

# Best practice guide for durability of asphalt pavements

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**Road Note 42**  
**Project: Performance and durability of asphalt roads**  
**Topic 2: Durability of asphalt pavements**

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## FOREWORD

Good road infrastructure is an essential requirement for national growth and prosperity by fostering efficient national and international trade as well as facilitating personal mobility to citizens. For communities and individuals, a road network opens up opportunities for accessing employment, markets, education and health facilities as well as contributing to social inclusion and security.

A road infrastructure can be defined as good when there are sufficient routes linking all relevant locations and those routes are maintained in a serviceable condition. In order to keep road pavements in a serviceable condition without having to have major rehabilitation at frequent intervals, they have to be built in a manner that will extend their durability. Maximising the durability of road pavements has the benefits of:

- reducing the delays to road users caused by maintenance;
- reducing the costs to the road authority of that maintenance; and
- improving the sustainability of asphalt pavement construction.

Improving durability is, in fact, generally regarded as the best long-term means of improving sustainability.

The importance of sustainability extends to making the best use of existing materials. In general, road users prefer asphalt surfacings because they are quieter and provide a smoother ride. There are also moves to overlay existing concrete pavements with asphalt to improve the driver comfort as well as to extend the service-life of the pavement. The choice of treatment is dependent on the type and condition of the concrete pavement and can affect the performance and durability.

The Highways Agency, Quarry Products Association and Refined Bitumen Association are separate organisations that are very aware of the benefits of improving asphalt durability. They have, for many years, jointly commissioned research at TRL on various subjects related to asphalt roads. The latest three-year programme, entitled *Performance and Durability of Asphalt Roads*, included a study to assess how durability could be improved. However, it was not possible to carry meaningful research on the subject that finished in three years using traditional methods. Therefore, two of the three topics within the project that covered durability (*Durability of Asphalt Pavements* and for

*Overlaying Concrete*) were carried out by garnering existing information. These topics included both literature searches and a number of industry workshops involving all sectors of the asphalt road construction industry and substantial input from the three sponsoring organisations.

The Steering Committee believes that the increased involvement of Highways Agency, Quarry Products Association and Refined Bitumen Association members through focus groups for these topics and the broader highways community through the consultative workshops has enhanced the programme, in terms both of the quality of the outputs and of the wider ownership of them. All parties now expect that the durability outputs will help to foster an environment where all parties in the industry co-operate in maximising the durability of the pavement.

There are three outputs from the study into improving durability; a revision to the *Specification for Highway Works* and two new TRL Road Notes (Road Note 41 and Road Note 42). TRL Road Notes are used very successfully in other sectors of the road construction industry and were considered ideal for this type of advisory document. The changes to be made to the *Specification for Highway Works* were to the 900 series and included the introduction of a new clause 903, *Placing and Compaction of Bituminous Mixtures*, that explicitly covers those subjects (although much was taken for it from the old Clause 901, *Bituminous Pavement Mixtures*).

Road Note 41, *Best Practice Guide for Overlaying Concrete*, identifies the different techniques for overlaying concrete pavements and bridges with asphalt, assists in the choice of treatment for a specific situation and gives advice on how to maximise the durability of the treatments. The basic durability of the asphalt material used for the overlay covered by Road Note 42.

Road Note 42, *Best Practice Guide for Durability of Asphalt Pavements* (this document), gives general guidance on the procedures for maximising the durability of asphalt pavements. Whilst it is appreciated that some concepts may not be practical in all circumstances, particularly for emergency repairs, the ideas should be used as ideals that are strived for whenever practicable.

## FOREWORD (CONT'D)

Both Road Notes are set out as sister documents in the same format with specific advice on design, materials and construction. Guidance and advice are also included to encapsulate the overall concepts. It is anticipated that these documents will become essential reading for all involved in road construction.

# CONTENTS

<b>Executive Summary</b>	<b>1</b>
<b>1 Introduction</b>	<b>2</b>
1.1 Development of this guide	2
1.2 Definition of durability	2
1.3 Aspects not covered	3
1.4 Use of this guide	3
1.5 The guiding principles for asphalt pavements	4
<b>2 Job planning</b>	<b>5</b>
2.1 Principal themes	5
2.2 Supervision	6
2.3 Risk assessment	7
2.4 Equipment and manpower availability	7
2.5 Timing	7
2.6 Continuity of work	8
2.7 Established practice and latest technology	8
<b>3 Constraining influences</b>	<b>9</b>
3.1 Foundations	9
3.1.1 <i>Principal themes</i>	9
3.1.2 <i>Impermeability</i>	9
3.1.3 <i>Strength</i>	10
3.1.4 <i>Consistency</i>	10
3.2 Drainage	10
3.2.1 <i>Principal themes</i>	10
3.2.2 <i>New pavement construction</i>	12
3.2.3 <i>Highway improvements</i>	12
3.2.4 <i>Coordinated design</i>	13
3.2.5 <i>Maintenance of drainage systems</i>	13
<b>4 Design</b>	<b>14</b>
4.1 Pavement	14
4.1.1 <i>Principal themes</i>	14
4.1.2 <i>Durability as performance requirement</i>	14
4.1.3 <i>Layer thickness</i>	15
4.2 Materials	15
4.2.1 <i>Principal themes</i>	15
4.2.2 <i>Selection of component materials</i>	16
4.2.3 <i>Temperature</i>	17
<b>5 Joints and sealing</b>	<b>18</b>
5.1 Joints	18
5.1.1 <i>Principal themes</i>	18
5.1.2 <i>Location</i>	19
5.1.3 <i>Method of forming joints</i>	19
5.1.4 <i>Free edges</i>	19
5.1.5 <i>Painting of joints</i>	20
5.1.6 <i>Surface sealing joints</i>	20

Cont'd...

<b>5</b>	<b>Joints and sealing (cont'd)</b>	<b>20</b>
5.2	Tack and bond coats	20
5.2.1	<i>Principal themes</i>	20
5.2.2	<i>Cleanliness of substrate</i>	21
5.2.3	<i>Properties</i>	21
5.2.4	<i>Sealing</i>	21
5.2.5	<i>Adhesion</i>	22
5.2.6	<i>Uniformity</i>	22
5.3	Edge sealing	22
5.3.1	<i>Principal themes</i>	22
5.3.2	<i>Advice</i>	23
<b>6</b>	<b>Application</b>	<b>24</b>
6.1	Compaction	24
6.1.1	<i>Principal themes</i>	24
6.1.2	<i>Job mixture trials</i>	25
6.1.3	<i>Number of rollers</i>	25
6.1.4	<i>Over-running of edges</i>	25
6.1.5	<i>Around ironwork</i>	26
6.1.6	<i>Weather</i>	26
6.2	Finish	26
6.2.1	<i>Principal themes</i>	26
6.2.2	<i>Advice</i>	27
6.3	Maintenance	27
6.3.1	<i>Principal themes</i>	27
6.3.2	<i>Advice</i>	28
<b>7</b>	<b>Conclusions</b>	<b>29</b>
	<b>Acknowledgements</b>	<b>29</b>
	<b>References</b>	<b>30</b>

## EXECUTIVE SUMMARY

The Highways Agency (HA), Quarry Products Association (QPA) and Refined Bitumen Association (RBA) all appreciate the need to maximise the durability of asphalt pavements. Therefore, one of the tasks in their jointly funded research project at TRL entitled *Performance and Durability of Asphalt Roads* was *Durability of Asphalt Pavements*. One of the principal aims of this task was to identify the techniques and procedures currently considered to produce the best practice and to produce a Best Practice Guide based on that knowledge.

Durability as a concept needs to be clearly defined for any guide on best practice, and it was decided to concentrate on the durability of the whole pavement rather than just that of the asphalt mixture. For this purpose, pavement durability is defined as:

the retention over the structure's expected service-life of a satisfactory level of performance without major maintenance for all properties that are required for the particular road situation in addition to asphalt durability.

The aim of the Best Practice Guide is to encourage everyone working in the asphalt industry to contribute to making pavements as durable as practical. To enable people to fulfil this aim, they need to know not only the actions they can take to enhance or damage durability, but also how their actions may impinge on the efforts of others. An understanding of the intentions and constraints during other phases should help to

produce designs that are buildable, materials that have the potential to perform and a pavement that is fit for purpose.

The desire to achieve longer durability for asphalt pavements is common among those involved in designing, specifying, producing and laying asphalt materials and pavements. Therefore, all parties have to work together in a spirit where positive actions are rewarded and negative actions or omissions are discouraged.

The main aspects that lead to durability are:

- the control of water (getting it away from the structure if not actually stopping it ever entering);
- limiting the number of and sealing joints (both vertical and horizontal); and
- adequate compaction (particularly at joints).

These aspects are likely to rise in importance with the predicted changes from global warming, with hotter, dryer conditions in summer but more intense rainfall, and possibly more of it, in the winter. Such conditions will exacerbate the potential for unwanted water to penetrate into the pavement, causing irreversible damage to the asphalt.

However, lack of maintenance, particularly of the drainage, can lead to premature failure even if the best practice was followed in design and construction.

# 1 INTRODUCTION

## 1.1 DEVELOPMENT OF THIS GUIDE

The Highways Agency (HA), Quarry Products Association (QPA) and Refined Bitumen Association (RBA) all appreciate the need to maximise the durability of asphalt pavements. Therefore, one of the tasks in their jointly funded research project at TRL entitled *Performance and Durability of Asphalt Roads was Durability of Asphalt Pavements*. One of the principal aims of this task was to identify the techniques and procedures currently considered to be best practice and to produce a Best Practice Guide based on that knowledge. This document is that Best Practice Guide. However, it is appreciated that it may well need updating in future when additional techniques, materials and procedures have been developed, and any suggested changes or information about developments will be gratefully received by the authors.

To oversee the durability task, the Best-practice Focus Group (BFG) was formed consisting of Colin Loveday (Convenor), Donna James (HA representative), Chris Southwell (RBA representative), David Williams (QPA representative) and Cliff Nicholls (TRL and secretariat). The work of identifying the best practice to maximise durability was considered not practical to achieve with pure research, monitoring a series of trials with different options to assess their relative durability. Therefore, the BFG initiated the triple pronged approach of industrial workshops, literature reviews and limited laboratory and pilot-scale studies.

Two industry workshops to provide the initial ideas were held on consecutive days in November 2005, one for designers and one for contractors. The workshops were led by a professional facilitator. Considerable information was gleaned from the workshops, both for this Guide and for possible changes to the *Specification for Highway Works*, the later being dealt with separately. A follow-up workshop of all parties in January 2007 was held in order to refine the findings and outcomes.

The literature reviews were undertaken to identify what is already known. These reviews were undertaken

using both conventional library sources and on the internet. Finally, the laboratory and pilot-scale studies were undertaken to fill in any minor knowledge gaps. However, there were a limited number of gaps that could be filled by such limited studies.

## 1.2 DEFINITION OF DURABILITY

An asphalt material or a pavement can be said to be durable if it maintains its structural integrity and functional properties at a satisfactory level within its nominal design-life when exposed to the effects of the environment and the expected traffic loading. However, two distinct definitions are proposed for this Guide, as follows:

- **Asphalt durability**  
Maintenance of the structural integrity of compacted material over its expected service-life when exposed to the effects of the environment (water, oxygen, sunlight) and traffic loading
- **Pavement durability**  
Retention of a satisfactory level of performance over the structure's expected service-life without major maintenance for all properties that are required for the particular road situation in addition to asphalt durability

This Guide primarily covers pavement durability.

### Notes on the definition of durability:

- 1 Asphalt durability** is dependent on:
- the component materials used
  - the weather conditions during laying
  - the mixture, both the generic type and the job mix design
  - the workmanship during mixing, transport, laying and compaction
  - the site conditions, including geometry, subsequent local weather conditions, drainage and (possibly) traffic.

**2 Pavement durability** is dependent on:

- the asphalt durability
- the traffic and other site conditions
- the performance requirements set
- the asphalt performance characteristics.

**3 The performance requirements** could include any or all of the following:

- stiffness
- resistance to fatigue
- texture depth
- transverse rutting
- longitudinal ride quality
- skid resistance
- noise level
- colour.

Not all the properties in the current list, which is not necessarily comprehensive, have in-service requirements.

### 1.3 ASPECTS NOT COVERED

There were several issues raised at the workshops that are considered to be outside the scope of the Guide. These issues include the availability of funds, the type of contract, the knowledge base and personnel.

The overlaying of concrete by asphalt raises specific issues that are not covered in this Road Note. Guidance on best practice for the relevant techniques is given in a separate document (Hassan *et al.*, 2008).

The only solution suggested for the availability of funds was lobbying, which is clearly outside the scope of a Best Practice Guide. The contract types and the associated definition of responsibilities can have an affect, particularly with the current trend to demand guarantees, but are not relevant here other than for the need to define them so that all relevant responsibilities are allocated to an appropriate person or organisation.

The knowledge base concerns included the loss of County Surveyors and experienced inspectors, which has led to less supervision, together with more designers who are not sufficiently aware of construction details and contractors whose skill-base has been eroded. The main worry, however, was the lack of accurate records about what is already there on the national network. The availability of skilled labour was expected to be an increasing problem with a declining operator skills base unless the industry can attract and train more young engineers. The panacea of increased salaries was widely accepted as the solution!

### 1.4 USE OF THIS GUIDE

The aim of this Best Practice Guide is to encourage everyone working in the asphalt industry to contribute to making pavements as durable as practicable. To enable people to fulfil this aim, they need to know not only the actions they can take to enhance or damage durability, but also how their actions may impinge on the efforts of others. An understanding of the intentions and constraints during other phases should help to produce designs that are buildable, materials that have the potential to perform and a pavement that is fit for purpose.

Each of the main sections is prefaced by one or more simple quotations or other short statements that have been selected to encapsulate the overall concept of that section. It is hoped that these statements will stimulate the reader to understand the wider implications of their specific role.

Following the quotation, the principal themes give general advice on what needs to be achieved to enhance, or at least not detract from, the goal of extended durability for the construction of asphalt pavements. This general advice is kept relatively brief so that the essence is not hidden among detailed considerations. It is intended to give advice about what issues should be covered but does not provide detailed instructions on precisely what to do in all cases. The latter would require a very large document that would need continual updating.

Each section contains more specific advice on design, materials and laying which is set out in different coloured boxes. Despite a wish for everybody to understand the full scenario of what can be done to enhance the durability of the final pavement, the advice on each aspect is split in this way to improve the clarity. For these boxes, it is assumed that the overall objectives of the associated activities are as follows:

- The objective of design is to produce a specification from which a high-quality pavement can be produced and which excludes the use of materials or techniques that have a high risk of making the pavement perform inadequately, whether initially or in-service.
- The objective of material production is to produce asphalt that can be transported and laid without unnecessary difficulty in a condition that it can meet all the functional requirements, including their long-term maintenance.

- The objective of laying is to install the asphalt under appropriate conditions and in a manner conducive to maximise the functional requirements, including durability.

However, the overriding objective for all involved must be to get it right first time. Replacement or even premature maintenance is not in the best interests of anybody – client, contractor or, most importantly, the motoring public.

The relative importance of the three sections varies on different aspects. The advice is split in this way to improve clarity, but it is not intended that designers, materials suppliers and site staff only read the advice on their aspect. Everyone should read all three sections, even if they then concentrate on the one(s) most closely related to their particular responsibilities.

### 1.5 THE GUIDING PRINCIPLES FOR ASPHALT PAVEMENTS

**‘Everything should be made as simple as possible, but not simpler’**

*Albert Einstein*

There are many approaches that can be used when striving for durable pavements. However, there are some universal truths that should be borne in mind at all stages of design and manufacture, including the following:

#### **The three core principles of asphalt**

- Pavements are designed to act as one layer
- All joints are weaknesses
- Sealing and bonding between layers are essential

#### **The three core virtues of asphalt**

- High binder content
- Small nominal size aggregate
- Low air voids content

#### **Three things water should not do**

- Get in from the side
- Get in from the joints
- Find its way between unbonded layers

#### **Three things to remember about drainage**

- It is essential
- It needs to be continuous
- It needs to be maintained

Underpinning these universal truths, the following are some general concepts that should be borne in mind at all stages of design and manufacture:

#### **General**

- Planning of the work can reduce the risk of under-achievement.
- Solid foundations allow good compaction.
- It is impossible to fully compact unsupported edges.
- The limiting factor on paving output is the rolling capacity rather than the paver speed or the available supply.

#### **Mixtures**

- High binder content is good.
- Smaller nominal sizes of aggregate are good to avoid segregation.
- Low air voids content is good.

#### **Layers**

- All joints (vertical and horizontal) are weaknesses.
- A few thick layers are better than multiple thinner layers.
- Pavements are designed to act as one layer.

#### **Drainage**

- Water ingress from the side is bad.
- Water will always find its way between unbonded layers.
- Water between layers will always result in deterioration.
- Water in asphalt with high voids content risks reduction in stiffness.
- Drainage of the structure is essential.
- Drainage will remove water from the pavement only if adequately maintained.

#### **Joints**

- Sealing and bonding between layers is essential.
- Sealing of joints (longitudinal and transverse) is good.

These truths will be repeated as short statements at the start of the relevant sections of this Guide.

## 2 JOB PLANNING

**‘A clever man overcomes problems that a wise man would have avoided in the first place’**

*Confucius*

### 2.1 PRINCIPAL THEMES

**Knowledge may be king, but that knowledge needs to be passed to all involved for true success**

#### **Contract size**

A continuous pavement with minimal joints will produce a more durable product but it can be achieved only on relatively large contracts.

#### **Compromising durability to minimise traffic disruption**

Minimising the immediate disruption to traffic by requiring a road to be reopened at peak periods may be detrimental to the long-term traffic disruption because working in small packages may increase the need for maintenance and bring forward the time when replacement is needed. The differences should be fed into the whole-life costing of the works in order to achieve true value engineering.

#### **Contractor involvement**

Early discussions between the designers and contractors are needed to ensure that everybody is working to a common, and practical, goal. The responsibilities for each aspect should be allocated to the relevant organisation by the contract, and the relevant person or persons within that organisation who will undertake that responsibility should be clearly identified. The identified people should have both the technical knowledge and the appropriate authority to make any decisions relevant to that responsibility. Systems for adequate communications between parties need to be established,

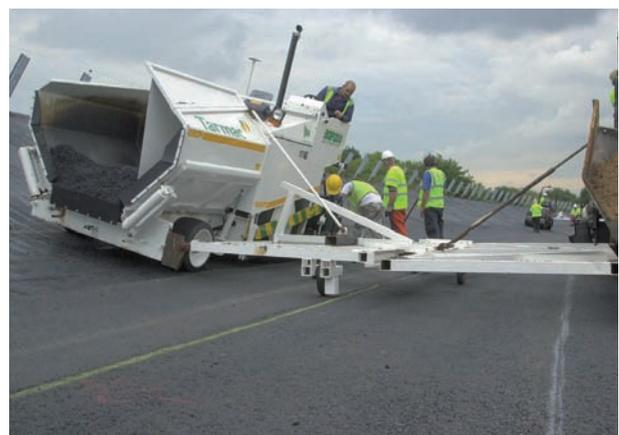
both between offices and on site. Good liaison should develop into trust between parties, which allows for issues to be resolved before they become problems. Problems usually result in errors that have repercussions on the durability.

#### **Method statements**

Requests for method statements should ensure that the contractor thinks about how to do an operation before he does it without being prescriptive. Ideally, they should be used in conjunction with performance requirements. A method statement should explain what equipment will be used, in what order and by whom as well as what tests will be carried out to ensure consistency. However, the acceptance of a method statement does not remove the contractor’s obligation to meet any specified performance requirements.

#### **Seasonal working**

Much greater attention to detail is required when the weather is inclement because such conditions have a substantial impact on the cost of the construction. Throughout the planning, the time of day and season when the work will be undertaken should be considered. Ideally, all work should be done in daylight during the summer when operatives can concentrate on their duties (rather than keeping warm and trying to see) and the hot asphalt will not cool too quickly. However, some projects are sufficiently large to span more than just the summer whilst others are for repairs that need to be undertaken quickly so that the ideal is breached without allowing for the political need to work in the winter or at night. Nevertheless, for safety as well as for durability, laying asphalt during winter nights should be avoided whenever possible. When winter and night work is to be undertaken, the shorter compaction times available and additional constraints will need to be allowed for in planning the programme. Planning can then alleviate some of the adverse effect on durability, but the final product is still likely to be inferior to that which can be obtained in benign, well-lit conditions.





edges of the mat. Such procedures could be as simple as putting cones to mark the edges or provide specific, prepared locations where any traffic that needs to transverse the new mat can gain access and egress.

**Maintenance**

A strategy for maintenance, particularly of the drainage, needs to be developed at initial design stage of any new build, reconstruction or major maintenance scheme. There then needs to be a procedure to ensure, as far as is practicable, that the strategy is implemented after the works have been completed.

**Logistics**

The haul, both in terms of distance and time, between the asphalt plant and the site, should be considered in terms of asphalt mixture(s) being laid, the likely weather conditions and the equipment laying it. Excessive haul times can lead to cool loads that will leave insufficient time for their compaction. The planning should also involve deciding on what equipment is needed to undertake the work and what reserves are necessary in case of breakdowns. Breaks in the supply or delivery will lead to additional joints, which are undesirable in terms of durability.



**Trafficking**

Both during construction and on opening to traffic, premature trafficking can damage the new pavement. In particular, procedures should be implemented to reduce the risk of site vehicles over-running any exposed

**2.2 SUPERVISION**

**Checking to avoid errors is time better spent than time spent sorting out those errors**

<p><b>Design advice</b></p> <ul style="list-style-type: none"> <li>Professional standards need to be maintained by regular review at all levels.</li> </ul>	<p><b>Materials advice</b></p> <ul style="list-style-type: none"> <li>Sector Schemes provide third-party monitoring that can be supplemented by additional testing to ensure continuing compliance.</li> </ul>	<p><b>Laying advice</b></p> <ul style="list-style-type: none"> <li>Sector Schemes provide third-party monitoring that can be supplemented by additional testing to ensure continuing compliance.</li> </ul>
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## 2.3 RISK ASSESSMENT

**A risk is truly frightening only when it has not been foreseen**

### Design advice

- A risk assessment should be carried out to identify scenarios that would have an adverse effect on durability and a reasonable probability of occurring. A decision should then be made about how to reduce the probability and/or the effect to an acceptable level.

### Materials advice

- A risk assessment should be carried out to identify scenarios that have an adverse effect on durability and a reasonable probability of occurring. A decision should then be made about how to reduce the probability and/or the effect to an acceptable level.

### Laying advice

- A risk assessment should be carried out to identify scenarios that have an adverse effect on durability and a reasonable probability of occurring. A decision should then be made about how to reduce the probability and/or the effect to an acceptable level.

## 2.4 EQUIPMENT AND MANPOWER AVAILABILITY

### Design advice

- A sufficient number of adequately experienced and well-motivated designers and specifiers are needed.

### Materials advice

- The plant needs to be well maintained and manned by adequately experienced and well-motivated staff.

### Laying advice

- A sufficient quantity of well-maintained equipment and adequately experienced and well-motivated staff are needed.

## 2.5 TIMING

**Timing is everything**

### Design advice

- The requirements should discourage night and winter working on site whenever possible.

### Laying advice

- More resources, including manpower, tend to be needed for night and winter working, particularly in terms of a reserve in case of breakdowns.
- For night working, high-quality artificial lighting is essential. Such lighting can be mounted on the mobile plant.
- The possibility of low-temperature conditions must be considered in winter.

## 2.6 CONTINUITY OF WORK

**The work needs to be continuous in order to minimise any change in density, level or other property that could initiate future problems**

### Design advice

- There should be a review of the need for restricted-hours working and of the extent of road that can be closed to traffic at any time, with a preference for longer times and lengths being available for working in order to attain greater durability.

### Materials advice

- The supply from the plant to each job should be consistent with the amount that can be laid by the gangs and equipment on those jobs.

### Laying advice

- When allowed to work long lengths and great widths at a time, the procedure should minimise the number of cold joints in the finished pavement.

## 2.7 ESTABLISHED PRACTICE AND LATEST TECHNOLOGY

**Experience tempered by innovation**

### Design advice

- Past experience should be used as the basis for selecting options when that experience is truly relevant, but not at the expense of potential technical developments.

### Materials advice

- Past experience should be used as the basis for selecting mixing procedures, mix designs and component materials when that experience is truly relevant, but not at the expense of potential technical developments.

### Laying advice

- Past experience should be used as the basis for selecting transporting, laying and compaction techniques when that experience is truly relevant, but not at the expense of potential technical developments.

## 3 CONSTRAINING INFLUENCES

### 3.1 FOUNDATIONS

#### 3.1.1 Principal themes

**Solid foundations allow good compaction**

##### Site investigations

Before the pavement, including its drainage, is designed, there should be sufficient inspection and assessment of the existing construction to be able to complete a meaningful design. Inadequate site investigation can lead to wrong assumptions that will require changes on site when the true situation is discovered. This can be costly, in both time and money, if a less than optimal design, in terms of performance and/or durability, is to be avoided.

##### Strong foundations

A strong foundation will allow overlying layers to be fully compacted whereas weaker ones may deform, particularly with vibratory compaction, to make the compaction equipment less efficient. However, it is not always practicable to adequately enhance the strength of weak foundations, particularly for minor roads.

##### Moisture control

Some sub-base materials weaken when wet, thus reducing the strength of the foundation. Therefore, the moisture in these materials needs to be controlled



before the full strength can be used in the design.

The alternative would be to design with a reduced strength in the foundation. When dealing with moisture control, knowledge of the permeability is important. Permeability allows moisture to enter as well as to pass through a layer provided there is an opportunity for that moisture to leave.

##### Trafficking on foundations

The function of a pavement foundation is to provide adequate support for the rest of the pavement, with each layer, bound or unbound, acting as support for the next one during construction and in-service. The unbound foundation, or any layer before the pavement is completed, is not necessarily suitable for use as a haul route unless it has been designed accordingly. The extent to which, and at what stages of construction, site traffic can be allowed access to a partially constructed pavement should be planned and this information clearly communicated to site staff.

#### 3.1.2 Impermeability

**To minimise the infiltration of surface water into the pavement, a good surface drainage is always required**

##### Design advice

- If it is necessary to determine the permeability of the sub-base or capping material, this assessment must be done on the full grading, and at the correct density under a low hydraulic head.

##### Materials advice

- Aggregates to be used in drainage layers should consist of sound, clean and open-graded materials that allow for free flow of any water that enters the pavement structure.

##### Laying advice

- With high water tables and moisture-sensitive subgrades, it may be beneficial to use slot drains.

### 3.1.3 Strength

**Other than water used during construction, the amount of water entering a foundation should be minimised at all costs**

#### Design advice

- It is vitally important to keep water out of the sub-base, capping and subgrade, both during construction and during the service-life of the pavement.
- In reconstruction and widening projects, it is necessary to maintain the continuity of drainage from existing capping and sub-base materials to adjacent new materials using appropriate thickness and cross-falls.

#### Materials advice

- A granular aggregate drainage blanket between 150 mm and 200 mm thick may be used to drain water that infiltrates through the pavement.
- It is important to consider the likely long-term equilibrium moisture condition of the subgrade. For some soils, determination of the moisture condition value is useful.

#### Laying advice

- During construction, every effort should be made to protect the subgrade by constructing foundation layers before rainwater can soften it.

### 3.1.4 Consistency

**Non-uniform foundation strengths and properties cause localised deflections and stress concentrations in the pavement, which can lead to premature failures**

#### Design advice

- Foundation strength test results should be closely monitored in order to identify any inconsistencies in strength results.
- Non-uniform foundation strengths and properties can lead to premature pavement failures.

#### Materials advice

- Pavement life can be increased and pavement performance improved through using more uniform foundations.

#### Laying advice

- Uniformity in pavement foundations requires close attention to construction methods and field quality control testing.

## 3.2 DRAINAGE

### 3.2.1 Principal themes

- **Water ingress from the side is bad**
- **Water will always find its way between unbonded layers**
- **Water between layers will always result in deterioration**
- **Water in asphalt with high voids content may lead to reduction in stiffness**
- **Drainage of the structure is essential**
- **Drainage will only remove water from the pavement if adequately maintained**

#### Coordination of drainage and pavement

There is not enough attention paid to drainage by those involved directly with the asphalt. The efficiency of most drainage systems is directly affected by the material properties achieved, particularly the air voids content and permeability, which in turn have a direct influence on the durability of the asphalt. Water retained in a pavement, particularly in joints, will reduce the longevity of the surrounding material. Therefore, there should be two-way dialogue between drainage and pavement designers in order to ensure that the drainage scheme and materials selected are mutually compatible and that this information is available should any changes to either be considered for whatever reason.

### Changes to drainage path

The effect on drainage of all changes to the pavement, including reconstruction, should be assessed. A change to the properties of the asphalt in a pavement can have implications on the drainage system. In particular, using more open-textured materials means that the drainage has to drain the surface to a lower level and, therefore, be set further down. Furthermore, the drainage needs to have continuous routes for the water, with no barriers from changes to the texture or continuous road markings across the route. These barriers can occur within layers when relatively permeable asphalt abuts a more impermeable material as well as on the surface. The damming of water within the layers is more likely to result in damage because it will be unobserved.

### Temporary drainage

Temporary drainage may also be required to protect the subgrade during construction. This requirement can be important in order to avoid softening of the layer by moisture.

### Reasons for drainage

The main reasons for drainage are to remove water both from the running surface and from the bound and unbound layers of the pavement. The first reason is for the safety and comfort of road users and the second is for the durability of the pavement. The latter is usually achieved by excluding water from entering the pavement, but there are cases where it is allowed to pass through the pavement, requiring permeable materials and clear exit routes that can be maintained.

### Water entry

Water can get into the pavement structure from all sides. It can enter from the surface, the sides and from below, with the duration being dependent on a number of factors. Unless the material and any tack or bond coat are relatively permeable, water gets in from the top via joints, either between asphalt rips, ironwork or other discontinuities, during rainfall and immediately afterwards. Moisture from the side and bottom can enter



whenever the surrounding material is damp, which will depend on the water table as well as whether there has been any precipitation. If the drains at the side are not maintained and water is held in them, that water is available to enter the side of the pavement for extended periods. Water at the sides and bottom of a pavement can be at higher pressures, encouraging its entry into available voids and any unbonded joints.

### Sealing of joints

To keep the water out, there is a need to seal all horizontal and vertical joints, together with the upper (and possibly lower) pavement edge, as well as to keep the drains maintained. The sealing must include the joint between the kerb and the mat.

### Impermeability

The drainage system often relies on the impermeability of the surface course, which is questioned by some engineers for some thin surfacing systems. However, the overall systems are generally impermeable in terms of not allowing water to pass through continuous lengths of the mat (i.e. away from joints of any type) into the layers below. The ingress of moisture due to high texture depth is usually just within that layer – if to a greater depth than in more dense materials – and not through the layers. Permeability is not just required of the surfacings but of all layers of most pavements because, however well the pavement is sealed, there is a chance that some water will enter at some point. In particular, binder course materials should be selected with due consideration of their impermeability. Of the asphalt concrete mixtures defined in PD 6691 (BSI, 2007), EME2 mixtures can be assumed to be effectively impermeable whilst the impermeability of DBM50 and similar mixtures will need to be assessed on a design-by-design basis.

### Global warming

If the predictions for global warming are correct, the summers will be drier but the winters will compensate

by being wetter. The winter rain will come in more intense storms, so that what is now a one in ten year storm, say, will occur more frequently. Therefore, drainage designers need to consider carefully for what intensity they need to design the pavement drainage when that pavement itself is designed for, typically, a 40-year life.

**Maintenance**

Most drainage systems, particularly filter and fin drains, need maintenance. Without that maintenance, the efficiency of the system will decline and excess water will remain where it can reduce the durability of the pavement as well as endanger and discomfort motorists. Therefore, the required maintenance regime needs to be defined for the drainage system and a procedure initiated that will ensure that it is carried out. Furthermore, when designing and building a pavement for, say, a 40-year life, it is necessary to ensure that the drainage has, or can have with appropriate maintenance and/or replacement, a similar or greater life. This consideration applies to maintenance as well as new construction, although the type of drainage may then be predetermined.



**3.2.2 New pavement construction**

**The drainage should be actively considered early in the pavement design**

**Design advice**

- Appropriate surface drainage systems should be put in place to prevent surface water from penetrating into the pavement structure.

**3.2.3 Highway improvements**

**Changes in the pavement can have significant effects on the drainage – positive or negative**

**Design advice**

- Evaluations should be made of the condition of all existing pavement courses in terms of permeability before deciding about the depth of milling and/or selection of new asphalt layers.
- Where the carriageway is to be widened, great care should be taken to ensure that the drainage paths under the old and new pavements are maintained, particularly where falls and elevation are being altered. Longitudinal sections and cross-sections should be produced to check that the drainage is not hindered.
- It is recommended that an appraisal of surface and sub-surface drainage systems be carried out as part of any highway improvement scheme.

**Laying advice**

- Simple clues to a failing pavement edge drain system include poor outlet flows following rainfall.
- Evaluations should be made of the condition of all existing pavement courses in terms of stripping and drainage before deciding about the depth of milling and/or selection of new asphalt layers.

### 3.2.4 Coordinated design

**‘He had hit upon the central secret of road-making: drainage was everything, all else was merely detail. If the foundation was dry, and the road surface was impervious, then the road would be satisfactory. Otherwise, the road would be unsatisfactory no matter how massively constructed.’**

*John Loudon McAdam (1756–1836)*

#### Design advice

- It is essential that the relationship between drainage and pavement materials, and how they interact, is well understood and coordinated.
- Subsurface drainage systems should be provided to eliminate excess water/moisture in pavement foundations and structures.
- If the subsurface drainage of the pavement is inadequate, moisture can move upwards due to capillary action and saturate the asphalt courses.

#### Materials advice

- Water will enter pavements and, for good pavement durability, materials should possess low permeability, that is contain sufficient binder and be satisfactorily compacted.
- Fine-graded mixtures have air voids that are not as interconnected as those in coarse-graded mixtures, therefore coarse-graded mixtures tend to be more permeable than fine-graded mixtures.
- The move towards thin surface courses in the UK has increased the risk of moisture damage. The tendency for water to penetrate the lower layers is greater owing to the open-textured nature of these materials. The use of binder courses with higher binder contents and a finer aggregate grading are recommended for use with thin surface courses.
- Material used for sealing joints should not change properties during different weather conditions. It should not soften during hot weather or harden during cold weather such that it fails in its function as a joint seal.
- For high water tables with moisture sensitive subgrades (Plasticity Index > 25), installation of a granular aggregate drainage blanket is beneficial.
- There is little risk of binder stripping in low air voids content asphalt mixtures. However, materials which are permeable to water, even those that are relatively dense, are at risk of binder stripping.

#### Laying advice

- Close attention should be given to sealing joints because joints represent points of weakness in pavements. Poorly sealed joints lead to moisture ingress into the pavement.
- It is recommended that construction joints should not coincide with the wheel-path and joints found in other layers. They should be staggered and stepped.
- Shoulders, cracks, joints and gaps should be sealed to reduce water ingress.
- Aggregates used for construction should be laid before rainwater can enter and soften the foundation.

### 3.2.5 Maintenance of drainage systems

**Drainage can enhance pavement life – but only if you maintain it!**

#### Laying/aftercare advice

- A more proactive maintenance inspection regime should be adopted wherever possible.

## 4 DESIGN

### 4.1 PAVEMENT

#### 4.1.1 Principal themes

**A few thick layers are better than multiple thinner layers**

##### Need for explicit durability requirements

Many criteria to ensure durability have been hidden away in the conservativeness of certain parameter selections when the recipe approach for materials and/or mixing and laying techniques was used in standards. With the move towards performance specifications, care must be taken to ensure that requirements for durability are not overlooked among the criteria to avoid more immediate modes of failure. Furthermore, due allowance should be made for local knowledge of component materials and/or site conditions that can have implications, positive or negative, on the overall durability by avoiding over-restrictive specifications that do not encourage the “best” material for specific situations.

##### Dangers of over-optimisation

A consequence of over-reliance on performance requirements without allowing for specific durability considerations is that pavements are designed down to minimum layer thicknesses and materials are designed down to minimum binder contents, both of which can be disastrous for longer-term performance. The overall thickness of the pavement and binder contents of the mixtures should always be reviewed to ensure that they have not been reduced to impractical values.



##### Full bond

The assumption of full bond in analytical design has not always been justified when layers have not been bonded together. When combined with any underestimation of the traffic, the effect of the increasing use of super-single tyres and poor appreciation of the effects of the road layout, poor bond can lead to unrealistic expectations from designs. Therefore, the assumption of bond should be followed through by ensuring that tack or bond coats are used at each interface, which is also necessary to preclude water from entering those interfaces, as well as obtaining reliable data on over factors.

##### Tie-in details

When undertaking designs, the tie-in details between the existing and new constructions or between two different parts of the new construction must not be overlooked. Although generally a relatively small proportion of the works, they do represent the potentially weakest locations with regard to both structural strength and drainage continuity.

#### 4.1.2 Durability as a performance requirement

**‘As we make the shift towards performance-based specifications, it becomes necessary to take a close look at what type of durability tests and criteria can be used to ascertain performance’**

*Karthik Obla (TRB 2007)*

##### Design advice

- Include requirements encouraging extra binder alongside those requiring strength and deformation resistance that encourage low binder contents.
- Ensure that the design is not so close to the margin that any local deficiency could escalate into a major failure.

##### Materials advice

- Ensure that there is sufficient binder in the mixture produced.

### 4.1.3 Layer thickness

#### Design advice

- Pavements must be designed to have an overall thickness that is consistent with the road usage. Thinning down layers is not acceptable if it results in excessively thin pavements, however strong the material.

#### Materials advice

- Ensure that the overall pavement thickness is not compromised.

## 4.2 MATERIALS

### 4.2.1 Principal themes

- **High binder content is good**
- **Low air voids content is good**
- **Smaller nominal sizes are good to avoid segregation**

#### Volumetrics

The quantities of component materials for a mixture are generally measured by weight, but the design of asphalt materials is based around volumetrics. Therefore, due allowance should be made for component materials, particularly aggregates, with densities that are significantly different from the norm.

#### Thick binder film

For durability, asphalt has to have a high binder content and low air voids content. These parameters are generally mutually compatible, although it is possible to get relatively high binder contents with high void contents; for example, in a well-designed porous asphalt. The importance results from the binder being the component material whose properties can change in-service. A thick binder film around each particle limits any change to the binder on the surface of the film whilst a low air voids content limits the surface of the film exposed to the air rather than cohering to the binder

films around other particles. The constraint on binder film thickness is the need to avoid binder drainage, but the use of fibres or polymers reduces the tendency of binders to drain and, hence, allows thicker binder films.

#### Harder binder rather than less binder

Over the last 20 years, there has been a tendency to reduce binder contents of mixtures in order to improve their deformation resistance and stiffness. It is now recognised that this tendency can compromise durability and the emphasis has changed to using harder or modified binders at higher binder contents.

#### Enrobé à module élevé

The introduction of the concept of richness modulus in the design for enrobé à module élevé class 2 (EME2) from France provides an estimate of the average binder thickness in a mixture. Although mechanics of the measure need to be modified to be consistent with currently used sieve sizes, the wider use of richness modulus should be encouraged for all mixture types.

#### Workability

Although a mixture can be designed so that it can have a low air voids content, to actually achieve that potential on site requires adequate compaction (Section 6.1). The amount of compaction required for it to be deemed adequate will be dependent on the workability of the mixture together with the pre-compaction achieved by the screed. The design of mixtures that are workable





will assist in achieving adequate compaction, particularly in adverse weather conditions which shorten the window when effective compaction can take place.

### Component materials

The selection and combination of component materials requires experience and can be helped by an in-depth knowledge of the locally available materials. Local knowledge allows generalised assumptions to be honed to fit what happens in specific cases. The options are becoming wider with the pressure to use secondary and reclaimed materials, but if sustainability is to be the justification for their inclusion, the durability implications need to be considered. Reducing the demand for virgin aggregate by, say, 30% is not sustainable if the asphalt has to be replaced, say, twice as often but it is sustainable if the change does not adversely affect the durability.

### Binder course

There is a need for the properties required for the binder course, particularly impermeability to limit any flow of water from the surface course downwards and/or from the base upwards. With surfacing materials being made thinner and more open and with base layers often being designed with relatively low binder contents, the need for an impermeable binder layer becomes vital. The low

binder content in base materials is the result of an over-emphasis on stiffness, which in itself is not conducive to asphalt durability.

### Maximum aggregate size

There is a change in the thinking about the relevant nominal aggregate size with a recognition that, particularly in bases, the use of smaller aggregate will reduce segregation and improve durability without compromising deformation resistance. For appropriately designed mixtures, maximum layer thicknesses much greater than those previously used are now considered suitable. The minimum ratio of size to nominal layer thickness is around two to two-and-a-half, but can differ from that for certain mixture types, whilst the maximum ratio can be as high as 10.

### Destructive testing

When checking the actual properties of the asphalt as achieved on site, the extent of destructive testing should be limited with a balance between the information gained by such testing and the damage to the pavement caused by it, even with good quality back-filling. There is no point in proving that the construction was perfectly constructed if the testing regime has developed a series of weak spots.

## 4.2.2 Selection of component materials

**Good-quality products are important, but over-specification is wasteful**

### Design advice

- Define the quality of products necessary for durability consistent with performance requirements and the use to which they will be put.

### Materials advice

- Make use of component materials with appropriate performance, including durability, for the use to which the asphalt will be put.

### 4.2.3 Temperature

**High bitumen and asphalt temperatures can cause premature ageing of the binder and failure of the pavement**

#### Design advice

- Do not demand excessive temperatures when not necessary to achieve full coating of the aggregate particles by the binder or to achieve a sufficiently workable mixture during compaction.

#### Materials advice

- Minimise the temperature of the binder consistent with:
  - being able to coat the aggregate fully in order to minimise both damage to the binder and energy demand;
  - supplying it to site at a sufficient temperature for it to be compacted effectively.

#### Laying advice

- Do not use any asphalt that will not retain a sufficient temperature throughout the compaction procedure to be fully compacted.

## 5 JOINTS AND SEALING

### 5.1 JOINTS

#### 5.1.1 Principal themes

- All vertical joints are weaknesses
- Sealing of joints (longitudinal and transverse) is good



#### Joins as weaknesses

All joints are potential weaknesses where the material is likely to be less well compacted and where there is increased opportunity for water to enter the pavement. The dangers of water entering the pavements in an uncontrolled manner are discussed under drainage in Section 3.2.1. Therefore, the number of both longitudinal and transverse joints in the mat should be minimised, with the ideal being that there are no joints at all. The ideal is not practical for the vast majority of sites, but a reduction in the number is practical on many sites.

#### No longitudinal joints in wheel paths or nearside lanes

Where there have to be longitudinal joints, it is beneficial to have those joints where the applied stresses are lowest. Therefore, longitudinal joints should not be in either wheel-path. Another means of reducing the stress is to avoid having a longitudinal joint in the nearside lane of motorways by laying a narrow hard shoulder first and then a wider mat spanning that lane.

#### Staggering of joints

The joints in different pavement layers should not coincide in order to avoid water being able to travel through several layers without being impeded. The minimum lateral distance between joints in adjacent layers is generally specified as 300 mm, but the distance should be the maximum practical.

#### Sealing of joints

All joints in all layers should be sealed. The bituminous seal is intended to ensure some bond between the adjacent sections as well as help to fill any excess of voids. Sealing will help minimise the water transfer between layers (Figure 5.1).

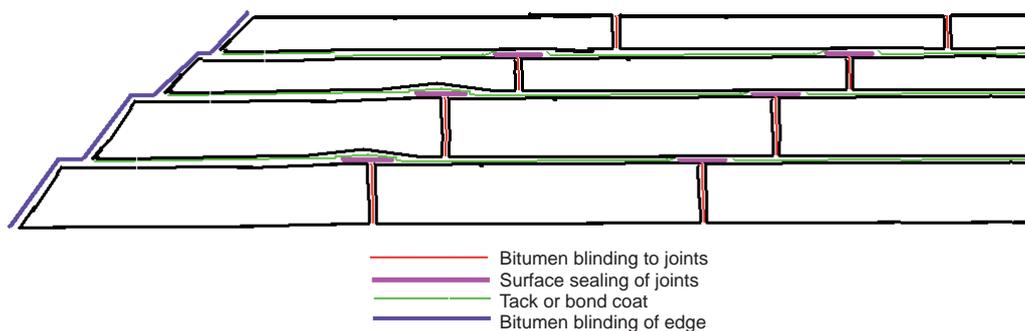


Figure 5.1 Overall sealing of all joints and edges in a pavement

### 5.1.2 Location

**Joints need to be away from sensitive areas, whether due to higher traffic stresses or limitations in the drainage**

#### Design advice

- Joints represent the weakest part of the pavement, and are susceptible to the formation of longitudinal cracks. Pavement performance can be significantly improved by limiting the number of longitudinal and transverse joints formed.

#### Laying advice

- Longitudinal joints in the surface course must coincide with either the lane edge or the lane marking, whichever is appropriate.
- Longitudinal joints in all layers must be situated outside wheel-track zones.
- All joints shall be offset at least 300 mm from parallel joints in the layer beneath.

### 5.1.3 Method of forming joints

**'Pavements with superior joint construction result in a longer pavement performance life and reduced life cycle costs'**

*Sebaaly and Barrantes (2004)*

#### Design advice

- Joints are a potential source of weakness and great care should be taken in their formation because they are often the first part of the pavement to show signs of distress.
- There is a clear need to select suitable joint construction technique(s) that will minimise or eliminate cracking and ravelling problems at the joint and improve its performance.
- Low density at the longitudinal joint is a major contributor to the premature loss of pavement performance.

#### Laying advice

- On completion, the joints must present the same texture as the remainder of the surface, and the accuracy of the surface across the joints must meet the criteria specified for all surface layers.
- Paving schemes should utilise experienced equipment operators who are well versed with paving and compaction techniques. This approach limits operator error, which in turn leads to construction of a good quality pavement.

### 5.1.4 Free edges

**'Maintaining continuity of density across the joint is generally considered a key factor in maintaining durability'**

*Toepel (2003)*

#### Design advice

- Request method statements to ensure the contractor has thought about how to minimise the increase in air voids content at joints.

#### Laying advice

- Lay in echelon whenever practicable.
- Consider possible means of providing a secure side against which to compact free edges that will be site specific. If there are no viable options (which will be a common case), consider how far the edge will need to be cut back to ensure continuity.

### 5.1.5 Painting of joints

**All vertical existing faces need to be painted with binder to enhance the adhesion with the new asphalt**

<p><b>Design advice</b></p> <ul style="list-style-type: none"> <li>Vertical or near-vertical faces of existing construction, including ironwork, kerbs and asphalt or concrete pavement, should be required to have an application of bituminous material to enhance adhesion to newly laid asphalt.</li> <li>In the specific case of porous asphalt, a painted joint can prevent the horizontal movement of water. Therefore, the thickness of the bituminous paint should be limited to avoid such sealing because it will affect the drainage.</li> </ul>	<p><b>Laying advice</b></p> <ul style="list-style-type: none"> <li>The bituminous material used to paint surfaces should be applied uniformly to the whole of the surface.</li> </ul>
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### 5.1.6 Surface sealing joints

**Joints need to be sealed, not only because of the discontinuity but also because of potentially inferior compaction**

<p><b>Design advice</b></p> <ul style="list-style-type: none"> <li>Joints, other than in the surface course, should be sealed with a thin film of bituminous sealer.</li> </ul>	<p><b>Laying advice</b></p> <ul style="list-style-type: none"> <li>The sealant should be increased at locations where the joint is not tight or where the asphalt on one or both sides of the joint has a particularly high air voids content. Elsewhere, it should be applied uniformly along all joints.</li> </ul>
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## 5.2 TACK AND BOND COATS

### 5.2.1 Principal themes

- Pavements are designed to act as one layer
- All horizontal joints are weaknesses
- Sealing and bonding between layers is essential

**Inhibiting water entry causing delamination**

The dangers of water entering the pavements in an uncontrolled manner are discussed under drainage in Section 3.2.1. Therefore, a tack or bond coat should be applied to all interfaces between all bound layers. The bond is required to inhibit water ingress into those interfaces which will then be pumped further into the structure by the action of passing vehicle tyres. The upper layer will then act independently, moving flexibly and allowing fatigue to become an issue. Such delamination will also invalidate the assumption, usually made in structural design, that the whole pavement will act together.



**Surface preparation**

Before applying any tack or bond coat, the previous layer must be clean and free from dust, leaves or other detritus in order to be able to ensure good adhesion. Once the tack or bond coat is applied, precautions should be taken to ensure that the coat remains clean until the asphalt is laid on it. These precautions should include limiting the time between the application of

the coat and the laying of the asphalt (consistent with the time necessary for any emulsion to break unless an integral sprayer is used) and stopping any trafficking of the coat not directly necessary for laying the asphalt.

### 5.2.2 Cleanliness of substrate

The pavement surface receiving the tack or bond coat should be clean and dry to promote maximum bonding

#### Design advice

- Slippage and delaminations will affect the pavement if the substrate is not clean.

#### Materials advice

- Material cleaned from the surface should be removed and disposed of prior to application of the tack or bond coat.

#### Laying advice

- Generally, traffic should not be allowed on tack or bond coats.

### 5.2.3 Properties

It is important to estimate the amount of tack or bond coat to be used as accurately as possible

#### Design advice

- Verify the bond to the existing pavement surfaces and between layers by checking cores.

#### Materials advice

- It is important to ensure that tack or bond coat emulsions have broken (changed colour from brown to black) before paving.

#### Laying advice

- Tack or bond coats should be applied to areas that can be covered by the same day's paving.
- Tack or bond coats should not be applied to pavement surfaces with excess binder on the surface.

### 5.2.4 Sealing

#### Design advice

- A bond or tack coat should have adequate stability and viscosity to properly penetrate the surface onto which it is applied.

#### Laying advice

- Tack or bond coats should be applied to all vertical surfaces of existing pavements, kerbs, gutters and joints where new pavement material is likely to be placed.
- Tack or bond coats should be applied between all pavement layers.

### 5.2.5 Adhesion

**Adhesion between two materials depends on the surface energy and the area of contact, which will be reduced by any detritus present**

<p><b>Design advice</b></p> <ul style="list-style-type: none"> <li>Inadequate bonding between layers can result in delamination (debonding) followed by longitudinal wheel-path cracking, alligator cracking and potholes.</li> </ul>	<p><b>Materials advice</b></p> <ul style="list-style-type: none"> <li>A bond or tack coat should have adequate stability and viscosity to properly penetrate the surface onto which it is applied.</li> </ul>	<p><b>Laying advice</b></p> <ul style="list-style-type: none"> <li>Tack or bond coats should be applied to areas that can be covered by the same day's paving.</li> </ul>
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### 5.2.6 Uniformity

**Tack and bond coats should be applied uniformly across the entire pavement surface**

<p><b>Materials advice</b></p> <ul style="list-style-type: none"> <li>Too much tack or bond coat can create a lubricated slippage plane between layers.</li> </ul>	<p><b>Laying advice</b></p> <ul style="list-style-type: none"> <li>Tack and bond coats should be applied uniformly across the entire pavement surface and result in good surface coverage.</li> </ul>
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## 5.3 EDGE SEALING

### 5.3.1 Principal themes

**Water entering the side of a pavement can often travel a long way through the layer interfaces, gaining pressure as it travels down gradients and cambers**



**Water entry from clogged drains**

The dangers of water entering the pavements in an uncontrolled manner are discussed under drainage in Section 3.2.1. If the upstream edge of the pavement abuts against a drain or other permeable material, it should be sealed to avoid ingress of water from the side, particularly at interfaces between layers. In the case of drains, regular maintenance is required to ensure that there is not a build up of water alongside the pavement.

**Sealing downstream edge**

For the downstream edge of pavements, sealing should be considered if seasonal water table movements could cause water to be pushed into the pavement at any level.

### 5.3.2 Advice

**Keep moisture out but, for when it does enter, give it an exit route**

#### Design advice

- Sealing the upstream edges of a pavement assists in prolonging its life.
- Sealing the downstream edge of a pavement needs to be considered in terms of whether water is likely to flow into or out of the edge on that side.

#### Laying advice

- Sealing the edge will need to be planned before construction because accessibility can be impaired once the structure is complete.

## 6 APPLICATION

### 6.1 COMPACTION

#### 6.1.1 Principal themes

- It is impossible to fully compact unsupported edges
- The limiting factor on paving output is the rolling capacity rather than the paver speed or the available supply

#### Continuity of supply

The continuity of supply of asphalt during laying is important to avoid problems with stopping and starting, as well as avoiding cold material from either being left in the paver awaiting further supplies or from being kept too long in the delivery vehicle because of oversupply. Stopping and starting will produce a poor ride quality which, in turn, can add dynamic loading to the pavement whilst cold material will have a more direct, and damaging, effect on durability.

#### Temperature of asphalt

The temperature of asphalt needs to be high enough to allow the binder to completely cover the aggregate during mixing and for the mixture to be fluid enough during compaction to achieve the required density. If the binder is too hot, it may be excessively hardened during manufacture or be too fluid to support the compaction equipment. The time available when the mixture is in the appropriate temperature range will depend on the properties of the mixture (particularly the binder), the layer thickness and the weather conditions (temperature and wind speed). Sufficient equipment should be available for the job to be completed in that time on a regular basis throughout the work.



#### Haulage distances

Long haulage distances make it more difficult to achieve a continuous supply because of potentially differing traffic conditions and increases any temperature loss during the operation, reducing the time available for compaction. When long haulage distance are involved, additional care must be taken to ensure the continuity of supply and avoid material being stored in delivery vehicles for excessive periods.

#### Ends of loads

The ends of loads are often significantly cooler than the rest because of the extra delay before being laid, particularly if the paver is not able to operate continuously. The cooler material can often be inadequately compacted, leading to premature ravelling. When the paver is not working continuously, the temperature of the material in the hopper should be monitored on a more regular basis and the material disposed of elsewhere if the temperature of the material should fall below the critical temperature to allow sufficient time for effective compaction.

#### Limits on air voids content

The aim of compaction should be to achieve the appropriate air voids content. The compaction should, as far as practicable, be uniform, but more care is likely to be needed at joints. There are several methods to improve compaction at free edges, including use of temporary restraints and cutting back of the less well-compacted material. Whichever method or combination of methods is used, the increase in the air voids content at joints should be limited. The limit currently suggested is a maximum increase of 2%, but this value is tentative. The smaller it is, the better the durability will be, but the limit must be practicable.

### Compaction in constrained areas

The methodology for laying and compacting up to ironwork, bridge joints and other specific disruptions in the mat need to be such that maximum practicable compaction is achieved up to them. The limit on air voids content may have to be eased in a similar manner to joints at free edges.

### Early trafficking with site vehicles

As few vehicles as possible should be allowed to run on pavements before they have been completed. In particular, newly laid mats should not have site vehicles on them which over-run their exposed edges to avoid damaging the compacted mat.



## 6.1.2 Job mixture trials

**The proof of the pudding is in the eating**

#### Design advice

- With novel or uncertain aspects, a requirement for job mixture trials can demonstrate their practicability.

#### Materials advice

- Job mixture trials can be used to assess the workability of mixtures.

#### Laying advice

- Job mixture trials can be used to assess the effectiveness of equipment and/or rolling patterns.

## 6.1.3 Number of rollers

**Adequate compaction is essential and has to be undertaken before the mat cools, which requires sufficient rollers to complete it everywhere**

#### Laying advice

- The number of rollers needs to be sufficient to consistently compact the asphalt to the required level irrespective of obstruction, delays or other influences.

## 6.1.4 Over-running of edges

**Corners and edges are always vulnerable, particularly in their early life**

#### Laying advice

- Routes should be identified and, where necessary, barriers erected to avoid traffic over-running the edges of freshly laid asphalt. Care should be taken to ensure that these routes are followed.

### 6.1.5 Around ironwork

**Ironwork can interrupt the rolling pattern, slowing work down**

**Laying advice**

- The rolling pattern employed should allow for any ironwork or other obstructions in the road.

### 6.1.6 Weather

**It has been said that the UK does not have a climate, it just has weather, so allowance has to be made for changing conditions**

**Design advice**

- If tenders are put out for work when adverse weather is likely, due allowance should be made to ensure that the materials can be laid successfully at that time and that appropriate precautions are taken.

**Laying advice**

- Workers will be less efficient in cold and/or dark conditions, so their work schedules need to allow for this factor.
- The available time for compaction will be less in cold conditions.
- Hot weather can result in significantly increased time before the newly laid material can be trafficked.

## 6.2 FINISH

### 6.2.1 Principal themes

**It is when the job is completed that, at least initially, the general public will judge the work**

**No joints**

Ideally, all interfaces should be avoided. However, it is not possible to lay the material in a single layer without longitudinal or transverse joints. Nevertheless, the number of interfaces should be kept to a minimum, as described for joints in Section 5.1. Minimising



the number of layers not only reduces the number of horizontal interfaces but also leads to thicker layers. The thickness should not exceed that which can be adequately compacted by the plant available, but thicker layers should avoid any problems with thin layer brittleness. Excessively thin layers, in particular binder course, may result in un-designed permeable pavements.

**Ride quality**

In order to minimise dynamic damage, the final layer should be laid to achieve a good ride quality rather than to predetermined levels provided:

- the overall thickness is adequate for strength and durability;
- the final levels allow the drainage system to work efficiently; and
- there are no conflicts with safety barrier heights and overbridge heights.

Therefore, the precise levels should not be sought to the detriment of the ride quality. The monitoring by the

“yellow submarine” is generally not adequate to provide the ride quality and more technical advanced methods should be encouraged. At the same time, laser and other modern methods of assessing the level should be used in preference to pins. Ideally, the set up should allow the paver to run continuously with a compatible system for monitoring both the layer thickness and level control.

### Overlays at tie-ins

At tie-ins and locations where a new carriageway overlays an existing one, the depth of the overlay used to regulate out the difference in carriageway levels should be at least the thickness appropriate for the asphalt mixture being used without dragging and not too thick to ensure effective compaction.



## 6.2.2 Advice

### The final touch

#### Design advice

- Levels should not be sought at the expense of ride quality.

#### Laying advice

- Levelling beams or other methods of ensuring a consistent finish should be used whenever practicable.

## 6.3 MAINTENANCE

### 6.3.1 Principal themes

#### Nothing is for ever

#### Importance of maintenance

Everything will deteriorate with usage and time, so maintenance is essential to ensure that deterioration does not occur. In particular, the drainage should be working efficiently because the repercussions on the pavement could be disastrous.

#### Maintain all layers

When maintaining a pavement, any maintenance that is superficial when the problems are deeper can only be a temporary solution. The surface course is the most accessible layer and the one that gets the most direct punishment from the traffic and the environment, but it is not the only one that requires maintenance.



### 6.3.2 Advice

#### Design advice

- The ability to maintain the pavement, particularly its drainage, should be positively built into any design.

#### Laying advice

- The maintenance procedures should be implemented as soon as the pavement is complete.

## 7 CONCLUSIONS

This project revealed a common desire from all parties involved in the industry (consultants, contractors and suppliers) to improve the durability of asphalt pavements. There was a high degree of agreement on the required strategies necessary to improve durability and, therefore, assist with sustainability and reducing the impact of climate change. The challenge now is for us all to work together to improve asphalt durability despite the constraints of the contractual framework.

The desire to achieve longer durability for asphalt pavements is common among those involved in designing, specifying, producing and laying asphalt materials and pavements. Therefore, all parties have to work together in a spirit where positive actions are rewarded and negative actions or omissions are discouraged.

The main aspects that maximise durability are:

- the control of water (getting it away from the structure, if not actually stopping it ever entering);
- limiting the number of joints (both vertical and horizontal), and sealing those joints; and
- adequate compaction (particularly at joints).

These aspects are likely to increase in importance with the predicted changes from global warming, with hotter, dryer conditions in summer but more intense rainfall, and possibly more of it, in the winter. Such conditions will exacerbate the potential for unwanted water to penetrate into the pavement, causing irreversible damage to the asphalt.

However, lack of maintenance, particularly of the drainage, can lead to premature failure even if the best practice was followed in design and construction.

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# Best practice guide for durability of asphalt pavements



Road Note 42 gives guidance on the procedures for maximising the durability of asphalt pavements. Some of the concepts may not be practical in all circumstances, particularly for emergency repairs, but the ideas should be used as ideals to be aimed at whenever practicable.

Together with the companion publication, Road Note 41 'Best practice guide for overlaying concrete', it is the result of a three-year project at TRL commissioned by the Highways Agency, Quarry Products Association and Refined Bitumen Association. The two guides provide guidance and advice on design, materials and construction, that encapsulate the overall concepts. These documents should become essential reading for all involved in road construction.

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