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Specification for Low Temperature Asphalt Mixtures

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Executive summary

The UK government, through the Carbon Trust, have strategically targeted and evaluated industrial products or processes for ways to reduce their carbon footprint. The energy used in manufacturing hot mix asphalt in the aggregates sector has been identified as a major contributor. In an attempt to increase the use of lower carbon asphalt, funding has been made available to accelerate the introduction of technologies that will encourage their wider use. As part of this initiative, funding was provided for a project to look at low temperature asphalt processes, and this was undertaken by Tarmac, Nynas, Atkins and Mineral Industry Research Organisation.

The second stage of this project has been funded from Business, Innovation and Skills Regional Growth Funds with TRL replacing Atkins in the consortium. One of the Work Packages for the project, WP5, was the Development of Specifications for low temperature and cold mix asphalts, which was allocated to TRL to undertake. This report is the output for that work package.

Low temperature asphalts, usually classified as warm mix asphalt, half-warm mix asphalt and cold mix asphalt, are increasingly being used. However, most of the current specifications are written around hot mix asphalt. There is no reason why specifications for hot mix asphalt cannot be modified to become applicable to the various categories of low temperature asphalt. Very little modification is required for warm mix asphalt, with increasing modification being required as the mix temperature departs from that for hot mix asphalt.

Examples of documents for use with low temperature asphalt mixtures have been drafted and are given in a series of appendices. These drafts cover the various levels of standard currently available for hot mix asphalt, being modelled on the current European standards, supporting national guidance documents or the *Specification for Highway Works* clauses.

It is intended that the availability of these documents will allow warm mix asphalt, half-warm asphalt and cold-mix asphalt to be procured and that feedback from their use will help to develop the European and national documents that will replace them in due course.

Abstract

Low temperature asphalts, classified as warm mix asphalt, half-warm mix asphalt and cold mix asphalt, are increasingly being used, but most of the current specifications are written around hot mix asphalt. The types of specification that are used for hot mix asphalt are discussed and a series of documents drafted to cover low temperature asphalt mixtures are attached as appendices. The appendices are modelled on the current European standards, supporting national guidance documents and the *Specification for Highway Works* clauses. It is intended that the availability of these documents will encourage greater use of low temperature asphalts until the standard specifications have been updated to explicitly incorporate these environmentally friendly materials.

1 Introduction

1.1 General

The UK government, through the Carbon Trust, have strategically targeted and evaluated industrial products or processes for ways to reduce their carbon footprint. The energy used in manufacturing hot mix asphalt in the aggregates sector has been identified as a major contributor. In an attempt to increase the use of lower carbon asphalt, funding has been made available to accelerate the introduction of technologies that will encourage their wider use. One such technology was low temperature asphalt, for which they funded a project to look at the process undertaken by Tarmac, Nynas, Atkins and Mineral Industry Research Organisation.

The second stage of this project has been funded from Business Innovation and Skills Regional Growth Funds with TRL replacing Atkins in the consortium. One of the Work Packages for the project, WP5, was the Development of Specifications for low temperature and cold mix asphalts, which was allocated to TRL to undertake. This report is the output for that work package.

1.2 Background

The issue of sustainable development and the identification of the need to conserve resources for use by future generations has been an international focus for decades. Damage or disruption to ecosystems is generally caused as a result of the destruction or finite use of natural resources and climate change. The Kyoto protocol, which was formalised in 1997 as part of The United Nations Framework Convention on Climate Change, formed an agreement between member states to bring greenhouse gas emissions down to the levels of 1990. The agreement came into force in February 2005 and several countries have now developed a "Climate Change Act", setting targets for the reduction of greenhouse gas emissions which are categorised as CO₂ or units of CO₂ equ

(equivalent). The UK climate change act of 2008 set a reduction target of 80 % (compared to a baseline value from 1990) by 2050 whilst the Scottish climate change act of 2009 goes a step further and has includes an interim target reduction of 42 % by 2020. However, during the last 10 years there seem to have been more abnormal weather patterns and freak events causing major disruption to sustainable living which has produced a greater emphasis on climate change and the Kyoto protocol has gained greater focus.

The main targets for reducing the carbon footprint within highway authority organisations have focussed on reducing energy consumption, reducing the use of paper and vehicular emissions. Therefore, the initial focus within the highways sector has tended to be targeted towards issues such as, for example, reducing electricity consumption of street lighting. The use of “sustainable procurement” whereby authorities are encouraged to purchase goods and services from low carbon sources is only now gaining momentum.

The sustainability argument on asphalt paving systems generally reflects the whole life value. The development of long-life (perpetual) pavements (defined as “An asphalt pavement designed and built to last longer than 50 years without requiring major structural rehabilitation or reconstruction, and needing only periodic surface renewal in response to distresses confined to the top of the pavement”) with reduced maintenance strategies has in recent times been viewed as the way forward in developing “sustainable asphalt paving”. Reducing the energy of asphalt manufacture will have a detrimental effect on the whole life argument if the products become vastly inferior and require maintenance intervention or replacement more frequently in their life. The use of warm and half-warm mix asphalts is generally still in its infancy and there is no real evidence that asphalt manufactured by these technologies is inferior in situ to traditional hot mix asphalts thus far. However, the use of cold mix asphalts, particularly emulsion-based cold mix asphalts, has been around internationally for decades but has struggled to gain market penetration in the UK due to differences in its physical properties compared to hot mix asphalt. The use of these materials in various applications is much more common in a number of countries across Europe and in the USA.

A major obstacle to gaining market penetration when developing new products and processes is the equivalence argument. Products are generally approved based on design criteria and equivalence to the hot mix asphalt laboratory design protocol; normal design procedures and specifications. However, these criteria may need to be changed to reflect the changes in the manufacturing process. This situation was the case in the UK when developing standards for cold mix using foam bitumen. In the UK, some evidence exists to support the use of emulsion based cold mix materials that have failed to meet the specifications set, based on hot mix equivalence. In some instances, these mixtures have still performed equally as well, and sometimes better than, conventional hot mix asphalt in situ. The use of emulsion based cold mix to meet the specifications set to comply with the Highway Authorities and Utilities Committee (HAUC) standard for permanent cold lay surfacing materials (PCSMs) resulted in materials failing to meet the specification and, therefore, failed to gain national approval. Some of these failed materials are still functioning satisfactorily in situ after 15 years in service.

1.3 Categories of low temperature asphalt

Low temperature asphalt mixtures are those that are intentionally manufactured and laid at temperatures less than the standard temperatures traditionally used for asphalt. They

are generally categorised into three types depending on the extent of the temperature reduction (EAPA, 2010) which, with the traditional mixtures, give the following:

- a) Hot mix asphalt – produced and mixed at temperatures roughly between 120 °C and 190 °C, the production temperatures depending on the bitumen used.
- b) Warm mix asphalt – produced and mixed at temperatures roughly between 100 °C and 140 °C.
- c) Half-warm mix asphalt – produced with heated aggregate at a mixing temperature (of the mixture) between approximately 70 °C and roughly 100 °C (also known as semi-warm mix asphalt).
- d) Cold mix asphalt – produced with unheated aggregate and bitumen emulsion or foamed bitumen.

These categories are normally characterised schematically as shown in Figure 1.1.

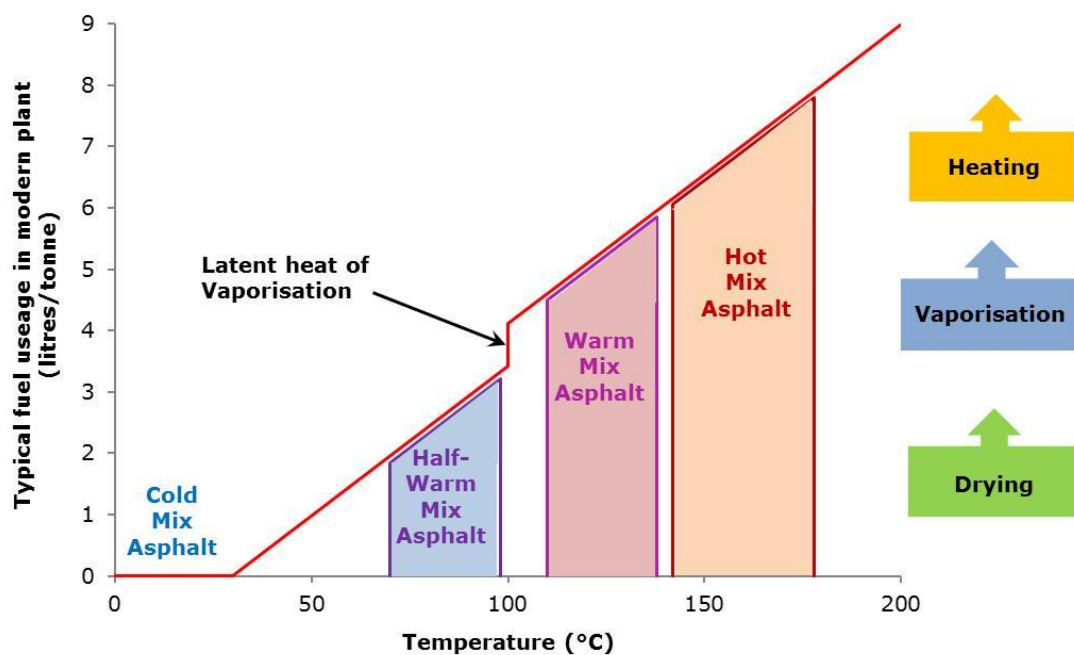


Figure 1.1 - Schematic of classification for hot, warm, half-warm and cold mix asphalt mixtures

The technologies behind these systems can vary quite markedly whilst there are also similarities. There is no direct correspondence between the classifications and the technologies, but the most common types of technology for the different classifications are:

- Incorporation of chemical additives
 - to modify the bitumen viscosity (such as waxes) Warm
 - to modify the frictional resistance of the mixture to compaction Warm
- Foamed bitumen
 - by the addition of moisture releasing additives (such as zeolites) within the mixture Warm
 - by foam generation equipment Warm or Half-warm
 - by the addition of moist aggregates Half-warm
 - other Half-warm or Cold
- Bitumen emulsion Cold

The chemical additives can either be pre-blended with the bitumen or added at the time of mixing.

1.4 Carbon savings

The sustainability of low temperature asphalt mixtures can also be assessed by the carbon dioxide equivalent (CO_2_{equ}) used to produce the asphalt. This estimate is probably better than just the fuel used as shown in Figure 1.1 for the different types. However, the reduced temperature is not the only parameter that will affect the CO_2_{equ} but also the supply of raw materials for, the production of, and the transport of any additives used in the mixture. As such, the different technologies will produce different savings and cannot be shown in a similar schematic.

Furthermore, the carbon savings cannot, at this time, be used in requirements when specifying asphalt and will not be covered in this report.

2 Specifications

2.1 Current situation

There are several layers of specifications for materials used in pavement construction as described figuratively in Figure 2.1.

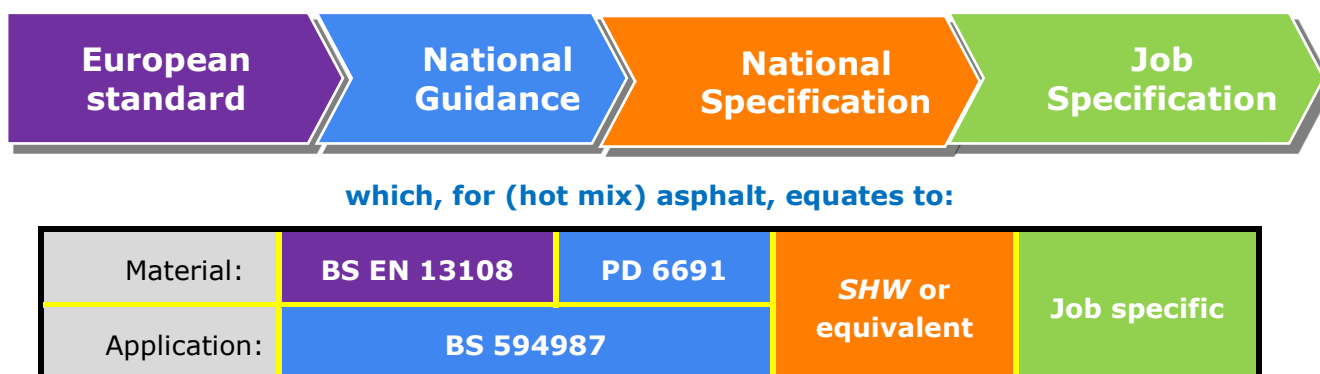


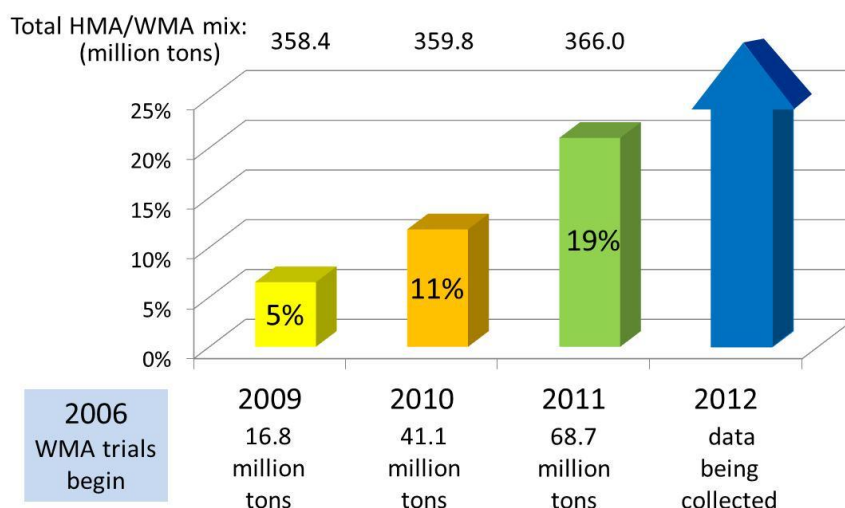
Figure 2.1 – Levels of specification

For asphalt materials, the European standard is the relevant part of BS EN 13108 (CEN, 2006), the national guidance document is PD 6691 (BSI, 2010a) and the national specification is usually the 900 series in the *Specification for Highway Works* (HA *et al.*, 2008) for roads and the standards for airfields (Defence Estates, 2009, 2010). For the transport, laying and compaction of asphalt, there is no European standard and the European standard and national guidance levels are combined into BS 594987 (BSI, 2010b); the national specification level documents cover both the materials and their transport, laying and compaction.

The BS EN 13108 series were originally drafted primarily for hot mix asphalt mixtures, although this limitation is not explicitly acknowledged in the title or text. However, the title of the associated test methods, the BS EN 12697 series (CEN, various), does acknowledge the limitation in its title of “Bituminous mixtures – Test methods for hot mix asphalt” although most of the test methods (as opposed to the specimen preparation procedures) are equally applicable to low temperature asphalt mixtures.

The BS EN 13108 series is currently under 5-year review with changes planned, including extending into warm mix asphalt, although how much will be done in this revision is still uncertain. It is assumed that it will be extended to explicitly cover warm mix asphalt (rather than the current situation whereby it is not excluded) whilst cold mix asphalt will require new parts, for which a part on cold emulsion-based mixtures has already been started. The position of half-warm mixtures is less clear. Meanwhile, the specimen preparation procedures in the BS EN 12697 series are being reviewed to make them applicable to low temperature asphalts, although again some new tests may be required for cold mix asphalt and the title of the series will need to be changed.

At the national specification level, reference is made to low temperature asphalt, but most clauses were drafted explicitly for hot mix asphalt and, with the increasing use of low temperature asphalt (about 20 % of asphalt production in the USA was warm or half-warm mix asphalt in 2011, Figure 2.2), a more comprehensive set of requirements are needed if the use of these materials is to be encouraged.



Source: Draft annual survey presented during Feb. 2013 NAPA Annual Meeting

Figure 2.2 - Development in the production of warm and half-warm mix asphalt in USA

2.2 Proposed specifications

2.2.1 Overview

Whilst there are plans to update various documents to incorporate the various categories of low temperature asphalt, there is a need for documents that can be used in the interim. Therefore, a series of documents have been drafted to cover the European standard, national guidance and national specification levels for warm mix, half-warm mix and emulsion-based cold mix asphalt. Only a slight modification has been made to warm mix because the existing hot mix documents can effectively be used. These documents have been prepared by TRL in collaboration with Lafarge Tarmac and Nynas UK AB for the Carbon Trust and the Region Growth Fund.

2.2.2 Warm mix standard

For warm mix asphalt, the only requirement that will not be complied with is the minimum temperature of the mixture, as given in clause 5.2.10 of BS EN 13108-1 (CEN, 2006) for asphalt concrete. The European standard temperature ranges are given for each paving grade of bitumen, but there is a statement that "The minimum temperature of the asphalt mix(ture) at delivery shall be declared by the manufacturer" which makes the lower bound informative rather than normative. These minimum temperatures are due to be removed in the next edition expected to be published in 2015. Until then, the current standards could be used for softer grades (when the minimum is below 140 °C) or with the exception being clearly identified. Nevertheless, Appendix A is provided as a draft specification for warm mix asphalt should one be felt necessary.

2.2.3 Half-warm mix standard

The exception is greater for half-warm mix asphalts, so Appendix B is provided as a draft specification that provides one approach of specifying half-warm mix asphalt. This approach specifies half-warm mix asphalt in terms of component materials and proportions with additional requirements based on performance-related tests. The main text follows the technical approach used in the various parts of BS EN 13108 (CEN, 2006)

and is based on the draft revisions following 5-year review of the harmonised European standards for hot mix asphalt. The specification includes reference to BS 594987 (BSI, 2010b) for transporting, laying and compaction together with compliance requirements to verify compliance.

2.2.4 Emulsion-based cold mix standard

Appendix C is a draft specification that provides one approach of specifying emulsion-based cold mix asphalt. This approach specifies emulsion-based cold mix asphalt in terms of component materials and proportions with additional requirements based on performance-related tests. The main text is based on the early drafts for a harmonised European standard that has the same technical approach as used in the various existing parts of BS EN 13108 (CEN, 2006) whilst the specification includes reference to BS 594987 (BSI, 2010b) for transporting, laying and compaction with compliance requirements to verify compliance.

2.2.5 Foamed-bitumen cold mix standard

Foamed-bitumen cold mix asphalt has not been covered because that family of materials is already well-established with a specification in TRL Report TRL611 (Merrill *et al.*, 2004) that is supported by clause 947 and 948 of the *Specification for Highway Works* (HA *et al.*, 2008).

2.2.6 Supporting appendices

The Appendix A and Appendix B specifications are supported by Appendix D defining how to treat the grading of reclaimed asphalt and, for Appendix B, there are three informative appendices equivalent to the example specifications given as figures in the Annexes of PD 6691 (BSI, 2010a) that are generally used in the UK. These draft national guidance documents are Appendix E for asphalt concrete, Appendix F for hot rolled asphalt and Appendix G for stone mastic asphalt.

As with Appendix B, the Appendix C specification is supported by Appendix D on how to treat the grading of reclaimed asphalt and an informative appendix, Appendix H, equivalent to the example specifications given as figures in the Annexes of PD 6691 (BSI, 2010a) that are general used in the UK.

2.2.7 Specification clause

Appendix J gives a series of specification requirements based on the 900 series in the *Specification for Highway Works* (HA *et al.*, 2008). There are separate sections for warm mix asphalt, half-warm asphalt and emulsion-based cold-mix asphalt. Appendix K gives the associated notes for guidance, again in three sections. As such, there is a certain amount of repetition in the sections of both Appendix J and Appendix K.

2.2.8 Cross-references

In these appendices, cross references are used to the hot mix asphalt documents where that information is equally appropriate in order to avoid potential conflicts. However, the references have been kept to the document rather than a specific clause or table (whose number may change in a future version) so that the document date does not have to be included in the reference. A referenced document without a date implies the current version of that standard whilst a dated reference implies that specific version and needs

to be updated when the reference has been revised or superseded. The lack of dated references is particularly important because the various parts of BS EN 13108 (CEN, 2006) together with PD 6691 (BSI, 2010a) and BS 594987 (BSI, 2010b) are all expected to be updated in the next few years. The one exception is that the specific Annexes in PD 6691 have been referenced without giving the date. This approach is technically incorrect but was considered pragmatic in order to avoid leaving it unclear which material annex was applicable without giving dated references that would have needed updating whenever PD 6691 is revised.

3 Conclusions

Low temperature asphalts (warm mix asphalt, half-warm mix asphalt and cold mix asphalt) are increasingly being used, but most of the current specifications are written around hot mix asphalt. However, there is no reason why these specifications for hot mix asphalt cannot be modified to become applicable to the various categories of low temperature asphalt. Very little modification is required for warm mix asphalt, with increasing modification being required as the mix temperature departs from that for hot mix asphalt.

Examples of documents for use with low temperature asphalt mixtures have been drafted and are given in a series of appendices. These drafts cover the various levels of standard currently available for hot mix asphalt, being modelled on the current European standards, supporting national guidance documents or the *Specification for Highway Works* clauses.

It is intended that the availability of these documents will allow warm mix asphalt, half-warm asphalt and emulsion-based cold-mix asphalt to be procured and that feedback from their use will help to develop the European and national documents that will replace them in due course.

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British Standards Organisation (2010b). Asphalt for roads and other paved areas – Specification for transport, laying, compaction and type testing protocols. *BS 594987:2010*. London: BSI.

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Appendix A Standard specification for warm mix asphalt

A.1 Scope

This Specification sets out requirements for mixtures of warm mix asphalt for use on roads, airfields and other trafficked areas. It includes requirements for the selection of the constituent materials. Warm mix asphalt can be used for surface courses, binder courses, regulating courses and bases.

A.2 Normative references

This Specification incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this Specification only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies (including amendments).

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

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

BS EN 13108-1, *Bituminous mixtures – Material specifications – Part 1: Asphalt concrete*

BS EN 13108-2, *Bituminous mixtures – Material specifications – Part 2: Very thin layer asphalt concrete*

BS EN 13108-4, *Bituminous mixtures – Material specifications – Part 4: Hot rolled asphalt*

BS EN 13108-5, *Bituminous mixtures – Material specifications – Part 5: Stone mastic asphalt*

BS EN 13108-7, *Bituminous mixtures – Material specifications – Part 7: Porous asphalt*

BS EN 13108-20, *Bituminous mixtures – Material specifications – Part 20: Type testing of asphalt mixes*

BS EN 13108-21, *Bituminous mixtures – Material specifications – Part 21: Factory production control*

A.3 Terms, definitions, symbols and abbreviations

A.3.1 Terms and definitions

For the purposes of this Appendix, the terms and definitions given in BS EN 13108-1 together with the following apply.

A.3.1.1 **asphalt**

homogenous mixture of coarse and fine aggregates, filler aggregate and bituminous binder which is used in the construction of flexible pavement layers

NOTE: The asphalt may include one or more additives to enhance the laying characteristics, performance or appearance of the mixture. Natural asphalt is defined in BS EN 13108-4.

A.3.1.2**warm mix asphalt**

asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at temperatures at least 20 °C below conventional hot mix asphalt mixtures but still above 100 °C

A.3.1.3**half-warm mix asphalt**

asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at temperatures in the range 70 °C to 100 °C

NOTE: Also known as semi-warm mix asphalt

A.3.1.4**cold mix asphalt**

asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at ambient temperature

A.3.1.5**emulsion-based cold mix asphalt**

cold mix asphalt in which the binder is a bituminous emulsion with a viscosity such that the mix is workable at ambient temperature

A.3.1.6**foamed asphalt**

asphalt in which, during mixing, the binder is caused to foam by the presence of steam, reducing the surface tension and easing coating of the aggregate particles

A.3.1.7**moisture content in the mix**

water content expressed in per cent of the dry aggregate mass

A.3.2 Symbols and abbreviations

WMA General designation for a warm mix asphalt.

XX *D* WMA Designation of mixture type followed by an indication of *D*, the upper sieve size of the aggregate in the mixture, in millimetres (mm), and the general designation for warm mix asphalt.

EXAMPLE: AC 14 WMA is a warm mix asphalt concrete with an upper sieve size of the aggregate of 14 mm.

A.4 Requirements for constituent materials**A.4.1 General**

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.4.2 Binder

A.4.2.1 General

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.4.2.2 Selection of binder

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

NOTE: The ageing of binder during the mixing and placement of hot mix asphalt, particularly when using batch mixers, in terms of the binder penetration is generally a reduction of the order of 33 %, or one binder grade, which does not occur to the same extent for warm mix asphalt. Consideration should be given to reducing the required binder penetration where equivalence is intended with hot mix asphalt.

A.4.2.3 Surface courses with reclaimed asphalt

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.4.2.4 Regulating courses, binder courses and bases with reclaimed asphalt

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; or BS EN 13108-5 for warm mix stone mastic asphalt.

NOTE: Not applicable for warm mix very thin layer asphalt concrete or warm mix porous asphalt.

A.4.3 Aggregates

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.4.4 Reclaimed asphalt

A.4.4.1 As with hot mix asphalt, reclaimed asphalt containing tar shall not be used.

A.4.4.2 As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.4.4.3 If reclaimed asphalt is controlled using analysis of particles without removing the binder, the aggregate grading in the reclaimed asphalt for calculation of the aggregate grading in the mixture shall be determined in accordance with Appendix D.

A.4.5 Additives

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt;

BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.5 Requirements for the warm mix asphalt mixture

A.5.1 General

A.5.1.1 The target composition of the mixture in terms of its constituent materials, the proportions (in per cent) passing the specified sieves, the target binder content and where relevant the binder from natural asphalt and the proportion(s) of additive(s) shall be declared and documented. The target grading curve shall be declared for the sieve 1.4 D and the sieves as called up in A.5.2.

A.5.1.2 At the target composition, the mixture shall conform to the specified requirements in accordance with this specification.

A.5.1.3 The test results shall be made available.

A.5.2 Composition and grading

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

NOTE: Coated chippings to BS EN 13108-4 are not included because they are not suitable for rolling into hot rolled asphalt at warm mix asphalt temperatures.

A.5.3 Binder content

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.5.4 Additives

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.5.5 Properties

A.5.5.1 Specimens

A.5.5.1.1 For application of this Specification, specimens shall be manufactured in accordance with clause 6.2 of BS EN 13108-20:2014 except for the temperature at which they are mixed and compacted.

A.5.5.1.2 The temperature at which samples shall be mixed and compacted shall be at the standard temperature for each operation less the difference between the temperature at which the warm asphalt will be prepared on site and the temperature at which hot asphalt will be prepared on site.

A.5.5.1.3 When testing a sample of warm asphalt for refusal density, the sample shall be heated to the same temperature as an equivalent hot mix asphalt before compaction.

A.5.5.1.4 The relevant technology that allows the asphalt to be mixed and laid at a reduced temperature shall be employed in the manufacture of samples used to demonstrate the properties of the asphalt mixture. If the technology cannot be replicated in the laboratory, plant-produced samples shall be used for type testing and factory production control.

A.5.5.2 Standard properties

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

NOTE: The ageing of binder during the mixing and placement of hot mix asphalt, particular when using batch mixers, in terms of the binder penetration is generally a reduction of the order of 33 %, or one binder grade, which does not occur to the same extent. Where equivalence is intended with hot mix asphalt and the binder grade selected has been adjusted, the selected categories of the standard mechanical properties may need to be adjusted when laboratory prepared mixtures are used to assess the performance.

A.5.6 Temperature of the mixture

A.5.6.1 The maximum temperature requirements apply at any place in the plant and shall be declared.

A.5.6.2 The minimum temperature of the mixture at delivery shall be declared.

A.5.6.3 Depending on local conditions and for specific application the minimum temperature, measured according to EN 12697-13, may be specified.

A.5.6.4 When using paving grade binder, the maximum temperature of a warm mix asphalt, measured according to BS EN 12697-13, shall target ≤ 140 °C (grades 20/30 to 70/100), ≤ 130 °C (grades 100/150 and 160/220) or ≤ 120 °C (grades 250/330 and 330/430).

A.5.6.5 When using modified bitumen or hard grade bitumen, additives or premix bitumen, different temperatures may be applicable. These shall then be documented and declared.

A.5.7 Dangerous substances

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.5.8 Conflicting specifications

As in BS EN 13108-1 for warm mix asphalt concrete; BS EN 13108-2 for warm mix very thin layer asphalt concrete; BS EN 13108-4 for warm mix hot rolled asphalt; BS EN 13108-5 for warm mix stone mastic asphalt; or BS EN 13108-7 for warm mix porous asphalt.

A.6 Identification

The delivery ticket shall contain at least the following information relating to identification:

- the manufacturer and mixing plant;
- designation of the mixture:

<i>AC/BBTM/HRA/SMA/PA</i>	<i>D</i>	<i>surf/base/bin</i>	<i>Binder</i>	<i>WMA</i>
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where:

<i>AC</i>	is Asphalt Concrete;
<i>BBTM</i>	is asphalt concrete for very thin layers;
<i>HRA</i>	is Hot Rolled Asphalt;
<i>SMA</i>	is Stone Mastic Asphalt;
<i>PA</i>	is Porous Asphalt;
<i>D</i>	is the upper sieve size;
<i>surf</i>	is the surface course;
<i>base</i>	is the base course;
<i>bin</i>	is the binder course;
<i>binder</i>	is the designation of binder used;
<i>WMA</i>	is warm mix asphalt.

NOTE: Example: SMA 14 *base* 40/60 WMA (in which 40/60 is the binder used and not the equivalent properties for hot mix asphalt).

A.7 Transport, laying and compaction

A.7.1 This clause gives general requirements for the transport, placing and compaction of bituminous mixtures, which are complementary and additional to the requirements of BS 594987. These requirements and the requirements of BS 594987 shall apply to all warm mix asphalt mixtures, unless otherwise specified in A.7.2 of this Appendix.

NOTE: BS 594987 states that it “does not cover the supply, laying and compaction of low-temperature warm mix and other reduced temperature asphalts”. Nevertheless, its main requirements, other than those on the temperature of the mixture, are generally applicable to warm mix asphalt.

A.7.2 Minimum delivery and rolling temperatures for warm mix asphalt mixtures shall be declared by the supplier with evidence to support their suitability.

A.8 Compliance

A.8.1 Compliance with the requirements for mixture composition and properties (A.4 and A.5) shall be by type testing and factory production control. The factory production control shall be in accordance with the principles and frequencies of BS EN 13108-21. A certificate defining compliance supported by test reports shall be made available for inspection.

A.8.2 Audit checking to confirm that the mixture composition and properties claimed are those of the mixture delivered to site may be undertaken.

A.8.3 Compliance with the requirements for transporting, laying and compacting the asphalt (A.7) shall be monitored against the requirements of BS 594987 and test reports demonstrating compliance shall be made available for inspection.

Appendix B Standard specification for half-warm mix asphalt

B.1 Scope

This Specification sets out requirements for mixtures of half-warm mix asphalt for use on roads, airfields and other trafficked areas. It includes requirements for the selection of the constituent materials. Half-warm mix asphalt can be used for surface courses, binder courses, regulating courses and bases.

B.2 Normative references

This Specification incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this Specification only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies (including amendments).

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

BS EN 1097-5, *Test for mechanical and physical properties of aggregates – Determination of particle density and water absorption*

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

BS EN 12697-14, *Bituminous mixtures – Test methods for hot mix asphalt – Part 14: Water content*

BS EN 13108-1, *Bituminous mixtures – Material specifications – Part 1: Asphalt concrete*

BS EN 13108-2, *Bituminous mixtures – Material specifications – Part 2: Very thin layer asphalt concrete*

BS EN 13108-4, *Bituminous mixtures – Material specifications – Part 4: Hot rolled asphalt*

BS EN 13108-5, *Bituminous mixtures – Material specifications – Part 5: Stone mastic asphalt*

BS EN 13108-7, *Bituminous mixtures – Material specifications – Part 7: Porous asphalt*

BS EN 13108-20, *Bituminous mixtures – Material specifications – Part 20: Type testing of asphalt mixes*

BS EN 13108-21, *Bituminous mixtures – Material specifications – Part 21: Factory production control*

B.3 Terms, definitions, symbols and abbreviations

B.3.1 Terms and definitions

For the purposes of this Appendix, the terms and definitions given in BS EN 13108-1 together with the following apply.

B.3.1.1***asphalt***

homogenous mixture of coarse and fine aggregates, filler aggregate and bituminous binder which is used in the construction of flexible pavement layers

NOTE: The asphalt may include one or more additives to enhance the laying characteristics, performance or appearance of the mixture. Natural asphalt is defined in BS EN 13108-4.

B.3.1.2***warm mix asphalt***

asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at temperatures at least 20 °C below conventional hot mix asphalt mixtures but still above 100 °C

B.3.1.3***half-warm mix asphalt***

asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at temperatures in the range 70 °C to 100 °C

NOTE: Also known as semi-warm mix asphalt

B.3.1.4***cold mix asphalt***

asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at ambient temperature

B.3.1.5***emulsion-based cold mix asphalt***

cold mix asphalt in which the binder is a bituminous emulsion with a viscosity such that the mix is workable at ambient temperature

B.3.1.6***foamed asphalt***

asphalt in which, during mixing, the binder is caused to foam by the presence of steam, reducing the surface tension and easing coating of the aggregate particles

B.3.1.7***moisture content in the mix***

water content expressed in per cent of the dry aggregate mass

B.3.2 Symbols and abbreviations

HWMA General designation for a half-warm mix asphalt.

XX D HWMA Designation of mixture type followed by an indication of *D*, the upper sieve size of the aggregate in the mixture, in millimetres (mm), and the general designation for half-warm mix asphalt.

EXAMPLE: BBTM 10 HWMA is a half-warm mix very thin asphalt concrete with an upper sieve size of the aggregate of 10 mm.

B.4 Requirements for constituent materials**B.4.1 General**

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt;

BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.4.2 Binder

B.4.2.1 General

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.4.2.2 Selection of binder

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

NOTE: The ageing of binder during the mixing and placement of hot mix asphalt, particularly when using batch mixers, in terms of the binder penetration is generally a reduction of the order of 33 %, or one binder grade, which does not occur to the same extent for half-warm mix asphalt. Consideration should be given to reducing the required binder penetration where equivalence is intended with hot mix asphalt.

B.4.2.3 Surface courses with reclaimed asphalt

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.4.2.4 Regulating courses, binder courses and bases with reclaimed asphalt

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; or BS EN 13108-5 for half-warm mix stone mastic asphalt.

NOTE: Not applicable for half-warm mix very thin layer asphalt concrete or half-warm mix porous asphalt.

B.4.3 Aggregates

B.4.3.1 General

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.4.3.2 Water content of aggregates

The water content of the aggregate prior to mixing shall be determined in accordance with BS EN 1097-5. The minimum and maximum water contents of the aggregate or a specified aggregate fraction shall comply with the selected category from Table B.1.

Table B.1 — Minimum and maximum water content of aggregate, WA_{min} and WA_{max}

Water content (%)	Minimum category	Maximum category
3.0	WA_{min} 3.0	WA_{max} 3.0
4.0	WA_{min} 4.0	WA_{max} 4.0
5.0	WA_{min} 5.0	WA_{max} 5.0
6.0	WA_{min} 6.0	WA_{max} 6.0
8.0	–	WA_{max} 8.0
10.0	–	WA_{max} 10.0
No requirement	WA_{min} NR	WA_{max} NR

NOTE: The range between the upper and lower limits selected should be at least 1 %.

B.4.4 Reclaimed asphalt

B.4.4.1 As with hot mix asphalt, reclaimed asphalt containing tar shall not be used.

B.4.4.2 As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.4.4.3 If reclaimed asphalt is controlled using analysis of particles without removing the binder, the aggregate grading in the reclaimed asphalt for calculation of the aggregate grading in the mixture shall be determined in accordance with Appendix D.

B.4.5 Additives

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.5 Requirements for the half-warm mix asphalt mixture

B.5.1 General

B.5.1.1 The target composition of the mixture in terms of its constituent materials, the proportions (in per cent) passing the specified sieves, the target binder content and where relevant the binder from natural asphalt and the proportion(s) of additive(s) shall be declared and documented. The target grading curve shall be declared for the sieve 1.4 D and the sieves as called up in B.5.2.

B.5.1.2 At the target composition, the mixture shall conform to the specified requirements in accordance with this specification.

B.5.1.3 The test results shall be made available.

B.5.2 Composition and grading

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt;

BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

NOTE: Coated chippings to BS EN 13108-4 are not included because they are not suitable for rolling into hot rolled asphalt at half-warm mix asphalt temperatures.

B.5.3 Binder content

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.5.4 Additives

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.5.5 Properties

B.5.5.1 Specimens

B.5.5.1.1 For application of this Specification, specimens shall be manufactured in accordance with clause 6.2 of BS EN 13108-20:2014 except for the temperature at which they are mixed and compacted and the time between the two operations.

B.5.5.1.2 The temperature at which samples shall be mixed and compacted shall be at the standard temperature for each operation less the difference between the temperature at which the half-warm asphalt will be prepared on site and the temperature at which hot asphalt will be prepared on site.

B.5.5.1.3 The time between the completion of mixing and the start of compaction of samples shall be (120 ± 10) min, during which time the specimens shall be stored in their moulds at 95 °C.

NOTE 1: Reheating of specimens should be avoided.

NOTE: Half-warm mixtures will slowly eliminate water after manufacture during the delivery and application process. Therefore, it is important not to compact laboratory prepared mixtures immediately because the excess water present may have a negative impact on some comparative tests. This phenomenon has been studied and conditioning at 95 °C for 2 h prior to compaction at 95 °C has produced samples with superior water sensitivity performance to ones compacted immediately.

B.5.5.1.4 When testing a sample of half-warm asphalt for refusal density, the sample shall be heated to the same temperature as an equivalent hot mix asphalt before compaction.

B.5.5.1.5 The relevant technology that allows the asphalt to be mixed and laid at a reduced temperature shall be employed in the manufacture of samples used to demonstrate the properties of the asphalt mixture. If the technology cannot be replicated in the laboratory, plant-produced samples shall be used for type testing and factory production control.

B.5.5.2 Standard properties

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

NOTE: The ageing of binder during the mixing and placement of hot mix asphalt, particular when using batch mixers, in terms of the binder penetration is generally a reduction of the order of 33 %, or one binder grade, which does not occur to the same extent. Where equivalence is intended with hot mix asphalt and the binder grade selected has been adjusted, the selected categories of the standard mechanical properties may need to be adjusted when laboratory prepared mixtures are used to assess the performance.

B.5.5.3 Water content of asphalt

The water content of freshly mixed half-warm mix asphalt shall be determined in accordance with BS EN 12697-14. The maximum water content shall comply with the selected category from Table B.2.

Table B.2 – Maximum water content of asphalt, WC_{max}

Maximum water content (%)	Category
1.0	$WC_{max\ 1.0}$
2.0	$WC_{max\ 2.0}$
3.0	$WC_{max\ 3.0}$
4.0	$WC_{max\ 4.0}$
5.0	$WC_{max\ 5.0}$
6.0	$WC_{max\ 6.0}$
No requirement	$WC_{max\ NR}$

B.5.6 Temperature of the mixture

B.5.6.1 The maximum temperature requirements apply at any place in the plant and shall be declared.

B.5.6.2 The minimum temperature of the mixture at delivery shall be declared.

B.5.6.3 Depending on local conditions and for specific application the minimum temperature, measured according to EN 12697-13, may be specified.

B.5.6.4 When using paving grade binder, the maximum temperature of a half-warm mix asphalt, measured according to BS EN 12697-13, shall target ≤ 100 °C but shall not exceed 110 °C.

B.5.6.5 When using modified bitumen or hard grade bitumen, additives or premix bitumen, different temperatures may be applicable. These shall then be documented and declared.

B.5.7 Dangerous substances

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.5.8 Conflicting specifications

As in BS EN 13108-1 for half-warm mix asphalt concrete; BS EN 13108-2 for half-warm mix very thin layer asphalt concrete; BS EN 13108-4 for half-warm mix hot rolled asphalt; BS EN 13108-5 for half-warm mix stone mastic asphalt; or BS EN 13108-7 for half-warm mix porous asphalt.

B.6 Identification

The delivery ticket shall contain at least the following information relating to identification:

- the manufacturer and mixing plant;
- designation of the mixture:

<i>AC/BBTM/HRA/SMA/PA</i>	<i>D</i>	<i>surf/base/bin</i>	<i>Binder</i>	<i>HWMA</i>
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where:

<i>AC</i>	is Asphalt Concrete;
<i>BBTM</i>	is asphalt concrete for very thin layers;
<i>HRA</i>	is Hot Rolled Asphalt;
<i>SMA</i>	is Stone Mastic Asphalt;
<i>PA</i>	is Porous Asphalt;
<i>D</i>	is the upper sieve size;
<i>surf</i>	is the surface course;
<i>base</i>	is the base course;
<i>bin</i>	is the binder course;
<i>binder</i>	is the designation of binder used;
<i>HWMA</i>	is half-warm mix asphalt.

NOTE: Example: SMA 14 *base* 40/60 HWMA (in which 40/60 is the binder used and not the equivalent properties for hot mix asphalt).

B.7 Transport, laying and compaction

B.7.1 This clause gives general requirements for the transport, placing and compaction of bituminous mixtures, which are complementary and additional to the requirements of BS 594987. These requirements and the requirements of BS 594987 shall apply to all half-warm mix asphalt mixtures, unless otherwise specified in B.7.2 of this Appendix.

NOTE: BS 594987 states that it “does not cover the supply, laying and compaction of low-temperature warm mix and other reduced temperature asphalts”. Nevertheless, its main requirements, other than those on the temperature of the mixture, are generally applicable to half-warm mix asphalt.

B.7.2 Minimum delivery and rolling temperatures for half-warm mix asphalt mixtures shall be declared by the supplier with evidence to support their suitability.

B.8 Compliance

B.8.1 Compliance with the requirements for mixture composition and properties (B.4 and B.5) shall be by type testing and factory production control. The factory production control shall be in accordance with the principles and frequencies of BS EN 13108-21. A certificate defining compliance supported by test reports shall be made available for inspection.

B.8.2 Audit checking to confirm that the mixture composition and properties claimed are those of the mixture delivered to site may be undertaken.

B.8.3 Compliance with the requirements for transporting, laying and compacting the asphalt (B.7) shall be monitored against the requirements of BS 594987 and test reports demonstrating compliance shall be made available for inspection.

Appendix C Specification for emulsion-based cold mix asphalt

C.1 Scope

This Specification sets out requirements for mixtures of emulsion-based cold mix asphalt for use on roads, airfields and other trafficked areas, such as gravel emulsion, dense and open graded mixtures. It includes requirements for the selection of the constituent materials. Emulsion-based cold mix asphalt can be used for surface courses, binder courses, regulating courses and bases. This Specification does not cover in-situ recycling or bagged cold ready-use mixtures.

C.2 Normative references

This Specification incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this Specification only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies (including amendments).

ASTM D6998, *Standard practice for evaluating aggregate coating using emulsified asphalts*

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

BS EN 1097-5, *Test for mechanical and physical properties of aggregates – Determination of particle density and water absorption*

BS EN 12591, *Bitumen and bituminous binders – Specifications for paving grade bitumens*

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 12697-6, *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 voids characteristics of bituminous specimen*

BS EN 12697-10, *Bituminous mixtures – Test methods for hot mix asphalt – Part 10: Compactibility*

BS EN 12697-12, *Bituminous mixtures – Test methods for hot mix asphalt – Part 12: Determination of the water sensitivity of bituminous specimens*

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

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

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

BS EN 12697-27, *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 12697-31, *Bituminous mixtures – Test methods for hot mix asphalt – Part 31: Specimen preparation by gyratory compactor*

BS EN 12697-33, *Bituminous mixtures – Test methods for hot mix asphalt – Part 33: Specimen prepared by roller compactor*

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

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

BS EN 13108-1, *Bituminous mixtures – Material specifications – Part 1: Asphalt concrete*

BS EN 13108-4, *Bituminous mixtures – Material specifications – Part 4: Hot rolled asphalt*

BS EN 13108-5, *Bituminous mixtures – Material specifications – Part 5: Stone mastic asphalt*

BS EN 13108-21, *Bituminous mixtures – Material specifications – Part 21: Factory production control*

BS EN 13501-1, *Fire classification of construction products and building elements – Classification using test data from reaction to fire tests*

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

BS EN 13924, *Bitumen and bituminous binders – Specifications for hard paving grade bitumens*

BS EN 14023, *Bitumen and bituminous binders – Framework specification for polymer modified bitumens*

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

C.3 Terms, definitions, symbols and abbreviations

C.3.1 Terms and definitions

For the purposes of this Appendix, the terms and definitions given in BS EN 13108-1 together with the following apply.

C.3.1.1

asphalt

homogenous mixture of coarse and fine aggregates, filler aggregate and bituminous binder which is used in the construction of flexible pavement layers

NOTE: The asphalt may include one or more additives to enhance the laying characteristics, performance or appearance of the mixture. Natural asphalt is defined in BS EN 13108-4.

C.3.1.2**warm mix asphalt**

asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at temperatures at least 20 °C below conventional hot mix asphalt mixtures but still above 100 °C

C.3.1.3**half-warm mix asphalt**

asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at temperatures in the range 70 °C to 100 °C

NOTE: Also known as semi-warm mix asphalt.

C.3.1.4**cold mix asphalt**

asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at ambient temperature

C.3.1.5**emulsion-based cold mix asphalt**

cold mix asphalt in which the binder is a bituminous emulsion with a viscosity such that the mix is workable at ambient temperature

C.3.1.6**foamed asphalt**

asphalt in which, during mixing, the binder is caused to foam by the presence of steam, reducing the surface tension and easing coating of the aggregate particles

C.3.1.7**emulsion content**

proportion of bituminous emulsion by mass versus dry aggregate mass in per cent

C.3.1.8**residual anhydrous binder**

binder in which water is evaporated

C.3.1.9**residual anhydrous binder content in the mix**

residual anhydrous binder content expressed in per cent of the dry aggregate mass

C.3.1.10**moisture content in the mix**

water content expressed in per cent of the dry aggregate mass

C.3.2 Symbols and abbreviations

CME	General designation for an emulsion-based cold mix asphalt.
XX D CME	Designation of asphalt mixture type followed by an indication of <i>D</i> , the upper sieve size of the aggregate in the mixture, in millimetres (mm), and the general designation for emulsion-based cold mix asphalt.
EXAMPLE:	SMA 6 CME is an emulsion-based cold mix stone mastic asphalt having an upper sieve size of the aggregate of 6 mm.

C.4 Requirements for constituent materials

C.4.1 General

As in BS EN 13108-1 for emulsion-based cold mix asphalt concrete; or BS EN 13108-5 for emulsion-based cold mix stone mastic asphalt.

C.4.2 Binder

C.4.2.1 General

C.4.2.1.1 The emulsion shall conform to BS EN 13808. The binder shall be emulsion from paving grade bitumen, modified bitumen, fluxed bitumen or hard grade bitumen conforming to BS EN 12591, BS EN 14023, BS EN 15322 or BS EN 13924, respectively.

C.4.2.1.2 Natural asphalt may be added and shall conform to BS EN 13108-4.

C.4.2.2 Category of bituminous emulsion

The cationic bituminous emulsion category (B, P, F and breaking value) shall be selected from BS EN 13808. Depending on the conditions of use, the grade of the bitumen, the type and grade of modified bitumen and the amount and category of natural asphalt may be specified.

C.4.3 Aggregates

As in BS EN 13108-1 for emulsion-based cold mix asphalt concrete; or BS EN 13108-5 for emulsion-based cold mix stone mastic asphalt.

C.4.4 Reclaimed asphalt

C.4.4.1 As in BS EN 13108-1 for emulsion-based cold mix asphalt concrete; or BS EN 13108-5 for emulsion-based cold mix stone mastic asphalt.

C.4.4.2 The use of reclaimed asphalt containing tar is permitted unless otherwise specified.

NOTE: All reclaimed asphalt containing coal tar has to be treated in accordance with the latest Regulatory Position Statement as published by the Environment Agency and also in line with the advice given in the latest ADEPT document.

C.4.4.3 If reclaimed asphalt is controlled using analysis of particles without removing the binder, the aggregate grading in the reclaimed asphalt for calculation of the aggregate grading in the mixture shall be determined in accordance with Appendix D.

C.4.5 Additives

As in BS EN 13108-1 for emulsion-based cold mix asphalt concrete; or BS EN 13108-5 for emulsion-based cold mix stone mastic asphalt.

C.5 Requirements for the cold mix asphalt mixture

C.5.1 General

C.5.1.1 The target composition of the mixture in terms of its constituent materials, the proportions (in per cent) passing the specified sieves, the target binder content and where relevant the binder from natural asphalt and the proportion(s) of additive(s) shall

be declared and documented. The target grading curve shall be declared for the sieve 1.4 *D* and the sieves as called up in C.5.2.

C.5.1.2 At the target composition the mixture shall conform to the specified requirements in accordance with this specification.

C.5.1.3 The test results shall be made available.

C.5.2 Composition and grading

As in BS EN 13108-1 for emulsion-based cold mix asphalt concrete; or BS EN 13108-5 for emulsion-based cold mix stone mastic asphalt.

C.5.3 Residual anhydrous content

C.5.3.1 The minimum residual anhydrous binder content shall be specified, either by requirement from Table C.1 or by requirement from the coating test in C.5.5.

C.5.3.2 The minimum residual anhydrous binder content of the target composition shall comply with the selected category from Table C.1. The binder content requirements shall be corrected by multiplying by the factor:

$$\alpha = \frac{2,650}{\rho_a}$$

where:

ρ_a is the apparent particle density, in megagrams per cubic metre (Mg/m³), determined on the weighted mean of the total mineral fraction according to BS EN 1097-5.

NOTE: The binder content includes binder in reclaimed asphalt and natural asphalt when used.

Table C.1 — Minimum residual anhydrous binder content, B_{\min}

Minimum residual anhydrous binder content (% to change)	Category	Minimum residual anhydrous binder content (% to change)	Category
3.0	B_{\min} 3.0	5.8	B_{\min} 5.8
3.5	B_{\min} 3.5	6.2	B_{\min} 6.2
4.0	B_{\min} 4.0	6.6	B_{\min} 6.6
4.5	B_{\min} 4.5	7.0	B_{\min} 7.0
5.0	B_{\min} 5.0	7.4	B_{\min} 7.4
5.4	B_{\min} 5.4	No requirement	B_{\min} NR

C.5.4 Air voids content

Specimens at the target composition shall be compacted in accordance with BS EN 12697-31 for 100 gyrations. The bulk density and maximum density shall be determined in accordance with BS EN 12697-6 (Procedure C, sealed specimen using wax) and BS EN 12697-6 (Procedure A, volumetric in water), respectively. The air voids content of the specimens, measured in accordance with BS EN 12697-8, shall lie between maximum and minimum values selected from the categories in Table C.2 and C.3.

Table C.2 — Maximum air voids content, V_{\max}

Maximum air voids content (%)	Category
8.0	V_{\max} 8.0
10.0	V_{\max} 10.0
12.0	V_{\max} 12.0
14.0	V_{\max} 14.0
16.0	V_{\max} 16.0
18.0	V_{\max} 18.0
20.0	V_{\max} 20.0
No requirement	V_{\max} NR

Table C.3 — Minimum air voids content, V_{\min}

Minimum air voids content (%)	Category
4.0	V_{\min} 4.0
4.5	V_{\min} 4.5
5.0	V_{\min} 5.0
5.5	V_{\min} 5.5
6.0	V_{\min} 6.0
No requirement	V_{\min} NR

C.5.5 Coating and homogeneity

The coating of specimens at the target composition compacted in accordance with BS EN 12697-31 for 100 gyrations and tested in accordance with ASTM D6998-11 shall comply with the selected category from Table C.4.

C.5.6 Water sensitivity

Four 150 mm diameter x 75 mm to 100 mm high, cylinder test specimens at the target composition shall be compacted to refusal by vibratory compaction in a cylindrical metal mould, using the compaction mould assembly and vibratory hammer described in BS EN 12697-32. The specimens shall be cured for a period of 72 h at a nominal temperature of 60 °C and then conditioned in air for a minimum period of 12 h at 20 °C. The specimens shall be tested in accordance with BS EN 12697-26 to determine the IT-CY stiffness (dry), then immersed in water at 20 °C for a minimum period of 24 h and the IT-CY stiffness tests (wet) repeated on each specimen. The water sensitivity shall be the wet IT-CY stiffness as a proportion of the dry IT-CY stiffness and shall comply with the selected category for the indirect tensile strength ratio or compressive strength ratio from Table C.5.

Table C.4 — Minimum coating, C_{\min}

Minimum coating (%)	Category
75	C_{\min} 75
70	C_{\min} 70
No requirement	C_{\min} NR

Table C.5 — Minimum water sensitivity, $IT-CY_{\text{wet/dry}}$

Minimum ratio (%)	Category
80	$IT-CY_{\text{wet/dry}}$ 80
70	$IT-CY_{\text{wet/dry}}$ 70
60	$IT-CY_{\text{wet/dry}}$ 60
50	$IT-CY_{\text{wet/dry}}$ 50
No requirement	$IT-CY_{\text{wet/dry}}$ NR

C.5.7 Resistance to permanent deformation (Rut depth and rut rate in wheel-tracking)

The resistance to permanent deformation of specimens at the target composition compacted in accordance with BS EN 12697-33 to the air voids content determined for $0 \pm 1.0\%$ and tested (28 ± 1) days later (when stored at ambient temperature) or ($7 \text{ days} \pm 4 \text{ h}$) later (when stored at $(40 \pm 5)^\circ\text{C}$) in accordance with BS EN 12697-22 shall comply with the selected category from Tables C.6 or C.7.

Table C.6 — Resistance to permanent deformation, small size device, Procedure B, conditioning in air, maximum wheel tracking slope, WTS_{AIR}

Maximum wheel tracking slope (mm per 10^3 load cycles)	Category
0.03	$WTS_{\text{AIR}} 0.03$
0.05	$WTS_{\text{AIR}} 0.05$
0.07	$WTS_{\text{AIR}} 0.07$
0.10	$WTS_{\text{AIR}} 0.10$
0.15	$WTS_{\text{AIR}} 0.15$
0.20	$WTS_{\text{AIR}} 0.20$
0.30	$WTS_{\text{AIR}} 0.30$
0.40	$WTS_{\text{AIR}} 0.40$
0.50	$WTS_{\text{AIR}} 0.50$
0.60	$WTS_{\text{AIR}} 0.60$
0.80	$WTS_{\text{AIR}} 0.80$
1.00	$WTS_{\text{AIR}} 1.00$
No requirement	$WTS_{\text{AIR}} \text{ NR}$

Table C.7 — Resistance to permanent deformation, small size device, Procedure B, conditioning in air, maximum proportional rut depth, PR_D

Maximum proportional rut depth (%)	Category
1.0	$PR_D \text{ AIR } 1.0$
1.5	$PR_D \text{ AIR } 1.5$
2.0	$PR_D \text{ AIR } 2.0$
3.0	$PR_D \text{ AIR } 3.0$
5.0	$PR_D \text{ AIR } 5.0$
7.0	$PR_D \text{ AIR } 7.0$
9.0	$PR_D \text{ AIR } 9.0$
No requirement	$PR_D \text{ AIR NR}$

C.5.8 Reaction to fire

Cold mix asphalt is class C_{fl} reaction to fire according to BS EN 13501-1 without testing.

C.5.9 Resistance to fuel for application on airfields

The resistance to fuel of specimens at the target composition measure in accordance with BS EN 12697-43 shall comply with the selected category from good, moderate, poor or no requirement.

NOTE: The classifications will have to be defined here after the current revision of BS EN 12697-43, which will remove the definition of the categories good, moderate and poor in that document, is published.

C.5.10 Marshall values for application on airfields

The Marshall stability, the Marshall flow and the Marshall quotient, of specimens at the target composition compacted in accordance with BS EN 12697-30 and tested (28 ± 1) days later (when stored at ambient temperature) or ($7 \text{ days} \pm 4 \text{ h}$) later (when stored at $(40 \pm 5)^\circ\text{C}$) in accordance with BS EN 12697-34 shall comply with the selected categories in Tables C.8, C.9 and C.10, respectively. When both a minimum and maximum value for Marshall flow are selected, the range shall be at least 2.

Table C.8 – Minimum and maximum Marshall stability, S_{\min} and S_{\max}

Marshall stability (kN)	Minimum category	Maximum category
15.0	–	S_{\max} 15.0
12.5	S_{\min} 12.5	S_{\max} 12.5
10.0	S_{\min} 10.0	S_{\max} 10.0
7.5	S_{\min} 7.5	S_{\max} 7.5
5.0	S_{\min} 5.0	–
2.5	S_{\min} 2.5	–
No requirement	S_{\min} NR	S_{\max} NR

Table C.9 – Marshall flow, F

Marshall flow (mm)	Minimum category	Maximum category
1	F_{\min} 1	–
1.5	F_{\min} 1.5	–
2	F_{\min} 2	F_{\max} 2
3	F_{\min} 3	F_{\max} 3
4	F_{\min} 4	F_{\max} 4
5	–	F_{\max} 5
8	–	F_{\max} 8
No requirement	F_{\min} NR	F_{\max} NR

Table C.10 – Minimum Marshall quotient, Q_{\min}

Minimum Marshall quotient (kN/mm)	Category
4.0	Q_{\min} 4.0
3.5	Q_{\min} 3.5
3.0	Q_{\min} 3.0
2.5	Q_{\min} 2.5
2.0	Q_{\min} 2.0
1.5	Q_{\min} 1.5
1.0	Q_{\min} 1.0
No requirement	Q_{\min} NR

C.5.11 Compactibility

The minimum air voids content of samples at the target composition, determined in accordance with BS EN 12697-10, after compaction by 10 gyrations shall comply with the selected category from Table C.11.

Table C.11 — Maximum void content at 10 gyrations, $V10G_{min}$

Maximum void content at 10 gyrations (%)	Category
25.0	$V10G_{min}$ 25
20.0	$V10G_{min}$ 20
18.0	$V10G_{min}$ 18
14.0	$V10G_{min}$ 14
11.0	$V10G_{min}$ 11
9.0	$V10G_{min}$ 9
No requirement	$V10G_{min}$ NR

C.5.12 Stiffness

The stiffness of specimens at the target composition cored in accordance with BS EN 12697-27 from a slab compacted in accordance with BS EN 12697-33 to the air voids content determined for $C.5.4 \pm 1.0$ % and tested (28 ± 1) days (when stored at ambient temperature) or ($7 \text{ days} \pm 4 \text{ h}$) (when stored at $(40 \pm 5) ^\circ\text{C}$) after compaction in accordance with BS EN 12697-26 shall comply with the selected category from Table C.12.

Table C.12 — Minimum stiffness, S_{min}

Minimum stiffness (MPa)	Category	Minimum stiffness (MPa)	Category
9 000	S_{min} 9 000	1 800	S_{min} 1 800
7 000	S_{min} 7 000	1 500	S_{min} 1 500
5 500	S_{min} 5 500	1 200	S_{min} 1 200
4 500	S_{min} 4 500	1 000	S_{min} 1 000
3 600	S_{min} 3 600	800	S_{min} 800
2 800	S_{min} 2 800	600	S_{min} 600
2 200	S_{min} 2 200	No requirement	S_{min} NR

C.5.13 Resistance to permanent deformation in tri-axial compression test

The creep rate of specimens at the target composition cored in accordance with BS EN 12697-27 from a slab compacted in accordance with BS EN 12697-33 to the air voids content determined for $C.5.4 \pm 1.0$ % and tested (28 ± 1) days (when stored at ambient temperature) or ($7 \text{ days} \pm 4 \text{ h}$) (when stored at $(40 \pm 5) ^\circ\text{C}$) after compaction in accordance with BS EN 12697-25 shall comply with the selected category from Table C.13.

Table C.13 — Maximum creep rate, f_{cmax}

Creep rate f_c ($\mu\text{m}/\text{m}/\text{N}$)	Category	Creep rate f_c ($\mu\text{m}/\text{m}/\text{N}$)	Category
0.2	$f_{cmax\ 0.2}$	2	$f_{cmax\ 2}$
0.4	$f_{cmax\ 0.4}$	4	$f_{cmax\ 4}$
0.6	$f_{cmax\ 0.6}$	6	$f_{cmax\ 6}$
0.8	$f_{cmax\ 0.8}$	8	$f_{cmax\ 8}$
1.0	$f_{cmax\ 1.0}$	10	$f_{cmax\ 10}$
1.2	$f_{cmax\ 1.2}$	12	$f_{cmax\ 12}$
1.4	$f_{cmax\ 1.4}$	14	$f_{cmax\ 14}$
1.6	$f_{cmax\ 1.6}$	16	$f_{cmax\ 16}$
		No requirement	$f_{cmax\ NR}$

C.5.14 Dangerous substances

As in BS EN 13108-1 for emulsion-based cold mix asphalt concrete; or BS EN 13108-5 for emulsion-based cold mix stone mastic asphalt.

C.5.15 Conflicting specifications

As in BS EN 13108-1 for emulsion-based cold mix asphalt concrete; or BS EN 13108-5 for emulsion-based cold mix stone mastic asphalt.

C.6 Identification

The delivery ticket shall contain at least the following information relating to identification:

- the manufacturer and mixing plant;
- designation of the mixture:

AC/SMA	<i>D</i>	<i>surf/base/bin</i>	<i>Binder</i>	<i>CME</i>
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where: AC is Asphalt Concrete;
 SMA is Stone Mastic Asphalt;
D is the upper sieve size;
Surf is the surface course;
base is the base course;
bin is the binder course;
binder is the designation of binder used;
CME is emulsion-based Cold Mix Asphalt.

NOTE: Example: AC 14 *surf* C60 B5 CME.

C.7 Transport, laying and compaction

C.7.1 This clause gives general requirements for the transport, placing and compaction of bituminous mixtures, which are complementary and additional to the requirements of BS 594987. These requirements and the requirements of BS 594987 shall apply to all emulsion-based cold mix asphalt mixtures, unless otherwise specified in C.7.2 to C.7.4 of this Appendix.

NOTE: BS 594987 states that it “does not cover the supply, laying and compaction of low-temperature warm mix and other reduced temperature asphalts”. Nevertheless, its main requirements, other than those on the temperature of the mixture, are generally applicable to emulsion-based cold mix asphalt.

C.7.2 The substrate onto which emulsion-based cold mix asphalt is to be laid shall have a stiffness determined by in situ testing using a dynamic plate from the selected category in Table C.14.

Table C.14 – Minimum stiffness of substrate, $S_{f \min}$

Minimum stiffness (MPa)	Category
500	$S_{f \min 500}$
400	$S_{f \min 400}$
300	$S_{f \min 300}$
250	$S_{f \min 250}$
200	$S_{f \min 200}$
150	$S_{f \min 150}$
100	$S_{f \min 100}$
50	$S_{f \min 50}$
No requirement	$S_{f \min \text{NR}}$

NOTE: Emulsion-based cold mix asphalt mixtures are hybrid granular materials and, therefore, need a slightly different approach to traditional hot mix asphalt.

C.7.3 Where the existing substrate fails to comply with C.7.2, the substrate shall be stabilised or replaced so that the stabilised or replaced substrate does comply.

C.7.4 No minimum delivery or rolling temperatures for cold mix asphalt mixture shall be enforced.

C.7.5 Compaction of emulsion-based cold mix asphalt shall include not less than four passes with a pneumatic tyre roller (PTR). For layers other than the surface course, this requirement can be omitted with prior approval by the Overseeing Organisation.

C.8 Compliance

C.8.1 General

C.8.1.1 Compliance with the requirements for mixture composition and properties (C.4 and 0) shall be by type testing to C.8.2 and factory production control to C.8.3. A certificate defining compliance supported by test reports shall be made available for inspection.

C.8.1.2 Audit checking to confirm that the mixture composition and properties claimed are those of the mixture delivered to site may be undertaken.

C.8.1.3 Compliance with the requirements for transporting, laying and compacting the asphalt (C.7) shall be monitored against the requirements of BS 594987 and test reports demonstrating compliance shall be made available for inspection.

C.8.2 Type testing

C.8.2.1 For each mix formulation, type testing shall be carried out to provide proof that the formulation meets the relevant requirements. A complete set of tests or other procedures shall be undertaken to determine the performance of samples of bituminous mixtures representative of the product type against all the required properties.

C.8.2.2 Where raw materials are used whose characteristics have already been determined by the material supplier on the basis of conformity with other technical specifications, these characteristics need not be reassessed provided that the raw material's performance remain the same.

C.8.2.3 All testing shall be carried out strictly in accordance with the appropriate test method on samples taken strictly in accordance with the appropriate sampling method to be representative of the normal constituents and mixed materials.

C.8.2.4 Type testing shall be carried out before the mixture is used and then at a frequency of at least once every five years.

C.8.3 Factory production control

C.8.3.1 The manufacturer shall establish, document and maintain a Factory Production Control (FPC) system to ensure that the products placed on site comply with the declared performance of the required properties. The FPC system shall consist of procedures, regular inspections and tests and/or assessments and the use of the results to control raw and other incoming materials or components, equipment, the production process and the product.

C.8.3.2 The manufacturer shall establish and maintain his policy and procedures for Factory Production Control in a quality plan. The quality plan shall particularly include a means for identifying and detailing the specific processes, which directly affect product quality and conformity. The quality plan shall particularly include:

- manufacturer's organisational structure relating to conformity and quality;
- document control;
- control procedures for constituent materials and purchaser supplied product;
- process control;
- requirements for the handling and storage of the product;
- plant calibration and maintenance;
- requirements for inspection and testing of processes and products;
- procedures for handling non-conformity
- frequencies of inspection and testing.

C.8.3.3 The quality plan shall identify those items of measuring equipment which require calibration. The frequency of such calibration shall comply with the requirements of Table C.15.

Table C.15 — Minimum plant calibration requirements

Item of plant	Inspection/test	Purpose	Minimum frequency
Weighing equipment	Visual inspection as described in procedures	To ascertain that weighing equipment is functioning correctly	Daily
	Testing of weighing accuracy — (recalibration)	To ensure accuracy within quality plan requirements	a) On installation *, b) Every year, and c) In case of doubt
Admixture dispensers	Organoleptic inspection	To ascertain that dispenser is functioning correctly	First batch of the day containing admixture
	Test for accuracy as described in procedures.	To ensure accuracy within quality plan requirements	a) On installation *, b) Every year, and c) In case of doubt
Flow meters	Comparison of the actual amount with the metered amount by reconciliation	To ensure accuracy within quality plan requirements	a) On installation *, b) Every year, and c) In case of doubt
Batching system (on batch plants)	Comparison of actual mass of constituents in the batch with the intended mass using the method prescribed in the quality plan	To ascertain the batching accuracy in accordance with the quality plan	a) On installation *, b) Every year, and c) In case of doubt
Proportioning system (on continuous plants)	Comparison of actual mass in a measured period of time with the intended mass using the method prescribed in the quality plan	To ascertain the accuracy in accordance with the quality plan	a) On installation *, b) Every year, and c) In case of doubt
Temperature, monitoring equipment	Visual as described in procedures	To ascertain the equipment is functioning correctly	Daily
	Test of accuracy as described in procedures.	To ensure correct temperatures are recorded	a) On installation *, b) Every year, and c) In case of doubt

NOTE: "In case of doubt" refers to the reasonable judgement of an experienced plant operator
 * Or after comprehensive repair

C.8.3.4 Incoming constituent materials shall be inspected and tested using procedures detailed in the quality plan and to a schedule complying with Table C.16 for aggregates, Table C.17 for filler, Table C.18 for binders, Table C.19 for additives and Table C.20 for reclaimed asphalt.

NOTE: These tables may include the results of tests and inspections by the supplier as part of his Factory Production Control.

Table C.16 — Minimum inspection and test frequencies for aggregates

Inspection/Test	Purpose	Frequency
Tests for intrinsic properties of aggregate (strength etc.)	To check suitability for intended use	Source approval before initial use in accordance with BS EN 13043
Inspection of delivery ticket *	To check consignment is as ordered and from correct source	Each delivery
Organoleptic check of stockpile *	For comparison with normal appearance with respect to source, grading, shape and impurities	Daily
By sieve analysis	To assess compliance with standard or other agreed grading	a) First delivery from new source, b) In case of doubt following organoleptic check, and c) 1 per 2 000 t / product / size
Shape, crushed particle index, etc.	To assess compliance with standard or other agreed specification	a) First delivery from new source, b) In case of doubt, and c) As indicated in quality plan
Moisture content	Process control	As indicated in the quality plan

* These requirements will not apply in the case of direct supplies from an aggregate production unit to an asphalt plant on the same site.

Table C.17 — Minimum inspection and test frequencies for filler

Inspection/test	Purpose	Frequency
Tests for intrinsic properties of filler (bulk density, stiffening properties etc.)	To check suitability for intended use	Supplier approval before initial use in accordance with BS EN 13043
Inspection of delivery ticket	To check consignment is as ordered and from the correct source	Each delivery
Sieve analysis	To check compliance with standard or other agreed grading	a) First delivery from new source, and b) As indicated in the quality plan

Table C.18 — Minimum inspection and test frequencies for binders

Inspection/test	Purpose	Frequency
Intrinsic properties of binder	To confirm characteristics of product and compliance with appropriate specification	Source approval before initial use in accordance with the relevant binder standards
Inspection of delivery ticket	To check consignment is as ordered and from the correct source	Each delivery

Table C.19 — Minimum inspection and test frequencies for additives

Inspection/test	Purpose	Frequency
Appropriate tests to determine intrinsic properties	To confirm characteristics of product or check compliance with specification	a) Source approval prior to initial use and b) As stated in the quality plan
Inspection of delivery ticket	To check that consignment is as ordered and from the correct source	Each delivery
Organoleptic check of consignment	For comparison with normal appearance	Each delivery, if practicable; otherwise in accordance with quality plan

Table C.20 — Minimum inspection and test frequencies for reclaimed asphalt

Inspection/test	Purpose	Frequency
Organoleptic check of feedstock	For comparison with normal appearance with respect to source, grading, shape and impurities	Daily
Moisture content	Process control	As indicated by the quality plan

C.8.3.5 The finished bituminous mixture shall be inspected and tested using procedures detailed in the quality plan and to a schedule complying with the requirements of this clause, Table C.21 and Table C.22. Appropriate statistical records shall be maintained in order to monitor and verify process capability and product characteristics.

Table C.21 — Minimum inspection/test frequencies for delivered product

Inspection/test	Purpose	Frequency
Organoleptic check on mixed asphalt	For comparison with normal appearance with respect to grading, evenness of mixing and adequacy of coating	Every load
Grading and binder content	To ensure material conforms to specification	Weekly
Other characteristics included in technical specifications	To assess conformity	As detailed in quality plan
Cleanliness of delivery vehicles by visual assessment	To avoid contamination	Every load prior to loading

C.8.3.6 The construction tolerances of individual measurements from the target grading and binder contents shall be as given Table C.22.

Table C.22 — Construction tolerances from the target in absolute proportion individual samples

Sieve size / binder content	Tolerance about target composition (%)	
	Small aggregates	Large aggregates
D	-8 +5	-9 +5
Characteristic coarse sieve	± 7	± 9
2 mm	± 6	± 7
Characteristic fine sieve	± 4	± 5
0,063 mm	± 2	± 3
Soluble binder content	± 0.5	± 0.6

NOTE 1: Small aggregate mixtures have $D < 16$ mm; large aggregate mixtures have $D \geq 16$ mm.

NOTE 2: A tolerance of -2 % shall apply to the requirement of 100 % passing 1.4 D .

Appendix D Aggregate grading of reclaimed asphalt

(Normative)

D.1 Approach

D.1.1 The grading of the reclaimed asphalt can be used as the grading of the aggregate in the reclaimed asphalt if:

- the reclaimed asphalt is sufficiently aged so that the conglomerated particles on it will not be broken down during the mixing process; and/or
- the reclaimed asphalt is to be added at a small enough proportion that the difference in the grading of the reclaimed asphalt and that of the aggregate particles in the reclaimed asphalt will not significantly affect the overall grading of the new mixture.

NOTE 1: The first option is when the reclaimed asphalt is regarded as “black rock”.

NOTE 2: The second option is generally when the reclaimed asphalt at proportions up to about 10 %.

D.1.2 If D.1.1 is not applicable, carry out a comparison in accordance with D.2 to D.5.

D.2 Fractions

A sample shall be taken of each fraction that the reclaimed asphalt will be separated into for production in accordance with BS EN 12697-27.

NOTE: The use of more fractions, whilst requiring more analysis, will allow the required aggregate and binder contents to be met more easily, particularly at high proportions of reclaimed asphalt.

D.3 Analysis

D.3.1 Take a sample of the reclaimed asphalt particles from each stockpile containing a fraction in accordance with BS EN 12697-27.

D.3.2 If required, determine the grading of each sample in accordance with BS EN 12697-2.

D.3.3 Analyse the sample in accordance with BS EN 12697-1 for binder content and the grading of the aggregate particles in the fraction in accordance with BS EN 12697-2.

D.4 Results

D.4.1 If required, the grading analysis from D.3.2 can be plotted against the analysis from D.3.3 to determine the extent of the difference.

D.4.2 The contribution to the binder content of the new mixture from the reclaimed asphalt shall be determined as:

$$b_{RA} = \sum (b_{f,i} \times p_{f,i})$$

where: b_{RA} is the binder content of the new mixture from the reclaimed asphalt

$b_{f,i}$ is the binder contents of fraction i determined in D.3.3

$p_{f,i}$ is the proportion of fraction i of the reclaimed asphalt added to the new mixture.

D.4.3 The contribution to the aggregate in the new mixture passing each sieve size from the reclaimed asphalt shall be determined as:

$$a_{RA,j} = \sum (a_{f,j,i} \times p_{f,i})$$

where: $a_{RA,j}$ is the proportion of aggregate in the new mixture that passes sieve size j and comes from the reclaimed asphalt

$b_{f,i}$ is the proportion of aggregate passing sieve size j from fraction i determined in D.3.3

$p_{f,i}$ is the proportion of fraction i of the reclaimed asphalt added to the new mixture.

D.5 Validity

D.5.1 The grading of the reclaimed asphalt particles in the fraction shall be determined not less than once per 500 tonnes of production of that fraction or whenever the source(s) of reclaimed asphalt change.

NOTE: Where the reclaimed asphalt is sourced from multiple sources, a change would be considered to have occurred if the proportion from any one of the sources changes by more than 20 %.

D.5.2 The conversion of the grading of the reclaimed asphalt particles into the grading of the aggregate particles and associated binder content shall only be valid providing the grading of the reclaimed asphalt particles in the fraction does not differ from that determined in D.4.3 by more than 5 % for each sieve size other than 0.06 mm and by more than 1 % for the 0.06 mm sieve.

Appendix E Example standard specification for half-warm asphalt concrete

(informative)

E.1 General

Half-warm mix asphalt concrete mixtures shall conform to the specification for half-warm mix asphalt in Appendix B.

E.2 Constituent materials

E.2.1 Binder

The binder shall be paving grade bitumen conforming to BS EN 12591 or polymer-modified bitumen conforming to BS EN 14023.

E.2.2 Bitumen

E.2.2.1 Paving grades

E.2.2.1.1 The preferred paving grades for half-warm mix asphalt concrete are 30/45, 40/60, 70/100, 100/150, 160/220 and 250/330.

NOTE: 70/100 and 100/150 pen paving grade bitumen may be produced by blending in the mixer at the asphalt plant.

E.2.2.1.2 Paving grades can be blended. The grades used for blending shall be not harder than 30/45 pen or softer than 160/220 pen, and shall conform to BS EN 12591. The producer shall be able to demonstrate that the plant is capable of adequately blending the bitumens. Measures for ensuring consistency of proportioning of the blend shall be included in plant quality management systems. These shall include evidence of type tests carried out on a laboratory blend of the bitumens to demonstrate conformity to BS EN 12591. The quality assurance/management systems shall also include the steps to be taken to demonstrate the continuing adequacy of the process following significant changes being made to those parts of the plant involved in the process of bitumen blending. No grades of bitumen harder than 70/100 pen shall be blended in the mixer.

NOTE 1: Other grades may be in-plant blended provided that the resulting bitumen can be sampled and tested before it is added to the aggregate to ensure it conforms to BS EN 12591.

NOTE 2: The grades of binders recommended here are suitable for machine-laid materials. For hand-laid mixtures and for deferred set and depot stock mixtures, petroleum bitumen conforming to BS EN 12591:2000, Table 1, Grade 160/220 or 250/330 pen, to which a flux oil conforming to the requirements shown in E.2.3 has been added, should be used.

E.2.2.2 Polymer modified bitumen

NOTE: Because polymer-modified bitumens in the UK are proprietary materials, selection of an appropriate polymer modified bitumen should be agreed between supplier and user.

E.2.3 Fluxing of hand-laid materials

As in Appendix B of PD 6691.

E.2.4 Aggregates

E.2.4.1 General

As in Appendix B of PD 6691.

E.2.4.2 Water content of aggregates

If the system has been pre-selected, the minimum and/or maximum water contents of the aggregate or a specified aggregate fraction can be limited, otherwise the aggregate shall be classed as $WA_{\min \text{ NR}}$ and $WA_{\max \text{ NR}}$.

E.2.5 Additives

As in Appendix B of PD 6691.

E.3 Mixture specifications

E.3.1 Binder content

As in Appendix B of PD 6691.

E.3.2 Designed base mixtures

E.3.2.1 Aggregate grading and binder content

As in Appendix B of PD 6691 except that the binder shall conform to BS EN 12591 grade 100/150, 70/100, 35/50 or 20/30.

E.3.2.2 Air voids content

As in Appendix B of PD 6691.

E.3.2.3 Resistance to permanent deformation

As in Appendix B of PD 6691.

E.3.3 Designed binder course mixtures

E.3.3.1 Aggregate grading and binder content

As in Appendix B of PD 6691 except that the binder shall conform to BS EN 12591 grade 100/150, 70/100, 35/50 or 20/30.

E.3.3.2 Air voids content

As in Appendix B of PD 6691.

E.3.3.3 Resistance to permanent deformation

As in Appendix B of PD 6691.

E.3.4 EME2 mixtures

E.3.4.1 Aggregate grading and binder content

As in Appendix B of PD 6691.

E.3.4.2 Air voids content

As in Appendix B of PD 6691.

E.3.4.3 Water sensitivity

As in Appendix B of PD 6691.

E.3.4.4 Deformation resistance

As in Appendix B of PD 6691.

E.3.4.5 Stiffness modulus

As in Appendix B of PD 6691.

E.3.4.6 Fatigue properties

As in Appendix B of PD 6691.

E.3.5 Recipe dense base and binder course**E.3.5.1 Aggregate grading and binder content**

As in Appendix B of PD 6691 except that the binder shall conform to BS EN 12591 grade 100/150, 70/100, 35/50 or 20/30.

E.3.6 Other base and binder course

As in Appendix B of PD 6691 except that the binder shall conform to BS EN 12591 grade 160/220, 100/150 or 70/100.

E.3.7 Recipe surface courses**E.3.7.1 Paving graded surface course**

As in Appendix B of PD 6691 except that the binder shall conform to BS EN 12591 grade 160/220 or 100/150.

E.3.7.2 Close graded surface course

As in Appendix B of PD 6691 except that the binder shall conform to BS EN 12591 grade 160/220, 100/150, 70/100 (preferred grade) or 50/70.

E.3.7.3 Dense, medium graded and fine graded surface course

As in Appendix B of PD 6691 except that advice on the selection of binder grade is given in Table E.1.

Table E.1 – Guidance on selection of binder grades

Paving grade	AC 6 dense surf	AC 6 med surf	AC 4 fine surf
50/70	✓	—	—
70/100	✓ *	—	—
100/150	✓	✓ *	✓ *
160/220	✓	✓	✓

* Preferred grade.

E.3.8 Water content of asphalt

The water content of freshly mixed half-warm mix asphalt shall be determined in accordance with BS EN 12697-14. The maximum water content shall comply with category $WC_{\max 2.0}$.

E.3.9 Temperature of the mixture

The maximum temperature of a half-warm mix asphalt concrete, measured according to BS EN 12697-13, shall target ≤ 100 °C but shall not exceed 110 °C.

NOTE: BS 594987 does not give guidance on suitable minimum temperatures at delivery and for compaction of half-warm mixtures; the supplier of the mixture should provide details.

E.4 Transport, laying and compaction

E.4.1 This clause gives general requirements for the transport, placing and compaction of bituminous mixtures, which are complementary and additional to the requirements of BS 594987. These requirements and the requirements of BS 594987 shall apply to all half-warm mix asphalt mixtures, unless otherwise specified in E.4.2 of this Appendix.

NOTE: BS 594987 states that it “does not cover the supply, laying and compaction of low-temperature warm mix and other reduced temperature asphalts”. Nevertheless, its main requirements, other than those on the temperature of the mixture, are generally applicable to half-warm mix asphalt.

E.4.2 Minimum delivery and rolling temperatures for half-warm mix asphalt mixtures shall be declared by the supplier with evidence to support their suitability.

E.5 Compliance

E.5.1 Compliance with the requirements for mixture composition and properties (E.1 to E.3) shall be by type testing and factory production control. The factory production control shall be in accordance with the principles and frequencies of BS EN 13108-21. A certificate defining compliance supported by test reports shall be made available for inspection.

E.5.2 Audit checking to confirm that the mixture composition and properties claimed are those of the mixture delivered to site may be undertaken.

E.5.3 Compliance with the requirements for transporting, laying and compacting the asphalt (E.4) shall be monitored against the requirements of BS 594987 and test reports demonstrating compliance shall be made available for inspection.

Appendix F Example of standard specification for half-warm hot rolled asphalt

(Informative)

F.1 General

Half-warm mix hot rolled asphalt mixtures shall conform to the specification for half-warm mix asphalt in Appendix B.

F.2 Constituent materials

F.2.1 Binder

As in Appendix C of PD 6691.

F.2.2 Paving grades

As in Appendix B of PD 6691 except for the notes 1 and 3.

NOTE 1: The preferred paving grade for HRA is 35/50. The following grades are also suitable: 30/45, 40/60, and 70/100.

NOTE 3: 35/50, 70/100 and 100/150 pen paving grade bitumen may be produced by blending in the mixer at the asphalt plant.

F.2.3 Aggregates

F.2.3.1 General

As in Appendix C of PD 6691.

F.2.3.2 Water content of aggregates

If the system has been pre-selected, the minimum and/or maximum water contents of the aggregate or a specified aggregate fraction can be limited, otherwise the aggregate shall be classed as $WA_{\min \text{ NR}}$ and $WA_{\max \text{ NR}}$.

F.2.4 Additives

As in Appendix C of PD 6691.

F.2.5 Coated chippings for application to the surface course

Chippings shall not be used in half-warm mix hot rolled asphalt surface courses.

F.3 Mixture specifications

F.3.1 Target binder content

As in Appendix C of PD 6691.

F.3.2 Base and binder course mixtures

As in Appendix C of PD 6691.

F.3.3 Surface course mixtures

As in Appendix C of PD 6691.

F.3.4 Water content of asphalt

The water content of freshly mixed half-warm mix asphalt shall be determined in accordance with BS EN 12697-14. The maximum water content shall comply with category $WC_{\max 2.0}$.

F.3.5 Temperature of the mixture

The maximum temperature of a half-warm mix hot rolled asphalt, measured according to BS EN 12697-13, shall target ≤ 100 °C but shall not exceed 110 °C.

NOTE: BS 594987 does not give guidance on suitable minimum temperatures at delivery and for compaction of half-warm mixtures; the supplier of the mixture should provide details.

F.4 Transport, laying and compaction

F.4.1 This clause gives general requirements for the transport, placing and compaction of bituminous mixtures, which are complementary and additional to the requirements of BS 594987. These requirements and the requirements of BS 594987 shall apply to all half-warm mix asphalt mixtures, unless otherwise specified in F.4.2 of this Appendix.

NOTE: BS 594987 states that it “does not cover the supply, laying and compaction of low-temperature warm mix and other reduced temperature asphalts”. Nevertheless, its main requirements, other than those on the temperature of the mixture, are generally applicable to half-warm mix asphalt.

F.4.2 Minimum delivery and rolling temperatures for half-warm mix asphalt mixtures shall be declared by the supplier with evidence to support their suitability.

F.5 Compliance

F.5.1 Compliance with the requirements for mixture composition and properties (F.1 to F.3) shall be by type testing and factory production control. The factory production control shall be in accordance with the principles and frequencies of BS EN 13108-21. A certificate defining compliance supported by test reports shall be made available for inspection.

F.5.2 Audit checking to confirm that the mixture composition and properties claimed are those of the mixture delivered to site may be undertaken.

F.5.3 Compliance with the requirements for transporting, laying and compacting the asphalt (F.4) shall be monitored against the requirements of BS 594987 and test reports demonstrating compliance shall be made available for inspection.

Appendix G Example of standard specification for half-warm stone mastic asphalt

(Informative)

G.1 General

Half-warm mix stone mastic asphalt mixtures shall conform to the specification for half-warm mix asphalt in Appendix B.

G.2 Constituent materials

G.2.1 Binder

G.2.1.1 General

As in Appendix D of PD 6691.

G.2.1.2 Paving grades

As in Appendix D of PD 6691 except that the preferred paving grade for SMA is 35/50; the following grades are also suitable: 40/60 and 70/100; and 35/50 paving grade may also be produced by blending in the mixer at the asphalt plant.

G.2.2 Aggregates

G.2.2.1 General

As in Appendix D of PD 6691.

G.2.2.2 Water content of aggregates

If the system has been pre-selected, the minimum and/or maximum water contents of the aggregate or a specified aggregate fraction can be limited, otherwise the aggregate shall be classed as $WA_{\min \text{ NR}}$ and $WA_{\max \text{ NR}}$.

G.2.3 Additives

As in Appendix D of PD 6691.

G.3 Mixture specifications

G.3.1 Composition

As in Appendix D of PD 6691.

G.3.2 Grading and binder content

As in Appendix D of PD 6691.

G.3.3 Target binder content

As in Appendix D of PD 6691.

G.3.4 Air voids content

As in Appendix D of PD 6691.

G.3.5 Binder drainage

As in Appendix D of PD 6691.

G.3.6 Water sensitivity

For half-warm mix SMA mixtures with foamed bitumen, the water sensitivity category shall be $ITSR_{80}$. For other half-warm mix SMA mixtures, the water sensitivity category shall be $ITSR_{NR}$.

G.3.7 Resistance to permanent deformation

As in Appendix D of PD 6691.

G.3.8 Water content of asphalt

The water content of freshly mixed half-warm mix asphalt shall be determined in accordance with BS EN 12697-14. The maximum water content shall comply with category $WC_{max\ 2.0}$.

G.3.9 Temperature of the mixture

The maximum temperature of a half-warm mix stone mastic asphalt, measured according to BS EN 12697-13, shall target ≤ 100 °C but shall not exceed 110 °C.

NOTE: BS 594987 does not give guidance on suitable minimum temperatures at delivery and for compaction of half-warm mixtures; the supplier of the mixture should provide details.

G.4 Transport, laying and compaction

The transport, placing and compaction of half-warm mix asphalt mixtures shall be in compliance with BS 594987.

G.5 Compliance

G.5.1 Compliance with the requirements for mixture composition and properties (G.1 to G.3) shall be by type testing and factory production control. The factory production control shall be in accordance with the principles and frequencies of BS EN 13108-21. A certificate defining compliance supported by test reports shall be made available for inspection.

G.5.2 Audit checking to confirm that the mixture composition and properties claimed are those of the mixture delivered to site may be undertaken.

G.5.3 Compliance with the requirements for transporting, laying and compacting the asphalt (G.4) shall be monitored against the requirements of BS 594987 and test reports demonstrating compliance shall be made available for inspection.

Appendix H Example specification for emulsion-based cold mix asphalt

(Informative)

H.1 General

Emulsion-based cold mix asphalt mixtures shall conform to the specification for emulsion-based cold mix asphalt in Appendix C.

H.2 Constituent materials

H.2.1 Binder

The cationic emulsion category shall comply with BS EN 13808 and the breaking value may be Class 0 (no performance declared, NPD).

H.2.2 Coarse aggregates

As in Appendix B of PD 6691.

H.2.3 Fine aggregate

As in Appendix B of PD 6691.

H.2.4 Added filler

As in Appendix B of PD 6691.

H.2.5 Reclaimed asphalt

Where reclaimed asphalt is to be used in asphalt concrete mixtures the following requirements shall apply.

- a) All reclaimed asphalt shall be classified in accordance with BS EN 13108-8.
- b) The reclaimed asphalt shall conform to foreign matter category F_5 .

H.2.6 Additives

As in Appendix B of PD 6691.

H.3 Mixture specification

H.3.1 Composition

As in Appendix B of PD 6691 for emulsion based cold mix asphalt concrete or as in Appendix D of PD 6691 for emulsion based cold mix stone mastic asphalt.

H.3.2 Properties

H.3.2.1 The mixture at the target composition shall have the selected categories of the physical properties as given in Tables H.1 and H.2 for roads and Tables H.1 and H.3 for airfields. For mechanical properties, these shall be as measured (28 ± 1) days (when stored at ambient temperature) or ($7 \text{ days} \pm 4 \text{ h}$) (when stored at $(40 \pm 5)^\circ\text{C}$) after compaction.

Table H.1 – Minimum property requirements for cold mix asphalt mixtures

Property		Base	Binder course	Surface course
Residual anhydrous content		B_{\min} 4.0	B_{\min} 4.5	B_{\min} 5.0
Maximum air voids content	Low stress sites	V_{\max} 18.0	V_{\max} 16.0	V_{\max} 14.0
	Medium stress sites	V_{\max} 16.0	V_{\max} 14.0	V_{\max} 12.0
	High stress sites	V_{\max} 14.0	V_{\max} 14.0	V_{\max} 12.0
Minimum air voids content		V_{\min} 6.0	V_{\min} 5.0	V_{\min} 4.0
Coating		C_{\min} NR	C_{\min} NR	C_{\min} NR
Water sensitivity	Low stress sites	$IT-CY_{\text{wet/dry } 50}$	$IT-CY_{\text{wet/dry } 50}$	$IT-CY_{\text{wet/dry } 60}$
	Medium stress sites	$IT-CY_{\text{wet/dry } 60}$	$IT-CY_{\text{wet/dry } 60}$	$IT-CY_{\text{wet/dry } 70}$
	High stress sites	$IT-CY_{\text{wet/dry } 70}$	$IT-CY_{\text{wet/dry } 70}$	$IT-CY_{\text{wet/dry } 80}$
Compactability		$V10G_{\min}$ NR	$V10G_{\min}$ NR	$V10G_{\min}$ NR
Resistance to permanent deformation in tri-axial compression test		f_{cmax} NR	f_{cmax} NR	f_{cmax} NR

Table H.2 – Minimum property requirements for cold mix asphalt mixtures to be used on roads

Property		Base	Binder course	Surface course
Resistance to permanent deformation	Low stress sites	WTS_{AIR} NR PRD_{AIR} NR	WTS_{AIR} 0.40 PRD_{AIR} 7.0	WTS_{AIR} 0.30 PRD_{AIR} 5.0
	Medium stress sites	WTS_{AIR} NR PRD_{AIR} NR	WTS_{AIR} 0.30 PRD_{AIR} 5.0	WTS_{AIR} 0.20 PRD_{AIR} 3.0
	High stress sites	WTS_{AIR} NR PRD_{AIR} NR	WTS_{AIR} 0.20 PRD_{AIR} 3.0	WTS_{AIR} 0.15 PRD_{AIR} 2.0
Resistance to fuel		No requirement	No requirement	No requirement
Resistance to de-icing fuels		β NR	β NR	β NR
Minimum Marshall stability		S_{\min} NR	S_{\min} NR	S_{\min} NR
Maximum Marshall stability		S_{\max} NR	S_{\max} NR	S_{\max} NR
Minimum Marshall flow		F_{\min} NR	F_{\min} NR	F_{\min} NR
Maximum Marshall flow		F_{\max} NR	F_{\max} NR	F_{\max} NR
Marshall quotient		Q_{\min} NR	Q_{\min} NR	Q_{\min} NR
Stiffness	Low stress sites	S_{\min} 800	S_{\min} NR	S_{\min} NR
	Medium stress sites	S_{\min} 1 000	S_{\min} 1 000	S_{\min} NR
	High stress sites	S_{\min} 2 000	S_{\min} 1 400	S_{\min} NR

Table H.3 – Minimum property requirements for cold mix asphalt mixtures to be used on airfields

Property		Base	Binder course	Surface course
Resistance to permanent deformation		WTS_{AIR} NR PRD_{AIR} NR	WTS_{AIR} NR PRD_{AIR} NR	WTS_{AIR} NR PRD_{AIR} NR
Resistance to fuel		No requirement	No requirement	Moderate
Resistance to de-icing fuels		β NR	β NR	β 70
Minimum Marshall stability	Low stress sites	S_{min} NR	S_{min} 5.0	S_{min} 7.5
	Medium stress sites	S_{min} 5.0	S_{min} 7.5	S_{min} 10.0
	High stress sites	S_{min} 7.5	S_{min} 10.0	S_{min} 12.5
Maximum Marshall stability		S_{max} NR	S_{max} NR	S_{max} NR
Minimum Marshall flow		F_{min} NR	F_{min} NR	F_{min} NR
Maximum Marshall flow		F_{max} NR	F_{max} NR	F_{max} NR
Marshall quotient		Q_{min} NR	Q_{min} NR	Q_{min} NR
Stiffness	Low stress sites	S_{min} 1 800	S_{min} NR	S_{min} NR
	Medium stress sites	S_{min} 2 200	S_{min} 1 500	S_{min} NR
	High stress sites	S_{min} 2 800	S_{min} 1 800	S_{min} NR

H.4 Transport, laying and compaction

H.4.1 Emulsion-based cold mix asphalt shall be transported, placed and compacted to the requirements of BS 594987 unless otherwise specified in H.4.2 to H.4.4 of this appendix.

H.4.2 The substrate onto which emulsion-based cold mix asphalt is to be laid shall have a stiffness determined by in situ testing using a dynamic plate of $S_{f \min 100}$.

H.4.3 Where the existing substrate fails to comply with H.4.2, the substrate shall be stabilised or replaced so that the stabilised or replaced substrate does comply.

H.4.4 Compaction of emulsion-based cold mix asphalt shall include not less than four passes with a pneumatic tyre roller (PTR). For layers other than the surface course, this requirement can be omitted with prior approval by the Overseeing Organisation.

H.5 Compliance

H.5.1 Compliance with the requirements for mixture composition and properties (H.1 to H.3) shall be by type testing to C.8.2 of Appendix C and factory production control to **C.8.3** of Appendix C. A certificate defining compliance supported by test reports shall be made available for inspection.

H.5.2 Audit checking to confirm that the mixture composition and properties claimed are those of the mixture delivered to site may be undertaken.

H.5.3 Compliance with the requirements for transporting, laying and compacting the asphalt (H.4) shall be monitored against the requirements of BS 594987 and test reports demonstrating compliance shall be made available for inspection.

Appendix J Specification requirements for low temperature asphalt mixtures

ROAD PAVEMENTS – BITUMINOUS BOUND MATERIALS

J.1 96X Warm Mix Asphalt Materials

J.1.1 General

1. The warm mix asphalt mixtures shall conform to the specification for warm mix asphalt in Appendix A of this Report; the relevant example specification in PD 6691; and requirements specified in Appendix 7/1.

2. The requirements in the Specification for Highway Works (SHW) for specific hot mix asphalt mixtures shall also apply to warm mix asphalt of the same material type. In particular:

- SHW 904 for warm mix hot rolled asphalt base
- SHW 905 for warm mix hot rolled asphalt binder course (recipe mixtures)
- SHW 906 for warm mix dense base and binder course asphalt concrete with paving grade bitumen (recipe mixtures)
- SHW 909 for warm mix 6 mm dense asphalt concrete surface course
- SHW 910 for warm mix hot rolled asphalt surface course (recipe mixtures)
- SHW 911 for warm mix hot rolled asphalt surface course (design mixtures)
- SHW 912 for warm mix close graded asphalt concrete surface course
- SHW 914 for warm mix fine graded asphalt concrete surface course
- SHW 916 for warm mix open graded asphalt concrete surface course
- SHW 929 for warm mix dense base and binder course asphalt concrete (design mixtures)
- SHW 937 for warm mix stone mastic asphalt (SMA) binder course and regulating course
- SHW 938 for warm mix porous asphalt surface course
- SHW 942 for warm mix thin surface course systems

- SHW 943 for warm mix hot rolled asphalt surface course and binder course (performance-related design mixtures)

3. The requirements of SHW 901 for bituminous pavement materials, SHW 902 for reclaimed bituminous materials, SHW 903 for placing and compaction of bituminous mixtures, SHW 907 for regulating course and SHW 920 for bond coats, tack coats and other bituminous sprays shall apply to warm mix asphalt mixtures.

J.1.2 Variations

4. The temperature at which samples for assessing the properties of the mixture are mixed and compacted shall be at the standard temperature for each operation less the difference between the temperature at which the warm asphalt will be prepared on site and the temperature at which hot asphalt will be prepared on site.

5. The relevant technology that allows the asphalt to be mixed and laid at a reduced temperature shall be employed in the manufacture of laboratory samples used to demonstrate the properties of the asphalt mixture. If the technology cannot be replicated in the laboratory, plant-produced samples shall be used for type testing and factory production control.

6. However, when testing samples of warm mix asphalt for refusal density, the sample shall be heated to the same temperature as an equivalent hot mix asphalt before compaction.

J.1.3 Additives

7. Evidence shall be provided on the suitability of any additive incorporated into the mixture to the Overseeing Organisation before work commences. This evidence may be based on research combined with evidence from practice.

J.1.4 Coated chippings

8. Coated chippings shall not be applied to HRA surf WMA mixtures.

J.1.5 Health and Safety

9. Health and Safety information and safe handling guidance shall be provided, including any COSHH data sheets for any component materials.

J.2 96Y Half-Warm Mix Asphalt Materials

J.2.1 General

1. Half-warm mix asphalt mixtures shall conform to the specification for half-warm mix asphalt in Appendix B of this Report; the relevant example specification in Appendix E, Appendix F or Appendix G of this Report; and requirements specified in Appendix 7/1.

2. If not a thin surfacing system, the mixture designation shall be one of the following:

- (i) HRA 60/32 base 35/50 HWMA.
- (ii) HRA 60/20 base 35/50 HWMA.
- (iii) HRA 60/32 bin 35/50 HWMA.
- (iv) HRA 60/20 bin 33/50 HWMA.
- (v) AC 32 dense base 35/50 rec HWMA.
- (vi) AC 32 dense base 70/100 rec HWMA.
- (vii) AC 32 dense base 100/150 rec HWMA.
- (viii) AC 32 dense bin 35/50 rec HWMA.
- (ix) AC 32 dense bin 70/100 rec HWMA.
- (x) AC 6 dense surf 70/100 HWMA.
- (xi) AC 6 dense surf 50/70 HWMA.
- (xii) HRA 0/2 F surf 35/50 HWMA.
- (xiii) HRA 15/10 F surf 35/50 HWMA.
- (xiv) HRA 0/2 F surf xx/yy des HWMA.
- (xv) HRA 55/10 F surf xx/yy des HWMA.
- (xvi) HRA 55/14 F surf xx/yy des HWMA.
- (xvii) HRA 0/2 C surf xx/yy des HWMA.
- (xviii) HRA 55/10 C surf xx/yy des HWMA.
- (xix) HRA 55/14 C surf xx/yy des HWMA.
- (xx) AC 10 close surf 70/100 HWMA.
- (xxi) AC 10 close surf 50/70 HWMA.
- (xxii) AC 14 close surf 70/100 HWMA.
- (xxiii) AC 14 close surf 50/70 HWMA.
- (xxiv) AC 4 fine surf 100/150 HWMA.
- (xxv) AC 4 fine surf 160/220 HWMA.

- (xxvi) AC 10 open surf 100/150 HWMA.
- (xxvii) AC 10 open surf 70/100 HWMA.
- (xxviii) AC 10 open surf 50/70 HWMA.
- (xxix) AC 14 open surf 100/150 HWMA.
- (xxx) AC 14 open surf 70/100 HWMA.
- (xxxi) AC 14 open surf 70/100 HWMA.
- (xxxii) AC 32 HDM base 35/50 des HWMA.
- (xxxiii) AC 32 dense base 35/50 des HWMA.
- (xxxiv) AC 32 HMB base 20/30 des HWMA.
- (xxxv) AC 20 HDM bin 35/50 des HWMA.
- (xxxvi) AC 32 HDM bin 35/50 des HWMA.
- (xxxvii) AC 20 dense bin 35/50 des HWMA.
- (xxxviii) AC 32 dense bin 35/50 des HWMA.
- (xxxix) AC 20 HMB bin 20/30 des HWMA.
- (xl) AC 32 HMB bin 20/30 des HWMA.
- (xli) SMA 6 bin 35/50 HWMA.
- (xl ii) SMA 6 bin 50/70 HWMA.
- (xl iii) SMA 6 bin 70/100 HWMA.
- (xl iv) SMA 6 bin PMB HWMA.
- (xl v) SMA 10 bin 35/50 HWMA.
- (xl vi) SMA 10 bin 50/70 HWMA.
- (xl vii) SMA 10 bin 70/100 HWMA.
- (xl viii) SMA 10 bin PMB HWMA.
- (xl ix) SMA 14 bin 35/50 HWMA.
- (l) SMA 14 bin 50/70 HWMA.
- (li) SMA 14 bin 70/100 HWMA.
- (lii) SMA 14 bin PMB HWMA.
- (liii) SMA 20 bin 35/50 HWMA.
- (liv) SMA 20 bin 50/70 HWMA.
- (lv) SMA 20 bin 70/100 HWMA.
- (lvi) SMA 20 bin PMB HWMA.
- (lvii) PA 20 surf HWMA.
- (lviii) PA 14 surf HWMA.
- (lix) PA 10 surf HWMA.

3. Unless otherwise specified in Appendix 7/1, the grade of bitumen for HRA surf xx/yy des HWMA mixtures shall be 35/50.

4. When the mixture designation is not specified in Appendix 7/1, the mixture selected by the Contractor shall be notified to the Overseeing Organisation prior to its use in the Works.

J.2.2 Coarse aggregate

5. To ensure adequate resistance to polishing and abrasion, the coarse aggregate of surface course mixtures shall have a minimum declared PSV and a maximum AAV, as specified in Appendix 7/1.

J.2.3 Additives

6. Evidence shall be provided on the suitability of any additive incorporated into the mixture to the Overseeing Organisation before work commences. This evidence may be based on research combined with evidence from practice.

J.2.4 Health and Safety

7. Health and Safety information and safe handling guidance shall be provided, including any COSHH data sheets for any component materials.

J.2.5 Coated chippings

8. Coated chippings shall not be applied to HRA surf HWMA mixtures.

J.2.6 Dense base and binder course asphalt course (design mixtures)

9. Half-warm mix asphalt dense base and binder course asphalt course (design mixtures) mixtures shall comply with SHW Clause 929 for volumetric properties, deformation resistance, stiffness and compaction control for the permanent works.

J.2.7 Stone mastic asphalt binder course and regulating course

10. Half-warm mix asphalt stone mastic asphalt binder course and regulating course mixtures shall comply with SHW Clause 937 for binder modification, deformation resistance and compaction control for the permanent works.

J.2.8 Thin surface course systems

11. Half-warm mix asphalt thin surface course systems shall comply with SHW Clause 942.

J.2.9 Percentage refusal density

12. When testing samples of half-warm mix asphalt for refusal density, the sample shall be heated to the same temperature as an equivalent hot mix asphalt before compaction.

J.3 96Z Emulsion-Based Cold Mix Asphalt Materials

J.3.1 General

1. Emulsion-based cold mix asphalt mixtures shall conform to the specification for emulsion-based cold mix asphalt in Appendix C of this Report; the relevant example specification in Appendix H of this Report; and requirements specified in Appendix 7/1.

2. The mixture designation shall be one of the following:

- (i) AC 6 dense surf CME.
- (ii) AC 10 close surf CME.
- (iii) AC 14 close surf CME.
- (iv) AC 4 fine surf CME.
- (v) AC 10 open surf CME.
- (vi) AC 14 open surf CME.
- (vii) AC 20 HDM bin CME.
- (viii) AC 32 HDM bin CME.
- (ix) AC 20 dense bin CME.
- (x) AC 32 dense bin CME.
- (xi) AC 20 HMB bin CME.
- (xii) AC 32 HMB bin CME.
- (xiii) AC 32 HDM base CME.
- (xiv) AC 32 dense base CME.
- (xv) AC 32 HMB base CME.
- (xvi) SMA 6 bin CME.
- (xvii) SMA 10 bin CME.
- (xviii) SMA 14 bin CME.
- (xix) SMA 20 bin CME.

3. The mixtures shall be design and not recipe mixtures.

4. When the mixture designation is not specified in Appendix 7/1, the mixture selected by the Contractor shall be notified to the Overseeing Organisation prior to its use in the Works.

J.3.2 Coarse aggregate

5. To ensure adequate resistance to polishing and abrasion, the coarse aggregate of surface course mixtures shall have a minimum declared PSV and a maximum AAV, as specified in Appendix 7/1.

J.3.3 Additives

6. Evidence shall be provided on the suitability of any additive incorporated into the mixture to the Overseeing Organisation before work commences. This evidence may

be based on research combined with evidence from practice.

J.3.4 Binder

7. Binder shall be bitumen emulsion complying with BS EN 13808.

J.3.5 Binder modification

8. The Contractor shall provide data sheets giving details of the properties of the modified binders or additives (including natural or man-made fibres) proposed, including those specified in Appendix 7/1. The information covered shall include rheological data for pre-blended polymer modified binders in accordance with SHW Clause 956.

J.3.6 Design proposal

9. The Contractor shall submit a Design Proposal which shall state the aggregate characteristics and sources, the binder to be used and provide an example of the target grading curve and binder content together with details of the proposed filler and fibre if used. In the works, the grading and binder content shall not differ from the proposed target values by more than the tolerances detailed in the Design Proposal.

J.3.7 Mixture Design Validation

10. When a mix design validation is required it shall be carried out on aggregates and binders representative of those to be used on the works. The validation may be carried out on emulsion-based cold mix asphalt at the target composition mixed either in the laboratory or on a pilot basis on a full scale plant.

11. Representative samples of the mixture shall be taken from which 150 mm diameter cylindrical specimens shall be produced. These specimens shall be between 70 mm and 75 mm high.

12. The density of each specimen shall be measured by dimensions to BS EN 12697-6 and, using the respective moisture content values, the dry density values shall be determined. The cylindrical specimens shall be conditioned and tested. The conditioning and testing regime shall be agreed with the Overseeing Organisation.

10. The performance properties of the conditioned specimens shall be declared. The results shall be considered as indicative only, because the compliance criterion applies only to specimens prepared during the execution of the works.

J.3.8 Process Control

11. Production of the emulsion-based cold mix asphalt mixture shall be subject to process control detailed in the quality plan and meeting the following requirements:

- (i) There shall be a description of the plant and the production process, preferably including a flow diagram, detailing how material is to be produced in accordance with this specification.
- (ii) Calibration schedules for all parts of the plant involved in determining mixture consistency shall be provided. These shall be accompanied by calibration records.
- (iii) Measures to avoid problems caused by extreme weather. In particular, production shall not proceed if the feedstock is frozen or excessively wet.

J.3.9 Inspection and Test

13. There shall be a schedule of inspection and test frequencies to be made during production of emulsion-based cold mix asphalt. This schedule shall cover the aggregate stockpiles, the binder, the combined grading of the mixture and the moisture content of the mixture.

J.3.10 Laying

12. A written procedure for the laying of the emulsion-based cold mix asphalt shall be provided.

13. The plant used for placing the material shall be capable of laying the material without significant segregation, evenly and to the required thickness across at least one lane width.

14. A method for the making of longitudinal and transverse joints, appropriate to the type of emulsion-based cold mix asphalt being laid shall be provided.

J.3.11 Compaction

15. The compaction of each layer shall be carried out as described in the laying procedure. Open edges shall be protected from traffic.

16. After trimming and final compaction of the layer, the material strength shall be assessed using a lightweight deflectometer. The stiffness determined shall be not less than 50 MPa before the layer can be overlaid or trafficked.

J.3.12 Sealing grit

17. Sealing grit may be applied to the surface when required to prevent pick-up from trafficking in the early life.

J.3.13 End Product Testing

18. The end product testing of the emulsion-based cold mix asphalt shall be assessed on the basis of representative specimens made up in accordance with the schedule in Appendix 7/1.

19. Representative samples shall be taken either at the mixing plant or from site. 150 mm diameter cylindrical test specimens shall be manufactured in sets of six by compacting to refusal in accordance with BS EN 12697-32. The test specimens shall have a nominal height of 75 mm and diameter of 150 mm.

20. Prior to testing, specimens shall be conditioned in a controlled environment. The purpose of this conditioning is to simulate the likely curing over the first year in the road.

21. The minimum specification compliance criteria for the process control tests shall be as described in Table J.1.

Table J.1: End Product Criteria

Material property or characteristic	Individual results	Mean from test set of six specimens
Particle size distribution	Zone	–
Moisture content	±2 %	–
Minimum relative in situ density	93 %	95 %
Layer thickness	±25 mm of specified	±15 mm of specified

J.3.14 Percentage refusal density

22. When testing samples of emulsion-based cold mix asphalt for refusal density, the sample shall be heated to the same temperature as an equivalent hot mix asphalt before compaction provided there is no water present in the mixture.

NOTE: The presence of water can present a safety issues from the generation of steam when heated. In such instances, the sample needs to be dried prior to raising to the relevant temperature.

J.3.15 Health and Safety

23. Health and Safety information and safe handling guidance shall be provided, including any COSHH data sheets for any component materials.

J.3.16 Layer thickness

24. When required, the minimum and/or maximum thickness of emulsion-based cold mix asphalt shall be as specified in Appendix 7/1.

J.3.17 Dense base and binder course asphalt course

25. Emulsion-based cold mix asphalt dense base and binder course asphalt course mixtures shall comply with SHW Clause 929 for volumetric properties, deformation resistance and compaction control for the permanent works.

J.3.18 Stone mastic asphalt binder course and regulating course

26. Emulsion-based cold mix asphalt stone mastic asphalt binder course and regulating course mixtures shall comply with SHW Clause 937 for binder modification, deformation resistance and compaction control for the permanent works.

Appendix K Notes for Guidance on specification requirements for low temperature asphalt mixtures

ROAD PAVEMENTS – BITUMINOUS BOUND MATERIALS

K.1 NG96X Warm Mix Asphalt Materials

K.1.1 General

1. Warm mix asphalt is asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at temperatures at least 20 °C below conventional hot mix asphalt mixtures but still above 100 °C.

2. There are several technologies intended to improve the workability of the mixture and, hence, allow the asphalt temperatures to be reduced in order to produce a warm mix asphalt. These methods are generally based on one of, or a combination of, the following:

- (i) Use of organic waxes
- (ii) Use of chemical additives
- (iii) Use of a bitumen foaming process

3. The properties of warm mix asphalt should be judged against the same criteria as hot mix asphalt. The difference is the reduced temperature at which the material is mixed, transported, laid and compacted.

K.1.2 Mixture temperatures

4. In order to assess warm mix asphalt fairly against hot mix asphalt, the samples used to determine the properties need to have been mixed and transported at the appropriate reduced temperature compared to standard hot mix asphalt temperatures.

5. There are a number of methods to reduce the temperature at which an asphalt mixture needs to be mixed, transported, laid and compacted, not all of which can be replicated easily in the laboratory. The same technology needs to be used in preparing specimens as will be used on site. If that technology cannot be replicated in the laboratory, samples will have to be manufactured from plant-mixed material.

6. When testing a sample of warm mix asphalt for refusal density, the sample will need to be heated to the same temperature as an equivalent hot mix asphalt before compaction.

K.1.3 Grading of reclaimed asphalt

7. Reclaimed asphalt is an accepted component material in asphalt mixtures that is encouraged in warm mix asphalt. However, the grading of the reclaimed asphalt particles will not be the same as the grading of the aggregate particles within the reclaimed asphalt. The reclaimed asphalt particles will include finer particles adhering to larger particles and occasional conglomerates of coarse particle stuck together. Therefore, if the grading of the reclaimed asphalt particles is to be used for control of the final grading, the relationship between the gradings for each reclaimed asphalt source will be needed. This conversion in gradings becomes more critical in achieving the required aggregate grading of the output mixture as the proportion of reclaimed asphalt is increased.

K.1.4 Tar

8. Tar was used as a binder in highway construction, but was subsequently identified as a carcinogen and is no longer used. However, tar can be found in reclaimed asphalt if the material being planed up is of sufficient age. Because that tar can be a health hazard if heated, reclaimed asphalt containing tar should not be used for hot mix asphalt, warm mix asphalt or half-warm mix asphalt; it can, however, be incorporated into cold mix asphalt.

K.1.5 Energy consumption and carbon dioxide production

9. When assessing the sustainability of warm mix asphalt as an alternative technology, the reduced temperature is not

the only change in the input to produce and lay the material. The energy consumption and carbon dioxide equivalent production from:

- the supply of raw materials for,
- the production of, and
- the transport of

any additives used in the mixture needs to be included in any calculation.

K.2 NG96Y Half-Warm Mix Asphalt Materials

K.2.1 General

1. Half-warm (or semi-warm) asphalt is asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure that is mixed and laid at temperatures in the range 70 °C to 100 °C.

2. There are several technologies intended to improve the workability of the mixture and, hence, allow the asphalt temperatures to be reduced in order to produce a half-warm mix asphalt. These methods are generally based on one of, or a combination of, the following:

- (i) Use of organic waxes
- (ii) Use of chemical additives
- (iii) Use of a bitumen foaming process

However, option (iii) is the most common for half-warm mixtures.

3. Some foam technology processes rely on the foaming of the bitumen from the use of specialist foaming equipment whilst others use the principle of foaming on contact with the mineral water. With the process of adding hot bitumen to damp aggregate, a portion of the water in the aggregate should vaporise and foam the bitumen whilst another portion should escape as steam, leaving a final portion to remain as water in the aggregate. The size of these portions will depend on the moisture content and the mixing temperature,

4. The mixture type(s) required for each layer should be stated in Appendix 7/1. The mixture designation for the selected mixture type should be chosen to suit the thickness of the layer as indicated in the relevant table of BS 594987:2010 (Table 1A for AC, Table 1B for HRA or Table 1C for SMA) as with hot mix asphalt mixtures.

K.2.2 Mixture temperatures

5. In order to assess half-warm mix asphalt fairly against hot mix asphalt, the samples used to determine the properties need to have been mixed and transported at the appropriate reduced temperature compared to standard hot mix asphalt temperatures.

6. There are a number of methods to reduce the temperature at which an asphalt mixture needs to be mixed, transported, laid and compacted, not all of which can be replicated easily in the laboratory. The same technology needs to be used in preparing specimens as will be used on site. If that technology cannot be replicated in the laboratory, samples will have to be manufactured from plant-mixed material.

7. When testing a sample of half-warm mix asphalt for refusal density, the sample will need to be heated to the same temperature as an equivalent hot mix asphalt before compaction.

K.2.3 Composition

8. The asphalt types, gradings and binder contents for half-warm mix asphalts should essentially be the same as for hot mix asphalts. The main difference will be the additives and/or the mixing sequence in order to be capable of being mixed and compacted at the lower temperatures.

9. The binder grades may need to have similar properties in the compacted mixture as that for hot mix asphalts in order for the asphalt to have similar properties, such as deformation resistance and stiffness. However, the binder may need different binder properties in the mixing and laying process. The binder grade can be stated in Appendix 7/1, but it could limit the half-warm asphalt mixtures that comply.

10. The ageing of binder during the mixing and placement of hot mix asphalt, particularly when using batch mixers, in terms of the binder penetration is generally a reduction of the order of 33 %, or one binder grade, which does not occur to the same extent with half-warm mixtures. Where equivalence is intended with hot mix asphalt, the binder grade may need to be adjusted down in order to get the same properties, such as deformation resistance.

K.2.4 Grading of reclaimed asphalt

10. Reclaimed asphalt is an accepted component material in asphalt mixtures that is encouraged in half-warm mix asphalt. However, the grading of the reclaimed asphalt particles will not be the same as the grading of the aggregate particles within the reclaimed asphalt. The reclaimed asphalt particles will include finer particles adhering to larger particles and occasional conglomerates of coarse particle stuck together. Therefore, if the grading of the reclaimed asphalt particles is to be used for control of the final grading, the relationship between the gradings for each reclaimed asphalt source will be needed. This conversion in gradings becomes more critical in achieving the required aggregate grading of the output mixture as the proportion of reclaimed asphalt is increased.

K.2.5 Tar

11. Tar was used as a binder in highway construction, but was subsequently identified as a carcinogen and is no longer used. However, tar can be found in reclaimed asphalt if the material being planed up is of sufficient age. Because that tar can be a health hazard if heated, reclaimed asphalt containing tar should not be used for hot mix asphalt, warm mix asphalt or half-warm mix asphalt; it can, however, be incorporated into cold mix asphalt.

K.2.6 Sample preparation

12. Due to the nature of the standard foaming equipment/process, it is difficult to make small batches of consistent binder content and sample size may need to be as much as 40 kg. Moisture levels need to be controlled and a standard procedure may be required for controlling aggregate moisture prior to laboratory mixing. Substantially inconsistent mixing times will result in variability in resultant mix moisture content; this in turn could affect compactability.

13. Half-warm mixtures will slowly eliminate water after manufacture during the delivery and application process. Therefore, it is important not to compact laboratory prepared mixtures immediately because the excess water present may have a negative impact on some comparative tests. This phenomenon has been studied and conditioning at 95 °C for 2 h prior to compaction at 95 °C has

produced samples with superior water sensitivity performance to ones compacted immediately.

K.2.7 Mixture temperatures

14. In order to assess half-warm mix asphalt fairly against hot mix asphalt, the samples used to determine the properties need to have been mixed and transport at the appropriate reduced temperature compared to standard hot mix asphalt temperatures.

15. There are a number of methods to reduce the temperature at which an asphalt mixture needs to be mixed, transported, laid and compacted, not all of which can be replicated easily in the laboratory. The same technology needs to be used in preparing specimens as will be used on site. If that technology cannot be replicate in the laboratory, samples will have to be manufactured from plant-mixed material.

16. The temperature ranges for mixing, laying and compacting a half-warm mixture need to be known for implementing and controlling those processes efficiently. In particular, the minimum compaction temperature at which the required air voids content on site can be achieved needs to be determined. The ranges should be identified by those developing the mixture and then used to assess the required properties; if the properties are not appropriate at those temperature ranges, in particular the binder coating, then either the ranges or some other aspect will need to be adjust until they do.

17. The validated range should be given to everyone involved in the production, laying, compaction and supervision of the material for use in their part for the works.

K.2.8 Water contents

18. Some half-warm asphalt technologies require the aggregates to contain some water in order for that water to be used to foam the binder. Other technologies inject water directly into the bitumen so that enters the mixture as foamed bitumen. In either case, the water entering the mixture needs to be controlled to the appropriate contents required for the particular half-warm asphalt technology being used. The required moisture content of aggregate and the quantity of any additional water to be added need to be declared in the declaration for the mixture.

19. With water being added to the asphalt in different ways for many of the half-warm technologies, there is a concern about whether that moisture can impair the longer-term performance of the material. Therefore, the water sensitivity of the mixture and its components becomes more critical.

K.2.9 Compaction

20. The compaction techniques required for hot mix asphalt may need to be reviewed for use with half-warm mix asphalt. However, the potential change from current practices associated with hot-mix asphalt will depend on the technology used to achieve the lower temperature and will need to be identified for each system.

21. The relationship between the field compaction and the final moisture content of the mixture needs to be established for each design. The compaction applied can then be controlled so that the compacted water content of the mixture is not going to impair the durability that can be achieved on site.

K.2.10 Energy consumption and carbon dioxide production

22. When assessing the sustainability of half-warm mix asphalt as an alternative technology, the reduced temperature is not the only change in the input to produce and lay the material. The energy consumption and carbon dioxide equivalent production from:

- the supply of raw materials for,
- the production of, and
- the transport of

any additives used in the mixture needs to be included in any calculation.

K.3 NG96Z Emulsion-Based Cold Mix Asphalt Materials

K.3.1 General

14. Emulsion-based cold mix asphalt is asphalt in which the aggregate particles are continuously graded or gap-graded to form an interlocking structure and the binder is a bituminous emulsion with a viscosity such that the mix is workable at ambient temperature.

K.3.2 Binder

15. The emulsion binder should comply with BS EN 13808. The binder shall be emulsion from paving grade bitumen, modified bitumen, fluxed bitumen or hard grade bitumen conforming to the relevant European Standard.

16. The emulsions which are manufactured for mixing techniques need to cope with some or all of the following depending on end requirement:

- The high surface area of the asphalt aggregate structure.
- Be suitably stable to the shearing forces exerted by the mixing and pumping processes adopted.
- Be able to coat the mineral materials used.
- Be able to give satisfactory adhesion of binder to aggregate once broken
- Remain in the mixture and not excessively drain.

The resultant mixtures will need to be well coated, workable, easily compactable, cohesive and capable of withstanding running traffic soon after laying.

K.3.3 Pre-treatment of aggregate particles

17. The double coating or pre-treatment of the aggregate particles can be used to overcome the variability in the chemistry of the mineral surface and the emulsions as well as the high volume liquid content in the final mixture. The processes include:

- Pre-coating of sand either with bitumen or emulsion.
- Pre-treatment of sand with a chemical agent.
- Pre-coating the coarse aggregate.
- Phase coating.

18. The use of reclaimed asphalt in mixtures reduces or eliminates the need to pre-coat the aggregate particles because binder already exists on the reclaimed asphalt planings.

K.3.4 Grading of reclaimed asphalt

11. Reclaimed asphalt is an accepted component material in asphalt mixtures that is encouraged in emulsion-based cold mix

asphalt. However, the grading of the reclaimed asphalt particles will not be the same as the grading of the aggregate particles within the reclaimed asphalt. The reclaimed asphalt particles will include finer particles adhering to larger particles and occasional conglomerates of coarse particle stuck together. Therefore, if the grading of the reclaimed asphalt particles is to be used for control of the final grading, the relationship between the gradings for each reclaimed asphalt source will be needed. This conversion in gradings becomes more critical in achieving the required aggregate grading of the output mixture as the proportion of reclaimed asphalt is increased.

K.3.5 Tar

19. Tar was used as a binder in highway construction, but was subsequently identified as a carcinogen and is no longer used. However, tar can be found in reclaimed asphalt if the material being planned up is of sufficient age. Because that tar can be a health hazard if heated, reclaimed asphalt containing tar should not be used for hot mix asphalt, warm mix asphalt or half-warm mix asphalt; it can, however, be incorporated into cold mix asphalt.

K.3.6 Sample preparation

20. The use of emulsions means that the physical properties of samples will change as the water in the emulsion is removed from the mixture. Hence, the age of specimens when samples are tested for mechanical properties can be an important parameter.

21. The standard for emulsion-based cold mix asphalt in Appendix C of this Report uses 28 days as the standard age when the samples are stored at ambient temperature but also gives an accelerated age of 7 days when the samples are stored at elevated temperature of 40 °C.

22. Greater acceleration could be achieved at higher temperatures, but if the temperature is excessive, it could age the binder. Any regime for greater acceleration would need to be validated against the standard conditions before it could be used for certifying the properties of a mixture.

K.3.7 Mixing plant

23. Cold mix asphalt made with emulsions can be manufactured using an array of plant. These include mobile, stationary, continuous or batch units, which can be further broken down into:

- Static hot mix asphalt plants which have been modified for cold feeding the aggregates and adapted to feed emulsion into the batch mixer.
- Static concrete plants.
- Mobile concrete plants.
- Mobile mix plants.

K.3.8 Ageing during manufacture

24. Hot mix asphalt binder ages during manufacture and continues to age until it has cooled. The rate of ageing in cold mix asphalt is substantially reduced compared to hot mix asphalt because of the lower temperature. This reduced ageing could explain the slower rate of stiffness development within the pavement and also the resistance to cracking and healing properties that have been observed.

K.3.9 Substrate

25. The substrate onto which emulsion-based cold mix asphalt is to be laid needs to have an acceptable stiffness in order to allow the longer-term gain of strength after construction. If the asphalt is disturbed excessively in its early life, it will not reach its potential strength.

K.3.10 Water content

26. The water content in an emulsion-based cold mix asphalt mixture after compaction needs to be limited in order to attain both the required gain in early-age physical properties and the maintenance of longer-term durability. However, the current limit of 5.0 % by mass of the dry aggregate 24 h after compaction is an arbitrary value that may need to be refined when further data is available.

K.3.11 Compaction

27. Compaction of emulsion-based cold mix asphalt is preferable with a pneumatic tyre roller (PTR). However, other types of rollers can be used with the recommended types of

compaction equipment being given in Table K.1.

K.3.12 Energy consumption and carbon dioxide production

28. Emulsion-based cold mix asphalt is one of the key processes for maximising savings in energy and greenhouse gas emissions. However, when assessing the sustainability of

cold mix asphalt as an alternative technology, the reduced temperature is not the only change in the input to produce and lay the material. The energy consumption and carbon dioxide equivalent production from:

- the supply of raw materials for,
- the production of, and
- the transport of

any additives used in the mixture needs to be included in any calculation.

Table K.1: Recommended type of compaction

Location	Pneumatic Tyre	Tandem	Mixed	Vibrating Plate*
Surface course				
– dense or semi-dense mixture	+++	+++	++	–
– open graded cold mixture	–	+++	+	–
Binder course and base				
– dense or semi-dense cold mixture	+++	+++	++	++
– open graded cold mixture	+	+++	+	++

* for local repairs only

+++ Highly suited

++ Possible

+ Possible with caution

– Not suited