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## Abstract

We report eight 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 10.0 (ACZA) to 8.2 (DOT, 2% BAE shell treatment) on the AWPA 10 - 0 scale after six years. This report updates the six-year results previously reported in IRG/WP 04-30343 (Grace *et al.* 2004).

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

## Introduction

As described by Grace *et al.* (1995, 2000, 2001, 2004), 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 attack occurs up to 10-times faster on untreated control samples 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.

Grace *et al.* (1995, 2000, 2001) and Tsunoda *et al.* (1998, 2000, 2002a, 2002b, 2004, 2006) 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 representative of the greater reliance on natural durability 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 eight years of field exposure in Hawaii. A comparable comprehensive report on the field study in Japan, describing the results after 10 years of exposure, has been prepared by Tsunoda *et al.* (2006).

## 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 previously described (Grace *et al.* 2004), 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). In Hawaii, untreated controls 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, we have carried over the ratings of 0 for the original controls to the sixth year. However, at the Year 3 inspection, the mean rating of the newly-placed control samples 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 boards were each rated 4 (mean rating of 0.8). Similar results were observed at the Year 5 inspection (March 2002), and the 10 controls were again replaced in July 2003. One of these new control pieces was low-density hemlock, while the other nine boards were high-density hemlock. At the Year 6 inspection (March 2003), we noted that the low-density hemlock board had been completely destroyed, as in prior years, but the high-density hemlock had sustained only very limited attack. This represents greater durability of the high-density boards 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. During years 7 and 8, these high-density control samples sustained progressively greater damage, moving from a mean visual rating of 7.8 in Year 6, to one of 6.0 in Year 8.

## Results and Discussion

Results of up to the most recent annual inspection in March 2005, are presented in Tables 1 and 2. Since these are large-dimensioned test samples (ca. 2 kg), and visual ratings are conducted independently each year, there is some fluctuation from year to year (i.e., apparent sample "recovery"). 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%). However, mean ratings for all treatments have remained consistently in the range of 8-10 for the past two years (Figure 1), with the lowest mean rating of 8.2 assigned to the 2% BAE shell treatment, and the highest rating of 10.0 assigned to the ACZA treatment. Paired test samples (except for ACZA) exposed for 10 years in Kagoshima, Japan, fall into the high end of this same mean range (8.8 to 9.6) (Tsunoda *et al.* 2006).

Only a single sample (belonging to the 2% BAE shell treatment group) was rated as 4 in the eighth year, and ratings for this particular sample have fluctuated between 4 and 7 for the past three years. We estimate that the low rating of this single test piece may represent a mass loss of approximately 20%. Chemical analyses are needed to determine whether this sample is exhibiting a different pattern of boron loss (possibly due to local moisture conditions) than the others included in this treatment, and such analyses are planned when this field study is concluded in its tenth year.

As in Japan (Tsunoda *et al.* 2006), a 3% BAE through treatment performed comparably in Hawaii to CCA (mean ratings of 9.7 and 9.8, respectively), followed very closely by the 2% BAE through treatment (mean rating of 9.5).

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

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**TABLE 1. Visual damage ratings for years 1-4 (1998 - 2001) on the AWPA 10 - 0 scale of 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 | 10.0-10.0-10.0-10.0 |

[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.

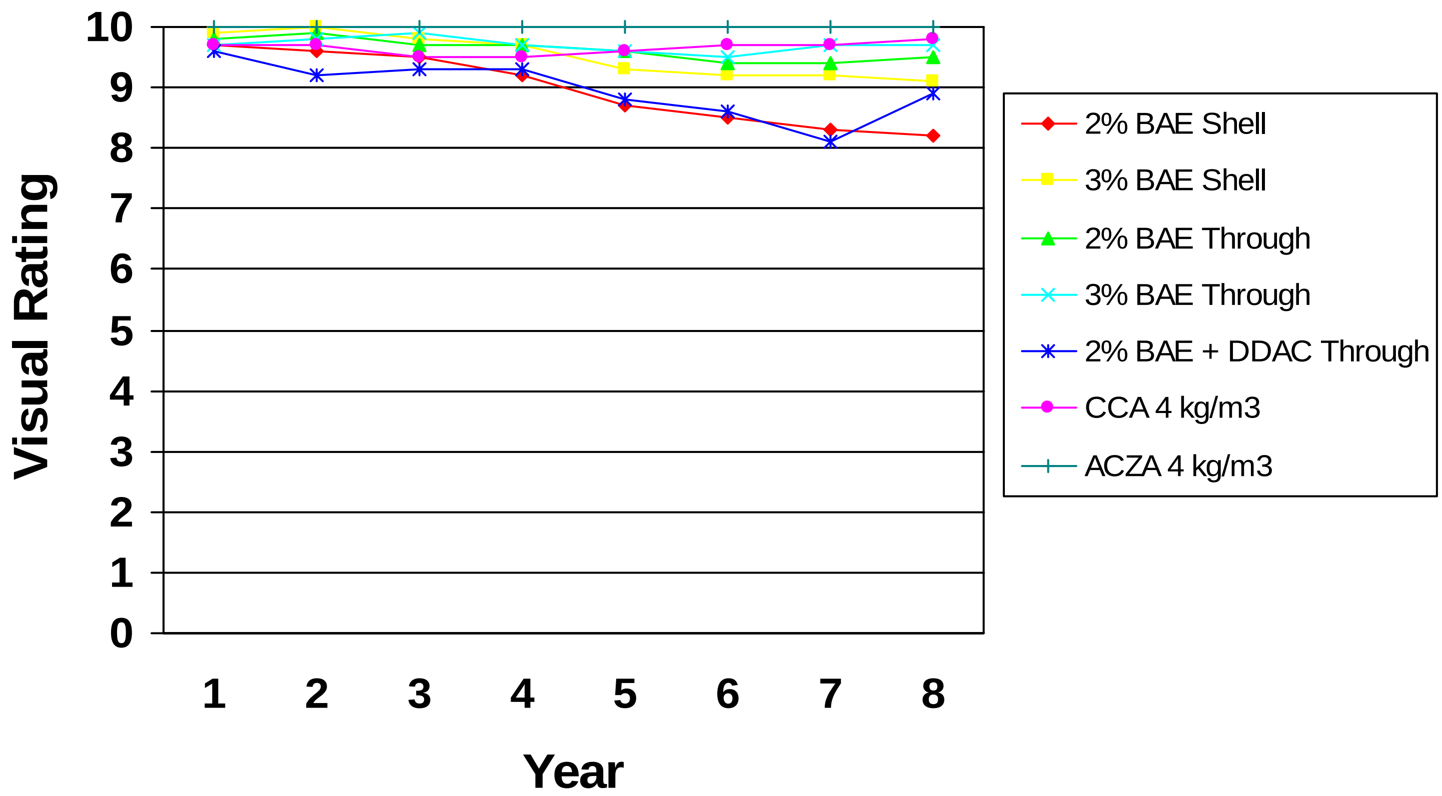
**TABLE 2. Visual damage ratings for years 5-8 (2002 - 2005) on the AWPA 10 - 0 scale of 10 x 10 x 40 cm sill plates exposed to Formosan subterranean termite attack in a protected above-ground field test in Waimanalo, Oahu, Hawaii.[a]**

| 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 | 7-4-7-4 | 9-9-9-9 | 10-10-10-10 | 10-10-10-10 | 9-9-9-9 | F 9-10-10-10 | 0-7-7-7 | 10-10-10-10 |
| #2 | 9-9-9-9 | 9-9-9-9 | 9-9-9-9 | 10-10-10-10 | 9-7-7-9 | F 9-9-9-9 | 4-9-7-7 | 10-10-10-10 |
| #3 | 9-9-9-9 | 9-9-9-9 | 9-9-9-9 | 9-9-9-9 | 9-9-9-9 | F 10-10-10-10 | 10-10-10-7 | 10-10-10-10 |
| #4 | 9-9-7-9 | 9-9-9-9 | 10-10-10-10 | 9-9-9-9 | 9-9-9-9 | F 10-10-10-10 | 0-9-7-4 | 10-10-10-10 |
| #5 | 9-9-9-9 | 9-9-9-9 | 9-7-9-9 | 10-10-10-10 | 10-10-9-10 | F 10-10-10-10 | 4-9-9-7 | 10-10-10-10 |
| #6 | 9-9-9-9 | 9-9-9-9 | 9-9-9-9 | 9-9-9-9 | 7-7-7-9 | H 9-9-9-9 | 0-7-7-7 | 10-10-10-10 |
| #7 | 9-9-9-9 | 10-9-9-9 | 10-10-10-10 | 10-10-10-10 | 7-7-4-7 | H 10-10-10-10 | 0-0-0-0 | 10-10-10-10 |
| #8 | 9-7-7-7 | 10-10-10-9 | 10-10-9-10 | 9-9-10-10 | 9-9-9-9 | H 10-10-9-10 | 0-7-4-7 | 10-10-10-10 |
| #9 | 7-7-7-7 | 9-9-9-9 | 10-10-10-10 | 10-9-10-10 | 10-10-9-9 | H 9-9-10-10 | 0-10-10-10 | 10-10-10-10 |
| #10 | 10-10-10-10 | 10-10-10-10 | 10-10-9-9 | 10-10-10-10 | 9-9-9-9 | H 10-10-10-10 | 0-10-4-4 | 10-10-10-10 |
| AVERAGE | 8.7-8.2-8.3-8.2 | 9.3-9.2-9.2-9.1 | 9.6-9.4-9.4-9.5 | 9.6-9.5-9.7-9.7 | 8.8-8.6-8.1-8.9 | 9.6-9.7-9.7-9.8 | 0.8-7.8-6.5-6.0 | 10.0-10.0-10.0-10.0 |

[a] All boards 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 Year 5 and 6 inspections (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.