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Section 3 **Wood Protecting Chemicals**

Performance of borate-treated lumber in a protected, above-ground field test in Japan

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ABSTRACT

This document is supplemental to the previous IRG document (Tsunoda *et al*., 2002).
An experiment to simulate the sill plate (dodai) of the Japanese houses was conducted at the termite field test site of the Wood Research Institute in Kagoshima, Japan where two economically important subterranean termite species [*Coptotermes formosanus* Shiraki and *Reticulitermes speratus* (Kolbe)] are established. DOT(disodium octaborate tetrahydrate)-treated hem-fir samples [*Tsuga heterophylla* (Raf.) Sarg. and *Abies amabilis* (Dougl.) Forbes]- 105 x 105 x 400 mm in size were placed on concrete blocks 19 cm the above ground surface. The test samples were prepared from sound wood samples pressure treated to supply 10 replicates of shell-treated materials at target levels of 2% BAE and 3% BAE. The subsequent diffusion storage produced another set of through-treated samples at the same target levels. Feeder stakes within the block hollows extended into the soil to facilitate the access of the termites to the wood samples. The assembled sets were covered with plastic boxes to protect the samples from the weather. Samples were annually inspected for termite attack and decay and visually rated according to AWPA standards since installation on December 21, 1995.

All treated samples still remained free from decay after 8 years' exposure, although slight progress in termite attack was observed on a few samples of 5 treatments within the last two years. Three samples with a target retention of CCA 4 kg/m3 were slightly attacked. On the other hand, 3% BAE through treatment performed best with mean rating of 9.8 against termite attack. After 8 years' exposure, 2-4 samples from each group of borate treatments (2% BAE shell, 3% BAE shell, 2% BAE through and 3 % BAE through treatments) were slightly attacked by termites. Untreated hem-fir and hinoki (*Chamaecyparis obtusa* Endl.) controls showed progressive termite attack starting in the first year and were heavily attacked after 8 years' exposure. Incipient decay was first found on 7 untreated hem-fir and sapwood portion of two untreated hinoki during the 5th year of exposure, whereas 9 and 4 sustained slight to heavy decay after 8 years' exposure, respectively.

Keywords: Borate-treatment, disodium octaborate tetrahydrate, subterranean termites, sill plate (dodai), above-ground use, field test

1.INTRODUCTION

Sodium borate is a diffusible preservative and unfixed in wood. These properties do not allow treatment with water-soluble borates to meet performance requirements of JIS K 1571 (1998) after severe leaching cycles. Revision of the related standard (JIS K 1571, 1998), however, will enable taking the mild evaporation method (60℃ for 7 days) into consideration. This method will be applied to evaluation of preservatives for treating wood in use class 2 above-ground conditions. The revised JIS K 1571 seems to extend options for actual applications of borate-treated wood in use class 2 to ensure a long service life for Japanese houses in the future. Although sill plates (dodai) in Japanese houses are situated in use class 2 conditions, the commodity will be treated as those in use class 3 (above-ground unprotected conditions) due to its importance as load-bearing component.

A test design to simulate the sill plate (dodai)-use was previously developed for evaluating the effectiveness of preservatives against subterranean termites (Grace *et al*., 1995; Tsunoda *et al*., 1998; Morris *et al*., 2003) over a long period of field exposure under protected above-ground conditions. The test method is also applicable to the evaluation of biological resistance of other wood materials without modification (Tsunoda 2003). The objective of the current investigation was to determine whether borate-treatments could provide wood products with resistance against both subterranean termites and decay fungi in an above-ground protected test in Japan.

2.MATERIALS AND METHODS

Sound, unseasoned hem-fir samples (105 x 105 x 1300 mm) were cut from lumber so that 400 mm long end-matched samples, free of large knots and checks, were obtained following treatments. The wood samples were pressure treated with aqueous solutions of disodium octaborate tetrahydrate (DOT) or DOT with didecyldimethylammonium chloride (DDAC). Ten replicates were produced of both shell- and through-treated cross sections treated to target retentions of 2% and 3% boric acid equivalent (BAE). Retentions of shell treated samples were determined by chemical analyses of the surface 16 mm zones.

For comparison to a standard preservative additional samples were also treated with chromated copper arsenate (CCA) to a retention of 4.0 kg/m^3. For each treatment half of the hem-fir samples were western hemlock [*Tsuga heterophylla* (Raf.) Sarg.] and half were Pacific silver fir[*Abies amabilis* (Dougl.) Forbes]. Untreated samples of both species and of hinoki [*Chamaecyparis obtusa* (Endl.)] a naturally durable softwood, were included in the field test.

After determining the air-dried weight of each wood sample, the samples were installed at the termite field test site in Kagoshima Prefecture, Japan on December 12, 1995. Each sample was placed on a concrete block with pine sapwood feeder stakes in the hollows of the concrete blocks. The feeder stakes were driven into the soil to encourage initial termite attack and these stakes were replaced after 3 and 5 years' service. The installed samples were placed in clusters of eight, one each of 8 treatments (Table 1) and each cluster was covered with a PVC box. The replication of 10 per treatment resulted in 10 boxes being installed. Annual visual inspection was conducted and the degree of termite attack was rated according to AWPA field stake test procedure [10: sound (no attack), 9: trace to slight attack (surface nibbling or shallow excavation), 7: moderate attack (obvious penetration), 4: heavy attack (deep penetration), and 0: failure (sample largely disintegrated) (American Wood Preservers' Association, 2001). A similar rating 0-10 was given for decay.

3.RESULTS AND DISCUSSION

3.1 Inspection results up to 6 years' exposure

We have already reported the inspection results for the first 6 years but, briefly summarize them here (see Table1 and Fig.1).

(1) First inspection: All treated samples were free from any biodeterioration, while untreated wood samples in 7 of the 10 boxes were attacked by termites. Seven untreated hem-fir and 6 untreated hinoki sustained slight to moderate attack.

(2) Second inspection: Termite attack was visible in 8 boxes and one replicate of treatment 5 (2% BAE shell with DOT/DDAC) was slightly attacked. This was the first record of termite attack on a treated sample.

(3) Third inspection: The number of boxes with termite attack increased with time and after three years every box showed some termite attack on the untreated controls. Nine replicates each of hem-fir and hinoki untreated controls sustained slight to heavy termite damage.

(4) Fourth inspection: The first slight termite attack on a CCA-treated sample was found. Termite attack was visible on 9 hem-fir and 10 hinoki untreated controls. Over the first 4 years' exposure in the field, no symptoms of decay were not observed, even on untreated wood samples, despite the fact that moisture contents were suitable for growth of wood-decaying fungi.

(5) Fifth inspection: Wood samples, treated with DOT only, regardless of borate distribution in the wood (shell or through treatment), or of preservative retention, showed no termite attack by the end of the fifth year. All untreated controls were finally attacked by termites, although no further progress in termite attack or decay was found on the treated samples. Signs of incipient decay were first found on 7 untreated hem-fir controls and on the sapwood portion of two untreated hinoki controls during the fifth year.

(6) Sixth inspection: Decay on the untreated controls progressed as expected. One or two borate-treated samples first sustained slight termite attack, and one and two of the treatments 5 (2% BAE shell with DOT/DDAC) and 6 (CCA 4.0 kg/m^3) respectively sustained new termite attack.

(7)

3.2 Inspection results after 7 years

Progress in termite attack was noticed in 2 treatments (2% BAE shell and through). Severe termite attack was found on most of untreated controls with mean scores of 4.3 and 4.9 for hem-fir and hinoki, respectively. Decay also became severe on untreated controls with mean scores of 4.3 and 5.2 for hem-fir and hinoki, respectively (see Table 2).

3.3 Inspection results after 8 years

All treated samples were found free from decay. Slow progress in termite attack was recorded on the samples of 5 treatments, except 3% BAE through treatment of which only two samples sustained very slight termite attack (Fig. 1). In contrast, both termite attack and decay on the untreated control developed as expected, and mean termite rating went down to 4.0 (severe damage) (see Table 2).

3.4 General discussion

The ability of DDT to control decay has been well established in literature (Drysdale,1994) and the low natual durability of hem-fir to decay has also been reported (Panshinn and De Zeeuw, 1970; Highly, 1995). Recent reviews indicate that the effectiveness of sodium borates to subterranean termites in above-ground situations varies with test methods and termite species (Drysdale, 1994; Grace, 1997; Tsunoda, 1999). However, borate retentions ranging from 0.5% to 2.5% BAE protect wood products from subterranean termites, including *Coptotermes* species (Preston *et al*., 1985 and 1996; Grace and Yamamoto, 1993 and 1994; Moffat and Peters, 1993; Peters and Allen, 1993; Peters and Fitzgerald, 1998) with a few exceptions (Archer et al., 1991; Kennedy et al, 1996). The present results seem to fit with these findings.

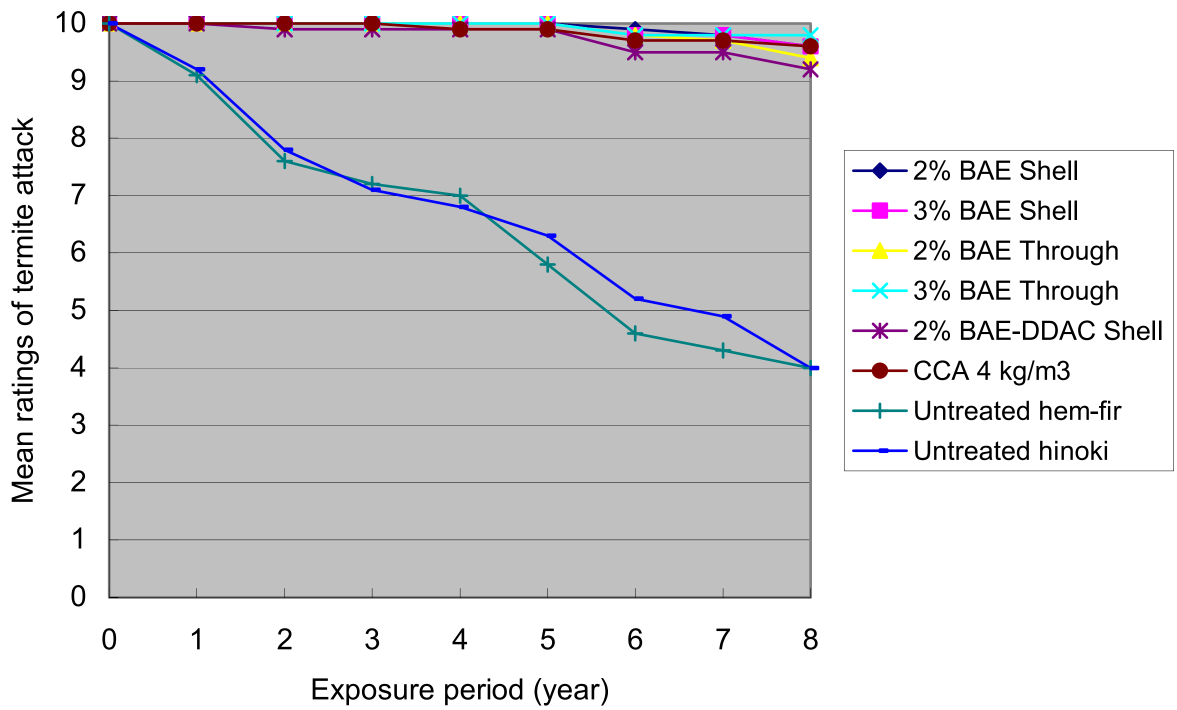

Fig. 1 Progress in termite attack on treated and untreated wood samples

Experimental design is clearly an important factor in the efficacy of unfixed preservatives such as DOT that must be used under protected above-ground conditions to prevent serious leaching. Therefore, the retention of a test preservative during the test period must be determined chemically in order to confirm that the method is suitable for testing leachable preservatives. Unfortunately, chemical analytical data was not given for the previously reported investigations where borate treatment failed against termites. Such failure could thus be attributable to low levels of borate, resulting from low initial retentions or from leaching of the preservative, or to the presence of borate-tolerant termites such as *Mastotermes* sp. (Peters and Fitzgerald, 1998) and *Nasutitermes* sp. (Gay *et al*., 1958).

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Table 1 Inspection results for the first 6 years (1995-2001)

	Treatment							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Box 1	EE10/10/10/10/10/10	BK10/10/10/10/10/10	HI10/10/10/10/10/10	HE10/10/10/10/10/09	EJ10/10/10/10/10/09	9F10/10/10/10/10/10	F1 09/07/07/07/07/07 10/10/10/10/10/10	1 09/07/07/07/07/07 10/10/10/10/10/10
Box 2	AU10/10/10/10/10/10	AS10/10/10/10/10/10	CS10/10/10/10/10/09	dN10/10/10/10/10/10	HC10/10/10/10/10/10	19F10/10/10/10/10/10	F5 10/07/07/07/07/04 10/10/10/10/09/07	2 07/04/04/04/04/04 10/10/10/10/1010
Box 3	BC10/10/10/10/10/10	AY10/10/10/10/10/09	EP10/10/10/10/10/10	dV10/10/10/10/10/10	HJ10/10/10/10/10/10	11F10/10/10/09/09/09	F4 07/07/07/07/07/04 10/10/10/10/09/09	3 09/07/07/07/07/07 10/10/10/10/10/10
Box 4	AC10/10/10/10/10/10	AW10/10/10/10/10/10	EF10/10/10/10/10/10	Ed10/10/10/10/1010	dT10/10/10/10/10/10	10F10/10/10/10/10/10	F3 09/07/04/04/04/04 10/10/10/10/09/09	4 09/07/07/07/07/04 10/10/10/10/10/10
Box 5	AG10/10/10/10/10/09	EG10/10/10/10/10/10	dR10/10/10/10/10/09	GM10/10/10/10/10/09	EL10/10/10/10/10/10	8F10/10/10/10/10/09	F2 09/07/07/07/07/04 10/10/10/10/09/09	5 09/07/07/0707/04 10/10/10/10/10/10
Box 6	BN10/10/10/10/10/10	CG10/10/10/10/10/09	FZ10/10/10/10/10/10	GE10/10/10/10/10/10	CH10/10/10/10/10/10	6H10/10/10/10/10/10	H4 09/07/07/07/04/04 10/10/10/10/09/09	6 09/07/07/07/04/04 10/10/10/10/09/09
Box 7	BQ10/10/10/10/10/10	AI10/10/10/10/10/10	GA10/10/10/10/10/10	Gd10/10/10/10/10/10	EM10/10/10/10/10/07	18H10/10/10/10/10/09	H5 09/07/07/07/04/04 10/10/10/10/09/09	7 10/09/09/09/09/07 10/10/10/10/10/10
Box 8	BJ10/10/10/10/10/10	CB10/10/10/10/10/10	FM10/10/10/10/10/10	FX10/10/10/10/10/10	ES10/09/09/09/09/09	22H10/10/10/10/10/10	H1 09/07/07/07/07/04 10/10/10/10/10/10	8 10/10/10/09/07/07 10/10/10/10/10/10
Box 9	CE10/10/10/10/10/10	AH10/10/10/10/10/10	FS10/10/10/10/10/10	FP10/10/10/10/10/10	HG10/10/10/10/10/10	15H10/10/10/10/10/10	H3 10/10/09/07/04/04 10/10/10/10/09/07	9 10/10/09/07/07/04 10/10/10/10/09/07
Box 10	CJ10/10/10/10/10/10	BR10/10/10/10/10/10	GI10/10/10/10/10/10	GN10/10/10/10/1010	dO10/10/10/10/10/10	5H10/10/10/10/10/10	H2 10/10/10/10/07/07 10/10/10/10/10/09	10 10/10/04/04/04/04 10/10/10/10/10/10
Mean	10/10/10/10/10/9.9 10/10/10/10/10/10	10/10/10/10/10/9.8 10/10/10/10/10/10	10/10/10/10/10/9.8 10/10/10/10/10/10	10/10/10/10/10/9.8 10/10/10/10/10/10	10/9.9/9.9/9.9/9.9/9.5 10/10/10/10/10/10	10/10/10/9.9/9.9/9.7 10/10//10/10/10/10	9.1/7.6/7.2/7.0/5.8/4.6 10/10/10/10/9.3/8.8	9.2/7.8/7.1/6.8/6.3/5.2 10/10/10/10/9.8/9.6

Treatment:1=2% shell, 2=3% shell, 3=2% through, 4=3% through, 5=2%-DDAC shell, 6=CCA 4 kg/m^3, 7=untreated hemlock and fir, 8=untreated hinoki

Upper figures for termite ratings and lower ones for decay ratings

Table 2 Inspection results after 7 and 8 years' exposure (2002/2003)

	Treatment							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Box 1	EE10/10/ 10/10/	BK10/09/ 10/10/	HI09/09/ 10/10/	HE09/09/ 10/10/	EJ09/09/ 10/10/	9F10/10/ 10/10/	F1 07/04/ 10/10/	1 0704/ 10/10/
Box 2	AU10/10/ 10/10/	AS10/10/ 10/10/	CS09/07/ 10/10/	dN10/10/ 10/10/	HC10/10/ 10/10/	19F10/10/ 10/10/	F5 04/04/ 07/07/	2 04/04/ 10/10/
Box 3	BC10/10/ 10/10/	AY09/09/ 10/10/	EP10/10/ 10/10/	dV10/10/ 10/10/	HJ10/10/ 10/10/	11F09/09/ 10/10/	F4 04/04/ 09/09/	3 07/04/ 10/10/
Box 4	AC10/09/ 10/10/	AW10/10/ 10/10/	EF10/10/ 10/10/	Ed10/10/ 10/10/	dT10/10/ 10/10/	10F10/10/ 10/10/	F3 04/04/ 07/07/	4 04/04/ 10/10/
Box 5	AG09/09/ 10/10/	EG10/10/ 10/10/	dR09/09/ 10/10/	GM09/09/ 10/10/	EL10/10/ 10/10/	8F09/09/ 10/10/	F2 04/04/ 07/04/	5 04/04/ 10/10/
Box 6	BN10/10/ 10/10/	CG09/09/ 10/10/	FZ10/09/ 10/10/	GE10/10/ 10/10/	CH10/10/ 10/10/	6H10/10/ 10/10//	H4 04/04/ 09/09/	6 04/04/ 09/09/
Box 7	BQ10/10/ 10/10/	AI10/10/ 10/10/	GA10/10/ 10/10/	Gd10/10/ 10/10/	EM07/07/ 10/10/	18H09/09/ 10/10/	H5 04/04/ 04/04/	7 04/04/ 09/07/
Box 8	BJ10/09/ 10/10/	CB10/09/ 10/10/	FM10/10/ 10/10/	FX10/10/ 10/10/	ES09/07/ 10/10/	22H10/09/ 10/10/	H1 04/04/ 10/09/	8 07/04/ 10/09/
Box 9	CE10/09/ 10/10/	AH10/10/ 10/10/	FS10/10/ 10/10/	FP10/10/ 10/10/	HG10/09/ 10/10/	15H10/10/ 10/10/	H3 04/04/ 04/04/	9 04/04/ 04/04/
Box 10	CJ10/10/ 10/10/	BR10/10/ 10/10/	GI10/10/ 10/10/	GN10/10/ 10/10/	dO10/10/ 10/10/	5H10/10/ 10/10/	H2 04/04/ 09/07/	10 04/04/ 10/10/
Mean	9.8/9.6/ 10/10/	9.8/9.6/ 10/10/	9.7/9.4/ 10/10/	9.8/9.8/ 10/10/	9.5/9.2/ 10/10/	9.7/9.6/ 10/10/	4.3/4.0/ 7.6/7.0/	4.9/4.0/ 9.2/8.9/

Treatment: 1=2% shell, 2=3% shell, 3=2% through, 4=3% through, 5=2%-DDAC shell, 6=CCA 4 kg/m^3, 7=untreated hemlock and fir, 8=untreated hinoki

Upper figures for termite ratings and lower ones for decay ratings