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COATINGS FOR EXTERIOR WOOD-BASED COMPOSITES

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COATINGS FOR EXTERIOR WOOD-BASED COMPOSITES

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1. INTRODUCTION

Wood-based composites (WBCs) such as hardboard, particleboard and fibreboards, are produced in large quantities in New Zealand. The main uses for these products are as interior lining materials (floors and walls) in buildings and in cabinet making. At the present time there are no exterior grade WBCs being manufactured in New Zealand. Exterior grade products have been manufactured in the past but have suffered from poor durability.

Wood-based composites are used extensively for exterior claddings in the USA and some are also used in Australia. At least one siding material from each of these countries is known to have been marketed in New Zealand and it seems likely that the usage of such materials will increase in the future.

Timber as a cladding material has a long history and the role of paint systems in extending the life of timber exposed to the weather is well known. Wood-based composites have a much shorter history, but like timber, are known to require protection with paint systems to get maximum performance when exposed to the weather. The importance of the paint system on WBCs depends upon the type of wood used, the resin and the manufacturing process, but in general it is more crucial than for most timber claddings. Several authors have reported outdoor weathering studies of wood-based composites using various coating systems. Carll (1) reported that all acrylic-based coating systems on urea formaldehyde (UF) bonded particleboard had failed after 15 months outdoor exposure whereas systems with oil-based primers lasted approximately twice as long. Bussjaeger and Haines (2) reported that acrylic latex systems performed better than oil/alkyd systems on hardboard (HB) sidings. Further work is needed to clarify which (if any) of these paint types will provide adequate protection for WBCs.

In this study two urea formaldehyde bonded products, particleboard (PB) and medium density fibre board (MDF)) and two high density hardboard sidings were exposed to the weather. The panels were coated with various paint systems of differing water vapour permeability. The PB and MDF samples were expected to show more rapid deterioration of mechanical properties than the hardboards (HB1 and HB2) and were therefore tested after twelve months' exposure along with uncoated samples of the hardboard sidings.

2. EXPERIMENTAL

2.1 Materials

Samples of two wood composite sidings for exterior use were obtained, one from Australia and the other from the USA. Two New Zealand-made interior grade WBCs, a particleboard and a medium density fibreboard, were also included in the study. The products are described in Table 1.

2.2 Outdoor Exposure

The PB and MDF sheets were cut into samples of 1220 x 320mm. The edges of the samples were rounded using a 6mm router bit. All cut edges were lightly sanded and the ends of the boards then sealed with two coats of coal tar epoxy paint. The two hardboards were purchased in weatherboard profiles and cut to lengths of 1220mm. HB1 had a width of 297mm and HB2 a width of 303mm. Two panels of each board type were coated with each of the paint systems described in Table 2. Uncoated controls were stored indoors at 65±5% RH and 20±2°C. The coatings were applied by brush according to the manufacturers' instructions.

Natural weathering of the panels was carried out on the BRANZ exposure site located in a rural area at Judgeford, 27 km northeast of Wellington, New Zealand. Exposure commenced on 2 May 1990. Samples were exposed facing due north mounted on vertical racks. The racks were constructed of 100 x 50 mm timber studs on a plywood backing. Bitumen impregnated breather building paper was fixed to the studs and the panels laid over the building paper with lapped edges (20 mm) simulating a typical New Zealand house wall construction. At approximately three-monthly

Table 1. Properties of WBCs

Board	Thickness (mm)	Density (kg/m³)	Binder	Description
PB	20	730	UF	particleboard
MDF	18	725	UF	medium density fibreboard
HB1	9.5	990	Lignin	hardboard (Australia)
HB2	10-11*	930	Lignin	hardboard (USA)

*Has a wood grain textured surface.

Table 2. Paint Systems Used on WBCs

System	Description
A	no coating applied
B	acrylic primer on all faces, two coats of acrylic gloss on front surfaces and edges
C	as for B except two coats of acrylic gloss applied to rear surface in addition to primer
D	oil/alkyd primer on all faces, oil/alkyd undercoat and alkyd enamel on front surfaces and edges
E	oil/alkyd aluminium leaf primer on all faces, oil/alkyd undercoat and alkyd enamel on front surface and edges
F	high build acrylic mastic base coat applied to all surfaces and edges, acrylic undercoat and acrylic gloss topcoat applied to front surface and edges.

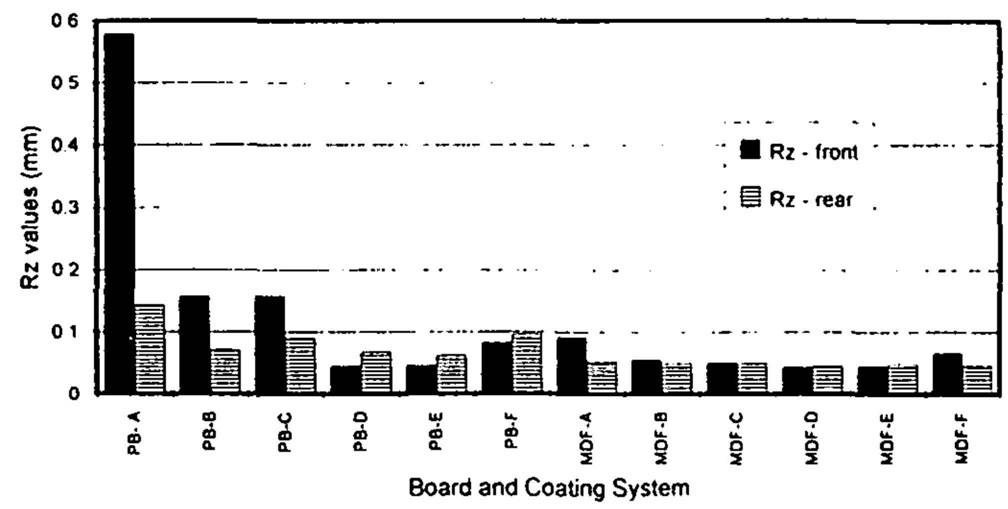

Figure 1. Surface Roughness Measurements (Rz) for PB and MDF.

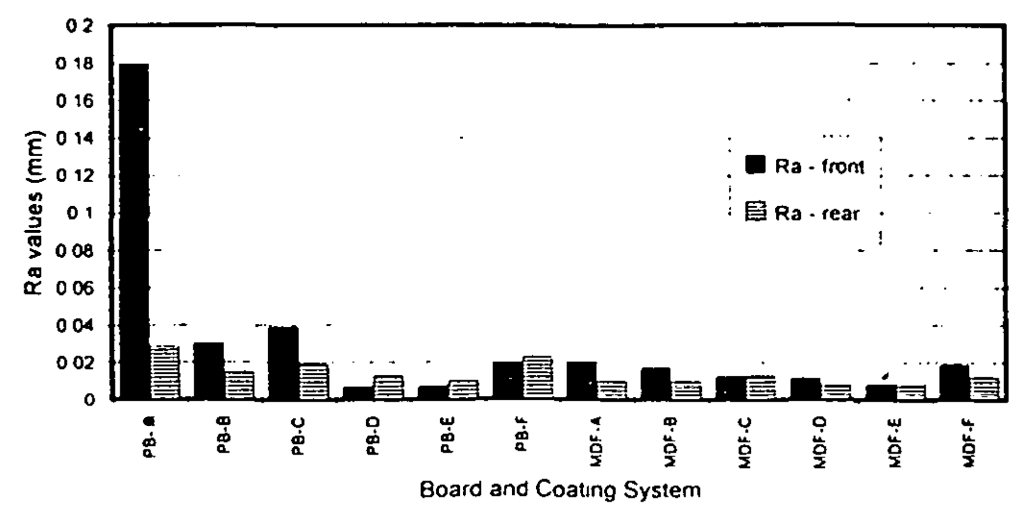

Figure 2. Surface Roughness Measurements (Ra) for PB and MDF.

intervals, readings were taken to determine panel weight and edge thickness. Thickness measurements were taken at four pre-marked points (two on the top edge and two on the bottom) using callipers.

After one year's exposure one set of samples from each paint system for PB and MDF were removed from the exposure site and conditioned at 20±2°C and 65±5% relative humidity until the weight change was less than 0.1% per 48 hours. One sample each (factory primed only) of boards HB1 and HB2 was retrieved and conditioned in the same manner. The remainder of the panels remained on the exposure site for testing at a future date.

2.3 Laboratory tests

Water Vapour Resistance

The water vapour flow resistance of the coating systems was determined using the wet cup method in general accordance with procedures B and BW of ASTM E96 (3). The test chamber was controlled at 25±1°C and the humidity maintained at 75% by saturated salt solution. Medium density fibreboard (5mm thick) was used as the substrate for the coatings which were as described in Table 2.

Surface Roughness

Surface roughness measurements were made on samples after one year's exposure using a Sangamo transducer mounted on a travelling platform. The transducer output was logged using a DAS 8 board with a PGA signal conditioning board and an IBM compatible 286 computer. The transducer was linked to a stylus with a 60 degree conical tip and 0.25mm flat end which travelled at a speed of 25mm/min. Approximately 1200 readings were taken over a 50mm line and the data treated as described by Östman (4) to produce values of R_z and R_a where R_z is an average of the maximum distance from the peak to valley over five 10mm intervals, and R_a is an arithmetic mean deviation calculated over the 50mm line.

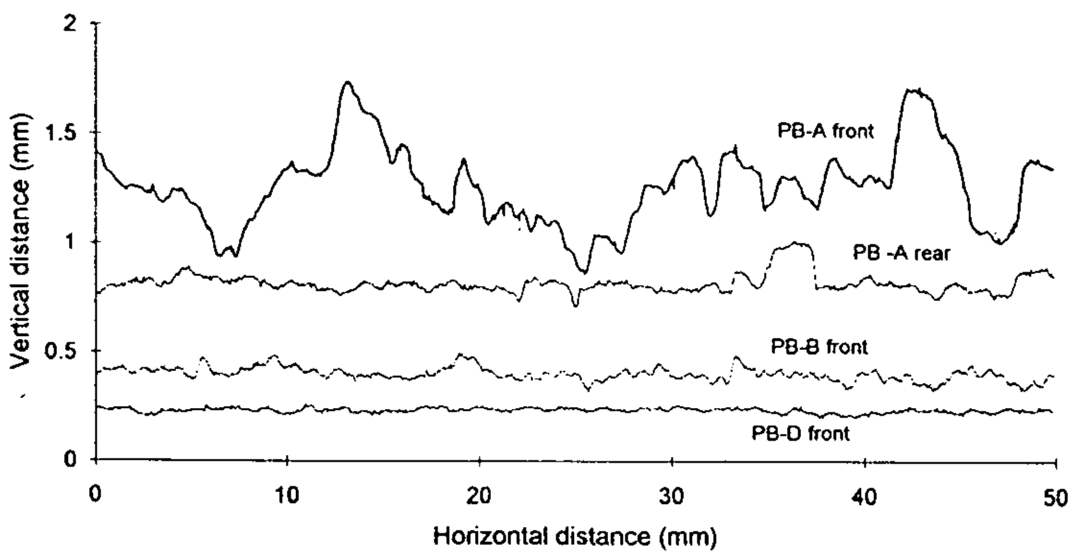

Figure 3. Surface Profile of PB after 12 Months Weathering.

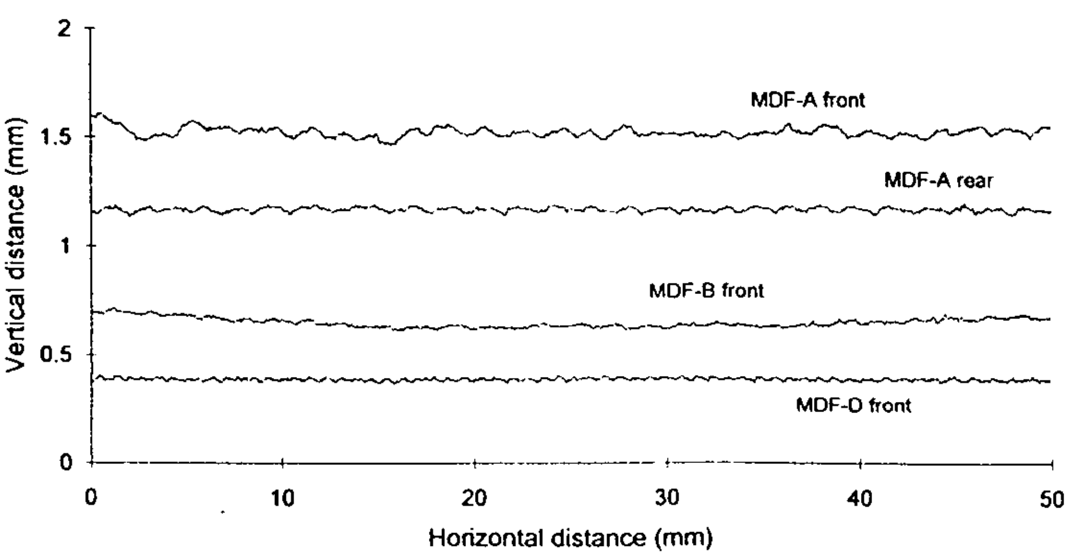

Figure 4. Surface Profile of MDF after 12 Months Weathering.

Mechanical Properties

Samples were conditioned to constant weight at 65±5% RH and 20±2°C then tested in general accordance with BS 5669 (5). The outer 10mm edge of each panel was cut off and discarded. The remainder was cut to yield 9 modulus of rupture (MOR) samples and 20 internal bond (IB) samples from each board. The tests were carried out on an Instron 6022 universal testing machine.

The modulus of elasticity (MOE) was calculated using the formula from BS 5669 (6) Section A6. The initial MOE testing of PB, MDF and HB2 control samples was carried out in general accordance with BS 5669:1989, but due to the size limitations of the exposed boards, the 1979 version of the standard was used from then on to achieve a reasonable sample number.

Internal Bond

Internal Bond Strength (IB) was determined in accordance with BS 5669(5):1989 Section A9 using aluminium blocks adapted for use with the Instron testing machine. Two-part epoxy adhesive was used to secure the samples to the aluminium blocks.

3. RESULTS

The panels were in good condition after twelve months' exposure apart from the uncoated PB and MDF samples. These panels showed considerable surface roughening and discoloration. The particleboard panels coated with paint systems B and C (conventional acrylics) had noticeable fibre swelling visible under the coating. Several particleboard panels coated with the alkyd gloss system had swelling visible in areas where the coating had been perforated. Coating system F, an experimental hi-build acrylic, exhibited crazing of the topcoat but was otherwise in good condition. The surface roughness measurements are summarised in Figures 1 and 2. The measurements confirm the visual observation that the uncoated and acrylic coated panels have greater fibre swelling than the alkyd and hi-build acrylic systems. Figures 3 and 4 show surface profiles for PB and MDF after 12 months' exposure for uncoated panels and the acrylic and the aluminium primer/enamel coated systems. The weight versus time plots for the exposed panels are summarised in Figure 5 and the edge thickness measurements in Figures 6 to 9. The uncoated panels for all four board types show variations in weight and thickness with a trend to increasing weight and bottom edge swelling after one year's exposure.

The results of the mechanical strength tests are summarised in Figure 10. Table 3 shows the results of the water vapour flow resistance tests. Table 4 shows the results of an analysis of variance of the mechanical strength data. Coating systems with the same value for MOR, MOE or IB in Table 4 have mean values that are not statistically different. For example for PB, the MOR values fall into three statistically different groups: (control, D and E), (B, C and F) and A.

4. DISCUSSION

After twelve months' exposure, little deterioration of the exposed panels was visible apart from the uncoated PB and MDF samples. The surface roughening and colour change seen with these samples is expected with interior grade UF bonded WBCs and is also observed on PB flooring exposed to the weather during house construction. The particleboard panels painted with paint systems B and C (conventional acrylics) had noticeable fibre swelling. Acrylic latex systems are known to be more water vapour permeable than oil/alkyd systems, but do not permit the passage of liquid water. The results in Table 3 show that the acrylic latex paint used in this study is approximately 11 times more water vapour permeable than the oil/alkyd paints used. The similarity between the wet cup and inverted wet cup (the cup is inverted so that the water sits on the paint film) vapour flow resistance, shows that the permeability is not changed by the presence of water on the paint film. The relatively high water vapour permeability of acrylic emulsion coatings is not generally a problem with timber and where it is a disadvantage it is, in most cases, outweighed by the good flexibility and weather resistance of these coatings. Wood composites (particularly UF bonded) are more water sensitive than timber as is shown by the results of the uncoated panels in this study. In New Zealand a maximum exposure time of two to three months for flooring particleboard is advised when building houses. During this time surface fibre swelling and edge swelling can occur. The surface deterioration is generally attributed to wood particle fibre swelling and some deterioration of the urea formaldehyde resin. A similar deterioration process occurs with MDF exposed to the weather. In addition to being sensitive to liquid water, WBCs are also affected by changes in moisture content caused by absorption of water vapour. Increasing moisture content results in a decrease in mechanical properties such as MOE and MOR and an increase in thickness swelling (6, 7). Only part of this decrease in physical strength properties is recovered when the composite is returned

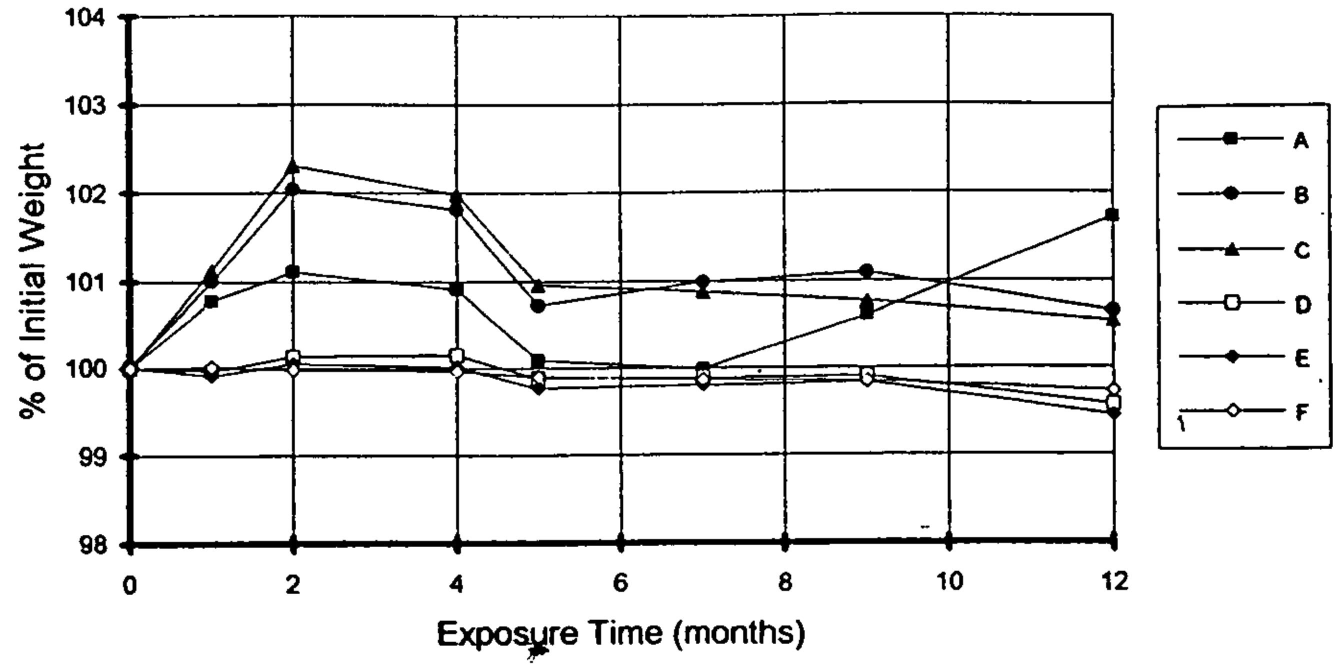

Figure 5a. Weight Change during exposure of PB.

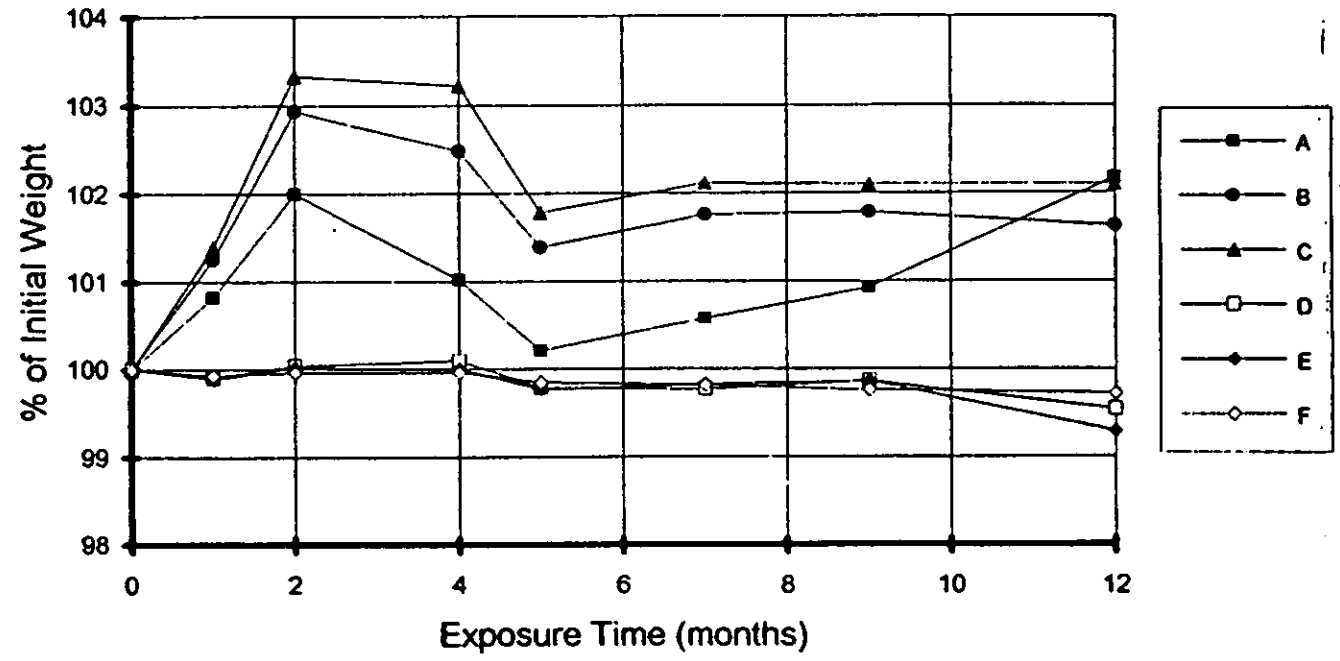

Figure 5b. Weight Change During Exposure of MDF.

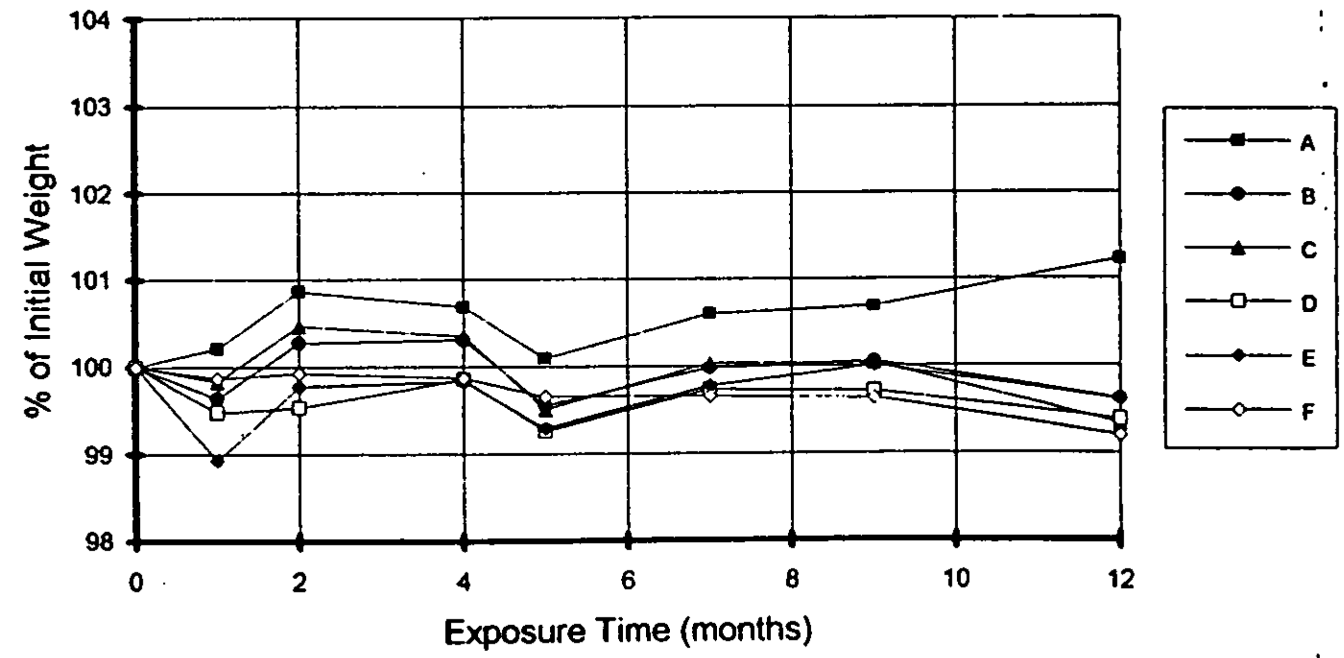

Figure 5c. Weight Change During Exposure of HB1.

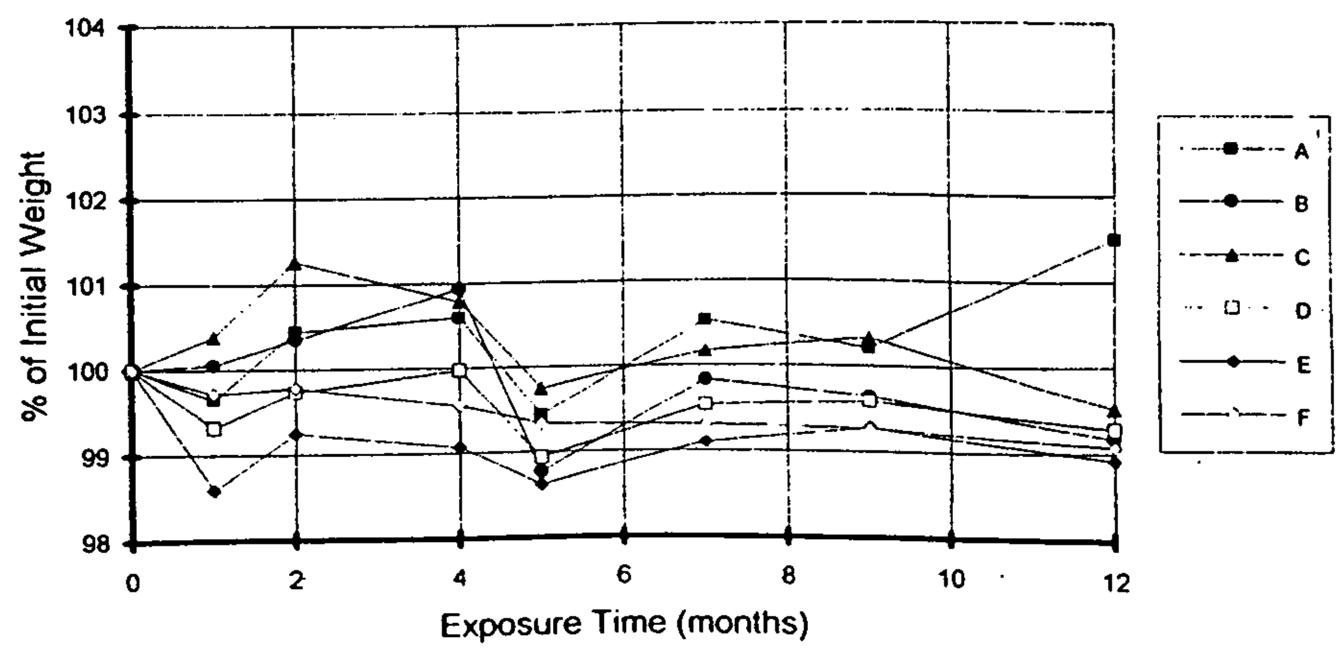

Figure 5d. Weight Change During Exposure of HB2.

to standard conditions (8). Much of the irreversible decrease in mechanical properties occurs during the first cycle of moisture content increase (9).

The fibre swelling observed on the panels coated with systems B and C was caused by an increase in the moisture content of the surface fibres. Swelling causes breakage of adhesive bonds between fibres and a release of compression set induced during pressing of WBCs. As a result, the swelling is partly irreversible when the WBC panels are re-conditioned back to their original moisture content.

The weight change data indicated a similar trend, with the acrylic latex coating systems and the uncoated panel showing greater variations in weight and larger weight gains. For all four wood composites there was little difference in the weight change data between the uncoated panels and the panels coated with the acrylic systems until after about ten months' exposure. At this point, the uncoated panels started showing an upward trend in weight gain. The edge thickness measurements for the bottom edges of the uncoated panels also showed an increase in the rate of edge swelling after 10 months' exposure for three of the panels (PB, MDF and HB2). No cracking was observed on the edges of the coated PB and MDF boards but cracking was present on the edges of the two factory primed hardboard panels.

The mechanical properties of the panels were relatively unaffected by twelve

Table 3. Wet-Cup Water Vapour Flow Resistance

Paint System	Vapour Flow Resistance (MNg/s) inverted wet cup	wet cup
A	0.07	0.65
B&C	0.63	0.67
D	7.8	8.5
E	9.1	10.3
F	19.5	64.7

Table 4. Analysis of Variance of Mechanical Test Results (Waller grouping from GLM analysis)

WBC	Coating system	MOR	MOE	IB
	control	1	1	2
	A	3	3	1
PB	B	2	2	1
	C	2	2	1
	D	1	1	1,2
	E	1	1	2
	F	2	2	1
	control	2	2	1,2
	A	5	6	4
	B	4	4	2,3
MDF	C	4	5	4
	D	1,2	1	2,3
	E	1	1	3
	F	3	3	1

Systems with different numbers have different means (at 95% confidence level). E.g. for PB MOR values, the control, D and E are not statistically different.

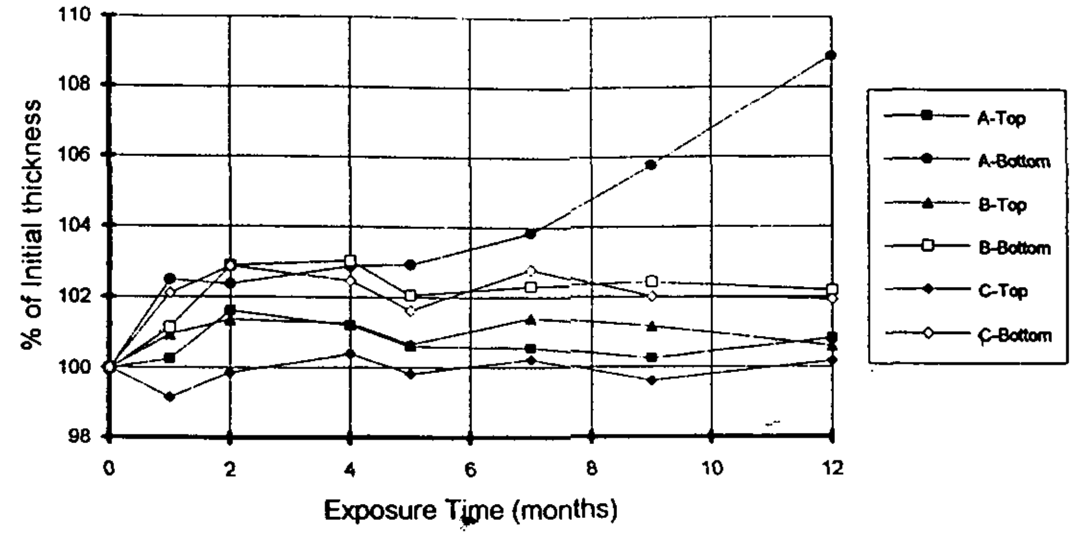

Figure 6a. Edge Thickness Swell with Weathering for PB.

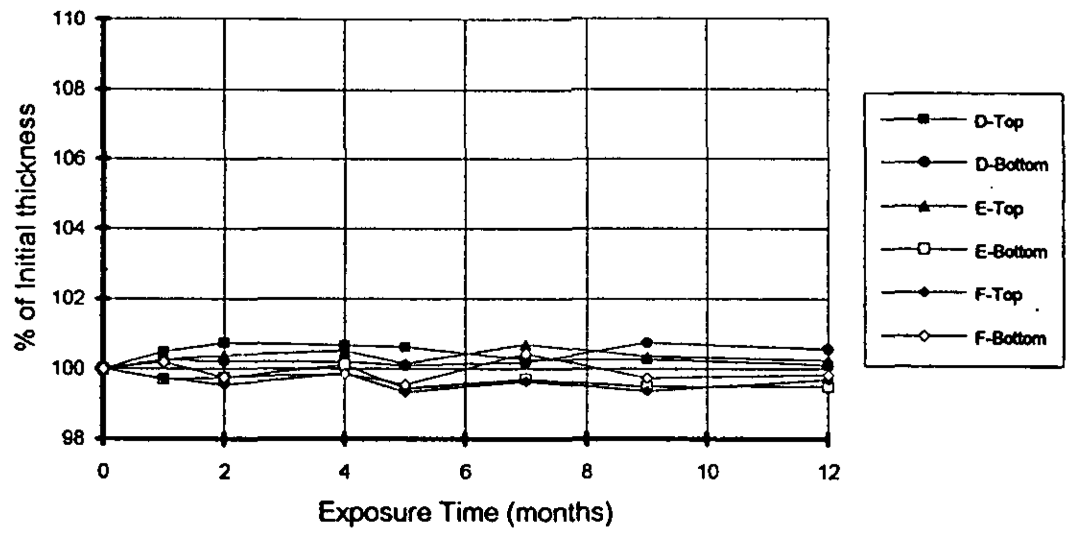

Figure 6b. Edge Thickness Swell with Weathering for PB.

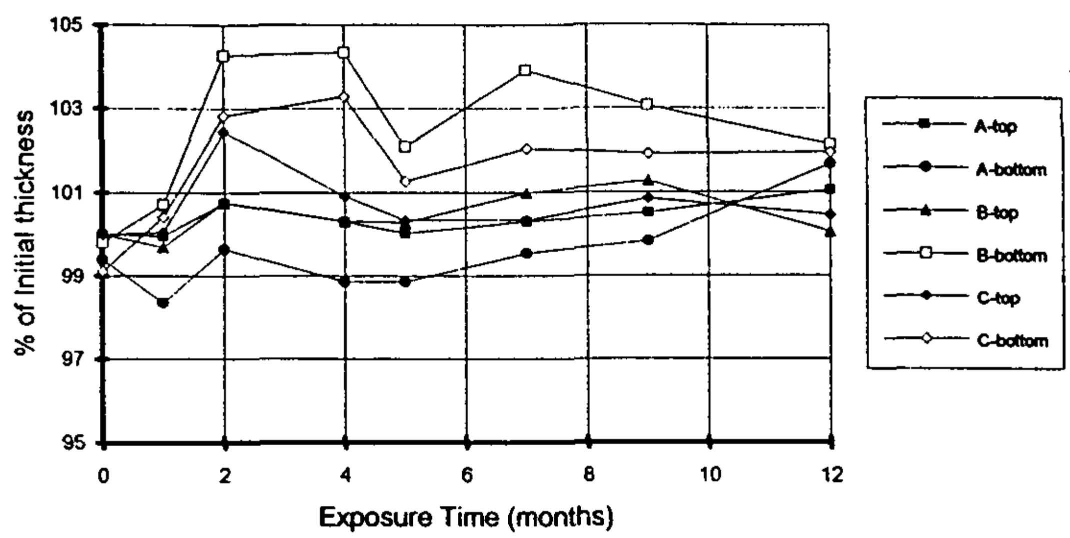

Figure 7a. Edge Thickness Swell with Weathering for MDF.

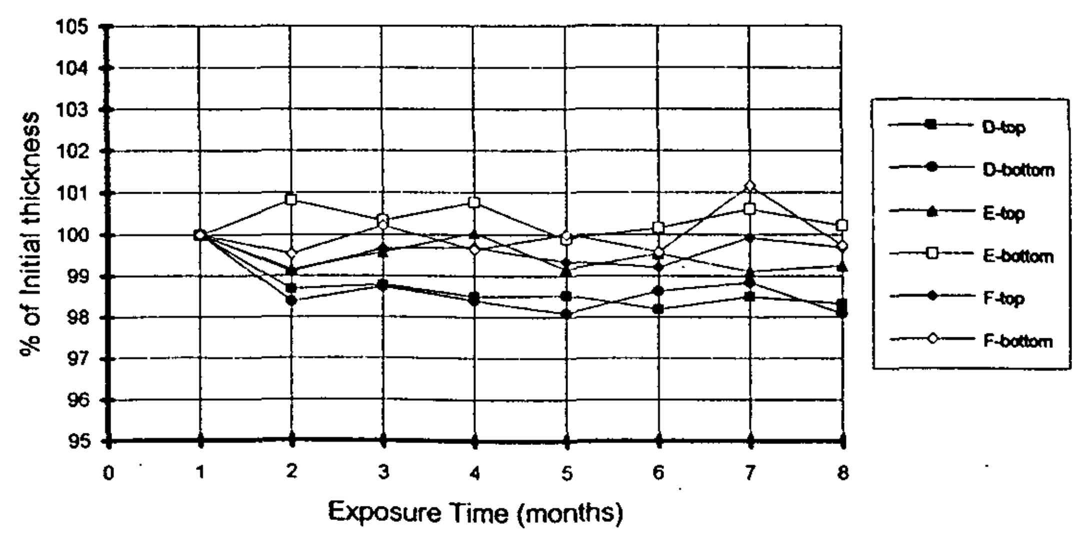

Figure 7b. Edge Thickness Swell with Weathering for MDF.

months' exposure but statistically significant (at the 95% confidence level) differences between the mean MOR, MOE and IB values were observed (Table 4) when an analysis of variance was carried out using a general linear model (10). The uncoated exposed panels of both PB and MDF had lower values (95% level) for both MOR and MOE than all the coated panels. The panels coated with systems B and C (acrylic latex) were below the values for all systems except A (uncoated). System F (hi-build acrylic) had higher MOR and MOE values than systems B and C but was lower than the controls and the oil/alkyd systems D and E. Significant differences were also observed in the results of internal bond testing, but the trends were different than for MOR and MOE. For PB, significant increases in strength were observed with systems A, B, C and F compared to the control and systems D and E. For MDF, systems A and C were lowest and system F highest.

Watkinson and van Gosliga (6) reported the results of mechanical strength tests on the same commercial brands of PB and MDF material as used in this study. These workers found that IB was relatively unaffected by the moisture content of these composites over the moisture content range of 6-13% for PB and for 6-10% for MDF. The MOR values for PB were unaffected over the moisture content range 7-12% whereas for MDF, they were found to vary over the full range of moisture contents tested. The weight versus time data in Figure 5 of this paper suggests that the moisture content of the panels (averaged through the panel) has remained in the approximate range of 10.5-12%. MOE and (to a lesser extent MOR) would therefore be expected to be a more sensitive indicator of differences between PB and MDF coated with the different coating systems than the IB tests. This is shown to some degree in the results in Table 4.

The results for system F (hi-build acrylic) are less clear. This sytem had the highest water vapour resistance and showed similar (very small) weight and thickness changes to the panels coated with systems D and E. The MOR and MOE values however, were similar to the panels coated with systems B and C. The experimental topcoat of system F had crazed on exposure but the thicker base coats appeared intact. Two possible explanations are: that the water vapour resistance of the system had decreased dramatically on exposure or, that the decrease in MOR and MOE were caused by absorption of water when the hi-build coating was initially applied. If the latter explanation is correct then the mechanical strength properties should show little decrease during the next two years' exposure.

Carll (1) reported results from outdoor exposure trials of UF bonded particleboard samples painted with a range of coating systems. A system consisting of a water repellent, oil/alkyd primer with aluminium flake pigment and two coats of acrylic-latex paint performed better than all acrylic systems and oil or acrylic stains. However, after

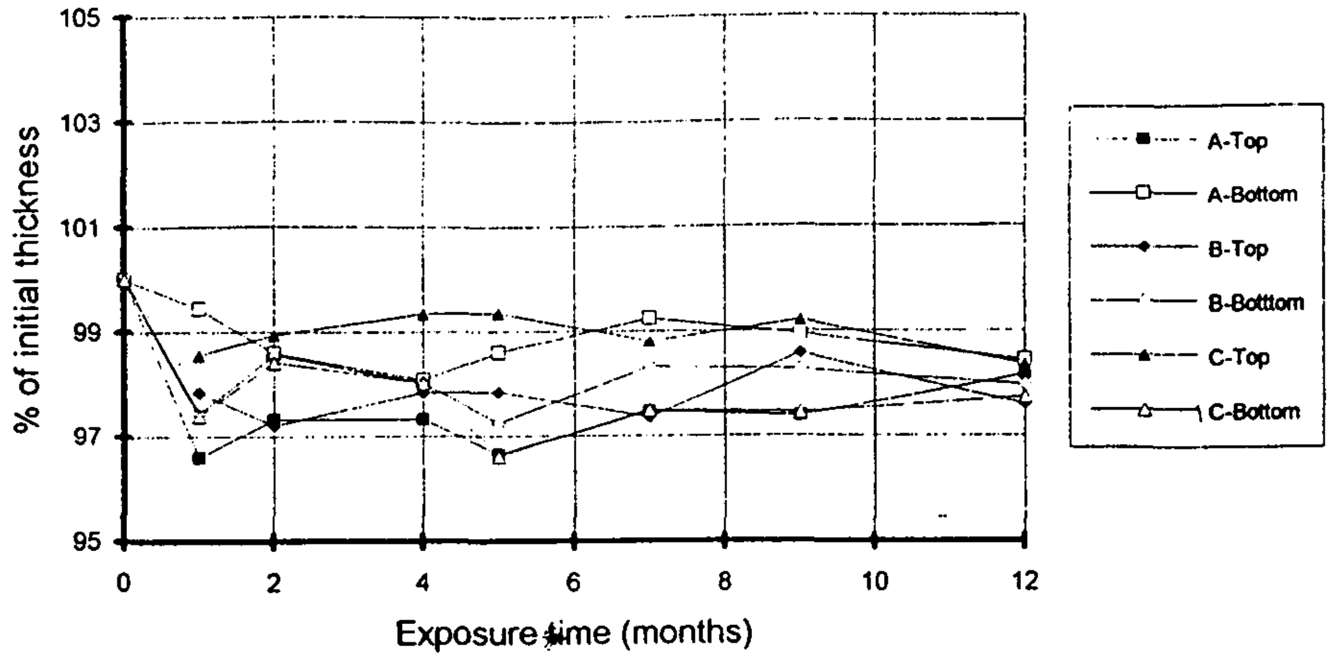

Figure 8a. Edge Thickness Swell with Weathering for HB1.

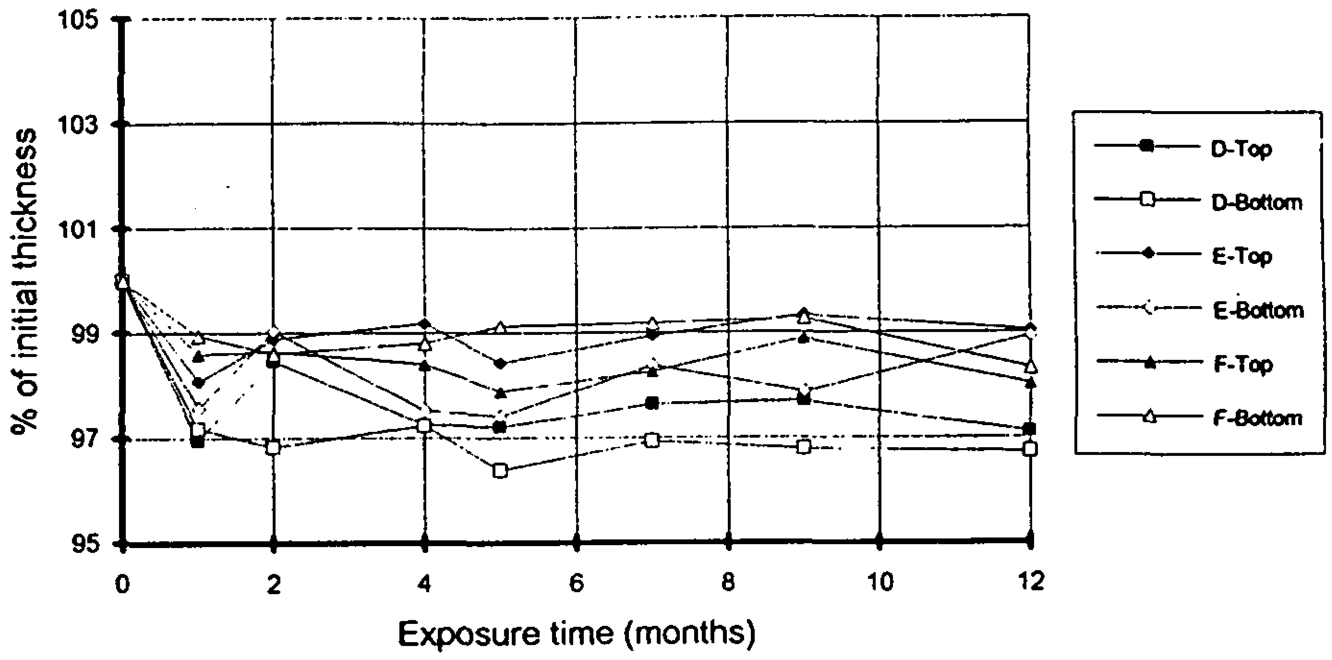

Figure 8b. Edge Thickness Swell with Weathering for HB1.

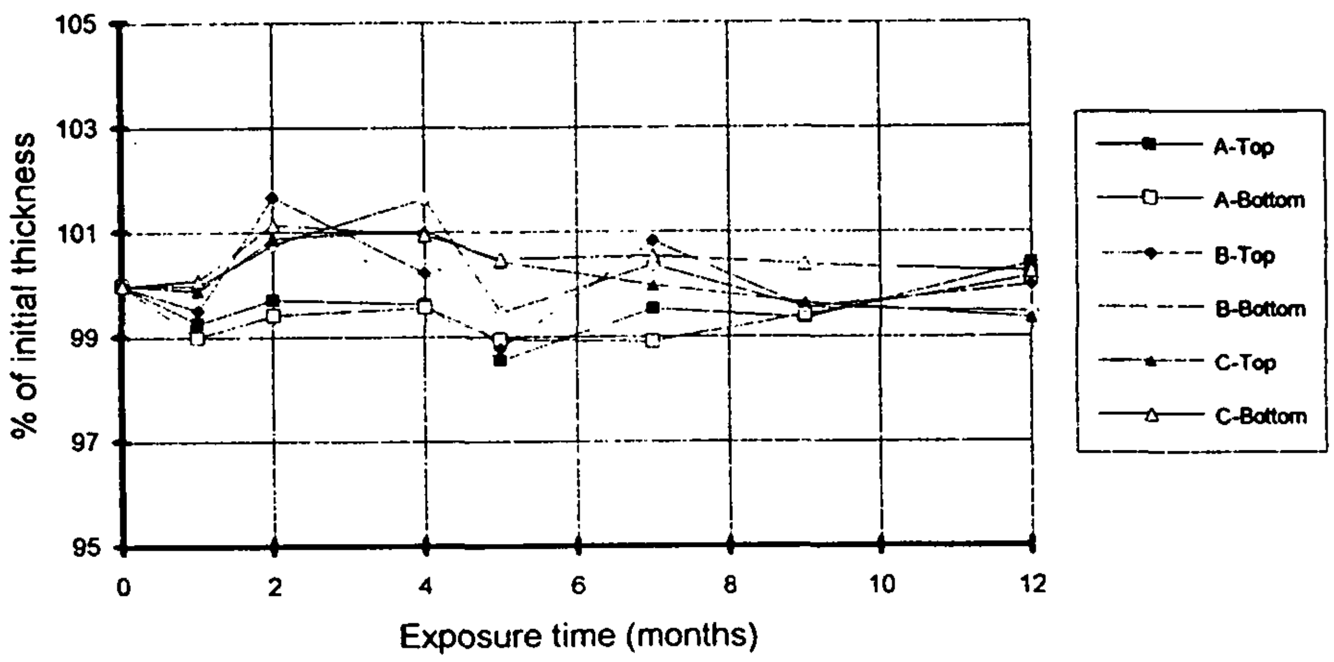

Figure 9a. Edge Thickness Swell with Weathering for HB2.

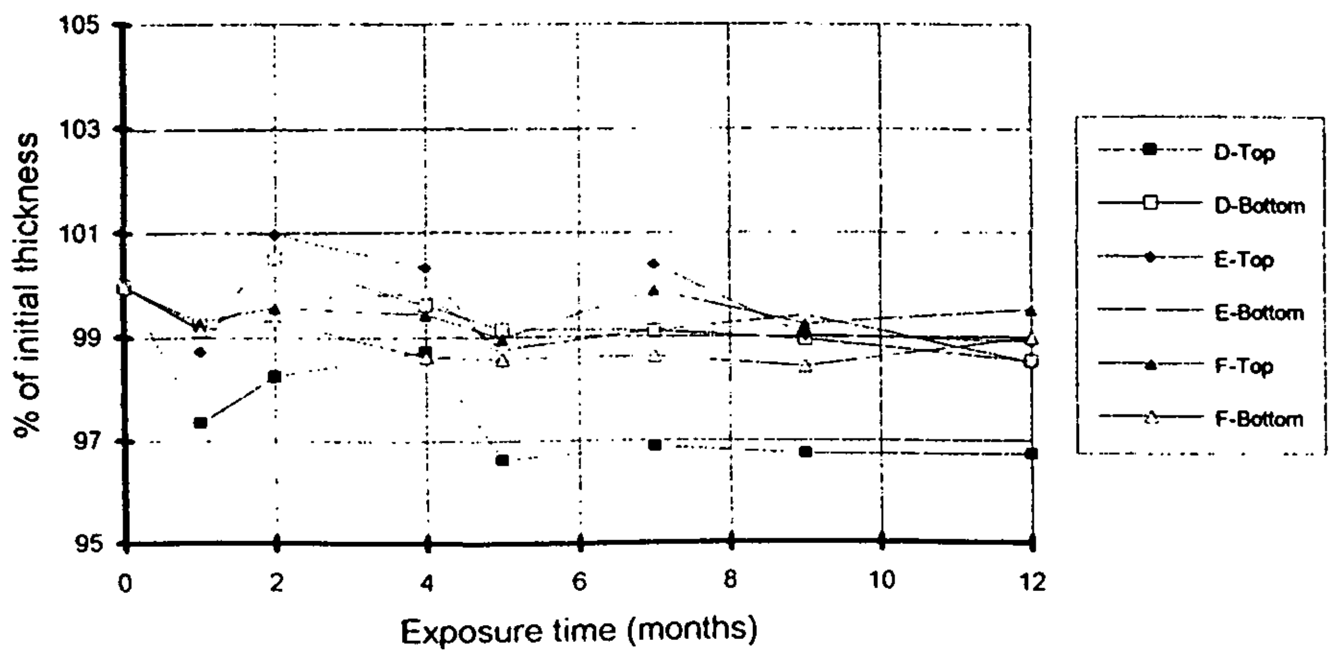

Figure 9b. Edge Thickness Swell with Weathering for HB2.

three years' exposure, none of the systems tested were free of deterioration. In the study reported here, the edges of the panels were rounded and protected with coal tar epoxy so that deterioration may not have been as rapid. Three-coat oil/alkyd system and hi-build acrylic systems were not tested by Carll, but his results are consistent with those reported here, in that coating systems need both liquid water and water vapour resistance to obtain optimum performance of UF bonded composites.

The exterior grade cladding materials, HBl and HB2, showed similar weight change trends to the PB and MDF samples but much reduced edge swelling and surface roughness. This type of product is generally expected to last at least 15 years in the New Zealand environment. After 12 months, exposure the MOR, MOE and IB of the primed only samples had decreased compared to the controls. The decrease in MOR and MOE was statistically significant (at the 95% level) for HB2 but not for HBl. The IB value for both HBl and HB2 had decreased significantly (95% level). Further testing of the coated samples will be carried out at a future date to determine whether the hardboard materials show similar performance trends with the different coating systems to those shown by PB and MDF.

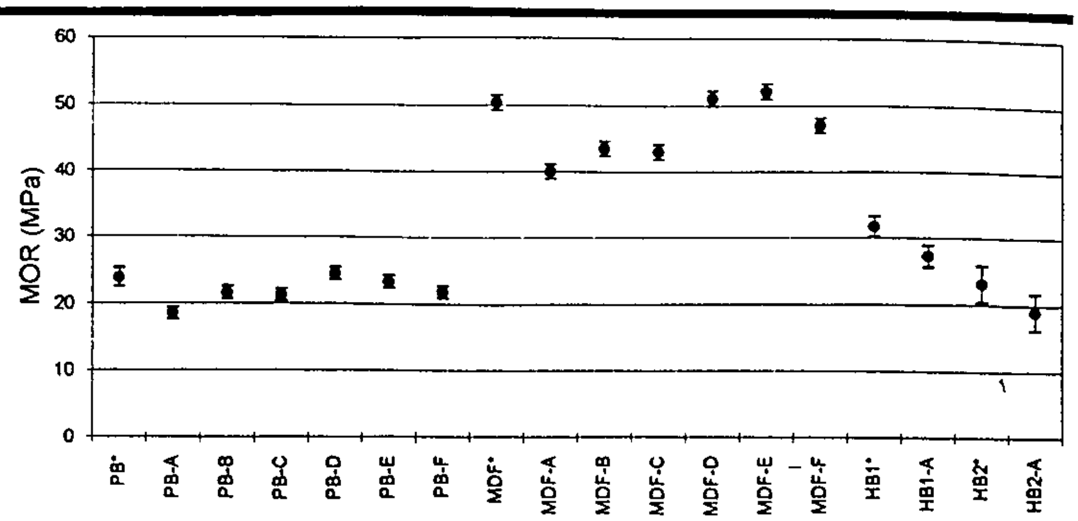

Figure 10a. Results of MOE testing (mean with 95% confidence levels)

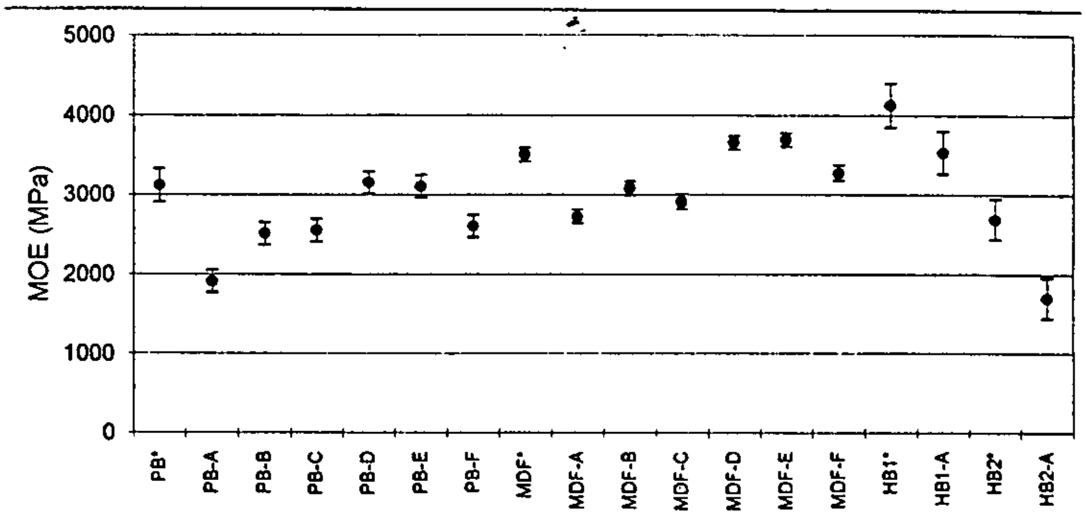

Figure 10b. Results of MOR testing (mean with 95% confidence levels).

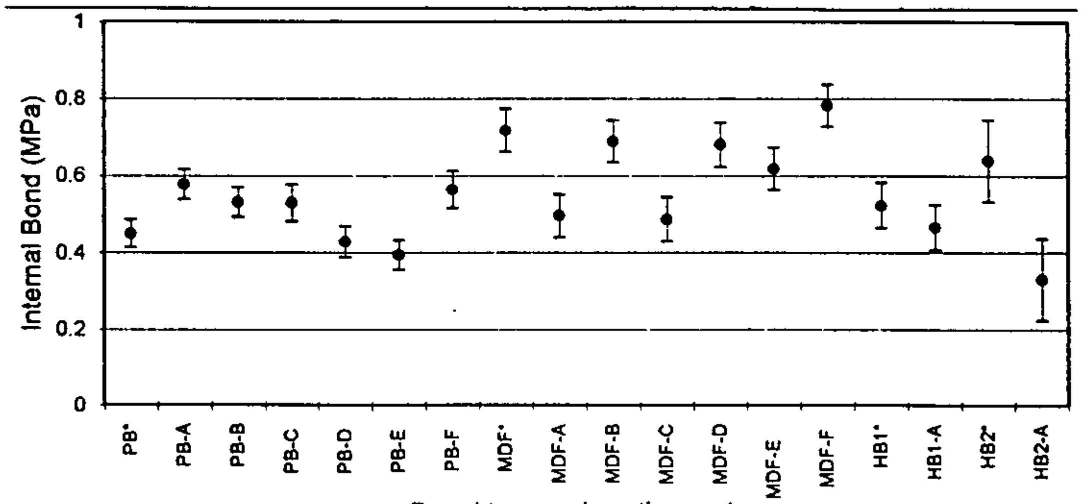

Figure 10c. Results of Internal Bond Tests (mean with 95% confidence levels).

5. CONCLUSIONS

The acrylic paint systems B and C offer less protection for particleboard and medium density fibreboard over short-term exterior exposure than D and E (oil/alkyds) and F (a hi-build acrylic). The main reason for this is believed to be the higher water vapour permeability of the paint which allows more rapid and extensive moisture changes in the composite panels. These moisture content changes lead to reductions in mechanical properties and swelling of surface fibres of the composites. The systems D and E, which have a higher water vapour resistance have provided greater protection. System F, a hi-build acrylic system, has proved excellent at minimising edge swell, weight gain and surface roughness, but decreases in MOR and MOE were observed after 12 months' outdoor exposure. Further testing will be required to determine whether these decreases are due to deterioration of the coating or are caused by the water introduced during application of the coating.

The optimum system for minimising deterioration in WBC mechanical properties, appears to be one which offers good moisture vapour barrier properties and good durability when exposed to the weather. A combination of a primer with a low moisture vapour permeability and two coats of acrylic topcoat would appear to meet these requirements. The swelling observed in areas of localised coating damage on the panels coated with oil/alkyd systems points toward a requirement for more strict coating maintenance schedules with composite wood board claddings than with timber claddings.

REFERENCES

1. *Carll, Charles G. 1988. Delamination rate of acrylic-latex finished urea-bonded particleboard in short term exposure. United States Department of Agriculture, Forest Prodücts Laboratory Research Note FPL-RN-0255. Madison.*
2. *Bussjaeger, Steve and Haines, Roger E. 1989. Performance of exterior flat finishes on medium density hardboard siding. Journal of Coatings Technology, Vol. 61, No.771, pp 39-42. April. Philadelphia.*
3. *American Society for Testing and Matérials. 1980. Standard test methods for water vapour transmission of materials. ASTM E 96. Philadelphia.*
4. *Östman, Birgit A. 1983. Surface roughness of wood-based panels after aging. Forest Products Journal Vol. 33 No. 7/8. pp 35-42. Madison.*
5. *British Standards Institution. 1979 and 1989. Specification for wood chipboard and methods of test for particleboard. BS 5669. London.*
6. *Watkinson, P.J. and van Gosliga, N.L. 1990. Effect of humidity on physical and mechanical properties of New Zealand wood composites. Forest Products Journal Vol. 40, No. 7/8. pp 15-20. Madison.*
7. *Halligan, A.F. and Schniewind, A.P. 1974. Prediction of particleboard mechanical properties at various moisture contents. Wood Science and Technology 8: pp 68-78.*
8. *McNatt, Dobbin J. 1984. How cyclic humidity affects static bending and dimensional properties of some wood-base panel products. In: Price, Eddie W., ed. Proceedings of a workshop on the Durability of Structural Panels; 1982, October 5-7; Pensacola, FL. Gen Tech Report. SO-53. New Orleans, LA: USA Department of Agriculture, Forest Service. pp 67-76.*

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