Relative tolerance of CCA by larvae and adults of the common shipworm, *Bankia gouldi* [1]

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1. Introduction

The use of Southern Pine lumber and timber treated with chromated copper arsenate (CCA) for marinas and waterfront bulkheading has increased markedly along the eastern and Gulf coasts of the United States during the past two decades. With that increase have come widespread reports of damage to bulkheads by marine borers (shipworms). This damage has been attributed to exposure of heartwood faces that are poorly penetrated with preservative, resulting in settlement and burrowing of shipworms (B. R. JOHXSON, 1986: B. R. JOHNSON and R. JACKSON, 1990). In some cases, shipworms that entered through the untreated heartwood have continued to burrow into treated sapwood.

Shipworms initially settle on wood surfaces in a free-swimming larval stage. They may explore the surface in search of an area suitable for penetration (W. D. KAMPF *et al.*, 1959); for example, an area that is relatively soft and free of toxicants. Research has shown that larvae are more sensitive to toxins than are adult borers (R. J. MENZIES and R. TURNZR, 1957), but this finding has not been quantified, at least in regard to CCA-treated wood.

In our study, we attempted to quantify the difference in CCA tolerance of larval and adult forms of the common shipworm, *Bankia gouldi* (Bartsch). The study was undertaken because of interest in reducing pre-

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servative retentions to the minimum necessary level and because of concern about exposed (untreated) heartwood. Laminates of treated and untreated wood were combined and exposed to shipworm attack for one or two seasons.

2. Methods

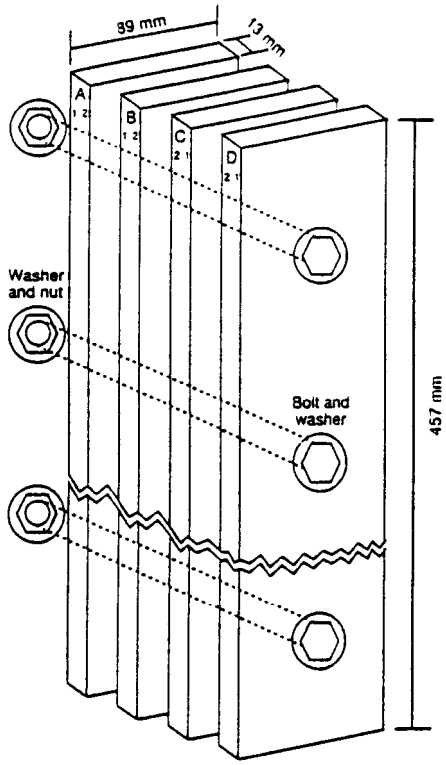
Southern Pine sapwood was quartersawn into 13- by 89- by 457-mm panels. Panels were conditioned to a constant moisture content, and then either left untreated or full cell treated with CCA-C (48 percent CrO_3, 18 percent CuO, 34 percent As_2O_5) to approximate average retentions of 4.0, 8.0, 16.0, 24.0, 30, or 40 kg/m^3. Target retentions were selected to reflect those used in service as well as a range of intermediate and lower retentions. Actual retentions, as determined by gross solution uptake, ranged from 3.9 to 44.5 kg/m^3. Post-treatment conditioning consisted of storing the laminates, wrapped in polyethylene, at 52°C for 2 weeks. followed by air drying for 2 weeks. After conditioning, marine test specimens were fabricated by bolting together four laminates per specimen. The laminates were arranged so that the treated wood was sandwiched between the untreated controls, which allowed the shipworms to become established in the untreated wood before penetrating the treated wood (Fig. 1)

Laminates were exposed for one or two seasons. For the one-season exposure (May to October 1990), four combinations of CCA retentions were tested (Table 1): average 7.9 and 16.2kg/m^3, 16.0 and 24.4kg/m^3. 24.3 and 29.4kg/m^3, and 29.4 and 43.9kg/m^3. Three combinations of CCA retentions were tested in the two-season exposure (May 1991 to October 1992) (Table 2): average 3.9 and 24.4kg/m^3, 7.8 and 41.3kg/m^3, and 7.8, 23.7, and 41.7kg/m^3. Note that for the last combination, only one outer laminate was untreated (Table 2).

For each exposure, three replicate assemblies (total of 12 specimens) were attached to fiberglass racks. The assembled test racks were suspended in shallow water of the Great Wicomico River near Burgess. Virginia, on the west shore of Chesapeake Bay. The one-season exposure encompassed the period of greatest borer activity and nearly the entire annual reproductive period. When the panels were removed from the test site and disassembled, salinity was 18 parts per thousand. The two-season exposure encompassed two periods of high shipworm activity. Salinity at the site was similar to that during the one-season exposure.

As the panels were disassembled, each laminate was rated for extent of shipworm damage on faces and edges, using ratings from the American Society for Testing and Materials (ASTM) Standard Test Method D 2481-81 (ASTM, 1990). A panel with no signs of shipworm attack was assigned a rating of 10; 9 indicated light attack; 7, moderate attack, 4, heavy attack: and 0, destruction of the panel. In addition, the number of burrows on each face of each laminate was closely estimated by overlaying a grid to allow estimation of the percentage of adult shipworms that were able to burrow into and through the treated laminates.

Several shipworms were collected from the panels and subsequently identified by pallet morphology as *B. gouldi* (Bartsch).



F i g u r e 1: Construction of test panels. For each laminate (A through D), the number 1 indicates the outer face and 2 the inner face.

3. Results and discussion

During the first summer of exposure, larvae of *B. gouldi* were found to be much more sensitive to CCA in wood than were the adult borers (Table 1). As indicated by the extent of attack on the edges of the panels, larvae were unable to settle on and penetrate Southern Pine that had been treated to a retention of 16kg/m^3 or higher. Even at the lowest retention (8kg/m^3), CCA greatly inhibited larval penetration at the edges of the laminate.

However, larvae that had initially penetrated untreated wood and metamorphosed to an adult form were able to continue burrowing into the CCA-treated wood. From 68 to 90 percent of the burrows present on the inner face (face 2) of the outer laminates (laminates A and D) contin-

Table 1: Shipworm damage to test panel laminates after one-season exposure

CCA retention (kg/m^3)[a]	Laminate position[b]	Average rating (low-high ratings)[c]		
		Face 1	Face 2	Edges
Untreated	A	0 (0-0)	0 (0-0)	0 (0-0)
7.9 (0.05)	B	6.0 (4-7)	8.0 (7-10)	9.3 (9-10)
16.2 (0.05)	C	5.0 (4-7)	9.3 (9-10)	10.0 (10-10)
Untreated	D	1.3 (0-4)	0 (0-0)	0 (0-0)
Untreated	A	1.3 (0-4)	1.3 (0-4)	1.3 (0-4)
16.0 (0.16)	B	5.0 (4-7)	8.3 (7-9)	10.0 (10-10)
24.4 (0.09)	C	5.0 (4-7)	8.3 (7-9)	10.0 (10-10)
Untreated	D	4.0 (4-4)	1.3 (0-4)	2.7 (0-4)
Untreated	A	2.7 (0-4)	2.7 (0-4)	2.7 (0-4)
24.3 (0.12)	B	6.0 (4-7)	7.7 (7-9)	10.0 (10-10)
29.4 (0.46)	C	6.0 (4-7)	7.7 (7-9)	10.0 (10-10)
Untreated	D	3.7 (0-7)	2.7 (0-4)	3.7 (0-7)
Untreated	A	0 (0-0)	0 (0-0)	0 (0-0)
29.4 (0.05)	B	6.7 (4-9)	9.0 (7-10)	10.0 (10-10)
43.9 (0.45)	C	7.7 (4-9)	9.0 (7-10)	10.0 (10-10)
Untreated	D	6.7 (4-9)	1.3 (0-4)	3.7 (0-7)

[a] Standard deviation in parentheses.
[b] See Figure 1.
[c] Average ratings of three panels per treatment. Face 1 refers to outermost face of laminate; face 2 to innermost face. 10 = no borer attack (sound wood); 9, light attack; 7, moderate attack; 4, heavy attack; 0, destruction of panel.

ued into the adjacent face of the treated laminate (Table 3). However, once the shipworms had penetrated a treated laminate, they were unlikely to burrow completely through the treated wood and exit the opposite face. A maximum of 3.9 percent of the shipworms accomplished this task (in laminates treated to $24.3 kg/m^3$), with even lower numbers of shipworms traversing laminates treated to higher retentions.

The results of the two-season exposure appear to confirm the results of the one-season exposure (Table 2). After the shipworms became established in the untreated and lower retention laminates, they were able to inflict slight damage on laminates treated to retentions as high as $41.3 kg/m^3$. Laminates with retentions of 4, 8, and $24 kg/m^3$ were nearly destroyed when attached to untreated laminates, continuing the trend noted with the one-season data. However, when not bounded by untreated wood, laminates treated to $24 kg/m^3$ were only lightly attacked

Table 2: Shipworm damage to test panel laminates after two-season exposure

CCA retention (kg/m^3)[a]	Laminate position[a]	Average rating (low-high ratings)		
		Face 1	Face 2	Edges
Untreated	A	0 (0-0)	0 (0-0)	0 (0-0)
3.9 (0.00)	B	0 (0-0)	0 (0-0)	6.7 (4-9)
24.4 (0.57)	C	2.7 (0-4)	3.7 (0-7)	10.0 (10-10)
Untreated	D	0 (0-0)	0 (0-0)	0 (0-0)
Untreated	A	0 (0-0)	0 (0-0)	0 (0-0)
7.8 (0.09)	B	1.3 (0-4)	3.7 (0-7)	7.0 (7-7)
41.3 (0.69)	C	8.3 (7-9)	8.3 (7-9)	10.0 (10-10)
Untreated	D	0 (0-0)	0 (0-0)	0 (0-0)
Untreated	A	0 (0-0)	0 (0-0)	0 (0-0)
7.8 (0.08)	B	1.3 (0-4)	2.7 (0-4)	7.0 (7-7)
23.7 (0.54)	C	10.0 (10-10)	7.0 (7-7)	10.0 (10-10)
41.7 (0.57)	D	10.0 (10-10)	10.0 (10-10)	10.0 (10-10)

[a] Standard deviation in parentheses.

Table 3: Effect of CCA retention on penetration of adult shipworms after one-season exposure

CCA retention (kg/m^3)	Penetration of burrows into treated wood (percent)	
	Partial[a]	Complete[b]
8.0	68	2.0
16.0	78	3.0
24.3	88	3.9
29.4	90	1.2
43.8	79	0.4

[a] Ability of shipworms, which have settled on untreated wood as larvae and burrowed through the wood as adult shipworms, to enter adjacent treated wood.
[b] Ability of adult shipworms to burrow completely through 12.7 mm of treated wood and exit opposite face of laminate.

and those treated to 40-42kg/m^3 were not attacked. Moreover, no larval entrances were found on laminates treated to 24kg/m^3 or higher, suggesting that retentions below 40kg/m^3 could be effective if no untreated or poorly treated wood is present.

In general, our study demonstrates the very great difference in CCA tolerance of larval and adult *B. gouldi.* Although this study was conducted with sapwood only, field observations and an earlier study that incorporated heartwood and sapwood panels at the same site (B. R. JOHNSON and R. JACKSON, 1990) suggest that these findings could directly relate to heartwood exposure. Commodity standards for CCA-treated Southern Pine in marine exposure that allow heartwood faces may increase the risk of premature failures resulting from larval settlement on untreated wood and subsequent burrowing into adjacent treated wood.

These findings suggest that if there are no exposed areas of poorly penetrated wood, then CCA retentions lower than the standard 40kg/m^3 would protect against *B. gouldi,* and possibly other shipworms, where conditions are comparable to those of the exposure sites in this study. However, additional, longer-term testing is advisable since preservative depletion at the surface and attack by preservative-resistant borers might become a problem at lower initial retentions.

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