CHAPTER III
PAVEMENT MAINTENANCE
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Chapter III – Pavement Maintenance

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1. Introduction

There has long been a debate within the road industry as to which pavement construction material is better; asphalt or concrete? Both sides of the argument ardently promote their case and there is much literature in the public domain, which apparently supports both positions. Of course, the truth probably lies somewhere in between, despite the arguments propounded. In such debates, the ground rules are rarely stated and in the multitude of individual road construction/maintenance contracts there are many factors, which will influence the final decision as to whether to use concrete, asphalt, or a combination of both. Within the maintenance sphere, these factors include, existing road condition and pavement type, road site environment and conditions, specified performance properties, desired surface characteristics, location of production plants, availability of suitable materials, speed of construction, traffic management considerations, weather conditions, cost and, even, personal, political or national preferences. Depending on the priorities set, these will often determine which material is actually used, however asphalt/bituminous materials are nearly always the preferred choice.

This document considers the role of bituminous and concrete materials used in the maintenance of the highway network. A literature search on maintenance practices worldwide was carried out and this document is largely based on a review of those papers that were considered to be of some importance. All historical data (more than 20 years old) which support either asphalt or concrete have been omitted from this study because many developments have taken place within both industries that have probably reduced their value. This paper will primarily focus on the contribution made by bituminous materials in highway maintenance.

2. Maintenance Programmes

All road pavements eventually will require some form of maintenance treatment, irrespective of design life, initial construction type or importance. The questions are normally, "how frequently?" and "at what cost?" to restore the pavement back to a serviceable level. In these days of whole life costing (which includes traffic delay and road user costs), the lowest initial cost treatment may not always be the most cost-effective option. Whole life costing (WLC) is a particularly difficult area in which to draw comparisons between different maintenance processes because various assumptions need to be made and costs of various aspects change. Further, there is often disagreement as to the assumptions to be used and the costs involved. However, what is agreed is that traffic delay costs can be significant at road works where the traffic intensity is heavy. Clearly, road users will more favourably receive any works that can minimise disruption. Increasingly, off-peak and night time working are favoured as long as the work can be finished within the often tight time windows of operation. Maintenance contracts using bituminous materials, particularly strengthening overlays or replacement surface courses are often carried out in these time windows, where delays are minimised and the road can be re-opened in time for the normal and rush-hour traffic flows. The fact that bituminous materials can be trafficked immediately once cool is a distinct advantage. Many strategic highway maintenance contracts are carried out during the night hours and it is routine for the works to be completed in time to allow the full weight of the morning traffic to freely flow.
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National policy and budgetary constraints will also dictate the frequency, type and nature of many maintenance and reconstruction contracts. As far as the road engineer is concerned, there are many choices that could be made, all of which will give an acceptable performance. Within either the bituminous or the concrete option, there is also a wide choice of options, especially so within the bituminous sphere.

One must be careful to differentiate between maintenance of the pavement structure and maintenance of the surface characteristics. The first relates to the structural performance of the pavement, i.e. its ability to carry loads, and thus the maintenance options primarily address the more usual failure mechanisms of cracking, fatigue and deformation. The second relates to the performance characteristics of the surface, i.e. texture, skidding resistance, ride comfort, noise reduction and other safety considerations. Maintenance of this second set will often mean restoring the "safety" and/or "environmental" properties even though the layer may still be perfectly serviceable from a structural viewpoint. Changes in government policy and road user expectations regarding highways may mean that what was acceptable or desirable in the past may not be the same as today. For this reason, it is sometimes misleading to use the design concepts and the expected lives of yesteryear and apply them to today’s designs and performance.

Assuming maintenance is required to the highway surfacing, the following shows what options might be available to the engineer:

**Bituminous treatments:**
- Surface dressing (or chip seal)
- Slurry surfacing (or microsurfacing)
- Overlays (thin or conventional) (porous to dense)
- Inlays
- Patching repairs

**Cementitious treatments:**
- Patching, joint sealing, small repairs
- Thin layer topping
- Inlay

However, policy considerations may restrict the final choice, for example, in the Netherlands all motorways are to be eventually surfaced with porous asphalt; in the UK, all surfaces on the strategic network, including concrete, will eventually be covered with noise-reducing bituminous materials.

A report produced by the Committee on Pavement Maintenance (TRB) [1] listed the maintenance options for both rigid and flexible pavements. The actual selection of a treatment is dependent on many factors, which usually reduces to an established procedure or policy. In addition, the performance of the various maintenance treatments are difficult to assess (and compare) because the same treatment used under different pavement conditions may perform differently. In fact, the concept of providing "the right treatment, to the right road, at the right time" is considered to be the key to maintenance practices. It is not, strictly, a debate between concrete and asphalt but a process to deliver the most appropriate solution to give the most cost-effective performance requirement. There have also been moves in specifications, particularly towards performance related ones, where "guarantees" of performance or aspects thereof, are required. Evaluation and validation of these newer specifications will be needed; especially as the road user requirements are becoming more demanding.
3. **Timely Maintenance**

In the United States, approximately 90 per cent of the highway network is covered in asphalt concrete [2], the proportion varying from state to state. Many studies have been carried out on pavement design and repair to both asphalt and concrete roads. An acronym commonly quoted in the literature is "SMART", which stands for "Surface Maintenance At the Right Time", recognising that if maintenance is not carried out at the right time, much more expensive repairs and/or total reconstruction will be inevitable. As an example, a comprehensive study carried out by South Dakota Department of Transportation [3] showed the various maintenance scenarios for both asphalt (flexible) and concrete (rigid) roads and further stated:

"Just as the case for flexible pavements, JPCP [Joint Plain Concrete Pavement] repair needs increase tremendously as the condition of the pavement deteriorates. However, prolonged delay in maintenance and rehabilitation can be even more costly in JPCP".

One aspect of SHRP (Strategic Highways Research Program) in the USA was the Long Term Pavement Performance (LTPP), which was to monitor the performance of materials over a 20-year period. One of its objectives was to develop improved design methodologies for the maintenance and rehabilitation of existing pavements. A Technical Brief issued by the FHWA (Federal Highway Works Administration) in October 2000 [4] concluded that the majority of AC (Asphalt Concrete) overlays included in the LTPP (GPS-6 sites) database had remained in-service for at least 15 years before the deterioration had necessitated rehabilitation. In fact, some sections were still performing well after 20 years with little, or nominal, signs of distress. Naturally, traffic density, type and thickness of the pavement structure and climatic variations all play a part, but the study does demonstrate that asphalt overlays offer durable in-service performance.

It is well known that the SHRP Asphalt program has had a significant effect within the North American market on the performance of asphalt mixtures. Recent evidence indicates that by moving to the new binder specification will result in significant savings in maintenance and reconstruction costs, because pavement life has been increased (by up to 25 per cent). The mixtures being made, using the SUPERPAVE procedure, (together with technology imported from Europe, e.g. SMA), are also performing markedly better than the previously used recipe asphalt mixtures adopted by many of the State Highway Authorities. With this evolution, and despite the fact that further research is necessary to fine-tune the performance properties, it is clear that bituminous materials have dramatically improved in performance in the USA. Developments within the concrete industry are also leading to newer, performance-driven, materials, which are competing in the cost-conscious road environment. One such material is "ultra-thin whitetopping" (UTW) a thin concrete overlay (50-100 mm), which can be used to overlay both concrete and asphalt roads, although its success has been limited to lower volume highways. In order for the applied, bonded, concrete not to warp or be subjected to undue stress build-up, UTW is laid with short joint spacing [5]. This material has been used successfully in the United States [6], albeit on low traffic volume roads, but is relatively less common elsewhere. There have been projects using more traditional, i.e. thick, concrete overlays, but their greater thickness often precludes them from being used where there are significant kerb, drain or bridge height restrictions.

The greatest benefit in using bituminous surfacing layers is that they can offer a wide range of performance properties. Within Western Europe, particularly on the strategic road network and in urban areas, the trend is toward safety, environment and comfort to both the road user and the wider community. As a result of this, surface layers tend to be viewed more for their ability to provide and maintain these performance characteristics rather than their contribution
to the overall structural strength of the road pavement (where the road is already structurally sound). The political climate has changed over the recent decades towards providing materials, which will both provide these benefits and be durable. Each country has its own priority over which properties are the most desirable, but they may be summarised as:

- Safety: skidding resistance and texture
- Environmental: noise reduction
- Comfort: ride, evenness
- Durability: maintenance of the above.

Obviously, other characteristics are important such as resisting rutting, cracking, fretting and fatigue but these can be largely minimised through the choice and design of the most appropriate material. Since the mid 1980s France has been developing asphalt thin surfacing layers, which have revolutionised the maintenance market. This has happened largely through "an encouragement to innovate" and by the development of speciality binders. As a result, the French Standards (AFNOR) include various thin layer types within their specifications. Other countries have followed suit (including for example, Poland) and this growing technology is capturing a greater proportion of the maintenance market. In fact, many new construction schemes are also using asphalt thin surfacing layers specifically for the provision of certain surface characteristics.

4. Changes in Asphalt Design

The structural design considerations and actual performance capability of fully flexible pavements are now much better understood leading to the concept of an indeterminate, or perpetual, structural life (and to the increasing use of high modulus bases, originally developed in France where they are known as EME (enrobé à module élevé). It is now generally realised that asphalt roads can be designed for at least a 40-year life, without structural strengthening during this time [7]. This very significant shift in bituminous pavement design has implications in terms of Whole Life Costing (WLC), such that asphalt’s generally highly competitive advantage has been significantly further improved, as well as for intervention maintenance options. Surfacing layers, in such designs, are consequently viewed as veneer treatments offering the road designer a multitude of options to give the desired, or specified, performance characteristics. In fact, a major conclusion from TRL Report 250 (page 28) states:

"A well constructed, flexible pavement that is built above a defined threshold strength will have a very long structural service life provided that distress, in the form of cracks and ruts appearing at the surface, is detected and remedied before it begins to affect the structural integrity of the road".

Herein lies a potential concern, which is highlighted in much of the available literature. Highway budgets are constrained and the fund of money made available for the maintenance of the total highway network is not sufficient to repair or maintain roads at "the right time". Many highways would cost less to maintain if preventative treatments were carried out before structural deterioration commenced. For example, it is estimated in the US that to maintain their highways at the existing level will require about $50 billion per annum [8]. The amount currently being spent is about half of this. In addition, to raise the US National Highway System to an acceptable standard would require about $200 billion. Given that this level of expenditure is unlikely, the dilemma that faces the US road industry is how to manage the investment whilst still providing a safe serviceable pavement to the road user.
It is considered the same dilemma prevails throughout most of the transport world.

A priority is to have a framework that will select the most effective maintenance strategy, by matching a specific material treatment to offer a durable, cost-effective solution taking into account both the traffic level and environment. It is in precisely this area where a wide range of bituminous products can help in the decision process. Preventative maintenance (PM) is not a new concept but to ensure the correct timing of a treatment, in order to maintain the in-service performance of the road, is the key to cost-effectiveness (see example reproduced in Figure 1 from TRR No. 1597, p. 2). The report [8] further discusses the various treatments available and various decision tree processes to select the most suitable bituminous option, depending on the distress mode.

![Figure 1 – Typical Pavement Life Cycle](image)

**5. Maintenance Options: Surface Layers**

The most common maintenance treatment used to restore texture and skidding resistance to a road is surface dressing (chip seal). For the majority of low-volume roads it is a highly cost-effective treatment and has additional advantages in that it seals the existing road against the ingress of water and is a fast process, with minimal traffic delays. Microsurfacing (slurry sealing) is also a common application in many countries for low to medium volume roads.

Often, many of these roads are only maintained once every 50 years or so (see a lot of rural roads in every country), because of budgetary constraints, and it is therefore quite remarkable that these low cost bituminous products perform so well.
These treatments can be, and are, used in more heavily trafficked applications, again with good performance results. However, these treatments are generally less good at performing in higher stress locations and, in the case of surface dressing, can be considered to be noisy. That said, these low-cost maintenance treatments are suitable for both concrete and asphalt roads, provided that they are structurally sound and they are likely to remain as cost-effective treatments for much of the highway network for the foreseeable future. Various developments have taken place in both processes in order to further improve their in-service performance and broaden their application suitability, including the use of polymer-modified binders.

For the strategic road network, surface layers were more usually maintained with either gap-graded or continuously graded mixtures using aggregates and recipes locally determined in each country. For instance, the UK generally had a preference for gap-graded hot rolled asphalt (HRA) for its major road network, Germany its gap-graded stone mastic asphalt (SMA) and generally for elsewhere, the commonly used continuously graded asphalt concrete (AC) surfacings.

In terms of maintenance of the strategic network, innovations in mixture design and developments in binder technology, especially polymer modification, together with cross-border transfer of technology have greatly improved the bituminous maintenance options. Further, with specific performance criteria being specified (noise reduction, skidding resistance etc), an appropriate asphalt design can be relatively easily proposed.

The newer materials comprise variations on the conventional materials (for example, porous asphalt) together with the multitude of thin surfacing systems. Although thin layers (typically less than 40 mm thick) are not new, their increasing use on heavily trafficked roads and on difficult road sites is. Thin surfacings have increased in popularity for at least five principal reasons:

- Environmental: saving on new aggregate extraction (hence, conservation of quarrying resources)
- Durability: through the increasing use of PMBs a longer life than with conventional bituminous surface layers is possible
- Serviceability: restore specified surface performance properties in order to maintain road users safety and comfort
- Operational: thin surface treatments can be laid quicker than conventional surface layers causing less traffic disruption and delays. Many can be opened up to traffic within 30 minutes of being laid meaning less traffic congestions and better mobility
- Generally, a lower cost per square metre than conventional surfacing

Thin layers may be laid over a range of thicknesses and machine developments allow for very thin paver-laid layers (less than 20 mm) to be successfully applied. It is essential that a good bond be established between the thin layer and the existing material. Gradings range from between super-porous (30 per cent voids) to dense (2 - 4 per cent voids). Obviously, the engineer must select the most appropriate solution for the site in question and this is considered to be easier, given the options available. Correctly designed bituminous materials can be used over a very wide temperature range even in thin layers. In urban situations, thin layers are an obvious attraction where consideration always has to be given to kerb levels, bridge clearances and ironwork. Not having to make adjustments to any of these will result in a much quicker job with associated less traffic disruption and lower costs.

Thus far, mention has only been made of typical highway applications. It should also be mentioned that speciality bituminous-based surfacings are increasingly used. One such group of materials is the fuel-resisting asphalts, where their use is increasing in fuel spillage
susceptible areas such as bus depots, lorry parking areas and service station stops. Not only are these materials replacing the now discontinued tar-based products but they are effectively competing with both concrete and block paving.

Coloured surfacings are another group where different pigments can promote differentiation or an aesthetic appearance to a highway or other paved area. Here again, various bituminous materials (as well as non-bituminous materials) can be tailored to suit the application. Furthermore bituminous surfacings have been developed that can be "imprinted" to give the appearance of block or stone paving.

Reviewing the maintenance options, it is clear that bituminous materials will continue to provide for a wide range of cost-effective solutions in the future. With more stringent safety demands being imposed on strategic highways, bituminous materials offer the greatest variety of options in order to ensure roads meet these demands. The often-voiced fears regarding rutting susceptibility can be overcome by the selection of an appropriate material.

6. Maintenance: General Benefits

Within Europe, many more, and different, maintenance treatments have been trialled and found to perform satisfactorily. Trials using thin layers in the UK, France, Germany, Poland and Sweden have resulted in their approval for use in many applications and locations. Moves towards performance specifications for the surfacing are likely to increase the use of specifically designed bituminous materials. Performance specified materials and proprietary asphalt surfacings are preferentially being considered for use in many road contracts. The benefits to be derived from performance specifications have been summarised [9] and are reproduced in Table 1.

An earlier study carried out by the Refined Bitumen Association in the UK [10] stated a number of benefits from using asphalt, which included:

- Good reservoir of construction plant and skills
- Best historical value for money in whole-life cost terms in the UK
- Flexibility in design: can be designed for short or long lives under light or heavy traffic
- Versatility of scale: equal facility with large and small jobs
- Best environmentally in terms of noise; lower energy use
- Best for safety: porous materials dramatically reduce blinding spray. Road markings easier to see
- Application is relatively easy: rapid to construct, repair and overlay
- Rehabilitation costs lower: relatively easy to plane and/or surface dress to restore skid resistance
- Stage construction easier
- Fewer delays due to weather or other construction activities
- Preferable for constructions on weak sub-bases but suitable for almost all kinds of sub-grade
- Can be trafficked immediately after paving
- Fewer early maintenance problems
- Waterproof and frost proof – especially full-depth asphalt; resistant to chemical attack
- Totally recyclable
Table 1 - Benefits of Performance Specifications for Bituminous Surfacing Materials

<table>
<thead>
<tr>
<th></th>
<th>Quality</th>
<th>Economy</th>
<th>Innovation</th>
<th>Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road User</strong></td>
<td>Reduces delays and accidents</td>
<td>Better use of available road funds</td>
<td>The road user will benefit from the new solutions that this form of specification encourages.</td>
<td>Less congestion at road works resulting in reduced traffic emissions</td>
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<td></td>
<td>Smoother and more consistent ride</td>
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<td></td>
<td>Improves reliability of journey time</td>
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<tr>
<td><strong>Infrastructure</strong></td>
<td>Improves performance of surfacing designs</td>
<td>Ensures value for money. Performance criteria can be changed to match circumstances</td>
<td>Encourages innovation</td>
<td>Road management can be carried out in a manner that is less harmful to the environment</td>
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<tr>
<td><strong>Owner</strong></td>
<td>High consistency of surfacing</td>
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<td></td>
<td>Reduces contractual risk</td>
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<td>Improves public image</td>
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<tr>
<td><strong>Construction Industry</strong></td>
<td>Reduces contractual risk. Provides an objective measurement of performance. Improves public image</td>
<td>Clear basis for alternative bids Reduces risk of defects. Potential to reduce material production costs</td>
<td>Rewards innovation and encourages industrial research initiatives</td>
<td>Removes barrier to the introduction of &quot;alternative materials&quot; Encourages sustainable solutions Reduced material haulage</td>
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</table>

Of particular importance in bituminous road construction and maintenance is the concept of staged construction, which has the following distinct advantages:

- If there are limits to initial finance, a minimum, fit for purpose, thickness of pavement could be laid followed, in time, by further overlays when money becomes available.
- If one is unsure of the likely traffic levels, then the construction could be staged to account for the rise in traffic volume.
- If the road is being opened in advance of other road sections that would eventually increase the traffic volume, then a lower volume design may be initially constructed to carry the interim traffic volume.

The importance with all of these is that the planned overlay(s) or strengthening must be carried out at the due time in order to provide the desired road performance over its design life.

7. Maintenance Options: Recycling

Asphaltic materials are 100 per cent recyclable [11]. For instance, in the Netherlands 70% and in Germany till 80% of the available reclaimed asphalt is reused in warm asphalt recycling.

Recycling itself can take many forms depending on location, convenience and cost and the processes include:

- Hot-mix recycling off-site ("in plant")
Hot-mix recycling in-situ ("in place")
Cold mix recycling off-site ("in plant")
Cold mix recycling in-situ ("in place")

Sometimes, concerns are raised regarding the suitability of recycling of some types of bituminous mixtures (for example, porous asphalt) but recent experience has shown that there are recycling options available that will give satisfactory results. A recent article [12] has reported that the technical feasibility of recycling porous asphalt, either to provide a new porous or dense material has now been demonstrated. Further, overlaying the existing porous asphalt with a further porous layer has been successful, provided the original porous layer has been appropriately prepared.

In addition, it is commonplace for old concrete roads to be recycled by overlaying with asphaltic materials. A US nation-wide detailed evaluation study of AC overlays placed on fractured PCC pavements was carried out on approximately 100 sites [13]. With about US$1 billion of AC layers placed every year on PCC (and likely to rise), the study was timely.

In this study, a number of PCC pavements were fractured using one of three methods; rubbilisation, crack and seat and break and seat, followed by an application of an AC overlay. Rubbilisation involves fracturing the layer into fragments similar to large aggregates and can be successfully used on all concrete pavement types. The crack/seat process is predominantly used on joint plain concrete (JPC) pavements and involves fracturing the layer into closely spaced cracks that permit load transfer across the cracks. The break/seat process is effective on joint reinforced concrete (JRC) pavements and the objective is to fracture the distributed steel or de-bond the steel from the concrete. In terms of the effectiveness of the AC overlays, the following conclusions and recommendations were:

- Rubbilisation of deteriorating PCC pavements followed by an AC overlay is an excellent rehabilitation method that is equally effective for all types of existing PCC pavements.
- The crack and seat technique followed by an AC overlay is a very effective rehabilitation method for deteriorating JPC pavements.
- The break and seat technique currently gives variable results, indicating inadequate breaking of the pavement.

In these studies, as in many others from North America, the benefits of asphalt materials in maintenance contracts for concrete highways are clearly demonstrated, provided the most appropriate conditioning of the concrete is carried out.

8. Conclusions

Chip seals and microsurfacing will continue to offer value for money solutions for much of the low volume road network, particularly where there is a lack of local asphalt production facilities. Where concrete roads have deteriorated, bituminous overlays will also continue to be used to improve the ride quality and prevent further damage to the structure. As far as the strategic highway networks are concerned, there is an increasing move towards safety, sustainability and durability, both at the time of construction and at any maintenance intervention.

The degree of flexibility with bituminous surfacings cannot be paralleled with any other product and it may be for this reason alone that bituminous materials tend to dominate in the maintenance sphere. The benefit to the road user is seen in speed of application; the benefit to the specifying agency is in targeting specific performance characteristics for particular sites; the benefit to the whole community is in safer roads and sustainable materials. The wide
range of products has led them to being used in most highway maintenance situations ranging from overlaying a multiple-cracked asphaltic concrete, to being used in new construction. The scope for bituminous innovation is high with a wide range of possible aggregate types and sizes, a multitude of possible grading envelopes (super-porous to super-dense) and a wide range of paving grade, speciality and modified bitumens from which to choose. This being so, it is possible to tailor, or design, a bituminous material able to meet a specific problem or a specific site requirement. For any contract, where there are a number of client requirements for the performance of the asphalt, there may be a number of engineering options (solutions) available. Asphalt is a highly versatile material and a number of suitable, and attractive, bituminous designs may give the desired performance specified.

Road works are regarded as a necessary evil and any process that reduces delays is regarded favourably. Again, bituminous materials can provide distinct advantages in this sphere as they can be laid during off-peak periods (including night working) and still allow for the road to be re-opened during the normal daytime traffic flows.

Asphalt is fully recyclable and is the most recycled product in many parts of the world. This environmental consideration should not be forgotten.

There is no doubt that bituminous mix design and bituminous surfacing materials have changed dramatically over the years such that they can meet the more stringent constraints demanded by society as a whole. In this regard, with this increasing emphasis on safety issues (reduction in accidents) and environmental issues (noise and sustainability), bituminous materials offer a number of viable and reliable maintenance solutions. The asphalt industry will not stand still as the continuing trend towards performance related specifications will drive research and develop further asphalt innovations and improvements for the future maintenance of our road networks.

9. References


9. TRL (2000): Surfacing systems for high performance asphalt pavements. TRL collaborative research with QPA, HA and RBA, promotional brochure. TRL, Crowthorne


