IRG/WP 04-30343

THE INTERNATIONAL RESEARCH GROUP ON WOOD PRESERVATION

Section 3 Wood Protecting Chemicals

Six-year Report on the Performance of Borate-treated Lumber in an Above-ground Termite Field Test in Hawaii

J. Kenneth Grace[1], Anthony Byrne[2], Paul I. Morris[2], and Kunio Tsunoda[3]

[1]Dept. of Plant & Environmental Protection Sciences, University of Hawaii, 3050 Maile Way, Honolulu, HI 96822, USA

[2]Forintek Canada Corp., 2665 East Mall, Vancouver, B.C. V6T 1W5, Canada

[3]Wood Research Institute, Kyoto University, Uji, Kyoto 611-0011, Japan

Paper prepared for the 35th Annual Meeting
Ljubljana, Slovenia
6-10 June 2004

IRG SECRETARIAT
SE-100 44 Stockholm
Sweden
www.irg-wp.com

Six-year Report on the Performance of Borate-treated Lumber in an Above-ground Termite Field Test in Hawaii

J. Kenneth Grace[1], Anthony Byrne[2], Paul I. Morris[2], and Kunio Tsunoda[3]

[1]Dept. of Plant & Environmental Protection Sciences, University of Hawaii, 3050 Maile Way, Honolulu, HI 96822, USA
[2]Forintek Canada Corp., 2665 East Mall, Vancouver, B.C. V6T 1W5, Canada
[3]Wood Research Institute, Kyoto University, Uji, Kyoto 611-0011, Japan

Abstract

We report the fifth and sixth years of field study results from a protected above-ground field test in Hawaii simulating the sill plate (dodai) used in conventional Japanese housing construction. Field tests were established in both Hawaii and Japan to examine the efficacy of disodium octaborate tetrahydrate (DOT, 2% and 3% BAE shell and through) wood treatments. In Hawaii, chromated copper arsenate (CCA, 4 kg/m^3) and ammoniacal copper zinc arsenate (ACZA, 4 kg/m^3) were included in the test, along with untreated western hemlock and Pacific silver fir controls. Both field sites support active Formosan subterranean termites, *Coptotermes formosanus* Shiraki, although termite pressure is greater in Hawaii due to the uniformly favorable environmental conditions. To date, all wood treatments have performed well, with mean visual damage ratings ranging from 10 (ACZA) to 8.5 (DOT, 2% BAE shell treatment) on the AWPA 10 - 0 scale after six years. This report updates the four-year results previously reported in IRG/WP 01-30265 (Grace *et al.* 2001).

Key Words: *Coptotermes formosanus*, disodium octaborate tetrahydrate, sill plate, dodai

Introduction

As described by Grace *et al.* (1995, 2000, 2001), a protected above-ground field test was devised to evaluate the efficacy against Formosan subterranean termite (*Coptotermes formosanus* Shiraki) attack of disodium octaborate tetrahydrate (DOT) wood treatments of hem-fir intended for use as sill plates (dodai) in conventional Japanese building construction. With only minor variations, this test is replicated in Waimanalo (Island of Oahu), Hawaii, and in Kagoshima Prefecture (Island of Kyushu), Japan. Both test sites support active Formosan subterranean termite populations, although our test results indicate that termite activity is on the order of 3-fold greater at the Hawaii site (Tsunoda *et al.* 2002b). Formosan subterranean termites are the major structural threat in both locations, but the more tropical environmental conditions in Hawaii facilitate year-round foraging and growth of the colonies, in comparison to the seasonality found in Kagoshima. This same test design has also been implemented in Kincardine, Ontario, Canada, with the eastern subterranean termite *Reticulitermes flavipes* (Morris et al. 2003). Alternative field test designs were employed in Hawaii by Preston *et al.* (1996), and in Australia by Peters and Fitzgerald (1998).

Grace *et al.* (1995, 2000, 2001) and Tsunoda *et al.* (1998,2000, 2002a, 2004) have described the test design and previous results from Hawaii and Japan, respectively. In addition to 2% and 3% BAE borate shell and through treatments, each test plot also includes chromated copper arsenate (CCA, 4.0 kg/m^3), untreated control samples of both western hemlock (*Tsuga heterophylla*) and Pacific silver fir (*Abies amabilis*) (commercially sold as hem-fir, a mixture of these two species), and a locally-used timber considered to be termite resistant. In Japan, this locally-used wood is untreated hinoki (*Chamaecyparis obtusa*), a naturally durable softwood used in Japanese construction (Grace 1999, 2000); while in Hawaii it is Douglas-fir (*Pseudotsuga menziesii*), incised and treated with ammoniacal copper zinc arsenate (ACZA, 4.0 kg/m^3).

This paper updates previous reports on this ongoing study to describe the results of six years of field exposure in Hawaii. A comparable comprehensive report on the field study in Japan has been prepared by Tsunoda *et al.* (2004).

Materials and Methods

The test plot on the island of Oahu, Hawaii, is located at the Waimanalo Experiment Station of the College of Tropical Agriculture & Human Resources, University of Hawaii at Manoa. As described by Grace *et al.* (1995, 2000, 2001), test samples ca. 10 by 10 by 40 cm in size (ca. 2 kg) were each placed on a concrete building block 19 cm above soil grade. Untreated softwood feeder stakes within the block hollows extend into the soil. Each replication of 8 wood samples (complete block design) is covered with an untreated plywood box. Design of the concurrent test in Japan is essentially the same, except that plastic covers are used rather than plywood. In Hawaii, the plywood covers are replaced as necessary due to termite damage and weathering.

Treatments included in the field study in Hawaii are ACZA (Douglas-fir, 4.0 kg/m^3, incised); CCA (hem-fir, 4.0 kg/m^3, incised); and DOT (hem-fir, disodium octaborate tetrahydrate) at 2% boric acid equivalent (BAE) shell treatment, 2% BAE through treatment, 2% BAE + DDAC (didecyldimethylammonium chloride) through treatment, 3% BAE shell treatment, and 3% BAE through treatment. Each of the 10 test units also contains an untreated western hemlock or Pacific silver fir control sample.

Annual inspections are non-destructive, utilizing a visual rating scale: 10 (sound), 9, 7, 4, 0 (complete failure). Samples are rated independently each year, without direct reference to data from the previous year. Due to the subjective nature of this rating scale, and the relatively large mass of the samples (ca. 2 kg), ratings of individual samples occasionally increase from one year to the next. This is an indication that the true condition of the test sample may in fact fall between these two ratings, since the condition of the samples clearly cannot actually improve over time. In this report, we have chosen to preserve the integrity of these field observations, rather than relying upon the lowest rating assigned each sample.

Results and Discussion

Results of the first four years of the field test are presented in Table 1 (from Grace *et al.* 2001), and the fifth (2002) and sixth (2003) year results are given in Table 2. Although continued minor degradation was apparent in some test samples, no dramatic treatment failures occurred between the fourth and sixth years of the field test. We should point out again that these are relatively large test samples, with an individual mass of ca. 2 kg. With samples of this size, a visual rating system is not entirely satisfactory, and a visual rating of 7 (significant attack, 5 or more deep penetrations) likely represents a very small mass loss (perhaps ca. 1-5%). Mean ratings of the seven wood treatments included in this study after six years in the field ranged from 8.5 - 10. In the replicated study in Kagoshima, Japan, mean ratings of these same treatments after eight years ranged from 9.2 - 9.8 (Tsunoda *et al.* 2004).

In Hawaii, untreated control samples must be replaced at 1-2 year intervals when they evidence complete failure, in order to ensure that an acceptable control is present in each replicate to monitor termite activity. In the present report, controls were replaced after Year 2 when all had failed completely, and again two months after the third-year inspection in 2000. For the sake of consistency, the ratings of 0 for the original controls are carried over through the 4th year in Table 1. However, at the Year 3 inspection, the mean rating of the newly-placed control pieces was 3.0, after only 10 months of field exposure. At the Year 4 inspection, eight of the controls replaced 10 months earlier were completely destroyed, while the remaining two samples were each rated 4 (mean rating of 0.8). Similar results were observed at the Year 5 inspection (March 2002), and the 10 control samples were again replaced in July 2002. One of these new controls was low-density hemlock, while the other nine samples were high-density hemlock. At the Year 6 inspection (March 2003), we noted that the single low-density hemlock sample (test box #7, Table 2) had been completely destroyed, as in prior years, but the high-density hemlock had sustained only very limited attack. It is very likely that this represents greater durability of the high-density hemlock rather than any decline in termite activity at the site, since termites were still present on all of the controls (and some of the treated test materials) and actively feeding on feeder stakes in every replicate

The treatment sustaining the greatest termite feeding by the sixth year was the 2% BAE shell treatment with a mean rating of 8.5, range of 7-10, and median rating of 9 (six test pieces). We plan to perform chemical analyses at a later point in this study to determine whether greater termite feeding is attributable to differences in the actual borate retentions achieved in individual test pieces, or to different patterns of boron redistribution in the pieces, possibly due to moisture flux in the concrete building blocks.

In summary, six years of field results in Hawaii and eight years in Japan, in relatively aggressive termite feeding situations, support the conclusion that these DOT treatments, as well as the CCA and ACZA treatments, can provide long-term protection from destructive termite attack to structural lumber.

Acknowledgments

Funding for this field study was provided in part by USDA-ARS Specific Cooperative Agreement 58-6615-9-018, McIntire-Stennis funding for forestry research, and US Borax. ACZA samples were provided by J. H. Baxter & Company. We are very grateful to Robert Oshiro for expert technical assistance.

References

Grace, J.K. 1995. Termite field evaluations in Hawaii: a brief review of methods and issues. International Research Group on Wood Preservation, Stockholm, Sweden. Doc. No. IRG/WP/95-10131. 4 pp.

Grace, J.K. 1997. Review of recent research on the use of borates for termite prevention. Proceedings of the 2nd International Conference on Wood Protection With Diffusible Preservatives and Pesticides. Forest Products Society, Madison, WI. Pp. 85-92.

Grace, J.K. 1998. Resistance of pine treated with chromated copper arsenate to the Formosan subterranean termite. Forest Products Journal 48(3): 79-82

Grace, J.K. 1999. Termite penetration of construction elements. Shiroari 115: 18-23 (in Japanese).

Grace, J.K. 2000. Termite attack on susceptible lumber above naturally durable support posts. International Research Group on Wood Preservation, Stockholm, Sweden. IRG Document No. IRG/WP 00-10370. 6 pp.

Grace, J.K., R.J. Oshiro, T. Byrne, P.I. Morris, and K. Tsunoda. 2000. Termite resistance of borate-treated lumber in a three-year above-ground field test in Hawaii. International Research Group on Wood Preservation. Stockholm, Sweden. IRG Document No. IRG/WP 00-30236. 5 pp.

Grace, J.K., R.J. Oshiro, T. Byrne, P.I. Morris, and K. Tsunoda. 2001. Performance of borate-treated lumber in a four-year, above-ground termite field test in Hawaii. International Research Group on Wood Preservation. Stockholm, Sweden. IRG Document No. IRG/WP 01-30265. 6 pp.

Grace, J.K., K. Tsunoda, T. Byrne, & P.I. Morris. 1995. Field evaluation of borate-treated lumber under conditions of high termite hazard. P. 240 in Wood Preservation in the '90s and Beyond. Forest Products Society Proceedings No. 7308.

Grace, J.K., and R.T. Yamamoto. 1994. Repeated exposure of borate-treated Douglas-fir lumber to Formosan subterranean termites in an accelerated field test. Forest Products Journal 44(1): 65-67.

Morris. P.I., J.K. Grace, K.Tsunoda and A. Byrne. 2003. Performance of borate-treated wood against *Reticulitermes flavipes* in above-ground protected conditions. International Research Group on Wood Preservation, Stockholm, Sweden. IRG Document No. IRG/WP/30309. 9 pp.

Peters, B.C and C.J. Fitzgerald. 1998. Field exposure of borate-treated softwood to subterranean termites (Isoptera: Rhinotermitidae, Mastotermitidae). Mat. u. Org. 32 (1): 41-66.

Preston, A. F. L. Jin and K. Archer. 1996. Testing treated wood for protection against termite attack in buildings. Proceedings of the American Wood-Preservers' Association 92: 205-220.

Tsunoda, K., A. Adachi, T. Yoshimura, T. Byrne, P.I. Morris, and J.K. Grace. 1998. Resistance of borate-treated lumber to subterranean termites in the field. International Research Group on Wood Preservation, Stockholm, Sweden. IRG Document No. IRG/WP 98-10255. 5 pp.

Tsunoda, K., A. Adachi, T. Yoshimura, T. Byrne, P.I. Morris, and J.K. Grace. 2000. Resistance of borate-treated lumber to subterranean termites under protected above-ground conditions. International Research Group on Wood Preservation, Stockholm, Sweden. IRG Document No. IRG/WP 00-30239. 6 pp.

Tsunoda, K., A. Adachi, T. Byrne, P.I. Morris, and J.K. Grace. 2002a. Performance of borate-treated sill plates (dodai) in a protected, above-ground field test in Japan. International Research Group on Wood Preservation. Stockholm, Sweden. IRG Document No. IRG/WP 02-30278. 6 pp.

Tsunoda, K., J. K. Grace, T. Byrne, and P. I. Morris. 2002b. Effectiveness of disodium octaborate tetrahydrate (Tim-bor[○,R]) in controlling subterranean termite attack and decay of house sill plates. Mokuzai Gakkaishi 48: 107-114 (in Japanese).

Tsunoda, K., A. Byrne, P.I. Morris, and J.K. Grace. 2004. Performance of borate-treated lumber in a protected, above-ground field test in Japan. International Research Group on Wood Preservation. Stockholm, Sweden. IRG Document No. IRG/WP 04- *in press*. 8 pp.

TABLE 1. Visual damage ratings for years 1-4 (1998 - 2001) on the AWPA 10 - 0 scale of ca. 10 x 10 x 40 cm sill plates exposed to Formosan subterranean termite attack in a protected above-ground field test in Waimanalo, Oahu, Hawaii.

Test Box	DOT 2% BAE, shell	DOT 3% BAE, shell	DOT 2% BAE, through	DOT 3% BAE, through	DOT + DDAC 2% BAE, through	CCA 4 kg/m^3	Untreated Hem-Fir[b]	ACZA 4 kg/m^3
#1	9-7-7-7	10-10-10-10	10-10-10-10	10-10-10-10	10-10-10-10	F 9-10-9-9	F 0-0-0-0	10-10-10-10
#2	9-10-10-10	10-10-10-10	10-10-10-10	9-9-10-9	9-9-9-9	F 10-10-10-10	F 4-0-0-0	10-10-10-10
#3	10-10-10-10	9-10-10-10	10-10-9-9	10-10-10-9	9-10-10-10	F 10-10-10-10	F 0-0-0-0	10-10-10-10
#4	10-9-9-9	10-10-10-10	10-10-10-10	10-10-9-9	10-10-10-10	F 10-10-10-10	F 0-0-0-0	10-10-10-10
#5[d]	na-na-9-9	na-na-9-9	na-na-9-9	na-na-10-10	na-na-10-10	F na-na-10-10	F na-na-0-0	na-na-10-10
#6	9-10-10-10	10-10-10-10	10-10-9-9	10-10-10-10	10-7-7-7	H 9-7-7-7	H 4-0-0-0	10-10-10-10[e]
#7	10-10-10-10	10-10-9-9	9-10-10-10	9-10-10-10	9-7-7-7	H 10-10-10-10	H 0-0-0-0	10-10-10-10
#8	10-10-10-10	10-10-10-10	9-9-10-10	10-10-10-10	9-10-10-10	H 10-10-10-10	H 0-0-0-0	10-10-10-10
#9	10-10-10-7	10-10-10-9	10-10-10-10	9-10-10-10	10-10-10-10	H 9-10-9-9	H 4-4-0-0	10-10-10-10
#10	10-10-10-10	10-10-10-10	10-10-10-10	10-10-10-10	10-10-10-10	H 10-10-10-10	H 4-4-0-0	10-10-10-10
AVERAGE	9.7-9.6-9.5-9.2	9.9-10-9.8-9.7	9.8-9.9-9.7-9.7	9.7-9.8-9.9-9.7	9.6-9.2-9.3-9.3	9.7-9.7-9.5-9.5	1.8-0.9-0.0-0.0	10-10-10-10

[a] All samples except ACZA treatment (Douglas-fir) are hem-fir. CCA and ACZA treatments are incised as per AWPA recommendations. Rated on the AWPA visual rating scale of 10 (sound), 9, 7, 4, 0 (failure).

[b] Fir (F) and hemlock (H) controls were replaced 2 months after the Year 3 check due to complete failure. After 10 months exposure, eight of the new controls were rated 0 (failure), and two were rated 4 (in boxes #9 and #10) in Year 4. Cumulative control ratings are presented for consistency.

[d] There was no evidence of past or present termite exploration or attack in test unit #5 during Years 1-2, so this unit is not included in average for those years.

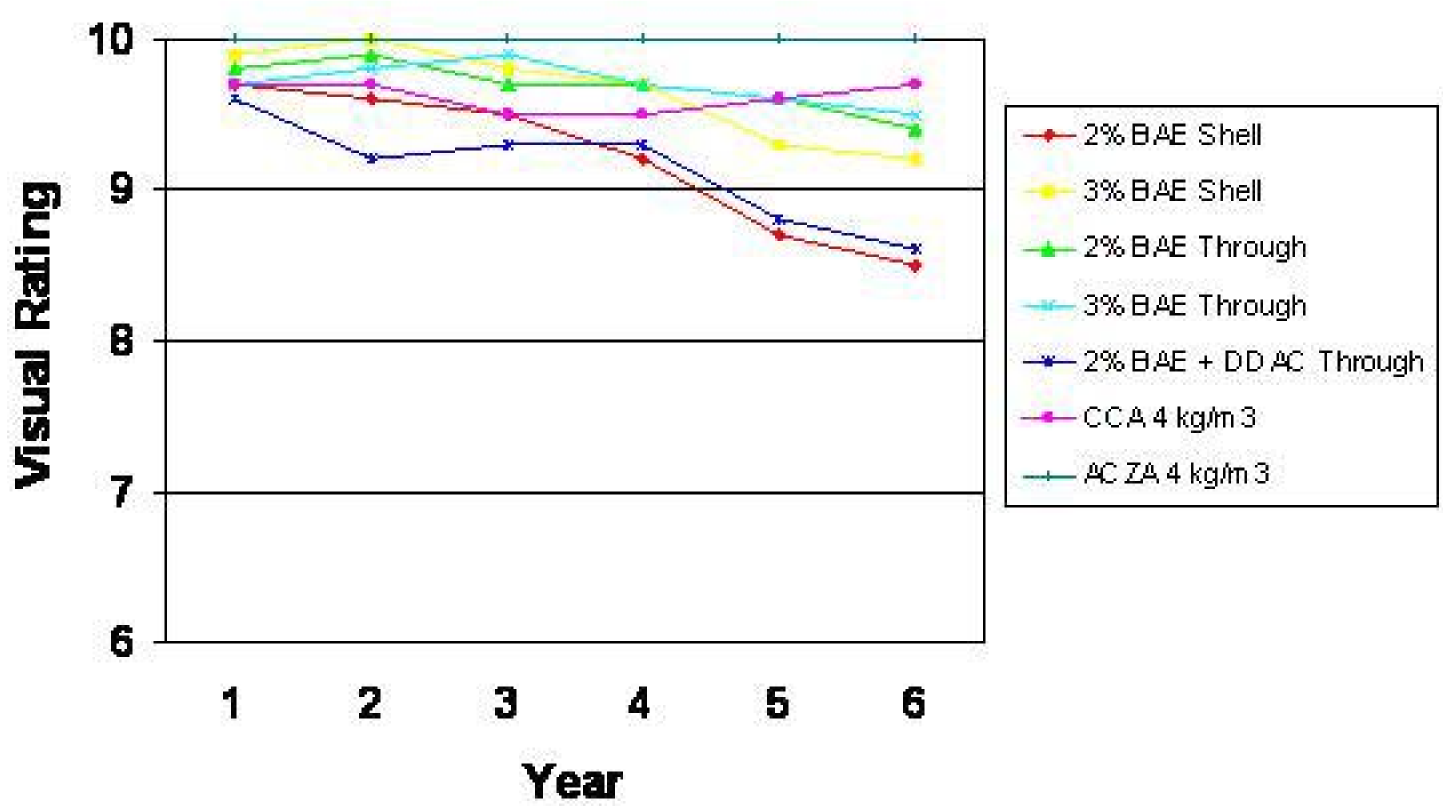
[e] Very minor surface etching noted in Year 3 on underside of ACZA treatment in unit #6 (ca. 1 mm deep by 3 mm wide by 20 mm long) unchanged in Year 4.

TABLE 2. Visual damage ratings for years 5-6 (2002 - 2003) on the AWPA 10 - 0 scale of ca. 10 x 10 x 40 cm sill plates exposed to Formosan subterranean termite attack in a protected above-ground field test in Waimanalo, Oahu, Hawaii.[a]

Test Box	DOT 2% BAE, shell	DOT 3% BAE, shell	DOT 2% BAE, through	DOT 3% BAE, through	DOT + DDAC 2% BAE, through	CCA 4 kg/m^3	Untreated Controls[b]	ACZA 4 kg/m^3
#1	7-7	9-9	10-10	10-10	9-9	F 9-10	0-7	10-10
#2	9-9	9-9	9-9	10-10	9-7	F 9-9	4-9	10-10
#3	9-9	9-9	9-9	9-9	9-9	F 10-10	0-10	10-10
#4	9-9	9-9	10-10	9-9	9-9	F 10-10	0-9	10-10
#5	9-9	9-9	9-7	10-10	10-10	F 10-10	4-9	10-10
#6	9-9	9-9	9-9	9-9	7-7	H 9-9	0-7	10-10
#7	9-9	10-9	10-10	10-10	7-7	H 10-10	0-0	10-10
#8	9-7	10-10	10-10	9-9	9-9	H 10-10	0-7	10-10
#9	7-7	9-9	10-10	10-9	10-10	H 9-9	0-10	10-10
#10	10-10	10-10	10-10	10-10	9-9	H 10-10	0-10	10-10
AVERAGE	8.7-8.5	9.3-9.2	9.6-9.4	9.6-9.5	8.8-8.6	9.6-9.7	0.8-7.8	10-10

[a] All samples except ACZA treatment (Douglas-fir) are hem-fir. CCA and ACZA treatments are incised as per AWPA recommendations. Rated on the AWPA visual rating scale of 10 (sound), 9, 7, 4, 0 (failure).
[b] Fir (F) and hemlock (H) controls were replaced 12 months prior to each inspection (i.e., in 2001 and 2002). In year 5, boxes 1-5 contained Fir controls, while boxes 6-10 contained low-density Hemlock. In year 6, all controls were high-density Hemlock, with the exception of box 7 which contained low-density Hemlock. All high-density Hemlock controls suffered less termite damage than low-density samples.

FIGURE 1. Mean visual damage ratings (AWPA 10 - 0 scale) in above-ground termite field test in Hawaii.



Note: Untreated hem-fir controls were all rated 0 (failure) after year 2.