

# Best practice guide for overlaying concrete

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I Carswell and K E Hassan





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**Road Note 41**  
**Project: Performance and durability of asphalt roads**  
**Topic 3: Overlaying concrete**

Road Note 41

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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 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 out 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 *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* (this document), 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 is covered by Road Note 42.

Road Note 42, *Best Practice Guide for Durability of Asphalt Pavements*, 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.

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## EXECUTIVE SUMMARY

The Highways Agency (HA), Quarry Products Association and Refined Bitumen Association all appreciate the need to maximise the durability of asphalt pavements. The jointly funded research project at TRL entitled *Performance and Durability of Asphalt Roads* included two topics, *Durability of Asphalt Pavements* and *Overlaying Concrete*, with the principal aim of identifying the techniques and procedures currently considered to be best practice and producing Best Practice Guides based on that knowledge in the form of Road Notes.

Road Note 42, *Best Practice Guide for Durability of Asphalt Pavements*, concentrates on the durability of the whole pavement rather than that of the asphalt mixtures. For this purpose, pavement durability was 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 aspects that lead to durability for asphalt pavements are the same when overlaying jointed and continuously reinforced concrete pavements and concrete bridges with asphalt. However, further aspects must be considered when overlaying concrete and these are covered separately in this Guide, Road Note 41, to give them the emphasis they deserve.

The aim of both Road Notes is to encourage everyone working in the asphalt industry to contribute to making pavements as durable as is reasonably 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.

The desire to achieve longer durability for asphalt pavements and overlays is common among those involved in designing, specifying, producing and laying asphalt materials. 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 that are discussed in this Guide are summarised as follows:

- *All reflection cracking in the UK is top down*  
Jointed concrete and continuously reinforced concrete pavements must be treated appropriately and overlaid with asphalt of sufficient thickness to resist such cracking.
- *A jointed concrete pavement can be broken into small lengths using the fractured slab technique and overlaid with asphalt of minimum thickness 150 mm*  
Rubblisation is necessary when there are major structural problems with the existing pavement, and an overlay of minimum thickness 200 mm is required. The performance of some interlayers, i.e. geotextiles and grids, stress-absorbing membrane interlayers and crack relief layers, has been variable so they should only be used with HA approval. Surface treatments that reduce the occurrence of reflection cracking in the surface course include the use of polymer-modified bitumens, and saw-cut and seal whereby joints are introduced into the asphalt directly above the joints in the concrete.
- *A continuously reinforced concrete pavement (CRCP) eliminates movement joints within the main slab, but develops narrow transverse cracks at a regular spacing*  
Before overlaying the concrete, the surface and pavement need to be restored to a condition that can successfully accommodate an overlay. A CRCP in good condition should only require an overlay of thickness up to 40 mm for noise and skid-resistance properties. A CRCP with large crack widths, intersected crack patterns, loose blocks of material and surface spalling and scaling requires an overlay of thickness up to 100 mm. An overlay of thickness less than 40 mm will not provide significant structural benefits. An overlay of thickness 100 mm or greater is required when a CRCP has a poor surface profile, has many structural defects or is in need of strengthening. Special treatments are required for the asphalt over the joints at terminations.
- *The control of water is critical to the performance of surfacing on concrete bridge decks*  
The upstands at edges and non-buried-type expansion joints form a "water tank" and it is better to prevent water entering the "tank" than to create a problem trying to remove it. Efficient surface drainage and mixtures with low air voids contents are required. The concrete deck should be treated so water cannot pond in depressions on the surface of the waterproofing system, with sub-surface drainage being provided where necessary. Because it is structurally weak, an additional protective layer



of sand asphalt should not be used unless required to prevent damage to the waterproofing system. There must be no large interconnecting voids at the interface between the waterproofing system and the overlaying asphalt with coarse aggregates; the layer should be of minimum thickness 45 mm and the waterproofing system may require a thick tack coat. Care is needed to prevent waterproofing systems being damaged by site staff and plant. Also, some waterproofing systems can be damaged if the asphalt overlaying them is laid and compacted at too high a temperature. However, asphalt will not bond well to the waterproofing system and form a dense layer if it is laid and compacted at too low a temperature. Higher bond strengths are required when the total thickness of the asphalt overlaying a waterproofing system is less than 120 mm. Extra attention is needed when laying asphalt near existing mechanical-type expansion joints so that it is well compacted and premature surfacing failures are prevented.

## LIST OF ACRONYMS

<b>APL</b>	Additional protective layer	<b>MCHW</b>	Manual of Contract Documents for Highway Works
<b>CBGM</b>	Cement bound granular material	<b>PMB</b>	Polymer-modified bitumen
<b>CRC</b>	Continuously reinforced concrete	<b>SAMI</b>	Stress-absorbing membrane interlayer
<b>CRCB</b>	Continuously reinforced concrete base	<b>SCCSO</b>	Saw-cut, crack and seat and overlay <i>Rehabilitation technique for reinforced concrete roads</i>
<b>CRCP</b>	Continuously reinforced concrete pavement	<b>SCS</b>	Saw-cut and seal <i>Rehabilitation technique for unreinforced and reinforced concrete pavements</i>
<b>CRL</b>	Crack relief layer	<b>TRACS</b>	TRAffic-speed Condition Surveys
<b>CSO</b>	Crack, seat and overlay <i>Rehabilitation technique for unreinforced concrete/CBGM road</i>	<b>TSCS</b>	Thin surface course system
<b>DMRB</b>	Design Manual for Roads and Bridges	<b>URC</b>	Jointed unreinforced concrete <i>Comprises a series of unreinforced concrete bays (generally 5 m to 6 m in length) separated by expansion or contraction joints</i>
<b>GPR</b>	Ground-penetrating radar	<b>VCS</b>	Visual Condition Survey
<b>HAPAS</b>	Highway Authorities Product Approval Scheme	<b>WLC</b>	Whole-Life Cost (Analysis)
<b>IAN</b>	Interim Advice Note		
<b>JRC</b>	Jointed reinforced concrete <i>Comprises a series of reinforced concrete bays (generally 5 m to 24 m in length) separated by expansion or contraction joints</i>		

# 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. The jointly funded research project at TRL entitled *Performance and Durability of Asphalt Roads* included three topics:

- *Surface Requirements for Asphalt Roads.*
- *Durability of Asphalt Pavements.*
- *Overlaying Concrete.*

The principal aim of the second and third topics was to identify the techniques and procedures currently considered to be best practice and to produce Best Practice Guides based on that knowledge in the form of Road Notes.

Road Note 42 (Nicholls *et al.*, 2008), *Best Practice Guide for Durability of Asphalt Pavements*, concentrates on the durability of the whole pavement rather than just that of the asphalt mixtures. For this purpose, pavement durability was 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 Guide is to encourage everyone working in the asphalt industry to contribute to making pavements as durable as practical.

The aspects that lead to durability for asphalt pavements are the same when overlaying concrete pavements and bridges with asphalt. However, further aspects must be considered when overlaying concrete and these are covered in this separate Guide, Road Note 41, to give them the emphasis they deserve.

To oversee the production of this Guide, an Advisory Group was formed consisting of Donna James (HA representative), David Lee (HA representative), Malcolm Simms (QPA representative), Nick Toy (QPA representative), Jukka Laitinen (RBA representative), Craig Coley (TRL), Mike Harding (TRL), Ian Carswell (TRL), Khaled Hassan (TRL) and Richard Jordan (TRL and secretariat). The Best Practice Guide is based on past and recent research carried out by TRL on the performance of the surfacing used to overlay concrete pavements and bridges. This research has involved the monitoring of numerous trials on pavements and bridges, detailed experimental test programmes,

literature reviews and consultations with the industry. Whereas Road Note 42 can apply to all pavements, the guidance in Road Note 41 is primarily for the HA's network.

## 1.2 WHAT IS COVERED BY THIS GUIDE

This Guide primarily covers:

### 1 Jointed concrete pavements:

- Reflective cracking.
- Overview of asphalt overlay options.
- Thickness of asphalt overlay and asphalt material requirements.

### 2 Continuously reinforced concrete (CRC) pavements:

- Advantages of CRC over jointed concrete pavements.
- Performance of CRC.
- Treatments at CRC terminations.
- Thickness of asphalt overlay and asphalt material requirements.

### 3 Concrete bridges:

- Removal of old surfacing and waterproofing system.
- Preparation of the bridge deck for waterproofing.
- Sub-surface drainage.
- General information on waterproofing systems.
- Requirements for the waterproofing system.
- Requirements for asphalt directly overlaying a waterproofing system.
- Surface drainage.
- Surface course requirements.
- Requirements at expansion joints.
- Installation of the waterproofing system.
- Requirements when overlaying the waterproofing.

## 1.3 ASPECTS NOT COVERED

Road Note 42 describes best practice to improve the durability of asphalt pavements. The guidance in Road Note 42 also applies to the overlaying of concrete pavements and bridges, but has not been included here to avoid repetition. However, the guidance in both documents should be considered together.

Concrete treatments prior to the overlaying of concrete pavements and bridges with asphalt are not covered in detail, but information sources are referenced. Similarly, detailed information on waterproofing systems and expansion joints is not included but referenced.

## 1.4 USE OF THIS GUIDE

The aim of this Best Practice Guide and Road Note 42 is to encourage everyone working in the asphalt industry to contribute to making the asphalt overlaying concrete pavements and bridges 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 an overlay that is fit for purpose.

As in Road Note 42, each main section of this Guide is prefaced with one or more simple statements that cover the key concepts of that section. Following the statements, 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 of asphalt overlaying concrete. More specific advice on design, materials and laying is set out in different-coloured boxes. 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 overlay can be produced, and which excludes the use of materials or techniques that have a high risk of making the overlay perform inadequately, whether initially or in-service.
- The objective of material selection and production is to produce an overlay that can meet all the functional requirements, including the long-term maintenance.
- The objective of laying is to install the overlay under appropriate conditions and in a manner conducive to maximise the functional requirements, including durability.

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, road users.

The relative importance of the three sections varies on different aspects. The thinking behind this separation is for clarity, but the titles do not imply that the advice of the sections is solely for designers, materials suppliers and site staff, respectively. 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 OVERLAYING CONCRETE

### 1.5.1 Asphalt generally

Road Note 42 states that there are many approaches that can be used when striving for durable asphalt pavements, and lists the following universal truths that should be borne in mind at all stages of design and manufacture, which also apply when overlaying concrete pavements and bridges:

#### 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.

Truths that apply specifically to jointed concrete and CRC pavements and to concrete bridges are given in Sections 1.5.2 to 1.5.4.

### 1.5.2 Jointed concrete pavements

- All reflection cracking in the UK is top down.
- The condition of the jointed concrete pavement determines the treatment and overlay thickness required.
- The fractured slab technique requires the concrete slabs to be broken into smaller lengths before an overlay is applied.
  - Crack and seat is subject to a minimum of 150 mm asphalt overlay to inhibit reflection cracking.
  - Rubblisation requires an asphalt overlay thickness in the range of 200 mm to 430 mm depending on the required design.

- An interlayer is a material layer placed between the concrete and new asphalt overlay or between layers of asphalt. This interlayer is designed to move relative to the concrete or inhibit movements in the concrete affecting the asphalt surface.
  - The performance of geotextiles and grids within the UK has proved to be variable and, therefore, they should only be used with HA approval.
  - The performance of stress-absorbing membrane interlayers (SAMIs) in the UK has been variable with regard to their ability to inhibit reflection cracking and, therefore, should only be used with HA approval.
  - Crack relief layers (CRLs) trialled in the UK have shown promising performance in the short term. Further, longer-term data is needed on their durability. Therefore, this technique should only be used with HA approval.
- Surfacing treatments are treatments that reduce the occurrence of reflection cracking within the surface course.
  - Saw-cut and seal (SCS) requires a minimum overlay thickness of 70 mm. However, for heavily trafficked high-stress sites, an increase of the overlay thickness may be required to reduce risk.
  - Programmed sealing is an intervention treatment and several visits may be required for further or repeat treatments. There may also be aesthetic, practical and contractual problems with such a regime. Therefore, this technique is not recommended.

### 1.5.3 Continuously reinforced concrete pavements

- CRC eliminates movement joints within the main slab, but develops narrow transverse cracks at regular spacing.
- Before overlaying with asphalt, the surface and pavement need to be restored to as good a condition as possible.
- The thickness of an asphalt overlay will depend on the condition of the pavement.
- A continuously reinforced concrete pavement (CRCP) in good condition should only require a thin overlay, up to 40 mm, for noise and skid-resistance performance.
- Medium and thick overlays will provide additional structural benefit.
- Special treatments are required for the asphalt over the joints at CRC terminations.

### 1.5.4 Concrete bridges

- Upstands at edges and non-buried-type expansion joints form a “water tank”.
- It is better to prevent water getting into the “tank” than to create a problem trying to remove it.
- Mixtures with low air voids contents are essential for the lower layers, and desirable for the surface course.
- Efficient surface drainage is essential.
- Water that does enter the “tank” must be removed by sub-surface drainage.
- After its application, it should not be possible for water to pond in depressions on the surface of the waterproofing system.
- An additional protective layer of sand asphalt should not be used unless required to prevent damage to the waterproofing system.
- There must be no large interconnecting voids at the interface between the waterproofing system and the overlaying asphalt with coarse aggregates.
- A waterproofing system with a thick tack coat is essential when the overlaying asphalt contains coarse aggregates.
- The asphalt layer directly overlaying the waterproofing system should be of minimum thickness 45 mm, and the total thickness of all asphalt layers overlaying the waterproofing system should be a minimum of 120 mm.
- Waterproofing systems can be easily damaged by site staff and plant.
- Procedures to prevent stripping of thick tack coats are required.
- Asphalt laying and compaction temperatures must be carefully controlled.
- The laying and compaction temperature requirements differ from one waterproofing system to another. They should be determined before work commences on site.
- Waterproofing systems can be damaged if the asphalt overlaying them is laid and compacted at too high a temperature.
- Asphalt will not bond well to the waterproofing system and form a dense layer if it is laid and compacted at too low a temperature.
- Unless the waterproofing system is to be replaced, planing within 40 mm of a waterproofing system should be avoided.
- Improving the durability of the asphalt layers below the surface course is good practice.
- Extra attention is needed when laying asphalt near existing mechanical-type expansion joints to prevent premature surfacing failures.



## 2 OVERLAYING CONCRETE PAVEMENTS

### 2.1 INTRODUCTION

An asphalt overlay is a common method for rehabilitating deteriorated concrete pavements. Case studies in the UK and elsewhere have shown that the main factor that has influenced the durability of the asphalt overlays is reflection cracking and its effects on modifying the design-life of the pavement. The thickness and type of asphalt will be related to the type of concrete pavement, the condition of the pavement, the causes of any deterioration and the requirement for strengthening the structure.

Concrete pavements comprise a pavement concrete layer, the main structural element, laid onto a bound or unbound sub-base layer. In the UK, there are four types of rigid pavement:

- Jointed unreinforced concrete (URC).
- Jointed reinforced concrete (JRC).
- Continuously reinforced concrete pavement (CRCP).
- Continuously reinforced concrete base (CRCB).

CRCB requires a 100 mm thick asphalt surface course.

Jointed pavements, URC and JRC, comprise a series of concrete bays separated by expansion or contraction joints. They can suffer from progressive defects, mainly occurring at the joints, resulting in increased maintenance costs.

The new rigid pavement construction preferred by the HA for motorways and trunk roads is CRC with a quiet surfacing. CRC was developed to overcome problems associated with joints. CRC contains continuous longitudinal reinforcement with no intermediate expansion or contraction joints. Thermal stresses within the concrete slab are relieved by transverse cracks, which are held tightly closed by the reinforcement. The elimination of joints within the slab enhances the structural integrity of the pavement, and reduces the amount of water penetrating into the pavement and the associated pumping of fine materials, leading to enhanced foundation durability. Updated designs for new CRCP have been proposed by Hassan *et al.* (2005) and are given in the *Design Manual for Roads and Bridges (DMRB)* 7.2.3, HD 26/06 (Highways Agency *et al.*, 2006).

The Government has recognised that noise from passing traffic is a concern for many people and gave a commitment in “A new deal for trunk roads in England”, published by the Department of the

Environment, Transport and the Regions (1998). It has been stated that, where noise is a particular problem, the most appropriate noise-reducing surfaces should be used in future. Any resurfacing programme should be based on the maintenance needs and consider whole life value. The *DMRB* 7.2.3, HD 26/06 (Highways Agency *et al.*, 2006) states that a CRCP requires a minimum thin surface course system (TSCS) of 30 mm, and a CRCB requires an asphalt overlay of 100 mm. When widening an existing jointed pavement, it will be desirable to maintain existing formation and surface levels and drainage paths.

### 2.2 REFLECTION CRACKING: A MAJOR PROBLEM WHEN OVERLAYING CONCRETE

**All reflection cracking within the UK trunk road network is top down**

When an asphalt overlay is placed over a jointed concrete or a CRC pavement, reflection cracking will often occur in the asphalt overlay. The cracks are generally transverse and will usually occur in the overlay directly above the joints or cracks in the underlying concrete layer due to the thermal expansion and contraction of the underlying concrete. In flexible composite pavements with a cement bound granular material (CBGM) base, the cracks occur above the irregularly spaced thermal shrinkage cracks formed during the curing/drying process of the CBGM.

In the early stages of development, reflection cracks may barely be visible and are not considered to be a structural problem. However, if they are left untreated,





or poorly maintained, they will often progress to the full thickness of the asphalt. Water infiltration can then weaken the road foundation and fine material can be pumped from the base to the surface under the action of traffic, resulting in the creation of voids beneath the base. Traffic loading further exacerbates the situation until, in the advanced stages of deterioration, structural support is impaired to such an extent that movement of the pavement structure, i.e. rocking, occurs with the passage of vehicles. This lack of support can lead to a loss of structural integrity, a reduction in riding quality and possible further cracking. The same mechanisms can occur both in unbound sub-bases under jointed concrete pavements and under CBGM layers in flexible composite pavements.

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### 2.3 ASSESSMENT AND TREATMENT SELECTION

The condition of both jointed concrete and CRC pavements is determined by assessing the ride quality, the amount of cracking and the performance of the joints between the individual concrete bays. These inspections are described in the *DMRB 7.3.2, HD 29/08* (Highways Agency *et al.*, 2008a). Examples of defects in the concrete slab and at the joints are illustrated in the *Concrete Pavement Maintenance Manual* (Highways Agency and Britpave, 2001).

In identifying pavements requiring maintenance, the annual routine assessment of the network, undertaken by Traffic-speed Condition Surveys (TRACS), is one of the key stages. The data from these surveys can indicate sections of the network with defects that have reached investigatory levels.

Having identified sections that potentially require maintenance, a detailed Visual Condition Survey (VCS) will usually be needed to identify factors such as pavement defects, drainage issues and kerb and barrier heights. Further specialised assessment may be needed to determine the cause of specific problems and defects.

Having identified a site that requires maintenance, the next step is to decide which maintenance treatment is appropriate. The maintenance treatments to be considered will be dictated by the residual life of the pavement. The actual treatment will be determined as a result of a Whole-Life Cost (WLC) Analysis of the various options available. When considering possible maintenance options, one factor to be taken into account is that the actual maintenance may not be undertaken for perhaps two or three years after the initial surveys, during which time the pavement may deteriorate further.

Information about treatment selection to jointed concrete pavements is given in the form of flow charts in TRL Report TRL657 (Coley and Carswell, 2006).

## 2.4 JOINTED CONCRETE PAVEMENTS

### 2.4.1 Techniques available

The following techniques may be considered for overlaying jointed concrete pavements. These techniques can be split into three categories:

#### Fractured slab:

- Where the characteristics of the concrete construction are changed.

#### Interlayers:

- Where materials are placed on the concrete surface or between layers of asphalt overlay.

#### Surfacing treatments:

- Where the surface course is treated or modified.



### 2.4.2 Fractured slab

**The fractured slab technique requires the concrete slabs to be broken into smaller lengths prior to an overlay being applied**

#### Crack and seat

The rationale behind the crack and seat technique is to reduce the effective slab length between the transverse joints or cracks in the existing concrete layer, prior to overlay. If the crack spacing in the concrete is reduced, the horizontal strains resulting from thermal movements of the concrete should be distributed more evenly throughout the pavement and are therefore less likely to cause transverse cracks in the overlay. The crack and

seat technique is suitable for unreinforced pavements only. Figures 2.1 and 2.3 show excessive longitudinal cracking and over-cracked cores, while Figures 2.2 and 2.4 show recommended crack patterns and a compliant core sample. Further information can be found in Clauses 716, 717 and 719 of the *Specification for Highway Works (SHW)* (Highways Agency *et al.*, 2008b).

#### Design advice

- Crack and seat is subject to a minimum of 150 mm asphalt overlay to inhibit reflection cracking. Whatever asphalt material is used, the thickness remains 150 mm to minimise reflection cracking, i.e. the overlay is not purely structural.

#### Materials advice

- Any asphalt materials can be used. Crack and seat schemes are typically constructed using asphalt concrete and are surfaced with a Highway Authorities Product Approval Scheme (HAPAS)-approved TSCS.

#### Laying advice

- It is important that the cracking operation produces cracks in the concrete that are fine, transverse and not longitudinal. These aspects can be checked visually by inspection of the concrete surface and by core samples.



**Figure 2.1** Example showing excessive longitudinal cracking



**Figure 2.2** Example showing good transverse crack pattern



**Figure 2.3** Non-compliant core, over-cracked



**Figure 2.4** Compliant core, fine, full-depth vertical crack

### *Saw-cut, crack and seat*

**Cracking and seating cannot adequately separate the concrete from the steel present in reinforced concrete pavements**

While effective on unreinforced pavements, cracking and seating cannot adequately separate the concrete from the steel present in reinforced concrete pavements and, therefore, thermal contraction will still be concentrated at the existing transverse joints. The procedure involves sawing narrow cuts transversely across the slab with the depth of the cut just sufficient to sever the longitudinal steel reinforcement. (This depth can be determined from coring and/or ground-penetrating radar (GPR) surveys.)

The following design, material and laying advice is given in addition to the advice given for crack and seat.





Figures 2.5 and 2.7 show non-compliant cores and spalled saw-cuts, while Figure 2.6 shows a good core. Figure 2.8 shows the use of a strike plate to prevent spalling during the cracking operation. Further information can be found in Clauses 715, 718 and 719 of the *SHW* (Highways Agency *et al.*, 2008b).



**Figure 2.5** Non-compliant core, steel reinforcement not severed



**Figure 2.6** Compliant core, fine, full-depth vertical crack



**Figure 2.7** Spalling of the saw-cut, no strike plate used



**Figure 2.8** Strike plate in use

### Design advice

- The spacing of the transverse saw-cuts is intended to mirror that used in conventional crack and seat. Due to the crack pattern being more controlled and the load transfer being reduced across the saw-cuts, a spacing of between 1 m and 2 m is likely to be most effective.

### Laying advice

- It is important that the cracking on the sawn joints is carried out without damaging the saw-cut in order to prevent loose material entering the saw-cut and so preventing future thermal movement.

**Rubblisation**

Developed in the USA, rubblisation is a technique that has been used since 1990. Rubblising effectively eliminates the problem of reflection cracking. However, it also removes much of the strength of the old concrete and should only be considered as a viable option when there are major structural problems with the existing pavement and it is nearing the end of its serviceable life.

In the UK, the rubblisation technique has only been used at a few non-trunk road sites. This limited use is due to the overlay requirements and the relatively low amount of concrete pavements nearing the end of their serviceable life. Because this is a fairly new treatment in the UK, further data are required on its durability.

**Design advice**

- The overlay thickness required ranges from 200 mm to 430 mm, and is controlled by:
  - The traffic requirements.
  - The quality of the material used in the original concrete pavement.
  - The quality of the existing foundation.
  - The thickness of the concrete pavement.
  - The size of the concrete fragments.

**Laying advice**

- The pavement is broken into fragments, varying in size from about 25 mm at the surface to 380 mm at the bottom of the layer.

**2.4.3 Interlayers**

**The introduction of a material layer between the concrete and the new asphalt overlay, called an interlayer, allows the overlay to move relative to the concrete**

***Geotextiles and grids***

**The performance of geotextiles and grids within the UK has proved to be very variable, with some sites showing cracking of the reinforced section before the control section with the same overlay thickness and, therefore, they should only be used with HA approval**

Geotextiles and grids are designed to enhance the tensile strength of the asphalt overlay by absorbing the horizontal tensile stresses above the joints in the concrete and distributing them over a wider area. It is thought that geotextiles and grids help prevent reflection cracking in the asphalt by being able to accommodate and dissipate the horizontal strains generated by the thermal expansion and contraction of the underlying concrete pavement.

***Stress-absorbing membrane interlayers***

**The performance of SAMIs in the UK has been variable with regard to their ability to inhibit reflection cracking and, therefore, they should only be used with HA approval**

SAMIs are designed to provide a flexible layer that is able to deform horizontally without breaking. This allows the interlayer to accommodate the stresses and strains developed by the expansion and contraction of the underlying concrete pavement. SAMIs also provide a waterproofing layer by helping to prevent the ingress of water from a crack in the asphalt into the structural layer of the pavement and foundation. Where a SAMI has been used as a targeted treatment to cracks, it has been found that it may generate reflection cracks from the edge of the treatment, while the performance from the application of the treatment to the entire site (blanket treatment) has shown variable results.

*Crack relief layers*

**CRLs trialled in the UK have shown promising performance in the short term; further, longer-term data is needed on their durability and, therefore, this technique should only be used with HA approval**

The use of CRLs has been pioneered in the USA on both jointed concrete and CRC pavements, albeit mainly overlaid with a relatively thick layer of asphalt.

In the USA, a 90 mm thickness of coarse, open-textured bitumen macadam, containing 20% to 35% interconnecting air voids, is generally used for the CRL. Due to the large amount of interconnecting voids, the layer provides a medium to prevent differential movements of the underlying concrete by disconnecting the movements at the joints/cracks from the overlaying surface course.

**2.4.4 Surfacing treatments**

**Surfacing treatments are treatments that reduce the occurrence of reflection cracking within the surface course**

*Modified asphalt*

Polymers are often used to improve the visco-elastic behaviour of the bitumen. To date, several polymer-modified bitumens (PMBs) are reported to improve resistance to reflective cracking when compared with unmodified materials.

In general, it is very difficult to predict precisely what effect the addition of a particular polymer will have on the properties of asphalt, although it is possible to carry out laboratory-scale experiments to accurately quantify the effect. The main problem of laboratory testing is its inability to accurately model the ageing of the bitumen (Ponniah and Kennepohl, 1996).

*Saw-cut and seal*

The main principle behind SCS is to accommodate the stresses and strains associated with expansion and contraction of the underlying jointed concrete by introducing joints into the asphalt overlay directly above the joints in the concrete. These joints are then filled with an approved sealant, which creates a highly flexible reservoir and stops the formation of reflection cracks at the surface while controlling their development from a crack-initiation slot below the surface.

Figures 2.9 and 2.10 show poor SCS, while Figure 2.11 shows good SCS with the sealant flush with the surface of the asphalt. Further information can be found in Clauses 713 and 714 of the *SHW* (Highways Agency *et al.*, 2008b).

**Design advice**

- Minimum overlay thickness required is 70 mm. However, for heavily trafficked high-stress sites, an increase of the overlay thickness may be necessary.

**Materials advice**

- Any asphalt materials can be used. SCS schemes are typically constructed using asphalt concrete and are surfaced with a HAPAS-approved TSCS.
- In the UK, the sealant should comply to BS EN 14188-1 (British Standards Institution, 2004) and be fully compatible with asphalt.

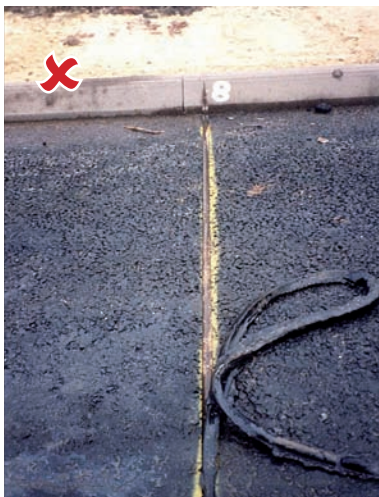
**Laying advice**

- It is essential that the locations of the joints in the concrete are accurately identified and the centre of the slot in the asphalt layer is directly above the concrete joint.
- The preferred method of application of the sealant is through a re-circulating pump applied directly from a heating unit.
- Recommended cleaning and drying techniques would be to water-jet the slot cutting to remove any detritus and then use a “hotdog” type lance for drying to minimise heating of the surrounding material.





**Figure 2.9** Overfilled saw-cut



**Figure 2.10** Sealant installed when outside temperature too low (moisture forming on side of slot)



**Figure 2.11** Good saw-cut and seal

### *Programmed sealing*

**Programmed sealing is an intervention treatment and several visits may be required for further or repeat treatments – there may also be aesthetic, practical and contractual problems with such a regime – therefore, this technique is *not* recommended**

Programmed crack sealing is more of a maintenance regime than a treatment. The theory is that it is very hard to prevent reflection cracking occurring in thin overlays and, therefore, a certain proportion of unhindered reflection cracks may occur in the overlay before being sealed. Therefore, if sealing is not carried out promptly, larger and more expensive treatments may be required.

This maintenance regime was used on a major motorway scheme, where the 25 m long JRC slabs were overlaid with a TSCS. Crack sealing was planned for two years later but was not carried out until after four years. Due to the amount of deterioration (and hence more expensive treatment costs), only part of the scheme was completed with the remainder planned for Year 7. The cracks were treated by planing out 300 mm to 600 mm strips of the TSCS at the cracks' locations and filling them with a proprietary joint-repair-type material.

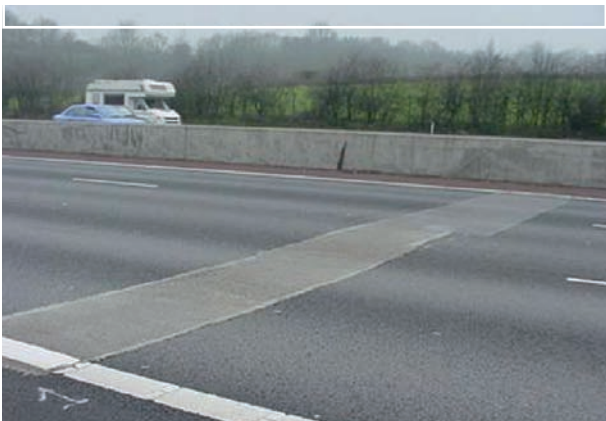
Figures 2.12 and 2.13 show the condition of the reflection cracks prior to treatment, while Figures 2.14 and 2.15 show the typical treatment.



**Figure 2.12** Condition of reflection crack prior to treatment



**Figure 2.13** Condition of reflection crack prior to treatment



**Figure 2.14** Typical patch repair



**Figure 2.15** Typical patch repair

## 2.5 CONTINUOUSLY REINFORCED CONCRETE PAVEMENTS

The combination of a CRC structural layer and an asphalt surfacing has great potential to provide long-life pavements with minimum maintenance

### 2.5.1 Overlay options

The thin surface course system on a continuously reinforced concrete pavement is considered to have only minimal structural benefit, unlike the 100 mm of asphalt on a continuously reinforced concrete base

Properly designed and constructed CRC pavements require comparatively little maintenance or repair. Correct identification of the cause of defects leading to deterioration of the pavement can only be made after careful inspection of the pavement. Not all defects have the same influence on the rate of deterioration of the pavement. Indeed, some defects evident at the time of construction do not deteriorate with time and traffic and are of little consequence. However, other defects can lead to deterioration of the pavement and will inevitably

require maintenance to restore the pavement to a satisfactory condition.

Although a large amount of CRCB has been laid, there is little information available on either the performance of these pavements or on any maintenance techniques employed. Limited visual observations indicate that reflection cracking is not a major problem.



The thickness of the asphalt overlay for a CRCP is based on the condition of the extant pavement. Examples of various thicknesses of surfacing used as a maintenance treatment to a CRCP are given by Hassan *et al.* (2008). It is well recognised that, before overlaying a CRCP with asphalt, it is assumed that all the defects will be repaired to a standard that brings the road up to a condition that can successfully accommodate an overlay. This maintenance includes replacing partial- and full-depth asphalt repairs with cementitious material and reinstating reinforcement where it has broken. Any defects left untreated can develop into a major repair in the future. The *DMRB* 7.4.2, HD 32/94 (Highways Agency *et al.*, 1994) and the *Concrete Pavement Maintenance Manual* (Highways

Agency and Britpave, 2001) include many of the maintenance techniques suitable for a CRCP before being overlaid with asphalt.

For this report, the asphalt thicknesses are indicative only and have been related to the condition of the extant concrete. The thicknesses have been defined as:

- Thin:  $\leq 40$  mm.
- Medium:  $>40$  mm to  $<100$  mm.
- Thick:  $\geq 100$  mm.

### 2.5.2 A thin asphalt overlay

A thin overlay ( $\leq 40$  mm) could be used where:

- *A CRCP is in good condition with no structural problems, but is suffering from an unacceptable level of skid-resistance and/or surface noise characteristics*  
This treatment will have the additional benefit of providing added durability to the concrete and the foundation. The acceptable crack pattern of a CRCP slab in good condition is regularly spaced transverse surface cracks of up to 0.5 mm in width, but with no longitudinal cracking.
- *A CRCP has minor crack defects classified as spalled and/or bifurcated, and an acceptable longitudinal and transverse profile*

Spalling at the arris of a crack is caused primarily by the wheels of passing traffic and so is more prevalent in the traffic wheel-paths. Where minor defects do not affect the structural integrity of the CRCP, a TSCS should not suffer reflection cracking. An example of a minor crack defect such as a bifurcated crack is shown in Figure 2.16.

Before applying the TSCS, it is important that the surface of the concrete is in sound condition and that there are no latent defects that could later reflect through the surfacing.



**Figure 2.16** Example of a bifurcated crack

#### Design advice

- A TSCS only is required for restoration of the surface characteristics where a CRCP is in good condition.

#### Materials advice

- The TSCS overlay should be HAPAS approved and should be able to resist the thermal movements across the cracks in the CRCP. Any reflection crack could form a path for surface water to damage the integrity of the overlay.

#### Laying advice

- Before applying the overlay, the surface of the concrete should be brought to a condition that can successfully accommodate the overlay.

### 2.5.3 A medium asphalt overlay

A medium asphalt overlay (>40 mm to <100 mm) could be used where:

- *There are large crack widths*  
Crack widths of between 0.5 mm and 1.5 mm have the potential for loss of aggregate interlock across the fracture, and cracks wider than 1.5 mm are associated with a complete loss of aggregate interlock and a high potential for failure of the steel reinforcement. Large spacings between transverse cracks in a CRCP increase the probability of the cracks being wide, resulting in reduced aggregate interlock and consequently increased stresses in the pavement slab with potential for rupture of the longitudinal reinforcement. In contrast, transverse cracks induced at a close spacing and connected by longitudinal cracking can lead to a localised defect where blocks of concrete become loose and break away from the surface. These are commonly known as a “punchout”, when pieces of material break away from the surface, or a “punchdown”, when pieces of material are pushed into the underlying layers. Examples of major crack defects arising from intersected crack patterns and loose blocks of material are shown in Figures 2.17 and 2.18.

Because the cracks propagate through the total thickness of the concrete, full-depth repairs will be required. At these locations, the underlying layers are probably no longer providing full support to the concrete and may need to be replaced. An asphalt layer substantially thicker than a TSCS is required to reduce the risk of reflection cracking should similar occurrences develop with age.



- *There is surface spalling and scaling*  
Pieces of material or aggregate that break away from the surface, either close to a crack or in the main slab, could cause a hazard to passing traffic. A CRCP with only a few minor isolated surface defects will require only thin bonded repairs with an appropriate cementitious repair material. Where there is extensive surface spalling, it may be more economical to mill the top of the concrete, but the thickness of the asphalt will need to take into account the reduction of structural capacity from the thinner concrete slab. Where the surface spalling has led to large pieces of concrete breaking away from the surface, a full-depth concrete repair may be required.



**Figure 2.17** Example of major crack defect:  
Intersected crack pattern



**Figure 2.18** Example of major crack defect:  
A “punchdown”



<p><b>Design advice</b></p> <ul style="list-style-type: none"> <li>• An asphalt overlay of &gt;40 mm to &lt;100 mm is required for a CRCP with severe crack defects or surface spalling.</li> <li>• When selecting the thickness of the asphalt layer, consideration should be given to the likelihood of other deficiencies occurring in the future.</li> </ul>	<p><b>Materials advice</b></p> <ul style="list-style-type: none"> <li>• The asphalt overlay should be able to resist the thermal movements across the cracks in the CRCP and be able to resist deformation from traffic. The TSCS should be HAPAS approved.</li> </ul>	<p><b>Laying advice</b></p> <ul style="list-style-type: none"> <li>• Before overlaying with asphalt, the road should be restored to as a good a condition as possible by: <ul style="list-style-type: none"> <li>- Undertaking full- and partial-depth repairs to the concrete in cementitious material.</li> <li>- Where full-depth repairs have been undertaken, the reinforcement should be reinstated and tied to the extant bars.</li> <li>- Undertaking thin bonded surface repairs in cementitious material or, in cases of extensive surface spalling, carrying out a milling operation to the concrete surfacing to the depth of the spalling.</li> </ul> </li> </ul>
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#### 2.5.4 A thick asphalt overlay

A thick asphalt overlay ( $\geq 100$  mm) could be used where:

- *Localised deformation and settlement has occurred in lengths of CRCP or CRCB constructed over areas with poor ground conditions*  
A CRC is considered the best solution for roads where settlement is anticipated because an asphalt overlay restores the surface profile, with the added advantage that it allows the surfacing to be easily renewed to address a changing situation. Increasing the pavement thickness when re-profiling the road surface has the added benefit of increasing the structural capacity of the pavement.
- *A CRCP has structural defects such as “punchouts”, settlement, stepping at cracks, severe spalls at crack arrises and has many temporary asphalt repairs and requires major maintenance*  
All the defects need to be repaired with concrete or a propriety cementitious repair material, then a site-specific thick asphalt overlay with a TSCS, applied in order to restore the road to a satisfactory state for a pre-determined life expectancy.

- *A CRC is in need of strengthening to carry the current and future predicted traffic*  
Provided that the extant road structure is sound, or one that was in a poor condition has been repaired to a standard acceptable for overlay, a thick asphalt overlay with a TSCS has been found to be a satisfactory solution. The thickness of the asphalt overlay will be site specific and related to the past and predicted traffic loading, the concrete strength and the foundation class. For a CRCP, new thickness equations and a family of design curves given by Hassan *et al.* (2008) can be used to determine the thickness required for the type of asphalt overlay to be used.



<p><b>Design advice</b></p> <ul style="list-style-type: none"> <li>• An asphalt overlay of <math>\geq 100</math> mm is required for: <ul style="list-style-type: none"> <li>- CRC with a poor surface profile.</li> <li>- A CRCP with many structural defects.</li> <li>- CRC in need of strengthening.</li> </ul> </li> </ul>	<p><b>Materials advice</b></p> <ul style="list-style-type: none"> <li>• The asphalt overlay should be able to resist the thermal movements across the cracks in the CRC and be able to resist deformation from traffic. The TSCS should be HAPAS approved.</li> <li>• The overlay thickness may vary along and across the road in order to obtain the correct surface profile.</li> </ul>	<p><b>Laying advice</b></p> <ul style="list-style-type: none"> <li>• Before overlaying with asphalt, the road should be restored to as good a condition as possible by: <ul style="list-style-type: none"> <li>- Undertaking full- and partial-depth repairs to the concrete in cementitious material.</li> <li>- Where full-depth repairs are undertaken, the reinforcement should be reinstated and tied to the extant bars.</li> <li>- Thin bonded surface repairs should be undertaken in cementitious material.</li> <li>- In cases of extensive surface spalling, a milling operation to the concrete surfacing to the depth of the spalling could be undertaken.</li> <li>- Where there is a poor surface profile, a detailed survey should be undertaken to establish the new surface levels. In extreme cases, some of the concrete surface may need to be milled to obtain the correct headroom under over-bridges.</li> </ul> </li> </ul>
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### 2.5.5 Continuously reinforced concrete terminations

Longitudinal movement of CRC takes place at the end of the slab and, if not accounted for, could cause damage to adjacent pavements or structures. *DMRB 7.2.3*, HD 26/06 (Highways Agency *et al.*, 2006) specifies that a site-specific/defined termination is submitted for consideration. For a CRCP, two systems described by Hassan *et al.* (2005) are commonly used. These are a ground beam anchorage or a wide-flange steel beam. In both cases, a series of expansion joints between transition bays is used to accommodate any residual or unforeseen movement of the slab end. In contrast to a CRCP, the CRCB sites constructed in the UK have no special end treatment, although a series of ground anchor beams would be beneficial in restricting the end movement.

Typical seasonal thermal movements up to 8 mm/30 °C at the expansion joints in a termination have been reported by Hassan *et al.* (2005). At wide-flange steel beam terminations, the largest movement was 13 mm/30 °C across the beam adjacent to the end of the CRCP. Hassan *et al.* (2005) concluded that a ground beam anchorage termination only restrained 40% of the CRCP end movement, but required no special maintenance apart from a SCS technique at the expansion joints (Figure 2.19). In contrast, a wide-flange steel beam can accommodate the CRCP end movement but requires a special treatment over the steel beam. A typical treatment is a plug joint (Figure 2.20).

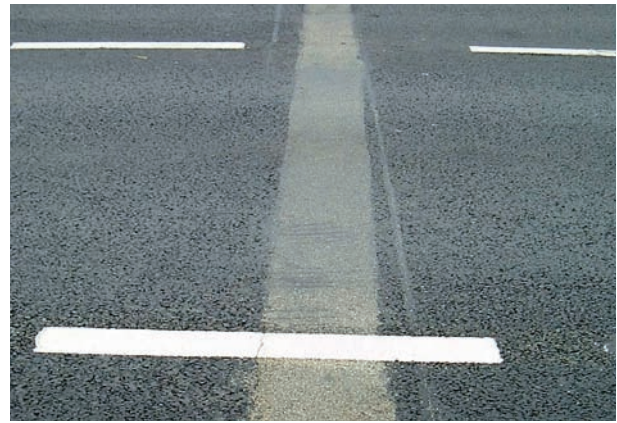
The thickness of the asphalt overlay used in the transition bays at terminations should be the same as that used over the main CRCP.

<p><b>Design advice</b></p> <ul style="list-style-type: none"> <li>• For overlaying CRCP terminations, consideration should be given to: <ul style="list-style-type: none"> <li>- Transition bays.</li> <li>- Joints.</li> </ul> </li> </ul> <p>(See Hassan <i>et al.</i>, 2005.)</p>	<p><b>Materials advice</b></p> <ul style="list-style-type: none"> <li>• The composition and thickness of the asphalt overlay should be the same over the transition slabs and the CRCP.</li> <li>• The asphalt overlay should be HAPAS approved, be able to resist reflection cracking from underlying cracks and be able to resist deformation from traffic.</li> <li>• The joint sealant should be a type approved by the HA. <ul style="list-style-type: none"> <li>- The type of joint sealant selected for use in both the asphalt and the concrete joints should be able to accommodate the anticipated thermal movements from the expansion joints between the transition bays.</li> <li>- Over a wide-flange steel beam, a plug joint should be used that will adhere to the underlying surface of the steel beam and be capable of withstanding the thermal movements without debonding at the vertical faces.</li> </ul> </li> </ul>	<p><b>Laying advice</b></p> <ul style="list-style-type: none"> <li>• The termination bays and the surface of the concrete should be in sound condition.</li> <li>• The expansion joints should be functioning correctly. Their location should be identified accurately to ensure that a saw-cut is made directly above each joint.</li> <li>• The location of the wide-flange steel beam should be identified accurately. It should be overlaid with a plug joint and there should be a good bond between the plug joint material and the vertical faces of the joint.</li> </ul>
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**Figure 2.19** Sealed expansion joint



**Figure 2.20** Plug joint over wide-flange steel beam

### 2.5.6 Materials for continuously reinforced concrete overlays

**The asphalt must be able to resist reflection cracks from the underlying concrete cracks and be resistant to permanent deformation from traffic**

The asphalt material used for an overlay to CRC must have properties that make it able to resist reflection cracks from the underlying concrete cracks and prevent rutting from the wheel loads applied by traffic.

The potential exists for an asphalt overlay on CRC to modify the temperature characteristics of the underlying concrete, and thus the amount of seasonal thermal movements of the cracks. Temperature measurements in CRC slabs have shown that, under the present climatic conditions, an asphalt overlay has the potential to reduce the range of temperatures that occur in the overlaid concrete, leading to a reduced seasonal thermal movement of the concrete surface cracks. However, the effects of climatic change on the concrete, with longer periods of sustained high temperatures, have yet to be assessed.

The different interactions between an asphalt overlay and a reinforced concrete substrate, in terms of the ability of a TSCS to prevent reflection cracking, were determined from the results of a laboratory investigation. The results have indicated that the following properties of asphalt overlays will reduce the incidence of reflection cracks from CRC (Hassan *et al.*, 2008):

- The use of a styrene-butadiene-styrene PMB enhances the elasticity of the TSCS and is better than a paving-grade bitumen with fibres.
- Thicker layers ( $\geq 35$  mm) perform better than thinner layers.
- A bond coat performs better than a tack coat.
- A TSCS with a 0/6 mm aggregate size performs slightly better than larger aggregate sizes.

Results from site tests to determine the bond between a TSCS and the underlying concrete, and an asphalt overlay and the underlying concrete, indicated that the average bond strength between the surface of the CRCP concrete and each overlay was higher in winter than in summer. This finding indicates that the bond strength may be susceptible to climatic conditions.

### 3 OVERLAYING CONCRETE BRIDGE DECKS

#### 3.1 INTRODUCTION

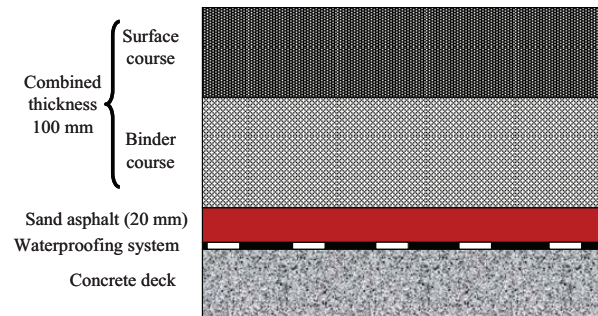
**It is now recommended that sand asphalt is not laid on bridge decks unless required to prevent damage to the waterproofing system**

Concrete bridge decks in the UK must be waterproofed with a bridge deck waterproofing system to prevent water and de-icing salts in solution from reaching the concrete and causing reinforcement corrosion. The *DMRB* 2.3.4, BD 47/99 (Highways Agency *et al.*, 1999a), subsequently referred to as BD 47, has required waterproofing systems to be overlaid whenever possible with a 20 mm thick additional protective layer (APL) of red sand asphalt and other asphalt layers that are a minimum total thickness of 100 mm (Figure 3.1). The 20 mm thick layer of sand asphalt was intended to prevent the membrane being damaged before the binder course is laid, or being damaged by the coarse aggregate particles in the binder course when laid. The *SHW* (Highways Agency *et al.*, 2008b) required the sand asphalt to be tinted red in order to indicate the proximity of the waterproofing system during planing operations.

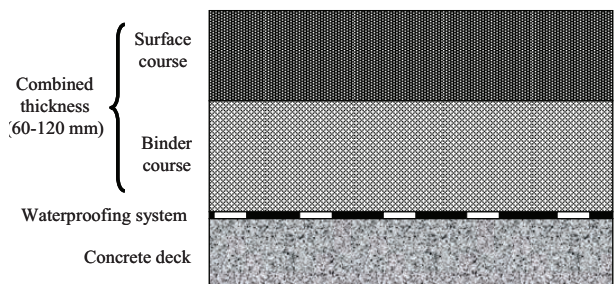
The total thickness of asphalt overlaying the waterproofing system has been less than 120 mm on some bridges because of a requirement to reduce the dead weight or increase the clearance height. On others where the surfacing has been less than 120 mm, there has been a reluctance to increase the thickness because of kerb and parapet heights. However, there have been premature failures on some bridges where the surfacing is less than 120 mm thick, which prompted research to identify the key contributory factors. The research has now been completed and the recommendations (Nicholls *et al.*, 2006; Jordan *et al.*, 2007) have been included in *Interim Advice Note (IAN) 96/07 Revision 1* (Highways Agency, 2007).

*IAN 96/07 Revision 1* recommends that the APL of sand asphalt is omitted unless it is required to prevent damage to the waterproofing system (Figure 3.2). *IAN 96/07 Revision 1* also includes detailed recommendations for the waterproofing system and all asphalt layers on bridges.

This Guide includes the recommendations in *IAN 96/07 Revision 1* and, although it concentrates on the surfacing requirements, includes information on other factors that affect durability. Further information on the waterproofing of concrete bridge decks can be found in *TRL Application Guide 33* (Pearson and Cuninghame, 1998).



**Figure 3.1** Surfacing specified in BD 47



**Figure 3.2** Surfacing when there is no APL of sand asphalt (120 mm minimum total thickness is recommended in *IAN 96/07 Revision 1*)

### 3.2 REMOVING SURFACING AND WATERPROOFING SYSTEM

**Care is needed when planing the surfacing from a bridge deck to ensure that the deck is not damaged and reinforcement cover is not reduced**

When planing, the intention should not be to plane down to the concrete. The planer should be set to around 20 mm above the level of the deck to enable indeterminate variations in the surfacing thickness across and along the deck to be accommodated without damage to the deck; the asphalt thickness can vary by up to 100 mm on some composite multi-span bridges. Jack hammers must not be used.

The remainder of the surfacing and the waterproofing system should be removed by other means, e.g. an excavator bucket or hand tools. Some waterproofing systems can be very difficult to remove, especially if the surface finish of the deck is poor, so there may be a risk that the removal process will reduce the reinforcement cover. In such cases, the risks associated with reduced cover must be balanced against those of applying the new waterproofing system over traces of the old system. It must be possible to achieve the adhesion requirements for the new waterproofing system even when any material is left on the deck (see Section 3.6.2.4).

#### Design advice

- If accurate records are not available, trial holes should be made or a GPR survey should be undertaken to determine the surfacing thickness.
- As much as possible of the old waterproofing system should be removed, but if any remains on the deck, checks should be made to ensure that it will not affect the performance of the new system.

### 3.3 PREPARATION OF THE BRIDGE DECK

**The preparation of the deck should be such that when the waterproofing system has been installed, it is free draining and water cannot accumulate in the asphalt in any trafficked area**

Careful preparation of the deck is required to ensure water cannot accumulate in hollows in trafficked areas, a continuous spray-applied membrane can be formed without pin or blow holes that is not too thick and the waterproofing system is firmly bonded to the deck. If the concrete is defective, the costs and benefits of proceeding with the application of the waterproofing system or making concrete repairs will have to be assessed. Further information on deck preparation is given in Jordan *et al.* (2007).





**Figure 3.3** A large depression in a primed deck where water has ponded (before it was filled with repair material)



**Figure 3.4** A large depression in a deck being filled with repair material

#### Design advice

- After the waterproofing membrane has been applied, there should be no depressions in trafficked areas in which water can pond on the surface of the membrane.
- The thickness of a spray-applied waterproofing membrane should be controlled so it is a minimum of 2 mm and nominally 3 mm. The thickness can be increased to 5 mm in areas of maximum dimension 150 mm in plan, provided the use of a repair material is not more cost effective.

#### Materials advice

- Repair materials should be compatible with the waterproofing system and have similar properties to the deck concrete (coefficient of thermal expansion and elastic modulus).

#### Laying advice

- Pull-off tests should be carried out where there is concern that the strength of the concrete may be less than the required bond of the waterproofing system to the concrete.
- Repair materials should not be used at less than their recommended minimum thickness. Layers less than 5 mm thick should be used only if a durable bond can be demonstrated.

### 3.4 SUB-SURFACE DRAINAGE

- The upstands at the edges of bridges and bridge deck expansion joints form a “water tank”
- When surfacing on bridges has failed prematurely, the presence of water has normally been a contributory factor



**Figure 3.5** Through-deck drains at a location on a bridge that is not free draining

The factors that affect the durability of surfacing on bridge decks are no different to those that affect the durability of asphalt pavements. However, certain types of premature surfacing failures are prevalent on bridges. Although they are the result of more than one mechanism, it is postulated that most premature failures have occurred because the surfacing has become saturated, allowing high hydrostatic pressures to be generated in the saturated surfacing by wheel loading, and these pressures have debonded the surfacing from the waterproofing system and/or caused the surfacing itself to fail. To prevent such failures, either water should be prevented from entering the surfacing or water that has entered the surfacing should be drained quickly before it can accumulate (see Nicholls *et al.*, 2008).



**Figure 3.6** Water and fines forced out of a cracked thin surfacing by heavy goods vehicles on a deck with no through-deck drains



**Figure 3.7** Extensive break-up of thin surfacing where high hydrostatic pressures were generated in the saturated surfacing

<p><b>Design advice</b></p> <ul style="list-style-type: none"><li>• Sub-surface drainage (through-deck drains or edge drains) should be provided at the level of the waterproofing system at all locations that are trafficked where water may accumulate on a bridge deck.</li><li>• Slotted 20 mm drains incorporated into expansion joints should not be relied upon as the only source of sub-surface drainage where significant quantities of water may accumulate.</li><li>• The outlets of drainage units should be such that discharges do not harm other parts of the structure or form a hazard to traffic, pedestrians or the environment. Closed drainage systems are required over water courses, and where icicles or freezing discharges may be hazardous. Open-ended pipes should discharge a minimum of 150 mm from the soffit, but this distance should be increased when wind-blown discharges may be hazardous.</li></ul>	<p><b>Materials advice</b></p> <ul style="list-style-type: none"><li>• Through-deck drains should be of minimum diameter 40 mm.</li><li>• Drainage units must be able to withstand the high temperatures encountered during surfacing without distorting.</li></ul>	<p><b>Laying advice</b></p> <ul style="list-style-type: none"><li>• Care should be taken when installing through-deck drains to avoid structural damage to the bridge. When the risk of damage is high, alternative drainage systems must be installed.</li></ul>
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### 3.5 WATERPROOFING SYSTEM SELECTION

**An effective waterproofing system is required to prevent damage to the bridge deck**

Waterproofing systems are frequently classified according to the type of their waterproofing membrane, i.e.:

- Spray-applied (or liquid-applied) systems.
- Sheet systems.
- Mastic asphalt.

A waterproofing system comprises:

- *Concrete primer*  
This helps to seal the concrete and optimise the bond of the waterproofing membrane to the deck.
- *Bonding agent (some systems)*  
Sheet systems may be bonded to the primer using oxidised or modified bitumen.
- *Waterproofing membrane*  
This is to prevent de-icing salts in solution and other contaminants from reaching the concrete deck. The

primer may afford some protection, but a membrane is required to prevent leakages through defects in the concrete at cracks.

- *Protection board or layer (some systems)*  
This may be required to prevent damage to the waterproofing membrane during the laying of hot asphalt.
- *Tack coat (some systems)*  
The tack coat is to optimise the bond of the overlaying surfacing to the waterproofing system. The tack coats of waterproofing systems are proprietary products that form part of the system. They should not be substituted by tack or bond coats used to optimise the bond between asphalt layers.

Further information on the factors to consider when selecting a waterproofing system for a particular application is given in Pearson and Cuninghame (1998).

**Materials advice**

- The waterproofing system should have a Roads and Bridges Agrément Certificate or its performance should have been demonstrated in performance tests such as those specified in BD 47 or equivalent European Standards.
- A waterproofing system with a thick tack coat<sup>1</sup> must be used when the system is to be overlaid with asphalt containing coarse aggregates (see Section 3.6.2.3).

## 3.6 SURFACING DESIGN

**Surfacing systems for bridge decks should not be designed without knowledge of the requirements of the waterproofing system**

### 3.6.1 Layer thicknesses

The total thickness of asphalt on bridges may range from less than 60 mm to over 120 mm, but a minimum thickness of 120 mm is recommended. Thicknesses less than 60 mm on concrete bridges are a special case and not covered by the recommendations in this Guide.

Bridges may require one, two or three asphalt layers, each of which can be a different material. On most bridges, there are small variations in the level of the deck that can be accommodated without varying the number of asphalt layers. However, it is necessary to vary the number of layers on some bridges, requiring some compromise in the regions where the number changes. Tapered areas should be trimmed to remove asphalt too thin to be well compacted. As stated in Nicholls *et al.* (2008), a few thick layers are better than multiple thin layers.

**Design advice**

- Whenever possible, the minimum total thickness of asphalt overlaying the waterproofing system should be 120 mm.
- A minimum thickness of 45 mm is recommended for the asphalt layer directly overlaying the waterproofing system. A layer of uniform thickness is also recommended, but regulation in this layer or any other asphalt layer below the surface course is preferable in order to provide a surface course of uniform thickness.
- The effect of regulation on the drainage of each layer of asphalt must be taken into account to ensure sub-surface water cannot accumulate in the surfacing.

<sup>1</sup> See Section 3.6.2.3 and associated footnote for the definition of “thick” tack coat.



### 3.6.2 Waterproofing system requirements

**Satisfying the requirements of the waterproofing system is a challenge because often they are conflicting**

#### 3.6.2.1 Tack coat activation temperatures

The Roads and Bridges Agrément Certificates for the different waterproofing systems currently registered for use on HA structures specify the temperatures at which asphalt should be laid or compacted in order to activate the tack coat and form a good bond to the system. Because there is inconsistency in the wording from certificate to certificate, waterproofing suppliers should provide details of the minimum temperatures at which the asphalt should be laid and compacted to activate the tack coat.

**If asphalt is laid and compacted at too *low* a temperature, a dense layer that is firmly bonded to the waterproofing system will not be formed**

##### Design advice

- Obtain from the waterproofing supplier details of the minimum laying and compaction temperatures needed in order to activate the tack coat of the waterproofing system and form a good bond with the overlying asphalt layer. Note carefully whether the compaction temperature refers to the mid-layer temperature or the temperature at the base of the asphalt layer.

##### Materials advice

- The temperature required to activate the tack coat of a waterproofing system varies from system to system. When the prevailing weather conditions are likely to cool rapidly the asphalt layer directly overlaying the waterproofing system, preference should be given to using waterproofing systems with tack coats with activation temperatures towards the lower end of the range.

#### 3.6.2.2 Asphalt temperatures

- **Some membranes may be punctured if mixtures with coarse aggregates are compacted at too *high* a temperature**
- **Some membranes can be damaged simply by being overlaid with asphalt at too *high* a temperature**

BD 47 requires waterproofing systems to pass certification tests that simulate the conditions when they are overlaid with hot asphalt. One test assesses crack-bridging ability by applying a thermal shock that induces a temperature of 145 °C at the waterproofing membrane, which is then followed by a period of heat conditioning. Another test assesses the resistance to aggregate indentation during compaction. The aggregate indentation test was developed to replicate the type of damage that can be induced during compaction. A probe heated to 125 °C applies a force of 1000 N to a membrane heated to 50 °C. During normal site practice, the membrane will be at a higher temperature than 50 °C but the force applied by a coarse aggregate may be less than 1000 N. However, this procedure is how waterproofing systems have been tested and why, prior to January 2008, Clause 901.9 of the *SHW* (Highways

Agency *et al.*, 2004) limited the temperature at which mixtures with coarse aggregates could be deposited on a waterproofing system to 125 °C. This limitation has been addressed in *IAN 101/07 Amendment 1* (Highways Agency, 2008).

On the basis of the above, it could be argued that compaction should not take place until the mid-layer temperature is 125 °C. Therefore, as is quite likely, if this temperature is likely to be exceeded during compaction of the asphalt directly overlaying the waterproofing system, evidence should be obtained to confirm that the waterproofing system will not be damaged at the higher temperature.

Furthermore, if the temperature of the waterproofing system is to exceed 145 °C, evidence should be obtained to confirm that its crack-bridging ability will not be impaired. If a system has performed satisfactorily when overlaid with, say, mastic asphalt at 220 °C on a steel bridge deck, this is of little significance because the ability to bridge cracks should not be required on a steel deck.

#### Design advice

- It must be possible to compact the asphalt directly overlaying the waterproofing system to form a dense layer without risking damage to the waterproofing system by thermal shock and aggregate indentation.
- If asphalt is to raise the temperature of the waterproofing system above 145 °C, or asphalt with coarse aggregates is to be compacted when the mid-layer temperature is above 125 °C, tests must be undertaken to determine if this will damage the waterproofing system.

#### Materials advice

- Use a waterproofing system that has passed the aggregate indentation test at 125 °C (stated on the Roads and Bridges Agrément Certificate) if it is to be directly overlaid with asphalt with coarse aggregates. Otherwise, overlay the waterproofing system with an APL of sand asphalt.

### 3.6.2.3 Void content of overlaying asphalt

**There must be no large interconnecting voids at the interface between the waterproofing system and the overlaying asphalt**

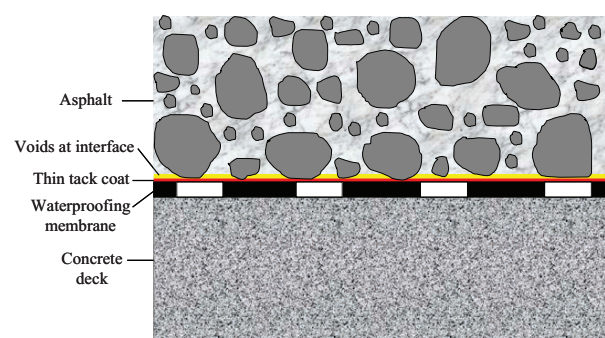
When asphalt with coarse aggregates is compacted onto a “hard” surface, the body of the material may have a low void content but there may be large voids at the base of the layer. The voids tend to be larger with larger aggregate sizes and with higher proportions of coarse aggregate. When there are voids at the interface between the waterproofing system and the asphalt directly overlaying it, water can accumulate in them and there is a risk of premature failure. Therefore, the void content at the interface should be low and the voids should not be interconnecting.

The permeability of the interface between the waterproofing system and the asphalt is dependent on the properties of both the asphalt and the tack coat. A tack coat for a waterproofing system may comprise more than one layer. The layer that is in contact with the asphalt and which aggregates can penetrate can be described as “thin” (generally <0.3 mm, applied at <0.5 kg/m<sup>2</sup>) or “thick” (generally >1.0 mm, applied at >1 kg/m<sup>2</sup>)<sup>1</sup>. When the tack coat is “thin”, an asphalt layer with a small aggregate size and low proportion

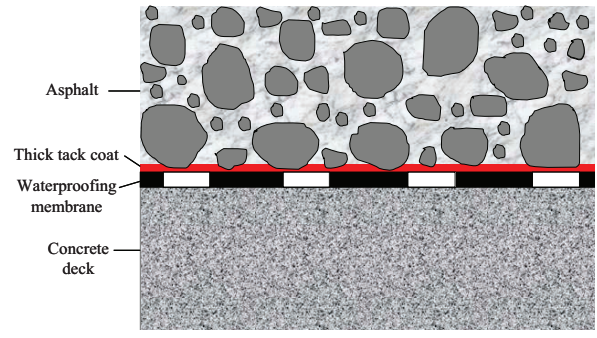
of coarse aggregate will yield no large interconnecting voids. However, as shown in Figure 3.8, any mixture that contains large aggregates contains some voids at the interface (coloured yellow) where water may accumulate, and results in a reduction in contact area between the mixture and the waterproofing system.

As shown in Figure 3.9, a “thick” tack coat can (partially) fill the voids at the base of an asphalt layer with coarse aggregates and thereby limit the accumulation of water and interconnecting voids and, potentially, improve the adhesion. The tack coat must not be too thick, otherwise “bleeding” of the excess binder through the overlaying asphalt layer may occur during its laying and compaction. Ideally, the coarse aggregates should almost fully penetrate the tack coat as the tack coat material fills the voids at the base of the layer.

<sup>1</sup> The term “thick” tack coat may appear to be an oxymoron to an asphalt engineer. However, the term tack coat is used for the component of a waterproofing system that is used to optimise the bond of the overlaying asphalt to a waterproofing system, whatever its thickness. The term bond coat is not used to describe a “thick” tack coat on Roads and Bridges Agrément Certificates.



**Figure 3.8** Interface between asphalt and waterproofing system with “thin” tack coat



**Figure 3.9** Interface between asphalt and waterproofing system with “thick” tack coat

<p><b>Design advice</b></p> <ul style="list-style-type: none"><li>• The waterproofing system and the asphalt directly overlaying the system should be selected so the void content at the base of the layer at the interface with the waterproofing system is low and there are no interconnecting voids.</li><li>• The asphalt layer directly overlaying the waterproofing system should have an air voids content of 4% or less.</li></ul>	<p><b>Materials advice</b></p> <ul style="list-style-type: none"><li>• A waterproofing system with a “thick” tack coat should be used when the layer directly overlaying the waterproofing system contains coarse aggregates.</li><li>• Unless an APL of sand asphalt is required, the waterproofing system should be overlaid with a layer of hot rolled asphalt binder course to Clause 943 of <i>IAN 101/07 Amendment 1</i> (Highways Agency, 2008).</li><li>• The hot rolled asphalt binder course should have Class 2 deformation resistance measured using the wheel tracking test (BS EN 12697-22 (British Standards Institution, 2003)).</li></ul>
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3.6.2.4 Adhesion and bond strength requirements

**A good bond between the overlaying asphalt and the waterproofing system is essential for durability**

Table 3.1 lists the minimum adhesion and bond strength requirements from *IAN 96/07 Revision 1* (Highways Agency, 2007) when the asphalt directly overlaying the waterproofing system contains coarse aggregates. The values in BD 47 should apply only to surfacing of thickness 120 mm or more with an APL of sand asphalt.

When a trial is required to determine whether the required adhesion and bond strengths can be achieved, it may be carried out on a concrete slab that is waterproofed in accordance with the manufacturer’s method statement. The asphalt should be laid in lengths of 5 m or more, each length at a different temperature and rolled after the normal time delay experienced on bridges. The laying temperature and the temperature at the interface or at the mid-layer immediately before compaction should be recorded.

The full depth of the slab can be cored so test sections can be tested in tension and shear in a laboratory under temperature-controlled conditions at –10 °C, 23 °C and 40 °C in accordance with BD 47. Alternatively, test sections can be prepared in each test length by coring or saw-cutting just into the concrete slab, and tensile bond tests can be carried out at a temperature between 10 °C and 23 °C and the results compared with the requirements at 23 °C in Table 3.1.

The laying and compaction temperatures that achieve the bond strengths specified in Table 3.1 should be at least equalled when the asphalt is laid on bridges.

**Table 3.1 Minimum adhesion and bond requirements for waterproofing systems when overlaid with coarse mixtures (from IAN 96/07 Revision 1 (Highways Agency, 2007))**

Test	Test temperature	Total thickness of asphalt		
		≥120 mm	120–90 mm	90–60 mm
Tensile adhesion test (waterproofing system to concrete)	–10°C	0.30 N/mm <sup>2</sup>	0.50 N/mm <sup>2</sup>	0.70 N/mm <sup>2</sup>
	23°C	0.30 N/mm <sup>2</sup>	0.50 N/mm <sup>2</sup>	0.70 N/mm <sup>2</sup>
	40°C	0.20 N/mm <sup>2</sup>	0.30 N/mm <sup>2</sup>	0.30 N/mm <sup>2</sup>
Shear adhesion test (asphalt to waterproofing system)	–10°C	0.30 N/mm <sup>2</sup>	0.30 N/mm <sup>2</sup>	0.40 N/mm <sup>2</sup>
	23°C	0.30 N/mm <sup>2</sup>	0.30 N/mm <sup>2</sup>	0.40 N/mm <sup>2</sup>
	40°C	0.10 N/mm <sup>2</sup>	0.15 N/mm <sup>2</sup>	0.15 N/mm <sup>2</sup>
Tensile bond test (asphalt to waterproofing system)	23°C	0.40 N/mm <sup>2</sup>	0.45 N/mm <sup>2</sup>	0.50 N/mm <sup>2</sup>

**Design advice**

- Adhesion and bond strength requirements should be specified appropriate for the total thickness of asphalt and type of asphalt directly overlaying the waterproofing system. Those in Table 3.1 should apply when the asphalt directly overlaying the waterproofing system contains coarse aggregates; the values in BD 47 should apply only to surfacing of thickness 120 mm or more with an APL of sand asphalt.
- When a “thick” tack coat is used, the bond can be dependent on the thickness of the tack coat. If necessary, trials should be carried out to determine the thickness required (and the laying and compaction temperatures of the overlaying asphalt) to optimise the bond.

### 3.6.3 Surface drainage

**Design advice**

- Surface drainage systems, longitudinal gradients and cross falls should be provided to minimise the amount of water that can enter and accumulate in the asphalt on bridge decks.
- The surfacing on masonry arch bridges should be shaped to shed water away from the spandrel walls.
- Whenever possible, surface drainage should be provided on the high side (before) bridges on gradients to reduce water flow over expansion joints and onto bridges.

### 3.6.4 Surface course requirements

#### 3.6.4.1 Sub-surface drainage and void content

Significant quantities of water can enter the body of the material of surface courses with a void content greater than 5%. Once in the surfacing, the movement of the sub-surface water is dependent on the permeability of the surface course and the lower asphalt layers. Whereas on pavements sub-surface water can permeate downwards through several bound and unbound layers as it flows towards sub-surface drainage systems, sub-surface water on bridges can only flow downwards as far as the waterproofing system. It must then flow horizontally across or along the deck towards any sub-surface drainage systems that are located at low points.

These may be well over 10 m away from where the water entered the surfacing. The flow of water vertically and horizontally will be impeded in areas where the surfacing is effectively impermeable, and at barriers such as the waterproofing system and expansion joints. The sub-surface water will follow the path of least resistance, which may be out of the surfacing or through defects in the waterproofing system or expansion joints. The former causes increased problems on bridges in winter conditions because of the tendency for bridge decks to be at lower temperatures than the pavement.

**Design advice**

- Edge drains are required to drain “relatively permeable” surface courses and subjacent asphalt layers with a void content greater than 4% to their full depth (i) at the low points of the deck and (ii) where the flow of sub-surface water through the surface is impeded, e.g. at expansion joints that are not the buried type.
- When it is impractical or difficult to install edge drains or other sub-surface drainage systems, a “relatively impermeable” surface course with a maximum air void content of 4% should be used to reduce the amount of water that enters the surface course.

**Materials advice**

- When edge drains are required, consideration should be given to using proprietary units that drain at different levels, including at the level of the waterproofing system.
- When a thin surfacing is required, preference should be given to those with a thick bond coat that can be applied uniformly to help seal the subjacent asphalt layer.

**Laying advice**

- Compaction should be such that the permeability of “relatively permeable” surface courses is reasonably uniform so sub-surface water that enters the surfacing where the void content is high is not prevented from flowing across a layer where the permeability is low.



### 3.6.4.2 Sealing at details, interfaces and joints

The use of impermeable layers will be inadequate without ensuring proper sealing at any details, interfaces or joints between rips, and any variations in permeability associated with defects such as cracks. The relevant details are kerbs, parapets and expansion joints. The relevant interfaces are between asphalt layers (Nicholls *et al.*, 2008).

Care is needed when joints are fully sealed to ensure they do not prevent the flow of sub-surface water horizontally across a bridge such that it can accumulate and high hydrostatic pressures can be generated by heavy goods vehicles. Figure 3.10 shows the surfacing on a bridge deck with through-deck drains in lane 2 on the low side. The longitudinal joint between lanes 1 and 2 prevented the flow of sub-surface water from lane 1 to lane 2 through the thin surfacing. A length of thin surfacing became saturated on the high side of the expansion joint in lane 1, failed and was replaced with hot rolled asphalt. Subsequently, another length of thin surfacing became saturated on the high side of the hot rolled asphalt, failed and was replaced. Figure 3.11 shows a close-up of the far end of the second section of hot rolled asphalt where more thin surfacing is saturated and at risk of failure. When the deck was re-waterproofed, further through-deck drains were installed in lane 1 and two pavers were used in echelon to surface the full width of the carriageway.



**Figure 3.10** Two sections of hot rolled asphalt laid in lane 1 that replaced thin surfacing on high side of expansion joint



**Figure 3.11** Close-up of far end of second section of hot rolled asphalt shown in Figure 3.10 where sub-surface water is coming out of the thin surfacing

#### Design advice

- Edges, cracks and joints should be sealed to prevent large volumes of water entering the surface course.
- The sealing of joints should not prevent the flow of water to sub-surface drainage systems. If this may occur, additional sub-surface drainage must be provided or paving should be in echelon to avoid the need for sealing.



### 3.6.4.3 Bond between asphalt layers

The bond between asphalt layers has become more important with the use of thin surfacing because of the proximity of the interface with the actual surface and the potential for higher shear forces to occur at this interface.

Bond, based on a torque bond shear test, is a required property for thin surfacing systems in order to obtain a HAPAS certificate, but there is no pass/fail criterion under the current guidelines. The test is carried out after 28 to 56 days of trafficking, and is intended as a type test. Non-proprietary surfacings should be tested to demonstrate that they satisfy the requirements.

#### Design advice

- The bond between asphalt layers should satisfy the requirements in Nicholls *et al.* (2006), i.e. a minimum torque bond strength of 700 kPa for interfaces within 20 mm of the surface and 400 kPa within 50 mm.

### 3.6.4.4 Resistance to deformation

#### Design advice

- The surface course requirements in tables NG 928 and NG 946 of the *Notes for Guidance on the Specification for Highway Works* (Highways Agency *et al.*, 2008c) should apply to each material type in the top 50 mm, with the requirements for the next level down applying to the next 50 mm.

### 3.6.4.5 Future maintenance

Although the *SHW* (Highways Agency *et al.*, 2008b) has required waterproofing systems to be overlaid with a red sand asphalt APL so it can be used as an indicator layer in resurfacing works, there has been limited success when the APL has been used in this way to replace a binder course without re-waterproofing a bridge. On some bridges, the APL has been damaged and it has been difficult to remove the damaged areas without damaging the waterproofing system. On others, the waterproofing system has been damaged because of local variations in the level of the deck and the depth of the surfacing. Only on a few bridges has replacement of the binder course been successful, and this was normally when the planer was set well above the top of the APL. In view of these observations, it is concluded that it is impractical to use a red sand asphalt APL on bridges and then to replace an asphalt layer directly overlaying or within 40 mm of a waterproofing system without re-waterproofing.

When the waterproofing system is overlaid with a layer of hot rolled asphalt binder course to Clause 943 of the *SHW* (Highways Agency *et al.*, 2008b) (see Section 3.6.2.3), the service-life of the layer will be more comparable with the service-life of the waterproofing system.

#### Design advice

- Unless the waterproofing system is to be replaced, planing within 40 mm of the system is not recommended because there is a risk that the system will be damaged and the bond of asphalt to the system will be weakened.

### 3.7 EXPANSION JOINTS

#### 3.7.1 General

**Many surfacing failures on bridge decks occur near expansion joints that prevent the flow of sub-surface water and where there is no sub-surface drainage**

Information on the factors that need to be considered when selecting and installing an expansion joint for a particular application is given in TRL Application Guide 29 (Barnard and Cuninghame, 1997).

Expansion joints are often at the low points on bridges and premature surfacing failures are often near them. This is partly because all types except buried types impede the flow of sub-surface water so it can accumulate if there is inadequate drainage. Furthermore, some mechanical joints are not replaced during resurfacing works. New asphalt laid adjacent to such joints is more difficult to compact and more likely to have a high void content, become saturated and, therefore, be at a higher risk of failure than asphalt elsewhere on the deck or adjacent pavement.

Buried-type expansion joints (Barnard and Cuninghame, 1997) will not impede the flow of sub-surface water, but they should be used only when the expected movements, including traffic-induced movements, are low. Buried joints have performed satisfactorily when overlaid with hot rolled asphalt of total thickness 100 mm or more. However, their performance with thin surfacing, in particular resistance to cracking and the need to incorporate a crack inducer, has yet to be determined.

##### Design advice

- Procedures should be developed for compacting asphalt adjacent to existing mechanical joints to ensure the requirements to form a dense layer that is firmly bonded to the waterproofing system are met.

##### Materials advice

- New buried joints should not be used with thin surfacing without evidence that they will perform satisfactorily.
- A hot rolled asphalt surface course over an existing buried joint should not be replaced by thin surfacing if the new surface course will not be resistant to cracking at the joint.

#### 3.7.2 Surface regularity

Buried joints provide excellent ride quality because intrusion at the surface course is limited to, at most, a saw-cut. Other types of joint are a discontinuity in the surfacing that can affect the ride quality and traffic-induced noise. In extreme cases, the ride quality can be such that impact loading beyond a joint can weaken the adjacent asphalt. Therefore, measures should be taken to optimise ride quality.

Asphaltic plug joints are installed so they are finished level with the surface course and they provide excellent ride quality until they deform more or less than the adjacent surfacing.

The ride quality of mechanical joints is dependent on their profile and how they are set relative to the surface course. They are normally installed just below the level of the surface course so that they are not proud of it after trafficking causes deformation of the surfacing.

Another possible cause of impact damage is the tendency for the fill behind abutments to sometimes settle. Measures should be taken to prevent this damaging the adjacent surfacing and expansion joint.

### 3.8 WATERPROOFING SYSTEM INSTALLATION

**The installation of the waterproofing system is a weather-dependent activity that must not be rushed if the durability of the system and the overlay is not to be compromised**

The installation of the waterproofing system should be completed in as short a time as possible so surfaces remain clean and dry before they are overlaid, while ensuring that there is sufficient time for materials to cure. The installation should not normally proceed until the surface temperature is greater than 4 °C and rising, the surface temperature is 3 °C above the dew point and the relative humidity is less than 90%. Beyond these limits, water may condense on the surface and affect the bond. Spray-applied materials should not be applied if high winds will cause excessive drift on the wind and form a hazard to site staff and road users and cause environmental damage.

All layers of the waterproofing system must be uniformly bonded to the underlying surface. Pull-off tests can sometimes be carried out on trial patches to check the bond before materials are applied to large areas. However, this introduces delays and the effect of changes in conditions during such delays should be taken into account.



**Figure 3.12** Priming a bridge deck



**Figure 3.13** Applying a waterproofing membrane



**Figure 3.14** A bridge deck tented to enable installation of the waterproofing system in adverse weather

**Design advice**

- Sufficient time must be made available to enable the waterproofing system to be installed in accordance with the supplier's Method Statement, making allowances for possible delays due to unfavourable weather.
- Environmental delays, e.g. wet or windy weather, are likely to be unacceptable so consideration should be given to tenting each part of the deck in order to create a suitable environment for the installation of the waterproofing system.

**Laying advice**

- All stages of the installation of the waterproofing system should be in accordance with the Method Statement.
- All surfaces/layers must be clean, dust free and dry before they are overlaid. Drying of the substrate after it has been subjected to rainfall should be sufficient to prevent out-gassing (see *DMRB* 2.3.5, BA 47/99 (Highways Agency *et al.*, 1999b)).
- The thickness of the waterproofing membrane should be monitored at regular intervals during application to demonstrate compliance, and the integrity of the membrane should be assessed before it is overlaid.
- Procedures should be developed to ensure "thick" tack coats are applied uniformly to the required thickness. They should be applied by mechanical methods to minimise the application time, and their thickness should be monitored at regular intervals.

**3.9 CARE OF THE WATERPROOFING SYSTEM**

**A bridge deck waterproofing system is easily damaged if care is not taken during site activities before it is overlaid with asphalt; any damage must be repaired**

**Design advice**

- Determine, from the supplier of the waterproofing system, the time between the application of the tack coat and the application of the surfacing that must not be exceeded if the bond of the surfacing to the waterproofing system is not to be compromised. Follow the supplier's recommendations if the time is exceeded.

**Laying advice**

- Unnecessary access to the waterproofing system by site staff and plant should be denied at all times until the surfacing has been laid.
- The time between the curing of the tack coat and when it is overlaid with surfacing should be kept to a minimum to reduce the risk of damage and contamination.
- The effect of any damage to the waterproofing system, including damage to the membrane and the removal of the tack coat prior to surfacing, should be assessed and appropriate repairs made.

**3.10 OVERLAYING THE WATERPROOFING SYSTEM**

**The temperature at which the asphalt directly overlaying a waterproofing system is laid and compacted must be controlled very carefully**



### 3.10.1 Laying and compaction temperatures

When a layer of asphalt is laid onto a waterproofing system, the base of the layer cools rapidly as heat is transferred from the layer into the waterproofing system and the concrete substrate. Within a short period of time, the temperature of the waterproofing system will rise to a maximum value before decreasing as the asphalt cools. The mid-layer temperature may be easier to measure on site but, dependent on the type and thickness of asphalt, it could be 10 °C or more above the temperature of the waterproofing system. The maximum temperature at the waterproofing system may be 20 °C or more lower than the maximum temperature at mid-layer (laying temperature), the maxima occurring at different times.

The objective should be to exceed the minimum temperature required to activate the tack coat by at least 10 °C (see Section 3.6.2.1). If necessary, a site trial should be carried out to ensure that the minimum temperature can always be achieved (see Section 3.6.2.4).

The method proposed by Daines (1994) may be used to determine the time after laying to reach a given temperature at mid-layer for different laying temperatures and environmental conditions and, hence, the time available for compaction.

#### Laying advice

- Laying and compaction should be coordinated so that the laying and compaction temperatures are in accordance with those required to activate the tack coat of the waterproofing system and form a dense layer that is firmly bonded to the waterproofing system.
- Asphalt temperatures should be measured and recorded during laying and compaction.

### 3.10.2 Avoiding tack coat damage

The tack coat can be stripped off a waterproofing membrane by the wheels or tracks of the paver and other site vehicles. It can be sticky at high ambient temperatures and when not cured, and can be brittle and break up at low temperatures.

Stripping can be reduced by:

- Limiting the number of vehicles that drive over the waterproofing system.
- Reducing the time that vehicles are on the system.
- Limiting the amount of asphalt in the paver so traction forces during start-up are reduced.
- Minimising the number of times the paver stops and starts.

The application of a dilute soap solution to the pre-cleaned wheels of the paver and other site vehicles has been effective in some cases.

On at least one bridge, repair patches of a thick tack coat were prepared that were inserted behind the wheels of the paver and in front of the screed bar where the tack coat had been removed. It was assumed that the tack coat was bonded to the waterproofing system when it was melted by the hot surfacing and the surfacing was compacted.

#### Laying advice

- A methodology should be developed to ensure that stripping of the tack coat by the paver and other site plant is minimised and can be repaired before and during surfacing. If necessary, a site trial should be carried out to demonstrate the effectiveness of the methodology in the prevailing environmental conditions.
- To reduce the effect of the possible stripping of the tack coat, the wheels of the paver should be positioned so they are not coincident with the wheel paths on the carriageway.

### 3.11 LAYING ASPHALT AT EXPANSION JOINTS

#### **Laying advice**

- The procedures developed for laying and compaction of the surfacing adjacent to existing mechanical-type expansion joints should be followed (see Section 3.7.1).
- Expansion joints should be finished at the correct height relative to the level of the surface course to minimise impact damage to the joints themselves and the adjacent surfacing.

## 4 CONCLUSIONS

During development of Road Notes 41 and 42, it became apparent that there is a common desire from all parties involved in the industry (consultants, contractors and suppliers) to improve the durability of pavements.

Road Note 42 covers the main aspects that lead to the durability of asphalt pavements and their component asphalt materials. These must be taken into account when designing, specifying, producing and laying asphalt overlays for concrete pavements and bridges, together with the more detailed aspects that are given in this Guide.

All reflection cracking in the UK is top down. Jointed concrete and CRC pavements must be treated appropriately and overlaid with asphalt of sufficient thickness to resist such cracking.

A jointed concrete pavement can be broken into small lengths using the fractured slab techniques and overlaid with asphalt. Rubblisation is an option when there are major structural problems with the existing pavement, although a thick asphalt overlay will be required. The performance of some interlayers, i.e. geotextiles and grids, SAMIs and CRLs, has been variable so they should only be used with HA approval. Surface treatments that reduce the occurrence of reflection cracking in the surface course include the use of PMBs, and SCS whereby joints are introduced into the asphalt directly above the joints in the concrete.

A CRCP eliminates movement joints within the main slab, but develops narrow transverse cracks at a regular spacing. Before overlaying the concrete, the surface and pavement need to be restored to a condition that can successfully accommodate an overlay. A CRCP in good condition should only require an overlay of thickness up to 40 mm for noise and skid-resistance properties. An overlay of thickness less than 40 mm will not provide significant structural benefits. A CRCP with large crack

widths, intersected crack patterns, loose blocks of material and surface spalling and scaling requires an overlay of thickness up to 100 mm. An overlay 100 mm thick or greater is required when a CRCP has a poor surface profile, has many structural defects or is in need of strengthening. Special treatments are required to the asphalt over the joints at terminations.

The control of water is critical to the performance of surfacing on concrete bridge decks. The upstands at edges and non-buried-type expansion joints form a “water tank” and it is better to prevent water entering the “tank” than to create a problem trying to remove it. Efficient surface drainage and asphalt with low air void contents are required. The concrete deck should be treated so the surface of the waterproofing system is free draining, with sub-surface drainage being provided where it is not. Because sand asphalt is structurally weak, an additional protective layer of this material should not be used unless required to prevent damage to the waterproofing system. There must be no large interconnecting voids at the interface between the waterproofing system and overlying asphalt with coarse aggregates; the layer should be of minimum thickness 45 mm and the waterproofing system must have a thick tack coat.

Care is needed to prevent waterproofing systems being damaged by site staff and plant, or asphalt laid and compacted at too high a temperature. However, asphalt will not bond well to the waterproofing system and form a dense layer if it is laid and compacted at too low a temperature. Higher bond strengths are required when the total thickness of the asphalt overlaying a waterproofing system is less than 120 mm. Extra attention is needed when laying asphalt near existing mechanical-type expansion joints so it is well compacted and premature surfacing failures are prevented.

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Road Note 41 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 treatment.

Together with the companion publication, Road Note 42 'Best practice guide for durability of asphalt pavements', 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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