CWPA Proceedings, 2004, pp 211-223

FIELD TESTING OF WOOD PRESERVATIVES IN CANADA XIII ACCELERATED GROUND CONTACT TESTS OF CCA-TREATED LUMBER

P.I. Morris and J.K. Ingram
Forintek Canada Corp., 2665 East Mall, Vancouver, B. C. V6T 1W5

Abstract

This paper reports on two accelerated tests with parallel objectives. One was to evaluate the effect on performance of improved preservative penetration; the other to determine what degree of penetration provides adequate protection. An accelerated decay test was set up to compare the performance of CCA-treated needle-incised white spruce and lodgepole pine heartwood with end-matched conventionally incised material. Short lengths of 2 x 4 and comparable untreated material were installed in a warmed soil bed in the open air. After 15 years of accelerated exposure (equivalent to 20 years' natural exposure), all the treated material, spruce and lodgepole pine, needle and conventionally incised, was almost completely sound, with minor patches of surface decay. In contrast, both the untreated spruce and the untreated lodgepole pine heartwood had failed due to decay. The performance of needle-incised and conventionally incised lumber has been very similar in both species. Material with mean CCA penetration of 6 mm and 40% of samples with over 5 mm of penetration was in good condition after the equivalent of 20 years natural exposure.

A more sophisticated soil bed test was set up to compare the performance of CCA-treated western spruce and lodgepole pine lumber treated to various depths of preservative penetration. Short lengths of treated 2 x 4s and comparable untreated material were installed in a soil bed. After 10 years of accelerated exposure (equivalent to 30 years' natural exposure), CCA treatment with as little as one or two millimeters penetration were still sound, while the untreated material had failed due to decay. Deterioration of the central untreated zone on the buried end of some material was caused by the failure of the field-cut preservative, not the CCA treatment, after the equivalent of 21 years.

1 Introduction

Most Canadian species have heartwood moderately resistant to impregnation with waterborne preservatives (Cooper 1973). Nevertheless, spruce-pine-fir (SPF) is the species group most commonly treated in Canada (Stephens *et al.*, 1994). Until 1997, all Canadian standards for treated lumber required 16 out of 20 pieces to have 10 mm penetration (CSA 1989). When the residential treated lumber market began to take off in the 1970s and 80s, this penetration requirement was impossible to meet consistently with SPF using the technology available to the industry. During the 70s and 80s, considerable effort was put in to meet this specification and the first experiment reported here derives from that work. During the late 80s and early 90s, the need for this depth of penetration was questioned, since data were generated demonstrating shell treatments can work well above ground (*inter alia* Morris and Ruddick, 1993) and a new residential decking standard with a 5 mm penetration requirement was introduced (CSA 1997). Further work showed thin shell treatments protect deck surface boards through preservative mobility (Choi *et al.*, 2004, Morris *et al*., 2004), additional performance data were generated (Morris and Ingram, 2002), and a new process standard is under consideration by the Canadian Standards Association. While attention focussed on the larger volume of residential lumber used in lower decay hazards above ground, data were also being generated on treated wood in ground contact (Morris and Motani, 1997, Morris 1999). Attempts were made to correlate performance to the penetration of material put in test many years earlier but this was not an entirely satisfactory approach. The second experiment reported here set out to install, in an accelerated ground-contact test, material with a range of defined preservative penetrations.

2 Background

White spruce (*Picea glauca* [Moench] Voss) and lodgepole pine (*Pinus contorta* Dougl.) have typically been used as representative species for treatability studies (Cooper 1973; de Lissa 1987; Ruddick 1985; Ross and Morris 1988). Attempts to overcome the problem of refractory species by roller incising concentrated on increasing the density of incisions and reducing the fibre damage associated with each tooth incision (Banks 197; de Lissa 1987; Kashiwasaki 1987; Kropf 1987; Ruddick 1989; Morris, Ruddick and Silcox 1991). An alternative approach to the same problem has been the use of needles, mounted on a flat platen, which perforate the lumber by a direct in and out motion (Burmester 1983).

In 1985, Ruddick reported a comparison of the treatment quality provided by needle incising and by one of the conventional North American roller incisors of that time. The roller incisor applied a typical staggered pattern, using blunt teeth, and was normally used for preserved wood foundation lumber, giving an acceptable treatment on western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). The needle incisor had been developed by PBH Weserhutte of West Germany and was in use by J.H. Benker KG Horgerts-Hausen for treatment of spruce lumber and siding.

The needle incisor not only gave a much better surface appearance than the conventional incisor, but also a better penetration and retention of preservative. Only needle-incised lodgepole pine would have met CSA 080.2 for ground contact use (CSA O80.2-M 1989). Needle-incised lodgepole pine and white spruce would have met CSA 080.32 for above-ground uses (CSA 080.32-96). In order to determine what effect these improvements in preservative distribution would have on commodity performance, Forintek set up an accelerated field exposure experiment in a heated outdoor soil bed (Ruddick and Doyle, 1986). Results from this experiment were last reported after 3 years' exposure (Morris 1989a). This paper presents the 15-year data.

Today, although fine tooth incisors are commonly used for structural members, they have still not met full consumer acceptance for appearance grade products, such as deck surface boards. Double density incising and needle incising have never been commercialized in Canada, mostly due to the practical difficulties inherent in day-to-day treating plant operation.

In the late 1980s when attention turned to questioning what degree of penetration was really necessary, Forintek had generated a large volume of CCA-treated white spruce and lodgepole pine from a study of high-speed incising technology (Morris 1989b, Walser 1989). Samples were selected with various depths of preservative penetration and installed in Forintek’s accelerated soil bed test. The soil beds are intended to provide optimum growing conditions for fungi year-round, protecting them from winter cold and summer drought which would hamper growth under natural conditions. The decay of wood in ground contact can thus be maintained at the maximum rate attained only for brief periods during the year in nature. The experiment described in this report was designed to yield data on the relationship between preservative penetration and commodity performance. Results after 6 years of exposure were reported by Morris and Ingram (1997). This report documents the condition of the samples after 10 years of exposure.

3 Materials and Methods

3.1 Heated Box Test of Incising Patterns

3.1.1 Preparation of Test Stakes

Preparation, incising and treatment of the test material was fully described by Ruddick (1985) and consisted of CCA-treated white spruce and lodgepole pine 2 x 4s incised with either a conventional roller incisor or the needle incisor. Incision depths were around 9 mm for the needle incisor and 6 to 8 mm for the roller incisor. For each wood species, 30 pairs of end-matched samples (one of each pair for each incising pattern) were cut to 50 cm long and the ends were painted with two brush coats of copper naphthenate (2% copper). These stakes, plus 10 unincised untreated controls of each wood species, were installed to a depth of 20 cm in the soil bed described below.

3.1.2 Heated Box Construction

The 1.2 x 2.4 x 0.5 m deep soil bed used in this investigation was fabricated from hem-fir plywood treated with ammoniacal copper arsenate (ACA) and hem-fir lumber (2 x 4) treated with chromated copper arsenate (CCA) and insulated with 4 cm thick styrofoam insulation. The bottom 10 cm of the bed was filled with pea-gravel to provide a drainage layer below the 40 cm of soil used to fill the bed. Two thermostatically controlled soil-heating cables (800 watts each) were installed in the soil, 5 cm above the gravel layer. This system maintains the soil temperature at 10 cm depth around 20°C throughout the year. The soil was loam-based horticultural soil modified by the addition of about 10% of washed river sand (Smith *et al.*, 1986). The soil moisture content was allowed to vary around the water-holding capacity (30% moisture content) maintained by rainfall and natural drainage. Additional water was occasionally supplied during prolonged periods without rainfall. Previous work (Morris 1989) found an acceleration factor of approximately 1.3 compared to natural conditions. Thus, 15 years' exposure in the heated soil is equivalent to about 20 years in a field test.

3.1.3 Inspection of Test Samples

The stakes were rated periodically over a period of 15 years using the AWPA scale described below. The stakes were removed from the soil, brushed free of adhering soil, and examined for areas of discoloration. Any suspicious areas were gently probed for softness, which indicates the presence of decay.

AWPA Rating System

10	Sound
9	Trace of decay
7	Moderate decay
4	Heavy decay
0	Failure due to decay

3.2 Soil Bed Test of Preservative Penetration

3.2.1 Stake Preparation

White spruce [*Picea glauca* (Moench) Voss] and lodgepole pine [*Pinus contorta* Dougl] 2x4s, 25 cm in length and treated with chromated copper arsenate, Type C (CCA), were cut from pieces selected on the basis of preservative penetration, which had been measured on cross-sections of the boards. These boards were from a previous study of the effect of high-speed incising (Morris 1989; Walser 1989). They had been treated with a 2.2% CCA solution using a standard treating cycle of 30 minutes vacuum, six hours of pressure at 1035 kPa, then 30 minutes of vacuum. Five pine and five spruce boards were selected with penetrations of 0 mm, 1-2 mm, 4-5 mm, 9-10 mm, and >16 mm of CCA, for a total of 50 samples. Both ends were given two coats of copper naphthenate field-cut preservative, then all samples were installed to half their length in a soil bed.

3.2.2 The Forintek Soil Bed Facility

The Forintek soil bed facility (Smith *et al.*, 1986) is a walk-in room enclosing four stainless steel troughs, 4.8 m long by 0.8 m wide, each filled with a loam-based horticultural soil modified by the addition of about 10 percent of washed river sand, overlaying a 10 cm layer of pea-gravel. The soil and gravel are separated by a fine plastic mesh to prevent soil from washing through the gravel. The air temperature and relative humidity are controlled by a microprocessor. Four ceiling fans provide air circulation and uniform temperature and humidity. For this experiment, the facility was operated at a temperature of 26°C, a relative humidity of 80%, and 24% soil moisture content. Soil moisture was maintained by periodically raising the water table in the bed at intervals based on gravimetric monitoring of soil moisture content. Previous work has shown an acceleration factor for this soil bed of approximately 3x for controls and CCA-treated stakes over a temperate test site with the same-sized stakes (Morris and Ingram, 1991). Thus, 10 years' exposure in the heated soil is equivalent to about 30 years in a field test.

3.2.3 Installation and Inspection of Test Material

The stakes were installed in May 1991 in a random array to a depth of 125 mm and with 75 mm between all faces. At six-month intervals each stake was removed from the bed, brushed free of adhering soil, and evaluated using the AWPA rating scale. For simplicity, data are presented here only for the yearly inspections.

4 Results and Discussion

4.1 Heated Box Test of Incising Patterns

The deeper penetration and closer spacing of the teeth in the needle-incised samples compared to those that were conventionally incised were reflected in the higher preservative retention and penetration (Table 1).

Table 1: Heated Box Test of Incising Patterns: Treatment Data[a]

Wood species	Incising	Mean Assayed CCA retention (kg/m^3)	Mean CCA penetration (mm)	% Samples with ≥10 mm of penetration	% Samples with ≥5 mm of penetration
White spruce	conventional	5.7 (1.7)	6.2 (3.2)	10	67
	needle	7.9 (2.2)	8.7 (2.2)	33	90
Lodgepole pine	conventional	5.0 (2.0)	5.9 (5.9)	20	40
	needle	7.0 (1.4)	16.2 (2.8)	93	97

[a] Standard deviations are given in parentheses

All of the treated material of both species and both incising patterns remained in excellent condition after 15 years of exposure in the heated bed (Table 2, Figures 1 and 2). Only small traces of decay were scattered over the below ground surfaces of the stakes. There was no discernible difference in performance between the two incising patterns in either species. Of particular note was the excellent performance of lodgepole pine in which only 20% of samples contained over 10 mm penetration and 40% over 5 mm. In contrast, the untreated material was severely decayed within 5 years of exposure, with five of 10 pine and eight of 10 spruce stakes failed. These results confirm data from field testing where hem-fir 4 x 4s with 45% of samples containing over 5 mm of preservative penetration were sound after 10 years' exposure at Westham Island, considered equivalent to 25 years' exposure at most other temperate locations due to detoxification of arsenic by soil iron. (Morris 1999).

Table 2: Heated Box Test of Incising Patterns: Mean Decay Ratings[a]

			Change in Mean[a] Decay Rating Over Time (years)							
Wood species	**Incising**	**Treatment**	**1**	**3**	**4**	**5**	**6**	**7**	**12**	**15**
White spruce	conventional	CCA	10.0 (0.0)	9.9 (0.3)	9.8 (0.4)	9.8 (0.4)	9.7 (0.5)	9.8 (0.4)	9.7 (0.4)	9.7 (0.5)
	needle	CCA	10.0 (0.0)	9.9 (0.3)	9.8 (0.4)	9.7 (0.6)	9.6 (0.8)	9.8 (0.4)	9.6 (0.4)	9.7 (0.5)
	None	none	8.2 (1.0)	4.8 (2.3)	1.2 (1.9)	0.8 (1.7)	0.8 (1.7)	0.4 (1.3)	0.0 (0.0)	0.0 (0.0)
Lodgepole pine	conventional	CCA	10.0 (0.0)	9.8 (0.4)	9.7 (0.5)	9.7 (0.6)	9.7 (0.6)	9.6 (0.5)	9.6 (0.5)	9.6 (0.5)
	needle	CCA	10.0 (0.0)	9.8 (0.4)	9.7 (0.5)	9.6 (0.5)	9.5 (0.5)	9.6 0.5)	9.6 (0.5)	9.4 (0.5)
	None	none	9.0 (0.0)	4.9 (1.4)	3.1 (2.3)	2.0 (2.1)	1.6 (2.1)	1.6 (2.1)	0.0 (0.0)	0.0 (0.0)

[a] Standard deviations are given in parentheses

Figure 1: Heated Box Test of Incising Patterns: Deterioration of Spruce

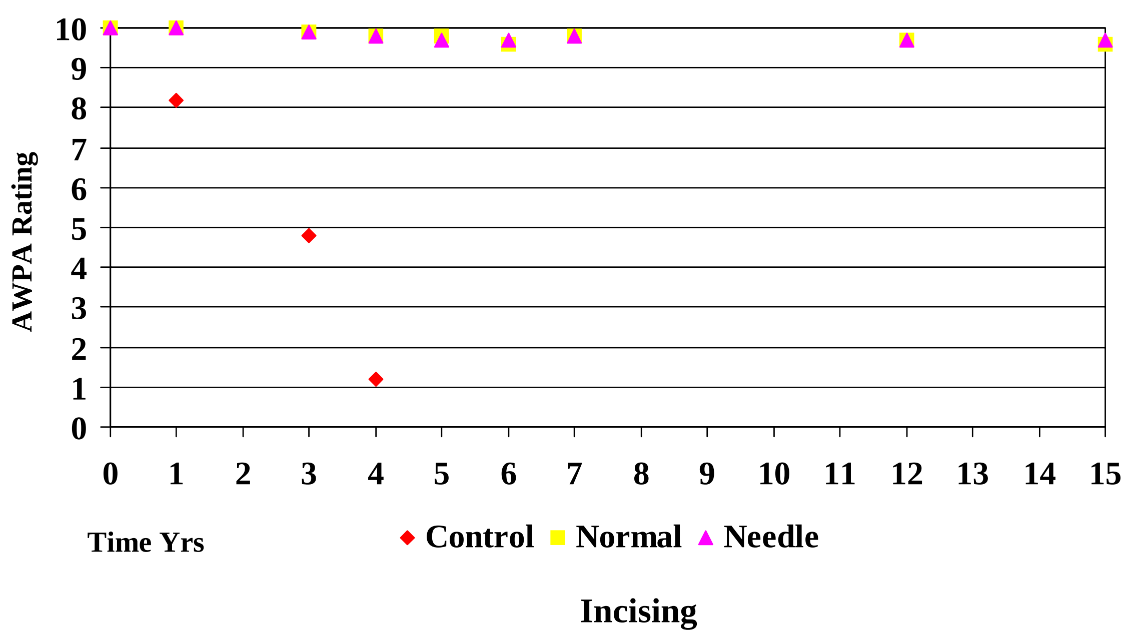
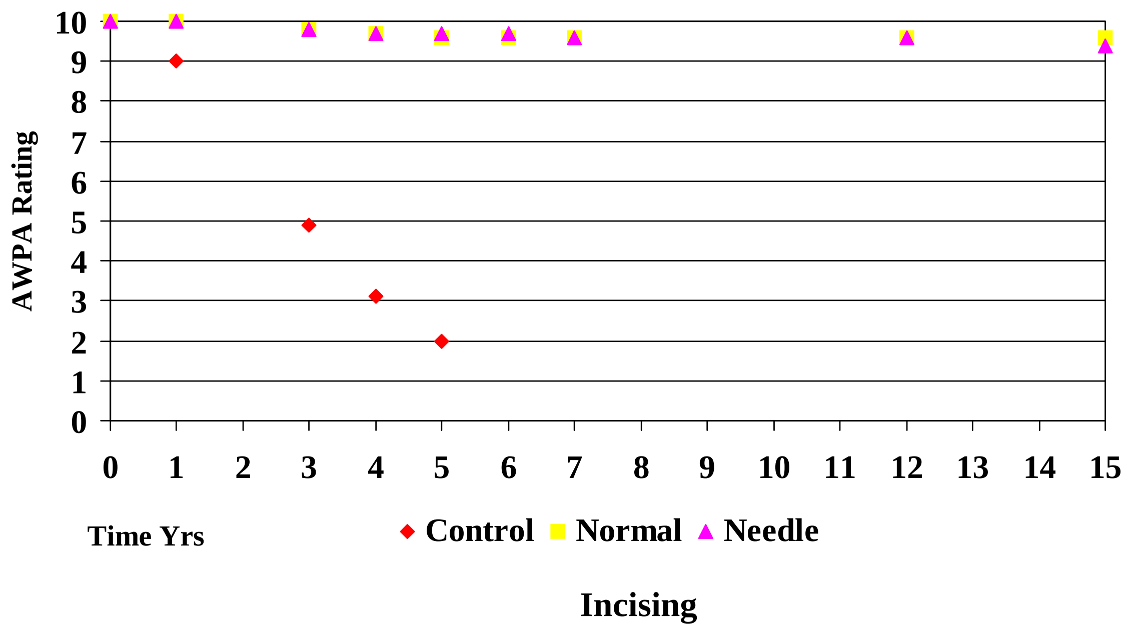


Figure 2: Heated Box Test of Incising Patterns: Deterioration of Pine



4.2 Soil Bed Test of Preservative Penetration

Untreated pine and spruce controls both reached a rating of 7 after two years and three years respectively (Table 3). By the 10-year inspection, the untreated controls had completely failed due to decay (Table 3, Figures 3 and 4).

At the seven-year evaluation, softening was noted on the centre of the buried end-grain of some treated pieces. This decay was identified as being due to tunnelling bacteria and possibly soft rot. This deterioration continued to expand and deepen over the ensuing three years of inspection (Table 3). In no instance was decay found in the treated outer shell portion of the cross-section. The breach in protection was through the field-cut preservative that coated the cut ends of the boards, rather than through the CCA pressure treatment. The samples with deeper CCA penetration presented a smaller cross-section of end-grain protected only by end-cut preservative hence there was a progression in decay related to depth of penetration (Table 3).

Table 3: Soil Bed Test of Preservative Penetration: Treatment Data and Mean Ratings

	Pen.	Ret.[a]	Change in Mean[b] Decay Rating over Time (Years)									
Species	mm	kg/m^3	1	2	3	4	5	6	7	8	9	10
	0	0.0	8.6 (0.9)	7.4 (0.9)	7.0 (0.0)	7.0 (0.0)	7.0 (0.0)	7.0 (0.0)	5.2 (1.6)	3.0 (3.0)	2.4 (2.2)	0.0 (0.0)
	1-2	4.4	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	7.8 (1.1)	6.6 (2.5)	6.8 (1.8)	6.4 (1.3)
White Spruce	4-5	3.4	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	8.4 (1.3)	6.8 (1.8)	7.4 (0.9)	7.0 (0.0)
	9-10	6.0	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	9.4 (1.3)	8.6 (2.6)	9.0 (1.2)	9.0 (1.2)
	≥16	5.7	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)
	0	0.0	7.4 (0.9)	6.4 (1.3)	5.6 (3.1)	5.0 (3.1)	5.0 (3.1)	3.8 (2.5)	3.8 (2.5)	1.4 (3.1)	0.8 (1.8)	0.8 (1.8)
	1-2	4.4	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	8.4 (1.3)	7.2 (2.0)	6.6 (2.5)	6.2 (2.2)
Lodgepole Pine	4-5	5.4	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	8.4 (1.3)	7.4 (2.3)	7.4 (2.3)	6.8 (1.8)
	9-10	6.3	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	9.6 (0.5)	8.0 (1.4)	8.0 (1.4)	8.0 (1.4)
	≥16	4.5	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)

a. Retentions were not for individual boards, but for composite groups of 20 boards from the same charge.
b. Standard deviations are given in parentheses
Decay in the highlighted areas was strictly in the end-grain of the samples

Figure 3: Soil Bed Test of Preservative Penetration: Deterioration of Spruce

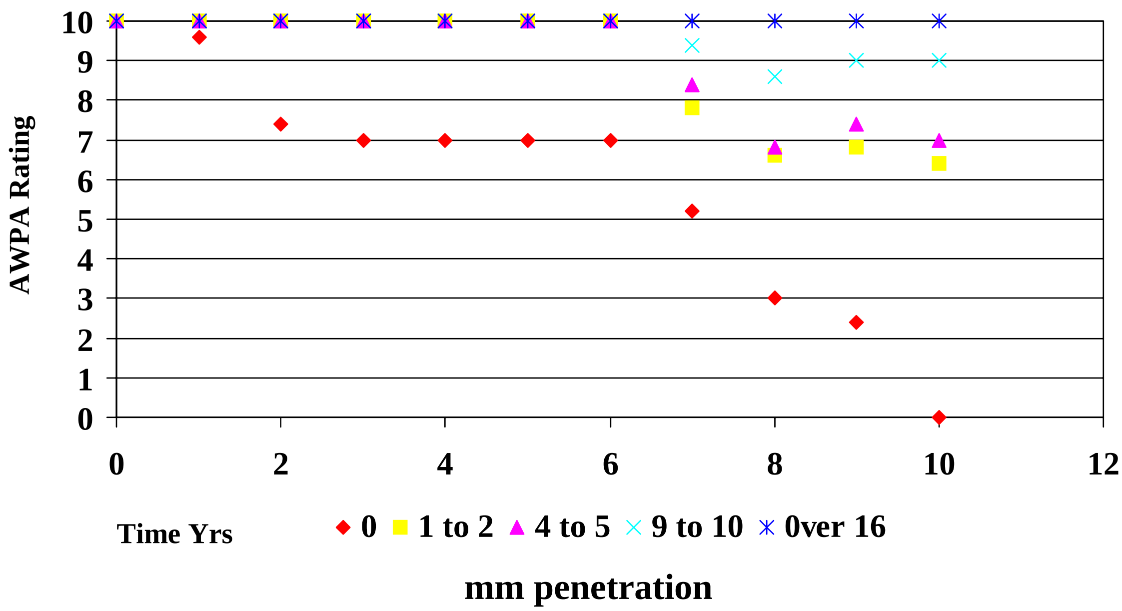
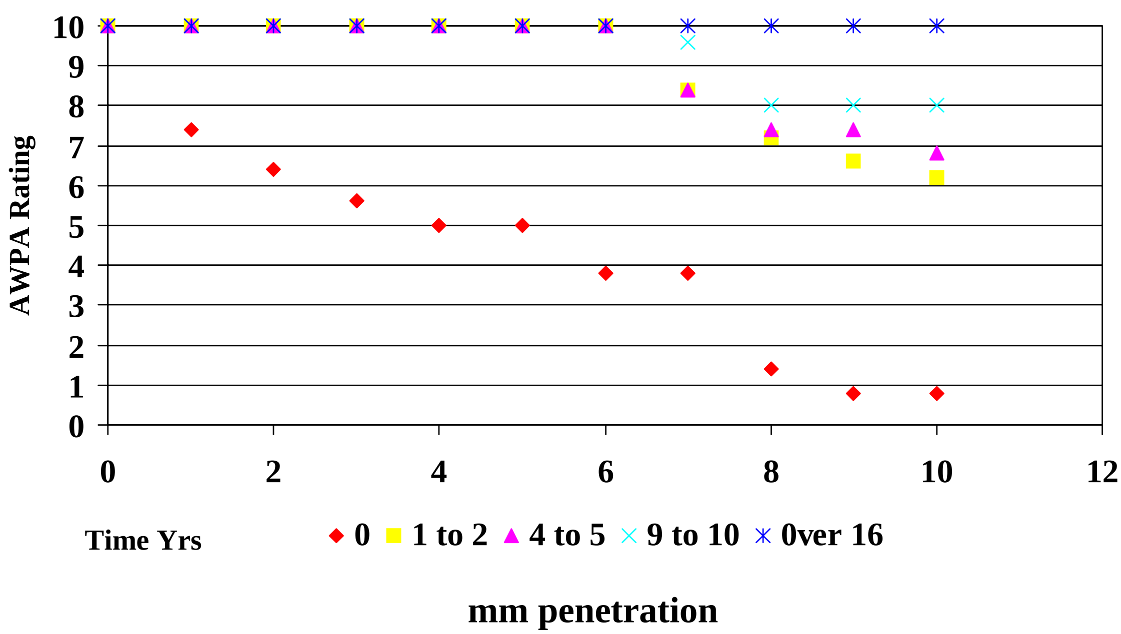


Figure 4: Soil Bed Test of Preservative Penetration: Deterioration of Pine



The soil bed provides a beneficial environment for soft rot fungi and bacteria. Soft rot fungi and bacteria are slower growing than basidiomycetes and are more preservative-tolerant. Soft rot fungi also grow better on hardwoods than softwoods. Consequently untreated softwood does not decay as fast in the soil bed as in a natural environment where soft rot fungi would be out-competed by basidiomycetes. However, well-treated wood does decay at an accelerated rate in the soil bed because soft rot and bacteria are the organisms that typically limit its service life in nature. Previous work has shown an acceleration factor for this soil bed of approximately 3x for controls and CCA-treated stakes over a temperate test site with the same-sized stakes (Morris and Ingram, 1991). The seven years in this experiment before any decay was detected in the end-grain of treated samples therefore extrapolate to over 20 years of real life service.

The decay results found in this study indicate that lumber which does not meet the CSA O80.2 requirement for ground contact use (6.4 kg/m^3 retention and 10 mm penetration in 80% of samples) can still perform well in service. A possible explanation may be the very high preservative loadings present in the treated zone. The mean retention for both the spruce and pine samples with just 1-2 mm of preservative penetration was 4.4 kg/m^3. A retention of 4.4 kg/m^3 in the 16 mm assay depth is equivalent to 35 kg/m^3 in the 2 mm treated zone.

The decision was made to terminate this experiment after 10 years, as this represented 30 years in a field test. Furthermore, the decay in the end-grain had progressed to the point that decay subsequently penetrating the CCA-treated zone would not have been distinguishable from that already present.

5 Conclusions

Material with a mean CCA penetration of 6 mm, and 40% of samples containing over 5 mm of penetration, remained sound in an accelerated test for the equivalent of 20 years' natural exposure.

Despite considerable differences in preservative penetration and retention, there was no difference in performance between needle and normal incising in spruce or pine over 15 years of accelerated test, considered equivalent to 20 years under natural conditions.

Spruce and pine lumber protected by a CCA-treated shell containing as little as 1 to 2 mm of preservative penetration remained sound over 10 years of accelerated test, considered equivalent to 30 years under natural conditions.

Field-cut copper naphthenate preservative protecting the untreated end-grain began to fail after seven years in an accelerated test, considered equivalent to 21 years under natural conditions.

These data suggest preservative penetration is not as important as preservative retention in determining long-term performance of CCA-treated wood.

6 References

Banks, W.B. 1973. Preservative penetration of spruce, close spaced incising an improvement. Timber Trades Journal 2285 (Supplement) 51-53.

Burmester, A. 1983. Influence of incising on the bending strength of spruce wood. Holz Als Roh und Werkstoff. 41:331-332.

Canadian Standards Association. 1989. CSA O80.2-M89. Preservative treatment of lumber, timber, bridge ties and mine ties by pressure processes. Rexdale, ON.

Canadian Standards Association. 1997. CSA O80.32-97. Preservative treatment of decking lumber with waterborne preservatives by pressure processes. Rexdale, ON.

Choi, S.M., J.N.R. Ruddick, and P.I. Morris. 2004. Chemical leaching and migration in CCA-treated decking. For Prod. J. 54(3):33-37

Cooper, P.A. 1973. Effect of species, precompression and seasoning on heartwood preservative treatability of six western conifers. Forest Products Journal. 23(7):51-59.

de Lissa, R. 1987. Improved CCA treatment of several western species using a fine-tooth close incising pattern. *In* Proceedings of the 1987 Annual Meeting of the Canadian Wood Preservation Association. Mississauga, ON, pp. 57-73.

Kashiwasaki, S. 1987. Current state of the art of incising in Japan. *In* Incising Workshop Proceedings. Forintek Special Publication No. SP28. Forintek Canada Corp. Vancouver, BC, pp. 35-50.

Kropf, F.W. 1987. Mechanical incising in Switzerland/Germany. *In* Incising Workshop Proceedings. Forintek Special Publication No. SP28. Forintek Canada Corp., Vancouver, BC, pp. 51-55

Morris, P.I. 1989a. Performance of needle incised and conventionally incised CCA treated white spruce and lodgepole pine under accelerated decay conditions. Report prepared for the AWPA Task Force on the Preservative Treatment of Spruce. Forintek Canada Corp., Vancouver, BC. 7 p.

Morris, P.I., 1989b. Incising preservation. In advances in sawmill technology. G.R. Middleton (Editor) Report for the Canada-British Columbia Forest Resource Development Agreement. Forestry Canada. Victoria, BC.

Morris, P.I. 1999. Field testing of wood preservatives in Canada IX: Performance of posts and lumber in ground contact. Proc. Cdn Wood Preservation Assoc. 20: 7-22.

Morris, P.I., and J.K. Ingram. 1991. Stake Tests of Wood Preservatives at Westham Island: 1990 Data (First of Two Reports). Report to the Canadian Forestry Service. No. 03-17-10-O-009. Forintek Canada Corp. Vancouver, BC. p. A-7.

Morris, P.I. and J.K. Ingram. 1997. Performance of spruce and pine lumber with various preservative penetrations in a soil bed test. Report to CSA Task Force E: Spruce in Ground-Contact Use and CSA Task Force D: Standard for Preservative Treatment of Dimensional Lumber for Aboveground Decking and Fencing Applications. Forintek Canada Corp. Vancouver, BC. 3 p.

Morris, P.I. and J.K. Ingram. 2002. Field testing of wood preservatives in Canada XI. Nine Year inspection of the CITW decking test. Proc. Cdn. Wood Preservation Assoc. 23:156-169.

Morris, P.I., J.K. Ingram, J.N.R. Ruddick and S.M. Choi. 2004. Protection of untreated wood by adjacent CCA-treated wood. For. Prod. J. 54(3):29-32.

Morris, P.I. and K Motani. 1997. Field testing of wood preservatives in Canada VII. Performance of treated lumber against termites in Ontario. Proc. a Conv. Cdn. Wood Preservation Assoc. 18:107-116.

Morris, P.I. and J.N.R. Ruddick. 1993. Performance of non-incised CCA-treated hem-fir decking. The International Research Group on Wood Preservation. Document No. IRG/WP/40004. IRG Stockholm, Sweden.

Morris, P.I., J.N.R. Ruddick and R. Silcox. 1991. Development, design and construction of a double-density incisor. Forest Prod. J. 41(2):15-20.

Ross, N.A. and P.I.Morris. 1988. Evaluation of the Forintek incising concept for the treatment of refractory wood species. Report No. 02-17 43-0202. Forintek Canada Corp. Vancouver, BC 18 p.

Ruddick, J.N.R. 1985. A comparison of needle incising and conventional North American incising processes for improving preservative treatment. Proceedings of the American Wood Preservers' Association 81:148-160.

Ruddick, J.N.R. 1989. Multi-head incisor for lumber, timber and the like. United States Patent No. 4,836,354

Ruddick, J.N.R. and E.E. Doyle. 1986. Field testing of treated and untreated wood products. Report to the Canadian Forest Service. No. 02-17-10-051. Forintek Canada Corp., Vancouver, BC. 39 p.

Smith, R.S., A. Byrne, J.E. Clark and L. Parker. 1986. Operation of a facility for accelerated biodeterioration (FAB). Report to the Canadian Forest Service. No. 02-17-10-397. Forintek Canada Corp., Vancouver BC. 23 p.

Stephens, R.W., G.E. Brudermann, P.I. Morris, M.S. Hollick, and J.D. Chalmers. 1994. Value assessment of the Canadian pressure treated wood industry. Report to Canadian Forest Service. Natural Resources Canada. 241p. Carroll-Hatch (International) Ltd. North Vancouver B.C.

Walser, D.C. 1989. Lumber incising. *In* Advances in sawmill technology. Rpt. for the Canada-British Columbia Forest Resource Development Agreement. Forestry Canada. Victoria, BC. p. 63.

Acknowledgements

The heated box test was set up under the supervision of J.N.R. Ruddick.

Forintek Canada Corp. would like to thank its industry members, Natural Resources Canada, and the Provinces of British Columbia, Alberta, Quebec, Nova Scotia, New Brunswick, Saskatchewan and Newfoundland and Labrador, for their guidance and financial support for this research.