VOLUME 7 **PAVEMENT DESIGN AND MAINTENANCE**

SECTION 5 **SURFACING AND SURFACING MATERIALS**

PART 2

HD 37/99 AMENDMENT NO 1

BITUMINOUS SURFACING MATERIALS AND TECHNIQUES

SUMMARY

This amendment is a correction to Chapter 8, Table 8.1 Areas of use for surface dressing binders.

INSTRUCTIONS FOR USE

1. Remove existing page 8/8, dated February 1999, from Volume 7, Section 5, Part 2, Chapter 8 and archive as appropriate.

2. Insert page 8/8 dated May 1999.

3. Enter the details of the amendment on the Registration of Amendments sheet, sign and date to confirm the amendment has been incorporated.

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SECTION 5 SURFACING AND SURFACING MATERIALS

PART 2

HD 37/99

BITUMINOUS SURFACING MATERIALS AND TECHNIQUES

SUMMARY

This Advice Note gives advice on the suitability, specification, laying and testing of bituminous surface courses. It supersedes HD 37/97 and also Chapters 4 and 5 of HD 27/94, revised versions of which are incorporated into Chapters 2 and 5 of HD 37/99.

INSTRUCTIONS FOR USE

1. Remove HD 37/97 from Volume 7, Section 5, Part 2, which is superseded by HD 37/99, and archive as appropriate.

2. Insert HD 37/97 into Volume 7, Section 5, Part 2.

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Design Manual for Roads and Bridges

Volume 7: Pavement Design and Maintenance

Bituminous Surfacing Materials and Techniques

Summary: This Advice Note gives advice on the suitability, specification, laying and testing of bituminous surface courses. It supersedes HD 37/97, HD 27/94, Chapters 4 & 5, and HD 28/94, Chapter 2.

Volume 7 home page

REGISTRATION OF AMENDMENTS

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PART 2

HD 37/99

BITUMINOUS SURFACING MATERIALS AND TECHNIQUES

Contents

1. INTRODUCTION

General

1.1 This Part gives advice on the suitability, specification, laying and testing of bituminous surface courses. It covers all materials using bituminous binders ranging from veneer coats like surface dressing and slurry surfacing to heavy duty surfacing material such as hot rolled asphalt. It also includes high friction surfacing, retexturing of bituminous materials and recycling using the Remix and Repave processes.

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.

Types of Bituminous Surfacing Materials

1.3 There are essentially three basic types of premixed bituminous material. Those with:-

- High stone content, full coarse aggregate interlock, and a gap grading (eg SMA);
- A continuous grading (eg DBM);
- A rich mortar and a gap grading where the coarse aggregate does not interlock (eg HRA);

Intermediate materials exist such as a high stone content hot rolled asphalt with crushed rock fines, which falls between the last two types. Slurry surfacing, and particularly micro-surfacing, normally have a continuous grading. Single chipping surface dressing does not fall into any of these classifications, but multi-layer dressings (like racked in, double and sandwich dressings) can be considered as a type of high stone content material with full coarse aggregate interlock.

High Stone Content Gap-graded Materials
1.4 High stone content materials with aggregate interlock can be divided into two main types:

- Those with very little or no fine aggregate (eg Porous Asphalt - PA), and
- Those in which the voids between the coarse aggregate particles are largely filled with a mastic of fine sand, filler and binder, often reinforced with fibres or polymer (eg a stone mastic asphalt - SMA).

1.5 Many of the new thin surfacing materials fall into this second type. The high strength of these materials is produced by the stone skeleton and they are inherently resistant to rutting. Because the stone skeleton is so important the aggregates used in these materials must be strong and hard, and must have a consistent shape and grading, or the final mix will vary in properties.

1.6 On roads where the width varies they are best laid using a paver with a variable width screed as they can be difficult to lay by hand and the overall grading needs close control. When properly compacted, dense materials such as SMA can be very durable, because air voids are low and the binder film thickness is generally high. If the air void content is too low however, achieving and retaining surface texture can be problematic and the SMA can be prone to deformation.

1.7 For long life, porous materials depend on the continuing integrity of the binder film. There are two main factors operating, adhesion of the binder to the aggregate and weathering of the binder. Some aggregates have a better affinity for bitumen than others and where there is doubt, (eg with quartzites), then adhesion agents should be used. The weathering of the binder and the means of overcoming the problem are dealt with in more detail in Chapter 5 of this Part.

Coated Macadams or Asphaltic Concretes
1.8 Materials with a continuous grading are often called asphaltic concretes or macadams. The current CEN name for all these types of material is asphaltic concrete. All the dense and close graded macadams in BS 4987 fall into this group. Macadams are not generally used as surface courses on trunk roads as they suffer from a number of disadvantages which are outlined in Chapter 13 of this Part.

1.9 The mixes are 'designed' to give a dense aggregate matrix, often based on the 'Fuller' curve. However this means that the voids in the mineral aggregate (VMA) are low, and in order to avoid filling all the voids with binder (making an unstable material prone to deformation) the binder content must be kept relatively low. This results in a relatively thin binder film thickness, which reduces its durability. However a thin binder film is not generally a problem in layers protected from the weather, which is why materials of this type make excellent load spreading layers in the roadbase and basecourse.

1.10 Materials in this group are sensitive to variations in grading and binder content and production will be monitored by the supplier under the QA Sector scheme to ensure consistency. They generally have low workability and therefore need good compaction if durability is to be achieved. When properly compacted, the texture depth obtainable is very low making them unsuitable as surfacing for high speed roads.

Hot Rolled Asphalt

1.11 Low stone content gap graded materials are normally referred to as hot rolled asphalt and are covered by BS 594. They usually have a high binder content and low voids. They depend for their rut resistance on the sand/filler/binder matrix and, of necessity, the binders are hard (low penetration grade).

1.12 With the requirements for higher stability and retention of high texture depth, asphalts have tended to become less workable, with lower binder contents, and hence are less forgiving of poor workmanship. This often shows up initially as fretting at joints, and joint sealing within the first few years of the life is not unusual. The causes of joint fretting are low binder content or over-raking, and poor compaction. It is therefore important that asphalts are adequately compacted up to the edge and that this compaction should be monitored.

1.13 High stone content hot rolled asphalt has a nominal stone content of 55%, and no chippings are rolled into the surface.

Properties of Bituminous Surface Courses

1.14 None of the surface course materials will provide all the desirable requirements for all situations. A surface course should be the best compromise between the various available properties. The main properties required are:

a) durability,
b) resistance to deformation,
c) load spreading ability,
d) texture depth,
e) skidding resistance,
f) low noise generation
g) the ability to keep water out of the pavement structure,
h) resistance to cracking.

These properties and others are discussed below.

Environmental durability

1.15 This is 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.

1.16 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 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 wearing 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; and the long term adhesion of the film to the aggregate. The durability of surface dressing and some of the bonded materials depends primarily on good adhesion to the underlying road structure. However with surface dressing, the use of dusty chippings may induce bond failure between the chippings and the binder in the short term.

Resistance to deformation

1.17 This is important in all layers of a bituminous road, but the need is greater for a surface course 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 given in BS 598 Part 110. With the very heavy traffic being carried on major roads it is also necessary for the basecourse, (ie the layer immediately below the surface course), to be designed for resistance to deformation.

1.18 Bitumens harden over the first few weeks after laying (steric hardening) and therefore a surfacing material is more prone to rutting during its very early life. Where heavy channelised 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.

Load spreading ability

1.19 This is assessed by measuring its 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. 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. In new construction, or where a structural overlay is being added, then an assessment of the load spreading ability is required.

1.20 For maintenance resurfacing the structural contribution of the surface course may be ignored:

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

Texture depth and skidding resistance

1.21 These should be specified as described in HD 36 (DMRB 7.5.1) and the standards required should be applied in all situations. For surface dressing to Clause 922 and thin surfacings to Clause 942, the Specification (MCHW1) requires texture depth to be maintained at or above the levels specified, at least until the end of the guarantee period, currently two years, to ensure a satisfactory overall life is achieved.

Surface noise

1.22 This 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 by 2 to 3 dBA 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 5 dBA, the voids absorbing sound. However this advantage reduces as the pores fill with detritus, giving a relative reduction of about 3dBA, similar to some thin surfacings. Further information on surface noise is given in HD 36 (DMRB 7.5.1)

Adhesion

1.23 The adhesion of a surface course to the underlying pavement structure is essential, particularly so with surface dressing and very thin materials. These are not thick enough to carry traffic induced stresses without excellent adhesion. 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 2 of this Part for information on Bond or Tack Coats)

Waterproofing

1.24 Sealing the surface of a pavement assists in prolonging its life. This is usually achieved in one of two ways. Either the bond coat is heavy enough to significantly reduce the permeability of the underlying layer, (eg. surface dressings, some thin surfacings and porous asphalt), or the material itself is dense enough to prevent or seriously impede water draining into the road structure. Normal tack coats to BS 594 or BS 4987 should not be assumed to greatly improve the waterproofing characteristics of the road.

Workability

1.25 This is necessary to achieve the intended properties of the surface course after laying and compaction. For example, workability is important in a hot rolled asphalt surface course, when 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 surfacings to achieve the necessary aggregate interlock, and rapid heat loss in cold weather can result in poor compaction.

Resistance to cracking

1.26 Cracking of surfacing materials is caused by a combination of factors:

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

1.27 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 alleviate this problem.

1.28 The fatigue characteristics of a mixture are largely governed by the volume and properties of the binder. Because binder ageing and the consequent embrittlement is a factor, fatigue cracking is likely to occur earlier in open graded materials than in impermeable ones since the binder can harden due to weathering throughout the depth of the more open 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, thus good adhesion between binder and aggregate is advantageous.

Moisture damage

1.29 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.

Macrotexture

1.30 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, materials will undergo secondary compaction under traffic, particularly in very hot weather. This almost invariably reduces the macrotexture. Very high texture depth is not desirable, as the noise level generated by the passage of traffic over the surface is increased.

Ride quality

1.31 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. Micro-surfacing can improve the transverse shape of the pavement but has limited effect on the longitudinal profile.

2. LAYING BITUMINOUS SURFACE COURSES

2.1 Advice on laying bituminous materials is given in Part 2 of both BS 594 and BS 4987. Additional advice regarding particular materials is given in the Chapters on specific materials in this Part.

Weather Conditions

2.2 The weather conditions during the construction of bituminous surface courses 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 a surface course laid in inclement weather may be reduced. The requirements of the specification should be strictly adhered to.

Available Research Reports and Weather Forecasting

2.3 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.

2.4 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.

2.5 The Meteorological Office can also provide 24-hour local forecasts, including wind speeds, from regional weather centres. Information on these services can be obtained from the Meteorological Office, Climatological Services (Met 03), London Road, Bracknell, Berkshire RG12 2SZ (Tel: 01344 420242). Planning the laying of surface courses should always be done in conjunction with an up to date weather forecast.

Specification

2.6 The Specification (MCHW 1) Series 700 and 900, with the associated Notes for Guidance (MCHW 2) set out the requirements for acceptable weather conditions for laying bituminous surface courses. For performance specifications Series 700 does not apply but it provides a useful guide to good practice. (For some special materials the requirements are included in Series 900). Where modified binders are used advice from the binder supplier via the Contractor should be obtained.

2.7 Various assumptions have been made in drafting the Specification (MCHW 1). These are:

a) no allowance has been made for solar gain,

b) the temperature of the substrate has been assumed to be at ambient temperature initially,

c) the binder is an unmodified bitumen to BS 3690, and

d) that for materials with 50 pen binder, the temperature of the asphalt immediately behind the paving machine is at least 140°C and compaction is effectively completed when the laid asphalt temperature has fallen to about 100°C. A similar temperature differential is applicable to other grades of binder.

2.8 Great care should always be taken when the temperature is, or has recently been below 0°C as ice may be present on 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 surface course.

Measuring Wind Speed and Temperature

2.9 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 2.1.

2.10 The Specification (MCHW 1) allows for wind speed to be measured at heights of either 2 m or 10 m. Measurement at 2 m height, using a portable anemometer, is appropriate for monitoring on site. Measurement at 10 m height is more suited for use on a major contract where there is a site office compound.

Force	Description	Description for use on land	Equivalent speed at 10 m above ground Knots	
			Mean	Limits
0	Calm	Calm, smoke rises vertically	0	<1
1	Light Air	Direction of wind shown by smoke but not by wind vane	2	1-3
2	Light Breeze	Wind felt on face; leaves rustle; ordinary vanes moved by wind	5	4-6
3	Gentle Breeze	Leaves and small twigs in constant motion; wind extends light flag	9	7-10
4	Moderate Breeze	Raises dust and loose paper; small branches are moved	13	10-16
5	Fresh Breeze	Small trees in leaf begin to sway; crested wavelets form on inland waters	19	17-21
6	Strong Breeze	Large branches in motion; whistling heard in overhead wires; umbrellas used with difficulty	24	22-27
7	Near Gale	Whole trees in motion, inconvenience felt when walking against the wind	30	28-33
8	Gale	Breaks twigs off trees; generally impedes progress	37	34-40
9	Strong Gale		44	41-47
10	Storm		52	48-55
11	Severe Storm		60	56-65
12	Hurricane			above 65

Table 2.1 The Beaufort Scale of Wind Speeds

2.11 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 10 m 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 10 m height is the preferred option. Measurements at a height of 2 m 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.

2.12 Ambient temperatures should be measured using a suitable device calibrated to ±1symbol 176°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 will be used to determine the air temperature. It should be noted that the quoted air temperature is always in the shade unless otherwise specified.

2.13 Surface temperature should be measured with an electronic thermometer having a surface measurement probe of low heat capacity 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. Where the Specification (MCHW 1) includes measured compaction limits, (eg void contents or PRD) 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, the temperatures should not be specified.

Consideration of Specific Materials

Hot Rolled Asphalt

2.14 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 compaction and chipping application is of necessity longer, at about 10 minutes, than for materials laid in a single operation without chippings. Careful control of laying and rolling temperatures is vital to ensure, with reasonable certainty, that the chippings will be retained.

2.15 In addition to normal cooling in ambient conditions, the application of cold chippings (12-15% by mass of hot asphalt) to the surface causes rapid cooling of the top few millimetres. 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 and the surface of the asphalt may be too stiff to allow adequate embedment of the chippings. 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.

2.16 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 5 m 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 traffic control which may cause long delays.

Porous Asphalt

2.17 From the temperatures set out in Clause 938 of the Specification (MCHW 1) an 8 minute compaction period may be assumed for a 50 mm thick layer of porous asphalt to cool from the minimum paver-out temperature to the temperature for substantial completion of compaction. This period has been estimated in accordance with TRL Research Report 4 and adjusted to take into account the difference between the expected rates of cooling of hot rolled and porous asphalt surfaces.

2.18 Laying in the rain should not be permitted as this cools the material too quickly, reducing compaction. Heavy rain may also affect the bond between the binder and the aggregate.

Thin Surfacings

2.19 Since these materials are thin they cool very rapidly, and the amount of time available for compaction is limited. As they are proprietary materials, it is the Contractor's responsibility to ensure adequate bond and compaction is achieved. Laying these materials on a wet surface or during falling rain may significantly reduce the initial bond to the underlying surface.

2.20 Some of the thinner variants of these proprietary products cannot be laid in winter, and their application on cold windy days, or at night outside the winter period, should be treated with caution. Local weather forecasts should be used to plan the works during more favourable conditions.

Slurry Surfacing and Micro-surfacing

2.21 These materials are made with bituminous emulsions and therefore should not be laid in icy conditions. It is necessary for a proportion of the initial water content to evaporate from the slurry before it can be trafficked. Laying in wet or humid conditions, particularly when combined with low temperatures, will significantly delay the setting process. It should be borne in mind that even in good conditions the material takes at least 30 minutes to become sufficiently stable to open to traffic. Adverse conditions can increase this period to several hours. Very high temperatures may cause problems such as pre-setting and efficient breaking of the emulsion may be inhibited, leading to failure.

2.22 With these constraints, slurry surfacing and micro-surfacing, like some of the hot paver-laid thin surfacings, have a closed season in winter. Their use is also restricted at maximum road temperatures, similar to surface dressing.

Surface Dressing

2.23 Surface dressing has a very short laying season, particularly for heavily trafficked roads, although the advent of superior binder grades and improved processes have lengthened the season. Full guidance is given in Road Note 39. The main reason for the short season is that the chippings have to adhere to the binder at temperatures close to ambient, while the binder must maintain sufficient cohesive strength to resist traffic forces when the road is opened.

2.24 For successful surface dressing, it must not be raining and the road surface should be dry. In wet conditions the binder will not adhere to the surface and rapid failure may occur. The sprayed binder film will not adequately adhere to wet or cold chippings and the time taken for the surface dressing to gain adequate stability to resist the traffic forces can significantly increase. Obtaining accurate weather forecasts and making good use of them is more important for the successful outcome of surface dressing than for most other surface treatments.

2.25 When emulsion binders are being used the work should stop if the relative humidity exceeds 80%, as the binder will not break properly and will lack adequate cohesion for the safe opening of the road to traffic. Relative humidities between 60% and 80% can lengthen the breaking time and care should be exercised when making the decision to open to traffic. The use of breaking agents and multiple-layer dressings may alleviate this problem.

Site Preparation

2.26 For all surface course materials it is essential that an adequate bond is achieved and maintained between the surface course and the underlying pavement structure. The thinner the surface course, the greater the traffic generated stresses at the interface. To achieve an adequate bond the substrate must be clean and free of all loose material.

2.27 Where the substrate is new or nearly new, with the binder film still intact, and no contamination, further treatment should not be necessary. Where it has been contaminated by site traffic for example, it is essential to remove the contamination by sweeping, and if necessary by the use of water jetting or other methods. Where an existing road is being resurfaced, all packed mud, excess oil droppings, any other accretions or organic growth must be removed.

2.28 Treatment with a suitable weedkiller may be necessary some days or weeks prior to the work being carried out. The advice of the weedkiller manufacturer should be followed with regard to timing. There are areas where the use of some weedkillers is constrained and the Overseeing Organisation should be consulted to check on any limitations that are in place.

2.29 Existing roads may need some pre-treatment or shaping before the proposed surface course can be used. This should be carried out using an appropriate basecourse material with the necessary properties, strength and resistance to rutting, for the expected traffic levels. Another way of regulating is to plane off any high areas. The most suitable method will depend on the amount of regulation necessary, threshold levels and the level of street furniture.

2.30 In order to obtain best value for money from the resurfacing, any local weaknesses in the underlying pavement should be repaired and cracks sealed using an appropriate treatment, see HD 31 (DMRB 7.4.1). In general the thinner the surfacing, the lower its ability to regulate the existing surface. Surface dressing follows the existing profile and will not smooth out irregularities. Similarly slurry surfacings, which are laid with a spreader box following the existing profile, are too thin to regulate the surface, although the thicker micro-surfacings can improve the transverse profile. Hot paver-laid thin surfacings can regulate the existing surface to a significant degree and guidance is given in the Notes for Guidance (MCHW 2). The limits on the regulating ability of proprietary thin surfacings may be given in the BBA HAPAS Certificates – see Chapter 6 of this Part. Porous asphalt must not be laid on a surface that will prevent the free drainage of water (ie the existing surface must be free of depressions).

2.31 For the thinnest surfacings it is best practice to remove all road markings before resurfacing. This is particularly relevant for surface dressing and very thin materials as the thickness of white lines is significant when compared to the thickness of the surfacing. It will also behave differently from the rest of the substrate if overlaid and may precipitate failure. It may be possible to mask thicker lines, for example the ribbed line between the hardshoulder and the slow lane.

2.32 With hot paver-laid materials all ironwork should be reset to its final level after laying any base 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. With slurry surfacing and surface dressing the ironwork or reflective studs should be masked as described in the Specification (MCHW 1).

Bond or Tack Coats

2.33 The purpose of bond or tack coats is to ensure that all the layers of a bituminous road behave monolithically. It is, therefore, extremely important that they are specified and applied in accordance with the Specification (MCHW 1)). When a permeable course is used, the bond coat also has to seal the existing surface against ingress of water into the pavement structure.

2.34 Bond or tack coats are normally required but there are occasions (eg laying a surface course on an existing road that has fatted up or on new basecourse or roadbase) when there is already sufficient bitumen at the interface between the new and the underlying layer such that an additional coat is not necessary.

2.35 All unmodified bond coats and tack coats are cationic bitumen emulsions. They are quick breaking and most conform to BS 434; these are designated K1-40, K1-60 or K1-70. K1-40 and K1-60 are sprayed at ambient temperature, but K1-70 must be heated to between 80°C and 90°C before it is sufficiently fluid for spraying.

2.36 All polymer modified emulsions are proprietary and will require BBA HAPAS Certification. They are typically either 60% or 70% binder content emulsions. The binder manufacturers instructions should be followed for spraying methods but typically the 60% emulsions are sprayed at ambient temperature and the 70% ones are sprayed at between 80°C and 90°C. Some proprietary surfacing materials include the bond coat as part of the process and the BBA HAPAS Certificate for the surfacing will include the bond coat requirement.

2.37 Conventional bitumen emulsions to BS 434 are normally suitable for use on roads where the existing surface is a bituminous material. Many conventional emulsions do not adhere well to concrete and the suitability of a particular type should be checked with the manufacturer before such use. A polymer modified emulsion specifically formulated for use on concrete may be a better choice.

2.38 There are a number of techniques that can be used for applying bond or tack coats. The traditional one with K1-40 and K1-60 is to use a hand lance, with either a hand or motorised pump, using material delivered in 200 litre drums. K1-70 binder, as used for porous asphalt, must, because it is sprayed hot, be applied using surface dressing equipment, ie. a heated tank and spray bar. A recently introduced technique is by integral spray bar attached to the paver, together with a tank for holding the emulsion.

2.39 The rate of spread of bond coats should be measured. The material usage divided by the area covered will be sufficient for all surface courses, except surface dressing or thin surfacings, where more precise methods should be used.

2.40 All methods of spraying bond coats have difficulties with either the control of the rate of spread, the evenness of spread, the completeness of break or pick up of material on the wheels of the delivery vehicles.

Rate of spread

2.41 It is very difficult to obtain an even rate of spread of binder with the hand lance because it is difficult to control a single nozzle. There is no correlation between the amount that is pumped and the speed of swing of the lance except for the skill of the operator.

2.42 The main difficulty with integral spray bars is the low rate in terms of volume. A conventional surface dressing bar sprays between 70 and 100 litres/min for each metre width, whereas an integral bar on a paver laying at 12 metre/min will be spraying about 6 litres/min per metre width when using K1-40 emulsion for a traditional tack coat. This means that the jets on the spray bar must be smaller and are therefore more difficult to manufacture to give the correct rate of spread. Some integral bars use intermittent or movable jets to give the correct rate of spread. It is important that these are checked for efficient operation.

Evenness of spread:

2.43 The hand lance has problems with evenness of spread, depending solely on the skill of the lance operator. However skilled, there will be significantly less sprayed around the edges of an area than in the middle, unless it is permitted to spray outside the area required.

2.44 When using surface dressing equipment there are few problems, providing it has been properly calibrated and the jets checked for blockages. With spray bars integral with the paver the main problem is likely to be blockage of the small jets. They should be checked prior to the start of each days work and whenever the paver has stopped for long enough for a transverse joint to be cut. Where the jets are movable or intermittent it is very important that evenness of rate spread of spread is checked regularly. The manufacturers procedures should be followed to ensure that the spray bar continues to operate correctly throughout the laying period.

Completeness of break:
2.45 Emulsions applied in front of the paving train need reasonably good weather conditions if they are to break prior to construction traffic using the sprayed surface. If the emulsion is not fully broken before trafficking there will be serious disruption to the binder film by the wheels of the lorries and the paver. Emulsions will not break in the rain, they break extremely slowly if the relative humidity is above 80%, and they form ice if the surface is below freezing. Emulsions should not be used in these conditions.

2.46 There should be no problems with the emulsion breaking when sprayed from an integral spray bar, as the hot material following immediately behind will break the emulsion quickly and completely by the evaporation of the water. Provided that it does not cause problems with evenness and rate of spread, there are advantages in using binder contents higher than 40% in the emulsion, as less water needs to evaporate off for the same amount of bitumen on the road. (This will also mean that less heat is lost from the bituminous material being laid).

Picking up:
2.47 When emulsions are sprayed ahead of the paving train there is always a risk that construction traffic will pick up even fully broken binder which remains sticky. This is a particular problem with the thicker films such as those used with porous asphalts. To overcome this if it occurs to any significant extent, it may be necessary to use a polymer modified emulsion, chosen for low adhesivity to vehicle tyres; or to use an agent to reduce the adhesivity.

2.48 The system used should ensure that site traffic does not pick up the bond or tack coat and transfer it to other areas such that the process is seriously affected. (eg Filling the surface voids in thin surfacings or porous asphalt).

Joints

2.49 Whatever surface course is used it will be necessary to construct joints, both longitudinally and transversely. Joints are a potential source of weakness and great care should be taken in their formation. The best technique to be used will depend greatly on the surface course material concerned.

2.50 The techniques used for materials to BS 594 or BS 4987 are given in Part 2 of each standard. The same methods are also suitable for use with stone mastic asphalt.

2.51 A proprietary material will have the correct jointing method described in the BBA HAPAS documentation. Joint formation in surface dressing, slurry surfacing and micro-surfacing are described in the relevant Clauses of the Specification and Notes for Guidance (MCHW 1 and 2) and appropriate chapters in this Part.

Aftercare

2.52 Aftercare is the practice that occurs after completion of rolling and prior to the gain of full strength by the surfacing. It is most important for surface dressing and is dealt with fully in Chapter 8 of this Part with further information given in Road Note 39. Slurry and micro-surfacing should not be trafficked until they have gained sufficient strength to resist the forces that are likely to be exerted, including braking. This type of surface will also need sweeping for a few hours or days after opening as traffic continues to consolidate the material. How quickly this happens depends on the location, the amount of traffic and the weather conditions.

2.53 Hot, paver-laid materials, in general, do not need any treatment after the completion of rolling. However heavy traffic should not run on the material until it has cooled and hardened sufficiently, because all bituminous materials are less resistant to deformation when they are new. As a guide, newly laid surfacing should not be opened to traffic if its surface temperature exceeds 25°C unless the maximum temperature within the mat has fallen below 35°C. The maximum temperature within the mat may be assumed to be at mid-mat. Guidance on the avoidance of wheel-track rutting in hot rolled asphalt, also relevant to other surfacing materials is given in the Notes for Guidance Clause NG 943 (MCHW 2). Further guidance may be given in BBA HAPAS documentation for proprietary surfacing materials and modified binders.

Road Markings

2.54 There are no particular difficulties with the application of road markings on any surfacing materials with the exception of porous asphalt which is dealt with in Chapter 5 of this Part. On some surface dressing types with high texture, (eg 14/6 mm racked-in), the first application of lane markings can be short lived unless the application thickness is at the upper end of the permitted range. This is because the majority of the material is below the peaks of the chippings.

2.55 Contra-flow and maintenance operations often require the application of temporary reflecting road studs. Many types of stud leave a sticky deposit of bituminous adhesive that clogs and blocks the surface voids (of porous asphalt and thin surfacings) and some types can also cause pluck-out of aggregate. Where surface dressing is subsequently applied such deposits may bleed through the dressing and leave fatty patches. Trials may need to be performed, at the back edge of the hardshoulder, to ensure that the studs proposed for use will come free from the surface without plucking out surface aggregate or leaving an excessive deposit.

2.56 Problems have also been reported with pre-formed marking tapes, in particular poor long term adhesion on negatively textured surfacings in wet weather.

Testing Bituminous Surface Courses

2.57 The Specification (MCHW 1), Series 100 and Appendix A, requires that asphalt mixes are produced in plants that are registered to the ISO 9000 ‘Sector Scheme for the Production of Asphalt Mixes’. Using the new CEN terminology this includes all bituminous mixtures. Under this scheme, producers are required to monitor asphalt production at predetermined frequencies to ensure the consistency of the various products. Plants are categorised as Q1, Q2 …or Q6, to demonstrate the consistency actually achieved, the lower the ‘Q’ value, the better the consistency. Testing asphalt in the ‘as delivered’ condition should therefore no longer be necessary. Nevertheless if obvious variations in a product do occur, for example as a result of binder drainage, audit testing should be undertaken to check whether or not the product complies with the requirements of the Specification (MCHW 1). Non-compliance should be reported to the Overseeing Organisation and the certification body.

2.58 When required, testing of bituminous surface courses should be carried out in accordance with the Specification and Notes for Guidance (MCHW 1 and 2), Series 700 and 900. The frequency of testing is specified in MCHW 1 with guidance given in MCHW 2 including Series NG 100 Table NG 1/1. Advice is also included in the appropriate Chapters of this Part for specific surfacing materials.

Interpretation of Test Results

2.59 A test result should never be considered in isolation unless it is so far outside the specified parameters that the probability of the material conforming to specification is minimal. Many standard test procedures give indications of the precision of the test and for a single result the figure given for reproducibility should be used as a guide to its precision. The more test results that are available the more precise the judgement that can be made on the compliance of the material as a whole.

2.60 Some requirements of the Specification (MCHW 1), for example, the void content of an HRA surface course or the binder content of porous asphalt, have different limits set for single results and for the mean of a number of results. By this means the risk of accepting large quantities of sub-standard material is reduced, whilst recognising the fact that not only do variations occur in the materials but also in sampling and testing, the latter not reflecting the actual values within the layer. The importance of accurate sampling cannot be emphasised strongly enough as this is a very common cause of disputes on site.

2.61 Where the test results demonstrate that there is a compliance problem a number of steps should be taken:

- Ensure that the samples were taken and tests carried out correctly. A NAMAS accredited sampling and testing laboratory will have records to demonstrate that the sampling and testing was, or was not, carried out correctly;

- If the procedures were correct then decide whether the results are so far outside specification that the material definitely does not comply;

- If the position is unclear, where possible carry out duplicate tests on samples already taken, or take other samples from the same location as the original samples, and repeat the tests;

- Compare the two sets of results: if they confirm each other (within normal testing variation), take the mean value in comparison with the specification. If the results differ significantly, give more weight to results from samples cut from the completed mat.

2.62 With performance based specifications a judgement can often be made on the likely effect of non-compliance on the life and performance of the surface course. Advice should be obtained from the Overseeing Organisation. Removal and replacement should be a matter of last resort as this process introduces additional joints and the final product is less likely to conform in terms of compaction and ride quality than the original, because of the limited area being replaced.

2.63 Once it is decided that material must be removed, the defective area must be determined. Occasionally the limits are obvious, eg when a delivery of low temperature material leads to high void content measurements, the start and end of the load can often be seen. When the extent of the non-conforming material cannot be identified in such a manner, the Contractor may reduce the remedial work by carrying out further testing to determine the limits of the area affected. Alternatively it will be necessary to replace all material covered by the result which is out of specification, up to but not including the location of compliant results on either side.

2.64 Whatever decisions are taken with regard to remedial works the Contractor and his supplier should investigate the cause of the non-compliance, as part of their normal quality assurance procedures, in order to reduce the likelihood of the problem recurring.

3. BINDERS AND BINDER MODIFIERS

Introduction

3.1 Conventional binders have been used successfully for many years in road surfacings, generally providing both satisfactory performance and durability even on the most heavily trafficked roads. However, some roads in certain areas of the country, surfaced with conventional rolled asphalt, have deformed prematurely due to a number of causes:

- Increasing traffic density;
- Increasing use of super single tyres;
- Early trafficking during lane rental contracts;
- Channelised traffic;
- Slow moving heavy vehicles on hills, particularly during prolonged hot periods.

3.2 For surface treatments such as surface dressing, the use of conventional binders, even when using the racked-in process, has limited ability to provide satisfactory performance on heavily trafficked roads and highly stressed sites. Detailed advice on the specification of binders for surface dressing is given in Chapter 8 of this Part. Similarly, porous asphalt using conventional binders (without additives or modifiers such as fibres or polymers) has not provided adequate durability on heavily trafficked roads. Thin surfacings, introduced from France in 1990, have utilised modified binders, either in the mixture or as a special bond coat, in order to ensure satisfactory performance.

3.3 With the introduction of end performance specifications for road surfacings, materials will have to be engineered to meet specific requirements. Where material designs indicate that the required level of performance cannot be achieved with conventional binders and available aggregates alone, the use of modified binders may be necessary.

3.4 This Chapter provides a brief introduction to binders for road surfacings used in road construction and maintenance. It describes the modification of bituminous binders to improve performance of mixtures, when necessary, especially for the more heavily trafficked and highly stressed sections of the road network. With increasing commercial vehicle traffic intensity, and increasing degree of site difficulty, the probability that modified binders will be needed increases. See Fig 3.1.

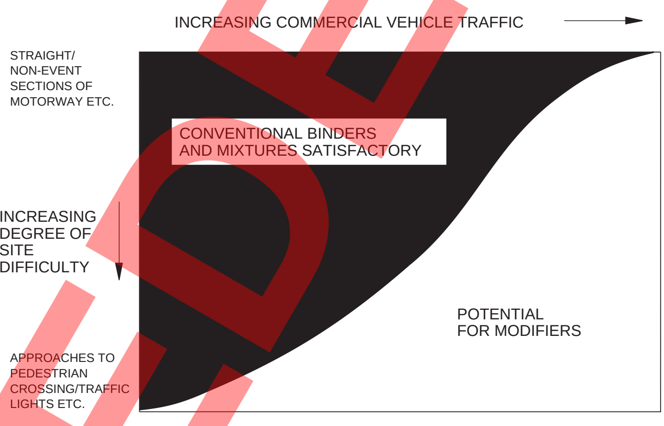


Figure 3.1 : The Need for Modifiers in Mixtures at Difficult Sites and at High Traffic Intensity.

3.5 Benefits which may be obtained by the use of 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 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.

Figure 3.1 summarises some of the claimed benefits from using binder modifiers.

3.6 Most modifiers will only be able to achieve some of the 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.

3.7 Where modified binders are used, the Specification (MCHW 1) Series 900 requires details of their performance characteristics in terms of both binder and mixture properties to be included in tenders.

		Improvements								
Modifier	Notes	Permanent Deformation	Fatigue Cracking	Thermal Cracking	Binder Drainage	Ageing	Moisture Damage	Recycling Difficulty	Cost Addition	Environmental Considerations
Fillers	2	Some				Some	Some	Low	Low	Dust suppression needed
Fibres	2		Some		Yes	Some		Low	Low	Fine material hazardous
Natural bitumens	1, 2	Yes				Some		Low	Med	
Chemical Modifiers	1, 2	Some					Some	Med	Med	Possibility of leaching should be considered
Thermo-setting Polymers	1, 2	Yes	Yes	Yes	Yes	Yes	Yes	High	High	Harmful when uncured
Thermo-plastic Plastomers	1 ,2	Yes	Some	Some	Yes	Some		Med	Med-High	Degradation if overheated
Thermo-plastic Elastomers	1, 2	Yes	Yes	Yes	Yes	Some	Yes	Med	Med-High	Degradation if overheated
Reclaimed Rubber	2	Some	Yes	Yes				High	Med	Use of waste material

Notes

1. Where permanent deformation is improved the mixture may be designed to have higher binder content, with the benefit of increased resistance to fatigue, thermal cracking, ageing and moisture damage.

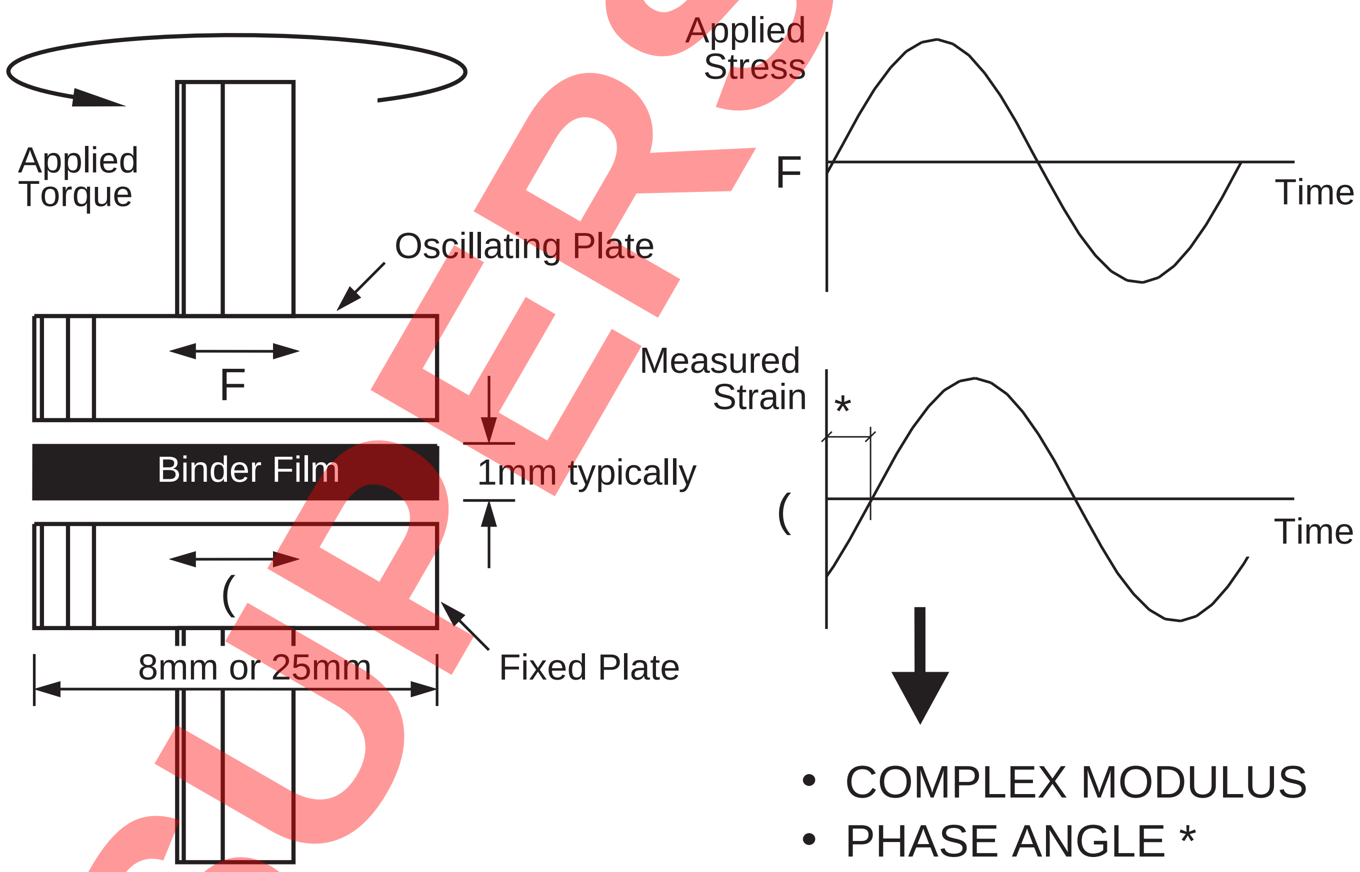
2. Within the same generic group there is a wide range of modifier composition and performance benefit. The general distinctions between Plastomers and Elastomers are becoming less well defined as innovation proceeds.

3. This table should be used as an overview and not for selection of a modifier for a specific purpose.

Table 3.1 Summary of the Potential Benefits from using Binder Modifiers in Mixtures

3.8 Binders are visco-elastic materials (that is to say, 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. Conventional binders are predominantly elastic and brittle at low temperatures and viscous fluids at high road temperatures depending on the frequency of loading.

3.9 The visco-elastic 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 (δ) between the stress and strain is also measured, see Figure 3.2. Elastic materials exhibit a phase angle of zero, viscous materials a value of 90° and visco-elastic materials some intermediate value. At low temperatures, unmodified bitumens tend towards purely elastic behaviour and their phase angle approaches 0 degrees. At high temperatures, unmodified bitumens behave purely viscously and their phase angle can reach 90 degrees at temperatures above 70°C. Dynamic 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 visco-elastic 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 visco-elastic behaviour, thereby characterising the material. An example of a master curve is shown in Figure 3.3. 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.



3.2 : Essential Parts of Dynamic Shear Rheometer and Definition of Phase Angle δ

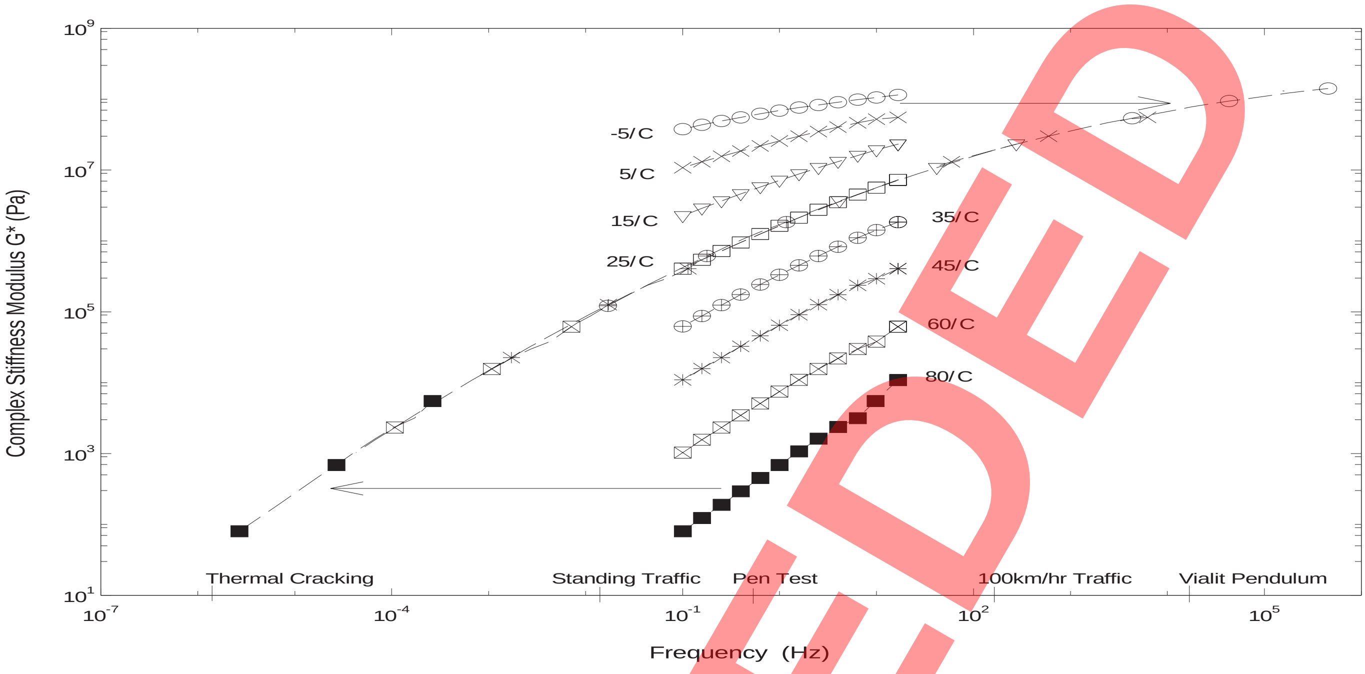


Figure Figure 3.3 : G* for an aged Bitumen showing derivation of Master Curve at 25°C using Time – Temperature Superposition

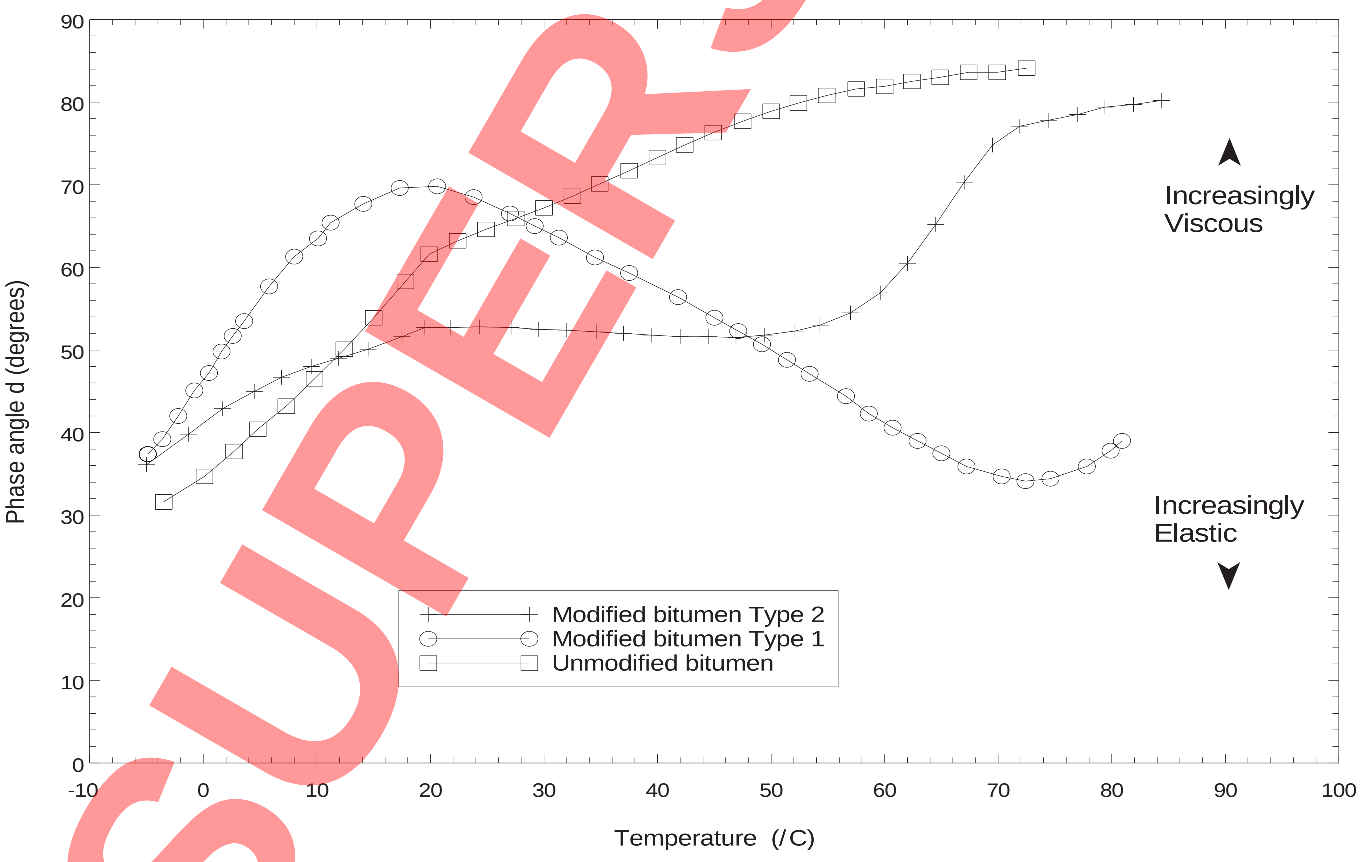


Figure 3.4 : Phase Angle versus Temperature at 0.4Hz for three binders (after RTFOT)

3.10 Master Curves, can be produced using a Dynamic Shear Rheometer (DSR) which is fully computer controlled and can produce much of the data automatically. As the response of binders is dependent upon temperature and loading time, it is important to select appropriate values to allow comparison of materials. In the Specification (MCHW 1) Clause 928, the frequency of 0.4 Hz has been chosen as the standard (loading time of 0.4 seconds, equivalent to slow moving traffic). A plot of complex stiffness modulus against frequency at a temperature of 25°C has been selected for the master curve.

Test Methods

3.11 The basic geometry of the DSR is presented in Figure 3.2. 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) 0.1 to 10 Hz 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, as illustrated in Figure 3.3.

3.12 The effect of binder modification can be seen from plots such as Figure 3.4 which relates Phase Angle and Temperature. The Modified Bitumens, Type 1 and Type 2, represent results that might be obtained for example, from the addition of an elastomer or a plastomer, respectively. The measurement can be used to help understand the engineering properties that are likely to be generated in situ. In Figure 3.4 for the unmodified binder, the phase angle increases with temperature in the range -5 to +80°C, indicating increasingly viscous behaviour. In contrast, the Type 1 elastomeric binder shows increasing elasticity in the temperature range 20 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.

3.13 Figure 3.5 plots Complex Stiffness Modulus against Temperature for the same three binders presented in Figure 3.4. This shows that both modifier types can increase binder stiffness at high service temperatures (50-70°C). The lower stiffness and more viscous response (see Figure 3.4) obtained from the elastomer (Type 1 binder) at low service temperatures (less than 0°C) will also assist in retarding thermally induced cracking.

3.14 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 3.5 shows that the Type 2 binder has a higher T_{2kPa} °C than the unmodified bitumen.

3.15 An 'Equi-Stiffness Low Temperature': T_{2MPa} °C has been defined. This is the temperature at which the complex stiffness modulus is 2 Mega Pascals (2×10^6Pa) 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 3.5 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 19dmm. 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.

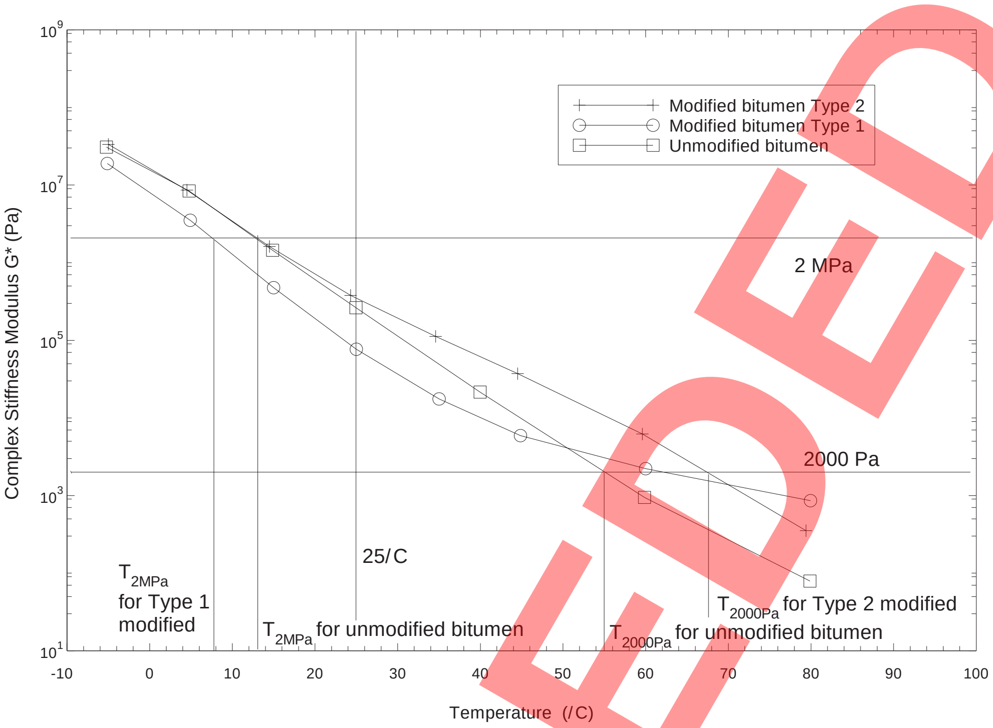


Fig 3.5 : Complex Stiffness Modulus versus Temperature at 0.4Hz for three binders (after RTFOT)

3.16 For surface dressing and micro-surfacing, the Specification (MCHW 1) Series 900 requires that penetrations at 5°C and 25°C are measured. Binder-aggregate adhesivity by the Vialit Plate Shock test (BS EN 12272-3) is also used for evaluating chipping-binder combinations.

3.17 The Vialit Pendulum test as specified in Clause 939 of the Specification (MCHW 1) is used to assess the cohesion of the binder, a measure of the forces holding the material together. This is probably more important for surface dressing, 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.

3.18 The Notes for Guidance (MCHW 2) Clause NG922, classify cohesion requirements for three binder grades; 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

3.19 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 basecourse and roadbase may actually contribute to enhanced performance. The rate of change of binder properties depends on the voids in the mixture, whether 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 - see Fig 3.6. 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 in the performance related specification for hot rolled asphalt; see the Specification (MCHW 1) Clause 943.

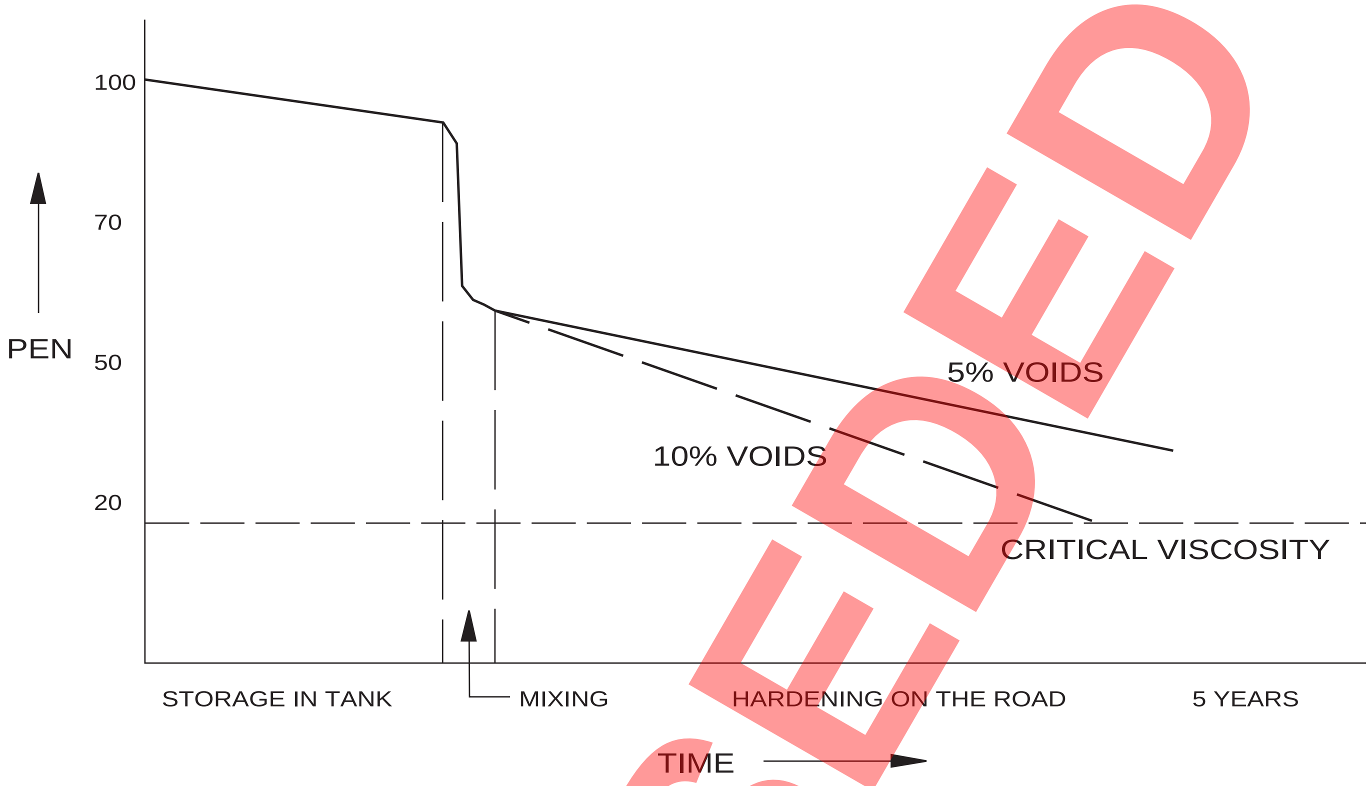


Fig 3.6 : Changes in Penetration of Conventional 100 pen Bitumen with Time, for Mixtures of differing Voids Contents

3.20 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.

3.21 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.

3.22 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.

3.23 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)
3.24 This test is used to simulate the loss of volatiles and oxidation that take place during mixing, transporting and paving the asphalt. This test is specified for all 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)
3.25 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.

3.26 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. A test for ageing mixtures has been developed, which involves storing cores at 85°C for 120 hours which may simulate several years on the road, prior to testing in devices such as the Indirect Tensile Stiffness Modulus Test.

End Product Performance Specifications

3.27 In the case of surface dressing, micro-surfacing and thin surfacing the Contractor has responsibility for performance during the guarantee period; this may be for only two years, whereas the life of surface dressing may be eight years and for thin surfacing ten years or more. It is imperative that the Overseeing Organisation has data to ensure that modifiers used successfully in the past, where durability has been confirmed in practice, are identified, so that they may be used again with confidence.

3.28 The end-performance tests currently available cannot fully predict durability and it is inevitable that some material component control will be part of specifications for some years to come. Polymer modified binders will require rheological identification, cohesion testing to determine low temperature performance and tests to determine resistance to ageing, so that performance limits may be determined for future specifications.

3.29 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.

3.30 Use of a polymer modified binder to reduce rutting in HRA 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. Similarly, 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. The approach adopted is to encourage innovation by allowing the use of proprietary products with BBA HAPAS certification. The scheme includes monitoring and surveillance which will provide assurance on the performance of the various products and systems.

3.31 Binder performance tests will not guarantee the performance of all binder/aggregate combinations, but can provide a useful indication of mixtures that are likely to be satisfactory.

4. HOT ROLLED ASPHALT

Background

4.1 The main strength of a hot rolled asphalt (HRA) mixture comes from the stiffness of the sand/filler/binder mortar. A major factor in the performance of the mortar is the binder, normally 50 pen grade bitumen to BS 3690. Filler stiffens the bitumen which binds all the aggregates together. Some filler is contained in the fine and coarse aggregates in the mixture, but most is added. Whilst cement is a permitted filler, most if not all HRA is made with limestone dust, 75% of which currently must pass a 75 micron sieve.

4.2 The coarse aggregate may be crushed rock, slag or gravel. In chipped HRA wearing courses, which are laid to nominal thicknesses of 45 mm or 50 mm, the nominal single size coarse aggregate is 14 mm. The coarse aggregate particles increase the volume of the asphalt and reduce its cost but, since they do not form a skeletal structure, they do not add very greatly to its deformation resistance.

4.3 The addition of coated chippings to the HRA prior to full compaction enables the macrotexture requirement for skidding resistance to be obtained. Good workmanship is required on site to ensure the correct embedment of chippings.

4.4 HRA wearing course has generally performed well, with good durability and levels of safety. A reasonable tolerance of weather conditions at the time of laying permits the placing of the material in winter and at night. However HRA has sometimes suffered from poor resistance to deformation in wheeltracks (rutting), which was particularly evident on roads with high concentrations of commercial vehicles after the hot summers of the mid 1970s and mid 1990s. The design of the mortar is critical for adequate rut resistance. Experience has shown that the sand fraction is important, with rounded particles performing poorly compared to crushed rock fines.

4.5 The rate of rutting of a particular wearing course depends on the temperature of the surface as well as the traffic loading/speed and material properties. The stability test (commonly known as the Marshall test) was introduced in 1976 to assess all sands, and criteria were introduced for various traffic categories on the basis of commercial vehicle traffic. There has been a significant increase in tyre pressures in the last 20 years which concentrates the load on the road, and recently there has been a considerable increase in the use of tri-axle trailers with 'super single' tyres, which concentrate the rutting forces into a narrower track. A more stringent requirement than the Marshall stability test has become necessary for the design of wearing courses. For this reason the wheeltracking test (BS 598: Part 110) has been introduced as a requirement for surface courses generally, and for HRA in particular.

Properties

4.6 In addition to the properties of the sand, binder properties are crucial to the production of a high rutting resistance. The HRA must have sufficient workability for placing, laying, compaction and pre-coated chipping retention. It must also have durability; adequate resistance to rutting, stiffness, resistance to water ingress and resistance to binder degradation. An earlier attempt to produce improved rut resistance by using a special grade of binder (40 pen HD) was unsuccessful, because it failed to provide the other properties required of a surface course, even though its rut resistance was improved.

4.7 The Specification (MCHW 1) Clause 943 requirement for minimum wheeltracking rates, which relate to the degree of site difficulty and traffic intensity, will probably result in the increased use of polymer modified binders. Such binders have been used to achieve low wheeltracking rates and mixtures have been found to be reasonably easy to lay and to compact. Their benefits in terms of reduced temperature susceptibility and elasticity have yet to be fully established, especially in the long term.

4.8 Performance improvements can be made by using materials such as Trinidad Lake Asphalt, which is favoured in some areas for special sites such as bridgedecks. Principally however, thermoplastic polymers have been used and these include Ethylene Vinyl Acetate (EVA) and Polyethylene (PE) (often termed plastomers); Styrene-Butadiene-Styrene block co-polymer (SBS) and Styrene-butadiene rubber (SBR) (sometimes referred to as elastomers). SBR is used mainly in the form of latex added at the mixing plant and care is required to ensure consistency is achieved. The differences between plastomers and elastomers are becoming less distinct as manufacturing processes develop and base bitumens are engineered to suit the polymer.

4.9 For designed mixes, the acceptance of the final product merely on an analysis of grading and binder content is a procedure open to considerable error. Clause 943 has been written in terms of performance criteria that can be measured from samples taken from the road. This end performance specification should always be used on the heavier trafficked roads. It leaves the supplier free to use his expertise to produce a mixture that will perform as required in the most cost effective manner. For less heavily trafficked roads an asphalt designed using stability criteria, Clause 911 Specification (MCHW 1), may continue to be used. In order to ensure long term durability, resistance to rutting must not be the only consideration; ageing is also important and is related to the voids in the mixture, binder characteristics and binder content.

4.10 It is unlikely, but not impossible, that the combination of properties needed at the highest levels of performance will be achievable using natural sand and an unmodified binder. However a great deal can be done by assessing the effects of different sands on the performance of the mixture and by blending sands. As an example, the addition of a proportion of crushed rock can both improve the resistance to rutting and may even, in some cases, improve the workability. The level of knowledge is currently insufficient to predict the result of blending fine aggregates, so appropriate performance testing is required.

4.11 With the advent of more stringent requirements for rutting resistance the need to retain chippings should not be forgotten. The less workable the mix and the more adverse the weather conditions during laying, the more likely the possibility of significant chipping loss. Rapid cooling of the top surface of the asphalt, forming a surface skin, can prevent adequate chipping penetration. This is particularly relevant when laying polymer modified HRA in cold or windy conditions.

4.12 Annex A describes a suitable procedure for the determination of the proportion of missing and broken chippings. This may be used initially and at the end of the maintenance period, to assess the degree of chipping loss and/or the number of broken chippings. Broken chippings are more likely to be lost in the early stages and are often a result of the asphalt cooling too much prior to rolling in the chippings. There is currently no specified limit for chipping loss but as a guide, a loss of less than 5% is considered reasonable.

High Stone Content Mixtures

4.13 A variant of HRA which has been used on trunk roads and motorways (prior to surface dressing) has a nominal stone content of 55%, with no added coated chippings. Although with this level of coarse aggregate there is some aggregate interlock, the material still depends primarily on the sand/filler/binder mortar for its stiffness. Nevertheless, a 55/14 mixture will typically have a stability about twice that of a 30/14 mixture made with the same constituents. Most experience has been gained using natural sand in the mixture (55/14F) and there have been no reported problems of rutting when appropriate mixes have been used.

Design

4.14 The method of design for the HRA wearing course will depend on whether the material has been specified to Clause 910, 911 or 943 in the Specification (MCHW 1):

- Clause 910 is a **recipe** specification and calls up the appropriate parts of BS 594.

- Clause 911 is for a **design** mix using the stability method in BS 598: Part 107 to meet criteria set out in BS 594.

- Clause 943 material is required to meet the **performance** criteria set out in the contract, but still requires aggregate grading to BS 594.

4.15 For Clause 911 materials the stabilities given in BS 594 are only appropriate for 30% stone content materials. Where high stone content asphalt (55% stone) is to be used, then the mixture should be made with the same constituent materials that would meet the stability requirements of BS 594 for 30% stone content asphalt, with appropriate adjustments to grading and binder content.

4.16 The definition for HRA Wearing Course in Clause 943 is a 35% stone content material complying with Clause 901 and BS 594: Part 1 except that the binder may be modified. A minimum binder content by volume is also specified, in order to give some confidence that the material will be reasonably durable. The layer thickness is required to be either 45 mm or 50 mm. The thicker layer may be necessary for structural or profile improvement, or during the winter period. (50 mm is recommended because of the problems caused by too rapid cooling of thinner layers).

4.17 For Clause 943 mixes, a ‘Job Mixture Approval’ trial carried out on or off site, is necessary to check performance and to obtain approval of the mix. If the constituents are then fixed as a Job Standard Mixture, the approved mix may be used for a period of eighteen months. The mixture tests are carried out on cores taken from the trial site. Wheeltracking, air voids, density and composition are recorded. The Overseeing Organisation can approve as a Job Standard Mixture, the results from a previous contract or trial carried out up to eighteen months previously.

4.18 Advice on the performance criteria required for different situations is given in NG943 of the Notes for Guidance (MCHW 2) for rut resistance, and HD 28 (DMRB 7.3.1) for macrotexture. The material needs to meet the criteria over the whole range of grading, binder contents and compaction levels that would be expected in normal production.

4.19 Basecourses should also be assessed for rut resistance. HRA basecourses should not be used under HRA wearing courses above rutting resistance Class 0, see Table NG 9/28 (MCHW 2). Class 1 wearing courses require at least DBM100 basecourses and Class 2 wearing courses DBM50 or HDM basecourses. All macadam basecourses should be designed and laid in accordance with Clause 929 of the Specification (MCHW 1).

Clause 943 Data Requirements

4.20 Binder data is required to assist in developing future End Product Performance Specifications. An overview of some of the tests is given in Chapter 3 of this Part. The following are requested under Clause 943 of the Specification (MCHW 1).

Penetration Test on the binder at 5°C
4.21 Penetration at 5°C, used before and after the Rolling Thin Film Oven Test, may provide some low temperature performance information. No criteria have been suggested as to levels or classes.

Rheological Data
4.22 Rheology is principally used for product identification. The complex stiffness modulus and phase angle characterise the binder and give an indication of performance at both high and low temperatures. The rheological data can also provide a calculated penetration, not only at 25°C (standard frequency 0.4Hz), but also at 5°C.

4.23 The Softening Point is commonly used to evaluate high road temperature performance, and as a guide to the temperature of the material at which it is safe to open to traffic. However for polymer modified binders the relationship between Softening Point and performance is poor. The high Softening Point values given for some elastomers (such as Styrene-Butadiene-Styrene modified bitumen) using the conventional test equipment may be due to the significant elastic component in the complex stiffness modulus (G*) even at temperatures above 60°C.

4.24 The temperature at which G* is 2000Pa at 0.4Hz is considered to be a more useful high temperature parameter for modified binders. For conventional bitumens this temperature is close to the Softening Point and for practical purposes may be used in its place. This temperature, T_{2000Pa}, may also provide a limit for trafficking; ie. 20°C to 30°C below this temperature may be the maximum temperature at which it is safe to open the section to traffic without premature rutting. For polymer modified binders the advice of the binder supplier should always be sought on this matter.

Storage Stability
4.25 Storage Stability is a test to determine which binders can remain homogenous in storage with normal tank circulation. Suppliers of binders that do not have adequate storage stability will have to demonstrate that, by using a method of stirring or circulation, their binder can be made effectively homogenous under practical conditions.

Photo-Micrographs
4.26 Photo-Micrographs of polymer modified binder are required as it is possible to identify the range of acceptable dispersions. If for any reason a marked change in performance is detected then these may help in the diagnostics process. At the present time, methods employed are not reproducible and should not be used for predicting performance or for product identification purposes.

Cohesion
4.27 Cohesion is measured by the Vialit Pendulum and may yield valuable information about the low temperature properties of polymer modified binders. Rheology does not examine the energy required to propagate a crack nor the forces of attraction at the very high frequency of loading in this destructive test. Data will be collected in order to see if performance levels may be determined for wearing courses.

Fraass Brittle Point
4.28 The Fraass test, as determined by IP80, has not been found to be reproducible for polymer modified binders. However new test equipment may improve the precision, and this is the only established low temperature test for binders. Comparison of results before and after ageing may be the only indicator that can be used.

4.29 Non-mandatory Data that is being collected includes the following:

- *Ageing*
  If Rheology, Fraass and Cohesion are examined after the High Pressure Ageing Test (HiPAT), some information about resistance to chain scission (degradation of the polymer) and oxidation of the binder may be generated.

- *Yield Strain*
  This test method is designed to determine when mixes have sufficient cohesion to resist fracture. A very stiff mixture, made to produce excellent wheeltracking, could crack or fret at low temperatures or under high frequency traffic loading.

4.30 An asphalt testing load frame such as a Nottingham Asphalt Tester may be used to determine a range of performance and durability measurements on mixes:

- *Indirect Tensile Stiffness Modulus (ITSM)*
  BS DD 213
  This test measures the indirect tensile stiffness modulus of a mix and may be used with the BBA HAPAS test procedure for water conditioning, when published, to determine mixture sensitivity to moisture. It is not known how modified materials behave under traffic in the presence of water. (A water immersion wheeltracking machine may be another investigatory tool).

- *Repeated Load Axial Test(RLAT)*
  BS 598 Part 111
  This may be used to predict resistance to permanent deformation in conjunction with an appropriate modelling procedure.

- *Indirect Tensile Fatigue Test (ITFT) BS DD ABF*
  This test may be used to examine the fatigue cracking associated with ageing. The proposed BBA HAPAS test procedure for ageing recommends subjecting samples to a temperature of 85 ±2°C in a forced draught oven for a period of 120±0.25 hours to age the specimens, which is intended to simulate several years in the road.

Annex A - Method for determination of loss of chippings and proportion of broken chippings

A.1 The method is based on the procedure used in surface dressing for the determination of chipping loss, but the method of counting is slightly different, as the chippings are not laid with 100% shoulder to shoulder coverage.

A.2 Equipment

a) A piece of plywood, hardboard or other suitable material approximately 400 mm square with a 300 ± 5 mm square hole cut into the centre of it.

b) A tape, notebook and pencil or pen.

c) Useful but not essential would be an assortment of coloured board chalks for marking counted chippings.

A.3 Method

a) Place the board onto the wearing course in the nearside wheeltrack with the hole sides parallel and at right angles to the direction of travel.

b) Count all the chippings that are present, entire or broken, that are visible through the hole, ignoring all those that are partly obscured by the board. This = N_1.

c) Count all indentions in the asphalt where chippings have been detached, again ignoring any partly obscured by the board: = N_2.

d) Count the chippings that are broken that have already been counted in b): = N_3. It may be easier to mark the broken chippings with coloured chalk and then count the marked chippings.

e) Repeat in two more locations at approximately 2 m intervals along the road.

A.4 Calculations

a) Percentage of lost chippings:
$= 100 \times N_2 \div (N_1 + N_2)$

b) Percentage of broken chippings:
$= 100 \times N_3 \div N_1$

The results should be reported to the nearest whole number for both the individual readings and the mean of the three locations.

5. POROUS ASPHALT

Background

5.1 Porous asphalt, PA, consists primarily of gap-graded aggregates held together by binder to form a matrix with interconnecting voids through which water can pass. It acts as a reservoir and, provided that the crossfall or longitudinal fall is sufficient, acts as a lateral drain throughout the time it is wet. It is important that porous asphalt surfacing is laid over an impermeable layer that protects the lower layers of the pavement from ingress of water.

5.2 Unfortunately the interconnected voids allow excellent access to air; so ageing and embrittlement is potentially exacerbated. Ideally a softer binder, together with thick binder films are desirable, so binder modification is necessary.

5.3 Trials of PA surfaces have considered the durability and drainage characteristics of mixtures made with different binders. Modifiers and additives tested have included synthetic rubber compounds such as Styrene-Butadiene-Styrene block co-polymer (SBS), natural rubber, Ethylene Vinyl-Acetate co-polymer (EVA), epoxy resins, natural and mineral fibres. Details of the trials are reported in TRL Laboratory Report LR 563, “Pervious bitumen macadam surfacings laid to reduce splash and spray at Stonebridge, Warwickshire”; Research Report 57, “Pervious macadam : trials on trunk road A38 Burton Bypass, 1984”; Research Report 323 “Trials of pervious macadam and rolled asphalt on the A38 at Burton” and TRL Report 264 “Review of UK Porous Asphalt Trials”. Further findings are reported by Szatkowski and Brown, “Design and performance of pervious surface courses for roads in Britain 1967 - 1976.”

5.4 The following findings of the trials are relevant:

- Durability of PA is improved by using softer binders (100 and 200 pen grade) and as high a binder content as possible. The quantity of binder incorporated into PA mixtures must be optimised, using the Binder Drainage Test.

- The target binder content determined in the Binder Drainage Test represents the maximum quantity of binder that can be safely incorporated into PA without introducing excessive binder drainage during mixing, transportation and laying.

- Excessive binder content and/or excessive mixing temperature causes binder drainage and mixture segregation during transportation from the mixing plant, leading to inconsistency of the finished surface, with areas either rich or lean in binder content.

- Lean areas have insufficient binder content and may lack fine aggregate, becoming more prone to premature failure due to ravelling and fretting.

- Rich areas have flushed, low skid-resistance, patches of binder on the road surface that are impermeable.

- Segregated PA is difficult to discharge from delivery lorries.

- Temperature controls and maximum target binder contents are to be incorporated into the specification to reduce the above problems.

- Insufficient binder content leads to a less durable material, as the binder film is thinner and consequently more prone to premature hardening, leading to a shorter life expectancy for the PA.

5.5 The incorporation of some modifiers during the trials, such as SBS or natural rubber, or additives such as fibres, were found to be effective in reducing binder drainage and allowed a higher binder content to be used. EVA was less effective in increasing the binder carrying capacity of PA and its use did not lead to improved durability, compared with other materials. However proprietary EVA modified binders for PA are now available that can achieve the required target binder content.

5.6 PA with 100 pen bitumen has an expected life of 7 to 10 years, at traffic levels up to 6,000 commercial vehicles per lane per day, compared with 10 years or more for similar surfaces constructed with an HRA wearing course.

5.7 The tack or bond coat used beneath PA is specified to further waterproof the underlying pavement layers and to maintain good adhesion. If it is necessary to improve the seal or the bond, polymer modified emulsions should be considered.

Benefits

5.8 Rain water on road surfaces can be hazardous to motorists; surface skidding resistance is reduced and spray generated by moving vehicles, particularly those travelling at high speeds, decreases driver visibility. PA reduces these problems due to its open texture which acts as a drainage layer, removing surface water during rainfall and reducing traffic generated spray. The Specification (MCHW 1) has a Relative Hydraulic Conductivity requirement to ensure sufficient interconnected voids are present. Unfortunately evidence from the Netherlands indicates that it is no safer than conventional surfacing. The reason for this may well be that drivers who are normally inhibited from driving at higher speeds in wet weather, tend to drive faster when spray is suppressed and in-car noise reduced.

5.9 The level of noise emitted at the tyre/road interface, on a PA surface, is lower than for most other surface courses offering comparable skid resistance. On high-speed roads surfaced with PA, the average reduction in dry road surface noise levels, compared with conventional surfaces is approximately 4dB(A) for 'light' and 3dB(A) for 'heavy' vehicles. The reduction is more pronounced in wet weather. Research suggests that it reduces traffic noise by acoustic absorption and in addition, during wet weather, the rapid drainage properties of the material reduce the incidence of noise caused by the generation of spray.

5.10 PA reduces the glare reflected from wet surfaces due to low incident level sunshine during the day, or vehicle headlights during the night. Carriageway markings are more visible in wet conditions.

5.11 PA gives most benefit on high-speed roads, particularly those with concentrations of commercial vehicles. Spray generation and dispersion is related to tyre width and tread, vehicle profile, vehicle speed and rainfall intensity, as well as road surface characteristics.

5.12 The most efficient method of draining water from PA is an open, free face at the edge of the carriageway. However a 50 mm vertical step may have undesirable safety implications for some road users. The guidance on edge of pavement details for PA and other aspects of drainage given in HA 79/97 (DMRB 3.2.4) should be followed.

5.13 PA performs best on roads such as motorways and rural dual carriageways. These tend to have:

- High-speed traffic;
- Good vertical and horizontal alignment;
- An effective drainage system, and
- Few, if any, junctions.

Limitations

5.14 The durability of PA is dependent on the quality of the laid material, the soundness of the base on which it is laid, the site characteristics, design layout, drainage and traffic flow. When water is retained within PA, because of poor drainage, its life will usually be reduced. Frequent braking and turning movements by heavy traffic may also cause surface fretting and early failure.

5.15 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. This causes a reduction in relative hydraulic conductivity and increased spray levels. Traffic noise levels also increase. 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.

5.16 There is currently no reliable and effective method of removing detritus from the voids. The wheel path areas seem to remain relatively clear, possibly due to the suction effect of passing tyres. The problem of detritus clogging the voids of PA is pronounced when it is used on the hardshoulder. This is considered to be due to detritus migrating within the PA towards the lower edge of the pavement.

5.17 PA should not be used in the following situations:

a) On areas where the pavement strength is sub-standard,

b) On areas where there is already ponding in ruts and depressions,

c) On areas where there is considerable acceleration, braking, turning and parking,

d) On tight radius curves, and loops with radii less than 75 m, or when gradients exceed 10%, without advice from the Overseeing Organisation,

e) On areas where excessive deposits of detritus or oil and fuel may be experienced; such as parking areas, exits from farms and quarries and other industrial sites,

f) On areas where the use of tracked vehicles, construction plant, farm equipment or similar industrial vehicles is expected,

g) On areas where the crossfall is insufficient to remove water to the road edge, such that flooding may occur in the porous asphalt,

h) At locations where free drainage cannot be accommodated along the low edge of the surfacing; for example abutting other types of construction such as a concrete carriageway,

i) Generally on lengths of carriageway of less than 100 m, because of spray carry-over from adjacent surfacings, unless special conditions prevail,

j) On steel decked bridges except where expressly permitted by the Overseeing Organisation,

k) In urban environments - in speed restricted areas where tyre/road surface noise generation is low - without approval from the Overseeing Organisation,

l) Where frequent excavations by statutory undertakers may occur,

m) Where traffic levels exceed 6,000 commercial vehicles per lane per day, at opening, except where expressly permitted by the Overseeing Organisation,

n) On carriageways having a 30 mph speed limit because there is no beneficial reduction in spray or noise levels achieved at low speeds.

5.18 There is a carry-over of rainwater for about 100 m by vehicles moving from impervious surfaces onto PA. To ensure satisfactory spray suppression for a particular length of road, the length of road surfaced with PA should extend for at least 100 m upstream of the section where treatment is required.

5.19 On multi-lane carriageways, where an impermeable surface is laid downstream of a PA surface, the lane ends of the PA 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 79/97 (DMRB 3.2.4).

5.20 On slip roads, PA should be continued until a convenient stop-point is identified, such as a straight alignment of constant gradient but not less than 50 m before a give-way or stop line. It should always be stopped before areas of high stress, such as intersections with roundabouts and other junctions, when high skid-resistant materials may be required. PA can be used on merging and diverging lanes, where it should extend the full width of the carriageway at the taper and should preferably also be used on the nose area and the slip road beyond.

Bridge decks

5.21 Where PA 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 PA, taking account of the expansion joints. For detailed guidance refer to HA 79/97 (DMRB 3.2.4).

Specification

5.22 Clause 938 of the Specification (MCHW 1) offers a balance between the requirements of durability, relative hydraulic conductivity, noise reduction and stability to give acceptable overall performance. PA should only be laid on an impermeable basecourse or directly on an existing uncracked wearing course.

Binder

5.23 The specified target binder content of 4.5% (Table 5.1), is a balance between improved durability (thicker binder films) and relative hydraulic conductivity (lower void content). Previous editions of the Specification (MCHW 1) permitted unmodified binders at a lower binder content, but it has been demonstrated that the benefits of enhanced durability with modified binders outweigh the extra cost. Therefore only modified binders or binders with fibre additives are permitted.

5.24 Modifiers or fibre additives that promote a thicker binder film on the aggregate improve durability. However, experience from previous trials indicates that not all modifiers offer the benefits sought, so evidence of likely performance must be provided, as described later. (Paragraphs 5.35-5.38).

5.25 For pre-blended modified bitumens, it is essential that the blend is made with a base bitumen having a penetration within the range of 100 to 200 and that the blend is stable. A Storage Stability Test for pre-blended modified bitumens is given in the Specification (MCHW 1).

5.26 All proprietary modified binders or binder modifiers, including fibre additives, will require a BBA HAPAS Certificate or in their absence a Departure from Standard from the Overseeing Organisation.

Traffic flow cv/lane/day	Binder	Target Binder content (%) by mass of total mix
up to 1500	100 or 200 pen bitumen and modifier or fibre additive, or pre-blended modified bitumen*	4.5
Over 1500	100 pen bitumen and modifier or fibre additive, or pre-blended modified bitumen*	

*base bitumen to have a penetration grade in the range 100-200 pen

Table 5.1 Binder Content and Penetration for Porous Asphalt

5.27 Where PA with modified binder is shown to have a degree of flexibility (elastic recovery) it may be used in areas where reflective cracking may be a problem. All cracks and surface defects in an existing surface should be repaired and sealed before overlaying with PA.

Aggregate

5.28 The Specification (MCHW 1) requires the coarse aggregate to be crushed rock or steel slag, or a mixture of both, and the fine aggregate may be either crushed rock or steel slag fines, natural sand or a mixture of these materials.

5.29 Comparative trials, still under study, of 20 mm, 14 mm and 10 mm maximum sized PA materials show the 20 mm material does not clog as fast as the finer gradings, thereby reducing potential maintenance requirements. It has been found to have superior performance in terms of retained spray suppression, relative hydraulic conductivity and acoustic durability (retained noise reducing properties). Therefore only 20 mm maximum sized material, with similar, but not identical, grading to the BS 4987 material is allowed.

5.30 A minimum of 2.0% hydrated lime is specified to assist in the prevention of binder stripping by water and to stiffen the binder. All filler may be hydrated lime. Increased hydrated lime content may enable a higher binder content to be achieved. Some aggregates are more prone to stripping by water than others and additional care should be taken with such aggregates.

5.31 The Binder Drainage Test should be performed using the combined aggregates and hydrated lime filler to ensure the target binder content specified can be achieved.

5.32 Although natural sand fine aggregates are permitted, the combined aggregate may not have sufficient surface area to carry the specified amount of binder when the mixture is tested using the Binder Drainage Test. In this case, the use of alternative aggregates should be investigated.

5.33 The aggregate grading should target the mid-point of the specified grading limits. Material manufactured towards the coarse side of the envelope will have a higher voids content but may lack cohesion and stability and be more subject to binder drainage. Material manufactured towards the fine side of the envelope will have a reduced voids content and consequently a lower relative hydraulic conductivity.

5.34 The aggregate shape and grading (within the overall envelope permitted) should be such that the relative hydraulic requirement is met consistently.

Contract Requirements

Information to be Supplied

5.35 Whichever binders are proposed, the Overseeing Organisation requires all available information on their specification and previous use, including trials, to be submitted. Rheology Master Curves produced as described in Chapter 3 of this Part should be provided for all proposed binders. Use of the proposed modifier or modified binder may be agreed without trials or further investigation if the information supplied, and previous use or trials, are considered satisfactory.

5.36 The Contractor should provide two copies of all the information, including test certificates, required for the evaluation of the proposed modifier or modified binder. Where the original documentation is in a language other than English, it should be accompanied by an English translation. The information and certificates should be supplied at least four weeks prior to an agreement for use is required.

5.37 Where use or trials of a modifier or fibre additive, or modified binder have taken place in another state of the European Economic Area, evidence of satisfactory results will be acceptable, provided the results obtained are at least equivalent to those obtained from the UK trials described in TRL Research Reports 57 and 323.

5.38 When information or suitable evidence of satisfactory use is not available for a modifier or fibre additive, or modified binder, as described above, the Overseeing Organisation may require trials to be undertaken before its use on trunk roads, including motorways, is permitted.

Manufacturing Tolerances

5.39 The durability and drainage performance of PA depends upon compliance with the Specification (MCHW 1) and careful control of manufacture and laying. In particular, it is important to ensure the specified maximum mixing temperature and binder content does not exceed those stated in the Specification (MCHW 1) to prevent the occurrence of binder drainage.

5.40 Different criteria for binder content compliance are given for samples taken at the plant and samples taken on site. This is to allow for the possibility of slight binder drainage taking place in transit and some slight segregation of aggregate sizes due to handling.

Mixing

5.41 The maximum mixing temperatures stated in the Specification (MCHW 1) relate to a binder viscosity, including any modifier, of about 0.5 Pascal seconds (Pa.s). Excessive mixing temperatures cause binder drainage. In the case of natural rubber modifier, they may also degrade the rubber. To limit hardening of the binder in the mixed PA, and reduce binder drainage within loads during transit, the elapsed time between mixing and the completion of laying and compaction should not exceed 3 hours, including any time spent in hot storage bins at the mixing plant.

5.42 Because of the low mixing temperatures specified compared to HRA or DBM materials, longer plant drying times are required for the aggregates, thus reducing plant production rates. Experience in other countries has indicated that batch-type plants are preferred over drum or continuous mix plants, as the aggregates have an extra period of time in the plant bins, where final drying of the aggregate occurs, prior to mixing.

5.43 Experience has indicated it is preferable for the mixing of component materials to be carried out on a continual basis, to avoid temperature fluctuations and contamination caused by plant changes to produce other materials, such as HRA and DBM.

Construction

Underlying Surface Profile

5.44 To ensure transverse flow of water, and to protect the lower layers of the pavement structure from surface water penetration, PA should only be laid on an impervious substrate and on carriageways with adequate crossfall or longitudinal fall. It should not be used to restore poor profile. It is essential to regulate underlying surfaces to remove depressions which may trap and hold water, particularly if the surface onto which PA is to be laid has been cold-milled. Application of a tack or bond coat is specified, prior to laying PA, to further protect the underlying pavement layers.

5.45 The crossfall of each area of surface should be a minimum of 2.5% to ensure rainwater will reach the carriageway edges quickly and easily. Maximum effect is obtained when the edge of the PA is free draining, with unobstructed discharge of water along its whole length, allowing water to enter the drainage system, so preventing localised flooding. Minor flooding may be experienced at locations with camber changes and it may be necessary to consider rolling crowns. Advice should be sought from the Overseeing Organisation.

Laying

5.46 The minimum paver discharge temperatures stated in the Specification (MCHW 1) relate to a binder viscosity, including any modifier, of about 5 Pa.s. A nominal laying thickness of 50 mm is specified not only to maximise compaction time but also to ensure adequate storage capacity and spray reducing life of the PA in service.

5.47 Laying should, where possible, commence on the low side of the carriageway and proceed towards the higher side. This is to prevent roller water, or surface water, draining into areas onto which PA is about to be laid.

Compaction and Joint Formation

5.48 Joint formation in PA is critical to its success and the procedure laid down in the Specification (MCHW 1) should be followed meticulously. Transverse joints should be formed against a 200 mm wide and 45 mm thick hard timber stop-end nailed to the road surface in advance of paving operations. An uncut joint is binder-rich so it is not necessary to apply bitumen to the joint prior to laying material abutting it.

5.49 Joint cutting should be avoided. However, where it is unavoidable it should be done with a power saw, taking appropriate measures such as suction extraction to prevent contamination of the surfacing with detritus. After cutting, a light coating of bitumen emulsion, such as K1-70 or a polymer modified emulsion, should be sparingly applied to the cold joint to promote adhesion : the binder is not there to seal the joint, as for dense materials.

5.50 Only steel-wheel tandem drum rollers are permitted for compaction. Vibrating rollers should not be used because of the possibility of aggregate crushing. Rubber-tyred rollers are not permitted as they knead and close the surface, thus reducing the drainage performance of the PA. Three wheel rollers should not be used as they have been found to leave roller marks that can be difficult to remove. It is recommended that at least 5 passes of each roller should be applied within the specified temperature range. The removal of all visible roller marks is an indication of practical completion of compaction.

5.51 In order to avoid foot-marks, no one should be permitted to walk on uncompacted PA, as the differential compaction caused is difficult to remove.

5.52 Where two or more lanes are to be surfaced, laying in echelon is preferred, with a maximum stagger of 20 m, so that the longitudinal joints can be effectively rolled together whilst hot. Provided the paving machines are close together, the materials will roll together without adverse crushing or loss of relative hydraulic conductivity. Longitudinal joints should not be painted with bitumen, or cut by chisels or saws, except as provided for in Paragraph 5.49 above.

5.53 To maintain drainage flow between areas of PA, construction joints should not be cut or chiselled. The action of cutting tends to close-up the voids and may cause local ponding. This effect is most marked in the longitudinal direction, causing areas of water to appear on the surface as it banks-up behind a cut transverse joint, so creating a wet area or localised flooding on the surface of the carriageway.

Existing Concrete Roads

5.54 When laying on an existing concrete road, hot spray-applied K1-70 emulsion should be applied to the concrete, at a rate of 0.4 to 0.45 l/m^2, immediately prior to laying the PA, in accordance with the Specification (MCHW 1) Series 700, 900 and 1000.

Scheduling of Work and Use of Porous Asphalt Surfaces

5.55 Laying of PA requires careful scheduling and control such that construction plant does not have to use the surface unnecessarily after completion and before opening to traffic. Particular care needs to be taken to avoid oil and fuel spillages. Landscaping operations should be scheduled such that soil is not placed on the surface, in order to prevent detritus and mud damage. PA should be allowed to cool to ambient air temperature before opening to traffic.

Assessment, Maintenance and Repairs

5.56 Visual condition survey methods can, with modifications, be used for assessment of PA surfaces. It is also anticipated that High-speed Road Monitor surveys and skidding resistance assessment techniques will be used. It is expected that some modification to the methods of survey may be required, (eg cracks are more difficult to see) or interpretation of results may need amendment (eg investigatory SCRIM values). The Overseeing Organisation will keep this aspect under review and publish advice as required.

5.57 The skeletal aggregate structure of the PA reduces secondary compaction due to traffic and PA has a high resistance to wheeltrack rutting. Therefore, if rutting occurs it is likely to result from deformation in underlying layers.

5.58 The repair of small potholes, or the reinstatement of utility trenches and the like, should be carried out promptly with PA or open graded macadam complying with BS 4987: Part 1. Dense Bitumen Macadam may also be used if necessary; however it should be replaced with a permeable material when circumstances permit.

5.59 For the repair of larger potholes, the damaged material should be excavated to form an irregularly shaped section. A coating of bitumen emulsion should be applied to the base of the patch to provide bond, and the patched area should be filled with either PA or open graded macadam. This should assist in minimising local flooding caused by any restriction to the flow of water through the area after repair. HRA may be used if the area to be patched is not too large, say no more than 0.5 m x 0.5 m.

5.60 Deterioration of PA may accelerate towards the end of its life. If patching requirements exceed 10% of the surface area, the PA may be deemed to have failed. If the surfacing was originally provided as part of a major improvement, then commitments made in any Environmental Statement regarding noise attenuation need to be maintained when it is replaced. Consequently, in order to restore the desired road surface properties, a new PA surface may be required. This will necessitate removal of the existing surface by cold-milling, followed by a regulating course and then replacement of the PA. When using the 10% criterion, judgement should be exercised. The failed areas should be random rather than localised; a localised failure can be dealt with by an appropriate treatment rather than resurfacing the whole section.

5.61 Failure to achieve a plane surface under PA has been recorded as precipitating failure of the surfacing. A particular problem occurs when fuel and oil spillage from vehicles passes through the PA and is deposited in the depression and then not flushed out by rain. The hydrocarbons attack the substrate and underside of the PA, stripping the bitumen and softening the pavement.

5.62 The problem manifests itself during subsequent rain, when pot holes form in the wheelpath and down the centre of the running lane. Potential trouble spots can be identified before potholes form, by observation of damp locations remaining on the road surface, after the remaining surface has dried.

5.63 After accidents or similar, spillage of fuel and oils should be promptly treated using water-based detergents followed by copious water flushing. Particulate and granular adsorbents such as grit or cement should not be used as these would clog the voids in the PA.

5.64 When carrying out any form of work, on or adjacent to a PA surface, materials should not be stockpiled or deposited on the surface without first taking precautions, to prevent contamination.

5.65 It is essential that regular cleaning of the drainage channel is carried out to prevent accumulation of detritus. Where kerbs, vehicle cross-overs and junctions are features, planned maintenance procedures are necessary. Experience has shown that drainage channels require cleaning at least annually. This can be accomplished by sweeping, pressure sluicing, and suction extraction.

Road Markings and Detector Loops

5.66 Road markings, such as sprayed thermoplastic resins and paints, or machine extruded markings, can be used on PA. In general, manual screeding of thermoplastic markings should not be permitted since the hot material has more time to permeate the surfacing. However, for directional signs, arrows and similar, screed markings can be used.

5.67 Detector loops are currently proposed to be installed 80 mm below surfacings on motorways, therefore problems are not anticipated. Refer to HD20 (DMRB 9.3.1) Loop Detectors for Motorways. Advice can be obtained from the Overseeing Organisation. Where possible, the installation of the detector loops before laying the PA will reduce the likelihood of the saw cuts precipitating failure.

5.68 Where the slot for the detector loop is cut through the PA the backfilling should be completed using well-rammed and compacted 6 mm size medium graded wearing course complying with BS 4987, in order to maintain the drainage path through the material.

Winter Maintenance

5.69 UK experience of winter maintenance on PA has been gained with only a small number of trial sites excluding bridges; therefore only limited advice can be given at this time. While grit-free salt is desirable, the current salt and grit spreading policy adopted for dense impervious road surfaces can also be adopted for PA surfaces, with some modifications.

5.70 Frost and ice form earlier compared with dense impervious surfaces, due to PA's porosity, lower heat conductivity and reduced thermal capacity. Snow and ice can also linger longer on PA. Research also indicates the temperature within a PA layer falls more rapidly than that within other surfacing materials.

5.71 Precautionary salting is recommended in advance of snowfall. The formation of brine in the PA voids lowers the temperature at which freezing will occur, so delaying the formation of ice. There is then a requirement for more frequent applications of salt, compared with a dense impervious surfacing, to clear settled snow. The overall rate of salting necessary may significantly exceed that which would have been applied to dense impervious surfaces. Prompt ploughing is recommended, but care is required to avoid damaging the surface. Ploughs must be fitted with rubber skirts on the blades.

5.72 Where PA is interspersed with sections of impervious surface, it is recommended that the individual lengths of both types of material are maximised to facilitate the operation of separate winter maintenance procedures for each type of surface. Signing of the start and finish of PA sections may assist maintenance staff to identify the location of PA during salting operations and snow-ploughing.

5.73 Experience in other countries, with similar climates to the UK, indicates slightly increased quantities of salt are needed on dense impervious surfaces immediately following a PA section, due to reduced salt transfer along the road from the PA section to the dense section.

5.74 Notwithstanding that ice appears to form faster on PA surfaces, experience to date, in the UK and other European countries, appears to indicate safety in winter conditions is not adversely affected, provided preventative measures are taken, as described above.

5.75 Winter maintenance techniques adopted for PA will be kept under review. Further advice will be issued as it becomes available. General advice on winter maintenance techniques can be obtained from the Overseeing Organisation.

6. THIN WEARING COURSE SYSTEMS

Background

6.1 Thin wearing course systems, or thin surfacings as they are more commonly described, are proprietary systems in which a hot bituminous bound mixture is machine-laid with a controlled screed paver onto a bond or tack coat to form, after compaction and cooling, a textured wearing course generally less than 40mm in thickness. Mixtures 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 bond or tack coat may be polymer-modified and sprayed hot or cold depending on the proprietary system used. Other types of thin surfacings using different techniques are described in the chapters on Surface Dressing (Chapter 8), and Slurry and Micro-surfacing (Chapter10).

6.2 Proprietary thin wearing course systems are suitable both for new construction and for maintenance. The British Board of Agrément (BBA) has classified thin surfacings into three types depending on their thickness as follows:

Type A <18mm

Type B 18-25mm

Type C >25 to <40mm

> 6.3 When used on trunk roads including motorways, proprietary thin wearing course systems shall have a British Board of Agrément HAPAS Roads and Bridges Certificate appropriate for the site classification and the level of traffic in commercial vehicles/lane/day to be carried. In the event that no such Certificates have been issued, thin wearing course systems shall have HA Type Approval in England and for those proposed for schemes in Wales, Scotland and Northern Ireland, a Departure from Standard shall be obtained from the Overseeing Organisation.

6.4 Type A and B thin wearing course surfacings, up to about 25 mm in thickness, were developed in France in the 1980s where in excess of 100 million sq m have since been laid. Type C thin wearing course systems, 25-40 mm in thickness have been developed in the UK and are proprietary versions of stone mastic asphalt (SMA) - see Chapter 7 of this Part. Stone mastic asphalt was developed in Germany over 25 years ago, originally as a very robust surfacing to combat wear from studded tyres in winter - the use of which has since been banned. Despite this however, SMA remains the most commonly used surfacing in Germany today.

6.5 All thin wearing course systems have been developed to meet the UK's safety requirements, necessitating the use of high PSV aggregates and the provision of initial and retained surface texture. The first proprietary thin wearing course systems were approved for use on trunk roads including motorways in 1994 and there are now a growing number of HA Type Approved products for use in England, with others undergoing assessment.

Specification

6.6 Specification requirements for Thin Wearing Course systems are set out in Clause 942 of the Specification (MCHW 1) with accompanying Notes for Guidance in NG 942 (MCHW 2).

> 6.7 A Thin Wearing Course system with a current BBA HAPAS Roads and Bridges Certificate or Type Approval shall only be laid by a Contractor approved by the System Proprietor. Installation and quality control procedures shall comply with the requirements of Clause 942 of the Specification (MCHW 1) and when issued, with the requirements of the BBA HAPAS Certificate and method statement agreed by the BBA.

Installation

6.8 Thin wearing course systems are proprietary products and as such their design, manufacture, transportation, laying and compaction are the responsibility of the Contractor.

Bond or tack coats

6.9 The thinner the surfacing, the more important the role of the bond or tack coat in the performance of the system. The type and rate of spread of the bond or tack coat for each type of substrate on which each system can be laid should be specified in the BBA HAPAS Certificate or method statement for the system. Emulsion bond or tack coats sprayed as a separate operation ahead of the paver should be fully broken prior to surfacing.

Audit Checks

6.10 It should not be necessary to carry out routine audit checks on proprietary products with a two year guarantee. 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 requirements of the Specification (MCHW 1) and, when issued, with the requirements of the BBA HAPAS Certificate and the system proprietor's method statement. Non-compliance should be reported to the Overseeing Organisation and the BBA, and may, if serious and ongoing, result in the suspension of Type Approval or the BBA certificate for the system.

Overlaying Concrete

6.11 Thin wearing course systems are generally suitable for application to both old and new continuously reinforced concrete (CRCP) surfaces. When laying on concrete however, conventional emulsions to BS 434 may not provide a sufficient combination of adhesion, cohesion and durability, so it is likely that a polymer modified emulsion will be required. When surfacing over jointed concrete, joint sealants in the concrete substrate should be replaced by Type N2 hard sealants to BS 2499, 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. The thin surfacing overlay should be laid continuously and the road monitored for the appearance of cracks in the surface. If cracks or depressions appear at a later date, the material can be sawn to encompass any cracks or depressions, and sealed with material complying with BS 2499 or BS 5212. It is important to ensure that, as far as is practical, the sawn edges of the joint should coincide exactly with the underlying edges of the concrete joint to minimise spalling or ravelling of the surfacing.

High Friction Surfacing

6.12 Where high friction surfacings (HFS) are to be applied over thin wearing course systems 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, resulting in premature chipping loss. To alleviate this problem the texture of the area of thin surfacing that will be covered by HFS should be reduced to between 1 to 2 mm as measured by the sand patch test. This may be achieved by any suitable means at the discretion of the system proprietor, for example by additional compaction with vibrating rollers whilst still hot or by the substitution of a smaller aggregate size in these areas. Alternatively a suitably sized grit may be applied and rolled in. If the thin wearing course system is to be trafficked prior to the application of HFS, then 3 mm grit should be applied and rolled in to provide enhanced short-term skid resistance. Temporary warning signs may be appropriate in such circumstances.

Benefits

Rapid Construction

6.13 Thin wearing course systems offer a very fast means of resurfacing roads and can be laid more speedily than hot rolled asphalt and possibly surface dressing. Faster application can result in lower costs for traffic management and reduced costs of delay to the travelling public. For the thinner systems outputs up to 20,000 m^2 per day, and sometimes even more, have been achieved under suitable conditions.

Reduced working area

6.14 Less working width is necessary to lay and compact thin wearing course systems compared to hot rolled asphalt which has to have chippings applied. The chipping machine is almost 5 m wide and can only be loaded from the side, sometimes necessitating a complete road closure for single carriageways.

Lower Cost

6.15 Being thinner and faster to lay, thin wearing course systems can be significantly lower in cost than hot rolled asphalt, but more expensive than surface dressing. Where applicable the cost of planing and removal is also reduced. Traffic management and delay costs are also reduced.

Noise Reduction

6.16 As a result of their flat, machine laid surfaces and uniform negative surface texture, thin wearing course systems can be significantly quieter than conventional surfacings such as hot rolled asphalt and brushed concrete. However, at the present stage of their development, they are not as quiet as newly laid porous asphalt. Some measurements have shown that slightly less noise reduction is achieved when systems using the larger aggregate grading are laid very thinly.

Spray Reduction

6.17 Thin wearing course systems 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 diminish with time, although to a much lesser extent, provided texture is maintained.

Surface Regulation

6.18 Thin wearing course systems have a skeletal structure and a high degree of compaction is achieved by the paver. Most systems permit minor regulation of existing surfaces and the recommendations of the system proprietor should be obtained in this respect. General guidance is given in Notes for Guidance (MCHW 2) Clause NG 942.

Rut Resistance

6.19 Due to their skeletal structure formed by the coarse aggregate particles, thin wearing course systems generally have a high resistance to wheel track rutting, although they are vulnerable to deformation originating in the lower pavement layers. Where a regulating layer is necessary below a thin surfacing, an SMA or a macadam basecourse, the latter designed and laid in accordance with the Specification (MCHW 1) Clause 929, may be appropriate to maintain a high resistance to deformation.

Limitations

Life Expectancy

6.20 Hot applied, machine laid thin surfacings, adapted from continental practice, have been in use in the UK for less than 10 years. Elsewhere in Europe the products from which they have been developed have demonstrated satisfactory working lives of between 10 and 20 years and more. In the UK, safety considerations, in particular high speed skid resistance - surface texture requirements - and low speed skid resistance (MSSC), are likely to limit the lives of thicker SMA derived systems to about 15 years, whilst very thin systems are unlikely to provide satisfactory working lives much in excess of 10 years. Parallels can be drawn between the likely deterioration of higher void content thin surfacings and porous asphalt.

6.21 This presupposes that the condition of the substrates on which they are laid is satisfactory. A reduced working life maybe anticipated for any bituminous surfacing applied over an existing surface or base that is not in a reasonably sound condition. This is particularly so for thinner surfacing systems.

6.22 Satisfactory working lives between 7 to 15 years may be expected for thin wearing course systems - depending on their thickness, void content, the level of trafficking and the condition of the underlying pavement.

6.23 The present HA type approval scheme for thin wearing course systems, soon to be superseded by BBA HAPAS Certification, requires a trafficking trial of at least 1000 cv/lane/day for a minimum period of 2 years after which the product shall be defect free - subject to a satisfactory substrate - and shall retain a minimum texture in the wheel tracks of 1 mm. The assumption is made that a product on the ‘primary’ trial, and other sites taken into consideration during this period, withstanding this level of trafficking for two winters and two summers will be robust, and that the level of risk after two years is acceptable. The product is then approved for use on trunk roads including motorways in England without limit to the level of trafficking, but a two year defect free guarantee is demanded for each site including texture retention. To date, when correctly mixed and laid, even the thinnest surfacings have proved to be satisfactory on very heavily trafficked sites.

Strength Contribution

6.24 Type A thin wearing course systems (less than 18 mm in thickness) are likely to have a lower stiffness than hot rolled asphalt due to the effect of their negative surface texture. A structural contribution of 50% of the same thickness of HRA is suggested. However when used in new construction or for major maintenance, the increased thickness of the stiffer roadbase required to achieve the overall design thickness given in HD 26 (DMRB 7.2.3) may be assumed to more than compensate in terms of load spreading ability for the reduced stiffness of the thin surfacing. The effect of surface texture reduces for thicker systems, many of which are proprietary versions of stone mastic asphalt, and a similar stiffness to HRA on a pro rata basis for thickness should be assumed.

Hand Application and reinstatement

6.25 It is preferable that thin wearing course systems should not be laid by hand except where a paver cannot operate, eg nosings of roundabouts, and then only in favourable weather conditions. Due to their low fine aggregate content, thin wearing course systems appear binder rich and ‘sticky’ and being thin, they lose heat rapidly making them difficult to hand lay and compact satisfactorily. Their use on urban sites for example, should be carefully planned. 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 14 mm nominal size coated chippings or dense bitumen macadam (DBM) laid by hand. Similarly the borders around any ironwork that cannot be raised in advance of the paving machine should be made good in this manner or with a proprietary cold lay material, mechanically compacted.

6.26 Minor repairs to thin wearing course systems which will not significantly affect noise generation - where this is an issue - or outside the wheel tracks, may be repaired, with the prior agreement of the Overseeing Organisation, using HRA or DBM as described above. However major trench reinstatements for example, should be reinstated with machine laid thin wearing course. In some circumstances it may prove expedient and more economic to resurface a complete lane width.

Adverse weather working

6.27 A high degree of the compaction necessary for thin wearing course systems is achieved by the paver, compaction being completed by the roller tight up behind the paving machine. In this respect, and because the application of chippings is unnecessary, the installation of thin wearing course systems in less than perfect weather conditions might appear straightforward. However the very thin Type A systems lose heat extremely rapidly and should not be laid in the winter months unless the pavement is adequately pre-heated. Conversely some thicker Type C systems can be laid and compacted successfully in temperatures as low as 2°C and rising, provided the air is still and the substrate is dry with a temperature above freezing. If however, the wind speed at a height of 2 m is 5 km/hr, then an air temperature of 10°C or more may be necessary to achieve full compaction. Thin wearing course systems are proprietary products and their design, manufacture, transportation, laying and compaction are the responsibility of the Contractor. Guidance should be obtained at tender stage with regard to any constraints on laying and compaction in adverse weather conditions.

7. STONE MASTIC ASPHALT

Background

7.1 Stone Mastic Asphalt (SMA) is a hot mix surface course relatively new to the United Kingdom but which was developed in Germany nearly 30 years ago to resist studded tyres. Despite a subsequent ban on the use of these in 1975, stone mastic asphalt has continued to be used because of its superior performance when compared to the asphaltic concrete surfacing. It was standardised in the German Technical Specifications in 1985 and is the most common surfacing in use in Germany today. Variants of the material have also been adopted in many other countries including Sweden, Denmark, the Netherlands, Belgium, France and Switzerland in Europe, and further afield in Japan, Australia and the USA.

7.2 In Germany the standard aggregate sizes used are 0/11 mm, 0/8 mm and 0/5 mm, there are however no macrotexture requirements. A TRL report by Nunn (PR65 1994) showed that by increasing the nominal aggregate size to 14 mm it is possible to achieve the macrotexture necessary to provide the high speed skid resistance required on trunk roads including motorways in the UK.

7.3 Stone mastic asphalt essentially consists of discrete and almost single sized aggregate particles forming a skeletal structure bonded together by mastic. 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 surface texture. Provided texture is maintained, this provides good skidding resistance at all speeds and facilitates the drainage of surface water. A careful choice of aggregate size, shape and grading is necessary to produce a surface that will meet UK texture requirements for high speed roads. The mastic consists of a blend of crushed rock, sand, filler (usually ground limestone) and an additive or modifier to prevent binder drainage while the material is hot. The most usual additive is cellulose fibres, but mineral fibres and polymers have also been used, both separately and in combination.

Properties

7.4 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 can occur resulting in a loss of surface texture.

7.5 Noise measurements in other countries have shown that SMA surfacing is significantly quieter than asphaltic concrete. Similarly work at the TRL has shown that 14 mm SMA with a texture depth of 1.67 mm is quieter than chipped Hot Rolled Asphalt at both 70 and 90 km/hr; and 10 mm SMA with a texture depth of 1.27 mm is quieter still.

7.6 Germany has used 0/16 SMA as a base-course where rutting has been a problem below the surface course. SMA has also been used in the UK as a rut resistant basecourse for high performance HRA and is suitable as a basecourse for proprietary thin wearing course systems. 10 mm SMA tested at TRL had a wheel tracking rate of 0.8 mm/hr and 14 mm SMA 1.1 mm/hr, both measured at 45°C. These results and others measured under contract conditions have confirmed that in general well designed SMA mixes have a high resistance to deformation.

Design

7.7 It is the supplier's responsibility to design the mix for the constituents that it is intended to use and for the site where the material is to be laid. The design of the material will depend on the aggregate grading and particle shape and the thickness at which the material is to be laid. A change in any of these parameters may mean a change in the design of the mix. The grading and binder content must be tightly controlled once the job mix has been agreed.

Laying

7.8 Laying the material has not proved to be a problem, but hand laying must be avoided as the very high stone content and fibre reinforced or modified binder make the material extremely difficult to hand work. The final appearance of hand laid or even hand worked material is very different from that of the machine laid material and may, because of higher void content, be significantly less durable.

Specification

> 7.9 Site trials undertaken in the UK have confirmed German experience that SMA mixes 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. In consequence stone mastic asphalt to a generic specification shall not be used as a wearing course on trunk roads including motorways in England, but it may be used as a basecourse. For schemes in Wales, Scotland and Northern Ireland where SMA is proposed, a Departure from Standard shall be obtained from the Overseeing Organisation.

7.10 To take advantage of the superior properties of SMA as a wearing course, proprietary versions designed for particular aggregate sources have been developed as thin wearing course systems to ensure surface texture is maintained. These require BBA HAPAS Certification, as described in Chapter 6 of this Part.

8. SURFACE DRESSING

8.1 Surface Dressing is a principal method of routine maintenance of road surfaces. The concept is straightforward: in its simplest form, a thin layer of bituminous binder is applied to the road surface and stone chippings, nominally single sized, are spread and rolled into it.

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 micro-texture of the road surface, with minimum usage 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 surface 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.

Tender Programming

8.5 Road hardness tests should be carried out in the summer or early autumn of the previous year 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, so late tendering will increase the risk of a contract being carried out by less experienced operators using poor quality equipment. In order to obtain best value for money and the most cost effective product, 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. Heavily trafficked roads are best surfaced dressed between mid-May and the end of July. If work is to be carried out at night then surface dressing should be completed earlier - by mid-July. High 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 Process

8.6 Although the concept is straightforward, until adhesion is ensured and an interlocked mosaic of chippings formed, the 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 medium and lightly trafficked roads are maintained by this process.

Where it may be used

8.7 Surface Dressing is one of the most common of all treatments and is a principal method of routine maintenance of road surfaces. It is one of the most common of all treatments, and one that has become increasingly important since the introduction of standards for skidding resistance on trunk roads. It is permitted on all types of roads from unclassified to motorways, but demands particular care during construction on high-speed roads. It is suitable for both concrete and bituminous roads, although hard surfaces, or soft and variable substrates present special problems. If the existing road surface has a poor profile or is deformed in the wheel tracks (a rut depth greater than 10mm) then pre-treatment by planing (milling) or surfacing may be required. Thin asphalt surfacing overlays in these circumstances may have greater economy as they have some ability to improve profile.

8.8 There are circumstances where it is not possible to provide controlled low speed trafficking which is normally used to settle a dressing down prior to sweeping and opening to unrestricted traffic. The most difficult of these are motorway sites where the traffic flows and speeds are 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 risk of loose chippings subsequently.

The Equipment

8.9 For trunk roads and motorways the sprayer and chipping spreader should 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 are joined longitudinally by binder overlap of up to 100mm at the full spray rate at the lane markings. This means that wet edges are formed and these must be protected from traffic during construction and excellent work has been achieved on even the busiest motorways, where special systems and techniques are employed.

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 the road surface. The road surface characteristics may thus be designed for site conditions. Chippings with a high polished stone value (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 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, thereby maintaining the structural integrity of the road pavement.

Conservation

8.12 An additional benefit of surface dressing is conservation of existing materials: the dressing has a thickness generally less than 10-12mm, so planing 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.

Environmental

8.13 Emulsions are environmentally friendly: the emissions are mainly water vapour. Cutback solvent is primarily kerosene (similar to domestic paraffin), one of the least hazardous low cost organic solvents. Waste materials (bitumen and chippings) are not currently classified as hazardous.

Appearance

8.14 Although chippings for surface dressing on trunk roads 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 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 as the binder sprayer is able to apply 10,000m² in about one hour. The ability to surface dress at night minimises traffic disruption.

Drawbacks

Structural strength

8.16 Surface dressing does not strengthen the road structure.

Profile

8.17 Defects such as rutting and shoving must be eliminated before the surface dressing is applied, the dressing making no improvement to the road profile. Soft patching materials, binder rich crack repair band sealing (including some hot screeded proprietary systems) and existing fatting in wheel tracks are 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 high texture depth (macro-texture) achieved with surface dressing may cause an increase in noise level, especially in the very early life before any chipping embedment and mosaic formation have taken place. The use of multiple dressings or smaller chipping sizes reduces noise generation and are often specified in urban areas for that reason.

Sensitivity to Weather Conditions

8.20 Given a proper design 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 from the binder (binder stripping) and traffic may dislodge them destroying the dressing in the wheel tracks. If traffic can be diverted until the road dries again and then re-introduced carefully, the dressing may be saved. In very hot weather during and immediately after construction the chippings may turn and be picked up by vehicle tyres. A maximum road temperature of 40°C may be specified, even for modified binders, to reduce this risk. Lightly coated chippings are especially vulnerable. Fine material, particularly absorbent light coloured 1-4mm chippings, (‘dust’), applied to the dressing may prevent this mode of failure, a racked-in or double dressing is less vulnerable due to the smaller chippings at the surface. Conventional emulsion binders are generally less of a problem in hot weather than cutbacks except when there is high humidity. However cutbacks have an advantage over emulsions at the lower operating temperatures when it is humid.

Surface Dressing Techniques

8.21 There are a number of different systems of surface dressing available. All of those current at the time of publishing this part are described below but others may be developed and their use should not necessarily be precluded because they are not described here.

Standard (single binder single chipping application)

8.22 The basic surface dressing technique using a single application of binder followed by a single application of chippings, usually 6 or 10 mm, is satisfactory for most lightly trafficked roads. (See Figure 8.1). When used with an unmodified binder it is suitable for lightly trafficked roads without significant areas of stress. It is also used with modified binder on somewhat more difficult sites such as cul de sacs where all the traffic, although small in quantity, is turning or braking. Modified binder dressings are more resistant to damage caused by power steering being used when vehicles are stationary.

Racked-in (single binder spray double chipping application)

8.23 Binder is applied at a higher rate than for single dressing, and the primary size chippings (typically 14 mm on fast heavily trafficked roads) applied at a lower rate (90% of that for a single dressing), followed immediately by small chippings (6 mm) to fill the gaps and achieve mechanical interlock (see Figure 8.2). The advantages of the racked-in method are high initial texture depth, early stability of the dressing, and a major reduction in the initial loss of large chippings.

Inverted double dressing (Pad coat)

8.24 Where the existing road surface is very hard or porous with high or variable macro-texture, a first dressing using small chippings (6 mm) can be made to provide a uniform softer surface to which the main dressing is applied (see Figure 8.3). It is common to leave the pad coat exposed to traffic for up to a year before applying the main dressing. The advantage of using a pad coat is that the main dressing chippings embed quickly, increasing resistance to chipping loss.

Double Dressing (Double binder spray, double chipping application)

8.25 Binder is applied at a little less than the normal rate (typically 1.3 l/m² of emulsion), and normal size chippings (usually 14 mm) are applied at slightly less than the normal rate for a single dressing. A second application of binder (typically 1.2 l/m²) and small chippings (6 mm) follows (see Figure 8.4). The advantages of the double spray double chipping method are moderately high texture depth, reduction in loss of large chippings, and the possibility of using larger chippings than would usually be selected for the road. Initial stability may be low, but builds up rapidly, and stressed areas may be treated using modified binders. It is usual to allow extended time for rolling and curing of an emulsion binder before opening the dressing to traffic. Solvent entrapment when using cutback binders may present problems unless sufficient time is allowed between layers to enable evaporation to take place.

8.26 The use of double dressings - even where traffic flows are low - on exposed sites such as hills or mountains enhances durability, and is standard practice in some European countries. Double dressings are beneficial on high speed, heavily trafficked dual carriageways and motorways where slow speeds to orientate the chippings and form a mosaic are difficult if not impossible to ensure. Interlocked double dressing systems have a high initial stability, particularly when used in conjunction with premium grade binders.

Schematic Representation of the Types of Surface Dressing Prior to Embedment

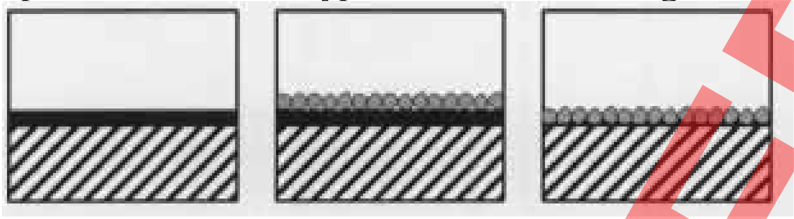


Figure 8.1 Single surface dressing

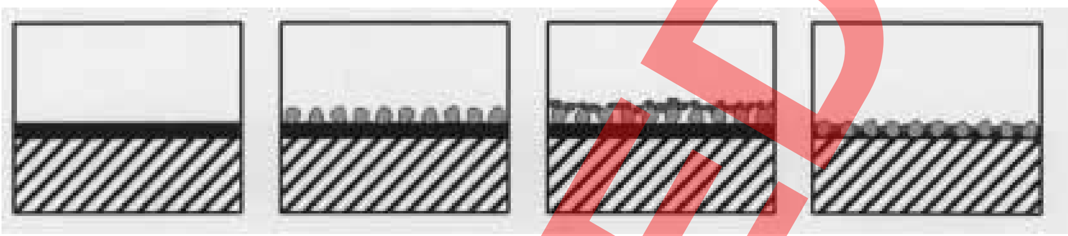


Figure 8.2 Racked-in surface dressing

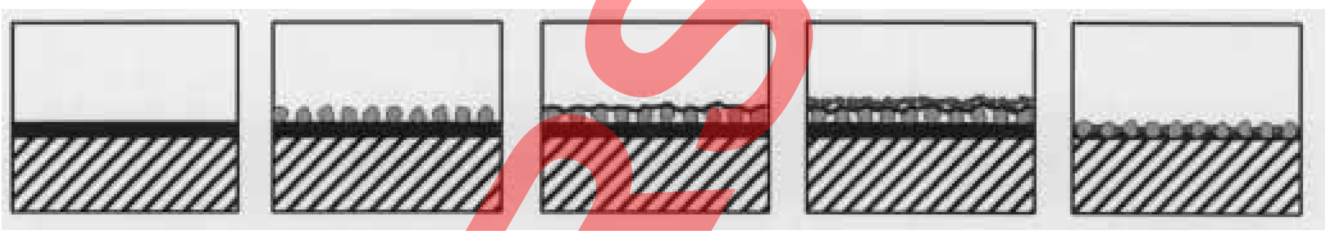


Figure 8.3 Inverted double dressing

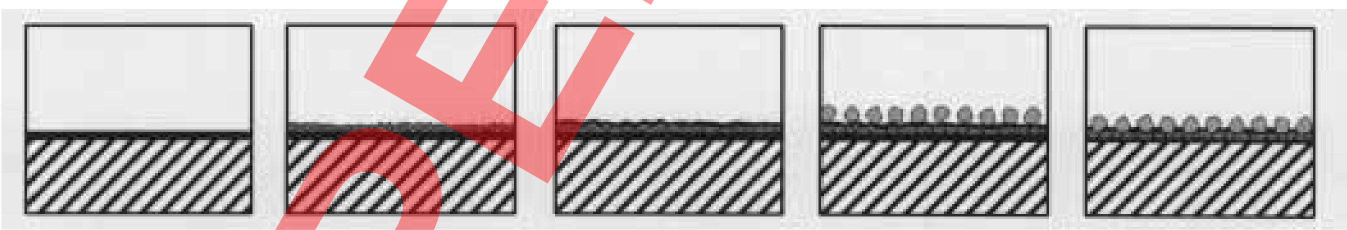


Figure 8.4 Double dressing

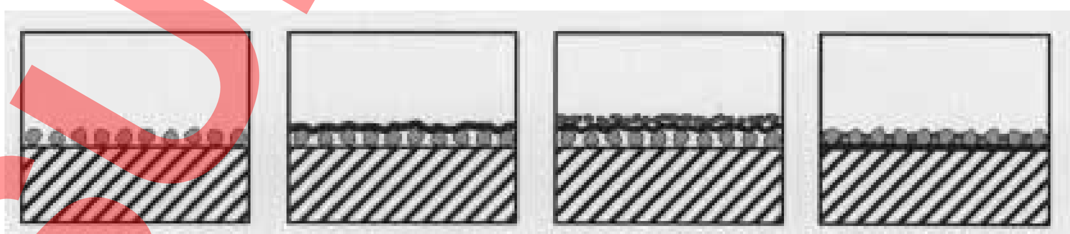


Figure 8.5 Pre-chipping Dressing (Sandwich dressing)

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Pre-chipping Dressing (Sandwich dressing)

8.27 The primary chippings are applied first (typically 14 mm) followed by a single surface dressing with low rate of binder spread (typically 1.2 l/m² of a modified emulsion and 6 mm chippings) (see Figure 8.5). It is important not to allow traffic to disturb the primary chipping layer, which has to be laid to close tolerances. This technique creates voids enabling the system to tolerate a binder-rich (or variable) surface, and allows a stable dressing to be constructed using larger than normal chippings. A variant of this with a rate of spread of binder of typically 2.2 l/m² has been used successfully on a heavily trafficked single carriageway, normal hardness site in very hot weather.

Differential Rates of Spread and Chipping Sizes

8.28 With some modern sprayers it is possible to vary the rate of spread across the road, (ie transversely) which enables lower rates of spread of binder 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 before the onset of fatting. Using larger chippings in the wheel tracks has the same benefit and may even improve transverse profile.

Cured Resin Binder Dressing

8.29 High performance thermosetting binder often used with calcined bauxite chippings. These dressings are significantly different from normal surface dressing. Reference should be made to Specification (MCHW1) Series 900, ‘Resin Based Skid Resistant Surface Treatment’.

Design Principles

8.30 Road Note 39 (1996) provides a complete guide to the design and practice of surface dressing. The information is based on systematic experiments and trials by TRL over many years, in close co-operation with both industry and the Highway Authorities. The Road Surface Dressing Association (RSDA) and Road Emulsion Association have published many documents, which complement this Chapter.

8.31 The decisions to be made when specifying surface dressing for a particular length of road are outlined in Figure 8.6, which is targeted primarily at surface dressings for high-speed roads carrying heavy traffic, circumstances under which a simple single dressing using unmodified bitumen will most probably be inadequate.

8.32 In situations where a simple surface dressing using unmodified bitumen will suffice, a traditional recipe specification based on the guidance in Road Note 39 (1996) is all that is needed.

8.33 For high speed roads carrying heavy traffic, modified binders and multiple layer surface dressings will almost certainly be required. For these the empirical approach to design is becoming less acceptable, and with end performance in mind, rational designs tailored to a ‘system’ are becoming favoured. This type of design is often best left to the contractor who has expertise with a particular system and will carry the risk of premature failure. It is important for the Overseeing Organisation to ensure that the correct performance levels of the surface dressing are specified and obtained, in particular any parameters specified must be measured to demonstrate compliance. The Overseeing Organisation will need to be satisfied that there is minimum risk of failure during the designed life, which may be much longer than the guarantee period.

Principal Chipping Size Selection

8.34 The size of chipping selected for use at a particular location is based on the degree of embedment of the chippings expected 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 (see Road Note 39 (1996)). If the hardness varies considerably along the site then it may be difficult for the contractor to achieve consistent high levels of end performance. In such situations, agreement between the Overseeing Organisation and contractor with regard to the practicality of achieving the specified levels will be necessary.

8.35 Chippings are nominally single sized. 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 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 - a function of PSV.

8.36 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

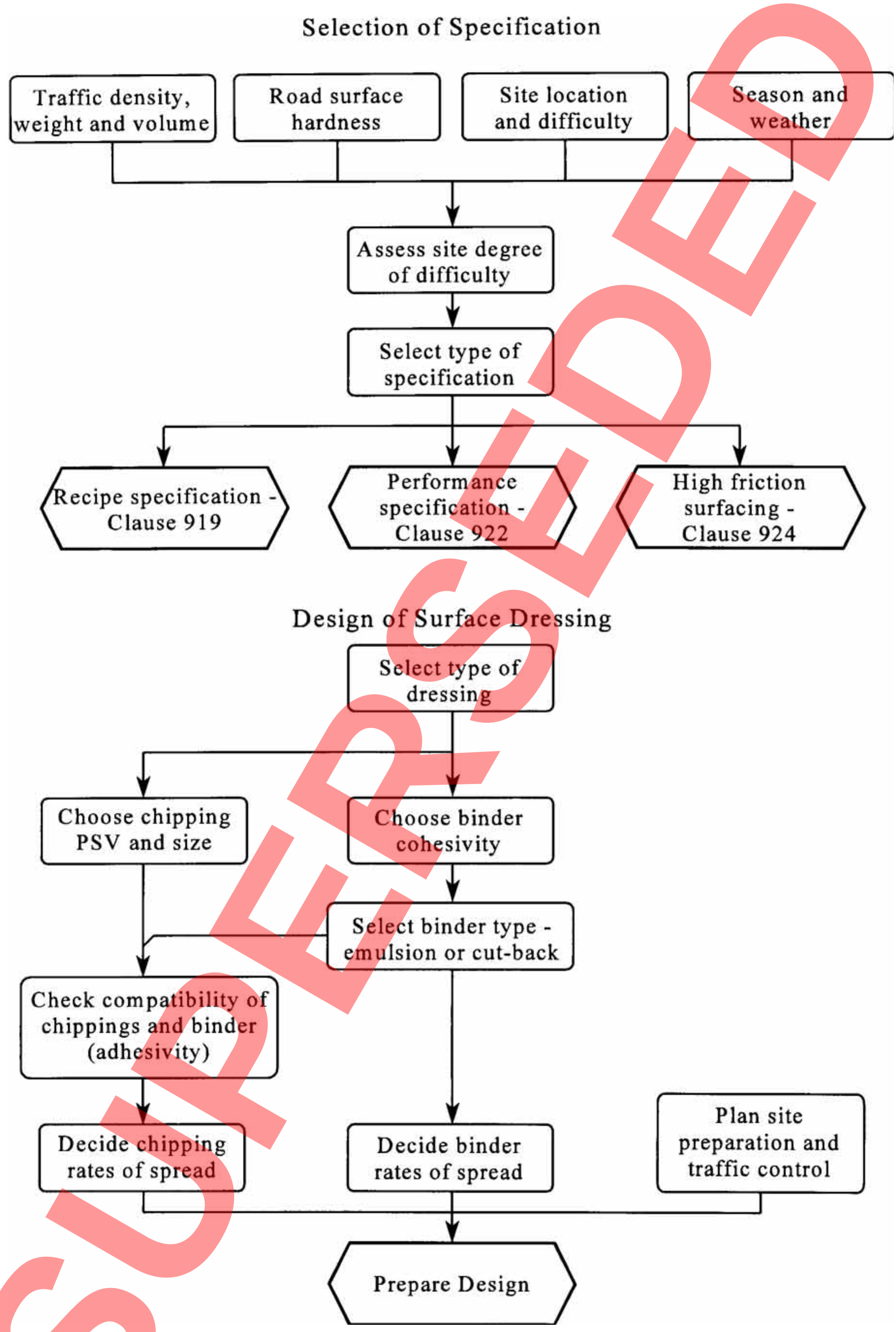

Figure 8.6 Flow Charts for Specification and Design of Surface Dressing

the risk of failure. These techniques, as well as the use of chemically or bitumen coated chippings should be considered for works on trunk roads, although the use of lightly coated chippings with emulsion binders are unlikely to be used, as this may slow down the rate of break of an emulsion and actually inhibit chipping adhesion.

8.37 Since the main purpose in using polymer modified binders is to provide a durable product and minimise the risk of loose chippings, it is pointless to use those expensive binders with chippings having low Polished Stone Value, high Flakiness Index, high Aggregate Abrasion Value, 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.

8.38 Table 2.1 in HD28 (DMRB 7.3.1.2) shows the minimum PSV requirements for use on roads of differing traffic intensity and stress, and Table 2.2 shows the AAV requirements for differing traffic levels. In order to conserve aggregates the highest PSV chippings should not be specified for all roads, but to consider each site individually. Unfortunately wear resistance generally improves with chippings of lower PSV, therefore durability and safety are a balance and savings may be made by optimum selection. 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. 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 PSV requirement of over 70 on some difficult sites necessitates the use of calcined bauxite. Resin based skid resistant treatments are generally employed (see Specification MCHW1), although 6mm calcined bauxite with polymer modified binder as a single dressing has been used successfully. 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.

8.39 When Racked-In techniques are used in surface dressing 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) then the PSV should be similar. For all other multiple chipping systems all sizes should have the design PSV. On trunk roads no chippings should have a PSV of less than 45.

8.40 Adhesion between binder and chippings depends on the chemical nature of the chippings, the binder properties (use of wetting or adhesion agents), 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 using a suitable adhesion test such as the Vialit Plate Shock Test.

Specification of Surface Dressing

Recipe or performance-related specification?

8.41 If consideration of Table 8.1 indicates that the proposed dressing falls comfortably in the easy type of site, a recipe specification may be used. For a difficult type of site with higher risk rating, a modified binder will be required (see paragraph 8.52) together with a racked-in dressing or other multiple treatment, and use of a performance-related specification is advised. Either route could be followed for average types of site. With a recipe specification responsibility for the design rests with the Overseeing Organisation; with a performance specification this responsibility is transferred to the contractor. It is anticipated that as experience is gained with performance related specifications the use of recipe specifications will diminish.

8.42 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. On very difficult sites only the highest quality 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 needs careful, informed assessment particularly with regard to safety aspects.

Recipe specification

8.43 Figure 8.6 gives a flow diagram for planning and specifying dressings. A break-out point for use of a performance-related specification is also given. Road Note 39 (1996) provides a sound basis for generating a recipe specification for surface dressing and Specification clause 919 (MCHW1) sets out the requirements; no further advice will be given here.

Performance-related specification

8.44 In the past specifications have been generally recipe specifications, with the Overseeing Organisation

Site Category		Site Definition	Traffic at Design Life (commerical vehicles / lane / day)													
			0 - 100	101 - 250	251 - 500	501 - 750	751 - 1000	1001 - 1250	1251 - 1500	1501 - 1750	1751 - 2000	2001 - 2250	2251 - 2500	2501 - 2750	2751 - 3250	> 3250
I	A	Motorway (main line)														
I	B	Dual carriageway (all purpose) non-event sections														
I	D	Dual carriageway (all purpose) minor junctions														
II	C	Single carriageway non-event sections														
II	E	Single carriageway minor junctions														
III	F	Approaches to and across major junctions (all limbs)														
III	G1	Gradient 5-10%, longer than 50m (dual downhill, single both ways)														
III	H1	Bend, radius 100-250m (not subject to a speed limit 40mph or less)														
III	L	Roundabout														
IV	G2	Gradient >10%, longer than 50m (dual downhill, single both ways)														
IV	H2	Bend, radius <100m (not subject to a speed limit 40mph or less)														
V	J/K	Approaches to roundabout, traffic signals, pedestrian crossing, level crossing, etc														

Key:

	Easy sites, conventional binders, minimum cohesion 0.5 J/cm^2 over a minimum temperature range of 15°C
	Fast and/or moderately difficult sites, intermediate grade binder, minimum cohesion 1.0 J/cm^2
	Difficult sites, premium binder, minimum cohesion 1.2 J/cm^2
	High friction surfacing systems
---	Not suitable for surface dressing or unlikely traffic levels

Table 8.1 Areas of use for surface dressing binders

specifying materials, quantities and procedures. This requires a degree of expertise in and experience of the materials and processes. With the introduction of modified binders, proprietary materials and novel techniques, new expertise is required. The dependence on the supplier to maintain properties of his product to ensure consistent road performance and the Contractor to determine the process technique for the site encourages the transfer of responsibility to the Contractor, in the short term at least.

8.45 Performance-based specifications are the logical conclusion of that process: all the design work is carried out by the contractor, with the Overseeing Organisation specifying only the level of performance required, and imposing no checks other than regular assessment of performance. However, this procedure presents a financial problem: *either* the contractor must guarantee the work for its design life, and accept that he will not be paid in full until the end of the design life, *or* the Overseeing Organisation must pay in full before the requested life has been achieved.

8.46 In the former case specification writing would be simple: the Overseeing Organisation would state their requirements and the contractor would fulfil them in any way he wished. This would be an unacceptable burden to contractors because of the financial aspect of payment delayed for several years. In the latter case the ideal solution would be to perform predictive tests on the materials before and immediately after application to the road, which would demonstrate beyond reasonable doubt that the work would last for the specified length of time. Unfortunately there is insufficient knowledge at the present time for this to be possible. The Overseeing Organisation would therefore not be willing to pay in full for the job until near the end of the specified life, which again would be unacceptable to the contractor. As a compromise, the specification to which this advice relates asks the contractor to do the design work for specified performance and carry out performance prediction tests, and in addition imposes testing requirements to ensure that the proposed design has been carried out with a reasonable degree of precision. The risk element is divided between contractor and Overseeing Organisation, by having a Guarantee Period of two years (which is much less than the Design Life of the dressing). During the two years, the contractor must make good any defects, after which period the Overseeing Organisation accepts the risk and any cost of future remedial work.

8.47 A further assurance of continuing performance to both contractor and Overseeing Organisation is the use of an approved binder - one which has been through an evaluation procedure. A formal materials approval scheme is being developed jointly by the Highways Agency, County Surveyors' Society and the British Board of Agrément (BBA). Until the Highway Authorities Product Approval Scheme BBA/HAPAS is in place the Overseeing Organisations will continue to operate the practice of informal approval, listing currently accepted materials and processes on the basis of established track record with guidance as to category of performance, where possible, and new materials under examination for approval. The combination of recipe tests (based on extensive past experience), predictive tests (developed comparatively recently and as yet not fully proven) and use of an approved binder 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.

Effect of existing surface

8.48 The assessment of need for the maintenance of a section of road is outside the terms of reference of this Chapter. Reference should be made to HD29 (DMRB 7.3.2) Structural Assessment Methods, HD 28 (DMRB 7.3.1) Skidding Resistance and the CHART visual assessment procedure. Once it has been decided that a section of road needs some form of treatment and that strengthening is not required, then 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 given in Road Note 39 (1996). The main variables of the existing surface that will affect the final dressing are porosity, roughness, amount of fatting, hardness and heterogeneity. Table 8.2 (based on French experience) shows the normally achievable performance, using best practice, of a correctly designed and appropriate system for different traffic levels and surface types. Two different performance criteria are given depending on speed (the difference is in the macrotexture required). As would be expected, the heavier the traffic the more critical is the state of the current surface. At the highest traffic end only the normal, non-porous, homogeneous, fairly smooth road can be surface dressed with a good

Category	Minimum Requirements for Surface Dressing Traffic (commercial vehicles/lane/day)														
	0-250			251-1000			1001-2500			2501-3250			> 3250		
	Suitability	Macro Texture	VA Class	Suitability	Macro Texture	VA Class	Suitability	Macro Texture	VA Class	Suitability	Macro Texture	VA Class	Suitability	Macro Texture	VA Class
No speed limit	H	1.05	2	H	1.05	3	H	1.05	3	H	1.05	4	H	1.05	4
30 or 40 mph	L	0.7	2	L	0.8	3	L	0.8	3	L	0.8	4	L	1.05	4
Existing surface characteristics	**Typical Achievable Performance Specifications for Surface Dressing**														
Porous	X	0.8	2	X	0.8	3	X	0.8	3	X	0.8	3	X	0.8	3
Rough	HL	1.05	3	HL	1.05	3	HL	1.05	3	X	1.05	3	X	1.05	3
Normal, homogeneous	HL	1.05	4	HL	1.05	4	HL	1.05	4	HL	1.05	4	HL	1.05	4
Soft, homogeneous	HL	1.05	4	HL	1.05	4	L	0.8	4	L	0.8	4	X	0.8	4
Fatting up	L	0.8	2	X	0.8	2	X	0.7	1	X	0.7	1	X	0.7	1
Bleeding	X	fail		X	fail		X	fail		X	fail		X	fail	
Heterogeneous, tracked A*	HL	1.05	3	HL	1.05	3	HL	1.05	3	X	1.05	3	X	1.05	3
Heterogeneous, tracked B*	L	0.8	4	L	0.8	4	L	0.8	4	L	0.8	4	X	0.8	4
Heterogeneous, patched	L	0.8	2	X	0.8	2	X	0.7	1	X	0.7	1	X	0.7	1

Notes:

- * A is for a design to optimise macrotexture.
- * B is for a design to minimise chip loss.
- The macro-texture is given in mm (HRM) and is that which is achievable for a given site.
- The Visual Assessment (VA) Class is the attainable visual assessment class Measurements of defects at the end of the 2 year guarantee period.
- H indicates that the requirements can be met on high speed roads.
- L indicates the requirements can be met on low speed roads.
- X and shading indicate surface dressing will not normally meet the requirements.
- This table shows that it is not possible to specify 1.05 mm texture depth with the highest performance in terms of minimal defects on roads other than for normal homogeneous sites. At the higher traffic levels the achievement of the minimum requirement becomes increasingly difficult to attain.

Table 8.2 Surface Dressing - Minimum Requirements and Typical achievable specifications on various existing surfaces for different sites

probability of success over an economic life. On very lightly trafficked roads a successful outcome is possible in virtually all cases subject only to proper design and execution.

8.49 There are a number of factors that can widen the type of surface that can be treated using surface dressing. The three main ones are to accept a lower standard, to accept a shorter life or to pretreat the surface in some way to improve its characteristics. Surface dressing systems 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 8.2 shows as not making the grade by only one level may well be successfully treated in some instances by an improved process, whether in the binder or in the system. As contractors gain knowledge of, and confidence in, performance specifications the type of site they will be willing to guarantee may also widen in scope.

8.50 Table 8.3 describes the various types of site that are stated in Table 8.2 and also describes possible pretreatments to overcome the constraints of the existing surface.

Specification parameters

Parameter description and limits

8.51 System of surface dressing permitted - 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.

8.52 Binder cohesivity is a measure of the ability of the binder to cope with traffic stresses. In general terms most manufacturers produce three levels of cohesivity in their range of binders, conventional, intermediate grade and premium grade. These are characterised by cohesivity levels of 0.5, 1.0 and 1.2 J/cm^2 respectively. (Note: when comparing two binders with the same cohesivity, the one maintaining the level over the widest temperature range is likely to perform better than the other). The more stressed the site the higher the cohesivity required but to some extent it is possible to compensate for low cohesivity values by using a more stress resistant surface dressing system. Not all standard 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. Suggested levels are given in Table 8.1 which uses the site categories from HD 28 (DMRB 7.3.1).

In a true performance specification no value would be specified leaving it to the contractor but it is recommended that in the early years of this type of specification until wide experience is gained, a value is always specified.

8.53 The minimum PSV of chippings is required to ensure adequate resistance to skidding and the values in Table 2.1 of HD 28 (DMRB 7.3.1.2) should be used.

8.54 The maximum AAV of chippings is required to ensure adequate resistance to abrasion by traffic and the values in Table 2.2 of HD 28 (DMRB 7.3.1.2) should be used.

8.55 The class of spraybar is a guide to the evenness of transverse distribution which the spraybar is capable of producing and class 4 is the most onerous. This class is not attainable except by very well maintained spraybars and should therefore only be specified where it can be most beneficial, ie 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. It is recommended that class 4 spraybars are reserved for motorways, class 3 for other dual carriageways and class 2 for other roads. Where a single carriageway is very heavily trafficked and the current surface is consistent along the whole length and across the whole width, then class 3 should be specified. The evenness of rate of spread should be checked at the start of, or recently before, the contract and then weekly. In addition to the class of spraybar, the class for tolerance on the rate of spread of binder should be specified and for this purpose the specification of class 3 is suitable for all sites as it is both achievable and adequate. The frequency of test is set out in Specification (MCHW1) Appendix 1/5.

8.56 The class of chipping spreader is a guide to the evenness of transverse distribution which it is capable of producing, class 2 being the most onerous. This class should be specified for the primary chipping in a multi layer surface dressing otherwise class 1 is adequate. The evenness of rate of spread should be checked at the start of the contract and then daily. In addition to the class of chipping spreader, the class for tolerance on the rate of spread of chippings should be specified and for this purpose the specification of class 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.

Surface Type	Description	Possible pretreatments
Porous	Surfaces like porous asphalt and open textured macadam	Surface dressing with 6mm chippings some weeks before the main dressing (or even the previous season)
Rough	A surface with a texture depth above 1mm 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 appearace over whole section, SMTD <1mm, hardness at least "normal"	None needed
Soft, homogeneous	As above but surface hardness is less	None needed
Fatting up	Has a surface layer of free bitumen, usually limited to the wheel tracks	If it is only in the wheel trackes 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 wheel tracks and often happens soon after a surface dressing has been applied	No pretreatment will avoid subsequent failure, in very bad cases even on virtually untrafficked roads
Heterogeneous, tracked	This is the normal state of 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
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 slurry surfacing. The slurry surface will have a low macrotexture and will have to be left to mature for a sufficient period before surface dressing, otherwise it will be very soft

Table 8.3 Description of surfaces prior to surface dressing

NOTE: SMTD = Sensor Measured Texture Depth

8.57 Macrotexture: for general guidance on the need for macrotexture and its measurement see HD 28 (DMRB 7.3.1). The generally accepted specification for high speed roads of 1.5 mm minimum using the sand patch test 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 relatively fluid binder-chipping matrix and chipping embedment occurs at a rate depending on the 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.

8.58 The decay of texture depth with time is not linear and is rapid in the first year or two; it depends on many parameters so it is difficult to extrapolate early life texture depth measurements. Figure 8.7 shows texture decay of single dressings with conventional binders on the M40 High Wycombe by-pass, reported by Jacobs, F.A., 1983. To obtain adequate texture at 2 years the initial texture has to be very much higher, for some processes over 3 mm 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 texture at the end of the initial bedding in period, say at 4 weeks.

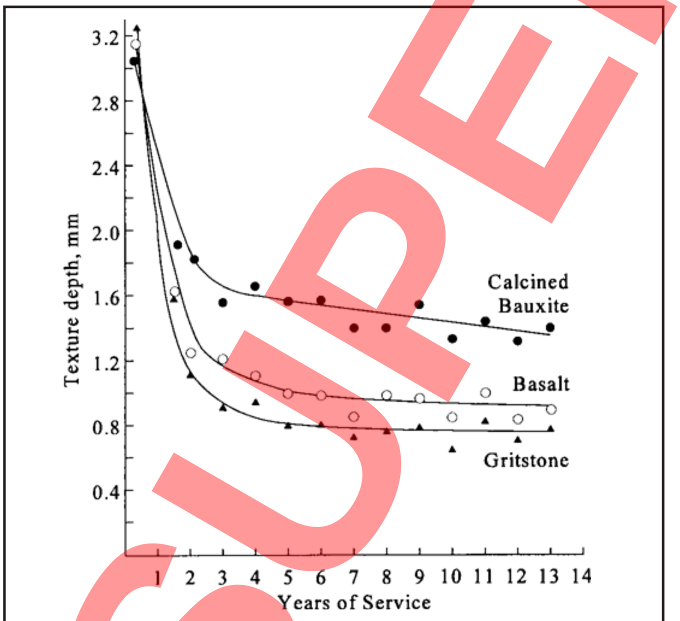

Figure 8.7 Effect of type of chipping on the reduction in texture depth with time. (conventional binder on a rolled asphalt substrate)

8.59 The end product performance specification to which this Chapter refers 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 the guarantee period (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.

8.60 All texture depths for surface dressing should be specified in terms of HRM measurement (other methods may be used provided they are converted to HRM equivalent values) and the level for high speed roads at 2 years would normally be specified at 1.03 mm (approximately the equivalent of 1.5 mm in the patch test). For roads carrying traffic at speeds below 90 km/hr lesser textures should be specified. See Notes for Guidance to Specification, Clause NG922 (MCHW2) for appropriate values.

8.61 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.

8.62 The level of fretting, P_1, as measured using the test method described below, is a guide to likelihood of failure by continued loss of chippings. Appropriate values of the maximum permitted percentage are given in Notes for Guidance to Specification, Clause NG922 (MCHW2).

8.63 The level of defects, P_2, as measured using the test method described below, is a guide to the likelihood of unsatisfactory performance of the dressing. Appropriate values of the maximum permitted percentage are given in Notes for Guidance to Specification, Clause NG922 (MCHW2).

8.64 The maximum level of localised loss of chippings in any given area, P_3, should not be greater than the specified percentage which is given in Notes for Guidance to Specification, Clause NG922 (MCHW2).

Tests specific to surface dressing

8.65 Tests used to check the aggregates and the binder used for surface dressing are covered in the sections on the constituent materials following this section. The tests used to ensure that the surface dressing system is suitable and the process is carried out correctly are dealt with in this section.

8.66 The test for accuracy of rate of spread of binder in BS prEN12272-1 (1996) 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 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 method used successfully during specification trials in 1996 used sections of carpet tile (250x100 mm) stuck to a length of aluminium sheet which was covered with 'cling film' thus enabling the whole testing to be carried out without the use of solvents. 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.

8.67 Although the test described in paragraph 8.66 gives the average rate of spread of binder a simpler test is recommended to assess this: in BS prEN12272-1 (1996) is a harmonised version of the test that has been used for many years in UK - the tray test, but now it may be carried out using absorbent tiles. These can be of any suitable material and there must be at least 5 tiles. There are a number of constraints on dimensions but 5 tiles consisting of a ½ or a ¼ of a standard 0.5x0.5 m carpet tile is suitable. The individual masses are determined and the average reported. The variance, which, in this case, is the highest rate minus the lowest rate, ie 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 test carried out.

8.68 Also in BS prEN12272-1 (1996) are tests for evenness of rate of spread and accuracy of rate of spread of chippings. These measures are particularly important in the context of multiple chip dressing where the rate of spread of the primary chipping is critical to the success of the dressing and the locking up of those chippings by the secondary chipping.

8.69 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 on the tanker must be working and must be giving the correct reading. In order to achieve this reliability, 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 principle and the contractor's QA scheme should contain a requirement for the regular reading of the duplicate gauges and if the readings differ by more than a stated amount they should, if necessary, be repaired and recalibrated, or replaced by previously calibrated gauges.

8.70 The standard method of measuring texture depth for surface dressing is different from the method used for coated materials. The reasons for this is that it is measured after the contract has finished and the High Speed Road Monitor (HRM) or its equivalents can carry out the work without needing traffic control and the lengths to be covered are often much greater than for a coated material contract. Other test methods are not precluded but the results must be converted to HRM 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.

8.71 In terms of defects like fretting (generalised chipping loss) surface dressing usually either fails extensively or it does not fail at all. Border line cases are rare both for fretting and for localised chipping loss, however assessment methods are given in draft prEN 00227055. They are somewhat tedious but it is unlikely that they will be needed very often.

Binder Data

8.72 In order to gather data which enable more precise advice to be given on binder requirements the specification for surface dressing, both to Specification clauses 919 and 922 (MCHW1) requires the provision of a wide range of data on the binder to be used and on its compatibility with the proposed aggregate. It is expected, over a period of time, that the amount of data required will reduce as it becomes clearer that some of the data is more useful than others in defining the performance of a binder. 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 he should either give a range of values that covers the variation across all sources or give the data for each individual source. 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 or the Overseeing Organisation to carry out any or all of the tests to check whether a particular consignment conforms with the declared limits. The date of test for any parameter should be given when providing a data sheet.

8.73 **The header data**, ie manufacturer, binder name, aggregate source etc, are required simply to ensure that the data is attached to the correct binder or binder/ aggregate combination. If the name of the binder is changed, say for marketing reasons, its previous one should also be given until all the data given is dated at least a year after the change of name. This is to enable names to be changed without unnecessary testing whilst enabling data to be traceable.

8.74 **The binder recovery method** used should be the British method using the RTFOT apparatus at 85°C in an inert nitrogen atmosphere. When the CEN (Austrian) method has been defined so that it can meet the requirements of EN45000 then that procedure may also be used for emulsions provided that all tests carried out subsequently state the recovery method. If a supplier changes his recovery method the whole suite of tests should be carried out using both methods at the time of changeover so that continuity of data can be maintained. A standardised recovery procedure is required so that the purchaser and the Overseeing Organisation can compare the results for a given consignment of binder with the manufacturer's claims as the purchasers of binder or of final dressing are not in a position to check the base binder. It is not intended that the recovered binder necessarily reflects any particular stage in the life of the binder after spraying although it may be found to do so and is likely to reflect its state fairly early in its life when it is still vulnerable to traffic damage.

8.75 **The penetration test at 25°C with 100g** load for 5 seconds is the test traditionally used in the United Kingdom to determine the grade of harder binders. Carrying out the test on the base binder determines the grade of binder making up the bulk of the final blend. Comparison with the penetration measured on the recovered binder indicates the changes that have occurred during the manufacture and recovery process.

8.76 **The penetration test at 5°C with 200g** load for 60 seconds is a test, in the absence of any suitable alternative, which can give some indication of the low temperature characteristics using a well known and common piece of test equipment. It may be possible to use the result together with the standard pen test to give an indication of the sensitivity of the binder to changes in temperature (analogous to PI).

8.77 **The penetration test at 5°C with 100g** load for 5 seconds for use on cut back binders as delivered is for use as quick quality control test to check consistency of a series of consignments. As an alternative a high temperature viscosity (between 100 and 160°C) can be used for the same purpose. As it is for comparison purposes the same test and test parameters should always be used by one supplier.

8.78 **The Vialit pendulum cohesion test** gives a measure of the ability of a binder to resist traffic stresses. For simplicity only the peak value is used to determine the grade of a surface dressing binder. The temperature range over which a given cohesion is maintained is at least as important as the peak level reached; this is why plots of the results are required. It has been suggested that the area under the graph above some arbitrary value, say 0.5J/cm^2, would be an alternative criterion by which to compare binders. Specifiers should be aware that very high levels of cohesion (over 2 J/cm^2) are sometimes associated with poor adhesion.

8.79 **The Vialit plate shock adhesion test** assesses a number of factors depending on how the test is performed, all the procedures are given in BS prEN 12272-3 (1997).

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

8.80 *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 on 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.

8.81 *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.

8.82 *Wetting temperature* is applicable to cut-back binders only and is a measure of the lowest road temperature at which work should take place. It can also indicate the sensitivity of the binder aggregate to road temperature at the time the dressing is carried out.

8.83 *Fragility temperature* provides an indication of whether or not problems are likely to occur in the early life of the 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.

8.84 **The 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 is a master curve of G* against frequency (Hz) at 25°C and δ against temperature at a frequency of 0.4 Hz over the range -10 to +60°C. 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. 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 only required on recovered binder.

8.85 **Spray temperature range** is the range of temperatures determined by the binder manufacturer over which the binder may be satisfactorily sprayed. The range may be different for slot jet and swirl jet spray bars, if so this should be made clear and the contractor should insert the temperature range appropriate to the spray bar proposed for the contract.

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

8.87 **Weather limits** should be indicated if they are different from those which would be applicable to conventional as set out in Road Note 39 (1996). The maximum and minimum road temperature and the maximum humidity should be given in all cases. Any limits not indicted will be assumed to be as given in Road Note 39 (1996).

8.88 **The minimum orifice viscosity** (STV or Redwood II) is that which the particular emulsion binder requires to prevent it flowing down any slope in 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.

8.89 **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

8.90 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

8.91 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

8.92 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. In addition to this document these include Road Note 39 (1996) for design, British Standards, Road Emulsion Association Ltd (REAL) and manufacturers' technical information, RSDA advice notes for materials and RN39 and RSDA code of practice for execution. The specification is the responsibility of the purchaser and advice on specification and the suitability of the existing surface to accept a surface dressing is given earlier in this chapter.

8.93 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. This 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 be inspected regularly and treated at the appropriate time.

Failure definitions

8.94 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.

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 macrotexture.

Bleeding - The exudation of bituminous binder from a road surface, often accompanied by "bubbling" of the surface and often spreading to 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 8.4.

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 to somewhat high. Immediate remedy is to dust at the first sign of it occurring (do not delay). Avoidance: ensure design is correct, check rate and evenness 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 surface dress 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 redressing using a sandwich construction 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 dressing using a planer equipped with chisel tips and redressing 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, too weak a binder 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 dressing. Check that the binder is adequately strong 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 or other materials, water jetting may be required. Proper preparation is cheaper than remedial action. The only remedy is spot dress areas when the problem occurs.
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 must be carried out before work each morning, whenever there is change of binder and whenever there has been a prolonged stoppage, particularly if the jets have not 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.
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 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. When it occurs 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 8.4 Causes, avoidance and remedies of failure for surface dressing

9. HIGH FRICTION SURFACING

Background

9.1 Experience over the last 30 years in the UK has shown these surfacings to be highly effective in reducing traffic accidents on sites with high traffic density and skidding risk. Typical sites are the approaches to signal controlled junctions, to roundabouts and pedestrian crossings subject to a heavy flow of vehicles. For the length of high friction surfacing necessary, reference should be made to Table 3.1 HD 36 (DMRB 7.5.1) and accompanying notes.

Systems in use
9.2 High friction surface treatments are now available based on a variety of binders, both thermosetting and thermoplastic. Depending on the type of binder, high PSV aggregates - most commonly calcined bauxite - are either broadcast over a pre-applied binder film or pre-blended with binder and the mixture applied. The resin binders used at present for broadcast systems are epoxy, polyurethane and acrylic all of which are thermosetting. The binders used for screeded systems are rosin esters which are thermoplastic.

System classification
9.3 On heavily trafficked sites, the durability of different systems can vary greatly. To avoid discriminating against those products that are suitable only for moderately or lightly trafficked sites, and also to encourage innovation, the BBA HAPAS certification scheme to assess high friction surfacings has been introduced. High friction surfacing systems are classified during the assessment into three types, as shown in Notes for Guidance, (MCHW 2) Table NG 9/15.

Life expectancy
9.4 Each type classification has an expected service life of between 5 to 10 years at the maximum traffic levels shown in Notes for Guidance, (MCHW 2) Table NG 9/15. Types 1, 2 & 3 are suitable for very lightly trafficked sites, Types 1 & 2 for moderately trafficked sites and Type 1 for heavily trafficked sites. A Type 1 system used on a moderately or lightly trafficked site can offer a much extended life, twenty years is not unknown. Conversely a Type 3 system used on a heavily trafficked site will have a much reduced working life. Site constraints and the time of year can favour the use of less robust systems, generally thermoplastic hot applied materials, for convenience. Until thermoplastic Type 1 or 2 systems are available, this should not be permitted unless safety or other reasons mean there is no alternative. In such circumstances replacement may be necessary within two to three years.

Specification

9.5 High friction surfacing systems shall be specified in accordance with the Specification, (MCHW 1) Clause 924 and shall have a current BBA HAPAS Roads and Bridges Certificate. The minimum polished stone value of the aggregate, determined in accordance with BS 812: Part 114, to be used in high friction surfacing systems, shall be specified in accordance with HD 36 (DMRB 7.5.1).

Installation

9.6 A high friction surfacing system with a current British Board of Agrément (BBA HAPAS) Certificate shall only be installed by a Contractor approved by the BBA and the Certificate Holder as an Approved Installer for that system. The installation and quality control procedures shall be in accordance with the BBA HAPAS Certificate for each system and the current Method Statement agreed by the BBA.

9.7 Systems should only be installed on surfaces which are dry, hard and sound, and free from dust, oil, excess bitumen or other contaminants that may cause lack of adhesion. Surfaces not suitable for treatment include slurry surfacing, micro-surfacing, fatted and multilayer surface dressings and surface dressings over soft or unsound bases.

9.8 To reduce the risk of premature failure, high friction surfacing systems are best applied to wearing courses that have been trafficked for some weeks prior to installation of the surfacing. Nevertheless applications to newly laid untrafficked wearing courses of different types have been made without any apparent problems. For reasons that are not entirely understood, on occasion cracking which extends into the wearing course can be induced by the application of high friction surfacing. The risk of this occurring is much greater when the wearing course is newly applied and untrafficked, although opinions differ on this point. Provided the high friction surfacing is well bonded to the substrate and with the agreement of the Overseeing Organisation, such cracking if it occurs, may be sealed using a suitable epoxy or similar resin and the high friction surfacing made good. Any cracks in excess of 0.5mm are the liability of the Contractor under the terms of the guarantee required in the Specification, (MCHW 1) sub-Clause 924.7.

Overlaying concrete

9.9 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 BBA HAPAS Certificate.

Overlaying Thin Wearing Course Surfacings

9.10 Where thermosetting high friction surfacings - such as epoxy resin - are to be applied over thin wearing course systems at approaches to roundabouts and other highly stressed sites, the deep 'negative' texture in the surface can reduce the coverage of resin binder to such an extent that the adherence of calcined bauxite chippings is reduced, resulting in premature chipping loss. To alleviate this problem, the texture of the area of thin surfacing to be covered by high friction surfacing should be reduced during or after laying to between 1 to 2 mm as measured by the sand patch test. This may be achieved by any suitable means at the discretion of the thin wearing course system proprietor, for example by additional compaction with vibrating rollers whilst the thin surfacing is still hot or by the substitution of a smaller aggregate size in these areas. Alternatively a suitably sized grit may be applied and rolled in. If the thin wearing course system is to be trafficked prior to the application of HFS, then 3 mm grit should be applied and rolled in to provide enhanced short-term skid resistance. Temporary warning signs may be appropriate in such circumstances.

Guarantee

9.11 A two year guarantee is required from the Contractor from the date of opening the surfacing to traffic. This is linked to minimum performance requirements set out in the BBA HAPAS 'Guidelines Document for the Assessment and Certification of High Friction Surfaces for Highways.' The guarantee excludes defects arising from damage caused by settlement, subsidence or failure of the carriageway on which the surfacing has been applied.

Limitations

9.12 High friction surfacings are expensive, particularly if productivity is affected by the geometry of a site and the number of areas to be treated. The use of cheaper alternatives should be considered, if traffic levels allow, such as improved road signs and markings, improved street lighting, or surface dressing with a high PSV natural aggregate bonded with a binder capable of withstanding the braking forces generated.

10. SLURRY SURFACING AND MICRO-SURFACING

Background

10.1 Slurry surfacing and micro-surfacings are mixtures of aggregates and plain or polymer modified bitumen emulsions, which may contain fibre additives. Slurry surfacings range in thickness from about 2 mm to 8 mm and micro-surfacings from about 10 to 20 mm. Slurry surfacings are suitable for footways; areas that are trafficked only occasionally and at low speeds; and for traffic delineation. Micro-surfacings are targetted at all roads, including high speed roads carrying significant traffic volumes, and in consequence require appropriate levels of skid resistance and texture retention. Both materials permit only limited surface regulation when laid in one pass. If greater surface regulation is necessary, an initial pass may be made to fill in surface irregularities, such as minor rutting, followed by a second pass to provide the complete overlay.

Specification

10.2 The Specification (MCHW 1) Series 900, with accompanying Notes for Guidance (MCHW 2) in NG900, sets out the requirements for these materials, dividing them into two types:

- Slurry surfacing, Clause 918, covering the thinner materials, with aggregate up to a nominal 4 mm maximum size. It is an end performance specification in which the slurry surfacing may be in accordance with either BS 434, or if a proprietary system, with the British Board of Agrément Highway Authorities Product Approval Scheme, Roads and Bridges (BBA HAPAS) certificate for the system.

- Micro-surfacing, Clause 927, which is an end performance specification covering materials with nominal aggregate sizes of 6 mm or more, all products requiring BBA HAPAS certification.

10.3 Proprietary slurry surfacing systems are less than 18 mm in thickness and are classified as Type A thin wearing course systems as defined by BBA HAPAS, see Chapter 6 of the Part. Micro-surfacing usually falls within Type A but may also be laid thick enough to fall within Type B (ie 18 to 25mm).

10.4 Slurry surfacings may be used on footways and on very lightly trafficked carriageways carrying low speed traffic (ie in areas with a 30 mph or lower speed limit). Some micro-surfacings have sufficient initial surface texture to enable their use on high speed roads, and are presently undergoing trials to determine what texture level will be retained. The performance in trials of proprietary slurry surfacing and micro-surfacing systems will determine their suitability for the site classifications and traffic levels to be set out in the BBA HAPAS ' Guidelines Document for the Assessment and Certification of Thin Surfacing Systems for Highways.'

> 10.5 When used on trunk roads including motorways, proprietary slurry surfacing and micro-surfacing systems shall have BBA HAPAS Roads and Bridges Certificates appropriate for the site classification and the level of traffic in commercial vehicles/lane/day to be carried. Prior to the issue of Certificates, a Departure from Standard shall be obtained from the Overseeing Organisation before slurry surfacings (except those complying with BS 434), or micro-surfacings, are used on schemes in the UK.

Benefits

Skid Resistance

10.6 Reasonable values for micro-texture (ie low speed skid resistance) and abrasion resistance may be obtained by selection of a suitable aggregate type with a minimum polished stone value (PSV) and maximum aggregate abrasion value (AAV) in accordance with Chapter 3 of HD 36 (DMRB 7.5.1). Aggregates with a high polished stone value (PSV) are required for stressed sites such as braking areas, hills or bends. Aggregates with a low aggregate abrasion value (AAV) are necessary for heavily trafficked sites to reduce the rate of wear. High speed skid resistance is determined by micro-texture and retained surface texture.

Appearance

10.7 Slurry and micro-surfacings 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. Slurry and micro-surfacings can be used on surfaces that are fretting, and on those showing early signs of ravelling, to halt further deterioration. Coloured aggregates or mixtures may be used for delineating hard shoulders and central reserves, or for traffic calming measures where traffic levels are appropriate.

Conservation

10.8 Planing before treatment is not necessary when the profile is acceptable, and ironwork may not need to be raised for slurry surfacings and Type A micro-surfacings. Material usage is low, components are mixed cold using damp aggregates and no energy is expended on drying and heating the constituents.

Environment

10.9 Bitumen emulsions are environmentally friendly, the emissions being mainly water vapour. Cutback solvent is usually kerosene (similar to domestic paraffin), one of the least hazardous low cost organic solvents.

Profile

10.10 Micro-surfacing improves the profile of the underlying surface, particularly in the transverse direction as these products are spread using a fixed screed mounted on either skis or a very short wheel- base frame.

Ride quality

10.11 Micro-surfacing may improve ride quality, particularly if the problem is caused by undulations of very short wavelength. Undulations with a wavelength greater than about 1 m may be slightly improved.

Noise

10.12 Tyre noise is relatively low because slurry surfacings have low or fairly low macro-texture. Micro-surfacings with a higher texture may be less quiet. How micro-surfacings compare with low noise, hot paver-laid thin wearing course systems has yet to be determined.

Preservation

10.13 Slurry and micro-surfacings can be used on surfaces that are fretting, and on those showing early signs of ravelling, to halt further deterioration.

Limitations

Macrotexture

10.14 There are currently no slurry surfacings that can maintain adequate surface texture for high speed roads for more than a few weeks; therefore these materials should not be used on high speed roads.

Profile

10.15 Slurry surfacing does not improve the profile, either transverse or longitudinal, of the existing surface, so defects of this nature should be reduced to acceptable levels before their use.

Speed of works

10.16 Laying slurry and micro-surfacings, particularly the thicker varieties, is relatively slow and 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 used however, traffic may use each layer as it becomes sufficiently stable.

Permeability

10.17 Although slurry and micro-surfacings arrest surface deterioration, most products are permeable to a greater or lesser extent. They should not be assumed to be entirely waterproof.

Structural Strength

10.18 Slurry surfacings do not increase the load bearing capacity of the pavement structure. Thicker micro-surfacings may add to the structural strength of the pavement, but any claims made by a system proprietor should be confirmed by the BBA HAPAS certificate.

Sensitivity to Weather Conditions

10.19 Slurry and micro-surfacings with emulsion binders 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.

Application Techniques

10.20 Slurry surfacing and micro-surfacing with BBA HAPAS Roads and Bridges Certificates shall only be laid by Contractors approved by the system Proprietors. Installation and quality control procedures shall comply with the requirements of Clause 918 and Clause 927, respectively, of the Specification (MCHW 1) and with the requirements of the BBA HAPAS Certificate and method statement agreed by the BBA.

Surface Preparation

10.21 The surface onto which the slurry or micro-surfacing 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 Chapter 11 of this Part. If the excess bitumen is not removed, it is likely to bleed through the slurry surfacing.

10.22 All ironwork, kerbs, edges, road studs, street furniture and when required, road markings should be masked with self adhesive masking material. Turves, oil, sand and similar materials must not be used. Junctions with surfaces not to be treated should be masked to produce well defined, clean joints.

Weather conditions
10.23 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 surface by means of a mist spray, to avoid the emulsion breaking too quickly. The surfacing should also be protected from the effects of rain or frost before the slurry or micro-surfacing has developed sufficient resistance.

Equipment
10.24 The equipment needed for installation is dependent on the process used and can vary from brooms and squeegees used for veneer coats of slurry surfacing on footways, to integrated mixing and placing equipment used for micro-surfacings.

1.5 mm and 3 mm thick Slurry Surfacing to BS 434
10.25 These materials are most suitable for footways with an acceptable profile, where the surface is beginning to fret or is in the very early stages of ravelling. They may be mixed on site using a variety of plant, or for small areas, delivered to site as premixed material in suitable containers, which may need remixing or stirring before use. The material may be applied using a small spreader box (the preferred method) or by hand using squeegees over the existing footway. The slurry should be worked into any cracks and up to the edge of kerbs and street furniture in order to seal the surface. The final finish should be made with a broom drawn across the surface in a consistent direction, in order to give the finished product a satisfactory appearance.

Slurry Surfacing, 0/2 and 0/4 Aggregates
10.26 These products are normally laid about 3-6 mm thick in a single layer and have little regulating ability. They may be used on footways in exactly the same manner as BS 434 materials, and also on cycleways and very lightly trafficked roads (eg on housing estates), where an existing bituminous surfacing is beginning to fret. 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. The speed of laying can be reasonably fast but, as with all slurries, 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.

Micro-surfacing
10.27 These products are normally laid in two layers with a total thickness up to 20 mm. They contain coarse aggregate up to about 10 mm within a continuously graded material. They may be laid in two, or occasionally more, layers using continuous flow mixers and spreader boxes, and therefore can regulate transverse irregularities to a considerable extent and arrest fretting and ravelling.

10.28 It is probable that some ironwork will need resetting because of the thickness of micro-surfacing 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 micro-surfacing 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.

Slurry surfacings to BS 434

Binders
10.29 Materials produced and applied in accordance with BS 434 should only use unmodified emulsion binders as specified in Part 1 of that Standard. The following are suitable:

- Class A4 Rapid Setting or Class K3, capable of producing slurries which are sufficiently stable during mixing and laying such that premature breaking of the emulsion binder is avoided, but developing early resistance to damage by traffic or by rain.

- Class A4 Slow Setting. This can be used where the rate of set is less important, when the slurry can be expected to dry out naturally before being subjected to traffic or to rain.

Aggregates
10.30 The aggregates should be crushed igneous rock, gritstone or slag, blended where necessary with clean sharp naturally occurring sand which is free from silt, clay or other fine material. The aggregate grading curve should be smooth and not gap graded. Slurry surfacing can be very sensitive to the source, grading and type of fine aggregate.

Additives
10.31 Additives normally used to control consistency, mix segregation, and setting rate are Portland Cement to BS 12, hydrated lime to BS 890 and/or chemical retardants.

10.32 With natural bitumen as the binder, red pigmentation is the most common colour used. The amount of filler that can be replaced by pigment has to be restricted otherwise the slurry will be adversely affected, thus colours are not bright.

Mixing

10.33 The precise proportions of each constituent should be determined after trials at the plant to be used in the works.

10.34 The binder content by mass should be appropriate to the bulk density of the aggregate. When blast furnace slag is used, the bulk density of the aggregate is generally less than that of natural aggregates or steel slag, and a higher target binder content by mass will be required. (The proportion by volume will be similar in the two cases).

10.35 The component materials should be measured into a mechanical mixer and mixed until the aggregate is uniformly coated with bitumen emulsion and the slurry is of a consistency that can be laid satisfactorily.

10.36 If a bond coat is required it should be applied in accordance with BS 434 Part 2 before the slurry surfacing is spread. The rate of spread of the bond coat will depend on the surface to be treated. For bituminous materials the rate should be within the range 0.15-0.3 l/m^2 and for concrete surfaces 0.4-0.6 l/m^2. The use of a polymer modified bond coat may be advantageous on concrete surfaces.

10.37 The slurry should be evenly spread such that the layer thickness conforms to the design requirements of the work. Care should be taken to ensure that all surface cracks, voids and depressions are completely filled with slurry. The slurry as discharged from the mixer should be used without any further addition and should be laid continuously by a mobile mixing machine feeding directly into the spreader box. In some areas, such as confined areas on footpaths, central reserves and the like, it is recognised that the material may have to be spread by hand. Even so, hand laying should be avoided wherever possible.

Visual Appearance

10.38 The finished surface should have a uniform texture and colour throughout the work. The finished product should be free from blow holes and surface irregularities due to scraping, scabbing, dragging, droppings, excessive overlap or badly aligned longitudinal or transverse joints. Variations in the colour of slurry surfacing can sometimes occur initially but these tend to stabilise with time, often within 24 hours, dependant on the weather conditions and trafficking. Efflorescence can occur during the first 24 hours with mixtures that use hydrated lime as an additive, and may remain for some time. This is not necessarily an indication of uneven mixing or segregation and it should normally disappear after 2 or 3 weeks.

End Performance Specification

10.39 Clauses 918 and 927 in the Specification (MCHW 1) and associated Notes for Guidance (MCHW 2) are end performance specifications, with a two year guarantee requirement, normally of two years duration. Almost all slurry and micro-surfacing systems are proprietary products and as such, require certification by BBA HAPAS. Thus the capability of each proprietary system to provide the desired performance will be assessed in advance. The only exception to this is slurry surfacing which complies with BS 434.

10.40 The BBA HAPAS 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 if any, and aftercare. The performance requirements for slurry surfacing to Clause 918 during the guarantee period relate to wear and to loss of the surfacing, and limits are set on the exposure of the substrate permitted. Clause 927 for micro-surfacing includes similar limits and in addition, sets limits for the minimum retained texture depth in the nearside wheel track and maximum 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 and micro-surfacing systems are monitored and compared against the specified requirements.

10.41 Clauses 918 and 927 of the Specification (MCHW 1) call for rheological product identification and Vialit Cohesion of the recovered binder to be provided by the Contractor. It is unlikely that performance can be determined from binder data alone as systems are highly dependent on the aggregate grading, its physico-chemical nature and the emulsion set. However these are all proprietary products and the data is required for product identification and thereby to ensure consistency.

Audit Checks

10.42 It should not be necessary to carry out routine audit checks on proprietary products with a two year guarantee. 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 requirements of the Specification and, when issued, with the requirements of the BBA HAPAS Certificate and the system proprietor's method statement. Non-compliance should be reported to the Overseeing Organisation and the BBA, and may, if serious and ongoing, result in the suspension of the BBA certificate for the system.

Description, Evaluation and Avoidance of Failures

10.43 Slurry and micro-surfacings can fail in a number of ways. Table 10.1 summarises possible causes of these failure, 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	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, ie 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 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.
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 opened 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 then 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 or micro-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	
Ridge		Check that the screed has no notches. 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 10.1 Defects in Slurry Surfacing

11. RETEXTURING (Bituminous)

11.1 The wet skidding resistance of an asphaltic road is generated primarily by the microtexture of the aggregate in the surface. This microtexture is gradually polished by traffic until an equilibrium level is reached. HD 36 (DMRB 7.5.1.3) provides advice on the choice of aggregate and HD 28 (DMRB 7.3.1) on the standards for the skidding resistance of in-service roads.

11.2 The ability of a surface to maintain adequate skidding resistance at high speeds is governed by the macrotexture of the surfacing. As a surfacing ages, the macrotexture may fall as chippings are embedded into the asphalt matrix or substrate or excess binder comes to the surface. In some circumstances, for example over-rolling, the chippings in a new surfacing may be embedded too far and the requirements for texture depth of a new road may not be met.

11.3 Retexturing is the mechanical reworking of a sound road surface to restore either skidding resistance, texture depth or both.

Retexturing techniques

11.4 The suitability and effectiveness of a retexturing treatment depends on the condition of the road prior to treatment. Some treatments can increase both skidding resistance and texture depth; others may increase skidding resistance but reduce texture depth. There are also treatments which increase texture depth with little effect on skidding resistance.

11.5 Advantages include:

a) conservation of natural resources by reworking an existing surface;

b) retexturing may be more economical than some traditional resurfacing methods, especially where small areas are to be treated;

c) most processes can be carried out at any time of year in all but the most severe weather conditions;

d) traffic disruption is reduced compared with conventional treatments because of short lead-in times and the speed of the processes;

e) can be used as a "stop-gap" measure to treat small, high-risk sites.

11.6 Disadvantages include:

a) retexturing should not be used on unsound roads where there is cracking or surface irregularities, or on roads with sealing or overbanding.

b) some processes cannot treat roads with severe transverse deformation, such as heavily rutted surfaces.

c) road surfacing features such as ironwork, white lining and traffic detection loops may have to be avoided or protected.

11.7 The durability of the results of a treatment will depend on the type and geometry of road, the quantity and behaviour of the traffic, the aggregate and the rate of spread of chippings, where used, in the wearing course. However, just as a new surfacing will polish under the action of traffic, the aggregate on a retextured surface will eventually polish back to an equilibrium skidding resistance level, close to that of the original surfacing. On a high stress site, where there is much braking and turning, the improvement may last a matter of months, but, in a low stress site, the same treatment may continue to show an improvement over the untreated surface for three years or more.

11.8 The following paragraphs give some comments on available methods and suggestions on their application for restoring skidding resistance and/or surface texture depth. Table 11.1 gives a summary of these methods and suggestions.

Impact methods

11.9 Processes in this category involve striking the road surface with either hard-tipped tools or hard particles. These treatments are effective where the loss of skidding resistance is due to polishing and affect mainly the aggregate particles and the weathered asphaltic matrix.

a) *Bush hammering*: The road surface is struck by a number of impact heads with chisel-ended hammers with hardened tips. This process enhances skidding resistance, but can sometimes reduce texture depth, depending on the condition of the existing road surface and the severity of the treatment.

b) *Shot blasting*: The impact is by steel shot projected at high speed from a rotating wheel. As the surface is scoured, both shot and arisings are recovered and separated, with the steel shot stored for reuse. This process improves both skidding resistance and surface texture depth of chipped rolled asphalt surfacings by removing the weathered asphaltic matrix and leaving the chippings (with renewed faces) exposed. There is a risk of chippings that are not properly embedded, such as in surface dressing, becoming loosened by this process, as the supporting matrix is removed.

Cutting and scabbling/flailing

11.10 This category includes cutting, sawing, grooving, grinding and scabbling/flail grooving. In the latter case, the cutting action is combined with impact on the cutting heads.

a) *Grooving/grinding*: Using diamond-tipped blades assembled in configurations to suit the patterns of cutting required. This process can be used to provide either discrete grooving patterns or for bump cutting. The treatment affects macrotexture and can reduce texture if the blades are in a close-spaced configuration. Microtexture is often unaffected because the plateaux between grooves are the original surface.

b) *Longitudinal scabbling*: Hardened tips set into the edges of steel washers are loosely mounted side-by-side and drawn across the road surface whilst being hydraulically loaded. This process enhances skidding resistance, by removing material from the tops of particles to expose new aggregate faces, but it reduces surface texture depth by the same process.

c) *Orthogonal grooving*: This consists of deeper longitudinal and transverse grooving combined with scabbling. The skidding resistance is improved but, whilst the surface texture depth is improved initially, the grooves may close up under heavy trafficking. Further, the regular grooves generated within the road surface can give rise to increased road noise. Although this treatment can provide significantly enhanced skidding resistance, it is not a preferred option as it can be less comfortable for all road users and may reduce the ride stability of motorcyclists.

Fluid action

11.11 This involves the surface being subjected to the action of a fluid at high temperature or pressure. These treatments are not mechanical reworking of the road surface to expose new aggregate surfaces, and as a result do not restore skidding resistance lost through the polishing action of traffic.

Other considerations

11.12 Although retexturing is a useful option to consider when addressing problems of skidding resistance or surface texture depth loss due to the action of traffic, there will always be other factors to be taken into account.

a) Some treatments will be more appropriate for some surfacings than others. For example, an aggressive cutting or flailing technique would be inappropriate for a surface dressing or other surfacing type where small aggregate particles are relatively loosely bound to the substrate or surrounding matrix. There would be a risk of the surfacing becoming separated from the substrate by direct action of the treatment of water ingress and frost action.

b) The effect of an individual process of both skidding resistance and texture depth must be considered in the light of what is required in a particular situation. For example, where surface texture is already at an acceptable level or where increasing it may be undesirable, a treatment that does not increase surface texture would be appropriate.

c) Retexturing is most effective on road surfacings that are generally sound. If some sealing action is required in addition to improved skidding resistance or texture, retexturing would be inappropriate. Similarly, a surface which is fretting or losing chippings may be damaged further by mechanical action.

11.13 As with all processes, the advice in this Chapter cannot cover all contingencies, it is appropriate to get advice from the contractors when sourcing these treatments as to details of a particular process and its suitability for a particular site.

Surfacing type	Original condition: effect required from treatment		Suitability of treatment processes: Bush hammering	Shot blasting	Grooving/ grinding	Longitudinal scabbling	Orthogonal grooving	Carbonising	Water-jetting
Chipped rolled asphalt	Polished aggregate: recovery of skidding resistance	good[1] texture	✔	✔	✔	✔	✔	O	O
		poor[1] texture	✔	✔	✔	x	x	O	O
	Embedded chippings: recovery of texture depth	good[2] SR	O	✔	O	x	✔	✔	✔
		poor[2] SR	O	✔	O	x	O	✔	✔
	Excessive noise/ excessive texture	good SR	✔	x	O	✔	x	x	x
Surface dressing	Polished aggregate: recovery of skidding resistance	good texture	✔	x	x	O	x	x	x
		poor texture	✔	O	x	x	x	x	x
	Fatted-up: recovery of texture depth	good SR	x	x	x	x	x	✔	✔
		poor SR	x	x	x	x	x	✔	✔
Thin surfacings	Polished aggregate: recovery of skidding resistance	good texture	✔	✔	✔	✔	x	x	x
		poor texture	✔	✔	✔	x	x	x	x
	Removal of binder film	good SR	O	O	x	x	x	O	O
Close textured macadams	Polished aggregate: recovery of skidding resistance	good texture	✔	✔	O	✔	x	x	x
		poor texture	✔	✔	O	x	x	x	x
	Removal of binder film	good SR	O	O	x	✔	x	✔	✔

Key:
- SR Skidding Resistance
- ✔ Appropriate treatment
- x Not recommended
- O Treatment may be appropriate in some circumstances but effects will be limited and depend on surfacing condition

Notes:
1. SMTD = Sensor Measured Texture Depth. When referring to texture in this context, "good" and "poor" are approximately the following: SMTD > 1.2 mm, good; SMTD < 0.6 mm, poor.
2. When referring to skidding resistance, "good" and "poor" denote above or below investigatory level respectively.

Table 11.1 Appropriate circumstances and treatments for retexturing bitumen-bound surfacings

General note: Except for thin wearing course systems, proprietary surface dressing and, where permitted, stone mastic asphalt surfacings, which have minimum in-service texture depth requirements at the end of their warranty periods, it has not been found necessary to introduce standards for in-service texture depth, adequate texture being maintained by erosion of the binder matrix. Nevertheless reduced texture may contribute to a reduction in low speed skidding resistance, although not necessarily to below the investigatory level, and which may be enhanced by an appropriate treatment.

13. MISCELLANEOUS SURFACING MATERIALS

13.1 There are a wide variety of surfacing materials that are not covered in the other chapters of this Part. These are products that are either undergoing development or that are little used on trunk roads.

Dense bitumen macadam

13.2 Dense bitumen macadam wearing course to BS 4987 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.

Open graded bitumen macadam

13.3 Open graded bitumen macadam wearing course to BS 4987 is available with both 10 and 14 mm nominal aggregate sizes. They are not however, designated 'preferred mixtures' in BS 4987. These products have low strength and their durability is suspect. They are not suitable as surfacings for high speed or heavily trafficked roads.

Close graded bitumen macadam

13.4 Close graded bitumen macadam to BS 4987 is available in both 10 and 14 mm nominal sizes. They are designated 'preferred mixtures' in BS 4987, however 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 must also be suspect and they are not suitable for use on heavily trafficked roads. In addition, as the texture depth obtained is low they are not suitable as surfacings for high speed roads.

Dense tar surfacing

13.5 Few suppliers carry tar routinely and the material is generally only available to special order. The only permitted use of dense tar surfacing is in vehicle standing or parking areas to take advantage of its resistance to fuel spillage, where traffic speeds are low, and significant texture depth is unnecessary. Dense tar surfacing (DTS) should comply with the requirements of BS 5273 with a coarse aggregate content of 50%. The narrow temperature range specified limits the time available for compaction and a minimum depth of 40 mm is required even in good conditions. If trafficking is very severe, the use of crushed rock fines should be specified to obtain sufficient resistance to deformation. Because tar based materials stiffen rapidly with age any deformation that occurs is more likely to happen in the first or second summer rather than subsequently. Dense tar surfacing has proved to be very durable although its texture can reduce in time. Because it is little used, the material is unlikely to be cost effective except in rare instances.

In-situ Macadams

13.6 In-situ macadams are proprietary products which are either applied as multilayer surface dressings to form a thin surfacing 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 BBA HAPAS certification.

Controlled Texture Asphalt

13.7 Controlled texture asphalt is a surfacing somewhat similar to a Dense Bitumen Macadam. It is designed to be placed with an initial texture depth that will be maintained for the life of the surfacing. As yet it does not provide an adequate initial texture depth to permit its use on high speed roads and it is also expensive. Controlled texture asphalt contains a mixture of two aggregates with significantly different resistance to abrasion; typically with aggregate abrasion values in the ratio of 2:1. The grading of the material is based on the packing properties of the selected aggregates to give a mixture with a controlled void content and surface texture. Once the target grading has been selected and the binder content determined, production tolerances have to be more precise than those specified for British Standard materials. Controlled texture asphalts are proprietary and will therefore require BBA HAPAS certification.

Cold laid materials

13.8 Cold laid materials are being developed for permanent reinstatements as a result of the 'Specification for the Reinstatement of Openings in Highways' issued by the Highways Authorities and Utilities Committee (HAUC). A number of products have HAUC approval for use in the reinstatement of trenches on roads carrying traffic up to 30 msa.

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