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Ten-Year Performance of Treated Northeastern Softwoods in Aboveground and Ground-Contact Exposures

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Abstract

The commercial value of several softwood species of the northeastern United States could be increased if these woods could be treated to meet existing American Wood Preservers' Association (AWPA) Standards and used in durable structures. We evaluated the long-term durability of incised and unincised white pine, red pine, eastern spruce, balsam fir, and eastern hemlock treated with ammoniacal copper arsenate (ACA) and chromated copper arsenate (CCA–Type C). The treated wood was exposed above ground and in ground contact in the southern and northeastern United States. Simulated decks were tested above ground in Cumberland, Maine, and Amherst, Massachusetts. Stakes were tested in ground contact in Saucier, Mississippi, and Cumberland, Maine. Replicates of all test species and conditions, including untreated controls, were represented in the test plots and decks. Both the stakes and deck material were monitored annually for structural condition and appearance. After 10 years of aboveground exposure, all untreated decks (controls) failed as a result of decay. Wood treated with CCA showed somewhat better durability than did wood treated with ACA. Except for white pine, treated incised wood species showed no evidence of decay. Incised white pine treated with ACA failed by excessive checking. Unincised white pine treated with CCA also failed, as a result of transverse scaling and radial checking. In ground-contact field trials, failure patterns of untreated stakes showed more differences than did performance patterns of treated stakes at different exposure sites. Overall, these results suggest that treated northeastern softwood species could be used for durable construction.

Keywords: CCA, ACA, deck, softwoods, incised

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Introduction

A number of softwoods in the northeastern United States would have greater commercial value if they could be successfully treated with preservatives. Balsam fir, eastern spruce (red, white, and black), and eastern hemlock are particularly susceptible to budworm attack. If these woods could be treated, opportunities for addition utilization are plentiful. From 1984 to 1996, the market for treated wood grew at an annual rate of 12% nationally. During this same period, the northeastern market for pressure-treated lumber and timber grew 20%/year. In all probability, this market has grown even more since 1996. The northeast is home to 67 treatment plants, which treated approximately 3.5 billion board feet of lumber and timber and 2.5 billion board feet of plywood in 1996. (Note: 1 board foot = 0.00236 m^3; billion = 10^9.) Lumber accounted for 49.8% of total 1996 production. An estimated 71.4% of the treated stock was southern yellow pine (AWPI 1996).

Experimental Design

This paper reports the results of phase 2 of a two-part study. In phase 1, effective levels of preservative penetration were determined for various combinations of wood species and preservatives using conventional preservatives and treating procedures in the laboratory (Gjovik and others 1992). In phase 2, selected species–preservative combinations were tested in the field for 10 years. Wood decks were exposed above ground and wood stakes were exposed in ground contact.

For the aboveground field trials, test decks were installed at exposure sites in Amherst, Massachusetts, and Cumberland, Maine. A single retention was used for these trials. Five replicates were used for each treatment combination and control. For the ground-contact field trials, wood stakes were installed at exposure sites in Saucier, Mississippi (Harrison Experimental Forest), and Cumberland, Maine. The stake tests involved a minimum of four preservative retentions for each preservative–species–site combination. Ten replicates were used for each variable.

Materials and Methods

For aboveground field trials, simulated decks were constructed of treated 50- by 150- by 750-mm (2- by 6- by 30-in.) members (Fig. 1). Variables for these field trials are shown in Table 1.

For the ground-contact field trials, 10 replicate 50- by 100- by 450-mm (2- by 4- by 18-in.) stakes were used for each treatment combination and control (Fig. 2). Variables for these trials are shown in Table 2. Stakes were tested using standard methodology for evaluating wood preservatives. The stakes were inserted into the soil to a depth of half their length and monitored periodically. The durability of the wood was determined by monitoring how effectively it resisted attack of naturally occurring microflora and fauna over time. The exposure sites represent severe and mild climates in terms of wood deterioration (Table 3). Plots were established in a randomized block design consistent with AWPA Standard E7 (AWPA 1997).

Treatment Procedures

All specimens were treated by full-cell process, using the schedules shown in Table 4. The lower pressure, 861 kPa (125 lb/in^2), was used for the treatment of eastern spruce and balsam fir to avoid cell-wall collapse. The other species (red pine, eastern white pine, and eastern hemlock) were treated using the higher pressure, 1,034 kPa (150 lb/in^2).

All specimens were precisely molded to 36.58 by 87.38 mm (1.44 by 3.44 in.) and precision end-trimmed to 457 mm (18 in.). This procedure allowed a single preservative volume for each specimen. Thus, the preservative retentions obtained during weighing of the specimens were very accurate.

Figure 1—Aboveground field trials: (a) view of entire test deck; (b) close-up of portion of deck.

Figure 2—Ground-contact field trials: (a) exposure site; (b) test stakes.

Table 1—Variables for aboveground field trials

Species	eastern spruce: red (*Picea rubens* Sarg.), white (*P. glauca* (Moench) Voss), and black (*P. mariana* (Mill.) B.S.P.)
	balsam fir (*Abies balsamea* (L.) Mill.)
	red pine (*Pinus resinosa* Ait.)
	white pine (*Pinus strobus* L.)
	eastern hemlock (*Tsuga canadensis* (L.) Carr.)
Pretreatment conditions	unincised and incised
Preservatives	chromated copper arsenate (CCA–Type C), ammoniacal copper arsenate (ACA)
Exposure sites	Amherst, MA; Cumberland, ME
Controls	five unincised and untreated specimens per species

Each specimen was weighed before and after treatment to determine the preservative or chemical oxide retention. The treating solution concentrations were analyzed and calculated in accordance with AWPA Standard A–11 (1997) and held constant at 2.5% oxide basis.

Rating Criteria

Rating criteria for decks and stakes are shown in Tables 5 and 6, respectively.

Table 2—Variables for ground-contact field trials

Species	eastern spruce: red (*Picea rubens* Sarg.), white (*P. glauca* (Moench) Voss), and black (*P. mariana* (Mill.) B.S.P.)
	balsam fir (*Abies balsamea* (L.) Mill.)
	red pine (*Pinus resinosa* Ait.)
	white pine (*Pinus strobus* L.)
	eastern hemlock (*Tsuga canadensis* (L.) Carr.)
Pretreatment conditions	unincised and incised
Preservatives	CCA–Type C, ACA
Exposure sites	Saucier, MS; Cumberland, ME
Controls	10 unincised and untreated specimens per species

Table 3—Environmental conditions at field plots for ground-contact trials

Location	Environment
Harrison Experiment Forest, Saucier, MS 2 km (1.2 mi) from Gulf of Mexico	Mean annual precipitation, 1,580 mm (62.2 in.); average annual temperature, 19.6°C (67.3°F); soil type, coarse fine sandy loam
Cumberland, ME	Mean annual precipitation, 1,135 mm (44.7 in.); average annual temperature, 7.5°C (45.5°F); soil type, Buxon silt loam

Table 4—Preservative treatments

Preservative[a]	Vacuum (inHg	(kPa))	Time (min)	Pressure (lb/in^2	(kPa))	Solution temperature (°F	(°C))	Final vacuum
ACA	28	(95)	30	125	(861)	135	(57)	None
				150	(1,034)			
CCA–Type C	28	(95)	30	125	(861)	Ambient	(Ambient)	None
				150	(1,034)			

[a]ACA is ammoniacal copper arsenate; CCA–Type C is chromated copper arsenate.

Table 5—Rating criteria for decks in aboveground trials

Level	Twist	Cup	Bow	Crook	Splitting	Grain[a]	Stain	Checking
1	None	None	None	Absent	None	Smooth	None	None
2	1/16–2/16 rise	1/16-rise	1/16-rise	Present	0–10%	<10%	<10%	0–10%
3	3/16–4/16 rise	2/16 rise	2/16 rise		10%–50%	10%–50%	10%–50%	10%-50%
4	5/16–6/16 rise	3/16 rise	3/16 rise		50%–80%	>50%	>50%	50%–80%
5	Failure	4/16 rise	4/16 rise		Failure	Surface broken	100%	Failure

[a]Percentages pertain to amount of grain (surface texture) affected.

Table 6—Rating criteria for stakes in ground-contact trials

Decay grade[a]	Description of condition
10	Sound—suspicion of decay permitted
9	Trace decay—to 3% of cross section
8	Decay from 3% to 10% of cross section
7	Decay from 10% to 30% of cross section
6	Decay from 30% to 50% of cross section
4	Decay from 50% to 75% of cross section
0	Failure

[a]AWPA E7–93. Methods of evaluating preservatives by field tests with stakes (AWPA 1997).

The aboveground decks at the Amherst and Cumberland field sites were constructed in 1985 with five replicates of each wood species/unincised or incised/preservative combination. Durability and physical appearance were evaluated according to the extent of defects and other considerations (Table 5). Defects included warp (twist, cup, bow, and crook), splitting, and checking. Other considerations were surface texture (grain) and discoloration from stain.

Warp refers to distortions in wood caused by variation from a true or plane surface. It includes twist, cup, bow, and crook, or any combination of these. Twist is caused by the turning or winding of the edges of a board so that the four corners of any face are no longer in the same plane. Cup is deviation flatwise from a straight line across the width of the board. Bow is deviation, in a direction perpendicular to the flat face, from a straight line from end to end of the piece. Crook is deviation, in a direction perpendicular to the edge, from a straight line from end to end of the piece.

Splitting refers to damage to the end grain all the way through the piece, measured as a percentage of the piece.

Grain refers to the direction, size, arrangement, appearance, or quality of the fibers in the wood. Grain was evaluated in terms of surface texture (smooth to broken).

In this study, stain refers to discoloration caused by fungi. The best rating indicates no or little discoloration (clear or gray wood) and the worst, extensive discoloration (wood covered with stain fungi). Checks are lengthwise separation of the wood that usually extends across the rings of annual growth and commonly results from stresses set up in the wood during seasoning.

For decks, a pass/fail system was used to simplify the evaluation process. A treatment–wood combination was given a "pass" rating if the average rating of the five replicates was between levels 1 and 2. A treatment–wood combination failed if the average rating was higher than level 2.

Stakes were evaluated according to the extent of decay, using the criteria shown in Table 6.

Results

Aboveground Field Trials

Results of aboveground trials of decks at the Amherst and Cumberland exposure sites are shown in Tables 7 and 8, respectively. After 10 years of exposure, untreated controls of all species failed at both locations as a result of decay. None of the treated materials failed as a result of decay. Failure of treated materials was attributed to physical condition or appearance of the wood.

Unincised white pine was the only deck treated with chromated copper arsenate (CCA–Type C) that failed. Failure was caused by transverse checks and splits around knots. However, the structural members appeared to be sound, with solid ends.

Several decks treated with ammoniacal copper arsenate (ACA) failed on the basis of surface characteristics. Incised white pine at the Amherst site failed as a result of transverse scaling, which resembled shelling. Unincised red pine at the Amherst site and incised Eastern hemlock at the Cumberland site failed as a result of a tendency to check and split, which marred the appearance of the wood.

Ground-Contact Field Trials

Results of ground-contact field trials of stakes at the Saucier and Cumberland exposure sites are shown in Tables 9 and 10, respectively. Overall, differences in performance were greater between control specimens than between treated stakes. At both exposure sites, stakes treated with ACA and CCA had acceptable (average < 7.0) ratings in general, but stakes treated to low retentions had low ratings. Relative to the performance patterns observed at both sites, preservative retention level was apparently more important than incising for eastern white pine and balsam fir. For these species, incising improved performance of wood treated at the lowest retention, but had little apparent impact at higher retentions. For red pine, eastern hemlock, and eastern spruce, incising apparently improved performance at all retentions. The relative contribution of incising as opposed to preservative retention was not evident for eastern larch. With eastern spruce, average ratings for each retention level were more indicative of good long-term performance than were the rating patterns at each exposure site.

Table 7—Condition of decks after 10 years of exposure at Amherst site[a]

Wood species	Treatment: Surface	Treatment: Preservative	Rating	Comment
White pine	Unincised	ACA[a]	Pass	Ends solid
		CCA[b]	Fail	Transverse checks, structurally sound; major splits around knots; ends solid
	Incised	ACA	Fail	Transverse scaling, structurally sound; radial checks in ends
		CCA	Pass	Ends solid
	Control		Fail	Decay in ends
Red pine	Unincised	ACA	Fail	Surface deterioration
		CCA	Pass	Ends solid
	Incised	ACA	Pass	Splitting of ends on annual rings
		CCA	Pass	Ends solid
	Control		Fail	Decay
Eastern spruce	Unincised	ACA	Pass	Ends solid overall
		CCA	Pass	Ends solid overall
	Incised	ACA	Pass	Ends solid overall
		CCA	Pass	Ends solid overall
	Control		Fail	Decay in ends
Balsam fir	Unincised	ACA	Pass	Beginning of radial damage in ends
		CCA	Pass	Ends solid
	Incised	ACA	Pass	Ends solid
		CCA	Pass	Ends solid
	Control		Fail	Decay in ends
Eastern hemlock	Unincised	ACA	Pass	Ends solid
		CCA	Pass	Ends solid
	Incised	ACA	Pass	Ends solid
		CCA	Pass	Ends solid
	Control		Fail	Decay

[a]Summary of observations for five replicates.

Conclusions

Data from 10-year field exposure trials show that northeastern softwoods treated with appropriate concentrations of CCA or ACA, regardless of whether the wood is incised or unincised, can be used for both aboveground and ground-contact applications. In this study, the contribution of incising to durability varied with wood species. Incising exerted the greatest effect for the lowest preservative retention. In ground-contact field trials, failure patterns of untreated stakes showed more differences than did performance patterns of treated stakes at different exposure sites.

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Table 8—Condition of decks after 10 years of exposure at Cumberland site[a]

Wood species	Treatment: Surface	Treatment: Preservative	Rating	Comment
White pine	Unincised	ACA	Pass	Some warp, cup
		CCA	Pass	Some stain
	Incised	ACA	Pass	Some warp, twist
		CCA	Pass	Some crook
	Control		Fail	Decay, stain
Red pine	Unincised	ACA	Pass	Minor cup, checking
		CCA	Pass	Good overall
	Incised	ACA	Pass	Checking
		CCA	Pass	Good overall
	Control		Fail	Decay, stain
Eastern spruce	Unincised	ACA	Pass	Ends solid overall
		CCA	Pass	Ends solid overall
	Incised	ACA	Pass	Ends solid overall
		CCA	Pass	Ends solid
	Control		Fail	Decay, checking, splitting
Balsam fir	Unincised	ACA	Pass	Good overall
		CCA	Pass	Solid overall
	Incised	ACA	Pass	Ends solid
		CCA	Pass	Ends solid
	Control		Fail	Decay, checking, stain
Eastern hemlock	Unincised	ACA	Pass	Stain
		CCA	Pass	Checking
	Incised	ACA	Fail	Surface deterioration
		CCA	Pass	Ends solid
	Control		Fail	Decay

[a]Summary of observations for five replicates.

Table 9—Incidence of decay in stakes after 10 years of ground-contact exposure at Saucier site

Wood species	Treatment: Surface	Treatment: Preservative	Retention (lb/ft^3)	Retention (kg/m^3)	Number of stakes with various decay ratings after 10 years of exposure[a]: 10	9	8	7	6	4	0	Average rating
White pine	Unincised	ACA	0.26	(4.16)		2	5	1	1		1	7.1
			0.42	(6.72)	7	2	1					9.6
			0.72	(11.52)	9	1						9.9
		CCA	0.31	(4.96)	9	1						9.9
			0.44	(7.04)	10							10.0
			0.65	(10.40)	10							10.0
	Incised	ACA	0.26	(4.16)	8	1	1					9.7
			0.42	(6.72)	10							10.0
			0.73	(11.68)	10							10.0
		CCA	0.33	(5.28)	9	1						9.9
			0.52	(8.32)	10							10.0
			0.74	(11.84)	9	1						9.9
	Control		0							1	9	0.4
Red pine	Unincised	ACA	0.29	(4.64)	2	3	3	1	1			8.4
			0.30	(4.80)	6	2	1				1	8.6
			0.44	(7.04)	10							10.0
		CCA	0.23	(3.68)	9	1						9.9
			0.32	(5.12)	8	1		1				9.6
			0.46	(7.36)	9	1						9.9
	Incised	ACA	0.31	(4.96)	4	6						9.4
			0.40	(6.40)	10							10.0
			0.64	(10.24)	10							10.0
		CCA	0.25	(4.00)	8	2						9.8
			0.40	(6.40)	10							10.0
			0.55	(8.80)	10							10.0
	Control		0								10	0
Eastern spruce	Unincised	ACA	0.16	(2.56)	1	1	1		1	1	5	3.7
			0.25	(4.00)	1	2	2	1		1	3	5.5
			0.39	(6.24)	7	3						9.7
		CCA	0.14	(2.24)	6	4						9.6
			0.20	(3.20)	8	1					1	8.9
			0.71	(11.36)	10							10.0
	Incised	ACA	0.24	(3.84)	7	2					1	8.8
			0.28	(4.48)	6	2		1	1			9.1
			0.48	(7.68)	9	1						9.9
		CCA	0.25	(4.00)	9	1						9.9
			0.35	(5.60)	9	1						9.9
			0.78	(12.48)	9	1						9.9
	Control		0							3	7	1.2
Balsam fir	Unincised	ACA	0.26	(4.16)	1	1	6		1		1	7.3
			0.32	(5.12)	6	4						9.6
			0.59	(9.44)	10							10.0
	Incised	ACA	0.29	(4.64)	9	1						9.9
			0.40	(6.40)	9	1						9.9
			0.73	(11.68)	9	1						9.9
	Control		0								10	0
Eastern hemlock	Unincised	ACA	0.20	(3.20)	7	3						9.7
			0.32	(5.12)	4	5	1					9.3
			0.37	(5.92)	10							10.0
	Incised	ACA	0.34	(5.44)	7	3						9.7
			0.38	(6.08)	9	1						9.9
			0.68	(10.88)	10							10.0
	Control		0								10	0
Eastern larch	Unincised	ACA	0.18	(2.88)	1	4	4			1		8.2
			0.23	(3.68)	6	2	1				1	8.6
			0.41	(6.56)	10							10.0
	Incised	ACA	0.25	(4.00)	4	6						9.4
			0.32	(5.12)	8	2						9.8
			0.60	(9.60)	10							10.0
	Control		0							1	9	0.4

[a]Total number of stakes, 10.

Table 10—Incidence of decay in stakes after 10 years of ground-contact exposure at Cumberland site

Wood species	Treatment: Surface	Treatment: Preservative	Retention (lb/ft^3)	Retention (kg/m^3)	Number of stakes with various decay ratings after 10 years of exposure[a]: 10	9	8	7	6	4	0	Average rating
White pine	Unincised	ACA	0.32	(5.12)	2	7	1				1	9.1
			0.38	(6.08)		9	1					8.9
			0.71	(11.36)	9	1						9.9
		CCA	0.30	(4.80)	8	2						9.8
			0.46	(7.36)	10							10.0
			0.66	(10.56)	10							10.0
	Incised	ACA	0.32	(5.12)	1	8			1			8.8
			0.44	(7.04)	8	2	1					9.8
			0.80	(12.80)	10							10.0
		CCA	0.32	(5.12)	9	1						9.9
			0.47	(7.52)	9	1						9.9
			0.72	(11.52)	10							10.0
	Control		0		1		1		4		4	4.2
Red pine	Unincised	ACA	0.29	(4.64)	1	5	4					8.7
			0.38	(6.08)	6	4						9.6
			0.67	(10.72)	10							10.0
		CCA	0.18	(2.88)	8	1	1					9.7
			0.33	(5.28)	10							10.0
			0.70	(11.20)	10							10.0
	Incised	ACA	0.26	(4.16)	1	6	3					8.8
			0.45	(7.20)	5	5						9.5
			0.53	(8.48)	10							10.0
		CCA	0.23	(3.68)	7	3						9.7
			0.45	(7.20)	10							10.0
			0.78	(12.48)	10							10.0
	Control		0					3	2	3	2	4.5
Eastern spruce	Unincised	ACA	0.13	(2.08)		3	3	4				7.9
			0.21	(3.36)	1	1	3	5				7.8
			0.26	(4.16)		5	5					8.5
		CCA	0.10	(1.60)	5	3	2					9.3
			0.13	(2.08)	6	3	1					9.5
			0.53	(8.48)	10							10.0
	Incised	ACA	0.20	(3.20)	1	1	6	1	1			8.0
			0.28	(4.48)		7	3					8.7
			0.39	(6.24)	4	4	2					9.2
		CCA	0.20	(3.20)	9	1						9.9
			0.28	(4.48)	10							10.0
			0.54	(8.64)	9	1						9.9
	Control		0					2	2		6	2.6

Table 10—Incidence of decay in stakes after 10 years of ground-contact exposure at Cumberland site—con.

Wood species	Treatment: Surface	Treatment: Preservative	Retention (lb/ft^3)	Retention (kg/m^3)	Number of stakes with various decay ratings after 10 years of exposure[a]: 10	9	8	7	6	4	0	Average rating
Balsam fir	Unincised	ACA	0.20	(3.20)		5	5					8.5
			0.25	(4.00)	2	5	2	1				8.8
			0.42	(6.72)	5	5						9.5
		CCA	0.19	(3.04)	9	1						9.9
			0.40	(6.40)	10							10.0
			0.59	(9.44)	10							10.0
	Incised	ACA	0.31	(4.96)	2	6	2					9.0
			0.35	(5.60)	5	5						9.5
			0.47	(7.52)	10							10.0
		CCA	0.29	(4.64)	10							10.0
			0.53	(8.48)	10							10.0
			0.73	(11.68)	9	1						9.9
	Control		0						5	1	4	3.4
Eastern hemlock	Unincised	ACA	0.22	(3.52)	2	7	1					9.1
			0.36	(5.76)	7	3						9.7
			0.38	(6.08)	6	2	2					9.4
		CCA	0.20	(3.20)	10							10.0
			0.30	(4.80)	9	1						9.9
			0.41	(6.56)	10							10.0
	Incised	ACA	0.28	(4.48)	5	4	1					9.4
			0.41	(6.56)	9	1						9.9
			0.56	(8.96)	10							10.0
		CCA	0.25	(4.00)	10							10.0
			0.38	(6.08)	9	1						9.9
			0.57	(9.12)	10							10.0
	Control		0			1	2		1	1	5	3.5
Eastern larch	Unincised	ACA	0.15	(2.40)	1	4	3		2			8.2
			0.23	(3.68)	4	6						9.4
			0.24	(3.84)	4	6						9.4
		CCA	0.10	(1.60)	10							10.0
			0.18	(2.88)	9	1						9.9
			0.33	(5.28)	10							10.0
	Incised	ACA	0.16	(2.56)	5	4	1					9.4
			0.25	(4.00)	6	3	1					9.5
			0.32	(5.12)	10							10.0
		CCA	0.14	(2.24)	10							10.0
			0.28	(4.48)	10							10.0
			0.49	(7.84)	10							10.0
	Control		0			1	2	3	1	1	2	5.6

[a]Total number of stakes, 10.