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Comparison of accelerated and natural weathering of coil-coated galvanised steel

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Abstract

Flat coil-coated galvanised steel samples from two sources were cut, bent and subjected to exposure at two natural weathering sites for five years. Results were compared to two accelerated salt-spray replicated tests. The paper discusses methods of measuring corrosion and compares performance of coated products. Cyclic weathering followed by salt-spray testing produced similar results to natural exposure tests when substrate pitting was examined but not when coating blistering was examined. Salt-spray pitting and blistering results were not similar to natural exposure results. Pitting of the substrate was regarded as a more accurate measure of coated metal performance than coating blistering, though removal of the coating is necessary. There was a large variation in T bend results for all exposures. Conclusions were that combination test methods should be further examined. Cyclic weathering followed by salt-spray testing proved a useful indicator of natural exposure results, but was less useful for product comparison work.

There is a widespread interest in the use of standard accelerated test methods for durability predictions of coated metal products for product development and for service performance assessment[1-4]. The salt-spray test is widely criticised[5-6] as being unable to reproduce degradation similar to that found naturally. The xenon arc light exposure test (a cyclic weathering test) was found to be of some value to product development[6] and provided useful comparative information on similar systems. Appleman has reviewed accelerated test methods and found that cyclic weathering tests can provide valuable screening data for products[5]. Natural weathering gives the best prediction of durability performance[6]. Campbell, Martin and McKnight reviewed various cyclic testing involving salt-spray cycles[7]. These tests have been developed by different industries and government bodies and have limited usage beyond the instigator.

This project examines the combination of the salt-spray test with a standard cyclic weathering test; the xenon-arc light exposure test. These tests are both covered by standard test methods (ASTM B117[8] and ASTM G26[9]) and facilities to perform these tests are readily available.

Experimental

Flat coil-coated galvanised steel sheet was received from two different sources. The coatings were silicon-modified polyester over an epoxy primer. Two different pretreatments had been applied to the galvanised sheets; one source used a chromate pretreatment and the other a phosphate pretreatment.

The sheets were cut into samples. Each sample had a 90 degree bend and a 180 degree bend (Figure 1). The 90 degree and 180 degree bends were bent over formers to the following T-bend diameters: 2T; 4T; 5T; 6T; 8T; 10T; 12T; 16T; 20T. For each T-bend diameter there were eight samples from each source. Samples were examined for coating microcracking along the axis of the 90 degree and 180 degree bends, and rated by comparison at 20× magnification with the photographic standards in ASTM D661 (1981)[10]. Microcracking was plotted against T-bend (Figure 2).

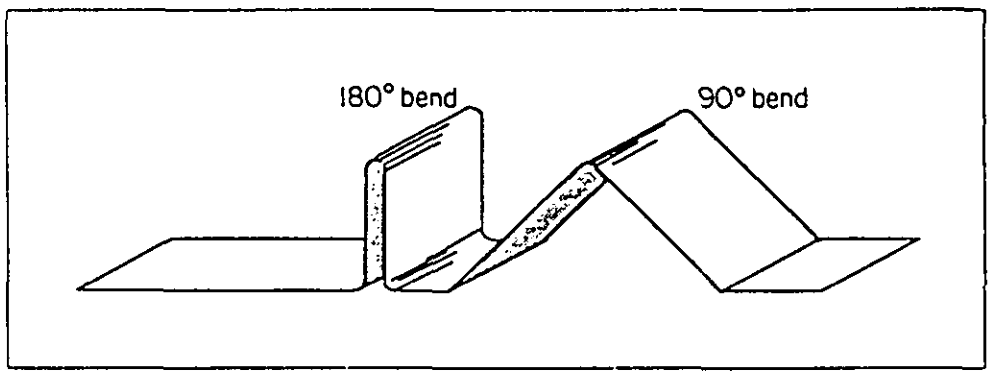

Fig 1 *Sketch of samples used for testing. Overall dimensions: accelerated weathering samples 230 × 79 mm; outdoor weathering samples 300 × 123 mm*

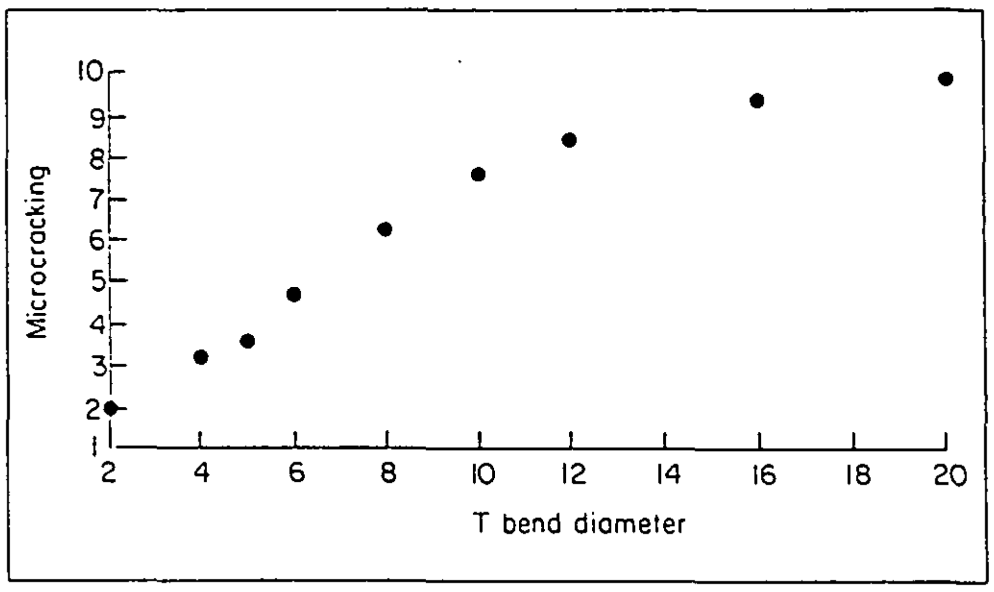

Fig 2 *Microcracking for each T bend diameter*

Four different exposure regimes were used, involving two natural weathering sites and two accelerated testing methods. Two replicates from each source were tested in each exposure.

Natural weathering testing involved sample exposure for five years with samples facing north and exposed at 45 degrees to the horizontal. One site, Otaki, was classified severe marine and the other, Judgeford, rural marine. Samples were exposed at the Otaki site in June 1983 and at the Judgeford site in April 1983. Samples

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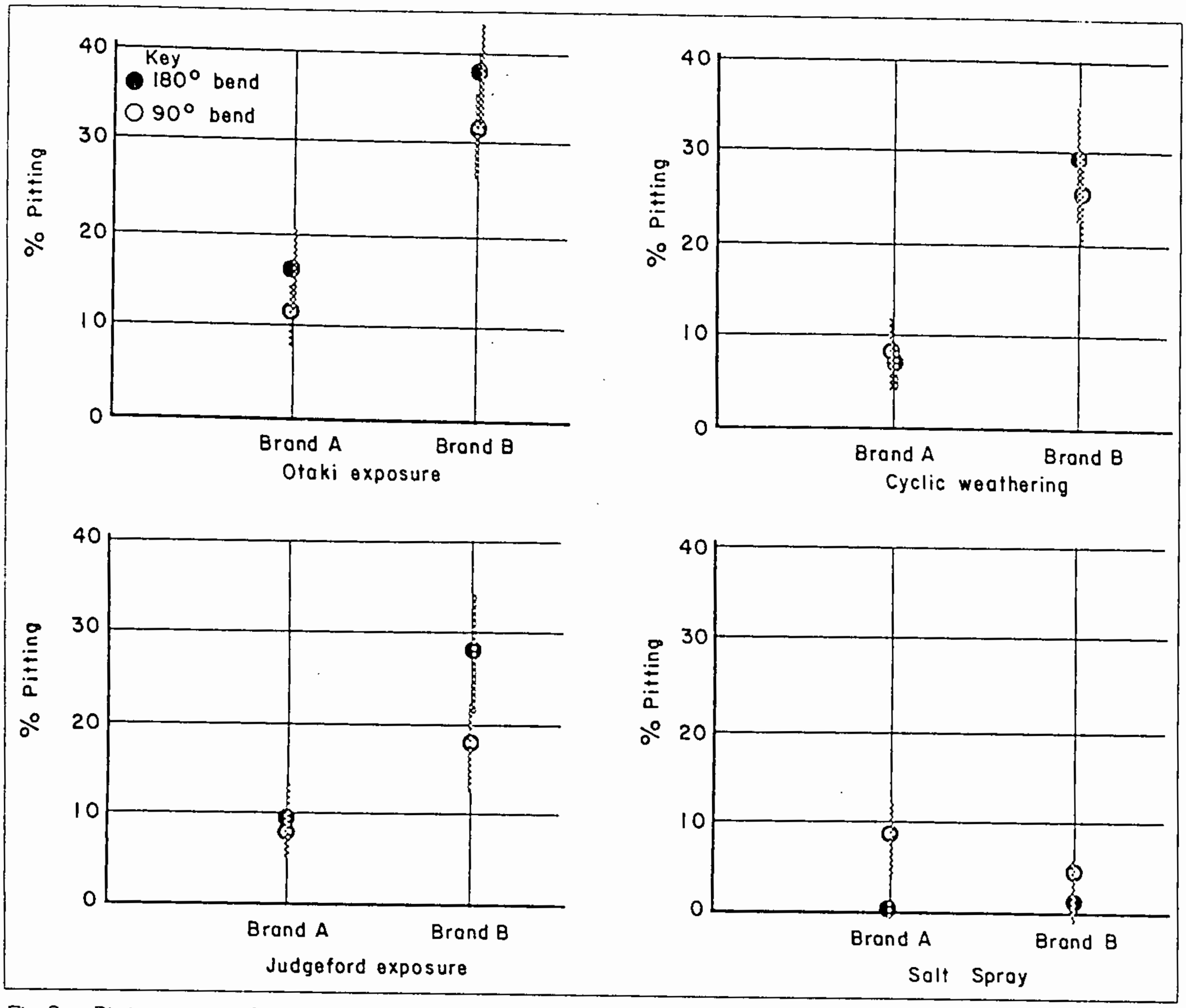

Fig 3 Pitting results for each exposure

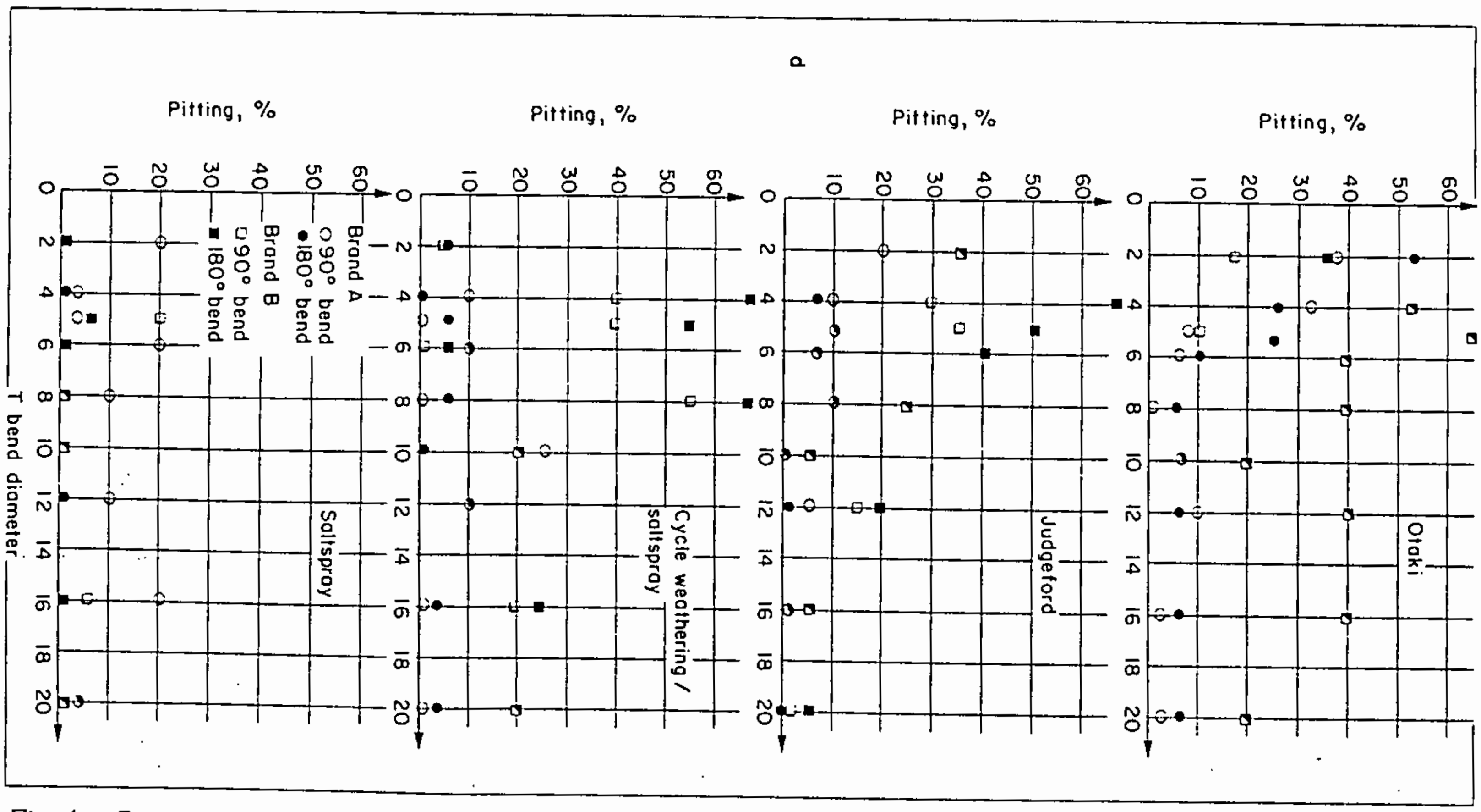

Fig 4 Pitting results for each T bend diameter

Table 1 Variances associated with pitting results for each T bend diameter at each exposure (Figure 4)

Exposure	Brand	Bend Angle (degrees)	T bend diameters 2T	4T	5T	6T	8T	10T	12T	16T	20T
Otaki	A	90	5	16	5	8	2	8	0	0	0
		180	30	30	8	0	10	8	8	8	8
	B	90	35	30	0	0	0	40	0	0	40
		180	70	30	0	0	0	40	0	0	10
Judgeford	A	90	40	0	0	8	8	2	8	0	0.5
		180	70	8	0	8	8	2	0	8	0.1
	B	90	70	39	8	8	30	10	10	8	2
		180	70	0	23	0	30	10	38	0	10
Cyclic Weathering /Saltspray	A	90	10	-	2	-	0	30	-	0	1.5
		180	10	-	9.5	-	9.5	0	-	10	8
	B	90	9.5	-	60	2	0	38	-	38	38
		180	9.5	-	30	8	30	38	-	30	38
Saltspray	A	90	40	-	1.5	38	8	-	0	38	0.5
		180	0	-	0	2	0	-	0	10	0.5
	B	90	-	-	38	0	-	0.5	-	9.5	-
		180	-	-	10	0.5	-	0	-	0	-

were removed from both sites in December 1988.

Accelerated testing method was salt-spray testing in accordance with ASTM B117 (1985) for 1000 hours, and xenon arc light-exposure testing in accordance with ASTM G26 (1984), method B for 2000 hours followed by salt-spray testing (ASTM B117) for 1000 hours (referred to as cyclic weathering/salt-spray testing). Samples were tested and examined in 1983.

Examination involved rating for blistering in accordance with ASTM D714 (1981)[11] on the top and face of the 180 degree bend (Figure 1). Ratings were expressed as percentages. After removal of the coating and corrosion products (ASTM G1 1981, method 7.5)[12], the surface was examined for percentage corrosion using the pitting rating chart developed by Cordner and Whitney[6].

Results

The graph of the mean microcracking rating of the 90 and 180 degree bends plotted against T-bend diameters is shown in Figure 2. There was minimal microcracking of unexposed samples at T-bends greater than 16T.

The mean results and variances for 90 and 180 degree bend pitting have been plotted for each weathering regime in Figure 3. The ranking of the two brands of material in the natural weathering exposures was reproduced by the cyclic weathering/salt-spray testing, but not by the salt-spray testing.

Figure 4 shows the mean pitting results for each T-bend diameter for 90 and 180 degree bends. The variances associated with Figure 4 are shown in Table 1. Pitting was found on both the 90 and 180 degree bends at diameters greater than 16T. The variability associated with the results was large and there was only one replicate for each T-bend.

Blistering was not observed on the natural weathering samples but was observed on the accelerated weathering samples.

Discussion

Methods of corrosion measurement

The performance of a coated galvanised steel product is related to the corrosion resistance provided by the synergistic effect of the paint coating and the zinc coating. One measure of performance is the degree of corrosion on the metal surface. Coating properties can also be a measure of performance by giving an indication of coating protection. Both methods of assessment (pitting corrosion of the substrate and blistering of the coating) were used on all samples. Blistering proved to be not as reliable as pitting as a measure of the performance of the coated metal products. The blistering produced in the accelerated weathering tests may be due to the high humidity associated with these tests. Cordner and Whitney found blistering present after salt-spray testing and they concluded that pitting was a more accurate measure of the performance of a coated metal product than coating properties[6].

Effect of microcracks in the coating

Coating deterioration, allowing salt and moisture to reach the substrate, had occurred in both natural exposures and the cyclic weathering/salt-spray test at all T-bend diameters. Pitting corrosion was present on T-bend diameters greater than 16T although minimal microcracking was observed on these diameters before testing.

Accelerated testing to predict natural exposure performance

The cyclic weathering/salt-spray testing sequence was reasonably successful at duplicating the degree of corrosion damage to the substrate that occurred in natural exposure in a marine atmosphere. Salt-spray testing on its own did not predict natural exposure behaviour, tending to underestimate the damage. However, salt-spray is the fastest of these tests, and the cheapest to perform, and thus seems a sensible first evaluative method for whether a product will be worth taking to the subsequent test methods – on the basis that if it has very poor performance in the salt-spray test, it will probably fail the other tests. However, care should be exercised – some primers for galvanised steel pigmented with inhibitive compounds have very poor performance in a salt-spray text, because of the continual wetting, but work well in natural exposure[1].

The effect of the cyclic weathering exposure before salt-spray testing is to produce some degradation of the coating, by thermal cycling (to open up microcracks in stressed areas) and simulated solar radiation. Other preliminary degradative processes prior to salt-spray testing may be able to produce testing results that also compare to natural weathering results, but may introduce difficulty of reproducibility from laboratory to laboratory. The accelerated test methods used in this work are those with the most widespread standardisation, with wide availability of the necessary equipment. This is in contrast to some of the more ad-hoc methods of test discussed by Appleman[5]. No previous reports seem to have discussed the combination of these standardised test methods in the way used here, *ie* to try to get some simulation of how the product will perform in a marine atmospheric environment once the coating has weathered a little.

Product performance predictions

The various T-bend diameters used on the specimens in this work reflect the variety in profiled metal products that are commercially available. The large variability in natural weathering and accelerated weathering results indicate that these methods are at best only indicative in showing comparative performance. It appears that the only reliable test remains an examination after natural exposure, with the opportunity taken where possible to assess the effects of microclimates (such as sheltering). Thus, there still remains no reliable means of durability prediction for such coated metal products prior to market launch.

Conclusion

Examination of the metal substrate surface on a coil-coated product was a better indicator of damage during testing than examination of the paint film. The degree of microcracking in the coating over deformed areas at the outset of testing was not a good predictor of subsequent corrosion of the substrate.

Subjecting the product to simulation of naturally-caused paint film deterioration before salt-spray testing improved the correlation of the damage in accelerated testing to that found after natural exposure in marine atmospheres. However, this method remains unsatisfactory for product comparison or for definitive durability predictions.

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