC	Holes drilled downwards at 1.2-m intervals into narrow face of 75- by 288-mm-wide chords
Pengra Covered Bridge, Fall Creek, OR	1938	Howe truss	Douglas-fir	—	Dazomet	Downward holes at 1.2-m intervals on timbers
Red Covered Bridge, Princeton, IL	1863	Howe truss	Red pine	12.6	Dazomet, MITC	Sloping holes in 163- by 225-mm diagonal supports
Cedarburg Covered Bridge, Cedarburg, WI	1876	Town lattice truss	Eastern white pine	13.7	Dazomet, MITC	Holes drilled downward at 1.2-m intervals in narrow face of 75- by 275-mm bottom chords near ends of the bridge

Treatment

Chemicals were applied by drilling 19-mm-diameter by 200-mm-long holes at various angles (depending on the bridge configuration) into the timbers or chords at 1.2-m intervals. Dazomet is a powder and was poured to within 50 mm of the hole top. The top of the MITC tube (MITC-FUME, Osmose Utilities Inc., Peach Tree City, GA) was removed and the tube was placed, open end downward, into the treatment hole. Approximately 30 g of dazomet or a single vial of MITC-FUME (~32 g of MITC) was applied to each treatment hole. The holes were plugged with tight-fitting preservative-treated wooden dowels that were slightly larger in diameter than the treatment hole to retard chemical loss. Four (Honey Run and Oregon Creek bridges) or five (Cedarburg, Cooley, and Red bridges) members were treated with each chemical system (Lebow and others 2012), except for the Pengra Bridge for which all members were treated with dazomet and then floor beams (bottom chords) were later randomly sampled across the bridge.

Wood species and moisture content at the time of treatment were determined by collecting drill shavings from the treatment hole and sealing them in plastic bags for all bridges except the Pengra Bridge. The shavings were weighed, ovendried, and reweighed. Mass differences between pre- and post-ovendried weight were used to calculate wood moisture content. This method may have slightly underestimated moisture content because of moisture loss from the shavings during drilling. Wood species was determined by microscopic analysis of the shavings.

Fumigant Analysis

The presence of MITC in the wood was assessed 1 to 2 years after treatment by removing 150-mm-long increment cores at selected distances from the treatment site. The MITC levels in the Pengra Bridge were assessed 300 and 600 mm away from the point of application 18 months after treatment, whereas MITC levels in the remaining bridges were assessed 300, 600, and 900 mm away from the treatment site 12 and 24 months after treatment.

The outer and inner 25 mm were cut from the increment cores removed from the Pengra Bridge. These 25-mm-long segments were placed into glass vials that were tightly sealed with Teflon-lined screw caps (Teflon, Chemours Company, Wilmington, DE). The entire core was analyzed without segmentation for cores removed from the other four bridges. Five milliliters of ethyl acetate were added to each vial, and the vial was stored at room temperature for 48 h. The resulting extract was decanted, and a subsample of that extract was analyzed for MITC by gas chromatography (GC). Briefly, 2 µL of extract were injected into a Shimadzu GC equipped with a flame photometric detector with filters specific for sulfur (Shimadzu Corp., Kyoto, Japan). A glass column (2.6-mm inner diameter by 2.1 m long) packed with 10% carbowax on 80/100 Supelcoport was used to separate materials, and nitrogen was used as the carrier gas at a flow rate of 60 mL/min. Injector, oven, and detector temperatures were 100, 150 and 200 °C, respectively. The MITC content was determined by comparison with prepared standards. The increment core segments were ovendried and weighed

Table 2. Methylisothiocyanate (MITC) content in Douglas-fir chords in the Pengra Bridge 18 months after application of dazomet with 1% copper naphthenate as a decomposition accelerant

	MITC content (µg/g of wood)[a]							
	300 mm from treatment site				600 mm from treatment site			
	Inner 25 mm		Outer 25 mm		Inner 25 mm		Outer 25 mm	
Location	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Floor	19.2 (9.9)	0–48.3	1.0 (1.0)	0–4.4	**20.4 (10.8)**	0–43.9	1.5 (2.3)	0–10.6
Diagonal	**77.6 (57.8)**	17.2–203.4	14.5 (22.7)	0–59.7	**80.6 (30.1)**	25.4–130.6	10.0 (7.7)	0–21.2

[a]Values represent means of 5 to 11 analyses depending on location. Figures in parentheses represent one standard deviation. Values in bold are above the threshold for protection against fungal attack.

to allow MITC content to be expressed on a microgram of MITC per ovendried gram of wood weight basis.

Results and Discussion

Dazomet Treatment

No MITC was detected in wood removed from the Red, Cedarburg, Cooley, Oregon Creek, or Honey Run covered bridges in zones that had received dazomet alone. The absence of MITC in wood removed from these locations was consistent with the moisture contents measured. Moisture levels in these bridges at the time of treatment ranged from 11% to almost 14%. Dazomet generally requires liquid or free water to decompose to produce MITC, and this does not occur in most wood species until moisture content exceeds 28% to 30% (or the fiber saturation point) (FPL 2010). From a protective perspective, this is not necessarily bad, because dry wood is not likely to experience fungal attack, which also requires that free water be present. The dazomet could provide insurance should a bridge element become wet. However, the absence of substantial decomposition to MITC could be an issue if dazomet were placed near a decaying area but in a drier zone. In that case, little or no decomposition to MITC would occur and the decay would continue.

The addition of a copper-based accelerant is typically recommended when dazomet is used to protect utility poles in drier climates. The copper accelerates decomposition and provides a boost in MITC release into the surrounding wood that can result in protective levels for 2 years after treatment. Treatment with dazomet and 1% copper naphthenate in the Pengra Bridge resulted in detectable MITC at most locations 300 and 600 mm from the treatment point, although the levels were much lower than those found in the MITC-FUME-treated bridges (Tables 2 and 3). The MITC threshold for protection against fungal attack is 20 µg/g of ovendried wood, based on an analysis of numerous previous field tests of Douglas-fir utility poles (Morrell and others 2012). Average MITC levels in the inner 25 mm of the increment cores removed from the timbers were at or above that level 300 and 600 mm from the treatment point, although there was a considerable amount of variation in individual values. The MITC levels in the outer zones of the wood were much lower and were mostly below the protective threshold. The differences between inner and outer chemical levels reflect, in part, the tendency of the treatment holes to direct chemical toward the center of the timber. Volatile chemicals such as MITC are also more likely to be lost near the wood surface. The presence of higher MITC levels in the interior regions of fumigant-treated wood is consistent with previous studies in poles and illustrates the fact that these treatments are best suited for controlling internal not surface decay.

MITC-FUME Treatment

The MITC levels in the covered bridges treated with MITC-FUME were almost all well above the protective threshold 1 and 2 years after treatment (Table 3). The exception was the Oregon Creek Bridge, where levels were only above threshold 300 mm from the treatment site 2 years after treatment. Unfortunately, inner and outer analyses of increment cores were not possible because of handling logistics, making it impossible to determine if MITC levels in the outer zone were above the threshold. However, this treatment is not intended to protect surfaces, and it would be impractical to depend on the presence of low levels of MITC near the surface of these timbers to provide consistent protection against fungal attack.

The MITC levels 300 mm from the treatment holes in the Cedarburg, Cooley, Honey Run, and Red bridges were 14 to 23 times the threshold level at 2 years. Levels were also above threshold 600 mm from the treatment zone 2 years after application but were below threshold at most locations 900 mm from the treatment site. The elevated levels of MITC are consistent with previous studies of this system, which tends to release very high quantities of MITC that remain in the wood at protective levels for 5 to 7 years. Fungi then very slowly recolonize the wood, resulting in a total

Table 3. Methylisothiocyanate (MITC) levels in covered bridges 12 or 24 months after application of MITC-FUME

Bridge	Time after application (months)	MITC levels (µg/g of wood)[a] 300 mm from treatment site Mean	Range	600 mm from treatment site Mean	Range	900 mm from treatment site Mean	Range
Cedarburg	12	**242 (136)**	57–448	**37 (44)**	0–119	6 (17)	0–44
	24	**469 (266)**	163–891	**90 (99)**	0–256	19 (45)	0–111
Cooley	12	**216 (195)**	0–594	**197 (123)**	41–338	18 (28)	0–66
	24	**469 (242)**	96–946	**82 (53)**	8–131	5 (8)	0–19
Honey Run	12	**327 (468)**	0–1373	**29 (64)**	0–184	13 (20)	0–43
	24	**358 (345)**	65–1098	**65 (116)**	4–339	3 (13)	0–13
Oregon Creek	12	12 (27)	0–78	0	0	0	0
	24	**51 (68)**	0–165	3 (4)	0–10	0	0
Red	12	**280 (361)**	60–1265	13 (10)	0–31	2 (5)	0–12
	24	**452 (309)**	40–913	**86 (75)**	2–234	**42 (99)**	0–99

[a]Values represent means of 6 to 9 analyses, and figures in parentheses represent one standard deviation. Values in bold are above the threshold for protection against fungal attack.

protective period that is typically between 10 and 12 years, depending on the environmental conditions at the site (Morrell and Corden 1986). The MITC levels in these bridges were consistent with this behavior and suggest that this system should perform at least as well in current timber bridges constructed with pressure-treated wood. An outer layer of creosote or oil-based preservative treatment may slow volatilization of MITC from the interior of timbers and extend the period of protection (Morrell and others 2013).

Conclusions

Dazomet performed poorly in covered bridges when applied without a copper-based accelerant, probably because too little moisture was available to hasten decomposition. The addition of copper naphthenate markedly enhanced decomposition to MITC in one bridge evaluated. Application of MITC-FUME resulted in exceptionally high MITC levels for 2 years after treatment and was unaffected by the low wood moisture content. The results suggest that MITC-FUME produced more consistent MITC levels in dry applications such as untreated covered bridges, whereas the application of dazomet required the use of a copper-based accelerant to achieve protective levels.

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