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FIELD TESTING OF WOOD PRESERVATIVES IN CANADA XII.

LONG TERM MARINE TESTS

By

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Summary

In CSA O80 Series 97 Wood Preservation, assay retentions lower than the old gauge retentions were introduced. Continued testing is needed to confirm that the lower retentions will still provide the service life required from marine structures.

The marine tests covered in this report were set up in 1978 in West Vancouver, BC and in 1984 at two sites in New Brunswick. Red pine sapwood coupons (6 x 50 x 200mm) were pressure-treated with a range of retentions of preservatives listed in the standards at the time. They were suspended in the water column on metal racks and inspected once a year until 2000 at West Vancouver and 1997 at the New Brunswick sites.

At the West Vancouver test site, coupons treated to the recommended assay retention with CCA-C (24 kg/m^3) were in excellent condition after 22 years' exposure. ACA-treated coupons at the recommended assay retention of 30 kg/m^3 had failed due to surface degradation by bacteria and fungi. While significant on a 6mm test coupon, such degradation on a marine pile or timber would have less effect on the strength of the structure. We are not aware of premature failures of ACA-treated piling and the industry has switched to ACZA, a better-fixed formulation. The performance of creosote at above the recommended retention was superior to ACA but significantly inferior to CCA.

Untreated coupons failed in less than a year at West Vancouver and between two and three years at the New Brunswick sites, Shediac Bridge and Whitehead Island. At Whitehead Island, coupons treated to the recommended assay retentions with CCA and ACA were still performing well after 13 and 10 years' exposure respectively. However, at Shediac, while CCA-treated samples treated to 24 kg/m^3 remained sound, coupons treated to 30 kg/m^3 ACA had deteriorated badly after 10 years in test. In contrast, samples treated to close to the recommended retention with creosote performed better at Whitehead Island than at Shediac Bridge.

1 Introduction

Some of the earliest records of wood preservative testing in Canadian waters were reviewed by Bramhall (1966). Although creosoted piling had been found to give a service life of more than 35 or 40 years, experiments on alternative preservatives were started by the Forest Research Branch (Western Laboratory) in 1962. Copper naphthenate gave the best performance, closely followed by chromated copper arsenate, copper chromate, copper arsenate and tributyl tin oxide plus dieldrin. All these treatments were more effective than creosote. Unfortunately, no records are available on the retentions of the preservatives used.

To identify the effective preservative retentions required for treated wood in service in Canadian coastal waters, further testing was initiated by the Western Forest Products Laboratory (now Forintek Canada Corp.) at the request of the Canadian Standards Association CSA O80 Technical Committee on Wood Preservation in the late 1970's. While the American Wood Preservers' Association had changed from gauge to assay retentions many years previously, there were no data to determine what assay retentions would be appropriate for Canadian conditions. The first test site was established in British Columbia at West Vancouver in 1978 when coupons (6 x 50 x 200mm) treated with various waterborne preservatives, and creosote, were placed in service (Hulme and Ostaff 1980). This material was inspected on an annual basis until 2000, and the results communicated to the appropriate codes and standards committees as required.

Performance data generated in Pacific waters would not necessarily be relevant for Atlantic coastal conditions. Factors such as water temperature, salinity, pollution levels, tides, etc., can affect the types of marine borer present and their activity level. The marine testing project was, therefore, expanded in 1984 to include two test sites in Atlantic waters at New Brunswick. The establishment of these sites, located originally at Shediac Bridge on the Northumberland Strait and Black's Harbour on the Bay of Fundy, was reported by Ruddick *et al.* (1985). The two sites represent two distinct marine borer environments in eastern Canada, with *Teredo navalis* being most active at Shediac, and *Limnoria lignorum* being the major borer in the Fundy region. Test material consisted of both waterborne- and creosote-treated coupons. The Black's Harbour site was relocated in 1986 to Whitehead Island, also in the Bay of Fundy, due to a very low level of marine borer activity being observed at the former site. Test material at these sites was rated annually until 1997, and the results reported to the Canadian Standards Association.

The performance of treated coupons at both the eastern and western marine test sites was reported by Ruddick (1981) and by Morris and Doyle (1993). Partly based on these data, new assay retentions for preservatives in the marine environment were approved by CSA O80, and standardized in 1997 (CSA 1997). The retention for chromated copper arsenate

(CCA) was changed from 40 kg/m^3 gauge to 24 kg/m^3 assay. For ammoniacal copper arsenate (ACA) it was changed from 40 kg/m^3 gauge to 30 kg/m^3 assay. Since preservatives do not penetrate the full cross section of treated material, assay retention will always be higher than gauge retention. Consequently, in the absence of performance data, assay retentions of more than 40 kg/m^3 would have had to be specified to ensure that a gauge retention of 40 kg/m^3 would be met. The much lower assay retentions mean that treatment costs and the potential for adverse environmental impact from preservative leaching have both been reduced.

Quite independently, a study by Ziobro and Baileys (1992) resulted in similar reductions in the retention requirement for CCA (to 24 kg/m^3) and creosote (to 256 kg/m^3) for northerly US waters in the AWPA C3-95 standard (AWPA 1995a,b). ACA was no longer used in the USA by then.

This paper updates the data to 22 years at West Vancouver, and 13 years at Whitehead Island and Shediac Bridge.

2 Materials and Methods

The test method was based on ASTM D2481-81 and AWPA M19-67 (more recently renumbered as E5)

2.1 Material in Test (West Vancouver Site)

Red pine (*Pinus resinosa* Ait.) sapwood coupons (0.6 x 5 x 20 cm in size) were pressure-treated with a range of waterborne preservative formulations, as described by Hulme and Ostaff (1980), and placed into test in 1978. These included CCA-C and two formulations of ACA, with 16 replicates per treatment.

Preservative	Formulation	Retentions
CCA-C	47.5% CrO_3 /18.5% CuO/34% As_2O_5	15, 22, 31, 50 kg/m^3
ACA	50% CuO/50% As_2O_5	29, 44, 63, 95 kg/m^3
ACA(modified)	63% CuO/37% As_2O_5	13, 20, 28, 43 kg/m^3

Ten coupons treated with creosote by the full-cell process and 32 untreated controls were also placed in test at this time. Coupons pressure-treated with ACA preservative to a lower range of retentions (8, 13, 19, 25, 30, 35, 39 kg/m^3) were added to the test in 1986. These particular coupons were wrapped in polyethylene immediately after treatment to simulate the drying rate expected for large dimension commodities.

2.2 Material in Test (New Brunswick Sites)

Red pine sapwood coupons (0.6 x 5.0 x 15.3 cm in dimension) were pressure-treated as described by Ruddick *et al.* (1985) with the following water and oil borne preservative formulations, and placed in test in July 1984.

Preservative	Formulation	Retentions
CCA-C	47.5% CrO_3/18.5% CuO/34% As_2O_5	7, 12, 15, 18, 24 kg/m^3
ACA	50% CuO/50% As_2O_5	4, 5, 9, 11, 16 kg/m^3
Creosote	(in perchloroethylene)	42, 76, 151, 156, 206 kg/m^3

A total of 36 coupons per retention were treated with each preservative and divided among 12 test racks, along with untreated controls. Six racks were installed at each site. Two additional racks containing coupons treated to higher retention levels (25 and 30 kg/m^3) of ACA were added to each test site in October 1986.

2.3 Test Sites

The West Vancouver test site is located in an area where *Limnoria* spp. (gribble) and *Bankia setacea* (shipworm) are active. Both *Limnoria lignorum* and *Limnoria tripunctata* have been found in the area, but, unlike further south, *L tripunctata* in B.C. waters does not appear to be creosote-tolerant (Bramhall 1966). Attack by *Limnoria* spp. is characterized by tunnelling at or just below the wood surface, with subsequent gradual erosion of the surface layers. Attack by *B. setacea* is characterized by pinhole entry points on the wood surface and extensive internal tunnelling.

The Shediac Bridge test site is located in an area where *Teredo navalis* (shipworm) is the principal active borer present. According to Bohn and Walden (1970), distribution of this species depends on a requirement that the water temperature exceed 15-16^oC at some period of the year if *T. navalis* spawning is to be successful. The water temperature recorded at the time of the August 1989 inspection was 25^oC. Attack by this organism is similar to that of *B. setacea*.

The Whitehead Island site is located in the colder waters of the Bay of Fundy. Water temperature recorded at the time of the August 1989 inspection was 12.5^oC. According to the survey of Bohn and Walden (1970), this site is located in an area where *L. lignorum* are active.

2.4 Inspection of Test Material

For inspection, the racks were removed from the water, and all samples carefully scraped to remove fouling. Each individual coupon was closely examined with the naked eye for surface erosion and/or entrance holes indicative of marine borer attack. The sample was either lightly flexed or probed to detect areas with loss in strength, indicative of tunnelling. Each coupon was then assigned a rating, using the rating scale recommended by the International Union of Forestry Research Organizations (Becker 1972) for evaluating field test stakes. Results were converted to the AWPA rating scale, as shown in Table 1, in order to permit direct comparison with other North American data.

After completion of the inspections, additional untreated controls were added to each test rack to replace those that had failed in service and as a means of demonstrating the continued biological activity of the sites. Test racks were then restored to position for further exposure.

3 Results and Discussion

In evaluating the overall results of the marine testing project, it is important to note that use of small treated coupons is principally a method of assessing the relative performances of various preservatives when exposed to a marine environment. The large surface areas of the coupons in relation to their actual volumes may tend to increase the leaching rates of the preservatives from the wood, thereby increasing the susceptibility of the coupons to borer attack. Thus, results obtained by the test may not relate directly to the performance of piles and large timbers when treated to equivalent retentions.

3.1 West Vancouver Test Site (Pacific Coastal Waters)

3.1.1 Performance of Individual Preservatives

Untreated controls at this site have required replacement every year because of marine borer attack, thus demonstrating the continued biological activity of the site.

CCA-C-treated coupons have performed very well at all retentions over 22 years in test (Figure 1). Even the lowest retention, 15 kg/m^3, had a mean AWPA rating of 77 after 22 years of exposure. Coupons treated to 22 kg/m^3, close to the assay retention of 24 kg/m^3 now specified in CSA O80.3 and CSA O80.18, were still virtually sound, with an AWPA rating of 91.

In contrast, ACA-treated coupons were not performing well (Figure 2). Coupons treated to 29 kg/m^3 ACA, close to the 30 kg/m^3 assay retention recommended in CSA O80.3 and CSA O80.18, had dropped to a mean rating of less than 40 after 17 years' exposure, and had failed after 22 years (mean rating of 4), as had coupons treated to 44 kg/m^3 ACA. Most of the damage was due to surface erosion by soft-rot fungi and tunnelling bacteria (Morris and Doyle 1993), and while the loss of surface has a major impact on the strength of a small coupon, it would have less effect on a full sized pile. We are not aware of premature failures of ACA-treated piling and the industry has switched to ACZA, a better-fixed formulation. Retentions of 63 kg/m^3 and 95 kg/m^3 showed better performance, although these levels of treatment would be uneconomic, and deterioration in these samples also appeared to be advancing rapidly at recent inspections.

Wrapped ACA, which was installed eight years after the original set of ACA-treated material, was performing poorly at retentions much lower than the original set (Figure 3). However, contrary to expectations, samples treated to 30 kg/m^3 and 35 kg/m^3 had also failed by 14 years of exposure, with AWPA ratings of 13 and 18 respectively, and those treated to 39 kg/m^3 had also deteriorated to a mean rating of 44.

Modified ACA was still performing reasonably well at the highest retention in test of 43 kg/m^3 after 17 years' exposure while retentions of 28 kg/m^3 and below had failed. Within a further five years of exposure, however, these samples had also degraded to a mean rating of 32 (Figure 4).

Finally, creosote (Figure 5), which was tested at only one retention level (348 kg/m^3), performed reasonably well with an average rating around 60 after 17 years, reduced to 39 after a further five years of exposure. This retention is slightly higher than the recommended retention for red pine in CSA O80.18. Due to the mobility of creosote in wood, the performance of creosote in small test coupons is commonly found to be less than that in full sized commodities.

3.1.2 Comparisons Among Preservatives

By comparing curves, it would appear that 63 kg/m^3 ACA and 43 kg/m^3 modified ACA have provided equivalent performance to 348 kg/m^3 of creosote over 22 years' exposure. A retention of 15 kg/m^3 CCA-C has exceeded the performance of creosote.

A comparison of preservative efficacy among waterborne preservatives can be readily made by examining performance at retentions around 30 kg/m^3 (Figure 6). CCA-C had by far the best performance with extremely slow deterioration at this retention. ACA was much less effective than CCA at this retention for the reasons discussed earlier. Wrapping after treatment did not appear to improve the performance of ACA (Figure 6). The increased copper content in the modified ACA formulation also appeared to result in no improvement in the long-term performance of the test coupons (Figure 6).

3.1.3 Comparison with Steel and Concrete

While no materials other than treated wood were installed in this test, some interesting inferences can be drawn from the performance of the test racks. These were constructed from 3.5 mm thick carbon steel and were installed with coupons attached in 1978. Moderate to advanced corrosion was noted on parts of these racks in 1988. In 1993, after 15 years exposure, these racks had to be replaced due to severe corrosion and failure of several members. Assuming corrosion from both faces, the rate of thickness loss can be estimated at 0.12 mm per year. This is comparable to rates of corrosion found in a large-scale study of steel piling between 10 and 55 years old in the Netherlands (Wijngaard 1982). In that study the maximum rates of steel corrosion were found in the intertidal and splash zone, 0.12 - 0.27 mm per year. A steel pile is commonly 12.5 mm thick (Barford 1995 personal communication) which would take 45 to 105 years to corrode through. However, localized corrosion rates can be up to 1.0 mm per year under certain conditions (Christie 2001).

A comparison can be made with ACA-treated coupons, which also suffer from a progressive surface deterioration. Coupons treated to 30 kg/m^3 with ACA will have lost 3 mm thickness in an average of 20 years, around 0.15 mm per year. A coastal Douglas fir pile will have a treated zone 19 mm thick (CSA O80.3), taking an average of 125 years to erode through.

Concrete is thought of as lasting forever, but the steel reinforcement is highly susceptible to corrosion, expanding and cracking the concrete. The following text is taken from an exhibit on the history of the Santa Monica Pier. “Constructed in 1908-1909, the 1600 x 35’ Santa Monica Municipal Pier was the first pier on the west coast to utilise precast concrete piles. …in 1919, the innovative concrete piles failed and were replaced with the traditional timber piling.”

3.2 New Brunswick Test Sites (Atlantic Coastal Waters)

3.2.1 Shediac Bridge Site

Failure of untreated control coupons at this site has generally taken two years. Typically, virtually no sign of attack would be visible after one year, but the sample would be completely destroyed by the second year. This may be due to the timing of the annual inspections and coupon installation, just after the settlement period for borers. It should be noted that some racks were not accessible for rating at this site for several years.

CCA-C-treated samples at retentions of 14 kg/m^3 and above remained in excellent condition after 13 years in service (Figure 7). ACA treatments have not performed well

(Figure 8). By the 13-year inspection, all retentions in test had deteriorated substantially. Samples treated to the recommended retention of 30 kg/m^3, which had been in test for 10 years, had an average rating of 27 at this evaluation.

Coupons treated with creosote at retentions of 150 kg/m^3 and above remained in good condition at the 13-year evaluation (Figure 9). This retention is well below the recommended level of 256 kg/m^3. Those treated to 76 kg/m^3 and 42 kg/m^3 had reached mean AWPA ratings of 40 and 3 at this inspection.

3.2.2 Whitehead Island Site

Untreated controls in service generally failed after two to three years in test at this site. The waterborne treatments have generally performed well. At the recommended assay retention for CSA O80.18 of 24 kg/m^3 CCA, almost all coupons were completely sound after 13 years of exposure, with an average rating of 99 (Figure 10). Similarly, ACA-treated coupons close to the recommended assay retention of 30 kg/m^3 showed negligible deterioration with a rating of 90 after 10 years' exposure (Figure 11).

As in Pacific waters, CCA-C (Figure 10) has performed better than ACA (Figure 11).
At the lowest creosote retention of 42 kg/m^3 all coupons had failed (Figure 12), and at the highest retention level of 206 kg/m^3, the average AWPA rating was only 45. The new requirement in the AWPA C3 (AWPA 1995a) standard is for minimum creosote retention of 256 kg/m^3 for red pine piling. The recommended assay retention for CSA O80.3 is 280 kg/m^3 and the results of this study support these higher retention requirements.

3.2.3 Comparison of Performance the Test Sites

One of the objectives of this work was to compare the marine borer hazard in Pacific and Atlantic coastal waters. Due to the difference in preservative retentions in test at the Western and Eastern sites, direct comparisons are possible only with some treatments.

Failures of lower retention CCA-C-treated coupons occurred more rapidly at Shediac Bridge (Figure 9) than at Whitehead Island (Figure 12). Samples treated to 7 kg/m^3 failed within seven years at Shediac, while this took 13 years at Whitehead Island. Similarly, after 13 years' exposure the average rating of coupons treated to 12 kg/m^3 CCA-C at Shediac was 28 compared to 75 at Whitehead Island. At approximately 15 kg/m^3 of CCA-C, performance at the three test sites after 13 years was comparable, with average AWPA ratings of 91, 87, and 93, at West Vancouver, Shediac, and Whitehead Island respectively. At CCA-C retentions of approximately the recommended level of 24 kg/m^3, no deterioration was visible at any of the sites after 13 years.

Coupons treated with approximately the recommended ACA retention of 30 kg/m^3 had average AWPA ratings of 84, 27, and 90 after 10 years of exposure at West Vancouver, Shediac, and Whitehead Island respectively. As was the situation with CCA-C, borers at the Shediac Bridge site caused more rapid deterioration of ACA-treated samples treated to less than threshold levels. It may be that there is some degree of copper-tolerance among organisms at this location.

In contrast to the waterborne preservatives, the performance of coupons treated with 76 kg/m^3 of creosote exposed at Shediac was equivalent to creosote treatment of 206 kg/m^3 at Whitehead Island. It appears that *L. lignorum* present at the Bay of Fundy Whitehead Island site is relatively creosote-tolerant, compared to the *T. navalis* present in the warmer waters off Shediac in the Northumberland Straight..

3.3 The Future of Marine Testing

The market for wood products in the marine environment is decreasing due to environmental concerns that appear to have no scientific support. Alkaline copper quat (ACQ) and Copper Azole (CA) are not being proposed for use in the marine environment. Unless the wood preservation industry expresses a continued need for testing, the three test sites will be closed down in 2004.

4 Conclusions

At the West Vancouver, Whitehead Island and Shediac Bridge test sites, coupons treated to around the recommended assay retention of 24 kg/m^3 with CCA were in excellent condition after 22 years' exposure.

Variabilty in relative preservative performance among the test sites illustrates the need for multiple sites for field testing.

All three marine test sites will be closed down in 2004 unless the wood preservation industry intends to test new preservatives for this application.

5 References

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Table 1: Comparison of IUFRO and AWPA/ASTM Rating Scales

IUFRO Rating	AWPA/ASTM Rating*	Description
0	100	Sound, no surface deterioration or signs of tunnelling
1	90	Suspicion of tunnelling or slight surface attack
2	70	Moderate surface attack or clearly defined areas of tunnelling, but board generally sound
3	40	Heavy attack with well established areas of tunnelling, but board integrity maintained
4	0	Boards destroyed or missing at time of inspection or virtual complete loss of strength due to borer attack

* AWPA Standard M19-67 (Now E5-95). Standard Method of Evaluating Wood Preservatives for Marine Service by Means of Small Size Specimens. (Refers to ASTM Standard D2481-81: Standard Test Method for Accelerated Evaluation of Wood Preservatives for Marine Service by Means of Small Size Specimens)

Figure 1: Performance of CCA-C-Treated Coupons at the West Vancouver Marine Site

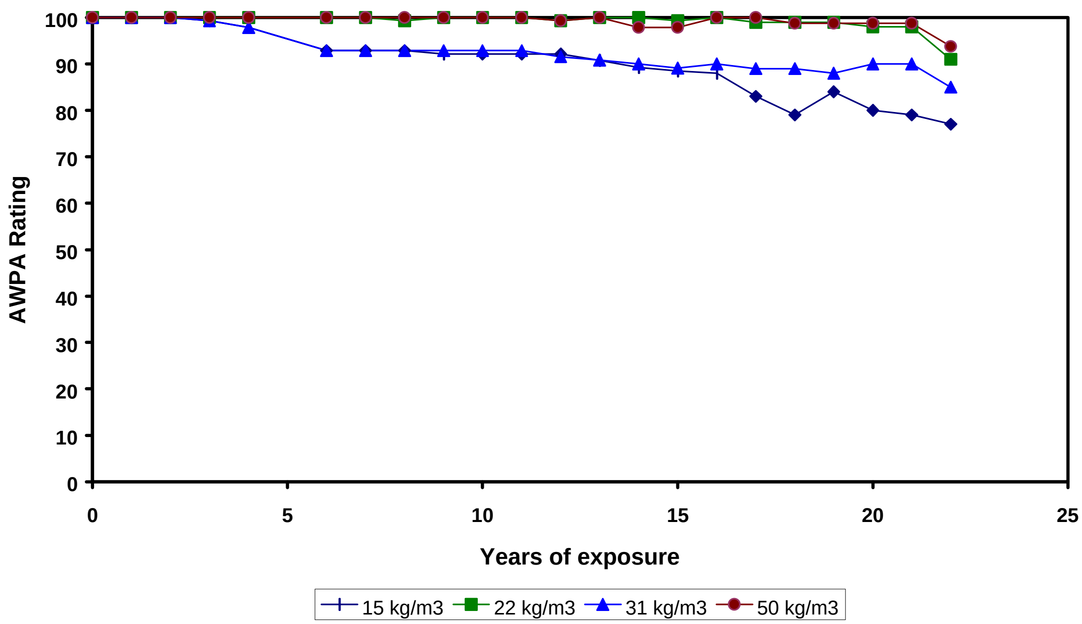

Figure 2: Performance of ACA-Treated Coupons at the West Vancouver Marine Site

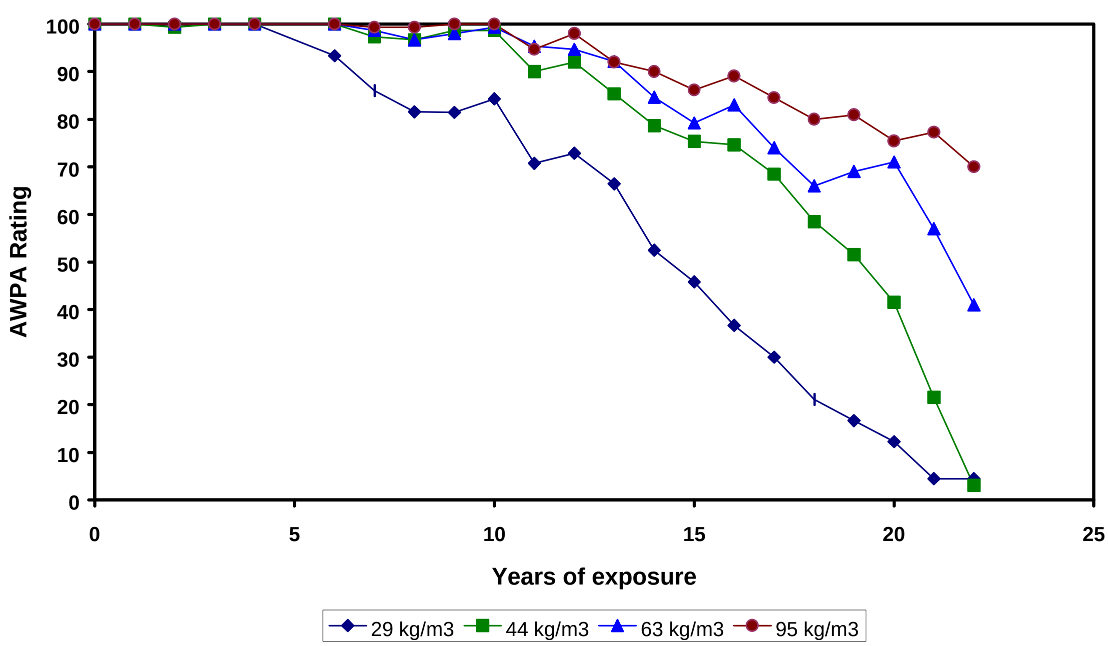

Figure 3: Performance of Wrapped ACA-Treated Coupons at the West Vancouver Marine Site

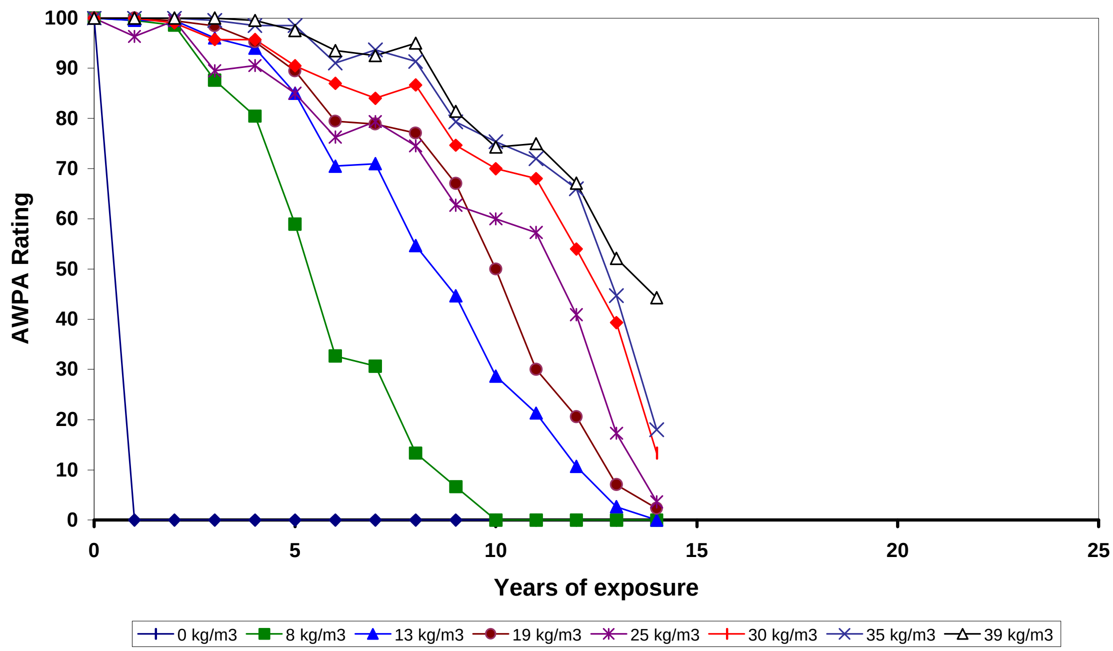

Figure 4: Performance of Modified ACA-Treated Coupons at the West Vancouver Marine Site

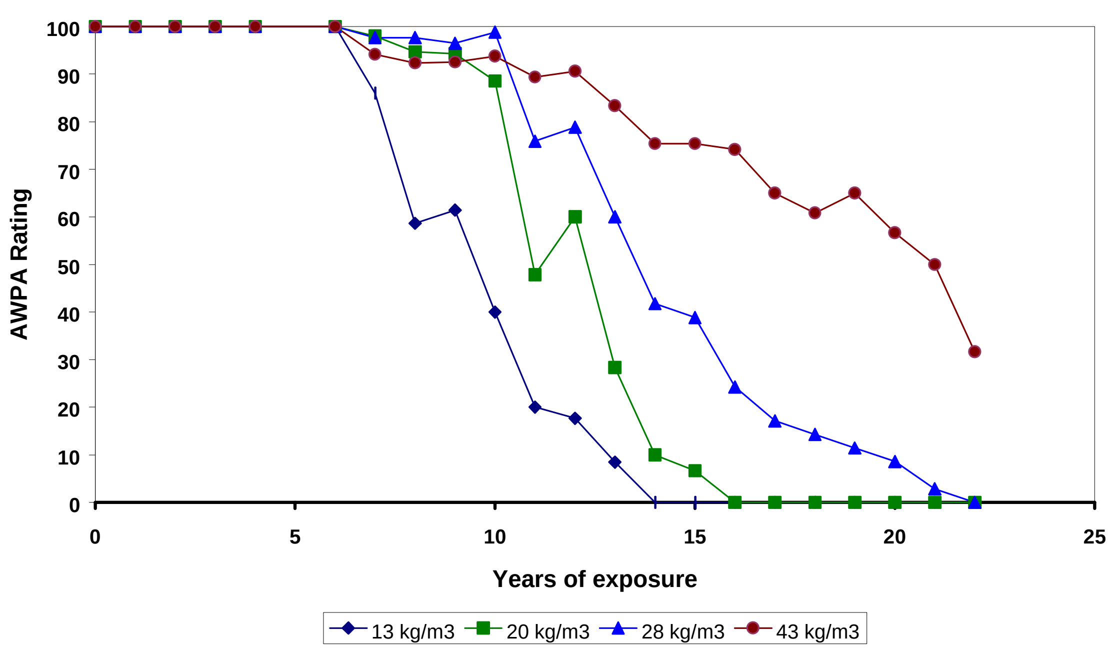

Figure 5: Performance of Creosote-Treated Coupons at the West Vancouver Marine Site

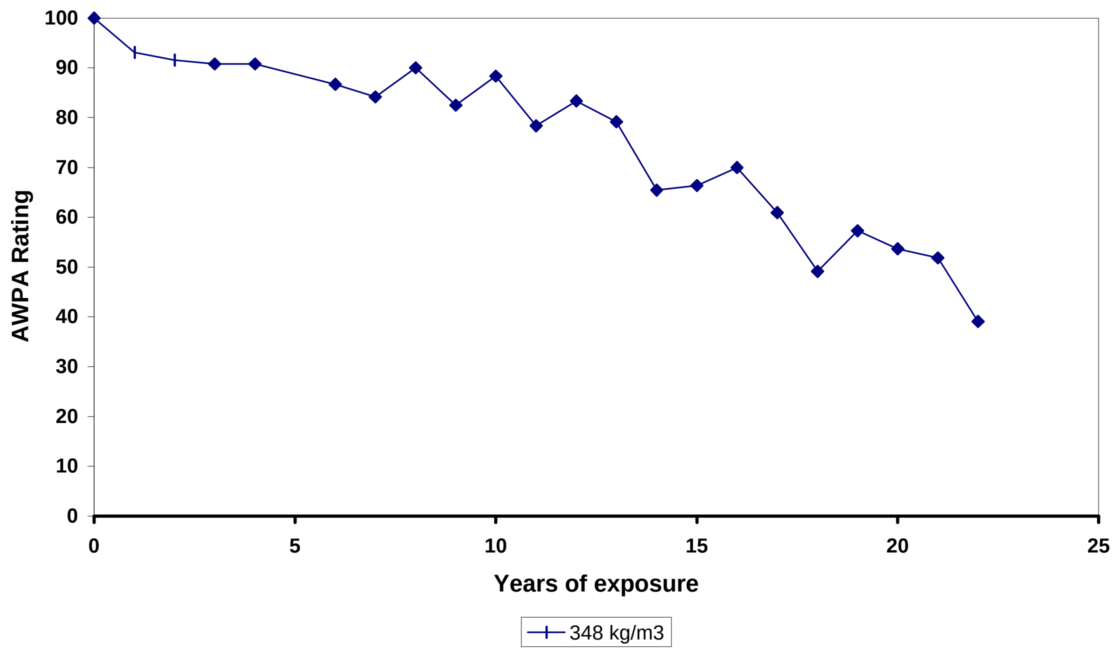

Figure 6: Comparison of Waterborne Preservatives at the West Vancouver Marine Site at Retentions of 30 +/- 2 kg/m^3

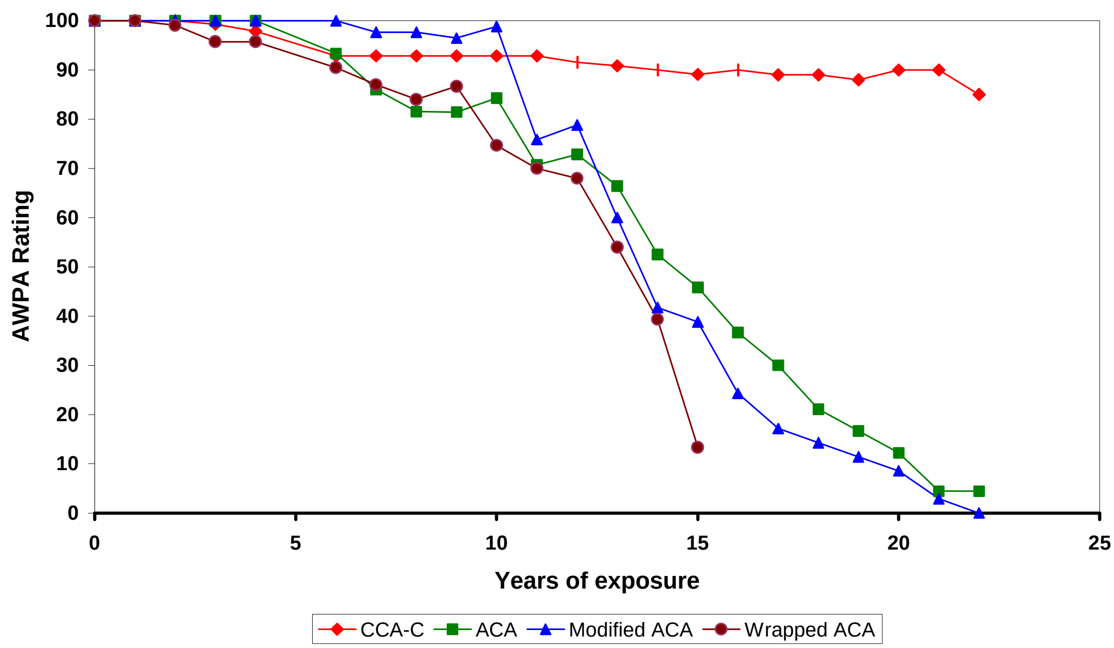

Figure 7: Performance of CCA-C-Treated Coupons at the Shediac Bridge Marine Site

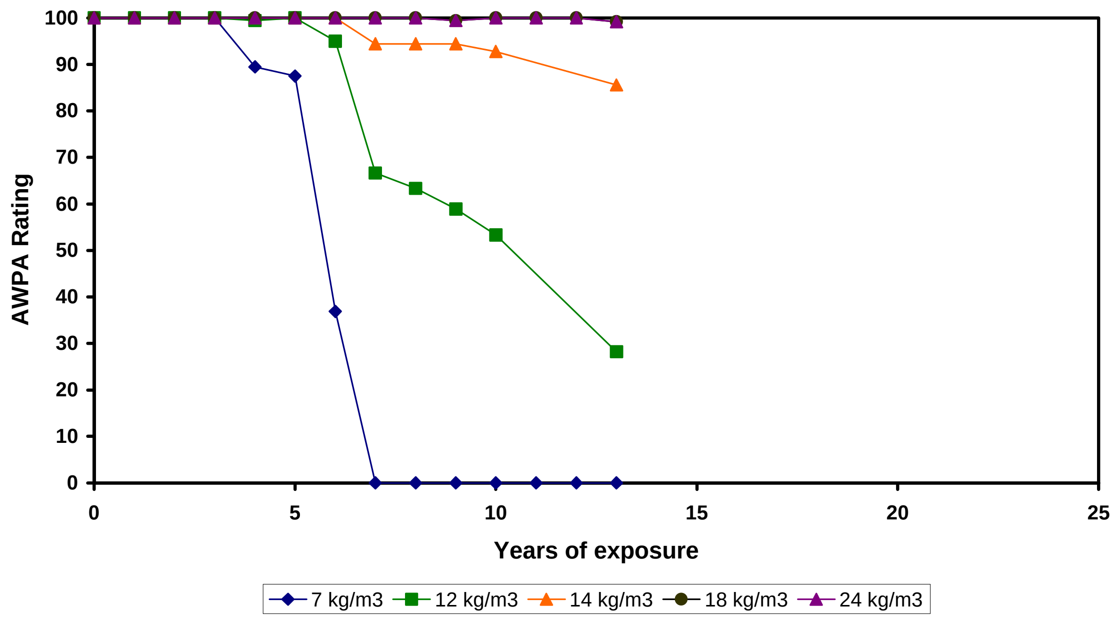

Figure 8: Performance of ACA-Treated Coupons at the Shediac Bridge Marine Site

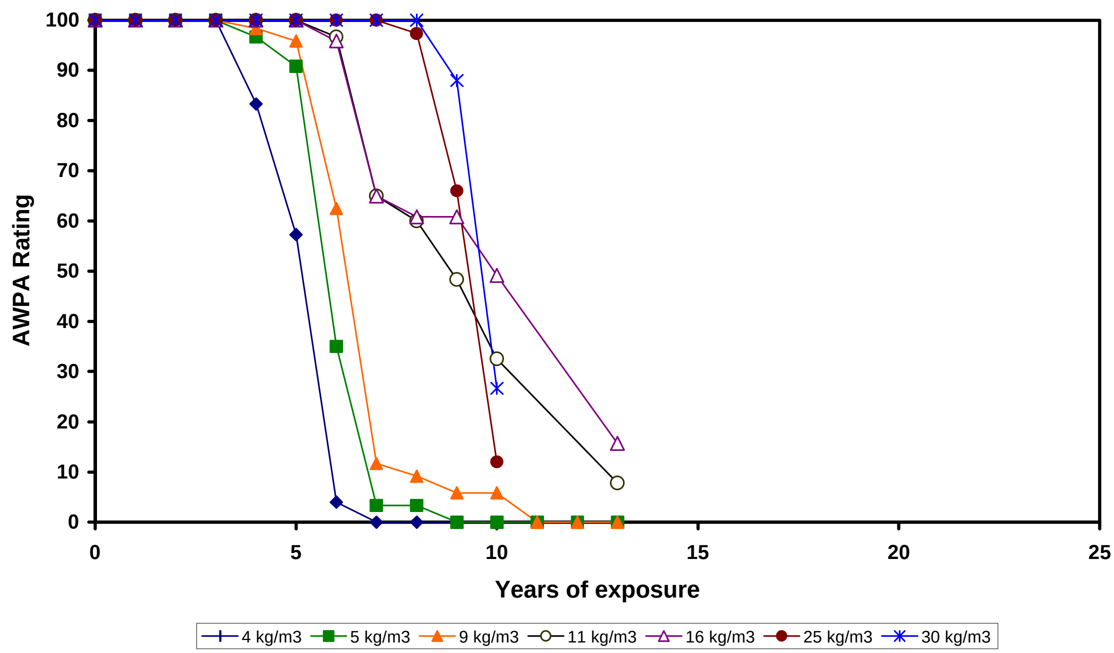

Figure 9: Performance of Creosote-Treated Coupons at the Shediac Bridge Marine Site

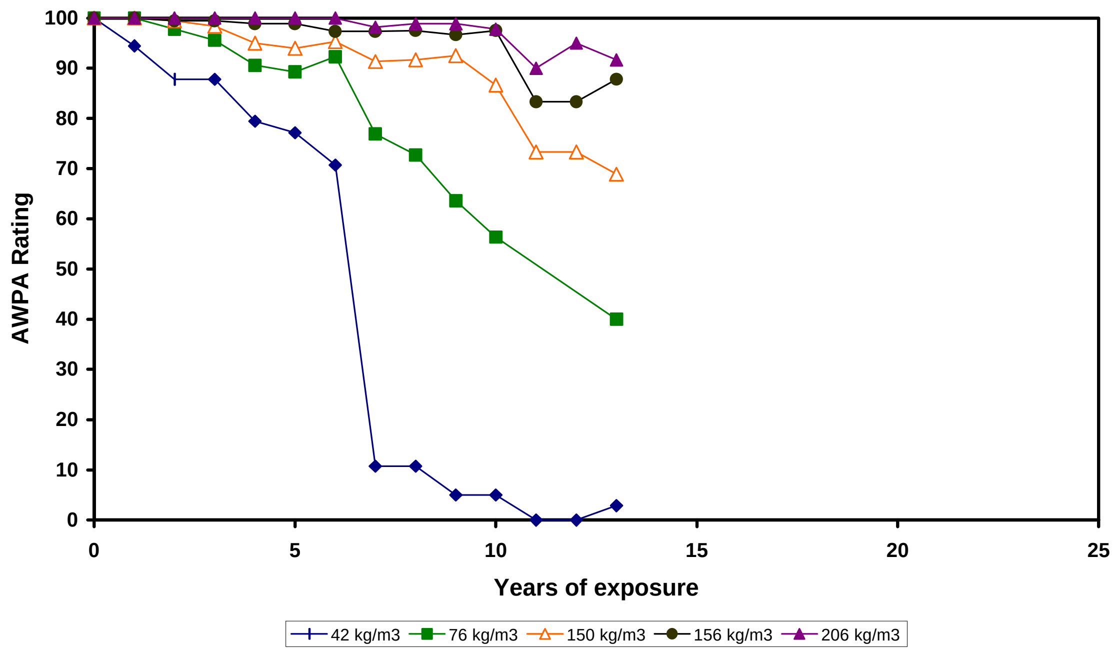

Figure 10: Performance of CCA-C-Treated Coupons at the Whitehead Island Marine Site

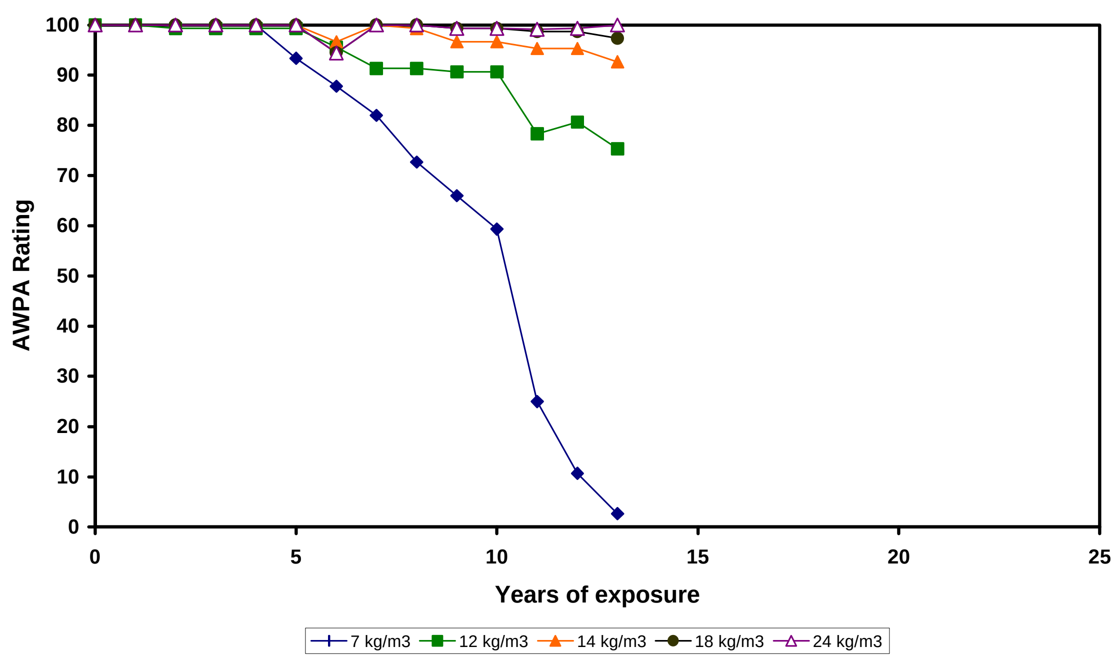

Figure 11: Performance of ACA-Treated Coupons at the Whitehead Island Marine Site

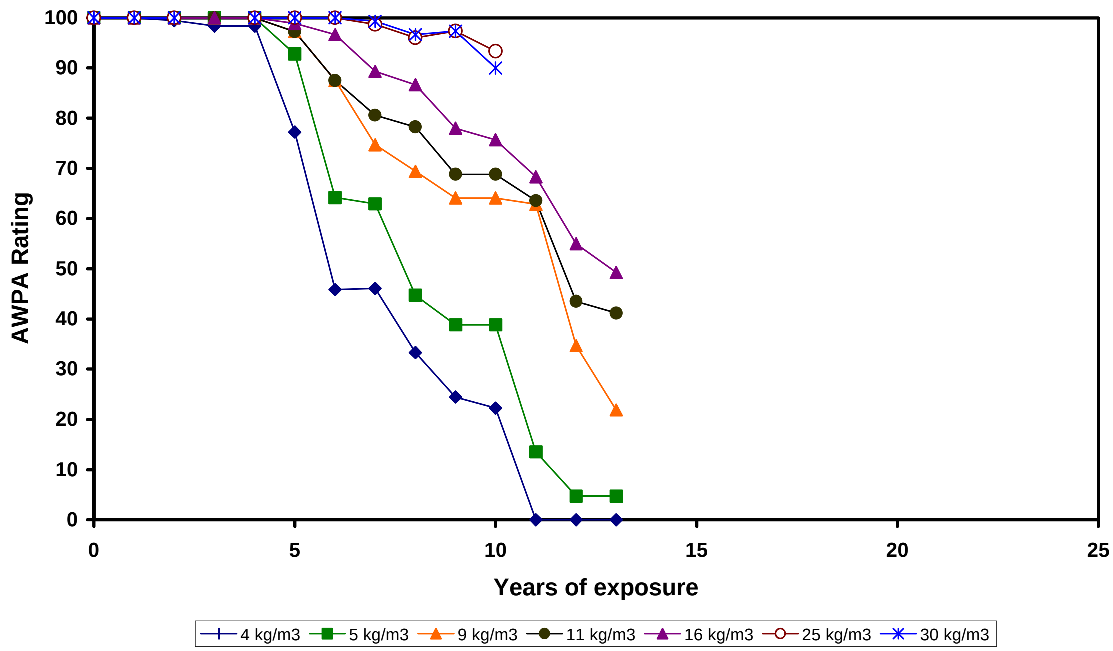

Figure 12: Performance of Creosote-Treated Coupons at the Whitehead Island Marine Site