BS 594987:2015

BSI Standards Publication

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

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 March 2015. It was prepared by Subcommittee B/510/1, *Asphalt products* and under the authority of Technical Committee B/510, *Road materials*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 594987:2010, which is withdrawn.

Relationship with other publications

This British Standard is published concurrently with PD 6691:2015 as the two documents have been revised and cross reference each other.

Information about this document

This edition takes into account the change from the Construction Products Directive to the Construction Products Regulation [1] and that CE marking in the UK is now mandatory.

It also clarifies errors and anomalies in the previous version and removes references to previous British standards which have been superseded by the European standards.

This British Standard specifies requirements for transporting asphalt mixtures, for preparatory site work and for laying and compacting asphalt mixtures, including the covering of concrete and sett paving. Annexes contain protocols to be used for initial product-type testing of asphalt materials in accordance with BS EN 13108-20.

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.

Annex A gives recommendations for delivery and rolling temperatures. Annex B provides indicative rates of spread for average mixture types. Annex C, Annex D, Annex E, Annex F and Annex G give recommendations on protocols for the initial product-type testing of asphalt materials in accordance with BS EN 13108-20; in particular, guidance is given on sampling by coring, assessing for target composition, voids, compaction and deformation resistance. Annex H provides recommendations for a mixture design that determines the design binder content of hot rolled asphalt surface course mixtures. Annex I provides advice on the calibration procedure for indirect density gauges. Annex J provides advice on the use of tack coats. Annex K gives a method for determining the maximum binder content that porous asphalt and other asphalt can carry without excessive binder drainage during transportation and subsequent laying. Annex L provides guidance on the design of BBA mixtures for airfield pavements.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its requirements are expressed in sentences in which the principal auxiliary verb is "shall".

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

Requirements in this standard are drafted in accordance with *Rules for the structure and drafting of UK standards*, subclause **J.1.1**, which states, "Requirements should be expressed using wording such as: 'When tested as described in Annex A, the product shall ...'". This means that only those products that are capable of passing the specified test shall conform to this standard.

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 British Standard specifies requirements for the transport, laying and compaction of asphalt mixtures conforming to BS EN 13108-1, BS EN 13108-4 and BS EN 13108-5, and described in PD 6691, from the time that they leave the mixing plant until they are placed on the road ready to receive a superimposed layer or traffic. It also includes requirements for preliminary work at the laying site needed to ensure that the substrate is fit to receive the asphalt and for the application of bond coats.

Although this standard does not contain explicit requirements for asphalt materials covered in other parts of BS EN 13108 or other proprietary asphalt mixtures, the general requirements of this standard can be applied to those mixtures, in addition to special requirements for particular mixtures specified in individual quality plans and/or method statements.

NOTE 1 The term "asphalt" used in this standard is the generic term used to describe the wide range of mixtures of aggregate and bituminous binder individually known as asphalt concrete (AC), hot rolled asphalt (HRA), stone mastic asphalt (SMA), porous asphalt (PA) or mastic asphalt and other proprietary materials which are available for use in constructing and maintaining roads and other paved areas that are on the market in the UK.

NOTE 2 Methods for ensuring that the correct surface drainage characteristics are imparted to pavements with PA surface course are outside the scope of this British Standard.

*NOTE 3 BS EN 13108-20 specifies tests for determining the conformity of a mix to any of the other parts of BS EN 13108. This is similar to a mix design validation or job mix trial. BS EN 13108-20 offers some choice in the way in which specimens are to be prepared for the purposes of product-type testing. Requirements for sample preparation for the demonstration of product-type test properties are given in PD 6691:2015, Clause **13** and are linked to the relevant protocols/annexes in this British Standard, as relevant.*

In the case of HRA, a mixture design protocol is provided as informative text in Annex H, and requirements are specified for providing a rough-textured surface on the surface course to provide skid-resistance.

This standard does not specify requirements for asphalt incorporating bitumen emulsion binders.

This standard does not cover additional or specific requirements relating to the laying and compaction of reduced temperature asphalts.

NOTE 4 BS EN 13108 is being reviewed and it is anticipated that any revisions might cover low-temperature and cold mixtures.

2 Normative references

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

BS 598-1:2011, *Sampling and examination of bituminous mixtures for roads and other paved areas – Part 1: Methods for the measurement of the rate of spread of coated chippings and the temperature of bituminous mixtures using non-contact temperature-measuring devices and for the assessment of the compaction performance of a roller*

BS 1707, *Specification for hot binder distributors for road surface dressing*

BS 2000-223, *Methods of test for petroleum and its products – Part 223: Determination of ash of petroleum products containing mineral matter*

BS EN 932-1, *Tests for general properties of aggregates – Part 1: Methods for sampling*

BS EN 932-2, *Tests for general properties of aggregates – Part 2: Methods for reducing laboratory samples*

BS EN 933-1, *Tests for geometrical properties of aggregates – Part 1: Determination of particle size distribution – Sieving method*

BS EN 1426, BS 2000-49, *Bitumen and bituminous binders – Determination of needle penetration*

BS EN 1427, BS 2000-58, *Bitumen and bituminous binders – Determination of softening point – Ring and ball method*

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

BS EN 12697-1, *Bituminous mixtures – Test methods for hot mix asphalt – Part 1: Soluble binder content*

BS EN 12697-2, *Bituminous mixtures – Test methods for hot mix asphalt – Part 2: Determination of particle size distribution*

BS EN 12697-5:2009, *Bituminous mixtures – Test methods for hot mix asphalt – Part 5: Determination of the maximum density*

BS EN 12697-6:2012, *Bituminous mixtures – Test methods for hot mix asphalt – Part 6: Determination of bulk density of bituminous specimens*

BS EN 12697-8, *Bituminous mixtures – Test methods for hot mix asphalt – Part 8: Determination of void characteristics of bituminous specimens*

BS EN 12697-13, *Bituminous mixtures – Test methods for hot mix asphalt – Part 13: Temperature measurement*

BS EN 12697-22:2003, *Bituminous mixtures – Test methods for hot mix asphalt – Part 22: Wheel tracking*

BS EN 12697-25:2005, *Bituminous mixtures – Test methods for hot mix asphalt – Part 25: Cyclic compression test*

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

BS EN 12697-27:2001, *Bituminous mixtures – Test methods for hot mix asphalt – Part 27: Sampling*

BS EN 12697-30, *Bituminous mixtures – Test methods for hot mix asphalt – Part 30: Specimen preparation by impact compactor*

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

BS EN 12697-34, *Bituminous mixtures – Test methods for hot mix asphalt – Part 34: Marshall test*

BS EN 12697-35, *Bituminous mixtures – Test methods for hot mix asphalt – Part 35: Laboratory mixing*

BS EN 13036-1, *Road and airfield surface characteristics – Test methods – Part 1: Measurement of pavement surface macrotexture depth using a volumetric patch technique*

BS EN 13036-7, *Road and airfield surface characteristics – Test methods – Part 7: Irregularity measurement of pavement courses – The straightedge test*

BS EN 13108 (all parts) [1)]

BS EN 13588, BS 2000-522, *Bitumen and bituminous binders – Determination of cohesion of bituminous binders with pendulum test*

BS EN 13808:2013, *Bitumen and bituminous binders – Framework for specifying cationic bituminous emulsions*

BS EN 14023, *Bitumen and bituminous binders – Specification framework for polymer modified bitumens*

BS EN 15322, *Bitumen and bituminous binders – Framework for specifying cut-back and fluxed bituminous binders*

BS EN ISO 3838, BS 2000-189/190, *Methods of test for petroleum and its products – Crude petroleum and liquid or solid petroleum products – Determination of density or relative density – Capillary-stoppered pyknometer and graduated bicapillary pyknometer methods*

PD 6691:2015, *Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS EN 13108 and the following apply.

3.1 bond coat
proprietary polymer modified bituminous binder used to promote adhesion between and/or sealing of layers in the construction and maintenance of roads and paved areas

NOTE 1 Bond coats are polymer modified binders classified in accordance with BS EN 13808, BS EN 15322 or BS EN 14023. Bond coats are generally cationic polymer modified bituminous emulsions such as C50BP3 or C65BP3, although other types are sometimes needed for particular purposes and the supplier should be consulted.

NOTE 2 Bonding and sealing between and around asphalt layers is essential to keep water out and enhance the durability of the road pavement.

3.2 tack coat
unmodified bitumen emulsion used to facilitate adhesion between layers in the construction and maintenance of roads and paved areas

NOTE Although tack coats have traditionally been used, they are no longer regarded as best practice.

4 Transport and delivery

4.1 Transport

Loading of asphalt shall be carried out such that segregation is minimized, which shall be identified from visual examination.

Asphalt shall be transported to the laying site in insulated and sheeted vehicles to minimize temperature loss and protect against adverse weather conditions.

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1) Dated references are made to BS EN 13108-4:2006, *Bituminous mixtures – Material specifications – Part 4: Hot rolled asphalt*; BS EN 13108 20:2006, *Bituminous mixtures – Material specifications – Part 20: Type testing*; and BS EN 13108 21:2006, *Bituminous mixtures – Material specifications – Part 21: Factory*.

When using release agents to facilitate discharge of the asphalt, substances that are likely to cause softening or damage to the asphalt (e.g. diesel oil or kerosene) shall not be used.

NOTE 1 Sealing grit, sand, soap solution, water or a proprietary release agent may be used on the floor and/or other surfaces of the vehicle to facilitate discharge of the asphalt. The amount used should be kept to a minimum.

NOTE 2 In the case of PA, only soap solution, water or a proprietary release agent should be used.

When transporting more than one material in the same vehicle, measures shall be taken to avoid cross-contamination.

NOTE 3 Annex K provides a method for determining the maximum binder content that PA and other asphalt can carry without excessive binder drainage during storage, transportation and laying.

4.2 Delivery to the site

Deliveries of asphalt to the site shall be planned to avoid the interruption of the laying process.

Asphalt shall be delivered at a temperature that allows it to be compacted in accordance with Clause **9**.

NOTE For delivery temperatures, see Annex A for further guidance. Minimum delivery temperatures, taken within 30 min after arrival on site, should ensure adequate time is available for compaction. However, other temperatures might be specified to suit specific site conditions and mixtures. Temperatures should be measured in accordance with BS EN 12697-13.

5 Preparatory works at the laying site

5.1 General

Where asphalt is to be laid, the surfaces shall be free from loose materials and foreign matter, e.g. mud, slurry or other deleterious material. Prior to commencement of laying, the underlying course shall be prepared to produce a stable surface of appropriate profile on which the asphalt can be placed.

NOTE 1 The surface on which the asphalt is to be laid should be of adequate strength to bear the equipment and compactive effort to be used in the laying of the asphalt. Some form of permanent lateral support should be given to the layers of asphalt, to minimize the risk of damage at unconfined edges, and also to optimize their compaction.

NOTE 2 Trafficking prior to completion of the surface course should, as far as possible, be restricted to plant and equipment used for laying and compaction of the asphalt.

5.2 Surface level tolerances

The sum of the deviations in the level of different pavement layers shall not result in a reduction of the nominal target surface course thickness of more than 12.5% from that specified in the design for the works.

For contracts not covered by the *Manual of Contract Documents for Highway Works – Volume 1* [2] the permitted deviation of the level of the finished surface, at any point on the pavement layer from the true surface level, shall not be greater than the following values:

a) sub-base to receive base: ${}^{+10}_{-30}$ mm;

b) base to receive surface course: ±8 mm;

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c) base to receive binder course: ±15 mm;

d) binder course to receive surface course on roads: ±6 mm; and

e) binder course to receive surface course on areas other than roads, e.g. car parks and playgrounds: ±10 mm.

5.3 Resurfacing

5.3.1 Existing surface and maximum permitted depressions

An existing surface shall only be used as a base or binder course where the maximum depression under a 3 m straight edge placed longitudinally or under a template placed transversely does not exceed:

a) 25 mm when the resurfacing is to consist of two-course work; or

b) 13 mm when the resurfacing is to be a single surface course.

If improvement of the surface is required, it shall be carried out by planing and/or by the addition of a regulating course.

NOTE 1 Prior to the laying of the new asphalt, all weak areas to be surfaced should be strengthened, major inequalities of profile remedied, and depressions filled and thoroughly compacted.

NOTE 2 Every effort should be made to prevent or to remove water ponding on the receiving course for the newly laid asphalt.

5.3.2 Existing surface and excess free binder

If the existing surface exhibits excess free binder, the excess shall be removed by planing, milling or other suitable methods.

NOTE Methods other than planing or milling should be agreed with the specifier.

5.3.3 Overlaying existing concrete pavements

Where asphalt is to be laid on existing concrete pavements with defective joints, in addition to the measures specified in **5.3.1** and **5.3.2**, the joints shall be made good by cleaning out and refilling with a joint-filling material. This material shall be compacted flush with the surface. The jointing material used shall not be adversely affected by, or itself adversely affect, the surfacing.

NOTE A bespoke design using non-standard materials and treatments should be used to delay the appearance of reflective cracking when overlaying concrete with asphalt. The details of this are outside the scope of this standard.

5.3.4 Overlaying existing sett paving

When overlaying existing sett paving, the following special measures shall be taken in addition to those specified in **5.3.1** and **5.3.2**.

a) All loose and weak areas of sett paving shall be removed and replaced with an equivalent thickness of either binder course or cement concrete.

b) Excessive bitumen or pitch used to grout the sett joints shall be removed.

c) To ensure the best possible key, all joints shall be cleaned of foreign matter to a depth of at least 15 mm.

d) Bond coat shall be applied in accordance with **5.5** or a surface dressing applied.

NOTE Where necessary, the bitumen emulsion can be covered with 2.8/6 mm chippings at approximately 6 kg/m^2.

5.4 Adjustment or regulation of levels

When regulating the levels of the base or underlying surface, whether to provide super-elevation or for any other purpose, binder course mixtures of appropriate nominal aggregate size conforming to BS EN 13108-1, BS EN 13108-4 or BS EN 13108-5 shall be used. Layer thicknesses shall be in accordance with Table 1A to Table 1D, as applicable.

NOTE 1 Further guidance can be found in PD 6691.

NOTE 2 For layer thicknesses greater than 100 mm, base mixtures may be used.

NOTE 3 If the total thickness of the regulating course is less than 40 mm, the use of regulating course HRA conforming to BS EN 13108-4 or SMA of appropriate aggregate size conforming to BS EN 13108-5 is recommended following the guidance provided by PD 6691.

NOTE 4 Materials shown in bold in Table 1A to Table 1D are preferred mixtures.

Table 1A **Nominal target and minimum compacted layer thicknesses for asphalt concrete (AC) mixtures conforming to BS EN 13108-1 (see PD 6691:2015, Annex B)**

Material description	**PD 6691 reference**	**Size**	**Nominal target layer thickness**	**Minimum compacted thickness at any point**
		mm	mm	mm
Fine graded surface course	AC 4 fine surf	4	15–25	10
Medium graded surface course	**AC 6 med surf**	**6**	**20–25**	**15**
Dense surface course	**AC 6 dense surf**	**6**	**20–30**	**15**
Open graded surface course	AC 10 open surf	10	30–35	25
Close graded surface course	**AC 10 close surf**	**10**	**30–40**	**25**
Open graded surface course	AC 14 open surf	14	35–55	30
Close graded surface course	**AC 14 close surf**	**14**	**40–55**	**35**
Open graded binder course	AC 20 open bin	20	45–75	40
Dense, heavy-duty and high-modulus binder course	**AC 20 dense/HDM/HMB bin**	**20**	**50–100**	**40**
Dense, heavy-duty and high-modulus binder course	AC 32 dense/HDM/HMB bin	32	70–150	55
Dense, heavy-duty and high-modulus base	**AC 32 dense/HDM/HMB base**	**32**	**70–150**	**55**
EME 2	AC 10 EME2 base/bin	10	60–100	50
EME 2	AC 14 EME2 base/bin	14	70–130	60
EME 2	AC 20 EME2 base/bin	20	90–150	80

Table 1B **Nominal target and minimum compacted layer thicknesses for HRA mixtures conforming to BS EN 13108-4 (see PD 6691:2015, Annex C)**

Material description	**PD 6691 reference**	**Size**	**Nominal target layer thickness**	**Minimum compacted thickness at any point**
		mm	mm	mm
HRA regulating and binder 50/10	HRA 50/10 reg/bin	10	25–50	20
HRA regulating and binder 50/14	**HRA 50/14 reg/bin**	**14**	**35–65**	**30**
HRA base and binder 50/20	HRA 50/20 bin/base	20	45–80	40

Table 1B **Nominal target and minimum compacted layer thicknesses for HRA mixtures conforming to BS EN 13108-4 (see PD 6691:2015, Annex C)**

Material description	PD 6691 reference	Size mm	Nominal target layer thickness mm	Minimum compacted thickness at any point mm
HRA base and binder 60/20	HRA 60/20 bin/base	20	45–80	40
HRA base and binder 60/32	**HRA 60/32 bin/base**	**32**	**60–150**	**55**
HRA surface course type F 0/2	**HRA 0/2 F surf**	**2**	**25**	**20**
HRA surface course type F 15/10	**HRA 15/10 F surf**	**10**	**30**	**25**
HRA surface course type F 30/10	HRA 30/10 F surf	10	35	30
HRA surface course type F 55/10	HRA 55/10 F surf	10	40	35
HRA surface course type F 30/14	**HRA 30/14 F surf**	**14**	**40**	**35**
HRA surface course type F 35/14 [A)]	**HRA 35/14 F surf**	**14**	**45–50**	**40**
HRA surface course type F 55/14	HRA 55/14 F surf	14	45	40
HRA surface course type C 0/2	HRA 0/2 C surf	2	25	20
HRA surface course type C 55/10	HRA 55/10 C surf	10	40	35
HRA surface course type C 30/14	**HRA 30/14 C surf**	**14**	**40**	**35**
HRA surface course type C 35/14 [A)]	**HRA 35/14 C surf**	**14**	**50**	**45**
HRA surface course type C 55/14	HRA 55/14 C surf	14	45	40

[A)] In favourable conditions, HRA surface course Type C 35/14 and Type F 35/14 may also be laid at a nominal target layer thickness of 45 mm with a minimum compacted thickness at any point of 40 mm. Further guidance can be found in Transport and Road Research Laboratory Research Report 4 [3].

Table 1C **Nominal target and minimum compacted layer thicknesses for SMA surface course mixtures conforming to BS EN 13108-5 (see PD 6691:2015, Annex D)**

Material description	PD 6691 reference	Size mm	Nominal target layer thickness mm	Minimum compacted thickness at any point mm
SMA 6	SMA 6 surf	6	20–40	15
SMA 10	SMA 10 surf	10	25–50	20
SMA 14	SMA 14 surf	14	35–50	30

Table 1D **Nominal target and minimum compacted layer thicknesses for other SMA mixtures conforming to BS EN 13108-5 (see PD 6691:2015, Annex D)**

Material description	PD 6691 reference	Size mm	Nominal target layer thickness mm	Minimum compacted thickness at any point mm
SMA 6	SMA 6 reg	6	15–40	10
SMA 10	SMA 10 reg	10	20–50	15
SMA 14	SMA 14 bin/reg	14	30–60	25
SMA 20	SMA 20 bin/base/reg	20	50–100	40

5.5 Application of bond coats

5.5.1 General

A bond coat shall be applied prior to the laying of a new asphalt layer on any bound substrate. Bond coats conforming to BS EN 13808, BS EN 15322 or BS EN 14023 having a minimum peak cohesion value of 1.0 J/cm^2 by pendulum test in accordance with BS EN 13588 shall be applied in accordance with **5.5.2**.

NOTE 1 The enhanced adhesive and cohesive properties of bond coats are designed to provide greater confidence in the adhesion between layers, or to allow heavier rates of application to improve the impermeability of the surface of the lower layer, when compared with conventional bitumen emulsion tack coats. Although tack coats have traditionally been used, they are no longer regarded as best practice. For specifiers who wish to use tack coats, information and guidance is given in Annex J.

NOTE 2 Hot applied polymer modified bituminous binders conforming to BS EN 15322 or BS EN 14023 with equivalent performance may also be used.

NOTE 3 Higher levels of cohesion for bond coats might be beneficial depending on the surface course thickness, the traffic stress and substrate type.

For application to planed, milled and existing substrates the minimum target rate of spread for bond coats shall provide not less than 0.35 kg/m^2 of residual binder.

For application to newly laid asphalt substrate, the minimum target rate of spread for bond coats shall provide not less than 0.2 kg/m^2 of residual binder (see Table 2).

NOTE 4 The above rates are minimums and higher rates may be specified when required.

Table 2 **An example of bond coat minimum target rate of spread in litres per square metre of emulsion**

Class of polymer modified bituminous emulsion [A]	**Newly laid asphalt substrate**	**Planed (milled) and existing substrates**
	Residual binder 0.2 kg/m^2	Residual binder 0.35 kg/m^2
C50BP(2 to 5)	0.40 L/m^2	0.70 L/m^2
C60BP(2 to 5)	0.33 L/m^2	0.58 L/m^2
C65BP(2 to 5)	0.31 L/m^2	0.54 L/m^2

[A] The breaking class 2 to class 5 from BS EN 13808:2013 is shown in brackets and does not affect binder content, but is agreed between producer and purchaser for the intended use.

5.5.2 Application by machine

Bond coats shall be machine applied at a uniform rate by calibrated metered mechanical spraying equipment, spray tanker or spraying device integral with the paving machine.

For adoptable highways, the contractor shall implement a quality management scheme, and document and record the findings. The scope of the quality management scheme shall include the application of bond coats, with documented procedures included for carrying out rate of spread and accuracy of spread tests in accordance with BS EN 12272-1.

NOTE 1 For works other than adoptable highways, suitable control systems may be implemented.

NOTE 2 The quality plan should have methods detailed to check the spraying equipment and to reconcile volume or mass used with areas treated and to visually assess accuracy of spread.

NOTE 3 Guidance on workforce competency is found in National Highways Sector Scheme 13 [4].

The tolerance on the specified rate of spread shall not exceed ±20% and the accuracy of the spread shall not exceed 15%.

During the works the contractor shall repeat the test for rate of spread of binder at a minimum frequency of one test for every 50 000 m^2, or once per month, whichever is the most frequent.

The accuracy of spread of binder, which should be in accordance with BS EN 12272-1, shall be tested every six months.

Alternatively the accuracy of spread of the sprayer shall be calibrated in accordance with BS 1707 using the depot tray test every six months. Documentation shall be recorded and retained.

The tests shall also be carried out whenever there is a change in binder source or the spraying system has been altered. The results shall be made available on request.

Where application is approved by the specifier to be carried out by hand, the rate of spread shall be measured by calculating the volume or mass applied per m^2. The maximum contiguous area sprayed by hand shall be no greater than 100 m^2 unless otherwise agreed by the specifier.

There shall be no bare strips or areas having less than the minimum specified rate of spread. Transverse joints shall have an overlap not wider than 300 mm. Longitudinal joints shall have an overlap to ensure that the minimum permitted rate of spread is achieved across the joint.

NOTE 4 For quartering (using part of the spraybar) the longitudinal joint overlap width may be extended to a maximum of 300 mm.

Paver integral sprayers shall provide a wet edge to ensure spray overlap under adjacent overlays such that the minimum permitted rate of spread is achieved across the longitudinal joint.

Where the longitudinal spray overlap causes the effective rate of spread to be increased by more than 50% of the specified rate, then the width of overlap shall be not greater than 100 mm and shall be outside the location of the wheel tracks for the lane.

NOTE 5 Most sprayers might have much greater accuracy than this and might therefore save material.

NOTE 6 Where additional protection against water ingress might be required, higher spread rates than the minimum might be applicable. For example, under permeable or porous surface courses.

The installation shall be undertaken to allow sufficient time for the bituminous emulsion 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, where the heat of the asphalt aids the break.

NOTE 7 Hot applied bond coats conforming to BS EN 14023 or BS EN 15322 may be overlaid immediately, but care is needed to obtain adhesion to the substrate when damp. Any bituminous emulsion accumulating in hollows should be dispersed by brushing and allowed to break before it is overlaid.

NOTE 8 In unduly cold or humid weather conditions breaking of the emulsion could be delayed; for example, where temperatures are below 5 °C or humidity is above 70%. Breaking can be accelerated by the use of chemicals and/or heat.

NOTE 9 During periods of hot weather, pick up of binder on the tyres of delivery vehicles and paver might be a problem, especially at the higher rates of spread. Avoidance measures include using special non-tacky bond coats, the sparing use of 6 mm or smaller single-sized chippings, or the use of breaking agents.

NOTE 10 Adjacent to pedestrian refuges, crossings, street furniture, kerbs, road markings, etc., hand application (canning and brushing) is acceptable. However, the specifier generally limits this to a width not exceeding 100 mm to be overlapped by machine spraying.

6 Laying

6.1 General

Asphalt shall be machine-laid by a self-propelled paver (see **6.3**), except when hand laying.

*NOTE 1 Further guidance on when hand laying is necessary is given in **6.4**.*

The laying operation shall be controlled and carried out by those trained in asphalt laying.

NOTE 2 Guidance on competencies of asphalt paving gangs for highways is in the National Highways Sector Scheme 16 [5].

6.2 Laying in adverse conditions

*COMMENTARY ON **6.2***

Materials laid in adverse conditions are unlikely to provide the same serviceability and durability as those laid in ideal conditions, so all reasonable steps to avoid or prevent the effects of adverse conditions should be taken and declared by the installer as part of the quality plan in the National Highways Sector Scheme 16 [5].

The following factors, which affect the rate of cooling of asphalt layers and hence the time available for compaction, should also be declared and put into a quality plan, and working practices adjusted accordingly:

- *thicker layers cool more slowly, and binder course and base layers of 60 mm or more thickness provide adequate time for compaction under most weather conditions. Thinner layers need more care and the details should be clear and declared by the installer in the quality plan (see National Highways Sector Scheme 16 [5] for further guidance);*
- *wind speed has a greater effect on the rate of cooling than ambient temperature;*
- *ambient temperature should be taken into consideration but is of less significance than wind speed; and*
- *the time available for compaction is also dependent on the type of binder in the mixture and the temperature of the mixture as it is laid.*

6.2.1 Wet weather

Laying shall not be carried out if standing water is present on the surface to be covered.

NOTE Laying should be avoided as far as is practicable during heavy rain. If wet weather is likely to be prolonged, laying should be suspended.

6.2.2 Low temperatures

Laying shall be carried out with due regard to ambient weather conditions so that materials can be properly compacted. The asphalt shall not be laid on any surface which is frozen or covered with ice or snow. Laying shall cease when the air temperature reaches 0 °C on a falling thermometer, except in calm dry conditions, when laying shall cease if the air temperature reaches –3 °C on a falling thermometer.

NOTE 1 When the surface on which asphalt is to be laid is dry and free from ice, laying may proceed at air temperatures at or above –1 °C on a rising thermometer, and only if compaction can be substantially completed before the asphalt cools below the temperature given in Table 4 or Table A.1, as appropriate.

NOTE 2 Further guidance is given in Transport and Road Research Laboratory Research Report 4 [3] and Manual of Contract Documents for Highway Works – Volume 1 [2].

6.2.3 Wind chill

When laying chipped HRA surface courses (see Clause **7**) in windy and/or cold conditions, the delivery vehicles and paving train shall be coordinated to minimize delays between discharging material into the paver, laying, application of coated chippings and initial rolling of the coated chippings into the freshly-laid surface course asphalt.

*NOTE 1 The embedment and adhesion of coated chippings is affected by surface chilling of asphalt, which occurs quickly in windy conditions, particularly if it is also cold. The guidance given in **6.2.2**, Note 1, should be taken into consideration in that the decision to lay or not to lay is dependent on factors such as temperature and wind speed. This is defined in Transport and Road Research Laboratory Research Report 4 [3] and should be used by the installer.*

NOTE 2 When chipped surface courses are to be laid in winter, some loss of chippings is likely, particularly when high rates of spread have been applied to achieve high levels of texture depth. The risk of loss of chippings increases if the surface course is first trafficked in cold weather.

NOTE 3 When laying in adverse conditions cannot be avoided, consideration should be given to using special binders or thicker layers which can extend the effective compaction time. Insulating the paver hoppers could also provide some benefit.

6.3 Machine laying

6.3.1 Paver laying

The paver used shall be capable of laying the asphalt continuously so as to produce an even and compact surface to the required widths, thicknesses, profiles, cambers and crossfalls. This shall be done without causing segregation, dragging, burning, surface defects or irregularities, which shall be checked by visual examination. It shall also be capable of operating at such a speed as to permit continuous laying as far as the asphalt supply and site conditions allow.

NOTE 1 A means of imparting an initial compaction via the screed should be fitted to the paver, together with the necessary apparatus for supplying heat to the finishing screed.

NOTE 2 Asphalt should be laid as soon as possible after delivery and should ideally be supplied continuously to the paver.

6.3.2 Narrow strips

When narrow strips are laid by hand alongside machine-laid work, they shall be rolled at the same time. They shall receive appropriate surcharge to ensure equivalent compaction.

6.3.3 Inspection before rolling

Immediately after asphalt in any course is laid, and before it is rolled, the surface shall be inspected by visual examination. All defects and irregularities in alignment, grade or texture shall be corrected by the addition or removal of material.

NOTE Corrective work such as scatter back should be kept to a minimum.

6.3.4 Cleaning after stoppages

Asphalt shall be cleared from all parts of the paver when any stoppage has resulted in the temperature of the material still to be laid being lower than the minimum rolling temperature defined in Table A.1. It shall also be cleared at the end of each working day. Cleaning solvent shall not be allowed to come into contact with any bituminous layer.

6.4 Hand laying

Asphalt shall be hand-applied only when site conditions make machine laying impractical or when small quantities of asphalt are being laid.

Asphalt shall be spread in a uniform layer, to achieve required levels and an even texture, and be thoroughly compacted immediately at appropriate temperatures for the material

NOTE 1 Guidance on the minimum rolling temperature is given in Table A.1.

Every precaution shall be taken to minimize segregation and avoid contamination, and in this regard the following requirements apply.

a) On delivery to the site the asphalt shall be protected from heat loss and adverse weather conditions.

b) Asphalt shall be taken directly from the delivery vehicle, which should be kept sheeted wherever possible.

c) Alternatively, it shall be protected in a portable hot box.

NOTE 2 If these means of protection are not available, as a last resort the asphalt may be deposited in heaps, on a clean hard surface (e.g. on boards or tarpaulin) below, and sheeted above to protect it from loss of heat and adverse weather. Excessive heat loss results in loss of workability and insufficient compaction.

6.5 Sampling during laying

Asphalt required for testing shall be sampled in accordance with BS EN 12697-27.

6.6 Thickness

The nominal target thickness of a layer and the minimum compacted thickness at any point shall conform to the thicknesses given in Table 1A to Table 1D, as applicable.

NOTE 1 Thicknesses in excess of those given in Table 1A to Table 1D can provide better compaction if adequate equipment is used, but could lead to problems with surface regularity and level control.

NOTE 2 A guide to the rates of spread likely to be obtained from different asphalt mixtures at different compacted thicknesses is given in Annex B.

6.7 Surface regularity, contour and falls

For contracts not covered by *Manual of Contract Documents for Highway Works – Volume 1 [2],* the new asphalt surface, on completion of rolling, shall conform to the required levels and contour within the dimensions given in Table 3.

For machine-laid work, the longitudinal and transverse regularity on straight crossfalls of finished surfaces shall be such that the maximum depression, measured under a 3 m straightedge (see BS EN 13036-7) placed parallel to or at right angles to the centre-line of the carriageway, shall be not greater than the dimensions given in Table 3.

Table 3 **Accuracy of finish**

Surface	Maximum permissible depth of the gap beneath a 3 m straight edge or a template	
	Machine-laid	Hand-laid
	mm	mm
Base	25	25
Binder course	13	13
Regulating course below surface course	13	13
Surface course	7	10

NOTE 1 For other transverse profiles, depressions or ridges that could obstruct drainage or cause traffic hazards should not occur.

NOTE 2 Although it is desirable for such tolerances to be achieved in all work, they might not always be achievable with hand-laid work.

NOTE 3 For non-planar profiles, a template may be used in place of a straight edge.

NOTE 4 Requirements for applicable levels and finish, for surfaces other than highways should be appropriate for the use to which the area is to be used. In particular, attention should be paid to drainage requirements.

NOTE 5 As a means of ensuring reasonable riding quality after patching operations the surface of the compacted patch should be flush with or slightly raised above the surrounding surface; it should not be left below the surrounding level or ponding could occur.

The finished surface shall be laid as follows unless specified otherwise.

- In the case of roads with a straight crossfall, the fall shall be no more than 3%, nor less than 2%.
- The average fall of the finished cambered surface from the crown to the channel shall be no more than 3%, nor less than 2%.
- Longitudinal drainage falls in the channel shall have a gradient no flatter than 0.8%.

6.8 Joints

6.8.1 General

When the information is available, all joints shall be offset by at least 300 mm from parallel joints in the layer beneath.

6.8.2 Surface course joints

All longitudinal and transverse joints in surface courses shall be made flush.

Before the adjacent width is laid, surface course joints shall be made by:

a) cutting back the edge to a vertical face that exposes the full thickness of the layer; and

b) discarding all loosened material and painting or spraying the vertical face completely with a thin uniform coating of hot applied 40/60 or 70/100 paving grade bitumen, or cold applied thixotropic bituminous emulsion of similar grade or polymer modified bitumen emulsion bond coat.

Surface course joints made in this way shall be:

- all transverse joints that have not been formed to a specific profile;
- joints where the asphalt abuts an existing surface; and
- all longitudinal joints.

NOTE 1 Two or more pavers may be operated in echelon where this is practicable and in sufficient proximity for adjacent widths to be fully compacted by continuous rolling.

NOTE 2 Longitudinal joints in surface course may also be formed by use of an edge compactor creating a chamfered edge during the laying process. Cutting back of the longitudinal joint is not necessary in this instance.

NOTE 3 Surplus bitumen on the surface after the joint is made should be avoided. The surface of the finished joint should not be painted because of the risk of skidding and slipping.

6.8.3 Joints in other courses

Joints in other courses (e.g. base and binder course) shall be treated in such a way as to enhance compaction and bonding.

NOTE For example:

- *as in* ***6.8.2***a)*;*
- *where two or more pavers are being operated in echelon, where this is practicable and in sufficient proximity for adjacent widths to be fully compacted by continuous rolling; and*
- *where edge compactors being used are fitted to rollers.*

6.9 Access chamber covers and projections

Asphalt shall abut against vertical faces of access chamber covers, gully frames, kerbs, channels and similar projections. Before the asphalt is laid, these vertical faces shall be cleaned and painted with a thin uniform coating of hot applied 40/60 or 70/100 paving grade bitumen, or cold applied thixotropic bitumen emulsion of similar grade, or polymer modified bitumen emulsion bond coat. The asphalt shall be tamped around and against such projections by means of tampers, and the finished surface shall be either left flush with the top of, or not more than 3 mm above, such projections.

NOTE Access chamber covers, gully frames and similar projections should be raised to their final level after laying the binder course, but before laying the surface course.

Gullies and channel blocks shall be set slightly lower than the adjacent asphalt surface to facilitate the flow of surface water and enable drainage.

7 Chipping of hot rolled asphalt (HRA)

COMMENTARY ON Clause ***7***

A mixture design protocol for surface course materials is given in Annex H.

7.1 General

If a minimum texture depth is specified for HRA surface course mixtures containing 35% or less nominal coarse aggregate content, then coated chippings conforming to BS EN 13108-4:2006, Annex C shall be applied to give that texture depth.

NOTE 1 Guidance is also given in PD 6691:2015, Annex C.

NOTE 2 Coated chippings cannot be successfully applied to HRA surface course mixtures containing more than 35% coarse aggregate. These mixtures are intended for use without coated chippings.

7.2 Rate of spread of coated chippings

If there is no texture depth requirement, then the rate of spread of chippings shall be not less than 60% of shoulder-to-shoulder cover.

The rate of spread of chippings shall be measured in accordance with BS 598-1:2011, **4.2**.

NOTE The rate of spread of coated chippings might not apply to all footpaths.

7.3 Method of applying coated chippings

7.3.1 Minimum rolling temperatures for HRA mixtures

After initial compaction by the paver or, in the case of hand laying, prior to the first pass of the roller, a uniform layer of coated chippings shall be applied to the HRA surface which shall then be rolled to compact the mixture and embed the chippings. Rolling shall be substantially completed at material temperatures above the minimum temperatures in Table 4.

Table 4 **Minimum rolling temperature for HRA mixtures**

Paving grade bitumen	Minimum rolling temperature °C
30/45	90
40/60	85
70/100	80
100/150	75

NOTE When using modified bitumen or additives, different temperatures might be applicable.

7.3.2 Use of mechanical chipping spreaders

A mechanical chipping spreader shall be used, where practicable.

NOTE Making preliminary adjustments to the chipping spreader by laying chippings on a clean hard surface allows the rate of spread across the width of the machine to be measured and adjusted as necessary.

7.3.3 Unchipped channels

Unchipped channels not less than 150 mm wide shall be left alongside the kerb to allow surface water to flow to the gullies.

8 Texture depth

8.1 General

The laid surfacing material shall achieve the required surface texture depth, where specified.

NOTE 1 For BBA materials for airfields, grooving can achieve satisfactory results. AC 14 BBA C or AC 10 BBA C may be used. For more heavily trafficked sites, the use of polymer modified bitumen may also assist retention of surface grooves, where required.

NOTE 2 The specification of texture depth is site-specific and outside the scope of this British Standard.

8.2 Measurement of surface texture

8.2.1 Where a texture depth is specified, it shall be measured as soon as possible after the surfacing has been laid and before trafficking. On highways, measurements shall be taken on regularly spaced 50 m lane lengths representative of the section of carriageway under consideration. For each 50 m lane length, 10 individual measurements shall be taken of the surface texture depth at approximately 5 m spacing along a diagonal line across the lane width. For paved areas other than highways, the positions of individual determinations of surface texture depth shall be agreed with the specifier and recorded.

NOTE The proportion of the finished work to be measured should be as agreed with the specifier.

8.2.2 Each individual measurement of texture depth shall be made by the volumetric patch test method specified in BS EN 13036-1.

8.2.3 The average texture depth for each section of carriageway lane tested shall be not less than the value specified, and the average of each set of 10 individual measurements shall be not less than 80% of the required value.

NOTE 1 On areas subjected to high turning stresses, such as on the circulating areas of roundabouts, the high levels of texture depth applied on high-speed carriageways should be avoided. As vehicle speeds in these areas are usually limited, skid resistance depends more on microtexture, arising from the use of aggregate of adequate polished stone value (PSV), rather than on the macrotexture of the surface itself.

NOTE 2 On roundabouts where vehicles are capable of maintaining relatively high speeds, traffic-induced stresses are less severe and the risk of chipping loss or fretting is reduced. Nevertheless, a lower average texture depth than for high-speed carriageways might be adequate.

NOTE 3 Chipping loss from chipped HRA should be kept to a minimum. However, surfaces that conform to a specified texture depth should not be rejected merely on the grounds of minor chipping loss.

NOTE 4 Chipping loss from areas of poor chipping embedment in HRA can sometimes be remedied by careful warming of the surface using infra-red heating and re-rolling. However, the addition of chippings to the surface, to replace lost chippings, is unlikely to yield satisfactory results with these techniques.

9 Compaction

*COMMENTARY ON Clause **9***

This standard covers a wide range of asphalt mixtures laid in a variety of circumstances using various compaction control procedures.

9.1 General

Compaction shall be undertaken in accordance with the following, as appropriate, according to the scale and nature of the work:

a) general requirements for compaction of machine-laid asphalt (see **9.2**);

b) general requirements for compaction of hand-laid asphalt (see **9.3**);

c) control requirements for end result compaction of design mix asphalt concretes (see **9.5.1**);

d) control requirements for compaction of performance-related HRA surface course (see **9.5.2**); and

e) Control requirements for compaction of SMA binder course (see **9.5.3**).

NOTE 1 End-result compaction is more appropriate for machine-laid work on major road contracts.

NOTE 2 The specifier should state which of these options is required.

Rolling shall be undertaken in such a way as to achieve the correct surface profile and finish and the required degree of compaction.

Laying of asphalt shall not commence until the rollers and their operators are at the place of laying and ready to commence compaction. The asphalt shall be compacted as soon as rolling can be undertaken without causing undue displacement or surface cracking of the asphalt.

Compaction shall be such that there are no distinct roller marks left on the surface. Rollers shall not be allowed to stand on compacted asphalt that is still warm enough to result in indentation.

9.2 General requirements for compaction of machine-laid asphalt

9.2.1 General

The requirements specified in **9.2** shall be met wherever practicable; where this is not practicable then the requirements specified in **9.3** shall be met.

9.2.2 Personnel

Rollers and other compaction equipment shall be operated by skilled, experienced personnel.

9.2.3 Rollers

9.2.3.1 Roller fittings

All rollers shall be fitted with smooth, quick-acting reverse mechanisms. Smooth steel-wheeled rollers shall have wetting devices of at least the width of the rolls fitted.

9.2.3.2 Roller types

Any roller used shall be one of the following types:

a) deadweight rollers with smooth steel wheels, a rear roll-width of not less than 450 mm and a weight of not less than 6 t; or

b) vibratory rollers of at least equivalent compactive capability to those in item a) (see the Note); or

c) pneumatic tyred rollers of at least equivalent compactive capability to those in item a) (see the Note); or

d) smaller rollers for sites having restricted access, limited working area, restricted width of surfacing or where the underlying construction does not support a heavier roller described in item a).

NOTE This might result in the need for an increased number of roller passes.

9.2.3.3 Steel-wheeled rollers

After the completion of compaction surface course and binder course, mixtures shall be surface-finished with a smooth steel-wheeled roller, which can be a vibratory roller operating in a non-vibrating mode.

NOTE 1 A method of assessing the compaction performance of rollers is given in BS 598-1:2011.

The frequency and amplitude of vibration and the speed of travel of vibratory rollers shall be correctly matched to layer thickness and mixture composition.

NOTE 2 The number of rollers of appropriate compactive effort to be used on a typical site may be:

a) at least one operational roller at all times;

b) a second operational roller when the daily tonnage exceeds either 100 t of surface course or 150 t of base or binder course; or

c) reasonable timely access to a third roller, when the daily tonnage exceeds either 200 t of surface course or 450 t of base or binder course.

NOTE 3 The number of rollers should be such that, while travelling at a low but steady speed, sufficient passes can be made to compact the asphalt adequately.

NOTE 4 These requirements are based on the assumption that water and fuel are readily available; otherwise an additional roller might be needed.

9.2.3.4 Designed AC mixtures conforming to BS EN 13108-1

COMMENTARY ON ***9.2.3.4***

Advice on the mix design of BBA mixtures for airfields is given in Annex L.

In the case of designed AC mixtures conforming to BS EN 13108-1, compaction shall be completed while the temperature of the mixed material is equivalent to or greater than the temperature given in Table 5, when measured in accordance with BS EN 12697-13.

Table 5 **Minimum rolling temperatures for designed AC dense, heavy-duty and high-modulus binder course and base (including EME2)**

Paving grade bitumen	Minimum rolling temperature °C
160/220 pen	60
100/150 pen	75
70/100 pen	90
40/60 pen	105
30/45 pen	110
10/20 pen or 15/25 pen	110

NOTE 1 Delivery temperatures and rolling temperatures for mixtures other than designed heavy-duty, high-modulus and dense base and binder course AC are given in Table A.1.

NOTE 2 Care should be taken to guard against surface cracking occurring as a result of rolling temperatures close to the appropriate minimum temperature. Finishing rolling may be carried out at a temperature below that given in Table 5, but no vibration should be employed.

NOTE 3 Rolling should normally be in a longitudinal direction, with the driven rolls nearest to the paver. The roller should first compact the asphalt adjacent to the joints and then work from the lower to the upper side of the layer overlapping on successive roller passes. To achieve uniform compaction, at least half of the roller passes should be along the edges of the layer. The positions at which the roller reverses should be staggered.

NOTE 4 Rolling asphalt when it is at an unduly high temperature can result in excessive displacement and cause smooth textures.

9.3 General requirements for compaction of hand-laid asphalt and areas with restricted access

In areas where the methods specified in **9.2** are not practicable for reasons of restricted access, limited working area or restricted width of surfacing, and for situations where the underlying construction does not support a heavy static roller, one of the following alternative methods of compaction shall be used:

a) on footpaths and similar areas, either static rollers of 2.5 t deadweight or vibrating rollers of a minimum deadweight of 750 kg, unless it can be demonstrated that an equivalent compactive effort can be provided by a vibrating roller of a lesser deadweight; or

   NOTE 1 A method of assessing the compaction performance of rollers is given in BS 598-1:2011.

b) in trenches and other extremely restricted areas, vibrating plate compactors.

*NOTE 2 In all cases the procedure adopted should be as close as is practicable to that specified in **9.2** for the larger scale work.*

NOTE 3 The compaction achieved depends on the workability and temperature of the mixture at the time of handling. Compaction should commence without delay without causing undue displacement, and should continue until subsequent passes result in no further roller marks.

9.4 Sampling and testing for assessment of compacted asphalt

9.4.1 Coring

9.4.1.1 General

If core specimens are required for the determination of properties of the laid and compacted asphalt, they shall be cut in accordance with BS EN 12697-27:2001, **4.7**, from locations that are representative of the area or material under investigation.

Cores shall be extracted without the use of excessive force and without causing damage to the cores. Cores shall not be taken from freshly-laid asphalt until it has cooled to an appropriate temperature.

9.4.1.2 Reinstatement of core holes

The walls and base of all holes from which core samples have been cut shall be dried and painted with hot 40/60 or 70/100 paving grade bitumen or cold-applied polymer modified bitumen emulsion immediately prior to being back-filled.

Hot binder course or base material similar to that in the existing pavement or permanent cold-lay surfacing material (PCSM) shall be used for reinstating core holes. The core hole reinstatement material shall be installed in layers not exceeding 75 mm thick. Each layer shall be compacted to refusal with a circular-headed vibrating hammer or equivalent device.

Surface course reinstatement material shall be either HRA, SMA, AC or PCSM surface course and be as similar as possible to the existing surface.

NOTE Similar techniques should be used for reinstating small cut outs.

9.4.2 Use of indirect density gauges

*COMMENTARY ON **9.4.2***

Indirect density gauges should be used in accordance with Annex I.

Where indirect density gauges are used they shall be calibrated.

NOTE Indirect density measuring devices may be used either as an alternative to coring or to augment the data between core locations. An appropriate frequency for such measurements is at 20 m spacing with successive measurements in alternate wheel tracks.

9.5 Compaction control

9.5.1 End result compaction control requirements for designed dense base and binder AC mixtures including EME2

9.5.1.1 General

End-result compaction shall be applied to designed dense base and binder AC mixtures.

NOTE 1 These should be product-type tested in accordance with Annex C or Annex D, and Annex E and Annex G.

A method of compaction shall be adopted and detailed in a suitable quality plan to ensure that the void content of the finished mat conforms to the required limits on void content. The equipment and techniques selected to achieve this level of compaction shall conform to **9.1** and **9.2**.

NOTE 2 This method is applicable for works intended to carry heavy traffic.

9.5.1.2 Air void content

Compaction shall be measured in areas of approximately 5 000 m^2 (3 × 500 lane metres) or, where there is less than 5 000 m^2, on the asphalt laid in any one day.

Within each area, air void content shall be determined at three locations at approximately 500 m spacing (or closer for more limited works) along each lane/mat, either from pairs of 150 mm diameter cores cut after the material has cooled to ambient temperature in accordance with **9.4.1** or from measurements made at the same frequency with a suitably calibrated indirect density gauge in accordance with **9.4.2**.

The average air void content for the three locations shall not exceed 6% for EME2 and 8% for other mixtures.

NOTE 1 For roads such as those covered in MCHW – Volume 1 [2], 7% may be more appropriate for mixtures other than EME2.

NOTE 2 For continuous control of large contracts, it could be convenient to apply the compliance criteria to a rolling mean of the values from three consecutive locations (six cores).

NOTE 3 On large contracts it might also be appropriate to use a combination of measurements from both cores and indirect density gauges.

9.5.1.3 Core location and density determination

Cores shall be cut in accordance with BS EN 12697-27. A pair of cores shall be taken, one from each wheel-track zone of the finished road pavement. The wheel-track zones shall be taken to be between 0.5 m and 1.1 m, and between 2.55 m and 3.15 m from the centre of the nearside lane marking or carriageway edge (when not marked) for each running lane. For non-highway applications, locations of cores shall be determined by the installer.

For each of the cores, the in situ void content shall be determined in accordance with BS EN 12697-8, using bulk density in accordance with BS EN 12697-6:2012, procedure B, saturated surface dry condition and the mean maximum density from the broken down core determined in accordance with BS EN 12697-5:2009, procedure A, in water.

9.5.2 Compaction control requirements for performance-related HRA surface course

*COMMENTARY ON **9.5.2***

*This subclause specifies procedures which can be used for demonstrating performance of compacted performance-related HRA surface course mixtures specified to BS EN 13108-4 (see PD 6691:2015, **C.2.5.1.3**). The exact combination of procedures which apply should be agreed with the specifier.*

Annex F provides further information on sampling and testing to measure performance characteristics.

9.5.2.1 Sampling from the laid material

9.5.2.1.1 Pairs of 150 mm diameter cores shall be cut for density determination every lane kilometre. One core of each of these pairs shall be taken from the centre of the lane and one shall be taken with its centre between 500 mm and 1 000 mm of the edge of the mat.

9.5.2.1.2 For non-highway applications, appropriate core locations shall be agreed.

9.5.2.1.3 For wheel tracking testing, a single 200 mm diameter core shall be taken from the centre of the lane.

NOTE The need for and frequency of wheel tracking testing should be agreed with the specifier. Intervals of one every lane kilometre are recommended.

9.5.2.2 Bulk density

For each 150 mm diameter core, the bulk density shall be determined in accordance with BS EN 12697-6:2012, procedure A, in a dry condition without removing the coated chippings. The bulk density shall be the mean value of the two cores taken at the sampling location. The maximum density shall then be determined from the pair of the cores in accordance with BS EN 12697-5:2009, procedure A, in water.

9.5.2.3 Air void content

The air void content of each pair of 150 mm diameter cores shall be calculated to ±0.1% as follows:

$$A\left(1-\frac{\rho}{\rho_{max}}\right)\times 100 \qquad (1)$$

where:

A is the air void content (in %);

ρ is the bulk density, determined in accordance with BS EN 12697-6 (in Mg/m^3);

ρ_{max} is the maximum density in accordance with BS EN 12697-5 (in Mg/m^3).

9.5.2.4 Wheel tracking

The resistance to permanent deformation of the 200 mm cores shall be determined in accordance with BS EN 12697-22:2003, small size devices, procedure A, at the appropriate temperature (45 °C or 60 °C).

9.5.2.5 Conformity criteria

9.5.2.5.1 When determined in accordance with **9.5.2.3**, the air void content shall be not greater than 7.5% for a pair of cores at a chainage and shall be not greater than 5.5% for the mean of any six consecutive determinations from pairs of cores from material from the same mixing plant.

9.5.2.5.2 The mean wheel tracking rate and mean wheel tracking rut depth of any six consecutive determinations shall be less than the specified value. Individual values of wheel tracking rate and rut depth shall not exceed the specified values by more than 50%.

9.5.3 Compaction control requirements for SMA binder course

*COMMENTARY ON **9.5.3***

This subclause specifies procedures which can be used for demonstrating contractual compliance of compacted SMA binder course mixtures specified to BS EN 13108-5 (see PD 6691:2015, Annex D).

9.5.3.1 Sampling from the laid material

9.5.3.1.1 Pairs of 150 mm diameter cores shall be cut for density determination every lane kilometre. One core of each of these pairs shall be taken from the centre of the lane and one shall be taken with its centre between 500 mm and 1 000 mm of the edge of the mat.

9.5.3.1.2 For non-highway applications, appropriate core locations shall be agreed.

9.5.3.1.3 For wheel tracking testing, a single 200 mm diameter core shall be taken from the centre of the lane.

NOTE The need for and frequency of wheel tracking testing should be agreed with the specifier. Intervals should be one every lane kilometre.

9.5.3.2 Bulk density

For each 150 mm diameter core, the bulk density shall be determined in accordance with BS EN 12697-6:2012, procedure B, in a saturated surface dry condition. The bulk density shall be the mean value of the two cores taken at the sampling location. The maximum density shall then be determined from the pair of the cores in accordance with BS EN 12697-5:2009, procedure A, in water.

9.5.3.3 Air void content

The air void content of each pair of 150 mm diameter cores shall be calculated to ±0.1% as follows:

$$A\left(1-\frac{\rho}{\rho_{max}}\right)\times 100 \qquad (2)$$

where:

- A is the air void content (in %);
- ρ is the bulk density, determined in accordance with BS EN 12697-6 (Mg/m^3);
- ρ_{max} is the maximum density in accordance with BS EN 12697-5 (Mg/m^3).

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9.5.3.4 Wheel tracking

The resistance to permanent deformation of the cores shall be determined in accordance with BS EN 12697-22, using the method specified in BS EN 13108-20:2006 at the appropriate temperature (45 °C or 60 °C) for wheel tracking small device procedure B.

9.5.3.5 Conformity criteria

9.5.3.5.1 When determined in accordance with **9.5.3.3**, the air void content shall be not greater than 6% for a pair of cores at a chainage and shall be not greater than 4% for the mean of any six consecutive determinations from pairs of cores from material from the same mixing plant. When the SMA is being used as a regulating course below 30 mm thick, the appropriate limiting air void contents shall be 8% and 6% respectively.

9.5.3.5.2 The mean wheel tracking slope and mean proportional rut depth of any six consecutive determinations shall be less than the specified value. Individual values shall not exceed the specified values by more than 50%.

10 Opening to traffic

Newly laid sections of asphalt shall not be opened to traffic until they have cooled sufficiently for traffic not to cause damage.

NOTE 1 If asphalt base or binder course is to be used as a temporary running surface, the skidding resistance may be maintained either by the choice of suitable aggregate or by surface dressing.

NOTE 2 Open textured binder course mixtures should not be used as temporary running surfaces because of the risk of ingress of dirt and damage by trafficking.

NOTE 3 Curing time, as well as cooling, is an important factor in the development of deformation resistance. In hot weather the surfacing should not, where possible, be opened to traffic until at least 24 h after paving, especially with contraflow working. Irrespective of the ambient temperature, but particularly when the lead time before opening is not practicable due to site-specific constraints, either the surface temperature should not be greater than 25 °C, the temperature anywhere within the mat should be less than 40 °C at the time of opening, or recommendations on temperature from the binder manufacturer should be followed. The maximum temperature within the mat may be at mid-layer depth.

Annex A (informative) Recommended delivery and rolling temperatures for recipe AC, HRA and SMA to BS EN 13108

Table A.1 shows the minimum delivery and rolling temperatures for recipe AC, HRA and SMA mixtures.

Table A.1 **Minimum delivery and rolling temperatures for recipe AC, HRA and SMA mixtures**

Material type		**Binder grade**	**Minimum temperature °C**	
			On arrival A)	**Immediately prior to rolling** B)
AC C)	Open surf and bin	160/220	95	75
		250/330	85	65
	Close, fine, medium, dense surf	70/100	130	100
		100/150	120	95
		160/220	110	85
		250/330	100	80
	Dense bin, base D)	40/60	130	100
		70/100	125	95
		100/150	120	90
		160/220	110	80
HRA	Surf E)	30/45	140	110
		40/60	140	110
		70/100	125	90
		100/150	120	85
	Reg, bin, base	30/45	130	105
		40/60	130	105
		70/100	125	90
		100/150	120	85
SMA	Surf, reg, bin	40/60	130	100
		70/100	125	90
		100/150	120	85

A) In the lorry within 30 min after arrival on site.
B) Greater compactive effort is required to achieve acceptable air void content as temperatures approach the lower limit.
C) For slag mixtures, temperatures may be 10 °C lower than the recommended values.
D) Requirements for temperatures for substantial completion of rolling of designed bin and base asphalt concretes are given in Table 5.
E) Requirements for temperatures for substantial completion of rolling when applying chippings to HRA are given in Table 4.

NOTE Temperatures for the supply, laying and compaction of low-temperature warm mix and other reduced temperature asphalts are outside the scope of this British Standard.

Annex B (informative) Approximate rates of spread of asphalt

Table B.1 gives an indication of rates of spread likely to be achieved with different asphalt mixtures at different compacted thicknesses. It is for guidance only. The ranges given take into account the fact that the covering capacity per tonne is influenced by such factors as the density and grading of the aggregates, condition of substrate and degree of compaction. They apply only when the accuracy of finish of the substrate is within the tolerances specified in **5.2**. On more irregular substrates, heavier rates of spread are to be expected.

Table B.1 **Approximate rate of spread**

Average thickness of course mm	**Approximate rate of spread** m² per tonne				
	AC med open	**AC Dense**	**HRA**	**SMA**	**EME2**
15	—	24–30	—	—	—
20	—	18–22	—	18–23	—
25	—	14–18	15–19	15–18	—
35	11–14	10–13	10–14	10–13	—
40	10–12	9–11	9–12	9–11	—
45	9–11	8–10	8–11	8–10	—
50	8–10	7–9	7–9	7–9	—
60	7–8	6–7	6–8	6–8	6–7
70	6–7	5–6	5–7	5–6	5–6
80	—	4–6	5–6	5–6	5–6
90	—	4–5	4–5	4–5	4–5
100	—	4–4	4–5	—	4–4
110	—	3–4	3–4	—	3–4
120	—	3–4	3–4	—	3–4
130	—	3–3	3–4	—	3–3
140	—	3–3	3–3	—	3–3
150	—	2–3	2–3	—	2–3

Annex C (informative) Protocol for determining void content of dense base and binder AC mixtures conforming to BS EN 13108-1 from trial strips for the purposes of product-type testing to BS EN 13108-20

C.1 Trial strip

Using full-scale paving equipment and conventional rollers, lay a trial strip of the mixture produced on a full-scale mixing plant:

a) with a mix composition as close as possible to target composition, as defined in **C.5**;

b) with a nominal target thickness in accordance with Table 1A;

c) with a mat width 3.0 m to 4.5 m;

d) on a bound substrate;

e) in accordance with Clause **9**.

NOTE The trial strip may comprise a defined length within a normal paving operation.

C.2 Sampling and testing of loose mixture

C.2.1 Take a sample for analysis prior to leaving the mixing plant in accordance with BS EN 12697-27:2001, **4.1.** During the laying of the trial strip, take two samples of loose mixture at each of three evenly-spaced locations along the trial length from around the augers of the paver in accordance with BS EN 12697-27:2001, **4.3**, at the same locations as the 150 mm diameter cores in **C.3.2**.

C.2.2 Determine the maximum density of one of the samples from each location on the trial strip in accordance with BS EN 12697-5:2009, procedure A, in water and calculate the mean of these three values.

C.2.3 Analyse all four samples to determine binder content and grading in accordance with BS EN 12697-1 and BS EN 12697-2, taking note of relevant guidance for modified binders and reporting any correction factors used.

C.3 Core sampling and testing of cores

C.3.1 Take the cores in accordance with BS EN 12697-27, not sooner than 12 h after the end of the laying process and/or when the asphalt has cooled to ambient temperature.

C.3.2 Take a pair of 150 mm diameter cores in accordance with BS EN 12697-27:2001, **4.7**, at each of the following two locations:

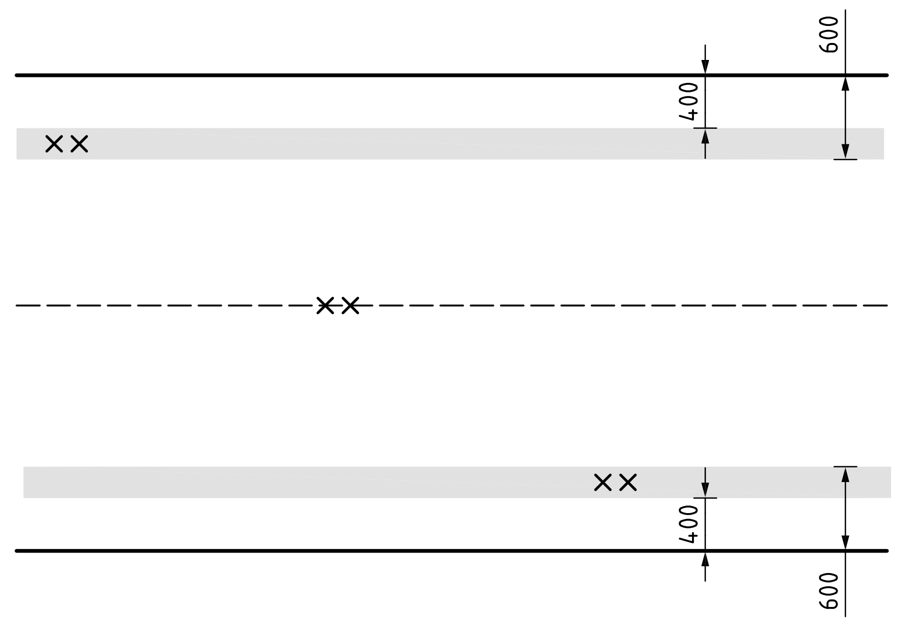
a) one on the centre line of the mat; and

b) the other two centred 0.4 m to 0.6 m from the edges of the mat.

C.3.3 Where possible, space the cores equally along the full length of the trial strip (see Figure C.1).

Figure C.1 **Spacing of cores**

Dimensions given in mm



Key

× 150 mm core

The shading area indicates the wheel track zone. The broken line indicates the centre line.

C.3.4 Determine the bulk density of each of the cores in accordance with BS EN 12697-6:2012, procedure B, saturated surface dry condition.

C.3.5 Heat and compact each core to refusal in accordance with BS EN 12697-32.

C.3.6 Determine the bulk density of each recompacted core specimen in accordance with BS EN 12697-6:2012, procedure B, saturated surface dry condition.

C.4 Calculations

C.4.1 For each of the cores, determine the in situ void content in accordance with BS EN 12697-8, using the bulk density from **C.3.4** and the mean maximum density from **C.2.2**.

C.4.2 For each of the cores, determine the refusal void content in accordance with BS EN 12697-8, using the bulk density from **C.3.6** and the mean maximum density from **C.2.2**.

C.4.3 Calculate the binder content by volume B_{vol} as a percentage (%) as follows:

$$B_{vol} = B \times \frac{\rho_{mix}}{\rho_b} \qquad (C.1)$$

where:

B is the mass of binder added at the mixer, as a percentage of the total mix;

ρ_{mix} is the mean bulk density in Mg/m^3 of the six 150 mm diameter cores from **C.3.2**;

ρ_b is the bulk density at 25 °C in Mg/m^3 of the binder.

C.4.4 Determine the binder volume (**C.4.3**), the mean value of in situ void content (**C.4.1**) and the mean value of refusal void content (**C.4.3**) for each location.

C.4.5 Determine the mean results of the four compositional analyses from **C.2.3**.

C.5 Verification of target composition

Check that the mean composition falls within the permitted deviation for the mean of four results quoted in BS EN 13108-21:2006, Table A.1, about the target composition.

C.6 Reporting

Report the results in accordance with BS EN 13108-20.

Annex D (informative) Protocol for determining resistance to permanent deformation of binder course and base asphalt mixtures conforming to BS EN 13108-1 (asphalt concrete) from trial strips for the purposes of type testing to BS EN 13108-20

D.1 Trial strip

Using full-scale paving equipment and conventional rollers, lay a trial strip of the mixture produced on a full-scale mixing plant:

a) with a mixture composition as close as possible to target composition, as defined in **D.5**;

b) with a nominal target thickness in accordance with Table 1A;

c) with a mat width 3.0 m to 4.5 m;

d) on a trial strip length 30 m to 60 m;

e) on a bound substrate; and

f) in accordance with Clause **9**.

NOTE The trial strip may comprise a defined length within a normal paving operation.

D.2 Sampling and testing of loose mixture

D.2.1 Take a sample for analysis prior to leaving the mixing plant in accordance with BS EN 12697-27:2001, **4.1**. During the laying of the trial strip, take two samples of loose mixture at each of three evenly-spaced locations along the trial length from around the augers of the paver in accordance with BS EN 12697-27:2001, **4.3**, at the same locations as the 150 mm diameter cores in **D.3.2**.

D.2.2 Analyse all four samples to determine binder content and grading in accordance with BS EN 12697-1 and BS EN 12697-2, taking note of relevant guidance for modified binders and reporting any correction factors used.

D.3 Core sampling and testing of cores

D.3.1 Take the cores in accordance with BS EN 12697-27, not sooner than 12 h after the end of the laying process and/or when the asphalt has cooled to ambient temperature.

D.3.2 Take six test cores either of:

a) 200 mm where the wheel tracking test method is employed; or

b) 150 mm where the uniaxial cyclic compression test method is employed, from the centre line of the trial strip, in accordance with BS EN 12697-27:2001, **4.7**.

D.3.3 Where possible, space the cores equally along the full length of the trial strip.

D.3.4 Determine the resistance to permanent deformation of the cores, either:

a) in accordance with BS EN 12697-22, using the method specified in BS EN 13108-20:2006 at the appropriate temperature (45 °C or 60 °C) for wheel tracking small device procedure B; or

b) in accordance with BS EN 12697-25:2005, procedure A, using the method specified in BS EN 13108-20 for cyclic compression.

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D.3.5 Report the resistance to permanent deformation.

D.4 Calculations

Determine the mean result of the four compositional analyses from **D.2.2**.

D.5 Verification of target composition

Check that the mean composition falls within the permitted deviation for the mean of four results quoted in BS EN 13108-21:2006, Table A.1, about target composition.

D.6 Reporting

Report the results in accordance with BS EN 13108-20.

Annex E (informative) Protocol for determining void content and stiffness of EME2 base and binder AC mixtures conforming to BS EN 13108-1 from trial strips for the purposes of product-type testing to BS EN 13108-20

E.1 Trial strip

Using full-scale paving equipment and conventional rollers, lay a trial strip of the mixture produced on a full-scale mixing plant:

a) with a mixture composition as close as possible to target composition, as defined in **E.5**;

b) with a mixture richness modulus of not less than 3.4;

c) with a nominal target thickness in accordance with Table 1A;

d) with a mat width 3.0 m to 4.5 m;

e) on a trial strip length 30 m to 60 m;

f) on a bound substrate; and

g) in accordance with Clause **9**.

NOTE The trial strip may comprise a defined length within a normal paving operation.

E.2 Sampling and testing of loose mixture

E.2.1 Take a sample for analysis from material prior to leaving the mixing plant, in accordance with BS EN 12697-27:2001, **4.1**. During the laying of the trial strip, take two samples of loose mixture at each of three evenly-spaced locations along the trial length from around the augers of the paver in accordance with BS EN 12697-27:2001, **4.3**, at the same locations as the 150 mm diameter cores specified in **E.3.2**.

E.2.2 Determine the maximum density of one of the samples from each location on the trial strip in accordance with BS EN 12697-5:2009, procedure A, in water and calculate the mean of these three values.

E.2.3 Analyse all four samples to determine binder content and grading in accordance with BS EN 12697-1 and BS EN 12697-2, taking note of relevant guidance for modified binders and reporting any correction factors used.

E.3 Core sampling and testing of cores

E.3.1 Take the cores in accordance with BS EN 12697-27, not sooner than 12 h after the end of the laying process and/or when the asphalt has cooled to ambient temperature.

E.3.2 Take a pair of 150 mm diameter cores in accordance with BS EN 12697-27:2001, **4.7**, at each of the following two locations:

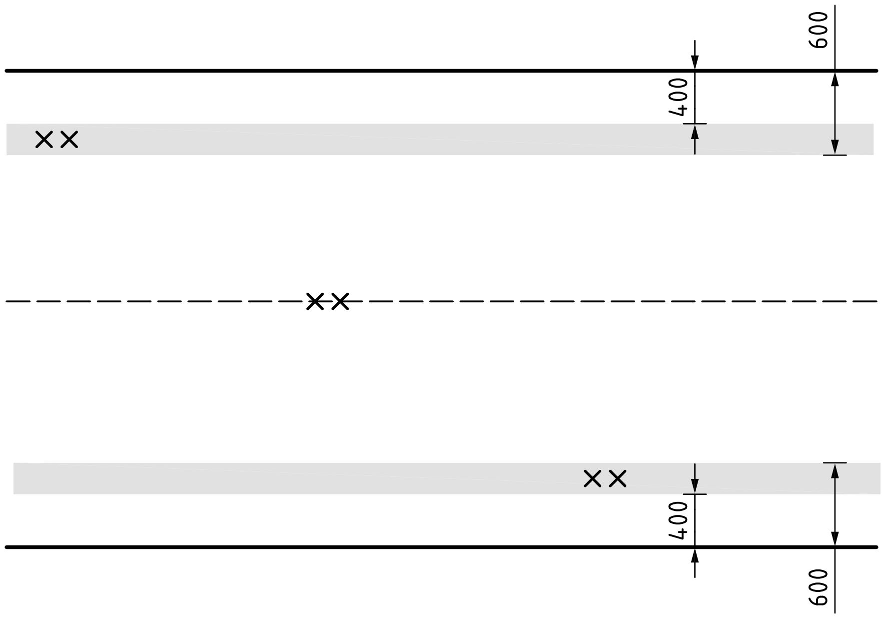
a) one on the centre line of the mat; and

b) the other two centred 0.4 m to 0.6 m from the edges of the mat.

E.3.3 Where possible, space the cores equally along the full length of the trial strip (see Figure E.1).

Figure E.1 **Spacing of cores**

Dimensions given in mm



Key

× 150 mm core

The shaded area indicates the wheel track zone.

The broken line indicates the centre line.

E.3.4 Determine the bulk density of each of the cores in accordance with BS EN 12697-6:2012, procedure B, saturated surface dry condition.

E.3.5 Cut test specimens from the cores to determine stiffness in accordance with BS EN 12697-26 (ITSM method 20 °C).

E.4 Calculations

E.4.1 For each of the cores, determine the in situ void content in accordance with BS EN 12697-8, using the bulk density from **E.3.4** and the mean maximum density from **E.2.2**.

E.4.2 For each pair of cores, determine the mean value of in situ void content.

E.4.3 Calculate the binder richness modulus of the target composition in accordance with the following.

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The binder richness modulus, *K*, is derived from:

$$B_{\mathrm{PPC}} = K \times a \times \sqrt[5]{\sum} \qquad (E.1)$$

where:

- B_{PPC} is the mass of soluble binder expressed as a percentage of the total dry mass of aggregate, including filler;
- K is the binder richness modulus;
- a is the correction coefficient;
- Σ is the specific surface area of aggregate.

NOTE B_{PPC} is different from the conventional UK expression of binder content B_{UK}, which is as a percentage by mass of the total mix:

$$B_{\mathrm{PPC}} = \frac{100 \times B_{\mathrm{UK}}}{100 - B_{\mathrm{UK}}} \qquad (E.2)$$

E.4.4 The correction coefficient, *a*, is defined as:

$$a = \frac{2650}{\rho_{mc}} \qquad (E.3)$$

where:

ρ_{mc} is the theoretical aggregate density (in Mg/m^3) (see PD 6691).

E.4.5 The specific surface area of aggregate, Σ, is defined as:

$$\sum = 0.25G + 2.3S + 12s + 135f \qquad (E.4)$$

where:

- G is the proportion by mass of aggregate over 6.3 mm;
- S is the proportion by mass of aggregate between 6.3 mm and 0.315 mm;
- s is the proportion by mass of aggregate between 0.315 and 0.08 mm;
- f is the proportion by mass of aggregate smaller than 0.08 mm.

NOTE The proportions of aggregate should be expressed as decimal fractions of the total mass (e.g. if there is 38% of the mass passing 6.3 mm and retained on 0.315 mm then S would be 0.38).

E.5 Verification of target composition

Check that the mean composition falls within the permitted deviation for the mean of four results quoted in BS EN 13108-21:2006, Table A.1, about target composition and that the richness modulus is not less than 3.4.

E.6 Reporting

Report results in accordance with BS EN 13108-20.

Annex F (informative) Protocol for determining void content, binder volume and resistance to permanent deformation of performance-related surface course HRA mixtures conforming to BS EN 13108-4 from trial strips for the purposes of product-type testing to BS EN 13108-20

F.1 Trial strip

Using full-scale paving equipment and conventional rollers, lay a trial strip of the mixture produced on a full-scale mixing plant:

a) with a mixture composition as close as possible to target composition, as defined in **F.5**;

b) with a nominal target thickness of 50 mm;

c) with a mat width 3.0 m to 4.5 m;

d) on a trial strip length 30 m to 60 m;

e) from a minimum of 20 t of laid asphalt on a bound substrate and chipped in accordance with Clause **7**;

f) which, when laid, leaves sufficient compacted area or areas unchipped to enable the taking of six 150 mm diameter cores.

NOTE The trial strip may comprise a defined length within a normal paving operation.

F.2 Sampling and testing of loose mixture

F.2.1 Take a sample for analysis from material prior to leaving the mixing plant in accordance with BS EN 12697- 27:2001, **4.1**. During the laying of the trial strip, take two samples of loose mixture at each of three evenly-spaced locations along the trial length from around the augers of the paver in accordance with BS EN 12697-27:2001, **4.3**, at the same locations as the 150 mm cores specified in **F.3.2.1** and **F.3.3.3**.

F.2.2 Analyse all four samples to determine binder content and grading in accordance with BS EN 12697-1 and BS EN 12697-2, taking note of relevant guidance for modified binders and reporting any correction factors used.

F.3 Core sampling and testing of cores

F.3.1 General

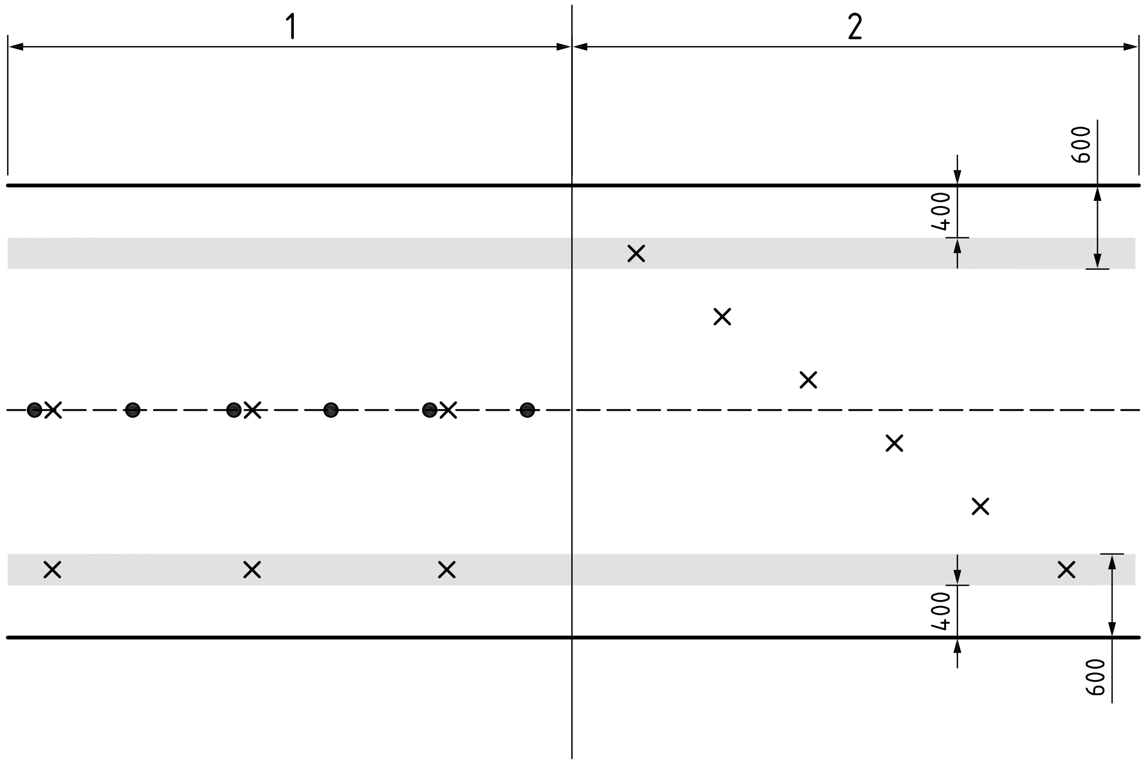
Take the cores as detailed in **F.3.2** and **F.3.3** in accordance with BS EN 12697-27, not sooner than 12 h after the end of the laying process and/or when the asphalt has cooled to ambient temperature.

F.3.2 Unchipped areas

F.3.2.1 Take six 150 mm diameter cores in accordance with BS EN 12697-27:2001, **4.7**, from the compacted but unchipped areas. Evenly space the cores along a diagonal line running between the centres of the two wheel track zones extending for the length of the unchipped area, as shown in Figure F.1. Take the wheel track zones to be between 0.4 m and 0.6 m from the edge of the mat.

Figure F.1 **Spacing of cores**

Dimensions given in mm



Key

1 Chipped area

2 Unchipped area

× 150 mm core

The black circles indicate a 200 mm core.

The shaded area indicates the wheel track zone.

The broken line indicates the centre line.

F.3.2.2 Determine the bulk density of each of the cores from **F.3.2.1** in accordance with BS EN 12697-6:2012, procedure A, dry condition.

F.3.3 Chipped areas

F.3.3.1 Take six 200 mm diameter cores from the centre line of the chipped trial strip in accordance with BS EN 12697-27:2001, **4.7**. Where possible, space the cores equally along the full length of the chipped area, as shown in Figure F.1.

F.3.3.2 Determine the resistance to permanent deformation of the cores from **F.3.3.1** in accordance with BS EN 12697-22:2003, small size devices, procedure A, at the appropriate temperature (45 °C or 60 °C).

F.3.3.3 Take pairs of 150 mm diameter cores in the chipped areas in accordance with BS EN 12697-27:2001, **4.7**, at each of two locations:

a) one core from each pair positioned on the centre line of the mat; and

b) the other core from each pair centred between 0.4 m and 0.6 m from the edge of the mat.

F.3.3.4 Where possible, space the cores equally along the full length of the trial strip (see Figure F.1).

F.3.3.5 Determine the bulk density of each of the cores from **F.3.3.3** in accordance with BS EN 12697-6:2012, procedure A, dry condition.

F.3.3.6 Combine the material from each pair of cores from **F.3.3.3** and determine the maximum density of the asphalt mixture in accordance with BS EN 12697-5:2009, procedure A, in water.

F.4 Calculations

F.4.1 Calculate the binder volume of the unchipped cores, B_{vol}, as follows:

$$B_{vol} = B \times \frac{\rho_{mix}}{\rho_b} \quad (F.1)$$

where:

B is the mass of binder added at the mixer, as a percentage of the total mix;

ρ_{mix} is the mean bulk density in Mg/m^3 of the six 150 mm diameter cores from **F.3.2.1**;

ρ_b is the bulk density at 25 °C of the binder in Mg/m^3.

F.4.2 For each of the 150 mm chipped cores from **F.3.3.3**, determine the in situ void content in accordance with BS EN 12697-8, using the mean bulk density from **F.3.3.5** and the maximum density from **F.3.3.6**.

F.4.3 Determine the mean results of the four compositional analyses from **F.2.2**.

F.5 Verification of target composition

Check that the mean composition falls within the permitted deviation for the mean of four results quoted in BS EN 13108-21:2006, Table A.1, about target composition.

F.6 Reporting

Report the binder volume (**F.4.1**), in situ void contents (**F.4.2**), the mean of the three in situ void contents (**F.4.2**), and the wheel tracking rate and rut depth.

Annex G (informative) Protocol for determining void content and resistance to permanent deformation of SMA binder course and regulating courses to BS EN 13108-5 from trial strips for the purposes of product-type testing to BS EN 13108-20

G.1 Trial strip

Using full-scale paving equipment and conventional rollers, lay a trial strip of the mixture produced on a full-scale mixing plant:

a) with a mixture composition as close as possible to target composition, as defined in **G.5**;

b) with a nominal target thickness of not less than 60 mm;

c) with a mat width 3.0 m to 4.5 m;

d) on a trial strip length 30 m to 60 m;

e) on a bound substrate;

f) in accordance with Clause **9**.

NOTE The trial strip may comprise a defined length within a normal paving operation.

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G.2 Sampling and testing of loose material

G.2.1 Take a sample for analysis from material prior to leaving the mixing plant, in accordance with BS EN 12697-27:2001, **4.1**. During the laying of the trial strip, take two samples of loose mixture at each of three evenly-spaced locations along the trial length from around the augers of the paver in accordance with BS EN 12697-27:2001, **4.3**, at the same locations as the cores specified in **G.3.2** and **G.3.4**.

G.2.2 Analyse all four samples to determine binder content and grading in accordance with BS EN 12697-1 and BS EN 12697-2, taking note of relevant guidance for modified binders and reporting any correction factors used.

G.3 Core sampling and testing of cores

G.3.1 Take the cores as detailed in **G.3.2** to **G.3.7** in accordance with BS EN 12697-27, not sooner than 12 h after the end of the laying process and/or when the asphalt has cooled to ambient temperature.

G.3.2 Take six 200 mm diameter test cores from the centre line of the trial strip in accordance with BS EN 12697-27:2001, **4.7**. Where possible, space the cores equally along the full length of the trial strip.

G.3.3 Determine the resistance to permanent deformation of the cores from **G.3.2** either:

a) in accordance with BS EN 12697-22, using the method specified in BS EN 13108-20:2006 at the appropriate temperature (45 °C or 60 °C) for wheel tracking small device procedure B; or

b) in accordance with BS EN 12697-25:2005, procedure A, using the method specified in BS EN 13108-20 for cyclic compression.

G.3.4 Take a pair of 150 mm diameter cores in accordance with BS EN 12697-27:2001, **4.7**, at each of the following two locations:

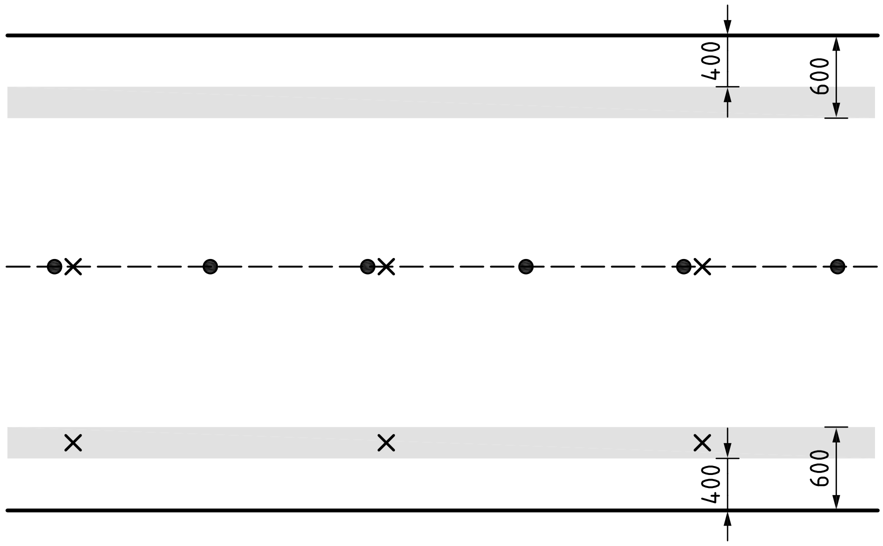
a) one core from each pair positioned on the centre line of the mat; and

b) the other core from each pair centred between 0.4 m and 0.6 m from the edge of the mat.

G.3.5 Where possible, space the cores equally along the full length of the trial strip (see Figure G.1).

Figure G.1 **Spacing of cores**

Dimensions given in mm



Key

× 150 mm core

The black circles indicate a 200 mm core.

The shaded area indicates the wheel track zone.

The broken line indicates the centre line.

G.3.6 Determine the bulk density of each of the cores from **G.3.4** in accordance with BS EN 12697-6:2012, procedure B, saturated surface dry condition.

G.3.7 Combine the material from each pair of cores from **G.3.4** and determine the maximum density of the asphalt mixture in accordance with BS EN 12697-5:2009, procedure A, in water.

G.4 Calculations

G.4.1 For each of the cores, determine the in situ void content in accordance with BS EN 12697-8, using the bulk density from **G.3.6** and the mean maximum density from **G.3.7**.

G.4.2 Determine the mean results of the four compositional analyses from **G.2.2**.

G.5 Verification of target composition

Check that the mean composition falls within the permitted deviation for the mean of four results quoted in BS EN 13108-21:2006, Table A.1, about target composition.

G.6 Reporting

Report the in situ void contents (**G.4.1**), the mean of the three in situ void contents (**G.4.1**), and the wheel tracking slope and proportional rut depth.

Annex H (informative) Protocol for determining the design binder content of designed HRA surface course mixtures to BS EN 13108-4

H.1 Sampling

Sample coarse aggregate, fine aggregate and filler in accordance with BS EN 932-1. Sample binder in accordance with BS EN 58.

NOTE Ideally the aggregates should be sampled from the asphalt plant in the processed condition at which the binder is normally added.

H.2 Specimen preparation

H.2.1 Test coarse aggregate, fine aggregate and filler in accordance with Table H.1 after preparing the test sample in accordance with **H.2.2** to **H.2.9**.

Table H.1 **Tests on material**

Material	Test	Standard
Coarse and fine aggregate	Grading	BS EN 933-1
Filler aggregate	Grading	BS EN 933-1
Binder	Penetration at 25 °C	BS EN 1426
	Softening point	BS EN 1427
	Relative density	BS EN ISO 3838
	Ash content of natural asphalt/bitumen blends when used as the binder	BS 2000-223

H.2.2 Dry the aggregates to constant mass at a temperature of (110 ±5) °C.

H.2.3 Obtain a representative sample of each aggregate by riffling in accordance with BS EN 932-2.

H.2.4 Sieve the coarse aggregate to remove the material passing the 2 mm sieve. Discard material passing 2 mm.

H.2.5 Sieve the fine aggregate to separate the material retained on the 2 mm sieve from that passing the sieve. Recombine the two fractions in the correct proportions (as determined by the sieve analysis on the fine aggregate) for the manufacture of test specimens.

H.2.6 Calculate and report the combined grading as part of the target composition of the mixture.

*NOTE If the constituent aggregates were received in the form of combined coarse and fine aggregate then steps **H.2.4** and **H.2.5** need not be carried out. The combined coarse and fine aggregate should be separated on the 2 mm sieve and recombined to give a grading as described in **H.2.7**.*

H.2.7 Proportion the aggregate for each mixing batch by mass as indicated in Table H.2. Weigh to the nearest gramme a sufficient quantity of each fraction into a container so that each batch is at the required target composition.

Table H.2 **Aggregate proportions for mix design**

Nominal coarse aggregate content	**Coarse aggregate retained on 2 mm sieve, A**	**Fine aggregate passing 2 mm and retained 0.063 mm sieve (wet sieving), B**	**Material passing 0.063 mm sieve, C**
% mass of total mixture	% mass of total aggregate	% mass of total aggregate	% mass of total aggregate
0	0	86	14
30	35	56	9
35 type F	39	53	8
55 type F	59	35	6
35 type C	41	51	8
55 type C	60	34	6

NOTE 1 When the binder is paving grade, modified or hard grade bitumen, calculate the proportion of the constituents shown in the Table from the following equations:

$$Y = 100 \times \frac{(100L - 100C - LA)}{(100L - 100H - KL)}$$

$$Z = \frac{(100C - HY)}{L}$$

$$X = 100 - Y - Z$$

where:

A is the percentage by mass of coarse aggregate given for A appropriate to the nominal coarse aggregate content selected;

C is the percentage by mass of material passing 0.063 mm for C appropriate to the nominal coarse aggregate content selected;

X is the percentage by mass of coarse aggregate retained on 2 mm;

Y is the percentage by mass of fine aggregate containing H% by mass passing 0.063 mm and K% by mass retained on 2 mm;

Z is the total percentage by mass of filler containing L% by mass passing 0.063 mm.

NOTE 2 When the binder is a natural asphalt/paving grade bitumen blend it is necessary to allow for the mineral matter in the natural asphalt.

H.2.8 Make up each mixing batch such that after compaction the specimens have a height of (63.5 ±3) mm. Sufficient batches to cover the desired range of binder contents have a minimum of nine binder contents at intervals of 0.5% of total mixture. Three specimens are required at each binder content.
Table H.3 gives the mass of binder to be added to each 100 g of aggregate for appropriate binder contents.

NOTE 1 The quantity of aggregate required to make up each mixing batch may be estimated from the results of past experience, calculation or trial mixes. For trial mixes the masses of aggregate given in Table H.4 are suggested.

NOTE 2 If there is no past experience or other information available for the aggregates to be employed then the binder contents given in Table H.3 are suggested as the middle of the range to be tested. In this case it might be necessary to test more than nine binder contents.

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Table H.3 **Binder proportions required for mix-design procedure**

Binder content, MA % mass of total mixture	Mass of paving grade, modified or hard grade bitumen to be added to 100 g of aggregate, N g
4.0	4.2
4.5	4.7
5.0	5.3
5.5	5.8
6.0	6.4
6.5	7.0
7.0	4.7
7.5	8.1
8.0	8.7
8.5	9.3
9.0	9.9
9.5	10.5
10.0	11.1
10.5	11.7
11.0	12.4
11.5	13.0
12.0	13.6
12.5	14.3
13.0	14.9

NOTE For paving grade, modified and hard grade bitumens:

$$N = \left(\frac{100 \times M}{100 - M}\right)$$

For a natural asphalt/bitumen blend with a total solubility of S%.

Binder mass per 100 g aggregate (g):

$$P(N) = \left(\frac{100 \times N}{S}\right)$$

For example, for a mixture with a nominal stone content of 30%, 7.0% soluble binder content (M) and an aggregate mass of 1 080 g, the mass of binder required for each specimen is (1 080/100) × 7.5 = 81 g.

Table H.4 **Mass of aggregate (coarse, fine and filler) and suggested binder contents for trial mixes**

Nominal coarse aggregate content % mass	Mass of aggregate in each specimen g	Suggested mid-point binder content % mass
0	980	10.0
30	1 080	7.5
35	1 090	7.0
55	1 140	5.5

H.2.9 Mix each batch of asphalt in accordance with BS EN 12697-35.

H.2.10 Compact the specimens in accordance with BS EN 12697-30, using 50 blows per side.

H.2.11 Determine the bulk density (ρ_b) of each specimen in accordance with BS EN 12697-6:2012, procedure A.

H.2.12 Calculate the compacted aggregate density (ρ_{cad}) from:

$$\rho_{cad} = \left(\frac{100 \times W_B}{100}\right) \times \rho_b \qquad (H.1)$$

where:

W_B is the percentage by mass of binder used in the specimen.

H.2.13 Determine the Marshall stability of each specimen in accordance with BS EN 12697-34.

H.2.14 Calculate the mean stability, aggregate density and bulk density for each set of three specimens and plot against binder content. Draw a smooth curve through the plotted values (see Figure H.1). Record the binder content, to the nearest 0.1%, for each of the following:

- maximum stability;

  NOTE 1 If the stability curve shows more than one peak, choose the value which most closely coincides with the binder content for maximum density of the mixture.

- maximum mixture density;
- maximum aggregate density.

  NOTE 2 Where no peak is obtained, take the value at which the curve starts to fall away from the horizontal.

H.2.15 Calculate the design binder content as the mean of the three binder contents determined in accordance with **H.2.14** with the addition of a factor, dependent on the coarse aggregate content of the mix, given in Table H.5.

Table H.5 **Factors for the calculation of design binder content**

Nominal coarse aggregate content % mass	**Addition factor** %
0	0
30	0.7
35	0.7
55	0

H.2.16 Report the following information:

a) target composition of the mixture;

a) proportion of coarse, fine and filler aggregates;

b) overall grading of combined aggregate;

c) binder type, penetration and softening point;

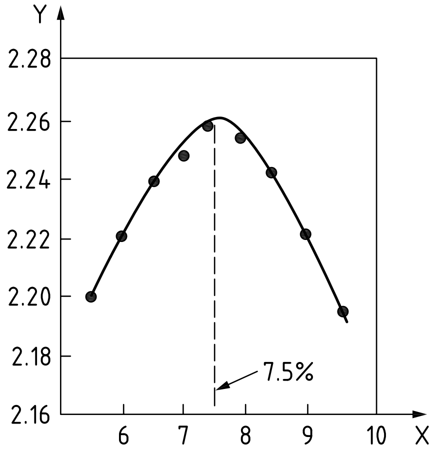
d) binder content for maximum stability;

e) binder content for maximum mixture density;

f) binder content for maximum compacted aggregate density; and

g) design binder content.

Figure H.1 **Example of mixture design**

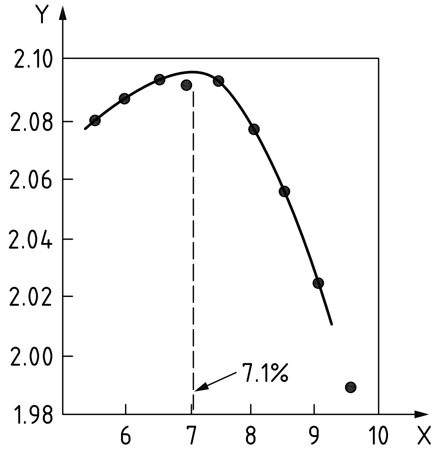


Plot 1

Key

X Percentage binder by mass

Y Mix density (g/mL)

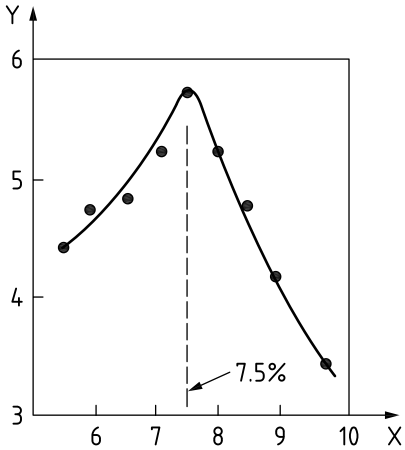


Plot 2

Key

X Percentage binder by mass

Y Compacted aggregate density (g/mL)

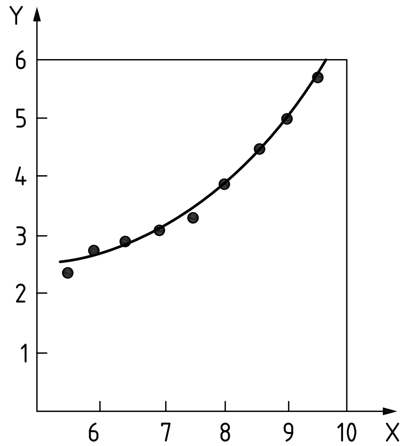


Plot 3

Key

X Percentage binder by mass

Y Stability (kN)



Plot 4

Key

X Percentage binder by mass

Y Flow value (mm)

NOTE 1 The plotted points through which the curves are drawn are averages of three specimens for each binder percentage.

NOTE 2 Plot 4 is not used in the calculation of design binder content but is reported.

Example calculation:

The optimum binder content for mix density from Plot 1 = 7.5%

The optimum binder content for compacted aggregate density from Plot 2 = 7.1%

The optimum binder content for stability from Plot 3 = 7.5%

The mean of the three optima $\frac{7.5+7.1+7.5}{3}$ *= 7.4% to which is added the appropriate factor from Table H.5 to arrive at the design binder content.*

Annex I (informative) Protocol for calibrating and operating indirect density gauges

I.1 Application

Indirect density gauges may be used to determine the in situ density of a compacted asphalt layer. The reported density should be the mean value of at least three gauge readings recorded with the gauge positioned in accordance with the gauge manufacturer's instructions. Alternatively, the gauge can be positioned in a single location and rotated through approximately 120° after each reading.

NOTE Indirect density gauges should not be used to monitor the density of chipped HRA surface courses.

I.2 Initial calibration

Each gauge should be calibrated to produce a relationship between gauge readings and core density. Calibration should be carried out at or adjacent to the location of six cores to be taken for the determination of air void content (see **9.5.1.2**). Gauge readings should be taken before the coring process.

This procedure should be carried out on at least two areas, one well inside the compaction compliance limit, and one close to or outside the compliance limit.

A graph should be plotted to show the relationship between the density gauge readings and the corresponding core densities.

If more than one gauge is to be used, each gauge should be individually calibrated, preferably using the same core positions.

NOTE 1 A suitable density range to produce results with the necessary spread of values has been found to be at least 4%.

NOTE 2 Careful selection of test positions is required to achieve a suitable density range. This can be achieved by locating some positions at the end of the test strip or close to joints. Small areas of the trial strip may be left under-compacted; however, these would not normally be retained as part of the permanent works.

I.3 Consistency of calibration

Re-calibrate the gauge if the results of subsequent tests on core samples and loose bulk samples indicate that a significant change to the correlation might have taken place or a bias might have developed.

NOTE 1 Indirect density gauges in general use can typically penetrate to a depth of about 80 mm. For thicker layers, the cores used for the calibration should be visually inspected to ensure that they are uniform throughout their depth.

NOTE 2 Further information about the use of nuclear density gauges is given in TRL Supplementary Report SR 754 [6].

Annex J (informative) Tack coats

Tack coats may be used when small quantities of asphalt are being laid on very lightly trafficked sites, such as footways and driveways. Tack coats should be bitumen emulsions conforming to BS EN 13808.

NOTE 1 The use of tack coats is no longer regarded as best practice.

NOTE 2 Emulsions conforming to BS EN 13808 are appropriate if they are formulated with bitumen having a maximum penetration value of 220 dmm and less than 3.0% w/w of added volatile flux oil.

For small and inaccessible areas, application of tack coats may be by hand-held sprayer.

The rate of spread for tack coats should be 0.15 kg/m² of residual bitumen when applied to newly laid asphalt or 0.2 kg/m² for planed or milled asphalt and existing surfaces.

NOTE 3 Residual bitumen is the bitumen remaining after evaporation of the water content of an emulsion and is assumed to be the binder content. Therefore, emulsion with 40% binder content should be sprayed at 0.5 L/m² to provide 0.2 kg/m² residual binder.

After application, the emulsion should be allowed to break (i.e. turn from brown to black), before the asphalt is laid. Any emulsion accumulating in hollows should be dispersed by brushing and allowed to break before it is over-laid.

NOTE 4 In unduly cold or humid weather conditions breaking of the emulsion could be delayed.

NOTE 5 Over-application or ponding should be avoided as this might result in the slippage or instability of the uppermost superimposed layer.

Annex K (informative) Protocol for determination of the maximum binder content of porous asphalt and other bituminous mixtures without excessive binder drainage

K.1 Principle

The quantity of binder lost through drainage after 3 h at the test temperature is measured in duplicate for mixtures with the same aggregate contents, but with different binder contents. The maximum target binder content, T_{max}, should be determined as the mixed binder content at 0.3% less than that at which 0.3% of the binder drains.

K.2 Apparatus

The apparatus to be used should be in accordance with BS EN 12697-18:2004, **4.3**.

K.3 Materials

Aggregates and binder should be sufficient to manufacture at least 20 kg of the mixed material. The aggregates should be dried and graded in the fractions appropriate to the specified grading.

K.4 Procedure

K.4.1 Procedure for individual determinations of drained binder

K.4.1.1 Determine the drained binder in accordance with BS EN 12697-18:2004, **4.4**. **K.4.1.2** to **K.4.1.4** contain additional requirements that should be followed to ensure the procedure is correct.

K.4.1.2 For unmodified binders in porous asphalt, the test temperature should equate to the temperature at which the binder viscosity is 0.5 Pa·s. In the absence of viscosity data, the test temperatures should be as given in Table K.1.

K.4.1.3 For modified binders in porous asphalt, the test temperature should be the maximum mixing temperature recommended by the supplier.

K.4.1.4 Prepare sufficient materials for the mixing of at least eleven batches, allowing for discarding of the first mixture, to give not less than five different mixed binder contents.

Table K.1 **Test temperatures for porous asphalt with unmodified bitumen**

Binder	Temperature °C
160/220 paving grade bitumen	125 ±1
100/150 paving grade bitumen	130 ±1

K.4.2 Procedure for determination of maximum target binder content

K.4.2.1 Determine the mortar drained in an aggregate skeleton in accordance with **K.4.1** for not less than five different mixed binder contents in 0.5% (*m*/*m*) steps.

K.4.2.2 Ensure that at least two binder contents are equal to or greater than the expected maximum target binder content of the mixture, and that at least three binder contents are equal to or less than the expected maximum target binder content of the mixture.

NOTE For 20 mm size porous asphalt, the binder contents should be 3.0%, 3.5%, 4.0%, 4.5% and 5.0% (m/m).

K.5 Calculations

K.5.1 Mortar drained

K.5.1.1 Calculate the mortar drained from each sample in accordance with BS EN 12697-18:2004, **4.5**.

K.5.1.2 For mixtures incorporating fibres, in addition to **K.5.1.1**, calculate the mortar drained from each sample *d*m as a percentage (%) from the equation:

$$d_m = 100 \times \frac{(W_2 - W_1)}{1100 + B + X} \tag{K.1}$$

where:

- $W1$ is the initial mass of the tray with foil (in grams);
- $W2$ is the final mass of the tray with foil and drained mortar (in grams);
- B is the initial mass of binder in the mixture (in grams);
- X is the initial mass of fibres in the mixture (in grams).

K.5.2 Maximum target binder content methods

Calculate the maximum target binder content from either:

a) the mean mortar drained, including any binder, fibres, filler and fine aggregate, in accordance with **K.5.3**; or

b) the binder drained after making an allowance for the fibres, filler and fine aggregate, in accordance with **K.5.4**.

NOTE In some current specifications, the maximum target binder content for porous asphalt mixtures is calculated from the binder drained, whereas it is calculated from the mortar drained for stone mastic asphalt mixtures.

K.5.3 Maximum target binder content from mortar drained.

K.5.3.1 For each binder content, calculate the mortar drained D_m (in %) as the mean of the mortar drained from the pair of samples.

K.5.3.2 Plot the values of mean mortar drained (D_m) for each binder content against the initial mixed binder content. Draw a smooth curve through the plotted values, as shown in Figure K.1.

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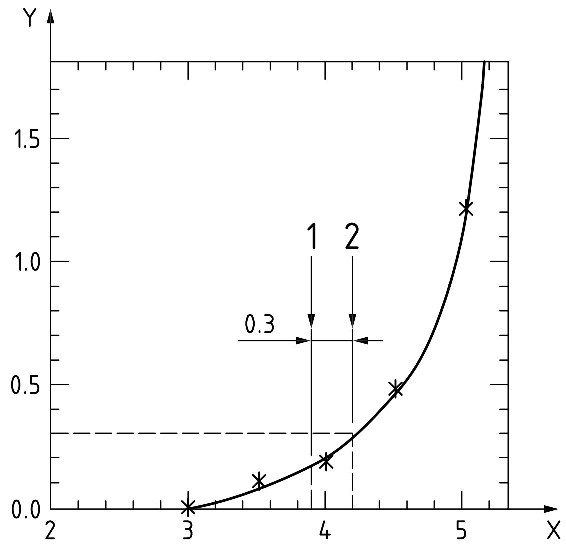
Figure K.1 **Typical diagram of mortar or binder drained**



Key
X Mixed binder content (%)
Y Mortar or binder drained (%)
1 Maximum target binder content, T_{max}
2 Mixed binder content for 0.3% drained

K.5.3.3 Determine the mixed binder content (M_m) where the mortar drainage is 0.3% from the smooth curve derived in **K.5.3.2**. Calculate the maximum target binder content, $T_{max,m}$ (in %), from the equation:

$$T_{max,m} = M_m - 0.3 \tag{K.2}$$

K.5.4 Maximum target binder content from binder drained

K.5.4.1 For each mixture, calculate the quantity of binder drained d_b as a percentage (%) from the equation:

$$d_b = \frac{B}{B + F + X} \times d_m \tag{K.3}$$

where:

d_m is the mortar drained (%) as derived in **K.5.1.1**;

B is the initial mass of binder in the mixture (in grams);

F is the initial mass of filler (all particles passing 0.063 mm sieve) in the mixture (in grams);

X is the initial mass of fibres in the mixture (in grams).

K.5.4.2 For each binder content, calculate the binder drained, D_b as a percentage (%), as the mean of the binder drained, d_b, from the pair of samples.

K.5.4.3 Plot the values of mean binder drained (D_b) for each binder content against the initial mixed binder content. Draw a smooth curve through the plotted values, as in Figure K.1.

K.5.4.4 Determine the mixed binder content M_b where the binder drainage is 0.3% from the smooth curve derived in **K.5.4.3**. Calculate the maximum target binder content, $T_{max,b}$ as a percentage (%), from the equation:

$$T_{\max,b} = M_b - 0.3 \quad (K.4)$$

NOTE The repeatability and reproducibility of this test method have yet to be determined.

K.6 Reporting of results

The test report should include the following information for each test specimen.

a) Date, time and place of test.

b) The source, type and grading of the aggregate skeleton.

c) The source, type and grade of the binder and any binder modifier.

d) The test temperature.

e) Whether the mortar drained or the binder drained was used to determine the maximum target binder content.

f) The individual determinations of mortar/binder drained at each binder content.

g) The plotted values with a smooth curve drawn through the averaged determinations of mortar/binder drained at each binder content.

h) The maximum target binder content, T_{max}.

i) Whether the determinations at any binder content had to be repeated.

j) The name of the person taking technical responsibility for the test.

k) The number and date of this British Standard, i.e. BS 594987:2015. [2)]

l) Any test conditions and operational details not provided in this British Standard, and any anomalies likely to have affected the results.

NOTE The test report may also include the name of the project.

Annex L (informative) Guidance for the mix design of BBA for airfields to BS EN 13108-1

There are four types of BBA material for airfields: close- and gap-graded, each graded as 10 mm and 14 mm mixtures. They can be used for binder and surface courses in new construction and overlay.

For these mixtures, there are five levels of mix design. The mix design level depends upon the course of the airfield pavement for which it is to be used (surface course or binder course) and the level of stress to which the pavement is exposed. The stress levels are a function of traffic and environment, and are determined by the specifying authority.

The five levels of mix design are:

- Level 0, aggregate grading curve and determining binder content. This level might be required for mixtures used for low-traffic areas, e.g. some airfield pavement shoulders.
- Level 1, air voids content and water sensitivity. This level might be appropriate for moderately stressed areas.

[2)] Marking BS 594987:2015 on or in relation to a product represents a manufacturer's declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant's responsibility. Such a declaration is not to be confused with third-party certification of conformity.

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- Level 2, air voids content, water sensitivity and deformation resistance. Level 2 that also includes the requirements of Level 1 might be appropriate for more highly stressed areas.
- Level 3, air voids content, water sensitivity, deformation resistance and stiffness modulus. Level 3 that also includes the requirements of Level 2 might be appropriate for highly stressed areas.
- Level 4, air voids content, water sensitivity, deformation resistance, stiffness modulus and fatigue. Level 4 is normally used in only very exceptional circumstances.

The test property criteria are a function of the stress level and the use to which the airfield pavement is put (e.g. parking and turning area). They are determined by the specifying authority.

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Further reading

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BS 598-110:1998, *Sampling and examination of bituminous mixtures for roads and other paved areas – Part 110: Methods of test for the determination of wheel-tracking rate and depth*

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

PD 6691:2010, (withdrawn) *Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications*

PD 6692, *Guidance on the use of BS EN 12697 Bituminous mixtures – Test methods for hot mix asphalt*

[3)] Available from TRL Limited, Crowthorne House, Nine Mile Ride, Wokingham, Berkshire, RG40 3GA, United Kingdom; Tel. +44 (0)1344 773131 Fax. +44 (0)1344 770356 Email. enquiries@trl.co.uk.

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