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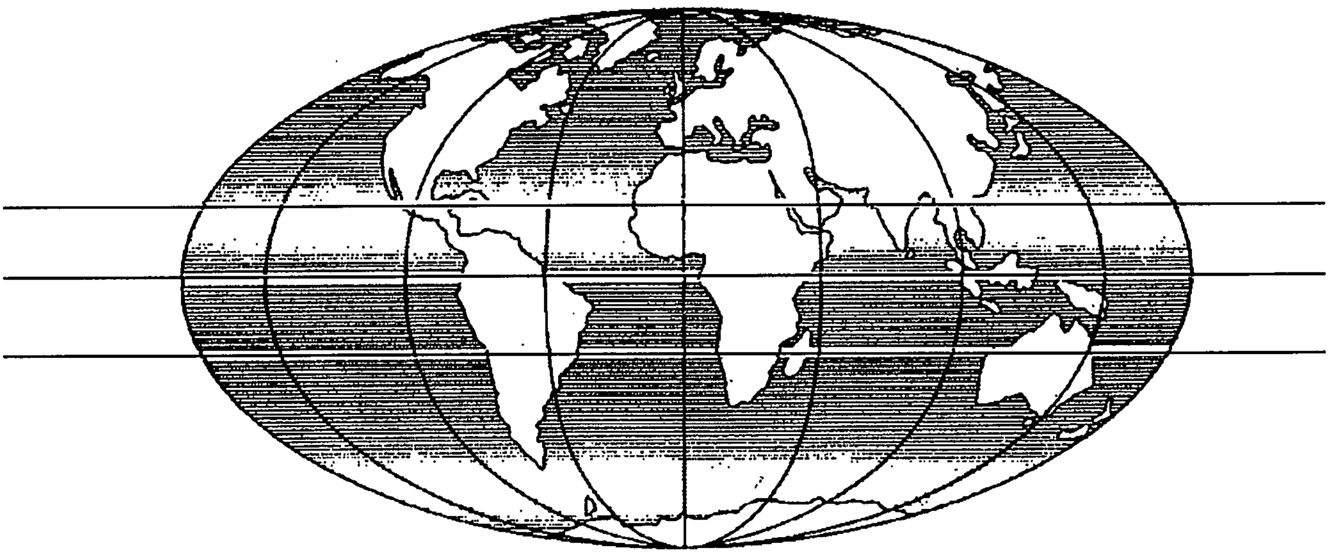

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THE BENEFITS OF USING CHIP SEALS IN MALAYSIA

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ABSTRACT.

This paper discusses the need to adopt alternative surfacings to correct the poor macro texture, required for high speed skid resistance, and to reduce the incidence of premature cracking and subsequent maintenance problems which are associated with the use of asphaltic concrete wearing courses. Results are presented from two full-scale trials designed to compare the performance of asphaltic surfacings and chip seals, both of which can be used for new roads or for maintenance, in terms of their skid resistance and durability. This study is being carried out under a cooperative research programme between the Jabatan Kerja Raya (JKR) of Malaysia and the Transport Research Laboratory (TRL) of the United Kingdom.

1. INTRODUCTION.

The provision of safe roads which also have long maintenance free lives should be two important objectives of the highway engineer. Concern about the number of traffic accidents lead to the formation of a Cabinet Committee on Road Safety, chaired by the Prime Minister, which set targets to significantly reduce accident rates over the next few years. Clearly, an important safety requirement is that road surfacings should have adequate skid resistance.

The premature failure of roads in tropical environments has often been shown to be related to poor quality control. However, even when this has been satisfactory poor durability of asphaltic surfacings has led to premature failures.

2. ROAD SURFACINGS IN MALAYSIA.

2.1 Skid resistance.

Asphaltic concrete (AC) has been used in Malaysia as the principal road surfacing material for many years. AC wearing courses provide a smooth surface which is popular with road users but this very dense material tends to have less than ideal skid resistance characteristics.

When advice was first given on skid resistance values (SRV) for heavily trafficked trunk roads and motorways in the UK a minimum SRV of 55 was recommended when measured with a Portable Skid Resistance Tester (Road Research Laboratory, 1969). Where traffic speeds were higher than about 95 km/h a minimum texture depth (TD) of 0.65mm was also required. This was because the SRV value is appropriate to vehicles travelling at about 50 km/h and as vehicle speeds increase there is a strong relationship between the reduction in skid resistance and the texture depth of the surfacing. Skid resistance drops by about 20 per cent, on a surface with a TD of 1mm, when speed is increased from 50 to 130 km/h. The corresponding reduction is about 30 per cent when the TD is 0.5mm, (Salt and Szatkowski, 1973). The significance of these values in relation to conditions in Malaysia is yet to be established but, in view of the frequent and intensive rainfall in the country it is unlikely that a lower standard will be appropriate. Current UK standards are related to the risk of accidents at a particular location.

Kwang et al (1992), confirmed that the controlling factor in determining the SRV of a road surface in Malaysia is the source of the aggregate used rather than the type of surfacing. Measurements showed that granite aggregate had generally acceptable values of SRV for main roads with a mean value of 55, corrected to a temperature of 35°C (Beaven and Tubey, 1978) which equates to a value of 58 in the UK where readings are corrected to 20°C. However, texture depth was always very much lower than is required with an average value of only 0.35mm. Clearly, if the skid resistance properties of Malaysian roads is to be improved then surface texture must be increased.

2.2 Durability.

In recent research work JKR has shown that Malaysian roads rarely fail through traditional fatigue failure, a mode of failure assumed in current pavement design methods, where cracks start at or near the bottom of the asphalt layer and propagate upwards. It has been found that cracks start at the top of asphaltic surfacings and propagates downwards. This type of cracking is associated with environmental degradation of the binder in the surface of the layer (Hasnur, 1990). A bitumen viscosity gradient develops with a brittle 'skin' forming at the surface which can be induced to crack by thermal stresses, heavy wheel loads or a combination of the two. This cracking can occur on roads which are otherwise structurally adequate and confirms the results of work carried out by TRL in many other tropical countries which also showed that adding more binder to achieve low air voids did not prevent age-hardening at the surface (Smith et al, 1990). This approach cannot in any case be recommended because the dense aggregate structure of AC wearing courses cannot accommodate the additional bitumen without significantly increasing the risk of plastic deformation and reducing surface texture to very low values.

Other cooperative studies between the JKR and TRL have shown that once cracks penetrate to the full depth of the bituminous layer the application of thin AC surfacings to seal them results in very early reflection cracking (Morosiuk et al, 1992). Slurry seals were also found to be ineffective in sealing this type of cracking (Jones et al, 1990). Not surprisingly the cost of rehabilitating roads which have suffered premature cracking has proved to be very expensive because of the countermeasures which are required to prevent reflection cracking.

Increasing the structural strength of the pavement is neither an economic or effective way of preventing 'surface down' cracking because the fundamental cause is associated with climatic conditions. Therefore, if the maximum potential life of a bituminous surfaced road is to be realised at minimum cost and the surface is to retain adequate surface texture it will be necessary to modify current pavement designs which require AC wearing courses.

3. SOME METHODS OF IMPROVING WEARING COURSE CHARACTERISTICS

The surface texture of wearing courses can be improved by using;

i) coarse textured slurry seals;
ii) porous asphalt;
iii) pre-coated chippings; and
iv) chip seals.

3.1 Slurry seals

Slurry seals are attractive to the road user because they look like an AC surfacing. This is because the materials have similar compositions but, unfortunately, they are similarly affected by age-hardening of the binder. Slurry seals can have high bitumen contents and suffer little deformation because of their thinness but careful design is needed to ensure that the correct aggregate is used to retain good surface texture.

3.2 Porous Asphalt

This is a coarse material with a high air voids content to allow water to drain through the layer. It was developed to reduce the amount of spray thrown up by vehicles during wet conditions. Clearly, by allowing water to move freely from under a vehicle tyre, the requirement for good surface texture is met but the very high air voids content may seriously affect durability. A compensating effect will be that the coarser grading allows the aggregate to carry a thicker binder film than would be possible in an AC wearing course. The rate at which voids fill with detritus is a factor which must be considered. JKR are assessing the performance of porous asphalt and it may be shown that this material has considerable potential as an alternative wearing course material.

3.3 Pre-coated chippings.

Texture can be improved by applying pre-coated chippings to the surfacing layer during construction. Chippings of 10-12mm nominal size and are made in an asphalt mixing plant in advance of construction. They are mixed hot with the maximum amount of bitumen as will allow them to remain free flowing when cold. During laying the cold chippings are spread onto the hot AC mat behind the paver and before rolling commences. This method provided good texture on a heavily trafficked road in Kenya for over 12 years. Because relatively small quantities of aggregate are required it may be economic to transport a stone of high SRV over considerable distances for use at dangerous sites.

3.4 Chip seals

Chip seals have played a major part in providing the surfacing on new roads and the means of maintaining large road networks in many countries. In the UK, for instance, many millions of square metres are constructed annually including applications to motorways.

The advantages of these seals include rapid construction at a cost which should be approximately one fifth of that for thin AC layers, very good surface texture and a thick durable film of bitumen with an effective thickness of several millimetres.

Average texture depths of 0.35mm were reported by Kwang, et al (1992) for AC surfacings carrying either light or very heavy traffic flows. The mean value for chip seals carrying light traffic was 1.47mm.

Chip seals have not been used on main roads in Malaysia in recent times. Therefore, as part of the cooperative studies being undertaken by JKR and the TRL, trial sections have been constructed on two heavily trafficked roads to assess the relative performances of chip seals and asphaltic wearing courses.

4. TRIAL SECTIONS.

4.1 Details of the experimental sites.

The trial sections are located on a straight section of Route 5 near Bota, Perak and on Route 11 between Bahau and Rompin, Negeri Sembilan. The existing road at Bota was in good condition with no cracking or deformation in the wheelpaths and FWD deflection tests confirmed that the pavement was structurally sound. At Bahau seals were constructed on the existing road which had suffered cracking and was being widened and overlaid. The trial was designed to determine the effectiveness of the different surfacings to seal cracks (Rolt et al, 1996) as well as to study changes in their surface textures with trafficking.

Traffic counts made by the Malaysian Highway Planning Unit, JKR, indicated that at Bota the unidirectional average daily number of buses and lorries totalled approximately 2500 in a 24 hour period whilst the equivalent figure for Bahau was between 1500 and 2000. Site conditions allow free traffic flow with, for the purpose of chip seal design, high speeds.

4.2 Details of the trial sections.

Details of the three sections at Bota and seven at Bahau, are given in Table 1.

Table 1. Details of the trial sections.

Bota	Bahau
Double chip seal	Single chip seal
20mm of Mediflex	Double chip seal
40mm of AC (ACWC20)	Double chip seal on a geogrid
-	Double chip seal on needlepunch fabric
-	'Racked-in' chip seal
-	50mm of AC (ACWC20)
-	50mm of AC (ACWC20) on a geogrid

4.2.1 Design of chip seals

The design of the single and double seals was based on the recommendations given in Overseas Road Note 3 (TRRL, 1980) whilst the 'racked-in' seal was designed after reference to Road Note 39 (TRL, 1993). The spray rates used for the seals on the fabric and the geogrid were as recommended by the suppliers of these materials.

The 'racked-in' seal consists of a single layer of bitumen, sprayed at a rate intermediate between that for a single seal and the total for a double seal. A larger stone is then spread at a rate which allows a smaller stone, applied immediately afterwards, to fit between and 'lock-in' the larger aggregate.

A medium curing cut back bitumen, MC3000 was used at Bota and a 200 penetration bitumen at Bahau. The slower curing rate of the cut back bitumen is ideal for slower work rates by inexperienced contractors, but is too soft for general use on major Malaysian roads.

4.2.2 Hot mix asphaltic wearing courses

The Mediflex laid at Bota is a proprietary gap-graded asphaltic material containing fibres and is laid on a tack coat of rubberised bitumen emulsion. The aim is to provide texture and a thick bitumen film on the aggregate in the mix. Claimed advantages of Mediflex are; the need for fewer passes of the compaction roller and rapid opening of the road to traffic. The trials tended to support both of these claims.

An AC wearing course (ACWC20), typical of materials used for resurfacing work in Malaysia, was laid at both sites. This material was also laid on a geogrid at Bahau.

5. THE PERFORMANCE OF THE TRIAL SECTIONS

The structural performance of the trial sections will be reported after significant deterioration has occurred on the trials.

5.1 Skid resistance

Skid resistance measurements are being made with the pendulum tester and the results of surveys carried out at the two sites are summarised in Table 2.

The chip seals appeared to retain a higher skid resistance in early life which is likely to be related to the rough surface texture rather than by any difference in aggregate properties. The results show that polishing of the aggregate occurred rapidly under the high traffic volumes and that it is the source of aggregate which determines the resistance to polishing and the long term SRV which has tended to a common value of approximately 50 indicating broadly similar results to those reported by Kwang et al. The SRV is slightly less than the minimum value recommended for similar roads in the UK.

Table 2 Skid resistance (SRV) measurements made at Bota and Bahau

Site	Bota			Bahau	
Age of surfacing (months)	8	23	50	3	18
ACWC20	55	48	58	50	52
ACWC20 on Geogrid	-	-	-	52	53
Mediflex	49	45	52	-	-
DCS	66	45	50	58	51
SCS				64	52
'Racked-in'				61	49
DCS on Geogrid				54	-
DCS on Fabric				57	53

5.2 Texture depths

Some surveys of texture depths have been measured by the sand patch test but a TRL Mini Texture meter has been used for most measurements. To enable comparison with a value of 0.9mm, which would be regarded as a satisfactory in the UK, the readings have been expressed as sand-patch values. Changes in texture depth have been summarised in Table 3.

Texture depths on all sections have reduced with trafficking but those on the ACWC20 and Mediflex have reduced to very low values compared to the chip seals.

Table 3. Changes in texture depth with time

Site	Bota			Bahau	
Age of surfacing (months)	8	23	50	3	18
ACWC20	0.62	0.54	0.44	0.51	0.41
ACWC20 on Geogrid	-	-	-	0.49	0.41
Mediflex	0.75	0.42	0.27	-	-
DCS	1.52	1.2	1.01	1.88	1.05
SCS				1.37	0.95
'Racked-in' CS				1.86	0.91
DCS on Geogrid				1.45	0.71
DCS on Fabric				1.29	0.97

5.3 Changes in binder viscosity.

The trends in increasing binder viscosity in the top 3mm of the ACWC20 and in the complete layer of DCS at Bota are summarised in Table 4.

Table 4. Change in bitumen viscosity with time at Bota

Surfacing	Viscosity after 16 months (Poise*10^3)	Average rate of increase per month (Poise)
AC	500	1400
DCS	160	240

It can be seen that a considerable increase in binder viscosity has occurred in the top of the ACWC20 over a period of 16 months at which time it was approximately three times more viscous than the binder in the chip seal and increasing at a considerably faster rate.

6. DISCUSSION.

Previous measurements on the Malaysian road network shows that several sources of granite aggregate gave mean SRV values of 55 at 35°C, whilst that used at Bota gave an SRV of approximately 50 which is likely to be satisfactory for most road locations. Sources of aggregate with higher resistance to polishing are not readily available in Malaysia and the cost of transporting a high SRV stone for use on dangerous sites would be minimised by using a chip seal.

Texture depth measurements at Bota have confirmed earlier JKR test results on the main road network which show that the texture depth of ACWC's is poor or grossly inadequate. In contrast the texture depth in the DCS was still satisfactory, at a mean value of about 1mm, after 4 years of heavy traffic. It has been shown at Bahau that at the construction stage very high values of texture depth can be designed into chip seals but if high bitumen spray rates are used to improve durability or to seal existing cracks then the texture depth will decrease considerably as a close matrix is developed under traffic.

The rate of increase in binder viscosity in the surface of the ACWC20 has been considerably higher than that in the DCS. The combination of the high volume of bitumen in the DCS and the slow rate of increase in viscosity means that this layer will remain more flexible and considerably more resistant to cracking than the ACWC20.

The benefits in improved texture and durability which chip seals can provide are large. The unpredictability of the occurrence of surface down cracking in unsealed AC surfacings makes it difficult to develop dependable maintenance strategies whereas the performance of a sealed AC will be much more predictable. The process involves well understood principles, does not require the development of new technology and it lends itself to the economic use of polymer modified bitumens for sites where traffic loading conditions are severe. Additional savings and less difficult quality control requirements could be realised by omitting the AC wearing course and applying a chip seal to a thicker layer of binder course.

Poor construction techniques or inappropriate materials can result in damage being caused by loose chippings thrown up by fast moving traffic. The process is often thought of as sub-standard, largely because of poor workmanship and a lack of awareness that surface texture is needed for safety reasons. It is important therefore that the process is treated as a mainstream operation and that good equipment, well trained staff and appropriate design methods are used. It is also important that the reasons for this type of construction are explained to road users.

7. CONCLUSIONS

1. The controlling factor in determining skid resistance, the most important factor at lower traffic speeds, is the source of aggregate. Granite aggregate should have adequate skid resistance properties for the majority of road locations in Malaysia, but a stone with higher resistance to polishing is likely to be required for severe sites or accident 'black spots'.

2. The AC surfacings on the main road network have been shown previously and in this study to have poor surface texture. The trials at Bota and Bahau have shown that only the chip seals have provided adequate surface texture. The seal at Bota has retained good texture for over 4 years under heavy traffic.

3. During the first 70 weeks after construction the rate of age-hardening of the binder in the AC surfacing at Bota has been markedly more rapid than in the chip seal indicating that a more crack resistant surfacing is being provided by the seal.

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