FIELD TESTING OF WOOD PRESERVATIVES IN CANADA
IV. PERFORMANCE OF PRESERVATIVE-TREATED VENEERED COMPOSITES:

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Summary

This report addresses a number of issues around the performance of preservative-treated plywood and laminated veneer lumber. These include the effect of various preservative penetration patterns on performance, the effect of field-cut preservatives and the use of alternative wood species.

The presence of small areas of untreated wood in CCA-treated hem-fir plywood did not accelerate decay compared to completely-treated solid-wood stakes at similar retentions. Stakes without field-cut preservative treatment decayed at a faster rate, but this may have been due to a lesser degree of initial preservative penetration which had occurred by chance. Hem-fir plywood treated with ACA did not perform as well as CCA-treated plywood in the Westham Island field test. This was probably due to the particular conditions of this site. With regard to the effect of penetration on performance, it is too early to draw conclusions from the soil-bed test about relative performance of plywood treated to meet the old and new CSA 080.15 PWF penetration requirements.

Plywood with lodgepole pine heartwood face veneers, CCA-treated to the PWF standard retention and edge-treated with copper naphthenate, performed as well as hem-fir plywood treated to the same level. Stakes with CCA edge treatment decayed more rapidly, and those without edge treatment decayed more rapidly still. Pine plywood with sapwood face veneers did not perform as well despite better preservative penetration.

Aspen LVL treated with up to 16 kg/m^3 of ACA fell below a rating of 70 within 8 years of installation in the field test. LVL with CCA treatment at 16.6 kg/m^3 remained above a rating of 70 after 11 years.

1. Introduction

The major use of preservative-treated plywood in Canada is for permanent wood foundations (PWF), but sign boards and bus and truck flooring are other significant uses. Smith (1982) reviewed the use of preservative-treated plywood and suggested that there were a number of information gaps relating to long-term performance. A number of these information gaps can be addressed by reference to data from field tests set up in the late 1970s. This report focuses on the performance of hem-fir and lodgepole pine/spruce plywood after 14 years' ground-contact exposure at the Westham Island test site. Performance of aspen laminated veneer lumber (LVL) at this test site is also reviewed.

Currently, Canadian standards only allow PWF to be constructed only with pressure-treated plywood made with a limited range of wood species. These include western hemlock (*Tsuga Heterophylla* Raf. Sarg. and amabilis fir (*Abies amabilis* (Dougl.) Forbes) otherwise known as hem-fir or hem-bal and coastal Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco.). This restriction was based on a comprehensive program of research into the treatability and performance of various types of plywood during the late 1970s and early 1980s by the Western Forest Products Laboratory, later Forintek (Smith and Cserjesi 1979, Cserjesi, Ruddick and Johnson 1987). The use of field-cut preservatives is mandatory for PWF but it may occasionally be missed. The effect on performance of not applying such preservatives therefore needs to be quantified. The hem-fir plywood in test at the Westham Island site consists of material with and without edge treatment.

The CSA O80.15 standard, covering PWF plywood, specifies very stringent preservative penetration requirements (Appendix 1). Because these requirements were almost impossible for treaters to meet, the penetration requirements were relaxed slightly in 1989 to allow small amounts of untreated wood to be present. This was based, in part, on penetration and performance data from Forintek's field tests of hem-fir plywood. To back up these data, a study was set up in a soil-bed facility to determine whether this change in penetration requirement would have an effect on performance of PWF plywood.

With the decline in the production of coastal plywood, there is increasing interest in the preservative treatment of plywood made from species such as lodgepole pine (*Pinus contorta* Dougl.) and western spruce (*Picea glauca* (Moench) Voss). Fortunately some test material was installed into Forintek's field test site at Westham Island, B.C. in the late 1970s. This material has been in test for 14 years and represents the only source of information on performance of treated pine-spruce plywood under Canadian conditions.

Engineered wood products are increasingly utilizing aspen as a raw material. Due to the extremely low natural durability of aspen, these products will require preservative treatment if they are to be used in exterior construction. Earlier laboratory work has suggested that aspen would require much higher loadings of waterborne, copper- and arsenic-based preservatives to provide equivalent performance to softwoods treated to standard retentions (Morris and Parker 1988b). Aspen LVL has been used as a test material to evaluate the performance of aspen composites that have been pressure treated with waterborne wood preservatives.

2. Methodology

Field Test Method

Test stakes were installed during the summer at Forintek's test site on Westham Island in the delta of the Fraser river in British Columbia. They were planted to half their depth in holes made with an iron bar. Temperatures at the site annually averaged 9°C with a December average of 2°C and a July average of 16°C. Annual precipitation totalled around 1000mm with 13mm in July and 150mm in December. The soil was an orthic gleysol, a silty clay loam with a high water table. Standing water was common in the winter months when the water table averaged 250mm below the soil surface. It lowered to 1250mm from the surface during the summer. The pH was 5.7 to 6.0 and the organic matter content was 4.7 to 9.3%.

This site has been found to be unusually aggressive in its rate of decay of copper/arsenic-based preservatives (Ruddick and Morris 1991, Morris and Ingram 1991b). This has been found to be due in part to detoxification of arsenic by iron (Morris 1993), which moves into the wood from the soil under the suboxic or anaerobic conditions which prevail during the winter and early spring (Ruddick and Morris 1991). It may also be due, in part, to leaching of copper possibly associated with bacterial action (Ruddick 1993).

During the annual inspection the stakes were removed from the ground, scraped free of adhering soil and examined for evidence of decay. They were assigned a visual rating as described in the IUFRO standard (Becker 1972). For presentation of results to North American audiences each data point was converted to the AWPA scale as follows:

AWPA rating	IUFRO scale	Description
10	0	Sound - no decay
9	1	Trace of decay
7	2	Moderate decay
4	3	Heavy decay
0	4	Failure due to decay

An average "log" stake score was then calculated on a 100 to 0 scale for each retention of each preservative.

Preparation of Hem-Fir Plywood

Twenty sheets of five-ply plywood were commercially prepared from hem-fir veneer. Half were commercially treated with 3% CCA Type-C and half with 3% ACA, using a full cell process with pressure of 830 kPa applied for four hours. Core samples were analyzed for preservative retention. Stakes of dimensions 1.5 x 5 x 50 cm were sawn from each sheet. Half of the CCA-treated stakes were brush-treated with copper naphthenate and half received no edge treatment. The ACA-treated stakes received 3.1% copper naphthenate, 5% CCA, 5% ACA or no edge treatments. The stakes were installed in the Westham Island site in 1979 and evaluated annually since then. After nine years of exposure a triangular piece was removed from the top corner of each CCA-treated stake and the preservative penetration was assessed.

Accelerated Test of Preservative Penetration

Sheets of hem-fir plywood, commercially treated with CCA, were cut into stakes, 5cm x 55 cm x the plywood thickness, taken from the central section of the sheets. The stakes were then cut into two 25cm long daughter stakes, with a 5cm central section being used to analyze penetration and CCA retention. Stakes that did not meet the retention requirement of 9.6 kg/m^3 were discarded. A total of 100 stakes were selected in four groups of 25: those meeting the current and pre-1989 CSA 080.15 penetration requirements, those meeting just the current requirement, those meeting just the pre-1989 standard and those that failed on penetration.

Two brush coats of copper naphthenate PWF field cut preservative were applied to all cut edges of the plywood stakes. They were allowed to dry for two weeks, then leached in running water for three days. After drying, the stakes were randomly installed in the Forintek soil-bed facility, with 75 mm between all faces. The soil-bed was maintained at 24-30% moisture content and the room was kept at 26°C and 80% RH. This facility has been fully described by Morris and Parker (1988a). At six-month intervals the stakes were removed from the soil, examined for signs of decay and rated according to the IUFRO rating scale (Becker 1972). This is converted to the AWPA scale for North American audiences.

Preparation of Pine-Spruce Stakes

Plywood panels were commercially prepared from various combinations of lodgepole pine sapwood, lodgepole pine heartwood and western white spruce veneers. In normal mill operation any veneer containing a little sapwood will be labeled "sapwood". For the purpose of this study veneers with 95% sapwood were selected on the basis of a visual inspection. The combinations studied were:

A) pine heartwood face veneers with sapwood inner plies
B) pine heartwood face veneers with heartwood inner plies
C) pine heartwood face veneers with spruce inner plies
D) pine sapwood face veneers with sapwood inner plies
E) pine sapwood face veneers with heartwood inner plies
F) pine sapwood face veneers with spruce inner plies

The plywood sheets were commercially treated with a 2% solution of CCA Type-C using a full cell process. The treating cycle consisted of an initial vacuum of 71 cm Hg for one hour, pressure at 1400 kPa for nine hours, then a final vacuum of 38 cm Hg for 10 minutes. Core samples from each sheet were analyzed for preservative retention and penetration. Penetration measurements at the time were not as detailed as those performed on the hem-fir plywood.

Stakes, 1.5 x 5 x 50 cm, were sawn from the middle of the plywood sheets with the face grain direction parallel to the longest dimension. The stakes with pine heartwood face veneers were divided into three groups. One received no edge treatment. The edges of the second group of stakes were brush-treated with two coats of 3.1% copper naphthenate and the third group with 5.0% CCA. The pine sapwood face stakes were not edge-treated. All of the treated stakes and a group of untreated control stakes were installed to half their length in the Forintek field test site at Westham Island, B.C. in the summer of 1979.

Preparation of Aspen LVL

Stakes were cut from aspen LVL to dimensions of 500 x 50 x 38 mm (LVL thickness). The stakes were pressure treated at Forintek's Ottawa laboratory to a range of retentions of CCA and ACA. Installation in the Westham Island site was completed in the summer of 1982.

3. Results and Discussion

Influence of Test Site Variables on Results

Before discussing the performance data it should be noted that the Westham Island test site presents an extremely severe decay hazard. It has an acceleration rate of 2.6 compared to both another Forintek test site in the Vancouver area and to other test sites in the temperate zones (Morris and Ingram, 1988, 1991a). The 14-year data from plywood exposures would therefore be comparable to 36 years exposure in most other locations.

Performance of Hem-Fir Plywood

The untreated control stakes failed during the first three years of exposure and had an average life of 2.2 years (Figure 1).

CCA-treated hem-fir plywood showed a gradual deterioration with time (Figure 1). The edge treated material had reached a mean rating of 82 after 14 years' exposure. As a benchmark for evaluating the performance of this plywood, a rating of 70 can be regarded as representing significant loss of strength. Solid ponderosa pine stakes treated to 10.3 kg/m^3 with CCA-C also had a log stake score of 82 after 14 years of exposure (Cook and Morris 1994). These solid wood stakes had no patches of untreated wood in them, unlike the plywood stakes. This may indicate that small areas of untreated wood do not have a major negative impact on the performance of treated wood products. This supports the 1989 revision to CSA O80.15 to allow up to 10% of face veneers to have up to 10% of untreated wood (Appendix 1).

McNamara (1982) concluded, from nine-year field test data, that complete preservative penetration was unecessary for adequate performance of CCA-treated plywood. He also concluded that there was no effect of edge treatment after nine years.

Performance of the CCA-treated hem-fir plywood without edge treatment was substantially reduced compared to that with copper naphthenate edge treatment (Figure 1). The estimated decay rate for edge-treated plywood was 1.1 units per year and for non-edge-treated plywood it was 1.8 units per year. This means it would take 27 years and 17 years respectively to reach a rating of 70. At sites other than Westham Island these times would be 70 and 44 years respectively. The difference in performance may also be due, in part, to the differences in the original CCA penetration which had occurred by chance in these two groups (Table 1).

ACA-treated hem-fir plywood, even with copper naphthenate edge treatment, has not performed well, with most rapid deterioration occuring in the last four years (Figure 2). The type of edge treatment did not appear to make a difference in this material. The poor performance of ACA-treated plywood is comparable with the poor performance of ACA-treated solid stakes at this site (Morris and Ingram 1991a). This has been attributed partly to tunnelling bacteria (Morris and Ingram 1991b), partly to leaching of copper (Ruddick 1992) and partly to the effect of soil iron in detoxifying arsenic (Morris 1993). None of the treated material in the field test would meet the current standard for preservative penetration for PWF in CSA 080.15 (Table 1), although all would meet the retention requirement of 9.6 kg/m^3.

Accelerated Test of Preservative Penetration

The stakes have been in test for 2.5 years. No decay has yet been found, even among those stakes that failed the penetration standards. Previous work has shown that there is a five-fold acceleration of decay processes in CCA-treated wood exposed in the soil bed when compared with similar material at the Westham Island test site (Morris and Parker 1988a). However, hem-fir stakes which did not meet the standard had early indications of decay at the field test site (AWPA rating 80 to 90) after 12.5 years. It is therefore difficult to determine the equivalent length of natural exposure to 2.5 years in the soil bed.

Performance of Pine-Spruce Plywood

Performance of the CCA-treated pine-spruce plywood with heartwood faces and copper naphthenate edge treatment has been similar to hem-fir plywood. Without edge treatment performance of pine-spruce plywood has not matched up to hem-fir (Figures 1, 3, 4 and 5). This does, however, demonstrate that effective edge-treatment can compensate for poor preservative penetration in the inner veneers (Table 2).

In most cases copper naphthenate was a more effective edge-treatment than CCA (Figures 3-6). This was likely due to better penetration of the organic-solvent-borne copper naphthenate, though no measurements were done on penetration of edge treatments. It is fortunate that copper naphthenate proved superior, since CCA is no longer registered for use as a field-cut preservative in Canada.

The best performance of pine-spruce plywood without edge-treatment was seen in the stakes with heartwood faces and sapwood inner veneers (Figure 4). These had the best penetrated inner veneers of any group; a finding which supports the 1989 increase in the penetration requirement for inner veneers of PWF plywood (Appendix 1).

None of the stakes with sapwood face veneers performed as well as stakes with heartwood face veneers (Figure 6), despite better, but incomplete, preservative penetration (Table 2). The type of inner plies had no effect on performance. Sapwood is more susceptible than heartwood to soft-rot attack, due to higher nutrient and lower extractive content. It has been shown that soft-rot fungi colonize CCA-treated plywood (Morris and Parker, 1987). This may suggest that Canadian species consisting predominantly of heartwood might outperform U.S.A. species which consist mainly of sapwood (Morris and Ingram, 1991a).

Field Testing of Aspen LVL

Stakes prepared from aspen laminated veneer lumber and treated with up to 16 kg/m^3 CCA and modified ACA have not performed well in the Westham stake test. The AWPA standard defines failure as a mean log stake score of under 70. Stakes at all retentions except CCA at 16.6 kg/m^3 reached that level within eight years of testing (Figures 7 and 8). Stakes at 16.6 kg/m^3 CCA had a rating of 75 after 11 years. This performance would be comparable to ponderosa pine stakes treated to between 4.3 and 6.5 kg/m^3 (Morris and Ingram 1991a), although the larger size of the LVL stakes may influence performance. Modelling of the effect of preservative retention on performance has shown that retentions of around 30 kg/m^3 of CCA may be required in aspen to give equivalent performance to 6.4 kg/m^3 CCA in pine (Cook and Morris 1994).

4. Conclusions

- The presence of small areas of untreated wood in CCA-treated hem-fir plywood did not accelerate decay compared to completely-treated solid-wood stakes at similar retentions.

- Failure to apply a field-cut preservative will substantially reduce the life of treated plywood cut on site.

- Hem-fir plywood treated with ACA did not perform as well as CCA-treated plywood in the Westham Island field test.

- It is too early to draw conclusions from the soil-bed test about relative performance of plywood treated to meet the old and new CSA O80.15 PWF penetration standard.

- Plywood with lodgepole pine heartwood face veneers, CCA-treated to the PWF standard retention and edge-treated with copper naphthenate, performed as well as hem-fir plywood treated to the same level.

- Aspen LVL treated with up to 16 kg/m^3 of ACA fell below a rating of 70 within eight years of installation in the field test. CCA treatment at 16.6 kg/m^3 remained above a rating of 70 after 11 years.

5. Recommendations

The field tests should be continued until the termination of tenure at the Westham Island test site in 1997 and ideally should be transferred to a new test site as appropriate. The accelerated soil-bed test should be continued indefinitely, as it will provide back-up data to support the current PWF Standard.

6. Acknowledgements

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7. Literature

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TABLE 1

Treatment characteristics of pine-spruce and hem-fir plywood.

Pine-Spruce Plywood Composition		Retention (kg/m^3) CCA-C	Penetration from Cores			
			% With Face Penetration		% With Inner Penetration	
Face	inner		100%	< 100%	100%	< 100%
Heart	Sap	11.4	33	67	61	39
Heart	Heart	10.4	33	67	0	100
Heart	Spruce	11.6	67	33	5	95
Sap	Sap	12.3	67	33	33	67
Sap	Heart	11.8	75	25	5	95
Spruce	Spruce	12.1	95	5	0	100
Hem-fir[1]		13.8	70	30	25	75
Hem-fir[2]		13.8	80	20	80	20
Hem-fir[3]		10.7	-	-	-	-

[1] CCA-treated with no edge treatment
[2] CCA-treated with copper naphthenate edge treatment
[3] ACA-treated

TABLE 2

Detailed penetration data for hem-fir plywood.

	CCA/No Edge	CCA/Cu Naph. Edge
% of all veneer 100%	43	80
% of face veneer 100%	70	80
% of face veneer 90-99%	17.5	20
% of inner veneer 100%	25	80
% of inner veneer 90-99%	65	20
# of cores with > 3 veneers 100%	13	0
# of cores with 2 face veneers < 100% penetrated	1	0

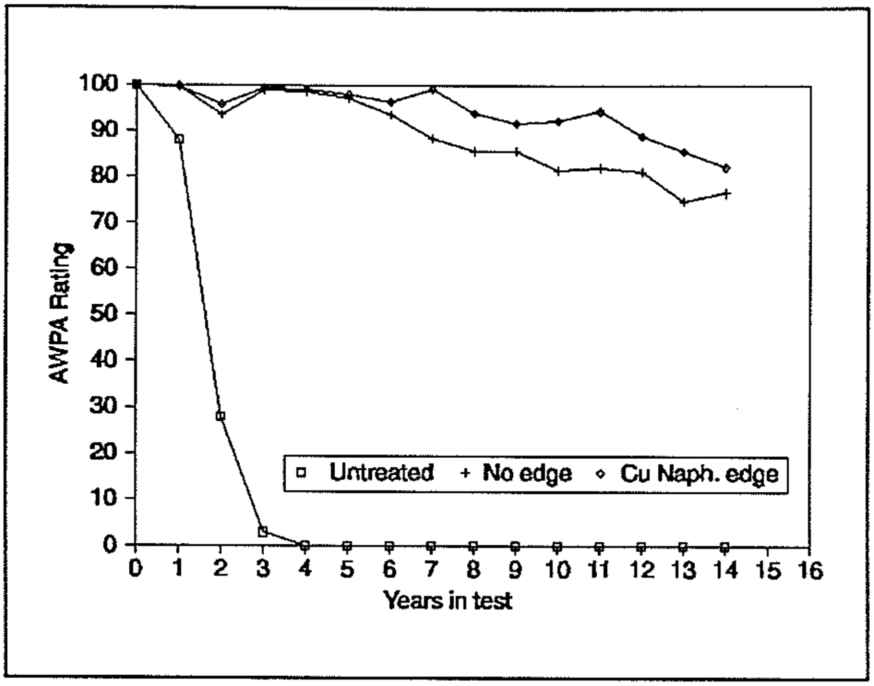

Figure 1 Decay of CCA-treated hem-fir plywood

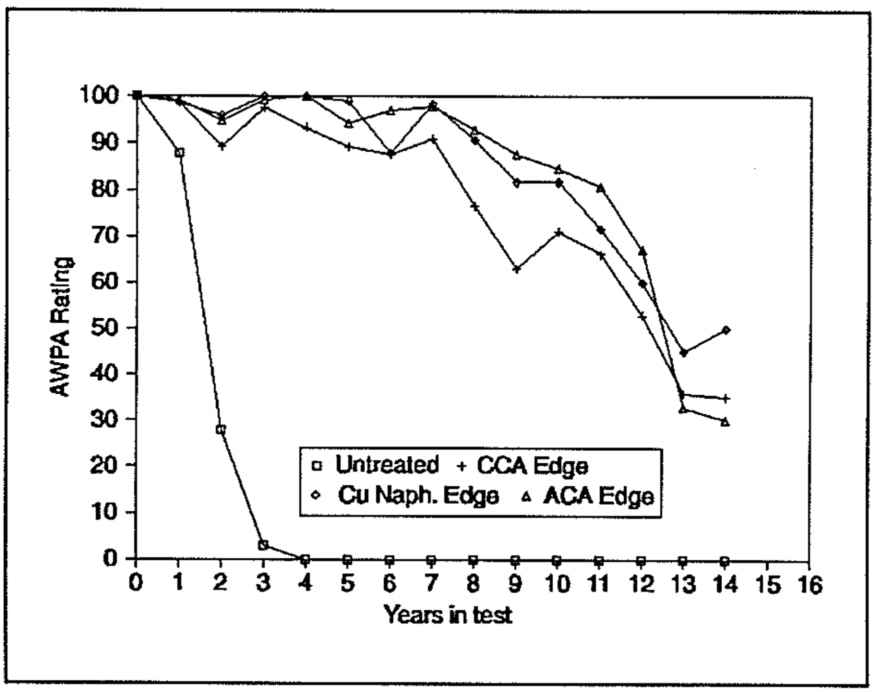

Figure 2 Decay of ACA-treated hem-fir plywood

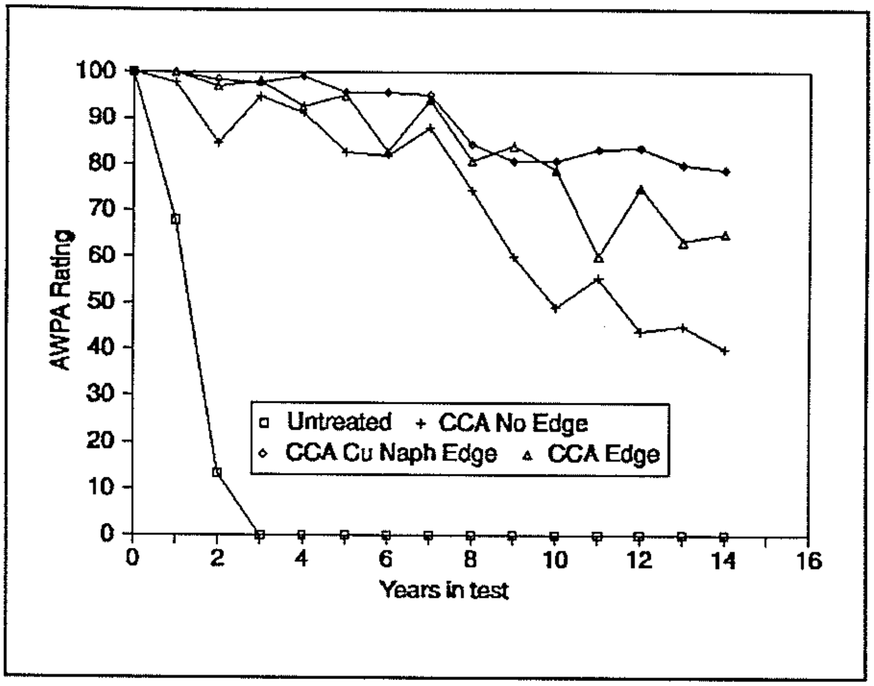

Figure 3 Decay of lodgepole pine plywood with heartwood face and heartwood inner plies.

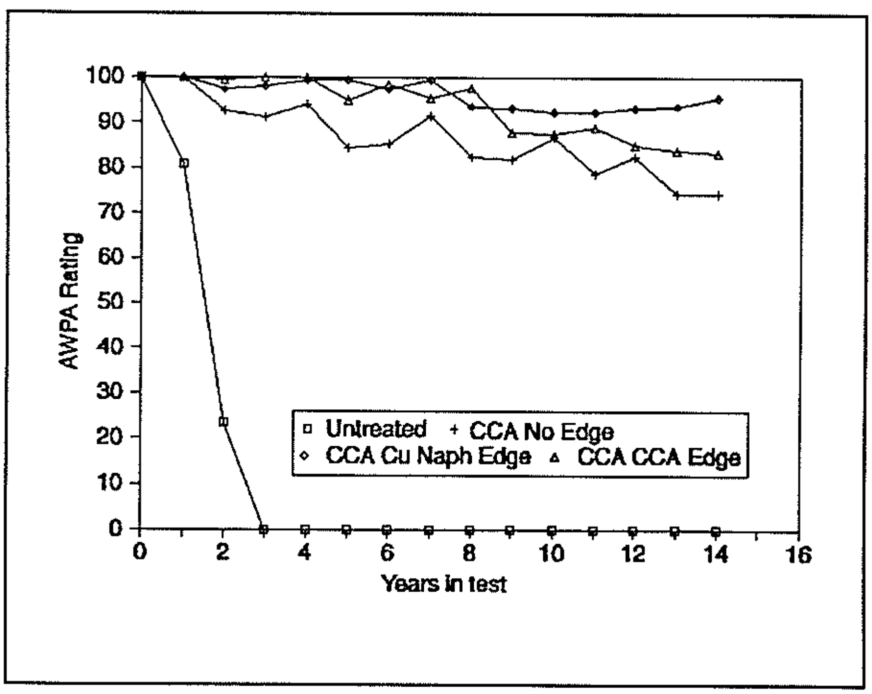

Figure 4 Decay of lodgepole pine plywood with heartwood face and sapwood inner plies.

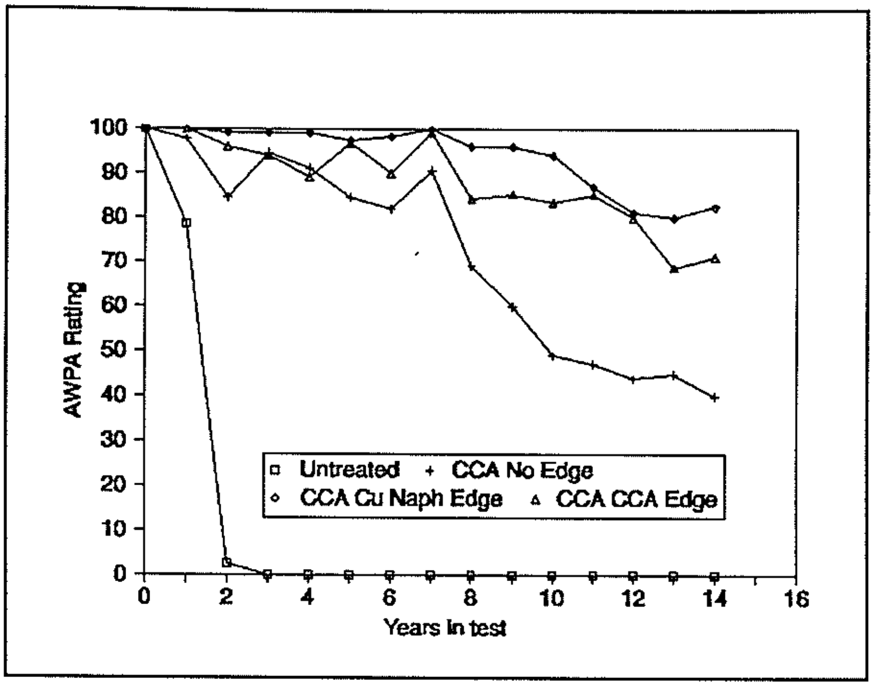

Figure 5 Decay of lodgepole pine plywood with heartwood face and spruce heartwood inner plies.

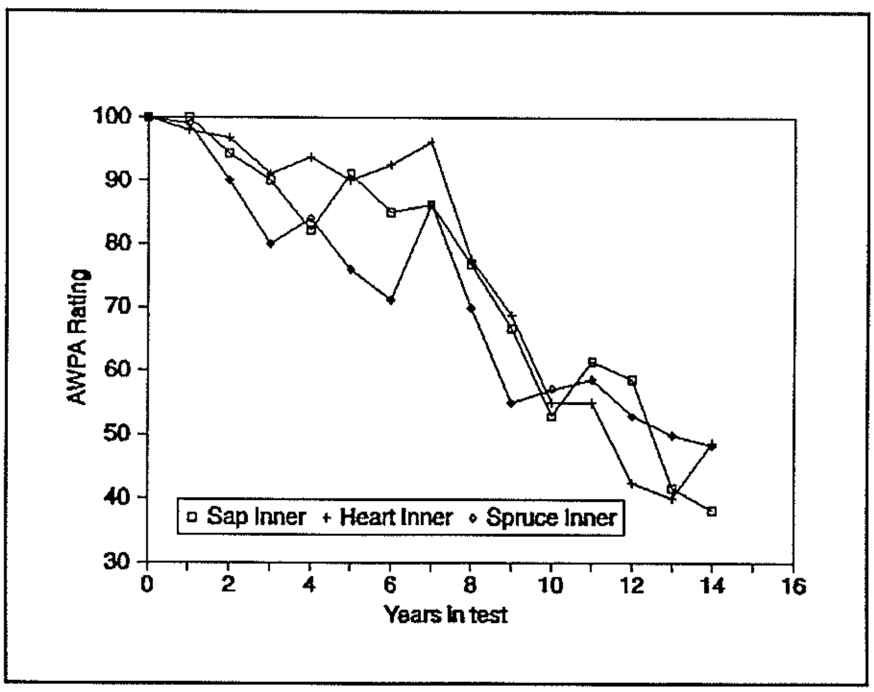

Figure 6 Decay of lodgepole pine plywood with sapwood face and various inner plies.

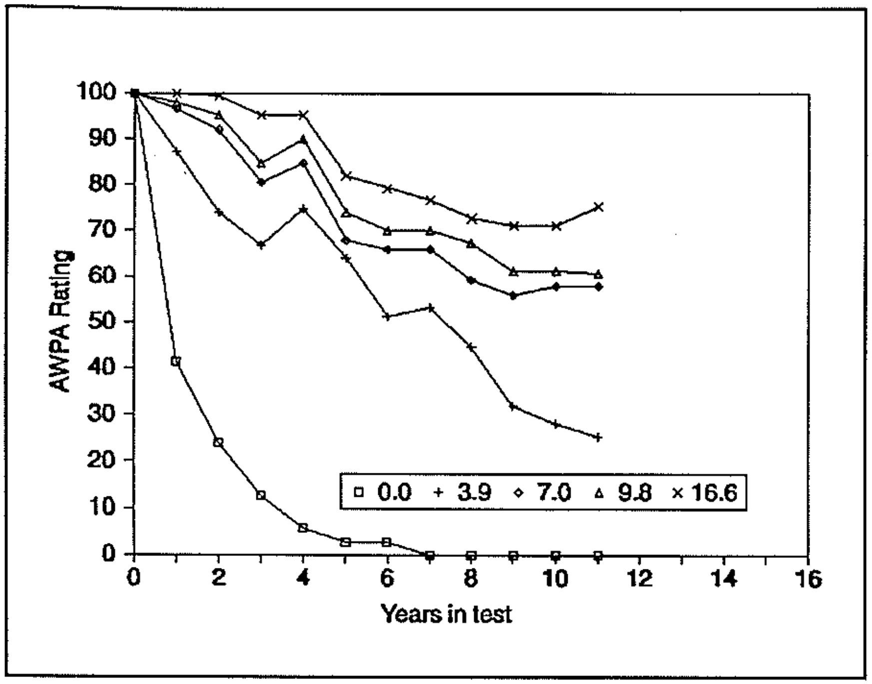

Figure 7 Decay of aspen LVL treated with a range of rentions of CCA

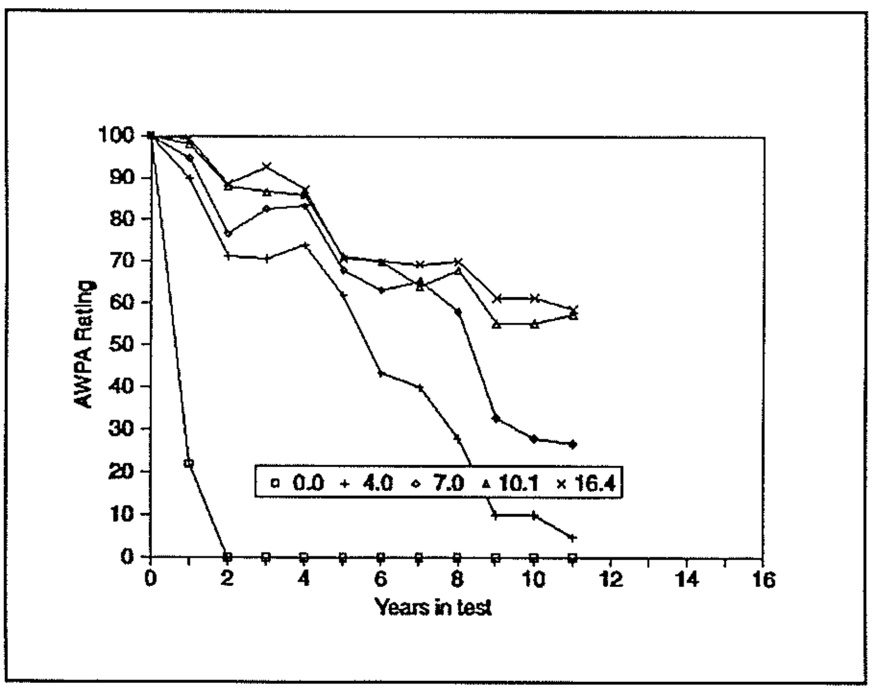

Figure 8 Decay of aspen LVL treated with a range of rentions of ACA

APPENDIX 1

CSA O80.15 Penetration Requirements

	Pre-1989 Requirements*		1989 Requirements*	
	Complete	Incomplete	Complete	Incomplete
Face veneers	40	0	36	4 (>90%)
Inner veneers	50	10 (>0%)	48	12 (>50%)
All veneers	90	10	85	15

* Based on 20 cores, 100 veneers