FIELD TESTING IN CANADA XXIV: TEN YEARS INSPECTION OF PROFILED DECKING

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Summary

In 2003, with the support of the BC Forestry Innovation Investment Ltd., FPInnovations initiated a study of subalpine fir profiled decking. An experiment was designed to compare the dimensional stability and durability of subalpine fir flat decking to ribbed decking, both untreated and treated with three copper-based preservatives. The decking was inspected over a period of ten years for checking, appearance, and decay. Surface profiling with a ribbed texture significantly reduced surface checking over the full ten years. No decay was detected in any of the preservative-treated decks at the five- and ten-year inspections. There was no significant difference in decay rating between untreated boards with and without profiling at this stage. With appropriate surface profiling and treatment with any of the preservatives in this study, subalpine fir is highly suitable for decking applications although CCA is no longer registered for use in residential decking.

Introduction

Subalpine fir (*Abies lasiocarpa* Hook Nutt.) is one of the four species harvested together in BC as spruce-pine-fir (SPF), and is considered difficult to process due to its low density, high moisture content, and slow drying rate. Examination of its properties suggested opportunities for new higher-margin products in applications where durability and dimensional stability are important such as decking (Knudson et al. 2008). Subalpine fir is classed as a moderately difficult to treat wood species, but FPInnovations research has shown that it has the most treatable heartwood of the species within the SPF mix. Incising the lumber substantially improves preservative penetration (Morris 1991). The preservatives that have replaced chromated copper arsenate (CCA) for most residential uses since 2004 can provide better penetration of Canadian species, including subalpine fir, than CCA (Morris et al. 2002).

Three key attributes for decking are appearance, dimensional stability, and durability. There were indications that edge-grain subalpine fir might provide a dimensionally stable decking product, particularly in the thinner dimensions. Five-quarter-inch decking has become increasingly popular for its appearance. It may also be less susceptible to warping and may dry out faster after rain events. Furthermore, even with a relatively shallow treatment, a considerable proportion of the cross section would be treated. At the time this work was initiated a new decking standard had been developed, CSA O80.32, with a reduced (5mm) penetration requirement. It was not possible to treat most Canadian wood species (including subalpine fir) to meet CSA O80.2 (10 mm penetration) or the decking standard CSA O80.32 (5 mm penetration), using CCA, without incising. However, it was anticipated there would be a greater chance of meeting the CSA O80.32 standard with the new preservatives. A process specification has since been standardized (CSA 2008) for small dimension and profiled wood products that cannot be incised due to excessive damage to the appearance and cannot be bored or cut for penetration measurements without making pieces unsaleable.

Profiled decking, where the wood surface is textured with grooves cut parallel to the grain, is extremely popular in the UK and Australia, but has not had a major impact on the market in North America. It had been suggested that profiling might increase moisture uptake and trapping of dirt and thus affect long term durability. Long-term field tests were therefore set up to address these issues. Results of this study were reported after 17 months (McFarling et al. 2009) and 23 months (McFarling and Morris 2005). It was noted that profiling substantially reduced the extent and appearance of checking. Checks were focussed at the base of the grooves making them difficult to see when standing on the deck or at a distance. A program of further product development was initiated. Checking evaluation on this material after five years' exposure was reported by Morris and McFarling (2008). In addition, test deck sections with two species, two orientations, two treatments, with and without coating, with four profiles plus flat, were constructed in the FPInnovations courtyard and inspected after one year (McFarling and Morris 2008). For post-MPB pine, the rippled-flat edge showed the lowest check length and depth while for Pacific silver fir, the ribbed-eased edge showed the lowest check length. This report updates the results of the initial experiment on subalpine fir to ten years of exposure.

Materials and Methods

Deck Preparation

Logs used for this study were supplied by Canadian Forest Products Ltd. (Canfor) from the Fort St. James region of BC. Canfor Ltd. in New Westminster, BC, manufactured decking boards from the rough sawn, kiln-dried subalpine vertical grain and flat grain lumber. Half of the boards were manufactured as flat-surfaced, radius edge decking using a molder. The other half were provided with a ribbed surface profile based on a product from Australia. Fifty boards of flat decking, 26 mm x 133 mm x 2.43 m, and fifty boards of profiled/ribbed decking, 26 mm x 131 mm x 2.43 m, were selected based on visual criteria (suitable grade for deck surface boards and no initial checking). The moisture content of the decking material was found to range from 15 to 18%. Ten boards from each group were put aside as untreated control specimens. These boards were cut into two end-matched samples 0.6 m long. Each of the remaining 40 boards per group was then cross-cut into three end-matched 0.8 m long samples, labeled, and end-sealed with three coats of a 2-part epoxy resin (Intergard 740, International Paint LLC).

Each of these three end-matched samples was treated at the FPInnovations Vancouver laboratory with a different aqueous preservative: 1.98% actives (w/v) of chromated copper arsenate type C (CCA-C) at 20°C, 1.62% actives (w/v) of alkaline copper quat type D [carb.] (ACQ-D) at 40°C, and 0.89 % actives (w/v) of copper azole (CA) type B at 40°C. The following treating schedule was used:

- 30 min. vacuum 635mm Hg
- Fill retort under vacuum with treating solution
- 5 minutes to full pressure
- 180 minutes at full pressure – 1035 kPa
- 10 min. pressure relief to atmospheric
- Empty retort
- 15 minute final vacuum 635 mm Hg

Boards were weighed before and after treatment to determine uptakes. The samples were then wrapped, in treatment groups, in polyethylene sheet to retard drying, and stored at approximately 25°C for 2 weeks to allow preservative stabilization. Following stabilization the specimens were unwrapped and allowed to air-dry.

Following drying, a 5 mm cross-section was cut from both ends of the samples to remove the end-seal. Two 25 mm cross-sections were then taken, from one end, for penetration and retention analysis. One of these cross-sections was sprayed with chrome azurol S indicator solution (American Wood Preservers' Association 2003a), and the treated zone was measured. The penetration measurement was taken on the edge of the sample to simulate the location typically sampled during quality assurance inspections. Using the second cross-section, a 5 mm deep by 15 mm wide sub-sample was cut from the edge, to represent an increment boring. The sub-sample was oven-dried, ground to pass through a 40-mesh screen, and 0.4 g of the resulting sawdust was combined with 0.1 g of cellulose and compressed to form a pellet. These pellets were analyzed on a Spectrace energy dispersive x-ray spectrometer which had been calibrated for chromium, copper and arsenic (American Wood Preservers' Association 2003b). The reference specific gravity of subalpine fir (331 kg/m³) was used to convert results from a weight per weight to the weight per volume unit (kg/m³) used to express preservative retention. Using the penetration and retention data, 20 samples were selected that met, or came close to meeting, the CSA O80.32 decking standard (Canadian Standards Association 1999).

Each deck base consisted of six nominal 2 x 6" boards, treated with the same preservatives, placed on edge and screwed together to form a frame, as shown in Figure 1. 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 pre-drilled with two holes near each end and attached in two rows of ten replicates to the frame (Figure 1). One row consisted of boards with end-cut preservative, while the other was uncoated. This decking test method has since been accepted for standardization by the American Wood Protection Association as AWPA E25 (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.

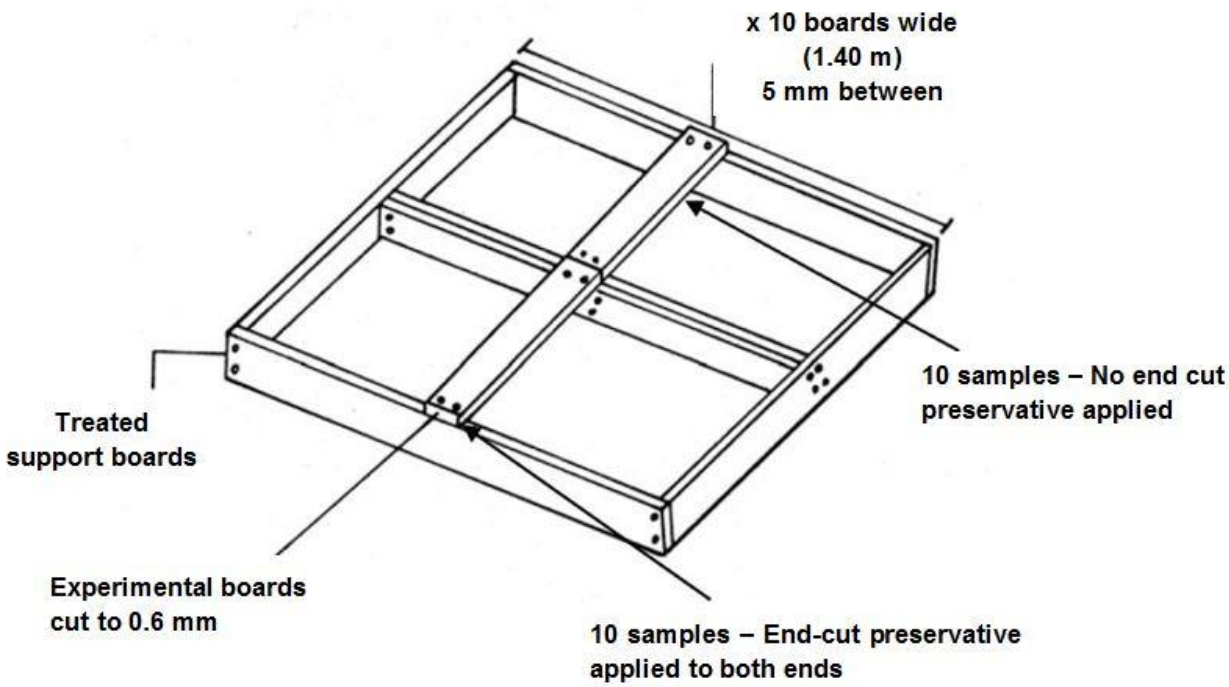

Figure 1 Deck Design

A total of eight decks were constructed, and labeled as follows: ACQ-D/ribbed, ACQ-D/flat, CA/ribbed, CA/flat, CCA/ribbed, CCA/flat, Untreated/ribbed, and Untreated/flat. The decking modules were constructed at FPInnovations' laboratory, then shipped to the FPInnovations field test site at Maple Ridge, BC and installed, level on cinder blocks, in September 2003.

Test Site

The test site at Maple Ridge, BC is located within the University of BC Malcolm Knapp Research Forest. This site has a rainfall of over 2150 mm per year and an average yearly temperature of 9.6°C with mean daily maximum and minimum temperatures of 6°C and 1°C in January, and 23°C and 12°C in July. It falls within the moderate decay hazard zone for outdoor above-ground exposure using Scheffer's climate index (Scheffer 1971; Setliff 1986), with an updated climate index of 56 based on 9-year data (Morris and Wang 2008). This zone includes most of the major population centres of North America.

Inspection of Test Material

The decking samples were rated 6, 17, 36, 60, and 120 months after installation for dimensional stability characteristics. Cupping was measured at the 6- and 17-mo month inspections only, as the maximum measurement was less than 0.5 mm after 17 months. The lengths of checks were measured only at the first three inspections. Check depth and width were measured for each board individually on the top (exposed) face. These properties were measured as follows:

- Check length: the total length of all the checks on a board added together (mm)
- Check depth: the deepest check measured with a 0.006" feeler gauge (mm)
- Check width: the maximum width of the largest check on the surface of the specimen (mm)

The overall checking appearance was visually rated on a 0 to 4 scale. Boards rated 0 had no checks. Boards rated 1 had minor checking that was barely noticeable when standing on the deck. Boards rated 2 had noticeable checking but would be acceptable to a homeowner. Boards rated 3 had severe checking such that a homeowner might consider replacing the board. Boards rated 4 had such severe checking that it may affect structural performance, and were considered to have failed. Data comparisons between flat and ribbed material were made using Student's t-test, while data comparisons among preservatives were made using Student's paired t-test since the samples were end-matched.

Due to the relatively slow progress of decay above ground the test units were inspected for decay on a 5-year cycle. Each board of the 20 per deck was examined visually for indications of decay such as the presence of fungal mycelium or discolouration. If decay was suspected, the area of interest was gently probed with a metal scraper. Each surface was then assigned a decay rating, based on the AWPA E7 (2008) grading system. After five and 10 years in test, in September 2008 and 2013, each board was individually assessed for decay using the AWPA E25-08 rating system:

Rating	**Condition of the board**
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 10-30% of cross-section decayed.
6	Severe attack. Sample has between 30-50% of cross-section decayed.
4	Very severe decay likely to affect load-bearing capacity but not readily broken.
0	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.

Results and Discussion

3.1 Decking Penetration and Retention

Penetration data are given in Table 1 as mean penetration and percent penetration over 5 mm. As expected, there was no apparent difference in preservative penetration between the flat and ribbed decks. The mean penetration for the CCA-treated deck boards was shown to be significantly lower ($p<0.05$) for the ribbed decking when compared to the CA- and ACQ-D-treated deck boards, confirming the better penetration of Canadian species of the new copper-based preservatives.

The Canadian decking standard, CSA O80.32-97, required 80% at or over 5 mm penetration for CCA- treated deck boards. The CA-treated deck boards, both ribbed and flat, and the ACQ-D-treated flat decking met the penetration requirement. The ACQ-D ribbed decking almost met the penetration requirement with 75% of the samples meeting the criteria. The CCA-treated deck boards failed to meet the standard with only 55% and 40% of the deck boards meeting the penetration requirement for the flat and ribbed decking, respectively.

The Canadian decking standard, CSA O80.32-97, required a retention of 6.4 kg/m³ in a 5 mm assay zone for CCA-treated deck boards. This would correspond to 6.4 kg/m³ retention requirement for ACQ-D and 3.3 kg/m³, as copper metal, for CA. All of the treatments, both flat and ribbed, met the retention requirement, as shown in Table 1. The target gauge retentions currently specified for Product Group B (CSA 2008) are 0.9 kg/m³ for CA-B and 2.0 kg/m³ for ACQ-D (CCA is no longer permitted for decking). The minimum solution strengths are now 0.8% for CA and 1.8% for ACQ-D.

Table 1 Penetration and retention in treated boards

Preservative	Decking type	Mean Penetration (mm)	Penetration % ≥ 5 mm	5mm Assay Retention (kg/m³)	Gauge Retention (kg/m³)
CA	Flat	9.4 (6.8)[1]	90	4.0 (1.1)	1.5 (0.6)
ACQ-D	Flat	14.1 (14.1)	80	9.6 (3.3)	3.6 (1.8)
CCA	Flat	8.4 (8.2)	55	11.9 (4.8)	3.5 (1.8)
CA	Ribbed	11.3 (10.7)	80	3.8 (1.1)	1.5 (0.4)
ACQ-D	Ribbed	10.1 (8.0)	75	9.7 (4.5)	3.7 (1.1)
CCA	Ribbed	5.3 (4.1)	40	9.6 (4.5)	3.0 (1.0)

[1] Standard deviation given in parentheses
[2] Maximum penetration measured = 16 mm

3.2 Dimensional Stability/Checking

Checks represent relief of stresses in the wood. All of the preservative-treated ribbed deck boards had significantly lower ($p<0.05$) average check lengths, shallower check depths, narrower check widths, and better average appearance ratings compared to the flat specimens treated with the same preservative over ten years in test (Tables 2 – 5).

The untreated boards, both ribbed and flat, had lower average check lengths, shallower check depths, narrower check widths and better average appearance ratings than their preservative-treated equivalents after six months. This is typical of chemically pressure-treated decking as the lumber has already been through severe wetting and drying and normally has a small increase in surface brittleness, making the lumber more susceptible to checking. However by 17 months of exposure this difference had disappeared.

An average appearance rating of 3 is our estimate of the level of checking at which the consumer would most likely want to replace the deck. Within three years, the flat decking boards were almost at the stage where replacement of the deck would be considered. The surfaces were noticeably checked when compared to the ribbed decking boards which had average appearance ratings of less than 1 (Table 5). Even after ten years in test, the preservative-treated ribbed decks looked substantially better than the preservative-treated flat decking. The checks that were noted within the ribbed decking were visible only close up (less than 2 feet or 0.6 m away), and virtually impossible to see at standing height (over 5 feet or 1.5 m). Within the ribbed decking profile, the checks followed parallel to the grooves, and were imbedded in the grooves,

Some surface collapse was noticeable on the preservative-treated decking boards on approximately 20-30% of flat, and 5-10% of the ribbed decking at the time of deck installation. After six months this washboarding effect had disappeared, possibly due to the uptake of moisture over the winter which would help to relieve stresses within the surface of the decking.

Table 2 Mean check length (mm) over the first three years of exposure

Preservative	**Decking type**	**6 months**	**17 months**	**36 months**
Untreated	Flat	193 (236)	1320 (891)	2695 (1576)
CA	Flat	737 (760)	2193 (1732)	3120 (2040)
ACQ-D	Flat	748 (747)	2115 (1604)	2874 (1885)
CCA	Flat	714 (573)	2130 (1584)	2898 (1896)
Untreated	Ribbed	75 (127)	108 (161)	263 (318)
CA	Ribbed	147 (311)	169 (303)	519 (566)
ACQ-D	Ribbed	109 (151)	131 (188)	532 (401)
CCA	Ribbed	48 (128)	114 (162)	325 (342)

Standard deviation given in parentheses

Table 3 Mean check depth (mm) over ten years of exposure

Preservative	Decking type	6 months	17 months	36 months	60 months	120 months
Untreated	Flat	3 (3)	3 (2)	7 (4)	8 (4)	13 (7)
CA	Flat	6 (5)	5 (3)	8 (4)	9 (4)	14 (5)
ACQ-D	Flat	5 (3)	4 (2)	7 (3)	9 (3)	13 (4)
CCA	Flat	6 (4)	4 (3)	8 (4)	9 (4)	14 (5)
Untreated	Ribbed	1 (1)	1 (1)	3 (5)	4 (5)	12 (8)
CA	Ribbed	1 (2)	1 (2)	6 (5)	7 (5)	9 (6)
ACQ-D	Ribbed	1 (1)	3 (4)	5 (3)	6 (4)	9 (6)
CCA	Ribbed	0 (1)	2 (4)	4 (3)	5 (5)	9 (6)

Standard deviation given in parentheses

Table 4 Mean check width (mm) over ten years of exposure

Preservative	Decking type	6 months	17 months	36 months	60 months	120 months
Untreated	Flat	0.3 (0.3)	0.3 (0.2)	0.6 (0.4)	0.9 (0.6)	1.5 (0.6)
CA	Flat	0.6 (0.4)	0.5 (0.3)	0.8 (0.4)	1.0 (0.3)	2.1 (0.6)
ACQ-D	Flat	0.6 (0.4)	0.6 (0.4)	0.8 (0.7)	0.9 (0.4)	1.6 (0.5)
CCA	Flat	0.5 (0.4)	0.5 (0.4)	0.7 (0.4)	0.8 (0.4)	1.3 (0.5)
Untreated	Ribbed	0.0 (0.1)	0.1 (0.1)	0.2 (0.2)	0.4 (0.3)	1.2 (0.8)
CA	Ribbed	0.1 (0.2)	0.2 (0.3)	0.2 (0.2)	0.5 (0.4)	1.3 (0.5)
ACQ-D	Ribbed	0.1 (0.1)	0.1 (0.2)	0.3 (0.2)	0.5 (0.4)	1.4 (0.8)
CCA	Ribbed	0.0 (0.1)	0.1 (0.1)	0.2 (0.2)	0.4 (0.3)	0.8 (0.4)

Standard deviation given in parentheses

Table 5 Mean appearance rating over ten years of exposure

Preservative	Decking type	6 months	17 months	36 months	60 months	120 months
Untreated	Flat	0.5 (0.5)	1.7 (0.9)	2.5 (0.9)	2.1 (0.9)	1.9 (0.9)
CA	Flat	1.4 (1.2)	1.9 (1.2)	2.5 (1.1)	3.0 (1.1)	2.9 (1.2)
ACQ-D	Flat	1.4 (1.1)	1.9 (1.2)	2.5 (1.2)	2.7 (0.7)	3.2 (0.9)
CCA	Flat	1.4 (1.1)	1.9 (1.1)	2.4 (1.2)	2.8 (1.3)	2.8 (1.2)
Untreated	Ribbed	0.1 (0.2)	0.3 (0.3)	0.5 (0.6)	0.9 (0.7)	1.3 (0.6)
CA	Ribbed	0.2 (0.4)	0.3 (0.4)	0.6 (0.7)	1.5 (0.8)	1.4 (0.7)
ACQ-D	Ribbed	0.1 (0.2)	0.3 (0.4)	0.7 (0.7)	1.3 (0.7)	1.5 (0.6)
CCA	Ribbed	0.1 (0.2)	0.3 (0.2)	0.4 (0.5)	1.4 (0.9)	1.9 (1.0)

Standard deviation given in parentheses

Table 6 Mean decay ratings after five and ten years of exposure

Preservative	Decking type	60 months	120 months
Untreated	Flat	10.0 (0.0)	9.1 (0.6)
CA	Flat	10.0 (0.0)	10.0 (0.0)
ACQ-D	Flat	10.0 (0.0)	10.0 (0.0)
CCA	Flat	10.0 (0.0)	10.0 (0.0)
Untreated	Ribbed	9.9 (0.3)	8.5 (1.2)
CA	Ribbed	10.0 (0.0)	10.0 (0.0)
ACQ-D	Ribbed	10.0 (0.0)	10.0 (0.1)
CCA	Ribbed	10.0 (0.0)	10.0 (0.0)

Standard deviation given in parentheses

3.3 Decay

No decay was detected in any of the preservative-treated decks at the five- and ten-year inspections.

At ten years, one of the untreated flat boards was rated 7, but the majority were rated 9, for a mean rating of 9.1. Some individual untreated ribbed boards were decayed: two were rated 6, two were rated 7, and four were rated 8, for a mean rating of 8.5. However, as a group of 20 boards per deck, there was no statistically significant difference in decay between untreated flat and ribbed boards ($p<0.05$).

General Discussion

More recent work by Evans *et al.* (2010) confirmed that ribbed profile is better than ripple at reducing checking and showed profiling works better on Pacific Silver fir than on Southern pine. Aktari and Nicholas (2014) found similar results with Southern pine. Mallet et al. (2014) showed that stresses concentrated at the base of the grooves during wetting and during drying thus focussing check initiation at the base of the grooves. Evans and Cheng (2015) characterized a wide range of commercial profiled decking samples. Cheng (2015) developed a range of representative profiles and showed two of these profiles were better than the others in terms of reducing the average area of the ten largest checks. One of these profiles is being commercialized in North America.

The performance of the treated decking is consistent with the long-term performance of decking shell-treated with CCA (Morris and Ingram 2013).

Conclusions

Over a period of ten years, surface profiling with a ribbed texture significantly reduced surface checking of subalpine fir decking. No decay was detected in any of the preservative-treated decks at the five- and ten-year inspections. With this profiling and treatment with any of the preservatives in this study, subalpine fir is suitable for decking applications, although CCA is no longer registered for use in residential decking.

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