BRITISH STANDARD

Bitumen road emulsions –

Part 2: Code of practice for the use of cationic bitumen emulsions on roads and other paved areas

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Contents

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Summary of pages

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Foreword

Publishing information

This part of BS 434 was published by BSI and came into effect on 29 December 2006. It was prepared by Technical Committee B/510, *Road materials*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 434 supersedes BS 434-2:1984, which is withdrawn.

Information about this document

This new edition represents a full revision of the standard, and introduces the following principal changes:

- refers to BS EN 13808;
- covers the use of polymer modified bitumen emulsions;
- includes guidance on the use of bitumen emulsions in the construction and maintenance of footways and cycleways;
- includes guidance on the use of bitumen emulsions as bond or tack coats;
- includes reference to permanent cold lay surfacing materials;
- includes a bibliography containing sources of further information on the various techniques included in this British Standard.

As a code of practice, this part of BS 434 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Any user claiming compliance with this part of BS 434 is expected to be able to justify any course of action that deviates from its recommendations.

Assessed capability. Users of this British Standard are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This part of BS 434 provides recommendations and guidance on the general usage of cationic bituminous emulsions on roads and other paved areas. The emulsions covered conform to BS 434-1, or BS EN 13808 (modified and non-modified), or are proprietary emulsions.

This British Standard provides guidance on where the various processes using bituminous emulsions are suitable for use and indicates where suitable design procedures may be found. Advice is also given on those situations in which the processes are unsuitable or marginally suitable.

Where there is an option, performance or outcome specifications have been used rather than input or recipe specifications. This follows the general approach adopted for European Standards and the general move towards performance specifications by many specifiers.

Anionic emulsions are covered only for exceptional circumstances. Cationic emulsions have been specified for most purposes, although in some cases an anionic alternative may be used.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 434-1:1984, *Bitumen road emulsions (anionic and cationic) – Part 1: Specification for bitumen road emulsions*

BS 594-2:2003, *Hot rolled asphalt for roads and other paved areas – Part 2: Specification for transport, laying and compaction of hot rolled asphalt*

BS 598-108, *Sampling and examination of bituminous mixtures for roads and other hard paved areas – Part 108: Methods for determination of the condition of the binder on coated chippings and for measurement of the rate of spread of coated chippings*

BS 1377-3:1990, *Methods of test for soils for civil engineering purposes – Part 3: Chemical and electro-chemical tests*

BS 3136-2, *Specification for cold emulsion spraying machines for roads – Part 2: Metric units*

BS 3892 (all parts), *Pulverized-fuel ash*

BS 4987-2:2003, *Coated macadam (asphalt concrete) for roads and other paved areas – Part 2: Specification for transport, laying and compaction*

BS 6463 (all parts), *Quicklime, hydrated lime and natural calcium carbonate*

BS EN 197-1, *Cement – Part 1: Composition, specifications and conformity criteria for common cements*

BS EN 12271 (all parts), *Surface dressing – Specifications*

BS EN 12272-1:2002, *Surface dressing – Test methods – Part 1: Rate of spread and accuracy of spread of binder and chippings*

prEN 12273, *Slurry surfacing – Specifications*[1)]

BS EN 12274 (all parts), *Slurry surfacing – Test methods*

BS EN 12697-26, *Bituminous mixtures – Test methods for hot mix asphalt – Part 26: Stiffness*

BS EN 12697-32, *Bituminous mixtures – Test methods for hot mix asphalt – Part 32: Laboratory compaction of bituminous mixtures by vibratory compactor*

BS EN 13808, *Bitumen and bituminous binders – Framework for specifying Cationic bitumen emulsions*

NOTE See the Bibliography for sources of further information on the various techniques included in this British Standard.

3 Terms and definitions

For the purposes of this part of BS 434, the following terms and definitions apply.

3.1 bitumen
virtually involatile, adhesive and waterproofing material derived from crude petroleum, or present in natural asphalt, which is completely or nearly completely soluble in toluene, and very viscous or nearly solid at ambient temperatures

3.2 bituminous binder
adhesive material containing bitumen

3.3 polymer modified bitumen
bitumen whose rheological properties have been modified during manufacture by the addition of one or more polymers

3.4 bitumen emulsion
dispersion of bitumen in water, which usually contains an emulsifier to assist in maintaining the stability of the emulsion

NOTE This term embraces emulsions in which the bitumen contains a small amount of flux derived from petroleum which has been added to facilitate emulsification and/or to enhance in-service characteristics.

3.5 anionic bitumen emulsion
emulsion in which the emulsifier imparts negative charges to the dispersed emulsion particles

3.6 cationic bitumen emulsion
emulsion in which the emulsifier imparts positive charges to the dispersed bitumen particles

3.7 polymer-modified bitumen emulsion
emulsion in which the dispersed phase is a polymer-modified bitumen or a bitumen emulsion modified with latex

[1)] prEN 12273 is currently still a draft European Standard. To be published by CEN as EN 12273 and adopted in the UK as BS EN 12273.

4 Emulsion types

4.1 General

The UK specification for bitumen emulsion (BS 434-1) was last published in 1984 and has remained substantially unchanged since then apart from two minor amendments. It has recently been replaced by BS EN 13808 which is a significantly different document. This clause attempts to explain the differences within the context of the changes that have occurred since 1984.

4.2 BS 434-1 classification

In BS 434-1:1984 emulsions are classified on the basis of:

a) polarity – anionic or cationic (A or K);

b) emulsion stability (on a scale of 1-rapid, 2-medium, 3-slow breaking);

c) binder content.

Thus a K1:70 emulsion is a rapid breaking cationic emulsion with a nominal binder content of 70%. An A2:50 emulsion is a medium breaking anionic emulsion with a nominal binder content of 50%.

The stability of emulsions can be changed by altering the type or quantity of emulsifier used in their manufacture. In recent years the development of tests to measure the break of the emulsion has resulted in numerical values, of breaking value or breaking index, being attributed to emulsion. This more accurately reflects their stability than the traditional allocation of 1, 2 or 3 in BS 434-1:1984 (see above) as an indication of stability, and has allowed the stability of emulsion to be defined numerically (breaking index) in BS EN 13808.

4.3 BS EN 13808 classification

BS EN 13808 classifies emulsions in a more detailed way than BS 434-1 utilizing up to seven characters, on the following basis:

- polarity, e.g. C;
- nominal binder content, e.g. 67;
- indicate type of binder:
  - B paving grade bitumen (BS EN 12591);
  - P addition of polymer;
  - F addition of more than 2% flux;
- class of breaking value (from 0 to 7) (see **4.5**).

Thus for example a C70 B2 emulsion is a cationic bitumen emulsion with a 70% nominal binder content, produced from paving grade bitumen (conforming to BS EN 12591) with a class 2 breaking value.

Similarly a C60 BPF6 emulsion is a cationic bitumen emulsion with a nominal binder content of 60% containing polymer and flux and having a class 6 breaking value.

4.4 Polymer modified bitumen products

4.4.1 Background

At the time of publication of BS 434-1:1984 almost all bitumen emulsions were produced using paving (penetration) grades of bitumen. A significant change since the initial publication of that British Standard has been the introduction and development of polymer modified bitumen products, the growing use of which has presented problems of specification.

Initially these products were sold as proprietary products to specifications produced by manufacturers, a situation which leads to confusion with no standard specifications for them. This problem was recognized by the introduction of an assessment and certification scheme for such products under the HAPAS (Highway Authorities Product Approval Scheme) administered by the British Board of Agrément (BBA) which produced a list of tests, including ageing and rheology, against which emulsions can be assessed. If the performance of the emulsion satisfies the requirements of the scheme it is eligible to receive a BBA Roads and Bridges Certificate.

The testing under this scheme goes beyond the requirements of BS 434-1 in that for surface dressing, for example, it not only requires testing of the emulsion and of the recovered binder from the emulsion (as in BS EN 13808) but also evidence of two years' satisfactory performance on the road at a minimum of three appropriate sites. Many of the binder testing requirements of the HAPAS binder specifications for polymer modified bituminous emulsions are also stipulated in the *Specification for Highway Works* (SHW) [1], Clauses 919 and 922 for surface dressing, Clause 920 for bond coats and Clause 918 for slurry surfacing and the Notes for Guidance and Appendices relating to them.

NOTE The British Board of Agrément/Highway Authorities Product Approval Scheme (BBA/HAPAS) is a scheme in which proprietary products may be validated and their performance measured and published. This ensures that a product, once placed on the market, has attached to it performance criteria which can be monitored by the purchaser and ultimately by BBA/HAPAS, as an independent UK certifying body. BBA is the UK representative of the European Technical Approval (ETA) system which is set up to validate products for which it has not been possible or is not yet possible to produce a British or European Standard. Further information on BBA/HAPAS and the certification status of products can be found on the BBA website at www.bbacerts.co.uk.

4.4.2 Polymer modified bituminous emulsions

The most significant advance in bituminous emulsions in the last two decades has been the introduction of polymer modified bituminous emulsions. The effect of polymer modification is to enhance the performance on the road, which can be observed in practice. Precisely how this improved performance is achieved, however, is more difficult to define.

Bitumen is a thermoplastic material, which softens when heated and becomes hard and brittle when cooled. Thus at higher temperatures it can become too soft to hold the chippings in a surface dressing system and at cooler temperatures it can become so hard and brittle that it fractures under traffic stresses and loses chippings. One effect of polymer modification is to widen the temperature range over which bitumen exhibits good binder properties. Table 1 compares the softening point (high temperature) and Fraass brittle point (low temperature) properties of three paving grade bitumens and a polymer modified bitumen (the difference in temperature Δ T).

Table 1 **Temperature susceptibility of bitumen**

Binder	**Softening point** °C	**Fraass** °C	**Δ T** °C
50 pen	50	−10	60
200 pen	38	−20	58
450 pen	28	−30	58
Polymer modified binder	76	−25	101

From Table 1 it is clear that the polymer modified material exhibits a good level of performance over a wider temperature range than the paving grade binders. In addition to increasing the useful temperature range, polymer modification also enhances the performance over this range. Enhancement of a number of physical properties has been recognized and measured including the following:

- cohesion (Vialit pendulum);
- adhesion;
- tensile strength (toughness/tenacity);
- viscosity (sliding plate rheometer);
- ductility/elastic recovery (ductilometer);
- forced ductility;
- cold temperature bending (bending beam rheometer);
- rheology (DSR).

4.4.3 Validation and use

While all of these improvements in the physical properties of polymer modified binders can be demonstrated, there is little validation of the direct relationship between any of the physical properties and performance on the road. Currently, cohesion (as measured by the Vialit pendulum test) is taken as a measure of performance for surface dressing binders, slurry surfacing binders and of bond and tack coats.

A number of different polymer types have been used in the modification of bitumen including:

- SBS (styrene butadiene styrene);
- SBR (styrene butadiene rubber);
- EVA (ethylene-vinyl acetate co-polymer);
- PB (polybutadiene).

All of the above polymers (and others) can be shown to modify the properties of bitumen, each modifying different properties to a different extent. In general, increasing the amount of polymer in a blend increases the change in properties. However, since polymers are significantly more expensive than bitumen, this tends to limit the amount of polymer in a blend, balanced against the level of improvement in properties.

Since different locations for surface dressing, for example, exhibit conditions which differ in severity, all do not require binders of the highest performance. The recommendations given in Road Note 39 [2] Figures 7.3a and 7.3b illustrate this by indicating the type of binder (conventional, intermediate and premium) that should be used on sites of differing severity and Figure 9.1.2 which defines the three grades of binder on the basis of their cohesion (in J/cm^2) as measured by the Vialit pendulum test.

4.5 BS EN 13808

BS EN 13808, the European specification for bitumen emulsion, replaces BS 434-1:1984. Its purpose is to bring together all the existing CEN member country specifications into one standardized specification to apply throughout Europe. In order to achieve this standardization, EN 13808 has been developed as a framework specification, which includes a number of classes for each property of bitumen emulsions. Each country may select from the framework specification those classes for properties it considers appropriate (including class 0 – no performance determined), based on climate, local conditions and experience. Thus each country's specifications for apparently similar materials may differ considerably.

It should be noted, however, that some properties, i.e. those specified by Mandate M/124, Road Construction Products, need to be measured on all bitumen emulsions. This is to ensure that the products conform to the essential requirements of the EU Construction Products Directive (89/106) [3].

The mandated properties to be measured in the specifications are:

- consistency at intermediate service temperature;
- consistency at elevated service temperature;
- cohesion (modified bitumen emulsions only);
- durability of consistency at intermediate service temperature;
- durability of consistency at elevated service temperature;
- durability of cohesion (modified bitumen emulsions only).

Satisfying the requirements of the Mandate ensures that bitumen emulsions are eligible for CE marking.

4.6 Emulsions volume/weight conversions

Emulsions are normally sold by mass, but for practicality rates of application are measured in litres per square metre (l/m^2). 1 kg of cold emulsion is approximately (0.98–1.0) l at ambient temperature, depending on the binder content. Similarly, 1 kg of 70% nominal binder content emulsion is approximately (1.02–1.03) l at a spraying temperature of (75–85) °C. As most applications fall within these limits, increments of 0.1 for both litres and kilograms can be considered synonymous.

Some standards specify emulsion rates of spread as kilograms per square metre (kg/m^2) of residual binder, which allows a choice of emulsion binder content. For example, the rate 0.15 kg/m^2 residual would approximately equate to 0.35 l/m^2 of emulsion with a 40% nominal binder content, or 0.25 l/m^2 of an emulsion with a 60% nominal binder content.

5 Handling, storage and safety

NOTE This British Standard cannot purport to cover all the issues of health, safety and environment associated with the various emulsion products. However, generic guidelines are available from the Road Emulsion Association [4], [5]. Furthermore, specific reference should be made to the Material Safety Data Sheets provided by suppliers.

5.1 Safe handling

Good hygiene practices should be exercised when dealing with emulsion products. In particular, relevant personal protective equipment should be worn to restrict contact with the skin (gloves, glasses, boots, etc.). Hands should be regularly washed, particularly before consumption of food or drink. The use of barrier creams is recommended. Solvents should never be used for skin cleaning.

5.2 Storage

The following key points should be considered when storing emulsions and emulsion products.

- In storage and use, cationic and anionic emulsions are incompatible and should be segregated.
- All emulsion products should be protected from frost and agitated according to manufacturer's recommendations to avoid excess settlement.
- When heating emulsions, there should be agitation to avoid localized overheating and the emulsions should never be heated in excess of 90 °C to avoid boiling.
- Drums should be protected, if possible, from high temperatures which could cause pressure hazards when the drum is opened. Bungs should remain tight.

NOTE Further guidance can be obtained from Road Emulsion Association publications [4] listed in the Bibliography.

6 Suitability of treatments and processes

The guidance in Table 2 should be used to establish the use and suitability of various treatments and processes for road surfacing. Once a particular process or treatment has been selected for use, the recommendations and more detailed guidance given in Clauses **7** to **17** should be followed.

Table 2 **Overview of processes**

Process	**Use and suitability**
Surface dressing (see Clause **7**)	Used to waterproof the pavement, and restore skid resistance and macrotexture. The process does not restore ride quality or rectify uneven surfaces. Correct design allows the majority of roads to be treated.
Bond coats and tack coats (see Clause **8**)	Used for adhesion and bonding of layers of asphalt. Bond coats are used to ensure a monolithic pavement structure and to resist traffic stresses while improving waterproofing of the roadbase.
Slurry surfacing (see Clause **9**)	Thin carriageway and footway resurfacing process which can restore skid resistance and macrotexture. Can be designed for most roads, cycleways and footpaths, particularly suited to urban areas.
Retread (see Clause **10**)	A method of recycling often using simple graders and reciprocating harrows. Suitable for regenerating and reshaping lightly trafficked urban and rural roads.
Deep recycling (see Clause **11**)	In-situ recycling of full width roads or haunches, using large specialist plant for large areas, or off-site recycling of recovered material, suitable for re-use on large or small sites.
Footway and cycleway construction (see Clause **12**)	Footways and cycleways are constructed to allow for lighter loads than carriageways, but they should be capable of carrying vehicles for access crossings and off-road parking.
Footway and cycleway maintenance (see Clause **12**)	Processes suitable for use include surface dressing and slurry surfacing to seal and restore the surface, or retread, where the condition is beyond resurfacing.
Patching and grouting (see Clause **13**)	The repair of broken, crazed or potholed areas to maintain the integrity of a surface, and/or to prepare for resurfacing treatment. Velocity patching is best suited to lightly trafficked rural roads.
Permanent cold lay materials (see Clause **14**)	Engineering grade cold lay materials, which may conform to BBA/HAPAS certification of performance. Used to enable road openings and other small areas in the highway to be reinstated.
Sealing and curing (see Clause **15**)	Sealing or curing of formations and subgrades, unbound bases and sub-bases, and cement bound materials in order to protect them from weather damage and site traffic during construction.
SAMIs (see Clause **16**)	Stress absorbing membrane interlayers (SAMIs) are used to delay reflective cracking in resurfaced road pavements. Additionally, they seal the roadbase and bond the new overlay to the existing surface.

NOTE Guidance on miscellaneous, specialist uses such as grass growing, sand dunes, slip-coats, protection of concrete pipes, crack filling, joints, rejuvenation and skid pans can be found in the various specialist publications listed in the Bibliography.

7 Surface dressing of carriageways

*NOTE This clause covers the surface dressing of carriageways. For footway, cycleway and untrafficked areas see Clause **12**.*

7.1 General

Surface dressing is a process which comprises the application of chippings and binder. It is critically dependent on correct design and execution by experienced personnel (see Foreword). Surface dressing is one of the most economic and efficient surfacing systems for waterproofing a pavement. One or more thick films of binder should be sprayed onto the surface upon which chippings, in various sizes or combinations of sizes, should be spread and rolled.

The following guidance should be followed when determining the most suitable type of surface dressing for use in a particular application.

Single dressing – Single layer of chippings on a single film of binder. The simplest form of dressing and best suited to lightly trafficked roads.

Racked-in surface dressing – A single thick film of binder plus two layers of chippings spread upon it. The first layer of chippings should be the larger and spread at approximately 90% shoulder to shoulder (in accordance with BS 598-108 or BS EN 12272-1) coverage. The second smaller chipping layer should be spread to slight excess in order to lock the larger chippings into place.

Double dressing – Two films of binder plus two layers of chippings. The first film of binder should be sprayed. Then the larger chipping should be spread followed in order by the second film of binder and the second, smaller, chipping. This is the most robust of the standard types of dressing and is less sensitive to variations in the substrate compared to single and racked-in dressings.

Sandwich dressing – Similar to a double dressing but the first film of binder is omitted. The larger chippings should be spread on the existing surface then a film of binder should be sprayed onto them and then the smaller chippings should be spread. This dressing is sometimes used where there is extensive fatting of the existing surface, or where there are wide variations in hardness transversely across a site. It is possible to combine double and sandwich dressing by using an initial spray in the areas that have not fatted if they are very rugose (for example outside the wheel tracks) and then continuing over the whole with the remainder of the sandwich process. Similarly it is also possible to combine single and sandwich dressings by using the first layer of larger chippings in, for example the wheel tracks and applying a single dressing over the whole.

Inverted double dressing – Used to be called pad-coat. An initial dressing of small chippings on a film of binder followed immediately or subsequently by a further single dressing of larger chippings. It is useful in some circumstances where the existing surface is very variable, particularly in hardness.

NOTE There are other, more complex, variations of surface dressing but they are usually proprietary and are designed for particular purposes, for example to provide quieter low tyre-road noise generation surface dressings.

7.2 Design and preparation

Road Note 39 [2] published by the TRL gives detailed guidance on the selection and design of surface dressing suitable for conditions in the United Kingdom. It also gives some guidance on the preparation of roads for surface dressing, however more detailed guidance on the practical aspects of the preparation of roads and the installation of surface dressing is given in the Code of Practice for surface dressing [7] available from the Road Surface Dressing Association.

NOTE National Highway Sector Scheme 13a, available from UKAS, provides a basis for quality assurance of the surface dressing process.

8 Tack coat and bond coat emulsions

8.1 General

NOTE Tack coats and bond coats are used to promote adhesion between layers of asphalt used in the construction of a paved area or used to bond a new surface course to an existing road surface when carrying out road maintenance. The choice of tack coat or bond coat depends on the condition of the substrate, the stiffness and binder richness of the layers and the type of site. This clause provides recommendations for the use of bond coats at high application rates, where additional waterproofing is required.

8.1.1 Tack coats

Tack coats should be K1-40 (C40 B 4/C40 BF 4) or K1-60(C60 B 3/C60 BF 3) bitumen emulsions conforming to BS 434-1:1984 or BS EN 13808.

Tack coats are conventional bitumen emulsions used to enhance the adhesion between layers of asphalt, which might otherwise be impaired due to minor dust problems or insufficient free bitumen on the surface of the layer being overlaid.

NOTE Tack coats are sensitive to over-application, which might result in the slippage or instability of a high binder content surface course with low air-voids.

8.1.2 Bond coats

Bond coats are proprietary materials and may have a BBA/HAPAS certificate detailing the performance claims made for the product (see notes). The certificates include guidance on application rates for the benefit of designers and specifiers. They are generally formulated to enable application at heavier application rates than are possible with tack coats and to provide greater cohesion.

Their use should be as specified in accordance with BS 594-2 or BS 4987-2.

NOTE 1 The provisions of this clause are not applicable to thin surface course systems produced under BBA/HAPAS certification, in which the bond coats are an integral part of the system.

NOTE 2 Further information on the specification of bond coats for motorways and trunk roads can be found in SHW Clause 920 [1].

NOTE 3 Until such time that BBA/HAPAS certificates are available (www.bbacerts.co.uk), producers of the bond coat should provide performance data for any claims made, detail the rates of spread suggested, which should be at least those included in the tables in BS 4987-2 and BS 594-2, and provide product identification in accordance with the BBA/HAPAS SG4 Guideline Document for bond coats [10].

8.1.3 Selection

The use of bond coat, in preference to tack coat, should be considered in the following circumstances.

- Where the designer or specifier wishes to achieve greater confidence in the adhesion between layers the use of a more cohesive (intermediate or premium grade) bond coat at the rates recommended in Table 3 and Table 4 of BS 4987-2:2003 and BS 594-2:2003 may be appropriate, e.g. between layers where bonding is likely to be difficult such as high stiffness modulus bases or aged and partly uncoated aggregate surfaces.
- Where the designer or specifier wishes to improve waterproofing at an interface the use of a more cohesive (intermediate or premium grade) bond coat at the rates recommended in Table 5 of BS 4987-2:2003 and BS 594-2:2003 may be appropriate. For maximized waterproofing (for example for bridge structures between the installed bridge deck waterproofing membrane and a stone mastic asphalt overlay) special hot-applied bond coats may be required at much higher rates of spread.
- Where the laying of the asphalt involves temporary trafficking by pedestrians or vehicles of the tack/bond coat, the use of "non-tacky" bond coat may be appropriate. Rates of application of bond coat should be in accordance with the rates detailed in Table 3, Table 4 and Table 5 of BS 4987-2:2003 and BS 594-2:2003 unless otherwise specified by the supplier.
- Bond coat should be considered when overlaying concrete with 100 mm or less thickness of asphalt. Target rates of application should be in accordance with Table 4 or Table 5 of BS 4987-2:2003 or BS 594-2:2003.

8.2 Application

A tack coat or bond coat should be applied prior to the laying of a new surface course, unless it is to be laid on a newly-laid binder course or base (roadbase), which is still in its "as-laid" clean condition.

NOTE 1 If tack coat or bond coat is not required under surface course laid on fresh binder course or base (roadbase) then this should be specified.

Tack coat or bond coat should be applied, when specified, at other layer interfaces.

Rates of application of tack coat should be specified in accordance with Table 1 or Table 2 of BS 4987-2:2003 and BS 594-2:2003.

NOTE 2 Application rates in these standards are quoted in kg/m^2 of residual bitumen. This differs from previous standards, which quoted rates in l/m^2 of total emulsion. For example, the rate 0.15 kg/m^2 residual bitumen would approximately equate to 0.35 l/m^2 of K1-40 or 0.25l/m^2 of K1-60 emulsion.

Rates of application of bond coat should be in accordance with the rates detailed in the BBA/HAPAS certificate, or, in the absence of such certificates, as specified in accordance with BS 4987-2 and BS 594-2, unless specified otherwise by the producer.

NOTE 3 The rates are given for guidance only and the purchaser should consider the requirements of each site on an individual basis.

Tack coats and bond coats should be applied at a uniform rate. For continuous laying operations, consideration should be given to specifying application by metered mechanical spraying equipment, spray tanker or, albeit of limited availability, spraying device integral with the paving machine. For small scale works and inaccessible areas application may be by hand held sprayer. After application, the emulsion should be allowed to break (i.e. turn from brown to black), before the asphalt is laid, unless it is applied by a paver with an integral spray bar Any emulsion accumulating in hollows should be dispersed by brushing before it is over-laid.

NOTE 4 Further guidance on the specification of the application of tack coats on motorways and trunk roads, including application tolerances and accuracy of spread, can be found in SHW Clause 920 [1].

BBA/HAPAS certified bond coats should be applied as specified by the certificate.

9 Slurry surfacing

9.1 General

Slurry surfacing is the generic name for a number of cold applied emulsion asphalt mixtures. These processes historically have had names such as slurry seal, slurry surfacing and microsurfacing (microasphalt) and are used for thin, intermediate and thick layers respectively using a range of nominal sized coarse aggregates and binders. Thickness ranges from 1.5 mm in a single layer to approximately 20 mm in two or more layers for sites from footpaths to motorways.

Originally some slurry seals were manufactured to recipe formulations. Others were mixtures designed by the provider for the situation in which it was to be used. With the progress towards European Standards (prEN 12273 and BS EN 12274 series) all slurry surfacings should now be designed to achieve an end performance with a continuum of gradings chosen by the contractor from very fine to relatively coarse.

9.2 Design and uses

9.2.1 General

The design of slurry surfacing is similar for all uses but different properties are optimized for different uses. These include the following.

- Slurry surfacing for reasonably fast roads with limited heavy traffic requires good skidding resistance with adequate macrotexture.

- Slurry surfacing for residential roads with parked vehicles and turning traffic requires good adhesion to the underlying surface with good resistance to disruption from, for example, powered steering.
- Slurry surfacing for airfields requires good resistance to breaking up under high stress which might produce foreign object debris (FOD) which, if ingested into a jet engine, might cause very expensive damage.
- Slurry surfacing for footways needs to provide a close texture yet retain the ability to resist indentation.

9.2.2 Design of slurry surfacing

The design of slurry surfacing should normally be carried out by the provider of the slurry surfacing in conjunction with the binder supplier. It is essential that the aggregate and the emulsion used, typically K3 (C55 B 7/C55 BF 7) or a proprietary polymer modified emulsion, are compatible with each other. Once a satisfactory design has been achieved with a particular source of aggregate and a particular binder replacing either, without carrying out further trials, might result in failure of the slurry surfacing to cure properly or to perform adequately. Additional constituents such as cement, chemical additive (see **9.2.3.4**) and water should be added to the mix at the time of production in order to control the flow and breaking characteristics of the mix.

Other constituents that may be added to increase the strength of the mixture or to enable the material to carry more binder are fibres and polymer modified emulsion.

9.2.3 Materials and constituents

9.2.3.1 General

The main requirements for all materials and constituents of slurry surfacing are that:

- they are consistent from batch to batch;
- they are delivered and stored in clean containers properly protected from the weather and from contamination such as leaves, rubbish and dust.

9.2.3.2 Aggregates

For many grades of slurry surfacing a continuously graded aggregate is used which is usually premixed at the point of supply to the required grading from a suitably-sized coarse aggregate and a suitable sand. Slurry surfacing designed to provide at least a minimum macrotexture over an extended period of time, often uses gap-graded aggregates which are more difficult to handle and are prone to some segregation, with the coarse aggregate rolling down the outside of any heap of the material. However, this can be avoided by good stock management, or by proportioning the coarse and fine aggregate separately into the mixer.

9.2.3.3 Binder

For slurries used in light duty areas, i.e. where there is little traffic and virtually no turning and braking, K3 emulsion should be used provided it is compatible with the relevant aggregate. However, with the introduction of powered steering on nearly all cars it is unlikely that K3 emulsion would be adequate in areas such as culs-de-sac, other residential roads or any road where traffic is braking and turning. In all of these areas, a suitable proprietary polymer modified emulsion should be used in order to improve durability. The use of polymer modified emulsion provides an emulsion that is engineered for optimum compatibility with the aggregate being used to meet performance requirements.

9.2.3.4 Other constituents

Other constituents of slurry surfacing may include some or all of the following.

a) *Filler*. Usually ordinary Portland cement conforming to BS EN 197-1. Other fillers include ground limestone, hydrated lime conforming to BS 6463 or pulverized-fuel ash (PFA) conforming to BS 3892.

b) *Fibres*. Their use is becoming more common as they enable thicker binder films to be held by the aggregate which improves durability and enables the use of a wider range of gradings, including gap gradings, especially when polymer modified emulsions are used.

c) *Chemical additive* (*"Dope"*). An additive that is added to the mix to control the speed of break. The amount added depends on the weather conditions occurring at the time of laying and the length of time available before the road has to be open to traffic.

d) *Water*. May be added to the mix in order to control the workability. Any water used should be of potable quality and free of contamination and harmful salts.

9.2.4 Preparation of the surface

The surface to be treated should be free of all loose material and dust as the slurry adheres to the topmost material of the existing surface. If this topmost material is not part of the structure the slurry delaminates and early failure becomes apparent. Cleaning should be undertaken to the level necessary to ensure the appropriate surface. Sweeping should be undertaken as a matter of course with additional scraping or pressure washing as necessary. Open cracks should be cleared of any vegetation. Care should be taken in the use of any weed killers as environmental limitations may be in place.

NOTE It may be appropriate to consult the Environment Agency[2)] to determine permitted regimes.

If the cracks are of sufficient size they should be filled with a suitable material such as grouting or other pre-treatment suited to the slurry surfacing being used.

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2) Contact the Environment Agency on 08708 506 506 or http://www.environment-agency.gov.uk

In some circumstances, such as treating a crazed or permeable surface or where there is traffic stress, a bond coat may need to be used. Bond coats should be applied in accordance with Clause **8**.

In hot weather it can be beneficial to use a light spray of water to prevent too rapid a break at the interface with the existing surface and to promote better adhesion.

The preparation of the site should include the masking, with self adhesive material, of all ironwork, road markings (if required, to permit their retention) and any dropped kerbs (if this is not done the slurry in the spreader box can spread over the dropped kerbs and stain them thus spoiling appearance).

9.3 Laying slurry surfacing

9.3.1 Equipment

9.3.1.1 General

All equipment, tools and machines used to lay slurry surfacing should be maintained in a satisfactory working condition at all times.

9.3.1.2 Proportioning and mixing

9.3.1.2.1 General

Materials may be proportioned by mass or by volume provided that this is consistent with the design. Individual devices should be used for each constituent of the mix. Each device should be clearly identified, calibrated and checked to ensure maintenance of its calibration status.

9.3.1.2.2 Mixing

Mixing should be carried out in a continuous mixer with sufficient dwell time to ensure complete and even mixing. The overall system of proportioning and mixing should be such that a product is consistent over time.

9.3.1.3 Spreading

The slurry mixture should be discharged from the mixer into a spreader box which is supported at two lateral positions on skids. The spreader box should have a seal at the front to prevent the mix flowing forwards and an adjustable strike off plate at the rear which controls the thickness of slurry. The strike off plate should be kept free of adherent particles to prevent surface scoring of the fresh slurry. Augers, within the spreader box, agitate the mix and spread it out to the limits of the box to ensure an even spread of the slurry. The spreader box should be mounted on the mixing vehicle in such a way that it can be moved sideways to compensate for variations in road geometry. The spreader box may be provided with a sacking or other drag to give a suitable texture to the surface. Any hand work that is necessary should be carried out in such a manner that the hand worked material has the same performance characteristics and appearance as the machine laid material.

9.3.1.4 Compaction

Compaction is not normally required for slurry surfacing but some contractors have found that the material breaks and becomes stable more quickly if it is rolled with a fairly light tandem steel roller.

9.3.2 Aftercare

It is usual for slurry surfacings to shed a small amount of their larger aggregate particles during a short period after treatment. This period may vary from a few days to a few weeks depending on the amount of trafficking. On public highways one or two sweeps should be sufficient during this period to remove the particles as they are not normally large enough to cause damage and are usually pushed by the traffic into the side of the road. On airfields more frequent sweeping may be necessary to prevent foreign object damage.

9.3.3 Ironwork

Ironwork should be raised, where required, to the final level immediately after completion of the final layer of slurry surfacing in order to enable the same slurry surfacing material to be laid around the ironwork after lifting as was used for the main area. This ensures an even appearance and a complete coverage of new material.

9.3.4 Testing

Tests on the constituents should be carried out to ensure consistency of the materials being used for manufacture. This may include aggregate grading, moisture and cleanliness.

NOTE 1 ***Assessed capability****. Users of this British Standard are advised to consider the desirability of quality system assessment and registration against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.*

NOTE 2 Where the materials are supplied under an ISO 9001 quality assurance scheme further testing is not normally necessary.

NOTE 3 National Highway Sector Scheme 13b, available from UKAS, provides a basis for quality assurance of the microsurfacing process.

The wet track abrasion test (in accordance with BS EN 12274-5) can be useful in the assessment of slurry surfacing for design purposes but it is not suitable as a test for specification purposes or for the acceptance of slurry surfacing. The visual assessment test in BS EN 12274-8 should be used for acceptance. The specification of the level for the visual assessment test should be conducted in accordance with prEN 12273 (when it is published as a British Standard[3)]). The qualitative visual assessment should be carried out on all work at the age of 12 months with the quantitative test being carried out on those sites where there is doubt about the quality determined by the qualitative test. Longitudinal and transverse regularity tests may be carried out where required.

[3)] prEN 12273 is currently still a draft European Standard. To be published by CEN as EN 12273 and adopted in the UK as BS EN 12273.

NOTE The contractor may have carried out a type approval installation trial (TAIT) in accordance with prEN 12273 or, when it becomes a full national standard (BS EN 12273), on the type of slurry to be used considering the traffic levels and difficulty of the site in question. The TAIT demonstrates the product performance and durability (macrotexture and visual assessment after one year) although it is advantageous in demonstrating long term performance and durability if it is assessed over a longer period and preferably until the site is resurfaced.

9.4 Coloured slurry surfacing

Pigmentation of K3 bitumen emulsions can be used to give a limited choice of colours for slurry surfacing. However, high levels of pigment are needed, and colour retention is limited by the black base. Coloured slurry surfacing is normally only used in non-vehicular traffic areas.

Emulsions based on transparent synthetic bitumen can give a range of strong, bright colours to slurry surfacing that is not possible with black bitumen. Polymer modified emulsions can be used to produce conventional and gap graded slurry surfacing for a wide range of applications. The same design and application criteria as for bitumen based emulsions should be followed, but, in addition, the colour of aggregates as well as their normal properties, particularly the coarse fraction of gap-graded designs, should be taken into consideration.

10 Retread

The retread process is essentially a recycling process in which the existing aggregate in the road is used, bitumen emulsion is added and the road is reshaped. It is suitable for use on lightly trafficked roads and has been used successfully in both urban and rural situations. The treatment is used typically on roads that have become deformed by trafficking or by work carried out by or on behalf of service providers because part of the process is reshaping and forming crossfalls and cambers. It can also be used on roads on which the existing material has become dry and lacking in binder and is showing signs of fretting and ravelling.

As the aggregate in existing pavements is usually still in good condition, it makes poor economic sense to remove and dispose of it. Reuse by means of a suitable treatment is environmentally sound and avoids landfill charges and aggregate tax. Furthermore, as the retread process is carried out entirely at ambient temperature no problems arise with, for example, fuming of tar products which are quite frequently found in old roads and cannot be recycled hot.

The retread process can be summarized as follows: the old road should be scarified or planed to a suitable depth, the material broken down to the required size and reshaped. The aggregate should then be mixed with a suitable binder by spraying and harrowing, and consolidated. Finally, a wearing surface of surface dressing, slurry, surface course or similar should be applied.

The process should be carried out in the following stages.

- The existing road surface should be pulverized up to a depth of about 75 mm. This pulverized material should then be worked using suitable tools such as reciprocating harrows and rollers to reduce it to a suitable grading with no material over 75 mm in size. If the grading is deficient in aggregate of one or more sizes, new aggregate may be added at this stage to rectify the grading. The surface should then be reshaped to the required profile.
- Depending on the grading and type of surface to be treated, bitumen emulsion conforming to BS 434-1:1984 class K2 or BS EN 13808 (C55 B 5/C55 BF 5) should be applied by bulk distributor conforming to BS 3136-2 at a total rate of 5.5 l/m^2 to 8 l/m^2 in two or three applications. After each application, except the last, the material should be mixed using suitable equipment to ensure good mixing and even distribution of the binder.
- Following the last application of emulsion, the road should be reshaped if necessary and then rolled with an 8 t to 10 t deadweight roller. Any surface voids should be filled with 10/14 mm chippings applied at a suitable rate and rolled.
- The surface should then be sealed by applying bitumen emulsion conforming to BS 434-1:1984 class K1-60 or BS EN 13808 (C60 B 3/C60 BF 3) or K1-70 (C69 B 3/C69 BF 3) at a rate of 0.9 l/m^2 to 1.2 l/m^2, blinding with 6 mm chippings and rolled.
- The retread layer should then be surfaced using a slurry, surface course, surface dressing or similar.

NOTE It is not uncommon to surface the retread the following year on rural sites, but it is preferable to surface urban sites during the same season.

11 Deep recycling

11.1 General

In addition to retread, a simple form of recycling described in Clause **10**, a number of processes exist in which existing material in the road is recycled using emulsions. These processes are usually proprietary and require specialist plant. The processes can be carried out in situ or off site and use either emulsion or foamed bitumen with or without cement and/or other pozzolanic binder.

NOTE Further information is given in Report TRL 611: A guide to the use and specification of cold recycled materials for the maintenance of road pavements [11].

Whichever process is chosen a specification of the outcome should be agreed between the purchaser and the provider. This specification may provide for a minimum stiffness to be achieved, and at what age, a minimum depth to be treated, a compaction specification, surface regularity and the maximum time allowed before opening to traffic. These specifications may vary from time to time and from site to site. The outcome also depends on the material being treated. An investigation of the current state of the road should be carried out and this taken into account when determining the relevant specification. As with all road works the location of all services should be ascertained.

Processes using a cementitious binder in addition to emulsion and foamed bitumen are stiffer than those using emulsion or foamed bitumen alone.

A fully flexible material (i.e. one which does not contain cementitious binder) normally takes longer to reach maximum stiffness than one that includes a cementitious binder. It is usual for the stiffness of flexible treatments to be measured at 12 months. In order to achieve an early indication of the likely outcome accelerated curing of laboratory made specimens should be conducted using samples of the treated material taken from the site and cured in accordance with TRL611 [11].

11.2 In situ recycling

In situ recycling may be carried out either on the full width of the road using a specialist recycler with an operating width of 2 m or greater, or haunch recycling with an operating width of 1 m or greater. Both processes enable materials to be recycled to depths of between 125 mm and 300 mm.

NOTE Larger specialist recyclers can pulverize up to 450 mm.

It is essential with in situ recycling that a good site investigation is carried out, as the material can vary considerably along the length of a road, particularly on roads that have developed over time in response to local variations, e.g. urban roads and nearly all un-kerbed lightly trafficked rural roads. Typical rates of treatment are 1 500 m^2 per day for full width recycling and 500 m^2 for haunching. As the plant used in recycling is large, the process should only be conducted on sites where a large area is to be treated.

11.3 Off site recycling

Off site recycling uses either emulsion or foamed bitumen. The process can be used where material is gathered from a number of sites and sources and treated, if necessary, by screening and crushing to provide a suitable feed material to the mixer. Care should be taken to mix the incoming materials to form a reasonably consistent material for treatment. The treated recycled material can either be used immediately or stockpiled for use as and when required and is thus suitable for use on small sites.

11.4 Aggregates

Aggregates that can be used in recycling processes include:

- pulverized pavement material including asphalt, concrete or granular material;
- primary, secondary or recycled aggregate from other sources;
- fillers from primary or secondary sources (e.g. PFA).

The processed aggregate including added filler should not contain deleterious material that adversely affects the performance of the mixture and not more than 2% of organic matter as determined in accordance with BS 1377-3:1990, Clause **3**. Lime may also be used to modify any cohesive sub-grade soil incorporated in the pulverized layer.

11.5 Bitumen emulsion

Stable bitumen emulsion conforming to BS 434-1 [Class A3 or K3 (C55 B 7/C55 BF 7)] may be used in recycling processes, as can proprietary grades. Although the emulsion readily combines with hydraulic binders, care should be taken to prevent stripping problems by selecting an emulsion that is compatible with the aggregates.

The early life and long term properties of mixtures with bitumen emulsion are similar to those for foamed bitumen.

11.6 Mix design

11.6.1 Aggregate grading

Table 3 should be used for guidance on the grading of the mixture for cold recycling, i.e. the aggregate together with the other constituents including hydraulic binders. The pulverized pavement material and any supplementary aggregate and/or filler should normally be granular material with not less than 4% and not more than 20% passing the 0.063 mm sieve (Zone A in Table 3). Zone B or Zone C graded material may also be used, but the results of a full mix design conforming to the required performance properties should be made available or evidence provided of satisfactory achievement of the performance requirements with a similar composition for previous work.

11.6.2 Design procedure

The mix design procedure should establish optimum moisture content (or optimum fluids content to include the bitumen in the emulsion) from a density/moisture content curve and target bitumen emulsion content that satisfies the requirements for mechanical test properties and durability. Durability should be assessed by using a water immersion mechanical property test. The emulsion content should normally be not less than 4% and typically between 4.5% and 6.5%, depending upon the particular type of emulsion and aggregates and the type of process.

Table 3 **Particle size distribution of mixture for cold recycling**

Sieve mm	**Zone A**	**Zone B**	**Zone C**
40	100	100	100
31.5	87–100	87–100	86–100
20	66–100	66–100	65–100
14	55–85	55–100	52–85
10	48–75	48–100	44-75
4	31–52	31–94	26–52
2	23–40	23–84	18–40
0.5	12–27	12–64	8–27
0.250	9–23	9–51	5–23
0.063	4–20	4–33	3–20

11.6.3 Mix design criteria

Suggested mix design test property criteria are given in Table 4.

Trial mixtures with added binder contents set at increments of 0.5% that maintain the optimum fluids content may be manufactured and sets of six 150 mm diameter by 75 mm high, cylindrical test specimens produced by compacting to refusal in accordance with BS EN 12697-32. Prior to testing, specimens should be conditioned in a controlled environment and sealed to retain moisture. The conditioning procedure should be determined to facilitate testing and need not simulate the likely curing in the road. Suggested conditions include 14 days at 35 °C and 20% relative humidity. A shorter period such as 3 days at or above 40 °C may also be appropriate for the purposes of determining a design mix composition.

The cured specimens should be cooled to room temperature and conditioned at 20 °C for indirect tensile stiffness modulus testing (ITSM) in accordance with BS EN 12697-26.

After stiffness testing, three specimens should be tested for bulk density. The other three specimens should be immersed in water under vacuum (100 mm mercury) for 1 h and left under water for an additional 1 h without vacuum. The percentage retained stiffness should then be determined.

Table 4 **Suggested mix design test property criteria**

Test property	**Minimum value**
Mean ITSM @ 20 °C, MPa	1 900
Mean retained ITSM, %	75

The optimum bitumen emulsion content should be selected to meet the specified test property requirements. Other design values may be set for the minimum mean ITSM, depending upon the conditioning procedure and intended use.

11.7 Compaction

The layer of stabilized material should be spread to level by a grader or a mechanical paving machine. Any furrow formed by prior excavation of edge materials should be re-filled by grading the adjacent stabilized material into the space using a minimum amount of re-working. Tie-ins to junctions or lay-bys, etc., should be formed prior to installation of the main sections in order to provide lateral support. Any open or segregated surface area should be blinded using fresh material and worked in prior to compaction.

Compaction of the mixture accelerates the rate of development of cohesion by laminating the bitumen globules and squeezing out the water. The compaction of each layer should be carried out to a defined rolling pattern, to achieve the required in situ density and until the recycled layer provides a stable and dense surface.

After trimming and final compaction of the recycled layer, the in situ bulk density should be measured using a nuclear density gauge in direct transmission mode, to a depth within 25 mm of the layer thickness. For more heavily trafficked roads, the in situ bulk density values obtained should be compared with the refusal density value of the job standard mix or of the refusal density of a specimen representative of the day's production. The average in situ bulk density of each set of five values should be at least 95% of the refusal density, with no individual in situ density value being less than 93% of the respective refusal density.

For lightly trafficked roads, i.e. designed to carry up to 2.5 million standard axles, it should be sufficient to describe the method to be used to determine the number of roller passes to achieve maximum density.

The stability of the layer after compaction should be deemed adequate if the finished surface does not show distress such as shoving, rutting or transverse cracking under the load of subsequent traffic prior to overlay.

11.8 Sealing

When required, the surface should be sealed using a sprayed membrane of Class KI-70 (C69 B 3/C69 BF 3) bitumen emulsion or bond coat conforming to the *Specification for Highway Works*, Clause 920 [1]. The bitumen emulsion should be sprayed at a rate of 0.7 l/m^2 to 1.2 l/m^2 to achieve a uniform and continuous seal to the surface of the layer. Where the surface is to be opened to traffic, the sealing membrane should be blinded with fine aggregate or sand applied at a rate of 5.5 kg/m^2 to 7.0 kg/m^2.

11.9 End product

For more heavily trafficked roads, in addition to in-situ density testing as described in **11.7**, the recycled stabilized material should be assessed on the basis of the results of ITSM testing of specimens of plant mix. It is recommended that a period of 28 days at a temperature of (40 ± 2) °C is used as one possible procedure to simulate curing in the road after 12 months. In the event of test specimens failing to achieve the required stiffness test results, compliance may be determined by the testing of cores extracted by air flushed coring after at least 12 months.

11.10 Surfacing

Depending upon the particular pavement design objective, the completed recycled layer may be overlaid with the appropriate bituminous surfacing layer or surface treatment (for recommendations and guidance see TRL Report TRL 611 [11]).

12 Footway and cycleway construction and maintenance

12.1 General

Although footways and cycleways generally carry a lighter load than carriageways, in many situations they should be capable of carrying vehicles either when they are parked or crossing to access properties. Guidance on the structural requirements and design of footways is set out in DMRB HD 39 [7]. Emulsions may be used in a number of ways to produce a durable and acceptable footway or cycleway for these classes of traffic.

Both footways and cycleways are used by all ages of the population many of whom are in wheeled vehicles without suspension and with hard tyres. It is, therefore, imperative that the ride quality is good without, in particular, short wavelength irregularities which make it uncomfortable for cyclists, babies and wheelchair users. The surface should be close textured, of low macrotexture (speeds are low) and have no loose materials, such as chippings, or trip hazards.

12.2 Construction

12.2.1 General

Emulsion can be used in a number of different ways in footway construction, many of which are similar to those used in carriageway construction. Reference should be made to the recommendations for surface dressing (see Clause **7**), slurry surfacing (see Clause **9**), recycling (see Clause **11**), cold asphalt mix and grouting (see Clause **13**). The recommendations in **12.2** cover the variations appropriate to the construction of footways and cycleways.

12.2.2 Base treatment

Base treatments (cement bound bases, sub-bases and lean mix concrete sealing) for footways and cycleways should be applied in accordance with the recommendations in **15.1**.

12.2.3 Tack coat

Where two or more layers of asphalt or emulsion mixed material are used a tack coat should be employed between layers to provide an adhesive and a dust free surface on which to place the next layer. The tack coat should be sprayed in accordance with Clause **8**.

12.2.4 Grouting

On footways subject to low stress it may be economical to prepare, in situ, a combined binder/surface course by means of the application of emulsion into the interstices of the aggregate, after the latter has been spread on the foundation and compacted, i.e. grouting. The emulsion employed should be K1-60 (C60 B 3/C60 BF 3) although when large areas are being treated and the use of a heated spray bar is feasible K1-70 (C69 B 3/C69 BF 3) may be more suitable. For footways a semi-grout process should be used where sufficient emulsion is applied to coat the aggregate in the upper level of the construction only.

12.3 Maintenance

12.3.1 Retread

Where a footway or cycleway has reached a state of disintegration such that surface dressing, slurry surfacing or a thin resurfacing are inadequate the way should be retreaded. The recommendations and guidance on retread for carriageways in Clause **10** should be followed. The recommendations in **12.3** cover the differences for footways and cycleways which are due to the more confined nature of the site; smaller plant may be needed and some hand working may be necessary. Extra care should be employed to ensure a good profile particularly at short wavelengths (e.g. 0.05 m to 2 m) in order to ensure comfort to users.

12.3.2 Surface dressing

Surface dressing may be used on lightly trafficked footways particularly rural ones in order to exclude water from the footway construction and to add binder to the surface to prevent or arrest fretting and ravelling. It is imperative that adequate amounts of binder are used and that any loose chippings are swept as soon as it is possible to do so. On cycleways loose chippings are a hazard on areas where braking and turning occur as cycles may slide.

A 2.8/6.3 chipping should be used but a 2/4 chipping size is also suitable. The use of light coloured chippings in unlit areas provides a useful contrast with the usually darker carriageway. On lightly trafficked footways polished stone value (PSV), is not an issue. Gravel, limestone, and the aggregates normally used on carriageways may be used.

Bitumen emulsion classes K1-60, K1-70 or polymer modified emulsions should be used for surface dressing of footways and cycleways at a rate of spread of 1.2 l/m^2 to 1.8 l/m^2. As there is unlikely to be any embedment of chippings into the underlying surface, the rate of spread should be as high as the existing surface so that the applied chippings can absorb the binder and the binder can reach approximately half way up the chippings after breaking.

NOTE Further guidance on rates of spread, including rates for double dressing, is available in Appendix A of Road Note 39 [2].

Where practical, the binder should be sprayed through a suitable spray bar. However, if a hand lance is used, accuracy of spread is essential. Once the emulsion has broken it is unlikely that the dressing will fat up and binder be picked up on pedestrians shoes. However, this risk can be minimized by using polymer modified emulsion.

Testing should be carried out in accordance with the recommendations for carriageway work.

12.3.3 Slurry surfacing

Slurry surfacing of footways and cycleways should be carried out in accordance with the recommendations and guidance for use on carriageways (see Clause **9**) although it is generally much more labour intensive. However, on some of the wider cycleways used in some towns a small road machine may be used provided the structure of the cycleway is checked to ensure that the construction is strong enough to take the weight.

Slurry surfacing on footways should be conducted using either a K3 (C55 B 7/C55 BF 7) or a polymer modified emulsion. Whichever emulsion is used it is essential that the binder and the proposed aggregate are compatible with each other. It should not be assumed that if another aggregate is substituted for one that is known to work the new combination will be equally successful. The purchaser should only define the thickness required or mass per unit area and not the design of the mixture.

It is essential that any repairs to the footway or cycleway are carried out before the slurry is placed. In particular it should be noted that properly designed and placed slurry surfacing, is essentially impermeable and therefore any depression or adverse slopes preventing drainage of the finished surface should be rectified. If the depressions are relatively shallow a preliminary pass of slurry to fill depressions should be used followed by the main treatment after the regulating treatment has fully broken and stabilized. Slurry surfacing only adheres to the layer on top of the footway or cycleway at the time of laying; if this is a layer of moss, detritus or other contaminant the slurry will not adhere to the structure and early failure will ensue. Depending on the contamination one or more of the following treatments may be necessary: sweeping, scraping (with shovels or mechanical tools) or pressure washing.

Slurry for footways should typically be mixed in batches by means of a small concrete mixer (e.g. 5/3) with the various components measured volumetrically. Care should be taken to ensure that the mixture is consistent from batch to batch as otherwise variations in appearance occur in the finished product, although this may not necessarily result in poor performance in service.

Testing should be carried out in accordance with the recommendations for carriageway work.

13 Patching and velocity patching

13.1 General

Patching and velocity patching are used for the treatment and repair of cracks, crazing, potholes and depressions in existing pavements. They are important maintenance processes, and are particularly effective when used prior to surface dressing.

13.2 Patching

13.2.1 Patching

The failed areas of existing surfaces should be cut cleanly to a regular shape, with vertical or slightly undercut sides. A diamond shaped cut is preferred for heavily trafficked roads. It is important that the extent of the cut is such that the edges of the repair material are in contact with good quality existing material. All loose and unstable material should be removed.

Tack coat emulsion conforming to BS 434-1, Class K1-40 (C40 B 4/C40 BF 4) or bond coat should be applied, either by spraying or by pouring and brushing around the sides of the prepared area. Where dry surfaces are experienced, these may be moistened with water to permit deeper penetration of the emulsion.

13.2.2 Application

For heavily trafficked roads the patching material should usually be a hot, dense bituminous mix, either bitumen macadam or asphalt. If the depth of the repair is more than 100 mm the opening should be filled with successive layers of these materials which are each levelled and compacted. The final layer should be suitably profiled. The patching material should contain a nominal size aggregate which is approximately, but no more than half the depth of the layer. A vibratory plate compactor should be used for the consolidation of the lower layers and small surfaces, while a roller should be used for larger areas. If the repair has an open texture, it should be sealed with emulsion class K1-60 (C60 B 3/C60 BF 3) at a rate of spread of 0.8 l/m^2 to 1.0 l/m^2 and blinded with grit, or with pre-prepared slurry surfacing.

On less heavily trafficked roads, alternative cold patching materials may be used, including deferred set macadams and permanent cold lay materials. In the past HAUC certification gave assurance of the proven performance of permanent cold lay materials (see **14.1**). This certification scheme was brought within the BBA/HAPAS scheme in 2001.

13.3 Velocity patching

Velocity patching is a fast and economic alternative to conventional patching for less heavily trafficked roads, mainly in rural locations. The operation should be carried out using specialized plant utilizing a nozzle with a high velocity airstream. After ensuring that any unsound material is removed, the airstream should be directed at the crazed or potholed area to be treated, to remove any dust or loose material; bitumen emulsion should then be introduced into the airstream to prime the exposed surfaces of the repair area, then clean aggregate should be fed into the airstream simultaneously with the bitumen emulsion. The emulsion coated aggregate should be forced at high velocity into the base of the repair, building and consolidating from the base upwards, until the finished level is achieved. The finished surface may be completed with dry aggregate.

The bitumen emulsion used is normally a proprietary material, formulated to give the optimum coating and breaking characteristics. Aggregate should be clean, washed surface dressing grade chippings, normally 2.8/6.3 c85/15 grading. The use of dirty or dusty chippings results in poor coating of the aggregate, and subsequent fretting or disintegration of the new surface.

As velocity patching is weather-dependant in the same way as surface dressing, it should not be carried out in cold, wet conditions. Velocity patching should ideally be carried out 4–6 weeks before the start of the surface dressing season, and ideally end at approximately the same time.

14 Permanent cold lay surfacing materials (PCSMs)

14.1 General

Permanent cold lay surfacing materials (PCSMs) have been developed to enable road openings and other small areas in the highway to be reinstated with engineering grade materials. They were introduced following the publication of the *Specification for the Reinstatement of Openings in Highways* [8] which was produced as a result of the New Road and Streetworks Act in 1991 [9]. This led to the development of a number of emulsion coated macadams which demonstrated conformity to the minimum performance criteria laid down in the *Specification*. These materials are all proprietary and were initially certificated by the Highway Authorities and Utilities Committee. The responsibility for certification was transferred to BBA HAPAS in 2001 and only certificates issued by the BBA are now valid (see **4.4.1** for further background information on BBA/HAPAS).

For good compaction the PCSM mixture should have sufficient total fluid, this is similar to but not necessarily identical to the optimum moisture content at which soils are most easily compacted. The mixture design process is fairly complex as a balance has to be struck between having a high enough fluid content for compaction, a low enough fluid level to prevent binder drainage and an optimum level of voids in the final material as laid to provide a high enough strength while enabling moisture from the emulsion to disperse.

14.2 Mixing

The mixing of constituents should take place at ambient or warm temperature using damp or water wetted aggregates. The binder should be stored in such a manner that settling of the emulsion is avoided. Sufficient heating should be available to avoid freezing. Water and emulsion should be added to the mixer, as necessary, in order to achieve the necessary fluid content. This should be added to the aggregate in a separate mixing operation or at the same time as the emulsion using a separate spray-bar in the mixer. Use of an asphalt plant for the manufacture of PCSM is common but is not essential as no heating is required. A mixer similar to a concrete mixer may be suitable provided adequate quality control is exercised.

14.3 Storage

As with all asphalt materials it is essential to ensure that PCSMs are adequately workable at the time of laying. To ensure that they are, they should be stored correctly under suitable storage conditions for the mixture. As the mixture should remain unbroken until compaction is complete, storage conditions should be such that evaporation of any water is prevented as this allows the emulsion to break making it unworkable and unusable. Where storage is outside (as it normally is) the storage bay should have an impermeable base and three impermeable, non-absorbent sides. The floor should slope by 2–3% towards the open side from where any water draining off should be properly dealt with. The material should be well sheeted to prevent evaporation and contamination with rain. Evaporation causes the binder to break; contamination with rain causes it to wash off. Both effects render the material unusable.

When material is in transit between the storage bay and the work site it should be carried in a compact heap which is sheeted for the same reasons as above.

14.4 Laying and compaction

Laying and compaction of PCSMs should be carried out by properly trained and experienced personnel (see the Foreword). Laying should not be carried out when there is a possibility of the material freezing before the emulsion has broken. Once the material has been fully compacted and the emulsion has fully broken weather damage is less likely. Compaction should be carried out with suitable equipment to at least the minimum density at which the particular material meets the engineering criteria that have been specified. When the weather is cool or the humidity is high the PCSM may take an appreciable time to gain sufficient resistance to traffic loading. Traffic should, therefore, be kept off the material for long enough for sufficient strength to develop.

15 Sealing and curing of cementitious materials

15.1 Cement-bound bases, sub-bases and lean mix concrete sealing

Lean mix concrete and cement-bound materials are used as bases and sub-bases in road construction. It is essential to ensure the curing of cement-stabilized materials in order to obtain the maximum designed strengths.

Formations and subgrades, unbound bases and sub-bases, and cement-bound bases and sub-bases should be sealed using surface dressing in order to protect them from weather damage and site traffic during construction. Cementitious materials may be cured by sealing them immediately after laying. Double surface dressings should be used on unbound surfaces where they are to be temporarily trafficked. Single surface dressings should be used on cement-bound materials. When cement-bound materials are used as the final structural layer a double dressing should be used.

K1-70 (C69 B 3/C69 BF 3) bitumen emulsion with 6 mm chippings should be used as the binder. When sealing is carried out steps should be taken to ensure that the material above the sealing layer is drained to prevent build up of water above the seal which weakens the construction.

Benefits of sealing cement-stabilized bases with bitumen emulsions include a reduction in the loss of fines during heavy rain, prevention of site traffic being held up by boggy conditions and water loss during hot conditions.

Spraying should be carried out in accordance with the *Specification for Highway Works*, Clause 920 [1].

15.2 Curing of pavement quality concrete used as a structural layer, prior to surfacing

15.2.1 Background

Bitumen emulsions are used as curing compounds to form non-breathable membranes that retain moisture in the slab and do not allow vapour transmission, so that the concrete continues to gain strength and drying shrinkage is delayed.

15.2.2 Emulsion

The emulsions used for curing should be class K1-40 (C40 B 4/C40 BF 4), K1-60 (C60 B 3/C60 BF 3), A1-40 or A1-55, the 40% grades normally being preferred. The concrete should be coated within 1 h of laying. Spraying should be carried out in accordance with the *Specification for Highway Works*, Clause 920 [1].

15.2.3 Application rate

The concrete should be given a coating of emulsion at a rate of 0.5 l/m^2 to 0.9 l/m^2 depending on the grade of emulsion and surface texture, followed by the application of sand or small grit. The road should be opened to traffic as soon as the concrete has attained the required strength as specified by the design.

15.3 Target rates of spread of binder for sealing and curing

The target rates of spread of binder for sealing and curing should be in accordance with the recommendations in Table 5.

Table 5 **Target rates of spread of binder for sealing and curing**

Type of chippings	Nominal size of chippings	Material type	K1-70 bitumen emulsion
Crushed rock, gravel and slag	6 mm	Formations and subgrade	Single dressing rate of spread 1.8 l/m^2 to 2.2 l/m^2 depending on surface texture and porosity
		Unbound base and sub-base	Double dressing rate of spread 1.3 l/m^2 for each application
		Cement-bound base and sub-base	Single dressing rate of spread 1.8 l/m^2 to 2.2 l/m^2 depending on surface texture and porosity
		Cement-bound base as a temporary road surface	Double dressing rate of spread 1.3 l/m^2 for each application

16 Stress absorbing membrane interlayer (SAMIs)

Stress absorbing membrane interlayers (SAMIs) are applied between existing surfaces and new asphalt overlays, to reduce the propagation of cracks from joints or faults in the underlying surface. An SAMI works by lowering the stress at the tip of an existing crack or joint. Furthermore, if a crack does eventually reflect through the overlay, the SAMI can provide a waterproof layer to protect the lower layers of road construction.

Non-proprietary SAMIs should be constructed as follows.

1) A layer of K1-70 (C69 B 3/C69 BF 3) grade bitumen emulsion should be sprayed onto the existing surface, and a synthetic paving fabric should be evenly rolled out onto the binder film, absorbing the binder up into the fabric and bonding it to the surface. The new surfacing should then be laid on the SAMI.

2) A layer of bitumen emulsion should be sprayed onto the existing surface, together with chopped reinforcing fibres, and a single layer of chippings should be applied and lightly rolled, to form an SAMI. The new surfacing should be laid on the SAMI.

A number of variations exist on these basic techniques, including the use of composite reinforced fabrics, meshes, polymer modified emulsions and pen grade bitumen. Specialist advice should be obtained from the suppliers of individual systems.

17 Miscellaneous uses

Bituminous road emulsions may be employed in a range of unusual or specialized uses, some of which are described in publications listed in the Bibliography. Miscellaneous uses of bituminous road emulsions include the following.

- *Grass growing*: The use of emulsions, usually in conjunction with a layer of sand, to assist germination of seed, and particularly on slopes to protect the surface from erosion and denudation until a sufficient grass root system to stabilize the surface has been established.
- *Sand dune stabilization*: The use of emulsions to give 25 mm to 50 mm depth of lightly stabilized surface on dunes and other areas where blowing sand creates problems. The treatment may be carried out in conjunction with the establishment of trees and other vegetation.
- *Slip coats*: The use of emulsions to create a membrane of bitumen between layers of concrete. This retains the strength of the upper layer by preventing water seepage into the lower layer and avoids rigid adhesion between layers of different ages and strengths so that they mature without setting up internal stresses.
- *Protection of concrete pipes*: The use of emulsions for the protection of exposed or buried concreted and iron work, chiefly against sulphate attack and corrosion. Emulsion incorporating latex is normally used.

- *Crack filling*: The use of emulsions containing latex for penetrating cracks in asphalt and concrete surfaces and filling with an elastic resilient sealant.
- *Joints in asphalt courses*: The use of bitumen emulsion as an alternative to hot paving grade bitumen for coating the cut vertical face of the exposed edge of asphalt layers when forming joints between laying widths or when forming transverse joints. Specially formulated emulsions may be sprayed or brush applied.
- *Surface rejuvenation*: The use of bitumen emulsion as a light spray on road surfaces showing signs of wear or aggregate erosion to hinder further deterioration. The treated surface is usually blinded with bitumen coated aggregate grit.
- *Skidpans*: The use of specially formulated emulsions containing hard bitumen applied onto a smooth surface to leave a hard shiny finish with a low resistance to skidding.

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