Ten-Year Performance of Stakes and Decking Treated with Copper Azole Type B and Alkaline Copper Quat Type D (Carbonate)

Paul Ian Morris
Rod Stirling
Janet Ingram

Abstract

Development of wood preservatives typically involves laboratory tests using mycelial inoculation and field tests with through-treated small-dimension pine sapwood samples. These preservatives are then commercialized for use also on refractory wood species in Canada and the western United States. A field test was established at two locations in Canada to assess performance of stakes and decks of three species, both untreated and treated with a range of retentions of copper azole type B (CA-B), and two species treated with a range of retentions of alkaline copper quaternary carbonate formulation (ACQ-D). The decking was inspected after 10 years of exposure. CA-B– and ACQ-D–treated boards were generally in excellent condition except at preservative retentions well below standard. Decay was extensive in boards without treatment at both test sites. At one test site, decay was also extensive in preservative-treated white spruce at low retention treated without incising and without end coat. The difference in performance between boards with and without end coat illustrated the beneficial effect of end-cut preservative.

At the ground-contact retention of 3.3 kg/m^3 CA-B, stakes of all three species were predominantly sound after 10 years of exposure at both sites. ACQ-D–treated stakes at retentions around 6.4 kg/m^3 were sound at one test site, but some stakes showed slight to moderate decay at the other site. Moderate decay was found at retentions below this. Both preservatives were effective against termite attack, but very severe decay and termite attack were present in untreated control stakes of all three species.

The development of new wood preservatives typically begins with laboratory tests of small samples challenged against mycelia of selected wood-rotting fungi (Freeman and McIntyre 2008), and are typically first evaluated on the wood species that dominate the treated wood market worldwide: those with larger volumes of sapwood, such as southern, Scots, or radiata pine. In North America, the American Wood Protection Association (AWPA) standards are typically specified to evaluate the performance of these treatments. Data from these tests, and relatively short-term aboveground field tests, are then used to determine preservative retentions for aboveground applications, despite the fact that in aboveground applications decay via spore germination is generally more likely than decay via mycelial attack (Savory and Carey 1976; Schmidt and French 1978; Bjurman 1984; Fougerousse 1984; Hegarty and Buchwald 1988; Croan 1994, 1995). Basidiospores are generally not as resistant to biocides as mycelia (Morton and French 1966, Schmidt and French 1979, Choi et al. 2002, Woo and Morris 2010), although the reverse is true with some preservatives (Savory and Carey 1976). For ground-contact stake tests (AWPA 2006), several sample dimensions are permitted, including 4 by 38-mm Fahlstrom stakes for screening tests, 19 by 19-mm stakes, 25 by 50-mm stakes, and full-size 38 by 89-mm (2 by 4) stakes. The smaller-dimension stakes are often preferred because they are easier to handle and generate data rapidly. Data generated from field tests of small cross-section sapwood stakes are then used to commercialize treatments for lumber of other species

The authors are, respectively, Research Leader – Wood Protection, Principal Scientist, and Wood Preservation Technologist, FPInnovations, Vancouver, British Columbia, Canada (paul.morris@FPInnovations.ca [corresponding author], rod.stirling@fpinnovations.ca, janet.ingram@fpinnovations.ca). This paper was received for publication in March 2016. Article no. 16-00013.

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that are composed largely of refractory heartwood (Morris and Morrell 2014), with little or no testing on the performance in these species or on full-sized commodities.

Preservatives such as chromated copper arsenate (CCA) that work well in these laboratory and field tests can provide good performance (Morris et al. 2012, Morris and Ingram 2013, Morris and Morrell 2014), but with a different mode of action (Choi et al. 2001, 2002, 2004), in decking that can only be provided with a shell of treatment. Factors influencing the performance of preservative-treated decking have been reviewed by Stirling and Morris (2015). Recently it has been found that the newer amine-copper–based preservatives may be less effective than CCA at protecting untreated wood exposed in checks from spore germination (Stirling et al. 2015). Fortunately, data from field tests of refractory species treated with these preservatives are being generated in Canada because of the requirements of the Pest Management Regulatory Agency (PMRA) of Health Canada for registration of new preservatives.

The wood-preserving industry in Canada and the United States voluntarily phased out the use of CCA for most residential uses effective January 1, 2004. Canadian registrations of the replacement copper-cobiocide formulations were based on data generated at test sites outside Canada using non-Canadian wood species. However, PMRA requires field tests to be set up to confirm appropriate preservative loadings for Canadian species and conditions. To address this need an aboveground decking exposure test of copper azole type B (CA-B) and alkaline copper quaternary ammonium carbonate (ACQ-D) was initiated in 2004 at two locations in Canada to represent conditions typical of coastal (Maple Ridge, British Columbia) and continental (Petawawa, Ontario) climates. To address the need for ground-contact data, an exposure test was set up in 2005 at test sites at Maple Ridge and at Kincardine, Ontario. It was hypothesized that aboveground and ground-contact retentions standardized for southern pine would provide effective protection against decay on predominantly heartwood species for at least 10 years.

Performance of the decking was previously assessed after 5 years of exposure (Morris and Ingram 2011), at which time decay was found in only two boards of spruce at the lowest retention of ACQ. No further inspections were done until the 10-year point. Performance in ground contact was assessed annually and was reported after 6 years (Morris and Ingram 2011, Morris et al. 2012), at which time early stages of decay were present only in ACQ-D–treated stakes at the lower retentions at Maple Ridge.

The importance of field-cut preservatives in providing protection to cut ends in aboveground applications is increasingly being recognized. Recent accelerated ground-contact and aboveground tests have confirmed the efficacy of 2 percent copper naphthenate in protecting cut ends (Morris et al. 2014b). The present work also examined the ability of a brush-on end-cut treatment to reduce the incidence of decay in a commodity-sized decking test. This report describes the condition of the stakes and decking in terms of decay after 10 years of exposure.

Materials and Methods

Deck preparation and installation

Eight-foot (2.4-m) 2 by 6-inch (38 by 140-mm) kiln-dried lumber was obtained of three species: jack pine (*Pinus banksiana* Lamb.), Pacific silver fir (*Abies amabilis* Dougl. Forbes), and white spruce (*Picea glauca* (Moench) Voss). Jack pine is a preferred species for treating because it has a permeable sapwood but its heartwood is impermeable and nondurable. White spruce has an impermeable nondurable heartwood and a low-permeability sapwood. Pacific silver fir is the more treatable component of the hem–fir mix, also with a nondurable heartwood (Cooper and Morris 2007). The jack pine was sourced from Tembec Inc. Forest Products Group, Timmins, Ontario; the white spruce from Tolko Industries, High Level, Alberta; and the Pacific silver fir from Weyerhaeuser Ltd., Vancouver, British Columbia. The single species were visually separated by a trained grader and confirmed, where necessary, by spot test reagent (Barton 1973, AWPA 2015b), in the case of spruce–pine–fir, or microscopy, in the case of hem–fir. The boards used for framing deck bases and half of the decking boards were incised at Western Wood Preservers Ltd. in Aldergrove, British Columbia, before treatment with a pattern density of 8,233 incisions per m^2 and an incision depth of 8 to 10 mm. All boards were marked for identification and end sealed with two coats of epoxy before treatment. After optimum treating conditions for each end result were established by preliminary treatments, the test boards were pressure treated. The treating schedule followed for incised boards was an initial 30 minutes of vacuum at 22 inches of Hg (75 kPa), followed by 120 minutes at a pressure of 150 psi (1,035 kPa), and then a final 15 minutes of vacuum. Unincised boards were treated at pressure for 60 minutes. Treatment was carried out at 20°C. Forty deck boards at each of three target retentions (low, medium, and high) were treated for CA-B (AWPA 2015d). Pacific silver fir and white spruce were similarly treated with ACQ-D (carbonate) (AWPA 2015c).

After a minimum of 10 days posttreatment, the 40 2.4-m deck boards per retention level were crosscut to produce two end-matched 0.6-m replicates, one to be installed at Maple Ridge and the other at Petawawa. Twenty boards each were used to construct one deck per retention per location. From each of the boards per retention level, cross-section samples were taken for individual preservative penetration measurement and pooled retention measurement. One cross section was sprayed with chrome azurol S for preservative penetration measurement, to a maximum of 16 mm, on the face and edge of the piece (AWPA 2014a). For determination of retention, three assay depths of 5, 10, and 16 mm, as well as treated sapwood only, were taken from each board because of the different assay zones for residential and industrial deck boards of refractory species in the AWPA (AWPA 2015e) and Canadian Standards Association (CSA) standards (CSA 2012). The 20 samples designated for each deck at each of the four assay zones were combined as one sample for retention analysis. The samples were ground using a Wiley mill to pass through a 40-mesh screen, and the resulting sawdust was analyzed for copper content using a Spectrace 5000 energy dispersive X-ray fluorescence spectrometer calibrated for copper (AWPA 2015a). Reference-specific gravities for each species (jack pine 420 kg/m^3, white spruce 350 kg/m^3, and Pacific silver fir 340 kg/m^3) were used to convert results from weight per weight CuO to give weight per volume (kilograms per cubic meter) of the formulation assuming a 2:1 CuO/quat ratio. For CA-B, results were converted from weight per weight

CuO to give weight per volume (kilograms per cubic meter) as copper metal plus tebuconazole (AWPA 2014b).

Each deck base consisted of six 38 by 140-mm preservative-treated boards of the same retention target placed on edge and screwed together to form a frame. The cut ends of deck base boards and half of the experimental deck boards were brush coated with two applications of copper naphthenate (2% copper) field-cut preservative. The decks were constructed using stainless steel screws, with the experimental deck boards predrilled with two holes near each end and attached in two rows of 10 replicates to the frame. One row consisted of boards with end-cut preservative, whereas the other was uncoated. This decking test method has since been accepted for standardization by the AWPA as AWPA E25-08 (AWPA 2008). A stainless steel tag was attached to the deck base to identify each unit, and each of the 20 boards had an identifying number on the underside of the board. The decking modules (Fig. 1) were constructed at the laboratory and then shipped to the field test sites. Note the AWPA E25 test deck design has since been modified on the basis of further experience with this test method. The decks were mounted on leveled concrete blocks in areas at test sites at Maple Ridge, near Vancouver, and Petawawa, near Ottawa, in October 2004.

Stake preparation

Eight-foot (2.4-m)-long 2 by 4-inch (38 by 89-mm) kiln-dried boards of jack pine, Pacific silver fir, and white spruce No. 2 and Better grade were obtained from the same sources as the deck boards. Material was mill run with no control over ring count. All of the boards were incised as for deck boards. After incising, all boards were crosscut into 1.0-m-long double-length stakes, with major defects removed but small tight knots allowed, and individually labeled. CA-B (AWPA 2015d) was obtained from Arch Wood Protection, Missisauga, Ontario. ACQ-D (carbonate) (AWPA 2015c) was obtained from Timber Specialties Co, Campbellville, Ontario.

After optimal treating solution strengths for each end result were established by water treatment of controls (50 per species group), the double-length stakes were pressure treated at the FPInnovations Vancouver laboratory in a large (0.8 by 3.0-m) laboratory retort using a full-cell process with CA-B. The treating schedule used for the Pacific silver fir was an initial 30-minute vacuum at 22 inches of Hg (75 kPa), followed by 1.5 hours at a pressure of 150 psi (1,035 kPa), and then a final 15 minutes of vacuum at 22 inches of Hg (75 kPa). For white spruce and jack pine, 4 hours of pressure was used. All treatments were carried out at 20°C. The same process was repeated with Pacific silver fir and white spruce for ACQ-D (carbonate). After treatment the double-length stakes were covered with lumber wrap for 10 days and then unwrapped to dry before installation at the test sites. After 10 days of air-drying, an analysis biscuit was crosscut from the center of each double-length stake for analysis of preservative retention and penetration. This created two 0.46-m end-matched daughter stakes, one for installation at each site.

For retention analysis, a 16-mm analysis plug was cut from the edge of each board and ground to sawdust to pass through a 40-mesh screen. The sawdust for each sample was analyzed as described above. A stake cross section was sprayed with chrome azurol S for preservative penetration measurement on a simulated center edge boring. Compliance with 5-, 8-, and 10-mm penetration requirements was determined because of the differences between the penetration requirements for residential-treated wood products and industrial wood products in Canadian standards (CSA 2012) and all wood products in the American standards (AWPA 2015e).

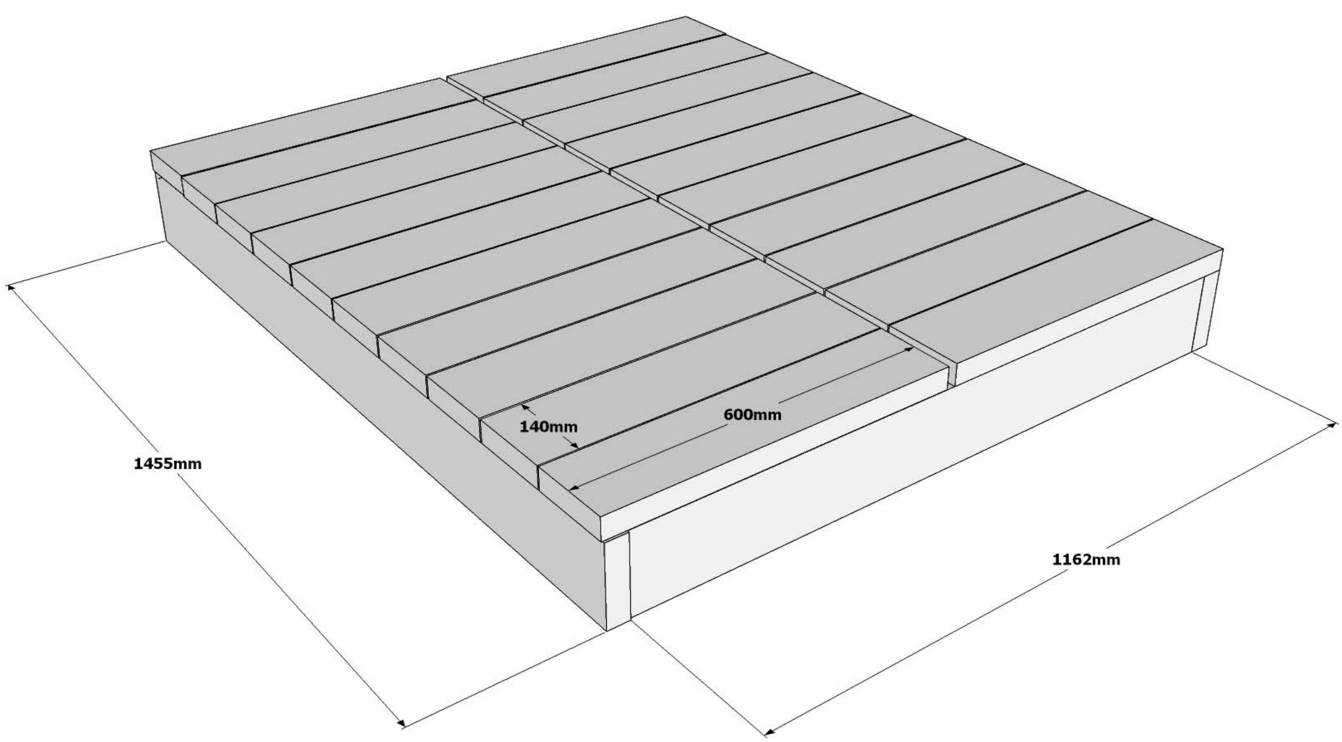

Figure 1.—Deck test module as per American Wood-Preservers' Association E25-08.

Stake installation

On the basis of the analysis results, 10 end-matched stake pairs (20 daughter stakes) from each target retention–species group were selected to average as closely as possible the target retention. End-matched daughter stakes were installed at test sites at Maple Ridge, near Vancouver, and Kincardine, located about 200 km NW of Toronto, in June 2005. Stake holes were predrilled using a 236-mm (6-in.) powered auger and the stakes were set into the holes to about half their length. To offset variations in soil conditions within the much larger Maple Ridge test site, the stakes were split between the four quadrants of this test site. Their locations within each plot were randomized, and a map was prepared.

Test sites

The test site at Maple Ridge is located within the University of British Columbia Malcolm Knapp Research Forest. The area is a clearing in second-growth coastal western hemlock forest, but was a grass field for decades. It was previously used as a deer pen. The soil is a sandy silt loam to a depth of 0.3 m. It has a pH around 5.1 and is relatively high in organic matter (15% to 21%). Below this is a layer of fine- to coarse-grained sand with some gravel and silt. In summer, groundwater is between 0.5 and 2.4 m below grade and flows in a predominantly southwest direction. During the winter months, the groundwater reaches the surface at the southwest end of the site. This site falls within the moderate-decay hazard zone for outdoor aboveground exposure using the Scheffer index (Scheffer 1971, Setliff 1986), with an updated value of 63 based on recent 30-year norms (Morris and Wang 2008). This zone includes most of the major population centers of North America. Soil-inhabiting strand-forming wood-rotting basidiomycetes including *Leucogyrophana pinastri, Fibroporia vaillantii, Tapinella* sp., and *Antrodia serialis* have been found on test material sporadically across the entire site.

The Petawawa test site is located on the grounds of the Petawawa Research Forest near Chalk River, Ontario. The original test site is located in a cleared natural forest area surrounded by a mixed coniferous–deciduous forest. Mean daily maximum and minimum temperatures are –7°C and –18°C in January and 25°C and 13°C in July. The site receives mean annual precipitation of 822 mm. It falls within the moderate-decay hazard zone for outdoor aboveground exposure using Scheffer's climate index (Scheffer 1971, Setliff 1986), with an updated climate index of 48 based on recent 30-year norms (Morris and Wang 2008). In 2013 the decks were relocated to another area within the Petawawa Research Forest and placed on landscape cloth to suppress weeds; these current inspections took place at this new site.

The Kincardine test site is located within the town of Kincardine in southern Ontario. The soil is a very well-drained sandy loam. The climate there also places it within the zone of medium out-of-ground decay hazard with an updated climate index of 49 (value for Owen Sound). The predominant type of decay at this test site is brown rot caused by *Coniophora arida, Coniophora olivacea* (Morris et al. 2014a), *Gloeophyllum sepiarium,* and *Gloeophyllum trabeum*. This test plot originally had a population of the subterranean termite *Reticulitermes flavipes*.

Decking inspection

In September 2014, each board of the 20 per deck was individually assessed for decay using the AWPA E25-08 rating system (Table 1). The presence of a fruit body, typically *G. sepiarium,* generated an automatic rating of no higher than 8 on the basis that the fungus must have degraded a substantial volume of wood to produce the fruit body.

The inspection method involved gentle probing of checks and end grain with a metal spatula for signs of softening or cavities. Particular attention was paid to areas of high moisture content, discoloration, or collapse visible on the surface, and areas sounding hollow or dull when tapped with the blunt end of the spatula. The weather was dry at Maple Ridge but wet at Petawawa during the inspections. This can influence the appearance and softness of the wood.

Stake inspection

In June 2015 in Kincardine and July 2015 in Maple Ridge, each stake was removed from the soil and loose grass and dirt were brushed off. The stakes were then examined visually for indications of decay such as the presence of fungal mycelium or discoloration. If decay was suspected, the area of interest was gently probed with a metal scraper. Each specimen was then assigned a rating, on the basis of the AWPA E7 grading systems (Tables 1 and 2; AWPA 2006), for decay at both sites and termite attack at Kincardine. For each stake at Kincardine, the lower of either the decay or the termite rating was used to calculate a combined termite–decay rating.

Results and Discussion

Decking

The mean retentions achieved in each treatment by uptake and by analysis are shown in Tables 3 and 4. The CSA O80 series of standards specifies gauge retentions of 0.9 kg/m^3 for CA-B and 2.0 kg/m^3 for ACQ-D in residential decking

Table 1.—Summary of American Wood Protection Association rating system.

Decay rating	Condition of the board or stake
10	Sound. No evidence of decay.
9.5	Trace or suspicion of decay.
9	Minor softening on end grain or on sides of checks. Up to 3% of cross section decayed.
8	Small pockets of decay on end grain or on sides of checks. Less than 10% of cross section decayed.
7	Moderate decay. Sample has between 10% and 30% of cross section decayed.
6	Severe attack. Sample has between 30% and 50% of cross section decayed.
4	Decking: Very severe decay likely to affect load-bearing capacity but not readily broken.
	Stake: Sample has between 50% and 75% of cross-sectional area decayed.
0	Decking: Failure when stepped on sharply by a person of moderate weight (60–80 kg). This could be by breakage of the board or severe surface collapse.
	Stake: Sample has functionally failed. It can either be broken by hand because of decay, or the evaluation probe can penetrate through the sample.

Table 2.—American Wood Protection Association termite attack ratings.

Termite attack rating	Description
10	Sound.
9.5	Trace. Surface nibbles permitted.
9	Slight attack. Up to 3% of cross-sectional area affected.
8	Moderate attack. 3%–10% of cross-sectional area affected.
7	Moderate/severe attack and penetration. 10%–30% of cross-sectional area affected.
6	Severe attack. 30%–50% of cross-sectional area affected.
4	Very severe attack. 50%–75% of cross-sectional area affected.
0	Failure.

(CSA 2012) and does not require incising. Decking for industrial uses requires incising and assay retentions of 1.7 kg/m^3 for CA-B and 4.0 kg/m^3 for ACQ-D.

Untreated

Decay in untreated decks of all species was well advanced after 10 years, with mean ratings of 7.0 and 7.6 for jack pine, 6.8 and 5.2 for Pacific silver fir, and 7.5 and 8.1 for white spruce at Petawawa and Maple Ridge, respectively. There were two failed Pacific silver fir boards at each site, and two failures in jack pine and one failure in white spruce at Petawawa.

Copper azole

Because the average ratings for all treated groups remained above 7.0 at the 10-year mark, the most useful information was in the percentage of samples with confirmed decay (rated 9 or below). In CA-B–treated jack pine after 10 years at Maple Ridge, the only confirmed decay was in unincised boards both with and without end coat at the lowest retention. At Petawawa, unincised jack pine at the low retention also contained early decay, as did one end-coated incised board at each of the low and medium retentions (Table 5).

In unincised treated Pacific silver fir at both test sites, particularly Petawawa, early decay was present in boards without end coat at the low retention, as well as with end coat at Maple Ridge. One unincised end-coated Pacific silver fir board at the medium retention was rated 9 for early decay at Maple Ridge, and one was rated 8 at Petawawa. One unincised Pacific silver fir without end coat at the high retention at each site was rated 9. However, all incised Pacific silver fir boards were sound at both sites regardless of retention level.

Low-retention unincised white spruce at Maple Ridge showed early decay, particularly in boards without end coat. At Petawawa, unincised white spruce treated to the low retention without end coat performed comparably with boards with no pressure treatment, and low-retention material with end coat was also attacked. White spruce incised before treatment was in excellent condition at both test sites, with the exception of boards at the low retention without end coat at Petawawa, where some decay was present.

Alkaline copper quaternary ammonium carbonate

The only confirmed decay (rated 9 or below) in ACQ-D–treated Pacific silver fir after 10 years at both test sites was present in unincised boards without end coat at the low and medium retentions. This was also the case for low-retention white spruce at Maple Ridge, although one unincised board with end coat at the medium retention was rated 8. However, at Petawawa, attack in unincised white spruce

Table 3.—Copper azole retention in treated deck boards.

				Retention (kg/m^3) of copper metal				
					By assay			
						Depth of analysis sample:		
Species[a]	Target	Incised	Solution strength (%)	By uptake	Sapwood	5 mm	10 mm	16 mm
JP	Low	No	0.18	0.27	1.58	0.81	0.71	0.41
JP	Medium	No	0.39	0.67	2.74	2.16	1.67	1.25
JP	High	No	0.64	0.90	3.59	2.14	1.34	1.04
JP	Low	Yes	0.23	0.58	1.75	1.39	1.23	0.78
JP	Medium	Yes	0.45	1.14	2.81	2.65	1.85	1.66
JP	High	Yes	0.61	1.55	3.62	3.39	2.42	1.80
PSF	Low	No	0.12	0.38	0.72	0.64	0.43	0.32
PSF	Medium	No	0.20	0.73	1.05	0.99	0.87	0.65
PSF	High	No	0.26	0.97	1.62	1.34	0.96	0.88
PSF	Low	Yes	0.20	1.02	1.28	1.32	1.22	0.96
PSF	Medium	Yes	0.27	1.32	1.74	1.90	1.47	1.27
PSF	High	Yes	0.37	1.77	2.14	2.44	1.98	1.42
WS	Low	No	0.21	0.15	1.52	0.53	0.24	0.14
WS	Medium	No	0.64	0.43	3.07	1.27	0.50	0.42
WS	High	No	1.14	0.82	5.32	2.01	1.54	0.83
WS	Low	Yes	0.21	0.42	1.40	1.05	0.76	0.50
WS	Medium	Yes	0.42	0.55	2.31	1.61	1.09	0.63
WS	High	Yes	1.34	1.91	6.40	4.88	3.57	2.03

[a] JP = jack pine; PSF = Pacific silver fir; WS = white spruce.

Table 4.—Retention in alkaline copper quaternary carbonate formulation (ACQ-D)–treated deck boards.

Species[a]	Target	Incised	Solution uptake (kg/m^3)	Solution strength (%)	Retention (kg/m^3) of ACQ-D				
						By assay			
							Depth of analysis core:		
					By uptake	Sapwood	5 mm	10 mm	16 mm
PSF	Low	No	351.6	0.26	0.90	1.59	1.23	1.11	0.85
PSF	Medium	No	354.7	0.34	1.19	2.18	1.86	1.44	1.00
PSF	High	No	415.3	0.46	1.90	2.76	2.52	1.95	1.89
PSF	Low	Yes	519.9	0.46	2.38	2.93	2.99	2.69	2.55
PSF	Medium	Yes	542.8	0.62	3.37	4.26	4.01	3.60	2.96
PSF	High	Yes	547.6	0.96	5.24	5.91	5.88	5.14	4.38
WS	Low	No	94.5	0.42	0.4	2.88	0.96	0.58	0.38
WS	Medium	No	80.6	1.09	0.88	5.49	2.44	1.70	0.96
WS	High	No	82.0	2.04	1.67	10.20	4.50	2.10	1.87
WS	Low	Yes	180.0	0.42	0.75	2.84	2.10	1.45	0.85
WS	Medium	Yes	233.4	1.09	2.55	6.19	5.29	4.06	3.00
WS	High	Yes	216.7	2.04	4.41	10.40	9.23	7.11	4.53

[a] PSF = Pacific silver fir; WS = white spruce.

was more extensive. Unincised white spruce treated to the lowest retention, both with and without end coat, performed comparably with boards with no treatment (Table 6). Some signs of early decay were also found at the two higher retentions of white spruce in unincised boards without end coat. White spruce incised before treatment was in excellent condition at both test sites, with only one board at the low retention without end coat rated 9 at Petawawa.

Decks: General discussion

The slightly greater attack at Petawawa in most types of material may be attributable to the unusually wet summers at that site recently, coupled with unusually dry summers at Maple Ridge. From October 2004 to September 2013, the Scheffer index for Petawawa was 60, and for Maple Ridge it was 56. Morris and Wang (2011) found that the Scheffer index does a remarkable job of parsing data on a climate with warm, dry summers and cool, wet winters versus a climate with hot, wet summers and cold, dry winters and accurately predicting similar rates of decay at the two locations.

At standardized retentions there was confirmed decay in only one sample at Maple Ridge and one at Petawawa. There were no significant differences between the performance of CA-B and ACQ-D at these loadings.

The number of uncoated boards with confirmed decay were compared with end-coated boards with decay. Of the 600 treated samples at both sites, 59 uncoated boards were rated 9 or less, whereas 29 end-coated boards were rated 9 or less. This is a statistically significant difference ($Z = -3.3221$, $P < 0.05$), confirming that end-cut preservative treatment with 2 percent copper naphthenate reduces the incidence of decay. These differences were largely confined to unincised treated boards. There was no such difference with incised treated boards, possibly because of better preservative penetration and higher loadings, resulting in more mobile copper (Morris et al. 2004). Using a new test method with high water-trapping potential at the Maple Ridge test site, Morris et al. (2014b) found no decay on copper naphthenate–treated samples, whereas 50 percent of treated samples showed confirmed decay after 6 years of exposure.

The decay data in this test are consistent with a previous study that evaluated CCA-treated decking using the same test design (Morris and Ingram 2013). This study included wood of several species, both untreated and treated with and without incising, installed in Vancouver, British Columbia, and Ottawa, Ontario. After 5 years in test, only incipient decay was found in untreated boards at both test sites. After 9 years, this had advanced to moderate decay and was severe after 15 years. In contrast, preservative-treated decks showed virtually no decay even after 20 years in test. CCA is no longer used for many residential applications, but ACQ and CA are widely used in the western United States for treatment of hem–fir and Douglas-fir decking for the residential market. The findings in this test provide an expectation of similar performance for species with similar shell treatment in regions of the United States with similar climate index.

Stakes

Untreated.—The untreated controls steadily decayed over the 10 years of exposure, at comparable rates at both sites. Almost all of the Pacific silver fir and white spruce and about half of the jack pine control stakes had failed within 10 years.

Termites, which were widespread during the first 6 years of stake exposure at the Kincardine site, vanished around 2011. This roughly coincided with the removal of a hedge near the site that had contained large amounts of woody debris and possibly the primary nest. In addition, there was a major upgrade to the building on the site in 2010, which may have eliminated a nest. Attempts to restore their activity were unsuccessful and in 2015, after the 10-year inspection, the stakes were relocated to a new test site in Kincardine with a confirmed termite population.

Some comments can still be made on performance against termite attack because ratings in controls dropped to an average of 3.5 for white spruce, 5.8 for Pacific silver fir, and 8.0 for jack pine in the first 5 years. Although the heartwood of all three species is considered nondurable, jack pine does have slightly more decay and termite resistance than the other two species.

Table 5.—Decay ratings in copper azole–treated decks after 10 years of exposure.[a]

Species	Target	Incised	Retention (kg/m^3)[b]	Maple Ridge 10-yr ratings End coating	Maple Ridge 10-yr ratings Mean (SD) rating	Maple Ridge 10-yr ratings Boards ≤ 9 (%)	Petawawa 10-yr ratings End coating	Petawawa 10-yr ratings Mean (SD) rating	Petawawa 10-yr ratings Boards ≤ 9 (%)
JP	None	No	NA	Uncoated	7.6 (0.9)	100	Uncoated	7.0 (2.7)	90
JP	Low	No	0.27	Uncoated	9.7 (0.9)	10	Uncoated	9.9 (0.3)	10
JP	Low	No	0.27	Coated	9.6 (1.0)	20	Coated	9.9 (0.3)	10
JP	Medium	No	0.67	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
JP	Medium	No	0.67	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
JP	High	No	**0.90**[c]	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
JP	High	No	**0.90**	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
JP	Low	Yes	0.78	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
JP	Low	Yes	0.78	Coated	10.0 (0.0)	0	Coated	9.8 (0.6)	10
JP	Medium	Yes	1.66	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
JP	Medium	Yes	1.66	Coated	10.0 (0.2)	0	Coated	9.9 (0.3)	10
JP	High	Yes	**1.80**	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
JP	High	Yes	**1.80**	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
PSF	None	No	NA	Uncoated	5.2 (2.3)	100	Uncoated	6.8 (2.5)	100
PSF	Low	No	0.38	Uncoated	9.6 (0.5)	40	Uncoated	9.0 (1.2)	50
PSF	Low	No	0.38	Coated	9.7 (0.5)	30	Coated	10.0 (0.0)	0
PSF	Medium	No	0.73	Uncoated	9.9 (0.2)	0	Uncoated	10.0 (0.2)	0
PSF	Medium	No	0.73	Coated	9.9 (0.3)	10	Coated	9.8 (0.6)	10
PSF	High	No	**0.97**	Uncoated	9.9 (0.3)	10	Uncoated	9.9 (0.3)	10
PSF	High	No	**0.97**	Coated	10.0 (0.0)	0	Coated	10.0 (0.2)	0
PSF	Low	Yes	0.96	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.2)	0
PSF	Low	Yes	0.96	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
PSF	Medium	Yes	1.27	Uncoated	10.0 (0.2)	0	Uncoated	10.0 (0.0)	0
PSF	Medium	Yes	1.27	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
PSF	High	Yes	1.42	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
PSF	High	Yes	1.42	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
WS	None	No	NA	Uncoated	8.1 (1.4)	90	Uncoated	7.5 (2.3)	85
WS	Low	No	0.15	Uncoated	9.6 (0.4)	30	Uncoated	7.6 (1.1)	100
WS	Low	No	0.15	Coated	9.9 (0.3)	10	Coated	9.0 (0.9)	70
WS	Medium	No	0.43	Uncoated	9.9 (0.3)	10	Uncoated	10.0 (0.2)	0
WS	Medium	No	0.43	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
WS	High	No	0.82	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
WS	High	No	0.82	Coated	9.9 (0.3)	10	Coated	10.0 (0.0)	0
WS	Low	Yes	0.50	Uncoated	10.0 (0.0)	0	Uncoated	9.6 (0.7)	30
WS	Low	Yes	0.50	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
WS	Medium	Yes	0.63	Uncoated	10.0 (0.2)	0	Uncoated	10.0 (0.0)	0
WS	Medium	Yes	0.63	Coated	10.0 (0.2)	0	Coated	10.0 (0.0)	0
WS	High	Yes	**2.03**	Uncoated	10.0 (0.2)	0	Uncoated	10.0 (0.0)	0
WS	High	Yes	**2.03**	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0

[a] JP = jack pine; PSF = Pacific silver fir; WS = white spruce; NA, not applicable.
[b] By uptake for unincised boards and by 16-mm assay for incised boards.
[c] Bold retention values meet Canadian Standards Association standards for residential (unincised) and industrial (incised) decking.

Copper azole.—Decay and termite attack after 10 years was relatively minimal in CA-B–treated stakes, particularly at Kincardine (Tables 7 through 9). At the recommended ground-contact retention of 3.3 kg/m^3, the 10-year mean rating for all species rounded to 10. Even at the lowest retentions (0.37 to 0.76 kg/m^3), none of the three species tested had fallen below an average rating of 8.5 for decay at either test site. One anomalous jack pine stake at the 1.0-kg/m^3 retention level failed from decay at the 8-year inspection.

The performance of copper azole against termites at Kincardine was also excellent, with no jack pine and only 1 of 60 Pacific silver fir stakes and white spruce stakes rated below 9.5 at the 6-year inspection (when termites were confirmed to still be present).

Alkaline copper quaternary ammonium carbonate.—None of the ACQ-D–treated sets had dropped below a mean rating of 7.0 after 10 years in test, and stakes at the recommended ground-contact retentions of 6.4 kg/m^3 and greater had mean ratings of 9.0 or higher (Tables 10 and 11). Confirmed early to moderate stages of decay, with ratings 8 or 9, were present in the majority of ACQ-D–treated stakes at Maple Ridge at the lower retentions. Mean decay ratings at Maple Ridge improved with increased preservative retention, from 8.2 at 1.3 kg/m^3 to 9.3 at 6.4 kg/m^3 in Pacific silver fir, and 8.0 to 9.0 in comparable retentions in white spruce. This improvement in performance correlated to preservative retention was not as obvious at Kincardine because of the lower degree of decay found at this site.

In contrast to Maple Ridge, virtually no decay or termite attack was found on ACQ-D–treated wood at Kincardine, where most ratings were 9.5 or 10. No confirmed decay (rating of 9 or less) was found above the 2.8-kg/m^3 retention level in Pacific silver fir or 0.8 kg/m^3 in white spruce.

Table 6.—Decay ratings in alkaline copper quaternary carbonate formulation–treated decks after 10 years of exposure.[a]

Species	Target	Incised	Retention (kg/m^3)[b]	Maple Ridge 10-yr ratings: End coating	Maple Ridge: Mean (SD) rating	Maple Ridge: Boards ≤ 9 (%)	Petawawa 10-yr ratings: End coating	Petawawa: Mean (SD) rating	Petawawa: Boards ≤ 9 (%)
PSF	None	No	NA	Uncoated	5.2 (2.3)	100	Uncoated	6.8 (2.5)	100
PSF	Low	No	0.90	Uncoated	9.7 (0.9)	10	Uncoated	9.5 (1.0)	30
PSF	Low	No	0.90	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
PSF	Medium	No	1.19	Uncoated	9.6 (1.0)	20	Uncoated	9.4 (0.9)	30
PSF	Medium	No	1.19	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
PSF	High	No	1.90	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
PSF	High	No	1.90	Coated	9.9 (0.2)	0	Coated	10.0 (0.0)	0
PSF	Low	Yes	2.55	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
PSF	Low	Yes	2.55	Coated	10.0 (0.2)	0	Coated	10.0 (0.0)	0
PSF	Medium	Yes	2.96	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
PSF	Medium	Yes	2.96	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
PSF	High	Yes	**4.38**[c]	Uncoated	10.0 (0.2)	0	Uncoated	10.0 (0.0)	0
PSF	High	Yes	**4.38**	Coated	9.9 (0.2)	0	Coated	10.0 (0.0)	0
WS	None	No	NA	Uncoated	8.1 (1.4)	90	Uncoated	7.5 (2.3)	85
WS	Low	No	0.40	Uncoated	9.6 (0.8)	20	Uncoated	5.6 (3.2)	100
WS	Low	No	0.40	Coated	10.0 (0.0)	0	Coated	8.3 (1.7)	90
WS	Medium	No	0.88	Uncoated	10.0 (0.0)	0	Uncoated	9.9 (0.3)	10
WS	Medium	No	0.88	Coated	9.8 (0.6)	10	Coated	10.0 (0.0)	0
WS	High	No	1.67	Uncoated	10.0 (0.0)	0	Uncoated	9.4 (0.5)	60
WS	High	No	1.67	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
WS	Low	Yes	0.85	Uncoated	10.0 (0.2)	0	Uncoated	9.9 (0.3)	10
WS	Low	Yes	0.85	Coated	10.0 (0.2)	0	Coated	10.0 (0.0)	0
WS	Medium	Yes	3.00	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
WS	Medium	Yes	3.00	Coated	10.0 (0.0)	0	Coated	10.0 (0.0)	0
WS	High	Yes	**4.53**	Uncoated	10.0 (0.0)	0	Uncoated	10.0 (0.0)	0
WS	High	Yes	**4.53**	Coated	10.0 (0.2)	0	Coated	10.0 (0.0)	0

[a] PSF, Pacific silver fir; WS, white spruce; NA, not applicable.
[b] By uptake for unincised boards and by 16-mm assay for incised boards.
[c] Bold retention values meet the Canadian Standards Association standards for residential (unincised) and industrial (incised) decking.

Kincardine is a very well-drained test site where the overwhelmingly dominant decay type is brown rot. Maple Ridge has brown rot, but also moderately aggressive soft rot.

Performance of ACQ-D against termites at Kincardine was excellent, with only 11 of 60 Pacific silver fir stakes rated 9.5 for a suspicion of termite attack at the 6-year inspection (when termites were confirmed to still be present). Only 3 of 60 white spruce stakes were rated 9.5, 1 was rated 9, and the remainder were rated as sound.

Stakes: General discussion

Apparent differences at Maple Ridge between the two preservatives at retentions close to the aboveground and ground-contact loadings in CSA standards were evaluated using the Mann-Whitney *U* test. For both Pacific silver fir and white spruce, there was no statistically significant difference ($P > 0.05$) in the mean rating between ACQ- and CA-treated stakes at the aboveground retentions. However, at the ground-contact loadings, CA-treated Pacific silver fir and white spruce performed better than the comparable ACQ-treated stakes. Although statistically significant ($P < 0.05$), it is likely that this difference would not be apparent to the average consumer, particularly because ACQ- and CA-treated wood are rarely used in the same construction under identical exposure conditions. No such differences were apparent at Kincardine.

Comparisons with published field test data on through-treated, small-dimension stakes of pine sapwood seem

Table 7.—Performance of copper azole–treated Pacific silver fir stakes.

Target retention (kg/m^3)	Retention by analysis (kg/m^3)[a]	Edge penetration: Mean (mm)	Edge penetration: % ≥ 5 mm	Edge penetration: % ≥ 8 mm	Edge penetration: % ≥ 10 mm	Mean (SD) 10-yr ratings: Decay, Maple Ridge	Decay, Kincardine	Termite Kincardine	Termite/decay Kincardine
0.0						0.8 (1.7)	1.8 (2.9)	5.8 (4.2)	1.8 (2.9)
0.6	0.65	11.7	100	70	70	9.4 (0.4)	9.4 (0.3)	10.0 (0.0)	9.4 (0.3)
1.0	1.02	14.8	100	100	100	8.9 (0.7)	9.5 (0.3)	10.0 (0.0)	9.5 (0.3)
1.5	1.53	14.9	100	100	100	9.3 (0.4)	9.9 (0.3)	10.0 (0.0)	9.9 (0.3)
2.2	2.29	14.2	100	90	90	9.9 (0.2)	10.0 (0.2)	10.0 (0.0)	10.0 (0.2)
3.3	3.32	15.0	100	100	100	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)
5.0	5.10	16.0	100	100	100	9.9 (0.4)	9.9 (0.3)	10.0 (0.0)	9.9 (0.3)

[a] As copper metal, assay zone of 16 mm.

Table 8.—Performance of copper azole–treated jack pine stakes.

Target retention (kg/m³)	Retention by analysis (kg/m³)[a]	Edge penetration: Mean (mm)	Edge penetration: % ≥ 5 mm	Edge penetration: % ≥ 8 mm	Edge penetration: % ≥ 10 mm	Mean (SD) 10-yr ratings: Decay, Maple Ridge	Decay, Kincardine	Termite, Kincardine	Termite/decay, Kincardine
0.0						3.9 (2.8)	3.0 (3.3)	8.0 (2.5)	3.0 (3.3)
0.6	0.76	7.7	90	30	30	8.9 (0.3)	9.6 (0.2)	10.0 (0.0)	9.6 (0.2)
1.0	1.24	6.6	90	30	20	9.2 (0.5)	8.7 (3.1)	10.0 (0.0)	8.7 (3.1)
1.5	1.84	8.4	100	80	30	9.4 (0.5)	9.9 (0.2)	10.0 (0.0)	9.9 (0.2)
2.2	2.43	9.2	100	70	40	9.4 (0.6)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)
3.3	3.23	10.7	100	100	60	9.5 (0.4)	10.0 (0.2)	10.0 (0.0)	10.0 (0.2)
5.0	4.86	11.2	100	100	91	10.0 (0.3)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)

[a] As copper metal, assay zone of 16 mm.

Table 9.—Performance of copper azole–treated white spruce stakes.

Target retention (kg/m³)	Retention by analysis (kg/m³)[a]	Edge penetration: Mean (mm)	Edge penetration: % ≥ 5 mm	Edge penetration: % ≥ 8 mm	Edge penetration: % ≥ 10 mm	Mean (SD) 10-yr ratings: Decay, Maple Ridge	Decay, Kincardine	Termite, Kincardine	Termite/decay, Kincardine
0.0						0.0 (0.0)	0.7 (2.2)	3.5 (4.9)	0.7 (2.2)
0.4	0.37	2.6	0	0	0	8.5 (0.5)	9.5 (0.3)	10.0 (0.0)	9.5 (0.3)
0.6	0.61	4.3	60	0	0	8.6 (0.5)	9.8 (0.3)	10.0 (0.0)	9.8 (0.3)
1.0	1.08	4.1	50	0	0	9.0 (0.0)	9.9 (0.2)	10.0 (0.0)	9.9 (0.2)
1.5	1.54	5.2	70	10	0	8.6 (0.5)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)
2.2	2.42	5.1	60	10	0	9.5 (0.5)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)
3.3	3.79	5.2	70	10	0	9.7 (0.5)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)

[a] As copper metal, assay zone of 16 mm.

Table 10.—Performance of alkaline copper quaternary carbonate formulation–treated Pacific silver fir stakes.

Target retention (kg/m³)	Retention by analysis (kg/m³)[a]	Edge penetration: Mean (mm)	Edge penetration: % ≥ 5 mm	Edge penetration: % ≥ 8 mm	Edge penetration: % ≥ 10 mm	Mean (SD) 10-yr ratings: Decay, Maple Ridge	Decay, Kincardine	Termite, Kincardine	Termite/decay, Kincardine
0.0						0.8 (1.7)	1.8 (2.9)	5.8 (4.2)	1.8 (2.9)
1.3	1.24	15.6	100	100	100	8.2 (0.6)	9.1 (0.2)	10.0 (0.0)	9.1 (0.2)
1.9	2.20	16.0	100	100	100	8.2 (0.5)	9.5 (0.3)	10.0 (0.0)	9.5 (0.3)
2.8	3.04	15.8	100	100	100	8.5 (0.5)	9.7 (0.3)	10.0 (0.0)	9.7 (0.3)
4.3	4.35	16.0	100	100	100	9.1 (0.2)	9.8 (0.3)	10.0 (0.0)	9.8 (0.3)
6.4	5.74	16.0	100	100	100	9.3 (0.4)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)
9.6	9.10	16.0	100	100	100	9.5 (0.5)	10.0 (0.2)	10.0 (0.0)	10.0 (0.0)

[a] As copper oxide plus didecyldimethylammonium chloride, assay zone of 16 mm.

Table 11.—Performance of alkaline copper quaternary carbonate formulation–treated white spruce stakes.

Target retention (kg/m³)	Retention by analysis (kg/m³)[a]	Edge penetration: Mean (mm)	Edge penetration: % ≥ 5 mm	Edge penetration: % ≥ 8 mm	Edge penetration: % ≥ 10 mm	Mean (SD) 10-yr ratings: Decay, Maple Ridge	Decay, Kincardine	Termite, Kincardine	Termite/decay, Kincardine
0.0						0.0 (0.0)	0.7 (2.2)	3.5 (4.9)	0.7 (2.2)
0.8	0.98	5.1	90	0	0	7.7 (0.7)	9.2 (0.5)	10.0 (0.2)	9.2 (0.5)
1.3	1.71	5.6	90	0	0	8.0 (0.5)	9.8 (0.3)	10.0 (0.0)	9.8 (0.3)
1.9	2.06	6.2	100	20	0	8.4 (0.5)	9.9 (0.2)	10.0 (0.0)	9.9 (0.2)
2.8	2.91	8.6	90	80	40	8.4 (0.5)	10.0 (0.2)	10.0 (0.0)	10.0 (0.2)
4.3	4.60	6.9	90	30	20	8.4 (0.7)	10.0 (0.2)	10.0 (0.0)	10.0 (0.2)
6.4	6.68	8.9	100	60	20	9.0 (0.6)	9.9 (0.3)	10.0 (0.0)	9.9 (0.3)

[a] As copper oxide plus didecyldimethylammonium chloride, assay zone of 16 mm.

specious. The only other field test data on incised commercial-sized lumber of refractory species treated with amine-copper–based preservatives that these authors are aware of is 3-year data on western hemlock (*Tsuga heterophylla*) and white spruce at test sites in Jinju, Korea, with decay and termites and Petawawa, Canada, with an aggressive population of soil-inhabiting strand-forming copper-tolerant basidiomycetes (Wang et al. 2014). That material shows comparable performance with the early data from this test. Part of the reason for the good performance of ACQ-D– and CA-B–treated refractory species at these three test sites with soil-inhabiting strand-forming copper-tolerant basidiomycetes may be the high surface loadings resulting from the requirements in the standards for 10-mm penetration and a 16-mm assay zone in refractory species (Morris and Morrell 2014). Goodell et al. (2007) generated substantial mass loss in wood blocks cut from full-size southern pine lumber commercially treated with ACQ-D and CA-B to ground-contact loadings, with several brown-rot fungi. Data presented by Freeman and McIntyre (2008) showed that the toxic thresholds in AWPA soil block decay tests against *Postia placenta,* a commonly occurring copper-tolerant brown-rot fungus, are above the ground-contact retention specified in AWPA standards for ACQ-D, although not for CA-B. High preservative loadings at the wood surface may also discourage nibbling by termites.

Conclusions

Unincised material that came close to meeting the CSA O80 standard for residential product group B and end coated, as per the requirements of the standard, showed no signs of decay after 10 years in aboveground tests with the exception of one board of white spruce at one test site. Incised material that met the CSA O80 standard for UC3.2 in industrial applications showed no signs of decay after 10 years, whether or not it was end coated. More advanced decay at Petawawa was likely related to a higher Scheffer index on the basis of 9 years' data during the test period.

After 10 years' exposure in ground contact at two test sites at Maple Ridge and Kincardine, none of the treated Pacific silver fir, jack pine, or white spruce sets had dropped below a mean rating of 7.0, and those treated to ground-contact retentions had mean ratings of 9.0 or higher. Very little decay or termite attack was found in CA-B–treated stakes at retentions down to 0.37 kg/m^3. At Maple Ridge, moderate decay was found in ACQ-D–treated stakes at the lower retentions. In contrast to stakes treated with either preservative, very severe decay and termite attack were present in untreated control stakes of Pacific silver fir, jack pine, and white spruce. Termite attack at the Kincardine site was confined to the untreated controls.

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