URS

SECTION 5 SURFACING AND BITUMINOUS MATERIALS

PART 2

HD 37/1X

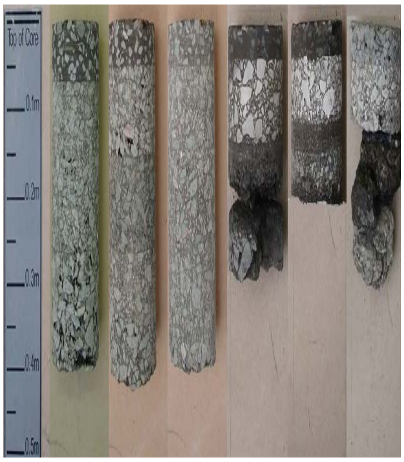
BITUMINOUS MATERIALS AND SURFACING TECHNIQUES

DRAFT FOR CONSULTATION

January 2013

Prepared for:
The Highways Agency

UNITED KINGDOM & IRELAND



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ACLAND INVESTMENTS LIMITED

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1. INTRODUCTION

General

1.1 This Part gives advice on the suitability, specification and techniques of laying bituminous materials. It covers all road products using bituminous binders, ranging from surface treatments and thin surface course systems to heavier duty surfacing materials such as hot rolled asphalt. It includes all bituminous bases and binder courses and bridge deck surfacing, but retexturing and recycling guidance is now given in HD 31.

Implementation

1.2 This Part shall be used forthwith on all schemes for the construction, improvement and maintenance of trunk roads including motorways, currently being prepared, provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay. Design organisations should confirm its application to particular schemes with the Overseeing Organisation.

This Chapter provides an overview of the document and a brief summary of the contents of each chapter. It also includes an outline description of possible properties of the various materials. Advice is provided and indications are given of where the individual materials may and may not be used.

The materials and processes covered are those which are involved in the provision and maintenance of flexible pavements. Table 1.1 summarises the contents of each chapter.

1.3 All construction materials used in the structural layers of pavements and for surface maintenance are expensive, therefore great care must be exercised in determining the most appropriate material to use in any given situation and to ensure that the material is installed in such a manner as to ensure maximum durability. The decision as to what material to use in any situation must be made by a person proficient and knowledgeable about the performance of materials.

It should be appreciated that, except for long term PFI type contracts, it is the road owner who carries the risk of any shortfall in durability so they should take a close interest in any decisions made that affect durability.

Chap-ter	**Title**	**Summary**
1	Introduction	This Chapter provides an overview of the document, general information on properties of materials and some recent developments.
2	Bases, Binder Courses and Regulating Courses	These layers are the main providers of structure in flexible pavements. The material types are described and the factors affecting durability are discussed. Information is given on selection criteria, the specification of the various options and the need for monitoring and testing to ensure compliance and durability.
3	Bituminous Binders	Binders are the 'glues' which hold everything together. This Chapter covers paving grade bitumens, bituminous emulsions, polymer modified binders and additives used for workability. This chapter also discusses binder ageing.
4	Thin Asphalt Surface Course (TASC)	This Chapter covers properties and the requirements of Clause 942, type testing (TAIT), certification and approval; performance and durability (highlighting the need for compaction measurement); monitoring and guarantee period. The fact that not all thin asphalt surface course systems are equivalent is stressed and therefore there is a need to assess the certificates and TAITs carefully.

5	Hot Rolled Asphalt (HRA) Surface Course	The properties of HRA and the types available are discussed, as well as the selection criteria including recipe and performance based requirements. The performance and durability including the use of additives and modifiers are described, and the restriction and the need for departure when used in some jurisdictions (as described in HD36) are highlighted.
6	Stone Mastic Asphalt (SMA) Surface Course	This Chapter describes the mix design as given in BS EN 13108-5 and also the approach in Scotland, which uses a high minimum binder content with no requirements for texture depth, but does include the requirement for the demonstration in a TAIT of adequate skidding resistance. The main use of SMA for the Strategic Road Network in England is as a designed material for binder course and regulating course under thin surface course systems.
7	Porous Asphalt Surface Course	The properties of porous asphalt, including comparisons with its use in other countries, are described. In England it is not permitted without previous permission from the Overseeing Organisation.
8	Surface Dressing	The assessment of the road surface type and the suitability of different types of surface dressing are described in detail, and the essential requirement for accurate assessment of the existing surface is stressed. Failure types and their avoidance are described. The use of surface dressing on the Strategic Road Network is not permitted in England unless it is a proprietary multiple-layered system using polymer modified binder and has a two-year TAIT with certification and approval as an Innovative Ultra-thin Treatment (IUT).
9	High Friction Surfacing (HFS)	The use of HFS is limited to those sites where there is an absolute necessity for it to be used and no other treatment will serve the purpose. HD36 and this Chapter should be consulted in detail before a final decision is made as to its use. For the Strategic Road Network in England, the use of hot applied systems is deprecated unless the use of a cold applied system is impossible (due to machine access restrictions and so on).
10	Slurry Surfacing and Microsurfacing	These are cold applied ultra-thin systems They are currently not permitted on the Strategic Road Network in England; however, Microsurfacing with bond coats as IUTs, having Third Party Approval following a two-year TAIT, are permitted, by means of a Departure from Standards.
11	Geosynthetics and Steel Meshes	The types and usage of these materials is described. The main objective of this Chapter is to provide information, to enable familiarisation with the techniques and data to be gathered on their performance. It is essential, therefore, that a long term monitoring process is instituted and maintained and the findings made known and consolidated with findings from other sites.
12	Laying Bituminous Materials	This Chapter presents the need for high levels of workmanship to ensure durability. In addition to the general requirements, it addresses the problems of laying in difficult areas, such as roundabouts, and demanding conditions such as adverse weather or night time working. It recommends that these problems are avoided by the use of flexible working requirements. In general, it adds to advice given in RN42 and highlights the need for adequate testing of the material as laid and the long term monitoring of all works, to enable best practice to be improved on a continuing basis.

13	Miscellaneous Surfacing Materials	A wide selection of materials that find minor use on the Strategic Road Network, but may have use in specific circumstances on other roads, are covered in brief.
14	Bridge Deck Overlays	This Chapter gives advice on causes of failure, the need for good drainage and the requirements for the overlay materials. It retains the requirement for 20mm sand carpet where the waterproofing system requires it, although its use is discouraged and this requirement is dropped for overlay thicknesses below 120mm. There is no longer any need for the sand carpet to be pigmented.

Note: although ultra-thin asphalt surface courses (hot material laid around 15mm thickness with integral bond coat using combined sprayer-pavers) and multiple-layered surface dressings (also around 15 mm thick), are in different chapters they are effectively competitor materials for the same intended use.

Table 1.1 Contents of HD37

Temperatures of Materials

1.4 A number of materials have descriptions such as warm or half-warm without any very specific temperatures being added. This is complicated by the fact that the same description for different materials may be covering a different temperature range. For clarity, a summary of the temperature ranges for each material is given in Table 1.2.

Material type	Description	Temperature range
All materials to BS EN 13108 or equivalent using penetration grade binders	Hot	140°C – 190°C depending on binder grade
	Warm	110°C – 135°C, using additives such as wax or zeolite or foamed bitumen with foaming bar
	Half-warm	70°C – 90°C, using hot coarse aggregate and binder with cold fine aggregate (patented technology)
	Cold	Emulsion or foamed bitumen
Surface dressing	Cold	Cold aggregate and binder at about 85°C
Slurry surfacing	Cold	Cold aggregate and binder
High friction surfacing	Hot	200°C and above – screeded material
	Cold	Binder either warm or cold and aggregate cold

Note: cold means at or near ambient temperature.

Table 1.2 Temperature Ranges for Temperature Descriptions

Carbon Footprint

1.5 It is government policy to reduce the carbon footprint of all of its activities. This includes road construction and maintenance, where it is the total carbon footprint from "cradle to grave" that needs to be minimised. This is made up of a number of discrete carbon "events":

- The production and delivery of the material to the laying site
- Laying and compaction of the material
- On-going maintenance not involving new material such as retexturing

The recyclability of the material should also be considered, although care should be taken not to double count the carbon saving achieved through recycling. Currently, the carbon reduction from using recycled planings is taken as part of the new material and not at end of life of the pavement. The total carbon footprint should be considered on an annual basis by dividing the total carbon footprint by the expected life of the material. One calculation has shown that although a new technology can reduce the carbon footprint by 25%, this is entirely lost if the life is reduced from 20 to 15 years.

1.6 In order for all bituminous materials to be compared on the same basis it is requirement that the calculation tool: asphalt Pavement Embodied Carbon Tool (asPECT) must be used. Information about asPECT can be found at www.sustainabilityofhighways.org.uk currently available free on registration.

For surface treatments (other than asphalt materials), the Pavement Road Treatment Embodied Carbon Tools (PRoTECT) available from the RSTA must be used and can be found at www.rsta-uk.org.

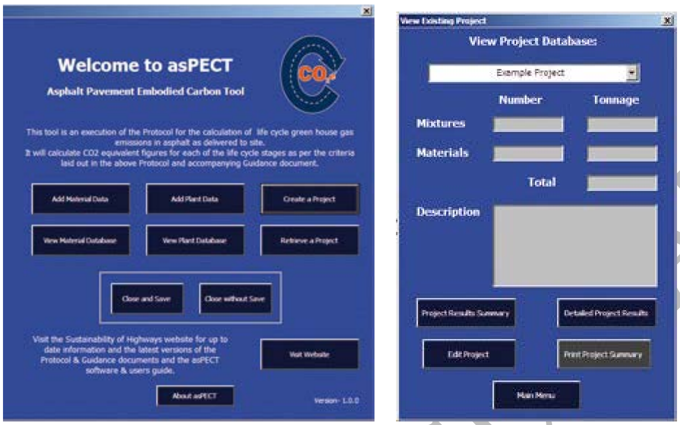


Figure 1.1 asPECT Computer Inputs

It should be noted that the carbon contained in the bitumen is ignored as it is bound and does not convert to CO_2; this means that the binder content is irrelevant for carbon calculation purposes.

Properties of Bituminous Materials

1.7 No bituminous material will provide all the desirable requirements for all situations. The material chosen should be the best compromise between the various available properties. The main properties required are:

- environmental durability,
- load spreading ability,
- resistance to deformation,
- macrotexture and skidding resistance,
- low noise generation,
- the ability to keep water out of the pavement structure,
- workability
- resistance to cracking
- ride quality

Some of these properties apply to all layers and some apply only to specific layers such as surface courses. In addition, it is important that all layers in the pavement are bonded together. These properties and others are discussed below.

1.8 The correct selection of material should be made for each site and performance requirement and this will require expertise. More detailed guidance on the properties of individual types of materials is given in the relevant product chapter.

Environmental Durability

1.9 This relates to the ability of a material to resist changes in its properties caused by environmental effects (such as rain, sun, frost, thaw, temperature changes, oxidation), and also by contaminants deposited on the material (such as oil, mud and animal detritus). Long exposure will affect binders and the properties of the mixture, and may affect the aggregate. Durability may be assessed by measuring the changes in the engineering properties of the material with time. Suitable tests include the Saturated

Ageing Tensile Stiffness (SATS) test and the binder ageing profile protocol followed by appropriate rheology testing. For greatest durability, the aggregate and binder combination should be chosen for maximum compatibility. Although surface courses are replaced after, typically, 10 to 15 years, structural layers are expected to perform for periods in excess of 40 years. Examples of continuous performance of over 70 years are known.

The durability of a mixed material depends on either its ability to keep the weather out, if it is intended to be a dense material, or its ability to resist the weather, if it is intended to be permeable. A dense material should have a void content of less than about 6% in situ. The design void content will not be achieved without proper control of mixing, placing and compaction. The durability of open-graded and porous surface courses having interconnected voids (which permit the ingress and flow of air and water) depends on: the thickness of the binder film on the aggregate; the susceptibility of the binder to oxidation; binder cohesion (polymer modification), and; the long term adhesion of the binder film to the aggregate. The durability of surface dressing and some of the ultra-thin bonded materials depends primarily on good adhesion to the underlying road structure.

For any given mixture type, a higher binder content and a lower void content will normally provide a more durable material, but care should be taken to ensure that other desirable properties, for example, resistance to deformation, are not sacrificed in the process.

Load Spreading Ability

1.10 This is assessed by measuring a material's stiffness. The design charts in HD 26 (DMRB 7.2.3) assume a minimum stiffness for the materials that will be used in the construction of a new road. In new construction, or where a structural overlay is being added, an assessment of the load spreading ability is required. Where only a surface course is being applied in a maintenance situation, the ability of the material to spread load is not considered to be a major factor.

Therefore, for maintenance resurfacing, the structural contribution of the surface course should be ignored:

- for materials with a nominal layer thickness of less than 15mm;
- for open-graded British Standard materials, and;
- for proprietary materials where the supplier or the Contractor has not provided the necessary information.

For materials with a nominal layer thickness of 15mm or more and where the supplier or Contractor has supplied the necessary information, an assessment can be made of the contribution. For thin surface course systems, general advice on the structural contribution is given in Chapter 6.

Resistance to Deformation

1.11 This is important in all layers of a bituminous road, but the need is greater in the top 100mm of the pavement because:

- the surface of a road gets hotter and the bitumen becomes softer compared to the lower layers;
- the stresses generated by traffic are greatest at the surface.

Susceptibility to rutting can be measured by the wheel tracking test. With the very heavy traffic now being carried on major roads it is also necessary for the binder course, (i.e. the layer immediately below the surface course), to be designed for resistance to deformation.

Bitumens harden during the first few weeks after laying and therefore a surfacing material is more prone to rutting during its very early life. Where heavy channelized traffic on new surfacing is likely to occur during the hottest period of the year, it may be necessary to use a material with an enhanced resistance to deformation, probably incorporating a polymer modified binder.

Macro-texture and Skidding Resistance

1.12 Macro-texture and skidding resistance should be specified as described in HD 36 (DMRB 7.5.1) and the standards required should be applied in all situations. For slurry surfacing to Clause 918, surface dressing to Clause 922 and thin surfacings to Clause 942, the Specification (MCHW1) requires macrotexture to be maintained at or above the levels specified, at least until the end of the guarantee period, to ensure a satisfactory overall life is achieved.

Texture depth can change with time, due to a number of different mechanisms. With surface dressing, the main cause is embedment of chippings into the underlying layer. Where compaction during laying is inadequate, asphalt materials will undergo secondary compaction under traffic, particularly in very hot weather; this almost invariably reduces the macro-texture. Very high macro-texture, particularly if it is positive texture, is not desirable, because the noise level generated by the passage of traffic over the surface is increased.

Surface Noise

1.13 Tyre/road noise generation can be a problem in some situations. Surfacing layers with ‘negative’ texture such as thin surfacings and stone mastic asphalt are quieter than conventional chipped hot rolled asphalt (with ‘positive’ texture) by 2 to 3dBA or more. It should be noted that tyre/surface noise generation is more of a problem at high speeds; at low speeds, engine and transmission noise are dominant. Porous asphalt - when newly laid - is currently the quietest material, with a reduction in noise (compared to new HRA) of about 4 to 5dBA, the voids absorbing sound. However, this advantage reduces as the pores fill with detritus, giving a relative reduction of about 3dBA, similar to that of some thin surface course systems. Further information on surface noise is given in HD 36 (DMRB 7.5.1), where the noise level is defined in a slightly different manner, but in effect uses the same units.

Adhesion

1.14 The adhesion of a surface course to the underlying pavement structure is essential, particularly so with surface dressing and very thin materials. These materials are not thick enough to carry traffic induced stresses without excellent adhesion to the underlying layer. Bond is even more important where there is a possibility of high braking and lateral stresses. Structural strength is only fully developed when all the layers in the pavement are well bonded, effectively forming a single layer. (Refer to Chapter 3 of this Part for information on Bond Coats). Tack coats cannot be assumed to help adhesion between layers and are no longer considered as “Best practice”. Recent research has shown that even a small loss of adhesion can significantly reduce fatigue life.

Waterproofing

1.15 Sealing the surface of a pavement assists in prolonging its life, and for the majority of roads in the UK this is achieved by the use of surface dressing. For the Strategic Road Network in England where asphalt surface courses are used, this is usually accomplished in one of two ways: either the bond coat is applied heavily enough underneath the surface course (as a sealer) to significantly reduce the permeability of the underlying layer, or; the material itself is dense enough to prevent or seriously impede water draining into the road structure. Bond coats used as sealers are considered “Best practice”.

Moisture Damage

1.16 Moisture damage, causing stripping of binder from the aggregate, leads to fretting and ravelling. The immediate cause is poor adhesion of the binder to the aggregate, which is usually related to the chemical composition of both aggregate and binder. Damage occurs more often with permeable, open graded materials, and the worst affected can be materials with air void contents in the range 9-14% which can neither drain nor dry out very easily.

Workability

1.17 Workability is necessary to achieve the intended properties of the bituminous material after laying and compaction. For example, poor workability in base and binder layers makes compaction difficult and may prevent achievement of the required structural properties. Workability is important in a hot rolled asphalt surface course, where cold pre-coated chippings have to be applied to the surface. Inadequate workability will lead to poor compaction and chip retention, particularly in adverse weather conditions.

Workability is also important in thin surface course systems to achieve the necessary aggregate interlock. Rapid heat loss in cold weather, resulting in poor workability, can result in poor compaction and high air voids, leading to moisture damage with associated fretting and ravelling.

Resistance to Cracking

1.18 Cracking of surfacing materials is caused by a combination of factors, including:

- thermal movement,
- repeated traffic loading and induced strain,
- embrittlement of binder due to ageing, and
- shrinkage of underlying soil.

Cracking has often been a problem associated with composite road construction, where thermal movement is concentrated above widely separated naturally forming cracks in the underlying cement bound material. Techniques introduced to induce cracks at closer spacings may help to alleviate this problem.

The fatigue characteristics of a mixture are largely governed by the volume and properties of the binder and its ageing characteristics. Fatigue cracking is likely to occur earlier in permeable materials than in impermeable ones since the binder can harden due to weathering throughout the depth of the more open graded materials.

Cracking in less permeable surfacing materials tends to initiate in the first few millimetres of the surface, where the binder is the most exposed and therefore the most embrittled, and propagate downwards. Cracks often start at the interface between the binder and aggregate; consequently, good adhesion between binder and aggregate is advantageous.

Ride Quality

1.19 This is generally improved for all materials laid with a paver incorporating a floating screed. This excludes slurry surfacing, which is laid with a spreader box, and surface dressing or other sprayed processes. Microsurfacing can improve the transverse shape of the pavement, but has limited effect on the longitudinal profile except for wavelengths less than about 1m.

Recent Developments

1.20 Two significant developments in the last few years have been warm asphalt and a greater understanding of the performance of negatively textured materials such as stone mastic asphalt (SMA).

Warm asphalts are now available for structural layers but further development is probably required before they would be suitable for surface courses, including the need to ascertain any effect on durability of the relevant warm process being used. It is thought that the durability of warm asphalt may be enhanced, because there is less binder hardening during mixing.

There has been considerable research over the last 5 years or so, both in Scotland and England, into the performance of negatively textured materials. These are usually SMAs to BS EN 13108-5 or they are TASCs and have approval certificates (see Chapter 4). The research in Scotland has resulted in SMA specification TS2010 (see Chapter 6). In England, the research has resulted in the TRL report PPR564 which has further resulted in the publication of IAN 156. This reduces the level of PSV needed for a given skidding resistance category from the levels given in HD36 and has also reduced the texture depth requirements. These two measures together should increase economy in their use (greater use of local aggregates) and potentially the durability of the material, since there will be less need for the higher air voids often needed to guarantee high macrotexture levels.

The importance of polymer modified bond coats to bond SMA and TASC to the substrate is also now better understood.

There have also been developments in the use of preservatives to delay binder oxidation at the surface of asphalt and these products provide another method of extending the life of surface courses (see Chapter 13). The treatment, once started, is repeated every few years; however, current surface applied products at ambient temperature cannot resurrect long-term aged materials, so intervention is required prior to minor deterioration. Surface dressings are also preservatives; although more expensive, they can be applied as soon as minor deterioration is detected and of course they improve skid resistance (see Chapter 8).

1.21 The Overseeing Organisation welcomes innovation and development; however there are specific arrangements for conducting trials of new and innovative materials on the SRN - contact the Overseeing Organization for further details, see:
http://www.dft.gov.uk/ha/standards/pilots_trials/section1/overview.htm

Normative References

BS EN 13108-5, Bituminous mixtures – Material specifications – Part 5: Stone Mastic Asphalt

Interim Advice Note 156

Manual of Contract Documents for Highway Works, Volume 1

Manual of Contract Documents for Highway Works, Volume 2

The asphalt Pavement Embodied Carbon Tool (asPECT), www.sustainabilityofhighways.org.uk

The Design Manual for Roads and Bridges, Volume 7 – HD 26

The Design Manual for Roads and Bridges, Volume 7 – HD 31

The Design Manual for Roads and Bridges, Volume 7 – HD 36

The Pavement Road Treatment Embodied Carbon Tools (PRoTECT), www.rsta-uk.org

Informative References

TRL Road Note 42. Best practice guide for durability of asphalt pavements. Transport Research Laboratory, 2008

TS2010. Surface Course Specification & Guidance Issue 01, Transport Scotland, Issue 02. January 2012

Roe, P G. and Dunford AI (2012). “The skid resistance behaviour of thin surface course systems”, TRL Report PPR564.

2. BASES, BINDER COURSES AND REGULATING COURSES

Introduction

2.1 Bases, binder courses and, to a lesser extent, regulating courses form the main structure of a flexible pavement. In flexible pavements incorporating Cement or other Hydraulic Bound Mixtures (collectively referred to as HBM), they work in conjunction with rigid binders such as hydraulic cement to form the structure of the pavement. See HD 26 for more information on the structural design of road pavements.

2.2 These materials may be based on various parts of BS EN 13108. The materials are specified in one of two broad categories: recipe mixes and designed mixes. The Overseeing Organisation carries significantly more risk for performance when recipe mixes are specified. A summary of the specification clauses used for bases, binder courses and regulating courses is given in Table A2.1 in the appendix to this chapter. British Standard Published Document PD 6691 sets out the use of BS EN 13108 for the UK.

2.3 Designed mixes are specified in performance-related terms. However, the degree of performance required can vary, from simply optimising the mixture properties to a complete performance-related specification, to include: compaction level (air voids); stiffness modulus; resistance to deformation, and; durability (effects of ageing in the presence of water and air) on laboratory specimens. At the most sophisticated level, only the traffic data and required life are given and the supplier is free to design the whole pavement structure, subject to demonstrating that it will provide the required performance for the works.

General Principles

2.4 These materials form the main structural layers of a pavement. Therefore they need to have the following characteristics:

- Good dynamic stiffness - to spread the load;
- Resistance to plastic deformation – to prevent rutting under traffic;
- Resistance to fatigue cracking – to avoid cracking, thus allowing water to enter the pavement;
- Impermeability – to prevent water entering the structure (except in pavements designed to be permeable, although these are not generally used on the Strategic Road Network).

2.5 In addition to the above direct performance characteristics, a suitable mixture also needs to be workable so that it can be placed easily and it should have inherent durability to avoid deterioration under the action of air, water and environmental stresses.

2.6 Pavements are now constructed on the basis of long life performance of the structural layers, with long life being variously defined internationally as: ‘in excess of 40 years’, ‘indefinite’, or even ‘75 years’. Over a decade ago, the European Long-Life Pavement Group (ELLPAG) was established with membership comprising representatives of European research institutes and the UK Highways Agency. One of the tasks was to produce a consensus definition of long-life pavements (LLP). A functional type definition, whereby the definition is based upon the expected performance characteristics rather than some specification of the design detail, was adopted by ELLPAG (Ferne and Sinhal, 2004) as follows:

“A Long-Life Pavement is a permanent structure that can be identified as one lacking any deterioration in the foundations and road base layers induced either by traffic loading, environmental conditions, material degradation or construction quality. Any distresses that might occur are confined to the surfacing layers only.”

2.7 Dense macadam (asphalt concrete) road base and base (binder) courses have been in use in the UK for 50 years. ‘Bituminous Materials in Road Construction’ published by RRL in 1962 makes no mention of this type of material, although the first edition of RN29 in 1960 gives a specification for dense base courses. Therefore, the oldest are only approaching 50 years of age. Since the pavement structure is now designed for long life it should be a corollary that the construction platform and drainage system should be designed to have a similarly long life; in the latter case, without any necessary maintenance. Different pavement construction thicknesses for various traffic loadings are illustrated in Figure 2.1.

Figure 2.1 Illustration of Different Pavement Materials and Thicknesses

2.8 A paper prepared for the American Asphalt Pavement Alliance (Newcomb et al, 2010) lists the following advantages of long life pavements:

- Low life-cycle cost by avoiding deep pavement repair or reconstruction;
- Low user-delay costs since minor surface rehabilitation of asphalt pavements only requires short work windows that can avoid peak traffic hours;
- Low environmental impact by reducing the amount of material resources over the pavement's life and recycling any materials removed from the pavement's surface.

PIARC Technical Committee 4.3 analysed 'success stories' for LLPs and concluded that good pavement design, good quality materials and good construction formed the basis for success (referenced in a paper by Dumond, Beuving, Piau, Sybilski, Van der Zwan 2008).

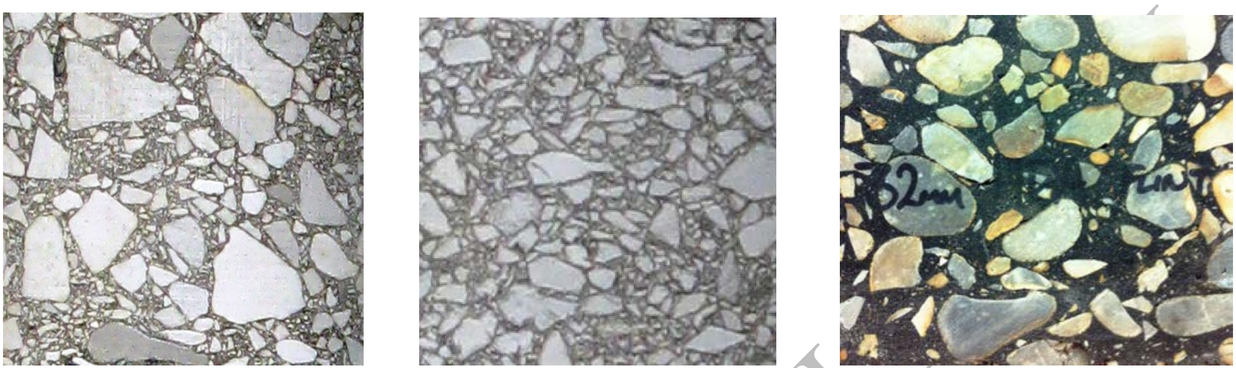
All the pavement structural materials used by highway authorities in the UK are now dense and all those specified in the MCHW1 are of this type.

Material Types

Dense Asphalt Concrete

2.9 These are continuously graded, dense materials and are generally in accordance with BS EN 13108-1. For new works and major maintenance, they should be specified using MCHW1 Clause 929. Bases use 0/32mm aggregate size whilst binder courses may use either 0/32mm or 0/20mm aggregate size; the latter is generally preferred, because a binder course layer is normally thinner than a base layer and the finer aggregate grading can provide better compacted density and lower air voids. The smaller size also helps to minimise segregation prior to completion of laying.

2.10 A number of variations have been used over the past 20 years as attempts have been made to produce stiffer materials, thus permitting thinner pavements to be constructed to accommodate the same traffic levels. These attempts have resulted in high modulus base (HMB) with 15, 25 or 35 pen binder (i.e. HMB15, HMB25 or HMB35, respectively); heavy duty macadam with 50 pen binder (HDM50) as well as dense bitumen macadam with 50 pen binder (DBM50). All of these either could, or were required to, be designed. In addition, for more lightly trafficked roads, dense asphalt concrete with 125 pen or 190 pen binder (DBM125 or DBM 190) is available; these are recipe only. Since Spring 2000, HMB15 and HMB25 (or modern equivalents) are no longer permitted, because serious problems arose with their performance in situ, such as mixture segregation, high void contents, disintegration following moisture ingress and lack of bond between layers. These HMBs (i.e. HMB15, HMB25 and HMB35) have been superseded by Enrobé à Module Élevé Class 2 (EME2, see below). To highlight the differences, the visual appearance of AC 32, AC 14 EME2 and HRA 60/32 is shown in Figure 2.2.



AC 32 base 40/60 AC 14 EME2 base 15/25 HRA 60/32 base 40/60

Figure 2.2 Visual Appearance of Different Asphalt Base Types

2.11 In the 2006 edition of HD26, the design chart for HMB35 has been withdrawn and replaced by that for EME2; DBM50 and HDM50 have been merged in the HD26 design chart.

Hot Rolled Asphalt (HRA)

2.12 BS EN 13108-4 sets out the specification for a number of base and binder course HRAs. The majority are generally of low stiffness and/or have low resistance to permanent deformation, because of their high binder content and lack of design. However, these materials are also known to be durable and have a very good resistance to cracking. Therefore, they may be useful on more lightly trafficked roads, including those which are built on a more flexible foundation, for example an underlying soil which undergoes large volume changes due to moisture movement, such as peats and shrinkable clays.

2.13 MCHW1 Clause 943 provides for a performance-related design mixture for HRA binder course, which is for use primarily for bridge deck resurfacing where a flexible, water resistant but rut resistant material is required. This clause encourages the use of polymer modified binders and polymers such as styrene-butadiene-styrene have been used successfully (see Chapter 3).

Stone Mastic Asphalt (SMA)

2.14 Stone mastic asphalts are covered in BS EN 13108-5, are based on an interlocking aggregate skeleton and are always designed, because the exact mixture depends on the grading, shape and surface roughness of the aggregate. Therefore, a different design is needed for each combination of constituent materials. They are specified in MCHW1 Clause 937 and again encourage the use of polymer modified binders. They are mainly use for regulating course under Clause 942 thin asphalt surface courses.

2.15 SMAs are binder rich and usually need the addition of fibres and/or the use of a polymer modified binder to prevent binder drainage.

Enrobé à Module Élevé Class 2 (EME2)

2.16 EME2 is a base and binder course material with a high content of hard bitumen and low air voids content designed to combine good mechanical performance with impermeability and durability. It has been in widespread use in France for nearly 20 years. The mixture is designed in the laboratory to be workable and durable and to have high elastic stiffness, high deformation resistance and good fatigue resistance. The binder content of these materials using 10/20 or 15/25 paving grade bitumen is some 2% above the typical dense base materials that have traditionally been used in the UK. The aggregate size in EME2 is somewhat smaller, but this does not account for very much of the binder content difference.

NOTE 1: EME2 should always have the '2' included. There is an 'EME1' in France which is much closer to UK DBM in concept; EME1 has a much lower binder content than EME2.

NOTE 2: MCHW1 Clause 930 specifies that either 10/20 or 15/25 paving grade bitumen shall be used, although binders with penetrations in the range of 15 to 20 dmm are preferred; Clause 930 also leaves the way open for EME2 using other proprietary binders, with the approval of the Overseeing Organisation.

2.17 The material is laid as base and/or binder course in lifts 60mm to 150mm thick using 0/10mm, 0/14mm, or 0/20mm aggregate sizes. The minimum layer thickness is 4 to 5 times the upper aggregate size rather than the 2.5 times conventionally used in the UK.

2.18 The design process goes through a procedure to determine the various mixture criteria in the order listed below, and if at any stage a criterion is not met the process starts again at the beginning; to ensure durability minimum binder content is specified. It should be appreciated that all the design procedures and measurements use laboratory methods and the various criteria measured are likely to produce different results on the laid material. However, rut resistance is measured on the completed mat and stiffness on a trial strip, both in accordance with MCHW1 Clause 930 and BS 594987 Annex E.

a. Select a composition which meets the minimum binder content;

b. Is the required workability achieved?

c. Does the mixture satisfy the moisture susceptibility requirement?

d. Is the rut resistance satisfactory?

e. Is the fatigue criterion satisfied?

f. Is the stiffness criterion satisfied?

g. If 'a' to 'f' are all satisfied, then a suitable mixture has been produced. For more detail see PD 6691 Annex B.

2.19 Compaction must be carried out at a high enough temperature to avoid the formation of micro-cracks. Finish rolling is often carried out in France using very heavy (up to 45 tonnes) pneumatic tyred rollers (PTRs), which are thought to knead the material and reduce the formation of micro-cracks.

Constituents of Bases and Binder courses

General

2.20 The major constituents of bases and binder courses are coarse and fine aggregates, filler and bituminous binder. Other constituents may include fibres, polymers and adhesion agents; these normally constitute less than 1% of the total mixture. For recipe mixes, prescription of the component materials should follow the specification clauses for constituents. For fully designed mixes, the total mixture should meet specified requirements and therefore less prescription is needed for the individual components.

Aggregates

Coarse Aggregate

2.21 For heavily trafficked roads the coarse aggregate is normally crushed rock, which in the UK usually comes from established quarries with a proven track record. On lightly trafficked roads, gravel aggregates have been used and can perform well provided the mixture is carefully designed. The adhesion of binder to some types of rock and many gravels can give rise for concern, although this can be addressed; this is further discussed under durability. Coarse aggregates should conform to the relevant clauses in BS EN 13043 and further advice on choosing aggregates can be found in British Standard Published Document PD 6682-2. The polished stone value of aggregates used in bases and binder courses is rarely a consideration (unless used as a temporary running surface; Clause 901 refers) and therefore the rock type can be any that occur in the UK including limestone, which, because it is easier to quarry and has good affinity with binder, is often the preferred type.

Fine Aggregates

2.22 Asphalt concrete materials to MCHW1 Clauses 906, 929 and 931 normally use crushed rock fine aggregate of the same type as the coarse aggregate. For lighter trafficked situations, where Clause 906 dense asphalt concretes would be the norm, natural sands or blends of crushed rock and natural sands can be used.

2.23 Clause 937 (MCHW1), SMA binder courses, permits crushed rock sands or a blend of crushed rock and natural sand ,with a maximum of 50% natural sand. Clauses 904 and 905 (MCHW1), hot rolled asphalt, permits any combination of crushed rock or natural sand or blends provided that the final mixture conforms to British Standard Published Document PD 6691.

Fillers

2.24 Filler for asphalt concrete is usually filler from the parent rock, but limestone filler may be used. When the aggregate is gravel, at least 2% by mass of the mixture should be hydrated lime or Portland cement; these are added to improve adhesion, which would otherwise be poor.

2.25 The use of 2% hydrated lime or cement improves the adhesion of binder to crushed rock and is particularly valuable where the SATS test or historical data have shown poor compatibility between the binder and the aggregate.

2.26 Added fillers (at least 2% is mandatory) for SMA binder courses are limited to crushed limestone, Portland cement or hydrated lime. Added filler for HRA is limited to crushed limestone or cement.

Binders

2.27 For more information and guidance on the specification and use of bituminous binders, refer to Chapter 3.

2.28 The conventional binders used in bases and binder courses are paving grade bitumens to BS EN 12591. These range from 30/45 paving grade bitumen (commonly called 35 pen) at the hardest end of the range up to 160/220 paving grade (190 pen) at the softest end.

2.29 EME2 uses a specific and much more closely controlled version of 10/20 or 15/25 paving grade, bitumen, ideally targeted in either case within the range 15 to 20 dmm.

2.30 The choice of binder for SMAs is limited to 40/60 paving grade bitumen or softer, but polymer modified binder is permitted where it has an appropriate certificate. The polymer should be preblended. Adding the polymer at the mixer is not permitted, because it introduces significant control problems particularly that of ensuring that the polymer is evenly distributed throughout the binder.

2.31 For performance asphalt binder courses, which are based on MCHW1 Clause 943 hot rolled asphalt surface course, any grade of binder between 30/45 and 100/150 may be used. These may be unmodified binders to BS EN 12591, natural asphalt/bitumen blends to BS EN 13108-4 Annex B or polymer modified binders or EN 14023. Polymer modified binders must be preblended.

2.32 Suppliers of any designed mixture for use as base or binder course are required to provide the Overseeing Organisation with rheological data regardless of whether the binder is modified or not. This is to provide the Overseeing Organisation with data on a range of binders, so that it has the necessary information to ensure that the asset is managed in an efficient manner.

Minor Constituents

2.33 Minor constituents usually contribute less than 0.5%, sometimes much less, to the total mixture. The most common are fibres and adhesion agents. Fibres may be natural or man-made, and are normally used to enable a thicker binder film (higher binder content) to be achieved without risking binder draining from the aggregate. They are most frequently used in SMA binder courses.

2.34 Adhesion agents are added to a mixture when it is known that there are problems with binder adhering to the aggregate. They are proprietary products and some have a relatively short life at high temperatures. They are usually effective, but they are only used to improve initial adhesion. Subsequent attacks on adhesion by the environment (such as water, road salt, climate, traffic stresses and ageing) may not be resisted by adhesion agents at the normal level of addition, although the improved initial adhesion will reduce the severity of any debonding.

Reclaimed Asphalt Materials

2.35 Reclaimed asphalt (pavement) materials (RAP) may be used in the production of bituminous binder course, regulating course and base; they should comply with BS EN 13108-8. Other materials for recycling in bituminous mixtures may only be used with the approval of the Overseeing Organisation. The mixed material must comply with the requirements of MCHW1 Series 900.

2.36 When the amount of RAP comprises 10% by mass or less, compliance with MCHW1 Clause 902 is not required. However, when it exceeds 10% by mass, the Contractor must carry out trials to demonstrate that the mixed materials comply with the requirements of this clause.

2.37 Reclaimed bituminous material may currently be added in proportions up to 50% in base and binder course mixtures, except that when added to HRA mixtures, and either the RAP or the final mixture includes polymers, the amount of RAP is limited to 20%.

2.38 Normally, the penetration value of the binder recovered from RAP should not be less than 15 dmm (BS EN 13108-8) on average, but, with the approval of the Overseeing Organisation this limit can be amended. The current limit thus precludes the recycling of any HMB15, or EME2 or most HMB25 materials. One of the factors affecting this limit is that the mixing temperature would need to be too high to ensure that the old binder is fully incorporated into the new and therefore contribute to the total binder content (see Chapter 3). If this does not happen, the mixed material will have a very low 'effective binder content' and this will affect the durability of the product; possibly to the extent that the reduced life would negate any carbon reduction from the use of RAP in the first place. If there is any doubt, further investigation should take place to demonstrate the efficacy of the process.

Factors affecting Material Durability

General

2.39 There are a number of factors in the design and construction of bituminous bases and binder courses that affect the durability of the material in the pavement. The major factors are:

a. aggregate durability;

b. binder durability;

c. binder/aggregate affinity;

d. filler;

e. binder content;

f. compaction;

g. fuel resistance;

h. healing.

2.40 Refer also to Chapter 12 for factors affecting the durability of the structure as a whole.

Aggregate Durability

Most aggregates in current use in the UK have a long history of use and their durability is judged on practical performance over many years. However, when new sources of aggregate are introduced, which do not have this history, their durability needs to be assessed. There are also some aggregates which have had a variable performance in the past. The introduction of BS EN 13043 has brought together a range of requirements including those which check for durability.

2.41 Problems associated with inadequate durability of aggregates are minimised when appropriate care has been taken to use aggregates of known durability and the requirements of MCHW1 Clause 901 are met.

Binder Durability

2.42 In general binders slowly harden with age and any binder showing unusually rapid hardening should be evaluated in the mixture.

Binder/Aggregate Affinity

2.43 One of the major requirements of the binder in an asphalt mixture is that it acts as an adhesive. To maintain mixture integrity, the binder must remain adherent to the aggregate in the presence of water and resist the effects of ageing. This adhesion is controlled by the interaction, at the molecular level, of the surface of the binder and the surface of the aggregate. Both binders and aggregates vary in their surface characteristics and it is important that when choosing a binder to coat a particular aggregate their compatibility is checked. As a rule, alkaline aggregates such as limestones are more tolerant of different binders than acid aggregates such as some granites, quartzites or flints.

2.44 It is a general requirement that the aggregate should be surface dry before attempting to coat it with bitumen. It is known that some aggregates 'sweat' in this condition and may need to be dried beyond the point of mere surface dryness before satisfactory long term adhesion can be achieved. It was reported as long ago as 1962 (see 'Bituminous Materials in Road Construction' (RRL 1962)), that quartzite minerals (which make up a high proportion of igneous rocks) never fully dry during the heating before mixing because they retain a monomolecular, or thicker, layer of water on their surface.

2.45 When washed sands are used, particularly if they have high filler content or are towards the fine limit of the grading, extra care will be needed to ensure that the aggregate is fully dry before using in the mixer. Failure to do this will increase the probability of binder stripping and will lead inevitably to poor performance.

2.46 Binder adhesion can be lost in the presence of water, because aggregate is hydrophilic and surface energy effects can cause stripping, especially if the binder is of low viscosity. With harder binders, the failure mechanism is associated with the balance of cohesion against adhesion. Thinner films of binder harden more rapidly with age and are likely to debond from the aggregate surface as cohesive forces and water displacement act together against adhesion.

2.47 The test specified to evaluate the effects of adhesion is the saturated ageing tensile stiffness (SATS) test MCHW1 Clause 953. The SATS test is used on the design mixture. The graph of retained stiffness against the degree of saturation is used to judge the suitability of the aggregate/binder combination.

Binder Cohesion

2.48 For the mixture to be durable there must be sufficient cohesion (internal integrity) in the bitumen to enable the mixture to remain coherent under traffic stresses and induced strains for the life of the material. This life is usually in excess of the structural design life of the pavement.

Filler

2.49 Fillers can have a significant effect on the durability of a mixture. When the aggregate is gravel, at least part of the filler (e.g. 2% of the mixture) must be hydrated lime or cement. It is likely that the use of these added fillers (instead of naturally occurring filler), when acidic aggregates are used, will have a beneficial effect on the durability of dense asphalt concrete. Comparative SATS tests could be used to demonstrate this.

Binder Content

2.50 Bitumen ages by hardening in the presence of oxygen, but it can only do so at, or close to, the surface of the bitumen film. Therefore, the thicker the bitumen film the longer it takes for the whole of the binder film to harden.

2.51 There is a limit to the amount of binder a mixture can hold; if too much binder is added, all the pores may be filled and a pore bitumen pressure could be developed, making the whole binder/aggregate matrix very unstable. Rutting can then occur under a relatively low number of load repetitions. To enable a high binder content to be used safely, the mixture as a whole must be designed to accommodate the binder, taking manufacturing tolerances into account.

Compaction

2.52 Good compaction is probably the most important factor affecting durability with the possible exception of binder content. Good compaction can be achieved by using a sound mixture design and good quality workmanship. Clause 929 specifies that a maximum of 7% voids, on average, must be achieved; however, a lower figure should be targeted to achieve this level consistently, see Chapter 12 for more information on compaction.

2.53 It has been found that at a void content of less than 6%, a 0/20mm dense asphalt concrete type material has very low water and air permeability. The comparable voids figure for hot rolled asphalt is about 1% higher because the binder content is high enough to prevent many air voids from being interconnected.

Fuel Resistance

2.54 Fuel resistance is not normally a requirement for bituminous materials used on carriageways; however, there may be some situations where defects associated with bituminous materials in contact with fuel may be greater, such as in lay-bys. Petrol spillage is not usually a significant problem as it evaporates quite quickly before it can have much effect on the bitumen; the worst offenders are diesel fuel and hydraulic fluid.

2.55 The best protection by far is prevention by adequate care, particularly by avoiding spillage of diesel oil or hydraulic fluid by construction plant. However, if spillage does occur then the affected material must be removed and replaced with sound material conforming to specification. If this is not done, the pavement will fail prematurely in the affected areas. Well compacted materials are less prone to damage than poorly compacted ones because the penetration of the offending fluids is reduced.

2.56 Materials designed specifically to provide high levels of fuel resistance are dealt with in Chapter 13.

Healing

2.57 A feature of bituminous materials that can improve their durability is that in warm weather many small cracks (micro-cracks) can heal up as a result of viscous flow and diffusion. Although healing is known to occur, it is difficult to quantify the effect with any degree of certainty and research considering dissipated energy and loading frequency is necessary, especially for hard paving grades.

Choosing a Base Material

2.58 The most commonly used base material for all roads is dense asphalt concrete to BS EN 13108-1. EME2 is specified within this part and has recently been used on trunk roads and motorways. The only choices to be made for dense asphalt concrete base are:

a. Design or recipe?

b. In the case of recipe, what grade of binder?

c. In the case of design, are there any limitations on permitted options? For example, limitations on aggregate type or binder grade.

2.59 On all new works, designed bases should always be used. They give the supplier most scope to use a design that maximises efficient use of resources. This will usually lead to the use of harder binders and therefore thinner layers, but in some circumstances this may not necessarily be so. There may, for example, be advantages in using thicker layers with a softer binder if is necessary to lay in adverse conditions such as winter nights. It should be noted that new works could be constrained to have thinner layers, for example, a new roundabout on an existing road.

2.60 Another option that has been used and could be considered, particularly where the unbound layers are likely to be or remain wet, is to use a mixture with a higher than normal binder content, such as hot rolled asphalt base, which would help to prevent stripping of binder from the bottom of the asphalt layers. Asphalt concretes with an extra 0.5% binder have also been used. Both of these strategies also help compaction in the bottom layer of asphalt, which is often more difficult than for subsequent layers as the reaction from the underlying unbound material can reduce the compactive effort of rollers. Resistance to rutting is not a problem at this level, but the likely higher resistance to fatigue could be advantageous.

2.61 For maintenance works, the choice will depend on the amount of base that is used. For very small amounts it is not usually economic to design a mixture specially and therefore a recipe mixture would be appropriate. However, if the supplier had a suitable design mixture available – for example one supplied to another site - then it should be used without further demonstration of suitability.

2.62 Where a road contains services, the use of recipe mixtures using 100/150 paving grade bitumen is preferred. When a utility company opens a road, the standard reinstatement material (HAUC specification) is based on equivalence to materials using 100/150 grade paving bitumen. Although 40/60 grade equivalent materials can be used, this would only be on roads that have been notified to them as special cases.

2.63 The specification includes bases to BS EN 13108-4 (MCHW1 Clause 904). These have the disadvantage of being more expensive than dense asphalt concrete bases because they have a much higher binder content, but their existence should be borne in mind for those areas with relatively light traffic and for parts of the country where natural sands are more economic than rock fines. Hot rolled asphalts are generally more flexible than asphalt concretes, so they have significant advantage for roads which traverse peat or shrinkable clays, which have a propensity to move under changing moisture regimes.

Choosing a Binder or Regulating Course Material

2.64 This is more complex than choosing a base. There are 5 basic types to choose from:

a. HRA binder course;

b. Dense asphalt concrete binder courses;

c. SMA binder course;

d. HRA performance specified binder course;

e. EME2 binder course.

2.65 HRA binder courses have the same advantages and disadvantages as base materials of this type. They could be useful on roads with surface levels that vary with the season but they are little used. If they are used for this purpose, then 50mm thickness of 0/14mm is preferred. If the thickness is above 60mm, 0/20mm could be used with advantage, although not a preferred mix.

2.66 For most purposes the binder course used will be dense asphalt concrete. It should preferably be 0/20mm with an appropriate binder. Where a base layer has been used, the binder course should match it. For example, a base using a 40/60 paving grade bitumen should have a binder course of matching type and bitumen grade.

2.67 In maintenance situations where the total thickness of the new asphalt layer is less than about 90mm (depending on the surface course), it is not possible to use dense asphalt concrete binder course. In this case, either an SMA binder course (MCHW1 Clause 937) or a performance-related HRA (MCHW1 Clause 943) should be used.

2.68 Performance-related hot rolled asphalt is intended essentially for the binder course layer as part of a bridge waterproofing/surfacing system. It is normally laid to fixed thickness, any regulating needed having been carried out in the layer below. This material is not intended for use as a regulating layer.

2.69 SMA (MCHW1 Clause 937) is typically used in maintenance situations where a new inlaid surface course is thinner than the surface course that has been planed out. Old surface course on major HA routes would typically be 45 to 50mm thick chipped HRA; they are often planed to a depth of 55mm to ensure removal of all the surface course, before being replaced by a Third Party accredited thin surfacing (typically about 30mm thick). In this situation, there could be a deficiency of about 25mm, which requires a material with appropriate aggregate size and good deformation resistance such as SMA regulating course (MCHW1 Clause 937). To ensure the target density is achieved, compaction should be very carefully monitored, especially when laying these thin layers in adverse weather conditions.

2.70 The use of a polymer modified bituminous emulsion bond coat to MCHW1 Clause 920 is even more important than normal when the layers are thin.

Performance Based Design

2.71 Performance based specifications for the design, compaction assessment and compliance of binder course and base asphalt concrete were initially introduced in the MCHW in 1991; this approach has also been seen as a means of removing barriers to trade and of encouraging innovation, consistent with a requirement of the Construction Products Directive of the European Union (Osborne, 1989). The benefits of a performance based specification are considered mainly to be: reduced variability; improved structural properties; thinner pavements or longer life, and; more economic use of materials through manufacturers producing their own designs (Richardson et al, 2000).

2.72 Clause 929 of MCHW1, in particular, specifies the requirements for the design, compaction assessment and compliance of binder course and base asphalt concrete, and represents a significant departure from the traditional recipe specification. The major differences are a contractor-defined composition, albeit within client-specified overall tolerances, and requirements for a minimum volume of binder and maximum in situ air voids content. Contractors must also have a means of designing materials and sufficient knowledge to make composition changes, should the materials initially fail to comply with the specified requirements (Nunn and Bowskill, 1994).

2.73 Following the successful outcome of six site trials carried out between 1992 and 1997 incorporating performance specified asphalt base (Weston and Mercer, 1997) which demonstrated the practical advantage from introducing stiffness requirements for this material, the 8th edition of MCHW1 was published in 1998, where provision is also made for the measurement of stiffness modulus and deformation resistance of (binder course and base) cores.

2.74 Subsequently, MCHW1 Clause 944 for performance-specified base was formally implemented in May 2001; this Clause stipulates a target level for stiffness modulus and also includes safeguards against cracking and internal deformation of the materials.

2.75 There are a number of factors that may influence the achievable performance of asphalt concrete mixtures, such as aggregate type, binder content, mixture volumetrics and composition. An example where performance based specification to Clause 944 was fully adopted was the successful construction of A43 Silverstone Bypass (Widyatmoko et al, 2004). Three aggregate sources were used to produce the material and indeed the construction records clearly demonstrated how mixture ingredients and compositions had influenced the achievable performance, specifically:

a. Stiffness was lower with smaller aggregate size (which also had higher binder content);

b. Stiffness was lower with granite aggregate;

c. Stiffness was highest on the lower base (LB).

Table 2.1 Effect of Aggregate Type on Stiffness Modulus at 20°C of AC Mixtures

Test Description		**Granite Aggregate**			**Gritstone Aggregate**		
		LB 0/32	**UB 0/32**	**BC 0/20**	**LB 0/32**	**UB 0/32**	**BC 0/20**
No of Tests	-	150	166	117	248	268	251
Mean	MPa	6000	5200	4600	7200	6200	5200
CoV	%	22	24	22	21	22	22

2.76 Clause 944 had to be withdrawn in 2008 following the harmonisation of European standards on construction materials. However requirements for stiffness modulus of designed base and binder course mixture have been retained in MCHW1 Clause 902 for mixtures containing more than 25 percent reclaimed asphalt, in Clause 929 for AC 40/50 and AC 30/45 and in Clause 930 for EME2.

2.77 For assessment of compliance, the mean value of stiffness modulus and deformation resistance must be determined from the trial sections and rigorous assessment of mixture volumetrics must be carried out on the laid material in accordance with MCHW1 Clause 929. Furthermore, if resistance to permanent deformation of material laid in the permanent work has been specified in Appendix 7/1, six cores must be taken from the first kilometre length of material from each mixing plant and thereafter one further core from each subsequent lane kilometre.

2.78 Categories of stiffness specified in the MCHW1 2008 edition are shown in Table 2.2; these values are lower than those previously specified in the MCHW1 2001 edition.

Table 2.2 Stiffness Categories for AC and EME2 Mixtures

Nominal binder grade in mixture	**Stiffness category (S_{min})** [note 1]
10/20	5500
15/25	5500
30/45	2800
40/60	1800

Note 1 *determined at 20°C in accordance with BS EN 12697-26 Annex C

2.79 Whilst BS EN 12697-22 specified the small device wheel tracker to assess deformation resistance of asphalt concrete base materials for CE marking purposes, the current UK guide PD 6691 still specifies the maximum permitted rut depth to the superseded BS 598-110 (wheel track testing) until the revisions to BS EN 13108 are published. The recommended threshold values can be found in PD 6691; a summary is reproduced in Table 2.3 (a). For EME2, the deformation resistance of the mixture at target composition, tested in accordance with the large wheel tracking test in BS EN 12697-22:2003, large device, must conform to category P7,5.

2.80 For HRA and SMA, the limiting wheel tracking requirements for site classification are presented in Table 2.3(b) and Table 2.3(c) respectively.

Table 2.3(a) Deformation Resistance for AC Base and Binder Course

Classification		**Test temperature**	**Category** WTS_{AIR}	**Category** PRD_{AIR}	**Requirements when tested to BS 598-110**	
		Test method	**BS EN 12697-22:2003 small device procedure B**	**BS EN 12697-22:2003, small device procedure B**		
No.	**Description**	**°C**	**Wheel track slope**	**Maximum proportional rut depth**	**Max rut rate (mm/hr)**	**Max rut depth (mm)**
1	Moderate to heavily stressed sites requiring high rut resistance	45	$WTS_{AIR1,0}$	$PRD_{AIR9,0}$	2	4
2	Very heavily stressed sites requiring very high rut resistance	60	$WTS_{AIR1,0}$	PRD_{AIRNR}	5	7
3	Other sites	N/A	WTS_{AIRNR}	PRD_{AIRNR}	-	-

Table 2.3(b) Deformation Resistance for HRA Binder Course

Classification		**Test temperature**	**Category WTR_{AIR}**	**Category RD_{AIR}**	**Requirements when tested to BS 598-110**	
		Test method	**BS EN 12697-22:2003 small device procedure A**	**BS EN 12697-22:2003, small device procedure A**		
No.	**Description**	**^oC**	**Wheel track rate µm/cycle**	**Maximum rut depth mm**	**Max rut rate (mm/hr)**	**Max Rut depth (mm)**
1	Moderate to heavily stressed sites requiring high rut resistance	45	$WTR_{AIR7,5}$	$RD_{AIR5,0}$	2	4
2	Very heavily stressed sites requiring very high rut resistance	60	$WTR_{AIR15,0}$	$RD_{AIR7,0}$	5	7
3	Other sites	N/A	WTR_{AIRNR}	RD_{AIRNR}	-	-

Table 2.3(c) Deformation Resistance for SMA Binder Course and Regulating Layer

Classification		**Test temperature**	**Category WTS_{AIR}**	**Requirements when tested to BS 598-110**	
		Test method	**BS EN 12697-22:2003 small device procedure B**		
No.	**Description**	**^oC**	**Wheel track slope mm/1000 cycles**	**Max rut rate (mm/hr)**	**Max rut depth (mm)**
1	Moderate to heavily stressed sites requiring high rut resistance	45	WTS_{AIR1}	2	4
2	Very heavily stressed sites requiring very high rut resistance	60	WTS_{AIR1}	5	7
3	Other sites	N/A	WTS_{AIRNR}	-	-

Specifying Base Materials

2.81 The guiding principles are that the maximum choice should be left to the contractor in conjunction with his supplier and a performance specification should be the preferred option. Therefore the normal specification will be:

a. either MCHW1 Clause 929 in its entirety, or;

b. EME2 MCHW1 Clause 930.

2.82 Bonding is required between all layers and therefore the requirements of MCHW1 Clause 903 should be met at all times. There is normally no situation where the use of an appropriate level of bond coat is not needed. Table 2.4 sets out the main alternative means of specification.

Table 2.4 Specification of Bases

Option	**Data to be provided *to* contractor**	**Specification**	**Data to be provided *by* contractor**
Maximum supplier choice, end performance	Design life Traffic flows	Clause 929 **Or** Clause 930	Thickness Material type Stiffness Material design Binder data
Structural design by client, material choice by contractor, performance-related	Thickness/material options	Clause 929 **Or** Clause 930	Which option has been chosen Stiffness Material design Binder data
Structural design and material by client, performance-related requirements	Thickness Material type	Clause 929	Stiffness Material design Binder data
Structural design and material by client, recipe	Thickness Material type	Clause 904 Or Clause 906	None

2.83 For some contracts with specific problems it may be appropriate to use options and combinations intermediate between those given above.

Specifying Binder course and Regulating Course Materials

2.84 As for bases, the guiding principles are that the maximum choice should be left to the contractor in conjunction with his supplier and that end performance should be the preferred option. However, there is greater choice of material and so there are more options available. There are 5 options for the binder course, some of which are also specifically designed to be used as regulating courses. Where both base and binder course are used on the same contract, the same method of specification should be used for both unless there are good reasons to do otherwise. Bonding is required between all layers and therefore the requirements of MCHW1 Clause 920 should be met at all times. There is normally no situation where the use of an appropriate level of bond coat is not needed. Table 2.5 sets out the main alternative methods of specification.

Table 2.5 Specification of Binder Course (and Regulating Layers)

Option	**Data to be provided *to* contractor**	**Specification**	**Data to be provided *by* contractor**
Maximum supplier choice, end performance note 1	Design life Traffic flows Deformation resistance class	Clause 929 Or Clause 930 Or Clause 937 Or Clause 943	Thickness Material type Stiffness when required Material design Binder data Deformation resistance
Thickness choice by supplier – regulating under thin surfacing inlay	Thickness of existing road structure to be removed	Clause 930 Or Clause 937 Or Clause 943	Material design General thickness to be used Binder data Deformation resistance
Thickness design by client, material choice by contractor, performance-related	Thickness/material options Deformation resistance class	Clause 929 Or Clause 930 Or Clause 937 Or Clause 943	Which option has been chosen Stiffness when required Material design Binder data Deformation resistance
Thickness design and material by client, performance-related	Thickness Material type	Clause 929 Or Clause 930 Or Clause 937 Or Clause 943	Stiffness when required Material design Binder data Deformation resistance
Thickness design and material by client, recipe note 2	Thickness Material type	Clause 904 Or Clause 906	None
As part of bridge waterproofing system, performance	Thickness Material type	Clause 937 Or Clause 943	Material design Binder data Deformation resistance

Note 1 can only be used on work where the base is also to supplier thickness design
Note 2 can only be used on lightly trafficked roads where there is no requirement to specify deformation resistance

2.85 For some contracts with specific problems it may be appropriate to use options and combinations intermediate between those given above.

Warm Mixes

2.86 Warm mixes are not currently specified in the MCHW1. The European Asphalt Paving Association (EAPA, 2009) defines Warm Mix Asphalt (WMA) as material manufactured using special techniques that have a mixing temperature in the range 100-140 ºC. This compares with hot mix asphalt (HMA) at 140-190 ºC and half warm asphalt (HWA) at 70-90 ºC. In the UK, cold mixes are defined as cold road materials where the aggregates are mixed at ambient temperature, although other constituents such as foamed bitumen or bituminous emulsions may be well above ambient immediately before adding to the mixer.

Any proposal to use warm mix on the Strategic Road Network would require a Departure from Standards, as the relevant rolling temperatures do not comply with the requirements of MCHW1.

2.87 In order to produce workable mixtures at these lower temperatures the mixture needs modification. This modification may be achieved by adding organic or chemical additives or by foaming the bitumen. The EAPA position paper 'The use of Warm Mix Asphalt' (EAPA, 2009) provides a good overview of these techniques together with their advantages. The main advantage is Carbon reduction, but there are others.

2.88 WMAs can be compacted to low void levels thus contributing to their durability. In contrast, half warm mixes (HWAs) contain a significant proportion of water so that the void content is inevitably high (3% water is equivalent to about 7.5% of voids); this would be in addition to any air remaining after compaction.

2.89 One disadvantage of WMA is that the temperature may not be high enough to enable incorporation of binder from RAP, if used in the mixture. Research is needed to produce a test that provides information about 'effective binder content' and 'effective properties' of the blended binder.

2.90 Further information on the binders for Warm Mix Asphalt can be found on the federal highways website at www.fhwa.dot.gov/pavement/asphalt/wma.cfm

Monitoring and Testing

2.91 Although there is a general tendency to use end performance specification to a greater or lesser extent, it is essential that the Overseeing Organisation ensures that all the required testing is carried out and that the results are provided in a timely manner; for example, within 72 hours in the case of Clause 929 density/air voids results. The Overseeing Organisation should also ensure that any remedial action needed as a result of non-compliance is carried out in a timely manner. It is easier for proper remedial action to be carried out when there is no pressure to complete it; an example of such pressure would be when it is required to be completed before laying the next layer.

2.92 Records must be kept of all test results and any reports of problems and anomalies that occur in the works so that long term monitoring can be carried out from a known base. All records must be stored in such a manner that they are easily retrievable in the future. This ensures that if failure occurs at *any time in the life* of the pavement the original data can be used to assist in the investigation.

Normative References

BS 594987, Asphalt for roads and other paved areas – Specification for transport, laying, compaction and type testing protocols.
BS EN 12697, Bituminous mixtures – Test methods for hot mix asphalt.
BS EN 13108, Bituminous mixtures – Material specifications.
BSI PD 6691, Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications.
The Design Manual for Roads and Bridges, Volume 7 – HD 31.
Manual of Contract Documents for Highway Works, Volumes 1 and 2
UKAS, National Highways Sector Schemes for Quality Management in Highway Works

Informative References

EAPA (2009) "The use of Warm Mix Asphalt", Position Paper, June.
Ferne, BW and Sinhal, R (2004) "Making Best Use of Long-Life Pavements in Europe – The Work of ELLPAG", 3rd Eurasphalt & Eurobitume Congress, Vienna, Paper 155.

Nunn, M.E. and Bowskill, G. (1994) “Towards a performance specification for bituminous roadbase”, The Asphalt Yearbook 1994, Institute of Asphalt Technology, United Kingdom, pp 72-77.
Osborne, J. (1989) “The Construction Products Directive of the European Communities”, Building Technical File, London, 1989.
Richardson, J.T.G., Elliott, R.C., Mercer, J. and Williams, J. (2000) "Laboratory Performance-Based Testing of Asphalt Mixtures in the United Kingdom", AAPT Volume 69.
TRL Report 636. The application of Enrobé à Module Élevé in flexible pavements. 2005.
Weston, D.J, and Mercer, J. (1999) “Development of a Performance-Related Specification for Asphalt Roadbase”, Proc. 3rd European Symposium on Performance and Durability of Materials and Hydraulic Stabilised Composites”, Leeds, April 1999, pp. 613-630.
Widyatmoko, I., Elliott, R.C., McCulloch, J., and Norman, J (2004) “Pioneering the Implementation of a Performance-based Specification for New Road Construction in the United Kingdom. Case Study: A43 Silverstone Bypass.”, Proceedings of the 3rd Eurasphalt & Eurobitume Congress, Vienna, Paper 122.

Appendix to Chapter 2

Table A2.1 Summary of Specification Clauses Concerning Bases and Binder Courses

MCHW clause	Material	Relevance of clause	Other relevant specs
005	All	Thickness and tolerance	
104 (104NI)	All	Standards, quality assurance, Agrément certificates and other approvals	
701	All	Pavement construction	
702 (702NI)	All	Horizontal alignments, surface levels and surface regularity	
706 (706NI)	All	Excavation, trimming and reinstatement of existing surfaces	Specification of the reinstatement of road openings (HAUC)
709	All	Cold milling (particularly finished regularity)	
901	All	Bituminous pavement mixtures	BSI PD 6691, BS 594897, BS EN 13043, BSI PD 6682-2, BS EN 12591, BS EN 14023 902, 929, 953
902	All	Reclaimed Asphalt	BSI PD 6691, BS EN 13108, BS EN 12697, 942, HD 31/94
903	Placing and compaction of bituminous mixtures	See Chapter 12	920
904	Rolled asphalt base	Refers to other specifications	BS EN 13108-4, BSI PD 6691
905	Rolled asphalt binder course	Refers to other specifications	BS EN 13108-4, BSI PD 6691
906	Recipe mixtures: dense base and binder course asphalt concrete with paving grade bitumen	Refers to other specifications	BS EN 13108-1, BSI PD 6691
907	Regulating course	Lists permitted regulating courses and refers to other clauses	702, 929, 937, 943
920	Bond coats, tack coats, and other bituminous sprays	Specifies bond coats	BS EN 13808, BS 594897, BS 434-2, BS EN 12271-2, BS EN 12591 BBA/HAPAS
925	All	Testing of bituminous materials and their constituents	BS EN 12697, BS EN 13108-20, BS EN 13108-21
929	Dense base and binder course asphalt concrete (design mixtures)	Specification for deformation resistance, stiffness, and air voids	BS EN 13108-1, BSI PD 6691, BS 594987, BS EN 12697-8,
930	EME2 Base and binder course	Binder specification, design	BS EN 13108-1, BSI PD

	asphalt concrete.	procedure for the various options, compaction requirements	6691, BS 594987, BS EN 13924 Plus various binder test method references
937	Stone mastic asphalt (SMA) binder course and regulating course	Design criteria for air voids, aggregate type and flakiness, binder content including binder drainage, grading, (requires ITSM values on trial area only), deformation resistance. Clause 945 does not apply	BS EN 13108-5, BSI PD 6691, BS EN 14023, BS EN 12591, BS 594987, HAPAS Clause 956, 957,
943	Hot rolled asphalt surface course and binder course (performance-related design mix)	Design criteria include: binder volume, wheel tracking including sensitivity to binder content, air voids, (referenced in BS 594-2)	BS EN 13108-4, BS PD 6691, BS 594897, BS EN 13043, HAPAS Clauses 956, 957,
945	Hot bituminous mixtures	Weather conditions for laying of bituminous materials	BS 594897
947	In situ cold recycled bitumen bound material	Specification for in situ cold recycled road materials to form the base for the road structure.	Many references depending on exact method used.
948	Ex situ cold recycled bitumen bound material	Specification for ex situ cold recycled road materials to form the base for the road structure.	Many references depending on exact method used.
953	All dense bituminous materials	Test method to assess durability of dense bituminous material–saturation ageing tensile stiffness (SATS) test.	BS EN 12697 (various parts), BS EN 14769, TRL 636 Annex A

All materials must be produced in plants complying with National Highways Sector Scheme 14

3. BITUMINOUS BINDERS

Introduction

3.1 This Chapter provides an overview of the characteristics of binders that are detailed in MCHW1 for data collection in the specification of bituminous materials.

Paving Grade Bitumens

3.2 The approach to specification of paving grade bitumens using the framework standard BS EN 12591 using penetration and softening point test methods and the relationship to performance of asphalt is well documented in the references and will not be repeated in this Chapter.

3.3 Necessary references to be consulted in conjunction with this Chapter are 'The Shell Bitumen Handbook' (Whiteoak et al, 2003), the Eurobitume web site, and the Eurasphalt & Eurobitume Congress Publications (see: http://www.eurobitume.eu/ and http://www.eapa.org/eapa.php)

Sector Scheme 15

3.4 For the Strategic Road Network (SRN) in England, the suppliers of bitumen are all registered to the National Highway Quality Schemes for Highway Works for Supply of Paving Bitumens. Sector Scheme 15 relates to the Quality Management System requirements for the supply of Paving Bitumens for paving construction and maintenance (Paving Grade Bitumens, Hard Paving Grade Bitumens or Polymer Modified Bitumens, including base binders used to produce bitumen emulsions, cut-back/fluxed bitumens for use in cold/warm mix asphalt, surface dressing binders, microsurfacing binders and bond coats); refer to www.ukas.com

Bitumen

3.5 Bitumen is a complex material. It is of interest to scientists and rheologists because it is viscoelastic and has a vast range of stiffness for the service range of temperatures experienced in a road pavement (five decades at normal temperatures, and for the range of bitumens used and extremes of temperature, there are further decades of stiffness). It does not behave like a fluid except at high temperatures. It is considered a colloid or a suspension of a range of large molecular weight hydrocarbons and other chemicals.

3.6 SARA (Saturates, Asphaltenes, Resins and Aromatics) analysis has been used to separate these various components using solvents, and an understanding of the way the elements are held together is being unravelled. The importance for road materials is that blending of bitumens or adding polymers without taking into account solubilities and colloidal stability may not provide the durability required. Some polymers absorb a part of the maltene phase and this can upset the balance unless replaced by other chemicals. This is understood by producers and their proprietary formulations (polymer content, or methods of cross-linking, for example) do not need to be revealed, provided there are some performance-related tests that can be used to identify the product. In this way, when a formulation is found to perform well in service, good work can be replicated and benefits evaluated.

Polymer Modified Bitumen

3.7 The subject of polymer modification and the specification for performance of bituminous materials is reported widely, but for the SRN, has not been set out as a comprehensive performance-related specification. There are a number of reasons for this:

- Data have not been provided in a consistent manner to correlate performance of bituminous materials with binder characteristics.
- Monitoring has been limited.

- The fundamental properties of proprietary binders that can predict performance in polymer modified bituminous materials are largely understood. However, the test methods for binders and mixtures are not agreed, while some are still being developed and, to complicate matters, the threshold values for performance vary according to the mixture design, the installation and the end use.
- Proprietary binder samples are seldom taken.
- Recovery of polymer modified binder from bituminous materials using solvents, when reconstituted, does not necessarily provide a sample that reflects the performance of the binder in the material.
- The focus is normally on failures, not on what has performed satisfactorily.
- Data provided as part of contracts are not utilised in a constructive manner and generally are not accessible.
- The material performance is only partly attributable to the binder characteristics. Mixture design and aggregate and filler properties dominate the system performance in the environment and complicate the binder requirements for a particular end use.

3.8 The collection of data is important for the increased use of polymer modified binders on the SRN and a Third Party Approval Certification of innovative products and systems is required. The Certificates will include binder product identification testing and some examples are shown in this Chapter.

Binder Rheology

3.9 Binder rheology provides information concerning proprietary materials and also provides product identification for monitoring.

3.10 The extensive binder research work carried out in the USA resulting from the Strategic Highways Research Program (SHRP) has shown that specification of a vast array of polymer modified and unmodified binders may be made. The result still appears to be a framework or menu, for the specialist to choose the appropriate binder, but the grade choice is controlled according to the local climate, so it is really a performance specification. The performance of the asphalt is treated separately.

3.11 There are some performance-related parameters that can be easily understood, such as the property of binder stiffness linked to resistance to deformation of asphalt. However, the influence of elasticity of the binder to enable some recovery of the deformation is more complicated and rheology can help provide this information. Tests on the asphalt such as wheel-tracking to measure deformation are straightforward and more easily specified.

3.12 Whilst the penetration test method has been found useful for polymer modified binders, softening point has some limitations and practical issues for the more modified materials and the results can be spurious. However, most suppliers still provide the information, because of the purchasers' familiarity with the parameter and because they have a 'feel' for the values. A high penetration binder for asphalt, for example equivalent to a 70/100 penetration grade bitumen with a high softening point, say 80°C, indicates that the binder would have good performance at low temperatures and yet would resist deformation (for unmodified bitumen to BS EN 12591 the softening point would be between 43°C and 51°C). The high softening point for the grade sets the proprietary binder apart from unmodified paving grades. Of course, this is not the whole story and many other characteristics need to be considered including workability, durability, cohesive and adhesive properties. Otherwise, oxidised grades, with high softening points, would be used in asphalt.

3.13 Binders are viscoelastic materials (they display both viscous and elastic behaviour). A viscous material, like all liquids, continues to flow all the time a stress is imposed on the material, whereas an elastic material deforms instantaneously under an applied load and does not undergo further deformation thereafter. When the stress is removed, a purely elastic material regains its original shape whereas a viscous material does not recover but remains in the deformed state. Unmodified bitumen is predominantly elastic and brittle at low temperatures and behaves as a viscous fluid at high road temperatures, depending on the frequency of loading.

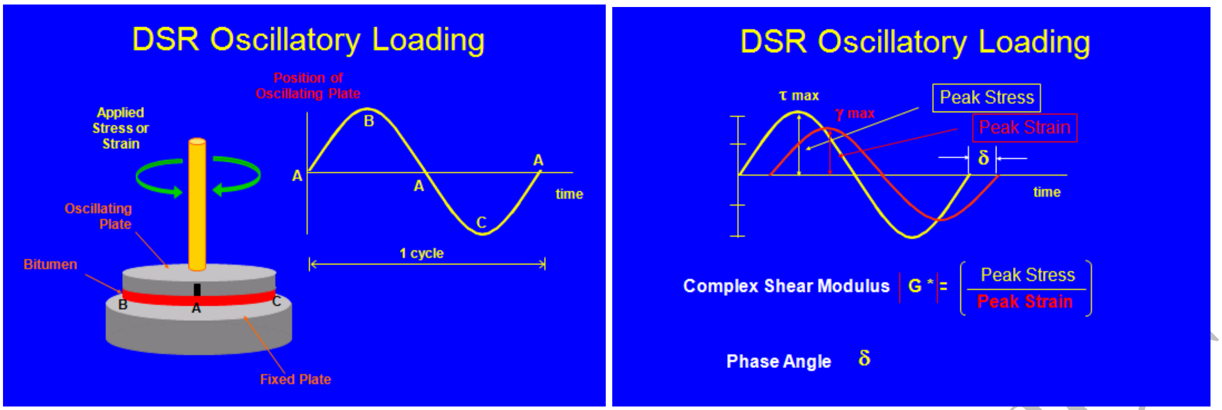


Figure 3.1 Dynamic Shear Rheometer - Definition of Shear (Stiffness) G* and Phase Angle delta (δ)

3.14 The viscoelastic behaviour of a binder is most conveniently assessed by dynamic shear testing. This involves subjecting the binder to an alternating shear stress and measuring the resulting alternating shear strain. The ratio of the stress to the strain is known as the complex stiffness modulus (G*). The lag or phase angle, delta (δ) between the stress and strain is also measured, see Figure 3.1. Elastic materials exhibit a phase angle of zero, viscous materials a value of 90 degrees and viscoelastic materials some intermediate value. At low temperatures, unmodified bitumens tend towards purely elastic behaviour and their phase angle approaches zero degrees. At high temperatures, unmodified bitumens behave purely viscously and their phase angle can reach 90 degrees at temperatures above 70 °C. Dynamic shear testing may be carried out over a wide range of frequencies and temperatures. The loading time (or frequency) and the temperature of the material are inter-related in their effect on the behaviour of viscoelastic materials. Hence the same response can be observed when measurements are made at low temperatures for long periods as at high temperatures for short periods. It is possible to represent the results of tests taken at different temperatures and loading times using one master curve of viscoelastic behaviour using the principle of time-temperature superposition, thereby characterising the material. The main mechanisms of road failure are being studied in order to relate these rheological properties to them so that it may be possible to predict the relative performance of binders from these properties.

3.15 Master Curves can be produced using a Dynamic Shear Rheometer (DSR), which is fully computer controlled and can produce much of the data automatically. The response of binders is dependent upon temperature and loading time, therefore it is important to select appropriate values to allow comparison of materials. In the Specification MCHW1 Clause 956 (Determination of the Complex Shear (Stiffness) Modulus (G*) and Phase Angle (δ) of Bituminous Binders Using a Dynamic Shear Rheometer (DSR)), the frequency of 0.4 Hz has been chosen as the standard (loading time of 0.4 seconds, equivalent to relatively slow moving traffic). This is a longer loading time than the SHRP testing (1.6Hz which simulates fast moving traffic), but is similar to the loading time of the penetration test method. A plot of complex stiffness modulus against frequency at a temperature of 25 °C has been selected for the master curve (the penetration test temperature).

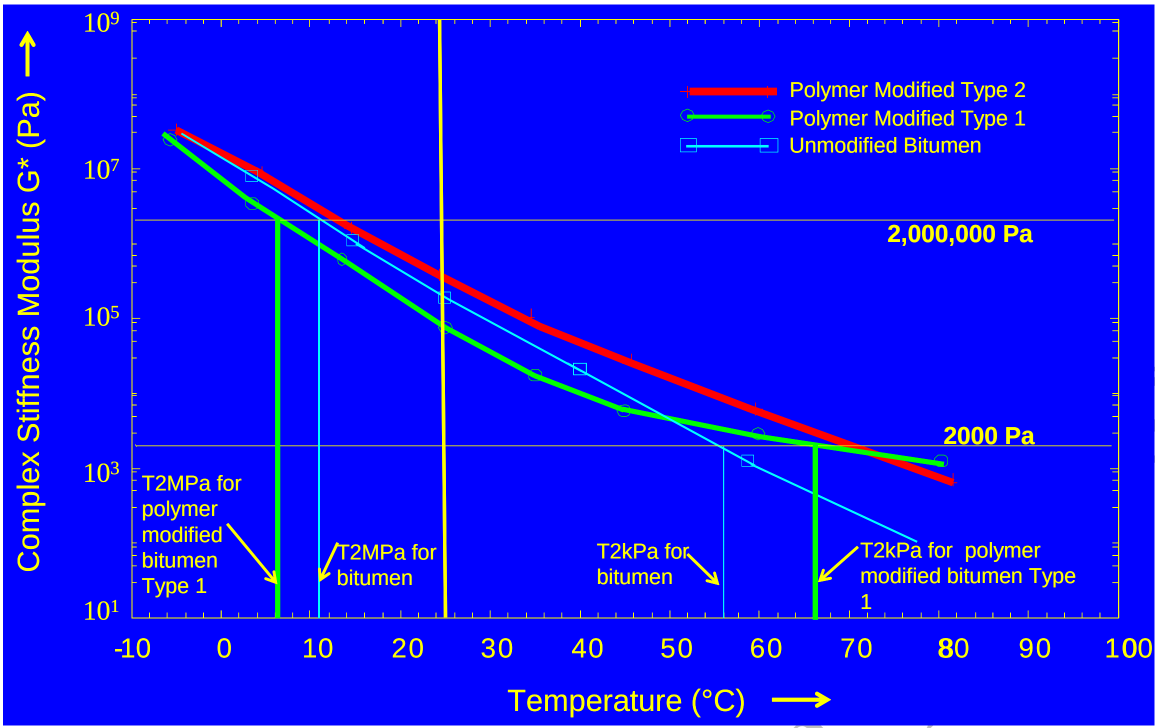


Fig 3.2 Complex Stiffness Modulus versus Temperature at 0.4Hz for Three Binders

3.16 The effect of binder modification can be seen from graphs such as Figure 3.2, which plots complex shear (stiffness) modulus G* measured in Pascals against temperature. The Modified Bitumens, Type 1 and Type 2, represent typical results from an elastomer and a plastomer, respectively. The measurement can be used to help understand the engineering properties that are likely to be found if used in asphalt. This shows that both modifier types can increase binder stiffness at high service temperatures (50°C to 70°C). The lower stiffness and more viscous response (see Figure 3.3) obtained from the elastomer (Type 1 binder) at low service temperatures (less than 0°C) will also assist in retarding thermally induced cracking.

3.17 An ‘Equi-Stiffness High Temperature’ (T_{2kPa}°C) has been defined for use with polymer modified bituminous binders. This is the temperature at which the complex stiffness modulus equals 2000 Pascals at a loading frequency of 0.4 Hz. This parameter indicates high temperature stiffness performance, much in the same way that softening point is used for conventional bitumens. Figure 3.2 shows that the Type 2 binder has a higher T_{2kPa}°C than the unmodified bitumen.

3.18 An ‘Equi-Stiffness Low Temperature’ (T_{2MPa}°C) has also been defined. This is the temperature at which the complex stiffness modulus is 2 Mega Pascals (2 x 10^6Pa) at a loading frequency of 0.4 Hz. It provides an indication of the relative stiffness of polymer modified binders against a standard bitumen. Figure 3.2 shows the Type 1 modified binder to have a lower T_{2MPa} than the unmodified bitumen. T_{2MPa}°C is approximately equal to the temperature at which the penetration value of the unmodified bitumen is equal to 19_{dmm}. It is possible that this temperature may provide an alternative parameter to penetration at 5°C, which is believed to be useful for prediction of low temperature performance.

3.19 It is possible to calculate a penetration index from the two stiffness values assuming they correlate with penetration and do not deviate too much from a straight line on the G* against temperature graph. This can give an idea of temperature susceptibility and may be compared to that for with unmodified binders.

3.20 The basic geometry of the DSR is presented in Figure 3.1. DSRs use very little binder, typically less than one gram, and tests have even been carried out on surface dressing binders scraped from a road surface. In order to cover the whole range of binder properties, tests are carried out over a frequency range of (typically) 0.1Hz to 10Hz at a number of different temperatures, usually at least six, ranging typically between minus 5°C and 80°C. Having obtained the data at individual temperatures, the principle of time-temperature superposition is used to produce a single Master Curve.

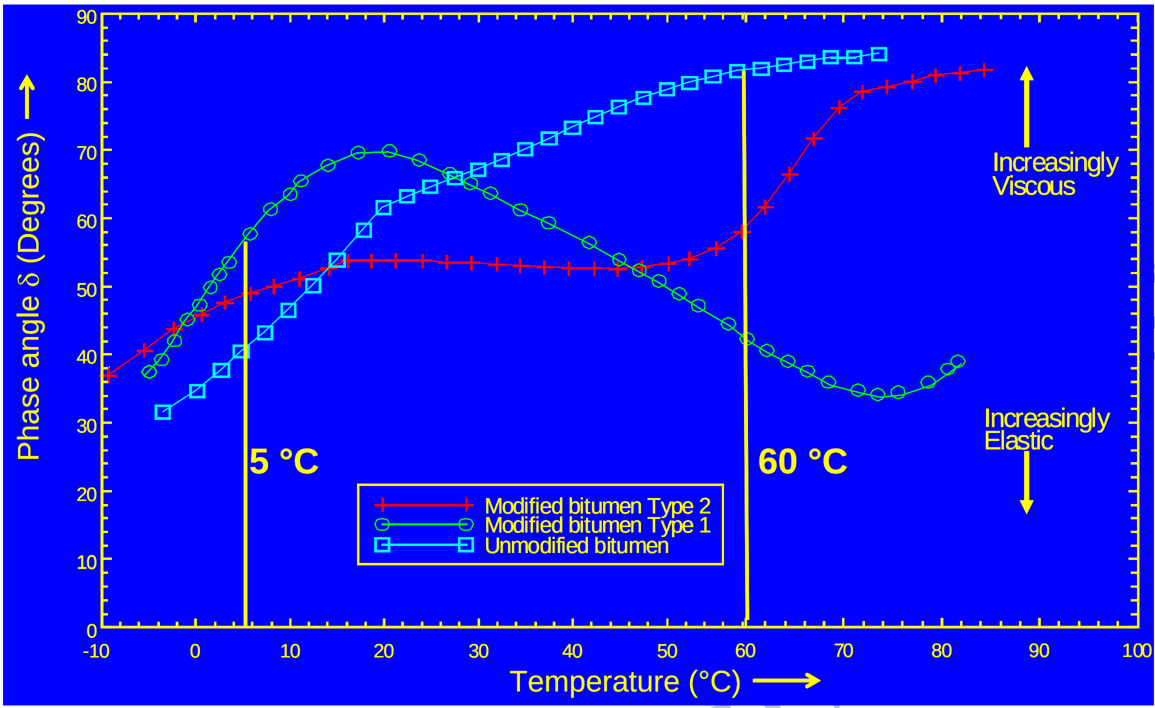


Figure 3.3 Phase Angle versus Temperature at 0.4Hz for Three Binders

3.21 In Figure 3.3, phase angle, delta (δ), for the same three binders presented in Figure 3.2 is plotted against temperature. For the unmodified binder, the phase angle increases with temperature in the range -5°C to +80°C, indicating increasingly viscous behaviour. In contrast, the Type 1 elastomeric binder shows increasing elasticity in the temperature range 20°C to 70°C. The Type 2 plastomeric binder shows almost constant phase angle from 10°C to 60°C, but the behaviour changes rapidly at both ends of this temperature range. The results show how polymers can assist in improving the deformation resistance of bituminous mixtures by increasing the elastic, recoverable strain component under loading at high temperatures.

3.22 Penetration values of proprietary binders provide a useful indication of stiffness and have been correlated to shear stiffness modulus, G*, using a dynamic shear rheometer, with similar conditions to the penetration test i.e. 25°C and 0.4Hz (Gershkoff, 1995), see Figure 3.4. Using this relationship, the values of G* at 25°C and 0.4Hz can be listed for the unmodified paving grades as shown in Table 3.1.

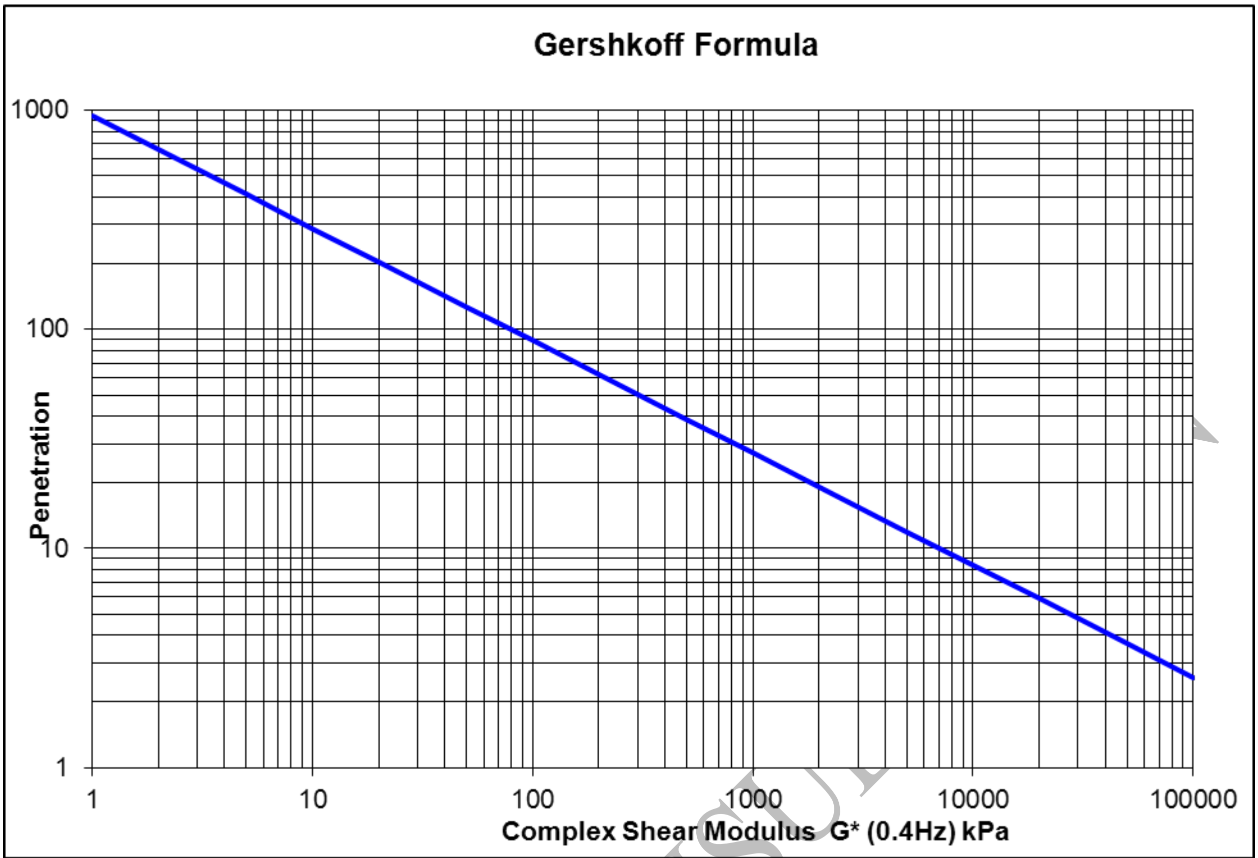


Figure 3.4 Relationship of G* (kPa) to Penetration Value (dmm) at 25°C after Gershkoff

Paving Grade Bitumens and G* limits at 0.4Hz and 25°C									
Grade	**10/20**	**15/25**	**20/30**	**30/45**	**35/50**	**40/60**	**70/100**	**100/150**	**160/200**
Upper limit G* kPa	**7080**	**3211**	**1832**	**831**	**615**	**474**	**159**	**79.4**	**31.8**
Lower limit G* kPa	**1832**	**1186**	**831**	**377**	**307**	**215**	**79.4**	**36**	**17.1**

Table 3.1 G* Specification Limits for Paving Grade Bitumens using Gershkoff Formula.

3.23 It can be seen from Table 3.1 that the hard end (upper limit) of the complex shear stiffness modulus for a hard grade bitumen, such as 10/20 grade (15 pen bitumen) is nearly four times the stiffness of the lower limit, whereas for 40/60 grade (50 pen), the comparable ratio is just over two times. This should be considered when designing asphalt mixtures and demonstrates why it is useful to consider a rheological parameter, rather than the depth of penetration of a needle, even for conventional bitumens. The SHRP specification is used for both proprietary and conventional binders. The comparison of the SHRP binder grading and CEN grades in performance terms has been reported (Carswell, 2000); the CEN paving grades and hard grades performed adequately and were shown to follow the SHRP grading system, see Figure 3.5. He also tested some 'refinery discards', bitumens that would not pass the range of tests in BS EN 12591 in terms of volatility or temperature susceptibility or retained penetration after short term ageing. These clearly were located in the 'poor performance' area above the line. Polymer modified binders were all below the line, demonstrating good low temperature performance (behaviour of say a 200 pen bitumen) with good high temperature performance (softening point of a 20 pen bitumen).

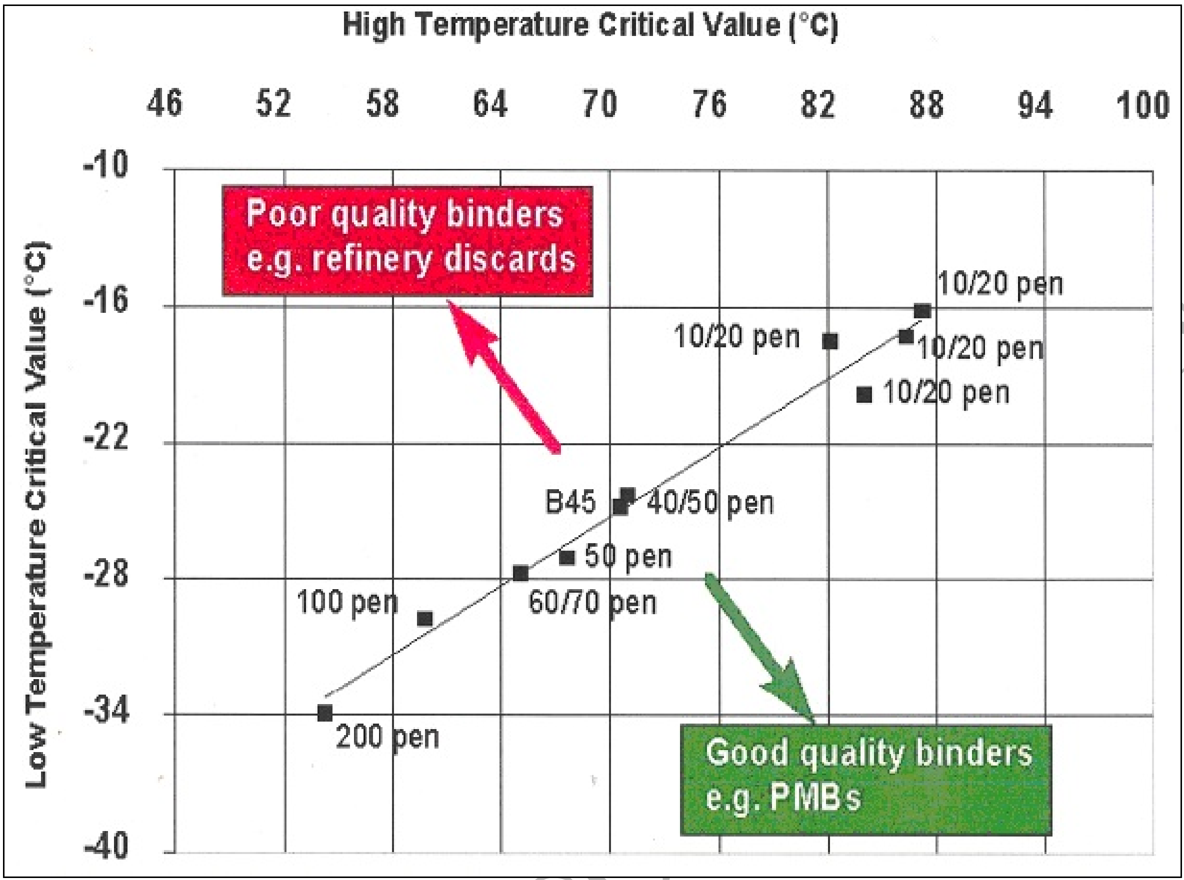


Figure 3.5 SHRP Grading of UK Paving Grade Bitumens (Carswell, 2000)

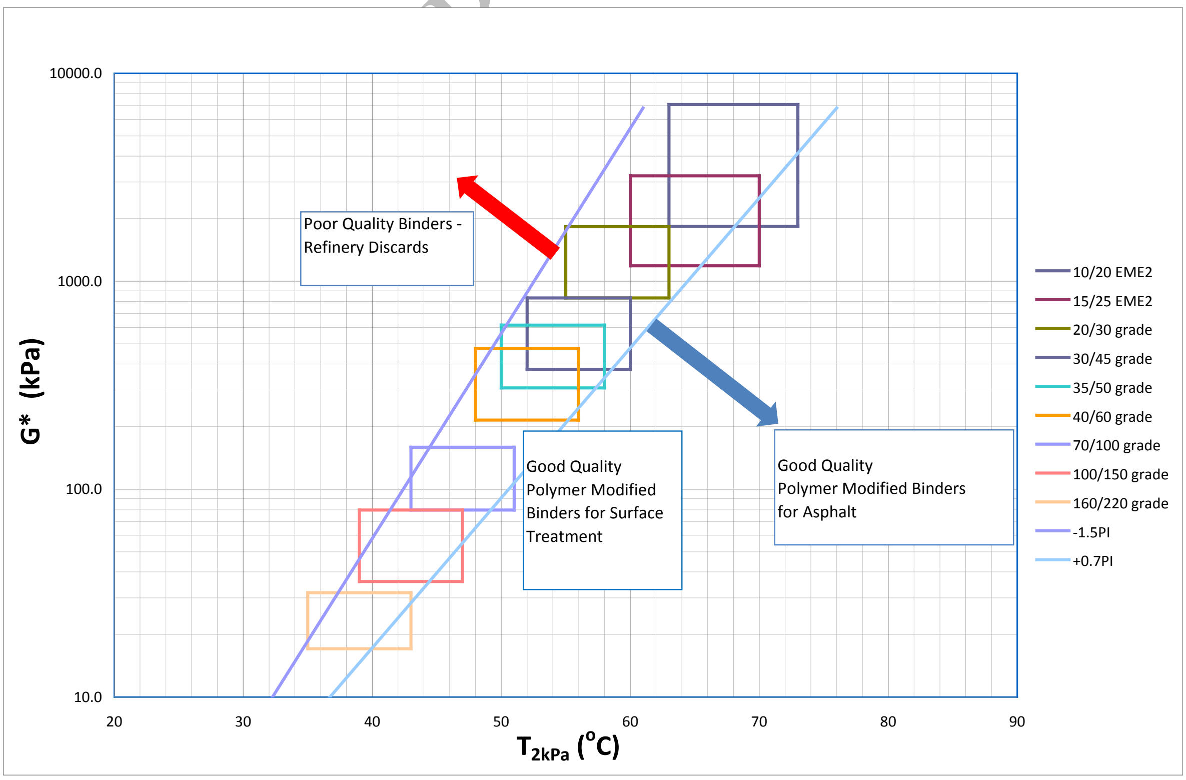


Figure 3.6 Plot of G* vs. T_{2kPa} with Paving Grade Bitumen Limits shown in Rheological Terms

3.24 Although softening point for binders has not been correlated with T_{2kPa} in the manner SHRP has used High Critical Temperature, a similar graph may be generated, see Figure 3.6. Most polymer modified binders use a softer bitumen to introduce low temperature performance and yet they maintain stiffness at high temperatures. Data from rheological measurements of conventional and proprietary binders will improve the grade boxes.

3.25 The CEN limits for penetration index are plotted to show that there are constraints, especially on hard grades, that are not revealed just by penetration and softening point limits. These limits are for unmodified air-rectified bitumens; oxidised grades have penetration indices above +2 (Eurobitume –Technical Committee Task Force 2011) and are not suitable for asphalt binders.

3.26 Polymer modified binders are especially formulated to extend the +ve PI limit (I_p) without becoming brittle and one route to examine the potential of a proprietary binder (in terms of stiffness only) is for the supplier to provide the G* and T_{2kPa} production limits. The polymer modified bitumens currently available on the market and suitable for asphalt, with elastomeric polymer contents over 6% and designed to have the properties of 100pen to 200pen binders yet stiffness at high temperatures equivalent to a 20pen to 50pen bitumen, generally fall in or near the box on Figure 3.6. Binders for surface dressing, bond coats and microsurfacing have residual binder properties with lower stiffness and lower T_{2kPa}, and generally fall below the blue arrow and nearer to conventional grades. Binders for asphalt bases requiring stiffer and tougher binders may be above the blue arrow. It is these data that are needed to both group and identify products and to provide performance-related information. Although elastic and other important properties (for example, resistance to ageing, cohesivity, adhesivity) are not determined by this plot, product identification in terms of stiffness is accomplished and a comparison with unmodified binder can be demonstrated. Other points can be plotted for the binder after short term and long term ageing.

Polymer Modified Binders

3.27 Benefits which may be obtained by the use of polymer modified binders include:

- Improved resistance to permanent deformation of mixtures at high service temperatures;
- Greater load spreading (increased stiffness) for a pavement layer of given thickness;
- Reduced fatigue of mixtures, giving reduced cracking under repeated load;
- Improved ductility at low service temperatures, giving reduced thermal cracking;
- Improved adhesion to aggregates, giving reduced stripping in mixtures and in surface dressings;
- Increased cohesion, giving better chipping retention in the early life of surface dressings;
- Improved workability of mixtures, reducing the risk of poor compaction;
- Reduced hardening or ageing in service, giving longer life in surface materials;
- Reduced temperature susceptibility throughout the service temperature range;
- Increased viscosity at low shear rates, allowing thicker binder films to be obtained in open mixtures and reduced bleeding in surface dressing.

3.28 Most modifiers will only be able to achieve some of these properties, so choice of modifier is site specific. Addition of a modifier will not automatically confer satisfactory performance to a base binder; indeed modifiers and bitumens have to be carefully selected to ensure compatibility. Further advice is given in the References to this Chapter.

3.29 Where modified binders are used, MCHW1 Series 900 requires details of their performance characteristics in terms of both binder and mixture properties to be included in tenders.

3.30 Within the same generic group there is a wide range of modifier composition and performance benefit. In particular, the general distinctions between Plastomers and Elastomers are becoming less well defined as innovation proceeds.

3.31 Whilst rheological data provide an insight into performance in terms of high service temperature behaviour (for example, rutting), the performance in terms of thermal cracking, fatigue and healing are not simply predicted.

3.32 Mixtures are complex systems. Bitumen and filler and aggregate is complex enough, but when polymers are added, a multi-phase system develops, which has impact on ageing and many other properties.

Surface Treatments

3.33 For surface dressing and microsurfacing, the Specification MCHW1 Series 900 requires that penetration at 5°C and 25°C is measured.

3.34 The Vialit Pendulum test as specified in MCHW1 Clause 957 is used to assess the cohesion of the binder, a measure of the forces holding the material together. Cohesion is probably more important for surface dressing, Innovative Ultra-thin Treatments (IUTs), thin surfacings and bond coats, where the binder is under more direct stress than at any other level in the pavement structure. A balance has to be struck between the cohesion of a binder and its ability to adhere to the aggregate.

3.35 The Notes for Guidance in MCHW2 Clause NG 922 classify cohesion requirements for four binder grades; Super Premium, Premium, Intermediate and Conventional. The peak value is specified, but the plot of cohesion against temperature must be provided so that, in future, temperature ranges can be set. Provided that the level of cohesion provided by a binder is sufficient, the temperature range over which the required level of cohesion is maintained is more important than the maximum level attained.

Ageing

3.36 Conventional binders, as thin films on the aggregate particles, age in the presence of air, leading to fretting and ravelling (loss of aggregate in the surface), cracking, and finally to failure. This is much more critical in surface courses - stiffening in a base may actually contribute to enhance performance. The rate of change of binder properties depends on the voids in the mixture, especially if they are interconnected, the binder film thickness and the composition of the binder after paving. There are some changes of binder properties, because of loss of volatiles and oxidation, during storage, manufacture and laying, after which the binder hardens slowly. Generally, the higher the penetration of the as-laid paving grade bitumen in the mixture, the longer it has before onset of brittle failure by the ageing process; however, the propensity to rutting increases with increasing softness (higher penetration) so a balance has to be drawn. With denser asphalt mixtures, ageing progresses more slowly, as the binder is less vulnerable to oxidation. This is the main reason for the limits imposed for maximum air voids content in performance related specifications for asphalt.

3.37 Modifiers such as fibres may be used to increase binder content and hence film thickness in order to reduce the effects of ageing in the more open mixtures, such as porous asphalt, where both air and water have ease of access.

3.38 Polymer modifiers may be used to increase the resistance to ageing, because softer base binders may be used. A balance between brittle elastic behaviour at low temperatures and adequate resistance to permanent deformation at high service temperatures must be obtained.

3.39 Adhesion of the binder to aggregate may also be improved by the use of modifiers. Enhanced adhesion reduces stripping caused by water and thereby minimises the associated loss of mixture strength. In order to understand better the long term properties of binders, and set limits on which to base performance specifications, some form of controlled ageing test is required.

Rolling Thin Film Oven Test (RTFOT) BS EN 12607-1

3.40 This test (the so-called 'Short Term Ageing Test') is used to simulate the loss of volatiles and oxidation that take place during mixing, transporting and paving asphalt. This test is specified for all asphalt binders, although validation has not been carried out for most polymer modified binders. Tests such as penetration, cohesion and rheology should be carried out, both before and after the test, to show any sensitivity of the binder to the manufacturing process and to simulate the condition of the binder immediately after laying.

High Pressure Ageing Test (HiPAT) BS EN 14769

3.41 This test is used to artificially age a binder without applying an unduly high temperature, which could destroy the integrity of the binder and initiate reactions that do not occur in practice. High pressure air at 2.1 MPa and a temperature of 85°C is used for a period of 65 hours. Cohesion and rheology measurements are carried out after this test, and information about resistance to oxidation of the binder may be obtained.

3.42 Aggregate binder interactions may inhibit the ageing of binders, but higher void contents and thinner binder films accelerate ageing, so a mixture test is preferred.

Workability

3.43 Workability and compactibility of mixtures are also of paramount importance for durability. Although it is the responsibility of the Contractor to ensure the material has been laid consistently, the Overseeing Organisation may evaluate this by examining cores, to control void content, and by visual assessment.

3.44 Use of a polymer modified binder to reduce rutting does not necessarily make the surfacing more durable. A modifier which provides high deformation resistance may make laying more problematic, resulting in an as-laid product that has poor performance.

3.45 Additives are available that can improve workability and actually reduce the temperature of working; the resulting products are classed as low energy asphalts.

3.46 A polymer modified binder for surface dressing may have a very high cohesion value and perform well in laboratory tests, but exhibit poor adhesion to chippings in practice, under realistic weather and traffic conditions. Therefore a balance has to be struck.

Third Party Approval Scheme

3.47 The approach adopted is to encourage innovation by allowing the use of proprietary and innovative products with Third Party Approval Certification. The scheme includes monitoring and surveillance which will provide assurance on the performance of the various products and systems.

3.48 For the binder, the requirement is to obtain product identification using some performance-related tests.

3.49 The example for binders for asphalt that was developed and used by HAPAS is shown in Table 3.2, with optional tests in Table 3.3.

Test	Property	Units	Test Method	As Manufactured	After RTFOT	After HiPAT
Penetration	Penetration @ 25°C,	dmm	BS EN 1426	√	√	√
	Penetration @ 5°C, 200g/60 sec.	dmm		√	√	√
Rheology By DSR BS EN 14770	T_{2kpa} @ 0.4 Hz	°C	Cl 956	√	√	√
	T_{2MPa} @ 0.4 Hz	°C		√	√	√
	G^* @ 25°C & 0.4 Hz	Pa		√	√	√
	Phase angle δ at 25°C & 0.4 Hz	Degrees		√	√	√
	G^* @ 60°C & 0.1Hz & 0.4Hz	Pa		√	√	√
	Phase Angle δ at 60°C & 0.1Hz & 0.4Hz	Degrees		√	√	√

Table 3.2 Mandatory Type Approval Tests for Modified Bitumens for Asphalts Developed for HAPAS for Third Party Approval of Asphalt Proprietary Binders

Test	Property	Units	Test Method	As Manufactured	After RTFOT	After HiPAT
Vialit Pendulum	Peak cohesion value	J/cm^2	Cl 957	√	√	√
	Peak cohesion temperature	°C		√	√	√
	Temperature range @ 'x' J/cm^2	°C		√	√	√
Fraass or BBR	Low temperature brittleness	°C	BS EN 12593	√	-	-
	Low temperature Stiffness	-	BS EN 14771	√	-	-

Table 3.3 Optional Type Approval Tests for Modified Bitumens for Asphalts

3.50 The ageing requirements may also be provided by MCHW1 Clause 955 when equivalence to HiPAT has been shown. This test is a modified RTFOT using aluminium cans coated with PTFE with a detachable lid that enables the aged binder to be removed easily. Stainless steel screws are used to provide a dynamic ageing procedure (Hill et al, 2009) which also prevents the polymer modified binder from creeping out of the bottles. Instead of 65 hours for HiPAT, the samples can be tested in 8 hours and collected at earlier times to provide an ageing profile. This is useful, because asphalts age at different rates depending on the air voids, binder content and position in the road pavement.

3.51 For Surface Dressing binders, Microsurfacing binders and Bond Coats the rheology tests are the same, but the Vialit cohesion tests are compulsory. There are also recovery tests applied to the emulsions to remove the water; refer to MCHW1 Clause 955.

EME2 Hard Grade Binders

3.52 For EME2 binders, the unmodified bitumens are specified to BS EN 13924, but some rheology and other requirements are added. These include low temperature tests such as Fraass and BBR and other properties are reported such as Viscous Elastic Transition Temperature, which may provide information on cracking, (Widyatmoko et al, 2005**).**

Characteristic	Test method	Unit	Binders for EME2 to BS EN 13924		FPC
			10/20 pen	**15/25 pen**	**Test frequency**
Penetration at 25˚C	BS EN 1426	0.1mm	10-20	15-25	D
Softening point	BS EN 1427	˚C	63-73 Target value 71 max (1)	60-70 Target values 68 max (1)	W
Penetration index, max	BS EN 13924 Annex A	-	+0.7 Target value +0.5 max(1)	+0.7 Target value +0.5 max(1)	W
Fraass breaking point, max	BS EN 12593	˚C	Target mean (2)(3) 0 max Range -10 to +5 (3)	Target mean (2)(3) 0 max Range -10 to +5 (3)	A (Q)
Viscosity at 135˚C, min	BS EN 12595	mm² /s	1100 (3)	900 (3)	A (Q)
Flash point, minimum	BS EN 22592	˚C	245	245	A
Solubility, minimum	BS EN 12592	%(m/m)	99.0	99.0	A
Pendulum cohesion, min	BS EN 13588 see Cl 957 Reported graphically	J/cm²	0.5 (3)	0.5 (3)	A (Q)
Binder characteristics after EN 12607-1 (RTFOT)					
Change of mass, max		%	0.5	0.5	A
Retained pen 25˚C, min	BS EN 1426	%	65 (3)	65 (3)	A (Q)
Increase in softening point, maximum	BS EN 1427	˚C	8	8	A (Q)
Fraass breaking point, min	BS EN 12593	˚C	Target mean (2)(3) +2 max Range -8 to +7(3)	Target mean (2)(3) +2 max Range -8 to +7(3)	A (Q)
Pendulum cohension, min	BS EN 13588 see Cl 957 Reported graphically	J/cm²	0.5 (3)	0.5 (3)	A (Q)

Table 3.4 Binder Characteristics Required for EME2 Binder

NOTES to Table 3.4:

1 Target max value based on a rolling mean of the last 6 consecutive results in compliance testing or FPC as appropriate.

2 Target max value based on a rolling mean of the last 3 consecutive results in compliance or FPC as appropriate.

3 Values are tentative and only indicative at present. More experience of tests and the test results is necessary before limits can be set with confidence. There is concern about the precision of the Fraass test in particular, and BBR values on the same samples should be obtained to establish a correlation, the long-term aim being to use BBR as the low temperature test in future.

Values for those properties that are tentative shall be agreed for each pilot contract on the trunk road network on a contract specific basis by the bitumen supplier, asphalt contractor and the Highway Agency. During the pilot stage when production may be intermittent, all test frequencies shall be agreed on a contract specific basis.

All tests to be carried out on sub-samples of a single bulk sample of binder.

Minimum test frequency: Indicated frequencies apply only if product is supplied to customers.

D = Daily, W = Weekly, A = Annually, A (Q) = Quarterly for the first year, then annually.

Binder for EME2				FPC frequency		
Characteristic	**Test method**	**Unit**		**AS**	**STA**	**LTA**
Brookfield viscosity T200cP	BS EN 13302	˚C	TBR	A		
T2000cP		˚C	TBR		A	
T5000cP		˚C	TBR		A	
G* and phase angle	BS EN 14770 see Clause 956 Graphical output	Pa, degrees	TBR	A	A	A
VET temperature, G'=G'', at 0.4 Hz		˚C	TBR	A	A	A
G* at the VET temperature		Pa	TBR	A	A	A
G' and G'' mastercurves 80˚C to 0˚C		Graphical output	TBR	A	A	A
G'' and phase angle at 15˚C, 10Hz and 20˚C, 1Hz		Pa, degree	TBR	A	A	A
Ts=300MPa by BBR	BS EN 14771	˚C	TBR	A(Q)	A(Q)	A(Q)
Tm=0.3, by BBR		˚C	TBR	A(Q)	A(Q)	A(Q)

Table 3.5 Binder Characteristics for EME2 to be Reported

NOTES to Table 3.5 Minimum test frequency: Indicated frequencies apply only if product is supplied to customers

D = Daily, W = Weekly, A = Annually, A (Q) = Quarterly for the first year , then annually.

AS= As supplied

STA = After BS EN 12607-1 (RTFOT)

LTA = After PAV85 BS EN 14769 or

MCHW1 Cl 955 equivalent

Normative References

Manual of Contract Documents for Highway Works, Volume 1

Manual of Contract Documents for Highway Works, Volume 2

BS EN 12591 Bitumen and bituminous binders. Specifications for paving grade bitumens

BS EN 1426 Bitumen and bituminous binders. Determination of needle penetration

BS EN 1427 Bitumen and bituminous binders. Determination of the softening point. Ring and Ball method

BS EN 12607-1 Bitumen and bituminous binders. Determination of the resistance to hardening under influence of heat and air. RTFOT method

BS EN 12592 Bitumen and bituminous binders. Determination of solubility

BS EN 12593 Methods of test for petroleum and its products. Bitumen and bituminous binders. Determination of the Fraass breaking point

BS EN 12595 Bitumen and bituminous binders. Determination of kinematic viscosity

BS EN 13302 Bitumen and bituminous binders. Determination of dynamic viscosity of bituminous binder using a rotating spindle apparatus

BS EN 13588 Bitumen and bituminous binders. Determination of cohesion of bituminous binders with pendulum test

BS EN 13924 Bitumen and bituminous binders. Specifications for hard paving grade bitumens

BS EN 14769 Bitumen and bituminous binders. Accelerated long-term ageing conditioning by a Pressure Ageing Vessel (PAV)

BS EN 14770 Bitumen and bituminous binders. Determination of complex shear modulus and phase angle. Dynamic Shear Rheometer (DSR)

BS EN 14771 Bitumen and bituminous binders. Determination of the flexural creep stiffness. Bending Beam Rheometer (BBR)

BS EN 22592 Methods of test for petroleum and its products. Petroleum products. Determination of flash and fire points. Cleveland open cup method

Informative References

Carswell, J., Claxton, M.J. and Green, P.J. "The classification of bitumens and polymer modified bitumens within the SHRP performance grading system", Eurasphalt & Eurobitume 2000.

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Hill, C., Heslop, M., Widyatmoko, I., Elliott, R. and James, D (2009). "Bituminous Binder – ageing profile test", Asphalt Professional No 41

Whiteoak, D., Read, J. and Hunter, R (2003). The Shell Bitumen Handbook

Widyatmoko, I., Heslop, M.W, and Elliott, R.C (2005). "The Viscous to Elastic Transition Temperature and the In Situ Performance of Bituminous and Asphaltic Materials", Journal of the Institute of Asphalt Technology, Asphalt Professional No 14

4. THIN ASPHALT SURFACE COURSE (TASC)

Background

4.1 Thin asphalt surface courses (TASCs) are proprietary paver-laid asphalt systems using a polymer modified bond coat to form, after compaction and cooling, a negatively textured surface course bonded to the substrate, with a thickness above 20mm and generally less than 50mm.

TASCs have a Third Party Approval Certificate (hereafter referred to as "Certificate" in this Chapter), appropriate for the site classification and the level of traffic and substrate condition, and have demonstrated compliance with Surfacing Integrity Performance in terms of defects, torque bond strength, noise (Road Surface Influence) and macrotexture, claimed for the differing substrates.

TASCs have been developed to provide safe, durable and quieter surfaces and have largely replaced chipped hot rolled asphalt (HRA) for the Strategic Road Network (SRN) in England. HRA has a positive macrotexture and this causes a greater tyre/road noise generation than TASC. In addition, there are practical complications with installation of HRA, particularly because the chipping spreader has to straddle the asphalt being laid (see Chapter 5 Hot Rolled Asphalt Surface Course).

Figure 4.1 TASC - High Speed Road

Figure 4.2 TASC – Urban Road

Innovative Ultra-thin Treatments (IUTs), either based on proprietary polymer modified multiple-layered surface dressing techniques (see Figure 4.3 below; also Chapter 8) or microsurfacing (see Chapter 10), have been developed to compete with Ultra-thin Asphalt Surface Course. The latter is not classified as a TASC, as it has a nominal thickness of less than 20mm (6mm maximum size coarse aggregate) and is laid by a paver with integral spraybar to apply the bond coat (see Chapter, 12 Laying Bituminous Materials).

All IUTs (hot and cold) are now specified in MCHW1 Clause 940.

Figure 4.3 Innovative Ultra-thin Treatment (IUT) Low Tyre/Noise Generation Surface Course, with Three Chipping Layers (14, 10 and 6mm) and Two Polymer Modified Binder Layers (One as a Grout)

Asphalt mixtures for TASCs consist of aggregate, filler and bituminous binder, which may be modified by the addition of polymers, rubber, resins, fibres or fillers such as hydrated lime or cement.

The bonding of TASC is critical to its performance and a polymer modified bituminous emulsion bond coat must be used in accordance with MCHW1 Clause 920 and BS 594987. The only exception is when the binder course and TASC are laid simultaneously by a “dual paver” or upon a hot workable substrate, resulting in a heat-welded interface; see Chapter 12, Laying Bituminous Materials.

TASC durability is limited by the condition of the substrate and pavement structural strength and these should be assessed for the site traffic category. Some local roads and a few trunk roads are not suitable for certain types of TASC (UK Roads Board 2006 – ‘Best Practice Guidelines for Specification of Modern Negative Textured Surfaces on Local Authority Roads’).

The use of a binder course may be needed to provide a suitable substrate for long term performance (to resist water penetration and increase bond strength). Thin regulating course underneath TASC is not recommended as a substrate, especially when laid in cool or damp conditions.

Polymer modified binders may be required to provide flexibility and durability (see Chapter 3, Binders).

Poor installation, adverse weather conditions and incorrect use of a bond coat will lead to early-life failure, (see Chapter 12, Laying Bituminous Materials).

The failure mode of TASC has been found to be different from the end-life for HRA, in that fretting and ravelling can occur suddenly and rapid remedial action is sometimes required. However, experience has shown that when these surfacings are specified and installed correctly they can achieve a serviceable life of up to 15 years (Nicholls et al, 2010; 2012).

4.2 TASCs are suitable both for new construction and for maintenance. TASCs may be laid at different thicknesses depending on the requirements and this determines the maximum coarse aggregate size and relevant asphalt standards see Table 4.1.

TASC Type	**Nominal Thickness**	**Asphalt Coarse Aggregate Maximum Sizes Recommended[1]**	**Asphalt Standards[2]**
Very Thin	20mm to 30mm	6 mm	BS EN 13108 Part 2
Thin	>30mm to <40mm	6 mm, 10 mm	BS EN 13108 Parts 1, 5
Thin	>40mm to <50mm	10 mm, 14 mm	BS EN 13108 Parts 1, 5

NOTE 1: When the thickness is more than three times the coarse aggregate size, there is a risk of loss of texture and the Certificate should be checked to see if it is suitable for the particular traffic category and macrotexture requirements.
NOTE 2: Thin asphalt may also comply with BS EN 13108 Part 4 high stone content HRA and BS EN 13108 Part 6 Mastic Asphalt; the former is used on areas such as roundabouts where macrotexture requirements are less onerous and the latter polymer modified version is used on bridge decks. Both are used for patching or re-instatement works in TASC.

Table 4.1 General Classification of TASC

Figure 4.4 Negative Macro-texture of a Freshly Laid Polymer Modified 0/10mm TASC

Figure 4.5 Close-up of 0/10mm TASC, One Year after Laying, Showing How the Surface Film of Binder is Wearing Off to Reveal the Micro-texture. Aggregate Particles are Held by the Polymer Modified Binder and They Contribute to the Overall Skid Resistance.

The asphalt used in TASC may have differing performance depending on the requirements for macrotexture and durability for the particular site type.

TASC may have fibres, to enable the mixture to retain an increased binder content without binder drainage, or may have polymer binder modification, or both, to improve durability and flexibility.

There is a need for categorisation of TASCs. High polymer content asphalt and the use of a premium bond coat have a much greater initial cost than that of an unmodified material. Therefore, in order to specify a product with enhanced performance characteristics and durability, the Certificate needs to include binder data, see Chapter 3, Binders and Binder Modifiers.

Experienced highway maintenance engineers can make the choice of system taking into account the initial cost, site type, substrate condition and required life.

4.3 TASCs are based on materials developed in other European countries over 20 years ago and are in widespread use in France and Germany. The materials generally rely on aggregate interlock to provide a material that is not prone to rutting (permanent deformation). If rutting occurs, it is usually attributable to the material in the binder course that supports the surfacing. Surface deterioration of the TASC is likely to follow the occurrence of such rutting. Very thin asphalt surface courses perform well when bonded to a newly laid binder course and with reduced macrotexture requirements denser materials similar to the French original material, béton bitumineux très mince (BBTM), may be used. Thin asphalt typically laid at 40 mm thickness can be made either to the Asphalt Concrete specification BS EN 13108-1, or to the Stone Mastic Asphalt specification BS EN 13108-5 more typical of the German products, see Figure 4.6.

Figure 4.6 SMA in Germany

As set out in Table 4.1 above, TASCs are based on various parts of BS EN 13108 and in particular:

- Part 1 – Asphalt Concrete
- Part 2 – Thin Asphalt Concrete
- Part 5 – Stone Mastic Asphalt

Part 4 – Hot Rolled asphalt may be used as a TASC and Part 6 – Mastic asphalt is used on bridges

The parameters that need to be specified for TASCs have been taken from the various parts of the above standards and are shown in Table 4.2 below; some are specific to national requirements (see also BSI Published Document PD 6691).

These parameters are highlighted in red in Table 4.2 which summarises the tables ZA.1 of the respective parts of BS EN 13108.

Requirement	**Values**	**Required in BS EN 13108**				
		Part 1	Part 2	Part 4	Part 5	Part 6
Layer thickness	Minimum and maximum	Yes	Yes	Yes	Yes	Yes
Aggregate size	Maximum	Yes	Yes	Yes	Yes	No
Void Content	Minimum and maximum	Yes	Yes	Yes	Yes	No
Binder content	Minimum	Yes	Yes	Yes	Yes	Yes
Water sensitivity	Minimum	Yes	Yes	Yes	Yes	No
Grading (this is usually designed by supplier)		Empirical only	Yes	Yes	Yes	Yes
Voids in mineral aggregate (not normally specified)	Minimum and maximum	Yes	No	No	No	No
Voids filled with bitumen	Minimum and maximum	Not usually	No	No	Yes	No
Resistance to permanent deformation	Minimum	Yes	No	Yes	Yes	No
Stiffness	Minimum and maximum	Fundamental only	No	Yes	Yes	No
Binder Drainage	Maximum	No	No	No	Yes	No
Indentation	Minimum and maximum	No	No	No	No	Yes
Durability of the characteristics against ageing, weathering, oxidation, wear, ravelling, chemicals and stripping	All requirements relevant	Yes	Yes	Yes	Yes	Yes

Table 4.2 Parameters that Need to be Specified for TASCs

National requirements include texture depth, skidding resistance (specified by the use of minimum PSV levels) and ride quality (specified by means of the rolling straight edge).

Other parameters are material specific and are set out in Table ZA.1 in each of the standards. The levels given in the standards are for materials as manufactured NOT as laid. However, it is important that some of the parameters are specified (and measured) on the as-laid material.

Figure 4.7 TASC being Laid on a Binder Course

Figure 4.8 TASC Polymer Modified 25mm Overlay over Bond Coat

4.4 TASCs have been developed to meet the UK's safety requirements, necessitating the use of high quality aggregates and the provision of initial and retained surface texture. The first proprietary TASCs were accepted for use on the Strategic Road Network in 1992 and there are now a significant number of products for use in England that meet HA performance specifications.

4.5 TASCs are not generally designed to treat pavements where structural deterioration or cracking is present in the underlying layer (whether this is asphalt, hydraulically bound material, or pavement quality concrete). Structural deterioration, cracking or open joints already present in the layer directly beneath the TASC will rapidly propagate to the surface, unless the TASC is specifically designed to overcome defects. Such defects in the surfacing mat tend to disrupt the integrity of the TASC resulting in a local loss of aggregate interlock. Consequently, surface disintegration (fretting) occurs, and reduced life of the surfacing is the likely outcome. However, assessment of durability of TASCs laid directly onto jointed concrete has shown that the difference between the actual overall condition and that for the condition ignoring any reflection cracks is negligible for at least 5 years (Nicholls et al, 2012), and satisfactory life may still be achieved in such circumstances.

Benefits

Rapid Construction

4.6 TASCs offer a rapid means of resurfacing roads. Faster application potentially reduces traffic management costs and costs of delay to the travelling public. Installation outputs up to 20,000 m^2 per day have been achieved under favourable conditions.

Reduced Working Area

4.7 Less working width is necessary to lay and compact thin surface course systems compared to hot rolled asphalt, which, using current technology, has to have chippings applied by machines at a fixed width of nearly 4.5 m, with supporting wheels running either side of the paved asphalt mat.

Lower Cost

4.8 TASCs are thinner and quicker to lay, therefore they may be significantly less expensive per unit area than hot rolled asphalt. For overlays, the cost of planing and spoil removal is also reduced compared to inlay. Traffic management and delay costs are also reduced.

Traffic Noise Reduction

4.9 The flat, machine laid surfaces and uniform negative surface texture mean that TASCs may be significantly quieter than conventional surfacings such as hot rolled asphalt and brushed concrete.

Tyre Spray Reduction

4.10 TASCs with adequate texture depth exhibit spray suppression capability at low levels of rainfall due to their more open 'negative' surface texture. This does not, however, approach that of new porous asphalt. Like porous asphalt, spray reducing properties of TASCs diminish with time.

Rut Resistance

4.11 Due to their skeletal structure formed by the coarse aggregate particles, TASCs generally have a high resistance to wheel track rutting, although they are vulnerable to deformation originating in the lower pavement layers

Limitations

Life Expectancy

4.12 TASCs, adapted from practice in other European countries, have been in use in the UK for 20 years. Elsewhere in Europe the products from which they have been developed have demonstrated satisfactory working lives of between 10 and 20 years. In the UK, safety considerations, in particular high speed skid resistance (macrotexture requirements) are likely to limit the lives to between 7 and 15 years, depending on their thickness, binder modification, void content, the level of trafficking and the condition of the underlying pavement.

4.13 The condition of the substrate on which a TASC is laid is critical in determining its life expectancy, see Table 4.3. A reduced working life should be anticipated for any bituminous surfacing applied over an existing surface or base that is not in a sound condition. This is particularly so for thinner systems.

Strength Contribution

4.14 Only those TASCs that have stiffness data provided in the Certificate may be considered as making a structural contribution and then only where the existing pavement is structurally sound. TASCs laid at less than 25mm thick make very little structural contribution. A number of materials have demonstrated higher stiffness than conventional products and this is recorded in the Certificate. A conservative option for design purposes is to consider a stiffness of half that described in the Certificate. This reduction allows for the variability of the parameter both within and between sites and from source to source. The contractor may use a higher value if he demonstrates it by measurement on the site where he intends to use the values for design. Where there is no data on stiffness, the TASC may still be used but the structural contribution should be assumed to be zero.

Site Evaluation
Surface layer defect
Nature of distress

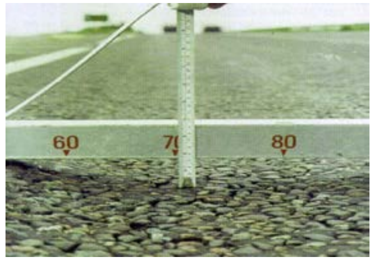
Oxidised and Fretting	Cracking or crazing	Minor crazing	Texture	Rutting
 **Stage 2 Fretting**				
Is surface intact? If yes then: ↓ Single layer of TASC 40mm or less, overlay or inlay. Inlay where fretting is at stage 2 or 3, see paragraph 4.49	TASC not suitable unless high stiffness substrate such as jointed concrete (see paragraph 4.5). Further investigation required. Single layer will have very short life. Two layers to 100mm may be suitable if kerb height not a problem. Needs full investigation. See HD 30	TASC not likely to be suitable. CASTs in the form of a polymer modified multiple-layered surface dressing should be considered	Within permitted range for type of road → Do nothing Too high or too low → Single layer resurface	Stable and less than 10mm → Do nothing 10mm or more or increasing max 20mm → Single layer resurface

Table 4.3 Site Evaluation

Specification

4.15 Specification and drafting requirements for TASCs are given in MCHW1 Clause 942 of the Specification with accompanying MCHW2 Clause NG 942. When used on the Strategic Road Network in England,, proprietary TASCs must have a Third Party Approval Certificate appropriate for the site classification and the level of traffic in commercial vehicles/lane/day to be carried.

4.16 The Approval Certification of TASC requires a trafficking trial for a minimum period of 2 years, after which the product must be defect free, have minimum torque bond strength and must retain an appropriate minimum texture depth in the wheel tracks.

4.17 The performance of a surfacing in the trial can be used to predict the level of traffic it will be capable of withstanding, whilst achieving the required retained texture depth. The trafficking trial can also be used to carry out measurements to predict the likely traffic noise (Road Surface Influence) from the TASC.

Harmonised European Standards for TASCs do not currently exist for the “as laid” properties of road surfacings trialled for a minimum of 2 years, therefore CE marking may only be provided for the asphalt material manufactured.

Inspection

4.18 MCHW1 Clause 942 and MCHW2 Clause NG942 give the five-year Surfacing Integrity Performance guarantee requirements for TASCs. Surface conditions are as defined in Appendix A of TRL Report TRL 674. Photographic examples of TASCs in a range of conditions are given in Appendix P of the same report.

4.19 In the 6 months preceding the expiration of the Surfacing Integrity Performance guarantee period of a proprietary TASC, normally 5 years, the material must be inspected for defects as described in MCHW 1 Clause 942. Surfacings that do not meet the acceptance criteria, and where the condition is not attributable to the condition of the substrate, must be notified to the supplier for correction under the terms of the guarantee.

Visual Assessment

4.20 At the end of the maintenance period and at the end of the guarantee period, if different, a visual assessment of the surfacing must be carried out.

The current guideline documents for approved TASCs are not appropriate for specification purposes or for carrying out comparisons over time.

A formal visual assessment should be undertaken at the end of the guarantee period using the procedure given in Appendix 4.A of this chapter. The procedure may also be used at other times to assess deterioration rates and for Certification purposes.

Design Preliminaries

4.21 The adequacy of the structure of the pavement to provide a sound and stable substrate for a TASC must be established before specifying a replacement surface course. Laying of TASC on an unstable substrate will result in reduced life of the surfacing, see Table 4.3.

4.22 Determination of whether or not the existing pavement substrate for the SRN is sound can be made by:

- Utilizing the pavement evaluation methods described in DMRB 7.3.3 (HD 30) to indicate that the pavement is 'long life';
- Examination of the existing surfacing to ensure that any rutting is limited to the material that will be removed;
- Investigation of cracking in the existing surfacing to determine that it is not caused by failure of layers below.

Installation

4.23 TASCs are proprietary products. Consequently their design, manufacture, transportation, laying and compaction are the responsibility of the contractor.

4.24 Many of the TASCs currently available were originally tested for performance when laid under ideal conditions on good substrates. To achieve the best possible installed performance from a TASC, these conditions must be equalled or exceeded, as far as it is practicably possible. This is especially relevant in the case of weather, where any deterioration in weather conditions at the time of laying will have an adverse effect on the durability of the TASC.

The opportunity now exists for TASCs to be laid on poorer quality substrates or in less than ideal weather conditions and a Certificate produced with associated, possibly lower, performances specifically for those conditions. This enables innovation and the use of modifiers to improve performance over such substrates, or other techniques such as heating or drying to cope with adverse weather.

4.25 The Certificate, together with the product's Quality Plan and Installation Method Statement, give minimum temperatures for laying and describe the acceptable moisture level of the substrate. These must be taken into account when planning surfacing works.

Adverse Weather Working

4.26 Much of the compaction necessary for TASCs is achieved by the screed on the paver, with the process being completed by the roller close behind the paving machine. In this respect, and because the application of chippings is unnecessary, the installation of TASC might appear straightforward. However, the thinner systems lose heat extremely rapidly and therefore should not be laid in the winter months unless the surfacing substrate is adequately pre-heated.

4.27 It is desirable to lay in conditions that exceed the minimum criteria for air temperature and dryness of the surface to be overlaid given in the Certificate or declaration of performance for the product. Surfacing must be scheduled to allow sufficient programme float to avoid periods of poor weather. Surfacing operations must be delayed if there is a forecast of precipitation during the planned laying period.

4.28 Minimum air temperatures are usually required to be measured on a rising thermometer. Due to restrictions on the availability of the highway for maintenance, TASC operations may be carried out during overnight closures. In such situations, the air temperature will usually be falling and allowances must be made to ensure that it does not fall below the minimum specified during the laying period

4.29 Hot asphalt materials lose heat most rapidly through the effects of wind speed. Substantial heat losses will also occur if the material is laid in standing water or on to ice, due to the latent heat of melting of ice or evaporation of the water.

4.30 Some thicker TASC can be laid and compacted successfully in air temperatures as low as 2°C and rising, provided the air is still and the substrate is dry. If, however, the wind speed at a height of 2m is 5km/hr, then an air temperature of 10°C or more may be necessary to achieve full compaction.

4.31 In common with other bituminous materials, it has been observed that TASCs laid during the winter period are likely to be less durable than those laid in the summer. TASC should normally be laid between the months of April to October inclusive, as during these periods the laying criteria given in MCHW1 are most likely to be met or exceeded. This period may be extended if ambient temperatures above 5ºC are forecast when the TASC is planned to be laid and other weather dependent criteria for the compliant performance of the installed materials will be met.

4.32 TASC must not be laid below the minimum temperature specified in the Certificate.

4.33 When laying is likely to occur at close to the minimum temperature or after rain, plant must be available on site so that the existing surface can be warmed and dried by means of infra-red or similar heating immediately in front of the paver. Where work must proceed when the ambient conditions are acceptable but the surface conditions do not meet the requirements described in the Quality Plan and Installation Method Statement, equipment must be provided and used on site to dry the substrate prior to paving operations. For instance, a substrate pre-heating system, that precedes the paver, may be employed. Further information on installation can be found in Chapter 2. These systems should have demonstrated that moisture is not driven in to the substrate voids, so that subsequent sweating leads to a weakening of the bond and delamination of the TASC.

Contracts let where TASC installation is predicted to be during poor weather conditions must provide incentives for the use of techniques to reduce early-life failure.

Paving at Joints

4.34 It has been observed, from examples of TASC approaching the limit of serviceability, that the longitudinal joint may begin to fail before the pavement surface. The failure mechanism begins with localised fretting of aggregate at the joint, which rapidly progresses. This highlights the need to pay attention to the detail of the joint when the TASC is being laid. The use of bond coats and heaters should be considered, see Chapter 12, Laying Bituminous Materials.

4.35 Wherever possible, the number and length of transverse and longitudinal joints should be minimised to reduce possible areas of vulnerability.

4.36 Echelon paving is the use of multiple paving machines laying the bituminous mat in adjacent rips concurrently. The material in all the rips is compacted at the same time after the last paving machine has passed.

Figure 4.9 Paving Machines in Echelon

4.37 The use of multiple paving machines laying in echelon should be the preferred laying method as there is no discernible longitudinal joint once compaction is complete, see Figure 4.9. Where laying in echelon is not possible, joints should be placed as far as possible from the wheel track zones. Where surfacing joints are placed in the wheel track zones, the durability of the surfacing will be adversely affected.

4.38 Information on the jointing of rips is given in the individual product Certificate, Quality Plans and Installation Method Statements. Those specifying works incorporating TASCs must ensure that they take account of these.

Roundabouts, Bends and Junctions

4.39 It has been observed that TASCs are more durable when smaller nominal aggregate sizes are used in locations where there are significant traffic turning movements. The surfacing requirements should be specified separately for these locations.

4.40 TASC with a nominal aggregate size greater than 10mm must not be used on roundabouts and other bends with a radius less than 250m which are subject to substantial sideways forces from heavy traffic.

4.41 Some junctions may also be subject to substantial sideways forces from heavy traffic, where small radius turning movements are required. The nominal aggregate size for TASC at these locations should not exceed 10mm.

4.42 There is less need to achieve high texture on a roundabout as traffic speeds are generally low. Damage to the surface from turning heavy vehicles can be a significant problem on roundabouts and invariably starts at joints. This can be mitigated by carefully planning the laying to avoid joints if possible and to place essential joints in lower stress areas. Consideration should be given to closing roundabouts completely to enable continuous surfacing. The main traffic flow of heavy vehicles should be examined and paver runs planned to follow the same tracks, to minimise scrubbing of heavy vehicle tyres across joints. TASC with a small nominal aggregate size, laid to the maximum permissible thickness, generally gives a more durable result. These thicker surfacing layers would also be more tolerant of adverse working conditions.

Bond or Tack Coats

4.43 The thinner the TASC, the greater the importance of an effective bond to the substrate. Bituminous emulsion bond coats must be applied at a minimum application rate to provide 0.35kg/m^2 of residual binder, which must not be damaged by installation plant or delivery vehicles. Polymer modified bond coats provide enhanced performance and must be specified for TASCs. Tack coats are not considered “best practice”, as stated in BS 594987: 2010; see Chapter 12, Laying of Bituminous Materials.

Audit Checks

4.44 It should not be necessary to carry out routine checks of grading and binder content on proprietary products. Nevertheless, if obvious variations in a product are occurring, then audit tests should be undertaken to determine aggregate properties and grading, binder content and binder characteristics. These should be carried out to check that the product complies with the Certificate and the system proprietor's method statement. When there is doubt, the contractor should be required to demonstrate that the degree of compaction achieved on site is at least equal to that obtained for the site for which certification was granted.

4.45 Non-compliance must be reported to the Overseeing Organisation and the Third Party Approval Certification Body and may, if serious and on-going, result in the suspension of the Certificate.

Overlaying Concrete

4.46 TASCs are generally suitable for application to both old and new continuously reinforced concrete (CRCP) surfaces. When laying on concrete, it is likely that a polymer modified bond coat or preparatory surface dressing will be required. Surfacing directly over jointed concrete is not generally recommended, although see paragraph 4.5 above. However, if undertaken, joint sealants in the concrete substrate should be replaced by BS EN 14188 hard sealants, brought up almost flush to the surface, and expanded polythene backing strips should not be used. These tend to be compressed by the roller and then recover, cracking the surface course.

High Friction Surfacing

4.47 Where high friction surfacings (HFS) are to be applied over TASC at approaches to roundabouts and other highly stressed sites, the deep 'negative' texture can reduce the coverage of resin binder to such an extent that the adherence of calcined bauxite chippings may be reduced. This may result in premature chipping loss, see the advice given in Chapter 9, High Friction Surfacing.

Maintenance of Existing TASC Pavements

End of Service Life

4.48 Research has shown that the serviceable life of a TASC is most influenced by the surfacing type, aggregate size and binder content. Properties of the recovered binder (penetration grade and softening point) did not provide a sufficiently clear relationship to be used as a serviceability indicator.

4.49 TASCs approaching or at the end of their serviceable life generally exhibit the following stages of deterioration:

Stage 1 Loss of isolated particles of aggregate.

Stage 2 Substantial loss of aggregate in discrete locations, not necessarily in the wheel track, and surface disintegration at longitudinal and transverse joints.

Stage 3 Loss of integrity of the surface, with fragmentation of the mat.

Figure 4.10 TASC Stage 1

Figure 4.11 TASC Stage 3

4.50 The time period for deterioration progression from Stage 1 to Stage 3 is variable and has been reported as between 6 months and 5 years.

4.51 Research is in progress to determine a method to monitor the amount of deterioration in TASC materials from routine traffic speed condition surveys and predict their residual life.

Local Repairs

4.52 The Certificates for TASCs contain instructions and guidance on appropriate methods and materials for repair of local surface defects. These must be referred to for the planning of repairs. For repairs not covered by the information in the Certificates, MCHW 1 Clause 946 must be used.

4.53 For small, local repairs, it is good practice to use a smaller nominal aggregate size for patching than that of the original surface, i.e. patch a 14mm TASC with 10mm TASC.

Replacement of Existing TASC

4.54 Due to the way TASCs behave structurally, any disturbance of the fabric of an aged TASC is likely to lead to rapid deterioration.

4.55 The following actions should be avoided as far as practicable, as they have been observed to accelerate the deterioration of adjacent TASC:

- Removal of painted and thermoplastic lines by pressurised water systems;

- Cutting of slots for detector loops and other traffic sensors;

Detector Loops

4.56 It has been observed that any cut in a TASC, such as those made to install detector loops, may cause the material to fail prematurely. To obviate this, two alternative methods of loop installation are detailed.

4.57 Loops may be installed in the pavement layer directly beneath the TASC, before the TASC overlay commences, or, in the case of repairs or reinstatements, the existing pavement may be planed out, loops installed and the new TASC overlay applied.

4.58 In both cases, the induction loops are installed before the TASC is laid. This will require coordination between those planning the resurfacing and those responsible for the induction loops, to ensure that work is scheduled accordingly and that the induction loops will be installed at the correct depth and to the correct design pattern to ensure the function of the loops.

4.59 Where induction loops are installed after completion of the surfacing, the cut slots can be closed using an infra-red patching technique rather than a poured sealant. If a poured sealant is used, installation of a bond breaking layer above the wires of the loop is likely to allow future planing of the surface without damage to the detector loop.

Hand Application

4.60 It is preferable that TASC should not be laid by hand except where a paver cannot operate, and then only in favourable weather conditions. Due to their low fine aggregate content, TASCs appear binder rich and ‘sticky’ and, being thin, they lose heat rapidly making them difficult to hand lay and compact satisfactorily.

4.61 Ironwork should be lifted in advance, and edge details and minor bell mouth openings (where it is not possible to lay by machine) should be surfaced by hand, but only in optimum weather conditions. Alternatively, providing prior agreement has been obtained from the Overseeing Organisation, such areas may be resurfaced with thicker hot rolled asphalt (HRA) and 8/14 mm coated chippings or dense bitumen macadam (DBM) laid by hand; 55/10 HRA without chippings and polymer modified mastic asphalt could also be considered.

Figure 4.12 Reinstatement Work

4.62 Reinstatement around ironwork, when it is raised after laying the surface course, is rarely if ever satisfactory and the practice is strongly deprecated. If, in extreme circumstances, it is necessary to raise ironwork subsequent to laying the TASC, high quality polymer modified mastic asphalt should be used. Any joint should be painted on the vertical face and overbanding should not be used - overbanding is usually used to cover up poor workmanship. Only inlaid crack sealing systems having Certificates showing suitability for use in openings of the size required should be used.

4.63 Minor repairs to TASC, which will not significantly affect noise generation or located outside the wheel tracks, may be done using HRA or DBM as described in 4.61, with the prior agreement of the Overseeing Organisation. However, major trench reinstatements should be completed with machine laid TASC and it may prove expedient and more economical in the long run to resurface a complete lane width.

Normative References

Manual of Contract Documents for Highway Works, Volume 1

Manual of Contract Documents for Highway Works, Volume 2

BS 594987, Asphalt for roads and other paved areas – Specification for transport, laying, compaction and type testing protocols

BS EN 13108-1, Bituminous mixtures. Material specifications. Asphalt Concrete

BS EN 13108-2, Bituminous mixtures. Material specifications. Asphalt concrete for very thin layers

BS EN 13108-4, Bituminous mixtures – Material specifications – Part 4: Hot Rolled Asphalt

BS EN 13108-5, Bituminous mixtures – Material specifications – Part 5: Stone Mastic Asphalt

BS EN 13108-6, Bituminous mixtures. Material specifications. Mastic asphalt

BSI PD 6691, Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications

The Design Manual for Roads and Bridges, Volume 7 – HD 30

BS EN 14188-1, Joint fillers and sealants. Specifications for hot applied sealants

BS EN 12272-2 Surface dressing. Test methods. Visual assessment of defects

BS EN 12274-8 Slurry surfacing. Test methods. Visual assessment of defects

Informative References

UK Roads Board, Best Practice Guidelines for Specification of Modern Negative Textured Surfaces on Local Authority Roads, 2006

Nicholls, J.C., Carswell, I., Thomas, C. and Sexton, B., Durability of thin surfacing systems, Part 4 Final report after nine years monitoring, TRL Report 674, 2010

Nicholls, J.C, Carswell, I. and James, D. J., Durability of Thin Surfacing Systems in the UK after 9 years monitoring, IAT Yearbook, 2012

Appendix 4

Visual Assessment of TASC

Results below the levels presented in Table A4.1 probably indicate poor long term durability of TASC materials for trunk roads and motorways.

All results should be sent to HA Bedford to enable refinement of the limits.

Test Methods for Visual Assessment of TASC

Visual assessment of TASC should be carried out by using qualitative or quantitative methods, in accordance with BS EN 12274-8 and BS EN 12272-2, which are already in use in MCHW1 and MCHW2 for microsurfacing and surface dressing, respectively. Minor modifications are needed to enable their use for TASCs.

The four tests to be used are:

1. for fatting up – the test for fatting up from EN 12274-8 (P_1 in that standard)
2. for delamination – the delamination test from EN 12274-8 (P_2 in that standard)
3. for chipping loss – the fretting test from BS EN 12272-2 (P_3 in that standard, using the frame)
4. for corrugation, bumps and ridges - the test from EN 12274-8 (P_3 in that standard)
5. for groups of small and repetitive defects in not more than (n) rectangles – the test from EN 12274-8 (P_4 in that standard and where n=1).
6. for longitudinal grooves and fretting of joints – the test from EN 12274-8 (L in that standard)

Parameter	Requirement in the wheel track*
Fatting up after 2 weeks and any time up to 2 years; P_1	Not more than 0.2 %
Delamination at 2 years; P_2	Not more than 0.2 %
Chipping loss at 2 years; EN 12272-2, P_3	Not more than 2%
Corrugation, bumps and ridges at 2 years; EN 12274-8, P_3	Not more than 0.2%
Groups of repetitive defects at 2 years; EN 12274-8, P_4	Not more than 0.2% where n=1
Longitudinal grooves and fretting of joints at 2 years; EN 12274-8, L	Not more than 1 m

NOTE*: where the location of the wheel track is indeterminate, as on roundabouts, the whole area should meet the wheel track criteria.

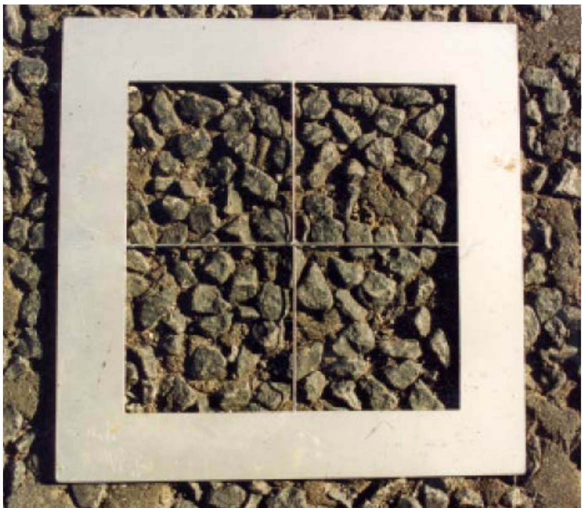
Table A4.1 Visual Assessment Levels

Examples are given below of the use of the measuring frame for measurement of chipping loss.

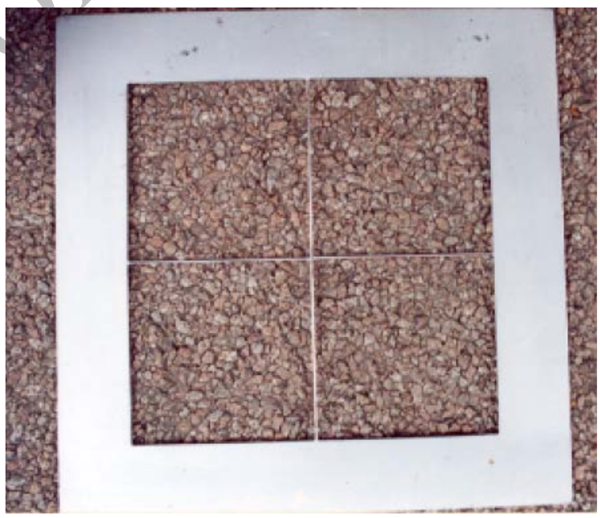
TASC 0/10mm (No Loss)

Evidence of Fretting - Low Percentage Loss Measured (2%) after Five Years, therefore Satisfactory

Inverted Double Dressing Age 15 years, Surface Comprising 14mm Chippings (No Loss)



Hot Rolled Asphalt, 20mm Pre-Coated Chippings



Multiple-layered Surface Dressing 6mm Top Surface

5. HOT ROLLED ASPHALT (HRA) SURFACE COURSE

5.1 Hot rolled asphalt (HRA) differs from nearly all other asphalt in that the material depends on the strength of the mortar (sand plus filler and binder) for its properties. The contribution of the coarse aggregate to the mixture properties is limited by the fact that the particles in general do not interlock.

HRA surface course must not be used on the Strategic Road Network in England without a Departure from Standards from the Overseeing Organisation, because the preferred surface course is a thin asphalt surface course (TASC) to MCHW1 Clause 942.

Hot rolled asphalt surface course is specified in the following Clauses of MCHW 1, see Table 5.1:

Clause Number	Clause Title
910	Hot Rolled Asphalt Surface Course (Recipe Mixtures)
911	Hot Rolled Asphalt Surface Course (Design Mixtures)
915	Coated Chippings for Application to Hot Rolled Asphalt Surfacing
943	Hot Rolled Asphalt Surface Course and Binder Course (Performance-Related Design Mixtures)
945 paragraph 4	Weather conditions for Laying of Hot Bituminous Mixture: Hot Rolled Asphalt with Pre-coated Chippings (see also Chapter 12)

Table 5.1 Applicable MCHW 1 Clauses for HRA

These Clauses refer to BS EN 13108-4, detailed requirements given in PD 6691 Annex C and particular requirements that need to be specified according to MCHW2 NG700 Sample Appendix 7/1.

Annex 5A to this Chapter gives a summary of the various HRA surface course mixtures in use in England together with the Clause numbers in MCHW1.

Hot Rolled Asphalt Surface Course Recipe Mixtures

5.2 These recipe materials are the traditional hot rolled asphalts which have been in use for over a century. They were initially proprietary materials but were codified into British Standard 594 at least as early as 1951. They are very durable because of the high binder content and also the likelihood that the air void content is low and/or generally less accessible to environment influences (air and water) than the air void content of, for example, asphalt concrete. They are eminently suitable for most of the local road network, but in high or channelised traffic locations can be prone to rutting in hot weather. Because of their ease of laying and high durability (when properly laid), they should be preferred over design HRA provided there is little risk of rutting.

Note: any HRA surface courses that are in situ and over 30 years old (not uncommon) will almost certainly be recipe mixtures.

Figure 5.1 Newly Laid Chipped HRA Surface Course

Clause 910 for recipe mixtures permits the use of the following materials: 0/2F, 15/10F, 30/10F, 30/14F, 35/14F. In addition to these mixtures, 45/6F and 45/10F are specified in DMRB HD 39 for use when hand laying on footways.

Two levels of binder content are specified: Schedule 1A and Schedule 1B for crushed rock aggregate. The equivalent Schedules for gravel are Schedules 2A and 2B, and for slag Schedules 3A and 3B. Historically, the ‘A’ Schedules have been those mainly used. The ‘B’ Schedules are typically reserved for high elevation locations, or cold, or very wet areas, i.e. very limited locations particularly in England.

The Overseeing Organisation should be aware that since the advent of design mixtures, most producers do not carry traditional asphalt sands, but use those which have a lower binder demand. Surface courses manufactured to recipe mixtures with these lower binder demand sands may therefore prove to have too high a level of binder and hence be at greater risk of deformation.

Hot Rolled Asphalt Surface Course Design Mixtures

5.3 Design mixtures are covered by two separate clauses. Clause 911 permits 10 varieties of HRA surface course whereas Clause 943 permits only 35/14F. Clause 911 permits more scope for the Overseeing Organisation to determine the degree of design required whereas Clause 943 requires minimum levels of rut resistance.

Although Clause 943 does not specifically state the type of HRA that is to be designed, it infers from other requirements that it is intended for 35/14 and this is confirmed by Clause C2.5.1.3 of BSI PD 6691, which states specifically that the design mixture shall be 35/14F. As is shown by Clause 911, there is no reason why the whole range of HRA mixtures should not be designed, and many other varieties have been used successfully over the last 30 years since the concept of designing surface courses was first introduced in the late 1970s. This anomaly may be amended in due course or other HRA types added to Clause 943.

Polymer modified binders may be required as part of the design approach, in particular to provide resistance to rutting (see Chapter 3 Binders).

Figure 5.2 HRA after 15 years' Service – Note Polishing of the Chippings, but Good Macro-texture Retention

Figure 5.3 HRA after a Similar Period to Figure 5.2; however, These Chippings have not Polished, but are Worn (Lower Macro-texture) because they are a Different Stone Type (Pennant Sandstone) which Retains Micro-texture. (Photographs from a Report to the Office of the Deputy Prime Minister and the Mineral Industry Research Organisation – Capita Symonds Ltd 2004: 'The Sustainable Use of High Specification Aggregates for Skid Resistant Road Surfacing in England').

Even where recipe mixtures are being considered, it may be necessary to design a suitable mixture to avoid one that is too rich; in this case, it would only be necessary to optimise the binder content using a suitable method. One method that has traditionally been used is the Marshall procedure. No requirement for Marshall 'stiffness' (stability/flow) would be needed, but, as a check, the ability of the material to be compacted to 4±2% voids should be established in a trial section. Where rutting resistance is required, the wheel tracking rate should be established from the same trial.

5.4 When designing 55% stone content mixtures, a softer binder can often produce Class 1 rutting resistance and 100/150 pen grade has been used for many years without problems with deformation even in towns. It is considered that at this level of stone content there is significant interaction between the aggregate particles.

Figure 5.4 55/10 HRA – Sufficient Macro-texture for Low Speed Roads

5.5 Where a high friction surfacing is to be applied to new HRA surfaces, the section of chipped asphalt under the proposed high friction section should be replaced with 55/10 HRA (RSTA/ADEPT code of practice for laying high friction surfaces). This is because the protruding chippings of chipped asphalt would preclude the provision of a durable high friction surface (the chippings would 'grin' through very quickly). The 55/10 HRA would need to have at least the same resistance to rutting as the rest of the road, or even better, as the high friction surfacing is likely to be in locations where traffic is more canalised. It may be necessary to place relevant signage to warn motorists between the time of laying the 55/10 HRA and the time of installing the high friction surfacing, because of the lower macro-texture.

Texture Depth

5.6 Clause 921 gives minimum texture requirements for all roads at all speeds whereas the advice in DMRB HD 36 states that macro-texture is only a requirement for traffic speeds above 65 km/hr. There is a need for further information regarding the level of texture depth required for low speed roads (specifically, those areas with 30 or 40 mile/hr speed limits). It is intended that the necessary advice will be provided in due course.

When high macro-texture is achieved using pre-coated chippings, the final surface is relatively noisy – typically 3dBA or more above the noise produced by Clause 942 thin surface course systems.

On low speed roads (30 or 40 mile/hr speed limits), this noise can be mitigated by reducing the texture depth (Clause 921) or not requiring any, an option in HD 36. If the HD 36 option is taken in these areas, which are urban or peri-urban, the workmanship can concentrate on getting the chippings properly embedded without the need to ensure that the rolling does not occur too soon. Provided that the necessary 70 % of the shoulder to shoulder coverage of the chippings is ensured, the rollers can be kept up close behind the chipping machine which should be running as close as possible to the paver. This assists in the provision of a good durable surface in these locations, which are often difficult due to variation in width, the presence of ironwork and the need to maintain access to premises adjacent to the highway for the maximum amount of time.

An alternative where a minimum texture depth is not needed is to use 55/10F or smaller pre-coated chippings (14mm) in 35/10 HRA.

Skidding Resistance

5.7 Where 30% or 35% stone content HRA surface course is used, the skidding resistance is provided by the, usually, 20 mm pre-coated chippings that are rolled into the surface. The polished stone value (PSV) of the chippings should be adequate to provide the skidding resistance required for the safe passage of traffic on the road. HD 36 gives advice on the suitability in various situations.

It should be particularly noted that the table in HD 36 is for designers that are not knowledgeable about skidding resistance. To quote Note 6 of Table 3.1 of HD 36: “Where designers are knowledgeable or have other experience of particular site conditions, an alternative PSV value can be specified”. Clause 3.11 of HD 36 also states that: “The minimum values of PSV given in Table 3.1 are the values to be used if no other information is available. On an existing site, if the life that has been achieved by the aggregates, the skid resistance and the skidding accident rate have all been satisfactory, then the continued use of the same aggregate source, albeit with a lower PSV than that given in Table 3.1 may be considered.”

Research has shown that for a given PSV, the smaller the chipping the higher the Characteristic SCRIM Coefficient (CSC). Therefore, although a lower proportion of high PSV aggregate is used for chipped HRA surface course, its safety level may need a chipping with a higher PSV than would be needed in a 10mm thin asphalt surface course.

Other Factors

5.8 Where pre-coated chippings are used they should be distributed using a purpose built chipping machine that spans the mat being laid. This generally precludes the use of echelon paving and therefore HRA surface course must be laid in lane widths with joints following the white lines. In addition to this width limitation there is also the need to feed the chipping machine, so it is necessary to close the adjacent lane to allow access for the loading shovel. It is inevitable, therefore, that any single carriageway road or one carriageway of a two lane dual carriageway will need the carriageway to be closed for the duration of the work.

Figure 5.5 Application of Pre-Coated Chippings

Figure 5.6 Applied Chippings before Rolling – Note Chippings not Laid at the Kerb Edge

5.9 On sites such as roundabouts it is very difficult to lay HRA well, particularly if the roundabout cannot be completely shut. Chipping machines are very difficult to drive round corners and the rate of spread will be compromised. The inner edge of the chipper will always deliver a much higher rate of spread than the outer edge, as the fluted roller delivers a constant rate of chippings, but the outer edge travels considerably further. The problem is exacerbated on small, less than 50m diameter, roundabouts. As an example: on a roundabout with a central 30m diameter island and laying the inner rip of 3.7m width, the rate of spread on the inside edge is (say) 70% of shoulder to shoulder cover but the outside edge will receive a rate of only 56% of shoulder to shoulder cover .

5.10 In urban areas, 55 % stone content HRA has been used for many years by a number of authorities very successfully, following the advice in HD 36 that texture is not required on low speed roads. It is very much easier to lay in confined areas and on single carriageway roads traffic management is easier; it may be possible to operate under traffic light control and if the site is difficult, convoying at10 mile/hr can also be used

5.11 The parameters that need to be specified for HRA have been taken from BS EN 13108 Part 4 and are shown in Table 5.2. Some are specific to national requirements (see also BSI Published Document PD 6691). These parameters are highlighted in red in Table 5.2 which summarises the various BS EN tables ZA.1.

Requirement for HRA	Values	Required in BS EN 13108 Part 4
Layer thickness	Minimum and maximum	Yes
Aggregate size	Maximum	Yes
Void Content	Minimum and maximum	Yes
Binder content	Minimum	Yes
Water sensitivity	Minimum	Yes
Grading (this is usually designed by supplier)		Yes
Voids in mineral aggregate (not normally specified)	Minimum and maximum	No
Voids filled with bitumen	Minimum and maximum	No
Resistance to permanent deformation	Minimum	Yes
Stiffness	Minimum and maximum	Yes
Binder Drainage	Maximum	No
Indentation	Minimum and maximum	No
Durability of the characteristics against ageing, weathering, oxidation, wear, ravelling, chemicals and stripping	Binder volume and all requirements relevant	Yes

Table 5.2 Parameters that Need to be Specified for HRA

National requirements include texture depth, skidding resistance (specified by the use of minimum PSV levels) and ride quality (specified by means of the rolling straight edge).

Other parameters are material specific and are set out in Table ZA.1 of BS EN 13108-4. The levels given in the standards are for materials as manufactured NOT as laid.

However, it is important that some of the parameters are specified (and measured) on the as-laid material.

Normative References

BS EN 13108-4, Bituminous mixtures – Material specifications – Part 4: Hot Rolled Asphalt.

BSI PD 6691, Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications.

The Design Manual for Roads and Bridges, Volume 7 – HD 36.

The Design Manual for Roads and Bridges, Volume 7 – HD 39.

Manual of Contract Documents for Highway Works, Volume 1

Manual of Contract Documents for Highway Works, Volume 2

Informative References

RSTA Code of Practice for High Friction Surfacing (RSTA, 2011)

Report to the Office of the Deputy Prime Minister and the Mineral Industry Research Organisation – Capita Symonds Ltd 2004: ‘The Sustainable Use of High Specification Aggregates for Skid Resistant Road Surfacing in England’

British Standard BS 594. Hot rolled asphalt for roads and other paved areas. Part 1 (Superceded)

British Standard BS 594. Hot rolled asphalt for roads and other paved areas. Part 2 (Superceded)

Annex 5A

HRA surface course mixtures known to be in current use in England are shown in the table below.

Desig-nation	Listed in EN 13108-4	Clause in SHW	Current use	Comments
0/2F	Yes	910/911	Rarely used because it is now deprecated as a protection to bridge deck waterproofing	Known as ‘sand carpet’ traditionally
0/2C	Yes	911	None known	
15/10F	Yes	910	None known	
30/10F	Yes	910	With 14 mm chippings	Can be laid 35 mm thick
30/10C	Yes	---	PD 6691 states ‘not used in UK’	Current documents list this as 0/10F which needs reviewing
30/14F	Yes	910/911	Surface course on lightly trafficked roads	
30/14C	Yes	911	None known	
35/14F	Yes	910/911/ 943	Surface course – only as design mixture for the trunk road network	
35/14C	Yes	911	Surface course	Crushed rock fines likely to reduce workability and make it more difficult to ensure retention of chippings
45/6F	No	---	Footway surface course, hand laid	Usually used with 160/220 pen binder. Specification given in HD 39 in terms of BS 594
45/10F	No	---	Hand laid footways and hand laid structural patching	Usually used with 160/220 pen binder. Specification given in HD 39 in terms of BS 594
45/14F	No	---	Hand laid structural patching	Usually used with 160/220 pen binder. Used less commonly than 45/10F
55/6F	No	---	Machine laid surface course where a very thin course is required	
55/10F	Yes	911	Machine laid surface course	Often used with 100/150 pen binder
55/10C	Yes	911	Machine laid surface course	Often used with 100/150 pen binder. Needs very tight control because of the crushed rock fines
55/14F	Yes	911	Machine laid surface course	Often used with 100/150 pen binder
55/14C	Yes	911	Machine laid surface course	Often used with 100/150 pen binder. Needs very tight control because of the crushed rock fines

6. STONE MASTIC ASPHALT (SMA) SURFACE COURSE

Introduction

6.1 The development of Stone Mastic Asphalt (SMA) began in the 1960s in Germany. The material was initially developed to provide a better alternative to chipped Gussasphalt to reduce the wear caused by studded tyres. Due to its enhanced resistance to deformation and improved durability, the potential of SMA was soon recognised and developments continued, leading to the first publication of a German Standard Specification for SMA material in 1984, and to further developments in other countries in Europe, USA, Japan and Australia. Currently in the UK, BS EN 12697-5 and BSI PD 6691 are the main standard references for generic SMA materials.

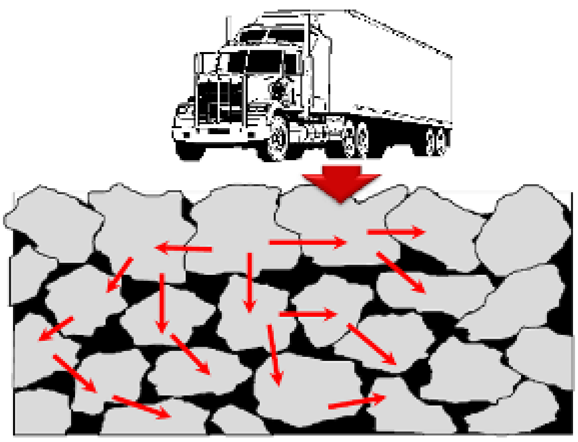
6.2 SMA to a generic specification must not be used as a surface course on the Strategic Road Network (SRN) without a Departure from the Overseeing Organisation.

Properties

6.3 SMA essentially consists of discrete and almost single sized coarse aggregate particles (typically around 70%) forming a skeletal structure bonded together by mastic. The mastic consists of a blend of crushed rock, sand, added filler and an additive or modifier, bound with bitumen (often modified). At the bottom, and in the bulk of the layer, the voids in the coarse aggregate are almost entirely filled by the mastic, while at the surface the voids are only partially filled resulting in an open (‘negative’) surface texture. Provided texture is maintained, this provides good skidding resistance at all speeds and facilitates the drainage of surface water. Figure 6.1 illustrates the typical appearance of an SMA surface course. A comparison of the grading curves of asphalt concrete and SMA (reproduced from EAPA, 1998) is given in Figure 6.2.

6.4 A correctly designed SMA mixture should exhibit the following properties:

- Strong aggregate skeleton, to promote high resistance to deformation;
- Binder rich, to promote durability and resistance to cracking;
- Much coarser surface texture than conventional dense graded asphalt, which provides the enhanced skid resistance and good light reflectivity.



Top view

Cross-section

Figure 6.1 Appearance of SMA Surface Course

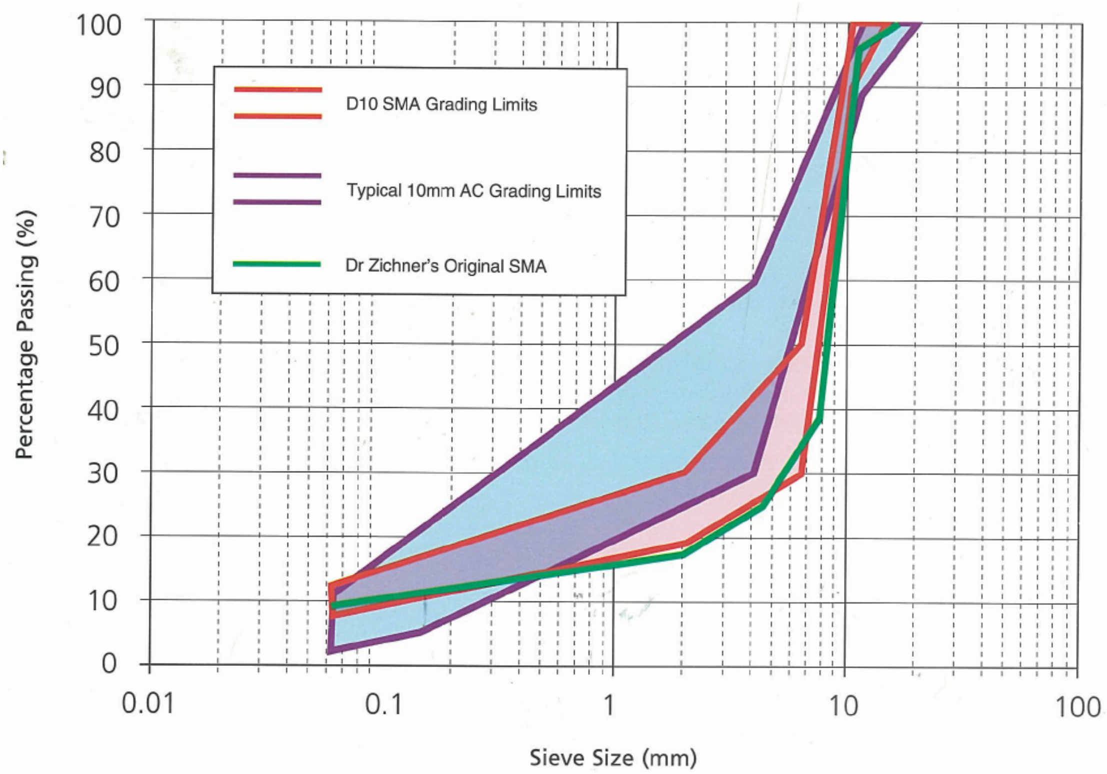


Figure 6.2 A Comparison of the Grading Curves of Asphalt Concrete and SMA (Source: EAPA, 1998)

Aggregate

6.5 Coarse aggregate must be crushed rock or steel slag complying with MCHW1 Clause 901 when tested in accordance with BS EN 13043. The coarse aggregate shall additionally have the following properties: Polished Stone Value (PSV), Aggregate Abrasion Value (AAV) – values to be recorded; Los Angeles Coefficient (LA) – not greater than LA_{30}, and; Flakiness Index (FI) - not more than FI_{20}. To prevent premature failure such as stripping or ravelling, the coarse aggregates should also have good affinity with binder. Further advice on aggregate properties can be found in HD 36 and BSI PD 6682-2.

Binder

6.6 Bitumen with paving grades ranging from 40/60 to 100/150 has been used for producing SMA. An optimum range of binder content is normally specified to ensure that the target binder content is sufficiently high to provide adequate resistance to oxidative hardening and moisture induced damage, without experiencing binder drainage during production, hot storage and transportation or fatting up in service during hot weather.

Added Filler

6.7 Added filler may be hydrated lime, crushed limestone or cement complying with the grading of BS EN 13043:2002 (Clause 5.2.1). The inclusion of hydrated lime or cement may enable a higher binder content and a stiffer mixture to be achieved. Hydrated lime can also assist in improving resistance against age hardening, moisture induced damage and low temperature cracking and may be added up to a maximum of 2.0%by weight of total aggregate.

Other Additives and Modifiers

6.8 Due to the increased binder content in the SMA mixture, in particular if paving grade bitumen is used, the inclusion of a good quality stabilising agent is essential. Although a significant variety of stabilising agents have been considered (i.e. cellulose, mineral wool fibres, glass fibres, artificial silica, rubber powder, rubber granules, polymers, even asbestos fibres), research studies carried out in Germany

(1982-1983) and the USA (early 1990s) demonstrated that cellulose fibres are the best technical and most cost effective option.

6.9 Cellulose fibres are often used as an additive to prevent binder drainage during production, storage and transportation when the material is hot. These fibres must be added in pelleted form, either wax-coated or bitumen coated, at not less than 0.3%by mass of the total mixture.

6.10 Improved performance and durability have been associated with the use of polymer modified binders (such as Styrene Butadiene Styrene) and crumb rubber in the stone mastic asphalt mixture design. The use of epoxy resin binder in SMA has been trialled in the UK as a part of OECD/ITF (Organisation for Economic Co-operation and Development/International Transport Forum) collaborative research work on long life surfacing. Monitoring of this trial is currently ongoing, and limited results to date have shown the potential of the epoxy modified material to provide improved resistance against rutting, fuel and moisture damage, and improved life, compared with conventional material. Modification of bitumen using polymers, crumb rubber or epoxy resin is a complex matter and requires specialist expertise to formulate and manufacture a consistent product for intended use.

6.11 Polymer modified binders must not be used on the SRN without prior approval from the Overseeing Organisation unless they have HAPAS or equivalent Third Party Approval Certification. Only manufacturer pre-blended polymer modified binders are permitted for use on the SRN since they are known to offer more consistent quality than those blended on site.

6.12 Other additives such as industrial wax and amines may be used to improve low temperature workability and aggregate affinity with binder, subject to approval from the Overseeing Organisation.

Reclaimed Material

6.13 Unless otherwise permitted by the Overseeing Organisation, reclaimed asphalt must not be used in SMA surface course. If approval for use of reclaimed asphalt is granted by the Overseeing Organisation, the best practice guide described in TRL Road Note 43 must be followed.

Mixture Design

6.14 The first essential step in designing a good quality SMA mixture is ensuring that the aggregate grading provides a strong skeleton that will accept the high binder content necessary to provide the durability without binder drainage. An incorrect aggregate grading, with an inappropriate binder demand, could have undesirable consequences, such as:

- Too much binder – could cause binder drainage during transport, ‘fatted’ areas on the surface, coarse aggregates being pushed apart;
- Not enough binder – could obstruct compaction, leading to high air void contents and not enough binder coating the aggregates.

6.15 Most of the mixture design work on SMA to date has been carried out using the Marshall Mixture Design principle, where test specimens are produced by using a Marshall (impact) compactor. It is believed, however, that SMA samples would be more efficiently manufactured using either a laboratory roller or a gyratory compactor (kneading type), rather than with an impact type compactor. The former two methods allow aggregate re-orientation during the compaction process, resulting in dense compacted material which more realistically simulates field compaction, and avoids aggregate fracture during the process (particularly problematic for stone-to-stone contact mixtures such as SMA).

6.16 SMA surface course does not necessarily fall within the classification of the MCHW1 Clause 942. This material has typically been specified either based upon BS EN 13108-5, which is a recipe based mixture design but with additional performance related testing requirements such as sensitivity to water, resistance to permanent deformation and resistance to fuel, or, based upon a performance-based mixture design, such as those proprietary thin surface course systems certified by HAPAS or equivalent Third Party Approval Certification for highways applications; Chapter 4 refers.

Transport Scotland Specification 2010 (TS2010)

6.17 In 2010, Transport Scotland issued an SMA surface course specification TS2010 which was derived from German specifications and experience, broadly conforming to BS EN 13108-5. Under TS2010, such conformity should be established in accordance with BS EN 13108-20 and BS EN 13108-21, although formal CE marking is not currently required.

6.18 Aggregates other than crushed rock or crushed gravel are not permitted. Furthermore, the use of reclaimed material is also not permitted. Three nominal maximum aggregate sizes are permitted in the SMA grading, specifically 0/6mm, 0/10mm and 0/14mm; these provide options to construct surfacing thicknesses between 20mm and 50mm depending upon the chosen aggregate sizes. Only polymer modified binder grade 75/130-75 conforming to BS EN 14023 is permitted for use under this specification.

6.19 The requirements for surface macrotexture have been relaxed to accommodate the use of smaller aggregate size, which is favoured to reduce noise and the risk of fretting. In fact, there is no minimum requirement for surface macrotexture; however, to ensure that this approach does not compromise wet friction resistance, precoated grit must be applied (see Figure 6.3) and a wet friction compliance test by a calibrated Grip Tester must be carried out.

6.20 There are two optional nominal sizes for precoated grit: 2/4mm for 0/14mm SMA and 1/2.8mm for 0/6mm or 0/10mm SMA, machine applied at 1.0 – 1.5kg/m^2 and 0.5 – 1.0kg/m^2, respectively, from hoppers attached to a roller. The grit is applied after the asphalt has been laid and after the initial compaction by roller. When the material has reached ambient temperature, any surplus grit must be removed carefully prior to the application of road markings and before the road is opened to traffic.

Figure 6.3 Gritting Application on SMA Surface Course (Source: Gartner, 2012)

Figure 6.4 Appearance of SMA Surface Course Before and After Gritting (Source: Prowell, 2009)

Performance and Durability

6.21 Research worldwide has demonstrated that SMA generally performs well; the main problems have been associated with fretting, 'fatting up' and damage due to the substantial use of de-icing chemicals, which are typically used in Northern Europe for winter maintenance. For example, in Finland, de-icing chemicals are suspected of being the cause for the appearance of some soft binder-rich, sticky surface spots with low friction. According to a European study (EAPA, 2007), well designed stone mastic asphalt may offer between 15 and 25 years service life on heavily trafficked European roads.

6.22 SMA has proved to be durable and resistant to age hardening as a consequence of its low void content and thick binder film. As a result, it is resistant to premature cracking, ravelling and moisture damage. Other advantages claimed for the material are its ability to shape an uneven or rutted surface, because the majority of the compaction is carried out by the paver and there is little further compression under rolling. It is necessary to limit the void content to ensure adequate durability. However, if the void content is too low, deformation usually occurs resulting in a loss of surface texture and rutting. The specified range of air voids content is typically between 3 and 6%.

6.23 It has been observed, however, that there is potentially a greater risk associated with open texture when larger aggregate sizes are used, leading to increased permeability of the SMA surface course. This may trigger fretting and other moisture induced damage within this layer and/or the layer underneath. On the other hand, the use of high binder content, if not balanced with suitable aggregate grading and/or other additives, may lead to 'fatting up' problems. Another risk reported is low early life skid resistance of SMA surface course; this is suspected to be related to the relatively thick bitumen film at the surface which, for some polymer modified binders, has very good adherence to the aggregate and takes a long time before being worn off by traffic. The application of precoated grit can effectively minimise this risk.

Figure 6.5 Variable Appearance of SMA Surface Course: Binder Rich (SMA 10) and Non-uniform Texture (SMA 14), (Source: Mangan, 2007)

6.24 Germany has used 0/16 SMA as a binder-course where rutting has been a problem below the surface course. For SMA binder courses, see Chapter 2 of this Part.

Restrictions

6.25 Site trials undertaken in the UK have confirmed German experience that SMA mixtures are vulnerable to small variations in aggregate grading and binder content, which can result in a reduction in surface texture. SMA to the same specification but using aggregates from different sources, laid on a variety of trial sites on roads in England have, whilst performing admirably in other respects, produced inconsistent results in terms of the texture retention essential for high speed skid resistance. Consequently, any proposal for use of this surface course should be supported by evidence of a track record for its use on a similar road category. This may include demonstration of in situ performance of the innovative product from pilot or field trials. A step-by-step guide to conduct these trials is available from the Highways Agency website via http://www.dft.gov.uk/ha/standards/pilots_trials/section1/overview.htm (Last accessed on 8 November 2012).

6.26 To take advantage of the superior properties of SMA as a surface course, proprietary versions designed for particular aggregate sources have been developed as thin asphalt surface course (TASC) systems to ensure surface texture is maintained. These are described in Chapter 4 of this Part.

Monitoring and Testing

6.27 Performance of approved SMA surface course must be monitored for at least two years after the completion of the installation under a Type Approval Installation Trial (TAIT) arrangement.

6.28 The purpose of the TAIT is to demonstrate that the product is able to be consistently produced in accordance with the requirements of the Work Specification, and that it demonstrates the necessary properties, such as:

- Aggregate and binder properties;
- Composition analysis (aggregate grading and binder content);
- Mixture volumetrics (including air voids content);
- Binder drainage;
- Resistance to permanent deformation;
- Surface macrotexture.

Furthermore, the above evaluation should include visual assessment of defects and surface skid resistance.

6.29 Unless otherwise specified in Appendix 7/1, an approved surface course product must carry a five-year guarantee against defects such as fretting, ravelling, stripping and loss of chippings.

6.30 This guarantee excludes defects arising from accidental damage or damage due to settlement, subsidence or failure of the underlying carriageway on which the surfacing material has been laid.

Normative References

BS EN 13108-5, Bituminous mixtures – Material specifications – Part 5: Stone Mastic Asphalt.
BS EN 13043, Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas.
BS EN 14023, Bitumen and bituminous binders – Specification framework for polymer modified bitumens.
BSI PD 6682-2, Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas — Guidance on the use of BS EN 13043.
The Design Manual for Roads and Bridges, Volume 7 – HD 36.
Manual of Contract Documents for Highway Works, Volume 1 - Clause 942.

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EAPA (1998). Heavy duty surfaces: the arguments for SMA. ISBN 90-801214-8-7.
EAPA (2007). Sustainable – Long Life Asphalt Pavements, European Asphalt Pavement Association, Position Paper. June.
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Elliott RC, Widyatmoko I, Chandler J, Badr A and Lloyd WG (2008). Laboratory and Pilot Scale Assessment of Long Life Surfacing for High-Traffic Roads, 4th Eurasphalt & Eurobitume Congress, Denmark, 21 – 23 May.
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TRL PR65. Evaluation of stone mastic asphalt: a high stability wearing course material.
TRL Road Note 43. Best Practice Guide for Recycling into Surface Course. Transport Research Laboratory, 2010.
TS2010. Surface Course Specification & Guidance Issue 01, Transport Scotland, Issue 02. January 2012

7. POROUS ASPHALT SURFACE COURSE

Introduction

7.1 Porous asphalt was introduced in the US in the 1930s as a single layer surface course with reduced spray characteristics to promote safety and wet skid resistance. In the mid 1980s, its reduced noise characteristics were recognised in the US and Europe as an attractive environmental benefit, especially in residential areas. In order to optimise the mixture's properties, particularly noise reduction, twin layer porous asphalt was introduced in the early 1990s in Europe and Japan, the surface layer being manufactured from smaller coarse aggregate (Morgan, 2007).

7.2 This material consists primarily of gap-graded aggregates held together by binder to form a matrix with interconnecting voids through which water can pass. Provided that the crossfall is sufficient it acts as a reservoir and a lateral drain throughout the time it is wet. Unfortunately, the interconnected voids allow excellent access to air; so ageing and embrittlement are potentially exacerbated. Ideally, a softer binder, together with a thick cohesive and adhesive binder film is desirable, so binder modification is necessary.

7.3 Porous asphalt must not be used on the Strategic Road Network (SRN) without prior approval from the Overseeing Organisation.

Properties

7.4 The current standard for porous asphalt mixture is BS EN 13108-7; it is also specified in Clause 938 of MCHW1. The material typically has over 20% air voids content, relies on aggregate interlock to resist deformation, and is heavily dependent upon binder characteristics to retain cohesion and durability. Desirable properties include: reduction in noise and spray; resistance to rutting and reflection cracking; wet skid resistance, and; good riding quality.

7.5 Polymer modified bond coat must be specified for use beneath porous asphalt to maintain good adhesion with the substrate; the bond coat must comply with Clause 920 of MCHW1. A higher application rate of polymer modified bond coat must be used to reduce the permeability of the underlying pavement layers.

Aggregate

7.6 Coarse aggregate for porous asphalt surface course must be crushed rock complying with MCHW1 Clause 901 when tested in accordance with BS EN 13043.

7.7 Aggregates should be strong, durable and have good affinity with bitumen. Premium quality aggregate is typically specified with maximum nominal sizes from 6mm to 20mm, to produce layer thicknesses between 20mm and50 mm. If used as a single layer, however, the preference has been towards smaller nominal sizes (and hence thinner layers) in order to obtain better noise reduction and longer service life. The coarse aggregate for surface course must additionally have the following properties: Polished Stone Value (PSV); Aggregate Abrasion Value (AAV) – values to be recorded; Los Angeles Coefficient (LA) – not greater than LA_{30}, and; Flakiness Index (FI) - not more than FI_{20}. Some aggregates are more prone to loss of binder adhesion by the action of water than others and additional care should be taken with such aggregates. Very high PSV aggregates generally have less resistance to crushing at the few points of contact of the particles in porous asphalt and should be specified with care.

7.8 Special attention is required during mixture design to produce a combined aggregate grading and aggregate packing which can provide good hydraulic conductivity and adequate surface macrotexture with good resistance to wet friction.

7.9 Further advice on suitable aggregate properties can be found in HD 36 and BSI PD 6682-2.

Binder

7.10 Bitumen with paving grades ranging from 40/60 to 160/220 has been used for producing porous asphalt. However, soft bituminous binders (such as paving grade 160/200) have been found to provide better longevity as they allow greater flexibility, age more slowly and possess better capability for healing. The use of a softer base binder generally requires polymer modification.

7.11 An optimum range of binder content (minimum and maximum) is normally specified, to ensure that the target binder content is sufficient to provide adequate resistance to disintegration, oxidative hardening and moisture induced damage, whilst maintaining the minimum air voids content for drainage of water and reduced noise and to avoid binder drainage during mixing, handling and laying.

7.12 Binder grade and content must be specified to ensure a balance between workability, durability and good relative hydraulic conductivity (high void content).

Added Filler

7.13 Added filler may be crushed limestone or hydrated lime. The inclusion of hydrated lime may enable a higher binder content and a stiffer mixture to be achieved. Hydrated lime can also assist in improving resistance against age hardening, moisture induced damage and low temperature cracking. To assist in preventing binder stripping and to promote durability, hydrated lime between 1.5 and 2% by mass of total aggregate/filler should be included for most binder systems.

The Use of Additives and Modifiers

7.14 The most usual additive is cellulose fibres, but mineral fibres and polymers have also been used, both separately and in combination.

7.15 Cellulose fibres (sometimes pre-coated with bitumen) are often used as an additive to prevent binder drainage during production, storage and transportation when the material is hot. These fibres should be added in pelleted form, either wax-coated or bitumen coated, at not less than 0.3% by mass of the total mixture.

7.16 Modification of bitumen using polymers such as Ethylene Vinyl Acetate (EVA), Styrene Butadiene Styrene (SBS), crumb rubber or epoxy resin is a complex matter and requires specialist expertise to formulate and manufacture a consistent product for the intended use. The binder performance relies on the base bitumen, the amount of polymer added and the method of manufacture. Improved performance has been associated with the use of pre-blended polymer modified binders in the porous asphalt mixture design, especially with a high percentage of polymer addition (e.g. 8% or higher) and soft base bitumen (such as paving grade 160/220).

7.17 Experience in Japan has shown that for long term performance, high polymer contents are necessary. They have shown that 9% of SBS can result in improved Cantabro results, (BS EN 12697-17 Bituminous mixtures – Test methods for hot mix asphalt – particle loss of porous asphalt specimen). For cold mountainous areas, they increase SBS content up to 13% (Motomatsu, 2004). In the UK, these high polymer percentages have not been trialled to any great extent and early-life failures of less highly modified systems, which were installed without bond coats, have impacted on the initial enthusiasm to use porous asphalt.

7.18 Polymer modified binders must not be used on the SRN without prior approval from the Overseeing Organisation unless they have a HAPAS or equivalent Third Party Approval certificate and have been demonstrated in a TAIT. Only pre-blended polymer modified binders are permitted for use on the SRN since they are known to offer more consistent quality than those blended on site.

7.19 Crumb rubber modified porous asphalt has been successfully used in some parts of Europe and USA to combat reflection cracking and rutting. The use of epoxy resin binder has been trialled in New Zealand with good results. Hydrated lime is not recommended for inclusion in epoxy porous asphalt.

Reclaimed Material

7.20 It is generally undesirable to use reclaimed asphalt in porous asphalt, because of the need to carefully control the coarse aggregate particle size and shape. The binder characteristics also require expert control.

7.21 Unless otherwise permitted by the Overseeing Organisation, reclaimed asphalt must not be used in porous asphalt surface course.

Mixture Design

7.22 Porous asphalt is traditionally designed by recipe, such that the combined aggregate grading and minimum binder content are specified; binder drainage and permeability tests are also commonly specified to ensure good workability and functionality, respectively. However, climate and traffic loading have progressively changed in the UK towards more severe conditions. This makes the traditional mixture design no longer sustainable and performance-related mixture design is required to accommodate these changes. A number of performance-related tests are now included in BS EN 13108-7, such as water sensitivity, bitumen-aggregate affinity, particle loss, resistance to fuel and de-icing fluid. In addition to these, the scuffing test has been found to be a useful tool to assess the material's resistance against shear force. Furthermore, the air voids must be designed at full compaction; poor compaction to increase void levels will result in rapid failure.

Figure 7. 1 Typical Porous Asphalt Grading on the Right Compared with the Continuous Grading of an Asphalt Surface Course on the Left

7.23 The typical appearance of single and twin layer porous asphalt is shown in Figures 7.2 and 7.3, showing single size 0/10mm aggregate, and a sandwich of 2/6mm and 11/16mm aggregate structures, respectively.

Figure 7. 2 Typical Porous Asphalt Material (Source: URS and EAPA)

Figure 7. 3 Typical Twin Layer Porous Asphalt Material (Source: EAPA and www.stillerverkeer.nl)

7.24 Good mixture design will ensure the presence of interconnecting air voids within porous asphalt. Assessment can be done in the laboratory or in situ by using the permeability or hydraulic conductivity tests to BS EN 12697-19 or BS DD 229, respectively. Figure 7.4 illustrates the setup for the hydraulic conductivity test; an operative would normally stand on each standing board throughout the test duration to secure the test apparatus in place and compress the rubber annular disc to provide a seal.

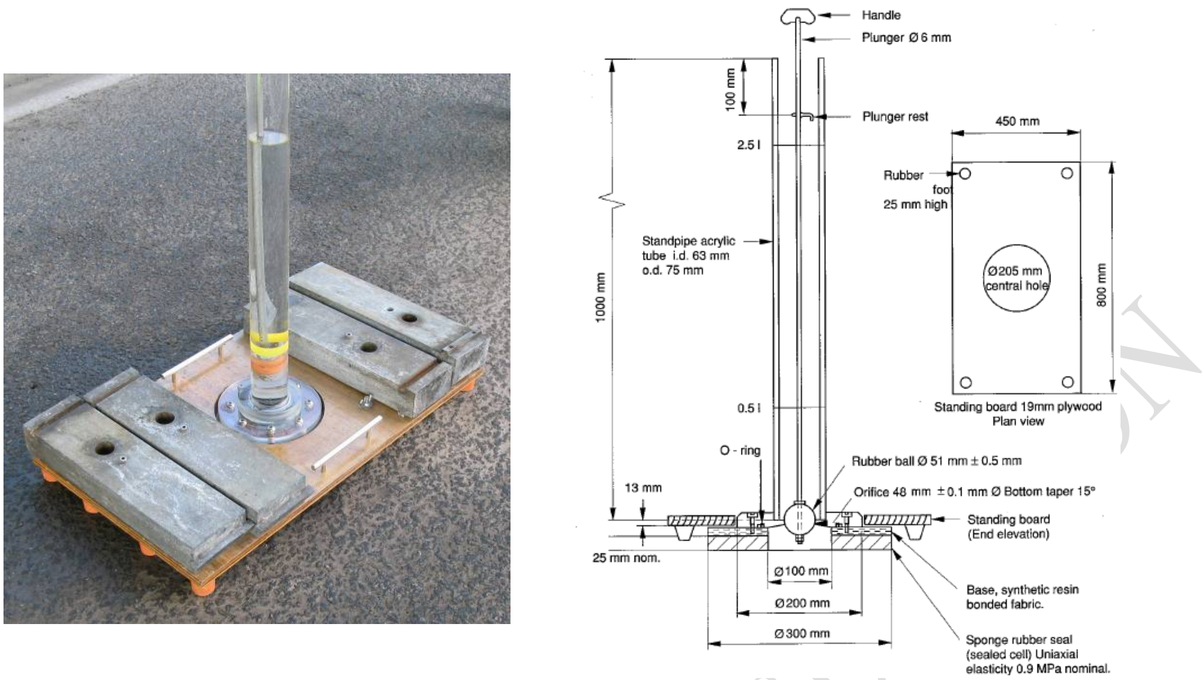

Figure 7. 4 Hydraulic Conductivity Apparatus (Source: URS and BS DD 229)

Performance and Durability

7.25 The durability of porous asphalt is dependent on the binder content (a minimum level should be specified), how well the material is laid, the soundness of the base on which it is laid, the site characteristics, design layout, drainage and traffic flow. Porous asphalt performs best on high speed roads having good vertical and horizontal alignment, an effective drainage system and few (if any) junctions. These tend to be the case for motorways and rural dual carriageways.

7.26 Until the 1980s, all porous asphalt laid on the SRN in the UK had been on trial sections. The earliest of these was recorded in May 1967 on the M40 High Wycombe by-pass in Buckinghamshire; a second was laid in September of the same year on the A452 Leamington to Stonebridge road in Warwickshire. Since then, a number of major resurfacing works on the SRN have been undertaken throughout the country with varying levels of success. The most successful major resurfacing projects have demonstrated a service life greater than 12 years, whilst the least successful one experienced catastrophic failure within 6 months of opening to traffic.

7.27 The surface appearance of porous asphalt surface course changes with time as the binder coating becomes aged or removed from the surface; this is illustrated in Figure 7.5.

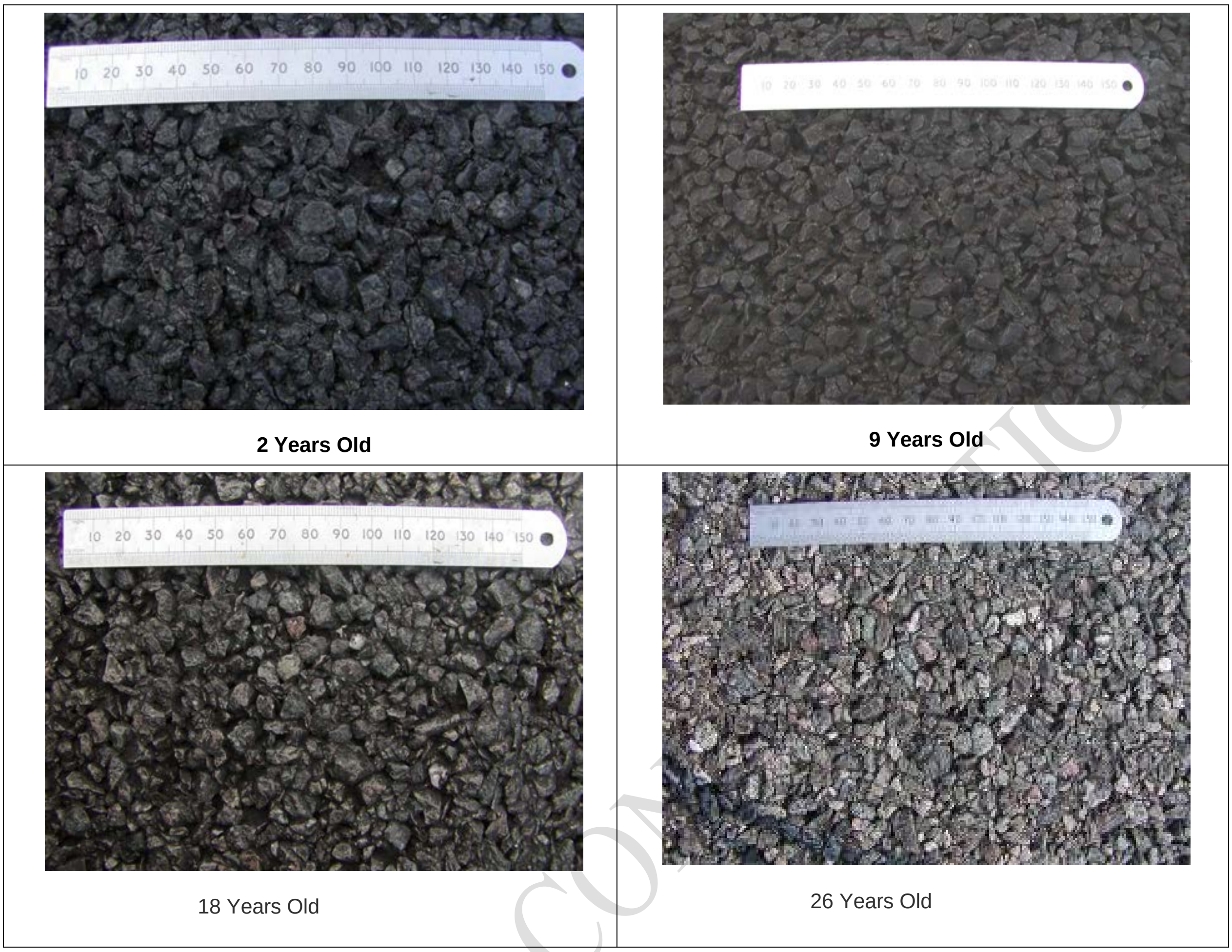

Figure 7. 5 Porous Asphalt Surfaces at Different Ages in Service (Source: URS)

7.28 According to a European study (EAPA, 2007), well designed porous asphalt may offer between 8 and 14 years service life as illustrated in Figure 7.6. Examples of mixture design and performance of overseas porous asphalt surface course are presented in Table 7.1.

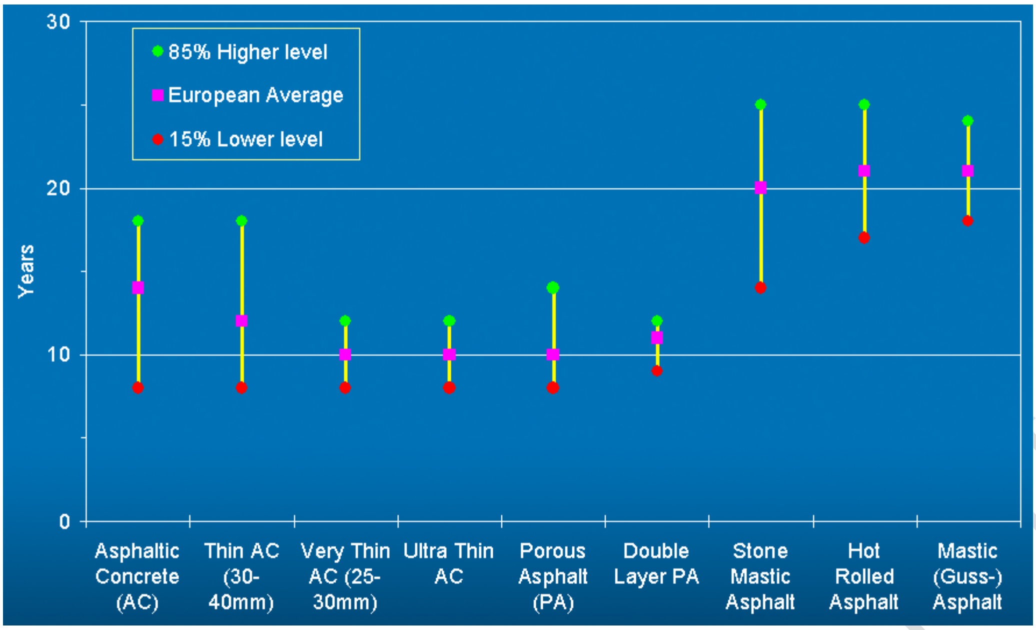

Figure 7. 6 Durability of Asphalt Surfacing on Heavily Trafficked European Roads (Source: EAPA)

Country	**Mix Design**	**Performance**
Netherlands	Twin layer porous asphalt (2/4mm over 11/16mm). Modifier only used for special purposes.	Reduced spray. Service life 10-12 years.
Germany	Single and twin layer porous asphalt (0/8mm) with modified binder.	Susceptible to ravelling and rapid ageing
France	Single layer porous asphalt (0/10mm and 0/6mm). Paving grade 50/70 and modified binders.	Binder richness modulus used to prevent ravelling. Average service life identical to conventional dense asphalt.
Austria	Single layer porous asphalt (0/11mm) with modified binder.	Rapid deterioration after first ravelling.
Spain	Single layer porous asphalt (0/12mm or 0/10mm).	Widespread use. Some ravelling issues.
Japan	Twin layer porous asphalt (0/13mm) with high percentage SBS-modified binder.	Reduced noise and spray
US	Single layer porous asphalt with crumb rubber modifier.	Reduced noise and spray. Widely use as a part of stormwater management. Good resistance to reflection cracking.
New Zealand (Field Trial)	Single layer porous asphalt with epoxy resin modified binder.	Increased strength. Reduced noise and spray.

Table 7.1 Use of Porous Asphalt Surface Course Overseas

7.29 Meiarashi and Oishi (2007) reported that there was no substantial difference between the permeability (spray suppression) of single layer and that of twin layer porous asphalt; however the latter has demonstrated better noise reduction.

7.30 Features associated with early life failure of porous asphalt include clogging, fretting, ravelling, debonding, shearing and indentation. When water is retained within porous asphalt, its life will usually be reduced. Frequent braking and turning movements by heavy traffic may cause ravelling and early failure. Once ravelling becomes noticeable, porous asphalt usually fails very rapidly, becoming much noisier in the process. Some reduction in void content and a closing up of surface voids occurs during service, due to the accumulation of detritus and surface compaction by traffic. However, even when the voids are closed up, it still provides a good reduction in noise levels and spray generation similar to thin surfacings, when compared to HRA surfaces, due to cross-surface drainage within the surface texture and sound absorbency. There is currently no reliable and cost-effective method of removing detritus from the voids although different water jetting and vacuum suction systems are used (Morgan, 2007). The wheel path areas seem to remain relatively clear. The problem of detritus clogging the voids of porous asphalt is more pronounced when it is used on the hard shoulder.

Restrictions

7.31 The substrate receiving new porous asphalt surface course must be sound and relatively impermeable unless the pavement structure is specifically designed to be pervious and self draining. The latter is often referred to as a Sustainable Urban Drainage System (SUDS), where all layers including the subbase will need to be porous and able to retain water until it soaks away naturally.

7.32 On multi-lane carriageways, where an impermeable surface is laid downstream of a porous asphalt surface, the lane ends of the porous asphalt should be staggered across the carriageway, in the direction of the drainage path. This will avoid excess water welling up over the transverse joint. For detailed guidance refer to HA 79 (DMRB 4.2.4).

7.33 Where porous asphalt is considered for surfacing concrete deck bridges, the sub surface water drainage system should be designed to permit an adequate water flow through and from the porous asphalt, taking into account the expansion joints. For detailed guidance refer to HA 79 (DMRB 4.2.4). Provision should also be made to ensure the porous asphalt system (including substrate) is well bonded to the concrete deck.

7.34 Porous asphalt can be laid over jointed concrete with an asphalt base. However, the joints have to be sufficiently tough to minimise the possibility of material being forced into the joints during compaction (Nicholls, 2001).

Normative References

BS EN 12697-19, Bituminous mixtures – Test methods for hot mix asphalt. Part 19: Permeability of specimen
BS EN 13108-7, Bituminous mixtures – Material specifications – Part 7: Porous Asphalt
BS EN 13043, Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas
BS EN 14023, Bitumen and bituminous binders – Specification framework for polymer modified bitumens
BSI PD 6682-2, Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas — Guidance on the use of BS EN 13043
BS DD229, Determination of the relative hydraulic conductivity of permeable surfacings
The Design Manual for Roads and Bridges, Volume 4 – HA 79
The Design Manual for Roads and Bridges, Volume 7 – HD 28
The Design Manual for Roads and Bridges, Volume 7 – HD36
Manual of Contract Documents for Highway Works, Volume 1 - Clause 938

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8. SURFACE DRESSING

Introduction

8.1 Surface dressing is the principal product used for routine maintenance of road surfaces; the product has a low carbon footprint and is an economic method of restoring skid resistance, sealing and preserving the road pavement. It is a cold-laid, sustainable product and optimises the use of high performance aggregates. The concept is straightforward: in its simplest form a thin layer of bituminous binder (generally a cationic polymer modified bituminous emulsion) is applied to the road surface and very clean stone chippings, nominally single-sized, are spread and rolled into it.

For the Strategic Road Network in England and for other stressed sites, more complex proprietary surface treatment products are specified as “Innovative Ultra-thin Treatments” (**IUTs**). They have Third Party Approval Certification of the installed product and are evaluated as competitor products to proprietary Ultra-thin Asphalt and Microsurfacing that use polymer modified bond coats as part of the system.

The industry ‘Design guide for road surface dressing’, Road Note 39 (RN39), the British Standards Institution Published Document PD 6689 Surface treatments, which provides guidance on the use of BS EN 12271 (‘Surface dressing – Requirements’), and the test method BS EN 12272-2 (‘Surface dressing. Test methods. Visual assessment of defects’), are necessary references.

Figure 8.1 Rural Road 10 mm Racked–in with 6 mm Surface Dressing Intermediate Polymer Modified Binder

Most lightly trafficked roads are successfully preserved with a 6mm single surface dressing, or 10mm racked-in with 3mm or 6mm chippings and intermediate grade polymer modified binders, depending on the design requirements. The specification of these chippings using BS EN 13043 – ‘Aggregates for use in bituminous mixtures and surface treatments for roads, airfields and other trafficked areas’ - is: 2/4, 2.8/6.3 and 6.3/10. Guidance concerning the specification of chippings is given in the BSI Published Document PD 6682-2 ‘Aggregates for bituminous mixtures and surface treatments for roads and airfields and other trafficked areas – Part 2: Guidance on the use of BS EN 13043’.

Figure 8.2 High-Speed Heavily Trafficked Road: Proprietary Surface Dressing (IUT) Comprising 14mm Primary Followed by 6mm Chipping Layer using Two Layers of a Premium Polymer Modified Bituminous Emulsion Binder

Surface dressings are not permitted on the Strategic Road Network (**SRN**) in England and Wales. However, Innovative Ultra-thin Treatments (**IUTs**), such as multiple-layered surface dressings using super premium or premium polymer modified binders and other proprietary surface dressings such as lock-sprayed or fibre-reinforced systems having a Third Party Approval Certificate following a two-year Type Approval Installation Trial (**TAIT**), are permitted for use on the SRN by means of a Departure from Standards in England and Wales. A specific MCHW1 Clause 940 is being drawn up to specify **IUTs**.

High-speed roads, heavily trafficked roads and urban roads, having greater traffic stress, require surface dressings with premium polymer modified bitumen binders, with two layers of binder and two layers of chippings (double surface dressing). Alternatively, for the highest durability, three layers of chippings and two or more layers of binder (multiple-layered surface dressing) may be used. For heavily trafficked roads, typically 8/14 chippings are used for double surface dressing followed by 2.8/6.3, although the design for lanes 2 and 3 of dual carriageways may require 6.3/10 primary chippings.

The specification for surface dressing has three separate approaches, recipe, performance-related and **IUT** specifications. Performance-related specifications may be acceptable for temporary works on the SRN in England.

These approaches differ with the risk taken by the Overseeing Organisation and the economic benefit evaluated against durability and robustness. Table 8.1 gives an overview, which is detailed later in this chapter.

CONTRACT TYPE	RECIPE	PERFORMANCE-RELATED	IUTs
Road Type (general description)	Rural, lightly trafficked or temporary work	Urban and rural and all traffic levels	Strategic Road Network in England with a Departure
Relative Cost	Low	Medium	Medium to High
Risk for Overseeing Organisation	Very high	Low	Very low
Guarantees for Performance	None	2 Years Macro-texture and defects	5 Years Declared skid resistance, macro-texture and defects
Clauses MCHW1	919 recipe	922 performance	940 IUTs
Type Approval Installation Trial	None	1 Year TAIT: PSV and Macro-texture	2 Years (Third Party Approval Certification)
Surface Dressing Types	Mainly single	Single, racked-in, sandwich and double	Proprietary double and multiple-layered
Binder	Low to medium modification BS EN 13808	Medium modification BS EN 13808	Highly modified Third Party Approval Certification for proprietary binders
Chippings	BS EN 13043	BS EN 13043	BS EN 13043
As-built Manual	None	Yes	Yes
Substrate Condition Requirements	Any	Reasonable	Sound
Monitoring	During installation	Years 1 and 2	Years 1, 2 and before 5

Table 8.1 Different Approaches to Specification Concerning Road Type, Cost and Risk

Surface dressing is also a suitable wearing surface for low cost construction and is normally used to seal in situ recycled bituminous roads and hydraulically bound bases. Further information is to be found in BS 434-2 – ‘Bitumen road emulsions (anionic and cationic). Code of practice for use of bitumen road emulsions ’.

The carbon footprint of surface dressing products used on the SRN in England and Wales must be evaluated and the Pavement Road Treatment Embodied Carbon Tools PRoTECT developed by RSTA should be used.

The Road Surface Treatments Association (RSTA) PRoTECT document and Codes of Practice for Surface Dressing Parts 1 to 9 are available on-line at www.rsta-uk.org and should be consulted when considering this Chapter.

Purpose of Surface Dressing

8.2 Surface dressing performs two functions which relate directly to Essential Requirements of the European Construction Products Directive:

Safety - Skid Resistance

8.3 Surface dressing increases the macro-texture and improves the micro-texture of the road surface, with minimum use of scarce high-quality aggregate. These properties directly influence the skid resistance of the road surface, a significant aspect of its contribution to safety.

Durability - Preventative Maintenance

8.4 Surface dressing seals the underlying road pavement against the ingress of water and air, which cause deterioration of the structural courses of the road. This is preventative maintenance, which directly influences the durability and therefore the life of the road; for this reason, surface dressings are sometimes referred to as Preservatives or Sealers. In order to maximise this protection, surface dressing should be applied as soon as minor crazing or fretting is first detected, which is well before the critical condition (major deterioration), when often the only solution is reconstruction.

Tender Programming

8.5 Tenders should be issued - based on a provisional programme if necessary - before the end of December preceding the summer in which the work will be carried out. Tenderers designing surface dressing systems will need time to visit each site to finalise their designs. After return of tenders, further time is necessary for tender evaluation and assessment including simple whole life cost comparison where appropriate.

Road hardness tests should be carried out in the summer or early autumn of the previous year to the installation, while road surfaces are above 20°C. Experienced contractors with premium quality plant are in limited supply and are committed to contracts on a first come first served basis. Consequently, late tendering will increase the risk of a contract being carried out by less experienced operators using poor quality equipment; however, using contractors registered to the Surface Dressing Sector Scheme 13A minimises this risk.

Contractors in possession of a quality assurance certificate ISO 9000 Series and National Highways Sector Scheme 13 have shown that they have the necessary skills and capability to ensure that surface dressing is installed in a safe, consistent and effective way. For this reason, it is a mandatory requirement for contractors wishing to tender for surface dressing contracts to be registered holders of the Sector Scheme, which satisfies ISO 9000. Sector Scheme 13: ‘For the supply and application of surface treatments to road surfaces’, is defined in Appendix A to the *Specification for Highway Works* (MCHW1)

There are risks of installing surface dressing outside a weather window, which are detailed in RN39. For the SRN in England and Wales, installation must be completed between mid-May and the end of July. If surface dressing is to be carried out at night, surface dressing must be completed earlier, by mid-July, unless otherwise stated in the Third Party Approval Certificate and with approval of the Overseeing Organisation.

Northern latitude, high, shaded and exposed sites have an even smaller weather window for minimal risk. The use of proprietary double surface dressing and multiple-layered surface dressing reduces this risk, especially when having to work late season.

High Polished Stone Value (PSV) chippings for heavily trafficked roads can be in relatively short supply during early summer when surface dressing is at its peak and to avoid delays and obtain best value for money, contracts should be let as early as possible.

The Product

8.6 Although the concept is straightforward, until adhesion is ensured and an interlocked mosaic of chippings formed, surface dressing is vulnerable to traffic, especially when site conditions are adverse: too wet, hot or cold. This might lead to the conclusion that, with the prevailing weather in the United Kingdom, there is little chance of success, but in fact the majority of roads are maintained by this process and techniques have been developed to increase early-life stability.

Where Surface Dressing may be Used

8.7 Hard uniform surfaces, including concrete roads, present minimal problems in terms of design; however, soft and variable substrates markedly reduce durability (performance) especially on heavily trafficked or stressed sites. If the existing road surface has a poor profile or is deformed in the wheel tracks (a rut depth greater than 10mm), pre-treatment by planing (milling) or surfacing may be required. In these circumstances, thin asphalt surfacing overlays or microsurfacing may have greater economy as they have some ability to improve profile.

8.8 There are some situations where it is not possible to provide controlled low-speed trafficking, which is normally used to settle a surface dressing down prior to sweeping and opening to unrestricted traffic.

Motorway and trunk road sites have traffic flows and speeds such that convoying could be dangerous. Lane switching may be permitted to enable sweeping after a period of unrestricted trafficking. In such circumstances, it is vital to produce a very stable dressing that can be fully swept prior to trafficking with minimal subsequent risk of loose chippings (whip-off). It is principally for this reason that only Third Party Approval Certificated proprietary multiple-layered surface dressings are permitted for use, with approval from the Overseeing Organisation, on the SRN in England and Wales. Systems that lock in the surface chippings by using a final binder spray that is not prone to pick up by vehicle tyres and is part of the Certificate may be specified to markedly reduce whip-off in such circumstances.

Equipment

8.9 Computerised sprayers that can spray variable widths on the move, and chipping machines with the same facility for applying chippings, are normal equipment and should be calibrated for accuracy and monitored in application using BS EN 12272-1 ‘Surface dressing Test methods Rate of spread and accuracy of spread of binder and chippings.’

Figure 8.3 Computerised Sprayer – Steam from a Polymer Modified Emulsion Sprayed at 85 °C

For the SRN in England and Wales, the sprayers and chipping spreaders must be capable of accurately placing a complete lane width, generally up to 3.8m, in a single pass with no joints or overlaps. The abutting lanes must be joined longitudinally by binder overlap of between 20mm and 100mm at the full spray rate at the lane markings. This means that wet edges need to be accurately formed and these must be protected from traffic during construction, see **Annex 8.1**.

Figure 8.4 14mm Racked-in with 6mm Surface Dressing using Premium Polymer Modified Emulsion

Figure 8.5 14mm Chippings Applied with a Truly Variable Phoenix Gritting Machine

There should be sufficient suction sweepers to remove any excess chippings during construction and to provide rapid removal of loose chippings after trafficking. They should have adequate water supplies to reduce to a minimum the production of dust especially during hot weather.

For the SRN in England and Wales there must be at least four functioning suction sweepers in use for each surface dressing section of 10,000m^2 to be carried out per visit and pro-rata, with a minimum of two. Any excess primary chippings in double surface dressings or multiple-layered surface dressings must be removed before subsequent application of binder or secondary chippings. The completed section must be swept to remove any excess chippings prior to trafficking.

Figure 8.6 Suction Sweepers are Used for IUTs to Remove any Loose Chippings from the Primary Layer during the Installation and then from the Final Surface Dressing Layer

It has been found that rubber coated vibrating rollers or pneumatic-tyred rollers are useful to consolidate the chippings and aid the break of the emulsion. Rolling of multiple-layered and double surface dressings on surfaces having good profile can also be accomplished using smaller vibrating steel wheeled rollers.

Figure 8.7 Rubber Coated Vibratory Roller

Figure 8.8 Pneumatic Tyred Roller

Rollers should not pick up binder and chippings and must have adequate water sprinkling systems or other debonding systems working properly, especially in hot weather, to avoid this disruptive problem. For the SRN in England and Wales, there must be sufficient rollers to provide at least four passes of every section of surface dressing; this number should be increased if the break time (coagulation) of the emulsion is delayed for any reason (temperature, humidity or product quality).

Aggregate (dust), such as a light coloured absorbent 1/4mm blast furnace slag or oolitic limestone, should be available in a machine, such as a salt gritting vehicle. The machine can then quickly be used to distribute the material across the carriageway, so that any binder pick-up by vehicles during hot weather or if rainfall occurs unexpectedly or any other incident can be counteracted. In hot weather, it has been found useful to distribute dust at the entrance to the contract to coat hot vehicle tyres and also immediately before opening to traffic stressed areas such as junctions, bends and hills.

For the SRN in England and Wales, sufficient suitable aggregate (dust) must be available for immediate distribution by a appropriate vehicle and distributor at any time during the installation.

Benefits

Skid Resistance

8.10 By selection of a suitable surface dressing technique, chipping type and chipping size, virtually any reasonable values for macro-texture (texture depth), micro-texture and abrasion resistance may be obtained for homogeneous road surfaces. The road surface characteristics may thus be designed for site conditions. Chippings with a high PSV are specified for areas of traffic stress such as braking areas, hills or bends, and low Aggregate Abrasion Value (AAV) chippings selected for heavily trafficked sites to reduce wear rate.

Preservation

8.11 Surface dressing is a preventative maintenance technique as well as a repair method. Regular applications of surface dressing will keep the upper structural layers of the road sealed against the ingress of air and water, thus reducing the rate of deterioration of these layers. Surface dressing also reduces the amount of water reaching the sub-grade, thus minimising deterioration and maintaining the structural integrity of the road pavement.

Conservation

8.12 An additional benefit is conservation of existing materials. Surface dressing has a thickness of around 10mm on heavily trafficked roads and can be as little as 5mm on lightly trafficked roads, therefore planing (milling) before treatment is not necessary when the profile is acceptable, and ironwork does not normally have to be raised. Chippings with appropriate PSV and AAV are required to provide continuing adequate safety standards on busy roads; with surface dressing, all of the high quality chippings are at the surface in contact with the traffic. Surface dressing has by far the lowest consumption of high PSV aggregate per square metre of any comparable maintenance process.

Environmental

8.13 The use of bituminous emulsion binders has been encouraged as they are environmentally friendly: the emissions are mainly water vapour and the installation is essentially a cold process having a low carbon footprint. Even hot applied emulsions are sprayed at temperatures around 80°C and the aggregate is normally at ambient temperature. This low spray temperature also results in minimal degradation of the polymer binder during storage and installation. Waste materials (bitumen and chippings) are not classified as hazardous.

Appearance

8.14 Although chippings for surface dressing will be chosen for their skid resistance and wear properties depending on traffic category and traffic stress, coloured chippings may be used for delineating hard shoulders and central reserves, or used in traffic calming measures.

Speed of Works

8.15 The speed of application of surface dressing is a major asset for reducing road closure during maintenance. For single carriageway work with coned off sections and traffic control, outputs of 10,000m² per day are possible. With contra-flow and safety lanes, output is really only limited by the supply of chippings to site and the frequency of testing, because the binder sprayer is able to apply 10,000m² in about one hour. The ability to apply surface dressing at night minimises traffic disruption.

Drawbacks

Structural Strength

8.16 Surface dressing does not strengthen the road structure, although by reducing water ingress the structural strength may be maintained.

Profile

8.17 Defects such as rutting and shoving must be eliminated before the surface dressing is applied, because surface dressing does not improve the road profile. However, it is possible to use larger chippings in the wheel tracks of less heavily trafficked roads to give longer life and reduce the effect of minor rutting. Soft patching materials, binder rich crack repair band sealing (including some hot screeded proprietary systems) and existing fatting in wheel tracks, are all likely to allow rapid embedment on heavily trafficked roads leading to early loss of texture.

Riding Quality

8.18 There is no improvement in riding quality.

Noise

8.19 The higher (mainly positive) macro-texture of single surface dressing generates considerable tyre/road interface noise. This tyre/road noise generation does, however, reduce with time due to wear and embedment. The use of multiple-layered surface dressings or double surface dressings or smaller granular chipping size reduces tyre/road noise generation and they are often specified in urban areas for that reason.

Sensitivity to Weather Conditions

8.20 Given a proper design (RN39) and good construction carried out at the correct time of year, surface dressing has a high probability of success unless the weather conditions unexpectedly deteriorate. Wet weather shortly after construction may cause the chippings to become detached and traffic may dislodge them, destroying the surface dressing in the wheel tracks. If traffic can be diverted until the road dries again and then re-introduced carefully, the surface dressing may be saved.

In very hot weather during and immediately after construction, the emulsion may break too quickly at the surface and form a skin with unbroken emulsion beneath. In this situation, the chippings may turn and be picked up by vehicle tyres. A maximum road temperature of 40°C may be specified, even for polymer modified bituminous binders, to reduce this risk. When polymer modified bituminous binders are in contact with warm rubber vehicle tyres, a strong bond develops and strings of binder can form floating in the air (cobwebbing). Fine material, particularly absorbent light coloured 1/4mm chippings, (“dust”), applied to surface dressing and at the beginning section of the installation, may prevent this mode of failure. Sprayer and chipping machine vehicle tyres can have water sprays or other protection systems fitted (e.g. debonding fluids or chalk dust) to prevent binder pick-up during operations.

A racked-in or double surface dressing is much less vulnerable to disruption by traffic due to the smaller chippings at the surface. Polymer modified bitumen emulsion binders are generally less of a problem in hot weather than fluxed polymer modified binders, except when there is high humidity. However, fluxed binders have an advantage over emulsions at lower road temperatures when it is humid and cool and heated or lightly coated chippings can be used. The development of environmentally friendly vegetable based fluxes has encouraged their use. Development of breaking control systems for emulsion binders has alleviated some of the problems and can extend the season for successful operations.

Advice must be obtained from the polymer modified bituminous binder manufacturer concerning maximum humidity and maximum and minimum air and road temperatures for proper installation.

Surface Dressing Techniques

8.21 There are number of different surface dressing types available: single, racked-in, inverted double (pad coat), pre-chipping (known as sandwich), double and multiple-layered. The binder commonly used is a polymer modified cationic bituminous emulsion. Further information, with schematic diagrams, is available in RN39 and in BS EN 12271, although multiple-layered surface dressings (three layers of chippings), double surface dressing using the same sized chippings, fibre-reinforced surface dressing and non-tacky sprays used to lock in the surface chippings after application are not included in the harmonized standard.

Multiple-layered surface dressings are combinations, such as a single surface dressing followed immediately by a sandwich or racked-in or double surface dressing. Sometimes the type is altered just for the wheel tracks to increase the life and to compensate for minor rutting. For example, a single 10mm chipping surface dressing may be applied in the wheel tracks followed by a single 6mm surface dressing over the entire road width, thus providing a double surface dressing with greater wear resistance in the wheel tracks.

Figure 8.9 Primary 14mm layer; Note Two Wet Edges and Binder Visible through the Chippings (Windows)

The primary layer of chippings is applied at a lower rate of spread (10% less) than for a single surface dressing. Single surface dressing always requires slight excess application of chippings in order to fill any binder windows and form a close mosaic. Chipping spreaders cannot provide a perfect distribution, but should be maintained and calibrated regularly to provide consistent results. Ideally, for double surface dressings, the primary chippings should not touch and binder should be visible for a distance depending on the chipping size (a simple on-site visual test is given in **Annex 8.2** that, with experience, can be used to assess the correct application).

Double and Multiple-layered Surface Dressing

8.22 The advantages of multiple binder applications combined with multiple chipping layers are:

- Initial stability builds up rapidly during installation, especially when using polymer modified bitumen emulsion binders, because the binder rate of spread is less for each application (e.g. 1.3L/m^2) than for example the single binder application of a racked-in surface dressing (e.g. 2.2L/m^2). The surface area of aggregate is also greater in two or more layers enabling water to quickly evaporate and for the emulsion to break.
- The aggregate interlock is greater, a close mosaic forms quickly and, when bound by a polymer modified bituminous binder, the strength is such that after removal of any excess chippings, trunk roads and motorways may be opened to traffic at speeds of 50 mph without a convoy. If installed correctly, only very few 6mm or better still 3mm chippings on the surface may be disturbed by traffic and these do not constitute a problem.
- Multiple-layered surface dressings may be carried out with less risk late season (for example on heavily trafficked roads during August) or during periods of unsettled weather, because of the early stability.
- Proprietary double surface dressings can resist turning traffic and are damaged less by urban parking (powered steering).
- Double and multiple-layer surface dressings can be used successfully on hills, exposed sites such as mountains and in the shade of trees and tall buildings.
- Durability is increased, because of the possibility of using larger chippings than would normally be selected for the road hardness and traffic category (embedment is less critical) – macro-texture consequently decays at a much lower rate.
- The tyre/noise generation of multiple-layered surface dressings is much lower than with single or racked-in surface dressings; they are often specified in urban areas and for the more rural trunk roads where low noise thin surface course systems are less cost effective and profile improvement is not required.

Figure 8.10 Initial Excess of 6mm Chippings from the Final Layer in a Double Surface Dressing

Figure 8.11 Excess 6mm Chippings Removed, Suction Swept – Carriageway Open to Traffic, 14mm Chippings Locked in by the 6mm Final Layer. No Loose Chippings to Damage Vehicles even at High Speed.

Figure 8.12 Double Surface Dressing Open to Traffic.

Figure 8.13 Long Life Example: 24 years A 452 - Premium Emulsion 14mm and 6mm Chippings

Differential Rates of Spread and Chipping Sizes

8.23 With some modern computerised sprayers with two sets of spraybar jets, it is possible to vary the rate of spread of binder across the road (transversely), which enables lower rates to be used in the most heavily trafficked parts of the road, namely the wheel tracks, where less binder will lead to a longer life. Using larger chippings in the wheel tracks has the same benefit and may slightly improve transverse profile.

Design Principles

8.24 RN39 provides a guide to the design of surface dressing. The information is based on systematic trials and considerable documented practical experience from Highway Authorities. However, RN39 does not attempt to deal with proprietary multiple-layered and double surface dressings, where proprietary polymer modified bituminous emulsion and fluxed polymer binders are used, relying on the proprietary binder or system producer to provide specific guidance. The Road Surface Treatments Association have published many documents which complement RN39, including the Guide to Surface Dressing Practice, see www.rsta-uk.org.

For high-speed roads carrying heavy traffic, double surface dressing or multiple-layered surface dressing using premium polymer modified bituminous binders must be used. The producer must be able to demonstrate that he has obtained advice concerning application and design from the proprietary binder producer.

For these situations the empirical approach to design has become less acceptable, and, with end performance in mind, rational designs tailored to a "system" are becoming favoured. This type of design should be left to the contractor who has expertise with a particular system and will carry the risk of premature failure.

The Overseeing Organisation must ensure that the correct performance levels for the surface dressing are specified and obtained, in particular any parameters specified must be measured to demonstrate compliance. The Overseeing Organisation must be satisfied that there is minimum risk of failure during the designed life, which is normally much longer than the guarantee period.

Figure 8.14 Chippings for Surface Dressing

Chipping Size Selection

8.25 The size of chipping selected for use at a particular location is based on the expected degree of embedment of the chippings, having regard to the hardness of the existing road surface and traffic intensity. The measurement of road hardness is a critical design factor and for a particular traffic category determines the size of chipping to be used (RN39). If the hardness varies considerably along the site, it may be difficult for the Contractor to achieve consistent high levels of end performance. In such situations, agreement between the Overseeing Organisation and the Contractor with regard to the practicality of achieving the specified levels of performance will be necessary.

8.26 Chippings are nominally single sized, see Table 8.2. A high flakiness index value for the chippings is undesirable; this may be measured by a simple mechanical test. The shape of the chippings influences the mechanical interlock between the chippings, the amount of binder needed to secure them and, more importantly, the durability of the surface dressing. The Contractor has to select chippings and a system suitable for the site, to enable the specified micro-texture and macro-texture to be maintained. It is macro-texture that largely determines high speed skid resistance and reduction in spray; at low speeds, skid resistance depends more on the micro-texture of the chippings, which is a function of PSV.

8.27 Dust is generated in the transportation and handling of surface dressing chippings. Pressure washing and heater drying, even on site, have been used to reduce the problem, to improve adhesion and reduce the risk of failure.

8.28 Since the main purpose in using a polymer modified binder is to provide a durable product and minimise the risk of loose chippings, it is pointless to use an expensive binder with chippings having low PSV, high Flakiness Index, high AAV, or high dust content. Some variation of these properties is to be expected even in chippings from a specific quarry, since there may be variation in the properties of the rock at different faces within the same quarry.

Recommended grading categories for surface dressing chippings within the UK				
General description	**14mm**	**10mm**	**6mm**	**3mm**
BS EN 13043 grading category	$8/14G_c85/15$	$6.3/10G_c85/20$	$2.8/6.3G_c85/15$	$2/4G_c85/20$

Table 8.2 Grading Categories for Surface Dressing Chippings (taken from BSI PD 6682-2)

A 6mm chipping is now specified according to BS EN 13043 as:

$2.8/6.3G_c85/15/FI_{30}/LA_{20}/PSV_{declared}/AAV_{10}/F_1$

A 10mm chipping is now specified as:

$6.3/10G_c85/20/FI_{25}/LA_{20}/PSV_{declared}/AAV_{10}/F_{0.5}$

In this description, the first number is “small d”, the second is “big D”; G_c means grading coarse and the number is minimum % by mass passing “big D”, the next number is the maximum % “passing small d”.

The specification continues with requirements for Flakiness Index, Los Angeles Abrasion Value, declared Polished Stone Value, Aggregate Abrasion Value and “dust content” fines value.

Although BS EN 13043 has maximum fines content of 1% (F_1), this quantity of fines would prevent adhesion of rapid setting cationic emulsions to 10mm chippings. A tighter requirement of 0.5% ($F_{0.5}$) is therefore specified as recommended in PD 6689 and double washing with careful transportation, storage and handling is required to achieve this.

8.29 HD 36 (DMRB 7.5.1) shows the minimum PSV requirements for use on roads of differing traffic intensity and stress, and the AAV requirements for differing traffic levels.

In order to conserve aggregates the highest PSV chippings must not be specified for all roads, but each site should be considered individually in accordance with HD 36.

Wear resistance generally improves with chippings of lower PSV; therefore, durability and safety are a balance and savings may be made by specifying a lower PSV. For trunk roads where contra-flow occurs during maintenance, each lane may be subject to the same traffic conditions and consequently the PSV and AAV are generally chosen to be the same. However, much lower traffic forces result in less embedment in the right hand lane of dual carriageways with three or more lanes (high speed, no commercial vehicles - except during contra-flow) and a smaller chipping may be used. The requirement for High Friction Surfacing (HFS) on some difficult sites necessitates the use of calcined bauxite and resin based skid resistant treatments (see MCHW1 Clause 924). 6mm calcined bauxite with polymer modified binder as a single dressing has been used successfully, but research shows that this size of aggregate may give lower levels of skidding resistance than the 3 mm chippings used in resin based HFS. Other artificial aggregates such as calcined flint, blast furnace or steel slag may be used to both economic and constructional benefit, provided skidding characteristics are maintained.

8.30 When racked-in surface dressing or double surface dressing is used on less heavily trafficked roads, a smaller size chipping with a lower PSV than the larger primary chipping may be permitted, since the small chippings will not predominantly come into contact with vehicle tyres. When, however, the second chipping is larger than half the principal size (for example 10mm followed by 6mm), the PSV should be similar. For multiple-layered surface dressings where the primary layer does not come into contact with vehicle tyres during the life of the product, primary chippings may be beneficially selected from lower PSV sources that have increased durability, provided that the TAIT has demonstrated no detrimental effect on skid resistance.

For the SRN in England and Wales, for racked-in or double surface dressings, all chipping sizes (primary and secondary) must have the designed PSV. All chippings must have an aggregate PSV greater than 45 and meet the requirements set out in HD 36 for traffic and site category. The AAV must be less than 10.

8.31 Adhesion between binder and chippings depends on the chemical nature of the chippings, the binder properties, and most of all on the amount of dust or clay/silt surrounding some types of chippings. The Contractor should test the chippings and binder combination using suitable adhesion tests such as the Vialit Plate Shock Adhesivity Test BS EN 12272-3 or BS EN 13614.

Specification of Surface Dressing

Recipe or Performance Specification?

8.32 If consideration of Table 8.3 indicates that the proposed dressing falls comfortably in the easy type of site (low stress and low traffic category), a recipe specification to Clause 919 of MCHW1 may be used. For a difficult or high-speed site with higher Investigatory Level (IL), a racked-in or double surface dressing will be required and use of a performance specification is advised (see MCHW1 Clause 922). With a recipe specification, responsibility for the design rests with the Overseeing Organisation; with a performance specification, this responsibility is transferred to the Contractor.

For the SRN in England and Wales where a Departure from standards is approved the Innovative Ultra-thin Treatments (IUT) specification must be used. If the treatment is temporary for operational reasons (haul road or surface is to be removed or overlaid within a year), MCHW 1 Clause 922 may be used with the agreement of the Overseeing Organisation.

8.33 It is in the areas of “high average” and “low difficult” sites that the design expertise of a Contractor can make the most significant cost savings; for example, by optimising the choice between binder grade and complexity of the surface dressing type. On very difficult sites, only the highest quality and best performing materials coupled with the highest standards of workmanship will be successful.

The Contractor’s Design Proposal and method for execution of the works must be assessed, particularly with regard to safety aspects.

Recipe Specification

8.34 In the past, specifications for lightly trafficked roads have generally been recipe specifications, with the Overseeing Organisation specifying materials, quantities and procedures. This requires a degree of expertise in, and experience of, the materials and processes and design. Monitoring during installation is essential. With the introduction of polymer modified binders, proprietary materials and novel techniques, much greater expertise is required. For temporary or lightly trafficked sites, RN39 provides a sound basis for generating a recipe specification and MCHW1 Clause 919 sets out the requirements; no further design advice will be given here. If the contractor applies the binder and chippings in accordance with the specification using binders and chippings that have Suppliers' CE Marking, there can be no dispute if defects arise; the risks are clearly carried by the Overseeing Organisation.

Performance Specification

8.35 The dependence on the binder and chippings suppliers to maintain properties of their materials to ensure consistent road performance, and the Contractor to determine the process technique and implementation for the site, encourages the transfer of responsibility to the Contractor.

8.36 Performance-based specifications require all the design work to be carried out by the Contractor, with the Overseeing Organisation specifying only the levels of performance required, and imposing no checks other than approving the applicability of the TAIT and regular assessment of performance.

8.37 The risk element is divided between Contractor and Overseeing Organisation, by having a Guarantee Period (which is much less than the Design Life of the dressing), at the end of which the Contractor must make good any defects. After this period, the Overseeing Organisation accepts the risk and any cost of future remedial work.

Monitoring performance characteristics of the installed surface treatment, such as fretting after the first frosts, rapid embedment after the first hot summer and macro-texture, must take place before the Guarantee Period has ended.

8.38 A further assurance of continuing performance to both Contractor and Overseeing Organisation is the use of an Approved System - one which has been through an evaluation procedure. The combination of recipe tests (based on extensive past experience), predictive tests and use of IUTs with Third Party Approval Certificates for the system should satisfy the Overseeing Organisation that there is a high probability of the work having the life estimated, which will be very much longer than the guarantee period.

MCHW1 Clause 922 provides for a surface dressing TAIT after one year and CE Marking is provided to demonstrate capability of the contractor and the product to perform for a given site category in terms of macro-texture and maximum defects. The binder has CE Marking to demonstrate compliance with the Framework Standard BS EN 13808.

MCHW1 Clause 940 IUTs have end performance system TAITs assessed over two years by a Third Party so that the declaration of performance in terms of defects and macro-texture decay can be measured. These aspects of "Safety in use" and "Durability" are critical for motorways and trunk roads. The component properties are declared; proprietary binders should normally have Third Party Approval Certificates and the chippings should comply with HD 36.

Site category	Site description	IL	Binder type required for given IL, traffic level and type of site — Traffic (cv/lane/day) at design life: 0-100	101-250	251-500	501-750	751-1000	1001-2000	2001-3000	3001-5000
A1	Motorways where traffic is generally free-flowing on a relatively straight line	0.30								
		0.35								
A2	Motorways where some braking regularly occurs (eg. on 300m approach to an off-slip)	0.35								
B1	Dual carriageways where traffic is generally free-flowing on a relatively straight line	0.3								
		0.35								
		0.4								
B2	Dual carriageways where some braking regularly occurs (eg. on 300m approach to an off-slip)	0.35								
		0.4								
C	Single carriageways where traffic is generally free-flowing on a relatively straight line	0.35								
		0.4								
		0.45								
G1/G2	Gradients >5% longer than 50m as per HD	0.45								
		0.5					HFS	HFS	HFS	HFS
		0.55			HFS	HFS	HFS	HFS	HFS	HFS
K	Approaches to pedestrian crossings and other high risk situations	0.5								HFS
		0.55				HFS	HFS	HFS	HFS	HFS
Q	Approaches to major and minor junctions on dual carriageways and single carriageways where frequent or sudden braking occurs but in a generally straight line	0.45								
		0.5								HFS
		0.55				HFS	HFS	HFS	HFS	HFS
R	Roundabout circulation areas	0.45								
		0.5								
S1/S2	Bends (radius <500m) on all types of road, including motorway link roads; other hazards that require combined braking and cornering	0.45								
		0.5					HFS	HFS	HFS	HFS
		0.55		HFS	HFS	HFS	HFS	HFS	HFS	HFS

Key to Table 8.3				
		Very easy sites, conventional binder possible, minimum cohesion 0.7 J/cm^2 with single or racked-in surface dressing		Difficult sites with higher IL, premium binder and double or multiple-layered surface dressing, minimum cohesion 1.2 J/cm^2
		High speed and/or moderately difficult sites, intermediate grade binder, minimum Vialit peak cohesion 1.0 J/cm^2 with racked-in or preferably double surface dressing		Difficult stressed sites, super premium binder, minimum cohesion 1.4 J/cm^2 with multiple-layered surface dressing. Traffic speeds upon opening 40 mph or 50 mph.
Site categories and IL are taken from HD36 It should be noted that the majority of roads in the UK fall into the first two traffic category columns of Category C and the table therefore provides an exaggerated view in terms volumes of where HFS and the highest specification binders and systems are applicable.			HFS	High friction surfacing systems
				Sites not suitable for currently available systems

Table 8.3 Areas of Use for Surface Dressing Binders

8.39 The assessment of need for the maintenance of a section of road is outside the terms of reference of this Advice Note. Reference should be made to HD 28 ‘Skidding Resistance’, HD29 ‘Data for Pavement Assessment’, HD 30 ‘Maintenance Assessment Procedure’, HD 31 ‘Maintenance of Bituminous Roads’ and HD 32 ‘Maintenance of Concrete Roads’. Once it has been decided that a section of road needs some form of treatment and that strengthening is not required, the suitability of surface dressing for the treatment should be assessed. For surface dressing to be suitable, there should be a high probability that the treatment will produce the level of performance required over a reasonable lifetime. The factors affecting the decision are traffic levels and speed, difficulty of the site and the existing road surface. Advice on the suitability of surface dressing with respect to traffic levels, speed and site difficulty is also given in RN39.

The main variables of the existing surface that will affect the final dressing are porosity, roughness, amount of fatting, hardness and heterogeneity.

Effect of Existing Surface

8.40 Table 8.4 shows the normally achievable performance, using best practice, of a correctly designed and appropriate system for different traffic levels and surface types.

The heavier the traffic, the more critical is the condition of the existing surface (substrate). At the highest traffic end only a normal, non-porous, homogeneous, fairly smooth road has a high probability of success for surface dressing to provide an economic life.

On lightly trafficked roads a successful outcome is possible in all cases, except in the case of bleeding, subject only to proper design and execution.

Any roads that are suffering from bleeding of binder, where water ingress has caused the binder to strip from aggregate beneath and come to the surface (sometimes visible as beads), are not suitable for surface dressing. Reconstruction (in situ recycling) is often the only solution.

The influence of the substrate has such an impact on the performance of surface dressing that records should be made prior to the surface dressing being installed. Ideally, this should include photographs and detailed locations of existing defects so that any problems arising during the guarantee period can be analysed properly.

For the SRN in England and Wales records of existing defects must be documented, ideally with photographs and accurate location information, before the installation of IUTs.

8.41 There are a number of factors that can widen the type of surface that can be treated with surface dressing. The three main ones are: (i) to accept a lower standard for defects; (ii) to accept a shorter life, or; (iii) to pre-treat the surface in some way to improve its characteristics. Surface dressing products are continually improving and it is likely that developments in the future will enable a wider range of surfaces to be successfully treated. Surfaces which Table 8.4 show as not making the grade may well be successfully treated in some instances by an improved product, using a higher performance binder or different type of surface dressing. As Contractors gain knowledge of, and confidence in, performance specifications and providing Type Approval Installation Trials, the type of site they will be willing to guarantee may also widen in scope.

Existing surface characteristic	Traffic Category (cv/lane/day at design life) 0-50	50-125	126-250	251-500	501-1000	1001-2000	2001-3000	>3001
Very Hard and homogeneous	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Hard and homogeneous	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Normal and homogeneous	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Soft and homogeneous	Yes	Yes	Yes	Yes	Texture	Texture	E	
Very Soft and homogeneous	Yes	Yes	Yes	Texture	E	E		
Fatting up in wheel tracks	Yes	Yes	Texture	Texture	E	E		
High macro-texture or fretted	Yes	Yes	Yes	Yes	Defects	Defects	E	
Porous	Yes	Yes	Yes	Defects	Defects	E		
Very variable	Defects	Defects	Defects	Defects	Defects	E	E	
Extensive patching	E	E	E	E	E			
Severe bleeding & extensive blackening								

Yes	The surface dressing may be designed to meet the most onerous performance requirements in terms of macro-texture and levels of defects (BS EN 12272-2)
Texture	It is difficult to maintain high macro-texture (1.5 mm required for high-speed roads), especially in the wheel tracks. Texture requirements for low speed roads may be achievable.
Defects	It is difficult to design to meet the most onerous requirements for the test method of visual assessment of defects (BS EN 12272-2) and they should not be specified.
E	In some circumstances, a suitable surface dressing may be designed by an expert using a proprietary system to meet less onerous performance levels; extra care in execution is required.
	Surface dressing is not an appropriate treatment.

Table 8.4– Effect of Existing Road Surface Characteristics on Achievable Performance Levels (taken from RN39)

8.42 Table 8.5 describes the various types of site and possible pre-treatments to overcome the constraints of the existing surface.

Surface type	**Description**	**Possible pre-treatments**
Porous	Surfaces such as porous asphalt and open-textured asphalt surfacing	Apply a single surface dressing with 2.8/6.3 mm chippings some weeks before the main dressing (or even the previous season)
High macro-texture or fretted	A surface with a texture depth above 1 mm sensor measured, usually with some fretting,	Application of slurry surfacing and some mechanical surface treatments can normalise or reduce texture
Normal, homogeneous	Minimal variation in appearance over whole section, texture below 1 mm sensor measured, hardness at least 'normal'	None needed
Soft, homogeneous	As above but surface hardness is less	None needed
Fatting up	Has a surface that is binder rich and blackened, with very low macro-texture, usually limited to the wheel tracks	If it is only in the wheel tracks and has taken at least 5 years to develop then it is worth removing the excess binder with high pressure water jetting.
Bleeding	Has a surface layer of free bitumen, usually extending beyond the wheel tracks and is caused by stripping of binder in the lower layers (displacement by water)	No pretreatment will avoid subsequent failure in most cases even on virtually untrafficked roads. Reconstruction or recycling is normally required using hydraulic binders
Heterogeneous, tracked	This is the normal state of a surface which has been previously surface dressed, because of the difference in texture and traffic across the lane it is possible to optimise design for texture in the wheel track or chip retention in the untrafficked areas	See fatting up above. Sometimes it is possible to carry out double surface dressing in the wheel tracks and single dressing of a smaller chipping over the whole road, minimising the risk of fretting in the untrafficked areas. Sprayers that can spray less binder in the wheel tracks can also improve performance.
Heterogeneous, patched	This occurs mainly in urban areas where most roads are subject to opening by statutory undertakings companies with subsequent reinstatement using materials which may have significantly different properties of porosity and hardness from the surrounding road surface	The problem is best reduced to a minimum by insisting on proper reinstatement with materials which match the hardness and porosity properties of the existing road. Low speed roads which are badly affected can sometimes benefit from a pretreatment with a pad coat surface dressing or a slurry surfacing. The slurry surfacing will have a low macro-texture and will have to be left to mature for a sufficient period before surface dressing otherwise it will be very soft.

Table 8.5 Description of Surfaces Prior to Surface Dressing

Specification Parameters

Surface Dressing Type

8.43 In order to allow the contractor the maximum choice, the Overseeing Organisation should allow any system unless there are particular reasons why a specific type is needed, for example, to reduce noise generation or for durability reasons.

Test Frequencies

Test frequencies must be specified as Appendix 1/5 using the frequencies in Table NG1/1

Binder Performance Test - Vialit Pendulum Cohesion (Clause 939 MCHW1)

8.44 Binder cohesivity is a measure of the ability of the binder to cope with traffic stresses. In general terms the levels of cohesivity define the range of binders used: conventional, intermediate grade, premium grade and super premium grades are available. These are characterised by peak cohesion levels of 0.7, 1.0, 1.2 and 1.4J/cm^2 respectively (see RN39). However, when comparing two binders with the same cohesivity, the one maintaining the level over the widest temperature range is likely to provide enhanced performance. The more stressed the site the higher the cohesivity required, but to some extent it is possible to compensate for moderate cohesivity values by using a more stress resistant surface dressing system such as double surface dressing. Not all unmodified binders necessarily meet the lowest level so that test certificates should always be required. It is always open for a contractor to use a higher grade than that specified. For a given traffic level, site category and investigatory level (HD36), the suggested levels are given in Table 8.3.

Chippings Performance Tests

8.45 The minimum PSV of chippings is required to ensure adequate resistance to skidding and the values detailed in HD 36 should be used.

The maximum AAV of chippings is required to ensure adequate resistance to abrasion by traffic and the values in HD 36 should be used.

Equipment Calibration

8.46 The category of accuracy of spread of binder (see BS EN 12272-1) provides a guide as to the evenness of transverse distribution for spraybars; category 3 is the most onerous. This category is not attainable except by very well maintained spraybars and should therefore only be specified where it can be most beneficial, for example, on roads where the current surface is very even and the traffic levels are high, where variations in the rate of spread would show up very quickly.

Figure 8.15 Transverse Distribution of Binder Test

Category 3 spraybars must be used for the Strategic Road Network in England and Wales and category 2 for other dual carriageways.

Where a single carriageway is very heavily trafficked and the current surface is consistent along the whole length and across the whole width then category 2 spraybars should be specified.

The evenness of rate of spread should be checked at the start of, or recently before, the contract and then weekly.

The test for accuracy of rate of spread of binder in BS EN 12272-1 measures the transverse distribution in working conditions and therefore overcomes the problems of assessing transients that are averaged out in the depot tray test. The test can be carried out quickly and easily on site using either contiguous absorbent tiles or trays that are sufficiently robust to take the sprayer running over them without losing their ability to absorb binder. The tiles may be of foam, carpet, or any other material which can absorb all the binder sprayed on them without loss. If the tiles are lightly stuck to a strong metal backing strip they can be picked up as a unit and removed to the side of road for the individual tiles to be weighed and any hold up of the surface dressing train is minimised. A successful method employed is to use sections of pre-weighed carpet tile (100 mm x 250 mm) stuck to a length of aluminium sheet covered with ‘cling film’ and the sprayed tiles placed immediately in pre-weighed plastic bags, thus enabling the whole testing to be carried out without the use of solvents, see Figure 8.8. The result is expressed as a mean rate of spread of binder and a coefficient of variation, which is the standard deviation of the mass of binder on each tile (which should have the same area) divided by the mean mass.

Figure 8.16 Rate of Spread of Binder Test, Note the Use of a Plastic Bag to Collect the 250 mm Square Carpet Tile

In addition to the category of spraybar, the category for tolerance on the rate of spread of binder should be specified and for this purpose the specification of category 3 is suitable for all sites as it is both achievable and adequate. The accuracy of rate of spread test also provides the average rate of spread of binder, but a simpler test recommended to assess this given in BS EN 12272-1 similar to the traditional UK carpet tile test. There are a number of constraints on dimensions, but 5 tiles consisting 250 mm square quarters of a standard 500 mm carpet tile are normally used. The individual masses are determined and the average reported. The variance, which, in this case, is the highest rate minus the lowest rate (i.e. the range of values) measured on individual tiles divided by the average, is also calculated and if it is above 0.2 the test is repeated and if the repeat test gives a variable result the cause must be investigated and possibly an accuracy of rate of spread test carried out.

Visual assessment of accuracy of spread (transverse distribution) should be part of factory production control and the use of jet tests each day is a useful discipline, see Annex 2.

8.47 It is essential for proper control of the rate of spread of binder that the temperature and pressure of the binder at the time of spraying are within the correct range. This means that the thermometers and pressure gauges or output management systems on the sprayer must be working and must be giving the correct reading. In order to achieve this reliably all the instruments should be calibrated before the start of season using a system traceable to national standards. It has been a requirement for many years for these gauges to be duplicated as the operating environment is very harsh. There is no reason to change this principal and the contractor’s Factory Production Control scheme should contain a requirement for the regular reading of the duplicate gauges and if the reading differs by more than a stated amount they should, if necessary, be repaired and recalibrated, or replaced by previously calibrated gauges.

8.48 Also in BS EN 12272-1 are tests for evenness of rate of spread and accuracy of rate of spread of chippings, see Figures 8.7, 8.8 and 8.9. These measures are particularly important in the context of double and multiple layered surface dressing where the rate of spread and accuracy of spread of the primary chippings are critical.

Figure 8.17 Checking Rate of Spread of Chippings BS EN 12272-1

8.49 The class of chipping spreader is a guide to the evenness of transverse distribution which it is capable of producing, category 2 being the most onerous.

Figure 8.18 Fitting the Clear Calibrated Sleeve Tops to the Chipping Rate of Spread Boxes

Category 2 chipping spreaders must be used for the primary chipping in double surface dressing or a multi-layered surface dressing.

Figure 8.19 Measuring the Rate of Spread of Chippings in Terms of Bulk Volume

The evenness of rate of spread should be checked at the start of the contract and then daily. In addition to the category of chipping spreader, the category for tolerance on the rate of spread of chippings should be specified and for this purpose the specification of category 2 is suitable for all sites as it is both adequate and achievable. The frequency of test is set out in Specification (MCHW1) Appendix 1/5.

Macro-texture

8.50 For general guidance on the need for macro-texture and its measurement see HD28. The generally accepted specification for high-speed roads of 1.5mm minimum using the Volumetric Patch test (BS EN13036-1) is based on hot rolled asphalt and pre-coated chippings. That material maintains its texture over a long period with changes varying from slow increase to slow decrease depending on the relative rates of wear of the chippings, embedment of the chippings and loss of matrix from the asphalt between the chippings. Because the changes are slow in HRA it is feasible to specify the texture depth prior to opening to traffic. With a surface dressing, however, the chippings re-orient themselves in the binder-chipping matrix and chipping embedment occurs at a rate depending on the type of surface dressing, traffic and the hardness of the substrate, with the consequent reduction in texture depth unless the substrate is very hard (concrete) when there is no embedment. The standard method of measuring texture depth for surface dressing is different from the method used for coated materials. The reason for this is that it is measured after the contract has finished and contactless laser devices can carry out the work on the move without needing fixed traffic management and the lengths to be covered are often much greater than for an asphalt contract. The results must be converted to Volumetric Patch values before comparison with the specified levels. There is no precision data on any method of measuring texture depth on surface dressing and care should be exercised when interpreting results, particularly those close to specification limits.

8.51 The decay of macro-texture with time is not linear and for single surface dressings is rapid in the first two years; it depends on many parameters so it is difficult to extrapolate early-life macro-texture measurements. To obtain adequate macro-texture at 2 years the initial value has to be very much higher, for some processes over 3mm may be necessary which generates considerable noise, particularly under high speed traffic. In order to keep noise down to an acceptable level in noise sensitive areas it may be necessary to specify a maximum macro-texture at the end of the initial bedding in period, say at 4 weeks. This will effectively require the use of double or multiple-layered surface dressings.

8.52 All texture depths for surface dressing should be specified in terms of Volumetric Patch measurement (other methods may be used provided they are converted to Volumetric Patch equivalent values) and the levels for high speed roads at 2 years would normally be those given in Notes for Guidance to Specification (MCHW 2) Clause NG 922. The end product performance specification provided in MCHW 1 Clause 922 requires texture measurement: initially, after mosaic formation, at between three and five weeks (only where noise is a problem), after eleven months and before thirteen months; and then at the end of two years; except new untried proprietary materials or systems, where the guarantee period should be one third of the offered design life. The reduction in texture over the period between 12 and 24 months provides some indication whether or not the texture depth will remain above the required minimum value for the design life of the dressing.

Macro-texture must be monitored between 11 and 13 months and between 23 and 24 months to assess rate of reduction and again before the end of the guarantee period.

8.53 The decrease in texture between 12 months and 24 months is a guide to the life of the dressing, the lower the value the longer the life of the dressing, unless failure mechanisms intervene. A maximum figure of 40% is an appropriate specification value with a minimum of 0% as any increase in texture indicates that the surface is losing chippings.

8.54 Skid resistance on most surface dressing products cannot be measured with reasonable precision before the end of the second or third year.

For IUTs the TAIT is monitored for macro-texture after two years and the installed multiple-layered surface dressing must be tested before the end of the guarantee period at 5 years (normally during routine testing).

Visual Assessment of Defects using BS EN 12272-2

8.55 The level of fatting up, tracking and bleeding, P_1, is a guide to likelihood of failure in terms of loss of macro-texture with time.

Figure 8.20 Bleeding and Tracking

Figure 8.21 Fatting Up

8.56 The level of scabbing and tearing, P_2, is a guide to the likelihood of unsatisfactory performance caused by initial damage and poor workmanship.

Figure 8.22 Scabbing – Poor Site Preparation – Surface Contaminants not Removed

Figure 8.23 Tearing – Poor Traffic Management – Binder Cohesion Too Low for Stress

Figure 8.24 Tearing – Powered Steering – Urban Work – Alternative Design needed

8.57 The maximum level of fretting, P_3, if exceeded, indicates durability problems in terms of chipping loss.

Figure 8.25 Fretting – Poor Specification – Chipping Size or Binder Rate of Spread or Adverse Conditions at the Time of Laying

8.58 The maximum length of streaking, P_4, is a guide as to the likelihood of unsatisfactory performance caused by poor application of binder.

Figure 8.26 Streaking – Spraybar Problems – Binder Temperature or Pressure Too Low, Blocked Filter or Jets, Spraybar Height Variations, or Pump Problems.

8.59 In terms of defects such as fretting, surface dressing usually either fails extensively in the first winter or it does not fail at all. Border line cases are rare for fretting, scabbing and tearing. Appropriate values of the maximum levels of P_1, P_2, P_3 and P_4 at the end of the guarantee period (normally 2 years except for motorways and trunk roads) are given in Notes for Guidance to Specification, Clause NG 922 (MCHW2). The test is likely to be carried out using the qualitative method, because it is normally obvious by a drive-over inspection that the levels have been achieved.

For the Strategic Road Network in England and Wales IUT performance levels (e.g. macro-texture and defects) must be monitored and checked before the end of the guarantee period, which is normally 5 years.

Binder Data

8.60 The specification for surface dressing MCHW1 Clause 922 requires the provision of a wide range of data on the binder to be used see Notes for Guidance for Specification NG700 Sample Appendix 7/3 (MCHW2). Most of the data is required once for any source and grade of binder although it is recommended that tests on the binder should be repeated at least annually. If a manufacturer uses a number of sources of bitumen or modifier a range of values that covers the variation across all sources or give the data for each individual source should be provided. This would also apply if the supplier manufactures the binder at a number of different plants. It will always be open to the purchaser of the binder and the Overseeing Organisation to carry out any or all of the tests to check whether a particular consignment conforms to the declared limits. The date of test for any parameter should be given when providing a data sheet.

Manufacturers of polymer modified bituminous binders must provide product identification and performance-related data for the TAIT and for IUTs with approved Third Party Certification.

8.61 **The binder recovery and ageing profile method** used for polymer modified bituminous emulsion binders should be the method given in MCHW1 Clause 955 or alternatively one demonstrated to be equivalent to BS EN 13074-1 and BS EN 13074-2 plus a long term ageing test. A standardised recovery and ageing procedure is required for polymer modified binders so that the purchaser and the Overseeing Organisation can compare the results for a given consignment of binder with the manufacturer's claims, because the purchasers of binder or of final surface dressing are not in a position to check the base binder. It is not intended that the recovered or aged binder necessarily reflects any particular stage in the life of the binder after spraying, although it may be found to do so: recovered binder is likely to reflect its state fairly early in its life when it is still vulnerable to traffic damage; and the ageing profile shows the capacity for ageing on the road.

8.62 **Vialit plate shock adhesion test** assesses a number of factors depending on how the test is performed; all the procedures are given in BS EN 12272-3. The factors are:

a) Active adhesivity which measures the bond between the binder and damp aggregates in their natural state

b) Mechanical adhesion is the adhesivity bonding the dry chippings to the binder with their natural dust or fines making an inhibiting screen

c) Wetting temperature is the lowest temperature of binder on the plate just before applying chippings for which the number of stained chippings is at least 90%.

d) Fragility temperature is the lowest test temperature at which 90% of the chippings remain bonded to the plate.

The test was originally developed for cut-back and fluxed binders and is being amended to be more discriminatory when testing bituminous emulsions, alternatively BS EN 13614 should be considered..

8.63 **Active adhesivity** assesses the compatibility between binder and damp aggregates and may be used to determine the effectiveness of adhesion agents or the effect of a change of aggregate. It is carried out at 5 °C in order to discriminate between binder/aggregate combinations; much work was carried out in France to determine the optimum test temperature. It is not designed to simulate conditions on the road. This simple test should be carried out a regular basis (say monthly) during the season to check the maintenance of compatibility between the binder and the aggregate as delivered. If there is a sudden change in the result further investigation should take place of both the binder and the aggregate and their combination to determine the cause and possible effects on the completed dressing.

8.64 **Mechanical adhesion** assesses the effect of dust on chippings and can be used to determine the level of dust and other fine material which has a deleterious effect on the adhesion of the aggregate to the binder. Different types of fine aggregate have different effects. Clay is particularly effective at preventing bond at very low concentrations - well below the fines content permitted in most Standards for chippings.

8.65 **Wetting temperature** is applicable to cut-back and fluxed binders only and is measure of the lowest road temperature at which work should take place. It may also indicate the sensitivity of the binder aggregate to road temperature at the time the surface dressing is installed.

8.66 **Fragility temperature** provides an indication of whether or not problems are likely to occur in the early life of the surface dressing, before embedment has taken place, and whether very low temperatures will affect the bond between the aggregate and the binder. Therefore it gives an indication of the suitability or otherwise of the system for late season work when no embedment is likely before the following spring.

8.67 **Product identification test** data from a dynamic shear rheometer is required, because it discriminates between binders made with different base bitumens and different polymers without in any way indicating the 'recipe' manufacturing process. The data required are curves of G* (complex shear modulus) and □ (phase angle) against temperature at a frequency of 0.4Hz over the range -10 to +60°C (see Chapter 3 Binders). The frequency has been standardised in order that comparison can be made between binders if required and to make the likely data bank of information as comparable as possible. G* at 25°C and 0.4Hz has a good correlation with penetration value (Gershkoff, 1995), because there is a similar loading time, also, the temperature when G* equals 2kPa provides a high temperature performance indicator similar to Softening Point). All the available data should be provided in tabular format. Some polymer modified binders do not permit temperature or frequency shifting to provide a single master curve and in these cases the separate curves should be provided together with the reasons why the provision of a master curve was not possible. The data from this test is required for recovered binder with an ageing profile.

8.68 **Spray temperature and pressure range** is the range determined by the binder manufacturer over which the binder may be satisfactorily sprayed. The range may be different for slot jet and swirl jet spraybars, if so this should be made clear and the contractor should insert the ranges appropriate to the spraybar proposed for the contract.

8.69 **Weather limits** should be indicated if they are different from those which would be applicable to conventional binders as set out in RN39. The maximum and minimum road temperature and the maximum humidity should be given in all cases. Any limits not indicated will be assumed to be as given in RN39.

8.70 **The minimum orifice viscosity** is that which the particular emulsion binder requires to prevent it flowing down any slope on a normal road (say up to 10% gradient) before the chippings are spread. Different binder formulations may have different requirements as their flow behaviour on a road may be different from that through an orifice, for example a thixotropic emulsion.

8.71 **Other properties** may be given if the tenderer considers that may be useful to the Overseeing Organisation in its consideration of the technical merits of the tender.

Description, Evaluation and Avoidance of Failures

8.72 Surface dressing has failed when it is either:

a) no longer able to meet the needs of the traffic using the surface, or

b) no longer protecting the structure of the carriageway from the ingress of water.

8.73 Failure occurs in one of three different and rarely overlapping time periods: during construction or shortly afterwards caused by extremes of weather and/or poor traffic management; during the first couple of years; or due to old age, which may be any length of time from 5 years after execution. Records exist of surface dressing performing satisfactorily in excess of 20 years. Early failures are almost always the result of inadequacies in one or more of the 4 stages in the production of a surface dressing on the road. The stages are:

a) Specification

b) Design

c) Materials

d) Execution including aftercare

8.74 In a performance specification the last 3 items are the responsibility of the Contractor and there are good sources already available from which to obtain advice and guidance on best practice, notably the RSTA Codes.

8.75 In a recipe specification the first two or sometimes three items are the responsibility of the purchaser.

8.76 All surface dressings fail eventually. This is due to a combination of factors including principally: embedment of chippings, fretting or wear of chippings and binder hardening. Multiple-layered surface dressings and double surface dressings have longer lives and maintained performance levels compared to single surface dressings. Long term failure is rarely catastrophic and appropriate maintenance surface treatment can be planned in advance. Surface dressings do not fail on a fixed time basis and each site should inspected regularly and treated when minor deterioration is detected as otherwise more costly maintenance is necessary. This preventative maintenance provides best value for money and extends the life of the road.

8.77 The rest of this section deals with short term failures: their definition, evaluation, avoidance and remedies. These failures may be anything from marginal to catastrophic.

Failure Definitions

8.78 The following are definitions of failure modes:

Whip-off - The normal removal by traffic of excess chippings shortly after the production of a surface dressing

Blacking-up - The appearance of binder at the surface very early in the life of the dressing, without significant loss of macro-texture

Bleeding - The exudation of bituminous binder from a road surface, often accompanied by ‘bubbling’ of the surface and is often evident in untrafficked areas

Fatting up - The result of almost total embedment, usually in the wheel tracks only

Fretting - Random loss of chippings from a completed surface dressing

Scabbing - The detachment of both binder and chippings after application from the existing road surface

Streaking - Loss of chippings from a completed surface dressing such that one or more lines appear parallel to the direction of application.

Tearing - The removal of chippings by traffic at points of high traffic stress.

Tracking - Fatting up or bleeding in wheel tracks caused by channelised traffic.

A summary of causes of failure, their avoidance and, where it is possible, their remedies is given in Table 8.6.

Failure mode	**Cause**	**Avoidance and remedy**
Whip-off	This normally occurs and is not a failure but can be a pre-cursor to fretting and if it continues for more than a few days should be monitored	If caused by hot weather then dusting may stop the problem developing. Additional sweeping may be required.
Blacking - up	Occurs where there is sufficient binder in surface dressing system to enable the traffic to draw it up to the surface of the chippings usually when the surface is very hot, occurs before the binder has fully cured	Can be a sign of poor design or execution. Binder rate slightly too high. Immediate remedy is to dust at the first sign of it occurring (do not delay). Avoidance - ensure design is correct, check rate and accuracy of spread of binder and stop work when road surface is too hot particularly with cut-back binders. Providing it is not too serious the excess binder will weather off during the first winter. It most frequently occurs with cut-back binders, subsequent loss of volatiles will reduce the likelihood of recurrence. High pressure water jetting in the spring can be used to remove excess bitumen if it does not weather off over the winter.
Bleeding	Caused by binder from the underlying road migrating up through the surface dressing to be seen first as beads. High road temperatures, low binder viscosity, excess binder and water pressure stripping binder from underlying aggregate are usual reasons	The only avoidance measure is not to install surface dressing at all. Only remedy is to plane off all binder rich material and resurface or recycle by scarifying with cement.

Fatting up (in early life, say before 2 years)	Binder appearing at the surface caused by the penetration of chippings into the underlying surface owing to traffic. Care should be taken to distinguish this from bleeding as the cause is different.	Usually caused by poor design. The chippings are too small for the combination of road hardness and traffic on the site (check hardness). Can only be avoided by proper design. No easy remedy. Sometimes a sandwich surface dressing may work. Water jetting to remove binder will extend life somewhat but problem will recur usually in the next spell of hot weather. The only long term solutions are either removal of the fatted surface dressing using a planer equipped with chisel tips and then using a correctly designed system or by overlaying with an asphalt surfacing. (A macadam surfacing will frequently allow the bleeding to recur.)
Fretting	The random loss of chippings can have a number of causes. The most usual are: too little binder for the size of chipping, too little embedment before the onset of winter, binder too low in cohesive strength for the quantity and speed of traffic. Poor adhesion of chippings to binder can also contribute.	Wrong combination of chippings and binder is a design fault. Check road hardness. Avoid late season work particularly with 14 mm chippings. Best remedy is to redress the site using the next smaller size of chipping, which will convert it into a form of double surface dressing. Check that the binder is adequately cohesive and has high enough shear stiffness for the site stresses. Check compatibility of chippings and binder using Vialit plate shock test.
Scabbing	The usual cause of this is inadequate site preparation and is due to the presence of mud and other contaminants on the road surface.	The only way to avoid this is to properly clean the site and if particularly badly contaminated with hard mud, oil or other detritus water jetting may be required. Proper preparation is cheaper than remedial action. The only remedy is intensive spot surface dressing repairs.
Streaking	This is usually due to a malfunctioning binder sprayer causing variations in rate of spread across the width of the road. Temperature of binder too low, pressure too low and spraybar height variations are typical causes	Avoided by proper care. The jet test should be carried before work each morning, whenever there is change of binder and whenever there has been a prolonged stoppage particularly if the jets haven't been 'blown' when the jets may have become slightly blocked by either cold or broken binder. The on-site transverse distribution test giving coefficient of variation should be used regularly. See Annex 2.
Tearing	This may be caused by traffic turning sharply (the usual mechanism), particularly at roundabouts. It also occurs less frequently when heavy vehicles brake hard with locked wheels. Both causes are most likely to occur in the early life of the dressing before the binder has gained adequate cohesion	Surface dressing should not be specified on very small roundabouts used by articulated vehicles, if a roundabout is to be surface dressed then the design should be very carefully carried out, the works executed at an appropriate time of day, either at dawn or in the evening when heavy traffic is at a minimum, traffic control should be particularly well executed until the system has gained adequate strength. Where braking is expected then the same factors apply. It can also occur at random but this is infrequent and is not a controllable failure.
Tracking	This may occur any time during the life of the dressing and is the usual mode of long term failure. It should not occur early in the life of the dressing.	When it occurs early then the fault normally lies with the design. Where channelised traffic occurs the design should allow for this, depending on degree of channelling, and designing the dressing for that higher level. Similar allowances should be made for very slow moving traffic as the loading time is longer. Advice on this matter is given in RN39.

Table 8.6 Causes, Avoidance and Remedies of Failure for Surface Dressing

Normative References

Road Note 39 Design guide for road surface dressing

BSI PD 6689 Surface treatments – Guidance on the use of BS EN 12271 and BS EN 12273

BS EN 12271 Surface dressing - Requirements

BS EN 12272-2 Surface dressing. Test methods. Visual assessment of defects

BS EN 13043 Aggregates for use in bituminous mixtures and surface treatments for roads, airfields and other trafficked areas

BSI PD 6682-2 Aggregates for bituminous mixtures and surface treatments for roads and airfields and other trafficked areas – Part 2: Guidance on the use of BS EN 13043

Manual of Contract Documents for Highway Works, Volume 1

Manual of Contract Documents for Highway Works, Volume 2

BS EN 13808 Bitumen and bituminous binders. Framework for specifying cationic bituminous emulsions

BS EN 13043 Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas

BS 434-2 Bitumen road emulsions (anionic and cationic). Code of practice for use of bitumen road emulsions

BS EN 12272-1 Surface dressing. Test methods. Rate of spread and accuracy of spread of binder and chippings

The Design Manual for Roads and Bridges, Volume 7 – HD 36

BS EN 12272-3 Surface dressing. Test methods. Determination of binder aggregate adhesivity by the Vialit plate shock test method

BS EN 13614 Bitumen and bituminous binders. Determination of adhesivity of bituminous emulsions by water immersion test

The Design Manual for Roads and Bridges, Volume 7 – HD 28

The Design Manual for Roads and Bridges, Volume 7 – HD 29

The Design Manual for Roads and Bridges, Volume 7 – HD 30

The Design Manual for Roads and Bridges, Volume 7 – HD 31

The Design Manual for Roads and Bridges, Volume 7 – HD 32

BS EN 13036-1 Road and airfield surface characteristics. Test methods. Measurement of pavement surface macrotexture depth using a volumetric patch technique.

BS EN 13074-1 Bitumen and bituminous binders. Recovery of binder from bituminous emulsion or cut-back or fluxed bituminous binders. Recovery by evaporation.

BS EN 13074-2 Bitumen and bituminous binders. Recovery of binder from bituminous emulsion or cut-back or fluxed bituminous binders. Stabilisation after recovery by evaporation.

BS 1707 Specification for hot binder distributors for road surface dressing.

Informative References

RSTA Code of Practice for Surface Dressing, Parts 1 to 9 (RSTA, 2008-2011).

National Highways Sector Schemes for Quality Management in Highway Works. 13. For the supply and application of surface treatments to road surfaces (UKAS, 2011).

Gershkoff, D. (1995). Polymer Modified Bitumens—Performance in Empirical and Rheological Tests. Proceedings of the 1st European Workshop on the Rheology of Bitumen Binders, Brussels, Paper 34.

ANNEX 8.1

Double Surface Dressing - Longitudinal Joints

The production of well-designed binder joints for double and multiple-layered surface dressing is essential, otherwise several layers of surface dressing between rips (sprayed lanes) can occur at the longitudinal joints leading to large ridges, which are unacceptable.

The example of a double surface dressing using a 14mm primary layer followed by a 6mm surface dressing in a three lane carriageway is considered below:

The primary chipping layer in lane 3 will provide the first wet edge at the longitudinal joint and this should be maintained between 20mm and 100mm maximum, which is possible with most sprayers. This binder film will be left exposed for some time and needs protecting from traffic and site vehicles. Only one lane is being treated at a time in this example, so the 6 mm surface dressing in lane 3 should be inset by at least 100mm from the edge of the 14mm chipping layer providing a wet edge overlaying the primary layer of between 20mm and 100mm. So there is now visible a wet edge from the 14mm surface dressing a few uncoated 14mm chippings then a wet edge from the 6mm surface dressing and then the constructed double dressing.

The adjoining primary layer in lane 2 abuts the existing 14mm primary layer of lane 3 and its wet edge coats the uncoated 14mm primary surface dressing lane 3. This extra binder, in excess of the design, potentially over 200mm, is at the line marking and will not result in fatting, being far away from any heavily trafficked area. The 6mm surface dressing over lane 2 is laid right up to the adjacent 6mm surface dressing in lane 3 and the extra binder over the wet edge again does not present a problem. The result is two adjoining double surface dressings overlapping each other in terms of binder but not with chippings producing a longitudinal joint with no ridges. See Figure A.1.

1 2 3 4 5 A B C D

Figure A.1 Double Dressing Joint preparation

1. Existing substrate, HRA surface course
2. Wet edge to first layer 14mm single surface dressing (1.2L/m^2 polymer bitumen emulsion) lane 3
3. 14mm chippings of primary layer not sprayed by second 6 mm surface dressing (wet edge of adjacent 14 mm surface dressing will coat these – see B)
4. Wet edge of 6mm second surface dressing (1.3L/m^2 polymer modified bitumen emulsion) coating the primary chippings
5. Top surface of second 6mm surface dressing ready for rolling

A. 14 mm surface dressing primary layer of adjacent lane 2
B. Wet edge of the adjacent primary layer coating the uncoated 14mm chippings remaining, see 3
C. Coated primary chippings (same as 4 although much later, after adjacent rip in lane 3 had been completed)
D. Same as 5

When the final 6mm surface dressing is applied over the adjacent primary layer in lane 2 it will be sprayed and chipped right up to the adjacent 6mm chipping top surface, i.e. over A, B and C. There will be more binder at 2 in the primary layer and B and C under the 6mm surface dressing, but this is not a problem if applied at the road markings out of the main trafficked area of the lane.

The 14mm lane 2 surface dressing will need to create two wet edges at both longitudinal joints (to lane 1 and lane 3) so the chipping spreader will be chipping inside the sprayed width to enable this and very good operator skills are needed.

ANNEX 8.2

Visual Assessment of Surface Dressing during Operations

Chipping Application

Although there have been major improvements in chipping machines, they are not perfect, because they cannot lay all the chippings for primary layers of double and multiple-layered surface dressings so that they do not touch one another, this leaves binder windows.

The 10% reduction from shoulder to shoulder coverage that is needed for multiple-layered and double surface dressing primary layers is not easy to assess for a given chipping size and shape.

Using the boxes in BS EN 12272-1 to calibrate the chipping machine in terms of 100 % (shoulder to shoulder) coverage and 90% coverage is a useful exercise for the chippings being used. The rate of spread will depend mainly on chipping size and flakiness.

The correct coverage on site can be visually assessed by standing near the surface dressing and looking to find a point in the surface dressing where the binder between the chippings is no longer in sight (caused by binder windows being obscured by the chippings). The distance may be established by a few strides for a particular chipping size or preferably by using a more sophisticated remote distance meter, quite repeatable results may be obtained and an appreciation is gained for instant evaluation of chipping rates of spread and evenness of spread.

The height of the operator impacts on the result and increasing precision can be obtained by using a fixed sight and laser measuring device detecting a pole held by an assistant at the point of obscurity.

Road shape and existing heterogeneity and variations in chippings (flakiness, average least dimension) will also impact on the result.

When the chipping distribution and binder windows appear to be not even the chipping spreader will require calibration.

Accuracy of Spraying – The Jet Test

When surface dressing commences the spray across the existing road should be examined. It is difficult to see any faults on a very variable substrate. If there are any apparent weak areas then the spraying should be stopped otherwise early failure in terms of streaking may occur. A simple test to clear any blocked jets and to check that each jet is spraying correctly is to carry out a jet test on site.

Swirl nozzle type spraybars are tested in pairs in a series of static positions so that the jets can be evaluated separately and this method is documented in RSTA Code of Practice for Surface Dressing, attention should be paid to the end jets as these are not tested in BS 1707 and need to provide full rate of spread right to the edge, baffles are often used to deflect the binder and they may become dislodged.

Slot jet nozzle type sprayers are tested on the move. Jets are opened so that they do not overlap i.e. every fourth jet, opening as many as possible. The rate of spread is set as light as possible (e.g. 0.7L/m^2). The sprayer then travels forward to spray a section of about half a metre. The next set of jets is opened and this is repeated so that a series of sprays are visible on the road. On some computerised sprayers this can be set up by a program. The width of spray and appearance can provide information about a problem jet or end jets not spraying sufficient binder for butt joints (angle not set correctly) or identify problems with overlaps when extending a variable spraybar (i.e. jet does not engage soon enough).

Obviously there is no substitute for carrying out the rate of spread and accuracy of spread of binder tests using BS EN 12272-1, but this is not normally required on a daily basis, hence the extra visual vigilance needed between tests.

Another method of evaluating accuracy of spread is to use a thermal imaging camera, which can see through the steam created during spraying, especially in humid conditions. A thermal map can be viewed in real time, where the temperature falls quickest can be attributed the lowest rate of spread and conversely where heat is retained the binder film is greater. This may prove to be a useful tool for the contractor to maintain very accurate spraybars and to eliminate streaking.

Combined Sprayer/Chipping machines

Combined Spraying and chipping machines, present problems for on-site testing, because of the short interval between spraying binder and application of chippings.

Chipping application may be tested for rate of spread and accuracy of spread as a calibration using a test section, without the binder. The chippings can then be removed for re-use.

Testing for rate of spread and accuracy of spread of binder is difficult, because for most machines the vehicle tyres would travel over the carpet tiles. However various systems have been used including: removing the tiles before the tyres destroy the test; only testing the jets between the tyres; collecting the output from individual jets in a stationary position using containers; calibration over a test bench e.g. BS1707; collecting in a tray both binder and chippings as a surface dressing and recovering the binder; using metal foil and film thickness measurements; and using infra-red detectors and cameras to monitor spraying.

9. HIGH FRICTION SURFACING (HFS)

Introduction

9.1 High friction surfacing (HFS) is a veneer coat normally using calcined bauxite aggregate attached to the road surface by a resin on which it is spread; alternatively, it is mixed with resin and then applied to the road. There are a number of different binders and processes.

High Friction Surfacing used on the Strategic Road Network in England must comply with MCHW1 Clause 924

HFS is costly and has a very high carbon footprint which is mainly due to the method of production of the raw materials. Advice on where to use HFS is given in DMRB HD 36.

The type of application, how the materials are applied, preparation and the prevailing ambient conditions at the time of installation are important to ensure long term durability of the product.

Although the calcined bauxite used in HFS is reputed to have a high PSV, a large factor is the size of the aggregate (3 mm) and other, natural, aggregates of this size have PSVs in excess of 70 [TRL 322: 1998]. The advantage of calcined bauxite is that it is extremely hard and only wears away very slowly under traffic.

Figure 9.1 HFS – Sprayed Epoxy Resin System using Chinese Calcined Bauxite

Types of HFS

9.2 There are two main categories of HFS – Cold Applied and Hot Applied.

9.2.1 Cold Applied

These systems comprise a resin (thermosetting) binder which also acts as an adhesive for the aggregate, typically graded 1-3mm. The aggregate is very hard with a low Aggregate Abrasion Value (AAV) and a high Polished Stone Value (PSV) that provides the necessary friction with the tyre.

Note: in some cases the binder may be sprayed warm but the aggregate is always laid cold.

Figure 9.2 HFS Cold Applied Resin System

Cold applied resins include epoxy, polyurethane and Methyl Methacrylate [MMA].

Cold applied resins are installed as continuous films of adhesive. They are either:

- blended and sprayed by machine onto the road onto which the aggregate is broadcast, or;
- blended mechanically and then manually applied by squeegee after which the aggregate is broadcast.

In both cases, after the resin has cured, excess aggregate is removed by sweeping.

9.2.2 Hot Applied

In hot applied materials, the pre-mixed resin and aggregate is heated in a truck mounted boiler at high temperature ensuring the material is mixed and workable. The hot thermoplastic material is screeded out in strips to cover the whole surface.

Figure 9.3 Hot Applied Screeded Mixed Resin System

Selection Criteria

9.3 HFS generates extremely high stresses in the surface, which are immediately transmitted, in full, to the layer below. It is essential, therefore, for the Overseeing Organisation to ensure that HFS is not specified on an existing surfacing and road structure that is not fully sound. It is unlikely that localised patching of the surface, particularly in the wheel tracks, will be adequate to support HFS.

9.3.1 Advice on where HFS should be used is given in DMRB HD 36. Because of the high cost it must only be used where it is necessary after eliminating other, less expensive options.

9.3.2 Recent research has shown that materials with 6mm aggregate and negative texture show enhanced skidding resistance compared to materials with larger aggregate – this is compatible with TRL 322 referenced above. This reduction is not yet included in HD 36 but should be borne in mind when needing to improve skidding resistance in a particular situation. Other factors should be considered, most of which are stated in HD 36:

- If the PSV of the current surface is providing adequate skidding resistance in accordance with HD 28 then the same aggregate can be reused
- Where designers are knowledgeable or have other experience of particular site conditions, an alternative PSV can be specified
- HFS should not be used on the circulatory parts of a roundabout (see IAN 154)
- Increasing the skidding resistance of a site is not cost effective when there have been no collisions currently

9.4 Cold applied thermosetting HFS is the preferred option on the Strategic Road Network in England. Hot applied should only be used where and when it is not possible or feasible to use cold applied HFS.

The Overseeing Organisation should be aware that, when hot applied is specified, either directly or by implication, there is a very significant health and safety risk, as hot applied requires manual handing of heavy and very hot (200 ºC and above) material in open buckets. This safety risk should be assessed as part of the client's responsibility to ensure as far as possible that safe methods of working are possible under the Construction, Design and Management Regulations 2007.

Generally, cold applied has a better appearance due to the method of placing and has proved to be more durable on sound substrates.

9.5 There are three classes of HFS; Type 1, Type 2 and Type 3. Their use depends upon the volume of commercial vehicles using the lane and the degree of braking and turning. Details are contained in the Guidelines Document for the Assessment and Certification of HFS obtainable from www.bbacerts.co.uk .

Type 1 materials are for the highest traffic levels and Type 3 for the lowest. Over-specification should be avoided, but there are very few Third Party Approved materials that are certified for other than Type 1.

All the materials must be laid on clean, dry and sound substrates. Failure on any of these counts will ensure early failure.

There are suitable materials for laying in any temperature range between 0ºC and 40ºC, but it is likely that curing of cold laid materials will take considerably longer at low temperatures. It is also much more difficult to ensure a fully dry road when ambient temperatures are low. Therefore, where feasible, daylight working in the period April to September, is preferred.

HFS must carry HAPAS or Third Party Approval certification and the installer must have HAPAS or equivalent certification for laying that particular product. This must be checked by the Overseeing Organisation on the HAPAS website or by making contact with Notified Bodies that have certified HFS.

Planning and Co-ordination

9.6 Careful and detailed planning before work commences is an essential element of successful HFS. Due to the nature of the majority of the sites, there must be close co-ordination between the Overseeing Organisation and the installers at every stage, commencing with a pre-works meeting, the purpose of which is to ensure total understanding of the way that the programme and site works will proceed.

Working under a road closure offers significant advantages in terms of speed of installation and safety, and technically by potentially reducing the number of construction joints in the installation. The road closure should encompass sufficient time to deal both with inclement weather and the length of curing time in the coldest likely temperature that occurs at the time of the year at which the work will be carried out. Road closures need a significant notice period to organize.

More detailed information on planning and the execution of the works can be found in the RSTA/ADEPT code of practice for HFS.

Surface Preparation

9.7 Prior to any HFS application being planned a detailed inspection must be undertaken jointly between the Overseeing Organisation and Installer to identify any imperfections within the road surface.

9.7.1 Considering HFS performance, substrate cracks are particularly undesirable as the HFS will crack in sympathy and the thermal and traffic stresses will increase crack width, letting in water and potentially leading to potholing.

Where this defect is present, at least the surface course should be replaced, prior to the installation of the HFS. Hot joint treatments that seal the existing joint may also be suitable; flexible inlay systems may provide inadequate support for the HFS.

9.7.2 A rutted surface may suggest that movement is taking place in the surface course or binder course below. HFS is often applied where traffic is channelised and slowing, activities that more easily rut the surface. In this instance, the rutted areas should be replaced prior to the installation of the HFS.

9.7.3 On ‘fatted’ road surfaces, HFS treatment will not perform as the fatted material is not likely to be able to resist the severe braking forces generated by the HFS. In these areas, the existing surfacing should be removed by milling and a new surface course applied prior to the application of a HFS.

9.8 Prior to works commencing, it is a condition of the contract review stage within the Quality Assurance (Sector Scheme) process that the installer informs the customer in writing whether or not the surface is acceptable for HFS installation, in accordance with the specification.

Where the installer believes a good quality HFS installation <u>cannot</u> be achieved (and a guarantee cannot therefore be provided), the Overseeing Organisation may agree to a derogation in writing, thus accepting a lesser life, or, preferably, carry out remedial measures prior to works commencing.

Where a new HFS is replacing an existing HFS, all the old HFS must be removed, preferably by milling.

If the system is to be applied to a new asphalt surface, a period of time must be agreed between the Overseeing Organisation and the installer prior to the new asphalt surfacing being laid and the HFS being applied. The different high friction systems that are available can determine the length of time that is acceptable between applications. This information is given against the individual systems and it can vary from 0 to 28 days. The time delay between laying new asphalt and installing the HFS is influenced by the porosity of the surface course as this influences the rate of volatile loss from the asphalt layer. It may be possible to lay some systems onto new asphalt without delay if recommended by the manufacturer. Table 9.1 provides guidance on the recommended time interval before installing HFS onto freshly laid asphalt.

System	HRA	Thin Surfacing	Microsurfacing	Surface Dressing
Machine Applied - Cold	Between 7 and 28 days	Between 14 and 28 days	Between 14 and 28 days	After 6 months
Hand Applied - Cold	Between 7 and 28 days	Between 14 and 28 days	Between 14 and 28 days	After 6 months
Hand Applied - Hot	Within 24 hours	Within 24 hours	After 14 days Traffic	After 14 days Traffic

Table 9.1: Time Interval before Installing HFS Systems onto Freshly Laid Asphalt

The Overseeing Organisation should ensure any appropriate measures necessary to maintain adequate traffic safety during this time interval are put in place.

The cleanliness of the existing road surface is critical to the adhesion of the HFS. The Overseeing Organisation must check that the road surface is clean and dry, free from ice, frost, loose aggregate, embedded topsoil, vegetation, oil, grease, road salt and any other loose material likely to impair the adhesion of the system to the whole area of the road surface to be treated.

Preparation should be carried out by hand work and by machine vacuum sweeping with drying if necessary. Surface contamination including any salt film should be removed by lancing with hot compressed air. Where any old HFS has to be removed by fine cold milling, the method must be agreed with the client, including a demonstration if necessary, as the risk of damage to the existing surface can be high.

The ambient and road surface temperatures should be measured. The installation of the systems should not be carried out if the road surface temperature is outside of the range given in the method statement for the system. Care should be taken with cold applied systems at the lower temperatures that allowances are made for extended curing times if the binder does not allow for on-site variation in the cure rate.

On new surfaces, the binder in all systems can run down into the voids; this may possibly leave insufficient material to ensure even adhesion of the Calcined Bauxite aggregate. It also uses considerably more resin than is necessary for adhesion as it effectively grouts up the surface. This is undesirable technically and very expensive. Any mitigation measures have to be permitted within the HAPAS or other Third Party Approval certificate for the system. New surfaces that will be subsequently treated may be gritted.

Constituents

9.9 **Binder**

The current binders that have been assessed and approved for the application of HFS are:

- Cold Epoxy Resin
- Cold Bitumen Extended Epoxy Resin
- Cold Polyurethane
- Cold Methyl Methacrylate
- Hot Rosin Ester (Thermoplastic)

- Hot Hydrocarbon Resin (Thermoplastic)

These approved systems must be applied in accordance with the HAPAS or equivalent Third Party Approval certificate.

9.10 Aggregate

The aggregate used in HFS will normally be Calcined Bauxite because this is the only type of aggregate with a proven track record in HFS. However, procedures for assessment of alternative aggregates are available; for example, the BBA have produced a data sheet (36/10) which gives the procedure for them to assess materials with alternative aggregates.

For cold applied systems where the aggregate dressing is applied on site, the installer is responsible for ensuring that the aggregate used comes with a valid certificate demonstrating compliance with the requirements.

For hot applied systems, the product manufacturer guarantees the complete product.

Suppliers of Calcined Bauxite should undertake annual testing for physical properties, mineralogy and chemical properties contained within Table 9.2.

Table 9.2: The Recommended UK Specification for the Properties of Calcined Bauxite

Physical Property	**Limits**	**Test Method**
PSV 10/6	70+	BS EN 1097-8:2009
Abrasion Value 10/14	≤ 4	BS EN 1097-8:2009 Annex A
Particle Density	≥ 2.8	BS EN 1097-6:2000
Moisture Content	≤ 0.5%	EN 1097-6:2000
Particle Angularity	Blocked shape (not flakes)	Visual Assessment
Grading % passing		**EN933-1:1997**
4.00 mm	100%	
3.35 mm	≥ 95%	
0.60 mm	≤ 0.5%	
Mineralogy		**XRD**
Diasporic or Gibbsitic Corundum	60-85%	
Chemical Composition		**EN 932-3**
Al2O3	≥ 82.0%	
Fe2O3	≤ 4.5%	
SiO2	≤ 12.5%	
K2O+Na2O	≤ 0.5%	
TiO2	≤ 4.5%	

Detailed Requirements for Each System

9.11 General

It is the responsibility of the manufacturer and installer of the system to ensure that the application of the materials is in accordance with the method statement and HAPAS or equivalent Certificate.

A copy of the method statement must be available on every site for use by the Overseeing Organisation, the operatives, and the Third Party Approval body. The Overseeing Organisation must always check on each site.

9.12 Cold Lay - Machine Application

Pre-works Calibrations

In addition to annual calibration by a UKAS test house, and prior to any application of HFS, the spray machine should be checked by the installer to ensure the proportions of each resin component, the volume sprayed and the uniformity of spray across the spray bar is in accordance with the calibration procedure.

Preparation

To ensure that a quality product is achieved, the existing surface preparation is critical to the success of a good HFS and meeting the specification.

The method statement should include detailed arrangements for site preparation and the checks carried out to ensure the site is satisfactory. The surface should be clean and dry.

It is critical on machine applied sites that the existing surface onto which the resin is to be applied is uniform and free from voids within the surface. An ideal surface, for example, would be a 55/10 HRA that was 3 or 4 weeks old.

Cold applied systems, machine laid, cannot be laid on existing HFS as they do not adhere. In addition, as the existing layer has thickness, an uneven road surface profile will be produced. All the existing HFS must be removed from the surface.

The minimum air and surface temperature for a successful durable HFS using machine applied systems is given in the method statement, typically 0-10ºC. This should be checked prior to work commencing. The binder manufacturer's chart should be available giving the curing time/temperature relationship so that the traffic management can be planned.

It is the responsibility of both the Overseeing Organisation and the Installer to agree areas of rectification works in advance of any works being undertaken on site.

Application of Resin

The process detail for machine applied systems is contained within the method statement and a copy must be available on site at all times.

The mixed resin is sprayed onto the prepared surface at a required coverage rate, which will vary according to the texture and porosity of the surface, but must not be less than 1.35kg/m².

The installer should inform the Overseeing Organisation and the spray machine operator of the designated rate of spread of resin prior to the installation.

Most modern high friction binder machine applicators are fitted with adjustable spray bars enabling the width of the spray bar to be varied. This enables the spray bar to be operated from 0.3m up to its maximum width, normally 3.6m.

The spray bar should be equipped with automatic ground speed control, with the operator pre-setting the required rate of spread; the controller then electronically controls the forward speed of the machine.

Alternatively, some machines are fitted with equipment that automatically adjusts the output from the spray bar to compensate for variations in the forward speed of the spray bar.

It is essential that the correct amount of selected resin is applied onto the road surface. It is also necessary to check that the spray bar is working correctly and the application of the A and B components mixed within the mixing head of the machine is in the correct proportions. The installer should ensure that regular checks are carried out on the machine prior to application to confirm that the materials have been mixed correctly in accordance with the method statement.

Although a successful calibration test result will show that any particular bar is capable of operating within the limits specified, checks should be made at the start of each day and during the day as appropriate, for example if there has been a long break in the continuity of the work, to ensure that the jets are continuing to operate satisfactorily.

Spray bars are fitted with slot jets. The output from any jet is affected by both the temperature of the binder and the spray bar pressure. The rate of spread of resin on the road surface is additionally affected by the speed at which the high friction spray tanker moves, but this should be corrected by the computer control systems.

The operating height of spray bars fitted with slotted jets is important if the correct resin distribution is to be achieved. The operating height of any particular spray bar should be indicated on the chart carried in the driver's cab. A typical operating height is about 450mm.

The height of the bar should be checked regularly and adjustments made if necessary. If the jets are at the wrong height this may be visible in the sprayed resin film. With slot jets, it is also important to ensure that the jets are fitted and locked at the right angle. This is normally achieved when the jets are correctly fitted into the bar but a visual check will quickly indicate if any particular jet is out of alignment.

Filters are fitted in the pipe work feeding resin from the tanker to the spray bar to prevent any solid material reaching the spray bar, where it could cause the total or partial blockage of a jet. It is essential that these filters are checked at the start of each day as well as during the work, particularly if a drop in pressure is observed during spraying.

On-site testing of transverse distribution and rate of spread is carried out using carpet tiles. The appropriate test is set out in BS EN 12272-1.

Once it has been established that a spray bar is operating correctly in a transverse direction, longitudinal distribution is controlled by the vehicle's computer system; however, further carpet tile testing should be carried out to monitor the rate. The appropriate test is set out in BS EN 12272-1.

The carpet tile test is an important method of ensuring that spray bars are working correctly at the actual time of spraying.

The rate of spread of resin over any section of road can also be calculated by comparing the area of the section treated with the amount of resin used, as indicated by the computer read out supplied from the machine. This exercise is carried out after the completion of each site. Within this check, the computer supplied information will also be able to provide the ratio of A and B materials applied within the mixed ratio.

Application of Calcined Bauxite

Once the resin has been applied to the surface, Calcined Bauxite aggregate is broadcast over the resin in as even a distribution as possible, but to an excess. This application can be applied mechanically or by hand, depending on the site conditions. If the application is by mechanical means, the Bauxite is applied to excess to ensure that the aggregate applicator does not damage the underlying resin. If the Bauxite is applied by hand, then a broom should be used to squeegee out the aggregate to get an even distribution.

Once the resin has sufficiently cured, the excess aggregate is removed by a vacuum sweeper, or by hand depending on site conditions. Rolling of the aggregate is not permitted.

Due to the cost of the Calcined Bauxite, it is recommended that the excess aggregate swept up is re-screened and re-used wherever possible.

Aftercare

On completion and prior to opening to un-restricted traffic the following checks should be undertaken by the installer:

i) A check that the binder film has fully cured and is hard

ii) A full visual check on the site to ensure that a uniform surface texture has been achieved

iii) Any identified surface blemishes and any discernible faults are noted and remedied where practicable

iv) All excess aggregate has been removed from the surface by sweeping

v) Advisory ‘Loose Chippings’ signs with supplementary plates stating ‘20mph’ and ‘Skid Risk’ to be erected in locations in advance of the site to advise motorists of the potential hazard over the next 48 hours

vi) A second sweep of the surface is undertaken within 24-72 hours of the application including adjacent footways where considered necessary.

vii) All advisory signs can be removed once this final sweep is completed

viii) The need for ongoing safety visits to check for further aggregate shedding and sweeping if necessary should be agreed with the Overseeing Organisation

Maintenance and Repair

Should the system be damaged or become de-bonded from the substrate, it may be repaired by cutting the damaged area back to firmly bonded material. This can be undertaken by fine milling, hydro blasting or other similar forms of removal.

The area is then to be fully prepared using compressed air, masking the perimeter and reinstating to the original specification. For small areas, this may be carried out using hand applied material. For larger areas, machine applied material may be used.

Cold systems machine laid do not adhere to themselves.

It should be noted that patching HFS introduces joints in the system that can lead to cracking of the layer and the surface below. This can lead to potholing if the joints are near the wheel path, so repairs in this area are most undesirable.

Durability

The results of the performance tests and the performance of the system in use indicate that, when used in an appropriate location, the system should have a service life of between 5 to 10 years. To attain this length of service, the material should meet the requirements after 2 years when tested in accordance with the test methods in Annex 9A.

9.13 Cold Lay - Hand Application

Pre-works Calibrations

The installer should have on site all necessary calibrated measuring equipment for correct batching of the constituents and relevant certificates.

Surface Preparation

To ensure that a quality product is achieved the existing surface preparation is critical to the success of a good HFS.

The method statement should include detailed arrangements for site preparation and the checks to be carried out to ensure the site is satisfactory. The surface should be clean and dry.

It is critical on hand applied sites that the existing surface onto which the resin is to be applied is uniform and free from voids within the surface. An ideal surface would be a 55/10 HRA that was 3 or 4 weeks old.

All the existing HFS must be removed from the surface.

The minimum air and surface temperature for a successful durable HFS is given in the system's method statement. This should be checked prior to work commencing. It is imperative that the Installer takes this into consideration when applying systems at the lower end of the ambient temperature range.

Application of Resin

The two or three constituent components are added together within a correct weight ratio and then mixed prior to application on the surface.

The materials are mixed together for a period of time in accordance with the manufacturer's recommendations and until a homogeneous product is produced. Mixing is normally carried out using a high-torque drill fitted with a helical mixing blade in a large bucket or similar container. The mixed binder is then immediately poured onto the prepared road surface and spread evenly with a notched squeegee.

The installer's operator should be informed of the area that one batch will cover and this should be marked on the highway so that at least the minimum coverage rate required is achieved. This will vary according to the texture and porosity of the surface but should not be less than 1.35kg/m^2.

Application of Calcined Bauxite

Once the resin has been applied to the surface, an excess of Calcined Bauxite aggregate is broadcast over the resin and is spread out evenly using a broom or squeegee. After the binder is sufficiently cured, the excess aggregate is removed by vacuum sweeper or by hand, depending on site conditions.

Rolling of the aggregate is not permitted.

Due to the cost of the Calcined Bauxite, it is recommended that the excess aggregate swept up is re-screened and re-used wherever possible.

After-care

On completion and prior to opening to un-restricted traffic the following checks must be undertaken by the installer:

i) A check that the binder film has fully cured and is hard

ii) A full visual check on the site to ensure that a uniform surface texture has been achieved

iii) Any identified surface blemishes and any discernible faults are actioned and remedied where practicable

iv) All loose and excess aggregate has been swept from the surface

v) Advisory 'Loose Chippings' signs with supplementary plates stating '20mph' and 'Skid Risk' to be erected in locations in advance of the site to advise motorists of the potential hazard over the next 48 hours

vi) A second and final sweep of the surface is to be undertaken within 48-72 hours of the application

vii) All advisory signs are to be removed once this final sweep is completed

viii) The need for on-going safety visits to check for further aggregate shedding and sweeping if necessary must be agreed with the Overseeing Organisation

Maintenance and Repair

Should the system be damaged or become de-bonded from the substrate, it may be repaired by cutting the damaged area back to firmly bonded material. This can be undertaken by fine milling, hydro blasting or other similar forms of removal.

The areas should then be fully prepared using compressed air, masking the perimeter and reinstating to the original specification. Some cold applied systems do not adhere to themselves and the system installer should be consulted.

It is the responsibility of both the Overseeing Organisation and the Installer to agree areas of rectification works in advance of any works being undertaken on site.

Durability

The results of the performance tests and the performance of the system in use indicate that when used in an appropriate location, the system should have a service life of between 5 to 10 years. To attain this length of service, the material should meet the requirements after 2 years when tested in accordance with the test methods in Annex 9A.

9.14 **Hot Applied - Hand Application**

Pre-works Calibrations

The installer should ensure that the thermometer(s) on the mixing pot are working correctly and calibrated and relevant certificates are available. It is recommended that installers monitor the temperature of the material by taking periodic readings using either a long handled or digital probe accurate to ± 2ºC, to control and maintain the application and safe heating temperature range.

Surface Preparation

To ensure that a quality product is achieved the existing surface preparation is critical to the success of a good HFS.

The method statement should include detailed arrangements for site preparation and the checks carried out to ensure the site is satisfactory.

Existing HFS must be removed from the surface.

Material Preparation

The materials arrive on site in bags, with the resins, aggregate and fillers already mixed together. They simply require to be heated and mixed in a suitable boiler, fitted with a vertical or horizontally mounted agitator.

The materials are to be prepared in accordance with the method statement which should always be available on site.

The material temperature should be periodically checked during the mixing and application process by the attached thermometers and by a long handled or digital probe accurate to ± 2°C, to ensure that the maximum and minimum application temperatures are maintained and the safe heating temperature is not exceeded.

Application

The mixed Thermoplastic HFS material is discharged from the boiler into buckets and transferred by hand to the screed box with a typical width of 300mm, to give an equivalent strip width on the road surface. Since the material is extremely hot (in excess of 200ºC), great care should be taken during this operation to avoid injury to the operators and any others in the vicinity of the works.

The HFS is applied to the prepared surface using a screed box with a suitably designed trailing edge to give a finished thickness of between 4mm and 6mm. This is achieved by combing the material transversely across the road surface, allowing the encapsulated aggregate to be evenly distributed, providing a well textured finish, free from lumps and similar blemishes. Some approved systems fall outside this thickness.

The screed box is passed repeatedly across the road surface with a minimum of 10mm overlap to ensure 100% coverage. The material shall flow out from the box so that the binder and aggregate is evenly distributed to provide the well textured finish described above.

On a road surface with an average texture depth of 1.5mm, the coverage rate of Thermoplastic HFS should be between 11kg/m² and 12.5kg/m². The coverage rate may need to be increased on a more highly-textured surface.

The number of bags used should be reconciled with the surface area treated, to confirm the correct rate of spread.

The Installer's method statement will determine how segregation and overheating of the materials is avoided.

Materials that have been overheated are likely to fail prematurely. As this cannot be measured later, it is advisable for the Overseeing Organisation to note the temperature at regular intervals.

After-care

On completion and prior to opening to un-restricted traffic the following checks should be undertaken by the installer:

i) A full visual check on the site to ensure that a uniform surface texture has been achieved

ii) Any identified surface blemishes and any discernible faults are recorded and remedied where practicable

iii) Advisory 'Loose Chippings' signs with supplementary plates stating '20mph' and 'Skid Risk' to be erected in locations determined by the Overseeing Organisation in conjunction with the installer

iv) The need for ongoing safety visits to check for further aggregate shedding and sweeping if necessary must be agreed with the Overseeing Organisation

Maintenance & Repair

Should the system be damaged or become de-bonded from the substrate, it may be repaired by cutting the damaged area back to firmly bonded material, cleaning the prepared area using hot compressed air or a propane torch, masking the perimeter and reinstating to the original specification. A minimum 25mm overlap onto the existing material should be made.

Durability

The results of the performance tests and the performance of the system in use indicate that when used in an appropriate location, the system should have a service life of between 5 to 10 years. To attain this length of service, the material should meet the requirements after 2 years when tested in accordance with the test methods in Annex 9A.

Performance Criteria

9.15 At the end of the maintenance period and at the end of the guarantee period, if different, a visual assessment of the HFS should be carried out. The HAPAS guidelines are not appropriate for specification purposes or for carrying out comparisons over time. A formal visual assessment should be undertaken at the end of the guarantee period using the procedure given in Appendix 9A. The procedure may also be used at other times to assess deterioration rates.

Other uses of HFS

9.16 HFS is often used in situations where its high friction qualities are either not required or may even be potentially hazardous. The material used is normally hot applied and has been coloured by some means; typically red, green, buff and occasionally blue.

The colours are used typically for

- Bus lane delineation
- Cycle lane surfacing – where this is on the carriageway
- Traffic management

Figure 9.4 Cycle Lane – Green Resin System

Figure 9.5 Cycle Route – Blue Resin System and Red Bus Lane

Figure 9.6 Reinforcing Speed Limits

Figure 9.7 Red Pigmented Resin Screeded System with Grey Guayanan Calcined Bauxite

Figure 9.8 Red Pigmented Resin Screeded System with Grey Guayanan Calcined Bauxite after a Few Years Wear at a Pedestrian Crossing – Note Loss of Pigmentation

There are other and potentially more durable or cheaper options for all these uses. There would also be a considerable reduction in carbon footprint, which is a Highways Agency objective (see Chapter 13 Miscellaneous Surfacing Materials for coloured materials).

Bus lane delineation may be simply a white line marking the edge of a lane or, as used by some authorities, coloured inlaid stone mastic asphalt using clear resin, pigment and aggregate of the appropriate colour.

Cycle lane surfacing using hot applied screeded material is very uncomfortable to ride on due to the many ridges and discontinuities which are necessarily a part of the process. There is also a potential for traffic hazard in that often traffic overlaps into the cycle lane and if sharp braking is needed then the braking effort can be very different between the two wheel tracks of the vehicle, which could cause problems. Delineation by means of white lines and cycle outlines in the lane are just as clear.

Traffic management uses are typically in normal or untrafficked areas and the high friction is unnecessary. In this case, it would be cheaper to replace the calcined bauxite with aggregate of approximately the desired colour. There are a number of aggregates available that cover the colours red, green and buff/light grey. Blue, which is not commonly used, does not have a known source of suitable aggregate although some blast furnace slags contain some bluish particles.

Overlaying Concrete

9.17 The bond to concrete substrates and therefore the long term performance can be inferior to that achieved on bituminous surfacings and the suitability of each system should be checked by reference to the HAPAS or other Third Party Approved Certificate.

Normative References

BS EN 12272-1 Surface dressing. Test methods. Rate of spread and accuracy of spread of binder and chippings

BS EN 12272-2 Surface dressing. Test methods. Visual assessment of defects

BS EN 12274-8 Slurry surfacing. Test methods. Visual assessment of defects

Construction, Design and Management Regulations 2007.

Interim Advice Note 54

Manual of Contract Documents for Highway Works, Volume 1

Manual of Contract Documents for Highway Works, Volume 2

The Design Manual for Roads and Bridges, Volume 7 – HD 28.

The Design Manual for Roads and Bridges, Volume 7 – HD 36.

Informative References

RSTA Code of Practice for High Friction Surfacing (RSTA, 2011)

ROE, P G and S A HARTSHORNE (1998), ‘The Polished Stone Value of aggregates and in-service skidding resistance’, TRL report 322, TRL, Crowthorne

Annex 9A – NOTE: This Annex could be incorporated into MCHW2 NG924

Test Methods for Visual Assessment of HFS

These are based on tests from BS EN 12272-2 and BS EN 12274-8 for surface dressing and slurry surfacing, respectively, which are already in use in MCHW1 Series 900 for those materials. Minor modifications are needed to enable their use for HFS.

The four tests to be used are:

1. for fatting up – the test for fatting up from BS EN 12274-8 (P_1 in that standard)
2. for delamination – the delamination test from BS EN 12274-8 (P_2 in that standard)
3. for chipping loss – the fretting test from BS EN 12272-2 (P_3 in that standard)
4. for 'grinning'* **-** the test for groups of small repetitive defects from BS EN 12274-8 (P_4 in that standard) except that the minimum defect size shall be 10mm and not 10D.

* 'Grinning' is where the high friction surface has worn off the top of chippings in the underlying surface and they are 'grinning' through the HFS.

Listed below in Table 9A.1 are the performance criteria that are required for HFS on the Strategic Road network in England when tested in accordance with Annex 9A.

Table 9A.1 Specification for Visual Assessment of HFS

Parameter	**Requirement in the wheel track***	**Requirement outside the wheel track***
Fatting up after 2 weeks and any time up to 2 years; P_1 BS EN 12274-8	Not more than 0.5 %	Not more than 2.0%
Delamination at 2 years; P_2 BS EN 12274-8	Not more than 0.5 %	Not more than 2.0%
Chipping loss at 2 years; P_3 BS EN 12272-2	Not more than 3%	Not more than 6%
'Grinning' at 2 years; P_4 BS EN 12274-8	Not more than 3%	Not more than 6%

* where the location of the wheel track is indeterminate, as on roundabouts, the whole area should meet the wheel track criteria.

In addition, the Pendulum skid resistance value should be in excess of 65 at any time. It is particularly important to check hot laid materials in the first few days after laying as the aggregate may not be exposed for some time after laying.

COMMENT

The note below taken from the RSTA Code of Practice should appear in the Appendix 7/xx for HFS – there is none currently and this could form the basis of one

Appendix 7/xx of MCHW2

The contract documents should state

a) The product and its installation shall comply with MCHW1 Clause 924 i.e. be manufactured and installed by companies with a HAPAS or other Third Party Approved Certificate for the relevant system

b) The type of system (see Para 9.4 above)

c) A clear site drawing indicating the area to be treated

d) The length and average width of each section, possibly by means of a schedule

e) The existing surface type on which the system is to be installed and whether it is new

f) The period over which the HFS may be applied

g) The material specification to be applied (if necessary)

h) The colour requirement for the site

i) Specific traffic management required. e.g. access period

j) Other site specific requirements e.g. noise

k) Treatment of road markings (e.g. mask existing / cover / remove and cover / new)

l) Treatment of manholes (e.g. masking or covering)

The documents shall be in sufficient detail for the scope of the works to be clearly identified and all the necessary Health and Safety issues identified.

10. SLURRY SURFACING AND MICROSURFACING

Introduction

10.1 Slurry Surfacing is a term used by the Comité Européen de Normalisation (CEN) and includes the product Microsurfacing. Slurry Surfacing and Microsurfacing are products used as alternatives to Surface Dressing for routine maintenance of road surfaces; like Surface Dressing the product has a low carbon footprint and is an economic method of restoring skid resistance and preserving the road pavement. It is a cold-laid, sustainable product and optimises the use of high performance aggregates.

10.2 Microsurfacing (sometimes known in the UK as Microasphalt) is distinguished from Slurry Surfacing in this Chapter in that the aggregate for Slurry Surfacing includes 0/2mm and 0/4mm aggregates, whereas Microsurfacing uses coarser aggregates, generally 0/6mm and 0/8mm, and is normally laid in two layers: a base layer and a surface layer. Slurry Surfacings and Microsurfacings are mixtures of aggregates, fillers (cement) and bitumen emulsions or polymer modified bituminous emulsions; they may contain fibre additives. Slurry Surfacings range in thickness from about 3mm to 6mm and Microsurfacings from about 8mm to 20mm. Thin Slurry Surfacings are suitable for footways and areas that are trafficked only occasionally and at low speeds. The majority of Slurry Surfacings and all Microsurfacings are manufactured using polymer modified bituminous emulsions.

Figure 10.1 Microsurfacing - Rural Road

10.3 For the Strategic Road Network (SRN) in England, more complex proprietary Microsurfacings with bond coats or bonding systems are specified as "Innovative Ultra-thin Treatments" (IUTs). IUTs are capable of maintaining the required levels of 'Surface Integrity Performance', skid resistance and macrotexture for high-speed roads and a particular traffic category.

10.4 IUTs have Third Party Approval Certification for the installed product and approved Microsurfacings are evaluated as competitor products to innovative proprietary Multiple-layered Surface Dressings and Ultra-thin Asphalts that use polymer modified bond coat as part of a system. IUTs rely for performance on the bond to the substrate as part of a system; they are not currently specified by any European Harmonised Standard. IUTs also include products such as Cape Seal, a combination of Surface Dressing and Slurry Surfacing.

10.5 Necessary references are: 'The Code of Practice for Slurry Surfacing and Microsurfacing' issued by the Road Surface Treatments Association (RSTA) and the Association of Directors of Environment, Economy, Planning & Transport (ADEPT), see www.rsta-uk.org, the British Standards Institution Published Document PD 6689, which provides guidance on the use of BS EN 12273 'Slurry surfacing –

Requirements', and the test method BS EN 12274-8 'Slurry surfacing. Test methods. Visual Assessment of Defects.'

Figure 10.2 Slurry Surfacing - Urban Road

10.6 Microsurfacings as IUTs are being developed for use on all roads, including high speed roads carrying significant traffic volumes. In Germany, Microsurfacings are being used on Autobahns. Slurry Surfacing permits only limited surface regulation when laid in one pass. If greater surface regulation is necessary, Microsurfacing is required and an initial base layer is used to fill in surface irregularities, such as minor rutting, followed by a second layer to provide the complete overlay.

Figure 10.3 Microsurfacing Second Layer - Motorway Work in Europe

Figure 10.4 Microsurfacing Surface Layer over Previously Laid Coarser Base Layer – Urban Road

10.7 Slurry Surfacings are not permitted on the SRN in England and Wales. However, Microsurfacings with bond coats as Innovative Ultra-thin Treatments (IUTs), having a Third Party Approval Certificate following a two-year Type Approval Installation Trial (TAIT), are permitted for use on the SRN by means of a Departure from Standards in England and Wales. A specific MCHW1 Clause 940 is being drawn up to specify IUTs.

10.8 The specification for Slurry Surfacing has two separate approaches: performance-related and IUT specifications.

CONTRACT TYPE	PERFORMANCE-RELATED	INNOVATIVE ULTRA-THIN TREATMENTS (IUTs)
Road Type (general description)	Urban and rural and all traffic levels	SRN in England with a Departure from Standards and other roads where high performance is required
Slurry Surfacing Types	Single Slurry Surfacing layer, or coloured materials, or Microsurfacing including base layer	Proprietary Microsurfacing (IUT) includes bonding system
Relative Cost	Medium	Medium to High
Risk for Overseeing Organisation	Low	Very low
Guarantees for Performance	2 Years Macro-texture and defects	5 Years Macro-texture, defects, 'Surface Integrity' and bond strength test
Clauses in MCHW1	918 Performance-related	940 IUTs
Type Approval Installation Trial **Binder** **Aggregate**	1 Year TAIT: PSV and Macro-texture Medium modification BS EN 13808 BS EN 13043	2 Years (Third Party Approval Certification) Highly modified Third Party Approval Certification for proprietary binders. BS EN 13043
As-built Manual	Yes	Yes
Substrate Condition Requirements	Reasonable	Sound
Monitoring	Years 1 and 2	Years 1, 2 and before 5

Table 10.1 Slurry Surfacing, Microsurfacing and IUT Specifications

10.9 The carbon footprint of Slurry Surfacing and Microsurfacing products used on the SRN in England and Wales must be evaluated and the Pavement Road Treatment Embodied Carbon Tools (PRoTECT) developed by RSTA should be used.

The RSTA PRoTECT document and Codes of Practice for Slurry Surfacing incorporating Microsurfacing are available on-line at www.rsta-uk.org and should be consulted when considering this Chapter.

Purpose of Slurry Surfacing and Microsurfacing

10.10 Slurry Surfacing and Microsurfacing perform two functions, which relate directly to Essential Requirements of the European Construction Products Directive.

Safety - Skid Resistance

Slurry Surfacing and Microsurfacing increase the macro-texture and improve the micro-texture of the road surface, with minimum use of scarce high-quality aggregate. These properties directly influence the skid resistance of the road surface, a significant aspect of its contribution to safety.

Durability - Preventative Maintenance

Microsurfacing with a bond coat, as an IUT, seals the underlying road pavement against the ingress of water and air, which cause deterioration of the structural courses of the road. This is preventative maintenance, which directly influences the durability and therefore the life of the road. In order to maximise this protection, Microsurfacing as an IUT should be applied as soon as minor crazing or fretting is first detected, which is well before the critical condition (major deterioration) is reached when often the only solution is removal of the surface course and even lower layers.

Tender Programming

10.11 Tenders should be issued - based on a provisional programme if necessary - before the end of December proceeding the summer in which the work will be carried out. After return of tenders, further time is necessary for tender evaluation and assessment including whole life cost comparison where appropriate.

Experienced contractors with premium quality plant are in limited supply and are committed to contracts on a first come first served basis, so late tendering will increase the risk of a contract being carried out by less experienced operators using less sophisticated equipment. However, using contractors registered to the Slurry Surfacing and Microsurfacing Sector Scheme 13 minimises this risk and should be considered an element in the tender evaluation process.

Ideally, patching should have been completed the previous summer. If this has not been done, a programme of hot laid patching should be carried out well in advance of the team arriving on site.

Contractors in possession of a quality assurance certificate ISO 9000 Series and National Highways Sector Scheme 13 registration have shown that they have the necessary skills and capability to ensure that Slurry Surfacings and Microsurfacings are installed in a safe, consistent and effective way. For this reason, it is sensible for contractors wishing to tender for Slurry Surfacing, Microsurfacing or IUT contracts to be registered holders of the Sector Scheme 13: Supply and Application of Surface Treatments to Road Surfaces. This is defined in Appendix A to the Specification for Highway Works (MCHW1)

10.12 There are risks of installing Slurry Surfacing and Microsurfacing outside a suitable weather window. For the SRN in England and Wales, installation must be completed between mid-April and mid-September; if the installation is to be carried out at night, it must be completed earlier, by mid-August, unless otherwise stated in the IUT Third Party Approval Certificate and with the approval of the Overseeing Organisation.

Northern latitude and high, shaded and exposed sites have an even smaller weather window for minimal risk. The use of proprietary Microsurfacing as an IUT reduces this risk, especially when having to work late season.

Figure 10.5 Wet Weather Failure - Slurry Surfacing with Insufficient Cohesive Strength before Thunderstorm, Damaged by Traffic

The Product

10.13 The majority of roads may be maintained by Slurry Surfacing and Microsurfacing, and techniques have been developed to increase early-life stability in cold and wet conditions. However, the cohesive strength sufficient to withstand traffic stresses, is not normally obtained before the product has dried out.

Where Slurry Surfacing and Microsurfacing may be Used

10.14 Hard uniform surfaces present minimal problems; however, soft and binder rich substrates markedly reduce durability of retained macro-texture, especially on heavily trafficked or stressed sites. If the existing road surface has a poor profile or is deformed in the wheel tracks (a rut depth greater than 10mm), pre-treatment by planing (milling) or surfacing may be required, although a base layer of Microsurfacing may be used to improve profile in these situations.

Figure 10.6 Rut filling using Microsurfacing, Before and After Treatment

10.15 There is always some initial loss of the coarse aggregate and there are some situations where it is not possible to provide controlled low-speed trafficking prior to sweeping and opening to unrestricted traffic. Motorway and trunk road sites have traffic flows and speeds such that convoying could be dangerous. Lane switching may be permitted to enable sweeping after a period of unrestricted trafficking. In such circumstances, it is vital to produce a very stable surface that can be fully swept prior to trafficking, with minimal subsequent risk of loose aggregate. It is principally for this reason that only Third Party Approval Certificated proprietary Microsurfacing IUTs are permitted for use, with approval from the Overseeing Organisation, on the SRN in England and Wales.

10.16 Computerised Slurry Surfacing and Microsurfacing machines that can spread variable widths are normal equipment and should be calibrated for accuracy, and monitored in application.

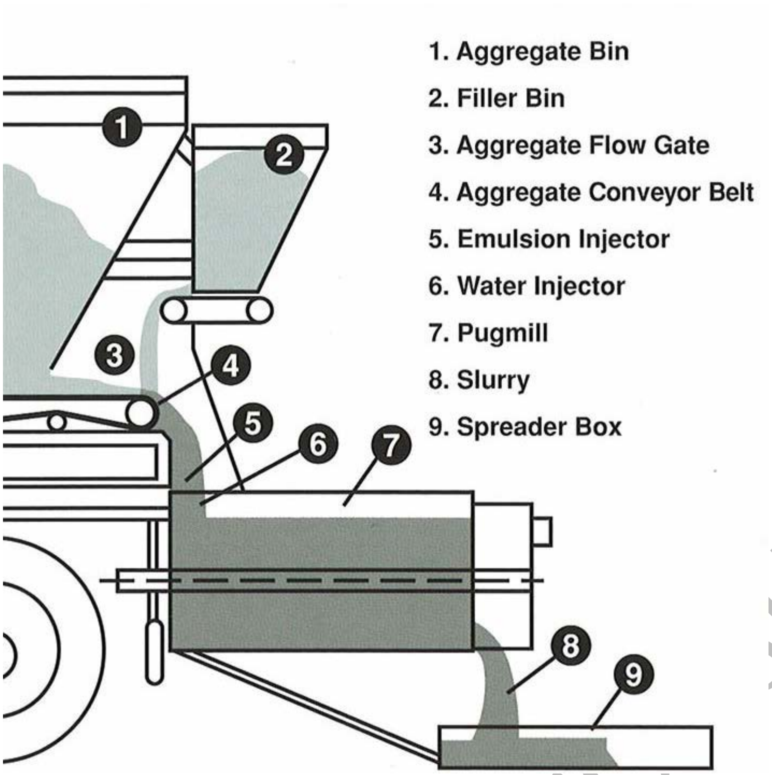

Figure 10.7 Schematic Diagram of a Typical Slurry Surfacing Machine

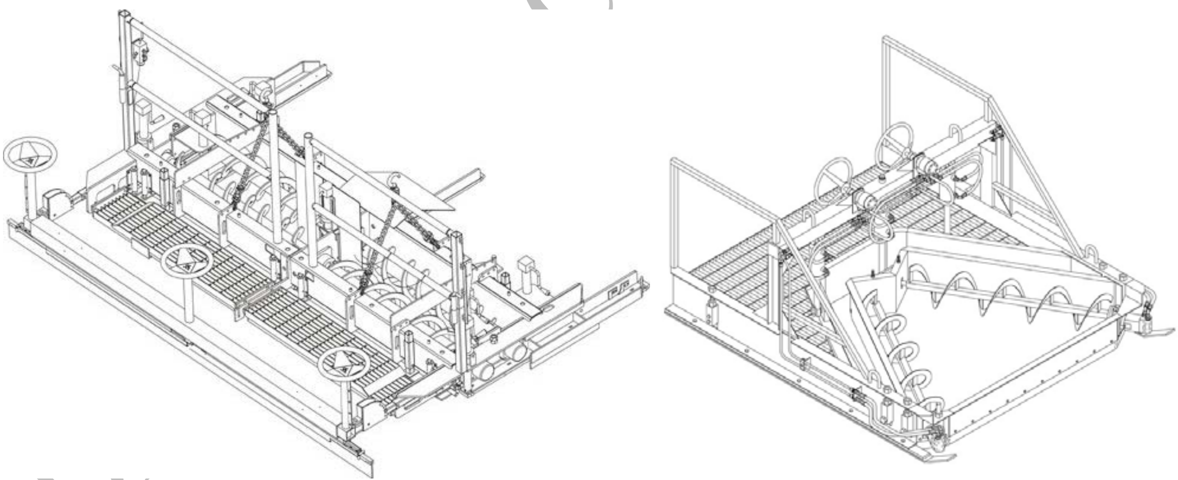

Figure 10.8 Examples of Spreader Boxes used for Microsurfacing – Carriageway and Rut Filling

10.17 Pneumatic-tyred rollers have been found to be useful to consolidate the material and aid the water removal and drying process.

10.18 Rollers should not pick up binder coated aggreate and must have adequate water sprinkling systems or other debonding systems working properly, especially in hot weather, to avoid this disruptive problem. For the SRN in England and Wales, there must be sufficient rollers to provide at least four passes of every section of Microsurfacing.

10.19 There should be sufficient suction sweepers to remove any loose aggregate during construction and to provide rapid removal after trafficking. They should have adequate water supplies to reduce to a minimum any pick-up by tyres during hot weather.

10.20 For the SRN in England and Wales, there must be at least two functioning suction sweepers in use for each Microsurfacing IUT section of 10,000m^2 to be carried out per shift, and pro-rata, with a minimum of two. The completed section must be swept to remove any loose aggregate prior to trafficking.

10.21 For the SRN, aggregate (dust), such as a light coloured absorbent 1/4mm blast furnace slag or oolitic limestone, should be available in a machine, such as a salt gritting vehicle. so that it can be quickly mobilised to distribute the material across the carriageway. This is so that any binder pick-up from badly installed binder rich areas by vehicles during very hot weather, or the effects of unexpected rainfall, or of any other incident such as that associated with the use of a polymer modified bond coat, can be counteracted.

10.22 For the SRN in England and Wales, sufficient suitable aggregate (dust) must be available for immediate distribution by an appropriate vehicle at any time during the installation.

Skid Resistance

10.23 Retained macro-texture (texture depth) for the SRN high speed roads is difficult to obtain and the Microsufacing IUT will detail this characteristic for the applicable TAIT. Aggregate with a high PSV is specified for areas of traffic stress such as braking areas, hills or bends, and aggregate with a low Aggregate Abrasion Value (AAV) selected for heavily trafficked sites to reduce wear rate, in accordance with HD 36 (DMRB 7.5.1).

Figure 10.9 Microsurfacing Used for an Urban Breaking Area

Environmental

10.24 The use of cold laid maintenance products using bituminous emulsion binders are encouraged because they are environmentally friendly: the emissions are almost entirely water vapour and the installation has a low carbon footprint. This also results in minimal degradation of the polymer binder during storage and installation. Waste materials (bitumen and aggregate) are not classified as hazardous.

Conservation

10.25 Planing before treatment is not necessary when the profile is acceptable, and ironwork may not need to be raised for Slurry Surfacings and most Microsurfacings. Material usage is low and the economic use of high PSV aggregate is a benefit; components are mixed cold using damp aggregates and no energy is expended on drying and heating the constituents.

Appearance

10.26 Slurry Surfacings and Microsurfacings may be used on road surfaces that have undergone a number of reinstatements, or significant patching, in order to provide a more uniform overall appearance. They can be used on surfaces that are fretting, and on those showing early signs of ravelling, to halt further deterioration.

Although aggregate for Microsurfacing is chosen for its skid resistance and wear properties depending on traffic category and traffic stress, coloured aggregate and pigments may be used in Slurry Surfacing for delineating hard shoulders and central reserves, or used in traffic calming measures where traffic levels are appropriate.

Figure 10.10 Coloured Slurry Surfacing Used for a Central Reserve

Profile

10.27 Microsurfacing can improve the profile of the underlying surface, particularly in the transverse direction, as these products are spread using a fixed screed mounted on skis.

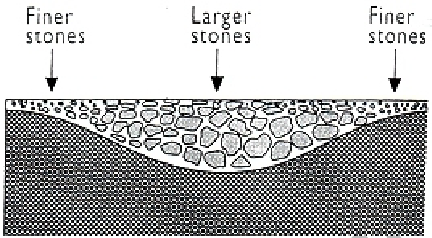

Figure 10.11 Microsurfacing Used for Rut Filling

Ride Quality

10.28 Microsurfacing with a base layer may improve ride quality, particularly if the problem is caused by undulations of very short wavelength. Undulations with a wavelength greater than about 1m may be slightly improved.

Speed of Works

10.29 Laying Slurry Surfacings, particularly Microsurfacing, is slow compared to Surface Dressing, but slightly faster than asphalt paving. The material must be left to break and stabilise prior to opening to traffic. In good weather conditions, warm with low humidity, this will take about half an hour, but in less satisfactory conditions it may take an hour or more. Where more than one layer is applied, however, traffic may use each layer as it becomes sufficiently stable. For single carriageway work with coned off sections and traffic control, outputs of 5,000m² per day are possible. With contra-flow and safety lanes, output is really only limited by the supply of materials to site and front feeders are currently available that can increase this dramatically. The ability to apply Microsurfacing at night minimises traffic disruption.

Figure 10.12 Front Loading Microsurfacing Machine

Sensitivity to Weather Conditions

10.30 Wet weather shortly after construction may delay the build-up of strength and traffic may disrupt the material in the wheel tracks. If traffic can be diverted until the road dries, the Slurry Surfacing or Microsurfacing may be saved. Slurry Surfacings are sensitive to high humidity and wet weather during construction. If heavy rain occurs before the emulsion has broken, the surface may be washed away, or if there is a frost within the first 24 hours, then the surfacing may be disrupted.

In very hot weather a maximum road temperature of 40°C may be specified in the Third Party Approval Certificate. When polymer modified bituminous bond coats are in contact with warm vehicle rubber tyres, a strong bond develops and strings of binder can form; traffic should not therefore be permitted over bond coats. Microsurfacing machine vehicle tyres can have water sprays or other protection systems fitted (e.g. debonding fluids or chalk dust) to prevent binder pick-up during laying operations.

Application should not be carried out when the ground temperature falls below 4°C or when standing water is present. When spreading in hot, dry conditions, it may be appropriate to slightly dampen the existing surface by means of a mist spray, where a bond coat is not used, to avoid the emulsion breaking too quickly. The surfacing should also be protected from the effects of rain or frost before the Slurry Surfacing or Microsurfacing has developed sufficient resistance.

10.31 Advice must be obtained from the Microsurfacing installer and polymer modified bituminous bond coat manufacturer concerning maximum humidity and maximum and minimum air and road temperatures for proper installation.

Structural Strength

10.32 Slurry Surfacing does not strengthen the road structure, although Microsurfacing as an IUT using a bond coat may reduce water ingress into the road pavement and the structural strength may be maintained. The Third Party Approval Certificate may claim improvement and should be considered.

Noise

10.33 The macro-texture of Microsurfacing is generally low and the coarse aggregate provides a slight positive texture, but the peaks are less regular than is the case with surface dressing and this generates less tyre/road interface noise. The tyre/road noise generation does reduce with time due to wear.

Permeability

10.34 Although Slurry Surfacings and Microsurfacings arrest surface deterioration, most products are permeable to a greater or lesser extent. They should not be assumed to be entirely waterproof. Where a bond coat has been used, or the treatment is over a newly laid surface dressing, a significant reduction in permeability may be expected.

Slurry Surfacing and Microsurfacing Techniques

10.35 The equipment needed for installation is dependent on the process used and can vary from simple batch mixing plant, brooms and squeegees used for veneer coats of Slurry Surfacing on footways, to integrated mixing and placing equipment used for Microsurfacings. Chemical additives are used to control the set and machines have augers in the spreader box to keep the material from segregating and setting before being screeded onto the road.

10.36 Thin Slurry Surfacings, 0/2mm and 0/4mm, are normally laid between 3mm and 6mm thick in a single layer and have little regulating ability. They may be used on footways, on cycleways and very lightly trafficked roads (e.g. on housing estates), where an existing bituminous surfacing is beginning to fret. For roads, they are normally mixed in a continuous mixer on site and immediately spread using a spreader box towed by the vehicle carrying the aggregates, binder and mixer. For footways, they are usually mixed in small batch mixers and spread by hand squeegee; for more information on their use on footways, see HD 40 (DMRB 7.4.3). The speed of laying can be reasonably fast but, as with all Slurry Surfacing, the traffic must be kept off until it has gained adequate strength. It is not normally necessary to adjust ironwork. They generally have a very low surface texture and should not be used where high speed skidding resistance is required.

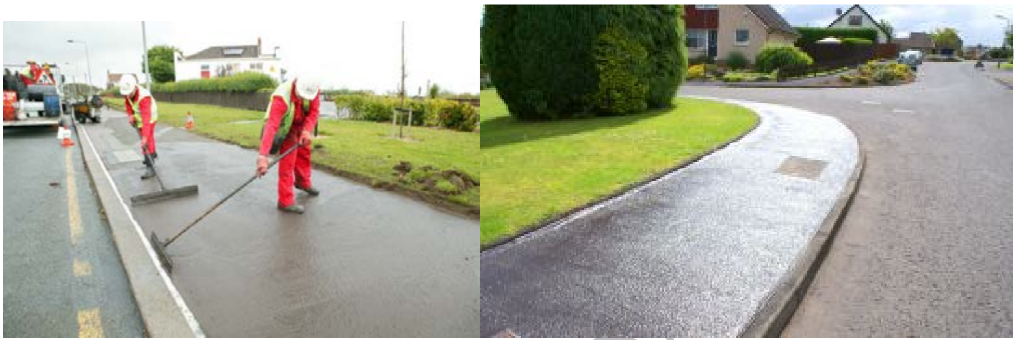

Figure 10.13 Footway Maintenance Slurry Surfacing – Street Furniture and Kerbs are Protected with Tape

Surface Preparation

10.37 The surface onto which the Slurry or Microsurfacing is to be applied should be clean and free from all contamination. All major depressions and potholes should be repaired. All oil deposits, dust, loose material, mud or other deposits should be removed by pressure washing or vigorous sweeping, as appropriate. Any weeds, moss, lichen or algae should be removed by the application of a residual weed killer approved by the Overseeing Organisation and subsequent pressure washing or other mechanical means. If water jetting has been used to prepare the surface, all free water should be removed before work begins. Surfaces which have 'fatted up' are generally not suitable unless the excess bitumen can be removed by retexturing - see DMRB HD 31. If the excess bitumen is not removed, it is likely to bleed through the Slurry Surfacing or Microsurfacing.

10.38 All ironwork, kerbs, edges, road studs, street furniture and, when required, road markings, should be masked with self-adhesive masking material. Turfs, oil, sand and similar materials must not be used. Junctions with surfaces not to be treated should be masked, or other suitable procedure used, to produce well defined, clean joints.

10.39 It is possible that some ironwork will need resetting because of the thickness of Microsurfacing systems. Care should be exercised in finishing round ironwork, to avoid an unsightly appearance. It is normal practice for ironwork to be raised after the application of the first layer of Microsurfacing because of the fixed screed in the spreader box, but before placing the second layer, so that an even finish is achieved. Although more normally used on road surfaces, these products may also be used on irregular footways to improve their shape. Hand laying should not be used except in limited areas where it is not possible to use a spreader box.

10.40 Slurry Surfacing and Microsurfacing machines are complex in that they are effectively a computerised cold asphalt manufacturing plant on wheels, combined with a paving machine. The mixing is a continuous system of a very fluid product (hence the term 'slurry') and the paver is a screed strike-off type, because there is no need to compact the material until after it is spread and has set, which may take up to an hour. Until the material has set or reached a sufficient cohesive strength, it is vulnerable to traffic, and proprietary systems have been developed to speed up this set/curing time.

Figure 10.14 Slurry Surfacing Consistency – Fluid Brown Unbroken Emulsion Mixture whilst Agitated

10.41 Slurry Surfacing and Microsurfacing machines cannot provide a perfect homogeneous surface appearance equivalent to paver-laid hot asphalt, but the machines should be maintained and calibrated regularly to provide consistent results.

10.42 The Overseeing Organisation must ensure that the correct performance levels of the Slurry Surfacing or Microsurfacing IUT are specified and obtained; in particular, any parameters specified must be measured to demonstrate compliance. The Overseeing Organisation must be satisfied that there is minimum risk of failure during the designed life, which is normally much longer than the guarantee period.

10.43 HD 36 (DMRB 7.5.1) shows the minimum PSV requirements for use on roads of differing traffic intensity and stress, and the AAV requirements for differing traffic levels.

10.44 In order to conserve aggregates the highest PSV chippings must not be specified for all roads, but each site should be considered individually in accordance with HD 36. For the SRN in England and Wales, the aggregate must have the designed PSV and meet the requirements set out in HD 36 for traffic and site category. The AAV must be less than 10.

10.45 Wear resistance generally improves with aggregate of lower PSV, therefore durability and safety are a balance and savings may be made by specifying a lower PSV. For trunk roads where contra-flow occurs during maintenance, each lane may be subject to the same traffic conditions; therefore, the PSV and AAV are generally chosen to be the same. Other artificial aggregates such as calcined flint, blast furnace or steel slag may be used to both economic and constructional benefit provided skidding characteristics are maintained.

10.46 For the SRN in England and Wales where a Departure from Standards is approved, the Innovative Ultra-thin Treatments (IUT) specification must be used for Microsurfacing. If the treatment is temporary for operational reasons (haul road or surface is to be removed or overlaid within a year), MCHW1 Clause 918 Slurry Surfacing may be used with the agreement of the Overseeing Organisation.

10.47 The Contractor’s Design Proposal and method for execution of the works must be assessed, particularly with regard to safety aspects.

Performance Specification

10.48 Performance-based specifications require all the design work to be carried out by the Contractor, with the Overseeing Organisation specifying only the levels of performance required, and imposing no checks other than approving the applicability of the TAIT and regular assessment of performance.

10.49 The risk element is divided between Contractor and Overseeing Organisation, by having a Guarantee Period (which is much less than the Design Life of the material) at the end of which the

Contractor must make good any defects, and after which period the Overseeing Organisation accepts the risk and any cost of future remedial work.

10.50 Monitoring performance characteristics of the installed Microsurfacing, such as initial installation defects, fretting after the first frosts, and macro-texture retained after the first hot summer, must take place and before the guarantee period has ended.

10.51 A further assurance of continuing performance to both Contractor and Overseeing Organisation is the use of an Approved System - one which has been through an evaluation procedure. The combination of recipe tests (based on extensive past experience), predictive tests and use of IUTs with Third Party Approval Certificates for the system should satisfy the Overseeing Organisation that there is a high probability of the work having the life estimated. This would normally be significantly longer than the guarantee period.

10.52 MCHW1 Clause 918 provides for a Slurry Surfacing or Microsurfacing TAIT after one year and CE Marking is provided to demonstrate capability of the contractor and the product to perform for a given site category in terms of macro-texture and maximum defects. The binder has CE Marking to demonstrate compliance with the Framework Standard BS EN 13808.

10.53 MCHW1 Clause 940 IUTs have end performance system TAITs assessed over two years by a Third Party, so that the declaration of performance in terms of defects, bonding, macro-texture and decay, and ‘Surface Integrity’ can be measured. These aspects of “Safety in use” and “Durability” are critical for the SRN. The component properties are declared; proprietary binders should normally have Third Party Approval Certificates and the aggregate should comply with HD 36.

10.54 The assessment of need for the maintenance of a section of road is outside the terms of reference of this Advice Note. Reference should be made to HD 28 ‘Skidding Resistance’, HD29 ‘Data for Pavement Assessment’, HD 30 ‘Maintenance Assessment Procedure’, HD 31 ‘Maintenance of Bituminous Roads’ and HD 32 ‘Maintenance of Concrete Roads’. Once it has been decided that a section of road needs some form of treatment and that strengthening is not required, the suitability of Slurry Surfacing or Microsurfacing for the treatment should be assessed. For a Microsurfacing IUT to be suitable, there should be a high probability that the treatment will produce the level of performance required over a reasonable lifetime. The factors affecting the decision are traffic levels and speed, difficulty of the site and the existing road surface.

Effect of Existing Surface

10.55 The main variables of the existing surface that will affect the final performance are porosity, roughness, amount of fatting, hardness and heterogeneity.

10.56 Table 10.2 shows the normally achievable performance, using best practice, of a correctly designed and appropriate system for different traffic levels and surface types.

The heavier the traffic, the more critical is the condition of the existing surface (substrate). At the highest traffic end only a normal, non-porous, homogeneous, fairly smooth road has a high probability of success for Microsurfacing to provide an economic life.

On lightly trafficked roads a successful outcome is possible in all cases, except in the case of bleeding, subject only to proper design and execution.

10.57 Any roads that are suffering from bleeding of binder, where water ingress has caused a fluxed binder to strip from aggregate beneath and come to the surface (sometimes visible as beads), are not suitable for Slurry Surfacing or Microsurfacing except as a temporary measure; reconstruction (in situ recycling) is often the only solution.

The influence of the substrate has such an impact on the performance of Slurry Surfacing and Microsurfacing that records should be made prior to the product being installed, ideally with photographs and detailed locations of existing defects, so that any problems arising during the guarantee period can be analysed properly. Routine machine surveys often include continuous high definition video.

10.58 For the SRN in England and Wales, existing defects must be recorded, ideally with photographs and accurate location information, before the installation of IUTs. The data must be stored for the life of the surfacing.

10.59 There are a number of factors that can widen the type of surface that can be treated with Slurry Surfacing. The three main ones are to accept a lower standard for defects, to accept a shorter life or to pre-treat the surface in some way to improve its characteristics. Slurry Surfacing and Microsurfacing products are continually improving and it is likely that developments in the future will enable a wider range of surfaces to be successfully treated. Surfaces, which Table 10.2 shows as not being able to attain the requirements, might be successfully treated in some instances by an improved product, using a higher performance binder or incorporating fibres or a novel system. As Contractors gain knowledge of and confidence in performance specifications and providing Type Approval Installation Trials, the type of site they will be willing to guarantee may also widen in scope.

Existing Surface Characteristic	**Traffic Category (cv/lane/day at design life)**							
	0-50	50-125	126-250	251-500	501-1000	1001-2000	2001-3000	>3001
Very Hard and homogeneous	Yes	Yes	Yes	Yes	Texture			
Hard and homogeneous	Yes	Yes	Yes	Yes	Texture			
Normal and homogeneous	Yes	Yes	Yes	Texture	Texture			
Soft and homogeneous	Yes	Yes	Texture	Texture	E			
Very Soft and homogeneous	Yes	Yes	Texture	E	E			
Fatting up in wheel tracks	Yes	Yes	Texture	E	E			
High macro-texture or fretted	Yes	Yes	Defects	Defects	E			
Porous	Yes	Yes	Defects	Defects	E			
Very variable	Defects	Defects	Defects	Defects	E			
Extensive patching	E	E	E	E	E			
Severe bleeding & extensive blackening								

Yes	Microsurfacing IUTs may be designed to meet the most onerous performance requirements in terms of macro-texture and levels of defects (BS EN 12274-8) for low-speed roads
Texture	It is difficult to maintain high macro-texture, especially in the wheel tracks. Texture requirements for low-speed roads may be achievable.
Defects	It is difficult to design to meet the most onerous requirements for the test method of visual assessment of defects (BS EN 12274-8) and they should not be specified.
E	In some circumstances a suitable Microsurfacing IUT may be designed by an expert using a proprietary system to meet less onerous performance levels; extra care in execution is required.
	Slurry Surfacings and Microsurfacings are not currently considered an appropriate treatment, except for use as a temporary surface on roads with less than 2000 cv/l/d for speed limits of 50 mph or lower.

Table 10.2 – Effect of Existing Road Surface Characteristics on Achievable Performance Levels

10.60 Table 10.3 describes the various types of site and possible pre-treatments to overcome the constraints of the existing surface.

Surface Type	Description	Possible Pre-treatments
Very hard or hard or normal and homogeneous	Minimal variation in appearance over whole section, texture below 1mm sensor measured	None needed
Soft and homogeneous	As above but surface hardness is less	None needed. Consider carefully macro-texture retention for the speed of traffic.
Fatting up	Has a surface that is binder rich and blackened, with very low macro-texture, usually limited to the wheel tracks	If it is only in the wheel tracks and has taken at least five years to develop, it is worth removing the excess binder with high pressure water jetting.
High macro-texture or fretted	A surface with a texture depth above 1mm sensor measured, usually with some fretting,	None needed. A bond coat should be considered
Porous	Surfaces such as porous asphalt and open-textured asphalt surfacing	Apply a single surface dressing with 2.8/6.3mm chippings a year before treatment with Slurry Surfacing or Microsurfacing
Heterogeneous, tracked with up to 10mm deformation in wheel tracks	This is the normal state of a surface which has been previously surface dressed	Slurry Surfacing and Microsurfacing may be used to normalise the difference in texture across the lane. Where transverse profile improvement is necessary, it is possible to use a Microsurfacing base layer
Heterogeneous, patched	This occurs mainly in urban areas where most roads are subject to opening by statutory undertakings companies. Subsequent reinstatement may be using materials which have significantly different properties of porosity and hardness from the surrounding road surface	The problem is best reduced to a minimum by insisting on proper reinstatement with materials which match the hardness and porosity properties of the existing road. Low speed roads which are badly affected can sometimes benefit from a pre-treatment of a single surface dressing with 2.8/6.3mm chippings a year before treatment with Slurry Surfacing or Microsurfacing
Bleeding	Free bitumen at the surface often in the form of beads, usually extending beyond the wheel tracks and caused by stripping of binder in the lower layers (displacement by water)	No pre-treatment will avoid subsequent failure in most cases, even on virtually untrafficked roads. Reconstruction or recycling is normally required using hydraulic binders

NOTE: Microsurfacing IUTs should be limited for use on surface types that are homogeneous and not too soft

Table 10.3 Description of Surfaces prior to Slurry Surfacing or Microsurfacing

Specification Parameters

Slurry Surfacing or Microsurfacing Type

10.61 The Overseeing Organisation should permit, with a Departure from Standards, any system complying with the IUT specification unless there are particular reasons why a specific type is needed, for example, highly polymer modified and fibre modified Microsurfacing for flexibility and toughness. The Third Party Approval Certificate and TAIT details will provide the information required.

End Performance Specification

10.62 MCHW1 Clause 918 is an end performance specification using BS EN 12273, with a guarantee requirement, normally of two years duration.

10.63 The TAIT Certificate and method statement for a product will set out the assessed performance levels, the site preparation, the mixing and laying procedure, bond coat requirements and aftercare. The performance requirements for Slurry Surfacing and Microsurfacing using Clause 918 during the guarantee period relate to wear and to loss of the surfacing. Limits are also set therein for the minimum retained macro-texture in the nearside wheel track and maximum macro-texture decay over the second year of the guarantee period, all measured by the sand patch test. It is therefore important that the actual performance of Slurry Surfacing and Microsurfacing systems are monitored and compared against the specified requirements.

10.64 The extra performance requirements for Microsurfacing when specified as an IUT are the need to report bond strength (measured by the test method for Microsurfacing in CEN/TS 12697-51) and a test for ‘Surface Integrity Performance’.

10.65 For the SRN in England and Wales, IUT performance levels (e.g. macro-texture, defects, bond strength and ‘Surface Integrity’) must be monitored and checked before the end of the guarantee period, which is normally 5 years.

Binder Data

10.66 MCHW1 Clause 918 requires rheological product identification and Vialit Cohesion of the recovered binder to be provided by the Contractor, see Chapter 3 Binders. It is unlikely that performance can be determined from binder data alone because systems are highly dependent on the aggregate grading, its physico-chemical nature and the set or cure. However, these are all proprietary products and the data are required for product identification and thereby to ensure consistency.

The specification for Slurry Surfacing incorporating Microsurfacing (MCHW1 Clause 918) requires the provision of a wide range of data on the binder to be used; refer to MCHW2 Notes for Guidance for choice of parameters to set out in Specification Appendix 7/7. Most of the data is required once for any source and grade of binder, although it is recommended that tests on the binder should be repeated at least annually. If a manufacturer uses a number of sources of bitumen or modifier, a range of values that covers the variation across all sources, or the data for each individual source, should be provided. This would also apply if the supplier manufactures the binder at a number of different plants. It will always be open to the purchaser of the binder and the Overseeing Organisation to carry out any or all of the tests to check whether a particular consignment conforms to the declared limits. The date of test for any parameter should be given when providing a data sheet.

10.67 Manufacturers of polymer modified bituminous binders must provide product identification and performance-related data for the TAIT, and for IUTs, a Third Party Approval Certification is necessary.

10.68 The binder recovery and ageing profile method used for polymer modified bituminous emulsion binders should be the method given in MCHW1 Clause 955, or alternatively one demonstrated to be equivalent to BS EN 13074-1 and BS EN 13074-2, together with a long term ageing test. A standardised recovery and ageing procedure is required for polymer modified binders so that the purchaser and the Overseeing Organisation can compare the results for a given consignment of binder with the manufacturer’s claims, because the purchasers of binder or of final Slurry Surfacing or Microsurfacing are not in a position to check the base binder. It is not intended that the recovered or aged binder necessarily reflects any particular stage in the life of the Slurry Surfacing or Microsurfacing, although it may be found to do so. Recovered binder is likely to reflect its state fairly early in its life when it is still vulnerable to traffic damage, and the ageing profile shows the capacity for ageing on the road.

10.69 Product identification test data from a dynamic shear rheometer is required, because it discriminates between binders made with different base bitumens and different polymers without revealing the 'recipe' manufacturing process. The data required are curves of G* (complex shear modulus) and delta (phase angle) against temperature at a frequency of 0.4Hz over the range -10 to +60°C (see Chapter 3 Binders). The frequency has been standardised in order that comparison can be made between binders if required and to make the likely data bank of information as comparable as possible.

G* at 25°C and 0.4Hz has a good correlation with penetration value (see Gershkoff, D., 'Polymer Modified Bitumens—Performance in Empirical and Rheological Tests,' Proceedings of the 1st European Workshop on the Rheology of Bitumen Binders, Brussels, Paper 34, April 1995), because there is a similar loading time; in addition, the temperature when G* equals 2kPa provides a high temperature performance indicator similar to Softening Point. All the available data should be provided in tabular format. Some polymer modified binders do not permit temperature or frequency shifting to provide a single master curve and in these cases the separate curves should be provided, together with the reasons why the provision of a master curve was not possible. The data from this test are required for recovered binder together with an ageing profile using the test in MCHW1 Clause 955.

Binder Performance Test - Vialit Pendulum Cohesion, MCHW1 Clause 939

10.70 Binder cohesivity is a measure of the ability of the binder to cope with traffic stresses. In general terms, the levels of cohesivity define the range of binders used: conventional, intermediate grade, premium grade and super premium grades are available. These are characterised by peak cohesion levels of 0.7, 1.0, 1.2 and 1.4J/cm^2, respectively. However, when comparing two binders with the same cohesivity, the one maintaining the level over the widest temperature range is likely to provide enhanced performance. The more stressed the site, the higher the cohesivity required. Not all unmodified binders necessarily meet the lowest level so that test certificates should always be required. It is always open for a contractor to use a higher grade than that specified.

Test Frequencies

Test frequencies must be specified in MCHW1 Appendix 1/5 using the frequencies in Table NG1/1

Audit Checks

10.71 It should not be necessary to carry out routine checks on proprietary products with a two-year guarantee. Nevertheless, if obvious variations in a product are occurring, audit tests should be undertaken to determine aggregate properties and grading, binder content and binder characteristics. These should be carried out to check that the product complies with the requirements of the Specification and, when issued, with the requirements of the Third Party Approval Certificate and the system proprietor's method statement. Non-compliance should be reported to the Overseeing Organisation and, where appropriate, the Third Party Assessor, and may, if serious and on-going, result in the suspension of the Certificate or CE marking for the system.

Acceptance Testing

10.72 At the end of the guarantee period, the whole of the work should be visually assessed using the visual test procedure in BS EN 12274-8 to check compliance with the specification. It is anticipated that for the majority of the work, the qualitative method will be sufficient and the more detailed quantitative method only used when there is disagreement between the contractor and Overseeing Organisation. Macro-texture should be checked on a representative section of the work.

Equipment Calibration

10.73 Calibration of the machine is required to control the use of aggregate, filler, emulsion and additives. This should form part of the installer's Method Statement.

10.74 The thickness should be controlled and outputs reported as detailed in the Method Statement. Thickness may be controlled by weighing input materials or with on-site depth tests or by throughput controls.

10.75 Transverse and longitudinal profile improvements should be measured to comply with any requirements set out in MCHW2 Appendix 7/7.

10.76 The appearance of the laid Slurry Surfacing or Microsurfacing should be monitored and regular maintenance and cleaning of spreader box, feeds, augers and ancillary equipment organised, to prevent minor score marks, segregation or contamination of the material.

10.77 Samples should be taken and binder content determined at the frequencies set out in Appendix 1/5.

Macro-texture

10.78 The decay of macro-texture with time is not linear and is greater in the first two years; it depends on many parameters so it is difficult to extrapolate early-life macro-texture measurements.

10.79 All texture depths for Slurry Surfacing and Microsurfacing should be specified in terms of Volumetric Patch measurement (other methods may be used provided they are converted to Volumetric Patch equivalent values) and the levels for high speed roads at 2 years would normally be those given in MCHW2 Clause NG 918 and specified in Appendix 7/7. The end product performance specification provided in MCHW1 Clause 918 requires texture measurement: (i) initially; (ii) after mosaic formation; (iii) at between three and five weeks (only where noise is a problem); (iv) after eleven months and before thirteen months, and; (v) at the end of two years. This is with the exception of new untried proprietary materials or systems, where the guarantee period should be one third of the offered design life. The reduction in texture over the period between 12 and 24 months provides some indication whether or not the texture depth will remain above the required minimum value for the design life of the Microsurfacing.

10.80 Macro-texture must be monitored between 11 and 13 months and between 23 and 24 months, to assess rate of reduction, and again before the end of the guarantee period.

10.81 The decrease in texture between 12 months and 24 months is a guide to the life of the Microsurfacing; the lower the value the longer the life, unless failure mechanisms intervene. A maximum figure of 40% is an appropriate specification value, with a minimum of 0%, as any increase in texture indicates that the surface is fretting.

10.82 Skid resistance on most Microsurfacing products cannot be measured with reasonable precision before the end of the second or third year.

10.83 For IUTs, the TAIT is monitored for macro-texture after two years and the installed Microsurfacing must be tested before the end of the guarantee period at 5 years (normally during routine testing).

Description, Evaluation and Avoidance of Failures

10.84 Microsurfacing has failed when it is either:

a) no longer able to meet the needs of the traffic using the surface, or

b) no longer protecting the structure of the carriageway from the ingress of water (bond coat has failed).

Failure occurs in one of three different and rarely overlapping time periods: (i) during installation or shortly afterwards caused by extremes of weather and/or poor traffic management; (ii) during the first couple of years, or; (iii) due to old age, which may be any length of time from 5 years after execution. Records exist of Microsurfacing performing satisfactorily for in excess of 10 years on less heavily trafficked roads. Early failures are almost always the result of inadequacies in one or more of the 4 stages in the production of a Microsurfacing on the road. These stages are:

a) Specification

b) Design

c) Materials

d) Execution including aftercare

In a performance specification, the last 3 items are the responsibility of the Contractor and there are good sources already available from which to obtain advice and guidance on best practice, notably the RSTA/ADEPT Code of Practice.

In a recipe specification, the first two or sometimes three items are the responsibility of the purchaser.

10.85 All Slurry Surfacings and Microsurfacings fail eventually. This is due to a combination of factors including, principally, fretting or wear and binder hardening. Microsurfacings, especially when combined with bond coats and specified as IUTs, have longer lives and maintained performance levels compared to thin Slurry Surfacings. Long term failure is rarely catastrophic, unless bonding has not been achieved and delamination occurs, and appropriate maintenance (surface treatment) can be planned in advance. Slurry

Surfacings and Microsurfacings do not fail on a fixed time basis and each site should be inspected regularly and treated when minor deterioration is detected, as otherwise more costly maintenance is necessary. This preventative maintenance provides best value for money and extends the life of the road.

Visual Assessment of Defects

Failure Definitions

10.86 The following are definitions of failure modes reproduced from the visual assessment test method used to assess performance, BS EN 12274-8.

Defect
State of Slurry Surfacing and Microsurfacing where the material is affected by one or more of the effects defined in BS EN 12274-8.

Bleeding, Fatting up and Tracking
Appearance of free binder at the surface

NOTE: This may be due to the binder migrating to the surface (bleeding) or to coarse aggregate migrating downwards (fatting up) or a combination of the two; it is often difficult to visually separate the two causes. Tracking is evident as shiny areas caused by traffic, resulting in loss of macro-texture, normally in the wheel tracks.

Figure 10.15 Slurry Surfacing – Mixture Problems: Fatting up and Delamination

Figure 10.16 Poor Workmanship at a Joint – also Mixture Binder Rich and will Fat up

Delamination
Detachment of the Slurry Surfacing from the underlying road or from a lower layer of a multi-layer Slurry Surfacing

Figure 10.17 Delamination – no Bond Coat

Wearing and Loss of Slurry Surfacing
Loss of mass of material

Loss of Coarse Aggregate
Loss of chippings due to the action of traffic before the Slurry Surfacing has gained sufficient strength, or by stripping of the binder from the aggregate

Figure 10.18 Fretting of Microsurfacing due to Mixture Problems – probably Low Binder Content

Lane Joint Gaps
Incomplete layer of Slurry Surfacing between adjacent lanes

Figure 10.19 Poor Overlap at Joint – More Pronounced when Road is Wet

Rutting
Permanent deformation, by flow, of the Slurry Surfacing layer, which occurs in the wheel tracks

Slippage
Horizontal deformation by flow of the Slurry Surfacing over the layer beneath or the underlying road due to the action of traffic

Corrugation
Transverse undulations at more or less regular spacing (the area encompassing the corrugation is measured)

Figure 10.20 Unacceptable Corrugation of Laid Material

Figure 10.21 Slight Corrugation Visible is not a Defect – Appearance will Improve with Traffic Wear

Bump (ridge)
Transverse or longitudinal raised area
NOTE: This may be caused by overlap during installation.

Figure 10.22 Transverse Bump and Some Localised Loss of Aggregate

Small Repetitive Defects or Groups of Small Defects
Defects less than $1m^2$ and greater than 10 times D^2, where *D* is the upper aggregate size as defined in BS EN 13043 for the Slurry Surfacing being visually assessed

NOTE: These may be grouped together for evaluation.

Longitudinal Grooves (Score Marks)
Marks parallel to the laying direction below the general finished level of the Slurry Surfacing

NOTE: Longitudinal grooves are often produced by larger aggregate particles or broken and hardened mix dragged by the spreader box.

Figure 10.23 Score Mark caused by Aggregate Contaminant (May also be Lumps of Cured Material)

Other Defects
Defects caused by operations on the road since the Slurry Surfacing was laid, for example damage caused by winter maintenance or accident. These are not considered as a defect in this document

Width of Lane
When there are no road markings, the lane width is the full road width. When there are road markings, the lane width is the distance between the centre marking and kerb or verge, When there are more than two lanes, the outside or centre lanes and hard shoulder (safety zone) are considered separately.

Figure 10.24 Slight Mixture and Segregation Problems and Spreader Box needs Maintenance. This Appearance is not Regarded as a Defect; the Skid Resistance will be Good and the Surfacing is Complete. Traffic Wear will Improve the Appearance with Time.

Figure 10.25 Developments to Ensure Retained Macro-texture for High Speed Traffic will Increase the Use of Microsurfacing

Figure 10.26 Microsurfacing on a Rural Road with Adequate Macro-texture – see Insert

10.87 Slurry Surfacings and Microsurfacings can fail in a number of ways. Table 10.4 summarises possible causes of these failure and suggests how they may be avoided and in some cases rectified.

Defect	Cause	Avoidance and Remedy
Lack of adhesion to underlying surface	Inadequate preparation and cleaning of existing surface. Incompatibility between slurry and underlying road. Inadequate bond coat used.	The only way to avoid this is to ensure that the existing surface is properly cleaned. If badly contaminated with hard mud or other materials, water jetting will be required. There is no remedy other than remove and repeat the work.
Lack of bond between layers	Lower layer contaminated or insufficient binder in the mix	Check the design of mixture and ensure site is kept clean. There is no remedy except to remove and resurface
Failure to set	Work done in adverse weather conditions or incompatible constituents	Work should not be carried out in adverse conditions, i.e. rain, cold or high humidity. Check the design of the mixture. Resurface the site in more appropriate conditions or with a more robust product.
Rapid wear	Material inappropriate to site. Opened to traffic too soon. Work done in adverse weather conditions.	Check design of mixture. The material must gain sufficient stability before opening to traffic. Do not work in adverse conditions. The only remedy is to re-surface the site with a more robust product or in more appropriate conditions.
Tearing	Material insufficiently strong for the location or has poor cohesion or poor bond.	Poor design of surfacing; reappraise site and traffic conditions. Only remedy is to remove and repeat the work using more robust materials. Consider using a bond coat if bond is likely to be a problem.
Too rapid set	Poor design of the mix or the work is being carried out in hot weather	Redesign the mix. Keep the existing surface damp or stop work until weather is cooler.
Pushing	Insufficient cohesion or road opened to traffic too early, or a defective mixture	Close the road to traffic until cohesion has improved; use a mixture with a higher cohesion. If the mixture is at fault, the only remedy is to remove and replace with a more robust product.
Deformation	The design of the mixture is incorrect for the amount of traffic on the site.	Use a more deformation resistant mix. Only remedy is to remove and replace.
Bleeding	Too much binder in the underlying surface; too much binder in the mix	Do not use Slurry Surfacing over a very fatty road surface. Check design of mixture. The only long term remedy, where the new road surface has fatted up due to excess bitumen in the underlying surface, is to remove the slurry, re-texture to remove the excess bitumen and re-apply. Alternatively, resurface using another type of surfacing. If the mixture is at fault, remove and replace with a redesigned product.
Fatting up - premature texture loss	The sand-filler-binder matrix is too weak to prevent embedment of the coarse aggregate.	No remedy. Remove and replace with a superior product.
Depression	Usually a reflection of a low area in the underlying layer	Low areas should be brought up to the general level before the final layer is placed.
Ridge		Check that the screed has no damage. Check that the slurry is contained and does not flow round the end of the screed.
Longitudinal tracks	Usually caused by material adhering to the screed	Ensure the screed is clean and free from adherent material; check slurry is not breaking too fast (most likely in hot, dry conditions)
Colour differences	Many factors can cause colour differences.	Variations in colour may occur as a result of inadequate mixing or workmanship, or a change in material sources or their proportions. Variations due to differing substrate porosity, for example, can often be temporary, the colour becoming more uniform within a few days.

Table 10.4 Defects in Slurry Surfacing, Avoidance and Remedy

Normative References

Manual of Contract Documents for Highway Works, Volume 1

Manual of Contract Documents for Highway Works, Volume 2

The Design Manual for Roads and Bridges, Volume 7 – HD 28

The Design Manual for Roads and Bridges, Volume 7 – HD 29

The Design Manual for Roads and Bridges, Volume 7 – HD 30

The Design Manual for Roads and Bridges, Volume 7 – HD 31

The Design Manual for Roads and Bridges, Volume 7 – HD 32

The Design Manual for Roads and Bridges, Volume 7 – HD 36

The Design Manual for Roads and Bridges, Volume 7 – HD 40

BS EN 12273 Slurry surfacing – Requirements

BSI PD 6689 Surface treatments – Guidance on the use of BS EN 12271 and BS EN 12273

BS EN 13043 Aggregates for use in bituminous mixtures and surface treatments for roads, airfields and other trafficked areas

BS EN 13808 Bitumen and bituminous binders. Framework for specifying cationic bituminous emulsions

BS EN 13074-1 Bitumen and bituminous binders. Recovery of binder from bituminous emulsion or cut-back or fluxed bituminous binders. Recovery by evaporation

BS EN 13074-2 Bitumen and bituminous binders. Recovery of binder from bituminous emulsion or cut-back or fluxed bituminous binders. Stabilisation after recovery by evaporation

BS EN 12274-8 Slurry surfacing. Test methods. Visual assessment of defects

CEN/TS EN 12697-51 Bituminous mixtures. Test methods for hot mix asphalt. Part 51: Interlayer Bonding (Compressed shear bond test - CSBT, Cyclic compressed shear bond test - CCSBT).

Informative References

RSTA Code of Practice for Slurry surfacing incorporating Microsurfacing (RSTA, 2011)

Gershkoff, D., ‘Polymer Modified Bitumens—Performance in Empirical and Rheological Tests,’ Proceedings of the 1st European Workshop on the Rheology of Bitumen Binders, Brussels, Paper 34, April 1995

11. GEOSYNTHETICS AND STEEL MESHES

Introduction

11.1 Cracking is a major failure mechanism of asphalt pavements and a significant proportion of the highway maintenance budget is devoted to appropriate treatment. One potential method of delaying the effects of cracking is the application of geosynthetics and steel meshes below the surface of the pavement. However, although such materials have been used in specific situations in the UK and more widely elsewhere in Europe, due to differing construction techniques, materials and traffic loading, their more general applicability to the UK road network is uncertain.

11.2 There is no conclusive evidence to date that geosynthetics and steel meshes (hereafter referred to generically as 'interlayers') are cost effective in controlling reflection cracking on roads typically in service on the Highways Agency network. Departure applications have been approved in the past on a "belt and braces" approach. That is, where a substandard pavement design must be implemented (due to other factors such as height restrictions at structures, traffic management restrictions, or widening), an interlayer can be included, on the basis that it should not reduce the design life. However, for the pavement constructions typically found on Highways Agency roads, there is no evidence to show that interlayers can increase design life or allow a reduction in overlay thickness.

11.3 Geosynthetic and steel mesh products are not covered in the Manual of Contract Documents for Highway Works Volume 1 (MCHW1) with respect to pavements and therefore require approval under the Departure from Standards procedure. However, a Departure from Standards is not required where a geosynthetic is used below at least 70mm of asphalt and over Hydraulically Bound Material, provided a control section without geosynthetic is installed and the site is monitored as described in this Chapter.

11.4 A major objective of this Chapter is therefore to familiarise the reader with procedures for the use of interlayers, to encourage their use and enable evidence to be gathered on their performance, thus facilitating a refinement of guidance and specification documents in the future. Further useful reading can be found in TRL 657, Road Note 41 and the RSTA Code of Practice for Geosynthetics and Steel Meshes.

11.5 This Chapter provides guidance and advice on the use of interlayers in asphalt pavements. Specifically, it sets out the requirements and process to be followed for their use, as part of a maintenance treatment for cracks and associated defects in flexible pavements, or in new construction. However, failures and degradation resulting from the following circumstances are not addressed:

- Asphalt deterioration
- Sub-grade failure and associated rutting
- Asphalt rutting associated with permanent asphalt strain.

Mutual Recognition

11.6 Any reference in this document to a "British Standard", or to a "British Standard which is an adopted European Standard", is to be taken to include reference also to the following standards:

(a) a standard or code of practice of a national standards body or equivalent body of any EEA state;

(b) any international standard recognised for use as a standard or code of practice by any EEA state;

(c) a technical specification recognised for use as a standard by a public authority of any EEA state, and;

(d) a European Technical Approval (ETA) issued in accordance with the procedure set out in directive 89/106/EEC.

11.7 Where there is a requirement in this document for compliance with any part of a British Standard or a British Standard which is an adopted European Standard, that requirement may be met by compliance with any of the standards given above, provided that the relevant standard imposes an equivalent level of performance and safety provided for by a British Standard or a British Standard which is an adopted European Standard.

"EEA State" means a state which is a contracting party to the EEA Agreement

"EEA Agreement" means the agreement on a European Economic Area signed at Oporto on the 2nd of May 1992 as adjusted or amended".

Cracking in Asphalt Pavements

11.8 Bituminous bound layers crack in situ because of their inability to withstand strain, shear and tensile stresses created by a number of factors, typically described in the following generic terms:

- Reflective cracking
- Fatigue cracking
- Cracking resulting from differential settlement (often prevalent in road widening schemes)
- Thermal cracking

11.9 The type of damage mechanism causing the cracks to appear at the pavement surface depends on the properties and nature of the pavement structure (for example, thickness, stiffness and severity of cracking in the existing pavement), the properties of the underlying soil, the traffic characteristics, the climatic conditions and the type of construction (particularly, whether it is new construction or maintenance in the form of relatively thin asphalt overlays).

11.10 A wide range of possible solutions (or combinations of solutions) for cracking exist. In addition to the application of an interlayer for stress-absorption or reinforcement, these solutions include local planing and reinstatement (and overlay), application of thick asphalt overlays and/or the use of modified asphalt mixtures (for example, with high bitumen content, polymer modified bitumen or designed in such a way that a porous nature is created). For new construction, applications for geosynthetics have included their 'prophylactic' use over cracked concrete and regulating material and before application of EME2 and new thin surfacing.

11.11 Particular benefits claimed for specific geosynthetic or steel mesh systems include the following:

- Reinforcement at low strain – the ability of the material to bind the asphalt layer together to resist crack propagation in either direction, spanning the potential crack.
- Stress absorption – the ability of the material to absorb transient stress in all directions
- Sealing - prevention of water penetration into lower layers and the avoidance of associated problems due to freeze/thaw effects and the need for lower drainage to remove subsurface water; potential reduction of oxidation of lower bitumen layers.

11.12 One key issue is that correct installation of these materials is an absolute necessity. The methods of manufacture, installation techniques and applications for interlayer materials have undergone significant changes over time. With an ever increasing number of proprietary products, installers and potential applications, it is important to ensure that where such materials are being considered, the product and its installation meet certain minimum requirements. This is considered in more detail below.

Geosynthetic and Steel Mesh Materials

11.13 The RSTA Code of Practice distinguishes between 5 main product types, and for convenience their classification and illustrative photographs are reproduced below:

- Steel meshes
- Glass grids (which may be coated with polymer or bitumen)
- Polymer grids
- Composites (combining polymer or glass grids and non woven textiles)
- Non-woven textiles

Figure 11.1: Steel Mesh (typically Galvanised Steel Wire, Double Twisted to form a Mesh with Reinforcing Bars at Intervals).

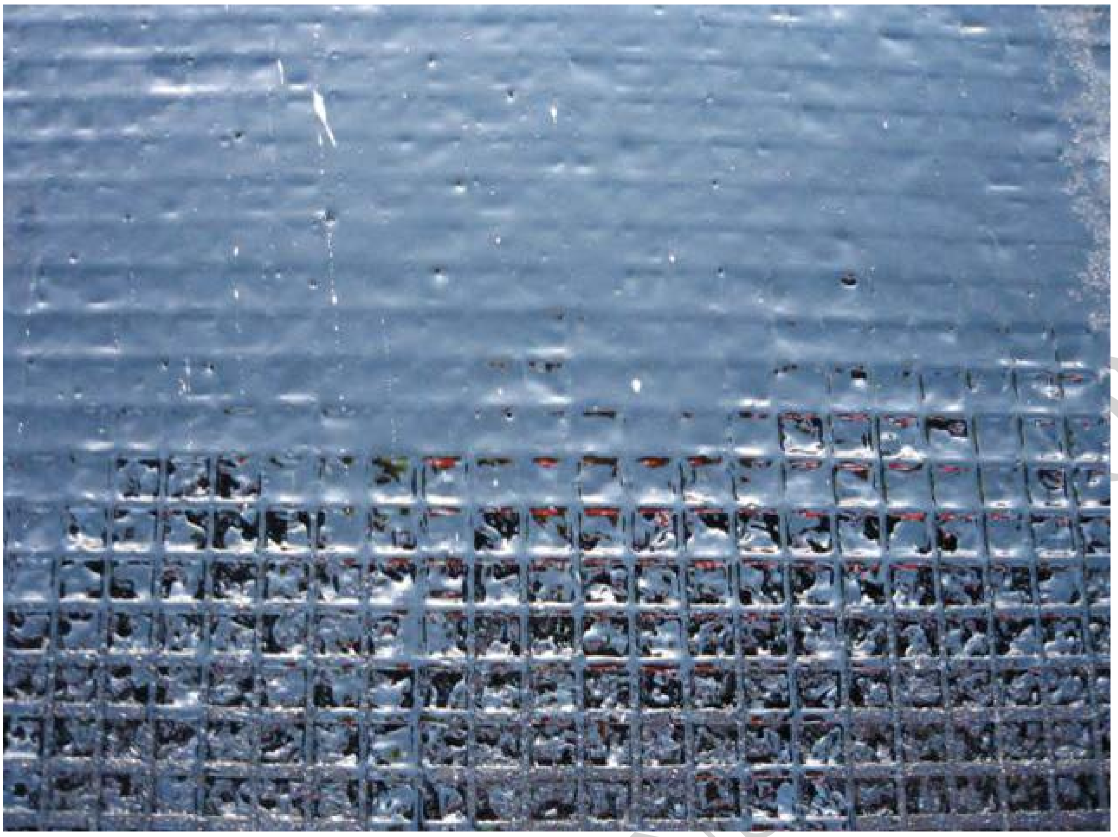

Figure 11.2: Glass Grids (typically Knitted and may be Coated with Polymer or Bitumen or a Combination, with or without Self-adhesive Backing).

Figure 11.3: Polymer Grids (typically Punched and Stretched Polypropylene or Knitted/woven Polyester).

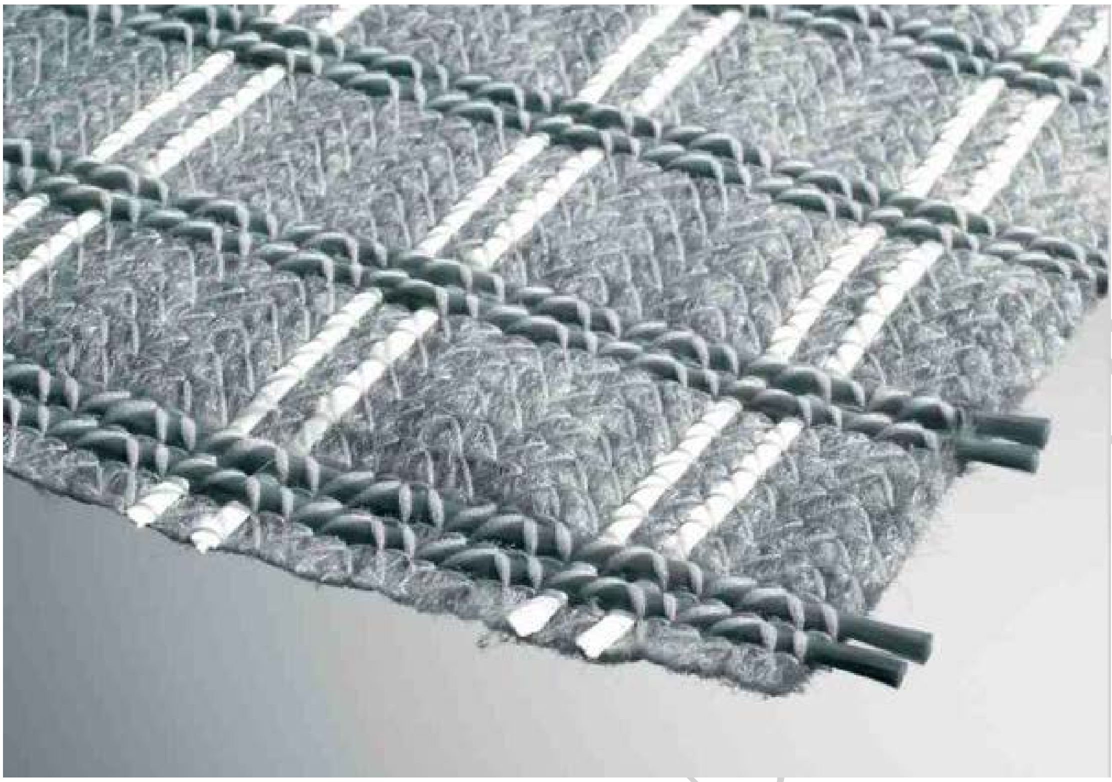

Figure 11.4: Composites (typically a Combination of Polymer or Glass Grids and Non-woven Textiles Combined by Lamination or Stitching).

Figure 11.5: Non-woven Fabrics (typically Needle Punched Polypropylene but Polyester and Combinations using Glass Fibres are also Available).

11.14 All the material listed above should be manufactured under quality controlled conditions and CE marked in accordance with BS EN 15381.

Procedure for Proposing the Use of an Interlayer

11.15 If it is proposed to include an interlayer in a bound layer as part of a maintenance treatment, a detailed proposal must be prepared. This proposal must be brought to a Stage 1 or Stage 2 Value Management Workshop for appraisal by a NetServ Pavements Team representative. Figure 11.6 shows the overall procedure which must be followed when considering this type of maintenance.

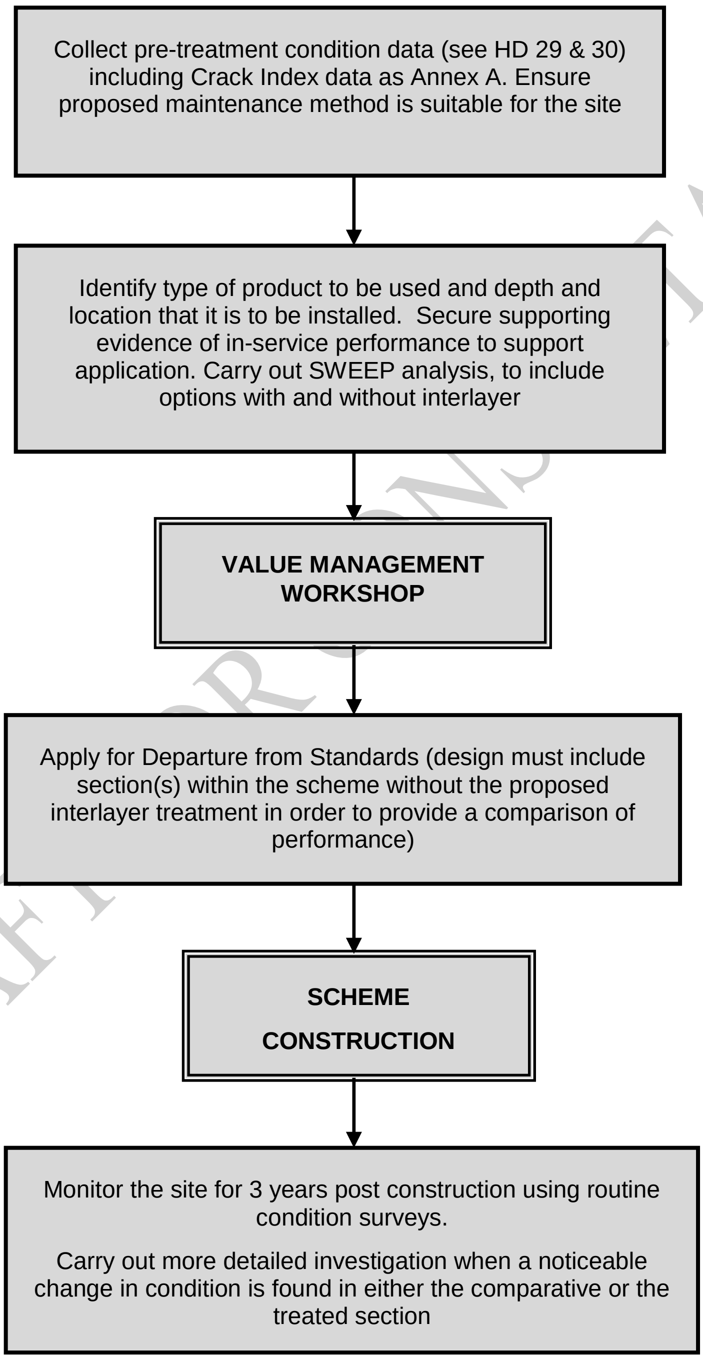

Figure 11.6: Procedure when Proposing Use of an Interlayer

Site Assessment

11.16 A comprehensive site assessment is essential prior to any planned remedial treatment. In particular, for any site being considered for application of an interlayer, detailed information on crack severity must be gathered. Options for crack assessment are set out in Annex A to this document. Further information on the collection of the required data for pavement assessment, and on maintenance assessment procedures, can be found in HD 29 and HD 30.

In order to further develop the MCHW and DMRB for the use of interlayers on the Highways Agency network, a “comparative section” with no interlayer must be incorporated into any works.

11.17 Appropriately selected comparative sections provide the only effective measure of how the site would have performed without treatment and provide the only true measure of the improved performance (with respect to service life) delivered by the treatment. These comparative sections must be representative of the rest of the site where the treatment has been applied so that meaningful comparisons can be made. The comparative section must only differ from the rest of the site in that the geosynthetic has been excluded.

11.18 More than one comparative section may be required if the interlayer is used in combination with other elements (e.g. a polymer modified binder course). This will allow evidence to be gathered on the performance of interlayers, enabling whole life cost and whole carbon accounting to be undertaken.

System Selection and Design

11.19 In terms of design philosophy related to reflective cracking, the various types of geosynthetics and steel meshes in use tend to be categorised as follows:

- Those which permit intimate contact between the overlay and the underlying asphalt or concrete and rely on reinforcing the upper layer to inhibit crack propagation
- Those which provide a change in horizontal stiffness between pavement layers thus reducing stress transfer between upper and lower layers. This is often known as the SAMI effect (Stress Absorbing Membrane Interlayer)
- Those which, via the use of composite materials, provide both of the above beneficial effects

11.20 However, there is no universally agreed classification system or design method available for the use of these materials at this time. Supporting evidence of proven in-service performance must therefore be provided in a Departure application to demonstrate the benefit. The value of any performance based evidence is greatly enhanced when the site reported on in the technical literature reflects the characteristics of the site proposed in the application for a Departure from Standards. Table 11.1 details the key factors to be considered in assessing the relevance of any evidence provided in support of in-service performance claims.

11.21 In addition to the items identified in Table 11.1, any proposal to use an interlayer should also consider:

- General site details, dimensions and traffic information
- The current condition of the pavement including details of a crack survey carried out in line with Annex A, the mode of failure/cracking mechanism at the site and how the proposed solution will address this
- The required mechanical and durability characteristics of the geosynthetic or steel mesh and how these are to be specified

- How the geosynthetic or steel mesh will interact with surrounding asphalt mixtures in order for the system to function
- The whole life cost benefit of the utilisation of the system for the project in question
- The recycling characteristics of the system, including removal of the geosynthetic or steel mesh at the end of its working life
- Details of the product and particular installation requirements associated with the proposed system (for example, location, depth and method of installation, need for regulating layer, minimum overlay type and thickness, particular type and quantity of bond coat)

Element	**Description**
Geographic location of site used as evidence	Section(s) should be located in UK or location with comparable climatic condition
Traffic loading at site used as evidence	Traffic loading (HGV) at site used as evidence not less than 75% of that at the proposed location
Pavement structure of site used as evidence	Pavement structure closely matching that at the proposed location
Comparative section	An appropriately designed comparative section was included at the evidence site (substrate in similar condition, all variations catered for)
Survey data	Supporting evidence from the survey data collected before and after treatment was carried out
Degree of pre-treatment cracking	The evidence site had a level of pre-treatment cracking equivalent to that of the proposed location
Past approved use on HA network	Evidence of a prior approved Departure

Table 11.1: Key Elements Needed to Validate In-service Performance Claims

Installation

11.22 The performance of the geosynthetic or steel mesh is critically influenced by the quality of the installation, which will usually be scheduled to take place immediately prior to the asphalt surfacing. Generally, the geosynthetic or steel mesh should not be left exposed for extended periods. The time allowed for installation will depend on the programme and site constraints but should not normally delay the surfacing works. As with all site operations, planning the execution of the work should take place well in advance of on-site commencement. Complimentary asphalt works should comply with the requirements of BS 594987.

11.23 The preparation required will vary according to the type of material to be installed. Textile backed geosynthetics, e.g. non woven fabrics and composite grids, are installed onto a bituminous bond coat sprayed onto an existing clean bituminous or concrete surface, a well planed surface without pot holes or loose material or a newly laid bituminous surface which must have cooled to ambient temperature. The receiving surface must be clean, dust free, relatively dry and free from standing water. All potholes must be made good and any cracks greater than 5mm wide must be sealed. Self adhesive geosynthetics should only be laid on smooth, even surfaces and generally should be installed onto a regulating layer, existing surface or new asphalt layer. Self adhesive grids will also require the application of bond coat either prior or post installation and the receiving surface must be thoroughly dry. Steel mesh can be laid onto an existing clean sound surface, or a well planed surface without potholes or loose materials. Steel mesh can be fixed by nailing, slurry or blinding with asphalt.

11.24 For geosynthetics requiring a bond coat for installation, it is vital to understand its importance in:

(1) Holding the geosynthetic in position during the asphalt paving process.

(2) Forming a seal between the underlying surface and the overlaying asphalt. Where a backing fabric is present, the heat and compaction of the overlying asphalt will soften the bond coat causing it to thoroughly impregnate the fabric.

11.25 Hot straight run bitumen and bitumen emulsion are also employed by some manufacturers. Whichever bituminous spray is used, it is essential that the correct type of material and the correct rate of spread are specified and adhered to. Rate and accuracy of spread should be determined in accordance with Clause 920 of MCHW1 and EN 12272 Part 1.

11.26 For installation of geosynthetics, a purpose made applicator capable of laying the fabric under tension without wrinkles or creases, and brushing it firmly into the bond coat, must be used (Figure 11.7). Rolling out the fabric by hand should be avoided except in the smallest or most inaccessible areas. Dependent on the type of geosynthetic and project limitations, either butt jointing or overlapping will be recommended to ensure continuous coverage without gaps and to avoid issues that may occur from reduced overlay thickness. Where overlaps are recommended, longitudinal overlaps should be a minimum of 50mm and transverse overlaps should be a minimum of 100mm. Direct trafficking of the geosynthetic should normally be restricted to the paving machine and delivery vehicles only. Steel drum rollers should not run directly over the geosynthetic.

11.27 For installation of steel mesh, the material should be unrolled with the outside of the roll facing upwards to keep the concave curvature downwards. Laps should be 150mm transversely and 300mm longitudinally and tied with wire. A staggered installation should be adopted to prevent overlaps of 3-4 meshes at one point. Once the rolls are in their final position, the mesh is rolled a minimum of two passes using a pneumatic tyred roller. The roller must cover the entire width of the roll ensuring that the steel mesh conforms to the prepared road surface. The mesh is initially secured at one end, then stretched to remove any curvature, before being fixed so that the first 4m of each mesh roll can be securely fastened. The mesh is then secured with nails, slurry seal, asphalt blinding or other methods, as appropriate, and this process is repeated as the material is unrolled.

11.28 It is important that the correct minimum thickness of overlay is achieved as insufficient thickness has been identified as a major cause of post installation issues and premature cracking. The minimum thickness of overlay must be achieved in a single lift rather than relying on the cumulative thickness of two or more lifts of asphalt. When laying asphalt over steel meshes, a tracked paver may be less likely to cause rucking than a wheeled paver. Paving is carried out in the normal way in accordance with BS 594987, but the paver must not be allowed to ‘push’ the asphalt delivery truck on the mesh. The delivery truck must either unload into the paving machine and then move away, or must drive under its own power, just ahead of the paving machine. Care must be taken by drivers of all vehicles on the mesh not to make aggressive turns, stops or starts that could disturb the mesh. Figure 11.8 shows a typical application.

Figure 11.7 Purpose Built Applicator for Installing Geosynthetics

Figure 11.8 Combination Grid with Asphalt Overlay

11.29 Installation of SAMI systems is similar to that described for the reinforcing geosynthetics, where the surface is cleaned, cracks filled and the material unrolled flat onto a sprayed tack coat followed by one or two layers of chippings of various sizes. The advantage the nonwoven interlayer brings is to act as a uniform retention layer for the tack coat preventing thinning of the bitumen. This in turn largely overcomes the problems of loose chippings being plucked from the surface due to lack of bond. In addition, the nonwoven interlayer provides stress absorption in combination with the bitumen layer i.e. the SAMI effect.

Performance and Durability

11.30 There is insufficient evidence at present to prove the long term durability and overall economy of these methods on the Strategic Road Network and the integral comparative sections required as part of the Departure will improve the Highways Agency's understanding of this.

Restrictions

11.31 A Departure from Standards is mandatory for any use of interlayers in asphalt pavements and overlays, except where a geosynthetic is used below at least 70mm of asphalt and over Hydraulically Bound Material, and provided a control section without geosynthetic is installed and the site is monitored as described in this Chapter. The provision for monitoring, assessment and reporting their use and performance is an essential requirement for such an application to be considered, to ensure value for money in whole life costs terms.

Monitoring and Testing

11.32 Future monitoring of any site where an interlayer has been installed must be performed as part of routine condition surveys and recorded in HAPMS.

11.33 The requirements for monitoring, condition surveys and HAPMS performance reports, and how these are to be incorporated into the contract documents, will need to be clearly identified in the Departure from Standards.

11.34 If a change in condition is identified that is considered worthy of further investigation, a more detailed survey must be undertaken. Such inspections will primarily comprise detailed visual condition surveys, but additional methods, such as coring or FWD, may also be appropriate. Further guidance on the methods for assessing cracking is given in Annex A.

11.35 For the first THREE years of service, an annual performance report must be input into HAPMS and additionally provided to the NetServ Pavements Team. Should cracking be identified within the scheme, the development of crack progression must be assessed using the extent and severity of cracking in the original surfacing prior to treatment as a baseline.

Normative References

BS EN 12272-1 Surface dressing – Test methods – Part 1: Rate of spread and accuracy of spread of binder and chippings

BS EN 15381 Geotextiles and geotextile-related products – Characteristics required for use in pavements and asphalt overlays

BS 594987 Asphalt for roads and other paved areas – Specification for transport, laying and compaction and type testing protocols

Manual of Contract Documents for Highway Works – Volume 1, Specification for Highway Works

HD 29 Data for Pavement Assessment (DMRB 7.3.2)

HD 30 Maintenance Assessment Procedure (DMRB 7.3.3)

Informative References

RSTA Code of Practice for Geosynthetics and Steel Meshes (RSTA, 2012)

TRL 657 Improved design of overlay treatments to concrete pavements (Coley and Carswell, 2006)

Road Note 41 Best practice guide for overlaying concrete (Jordan et al, 2008).

Annex A: Crack Assessment Options

The severity of the crack is defined as follows:

a: Wide (greater than 2mm), often with spalling or bifurcation.
b: Easily visible (less than 2mm wide), single crack.
c: Fine (including cracking only seen when the road surface is drying).

The following three measures can be used to quantify crack development for each section:

1. The proportion of original transverse cracks that have subsequently initiated a reflection crack in the asphalt surface expressed as a percentage. The percentage for a section reaches 100% when a reflection crack has occurred at the position of every existing crack in the original surfacing prior to inlay. A value greater than 100% is possible if the number of cracks visible in the new surface is larger than the number of cracks in the original surface.

2. The ratio of the total length of transverse cracking observed in the asphalt surface to the total length of transverse cracks in the original surface, expressed as a percentage. The percentage for a section reaches 100% when the total length of transverse reflection cracking in the asphalt surfacing is equal to the total length of transverse cracking observed prior to inlay. A value greater than 100% is possible if the length of reflection cracking visible in the new surface is greater than the number of cracks in the original surface.

3. Crack Index. The Crack Index (CI) is a quantitative measure designed to take into account the visual severity rating within the overall assessment of transverse crack propagation. The CI is used to differentiate between sections with similar numbers of cracks and crack lengths, but with differing visual severities. The CI value can be calculated using the following formula:

$$\mathrm{CI} = \frac{(\text{length of 'c' cracks} \times 1 + \text{length of 'b' cracks} \times 1.5 + \text{length of 'a' cracks} \times 2)}{\text{total length of transverse joints within section} \times 2}$$

Hence, for a CI of unity, all cracks would be full width and category ‘a’, Wide.

Option 3, using the Crack Index, is the preferred method for measuring crack severity as this takes into account the length and severity of cracking in each section and provides a useful comparison between sections.

12. LAYING BITUMINOUS MATERIALS

Introduction (Best Practice for Durability)

12.1 Good laying practice is absolutely essential for the long term performance of bituminous materials and hence the structure of bituminous roads. Good laying practice can maximise the potential of even relatively poor bituminous materials, but poor technique and in particular poor compaction can destroy the durability of even the highest quality material.

The overarching specification for the placing and compaction of bituminous materials is given in MCHW1 Clause 903. This clause references British Standards Institution BS 594987 ‘Specification for transport, laying, compaction and type testing protocols’. Additional guidance can be found in Road Note RN42 ‘Best practice guide for durability of asphalt pavements’. BS 594987 and RN42 are essential reading for all those involved in the specification and laying of bituminous materials.

RN42 defines durability as:

> “An asphalt material or a pavement can be said to be durable if it maintains its structural integrity and functional properties at a satisfactory level within the nominal design-life when exposed to the effects of the environment and the expected traffic loading”.

12.2 Most bituminous materials are specified in accordance with British Standards Institution Published Document PD6691 which provides UK guidance on the use of EN 13108. It is important to understand that materials to these specifications are only valid at the time of discharge from the mixer. All performance requirements are based either on samples made at that time or at the laboratory design stage. The reason why good installation technique is needed is to ensure that the assumed performance obtained from materials on the basis of these design parameters is actually obtained in the road pavement.

12.3 This Chapter is principally concerned with bituminous materials premixed and laid hot through a paver. Other materials, such as surface dressing and microsurfacing, are covered in their specific chapters.

Examples of cores taken from roads where early life problems have occurred are given in the appendix to this Chapter.

Job Planning

12.4 This is such an important aspect of the successful laying of bituminous materials that this section is quoted verbatim from RN42:

> *“Contract size*
>
> A continuous pavement with minimal joints will produce a more durable product, but it can be achieved only on relatively large contracts.
>
> *Compromising durability to minimise traffic disruption*
>
> Minimising the immediate disruption to traffic by requiring a road to be reopened at peak periods may be detrimental to the long term traffic disruption because working in small packages may increase the need for maintenance and bring forward the time when replacement is needed. The differences should be fed into the whole life costing in order to achieve true value engineering.
>
> *Contractor involvement*
>
> Early discussions between the designers and contractors are needed to ensure that everybody is working to a common, and practical, goal. The responsibilities for each aspect should be allocated to the relevant organisation by the contract, and the relevant person or persons within that organisation who will undertake that responsibility should be clearly identified. The identified people should have both the technical knowledge and the appropriate authority relevant to that responsibility. Systems for adequate communications between parties need to be established, both between offices and on site. Good liaison

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

Method statements

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

Seasonal working

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

Logistics

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

Trafficking

Both during construction and on opening to traffic, premature trafficking can damage a new pavement. In particular, procedures should be implemented to reduce the risk of site vehicles over-running any exposed edges of the mat. Such procedures could be as simple as putting cones to mark the edges or provide specific, prepared locations where any traffic that needs to traverse the new mat can gain access and egress.

Maintenance

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

Weather Conditions

12.5 The weather conditions during the laying of bituminous materials affect both the laying operation and the subsequent performance. Although materials may appear satisfactory in the short term, even to the end of their maintenance period, the life expectancy of bituminous materials laid in inclement weather may be reduced. The requirements of the specification should be strictly adhered to.

12.6 RN42 recommends avoiding winter and night working wherever possible and in particular winter night working when adverse conditions will almost inevitably be present. If night working is necessary for traffic reasons then the months with shorter periods of darkness should be used, ideally April to August. For overall best practice RN42 advocates maximum use of day time in summer.

Laying in Adverse Conditions

12.7 When laying in adverse conditions is unavoidable, there are various techniques that can reduce the risk of poor durability. Some of these techniques can be instituted at minimal cost, but many will add to the cost of laying and an assessment should be made to balance the initial cost against the whole-life costs including traffic disruption.

Such techniques, generally with increasing cost from a) to g), include:

a. Maximising workability by mixing towards the upper permitted temperature limit. This can produce problems in terms of fuming. The increased loss of volatile oils is associated directly with bitumen hardening and may be counter-productive.

b. Maximising workability by using binder at the upper limit of the penetration grade. It should be noted that bitumen with a penetration value of 60 dmm has half the stiffness of bitumen with a penetration value of 40 dmm at the same temperature, while both conform to 40/60 paving grade bitumen. The effect on the total mix will be less dramatic, depending on the material, but is noticeable.

c. Use a mixture designed for enhanced workability – this may be a specially designed mixture for such situations, or from an alternative source, or manufactured by blending of sands or by using a proprietary binder (see Chapter 3 Binders).

d. Where a thin regulating course would be needed under thin asphalt surface course, consideration should be given to laying the whole thickness with a suitable material to Clause 942, thus using a single thicker layer, which would be less prone to adverse weather problems.

e. Using road surface dryers, such as infrared heaters covering the laying width.

f. Using a shuttle buggy (see Fig 12.1); the advantages are that it can store a delivered load of asphalt to maintain a uniform temperature of the material, a mixer auger reduces segregation, the system helps throughput by minimising the need for the paver to stop and the paver hopper is continuously fed, reducing cold spots. The high initial cost is counteracted by increased productivity and reduced compaction problems with improved durability.

Figure 12.1 Shuttle Buggies Being Loaded without Interfering with Paving Operations

g. Using dual laying pavers (see Fig 12.2), which can lay binder course and surface course simultaneously providing a thicker, bonded, heat retaining layer, which is much less susceptible to adverse conditions. The extra cost is in part offset by increased productivity, not needing a bond coat between the layers and increased durability.

Figure 12.2 Dual Laying Paver (Compact Asphalt Paver) with Separate Feeds

12.8 Innovative techniques should be encouraged by financial incentives linked to performance and in the development phase the risks should be evaluated and methods considered to share those risks.

12.9 Contracts let where asphalt installation is predicted to be during poor weather conditions must provide incentives for the use of techniques to reduce early-life failure.

Available Research Reports and Weather Forecasts

12.10 TRL Research Reports RR 4 and RR 280 provide details of research into the effects of various factors that influence the rate of cooling of an asphalt layer. In order of priority, the principal factors are layer thickness, wind speed and ambient temperature.

12.11 The Meteorological Office can provide historical information relating to weather conditions, such as month by month analysis of temperatures, to form a statistical forecast of conditions that affect aspects of road building and, in particular, the weather sensitive operation of surfacing.

12.12 There is now publically available local forecasting at 3 hour intervals for 5 days, giving temperature, likelihood of rain, wind speed, humidity and effective temperature, on the meteorological office website. Further more detailed information on these services can be obtained from the Meteorological Office, FitzRoy Road, Exeter, EX1 3PB; Telephone 0870 900 0100; Fax 0870 900 5050; Web www.metoffice.gov.uk. Planning the laying of bituminous courses should always be done in conjunction with an up to date weather forecast.

Specification

12.13 Clause 945 of MCHW 1 sets out the requirements for acceptable weather conditions for laying bituminous materials. Where modified binders are used advice from the binder supplier via the Contractor should be obtained.

12.14 Great care should always be taken when the temperature is, or has recently been, below 0°C as ice may be present on, and possibly in, the substrate. Under no circumstances should material be laid on a frozen substrate as inevitably the lower part of the layer will cool prematurely and may not be compacted properly. A zone of weak material may then be present which is likely to shorten the life of the material and probably prevent bonding between the layers, thus reducing structural life. In extreme cases, a slip plane can be generated within the layer being compacted thus negating the effect of bond.

Measuring Wind Speed and Temperature

12.15 Except where local conditions apply, such as shelter in a cutting or exposure on an embankment, or when conditions are transient with gusting or squalls, wind speed is fairly consistent over a sufficiently large area to enable a single wind speed to characterise a whole site. To account for gusting, it is necessary to define wind speed as the average over the preceding hour. It should be measured using a recording anemometer with an accumulative digital output. Hand-held devices averaging readings over a few seconds should only be used as approximate indicators. For general guidance, the Beaufort scale is given in Table 12.1.

12.16 The Specification (MCHW 1) allows for wind speed to be measured at heights of either 2m or 10m. Measurement at 2m height, using a portable anemometer, is appropriate for monitoring on site. Measurement at 10m height is more suited for use on a major contract where there is a site office compound.

12.17 The siting of an anemometer should be away from, and upwind of, obstructions, and at positions agreed with the Overseeing Organisation. Wind speed measured at a height of 10m is more representative of prevailing conditions, being less affected by low level obstructions. For large works with a permanent site office in a compound, the installation of a recording station at 10m height is the preferred option. Measurements at a height of 2m on site may be subject to local obstruction, turbulence and traffic induced gusts and the anemometer may require frequent repositioning as work proceeds. Nevertheless, it may be the only option for small sites without an office compound. Small pocket anemometers are available, some of which include air temperature and humidity measurement capability. All devices should have a current calibration certificate.

Force	Description	Description for use on land	Equivalent speed at 10 m above ground Knots (m/s)	
			Mean	**Limits**
0	Calm	Calm, smoke rises vertically	0	<1 (0.5)
1	Light Air	Direction of wind shown by smoke but not by wind vane	2 (1.0)	1-3 (0.5-1.5)
2	Light Breeze	Wind felt on face; leaves rustle; ordinary vanes moved by wind	5 (2.6)	4-6 (2.1-3.1)
3	Gentle Breeze	Leaves and small twigs in constant motion; wind extends light flag	9 (4.6)	7-10 (3.6-5.1)
4	Moderate Breeze	Raises dust and loose paper; small branches are moved	13 (6.7)	10-16 (5.1-8.2)
5	Fresh Breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters	19 (9.8)	17-21 (8.8-10.8)
6	Strong Breeze	Large branches in motion; whistling heard in overhead wires; umbrellas used with difficulty	24 (12.4)	22-27 (11.3-13.9)
7	Near Gale	Whole trees in motion; inconvenience felt when walking against the wind	30 (15.4)	28-33 (14.4-17)
8	Gale	Breaks twigs off trees; generally impedes progress	37 (19.1)	34-40 (17.5-20.6)
9	Strong Gale		44 (23)	41-47 (21-24)
10	Storm		52 (27)	48-55 (25-28)
11	Severe Storm		60 (31)	56-65 (29-34)
12	Hurricane			above 65 (34)

Table 12.1 The Beaufort Scale of Wind Speeds

12.18 Ambient temperatures should be measured using a suitable device calibrated to ±1°C and readable to ±0.5°C, which ideally should be placed in a suitably screened enclosure upwind of any heat source. It will reduce discussion on site considerably if all personnel can agree that a single thermometer is used to determine the air temperature. It should be noted that the quoted air temperature is always in the shade unless otherwise stated.

Surface temperature should be measured with an electronic thermometer having a surface measurement probe of low heat capacity, for example a bare thermocouple, and calibrated and readable to ±1°C. The temperature of the laid material should be measured at the mid-depth of the layer using an electronic thermometer with reasonably quick response, and as low a heat capacity as possible, compatible with adequate robustness.

12.19 Where the Specification (MCHW 1) includes measured compaction limits, for example void contents, it is the Contractor's responsibility to determine the temperatures necessary to achieve full compaction. In these circumstances, except for the maximum mixing temperature specified to avoid undue hardening of the binder, temperatures should not be specified.

Laying Specific Materials

Structural Layers

12.20 The design thickness of structural layers assumes:

a) compliance with maximum air void content requirements (usually 6% or 7%), and;

b) that all layers are fully bonded – without complete bonding, the structure is weaker and therefore has reduced life.

12.21 It is essential, therefore, that the material is laid and rolled sufficiently quickly before the temperature drops below the temperature at which density ceases to improve. It should be remembered that materials cool more quickly at the top and bottom surfaces of a layer than in the bulk and therefore the compaction at the top and bottom of a layer is often poorer than the average. Thicker layers keep hotter longer and therefore are easier to compact, but care should be taken not to continue rolling too long because surface cracking may occur, where the top surface has cooled too quickly with the interior still deforming under the roller.

Road Note 42 states that:

> The limiting factor on paving output is the rolling capacity rather than paver speed or the available supply.

Regulating Course

12.22 Regulating courses are probably the most difficult materials to lay successfully. They are often very thin, so heat loss is a serious problem leading to poor compaction, and the thickness can be very variable, leading to difficulty in selecting the 'best' material. A major use of a regulating course is where a chipped hot rolled asphalt surface course has been planed out and replaced with thin surface course asphalt to Clause 942. The latter is typically laid 20 mm thinner, and a regulating course of similar thickness is therefore required. The problem of heat loss is often exacerbated on motorways by the need to carry out the work at night, often in winter and in less than ideal weather conditions.

12.23 The problem of heat loss in thin layers should be prevented by sensible design. Possible options include removal of more material thus permitting a thicker layer, lay Clause 942 material to the full thickness of the removed material, or, overlay the existing where this is possible as it is the cheapest option.

Hot Rolled Asphalt (HRA) Surface Course

Figure 12.3 Hot Rolled Asphalt (HRA) Surface Course

Figure 12.4 HRA Surface Course Application of Pre-coated Chippings Prior to Rolling

Hot Rolled Asphalt

12.24 In England HRA is no longer a preferred material for the Strategic Road Network. Thin Asphalt Surface Courses (TASCs) have replaced this material during the last decade, although it is still used on local roads (see Figure 12 .3), see Chapter 4 Thin Asphalt Surface Courses. In Scotland HRA is permitted on all roads for new construction and major maintenance except over rigid construction.

12.25 The application of coated chippings to hot rolled asphalt and their retention thereafter is particularly sensitive to the weather conditions prevailing during laying. The time for chipping application and compaction is of necessity longer, by about 10 minutes, than for materials laid in a single operation without chippings (see Figure 12.4). Careful control of laying and rolling temperatures is vital to ensure, with reasonable certainty, that the chippings will be retained.

12.26 In addition to normal cooling in ambient conditions, the application of cold chippings to the surface causes rapid cooling of the top few millimetres. These cold 14/20 mm pre-coated chippings constitute 12% to 15% by mass of the hot asphalt and are of a much higher proportion at the top, which is the most affected part of the layer. If the chippings are wet or if laying takes place during rain, surface cooling will be accelerated. If the surface temperature is too low during chipping application, the bitumen coating on the chippings may not soften sufficiently to bond the chippings into the asphalt mortar and the surface of the asphalt may be too stiff to allow adequate embedment of the chippings, see Figure 12.5. The use of frozen chippings exacerbates this problem and almost invariably results in rapid chipping loss. To protect chippings from frost and contamination by dust, the sheeting of stockpiles is recommended.

Figure 12.5 Loss of Pre-Coated Chippings due to Poor Weather Conditions

12.27 The type of polymer modified binder, used to improve the resistance to permanent deformation of Performance-Related Design Mixture hot rolled asphalt to Clause 943, can also have a detrimental effect on bonding of pre-coats and this should be considered. Recent developments using elastomeric systems together with workability agents that reduce minimum rolling temperatures may lessen the risks associated with laying high performance HRA, when working in adverse conditions.

12.28 Unless very benign weather conditions apply, winter night working with conventional hot rolled asphalt will almost guarantee failure.

HRA Chipping Machine

12.29 It is important to calibrate the chipping machine to provide the correct rate of cover and the method is described in BS 598-1:2011.

300 mm square trays are used to collect the distributed chippings across the machine width and the accuracy of the machine can be examined.

12.30 The use of 8/14mm pre-coats reduces the risk of application in cold weather (25% less mass) and is suitable on roads where macrotexture requirements are lower and reduced tyre/road noise generation is important. However, the chipping machines currently in use cannot switch easily from the normal 14/20mm to the smaller size, because the chipping distributor-roller has to be changed.

Figure 12.6 Chipping Machine

12.31 Both the width of the chipping machine and the necessity to feed it from the side using a loading shovel cause logistical problems, particularly on live carriageways. The chipper is nearly 5m wide and overhangs each side of the asphalt mat by some distance, reducing the width of the footway (where present) on one side and the trafficable width on the other. For safety reasons on narrow roads a formal road closure may be required or additional traffic controls put into place, which may cause long delays.

Figure 12.7 Chipping Machine Straddling the Paved HRA Surface Course

Thin Asphalt Surface Courses (TASC)

12.32 Thin surface course systems (TASC) are proprietary products, see Figure 12.8 (see also Chapter 4 Thin Asphalt Surface Courses). Consequently their design, manufacture, transportation, laying and compaction are the responsibility of the contractor. Many of the TASCs available were originally tested for performance when laid under ideal conditions. To achieve the best possible installed performance from a TASC, these conditions must be equalled or exceeded, as far as it is practicably possible. This is especially relevant in the case of weather, where any deterioration in weather conditions at the time of laying will have an adverse effect on the durability of the TASC.

Figure 12.8 Thin Asphalt Surface Course System (TASC)

12.33 The TASC Third Party Approval Certification, together with the product's Quality Plan and Installation Method Statement, give minimum temperatures for laying and describe the acceptable moisture level of the substrate. These must be taken into account when planning surfacing works.

Adverse Weather Working

12.34 Much of the compaction necessary for TASC is achieved by the screed on the paver, with the process being completed by the roller close behind the paving machine. In this respect, and because the application of chippings is unnecessary, the installation of thin surface course systems might appear straightforward. However, the thinner systems lose heat extremely rapidly and therefore should not be laid in the winter months unless the surfacing substrate is adequately pre-heated.

12.35 It is desirable to lay in conditions that exceed the minimum criteria for air temperature and dryness of the surface to be overlaid, as given in the certification or declaration of performance for the product. Surfacing should be scheduled to allow sufficient programme float to avoid periods of poor weather. Surfacing operations should be delayed if there is a forecast of precipitation during the planned laying period.

12.36 Minimum air temperatures are usually required to be measured on a rising thermometer. Due to restrictions on the availability of the highway for maintenance, thin surfacing operations may be carried out during overnight closures. In such situations, the air temperature will usually be falling and allowances must be made to ensure that it does not fall below the minimum specified during the laying period.

12.37 Some thicker TASC can be laid and compacted successfully in air temperatures as low as 2°C and rising, provided the air is still and the substrate is dry. If, however, the wind speed at a height of 2m is 5km/hr, then an air temperature of 10°C or more may be necessary to achieve full compaction.

12.38 In common with other bituminous materials it has been observed that TASC laid during the winter period are likely to be less durable than those laid in the summer. TASC should normally be laid between the months of April to October inclusive, as during these periods the laying criteria given in MCHW1 are most likely to be met or exceeded. This period may be extended if ambient temperatures above 5ºC are forecast when the TASC is planned to be laid and other weather dependent criteria for the compliant performance of the installed materials will be met.

12.39 Thin Asphalt Surface Courses must not be laid below the minimum temperature specified in the product’s Third Party Approval Certification.

12.40 When laying is likely to occur close to the minimum temperature or after rain, plant must be available on site so that the existing surface can be warmed and dried by means of infra-red or similar heating immediately in front of the paver. The drying process should not force moisture into the substrate so that subsequent sweating can occur, possibly leading to delamination.

12.41 Where work must proceed when the ambient conditions are acceptable but the surface conditions do not meet the requirements described in the Certificate, Quality Plan and Installation Method Statement, equipment must be provided and used on site to dry the substrate prior to paving operations. For instance, a substrate pre-heating system, that precedes the paver, may be employed.

Figure 12.9 Pre-heating Cold and Wet Asphalt Substrate before Overlaying with a Thin Asphalt Layer.

12.42 This proprietary process shown in Figure 12.9 heats and also scarifies the substrate, bonding the overlay, and can be carried out in adverse conditions.

Paving at TASC Joints

12.43 It has been observed, from examples of thin surfacing approaching the limit of serviceability, that the longitudinal joint may begin to fail before the pavement surface. The failure mechanism begins with localised fretting of aggregate at the joint, which rapidly progresses. This highlights the need to pay attention to the detail of the joint when the thin surfacing is being laid.

Figure 12.10 Fretting at a TASC Joint

12.44 Wherever possible, the number and length of transverse and longitudinal joints should be minimised to reduce potential areas of vulnerability.

Echelon Paving
12.45 Echelon paving is the use of multiple paving machines laying the bituminous mat in adjacent rips concurrently. The material in all the rips is compacted at the same time after the last paving machine has passed. The joints are thus seamlessly welded, bonded and compacted.

12.46 However, in order to achieve successful results, it is necessary to provide sufficient supply of material to ensure that there is continuity of laying. Any stop/start operation will detract from the overall durability of the pavement, because it risks material already in and conveyed through the paver being below the temperature needed for good compaction. There is also a need for training of the roller drivers to ensure that the compaction across the mat is even, as this is more difficult with two-lane, rather than single lane, laying.

Figure 12.11 The Second of Two Paving Machines, in Echelon, Laying the Second Rip of a TASC so that Both Rips can be Compacted Simultaneously Whilst Hot

Figure 12.12 Three Paving Teams in Echelon Laying Stone Mastic Asphalt

12.47 The use of multiple paving machines laying in echelon should be the preferred laying method as there is no discernible longitudinal joint once compaction is complete. Where laying in echelon is not possible, joints should be placed as far as possible from the wheel track zones. Where surfacing joints are placed in the wheel track zones, the durability of the surfacing will be adversely affected.

12.48 Information on the jointing of rips is given in the individual product's Third Party Approval Certification , Quality Plans and Installation Method Statements. Those specifying works incorporating TASC must ensure that they take account of these.

Roundabouts, Bends and Junctions

12.49 It has been observed that TASC are more durable when smaller nominal aggregate sizes are used in locations where there are significant traffic turning movements. The surfacing requirements should be specified separately for these locations.

12.50 Thin surfacing with a nominal aggregate size greater than 10mm must not be used on roundabouts and other bends with a radius less than 250m, where the material will be subject to substantial sideways forces from heavy traffic.

12.51 Some junctions may also be subject to substantial sideways forces from heavy traffic, where small radius turning movements are required. The nominal aggregate size at these locations must not exceed 10mm.

12.52 Damage to the surface from turning heavy vehicles can be a significant problem on roundabouts and invariably starts at joints. This can be mitigated by carefully planning the laying to avoid joints if possible and to place essential joints in lower stress areas. Consideration should be given to closing roundabouts completely to enable continuous surfacing. The main traffic flow of heavy vehicles should be examined and paver runs planned to follow the same tracks, to minimise scrubbing of heavy vehicle tyres across joints. Thin surfacings with a small nominal aggregate size, laid to the maximum permissible thickness, generally give a more durable result. These thicker surfacing layers would also be more tolerant of adverse working conditions. There is less need to achieve high texture on a roundabout as traffic speeds are generally low.

Replacement of Existing TASC

12.53 Due to the way thin surfacings behave structurally, any disturbance of the fabric of an aged thin surfacing is likely to lead to rapid deterioration.

The following actions should be avoided as far as practicable, as they have been observed to accelerate the deterioration of adjacent thin surfacings:

- Removal of painted and thermoplastic lines by pressurised water systems;
- Cutting of slots for detector loops and other traffic sensors.

Detector Loops

12.54 It has been observed that any cut in a TASC, such as those made to install detector loops, may cause the material to fail prematurely (see Figure 12.13). To obviate this, two alternative methods of loop installation are detailed.

12.55 Loops may be installed in the pavement layer directly beneath the TASC, before the TASC overlay commences or, in the case of repairs or reinstatements, the existing pavement may be planed out, loops installed and the new TASC overlay applied.

Figure 12.13 Detector Loops may Cause Material Failure

12.56 In both cases, the induction loops are installed before the TASC is laid. This will require coordination between those planning the resurfacing and those responsible for the induction loops, to ensure that work is scheduled accordingly and that the induction loops will be installed at the correct depth and to the correct design pattern to ensure the function of the loops.

12.57 A delamination strip should be used so that future planing operations are less likely to damage the loop.

12.58 Where induction loops are installed after completion of the surfacing then the cut slots can be closed using an infra-red patching technique rather than a poured sealant. If a poured sealant is used, then installation of a bond breaking layer above the wires of the loop is likely to allow future planing of the surface without damage to the detector loop.

TASC Bonding

12.59 The thinner the surfacing, the greater the importance of an effective bond coat to the performance of the TASC surfacing.

Figure 12.14 Lack of Bond to Substrate can have Catastrophic Results

12.60 Emulsion bond or tack coats sprayed as a separate operation ahead of the paver should be allowed to break completely (turn from brown to black) prior to surfacing. Polymer modified bond coats are likely to provide enhanced performance and should be specified for thin surfacings laid in high stress areas.

12.61 Where bond coats are permitted in the Third Party Approval Certification for the material they should be used in all types of location and must be used on the Strategic Road Network in England.

For further detail concerning bond coats see the “Bond Coats” section below and Chapter 3 Binders.

Hand Application

12.62 Hand application should be avoided wherever possible. Stone mastic asphalt type materials are virtually impossible to lay by hand as the coarse aggregate content is so high it tends to rake to the surface and leaves the material prone to early ravelling and failure. The organisation of the laying should be done in such a way as to minimise hand laying.

Site Preparation

12.63 The amount and type of site preparation necessary will depend heavily on the type of work being carried out. This may range from the construction of a new section of highway to minor lengths of inlay. As stated in RN42, water ingress has a major impact on the durability of a pavement structure in the long term. Water may be between the bituminous layers, or, if the material has a void content above about 6%, within the material itself and gain entry through cracks. Additionally, water may be within the underlying platform consisting of capping layer and sub-base. If the foundation is not properly drained, the foundation will be weakened and this will increase the tensile stress at the bottom of the bound layer which in turn will shorten the life of the pavement.

12.64 In new works, it is essential that the foundation is properly constructed so that water is not, and cannot be, trapped; this requires careful construction of the top layers of earthworks and the capping layer/sub-base platform. This implies the need for properly designed and maintained drainage systems. If the sub-base is above optimum moisture content at the time of laying the first bituminous layer, then it will be very difficult or impossible to adequately compact that layer and the whole structure will be both weakened and made much more susceptible to water damage during the ensuing life. This could lead to early reconstruction which will be very costly both in terms of the work carried out and in delay costs to the highway user. Type 1 sub-base (Clause 803) is known to be difficult to drain once it is waterlogged, so it is very necessary to keep the sub-base dry at all times during construction.

12.65 In the case of major maintenance works, i.e. replacing more than the surface course, all drainage systems should be inspected and, if required, they should be brought back to full functionality. Failure to do so will again shorten the life of the pavement. More detail can be found in RN42.

12.66 Where it is a case of replacing the surface course only, the existing material should be milled off using a planer that is capable of producing a finish with the tolerances required at the top of binder course. Where the milling exposes areas of fragile material, this material should also be milled out and replaced with suitable regulating material of sufficient performance so that it will maintain the structural integrity of the pavement. The most likely material to be suitable would be stone mastic asphalt (SMA) to Clause 937.

Figure 12.15 Road Markings may Encourage Fretting Beneath more Open-textured Materials

12.67 Where an overlay of 40mm or less is to be placed, all road markings should be removed particularly if they are of more than minimum thickness. The reason for this is that the adhesion of bituminous material to road markings can be suspect, and if the road markings are of significant thickness they will subtract from the thickness of the surface course, increasing the likelihood of local early failure.

12.68 With hot paver-laid surface courses all ironwork should be reset to its final level after laying any binder or regulating course and before laying the surface course. It is impossible to patch round any ironwork that is lifted after laying the surface course without introducing potentially weak areas and damaging the sealing effect of the new surfacing.

Figure 12.16 Defects around Ironwork

12.69 If it is imperative for ironwork to be reset after laying the surface course, the reinstatement should be done using a proprietary material such as polymer modified mastic, which has been certificated for the size of reinstatement required. Not requiring compaction and being very hot, polymer modified mastic has benefit over any other asphalt material and is also used to seat manhole frames.

Figure 12.17 Polymer Modified Mastic Asphalt used for Bedding and Sealing Round Ironwork

Bonding between Asphalt Layers

Tack Coats

12.70 A tack coat is normally a low binder content cationic bitumen emulsion (40% bitumen) capable of being sprayed cold and formerly used as a dust palliative when an asphalt substrate had been contaminated. A high penetration (soft) bitumen is used, made softer still with kerosene, reducing the tendency to sediment, especially during the winter period, which enabled 200kg drums to be used. With increasing diluent oil, the density of the bitumen globules is nearer that of the water phase and less stability agents are needed in the emulsion.

12.71 The various international papers examining the performance of tack coats in practice generally conclude that if they are applied too thinly, then they have little effect, and if applied too heavily, they tend to lubricate and actually cause slippage, totally the opposite of what is required. The bitumen, being initially often equivalent to 500 pen, flows easily within the material and sometimes in wheel tracks; with materials having low voids, the bitumen has been seen bleeding to the surface. The ability to bond is poor because the cohesion is low.

Their use is now deprecated and BS 594987 notes that tack coats are no longer considered best practice.

The application by hand canning is often poor and not much attention was ever paid to tack coats as part of asphalt installation, especially because the lack of care was soon covered up, see Figure 12.18

Figure 12.18 Poor Accuracy of Distribution of Tack Coat by Hand, using Watering Can

Figure 12.19 Hand Spraying Requires Expertise and after a Short Period Research has shown Rates of Spread Varying Markedly due to Tiring and Lapses in Concentration

Bond Coats

12.72 Bond coats are generally cationic bituminous emulsions meeting the specification of EN 13808, although they may be supplied as hot binders (used on bridge decks).

Bond coats are specified in (MCHW1) Clause 920.

Bond coat emulsions have a binder content over 60%, which helps speed the break, and are often heated to around 40°C in order to spray evenly. 40% emulsions have a low viscosity on the road. The sprayer needs special nozzles to spray at reasonable speeds and the emulsion takes considerable time to break at the specified minimum residual binder rate of 0.35kg/m^2, because over 500ml of water has to evaporate per square metre.

Figure 12.20 Example of Even Application of Bond Coat

Figure 12.21 Example of Poor Transverse Distribution of Bond Coat

12.73 Higher binder contents are now being used (70%), but they have to sprayed hot (up to 85ºC); careful control is necessary, because above 90°C foaming and boiling can commence damaging the emulsion. Re-heating can be a problem, and if there are delays of a few days on site sometimes the emulsions have to be returned to the supplier for re-processing.

12.74 Bond coats are proprietary polymer modified binders and have a cohesion (EN 13588) of class 4 (intermediate grade) or class 5 (premium grade). The specification of higher cohesion class provides for increasing bond strength, which relates to increased polymer content and therefore cost.

The high cohesion (polymer modification) removes the risk of binder moving through the layer causing bleeding; the binder remains at the interface, transferring stresses and maximising structural integrity and performance.

Premium and even super premium (class 6) bond coats are now supplied and are chosen depending on the location of the layer in the pavement structure, thickness of the layer, substrate condition and traffic stress.

An asphalt ultra-thin layer surface course, being less than 20mm thick, should be bonded with a class 5 bond coat for even moderate traffic stress, especially on existing aged substrates (see **Figure 12.22**).

Varying thickness regulating courses also require good bonding.

A base course to binder course interface may be satisfactory with a class 4 bond coat.

Figure 12.22 Asphalt Ultra-thin Layer (AUTL) Being Laid on Class 5 Bond Coat that has Broken

12.75 Several of the suppliers of bond coats have available 'non-sticky' bond coats, which are designed to be not picked up on construction traffic tyres and are useful in urban areas when laying surface courses. They need to be activated by hot materials laid on them. Checks should be carried out to ensure that the asphalt is hot enough to activate the bond coat being used and bond strength tests meet the requirements. This is even more important with Warm Asphalt Mixes (see Chapter 3 Binders).

Figure 12.23 Bond Coat Being Picked up by Warm Paver Tyres.

Figure 12.24 Non-sticky Bond Coat, not Being Picked up on the Asphalt Delivery Tyres

12.76 Before spraying a bond coat the surface being sprayed should be clean and free from loose materials, in particular any soil arising from construction operations. If necessary, sweeping, or even in extreme cases pressure washing, should be used to ensure that the bond coat adheres well to the existing surface. If it does not it is pointless carrying out the work as there will always be a slip plane in the completed pavement. This is particularly important for maintenance operations when overlaying existing aged substrates, where debris and mud are evident in the macrotexture (less of a problem on heavily trafficked roads).

12.77 There must be a bond coat between all layers of the road pavement structure. Bond coats must be in accordance with Clause 920 and must be sprayed by tanker, which has a calibration certificate for the rate of spread, and must be tested on site during application, see Figure 12.25. The bond coat must be fully broken before the next layer of asphalt is placed, unless the bond coat is applied by asphalt paver with integral sprayer.

Figure 12.25 Rate of Spread of Bond Coat Carpet Tile Test (EN12272-1)

12.78 The importance of bond is stressed in Road Note 42. BS 594987 requires a minimum rate of spread of bond coat (measured as residual binder content). Differing binder content emulsions are sprayed at different rates to achieve this minimum requirement. For rugose or binder lean substrates or under porous asphalt or on bridge decks, the minimum rate may be required to be increased. Applying excess of a class 5 bond coat is not a problem compared to the slippage and bleeding problems caused by excess tack coat.

12.79 Asphalt pavers with integrated bond coat sprayers are increasingly being used, especially for thin asphalt surface courses. This removes the problem of sticky bond coats and having to wait for the bond coat to break (turning from brown emulsion to black residual binder), see Figures 12.26 and 12.27.

Figure 12.26 Combined Paver Bond Coat Sprayer laying TASC

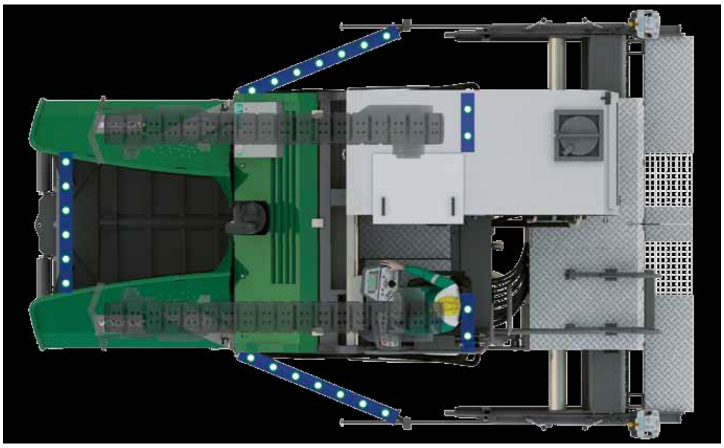

Figure 12.27 Top View of Paver. Bond Coat Spray Jets (Blue Dots) and how they are Spaced to Avoid the Paver Tracks

12.80 The Torque Bond Test has been developed to check the bond strength between layers and is part of the Third Party accreditation of TASC. The correlation with the modified Leutner test in Clause 954 is quite good and the test is one of the few world-wide that can be carried out on site. The values achieved relate in part to the bond coat cohesion class, but a highly textured substrate that has sufficient binder can provide a good bond in its own right by virtue of interlock. So the bond coat is not the only issue; a sound, clean, textured substrate that is not aged, is extra insurance of bond and structural integrity.

12.81 Bond coats also reduce water vapour from permeating and transferring between layers. Many asphalt products are permeable and sealing of layers makes sense. The measurement of permeability may provide more clues as to how to construct long-life pavements, in addition to the measurement of air voids and stiffness.

12.82 When overlaying a concrete pavement with a bituminous material, the bond coat should be assessed as being suitable for use in this situation and to confirm it will adhere properly to both layers.

Joints

12.83 Every joint whether longitudinal, transverse or horizontal (i.e. between layers) is a potential source of weakness. Joints should be kept to a minimum. This requirement can be incompatible with the need for working in short time windows on live carriageways. It is not a problem in new construction.

12.84 All longitudinal joints should be in areas of low traffic, between lanes or, as a less satisfactory alternative, in the centre of a lane between the wheel tracks. This latter location, if it is on the surface, could be a problem for motorcyclists unless great care is exercised in construction and there is no difference in level and no exuding of joint sealing material onto the surface. All longitudinal joints should be staggered by at least 300mm from the joint in the layer below and preferably be staggered from the joint in the layer below that. A Departure is required if this cannot be achieved.

12.85 The number of longitudinal joints can be reduced by the use of echelon paving thus ensuring full compaction across what would otherwise have been a joint. This is a particularly useful technique for surface courses although other layers benefit from its use. The number of construction layers and hence the number of horizontal joints can be minimised by laying each layer as thick as possible; either the full layer thickness or the maximum that can be properly compacted. With modern compaction plant there should be no need for more than four layers in any new construction.

12.86 Road Note 42 should be consulted to obtain much more detailed advice on problems of joints and techniques to improve the performance of pavements in their vicinity.

12.87 With the exception of porous asphalt, vertical joints in all materials should be coated with a suitable bituminous material designed for use in joints. This applies to all layers and not just the surface course, the aim being to keep water from percolation through joints.

12.88 Where echelon paving is not possible and a longitudinal joint is unavoidable, it should be cut back to fully compacted material before painting with bond coat and laying the next rip. The surface course should always be so treated, and it is recommended that any regulating course less than about 40mm thick is also treated in this manner (see Figure 12.28).

Figure 12.28 Cutting Back Thin Asphalt Overlay Preparing a Vertical Joint

12.89 The materials being used for painting of vertical joints range from 40/60 paving grade bitumen applied hot to polymer modified bituminous emulsion binders with cohesion of Class 6.

12.90 Polymer modified binders are to be preferred for joints in surface courses. Only the joints in layers below the surface course are painted on the horizontal surface; the surface course joint should not be so painted, and much more care applied to providing sufficient binder to the vertical faces, see Figures 12.30 and 12.31 for spraying techniques. Re-instatements and patching also require the proper application of bond coats to the base as well as vertical faces

12.91 Joint heaters can also be used to improve the continuity of joints but care should be taken to ensure the material under the heater is not overheated as this will lead to early, if localised, failure.

Figure 12.29 Example of an Infra-red Joint Heater, which Automatically Cuts Out when Paver Stops

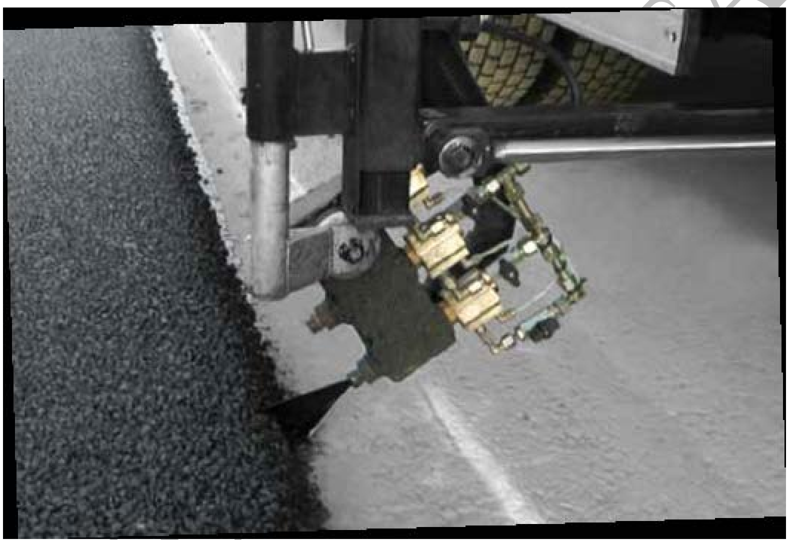

Figure 12.30 TASC Joint Spraying Machine for Rapid Vertical Edge Sealing and Joint Bonding

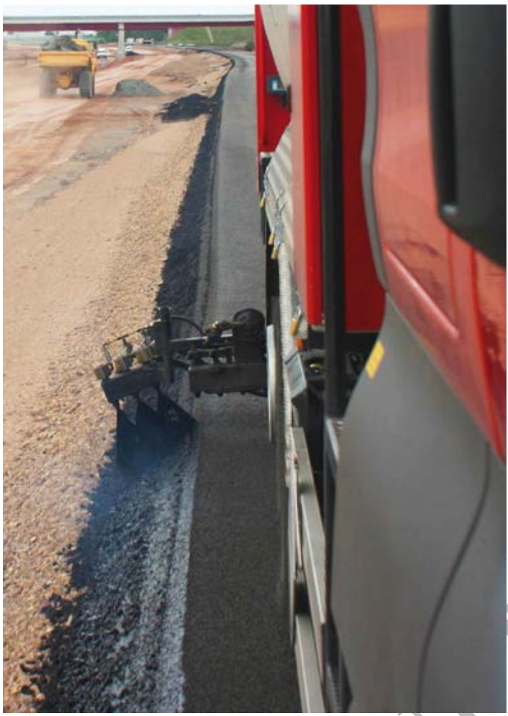

Figure 12.31 Side Jet Spray on Modified Bond Coat Sprayer to Seal Vertical Joints and Edges

Figure 12.32 Edge Compaction to Provide an Overlap Type Joint

Figure 12.33 Edge Compactor Attached to the Paver

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12.92 Other methods of forming joints are being tested. In Figures 12.32 and 12.33 the stepped joint is painted with bond coat and overlaid; a jointer heater is used in adverse conditions (see Figure 12.29). Joints are cored to check voids.

Further advice on the treatment of joints can be obtained from RN42.

Asphalt Compaction

12.93 Road Note 42 states: "the limiting factor on paving is the rolling capacity rather than the paver speed or the available supply". It is necessary, therefore, for there to be sufficient rollers of sufficient capability to be used to ensure proper levels of compaction. The operators should be properly trained in the coordination of their individual rolling patterns to ensure even compaction across and along the layer.

12.94 Workability is important to achieve the desired degree of compaction economically. The design process for EME2 addresses this directly as a measure of workability is a determining factor in the design of the material. No other material in common use in the UK uses workability as part of the decision process. It is well known that similar materials from different sources have very different workabilities and hence vary in the efficiency with which they can be compacted. Special care to ensure full compaction should be exercised particularly for those materials from sources known to have inferior workability.

12.95 Once a material has been decided upon, by far the most important factor contributing to its durability is the level of compaction imparted to it. All bituminous materials are designed on the basis that they are laid and installed properly. They will not perform as expected if the compaction level is below that assumed when designing the material.

12.96 In addition to this, if the material is designed to have a target air void content of 4%, and when laid in situ it is above this by more than the permitted tolerance (± 2%), then water can penetrate more easily thus adding a second factor contributing to early failure. Conversely, if a dense material is compacted to less than about 1 % air void content there is the possibility of the development of 'pore bitumen pressures' which will significantly increase the risk of early life rutting.

NOTE: 'pore bitumen pressure' is used by some by analogy to 'pore water pressure' in soils which likewise leads to instability.

12.97 For Clause 942 TASC, the aim should be to achieve the same level of compaction as that obtained during the Third Party Certification trial. If necessary, the void content achieved on the trial should be obtained in order to make a comparison. Even if the void content was not obtained specifically the density may well have been measured as part of other tests.

Intelligent Compaction (IC)

12.98 Recent developments in the technology of compaction have made IC a possibility. This is a major development involving: (i) applying compaction effort (increased amplitude of vibration) where it is needed depending on density measurement; (ii) plotting where the density has been achieved (GPS), and; (iii) informing the roller driver where more effort is required before the temperature is too low, and where not to roll otherwise microcracking will occur.

12.99 The measurement of temperature across the laid asphalt, plotting a thermal image to indicate where cold spots exist and relaying this information to the roller driver in real time will enable cold spots to be treated first. In adverse conditions, the increased durability obtained more than offsets the cost of this technology.

12.100 The technology is available on some vibrating rollers today and the infra-red detectors providing temperature plots are being attached to pavers; see Figures 12.34 and 12.35.

Figure 12.34 Infra-red Detectors to Monitor Heat from Paved Asphalt

Figure 12.35 Infra-red Detectors Attached to Paver with Monitor Mounted Above

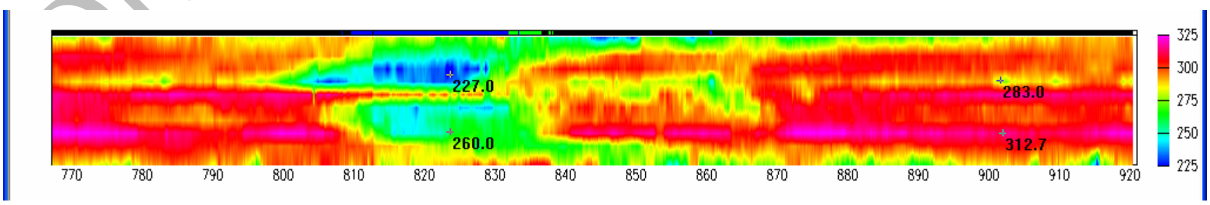


Figure 12.36 Typical Thermal Map Showing a stop for Recharging the Paver (Cold: Blue Area)

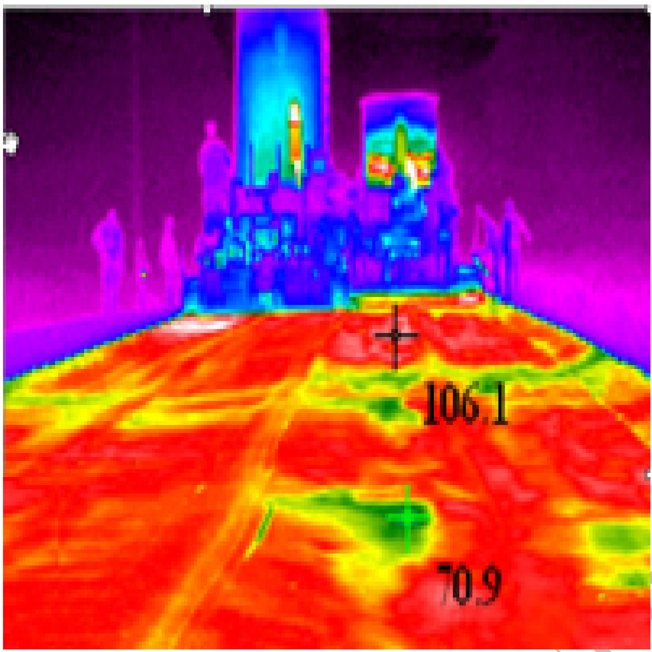


Figure 12.37 Thermal Map of Cold Spots which Resulted Subsequently in Surface Fretting at those spots. Note Echelon Work in the Picture Resulted in a Good Heat Bonded Longitudinal Joint

Figure 12.38 Rollers with Density and Temperature Monitoring and GPS Location

Figure 12.39 Monitor Output in Roller Cab to Indicate Areas of Low Density and Low Temperature

Warm Materials

12.101 The laying of warm asphalts should follow the general principles of laying conventional hot materials with suitable adjustments for their generally lower temperatures at all stages of the laying process.

Roundabouts, Bends and Junctions

12.102 Laying bituminous material round bends is not usually a problem. Right hand bends needing super-elevation are more complex as the crossfall changes direction, which means that a crown needs to be formed diagonally across the road as it is not possible to reverse crossfall instantaneously. There are two competing requirements: the change should be as gradual as possible to maintain best ride quality, but the change needs to be as quick as possible to minimise the area of the surface which is flat on top of the crown. Any flat areas could potentially cause thick water films on the road surface during rainfall, causing a spray or an aquaplaning hazard. It needs great skill on the part of laying crew to produce a good quality change over from cross fall to super-elevation and back.

12.103 The main difficulty with laying bituminous materials on roundabouts is determining the best laying pattern to minimise traffic crossing joints, which can cause early failure if they not exceptionally well installed. This will also depend on whether it is a new roundabout or one which is already carrying live traffic. If the latter, it is not usually possible to lay the optimum layout of joints. The planning of the layout of the rips should take place in conjunction with the proposed layout of the road makings, which are often spiral in form to assist in the guidance of traffic to the correct exit; this is particularly so on large interchange islands. Because there is inevitably significant traffic overrun of joints, it is even more important than usual that they are formed to the highest quality

12.104 Where the junction is a simple T junction or cross roads, the main road should be laid in such a manner that transverse joints within the junction area are avoided altogether; up to 50m either side of the junction is good practice, as this will avoid turning movements across the joint. On the side roads, the layers should be laid away from the main road thus enabling best level matching. This will also allow early access for the compaction plant to compact the transverse joint, which will inevitably be subject to braking and turning movements thus stressing it to high level.

Overlaying Concrete

12.105 Overlaying concrete roads with bituminous material is complex. It depends on the type of concrete pavement, the state of deterioration, the traffic levels and the life required after treatment. The thickness of bituminous material can range from a single surface course of 30mm up to a complete bituminous pavement when treating the concrete (after complete breakup) as the sub-base.

12.106 To set out all the options would consume a lot of space and merely repeat that which is already set out clearly in Road Note 41: 'Best practice guide for overlaying concrete'. RN41 should, therefore, be considered as an integral part of this advice note.

Road Marking

12.107 Road markings are specified in Clause 1212 (MCHW1). Ideally, to minimise user cost in the future, the life of a road marking should equal the life of the new road surface. In practice, this is very difficult to achieve, particularly in the case of markings subject to traffic overrun such as entry and exit markings on roundabouts or markings within a traffic lane such as route indications. If this not possible, the target should be to provide markings that last, in a satisfactory state, for half the life of the surface, leading to a need for replacing them only once.

12.108 Although Clause 1212 specifies methods for removal of markings, no method in current use removes them without leaving a shadow of the mark. This can be confusing in some conditions where the shadows show up particularly well, such as in the dark when it is raining. As a corollary of this, it is extremely important to ensure that they are installed correctly first time so that errors do not have to be corrected, thus spoiling new work.

Maintenance (End of Service Life and Local Repair)

12.109 There are two main aspects to this:

- end of service life of the surface course
- end of service life of the pavement

Surface Course End of Life

12.110 The road user is more concerned with the surface course as that is what is seen by them. The life of a surface course is variable but is typically in the range 10-20 years. Some surfacing materials fail 'gracefully' i.e. they fail steadily and in a predictable manner; an example of this is HRA and chippings, which fails either by steady weathering of the matrix until chip loss starts to occur, or by embedment of the chippings until the macrotexture is too low. Other surfacing types fail 'catastrophically' i.e. they fail suddenly and quickly; an example of this type is an SMA surface course (most Clause 942 materials are of this type, see Chapter 4 TASC), where significant material loss can occur over a single winter.

12.111 Remedial works on materials that 'fail gracefully' can be planned for, often up to 2 years in advance of the need to carry out work. Careful use of traffic speed surveys (TRACS), and in particular texture depth measurements, can assist. HD29 explains the use of TRACS in detail. TRACS also measure rutting, ride quality and cracking, all of which can be used to inform the need for and the design of maintenance treatments.

12.112 The normal maintenance options for surface course failure are to use inlay, or, where possible, overlay. The use of overlay increases the pavement life and also saves the cost of planing.

12.113 With catastrophic type failures, planning for the works on any particular section is not possible but a plan should be in place to deal with failed sections. The usual indication of failure is the appearance of pot-holes, often penetrating the full depth of the surface course with near vertical sides. Once a pothole has developed, it can increase in size at considerable speed. A holding operation of patching, sometimes on a daily basis, should be instigated and the remedial plan brought into operation as soon as possible. Before instigating the plan on site, a full inspection of the length of road surface that is failing should be carried out and the work extended to include all the length that is doubtful.

12.114 Short lengths of remedial work should be avoided and if a new section finishes close to an earlier remedial section the two should be joined to ensure consistency of behaviour of the tyre/road interface.

Pavement End of Life

12.115 This is much rarer but also much more expensive to deal with than a surface course failure. Fortunately, with the advent of long life pavements, the likelihood of whole pavement failure will become rarer. However, there are considerable lengths of motorway and all purpose roads which were constructed before the advent of long life pavements.

12.116 Where it is obvious from survey data and visual inspections that structural problems are occurring in a pavement, a full survey and assessment of the failure should be carried out. An economic solution should be sought, noting that the best option will be different in each case, and the final remediated construction should be consistent with a long life pavement. HD 29 will assist in the assessment process.

Loop Detectors

12.117 The surfacing around these devices should be monitored very carefully. The very act of installing them by means of saw cutting the surface and inserting the detector into the saw cut ensures that a crack inducer has been put into the surface. The earlier section on laying thin surfacing provides methods of overcoming this problem.

Normative References

BS 594987, Asphalt for roads and other paved areas – Specification for transport, laying, compaction and type testing protocols

BS EN 13108, Bituminous mixtures – Material specifications.

BSI PD 6691, Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications.

The Design Manual for Roads and Bridges, Volume 7 – HD 26 and HD 29.

Manual of Contract Documents for Highway Works, Volumes 1 and 2.

Informative References

TRRL RR4. Cooling of bituminous layers and time available for their compaction. Transport and Road Research Laboratory, 1985.

TRRL RR280. Adverse weather conditions for laying rolled asphalt. Transport and Road Research Laboratory, 1991.

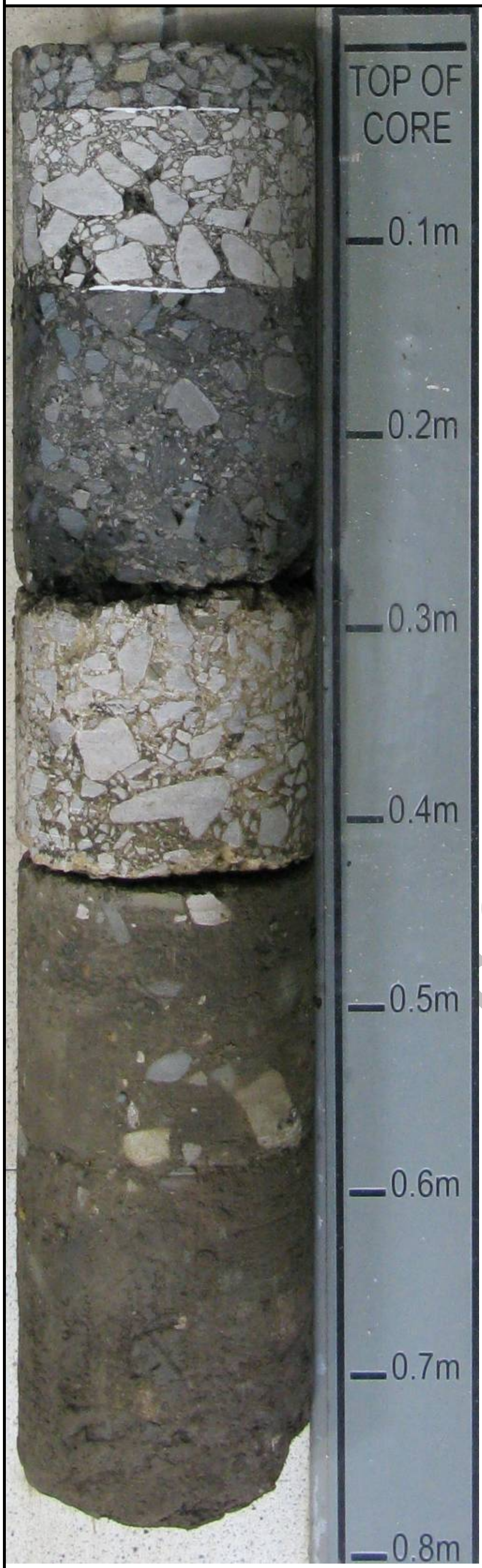
TRL Road Note 41. Best practice guide for overlaying concrete. Transport Research Laboratory, 2008

TRL Road Note 42. Best practice guide for durability of asphalt pavements. Transport Research Laboratory, 2008.

Appendix to Chapter 12.

Photographs of cores taken from roads showing distress.

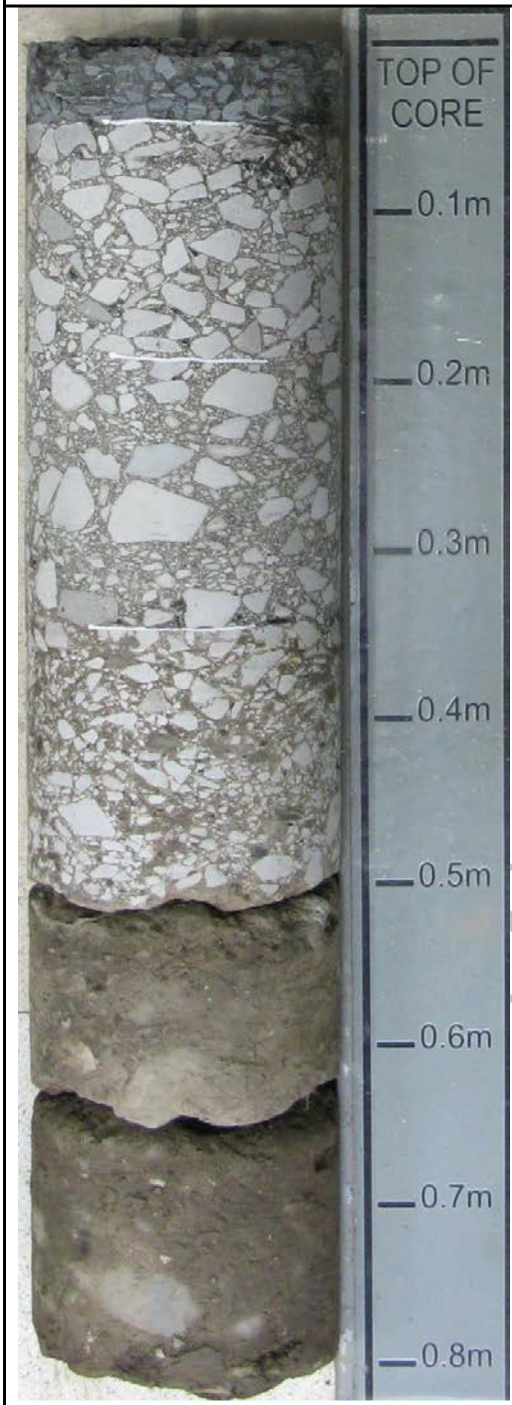
Core 01: Voids and debonding	Layer	Depth From	Depth To	Thickness (see Note 2) (mm)	Material description
	1	0	34	34	Asphalt Concrete (Thin Surfacing) voided
	2	34	115	81	Asphalt Concrete (HMB15 - Upper RB) voided
					Layers 2 & 3 debonded
	3	115	260	145	Asphalt Concrete (HMB15 - Lower RB) voided
	4	260	360	100	Lean Concrete (Stabilised SB - CBM1) broken @ base
					Loose Granular Material



Core 04	Layer	Depth		Thickness (see Note 2)	Material description
Voids and debonding		From	To	(mm)	
	1	0	34	34	Asphalt Concrete (Thin Surfacing) voided
	2	34	120	86	Asphalt Concrete (HMB15 - Upper RB) voided
	3	120	267	147	Asphalt Concrete (HMB15 - Lower RB) voided
					Layers 3 & 4 debonded
	4	267	410	143	Lean Concrete (Stabilised SB - CBM1) voided
					Layers 4 & 5 debonded
	5	410	556	146	Stabilised Clay
	6	556	752	196	Stabilised Clay

Core 20

Generally good material and construction



Layer	Depth From	Depth To	Thickness (see Note 2) (mm)	Material description
1	0	48	48	Asphalt Concrete (Thin Surfacing) damaged face
2	48	178	130	Asphalt Concrete (HMB15 - Upper RB)
3	178	328	150	Asphalt Concrete (HMB15 - Lower RB)
4	328	490	162	Lean Concrete (Stabilised SB - CBM1)
				Layers 4 & 5 debonded
5	490	615	125	Stabilised Clay
				Layers 5 & 6 debonded
6	615	790	175	Stabilised Clay

Core 29A

Well bonded

Layer	Depth		Thickness (see Note 2)	Material description
	From	To	(mm)	
1	0	44	44	Asphalt Concrete (Thin Surfacing)
2	44	138	94	Asphalt Concrete (EME2)
2	138	270	132	Asphalt Concrete (HMB15 - Lower RB)
				Loose Granular Material

13. MISCELLANEOUS SURFACING MATERIALS

13.1 There is a wide variety of flexible surfacing materials not covered in the other Chapters of this Part. These are products that are either undergoing development or are little used on the Strategic Road Network (SRN).

13.2 **Dense AC Surface Course**

Dense AC (asphalt concrete) surface course to BS EN 13108-1 and BSI PD 6691 is available with a 6 mm nominal aggregate size. It has a very low texture depth and therefore it is only suitable as a surfacing for roads with a low speed restriction. With good compaction it is reasonably durable; however, its resistance to deformation does not make it suitable for very heavily trafficked roads carrying a large proportion of commercial vehicles.

13.3 **Open Graded AC Surface Course**

Open graded bitumen macadam surface course to BS EN 13108-1 and BSI PD 6691 is available with 10 and 14mm nominal aggregate sizes. These products have low strength and their durability is suspect. They are not suitable as surfacings for high speed or heavily trafficked roads.

13.4 **Close Graded AC Surface Course**

Close graded surface course to BS EN 13108-1 and BSI PD 6691 is available in both 10 and 14mm nominal sizes. Although designated close graded, their void content can be relatively high and their durability is therefore suspect. Furthermore, these products are sensitive to small variations in binder content and aggregate grading, with the result that their void content can fluctuate from one load to the next unless tight control is exercised at the mixing plant. In consequence, their resistance to deformation is also suspect and they are not suitable for use on heavily trafficked roads. In addition, because the texture depth obtained is low, they are not suitable as surfacings for high speed roads.

13.5 **Other Asphalt Concretes**

There are two other asphalt concrete mixture types included in BS EN 13108-1 and BSI PD 6691 which are included here for completeness. They have minimal potential for use on the SRN. They are: 6mm medium graded AC and 4mm fine graded AC.

13.6 **In-situ Macadams**

In situ macadams are proprietary products, which are either applied as multiple-layered surface dressings to form a thin surface course system, or as graded aggregates onto which a binder is sprayed, followed by mixing in situ, grading and compaction. As these are proprietary systems they will require third party approval certification. Only polymer modified binder multiple-layered surface dressings are currently in use on the SRN in England, see Chapter 8 Surface Dressings.

13.7 **Coloured Surfacings**

Coloured surfacings are generally little used on the SRN in England. However, they are often used for aesthetic reasons to improve the street scene, and they can also be useful in delineating particular lanes or areas where traffic is discouraged from entering, such as tapers to right turn lanes.

Figure 13.1 Coloured Pre-coated Chippings in Pigmented Hot Rolled Asphalt

Most surfacing materials can be obtained in coloured form. The colour is imparted in one of two main ways – by pigments or by choice of aggregate; a combination of both provides greater colour durability.

The various surfacing types are:

- Hot Rolled Asphalt – the binder may be pigmentable and naturally red pre-coated chippings may be used, see Figure 1.
- Stone mastic asphalt or thin surface course systems – again using a pigmentable binder, the colour may be introduced using pigments or, with greater durabilty, coloured aggregate with possibly a small amount of pigment to give a good initial colour, see Figure 2.
- Surface dressing – colour is introduced by the use of suitable naturally coloured aggregates. The colour is very durable, because it lasts the life of the surface dressing.
- Slurry surfacing – very limited colour range for conventional bitumen emulsion systems, therefore only a 'muddy' red-brown is available at anything like economic cost (and available in buckets for hand application). Some developments of pigmentable bituminous emulsions have improved colour retention.
- Thermosetting resin binder, spread or spray applied, with coloured chippings broadcast (see Figure 3),
- Thermosetting resin system mixed with pigments and chippings and spread by hand. Colour durability can be an issue, see Figure 4, loss of colour with time. Some stunning colours are available such as the blue cycle lanes specified by Transport for London, see Figure 5.
- Thermoplastic resin - premixed hot with chippings and pigment and spread. Colours can change with mix temperature and time of mixing.

Figure 13.2 Thin Surface Course Coloured Asphalt

Figure 13.3 Pigment Coated Chippings Applied to Resin Binder

Calcined bauxite used to obtain high friction can reduce the colour permanence, because the pigment wears away and fades. In Figure 4 the left hand picture is as laid and the right hand picture is after two years in service.

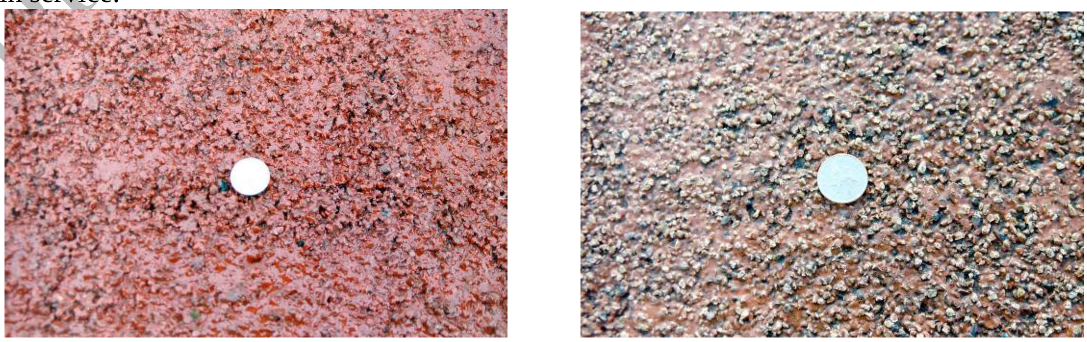


Figure 13.4 Loss of Colour after Two Years in Service (Thermosetting Resin System)

If pigments are used on the network, care should be taken to assess their toxicity both for handling purposes and for dust generated from wear of the surface. This may preclude the use of some mineral colours. Organic chemicals are being developed to replace toxic pigments; however, these are very expensive.

Pigments generally fade over time, making it almost impossible to match the colour if any remedial or reinstatements works are needed. If the colour is generated by the use of naturally coloured aggregate then wear is very slow and is mostly by weathering, which tends to generate silt size particles and the colour is very stable and durable, lasting the life of the surfacing. Colour matching is usually only a case of using the same source of aggregate for the repairs.

Pigments are available in a wide range of, often, very bright colours including orange and blue. Aggregates are available in a smaller range of colours and they are generally more subdued, although near white, greys, greens, reds and browns can be sourced with the UK, often with a choice of shade and of aggregate properties.

Figure 13.5 Coloured Cycle Lanes in Coloured Resin and Pigmented Chippings

13.8 Cold Laid Materials

Cold laid materials are used mainly for patching and traditionally have been made with fluxed bitumen or bituminous emulsions to enable them to be worked cold. They were suitable for temporary repair only and had poor durability. On major routes, current un-modified materials of this type are completely unsatisfactory.

Recent developments have included polymer modified bituminous materials, which are fairly durable when moderately trafficked.

Emergency Patching Materials (EPM)

For heavily trafficked sites including motorways, fast curing resin based materials (acrylic, polyurethane, epoxy) are now available, with the potential to reopen to full traffic within 10 minutes at 10 °C or above and no more than 30 minutes even at freezing point, see Figure 6. These resin based types are obviously more expensive, but, when traffic management is taken into account and particularly the fact that repeat treatments are usually unnecessary, they are much better value. Clause 946 of MCHW1 provides requirements for these special materials in terms of performance; EPMs have to be third party approved with Certificates for use on the SRN in England.

Figure 13.6 Emergency Patching Materials; note Application of Chippings on the Resin System

Spray Injection Patching

Patches can be filled by means of "spray injection-patching". These systems use specially designed compressed air equipment, which mixes aggregate (small clean chippings) and bituminous emulsion binders in a nozzle and ejects the mixture into the patch. The material generally performs well, as the pothole is cleaned by the compressed air prior to the binder being added to the air stream as a prime coat, followed by the aggregate/binder mixture completed with a topping of un-coated aggregate to prevent pick up by vehicle tyres. The ride quality of the resulting patch is very dependent on operator competence (over or under filling the patch is a problem, together with binder content control). Ejection-patching is suitable for roads with light or moderate traffic, see Figure 7, although developments with equipment quality, polymer modified systems and bond coats have improved the performance.

Figure 13.7 Spray Injection Patching

Highways Authorities and Utilities Committee (HAUC)

Cold laid materials for permanent reinstatements (PCSM), as described in the 'Specification for the Reinstatement of Openings in Highways' issued by the Highways Authorities and Utilities Committee (HAUC), need Third Party Certification. Previously issued HAUC certificates ceased to be valid some years ago.

13.9 Warm Asphalts

The use of warm asphalts in bases and binder courses is dealt with in Chapter 2. For other layers see 'Recent developments' in Chapter 1.

Any proposal to use warm mix on the Strategic Road Network would require a Departure from Standards, as the relevant rolling temperatures do not comply with the requirements of MCHW1

13.10 Preservatives

Preservatives are products designed to impact on the properties of the ageing binder at the exposed surface of asphalt and therefore they have the potential to extend the life of surface courses. Solvent based materials have shown that after spray application they may penetrate a few millimetres and delay the ageing process; they also reduce water ingress, but not as efficiently as surface dressings. Preservatives include sealers that bridge very small cracks in the surface; these are often emulsion systems with replacement components to restore those lost by binders during ageing, such as aromatic resins, see Chapter 3 Binders. After spraying, most preservatives need small chippings to be applied to provide some initial skid resistance. They may be partly assessed by treating prepared aged bitumen with the preservative and studying the way the combination ages using rheology. Third party approval certificates taking into account service performance are necessary for treatment of the SRN in England.

13.11 Road Energy Systems

These systems have been developed and demonstrated in the past 5 years and utilise the heat absorption of a black body, namely asphalt. A pipe network is incorporated into the surface layers of the road and a fluid is pumped through. In summer, the warm fluid is pumped to a storage volume underground, which warms up. In winter, this stored heat can be used to either heat an adjacent building or used to prevent ice forming on the road by reversing the flow of fluid through the pipe network, see Figures 8 and 9.

Figure 13.8 Pipes Embedded in Road Structure to Recover Heat, to Keep Fly-over Clear of Ice in Winter (Source: Ooms, the Netherlands)

Figure 13.9 Heat Recovery System used for Community (Source: Ooms, the Netherlands)

13.12 **Crack Filling, Repair around Ironwork and Overbanding**

There are a number of Third Party approval certificates covering this type of product. More information on their use is given in HD 31. At least one of the materials (flexible voidless polymer modified mastic asphalt) used for flexibly sealing around ironwork has also been used for setting the frames and can demonstrate success over several years even in high stress situations such as wheel tracks, see Figures 10, 11 and 12.

Figure 13.10 Polymer Modified Mastic for Manhole Repair, note the Hot Bond Coat

Figure 13.11 Seating the Frame and Sealing

Figure 13.12 Final Application of Pre-coated Chippings

13.13 Grouted Asphalt

Grouted asphalts are used where there is likely to be significant contamination from hydrocarbon leakage, for example at fuel filling areas. They are suitable for heavily used bus stops or very heavy and slow moving traffic (tank tracks and dock loading areas). Essentially, they are open graded or porous asphalts, which are grouted with a cementitious grout to form a very low void content and deformation resistant material, see Figures 13 and 14. They typically have very low macrotexture although the skidding resistance is usually good. Preparation is slow, as the porous asphalt has to cool and the grout has to cure to achieve high strength.

They have little application on the SRN in England. Several of them have Third Party approval certificates, which give further information.

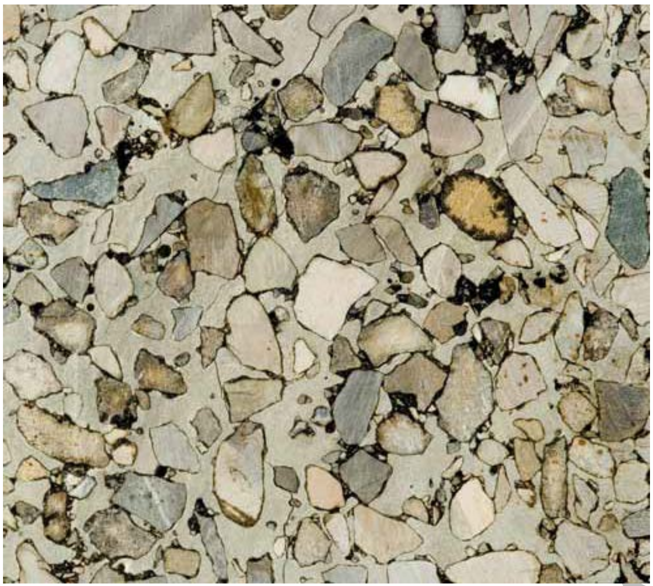


Figure 13.13 Cement Grouted Porous Asphalt Cross-section

Figure 13.14 Cement Grouted Porous Asphalt Dock Area

13.14 Recycled Asphalts

Recycled asphalt is covered in DMRB 7.4.1 (HD 31).

13.15 Retexturing

Retexturing is covered in DMRB 7.4.1 (HD 31)

Normative References

BS EN 13108-1, Bituminous mixtures. Material specifications. Asphalt Concrete

BSI PD 6691, Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications

Manual of Contract Documents for Highway Works, Volume 1

Manual of Contract Documents for Highway Works, Volume 2

The Design Manual for Roads and Bridges, Volume 7 – HD 31

Informative References

New Roads and Street Works Act 1991, Specification for the Reinstatement of Openings in Highways, Third Edition, Code of Practice for England, Department for Transport, April 2010

14. BRIDGE DECK OVERLAYS

Introduction

14.1. Highways Agency (HA) requirements relating to bridge deck waterproofing and surfacing are contained in Departmental Standard BD 47 'Waterproofing and Surfacing of Concrete Bridge Decks' (Design manual for Roads and Bridges, Volume 2, Section 3, Part 4). These requirements concern the total thickness of the surfacing (a minimum of 120mm), the material that directly overlays the waterproofing system (sand asphalt), the bond of the surfacing to the waterproofing system and the sub-surface drainage.

14.2. While the performance of surfacing is generally satisfactory if the total thickness is at least 120mm (as specified in BD47), premature failures have occurred when the thickness has been reduced. Although this reduction is outside current standards there may be good practical and/or economic reasons for considering reducing the thickness of the surfacing. The first part of this Chapter reviews research carried out to understand the performance of surfacing to bridge decks, particularly where it is less than 120mm thick, and provides guidance on reducing the risk of failure by emphasising the importance of sub-surface drainage, strengthening the bond requirements, specifying deformation requirements and specifying maximum air void contents on all asphalt mixtures.

14.3. BD 47 also specifies the requirements relating to the application of bridge deck waterproofing, which leads to waterproofing systems being normally applied a minimum of 28 days after decks are cast. Recent research has shown that the performance of waterproofing systems should not be adversely affected by application to concrete aged 7 days or more. Therefore, the second part of this Chapter provides advice on the application of bridge deck waterproofing systems to concrete aged less than 28 days.

14.4. The risks associated with these proposals can be mitigated by careful planning and observing the advice/procedures within this advice note. However, as these risks will be taken by the Highways Agency, contractors must seek formal approval from the HA Project Manager for that particular scheme, through the Departure from Standards procedure.

14.5. Project Managers should confirm that proposals comply with the requirements of this Chapter and that the identified justification (cost/time savings) are appropriate. Project Managers should be aware that significant benefits can be realised by the reduction in programme offered by this Chapter and these should be reflected in the magnitude of the identified benefits. The decision to implement these procedures is at the discretion of individual HA Project Managers.

14.6. The requirements relating to bridge deck waterproofing and surfacing on steel bridge decks are not covered by this Chapter or by BD 47. Contractors wishing to construct such schemes must seek formal approval from the HA Project Manager.

Mutual Recognition

14.7. Any reference in this document to a "British Standard", or to a "British Standard which is an adopted European Standard", is to be taken to include reference also to the following standards:

(a) a standard or code of practice of a national standards body or equivalent body of any EEA state;

(b) any international standard recognised for use as a standard or code of practice by any EEA state;

(c) a technical specification recognised for use as a standard by a public authority of any EEA state, and;

(d) a European Technical Approval (ETA) issued in accordance with the procedure set out in directive 89/106/EEC.

14.8. Where there is a requirement in this document for compliance with any part of a British Standard or a British Standard which is an adopted European Standard, that requirement may be met by compliance with any of the standards given above, provided that the relevant standard imposes an equivalent level of performance and safety provided for by a British Standard or a British Standard which is an adopted European Standard.

14.9. "EEA State" means a state which is a contracting party to the EEA Agreement

14.10. "EEA Agreement" means the agreement on a European Economic Area signed at Oporto on the 2nd of May 1992 as adjusted or amended".

Materials

14.11. BD 47 requires waterproofing systems on concrete bridge decks to be overlaid with a 20mm thick sand asphalt additional protective layer (APL), and binder and surface courses, so that the total thickness of the three layers is 120mm. The surfacing materials must comply with Series 900 of the Manual of Contract Documents for Highway Works, Volume 1 (MCHW1).

14.12. This minimum thickness should always be aimed for; however, for practical and/or economic reasons, the total thickness on some bridges has to be reduced. Where this is the case, the APL should be omitted unless it is specifically required by the individual waterproofing system, and the waterproofing system should be overlaid directly with a layer of hot rolled asphalt (HRA) Performance-Related Design Mixture binder course to Clause 943 of MCHW1. A uniform thickness, not less than 45mm, is recommended. Variations in the total surfacing thickness over bridges should be accommodated in the upper layers, and tapered areas should be trimmed to remove asphalt too thin to be sufficiently well compacted.

14.13. It is government policy to use quiet surfacings on all trunk roads in England, including motorways. The capacity of these proprietary systems to waterproof the base layers below often appears to depend more on the bond or tack coat applied than the apparent 'porosity' of the surface course. Anecdotal evidence suggests that thin surfacing systems with an open texture laid on a heavy polymer modified bond coat can be more effective at sealing and waterproofing the base layers than thicker, less open systems (SMAs) laid on a thin tack coat.

14.14. Where the bridge deck has not been designed with a drainage system appropriate for a thin asphalt surface course system, HRA surface course complying with Clause 943 of MCHW1 may be used without a Departure from Standards.

14.15. Further guidance on improving the performance of bridge deck surfacing when the overall surfacing thickness is less than120mm is given in the next section of this Chapter. Indeed, this guidance represents best practice whatever the surfacing thickness.

Improving Surfacing Performance

Introduction

14.16. A bridge-deck overlay is more vulnerable the thinner it is. Modern waterproofing systems are very effective at waterproofing. However, they are resilient and, although they are designed to be applied in very thin layers, concrete bridge decks to which they are applied are often quite rough. This can result in thicker areas of membrane, increasing the resilience. In such cases, in combination with a sub-standard thickness overlay, a number of premature failures have occurred when the asphalt has broken up and potholes have developed (an example is shown in Figure 14.1).The failures have been attributed to several factors, including:

- The accumulation of sub-surface water in the asphalt
- Poor bond of the asphalt layers to the waterproofing system
- Excessive thickness of the waterproofing membrane
- Low compressive modulus of the waterproofing system
- Low fatigue resistance of the asphalt layers

Figure 14.1 Premature Failure of sub-120mm Thick Bridge Deck Surfacing

14.17. Research to investigate these failures has highlighted several changes which are necessary to further develop HA's guidance to improve the performance of bridge deck surfacing. The following actions should be considered before applying for a Departure from Standards to use an asphalt overlay less than 120mm in thickness:

- Re-assessment of the structure to maximise the thickness of the bituminous overlay.
- Specification of the highest modulus approved proprietary waterproofing system obtainable *(note: the need for this will diminish with increasing thickness of overlay and where the thickness of the membrane can be kept to a minimum).*
- Omission of the sand asphalt layer above the waterproofing system *(note: sand asphalt is an inherently weak pavement material and, if not a specific requirement of the chosen waterproofing system, it should be omitted and replaced with a structurally more competent material).*
- Specification of a waterproofing system which includes the provision of a bond coat for the asphalt overlay, and strengthening bond requirements generally. Where the waterproofing system offers alternative bond promoting treatments, the specification of the treatment claimed to provide the maximum bond shall be specified. Any proprietary bond coat between the waterproofing system and the overlay shall be a 'tack-free' material, such that it does not adhere to tyres of vehicles delivering asphalt to the paver.
- Provision of sub-surface, edge and joint drainage as appropriate, to reduce or eliminate water pressure under traffic.
- Specifying deformation limits for all mixtures within 100mm of the surface
- Specifying maximum air void contents for all asphalt mixtures.
- Specification of a thin surface course system which incorporates a heavy elastomeric-polymer modified bond coat.

Surface and Sub-surface Drainage

14.18. All asphalt surfacing is porous to some extent, for example through joints, and the use of more porous quiet surfacings may well exacerbate this (see Figure 14.2).

Figure 14.2 Moisture Trapped in Thin Surfacing

14.19. Accordingly, bridge deck overlays (the surface course and binder/base layers) should always be regarded as porous and drainage should be provided below the overlay at low points over the bridge deck waterproofing. Advice is given in BD 47 (DMRB 2.3.4) Chapter 4 'Drainage' and in BA 47 (DMRB 2.3.5), and this advice is developed further below.

14.20. Surface drainage systems, longitudinal gradients and cross falls should be provided to minimise the amount of water that can enter and accumulate in the surfacing on bridges.

14.21. Edge drains should be provided to drain the full depth of relatively permeable surface courses (e.g. air void content > 6%): (i) at the low points of the deck, and; (ii) where the flow of sub-surface water though the surface course is impeded, e.g. at expansion joints that are not the buried type.

14.22. Sub-surface drainage should be provided at the level of the waterproofing system as specified in BD 47 at all locations were water may accumulate.

14.23. The vertical faces of the joints between adjacent laid widths (rips) of asphalt are normally sealed with bitumen to prevent water ingress. However, a fully sealed joint will prevent the horizontal flow of water through the asphalt layers. Provision must be made to ensure good bond between the adjacent laid widths, but in a way that does not allow water to accumulate in parts of the asphalt layers.

Surface Preparation and Application of the Waterproofing System

14.24. All waterproofing systems shall have a certificate appropriate to the works to be undertaken, in accordance with MCHW1 Clause 2003, such as a HAPAS Roads and Bridges Certificate or similar Third Party Approval documentation provided by an equivalent organisation.

14.25. After the waterproofing membrane has been applied, there should be no hollows or depressions of maximum dimension 150mm in plan and depth greater than 2mm in trafficked areas of the deck that are not drained naturally by the longitudinal gradient or cross fall, or by the provision of subsurface drainage.

14.26. The waterproofing system must be uniformly bonded to the deck and it must not be applied if there is any contamination of the deck, or if the environmental conditions threaten to compromise the bond. It is expected that grit blasting may be necessary on most existing decks where the waterproofing system is being replaced. On new concrete decks, it is important to ensure all laitance is removed. Pressure washing is not generally recommended as additional time has to be allowed for this water to evaporate from the concrete substrate. All waterproofing systems require a good bond and require the same level of preparation to the concrete substrate. Any proposals for application to a deck with a reduced level of preparation must be submitted formally through the Departure from Standards procedure.

14.27. The thickness of spray applied waterproofing membranes should be a minimum of 2mm overall, including peaks and arrises in the concrete deck, but should not be greater than 3mm.

14.28. Concrete repair materials should be compatible with the waterproofing system and have similar properties to the deck concrete (strength, coefficient of thermal expansion and elastic modulus). Repair materials less than 5mm thick should be avoided as they are more likely to de-bond. Repairs of lower thickness should be used only if a durable bond can be demonstrated.

Surfacing and Waterproofing System

14.29. The BD 47 specification for surfacing over waterproofing includes the requirement for an additional protective layer (20mm of red sand carpet) overlying the waterproofing system. There is a general desire for the surfacing (all layers) to be well compacted to minimise permeability, as water in the surfacing structure can develop extremely high pressures under traffic which can destroy the bond between layers. In particular, this has been known to destroy the red sand carpet to the extent that it is pumped to the surface as a red slurry and the overlying material has totally failed (see Figure 14.3).

Consequently, an additional protective layer (APL) of sand asphalt should only be used when required by the individual waterproofing system. A separate Third Party Approval assessment of the waterproofing system's resistance to aggregate indentation at 125°C is required for each type of asphalt overlay that can be used with a proprietary waterproofing system. Care should be taken to minimise damage to the waterproofing system after if has been applied and before it has been overlaid with asphalt, especially when the APL is not laid. Any damage to the waterproofing system should be repaired in accordance with the Certificate holder's agreed method statement for the system.

Figure 14.3 Breakdown of Sand Asphalt APL

14.30. When an APL is required, consideration should be given to using black sand asphalt.

14.31. The laying of an APL of sand asphalt by hand should be discouraged because of the difficulties of laying and rolling such a thin layer at sufficiently high temperatures to achieve a good bond and form a dense layer. A stronger and thicker layer than sand asphalt, for example 50mm thick no-fines concrete, should be used in verges and footways to prevent utility companies from damaging waterproofing systems.

14.32. During prolonged periods of hot weather, asphalt overlays to suspended structures experience the highest temperatures and their deformation resistance should be specified accordingly. The deformation resistance of the thin surfacing course should comply with the requirements of Clause 942 of MCHW1. The resistance to permanent deformation of the hot rolled asphalt binder course directly overlaying the waterproofing system, and of all binder course layers (and base if applicable), when measured in accordance with BS EN 12697-22 (small size device, procedure A), shall be Classification 2 to Table C3 of BS PD 6691. Coring for test samples should not be undertaken from asphalt laid over the waterproofing membrane. Where materials are nominally laid at a thickness less than 40mm, testing is permitted to composite samples made up of more than one of the different layers to be used in the pavement, provided no part of the layer has a thickness less than twice its maximum aggregate size.

14.33. The flow of sub-surface water into the binder course(s) (and APL if present) should be minimised by specifying:

a. thin surface course system (TSCS) with a thick bond or tack coat that will help to seal the binder course, and;
b. binder course(s) which have a low void content.

14.34. The asphalt layer directly overlaying the waterproofing system should have a design air void content of no more than 4% so that the amount of sub-surface water that enters the layer is low. When the asphalt layer directly overlaying the waterproofing system contains coarse aggregates, the waterproofing system should have a thick bond coat that fills the voids at the base of the layer and prevents them from being interconnecting.

14.35. Higher asphalt laying and rolling temperatures are beneficial for obtaining low void contents, and will improve the likelihood of the bond coat being fully activated. Waterproofing systems vary significantly in their resistance to heat damage and the holder of the HAPAS or equivalent Third Party Approval certification should be consulted to obtain the maximum acceptable laying temperature for the particular waterproofing system used. Accordingly, contractors should give details of:

a. the temperatures at which the surfacing should be laid and compacted to ensure that the bond or tack coat of the waterproofing system is activated, and;
b. how stripping of the bond or tack coat is to be minimised and repaired before and during surfacing.

14.36. If the surfacing is to be laid and compacted at temperatures that exceed those permitted by MCHW1, it must be demonstrated before works commence on site that this will not damage the waterproofing system.

14.37. The asphalt directly overlaying the waterproofing system should be laid and compacted at temperatures that are sufficiently high:

a. to form a dense layer, and;
b. to activate the bond coat so the asphalt is uniformly and well bonded to the system.

14.38. The temperature at the level of the waterproofing system should be measured immediately after the asphalt has been laid, and when compaction is essentially completed. Laying and compaction temperatures should be chosen to take into account the requirements to form a dense layer that is firmly bonded to the waterproofing system. The objective should be to exceed the minimum temperatures required to activate the bond or tack coat by at least 10°C. If necessary, a site trial should be carried out to ensure that the minimum temperatures can always be achieved. If recorded temperatures are below the required level then the surfacing must be removed and the waterproofing prepared again.

Bond of Surfacing to the Waterproofing System

14.39. The minimum adhesion and bond strength requirements in BD 47 apply only to surfacing of thickness 120mm or more including an APL of sand asphalt.

14.40. Higher minimum values should be specified when the waterproofing system is overlaid with asphalt with coarse aggregates and/or is less than 120mm thick. The minimum tensile adhesion and shear and tensile bond strength requirements for such situations are given in Table 14.1.

Table 14.1 Minimum Adhesion and Bond Strengths for Waterproofing Systems Overlaid with Asphalt with Coarse Aggregates and/or less than 120mm Thick

Surfacing thickness		**≥120mm** note 1	**120-90mm** note 1	**90-60mm** note 1
Tensile adhesion test (waterproofing system to concrete)	@ -10°C	0.30MPa	0.50MPa	0.70MPa
	@ 23°C	0.30MPa	0.50MPa	0.70MPa
	@ 40°C	0.20MPa	0.30MPa	0.30MPa
Shear bond test (surfacing to waterproofing system)	@ -10°C	0.30MPa	0.30MPa	0.40MPa
	@ 23°C	0.30MPa	0.30MPa	0.40MPa
	@ 40°C	0.10MPa	0.15MPa	0.15MPa
Tensile bond test (surfacing to waterproofing system)	@ 23°C	0.40MPa	0.45MPa	0.50MPa

Note 1 A separate Third Party Approval assessment of the waterproofing system with this surfacing thickness will be required. An example of the assessment required, including details of the test and the make up of the mixture used for the surfacing, can be found in the HAPAS Guidelines Document for the Assessment and Certification of Waterproofing Systems for use on Concrete Decks of Highway Bridges.

Lapping onto Existing Waterproofing Systems

14.41. Problems can arise when lapping waterproofing systems with significant differences in adhesion levels. For example, there are significant differences in bond strengths when a spray applied waterproofing membrane is applied to a sheet waterproofing membrane.

14.42. When carrying out repairs to, or partially replacing, existing waterproofing systems, an initial assessment of bond strength should be made by undertaking pull off tests on the existing waterproofing system (before the breakout of concrete). If the adhesion is of similar magnitude to that of the proposed waterproofing system, the joint and overlap with the new waterproofing system can be prepared in accordance with the Certificate holder’s Third Party Approval method statement. The minimum overlap is to be as specified by the waterproofing contractor.

14.43. Where the adhesion is significantly different the procedure below should be used:

a. The new certified waterproofing system should be butted up to the existing waterproofing system.

b. A protective banding layer should be provided that laps a minimum of 150mm onto both the new and existing waterproofing systems.

c. Where the existing waterproofing system on the deck has been formed using mastic asphalt, there will be a significant difference in thickness between the new and existing waterproofing systems. In order to facilitate the lapping of the protective banding layer on to both new and existing waterproofing systems, a 45° chamfer in the mastic asphalt should be formed. If this is not possible, due to either break up of the mastic asphalt or poor adhesion to the deck, this chamfer shall be formed in concrete. Where concrete is to be used to form the required chamfer, record the presence of the concrete chamfer on both the as-built record drawings and within the Structures Management Information System (SMIS).

d. Record the structure in SMIS as 'At Risk' of failure of the waterproofing system and monitor for signs of failure at routine future inspections.

Waterproofing Systems applied to 'Young' Concrete

Introduction

14.44. Waterproofing systems that have satisfied the requirements of the certification tests as specified in BD 47 are considered suitable for use on bridge decks where the concrete is aged 28 days or more. Therefore, currently, waterproofing is normally applied a minimum of 28 days after decks are cast. However, any decrease in the age at which concrete can be waterproofed would be beneficial, as it may reduce congestion on the road network and realise cost benefits from a reduced construction programme.

14.45. Research carried out to investigate the factors that affect the performance of waterproofing systems applied to concrete less than 28 days old has shown that the performance of waterproofing systems should not be adversely affected by application to concrete aged 7 days or more. The findings of the research and guidance on the application of waterproofing systems to concrete 7 to 28 days old are given below.

Factors affecting Performance

14.46. The most significant differences in the performance of a waterproofing system applied to 28-day old and younger concrete are likely to be dependent on:

a. the resistance to blow/pin holing and blistering of the system;
b. the bond of the system to the concrete;
c. the effect of the moisture content of the concrete on the curing of components of the system, and;
d. shrinkage and load induced cracking.

14.47. These factors are dependent on:

a. the type of concrete;
b. the surface finish of the concrete;
c. the moisture content of the concrete when the waterproofing system is applied;
d. the temperature of the concrete when the waterproofing system is applied;
e. the type of the waterproofing system, in particular the type of primer;
f. the temperature history after the waterproofing system has been applied, including the temperature of surfacing materials.

14.48. Blow/pin holes and blistering are formed by out-gassing when air, water vapour or solvents in primers within voids in concrete are expelled due to changes in temperature or, sometimes, barometric pressure. Pin/blow holes are formed only when liquid-applied systems are curing: the longer it takes for them to cure, the greater the likelihood that they will form. Blisters may form any time after installation.

14.49. Out-gassing is most likely to occur when the temperature of a deck changes rapidly due to solar radiation or due to the application of hot surfacing materials. As concrete ages, the size of the pores decreases; therefore, concrete aged less than 28 days may be more prone to out-gassing than older concrete.

14.50. A waterproofing system should remain uniformly bonded to a concrete deck throughout its service life. Almost all membranes can have small defects through which chloride ions can pass. If the membrane is firmly bonded to the concrete, the number of chloride ions that can pass through a defect is normally low and the ions can reach only a small area of the deck. However, if the membrane has a defect where it is not bonded to the deck, many chloride ions can pass through the membrane and the likelihood that they can penetrate the concrete and cause reinforcement corrosion is much higher.

14.51. The initial bond of most waterproofing systems to concrete is dependant on the surface moisture content of the concrete during waterproofing. The bond strength will be reduced if surface moisture is present, especially if it impairs the curing of liquid applied components. Over time, even if out-gassing does not form blisters, it may weaken the bond of the system to the concrete. The bond may also change as the concrete ages and cures.

14.52. Shrinkage and load induced cracking may be significant in the hogged regions of continuous multi-span decks. A waterproofing membrane and its overlaying structure may be subjected to larger tensile strains if they are applied to the deck before the onset of cracking.

Guidance on the Application of Waterproofing Systems to 'Young' Concrete

14.53. The performance of waterproofing systems should not be adversely affected by application to early aged concrete (i.e. 7 to 28 days), provided they are applied in accordance with the guidelines given below:

- Any waterproofing system to be provided shall have a HAPAS Roads and Bridges Certificate, or similar Third Party Approval documentation, in accordance with MCHW1 clause 2003.
- 'Young' concrete tends to have higher surface moisture contents; therefore, extra care is needed to ensure that the required moisture content has been achieved before application of the waterproofing system. Considerable flame drying may be required. After a period of sustained rainfall it is likely that the substrate will be saturated; while flame drying may dry the immediate surface, a significant amount of moisture may remain. Care should be taken to establish that the substrate has an acceptable moisture content before application of waterproofing, and/or the moisture content must be below 6%.The accuracy of measurement should be taken into account (for example, most hand held moisture meters only have an accuracy ± 2%).
- Extra care is required when using primers on early-age concrete and to ensure that these are fully cured prior to application of the waterproofing system. (This relates to the primer that is part of the certified procedure for that waterproofing system; it does not relate to concrete curing compounds or surface impregnates which must be removed/treated before application of waterproofing).
- Tensile adhesion is particularly important when applying sheet waterproofing membranes at high ambient temperatures. The minimum tensile adhesion and bond strengths given in Table 14.1 shall apply.
- Pull-off tests should be conducted on site after the installation of the waterproofing membrane and before surfacing, to confirm that the condition and dryness of the surface of the concrete is appropriate for adequate initial tensile adhesion of the waterproofing system to the concrete. Any requirements for acceptability of adhesion (in addition to those specified in Table 14.1) should reflect the properties of the systems being used. For example, 0.3 MPa is too low for spray applied membranes and would be indicative of a potential problem if recorded on a site trial. Advice should be sought from the manufacturer prior to commencing trials.
- Bond tests have shown that the tensile bond strength of the surfacing to the waterproofing system and/or the tensile strength of the surfacing can be weakened by wheel loading when the surfacing is saturated. A thick bond or tack coat should be applied to limit the amount of water that can accumulate on the surfacing at the interface with the waterproofing system.

Performance and Durability

14.54. A very high level of care and workmanship is required for <u>all</u> bridge deck surfacing to have a long life. There is insufficient evidence at present to prove the long term durability and overall economy of sub-standard thickness asphalt overlays on bridge decks on the Strategic Road Network, and the risk of premature failure in these situations is considerable.

14.55. Satisfactory drainage provision is essential, the basic requirements for which are set out in this Chapter. Further information is given in TRL Application Guide 33 'Water Management for Durable

Bridges' in the drainage section. Other useful references are BD 33 (DMRB 2.3.6) and BA 26 (DMRB 2.3.7), both concerning expansion joints and covering their drainage.

14.56. Full bond is a very significant requirement for a durable surfacing. The aim when surfacing should be for all the layers to be compacted as far as possible to minimise permeability and for all the layers to act monolithically with each other, the waterproofing membrane and the bridge itself. Achieving a satisfactory end product will involve significant levels of consultation between the waterproofing supplier and contractor and the surfacing supplier and laying contractor.

Restrictions

14.57. A Departure from Standards is mandatory for any use of asphalt surfacing thickness less than 120mm and/or for application of waterproofing to concrete less than 28 days old.

Monitoring and Testing

14.58. Future monitoring of bridge deck overlays considered to be ‘At Risk’, for example where bespoke methods have been adopted to marry new and existing waterproofing systems, must be appropriately identified in SMIS.

14.59. The requirements for monitoring and testing substrate, waterproofing and surfacing as set out in this Chapter, and how these requirements are to be incorporated into the contract documents, will need to be clearly identified in the Departure from Standards.

Normative References

BSI PD 6691 Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications
BS EN 12697-22 Bituminous mixtures —Test methods for hot mix asphalt — Part 22: Wheel tracking
Manual of Contract Documents for Highway Works – Volume 1
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