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# FIELD TESTING OF WOOD PRESERVATIVES IN CANADA XV

## Durability of Shingles and Shakes

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## Abstract

The impact of preservative treatment on long-term durability of wooden roofing materials has been evaluated in a series of tests set up over the last 30 years. After 30 years' exposure at an extremely wet site, virtually no decay was found in CCA- and ACA-treated western red cedar shakes. In contrast, advanced decay was present in the equivalent untreated samples. After 25 years exposure at a different site, moderate erosion and splitting was present in both treated and untreated, western red cedar shakes and shingles, but virtually all treated samples were free from decay. Minor amounts of decay were detected on some of the untreated western red cedar shakes, and to a greater extent, the untreated western red cedar shingles. After 10 years exposure CCA-treated pine, spruce and aspen shingles were free of fungal attack, and decay of the untreated wood was generally moderate, with a few failures of spruce and aspen. In terms of splitting, untreated western red cedar was superior to the other species while spruce was the worst. Splitting was not affected by CCA treatment after ten years in service. In terms of erosion, there was little difference between the untreated species. In all cases treatment with copper- or chromium-based preservatives reduced erosion of the shake and shingle surfaces.

## 1 Introduction

The impact of preservative treatment on the long-term durability of wooden roofing materials has been evaluated in a series of field tests set up by the Western Forest Products Laboratory and it successor, Forintek Canada Corp.

Due to its natural durability and dimensional stability, western red cedar (*Thuja plicata* Donn) has for many years been the preferred species for the manufacture of wood roofing materials. Thujaplicins are natural fungicidal extractives found in the outer heartwood of old-growth trees and are mainly responsible for this durability. However old-growth trees are now less abundant, and second-growth trees contain lower concentrations of thujaplicins and are therefore less decay-resistant. In addition, thujaplicins gradually leach out, to the extent that after three years' exposure they were almost entirely lost from the butts of untreated shakes (Johnson and Cserjesi 1980). Untreated cedar roofs have failed within ten years in warm humid environments (Smith and Swann 1975). To supplement the natural durability of western red cedar shakes and shingles, pressure treatment with wood preservatives is therefore recommended for high decay hazard areas (Canadian Standards Association 1999).

Between 1973 and 1980 Forintek initiated a series of exposure trials of treated and untreated western red cedar shakes and shingles. The original tests of western red cedar shakes was set up at UBC's Malcolm Knapp Research Forest, Haney BC in 1973. This was followed in 1980 by tests of western red cedar shakes set up at Westham Island, BC and western red cedar shingles at both Westham Island and Haney. In 1991, the Westham Island tests were relocated to the rear courtyard of Forintek's Vancouver laboratory.

In 1995, supported by the Alberta Government, a test of pine, spruce and aspen shingles was set up at the Vancouver site. The original purpose of this study was to support the developing pine shingle market. Developments since the establishment of this test have shown it to be ten years too late. Dr. Roger Smith of Forintek had proposed such work during the late 1970s but it was not supported by the lumber industry. During the late 1980s a new industry developed in Alberta around the manufacturing and installation of untreated pine shakes. Based on historical information and inspections of pine shake roofs in the prairie provinces and the arid western states of the USA, the Canadian Standards Association developed a standard for northern pine shakes (Canadian Standards Association 1993) which required pine shakes to be pressure-treated with CCA only in areas where rainfall is higher than 500 mm per year. In Canada, this requirement for treatment based on rainfall would not apply in the North, parts of the interior of BC, and the Prairie provinces (Hare and Thomas 1974). Thousands of untreated pine shake roofs were installed on new homes in Alberta between 1989 and 1997. By 1996 homeowners in Edmonton had discovered that their untreated pine shake roofs were starting to rot after as little as four to seven years. Investigation of this problem revealed that brown-rot fungi, mainly *Gleophyllum sepiarium* (Wulf.:Fr.) Karst were infecting shakes on the roofs via airborne spores (Morris 2000). This fungus is particularly resistant to the high temperatures and cyclic wetting and drying typical of a roof environment. In 1998 Alberta put a requirement for preservative treatment of all pine shakes into its building code. In 1999 the Canadian Standards Association published a standard covering pressure treatment of shakes with CCA (Canadian Standards Association 1999).

The western red cedar tests installed up to 1980 were previously reported to the CWPA in 1995 (Morris, Byrne and Ingram 1995). This paper provides an update on those earlier tests and also reports on the performance of pine shakes after 10 years' exposure.

# 2 Materials and Methods

## 2.1 Treatment of Test Material

### 2.1.1 Western Red Cedar Installed in 1973

These shakes were commercially treated with chromated copper arsenate (CCA-C and CCA-B) and ammoniacal copper arsenate (ACA). Modified ACA treatments were performed at the Eastern Forest Products Laboratory (susequently Forintek's Eastern Laboratory) in Ottawa. Samples were analyzed at the butt and at the midpoint of the shakes. The shakes were installed at the Malcolm Knapp Research Forest at Haney , BC.

### 2.1.2 Western Red Cedar Installed in 1980

The shakes and shingles were pressure-treated at Forintek's laboratory in Vancouver, and retentions were based on gauge uptake. Treatments included chromated copper arsenate Type-C (CCA-C), ammoniacal copper arsenate (ACA), and acid copper chromate (ACC). Analysis samples were taken at 0 to 25 mm from the butt and at the midpoint of the shake, and analyzed for preservative retention using x-ray fluorescence (XRF) spectrometry. The majority of shakes panels, and half of the shingles panels, were located for eleven years at Forintek's field test site at Westham Island, BC. These racks were moved in 1991 to the rear of the Forintek facility in Vancouver. The remaining half of the shingles as well as two ACC-treated shakes panels were located at the Malcolm Knapp UBC Research Forest (MKRF) at Haney, BC.

### 2.1.3 Pine, Spruce and Aspen Installed in 1995

Pine, spruce and aspen shakes in green condition were obtained from Majestic Forest Products in Edmonton, AB. Western red cedar shakes, to be used as reference material, were obtained from Western Wood Preservers in Aldergrove, BC. The shakes were 600 mm in length, between 100 to 150 mm wide, and approximately 20 mm thick at the butt. The species of the individual shakes was confirmed and the bundles randomized. Each species was separated into three equal sets. One of the sets was left untreated as a control. In order to meet a target retention of 4.0 kg/m$^3$, a test set of material was treated first, then the solution strength was adjusted for the experimental set.

The retention of 4.0 kg/m$^3$ was selected because it is the retention specified in the AWPA standard for southern pine shakes (American Wood Preservers' Association 1994a), and it is the retention specified by the Canadian Standards Association for most wood products for above-ground exposure (Canadian Standards Association 1989). Since this test was set up in 1995, the Canadian Standards Association has specified this CCA retention for pressure treatment of shakes (Canadian Standards Association 1999).

The preliminary test set of each species was pressure treated with a 1.83% solution of CCA-C using the following schedule: 30 minute vacuum at 740 mm Hg, filling retort under vacuum, applying pressure for 1 hour at 1035 kPa, emptying retort, then a final 15 minute vacuum at 740 mm Hg.

Twenty shakes from each species were weighed before and after treatment to determine solution uptake, stored outside covered with a tarpaulin for one week to allow CCA fixation to occur and oven-dried at 60°C for 48 hours. A sample was taken from each of the 20 shakes according to AWPA M3-84 Method 1 (American Wood Preservers' Association 1994b). A cut was made across the width at a point where the thickness was approximately 15 mm, and the sawdust was collected. This was combined from the 20 replicates and ground into one composite sample. The CCA content was then determined by x-ray spectroscopy (American Wood Preservers' Association 1994c)

The retentions achieved in the test treatment were lower than the target retention for all three species (Table 1), therefore the solution strength was adjusted appropriately for each species before treatment of the experimental shakes. These shakes were cut to specific sizes before treatment so as to fit onto the test panel. The following CCA concentrations were used: 2.2% for pine, 3.3% for spruce, and 3.0% for aspen. The same treating schedule and analysis techniques were used as for the test treatment, but these shakes were left to air-dry after the fixation period. Retentions in the experimental shakes are also shown in Table 8. The test was set up in the rear courtyard of Forintek’s Vancouver laboratory.

### 2.2 Installation Method for All Tests

Experimental roof panels were constructed using the shakes or shingles laid on 1.2 m x 1.2 m squares of 19 mm plywood with a building paper interlayment. The treatments plus untreated controls were applied to two panels each for shakes and four panels each for shingles. Application to the panels was according to procedures recommended by the Council of Forest Industries of British Columbia (COFI 1972). Approximately 40 shakes or shingles were applied to each panel. The test panels were installed on frames about one meter above ground level, sloped about $20^{o}$ to the horizontal, facing south, and without obstruction to sunlight.

### 2.3 Test Sites

The Westham Island and Vancouver sites have the same climate, with about 1900 hours of bright sunshine and approximately 1250 mm of precipitation per year. The climate index here was 45 (Setliff 1986). The Haney site is an area of high rainfall of over 2000 mm per year and relatively high sunshine, and falls within the moderate decay hazard zone for outdoor above-ground wood using Scheffer's climate index, with the climate index 55 (Setliff 1986).

### 2.4 Inspection

The shakes and shingles were visually evaluated for physical condition, appearance, and the presence of decay, and rated based on the following criteria (Table 1):

Table 1 Shake and shingle inspection criteria

| Rating | Decay | Erosion | Splitting |
|---|---|---|---|
| 0 | None | None | None |
| 1 | Trace | < 1 mm | 0 – 10 mm |
| 2 | Moderate | 1 – 3 mm | 10 – 50 mm |
| 3 | Advanced | 3 – 5 mm | 50 mm – full |
| 4 | Failure | > 5 mm | Full length |

# 3 Results and Discussion

### 3.1 Western Red Cedar Shakes Installed in 1973

The target retention for these shakes was 9.6 kg/m³, the recommended loading in 1973. This target was not accurately met due to the small quantities of test material included in commercial charges (Table 2). However the assayed face retentions of the CCA-B and ACA-treated shakes was very close to the current recommendation of 4.0 kg/m³. CCA-B is no longer used in Canada, but CCA-C, a better balanced formulation, would be expected to perform better than CCA-B.

Table 2 Western red cedar shake preservative retentions by gauge uptake and assay

| Preservative | Gauge retention kg/m³ | Assay retention kg/m³ | |
|---|---|---|---|
| | | Face | Butt |
| CCA-C | 11.1 | 8.8 | 29.2 |
| CCA-B | 4.7 | 3.8 | 16.5 |
| ACA | 9.3 | 4.7 | 21.6 |
| Modified ACA | 4.7 | 2.1 | 11.3 |

Table 3 shows the mean decay ratings for the shakes at Haney after 25 and 30 years' exposure. Decay in untreated controls progressed to severe, with a mean rating of 3.0. This contrasts markedly with all preservative-treated shakes, which apart from a few replicates rated 1, were free from decay. Comparing the performance after 25 years of these shakes and those exposed at Westham Island/Vancouver (Table 6) shows increased erosion with an average of 1.6 for CCA and 2.0 for ACA. The untreated shakes were in worse condition than those in the Vancouver test.

This difference could possibly be due to the different sources of wood being used in the shake test set up in 1973 and the latter test initiated in 1980. The higher climate index at Haney (55 vs. 45 at Vancouver and Westham Island) was probably even a more important factor. Most future studies by Forintek using both in-ground and above-ground methods are planned to be installed at our new test site at Haney. These results reinforce the soundness of this decision.

Table 3 Western red cedar shake ratings after 25 and 30 years' exposure at Haney, BC

| Preservative | Mean rating | | | | | |
|---|---|---|---|---|---|---|
| | Decay | | Erosion | | Splitting | |
| | 25 yr | 30 yr | 25 yr | 30 yr | 25 yr | 30 yr |
| Control | 2.3 (0.6) | 3.0 (0.8) | 2.7 (0.5) | 3.1 (0.3) | 1.8 (1.5) | 2.3 (0.7) |
| CCA-C | 0.0 (0.2) | 0.0 (0.0) | 1.6 (0.5) | 2.0 (0.2) | 2.2 (1.4) | 2.3 (1.3) |
| CCA-B | 0.1 (0.3) | 0.0 (0.0) | 1.9 (1.4) | 2.0 (0.0) | 1.5 (1.4) | 1.7 (1.3) |
| ACA | 0.3 (0.5) | 0.0 (0.2) | 2.0 (0.2) | 1.9 (0.2) | 2.3 (1.2) | 2.4 (0.8) |
| Modified ACA | 0.1 (0.3) | 0.0 (0.2) | 2.0 (0.2) | 2.0 (0.2) | 1.9 (1.2) | 2.1 (1.1) |

### 3.2 Western Red Cedar Shakes and Shingles Installed in 1980

Shake preservative retentions as determined by gauge uptake and by assay are shown in Table 4. In 1980, when the shakes and shingles were treated with the three waterborne preservatives, the CSA shakes and shingles standard (CSA O118.1 1980) recommended a gauge uptake of 9.6 kg/m³. Since then the recommended retention has been reduced to 4.0 kg/m³ (CSA O80.35-99 1999). The gauge uptakes achieved in these shakes were slightly higher than the recommended level, but the assayed retentions of the faces were very close to 9.6 kg/m³.

Table 4 Western red cedar shake preservative retentions by gauge uptake and assay

| Preservative | Gauge retention kg/m³ | Assay retention kg/m³ | |
|---|---|---|---|
| | | Face | Butt |
| CCA-C | 9.7 | 8.0 | 26.3 |
| Modified ACA | 13.9 | 9.9 | 30.2 |
| ACC | 13.0 | 9.5 | 30.9 |

Preservative retentions in the shingles as determined by gauge uptake and by assay are shown in Table 5. The gauge uptakes achieved in these shingles are three to four times higher than the current recommended level. However, preservative penetration, which is a very important factor in decay prevention, would not be much affected by the high loading. The performance of the three preservatives relative to each other and to untreated controls can still be evaluated.

Table 5 Shingle preservative retentions by gauge uptake and assay

| Preservative | Gauge retention kg/m³ | Assay retention kg/m³ | |
|---|---|---|---|
| | | Face | Butt |
| CCA-C | 17.6 | 18.0 | 31.0 |
| Modified ACA | 17.0 | 14.3 | 32.3 |
| ACC | 14.6 | 15.6 | 19.4 |

Mean decay ratings of the shakes in Vancouver are given in Table 6. The untreated control shakes contained minor decay, with 12 samples on the two panels rated 1, and one rated 2. Algae growth was very heavy on these panels. Erosion had progressed significantly since the inspection at 15 years at which time all but one sample was rated 1. After 25 years in test the majority of samples were rated 2 for erosion. Splitting was also moderate overall, but three shakes were split the full length, rated 4.

Shakes treated with CCA-C exposed at Vancouver were virtually free from decay, with just one sample on the two panels with a suspicion of decay, rated 1. As was the case with the untreated shakes, erosion had progressed significantly since the 15-year inspection when all but one sample was rated 0. At this evaluation all of the shakes were rated 1. Splitting was significantly more extensive than in the untreated controls using a two sample *t*-test, with 10 shakes on the two panels split through the whole length. Increased splitting is considered to be a concern with CCA-C-treated shakes and shingles. However, Forintek's previous data on shakes at the Haney test site (Morris and Ingram 1994) have indicated that CCA-C treatment simply accelerates checking in the first year of exposure that would have occurred anyway on the same untreated sample. Algae growth was significant on these panels (Figure 1).

Table 6 Western red cedar shake ratings after 25 years' exposure at Westham Island/Vancouver and Haney, BC

| **Preservative** | | **Mean rating** | | |
|---|---|---|---|---|
| | | **Decay** | **Erosion** | **Splitting** |
| A) | Westham Island/Vancouver test site | | | |
| | Control - panel 1 | 0.1 (0.2) | 1.9 (0.3) | 1.0 (1.2) |
| | - panel 2 | 0.2 (0.5) | 2.0 (0.0) | 0.7 (1.1) |
| | CCA-C - panel 1 | 0.0 (0.2) | 1.0 (0.0) | 2.3 (1.3) |
| | - panel 2 | 0.0 (0.0) | 1.0 (0.0) | 1.8 (1.2) |
| | Modified ACA - panel 1 | 0.0 (0.0) | 1.0 (0.0) | 1.4 (1.5) |
| | - panel 2 | 0.0 (0.0) | 1.0 (0.2) | 1.8 (1.2) |
| | ACC - panel 1 | 0.0 (0.0) | 0.9 (0.4) | 2.3 (1.3) |
| | - panel 2 | 0.0 (0.0) | 1.0 (0.2) | 1.8 (1.4) |
| B) | Haney test site | | | |
| | ACC - panel 1 | 0.2 (0.4) | 1.2 (0.4) | 1.9 (1.4) |
| | ACC - panel 2 | 0.0 (0.0) | 1.0 (0.0) | 1.5 (1.6) |

*Standard deviations are given in parentheses*

Shakes treated with modified ACA and ACC exposed at Vancouver contained no visible decay. Erosion and splitting of both treatments were comparable to the CCA-C panels. All three chemical treatments reduced erosion, relative to untreated samples (Table 6). Three ACA-treated samples were badly split, rated 4. ACC-treated samples were similarly split, with eight on two panels rated 4.

At Haney the two ACC-treated panels contained minor decay. Eight shakes on one panel were rated 1 for a suspicion of decay. In some cases this was associated with fasteners. Eight ACC-treated shakes were rated 4 for splitting, comparable to the Vancouver sites. Erosion was also comparable to the shakes at Vancouver.

It would not be unexpected to find the preservative-treated shakes in this test to be in excellent condition after 25 years, considering by today's standard they were overtreated by a factor of more than two.

Figure 1 CCA-treated shakes (left) and shingles (right) at Vancouver

Algae growth was not as extensive on CCA-treated shingles as on the shakes (Figure 1). This may be a result of the much higher preservative loading of the shingles.. Another factor may be the shingles being sawn while shakes are split. This results in endgrain being exposed on shingles but not on shakes, which may result in shingles drying out better after rain

Mean ratings of the shingles are given in Table 7. The untreated control shingles located at Vancouver contained moderate decay, with several samples on the two panels rated 2, and mean ratings of 1.2, which had increased from a mean rating of 0.2 ten years earlier (Ingram and Morris 1995). Lichen growth was also present on these panels. The untreated shingles on one panel at Haney were surprisingly free of decay, while the other panel was decayed comparably to the Vancouver samples. This decay had also increased from a mean rating of 0.2 in 1995. Erosion was significant at both locations, with the majority of samples in Vancouver rated 2 and a mean rating of 1.9. At the higher rainfall site in Haney, erosion was more severe, with mean ratings of 3.0 and 2.1 for the two panels. Splitting was significantly more severe at Vancouver where five shingles were rated 4 for full length splits while at Haney only one untreated shingle was split through.

Table 7 Western red cedar shingle ratings after 25 years' exposure at Westham Island/Vancouver and Haney, BC

| Preservative | | Mean rating | | |
|---|---|---|---|---|
| | | Decay | Erosion | Splitting |
| A) | Westham Island/Vancouver test site | | | |
| | Control - panel 1 | 1.3 (0.9) | 1.7 (0.5) | 1.0 (1.5) |
| | - panel 2 | 1.2 (0.9) | 2.0 (0.0) | 0.8 (1.3) |
| | CCA-C - panel 1 | 0.0 (0.0) | 1.0 (0.0) | 2.0 (1.7) |
| | - panel 2 | 0.0 (0.0) | 1.0 (0.0) | 2.0 (1.6) |
| | Modified ACA - panel 1 | 0.0 (0.0) | 1.0 (0.0) | 1.1 (1.5) |
| | - panel 2 | 0.0 (0.0) | 2.0 (0.0) | 2.1 (1.6) |
| | ACC - panel 1 | 0.0 (0.1) | 1.0 (0.0) | 2.6 (1.7) |
| | - pannel 2 | 0.0 (0.0) | 1.0(0.0) | 1.9 (1.6) |
| B) | Haney test site | | | |
| | Control - panel 1 | 0.0 (0.0) | 3.0 (0.0) | 0.2 (0.8) |
| | - panel 2 | 0.7 (0.8) | 2.1 (0.3) | 0.2 (0.7) |
| | CCA-C - panel 1 | 0.1 (0.3) | 1.0 (0.0) | 1.4 (1.7) |
| | - panel 2 | 0.0 (0.0) | 1.0 (0.0) | 1.3 (1.6) |
| | Modified ACA - panel 1 | 0.0 (0.2) | 1.2 (0.4) | 1.3 (1.5) |
| | - panel 2 | 0.0 (0.0) | 1.3 (0.5) | 1.6 (1.8) |
| | ACC - panel 1 | 0.0 (0.0) | 1.0 (0.2) | 1.8 (1.7) |
| | - panel 2 | 0.0 (0.0) | 1.0 (0.2) | 0.7 (1.4) |

*Standard deviations are given in parentheses*

All shingles treated with the three preservatives and exposed for 25 years at Westham Island/Vancouver were free from decay with the exception of two ACC-treated samples rated 1. At Haney, one CCA-C-treated shingle was rated 1 and one was rated 2 for moderate decay, and four shingles treated with modified ACA were rated 1. At both locations most of the preservative-treated shingles were rated 1 for erosion (Table 7), which was significantly less than the untreated controls. Chemical treatment thus reduced erosion of the wood surface. Chromium, present in CCA-C and ACC, is known to have a protective effect against ultra-violet radiation (Ingram and Morris 1995). Splitting was comparable in the three treatments at both sites and was significantly more extensive than in the untreated controls.

By today's standard the shingles were overtreated by a factor of three to four, so the lack of decay after 25 years is not surprising.

### 3.3 Pine Spruce and Aspen Installed in 1995

In pine and spruce shakes, the CCA retentions determined by analysis came very close to the target of 4.0 kg/m³ (Table 8); however, in aspen, the retention was 6.1 kg/m³. Although this was 50% higher than intended, the material was installed since aspen requires a higher CCA retention than pine or spruce to provide the same performance

(Morris and Cook 1994). The inspection immediately after installation showed no decay or erosion on any of the test material, as would be expected (Table 9).

Table 8 Analysis results of Pine, Spruce and Aspen samples used for exposure

| **Species** | **Target retention kg/m³** | **Exposure samples analysis retention kg/m³** |
|---|---|---|
| Pine | 4.0 | 4.2 |
| Spruce | 4.0 | 4.1 |
| Aspen | 4.0 | 6.1 |

After five years in test, no decay was found on CCA-treated panels of any species. This was still the case after ten years in test, with the exception of three aspen shakes rated 1 for a suspicion of decay. At five years, some limited decay was present: one pine shake was rated 1, one spruce shake was rated 1 and one was rated 2. Seven aspen shakes were rated 1 and four were rated 2. Fruiting bodies of *G. sepiarium* were noted on two spruce and several aspen shakes. In contrast, decay on untreated panels had progressed considerably since the five-year inspection. By the ten-year inspection, four shakes on one aspen panel had failed (rated 4), and five were rated 3, while on the second panel one shake had failed and three contained advanced decay, rated 3. The natural variability of decay germination via airborne spores was evident when comparing the duplicate panels. In each of the species, one of the panels contained substantially more decay than the other (Table 9). One of the spruce panels in particular was much more severely decayed than the other: it contained five failed shakes (rated 4) and three shakes rated 3, while the duplicate panel had no shakes rated greater than 2. Pine was in slightly better condition than either aspen or spruce. On the worst pine panel, two shakes were rated 3. Although the untreated western red cedar control shakes were essentially free from decay (four shakes rated 1 on one panel), algae and lichen growth was heavy on these panels.

Erosion was noticeable on untreated shakes of all species, with mean ratings at the ten-year inspection of approximately 1.5 for pine and 2 for spruce, aspen, and western red cedar. No erosion was found on CCA-treated samples after five years of exposure (Table 9). CCA treatment is known to reduce erosion of shakes (Byrne *et al.* 1987), probably through the UV absorption properties of the chromium (Feist and Ross 1989) and copper (Liu, Ruddick and Jin 1994). However, at the ten-year inspection erosion was starting to appear on both aspen and one of the two spruce CCA-treated panels, with average ratings of 1. Treated pine was still free from erosion.

Treated pine and spruce shakes had already split more than the untreated material within days of installation (Table 9). This was probably promoted by rapid wetting of the surface layers of the shake inherent in the pressure treatment process. At that stage, there were no discernable differences in splitting between pine, spruce and aspen. There was no splitting in the untreated western red cedar shakes. At the five-year inspection

untreated western red cedar still contained significantly fewer splits than the other three untreated species, as shown by *t*-tests ($p<0.05$). Pine shakes, both untreated and CCA-treated, were significantly less split than the equivalent spruce or aspen shakes ($p<0.05$). By ten years in test the difference in splitting between CCA-treated and untreated shakes had disappeared. Spruce was still more badly split than the other species, and western red cedar, which is known for its dimensional stability, contained very little splitting.
The results for untreated pine shakes after ten years of exposure at this location did not duplicate the experience of homeowners in Alberta. One explanation for this may be the difference in climate (Hare and Thomas 1974). Although Vancouver, BC receives more than twice the annual precipitation of Edmonton, AB, it is distributed quite differently throughout the year. The warmest months of the year, June to August (Figure 2), is the period when the maximum rain falls in Edmonton. This is also when decay fungal activity would be expected to peak. In contrast, Vancouver has relatively dry summers, with about half the amount of rain as Edmonton in the summer months (Figure 3). The areas which remain wet for prolonged periods during warm weather present ideal conditions for the growth of decay fungi. Protected regions of the shakes on a roof such as the area covered by the shake above are expected to be the slowest to dry out after rain. Another area which would be slow to dry after wetting is a short distance in from the butt, since end-grain and exposed surfaces would wet up during rain but also dry out rapidly.

*G. sepiarium*, the fungus found to have infected the roofs in Edmonton, is particularly well-adapted to the conditions present on a roof. It withstands changes in the wood moisture content from air-dry to nearly saturated, and its optimum growing temperature is 35°C. This compares to optimum temperatures of 23°C and 22°C for the common wood-destroying fungi *Coniophora puteana* and *Serpula lacrymans* respectively (IRG 1979). It should be noted that the temperature of roof shingles would be higher than the mean air temperatures in Figure 2. No data are available on the temperature of shingles, however plywood roof sheathing under black fiberglass shingles in Madison, WI reached maximum temperatures of over 70°C (Winandy and Beaumont 1995). Wood shingles would not be expected to reach such extreme temperatures.

Table 9 Inspection data at the time of installation and after five and ten years of exposure

| Species | Treatment | Rack | Decay | | | Erosion | | | Splitting | | | Cupping (mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 yrs | 5 yrs | 10 yrs | 0 yrs | 5 yrs | 10 yrs | 0 yrs | 5 yrs | 10 yrs | 5 yrs |
| Pine | None | 1 | 0.0 (0.0) | 0.0 (0.2) | 1.0 (1.0) | 0.0 (0.0) | 0.9 (0.4) | 2.0 (0.0) | 0.1 (0.5) | 1.1 (1.1) | 2.0 (1.0) | 3.0 (1.6) |
| | | 2 | 0.0 (0.0) | 0.0 (0.0) | 0.5 (1.0) | 0.0 (0.0) | 1.0 (0.0) | 1.0 (0.0) | 0.2 (0.9) | 0.8 (1.1) | 2.1 (1.0) | 3.4 (1.8) |
| | CCA | 1 | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.2) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.2) | 0.2 (0.7) | 1.6 (1.2) | 2.2 (1.0) | 3.5 (1.7) |
| | | 2 | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 1.1 (1.4) | 1.0 (1.4) | 2.2 (1.0) | 3.5 (1.1) |
| Spruce | None | 1 | 0.0 (0.0) | 0.1 (0.4) | 2.1 (1.3) | 0.0 (0.0) | 1.0 (0.0) | 2.0 (0.0) | 0.0 (0.0) | 2.7 (0.8) | 3.0 (0.7) | 4.5 (2.7) |
| | | 2 | 0.0 (0.0) | 0.0 (0.0) | 0.5 (0.7) | 0.0 (0.0) | 1.0 (0.3) | 2.0 (0.0) | 0.1 (0.5) | 0.9 (0.9) | 1.4 (1.2) | 3.8 (1.9) |
| | CCA | 1 | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 1.0 (0.0) | 0.3 (1.0) | 2.5 (1.2) | 3.1 (0.6) | 4.2 (2.0) |
| | | 2 | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.9 (1.4) | 2.4 (1.3) | 3.1 (0.8) | 4.5 (1.6) |
| Aspen | None | 1 | 0.0 (0.0) | 0.3 (0.6) | 1.6 (1.3) | 0.0 (0.0) | 1.9 (0.3) | 2.0 (0.0) | 0.4 (1.1) | 1.7 (1.2) | 2.2 (1.3) | 6.1 (3.3) |
| | | 2 | 0.0 (0.0) | 0.1 (0.4) | 0.8 (1.1) | 0.0 (0.0) | 2.0 (0.2) | 2.0 (0.0) | 0.1 (0.5) | 1.0 (1.1) | 1.6 (1.2) | 6.0 (2.3) |
| | CCA | 1 | 0.0 (0.0) | 0.0 (0.0) | 0.1 (0.3) | 0.0 (0.0) | 0.0 (0.0) | 1.0 (0.0) | 0.1 (0.5) | 2.1 (0.7) | 2.6 (0.5) | 6.1 (2.0) |
| | | 2 | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.2) | 0.0 (0.0) | 0.0 (0.0) | 1.0 (0.0) | 0.2 (0.7) | 1.4 (1.3) | 2.1 (0.9) | 4.9 (1.8) |
| WRC | None | 1 | 0.0 (0.0) | 0.0 (0.0) | 0.1 (0.4) | 0.0 (0.0) | 1.2 (0.4) | 2.1 (0.5) | 0.0 (0.0) | 0.4 (0.9) | 0.6 (1.1) | 3.7 (1.4) |
| | | 2 | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 0.0 (0.0) | 1.6 (0.5) | 2.1 (0.3) | 0.0 (0.0) | 0.2 (0.6) | 0.4 (1.0) | 3.1 (1.1) |

*Standard deviations are given in parentheses*

# 4 Conclusions

After 25 to 30 years of exposure in field tests at two locations in southwestern BC, western red cedar shakes treated with CCA-C, CCA-B, ACA, modified ACA, and ACC at gauge retentions close to that recommended in CSA O118.1 (1980) are in very good condition, with virtually no visible decay.

Shingles treated at gauge retentions well above that recommended in CSA O118.1 (1980) were in excellent condition after 25 years, with no visible decay.

Untreated shakes exposed at Vancouver were also still in good condition after 25 years, slightly better than untreated shingles. Shakes exposed at the higher rainfall location of Haney were severely decayed after 30 years in test.

Generally moderate decay was found in untreated pine, spruce and aspen shakes after ten years of exposure in Vancouver, BC, although some failures had occurred in spruce and aspen.

Little decay was noted in untreated western red cedar or CCA-treated pine, spruce, and aspen shakes.

Treatment with CCA protected against erosion of the shake surfaces.

Untreated western red cedar was significantly less split than the other three species, while spruce was more badly split than pine or aspen.

CCA treatment did not affect the degree of splitting of pine, spruce or aspen after ten years' exposure

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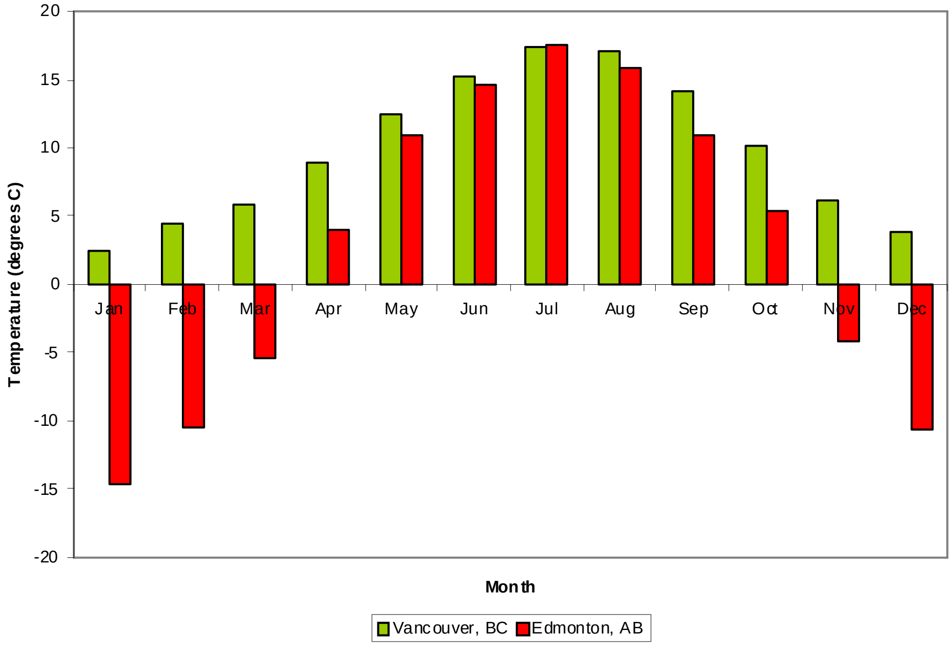


Figure 2 Comparison of mean monthly air temperature in Vancouver, BC and Edmonton, AB (Note: Roof surface temperatures can be considerably higher)

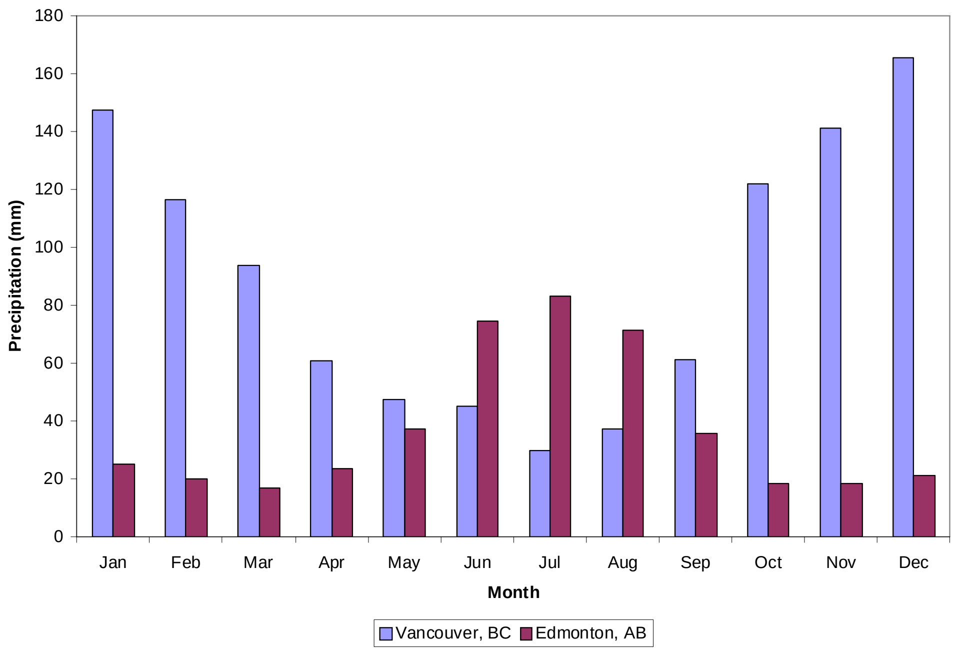


Figure 3 Comparison of mean monthly precipitation in Vancouver, BC and Edmonton, AB