Repeated exposure of borate-treated Douglas-fir lumber to Formosan subterranean termites in an accelerated field test

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Abstract

Douglas-fir boards (ca. 74.5 g) pressure treated with disodium octaborate tetrahydrate (DOT) to retentions of 0 (controls), 0.88, 1.23, 1.60, or 2.10 percent (weight/weight) DOT were sequentially exposed to four active field colonies of Formosan subterranean termites, *Coptotermes formosanus* Shiraki (Isoptera: Rhinotermitidae), in an aboveground field test. Samples were placed in contact with each colony for 10 weeks, with ovendry weight losses determined between exposures, for a total termite exposure period of 40 weeks. Feeding activity differed among termite colonies. The two lower borate retentions (0.88% and 1.23% DOT) were virtually equal in efficacy, with mean wood weight losses during each individual 10-week exposure ranging from 1.2 to 4.6 percent. Feeding was negligible on wood treated to the two higher borate retentions. Mean wood weight losses from termite feeding during each 10-week period ranged from 0.7 to 1.3 percent with an initial retention of 1.60 percent DOT, and 0.3 to 0.9 percent with 2.10 percent DOT. Total cumulative wood weight losses over the 40-week exposure were: 10.2 percent (0.88% DOT), 8.7 percent (1.23% DOT), 3.6 percent (1.60% DOT), and 2.4 percent (2.10% DOT). Under conditions of high termite hazard, wood treatment to retentions greater than 1 percent DOT can be expected to provide protection from serious structural damage, although minor feeding may still occur. Treatment to higher retentions can be expected to progressively minimize the possibility of minor cosmetic damage.

Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) lumber, pressure treated with various wood preservatives, is used extensively in building construction in western North America and Hawaii (9). In Hawaii, termites (Isoptera) are generally more destructive than decay fungi to wood in service, and the most destructive termite species is the Formosan subterranean termite, *Coptotermes formosanus* Shiraki (Family Rhinotermitidae). Recently, disodium octaborate tetrahydrate (DOT, as TIM-BOR®) has become available in Hawaii as a pressure treatment for Douglas-fir (1). Lumber stamped with the HI-BOR® quality mark has a minimum retention of 1.1 percent DOT (1.32% boric acid equivalent (BAE)) by weight in an 0.6-inch assay zone (4).

A previous 23-week field test established that a cross-sectional retention of 0.85 percent DOT (1.02% BAE) was sufficient to restrict wood weight loss from termite feeding to less than 3 percent of the initial weight (3). These results raised the question of whether this very minor feeding could be further minimized by treatment to even higher DOT retentions; that is, whether any retention of DOT was sufficient to guarantee that minor cosmetic damage would not occur. We also wished to determine whether repeated termite invasions over the life of a structure and attempts to feed on the treated wood by different Formosan subterranean termite colonies could lead to greater cumulative damage to the wood.

In the present study, Douglas-fir lumber pressure-treated to cross-sectional retentions from 0.88 to 2.10 percent DOT (1.06% to 2.52% BAE) was exposed

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TABLE 1. — *Weight losses of borate-treated Douglas-fir boards (ca. 74.5 g) during each sequential 10-week exposure to four Formosan subterranean termite field colonies.*

DOT	BAE	Wood weight losses during each 10-week termite exposure[a]							
		1st		2nd		3rd		4th	
------- (%) -------		(g)	(%)	(g)	(%)	(g)	(%)	(g)	(%)
2.10	2.52	0.7 ± 0.2 A	0.9 ± 0.2	0.4 ± 0.3 A	0.6 ± 0.4	0.3 ± 0.2 A	0.4 ± 0.3	0.5 ± 0.2 A	0.7 ± 0.3
1.60	1.92	0.6 ± 0.1 A	0.7 ± 0.1	0.7 ± 0.5 AB	0.8 ± 0.5	0.8 ± 0.4 AB	0.9 ± 0.5	1.0 ± 0.4 A	1.3 ± 0.5
1.23	1.48	1.3 ± 0.7 A	2.0 ± 1.0	0.7 ± 0.2 AB	1.2 ± 0.4	2.7 ± 2.1 B	4.4 ± 3.4	0.9 ± 0.8 A	1.5 ± 1.3
0.88	1.06	1.6 ± 1.2 A	2.0 ± 1.4	1.0 ± 0.5 AB	1.2 ± 0.5	2.5 ± 2.2 AB	3.1 ± 2.7	3.4 ± 1.2 AB	4.6 ± 1.7
0	0	10.9 ± 4.3 B	15.1 ± 5.9	1.1 ± 0.4 B	1.6 ± 0.5	1.0 ± 1.0 AB	1.3 ± 1.4	10.1 ± 10.4 B	14.1 ± 14.7

[a] Each mean (±SD) represents four boards pressure impregnated with disodium octaborate tetrahydrate (DOT) (expressed as cross-sectional weight/weight percent DOT or boric acid equivalents (BAE)). New control boards were used during each exposure. Means within a column followed by the same capital letter are not significantly different (ANOVA, Duncan's Multiple-Range Test, $p = 0.05$).

TABLE 2. — *Cumulative weight losses of borate-treated Douglas-fir boards (ca. 74.5 g) during four 10-week exposures to Formosan subterranean termite field colonies.*

DOT	BAE	Cumulative percent wood weight loss[a]				Final wood weight loss
		10 weeks	20 weeks	30 weeks	40 weeks	
----- (%) -----		(%)				(g)
2.10	2.52	0.9 ± 0.2	1.4 ± 0.2	1.8 ± 0.5	2.4 ± 0.8	1.9 ± 0.5 A
1.60	1.92	0.7 ± 0.1	1.5 ± 0.5	2.4 ± 1.0	3.6 ± 0.8	3.1 ± 0.7 AB
1.23	1.48	2.0 ± 1.0	3.1 ± 0.6	7.4 ± 3.0	8.7 ± 2.3	5.6 ± 1.5 B
0.88	1.06	2.0 ± 1.4	3.1 ± 0.8	6.1 ± 3.4	10.2 ± 3.6	8.5 ± 3.1 C

[a] Each mean (±SD) represents four boards pressure-impregnated with disodium octaborate tetrahydrate (DOT) (expressed as the cross-sectional weight/weight percent DOT or boric acid equivalents (BAE)). Means within the last column followed by the same capital letter are not significantly different (ANOVA, Duncan's Multiple-Range Test, $p = 0.05$).

sequentially to three separate *C. formosanus* field colonies, and twice to the first termite colony, for a total of four sequential 10-week field tests. We used a rigorous field test protocol, in which the wood samples were placed directly into active termite feeding sites within traps established to monitor and collect termites from each of these colonies (2,7,8).

Experimental procedure

Douglas-fir heartwood boards (nominal 1 by 4 in. lumber) measuring 8.5 by 8.5 by 1.8 cm (averaging 74.5 g each) were pressure impregnated with DOT (TIM-BOR, United States Borax and Chemical Corporation, Los Angeles, Calif.) by a modified full-cell process (4). DOT retentions were determined by weight gain, and confirmed by ashing selected samples, extracting the residue, and using inductively coupled plasma (ICP) spectroscopy to determine boron in solution (4). Four wood samples each were pressure impregnated to retentions of 0.88, 1.23, 1.60, or 2.10 percent DOT.

Four sequential 10-week aboveground field tests (total 40-week exposure) were conducted using Formosan subterranean termite colonies located on the Manoa campus of the University of Hawaii, and at the Poamoho Experiment Station near Waialua on the island of Oahu, Hawaii. Boards were ovendried (90°C for 72 hr.) before and after each termite exposure to determine weight losses from termite feeding. Each board was placed over the open end of a rectangular box (termite trap) constructed of untreated Douglas-fir and placed on the soil surface, protected by a covered 5-gallon metal can with the bottom removed. This trap design was first described as a means of collecting termites (7), and has been used in field evaluations of ACZA (8) and DOT (3). In all cases, termites had been actively foraging on an untreated wood box placed within each can immediately prior to its replacement with a new box and the test sample.

After three sequential 10-week exposures, each to a different termite colony, the samples were exposed again for 10 weeks to the first colony tested, since this colony was noted to have fed considerably more on the control (untreated) samples than either of the other two termite colonies. Differences in feeding activity among termite colonies have been documented in other studies (6), although the basis for these differences is not understood. The foraging populations of the three colonies were estimated, using a mark-release-recapture method (2), to be approximately 1.0, 1.6, and 2.4 million.

Weight losses of the test samples after each 10-week termite exposure and cumulative weight losses after 40 weeks were subjected to analysis of variance (ANOVA) and means significantly different at the 0.05 level were separated by Duncan's Multiple-Range Test (5).

Results and discussion

At least minor evidence of termite feeding was noted on all test boards, and the degree of cosmetic damage was negatively correlated with DOT retention. With wood treated to the highest retention of 2.10 percent DOT (2.52% BAE), extremely shallow feeding depressions were visible on the wood surface at the end of the 40 weeks of termite exposure. However, weight losses from termite "tasting" at 2.10 percent DOT averaged less than 1 percent of the initial wood weight during each 10-week exposure, for a cumulative weight loss of only 2.4 percent after 40 weeks (Tables 1 and 2).

With wood treated to the lowest preservative retention of 0.88 percent DOT (1.06% BAE), the mean cumulative wood weight loss after 40 weeks of 10.2 percent (Table 2) exceeded the 2.5 percent weight loss recorded in our previous field test with wood treated to a comparable retention (0.85% DOT) after 23 weeks of exposure to a single *C. formosanus* colony (3). These results indicate that increasing damage to DOT-treated wood can occur from repeated exploratory attacks by different termite colonies, although each attack may be of brief duration. However, it must be emphasized that this was an extremely rigorous field test in which wood samples were physically moved from colony to colony. In practice, the likelihood of attack on wood in service in structures by multiple Formosan subterranean termite colonies should be much less than was the case in this field test, and such attacks would likely occur over a period of many years. It is also possible that the repeated drying cyles to which our wood samples were exposed might modify boron distribution in the wood samples to some extent. The affects of such rigorous conditions on boron distribution in pressure-treated wood are currently under investigation (4).

In our view, it is prudent to consider any preservative-treated wood as "termite resistant" rather than "termite proof," and as one component of a termite management program. Termite-resistant architectural design, frequent building inspections, and the presence of chemical or physical barriers in the soil beneath and around the structure are important in reducing termite pressure on both the treated wood and other cellulosic materials within the structure. Under conditions of high Formosan subterranean termite hazard, wood treatment to retentions greater than 1 percent DOT can be expected to provide protection from serious structural damage, although some termite feeding may still occur. Our results demonstrate that wood treatment to progressively higher DOT retentions can be expected to progressively minimize, although not completely eliminate, the possibility of minor cosmetic damage to the wood surface.

Literature cited

1. Anonymous. 1991. Material-method request no. MB91-4 (1): Report of action on request for approval of methods and materials under Building Department codes and regulations. Building Dept., City and County of Honolulu, Hawaii.
2. Grace, J.K. 1992. Termite distribution, colony size, and potential for damage. Proc. National Conf. Urban Entomology, College Park, Md. pp. 67-76.
3. ________, R.T. Yamamoto, and M. Tamashiro. 1992. Resistance of borate-treated Douglas-fir to the Formosan subterranean termite. Forest Prod. J. 42(2):61-65.
4. Manning, M.J. 1993. Personal communication. U.S. Borax Inc., Valencia, Calif.
5. SAS Institute. 1987. SAS/STAT guide for personal computers. Version 6 ed. SAS Institute Inc., Cary, N.C.
6. Su, N.-Y. and J.P. LaFage. 1984. Differences in survival and feeding activity among colonies of the Formosan subterranean termite (Isoptera: Rhinotermitidae). J. Appl. Entomol. 97:134-138.
7. Tamashiro, M., J.K. Fujii, and P.Y. Lai. 1973. A simple method to observe, trap and prepare large numbers of subterranean termites for laboratory and field experiments. Environ. Entomol. 2:721-722.
8. ________, R.T. Yamamoto, and R.H. Ebesu. 1988. Resistance of ACZA treated Douglas-fir heartwood to the Formosan subterranean termite. Proc. Am. Wood-Preservers' Assoc. 84:246-253.
9. Wilcox, W.W. 1984. Observations on the structural use of treated wood in Hawaii. Forest Prod. J. 34(6):39-42.