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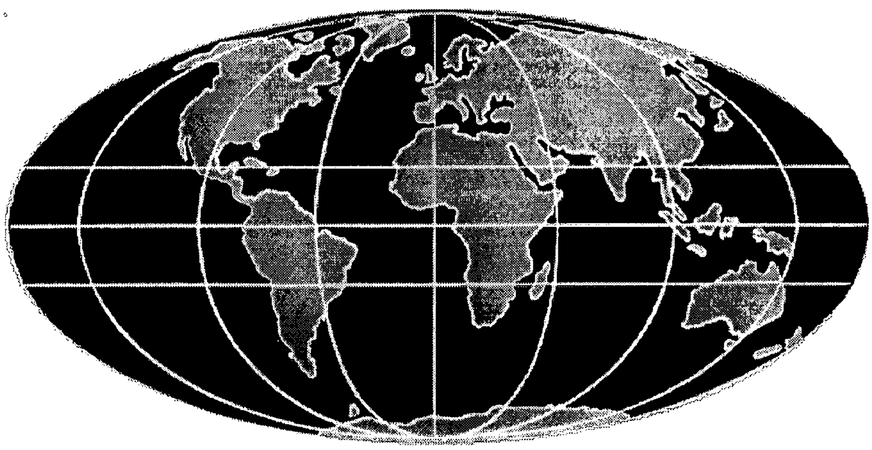

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THE MAINTENANCE OF PAVED ROADS IN MALAYSIA: PERFORMANCE OF TWO FULL-SCALE EXPERIMENTS

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1. INTRODUCTION

The Federal and State paved road network in Malaysia is about 26,000 kms in length. The majority of the network is maintained by the State Authorities either by direct labour or under relatively small contracts. The standard maintenance technique is the application of 40mm thick bituminous overlays which are often applied regardless of the strength of the existing road pavement or the particular mode of failure. This policy has resulted in substantial lengths of the network having bituminous surfacings consisting of multiple layers of bituminous overlay often totalling more than 150mm. This is not unique to Malaysia. In many other countries similar policies have been adopted leading to similar road behaviour.

The primary mode of failure of this type of road pavement is often reflection cracking. Reflection cracking is caused by excessive strain at the top of the crack in the existing road which results in a fatigue failure of the overlay material immediately above it. The original crack effectively propagates upwards through the new overlay. Where the bitumen at the top of the surfacing has oxidised (Smith et al, 1990) and become brittle, reflection cracks have also been observed to start at the top of the overlay and propagate downwards towards the crack in the lower layer.

There are a number of alternative methods of maintaining cracked dense bituminous surfacings. These include the use of crack relieving interlayers under thin overlays, increasing the thickness of the overlay itself and sealing the surfacing with alternative forms of surface dressing.

During the early 1990s a number of full scale trials were constructed in Peninsular Malaysia by the Public Works Department (JKR) which were designed to establish the most cost effective method of maintaining cracked asphaltic concrete surfacings. The construction and condition of these trials has been monitored under a cooperative JKR/TRL research programme. This paper describes the performance of two of the trials based on condition measurements taken in January/February 1997.

The trial constructed on Route 5 was designed to evaluate the performance of thin bituminous overlays with various crack relieving interlayers. The trial on Route 10 was designed to compare the performance of different thin bituminous seals. The construction and early performance of the trials has been reported elsewhere (Rolt et al, 1996)(Suffian et al, 1996)

2. TRIAL ON ROUTE 5

This trial, located between Melaka and Muar, was constructed in June/July 1993, The trial has 8 experimental sections. Each section, besides the control sections, employed a different crack relieving interlayer and was then overlaid with 50mm of a 20mm nominal size asphaltic concrete wearing course (ACWC20).

The road selected for the trial is typical of long lengths of the Federal and State network of Malaysia. It has a single 7.3 metre wide carriageway and the pavement construction consisted of a gravel sub-base, crushed stone roadbase and a dense bituminous surfacing. A coring survey showed that the road had been overlaid at least twice since its construction.

2.1 Design of the Trial

Six different crack relieving interlayers were used in the trial and are summarised in Table 1. Their relative performance was compared to two control sections. The first control was a 50mm overlay of ACWC20. The second was a thicker 90mm overlay, comprising of a 40mm layer of asphaltic concrete binder course material underlying 50mm of ACWC20.

Geogrids are claimed to retard crack propagation by reinforcing the new overlay immediately above a crack. The glass fibre geogrid used in the trial had a mesh size of 30mm and a tensile strength of 50kN/m at 3 per cent strain.

The concept behind using needle punched material is that the bitumen filled fabric will dissipate the strain at the top of the crack thereby reducing the strain applied to the overlay and retarding crack propagation. The polypropylene needle punched fabric used in the trial, had a tensile strength of 9kN/m and a minimum extension at ultimate breaking strength of fifty per cent.

'Cut and Patch' is the standard JKR procedure and requires that 'surfaces with cracks of 4mm or greater in width should be removed and patched prior to the overlay being applied'. In practice this usually results in forty millimetres of cracked material, the previous overlay, being removed and patched. Previous research (Morosiuk et al, 1992) had shown that the rate of propagation of reflection cracks is dependent on the intensity of cracking and therefore areas of surfacing having a crack intensity of 3 or greater (see paragraph 2.2.1) were patched in this section prior to overlay.

Previous research in Malaysia (Emby et al, 1992) had also shown that interlayers with relatively high voids significantly reduce the rate of propagation of reflection cracking. Strains cannot be readily transferred through a medium with substantial voids if the layer is sufficiently thick. This concept was employed during the design of two sections with interlayers constructed from surface dressings, having two different stone sizes, and one section with a pervious macadam interlayer (BSI, 1988).

2.2 Performance Measurements

After construction of the overlays each 210m section was marked out in 10 metre blocks, 21 in each direction. These blocks have then been used as discrete units to quantify the condition of each section. Performance has been assessed by carrying out surface condition surveys and deflection surveys at regular intervals since construction. A number of cores have been taken to establish the cause of any cracking and any other forms of surface distress. Traffic data are also collected on an annual basis. This report describes the results from the trial based on the condition of the sections in February 1997, 43 months after construction.

2.2.1 Cracking

The cracking in each of the blocks has been quantified, before and after construction, by recording its intensity and extent. These criteria are described below.

Intensity	Description
0	No cracks
1	A single crack
2	More than one crack - not connected
3	More than one crack - interconnected
4	Crocodile cracking (block < 300mm)
Extent	
1	<10% by length of the block
2	10% < extent < 50% by length of the block
3	>50% by length of the block

Table 1: Cracking After 43 Months

Description of crack relieving interlayer	No of blocks cracked †,‡ (%)
Geogrid reinforcement *	4
Needlepunch fabric *	0
Cut and patch - 40mm layer *	8
Surface dressing - 14mm stone *	40
Surface dressing - 10mm stone *	4
Control - 50mm overlay	37
Control - 90mm overlay	0
Pervious macadam - 40mm layer *	0

* These sections were overlaid with 50mm ACWC20
† Blocks having crack intensity 3 and 4 prior to overlay
‡ A block was deemed to be cracked after overlay if more than 10 per cent by length was cracked (extent 2 and 3).

2.3 Performance of the Trial Sections

Table 1 shows that only the 50mm thick control section and the section having an interlayer constructed with a 14mm surface dressing had any substantial reflection cracking after 43 months of traffic. In both cases approximately 40 per cent of the blocks, which had crack intensities of 3 or 4 prior to overlay, are suffering from reflection cracking.

During construction, the 10mm surface dressing interlayer was trafficked overnight and overlaid the following day. However, because of the possible damage to vehicles caused by loose chippings, the 14mm surface dressing was overlaid on the same day as it was constructed. As a result the cut-back bitumen used for the surface dressing was not fully cured and this resulted in substantial amounts of the 14mm aggregate being incorporated in the overlay material by the paver augers. No such problem was encountered whilst paving the 10mm surface dressing and this probably accounts for its better performance.

After 43 months, neither of the sections with geotextile interlayers had any significant amount of reflection cracks, but the overlays on both sections were slipping. The geogrid was slipping at the geogrid/regulating layer interface and the needlepunch fabric was slipping at the old road/fabric interface. Twenty nine per cent of the blocks in the geogrid section and 17 per cent of the blocks with the needlepunch fabric were affected by this type of failure. This behaviour reinforces previous experiences in Malaysia and elsewhere (Barksdale, 1991) which indicate that field-related construction problems with geotextiles can often outweigh possible improvements in road performance.

2.3.1 Relative Performance of the Crack Relieving Interlayers

The relative performance of the interlayers has been quantified by comparing the area of cracking after overlay to the area of cracking recorded prior to overlay. The area before overlay was assessed by the direct 'mapping' of the cracks.

The development of reflection cracking is illustrated in Figure 1. The two sections with the geotextile interlayers and the section with the 14mm surface dressing interlayer have not been included in this analysis because of the construction problems, described earlier.

The form of the relation for the progression of reflection cracking, based on that observed in the 50mm thick control section, is given in eqn (1).

$$A = k\,10^{(-3.646 + 1.627\,\mathrm{Log}T)} \qquad (1)$$

where
A = Area of reflection cracking (%)
T = Number of commercial vehicle passes (in thousands)
k = Constant depending on crack relieving layer

The area of cracking in the other sections, recorded after 43 months, has then been used to calculate the value of the constant 'k' for the different sections shown in Table 2. Equation(1) and the 'k' values are necessarily based on the data available at present and it is likely that the model will need to be modified as more data becomes available.

The benefits of the different crack relieving layers has been assessed by calculating the whole life cycle costs over a period of 15 million commercial vehicle passes. Assuming a traffic growth rate of 5% per annum this represents approximately 20 years trafficking on the Melaka to Muar road. The results are given in Table 2. It has been assumed that at the time of the first overlay (traffic = 0), fifty per cent of the surfacing was cracked and that subsequent overlays have been constructed when twenty per cent of the surfacing was affected by reflection cracking. The costs are given in Malaysian Ringgits (RM) and have been discounted at a rate of 10%.

Table 2: Whole Life Cycle Costs

Crack relieving interlayer	Constant 'k'	Total cost per kilometre RM×10^3	Whole life costs RM×10^3 Approx 20 years discounted at 10%
50mm thick control	1.000	115.2	312.2
Cut and patch - 40mm layer	0.115	187.2*	225.9
Surface dressing - 10mm stone	0.227	172.8	269.2
90mm thick control	0.123	194.4	251.0
Pervious macadam - 40mm layer	0.144	266.4	367.1

* 50% of existing surface cut and patched.

The whole life costs show that cut and patching cracks, increasing the thickness of overlay by incorporating a binder course, or applying a 10mm surface dressing interlayer are all more cost effective maintenance strategies than simply overlaying cracked surfacings with a 50mm layer of asphaltic concrete. The early results indicate that over a twenty year period, 'cut and patching' interconnected cracks prior to overlay can produce an estimated life cycle cost saving of 28% compared to a single application of a 50mm thick overlay.

3. TRIAL ON ROUTE 10

Surface dressing is an effective maintenance technique which is used in many parts of the world. It can restore skid resistance, prevent premature cracking caused by the age-hardening of bitumen in asphalt surfacings and also arrest the deterioration of an existing road surface that is showing signs of distress. The full-scale trial, described here, was designed to evaluate the effectiveness of different forms of surface dressing in sealing cracks in dense bituminous surfacings. The 4km trial was constructed on Route 10, between Bahau and Rompin.

3.1 Design of the Trial

The two types of seal used in the trial were a double surface dressing and a racked-in surface dressing, both constructed with coated chippings. These were compared to the performance of 50mm asphaltic concrete.

3.1.1 Double Surface Dressing

This is the recommended seal for use on existing bituminous road surfaces which are appreciably cracked or patched. The method employs two applications of binder and chippings. In the trial a 200 penetration binder and nominal 14mm and 6mm coated chippings were used.

3.1.2 Racked-in Surface Dressing

This system is recommended for use where traffic is particularly heavy or fast. A heavy single application of binder is made and the first layer of larger chippings spread to give approximately 90 percent coverage. This is followed immediately by the application of the smaller chippings which 'lock-in' the larger aggregate. As with the double seal, 14mm and 6mm nominal size chippings were used. The amount of bitumen used, is slightly more than would be used with a single seal but less than for a double seal.

3.1.3 Asphaltic Concrete

The effectiveness of the different treatments in sealing cracks is being compared with that of a 50mm overlay of ACWC20.

3.2 Performance of the Trial Sections

3.2.1 Cracking

The location, intensity and extent of cracks prior to construction were recorded in a similar manner as for Trial 1, described in para 2.2.1. Table 3 summarises the area of reflection cracking that has developed in each type of seal after 30 months. The results indicate that after 30 months, double surface dressing has been more effective in preventing reflection cracking than either the racked-in surface dressing or the ACWC20. The improved performance of the double surface dressing over the racked-in surface dressing is attributed to the greater quantity of binder used in the construction of double surface dressing.

Table 3: Area of Cracking after 30 Months

Type of treatment	Area of reflection cracking (%)
Double surface dressing	17
Racked-in surface dressing	56
Asphaltic concrete overlay	34

3.2.2 Texture Depth

A TRL Mini Texture meter has been used to monitor texture depth in the nearside wheelpath along the full length of the trial. The results are shown in Figure 2 where they are expressed as sand patch values.

The figure illustrates the benefits that can be gained by surface dressing. Although there has been a reduction in texture in all of the sections, the texture depths of the surface dressed sections remains satisfactory at a value of approximately 0.9mm. The section having the ACWC20 overlay had a poor initial value immediately after construction and decreased to the relatively low value of 0.4mm after 30 months.

3.2.3 Skid Pendulum Tests

Measurements of skid resistance value standardised to 35° C (SRV_{35}) were made with a portable pendulum tester. The results in Figure 3 show a rapid polishing of the surfacing aggregate and confirms the findings of a previous study carried out in Malaysia (Han and Morosiuk, 1991) which showed that the granite aggregates asymptote to an SRV_{35} of approximately 50 at these levels of traffic.

4. COMPARISON OF THE TWO TRIALS

Previous studies have shown the rate of propagation of reflection cracking through bituminous surfacings (Jones et al, 1992)(Rolt et al, 1996) is dependent on both the level of commercial traffic and the strength of the pavement as indicated by deflection. Deflections on both Trials 1 and 2 were measured before construction with the Falling Weight Deflectometer and the strengths of the roads were found to be broadly similar.

This allows the rate of propagation of cracking at the two trials to be compared. This is done in Figure 4 where the progression of reflection cracks in the alternative seals at Trial 2 have been superimposed on models developed from the results of Trial 1, previously illustrated in Figure 1 of this paper.

The figure shows that the rates of progression of reflection cracking through the 50mm ACWC20 overlays, at both trials, and the double surface dressing at Trial 2 are broadly similar. The rapid development of reflection cracks in both these types of maintenance treatment illustrates that they should only be used to maintain cracked asphaltic concrete surfacings when either areas of interconnected cracks are 'cut and patched' prior to construction or alternatively a crack relieving layer is used.

The figure also shows that the racked-in surface dressing has been less effective in sealing cracked asphaltic concrete surfacings.

5. CONCLUSIONS

- The most common forms of maintenance for asphaltic concrete surfacings in many parts of the world are either double surface dressings or thin overlays. The trials in Malaysia have shown that, where interconnected cracks were not treated prior to construction, the rate of progression of reflection cracks was similar in both types of surfacing. Neither of these maintenance treatments should be used unless areas of interconnected cracks are either 'cut and patched' prior to construction or, alternatively, a crack relieving layer is used.

- The results from Trial 1 have shown that cut and patching cracks, increasing the thickness of overlay or applying a 10mm surface dressing interlayer are all more cost effective maintenance strategies than simply overlaying cracked surfacings with a 50mm layer of asphaltic concrete. A preliminary relationship derived from the early results indicate that 'cut and patching' interconnected cracks prior to overlay can reduce whole life cycle costs by approximately 28% over a twenty year period.

- At Trial 2 those sections having a surface dressing have continued to maintain a satisfactory level of texture depth of approximately 0.9mm. After 30 months the texture depth of the asphaltic concrete overlay was less than 0.4mm.

6. ACKNOWLEDGEMENTS

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Fig. 1: Progression of Reflection Cracking at Trial 1

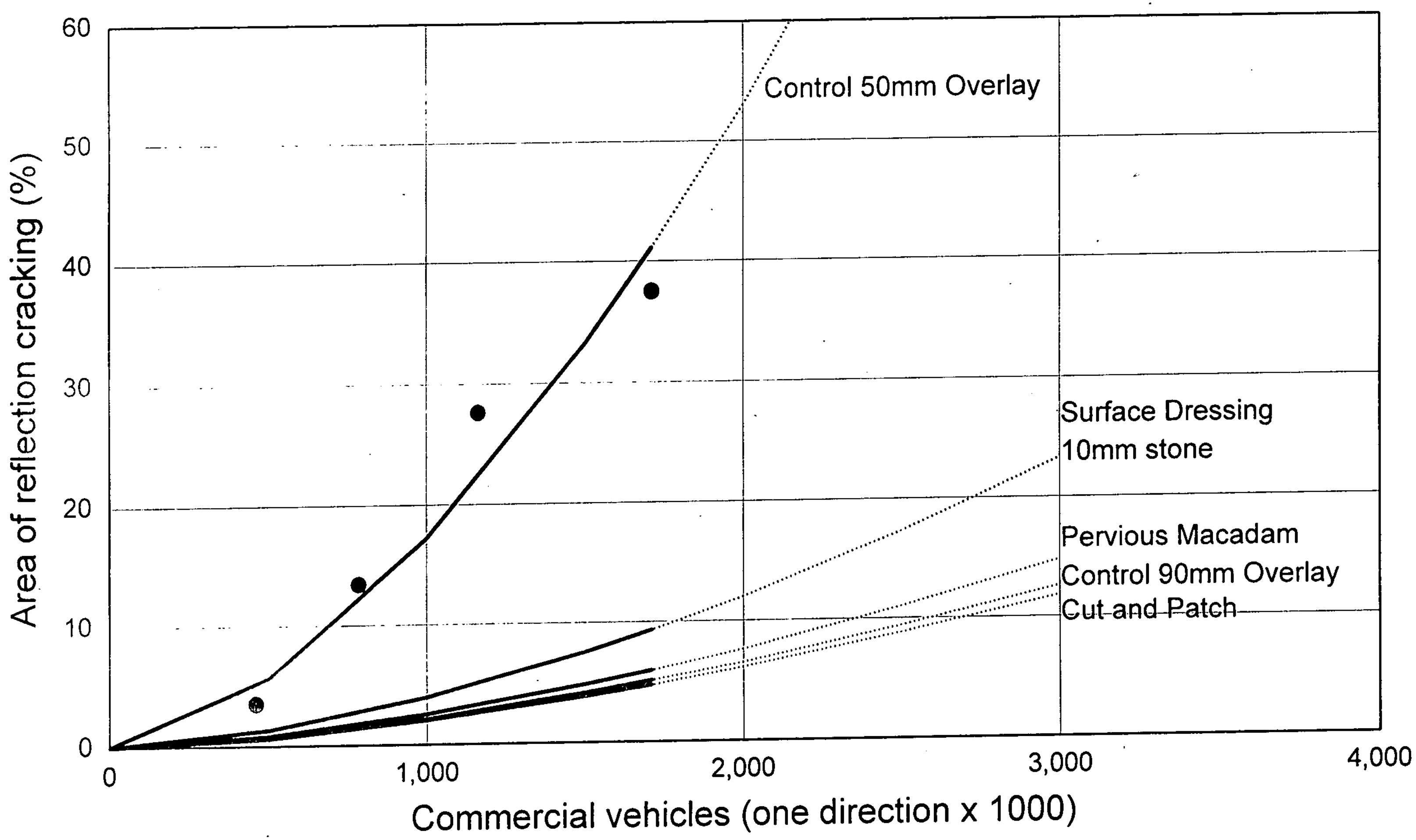

Fig. 2: Change in Texture Depth at Trial 2

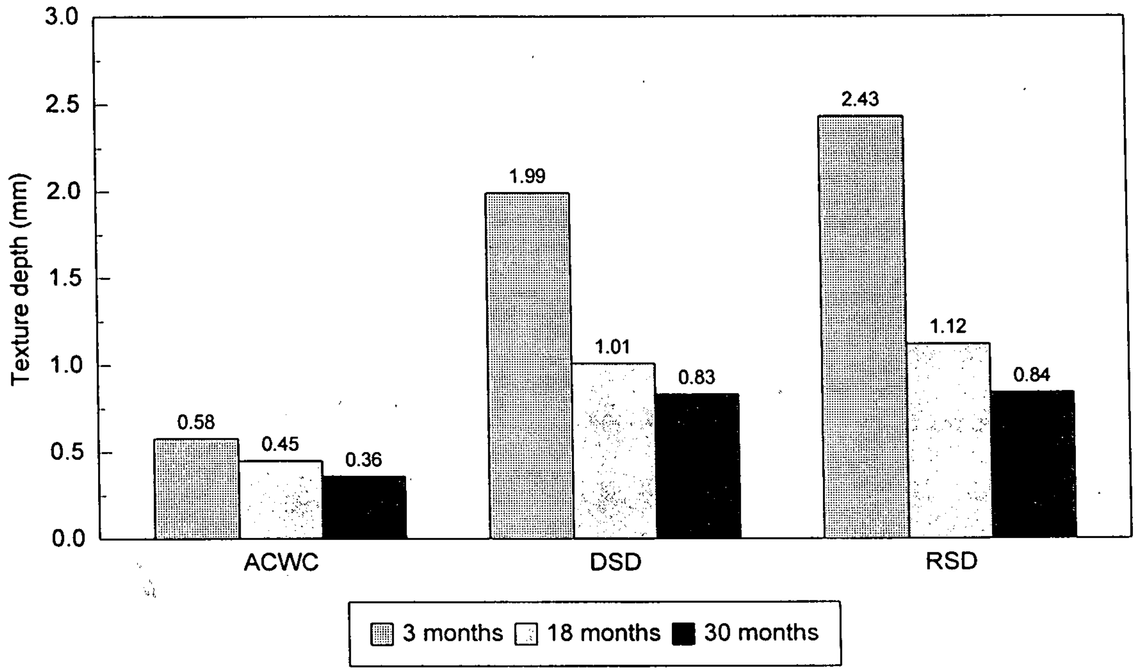

Fig. 3: Change in $SRV_{(35)}$ at Trial 2

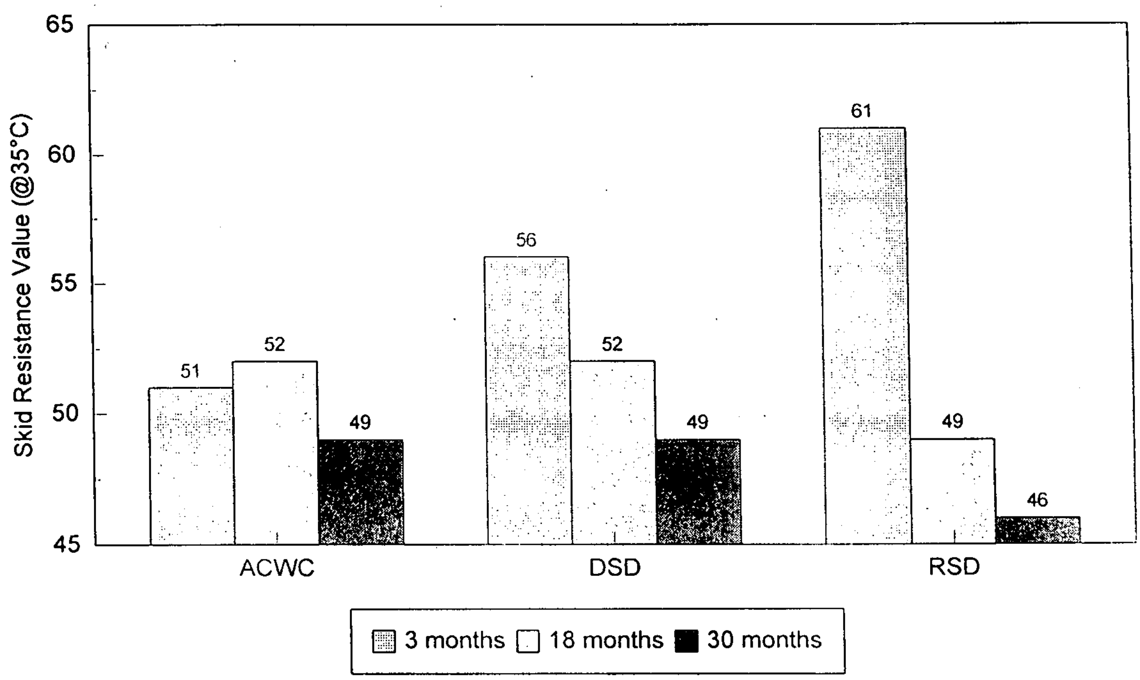

Fig. 4: Progression of Reflection Cracking at Trial 2