



**136(4/45/12)ARPS
Performance Specified Surface Dressing for Trunk Roads**

**Sub-tasks 1 and 2
Review of Clause 922 and TAIT**

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1. Introduction

In April 2013, Arup URS Consortium was commissioned by the Highways Agency to carry out a programme of work on “Performance Specified Surface Dressings for Trunk Roads”, under the Department for Transport (DfT) Framework for Transport Related Technical and Engineering Advice and Research – Lot 2: 4/45/12, Package Order reference: 136(4/45/12)ARPS.

Following the inception meeting on 9 May 2013, it was confirmed that the work comprised three sub-tasks:

- Sub-Task 1: Review of Manual of Contract Document for Highway Works (MCHW) Clauses 922 and 955, including Note for Guidance
- Sub-Task 2: Brief letter report on Confidential Review of TAIT
- Sub-Task 3: Desk study report associated with “wear test” of High Friction Surfacing (HFS), currently being adopted as part of certification tests of HFS for Strategic Road Network in the UK.

This report presents the findings from Sub-Tasks 1 and 2.

2. Critique of MCHW Clause 922 - Summary

- It is recommended for clarity that clause 922 be re-written to cater for all roads excluding the Strategic Road Network (SRN).
- Clause 922 should have a 2-year guarantee. A 2-year Type Approval Installation Trial (TAIT) considered necessary for safety reasons, for the higher risk rating sites, cannot form part of CE marking (the TAIT in the standard BS EN 12271 is accepted by Notified Bodies as being evaluated after one year). It is possible that longer periods can be made voluntary.
- Clause 922 binder product identification and performance tests will no longer be provided by BBA/HAPAS certificates. It is proposed that these will be declared in terms of “binder designation”. The data provided in Appendix 7/3 will be based on the BBA/HAPAS SG4 Guideline document enabling existing certificate holders to comply immediately.
- Ultra-thin surface treatments including proprietary surface dressing and microsurfacing that have been proven to be low risk and meet the requirements of safety in use on the SRN should be specified by a separate clause 9xx.
- Clause 9xx needs to be similar to the new draft clause 942, but tailored for Cold Applied Ultra-thin Surfacing (CAUTS), which will permit the existing HAPAS certificated ultra-thin surface treatment products to comply immediately.
- Clause 9xx should require a bond test, which will differentiate it from clause 922, which uses visual assessment with the associated greater safety risk.
- Clause 9xx for the SRN should have a 5-year guarantee in line with draft clause 942.
- Clause 922 will require documentation for factory production control and method statements for installation. The National Highways Sector Scheme 13 for The Supply and Application of Surface Treatments to Road Surfaces

registration can no longer be a requirement, but will be proposed as being voluntary.

- Clause 9xx should enable all innovative ultra-thin surfacings. Safedress 6mm with BBA/HAPAS certificate H01/48 is designed to be laid at 15mm so does not comply with draft clause 942 (minimum 20mm). Novel eco-friendly vegetal fluxed hot polymer binders can be used for surface dressing therefore “Cold Applied” should be defined to include these binders.

3. 922 (08/08) Surface Dressing: Design, Application and End Product Performance

3.1 Background

Clause 922 surface dressing is used for maintenance of the majority of the road network in England. Clause 919 Recipe is still used by some authorities that have the design expertise and sufficient resources to control and monitor the work, but volumes are diminishing mainly due the increased risk to the authority of not having performance requirements with an installed product guarantee.

Surface dressing is currently seldom used on the Strategic Road Network and tends to be either closely specified using clause 922 with a two year guarantee and type test (TAIT) or as a proprietary Thin Surface Course System (TSCS), until recently specified using clause 942 (08/08) with a 5-year guarantee.

Draft clause 942 TSCS revision 2013 now excludes the use of surface dressing, microsurfacing and other cold applied surface treatment systems; only asphalt materials to BS EN 13108 Parts 1, 2 and 5 designed to be laid between 20mm and 50mm are specified.

It is recommended that proven durable low risk proprietary surface dressing systems should be specified using a new clause Cold Applied Ultra-thin Surfacing (CAUTS). The new clause 9xx should be tailored to include those cold applied products that achieved BBA/HAPAS approval for the previous clause 942, Thin Surface Course Systems (TSCS). It is recommended that clause 9xx should be similar to draft clause 942 (2013), but without the asphalt requirements such as wheel tracking.

The safeguards in clause 9xx, such as the bond test and proven performance, may enable CAUTS, proprietary surface dressing and microsurfacing, provided they have demonstrated a Surface Integrity Performance Trial (SIPT) for the intended use, to be used without requiring a Departure.

Historically, clause 922 has been used successfully on trunk roads and some less heavily trafficked motorways (such as A12, A66, A590, and M40). However, memories of work that failed before clause 922 was properly implemented, such as that on the M1 in Northants, have suppressed the demand owing to perceived risk. A trial on the M62 was successfully carried out using double surface dressing by Lanfina before their acquisition by Total (Acland provided the management for this work on behalf of HA) and this eventually led to the BBA/HAPAS TSCS certificate for Finatex, now taken over by Road Maintenance Services Limited. At the same time Surphalt an interlocked triple chipping layered system with two binder applications (one as a grout) of a premium emulsion (cohesion 1.8 J/sqcm) to provide similar performance to ultra-thin asphalt overlays (macadam style), also

achieved SG3 BBA/HAPAS certification to satisfy the previous clause 942 TSCS (08/08) and is being increasingly used owing to its durability in stressed areas.

The revised clause 922 needs to focus on the majority of the road network where surface dressing is applied and must be clearly seen to be separate from clause 9xx CAUTS, which will cater for the Strategic Road Network.

Initial cost is critically balanced against durability and risk for the intended use.

It is essential to prevent over-specification.

The benefit of a two-year guarantee has been demonstrated for local authority roads and should remain. However, a two-year evaluation of performance by a TAIT for the intended use would need some clarification of the wording in BS EN 12271. There appears to be no fixed time limit for the TAIT in the current standard BS EN 12271 for surface dressing. CE marking generated from a two-year TAIT would provide extra confidence to purchasers. This could be provided voluntarily or possibly written into contracts, because it is a safety issue (such as National safety requirements for skid resistance).

All ultra-thin systems hot or cold rely on the performance of the binder to adhere to aggregate and to bond the system to the substrate and these binders are generally proprietary products, which are not adequately specified by the current harmonized binder framework standards.

The fact that components are assembled on site and that the CE marking is self-assessed by suppliers for those binder framework standards, does not provide adequate controls to minimise safety risks.

A two-year SIPT is needed to ensure capability of the supplier and that the product is satisfactory in terms of performance for the intended use. This is considered necessary for the CAUTS clause 9xx.

CE marking for clause 922 provides currently a TAIT for a minimum of one year, however this is not considered long enough for evaluating products for the SRN. The 2-year SIPT for CAUTS will be different to that for clause 922 Surface Dressing, because like draft clause 942 (2013) it will include a test for bond. The bond test proposed for clause 9xx is prEN TS/12697-51 Shear Bond Strength Test rather than prEN12697-48 Torque Bond Test (the equivalent hEN to the BBA/HAPAS Guideline Test for Bond), because the former is for ultra-thin surfacings and for in situ testing, costly coring used for the latter, is not required.

The National Highways Sector Scheme 13 for the Supply and Application of Surface Treatments to Road Surfaces, described in **Appendix A**, can no longer be specified in clause 922 because CE marking covers the installed product. However, having the registration, or equivalent, does give some additional confidence to the purchaser, so a voluntary requirement would be beneficial and should be mentioned in guidance documents.

3.2 Proposed clauses

9xx CAUTS

The CAUTS clause 9xx is proposed to be the principal clause for the Strategic Road Network for the specification of surface dressing, microsurfacing and other innovative ultra-thin surfacing systems.

Clause 9xx should be a tailored version of draft clause 942 TSCS to include Shear Bond Strength Testing CEN prEN TS/12697-51 which is for ultra-thin layers, rather than prEN12697-48 (which is for thicker asphalt layers) and have a Surface Integrity Performance requirement.

922 Surface Dressing: Design, Application and End Product Performance

Clause 922 is proposed to be the principal clause for specification of surface dressing products for the maintenance of roads other than the Strategic Road Network. See **Appendix A**.

4. Proposed Clause 922 amendments

Sector Scheme

References to requirements concerning the NHSS 13 should be modified to be made voluntary and replaced by: requirements for certification to BS EN 12271 with FPC documentation concerning the installation, together with method statements.

Guarantee

Two-year guarantee should remain.

The System

NHSS 13 should be made voluntary, (see above).

Locations of TAIT, to be detailed. Voluntary extended second-year TAIT.

BS EN 12271 currently does not limit the TAIT to one year (“tested **after** one year of completion of the installation” see C2) so theoretically a TAIT could be voluntary at 24 months or even after 36 months duration. The current revision for CPR compliance could clarify this with the agreement of CEN/TC227 WG2.

Materials and Equipment – Binder

It is for the producer (Contractor) to consider the CE marking for the binder(s) he uses.

The purchaser of surface dressing needs information about the potential performance of the installed product. CE marking of surface dressing associated with the intended use based on TAITs is required.

The defined designations for binders (intermediate, premium and super-premium) should continue to be used so that they may be specified. Categories from the relevant binder hENs for peak cohesion are listed for surface dressing CE marking purposes.

No longer can the binders be required to have BBA/HAPAS certificates or equivalent. However, because the standards that provide CE marking of binders are only described as “Framework” standards there is a need to have product identification using performance related-tests for the binders.

These tests should be specified in Appendix 7/3 and it is proposed that they should follow those specified in the Guideline document developed by BBA/HAPAS SG4. This will need support from the binder suppliers (Road Emulsion Association and Refined Bitumen Association) as they will be providing the data. Most of the information has been available for some time so this should not be a problem.

It is recommended that any existing BBA/HAPAS binder certificates specified under clause 922 and certificated prior to December 2013 under the BBA/HAPAS Scheme should be exempt from the product identification tests until they become due for re-certification, providing that the producer's BBA/HAPAS certification remains current. (Certificate review by a Technical Approval Body is required a maximum of 5 years after last certification or certificate review). The two major suppliers have these binder certificates.

Sub-clause 6 does not state the details of the method of test or presentation of graphs and data. For example now that clause 956 has been deleted and only the Dynamic Shear Rheometer test method is referenced (BS EN 14770), the frequency (0.4Hz) and temperature (25 °C) to determine G^* and other parameters, now need to be detailed, otherwise different conditions could be used causing confusion. For data and graphs to be compared, again some requirements are necessary and these have similarly been deleted. These could be detailed in Appendix 7/3 and clause NG922 adding much text, but it is recommended to reinstate most of clause 956 removing the reference to IP PM CM/02 and replacing with BS EN 14770. (See amended clause 956 **Appendix B** attached).

Binders should be detailed in the TAIT for the particular intended use and should have all the data specified in Appendix 7/3. Notes for Guidance should indicate PD 6689 requirements and repeat them for clarity and transparency.

Sub-clause 7 will no longer refer to SRN roads, a reference to clause 9xx CAUTS should be made.

It will be made clear in clause NG922 that BS 1707 certificates are useful for the contractor for calibration of his spraying equipment, but cannot be used in place of certificates to EN 12272-1.

The remainder of clause 922 does not need much amendment except in sub-clause 19 where reference to trunk road and motorways should be removed. ADEPT will be consulted to see if TRACS is their preferred equipment to measure SMTD for heavily trafficked roads and if they see the transition between clause 922 and clause 9xx CAUTS is needed for example at 500cvld or higher. This could be made clear in NG922 and/or ADEPT/RSTA code of practice. In a preliminary discussion with RSTA it appears that only clause 922 is needed, because there is insufficient interest to tender for the limited surface treatment work on the SRN and they would prefer clause 922 to be for all roads other than the SRN removing any potential for confusion.

5. Clause NG922 proposed amendments

The proposed amendments in clause 922 impact on the NG, for example: references to motorways and trunk roads should be deleted and BBA/HAPAS specifications amended.

There are also amendments needed to the tables depending on the decision by ADEPT and RSTA for the cut-off in terms of traffic category between clause 9xx CAUTS and clause 922.

The requirement for a maximum macrotexture decay from 12 months to 24 months may have to be removed, except on a contract-by-contract basis, because this durability test is not covered in the standard BS EN 12271.

The macrotexture requirements in clause 921 may need amendment, because it is thought that it will be impossible to meet the maximum initial requirements of 1.7 mm and the measurement is different (diagonal rather than in the wheel track). Forcing the use of smaller chip size is not good for the more heavily trafficked sites especially on roads with existing surface dressing (embedment rate for normal or soft substrates will cause fattening/tracking).

It is recommended that the reference to “surface dressing” is removed from draft clause 921 Table 9/3 in line with separating clause 9xx CAUTS for SRN from clause 922 all other roads.

APPENDICES

APPENDIX A

922 Amendments - tracked

922 (08/08/10/13) Surface Dressing: Design, Application and End Product Performance

- 1 (08/08) The Contractor shall be responsible for the design of the Surface Dressing, choice of materials, techniques and processes based on site and traffic data specified in Appendix 7/3 and the schedule of constraints on site availability in Appendix 1/13.
- 2 (08/08) The Contractor shall:
- (i) Provide a Design Proposal to achieve the performance requirements in terms of macrotexture and maximum levels of defects as set out in this Clause and in Appendix 7/3 ensuring that the Surface Dressing has an initial stability such that it is capable of withstanding the normal traffic for the site when first opened.
 - (ii) State the Estimated Design Life of the Surface Dressing in the Design Proposal.
 - (iii) Provide the CE marking for the Surface Dressing product to be installed in accordance with BS EN 12271 or European Technical Approval Guideline and the Construction Products Regulation (Regulation (EU) No 305/2011) (CPR).
 - ~~(iv) Be registered to the BS EN ISO 9001 'Sector Scheme 13 for The Supply and Application of Surface Treatments to Road Surfaces', described in Appendix A.~~
 - ~~(iv) Provide a Quality Plan containing at least the information required by the Sector Scheme 13 for The Supply and Application of Surface Treatments to Road Surfaces, described in Appendix A.~~
 - ~~(v) Carry out Install the Surface Dressing in accordance with BS EN 12271 and the Design Proposal to the tolerances specified in Appendix 7/3.~~
 - (v) Provide a Declaration of Performance, factory production control (AVCP) documentation and method statements for the installation.
 - (vi) As an option, voluntarily declare registration to the National Highways Sector Scheme 13 for The Supply and Application of Surface Treatments as described in Appendix A.
- 3 (08/08) The Contractor shall guarantee the design, materials and workmanship against defects and against failure to meet the end product performance requirements for a period of two years, or as otherwise specified in Appendix 7/3, from the date of completion of the work. The Overseeing Organisation will monitor the performance levels of the surface dressing during the guarantee period, and bring any defects to the attention of the Contractor.

(08/08) The System

- 4 (08/08) The proposed Surface Dressing shall have been subject to a Type Approval Installation Trial (TAIT) in accordance with BS EN 12271, which shall be self-certified, ~~within the quality management scheme described in Appendix A.~~ The TAIT shall have been carried out on a site with similar characteristics and traffic category to that to be treated in the Contract. The Contractor shall provide, with his Design Proposal, a Data Sheet giving details of the properties of each system proposed, including the data specified in this Clause and in Appendix 7/3.

(08/08) Materials and Equipment - Binder

- 5 (08/08) Modified binders shall be Intermediate, Premium or Super-premium Grade, ~~having a HAPAS or equivalent Roads and Bridges Certificate or be CE marked~~ as stated in Appendix 7/3. Conventional binder shall be bitumen emulsion complying with BS EN 13808.

6 (08/08) The Contractor shall provide, with his Design Proposal, a Binder Data Sheet giving details of the properties of each binder proposed, including those specified in Appendix 7/3. The recovery of the binder shall be carried out in accordance with Clause 955. The test to determine ~~Vialit Pendulum~~ Cohesion shall be carried out in accordance with BS EN 13588. The Contractor shall provide rheological product identification data for modified binders in accordance with BS EN 14770 and clause 956. The data provided shall be not more than 6 months old and obtained on samples of binder representative of binder manufactured and supplied using the same source and processes as the proposed binder. Health and Safety information and a safe handling guide from the manufacturer shall be provided together with details of any weather restrictions placed upon use of the binder.

7 (08/08) The binder application shall be uniform ~~and for motorways, trunk roads and~~ heavily trafficked and highly stressed roads, shall be of sufficient width to allow a full lane to be dressed in a single pass. Before spraying begins, the Contractor shall provide the Overseeing Organisation with a test certificate showing test results for rate of spread and accuracy of spread of binder carried out in accordance with the test methods in BS EN 12272-1 and issued by, an appropriate organisation, accredited in accordance with sub-Clauses 105.3 and 105.4 for those tests, or tests carried out under his own Quality Assurance Scheme, demonstrating that the binder sprayer has been tested, using the binder to be used in the Contract, not more than six weeks before the commencement of the work, and that it complies with the requirements set out in Appendix 7/3.

(08/08) Materials and Equipment - Chippings

8 (08/08) The chippings shall be crushed rock, slag, gravel or calcined bauxite complying with the general requirements of BS EN 13043. The aggregate shall have a minimum declared PSV and a maximum AAV as specified in Appendix 7/3.

9 (08/08) Chipping spreaders shall have controlled metering and be capable of variable or fixed width application to match the binder sprayer. Before a spreader is used, the Contractor shall provide the Overseeing Organisation with a test certificate showing test results for rate of spread and accuracy of spread of chippings carried out in accordance with the test methods in BS EN 12272-1, and issued by an appropriate organisation, accredited in accordance with sub-Clauses 105.3 and 105.4 for those tests, or tests carried out under his own Quality Assurance Scheme, demonstrating that the chipping spreader has been tested, using chippings similar to those to be used in the Contract, not more than six weeks before the commencement of the work, and that it complies with the requirements set out in Appendix 7/3.

(08/08) Preparation

10 (08/08) Any necessary remedial works to the road surface and structure shall be completed prior to or as part of the Contract and agreed as acceptable by the Overseeing Organisation and the Contractor before Surface Dressing commences.

11 (08/08) Before binder is applied, street furniture shall be masked using self-adhesive masking material. Oil, sand or similar materials shall not be used. Any packed mud or other deposits on the road surface shall be removed, and the road surface shall be swept free of all loose material.

(08/08) Traffic Safety and Management

12 (08/08) Traffic Safety and Management for trunk roads including motorways shall be in accordance with the requirements of Series 100 and any site specific additional requirements specified in Appendix 1/13.

(08/08) Application

13 (08/08) Restrictions to be observed in the event of adverse weather shall be as specified in Appendix 7/3. Transverse joints shall be formed with spraying starting and finishing on a protective

strip not less than 1 metre wide at each end of the lane length being treated. Transverse joints shall be of binder overlap only and not wider than 100 mm. There shall be no ridges or bare strips. Longitudinal joints shall coincide with lane markings. Longitudinal joints shall be of binder overlap only, while ensuring that the proposed rate of spread is achieved across the joint, for quartering (using a part of the spraybar) the overlap may be extended to a maximum of 300 mm. There shall be no ridges or bare strips.

14 (08/08) The Contractor shall carry out the tests for rates of spread and accuracy of application of binder and chippings in accordance with the test methods in BS EN 12272-1 at the frequency specified in Appendix 1/5 and report the results verbally to the Overseeing Organisation within twenty-four hours of carrying out the test and confirm in writing within seven days. The Contractor shall facilitate duplicate testing by the Overseeing Organisation if required.

(08/08) Aftercare

15 (08/08) Masking shall be removed after the Surface Dressing has been applied and before opening the road to unrestricted traffic. The time period before unrestricted traffic may use the Surface Dressing shall not exceed that specified in Appendix 7/3. The Contractor shall remove surplus chippings from the road by suction sweeping before it is opened to unrestricted traffic.

16 (08/08) The Contractor shall monitor the Surface Dressing closely for a minimum period of 2 hours, or as specified in Appendix 7/3, after the road is opened to traffic. The Contractor shall reinstate traffic safety and management procedures or institute other such remedial action where necessary, such as dusting, if there are signs of distress, such as turning of the chippings, in order to prevent further damage to the Surface Dressing.

17 (08/08) Further operations to remove subsequently loosened chippings shall be carried out over the next 48 hours. The road, and adjacent side roads, footways and paved areas, shall be kept substantially free of loose chippings for a period of 30 days after completion of the work.

(08/08) As Built Manual

18 (08/08) Not more than 30 days after completion of the work the Contractor shall provide a record of the progress of the work in the form of an As Built Manual incorporating all relevant information, including: all test results; variations to the Design Proposal and those necessitated by localised site conditions; a record of traffic control carried out; weather information; unforeseen problems; a list of complaints, if any, from the general public or road users; and any other information that the Overseeing Organisation may reasonably require to be included.

(08/08) Performance Standards During the Guarantee Period

(08/08) Surface Macrotexture

19 (08/08) The Contractor is responsible for maintaining the surface macrotexture requirements set out in Appendix 7/3 throughout the guarantee period. The Overseeing Organisation will monitor the surface macrotexture.

The definitive test is the volumetric patch technique measured in accordance with BS EN 13036-1 except that 10 individual measurements shall be made on the nearside (inside) wheel-track of the most heavily trafficked lane or for low traffic category sites the track carrying the most stress. The average macrotexture depth of each lane kilometre, or the complete carriageway lane where this is less than 1,000 metres, shall be as specified in Appendix 7/3. The average of each set of 10 individual measurements shall be not less than 80% of the minimum permitted.

The Overseeing Organisation will use the TRAFFIC-speed Condition Survey (TRACS) or other suitable equipment to determine the Sensor Measured Texture Depth (SMTD) for ~~trunk roads~~ including motorways and other highly heavily trafficked or highly stressed roads. Measurements of

SMTD shall be made in the nearside and offside wheel-tracks of all lanes. For other roads where road closure is less critical the volumetric patch technique or other measuring device such as the Mini Texture Meter may be used.

The SMTD or results from other devices shall be calibrated for the particular Surface Dressing product design and condition against volumetric patch values to provide the Volumetric Patch Equivalent value. The macrotexture depths will be measured after 11 months and before 13 months and additionally for two year guarantee period contracts after 22 months and before 24 months unless otherwise specified in Appendix 7/3. When required, the Contractor shall design the Surface Dressing to limit the maximum macrotexture after four weeks trafficking to that specified in Appendix 7/3 and the macrotexture depths will be measured, for this purpose, between three weeks and five weeks after completion of the Works.

(08/08) Defects

20 (08/08) The extent of chipping loss or other defects will be monitored by the Overseeing Organisation using a visual method of assessment. The performance standard is that any section of the Works shall be deemed as having failed if the areas of defects do not comply with the classes specified in Appendix 7/3. If there is a failed section, the Contractor will be invited to inspect the site in order to agree remedial measures.

In the event that the Contractor and Overseeing Organisation are unable to reach agreement on whether a section has failed by qualitative visual assessment described in BS EN 12272-2, the level of defects shall be determined in accordance with the quantitative test methods in BS EN 12272-2. Any section failing to meet the required standard as specified in Appendix 7/3 shall be subject to remedial action by the Contractor after agreement of the Overseeing Organisation.

APPENDIX B

Proposed amendments to clause 956 for consideration by ADEPT and RBA

956 (10/13) Complex Shear (Stiffness) Modulus (G^*) and Phase Angle (δ) of Bituminous Binders Reporting Criteria using a Dynamic Shear Rheometer (DSR) to BS EN 14770

(10/13) Scope

1 (10/13) This Clause describes the test method parameters for the determination of the Complex Shear (Stiffness) Modulus (G^*) and Phase Angle (δ) of a bituminous binder over a range of temperatures and frequencies when tested in harmonic, sinusoidal oscillatory shear mode using a dynamic shear rheometer (DSR) with parallel plate test geometry and where both plates are controlled at the same temperature. Two methods are described. The first is the conventional equilibrated temperature method using frequency sweeps and is detailed in BS EN 14770 and with the amendments stated in this Clause shall be used for Type Approval (type testing) purposes. The second is the temperature sweep method, where the temperature of the binder is raised at a known rate and tested at a fixed frequency. The second test, which also uses BS EN 14770, requires less time to perform, may be used for quality control purposes.

2 (10/13/10/13) This Clause is applicable to unmodified and polymer modified binder as supplied, after the Rolling Thin Film Oven Test (RTFOT), after an Ageing Test or as recovered from a mixture. Bituminous binders containing fine mineral or organic matter or fibres may also be tested. For hot polymer modified bitumens, fluxed bitumens, bituminous emulsions and polymer variants the binder shall be sampled from the delivery and prepared in accordance with Clause 955

(10/13) Definitions

3 (10/13) For the purposes of this Clause the following definitions apply:

- (i) Complex Shear Modulus (G^*) (sometimes referred to as Complex Stiffness Modulus): ratio of peak stress to peak strain in harmonic, sinusoidal oscillation mode.
- (ii) Phase Angle (δ): the phase difference between stress and strain in harmonic, sinusoidal oscillation mode.
- (iii) Isotherm: an equation or curve on a graph representing the behaviour of the material at a constant temperature.
- (iv) Linear region is defined as the range of strain over which the strain is directly proportional to the applied stress.
- (v) High Equi-stiffness Temperature ($T_{2\text{kPa}}$): the temperature at which G^* is equal to 2 kPa at 0.4 Hz determined from the plot of G^* vs. temperature.
- (vi) Low Equi-stiffness Temperature ($T_{2\text{MPa}}$): the temperature at which G^* is equal to 2 MPa at 0.4 Hz determined from the plot of G^* vs. temperature.
- (vii) $G^*_{(\text{pen})}$: the Complex Stiffness Modulus at 25°C and frequency 0.4 Hz.
- (viii) $\delta_{(\text{low})}$: the Phase Angle from the temperature equilibrated data at 5°C and at a frequency of 0.4 Hz.
- (ix) $\delta_{(\text{high})}$: the Phase Angle from the temperature equilibrated data at 60°C and at a frequency of 0.4 Hz.
- (x) Black Diagram: a graph of the magnitude of G^* against δ .

(10/13) **Apparatus**

4 (10/13) The apparatus for the test is detailed in BS EN14770. The rheometer and the temperature control system shall be calibrated and traceable to national standards, where applicable, at intervals not exceeding 13 months.

(10/13) **Determination of Complex Shear (Stiffness), Modulus (G^*) and Phase Angle (δ)**

5 (10/13) Determination of G^* and δ for binders used to manufacture products at temperatures above 120°C (for example asphalt) shall be as described in BS EN 14770, except that the target strain shall be set within the range 0.005 and 0.02 and the sample preparation shall be Method A. For binders used at lower temperatures such as bituminous emulsions, or where volatile flux oil is present (for example cutback bitumen), the maximum 100°C and preferably less than 85°C. BS EN 14770 shall be amended as follows:

6 (10/13) Method for Emulsions and Fluxed binders:

- (i) Sample preparation: Warm the recovered binder obtained using Clause 955 sufficiently to be able to remove small quantities from the bulk using a suitable spatula or other tool (A temperature around the softening point or the High Equi-stiffness Temperature (T_{2kPa} °C) is usually found to be suitable). The binder shall not be heated above 100°C and not stored for longer than 1 hour at the target temperature. The binder shall be sealed with silicone release paper and/or metal foil to minimise ageing and loss of volatiles.
- (ii) Sample loading: Weigh a pre-calculated amount of binder, to suit the geometry, directly onto one of the rheometer plates or onto a silicone-based material for subsequent transfer to one of the plates. The time for transfer shall be recorded.
- (iii) Sample gapping: The plates shall be at the same temperature prior to setting the gap. The required gap shall be set immediately and no trimming is required.
- (iv) Allow the sample and both plates to equilibrate at a temperature above the softening point or T_{2kPa} °C for at least 15 minutes prior to commencement of the test
- (v) If the recovered binder is heavily modified such that the elastic properties prevent normal loading of the sample then a higher temperature shall be selected as near to 100°C as possible and this shall be reported in the test report.

(10/13) **Data Acceptability Criteria**

7 (10/13) The acceptability criteria detailed in BS EN 14770 shall be used for different test geometries or for at least two samples.

8 (10/13) If the acceptability criteria are not met for two samples then a third verification test shall be carried out, the shortened procedure may be used (25°C and frequency sweep) for the second and subsequent samples. If the acceptability criteria are met for the first and third tests, the results of the first test shall be accepted. If the acceptability criteria are met for the second and third tests, discard the results for the first test and continue testing the third sample by the full procedure used for the first sample, these results are verified by the second test. If none of the three tests are within the acceptability criteria then the mean of the results obtained in two full tests shall be reported with a note that the acceptability criteria could not be met.

(10/13) **Temperature Sweep Test Procedure for Quality Control**

9 (10/13) After equilibration of the sample above the softening point or the High Equi-stiffness Temperature (T_{2kPa} °C) for at least 15 minutes a temperature sweep shall be carried out from the lowest test temperature to at least 60°C or T_{2kPa} °C whichever is the higher. The test frequency shall be 0.4 Hz (± 0.04 Hz). G^* and Phase Angle (δ) shall be measured at temperature intervals not greater than 5.5°C. The rate of temperature increase shall be 2.5 °C per minute or a lesser-fixed rate, which shall be stated with tolerances (not greater than ± 0.5 °C).

10 (10/13) The plot of G^* and Phase Angle (δ) against temperature may be used to compare a sample with a type test for the product by the equilibrated temperature method. If the value for G^* is within $\pm 30\%$ and Phase Angle (δ) within ± 10 degrees at 25°C then the data is deemed to be valid for comparison. If not, then a second sample shall be tested, if the values for G^* are within $\pm 30\%$ and Phase Angle (δ) are within ± 10 degrees for 90% of the results for the first test the data is deemed to be valid and different to the type test. If the supplier has reasoned that higher tolerances are necessary for the particular product at Type Approval (type testing) stage these shall be used instead for comparison. The supplier may also state the sample preparation technique to be used for this comparison.

11 (10/13) Alternatively the equilibrated temperature data from frequency sweeps (BS EN 14770) may be used, although the number of equilibrated temperature tests at 0.4 Hz will need to be increased (5°C intervals).

12 (10/13) If required the temperature sweep shall be carried out with a reducing temperature from 80°C to the lowest test temperature in addition to the normal test, this shall be noted in the test report.

(10/13) **Expression of Results**

13 (10/13) A table of results, based on the individual test results, shall be produced which shall include the following information at each temperature:

- (i) Test temperature $^\circ\text{C}$.
- (ii) Test frequency Hz.
- (iii) Strain %.
- (iv) Phase Angle (δ) Degrees.
- (v) Complex Stiffness Modulus (G^*) Pascals.

14 (10/13) A graph of G^* against temperature shall be produced, in decades from 101 to 108 Pa as a curve at $0.4 \text{ Hz} \pm 0.04 \text{ Hz}$ with a linear temperature x-axis of -10°C to 90°C .

15 (10/13) A graph of Phase Angle (δ) against temperature shall be produced from 20 to 90 degrees ascending with a linear temperature x-axis of -10°C to 90°C at a frequency of $0.4 \text{ Hz} \pm 0.04 \text{ Hz}$.

16 (10/13) A graph of G^* against Phase Angle (δ) (Black Diagram) shall be produced in decades from 101 to 108 Pa with a linear x-axis of 90 to 20 degrees descending

17 (10/13) Plots of isotherms for G^* against frequency tested at each test temperature shall be produced in decades from 101 to 108 Pa with an x-axis in decades of frequency from 10-2 Hz to 101 Hz.

18 (10/13) Plots of isotherms for Phase Angle (δ) against frequency tested at each test temperature shall be produced from 20 to 90 degrees with an x-axis in decades of frequency from 10-2 Hz to 101 Hz.

19 (10/13) The x-axes of the graphs shall have dimensions of at least 200 mm and the y-axes at least 150 mm.

20 (10/13) The following test values shall be reported:

- (i) $T_{2\text{kPa}}$: the High Equi-stiffness temperature.
- (ii) $T_{2\text{Mpa}}$: the Low Equi-stiffness temperature.
- (iii) $G^*_{(5^\circ\text{C})}$: the value of G^* at the equilibrated temperature of 5°C and 0.4 Hz.
- (iv) $G^*_{(\text{pen})}$: the value of G^* at the equilibrated temperature of 25°C and 0.4 Hz.
- (v) $G^*_{(60^\circ\text{C})}$: the value of G^* at the equilibrated temperature of 60°C and 0.4 Hz.

- (vi) $\delta_{(low)}$: the value of δ at low temperature 5°C and loading time of 0.4 Hz.
- (vii) $\delta_{(high)}$: the value of δ at high temperature 60°C and loading time of 0.4 Hz.

The complex stiffness modulus (G^*) shall be reported to three significant figures, phase angle to the nearest 0.1 of a degree and temperature to 0.1 °C.

(10/13) Test Report

21 (10/13) The test report shall contain at least the following information:

- (i) A reference to this test procedure.
- (ii) Place of test.
- (iii) The rheometer type, model and test geometries (plates and gaps) used.
- (iv) The compliance limitations of the machine/geometry (including whether software corrections have been applied in terms of the maximum sample stiffness at which the result reported will be in error by less than 10%). The limitations shall be reported for each plate geometry used to obtain the results reported.
- (v) The type and identification of the product tested.
- (vi) Sample thermal history: how, when and where the sample was taken; the size of the sample and whether it was sub-divided; the period it was stored and the conditions of storage; and whether it was treated by RTFOT and/or Ageing Test or was a recovered binder from emulsion or cutback in accordance with Clause 955, or recovered from an asphalt, with the recovery test method detailed.
- (vii) Strain conditions of the test at 25°C and 0.4 Hz and at the extremes of the temperature and frequency ranges used to provide data.
- (viii) Sample loading method, temperature and time for transfer.
- (ix) Frequency sweep direction for BS EN 14770.
- (x) Temperature sweep direction for the method if used and target rate of change with tolerances.
- (xi) The results of the test as set out under this Clause.
- (xii) Whether the Data Acceptability Criteria in this Clause were met.
- (xiii) Any deviation, by agreement, or otherwise, from the procedure specified.
- (xiv) Date of test.
- (xv) Name of the person responsible for the test.

22 (10/13) The test report and graphs, uniquely identified shall be provided to the Overseeing Organisation with the Contractor's Proposal.

23 (10/13) A copy of the data in digital format suitable for graphical production shall be provided to the Overseeing Organisation.