TITLE: Long-Life Pavements

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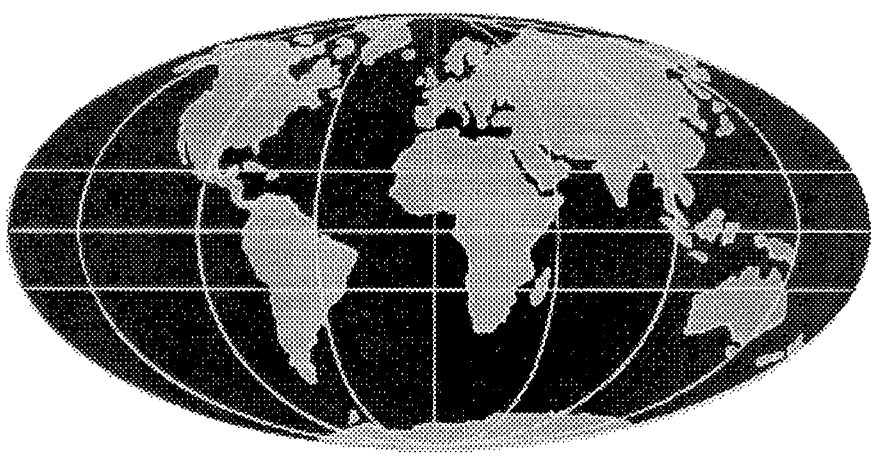

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LONG-LIFE PAVEMENTS

ABSTRACT
The road pavement design charts used in the UK, like most of those in use throughout the world, involved considerable extrapolation of the results of full-scale trials to much higher traffic levels than experienced in the past. If this extrapolation is not accurate then resources may be wasted in the future. It was therefore important to examine the accuracy of this extrapolation.

The performance of heavily trafficked roads in the UK was investigated, especially structural deformation, fatigue in the asphalt surfacings and the nature of the observed surface cracking. The results were surprising and showed that some of our traditional ideas about road behaviour needed to be fundamentally revised. They showed that traditional structural deterioration is very rare on the principal trunk roads of the UK and that most of the repair and maintenance works that are required are concerned solely with the surfacing.

New road pavement design charts have been developed which place an upper limit on pavement thicknesses when roads are sufficiently strong to meet the criteria established for long life behaviour.

The research also showed how to identify long life pavements and developed new assessment procedures to determine their maintenance requirements. The research had a significant impact on the asphalt industry which has concentrated, in recent years, on developing high quality thin surfacings with the primary aim of satisfying the functional requirements such as appropriate skid resistance, low noise properties, reduced spray in wet weather.

1 INTRODUCTION

The current pavement design method used in the UK for fully flexible pavements was established by studying the performance of a wide range of experimental pavements forming part of the trunk road network. The method was based on the interpretation of the structural performance of these roads in terms of theoretical design concepts (Powell et al 19984).

Calculation of the whole life costs of flexible roads over 40 years, taking into account the cost of traffic delays and other costs associated with strengthening, showed that the optimum design strategy was to design the road to reach an *investigatory condition* after about 20 years. At this time it is then necessary to strengthen the road to enable it to carry traffic for a further 20 years. If the road passed beyond the investigatory condition the costs increase because a strengthening overlay is less effective and reconstruction becomes necessary.

Since this method of design was introduced, traffic levels and the consequent disruption at roadworks has continued to increase. Economic considerations have indicated that it is now more cost effective to increase the design life of very heavily trafficked routes to at least 40 years *without* the requirement for structural strengthening.

The question is, can this be done, and if so are thicker pavements needed to achieve longer life or is there a minimum strength above which structural damage by traffic does not occur?

2 DETERIORATION MECHANISMS

2.1 Rutting.

Rutting is the result of deformation in one or more of the pavement layers. At one extreme it is restricted to the uppermost asphalt layers (surface rutting) and does not have a serious effect on the structural integrity of the pavement. At the other extreme, the main component of deformation occurs in the subgrade. This is structural deformation and is a symptom that the load spreading ability of the road pavement is insufficient to protect the subgrade. If unchecked, this will eventually lead to a break-up of the pavement structure. The consequences for pavement design and maintenance of deformation originating solely at the surface or deep within the pavement structure are very different.

Recent research has shown that pavements with more than about 180 mm thickness of asphalt material deform at a low rate and that thinner pavements deform considerably faster; the sudden transition suggests a threshold effect (Figure 1). For the thicker pavements nearly all the rutting is caused by deformation within the upper layers as the traffic-induced strains in the subgrade are too low to cause structural deformation (Nunn et al., 1997)

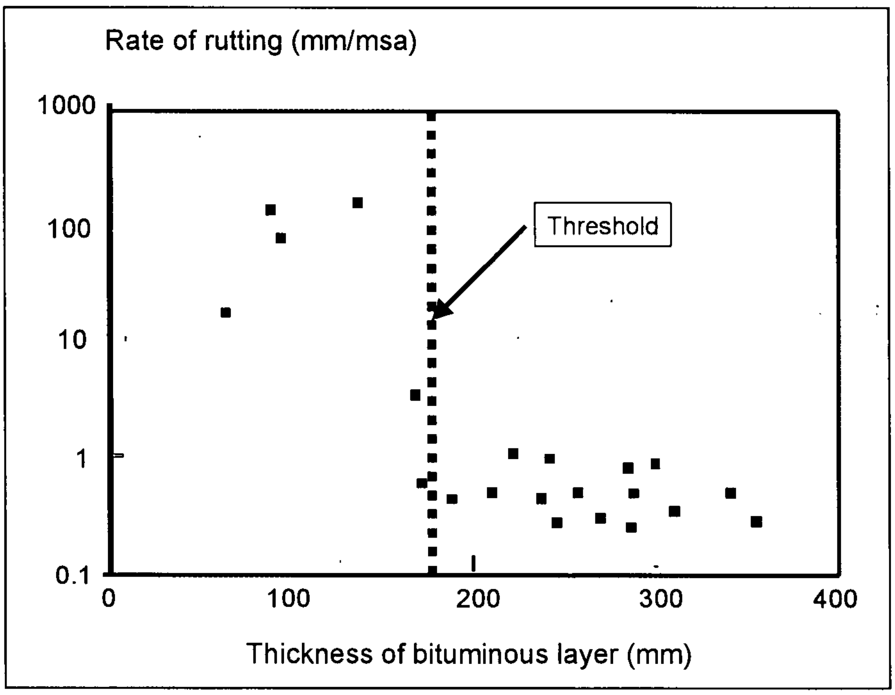

Figure 1 Rutting versus thickness of bound layer

2.2 Fatigue.

All modern analytical design methods for flexible pavements include a criterion to guard against the possibility of fatigue cracks initiating at the underside of the bound roadbase. In such methods this fatigue cracking is considered one of the two main components of structural deterioration. However, although surface cracking is often observed on the trunk roads in the UK, there is no evidence that it is related to this form of fatigue cracking. Furthermore, it is known that the stiffness of bituminous roadbases increases with time, and this influences its fatigue resistance. However, this effect has received little attention in the past.

The lack of visual evidence for 'traditional' fatigue cracking led to an investigation of the fatigue characteristics of bituminous layers extracted from existing roads. If fatigue was occurring, the residual fatigue lives of samples taken from the heavily trafficked wheel-paths should have been considerably lower than from samples taken from outside the wheel-paths on lanes not used by heavy vehicles. For relatively old roads, this difference in residual fatigue life should have been very large. A comparison of samples from motorways revealed *no* significant difference between the residual fatigue life of materials from the heavily loaded and lightly loaded locations, thus showing that traditional fatigue was not occurring.

2.3 Surface cracking.

Nevertheless, cracking at the surface of thick, mature flexible pavements is relatively common. Frequent coring investigations have shown that these cracks invariably begin at the top surface and propagate downwards (Figure 2).

The mechanism of this form of surface cracking is complex and not yet fully understood, but the principal reason is the age hardening of the bitumen in the wearing course, especially in the top few millimetres. Gradual hardening of the main structural layers appears to be beneficial but excessive ageing of the binder at the surface of the wearing course (Figure 3) can lead to cracks being initiated at the surface and propagating downwards.

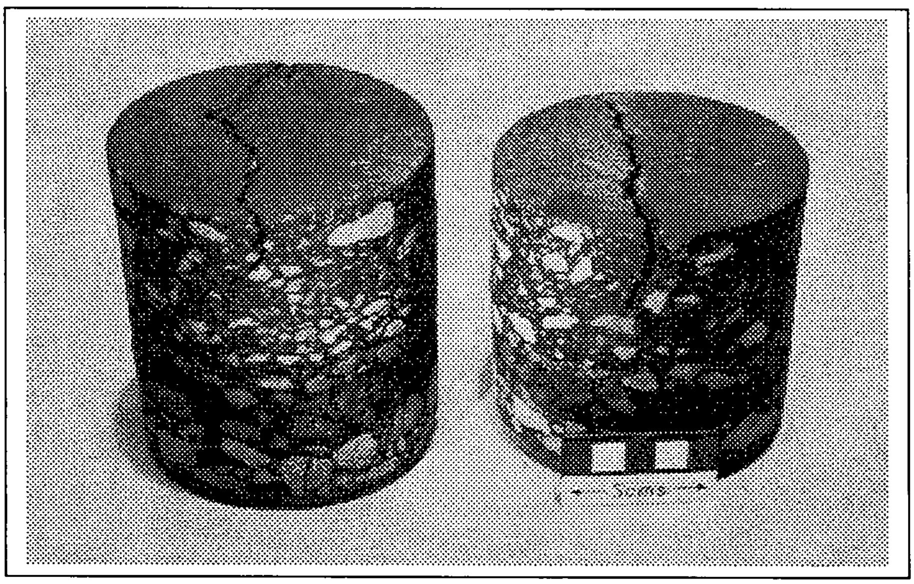

Figure 2 Top-down cracking

The ageing of the bitumen at the surface of bituminous mixes is particularly severe in areas of the world where road temperatures are high. In Jordan, for example, samples taken from the road from Ras Al Naqab to Wadi Yutum showed that the ageing of the bitumen in the top 3 mm was independent of the air voids in the material and that the viscosity of the bitumen had increased to approximately 6.6 Log(Poise) (measured at 45°C in a sliding plate viscometer) after 15 years of service. This is about 30 times the as-laid value and equivalent to a binder penetration of about 12.

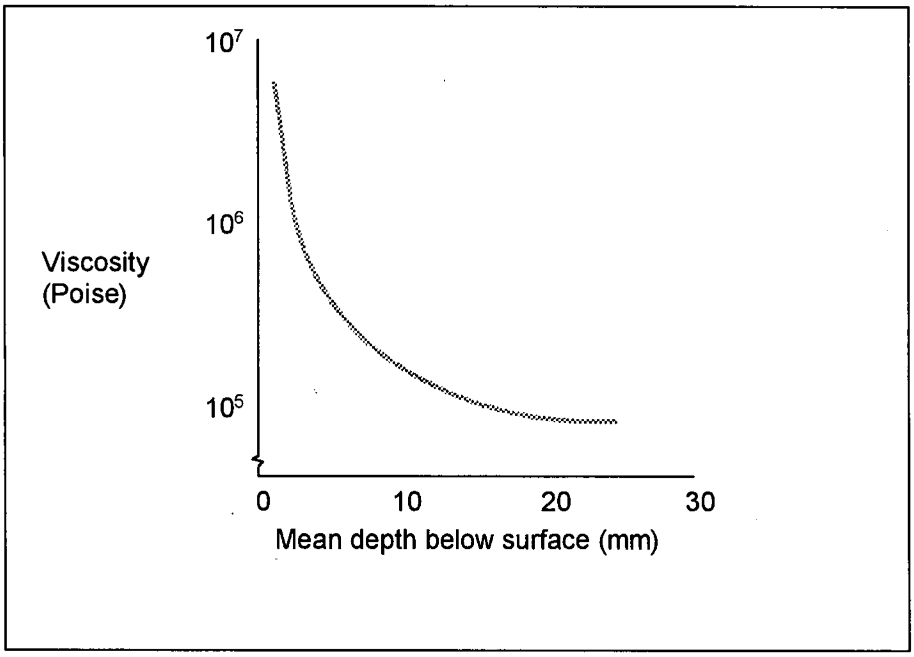

Figure 3 The ageing of bitumen with depth

The characteristics of this ageing process are critical for understanding the performance of the pavement and have major implications for pavement design. As the bitumen and the mix become stiffer (Figure 4), the stresses on the underlying layers of pavement are reduced. This is confirmed by regular deflection surveys which show that deflections on heavily trafficked motorways remain relatively constant or, more often, decrease steadily with time. On the other hand, the fatigue properties of the materials deteriorate with ageing making the material more susceptible to cracking (Figure 5).

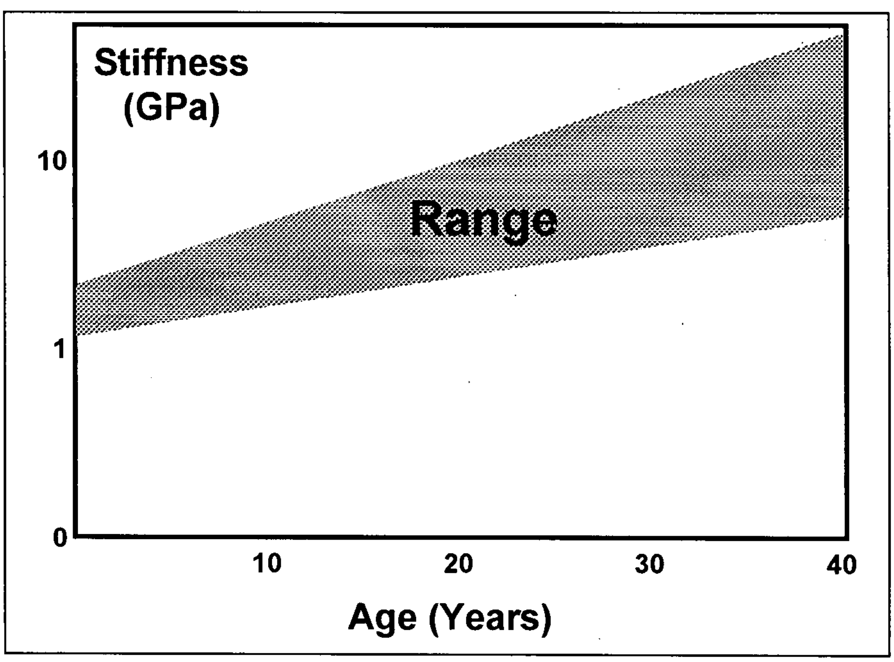

Figure 4 Stiffness of bitumen mixes with time

Thus the effect of increased stiffness and decreased fatigue properties act in opposite directions, the first acting to increase life, the second to decrease it (Figure 6). The experimental data obtained from the road samples, and subsequent calculations, have shown that the *net* effect is for the fatigue life of the pavement to increase with ageing, typically by 100 per cent as shown in Figure 7.

3 LONG-LIFE DESIGN

Provided that the road is strong enough initially, so that its main structural layers are not weakened by early traffic loading, ageing in the bituminous surfacing will improve the load spreading ability and make the road progressively less vulnerable to traffic-induced structural damage. There is thus a minimum threshold strength above which the pavement should have a very long but indeterminate structural life.

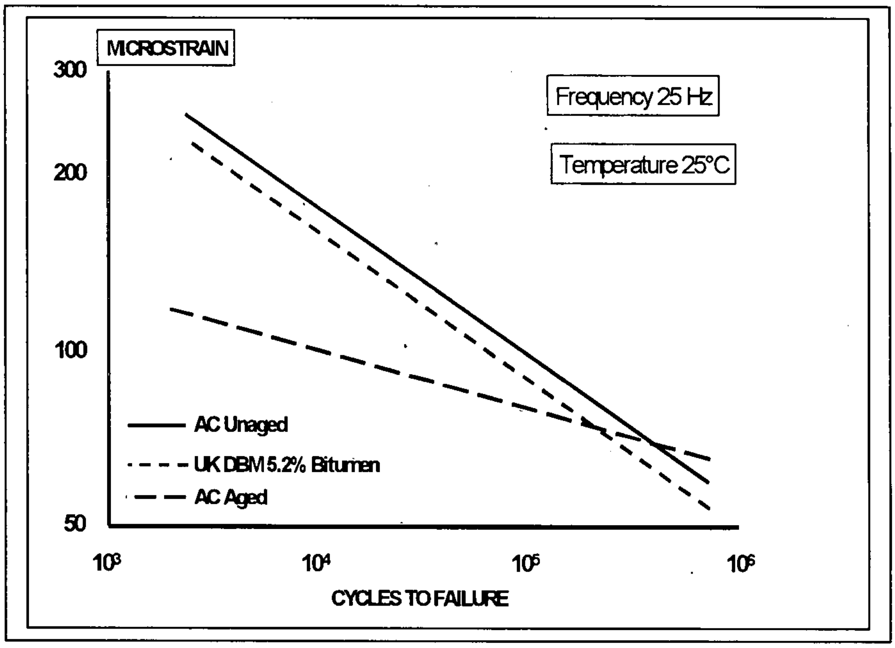

Figure 5 Fatigue properties of aged asphaltic concrete

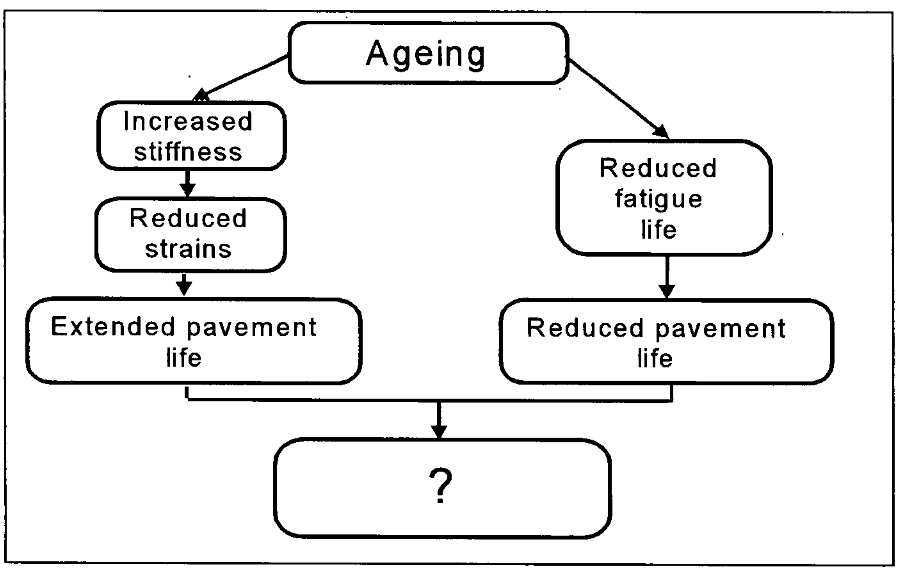

Figure 6 Possible effects of ageing

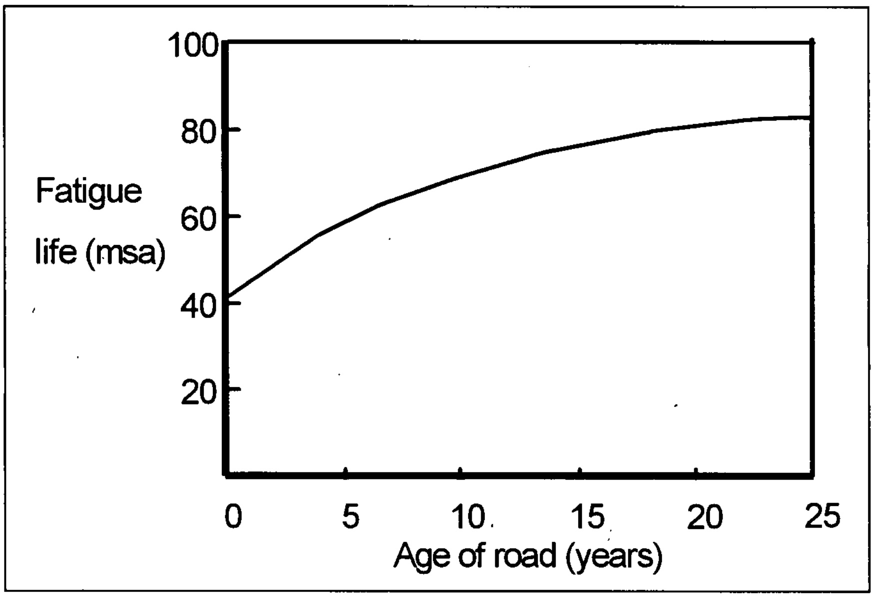

Figure 7 Overall effect of ageing on life the bound layer

Roads constructed for present-day traffic levels, which may be 10 or 20 times higher than encountered on many of the older in-service roads, will need to be stronger initially to avoid excessive deterioration in early life (i.e. before ageing has produced its strengthening effect). A conservative calculation shows that a road constructed with a thickness of more than 270 mm of asphalt will have a long but indeterminate life for any traffic level. This thickness will ensure long life even if ageing does not take place provided that cracking does not reduce the effective thickness of the asphalt layer. Surface cracking will weaken the road and accelerate deterioration. To prevent this occurring, it is necessary to adopt conservative designs to enable the road to withstand some surface cracks. Timely remedial action should be taken before these cracks have a structural impact on the road. Cracks may propagate up to 100 mm into the road before this action is taken. A conservative assumption is to assume that the material down to the depth of the crack penetration does not contribute to load spreading. This implies that a road constructed with a total of 370 mm of asphalt material will tolerate a surface initiated crack, which extends 100 mm into the road, even if the effect of ageing is very small. The UK design charts are shown in Figure 8.

4 IDENTIFICATION AND MAINTENANCE

The present approach to monitoring the condition of the trunk road network in the UK is still dominated by estimates of structural residual life based on deflection measurements. The aim is to identify the optimum time for the application of a strengthening overlay to increase structural capacity and to minimise whole life costs. However, long-life pavements do not require structural strengthening and therefore it is important to distinguish long-life pavements from those which have a determinate life.

Long-life pavements are likely to be well built and will have low deflections. The thickness of bituminous material will be greater than 300 mm but the surfacing may show signs of deterioration. Presently in the UK three categories of pavement are defined based on thickness and deflection criteria.

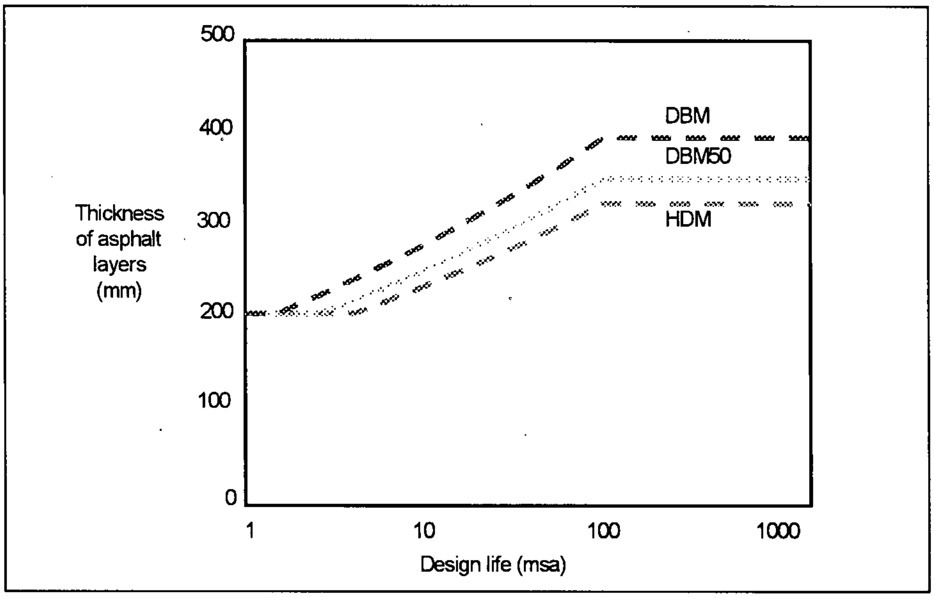

Figure 8 UK design charts

Thin pavements or pavements with high deflections are classified as pavements with a 'determinate life' and are dealt with in terms of maintenance and strengthening as in the past. Pavements with thick surfacings and low deflections are classified as 'long-life'. In addition there is an intermediate category which may or may not be long-life but which may readily be converted to long-life by means of an overlay; these are classified as 'upgradeable' pavements (Figure 9) (see for example, Nunn, M E and B W Ferne, 1997).

Applying these tentative criteria to a sample of the network suggests that around 80% of the flexible pavements on the motorway and about 20% of the all-purpose trunk road network may consist of long-life pavements.

It should be remembered, however, that 'long-life' does not mean an infinite or maintenance-free life. The surface will deteriorate, as for determinate life pavements. Accumulated deformation will cause rutting which will need to be treated before it becomes a safety hazard. Cracking initiating at the surface will need treating by replacing the surfacing before the cracks penetrate into the structural components of the pavement. Skid resistance will decrease and appropriate remedial treatment will be needed.

5. SUMMARY

The overall conclusion is that well-constructed pavements built above a minimum strength are not likely to exhibit structural damage when subjected to very high levels of commercial traffic for a long time. However it is important that any deterioration originating in the asphalt surfacing as either rutting or top-down cracking is detected and remedied before it has a serious impact on the structural integrity of the road.

The existence of long-life pavements has increased the importance of reliable methods of assessment of surface condition, in particular the identification of surface cracks and their depth of propagation. Recent developments of new equipment, which operates at traffic speeds, and automatically identify the existence of cracks helps with this but further techniques still need to be developed to establish the depth of propagation.

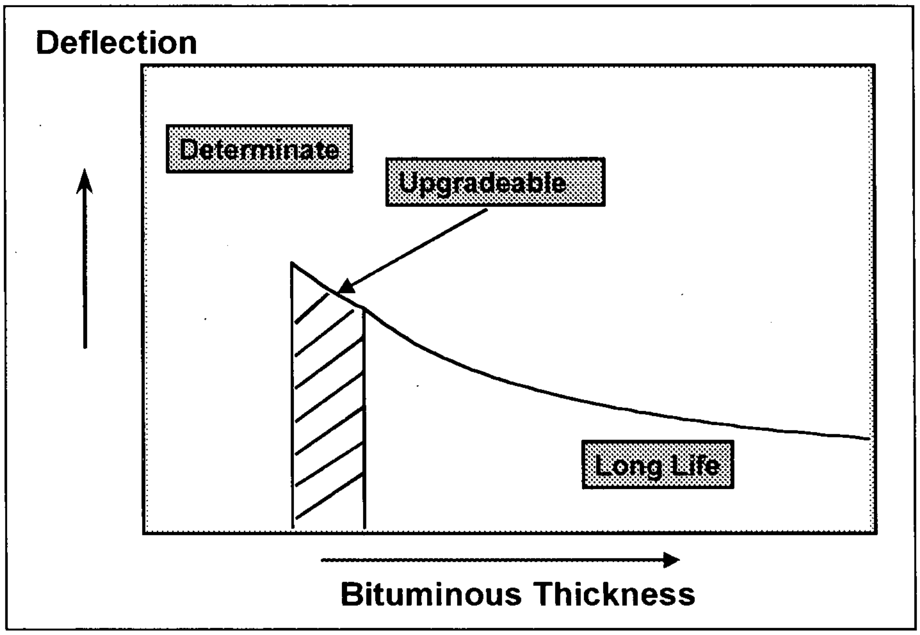

Figure 9 Criteria for long life pavements

6. ACKNOWLEDGEMENTS

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