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## Abstract

We report the fourth year 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% 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. This report updates the three-year results previously reported to IRG (Grace *et al.* 2000). After four years, minor damage (visual rating of 7) has been noted to five individual treatment dodai (out of a total of 10 boards per treatment) as follows: 2% BAE shell treatment (2 boards), 2% BAE + DDAC through treatment (2 boards), and CCA treatment (1 board). Between the third and fourth years of the test, only four treated boards progressed to lower visual ratings: one 2% BAE shell treatment (from 10 to 7), one 3% BAE shell treatment (from 10 to 9), and two 3% BAE through treatments (from 10 to 9). In contrast, all untreated control boards were virtually destroyed during the past ten months of exposure. Mean ratings for all wood treatments ranged from 9.2 to 10. These four-year results suggest that each these DOT, CCA and ACZA treatments would provide long-term protection to dodai from termite attack.

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

## Introduction

As described by Grace *et al.* (1995, 2000), 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.

Grace *et al.* (1995, 2000) and Tsunoda *et al.* (1998, 2000) 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$^3$).

The results of four years of field exposure in Japan were reported by Tsunoda *et al.* (2000), while Grace *et al.* (2000) reported the first three years of results in Hawaii. Here, we report the results of four years of field exposure in Hawaii.

## 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), 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 + D (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 board.

Annual inspections are non-destructive, utilizing a visual rating scale: 10 (sound), 9, 7, 4, 0 (complete failure). In Hawaii, untreated control boards 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, control boards 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 fourth year. However, at the Year 3 inspection, the mean rating of the newly-placed control boards was 3.0, after only 10 months of field exposure. At the Year 4 inspection (February 2001), 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). Thus, termites have continued to be extremely active throughout the test site, virtually destroying the 2 kg control boards in less than one year in each of the ten replicated test units.

**Results and Discussion**

Results of the 4-year inspection in February 2001 are presented in Table 1. The untreated control boards were all severally attacked, while increased attack from Year 3 was only noted with a total of four of the treated boards, and in no case did damage from termite feeding produce a visual rating of less than 7. Due to the size of the wood pieces (ca. 2 kg), it should be pointed out that 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 ranged from 9.2 - 10.

During the first two years of the study, termites were active in all test units except #5. Since there was no attack on the untreated control in this unit, nor any evidence of termite exploration, this unit was not included in calculating the average visual damage ratings during these first two years. However, termites discovered and attacked the wood in this test unit during the third year of the test to the point where the control was rated 0, and again completely destroyed the new control board (rating of 0) during the fourth year of the test. Thus, ratings for unit #5 are included in the Year 3 and Year 4 averages. Termites also unexpectedly vacated test unit #2 between the Year 2 and Year 3 inspections. We included ratings of the treated wood samples in this unit in the Year 3 average ratings with the expectation that termites would return to this unit. This proved to be a valid expectation, as termites indeed returned to unit #2 after the Year 3 inspection, and completely destroyed the newly-placed control board (rating of 0).

In comparison to the consistent rapid destruction of the control boards throughout this 4-year field test, all the wood treatments have provided excellent protection, with mean visual ratings ranging from 9.2 to 10 in the fourth year. As was the case in Year 3, the lowest individual board rating in Year 4 was 7, occurring with the 2% BAE shell treatment (2 boards), 2% BAE + DDAC through treatment (2 boards), and CCA treatment (1 board). As has been noted in previous work (Grace & Yamamoto 1994, Grace 1998), neither DOT nor CCA are repellent to termites, and minor damage is not unexpected. All but one of the boards rated 7 in Year 4 had also been rated 7 during the second and third inspection years, and there has been no further visible deterioration. The exception to this was one of the 2% BAE shell treatments, which declined from a rating of 10 in Year 3 to a rating of 7 in Year 4.

The only other changes in treatment ratings in from Year 3 to Year 4 occurred with one of the 3% BAE shell treatments and two of the 3% BAE through treatments, which declined from 10 to 9. It is noteworthy that the mean ratings of all five borate treatment remain in the range of 9.2 - 9.7, while the CCA mean is 9.5, and the ACZA mean is 10 (with minor surface etching by termites of a single board). Despite the consistently severe attack on the untreated controls during the four year field

exposure, necessitating annual replacement of these boards, none of the treated boards have declined to a rating of less than 7; and decline to this level of moderate attack has only occurred with a total of 5 boards. The lack of progression of attack beyond a rating of 7 during four years of exposure, despite the location of each of these samples within the test array immediately adjacent to untreated controls that were completely destroyed within a single year, is consistent with the "delayed deterrence" of DOT hypothesized from other studies (Grace 1997).

Tsunoda *et al.* (2000) reported that four years of similar field exposure in Japan resulted in only minor surface damage (rating of 9) to a single board each in the 2% BAE+DDAC through treatment and the CCA treatment. Thus, our Year 4 results continue to support the conclusion that termite activity is at least 3-fold greater in Waimanalo, Hawaii, than in Kagoshima Prefecture, Japan. Formosan subterranean termites are well established and 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 contrast to the seasonality found in Kagoshima. Extrapolation of our results in Hawaii to conditions in Japan suggest that these DOT treatments, as well as the CCA and ACZA treatments can provide long-term protection to otherwise susceptible sill plates (dodai) from termite attack.

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**TABLE 1. Visual damage ratings on the AWPA 10 - 0 scale of ca. 10 x 10 x 40 cm boards exposed to Formosan subterranean termite attack for four years in a protected above-ground field test in Waimanalo, Hawaii. Bold face indicates a change in rating from Year 3 to Year 4.[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 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 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 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.