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LATEX ROOF PAINTS ON GALVANISED STEEL — WEATHERING TRIALS*

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BUILDING RESEARCH ASSOCIATION OF NEW ZEALAND branz

The fastness of the pigments against solutions and against migration was good on average. But in some cases it was affected by an excess adsorption of the original dyestuff. The fastness of the pigments against light was about 3 degrees lower than the known fastness against light on other substrates. Enders and Pusch[16] gave an interpretation of the decreasing fastness of dyestuffs against light in N-methylol resins. They assumed that free methyl radicals from the monomers and the easy oxidation of the methylol groups are responsible for this phenomenon. This assumption can also be applied here to the condensate under investigation. The condensation product acetone-formaldehyde 1:4 reacts, in principle, in the same manner as acetone-formaldehyde 1:2; but the described reactions go at only about half of the reaction rate.

It was also possible to condense acetone with formaldehyde and organic dyestuffs in only a one step reaction at 80°C in the presence of NaOH with vigorous stirring. The result was a fine powder with a particle size of 2-6 μm. The condensate quality is apparently lower that that obtained by the two step reaction. Inspite of the fact that the one step condensate is unable to form fibres, it does not hinder the formation of fibres or the colouring of PAN fibres (polyacrylonitrile) if 20 per cent by weight of the condensate relative to PAN is added to the spinning mass.

IR, UV, visible and fluorescence spectra were used for the identification of the reaction products and the reaction steps.

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Latex roof paints on galvanised steel – weathering trials*

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Summary

Commercially available latex roof paints were used for this five year weathering trial. Standard acrylic formulation and oil/alkyd paints were included for comparison. Visual defects, chalking, adhesion and pitting of the galvanised steel substrate were assessed. Combined defect indices were calculated to aid evaluation of the results, each defect being weighted according to its seriousness. Priming considerably improved paint performance: with latex paints it reduced the incidence of white rusting and pitting of the galvanising; and it reduced flaking of the oil/alkyd paints. Two top coats were also beneficial, particularly when no primer was used. Green chrome oxide proved the most effective top coat pigment.

Introduction

Traditionally, New Zealand has used galvanised steel sheeting for the roofs of a high proportion of buildings. With the majority of cities and large towns situated close to the sea or geothermal areas, these roofs are painted both for protection from corrosion and for aesthetic reasons.

The early types of galvanised steel roof paints based on oils or alkyds, or a combination of the two, had poor adhesion to new galvanised steel, and it was customary to use a primer or to allow the galvanised steel to weather for at least six months before painting. This resulted in the extra expense of the application of a primer or in a shortening of life of the galvanised steel due to the six months weathering in a corrosive atmosphere.

Following the introduction of acrylic and other water-based paints which adhered very well to galvanised steel, it was considered by some that the use of primers and/or lengthy preweathering were unnecessary.

An exposure trial was set up to investigate whether this was in fact so. The early results of this trial have been reported by Fry[1,2]. This paper discusses the results after five years weathering, which is roughly the expected life to first maintenance of the paint systems.

The trial included a range of commercially available latex roof paints with and without primers, and using both one and two top coat systems. The performance of these paints was compared with that of traditional oil/alkyd-based paints and two control acrylic paints of known formulation.

Originally, the most common roof paint was one pigmented with red iron oxide, but over the years; paints pigmented with green chromium oxide have proved to be as durable as the red iron oxide. With the changing tastes of the public, other colours have been introduced, some of which are proving to be durable, whilst others, especially paints based on blue organic pigments, are failing fairly rapidly.

Micaceous iron oxide pigments have been incorporated into roof paints, presumably because they have been shown to impart good corrosion resistance to structural steel work, their plate-like shape decreasing the moisture permeability of the paint film. However, problems with paints pigmented in this manner have been observed[1].

Experimental design

To ensure that the range of resins, media, pigments and formulations available were adequately covered, latex roof paints were obtained from each of the nine major paint manufacturers in New Zealand.

Paints pigmented with red iron oxide, green chromium oxide and blue organic pigment from all nine manufacturers were included in the trial. In addition, grey micaceous iron oxide

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paints were included where available, together with some miscellaneous paint colours. A description of the paint resin type was obtained from the manufacturer.

In order to compare the performance of the latex paints with commercial paints, four oil/alkyd resin solvent-based paints (three red iron oxide, one grey micaceous iron oxide) were included in the trial. Finally, two known formulation acrylic paints (red and grey) (Table 1) supplied by Rohm & Haas were included as control paints.

Table 1a

Formulations of control paints used

	Formulation per 100 litres			
	Red		Grey	
	kg	Litres	kg	Litres
Water	3.02	3.02	3.32	3.32
Tamol 731, 25%	1.15	1.04	1.17	1.06
Triton CF-10	0.26	0.25	0.26	0.25
Antifoamer	0.26	0.30	0.26	0.30
Ethylene Glycol	2.57	2.30	2.60	2.34
2% hydroxyethyl cellulose	11.66	11.71	9.69	9.74
Germantown Lampblack*			0.71	0.40
Preservative	0.06	0.03	0.06	0.03
Rutile titanium dioxide	5.82	1.39	24.75	5.89
Red iron oxide	23.61	4.83		
Water-ground mica (325 mesh)	3.09	1.10	3.07	1.09
Precipitated calcium carbonate	20.03	7.56	14.82	5.60
Zinc oxide	0.71	0.13	0.72	0.13
Oncor M-50 (basic lead silico chromate)			9.45	2.31
Grind the above in a high speed impeller mill at 1150 to 1400 M/min for 10 to 15 minutes. At a slower speed, let down as follows:				
Rophlex MV-1, 46% (Premix)	70.05	65.62	71.01	66.53
Tributyl phosphate (Premix)	0.30	0.31	0.59	0.61
Antifoamer (Premix)	0.26	0.30	0.26	0.30
Ammonium hydroxide, 28% (Premix)	0.12	0.13	0.12	0.13
	142.97	99.97	142.86	100.03
Pigment volume content	34.9%		35.2%	
Per cent solids				
by weight	59.7%		60.3%	
by volume	42.8%		43.7%	
pH	9.3 to 9.7		9.3 to 9.8	
Viscosity – Krebs units	67 to 73		68 to 73	

*Lampblack should be added to the ingredients listed above it and premixed before the addition of preservative and other pigments and extenders.

To ensure that the paints (except the control paints) were of a normal commerical formulation, all the paints were purchased from retailers. Details of the batch number of each paint were supplied to the manufacturer to verify that it was a current formula and of recent manufacture. Additional purchases were made if this was not the case.

Primers were purchased in a similar manner to the roof paints, using a primer recommended by the manufacturer. Where the manufacturer did not recommend or market a primer, and for the control paints, a commercially available calcium plumbate primer was used. Included in this series are experimental water-based primers which were supplied direct from three manufacturers. The experimental design is summarised in Figure 1. Three replicates of each paint primer system were used.

Sample preparation

Flat panels of galvanised steel were used as the substrate for the paint trials. This eliminated the problems of non-uniform coverage and facilitated microscopic examination. The galvanised steel was the quality normally used in corrugated steel roofing, being a low carbon steel, 0.5 mm thick and coated with zinc at a nominal rate of 460 g/m^2 (230 g/m^2 per side). The size of the panel, 300 mm × 300 mm, was selected as being small enough to handle, yet large enough to minimise any edge effect that might occur. As a further measure, to minimise the effect of the cut edges and the exposed backs of the panels, the edges and backs were sealed with an epoxy coal tar composition after the roof paints had dried.

The galvanised steel panels were weathered for one month prior to painting, as this was considered to be typical of the minimum delay likely to occur between fixing and painting the roof on a new building. The panels were then brought into the laboratory, washed with tap water, drained and dried.

The primer was applied across the top of the panel as a band 100 mm wide. After 24 hours drying, a coat of roof paint was applied over the whole of the face of the panel. A second coat of roof paint was applied, after a further 24 hours drying, as a band 150 mm wide down the right-hand side of the face of the panel (see Figure 2). Thus on each panel there were four areas: one coat unprimed, one coat plus primer, two coats unprimed, and two coats plus primer.

A total of 174 panels were prepared, being three replicates of 58 paint systems using 45 paints and 10 primers.

Table 1b

Raw materials used in formulations

Material	Trade name	Manufacturer
Antifoamer	Balab 748	Balab, Inc.
Hydroxyethyl cellulose	Cellulosize WP-4400	Union Carbide Chemical Corpn
Calcium carbonate	Suspenso Whiting	Diamond Alkali Company
Zinc oxide	Kadox 15	New Jersey Zinc Company
Lampblack	Germantown Lampblack	Columbian Carbon Company
Red iron oxide	RO-8097	C. K. Williams Company
Basic lead silico chromate	Oncor M-50	National Lead Company
Water-ground mica (325 mesh)		English Mica Company
Preservative	Metasol 57 (100%)	Metalsalts Inc.
Rutile titanium dioxide	Ti-pure R-610	E. I. DuPont de Nemours & Co. (Inc.)
	Tamol 731, 25%	Rohm & Haas Company
	Triton CF-10	Rohm & Haas Company
	Rhoplex MV-1	Rohm & Haas Company

BRAND	PRIMER	COLOURS					TYPE
A	EXPTL.	red	BLUE	GREEN		GREY	
B	METALLIC LEAD	RED	BLUE	GREEN			
C	CALCIUM PLUMBATE	RED	BLUE	GREEN	MIO	ORGANIC RED	
D	VINYL ETCH	RED	BLUE	GREEN	MIO		
E	TITANIUM DIOXIDE	RED	BLUE	GREEN	MIO		
F	CALCIUM PLUMBATE	RED	BLUE	GREEN		GREY	
G	ZINC DUST ZINC OXIDE	RED	BLUE	GREEN			LATEX
G	EXPTL.	RED	BLUE	GREEN			
H	RED LEAD PLUMBATE	RED	BLUE	GREEN	MIO		
I	ZINC CHROMATE	RED	BLUE	GREEN		ORANGE	
I	EXPTL.	RED	BLUE	GREEN		ORANGE	
I	EXPTL.	RED	BLUE	GREEN		ORANGE	
CONTROL	CALCIUM PLUMBATE	RED					
I	ZINC CHROMATE	RED					
I	EXPTL.	RED					
I	EXPTL.	RED					
G	ZINC DUST ZINC OXIDE	RED					OIL/ ALKYD
G	EXPTL.	RED					
D	VINYL ETCH	RED					
B	METALLIC LEAD				MIO		

Figure 1. Experimental design

The painted panels were allowed to dry for seven days before the exposure trial commenced. During this period the edges and backs were sealed. All the paints were applied uniformly and wherever possible at the coverage recommended by the manufacturer.--

Exposure trials

The exposure trials began at the BRANZ Exposure Site in July 1973 and were completed five years later in July 1978.

The BRANZ Exposure Site is located at Judgeford, a rural location approximately 25 km north-east of Wellington, New Zealand. The site is exposed to winds from both the north and south quarters and some salt contamination is anticipated with the sea 10-15 km north and south of the site. The conditions at this site are considered reasonably typical of many suburban areas in New Zealand.

The panels were attached to the exposure racks in polyvinyl chloride channels set at an angle of 45° from the horizontal and facing due north to receive maximum solar radiation throughout the year.

The polyvinyl chloride channel provided good drainage, eliminating prolonged contact with moisture. It did cause some damage to the side edges of the panel. This damage was disregarded during the periodic examinations.

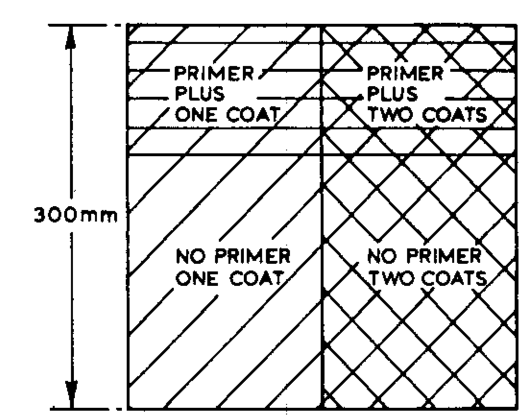

Figure 2. Painting scheme for galvanised steel panels

Examination of panels

Full details of the examination procedures have been given in earlier reports on the exposure trials[1,2]. The examination procedure consisted of visually assessing in the laboratory all four areas of each panel for defects and measuring chalking, adhesion and the amount of substrate pitting. Mildew and chalking were assessed before washing. The other properties were assessed after washing with warm water plus detergent and then rinsing. All ratings were made on a 10 (excellent) to 1 (most severe) scale.

Defects were assessed by comparison with photographic standards in the "Exposure Testing Manual"[3]. Defects noted were mildew, checking, cracking, blistering (size and density), erosion and white rust. The checking and cracking comparison was made by viewing the paint film at ×20 magnification.

Chalking was assessed by drawing a soft white cotton cloth for 200 mm down the two-coat side of the panel. Constant pressure was applied with a finger tip. The degree of chalking was also rated by comparison with published photographic standards[3]. It was assumed that the degree of chalking would be the same for all four areas of the panels. The adhesion tests were performed using the 8-bladed cutting head type drawn in BS 3900 E6[4] which produces a 5 × 5 grid pattern of 1 mm squares. The cut area was covered with adhesive tape which was then pulled off. Assessment of the adhesion was by examination of the panel after the test. The scale used for this assessment was one previously described by Fry[2]. Adhesion was measured on the one coat areas of one of the three replicates for each paint system. It was assumed adhesion for the two coat areas would be the same.

Pitting was assessed on two 50 mm × 50 mm squares cut from each area of one replicate for each paint system. The paint film was stripped off with acetone and mechanical scrubbing. The galvanised steel squares were then cleaned in chromic acid and the pitting assessed on a 10 to 1 scale. The ratings from ASTM G46-76[5] which correspond to the various points on the 10 to 1 scale used for the pitting assessment are given in Table 2.

Table 2

Pitting ratings for galvanised steel substrate

BRANZ rating	Closest ASTM[5] rating ( ) Density	Size	Penetration
10			no corrosion
9	$2.5 \times 10^3/m^2$ (1)	$0.5\ mm^2$ (1)	surface etching only
8	$5 \times 10^5/m^2$ (5)	$0.5\ mm^2$ (1)	surface etching only
7	$2.5 \times 10^3/m^2$ (1)	$0.5\ mm^2$ (1)	50% of pits penetrating to steel substrate
6	$5 \times 10^4/m^2$ (3)	$0.5\ mm^2$ (1)	50% of pits penetrating to steel substrate
5	$1 \times 10^5/m^2$ (4)	$0.5\ mm^2$ (1)	50% of pits penetrating to steel substrate
4	$5 \times 10^5/m^2$ (5)	$0.5\ mm^2$ (1)	most pits penetrating to steel substrate
3	$5 \times 10^5/m^2$ (5)	$2.0\ mm^2$ (2)	most pits penetrating to steel substrate
2	$5 \times 10^5/m^2$ (5)	$2.0\ mm^2$ (2)	very little zinc left
1			no zinc left

Numerical interpretation of results

A combined score for each paint system was calculated to facilitate analysis of the results. The combined score used (defect index, D) was a summation of paint defects, weighted for the seriousness of the defect:

$$D = \Sigma(10\text{-}r)\,w/\Sigma w$$

This summation is made over all defect scores (r). Defect types were placed in one of four groups according to the seriousness of the defect; from corrosion protection, repaintability and aesthetic considerations. A differential weighting (w) was applied to the defects in each group based on a geometric progression of 10. The groupings and weightings selected are set out in Table 3.

Table 3

Defect groupings and weighting

	Defect type			
	White rust Pitting Flaking	Erosion Cracking Adhesion	Blister size and density Checking	Mildew Chalking
Seriousness	major	moderate	minor	slight
Weighting	1	0.1	0.01	0.001

As pitting and adhesion had only been assessed on one of the three replicates for each paint system, a combined defect index for the three replicates was calculated using the average rating for the other defects.

With this weighting system, the major defects have a big influence on the performance rating of the paint. Thus a paint with a very serious (score = 1) major defect would have a defect index of 2.7; if it had two very serious major defects the defect index would be 5.4. With no major defect but a complete failure at the next level of defect, the defect index would be 0.27.

The selection of the geometric progression of 10 was arbitrary. However, the defect indices were recalculated using geometric progressions of 2 and 100. It was found this did not have any major effects on the distribution of results, the ranking of paint systems or the general effects of priming, number of coats and colours.

On the other hand, the grouping of defects was critical to the evaluation. The reasons for assigning the various defect ratings were:

Major defects

The major defects, given a weighting of 1, are those defects which by their presence show that the paint is failing to adequately protect the substrate, that there will be maintenance difficulties, or that there is a serious aesthetic problem.

Pitting

Pitting of the galvanising shows that the paint film is failing to completely protect the substrate. Serious pitting indicates that in localised areas the corrosion of the galvanising has accelerated under the paint film, compared with unpainted galvanised steel. Serious pitting will lead to red rusting, subsequent paint adhesion failures and loss of serviceability of the roof cladding.

White rusting

White rust is produced when the galvanising corrodes. It may be associated with either generalised corrosion or pitting, will detract from the appearance of the roof, and is likely to reduce the effectiveness of subsequent maintenance coatings.

Flaking

This defect is considered to be as serious as white rusting in that it spoils the appearance of the roof and creates many problems when the roof has to be prepared for repainting. In a corrosive environment the loss of paint will lead to the corrosion of the galvanised steel roofing.

Moderate defects

These defects indicate that the paint film is losing one of the properties which is necessary for it to function properly. Either it is no longer a coherent film protecting the substrate, or it is no longer adherent to the substrate. The defects have been given the weighing 0.1.

Erosion

Erosion is the result of prolonged or excessive chalking where the substrate becomes visible, generally at first in the valleys created by the bristles of the paint brush. This reduction of thickness in the paint film can lead to pitting or white rusting of the galvanised steel. Erosion also detracts from the appearance of the painted surface.

Cracking

Cracking is defined as being when the paint film has broken to expose the substrate. On poorly adhered paint films, cracking will initiate flaking. The exposed galvanised steel is prone to white rusting and pitting. Cracking can also detract from the appearance of the painted surface.

Adhesion

Poor adhesion is likely to lead to flaking and repainting problems. In addition, it is claimed[6,7] that good adhesion is important for corrosion protection.

Minor defects

This group includes defects which will not in themselves cause serious problems, but which are the precursors of moderate or major defects. The substrate is not exposed, the appearance and maintainability has not been markedly affected. A weighting of 0.01 is assigned.

Checking

Checking is generally the precursor of cracking where stresses in the paint film have caused localised thinning. Various forms of checking were observed and some were related to coalescence problems with latex paints.

Blister size and density

The classification looks at both the size and density of blistering. Blistered paint films are still intact but are susceptible to flaking. In addition, corrosion can occur under the blisters. There is some loss of appearance with blistering.

Slight defects

Providing these defects do not occur in excess, it is arguable whether they are in fact defects. They are given the low weighting 0.001.

Chalking

This is a natural phenomenon on all pigmented surface coatings. Limited chalking is desirable as it keeps the paint looking clean and presents a surface suitable for repainting. Excessive chalking leads to erosion.

Mildew

Galvanised steel is a non-nutritive substrate. The mildew that did occur was confined to the surface of the paint and was easily removed by washing.

Results and discussion

There was a wide variety of paint performance. Some paint systems remained in excellent condition, while others had deteriorated very badly. Different systems exhibited different paint defects. The results for each area of each paint system were weighted as described earlier (see Table 3) and combined to give a defect index. Indices as low as 0.37 were recorded. Areas with performance this good exhibited no visual defects and obtained good scores in the chalking, adhesion and pitting assessments.

Table 4

Analysis of variance of ten brands of latex paints with red, green and blue pigments

		Degrees of freedom	Mean square	F ratio
Main factors	Brand (B)	9	0.51	4.8
	Colour (C)	2	1.8	17.2
	Coats (K)	1	4.5	42.0
	Primer (P)	1	9.3	87.0
1st Order interactions	BC	18	0.41	3.9
	BK	9	0.17	1.7
	BP	9	0.21	2.0
	CK	2	0.58	5.4
	CP	2	0.90	8.5
	KP	1	0.22	11.4
2nd Order interactions	BCK	18	0.12	1.2
	BCP	18	0.21	2.0
	BKP	9	0.11	1.1
	CKP	2	0.24	2.2
Error	BCKP	18	0.11	
	Total	119	0.39	

Note: Analysis of variance is used to illustrate the important effects and interactions. Accurate probabilities have not been calculated because of the arbitrary nature of the differential weightings.

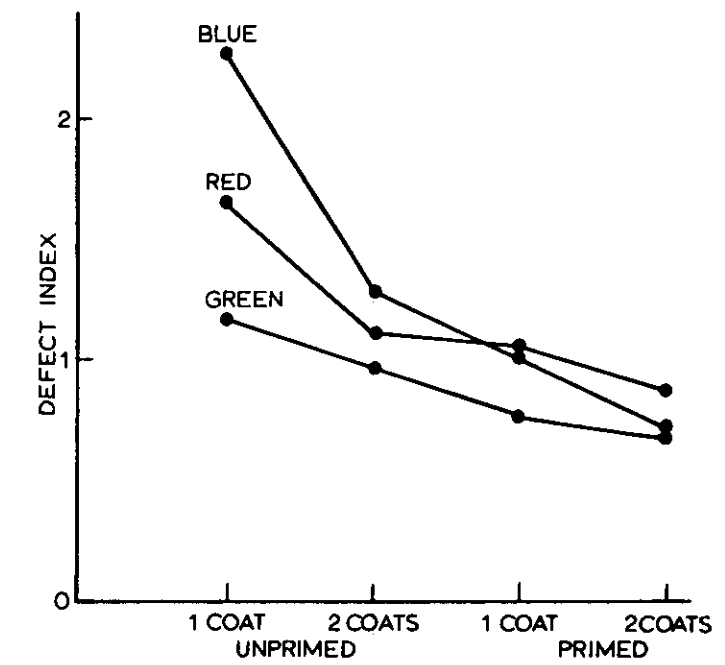

Figure 3. Average defect indices for ten brands of latex paints showing comparative performance of red, green and blue paints

Other paint systems had defect indices as high as 4 or 5. These poor results would represent, for example, very bad flaking or white rust, and a high degree of pitting.

Analyses of variance were carried out on the defect indices. The Teddybear statistical package was used[8]. Tests for skewness, kurtosis and the distribution of residuals showed that the data did not differ significantly from a normal distribution. The analyses reported in this paper were carried out on balanced blocks of data taken from the total set of data. The same trends were evident over all paint systems.

Analysis of the 12 latex paint systems (9 brands with 3 duplicates; using different primers; red, green and blue colours in each system) showed one brand (2 systems) to be markedly inferior to all the other paints. As three different colours were tested, this was assumed to be a formulation deficiency rather than a defective batch of paint. This brand of paint showed very serious white rusting on unprimed areas from early on in the trials. An examination of the galvanised steel substrate showed extensive pitting with a large proportion of exposed steel; between 100 and 150 g/m^2 of the nominally 230 g/m^2 galvanising had been lost. The manufacturer concerned has now withdrawn this formulation. As the results for this brand were atypical of the other latex paints, the analysis was repeated excluding this brand. The results of this analysis are summarised in Table 4 and Figure 3.

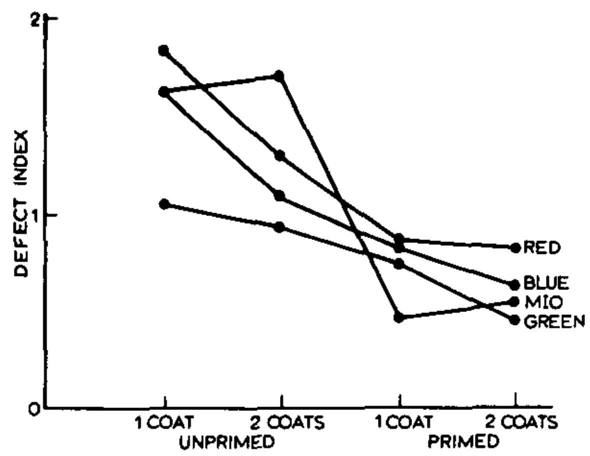

Figure 4. Average defect indices for the four brands of micaceous iron oxide latex paints (the results for the other colours of the same brands are also shown)

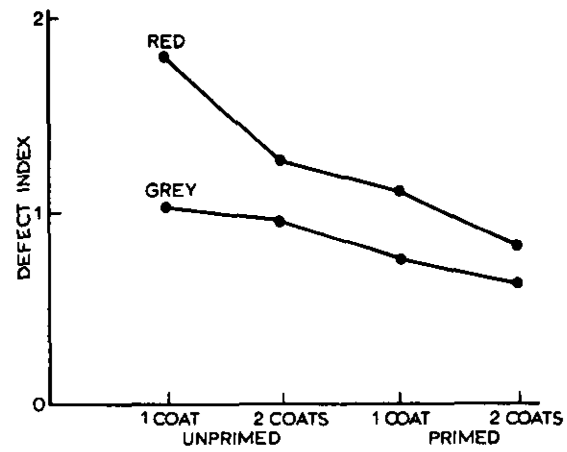

Figure 5. Average defect indices for the three brands of grey paint (the results for red paints of the same brands are also shown)

Separate analyses were carried out, again on balanced sets of data, to assess the performance of paints containing micaceous iron oxide pigments, grey pigments and the performance of the control acrylic paint and the oil paints (figures 4 to 6).

Priming

Figure 3 illustrates the advantages of using a primer with latex roof paints, particularly when using only one top coat. Analysis of variance (Table 4) confirms the very large primer effect on the performance of the paint system.

The summaries of results in tables 5 and 6 show how the primers assist paint performance. The primed areas show less pitting than the unprimed areas and virtually no white rust.

Unlike alkyd/oil paints, there are few problems of unprimed latex paint flaking, and their adhesion to the weathered galvanised steel is good. However, adhesion problems can

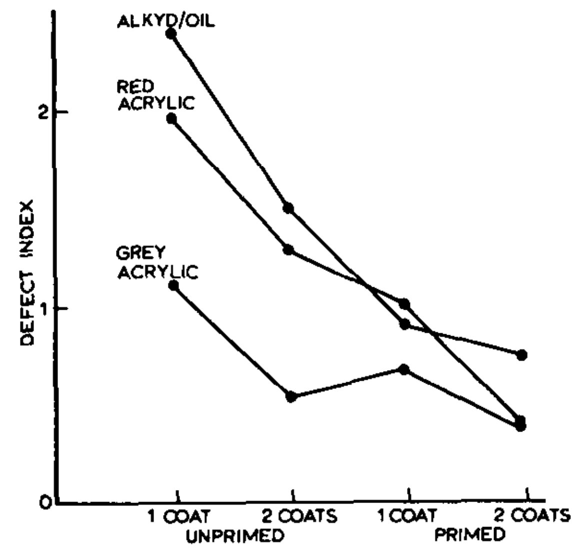

Figure 6. Average defect indices for the alkyd/oil paints and the control acrylic paints

Table 5

Percentages of paint systems with visual defects

	Latex				Alkyd/oils			
	Unprimed		Primed		Unprimed		Primed	
	1 coat	2 coats	1 coat	2 coats	1 coat	2 coats	1 coat	2 coats
Mildew	1	1	1	2	3	10	3	10
Blisters	55	70	78	81	33	20	54	40
Checks	38	49	38	43	37	27	20	23
Cracks	17	17	17	7	70	37	47	50
Erosion	19	0	20	0	20	0	30	0
Flaking	1	2	1	1	60	53	3	17
White rust	44	23	11	6	0	0	3	0

Table 6

Average scores for chalking, adhesion and pitting

	Latex				Alkyd/oils			
	Unprimed		Primed		Unprimed		Primed	
	1 coat	2 coats	1 coat	2 coats	1 coat	2 coats	1 coat	2 coats
Chalking	← 5.11 →				← 2.7 →			
Adhesion	← 6.54 →		← 6.46 →		← 1.0 →		← 1.9 →	
Pitting	5.97	6.24	7.38	7.81	5.4	7.9	7.3	8.1

Table 7

Summary of results for control red iron oxide acrylic paint

Replicate	1				2				3			
Primed	No		Yes		No		Yes		No		Yes	
Top coats	1	2	1	2	1	2	1	2	1	2	1	2
Mildew	10	10	10	10	10	10	10	10	10	10	10	10
Blister size	10	8	9	9	10	10	9	9	10	9	9	9
Blister density	10	9	9	9	10	10	5	9	10	9	5	9
Checking	10	10	10	10	10	10	10	10	10	10	10	10
Cracking	10	10	10	10	10	10	10	10	10	10	10	10
Erosion	10	10	10	10	9	10	10	10	9	10	10	10
Flaking	10	10	10	10	10	10	10	10	9	10	10	10
White rust	8	10	10	10	9	10	10	10	9	10	10	10
Chalking		2				2				2		
Adhesion					8		7					
Pitting	5	6.5	7	9								

All results are scores: 10 is no defect, 1 is a complete failure. No entry means that the result was not assessed.
Defect index: unprimed 1 coat = 1.97, unprimed 2 coats = 1.12, primed 1 coat = 1.01, primed 2 coats = 0.40.

Table 8

Summary of results for control grey acrylic paint

Replicate	1				2				3			
Primed	No		Yes		No		Yes		No		Yes	
Top coats	1	2	1	2	1	2	1	2	1	2	1	2
Mildew	10	10	10	10	10	10	10	10	10	10	10	10
Blister size	9	9	9	8	8	9	9	9	9	9	9	9
Blister density	9	9	5	5	3	5	5	5	5	5	5	5
Checking	8	8	8	8	9	9	9	9	10	9	9	10
Cracking	10	10	10	10	10	10	10	10	10	10	10	10
Erosion	10	10	10	10	10	10	10	10	10	10	10	10
Flaking	10	10	10	10	10	10	10	10	10	10	10	10
White rust	10	10	10	10	10	10	10	10	10	10	10	10
Chalking		4				3				3		
Adhesion					8		8					
Pitting									6	8.5	8	9

All results are scores: 10 is no defect, 1 is a complete failure. No entry means that the result was not assessed.
Defect index: unprimed 1 coat = 1.29, unprimed 2 coats = 0.53, primed 1 coat = 0.69, primed 2 coats = 0.38.

occur when latex paints are applied to new galvanised steel. In a separate project, Duncan[9] has shown how a primer will reduce or eliminate these problems.

The BRANZ Exposure Site is moderately marine. In addition, the paints were applied under ideal conditions. In practice, the paint film will not be applied under optimum conditions and even if the macro-environment is no more corrosive than the BRANZ site, more corrosive micro-environments could well exist around flues or on sheltered areas of the roof. For this reason we believe that the added insurance of a corrosion resistant primer is invaluable when using latex roof paints under New Zealand conditions.

All primers improved the performance of the top coat systems. Detailed comments are not made about the performance of primer types as different types of primer were obtained from different manufacturers. However, all the experimental water-based primers scored poorly when compared with the solvent-based primers.

Number of top coats

Figure 3 shows that the use of two top coats improves the performance of the paint system. The improvement with a second coat is more pronounced when a primer is not used, but is still real when a primer is used.

Tables 5 and 6 illustrate that the second coat eliminates erosion defects and reduces the incidence of white rusting and pitting.

The erosion was generally coincident with the pattern of brush marks. Both white rusting and pitting were found to be associated with the thin paint areas in the brush marks.

Colour

Top coats pigmented with green chrome oxide pigment were superior to top coats pigmented with red iron oxide or organic blue pigments. The blue paints were particularly poor when used without primers. This colour effect is probably indicative of the relative corrosion inhibition of the three pigment types.

Figure 4 illustrates the results for the four paints pigmented with micaceous iron oxide. The averages for green, red and blue paints of the same four brands are shown. Micaceous iron oxide performed in a similar manner to red iron oxide. There is an indication of slightly poorer performance when two top coats were used, but this effect was not statistically significant.

Figure 5 illustrates the results for the grey paints. Three brands of grey paints were used (including the control paint) and the red paints of the same brands are included in the Figure for comparison. Analysis of these results showed the grey paints have better performance than the red. The result was marginally significant.

The trial also included two brands pigmented with a bright organic red and one brand with an orange pigment. One bright red pigmented paint suffered from erosion, otherwise these paints performed as well or better that the others of the same brand.

Resin type

Acrylic or copolymer

The latex paints used included some based on 100 per cent acrylic resin and others based on PVA copolymers. The 100 per cent acrylic paints did not out perform the other media. The two brands of paint based on PVA copolymers were amongst the highest performers.

The control acrylic paints had typical and slightly above average performance (see Figure 6). Detailed results for the control paints are given in tables 7 and 8.

Alkyd/oil paints

The limitations of the experimental design meant that a balanced comparison between latex and oil alkyds was not possible. As with latex paint, use of a primer and two top coats was beneficial. However, in this case white rusting was not a problem. As might be expected, the most serious common defect was flaking and this was reduced considerably by use of a primer.

Figure 6 summarises the results for three brands of alkyd/oil paints. The fourth brand was found to be a defective batch and was omitted from the analysis.

Conclusions

Priming has a beneficial effect for both latex and oil/alkyd types of galvanised steel roof paints. Priming reduces white rusting in latex paints, flaking in oil/alkyd paints and the incidence of pitting of the galvanised steel with both types of paint.

The use of two top coats improves the performance of the paint system, particularly when no primer is used. Single coat systems were prone to erosion leading to loss of protection of the substrate.

Green chrome oxide was the most stable pigment type, organic blues the least.

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short communication

A possible means of identifying inhomogeneities in organic coatings using a dyeing technique*

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Pores in paints have been a controversial issue for many years. A body of evidence exists supporting the presence of pores[1-3] and an opposing case can be equally easily made[4-6]. A major contribution towards the resolution of this problem was the discovery of the presence of so-called "D" and "I" areas by Mayne and his co-workers. These areas were identified originally from the electrical behaviour[7] of areas of the paint film. Subsequently it was suggested that structural differences were responsible for these electrical differences[8] and that the presence of D areas was associated with subsequent corrosion of the ferrous substrate[9].

Recently a chance observation has shown that structural differences in epoxy films on mild steel may be identified by immersing such panels in an aqueous solution containing organic dyes. Originally this was shown using pen recorder ink in a 3 per cent sodium chloride solution, which caused small areas of the order of 1 mm in diameter to become stained. Subsequent examination of these areas under an optical microscope showed them to differ from the rest of the film. On further immersion, rust spots developed in association with these areas. The dye used fluoresced under UV illumination. When the dyed panels were examined using this method, the amount of fluoresence differed at a macro level across the panels; it is thought that the level of fluorescence has a bearing on the amount of crosslinking in the polymer.

This series of observations represents a novel method for the examination of coatings on metals, and is in line with similar work reported by Peters on the uptake of dyes by polymer fibres[10]. He has shown that dyes are preferentially taken into areas in fibres which are structurally different from the bulk.

It may be possible to use a series of related dyes of differing charge and size to identify more closely differences in the size and structure of pores in paints.

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