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The Effect of Coatings on Wood Composite Siding Performance

Adrian F. Bennett

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Preface

This report describes the results at completion of a project set up to look at the effect of coating type on the performance of hardboard sidings.

Acknowledgments

This work was carried out with assistance from the Public Good Science Fund of the Foundation for Research, Science and Technology and the Building Research Levy. The assistance of N.J. Kell in carrying out test work is acknowledged.

Note

This report is intended for those involved in the manufacture, coating and maintenance of hardboard cladding panels.

THE EFFECT OF COATINGS ON WOOD COMPOSITE SIDING PERFORMANCE

BRANZ Study Report SR 84 **A F Bennett**

REFERENCE

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KEYWORDS

Hardboard, Siding, Cladding, Painting, Weathering, Exposure, Properties.

ABSTRACT

This project was set up to investigate the effects of different coating types on the performance of hardboard sidings. Problems experienced in the 1980s with a New Zealand-produced product indicated that moisture entry was a key factor in the deterioration of these products. Coatings play an important role in controlling the up-take and release of moisture in wood-based materials. With the introduction of imported hardboard cladding materials into the New Zealand market, further information on the effectiveness of different coating types was felt necessary.

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1. INTRODUCTION

Hardboard has become a widely and successfully used material since its invention in 1924. Its use as an exterior cladding material began in the early 1960s (Reith, 1987). Since then hardboard sidings have become one of the major cladding materials used in the USA with Reith (1987) stating that it had a 21% share (over 1 billion square feet) in 1985.

Hardboard is a medium to high density fibreboard which is pressed at high temperatures and pressures, utilising lignin as the binder. It can be manufactured with a smooth or textured surface which accepts paint well and comes in differing widths and lengths. The thickness of common claddings is 10-11 mm with typical densities of 800-1100 kg/m^3.

Hardboard siding was manufactured and marketed in New Zealand during the late 1970s and through the 1980s. Shipments of product imported from the USA were also landed during this time and Australian material was marketed in New Zealand from the late 1980s. Media reports of problems with some sidings surfaced in the mid 1980s and it became clear that performance in some cases was less than expected. A range of symptoms were reported concerning board failure, including softness, swelling, paint problems and edge cracking. The New Zealand produced board was withdrawn some time later.

Hardboard generally has a reasonable durability compared with other wood composites, but this can vary depending on the manufacturing process used, source of fibre, coating system and climate. Marck (1974) reports that guarantees given by USA suppliers ranged from five years, but were commonly from 15 years to the life of the building. Given that the basic properties of the hardboard are set during manufacture, this study investigates whether the choice of coating used on a hardboard cladding significantly affects the service life. In particular, whether the improved flexibility and durability of acrylic systems outweighs the superior water vapour resistance of alkyd systems.

2. METHODOLOGY

2.1 Materials

Samples of two wood composite sidings for exterior use were obtained, one from Australia and the other from the USA. The Australian product was smooth finished and the USA product had an embossed surface simulating rough sawn timber. Both panels were factory primed. The board properties are shown in Table 1.

2.2 Outdoor Exposure

The two hardboards were purchased in weatherboard profiles and cut to lengths of 1220 mm. HB1 had a width of 297 mm and HB2 a width of 303 mm. Two panels of each board type were coated with each of the paint systems described in Table 2. Factory primed-only controls, which are the same as system A, were stored indoors at 65±5% RH and 20±2°C. The coatings were applied by brush according to the coating manufacturers' instructions. The ends of panels were sealed with coal tar epoxy paint.

Natural weathering of the panels was carried out on the BRANZ exposure site, located in a rural area at Judgeford 27 km north-east 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. The panels were restrained by means of a scriber board fitted at each end to avoid fixings penetrating the coatings. At approximately three-monthly intervals, readings were taken to determine panel weight and edge thickness. Thickness measurements were taken at four pre-marked points on each panel (two on the top edge and two on the bottom) using callipers.

After one year's exposure, one sample each (factory primed only) of HB1 and HB2 were retrieved for testing. After three years one set of the hardboard sidings (minus system A) were removed for testing. The remaining hardboard samples were removed for testing after a total of seven years exposure.

2.3 Laboratory tests

Mechanical Properties

Samples were conditioned to constant weight at 65±5% RH and 20±2°C. The outer 10 mm 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) and modulus of rupture (MOR) were calculated using the formula from BS 1142 (BSI, 1989) but due to the size limitations of the exposed panels, the span was set at 16T for testing of exposed panels to achieve a reasonable sample number. Changes in span are accounted for in the MOE and MOR formulae and under ideal conditions will result in no change to the calculated results. In practice, as the span is reduced beyond a minimum value, crushing of the sample and shear stresses can be introduced. The span of 16T used in this case is typical of the minimum (King, 1995) used for timber, and should introduce little variation into the results.

Internal Bond

Internal bond strength (IB) was determined in accordance with BS 1142:1989 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.

2.4 Statistical Analysis

Statistical analysis of the MOR, MOE and IB test results was carried out using Statistica for Windows (Statsoft 1997). An analysis of variance technique (ANOVA) was used to determine whether differences observed within the same hardboard with differing coatings and exposure were significant.

3. RESULTS

The hardboard panels were generally in reasonable condition after the seven years exposure, with no major board deterioration visible. Some paint loss occurred, with the primed-only panels losing approximately 50% of the primer from the exposed surfaces. The loss of primer had had little visible effect on the condition of HB1 (Photograph 1) but HB2 had developed cracking and softening of the lower edge (Photograph 2).

Systems B and C (conventional acrylics) were in good overall condition, with minor chalking and some areas of cracking and blistering starting to become evident on the edges of the raised texture on the surface of HB2. HB1 B had developed edge cracking along approximately 30% of the bottom edge (Photograph 3).

The alkyd system D showed more deterioration than E with HB1 D showing edge cracking and loss of paint over 50% of its length (Photograph 4). HB2 D had only minor edge cracking visible but approximately 20% of the front surface had flaking topcoat (Photograph 5). HB1 E had only minor edge cracking visible (Photograph 6) and HB2 E had only minor localised edge swelling.

Coating system F was an experimental three-coat high-build acrylic which did not weather as well as was expected. The top coat developed crazing within the first year of exposure and areas where the paint had flaked were visible after seven years (Photograph 7).

The results of monitoring weight change and edge thickness swell for the four composite materials with each coating system are shown in Figures 1-12. Apart from thickness swell on the bottom edge of Hardboard 2 coated with only the factory primer (up to 40%), relatively little change was observed for either of the two hardboards with the various coating systems. Those panels which exhibited higher than average edge swell were HB1 B, HB1 D and both HB1 and HB2 with system F. Weight change was minimal for all panels even when edge damage had occurred during the exposure.

The effects of weathering on MOR are shown in Figures 13-14, MOE in Figures 15-16 and IB in Figures 17-18. HB1 showed less change in mechanical properties over the seven-year period than HB2. For HB1, decreases in MOR compared to the control panel were observed for systems A, B and D after seven years. While the decreases were small (8-12%), they were significant at the 95% confidence level. Decreases in MOE were observed for all HB1 systems compared to the control but only systems A, B and F were significantly lower at the 95% level. Only HB1 systems A (decrease) and F (increase) had significant changes in IB.

The MOR values after seven years for HB2 showed a statistically significant decrease for system A only. MOE however, had decreased for systems A, D and F (significant at the 95% level). Significant IB decreases were recorded for A, C, D and F.

The results of MOR, MOE and IB testing after one year (system A) and three years exposure (systems B-F) are also shown in Figures 13-18. The results show decreases in physical properties for some hardboard/paint system combinations and increases for others. These differences are difficult to explain given that the increased number of moisture cycles the panels have been exposed to after seven years could be expected to have a cumulative deleterious effect, resulting in generally lower values after seven years compared with three years exposure. The moisture content of wood composites can have a large effect on the physical properties of wood composite products (Watkinson and van Gosliga, 1990). While all panels were conditioned before testing at 65% RH and 20 °C until they were at constant weight (< 0.1% weight change per 24 hours), the presence of the different coatings may have slowed the rate of moisture change sufficiently so that moisture variations occurred. Another possible reason for the differences is inter-panel variation. Due to the limited number of panels available for this study, the control and coated panels were drawn randomly from the short lengths of material provided. At the inception of this project, the degree of inter-panel variation was expected to be outweighed by the degradation induced over seven years outdoor exposure.

4. DISCUSSION

The performance observed over seven years exposure of the two hardboards, appears to be influenced predominantly by the durability of each hardboard and the condition of the exposed drip edge rather than the type of coating system. HB1 showed good performance when exposed coated with only the factory primer. Not surprisingly, the coated panels also performed well. The bottom edge of hardboard sidings has long been recognised as the point at which failure is likely to start (Marck, 1974). After rain and heavy dew, drops of water hang on the bottom edge of horizontal cladding materials. The gap between siding panels where they overlap in the horizontal plane, is small and likely to encourage the retention of water by capillary action. Thus both the bottom edge and lower portion of the rear surface will be wet longer than the front surface. Moisture changes in wood-based products induce thickness change, some of which is irreversible. Once cracks develop, absorption of liquid water will be rapid leading to further deterioration. Most film-forming paint coatings dramatically reduce the passage of liquid water but still allow the flow of water vapour. Once cracks in the bottom edge have caused rupture of the coating, absorption of water is likely to be as rapid as on uncoated boards. The presence of the coating however, will slow the drying process leading to increased swelling. This was observed during this study where bottom edge swell was in fact worse on three of the top-coated panels (two acrylic, one alkyd) than the factory primed-only panel.

The edges of the panels were removed during the preparation of MOR, MOE and IB test specimens, so the effects of minor swelling have not had a significant impact on the results. The exception was HB2 coated with only the factory primer. The degree of edge swelling on this panel was approaching 50% and softening was detectable. Significant decreases in IB (78%), MOR (52%) and MOE (33%) were recorded on this panel. HB2 coated with system F also exhibited edge cracking and recorded decreases in MOR, MOE and IB.

Thickness swell is an indicator of the likely performance of wood composite cladding used in exterior applications (Carll, 1997). Factors which influence edge swell include; fibre source, size and orientation, resin types and loadings, presence of wax additives fibre source, size and orientation, resin types and loadings, presence of wax additives and differences in the manufacturing process (e.g. wet or dry mat formation). Carll (1997) has published a review of some reports in this area. The properties (including thickness swell) of commercial hardboards in the USA have been reported to vary (Biblis 1989, McNatt and Myers 1993). It is not surprising therefore, that significant differences in performance between the two hardboards were observed over seven years of weathering.

A number of researchers have reported the results of similar studies with different types of wood composite. Carll (1988) 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 (1989) reported that acrylic latex systems performed better than oil/alkyd systems on hardboard (HB) sidings. Smith and Paxton (1981) reported the results of outdoor exposure testing of a range of commercial fibreboards. Standard and oil-tempered hardboards were included, along with low and medium density boards (assumed to be mainly lignin bonded). Panels coated with alkyd or vinyl paint both provided good protection for five years with a high level of retention of mechanical properties. A chlorinated rubber coating proved slightly better whereas a textured acrylic system provided significantly less protection. Smith and Paxton (1981) suggested re-coating for both the alkyd and vinyl painted panels would have been appropriate after five years exposure.

The results reported in this study show no consistent differences between the different coating systems apart from system F (which deteriorated rapidly). After seven years exposure, most deterioration has occurred at the bottom edge where cracking and paint loss has occurred. Maintenance (or lack of) of the coating system, particularly on the bottom edge, has proved more important than whether an alkyd or acrylic system is selected. The condition of the paint system on the front surface of the panels after seven years was good and maintenance based on this would be appropriate within the next 1-3 years. The bottom edge condition however, indicates that for optimal panel performance, edge re-coating should have been carried out after approximately five years exposure.

As with all timber-based products, achieving a satisfactory film build is also essential. All systems used in this study have been a minimum of three coats. Feist (1982) reported results of weathering studies on a range of timber and timber-based products including hardboard. He concluded that two- and three-coat systems were far superior to single coat products such as latex stains.

5. CONCLUSION

The performance of coated hardboard cladding is predominantly influenced by the composition of the hardboard itself. Both alkyd and acrylic paint systems can provide adequate weather protection for hardboard cladding materials. The key to performance is to ensure that a three coat system is specified and that the bottom edges of the panels are maintained by cleaning and re-painting to prevent edge swelling and softening of the panel. The required maintenance interval will vary depending on the composition of the hardboard, the exposure location and type of coating system. However, maintenance of the bottom edge is likely to be required several years before the front face shows obvious deterioration.

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Table 1: Properties of Hardboard Claddings

Board	Thickness (mm)	Density (kg/m^3)	Description
HB1	9.5	990	hardboard Australia)
HB2	10-11*	930	hardboard (USA)

* Has a wood grain textured surface

Table 2: Paint Systems Used on Exterior Sidings

System	Description
A	factory primed only
B	factory primed plus additional acrylic primer and 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	factory primed plus additional oil/alkyd primer on all faces, oil/alkyd undercoat and alkyd enamel on front surfaces and edges
E	factory primed plus additional oil/alkyd aluminium leaf primer and oil/alkyd undercoat and alkyd enamel on front surface and edges
F	factory primed plus additional 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. HB1 System A - Physical Properties vs Exposure Time

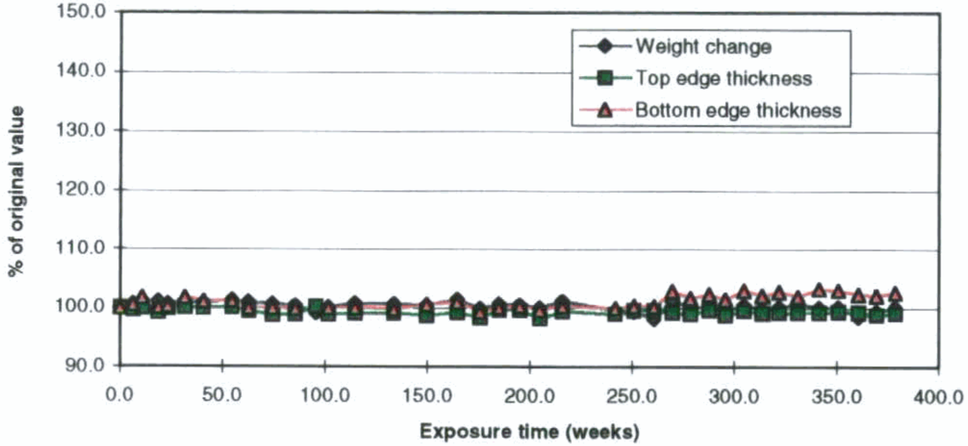


Figure 2. HB-2 System A - Physical Properties vs Exposure Time

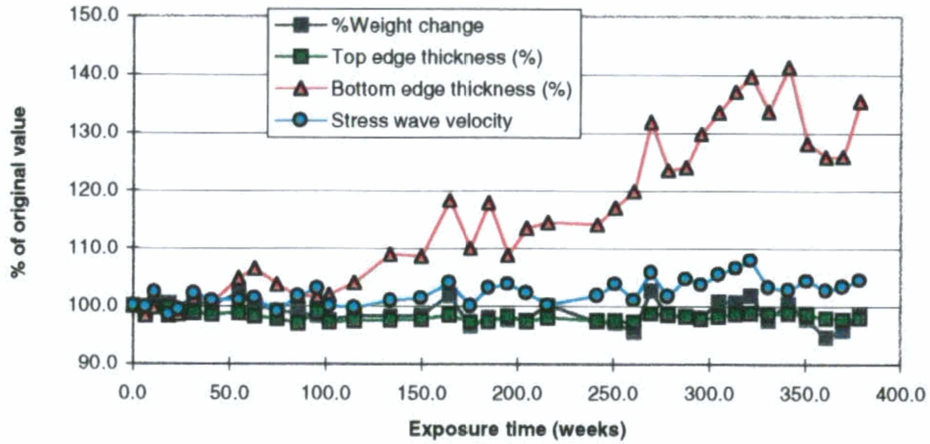


Figure 3. HB1 System B - Physical Properties vs Exposure Time

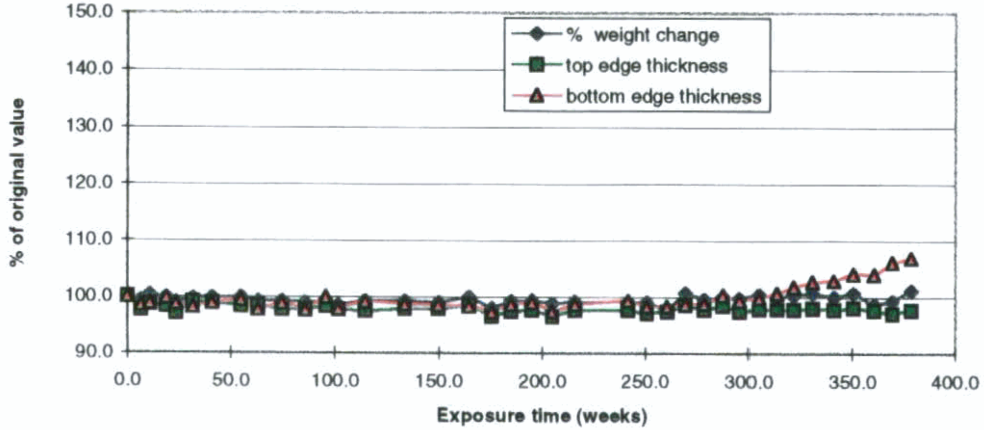


Figure 4. HB2 System B - Physical Properties vs Exposure Time

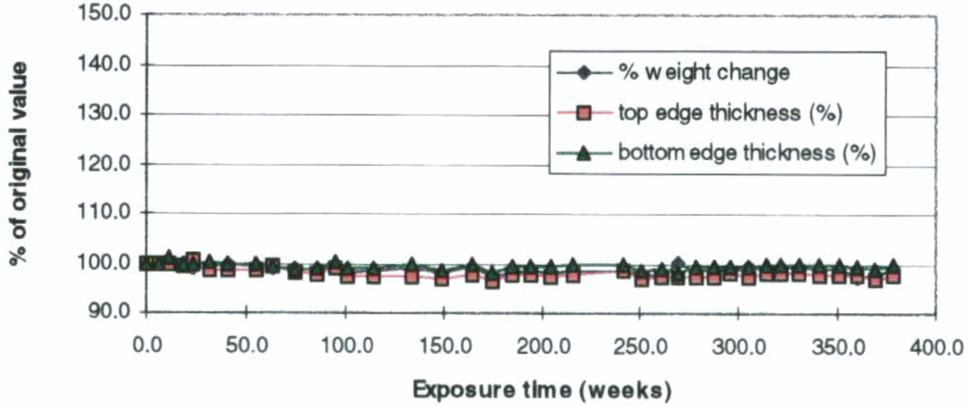


Figure 5. HB1 System C - Physical Properties vs Exposure Time

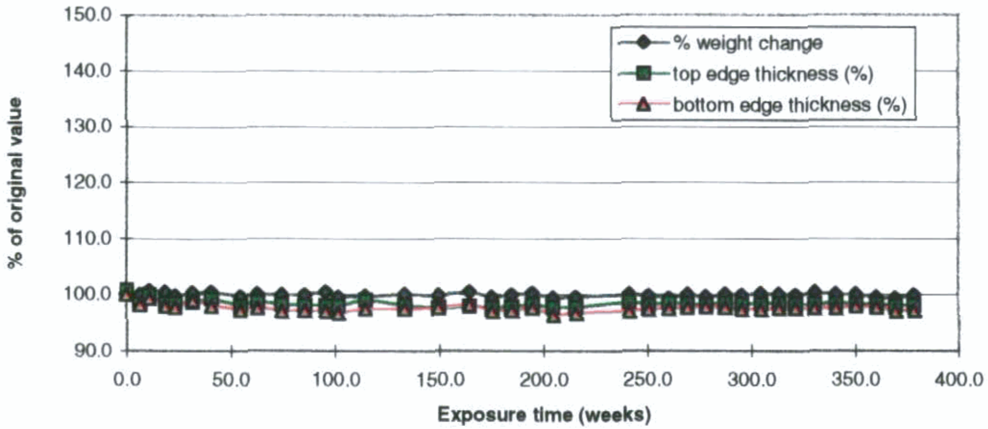


Figure 6. HB2 System C - Physical Properties vs Exposure Time

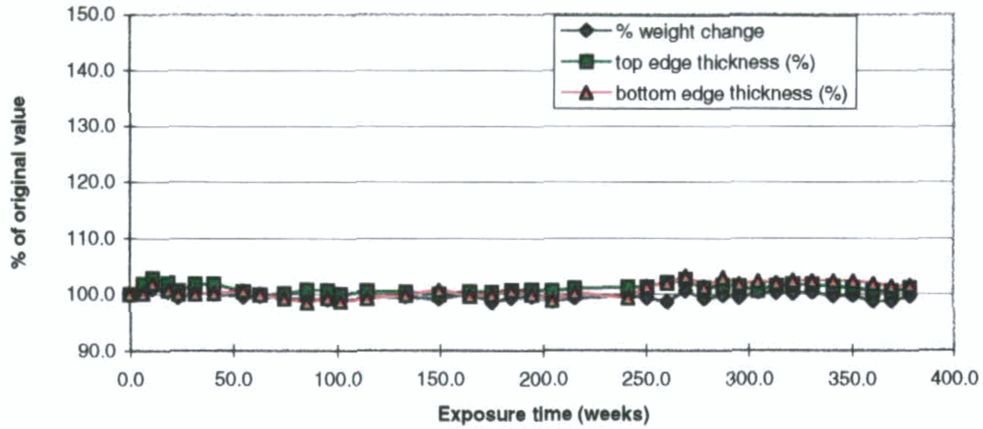


Figure 7. HB1 System D - Physical Properties vs Exposure Time

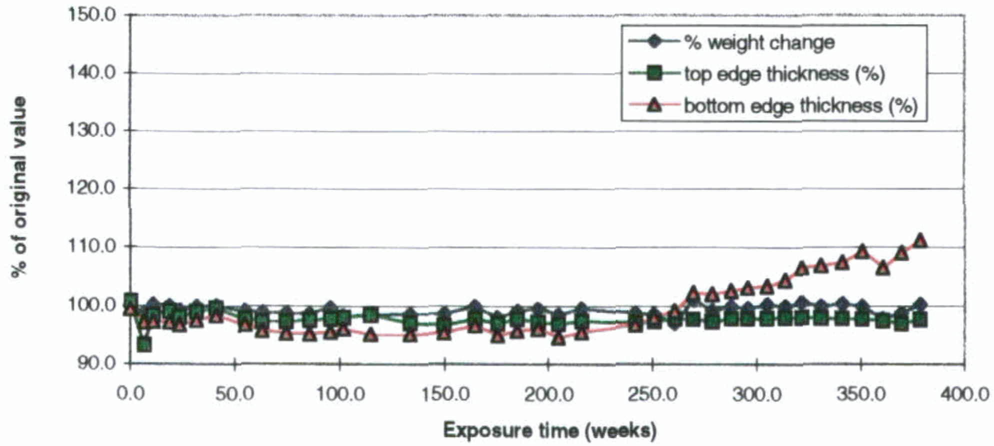


Figure 8. HB2 System D - Physical Properties vs Exposure Time

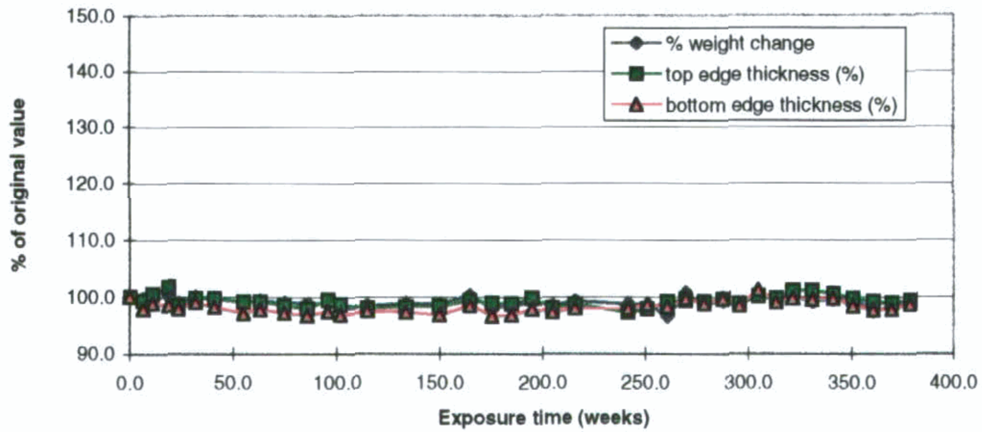


Figure 9. HB1 System E - Physical Properties vs Exposure Time

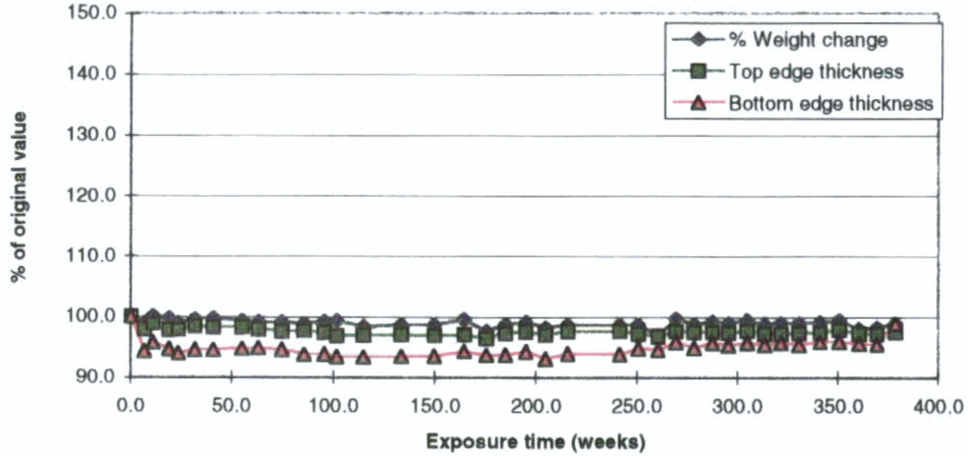


Figure 10. HB2 System E - Physical Properties vs Exposure Time

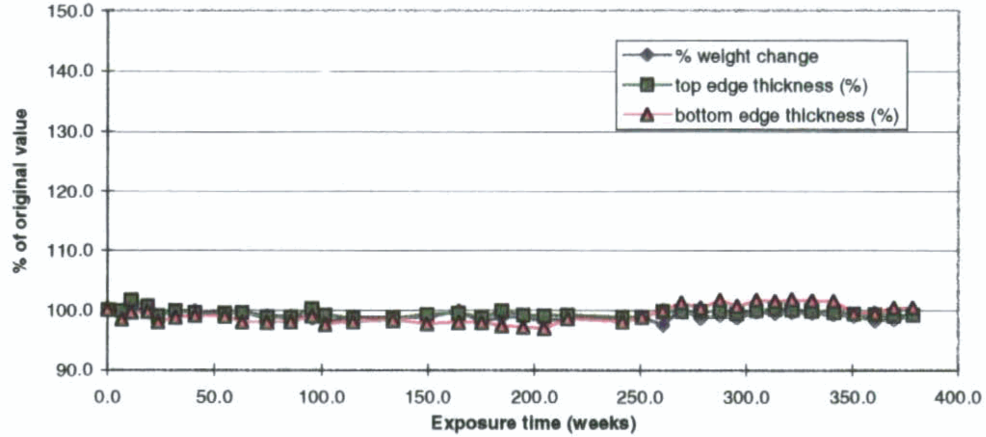


Figure 11. HB1 System F - Physical Properties vs Exposure Time

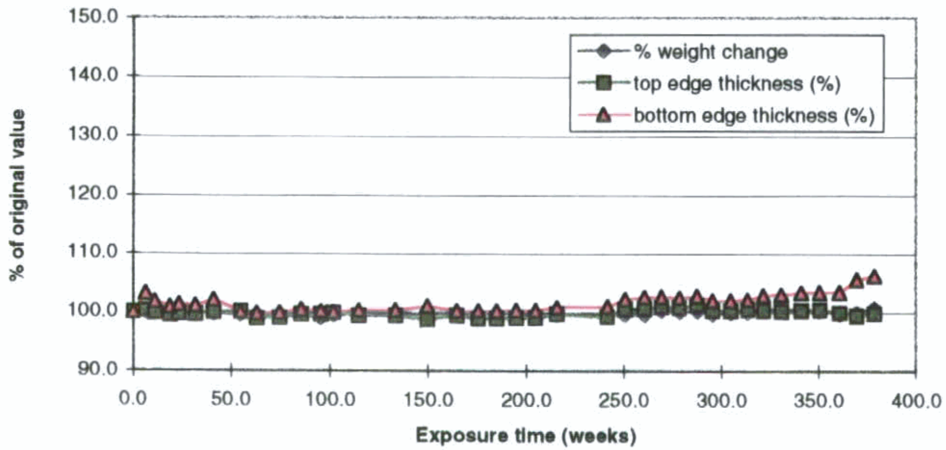


Figure 12. HB2 System F - Physical Properties vs Exposure Time

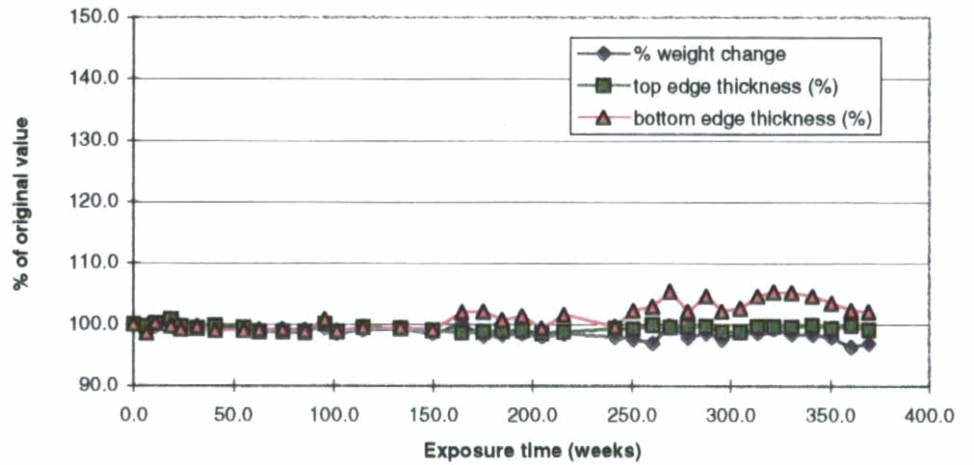


Figure 13 HB1 - MOR vs Exposure Time

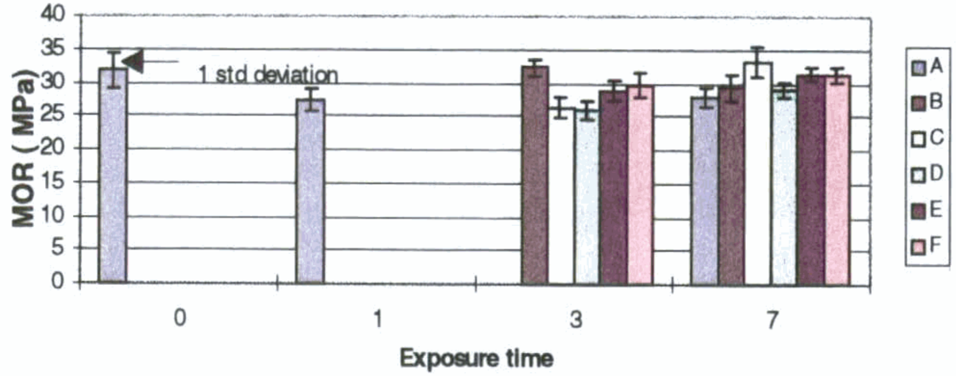


Figure 14 HB2 - MOR vs Exposure Time

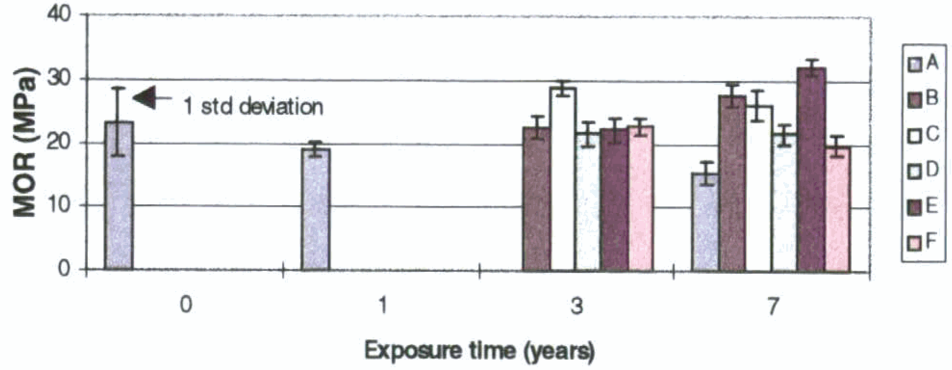


Figure 15 HB1 - MOE vs Exposure Time

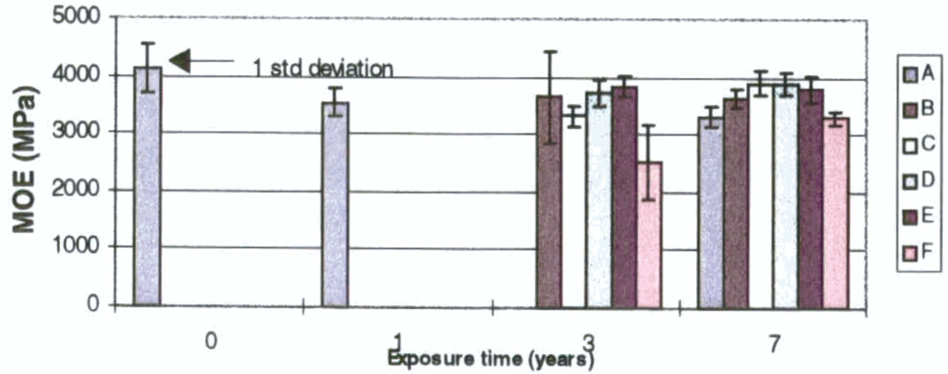


Figure 16 HB2 - MOE vs Exposure Time

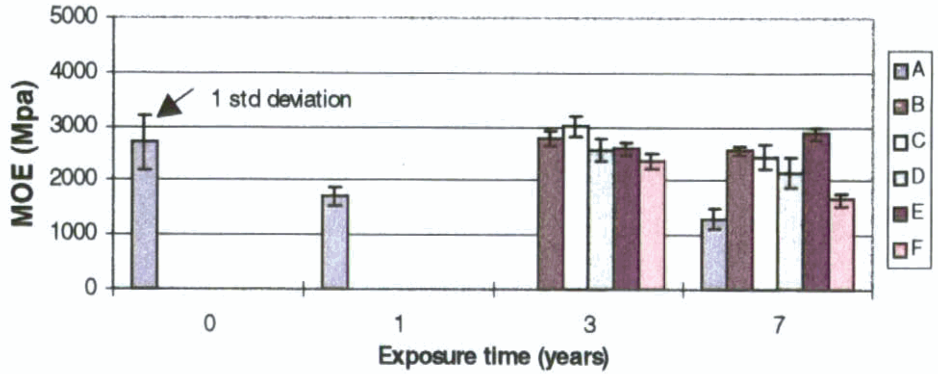


Figure 17 HB1 - IB vs Exposure Time

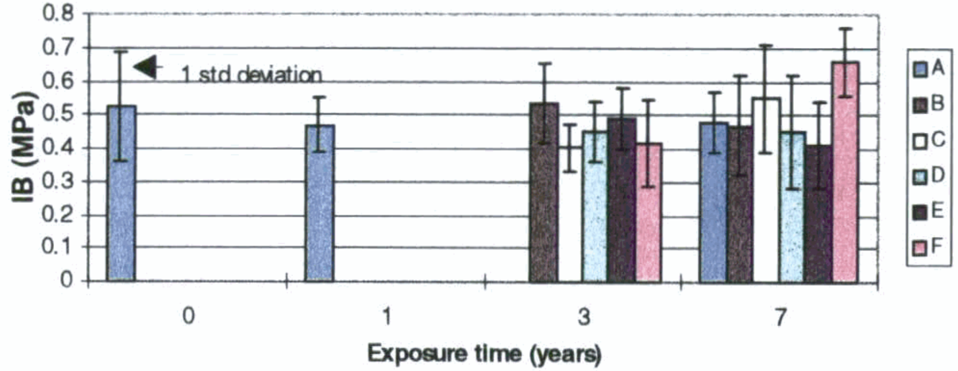
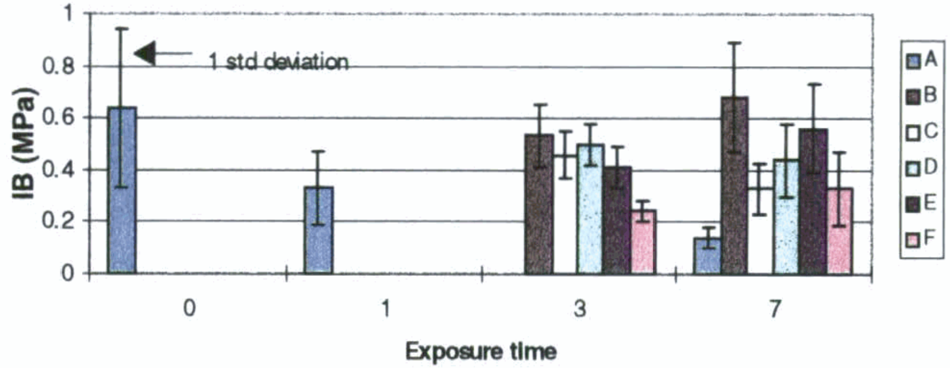
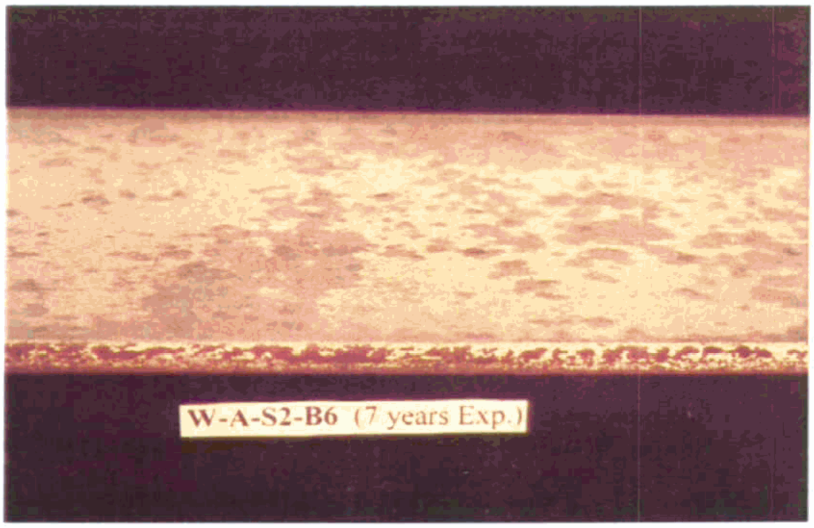


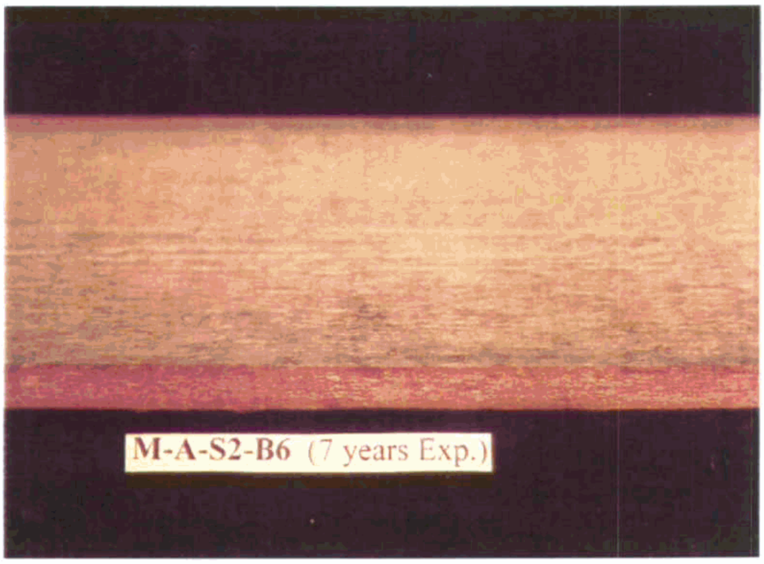
Figure 18 HB2 - IB vs Exposure Time



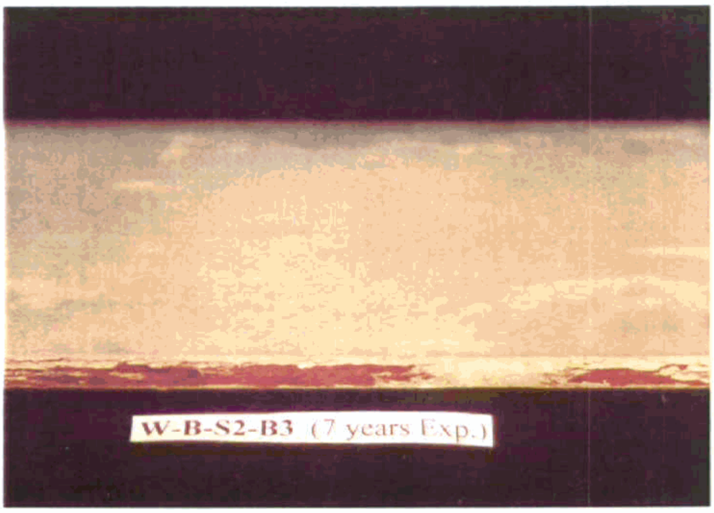
Photograph 1. HB1 Coating System A



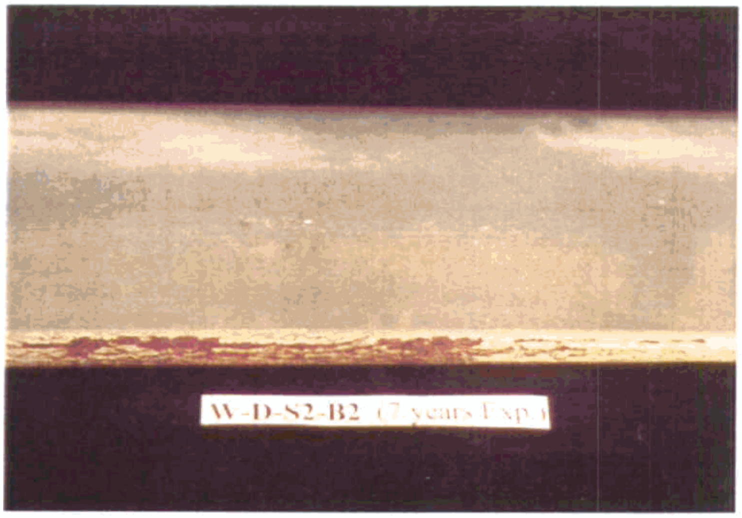
Photograph 2. HB2 Coating System A



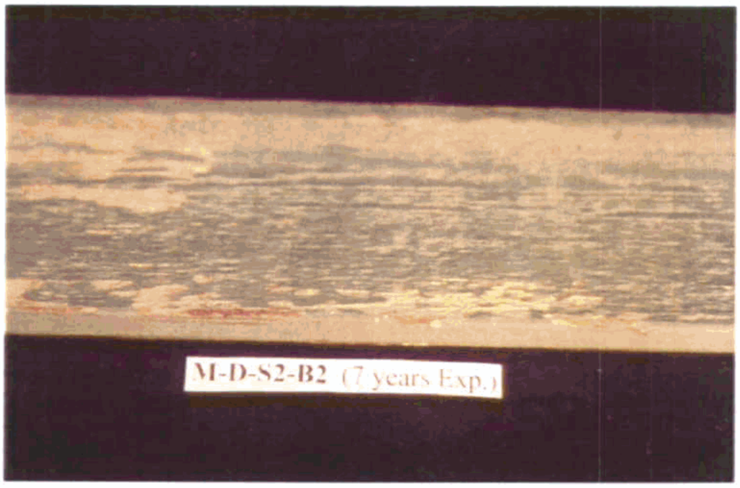
Photograph 3. HB1 Coating System B



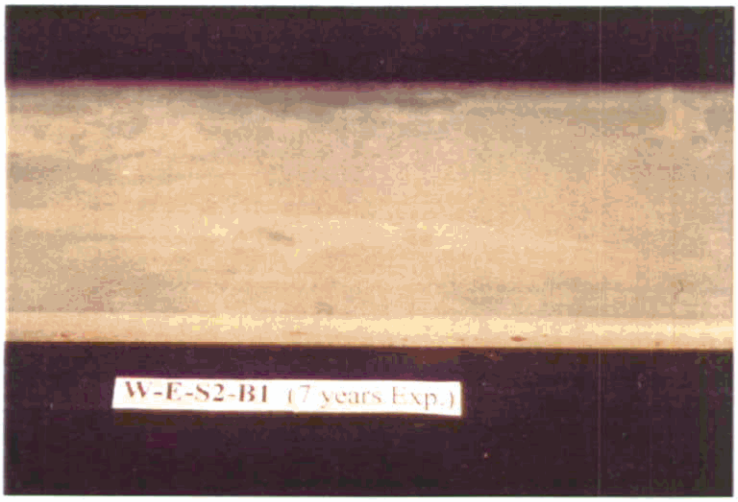
Photograph 4. HB1 Coating System D



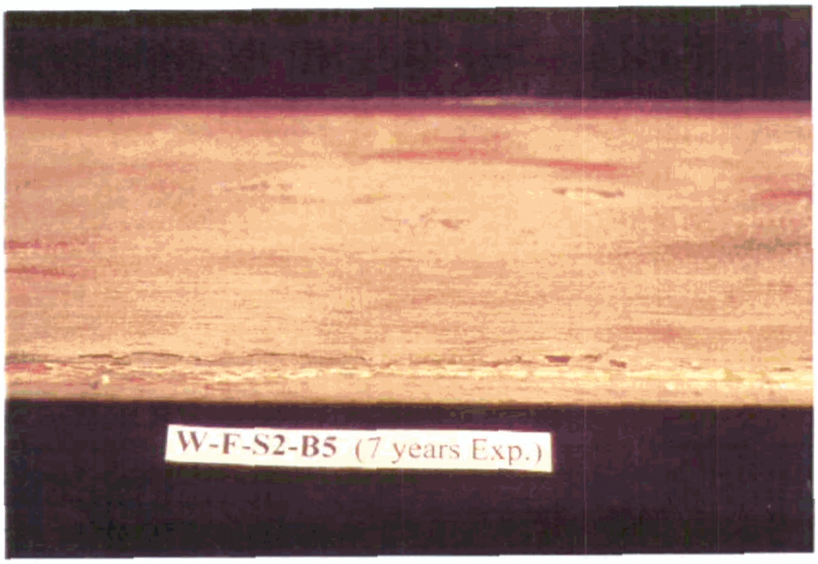
Photograph 5. HB2 Coating System D



Photograph 6. HB1 Coating System E



Photograph 7. HB1 Coating System F



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